Table of Contents

Laboratory Exercise 1

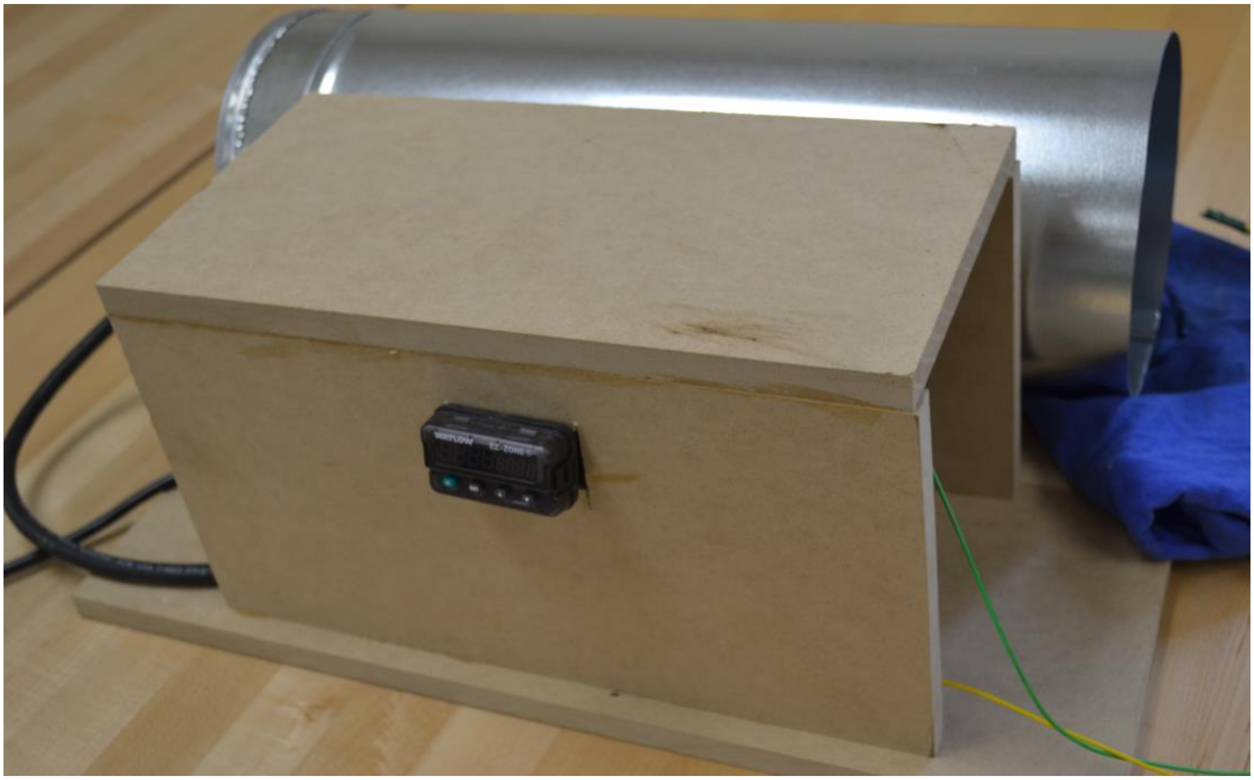
Watlow EZ Zone PM Oven Controller

Introduction

The thermal chamber below is to be controlled to a set temperature using a single 50 Watt light bulb. The chamber will first be heated with the bulb on through the entire range. Then the Watlow controller will be used to control the temperature in the chamber to a set temperature.

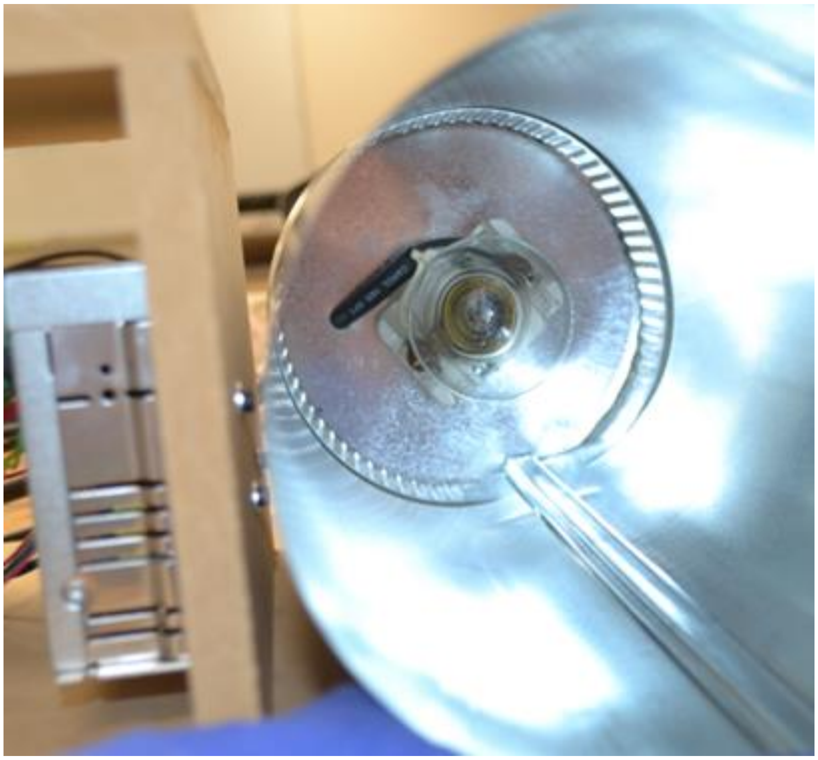
Procedure

The picture below shows the entire set-up of the thermal chamber with controller. The light bulb can be seen by looking down the tube when the insulation is removed. The controller is attached to the front of the box and is to be used either to turn on the light bulb in manual mode (constant) or to control temperature in auto mode (variable).

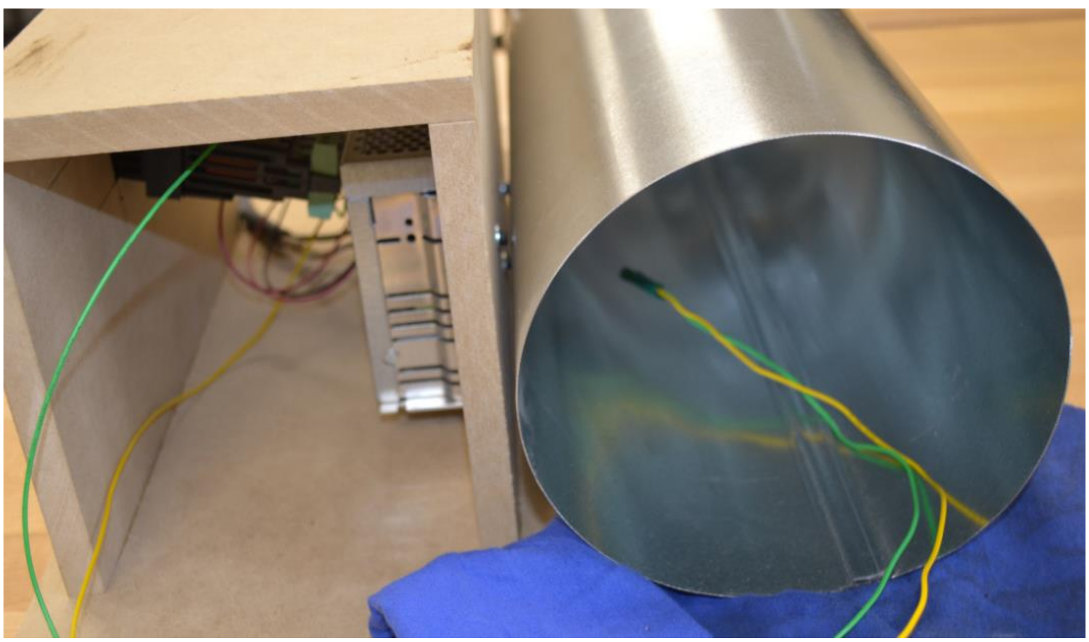


In part 1, the controller will be used in the manual mode.

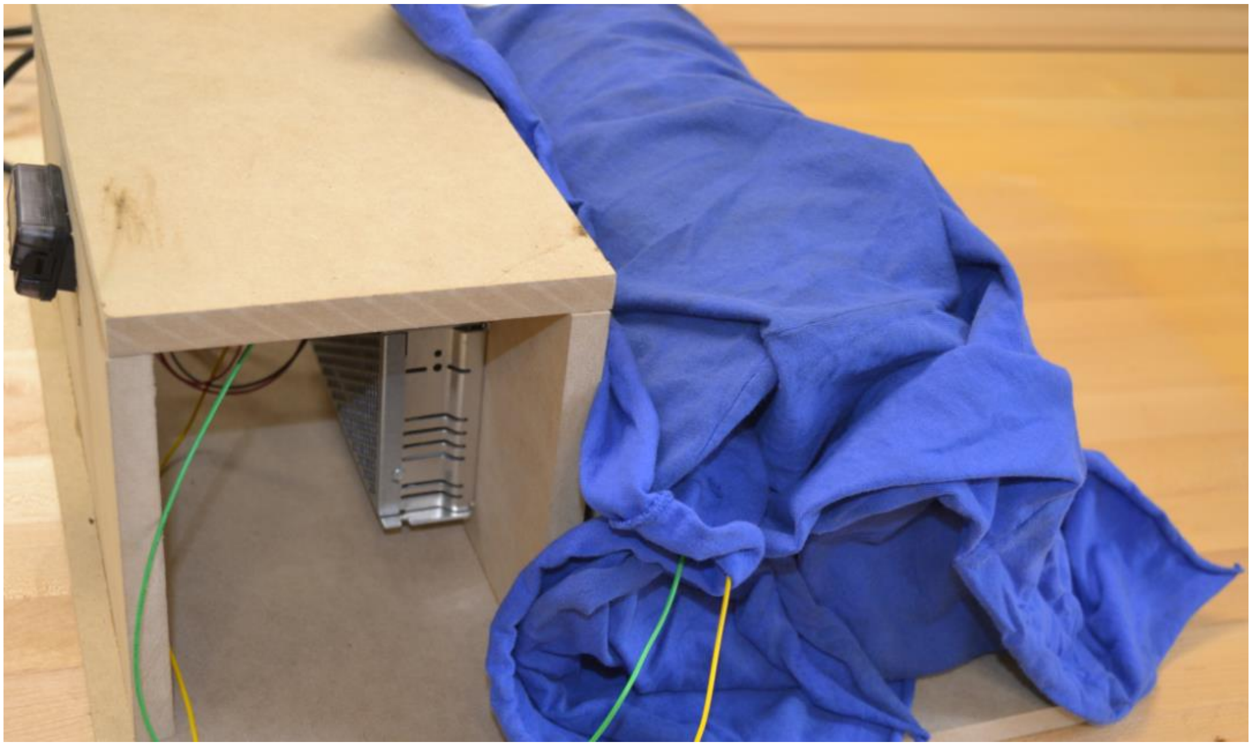
In the picture below the light bulb can be seen. It is mounted in the end of the chamber and is fed from the 24 Vdc source in the back of the wooden rack. All components in the enclosure operate at 24 Vdc other than the power cord attached to the power supply.



The RTD sensor can be seen here. It protrudes into the chamber and is used as the input device for sensing the temperature. Details of this sensor can be seen in Appendix B. The chart for temperature conversion can be printed as well from the XLS spreadsheet found with this data.



Use a rag similar to the one below to insulate and block the exit end of the thermal chamber.



Part 1

Using the RTD, record the initial temperature in the thermal chamber.

Start the temperature to rise by turning on the controller and place the output on in the <u>manual</u> mode at 100%. Every 10 seconds, record the temperature and save this data until the temperature reached 150 degrees F or the reading is stable for 3 consecutive readings. Graph the data and analyze the data per your professor's instructions.

Remove the heat input to the thermal chamber.
Allow the chamber to cool to within 10 degrees of the initial temperature.

Repeat with the controller set in manual at 70%:
Every 10 seconds, record the temperature and save this data until the temperature reached 150 degrees F or the reading is stable for 3 consecutive readings. Graph the data and analyze the data per your professor's instructions.

Part 2

Set the temperature controller into auto mode and give a setpoint temperature as indicated by your instructor. Every 10 seconds, record the temperature and save this data until the temperature reaches 150 degrees F, or stabilizes for 3 consecutive readings.

In the lab report, include:

The data tables from 100% PWM, 70% PWM, and Automatic control.

Graph the data for the above trials and analyze the data per your professor's instructions.

Comment on the action of the controller as the temperature nears the setpoint.

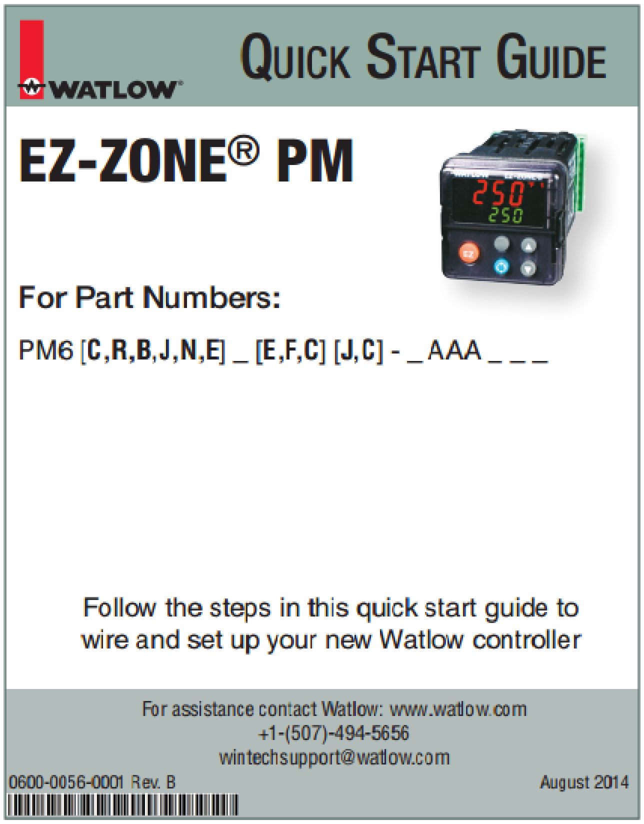
Partially remove the insulation to allow some room-temperature air to enter the chamber. Observe the response of the controller and the system, in response to this disturbance.

Comment on the action of the controller after the temperature has reached setpoint.

Report on the automatic settings for your controller including the P, I, and D settings for your controller.

Compare these settings to those of other groups around you.

Manual for Watlow EZ-ZONE PM Controller



WATLOW

QUICK START GUIDE

EZ-ZONE® PM

For Part Numbers:

PM6 [C,R,B,J,N,E] _ [E,F,C] [J,C] - _ AAA _ _ _

Follow the steps in this quick start guide to wire and set up your new Watlow controller

For assistance contact Watlow: www.watlow.com
+1-(507)-494-5656
wintechsupport@watlow.com

0600-0056-0001 Rev. B

August 2014

From DigiKey Catalog, the RTD Temperature Sensor is shown below:

Product Index > Sensors, Transducers > RTD (Resistance Temperature Detector) > US Sensor PPG101B1

All prices are in US dollars.

Digi-Key Part Number	615-1038-ND
Quantity Available	Digi-Key Stock: 802 Can ship immediately
Manufacturer	US Sensor
Manufacturer Part Number	PPG101B1
Description	DETECTOR RTD TF 100 OHM +/-0.12%
Lead Free Status / RoHS Status	Lead free / RoHS Compliant
Moisture Sensitivity Level (MSL)	1 (Unlimited)

Price Break	Unit Price	Extended Price
1	4.66000	4.66
10	3.63100	36.31
25	2.94560	73.64
50	2.60300	130.15
100	2.53450	253.45

Quantity	Item Number	Customer Reference	
1	615-1038-ND ▼		Add to Cart

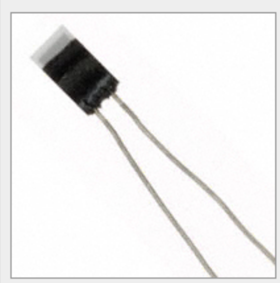
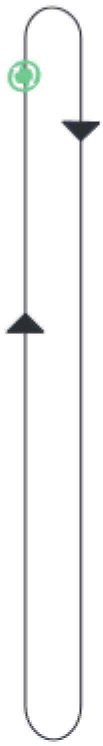


Image shown is a representation only. Exact specifications should be obtained from the product data sheet.

Start-up of the Watlow and setting of the controller to Manual or Auto are covered in the following:

Upon power up of the control, using the advance key will scroll through the various prompts found in the Operations Menu. At any point within the Operations menu to return to the default display push the Infinity ⊜ key.

Operations Menu



- PAr1
- PAr2
- [AUt] Autotune
- [C.M] Control Mode
- [h.Pb] Heat Proportional Band
- [C.Pb] Cool Proportional Band
- [ti] Time Integral
- [td] Time Derivative
- [o.tb1] Time Base
- [o.tb2] Time Base
- [A.Lo] Alarm Low Set Point
- [A.hi] Alarm High Set Point
- [i.CA] Calibratin Offset

Operations Menu

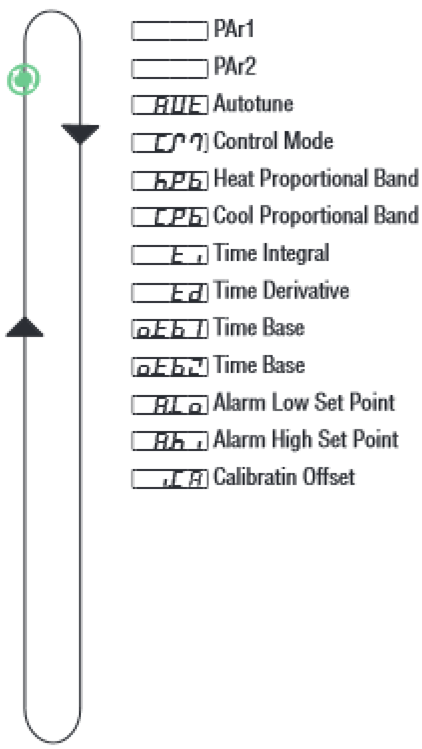
Display	Parameter Name Description
[AUt]	***Autotune*** Start an autotune. While active the upper or left and lower or right display will flash [tUn1] and [bEEn]. Appears if: Heat or cool algorithm set to PID
[C.M]	***Control Mode Active*** View the current control mode. Appears if: Always
[h.Pb]	***Heat Proportional Band*** Set the PID proportional band for the heat outputs. Appears if: Heat algorithm set to PID
[C.Pb]	***Cool Proportional Band*** Set the PID proportional band for the cool outputs. Appears if: Cool algorithm set to PID
[ti]	***Time Integral*** Set the PID integral for the outputs. Appears if: Heat or cool algorithm set to PID
[td]	***Time Derivative*** Set the PID derivative time for the outputs. Appears if: Heat or cool algorithm set to PID
[o.tb1]	***Time Base Output 1*** Set the time base for fixed-time-base control. Appears if: Output 1 set to heat or cool with control algorithm set to PID.
[o.tb2]	***Time Base Output 2*** Set the time base for fixed-time-base control. Appears if: Output 2 set to heat or cool with control algorithm set to PID.
[A.Lo]	***Alarm Low Set Point*** Process - set the process value that will trigger a low alarm. Deviation - set the span of units (using negative numbers) from the closed loop set point that will trigger a low alarm. Appears if: If Alarm Type [AtY] is set to Process or Deviation Alarm

EZ-ZONE PM Express (PID) • 18 • Operations Menu

Range **(Defaults are shown bold)**
no **No** YES Yes
oFF Off AUto **Auto** MAn Manual
0 to 9,999.000°F or units 0 to 5,555.000°C **Units, 25.0°F or 14.0°C**
0 to 9,999.000°F or units 0 to 5,555.000°C **Units, 25.0°F or 14.0°C**
0 to 9,999 seconds per repeat **180**
0 to 9,999 seconds **0 seconds**
0.1 to 60.0 seconds (solid-state relay or switched dc) 5.0 to 60.0 seconds (mechanical relay & NO-ARC power control) **1 sec. [SSR & sw dc], 20.0 sec. [mech. relay & NO-ARC]**
0.1 to 60.0 seconds (solid-state relay or switched dc) 5.0 to 60.0 seconds (mechanical relay & NO-ARC power control) **1 sec. [SSR & sw dc], 20.0 sec. [mech. relay & NO-ARC]**
-1,999.000 to 9,999.000°F or units -1,128.000 to 5,537.000°C **Units, 32.0°F or 0.0°C**

Upon power up of the control, using the advance key will scroll through the various prompts found in the Operations Menu. At any point within the Operations menu to return to the default display push the Infinity ⊜ key.

Operations Menu

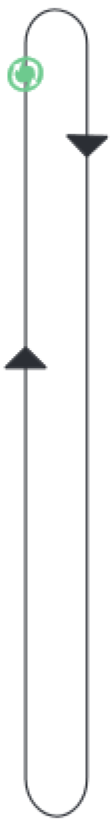


Operations Menu (cont.)

Display	***Parameter Name Description***	***Range* (Defaults are shown bold)**
[A.hi]	***Alarm High Set Point*** Process - set the process value that will trigger a high alarm. Deviation - set the span of units from the closed loop set point that will trigger a high alarm. Appears if: If Alarm Type (A.ty) is set to Process or Deviation Alarm	-1,999.000 to 9,999.000°F or units -1,128.000 to 5,537.000°C **Units, 300.0°F or 150.0°C**
[i.CA]	***Calibration Offset*** Set an offset value for a process output. Appears if: Always	-1,999.000 to 9,999.000°F or units, -1,110.555 to 5,555.000°C, **0.0**

To enter the Setup Menu push and hold the up and down arrow keys for approximately 3 seconds. Once there, push the green advance key to scroll through to the prompt of choice and then use the up and down arrow keys to change the range. At any point within the Setup menu to return to the default display push the Infinity ∞ key.

Setup Menu



- Lockout Menu
- Sensor Type
- Linearization
- Thermistor Curve
- Resistance Range
- Decimal
- Display Units
- Range Low
- Range High
- Function Output 1
- Output Type
- Function Output 2
- Heat Algorithm
- Hysteresis (Heat & Cool)
- Cool Algorithm
- Alarm Type
- Alarm Hysteresis
- Alarm Logic
- Alarm Latching
- Alarm Blocking
- Alarm Silencing
- Alarm Display
- Ramp Action
- Ramp Rate
- Scale Low
- Scale High
- Power Scale High Output 1
- Power Scale High Output 2
- Zone Address

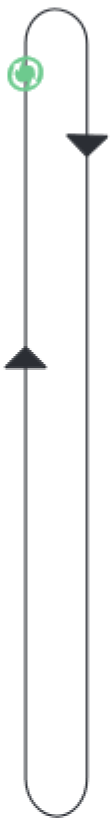
Setup Menu

Display	*Parameter Name Description*
[LoC]	***Lockout Menu*** Set the security clearance level. The user can access the selected level and all lower levels. Appears if: Always
[SEn]	***Sensor Type*** Set the analog sensor type to match the device wired to this input. Appears if: Always
[Lin]	***Linearization*** Set the linearization to match the thermocouple type wired to this input. For example, select H for a type K thermocouple. Appears if: Sensor Type is set to Thermocouple.
[t.C]	***Thermistor Curve*** Select a curve to apply to the thermistor input.
[r.r]	***Resistance Range*** Set the maximum resistance of the thermistor input.
[dEC]	***Decimal*** Set the precision of the displayed value. Appears if: Always
[C_F]	***Display Units*** Select which units will be displayed. Appears if: Always
[r.Lo]	***Range Low*** For process signals, this value scales the units to minimum electrical units (0 volts or 4 mA) Appears if: Always
[r.hi]	***Range High*** For process signals, this value scales the units to maximum electrical units (10 volts or 20 mA) Appears if: Always

Range (Defaults are shown bold)
1 to 5 1 Operations Menu (read only, A/M button disabled)* 2 Operations Menu (A/M button disabled, Set point R/W)* 3 Operations Menu (A/M button enabled, Set point R/W, Control Mode R/W)* 4 Operations Menu R/W access* **5 Operations Menu and Setup Menu full R/W access** *You can change the security level at any level
[tC] **Thermocouple,** [VoLt] Volts dc, [MA] Milliamps dc [r0.1H] RTD 100 Ω, [thEr] Thermistor
[b] B, [J] J, [t] T [c] C, [H] K [d] D, [n] N [E] E, [r] R [F] F, [S] S
[A] Curve A, [b] Curve B, [C] Curve C [CUSt] Custom
[5] 5K, [10] 10K, [20] 20K, [40] 40K
[0] **Whole,** [00] Tenths, [000] Hundredths
[F] **°F** [C] °C
-1,999.000 to 9,999.000 **0.0**
-1,999.000 to **9,999.000**

To enter the Setup Menu push and hold the up and down arrow keys for approximately 3 seconds. Once there, push the green advance key to scroll through to the prompt of choice and then use the up and down arrow keys to change the range. At any point within the Setup menu to return to the default display push the Infinity ⊖ key.

Setup Menu



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- Ramp Action
- Ramp Rate
- Scale Low
- Scale High
- Power Scale High Output 1
- Power Scale High Output 2
- Zone Address

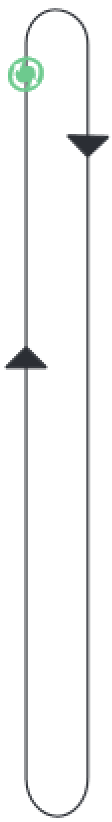
Setup Menu

Display	Parameter Name Description
[fn1]	***Function of Output 1*** Select which function will drive this output. Appears if: If output 1 is ordered
[o.ty]	***Output Type*** Select whether the process output will operate in volts or milliamps. Appears if: A process output (PM _ C _ F _-_ AAAB _ _)
[fn2]	***Function of Output 2*** Select which function will drive this output. Appears if: If output 2 is ordered
[h.Ag]	***Heat Algorithm*** Set the heat control method. Appears if: Output 1 or 2 set to heat
[hSC]	***Hysteresis (Heat & Cool)*** Set the control switching hysteresis for on-off control. This determines how far into the "on" region the process value needs to move before the output turns on. Appears if: Heat or Cool Algorithm is set to On-Off.
[C.Ag]	***Cool Algorithm*** Set the cool control method. Appears if: If Output 1 or 2 is set to cool
[A.ty]	***Alarm Type*** Select how the alarm will or will not track the set point. Appears if: Always
[A.hy]	***Alarm Hysteresis*** Set the hysteresis for an alarm. This determines how far into the safe region the process value needs to move before the alarm can be cleared. Appears if: When alarm type is set to process or deviation alarm
[A.Lg]	***Alarm Logic*** Select what the output condition will be during the alarm state. Appears if: Always

Range **(Defaults are shown bold)**
[oFF] Off, [CooL] Cool, [hEAt] **Heat**, [ALM] Alarm
[uoLt] **Volts** [mA] Milliamps
[oFF] **Off**, [CooL] Cool, [hEAt] Heat, [ALM] Alarm
[oFF] Off, [Pid] **PID** [onoF] On-Off
0 to 9,999.000°F or units 0 to 5,555.000°C **Units, 3.0°F or 2.0°C**
[oFF] **Off**, [Pid] PID [onoF] On-Off
[oFF] **Off**, [PrAL] Process Alarm [dEAL] Deviation Alarm
0.001 to 9,999.000°F or units 0.001 to 5,555.000°C **Units, 1.0°F or 1.0°C**
[ALC] **Close on Alarm** [ALo] Open on alarm

To enter the Setup Menu push and hold the up and down arrow keys for approximately 3 seconds. Once there, push the green advance key to scroll through to the prompt of choice and then use the up and down arrow keys to change the range. At any point within the Setup menu to return to the default display push the Infinity ⊖ key.

Setup Menu



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- Alarm Blocking
- Alarm Silencing
- Alarm Display
- Ramp Action
- Ramp Rate
- Scale Low
- Scale High
- Power Scale High Output 1
- Power Scale High Output 2
- Zone Address

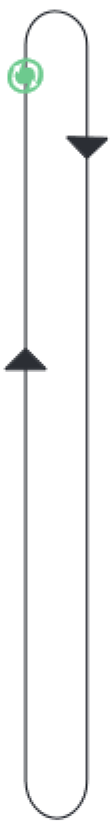
Setup Menu

Display	Parameter Name Description
[A.LA]	***Alarm Latching*** Turn alarm latching on or off. A latched alarm has to be turned off by the user. Appears if: When alarm type is set to process or deviation alarm
[A.bL]	***Alarm Blocking*** Select when an alarm will be blocked. After startup and/or after the set point changes, the alarm will be blocked until the process value enters the normal range. Appears if: When alarm type is set to process or deviation alarm
[A.Si]	***Alarm Silencing*** Turn alarm silencing on to allow the user to disable the output tied (configured) to this alarm Appears if: When alarm type is set to process or deviation alarm
[A.dSP]	***Alarm Display*** Display an alarm message when an alarm is active. Appears if: When alarm type is set to process or deviation alarm
[rP]	***Ramp Action*** Select when the controller's set point will ramp to the defined end set point. Appears if: Always
[r.rt]	***Ramp Rate*** Set the rate for the set point ramp. Set the time units for the rate with the Ramp Scale parameter. Appears if: Ramp Action is set to Startup, Set Point or Both.
[S.Lo]	***Scale Low Output 1*** Set the scale low for process output in electrical units. This value; in volts or milliamps, will correspond to 0% PID power output. Appears if: Output 1 is a *Process* set to heat or cool

Range (Defaults are shown bold)
nLAt **Non-Latching** LAt Latching
oFF **Off** Str Startup StPt Set Point both Both
oFF **Off** on On
oFF Off on **On**
oFF **Off**, Str Startup StPt Set Point Change, both Both
1.0°F degrees or units per hour **1.0**°C
-100.0 to 100.0 **0.0**

To enter the Setup Menu push and hold the up and down arrow keys for approximately 3 seconds. Once there, push the green advance key to scroll through to the prompt of choice and then use the up and down arrow keys to change the range. At any point within the Setup menu to return to the default display push the Infinity ⊖ key.

Setup Menu



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- Power Scale High Output 2
- Zone Address

Setup Menu

Display	*Parameter Name Description*
[S.hi]	***Scale High Output 1*** Set the scale high for process output in electrical units. This value; in volts or milliamps, will correspond to 100% PID power output. Appears if: Output 1 is a *Process* set to heat or cool
[o.hi1]	***Power Scale High Output 1*** Set maximum value of output 1 range. Appears if: Output 1 is *Switched* and set to heat or cool
[o.hi2]	***Power Scale High Output 2*** Set maximum value of output 2 range. Appears if: Output 2 is *Switched* and set to heat or cool
[PAr1]	***Upper or Left Display*** Select parameter to display. Appears if: Always
[PAr2]	***Lower or Right Display*** Select parameter to display. Appears if: Always
[Ad.S]	***Zone Address - Standard Bus Communication*** Set zone address from 1-16. Appears if: Always

Laboratory Exercise 2

Hot Dog Counter

Introduction

Fred and Rudy are making hot dogs at the ballpark. Fred dispenses mustard and Rudy dispenses catsup. A hot dog is not sold without each Fred and Rudy putting both mustard and catsup on the dog. As each pushes the button for their ingredient, a signal is fed to the PLC for the action. Either button may be pushed first.

Procedure

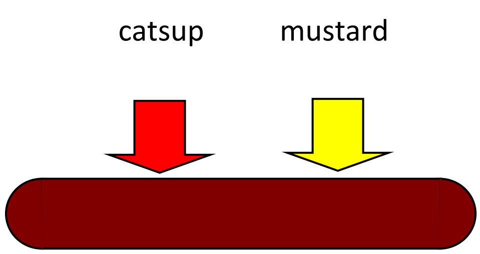
Design a program to count the total number of hot dogs made. Inputs should be wired to contacts and labeled as mustard and catsup. A display is kept in the PLC showing up-to-date counts of hot dogs made by Fred and Rudy.

To complete the lab, enter the program shown later in the lab into the PLC and wire the two inputs.

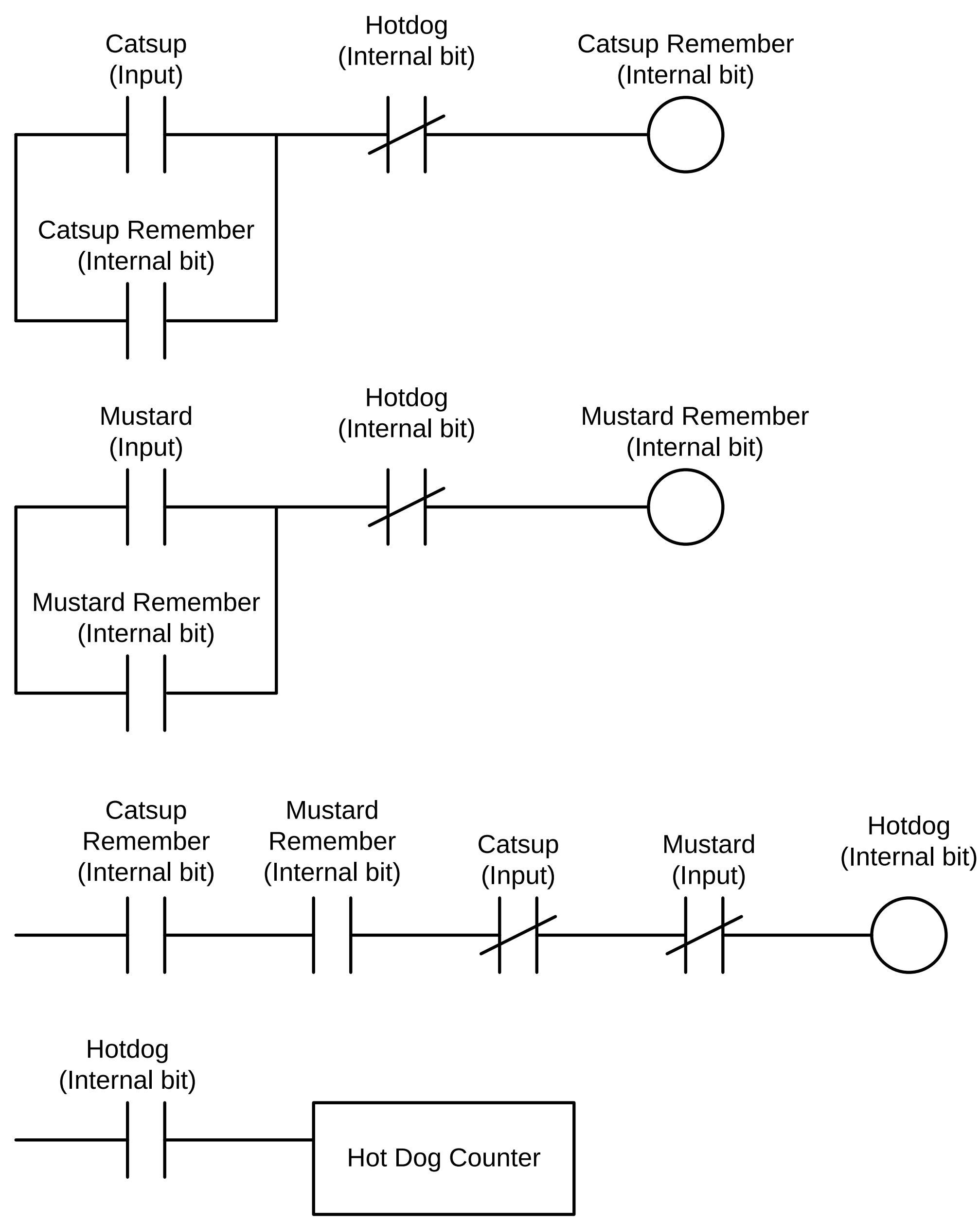
Watch the count accumulate in the counter as the two buttons are pressed in any order.
Get a listing from the listing software on the programming software package.
The documented listing of the program may be used as the final lab report.

Wire the PLC to the inputs for this lab and to inputs or outputs for other labs per the diagram on the next page.

The next page shows the layout of the PLC on the trainer and the PLC wiring schematic. To wire the two inputs, wire through the two pushbuttons selected so that 24 volts is at the terminals of I/0 and I/1 when the two buttons are pushed.

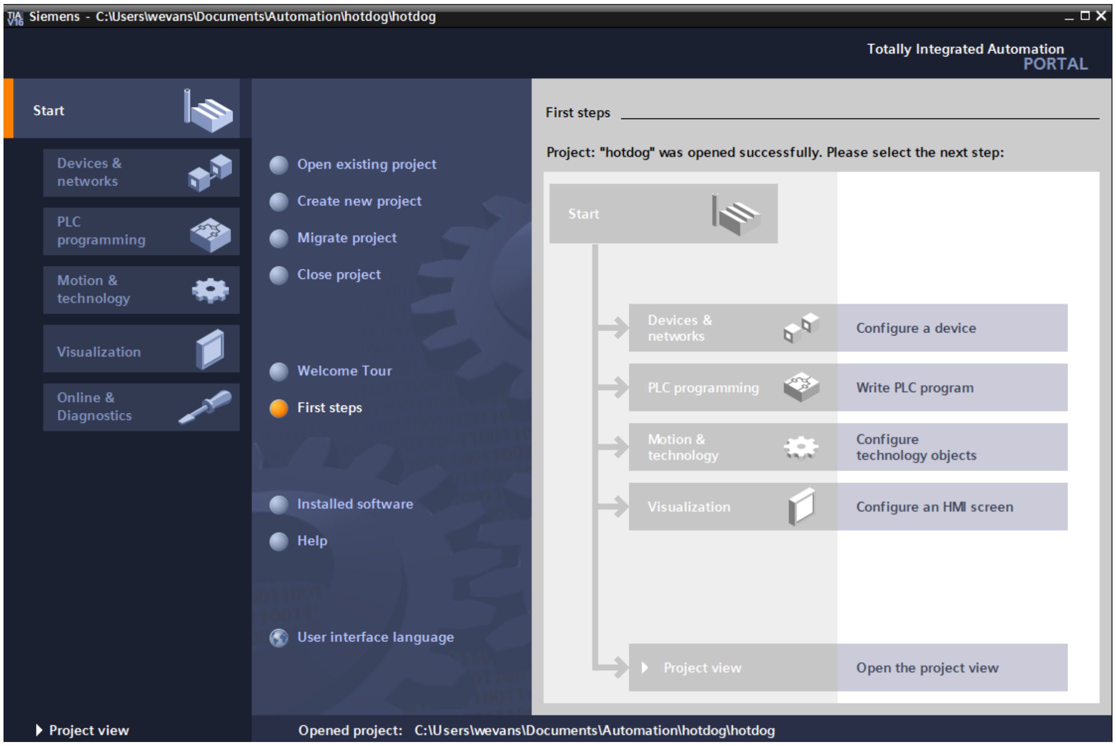


Enter the following 4 rung program in Siemens TIA Portal. Download and wire the inputs.

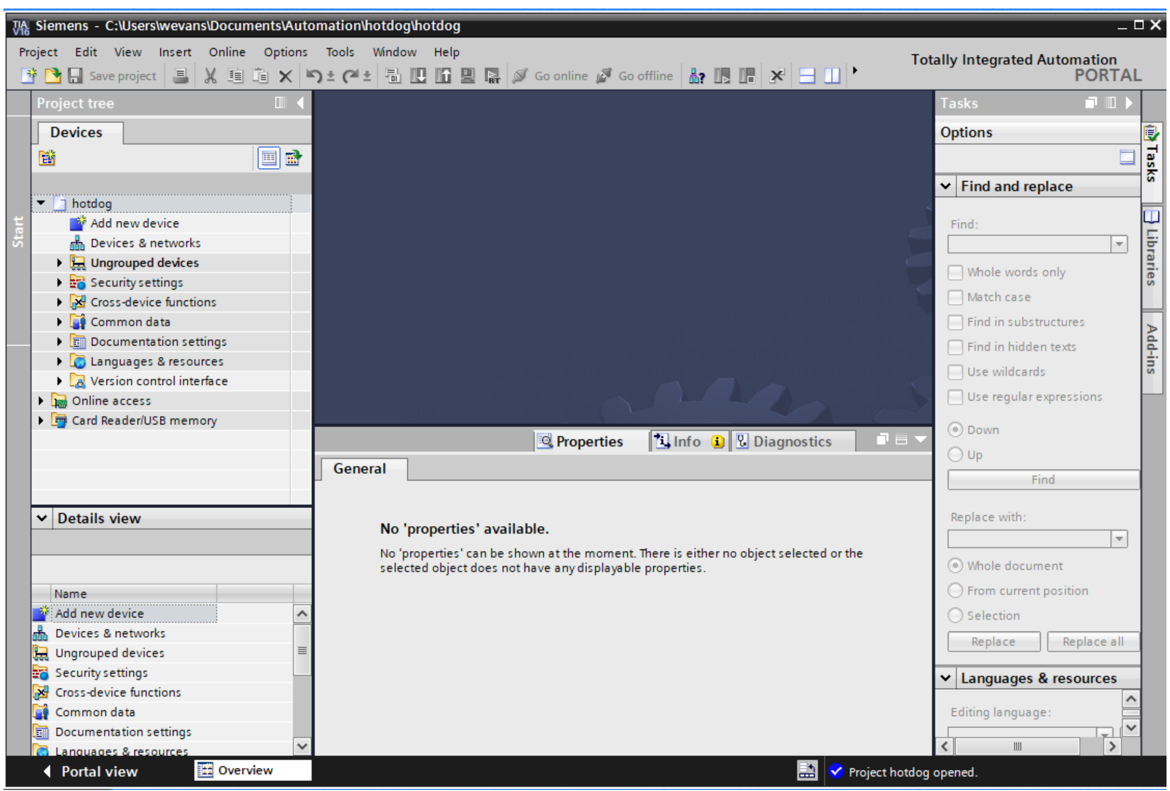


The count of hot dogs made is found in the accumulated value of the counter.

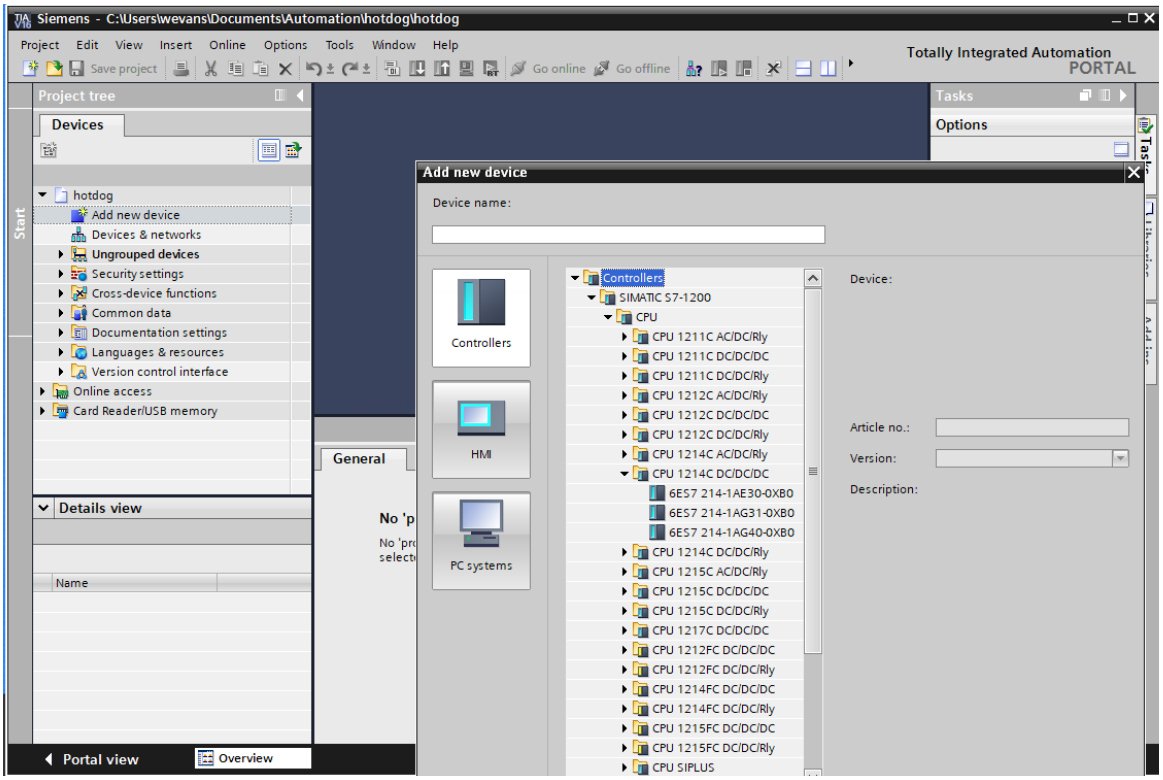
To start, select from the screen TIA – Siemens. Begin with a new project and name it 'Hotdog'. A screen similar to the following will appear:



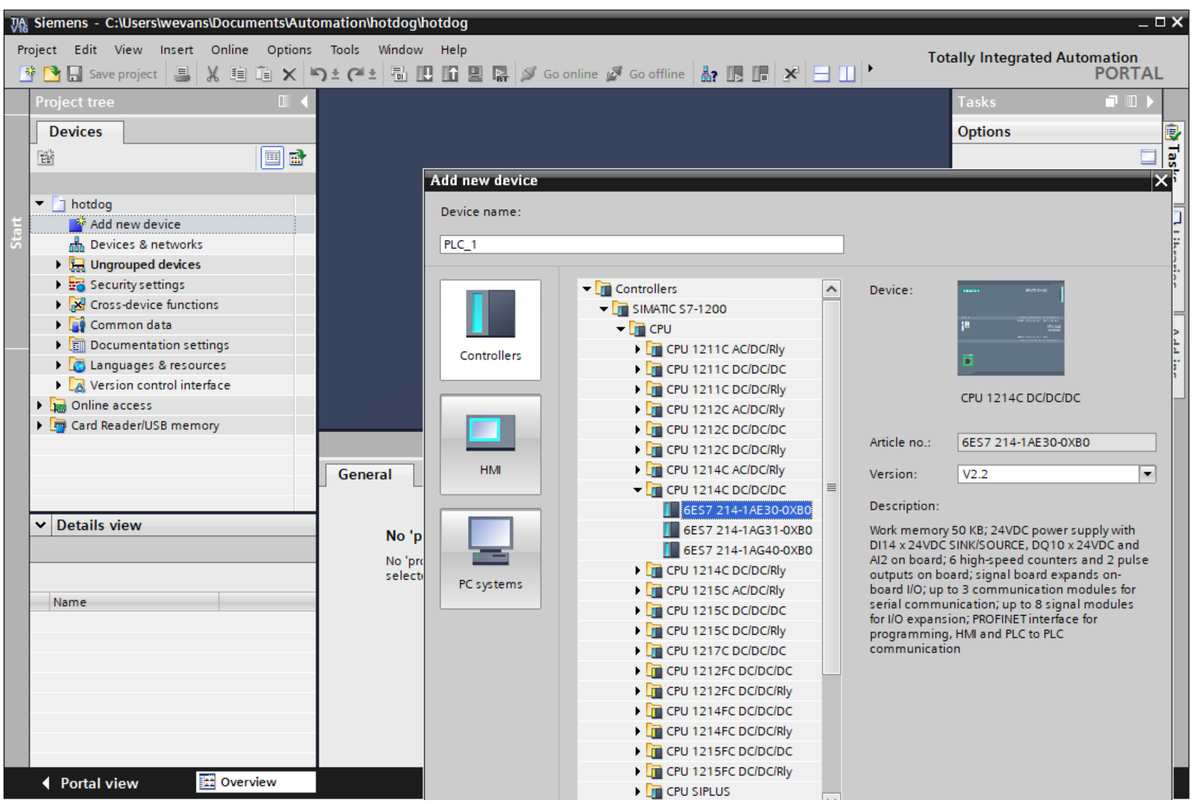
In the lower left, select 'Project view' and the following screen appears:

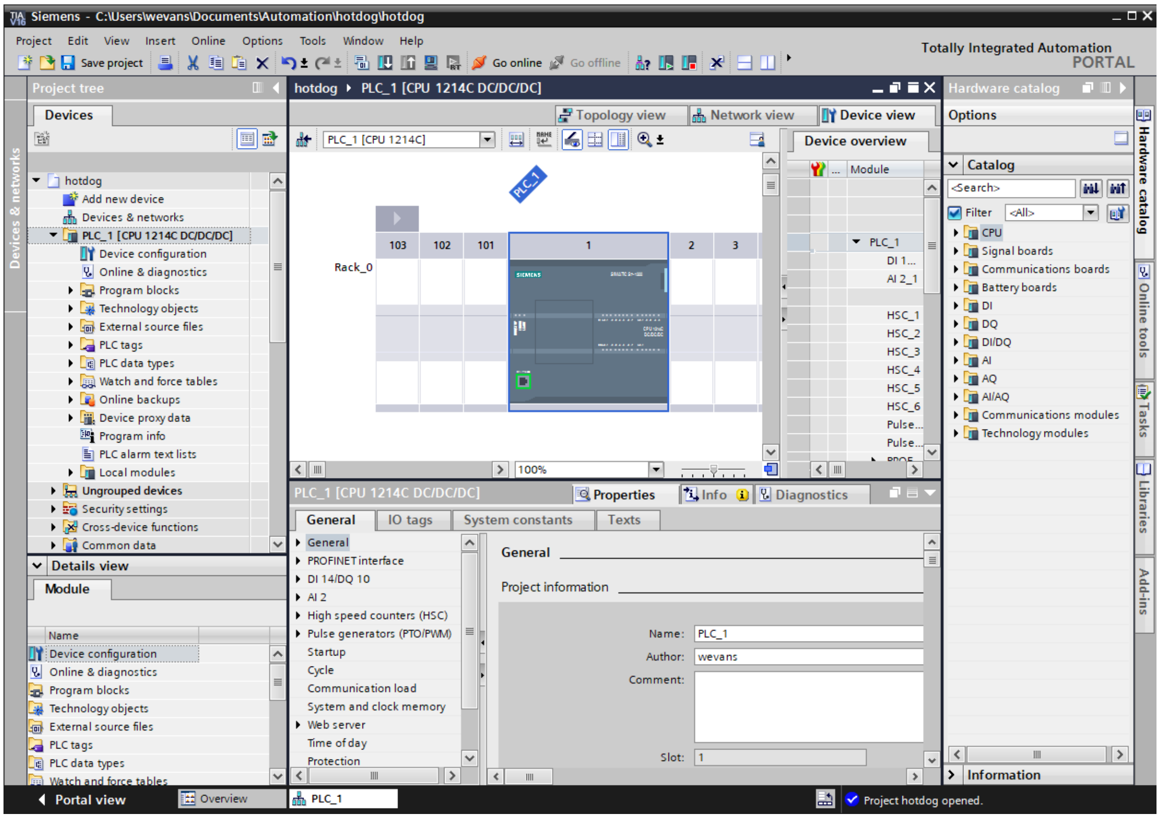


From the upper left, select 'Add new device' and follow the selection screen as show below:

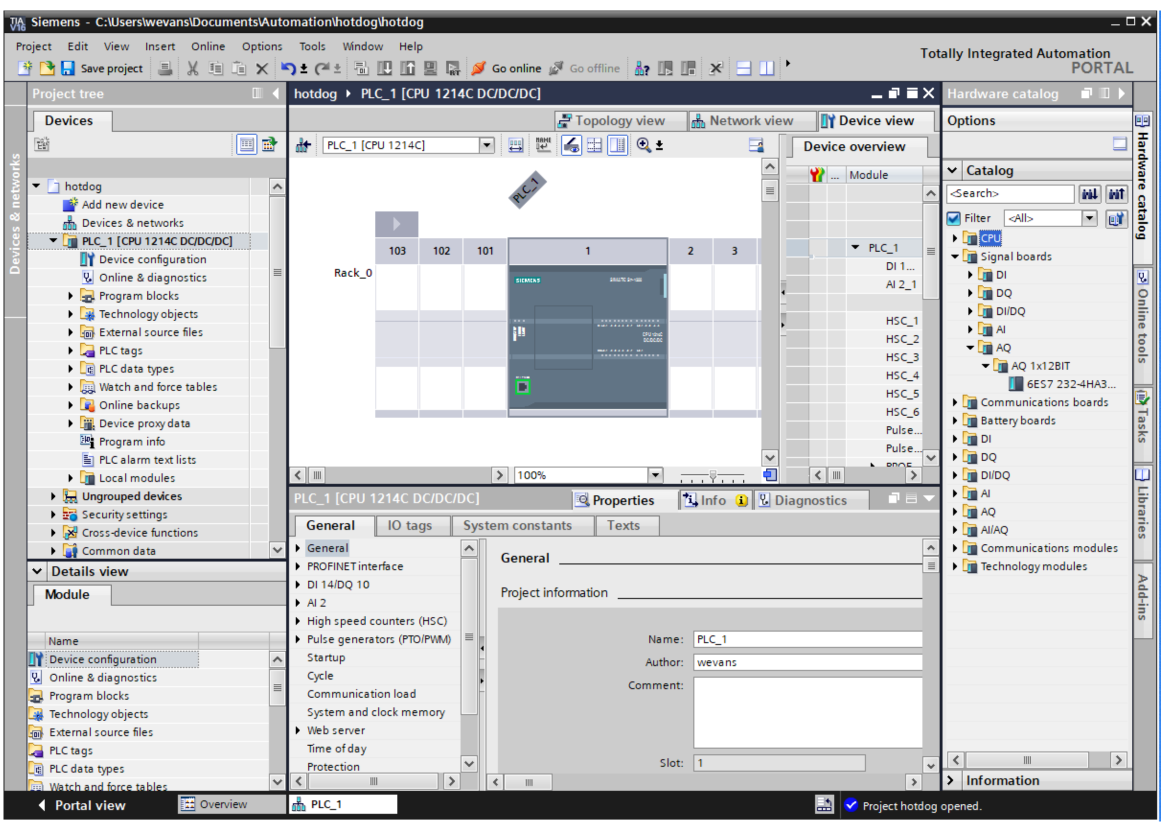


Once selected, the screen will look like:

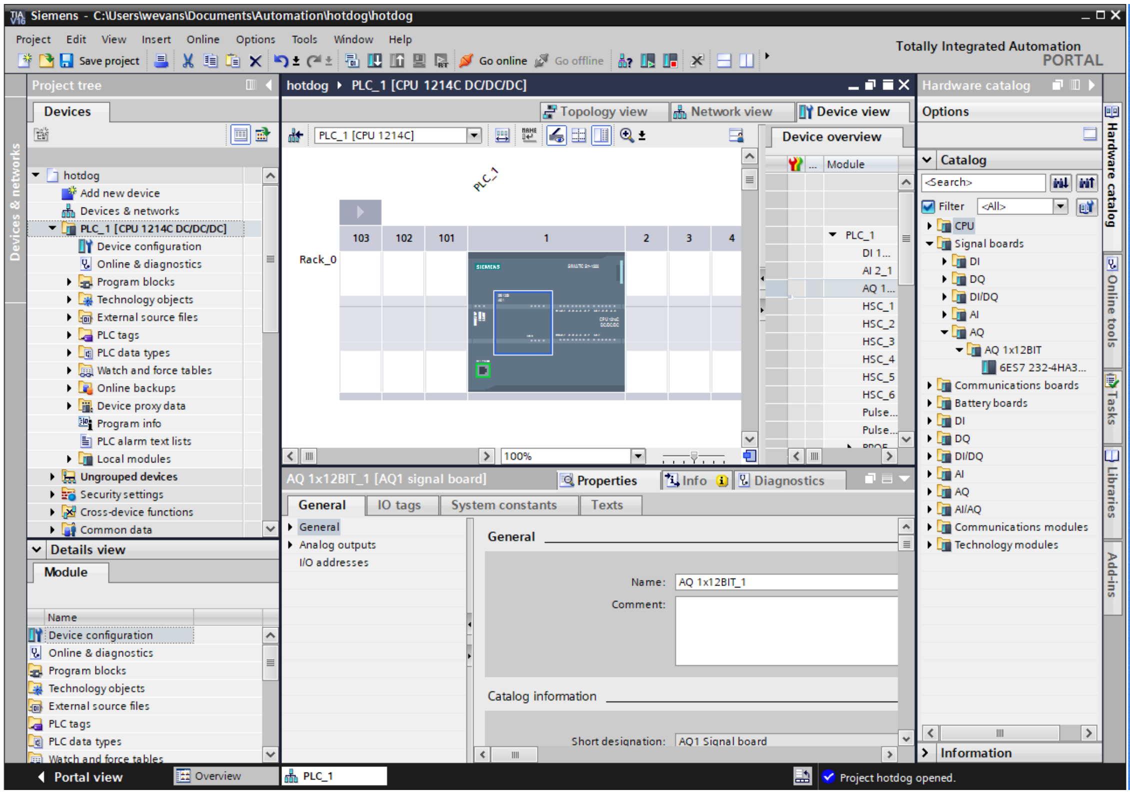




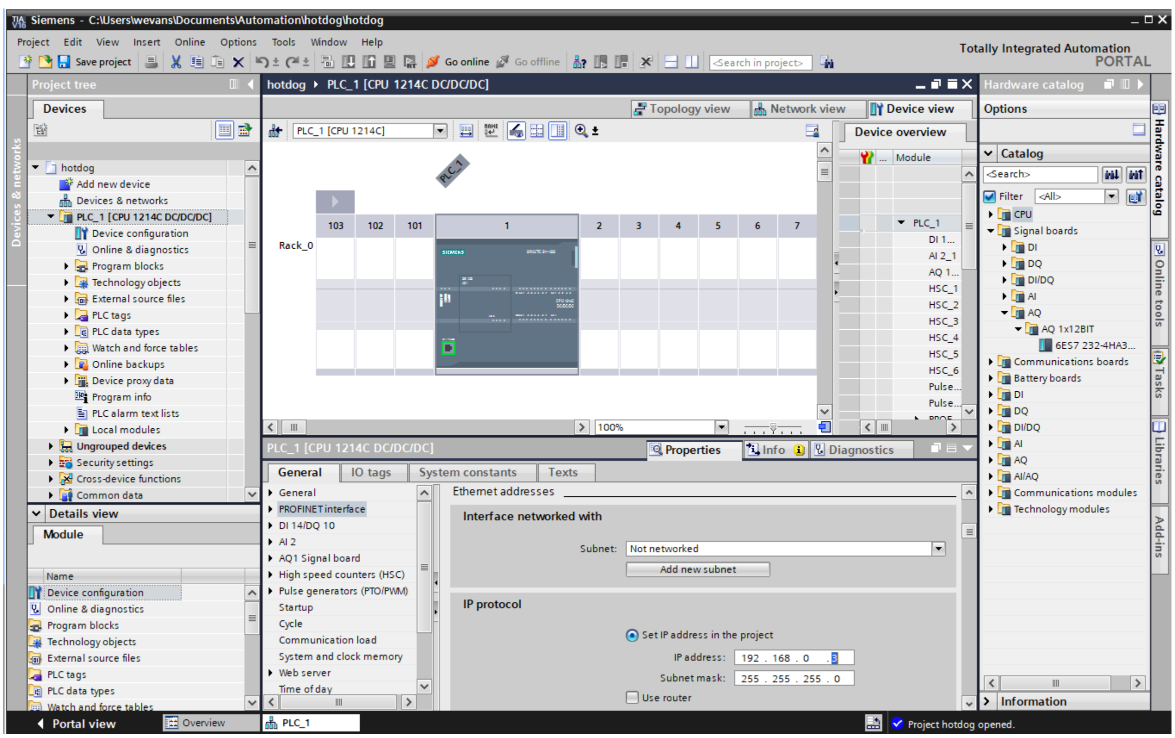
We need to add a signal board if your PLC has one. This is done with a drag and drop:



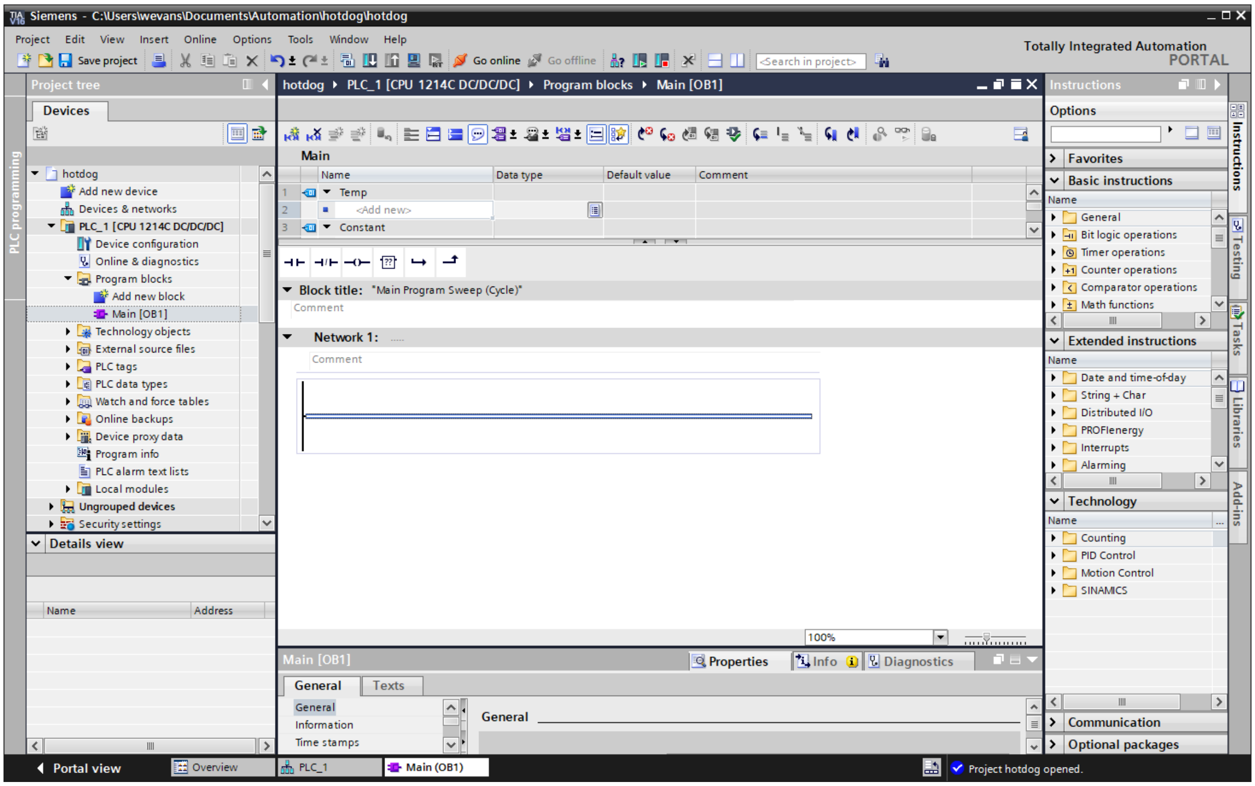
Your screen will resemble the following:



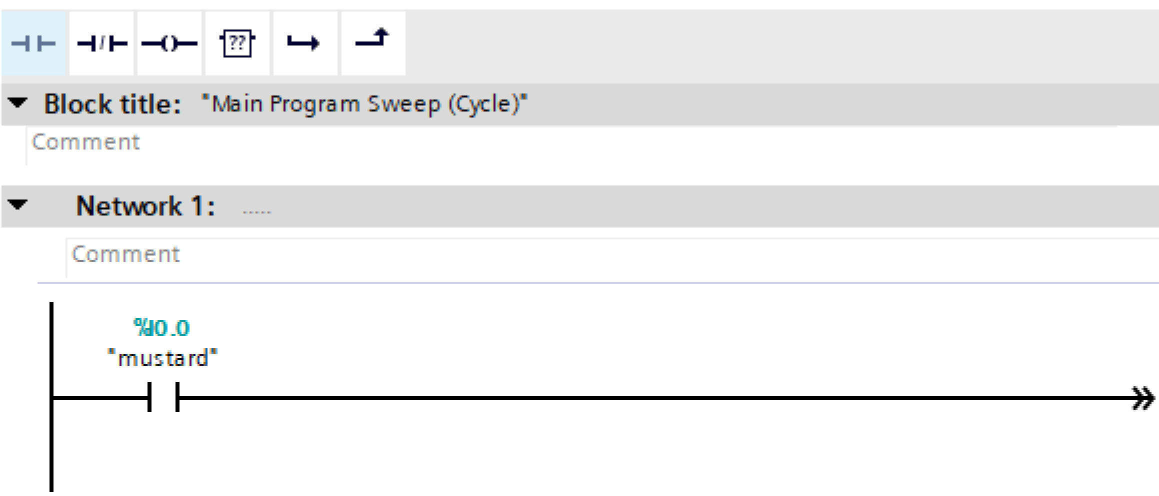
To change the ethernet port, click on the little green port on the processor. Change to 192.168.0.3.



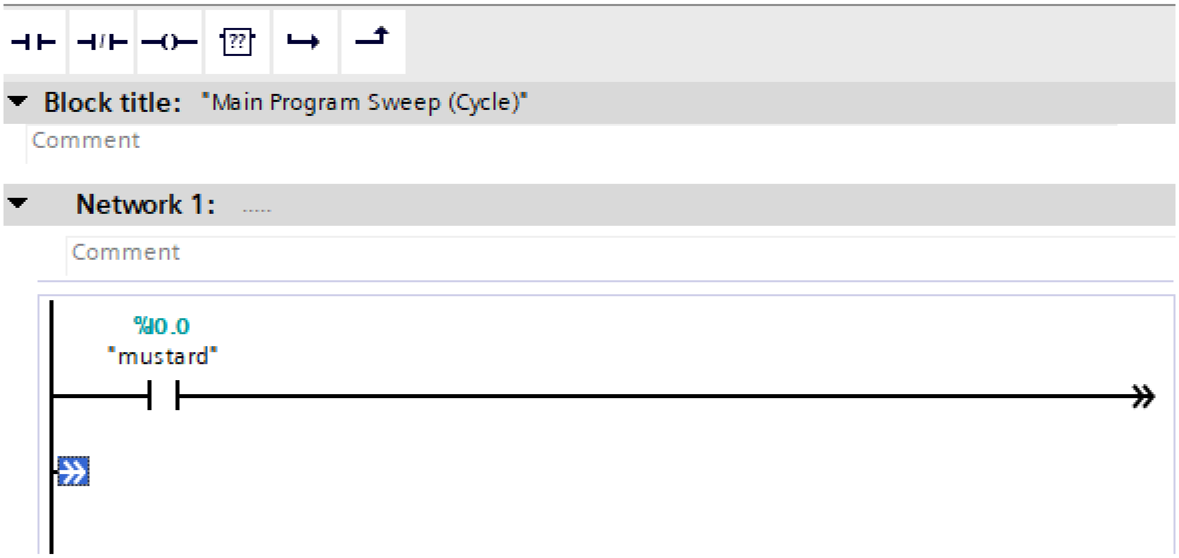
Next, find OB1 under Program Blocks and begin programming the application:



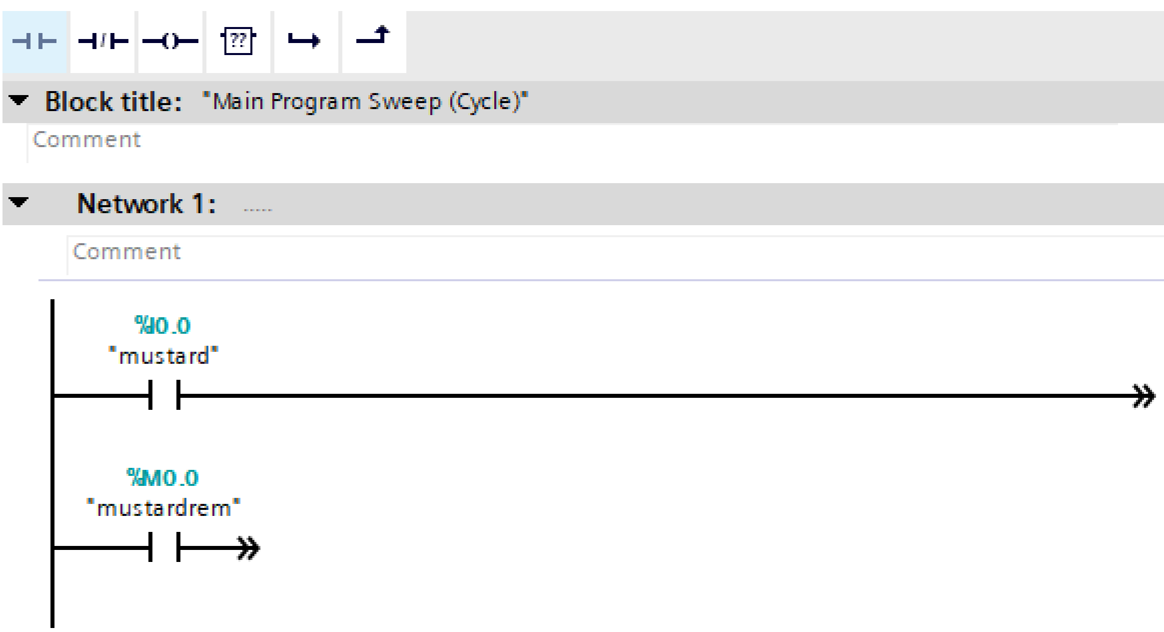
Drag down a normally open contact and define it as an Input



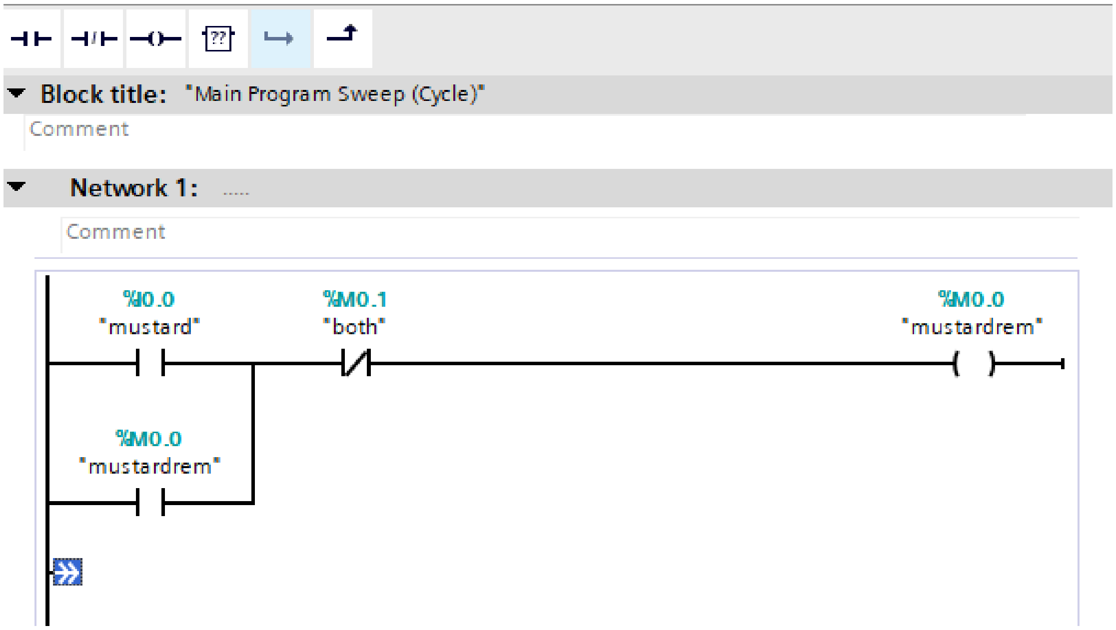
Start the parallel path as follows:



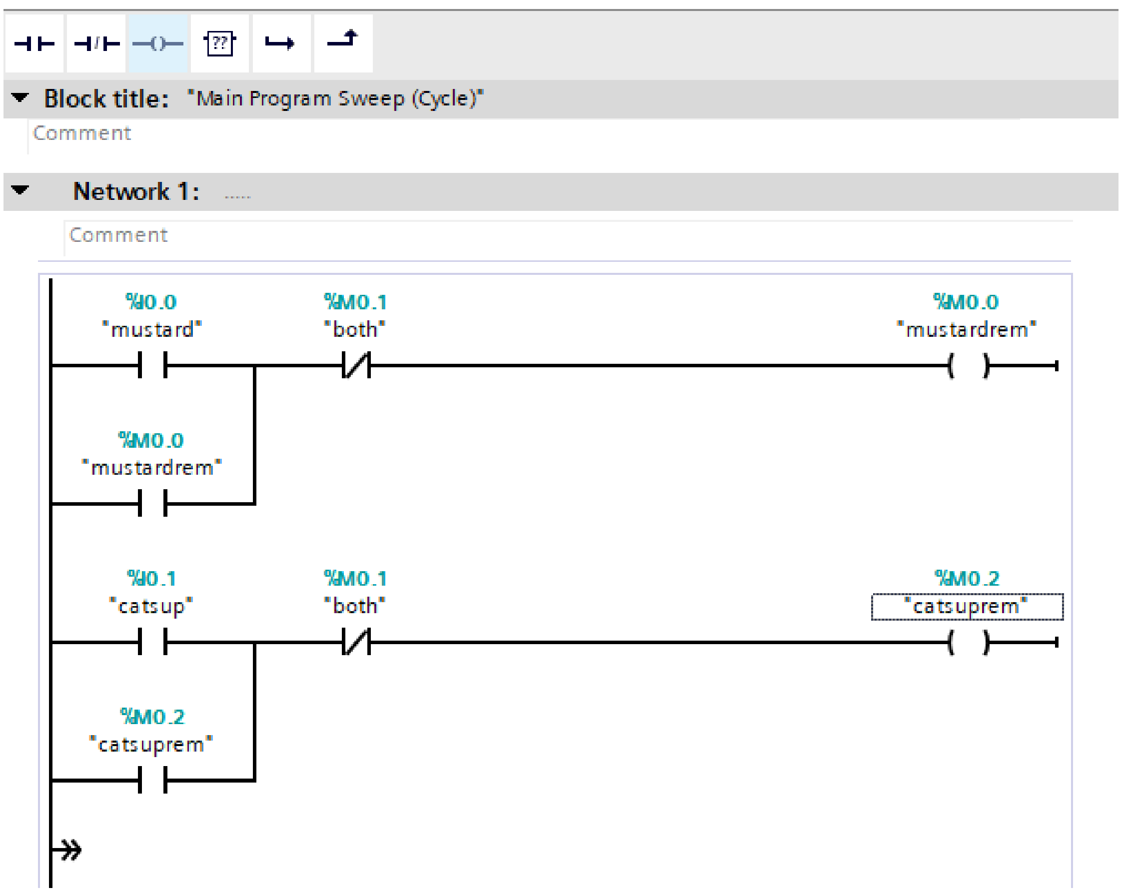
Then add the contact:



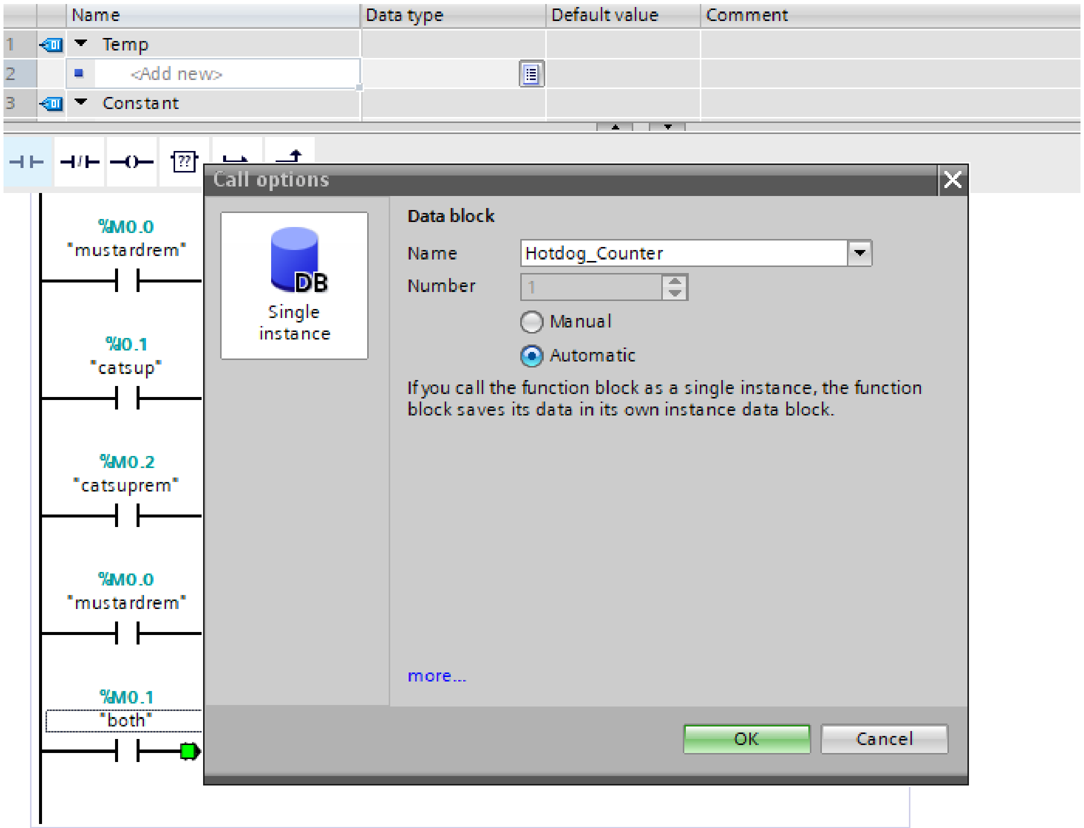
Finish the first rung and start the second one while still in Network 1:



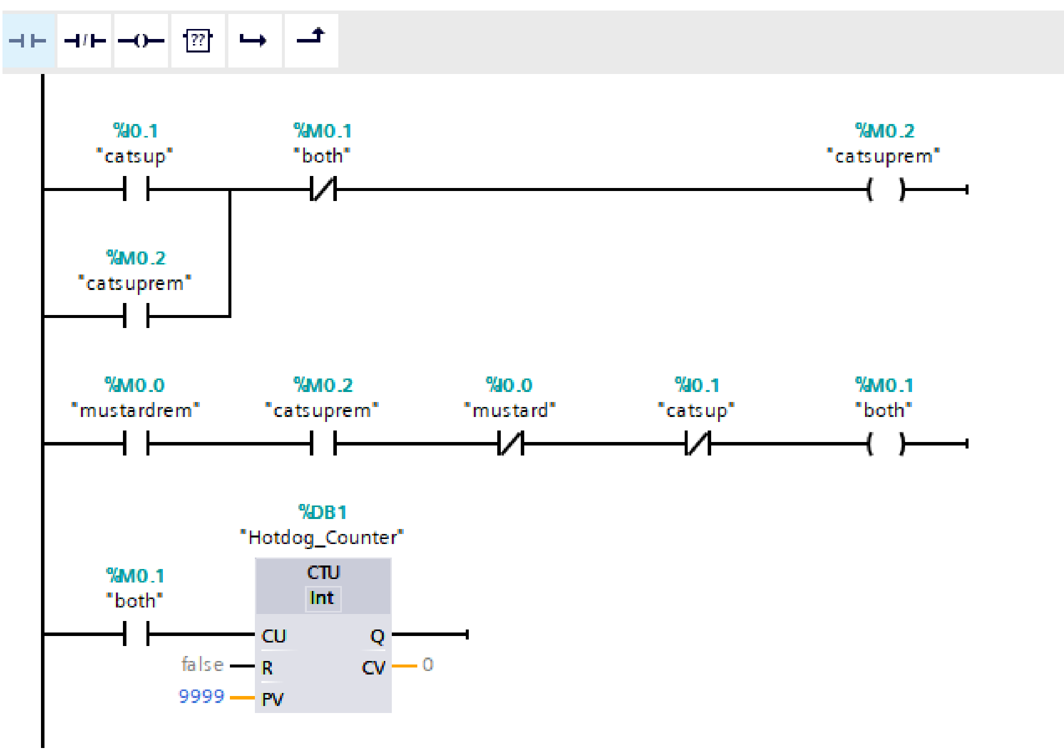
Keep going:



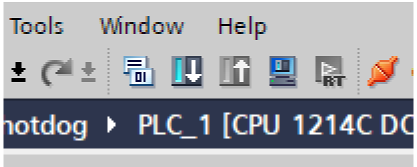
Then add the counter:



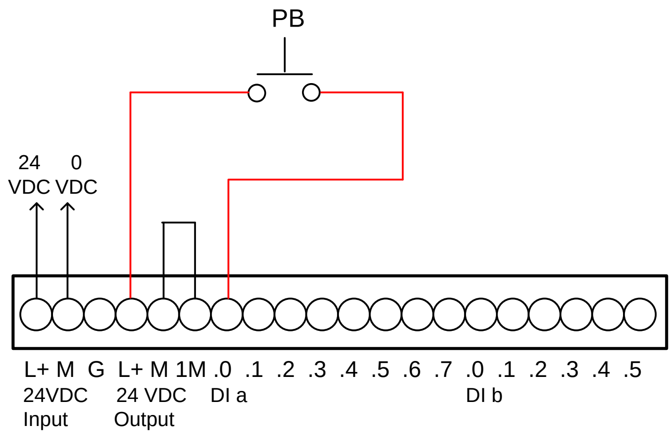
Final Result:



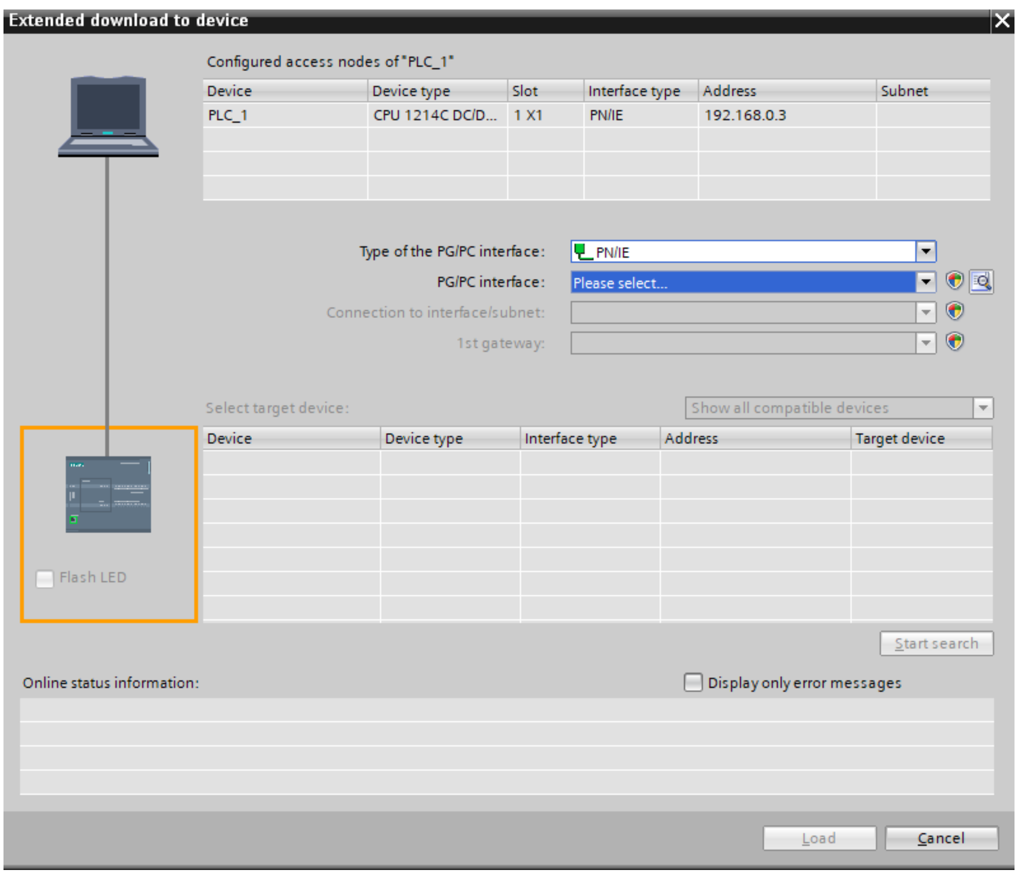
Compile, download and run:



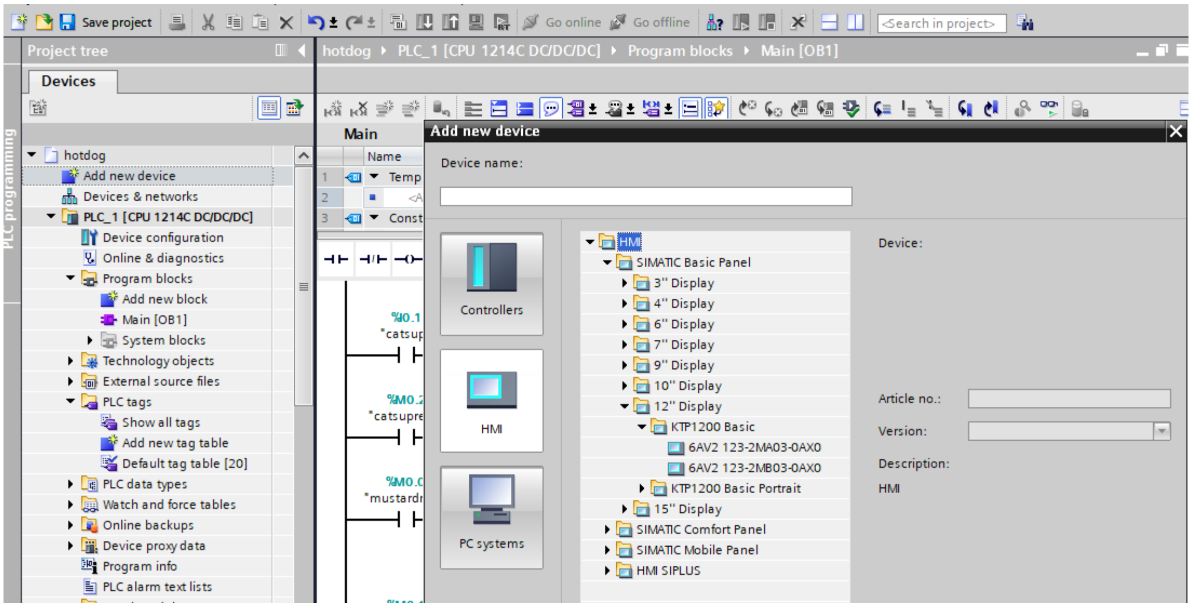
Siemens wiring of input I0.0 is below:



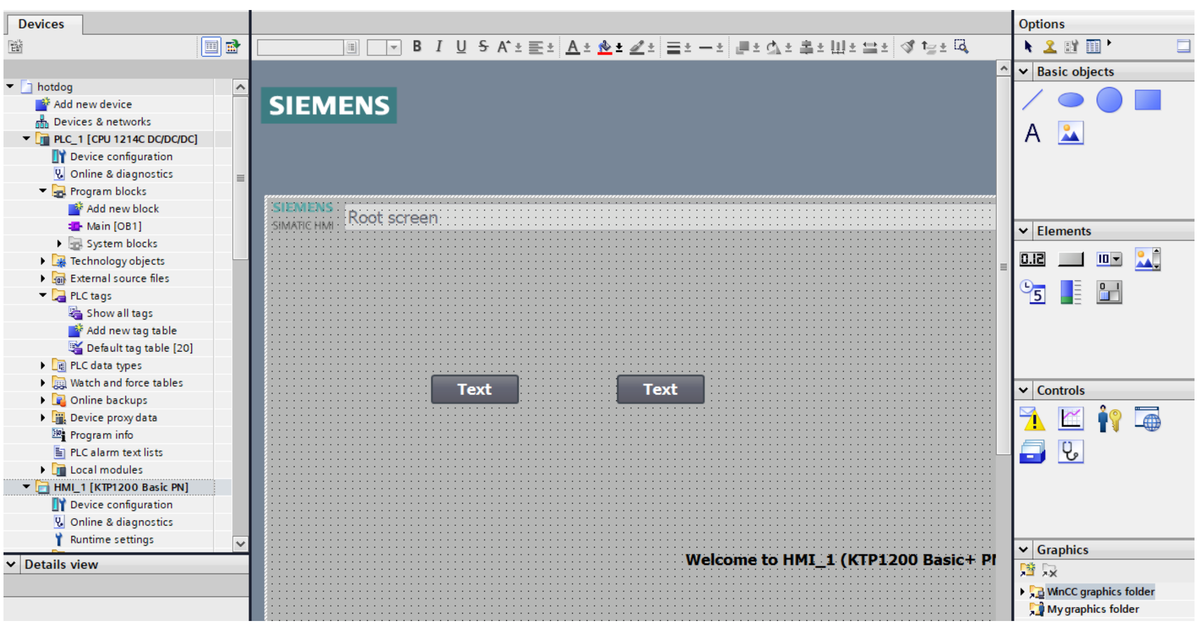
Stop here and get help from instructor:



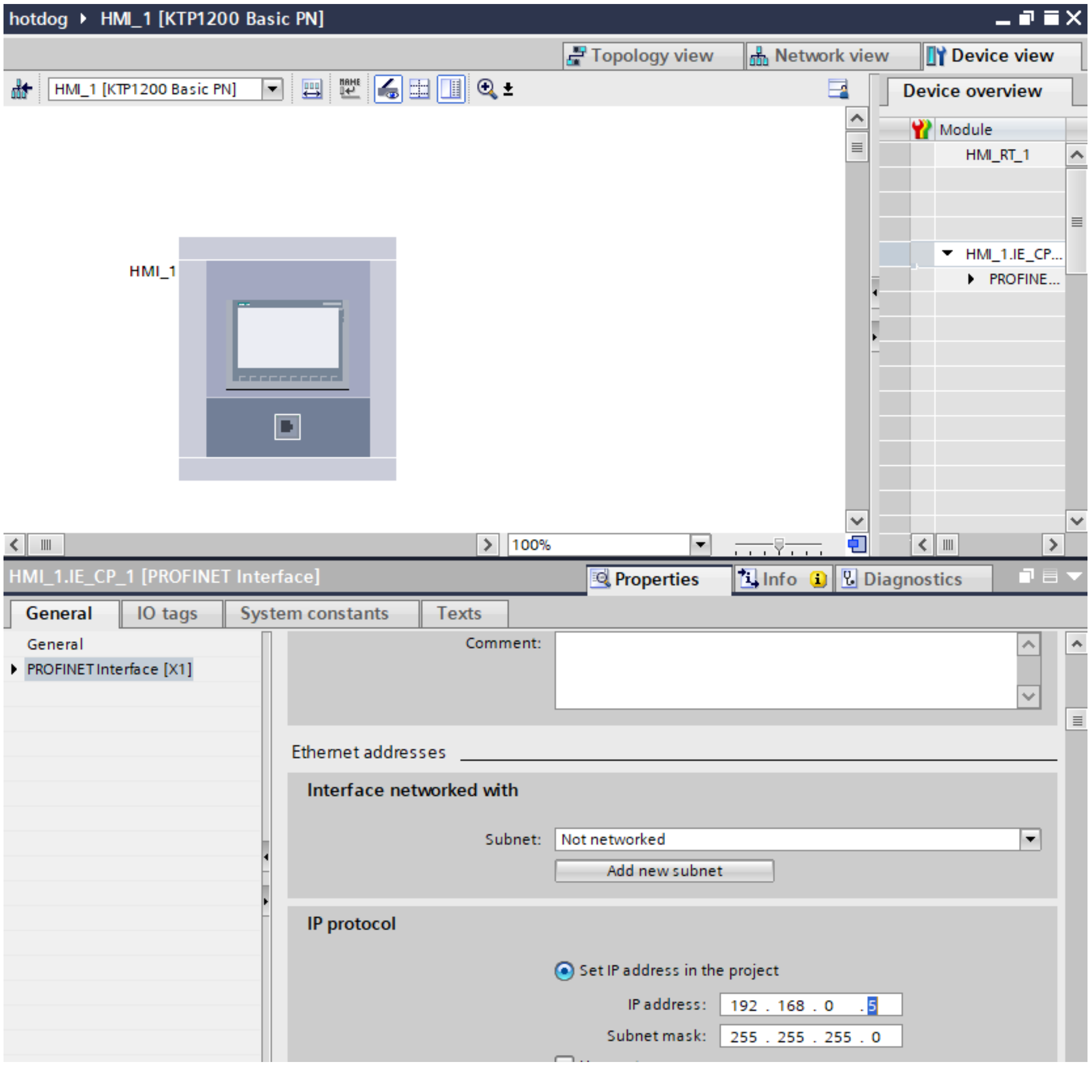
Next, after seeing the counter count up, add a display:



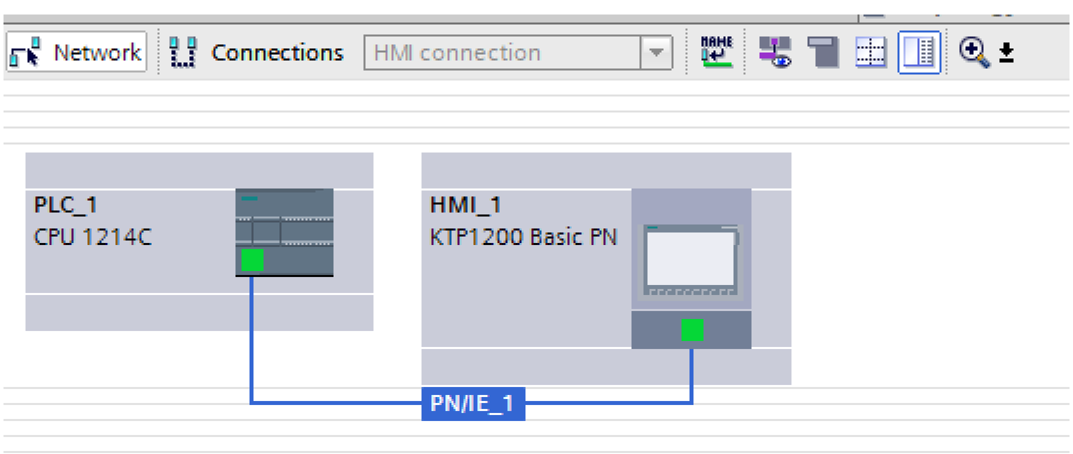
Substitute buttons for the two inputs and run the application using these buttons. Add the counter to the screen showing active count.



Make sure to set the IP address to 5 or 6.



Link the PLC and HMI using a drag/drop between the two:



This time, don't download. Rather, run the simulator from the screen of the computer. If needed, see instructor for this step.

To show that you have completed the lab, get screen shot of counter with counter greater than 0. Also, get screen shot of root screen with counter on it showing count greater than 0.

Laboratory Exercise 3

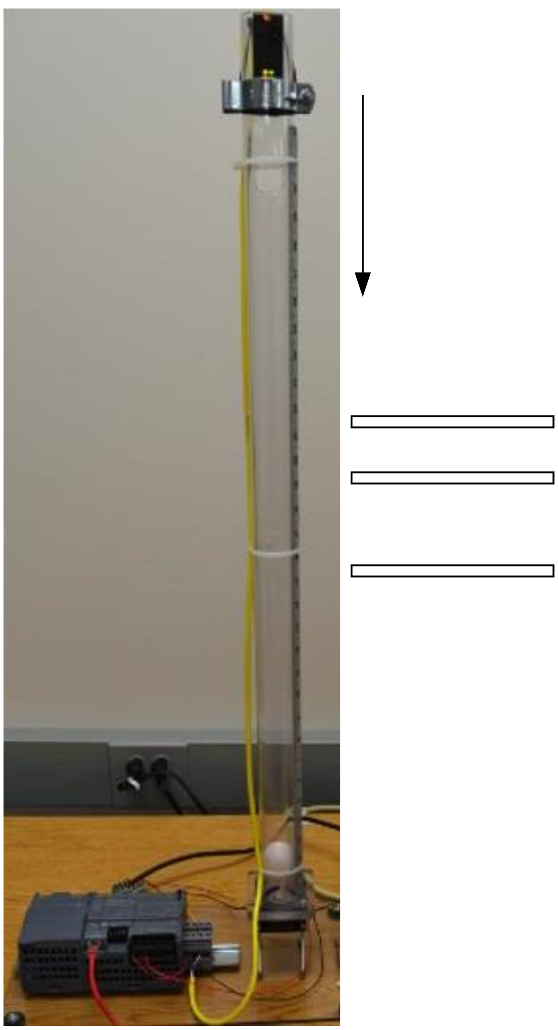
Laser Accuracy and Calibration

Introduction

The accuracy and range of a laser sensor is established in this lab. The laser used is an Allen- Bradley 45LMS. It has a range of about 8 feet. We will check accuracy with a yard stick. Wewill take measurements multiple times over the range to check for accuracy of our measured data.

Procedure

The laser will be removed but remain connected electrically to the stand. The PLC (Siemens S7-1200) will be used as the data collection device. The computer will be attached to the PLC via a coax cable and the Siemens program will display the raw data from the laser. This data will be recorded and analyzed for accuracy.



Remove the laser from the tube carefully anduse tape to affix it to the side of the tube focusing downward.

Align it with the yardstick.

At 1 inch increments place a book or index cardin the laser's path and read the laser output from the PLC. Record the yardstick measurement and the laser output reading.

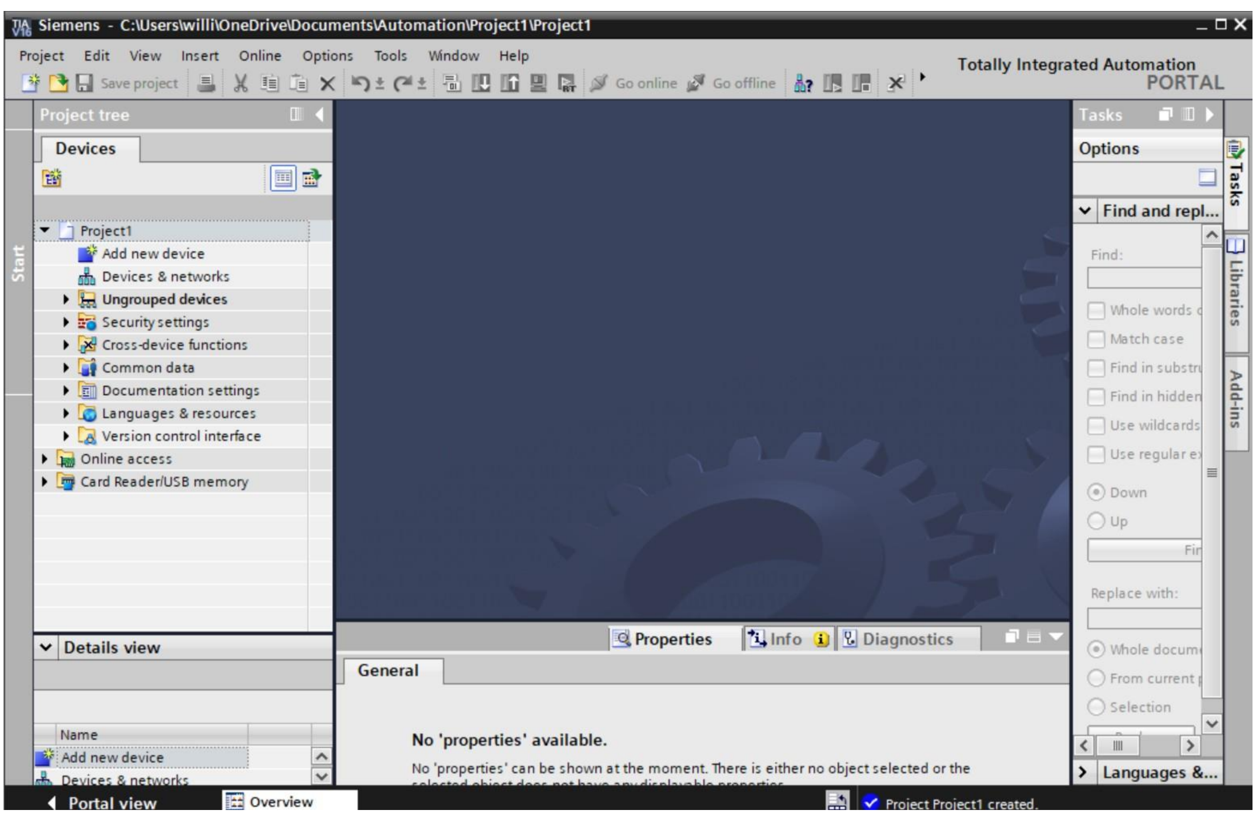
36 in	xxxxx
35 in	xxxxx
34 in	xxxxx
33 in	xxxxx
.	.
.	.
.	.

.	.
.	.
.	.
.	.
2 in	xxxxx
1 in	xxxxx
0 in	xxxxx

To read the values in the PLC, use the following instructions:

From the ‘Start’ button lower left, select ‘Siemens Automation’ and then ‘TIA Portal 16’. When the Siemens program opens, choose ‘Create new project’ and enter a name and choose ‘create’. Then from the lower left, choose ‘Project view’.

The following screen should appear:



First choose ‘Add new device’, then ‘Controllers’, then ‘Simatic S7-1200’, then ‘CPU’, then ‘CPU1214 DCDCDC’, then the first choice – ‘1AE30’, then ‘OK’ (green button at bottom of page).

From the right side of the page, choose ‘Signal boards’, then ‘AQ’, then drill down to the board and drag it to the blank square space in the middle of the CPU at the center of the page. This places the signal board chosen on the CPU itself. If your CPU does not have this separate signalboard, skip this step.

Then click on the green square lower left on the CPU and at the bottom of the page, set theEthernet address to ‘192.168.0.3’. Leave other ethernet settings as is.
Then right click on the CPU itself and choose ‘compile’. Then choose ‘download’. At this point, wait for further instructions from the lab instructor.

Next, choose ‘Go Online’ from the upper bar. Choose the glasses. Choose ‘Watch and force tables’, ‘Add new watch table’ and again, the glasses.

From the Watch Table, choose to watch location IW64. Enter this value in the table and beginrecording the numbers as you move down the yardstick.

Provide 2 sets of data starting at the top and working to the bottom of the yardstick. Also provide2 sets of data starting at the bottom and working to the top of the yardstick. If there are significant differences between top to bottom and bottom to top, hysteresis is a possibility.

Graph the data using either the EXCEL graphing program or using the regression analysis package from the statistical add-in. In either case, find the slopes and y intercept of the line. Find the maximum error of the data from the line for each set of data. Compare the four sets of data. Determine if there were any outliers and if the laser inputs were linear and by what percentof full scale.

The most straight-forward analysis of the data is to insert a chart in EXCEL. Highlight the tableof x, y values and simply choose ‘Insert’ and then under chart, the linear chart. A line will be drawn connecting the points. If it is reasonably linear, then the function is linear.
Another choice is under the choice ‘Data’, then ‘Data Analysis’, then ‘Forecasting’. This shows relative lines of high and low values the function can have.

A third alternative is the following – Linear Regression. This gives much more detail and may require an additional upload of add-ons.

Discuss your results.

How to Perform Multiple Linear Regression in Excel
Posted by ‘Zack’ on https://www.statology.org

Lab Exercise 4

Ultrasonic Sensor Accuracy and Calibration

Introduction

The accuracy and range of an ultrasonic sensor is established in this lab. The ultrasonic sensor used is a Banner Engineering U-Gage S18U Sensor. It has a range of about 12 inches. We will check accuracy with a micrometer dial instrument. We will take measurements multiple times over the range to check for accuracy of our measured data.

Procedure

The ultrasonic sensor will not be removed but left as is and remain connected electrically to the tank. The PLC (Siemens S7-1200) will be used as the data collection device. The computer willbe attached to the PLC via a coax cable and the Siemens program will display the raw data from the sensor. This data will be recorded and analyzed for accuracy.

The PLC (Siemens S7-1200) will be used as the data collection device. The computer will be attached to the PLC via a coax cable and the Siemens program will display the raw data from theultrasonic sensor. This data will be recorded and analyzed for accuracy.

To read the values in the PLC, use the following instructions:

From the ‘Start’ button lower left, select ‘Siemens Automation’ and then ‘TIA Portal 16’. When the Siemens program opens, choose ‘Create new project’ and enter a name and choose ‘create’. Then from the lower left, choose ‘Project view’.

To choose the correct processor, select the 1200 PLC again but instead of the 1214, select the 1215 DCDCDC. Then look at the tank you are using to find the firmware version. It will be a large tag taped to the tank. It will say ‘4.2, 4.3 or 4.4’. Make sure to choose the correct firmware or it will not load. Also, the signal board may or may not be present. It is not the Analog Output board this time. It probably is the 5V Digital Input board. Please check before proceeding. This will also cause your program to not load. Again, use IW64 as the input point.

Provide 2 sets of data starting at the top and working to the bottom. Also provide 2 sets of data starting at the bottom and working to the top. If there are significant differences between top to bottom and bottom to top, hysteresis is a possibility.

Graph the data using either the EXCEL graphing program or using the regression analysis package from the statistical add-in. In either case, find the slopes and y intercept of the line. Find the maximum error of the data from the line for each set of data. Compare the four sets of data. Determine if there were any outliers and if the ultrasonic sensor was linear and by what percent of full scale.

Laboratory Exercise 5

The Traffic Light

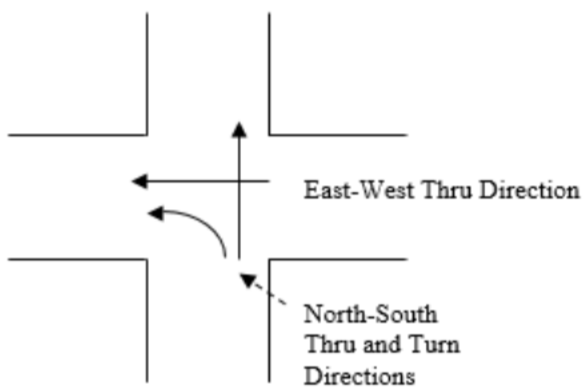
Introduction

The use of timers is explored in this lab as well as interfacing of outputs, either to the colored lights on the interface board or using the HMI to simulate these lights.

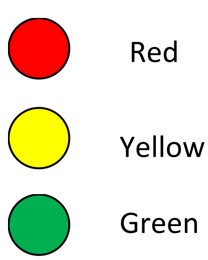
Procedure

A traffic intersection has the following three lane assignments:

East-West Thru
North-South Turn
North-South Thru



Two sets of traffic lights are found for each turn direction although the lab uses only one set. Each turn direction has a set of three lights as follows:



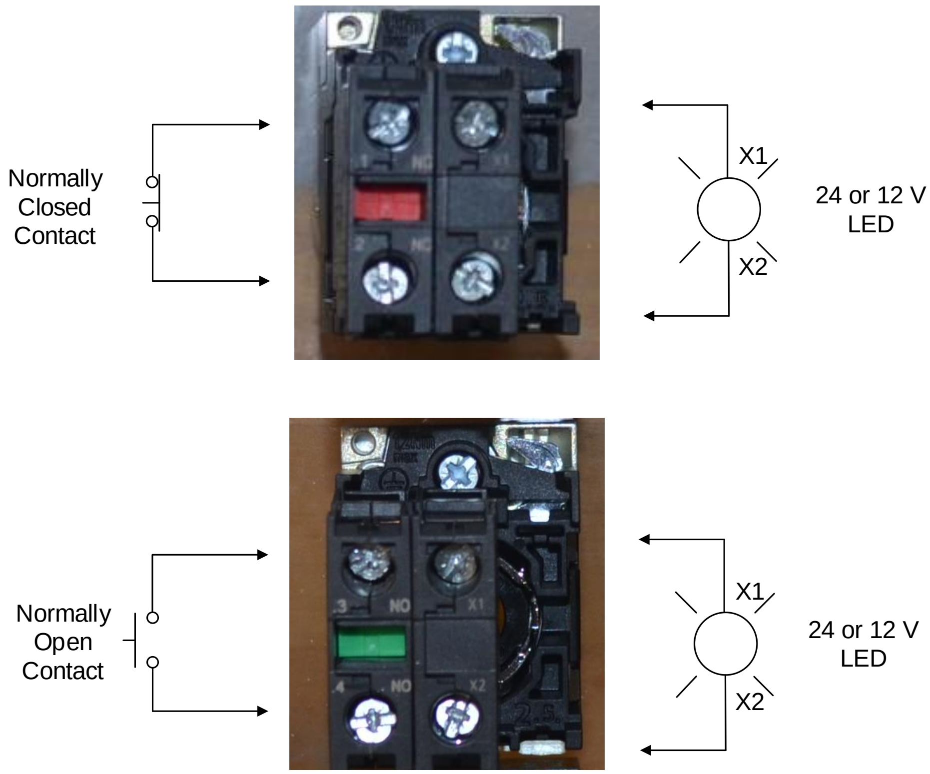
Although traffic intersection logic tends to be very complicated in order to provide fool-proof operation of the traffic intersection, a simplified chart of the operation of the lights can be used to program the lights and operate the intersection. Each interval is an interval of time and after the last interval, the process repeats from the top. The intersection's operational chart:

Interval	N-S Thru Lane	N-S Turn Lane	E-W Thru Lane
1	Green	Red	Red
2	Yellow	Red	Red
3	Red	Green	Red
4	Red	Yellow	Red
5	Red	Red	Green
6	Red	Red	Yellow

This lab consists of programming the nine lights to cycle through the proper sequence to control traffic flow at the intersection described above.
A helps program can be found accompanying this lab to start the process of setting up timers, especially to cycle and repeat a sequence.

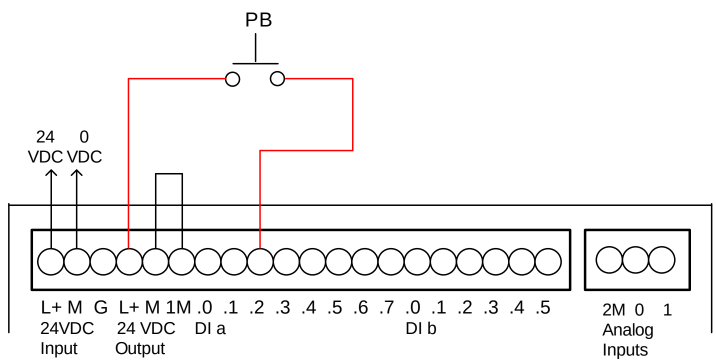
The wiring of the outputs to the lights can be accomplished using the following interface board:

Front side of New Pushbutton Stations

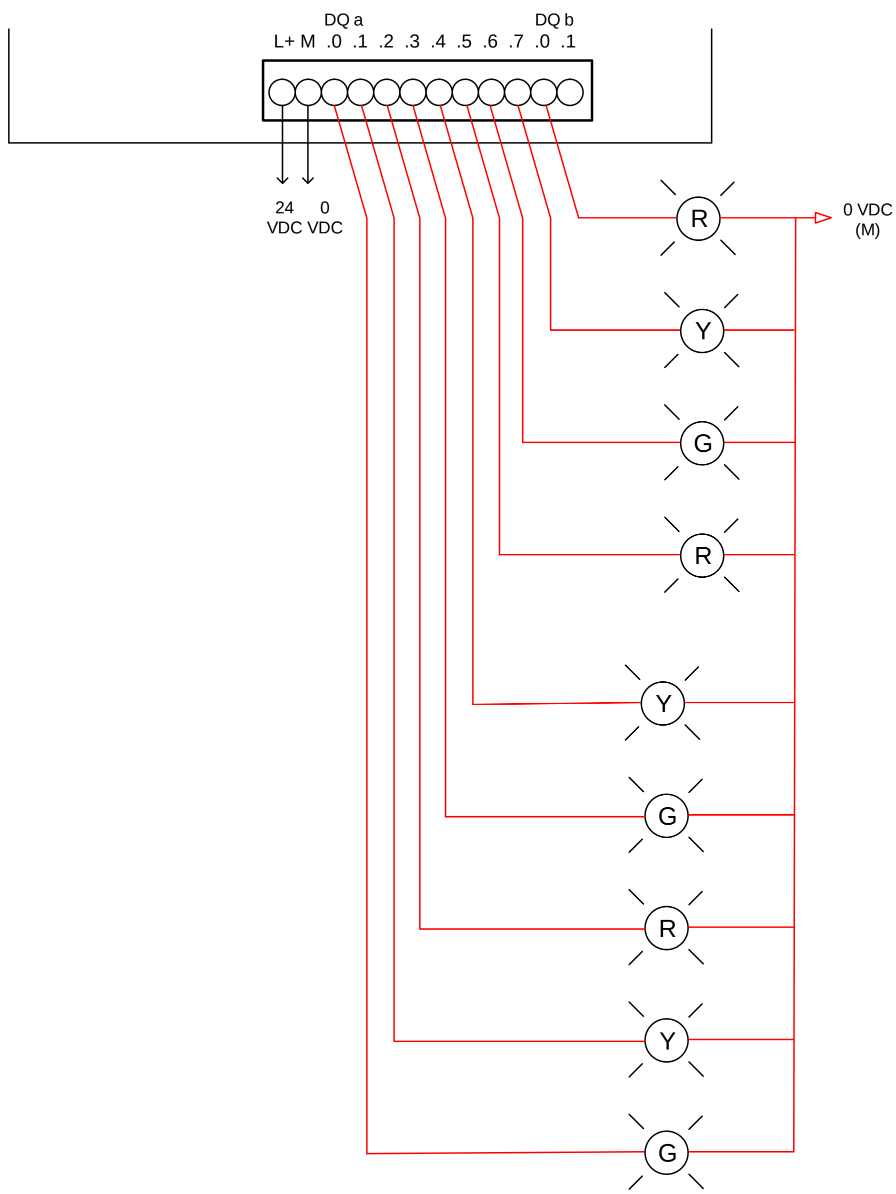


Back side of New Pushbutton Stations

Wiring for the lights and pushbuttons can be found on the following diagram.

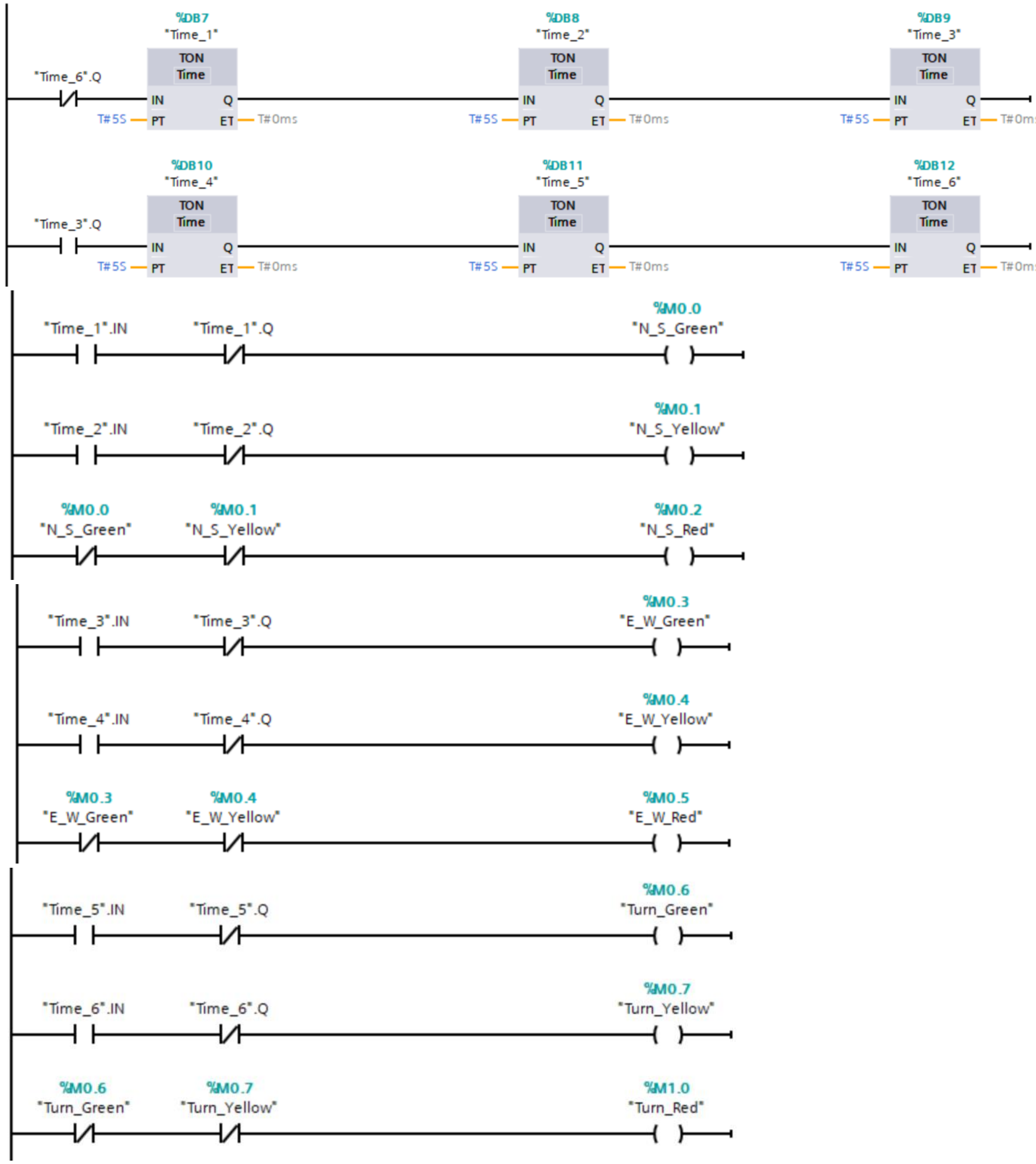


Wire Lite to output Q0.5



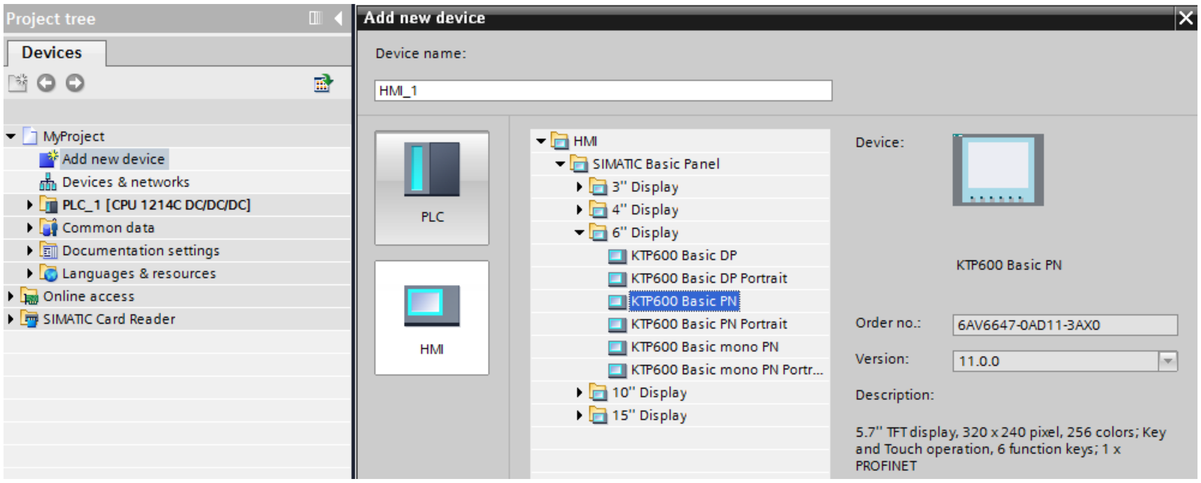
Or the student may choose to 'wire' the output lights using an HMI panel running in the virtual mode. If you choose to wire the outputs as shown above, the addresses for the output coils below need to be changed to actual outputs starting with Q0.0 and going through Q1.0.

Programming of the lights is below:

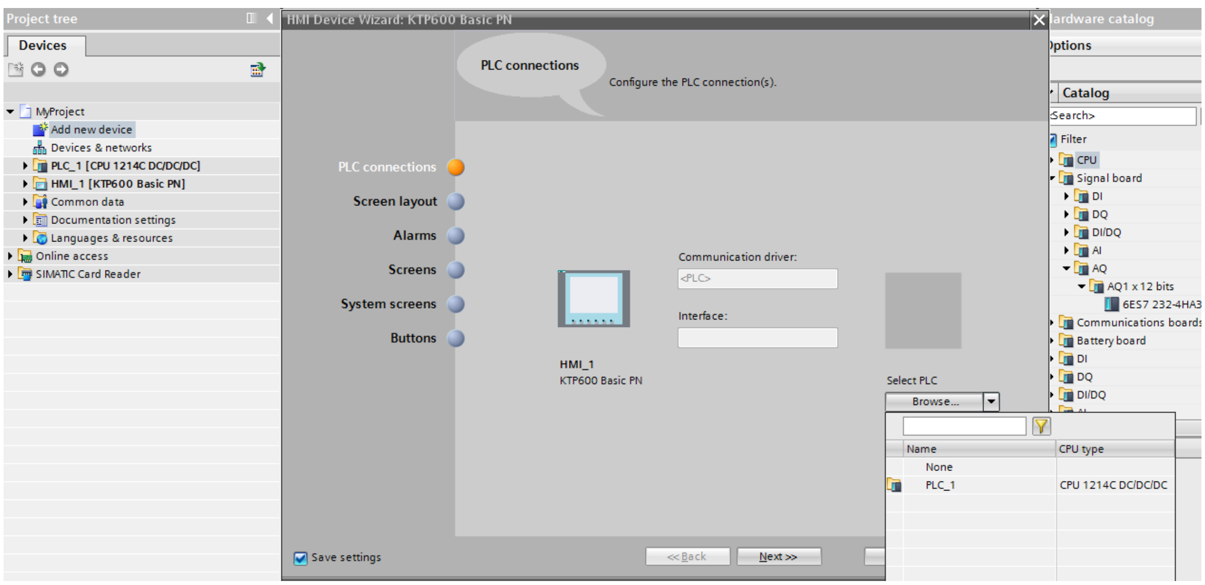


If you choose to use lights programmed on a screen, the following will help. You will not be required to connect to an actual HMI panel but rather use the virtual screens associated with the TIA software that run on the computer.

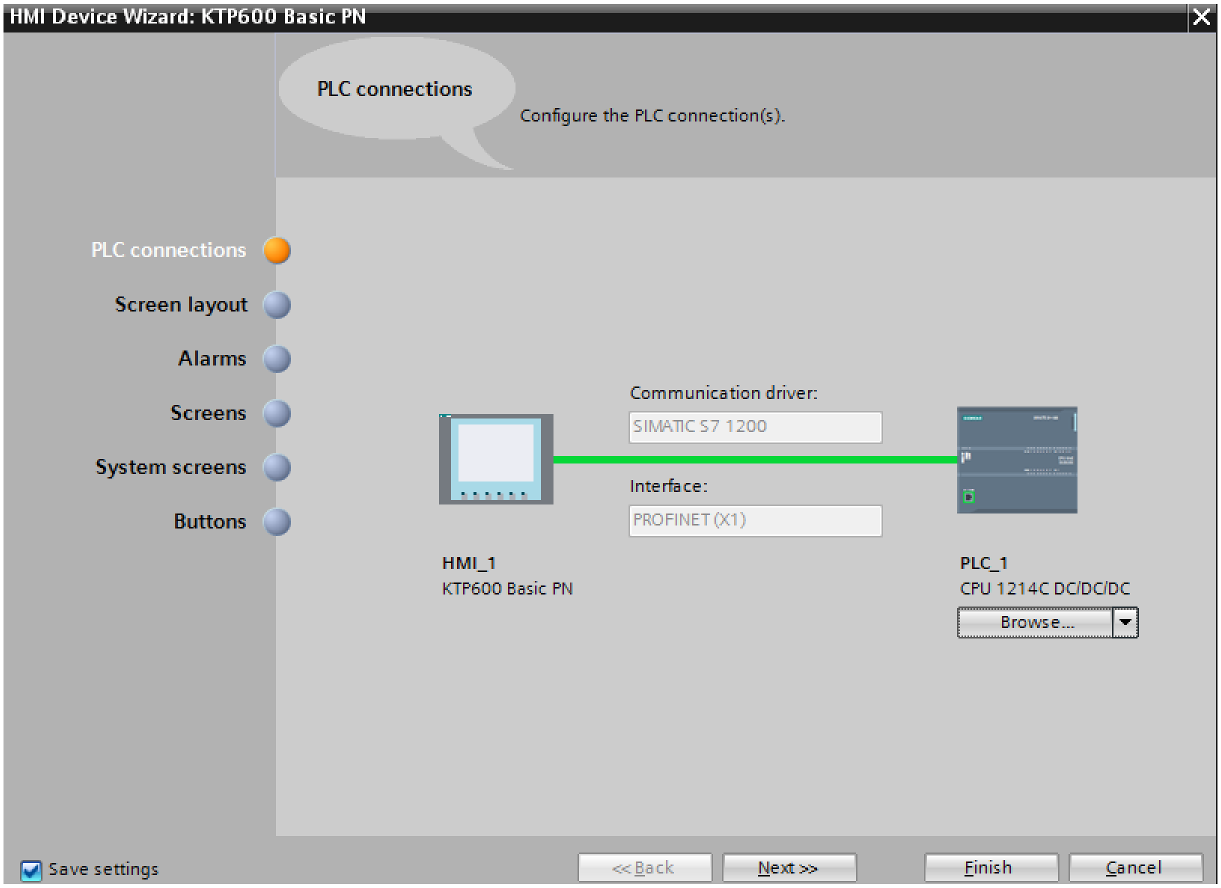
Addition of the HMI used in the labs:



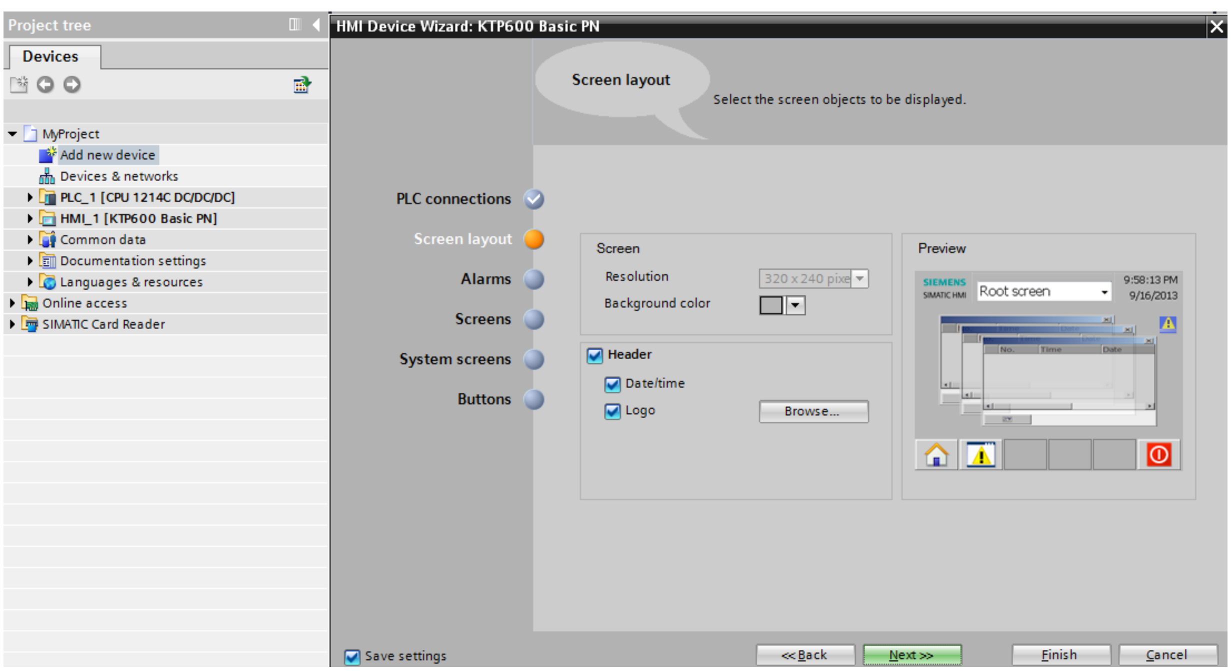
The HMI Device Wizard:

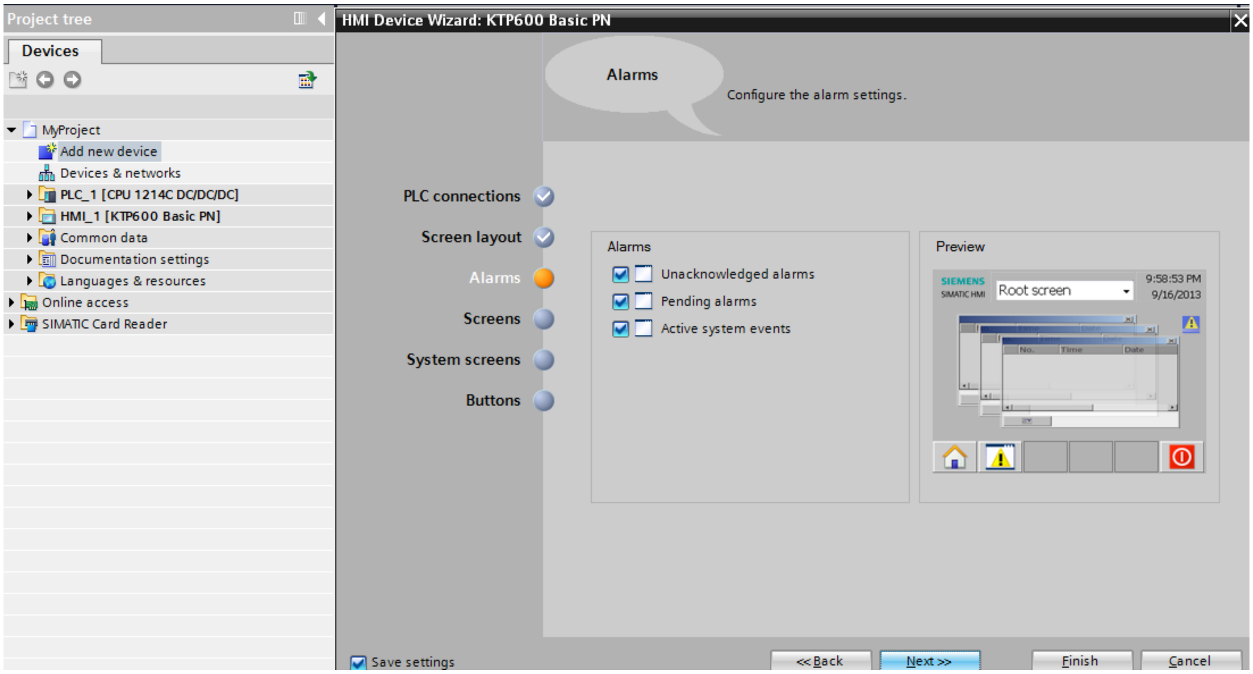


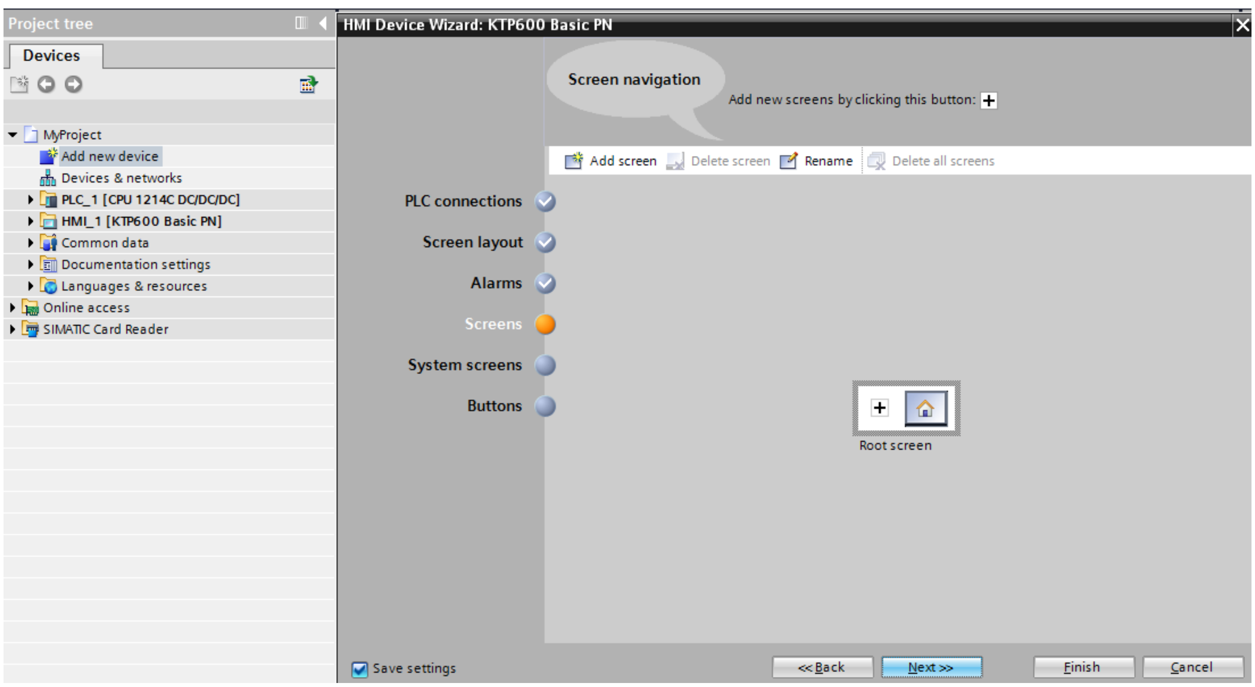
Keep answering Next>>



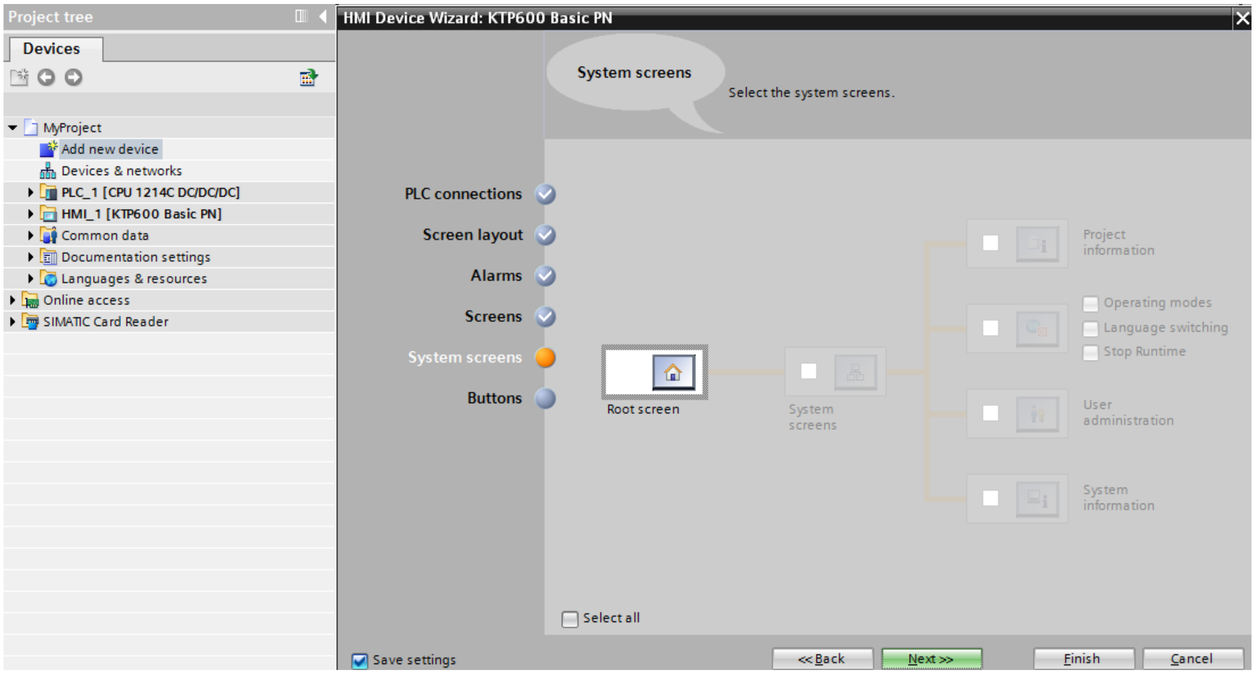
Keep answering Next>>

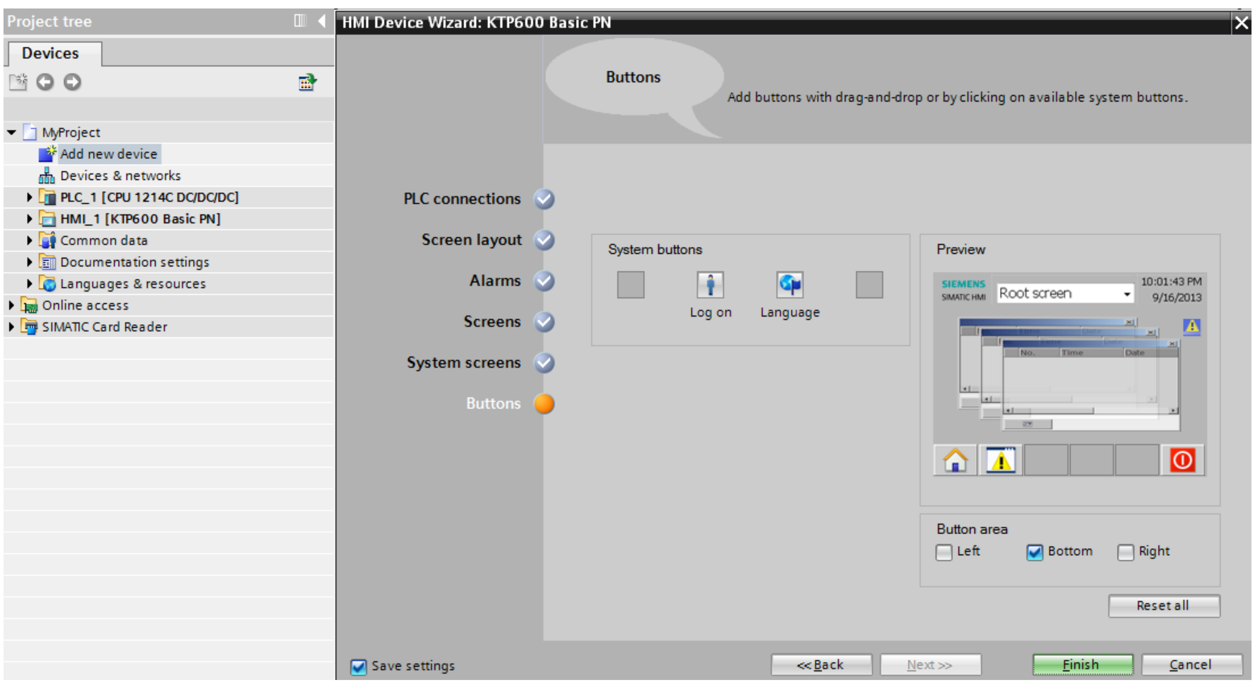






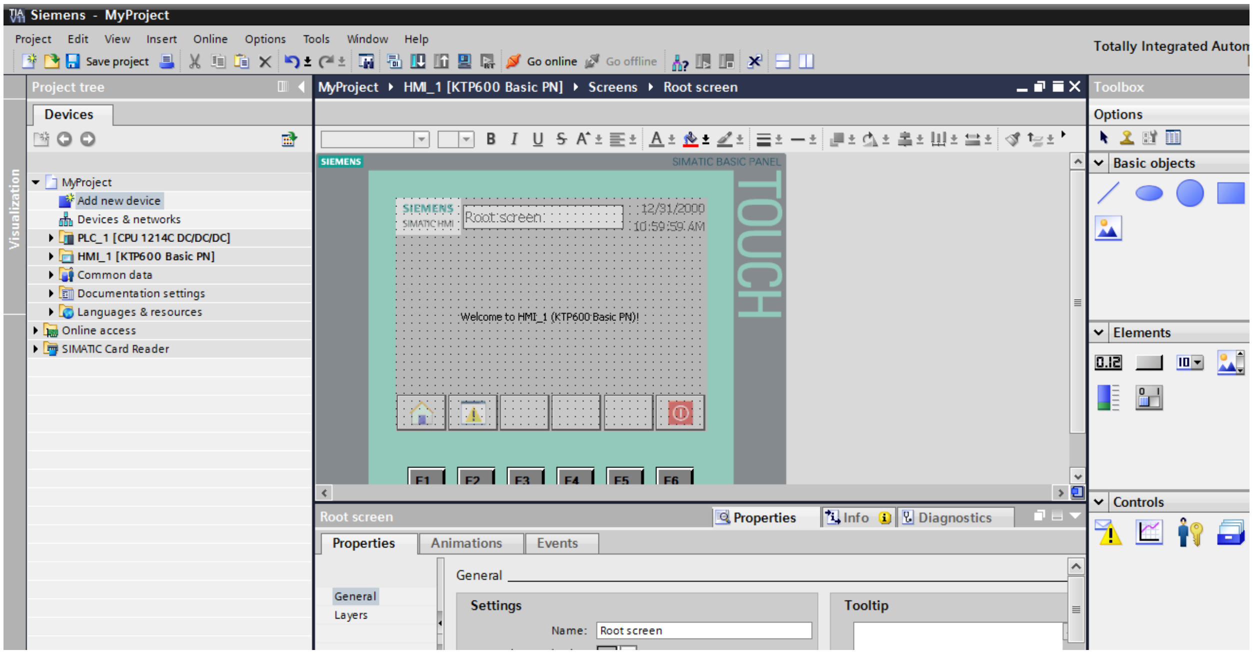
Keep answering Next>>



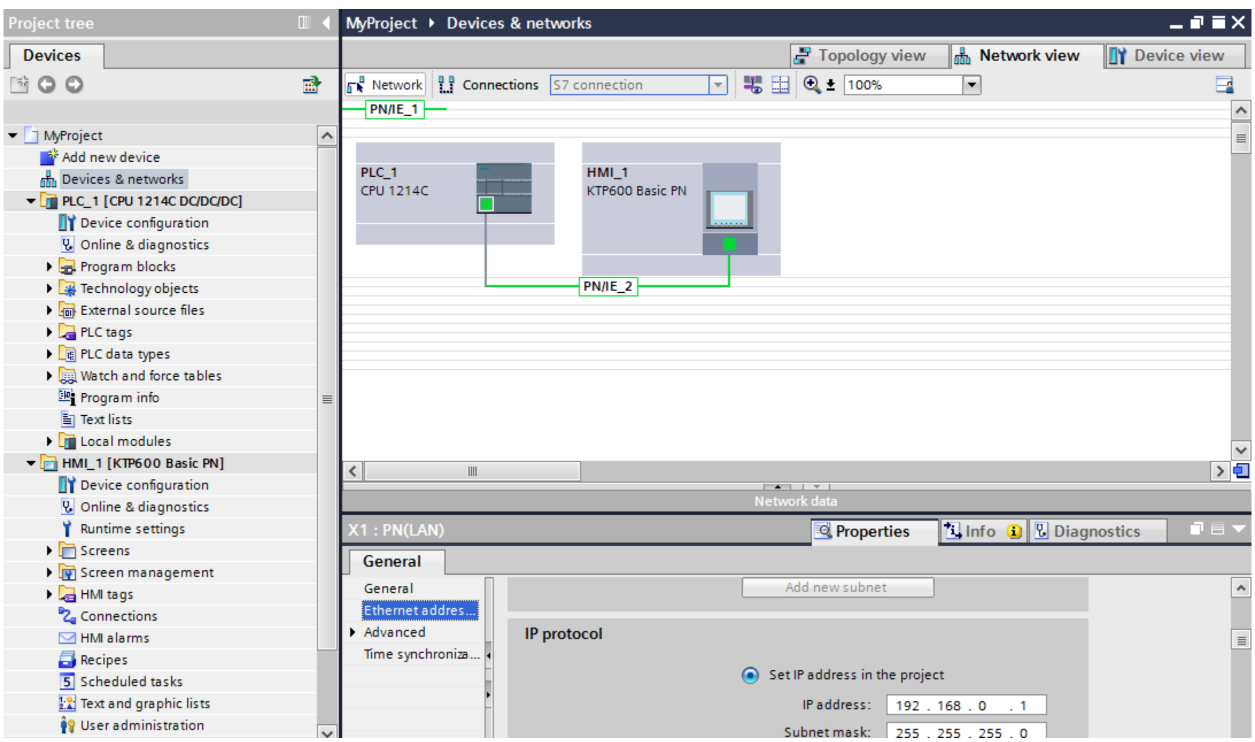


Then Finish

From the Devices and Networks choice in the Project Tree:

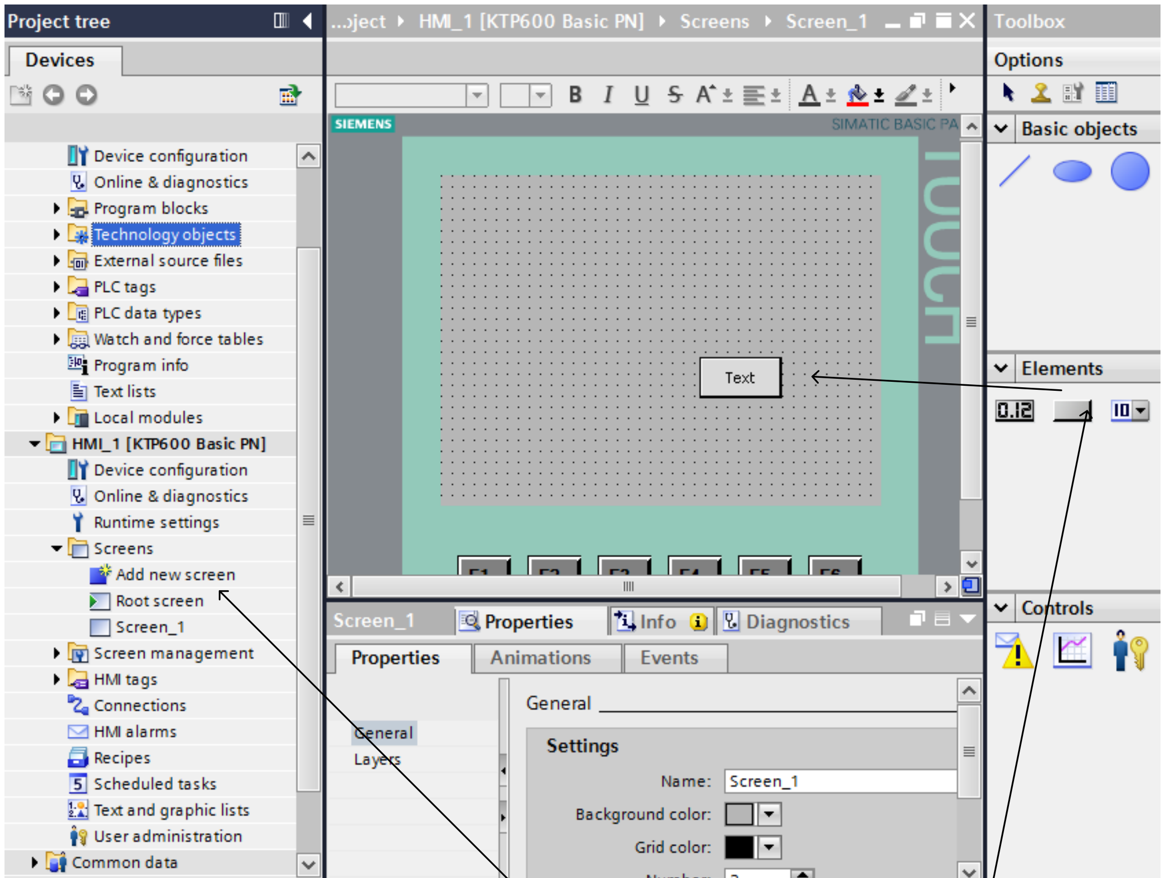


Choose Devices & networks

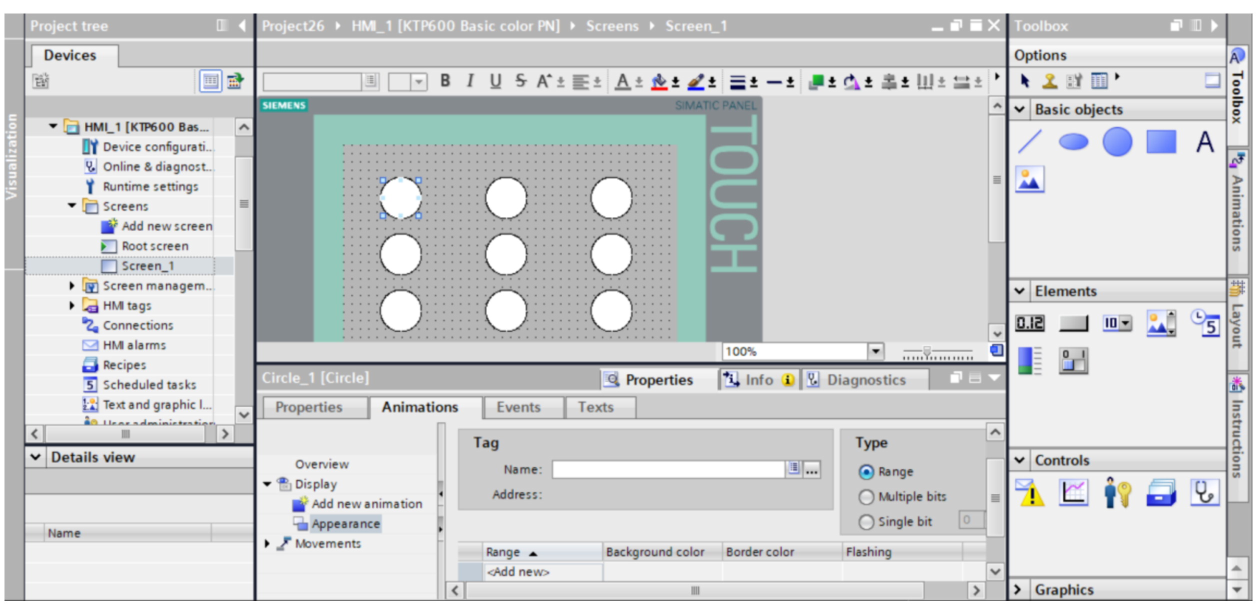


and set up both the IP address and Subnet mask for the PLC as well as the HMI.

Set up the IP address of the PLC to 3 (192.168.0.3, 255.255.255.0).
Set up the IP address of the HMI to 5 (192.168.0.5, 255.255.255.0).



To add a new screen, double click on “Add new screen” in the Project Tree.
To begin a design, select a button from the Elements Toolbox at right. Drag the button onto the screen.



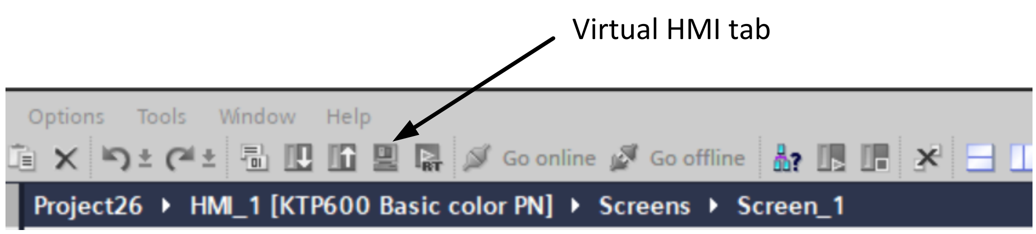
Create a second screen and use the circle object to create a screen resembling the above.

Then in each light, animate the light by tying the circle to an output from the PLC. If the bit is off, identify the color as black. If the bit is on, identify the bit by the color of the light that makes sense - Red, Yellow or Green.

When done, download the PLC program but **not** the HMI program. Run the PLC program and verify that the timers are actually moving the outputs associated with the various lights.

Compile the HMI:

Run the HMI program using the virtual tab shown below (will turn blue when able to run):



The screen will show the outputs of the various lights.

To complete the lab, either a screen shot of the HMI panel with lights changing will suffice or a selfie with the wiring of at least three lights working is acceptable.

Also, a short commentary on the use of timers is required. As you look at the timers working, what does the logic show that allows the timers to run?

Lab Exercise 6

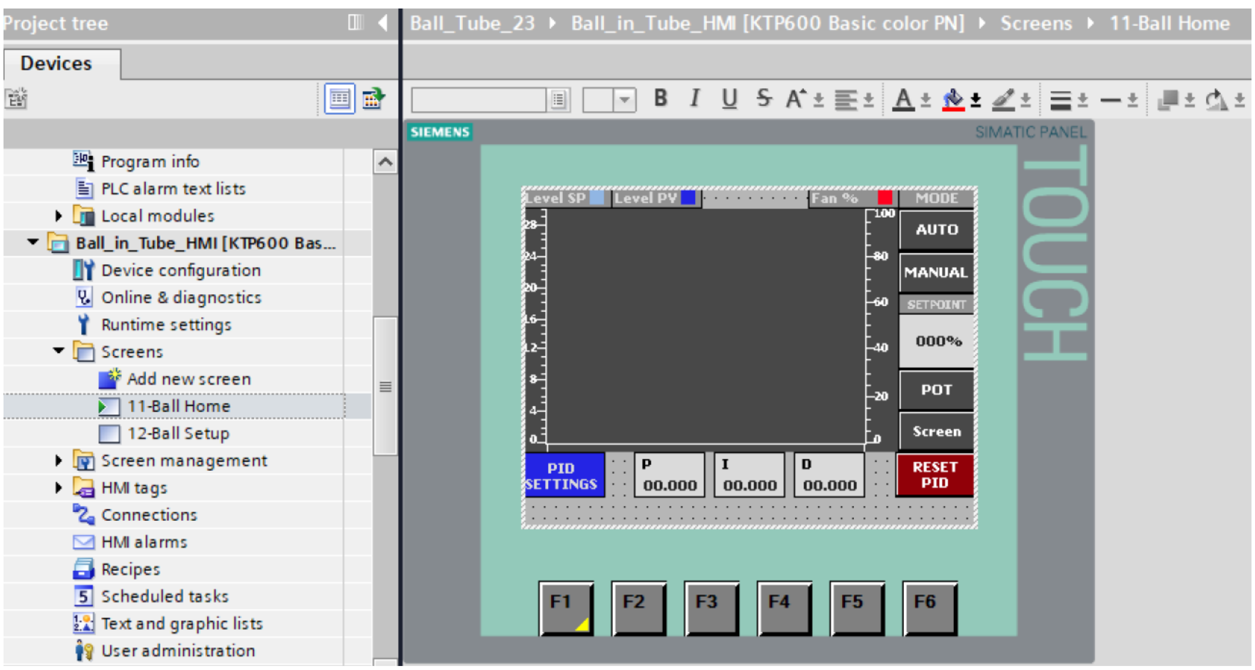
Ball and Tube - Parameter Scaling and PID Tuning Effects

Introduction

In a previous lab exercise the linearity of the laser distance sensor was explored and verified. This follows up exercise will put the data from that sensor to use in a closed loop PID control system. In this lab you well set up the PLC control system to interpret the raw sensor data in a meaningful way and explore how the Proportional, Integral and Derivative terms contribute to the overall stability of a controlled process.

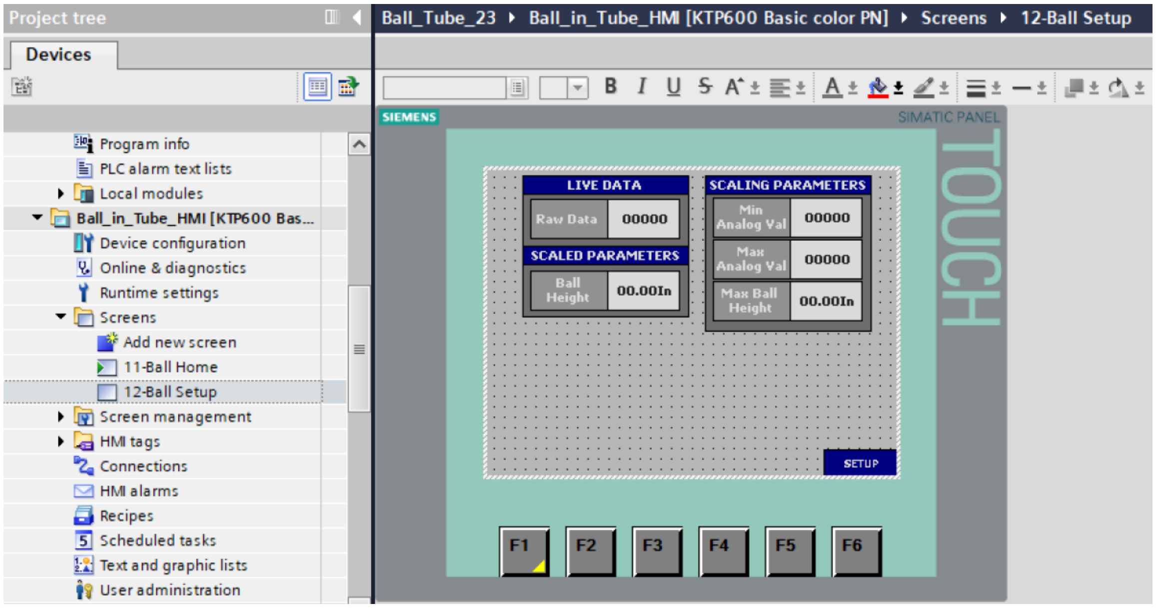
Hardware Setup

For this lab you will be using the same Ball in Tube trainer from Part 1. Instead of beginning with a new program and using the Watch Table to observe data, this time the HMI screens will be used in the simulate mode. There are two screens which can be toggled from one to the other using the F1 key.

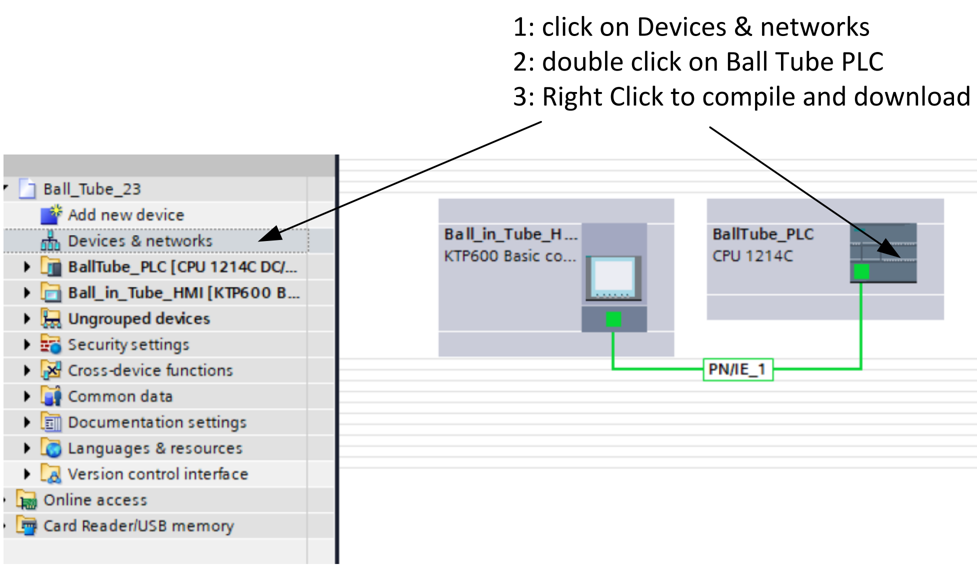


This screen is called 'Ball Home' and is used to toggle between auto and manual as well as choosing of the POT or data entry from the screen.

The second screen seen below is used for setup of the initial parameters. Remember that you can toggle between the two screens by using 'F1'.

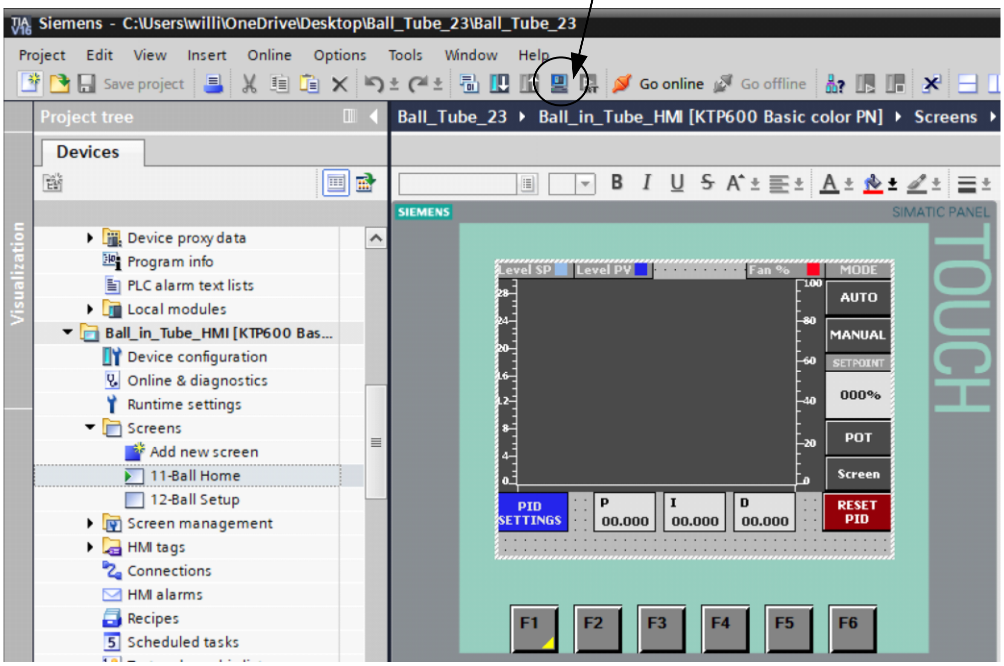


- Previous labs may have altered the placement of the laser head. Ensure the laser is looking **down the tube**, with the laser spot centered on the top of the ball from a top-down perspective.
- Ensure the ruler's 0 mark is aligned with the top surface of the ball with the ball at rest in the bottom of the tube. The laser is observing the balls top surface as its measuring point.
- After loading the program Ball_Tube_23 from the website, compile the PLC program and download it. To do this, you must have the PLC program displayed or cursor over the PLC in the Devices & networks page. Double click on the PLC, then right-click in the gray area of the PLC and choose compile, hardware and software. Let the program compile. Then choose download and follow the directions for downloading the program to the PLC as you have in earlier labs. This time, however, there is a program to download, not just an empty shell.



After the program is downloaded to the PLC, position the cursor over the HMI portion of the project tree on the left side. Click on the blue RT (Run Time) tab just left of the orange Go Online button (Blue button in circle).

To run simulation of HMI, click this blue button while the project tree at left shows the HMI program expanded.



Now you are ready to run the PID process from the simulation HMI panel. You can toggle between the two screens using the F1 button at the bottom of the screen.

Scaling The Process

One of the first things a PLC engineer needs to do when programming a system is understand how the various sensing devices employed provide their data to the PLC, and how that data relates to the real-world quantities being measured. As you will have learned in class, sensors typically provide their data in 3 ways; A 0-10V signal, 4-20mA signal, or Pulse Train. For the trainers being used in this lab, the laser head is a 4-20mA device being interpreted as a 0-10V device through use of a voltage divider. While this isn't strictly important, as you saw previously the PLC only understands this data as a raw integer value between 0 and 27648 – it has no concept of how this relates to a real-world value. Its up to the system engineer to give it that insight. For now, when in auto or manual, set the screen/POT button to screen. We will use the POT button later with the potentiometer.

To run this process the PLC needs 4 important pieces of information. The Minimum analog value from the laser head and its corresponding ball height in inches, and the Maximum expected analog value and its corresponding ball height in inches. For this lab the PLC assumes the minimum ball height is zero inches corresponding to the ball at rest, the remaining 3 quantities need to be entered manually in the "Setup" screen (Which can be accessed by pushing F6). To accomplish this, follow these steps:

1. With the system in Manual mode at 0% output, enter the current raw analog value in the "Min Analog Val" field and record this value for your lab.
2. Set the fan output to 100%. Enter the new raw analog value in the "Max Analog Val" field.
3. The maximum height is already inserted in the program as 36 inches. This field is fixed.
4. Set the fan output back to 0% and record your found values for your lab report.

<u>Question:</u> If the laser measuring device was found to be <u>*non-linear*</u>, how might this affect the PLC's ability to interpret the sensor data using this simple 2-point approach?

Exploring PID and System Stability

Now that the PLC can interpret the raw sensor data properly the process can be run. Normally the controls engineer would need to "tune" the system response to provide accurate control. In this case that procedure has already been done and the controller is pre-loaded with good PID parameters. Instead in the following steps you will be deliberately de-tuning the PID controller and observing how each parameter contributes to the stability of the process.

- In the following steps changes you make to the PID parameters are applied immediately, however the change in system stability may not be immediately apparent.
- Should the system become unstable, reset the PID values with the "RESET PID" button between steps. The changes to the system are best observed when the system is initially in a stable condition.
- Before the following steps, switch the controller into "AUTO" mode and try entering in a few setpoints to familiarize yourself with how the system behaves with good PID parameters. Feel free to experiment!
- If you are working in a group, all group members may utilize a single set of HMI pictures for each members respective lab report.

Proportional

Start with the system in AUTO mode, using the known good PID parameters. Enter a lowish setpoint of your choosing (10in for example) and do the following:

1. Reduce the Proportional value to 2.0. Observe and write down any changes to the systems operation for your lab report.
2. Enter a higher setpoint (20in for example). Observe how the system behaves and write down the behavior for your lab report. Using a cellphone, capture an image of plotter area showing the setpoint change and following behavior.
3. Press the "RESET PID" button and allow the system to settle.
4. Once more reduce the Proportional value to 2.0

5. Enter a lower setpoint (10in for example). Observe how the system behaves and write down the behavior for your lab report. Using a cellphone, capture an image of plotter area showing the setpoint change and following behavior.

- Repeat the above procedure, but substitute Proportional values of 1.0 and eventually .3

Integral & Derivative

As you will have learned in class, the proportional value in a PID controller is merely a measure of the difference between Process Value and Setpoint, but what exactly are these Integral and Derivative terms? Well, it's not just control system witchcraft. In PID systems the Integral and Derivative terms are being taken with respect to ***time***. In effect, this allows the control algorithm to factor in the state of the system in the ***past*** as well as attempt to predict the state of the system in the ***future***.

The Integral and Derivative terms often correspond to real-world values, although they may not necessarily be visible to the human eye. In the case of the Ball-In-Tube system, the Proportional term is the balls **Displacement.** Taking the Integral of a Displacement with respect to Time results in a quantity known as **Abasement**, a measure of sustained displacement of an object from its initial position; or in more simplistic terms, a measure of how far away and for how long. Taking the Derivative of a Displacement with respect to time results in the balls **Velocity**.

Integral

Start with the system in AUTO mode, using the known good PID parameters. Enter a lowish setpoint of your choosing (10in for example) and do the following:

1. Reduce the Integral value to .75. Observe and write down any changes to the systems operation for your lab report.
2. Enter a higher setpoint (20in for example). Observe how the system behaves and write down the behavior for your lab report. Using a cellphone, capture an image of plotter area showing the setpoint change and following behavior.
3. Press the "RESET PID" button and allow the system to settle.
4. Once more reduce the Derivative value to .75
5. Enter a lower setpoint (10in for example). Observe how the system behaves and write down the behavior for your lab report. Using a cellphone, capture an image of plotter area showing the setpoint change and following behavior.

- Repeat the above procedure, but substitute Integral values of .45 and eventually .1

Derivative

Start with the system in AUTO mode, using the known good PID parameters. Enter a lowish setpoint of your choosing (10in for example) and do the following:

1. Reduce the Derivative value to .100. Observe and write down any changes to the systems operation for your lab report.

2. Enter a higher setpoint (20in for example). Observe how the system behaves and write down the behavior for your lab report. Using a cellphone, capture an image of plotter area showing the setpoint change and following behavior.
3. Press the "RESET PID" button and allow the system to settle.
4. Once more reduce the Derivative value to .100
5. Enter a lower setpoint (10in for example). Observe how the system behaves and write down the behavior for your lab report. Using a cellphone, capture an image of plotter area showing the setpoint change and following behavior.

- Repeat the above procedure, but substitute Derivative values of .05 and eventually 0

Other Modes

In auto, switch to POT. Turn the potentiometer. Notice that the system tries to stay up with your change. It does so in an automatic mode. This mode is sometimes referred to as Remote or Cascade. The output tries to follow the wishes of the potentiometer (process) as close as possible. As a process goes faster or slower, so does the height of the ball go higher or lower.

Now switch to manual and POT. In this mode, you are in control of the height of the ball. See if you can keep the ball at a constant height. Is this possible? You control the output % on of the fan through the potentiometer. Picture yourself doing this for 10 minutes/an hour? Can you see the importance of the auto control of the PID algorithm. Comment on both of these modes.

Early in the semester, the example of flying a plane was first invented without auto control of the level of flight. How could a pilot have controlled the height of his airplane without constantly moving the stick controlling height? He couldn't. He need a controller similar to the PID controller in this lab to aid in his control. Thus the Curtis flying controller.

Closing

Hopefully this lab exercise has given you some insight into exactly how the Proportional, Integral and Derivative parameters contribute to system control and stability. For your lab report be sure to answer any questions posed during the lab procedure. Again, if you are working in a group, all group members may utilize a single set of HMI pictures for each members respective lab report.

Laboratory Exercise 7

Tank over Tank – Loop in Loop

Introduction

In this lab demonstration we will be exploring a unique application of PID control devices. In prior exercises you experimented with the most common application of PID control, where a single PID controller gets input from a sensing device and provides control over an actuator or output device. PID control is not limited to this kind of application. In this demonstration, we will be exploring another application: cascaded PID control.

In a cascaded system multiple PID controllers can be tied together so rather than having a control flow of **Sensing Device → PID →Actuator Device**, we construct a system with a **Sensing Device → PID → PID → Actuator Device**. Theoretically, any number of PID instances could be chained together depending on the process being controlled.

The Tank-Over-Tank trainers operate using a cascaded system. In these trainers the goal of the control system is to maintain the water level in the uppermost tank at a preset value, to do this two PID control loops are used. The outermost PID loop monitors the water level in the upper tank using an ultrasonic sensor and provides a flow setpoint to the inner PID loop. The inner loop monitors the flow provided by a small DC pump using a turbine flow meter and provides a flow of water to the upper tank as demanded by the level control loop.

Sensor Data Scaling

Just like the ball-in-tube lab, the PLC needs environmental context to control the process since the sensors only provide a 0-10V signal, or a pulse frequency. It needs some scaling parameters to linearize and map the raw data to real-world quantities the sensors measure.

However, cascaded systems provide a unique controls challenge since the PLC's ability to control the water level in the upper tank is directly dependent on its ability to control the flow provided by the pump. This means that the control loops need to be set up and tuned from the innermost loop outwards.

Water Flow Control

Since the Flow PID loop is the innermost loop, it needs to be set up and tuned before any work can begin on the Level Control PID loop. The sensor used to measure the water flow provided by the pump is a Turbine Flowmeter, a new sensor device you probably have not seen yet. These sensors provide a "pulse train" output where the frequency of the pulses (in Hertz) is correlated to the fluid flow through the sensor.

Similarly to the other labs, to enable the PLC to convert between Frequency and Gallons Per Minute, it needs two points to map the sensor data. The minimum and maximum flows in GPM the sensor is rated for, and the correlated pulse frequencies. For these sensors, rather than finding these two points experimentally, we can simply use manufacturer provided specifications.

Water Level Control

Once the PLC can accurately control the flow provided by the pump, the outer water level control loop can be set up. Just like the ball-in-tube labs, a displacement is being measured here – however in this case an ultrasonic sensor is being employed rather than a laser. For the PLC to make sense of the analog data it still needs the same two data points: the analog value corresponding to the tanks bottom, and the analog value correlating to the tank being "full". Because the water level control loop is providing a setpoint to another control loop rather than an actuator it also needs one extra piece of information: the maximum water flow rate it can demand from the water flow control loop.

Specifications for Instruments

GEMS SENSORS

Flow Rate Sensor, 3/8 MNPT, 0.2 to 2.0 GPM

Zoro #: G0875935 **Mfr #:** FT-330, 226000

0 0 reviews Write a Review

Key Features

Type: Turbine
Length (In.): 2 15/64 in
Flow Range (GPM): 0.2 to 2.0
Max. Voltage: 24
Output Frequency (Hertz): 34 to 343
Burst Pressure (PSI): 1,000
Recommended Filtration (microns): Less Than 50
Max. Viscosity (SSU): 32 to 81

S18UUAQ BANNER ENGINEERING ULTRASONIC, VOLTAGE QD SENSOR

BANNER

S18UUAQ

Price: $285.00
Manufacturer SKU: S18UUAQ
Manufacturer ID: 02700

This item qualifies for FREE SHIPPING over $300!

Availability: Usually Ships in 3 to 5 Business Days
Part Number: S18UUAQ

Qty: 1

ADD TO CART

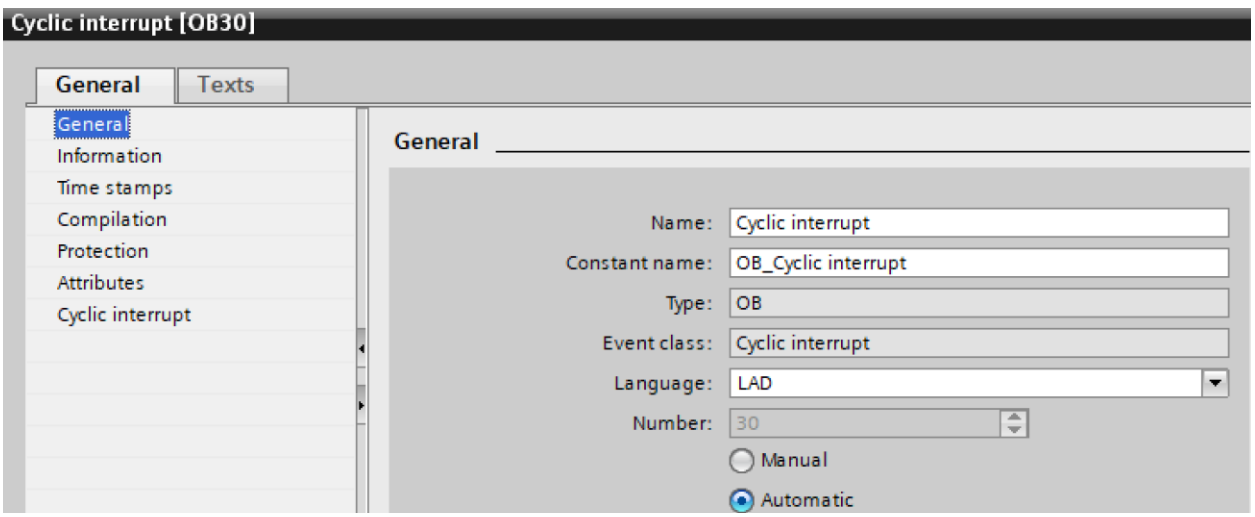
Download the Program

After loading the program Tank_Over_Tank_23 from the website, compile the PLC program and download it. To do this, you must have the PLC program displayed or cursor over the PLC in the Devices & networks page. Double click on the PLC, then right-click in the gray area of the PLC and choose compile, hardware and software. Let the program compile. Then choose download and follow the directions for downloading the program to the PLC as you have in earlier labs. This time, however, there is a program to download, not just an empty shell. After the program is downloaded to the PLC, position the cursor over the HMI portion of the project tree on the left side. Click on the blue RT (Run Time) tab just left of the orange Go Online button (Blue button in circle).

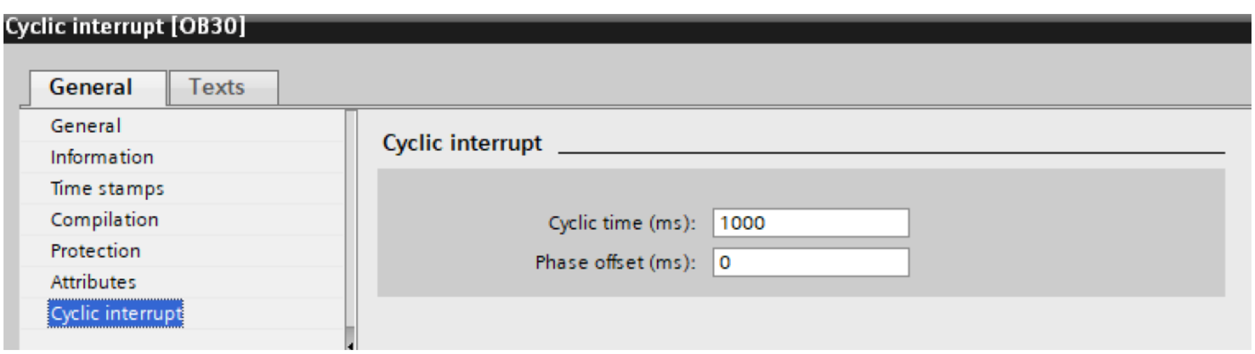
Now you are ready to run the PID process from the simulation HMI panel. You can toggle between the two screens using the F1 button at the bottom of the screen.

Setting up the PID Time Base

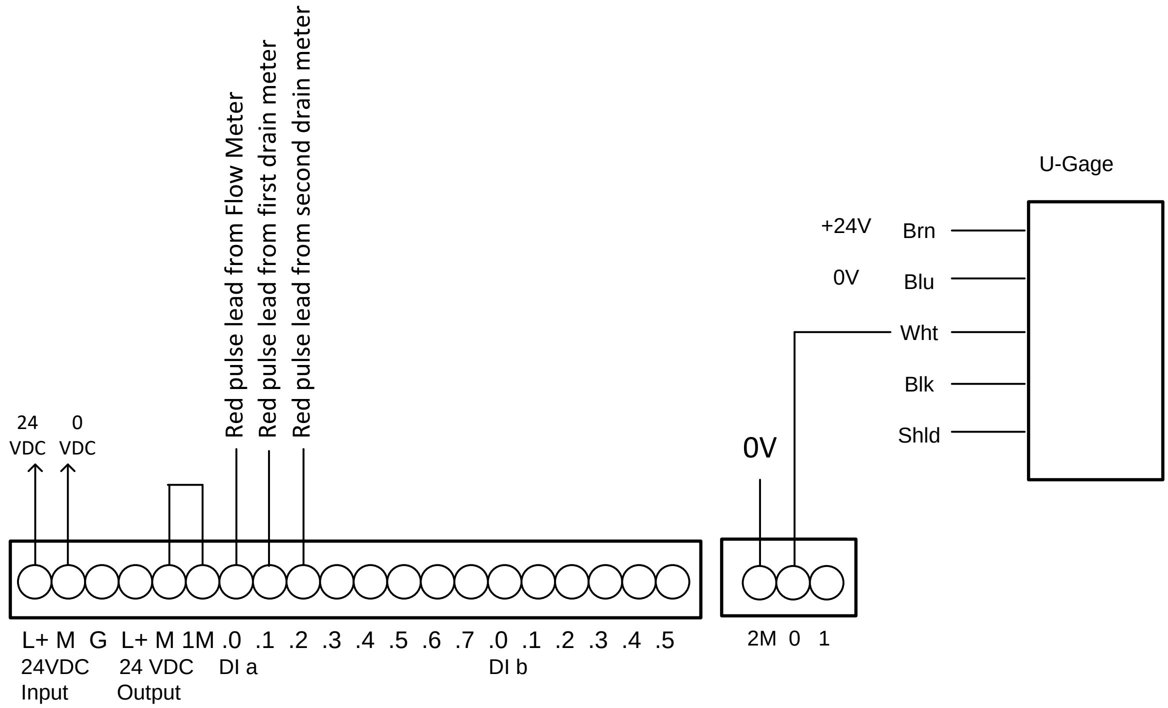
The following screen shows the setting of the Object Block used for programming the PID algorithm. This is OB 30 and its settings are:



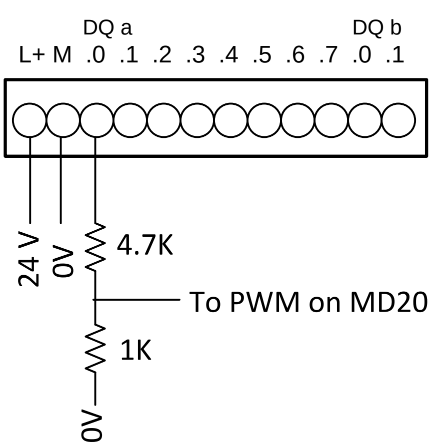
The time base for the application is 1 second or 1000 msec.



Input/Output Wiring Diagram



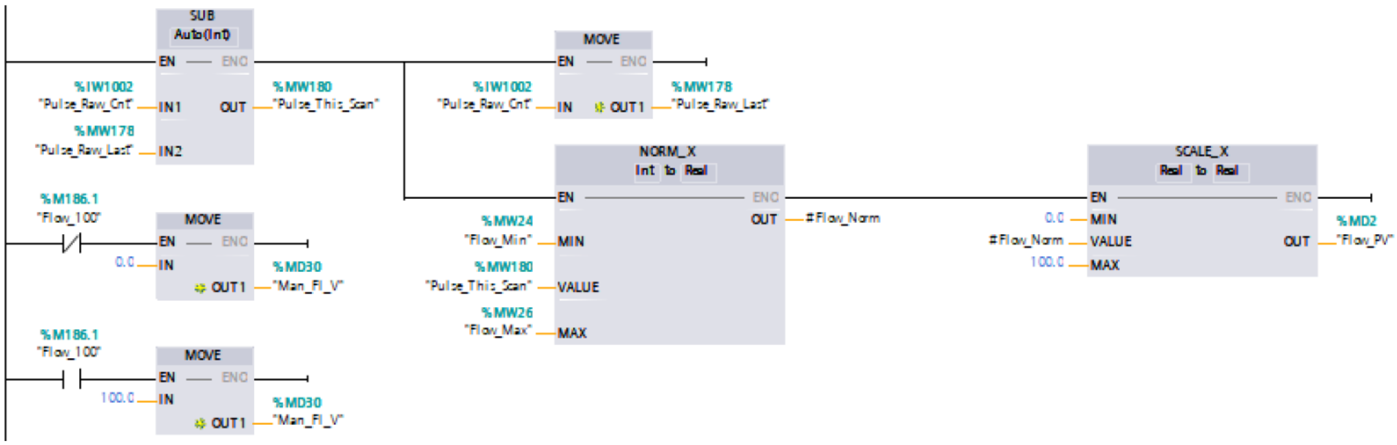
Input Wiring

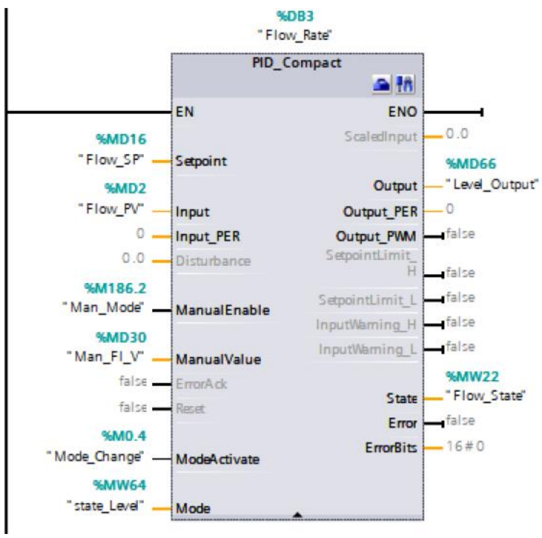


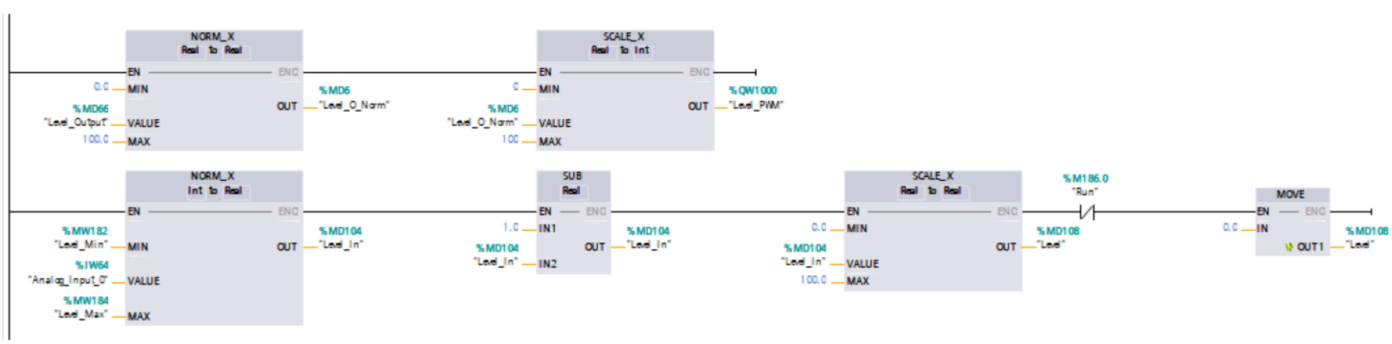
Output Wiring

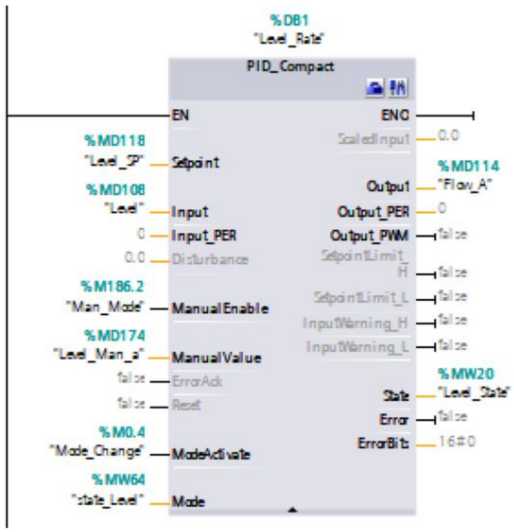
The Program

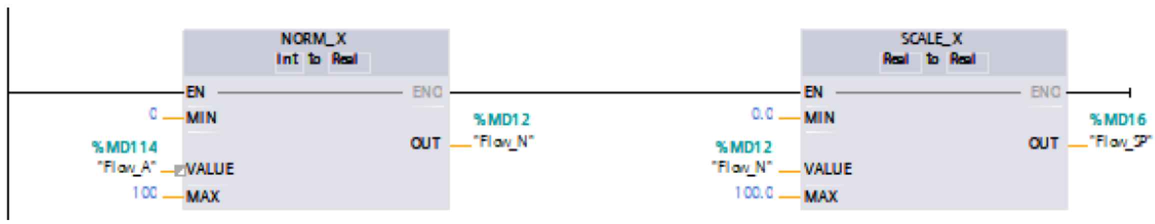
The following is the OB 30 program. We need to look at it to discern what is actually happening in the PLC.





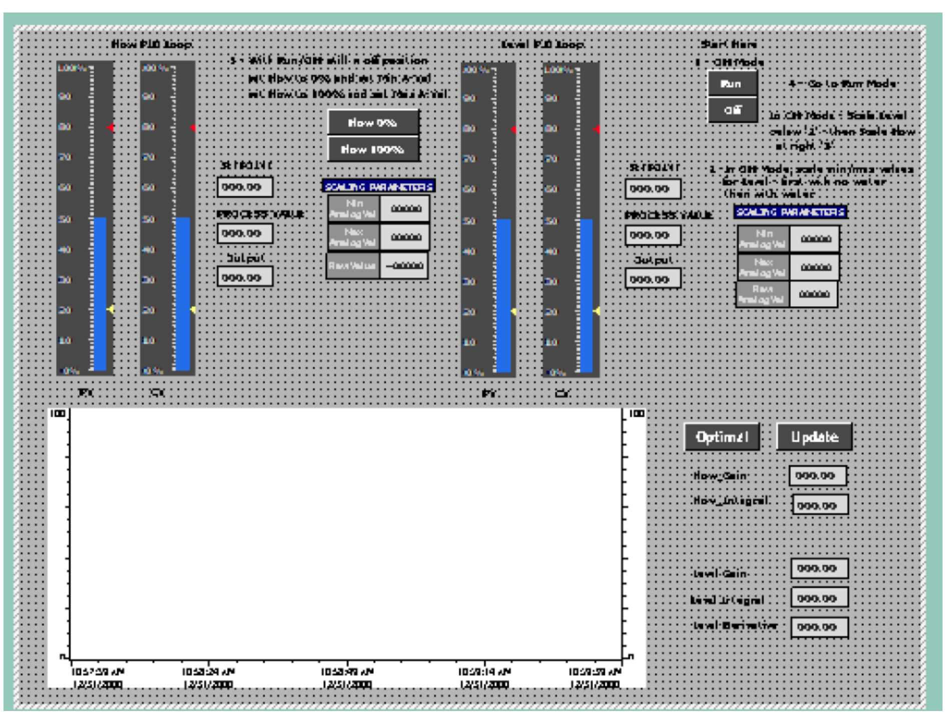




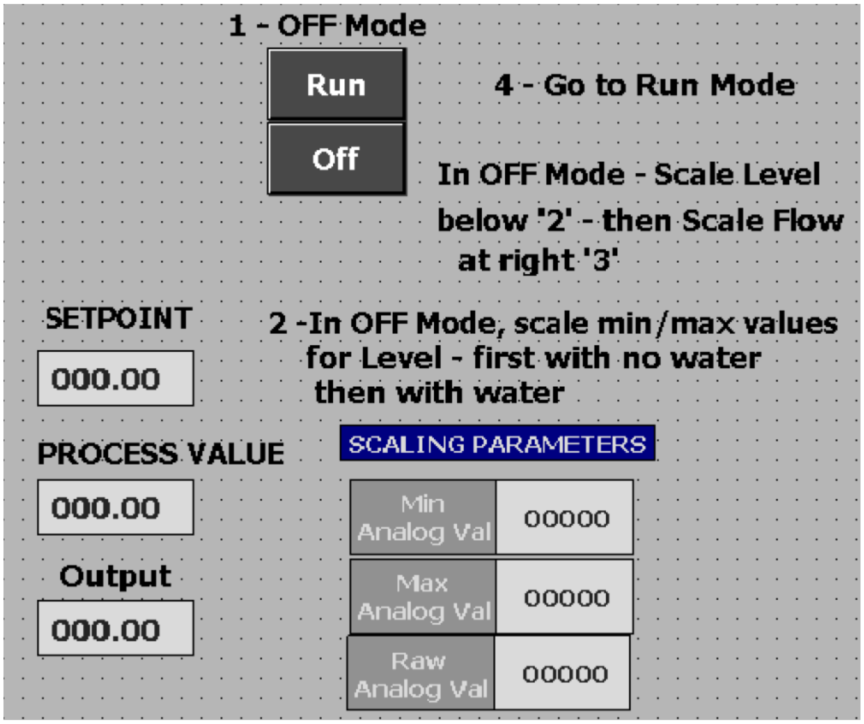


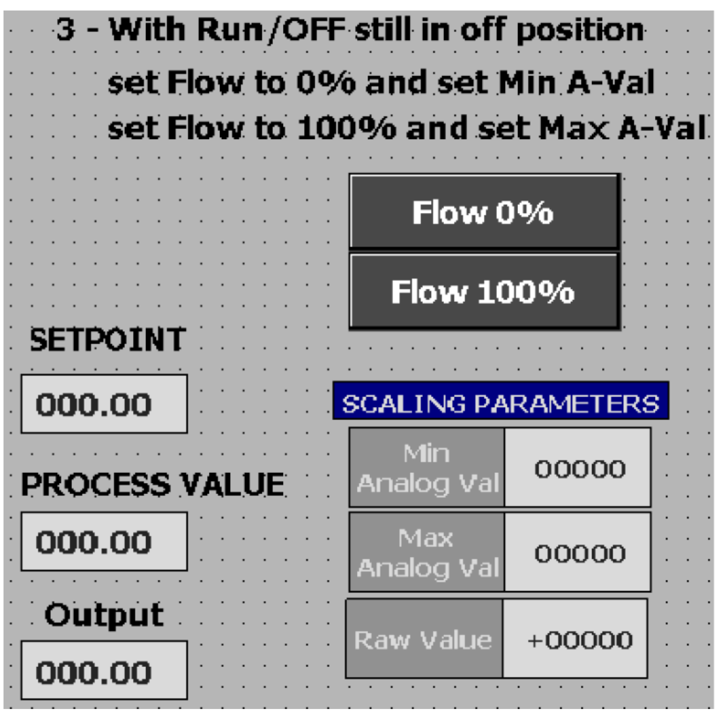
HMI Panel

The following is the HMI Panel for setting up and operating the Cascaded PID Blocks. There are instructions on the panel giving steps to properly set up the range for the flow meter and the level gauge.



On the next page is shown the instructions on the HMI for proper start-up of the ranges before going to Auto. When Run is toggled, the program runs the PID blocks in auto with the output of the Level PID block producing the setpoint of the Flow PID block.





System Operation

Now that the two control loops have been provided the data necessary to operate, they can be run. Observe the way the system behaves during the demonstration, take notes where necessary and answer the following questions:

1. If both drain valves are closed, how does the system behave as the water level in the upper tank approaches the setpoint.

2. Once the water has reached the setpoint, how does the system behave if one of the drains is opened partially?

3. How does the system behave when the partially opened valve is opened further?

4. With the water level in the upper tank at the setpoint level and both drains closed, how does the system behave when:

a. The setpoint is decreased below the current water level in the upper tank

b. The setpoint is increased above the current water level in the upper tank

5. The faceplate for the Flow Control Loop provides the ability to run the PID loop in both its automatic mode where a Flow setpoint in GPM, or its manual mode where the pump speed can be directly controlled by entering an output percentage. However, the Water Level Control loop has no ability to be run using a manual output percentage. Why is this?

6. How does increasing the cycle time of the Flow PID loop affect overall system stability? Why does it have this effect?

Questions

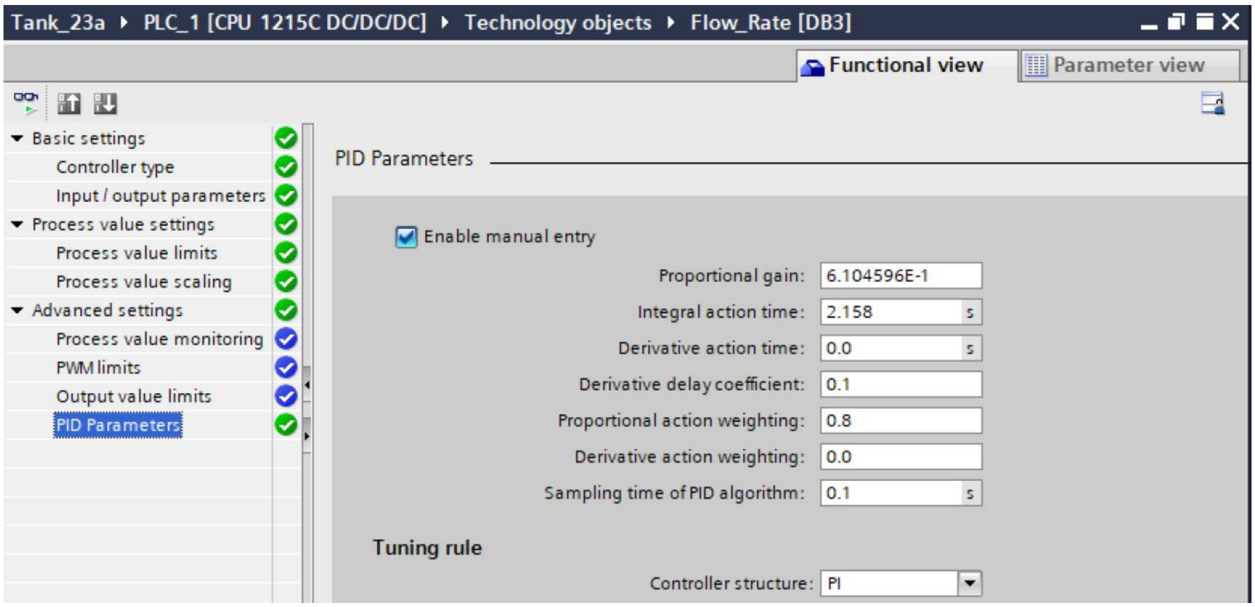
1. Which control loop would need to have its PID values tuned first? Why?

2. Why does the level control loop need to be provided with the maximum flow rate the pump can provide?

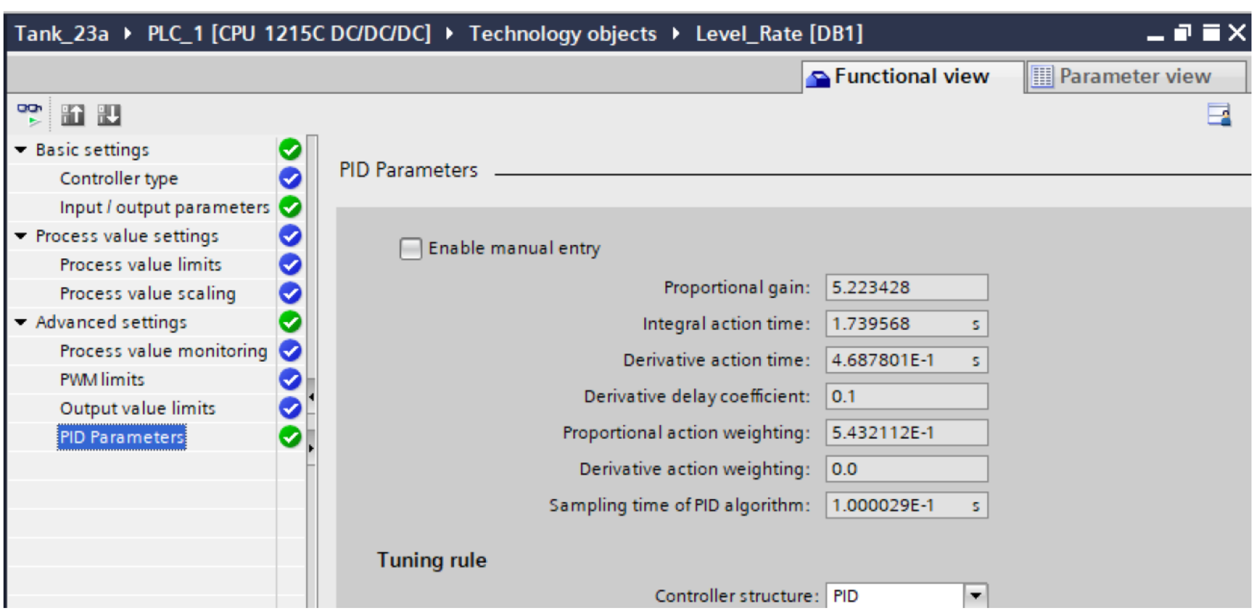
3. FT-110 Turbine flowmeters are available in a variety of measurement ranges. For this system a model capable of measuring .17-2.0GPM was selected which closely matches the flows the pump can provide. However, the current pump cannot provide enough flow to maintain the water level with both drains open. If a more powerful pump were to be installed, could the original flowmeter be reused? Why or Why Not?

Troubleshooting:

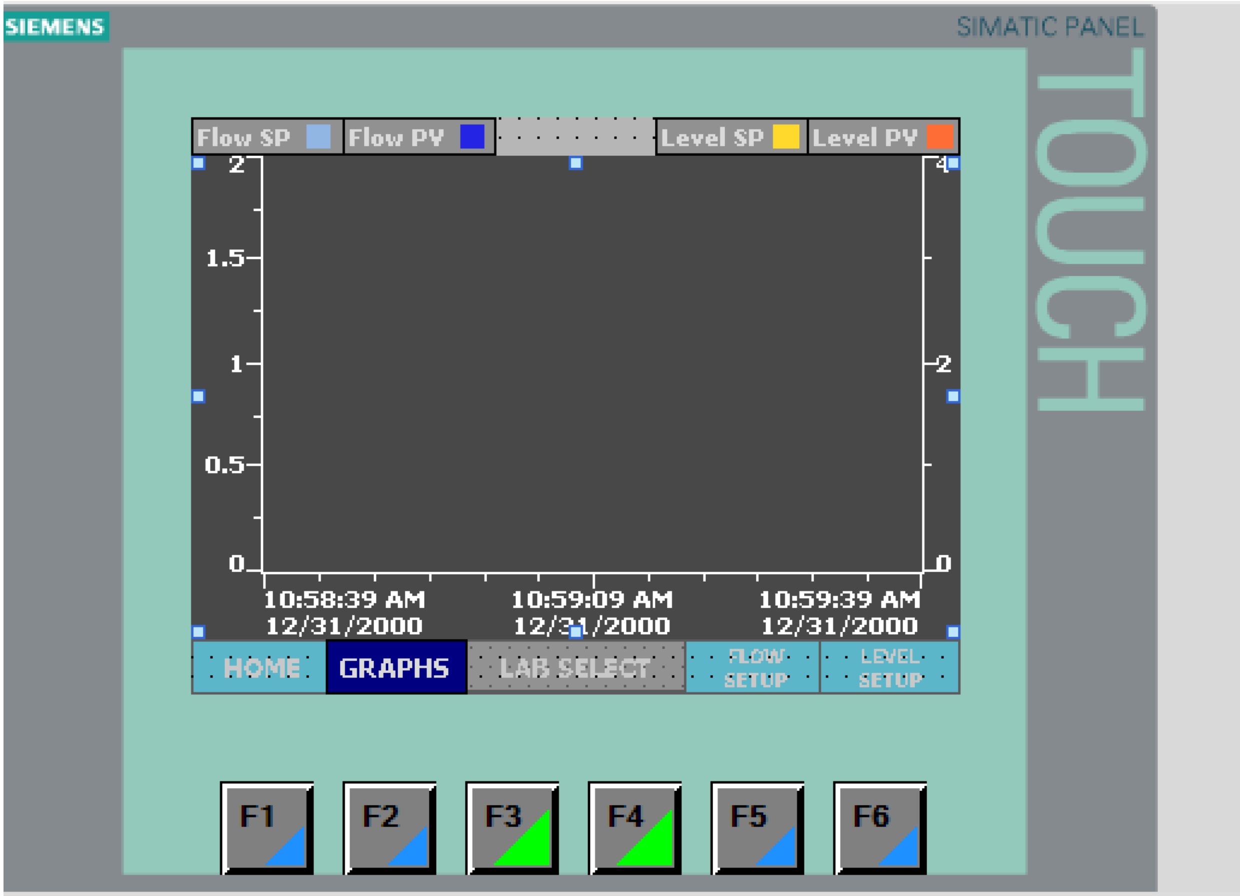
The Tank program may not work in Auto even though the program has been successfully downloaded and all actions have been performed successfully. If the CPU is in run mode and the program does not work at all, the problem may be the PID Parameters. They may be zeroed out. These parameters may be found by clicking on the left symbol in the upper right corner of the PID block. Then go to the lower left under Advanced settings to PID Parameters. If zeroed, then click on 'Enable manual entry' and proceed to enter good numbers for each parameter. Check with the figures below for a list of good variables.

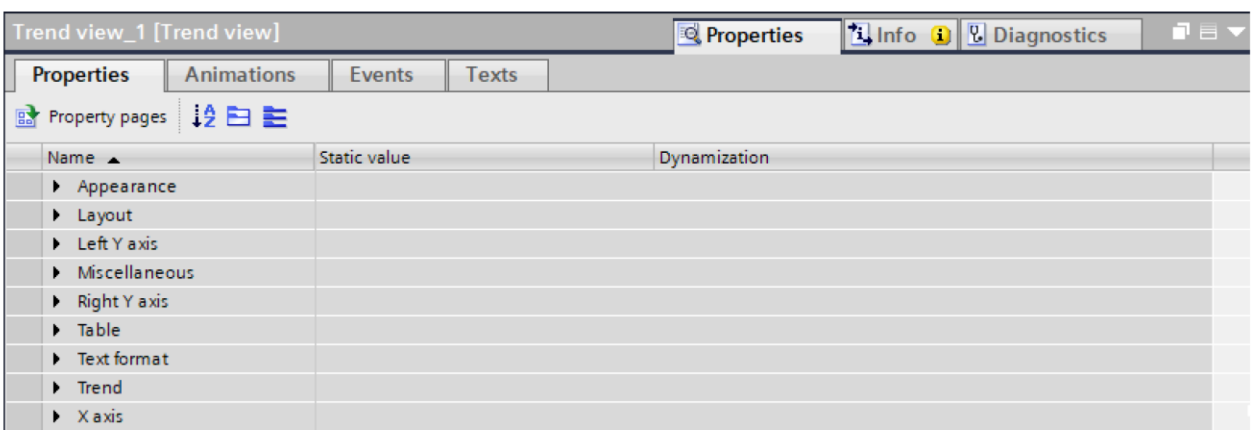


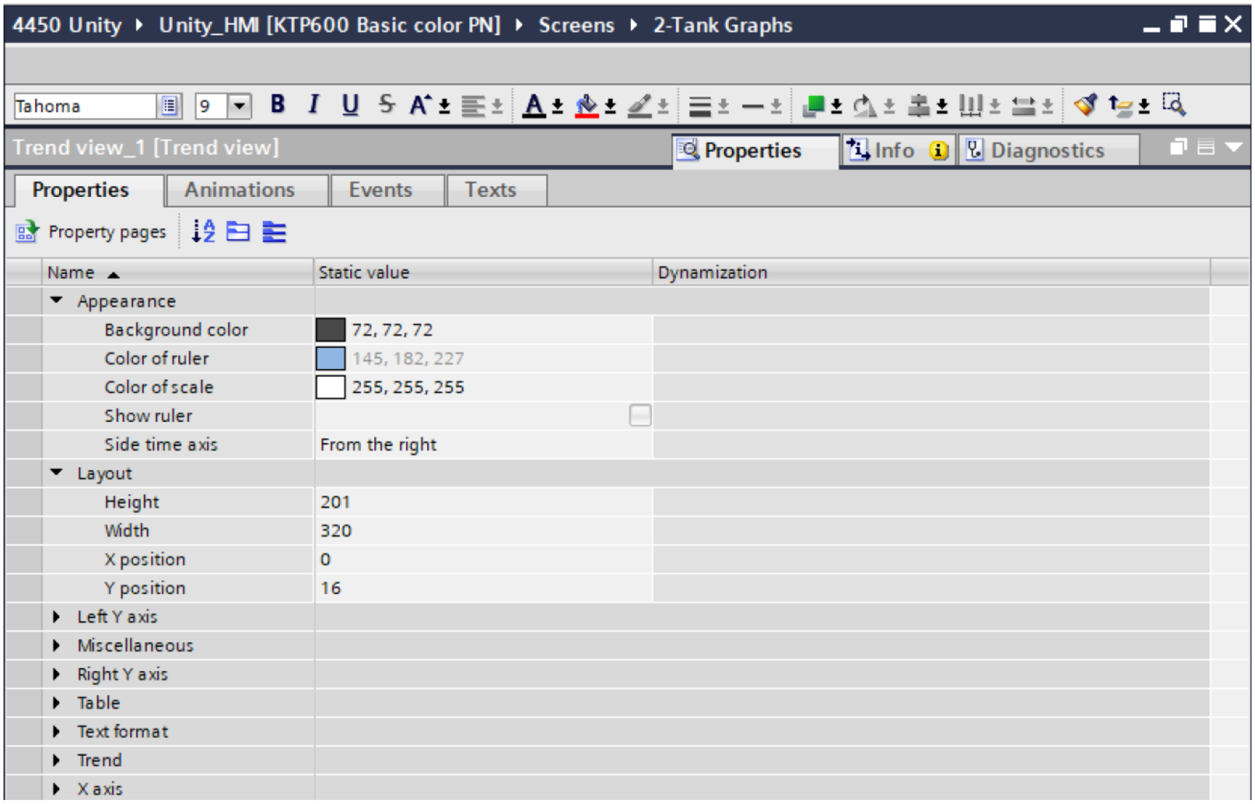
Above is the list of parameters for the Flow Rate PID block. Below is the list for the Level Rate PID block.

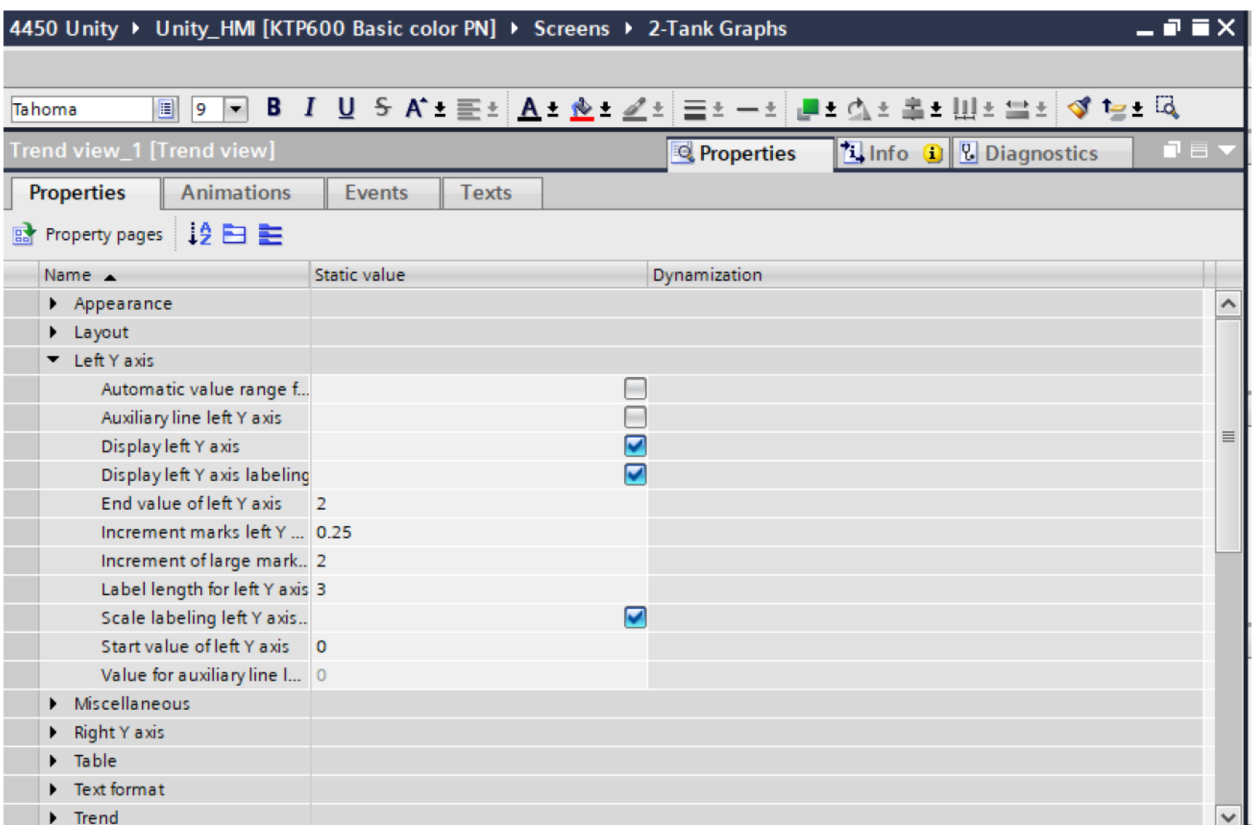


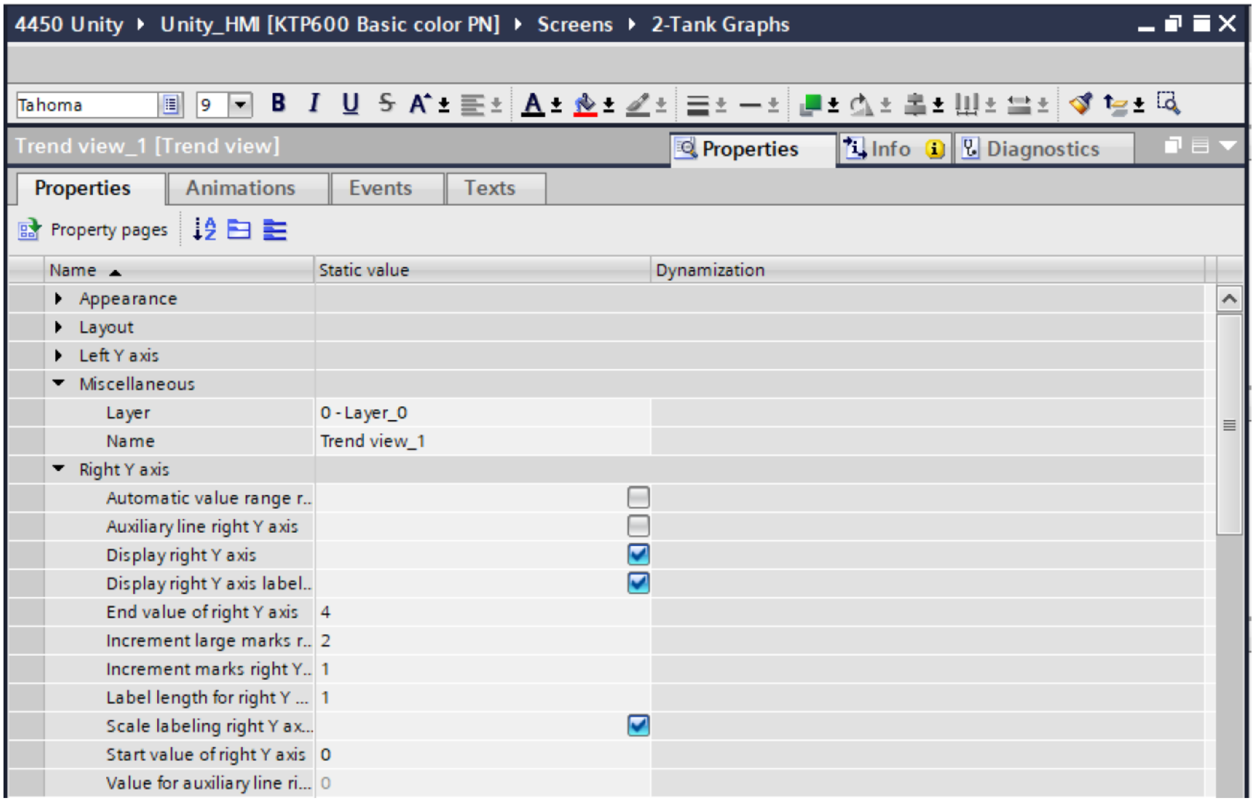
If time allows, set up the Trend Graph furnished with the HMI screen. The instructions for proper setup of the graph are given. The example is for another program but the same principles apply:

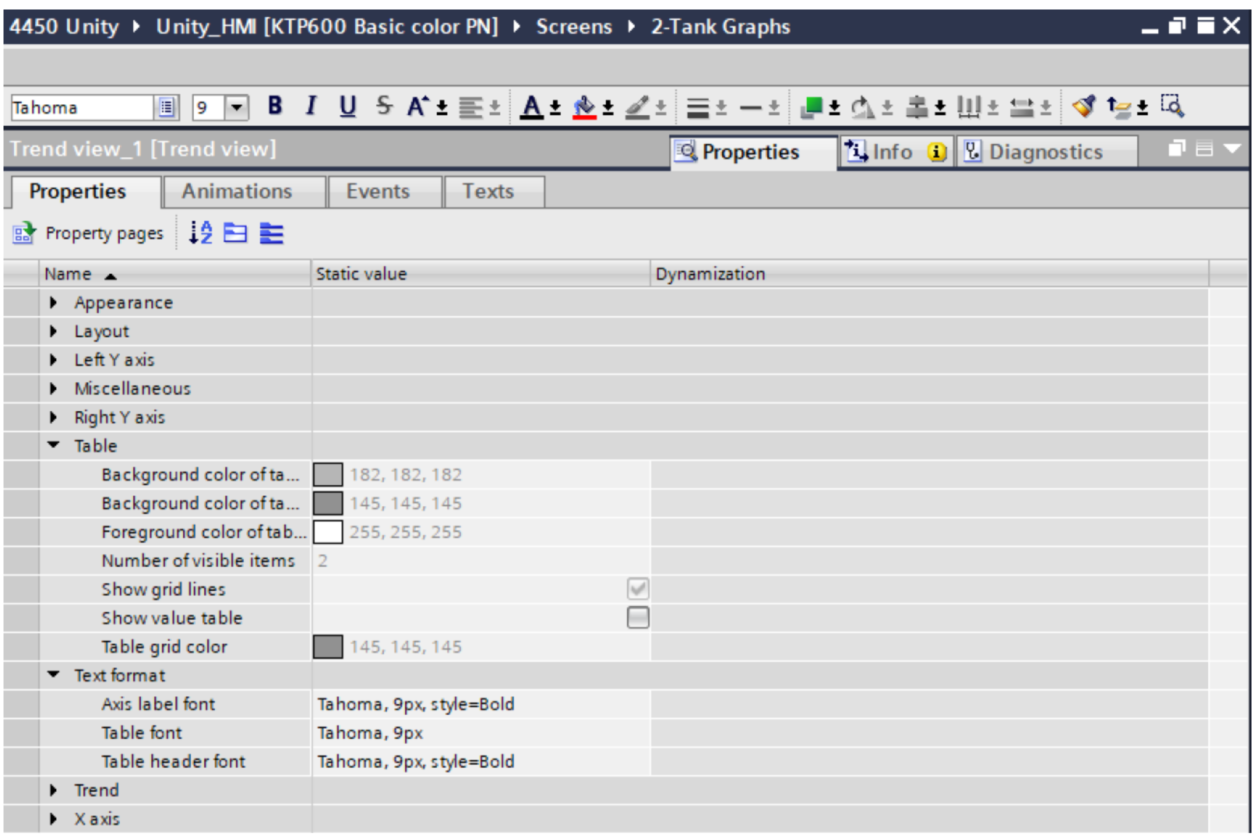


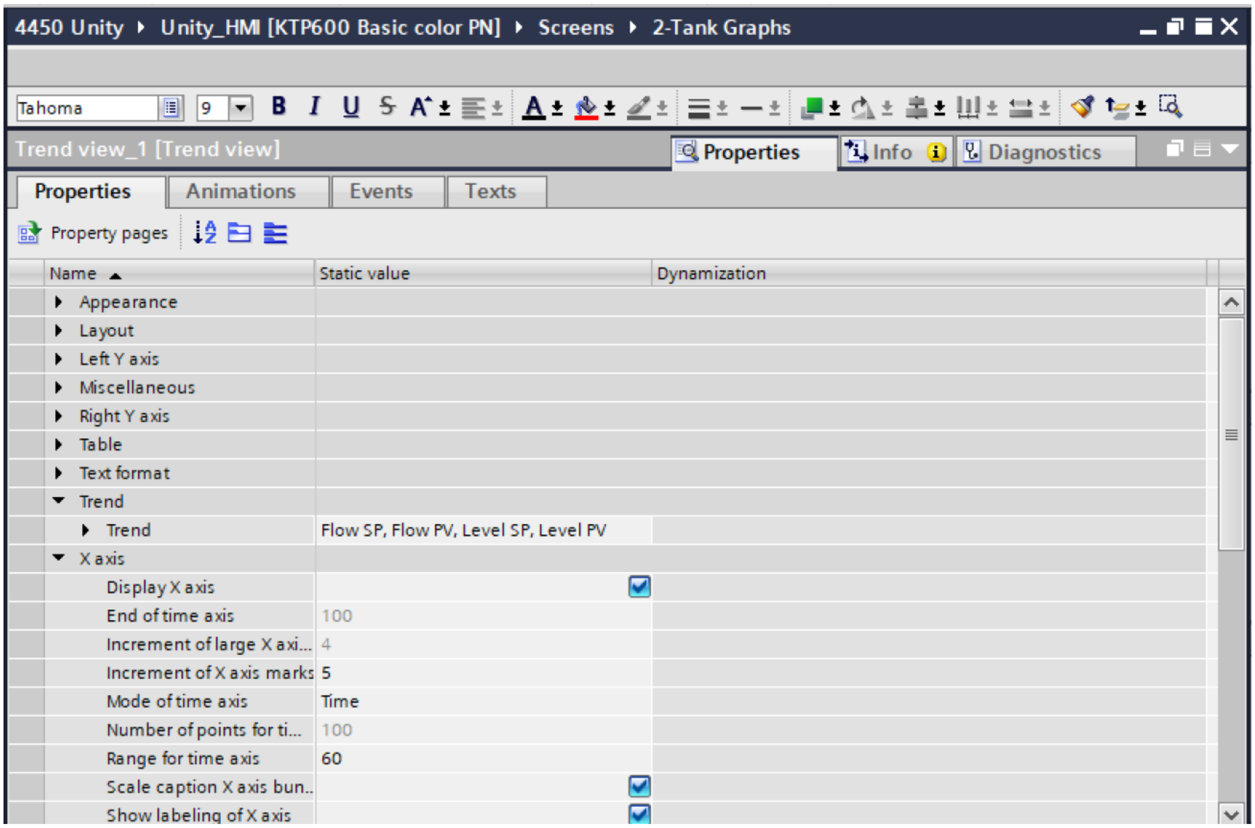



4450 Unity ▸ Unity_HMI [KTP600 Basic color PN] ▸ Screens ▸ 2-Tank Graphs
Tahoma
9
Trend view_1 [Trend view]
Properties
Info
Diagnostics
Properties
Animations
Events
Texts
Property pages
Name
Static value
Dynamization
Appearance
Background color
72, 72, 72
Color of ruler
145, 182, 227
Color of scale
255, 255, 255
Show ruler
Side time axis
From the right
Layout
Height
201
Width
320
X position
0
Y position
16
Left Y axis
Miscellaneous
Right Y axis
Table
Text format
Trend
X axis


4450 Unity ▸ Unity_HMI [KTP600 Basic color PN] ▸ Screens ▸ 2-Tank Graphs
Tahoma
9
Trend view_1 [Trend view]
Properties
Info
Diagnostics
Properties
Animations
Events
Texts
Property pages
Name
Static value
Dynamization
Appearance
Layout
Left Y axis
Automatic value range f...
Auxiliary line left Y axis
Display left Y axis
Display left Y axis labeling
End value of left Y axis
2
Increment marks left Y ...
0.25
Increment of large mark...
2
Label length for left Y axis
3
Scale labeling left Y axis...
Start value of left Y axis
0
Value for auxiliary line l...
0
Miscellaneous
Right Y axis
Table
Text format
Trend


4450 Unity ▸ Unity_HMI [KTP600 Basic color PN] ▸ Screens ▸ 2-Tank Graphs
Tahoma
9
Trend view_1 [Trend view]
Properties
Info
Diagnostics
Properties
Animations
Events
Texts
Property pages
Name
Static value
Dynamization
Appearance
Layout
Left Y axis
Miscellaneous
Layer
0 - Layer_0
Name
Trend view_1
Right Y axis
Automatic value range r...
Auxiliary line right Y axis
Display right Y axis
Display right Y axis label...
End value of right Y axis
4
Increment large marks r...
2
Increment marks right Y...
1
Label length for right Y ...
1
Scale labeling right Y ax...
Start value of right Y axis
0
Value for auxiliary line ri...
0


4450 Unity ▸ Unity_HMI [KTP600 Basic color PN] ▸ Screens ▸ 2-Tank Graphs
Tahoma
9
Trend view_1 [Trend view]
Properties
Info
Diagnostics
Properties
Animations
Events
Texts
Property pages
Name
Static value
Dynamization
Appearance
Layout
Left Y axis
Miscellaneous
Right Y axis
Table
Background color of ta...
182, 182, 182
Background color of ta...
145, 145, 145
Foreground color of tab...
255, 255, 255
Number of visible items
2
Show grid lines
Show value table
Table grid color
145, 145, 145
Text format
Axis label font
Tahoma, 9px, style=Bold
Table font
Tahoma, 9px
Table header font
Tahoma, 9px, style=Bold
Trend
X axis


4450 Unity ▸ Unity_HMI [KTP600 Basic color PN] ▸ Screens ▸ 2-Tank Graphs
Tahoma
9
Trend view_1 [Trend view]
Properties
Info
Diagnostics
Properties
Animations
Events
Texts
Property pages
Name
Static value
Dynamization
Appearance
Layout
Left Y axis
Miscellaneous
Right Y axis
Table
Text format
Trend
Trend
Flow SP, Flow PV, Level SP, Level PV
X axis
Display X axis
End of time axis
100
Increment of large X axi...
4
Increment of X axis marks
5
Mode of time axis
Time
Number of points for ti...
100
Range for time axis
60
Scale caption X axis bun..
Show labeling of X axis

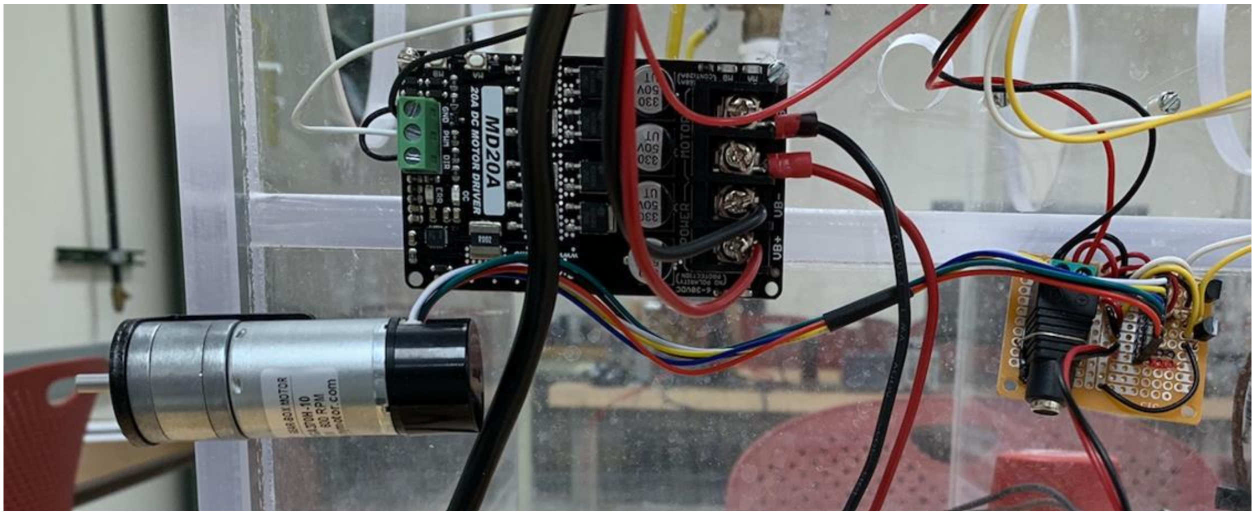
Laboratory Exercise 8

DC Motor with Encoder Feedback

Introduction

The DC Motor attached to the Tank over Tank Lab is set up to be controlled by a PID block similar to the two previous labs

The PID block controlling a dc gear motor is used to control the DC motor seen in the figure below. The control loop is to control the speed of the motor to a setpoint. The controller is a Siemens S7-1200 with encoder inputs and PWM output.



Connections are seen in these figures. The motor connects its encoder logic through the breadboard. The power to the motor is furnished through the controller at top. The power is provided by the 24 V supply at left and a 5 V supply which is not shown.

Wiring from Motor and Encoder Connection:

- Red Wire - positive power supply of motor(+)
- White Wire - negative power supply of motor(-)
- Black Wire - negative power supply of encoder(-) (positive and negative power supply of encoder do not allow connect wrong; voltage is 3.3 -5V)
- Blue Wire - positive power supply of encoder(+) (positive and negative power supply of encoder do not allow connect wrong; voltage is 3.3 -5V)
- Yellow Wire - signal feedback (11 signals per motor turns a circle)
- Green Wire - signal feedback (11 signals per motor turns a circle)

The S7 1200 v2.2 CPU in relation to the Quadrature encoder:

The 1200 with 24V DC inputs support up to six High Speed Counters.

a. Up to 3 of the addresses Ia.0 to Ia.5 can be used for Quadrature Mode at 80Khz.
b. Up to 3 of the addresses Ia.6 to Ib.5 can be used for Quadrature Mode at 20Khz.

The DI4 5 VDC signal board with part number 6ES7 221-3AD30-0XB0 is used in this example since the encoder pulse signals are 5V. It supports 160 KHz for Quadrature Mode. The input is "source" type. So, the encoder must support this which means that it is NPN or Open Collector type. The encoder and card work together in this example.

For the S7 1200 v2.2 when configuring the HSC, please select the Input Source as "signal board input". Please note that the option is only available if the signal board has been added in the hardware configuration. Please note that the addresses of the HSC will be the address of signal board (default 4.x). In v4.x S7 1200's, the user selects the address rather than the Input Source.

Cytron Technologies MD 20A

20 A 6V-30 V DC Motor Driver

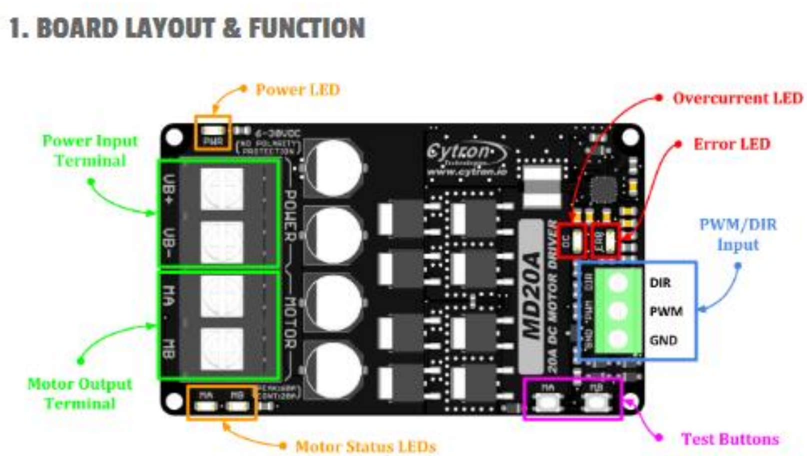


Figure 1: MD20A Board Functions

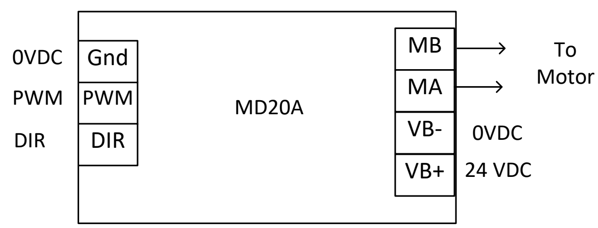
The wiring diagram shown below gives the complete wiring diagram for the motor shown in the figures above.

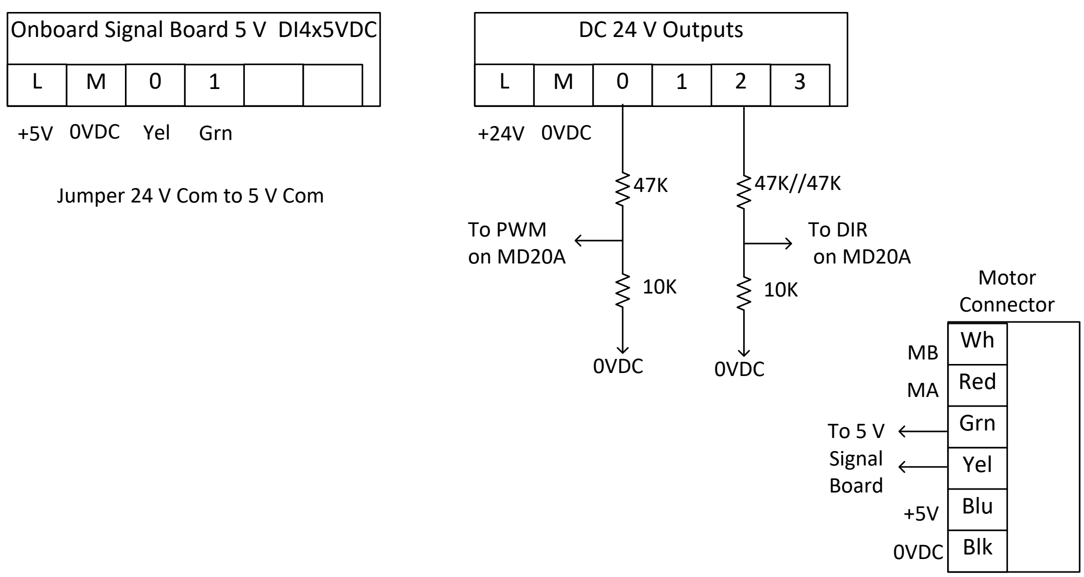
To start the lab, download the program from the hybridplc.org website for this lab (Lab 8) and place it on the desktop. Start the program as before. The program's name is DC_Motor_23.

Check the firmware version of your machine. The firmware number is located inside the tank. If the number is not 4.4, then it must be changed. To do this, go to properties in the project tree for PLC_1. Under catalog information, change the firmware to the proper number. You must click ‘enter’ to save the change. Verify.

Other wiring: Unplug the connector to the bilge pump (brown, black wires) and plug in the dc motor drive connection (red, black wires). Also, plug in the white (except one unit which is black) 5V connector to the drive board. Then continue with compiling and downloading the program as before. When ‘synchronization’ is asked for, respond ‘no’. There is no need since you are the only programmer on this system. Synchronization only applies if more than one programmer is active with this program at this time.

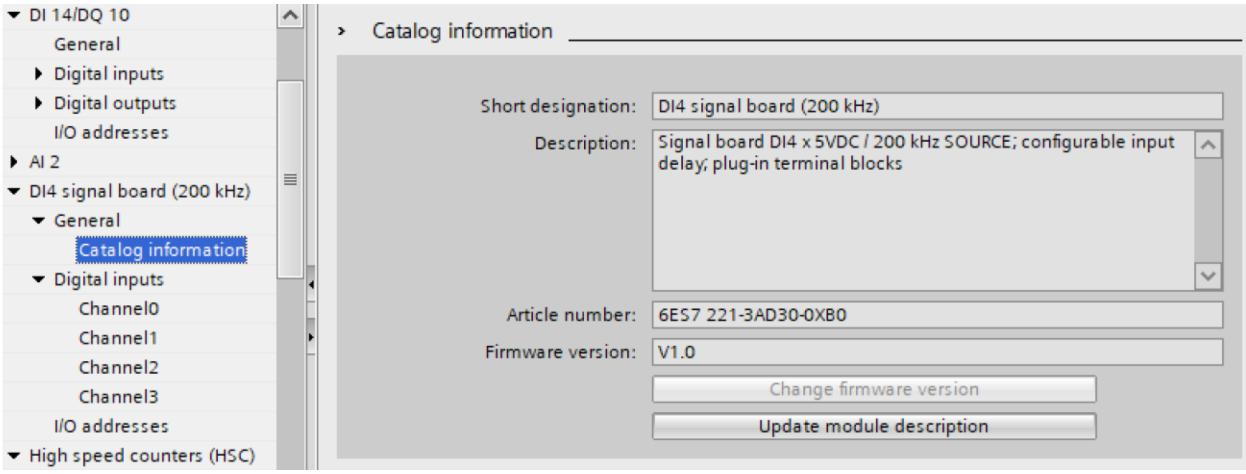
If a pink box appears, you must address it. ‘Stop All’ is a usual response.



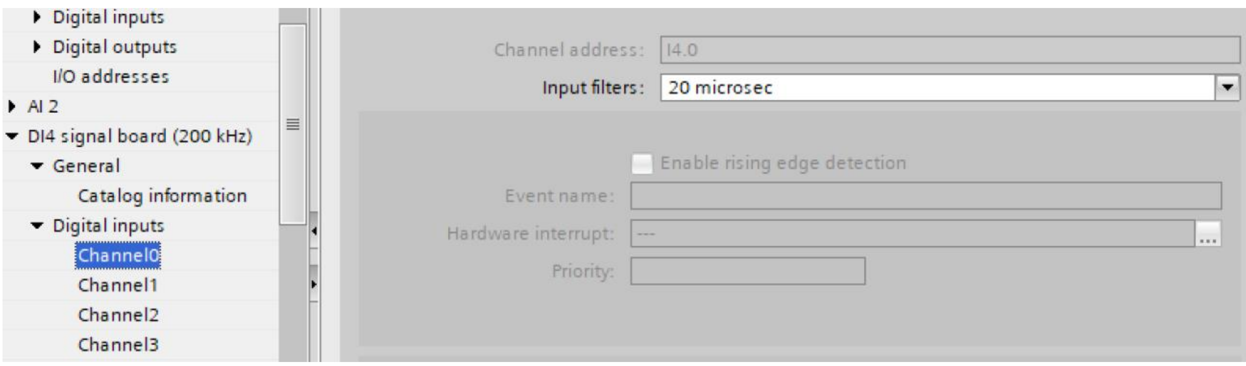


Configuration of the PLC is given in the following tabs. While these have already been set up, it is good to look over the pages to familiarize yourself with how the configuration affects program responses.

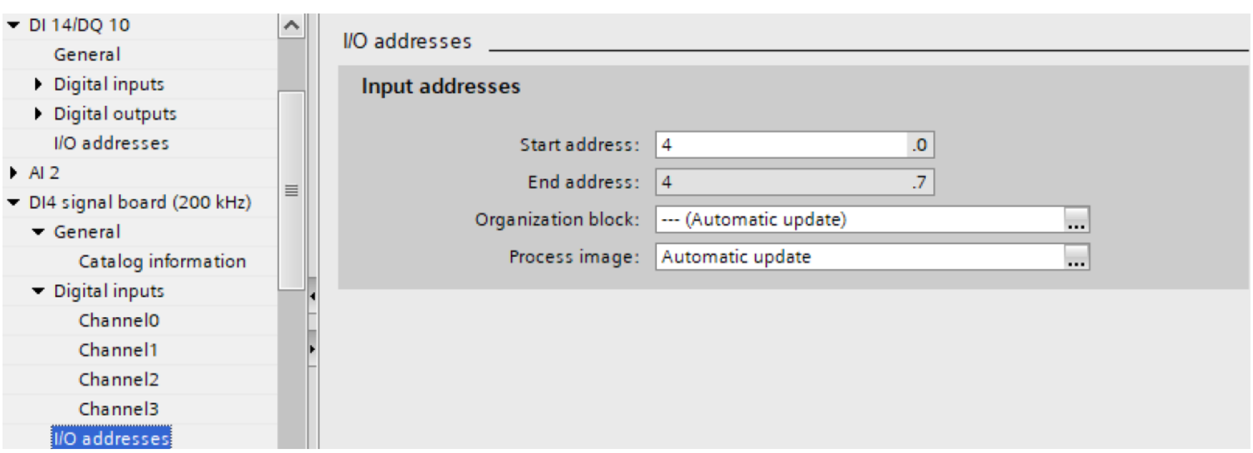
The 5V signal board is included in this project to provide direct input of the encoder. The inputs must be buffered through an NPN transistor, however, since the inputs are true low and the encoder true high.



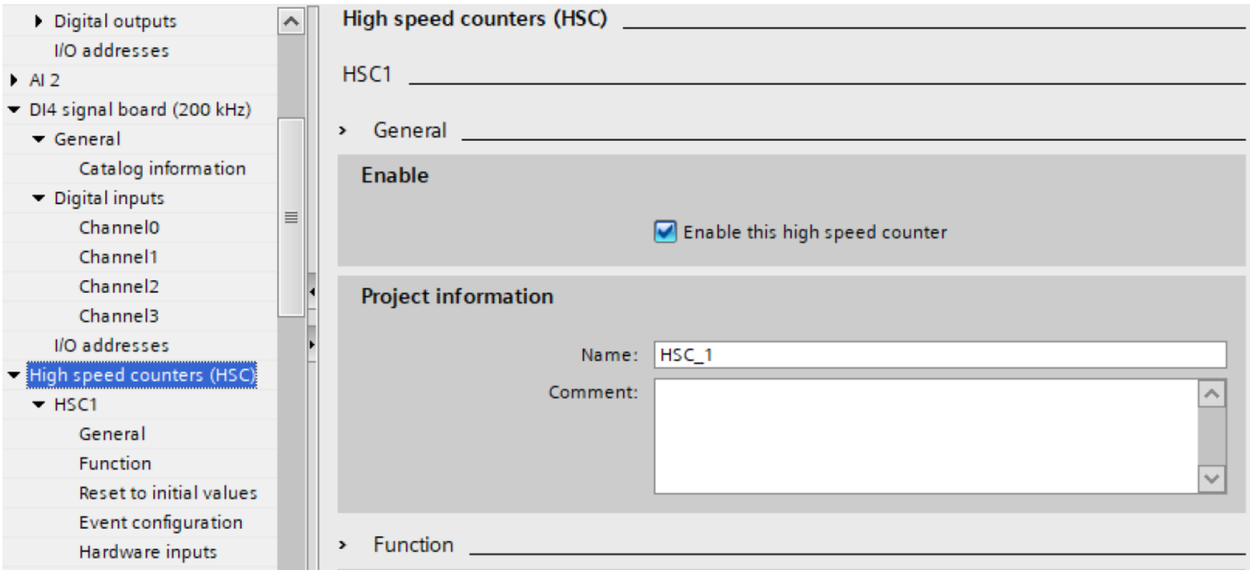
The Signal Board must be changed to allow for the fast pulse inputs:

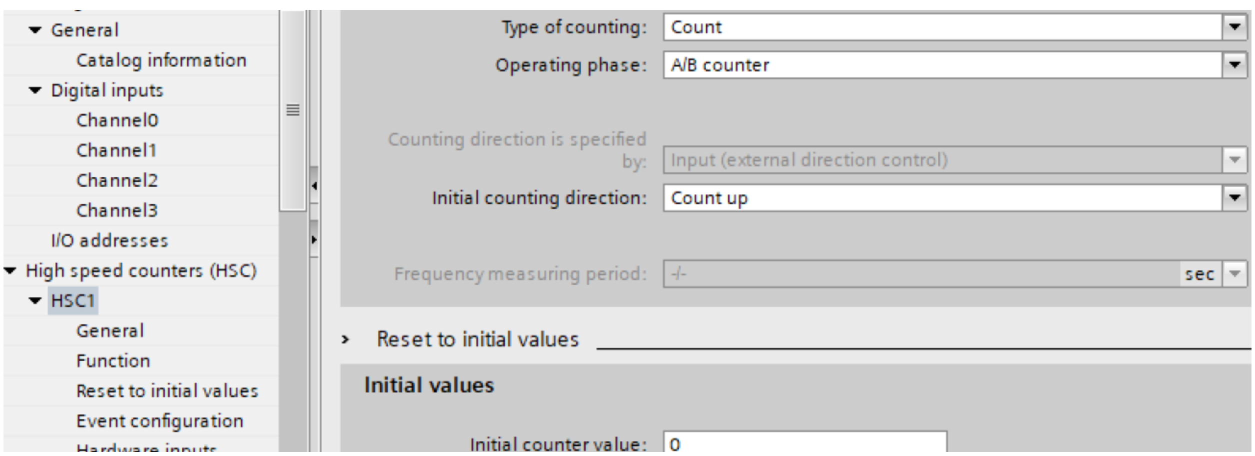


Addressing of the Digital Inputs for the encoder from the Signal Board are shown here:

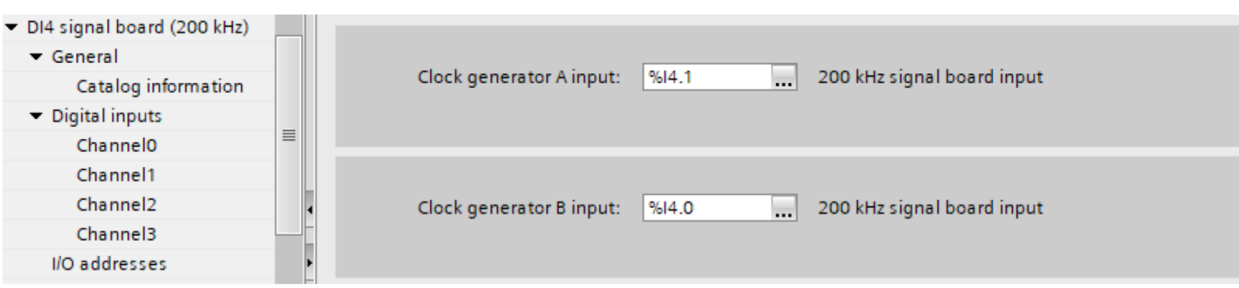


The encoder feedback is routed through configured High Speed Counter inputs. These are configured as seen below:

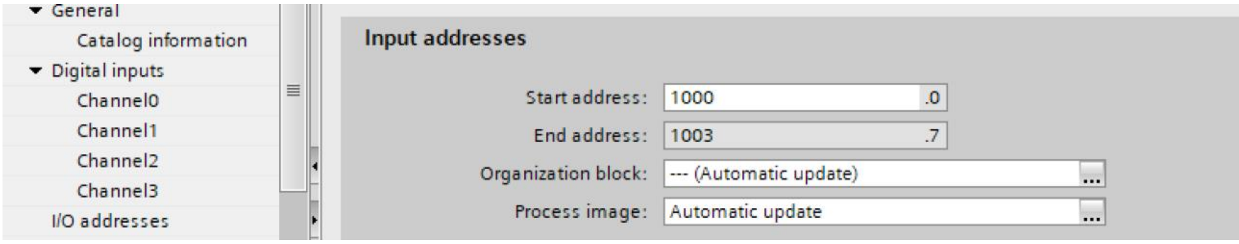




The address of the encoder is configured below:

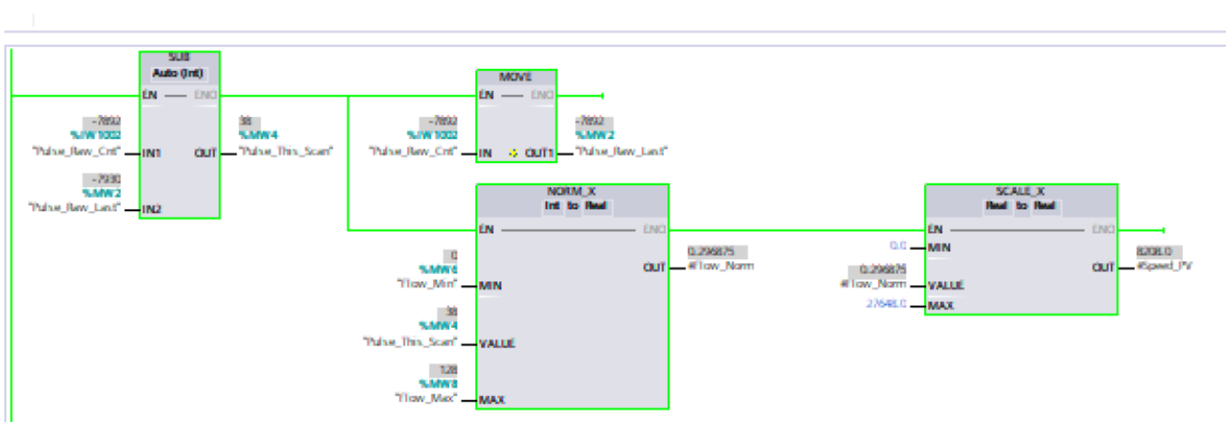


The high-speed input enters the PLC as a pulse in ID1000. This is the address used to calculate the pulses received in the last 100 msec.



The program is in a cyclic interrupt program that is executed each 100 ms. It consists of a rung to get the input count for the last 100 msec followed by the PID block and finally the output to the PWM block.

The choice of 100 ms is chosen due to the observation that with 11 pulses per revolution of the motor, we only receive about 125 pulses in 100 ms. If we were to choose 10 ms as our cycle time, we would only expect 12 pulses per scan at full speed. We need more accuracy than 1/12. If one were to spend more for a more sophisticated motor, more pulses would give greater accuracy and the scan could be reduced.

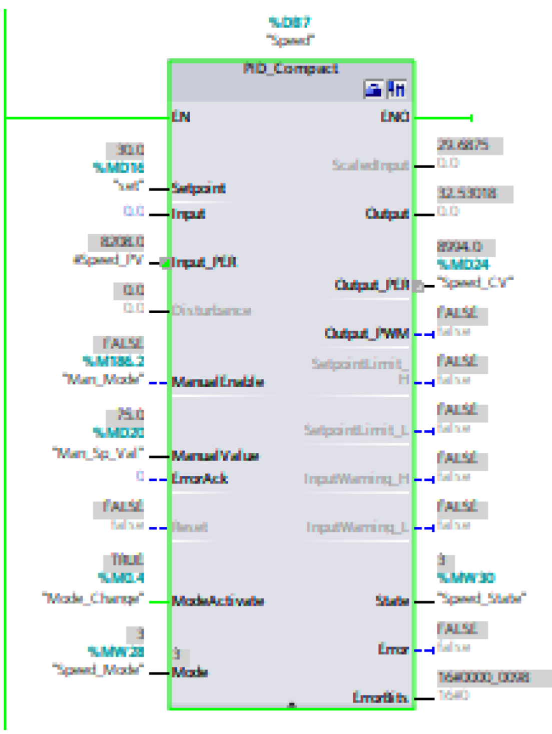


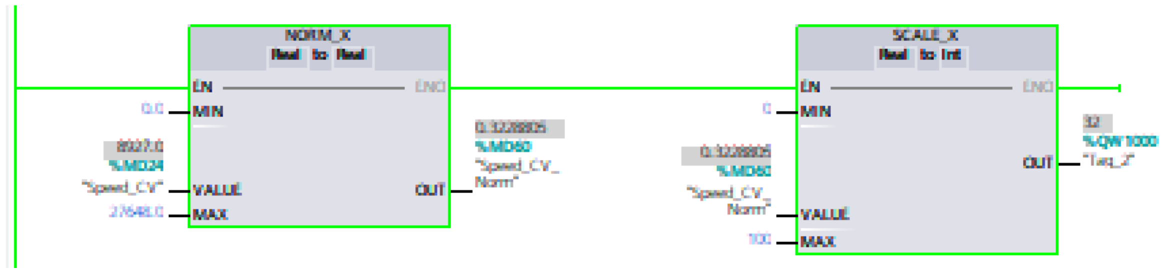
The PID block is shown after the Watch Table. The values for the numeric inputs controlling the PID block are found in the Watch Table. Boolean variables can be set directly by modifying the input in online mode. Remember the 3 state is auto and the 4 state is manual. To change the state, both the mode must be entered with the proper number and the node change bit toggled. Flow max is set and is the maximum number of pulses the encoder can send in the 100 msec time period between executions of the PID block.

Speed mode is the input of the state to the PID block (number to be entered). Speed state is the actual state of the PID block.

Name	Address	Display format	Monitor value	Modify value	
"Speed_CV_Norm"	%MD60	Floating-point nu...		100.0	
"Speed_CV"	%MD24	Floating-poin...		16#0000_0001	
"Speed_Mode"	%MW28	DEC+/-		3	
"Mode_Change"	%M0.4	Bool		TRUE	
"Man_Mode"	%M186.2	Bool		FALSE	
"set"	%MD16	Floating-point nu...		20.0	
"Flow_Max"	%MW8	DEC+/-		128	
"Speed_State"	%MW30	DEC+/-		3	
"Man_Sp_Val"	%MD20	Floating-point nu...		75.0	
	<Add new>				

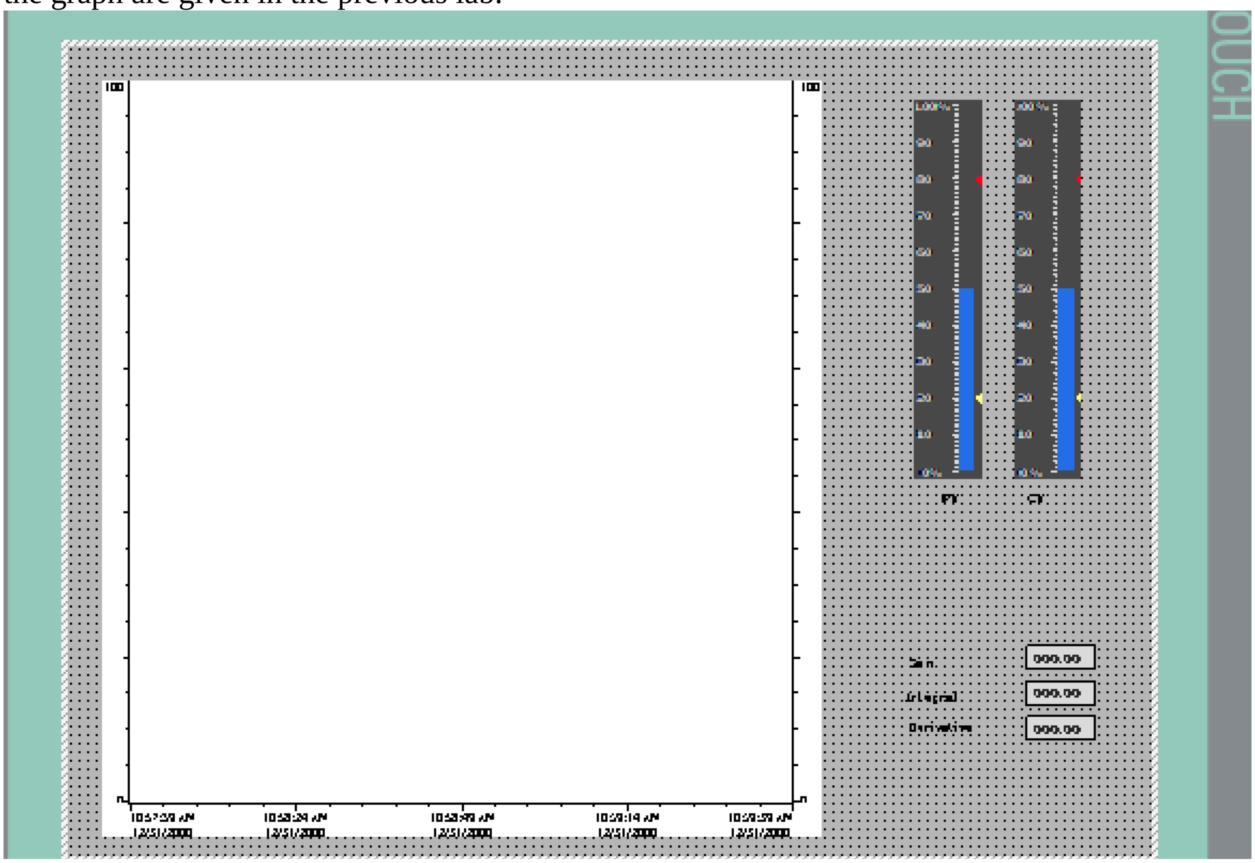
Upper and lower limits for each variable are set so there is no need for the student to set any of these variables. However, the student can set the variables for the setpoint in auto and manual using the Watch Table above. To move between auto and manual, the variable ‘Speed Mode’ must be set to either 3 or 4. Three is auto and 4 is manual. To change mode, the variable ‘Modify State’ must be toggled to 1 and then back to 0. The toggle should be done through the Watch Table.



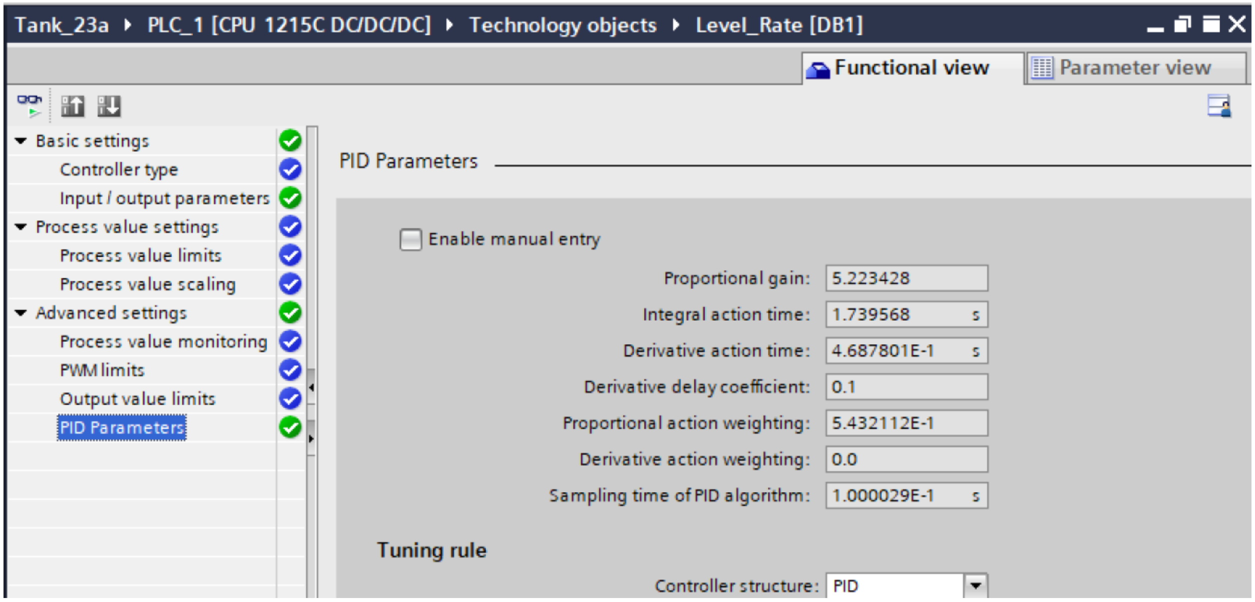


Finally, record the variables that will plot the output of the PID block and enter them into the property list for the histogram and the bar graphs. Also, enter the variables in the digital readouts shown on the HMI. A screen capture of the HMI is sufficient proof that the lab was accomplished.

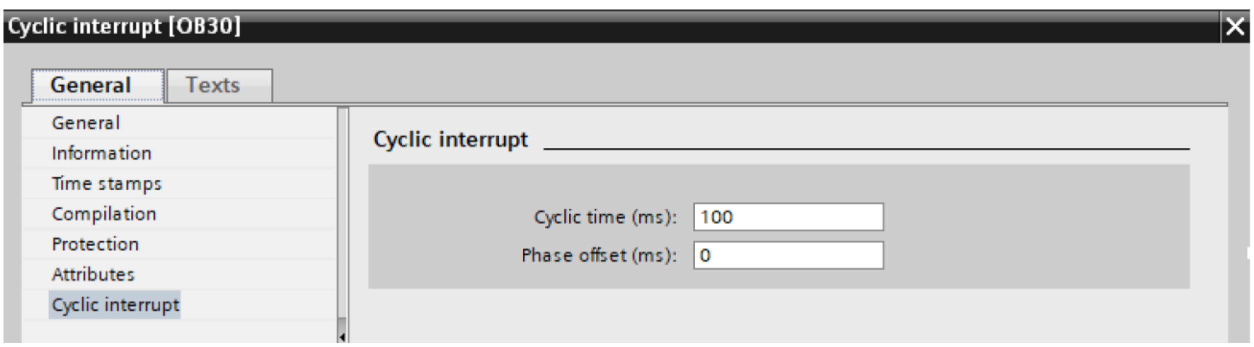
The three variables to be graphed on the histogram are PV, SP and CV. Instructions for setup of the graph are given in the previous lab.



The setup of the PID block may be zeroed again per the previous lab. If needed, the variables for the block are given again below:



The following is the Cyclic Interrupt Configuration page for the PID block. It runs every 100 msec. If the block were to be run faster, what compromise would take place? How much money are you willing to spend on an encoder?



Laboratory Exercise 9

In-Sight Spreadsheet Standard Section 1, 2, and 3

Hand in questions in section 01_03_SkillsJournal_Gettng_Connected in SS Standard Manual.

Hand in questions in section 02-03_SkillsJournal_ImageAcquisition in SS Standard Manual.

Hand in questions in section 03_03_SkillsJournal_Logic in SS Standard Manual

Laboratory Exercise 10

Hand in questions in section 04_03_SkillsJournal_ExtractHistogram

Laboratory Exercise 11

Hand in questions in section 05_03_SkillsJournal_ExtractBLobs

In-Sight Spreadsheet Standard Section 5- end at Section 5.2 Complete program with demo of complete inspection to this point. Must be signed by instructor ‘complete’.

This sign-off sheet plus a two page report on what was learned from the entire Cognex lab exercise constitute your grade for Exam 3.