Embedded Linux Moves into High School

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What We'll Talk About

- Goals
- Why switch controls?
- The roboRIO Controller
- Peripherals
- CAN bus
- Example code
- Summary

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Goals

- The goal of this presentation discuss the deployment of embedded Linux into high school robotics programs
  - New FIRST Robotics Competition roboRIO controller
- We clearly can’t explain all of the aspects because we don’t have the time
  - But, you should leave here some idea of the new direction for FIRST controllers
- Come to the showcase for more info

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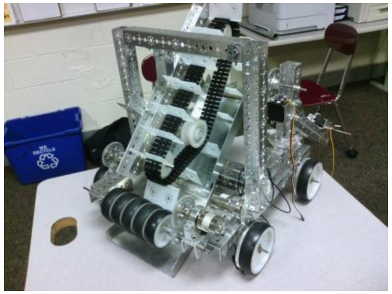
FIRST High School Robotics

- FIRST Robotics Competition (http://USFirst.org)
  - For Inspiration and Recognition of Science and Technology
  - Founded by Dean Kamen (inventor of Segway among others)
  - ~2904 teams reaching ~73,000 students in 19 countries
- Two primary programs in high schools
  - FIRST Tech Challenge
    - New game every year
    - Smaller robots using newly announced Android-based robot controller
    - Typically fits into an 18" cube
    - Code in Java (maybe C/C++ via NDK)
  - FIRST Robotics Competition
    - New game every year
    - 6 week build season
    - Robots up to 120 lbs
    - Powered by 12V SLA battery
    - Code in labVIEW, C/C++ or Java



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Why Change the Controls?

- The cRIO was getting very long in tooth
  - 400 MHz PPC running VxWorks™
- Many teams had started using BBBs, Rpi and Arduinos to supplement the sensor and vision processing

- The chassis had become a limitation
  - The number of slots and bus architecture became a bottleneck
  - Weight was also an issue
- The cRIO is an industrial device that is expensive to build (and buy)
  - Limits the number that the average team could afford

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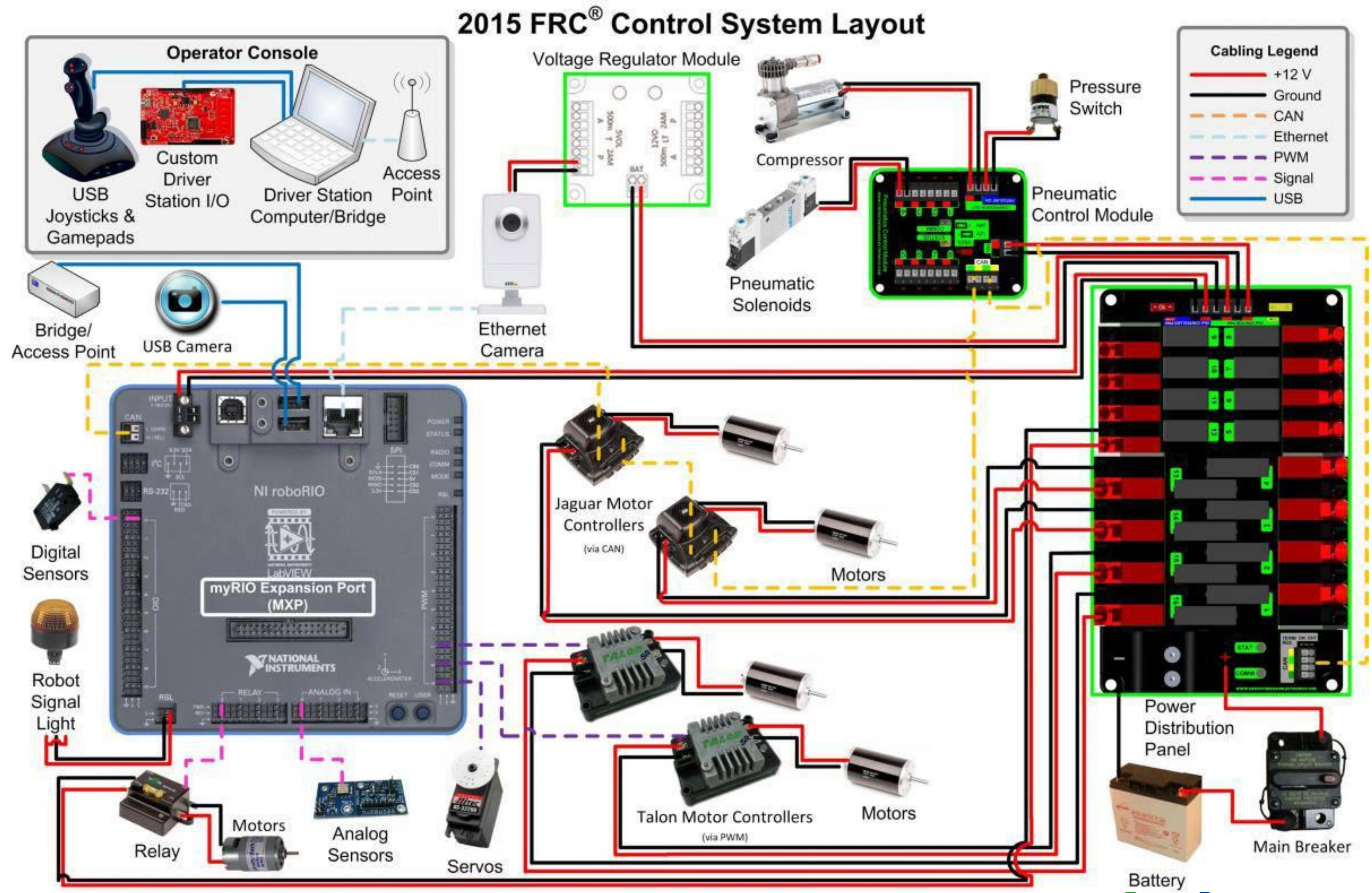
New 2015 Control System



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The RoboRIO

- Made by National Instruments expressly for high school STEM applications
  - Similar to myRIO unit built for college-level applications
- An ARM-based single board computer that increases performance and combines the digital side car into a smaller and lighter platform
  - Dual-core, 667 MHz ARM Cortex A9 with:
    - 256 MBs RAM (232 MBs usable)
    - 512 MBs flash (386 MBs usable)
    - Xilinx Zync-7020 All Programmable SoC

- Running NI RT-Linux
  - 3.2.35-rt52 Linux kernel
- File system is derived from Yocto/OE project
  - Uses the same packages as the ARM Angstrom/Poky distribution
  - ipk format packages that use *opkg* package manager

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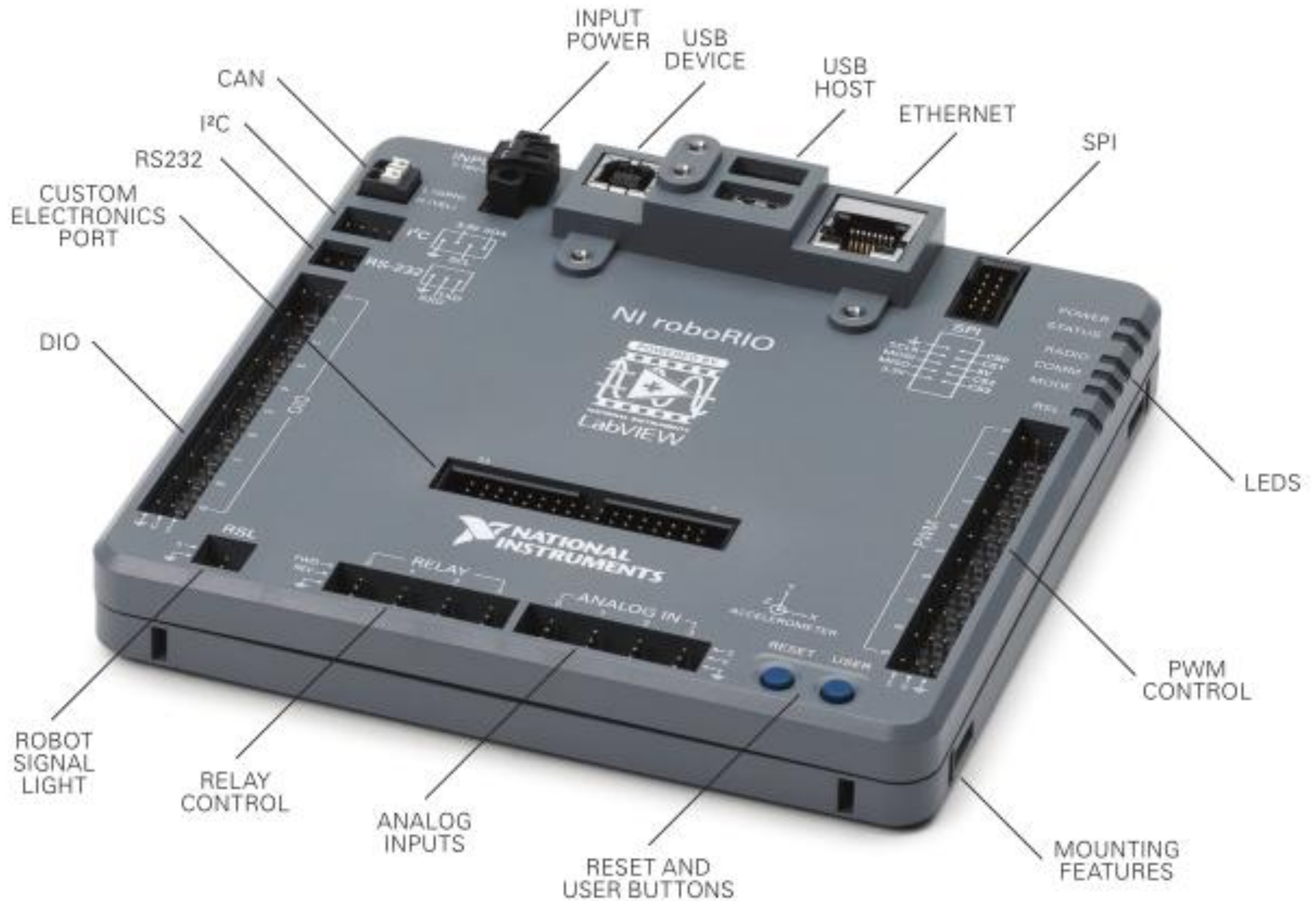
Annotated RoboRIO



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Power-Related Info

- The RoboRIO requires 7-16VDC
  - Max current 45W
  - Idle current 5W
- Most of the signals are 5V tolerant
- Voltages are:
  - 3.3V (max 1.225A)
  - 5V (max 1A)
  - 6V (max 2.2A)
  - 7-16V (120mA)
- The UART is 5V EIA RS232
  - Ready to plug into a PC
  - Do not plug directly into BBB, Rpi or Arduinos
    - Need to use level shifters on the UART or the magic blue smoke will escape!

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RoboRIO MXP Pin-out

- The *M*yRIO E*x*pansion *P*ort allows for additional I/O opportunities
- MXP has
  - 16 additional DIOs
    - Some pins can be used as aux I2C and SPI
  - 4 analog inputs
  - 2 analog outputs
  - 1 UART

+3.3V	DIO 10 / PWM6	DIO 9 / PWM5	DIO 8 / PWM4	DIO 7 / SPI MOSI	DIO 6 / SPI MISO	DIO 5 / SPI CLK	DIO 4 / SPI CS	DIO 3 / PWM3	DIO 2 / PWM2	DIO 1 / PWM1	DIO 0 / PWM0	AI3	AI2	AI1	AI0	+5V
33	31	29	27	25	23	21	19	17	15	13	11	9	7	5	3	1
34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2
DIO 15 / I2C SDA	DIO 14 / I2C SCL	DGND	DGND	DIO 13 / PWM9	DGND	DIO 12 / PWM8	DGND	DIO 11 / PWM7	DGND	UART.TX	DGND	UART.RX	DGND	AGND	AO1	AO0

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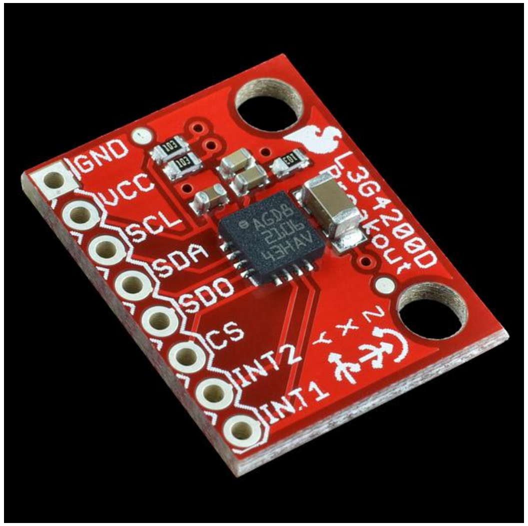
Digital I/O

- The main roboRIO has:
  - 10 DIO lines (each can be programed as input or output)
    - 20ns minimum pulse width
  - 1 I2C (1 SDA and 1 CLK)
    - 3.3V
    - 400KHz max frequency
  - 1 SPI bus (up to 4 devices)
    - 4 MHz max frequency



- Logic level:
  - 5V-compatible LVTTL input
  - 3.3V LVTTL output

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PWM and Relay Lines

- 10 PWM channels
  - Output only
  - 15mA max output current
  - 330 ohm resistor in series
- 4 relay channels
  - 4 forward, 4 reverse
  - 5V output
  - 7.5mA max current
  - 680 ohm resistor in series
- Max frequency 150 KHz
- Output High Voltage: 4.75V-5.25V max
- Output Low Voltage: 0.0V-0.25V max

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Analog I/O

- Analog input:
  - 500 kS/s @ 12-bit resolution
  - +/- 16V overvoltage protection
  - 500k ohm input impedance @ 500 kS/s
- Analog output:
  - 345 kS/s @ 12-bit resolution
  - +/- 16V overvoltage protection
  - 0-5V output range
  - 50 mV accuracy
  - 3mA current drive

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Onboard 3-axis Accelerometer

- +/- 8G range
- 12-bit resolution
- 800 S/s
- Very little information available during the beta cycle about programming

Built-In Accelerometer

Information about the Built-in accelerometer and class should go here

Accelerometer interface

Information about using the generic Accelerometer interface should go here.

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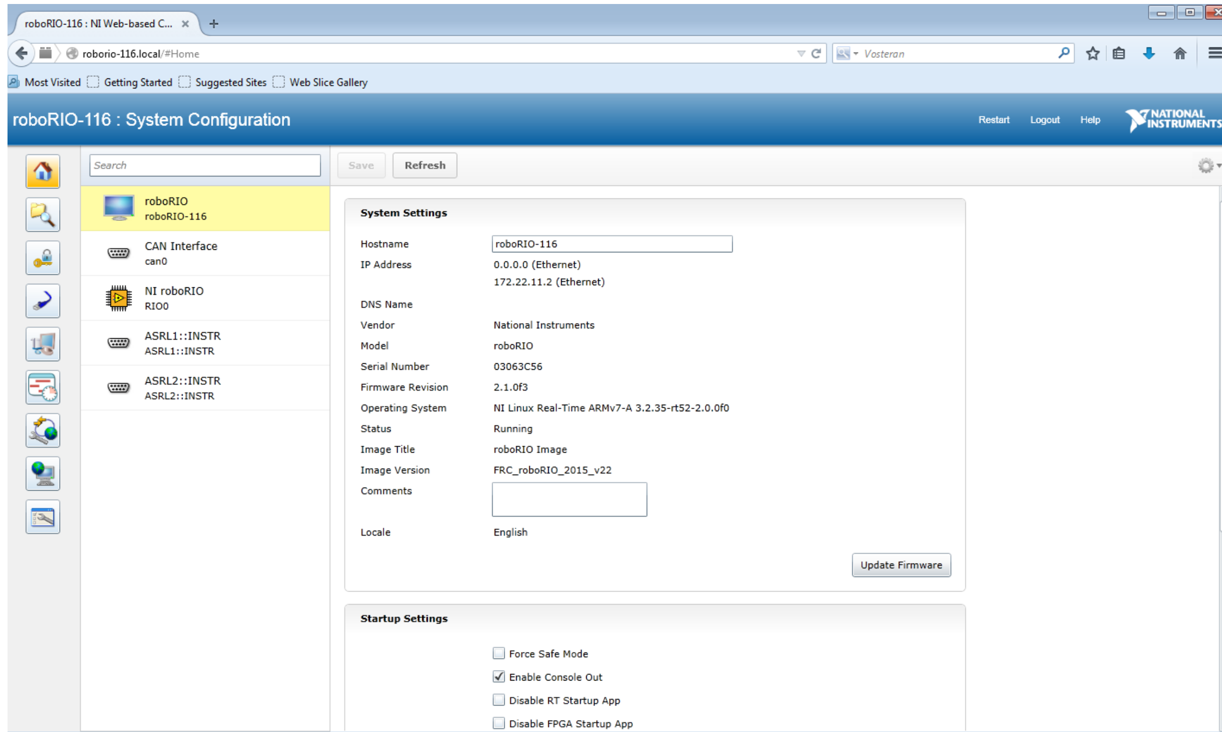
New RoboRIO Web Server

- New interface for roboRIO
  - Used to load new firmware
- Requires Microsoft Silverlight ☹



- Addressing is now done via mDNS
  - roborio-<team #>.local
- Option for enabling ssh server

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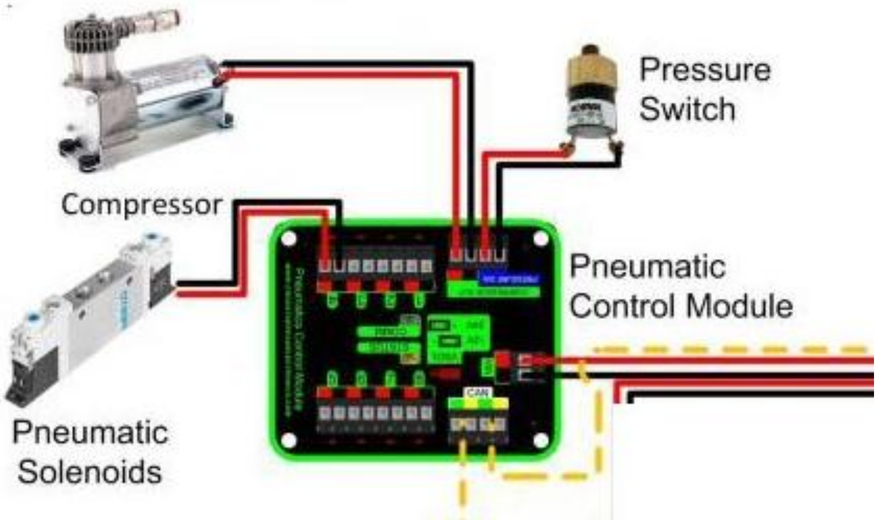
Pneumatics Control Module (PCM)

- CAN-controlled
- Supports more than 1 PCM
- Closed-loop operation
- Jumper selectable 12V or 24V solenoid operation



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Voltage Regulator Module

- Regulated 5V and 12V
  - Both 500mA and 2A
- Great for powering Wi-Fi access point
- Good brown-out capability

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Power Distribution Panel

- PDP is smaller than 2014 unit
- Dedicated outputs for roboRIO, PCM and VRM
  - Separate fuses
- Power input is now shielded
  - Requires 2.5mm metric hex drive
- CAN bus interface
  - Allows measurement of current draw from slots
  - Has option for CAN bus termination

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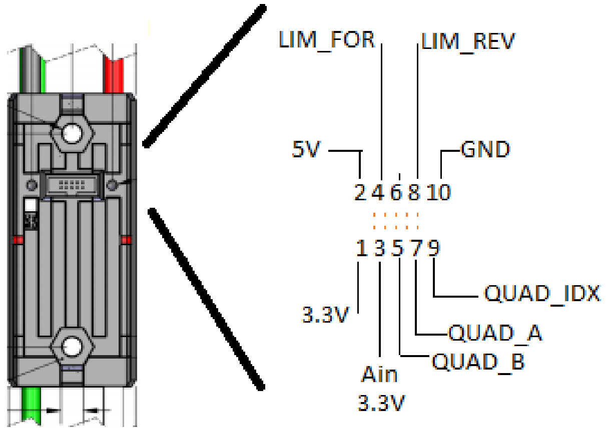
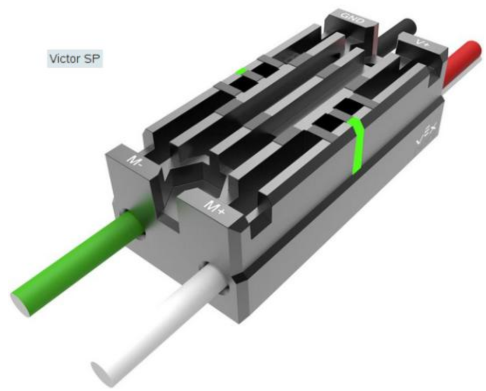
New Motor Controllers

- Talon SRX
  - CAN-based equivalent to earlier TI/Vex Jaguar controller
  - Quadrature encoder input
  - Forward and reverse limit switch inputs
- VexPRO Victor SP
  - Essentially, PWM-based Talon SRX
  - No additional inputs or capability





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CAN Bus

- Controller Area Network
  - If you've got a car made since 1968, you've got CAN bus
  - CAN is very reliable
- CAN bus got a bad rep from the early Jaguar motor controllers
  - Finicky RJ12 (6P4C) connectors
  - Tricky termination requirements
  - Slow update speeds
  - Thin traces would melt if the motor stalled for excessive time

- If you want to use Jaguars, they must be wired separately
  - Their CAN packet format is different than the rest of the CAN control system
  - Suggest using CTRE 2CAN to speed Jaguar CAN updates

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CAN Bus #2

- New PCM, PDP, Talon SRX and roboRIO all have CAN bus support
  - Two-wire daisy chain with fail-through capability
    - Failed component doesn’t kill the bus
  - Much faster than serial CAN from earlier seasons
- RoboRIO has CAN termination
  - PDP has a jumper to select termination option
- CAN bus is *required* for PCM and PDP (if you want current-related data)
  - You can have more than one PCM on the robot if you need more solenoids

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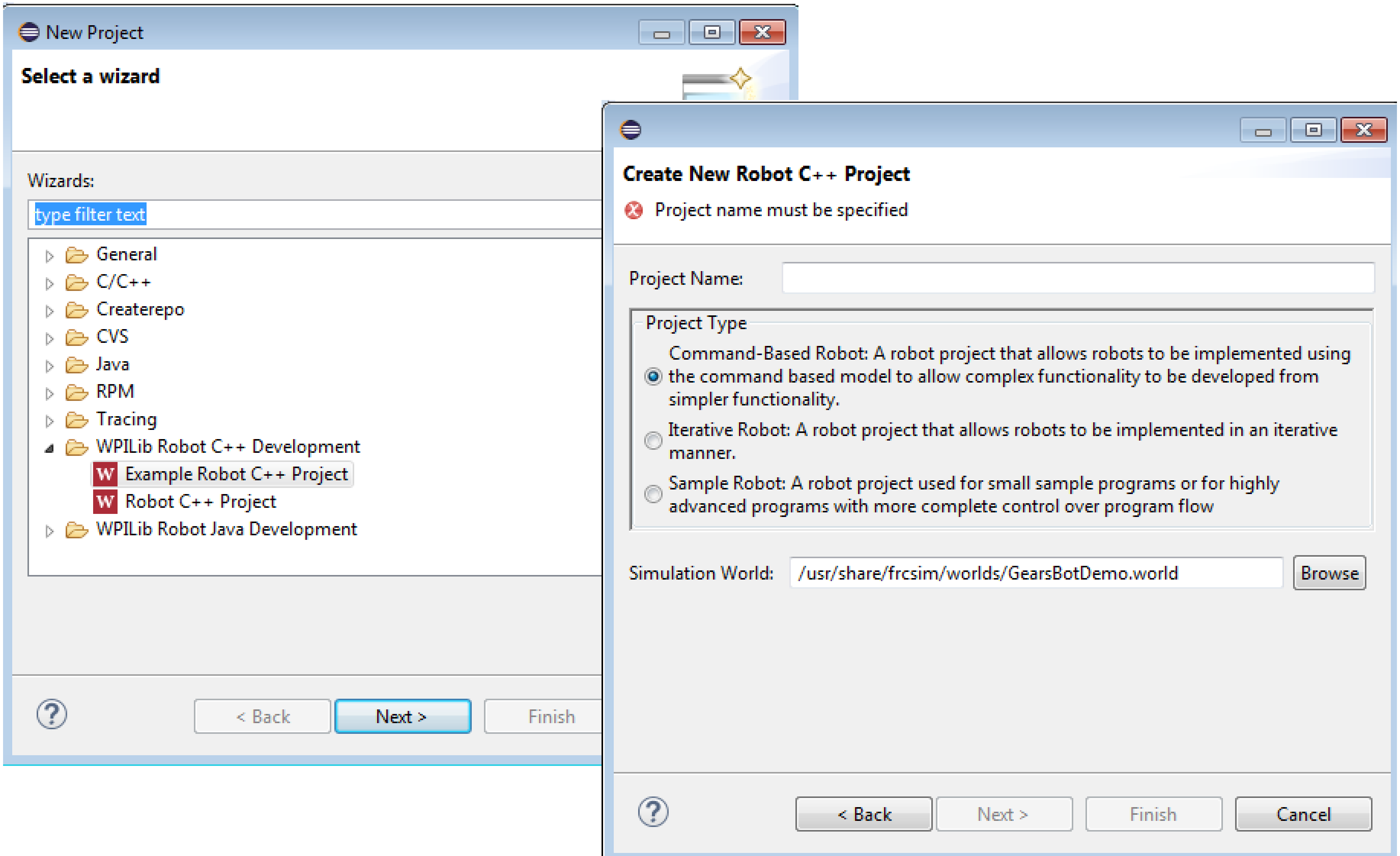
New Project -- Simple Robot



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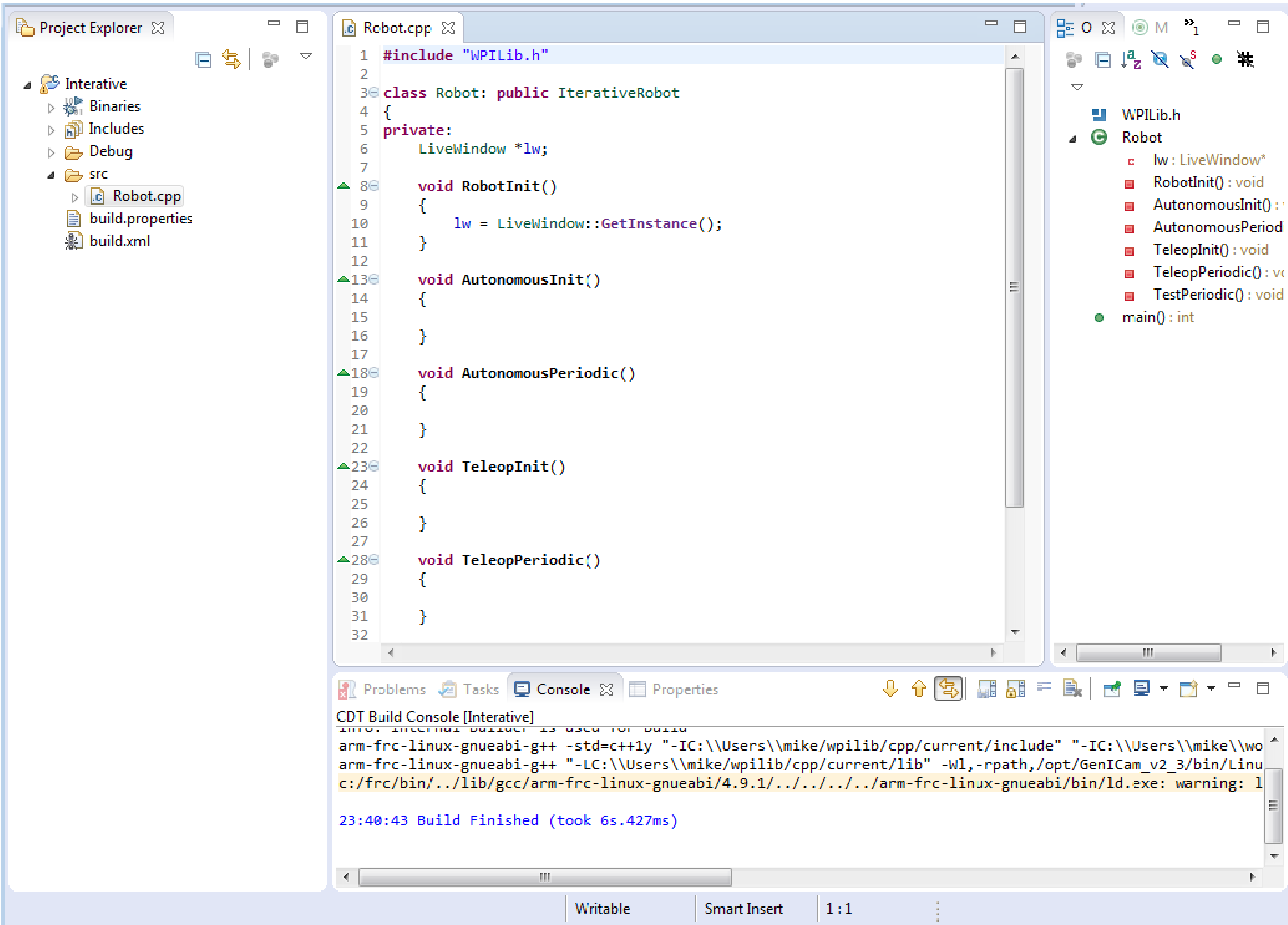
New Project Result



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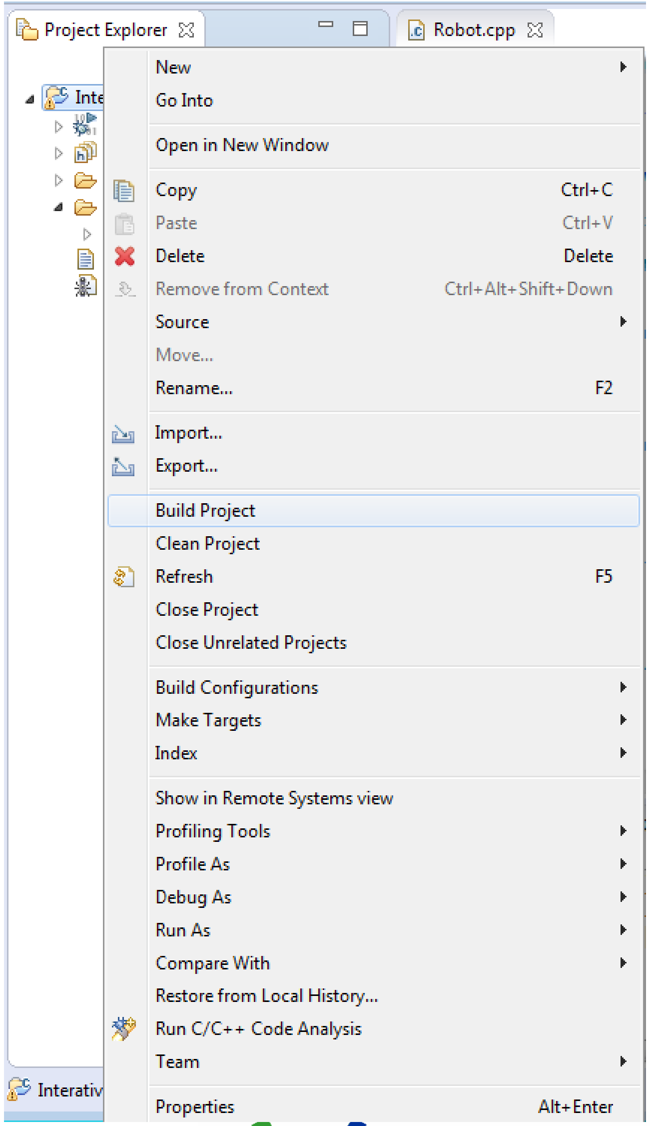
Build the Project

- Eclipse will default to building the project automatically
- However, you can clean and build the project manually
- Use the Project menu to configure the auto-build feature



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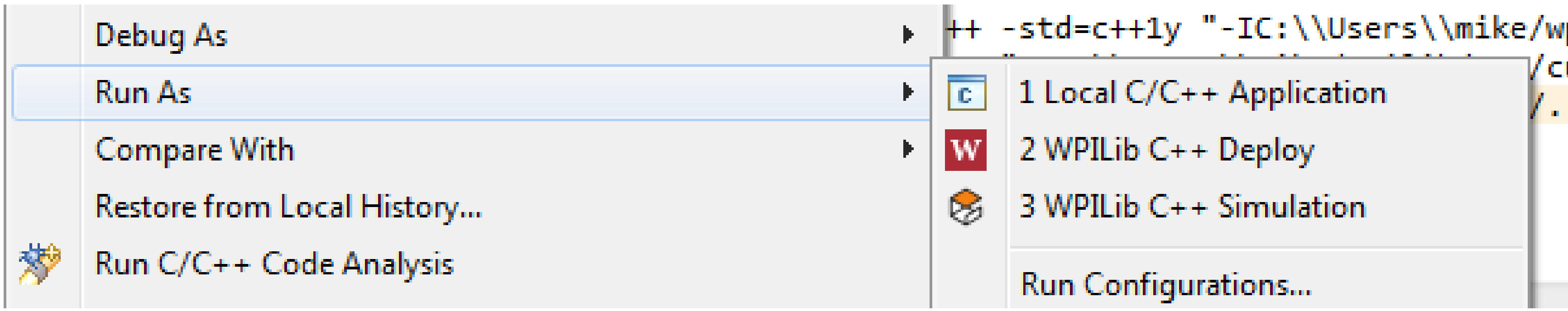
Deploying to the Target

- When the code is built, you can select Run As->WPILib C++ Deploy



- This will open an SFTP connection to the roboRIO (as “admin”) and copy the application to the file system
- The application will then start running
  - Waiting for the driver station

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Example WPILib Robot Program

```
#include "WPILib.h"
#include "CameraFeeds.h"

class IntermediateVisionRobot: public SampleRobot {

        CANTalon *m_motor1;
        CANTalon *m_motor2;
        CANTalon *m_motor3;
        CANTalon *m_motor4;

        // Camerafeeds
        CAMERAFEEDS *cameraFeeds;

        // Encoder
        Encoder *omniWheel;

        // Joystick with which to control the relay.
        Joystick *m_stick;

        RobotDrive *robotDrive; // robot drive system

        // Numbers of the buttons to be used for controlling the Relay.
        const int  kCam0Button = 1;
        const int  kCam1Button = 2;
        const bool kError      = false;
        const bool kOk         = true;
```


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Example WPILib Robot Program #2

```
public:
        void RobotInit() override {
                m_motor1 = new CANTalon(1);
                m_motor2 = new CANTalon(2);
                m_motor3 = new CANTalon(3);
                m_motor4 = new CANTalon(4);

                omniWheel = new Encoder(0, 1, false, Encoder::k4X);
                omniWheel->Reset();

                robotDrive = new RobotDrive(m_motor1, m_motor3, m_motor2, m_motor4);
                robotDrive->SetSafetyEnabled(1.0);
                // invert the left side motors
                // you may need to change or remove this to match your robot
                robotDrive->SetInvertedMotor(RobotDrive::kFrontLeftMotor, true);
                robotDrive->SetInvertedMotor(RobotDrive::kRearLeftMotor, true);

                m_stick = new Joystick(0); // Use joystick on port 0.

                cameraFeeds = new CAMERAFEEDS(m_stick);
                cameraFeeds->init();

        }
```


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Example WPILib Robot Program #3

```
        void OperatorControl() override {
                int32_t encoderValue = 0;
                while (IsOperatorControl() && IsEnabled()) {

                        robotDrive->MecanumDrive_Cartesian(m_stick->GetX(),
                                                m_stick->GetY(), m_stick->GetZ());
                        cameraFeeds->run();
                        encoderValue = omniWheel->GetRaw();
                        if (m_stick->GetRawButton(3)) {
                                printf("Encoder Value = %d\n", encoderValue);
                        }

                        if (m_stick->GetRawButton(4)) {
                                omniWheel->Reset();
                                encoderValue = omniWheel->GetRaw();
                                printf("Encoder Value = %d\n", encoderValue);
                        }

                }
                // stop image acquisition
                cameraFeeds->end();
        }
};

START_ROBOT_CLASS(IntermediateVisionRobot);
```


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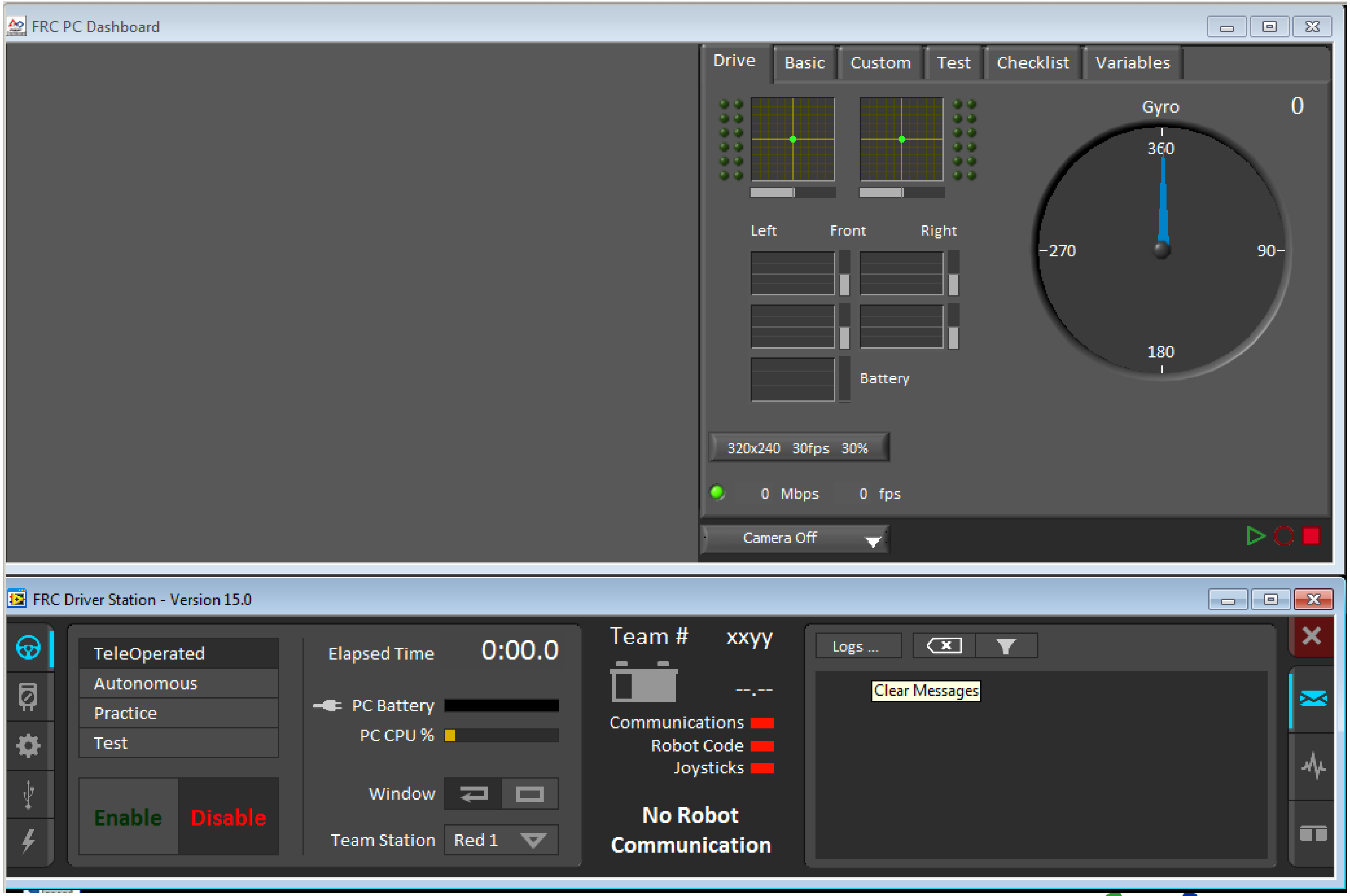
Driver Station (WinDoze Only ☹)



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Summary

- The new control system is working pretty well at this point
  - The students are starting to develop in Linux for Java and C/C++
  - The robot simulator *only* runs on Linux
- Expanded use of CAN bus give the students real-world control experience
  - Sensors via I2C and SPI as well
- New motor controllers are smaller and easier to work with than previous versions
- WPILib simplifies most of the effort to control various robot functions
- Check out US FIRST website for teams near you

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