PLC Toaster Project Overview

1. Overview

This multi-week laboratory project consists of using the TRiLOGI program and TRI PLC to control a pneumatic robot. The robot is set up to place a piece of bread into a toaster and activate the toaster. You must write a ladder logic program that completes the following tasks:

1. Start at the default home position (-x limit stop, +y limit stop, -z limit stop)
2. When the "Start" button is pressed and held for 3 seconds the robot arm will move and grab the bread from the toast holder.
    a. The arm must move first move up
    b. Then in the -y direction
    c. Then in the -z direction
    d. Then clasp the bread from the bread holder
3. The robot clasp must then rise up, move over, and drop the bread in the toaster.
    a. Move in the +z direction
    b. Then move in the +x direction
    c. Release clasp to drop the bread
4. The clasp must then push the toaster lever down with part of the clasp that has black tape.
    a. The clasp must be rotated before depressing the toaster lever
5. The program must then cook the toast according to the specified cook cycle. This is accomplished by measuring toaster temperature and turning on/off the heater coils to follow the given temperature profile.
6. Once complete the robot arm must return to the default home position (-x limit stop, +y limit stop, -z limit stop)

2. Specific Program Requirements

1. The program will not start until the "Start" button (normally open) is held down for 3 seconds. Requiring a button to be held down for 3 seconds increases safety by not allowing a user to accidentally bump it and have the equipment start moving.
2. Limit switches detect when the robot arms have reached the maximum position in the X, Y, and Z directions. Limit switches should be used where possible to sequentially control the steps of the program. Timers can be used for actions that have no limit switches (such as clamping, rotating, and cook timers).
3. The cooking temperature should follow the temperature profile shown below in Figure 1. When the bread is dropped into the toaster and the lever is pushed down the set temperature immediately becomes 100°F and over 100 seconds the set temperature should raise to 150° and then be maintained for 20 seconds before shutting off.
   a. Bang-bang control: This is the simplest way to control the heater coils. If the measured temperature is above the set temperature, turn the coils completely off (0% duty cycle) and if the measured temperature is below the set temperature then turn the coils on (100% duty cycle).
4. At any time in the routine if the stop button is pressed, the robot will/should shut off and return to the default home position (-x limit stop, +y limit stop, -z limit stop).

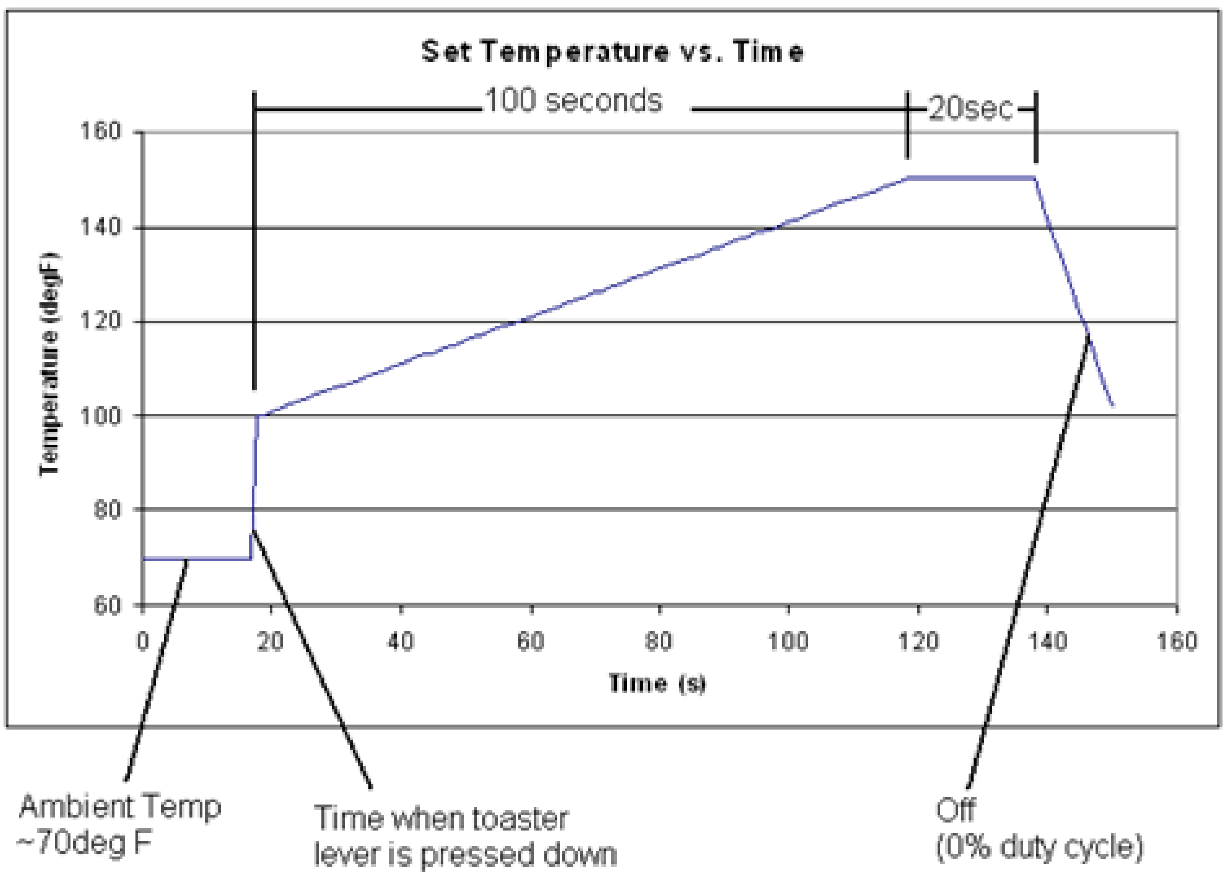

Figure 1: Cooking temperature profile

3. Robot Description

The robot has an arm with a clasp that can rotate 180°. This rotating clasp is located on a point with freedom in the x, y, and z-axis. These axes can be viewed on the next page of this hand out.

Each degree of freedom is created by a double acting cylinder. The system has three double acting piston/cylinder devices along with a rotary actuator and clamp. Movement in the x and y directions are by two way valves that need **momentary** actuation in each direction. Movement in the z direction, rotation, and clamping require **continuous** valve actuation while the action is being completed.

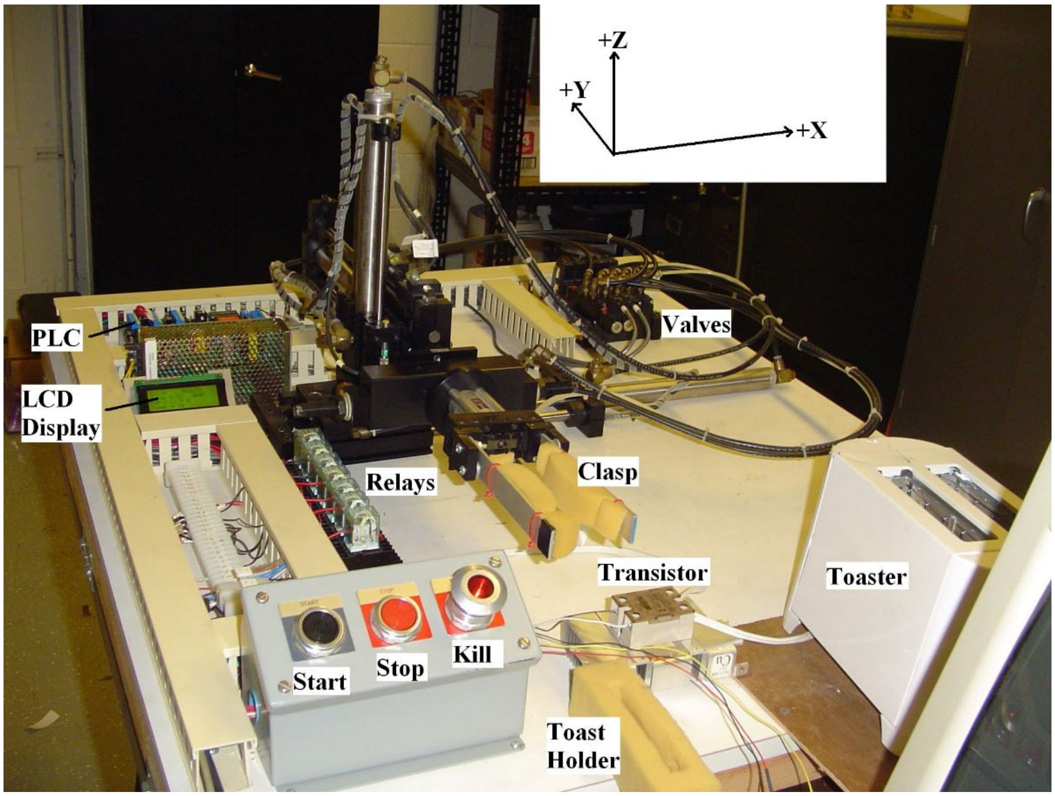

Figure 2: Robot test stand layout

Video of the correct robot movements:

https://www.youtube.com/watch?v=X6M52Qwtjd0

4. Programmable Logic Controller (PLC) Description

4.1 PLC Digital Outputs

- DO 10: moves assembly in the +y direction
- DO 11: moves assembly in the -y direction
- DO 12: moves assembly in the -x direction
- DO 13: moves assembly in the +x direction
- DO 14: moves assembly in the +z direction (output command must be continuously given; if not, the arm will move to the -z limit stop)
- DO 15: rotate gripper 180° (output command must be continuously given; if not, the gripper will rotate back to its default position)
- DO 16: clamps gripper (output command must be continuously given; if not, the gripper will un-clamp)
- Notes:
  - Outputs 10 – 13 only need a momentary command
  - Outputs 14 – 16 have to give a constant command

4.2 PLC Digital Inputs

- DI 9: start button (normally open)
- DI 10: stop button (normally closed)
- DI 11: +y direction limit switch
- DI 12: -y direction limit switch
- DI 13: +x direction limit switch
- DI 14: -x direction limit switch
- DI 15: +z direction limit switch
- DI 16: -z direction limit switch

5. Remaining Lab Schedule

- Week 11 (10/29 & 10/31)
    - Overview discussion of PLCs and ladder logic programming
    - Read through the tutorials and run demo simulations.
- Week 12 (11/5 & 11/7)
    - Prelab Lecture: Instructions on hardware/software mapping, pneumatic table definitions, and PLC interfaces with the hardware. How to make state tables.
    - Make a state table showing the operation states of the toaster.
    - Key things to think about when making a state table are…
        - What inputs (timer, limit switch, button, etc.) trigger transition to the next state?
        - What are the outputs at that state? (Which valves are on? Are the clasps rotated or clamped? Are the toaster coils on?)
- Week 13 (11/12 & 11/14)
    - Prelab Lecture: How to write ladder code from a state table
    - I will take one group at a time to test the state tables you created. You do not need to code your state table in order to test it.
    - Begin coding ladder logic from your state table. Simulate the program where possible. We can upload and test programs but only one group at a time.
- Week 14 (11/19 & 11/21)
    - No lab: Thanksgiving holiday
- Week 15 (11/26 & 11/28)
    - Prelab Lecture: How to use custom functions
    - Write custom function for bang-bang control of the heater coils using pulse width modulation (PWM)
    - Continue working on the ladder code and testing on the PLC when necessary
- Week 16 (12/3 & 12/5)
    - Dead week
    - Demonstrate operation of robot system