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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.

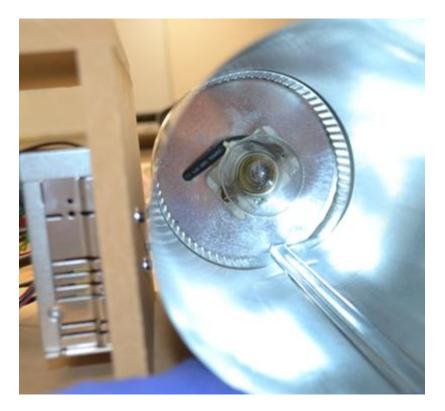
Procedure

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).

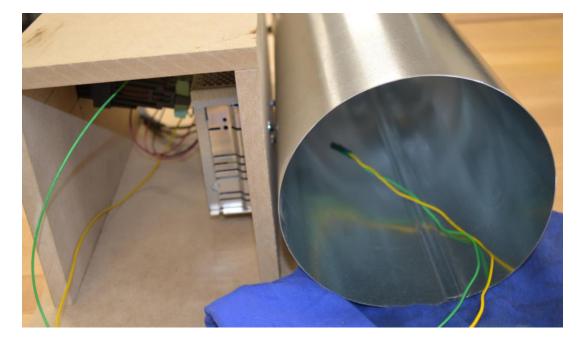


In part 1, the controller will be used in the manual mode.

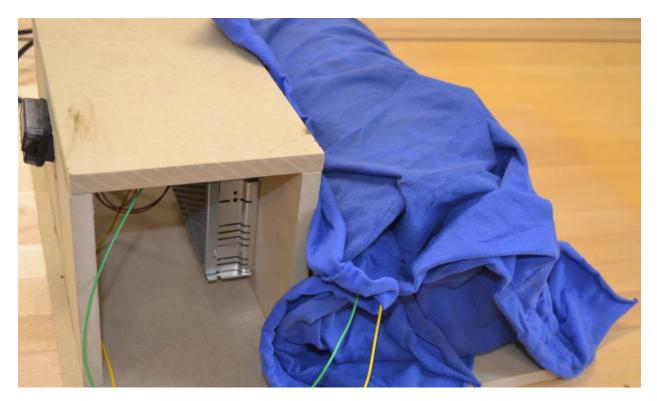
In the picture below the light bulb can be seen. It is mounted in the end of the chamber and is fed from the 24 Vdc source in the back of the wooden rack. All components in the enclosure operate at 24 Vdc other than the power cord attached to the power supply.



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 <u>auto</u> 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.

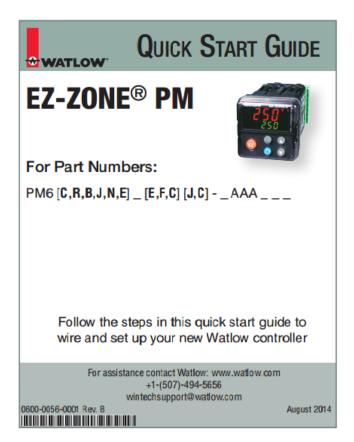
Partially remove the insulation to allow some room-temperature air to enter the chamber. Observe the response of the controller and the system, in response to this disturbance.

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



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

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

		All prices are in US dollars.		
Digi-Key Part Number	615-1038-ND	Price Break	Unit Price	Extended Price
Quantity Available	Digi-Key Stock: 802	1	4.66000	4.66
Quantity Available	Can ship immediately	10	3.63100	36.31
Manufacturer	US Sensor	25	2.94560	73.64
Manufacturer Part Number	PPG101B1	50	2.60300	130.15
Description	DETECTOR RTD TF 100 OHM +/-0.12%	100	2.53450	253.45
Lead Free Status / RoHS Status	Lead free / RoHS Compliant	1		
Moisture Sensitivity Level (MSL)	1 (Unlimited)	1		
Quantity Item Number 👔	Customer Reference			
1 615-1038-ND 🔻	Add to Cart			



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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.

EZ-ZONE PM Express (PID)

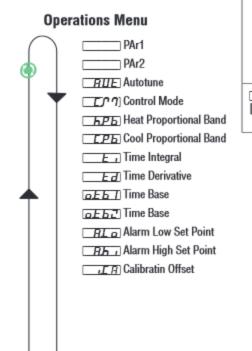
Operations Menu Display Parameter Name Description RUE Autotune [AUt] Start an autotune. While active the upper or left and lower or right display will flash EUn I and REEN. Appears if: Heat or cool algorithm set to PID Control Mode Active View the current control mode. [C.M] Appears if: Always Heat Proportional Band - БРБ [h.Pb] Set the PID proportional band for the heat outputs. Appears if: Heat algorithm set to PID Cool Proportional Band СРЬ Set the PID proportional band for the cool [C.Pb] outputs. Appears if: Cool algorithm set to PID Time Integral E, Set the PID integral for the outputs. [ti] Appears if: Heat or cool algorithm set to PID Time Derivative Еd [td] Set the PID derivative time for the outputs. Appears if: Heat or cool algorithm set to PID Time Base Output 1 оŁЬТ Set the time base for fixed-time-base [o.tb1] control Appears if: Output 1 set to heat or cool with control algorithm set to PID. Time Base Output 2 oŁbZ [o.tb2] Set the time base for fixed-time-base control. Appears if: Output 2 set to heat or cool with control algorithm set to PID. Alarm Low Set Point - RL o [A.Lo] 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 REY is set to Process or Deviation Alarm

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Operations Menu

Range (Defaults are shown bold)	
Ses No	
「夏日子」 Off 「夏日子」 Auto 「アク語」 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	
EZ-ZONE PM Express (PID) • 19 •	Operations Men

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 (cont.)

-	. ,
Display	Parameter Name Description
 [A.hi]	Alarm High Set Point Process - set the process value that will trig- ger 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
[i.CA]	Calibration Offset Set an offset value for a process output. Appears if: Always

Range (Defaults are shown bold)

-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

-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 EI Thermistor Curve Resistance Range **Decimal E**_**F** Display Units CLO Range Low Range High En T Function Output 1 Output Type For Function Output 2 Englishing Heat Algorithm Hysteresis (Heat & Cool) Cool Algorithm REY Alarm Type ПЛЭ Alarm Hysteresis Alarm Logic RLR Alarm Latching REL Alarm Blocking Alarm Silencing RASP Alarm Display Ramp Action E Ramp Rate 5L o Scale Low Scale High Def T Power Scale High Output 1 Power Scale High Output 2 Tas Zone Address

EZ-ZONE	PM	Express	(PID)	

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 thermo- couple type wired to this input. For example, select <u>H</u> for a type K thermocouple. Appears if: Sensor Type is set to Thermo- couple.	
<u> </u>	Thermistor Curve Select a curve to apply to the thermistor input.	
[r.r]	Resistance Range Set the maximum resistance of the thermis- tor 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	
<u>гГо</u> [r.Lo]	Range Low For process signals, this value scales the units to minimum electrical units (0 volts or 4 mA) Appears if: Always	
<u>сь</u> [r.hi]	Range High For process signals, this value scales the units to maximum electrical units (10 volts or 20 mA) Appears if: Always	

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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	
<u>E</u> Thermocouple, <u>Lef</u> Volts dc, <u>P</u> 7 <u></u> Milliamps dc <u>C. TH</u> RTD 100 Ω, <u>EFF</u> Thermistor	
EB EJJET EC HK JD EN EE ER EF ESS	
E Curve A, E Curve B, Curve C Curve C	
5 5K, 10 10K, 20 20K, 40K	
D Whole, DD Tenths, DDD Hundredths	
<u> </u>	
-1,999.000 to 9,999.000 0.0	
-1,999.000 to 9,999.000	

EZ-ZONE PM Express (PID)

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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 to key. **Setup Menu**

	Setup Menu
	Lockout Menu
	Sensor Type
	Linearization
	EI Thermistor Curve
\bigcap	Resistance Range
	Decimal
ΥI	E_F Display Units
+	Range Low
	Range High
	Fo 1 Function Output 1
	Output Type
	Enc: Function Output 2
	Heat Algorithm
↑	
	Cool Algorithm
	REY Alarm Type
	ПЕЛЕТ Alarm Hysteresis
	Alarm Logic
	RLR Alarm Latching
	<u> ЯБ</u> Alarm Blocking
	Alarm Silencing
	RASP Alarm Display
	Ramp Action
	Ramp Rate
	Scale Low
\bigcirc	בה Scale High
	Dever Scale High Output 1
	Dever Scale High Output 2
	Zone Address

EZ-ZONE PM Express (PID)

Setup Menu		
Display	Parameter Name Description	
<u>Fo</u>] [fn1]	Function of Output 1 Select which function will drive this output. Appears if: If output 1 is ordered	
<u>оЕ</u> 9 [o.ty]	Output Type Select whether the process output will operate in volts or milliamps. Appears if: A process output (PM _ C _ F AAAB)	
<u>Fo</u> 2 [fn2]	Function of Output 2 Select which function will drive this output. Appears if: If output 2 is ordered	
<u>ья</u> д [h.Ag]	Heat Algorithm Set the heat control method. Appears if: Output 1 or 2 set to heat	
<u>55</u> [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.	
<u>сяэ</u> [C.Ag]	Cool Algorithm Set the cool control method. Appears if: If Output 1 or 2 is set to cool	
<u>RE9</u> [A.ty]	Alarm Type Select how the alarm will or will not track the set point. Appears if: Always	
[А.hy]	Alarm Hysteresis Set the hysteresis for an alarm. This deter- mines 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	

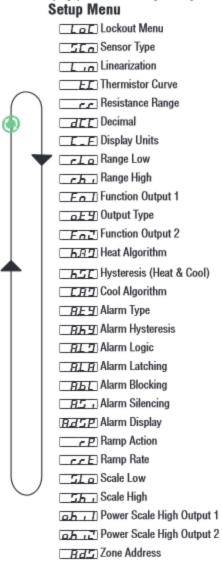
• 24 •

	Range (Defaults are shown bold)
Off, [ool, (<u>הרחר</u> Heat, (חר מין) Alarm
UDLE Volts	
ニア1日 Millian	ips
Off, [_	ooL Cool,
FERE Heat, [<u>ארריז</u>) Alarm
OFF Off,	
On-Off عمم	
0 to 9,999.000°	
0 to 5,555.000° Units, 3.0°F or	
Off, 	
	FRE Process Alarm
<u>JERE</u>) Deviat	ion Alarm
0.001 to 9,999.	000°F or units
0.001 to 5,555.	
Units, 1.0°F or	1.0°C
(0*	
<u>RLC</u> Close RLO Open	
HLO UDEN	UII didiiii

EZ-ZONE PM Express (PID)

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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 \textcircled key.



Setup Menu		
Display	Parameter Name Description	
<u>RL R</u> [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	
<u>ВЬ</u> [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	
<u>R5</u> [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	
885P [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	
<u>с</u> Р [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 electri- cal 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	

EZ-ZONE PM Express (PID)

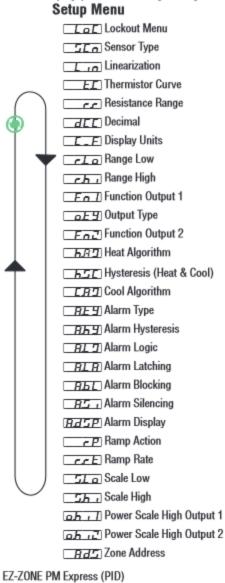
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	Range (Defaults are shown bold)	
(<u>al Re</u>) Non-L	Itching	
<u>LRE</u> Latchir	g	
OFF Off		
Startup		
SEPE Set Poi	it	
<u>БоЕЋ</u> Both		
oFF Off		
0n		
FF Off		
00 On		
Off, []	F - Startup	
	t Change, <u>GoEF</u> Both	
1.0°F degrees o	units per hour	
1.0°C		
-100.0 to 100.0		
0.0		

EZ-ZONE PM Express (PID)

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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			
Display Parameter Name Description			
56 [S.hi]	Scale High Output 1 Set the scale high for process output in elec- trical 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		
<u>oh , 1</u> [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		
oh , Z [o.hi2]	Power Scale High Output 2 Set maximum value of output 2 range. Appears if: Output 2 is <i>Switched</i> and set to heat or cool		
<u>PRe 1</u> [PAr1]	Upper or Left Display Select parameter to display. Appears if: Always		
<u>РЯс 2</u> [PAr2]	Lower or Right Display Select parameter to display. Appears if: Always		
 [Ad.S]	Zone Address - Standard Bus Com- munication Set zone address from 1-16. Appears if: Always		

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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

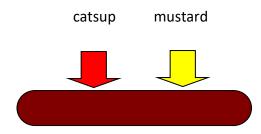
Design a program to count the total number of hot dogs made. Inputs should be wired to contacts and labeled as mustard and catsup. A display is kept in the PLC showing up-to-date counts of hot dogs made by Fred and Rudy.

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

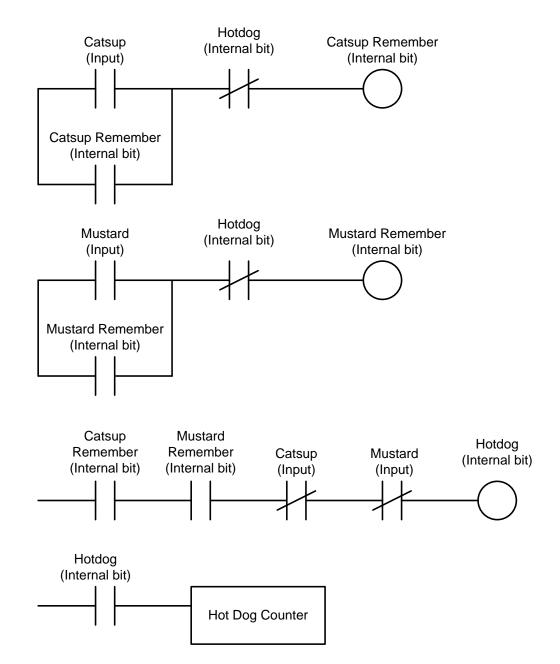
Watch the count accumulate in the counter as the two buttons are pressed in any order. Get a listing from the listing software on the programming software package. The documented listing of the program may be used as the final lab report.

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.

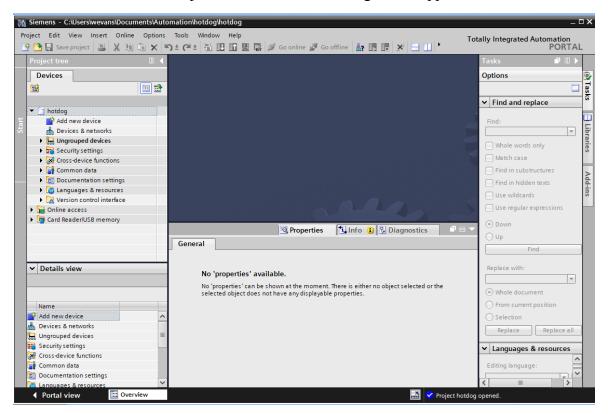


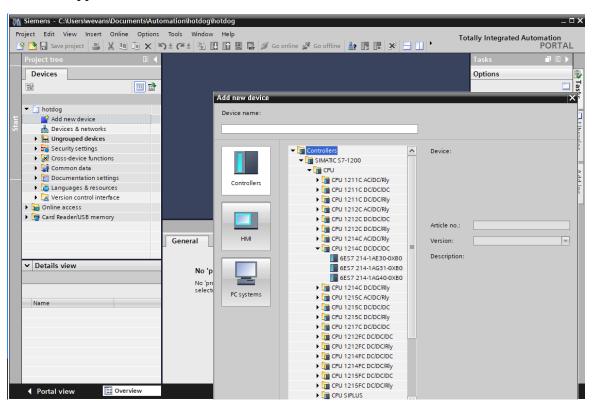
The count of hot dogs made is found in the accumulated value of the counter.

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:

Via Siemens - C:\Users\wevans\Document	s\Automation\hotdog\hotdog		_ ¤ ×
			Totally Integrated Automation PORTAL
Start 🏻		First steps	
Devices &	Open existing project	Project: "hotdog" was opened successf	ully. Please select the next step:
networks	Create new project	Start	
PLC programming	Migrate project		
Motion & 🗱	Close project		
Visualization	2	Devices & networks	Configure a device
Online &	Welcome Tour	PLC programming	Write PLC program
Diagnostics	First steps	Motion &	Configure
		technology	Configure technology objects
	Installed software	Visualization	Configure an HMI screen
	🔵 Help		
	011001		
	🕥 User interface language		
	01100	Project view	Open the project view
Project view	Opened project: C:\Users\wevans\D	ocuments\Automation\hotdog\hotdog	

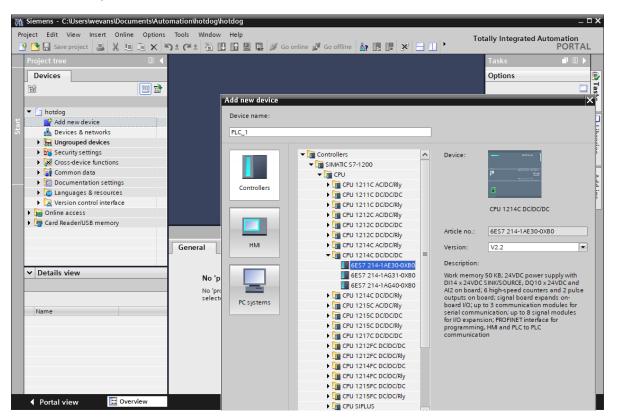
In the lower left, select 'Project view' and the following screen appears:





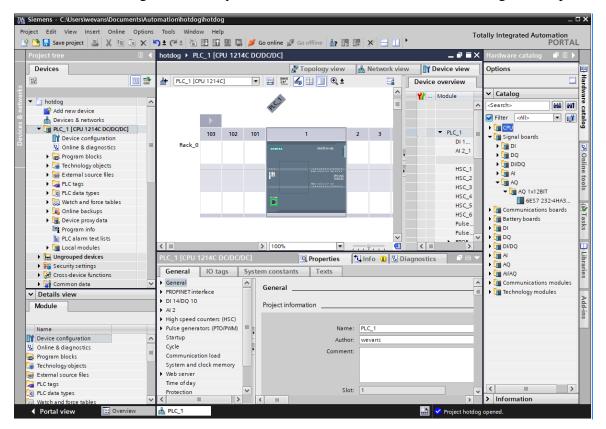
From the upper left, select 'Add new device' and follow the selection screen as show below:

Once selected, the screen will look like:



Reference - C:\Users\wevans\Documents\Auto	mation\hotdog\hotdog	_ - X
Project Edit View Insert Online Options		stally Integrated Automation
📑 📑 🔚 Save project 📑 🐰 🛅 🏹 🗶) 🛨 (🍽 🖆 🛄 🛄 🔛 🙀 💋 Go online 🖉 Go offline 🛔 🖪 🖪 👫 😹 📃 🛄 🎽	PORTAL
Project tree 🔲 🖣	hotdog → PLC_1 [CPU 1214C DC/DC/DC]	Hardware catalog 🛛 🗊 🕨 🕨
Devices	🚝 Topology view 🛛 👗 Network view 🛛 🛐 Device view	Options
1 I I I I I I I I I I I I I I I I I I I	# PLC_1 [CPU 1214C] ▼ 🗒 🕎 🏹 🍕 🗮 🛄 🔍 ± 📑 Device overview	Options
s z		✓ Catalog
🕺 🔻 🗋 hotdog	🖉 🖞 Module	<pre>< catalog</pre>
Add new device		
😤 🚠 Devices & networks		Filter <all></all>
PLC_1 [CPU 1214C DC/DC/DC]	103 102 101 1 2 3 V PLC_1	· • • • • • • • • • • • • • • • • • • •
Device configuration		Signal boards
Online & diagnostics	Rack_0 AI 2_1	Communications boards
Program blocks		▶ 🛅 Battery boards 🧕 🤤
Technology objects	HSC_1	Communications boards Gommunications boards Di DI DI DU DU DU DU DU DU DU S
External source files	III BUTHE HSC_2	• <u>n</u> PQ
PLC tags	HSC_3	▶ 🛄 DI/DQ
E PLC data types	HSC 4	
Watch and force tables	HSC 5	AQ A
Online backups	HSC 6	→ 🛺 AI/AQ
Device proxy data	Pulse	Communications modules
Program info	Pulse	🕨 🖬 Technology modules 🦷 ត
PLC alarm text lists		
Local modules	< III > 100%	- 1
Ungrouped devices	PLC_1 [CPU 1214C DC/DC/DC] 🔄 Properties 🚺 Info 👔 🗓 Diagnostics 📰 🗏 🤜	- Libraries
Security settings	General IO tags System constants Texts	ar.
Cross-device functions		
🕨 🙀 Common data 🛛 🗠	General General General	
✓ Details view	KOFINE I Interface DI 14/DQ 10	>
Module	Al 2 Project information	Add-ins
	High speed counters (HSC)	
Name	Pulse generators (PTO/PWM) Pulse generators (PTO/PWM) Pulse generators (PTO/PWM)	
Device configuration		
Online & diagnostics	Cycle Author: wevans	
Program blocks	Communication load	
Technology objects	System and clock memory	
External source files	Web server	
PLC tags	Time of day	
PLC data types	Protection V Slot: 1	, < III >
Watch and force tables		> Information
Portal view Overview	🚠 PLC_1 🔛 😪 Project hotdo	g opened.

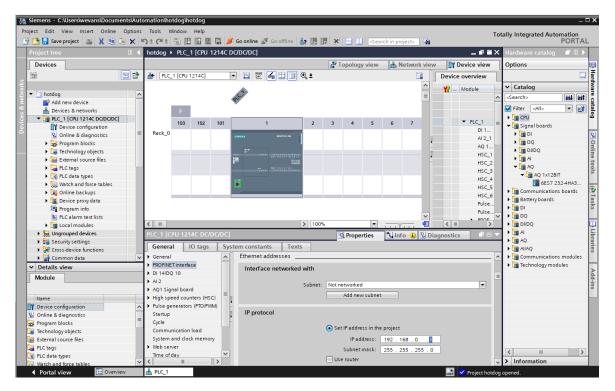
We need to add a signal board if your PLC has one. This is done with a drag and drop:



Siemens - C:\Users\wevans\Documents\Auto	mation\hotdog\hotdog	_ ¤ ×
Project Edit View Insert Online Options	Tools Window Help Tot	ally Integrated Automation
📑 📑 🛃 Save project 📑 🐰 🛅 😭 🗙 🎙) 🛨 (🖆 🗄 🗓 🗓 🖳 🖉 Go online 🖉 Go offline 🏭 🖪 📑 💥 🚽 🛄 🔭	PORTAL
Project tree	hotdog → PLC_1 [CPU 1214C DC/DC/DC]	Hardware catalog 🛛 🗊 🕨 🕨
Devices	🛃 Topology view 🛛 🔒 Network view 🔢 Device view	Options 📃
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	🔐 PLC_1 [CPU 1214C] 🔻 📰 🌠 🔛 🔳 🔍 🛨 🔤 Device overview	Options ↓ Catalog ✓ Catalog ✓ Catalog ✓ Catalog ↓ Catalog ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓
st	Module	✓ Catalog
🕺 🔻 🗋 hotdog 📃 🔨	₹C. Module	Search>
🖁 🎽 Add new device		
Devices & networks		Filter All>
2 • [] PLC_1 [CPU 1214C DC/DC/DC]	103 102 101 1 2 3 4 V PLC_1 =	
Bevice configuration	Rack 0	✓ Im Signal boards
Conline & diagnostics	Rack_0 SIGNING SIGNING ALL 2_1	↓ m pl ↓ ↓ m pQ On line ↓ m pl/pQ In et to of s ↓ m AQ ↓
Program blocks	AQ 1	DQ Q
Technology objects	HSC_1	▶ 🛄 DI/DQ
External source files	ill Brock	AI To AI To AQ
PLC tags	HSC_3	AQ A AQ A
PLC data types	HSC_4	6ES7 232-4HA3
Watch and force tables	HSC_5	Communications boards
Conline backups	HSC_6	Communications boards Communications boards Battery boards DI
Device proxy data	Pulse	DI Di
Program info	Pulse	
PLC alarm text lists		▶ D I/DQ
Local modules		
Ungrouped devices	AQ 1x12BIT_1 [AQ1 signal board]	AI Libraries
Security settings Kernel Cross-device functions	General IO tags System constants Texts	
Cross-device functions) General	Communications modules
	Analog outputs General	Technology modules
Details view	I/O addresses	>
Module	Name: AQ1x12BIT_1	Add-ins
		ns
Name	Comment:	
Device configuration	4	
Online & diagnostics		
Regram blocks	-	
Technology objects		
External source files	Catalog information	
PLC tags		
PLC data types	Short designation: AQ1 Signal board 🛩	<
Watch and force tables	K III	> Information
Portal view 🗄 Overview	👬 PLC_1 🔜 🛃 🗹 Project hotdog	opened.

Your screen will resemble the following:

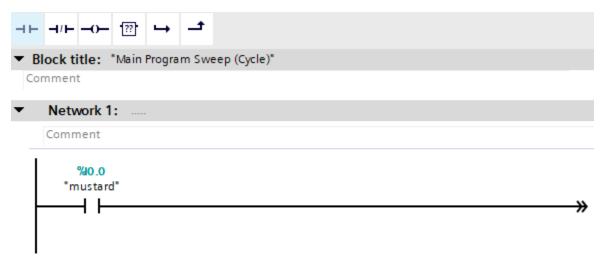
To change the ethernet port, click on the little green port on the processor. Change to 192.168.0.3.



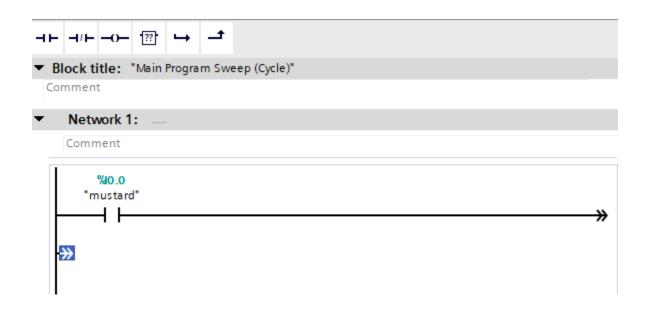
Siemens - C:\Users\wevans\Documents\Aut	omation\hotdog\hotdog	_ □ X
Project Edit View Insert Online Options	Tools Window Help Tot	ally Integrated Automation
📑 📑 🔚 Save project 📑 🐰 🗉 🗂 🗙	ዓ 🛨 👎 🗓 🗓 🖀 🖉 Go online 🦨 Go online 🌡 🕞 📑 🗱 🛃 🔄 📋 <search in="" project=""> 🕌</search>	PORTAL
Project tree 🔲 🖣	hotdog → PLC_1 [CPU 1214C DC/DC/DC] → Program blocks → Main [OB1]	Instructions 📑 🔳 🕨
Devices		Options :
🖬 🔟 🖬	🕺 🕼 🕾 🖆 🔚 🚍 비 🗄 🔚 🔤 🕹 😫 비 🔛 😢 🕼 😢 😂 👘 😫 🔛 🔤 👘 🚱 👘 🖓 👘 🔒 👘 📮	
2	Main	Favorites Basic instructions
🗧 💌 📄 hotdog 📃 🔨	Name Data type Default value Comment	✓ Basic instructions
🗧 📑 Add new device	1 🕣 🔻 Temp	Name
🗟 🚠 Devices & networks	2 • <add new=""></add>	
PLC_1 [CPU 1214C DC/DC/DC]	3 🕣 👻 Constant	Bit logic operations
Device configuration		General G
Soline & diagnostics	⊣⊢⊣⊢⊕ ഈ ↦ –ੈ	Counter operations
▼ 🕞 Program blocks	▼ Block title: "Main Program Sweep (Cycle)"	Comparator operations
Add new block	Comment	Math functions
Technology objects		< III > 🎽
External source files	▼ Network 1:	Math functions Math functions Extended instructions
PLC tags	Comment	Name
PLC data types		Date and time-of-day
Watch and force tables		Date and time-of-day String + Char Distributed I/O PROFlenergy Interrupts
Online backups		Distributed I/O
Device proxy data		PROFlenergy
Program info		
PLC alarm text lists		Alarming V
Local modules		✓ Technology
Ungrouped devices		
🕨 😽 Security settings 🛛 🗸 🗸		Name 🖥
✓ Details view		PID Control
		Motion Control
		SINAMICS
Name Address		_
	100%	
	Main [OB1]	
	General Texts	
	General A	< III >
		> Communication
		> Optional packages
Portal view Overview	📩 PLC_1 🔹 Main (081)	

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

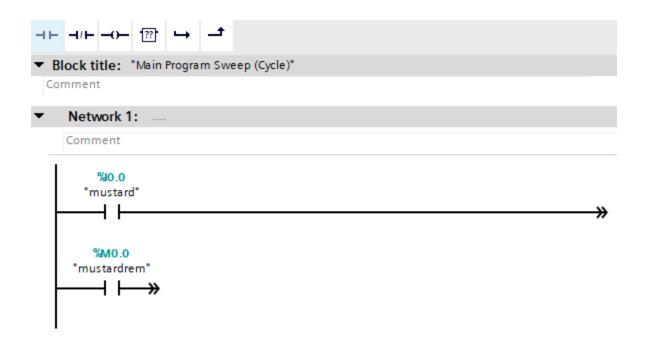
Drag down a normally open contact and define it as an Input



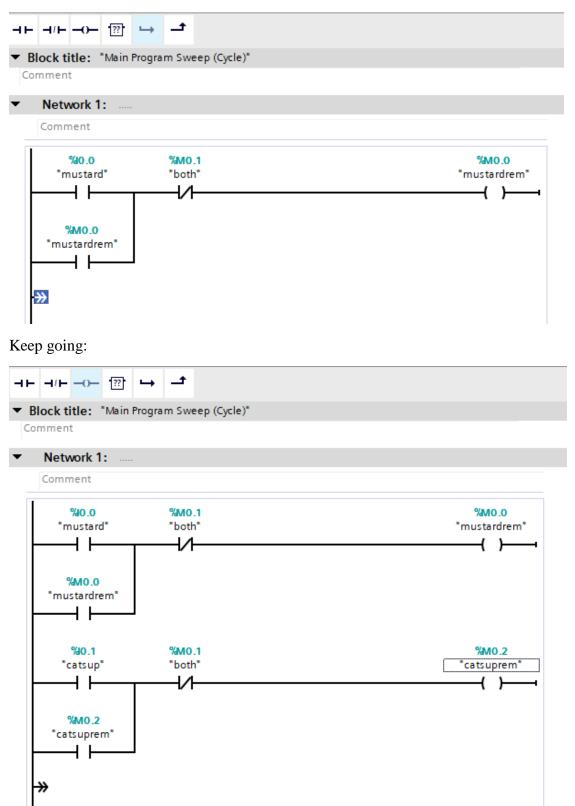
Start the parallel path as follows:



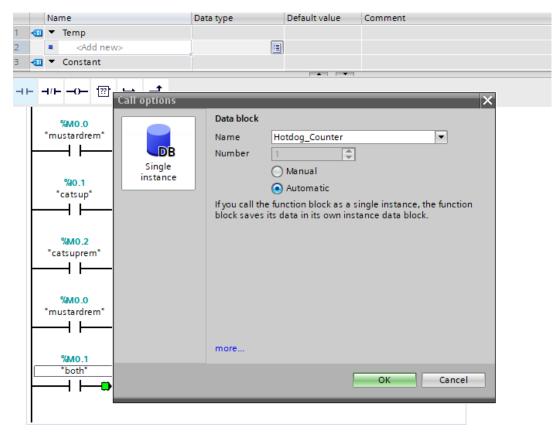
Then add the contact:



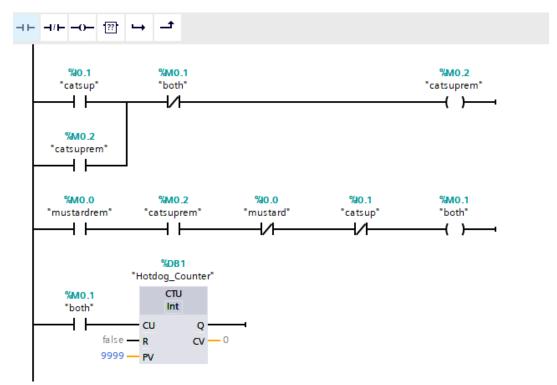
Finish the first rung and start the second one while still in Network 1:



Then add the counter:



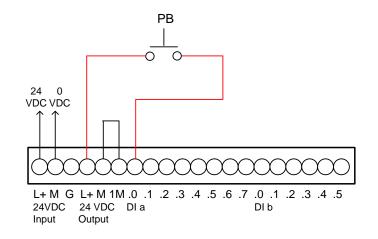
Final Result:



Compile, download and run:



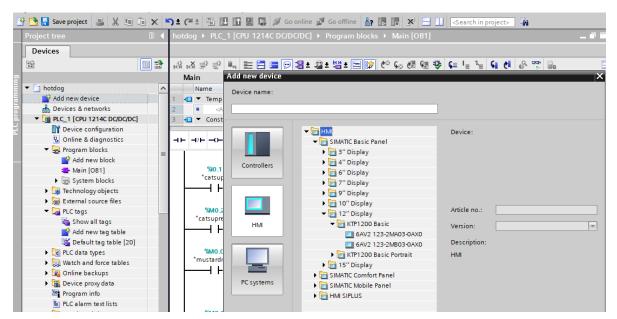
Siemens wiring of input I0.0 is below:



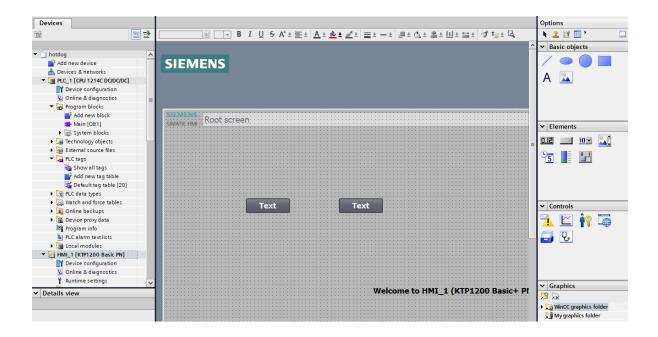
Stop here and get help from instructor:

	Device	Device type	Slot	Interface type	Address	Subnet	
	PLC_1	CPU 1214C DC/D	1 X1	PN/IE	192.168.0.3		
		Type of the PG/PC inte PG/PC inte		PN/IE		▼	
		Connection to interface/su		Please select		▼ ▼) 😨
		1st gat				· · · · · · · · · · · · · · · · · · ·	•
	Select target de	vice:		[Show all compatible	devices	
	Device	Device type	Interfa	ace type Add	ress	Target device	e
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h LED							
1 LED						<u>S</u> tart s	earc
sh LED atus informatior				ſ	Display only error		ear

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.

hotdog → HMI_1 [KTP1200 Basic PN]	_ # = ×
	Topology view 🐘 Network view 📑 Device view
🕌 HM_1 [KTP1200 Basic PN] 💌 🖽 🖽 🛄 🔍 ±	Device overview
	Module
	HMI_RT_1
	=
HMI_1	→ HML1.IE_CP PROFINE
	PROFINE
	Ţ
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	×
< III > 100%	
HMI_1.IE_CP_1 [PROFINET Interface]	🔍 Properties 🚺 Info 🚺 🖞 Diagnostics 👘 🗉 🖃 🗸
General IO tags System constants Texts	
General Comment:	<u>^</u>
PROFINET Interface [X1]	
Ethernet addresses	
Interface networked with	
C. has	Not networked
Subnet:	Not networked Add new subnet
	Add new subnet
IP protocol	
	Set IP address in the project
	IP address: 192, 168, 0, 5
	IP address: 192 . 168 . 0 . 5 Subnet mask: 255 . 255 . 255 . 0

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

Network	Connections	HMI connection	💌 🖭 🖫 T	1 💷 🛄 🍳 ±
PLC_1 CPU 1214C		HMI_1 KTP1200 Basic PN		
		PN/IE_1		

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

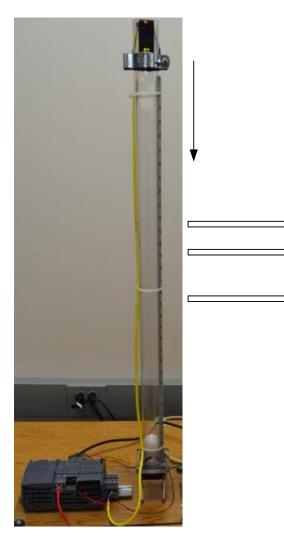
Laser Accuracy and Calibration

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. We will 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.

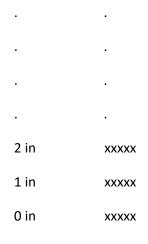


Remove the laser from the tube carefully anduse tape to affix it to the side of the tube focusing downward.

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.

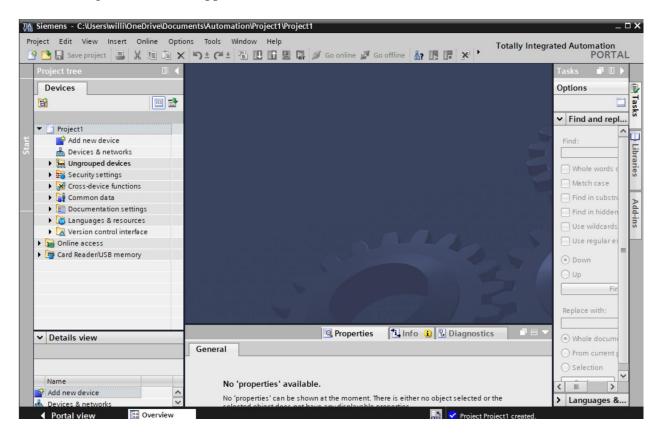
36 in	XXXXX
35 in	ххххх
34 in	ххххх
33 in	ххххх
•	



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

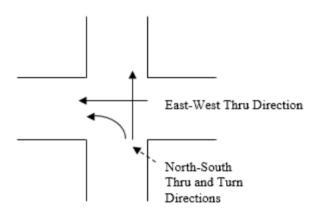
Introduction

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.

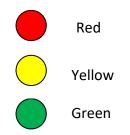
Procedure

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

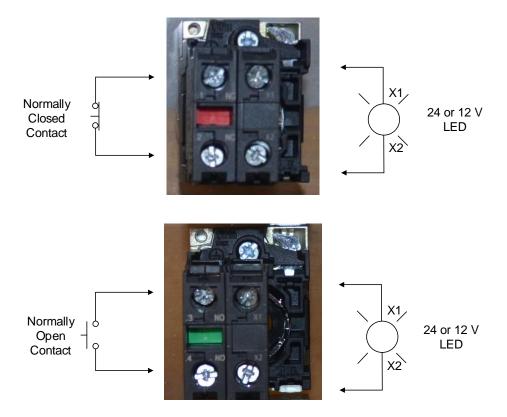
This lab consists of programming the nine lights to cycle through the proper sequence to control traffic flow at the intersection described above.

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:

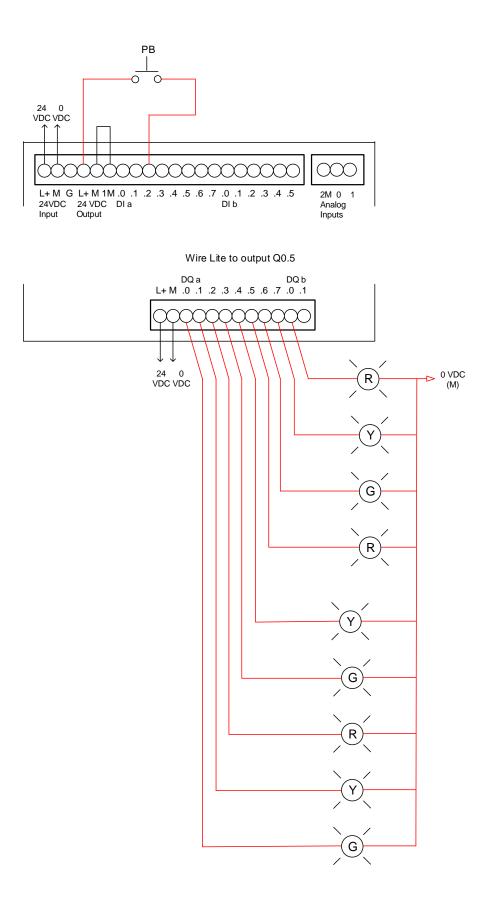


Front side of New Pushbutton Stations

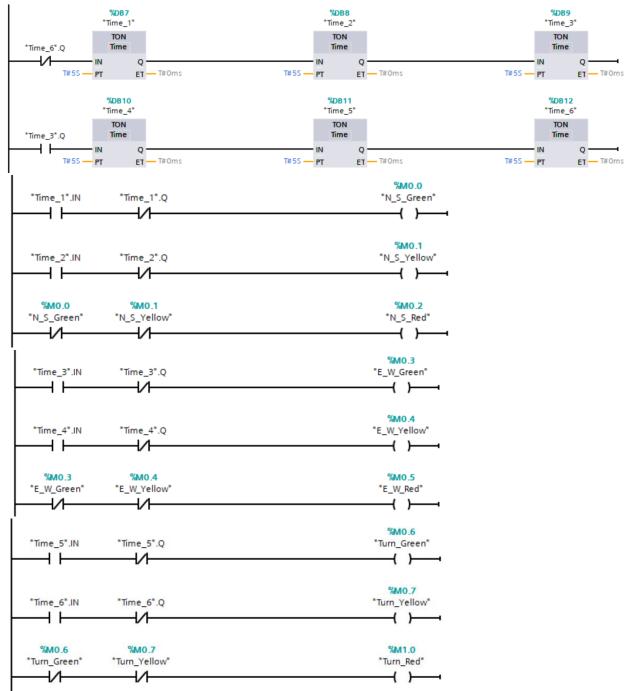


Back side of New Pushbutton Stations

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



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.

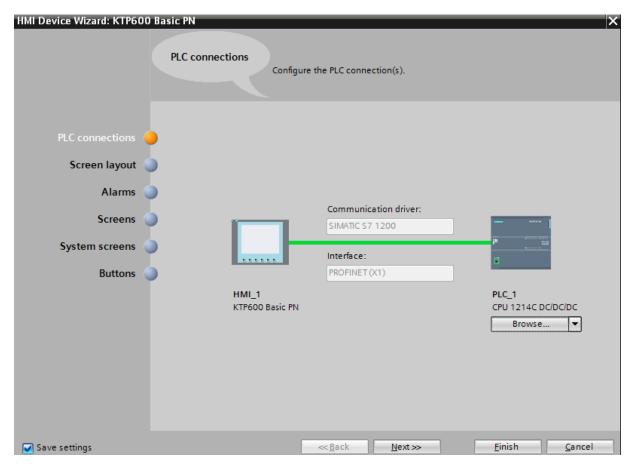
Addition of the HMI used in the labs:

Project tree		Add new device				×
Devices		Device name:				
1 C O		HM_1				
 MyProject Add new device Devices & networks PLC_1 [CPU 1214C DC/DC/DC] Common data Documentation settings Languages & resources Online access SIMATIC Card Reader 		PLC HM	 IMM SIMATIC Basic Panel 3" Display 4" Display 6" Display 6" Display KTP600 Basic DP KTP600 Basic DP Portrait KTP600 Basic PN Portrait KTP600 Basic mono PN KTP600 Basic mono PN KTP600 Basic mono PN To Display 15" Display 	Device: Order no.: Version: Description:	KTP600 Basic PN 6AV6647-0AD11-3AX0 11.0.0	<u></u>
			, and to objerv		lay, 320 x 240 pixel, 256 colors; F peration, 6 function keys; 1 x	<ey< td=""></ey<>

The HMI Device Wizard:

Project tree		HMI Device Wizard: KTP600 Basic PN					×	lardware catalog		
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	_			Configure t	he PLC connection(s).				· Catalog	-
🕶 🛅 MyProject									Search>	ī
Add new device									Filter	ď
Devices & networks									CPU	
▶ []] PLC_1 [CPU 1214C DC/DC/DC])						 Signal board 	
HML_1 [KTP600 Basic PN] Gommon data		Screen layout							DI	
Documentation settings		Screen layout							DQ	
G Languages & resources		Alarms							DI/DQ	
Online access					Communication driver:				🕨 🛅 Al	
SIMATIC Card Reader		Screens			PLC				▼ aQ	
			_						🗕 🗖 AQ1 x 12 bits	
		System screens			Interface:				6ES7 232-4HA	
		Buttons							 Communications boar Battery board 	ds
		Duttons							DI	
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				KIPOU Basic PN		50	Browse	_	DI/DQ	
							Browse		- Frank Al	
								7		
							Name		CPU type	
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							PLC_1		CPU 1214C DC/DC/DC	
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Keep answering Next>>



Keep answering Next>>

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Devices			Screen layout		
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		🖌 Save settings		≪ <u>B</u> ack <u>N</u>	ext » <u>F</u> inish <u>C</u> ancel

Project tree 🔲 🖣	HMI Device Wizard: KTP600 Basic PN 🛛 🕹
Devices	Alarms Configure the alarm settings.
MyProject MyProject MyProject Devices & networks Multicological contents Multicological c	PLC connections Screen layout Alarms Screens System screens Buttons Buttons Construction of the system events Construction
	Save settings

Project tree		HMI Device Wizard: KTP600 Basic PN
Devices		
B 0 0	1	Screen navigation
		Add new screens by clicking this button: +
▼ 📄 MyProject		
💕 Add new device		📑 Add screen 🔜 Delete screen 🗹 Rename 🗔 Delete all screens
📩 Devices & networks		
PLC_1 [CPU 1214C DC/DC/DC]		PLC connections 🥥
HMI_1 [KTP600 Basic PN]		
🕨 🙀 Common data		Screen layout 🤡
Documentation settings		
Languages & resources		Alarms 🥝
Online access		
SIMATIC Card Reader		Screens 🥚
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Keep answering Next>>

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Common data		Screen layout 🕥				Project
Documentation settings						information
Languages & resources		Alarms 🥑				
Online access						Operating modes
SIMATIC Card Reader		Screens 🕑				Language switching
		System screens				Stop Runtime
		Buttons 🥥	Root screen	Custom.		User
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						System information
						mornation
			Select all			
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Project tree		HMI Device Wizard: KTP600 Basi	sic PN 🗙
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			Add buttons with diagrand-drop or by clicking on available system buttons.
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B Devices & networks			
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Common data		Screen layout 📀	
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Canguages & resources		Alarms 📀	SIEMENS Root screen 10:01:43 PM
 Online access 			3/10/2013
SIMATIC Card Reader		Screens 📀	Log on Language
			No. Time Date
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			Reset all
		Save settings	<< <u>B</u> ack Next>>> Einish Cancel
		Save settings	Concer

Then Finish

From the Devices and Networks choice in the Project Tree:

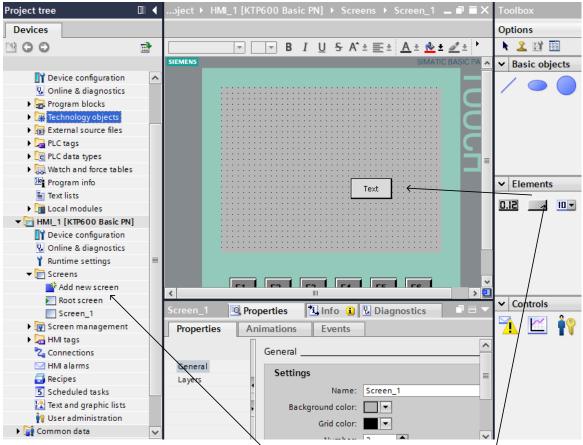
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	Project tree	MyProject → HML_1 [KTP600 Basic PN] → Screens → Root screen _ ■ ■ X	Toolbox
	Devices		Options
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	Common data		
	Common data Documentation settings		
	Languages & resources		
	Online access	Welcome to HML_1 (KTP600 Basic PN)	✓ Elements
	SIMATIC Card Reader		
			<u>5.12</u> 🛄 🛄 51.0
		F1 F2 F3 F4 F5 F6	
		< > 2	✓ Controls
		Root screen 🔍 Properties 🗓 Info 🚺 😨 Diagnostics 🗊 🖃 🤝	
		Properties Animations Events	🄼 🖾 🙌 🖃
		General	
		General	
		Layers Settings	
		Name: Root screen	

Choose Devices & networks

Project tree		MyProject → Devices & networks
Devices		🔐 Topology view 🛛 🛔 Network view 🔢 Device view
⊠ 0 0	B	💦 Network 🔢 Connections 57 connection 🔽 🐫 🖽 🍳 ± 100% 💌
		PN/IE_1
▼ 🔄 MyProject	^	
💕 Add new device		
📅 Devices & networks		PLC_1 HMI_1
PLC_1 [CPU 1214C DC/DC/DC]		CPU 1214C KTP600 Basic PN
Device configuration		
🛂 Online & diagnostics		
🕨 🚘 Program blocks		
Technology objects		PN/IE_2
🕨 词 External source files		
🕨 🏣 PLC tags		
PLC data types		
Watch and force tables		
📴 Program info	=	
Text lists		
Local modules		
▼ → HMI_1 [KTP600 Basic PN]		X
Device configuration		
🛂 Online & diagnostics		Network data
🍸 Runtime settings		X1 : PN(LAN)
Screens		General
🕨 👿 Screen management		
🕨 🔁 HMI tags		General Add new subnet
🄁 Connections		Ethernet addres
🖂 HMI alarms		Advanced IP protocol
📑 Recipes		Time synchroniza
5 Scheduled tasks		 Set IP address in the project
🔛 Text and graphic lists		IP address: 192 . 168 . 0 . 1
💡 User administration	~	Subnet mask: 255 . 255 . 0

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.

roject tree		Project26 > HMI_1 [KTP6	00 Basic color PN] 🕨 Sc	reens 🕨 Screen_	_1	_ = = >	Collock	. .
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😵 Online & diagno	st							-
🍸 Runtime setting:		· · · · · · · · · · · · · · · · · · ·	$\sim \sim $				= L	
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🚬 Root screen								
Screen_1								
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🖂 HMI alarms					100%	·		
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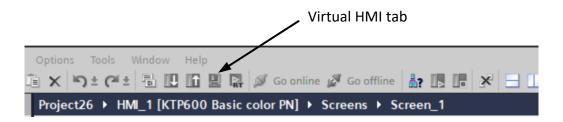
Create a second screen and use the circle object to create a screen resembling the above.

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

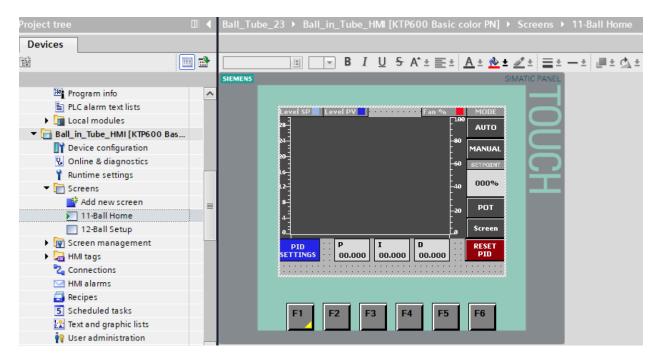
Ball and Tube - Parameter Scaling and PID Tuning Effects

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.

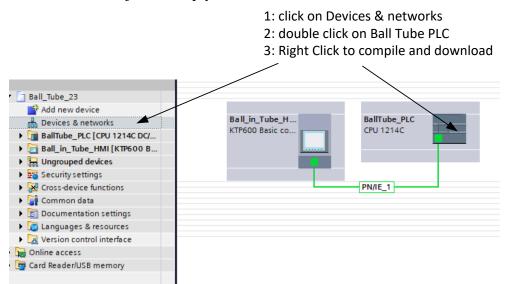


This screen is called 'Ball Home' and is used to toggle between auto and manual as well as choosing of the POT or data entry from the screen.

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'.

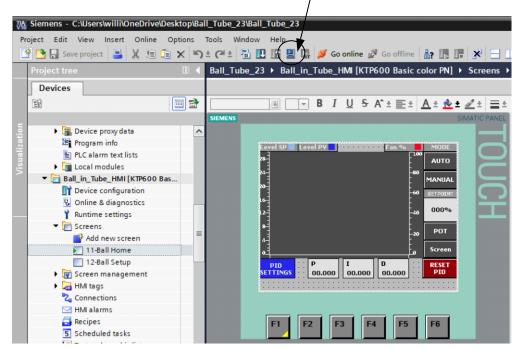
Project tree	Ball_Tube_23 Ball_in_Tube_HMI [KTP600 Basic color PN] Screens 12-Ball Setup
Devices	
1 H	· B I U S A*±≣± A± ± ± ± ± ± ± ± ± ± ± ± ± ± ± ± ± ±
	SIEMENS SIMATIC PANEL
📴 Program info 🛛	
PLC alarm text lists	
Local modules	LIVE DATA SCALING PARAMETERS
▼ 📄 Ball_in_Tube_HMI [KTP600 Bas	Raty Data 00000 II Min Analog Val 00000
Device configuration	
Q Online & diagnostics	Analog Yal
Y Runtime settings	Ball Height 00.00In Max Ball 00.00In
▼ ☐ Screens	Height UCOUN
🗳 Add new screen	
💽 11-Ball Home	
12-Ball Setup	
Screen management	
🕨 🔚 HMI tags	
迄 Connections	SETUP
🖂 HMI alarms	
🗐 Recipes	
5 Scheduled tasks	F1 F2 F3 F4 F5 F6
🔛 Text and graphic lists	
💱 User administration	

- 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** \rightarrow **PID** \rightarrow **Actuator Device**, we construct a system with a **Sensing Device** \rightarrow **PID** \rightarrow **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

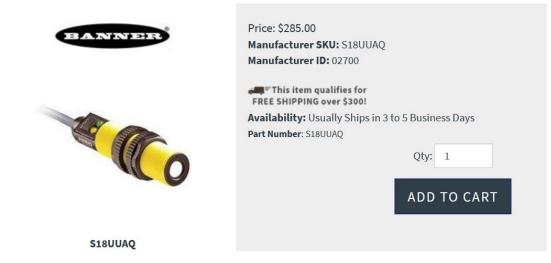
Flow Rate Sensor, 3/8 MNPT, 0.2 to 2.0 GPM

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

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



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

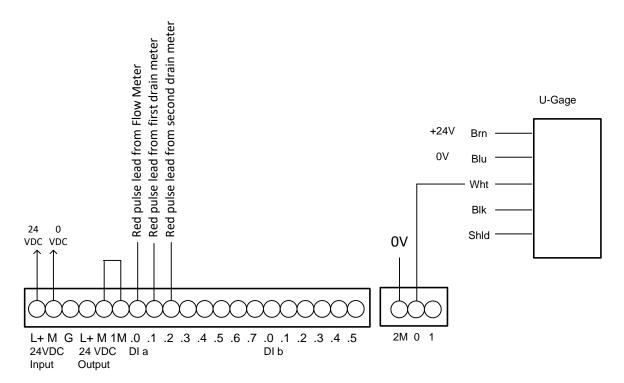
The following screen shows the setting of the Object Block used for programming the PID algorithm. This is OB 30 and its settings are:

Cyclic interrupt [OB30]		
General Texts		
General	Conoral	
Information	General	
Time stamps		
Compilation	Name:	Cyclic interrupt
Protection	Constant name:	OB_Cyclic interrupt
Attributes		
Cyclic interrupt	Type:	OB
	Event class:	Cyclic interrupt
	Language:	LAD
	Number:	30
		O Manual
		Automatic

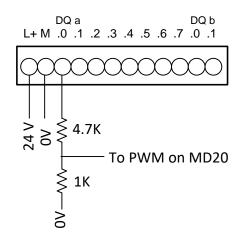
The time base for the application is 1 second or 1000 msec.

General Texts General Information Time stamps	
Information	
Information	
Time stamps	Cyclic interrupt
Compilation	Cyclic time (ms): 1000
Protection	Phase offset (ms): 0
Attributes	These obset (ins).
Cyclic interrupt	

Input/Output Wiring Diagram



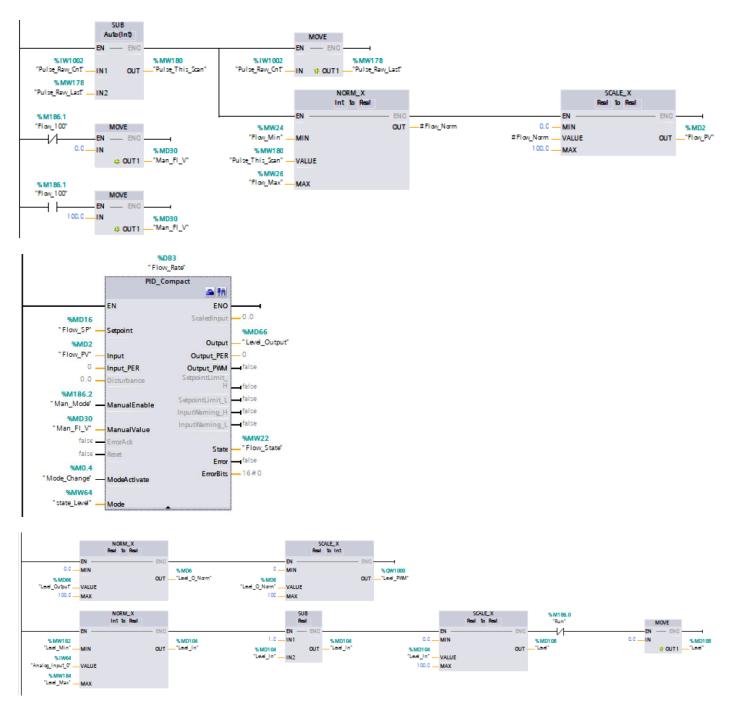
Input Wiring

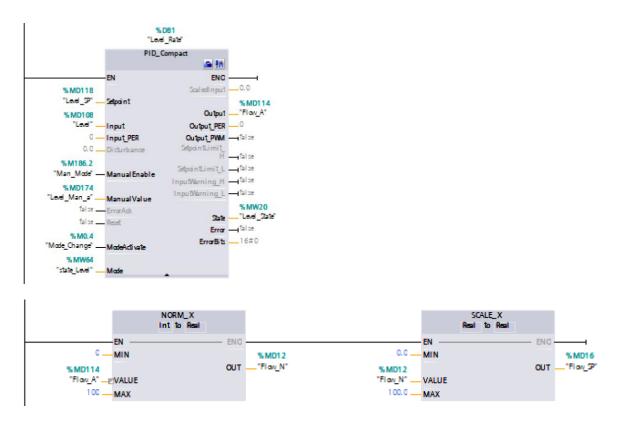


Output Wiring

The Program

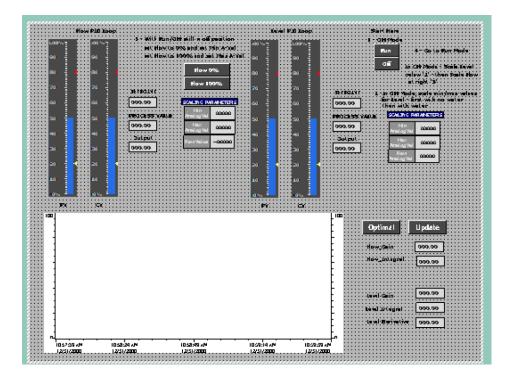
The following is the OB 30 program. We need to look at it to discern what is actually happening in the PLC.





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.

. . <u>.</u> .	1 - OFF Mode			
	Run 4 - Go to Run Mode			
	Off	In OFF Mode below '2' - th at right '3'	- Scale Level en Scale Flow	
SETPOINT 2		Mode, scale mi	in/max values	
000.00		el - first with r vith water	10 water	
000.00 PROCESS VALUE	then v			
	then v	vith water		
PROCESS VALUE	then v SCAL	vith water		

3 - With Run/OFF still in off position set Flow to 0% and set Min A-Val set Flow to 100% and set Max A-Val		
· · · · · · · · · · · · · · · · · · ·	Flow 0%	
· · · · · · · · · · · · · · · · · · ·	Flow 100%	
SETPOINT	· · · · · · · · · · · · · · · · · · ·	
000.00	SCALING PARAMETERS	
PROCESS VALUE	Min Analog Val	
000.00	Max Analog Val	
Output	Raw Value +00000	

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:

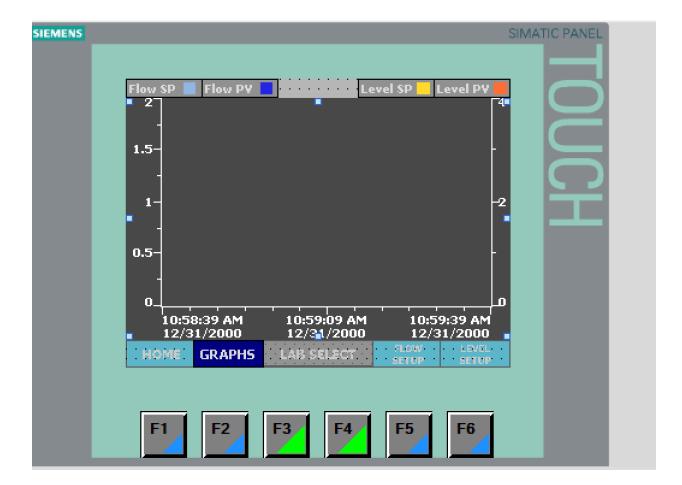
The Tank program may not work in Auto even though the program has been successfully downloaded and all actions have been performed successfully. If the CPU is in run mode and the program does not work at all, the problem may be the PID Parameters. They may be zeroed out. These parameters may be found 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.

Tank_23a 🕨 PLC_1 [CPU 121	5C DC/DC/DC] 🕨 Technology objects 🕨 Flow_Rate [[DB3]	_∎≡×
	4	Functional view	Parameter view
🝷 Basic settings 🛛 🥑			
Controller type 🥑	PID Parameters		
Input / output parameters 🥪			
🕶 Process value settings 🛛 🥑	Enable manual entry		
Process value limits 🛛 😔			
Process value scaling 😔	Proportional gain:	6.104596E-1	
 Advanced settings 	Integral action time:	2.158 s	
Process value monitoring 🤝	Derivative action time:	0.0 s	
PWM limits 🥑			
Output value limits 😔	Derivative delay coefficient:		
PID Parameters 🥪	Proportional action weighting:	0.8	
	Derivative action weighting:	0.0	
	Sampling time of PID algorithm:	0.1 s	
	Tuning rule	: PI 💌	

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

Tank_23a → PLC_1 [CPU 1215C DC/DC/DC] → Technology objects → Level_Rate [DB1]			
	Sectional view	Parameter view	
🍄 🛍 🖽			
Controller type	PID Parameters		
Input / output parameters			
 Process value settings 	Enable manual entry		
Process value limits			
Process value scaling	Proportional gain: 5.223428		
 Advanced settings 	Integral action time: 1.739568 s		
Process value monitoring	Derivative action time: 4.687801E-1 s		
PWM limits 🗧	Derivative delay coefficient: 0.1		
Output value limits			
PID Parameters	Proportional action weighting: 5.432112E-1		
	Derivative action weighting: 0.0		
	Sampling time of PID algorithm: 1.000029E-1 s		
	Tuning rule		
	Controller structure: PID		

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:



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				
X axis				

4450 Unity ► Unity_HMI [KTP	P600 Basic color PN] → Screens → 2-Tank Graphs _ 🖬 🖬 🗙
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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 [KTP6	600 Basic color PN] → Screens →	2-Tank Graphs	- - - ×
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Trend view_1 [Trend view]		Properties	
		roperties A mile Diagnostics	
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🔡 Property pages 🛛 🚦 🗮			
Name 🔺	Static value	Dynamization	
Appearance			^
Layout			
 Left Y axis 			
Automatic value range f			
Auxiliary line left Y axis			
Display left Y axis		2	≡
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 I	0		
 Miscellaneous 			
Right Y axis			
▶ Table			
Text format			
Trend			×

4450 Unity > Unity_HMI [KTP	600 Basic color PN] > Screens > 2-Tank Graphs	_ = = ×
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🔡 Property pages 🛛 😫 🗮		
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Appearance		~
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 Miscellaneous 		
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Auxiliary line right Y axis		
Display right Y axis		
Display right Y axis label		
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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	

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	Static value	Dynamization
Appearance		
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 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 [KTP	600 Basic color PN] → Screens →	2-Tank Graphs 🗕 🖬 🗖	×
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Properties Animations	Events Texts		_
			_
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 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			
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	6		\sim

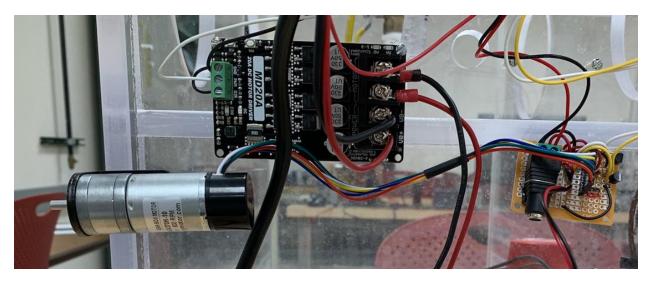
Laboratory Exercise 8

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.

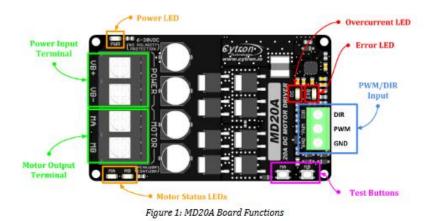
- a. Up to 3 of the addresses Ia.0 to Ia.5 can be used for Quadrature Mode at 80Khz.
- b. Up to 3 of the addresses Ia.6 to Ib.5 can be used for Quadrature Mode at 20Khz.

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



1. BOARD LAYOUT & FUNCTION

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

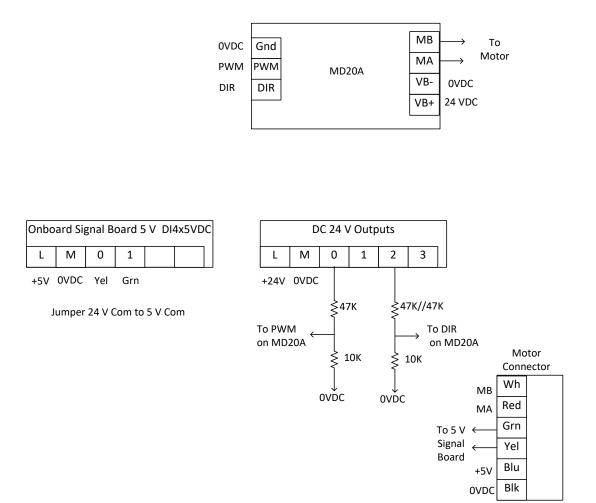
To start the lab, download the program from the hybridplc.org website for this lab (Lab 8) and place it on the desktop. Start the program as before. The program's name is DC_Motor_23.

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.

 DI 14/DQ 10 	^		Catala a information	
General		>	Catalog information	
Digital inputs				
Digital outputs			Short designation:	DI4 signal board (200 kHz)
I/O addresses			Description:	Signal board DI4 x 5VDC / 200 kHz SOURCE; configurable input
AI 2			Description.	delay; plug-in terminal blocks
▼ DI4 signal board (200 kHz)	≡			
▼ General				
Catalog information				
 Digital inputs 		•		×
Channel0			Article number:	6ES7 221-3AD30-0XB0
Channel1		•	Firmware version:	V1.0
Channel2			Firmware version:	
Channel3				Change firmware version
I/O addresses				Update module description
 High speed counters (HSC) 				

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

Digital inputs				
Digital outputs		Channel address:	14.0	
I/O addresses		Input filters:	20 microsec	
AI 2		input inters.	201110300	
▼ DI4 signal board (200 kHz)	≣			
▼ General			Enable rising edge detection	
Catalog information		Event name:		
 Digital inputs 		Hardware interrupt:	-	
Channel0		Priority:		
Channel1	•	Phonty:		
Channel2				
Channel3				

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

▼ DI 14/DQ 10	^	I/O addresses
General		
Digital inputs		Input addresses
Digital outputs		
I/O addresses		Start address: 4 .0
AI 2		End address: 4 .7
▼ DI4 signal board (200 kHz)	≡	
▼ General		Organization block: (Automatic update)
Catalog information		Process image: Automatic update
 Digital inputs 		•
Channel0		
Channel1		•
Channel2		
Channel3		
I/O addresses		

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

Digital outputs	^	High speed counters (HSC)
I/O addresses		
▶ AI 2		HSC1
 DI4 signal board (200 kHz) 		
▼ General		> General
Catalog information		Enable
 Digital inputs 		
Channel0		Enable this high speed counter
Channel1		
Channel2	4	Project information
Channel3		
I/O addresses	Þ	Name: HSC_1
 High speed counters (HSC) 		
		Comment:
General		
Function		
Reset to initial values		
Event configuration		
Hardware inputs		> Function

▼ General		Type of counting:	Count	•
Catalog information		Operating phase:	A/B counter	-
 Digital inputs 				_
Channel0				
Channel1		Counting direction is specified by:	Input (external direction control)	
Channel2	4			-
Channel3		Initial counting direction:	Count up	•
I/O addresses	Þ			
 High speed counters (HSC) 	-	Frequency measuring period:	-/- sec	-
General		Reset to initial values		
Function				
Reset to initial values		Initial values		
Event configuration				
Hardware inputs		Initial counter value:	0	

The address of the encoder is configured below:

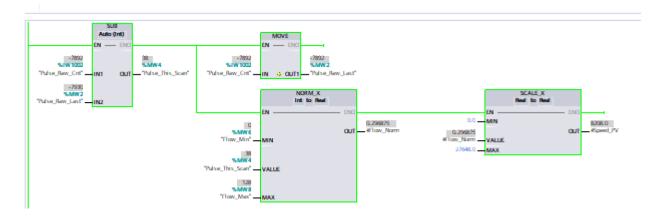
 DI4 signal board (200 kHz) General 					
Catalog information			Clock generator A input:	%14.1	200 kHz signal board input
 Digital inputs 					
Channel0	≡				
Channel1					
Channel2		•	Clock generator B input:	%14.0	200 kHz signal board input
Channel3					
I/O addresses	,	•			

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.

 General 					
Catalog information		Input addresses			
 Digital inputs 					
Channel0	=	Start address:	1000	.0	
Channel1		End address:	1003	.7	
Channel2	4	Organization block:	(Automatic updat	te)	
Channel3				(c)	
I/O addresses	•	Process image:	Automatic update		

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.

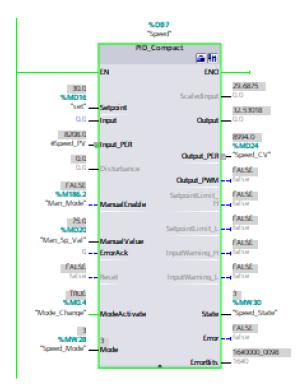


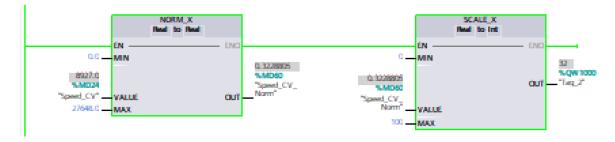
The PID block is shown after the Watch Table. The values for the numeric inputs controlling the PID block are found in the Watch Table. Boolean variables can be set directly by modifying the input in online mode. Remember the 3 state is auto and the 4 state is manual. To change the state, both the mode 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	9
"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=""></add>				

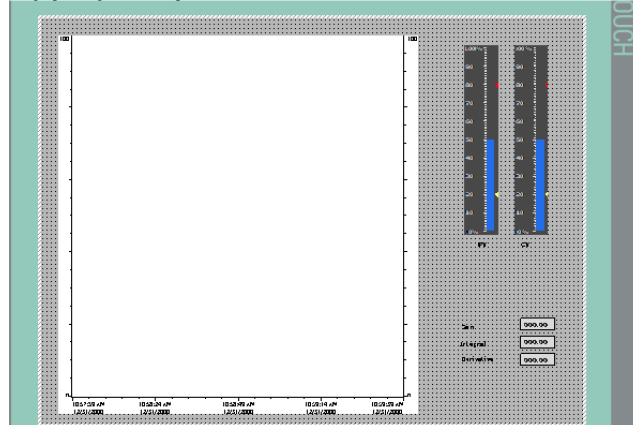
Upper and lower limits for each variable are set so there is no need for the student to set any of these variables. However, the student can set the variables for the setpoint in auto and manual using the Watch Table above. To move between auto and manual, the variable 'Speed Mode' must be set to either 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:

Tank_23a → PLC_1 [CPU 1215C DC/DC/DC] → Technology objects → Level_Rate [DB1] _ ■ ■ ■ ×				
	Sector Functional	view Parameter view		
👻 Basic settings 😔				
Controller type 🤝	PID Parameters			
Input / output parameters 😔				
▼ Process value settings 📿	Enable manual entry			
Process value limits 🤝				
Process value scaling 😔	Proportional gain: 5.223428			
▼ Advanced settings	Integral action time: 1.739568	s		
Process value monitoring 🤝	Derivative action time: 4.687801E-1	s		
PWM limits 🤝	Derivative delay coefficient: 0.1			
Output value limits 🥪				
PID Parameters 🥑	Proportional action weighting: 5.432112E-1			
	Derivative action weighting: 0.0			
	Sampling time of PID algorithm: 1.000029E-1	s		
	Tuning rule			
	Controller structure: PID	•		

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?

Cyclic interrupt [OB30]	×
General Texts	
General	Carlis interment
Information	Cyclic interrupt
Time stamps	
Compilation	Cyclic time (ms): 100
Protection	Phase offset (ms): 0
Attributes	
Cyclic interrupt	
	4

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.