Create an Advanced PLC Program

Introduction:

Most industrial equipment operation must follow specific sequences. The sequence of operation is typically controlled by a Programmable Logic Control (PLC) processor. This lab exercise is designed to help students create a complex PLC program to control advanced machine operation. It includes OSHA anti-tie down circuit and cycle too long alarm timer.

Objective: Using PLC software, students should create a **ladder logic** program to control a simple machine sequence.

Equipment:

Advanced PLC trainer with motion devices.

For this lab, we are utilizing more advanced PLC trainers with motion elements including two cylinders and two electric motors. If the specific trainer does not have all the specified devices, some of the motion components might be substituted with a lights e.g. turning on an electric motor can be substituted by turning on an LED.
Below are links for some more advanced PLC trainers based on Allen-Bradley.

- Miniature Machine - Ultimate PLC Trainer - Conveyor Part Detection - Electrical Training - Allen Bradley (www.plccable.com)
  https://www.plccable.com/miniature-machine-ultimate-plc-trainer-conveyor-part-detection-electrical-training-allen-bradley/
- Amatrol - Portable PLC Learning System 990-PABCL1F (https://amatrol.com/)
  https://amatrol.com/coursepage/portable-hands-on-plc-training-for-compactlogix/

Procedures:

A very common production sequence involves two main steps:

- First securing/clamping a part
- Then running an operation on the part

An example of such operation is first clamping a part and then machining a hole using industrial drill, forming the part on a press brake, or spot welding parts together.
For this exercise we will create a more advanced machine that will include four motion devices (two double acting cylinders and two electric motors). For safety, we will create an anti-tie down circuit to force operator to press both push button simultaneously (within one second).

Two cylinders will indicate a clamping device (clamp close and clamp open) and movement of the operation device (drill up and down motion). Two electric motors will represent spinning of operation device (e.g. drill motor) and lubricating/cooling pump.

Input / Output (I/O) list should be as follows (see the picture below):

Inputs:

Sequence Start Push Button Left - **PB #1**
Sequence Start Push Button Right - **PB #2**
Alarm RESET Push Button - **PB #3**
Cylinder #1 Return Limit Switch - **Clamp Open (RET LSW)**
Cylinder #1 Extend Limit Switch - **Clamp Close (EXT LSW)**
Cylinder #2 Return Limit Switch - **Drill UP (RET LSW)**
Cylinder #2 Extend Limit Switch - **Drill DN (EXT LSW)**

Outputs:

Electric Motor #1 - **Drill Motor**
Electric Motor #2 - **Pump Motor**
Cylinder #1 Return Solenoid - **Clamp Open (RET SOL)**
Cylinder #1 Extend Solenoid - **Clamp Close (EXT SOL)**
Cylinder #2 Return Solenoid – **Drill UP (RET SOL)**
Cylinder #2 Extend Solenoid – **Drill DN (EXT SOL)**

Figure 1 -ssketch of sample drill machine
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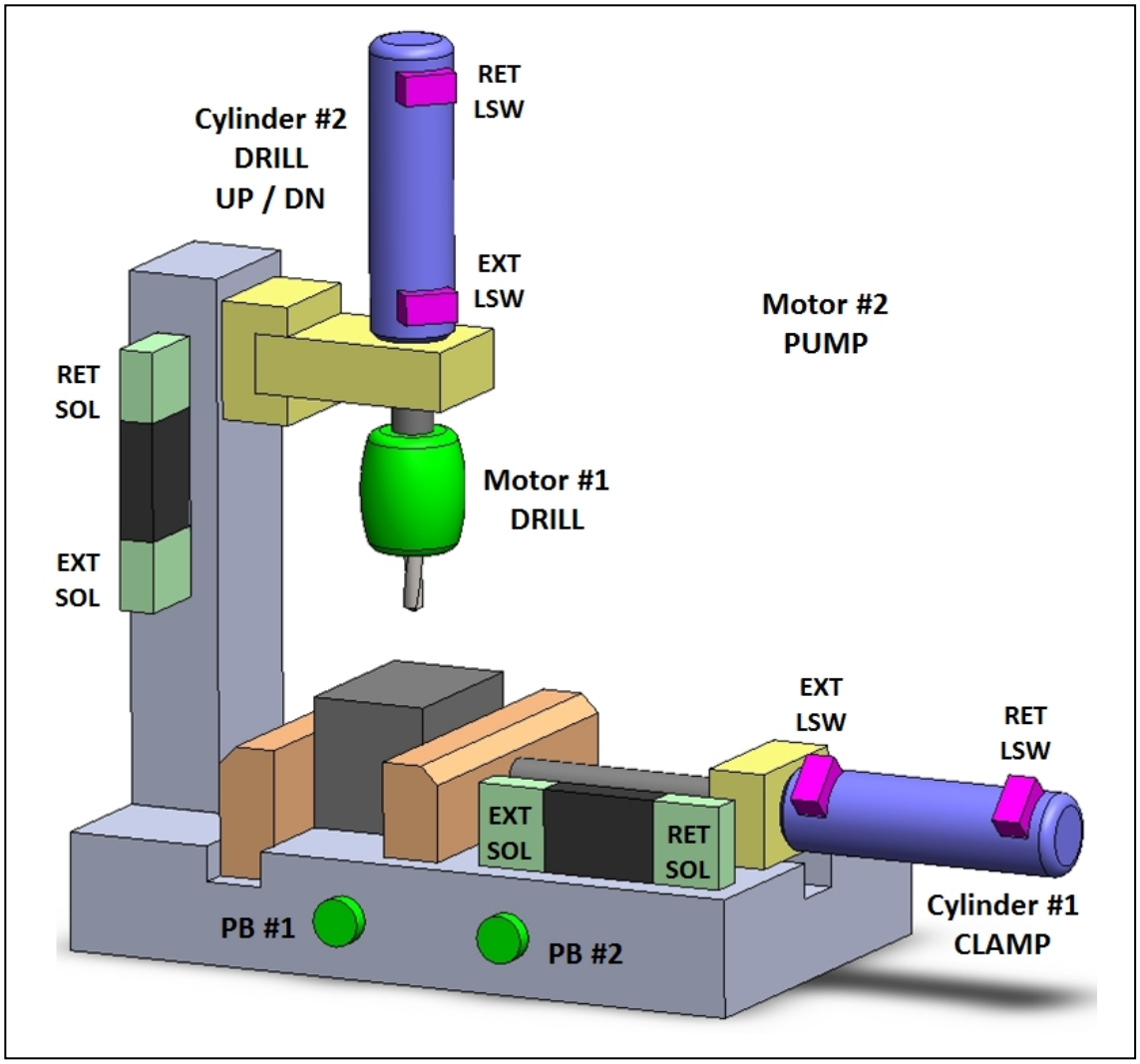

Figure 1 - Sketch of sample drill machine

The mechanical sequence of the machine:

1. Press **PB #1** and **PB #2** simultaneously (within one second) to clamp the part and start the drill motor (turn ON **Clamp Close SOL** and **Drill Motor).**
2. Once clamp is closed (**Clamp Close LSW** turns ON), start drilling and lubricating / cooling (turn ON **Drill DN SOL** and **Pump Motor**).
3. Run the lubricating/cooling pump (keep ON **Pump Motor**) for three additional seconds past the drill cycle done (**Drill DN LSW**).
4. Once the drilling process is done (**Drill DN LSW** turns ON), return the Drill to up position (turn ON **Drill UP SOL).**

Note: If the cycle takes too long (e.g. broken or dull drill), return the drill to the up position, stop the drill motor, and activate alarm light.

5. Once the drill returns (**Drill UP LSW** turns ON), turn off the drill (turn OFF **Drill Motor**), and open the clamp (turn ON **Clamp Open SOL**).
6. Once the clamp opens (**Clamp Open LSW** turns ON) and both **PB #1** and **PB #2** are open, the cycle is complete.

We will need to construct a PLC program with ladder rungs to perform the machine sequence as specified above. The ladder program is shown and explained below.

Rung #0, rung #1, and rung #2 are part of the anti-tie down function to comply with OSHA safety regulations (both cycle start push buttons must be pressed simultaneously to start each cycle).

Rung #0 – Pressing **PB #1** activates **Start Timer #1**.

Rung #1 – Pressing **PB #2** activates **Start Timer #2**.

Rung #2 – This will latch the **Cycle Start Latch Bit (B3/0)** only if there is no alarm and both push buttons are pressed within the one second time window (timer TT bit is only ON for timer duration/preset value). Note that if either push button is pressed too slowly or is tied down, both buttons must be released and pressed again to get the cycle started.

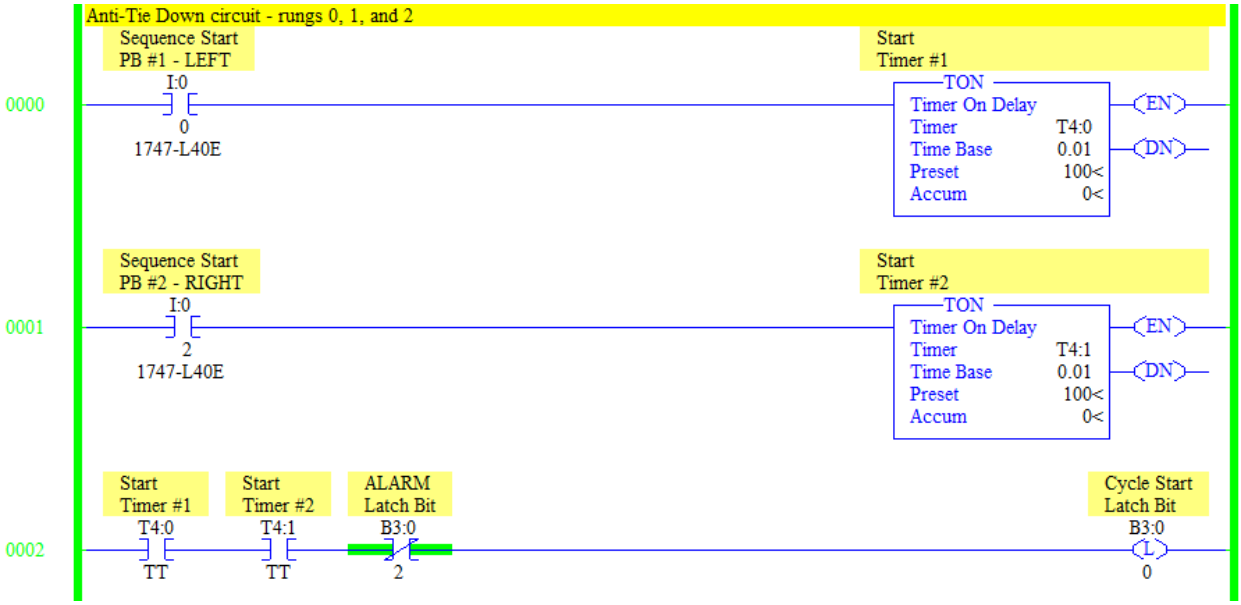

Figure 2 - Sample program (rungs 0-2)

Rung #3 – If the cycle start latch bit is on (B3/0), there is no alarm, and the drill has not been down yet (B3/1 not); the rung closes the clamp (turns ON **Clamp Close SOL**) and latches the drill motor (turns ON **Drill Motor**). The Drill Down Latch Bit (B3/1 not) element is necessary to release

the clamp close solenoid and drill motor since the B3/0 bit will still be on when we want to release the clamp and turn off the drill motor.

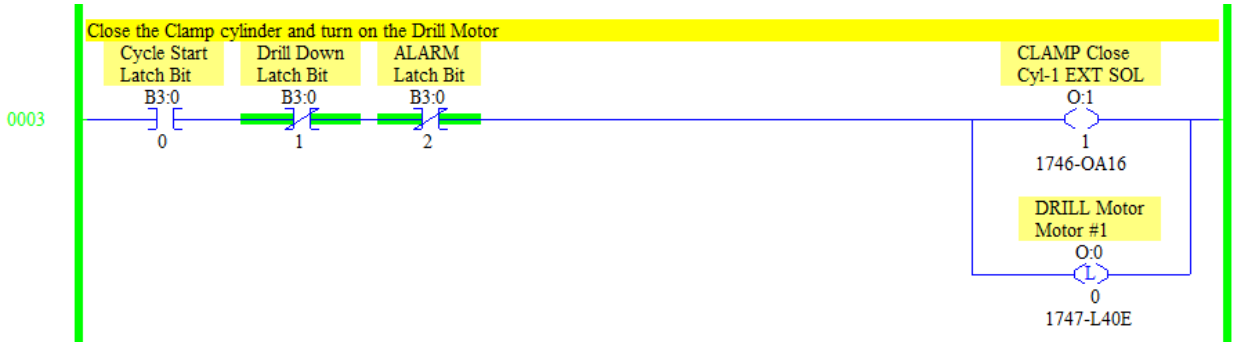

Figure 3 - Sample program (rung 3)

Rung #4 – Once the clamp is closed (**Clamp Close LSW** turns ON), the rung starts the drill down motion (turns ON **Drill DN SOL**). This output is shut off once the Drill Down Latch Bit (B3/1) or Alarm Latch Bit (B3/2) activates.

Rung #5 – This starts the Oil Feed Timer. This TOF timer will start the pump motor as soon as drilling starts, and keep it on for the required three additional seconds.

Rung #6 –This turns on the oil feed motor (turns ON **Pump Motor**) output for as long as the Oil Feed Timer Done (DN) bit is on.

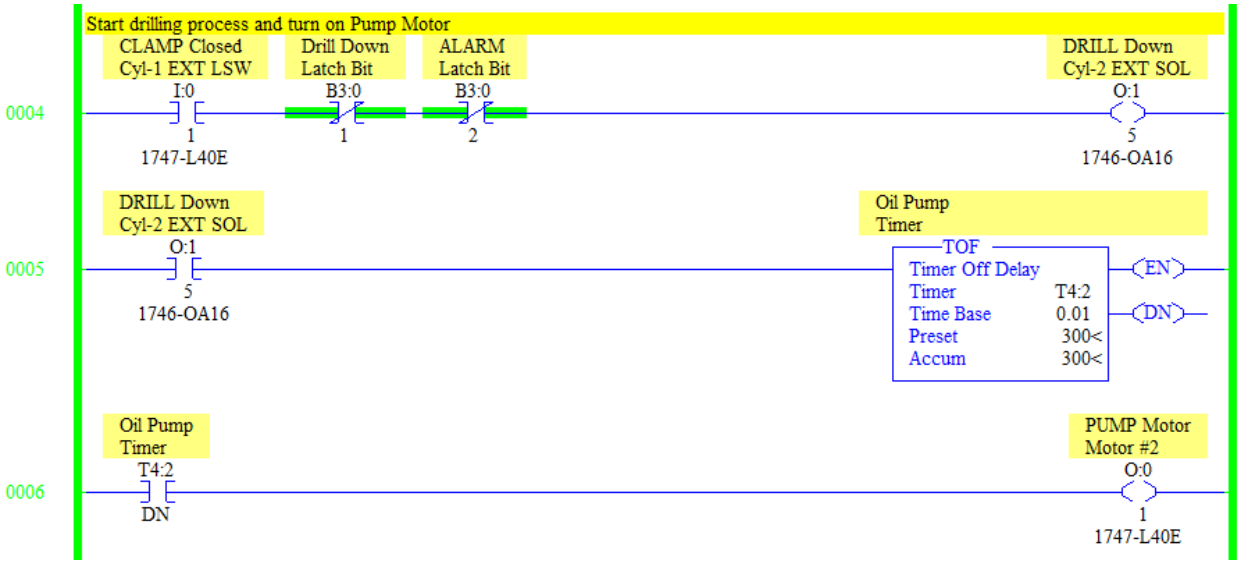

Figure 4 - Sample program (rungs 4-6)

Rung #7 – This latches the **Drill Down Latch Bit (B3/1)** when the drilling process is done (**Drill DN LSW** turns ON). It is important that this bit is latched, as the Drill DN LSW will release as soon as the drill head begins to move up.

Rung #8 – This starts backing up the drill (turns ON **Drill UP SOL**) when the Drill Down Latch Bit (B3/1) has been set or the Alarm Latch Bit (B3/2) comes up.

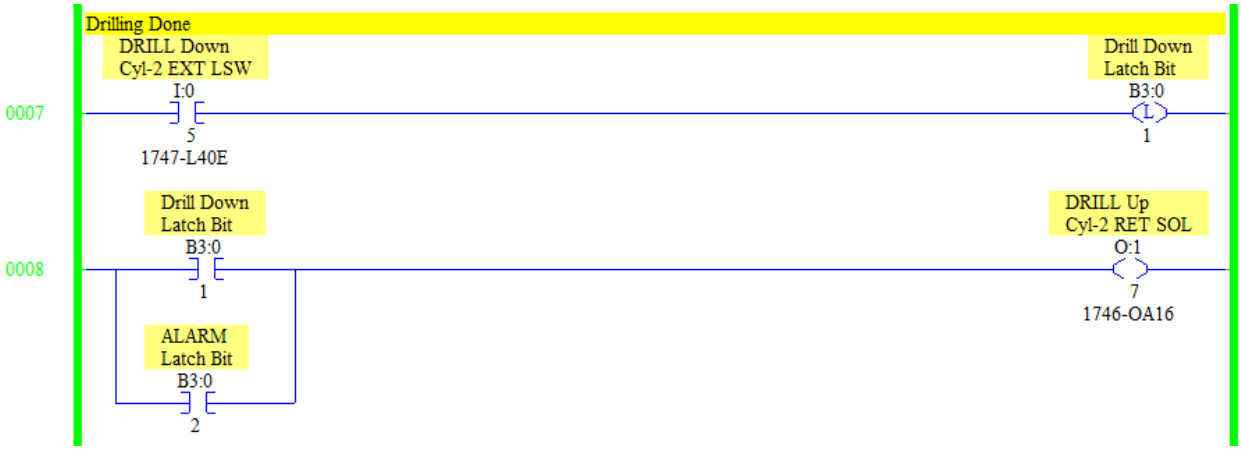

Figure 5 - Sample program (rungs 7-8)

Rungs 9 through 12 are used to set Alarm if the cycle takes too long (over 10 seconds).

Rung #9 – This is used to time the length of the drill down cycle. During normal operation, the timer should always reset before the time out preset time elapses (set to 10 seconds).

Rung #10 – This latches the Alarm Bit B3/2 if the T4:3 timer times out (T4:3 DN bit activates).

Rung #11 – This turns on the Alarm Lamp if the Alarm Latch Bit (B3/2) is set.

Rung #12 – This unlatches the Alarm Latch Bit if the alarm reset push button (**PB #3**) is pressed.

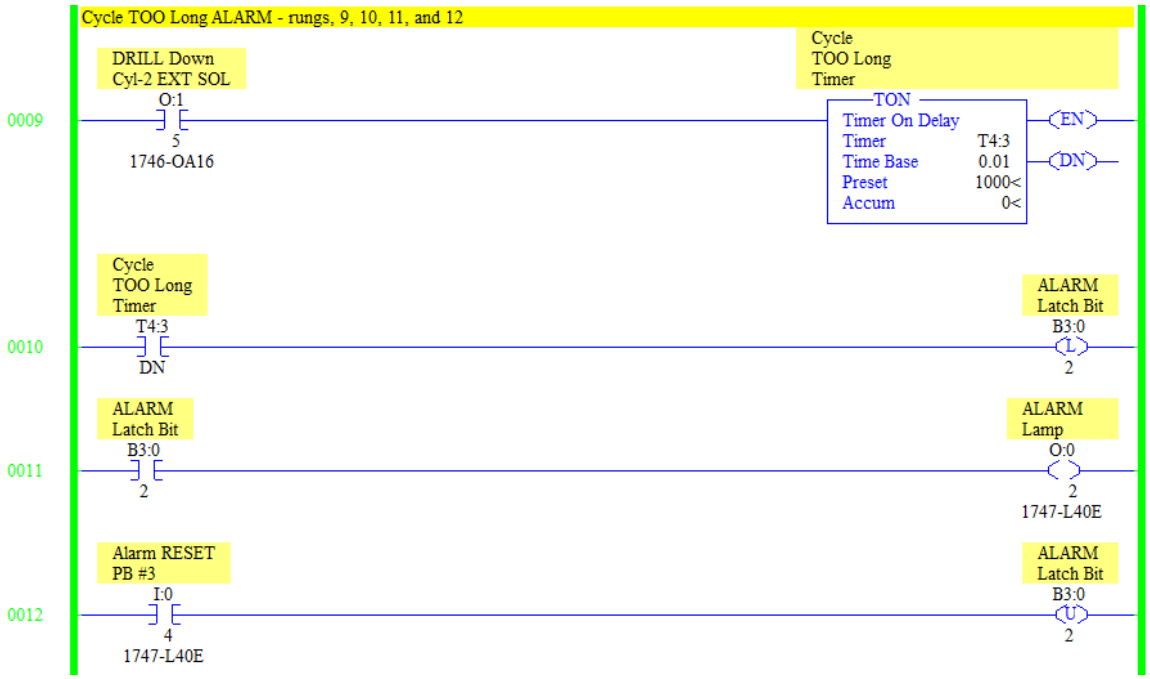

Figure 6 - sample program (rungs 9-12)

Rung #13 – Once the drill is in the up position (**Drill UP LSW** turns ON) and the Drill Down Latch Bit (B3/1) is set, the rung turns off the drill and opens the clamp (unlatch **Drill Motor** and turn ON **Clamp Open SOL**).

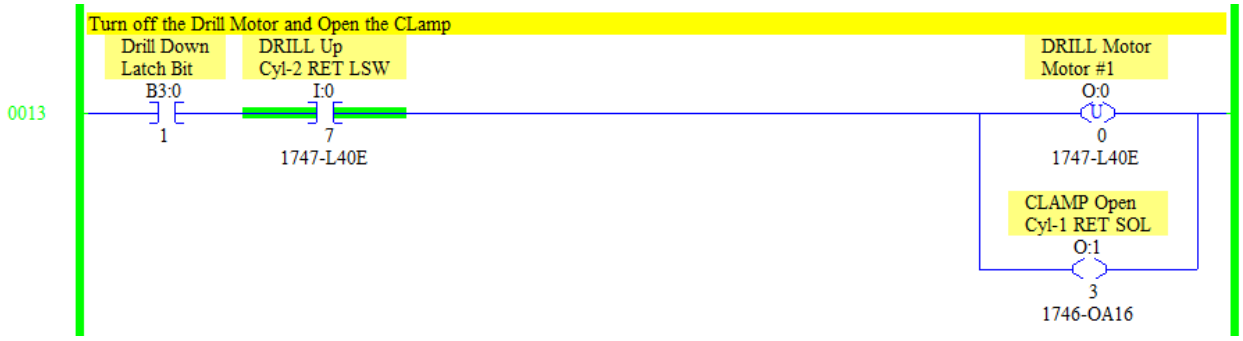

Figure 7 - Sample program (rung 13)

Rung #14 – This detects the end of cycle. It unlatches the two cycle latch bits **B3/0** and **B3/1** only if both start push buttons are open, the drill is up, the clamp is open, and both motors (drill and pump motors) are off. This rung releases the cycle and allows the operator to start a new cycle.

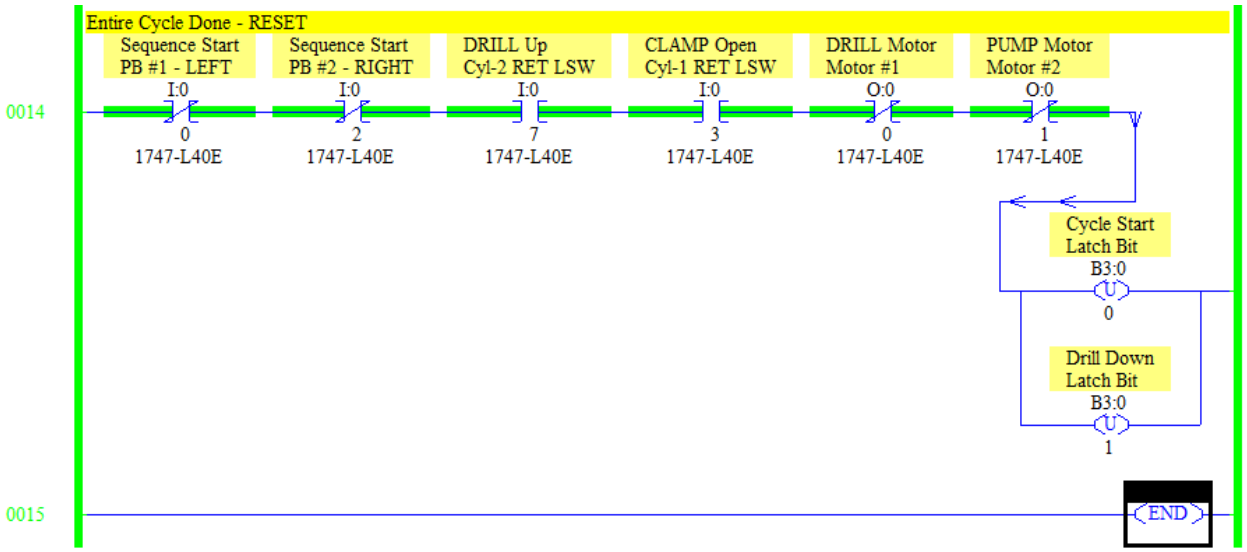

Figure 8 - Sample program (rungs 14-15)

Analysis:
Students should check, and if necessary correct, their ladder logic program by downloading and testing a sequence on a physical PLC trainer.

Conclusion:
Properly written PLC program can control an industrial equipment.

References:
Allen-Bradley - Programmable Controllers
https://ab.rockwellautomation.com/Programmable-Controllers

Siemens - SIMATIC Controllers
https://www.industry.usa.siemens.com/automation/us/en/automation-systems/industrial-automation/plc/pages/plc.aspx

Wikipedia - Programmable logic controller
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https://www.youtube.com/watch?v=0_b0S_UL0u4&list=PLDiXbC2f4yX288Yk9LCyKYkPFJSL7YIGg

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