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## **OPTO 22 PAC CONTROL for CAL POLY POMONA'S ME439 CONTROLS LAB**

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### **REFERENCES**

- [1] OPTO 22, “*Snap Pac Learning Center User’s Guide*,” 43033 business Park Drive, Temecula CA, 92590. Form 1638-080801 – August 2008. Electronic. Pgs. 1 – 146.
- [2] OPTO 22, “*Pac Control User’s Guide*,” 43033 business Park Drive, Temecula CA, 92590. Form 1700-140926 – September 2014. Electronic.
- [3] Alvarado, M. et. al. “*Control of Mechanical Systems Laboratory ME439L Lab Manual*,” Department of Mechanical Engineering, California State Polytechnic University, Pomona. 3801 West Temple Ave. Pomona Ca, 91768. ME439 Controls Lab Bldg. 17 Rm 2238.
- [4] Sun Equipment Corporation, *Compact Mechatronics System: CML – 61600*. 1352 S. Grove Ave. Suite A, Ontario, CA. 91761

### **EXECUTIVE SUMMARY**

Over the course of the 2015 fall quarter at the California State Polytechnic University at Pomona (CPP) Undergraduate Research Assistant Thomas Gross, under the supervision of Dr. Nolan Tsuchiya, successfully learned the OPTO 22 PAC Project environment and used it to communicate with the donated OPTO 22 Snap Pac Learning Centers located in CPP’s ME439 Controls Lab Building 17 Room 2238. The convenience store model presented in [1] was used as a learning guide and was completed up to and including the Analog Control section. Building off the achievements of [3], with the addition of pneumatics and power hook ups to the OPTO 22 station in the ME439 Controls Lab, the donated Sun CML-61600 Compact Mechatronics Load System is ready to be installed which will allow a wide variety of industrial plant control projects to be implemented into the ME439L schedule giving students hands on experience with actual industrial control equipment.

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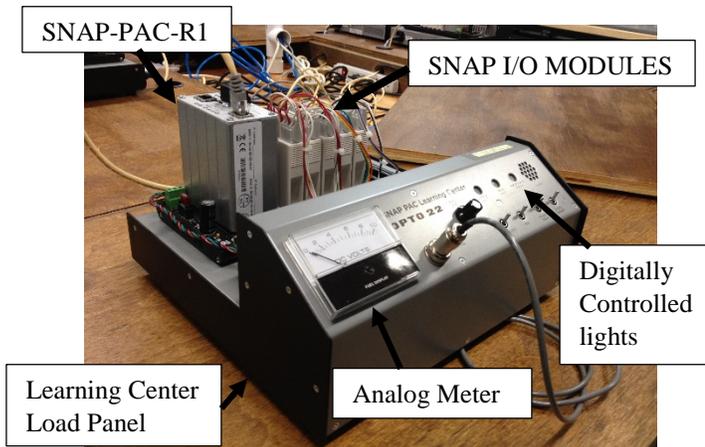
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## PROBLEM DEFINITION

This project is the result of the Cal Poly Pomona Mechanical Engineering Department's desire to give ME student's hands on experience using industrial control systems and equipment. At this time there is no official controls lab for CPP ME students to gain experience using industry control equipment. The current controls course on campus is mainly focused on classical controls such as PID (Proportional Integral Derivative) controls and the students are required to build their own projects on their own budget. Although this system is good, where implementing PID loops into common Arduinos is good experience and affordable for the student, it is not all encompassing. With the addition of the OPTO 22 controls lab to the department, students will gain experience using equipment they would normally see for the first time on the job sight. Adding the donated Sun Equipment miniature portable plant [4], as seen in Figure 10, students will be able to simulate actual industrial controls inside the lab. Figure 1 shows the OPTO 22 learning center used in this project.



**Figure 1** - OPTO 22 Snap Pac Learning Center with various components labeled.

## SCOPE OF PROJECT

The scope of the project is to hook up the SNAP I/O to the SUN plant and use the workstations in the lab to write a strategy inside PAC Manager to Control the Sun plant with the SNAP-PAC-R1. This is broken down into three phases.

Project Phases:

1. User interface with the workstation, learning the Pac Project environment and setting up initial communication with the OPTO via Ethernet configurator
2. Control the learning centers digital and analog I/O through Pac Manager
  - a. Establish variables
  - b. Create strategies
  - c. Execute and debug strategy
3. Use OPTO 22 to control a mini plant via Pac Manager user interface installed on the workstations in the lab.

Phases 1 and 2 summarize the project objectives for the current quarter, while phase 3 constitutes the portion of the project to be performed during the CPP Winter quarter. Phase 1 was performed by [3] in a separate project, leaving only the Pac Project environment to be learned in that phase.

## RESULTS

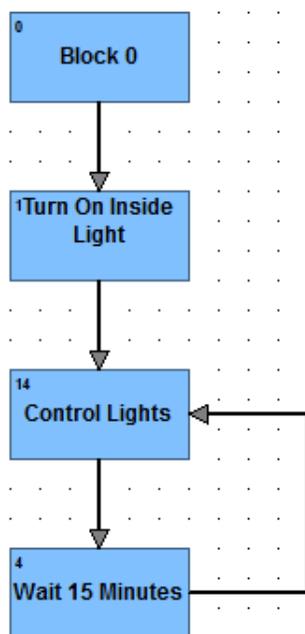
Learning how to control the OPTO 22 Learning Center Load Panel through PAC Manager consisted of 5 major steps: 1.) communicating with the SNAP-PAC-R1 controller, which processes input/output and can be controlled via flowchart strategies, 2.) creating a new strategy, configuring the control engine and setting up the I/O points, 3.) creating flow charts and variables, 4.) digital control and 5.) analog control.

[3] is responsible for setting up the initial communication between the workstations and the OPTO 22 units. Each workstation in the lab is connected to a single OPTO 22 with the corresponding letter identifier. It was found that the best way to re-communicate with the OPTO's was through the use of Ethernet Configurator. The following steps set up by Dr. Tsuchiya can be used to connect each workstation with its OPTO 22. This step need only to be completed once per workstation, after which the configuration file (.otg) can be saved and recalled each time the user logs on.

Ethernet Configurator:

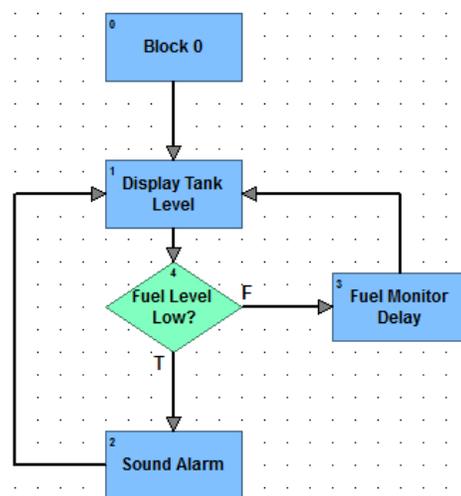
1. Start > OPTO 22 > EthernetIP > EthernetIPconfigurator
2. Delete existing blank device (unnamed device)
3. Add new device (named letter of workstation) and select proper device type (snap pac r1)
4. Type IP address (located on corresponding OPTO)
5. Tools > upload configuration from OPTO 22 device
6. Save file (.otg) to computer

Steps 2 – 5 constituted following the learning tutorial in [1]. Figures 2 – 8 show the results of this process. Figure 2 shows the lighting control flow chart created within the control strategy. Block 1 simply uses the Turn On instruction to turn the convenience stores inside lights on once the strategy is running. Block 14 uses the NOT instruction which copies the inverse of information from the photo sensor digital input into the outside light digital output i.e. if the sun is on the outside lights are off. The strategy then waits 15 minutes before checking if the sun is still up.



**Figure 2 - Lighting Control Chart**

Figure 3 shows the Fuel Monitor chart used to monitor the fuel levels of the on sight gas station and notify the convenient store operator via an alarm once fuel levels get to low. This chart uses a conditional control block (green). This chart simply scans the fuel level, which is controlled with a potentiometer located on the learning center, and sounds an alarm if the fuel level is to low or just loops back. The display tank level block takes analog input from the potentiometer and uses the Move instruction to move the input to the analog output meter.



**Figure 3 - Fuel Monitor Chart**

Figure 4 shows the Fuel Monitor chart running in debug mode with a break point placed on the display tank chart. The break point and auto stepping tools in debug mode were used to analyze the flow of information through the charts and check for possible errors in the strategy. Breakpoints could be placed on each block and then each block could be methodically stepped through individually. Figure 5 shows the fuel monitor chart watch window. The watch window was used to observe I/O points internal and external values and variable values while the chart was in debug mode. The dialog box for each I/O point or variable present in watch window could be easily accessed. Figure 6 shows the SNAP PAC I/O that was set up. Each I/O point's

internal value or external value could be overridden in order to force input and output.

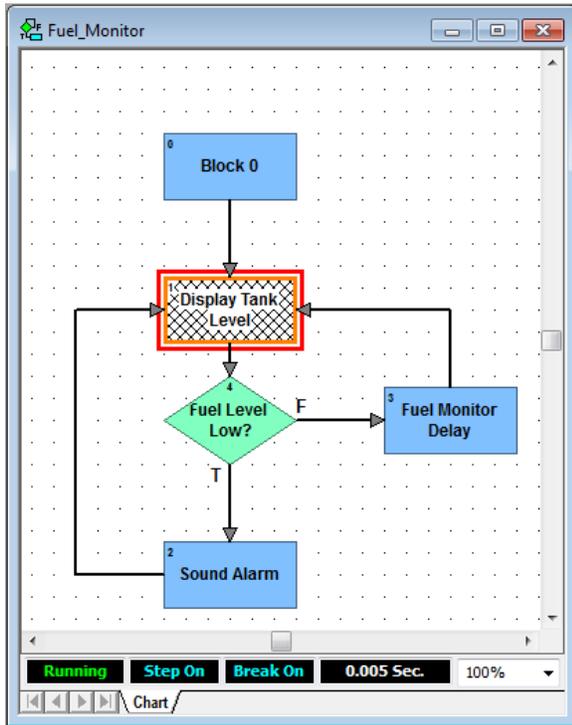


Figure 4 - Using Auto Step and Breakpoint

Name	Type	IVAL	XVAL
Fuel_Low_Limit	Float Variable	1000	
Fuel_Monitor_Delay	Integer 32 Variable	5	
(128) Fuel_Level	Analog Input - Gallons	5274.398	5274.398
(64) Fuel_Display	Analog Output - Gallons	5274.398	5274.398
Alarm_Sound_Duration	Integer 32 Variable	1000	
Alarm_Delay	Integer 32 Variable	1000	

Figure 5 - Fuel Monitor Chart Watch Window

In order to analyze how the alarm in the fuel monitor chart reacted to changing fuel levels the fuel level analog input communication was disabled and its internal value was altered. This allows debugging the control strategy without physically changing the input. Although in this case it is easy to change inputs on the Learning Center, in most industrial applications it is not possible to willingly change an input, such as the level of fuel in the storage tank. Figures 7 and 8 show the instruction sequence within the Sound Alarm command block and within the Control Lights command block. The fuel level alarm was modified from the learning tutorial model to include a variable that dictated the duration of each alarm sound and to dictate the

delay in between alarm sounds. The control lights command block was also modified to move digital input from the freezer door switch and the alarm switch on the load panel into their respective digital output.

Module	Ch#	Name	Type	IVAL	XVAL
[00] SNAP-IDCS0	0	Emergency	D Input	OFF	OFF
	1	POS	D Input	OFF	OFF
	2	Freezer_Door	D Input	OFF	OFF
	3	Photo_Sensor	D Input	OFF	OFF
[01] SNAP-ODCSSRC	0	Alarm	D Output	OFF	OFF
	1	Freezer_Door_Status	D Output	OFF	OFF
	2	Inside_Light	D Output	ON	ON
	3	Outside_Light	D Output	ON	ON
[02] SNAP-AOV-27	0	Fuel_Display	A Output	5274.398	5274.398
	1	Not Used			
[03] SNAP-AICTD	0	Store_Temperature	A Input	0	22.01712
	1	Not Used			
[04] SNAP-AIV	0	Fuel_Level	A Input	5274.398	5274.398
	1	Not Used			

Figure 6 - Snap Pac Input Output

Turn On	Alarm
Delay (mSec)	Alarm_Sound_Duration
Turn Off	Alarm
Delay (mSec)	Alarm_Delay

Figure 7 - Sound Alarm Command Block

NOT	Photo_Sensor
Put Result in	Outside_Light
Move	From: Freezer_Door
	To: Freezer_Door_Status
Move	From: Emergency
	To: Alarm

Figure 8 - Control Lights Command Block

For this scenario it was okay to have the control lights command block also control the emergency alarm and freezer door light since the delay command block in the lighting control chart was set to only delay for 2 seconds, instead of 15

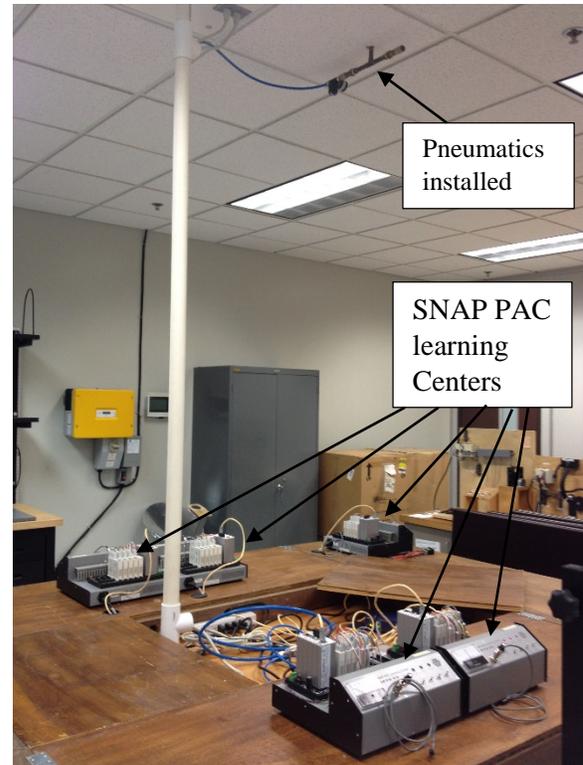
minutes, which allowed easy testing of the input and output. However under normal operation a 15 minute delay would be too long in between each check of the freezer door and emergency input points. Thus a separate command block should have been created to handle these I/O points, branching out from the Turn on Inside Light command block and using their own delay command block before looping back.

## LOOKING AHEAD

As mentioned in the executive summary, the controls lab has been fitted with cable runs for the power and for the pneumatics, as seen in Figure 9, required of the SUN Unit compact mechatronics load system. With these updates to the laboratory and the experience gained working with the OPTO 22 Learning Centers over the course of the quarter, the SUN unit, as seen in Figure 10, is ready to be controlled via the OPTO's using the workstations in the lab as user interface.

Using the Sun Plant can help students become familiar with subjects such as DC motor control, sensor application, pneumatic control, screw-rod robotic-arm mechanism control, PLC wiring and programming [4].

Along with controlling the mini industrial plant via the OPTO 22's, the plant must be installed into the controls lab so that it is safe, secure, and unable to be tampered with during off hours. A simple solution to this would be using the brief case as the storage container, drilling it directly into the workstation bench and using a lock on the hinges. Another possible route would be the fabrication of a clear acrylic container that opens with a hinge at the top and allows students to access the unit when working in the lab.



**Figure 9** – ME436L Controls Lab at Cal Poly Pomona 3801 West Temple Ave. Bldg. 17 Rm. 2238.



**Figure 10** - CML-61600, Compact Mechatronics Load System: Cf. Sun Equipment Corporation, 1352 S. Grove Ave. Suite A, Ontario, CA. 91761

**SUMMARY**

At the end of the 2015 fall quarter at the CPP phase 1 and phase 2 of the ME439 OPTO 22 Controls Lab Project has been completed. Communication between the workstations and OPTO units has been re-established and the PAC control PAC Manager environment has been learned and successfully used to control the digital and analog I/O on the learning center load panel. With the addition of pneumatics and power hook ups to the OPTO 22 station the Sun CML-61600 Compact Mechatronics Load System is ready to be installed which will allow a wide variety of industrial plant control projects to be implemented into the ME439L schedule giving students hands on experience with actual industrial control equipment.