Lawnmower Tether Test Control

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Category:
Mechatronics

Products Used:
cRIO-9004 Real-Time Controller with 64 MB DRAM, 512 MB CompactFlash
cRIO-9103 4-Slot, 3 M Gate CompactRIO Reconfigurable Embedded Chassis
NI 9205 32-Ch ±200 mV to ±10 V, 16-Bit, 250 kS/s Analog Input Module
NI 9403 32-Ch, 5 V/TTL Bidirectional Digital I/O Module
NI 9263 4-Channel, 100 kS/s, 16-bit, ±10 V, Analog Output Module
NI 9211 Thermocouple Module
NI WAP-3701 802.11g Wireless Access Point
LabVIEW Real-Time 8.2.0
LabVIEW 8.2.0
NI RIO 2.3.0
LabVIEW FPGA 8.2.0
LabVIEW Internet Toolkit 6.0.0
LabVIEW PID Control Toolset

Exlar Tritex TLM-20-0601 Six inch stroke intelligent actuator
Exlar Tritex TLM-20-1201 Twelve inch stroke intelligent actuator
O'Conner Engineering Analog Low Speed Ground Speed Sensor
Zahn DCDC12/24/300 12-to-24VDC Upconverter
Stahlin Enclosures
Unimeasure LX-PA-10 Analog Position String Potentiometers
Moxa ANT-1-O-09 Omni directional Antenna for WAP-3701
Banner QS18VP6LV Retroreflective Photoelectric Sensor

The Challenge:
Develop an automated system to control a tethered tractors engine speed and ground speed for extended quality control testing. The control system had to be robust enough to withstand high vibrations induced from obstacles in the tractor's path such as ramps and speed bumps. Wireless communication to a base station PC running a LabVIEW Windows based Host program would allow remote starts and extended data logging and intermittent test status updates for operators.

The Solution:
The solution was based around the robust cRIO platform. LabVIEW Real-Time and LabVIEW FPGA allowed a stand-alone automated control and monitoring system (Figure 1) to be installed on the tractor. An intelligent system architecture allowed for a reconfigurable on-board system that could be tailored to multiple test unit types.

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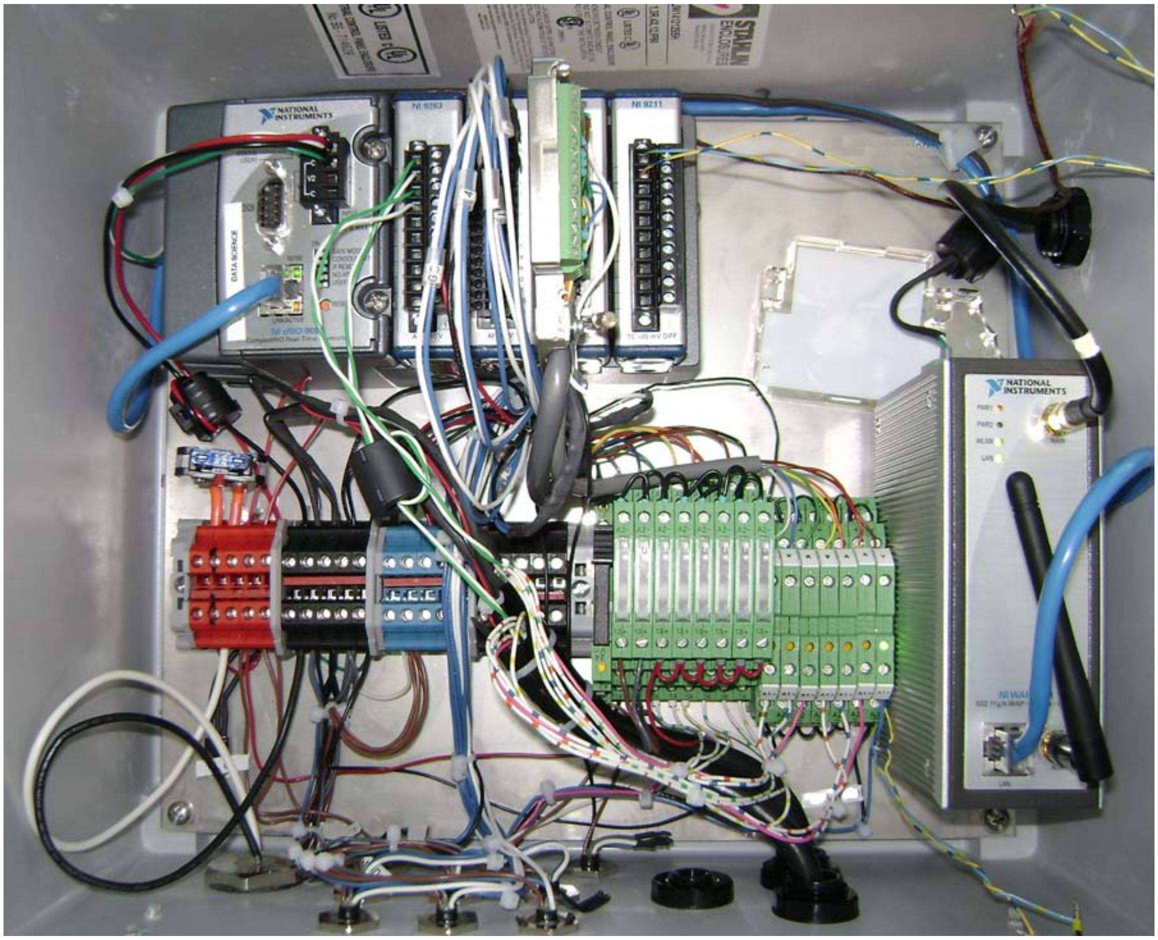

Figure 1 – cRIO Control System with WAP-3701 for 802.11g Wireless Communication (during assembly)

Abstract:
A lawn tractor manufacturing company desired to automate tethered tractor quality control testing to increase test engineer safety and increase data collection capabilities. Data Science Automation was able to provide a robust platform to withstand the outdoor testing environment and high vibration induced by the tracks built-in obstacles such as ramps and bumps. Data collected from the system is used to increase the robustness of the tractor components and also pinpoint component failure areas.

The LabVIEW PID Control Toolset allows the cRIO unit to control the engine speed and ground speed of the tractor through electric actuators manipulating the tractor controls. Using the LabVIEW Real-Time and LabVIEW FPGA modules the system was configured to read an engine RPM sensor and ground speed sensor to provide the feedback to the PID control loops.

Long Distance Calls
The WAP-3701 attached to the cRIO-9004 allows communication to a host laptop running a Windows LabVIEW program. The host program is used to remotely start the executable cRIO program as well as send updated control parameters to the cRIO unit. See Figure 2.

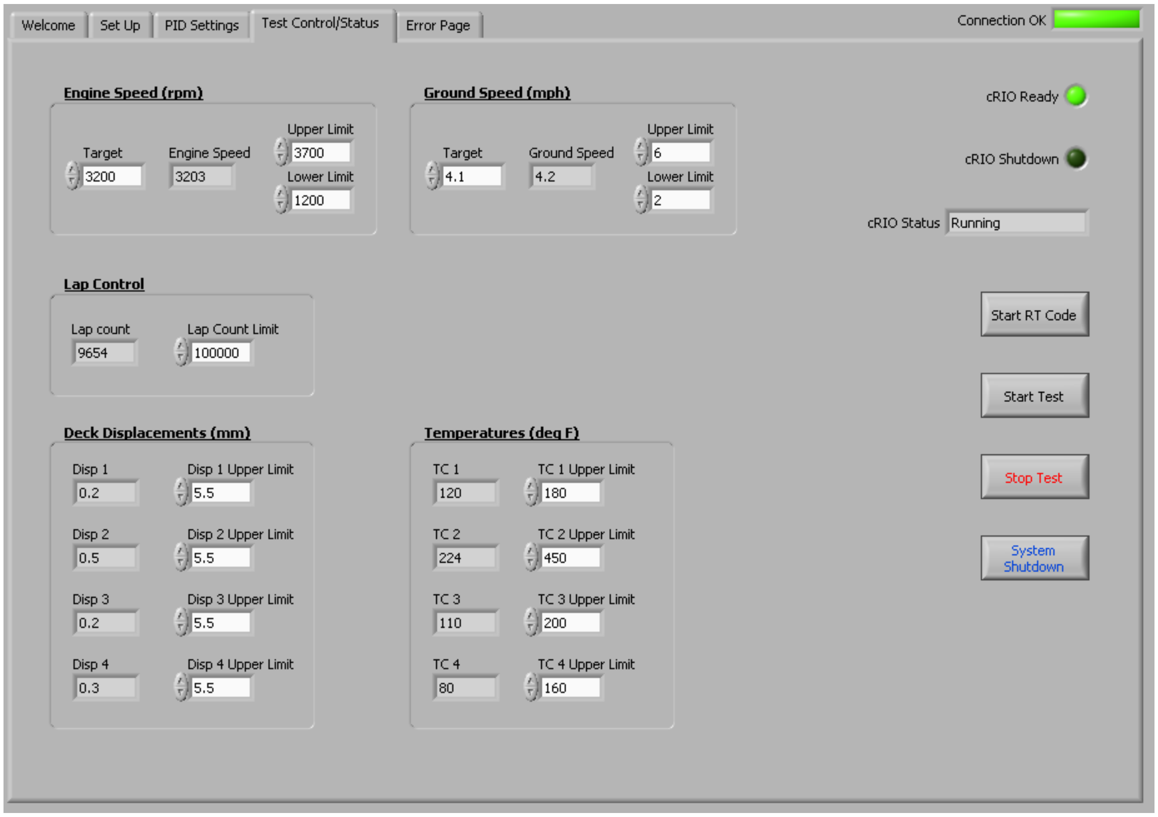

Figure 2 – Windows Host Program - Test Control/Status Tab

When connected to the cRIO via the wireless network the laptop computer receives periodic updates via shared variables to indicate the current status of the tractor during ongoing testing.

Playing it Safe

One of the main reasons for moving this test to a stand alone system was to remove the tractor operator from the area where the tractor is running on the course. Another safety feature incorporated into the system was a light curtain that covers the open area inside the outer fencing that surrounds the system.

The NI 9403 module was wired with a digital input from the safety light curtain. FPGA code was written to monitor the state of the light curtain. At any point if a person crossed the light curtain the FPGA code would fire an interrupt that the 9004 Real Time controller LabVIEW code could respond to without polling. Utilizing the interrupt instead of polling for the status of the safety bit in the real time code prevents the missing of the state change data, which in this case would be unacceptable. See Figure 3.

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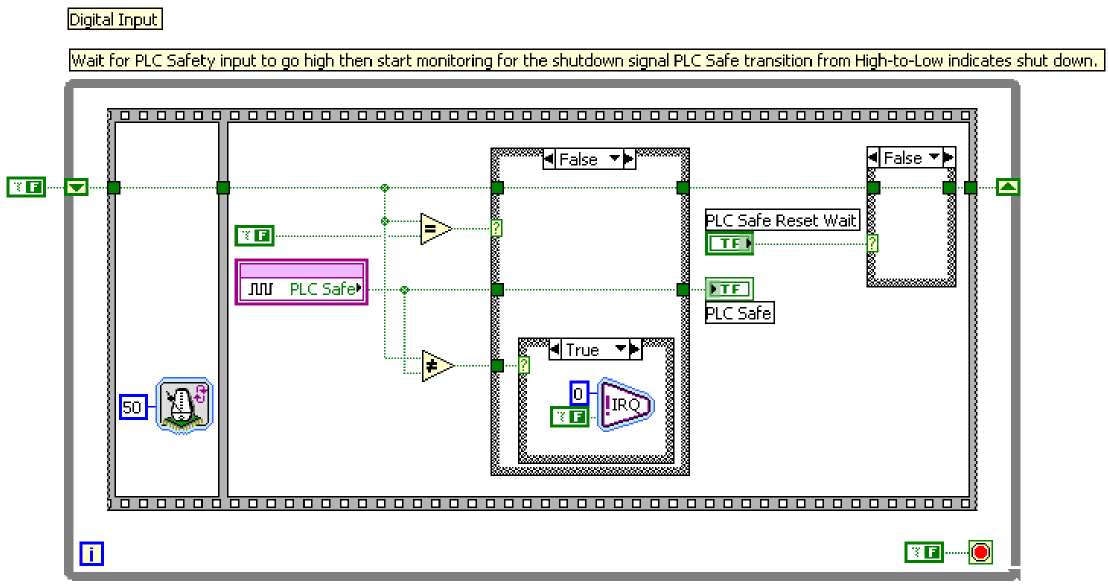

Figure 3 –FPGA Code – Safety Input Line Monitor

The Real-Time system code utilizes the Wait on IRQ method to monitor for the status of the safety bit. If the interrupt is received in the Real-Time code, the engine kill circuit is immediately turned off and the rest of the sub-system State Machines are notified of a Safety shutdown by a functional global. See Figure 4.

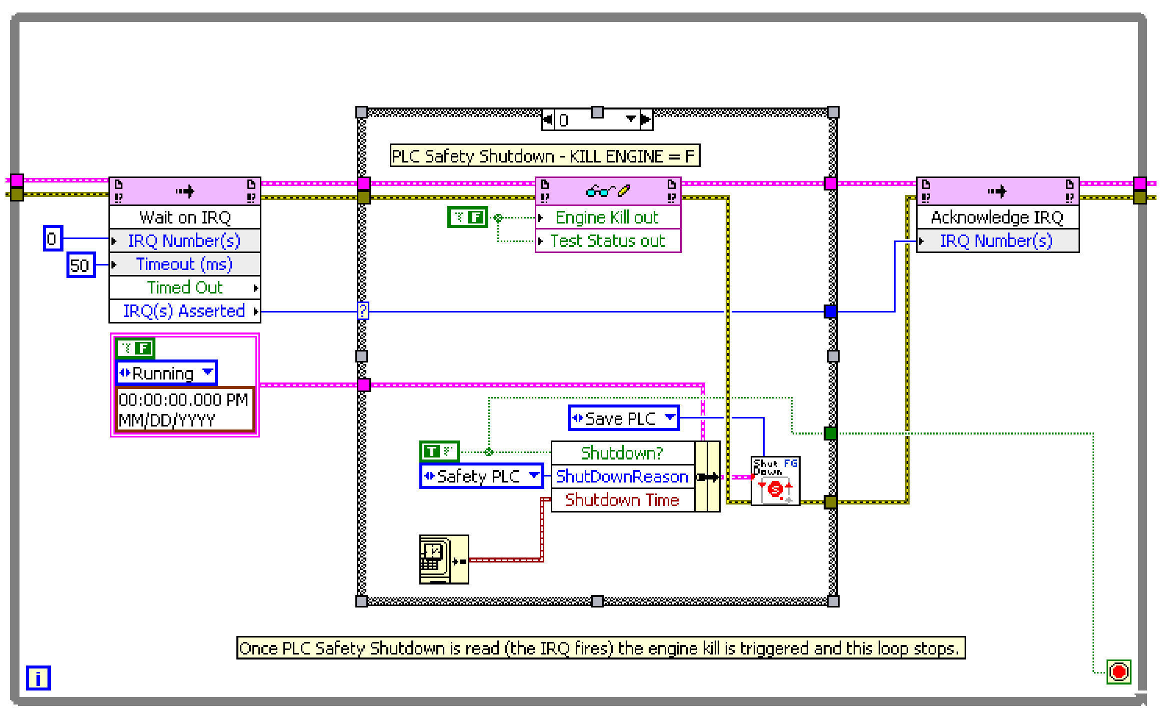

Figure 4 – Real-Time Wait on Interrupt – Safety Input

The use of the functional global allows the two actuator state machines to respond by immediately returning their associated actuators to the home (zero) positions, halting forward motion of the tractor even if the engine kill circuit were to fail.

Cruise Control

Of the two PID loops running on the cRIO Real-Time software, the ground speed control loop is the key feature of this system that lets it run without the need for an on-board operator. The FPGA is used to read in the analog voltage speed signal from the ground speed sensor mounted on the back of the tractor. The Real- Time code converts the binary voltage readings into Engineering Units of MPH based on the user defined sensor sensitivity.

The Ground Speed PID loop running on the Real-Time target utilizes the PID Control Toolset for determining the 0-10V output level to the linear actuator connected to the forward drive control stick. The PID gains are sent to the cRIO unit from the Laptop at the start of the test, and any time the user has changed one of the gains. PID control of the ground speed is not engaged until the operator selects a ground speed target set point greater than zero mph. The NI 9263 Analog output C Series I/O module handled the analog output to the Tritex controller.

If the Ground Speed is detected to be outside the upper or lower limits set by the operator on the Windows Laptop, the Ground Speed PID loop shuts down the system.

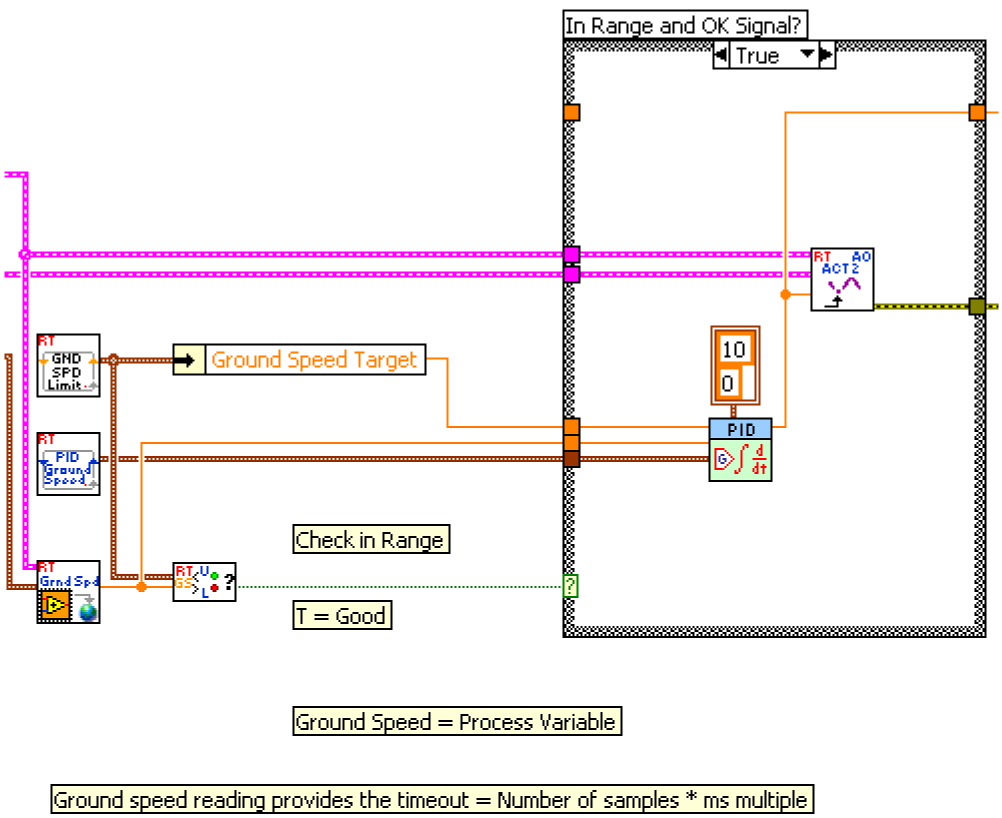

Figure X – Ground Speed PID Control Loop Code

The second PID loop running on the cRIO unit is the engine speed control loop. This control loop keeps the engine RPMs at the desired speed set by the test operator. The FPGA code keeps track of the number of pulses read by the photoelectric sensor and the elapsed time between the desired number of pulses and sends this information back to the RT code for motor RPM calculation.

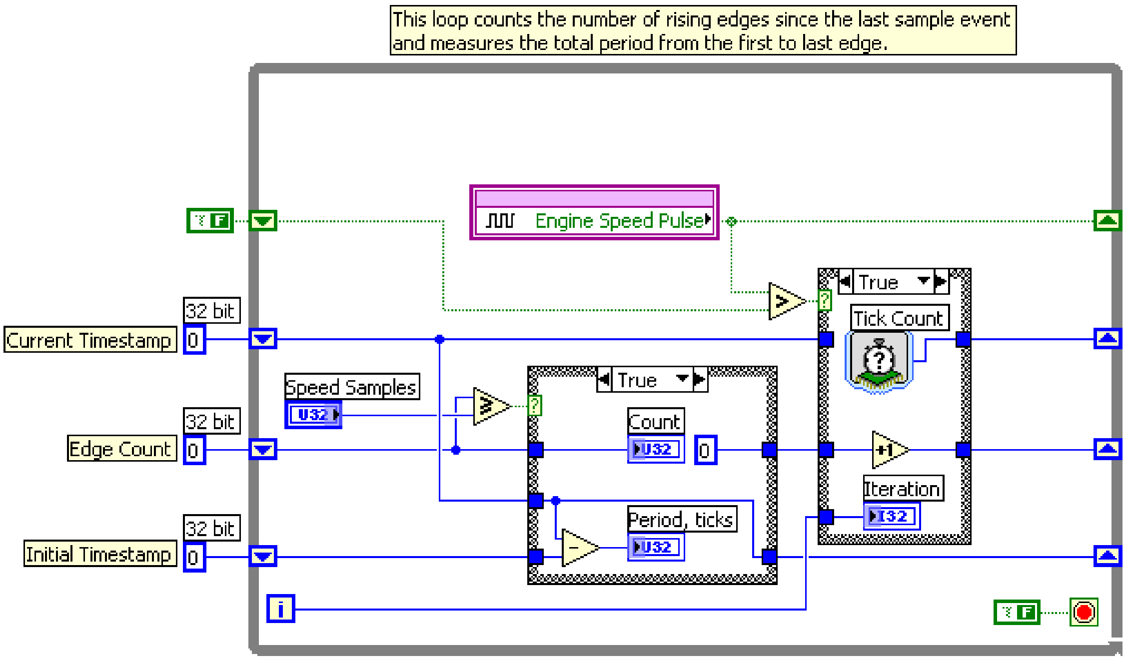

Figure X – FPGA Custom Counter – Engine Speed

The Real-Time state machine for the control of engine speed converts the counts per period into the engine RPM and this is used as the feedback to control the 0-10V analog output to the Tritex Actuator connected to the engine throttle stick. See figure X. The NI 9263 Analog output C Series I/O module was again utilized to handle the analog output to the throttle system Tritex controller.

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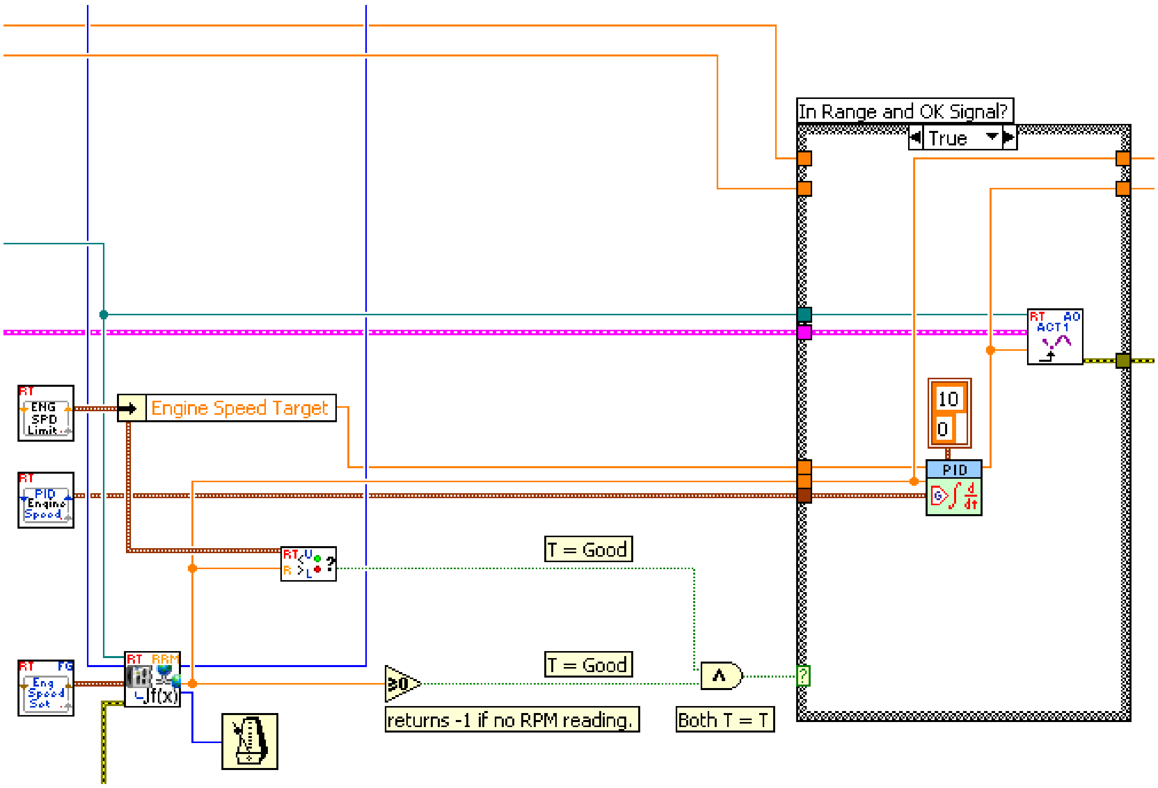

Figure X – Engine Speed PID Case of State Machine

The Ground Speed PID control loop is designed to shut down the tractor system if it does not receive an actual update from the FPGA code or if the Engine Speed is sensed to be out of range of the lower limit and upper limit bounds. During throttle up the control logic does not apply the lower limit until the Engine RPM is detected to be above the minimum RPM.

Self Empowerment

Even though this system is running on a tethered tractor the customer desired that the power for the entire system including the cRIO, wireless access point, and motion actuators come directly from the 12V system already in place on the tractor. This was not a problem for the WAP or the cRIO system which can both run on twelve volts input power.

The two electric actuators in the system that control the ground speed transmission stick displacement and the throttle displacement required a minimum of 24 volts DC. This power requirement was handled by selecting the Zahn DCDC12/24/300 12-to-24VDC Upconverter. See Figure X.

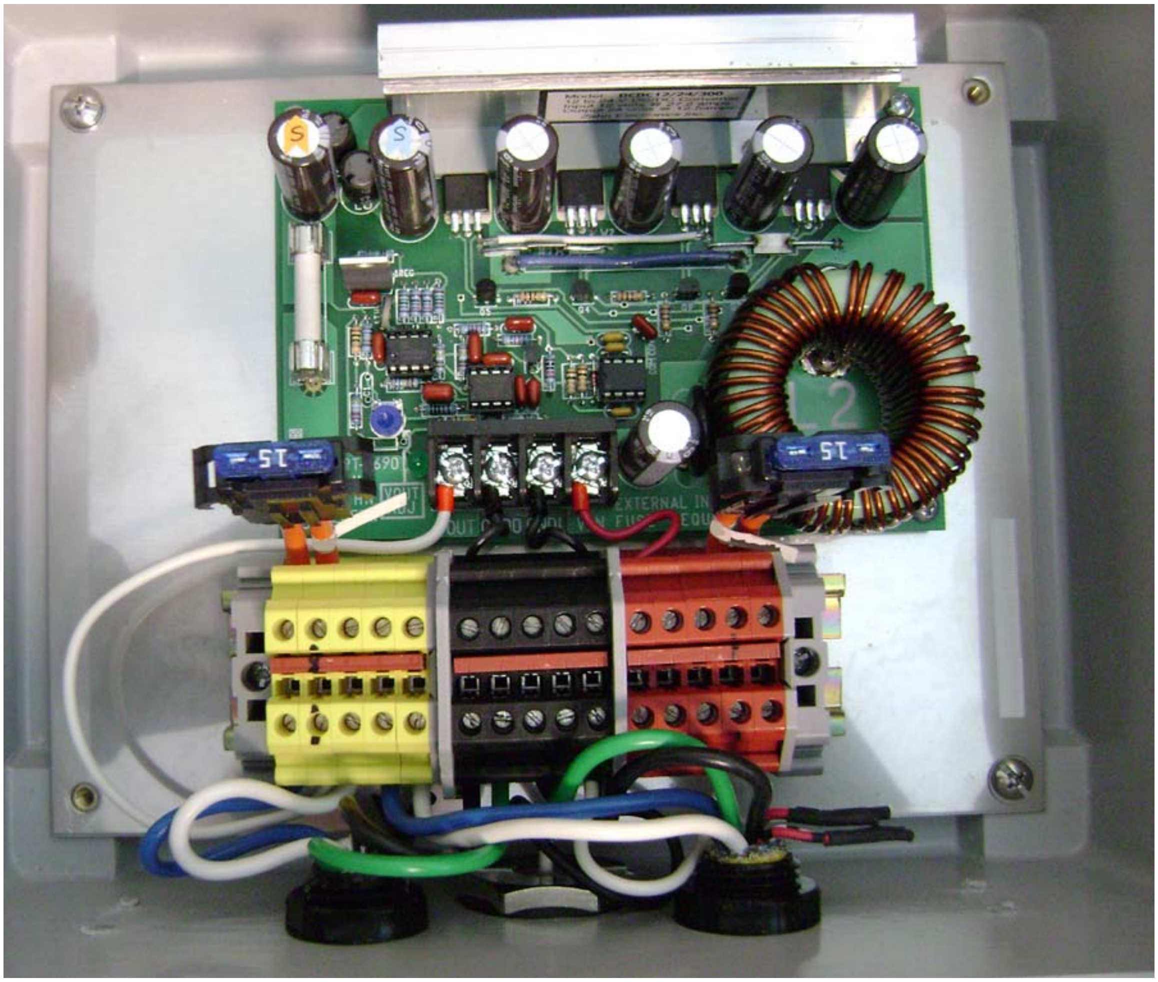

Figure X – 12V to 24V Step Up Converter from Zahn Electronics

This DC/DC Step Up converter is able to output a maximum of 300 Watts of power. This was more than enough output to handle the draw from the two Tritex TLM20 actuators.

The other challenge for powering this system was sourcing a five volt DC source for use in the relay system to drop the 12V incoming relay logic signals to the 5V DC level required by the NI 9403 C Series Module. The 5V DC source for the NI 9403 module and relays was created by utilizing a Fairchild Semiconductor LM7805 3-Terminal 1A Positive Voltage Regulator. The one amp rating provided more than enough current to drive the low level relays and inputs on the NI 9403 Bidirectional Digital I/O Module. The LM7805 input pin was wired with the tractor 12V source power and the 5V DC output was then routed to the blue terminal blocks in the cRIO control box for distribution to the necessary sub-systems.

Data Collection

The main reason for obstacle course testing of the tractor units is to help determine tractor component life cycles and design robustness. Towards this end the cRIO system is configured with the C Series NI 9205 32 channel 16-Bit Analog Input Module and C Series NI 9211 Thermocouple Module.

The 9205 Analog Input Module is utilized to measure string displacement potentiometers that are attached to the mower deck. These potentiometers are utilized to track the displacement of the deck. The operator has the ability to set the displacement limits on a per sensor basis. If the cRIO system detects that a displacement sensor has extended beyond the limit set by the test operator the system records that as a system failure and shuts down the test.

In addition to the displacement sensors up to four temperature sensors can be placed on tractor subcomponents such as the engine compartment, inside the cRIO control box, etc. In order to allow recording and tracking of component temperatures during the duration of the test. The test operator has the ability to set temperature limits for each of the four temperature sensors. Any deviation above this limit is recorded as a system failure and shuts down the test.

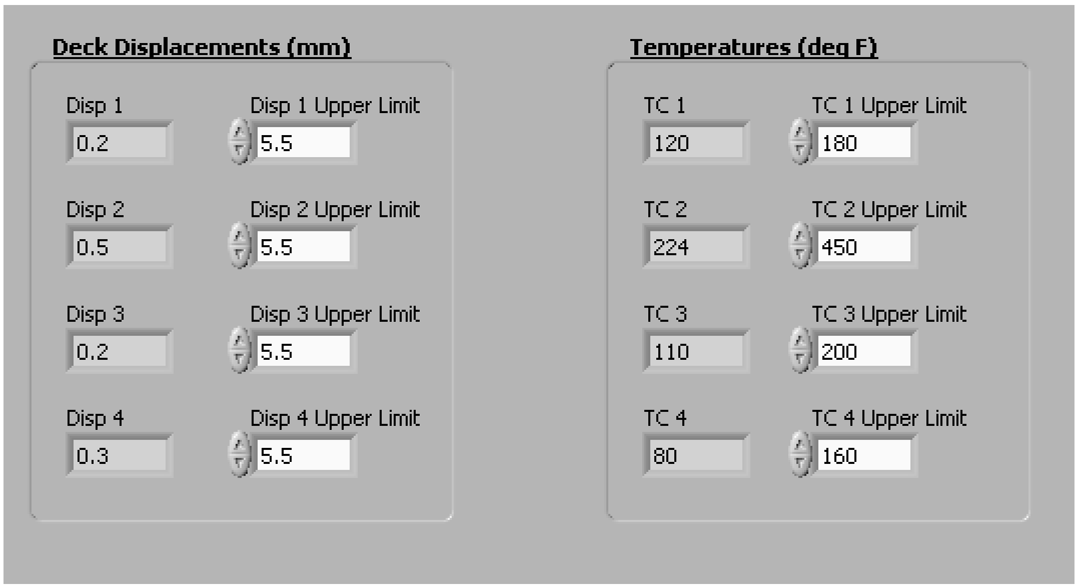

Figure X – Displacement and Temperature Indicators and Limit Settings

Other system information is recorded locally to a file on the cRIO along with displacement information and componenent temperatures. Data information is also comprised of engine rpm, ground speed, lap count and all of the current limits for the individual data points used to control test shutdown. These data files are created and stored at specific timed intervals. These individual data files are automatically transfered back to the host PC via FTP and and are then appended into the single test file. If the host laptop is moved out of wireless range the data files are saved on the cRIO system and can be downloaded at a later time after the test is finished.

The periodic collection of sensor data during the complete test cycle allows the product engineers to understand which components are failing over time.

Summary
The success of this project was due to the robustness of the Compact RIO system and the modularity of system utilizing the C Series I/O modules. Not only is the system able to withstand the rigorous testing involved in running the tractor over various obstacles on the test course, but it is also completely reconfigurable from the control software standpoint thanks to the Field Programmable Gate Array utilized on the cRIO backplane. This remote tractor controlling system made the obstacle course testing of tractor component failures less costly and much safer for the customer. Prior generations of this system required operator supervision and interaction.

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