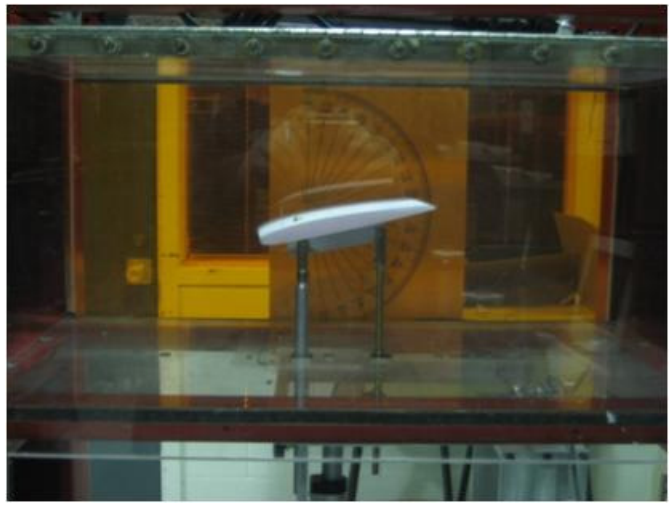
Automated Industrial Wind Tunnel Network Control with LabVIEW

Matt Draear

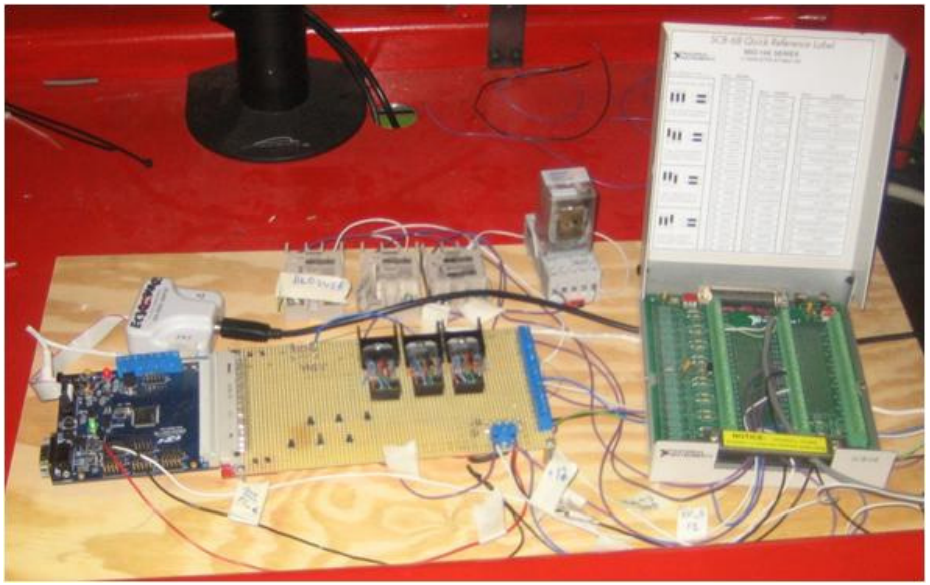
Advisor: Dr. Malinowski

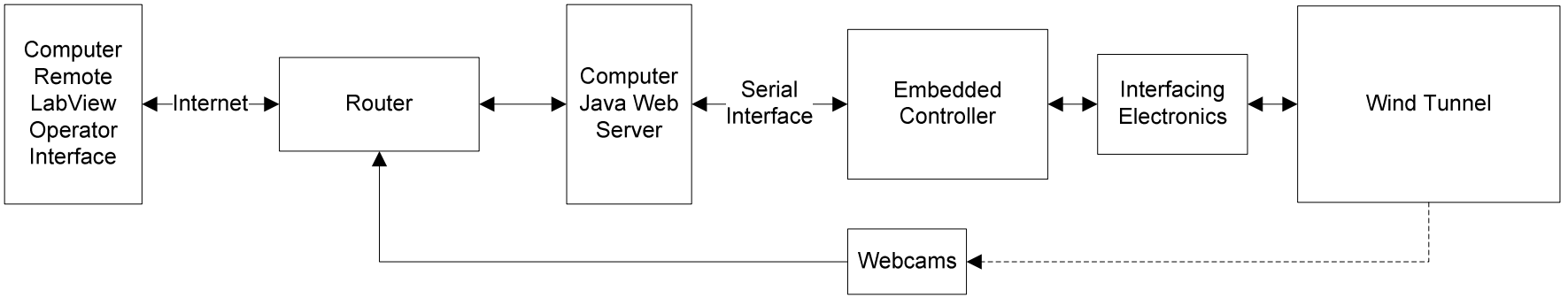
Presentation Outline

- Overview of Old Hardware
- Overview of New Hardware
- Details of New Hardware
- FPGA LabVIEW Code
- Real-Time Controller LabVIEW Code
- Wind Tunnel Test Results



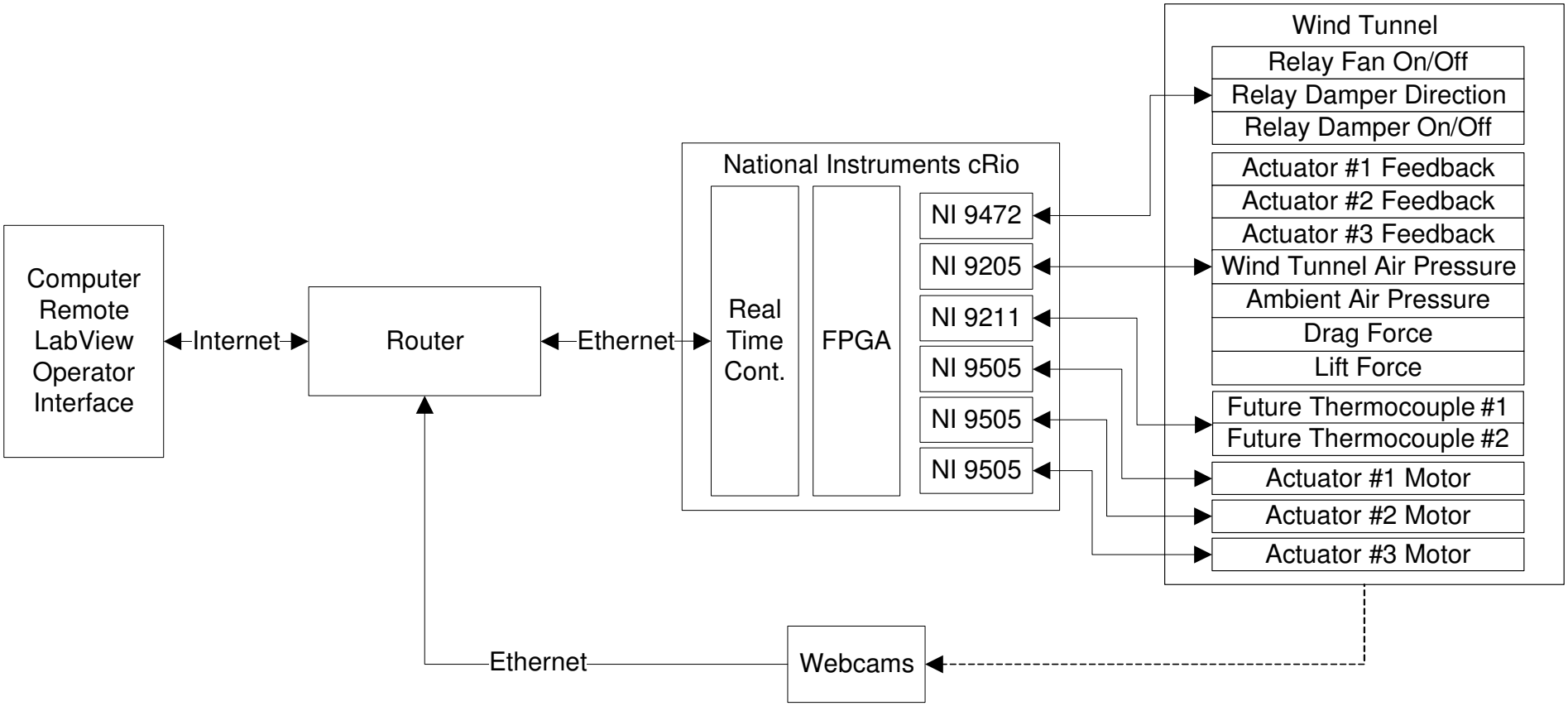
Old Hardware Overview





New National Instruments Hardware

System Diagram With New Hardware



National Instruments cRIO – 9074

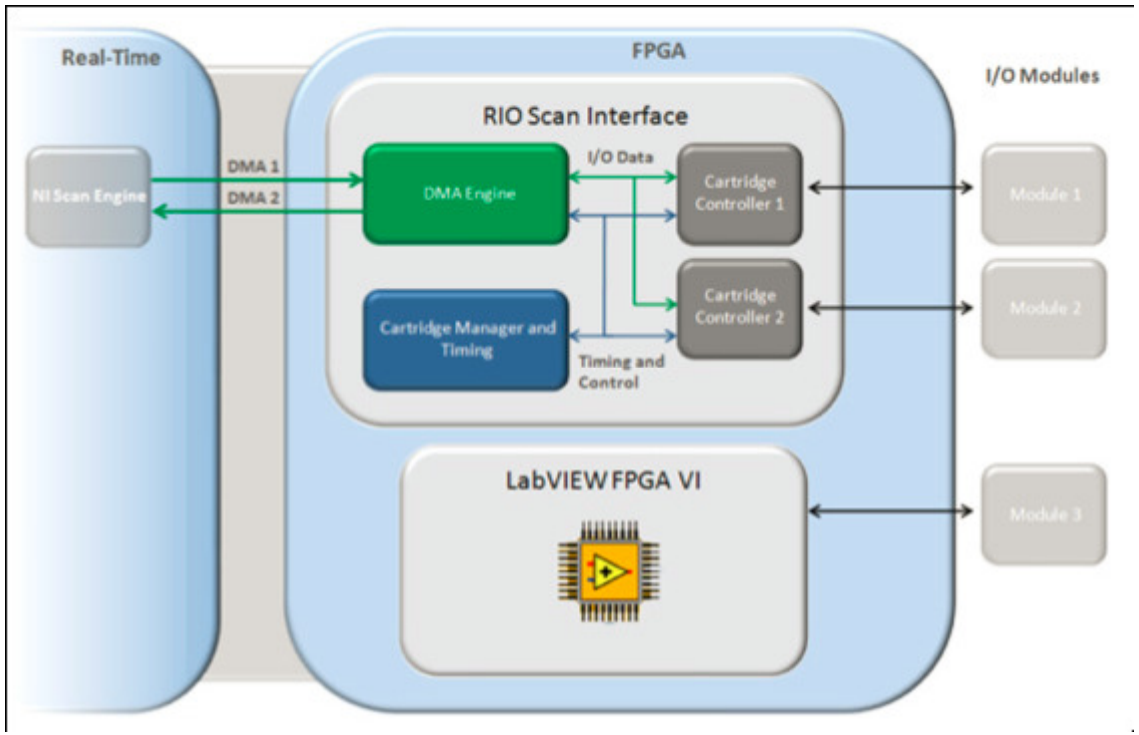
Analog Input NI - 9205

Thermocouple Input NI - 9211

Digital Output NI - 9472

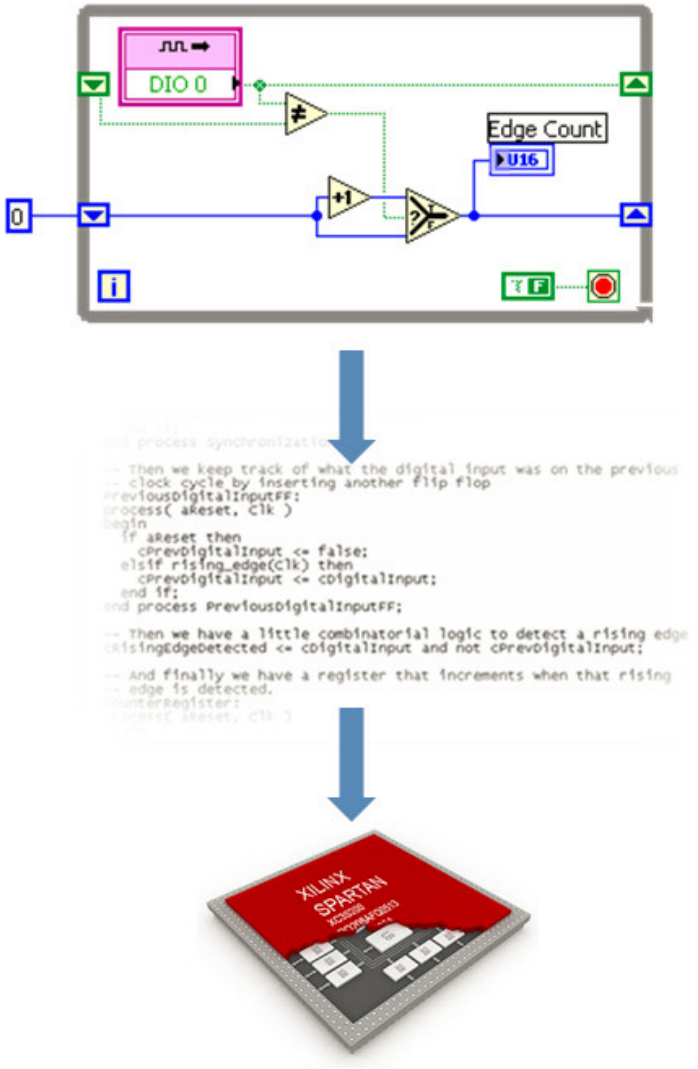
Motor Controller NI - 9505

FPGA Interface



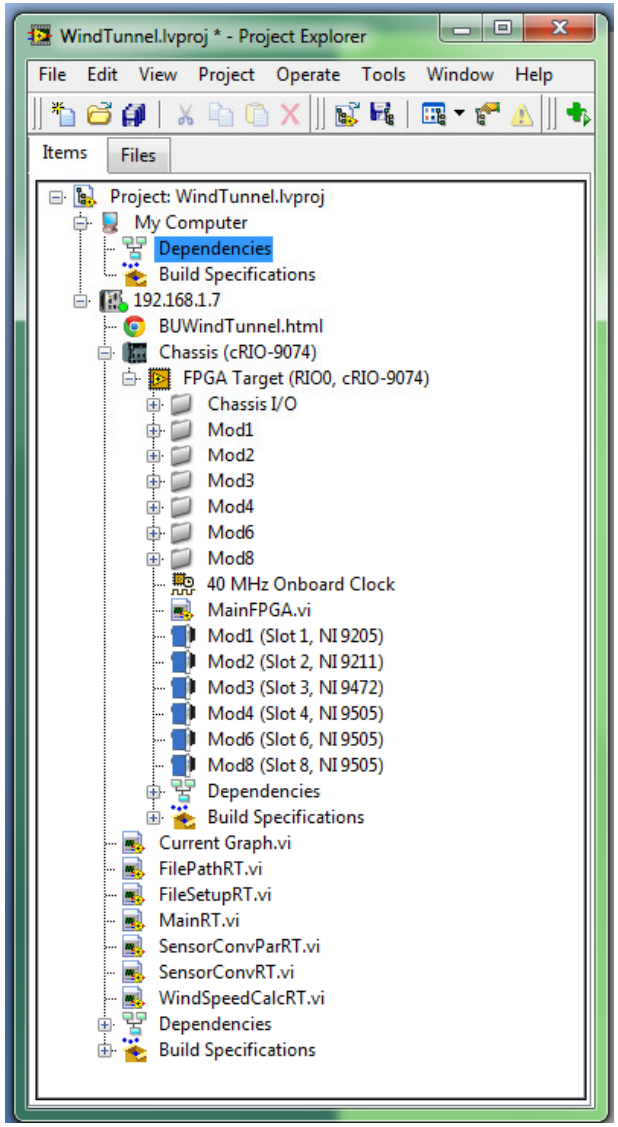
http://www.mit.bme.hu/system/files/oktatas/targyak/7258/criodevgudfull.pdf

Downloading LabVIEW Code to FPGA

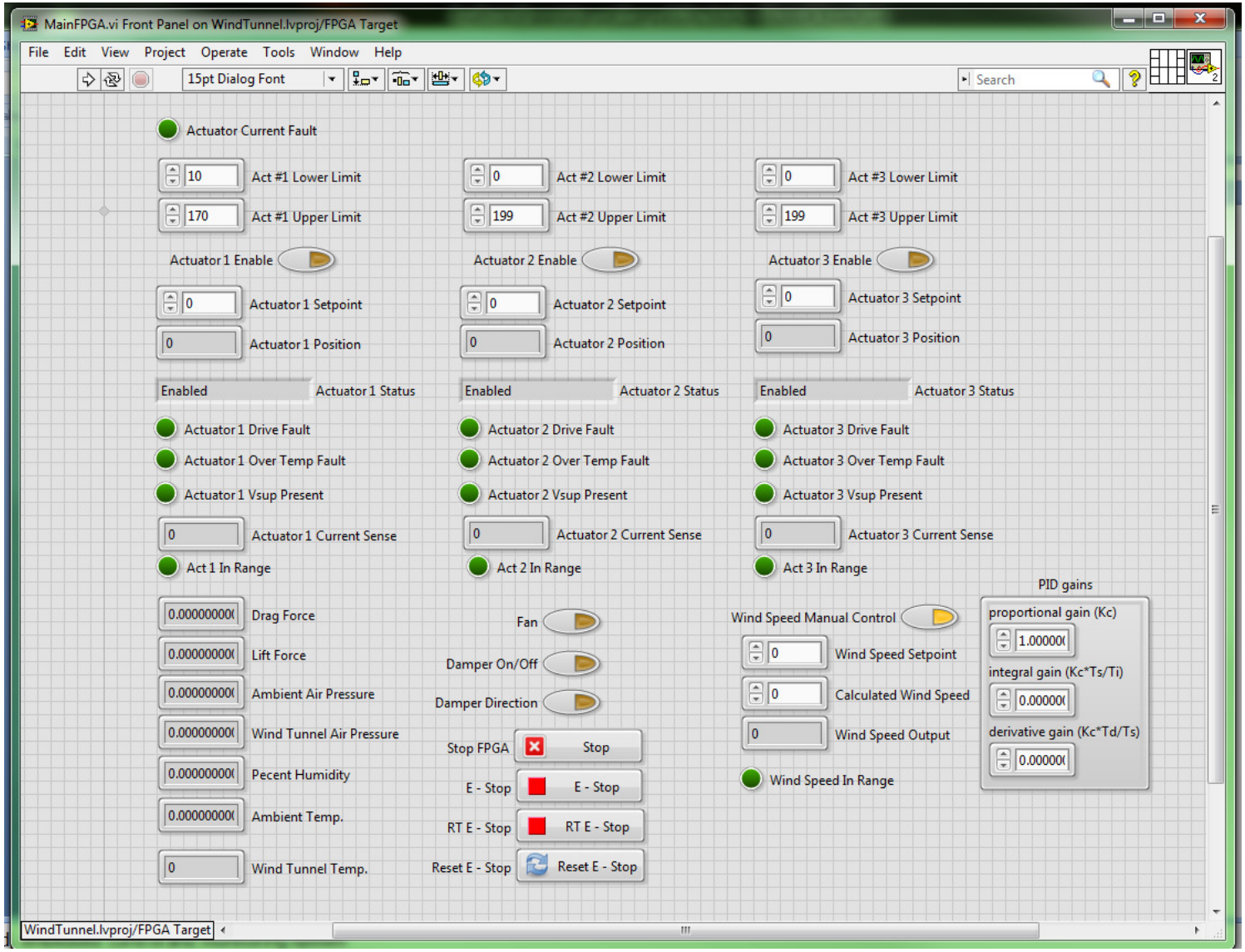


http://www.mit.bme.hu/system/files/oktatas/targyak/7258/criodevgudfull.pdf

LabVIEW Project with FPGA / Real Time Controller / IO

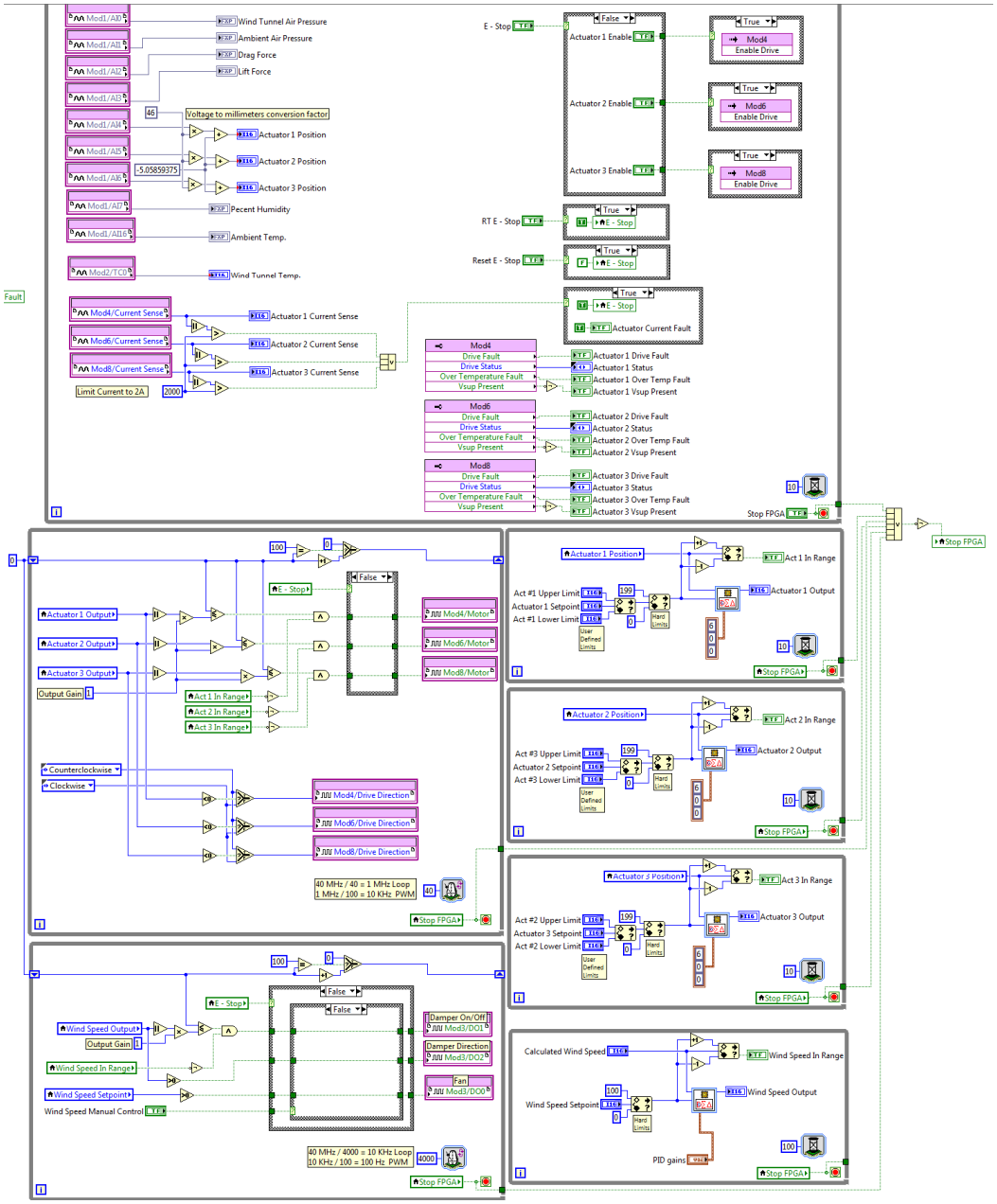


FPGA Front Panel



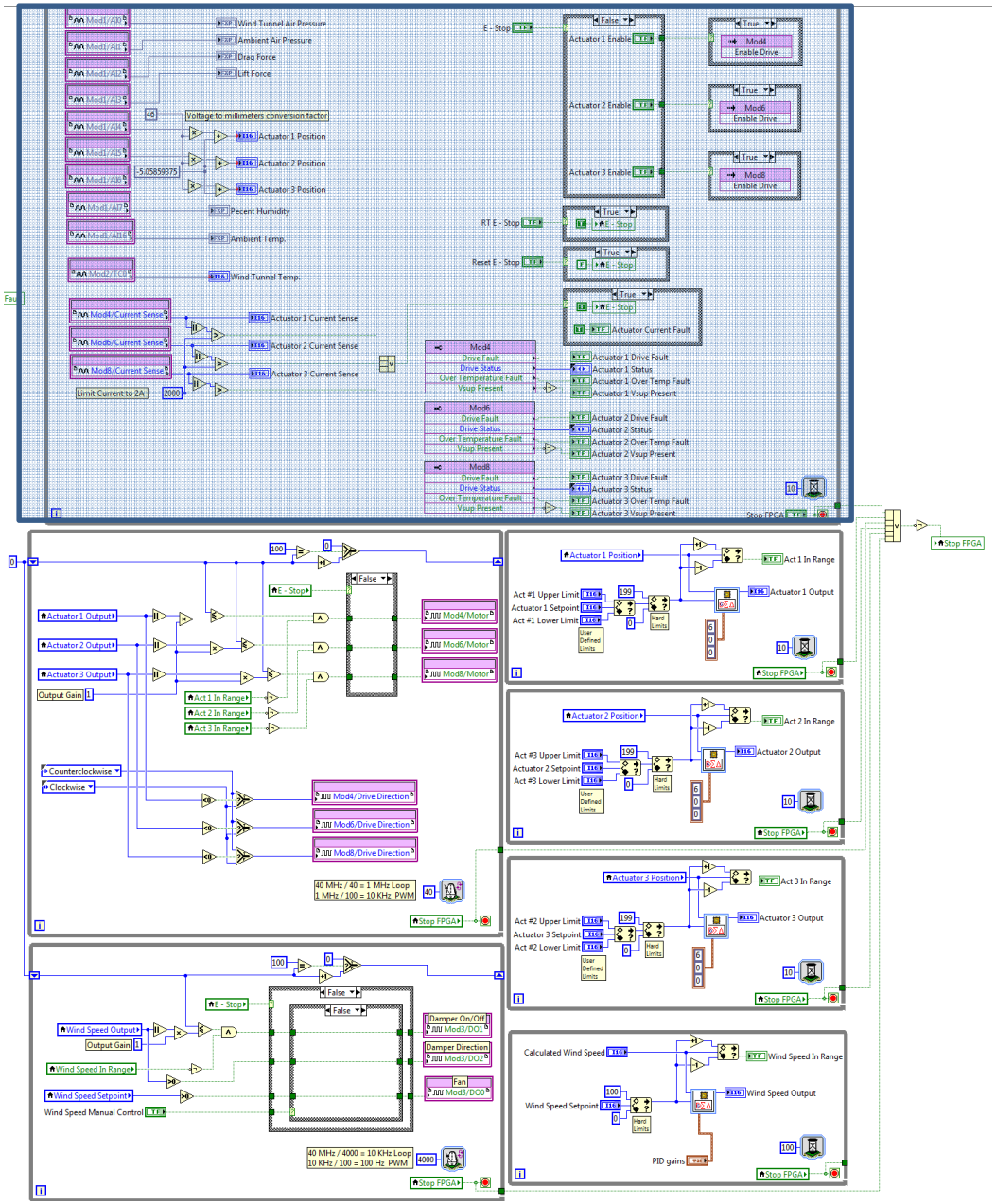
FPGA LabVIEW Code

- Hardware I/O
- Actuator PID Control Loop
- Actuator Control PWM
- Wind Speed PID Control Loop
- Damper Control PWM

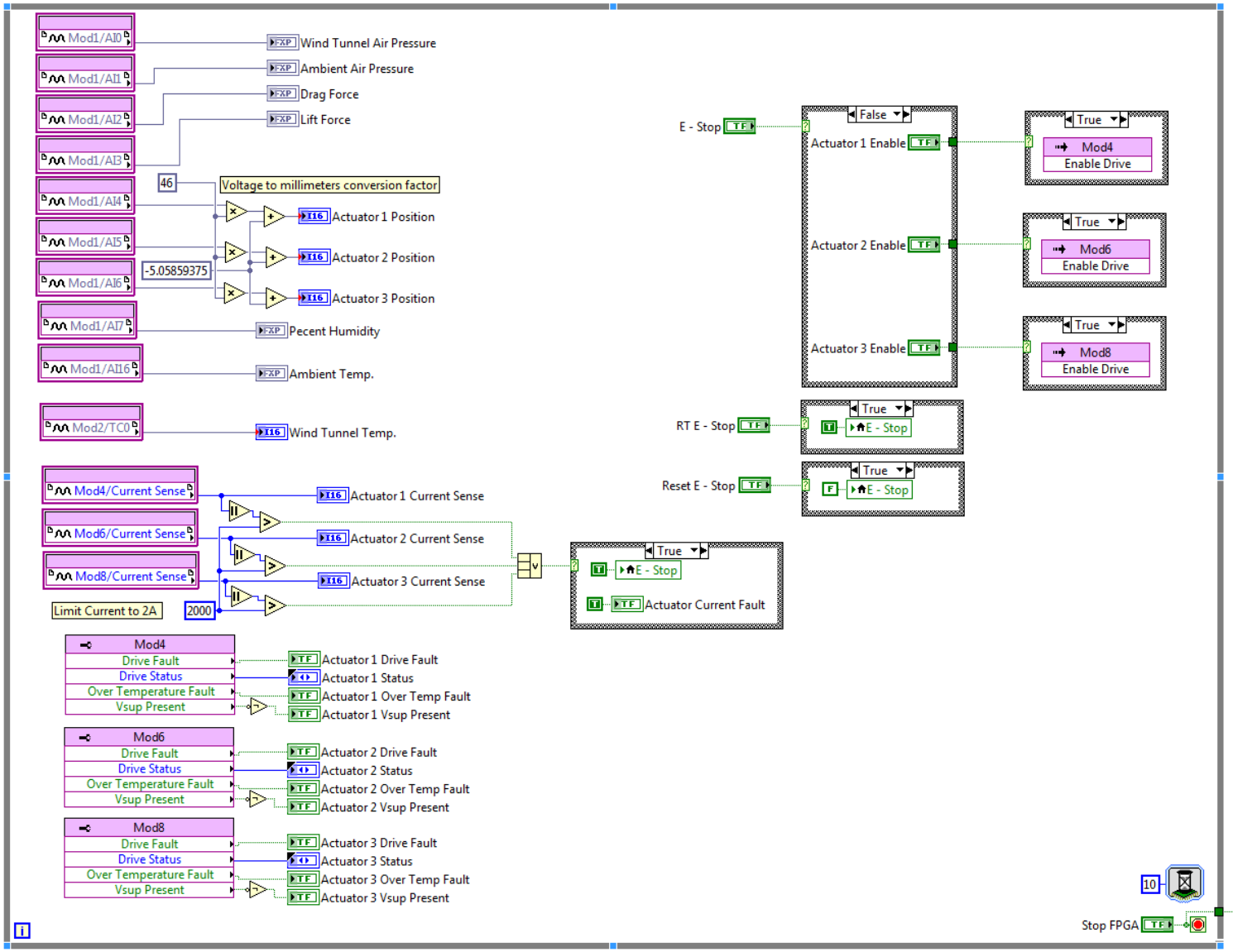


FPGA LabVIEW Code

Hardware I/O

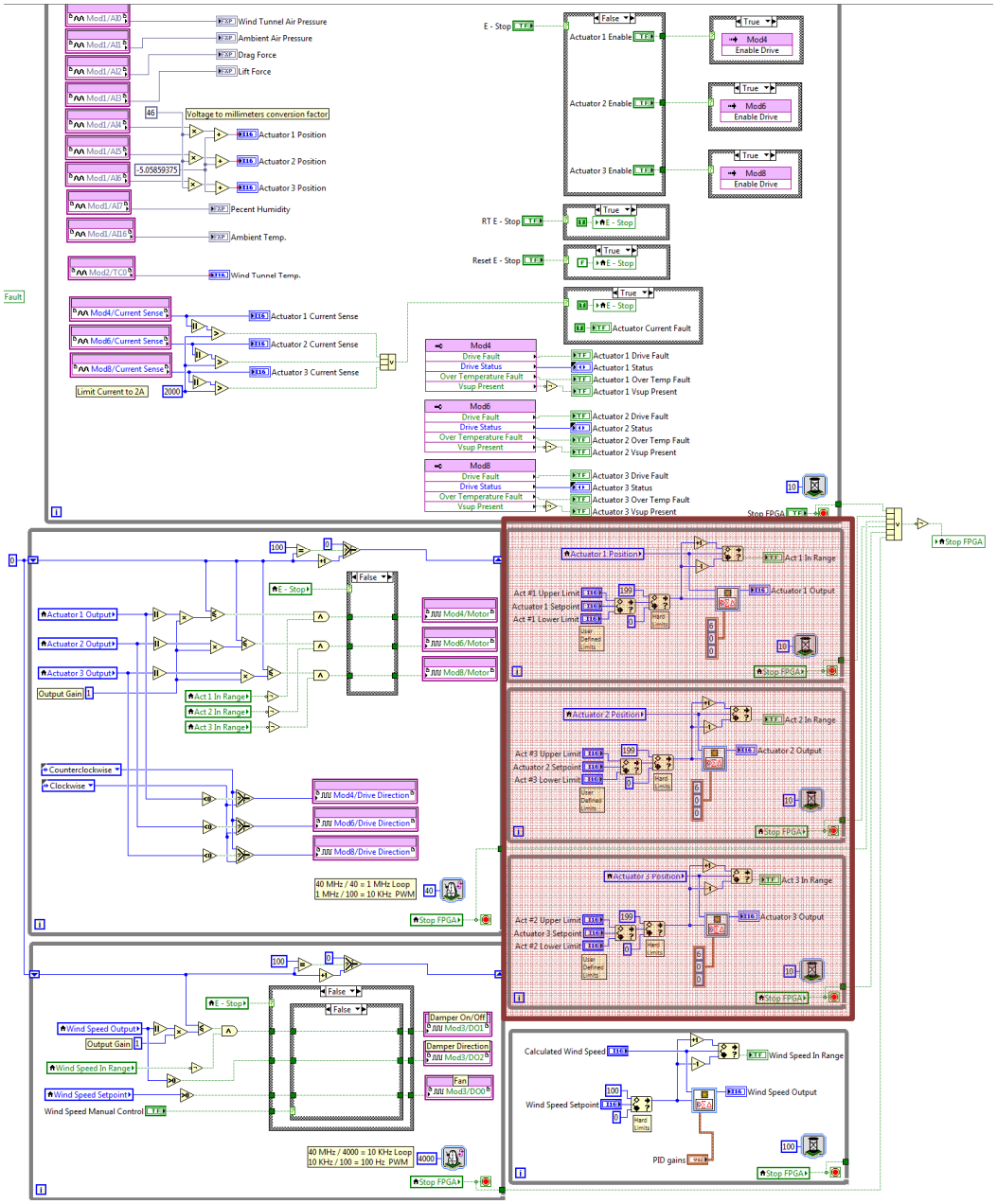


Hardware I/O Interface With FPGA

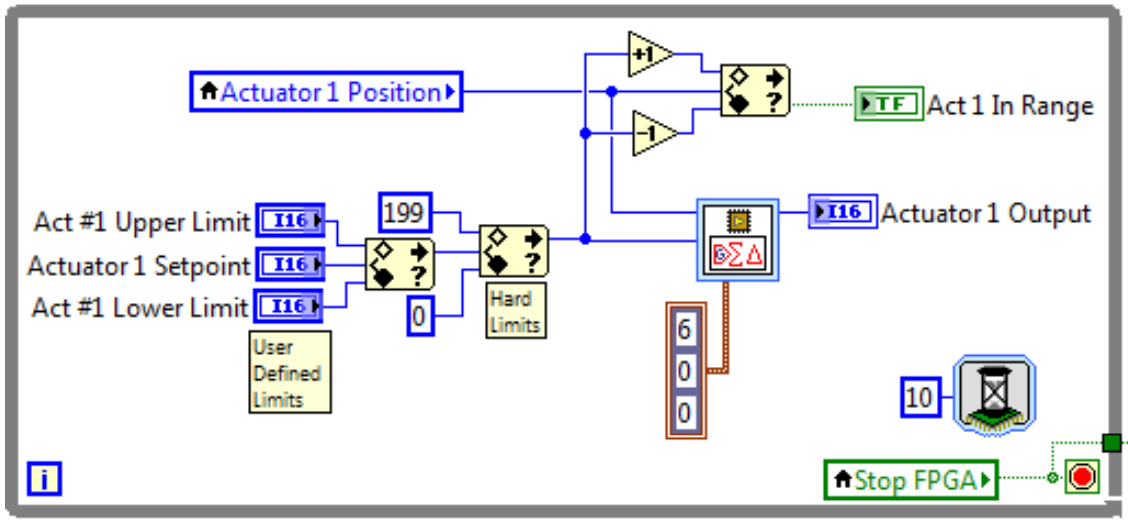


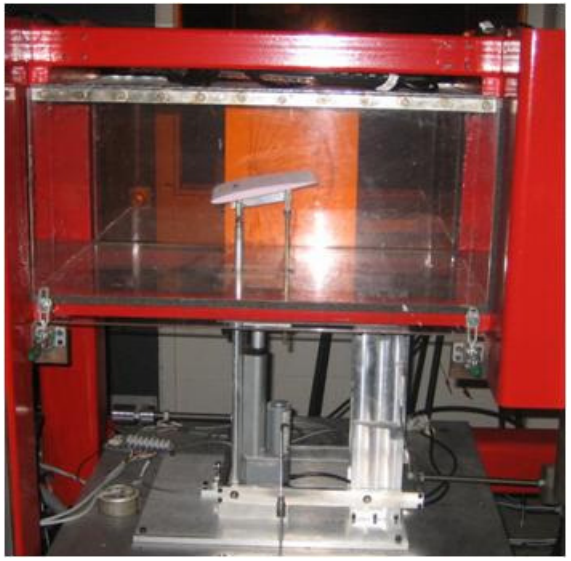
FPGA LabVIEW Code

Actuator PID Control Loop

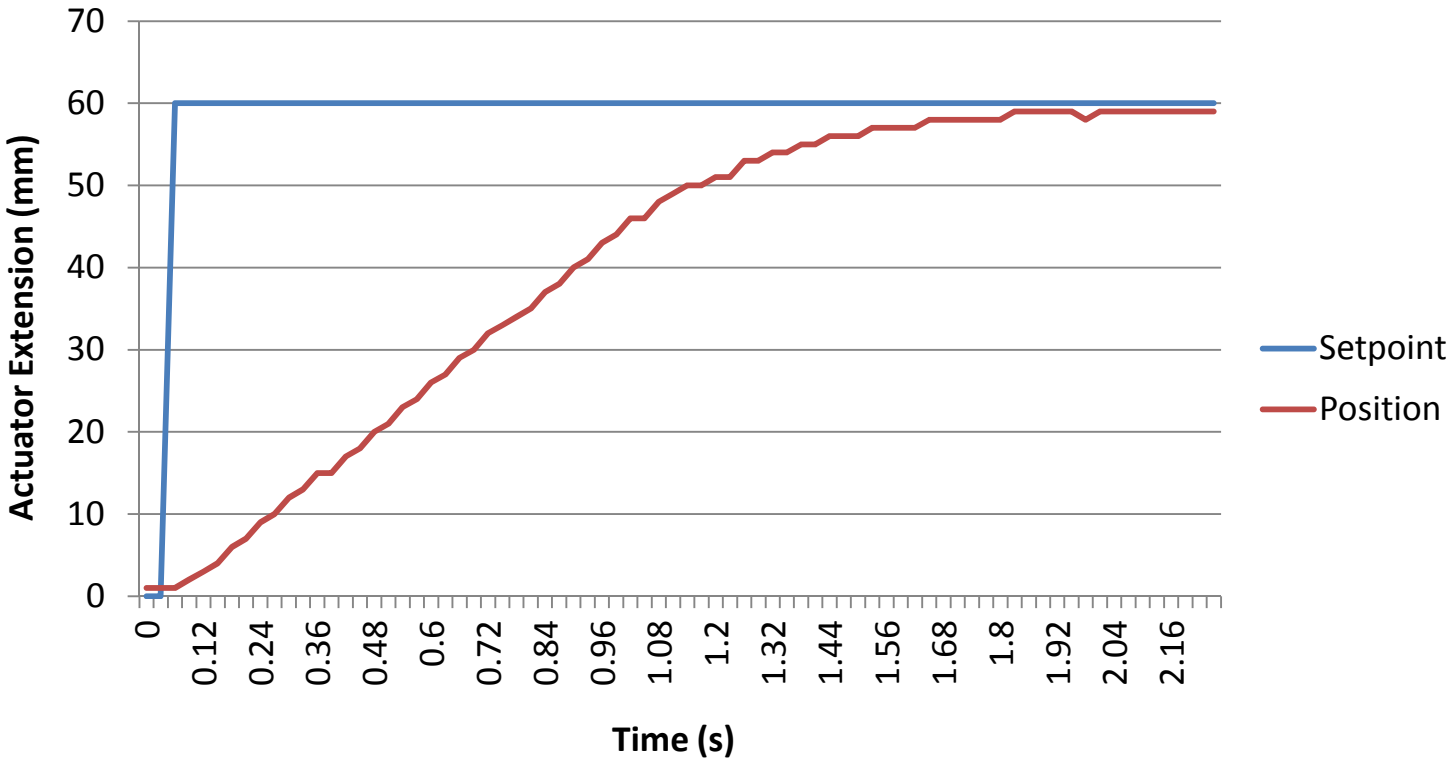


Actuator PID Control Loop



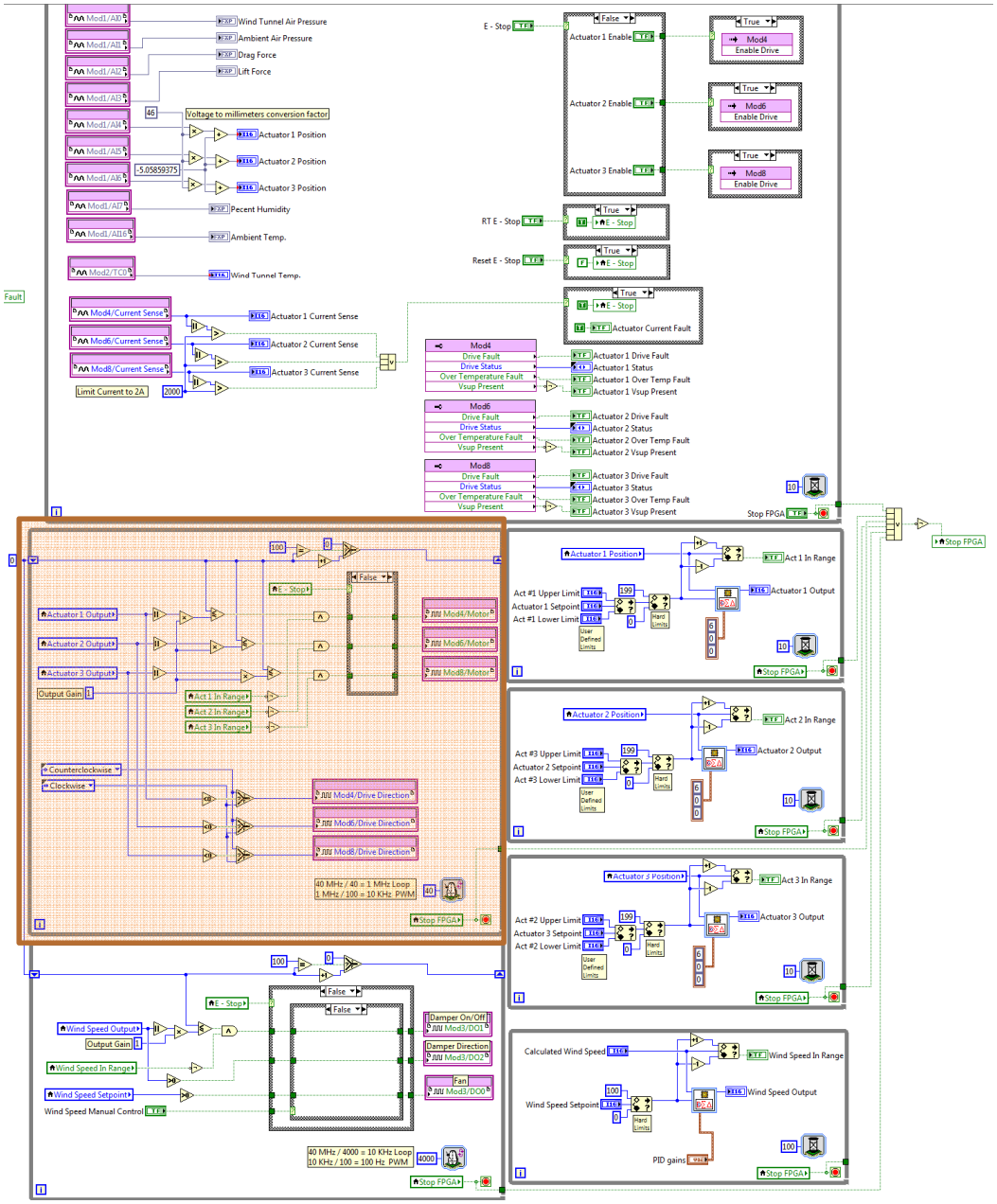


Linear Actuator Distance Versus Setpoint

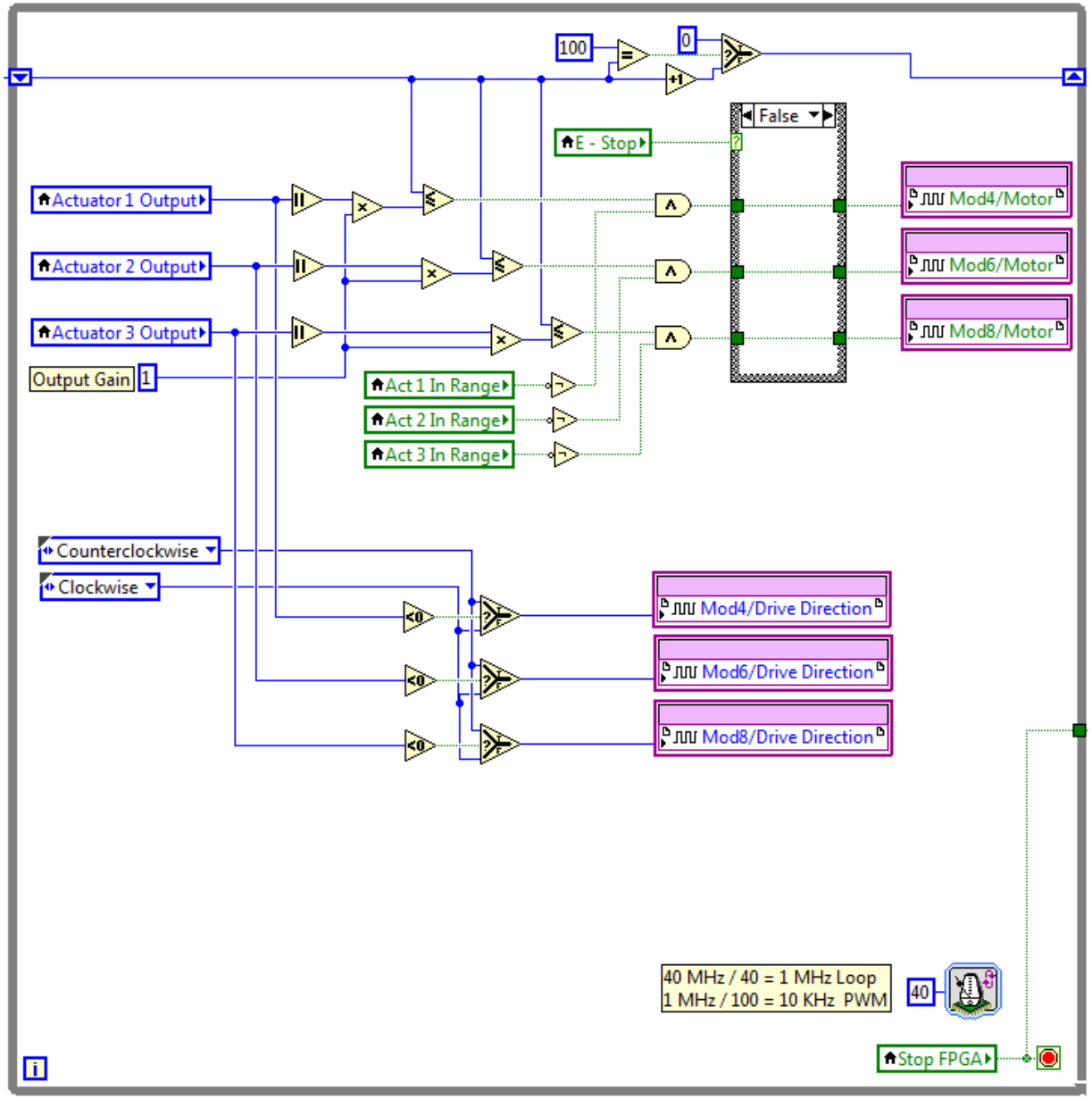


FPGA LabVIEW Code

Actuator Control PWM

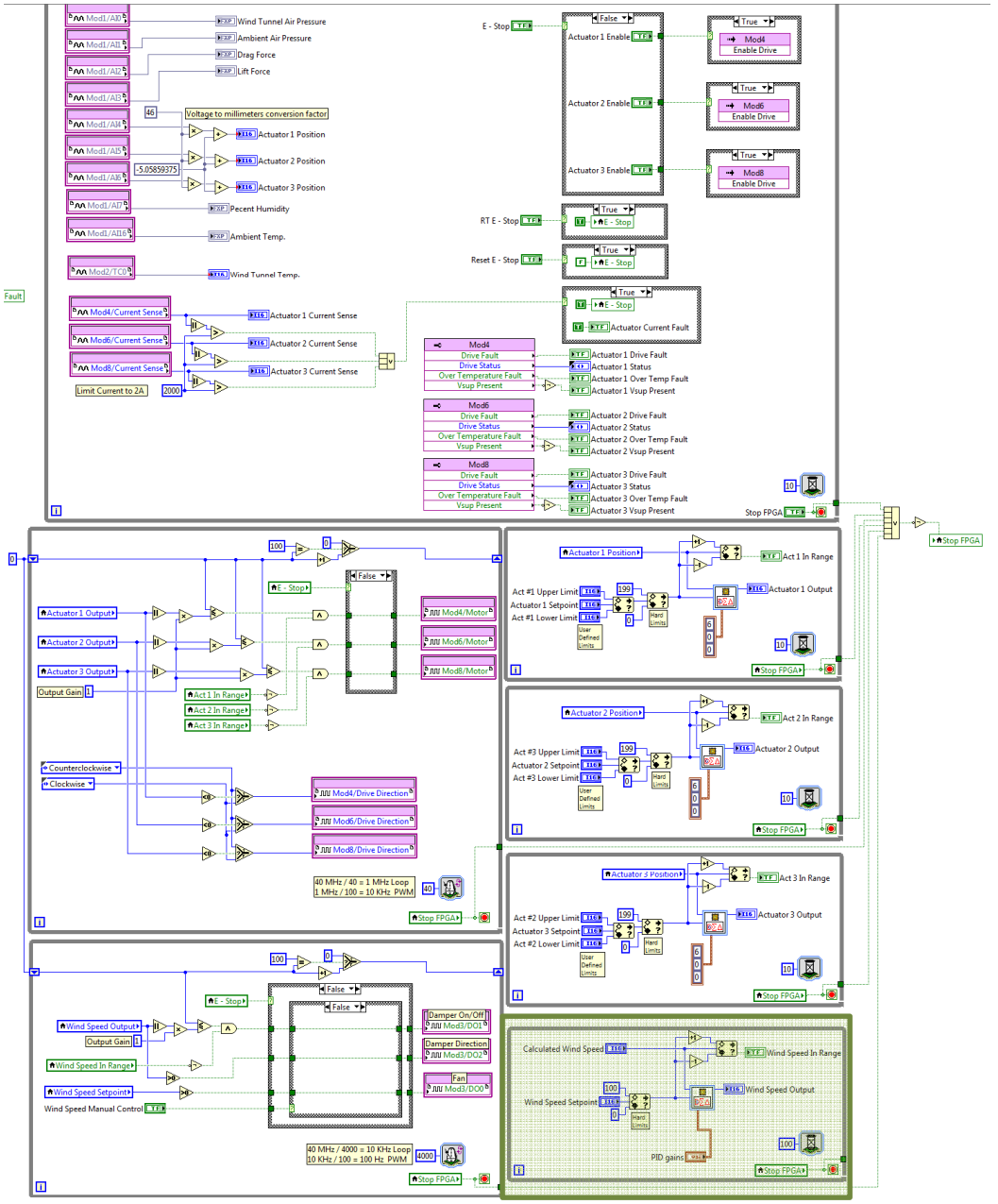


Actuator Control PWM Generation

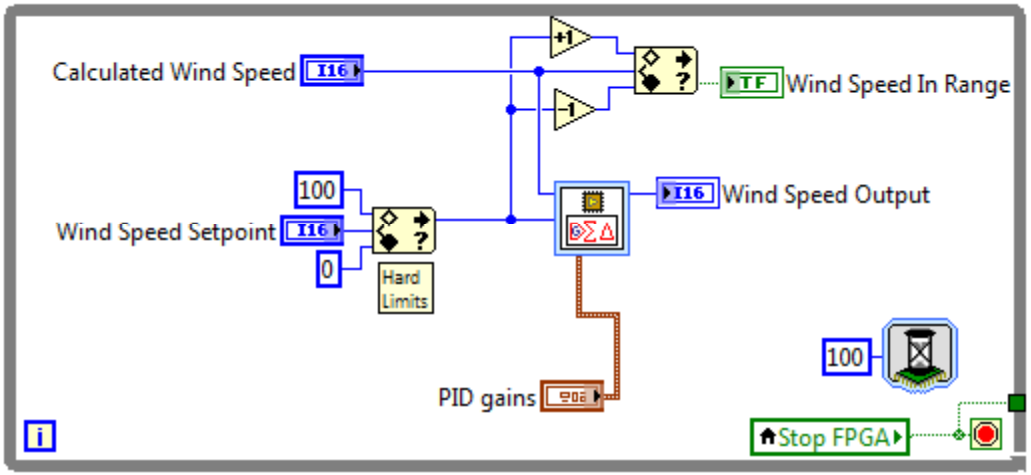


FPGA LabVIEW Code

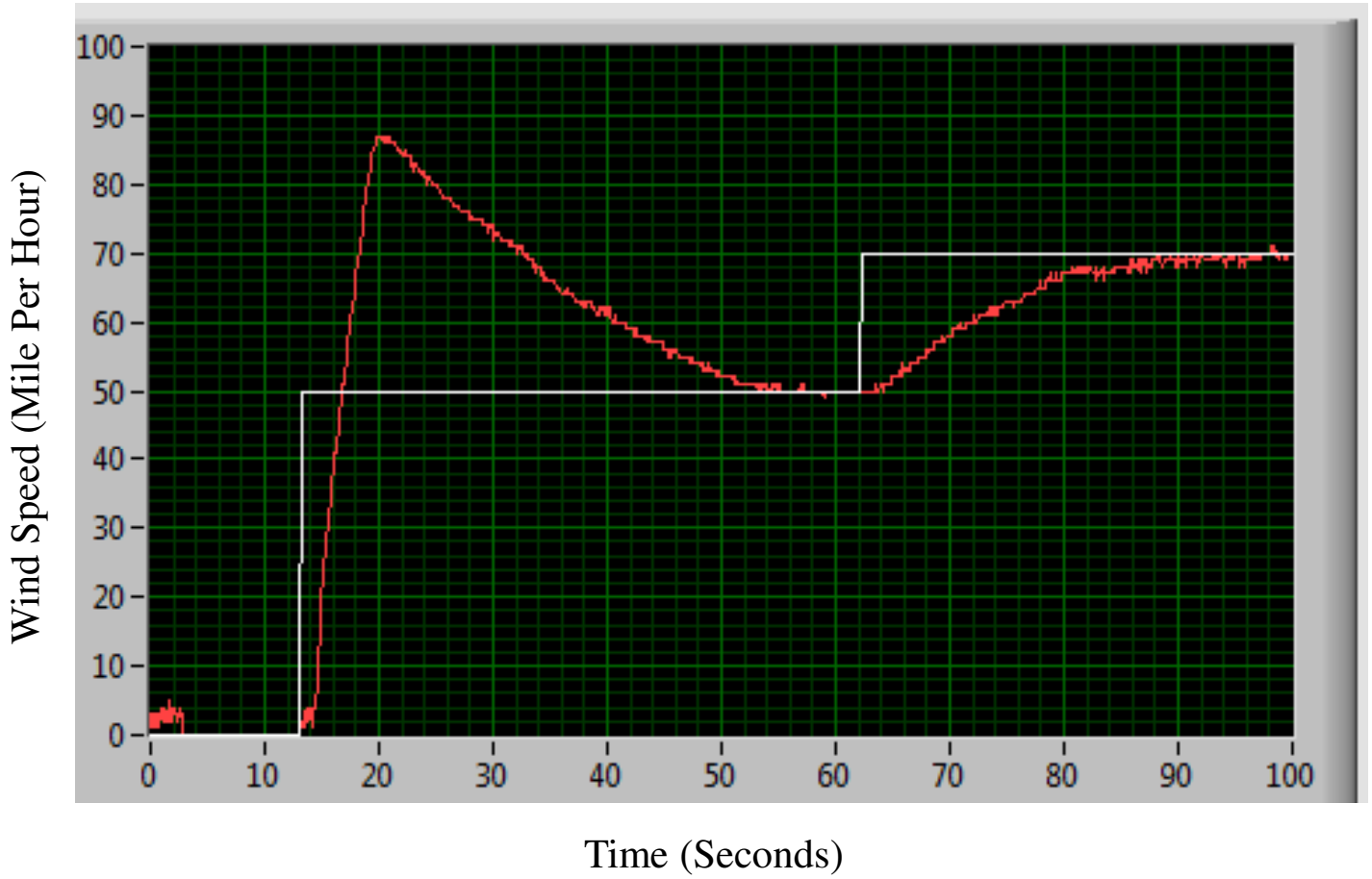
Wind Speed PID Control Loop



Wind Speed PID Control Loop

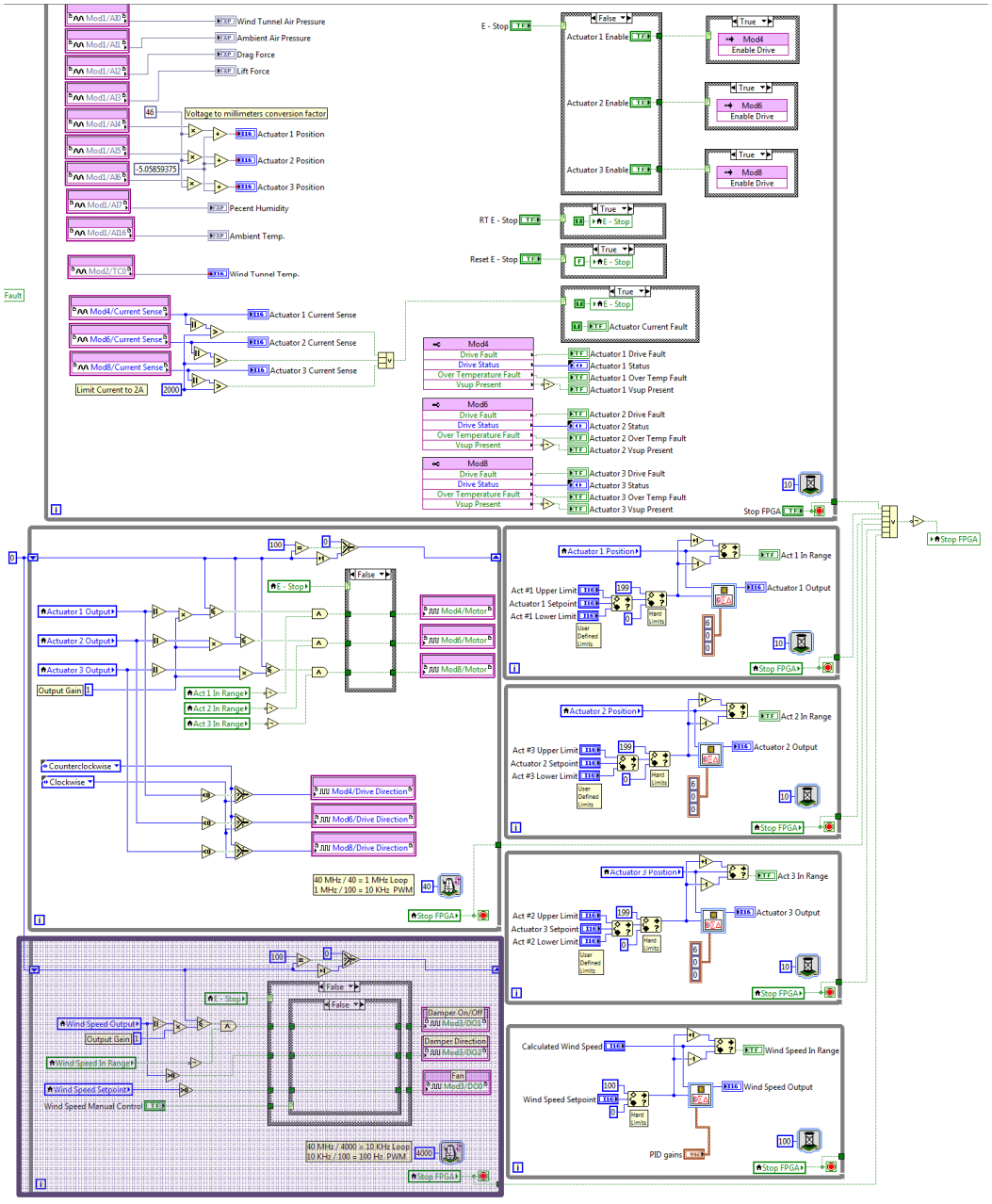


Wind Speed Versus Setpoint

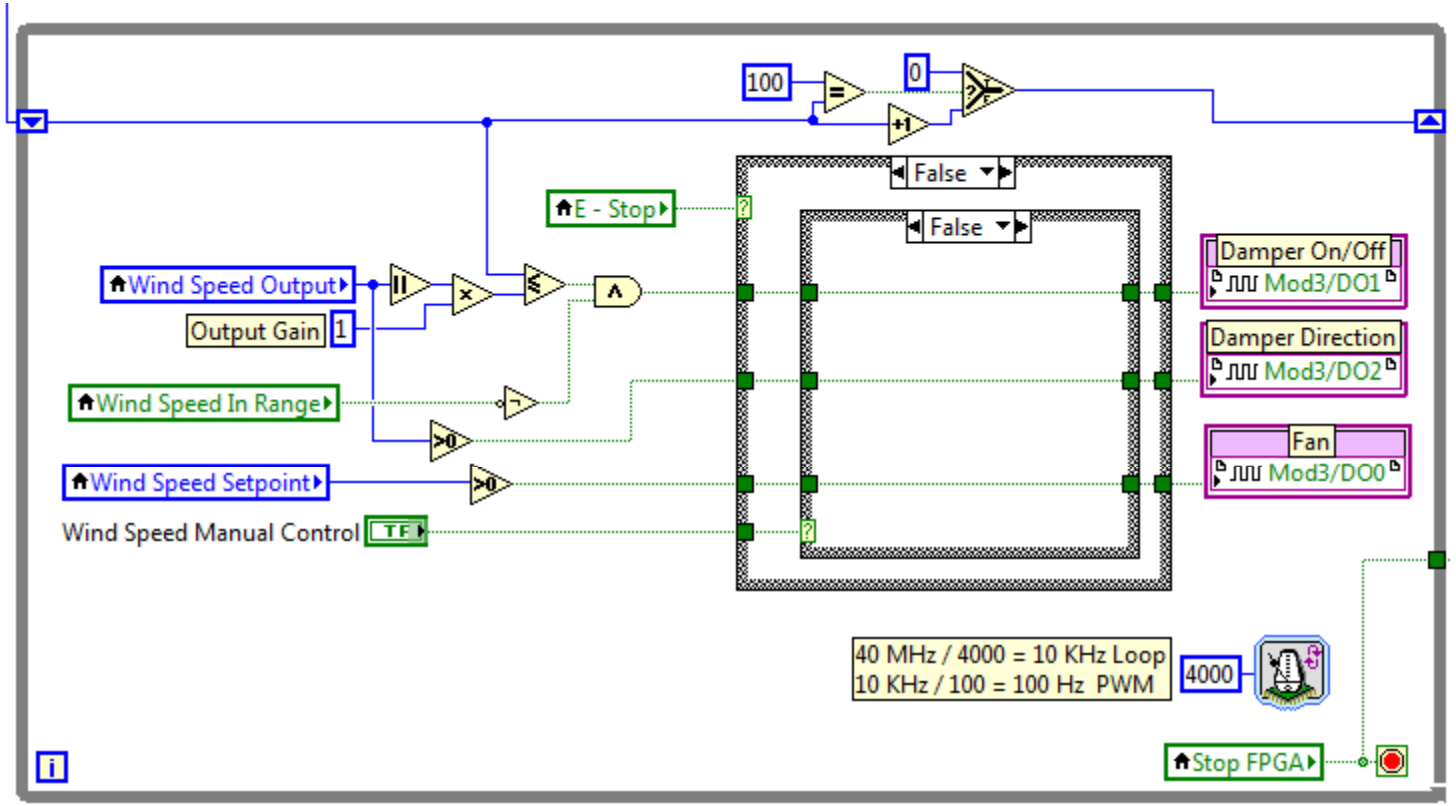


FPGA LabVIEW Code

Damper Control PWM

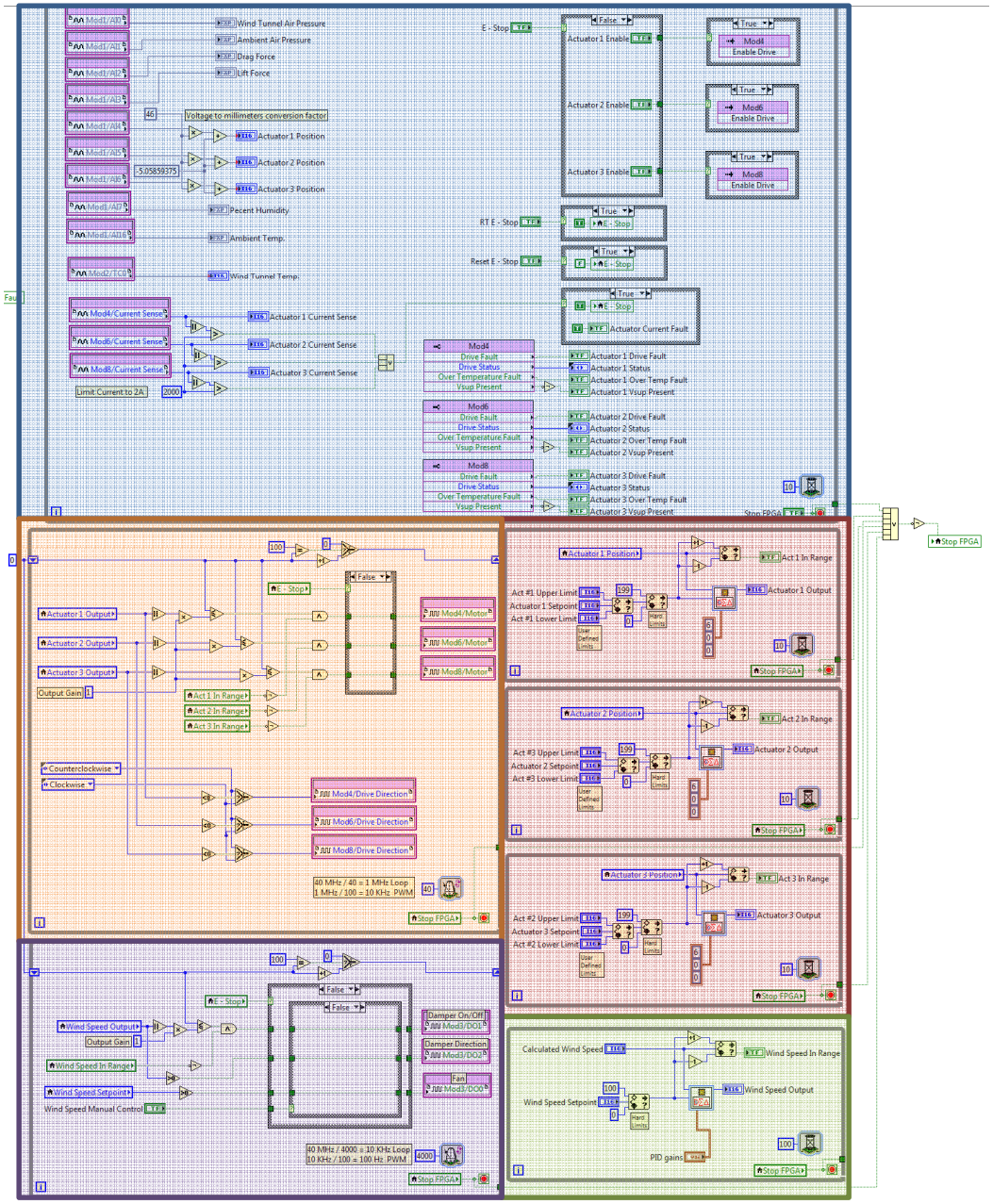


Damper Control PWM Generation

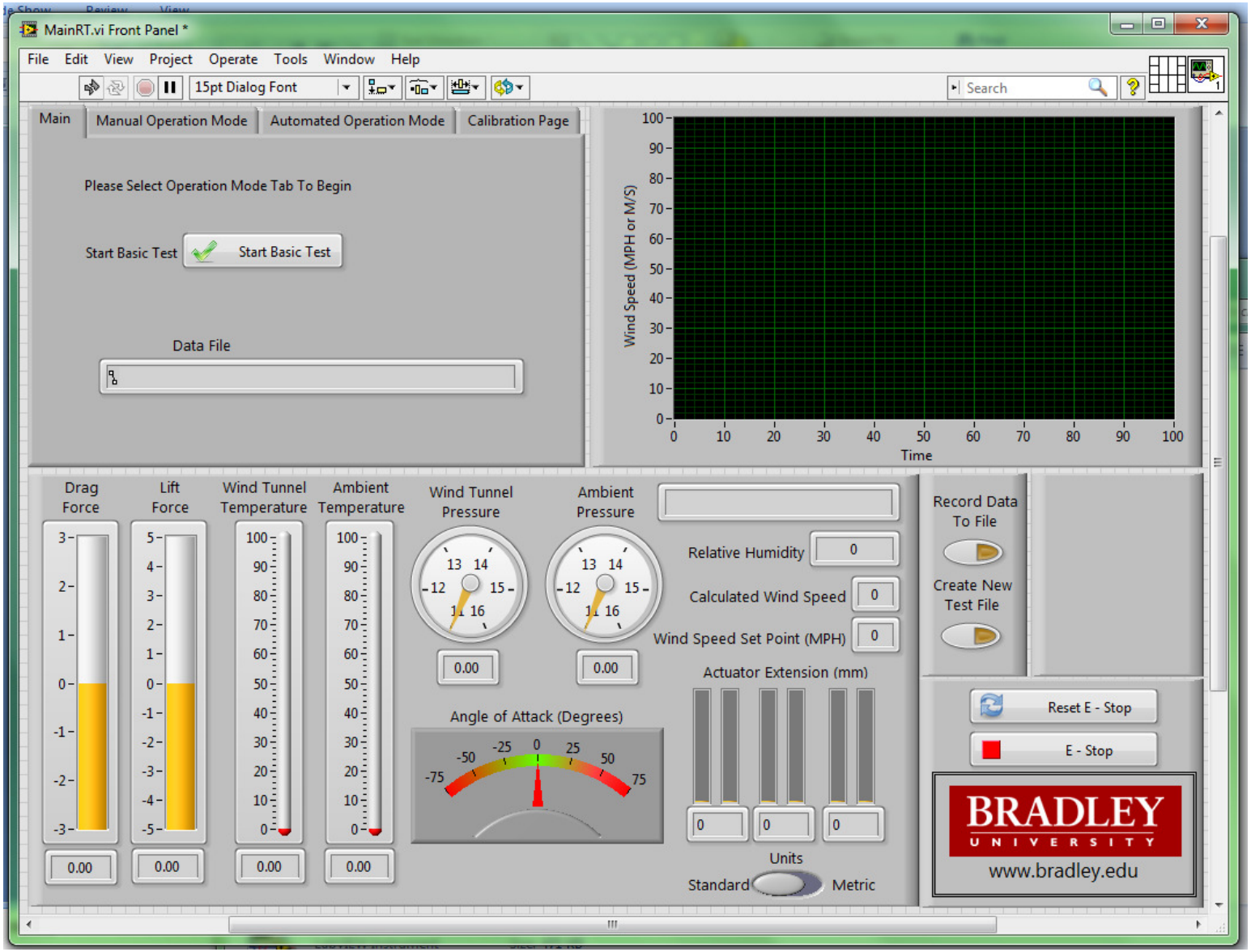


FPGA LabVIEW Code

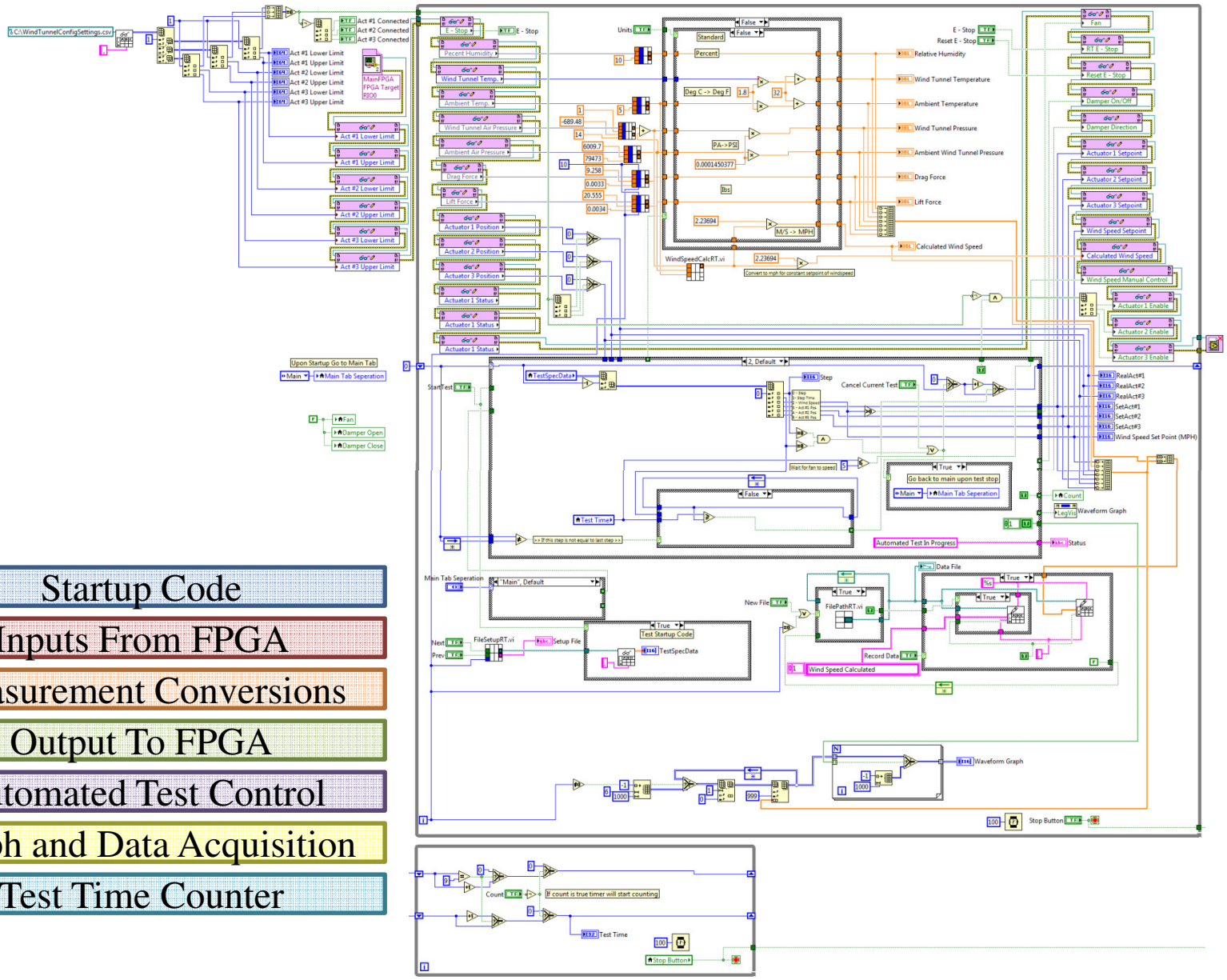
- Hardware I/O
- Actuator PID Control Loop
- Actuator Control PWM
- Wind Speed PID Control Loop
- Damper Control PWM



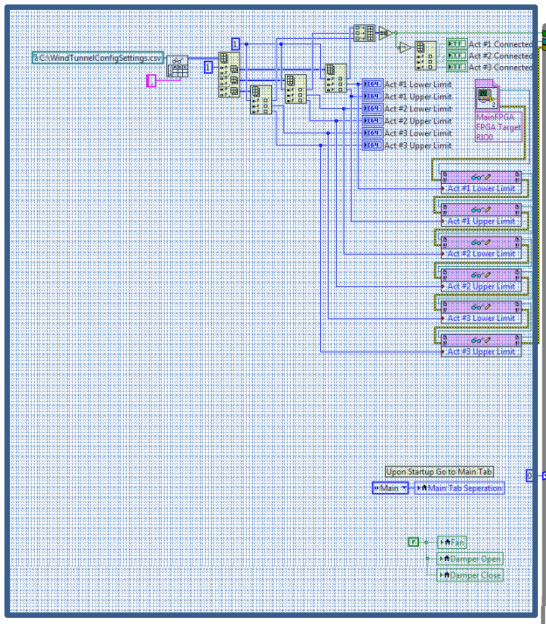
Real Time Target LabVIEW Code



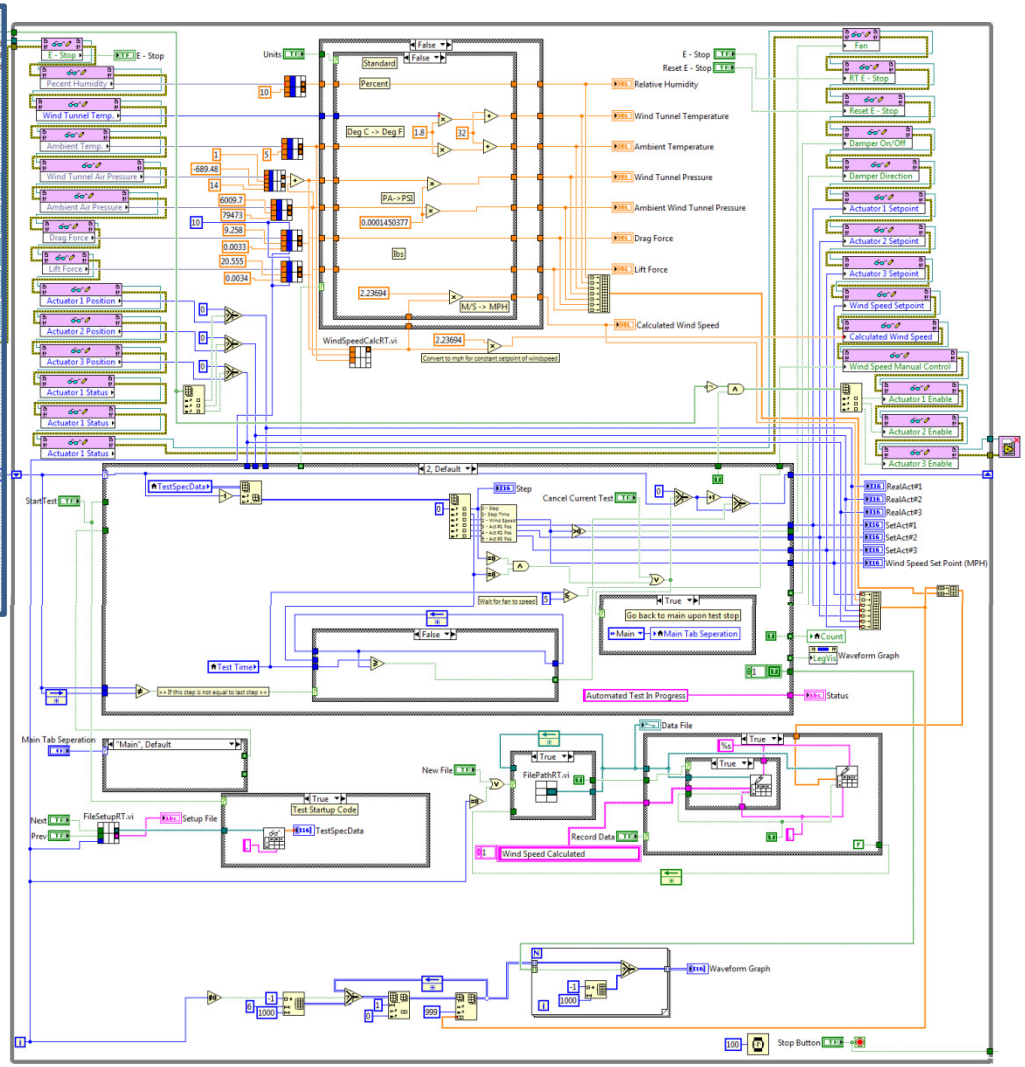
Real Time Target LabVIEW Code

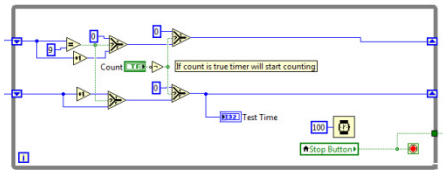


Real Time Target LabVIEW Code

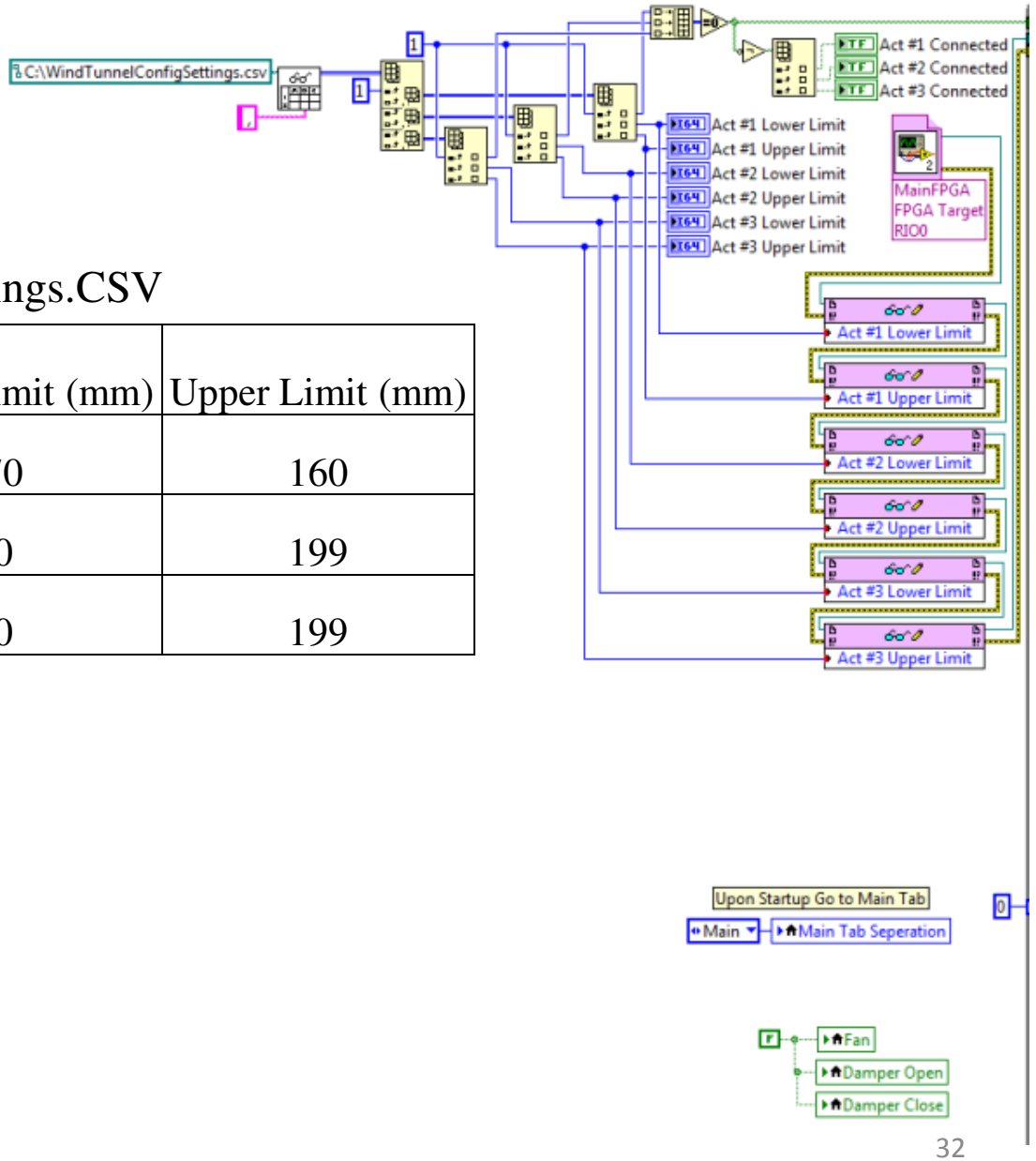


Startup Code





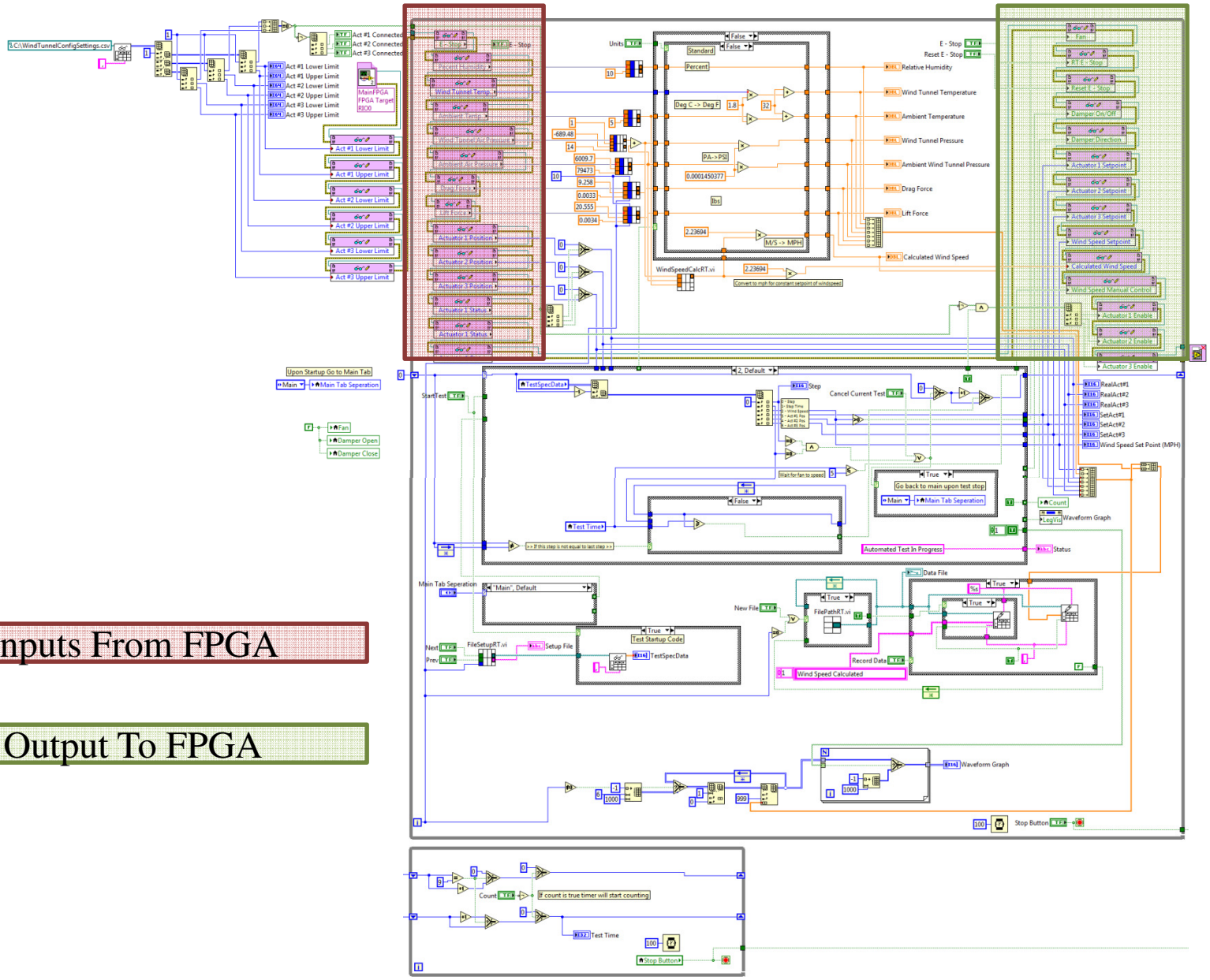
Startup Code



WindTunnelConfigSettings.CSV

	Enable(1)/Disable(0)	Lower Limit (mm)	Upper Limit (mm)
Actuator #1	1	70	160
Actuator #2	1	0	199
Actuator #3	0	0	199

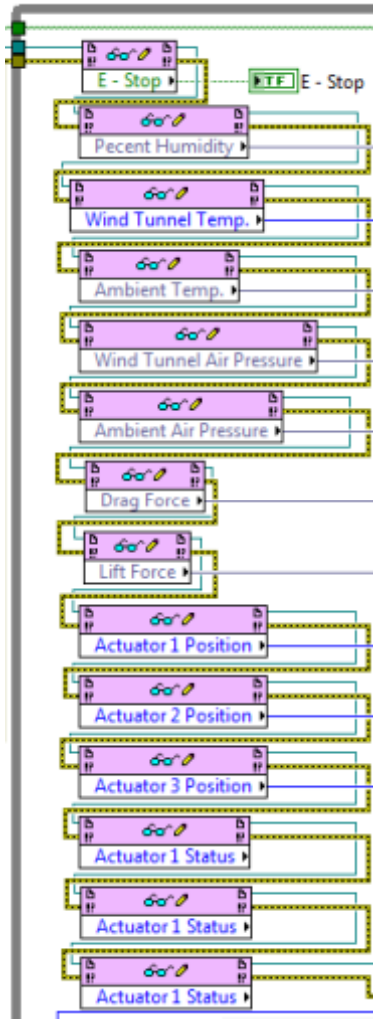
Real Time Target LabVIEW Code



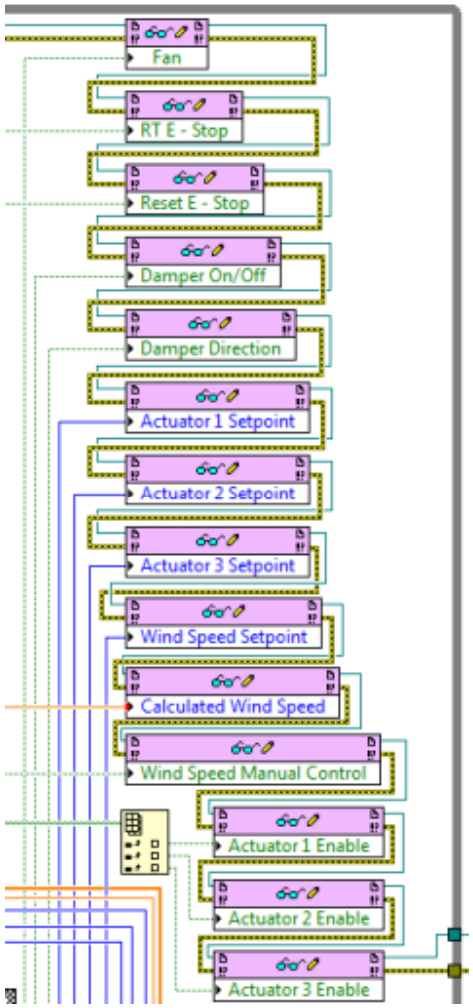
Inputs From FPGA

Output To FPGA

FPGA I/O

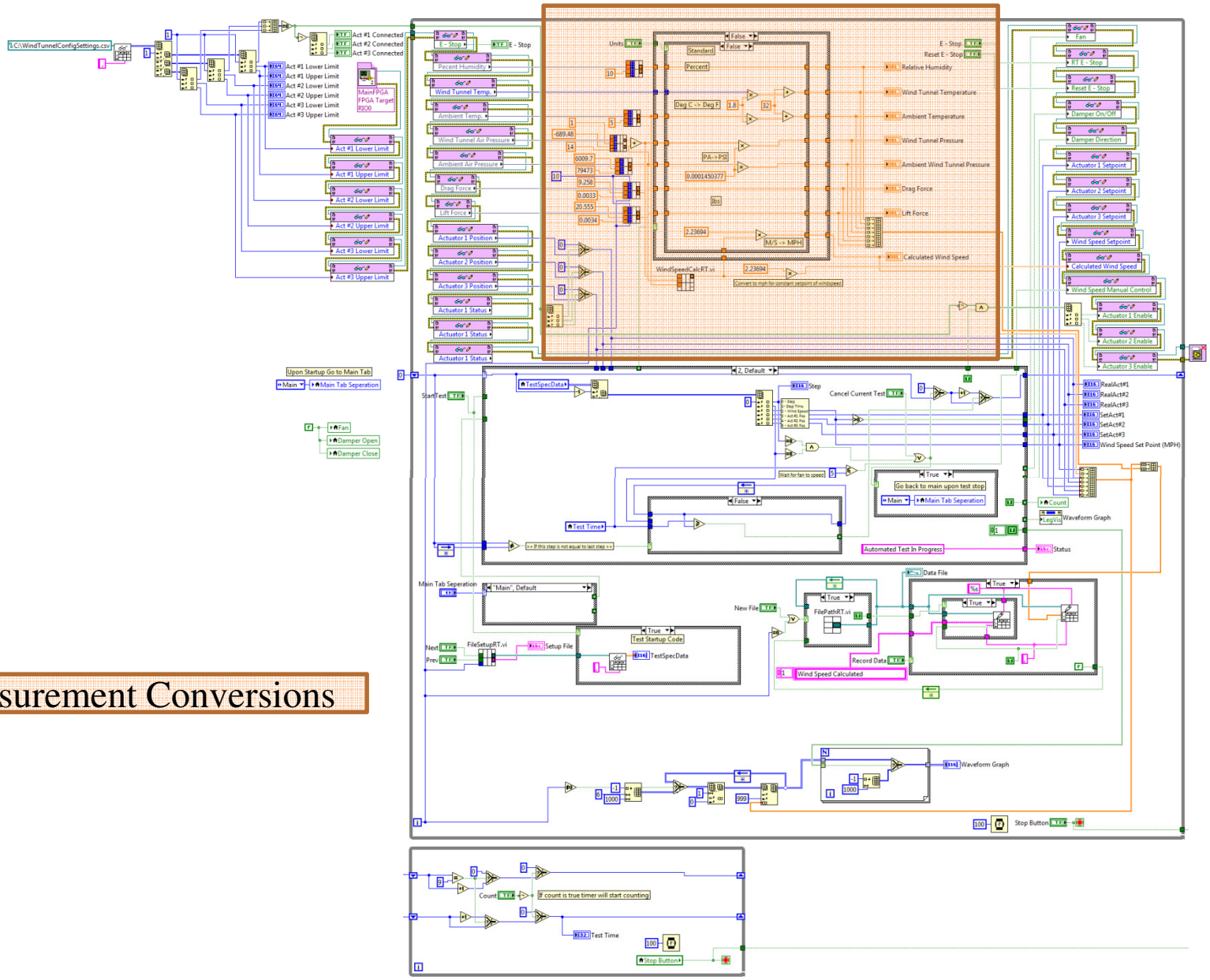


Inputs From FPGA

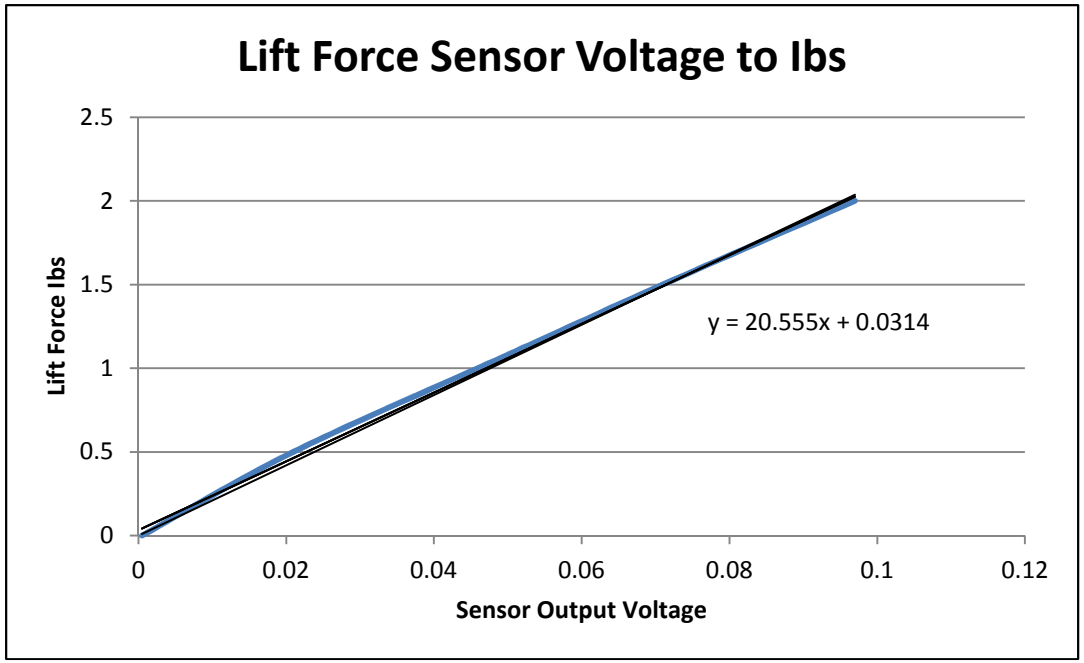


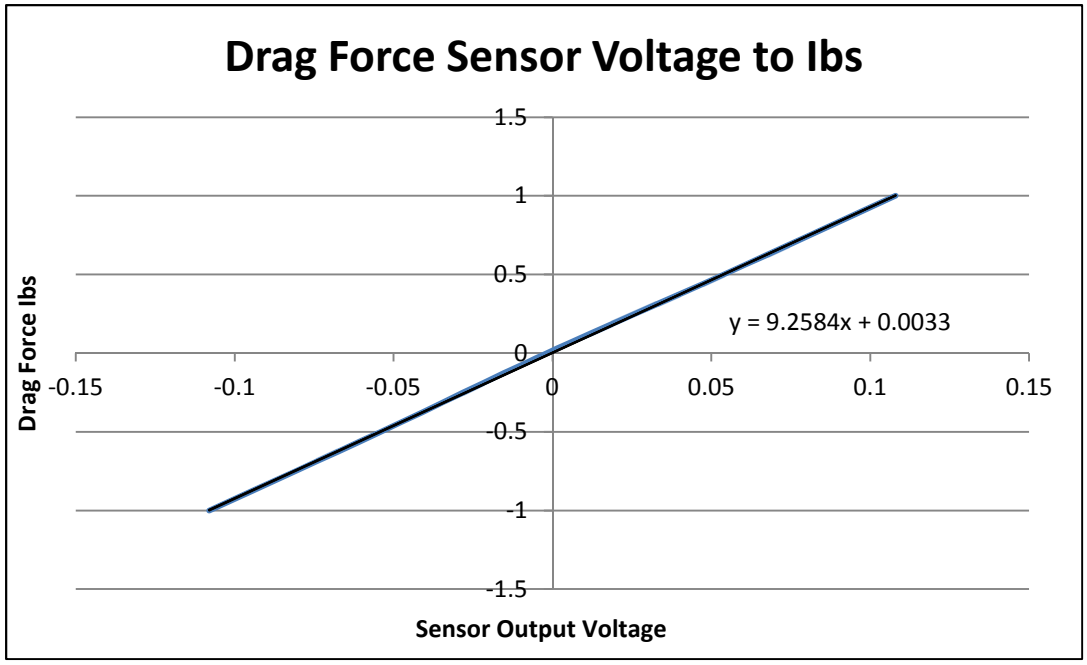
Outputs To FPGA

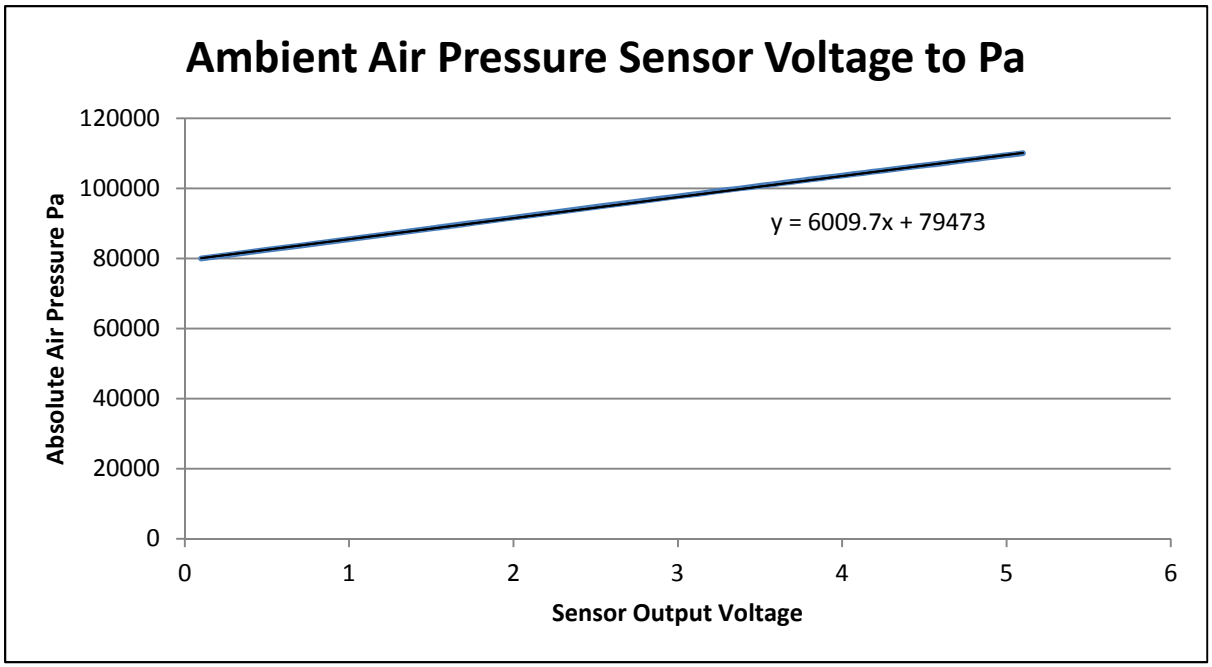
Real Time Target LabVIEW Code

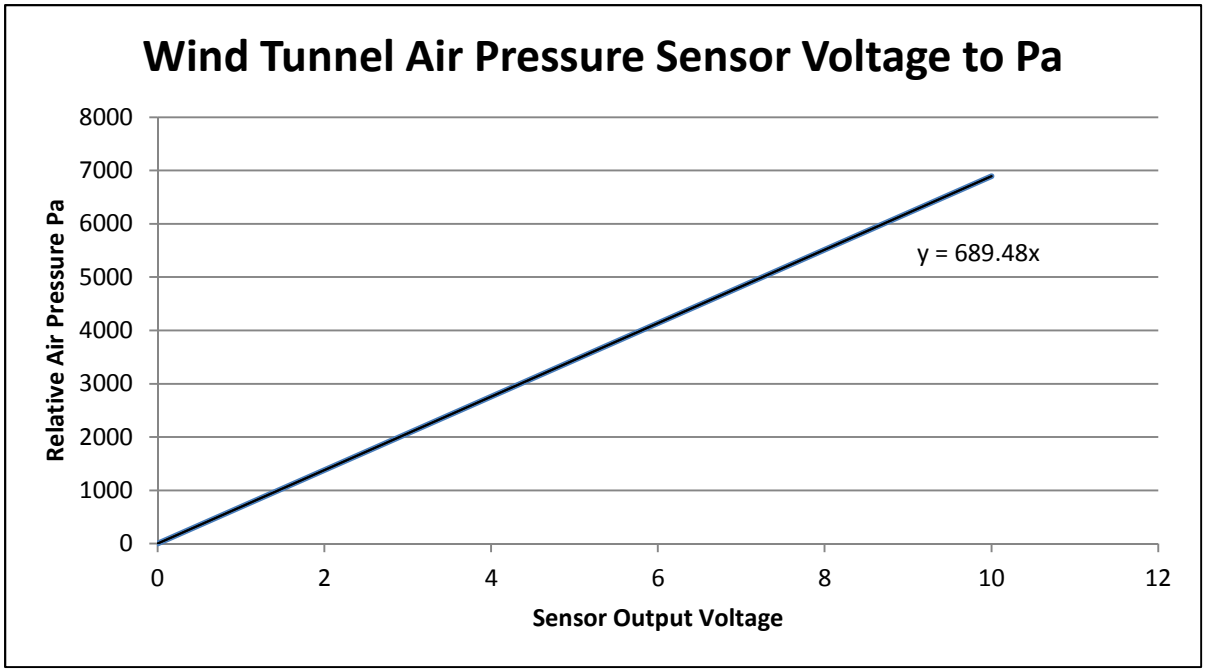


Measurement Conversions

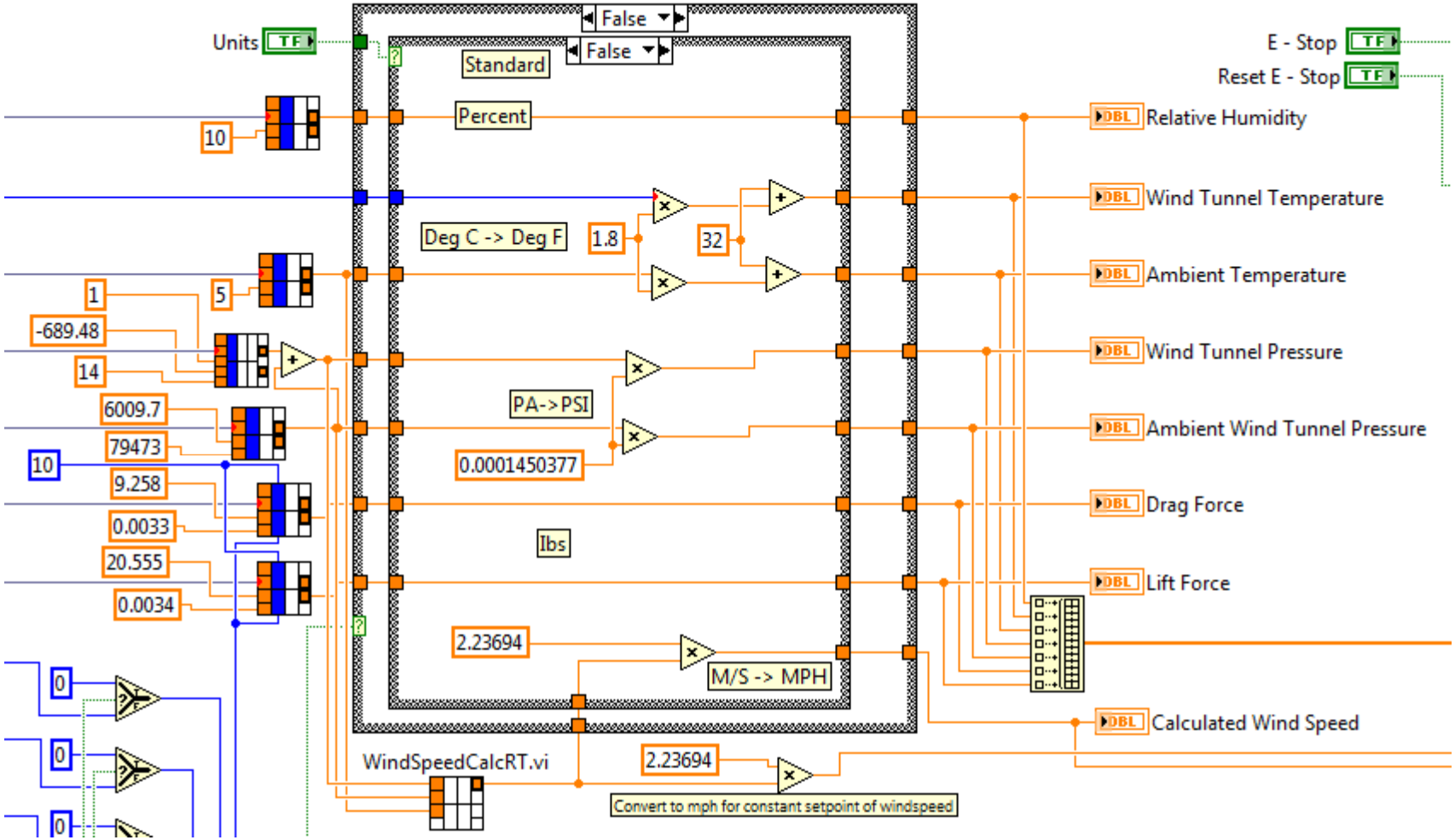

Lift Force Sensor Voltage to lbs
2.5
2
1.5
1
0.5
0
Lift Force lbs
y = 20.555x + 0.0314
0
0.02
0.04
0.06
0.08
0.1
0.12
Sensor Output Voltage


Drag Force Sensor Voltage to lbs
1.5
1
0.5
0
-0.5
-1
-1.5
Drag Force lbs
y = 9.2584x + 0.0033
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
Sensor Output Voltage

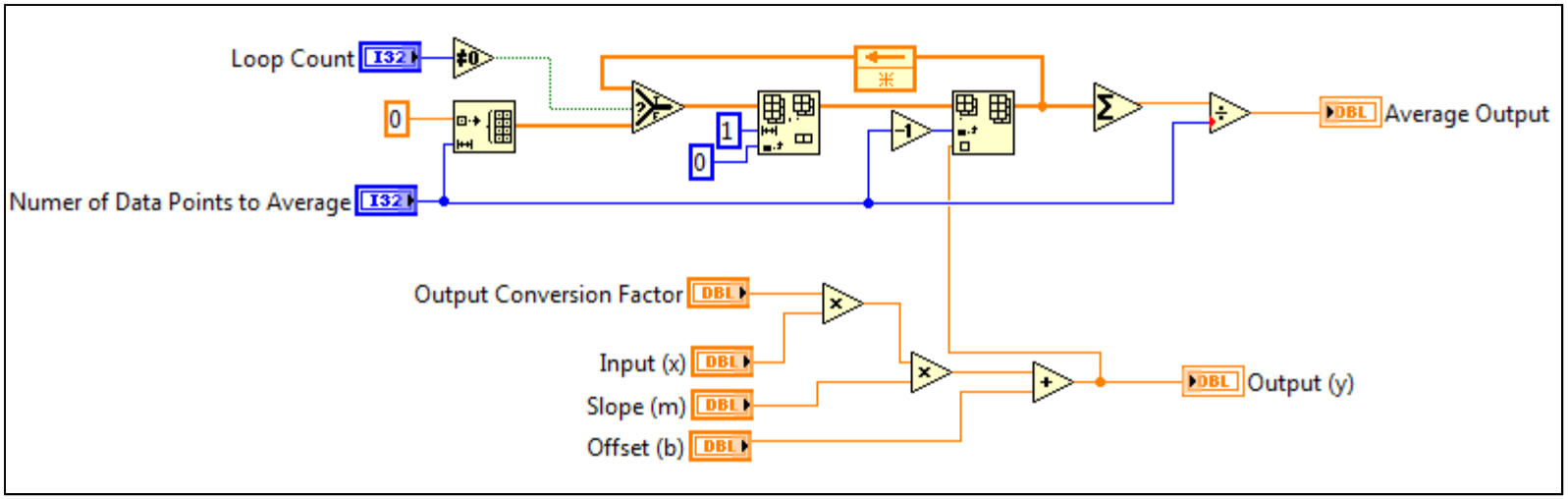

Ambient Air Pressure Sensor Voltage to Pa
120000
100000
80000
60000
40000
20000
0
Absolute Air Pressure Pa
y = 6009.7x + 79473
0
1
2
3
4
5
6
Sensor Output Voltage


Wind Tunnel Air Pressure Sensor Voltage to Pa
8000
7000
6000
5000
4000
3000
2000
1000
0
Relative Air Pressure Pa
y = 689.48x
0
2
4
6
8
10
12
Sensor Output Voltage

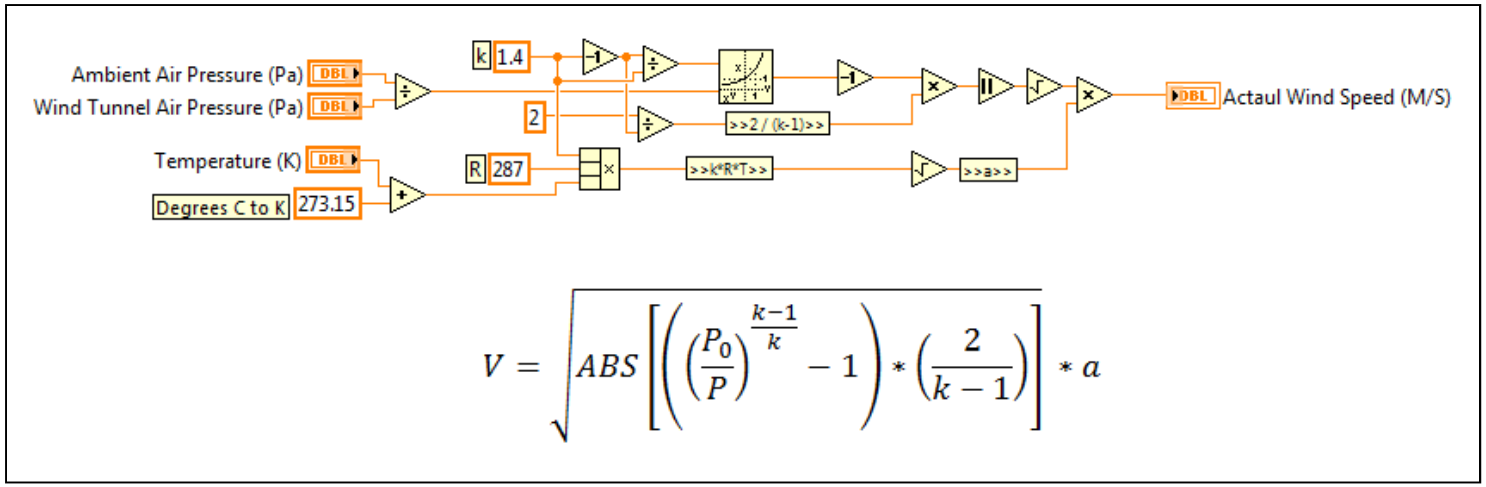
Measurement Conversions



Measurement Conversion Sub VIs



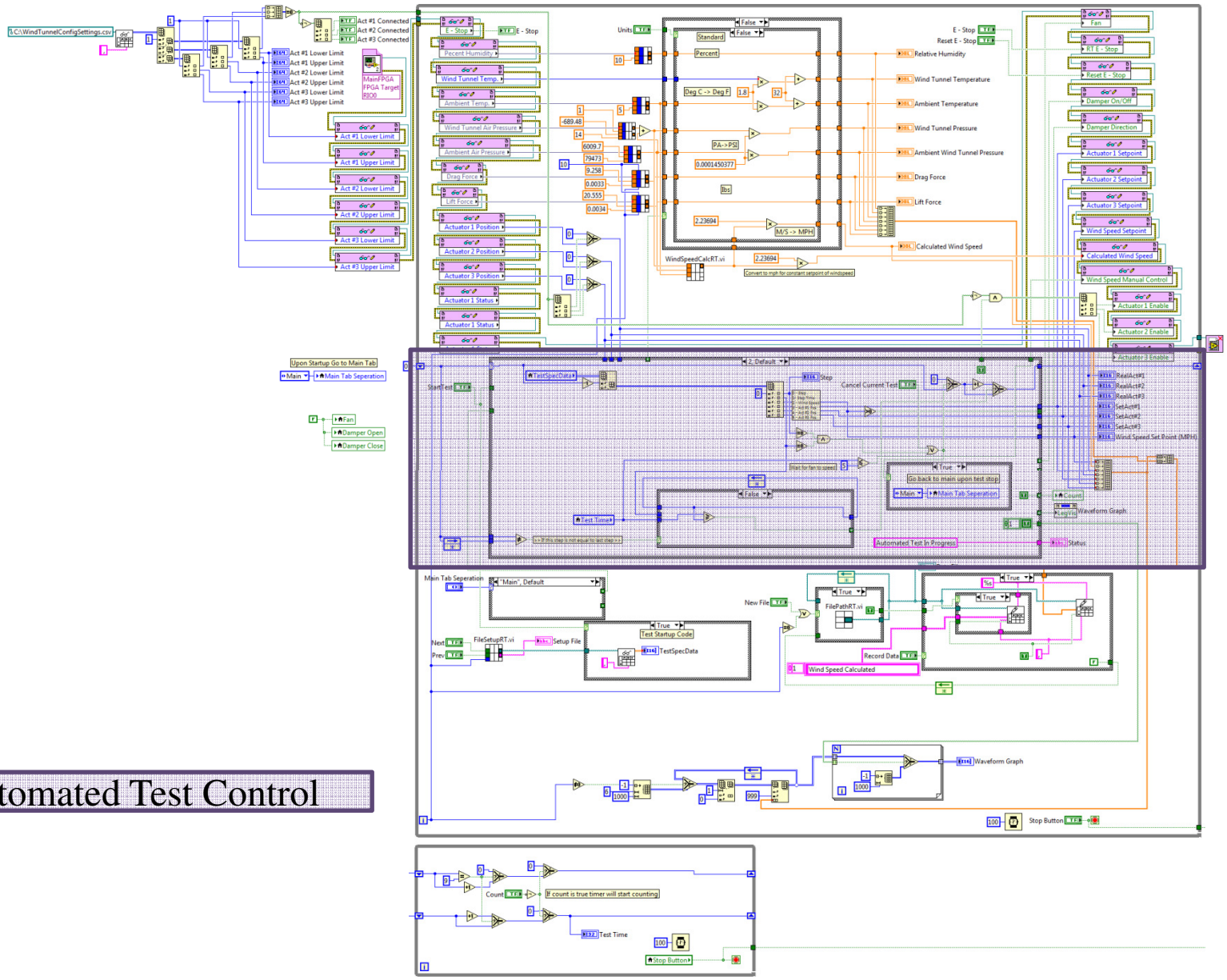
SensorConvRT.VI



$$V = \sqrt{ABS\left[\left(\left(\frac{P_0}{P}\right)^{\frac{k-1}{k}} - 1\right) * \left(\frac{2}{k-1}\right)\right]} * a$$

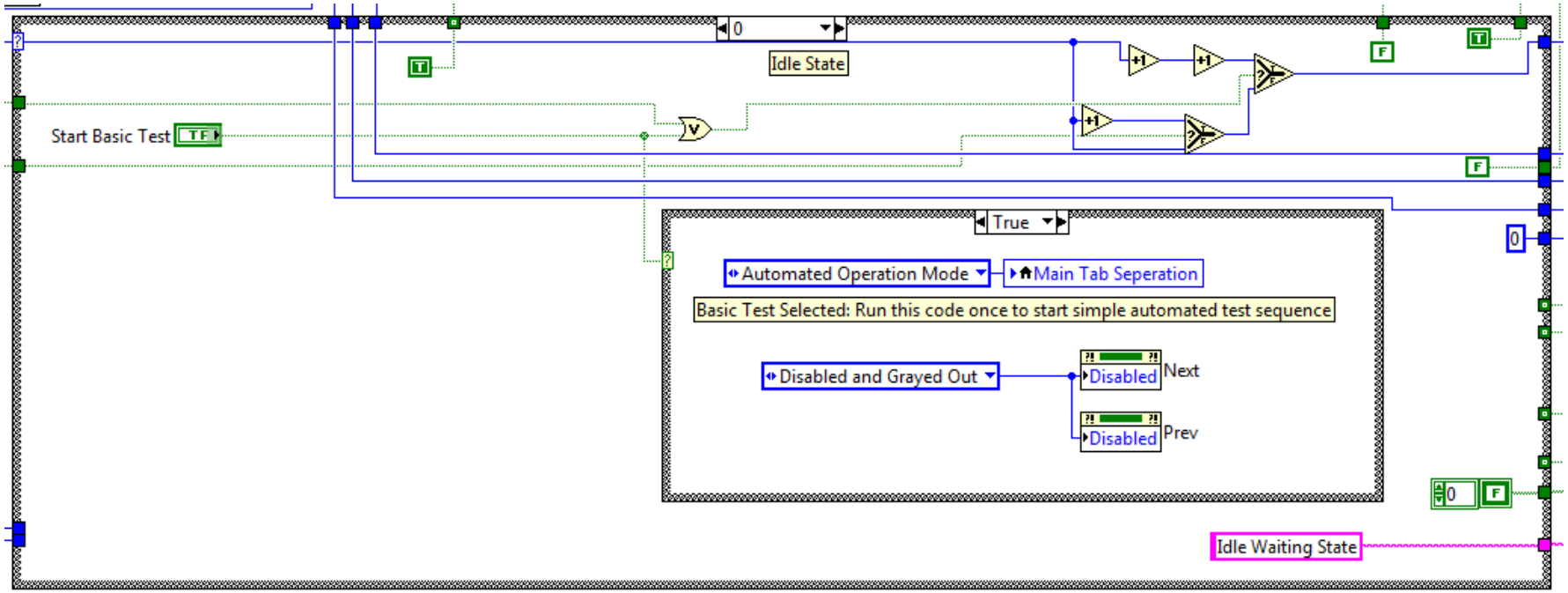
WindSpeedCalcRT.VI

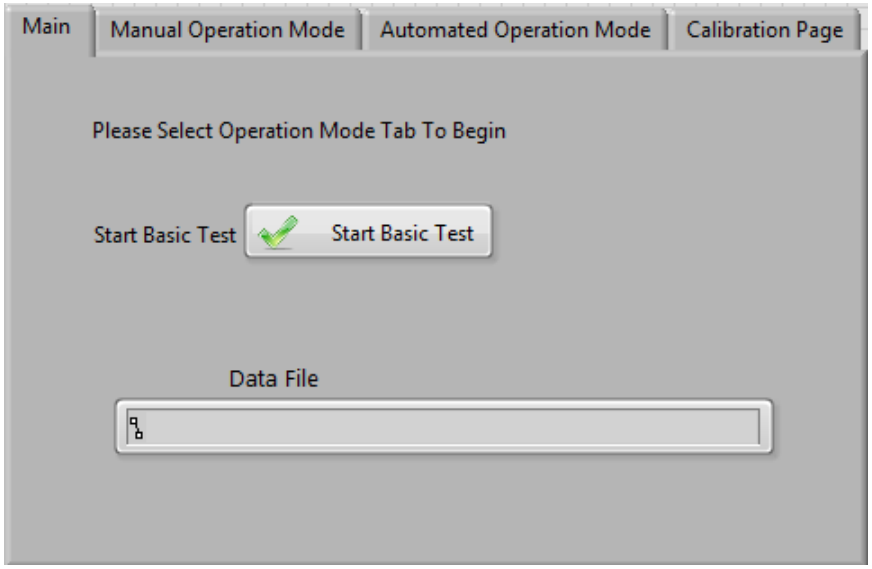
Real Time Target LabVIEW Code



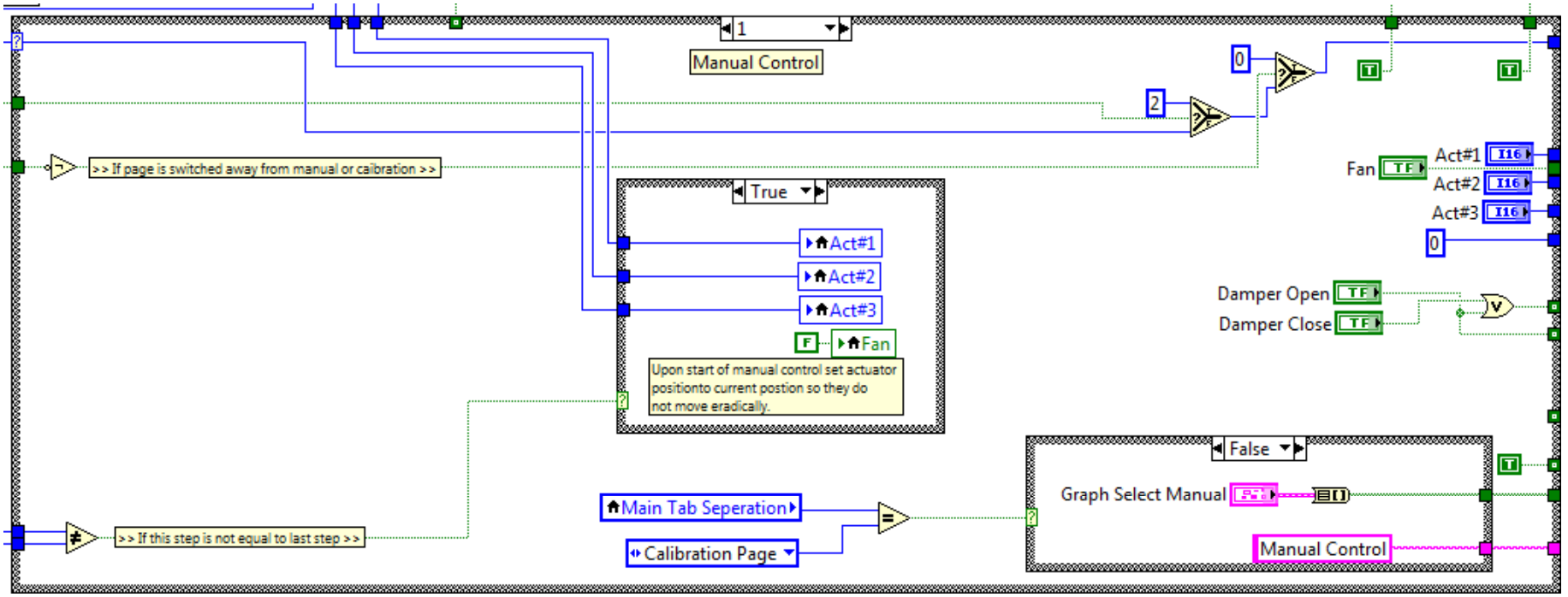
Automated Test Control

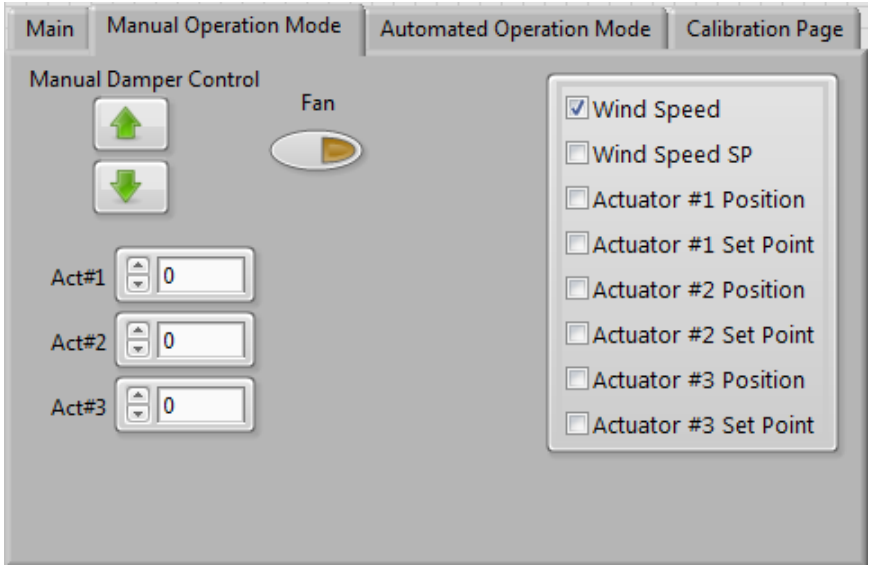
Automated Test Control



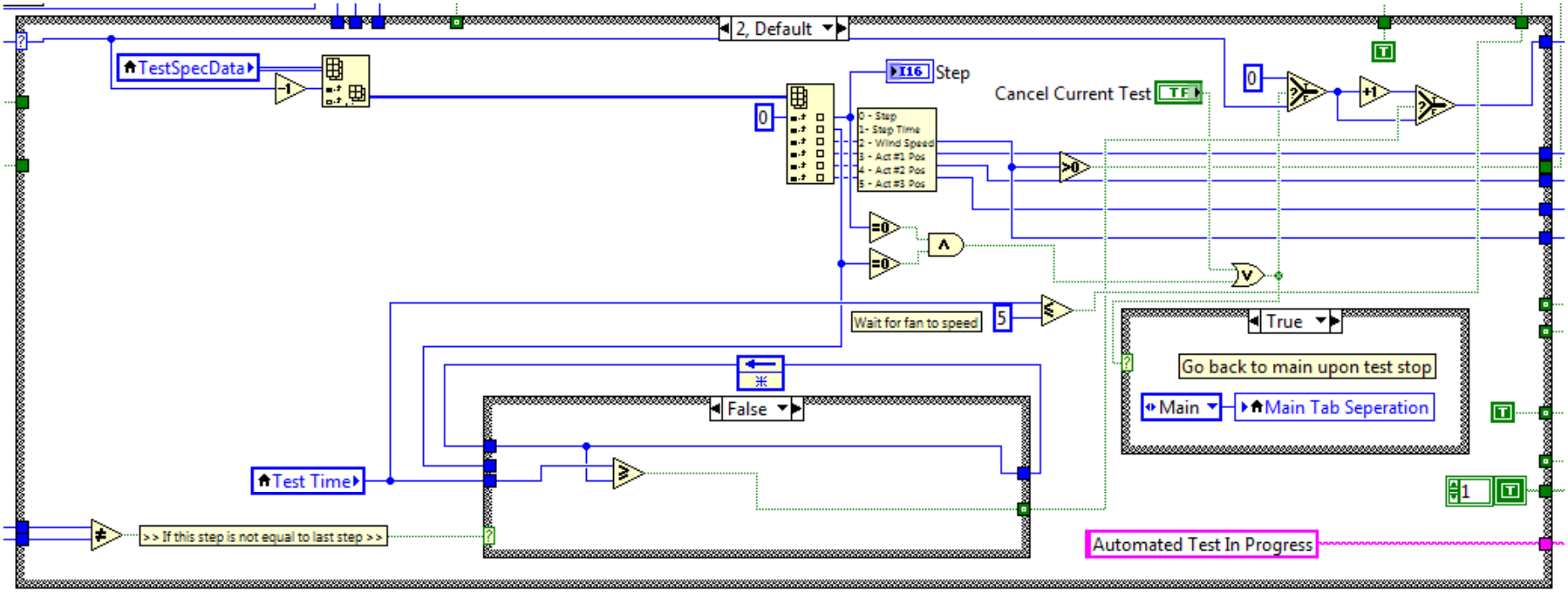


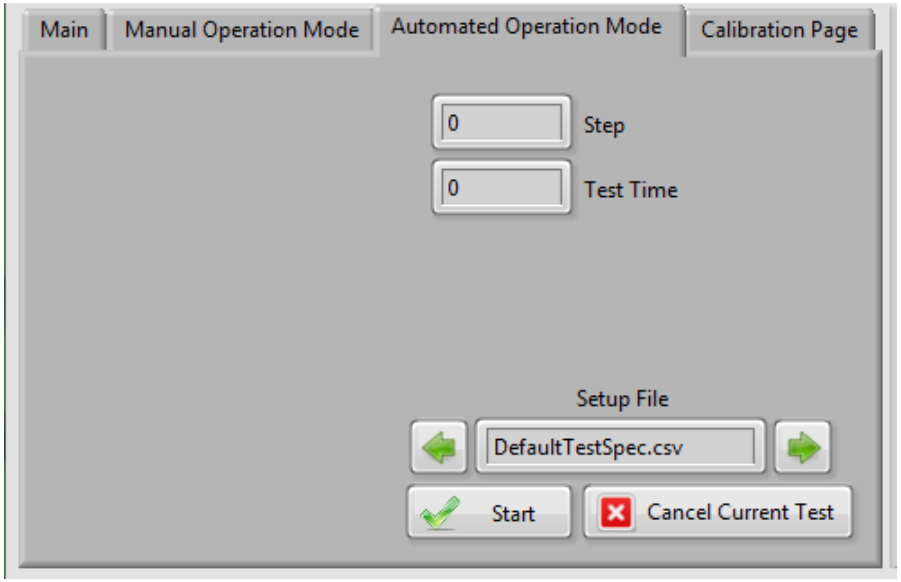
Automated Test Control



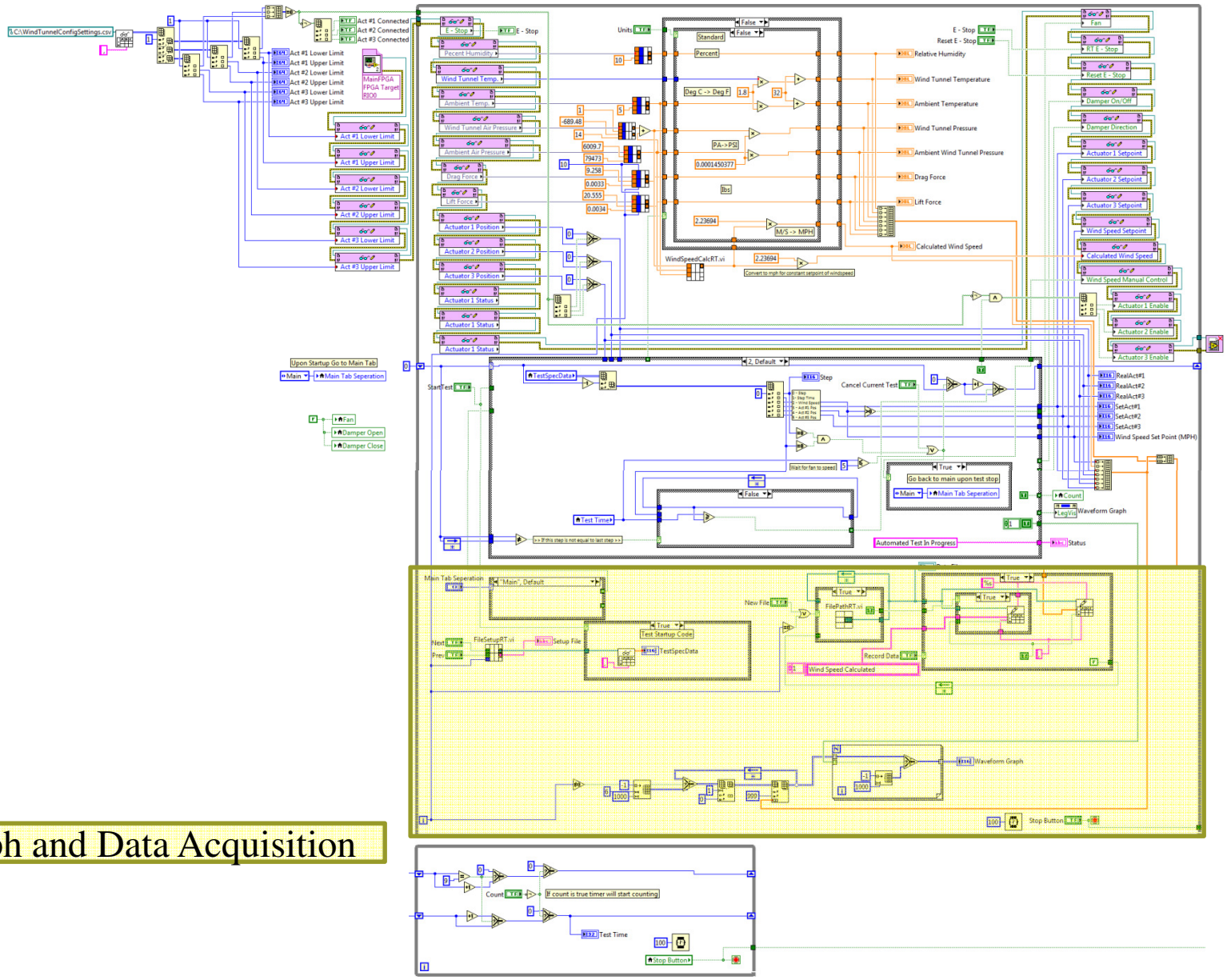


Automated Test Control



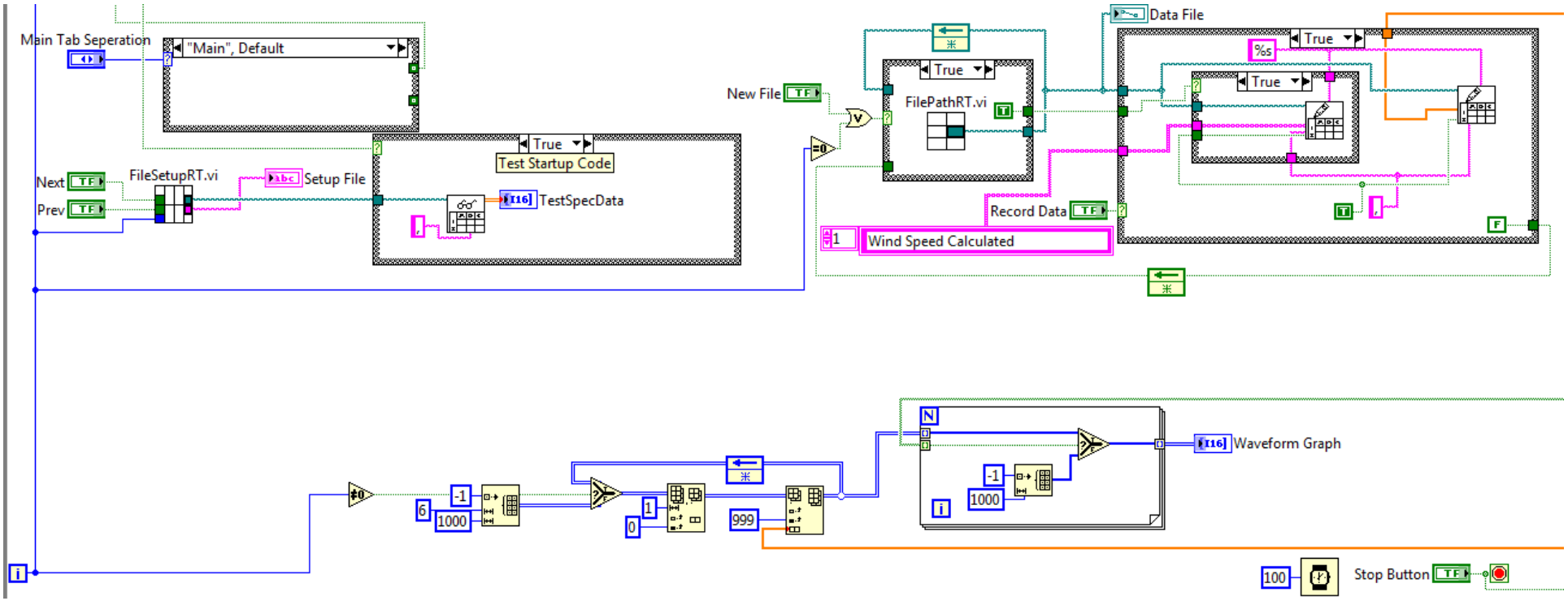


Real Time Target LabVIEW Code



Graph and Data Acquisition

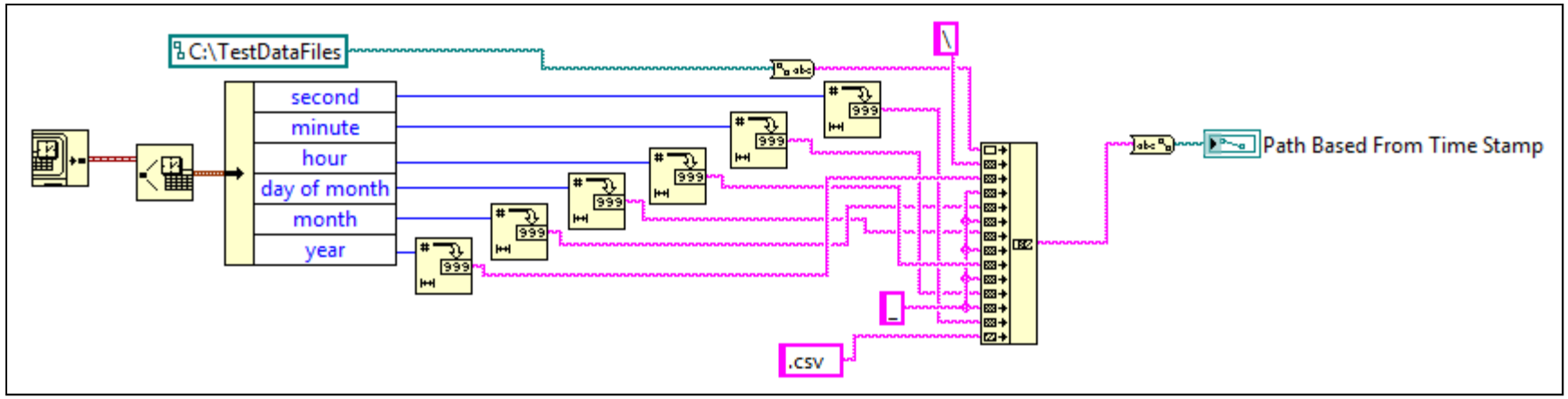
Graphing and Data Acquisition



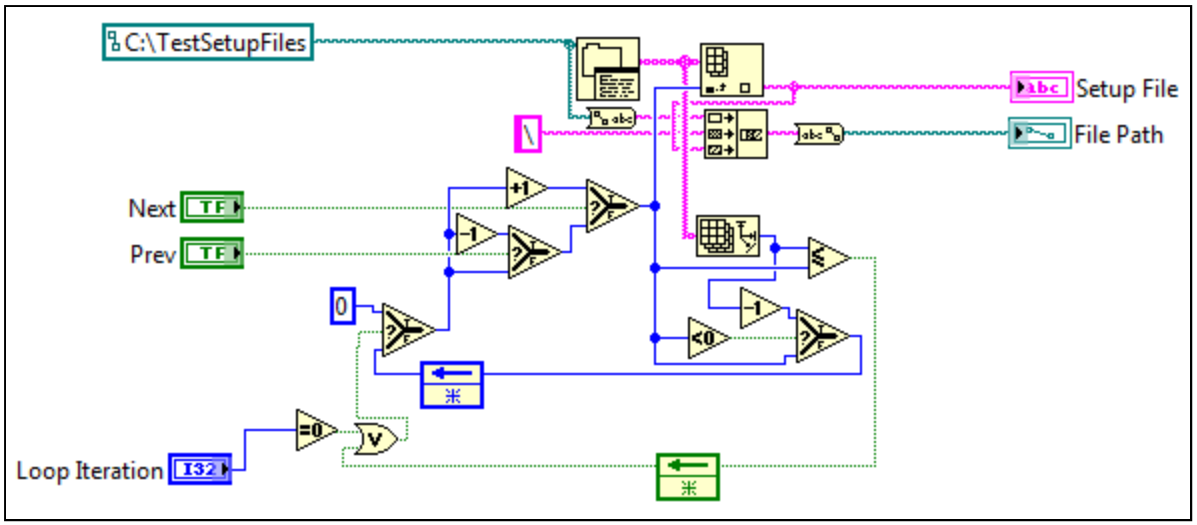
WindSpeedTest.CSV

Step	Step Time (s)	Wind Speed	#1 Actuator Position (mm)	#2 Actuator Position (mm)	#3 Actuator Position (mm)
0	20	50	120	90	0
1	15	50	90	90	0
2	15	50	150	90	0
3	20	70	120	90	0
4	15	70	90	90	0
5	15	70	150	90	0
6	20	60	120	90	0
7	15	60	90	90	0
8	15	60	150	90	0
9	15	80	120	90	0
10	15	90	120	90	0

Data Acquisition Sub VIs

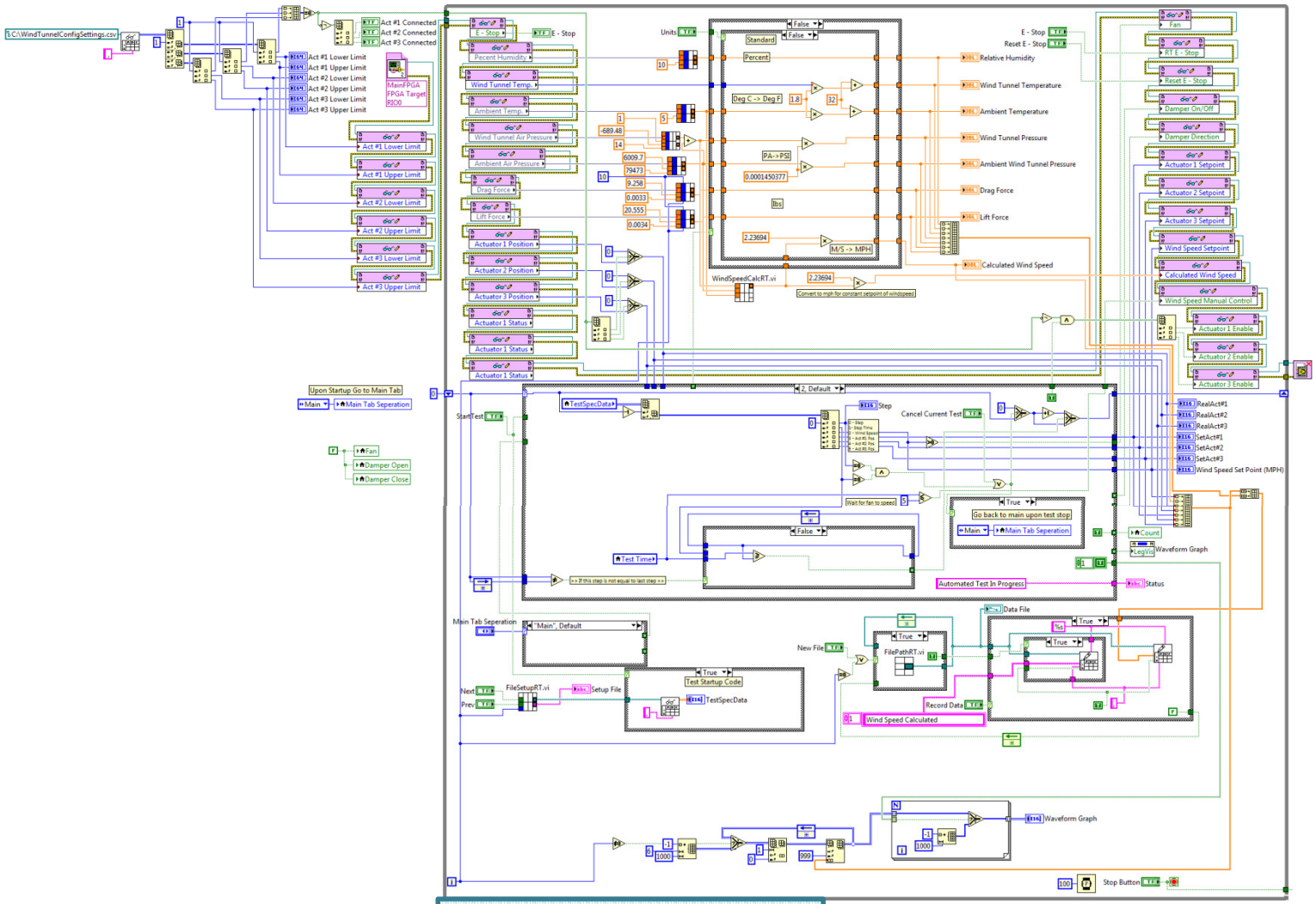


FilePathRT.VI



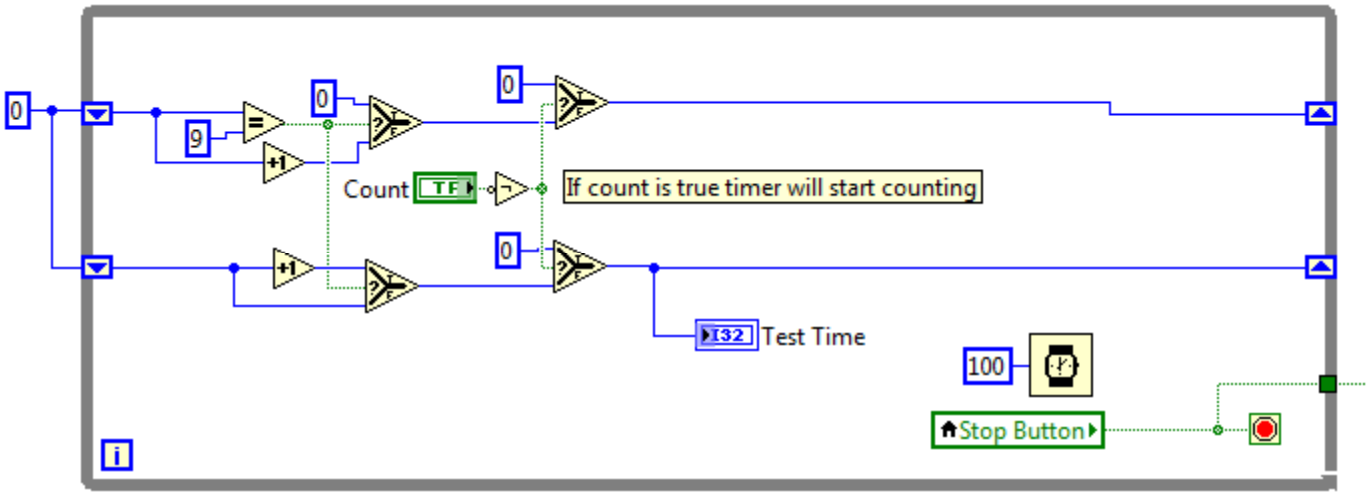
FileSetupRT.VI

Real Time Target LabVIEW Code

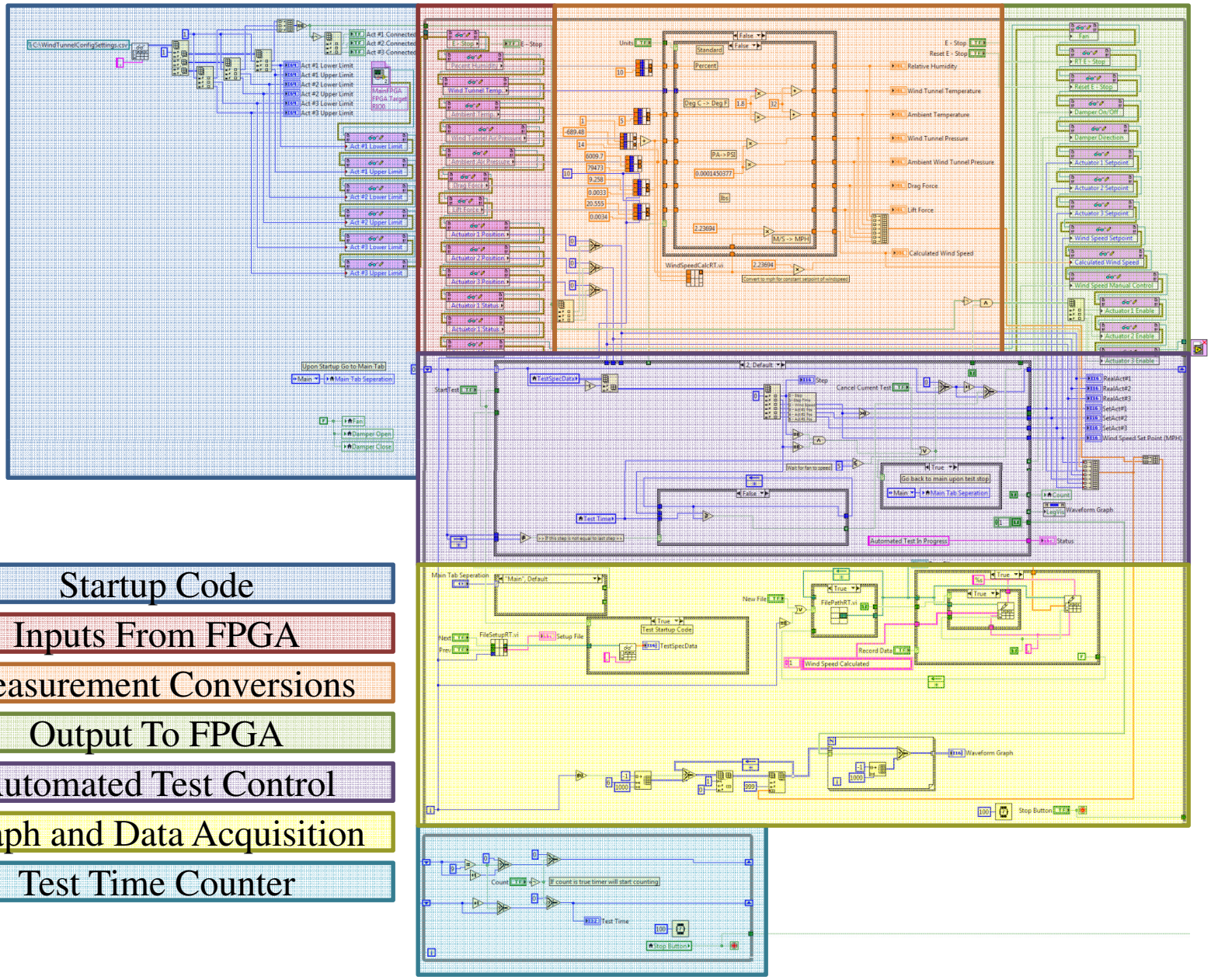


Test Time Counter

Test Time Counter

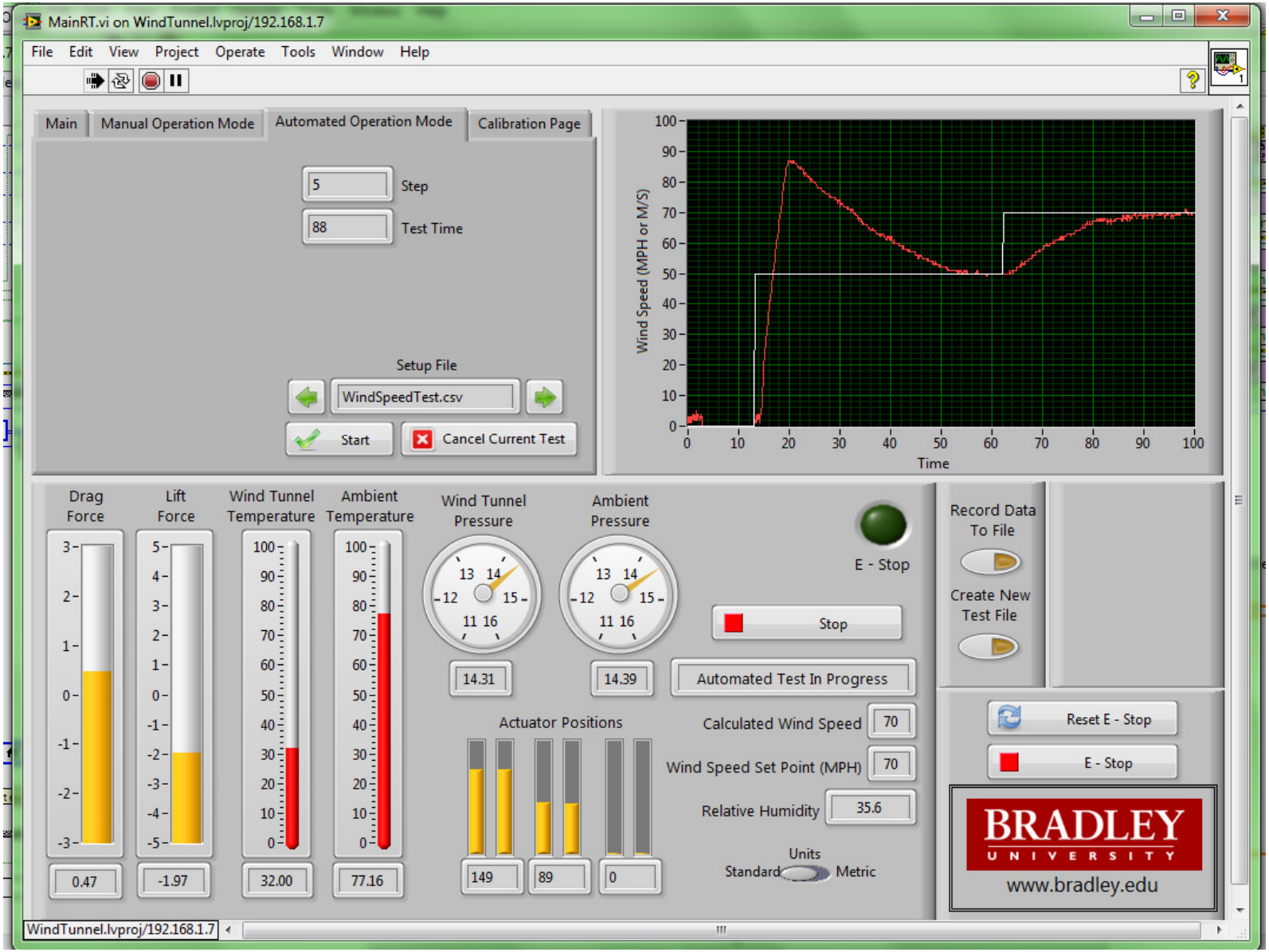


Real Time Target LabVIEW Code

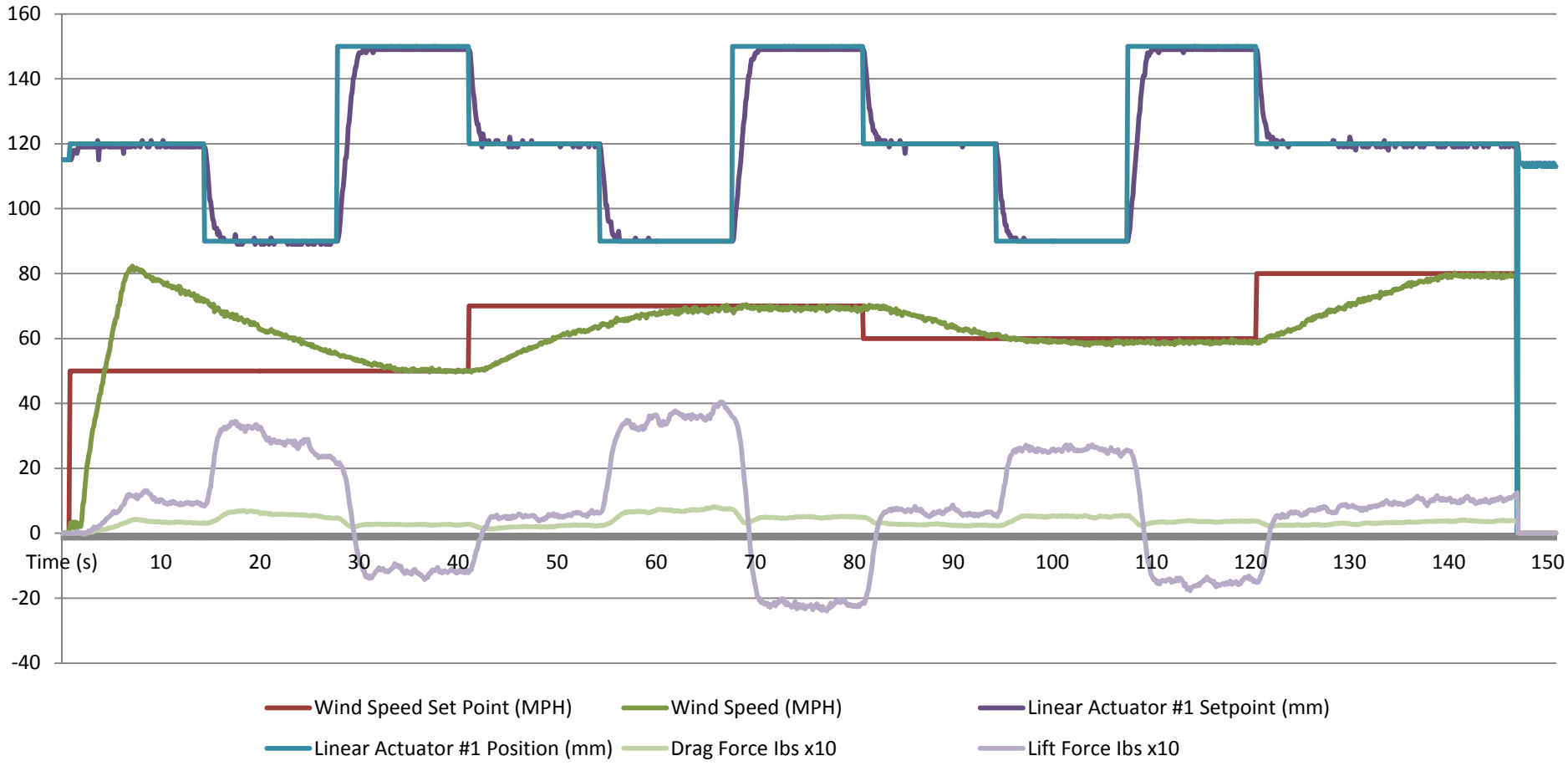


- Startup Code
- Inputs From FPGA
- Measurement Conversions
- Output To FPGA
- Automated Test Control
- Graph and Data Acquisition
- Test Time Counter

Test Results and Debugging



Plot From Test Data Recorded to Spreadsheet



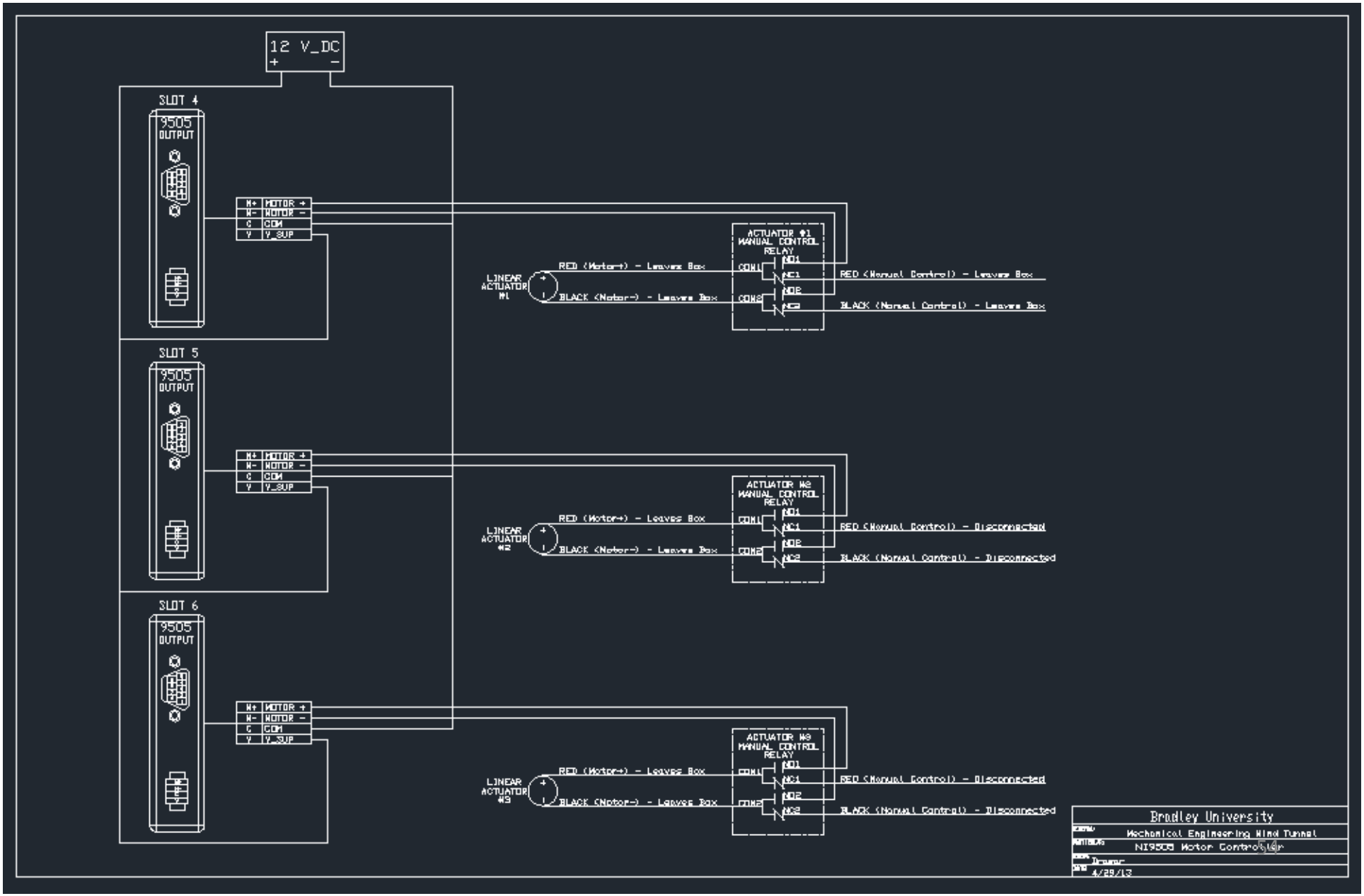
Sources

[1] Ben Morrison and Mike Firman. “Web Enabled Wind Tunnel System”, Senior Project, Electrical and Computer Engineering Department, Bradley University, March 2010, http://cegt201.bradley.edu/projects/proj2010/webwind/

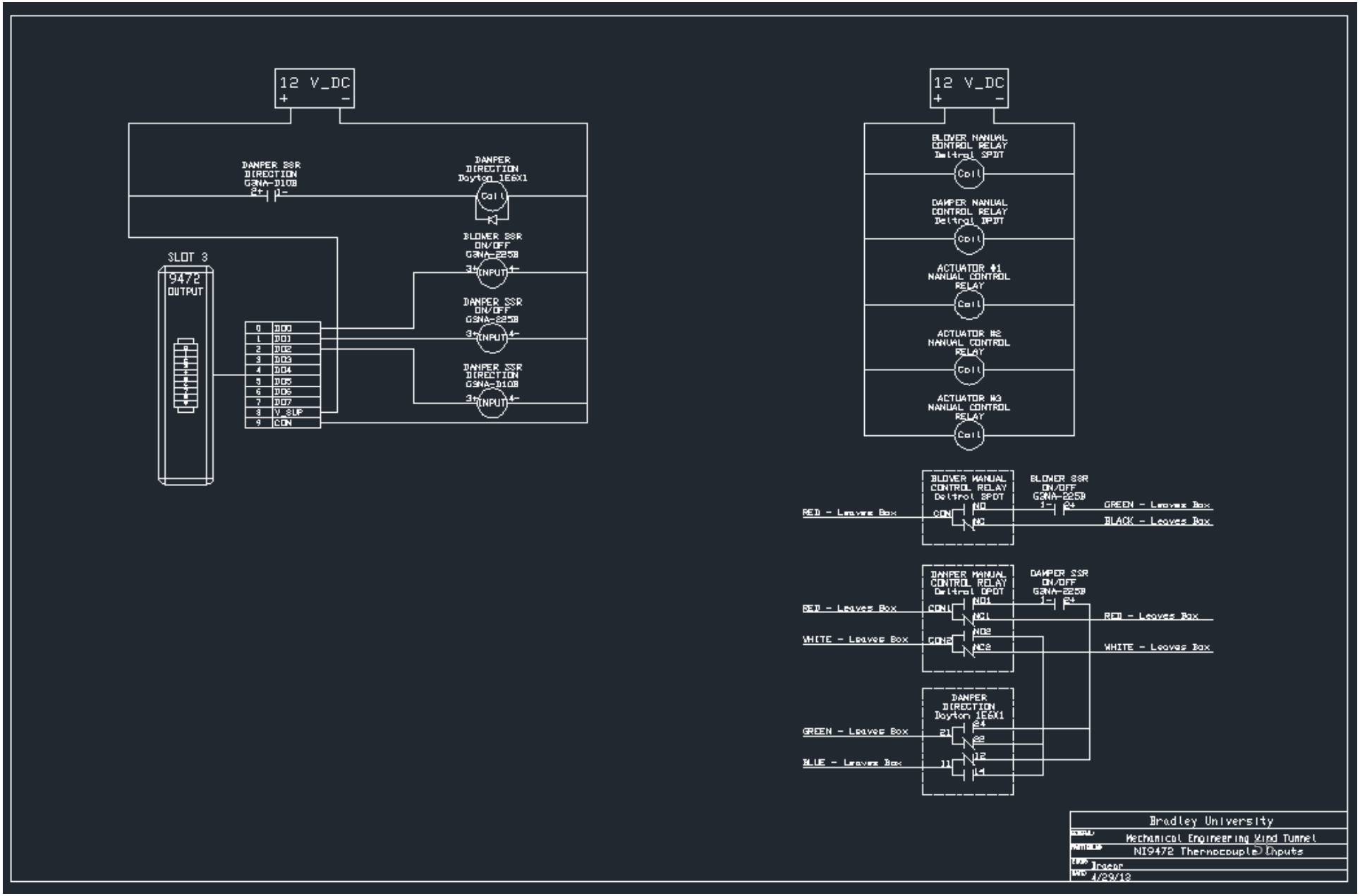
[2] Nick Detrempe and Daniel Monahan. “Automated Industrial Wind Tunnel Controller”, Senior Project, Electrical and Computer Engineering Department, Bradley University, April 2012, http://cegt201.bradley.edu/projects/proj2012/aiwt/

[3] NI CompactRIO, National Instruments, [Online] 2012, http://www.ni.com/compactrio

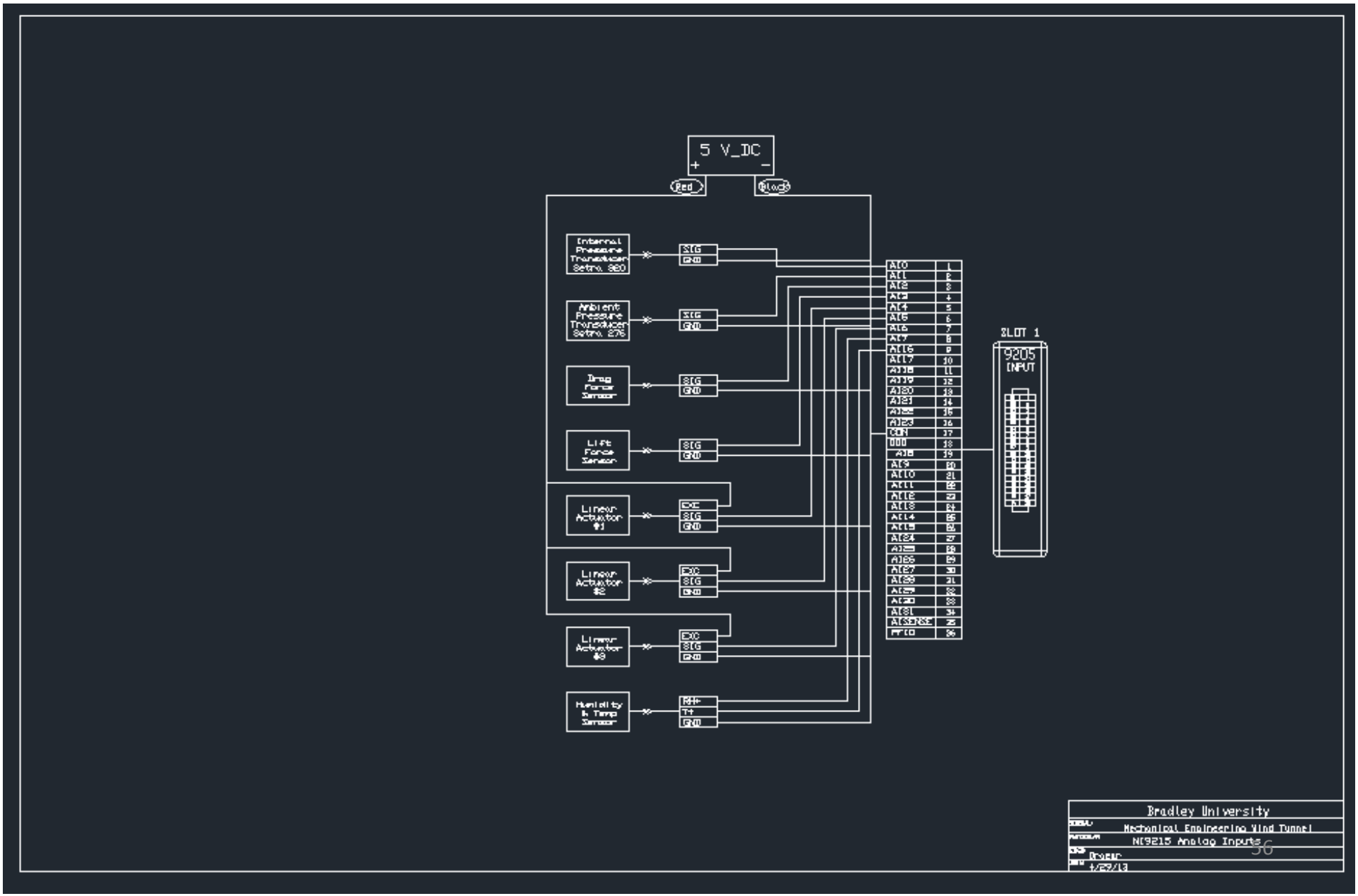
NI 9505 Wiring Diagram



NI 9472 Wiring Diagram



NI 9205 Wiring Diagram



NI 9211 Wiring Digram