DRIVE SYSTEM TEST – PERFORMANCE AND POWER CONSUMPTION

CYBER BLUE – FRC 234 FALL SPECIAL PROJECT Test Report
December 2014

INTRODUCTION

In the fall of 2014, Cyber Blue 234 completed a project to determine and compare the performance of multiple drive motor configurations in order to determine acceleration, top speed, power consumption and pushing performance.

The project was based around "Design of Experiments" methodology where there was a detailed plan and structure put in place to support the testing and isolate the key variables to improve the accuracy and conclusions of the testing.

For the testing, we used a single reduction gearbox, 2014 FRC legal motors, a special built chassis, and the new RoboRIO to capture data.

OBJECTIVES OF TEST

The primary objective of the testing was to determine acceleration rates, top speeds, power consumption, and pushing performance of 2, 4, and 6 CIM, and 4 CIM + 2 mini-CIM drives.

A second objective was to utilize the new control system for 2015, "RoboRIO", and data recording capability as part of our beta-testing of this new system.

TESTING DISCIPLINE

Test Methodology

The high-level test process goals were:

1. Build a robot drive chassis and control system that could be adapted for each test.
2. Minimize the changes to the robot drive chassis for each variation of the test.
3. Follow a prescribed test sequence to minimize the test process impact on the results.

To accomplish this, the following steps were taken:

1. A specialized 4 WD robot chassis was built so that the motors could be easily changed or added with minimal other changes to the chassis / drive system.

3. A weight plate was made to enable getting the test chassis very close to 140 pounds to simulate a 2014 robot with bumpers and a battery installed.
4. An autonomous program was written to run each test case to assure each was run in an identical process.
5. A "test track" was identified so each run was in the same location.

6. Data recording parameters were identified for capture / recording.

Managed Variables

The following parameters were managed with each test.

This list is variables that were held constant:

Variables - Held Constant	
Chassis System	Software
Wheels	Test Track / Test Surface
Belt Drive Sprockets	Autonomous Code
Belt Drive Belts	Gearboxes, Ratios
Battery	Control System
Weight Distribution	

This list is variables that changed with each test:

Variables	
Motor Count and Type	Battery Voltage
Robot Weight	
Date / Time	

Test Cases

1. <u>2 CIM Drive.</u> 7:1 Reduction VEXPRO Gearbox PN 217-2752, 37 – 42 Tooth Belt Sprocket Step Up, 4” AM Performance Wheels, Blue Nitrile Tread, Single 12V *FIRST* Battery. Final Drive ratio ~ 7.95:1. 4 WD.

2. <u>4 CIM Drive.</u> 7:1 Reduction VEXPRO Gearbox PN 217-2752, 37 – 42 Tooth Belt Sprocket Step Up, 4” AM Performance Wheels, Blue Nitrile Tread, Single 12V *FIRST* Battery. Final Drive ratio ~ 7.95:1. 4 WD.

3. <u>6 CIM Drive.</u> 7:1 Reduction VEXPRO Gearbox PN 217-2752, 37 – 42 Tooth Belt Sprocket Step Up, 4” AM Performance Wheels, Blue Nitrile Tread, Single 12V *FIRST* Battery. Final Drive ratio ~ 7.95:1. 4 WD.

4. <u>4 CIM + 2 Mini-CIM Drive.</u> 7:1 Reduction VEXPRO Gearbox PN 217-2752, 37 – 42 Tooth Belt Sprocket Step Up, 4” AM Performance Wheels, Blue Nitrile Tread, 4 CIM + 3 Mini-CIM Drive, Single 12V *FIRST* Battery. Final Drive ratio ~ 7.95:1. 4 WD.

TEST CONFIGURATION:

The team conducted the testing on a standard “kit-bot” chassis with a 4 Wheel Drive configuration. VEXPRO single reduction gearboxes, mounted on top, were used to provide easy access to add, remove, and change motors. The robot used 4 - 4” AndyMark Performance Wheels and belt drives. To provide an even weight distribution, a center weight bar was added. Barbell weights were used to keep each test configuration close to the same weight (within 1 pound).

For each test configuration, 3 test runs were completed with data captured on each run.

On the data plots, the Legend convention is Number of Motors, Type, Test Number, and Data Type. For example, 6CIM1Amp is 6 motors, CIM, Test 1, and Amperage.

The photo below shows the standard robot setup. The battery is removed.

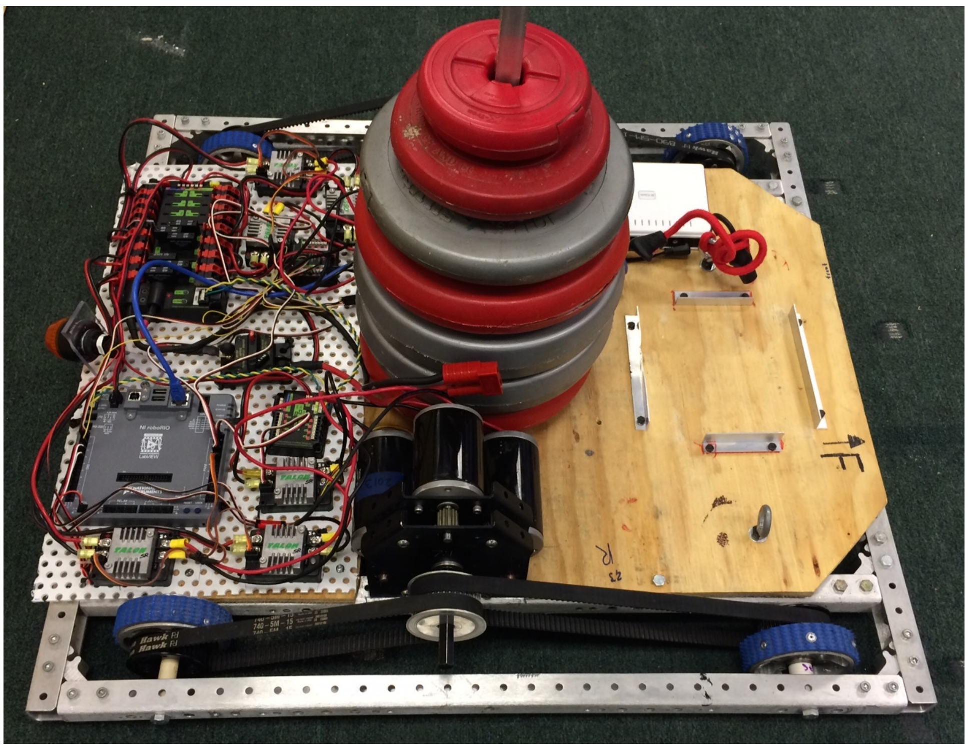


Photo 1 – Standard Test Set-up

The photo below shows the standard set-up for the pushing configuration. The test robot (pushing) was frame to frame with the pushed robot.

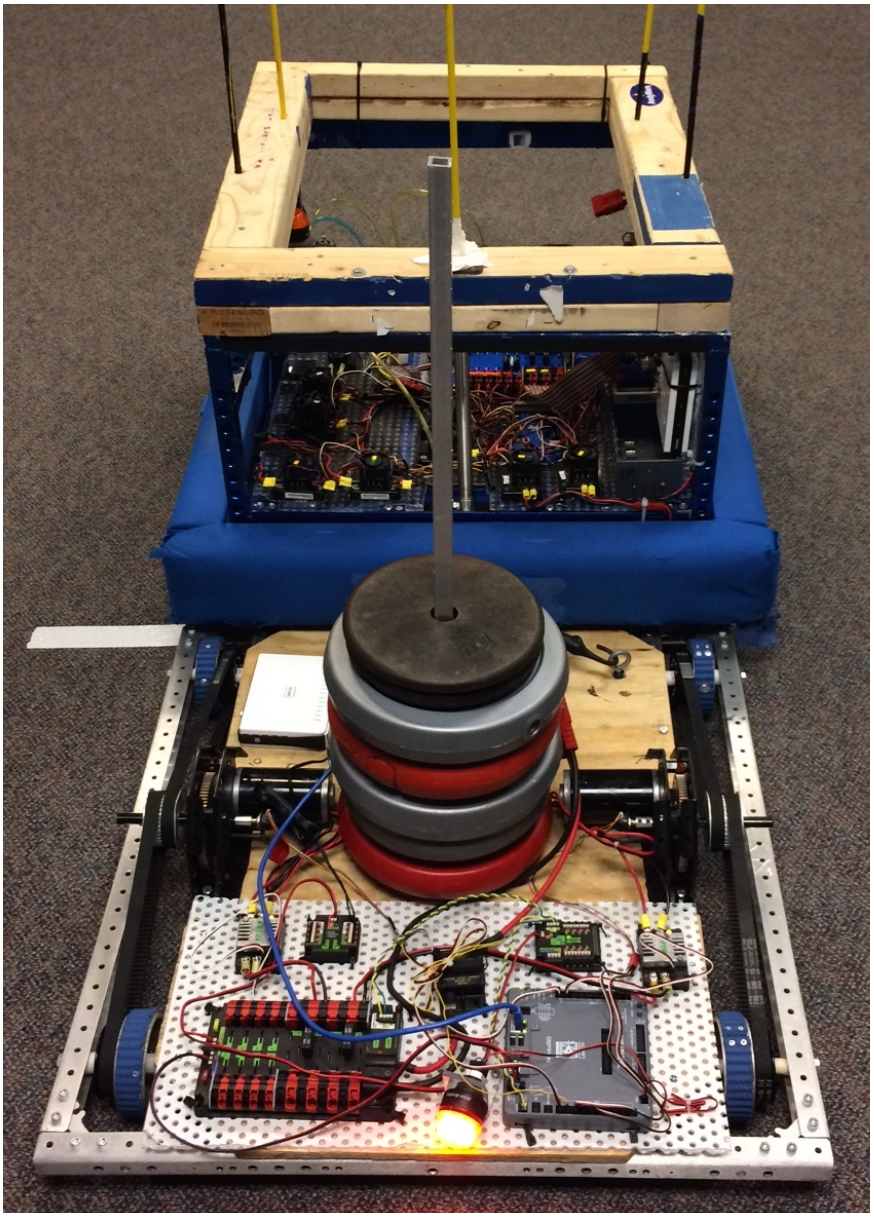


Photo 2 – Standard "pushing" set-up.

TEST CONDUCT AND DATA RECORDED

The data was taken by running an autonomous program to go quickly from 0 to 100% power. The same code ran every test, with the only change being to the duration (encoder counts) in the pushing tests.

The RoboRIO recorded a time stamp and encoder count (left and right) for the test runs. All of the reported data is for the left encoder count for consistency.

Before beginning the testing, the encoder count was set to zero and the robot was pushed for a measured 50-foot distance. This gave a very accurate encoder count for the full 50-foot course and also provided an accurate measure of counts per foot for the data analysis. This encoder count was 12300, which calculates to 246 counts per foot.

Each test was run 3 times and the data set captured and recorded in case there was an error in a data set. All of the data in this report is from the first run for consistency.

Data was then analyzed to determine the acceleration, top speed, and power consumption.

RESULTS

The summary results are in the table below. Yellow highlights data above protection levels.

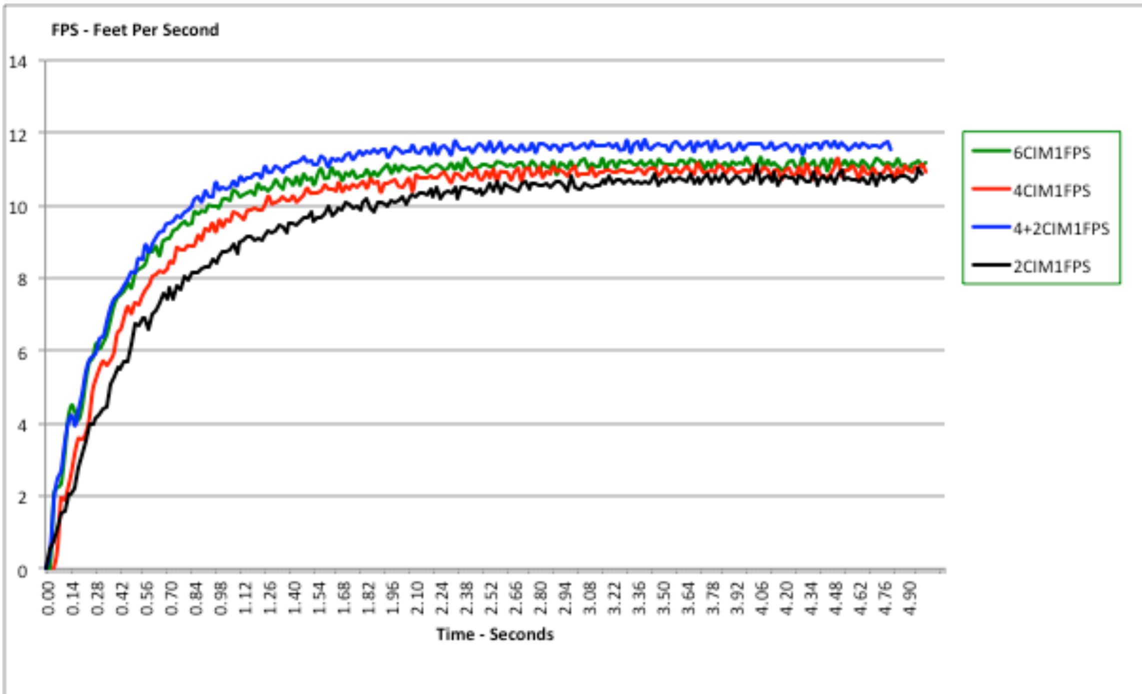
Definitions:
SINGLE ROBOT RUN - Single Robot, Flat Course, Autonomous Run
PUSHING 130 POUND ROBOT – Single Powered Robot, Pushing A 130 Pound non-powered robot (Victors in "brake" mode)
PUSHING v. SINGLE – Ratio of the PUSHING to the SINGLE, expressed as a Percentage. (Greater than 100% means PUSHING is higher value)
Time to 50', Time to 25' – Time, in seconds, from stopped to 50 feet or 25 feet.
Max FPS – Peak sustained speed observed, in Feet Per Second
Peak Total Amps – Peak single point Amperage from the sum of all motors
Peak Amps – 1 Motor – Peak single point reading from a single motor
Average for 5 Sec Run, Average for 3.5 Sec Run – Average Total Amperage for the run

SINGLE ROBOT RUN	**2 CIM**	**4 CIM**	**4+2 CIM**	**6 CIM**
Time to 50'	5	4.72	4.41	4.58
Time to 25'	2.84	2.56	2.44	2.51
Max FPS	10.34	10.76	11.55	11.06
Peak Total Amps	132	209	260	245
Peak Amps - 1 Motor	67	56	47	48.4
Average for 5 Sec Run (Total)	33.4	39.9	47.2	46.3
PUSHING 130 POUND ROBOT	**2 CIM**	**4 CIM**	**4+2 CIM**	**6 CIM**
Time to 25'	3.96	3.54	3.18	3.24
Max FPS	6.95	7.41	8.21	8.13
Peak Total Amps	132.3	222	231	237.7
Peak Amps - 1 Motor	67.5	58.5	43.1	46
Average for 3.5 Sec Run (Total)	75.9	99.1	121.3	113.1
PUSHING v. SINGLE	**2 CIM**	**4 CIM**	**4+2 CIM**	**6 CIM**
Time to 25'	139%	138%	130%	129%
Max FPS	67%	69%	71%	74%
Peak Total Amps	100%	106%	89%	97%
Average Total Amps	227%	248%	257%	244%

PLOT DATA – SINGLE ROBOT

Below are grouped plots of the data from each test configuration when the test robot was operating alone.

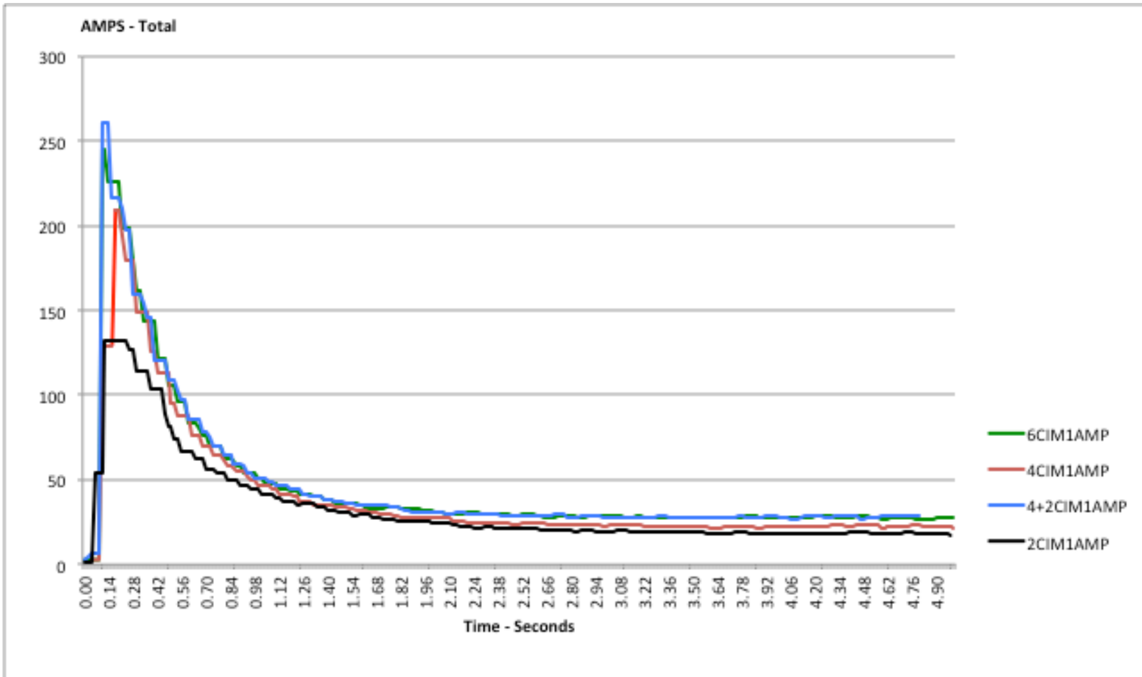
<u>Acceleration and Speed – Feet Per Second</u>



PLOT 1A - FPS – Feet Per Second (Single Robot)

FPS – Feet Per Second – This plot shows the acceleration and top speed of each motor combination. The 6 CIM and 4+2 CIM have comparable Acceleration. The 4+2 CIM has a slightly higher top speed, driven by the higher output speed of the mini-CIM.

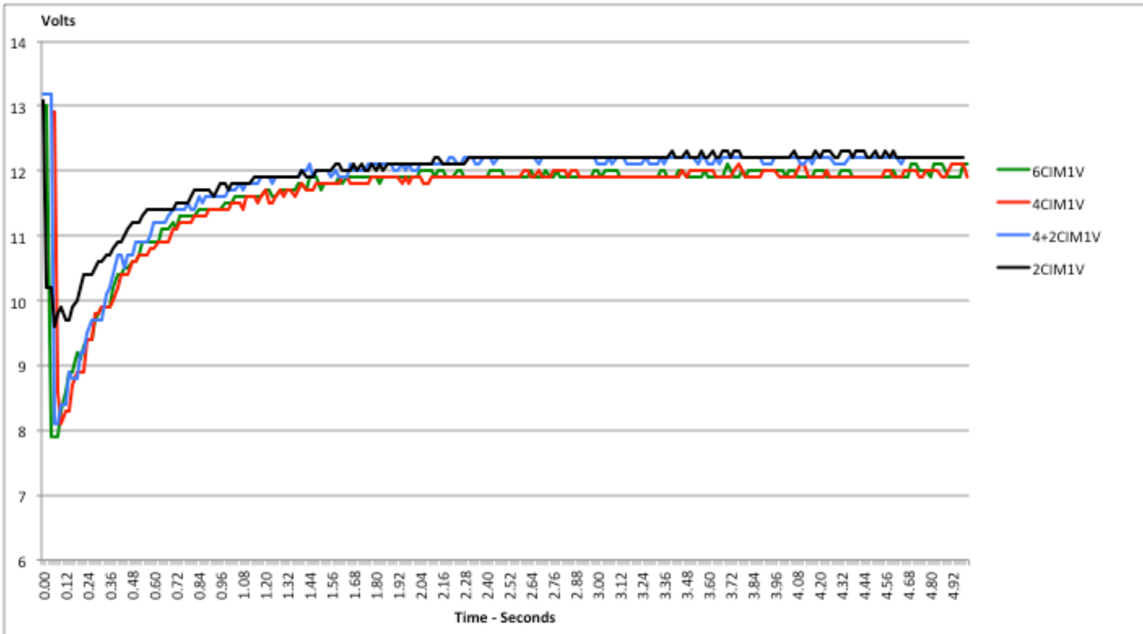
Amperage



PLOT 2A - AMPS – Total (Single Robot)

AMPS – Total – This plot shows the total Amperage for all motors in the configuration under test. The 6 CIM and 4+2 CIM are comparable and the slight peak difference may be driven by the data capture rate of the control. Once stabilized, the total Amperage draw to maintain speed is consistent for all configurations.

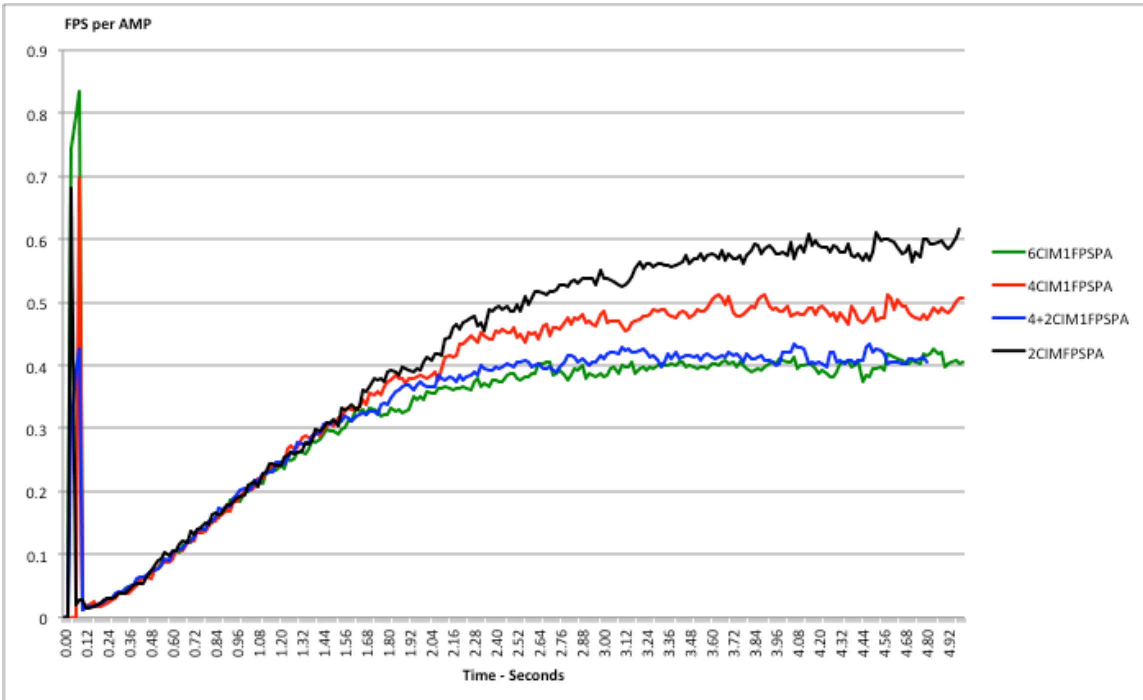
Volts



PLOT 3A - Volts (Single Robot)

Volts – This plot shows the total Voltage for the robot. The 4, 6, and 4+2 CIM configurations all show a similar voltage drop at the start, and then recovery is similar before stabilizing near 12V. The voltage drop for the 2 CIM configuration is less and the stabilized voltage is slightly higher.

Efficiency – FPS / AMP



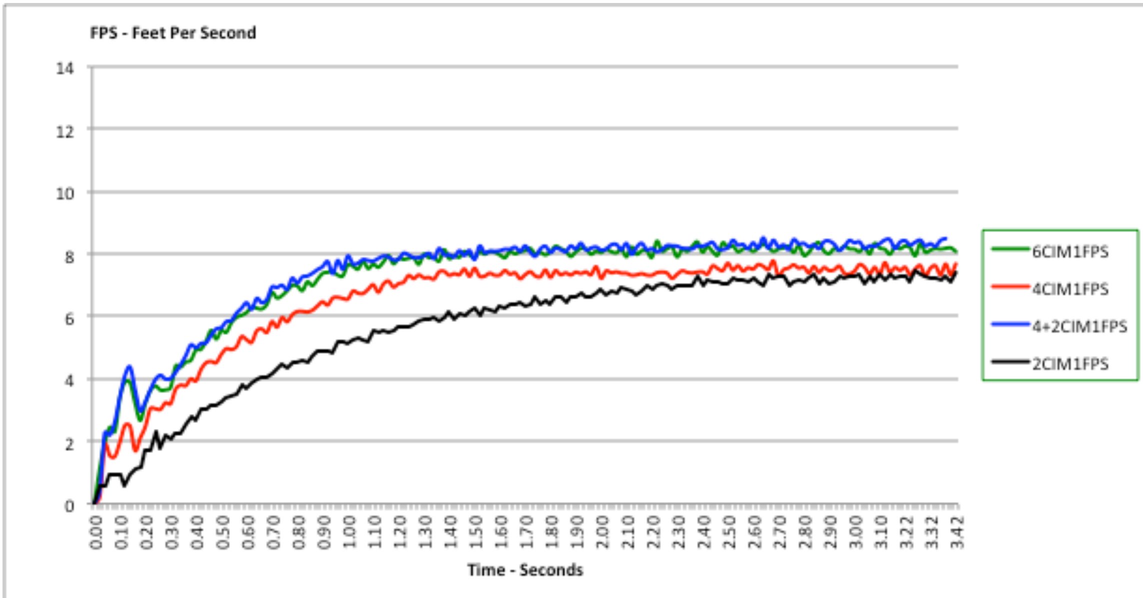
PLOT 4A - FPS per AMP (Single Robot)

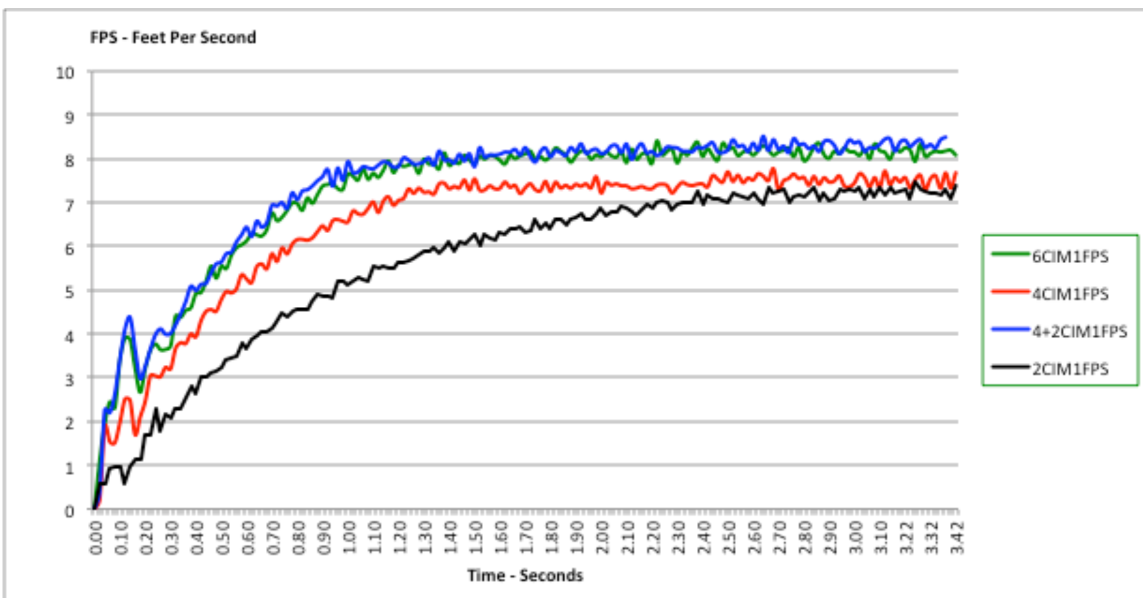
FPS per AMP - This plot shows a calculation of an "efficiency" measure of each configuration. This data compares the speed (FPS) to the total Amperage to determine Speed per Amp (similar to Miles per Gallon). All configurations are similar until the robot is near its' peak speed, then the 2 CIM and 4 CIM configurations become more efficient at keeping the robot moving.

PLOT DATA – PUSHING 130 LB. ROBOT

Below are grouped plots of the data from each test configuration when the test robot was pushing a second, unpowered robot.

<u>Acceleration and Speed – Feet Per Second</u>

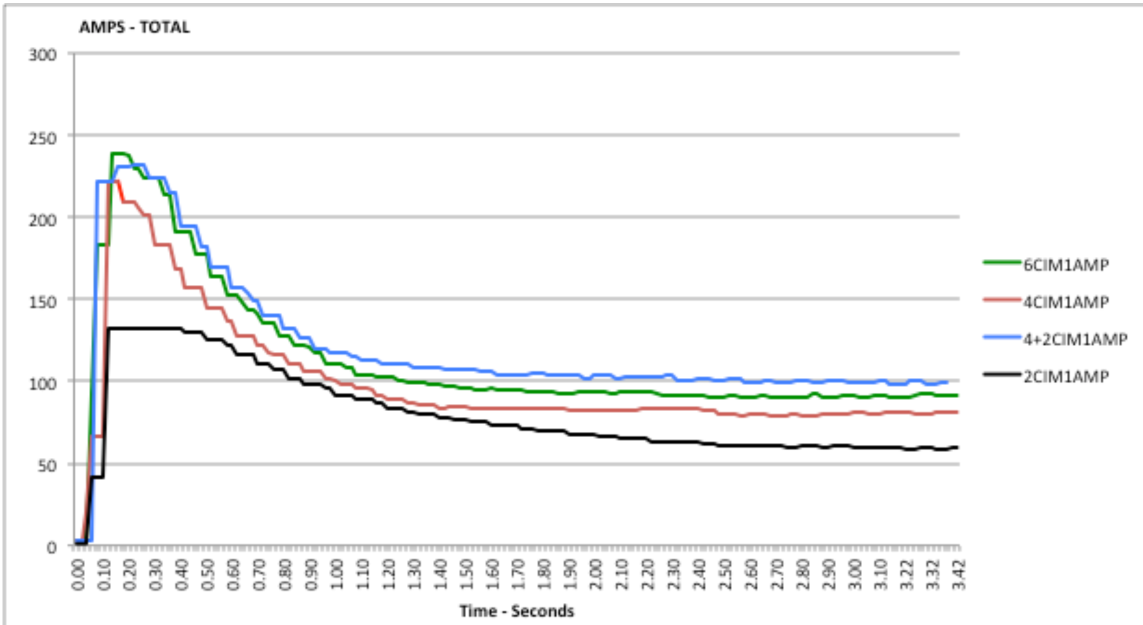




PLOT 1B and 1C - FPS – Feet Per Second (Pushing 130 Lb. Robot)

FPS – Feet Per Second – These plots show the acceleration and top speed of each motor combination. The 6 CIM and 4+2 CIM have comparable Acceleration. There is minimal difference between the 6 CIM and the 4+2 CIM. (The only difference in the plots is the scale. The 0 – 14 range was maintained for consistency with the 1A plot and the 0 – 10 scale is shown for better separation of the curves.)

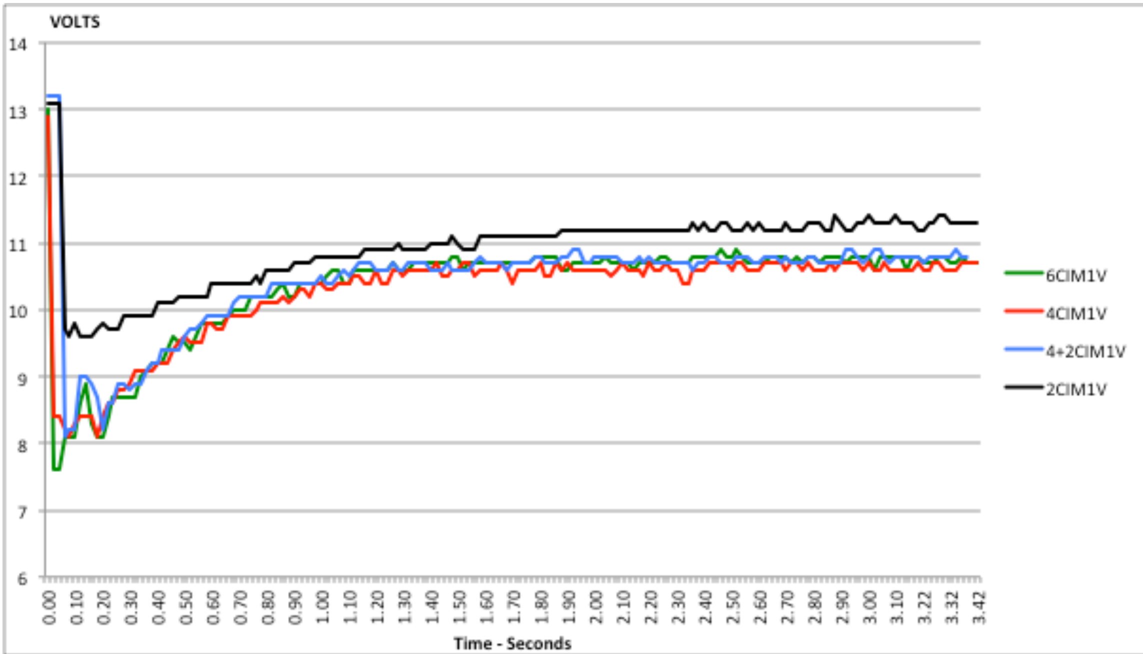
Amperage



PLOT 2B - AMPS – Total (Pushing 130 lb. Robot)

AMPS – Total – This plot shows the total Amperage for all motors in the configuration under test. The 6 CIM, 4+2 CIM, and 4 CIM are comparable at the peak and the slight peak difference may be driven by the data capture rate of the control. There is a difference is the stabilized total Amperage draw to maintain the push.

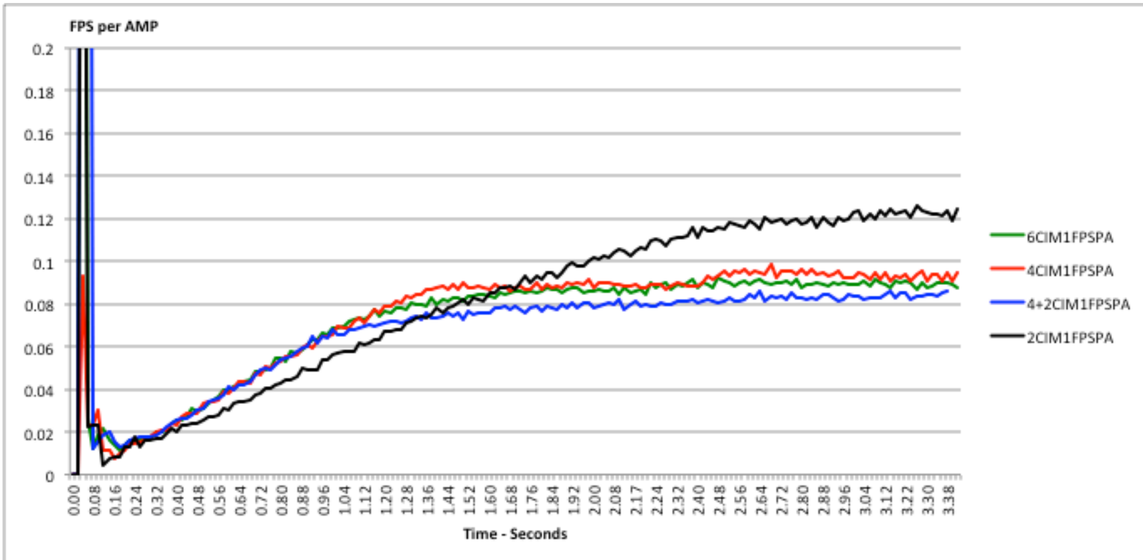
Volts



PLOT 3B - Volts (Pushing 130 lb. Robot)

Volts – This plot shows the total Voltage for the robot. The 4, 6, and 4+2 CIM configurations all show a similar voltage drop at the start, and then recovery is similar before stabilizing just below 11V. The voltage drop for the 2 CIM configuration is less and the stabilized voltage is slightly higher.

Efficiency – FPS / AMP



PLOT 4B - FPS per AMP (Pushing 130 lb. Robot)

FPS per AMP - This plot shows a calculation of an "efficiency" measure of each configuration. This data compares the speed (FPS) to the total Amperage to determine Speed per Amp (similar to Miles per Gallon). All configurations are similar until the robot is near its' peak speed, then the 2 CIM configuration becomes more efficient at keeping the two robots moving.

ANALYSIS / OBSERVATIONS

There was minimal performance difference between the 4+2 CIM and the 6 CIM configuration in this testing. Given previous *FIRST* limitations on the number of CIMs and Mini-CIMs, this data could help support a design decision to replace 2 of the "Drive CIMs" with Mini-CIMs to allow the CIMs to be used in another critical area.

The 4 CIM configuration provides strong performance with a lower power consumption. Depending on the game and team strategy, using a 4 CIM drive could allow the team to use CIMs and other motors in other areas and minimize the risk of tripping a breaker or dropping voltage to an undesirable level.

The 2 CIM configuration was not able to accelerate the robot near its' calculated top speed. This indicates that there is not enough power provided by the 2 CIM option, so if a team uses 2 CIMs and needs a specific top speed, the gearing will need to be adjusted to compensate for this limited capability.

In the single robot testing, if we assume the 6 CIM provides the maximum possible speed for the gear reduction, wheels used, overall system efficiency and weight being moved, (11.06 FPS), the 2 CIM achieved 93% and the 4 CIM achieved 97% of this speed. The 4+2 configuration achieved 104%, however, the mini-CIM has a higher output speed.

In the pushing robot testing, if we assume the 6 CIM provides the maximum possible speed for the gear reduction, wheels used, overall system efficiency and weight being moved, (8.13 FPS), the 2 CIM achieved 85% and the 4 CIM achieved 91% of this speed. The 4+2 configuration achieved 101%, however, the mini-CIM has a higher output speed. The change in percentage speed (reduction) compared to the single robot testing indicates all configurations lose more relative capability in the pushing mode when compared to the 6 CIM configuration.

The 2 CIM and 4 CIM configurations have a higher single motor peak amperage and could have a higher risk of tripping the individual breakers (40 Amp) if the peak was sustained.

The 4 CIM, 6 CIM and 4+2 CIM configurations have a higher total motors peak amperage and could have a higher risk of tripping the main breaker (120 Amp) if the peak was sustained.

Sustained pushing provides a significant step in power draw (Amps), in all cases the average Amperage for the duration of the test was approximately 250% of the single robot power draw. With this knowledge, a team could limit the duration of "pushing matches".

The 2 CIM configuration could be beneficial if a game required sustained "pushing" of an object, as it provides an efficient use of power once the load is underway.

CONCLUSIONS

This testing was conducted to gather data and learn. The information will be useful in future robot design decisions when determining the most important requirements of a robot drive system and the requirements for other systems.

As with other “research” types of work, this testing provides some insights and data to support decisions and may prove or dis-prove some assumptions regarding drive performance. Since this testing was very limited (single speed, single drive system) in scope, and since every *FIRST* game is different and every team has slightly different goals and objectives for their drive, this testing does not provide a “best” answer for an FRC drive system design.

Given the abilities of the new control system with data recording, it would be beneficial for teams to record data during practice time and matches to allow them to analyze and understand the robot performance and any risks to excessive power consumption.