POLITECHNIC UNIVERSITY OF PUERTO RICO
MECHANICAL ENGINEERING DEPARMENT

EXPERIMENT #3: PLC

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MECHATRONICS LAB (ME-4011-22)

GROUP #2

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Abstract:

This laboratory focuses on identifying and differentiating mechatronics elements such as inputs, outputs, and controller components through hands-on experimentation using a Programmable Logic Controller (PLC). The main objectives are to set up and operate circuits with a PLC as a controller, interpret ladder diagrams, and explain their behaviors by using TRiLOGI and DirectSoft 6 softwares.

In this lab activities, two specific mechatronics applications were simulated: a traffic light control system and an automated conveyor with a drilling mechanism. The first activity involves designing a ladder logic circuit to control traffic lights in a timed sequence, while the second activity requires creating a circuit to manage the movement and drilling of boxes based on their height. Both activities involve designing and simulating the ladder logic, programming the PLC, and verifying system functionality. Throughout the experiments, we connect input/output elements, simulate system behavior, and test PLC functionality, gaining practical experience with mechatronics and control systems.

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Experiment Objective:

- Identify and differentiate the mechatronics elements such as the input, output and controller elements.
- Setup and operate circuits using a PLC as a controller element.
- Interpret a Ladder diagram and explain its behavior.

Theory:

The PLC or Programmable Logic Controller is a computerized device that was created to consolidate the significant amount of labor and space that a hard-wire relay logic system would take. It was developed back in the 1960s in the automotive industry to ease the control of manufacturing processes. The controller can be easily programmed to perform multiple tasks.

The PLC was designed to have an effect depending on its cause. The causes were identified as Inputs and the effects, as Outputs. So, by activating an input, the controller would send a signal to turn on or off the output.

It is necessary to follow three steps to program a PLC device:

A. Find a solution to a problem – Its starts by defining what is needed to control and creating the order of operations. Inputs and outputs are identified depending on the devices used and names are assigned to each one. Some examples of input are sensors, push buttons and switches. As for outputs, they can be lights, pumps, timers, motors, etc.

B. Develop the logic path – Transform the solution into a ladder logic program that successfully performs the function needed to control the operation. The program allows to simulate the activity and can expose any malfunction that may arise so that it can be reconstructed.

C. Apply ladder solution to PLC – Transfer program from computer to PLC device via a serial port. Software, such as DirectSOFT 6, uses RS-232 serial port.

The ladder logic program is shown as a diagram with vertical and horizontal lines. The vertical lines indicate the positive (left line) and negative (right line) regions from the DC power source. These two are connected to a range of horizontal lines called rungs which will start, at the left side, with the inputs and end with the outputs at the right side.

The inputs will have two configurations, normally open or normally closed, and will energize or deenergize the power line to the outputs at the other extremity of the rung. The PLC has other components that are not connected to physical devices, like inputs and outputs. They are the internal auxiliary relays, timers, counter and registers.

The internal auxiliary relays are simulated within the PLC without any external signal, and it is what replaced the big and expensive hard-wire external relays. It has two elements that are treated as output and input, the coil and contact respectfully. The main function of the output coil is to activate all related contacts on the left side of the rungs. So, disconnecting the coil will also disconnect the contacts.

The timers work similarly as the relays, so they have a coil and contacts, but the main difference is that the activation of the coil starts a specific time count that energizes all the linked contacts once it is finished. This component returns to its normal state when it is disconnected from the power supply. The timer within the PLC has a magnitude of 0.1s so an amount must be added to set up an intended time.

Counter, on the other hand, has also a coil output and contact input as the previous non-physical elements. Each activation of the coil will add or subtract a count by 1 and will energize the power line to the contact once it reaches an indicated amount until the counter is restarted within another step of the ladder.

The controller has also registers which keep data saved within it so that the ladder info is not eliminated when the device is disconnected from the power source.

Procedure:

Material:

1. Lab-Volt electrical components (pushbuttons)
2. Traffic Light
3. Conveyor (motor DC)
4. Pump (AC) and beakers with water
5. Electrical Extension and multi-plug
6. Power supply 24VDC
7. Stacking cables
8. Sensors
9. Compressor
10. Mechatronics Lab's manual
11. Notes from the Mechatronics class

Activity #1:

1. Design a ladder logic circuit that simulates the traffic light system; in the following order and time:
   - Red in 7 seconds then
   - Yellow in 2 seconds then
   - Green in 4 seconds

   Only One light ON at a time
2. Simulate the ladder logic diagram using the internet TRiLOGI software.
3. Program the PLC using DirectSOFT 6 shown in Appendix G in the Laboratory Manual.
4. Connect the input and output elements to the PLC and External power supply. Be sure that the power supply and PLC are turned off and unplugged from the ac outlet. Refer to appendix F in the manual Lab. to connect correctly the elements to the PLC.

5. Test the inputs with the PLC plugged in the ac outlet but the external power supply OFF. When all the inputs are verified then test the complete system after the approval of the instructor. Observe the behavior and make some conclusions.
6. Disconnect all the equipment and store it in the closet (when approved by the instructor).

Activity #2:

1. Design a ladder logic circuit in order that boxes pass through a conveyor, and manage to drill and make a hole, but only for the short boxes and not the tall ones. Design/Program the ladder logic circuit so that the following components do the following things:
   - Move the Conveyor
   - High and Low Sensors are active
   - If the box is High, the high and low sensor detect it, and let the box pass
   - If the box is low, only the Low sensor (sensor#1) will be detected. Therefore, the conveyor stops or is deactivated, then extend the piston#1 that is to grab the box. (The Piston#1 is extended for 2 seconds)
   - After this piston #2 turns on and extends the drill for 1 second and then retracts the drill for 3 seconds.
   - Please note that the drill turns on at the same time as piston #2 and turns off when piston #2 finishes retracting; Therefore, the time that the drill is on is 4 seconds.

     At the end of this process, the conveyor is turned on again.
2. Simulate the ladder logic diagram using the internet TRiLOGI software.
3. Program the PLC using DirectSOFT 6 shown in Appendix G in the Laboratory Manual.
4. Connect the input and output elements to the PLC and External power supply. Be sure that the power supply and PLC are turned off and unplugged from the ac outlet. Refer to appendix F in the manual Lab. to connect correctly the elements to the PLC.

5. Test the inputs with the PLC plugged in the ac outlet but the external power supply OFF. When all the inputs are verified then test the complete system after the approval of the instructor. Observe the behavior and make some conclusions.
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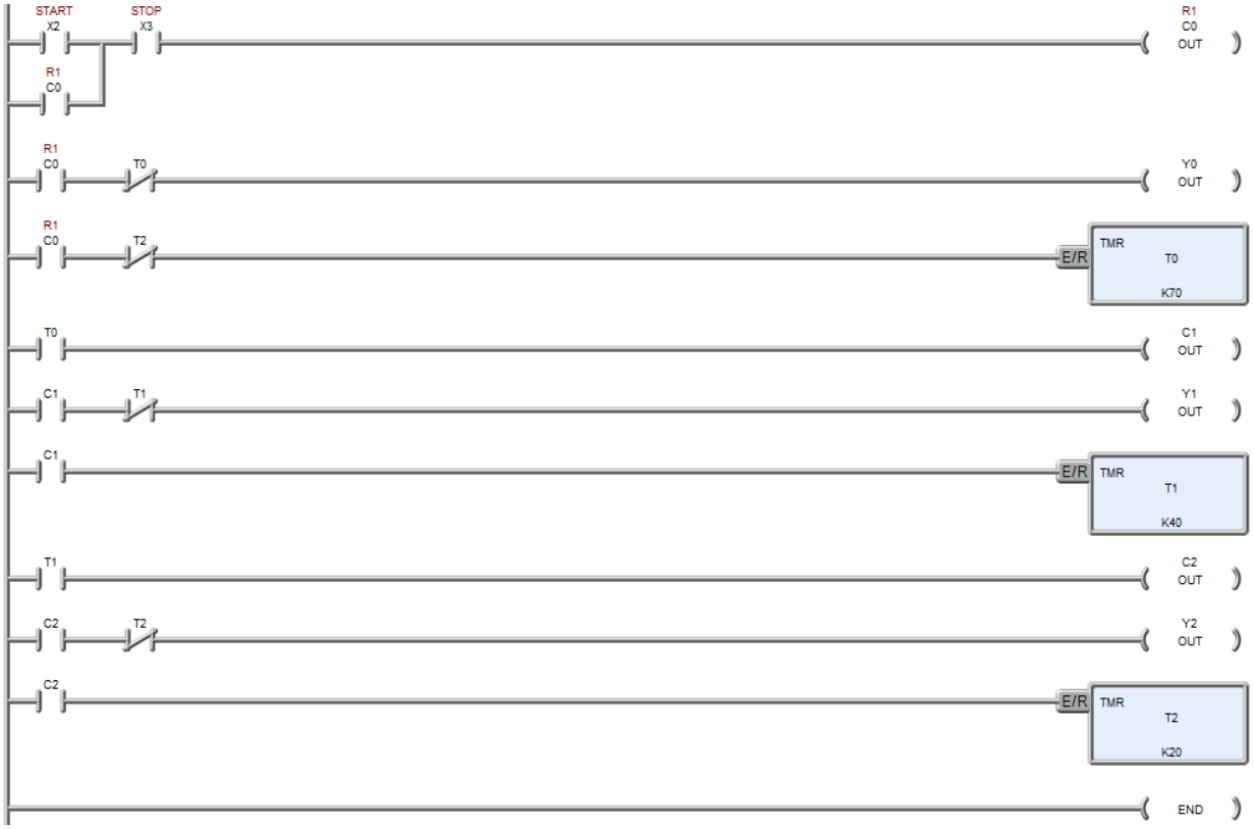
Results:

Ladder Code: Activity #1



List of Inputs & Outputs:

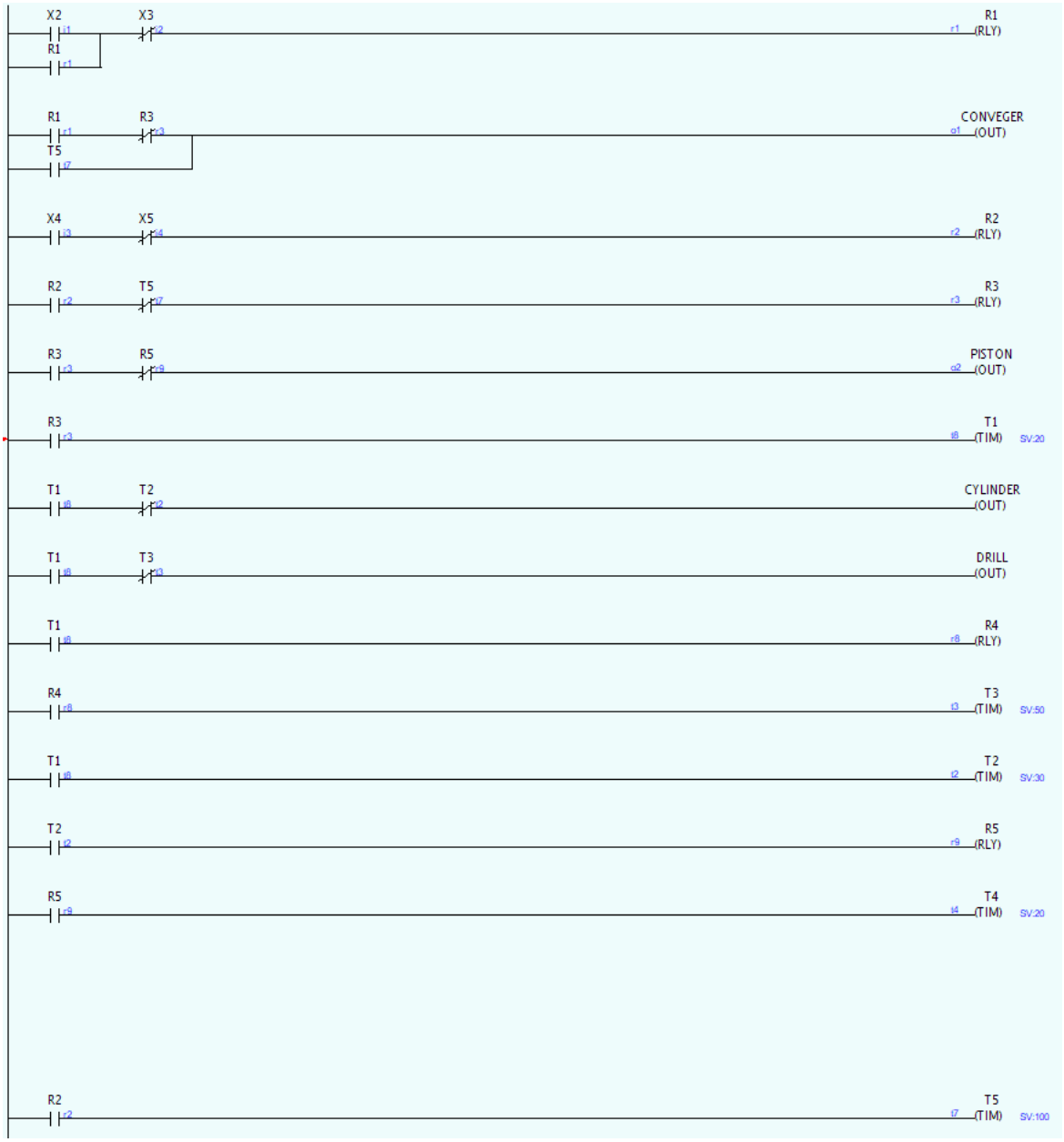
	INPUTS	OUTPUTS	
START	X2	Y0	RED
STOP	X3	Y1	GREEN
		Y2	YELLOW

Verbal Description:

The PLC program begins by sending a relay signal C0 that maintains the circuit on, turns the red light and activates a 7 second timer. Once the 7 second timer passes it

blocks the signal powering the light and shuts it off, at the same time it sends the relay signal C1 that turns the green light with a timer of 4 seconds. Once those 4 seconds pass the timer signal shuts the light off and sends the last relay C2 responsible for turning the yellow light for 2 seconds. After those 2 seconds the yellow light shuts and the relay C0 starts the circuit all over again.

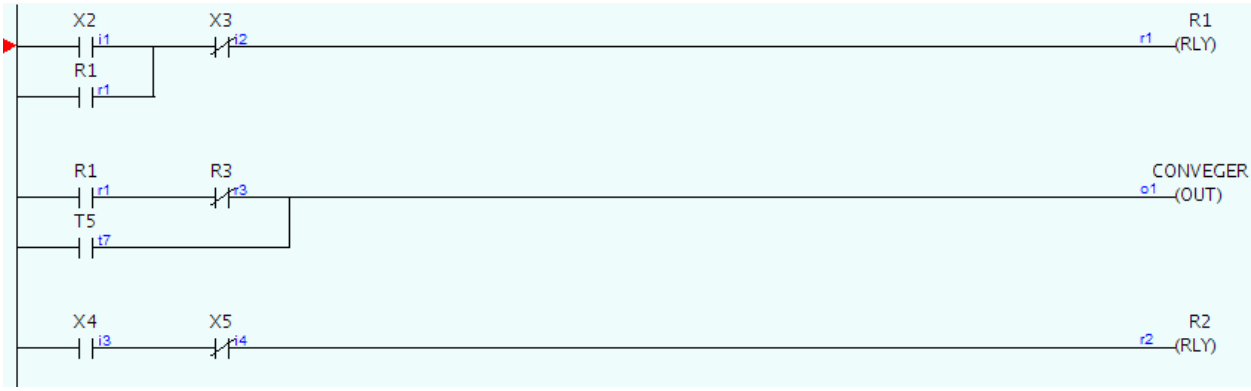
Ladder Code: Activity #2



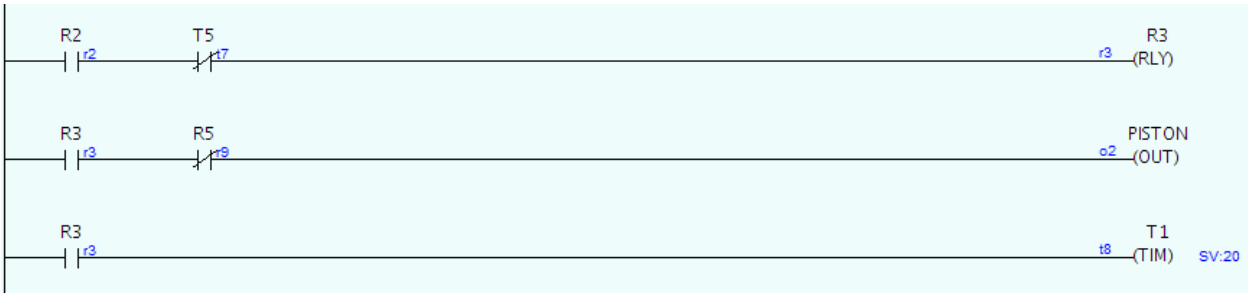
List of Inputs & Outputs:

	INPUTS	OUTPUTS	
START	X2	Y2	CONVEGER
STOP	X3	Y3	PISTON
SENSOR 1	X4	Y4	DRILL
SENSOR 2	X5	Y5	CYLINDER

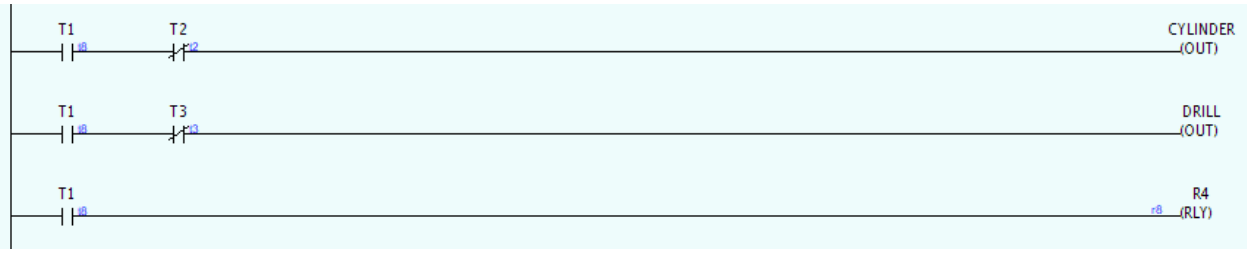
Verbal Description:



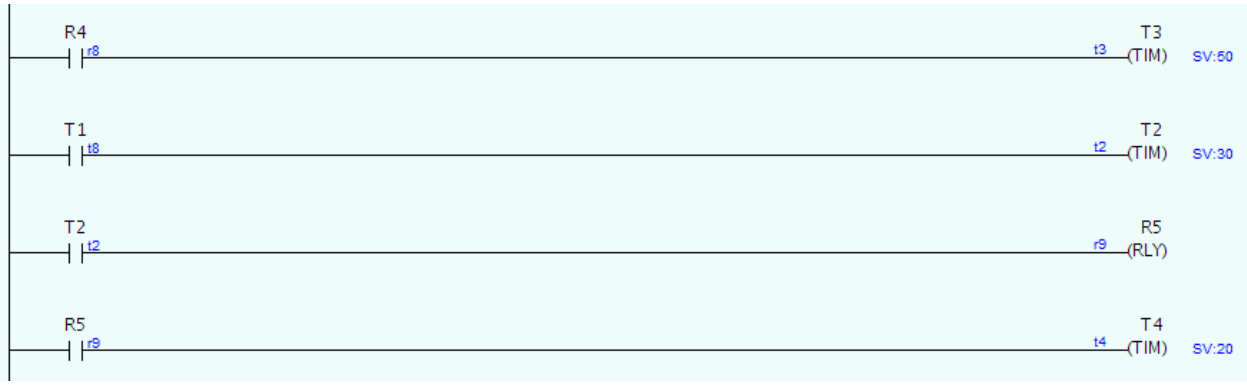
The start button X2 activates the first relay R1 which has two functions. The first one is to maintain the relay R1 on and the second functionality is to activate the conveyer. In the conveyer belt there are two sensors X4 and X5 which function as input for the relay R2. In this case R2 activates when the lowest sensor is activated, and the highest sensor is not activated. Once that R2 continues the ladder code.



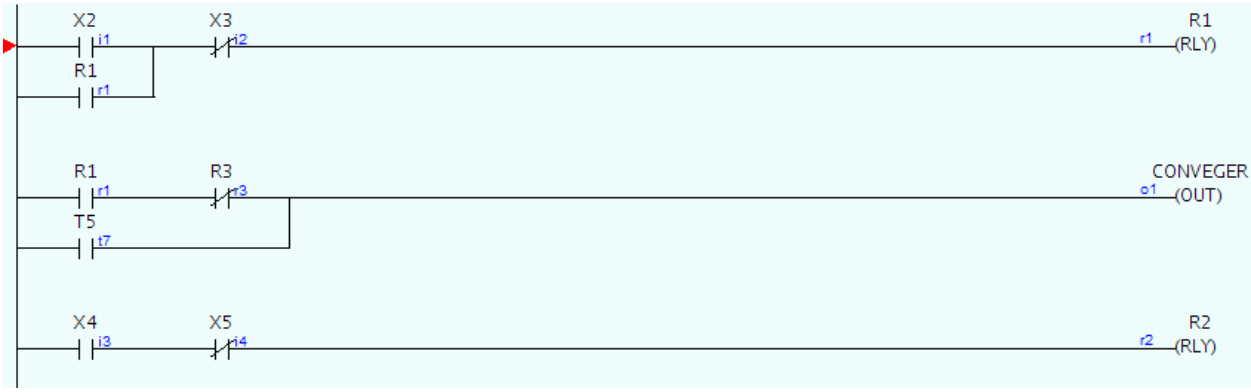
Right after R2 is activated it sends a signal to another relay R3 which is responsible for activating both the piston and as well as to activate the piston which functions as one of the outputs of the PLC code. This first timer has a time of 2 seconds.



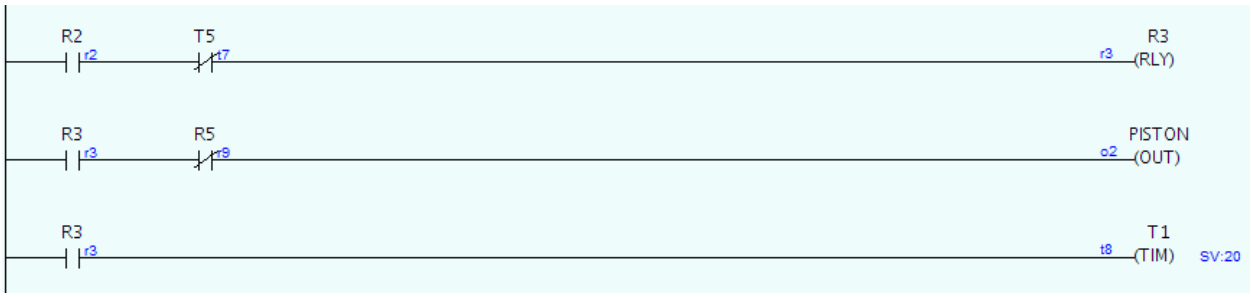
Now T1 will activate the drill and the cylinder, it also activates the relay R4.



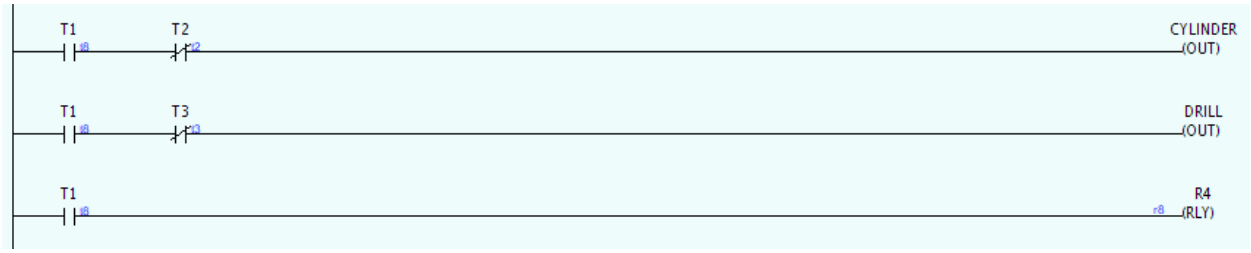
The R4 will activate the third timer T3 with a 5 second condition. The first timer will also activate the second timer which activates the relay R5 and lastly R5 activates T4 with a 2 second time.



Right when R3 becomes activated it activates turning from normally close to opened causing the conveyer to turn on once again.

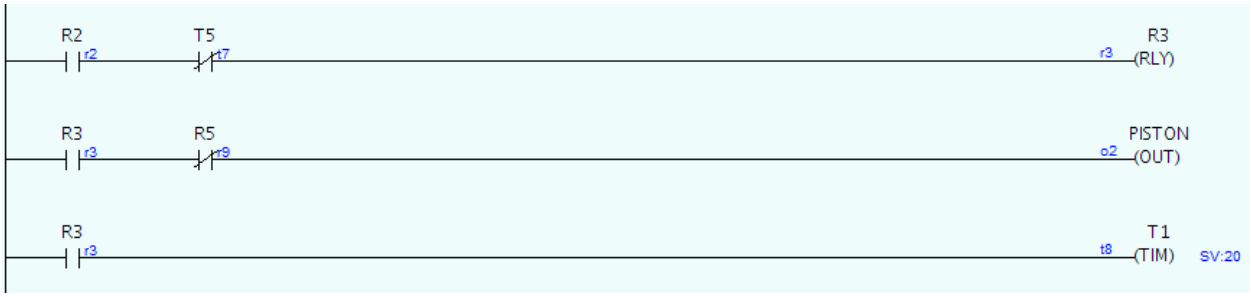


After T2 and once R5 activates it makes the piston shutoff.

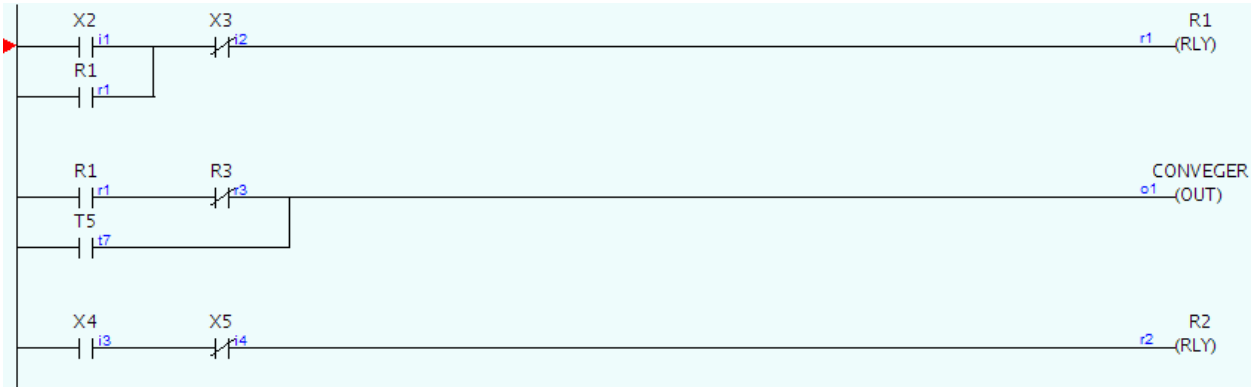


Once T2 time passes it shuts off the drill, and the same happens with the cylinder with T3.

Lastly R2 from the begging activated a timer T5 of 10 seconds for when the process has been complete the conveyer starts once again.



Then T5 stops the relay responsible for maintaining the piston on, therefore shutting it off.



For the last step T5 will be responsible for turning on the conveyer once again.

Analysis of the Results:

For the first activity results were as expected. The group assembled the circuit as said by the laboratory manual and resulted in a complete success.

The PLC ladder code for the second activity also worked as expected when tested in the laboratory. Continuing with the construction of the PLC circuit, we used and followed the instructions given by the laboratory manual. The program starts by pressing the start button and that causes the conveyer to run. Once sensor 1 detects a small box it sends the respective signals to commence the deactivation of the conveyer belt and the activation of the pushing piston for a time of 2 seconds and it activates the drill and the cylinder. Following those commands, after those 2 seconds the piston and the cylinder will be active for another 3 seconds and the drill will be on for a total time of 5 seconds after the piston is activated. Once the timer of the pushing piston stops it starts the drill and the cylinder will push down the cylinder to perform the hole on the box. For that reason, the group programed two timers. Both the cylinder and the drill turn on at the same time, nonetheless the cylinder shut off before the drill to avoid any damage to the drill. For last, right when the last timer passes it turns on the conveyer belt once again.

Conclusion:

In conclusion, this experiment exhibited some of the benefits of a PLC device and the extent of its uses by creating multiples ladder logic program. It allowed the development of the activities' purpose to be successful and productive by employing the codes inside the controller and setting up circuits with the correct order of elements to perform the tasks. At the end, on this exercise, it was evident how this device revolutionized the automotive industry and, consequently, the world.

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