

**INSTRUCTION**  
**MANUAL**

Spatio-Temporal Pressure Loading Actuator (SPLA)



## Table of Contents

ABOUT THE SPLA.....	2
COMPONENTS AND SPECIFICATIONS .....	2
OPERATING THE SPLA .....	4
Safety Considerations .....	4
Prior to Getting Started .....	5
PHYSICAL SETUP.....	5
INSTALL PRESSURE TRANSDUCERS.....	5
SET UP CONFIGURATION FILES.....	5
SETUP TRACE FILES.....	6
POWER ON VFD .....	6
POWER ON PLAS.....	7
POWER ON BLOWER .....	7
Operating the Software .....	7
STEP 1. POWER ON THE PC .....	7
STEP 2. OPEN THE SPLA PROJECT .....	8
STEP 3. EXECUTE THE SPLA SOFTWARE.....	8
STEP 4. LOGIN .....	8
STEP 5. LOAD CONFIGURATION FILES .....	9
STEP 6. [OPTIONAL] VIEW PLA CONFIGURATION AND TRACE FILES .....	9
STEP 7. POWER ON THE PLAS.....	11
STEP 8. [OPTIONAL] PERFORM A VALVE MAP.....	11
STEP 9. RUN THE LOADED TRACE(S).....	12
STEP 10: DATA ACQUISITION .....	14
STEP 11: POWER DOWN THE SPLA .....	14

## ABOUT THE SPLA

The Spatio-Temporal Pressure Loading Actuator (SPLA) is a four-axis testing apparatus that provides static or dynamic wind pressures on up to four surfaces simultaneously, realistically simulating the action of the wind on built structures. The SPLA can be configured to test roof and/or wall systems and by default is used in tandem with a 7.3 m by 3.6 m x 0.25 m deep steel pressure chamber which can be subdivided into as many as four zones. However the SPLA itself is portable to an extent, so that any number of configurations are possible to best meet the needs of the researcher.

The SPLA can simulate customizable dynamic traces for both positive and negative pressures, with peak pressures of  $\pm 7.66$  kPa in each of the four individual PLAs.

## COMPONENTS AND SPECIFICATIONS

The SPLA uses four pressure control valves, developed by University of Western Ontario for the PLAs, coupled to a single fan blower to produce the pressure and required airflow rates. A Variable Frequency Drive (VFD) controls the fan speed. The fan output is routed through four air-balancing dampers to adjust the distorted air velocity profile immediately leaving the fan impellor and distribute the flow to each PLA. Polyester air filters with nine silencing tubes for sound attenuation are connected in-line to each PLA. Flexible ducts with 8.9 cm diameter provide the airways between the PLAs and the test chamber. Servo motors and drives regulate the position of the pressure valve and thus the pressure in the test chamber by means of a motion controller connected to a desktop PC.

Details of the components are provided below:

<p><b>Blower</b></p> <p>1240 SS Spencer Centrifugal Blower</p> <ul style="list-style-type: none"><li>▪ 40 HP,</li><li>▪ 3-phase 460 V</li><li>▪ Peak Airflow of 1.44 m<sup>3</sup>/s (3050 CFM)</li><li>▪ 10 kPa at a peak airflow</li></ul>	
<p><b>Steel Duct</b></p> <ul style="list-style-type: none"><li>▪ 1.29 mm thickness (16 GA)</li><li>▪ 1.22 m long x 0.40 inside diameter round intake with four 8.9 cm (3.5 inch) circular ports</li><li>▪ 1.22 m long x 0.34 m inside diameter square supply</li><li>▪ Galvanized steel</li></ul>	
<p><b>Balancing Dampers</b></p>	

**Greenheck Model HCD-120 Control Damper**

- Four air-balancing dampers
- Velocity Range: 10 – 15 m/s
- Pressure Range: up to 28 kPa



**Variable Frequency Drive (VFD)**

**ACS550-01-059A-4 VFD**

- Integrated PID controller
- Motor Power: 30 kW
- Voltage Rating: 380 – 480 V AC
- Continuous RMS Current: 59 Amps



**Servo Motors**

**Kollmorgen AKM-54H Servo Motors**

- Resolution:  $2^{24}$  counts per revolution
- Accuracy: 0.26 deg
- Maximum Mechanical Speed: 8000 RPM
- Peak Current: 5.5 Amps
- Peak Torque: 37.5 N-m



**Servo Drives**

**Kollmorgen AKD-P00606 Servo Drives**

- RMS Current Rating: 6 A
- Voltage Rating: 120/240 Vac
- Current loop updates: 1500 kHz
- Velocity loop updates: 16 kHz
- Position loop updates: 8 kHz



**Motion Controller**

**National Instruments UMI 7774**

- Four independent axes
- Four channel analog input with 100 kHz noise filter
- D-sub connectivity to servo drives
- Encoder Rate: 20 MHz
- Inhibitors to protect against power loss



## OPERATING THE SPLA

### Safety Considerations

ALWAYS WEAR PERSONAL PROTECTION EQUIPMENT (SAFETY GLASSES, CLOSED-TOE BOOTS, HARD HAT) WHILE OPERATING THE SPLA. FAILURE TO DO SO COULD RESULT IN SERIOUS INJURY.

NEVER LEAVE THE SPLA OPERATING UNATTENDED.

ENSURE ALL HOSE AND OTHER CONNECTIONS ARE ADEQUATELY TIGHTENED PRIOR TO TURNING ON THE FAN.

## Prior to Getting Started

Prior to executing the software and running an experiment, several actions must be completed to ensure the SPLA is set up and able to run properly.

### PHYSICAL SETUP

Ensure all flexible ducts for each PLA are properly attached and firmly secured to their respective ports, whether on the PLA valve, the blower ductwork, or the pressure chamber. Hose clamps around the flexible duct must be securely fastened.



### INSTALL PRESSURE TRANSDUCERS

There must be a pressure transducer installed for each Master PLA. Four ports are provided in the side of the electronics cabinet for the installation of the pressure transducers. Ensure each pressure transducer is properly matched to the pressure chamber and port.



### SET UP CONFIGURATION FILES

Navigate to C:\PLA\_DATA\Configuration Files\PLA Experiment Setup Files to create or edit configuration files. There are two types of configuration files in this folder.

1) Universal PLA Configuration File. DO NOT EDIT OR ALTER THIS FILE. This sets the board IDs and other communication channels between the Labview environment and the physical SPLA hardware. The SPLA software reads from this file automatically and it cannot be loaded into the software manually.

2) Unique PLA Configuration Files. These configuration files determine the operation of the SPLA. New files should be created as necessary but do not need to be created for every experiment. Use existing

Configuration Files whenever possible.

The Configuration Files have the following inputs, editable in any basic word processor as shown in the example below:

[PLA_A]	
Fan Speed (Hz) = 60.000000	<i>Sets the value of the constant fan speed</i>
Gain (K) = 1.000000	<i>PID Control Parameter</i>
Integrator Gain (K_I) = 1.389000	<i>PID Control Parameter</i>
Differential Gain (K_d) = 0.013890	<i>PID Control Parameter</i>
Integrator (I) = 0.000000	<i>PID Control Parameter</i>
tau_init = 0.050000	<i>PID Control Parameter</i>
Look ahead = 50.000000	<i>Sets the number of points the program looks ahead to anticipate the next valve positions</i>
Saturation % of Look ahead = 1.100	<i>Number of points at valve position of 1 or -1 before valve is deemed saturated and run aborted, given as ratio of Look Ahead</i>
Saturation Count Limit = 50.000000	<i>Maximum number of points valve position can remain at 1 or -1 before being saturated</i>
Pressure Tracking Steps = 350.0000	<i>Number of points the software tracks the target and actual pressures to determine whether a tracking error has occurred</i>
Pressure Tracking Threshold = 750000000	<i>Cumulative error over the pressure tracking steps required for a tracking error to occur and the run aborted</i>
PLA MASTER = 0	<i>Determines whether the PLA is its own Master or follows another PLA. 0 indicates the PLA is its own Master, a number between 1 and 4 identifies the PLA it follows.</i>
Pressure Sensor Serial # = "PT10053"	<i>Gives the ID of the pressure transducer linked to this PLA. This is used to lookup the proper calibration file.</i>

## SETUP TRACE FILES

The SPLA software automatically loads PLA traces located at the path C:\PLA\_DATA\Traces. A trace is required for every Master PLA, with a filename of PLA\_A, PLA\_B, PLA\_C or PLA\_D as appropriate. Each trace file is a single column vector, with the first line giving the sampling frequency of the pressure trace, and the remaining lines giving target pressures in kPa. Be careful to ensure that no spaces or characters are present in any adjacent columns as this will prevent the SPLA from performing properly.

## POWER ON VFD

First push the lever up on the PLA junction box to provide the necessary power to the VFD. Then turn the red handle on the VFD clockwise to power on the VFD. Once power is on and the VFD is initialized, press the Local/Remote button on the top panel of the VFD to switch control of the VFD to the PC.



### POWER ON PLAS

Plug the 120 Vac power cord of each PLA into the nearest outlet. Ensure that the outlet is not a GFI outlet as the operation of the servo motors trips the circuit of these outlets.

### POWER ON BLOWER

The SPLA blower is located outside the southeast corner of the Powell Family Structures Laboratory Annex building. Adjacent to the blower is an electrical junction box that provides power to the blower. Push the lever up to engage the circuit.



## Operating the Software

### STEP 1. POWER ON THE PC

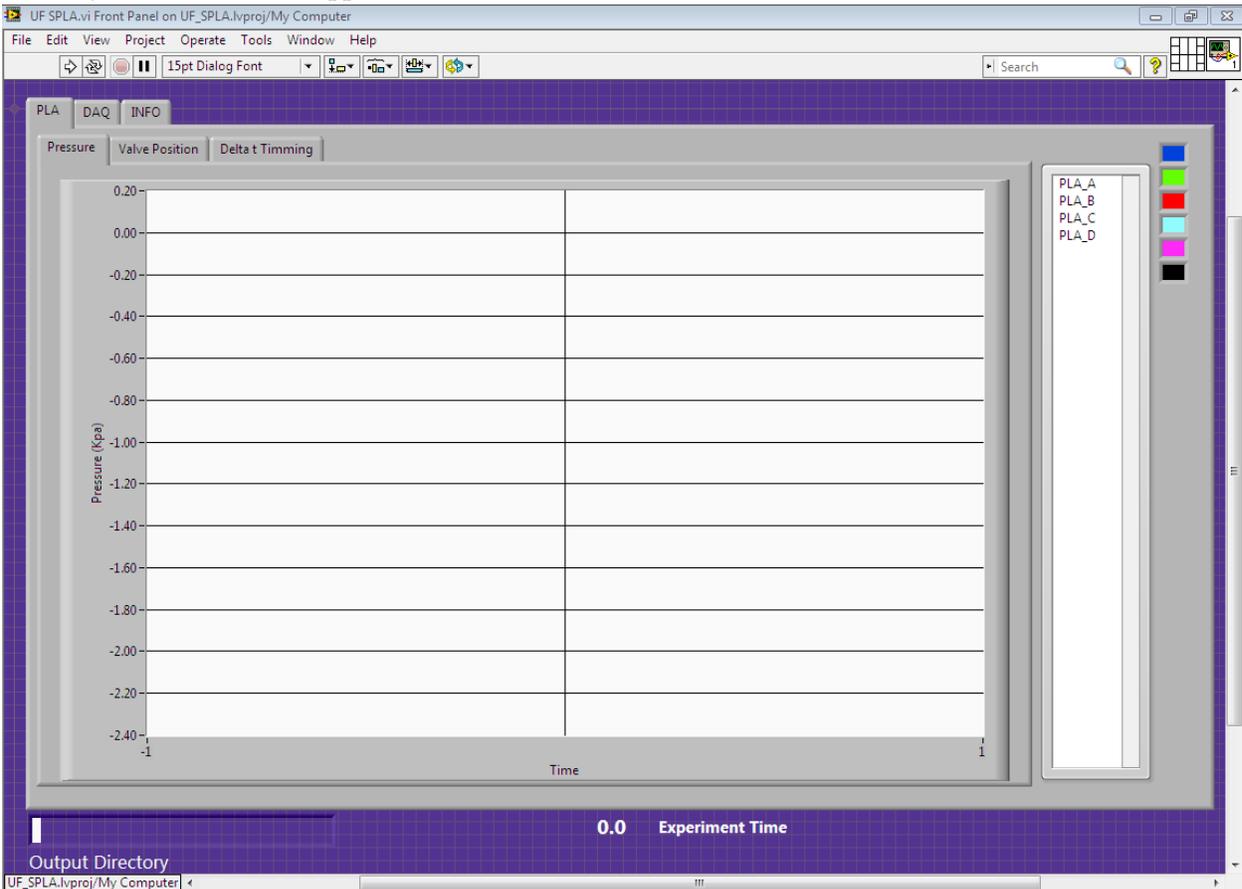
Power on the Dell Optiplex GX620 desktop computer and login with the credentials provided to you by the laboratory manager.

## STEP 2. OPEN THE SPLA PROJECT

Double-click the “SPLA Project” icon on the desktop to load the Labview project containing the SPLA software.

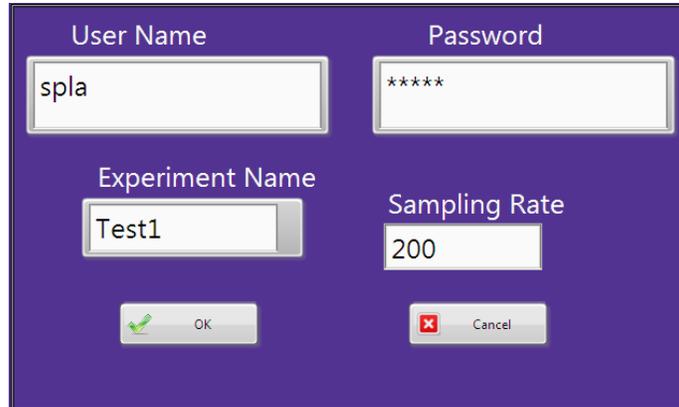
## STEP 3. EXECUTE THE SPLA SOFTWARE

Expand the GUI section and double-click “UF SPLA.vi” to start the program. Once it has loaded the following home screen will appear.



## STEP 4. LOGIN

Select the file menu and choose “Login”. The following dialog will appear. The user name is “spla”, the password is “\*\*\*\*\*”. The Experiment Name can be chosen from a list of existing experiments or a new experiment can be created by typing a new Experiment Name into the dialog box. The Sampling Rate determines the frequency at which the software samples the input signals (e.g., the pressure transducers, servo drives, etc).



The image shows a configuration dialog box with a dark purple background. It contains four input fields arranged in a 2x2 grid. The top-left field is labeled 'User Name' and contains the text 'spla'. The top-right field is labeled 'Password' and contains six asterisks '\*\*\*\*\*'. The bottom-left field is labeled 'Experiment Name' and contains the text 'Test1'. The bottom-right field is labeled 'Sampling Rate' and contains the number '200'. At the bottom of the dialog, there are two buttons: 'OK' with a green checkmark icon and 'Cancel' with a red 'X' icon.

### STEP 5. LOAD CONFIGURATION FILES

Select “File” from the menu again and choose “Load Configuration File”, and, if REQUIRED, “Load Data Acquisition File”.

“Load Configuration File” loads a “.in” file that determines how the PLAs will operate, as described in the Section Above “Prior to Getting Started”. It is necessary to load a configuration file before operating the SPLA. Loading the configuration file also automatically creates a new folder at the location “C:\PLA\_DATA\Experimental Data\[Experiment Name]” into which all of the data for the experiment is saved.

“Load Data Acquisition File” brings up a dialog box to choose from a list of Tasks previously set up in the National Instruments software “Measurement & Automation Explorer”. This allows the user to acquire external data from a load cell, string potentiometer or other device within the SPLA software.

### STEP 6. [OPTIONAL] VIEW PLA CONFIGURATION AND TRACE FILES

Select “View” and choose from the following options:

Option 1. “View PLA Variables”.

Selecting this menu item brings up the screen below showing the configuration and parameters association with each of the four PLAs. To view a different PLAs parameters, select from the list of PLAs at the bottom of the screen. The values shown cannot be edited here, they only reflect what was loaded in the PLA Configuration File.

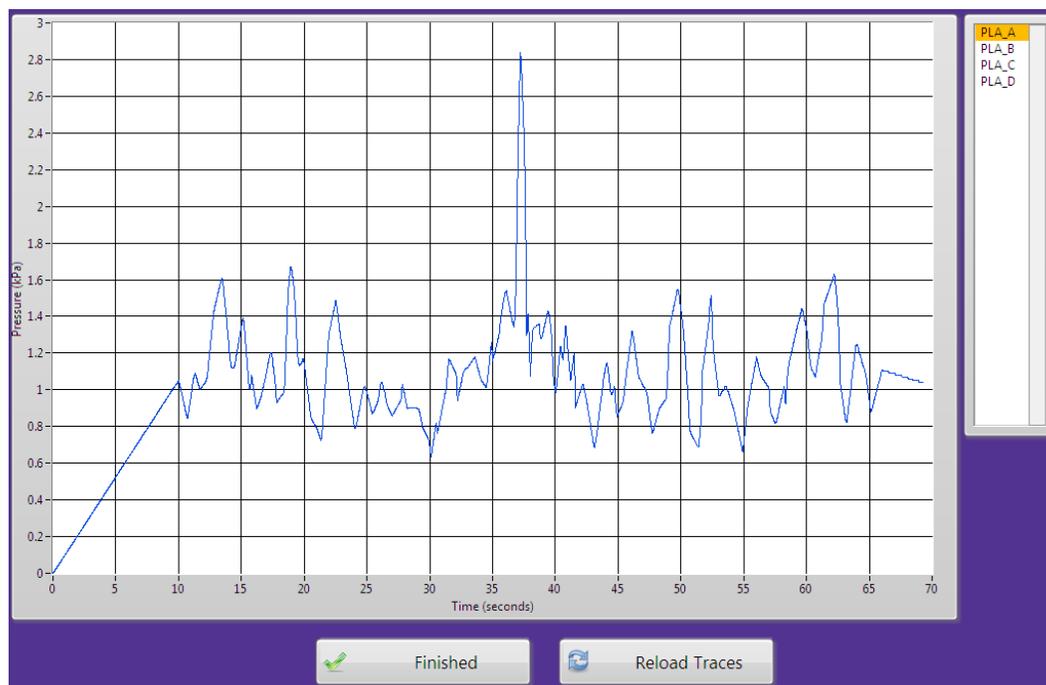
The screenshot shows a configuration window with three main sections:

- Physical PLA Details:**
  - Box Name: PLA\_B
  - Board ID: 3
  - Axis: 2
  - Fan Speed (Hz): 40
  - Home2Neutral Angle (Counts): -1147
- PLA Setup Parameter:**
  - K: 1
  - KI: 1.389
  - Kd: 0.01389
  - I: 0
  - tau: 0.05
  - PLA Master: PLA\_A
- Error/Trace Fidelity Details:**
  - Look Ahead Steps: 50
  - Saturation % of look ahead: 11
  - Staturation Count Limit: 50
  - Pressure Tracking Threshold: 7.5E-8
  - Pressure Tracking Window Size: 350

At the bottom, there is a list of PLA units: PLA\_A, PLA\_B (highlighted in yellow), PLA\_C, and PLA\_D. A "Finished" button with a green checkmark is located at the bottom center.

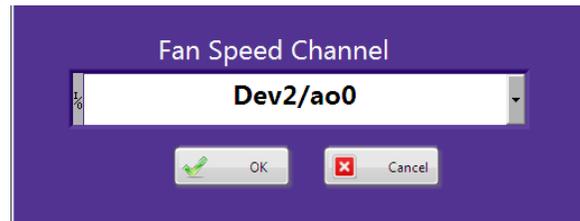
### Option 2. “View Trace Files”.

This option brings up a graph showing the current trace files loaded into the SPLA software. Cycle through the trace files by choosing a PLA from the list on the right-hand side. If changes are made to the trace files after performing Step 5 “Load PLA Configuration File”, select “Reload Traces” to update the traces with the changes without having to reload the configuration file. After reloading, close out of the “View Trace Files” dialog box and reopen to see the updated traces.



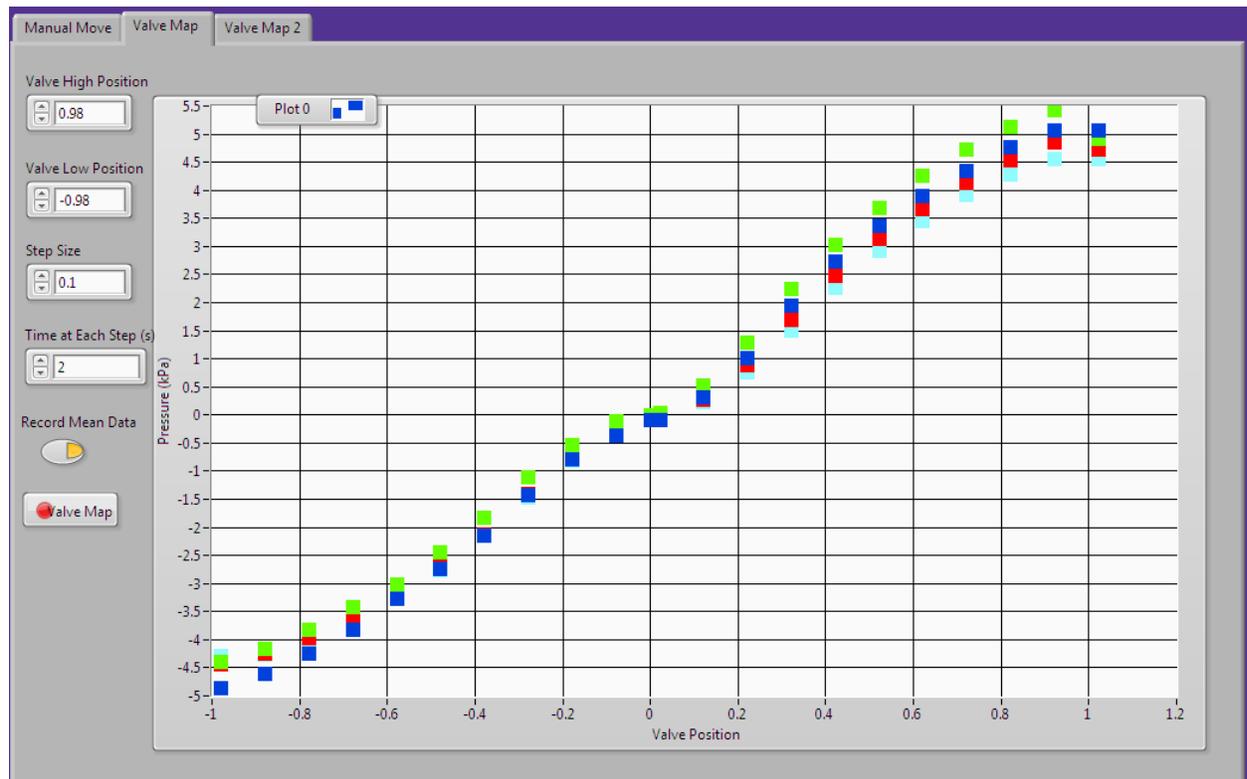
### STEP 7. POWER ON THE PLAS.

Select “Run” and then “Power on PLA” from the menu options. This brings up the following dialog box to choose the channel that will control fan speed. Select “Dev2/ao0”. The PLAs now go through an initialization routine that finds the neutral position of each PLA and engages the fan at the specified speed.



### STEP 8. [OPTIONAL] PERFORM A VALVE MAP.

If testing a physical setup for the first time, it is recommended that a Valve Map be performed. This maps the pressure in the test chamber(s) to the valve position of the PLAs, which is essential for the PID control portion of the software to determine the valve position necessary to achieve the desired pressure. Leakage and changes in pressure chamber size can alter the valve map significantly. Choose “Exit” when finished.



**Valve High Position** and **Valve Low Position** choose the maximum and minimum valve positions that will be mapped. Valve positions vary between -1 and 1.

**Step Size** sets the interval between valve positions being mapped.

**Time at Each Step (s)** determines the length of time over which the pressures are averaged for any valve position.

**Record Mean Data** is a toggle that determines whether only average values are recorded or the entire dataset is recorded.

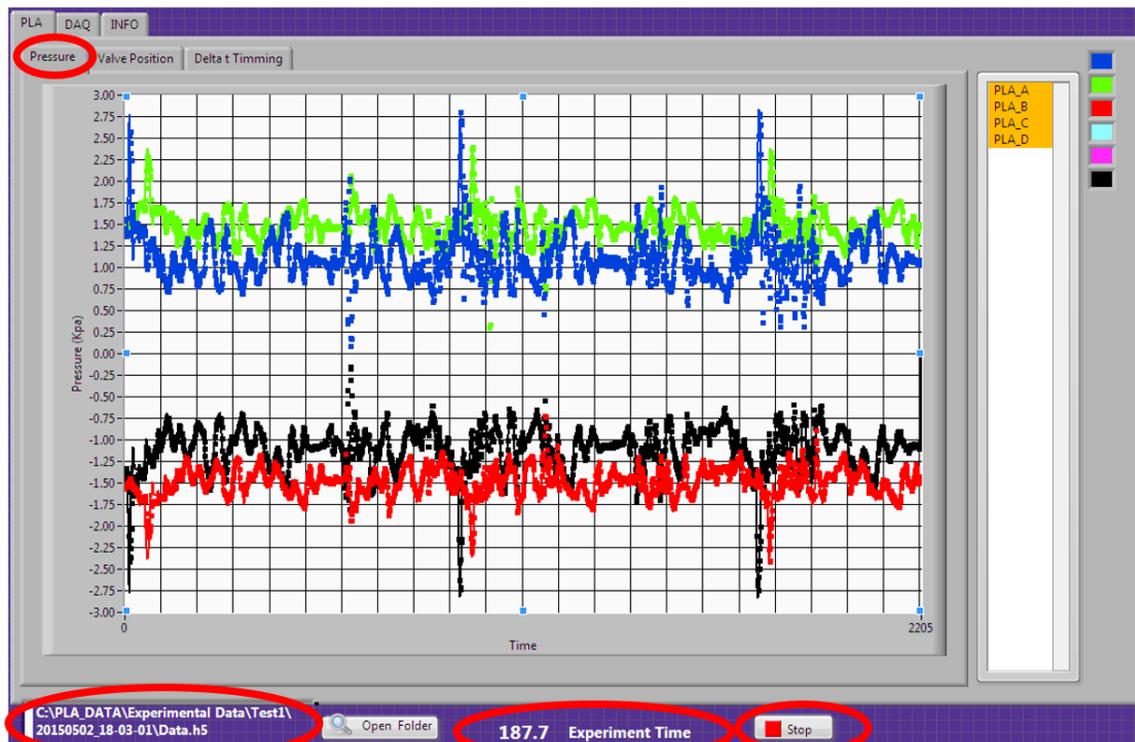
**Output Directory** sets the folder into which the Valve Map data is saved. By default this is the new folder that is created when the configuration file is loaded.

### STEP 9. RUN THE LOADED TRACE(S).

On the menu title bar select “Run” and then “Start”. This begins the experiment and executes the traces shown in the “View Traces” menu option described above. The data from the experiment is by default saved with the filename “Data” in the new folder created when the configuration file is loaded. The data is saved as an HDF5 file, a structure file format which is readable in Matlab, Python and other programming languages.

While running the trace, different variables can be viewed by selecting either PLA, DAQ or INFO from the top row of tabs. Under the PLA tab are three sub-tabs:

**Pressure** displays the pressures in the test chamber(s) associated with each PLA. A single PLA pressure trace can be viewed or by holding Ctrl on the keyboard multiple traces can be viewed. For each PLA pressure trace, solid line represents the target trace and markers represent the actual data.

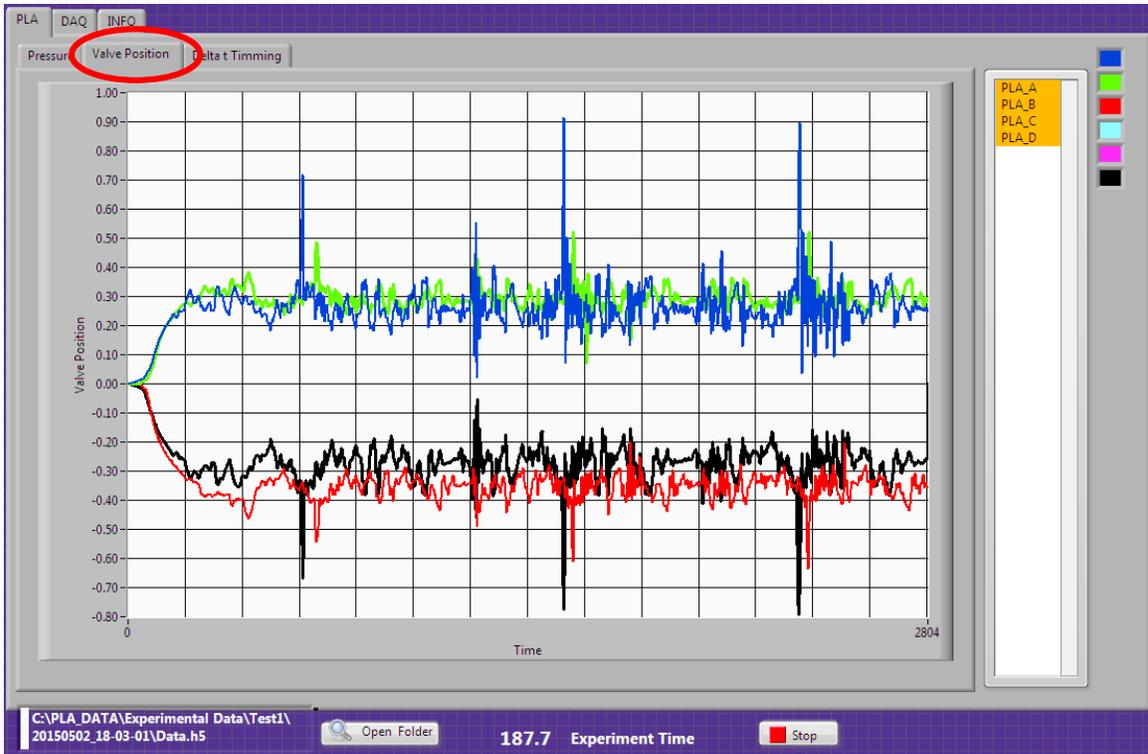


Output data folder

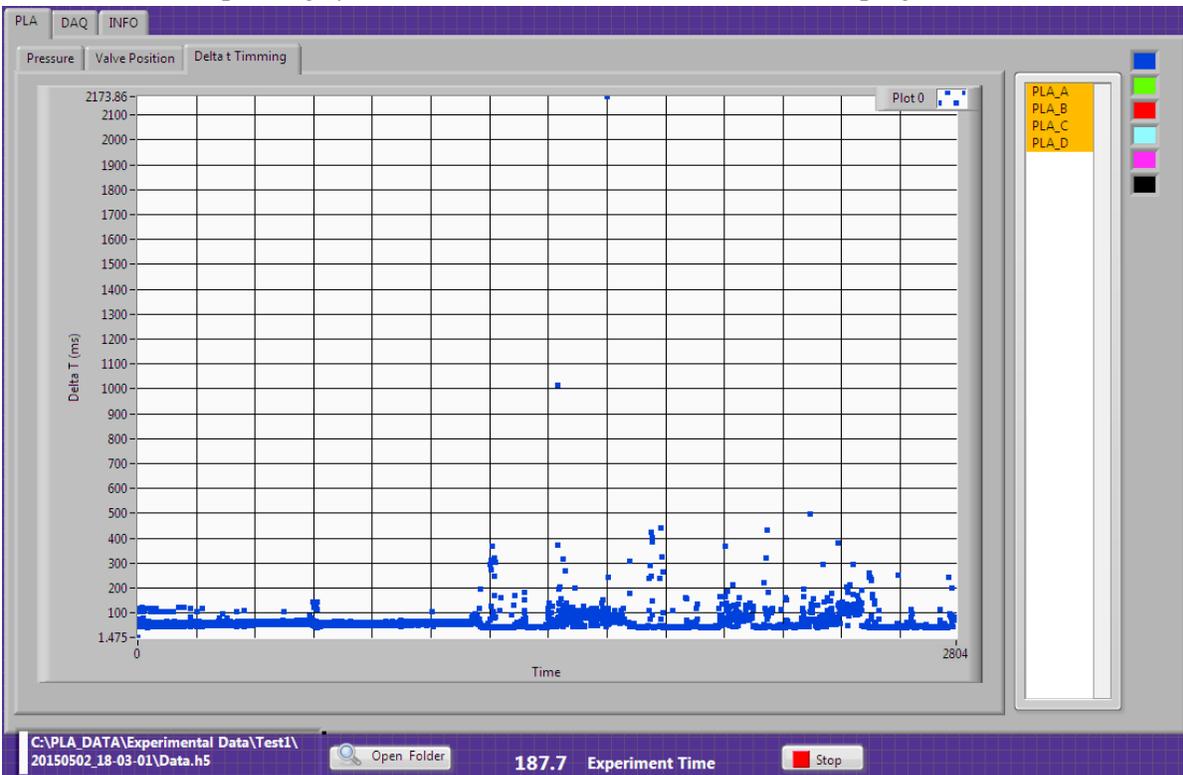
Duration of the  
experiment (seconds)

Force the experiment to  
stop. Data is still saved.

**Valve Position** displays the position of one or more PLA valves with time as it follows the input trace.



**Delta t Timing** displays the time between loops of the SPLA software. This can vary depending upon how the Windows operating system allocates resources to LabView as the program executes.



## STEP 10: DATA ACQUISITION

After the experiment has concluded, navigate to the output folder to find the file containing all of the data for that experiment. Data is saved in hdf5 format under the filename Data.h5, and can be read into Matlab using the hdf5read function or the contents can be explored using the hdfinfo function. The file is configured to contain separate data structures for each PLA (A through D). Within each PLA data structure are variables related to the PID parameters, errors and the pressure data. Key variables include the following:

<i>t</i>	time in seconds
<i>r</i>	target pressure trace
<i>y</i>	actual pressure trace
<i>u</i>	valve position
<i>I</i>	integral term of the PID controls
<i>K</i>	proportional gain constant of the PID controls
<i>Ki</i>	integral gain constant of the PID controls
<i>Saturated</i>	a binary variable where value of 0 indicates valve has not saturated, and 1 indicates the valve has saturated.

## STEP 11: POWER DOWN THE SPLA

After testing has concluded, reverse the power on cycle described in the section “Prior to Running”.

- Switch the VFD from Remote to Local mode, then turn the power lever counter-clockwise.
- Pull the lever of the interior SPLA junction box down to shut off power to the VFD.
- Shut off power to the blower on the exterior of the building.
- Disconnect the power from the PLA motors by unplugging the 120 Vac power cords from the wall outlets.
- Uninstall and put away all pressure transducers used in the experiment.
- Power down the desktop PC.