Electrical Tech Note — 352

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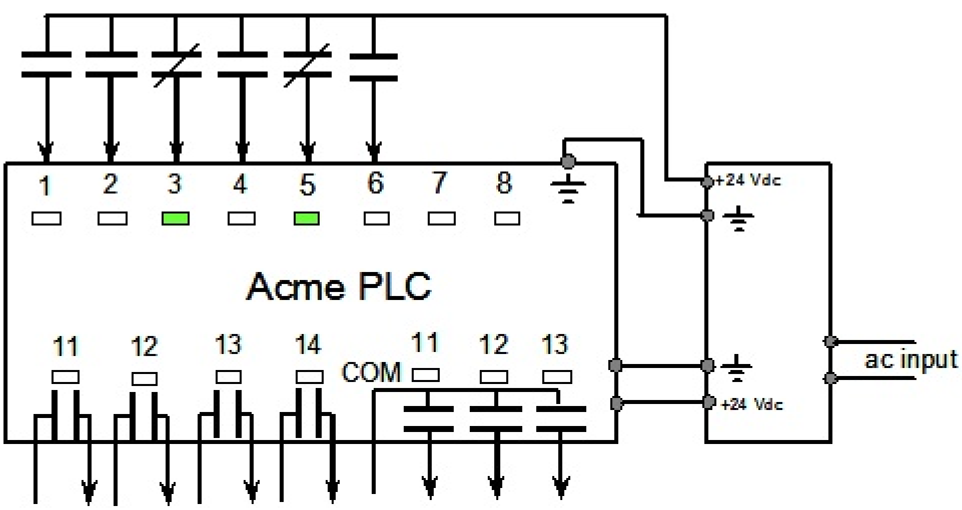
Programmable Logic Controller (PLC) Basics[1]

With a conventional hard wired control system it is necessary to complete a circuit in order to energize a device such as the solenoid coil in a controller. In the case of a programmable logic controller (PLC) all of the inputs are simply connected to the input ports. They will provide a logic state of zero (0) or one (1) to the input ports. Decisions will be made by a central processing unit which will control the output ports. In most cases the outputs are either solid state switches that are open and close a circuit that supplies a solenoid in a controller, operates a pilot light, or in some cases operates a device directly. Sometimes control power is supplied to a common terminal that supplies several output ports. When the PLC directs the port to close, power is supplied at the output port. In these cases, the output port can supply ac power or dc power depending upon the type of power desired and what is supplied to the output port common terminal. Most PLCs run on 24 volts dc and a dc power supply is also a necessary part of the system. A general schematic diagram of a PLC installation is shown in the diagram.



The remainder of this Tech Note will discuss common control strategies and show a conventional control circuit. The conventional control circuit actually completes a path for current to flow to activate a solenoid that turns on the device or motor. In the case of a PLC, instructions in the form of a ladder diagram are developed indicating which input ports are involved in the decision and which output port is to be controlled. An actual circuit is not necessarily completed. The PLC is told to look for a zero (0) or one (1) state at the input port and told what action is to be taken. The PLC can be told to turn on a device is the status on an input port is either one or zero.

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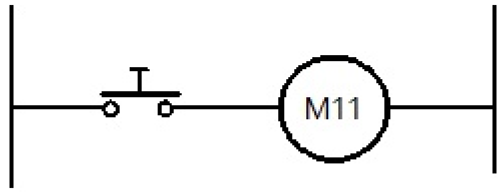
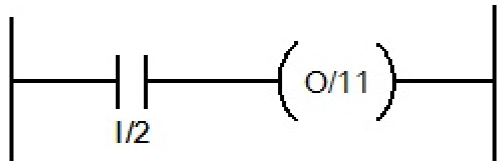
Programming a simple two-wire circuit: The diagram shows a normally open (NO) push button used to complete a circuit for a solenoid in a controller. Since the PLC is programmed to make decisions based upon the status of an input port, it will be shown how the normally open push button can act like it is normally open (NO) or normally closed (NC). Each input and each output must be assigned an address and connected to the correct PLC port. Obviously "**I**" is for input and "**O**" is for output.

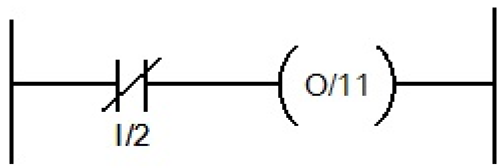
Assume the device connected to input port 2 is a normally open push button. The status of input port 2 should be zero unless the push button is pressed.

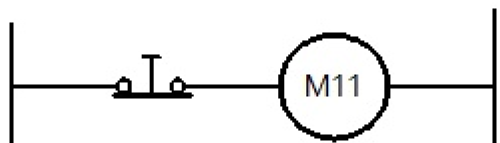


Program the PLC based upon the condition when the designated output is to be turned off. If the condition is satisfied (true) then the designated output will remain off. If the statement is not satisfied (false) the PLC will turn on the designated output. Note in the ladder diagram that the PLC is told to keep O/11 open (off) if there is a zero state at I/2. The statement is true and O/11 remains open. Pressing the push button will put a one state at I/2 and the O/11 switch will close thus energizing the external device connected to O/11.



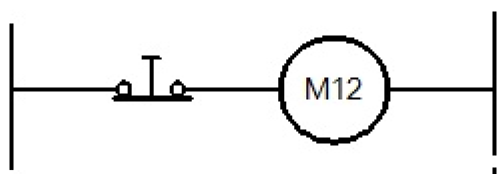
Now assume the PLC was told it should look for a one state at I/2 for O/11 to remain off. Keep in mind that a normally open (NO) push button is still connected to input port I/2. The ladder diagram is not satisfied and the switch at O/11 closes thus energizing the attached device. In order to stop the device (open O/11) it is now necessary to push the button. A normally open push button can be programmed to act like a normally closed push button.



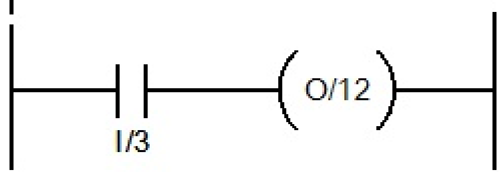


Acts like this

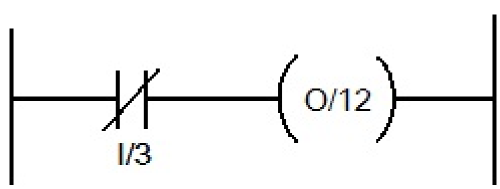
Now the push button at input port 3 (I/3) is normally closed (NC) as shown in the diagram. There will be a one state at I/3 unless the push button is pressed.



First the PLC is programmed to be looking for a zero state at I/3 to keep the switch open (off) at output port 12 (O/12). The statement is false and the switch at O/12 will close energizing the device connected to O/12. This example is important. For a normally closed (NC) push button to act like a stop button in a three-wire control circuit it is necessary to program it to be normally open.

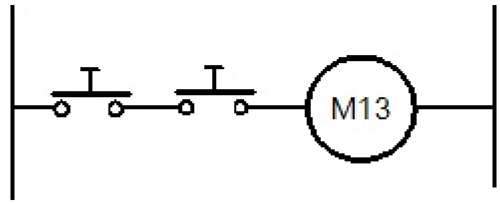


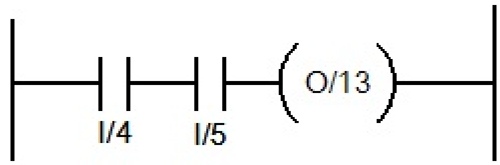
The same normally closed push button is connected to I/3, and the PLC is programmed to be looking for a one state at I/3. The statement is satisfied and the output switch remains open (off). Push the NC button connected to I/3 and the status of I/3 will become zero, the off condition is false, and the switch at O/12 will close thus energizing the device attached.



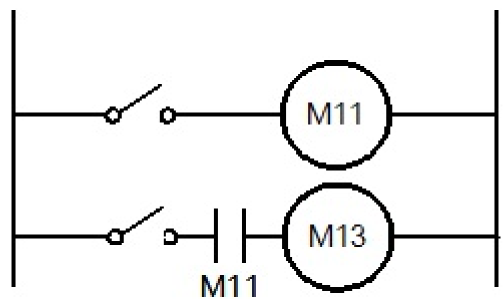
Multiple Input Devices: For the following example assume it is to be necessary to press two normally open push buttons in order to energize the device connected to O/13. The conventional ladder diagram is shown in the diagram.

Remember to tell the PLC the status of I/4 and I/5 when the device attached to O/13 is to be off (switch open). The two normally open push buttons are shown connected in series.

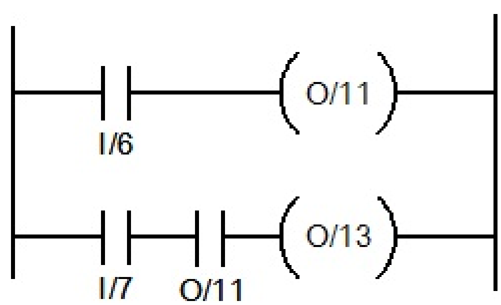




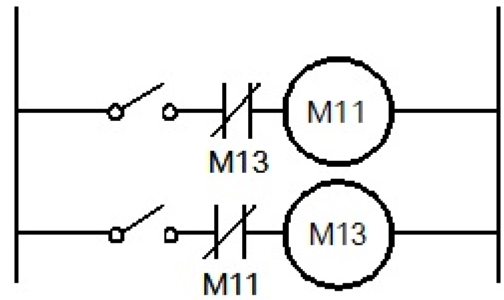
Sequencing Devices: Next assume it is to be necessary for the device at O/11 to be operating before the device attached to O/13 will operate. A ladder diagram is shown where simple toggle switches are used to turn on the loads. Note there is a normally open contact in the circuit of the device M13 that must close before device M13 will operate. The address on that contact is M11 which means the device at M11 must operate in order for the contact to close.



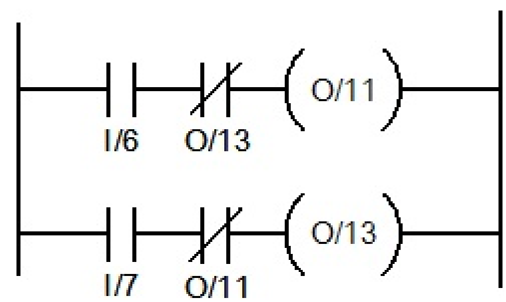
When the previous control circuit is programmed into a PLC no wiring of the extra normally open contact with the address M11 is required. Just add another set of contacts in the ladder diagram and give it the address O/11. Assume toggle switches are connected to I/O port 6 and 7. They are programmed into the ladder diagram as normally open contacts. When the toggle switch attached to I/6 is closed device M11 attached to O/11 will operate. The normally open contact with address O/11 in the circuit of device M13 will be false and will tell device M13 to turn on. The device will not turn on because toggle switch I/7 must also close. When both conditions are false, the device at O/13 will operate. This demonstrates how devices can be sequenced.



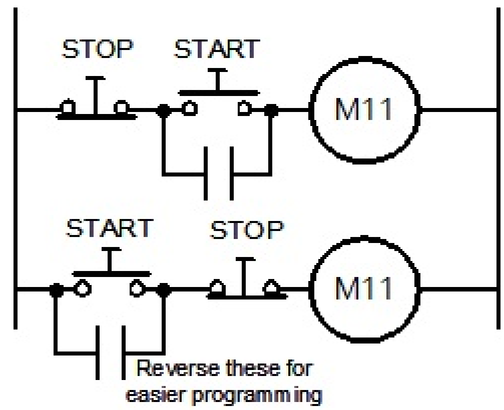
Interlocked Circuits: The next common control situation is where two or more devices are interlocked so that only one can operate at any one time. This is accomplished in an actual wired control circuit by placing a normally closed contact in each control circuit that is opened when the other device operates as indicated in the diagram.



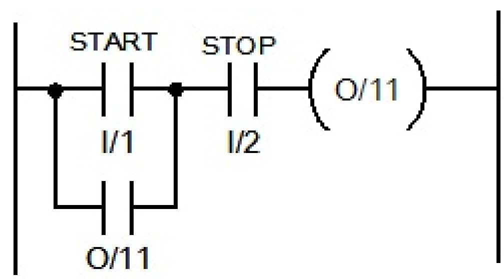
The ladder diagram to interlock two devices so that only one can operate at any one time is shown. Keep in mind that an actual circuit is not completed, but instead a set of logic conditions must be satisfied. The diagram shows the status for the devices to be off. To be off the normally closed contact in the circuit of device M11 is looking for a 1 state. A 1 state is not found, therefore, the result is that it tries to turn on the device attached to O/11 but cannot because I/6 is still open. When I/6 closes, the device at O/11 will operate. As soon as O/11 is at the 1 state, the normally closed contact with the address of O/11 that is programmed into the circuit of M13 will be satisfied because it is looking for a 1 state. The result is that it will act like an open switch and the device attached to O/13 will not operate. The same situation exists in reverse for the other control circuit. In this manner two devices can be interlocked so that one will not operate if the other is operating. The contacts with the addresses O/11 and O/13 do not actually exist in physical reality, they are programmed into the circuit.



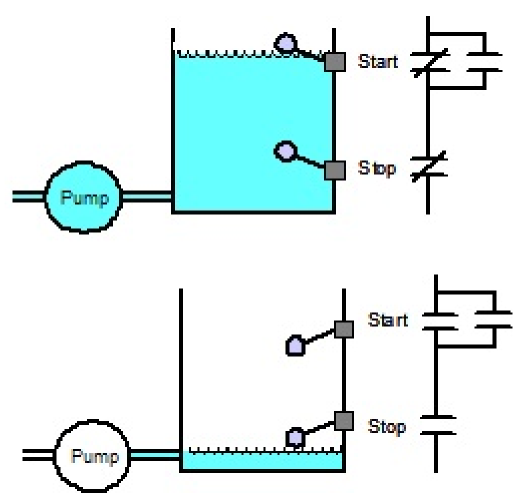
Three-wire Control Circuit: This is the type of circuit where one switch turns on a device and another switch turns off the device. This can be a start-stop push button station or it can be switches such as in the case where a tank is filled with one switch at the bottom to start the filling, and the other at the top to turn off the pump. A simple start-stop push button station to operate a device is shown in the diagram. When such a control system is actually installed it is customary to install the stop device first in the circuit. To simplify the programming of such a circuit into a PLC it is best to reverse the position of the start and stop devices. Note that a holding contact is wired in parallel with the start control device.



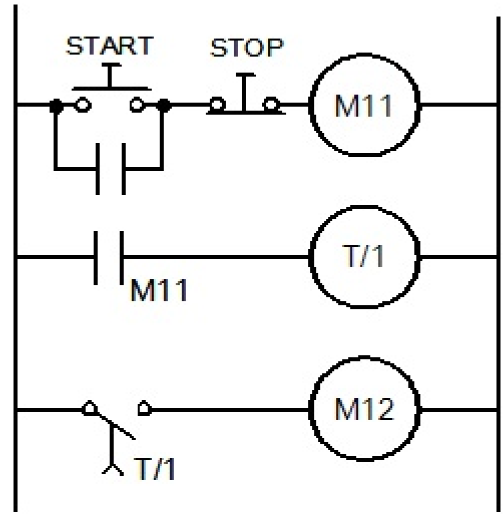
When programming the 3-wire control circuit a normally open push button will be run to one input port as the start and a normally closed push button will be run to another input port as the stop. It is recommended that a normally closed push button be used as the stop to that a 1 state must be at that port for the device to operate. If the push button should fail, a wire breaks or comes loose from a terminal the device will automatically stop. This is a safety issue. The stop push button can be normally open, but that technique is not fail safe. Note that the stop contact is programmed as normally open even though the actual push button is normally closed. This is done because we intentionally want the logic command to be false so the contact will tell the device to operate. The holding contact is programmed as a normally open contact connected in parallel with the start contact. The address for the holding contact is the same as the output port that is used to operate the device.



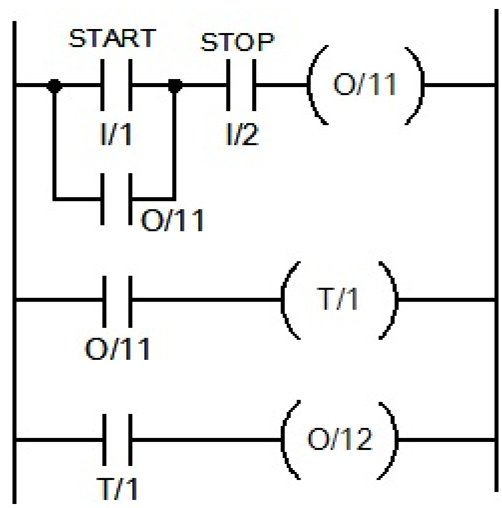
An example of a 3-wire control is a liquid container that is emptied with a pump with a float switch at the top to turn on the pump and another float switch at the bottom to turn off the pump. A diagram of the container is at the right where both float switches are closed when the container is filled with liquid, and both float switches are open when the container is empty. Notice that as the pump starts to empty the container the top float switch will eventually open, but the pump must remain operating until the bottom float switch opens. The top float switch is just like the start push button above. It must be bypassed with a holding contact for a conventional control system, but in the case of a PLC the holding contact is simulated by a one state at the output. The bottom float switch acts at the stop push button where a zero state will turn off the pump. The 3-wire control circuit is a frequently used control system.



Timers: Time delays can be programmed to turn on devices after a set time delay or they can be programmed to keep a device operating for a time period after other devices have been turned off. There are two types of time delays that can be programmed. One is instant reset or non-retentive which means that if the timing cycle is terminated the time will be reset back to zero. The other time delay is retentive which means the previous elapsed time is remembered if timing is terminated and the count will continue from the time that existed when timing was halted. With the retentive time delay a command must be provided that will reset the time to zero. The default type of time delay is different for various brands of PLCs. A typical time delay on energize circuit is shown where device M11 is started with a start-stop push button station and device M12 is started by the timer after the preset time delay.



The PLC program for the time delay on energize is quite similar to the actual wired time delay circuit except that an actual timer and time controlled set of contacts does not physically exist. In the second rung of the ladder diagram the normally open set of contacts has the address O/11 and when the time period has elapsed the normally open set of contacts that closes output O/12 has the address of the timer used which in this example is T/1.



In the case of a time delay on de-energize, one device continues to operate for a set time after some particular part of the process is terminated. The actual programming steps to accomplish this task are generally specific to the brand of PLC.