

Fall 10-13-2017

Digital Storage Oscilloscope Tools

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Shop made DSO tools

Recommended Citation

Boyle, Sean. "Digital Storage Oscilloscope Tools." (Fall 2017).

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ICAIA 2017

DSO Tools

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DSO Tools

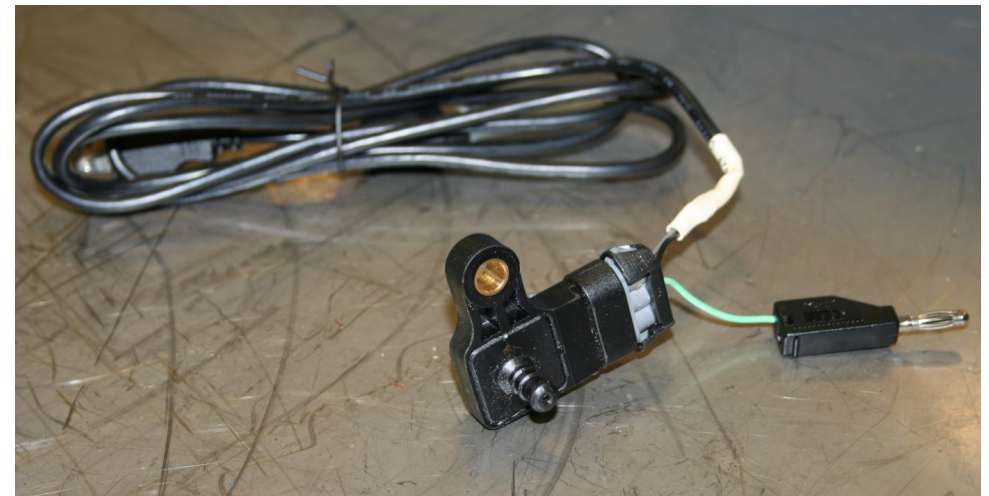
- Common “store bought” tools
 - Amp clamp
 - Inductive pick-ups (secondary ignition)
 - Pressure transducer
 - PV350
 - WPS
 - Pulse sensor
 - First look
- Shop made tools
 - Pressure transducers
 - Amazon/ebay
 - Transmissions on hand
 - Map sensor
 - FTP sensor
 - Pulse sensor
 - Piezo microphone/buzzer
 - Noise/Vibration
 - Chassis Ear
 - Ardurino
 - Knock sensor
 - Speed sensor/trigger
 - Temp Sensor
 - NTC



Pressure Transducers

Pressure

- Store Bought
 - PV350 - \$400
 - WPS – \$780 – \$1500
- Shop made
 - Search Amazon/Ebay for “500 psi transducer”
 - \$16 will get you a sensor and pigtail
 - These will test vac and pressure
- Transmissions on hand
 - 545rfe transmissions have a 500psi transducer for line pressure
- MAP sensor
- FTP sensor



Amazon transducer

- Wire to USB cable
- Use quick disconnect fittings
- Use ¼" HDPE Tubing (300psi)



Pressure

- Amazon transducer

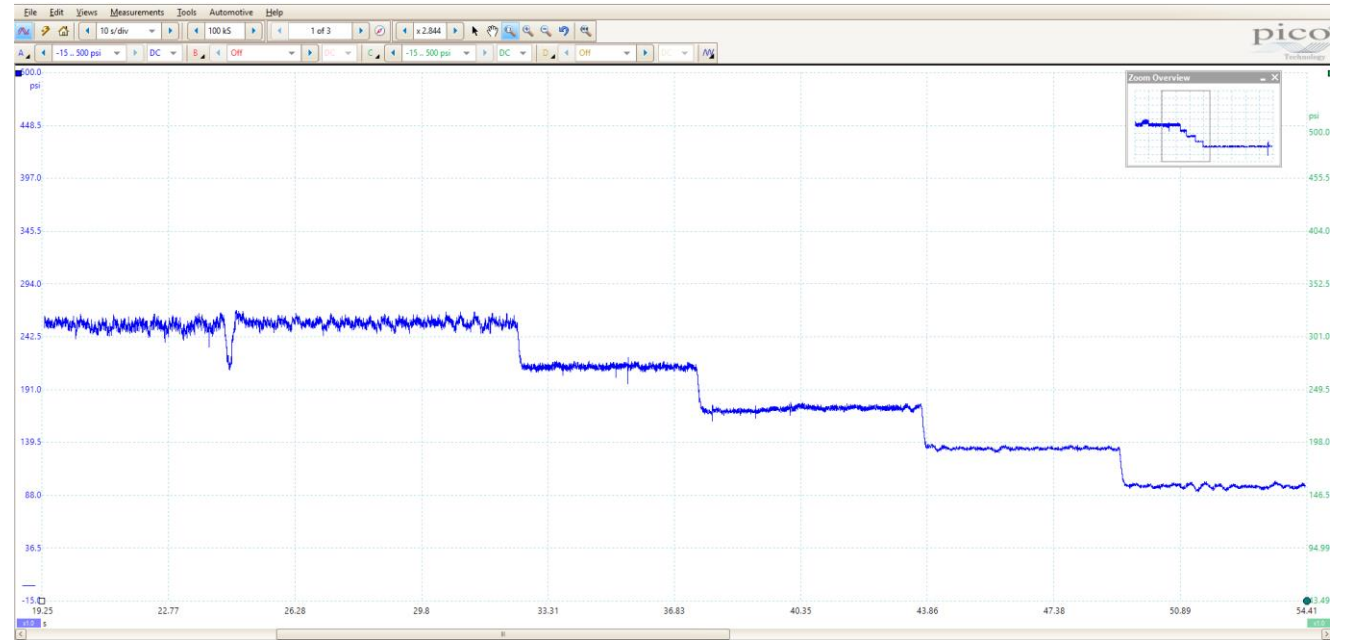
0v = 30 in Hg

.5v = 0 psi

2.5v = 250 psi

4.5v = 500 psi

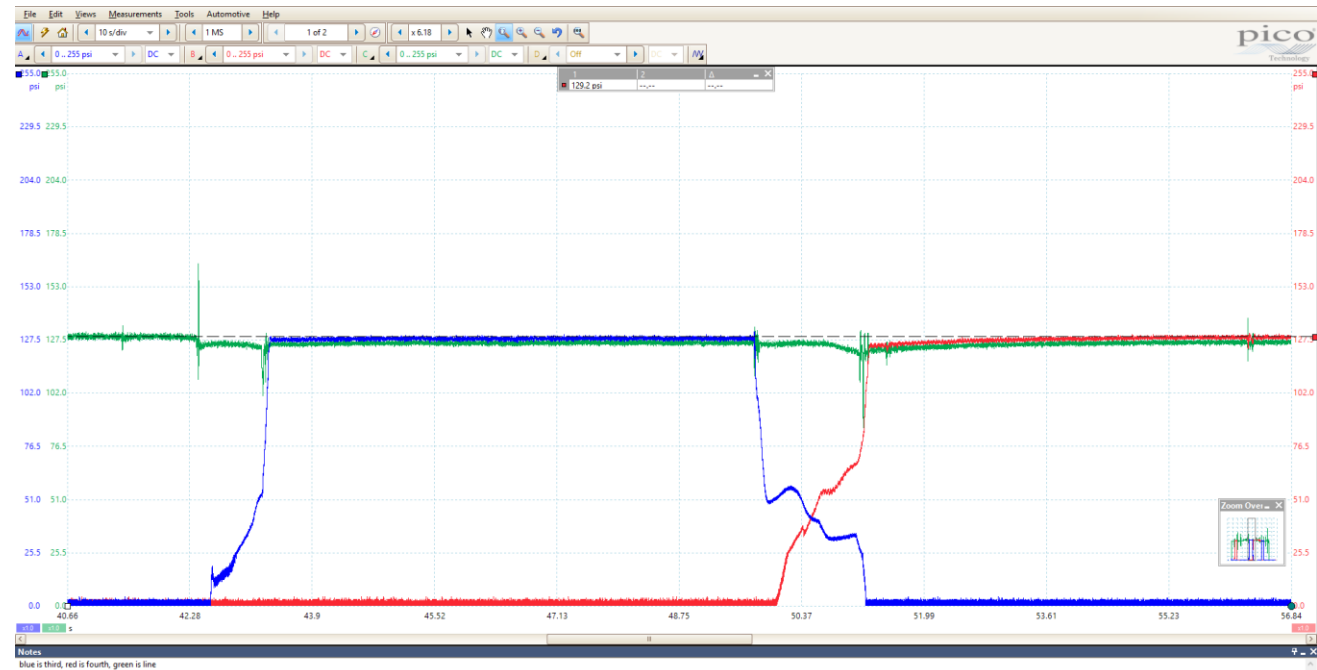
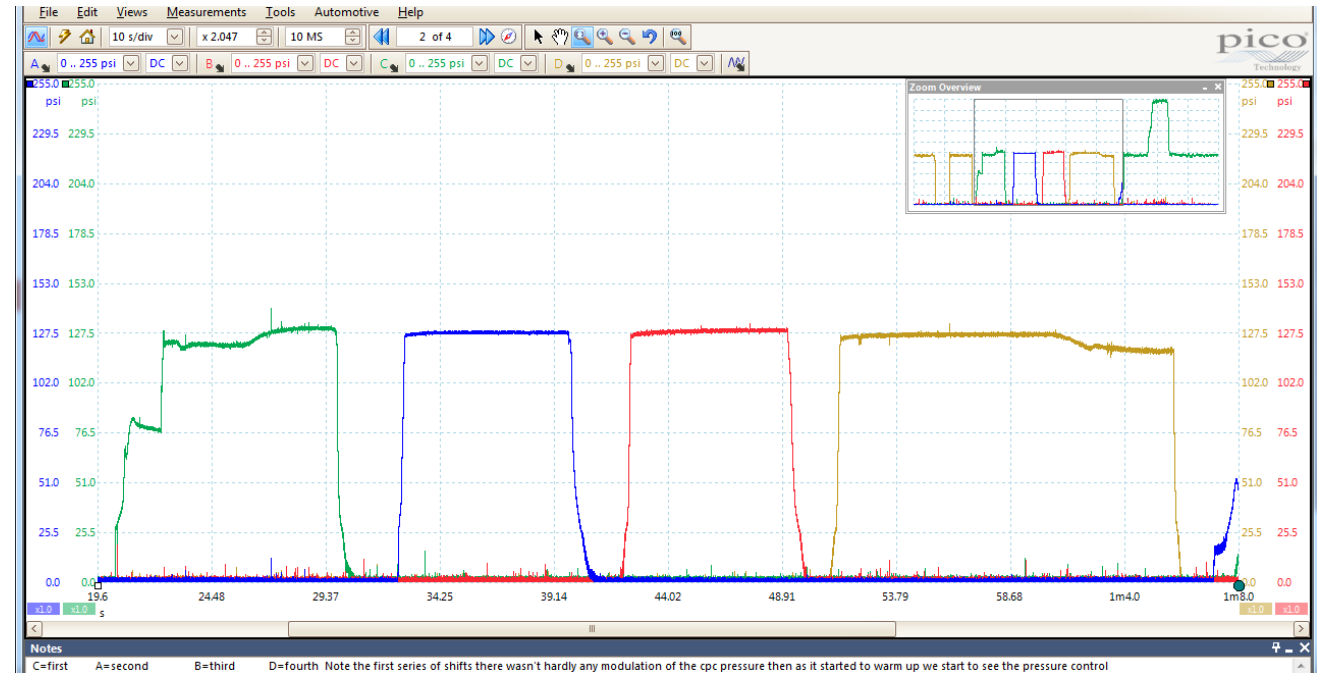
- Set up a custom range in the scope to display the correct pressures



Pressure

- Example

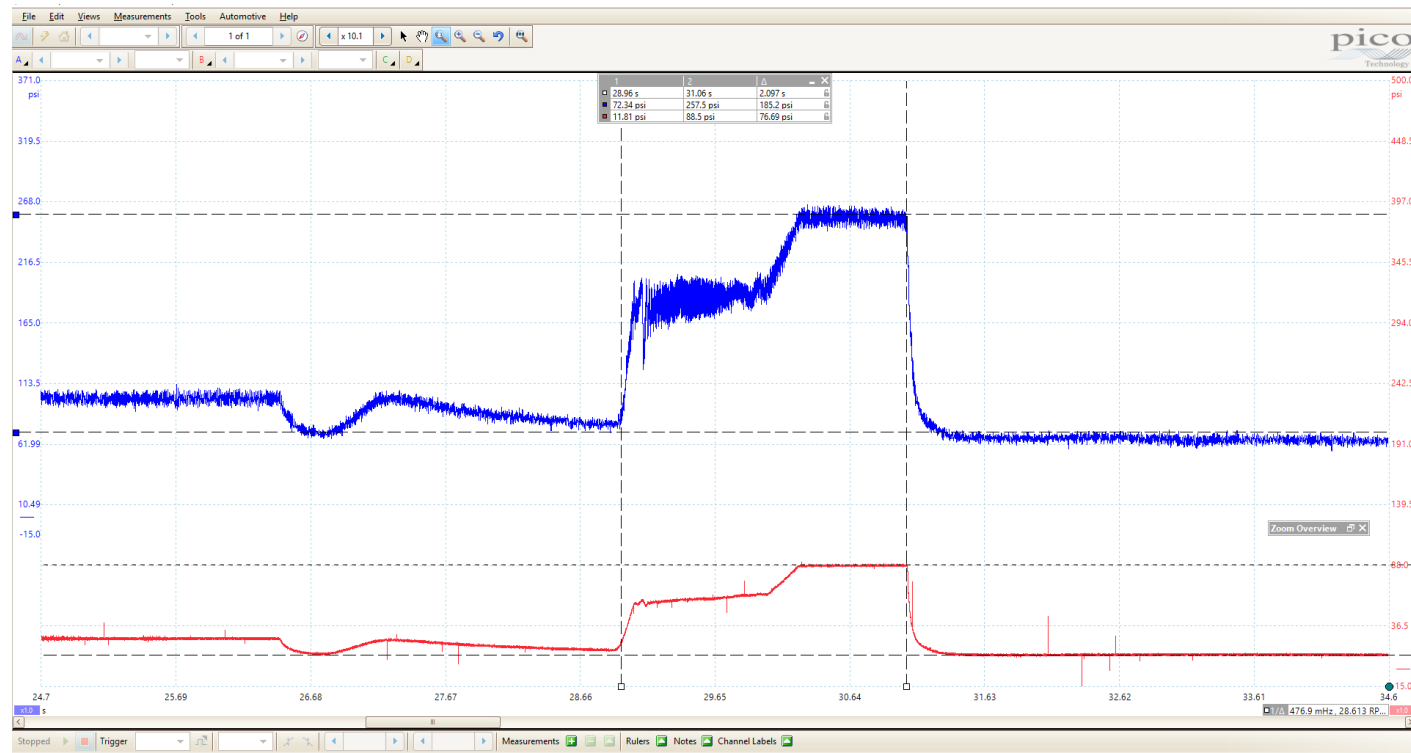
- Honda transaxle
- Top scope image is pre-repair
 - Notice the gaps between gears
 - This transmission had flares during shifts
- Bottom scope image
 - Rebuilt transmission, with new pressure switches and cleaned cpc solenoids
 - Notice the overlap between 3rd and 4th (blue and red)



Pressure

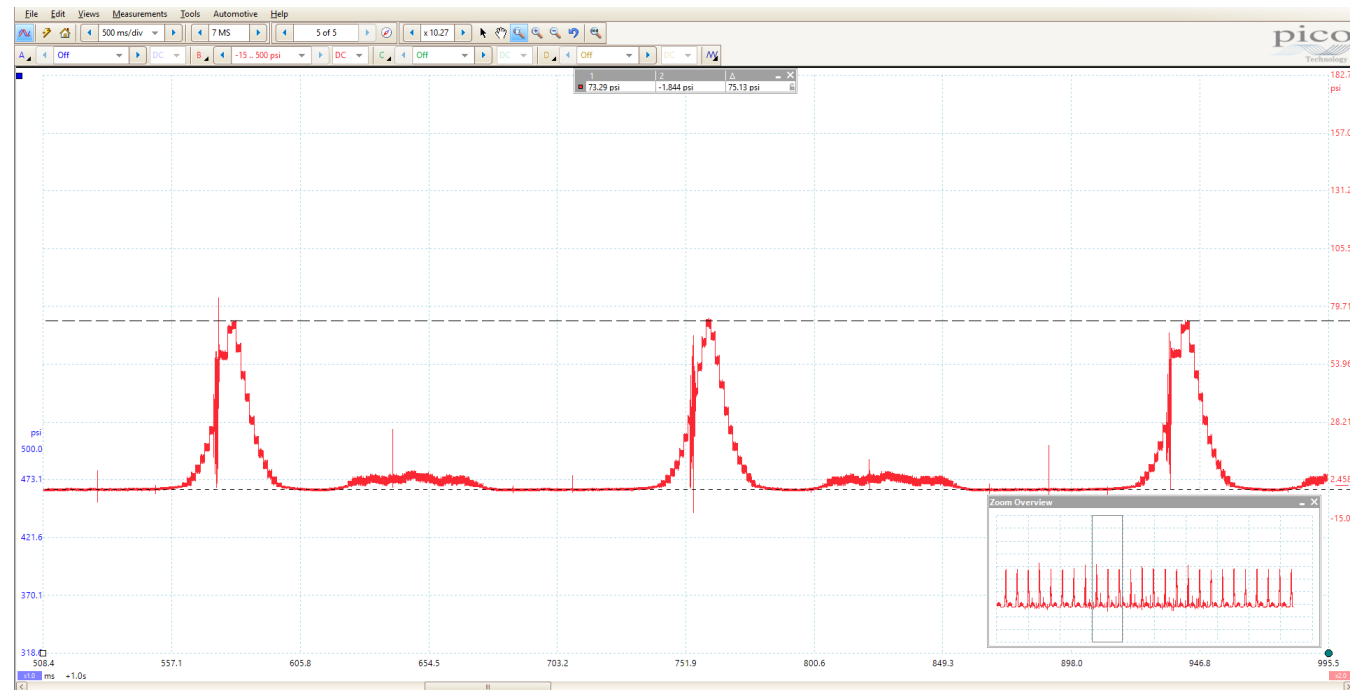
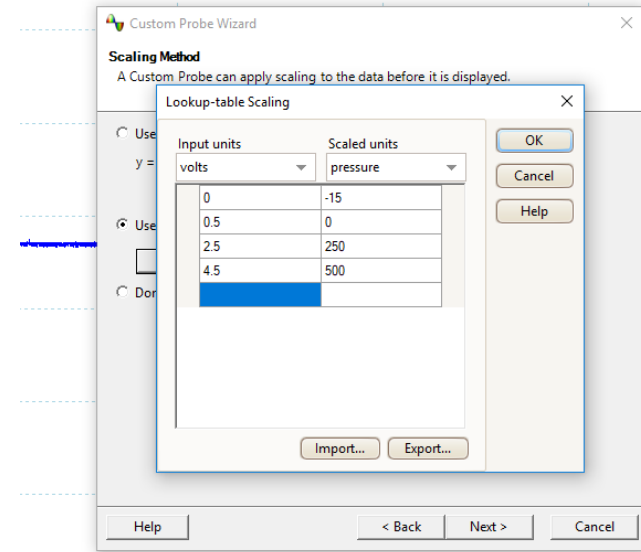
- Example

- Ford transaxle
- Shift into second, then short flare
- Trans is adapting to slippage and adjusting pressures to the max during the shift



Pressure

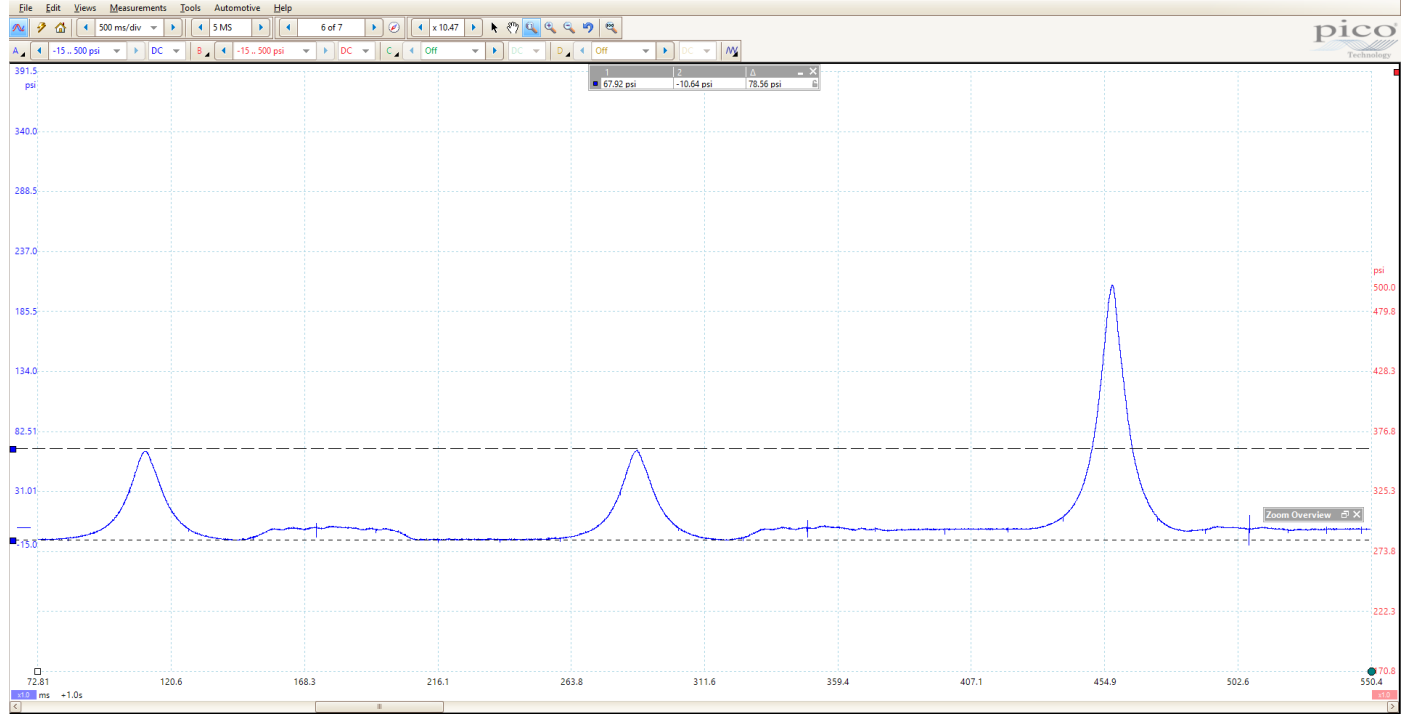
- China transducer
- Pros
 - Cheap
 - Small
 - Wide range of pressures available (5psi to 1600psi)
- Cons
 - .5v = zero makes it hard to use unless you can set custom ranges
 - Needs power supply (usb work fine)
 - Slower response rate than a PV350 or WPS, so it won't work as well when checking combustion events



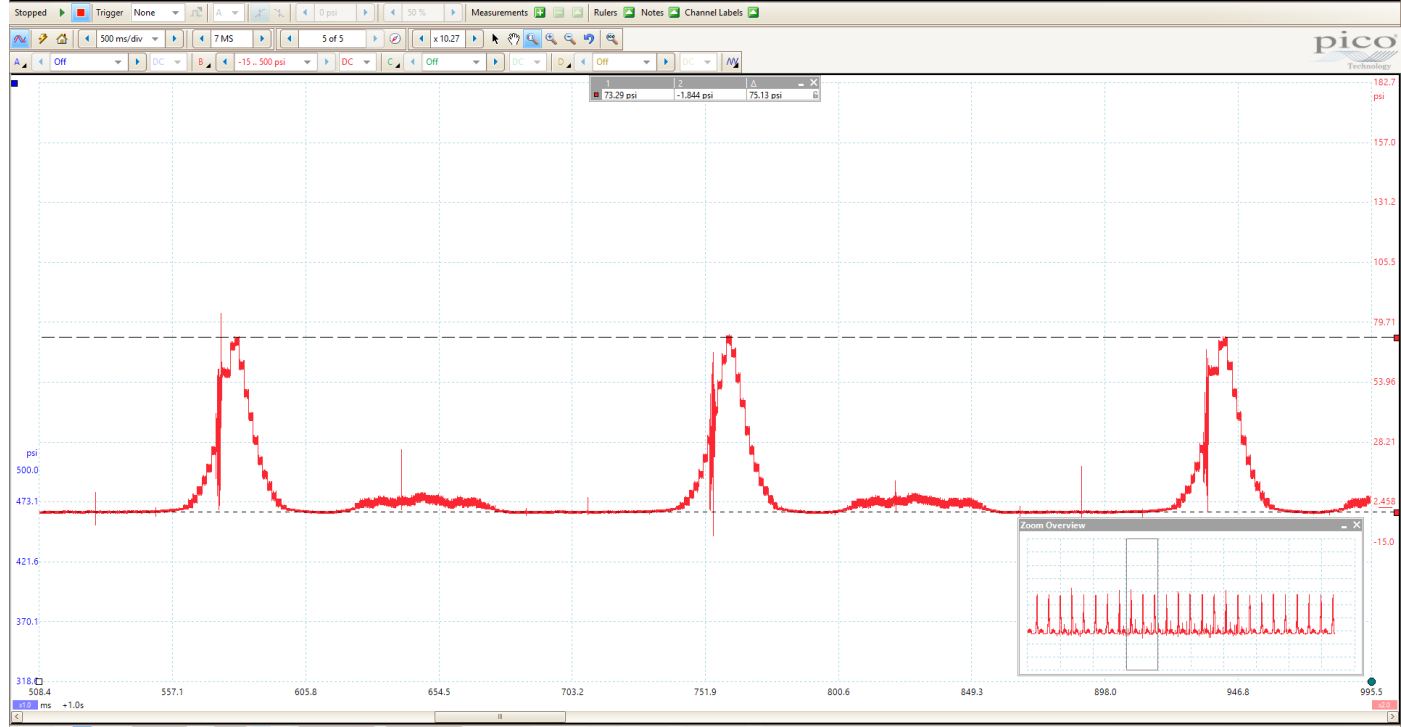


Pressure

PV350

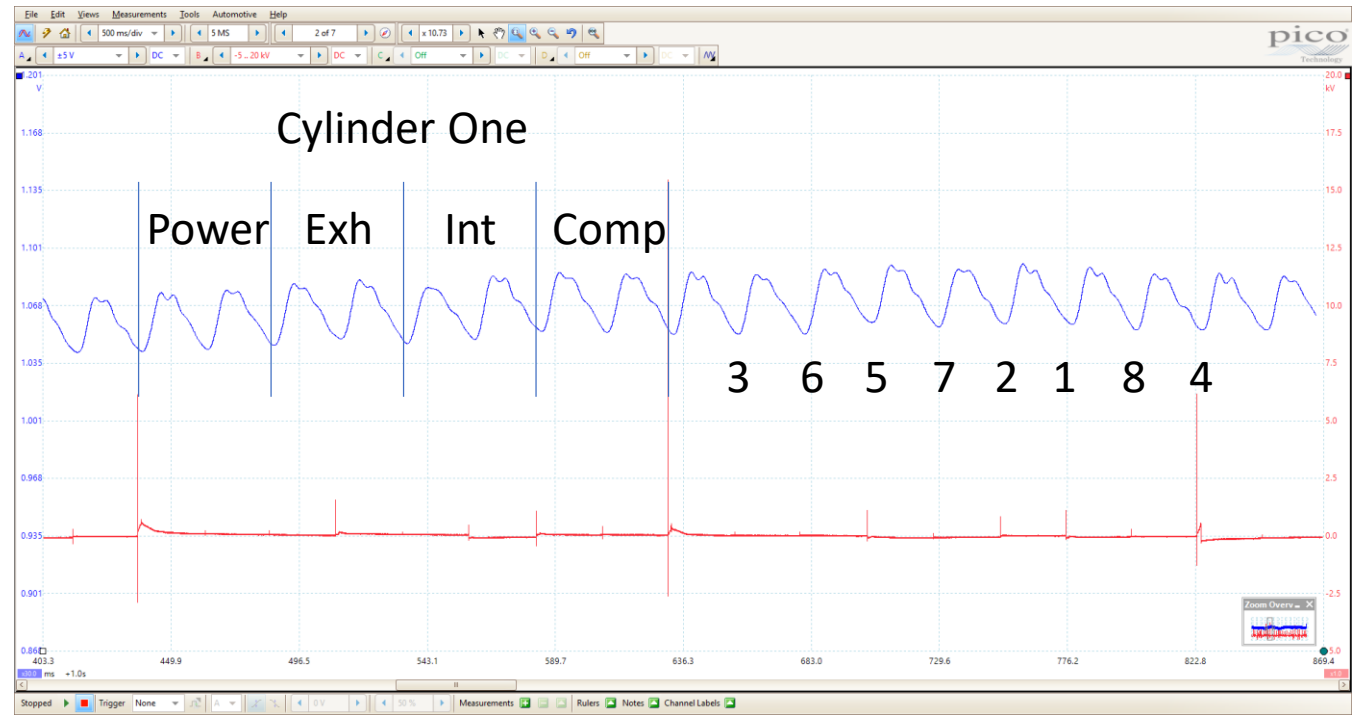
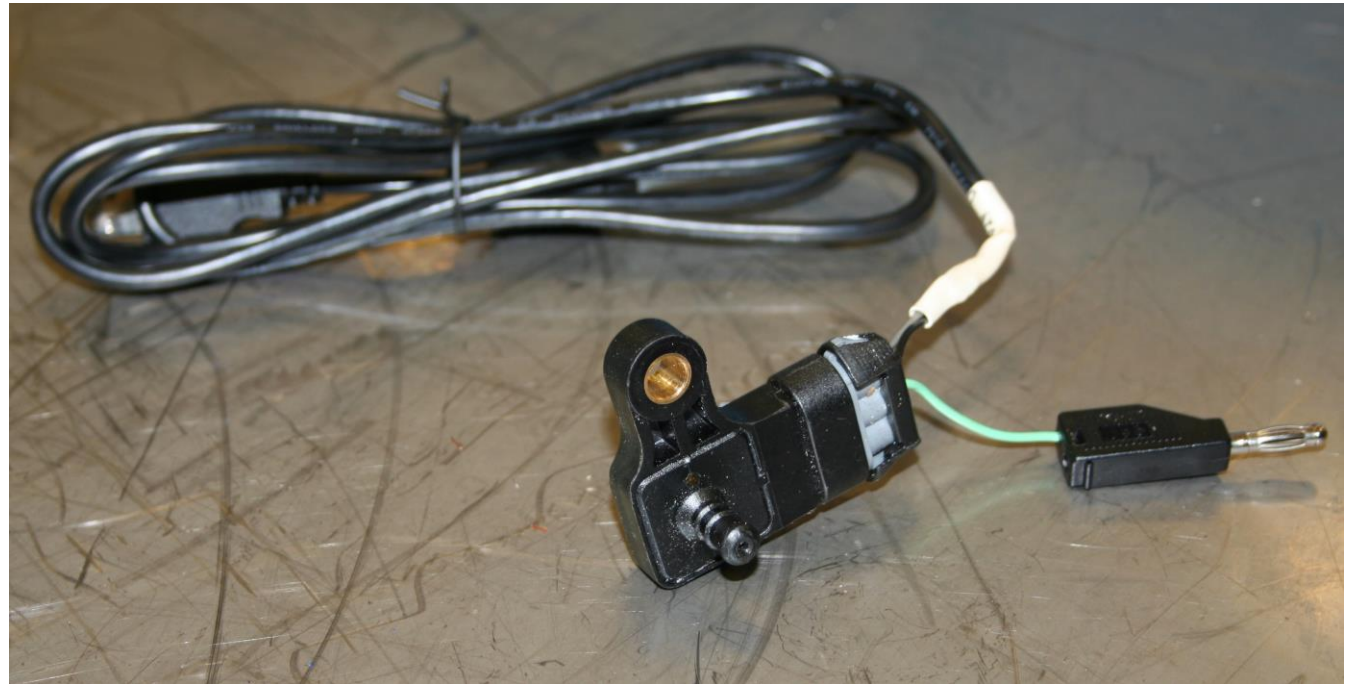


Amazon



Pressure

- MAP Sensor
 - Digital vacuum gauge
 - Measure cylinder pumping contribution



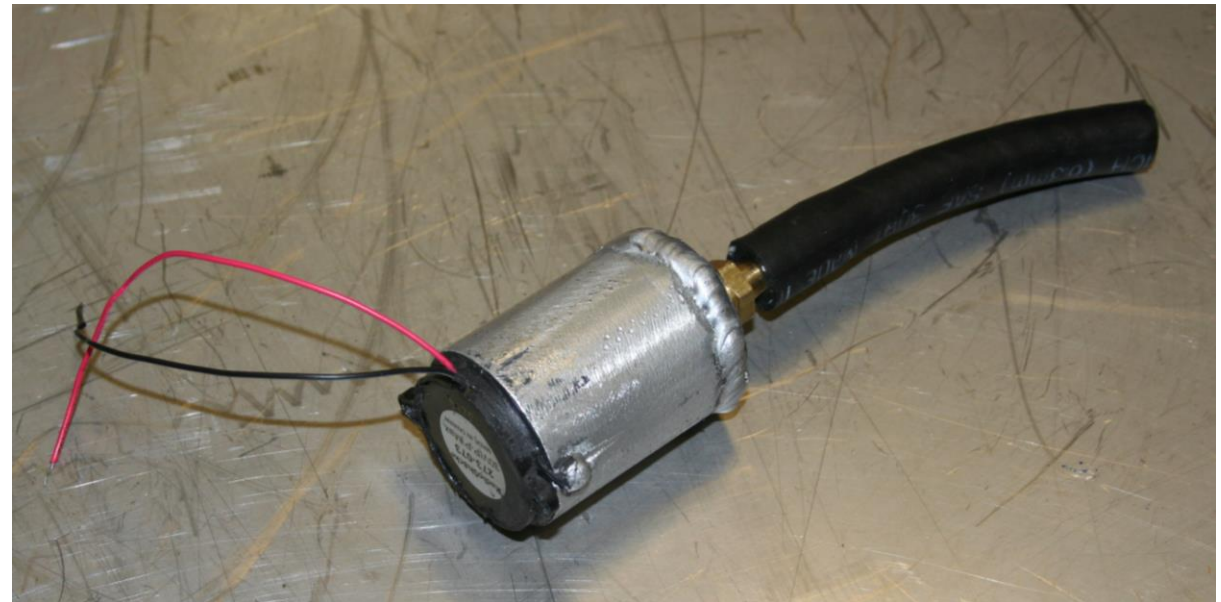
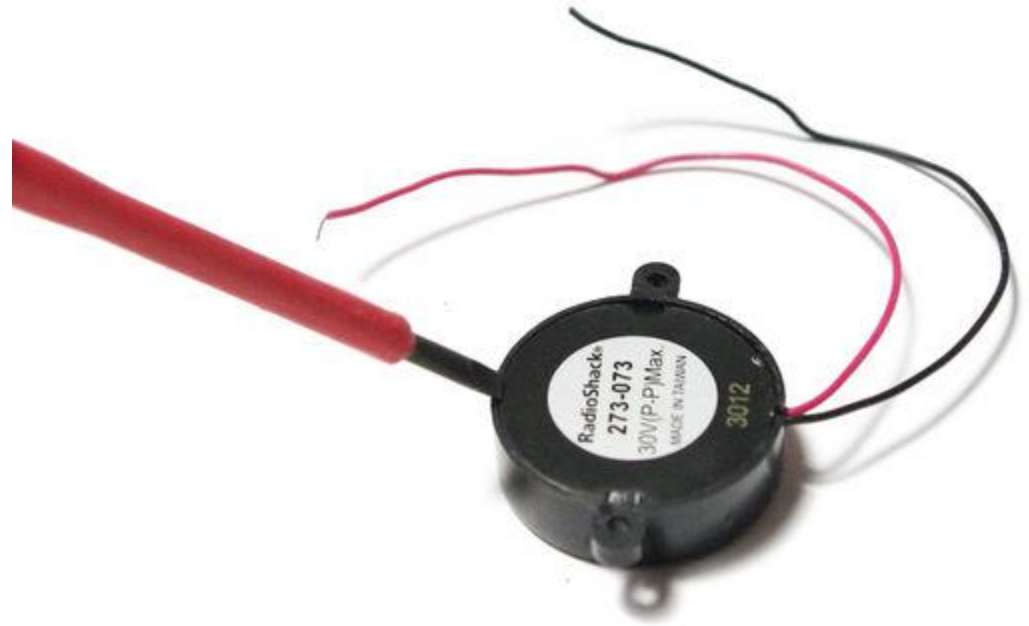


Pressure Transducers

Pulse sensor

Pulse sensor

- First Look
- Shop made tools
 - Pulse sensor
 - Piezo speaker/microphone

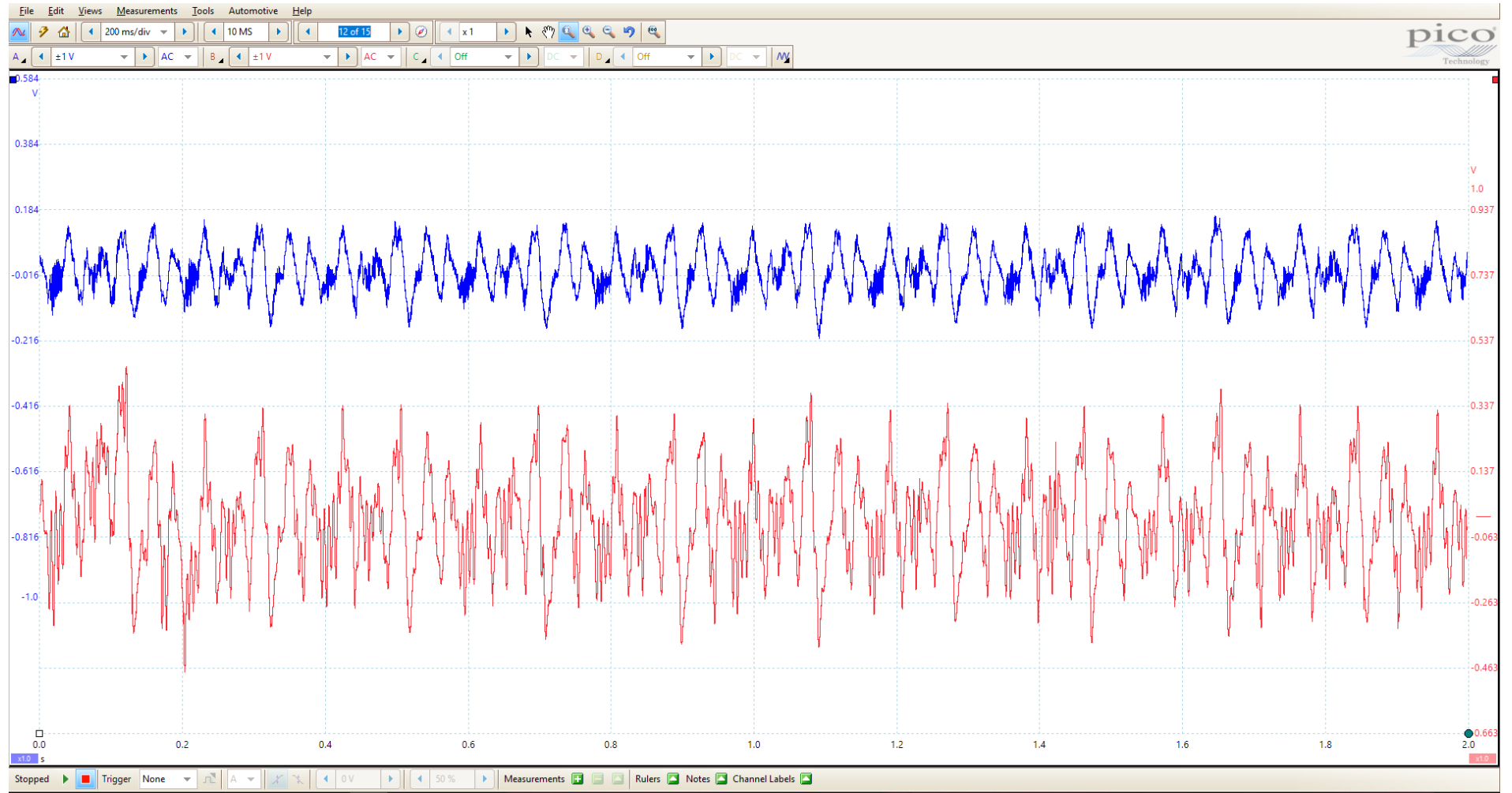


Pulse sensor- exhaust



1st Look

Buzzer

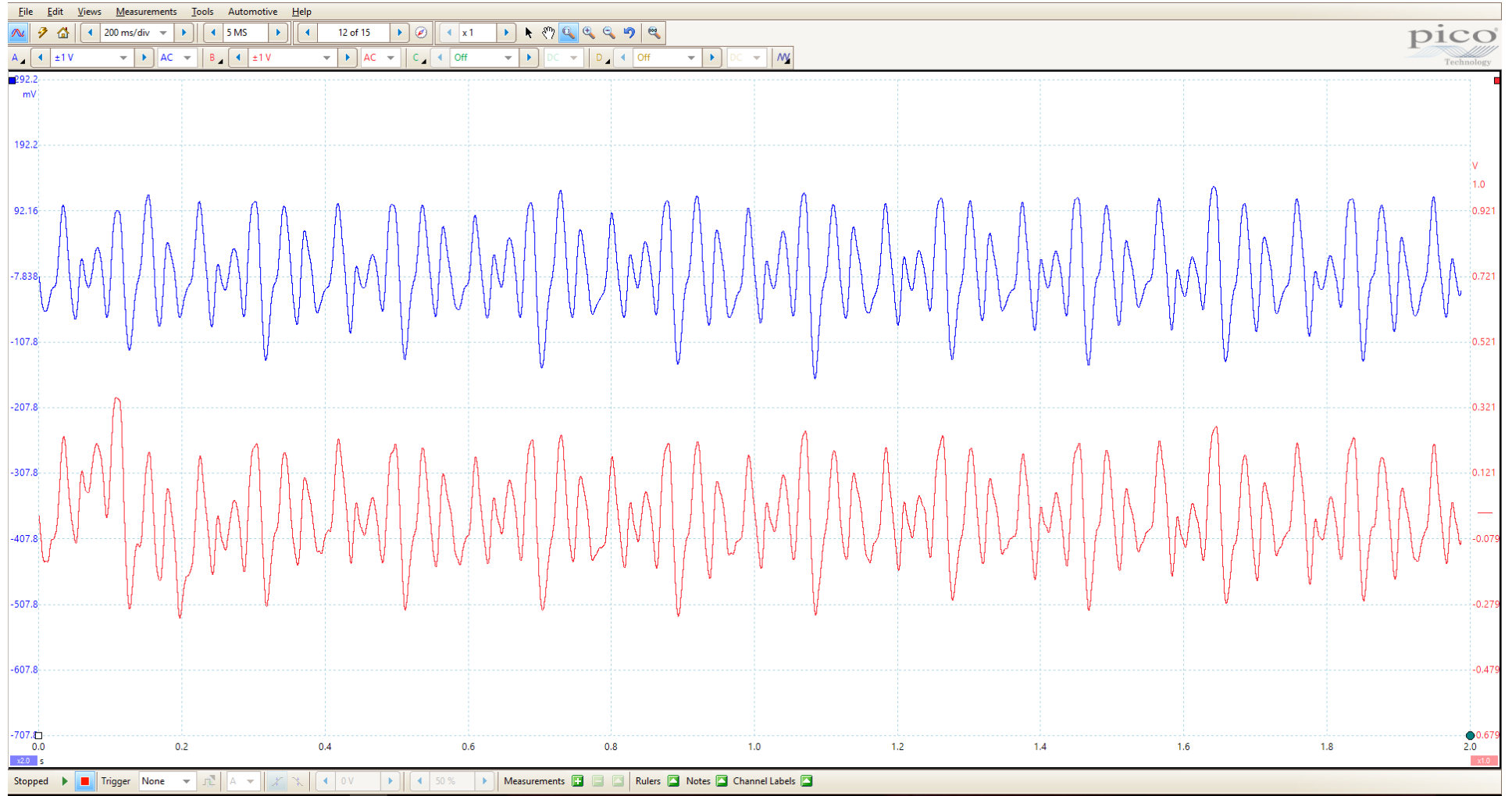


Pulse sensor- exhaust (filtered)

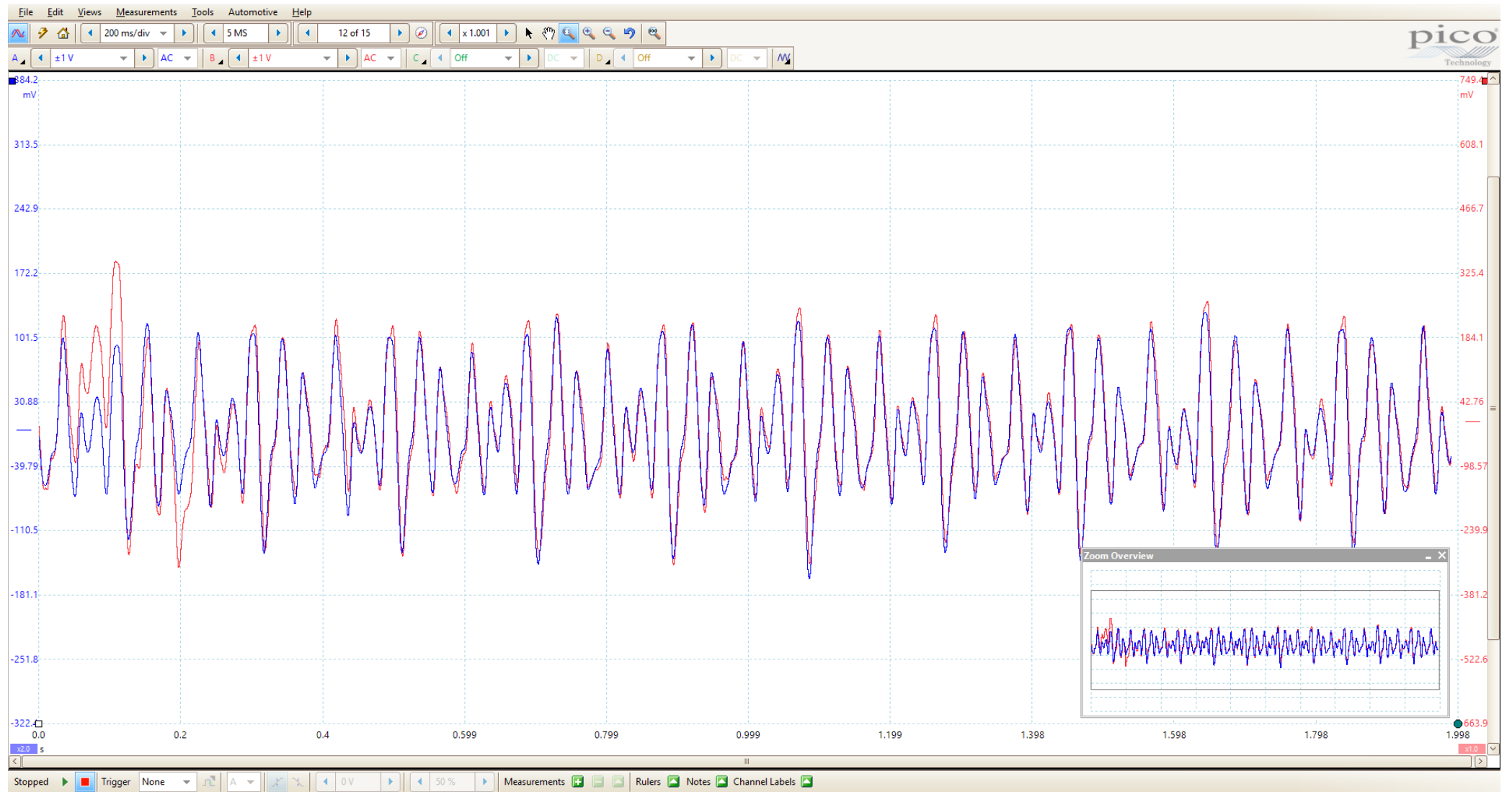


1st Look

Buzzer



Pulse sensor- exhaust (filtered and overlaid)

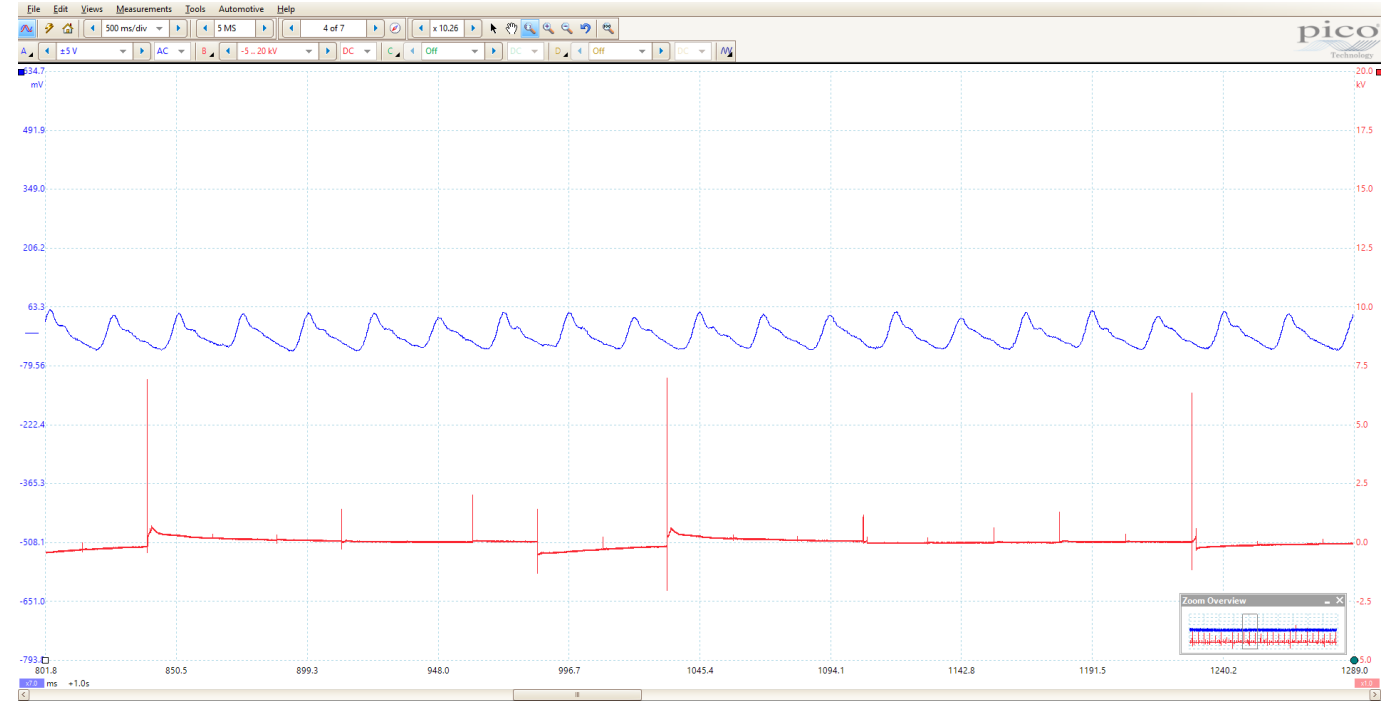




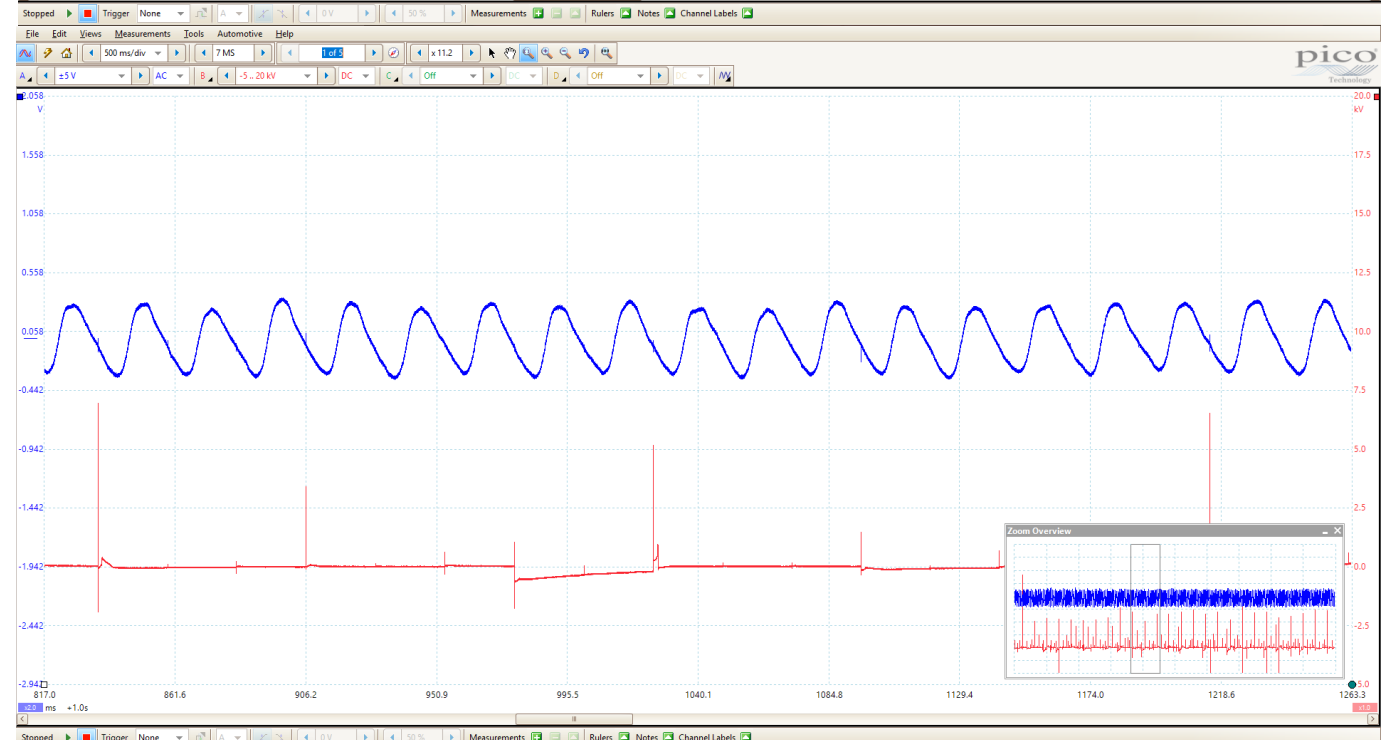
Pulse sensor

- Intake
- Idle

1st Look



Buzzer

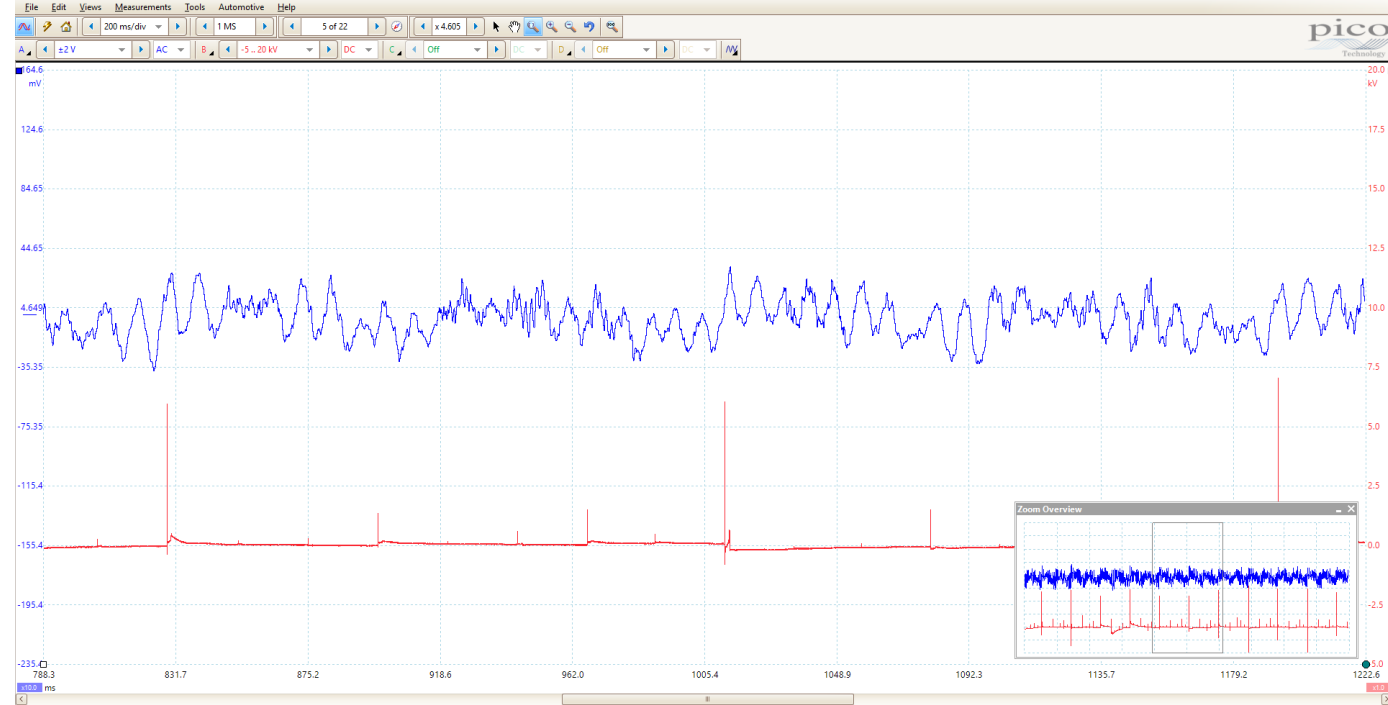




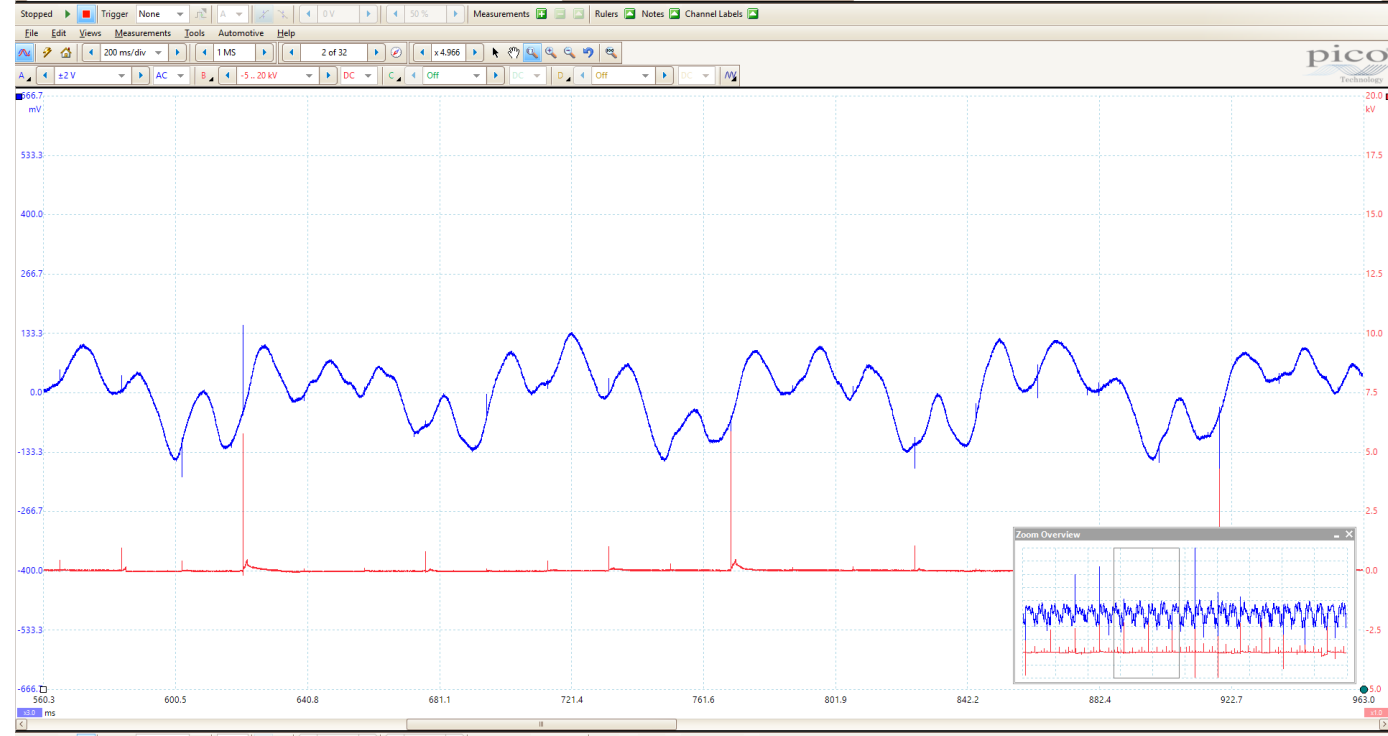
Pulse sensor

- Crankcase
 - Idle

1st Look



Buzzer

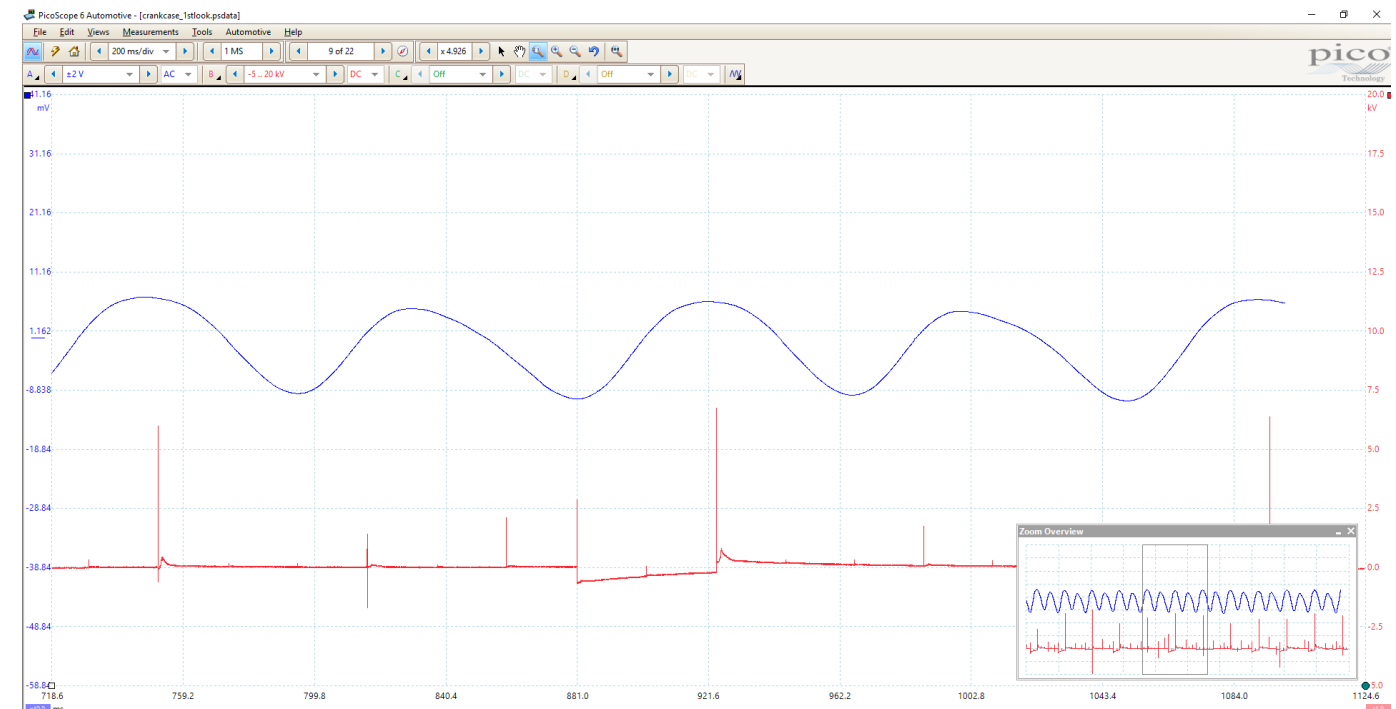




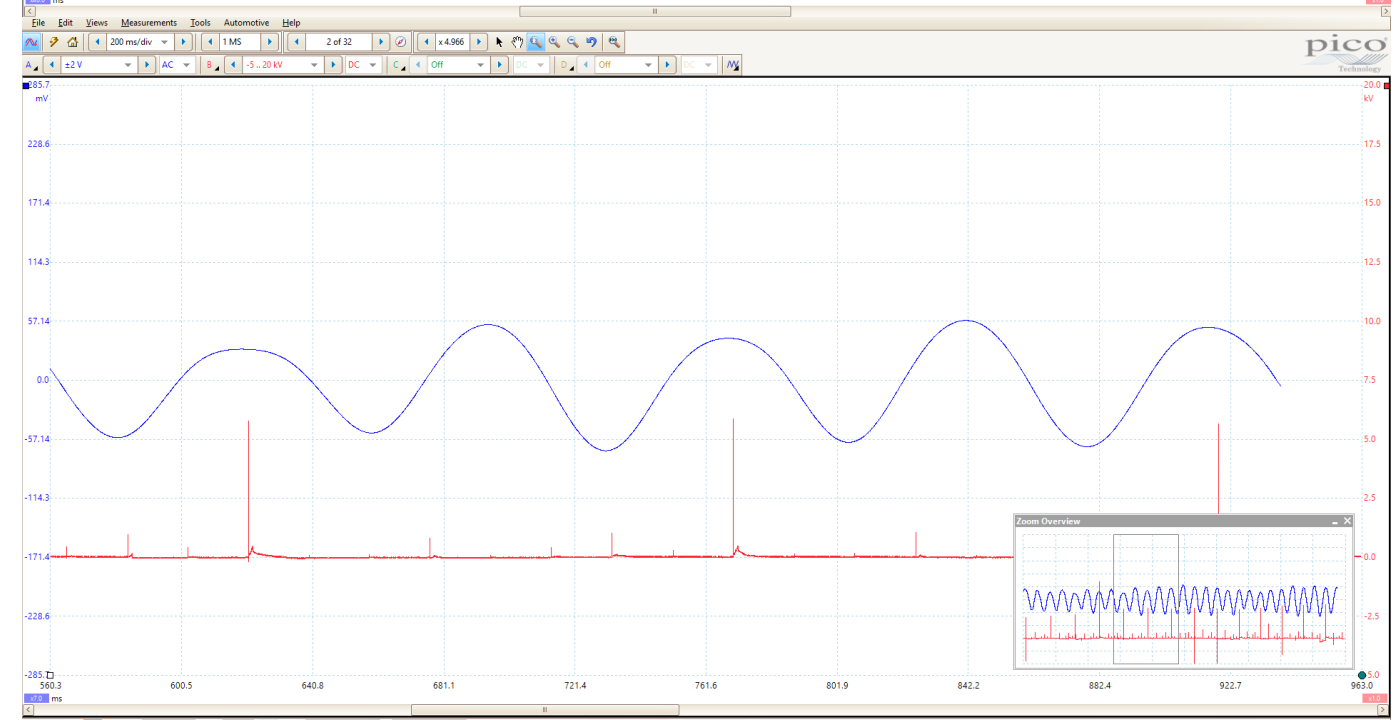
Pulse sensor

- Crankcase
 - Idle

1st Look



Buzzer

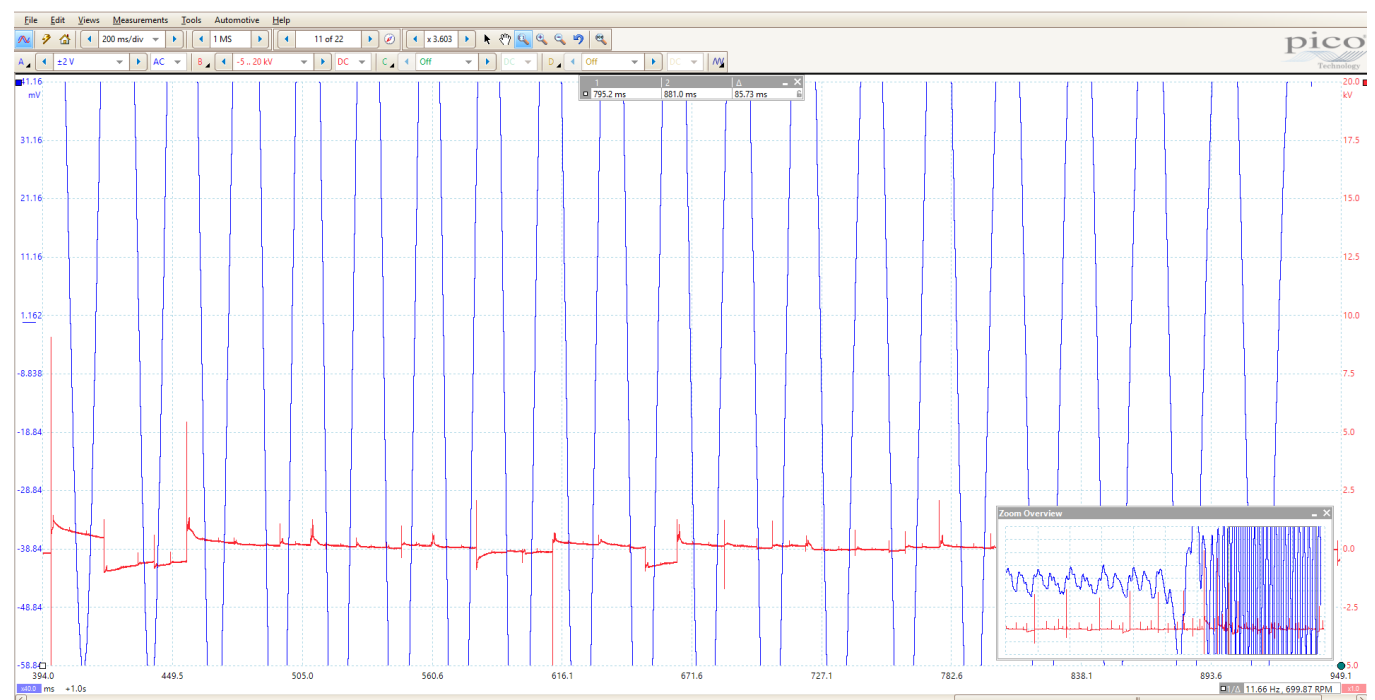




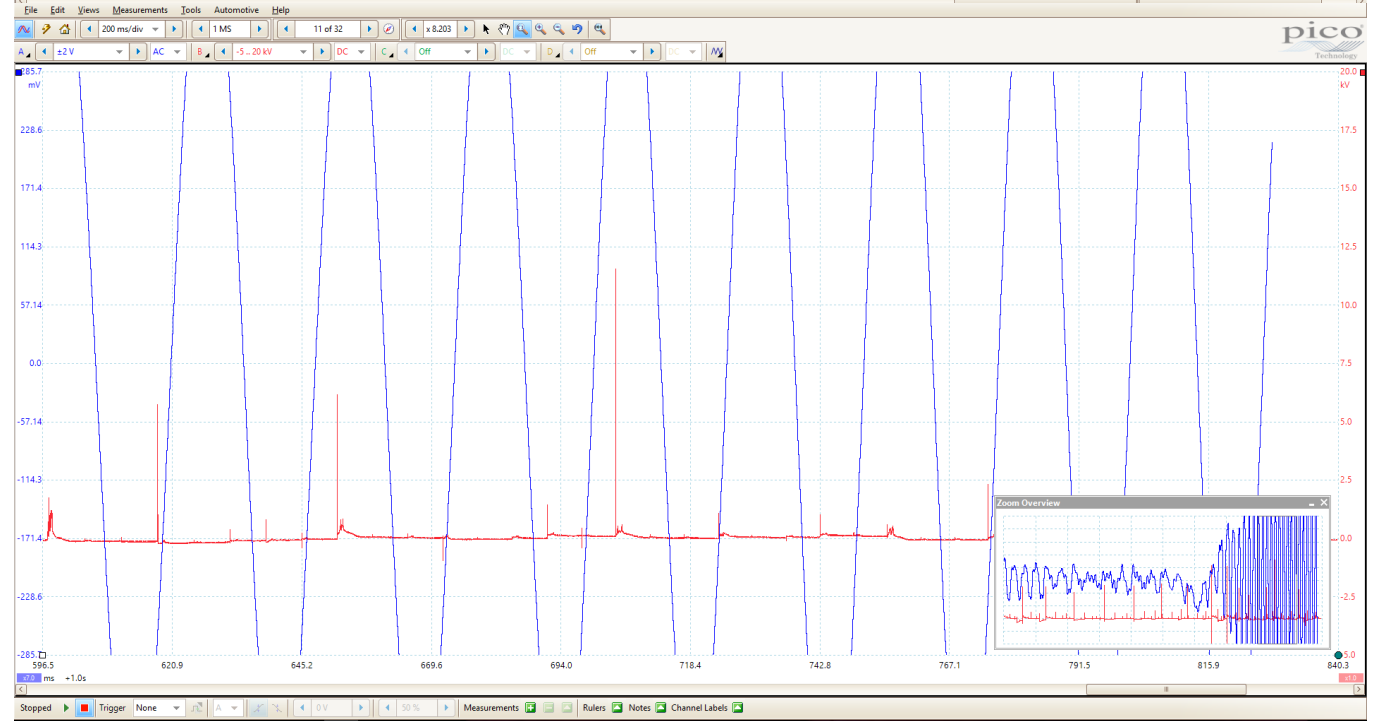
Pulse sensor

- Crankcase
 - Idle

1st Look



Buzzer

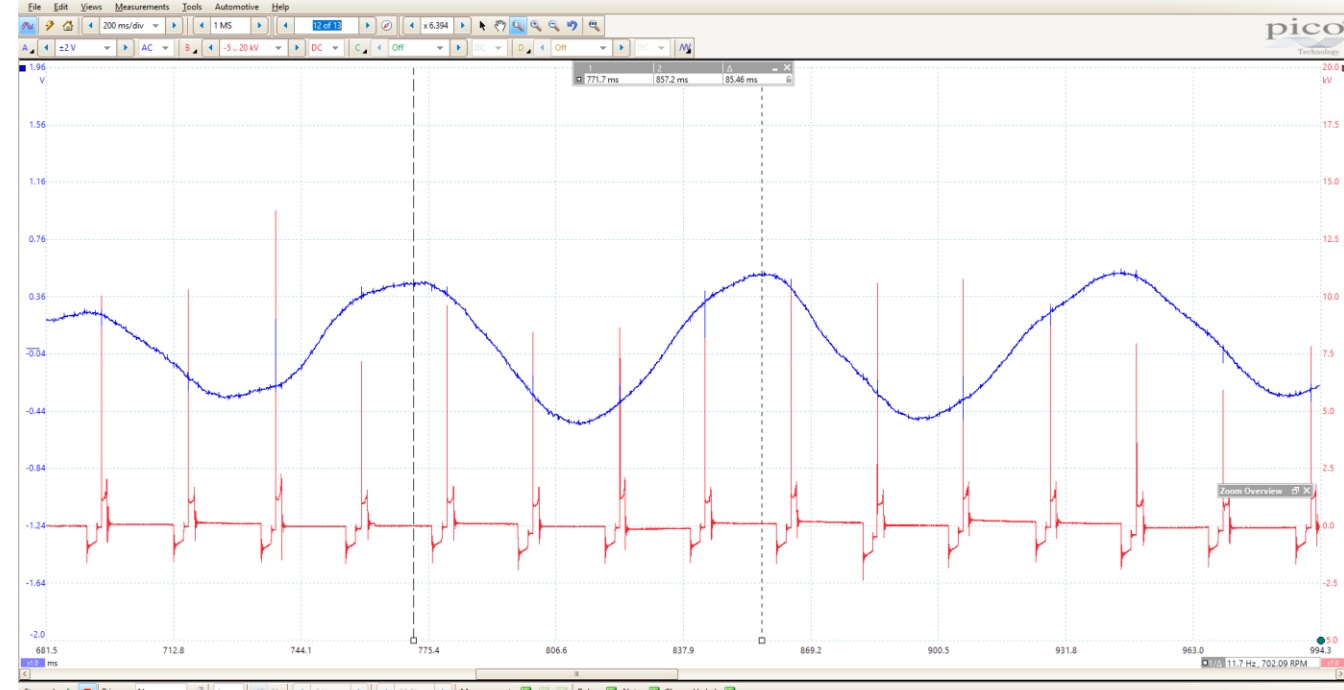




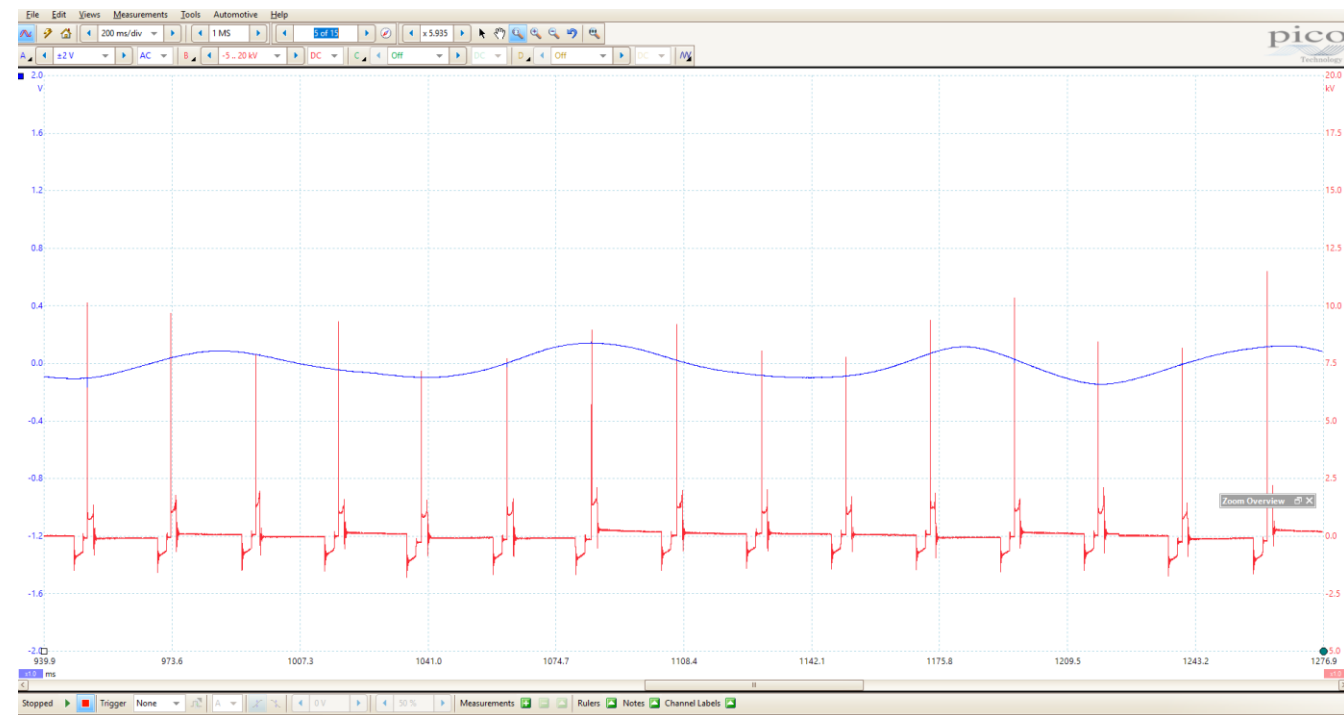
Pulse sensor

- Cooling system
 - Check for combustion pulses

Piezo Buzzer



1st Look



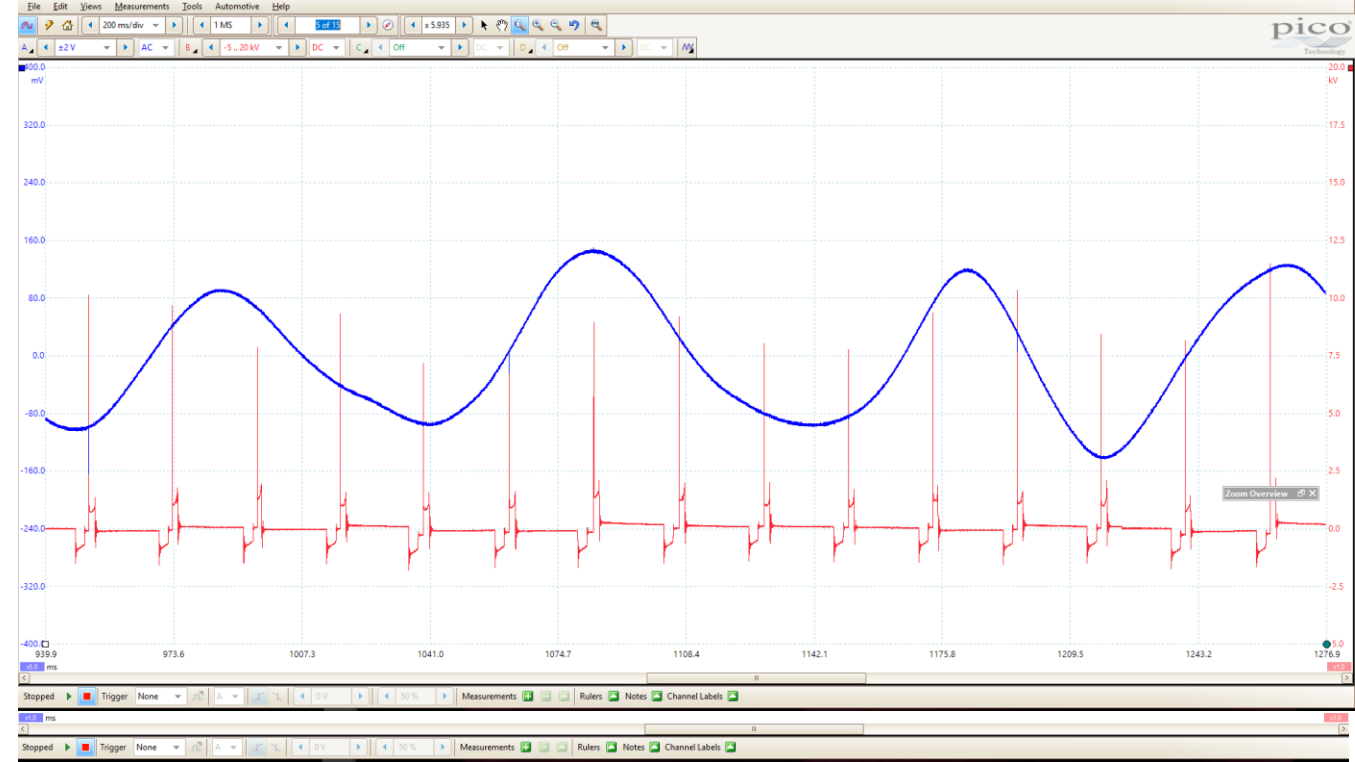
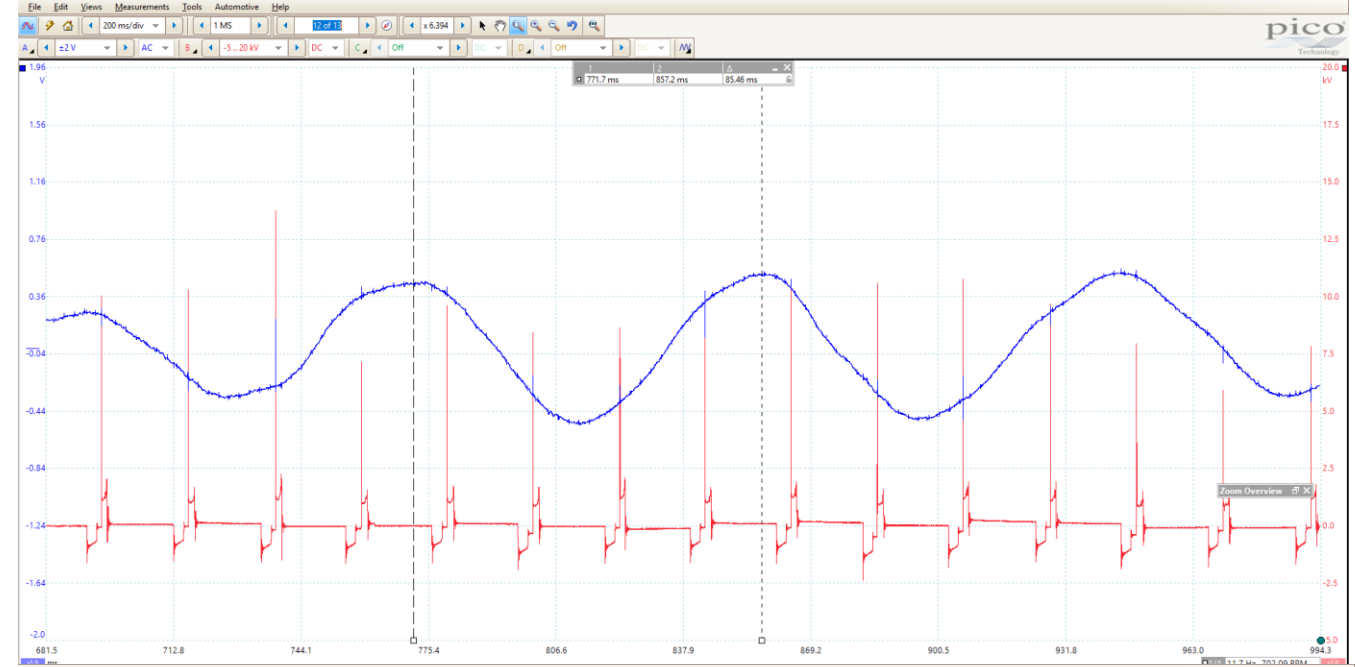


Pulse sensor

- Cooling system
 - Check for combustion pulses

Piezo Buzzer

1st Look
zoomed in

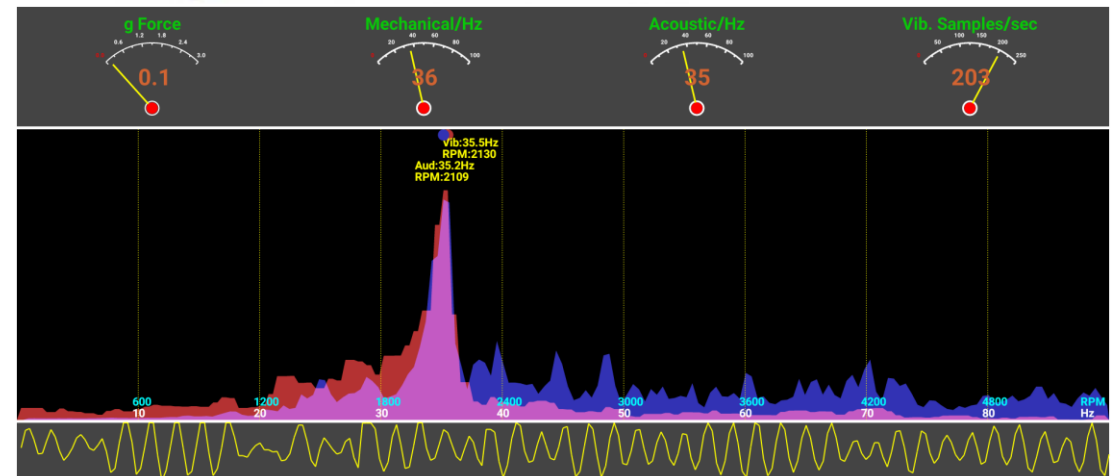




Noise, Vibration, and Harshness

DSO Tools

- Noise/Vibration
 - Store bought
 - Low tech
 - Reed tach
 - Electronic
 - EVA on ebay for \$350 +
 - MTS4100 - \$4800
 - Pico NVH \$778
 - Smart phone
 - Shop Made
 - Chassis Ear
 - Reuse an old Chassis Ear clip and wire it to the scope
 - Knock sensor
 - Ardurino
 - \$15 accelerometer chip



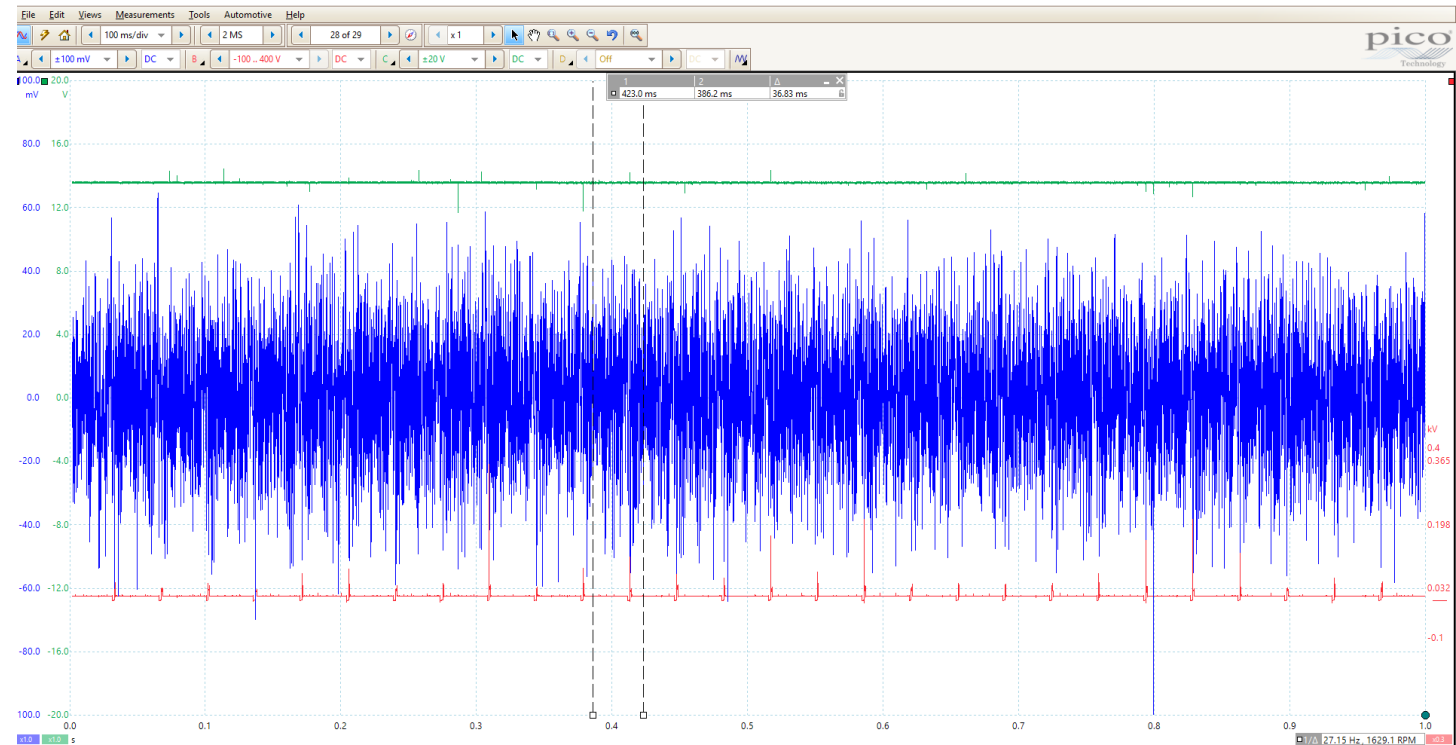


Noise, Vibration, and Harshness

Noise Analysis

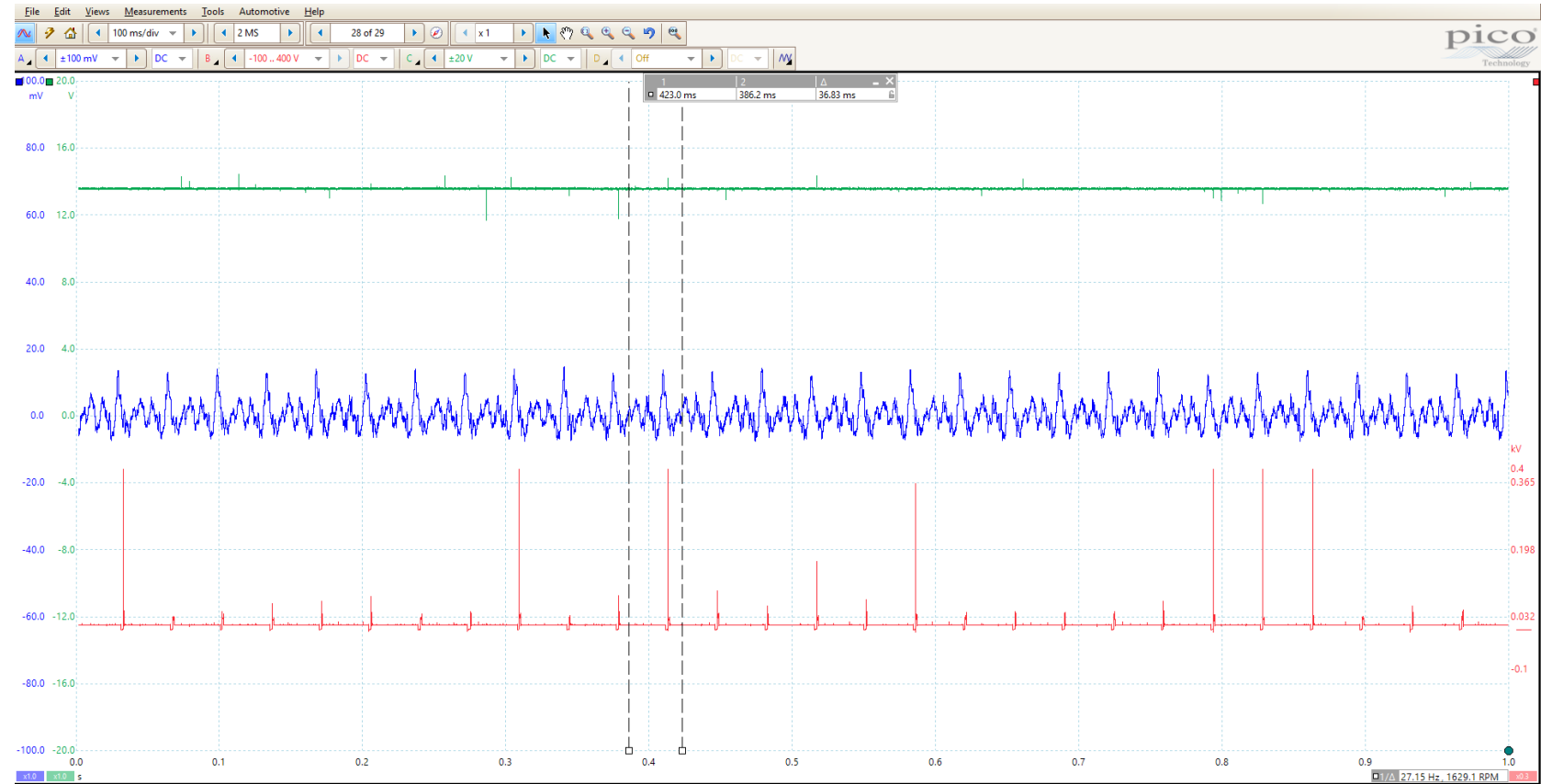
Noise

- Chassis Ear
- Engine noise example
 - A lot of interference



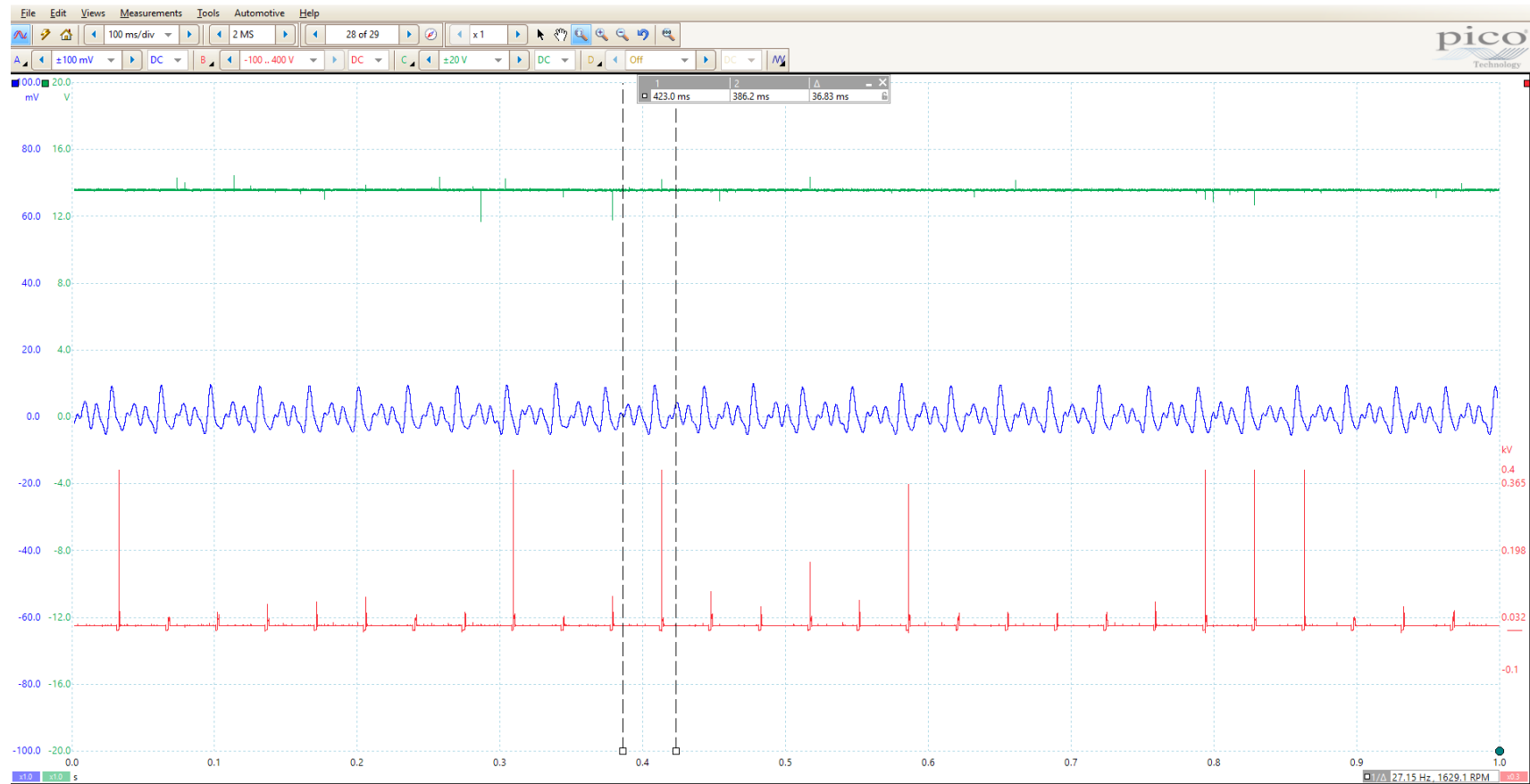
Noise

- Chassis Ear
- Engine noise example
 - Filter with 16 bit resolution



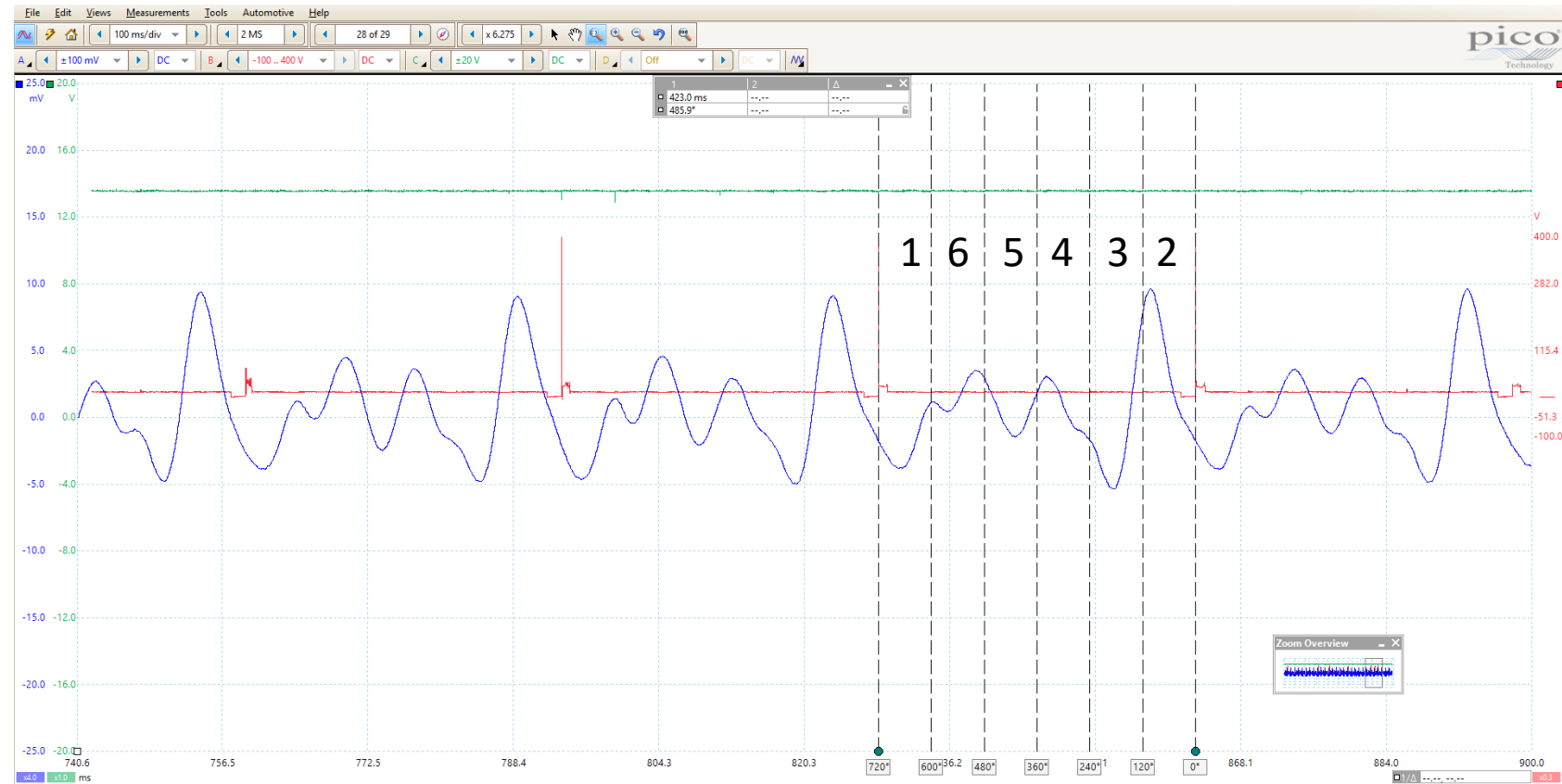
Noise

- Chassis Ear
- Engine noise example
 - Filter with “low pass filtering” at 80Hz



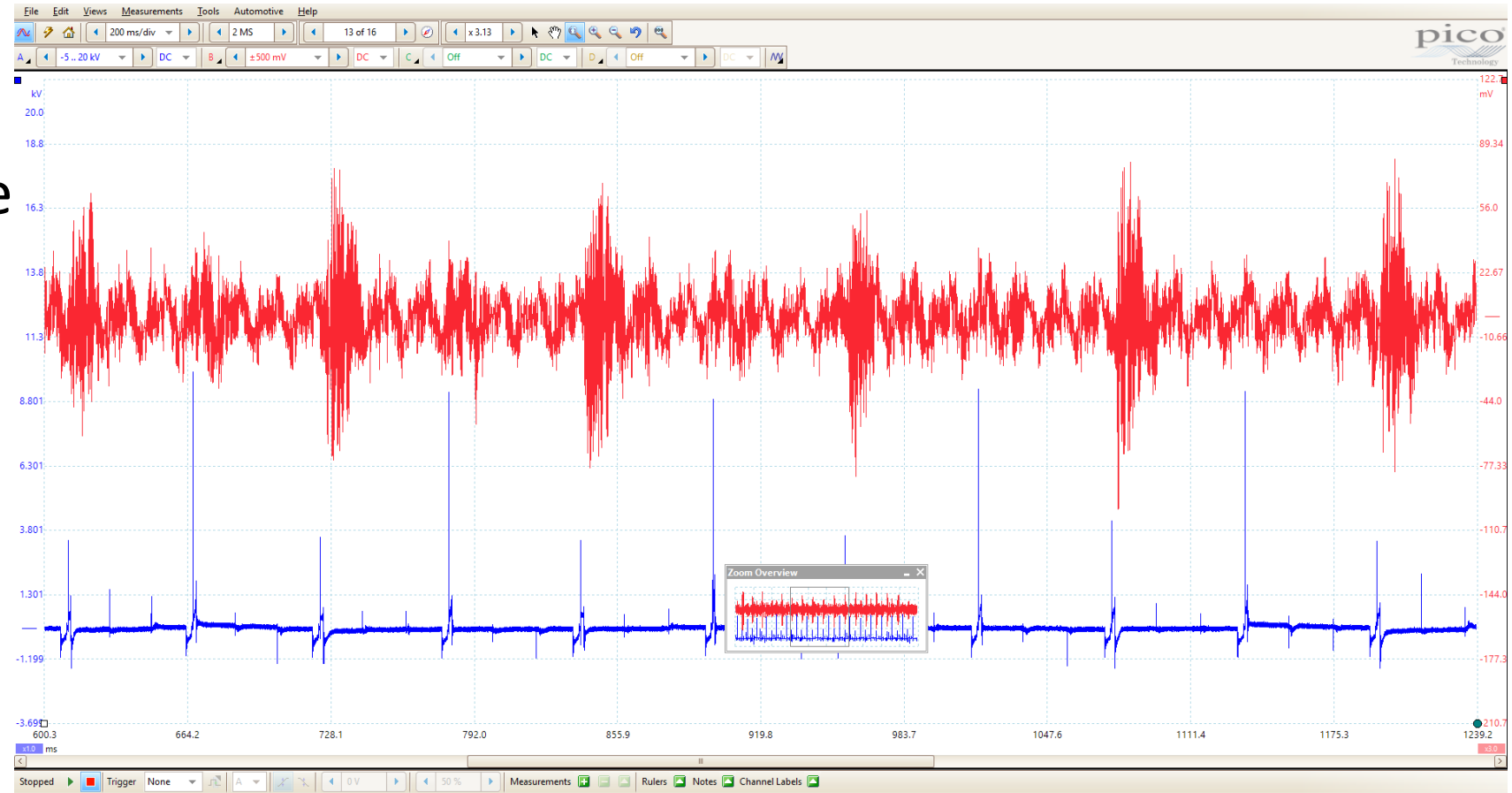
Noise

- Chassis Ear
- Engine noise example
 - Zoom in 4X on noise and move primary over noise pattern
 - Put a ruler overlay indicating ignition events for all 6 cylinders



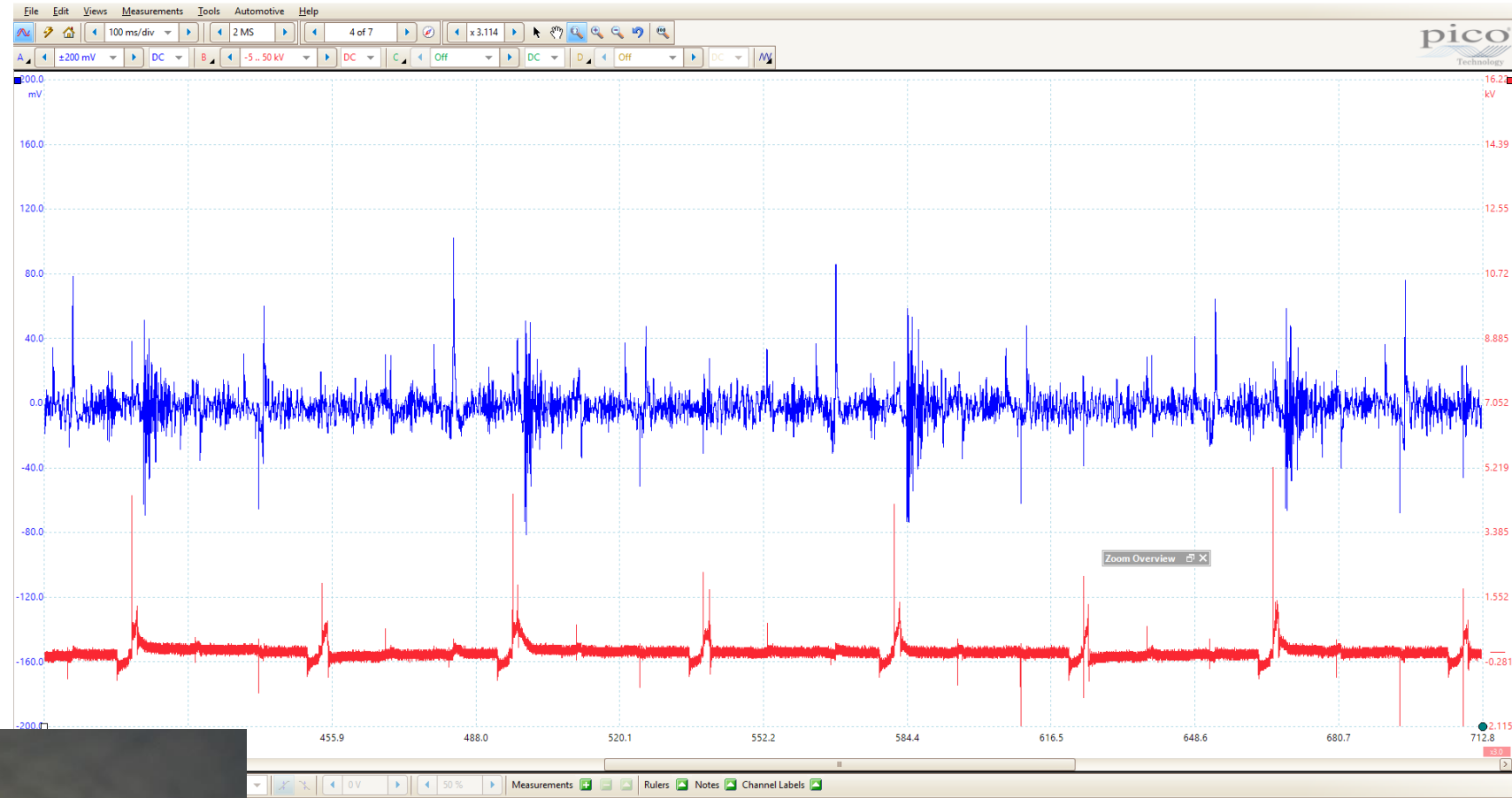
Noise

- Chassis Ear
- Another example
 - Piston slap



Noise

- Same vehicle
- Knock Sensor



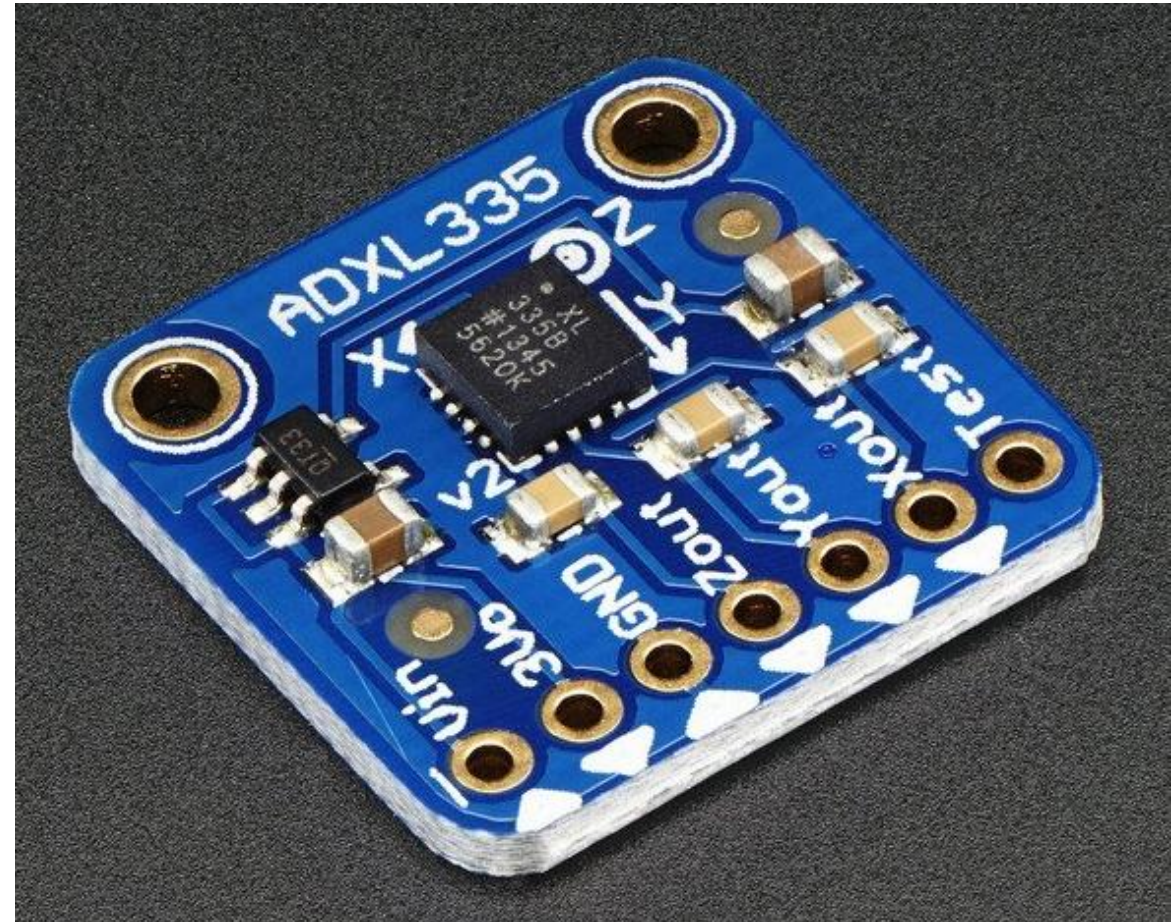


Noise, Vibration, and Harshness

Vibration Analysis

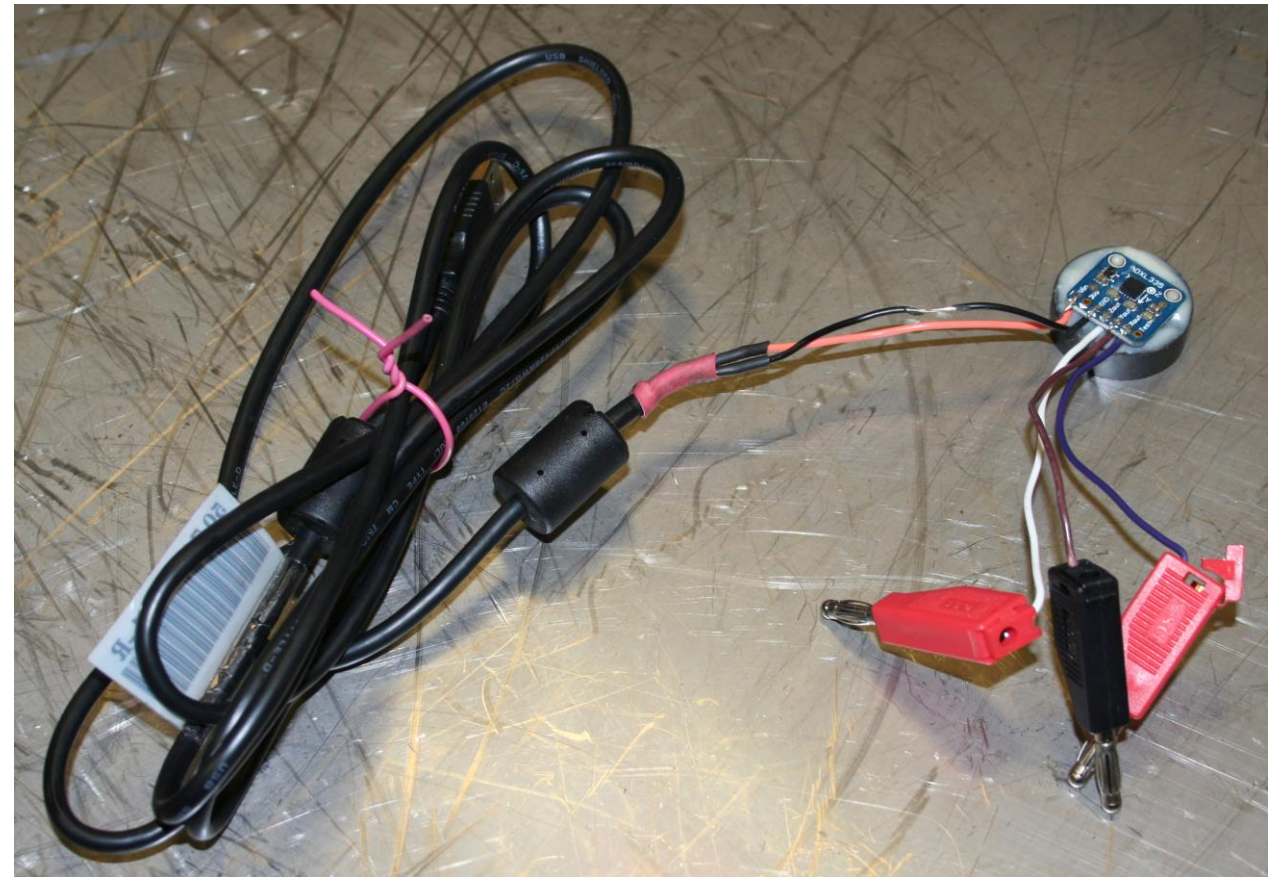
DSO Tools

- Vibration
 - ADXL335 - 5V ready triple-axis accelerometer ($\pm 3g$ analog out) (\$15)
 - [Adafruit.com](http://adafruit.com)



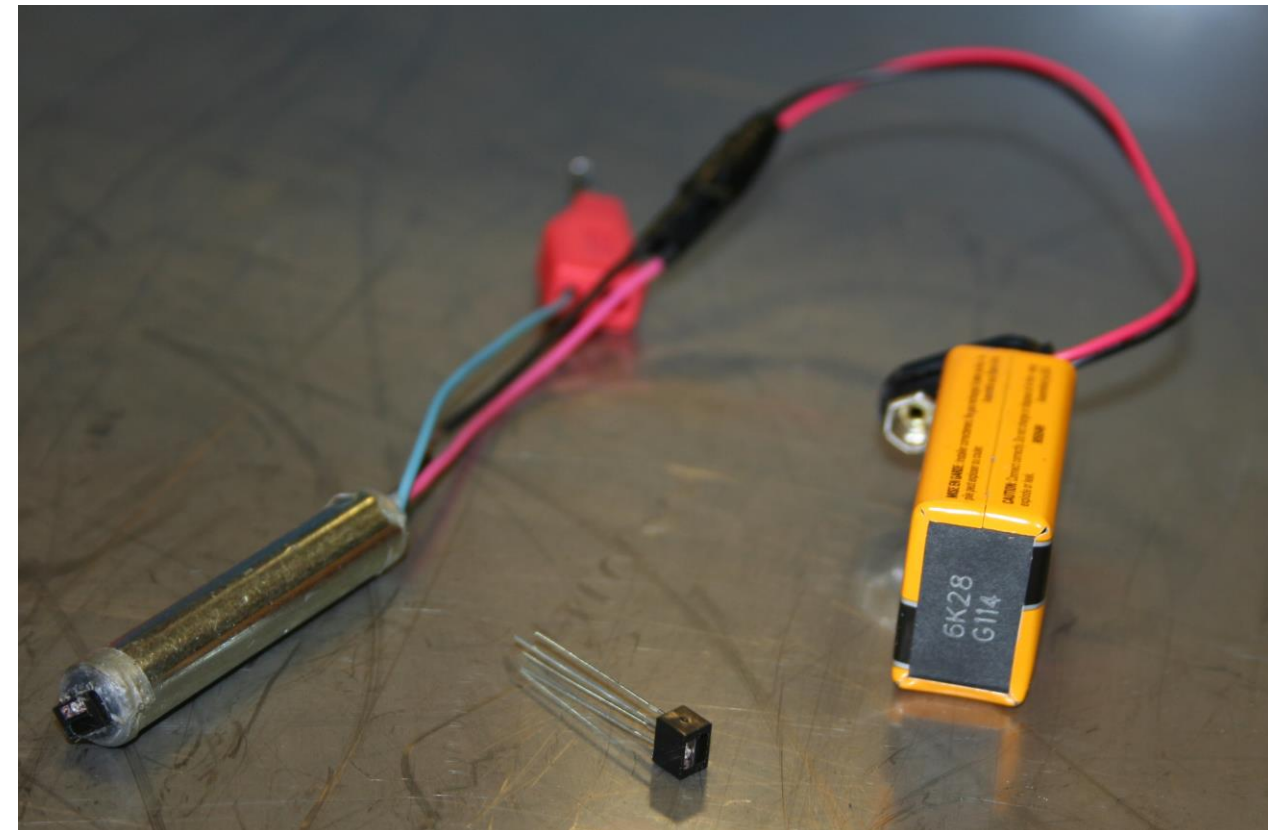
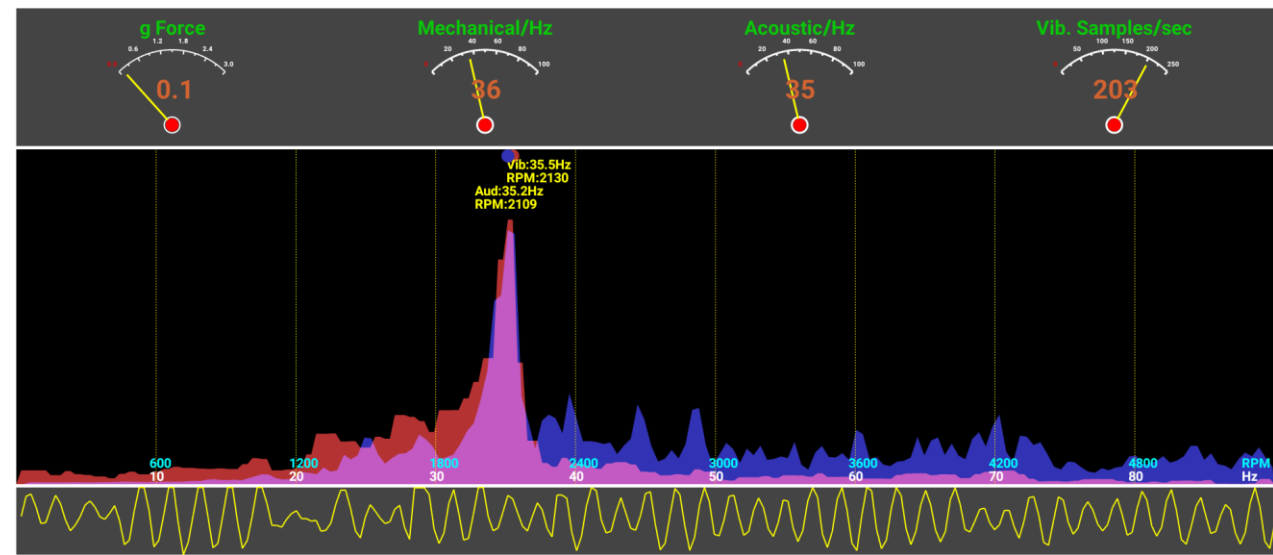
DSO Tools

- Vibration
 - Wire the sensor to a USB for 5v supply
 - Wire three leads for the X, Y, and Z axis



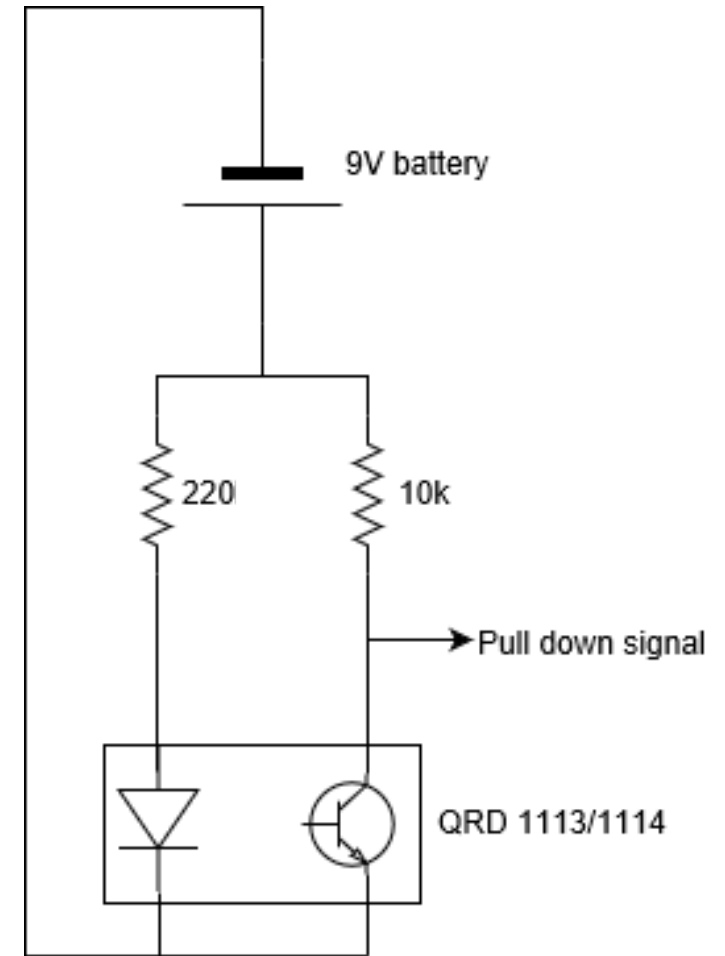
DSO Tools

- Vibration
 - Assigning a frequency is simple through a reed tach, accelerometer, vibration app
 - Discovering the location of imbalance is the difficult part
 - Optical sensor with vibration sensor



Optical Sensor

- Experiment
 - Infrared sensor qrd1113/1114 (1.90 per sensor)
 - I haven't tried an optical LED type sensor, but I assume it might work as well



Shop made vibration analyzer

- Pros

- Cheap (\$20 total)
- Great teaching tool
- Forces you to do the math

- Cons

- Experience needed to determine the actual FORCE of the vibration
- Need a solid understanding of what you are doing
- Forces you to do the math!



NVH Math

Tire and Wheel Frequency

1. Vibration occurs at ____ MPH divided by 5 = increments of 5 MPH
2. # of inc of 5 MPH ____ X Tire Revs per Sec @ 5 MPH ____ = 1st Order Tire/Wheel Frequency ____ Hz
3. 1st order X 2 = ____ = 2nd Order Tire/Wheel Frequency ____ Hz

Driveshaft Frequency

1. Tire/Wheel Frequency 1st order Hz ____ X Axle Ratio ____ = driveshaft frequency
2. 1st order driveshaft freq ____ X 2 = 2nd order driveshaft frequency

Engine Frequency

Engine Speed ____ rpm divided by 60 = Engine Vibration 1st order Hz

**Tire Diameter Formula

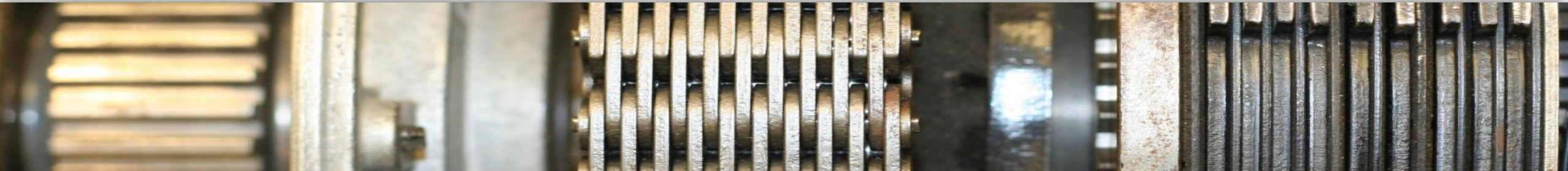
$$\frac{2(\text{aspect ratio X tire size}) + \text{Wheel Diameter}}{2540} = \text{Tire Diameter}^{**}$$

*Revolutions per Second @ 5 MPH Formula

$$\frac{20800}{\text{tire diameter}} \div 3600 \times 5 = \text{Revolutions per Second @ 5 MPH}$$

$$1 \text{ mph} = 1.6 \text{ km/h}$$

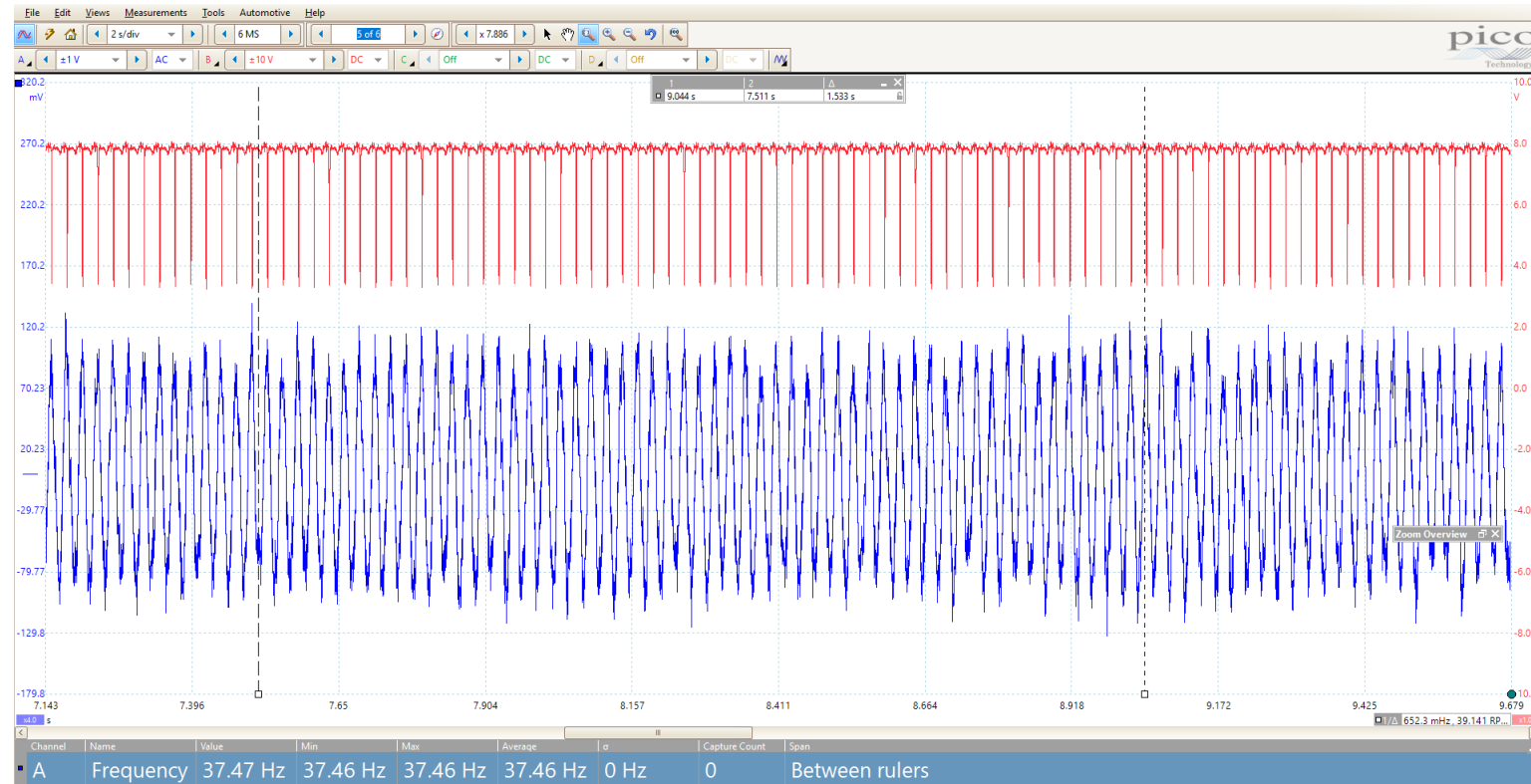
$$1 \text{ inch} = 25.4 \text{ mm}$$



NVH Math

Vibration – driveline example

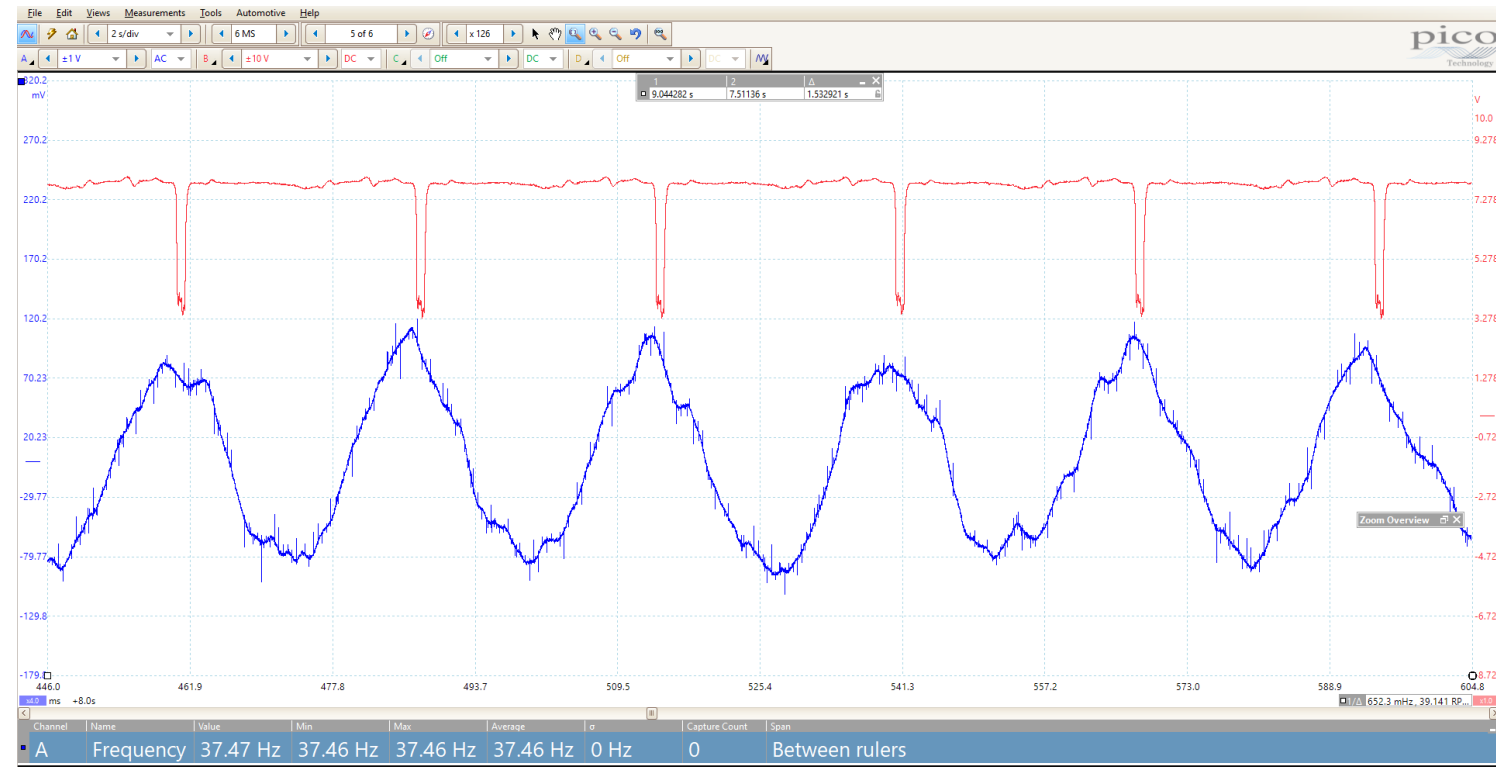
- 2wd truck with vibration at 67mph
- Red channel is optical pulse
- Blue is z-axis vibration



NVH Math

Vibration – driveline example

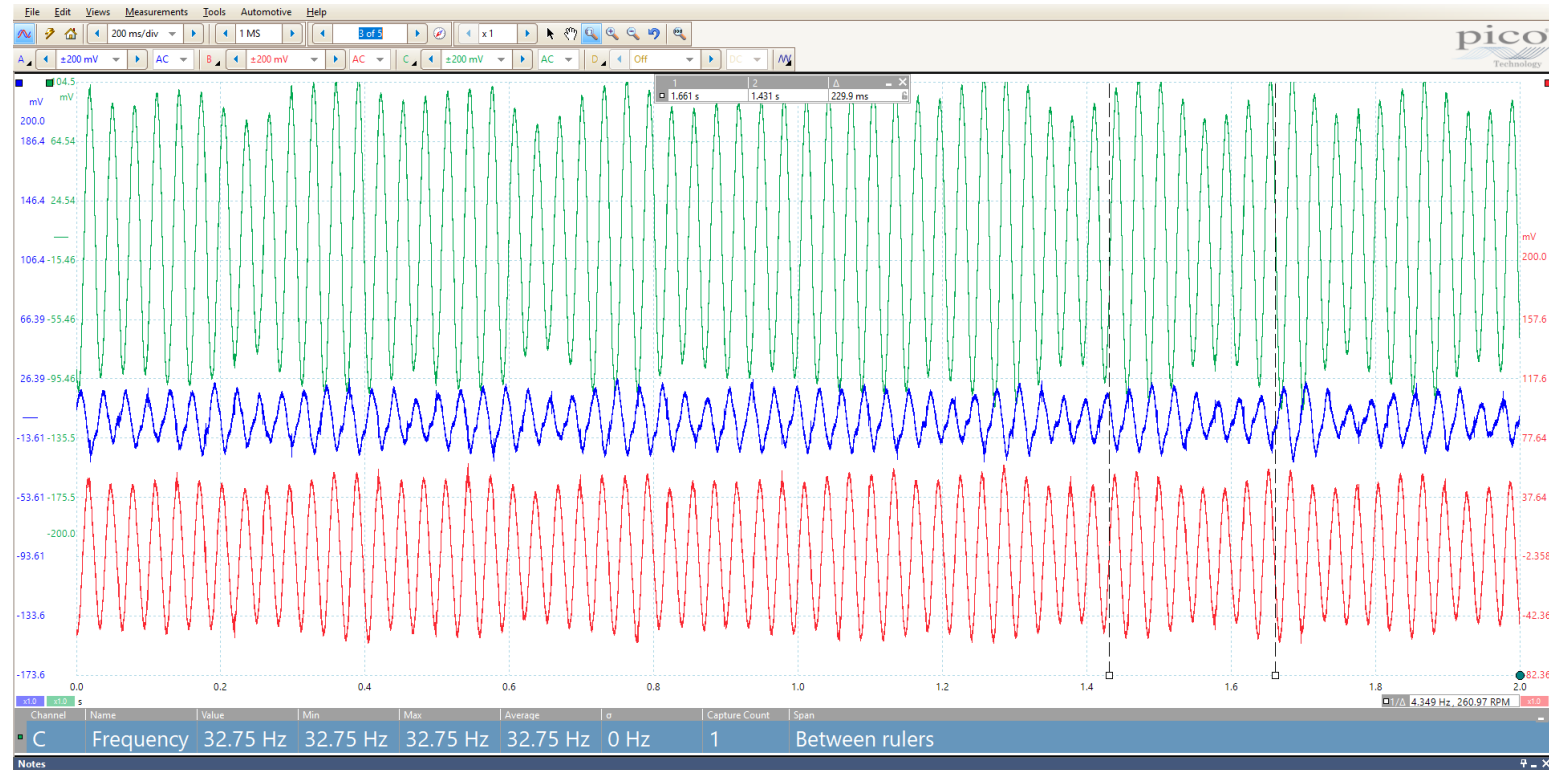
- Zoomed in
- 2wd truck with vibration at 67mph
- Red channel is optical pulse
- Blue is z-axis vibration



NVH Math

Vibration – engine example

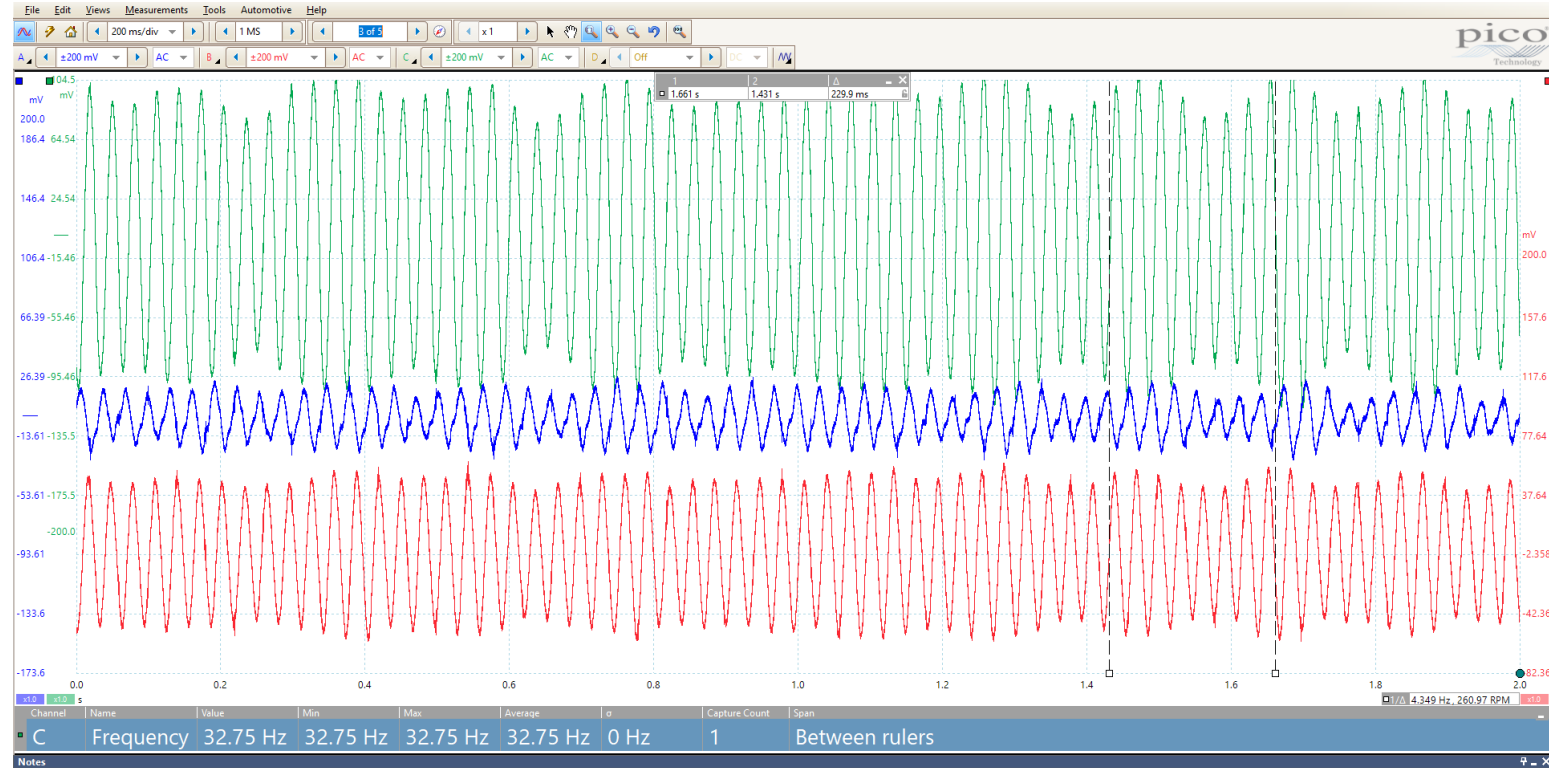
- V-6 Engine is idling around 650 RPM
- Vibration is felt in steering wheel
- Sensor is placed on steering wheel



NVH Math

Vibration – engine example

- $32.75 \times 60 = 1965$ pulses per minute
- $1956/3 = 655$
- 650 rpm engine has a 1950 pulse 3rd order vibration
- Bad engine mounts



The End!

Questions???

