Falcon 500 temperature test under maximum load conditions

Stryke Force

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- The purpose of this test sequence is to evaluate the thermal performance of the Falcon 500 motor / controller under the most challenging circumstances likely to be encountered in a typical FRC match.

- The test sequence will be performed in a controlled bench top setup to eliminate the random nature of robot test matches

- The test load will consist of two elements
    1. An inertial flywheel placed directly on the Falcon 500 output shaft (constant for all tests)
    2. An airplane propeller placed directly on the output shaft to provide drag (varied for different tests)

- There will be two load conditions

    1. Inertial load plus a prop load sufficient to draw 40-45 amps of supply current 100% command output
        a) 45 amps represents the absolute maximum current that can pass through the 40 amp breaker and not trip it in a two min match
        b) At 100% output there is no chop on the high side FETS (this minimizes drive bridge heat)
        c) At 100% output the I2R heat rise in the stator windings is minimized for a 480 watt load
        d) At 100% output the power supply current and the motor stator current are the same
        e) This is a 480 watt (12 volts * 40 amps) constant load

    2. Inertial load plus a prop load sufficient to draw 40-50 amps of supply current at 50% command output
        a) 45 amps represents the absolute maximum current that can pass through the 40 amp breaker and not trip it in a two min match
        b) At 50% output there is chop on the high side FETS (this increases drive bridge heat)
        c) At 50% output the I2R heat rise in the stator windings is <u>significantly</u> increased for a 480 watt load
        d) At 50% output the motor stator current is roughly double of the power supply current
        e) This is a 480 watt (12 volts * 40 amps) constant load

- These two load conditions where chosen to evaluate both ends of the spectrum on Falcon 500 thermal performance. The most favorable approach is to run the 40 amp breaker right on the limit for a whole match with the Falcon output at 100%. A much more challenging approach is to the run the Falcon at 50% output while still delivering 480 watts of power (40 amp breaker on the verge of tripping)

- At the end of the day if you can run a Falcon 500 at the limit of the 40 amp breaker for the entire match and not reach temperature shutdown OR damage the Falcon 500 in any way, then they are pretty much bullet proof when sitting behind a 40 amp FRC breaker.

- CTR has recently released a firmware update that moves the temperature shutdown from 85c to 110c. The original beta units were set to 85c. CTR provided a proto version of this “110c firmware” to Stryke Force for early testing. The proto 110 firware significantly improved the run time of the Falcons. The formal release of the 110c firmware includes temperature enhancements beyond the original “proto 110c” firmware. So in this test we will evaluate three different setups
    1. The original “proto 110c” firmware provided to Stryke Force with no back cap on the electronics
    2. The recently released 110c firmware 4.59.1.0 with no back cap on the electronics
    3. The recently released 110c firmware 4.59.1.0 with the back cap installed on the electronics

- This test sequence will measure these elements
    1. How long can you run before reaching temperature shutdown with each setup
    2. What are the maximum temperatures of the critical components at shutdown
        a) Did those element reach a threshold of possible damage.

- The following items will be instrumented with micro thermocouples to measure actual temperature
    1. One of the high side FETS in the drive bridge (higher heat based on modulation chop vs low side FETS)
    2. The temperature sensor being used by CTR to determine the actual temperature of the motor controller
    3. The uP that runs the controller.
    4. The stator windings

Overview of the results:

- It is highly unlikely that a Falcon 500 with the latest firmware (4.59.1.0) will reach thermal shut down in a typical FRC match
- It is nearly impossible to thermally damage any part of the controller or motor given the thermal shut down provisions
- The electronics back cap does help dissipate heat generated by the controller
- The electronics back cap significantly increased the temperature sensors ability to track FET temperature

- With the latest firmware and the backcap in place:
- It took 4:41 (double a FRC match) to reach temperature shutdown at 100% duty and a constant 45 amps power supply draw
- It took 1:43 (almost a full FRC match) to reach temperature shutdown at 50% duty and a constant 45 amps power supply draw

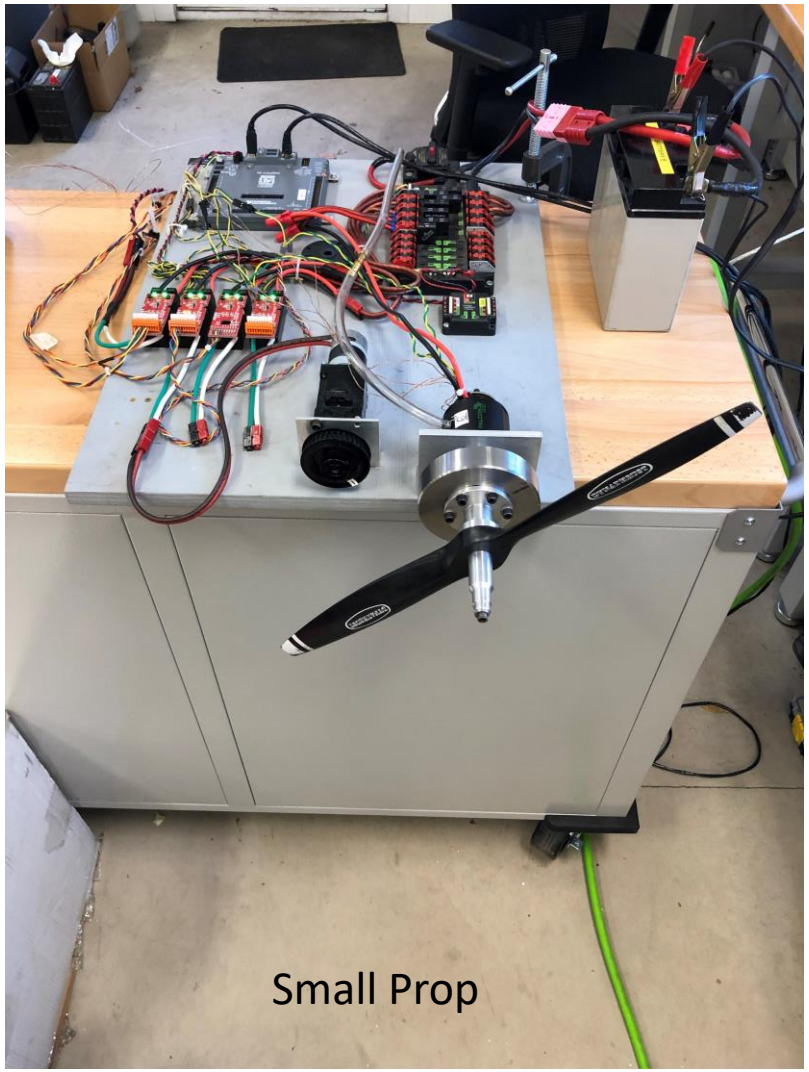
- Keep in mind that all test were conducted at 480 watts of constant output for the entire test duration
- It is highly unlikely any motor in FRC will ever run wide open for the entire match

Test	Firmware	Electronics Backcap	Power Supply Amps	Percent Command	Propeller	Time to 110c shutdown Min:Sec	Max FET temp deg C	Max Stator temp deg C
1	110 proto	no	45	100	small	2:14	104	106
2	110 proto	no	45	53	big	0:32	111	95
3	110 (4.59.1.0)	no	45	100	small	3:13	120	137
4	110 (4.59.1.0)	no	45	53	big	0:59	126	112
5	110 (4.59.1.0)	yes	45	100	small	4:41	116	153
6	110 (4.59.1.0)	yes	45	53	big	1:43	118	142

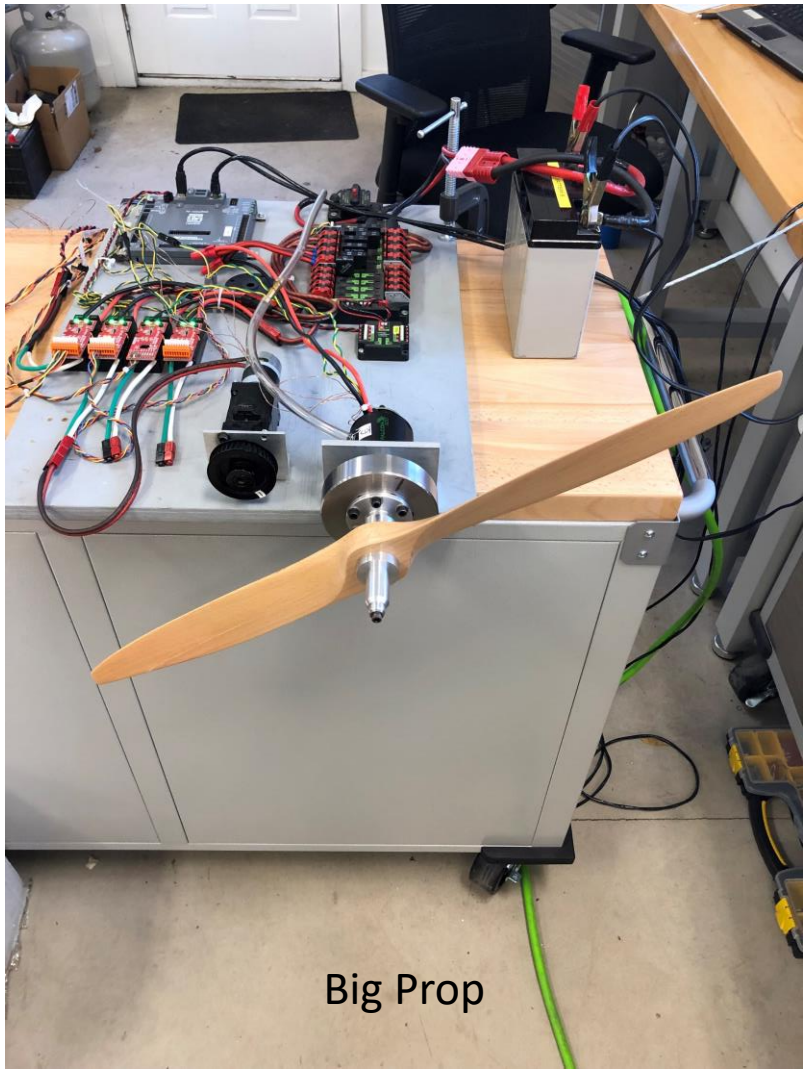
Notes:

- Stryke Force was given special permission from CTR to remove the backcap and instrument the electronics. We would not recommend removing the backcap in normal circumstances. There is simply no reason to remove it and a number of reasons not to!
- At the end of the big prop test (53%) I let the Falcon hit the temperature shutdown three times to observe what that sequence looked like. It shuts down at 110c and fires back up at 90c.
- The released 110c firmware (4.59.1.0) changes what is reported in the old Talon SRX current get. That is why the blue current trace looks different in the tests with the new firmware. Supply current was verified to be the same with a clamp on amp meter.
- In order to make the prop blow the air away from the operator (me) the Falcons were run in reverse (negative command). That is why the output voltage and velocity are negative in the graphs
- The big prop was run at 53% vs 50% in order to drive the supply amp draw up to 45 amps

Test load setup pictures

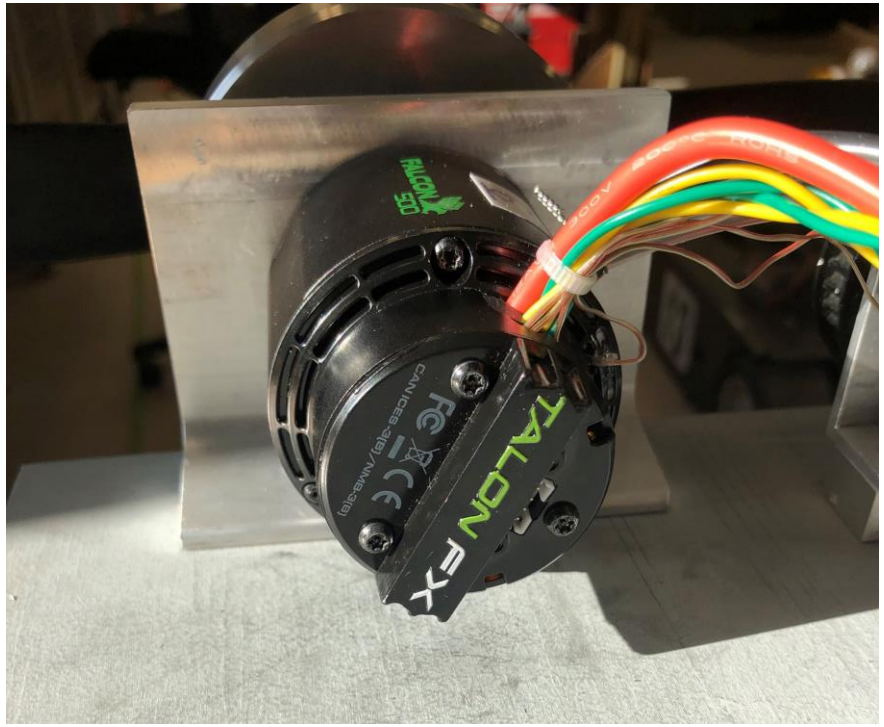


Small Prop

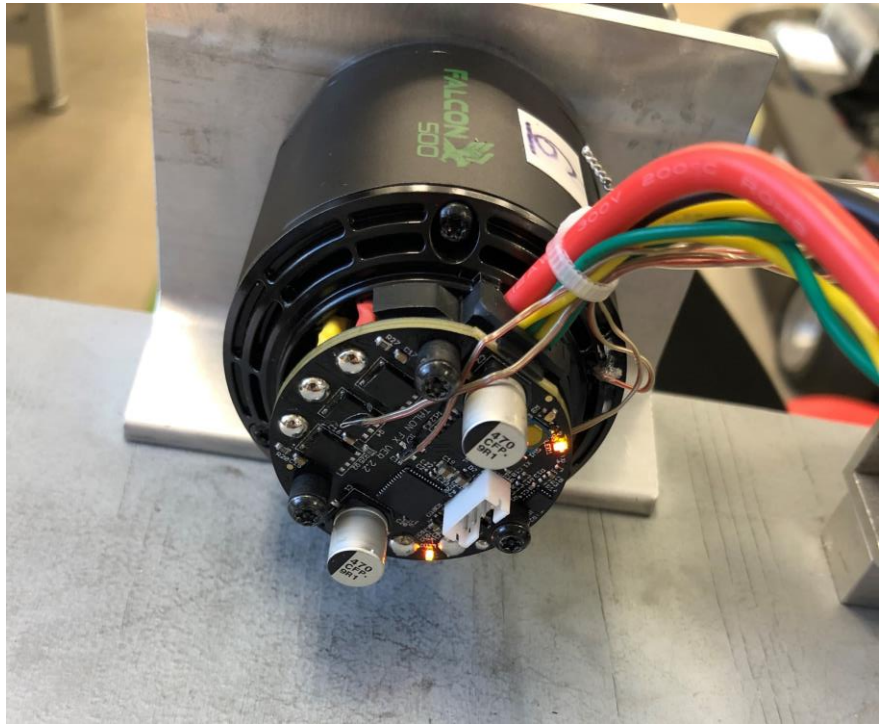


Big Prop

Instrumentation setup pictures

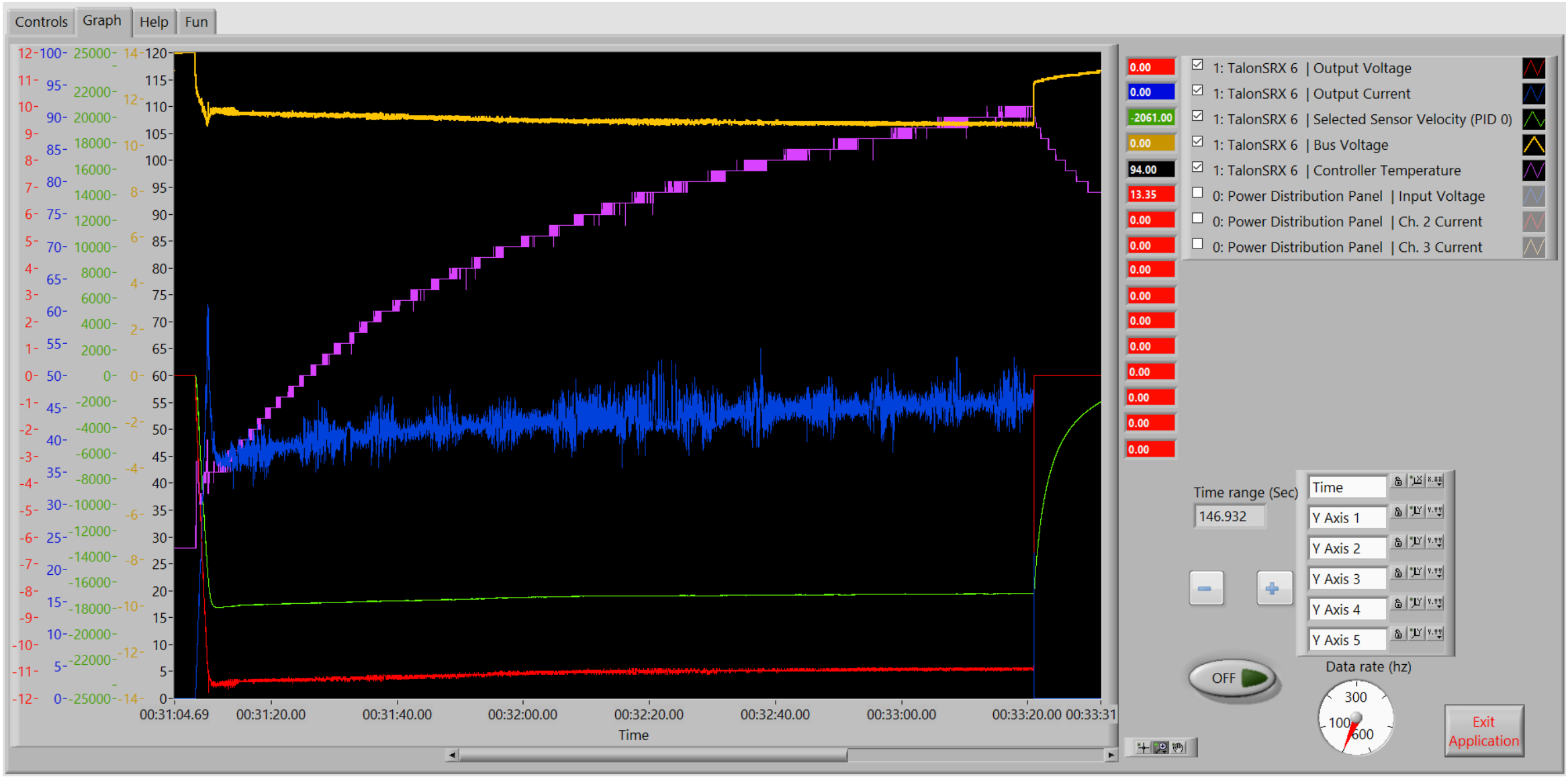


With Back Cap



Without Back Cap

Test 1 – Proto 110 firmware, 100% output, small prop, no backcap



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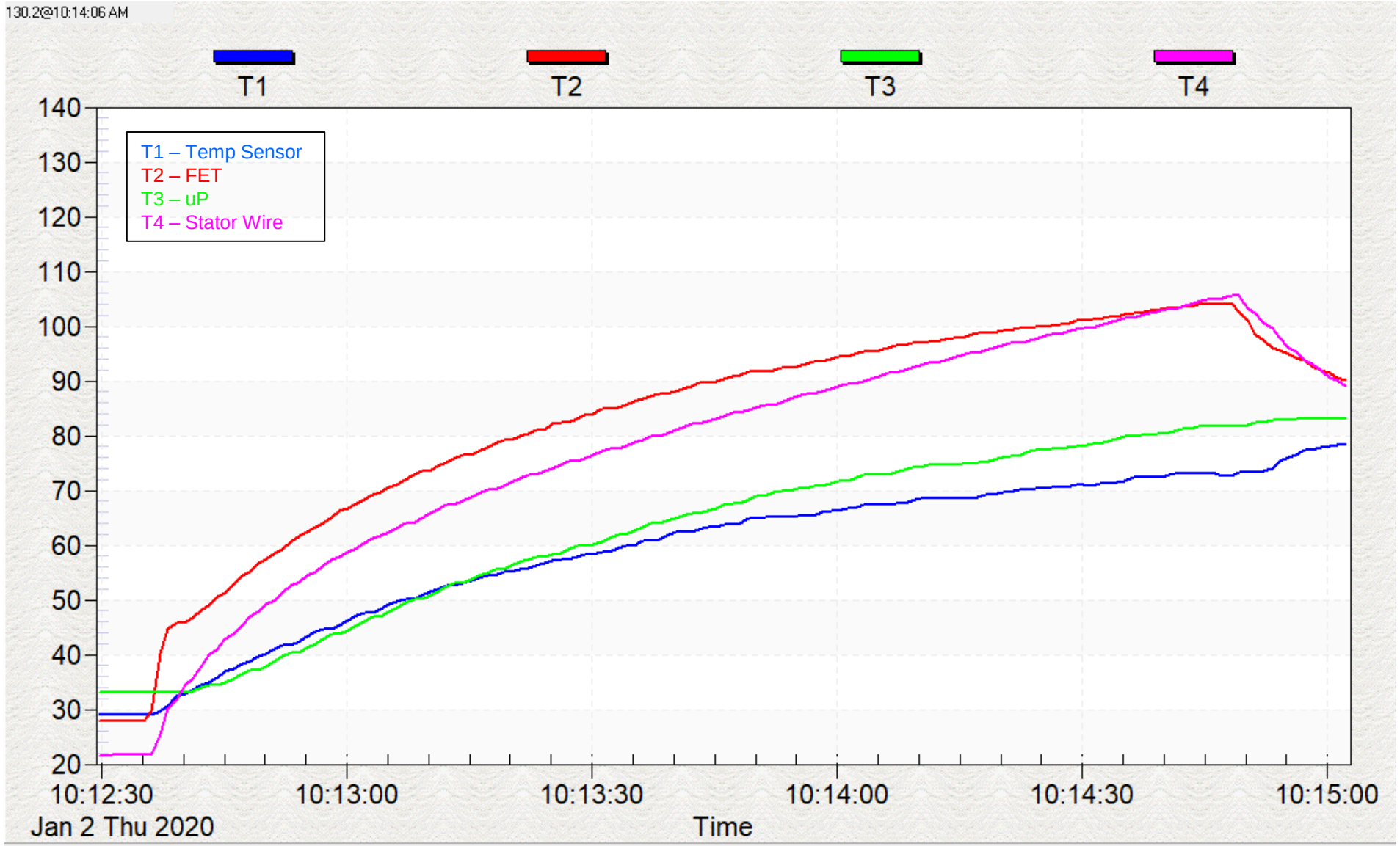
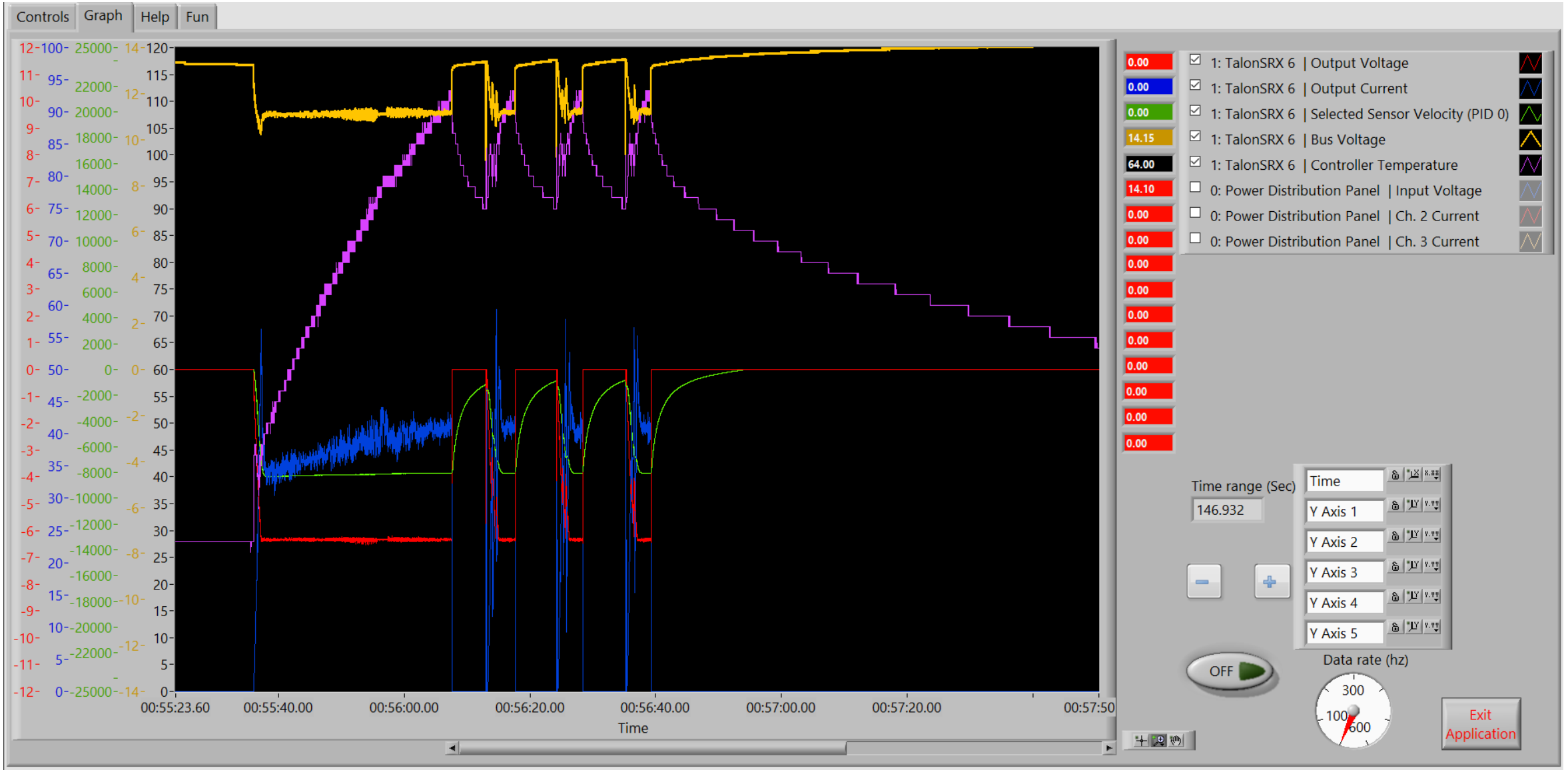


Test 2 – Proto 110 firmware, 53% output, big prop, no backcap



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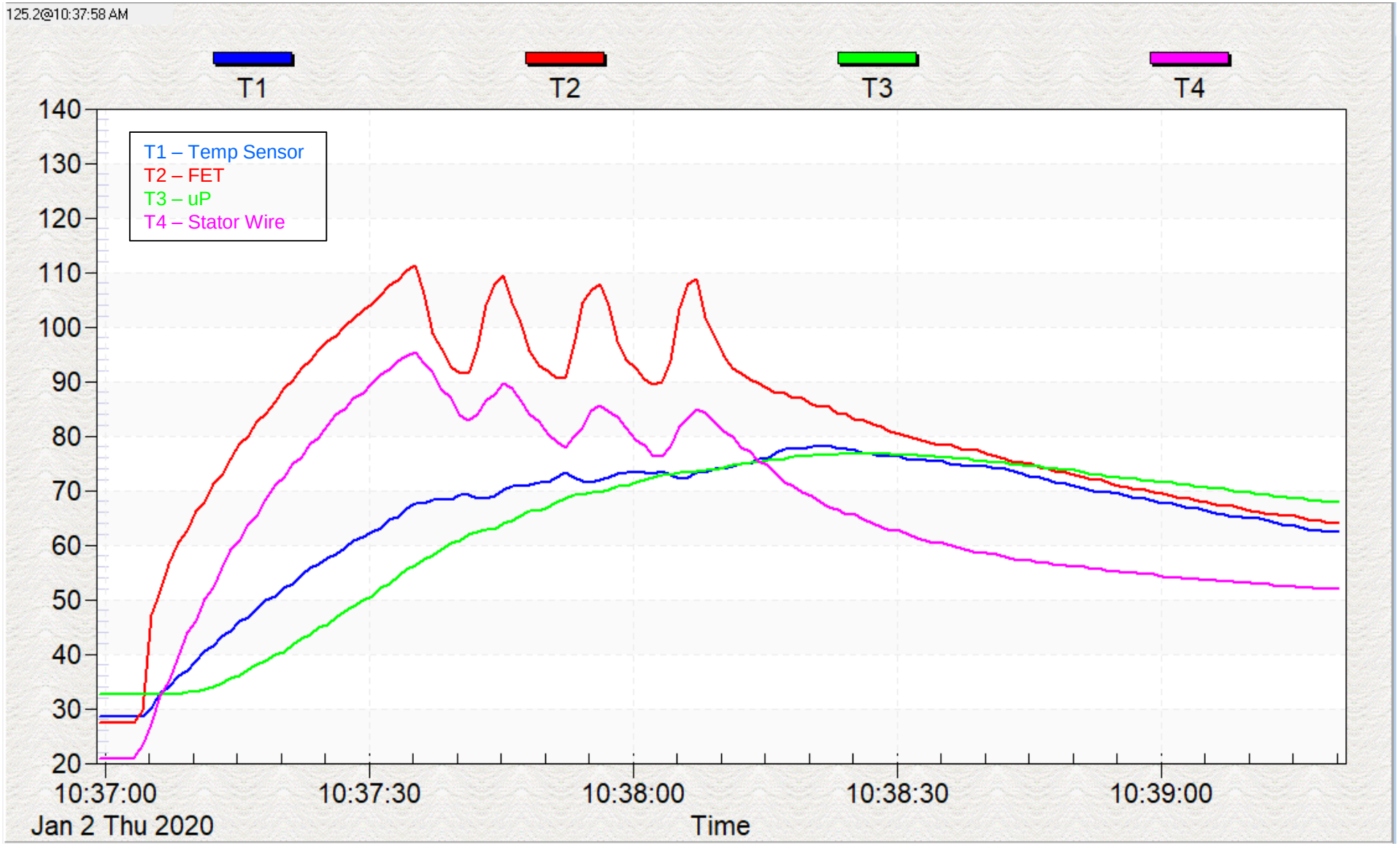
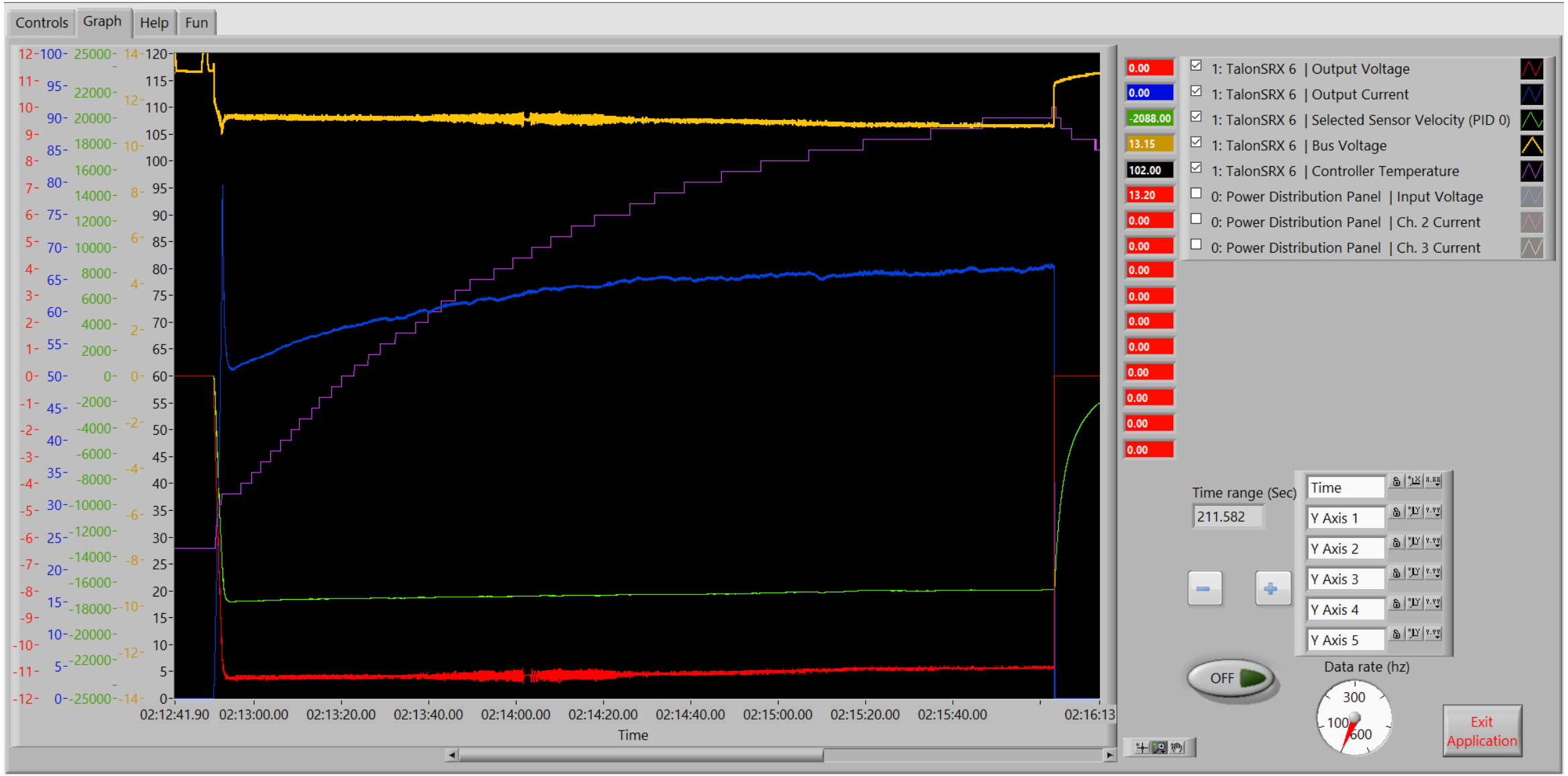


Test 3 – Released 110 firmware, 100% output, small prop, no backcap



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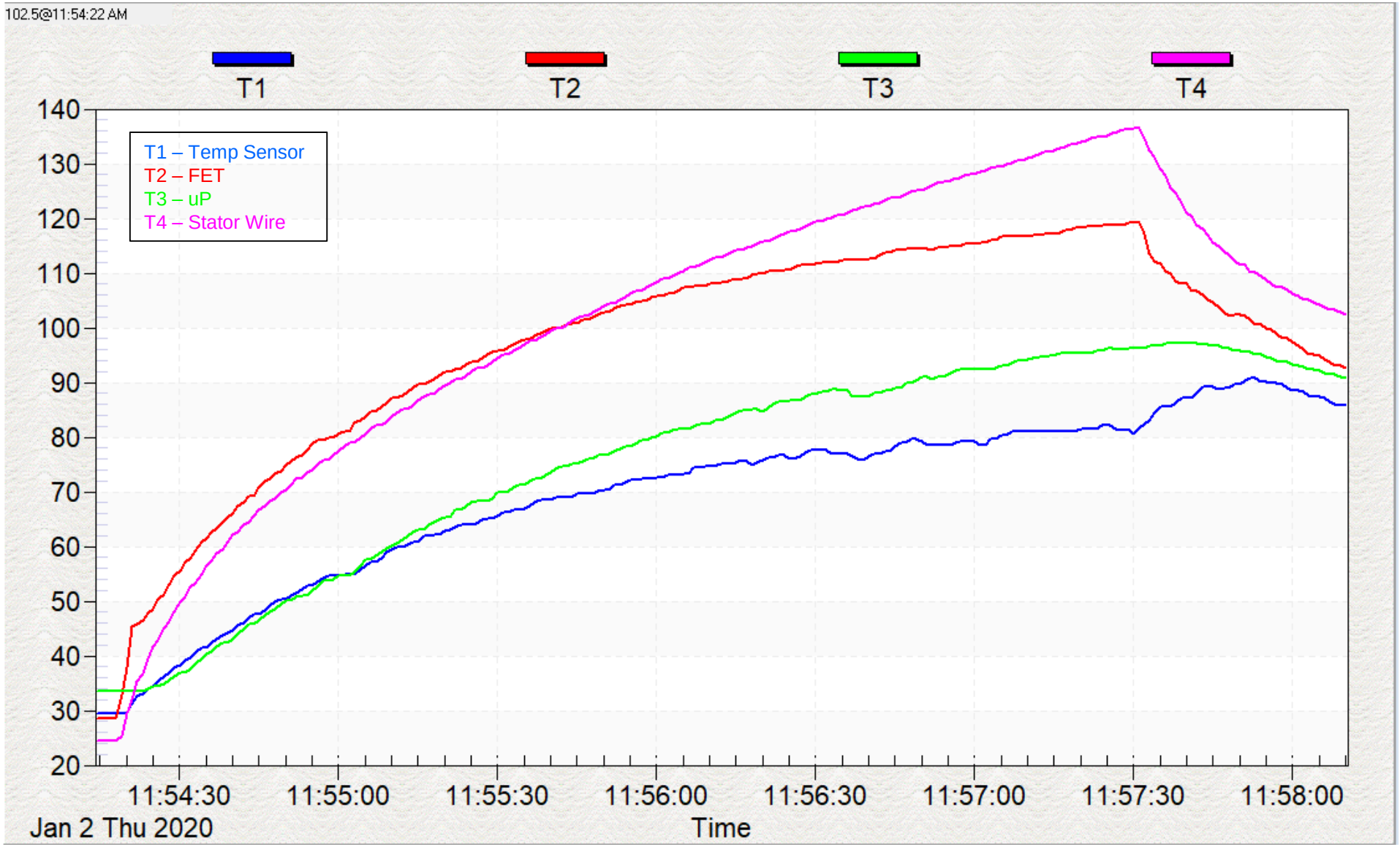
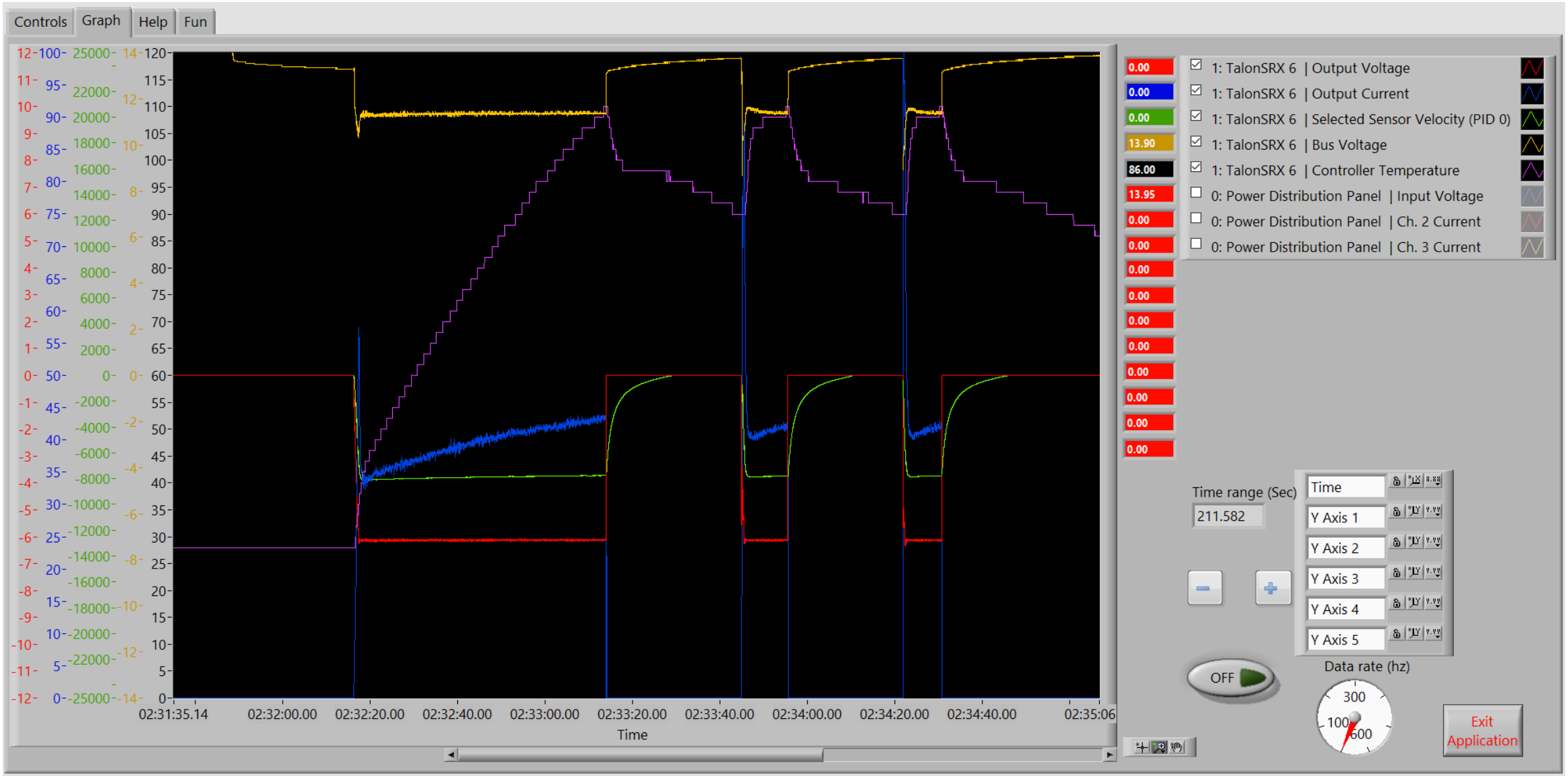
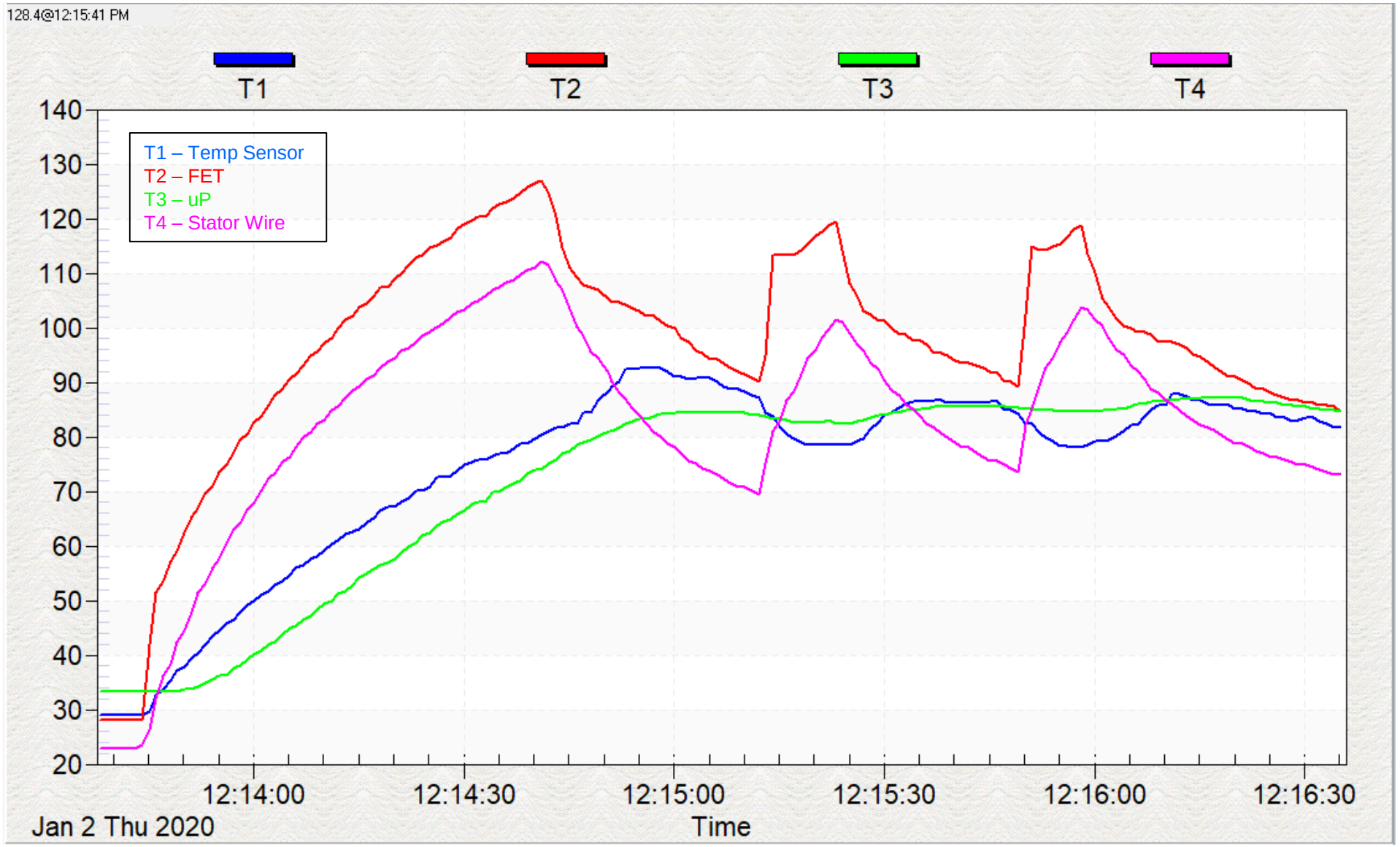


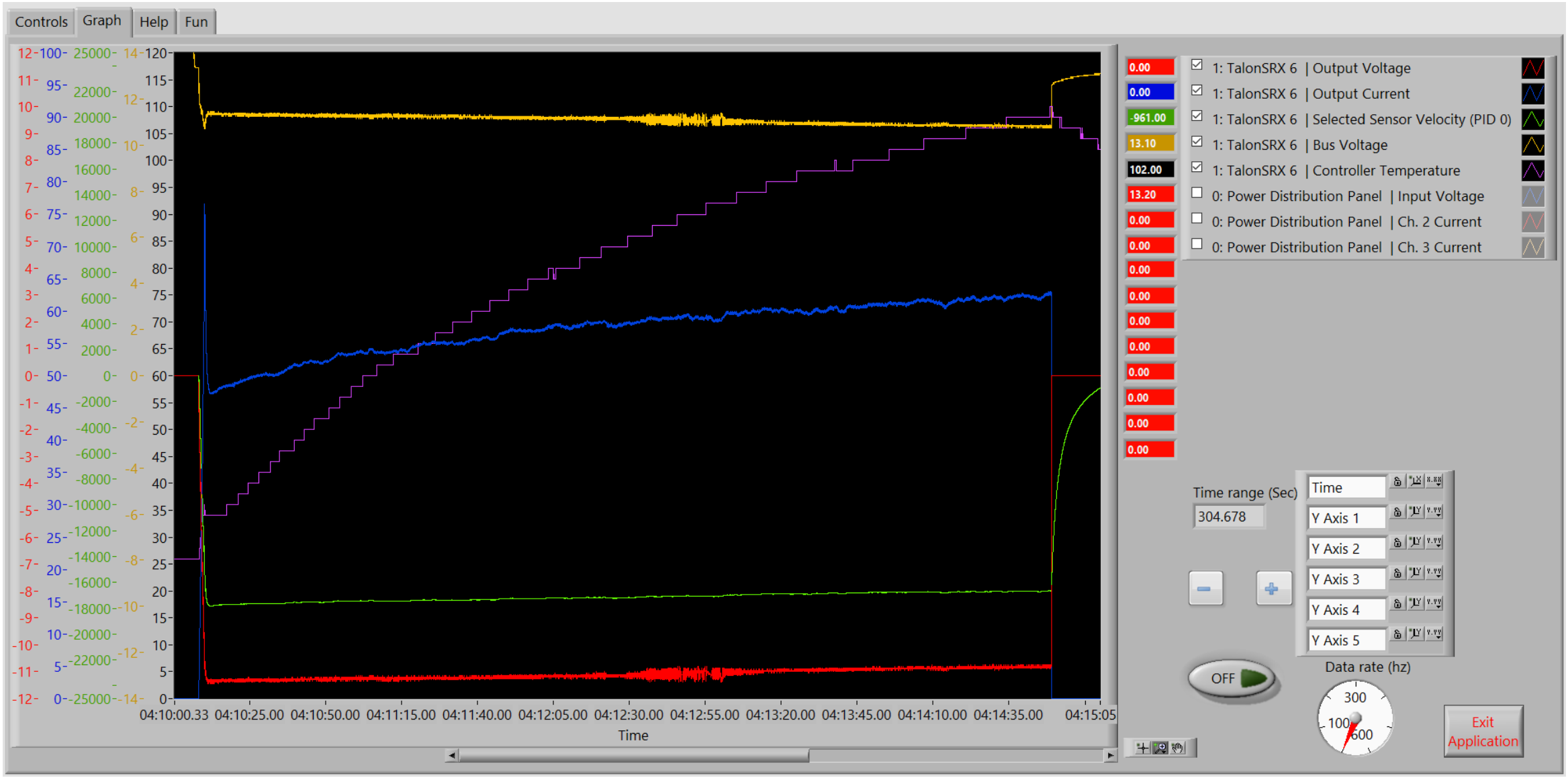
Test 4 – Released 110 firmware, 53% output, big prop, no backcap



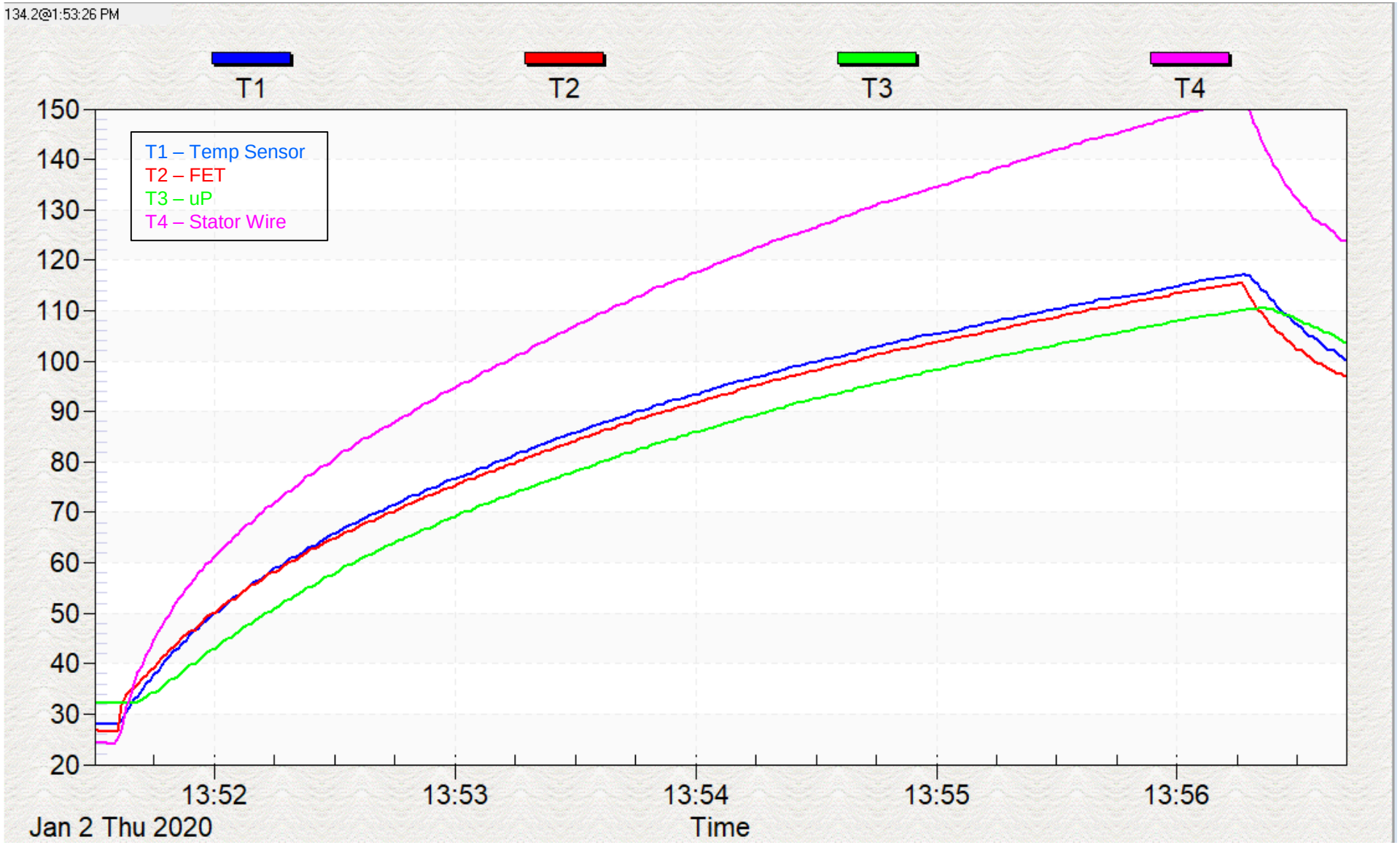
Test 4 – Released 110 firmware, 53% output, big prop, no backcap



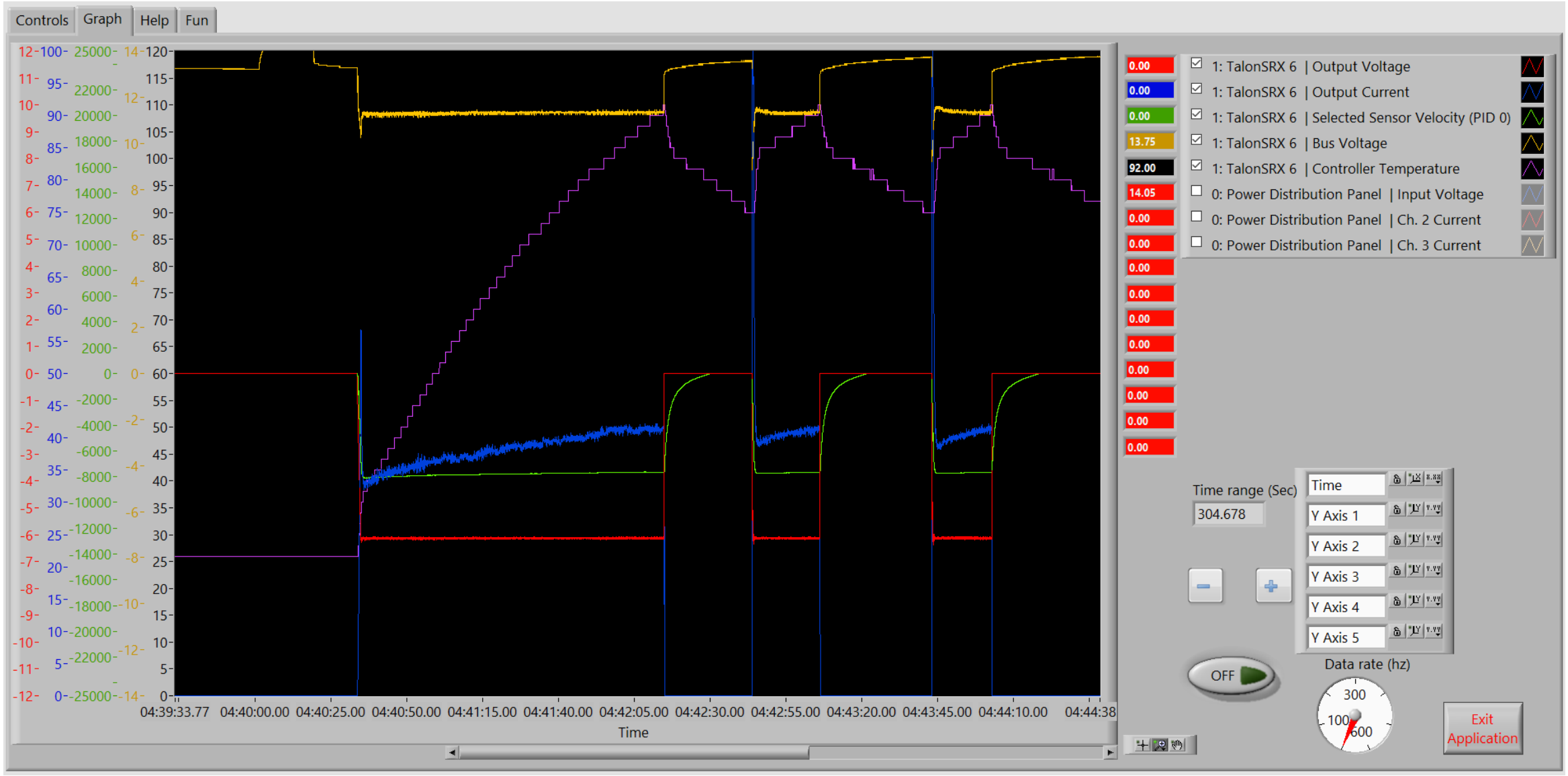
Test 5 – Released 110 firmware, 100% output, small prop, with backcap



Test 5 – Released 110 firmware, 100% output, small prop, with backcap



Test 6 – Released 110 firmware, 53% output, big prop, with backcap



Test 6 – Released 110 firmware, 53% output, big prop, with backcap