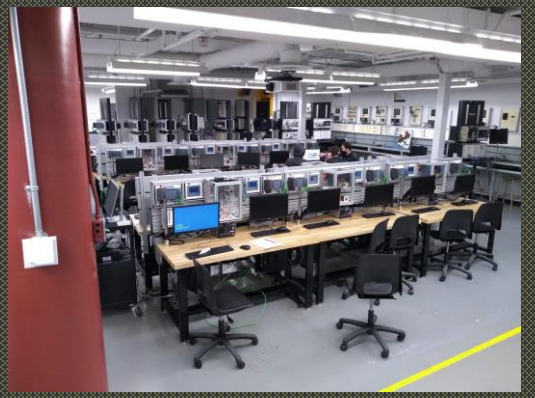

PROGRAMMABLE LOGIC CONTROLLERS
MENG 3500

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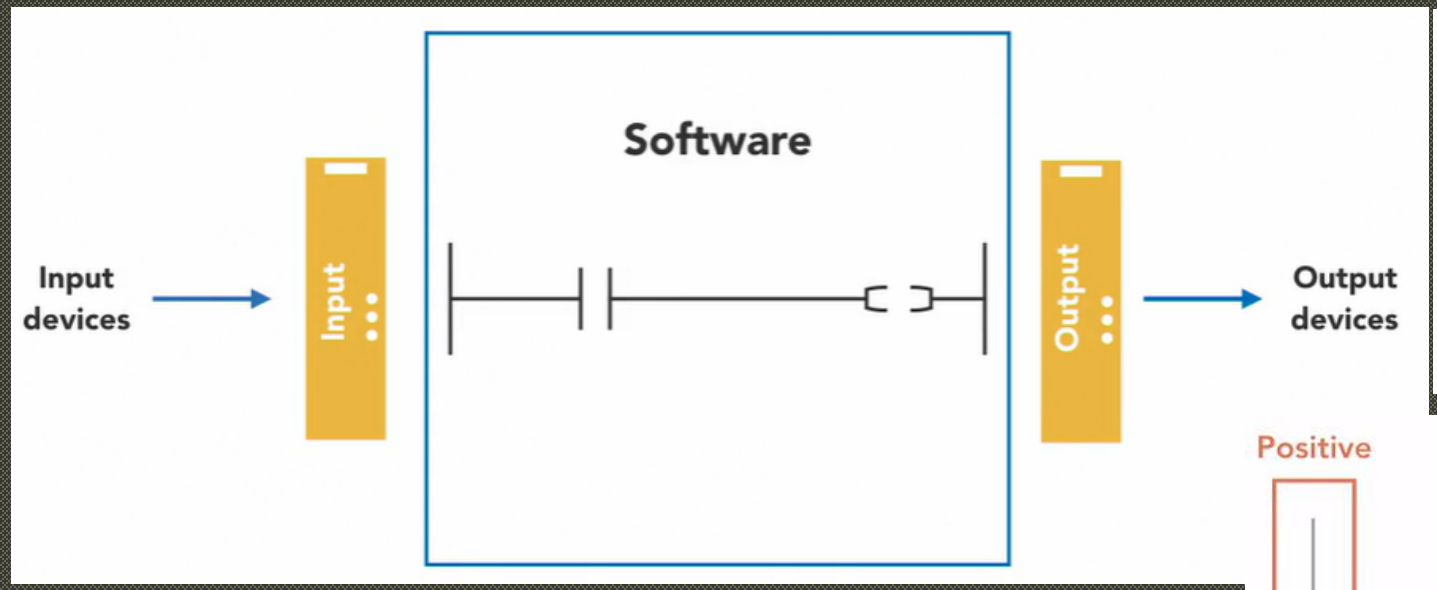
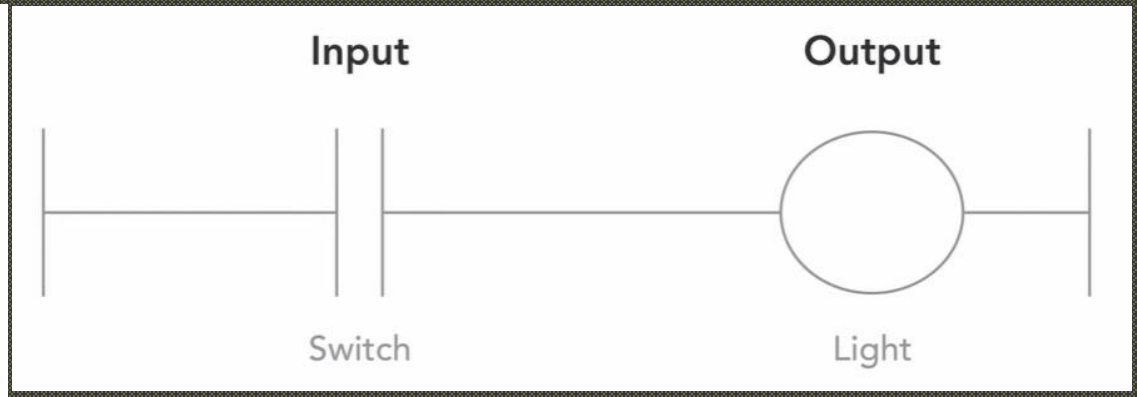
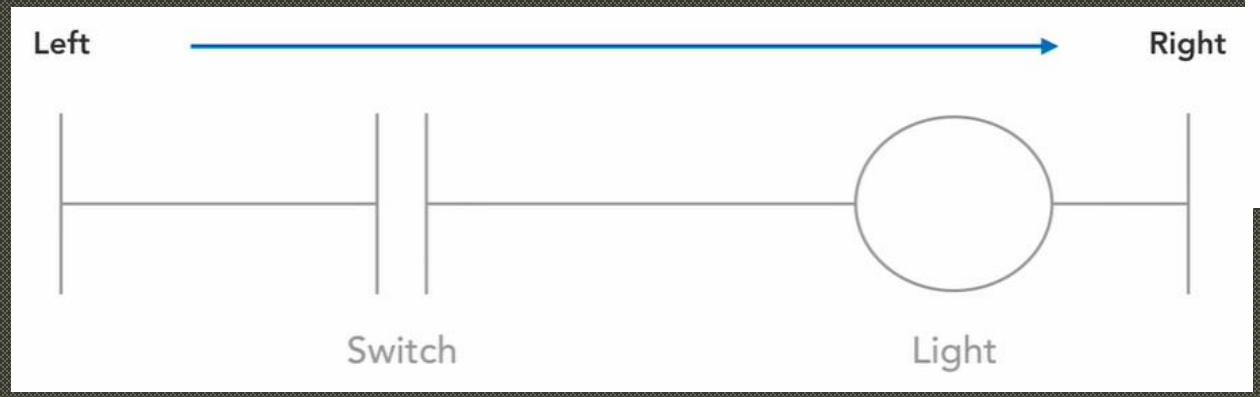
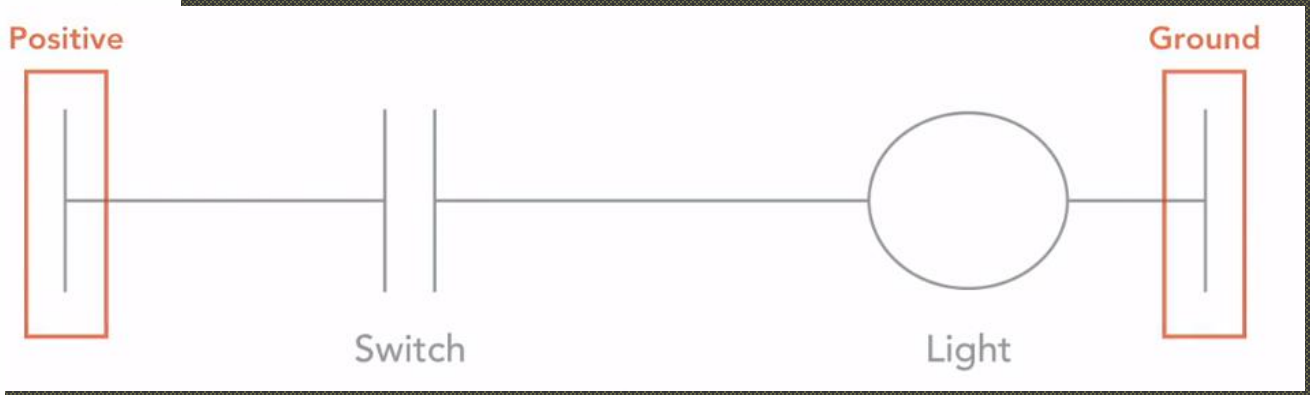
XIC, XIO and OTE INSTRUCTONS









Inputs are inserted on the left side and Outputs are inserted on the right side of the ladder logic.
Not all inputs and outputs are necessarily connected to the field/physical devices.

HUMBER

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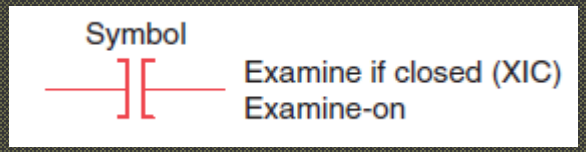
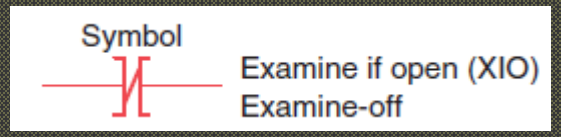
XIC, XIO and OTE INSTRUCTONS

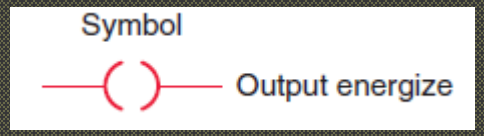
- **XIC – Examine if Closed** – Anticipating a high-level signal originating from a field device such as a pushbutton, sensor, or switch is the objective of this program segment. An alternate interpretation for this instruction could be "Examine if ON" or "Examine if 1." In the context of the XIC (Examine If Closed) instruction, a high level is regarded as TRUE, while a low level is considered as FALSE.



- **XIO – Examine if Open** – The anticipated scenario involves a low-level signal generated by the field device within this program section. Other expressions for this instruction include "Examine if OFF" or "Examine if 0." In the context of the XIO (Examine If Open) instruction, a high level is interpreted as FALSE, while a low level is deemed as TRUE.

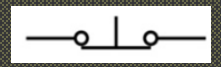


- **OTE – OUTPUT ENERGIZE** - The OTE instruction is used to energize an output, turning it on or making it true when the specified condition is true. It is like the coil or output coil in traditional ladder logic. When the condition connected to the OTE is true, the output is energized. It represents the action when the input instruction/instructions are true.



- A Normally Open (N.O.) pushbutton creates an open circuit when not pressed and closes the circuit, allowing current flow, when pressed.

- Normally Closed (N.C.) devices have closed contacts and conduct electrical signals when not activated but create an open circuit when activated.



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XIC, XIO and OTE INSTRUCTONS

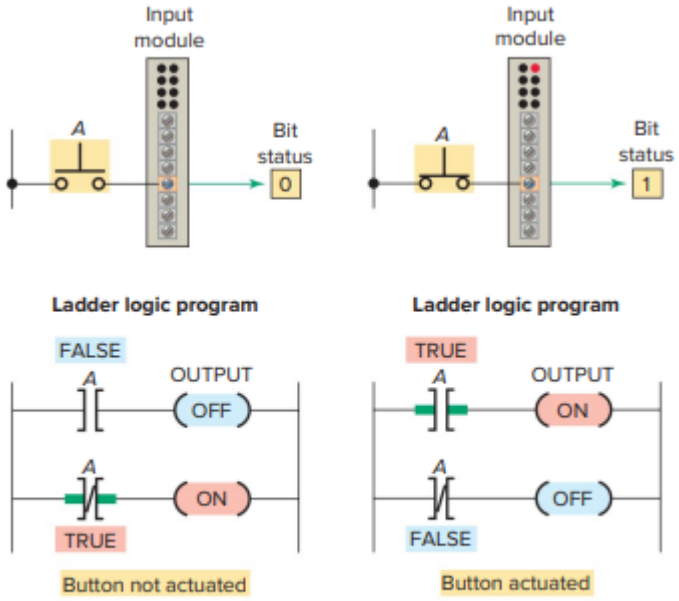


Figure 5-24 Separating the action of the field device and PLC bit.

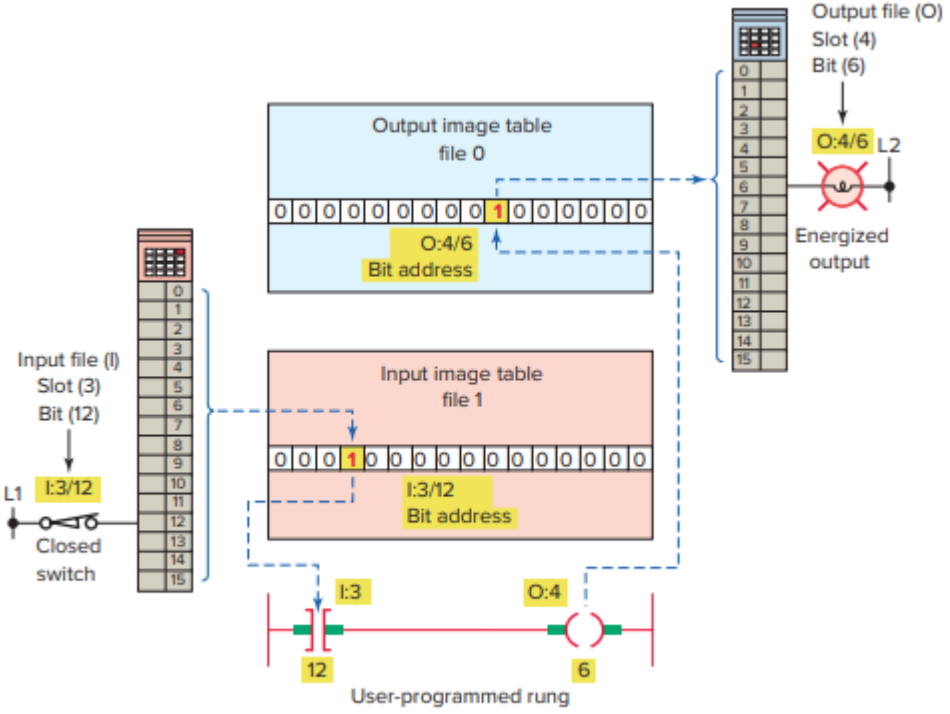


Figure 5-27 Addressing format for an Allen-Bradley SLC 500 controller.

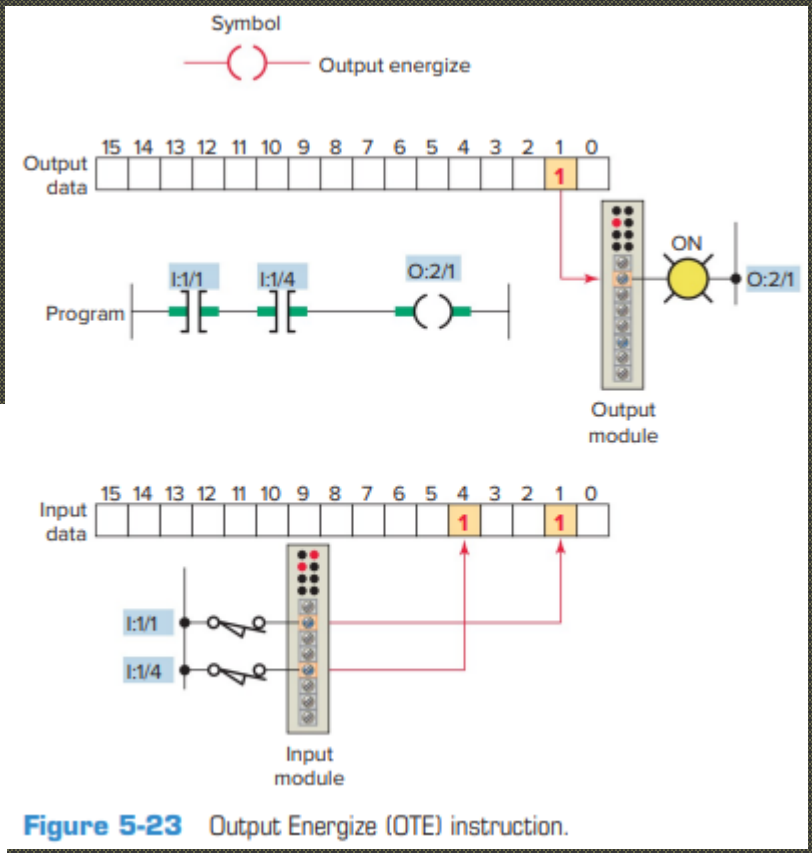
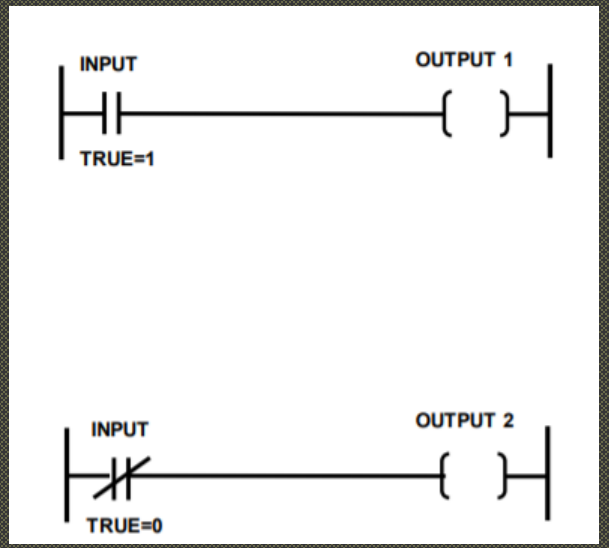


Figure 5-23 Output Energize (OTE) instruction.

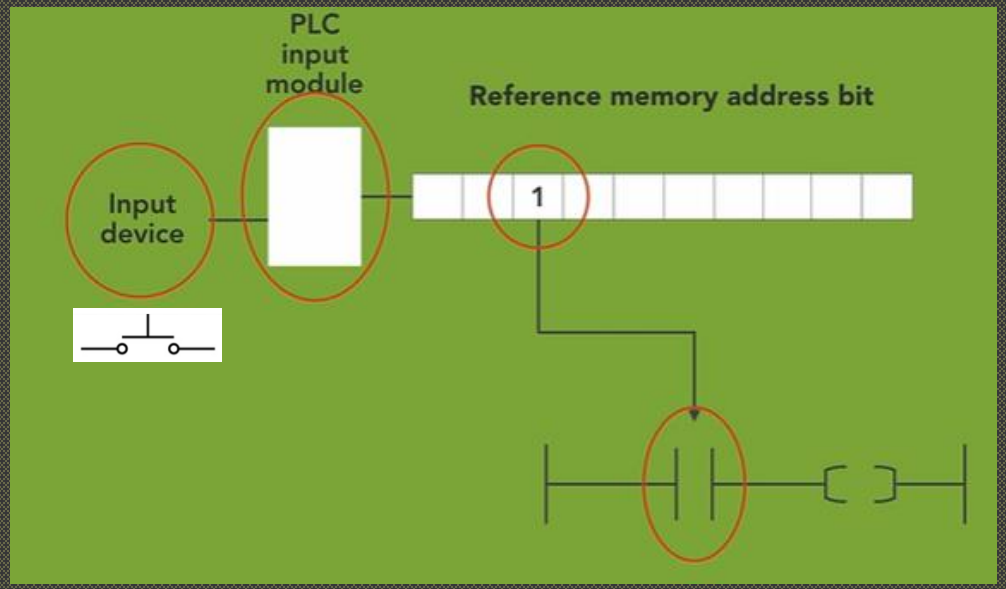
(Frank D. Petruzella Programmable Logic Controllers 4th edition)

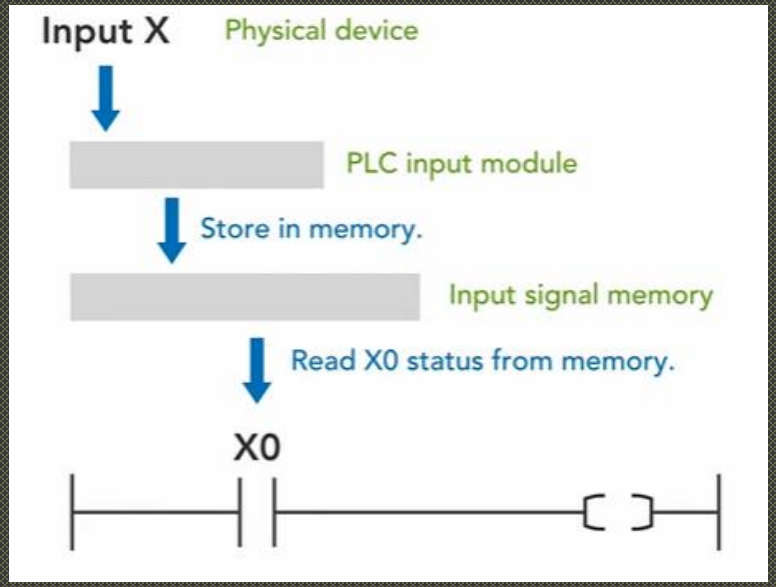
XIC, XIO and OTE INSTRUCTONS

A basic logical rung can be as straightforward as a single input and output instruction. The essence of this rung relies on the fundamental IF-THEN logic: if the INPUT is TRUE, then the OUTPUT will be activated (set to TRUE). The representation of this elementary logic involves specific symbols: XIC (Examine If Closed) signifies checking if a condition is true, while OTE (Output Energized) denotes energizing the output if the condition is met.



IF INPUT is TRUE THEN OUTPUT 1 will be ON





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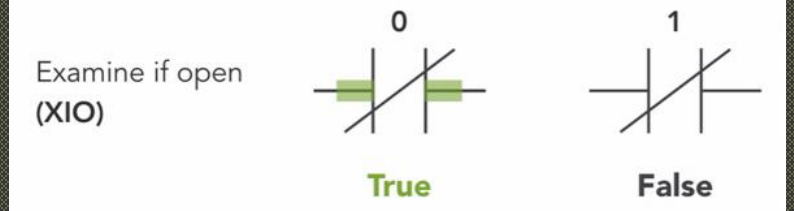
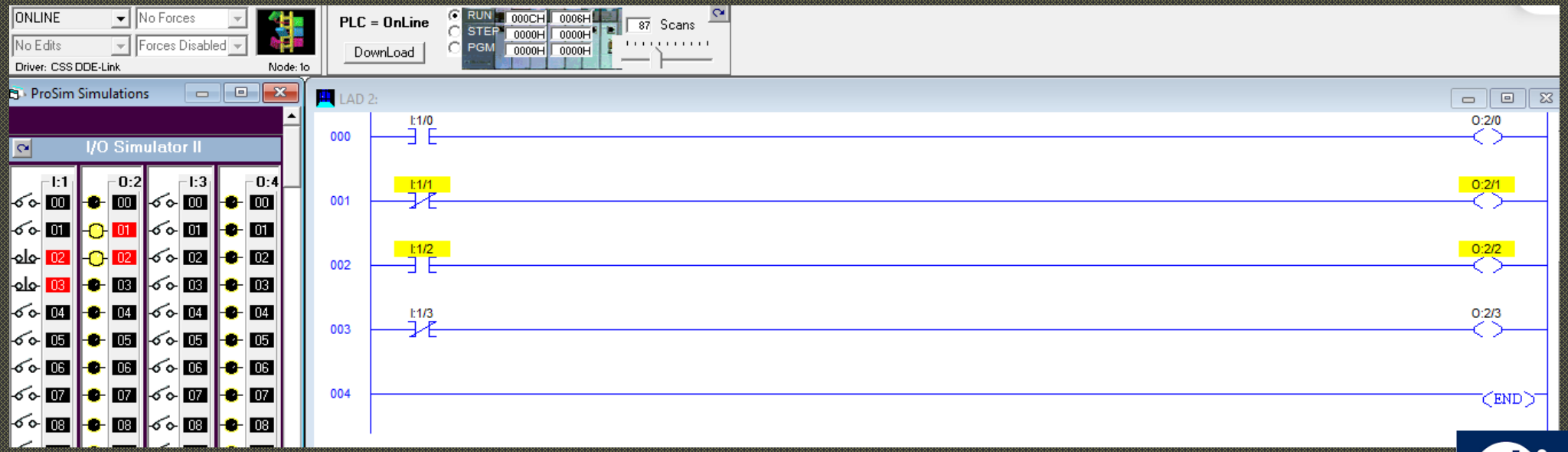
XIC, XIO and OTE INSTRUCTONS

Examine if Closed (XIC) Input

Examine if Open (XIO) Input



Field devices and program instructions are not the same thing.



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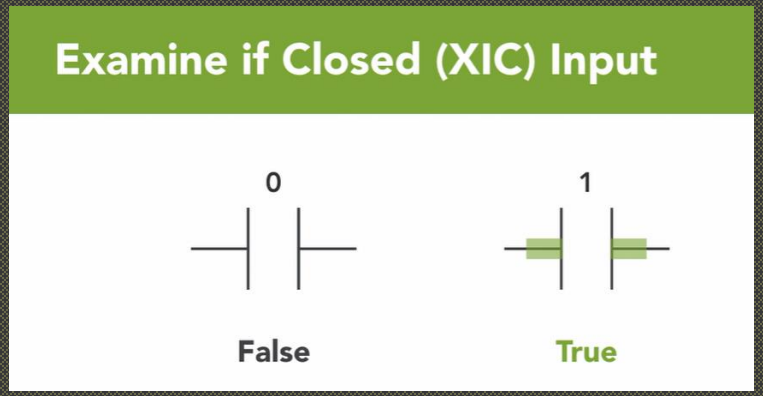
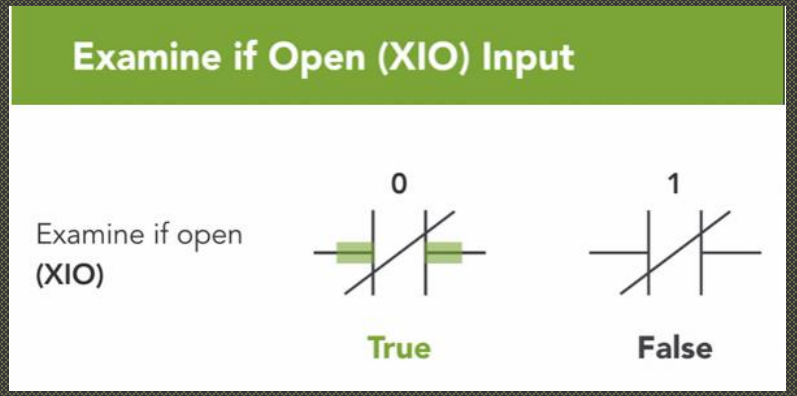
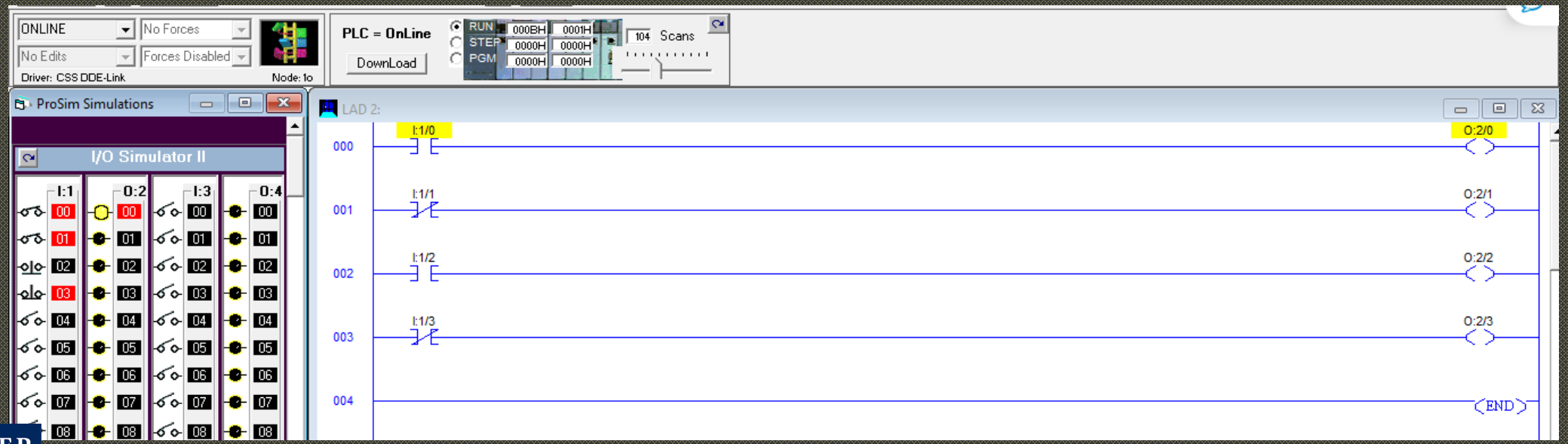
XIC, XIO and OTE INSTRUCTONS

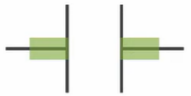




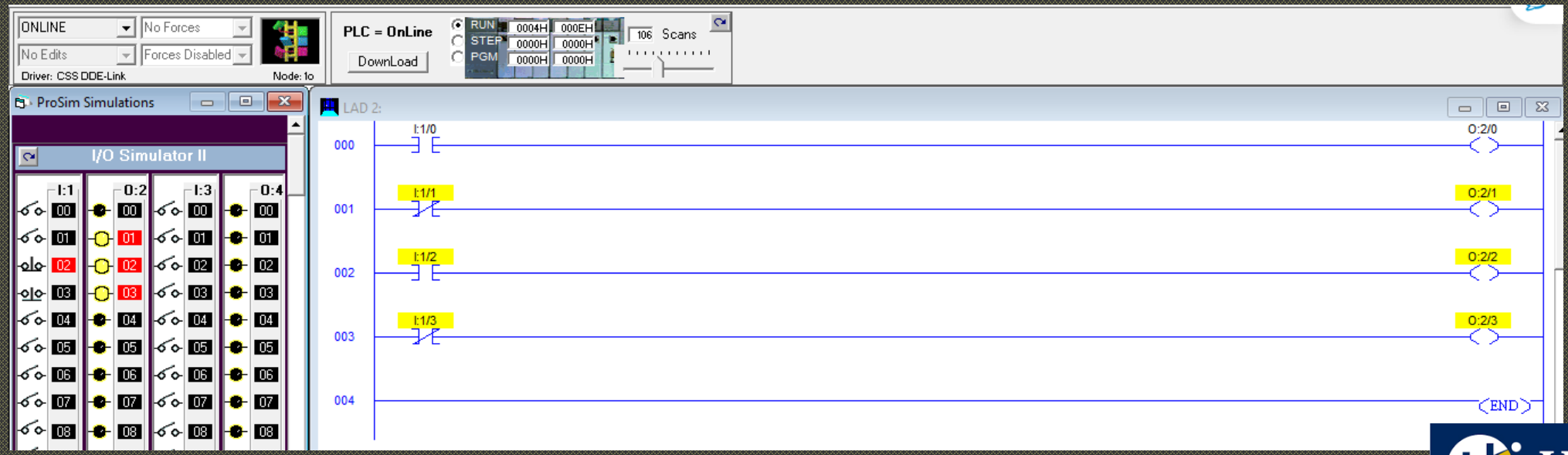
- It is important to remember that the user program is not an electrical circuit but a logic circuit.
- In a PLC rung, we need to establish logic continuity to activate an output.



XIC, XIO and OTE INSTRUCTONS

	0	1
Examine if closed **(XIC)**		
Examine if open **(XIO)**		

In the ladder program, the instruction is highlighted when its logical state is true.



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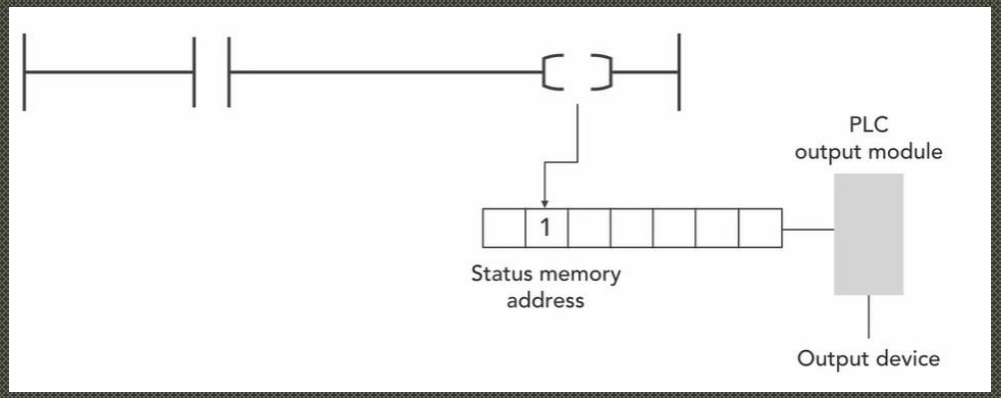
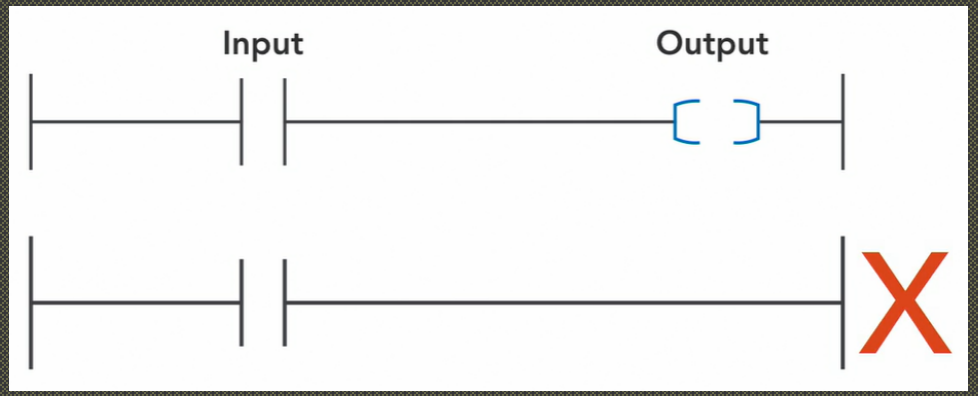
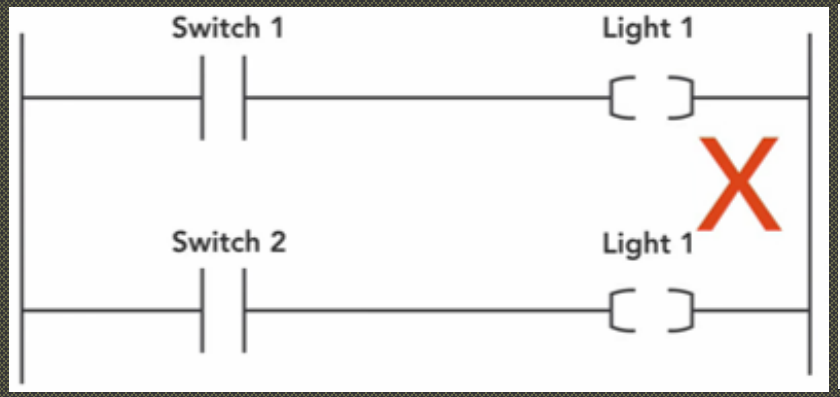
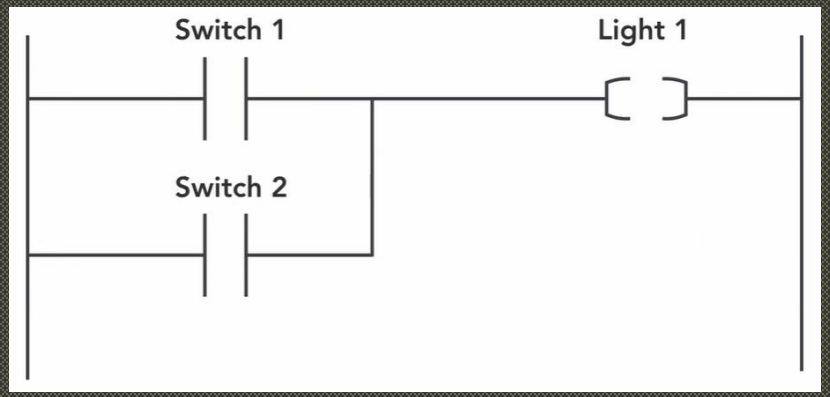
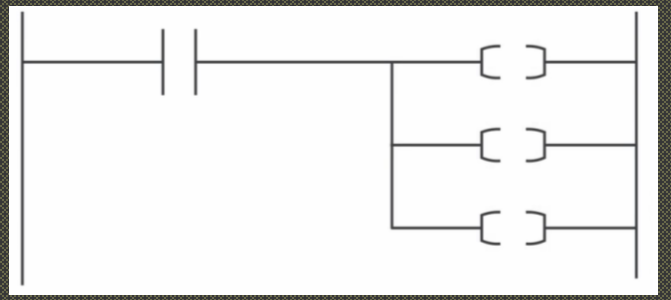
XIC, XIO and OTE INSTRUCTONS











Output is always the last instruction before the right power rail.
Everything in front of the output tends to be inputs for that output.
Every rung must have a minimum of one output instruction.
Output instruction is used only one time (in only one rung) in the PLC program.

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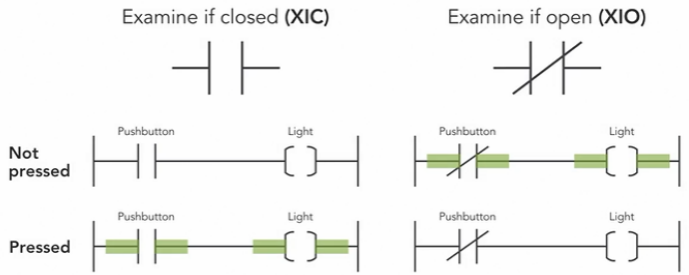
XIC, XIO and OTE INSTRUCTONS

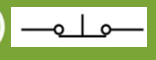
Truth Table

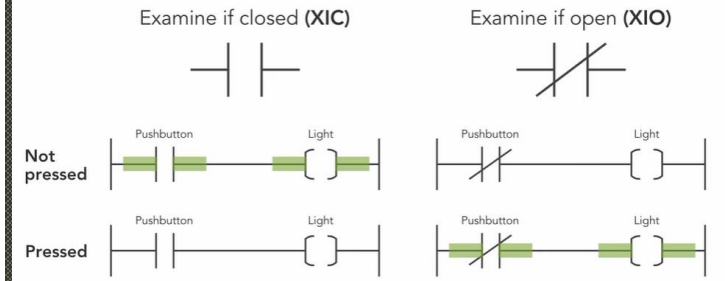
	0	1
Examine if closed **(XIC)**		
Examine if open **(XIO)**		
Output		

Normally Open Contact (NO)



Normally Closed Contact (NC)





Field devices and program instructions are not the same thing.

If the data table bit is	The status of the instruction is		
	XIC EXAMINE IF CLOSED	XIO EXAMINE IF OPEN	OTE OUTPUT ENERGIZE
Logic 0	False	True	False
Logic 1	True	False	True

Time	Instruction outcome		
	XIC	XIO	OTE
t_1 (initial)	False	True	False
t_2	True	True	Goes true
t_3	True	False	Goes false
t_4	False	False	Remains false

Input bit status		
XIC	XIO	OTE
0	0	0
1	0	1
1	1	0
0	1	0

Figure 5-42 Simple program using both the XIC and XIO instructions.

(Frank D. Petruzella Programmable Logic Controllers 4th edition)

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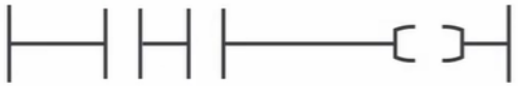
XIC, XIO and OTE INSTRUCTONS

Multiple Inputs

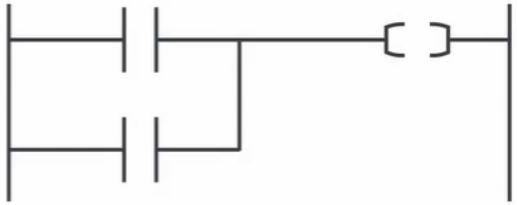
AND

AND inputs are added in series.

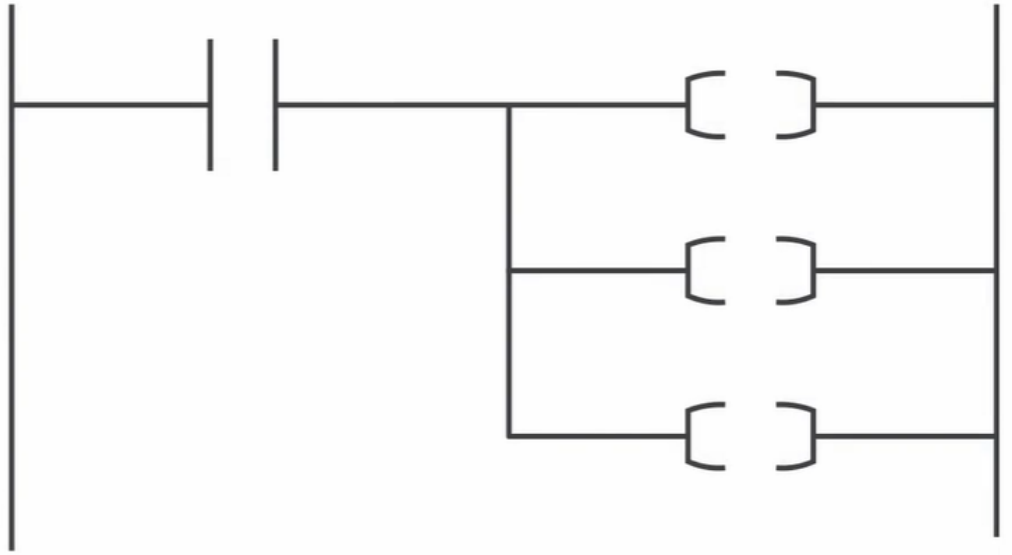


OR

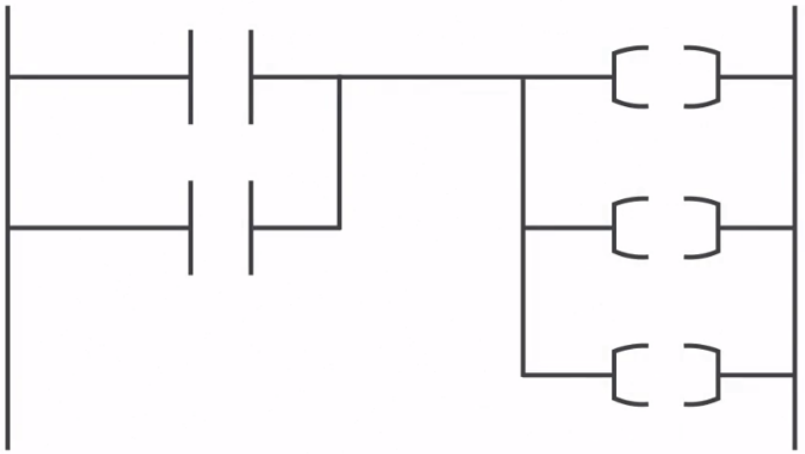
OR inputs are added in parallel.

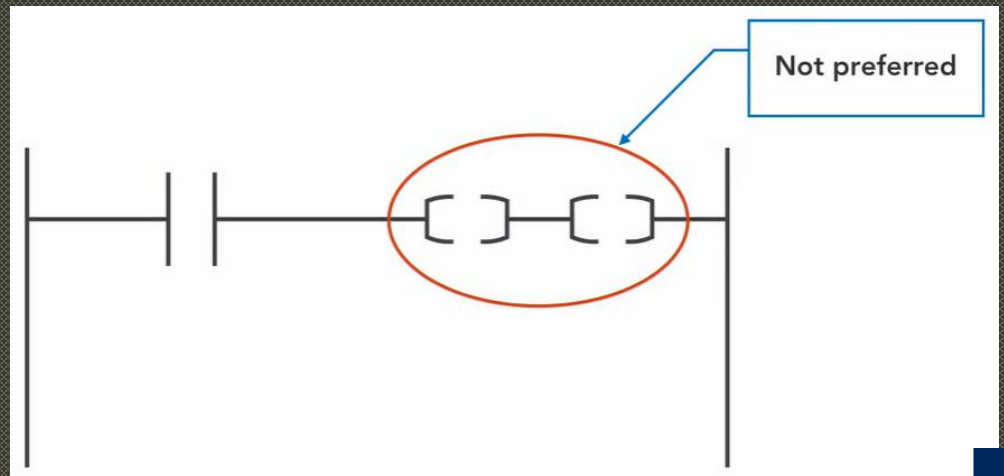


Multiple Outputs



Multiple Inputs and Multiple Outputs





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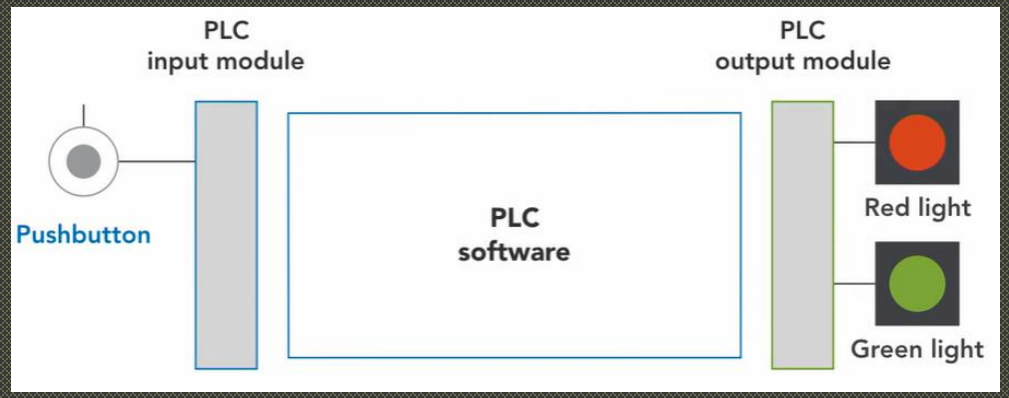
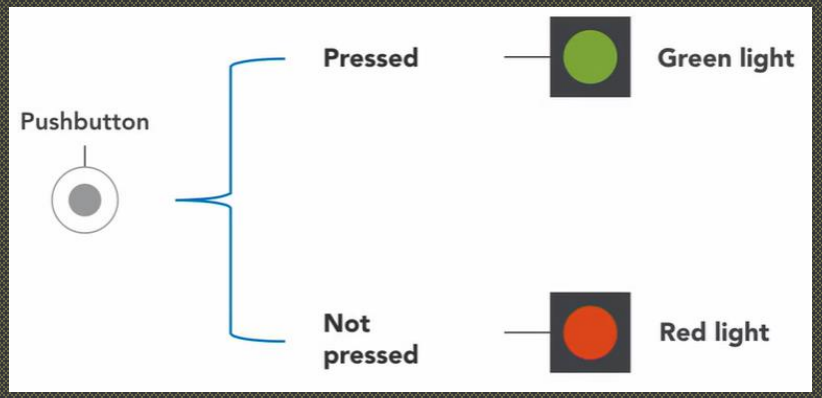
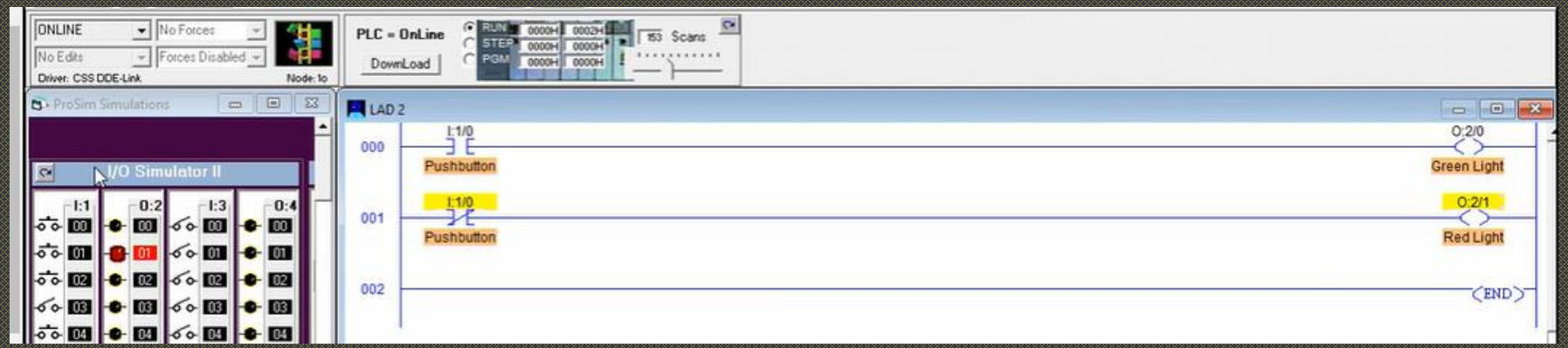
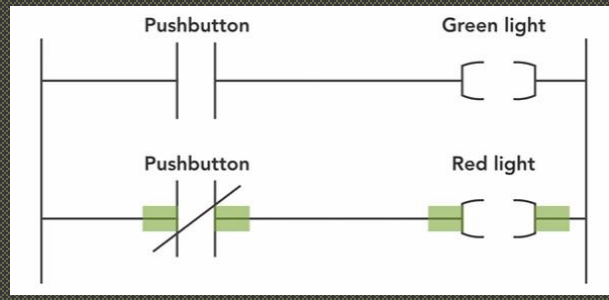
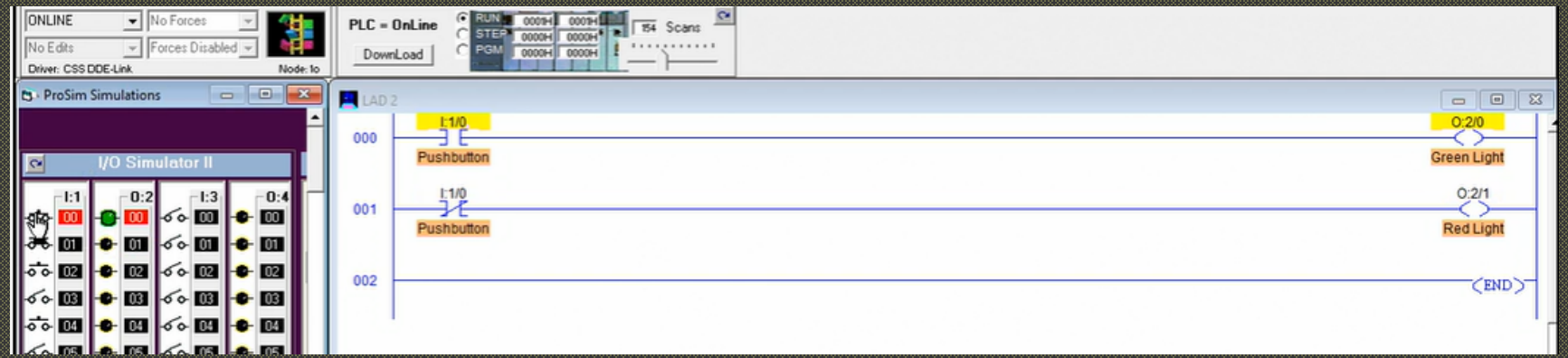
XIC, XIO and OTE INSTRUCTONS











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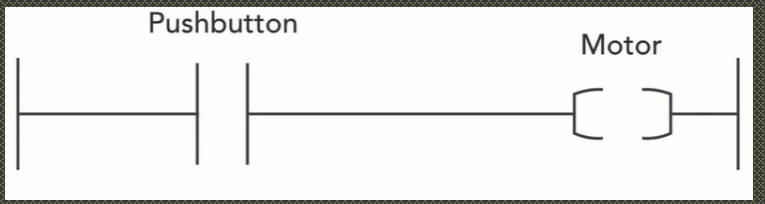
Seal-In or Hold-in Instruction

1



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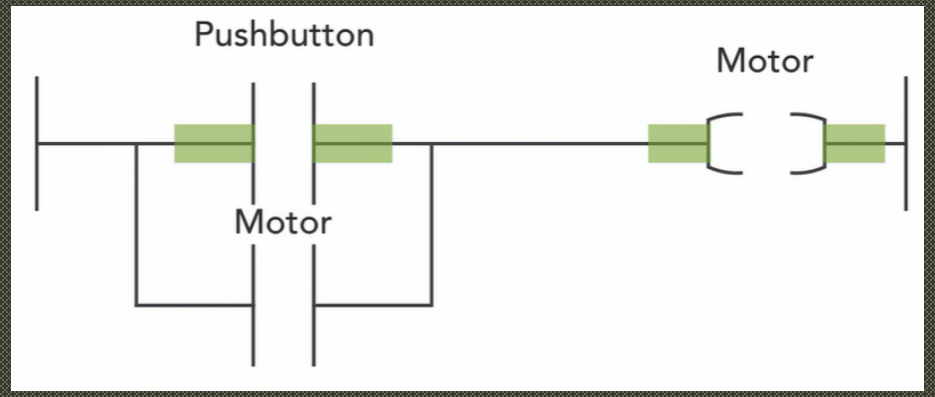
2



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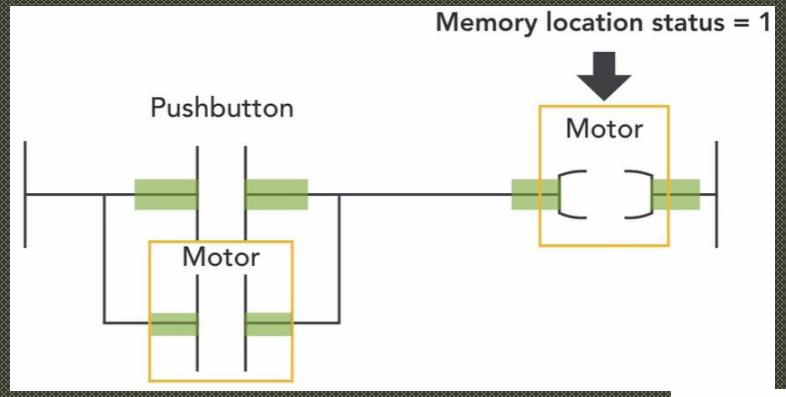
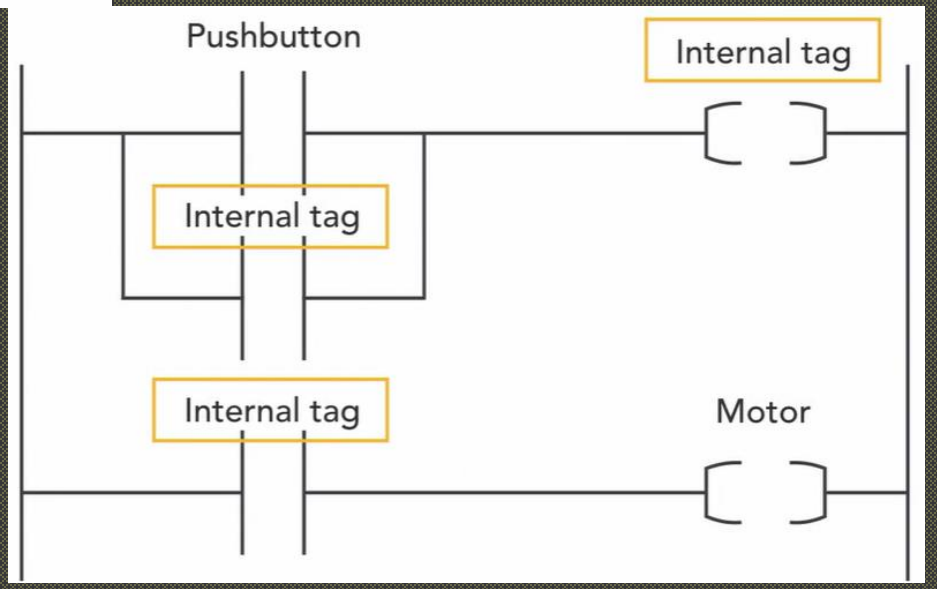
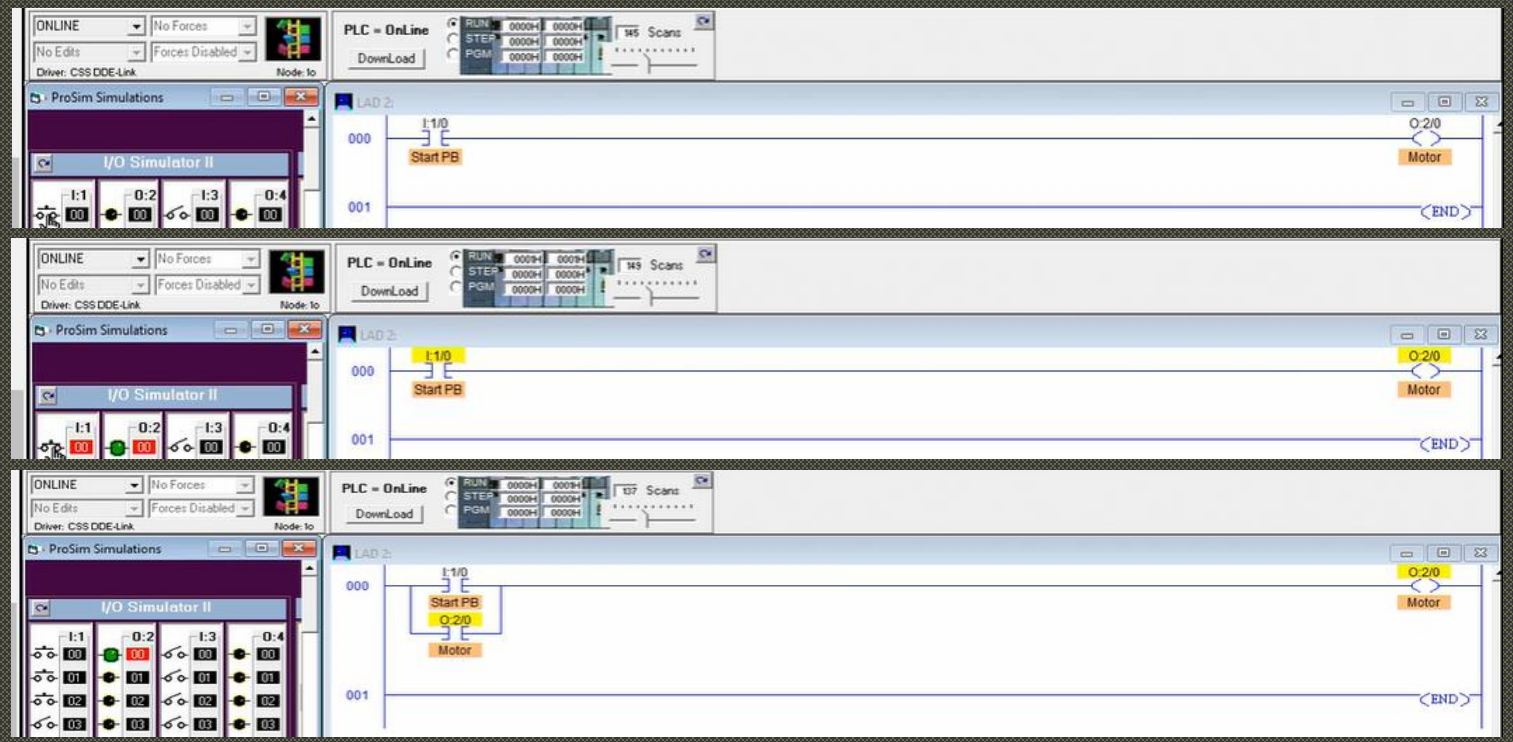


4





HUMBER

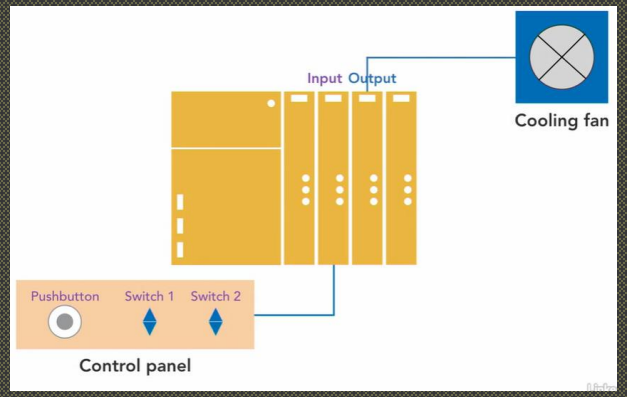
Branching Operation Examples

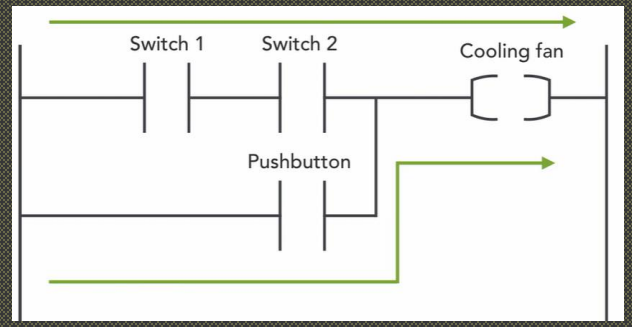
To Turn on the Cooling Fan:

1. Two switches, both need to be turned on

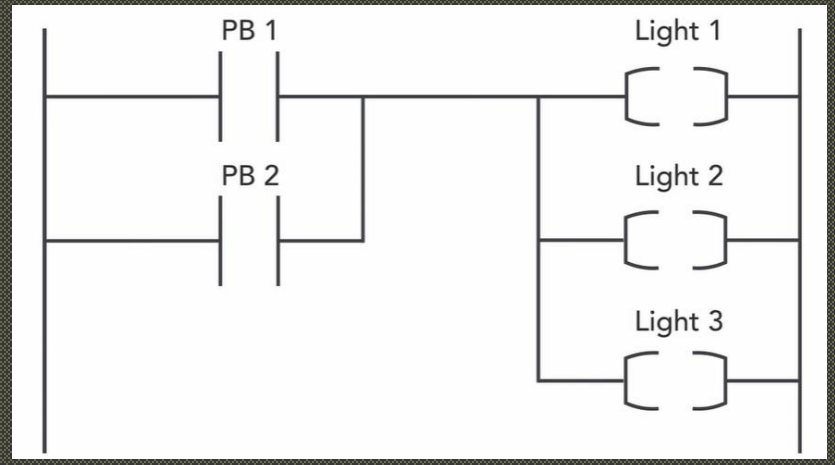
Or

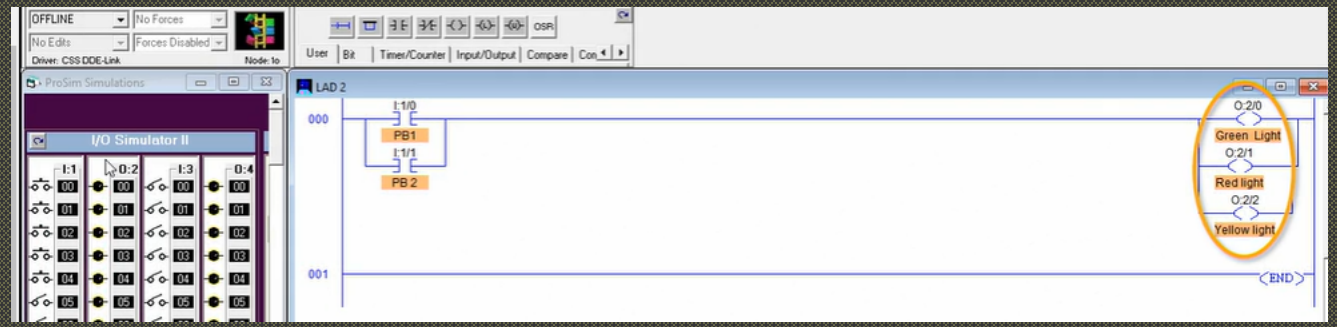
2. Pressing a pushbutton





Two pushbuttons – if any of them pressed – three lights will turn on





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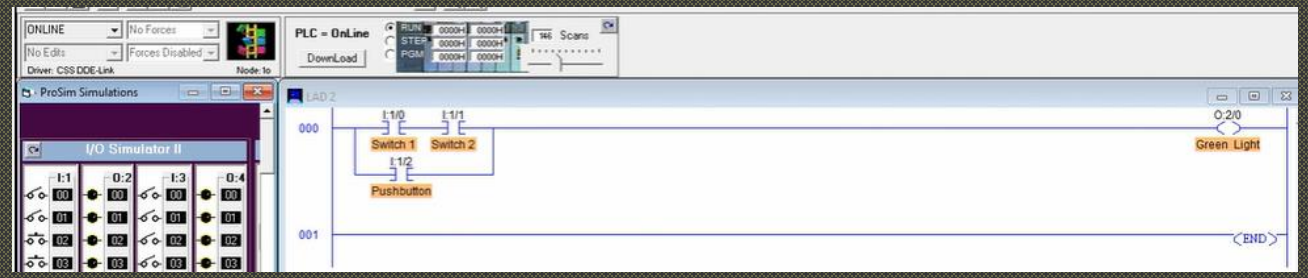
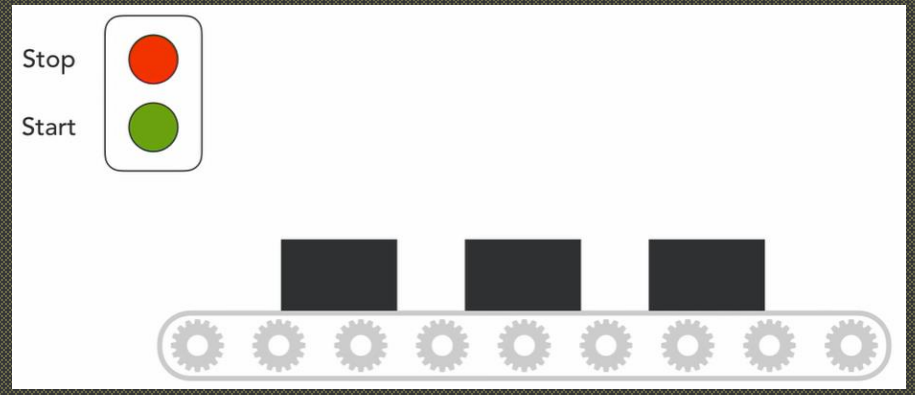
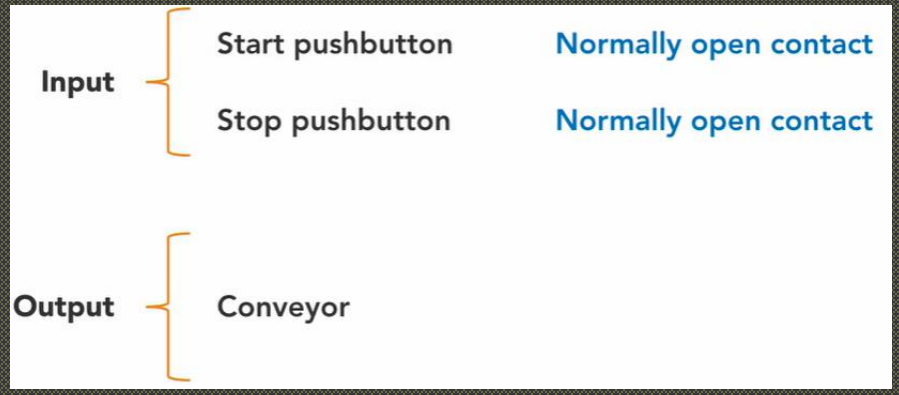


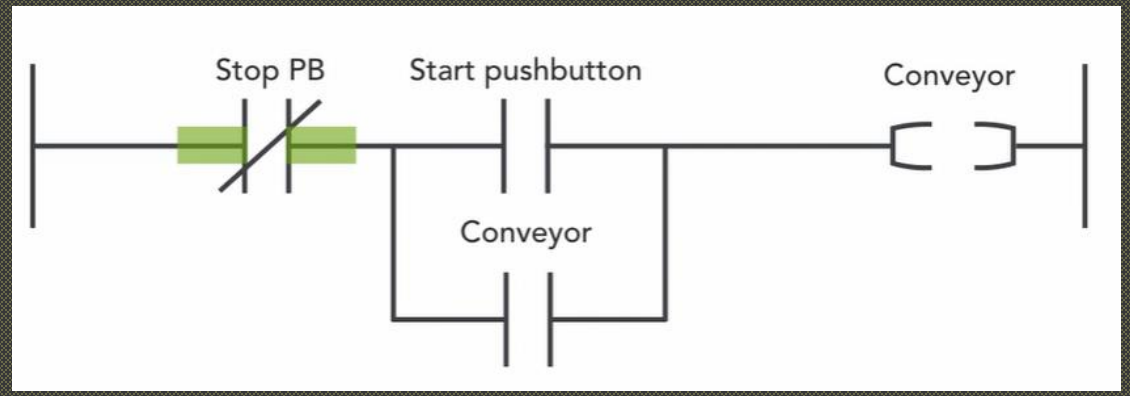
HUMBER

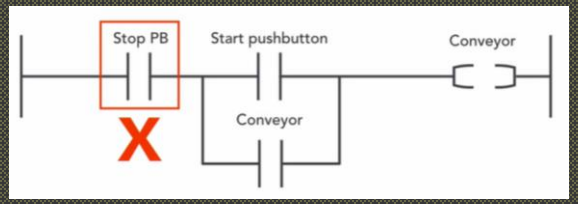
Example 1

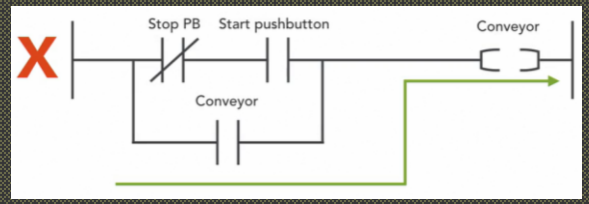
Use Start and Stop Pushbutton to start and stop the conveyor











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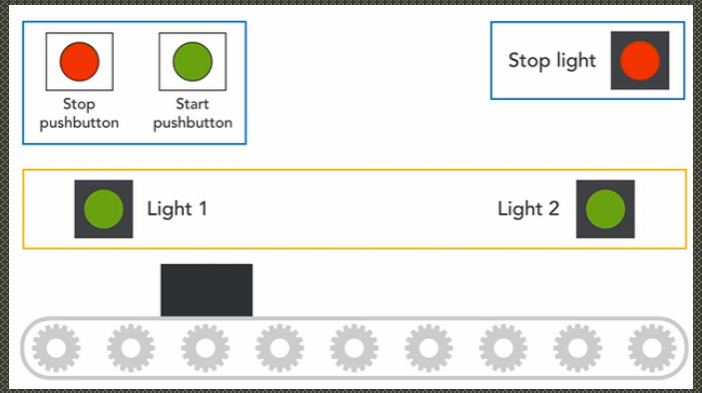
HUMBER

What will change in the ladder logic if the Stop Pushbutton uses the Normally Closed Contact?

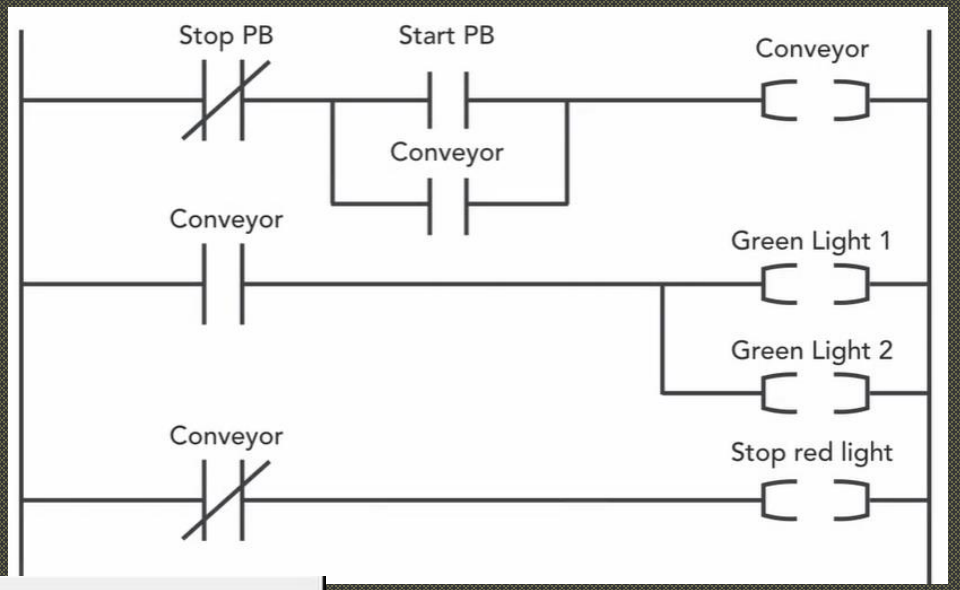
Example 2

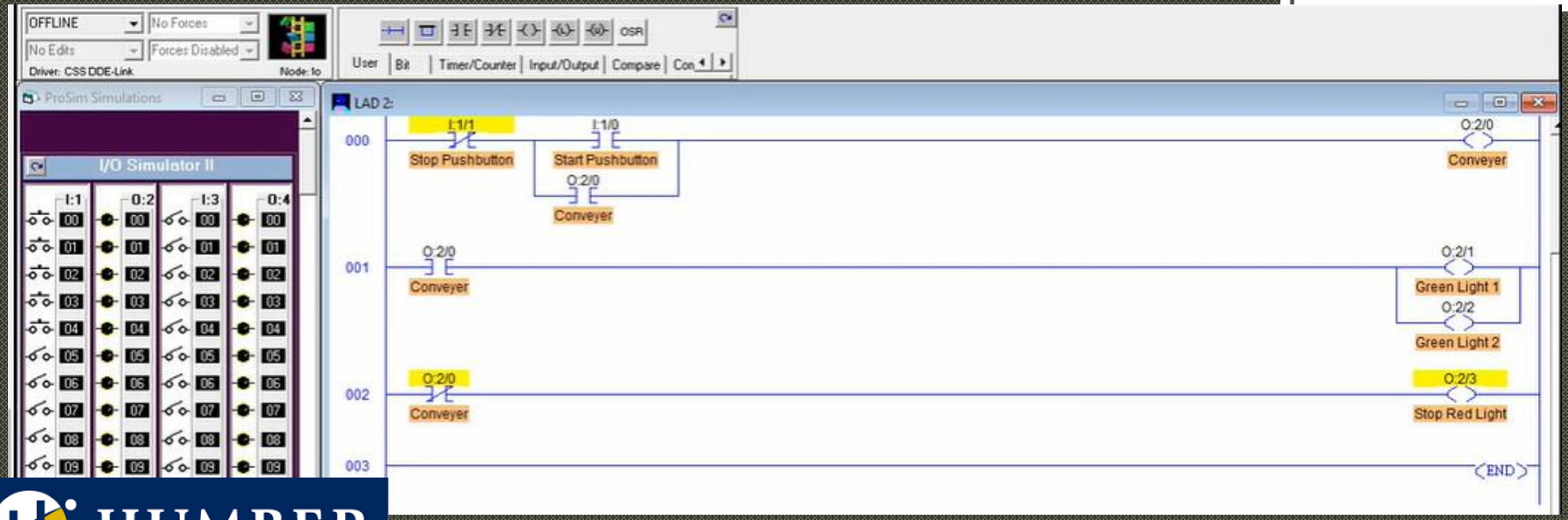
Add the red and green lights



Input
- Start pushbutton
- Stop pushbutton

Output
- Green light 1
- Green light 2
- Stop red light
- Conveyor





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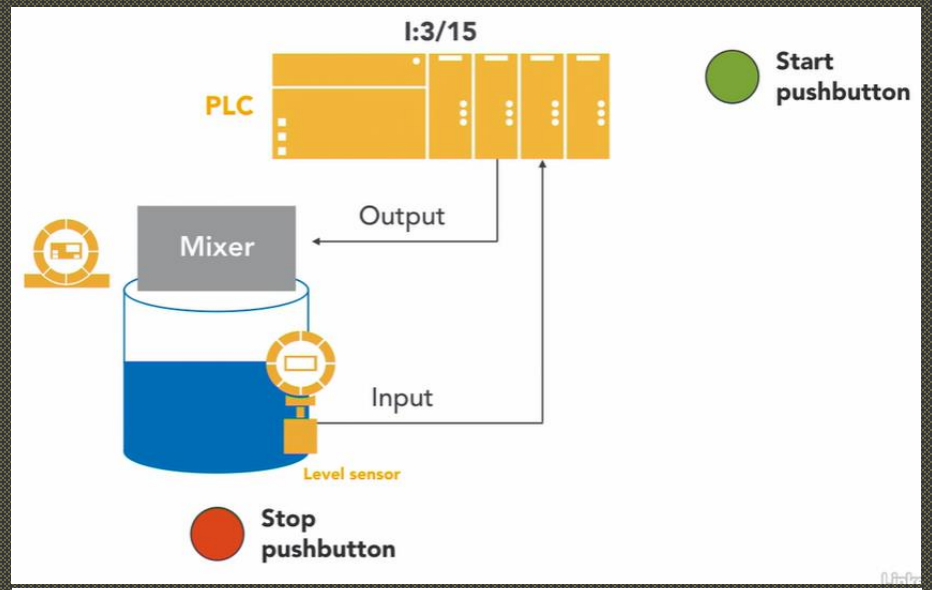
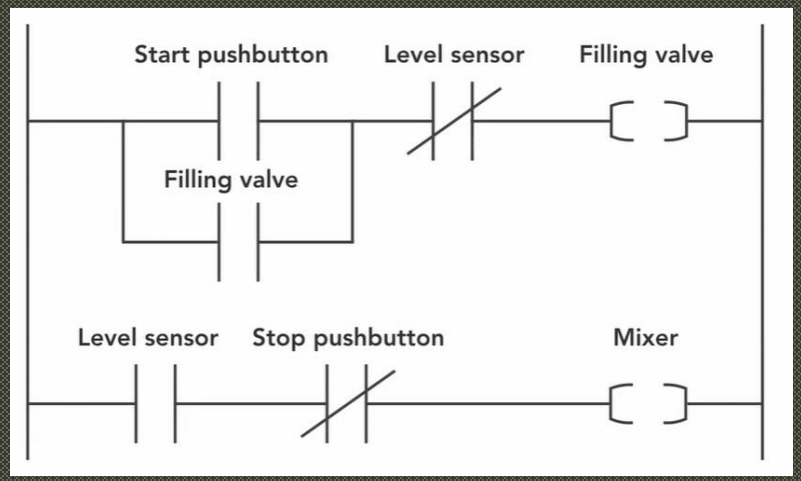
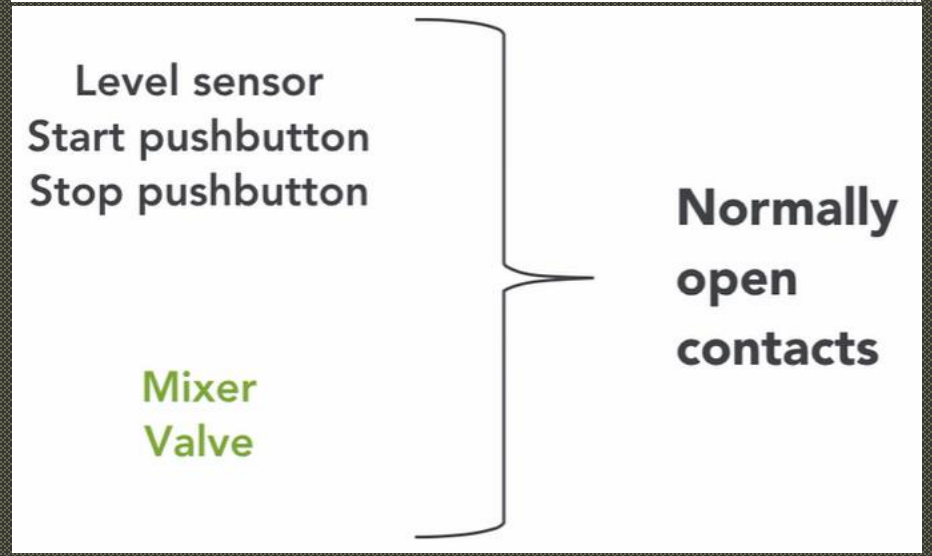
Example 3

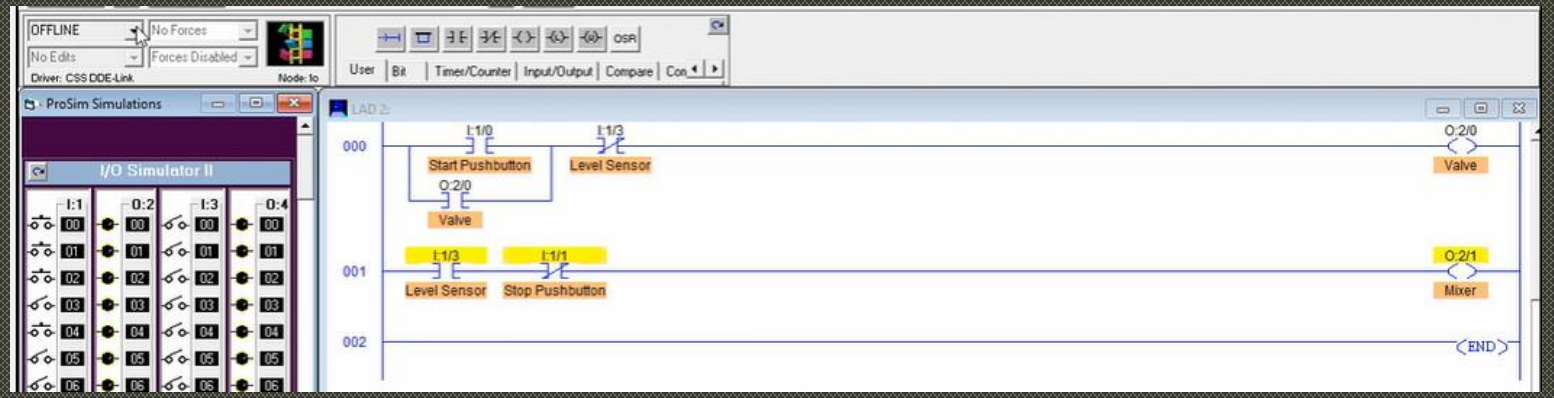
A start pushbutton to open a valve to fill the tank.
A level sensor to indicate a certain level of liquid in the tank: close the valve and start the mixer.
The mixer stays on until the stop pushbutton is pressed.





- Identify the main issue with this logic implementation





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Example 4 – Converting Relay Schematics into PLC Ladder Programs

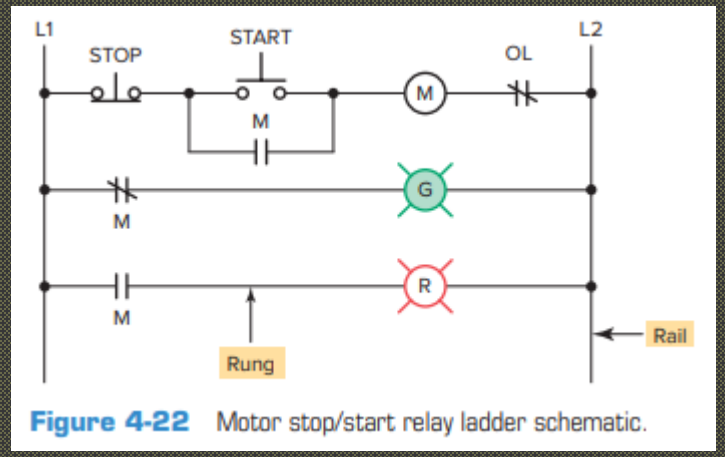

Figure 4-22 Motor stop/start relay ladder schematic.

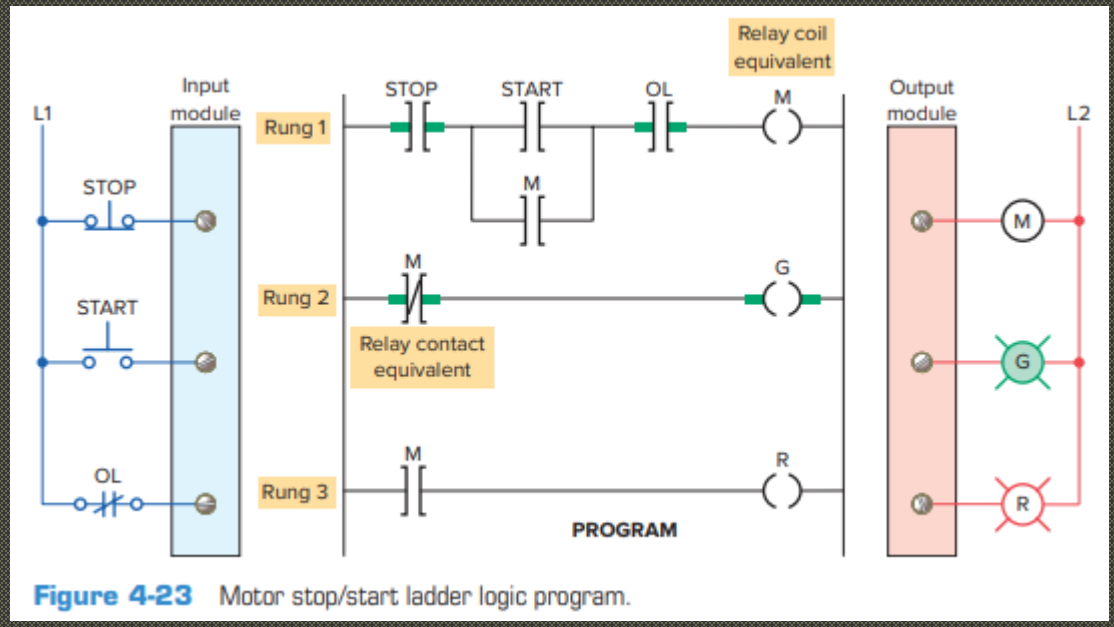

Figure 4-23 Motor stop/start ladder logic program.

(Frank D. Petruzella Programmable Logic Controllers 4th edition)

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Example 5 – Converting Relay Schematics into PLC Ladder Programs

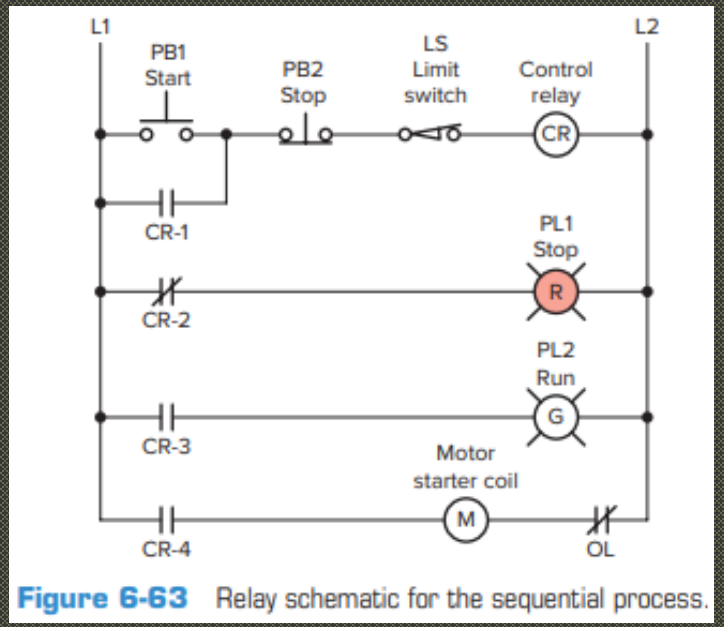

Figure 6-63 Relay schematic for the sequential process.

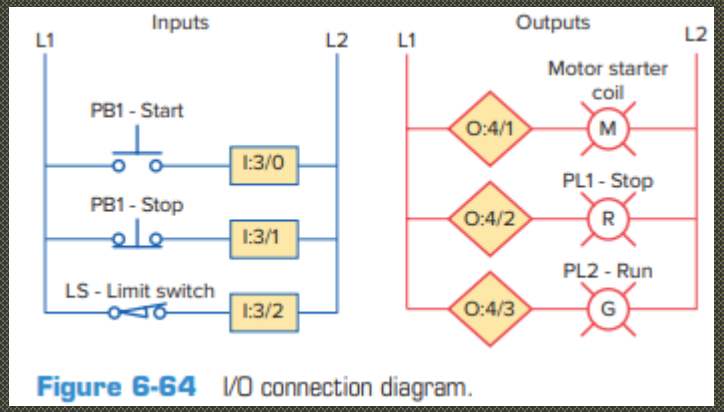

Figure 6-64 I/O connection diagram.

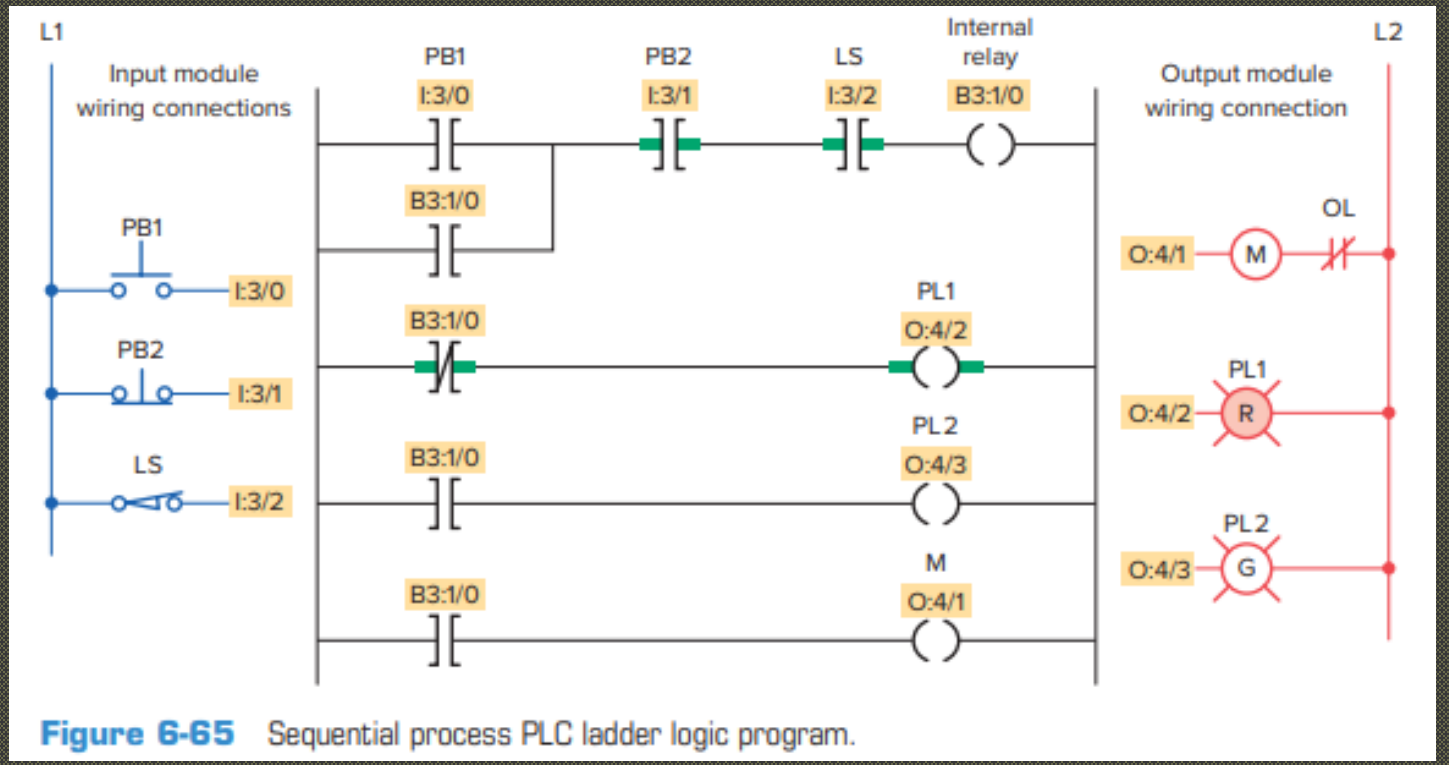

Figure 6-65 Sequential process PLC ladder logic program.

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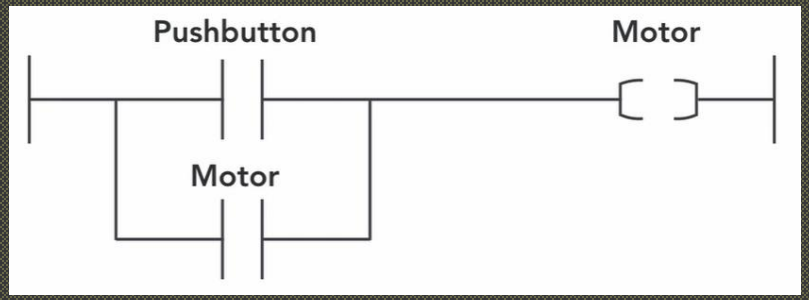
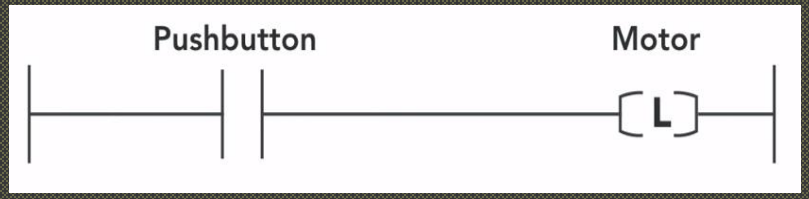
HUMBER

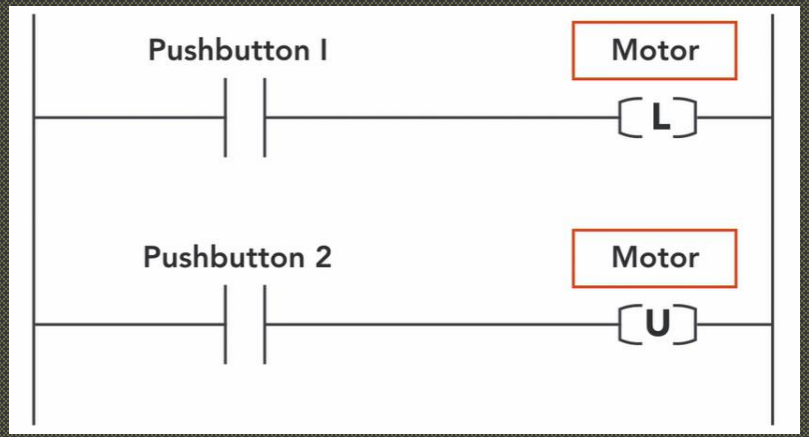
LATCH AND UNLATCH INSTRUCTIONS

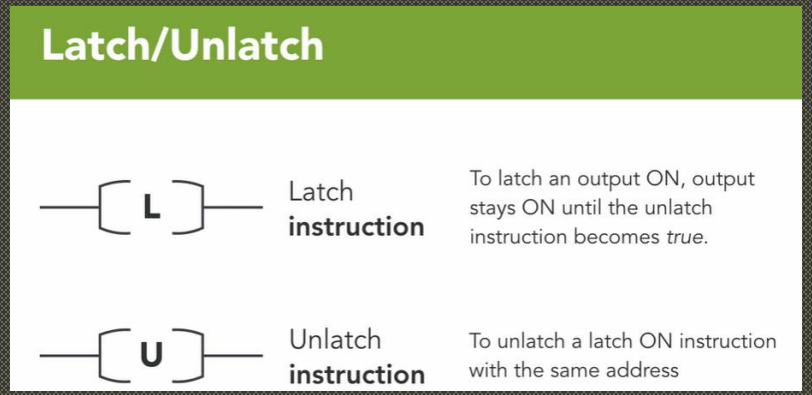
The Latch (OTL) and Unlatch (OTU) instructions serve as concise alternatives to holding logic,

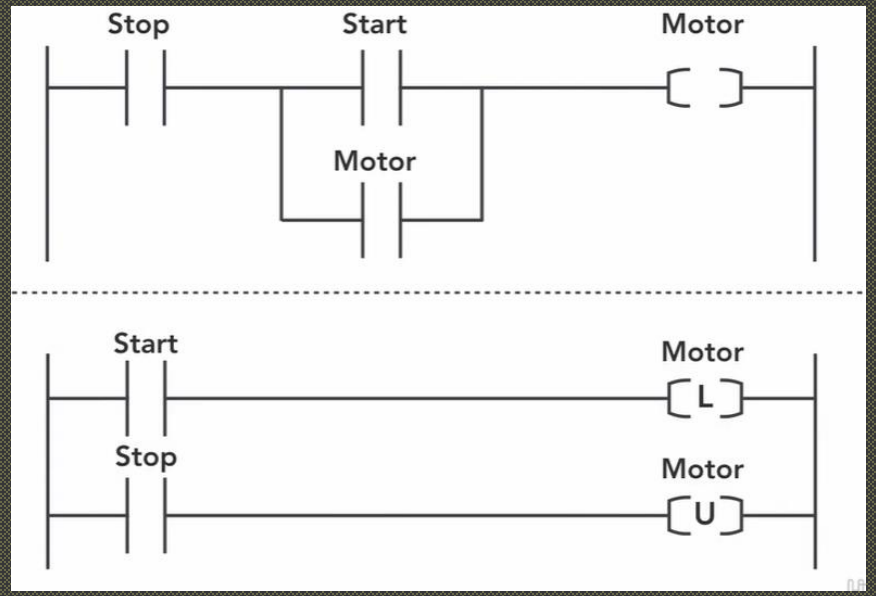
- Always operating in tandem within the program and having the same address.
- They are retentive instructions. What does it happen when power goes off?











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HUMBER

LATCH AND UNLATCH INSTRUCTIONS

- OTL must always be accompanied in the program with the OTU having the same address. Moreover, the OTL is a retentive instruction, which means that the bit latched in the program will stay latched until the OTU instruction is executed, even if the processor mode is changed from RUN to PROGRAM, or if the PLC loses the power.

- The return to the RUN mode may be dangerous and contain very unpredictable consequences, such as automatic unexpected restart of motors or opening of valves. The latch types of controls must be carefully analyzed and if necessary, automatic unlatch condition must be programmed to avoid unexpected working modes.

Command	Name	Symbol	Description
OTL	Output latch	(L)	OTL sets the bit to "1" when the rung becomes true and retains its state when the rung loses continuity or a power cycle occurs.
OTU	Output unlatch	(U)	OTU resets the bit to "0" when the rung becomes true and retains it.

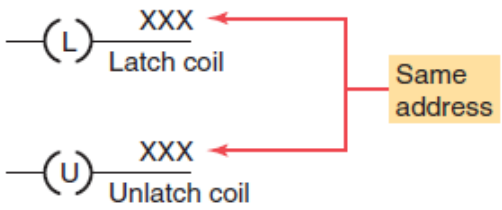

Figure 6-48 Output latch and output unlatch instruction.

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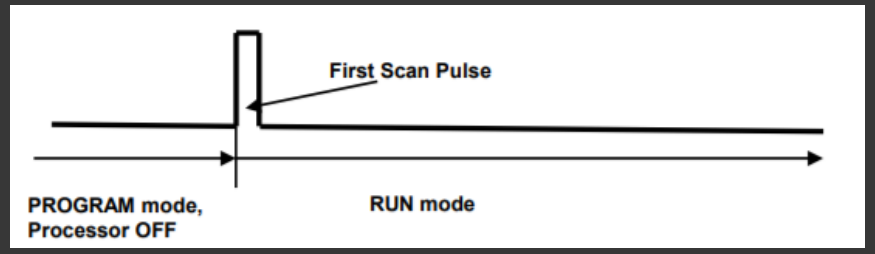
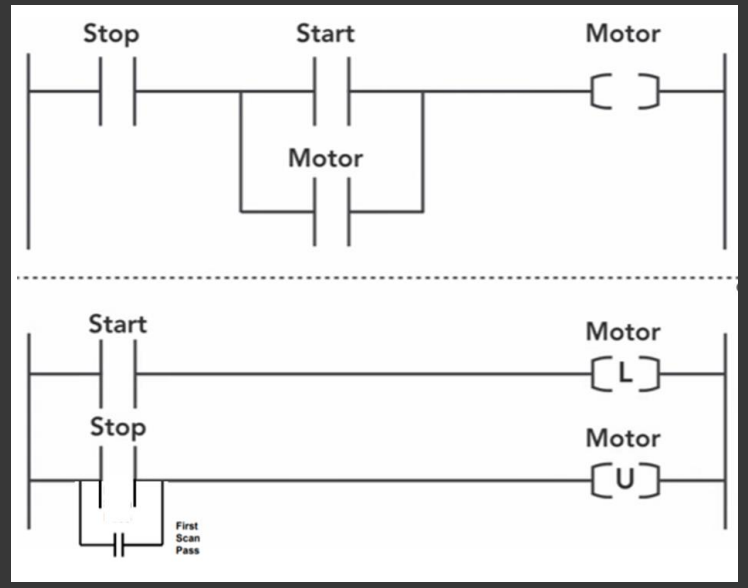
LATCH AND UNLATCH INSTRUCTIONS

One of the most effective ways to unlatch automatically the latched address is the implementation of **First Scan Pass status bit (S:FS** – Rockwell addressing). This bit turns ON every time the processor switches to the RUN mode, stays for the first scan only and stays OFF the rest of time. **S:FS - First Scan Pass status bit**





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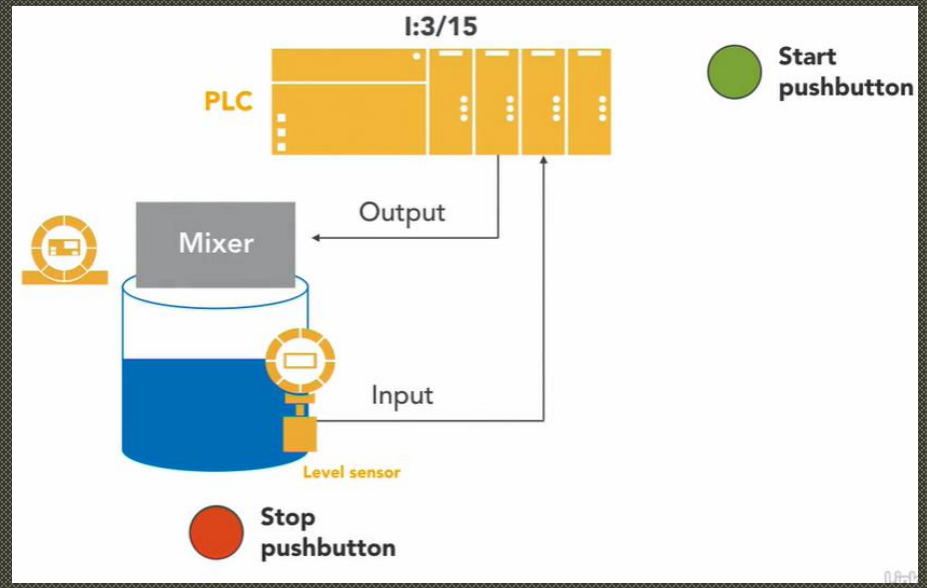
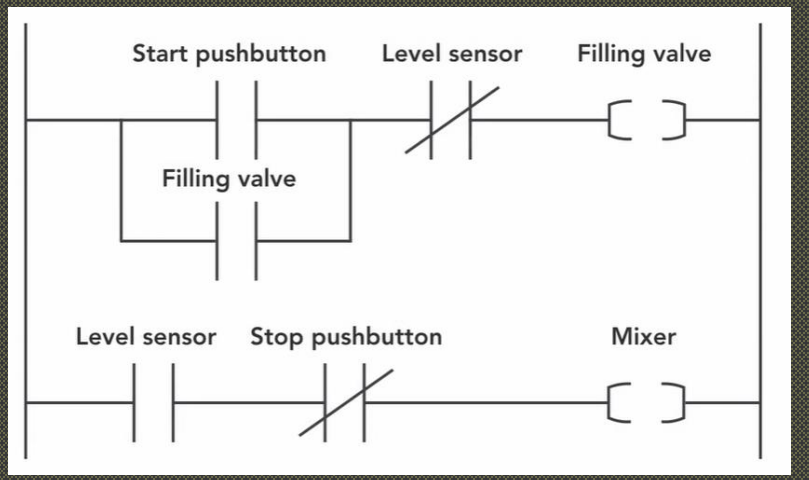
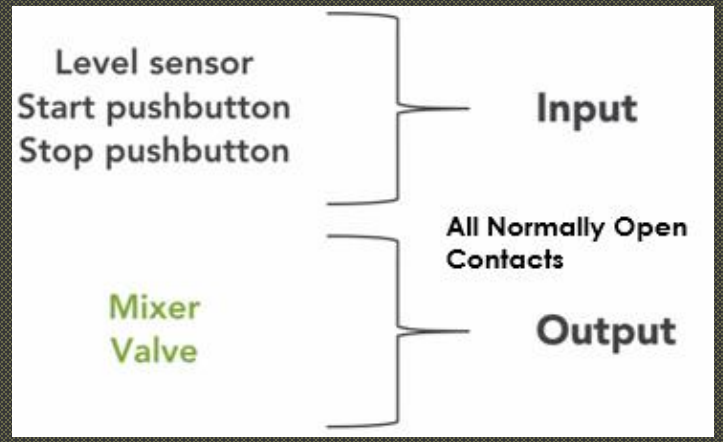
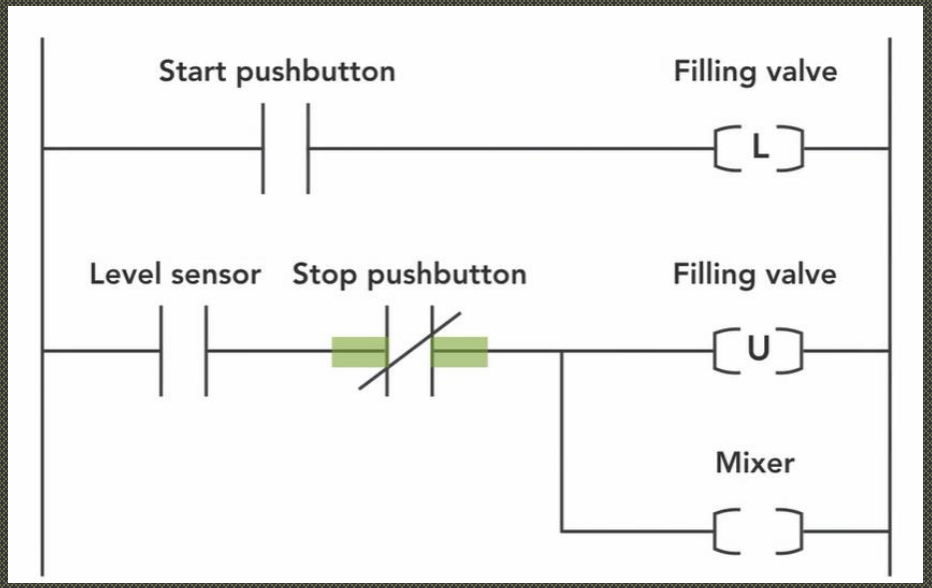
LATCH AND UNLATCH INSTRUCTIONS -Example









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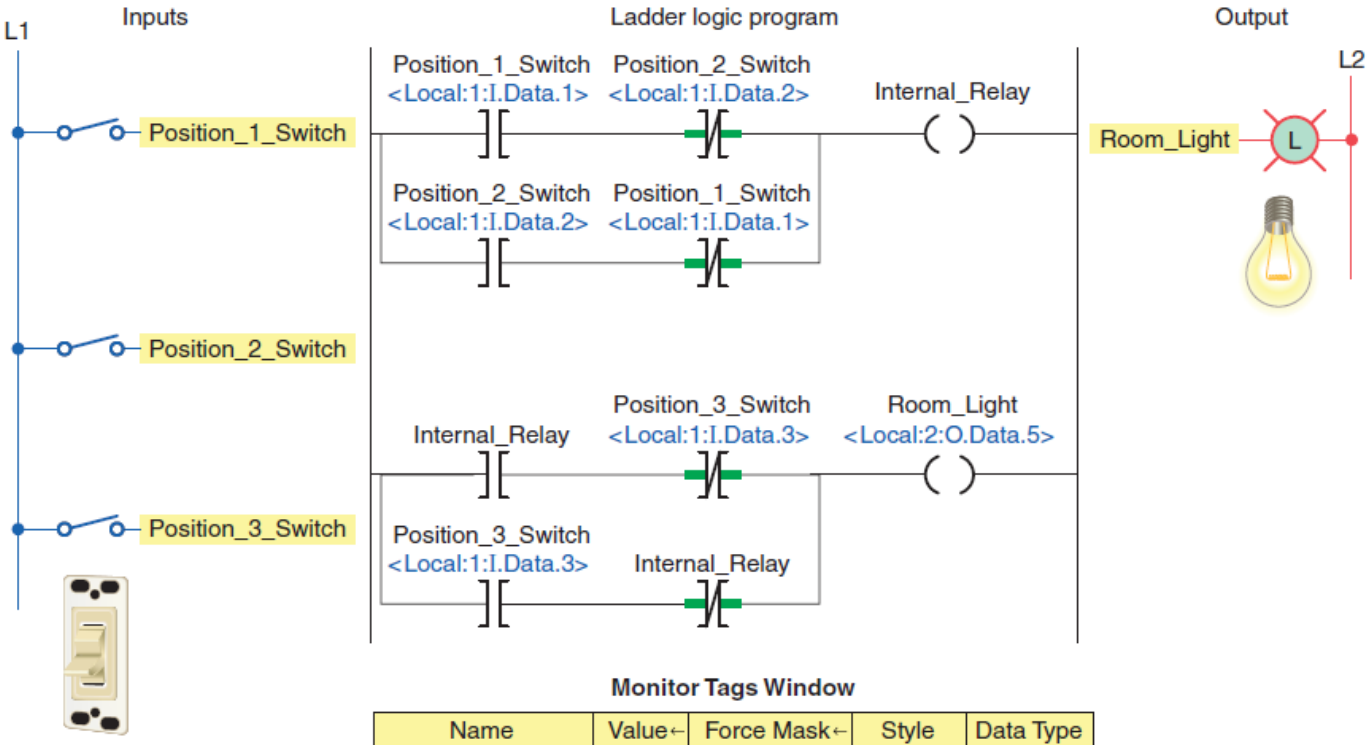
XIC, XIO and OTE INSTRUCTONS

Case Study – Room Light Control

An internal relay is used to turn on/off the room light from three different entrances without requiring real-world output.

- When all input switches are open:
  - The status value stored in memory for all tags is 0.
  - The room light remains off.
- Closing the Position_1_Switch:
  - Changes the status of its XIC instruction from false to true.
  - Establishes logic continuity for Rung 1.
- The status of the internal relay coil and its XIC contact changes from false to true:
  - This establishes logic continuity for Rung 2.
  - The room light turns on.
- A change in the state of any input switches will alter the current state of the room light.



Monitor Tags Window

Name	Value←	Force Mask←	Style	Data Type
Internal_Relay	0		Decimal	BOOL
Position_1_Sw...	0		Decimal	BOOL
Position_2_Sw...	0		Decimal	BOOL
Position_3_Sw...	0		Decimal	BOOL
Room_Light	0		Decimal	BOOL

Figure 15-36 Internal relay to implement on/off control of a room light from three different entrances.

HUMBER

(Frank D. Petruzella Programmable Logic Controllers 4th edition)

XIC, XIO, OTE, OTL and OTU INSTRUCTONS

Case Study – Motor Level Control

Three modes of operation to be programmed:

- **OFF Position** - The water pump will *stop* if it is running and will *not* start if it is stopped.
- **Manual Mode** - The pump will start if the water in the tank is at any level except low.
- **Automatic Mode** - If the level of water in the tank *reaches a high point*, the water pump will *start* so that water can be removed from the tank, thus lowering the level.
  - When the water level *reaches a low point*, the pump will *stop*.
- **Status Indicating Lights**
  - Water pump running light (green)
  - Low water level status light (red)
  - High water level status light (yellow)

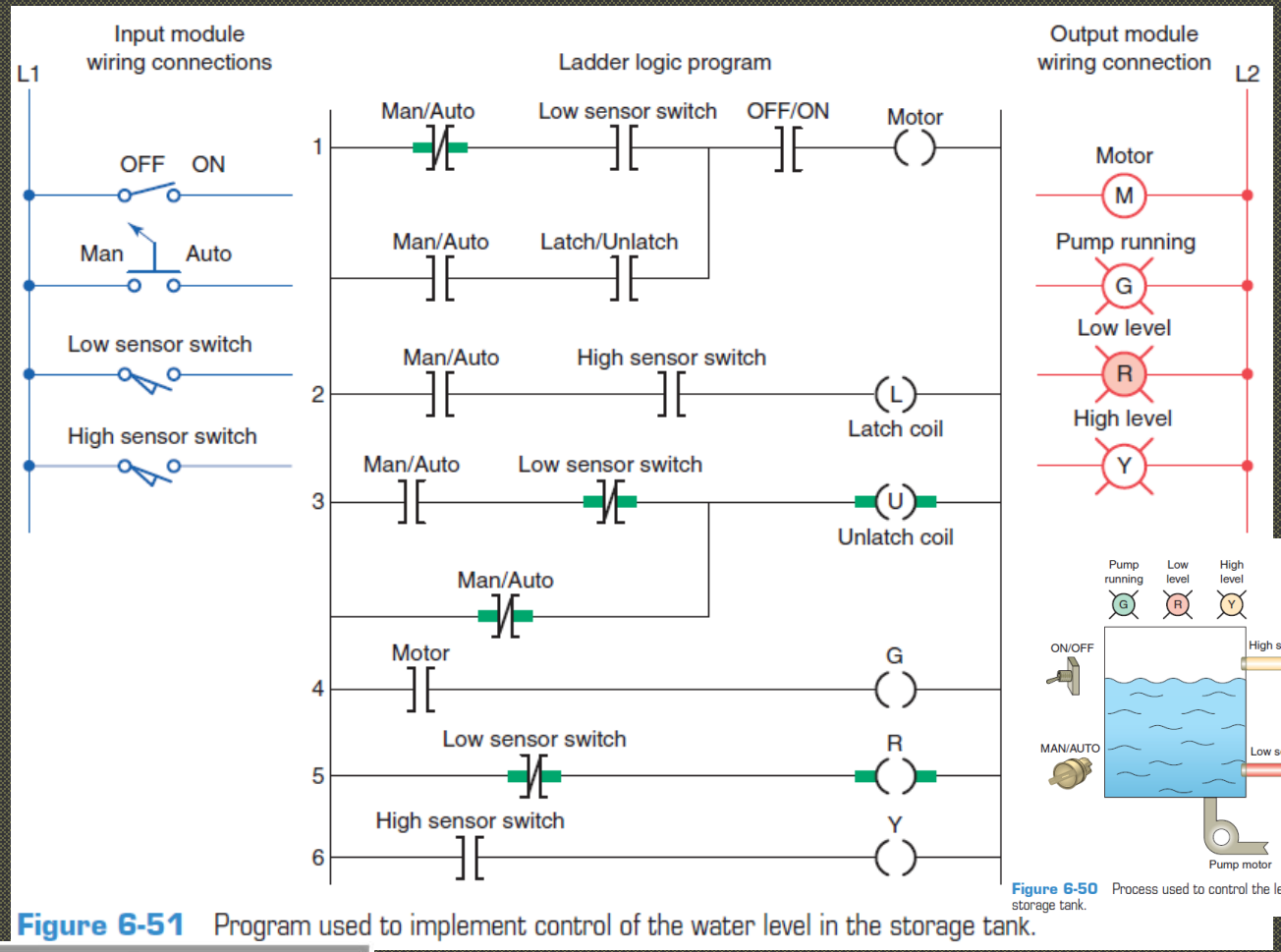
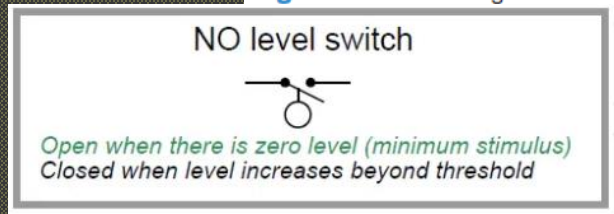


Figure 6-51 Program used to implement control of the water level in the storage tank.

Figure 6-50 Process used to control the level of water in a storage tank.



(Frank D. Petruzella Programmable Logic Controllers 4th edition)

XIC, XIO, OTE, OTL and OTU INSTRUCTONS

Case Study – Motor Level Control

- An internal storage bit is used for the latch and unlatch with the same addresses.
- The rung 1 Examine-on instruction addressed to the OFF/ON switch prevents the pump motor from starting under any condition when in the OFF (open) state.
- In the MAN mode, the rung 1 Examine-on instruction addressed to the low sensor switch allows the pump motor to operate only when the low-level sensor switch is closed.
- In the AUTO mode, whenever the high sensor switch is momentarily closed the Examine-on instruction of rung 1 addressed to it will energize the latch coil. The pump will begin running and continue to operate until the unlatch coil is energized by the rung 3 Examine-off instruction addressed to the low sensor switch.
- The pump running status light is controlled by the rung 4 Examine-on instruction addressed to the motor output.
- The low-level status light is controlled by the rung 5 Examine-off instruction addressed to the low sensor switch.
- The high-level status light is controlled by the rung 6 Examine-on instruction addressed to the high sensor switch.

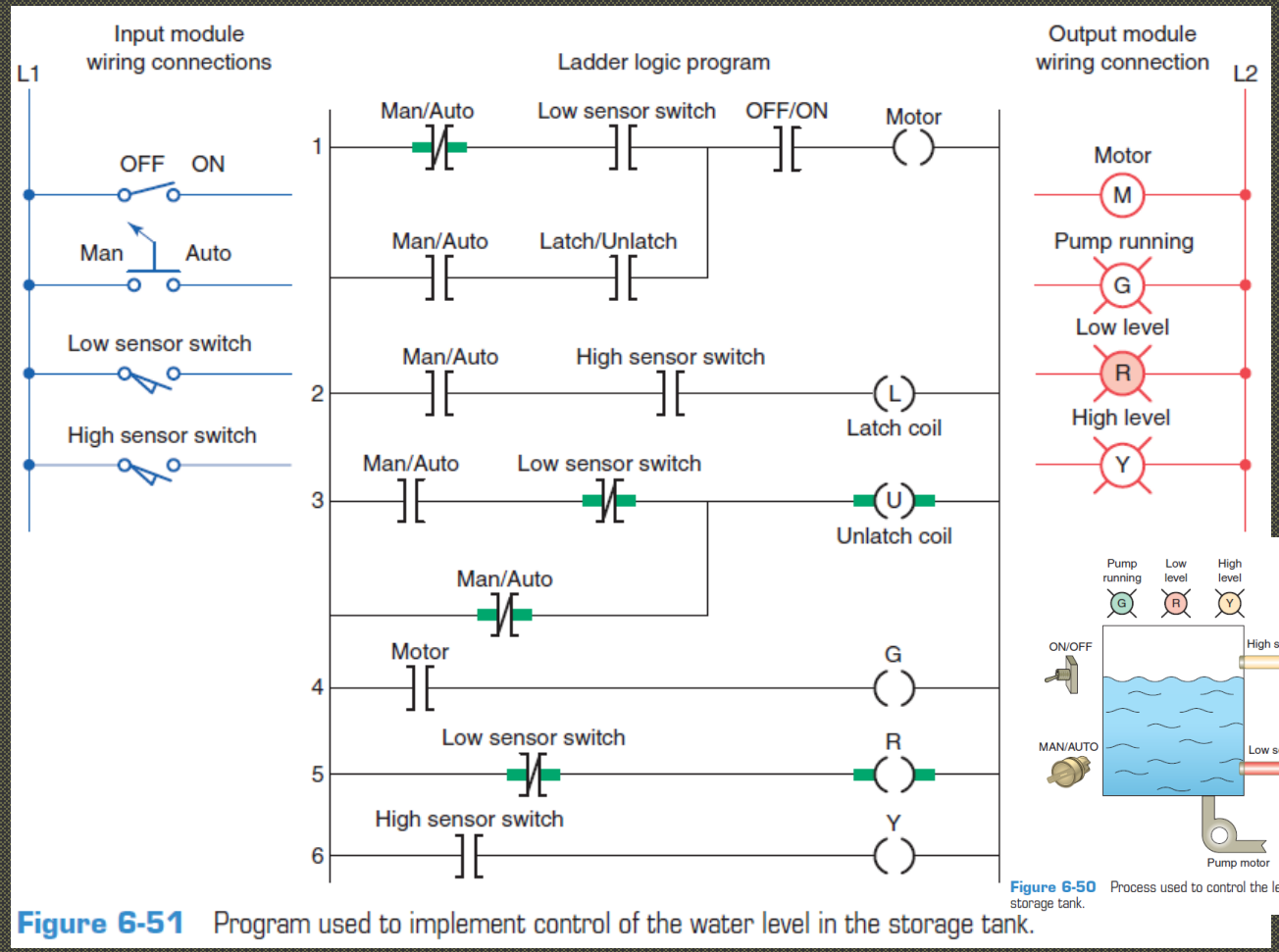


Figure 6-51 Program used to implement control of the water level in the storage tank.

Figure 6-50 Process used to control the level of water in a storage tank.

Man	OFF
Auto	ON

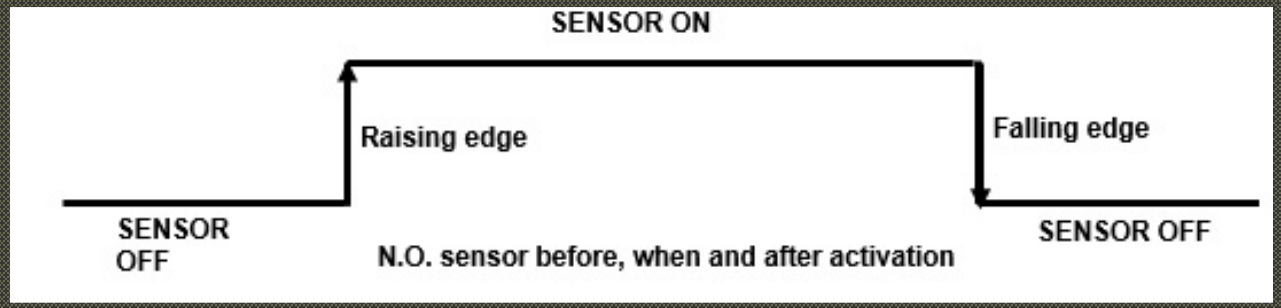
(Frank D. Petruzella Programmable Logic Controllers 4th edition)

HUMBER

RISING AND FALLING EDGE SEPARATION FROM THE SIGNAL

Separation of raising/leading and falling/trailing edges of the signal is one of very powerful features of PLC software, which finds a great number of applications in the programming. The idea of the separation is based on necessity to neglect the whole signal and use only either the rising or falling edges depending on the application.

- Imagine a normally open sensor that is activated by an object. The sensor will produce the following shape of the signal:



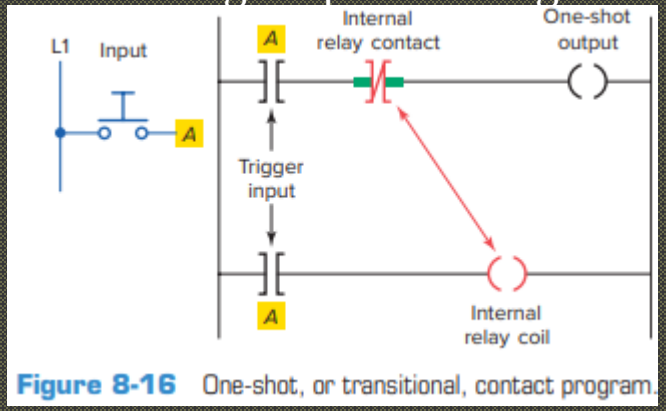
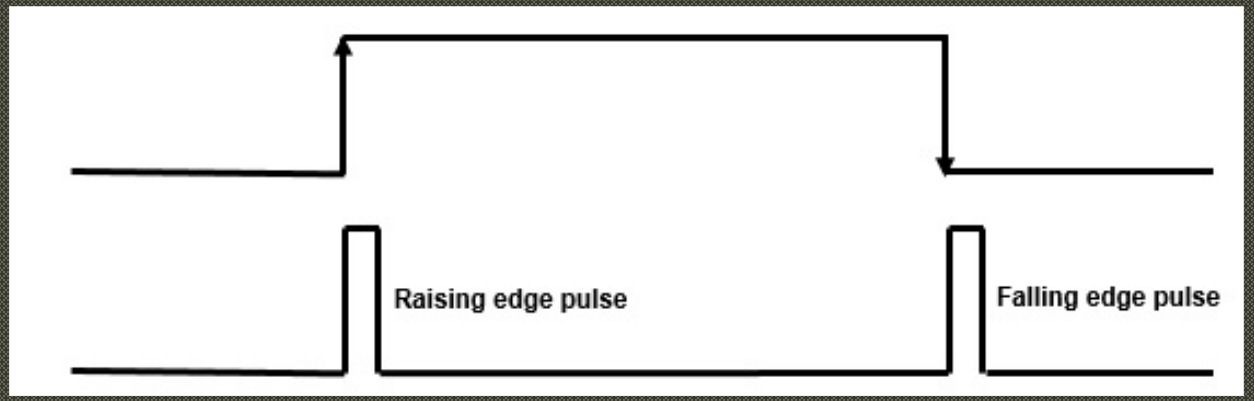


Figure 8-16 One-shot, or transitional, contact program.

(Frank D. Petruzella Programmable Logic Controllers 4th edition)

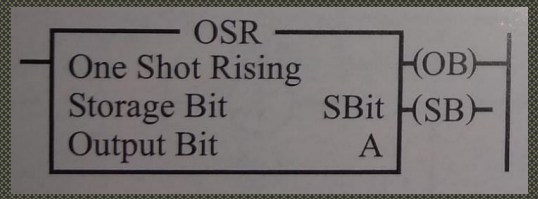
- **Raising edge** is a transition from low level of the signal to its high level, while **Falling edge** is the high to low transition. The separation of edges is made by creation of pulses which have a duration of one scan.

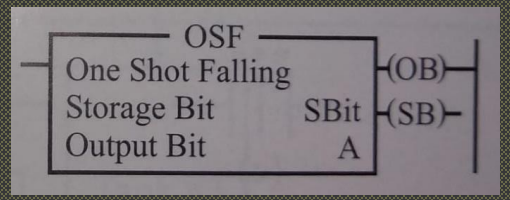


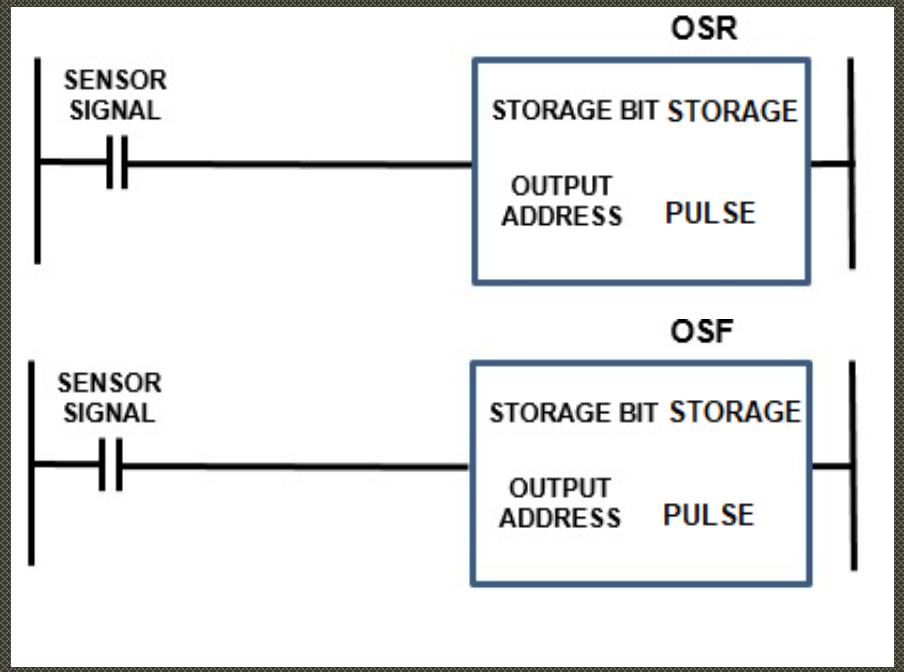
HUMBER

RISING AND FALLING EDGE SEPARATION FROM THE SIGNAL

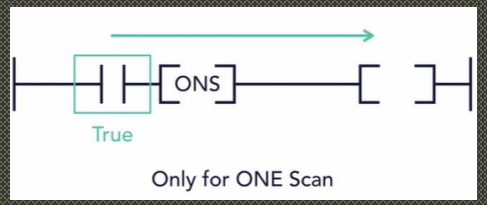
- Rockwell provides two instructions (not for all models) **OSR – One Shot Rise** and **OSF – One Shot Fall** for both transitions.

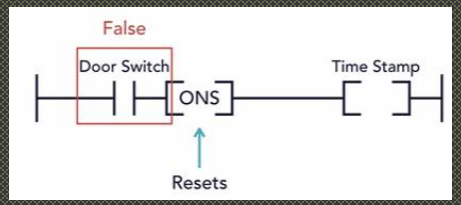


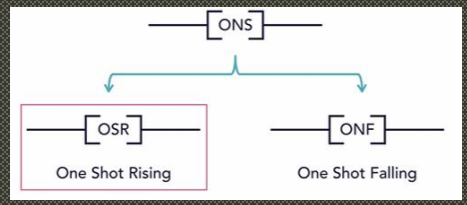




- The OUTPUT ADDRESS (PULSE Tag) corresponds to the Rising or Falling Edge Pulse depending upon the instruction.





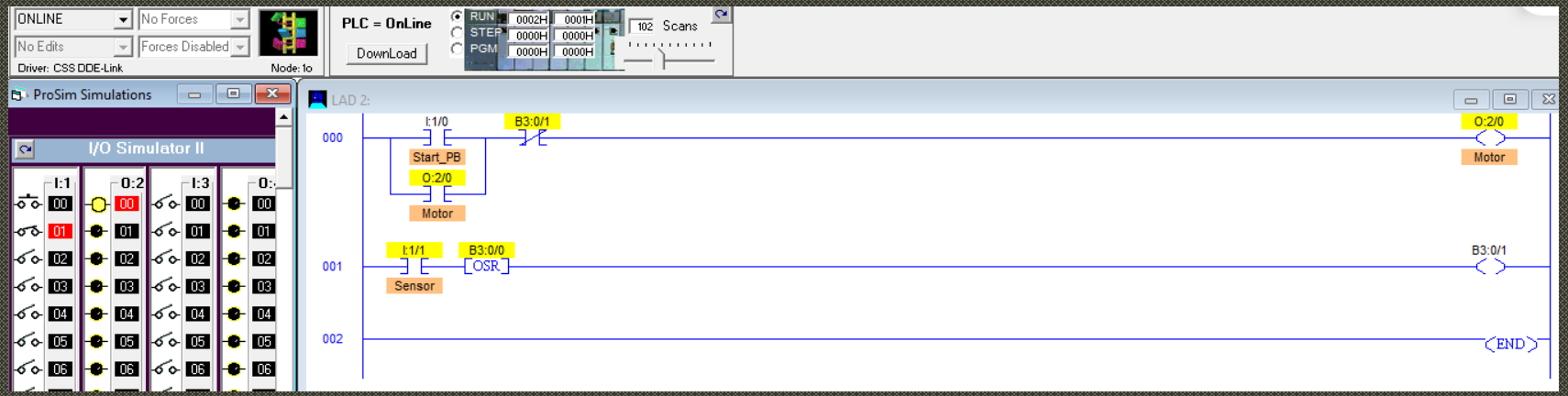


HUMBER

RISING AND FALLING EDGE SEPARATION FROM THE SIGNAL

OSR and OSF Application Problems

Problem 1. N.O. Start pushbutton turns ON a motor, which operates a conveyor belt. Motor is supposed to be stopped when a box locating on the conveyor belt activates a N.O. optical sensor. After visual inspection of the box, the operator restarts the motor, pushing the Start pushbutton. Write an RSLogix5000 program.



HUMBER

RISING AND FALLING EDGE SEPARATION FROM THE SIGNAL

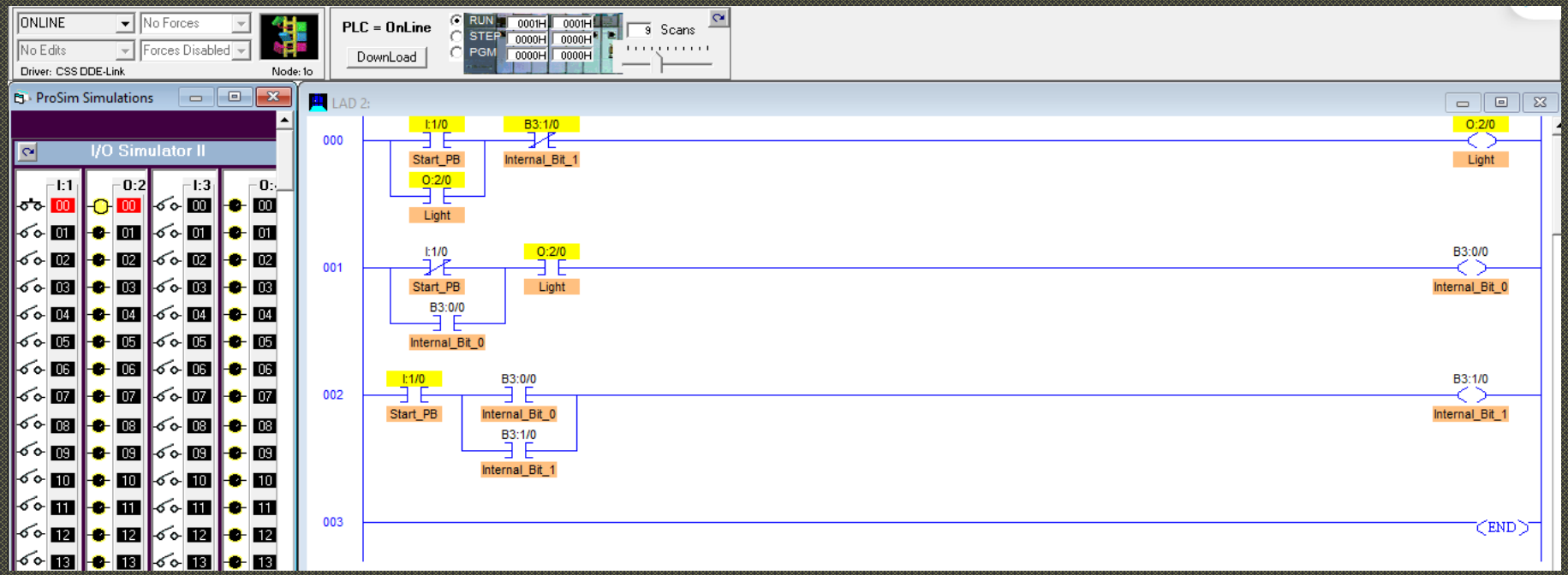
OSR and OSF Application Problems

Problem 2. Repeat the Problem #1 but stop the box immediately after it passes the optical sensor.

RISING AND FALLING EDGE SEPARATION FROM THE SIGNAL

OSR and OSF Application Problems

Problem 3. Write a program to turn ON and OFF a light with a single pushbutton. The light must stay ON after pressing and releasing the button first time. It will turn OFF after the button is pressed and released second time. Use XIC, XIO, OTE and OSR instructions only.

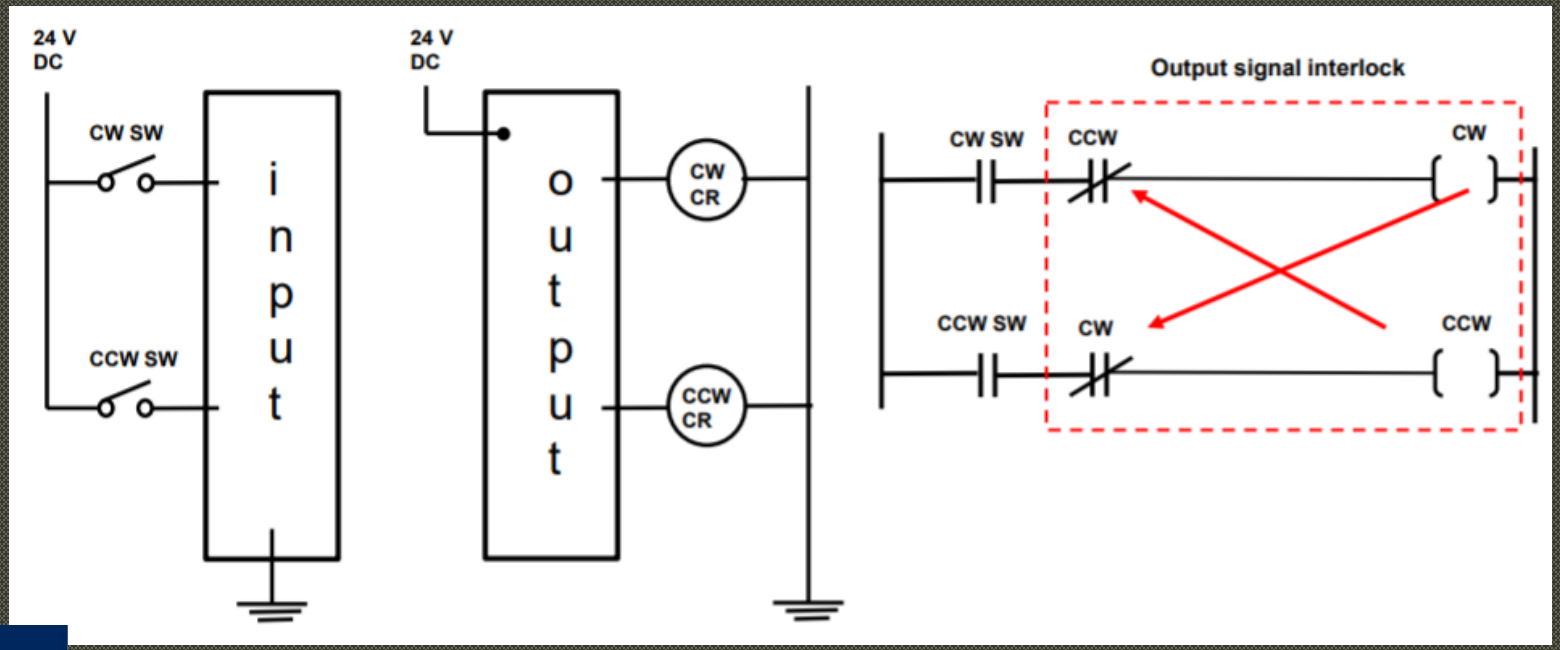


HUMBER

SIGNAL INTERLOCK

For many practical applications where two objects are not allowed to work concurrently, the signal interlocking guaranties their separate functionality.

Consider a reversible motor that provides a rotation of the shaft in both directions: clockwise CW and counterclockwise CCW. Two switches: CW SW and CCW SW are connected to the input terminals of the PLC. The following will describe the motor control logic with the output signal interlocking. With this logic, only one output can be turned ON, even if both switches are ON.



HUMBER

PROGRAMMABLE LOGIC CONTROLLERS

Basic Ladder Logic Programming

Erickson, K. (2016) Programmable logic controllers: An emphasis on design and application (3rd edition). Rolla MO: Dogwood Valley Press.

Chapter 2.6 – 2.8

Thank you!

Discussions?