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CRANKSHAFT POSITION SENSOR (CKP) TEST REPORT

Ron Kessler
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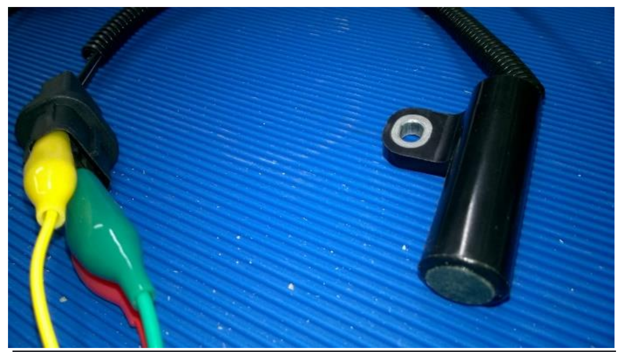
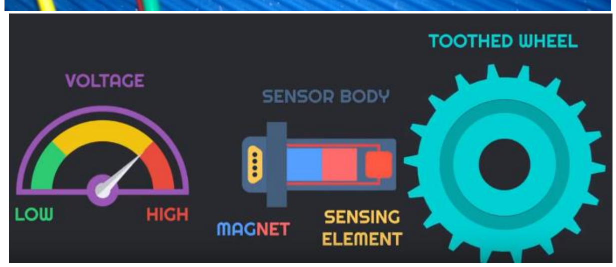
STATEMENT OF THE PROBLEM

This year, the Baja team will compete in the SAE competition in Tucson, Arizona. However, the traditional hill climb event has been replaced with a sled-pull challenge. To be competitive in the sled-pull the Continuously Variable Transmission (CVT) and the engine must be tuned to work together in order to provide maximum torque. However, other challenges such as the endurance race require higher speeds from the car and the CVT must be recalibrated for this event.

It was decided that RPM data and vehicle acceleration data should be matched in such a way that the CVT can be calibrated for each event. But before data acquisition can begin some method of reading engine RPM is required since the engine is not equipped with a tachometer device. This report summarizes the efficacy of two automotive sensors/devices which could be incorporated into the vehicle. The first experiment tests a Hall effect **C**ran**k**shaft **P**osition sensor (CKP). The second device tested was an ignition distributor Reluctor wheel.

Figure 1: Jeep CKP Hall Sensor





PURPOSE OF TESTS

- Evaluate the ability of a Hall CKP sensor to be activated by a magnet attached to a spinning motor.
- Determine if the Crank Position Sensor would trigger *without* a magnet by using a Reluctor wheel.
- Test the MCU's (Arduino in this case) ability to accurately measure RPM and transmit data via CANBUS.

TEST DESIGN (Part 1)

Figure 1 shows the Hall sensor used. It is an AUTEX 71-4984 crankshaft sensor from a 2004 Jeep. It was tested with a CANBUS demo board designed to gather RPM, temperature, battery voltage, and obstacle avoidance data (Figure 2).

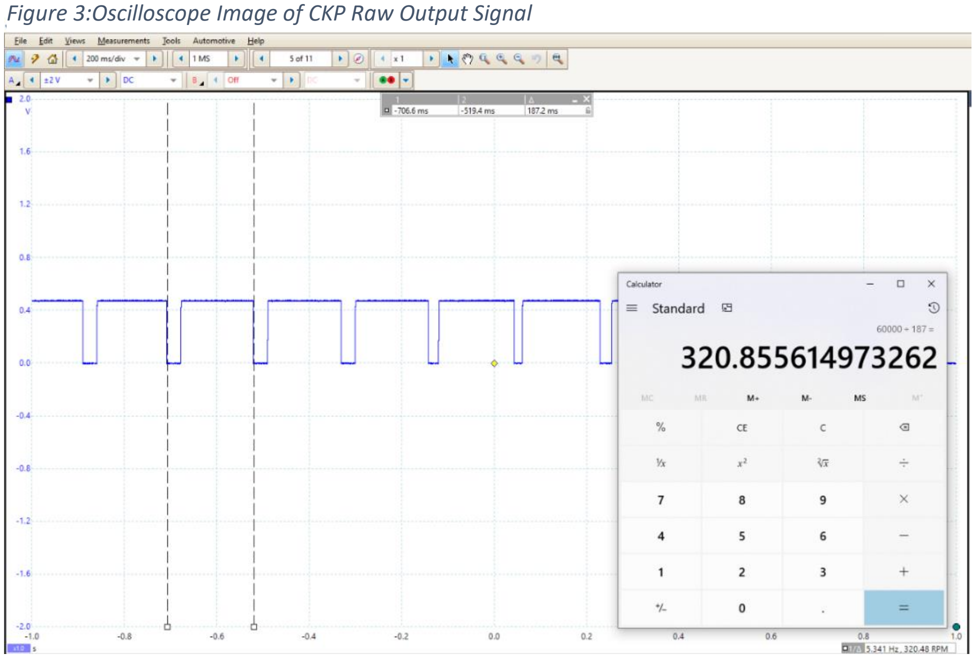
To trigger the sensor, a magnet or a toothed wheel (Reluctor) can be used. For the first test, a strong magnet was attached to a small rotating drill motor and placed within 5mm of the Hall sensor. The magnet on the drill disrupts the magnetic field on the end of the sensor as it moves in proximity to the sensor. That change in magnetic flux is converted into a digital signal via a Schmitt trigger and small amplifier circuit inside the sensor itself. This change in voltage is easy for the Arduino to detect and measure the pulse frequency. This can be turned into RPM readings.

Figure 2: Canbus Setup Showing RPM

RESULTS

- The results supported the hypothesis that an automotive sensor can indeed be used to gather RPM data from the Baja vehicle and transmit it via CANBUS. From figure 3, when a single magnet was used, a strong, reliable, and clean digital signal was produced. All data processing is handled inside the sensor and the MCU (Arduino in this case) without the need for any external components. This bodes well for use in a harsh environment.

Figure 3:Oscilloscope Image of CKP Raw Output Signal



- Notice the signal is about +.45V when idle. When the sensor is triggered, the pulse goes low (to zero volts). The Arduino NANO is pulling the digital input pin for the sensor data high. That allows my code to catch the instant the signal goes low which means the Hall sensor magnetic field has been disrupted.

- The dotted vertical lines show the time between two low pulses (1 cycle). The delta shows 187ms.

- RPM calculation:
    - There are 60,000ms per minute so:
    - **RPM = 60,000/187.2 which is 320.8 and that corresponds to the LCD value in figure 2.**

TEST DESIGN (Part 2)

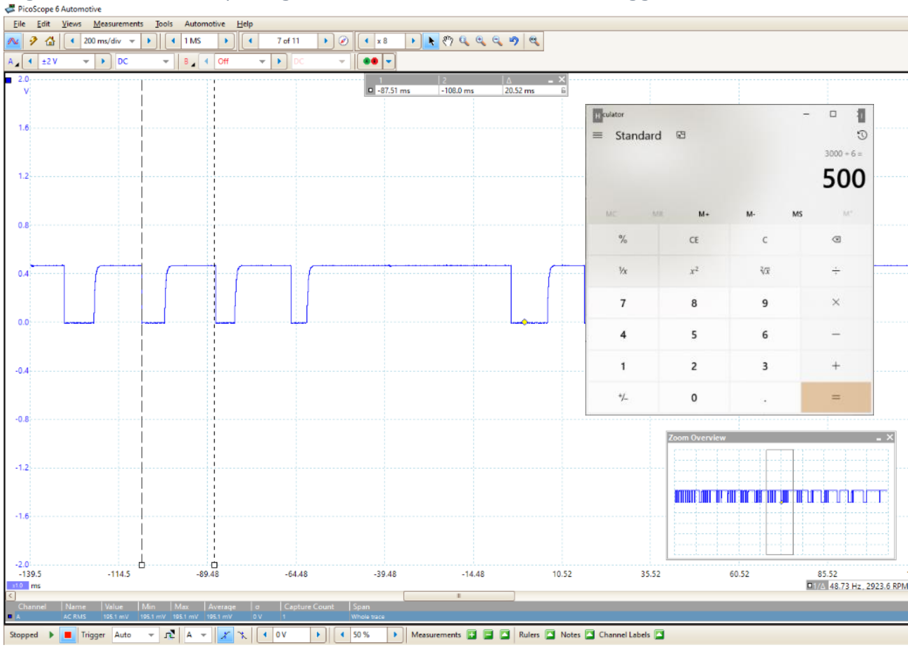
There are some drawbacks to using a magnet on the output shaft of an engine. Most notably, it might become dislodged during operation and cause problems. In order to test the hypothesis that the CKP can be triggered *without* a permanent magnet, a distributor Reluctor wheel was tested. Figure 4 shows the NTK 1A4012 used. This device is used inside a distributor and replaces traditional ignition points and condenser. As the teeth of the wheel pass near a pickup coil, the pulse causes the ignition coil to charge and ultimately deliver high voltage to the spark plugs.

Figure 4:Distributor Reluctor (6 teeth)

In this test, the Reluctor was attached to the small rotating drill motor as before and held close to the crank sensor.

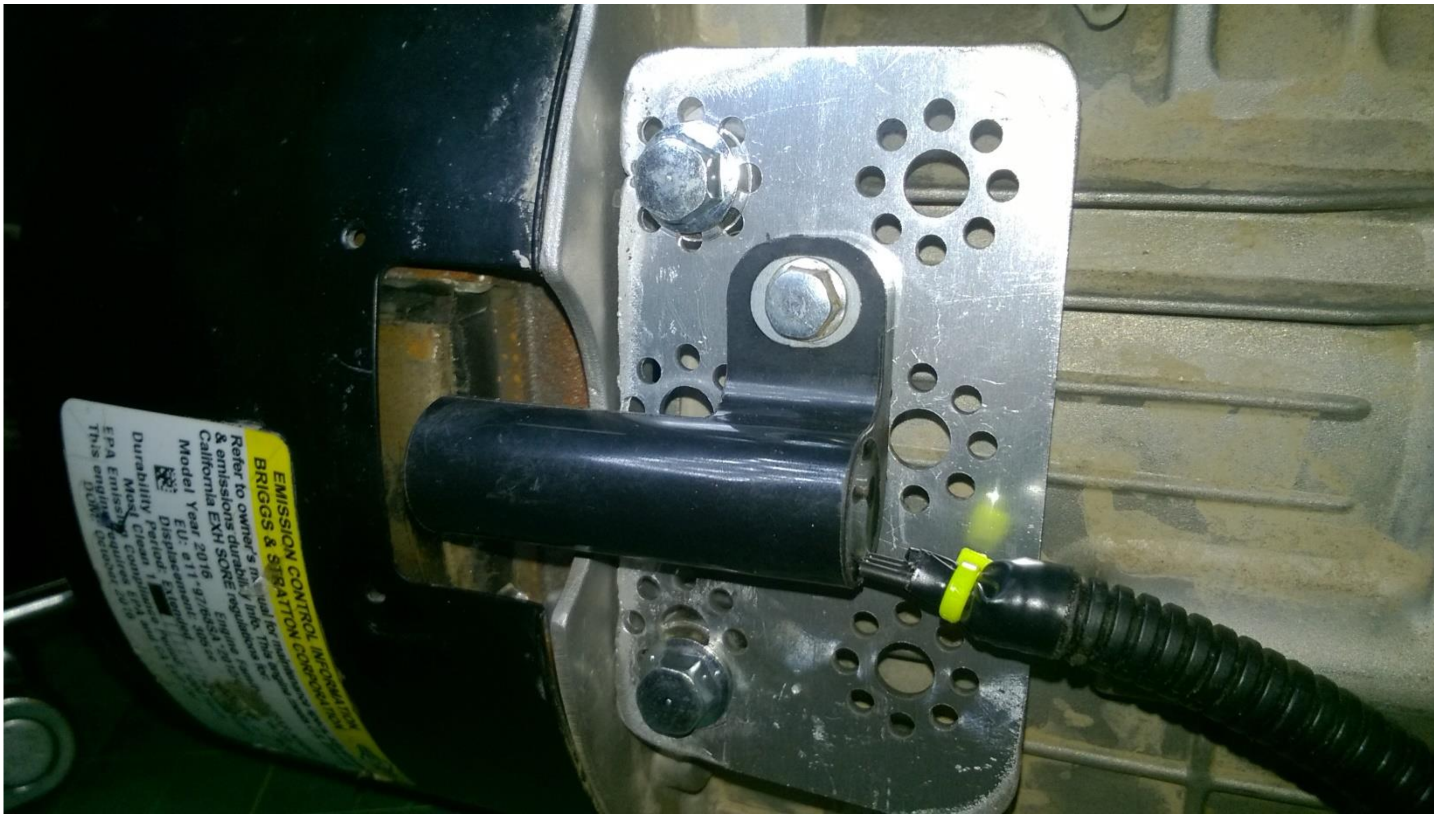
- **DESCRIPTION**
  - This is a steel ignition Reluctor which triggers pulses in a distributor pick-up coil for a 6-cylinder engine. The CKP requires a ferrous material in order to produce an output. Therefore, plastic and aluminum rings were not considered.
- **PURPOSE OF TEST**
  - Evaluate the ability of a Reluctor to measure RPM on the Baja car.
  - Determine if the Crank Position Sensor would trigger without a magnet.
  - Test the MCU's (Arduino in this case) ability to accurately measure RPM with six (6) flux changes per revolution. There was some concern the Arduino interrupts could not respond fast enough at high RPMs.
- **RESULTS**
  - Just as in part 1, Figure 5 shows a clean and reliable signal. With 6 teeth the signal was higher frequency because it was like having 6 magnets on the drill motor.
  - There was 20.5ms between pulses (1 cycle from low-to-low pulse). When a single magnet was used, the duration of 1 cycle was 187ms.
  - RPM was computed in the same way as with the single magnet:
    - RPM = 60,000ms / 20ms = 3000 pulses/revolution.
    - **RPM = 3000 pulses / 6 teeth = <u>500</u>**
  - The results support the theory that an automotive Hall Crank Position Sensor can be used without a magnet. The sensor responds to any ferrous material that disrupts the magnetic field in the Hall Effect circuitry.

Figure 5:CKP RAW Output Signal with Distributor Reluctor As Trigger Device

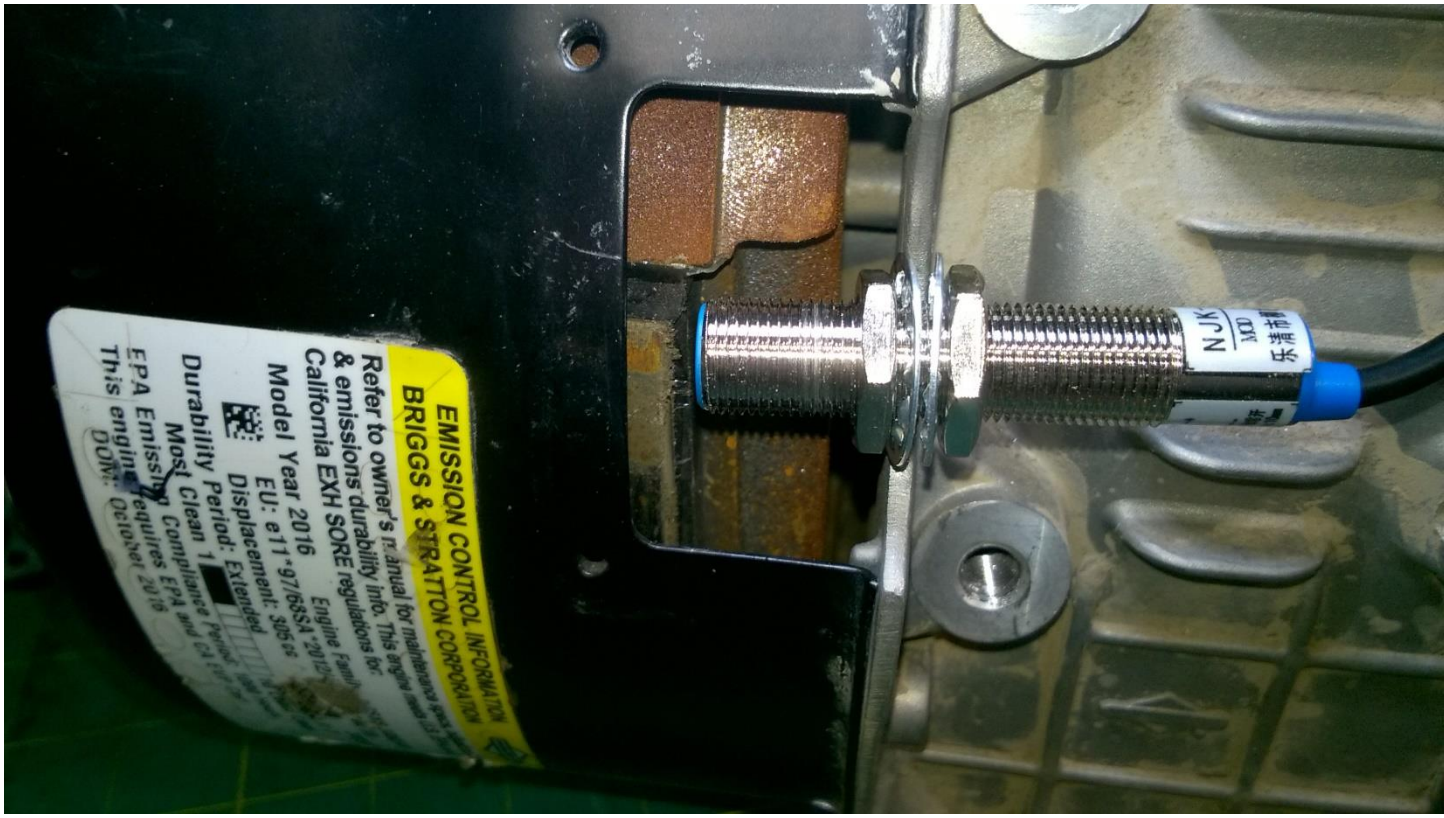


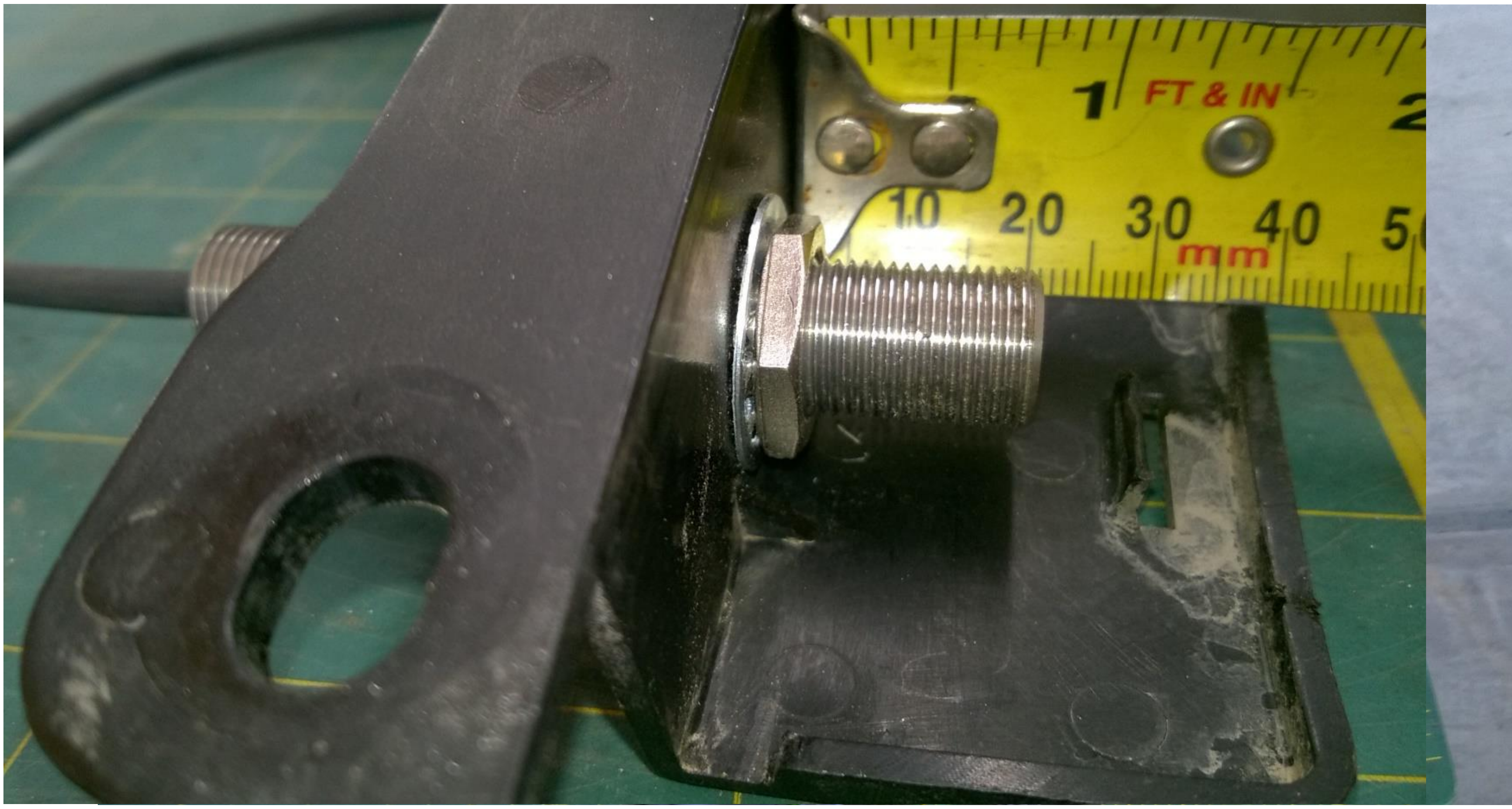
- **APPLICATION**
  - This proof-of-concept experiment suggests that a Reluctor attached to the output shaft of the Briggs & Stratton engine can be used to gather RPM data in order to calibrate the constant velocity transmission.
  - More specifically, RPM and accelerometer data can be combined in order to tune the CVI to match the engine's peak horsepower.

PRELIMINARY TESTING ON ENGINE PHOTOS

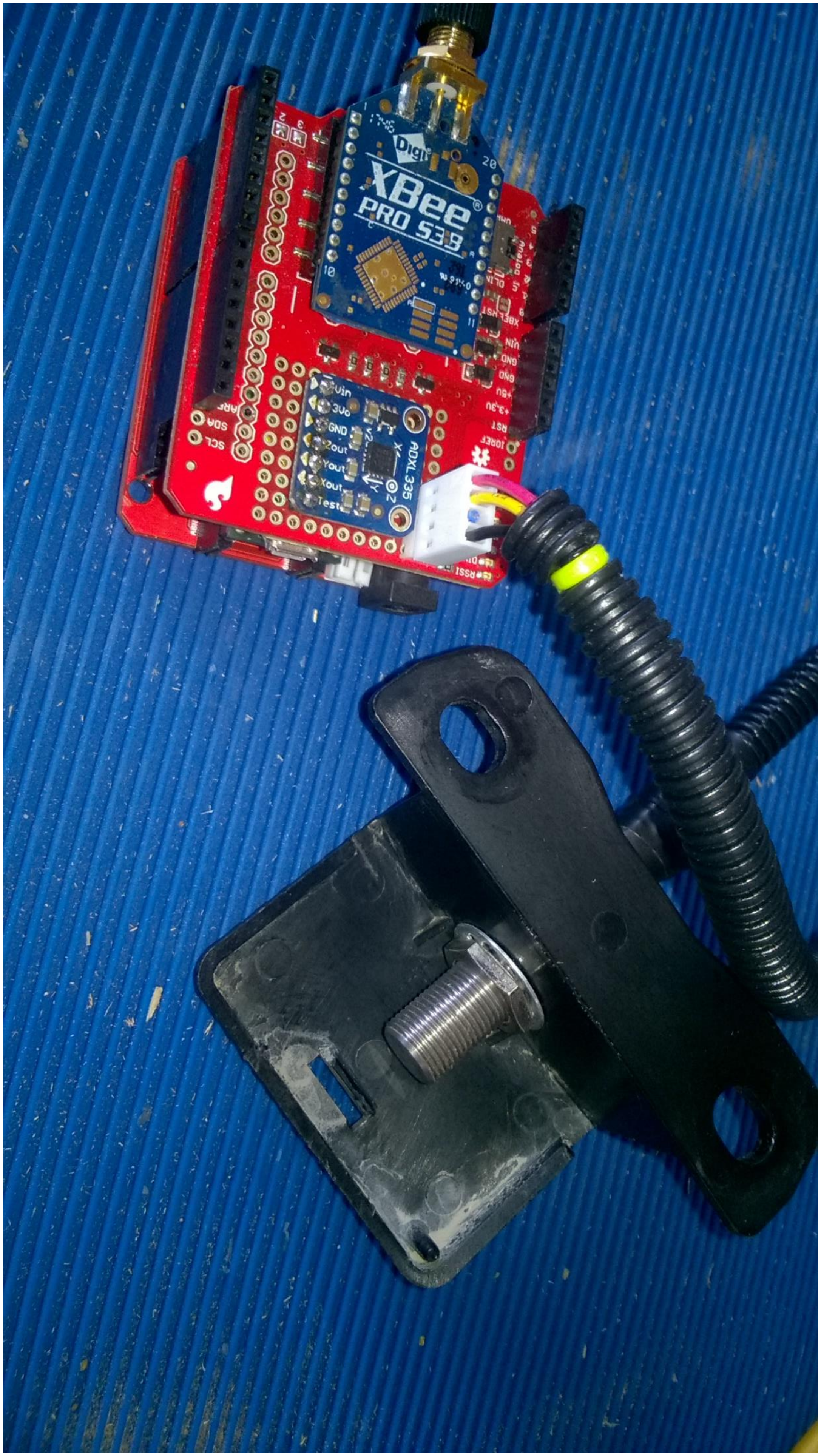


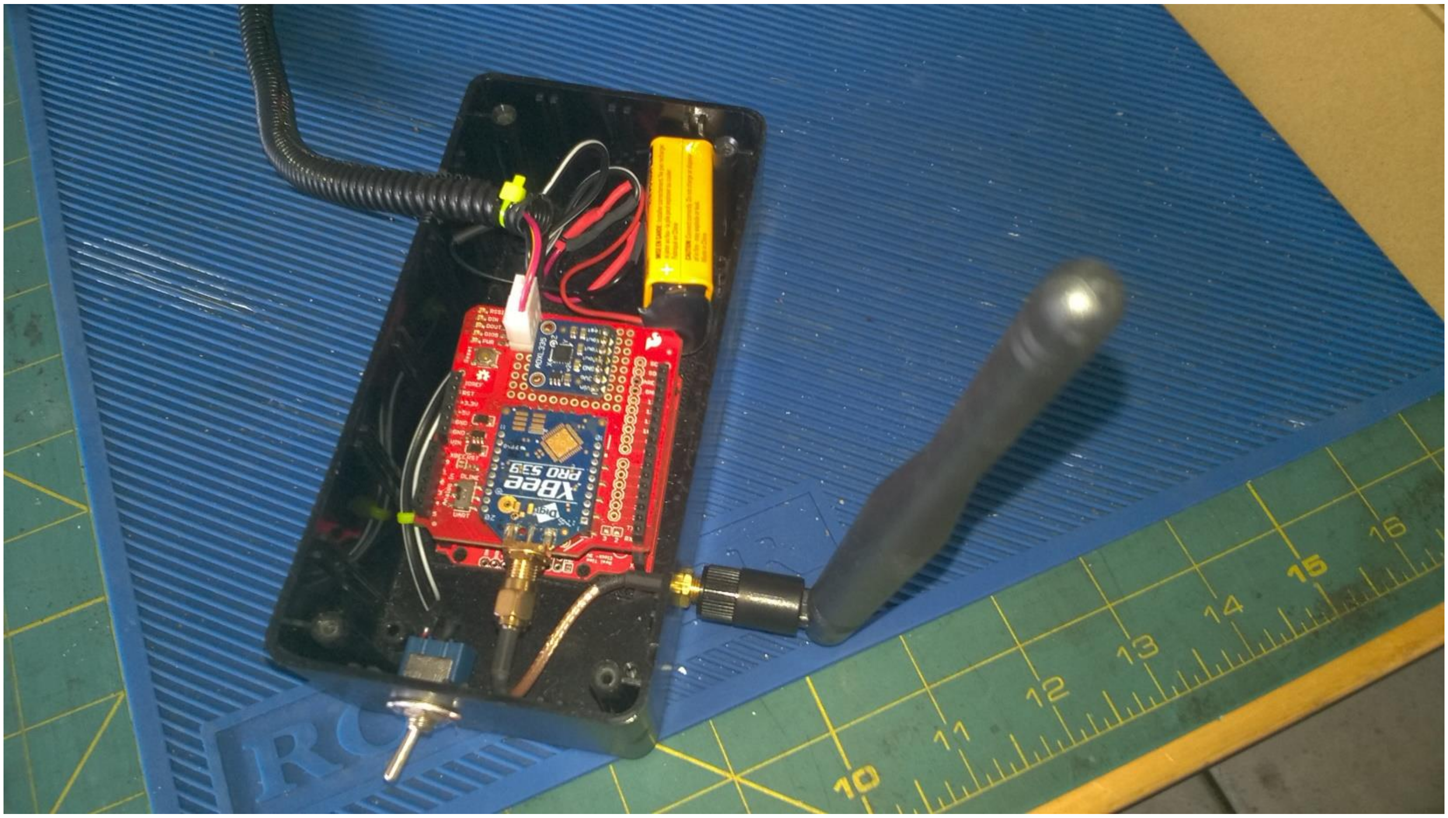

Model Year 2016
Durability Period: Extended


EMISSION CONTROL INFORMATION
BRIGGS & STRATTON CORPORATION
Model Year 2016
Durability Period: Extended
NJK


1 FT & IN 2
10 20 30 40 50
mm


MEXICO
1 FT & IN 2 3
10 20 30 40 50 60 70 80
mm
8m/26'
C
19 20 22 23 24 25 26


Digi
XBee
PRO S3B
ADXL335
Vin
3Vo
GND
Zout
Yout
Xout
Test


XBee
PRO S3B
10
11
12
13
14
15
16


MEM
TEST
DT-2234C+
DIGITAL TACHOMETER
Milwaukee
WARNING
2
14
45°
60°

The PC application has been updated to handle RPM readings and graphing on a new Y-Axis. The current readings can be examined by scrolling throught the list box. Data can be saved locally or in a remote SQL database for later analysis.

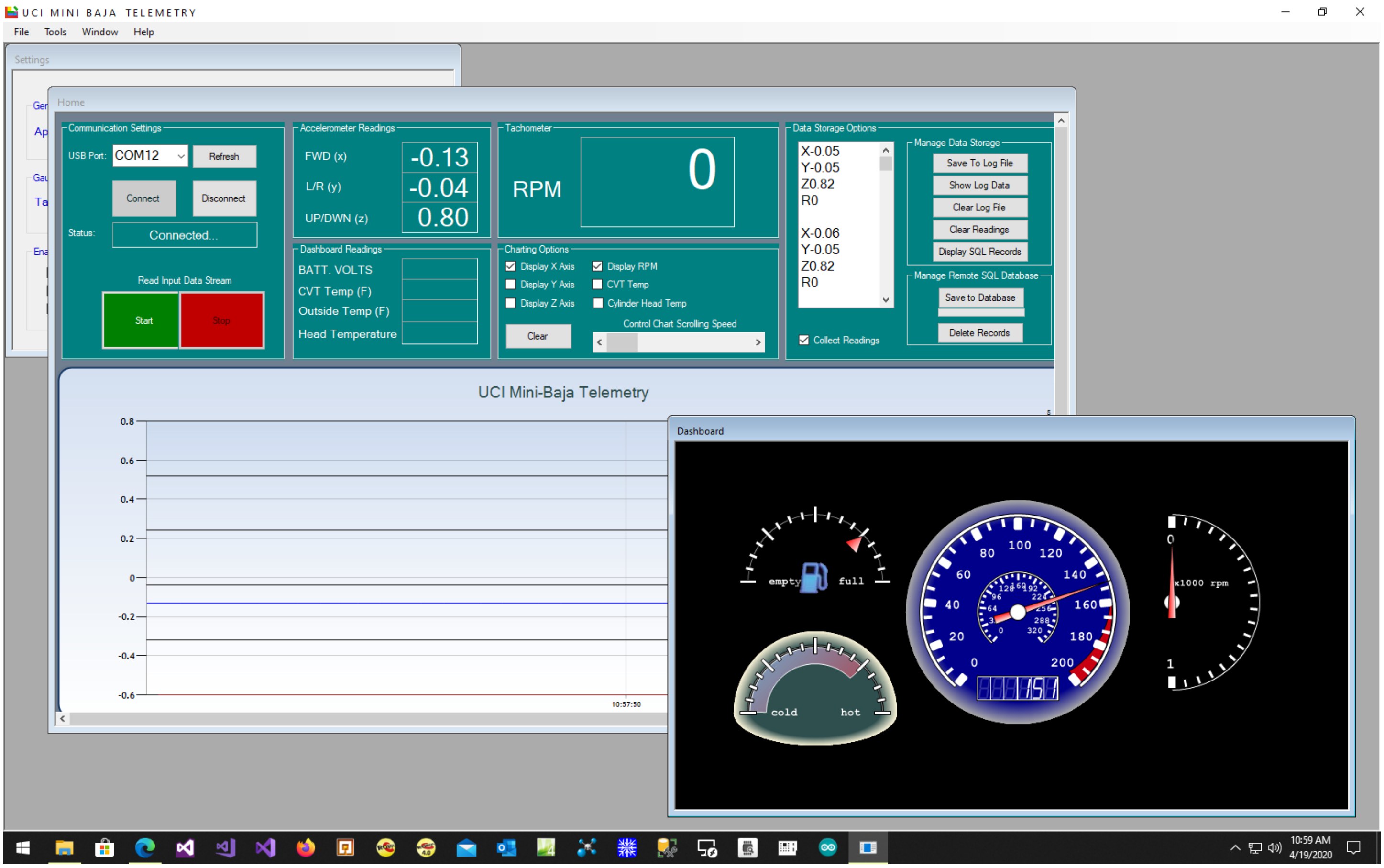


Figure 6: Updated PC Application. Chart Showing RPM and X-Axis Accelerometer Readings & Captured Data.