Making Sense of Sensors

NAPA AUTOTECH

Course # 7302

Making Sense of Sensors

Electrical Sensor Testing & Diagnostics

Class Objectives

- ❑ Discuss Proper Tools & Test Methods
- ❑ Cover Sensor Types and Common Applications
- ❑ Consider Sensor Locations and Access
- ❑ Review Types of Sensor Faults and Codes

TECH UPDATES

Proper Tooling

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Accurate sensor testing, leading to conclusive results, requires the correct tool(s) for the job!

The goal is diagnostic accuracy and efficiency!

Why?

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Proper Tooling

Essentials:

- <u>DVOM/DMM </u>still has value but limited in this subject
- <u>Graphing MM </u>can be used in many cases but not all
- <u>Oscilloscope</u> – today is irreplaceable
- <u>Terminal adapters </u>for pin fitment testing and circuit testing
- <u>Backprobes/Piercing probes </u>for proper circuit connection
- <u>Circuit loading devices </u>such as an incandescent bulb

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DVOM/Digital MultiMeter

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- DMM's are not fit for fast changing signals (3 to 4 times per second updates)
- Displayed values are averages

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Graphing MultiMeter

- GMM's function like a scope with lower sample rates
- Resolution is too low to display an active sensor waveform
- Useful during static circuit testing

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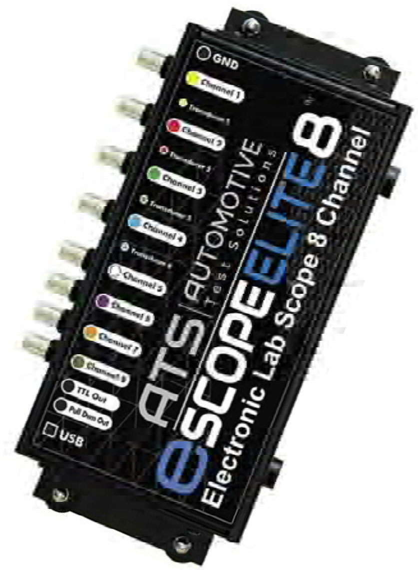
Oscilloscope/Lab Scope

Whether you have a 1, 2, 4, or 8 channel scope, the challenge for many is simply adapting it into your workplace



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Oscilloscope/Lab Scope

- ❑ **Many say "it takes too long to set up"**
- ❑ **This would be true until you familiarize yourself with the equipment**

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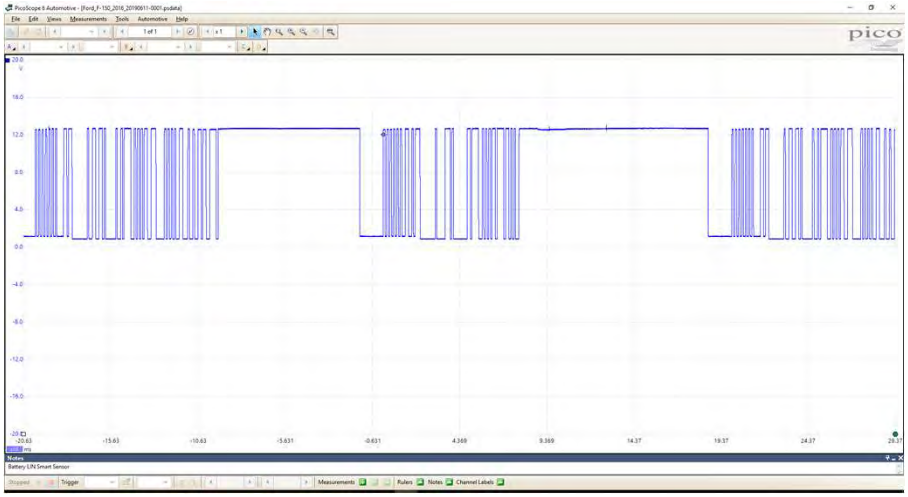
Oscilloscope/Lab Scope

- A scope provides more information than a multimeter

- A low amp probe may be of use for complete sensor testing



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Terminal Adapters

Terminal adapters allow checking of pin to socket interference easily and accurately.

The easiest way to check pin fit (drag) is by using new male/female terminals to check the circuits' mating pins.

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Circuit Loading

- Circuit loading tooling allows you to provide a fixed max current into a circuit to check circuit integrity
- An example would be an incandescent test bulb
- If max current of the bulb is 150 mA with 12v applied but you're loading a circuit and the light glows dim, then this is a visible indicator of an issue
- When used properly, these are invaluable

Circuit Loading

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- A circuit loading tool can be used to check circuit integrity
- A low-current test-lamp (not an LED) can be used to pull a 5v signal up or down

Circuit Loading

- This MAF has a fused 12v feed, 2 sensor grounds and 1 MAF signal circuit
- Here load testing the B+ circuit for the MAF

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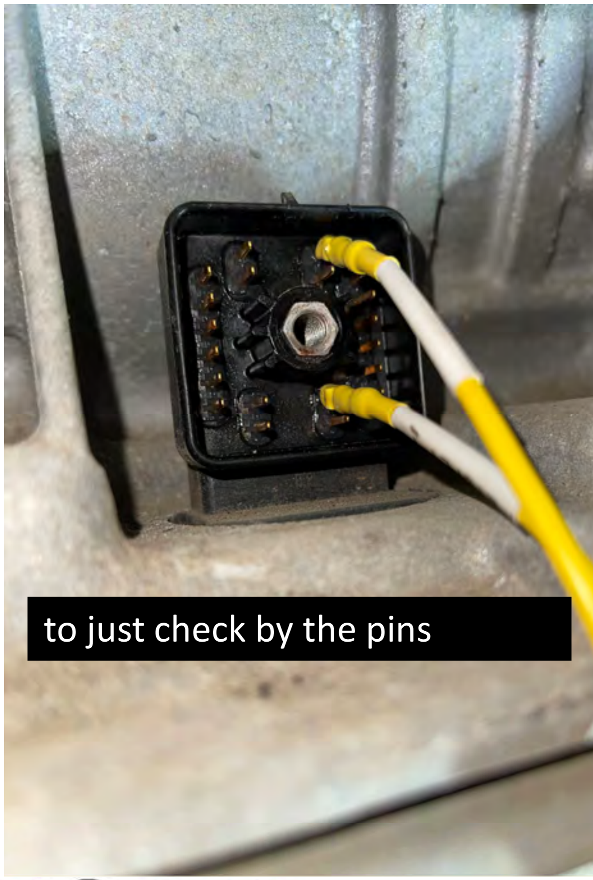
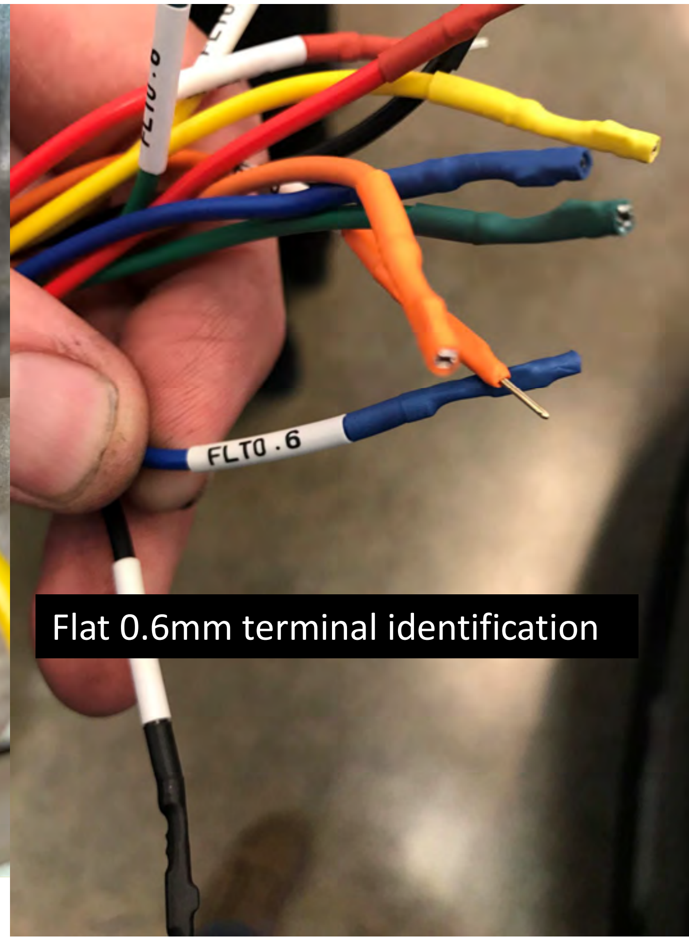
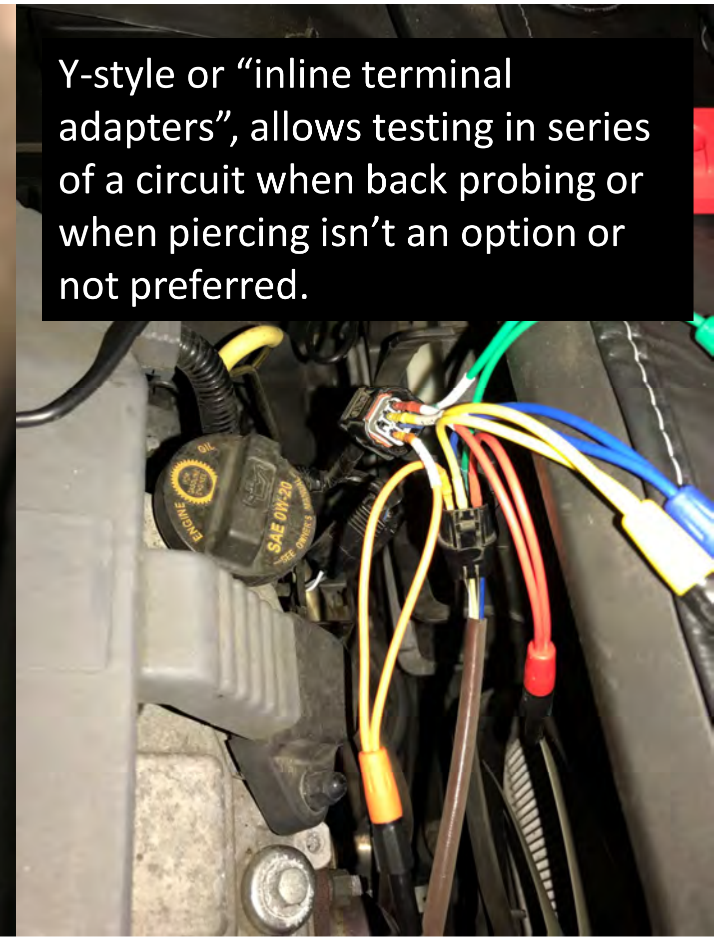
Terminal Adapter use



to just check by the pins



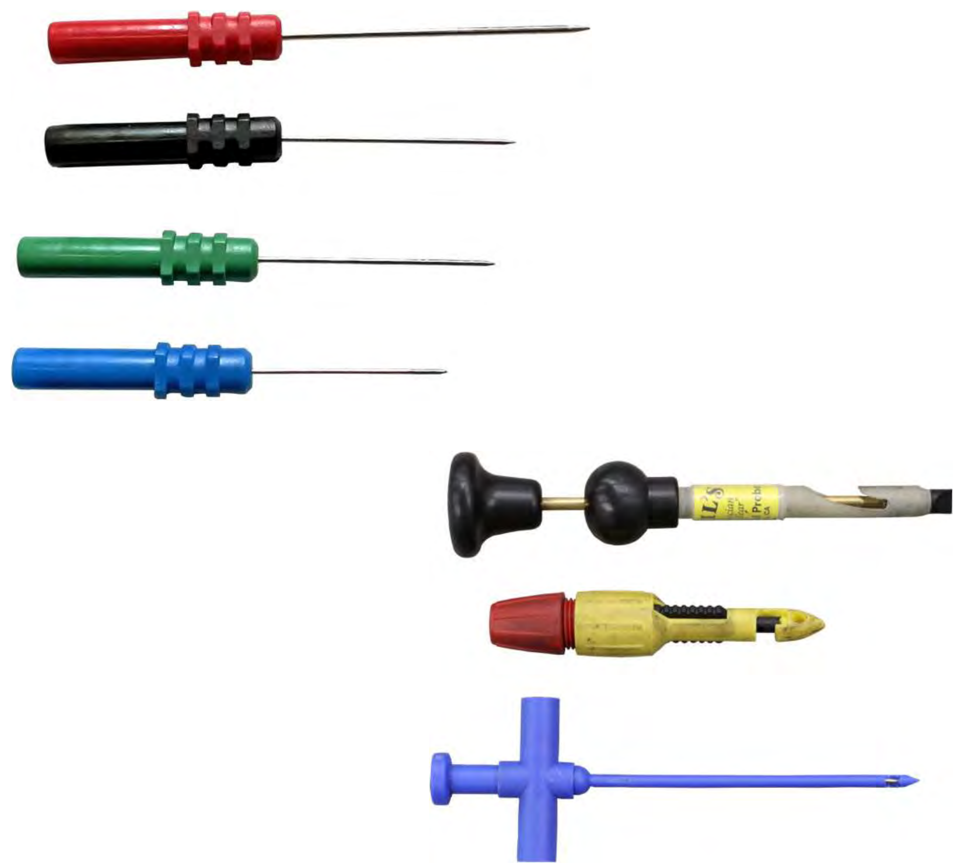
Flat 0.6mm terminal identification



Y-style or "inline terminal adapters", allows testing in series of a circuit when back probing or when piercing isn't an option or not preferred.

Backprobes and Piercing Probes

When used properly, harness and connector/terminal integrity will remain unaltered when using either a backprobe or a piercing probe



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Backprobes and Piercing Probes

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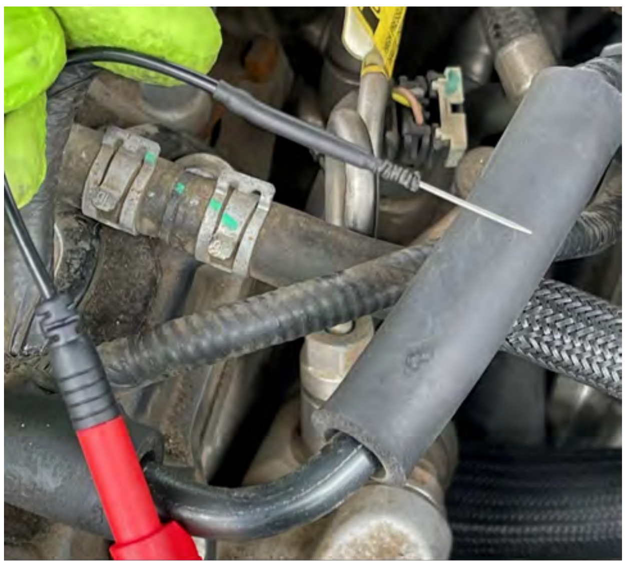
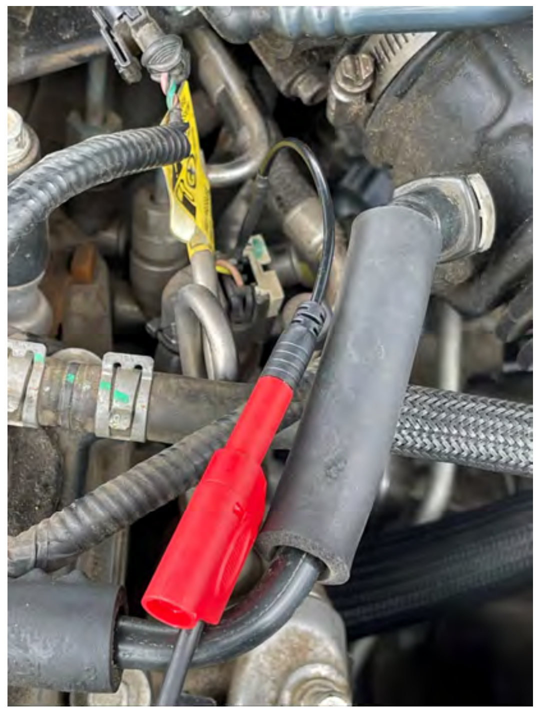
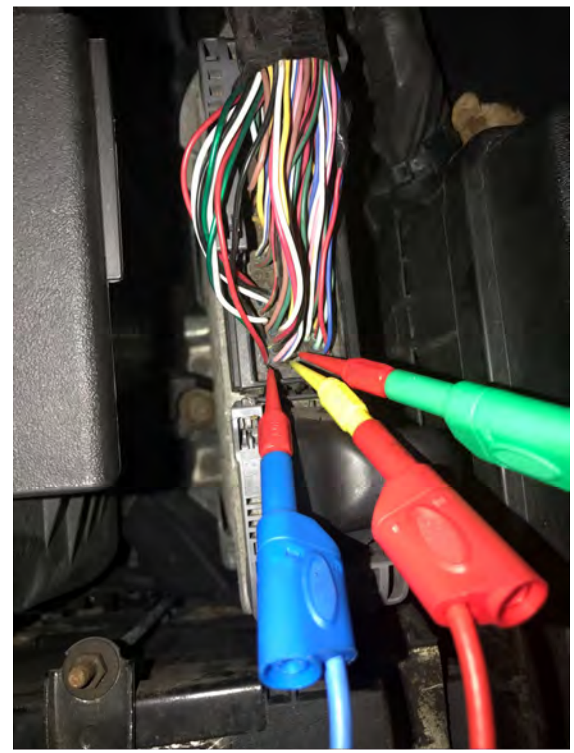
Backprobes and Piercing Probes

- Here some common backprobes and applications







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Backprobes and Piercing Probes

- Back-probing is not an option for some connector designs
- Some connectors do not allow enough space for the probing needle
- Terminal damage can result on some designs (BMW MQS style connectors are an example)

MQS Micro Terminal
DO NOT BACKPROBE

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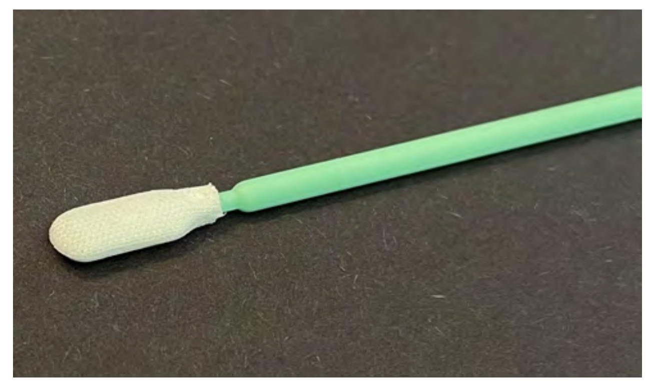
Backprobes and Piercing Probes

- Never perform backprobing or piercing on any shielded, multi-conductor, or coaxial harness/cabling
- If performed, that harness/cable must be replaced!
- Multi-conductor cables can be tested at connector terminal

Backprobes and Piercing Probes

- Always seal punctures to prevent water intrusion and future corrosion
- Liquid electrical tape is a great solution
- Apply sparingly (lint-free swabs work well)
- Product is only needed to seal the hole(s), so a large glob is unneeded
- Clear gel-type nail polish can be used but must be cured with a UV-light, and remains flexible after curing



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What is a sensor ?
What does it do ?

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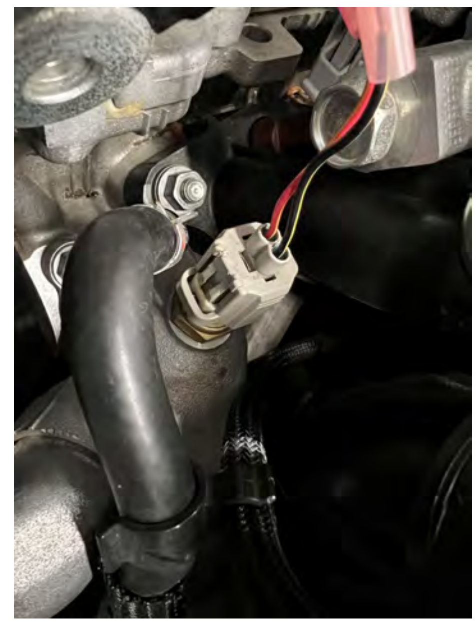
Sensor Types and Common Applications

❑ Let's Discuss:

- How many automotive sensor types exist?
- How do they operate?
- What are there designs and element types?
- Where are they used?

Sensor Types

- VRS
- Magneto-Resistive
- PTC/NTC Resistor
- Potentiometer
- Rheostat
- Zirconia
- Thermocouple
- RTD
- Piezo
- Capacitive and Strain-gauge
- Frequency



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VRS – Variable Reluctance Sensor

- Produces an AC sine wave
- Sensitive to air gap, resistance, and counter-magnetism
- Not reliant on supply voltage from module to work
- Output voltage is proportional to signal frequency
- Some VRS applications May Bias Circuit For Diagnostics

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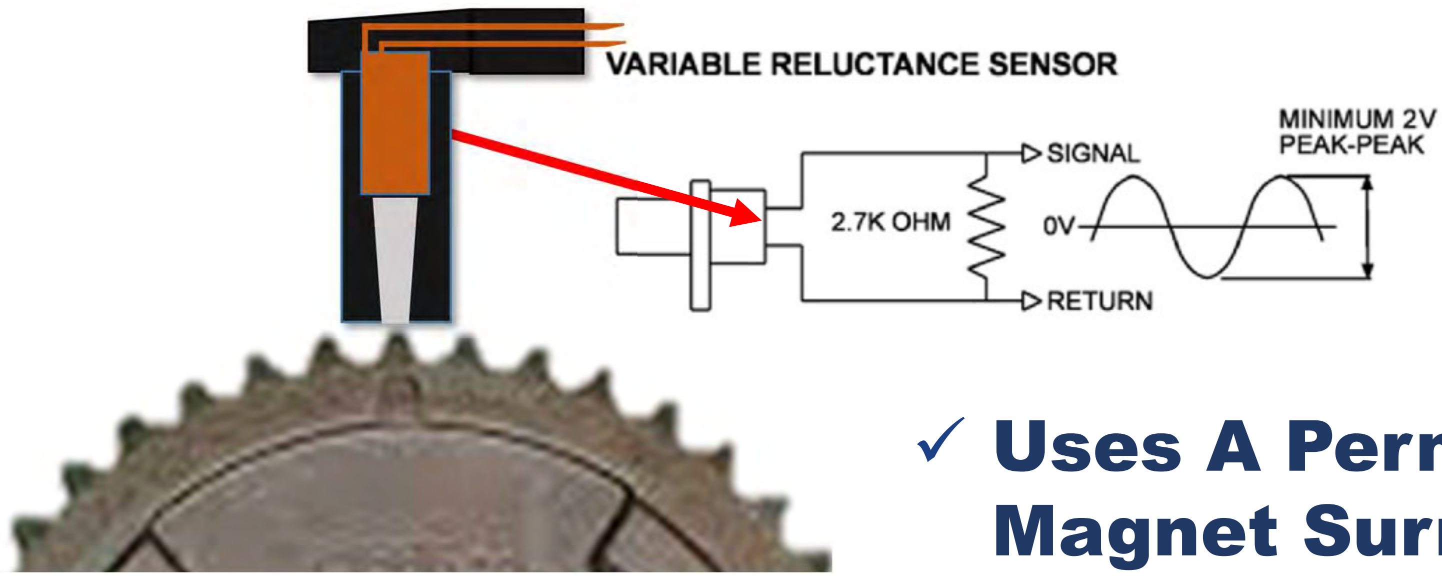
Variable Reluctance Sensor (VRS)

- ❑ Reliably used on earlier systems.
- ✓ Signal generating sensor types.
  - VSS, CMP, CKP, Trans output Shaft RPM, etc.



- ✓ Uses A Permanent Magnet Surrounded By A Coil Of Wire

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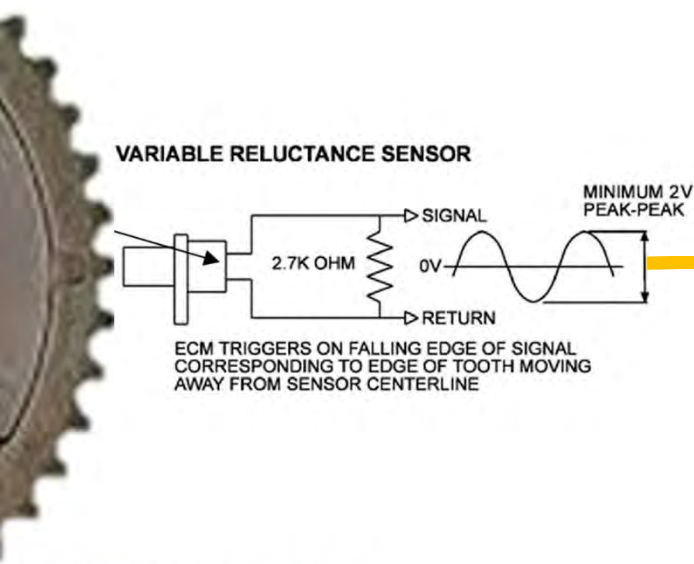
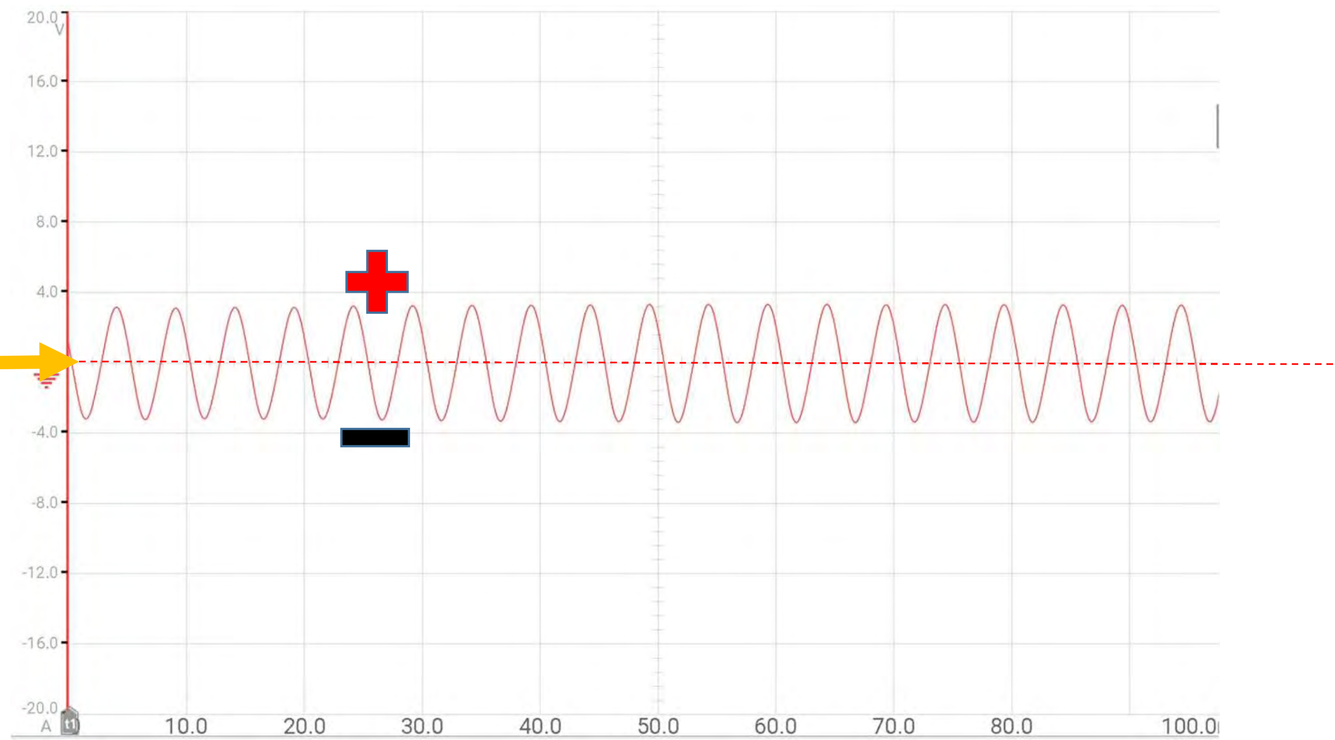
Variable Reluctance Sensor (VRS)

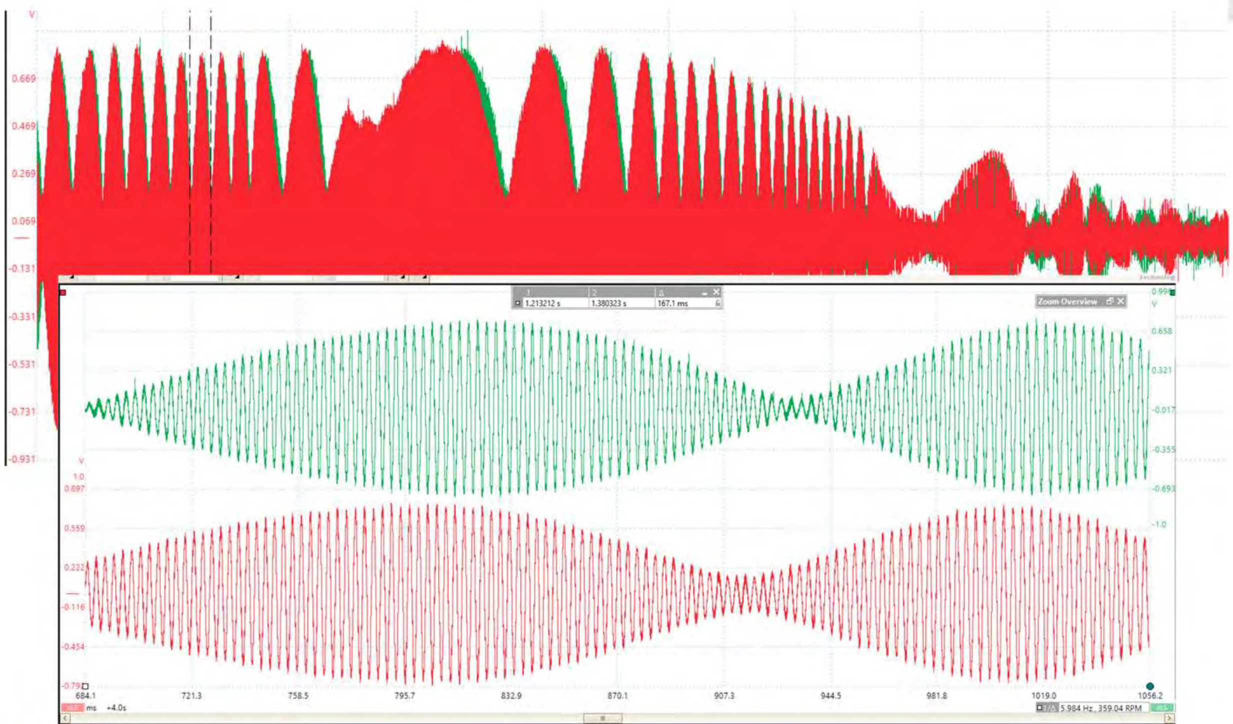
- ✓ **Variable peak to peak Voltage.**
- ✓ **Variable frequency.**

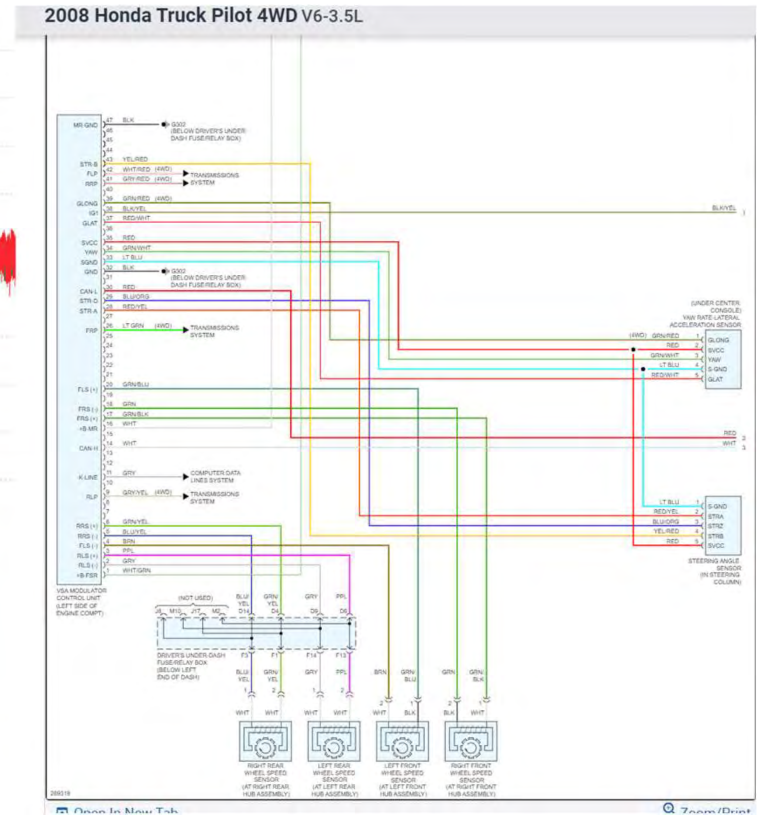




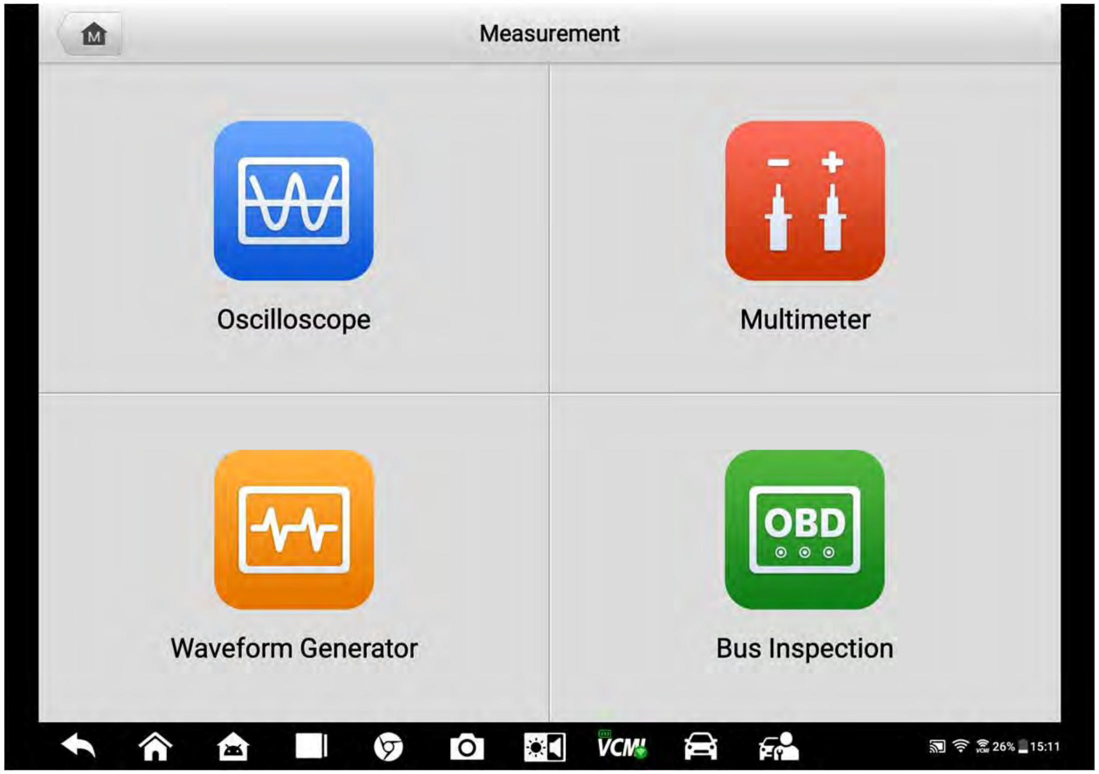
VRS

❑ 2008 Honda Pilot VTM-4 rear wheel speed sensors





Using Scope For VRS Testing



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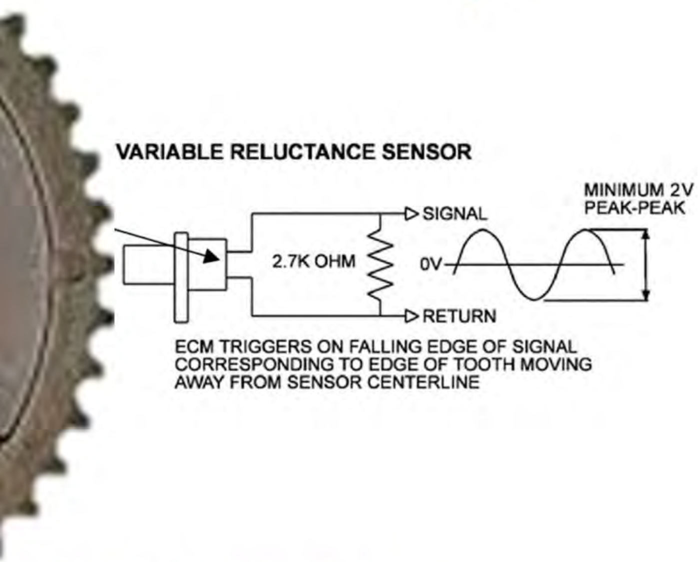
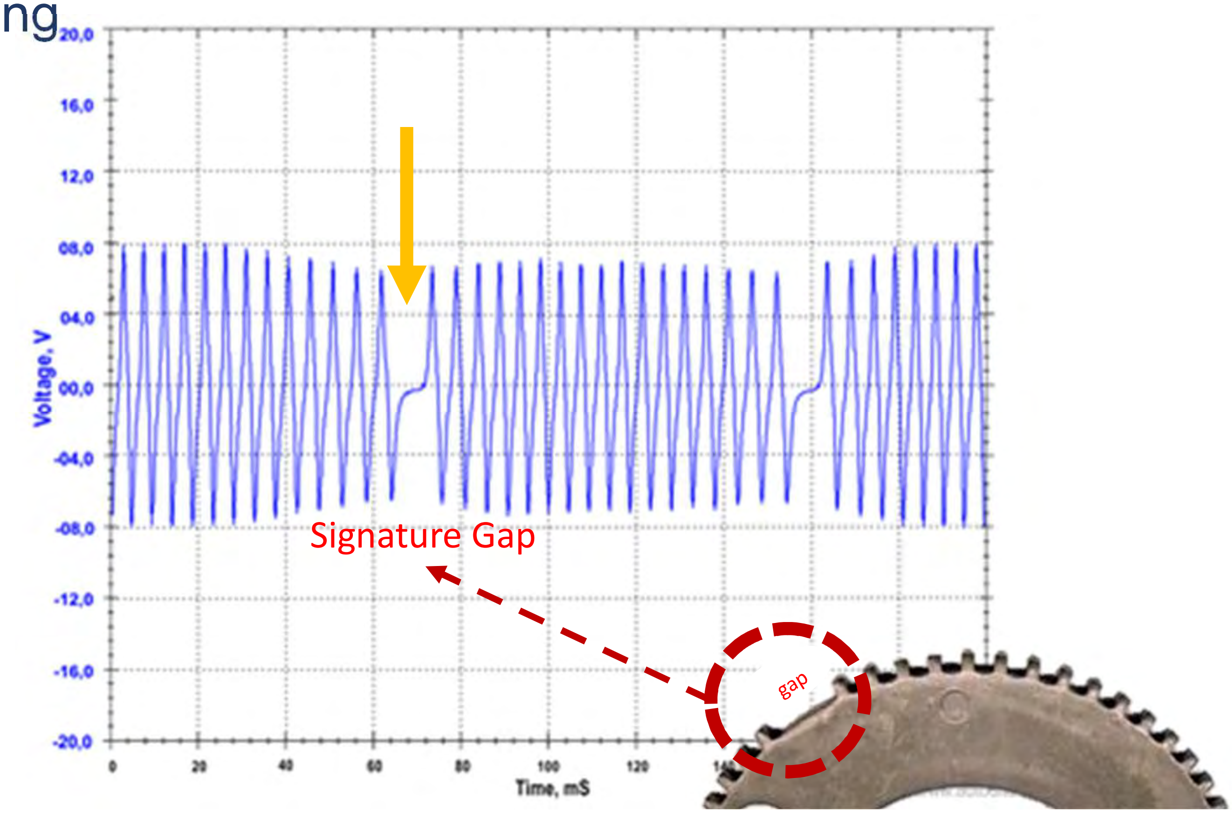
❑ Reluctor Signature Gap

- ✓ used for indexing
- ✓ Single or multiple spacing
- ✓ Varied Lengths

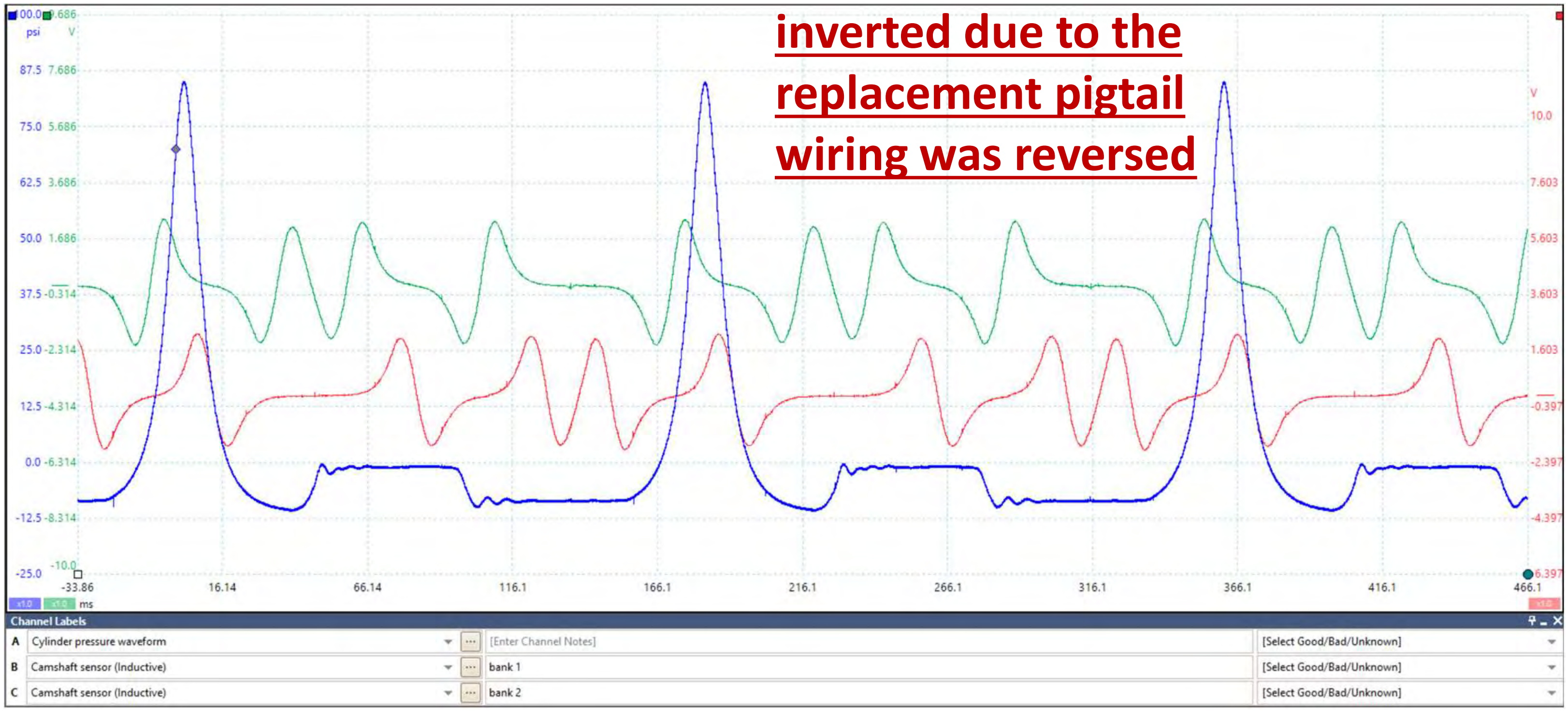




VRS

- Land Rover LR3, new CMP on B2 (green)
- Setting cam/crank correlation code for B2
- What do you see

B2 CMP signal is inverted due to the replacement pigtail wiring was reversed



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94 Ford F150 No Speedometer ABS Light

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Service Information

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SPEEDOMETER

1. Turn ignition on.
2. Observe odometer. If odometer display is on and digits appear normal, go to next step. If odometer display is not on and/or digits do not appear normal, go to step 6).
3. Observe odometer. If word ERROR appears, replace speedometer. If word ERROR does not appear, go to next step.
4. Test drive vehicle. If odometer accumulates mileage, go to step 9). If odometer does not accumulate mileage, go to next step.
5. Test drive vehicle. If indicated speed on speedometer increases with increasing vehicle speed, replace speedometer. If indicated speed does not increase, go to step 8).
6. Remove, check, and install fuses No. 8 and 17. If fuses are okay, go to next step. Replace fuses and repair shorted wires, if necessary. If speedometer and odometer still do not operate, go to next step.
7. Turn ignition on. Backprobe terminals No. 1 (Light Green/Yellow wire) and No. 3 (Pink/Black or White/Purple wire) of Programmable Speedometer/Odometer Module (PSOM) harness connector, located behind instrument cluster. If battery voltage does not exist, repair appropriate wire from fuse panel. With ignition off, measure resistance between terminal No. 2 (Black/White or Pink/Orange wire) and ground. If resistance is greater than one ohm, repair Black/White or Pink/Orange wire.
8. Set DVOM to measure AC voltage. Backprobe PSOM terminals No. 4 Red/Pink wire) and No. 5 (Light Green/Black wire). Test drive vehicle. If voltage increases smoothly from zero to approximately 3.5 volts as vehicle accelerates to 30 MPH, replace speedometer. If voltage does not increase as specified, repair speed sensor circuit. See chassis wiring diagram in WIRING DIAGRAMS.
9. Test drive vehicle. If indicated speed on speedometer increases with increasing vehicle speed, speedometer is okay. If operation is not as specified, replace speedometer.

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Wiring Diagram For Sensor

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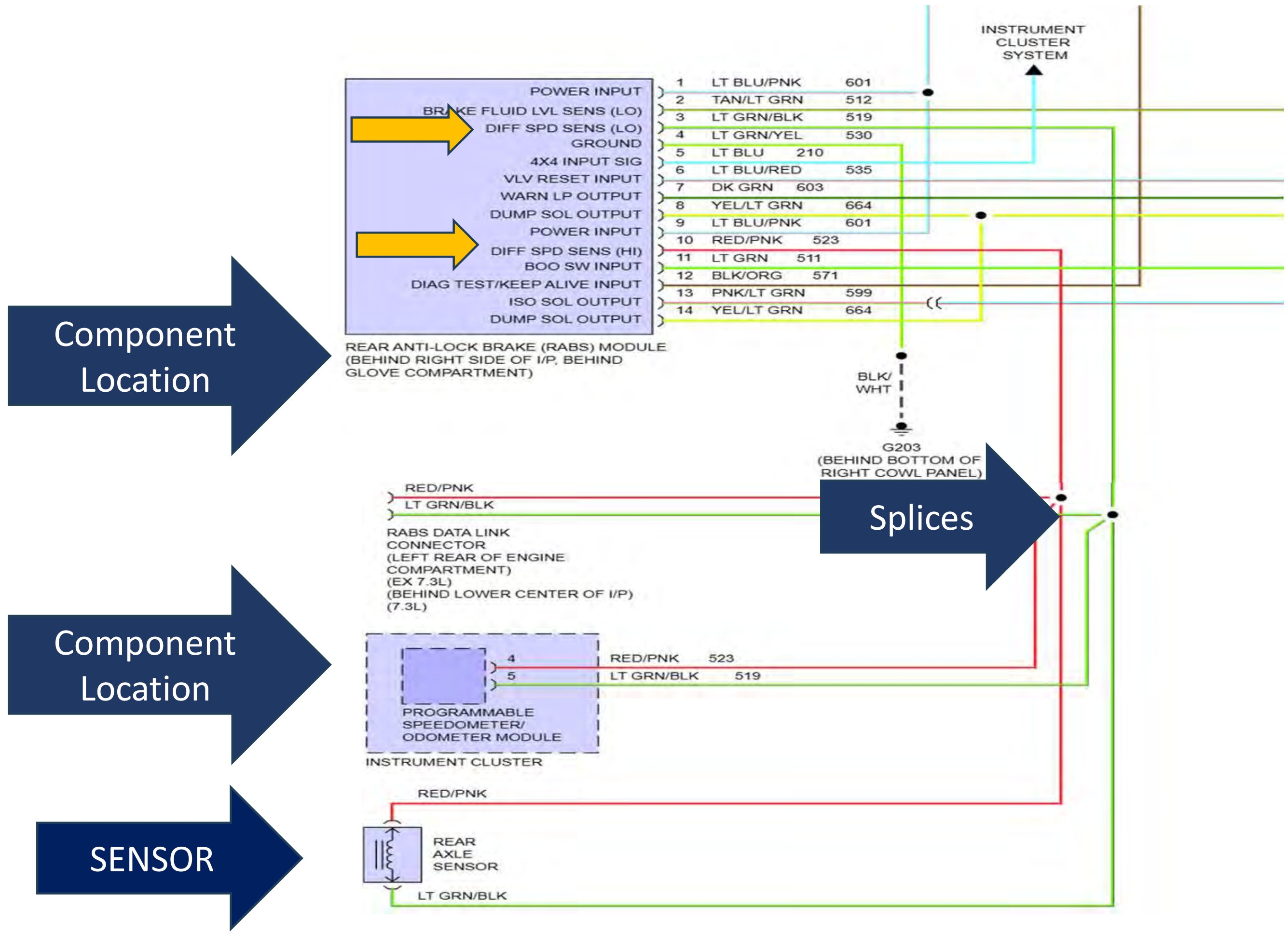
Using our "roadmap" we can form a plan of where to test



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Easy hook up at the sensor (A/C Wheel Speed)

- ❑ **Green is Low**
- ❑ **Red is High**
  - **Both Analog And Digital wheel speed sensors exist**
  - **Understanding the circuit is critical**

What Will A DVOM Reveal

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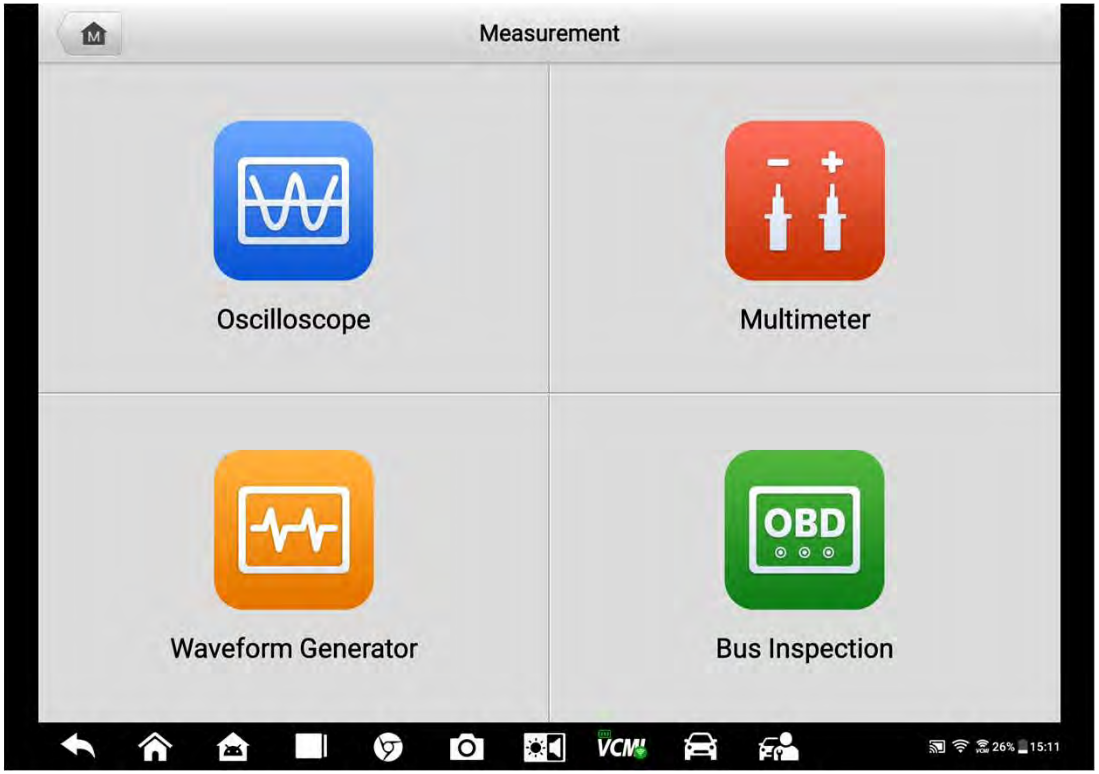
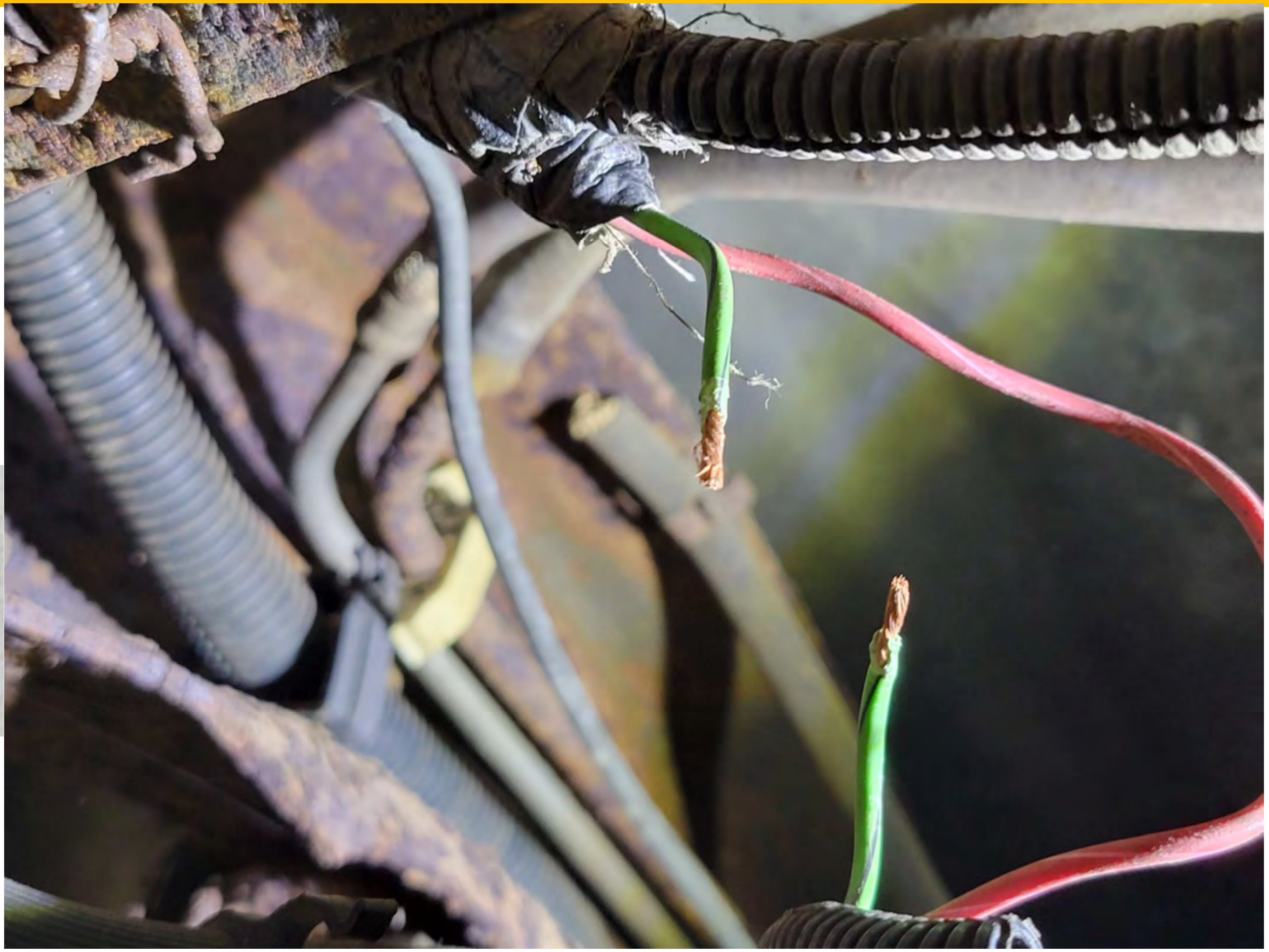
Is There More Information On A Scope



Broken Wires



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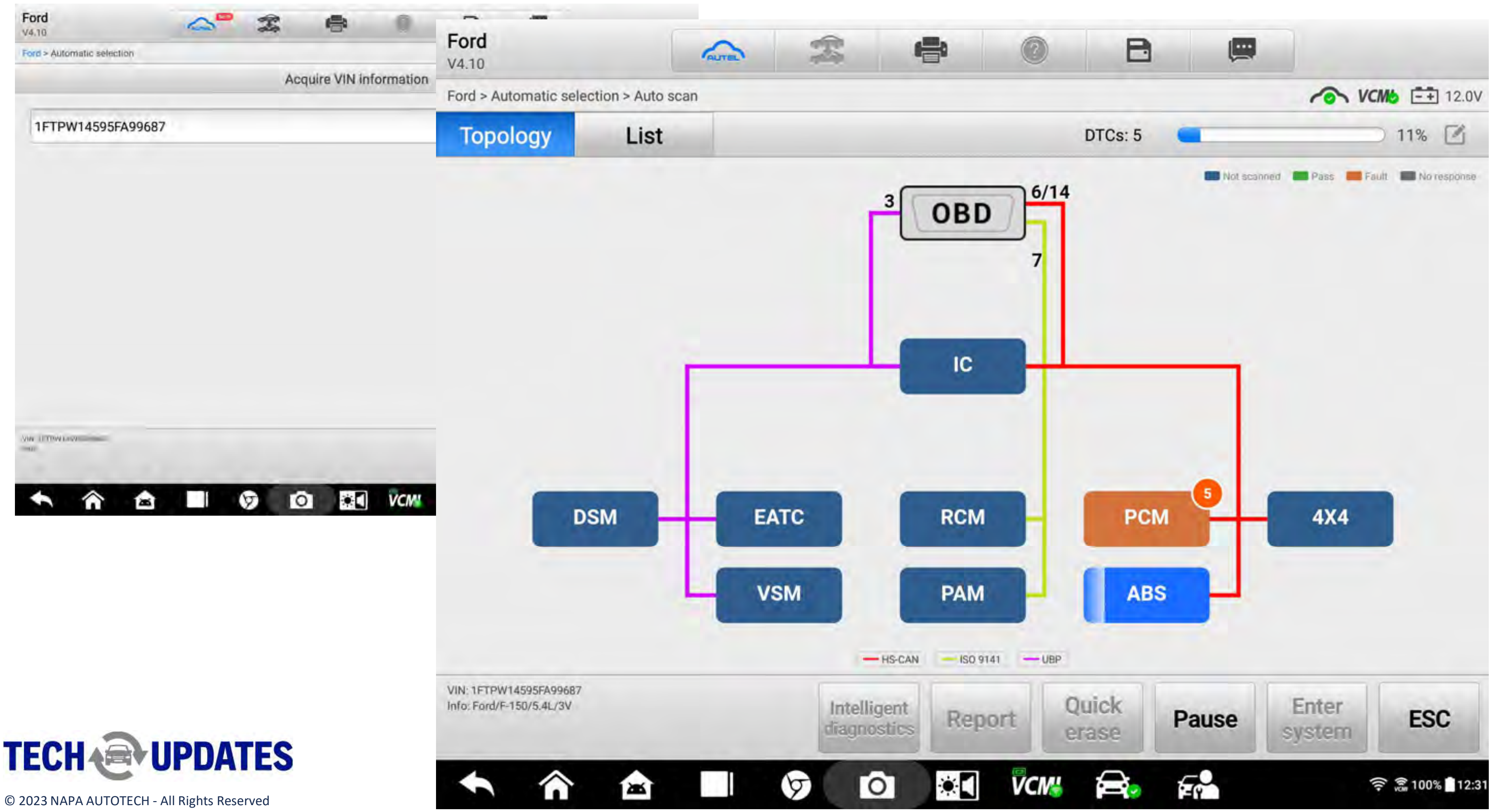
05 F150 Poorly running engine



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5 codes to start We will focus on sensor

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DTC Details

1. PCM(Powertrain Control Module)(5 DTCs)

Codes	Description	Status
P0171:FF	System Too Lean Bank 1	CMDTCs
P0303:FF	Cylinder 3 Misfire Detected.	CMDTCs
P0345:FF	CID(Camshaft Position Sensor) A Circuit (Bank 2)	CMDTCs
P0349:FF	CID(Camshaft Position Sensor) A Circuit Intermittent (Bank 2)	CMDTCs

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Service Information P0345

DTC P0345: Camshaft Position (CMP) Sensor Circuit Malfunction (Bank 2)

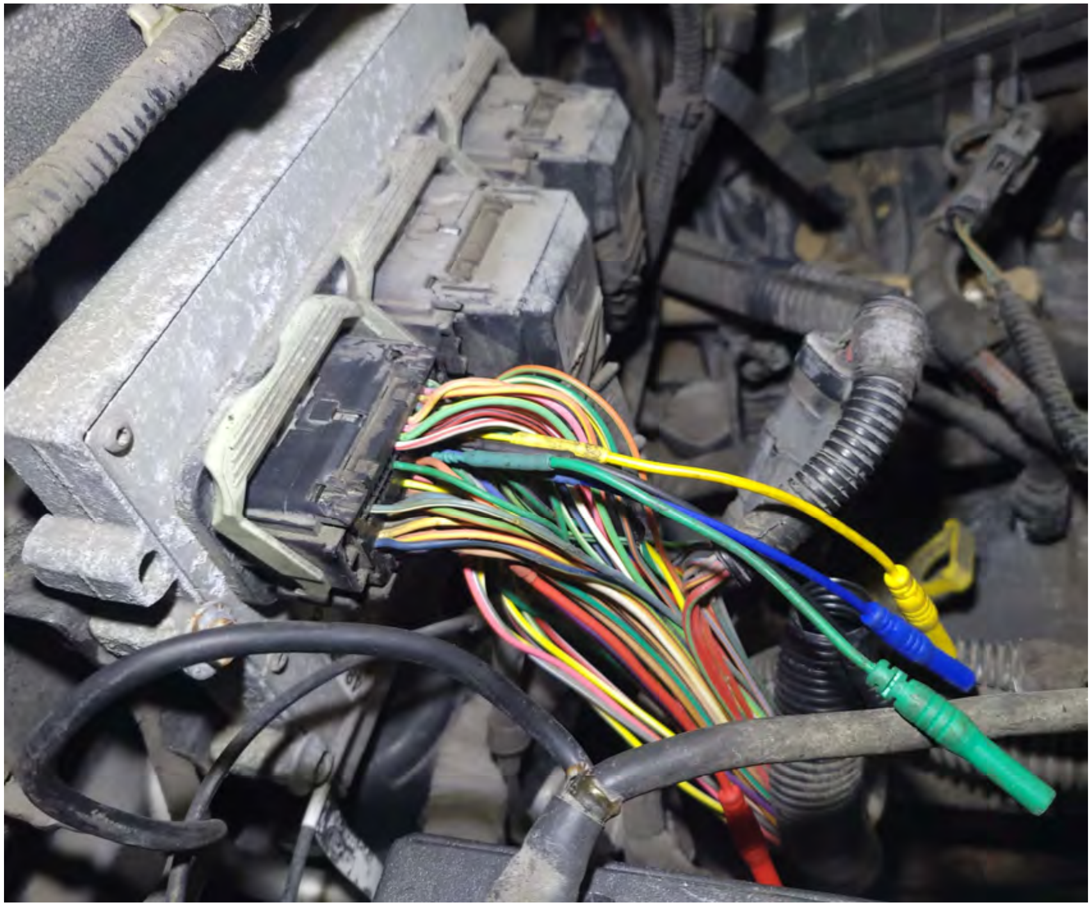
DTC P0340: Camshaft Position (CMP) Sensor Circuit Malfunction (Bank 1)

P0340 - CAMSHAFT POSITION (CMP) SENSOR CIRCUIT MALFUNCTION (BANK 1)

Description:	The test fails when the powertrain control module (PCM) can no longer detect the signal from the CMP sensor on bank 1.		
Possible Causes:	• CMP circuit open • CMP circuit short to GND • CMP circuit short to PWR • SIG RTN open (VR sensor) • CMP GND open (Hall-effect sensor) • CMP circuit short to CMP2 circuit (if equipped) • CMP incorrectly installed (Hall-effect sensor) • Damaged CMP sensor shielding • Damaged CMP sensor • Damaged PCM		
Diagnostic Aids:	Harness routing, harness alterations, improper shielding, or electrical interference from other improperly functioning systems may have an intermittent impact on the CMP signal.		
Application	**Key On Engine Off**	**Key On Engine Running**	**Continuous Memory**
All	GO to DR: Camshaft Position (CMP) Sensor STEP DR1.		

Fist look at PCM CPK CMP1 CMP2

- Easiest to test at PCM
- Back probing chosen
- Removed harness hood



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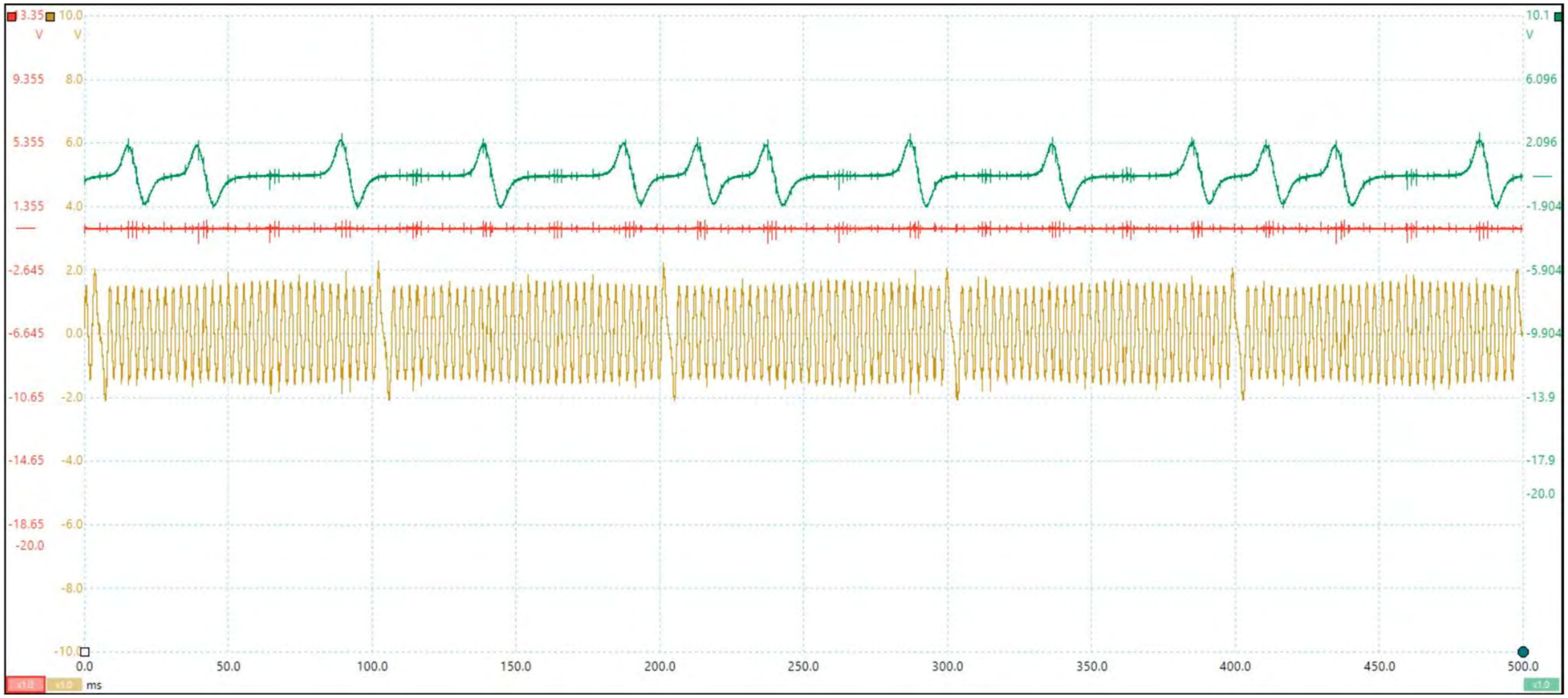
CMP1=green CMP2=red CPK=gold at PCM



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Going There

- We have proven the PCM is not receiving a signal
- Sensors aren't always mounted in easy access spots
- This example had little teardown to access sensor itself

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Backprobe or Terminal Adapter At the CMP Sensor

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- ❑ Y-terminal adapter installed for easy scope connection in-series
- ❑ Provides easy access for sensor resistance testing as well

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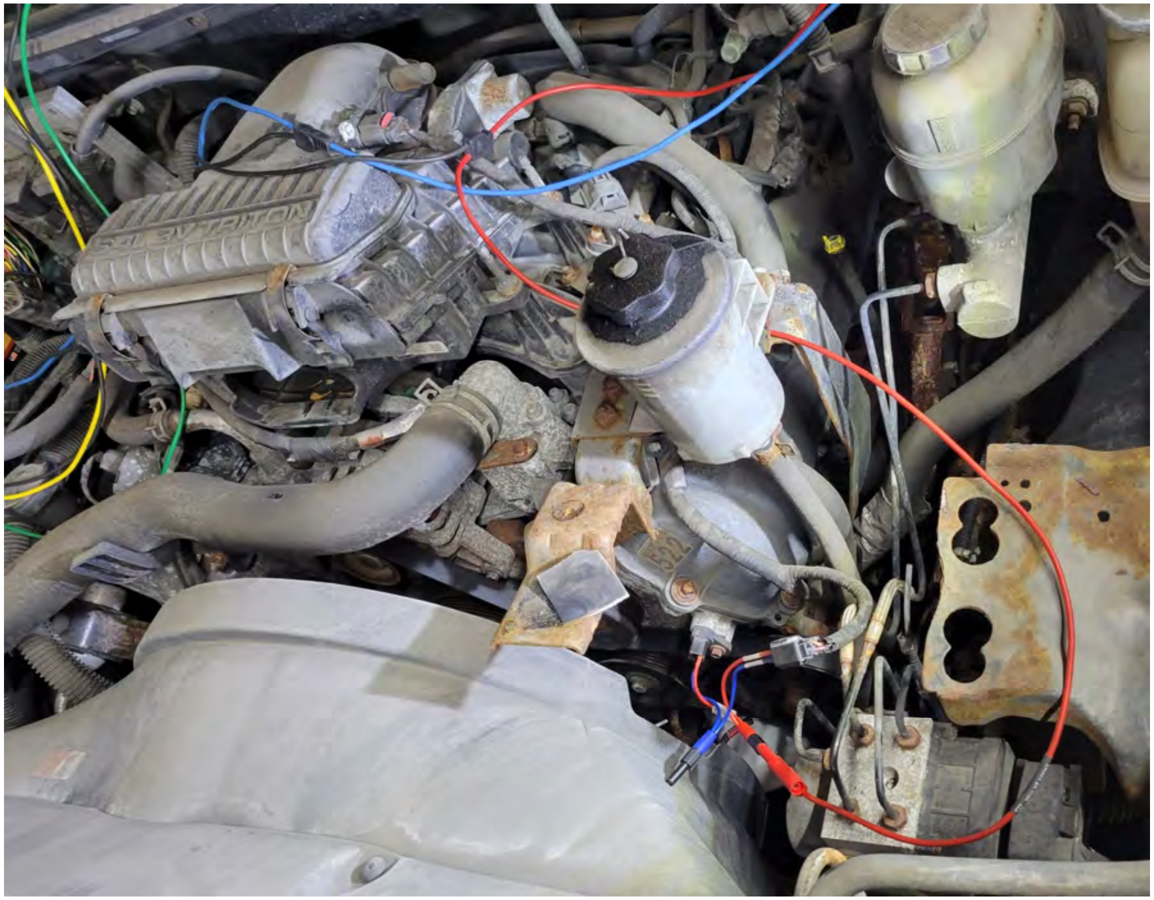
PCM back probed & compared to @ sensor



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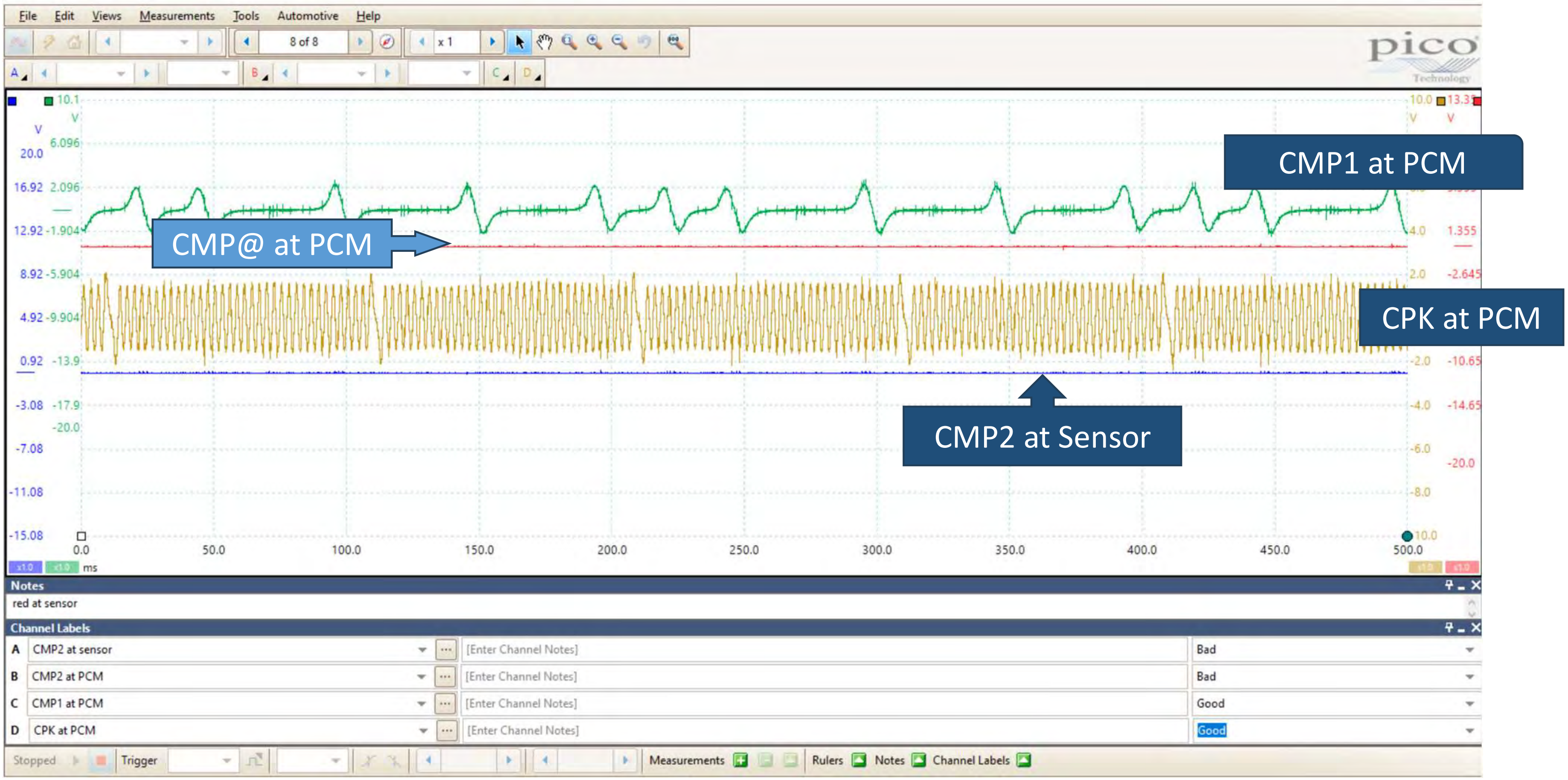
Now with 4th channel at sensor



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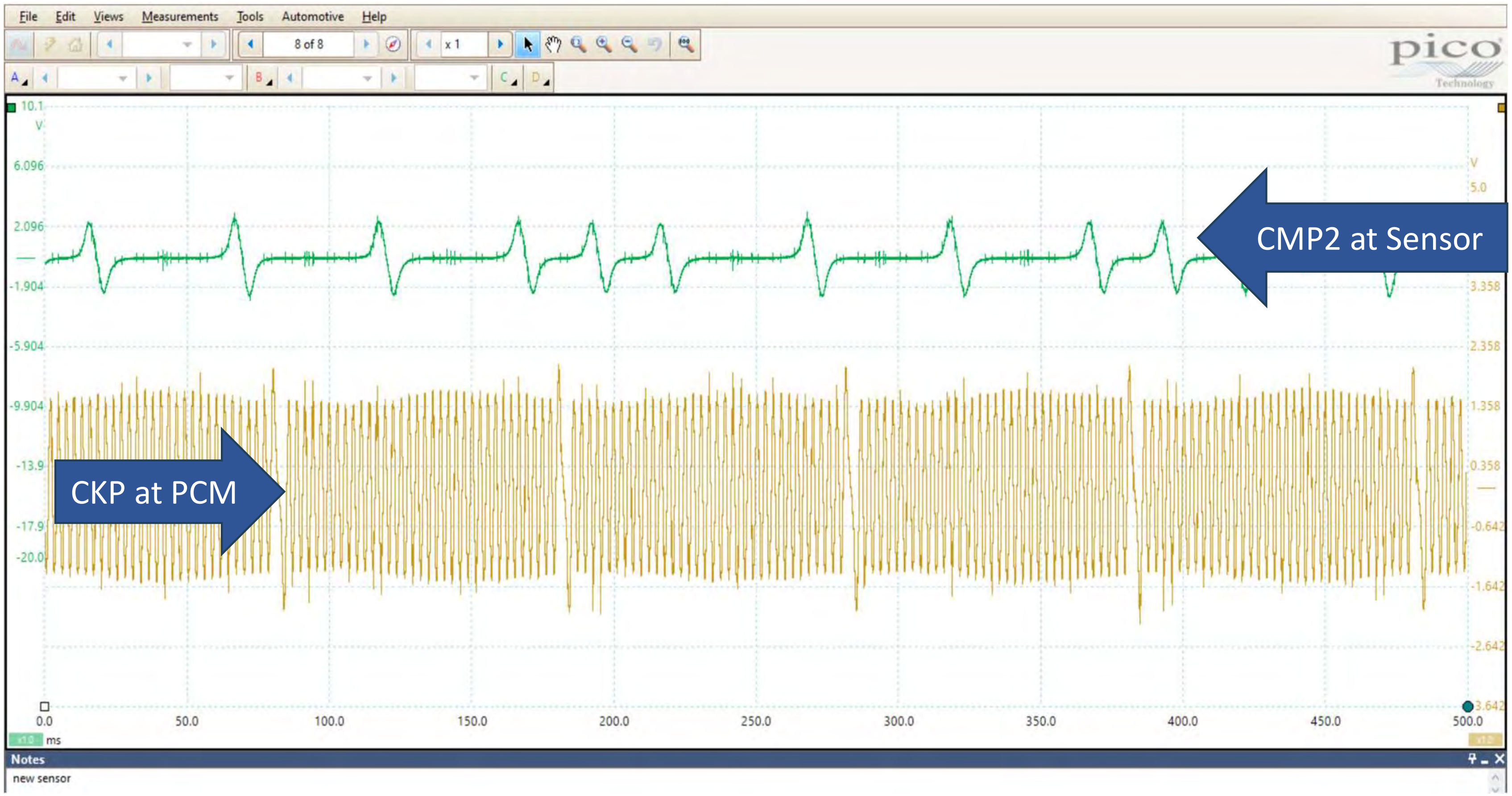
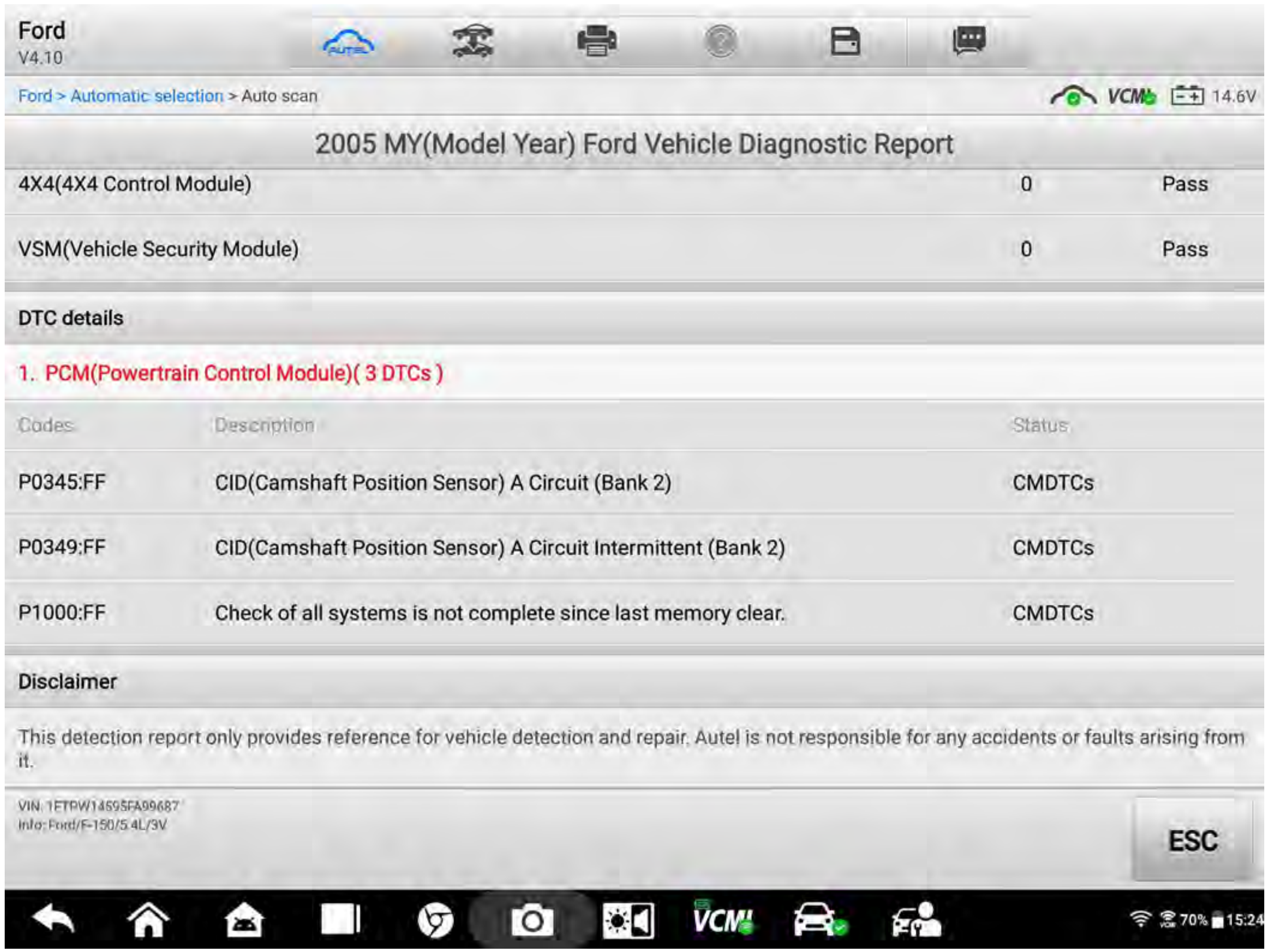
After CMP2 sensor replacement at PCM



Didn't take long to set code again



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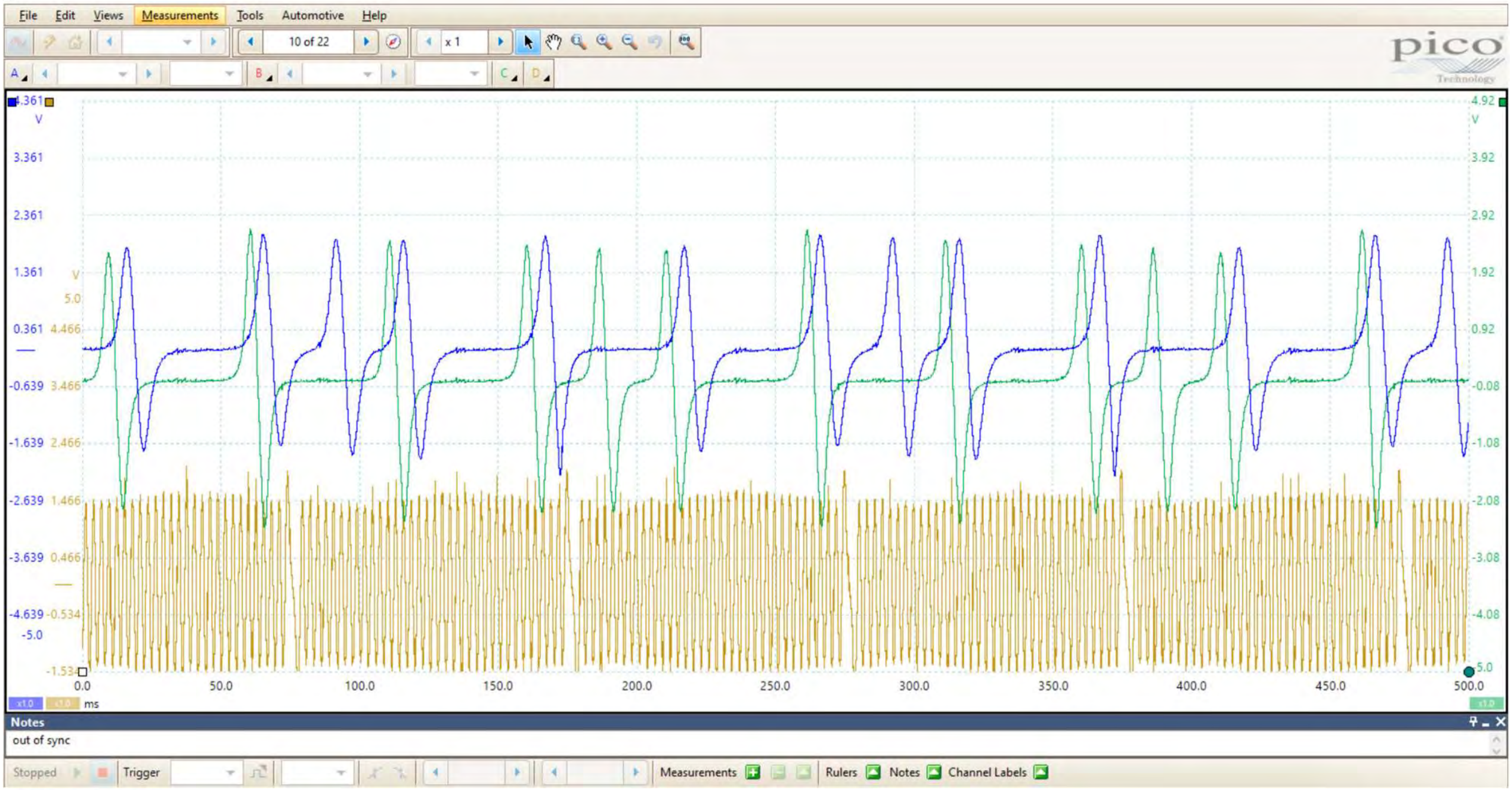
Both CMPs and CPK at PCM



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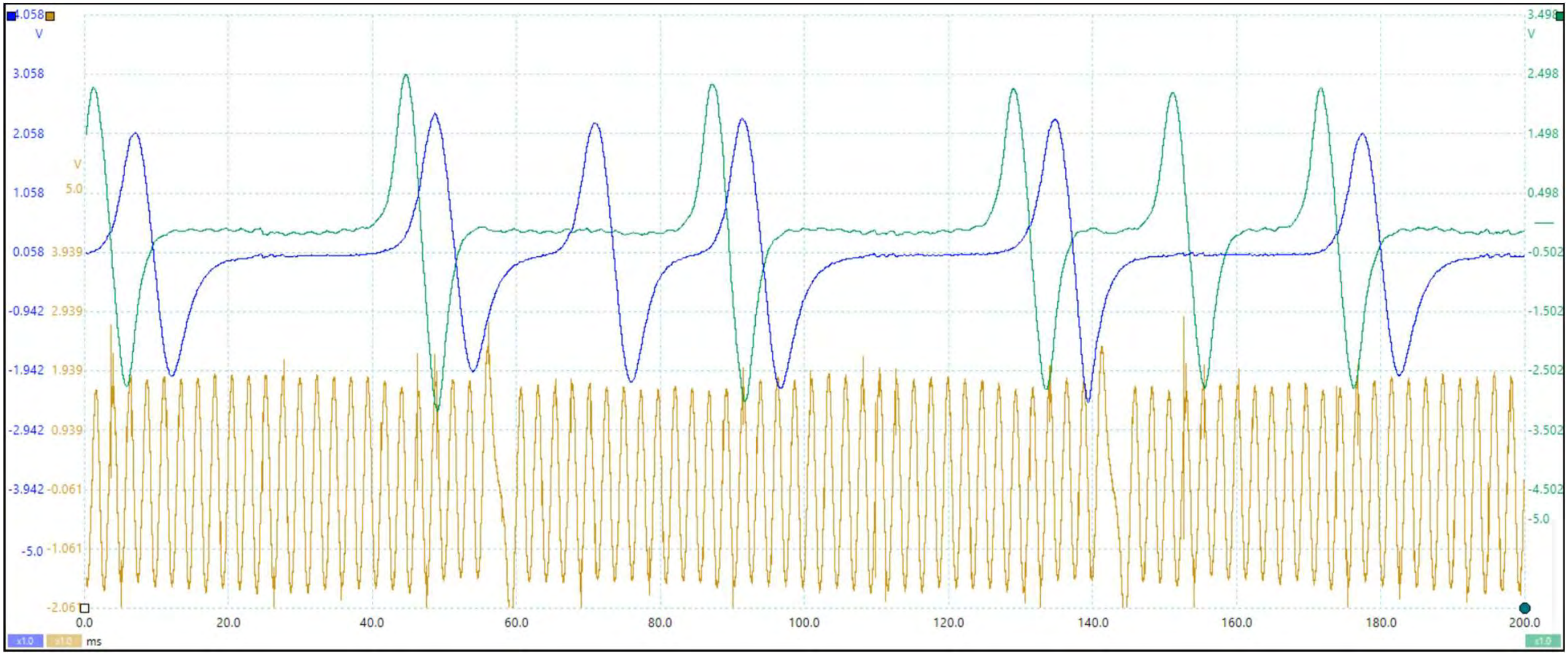
We now have both CMPs and CPK

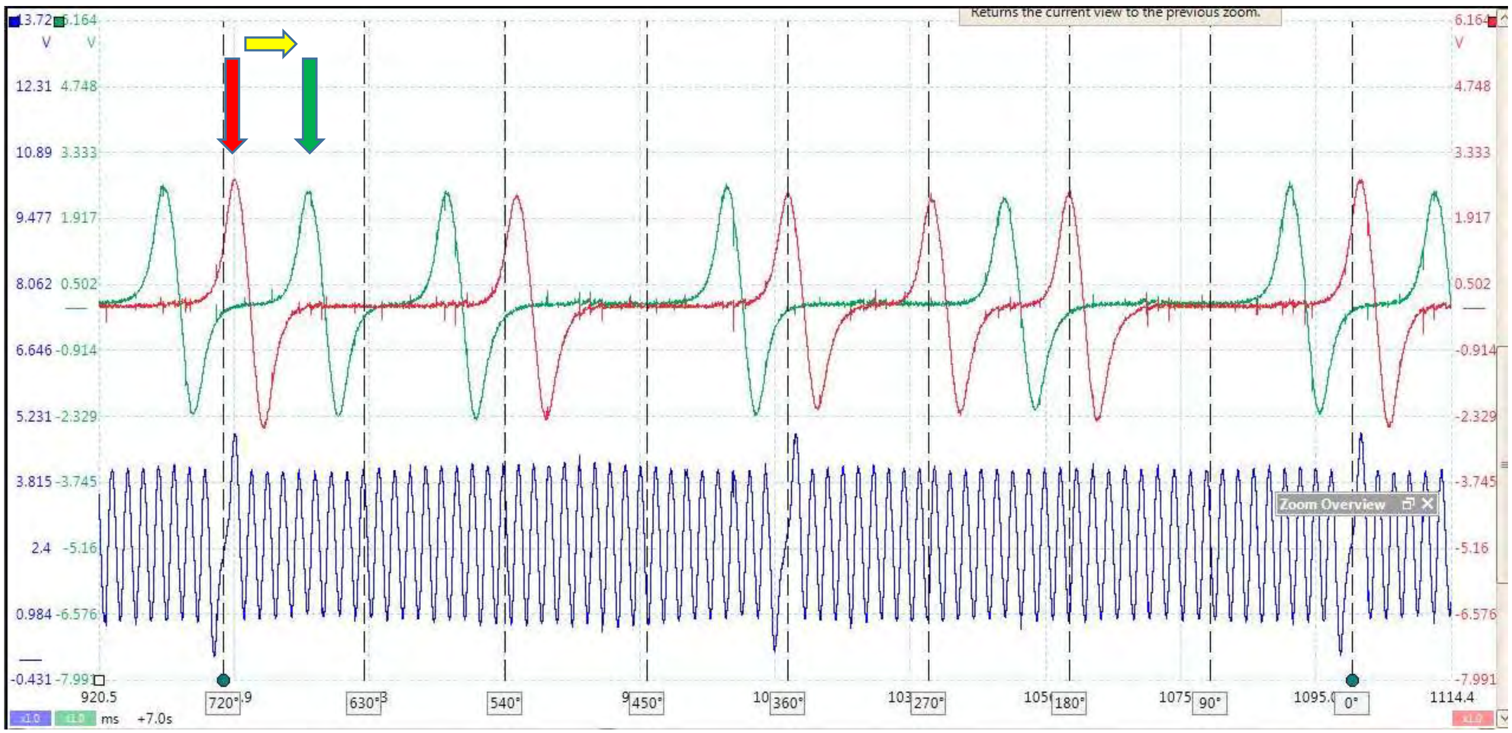


Circuit Fault Explanation

- Ford 5.4 3V setting P0345 CMP 2 Circuit Fault
- Shop already installed new sensor
- Red trace at arrow should be where the Green is
- Mechanical timing is not producing a sensor signal voltage when the PCM expects it

We Started With No Signal

No amount of sensors can fix a timing issue!!!



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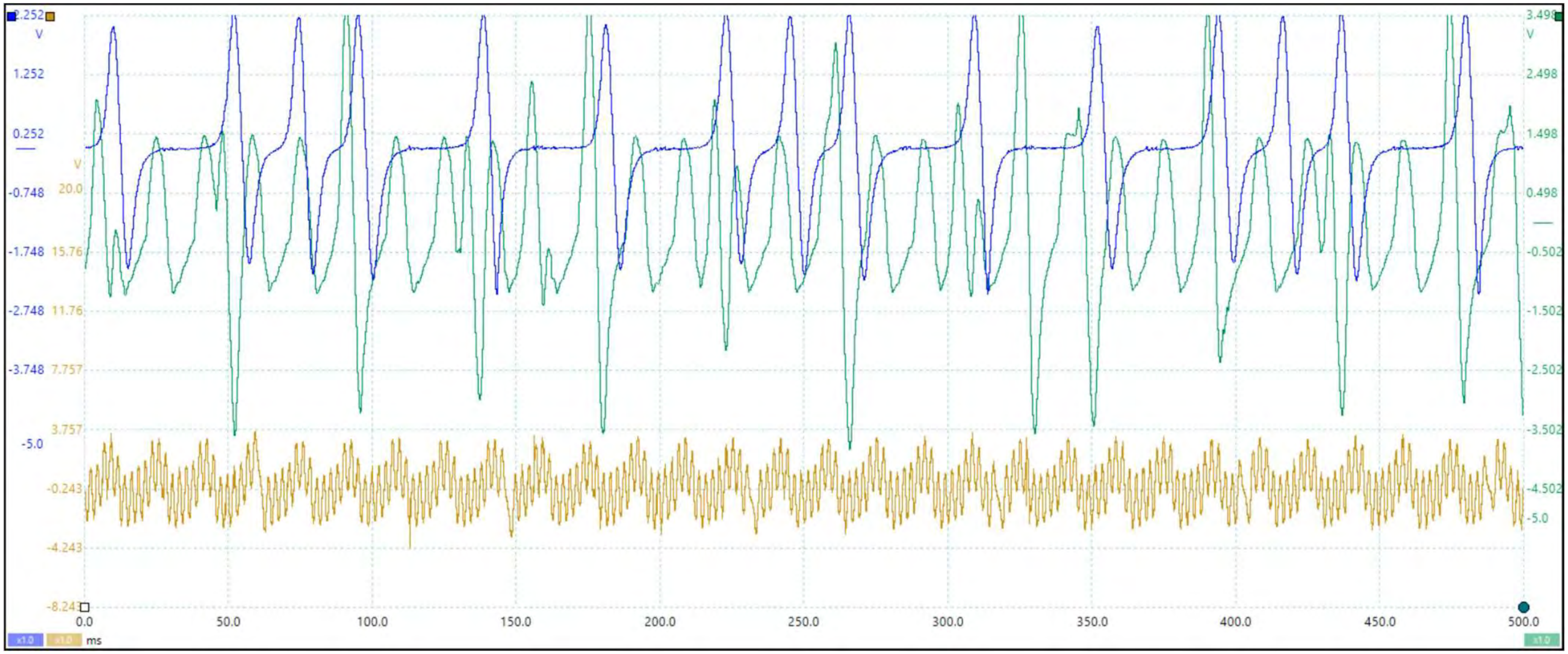
Bonus Knowledge

After repair this is what is first observed



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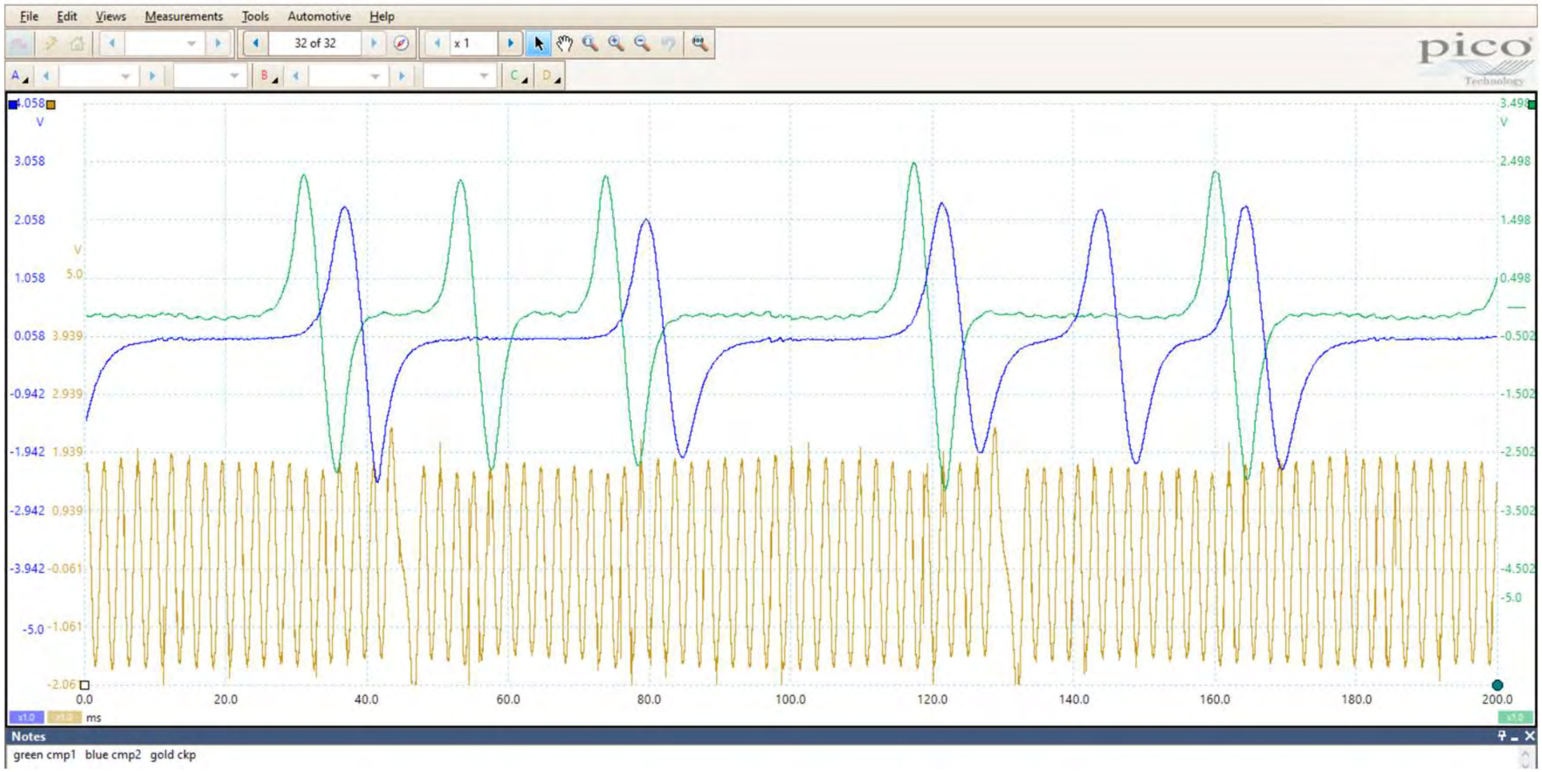
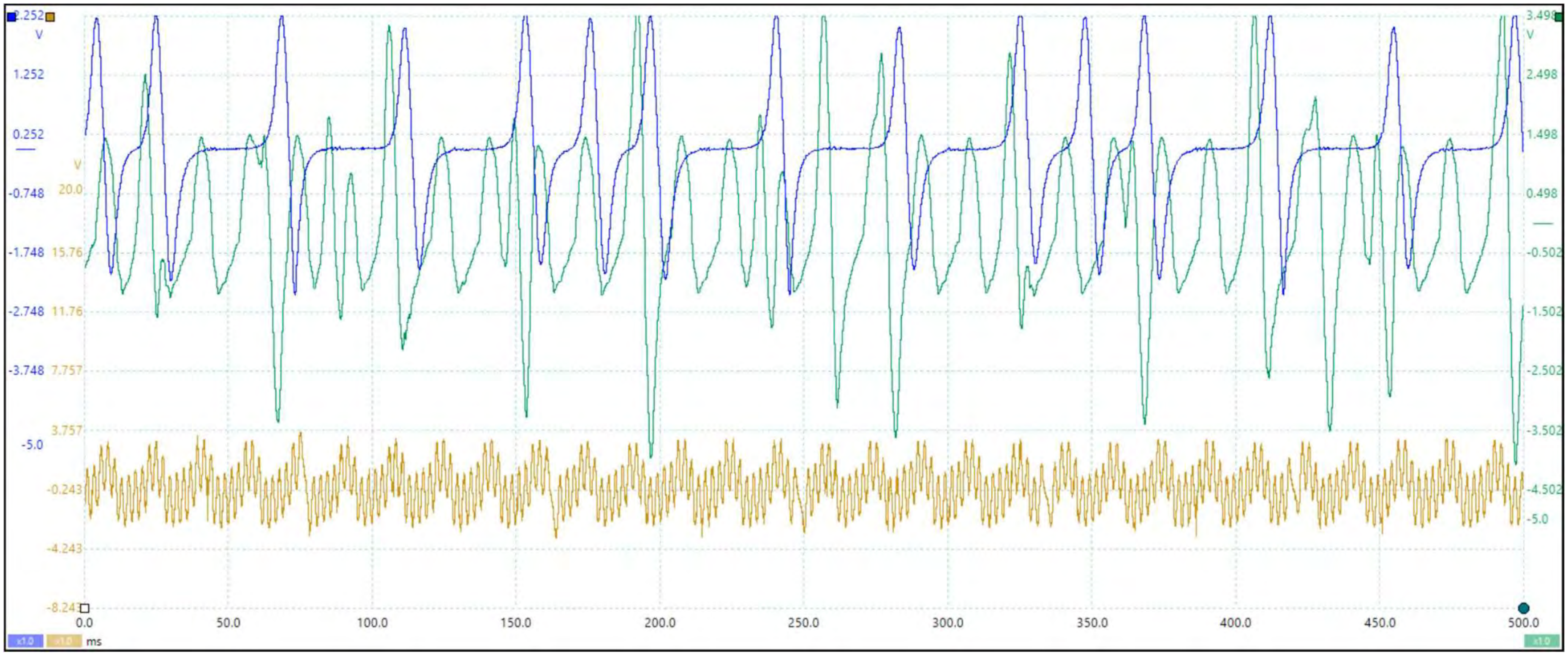
What changed now?



Second look



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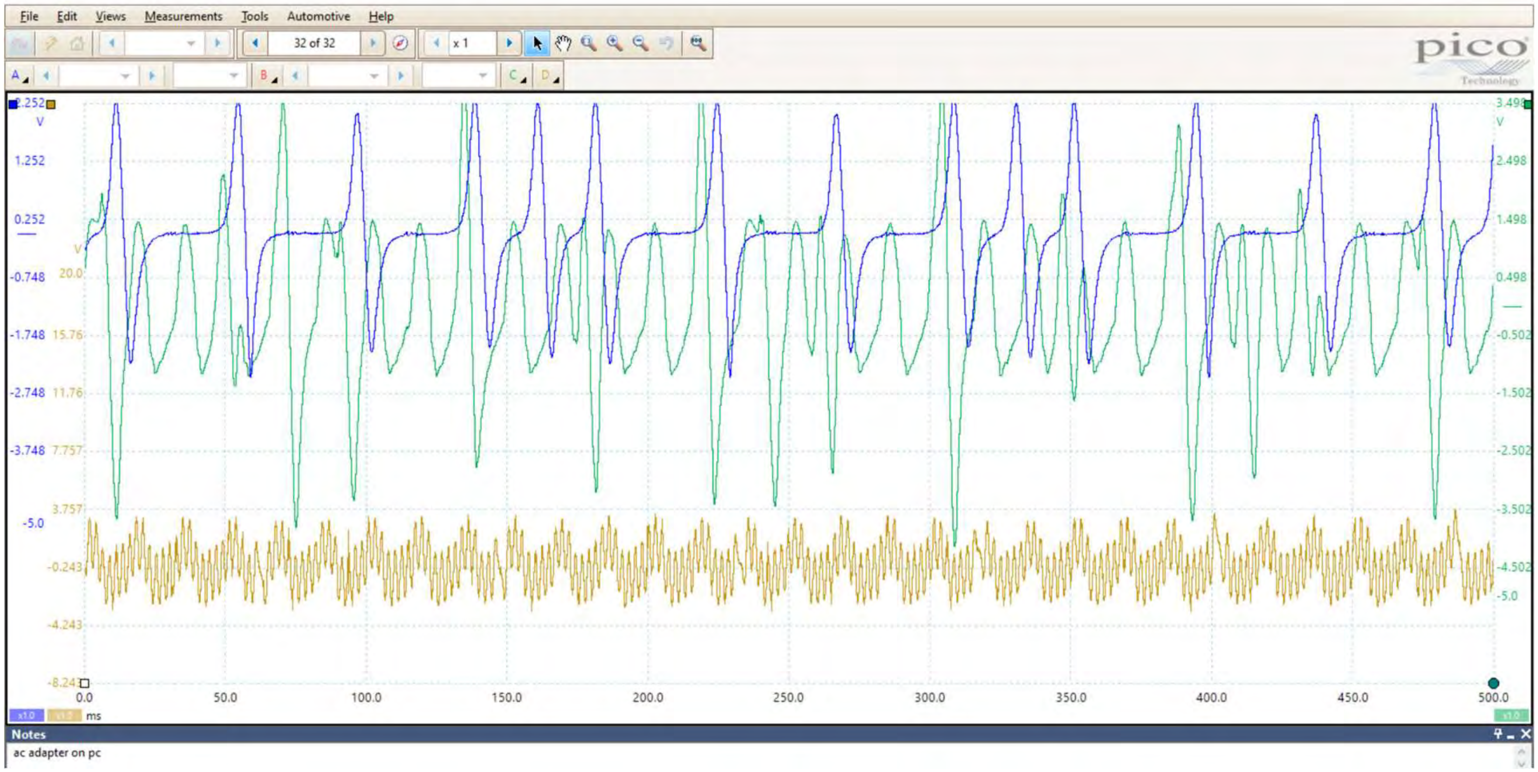
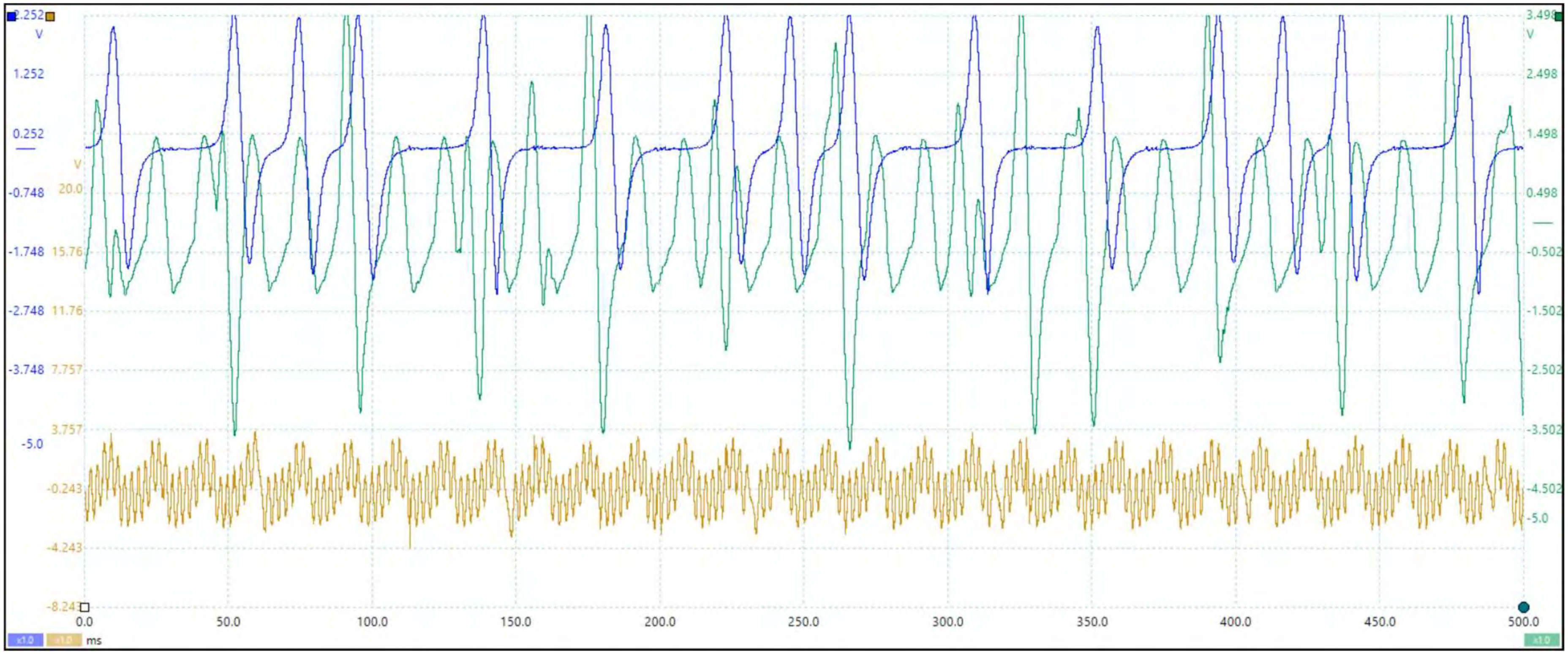
How many “surges” in the CPK sweep?



Laptop AC power on / removed / on



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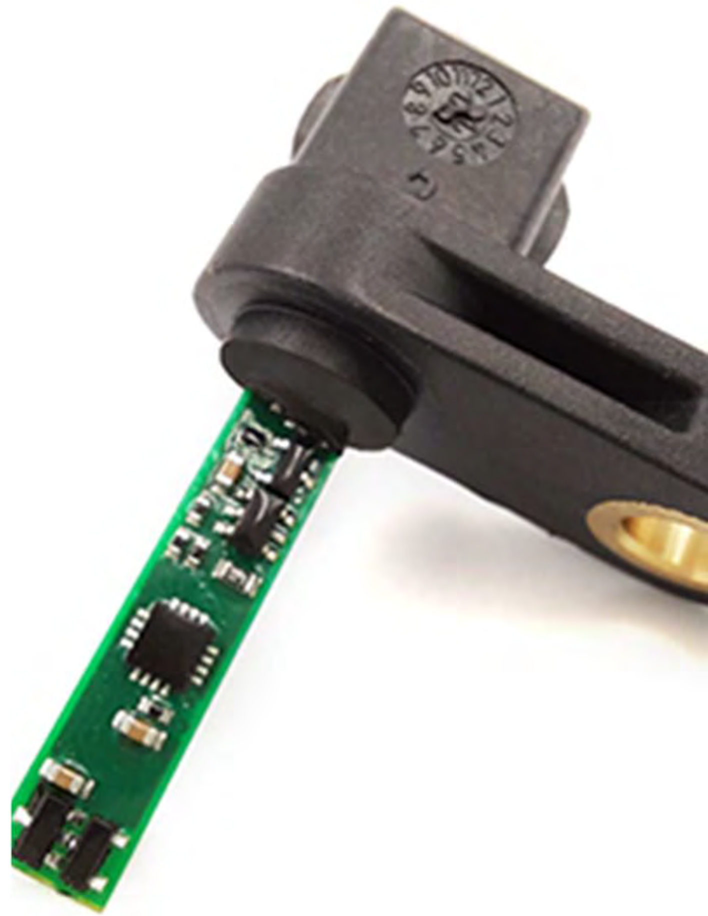
Magneto Resistive 2 Wire

- Active Wheel Speed sensors
- ECU Provides voltage and constant monitored current
- 7 to 14 ma Toggle from sensor
- Signal Can Be On Either Side Of Circuit
- ECU Monitors Via A/D Converter
- Causes slight Voltage Change On One Side



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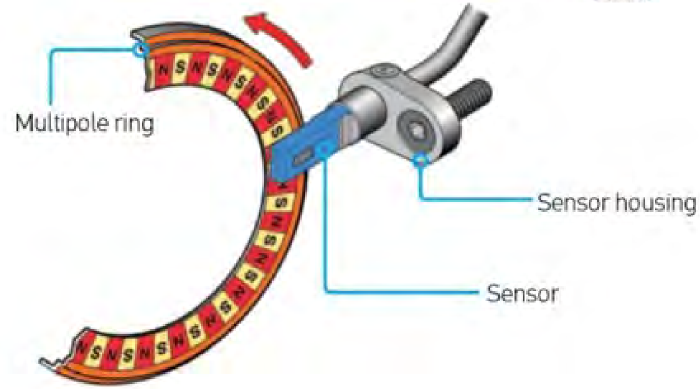
Magneto Resistive Sensors

- ❑ Can Detect No Or Low Speed
- ❑ Can Detect Direction
- ❑ Small Packaging
- ❑ Semi Active, Magnet In Sensor Ferrous Trigger
- ❑ Fully Active, Magnet Encoder Ring Trigger



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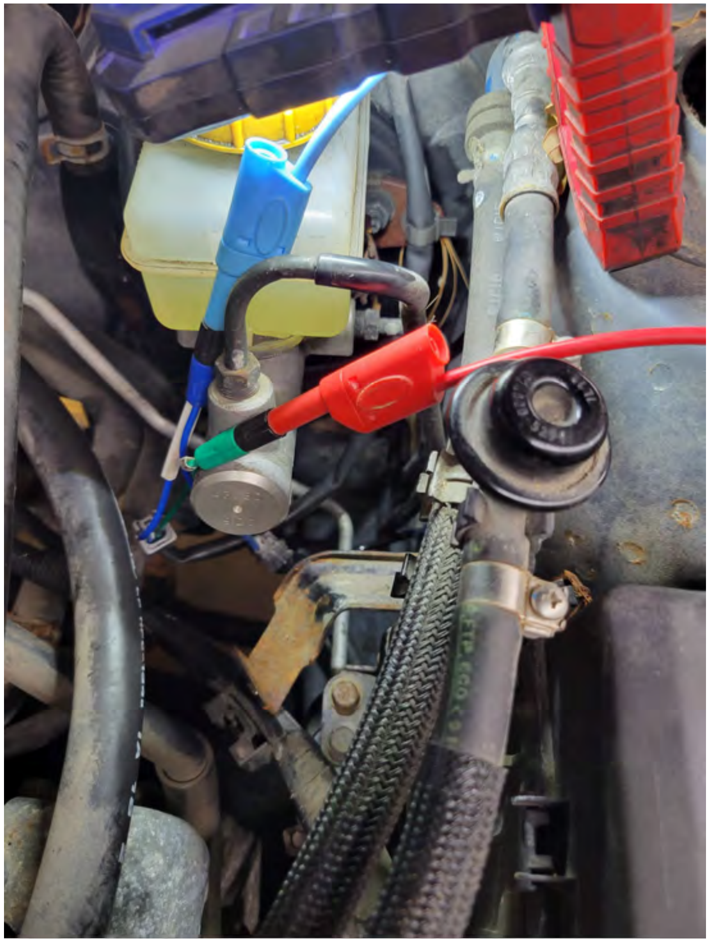
Comparing Known Good Signals

- If a signal is missing compare it to another known-good signal
- Here we compare a Subaru wheel speed signal from one side to the other



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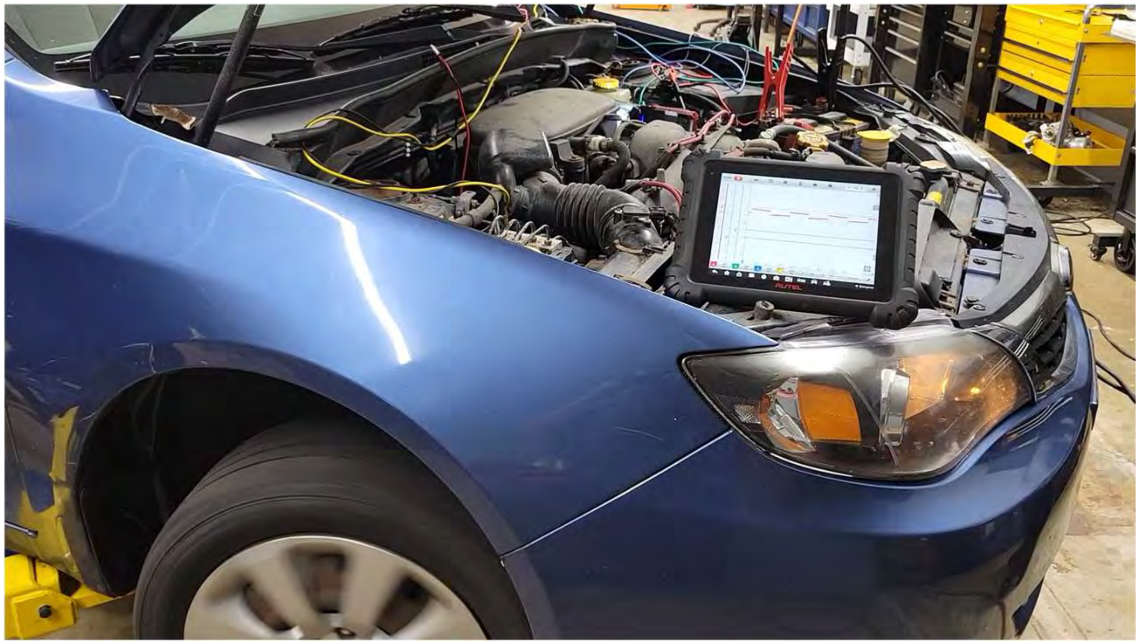
Subaru Missing WSS

- ❑ **Before** scoping, first test drive w/Scan tool to observe all wheel speed sensor live data
- ❑ Verify Customer Concern…No FL Output
- ❑ Let's take a look



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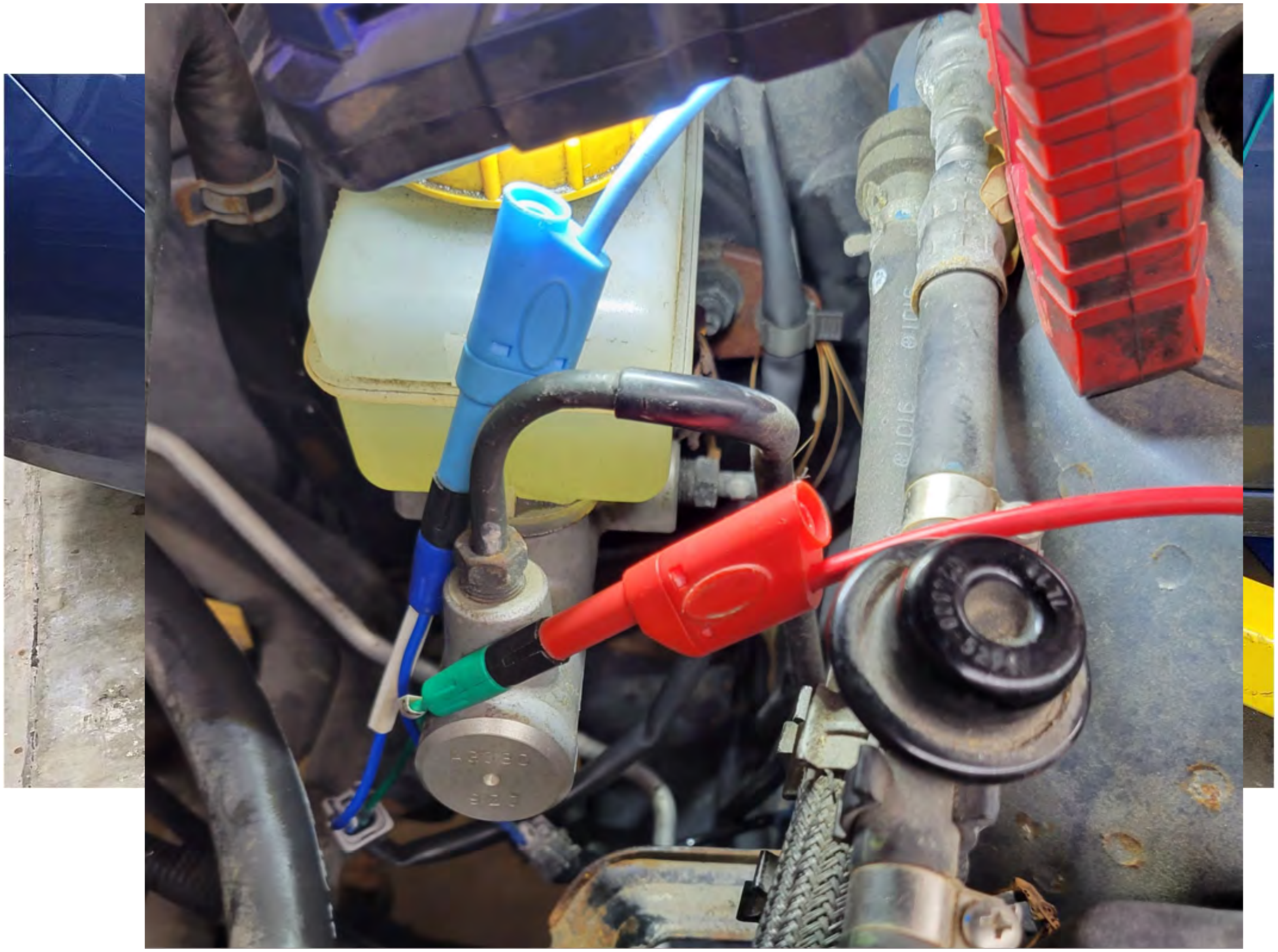
Shared FR Voltage To FL Sensor



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Adding Voltage To Sensor

- Sensor bias voltage was **not** being provided by the ABS module (to FL wheel)
- As a test, FR Sensor Reference Voltage supply was provided
- Correct speed signal was then generated

Name 0 items selected	Value	Unit
FR wheel speed	1.86	mph
FL wheel speed	1.86	mph

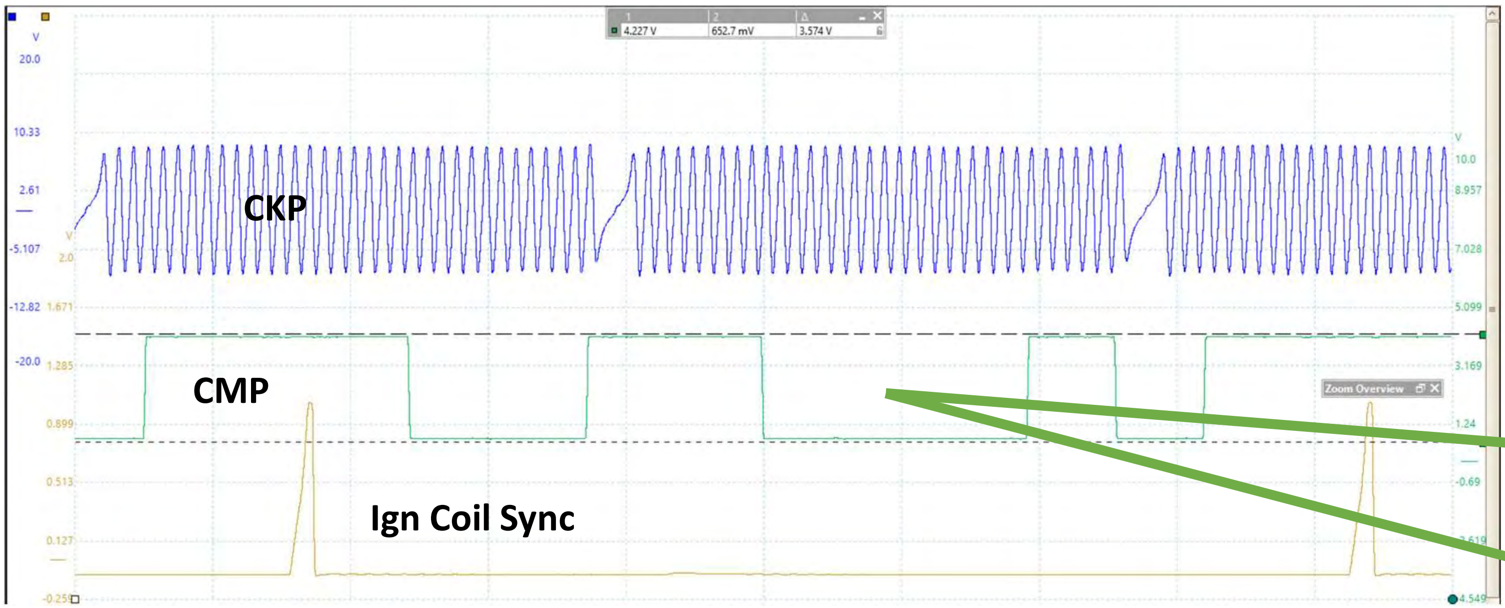
- After proving out vehicle wiring, ABS module replacement was Recommended Repair

Magneto Resistive

- 3 Wire MR sensors:
  - Pull-up
  - Pull-down
- May Verify type by unplugging and checking for two 5-volt measurements at the connector
- A pull-down will have a 5v ref, a ground, and a current limited 5v to 12v signal circuit that gets pulled toward ground by the sensor
  - NOTE: if the pull-down sensor is missing the ?v signal supply, then you can easily mis-diagnose these as a bad sensor

Magneto Resistive

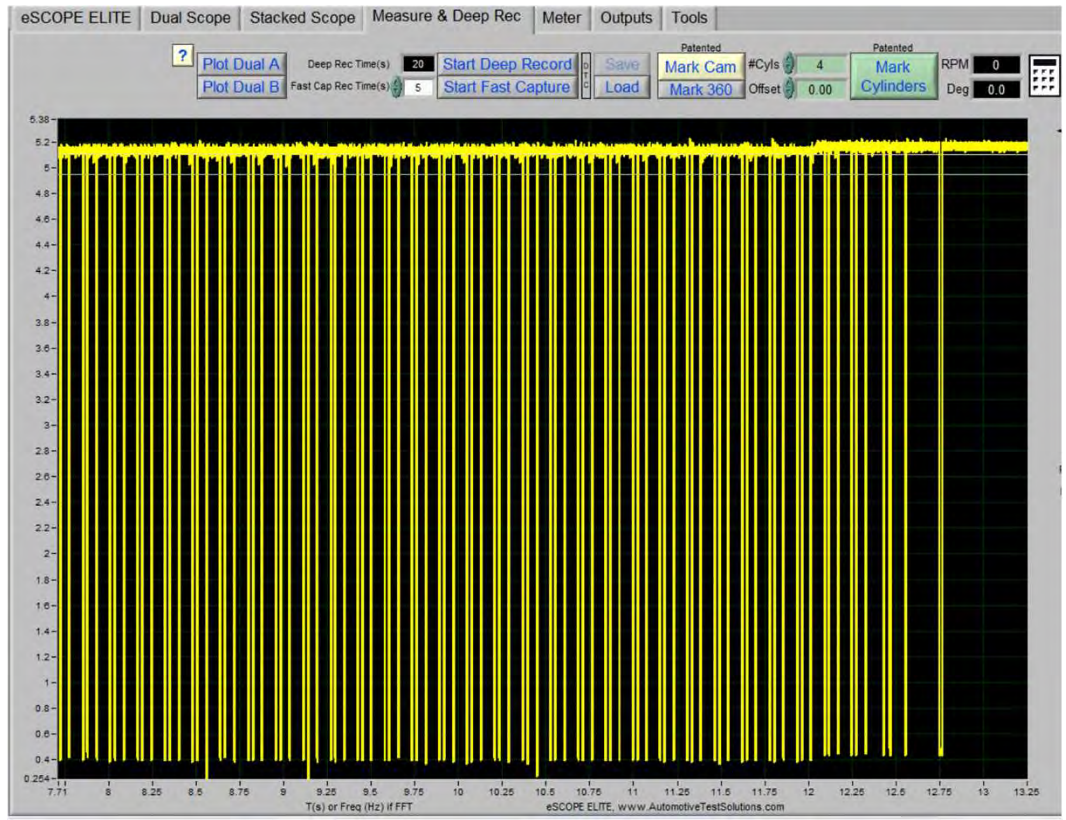
- Toyota 4.0L V6 CMP signal (biased 750 mv off ground)
- Green trace shows 3 different width reluctor windows



TECH UPDATES

Magneto Resistive

- 2007 Honda CMP
- 5v signal
- Goes high when disconnected
- Pull-up or Pull-down sensor?
  - **Pull Down**
  - **PCM supplies vRef of 5v, (current limited)**
  - **Sensor pulls signal low when switching**
  - **Biased off ground – Why?**



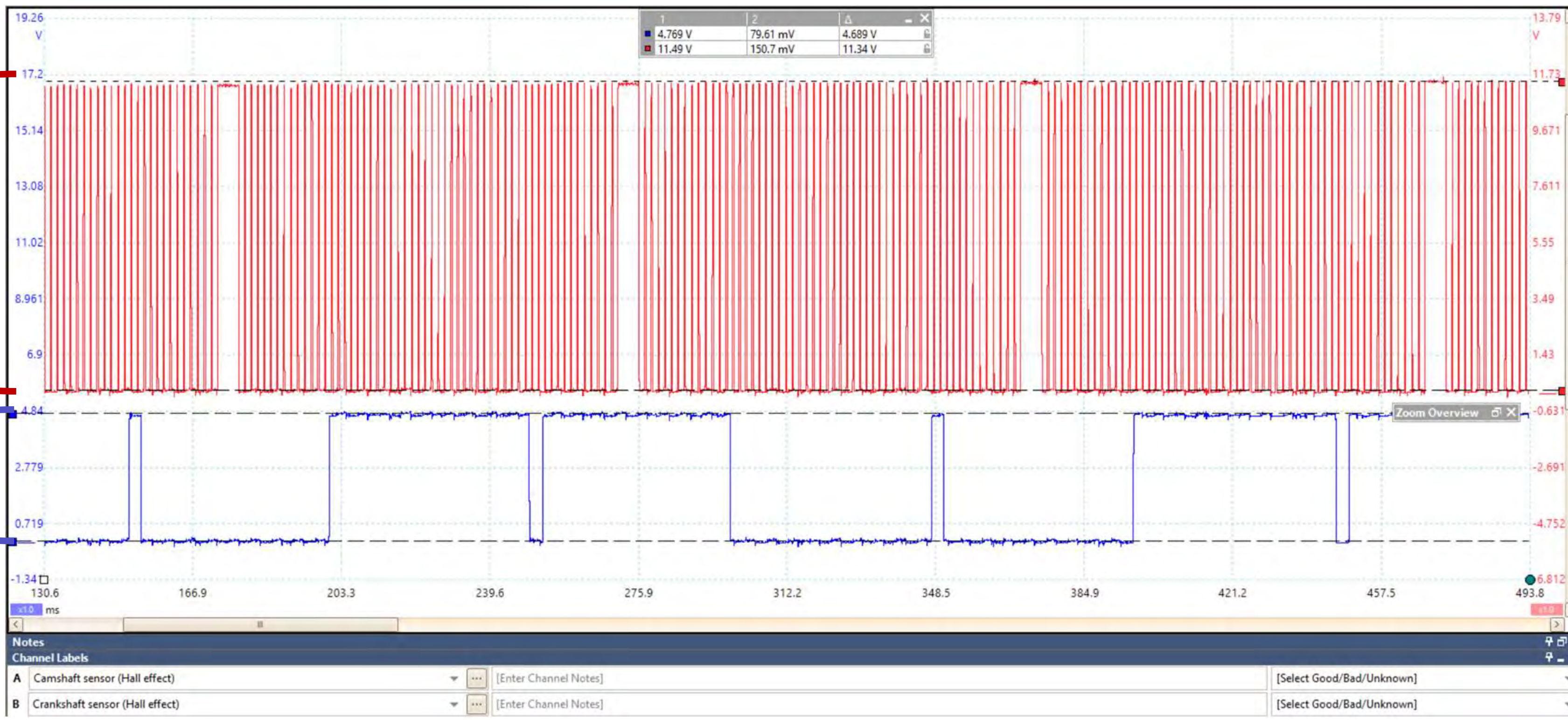
TECH UPDATES

Magneto Resistive

- Not all MR sensors use 5v vRef
- These CKP and CMP sensors have different output voltages (Duramax 6.6 LLY)

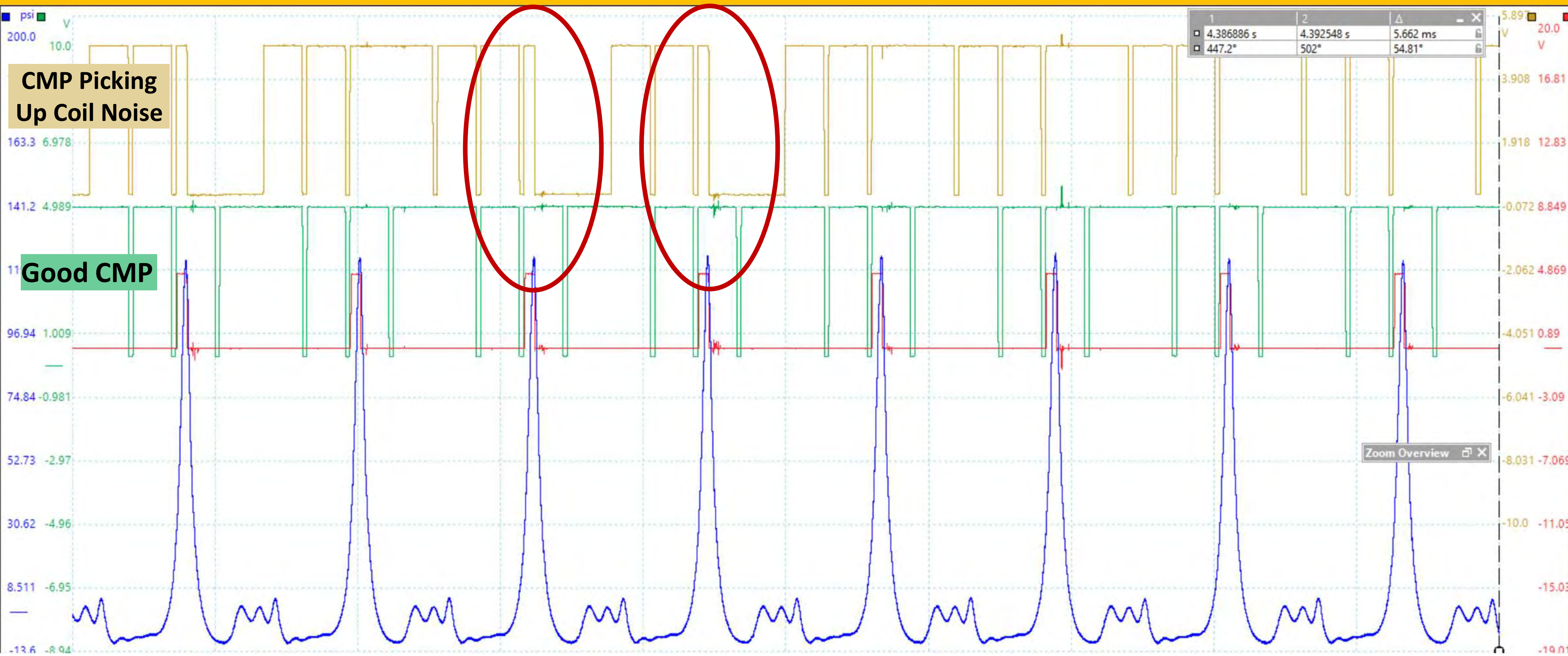
CKP 12 Volts

CMP 5 Volts



TECH UPDATES

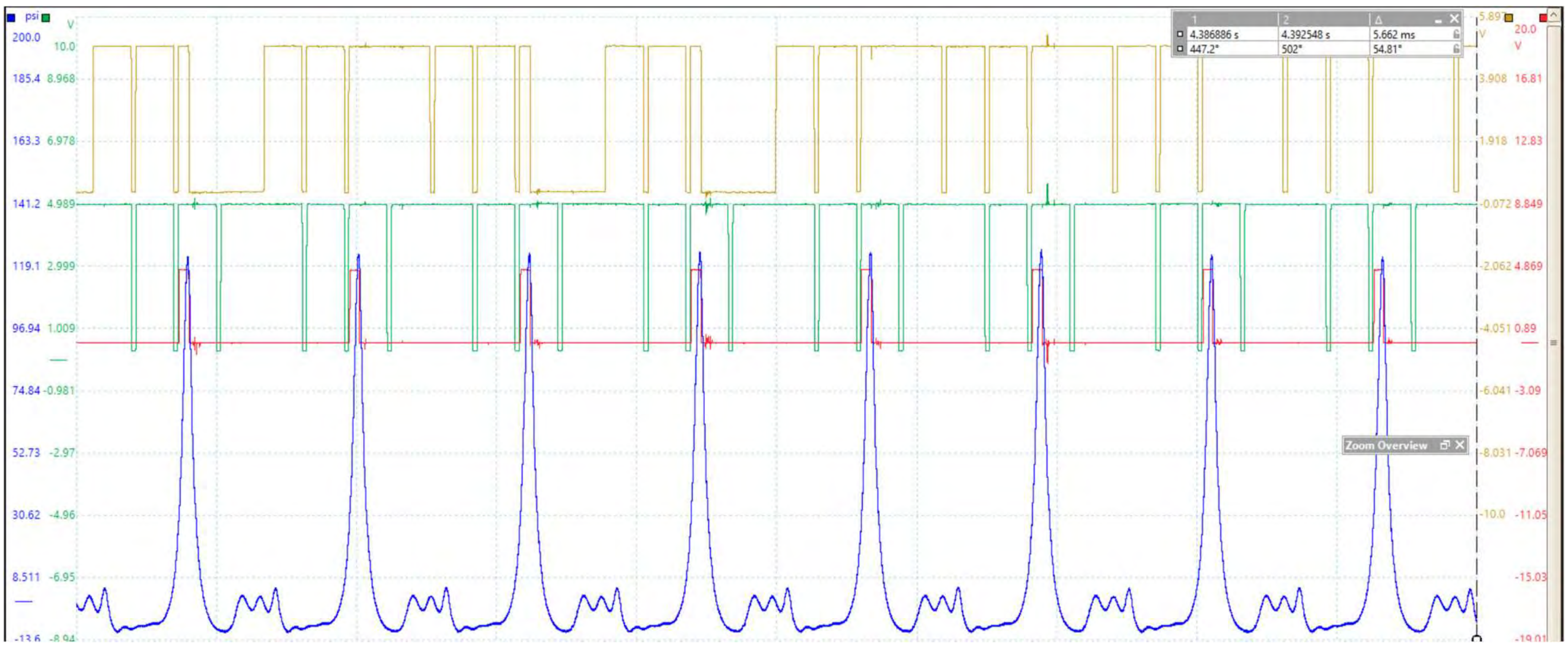
Subaru Cam Sensor Codes



TECH UPDATES

Magneto Resistive

- This Subaru CMP is showing magnetic interference at times after a specific ignition event and is consistently the same one
- Replaced Failing ignition coil to fix

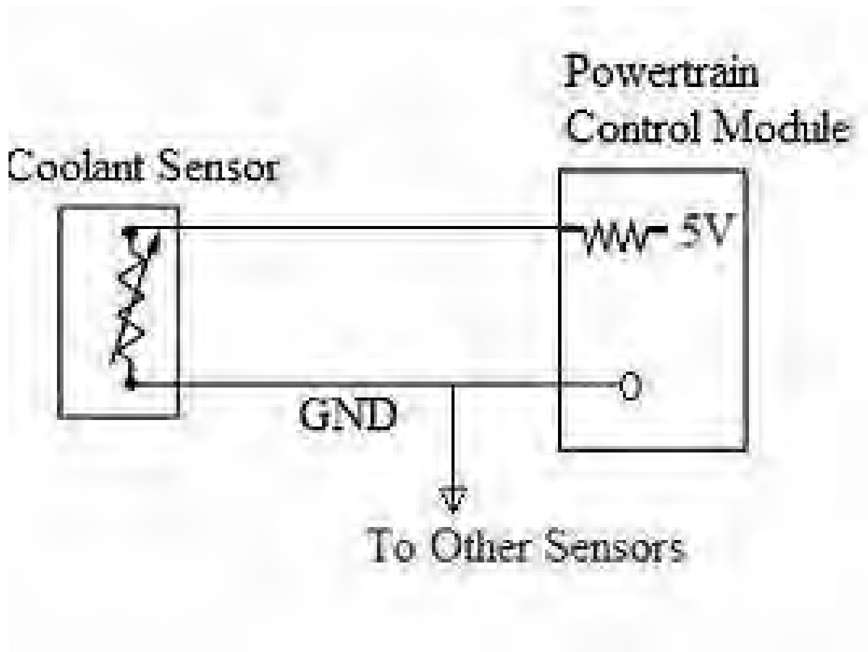


Temperature Sensors

Thermistors and Thermal couples

Thermistors

- Thermistors Use Resistance To Measure Temperature Change
- Reference Voltage Is Influenced By Changing Resistance



TECH UPDATES

PTC/NTC Thermistor

- PTC- Positive Temperature Coefficient
  - PTC- Temperature and Sensor Resistance have a linear relationship:
  - As temp increases, resistance increases

- NTC- Negative Temperature Coefficient
  - NTC- Temperature and Sensor Resistance have an inverse relationship:
  - As temp increases, resistance decreases

TECH UPDATES

NTC Thermistor

- NTC is the more common temperature sensor
- 5v ref is pulled down across sensor as temperature increases
- Circuit is current limited, and sets fault codes when voltage goes below ~ 0.2v or above 4.8v
  - Below ~ 0.2 = Shorted Circuit Code
  - Above ~ 4.8v = Open Circuit Code
- What is a typical current limit?

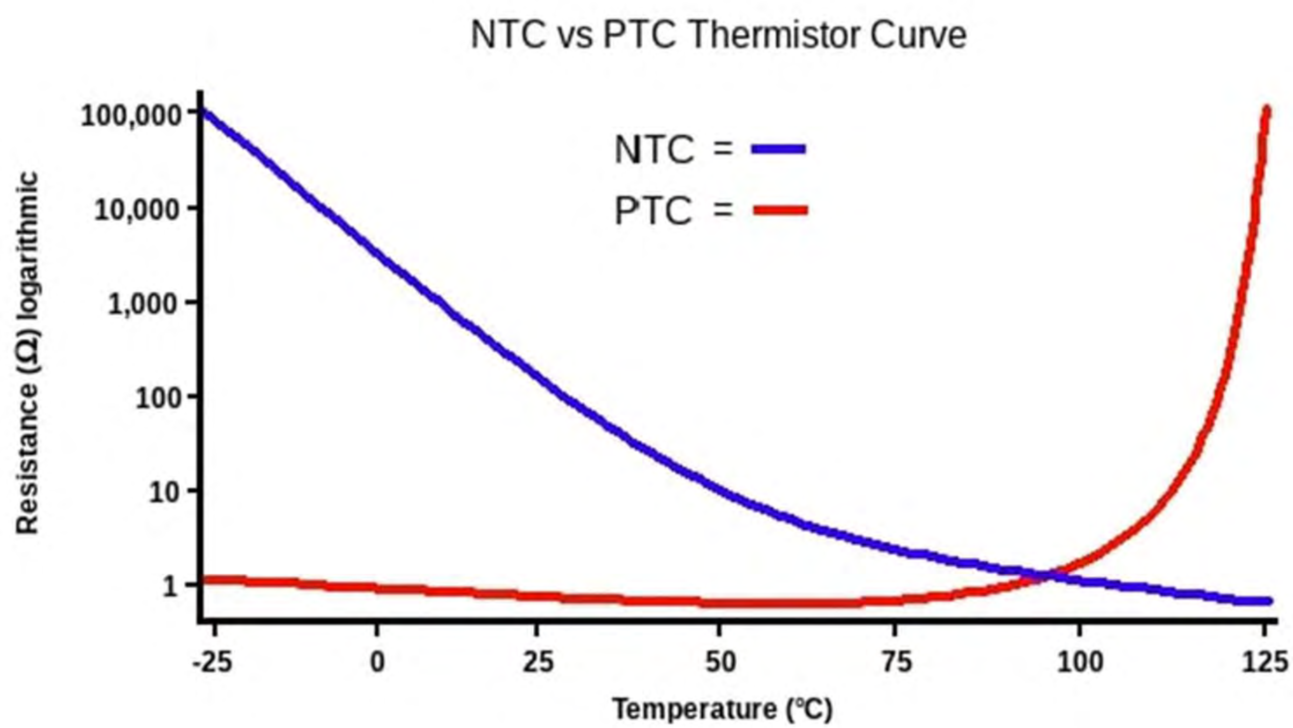
TECH UPDATES

PTC Thermistor

- ❑ PTC is not as common as NTC
- ✓ A well-known application is a hot-wire MAF
  - Increasing air cools the sensing element and decreases resistance.
  - Less resistance = increased current flow.
  - Offset to maintain a constant temperature.

TECH UPDATES

PTC/NTC Thermistor



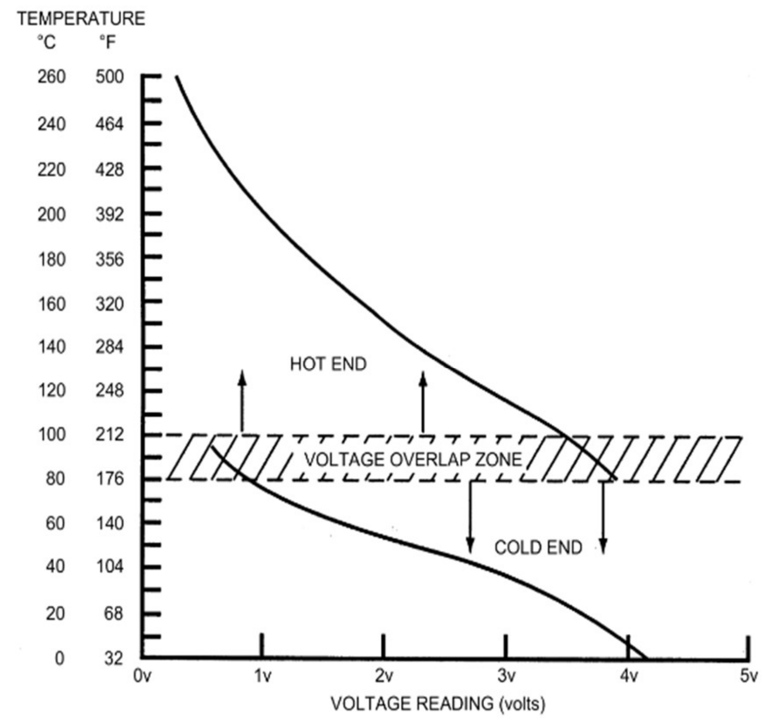
TECH UPDATES

PTC/NTC Thermistor

- It is common now to see dual-range temperature sensors
- These are used in applications so that 1 sensor can perform the role of 2
- At a specified temperature/resistance, sensor switches from “Cold Range” to “Hot Range”

Cylinder Head Temperature (CHT) And CHT2 Sensor Expected Val

Temperature		CHT Sensor Values		
°C	°F	Cold End (volts)	Hot End (volts)	Resistance (K ohms)
-40	-40	4.89	-	965.808
-30	-22	4.81	-	513.019
-20	-4	4.67	-	283.664
-10	14	4.45	-	162.584
0	32	4.14	-	96.255
10	50	3.73	-	59.175
20	68	3.26	-	37.387
30	86	2.74	-	24.215
40	104	2.23	-	16.043
50	122	1.76	-	10.85
60	140	1.36	-	7.487
70	158	1.04	-	5.268
80	176	0.79	3.99	3.775
85	185	0.69	3.86	3.215
90	194	0.60	3.71	2.75
95	203	0.53	3.56	2.361
100	212	0.46	3.41	2.034
110	230	-	3.07	1.523
120	248	-	2.74	1.155
130	266	-	2.41	0.8866
140	284	-	2.10	0.6891
150	302	-	1.81	0.5417
160	320	-	1.55	0.4301
170	338	-	1.33	0.3449
180	356	-	1.13	0.2791
190	374	-	0.96	0.2278
200	392	-	0.82	0.1875
210	410	-	0.70	0.155
220	428	-	0.60	0.130
230	446	-	0.51	0.109
240	464	-	0.44	0.092
250	482		0.35	0.078
260	500		0.33	0.067



TECH UPDATES

Thermocouple

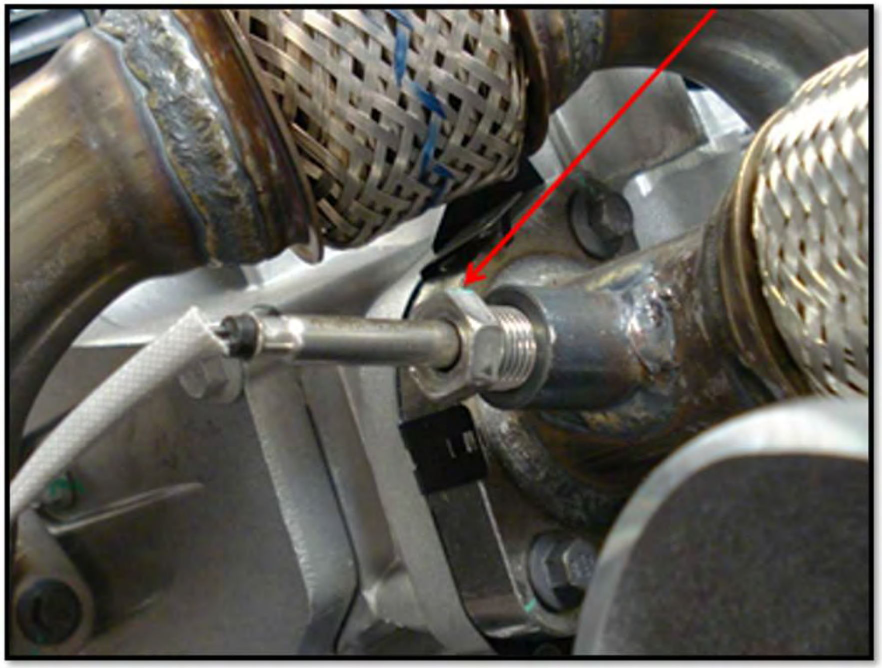
- Thermocouples Use Voltage To Sense Temperature
- Consists Of Two Dissimilar Metal Wires Joined At One End (Nickel-Chromium/Nickel-Alumel)
- When Exposed To Temperature Gradients It Generates Voltage Proportional To Change
- Accurate Above 2000°c (3632°f)
- Fast Response

Resistive Temperature Sensor

- RTDs Use Resistance To Sense Temperature
- Mid Temperature Range Up To 600°c (1112°f)
- RTDs Offer Stable, Linear, And Highly Accurate Temperature Detection

Exhaust Gas Temperature

- In automotive, RTDs are generally associated with high temperature environments, although they are found other places as well



RTD Resistive Temperature Detector

- RTDs are another form of a thermistor
- As they increase in temperature, resistance increases as well (PTC)
- Typical application today is exhaust gas temperature (EGT) sensor
- Able to measure 2,000+ °F

TECH UPDATES

RTD

- 2018 GM 6.6L Duramax example - EGT resistance is around 220 ohms @ 77 F
- 1,000 F would be close to 600 ohms
- 1,500 F would be close to 750 ohms
- With a 5v ref from a module, voltage will be lower with a cold sensor, and rise as the sensor warms up
- Default for open circuit is max temperature

TECH UPDATES

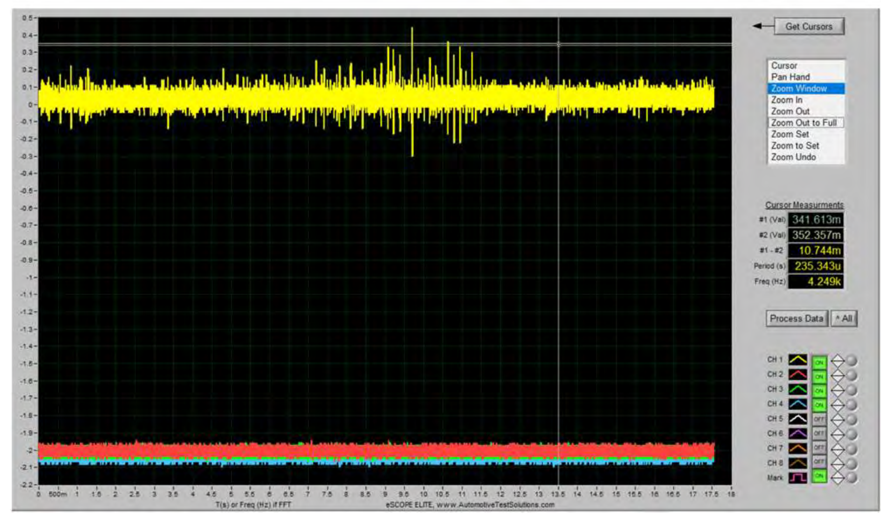
Open Circuit Logic

- If a module detects 1 or more open EGT's, depending on programming, will force engine into reduced power
- Reduction could be great enough to leave the vehicle inoperable

TECH UPDATES

Piezo

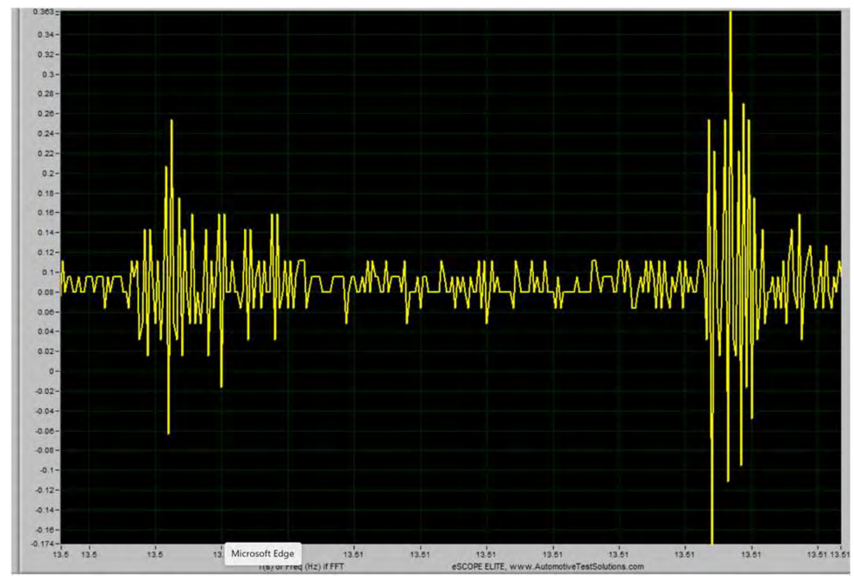
- Piezo elements generate voltage from either pressure or vibration
- Commonly used for knock sensors
- Sensor circuits are shielded to prevent RFI/EMI in the signal



TECH UPDATES

Piezo

- Piezo sensors produce both voltage and Frequency
- Incorrect sensor frequency will result in sensor circuit faults
- Mountings under intake cause access issues
  - Light tapping on cylinder head near sensor



TECH UPDATES

Potentiometer

- 3-wire sensor
  - 5v ref, Ground, Signal
- Voltage signal changes as swiper contact moves across resistive elements
- Measures rotational movement within a specified range
- Wears out over time

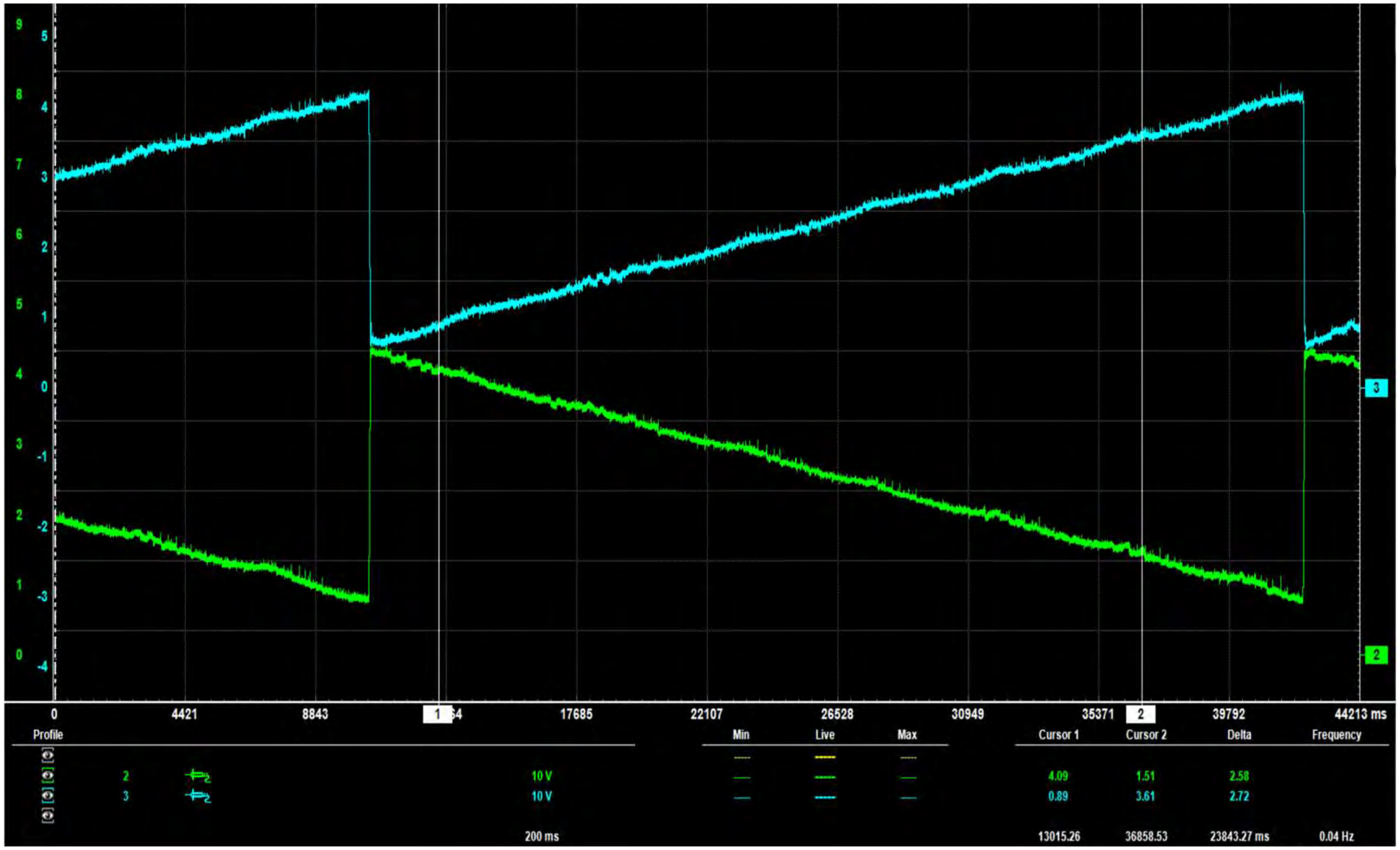
Applications;

- Steering Angle Sensor
- TPS/APP
- Turbocharger
- EGR valve
- Brake pedal
- And more…

TECH UPDATES

Potentiometer

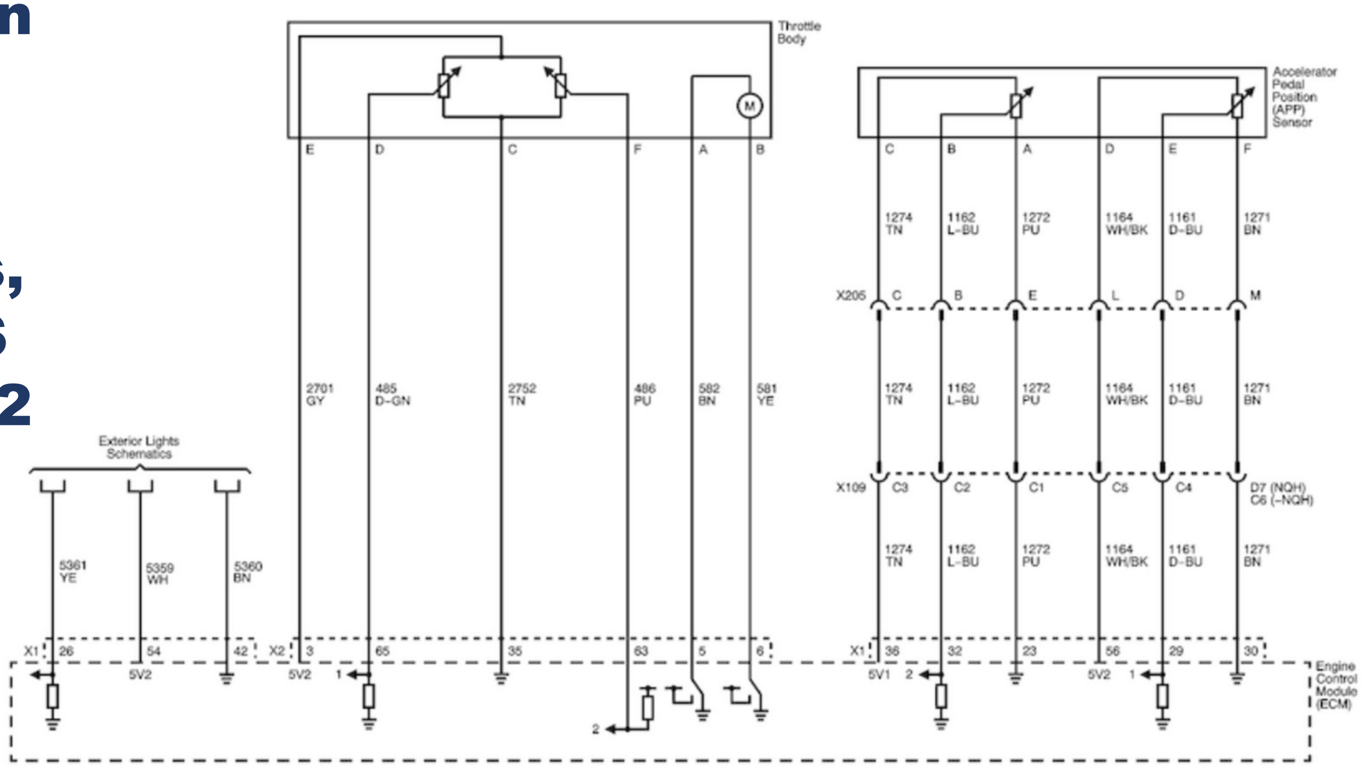
- 2012 GMC throttle sweep test with scan tool
- TPS 1 & 2 voltages should add up to the 5v ref at any sample point



TECH UPDATES

Potentiometer

- Note the 2 potentiometers in this system
- APP has 2 separate 5V sets, whereas the TPS has 1 5V ref but 2 outputs
- What would happen if 1 failed?



Rheostat

- Same principle as Potentiometer but has only 2 wires
- Has a minimum and maximum resistance range
- Carries a small amount of current that is proportional to its position and resistance
- Commonly used in fuel level sensors
- With 2-wires, correct polarity is a must
- Best to use a GMM or scope to perform a sweep test and watch for dropouts

TECH UPDATES

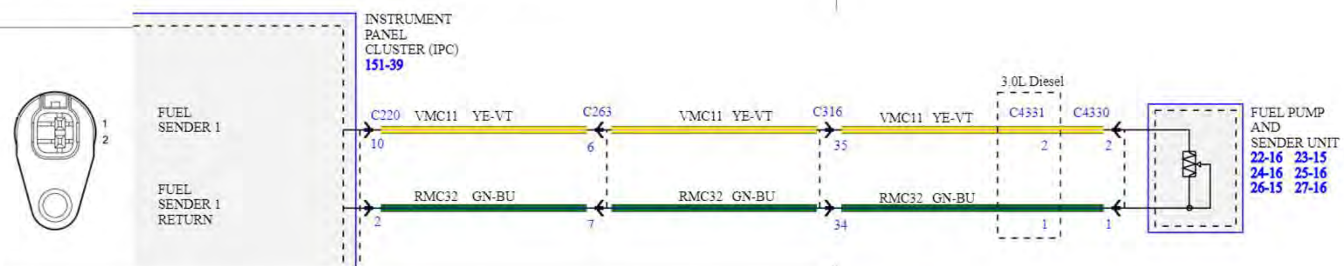
Rheostat

- ❑ **Correct polarity is a must**
- ❑ **Use a GMM or scope to perform a sweep test**

C13 CHECK THE FUEL PUMP AND SENDER UNIT FOR CORRECT OPERATION

- Disconnect the fuel level sender (float and card) input wire from the fuel pump and sender unit.
- Measure the resistance between the fuel level sender (float and card) input wire and the fuel level sender (float and card) ground while slowly moving the float arm between the lower and upper stop position.

Connectors:



Positive Lead	Measurement / Action	Negative Lead
Fuel Level Sensor (Component Side) - Pin 1	Ω	Fuel Level Sensor (Component Side) - Pin 2

Does the resistance slowly decrease from approximately 180 ohms at the lower stop to 10 ohms at the upper stop?

Yes	INSTALL a new fuel pump and sender unit. Refer to the appropriate section in Group 310 for the procedure.
No	INSTALL a new fuel level sender (float and card). Refer to the appropriate section in Group 310 for the procedure.

TECH UPDATES

Zirconia

- While commonly referred to as an “Oxygen Sensor”, the zirconia element is only one of the several sensor parts
- Known as a galvanic battery, the zirconia element produces a voltage as a reaction to differences in oxygen levels on opposite sides
- The O2 signal represents the amount of imbalance between oxygen inside vs outside of the exhaust pipe

TECH UPDATES

Zirconia

- These are not to be confused with a Lambda sensor, aka Air-Fuel Ratio sensor
- O2 reference signal is often drawn thru the wiring insulation of the sensor
- Circuit repairs on the sensor harness should not be done

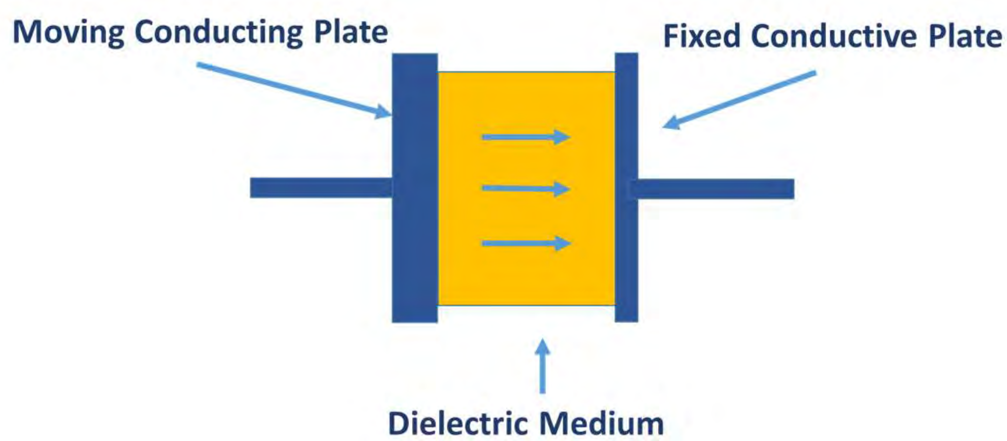
Capacitive & Strain-Gauge

- A Capacitive Sensor, or Transducer converts pressure into voltage
- Uses 2 plates separated by a "dielectric medium." 1 plate moves and the other is fixed
- Applied pressure decreases plate distance, causing output voltage changes

TECH UPDATES

Capacitive & Strain-Gauge

- Capacitive sensors are very sensitive and extremely accurate
- If anything contaminates the dielectric medium, the sensor will no longer report correctly



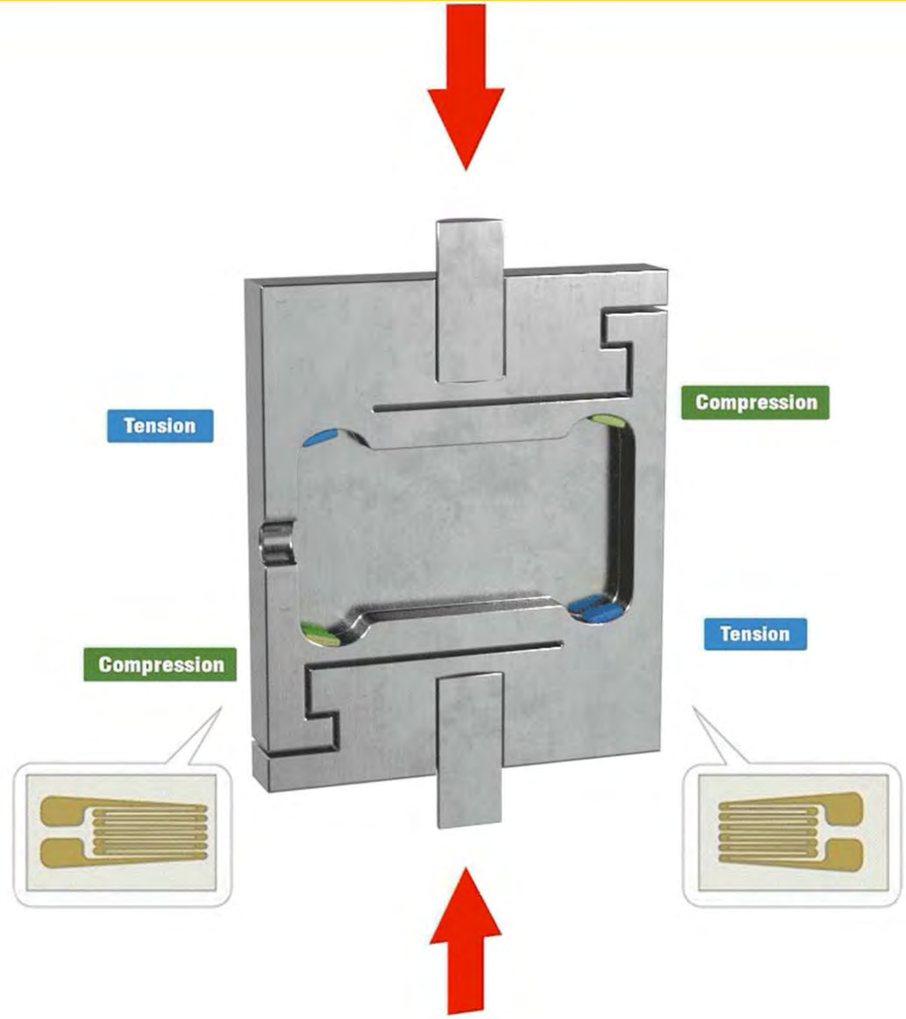
Capacitive & Strain-Gauge

- Strain-gauge sensor/transducers also change voltage relative to pressure applied
- Made up of a film placed over a substrate
- The circuit is precisely woven from end to end
- Force deflects the substrate causing distance changes between the segments that alter resistance
- One end is fixed, while the other end can move

TECH UPDATES

Capacitive & Strain-Gauge

- ❑ A Wheatstone Bridge is used to measure actual resistance changes
- ✓ These provide accurate measurements for load, torque, pressure, acceleration, etc.



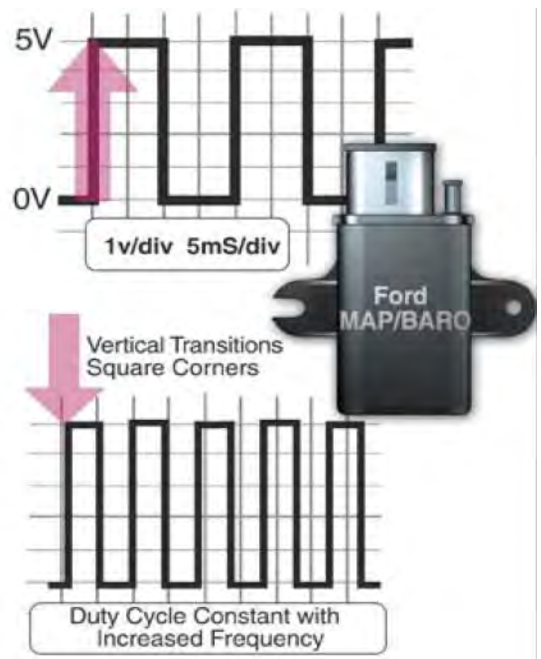
TECH UPDATES

Frequency Sensors

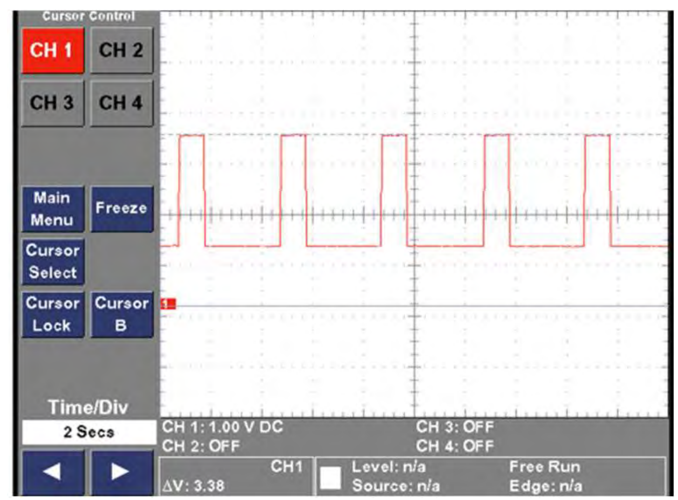
- Frequency-type sensor have been in use in automotive for many years
- They have no rotating or moving parts
- Commonly used in MAP and MAF sensors
- Other sensors use frequency signals coming from modules, rather the sensors themselves
- A reductant level sensor is a good example

TECH UPDATES

Frequency



Ford 6.7 Reductant Level Sensor



TECH UPDATES

Types Of Sensor Faults and Codes

- There is no DTC saying “This part is bad”
- An “O2 sensor signal stuck rich” or “O2 sensor no signal” does not mean the sensor has failed
- Many reasons to set a DTC
  - Parts replacement can get expensive “REALLY” quick!
  - ALWAYS refer to the OE information

TECH UPDATES

Sensor Fault Descriptions

- ❑ Circuit Fault
- ❑ Circuit High
- ❑ Circuit Low
- ❑ Range/Performance
- ❑ Signal Stuck …
- ❑ No Signal
- ❑ Short to Positive
- ❑ Short to Ground

Which one means the sensor is bad???

TECH UPDATES

Circuit Fault

- The MOST common and generic code when dealing with sensors
- Module has not seen **what** it expected **when** it expected it
- Not always a sensor fault or a wiring/circuit issue
  - Common description with engine timing faults

CMP Ignition System Check Operation:	
DTCs	P0340 - Intake Cam Position Circuit, Bank 1 P0344 – Intake Cam Position Circuit Intermittent, Bank 1 P0345 - Intake Cam Position Circuit, Bank 2 P0349 – Intake Cam Position Circuit Intermittent Bank 2 P0365 - Exhaust Cam Position Circuit, Bank 1 P0369 – Intake Cam Position Circuit Intermittent, Bank 1 P0390 - Exhaust Cam Position Circuit, Bank 2 P0394 – Exhaust Cam Position Circuit Intermittent Bank 2
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	
Monitoring Duration	< 5 seconds

Typical CMP ignition check entry conditions:		
Entry Condition	Minimum	Maximum
Engine RPM for CMP	200 rpm	

Typical CMP ignition check malfunction thresholds:
Ratio of PIP events to CMP events: 4:1, 6:1, 8:1 or 10:1 based on engine cyl. Intermittent CMP signal – CMP signal in unexpected location

Sensor Locations and Access

- Sensors are not always easy to access
- What if you can't access the sensor?
- Start with easiest circuit entry point for testing
- Testing @Sensor vs @Module
- What to look out for

TECH UPDATES

Circuit High

- Can be set from
  - Poor or open connection
  - Corrosion
  - Short to 5v Ref in component or harness
  - Short to 5v Ref in module
  - Failed component
  - Short to another circuit with a normal higher voltage
  - Failed sensor ground
  - False code set from failed module

TECH UPDATES

Circuit High

- For a 5v sensor, a "circuit high" sets when the sensor signal voltage has been above a maximum specified voltage for at least a certain length of time
- Refer to service info for code setting criteria to ensure proper testing
- Same description can also set from a measured resistance value

CKCP Sensor Electrical Check Operation	
DTCs	P051C – Crankcase Pressure Sensor Circuit Low
	P051D – Crankcase Pressure Sensor Circuit High

EGR Electrical Check Operation:	
DTCs	P1400 or P0405 - DPFE Circuit Low
	P1401 or P0406 - DPFE Circuit High

Rear HO2S "Over Voltage Test" Operation:	
DTCs	P0138 - HO2S12 Circuit High Voltage
	P0158 - HO2S22 Circuit High Voltage

Fuel Level Input Check Operation:	
DTCs	P0461 – Fuel Level Sensor A Circuit Noisy P0462 – Fuel Level Sensor A Circuit Low P0463 – Fuel Level Sensor A Circuit High P2067 – Fuel Level Sensor B Circuit Low P2068 – Fuel Level Sensor B Circuit High
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	30 seconds for electrical malfunctions,

Typical Fuel Level Input check malfunction thresholds:
P0460 or P0462 (Fuel Level Input Circuit Low): < 5 ohms (< 1 A/D count)
P0460 or P0463 (Fuel Level Input Circuit High): > 200 ohms (>253 A/D counts)
P0461 (Fuel Level Input Noisy): > 40% change between samples, > 100 occurrences, sampled every 0.100 seconds

TECH UPDATES

Circuit Low

- Setting criteria similar to a "circuit high" fault in some ways
- Voltage lower than expected for certain time
- Can also be set by low resistance detected

BARO Sensor Transfer Function		
Vout=Vref * (0.007895 * Pressure (in kPa)		
Volts	Pressure, kPa	Pressure, Inches Hg

Intake Air Temperature 1 Sensor Circuit Range Check	
DTCs	P0112 Intake Air Temperature Sensor 1 Circuit Low (Bank 1)
	P0113 Intake Air Temperature Sensor 1 Circuit High (Bank 1)

EGR Electrical Check Operation:	
DTCs	P1400 or P0405 - DPFE Circuit Low P1401 or P0406 - DPFE Circuit High P1409 or P0403 - EVR circuit open or shorted
Monitor execution	Continuous, during EGR monitor
Monitor Sequence	None
Sensors OK	
Monitoring Duration	4 seconds to register a malfunction

Typical EGR electrical check entry conditions:
EGR system enabled

Typical EGR electrical check malfunction thresholds:
DPFE sensor outside voltage: > 4.96 volts, < 0.0489 volts
EVR solenoid smart driver status indicates open/short

DPFE Sensor Transfer Function		
ESM DPFE volts = Vref [(0.683 * Delta Pressure) + 10] / 100		
Volts	A/D Counts in PCM	Delta Pressure, Inches H_2O
0.0489	10	-13.2
0.26	53	-7.0

TECH UPDATES

Circuit Low

- **Can be set from:**
  - **Circuit short to ground**
  - **Short to ground in component or module**
  - **Loss of or low 5v Ref**
  - **Failed component**
  - **Open connection**
  - **Harness short to another circuit**
  - **False code set from failed module**

TECH UPDATES

Circuit Range/Performance

NAPA AUTOTECH

- This fault description uses more logic-based criteria
- Multiple parameters are often compared to each other, with specific condition requirements, to determine if there is a fault
- If 1 of the parameters is different enough from the others, then a range/performance fault sets

BARO, TCB-A, MAP Sensor 3-Way Correlation Check at Key-Up

At key-up BARO, TCB-A, and MAP are compared. If any two agree and one does not, that sensor is declared faulted.

- At low engine air flows no turbocharger boost is commanded and BARO should be very close to TCB-A.

IAT1, CACT, IAT2 Out of Range Hot Check

The IAT1, CACT, IAT2 are all checked for maximum expected temperature readings during a steady state driving condition. When parked at hot ambient temperatures or after heavy load operation, these temperatures can climb to unusually high temperatures thus the "too hot" check is not done at those conditions.

Engine Air Temperature Sensor Out of Range Hot Check	
DTCs	P0111 Intake Air Temperature Sensor 1 Circuit Range/Performance (Bank 1) P007B Charge Air Cooler Temperature Sensor Circuit Range/Performance (Bank 1) P0096 Intake Air Temperature Sensor 2 Circuit Range/Performance (Bank 1)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	ECT/CHT, IAT, VSS
Monitoring Duration	250 seconds to register a malfunction

Engine Air Temperature Sensor Out of Range Hot Check Entry Conditions		
Entry condition	Minimum	Maximum
Vehicle speed	40 mph	
Time above minimum vehicle speed (if driving req'd)	5 min	
For IAT1, Load below a maximum load threshold	1.0	

Typical Engine Air Temperature Sensor Out of Range Hot Check Malfunction Thresholds	
P0111	IAT1 > 150°F
P007B	CACT > 220°F
P0096	IAT2 > 240°F

TECH UPDATES

Circuit Range/Performance

NAPA AUTOTECH

- **Can be set from:**
  - **Module software that needs to be updated**
  - **Single problem affecting multiple circuits**
  - **Sensor biased**
  - **Corrosion**
  - **Restriction in a tube/hose going to sensor**
  - **Environmental effects such as radiant heat off of a surface near a parked vehicle**

TECH UPDATES

Signal Stuck

- In the event a sensor signal circuit's voltage stays in a small range or doesn't change at all, a "signal stuck" code will set

2011 MY and beyond vehicles with Conti-Moto CBP-A2 PCM will also continuously monitor the rear HO2S signal for out of range low voltage, below -0.2 volts and store DTC P2A01, P2A04. An out of range low voltage condition is caused by swapped sensor wires (sensor signal and signal return) and sensor degradation.

Furthermore, the rear HO2S signal will also be monitored continuously for circuit open or shorted to ground beginning 2011 MY as the PCM hardware becomes capable of measuring HO2S impedance. An intrusive circuit test is invoked whenever the HO2S voltage falls into a voltage fault band. A pull-up resistor is enabled to alter the HO2S circuit characteristics. A very high HO2S internal resistance > 500 k ohms will indicate an open HO2S circuit while a low HO2S i… circuit open and shortec… threshold.

Beginning 2015MY, Cont… included on the chip. The…

Rear HO2S Function…
DTCs Sensor 2
Monitor execution
Monitor Sequence
Sensors OK
Monitoring Duration

Typical Rear HO2S functional check entry conditions:		
Entry condition	Minimum	Maximum
Stream 1 HO2S not in CSD recovery mode		
Flex Fuel Composition not changing		
Not in Phase 0 of Evaporative System Monitor		
No Purge System reset		
Purge intrusive test not running		
Not performing CSER spark retard		
Engine Coolant Temp	150 °F	240 °F
Intake Air Temp		140 °F
Time since entering closed loop fuel	10 seconds	
Inferred Catalyst Midbed Temperature		1600 °F
Heater-on Inferred Sensor(s) 2/3 HO2S Temperature Range	400 °F	1400 °F
Sensor(s) 2/3 HO2S heater-on time	90 seconds	
Short Term Fuel Trim Range	-9%	11%
Fuel Level (forced excursion only)	15%	
Throttle position	Part throttle	
Engine RPM (forced excursion only)	1000 rpm	2000 rpm
UEGO ASIC not in recalibration mode		
No air passing through during valve overlap (scavenging).		
Battery Voltage	11.0 Volts	18.0 Volts

Typical Rear HO2S functional check malfunction thresholds:
Does not exceed rich and lean HO2S voltage threshold envelope:
Rich < 0.42 volts
Lean > 0.48 volts

TECH UPDATES

Signal Stuck

- Not limited to O2 sensors
- Any value that should have changed after a certain amount of time of vehicle operation and the monitor criteria have been met can set this fault

Transmission Fluid Temperature Sensor Functional Check Operation:	
DTCs	P0711 – in range failure
Monitor execution	
Monitor Sequence	
Sensors OK	
Monitoring Duration	

Typical TFT Stuck Low/High cl
Auto Transmission Entry Conditi
Engine Coolant Temp (hot or col
Time in run mode
Time in gear, vehicle moving, po:
Vehicle Speed
Time with engine off (cold start) (
Engine Coolant Temp AND Tran

Typical TFT malfunction thresl
Opens/shorts: TFT voltage <0.05
TFT Stuck low/high, i.e. TFT stuc
Stores a fault decreasing if te MIL tests are approximately code will be sto the normal oper

In the range above 85%, a 60% difference between fuel consumed and fuel used is typical. The actual value is based on the overfill capacity of the fuel tank and the fuel economy of the vehicle. Note that some vehicles can be overfilled by over 6 gallons.

Fuel Level Input Stuck Check Operation:	
DTCs	P0460 – Fuel Level Input Circuit Stuck
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	Between 15 and 85%, monitoring can take from100 to 120 miles to complete

Typical Fuel Level Input Stuck check malfunction thresholds:
P0460 (Fuel Level Input Stuck):
Fuel level stuck at greater than 90%: > 60% difference in calculated fuel tank capacity consumed versus change in fuel level input reading
Fuel level stuck at less than 10%: > 30% difference in calculated fuel tank capacity consumed versus change in fuel level input reading
Fuel level stuck between 10% and 90%: > 25% difference in calculated fuel tank capacity consumed versus change in fuel level input reading

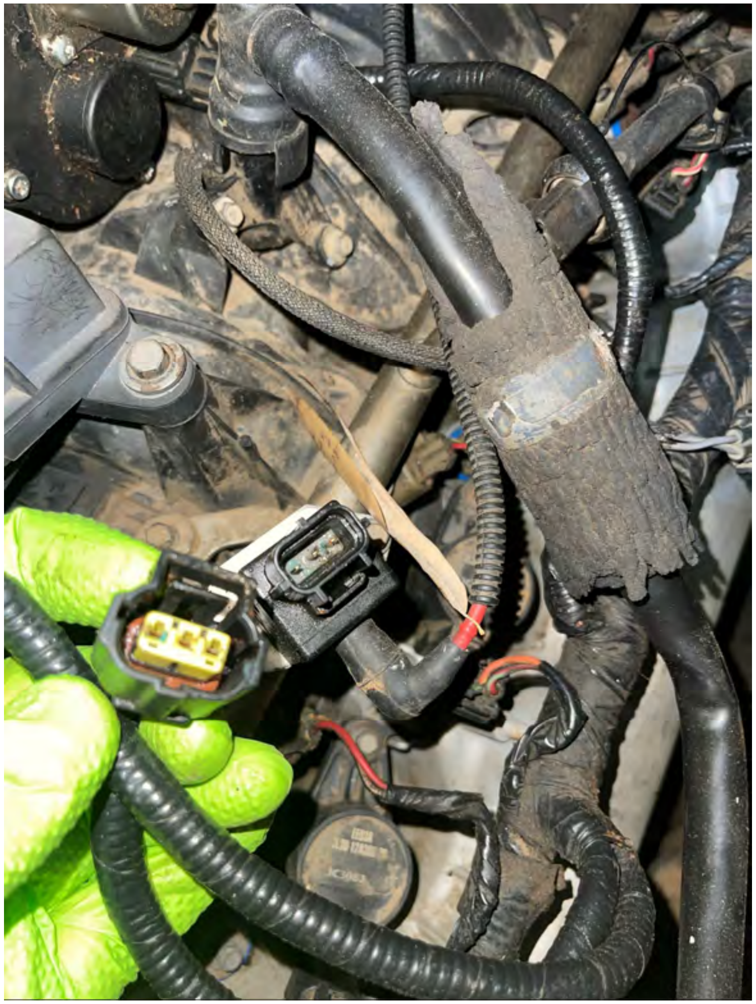
The **Evap Monitor Microprocessor** is checked for proper microprocessor operation or loss of CAN communication with the main microprocessor (P260F). Applies only if EONV is in separate microprocessor.

Evap Monitor Microprocessor Performance:	
DTCs	P260F - Evap System Monitoring Processor Performance
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	5 seconds

TECH UPDATES

Signal Stuck

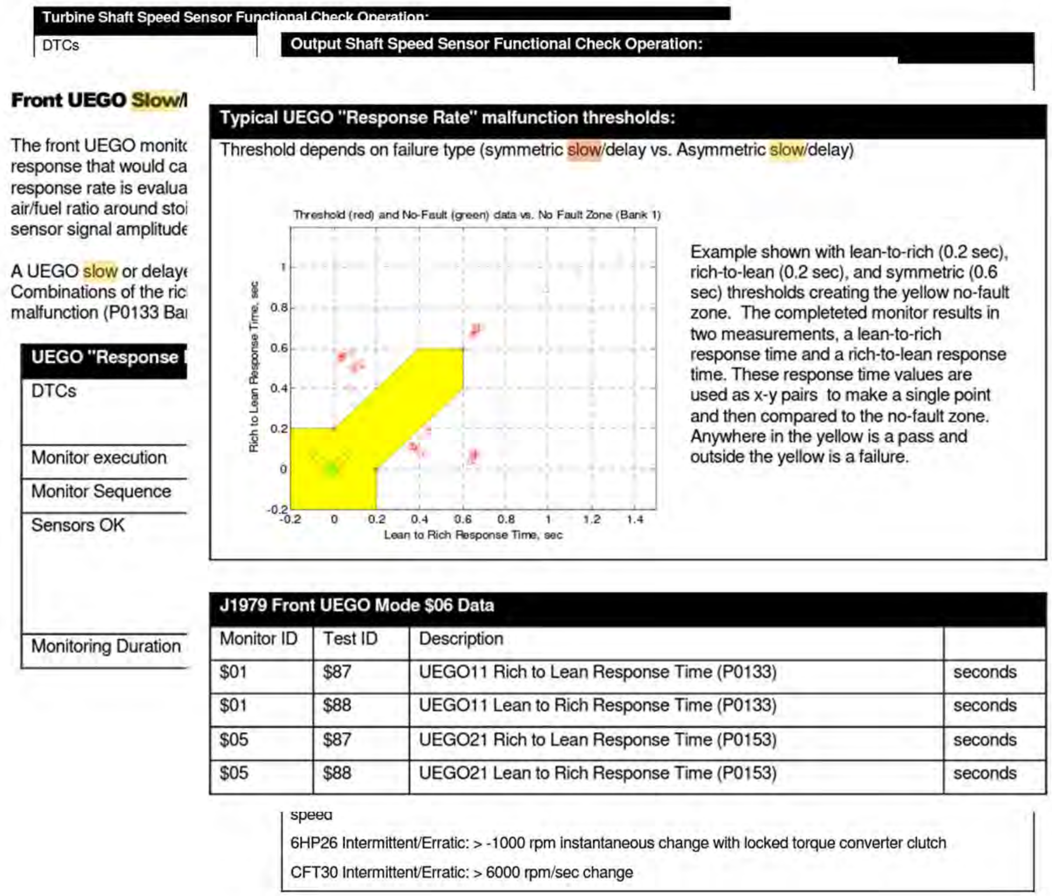
- Can be set by:
  - Biased sensor
  - Temperature sensor surface contaminated
  - Fuel level sensor mechanically stuck
  - Shorted segment of fuel level sensor
  - Low fluid level
  - Faulty O2 heater
  - Contaminated O2 sensor



TECH UPDATES

No Signal/Slow/Delayed

- Depending on the OE's setting criteria, the vehicle can set either of the 3
- Variables can include:
  - When the vehicle tests
  - Length of test
  - Health of sensor at time of testing


Turbine Shaft Speed Sensor Functional Check Operation:

DTCs

Output Shaft Speed Sensor Functional Check Operation:

Front UEGO Slow/

The front UEGO monit
response that would ca
response rate is evalua
air/fuel ratio around stoi
sensor signal amplitude

A UEGO slow or delay
Combinations of the ric
malfunction (P0133 Ba

UEGO "Response

DTCs

Monitor execution

Monitor Sequence

Sensors OK

Monitoring Duration

Typical UEGO "Response Rate" malfunction thresholds:

Threshold depends on failure type (symmetric slow/delay vs. Asymmetric slow/delay)

Example shown with lean-to-rich (0.2 sec), rich-to-lean (0.2 sec), and symmetric (0.6 sec) thresholds creating the yellow no-fault zone. The completed monitor results in two measurements, a lean-to-rich response time and a rich-to-lean response time. These response time values are used as x-y pairs to make a single point and then compared to the no-fault zone. Anywhere in the yellow is a pass and outside the yellow is a failure.

J1979 Front UEGO Mode $06 Data

Monitor ID	Test ID	Description	
$01	$87	UEGO11 Rich to Lean Response Time (P0133)	seconds
$01	$88	UEGO11 Lean to Rich Response Time (P0133)	seconds
$05	$87	UEGO21 Rich to Lean Response Time (P0153)	seconds
$05	$88	UEGO21 Lean to Rich Response Time (P0153)	seconds

speed

6HP26 Intermittent/Erratic: > -1000 rpm instantaneous change with locked torque converter clutch

CFT30 Intermittent/Erratic: > 6000 rpm/sec change

TECH UPDATES

No Signal/Slow/Delayed

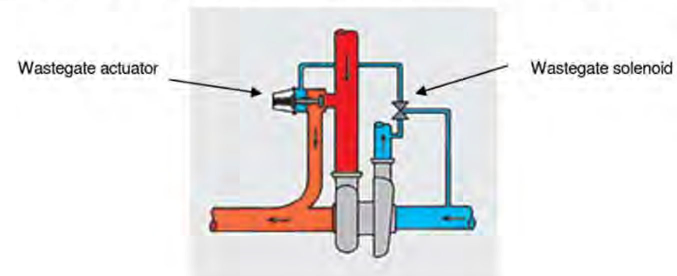
- Can be set by:
  - Sensor contamination
  - Magnetized reluctor that isn't supposed to be
  - Failed magnet or component
  - O2 heater fault
  - Air/fuel ratio control problem

Short to Power/Ground

- For a short to power (battery +) code to set, a module is detecting voltage either equivalent to B+ or above a normal range when that circuit should be @ low voltage or within a specified range
- For a short to ground fault to set, a module is not detecting voltage present that it's expecting

Typical 5 Volt Sensor Reference Voltage A check malfunction thresholds:
P0642
Short tc
P0643
Short tc

As the compressor outlet pressure increases, a pneumatically powered actuator opens each turbocharger wastegate to limit compressor outlet pressure. The wastegate pneumatic solenoid valve modulates that feedback pressure to increase the boost pressure limit. A duty cycle of 100% vents feedback thus eliminating any wastegate controlled boost limit. A duty cycle of 0% results in the base boost limit of approximately 5 psi gauge.



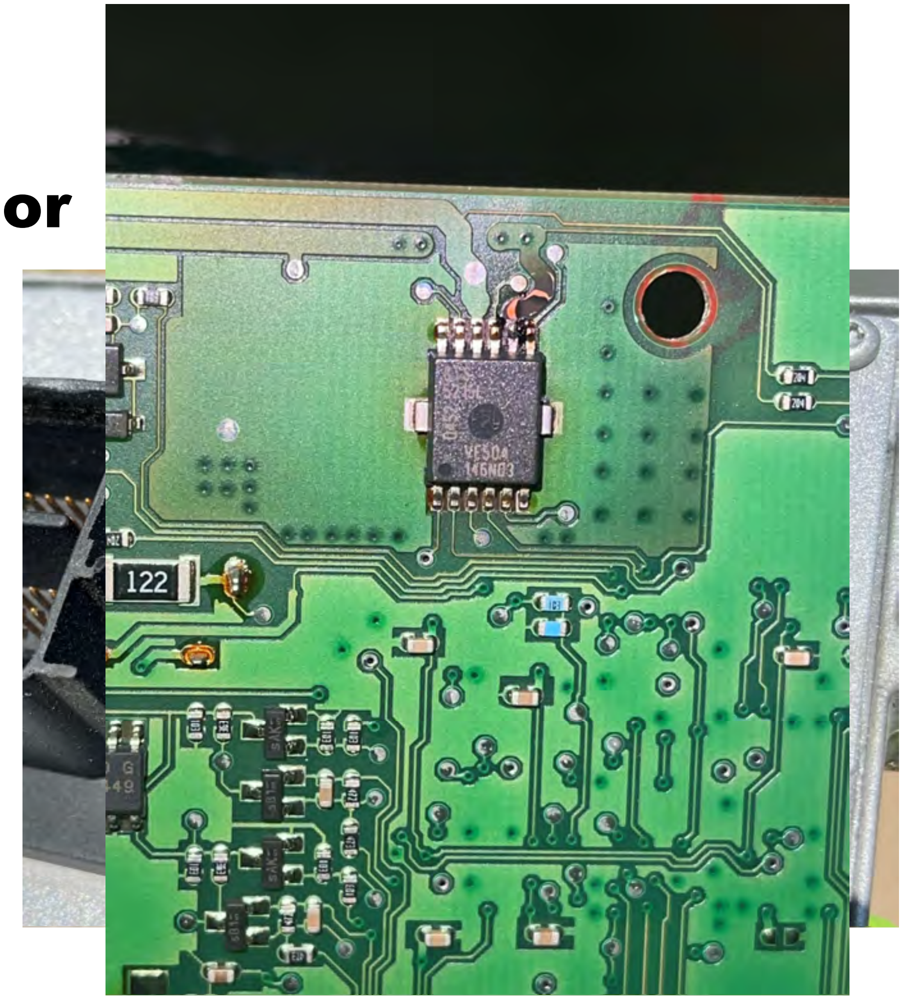
Wastegate Pneumatic Solenoid Valve Circuit Check Operation	
DTCs	P0245 Turbocharger/Supercharger Wastegate Solenoid A Low P0246 Turbocharger/Supercharger Wastegate Solenoid A High
Monitor execution	Continuous
Monitor Sequence	None
Monitoring Duration	5 seconds

Wastegate Pneumatic Solenoid Valve Circuit malfunction thresholds:
PCM smart driver hardware detects faults for circuit short to battery, short to ground, and open circuit. Fault status reported to PCM to set appropriate DTC.

TECH UPDATES

Short to Power/Ground

- Can be set by:
  - Open circuit in the harness or component
  - Spread terminals at module
  - Bent pin at module
  - Corrosion at connection or eyelet
  - Harness chafing
  - Failed driver in module



Short to Power/Ground

TECH UPDATES

Easier Access

- A lot of sensors are easily accessed for testing and service
- This one happens to be on the top and front of the engine facing the radiator area
- Now just need a wiring diagram and tools for testing

TECH UPDATES

Not So Easy

- You may recognize this component
- Ford 5.4 3V IMRC actuator mounted to the back of the intake manifold
- Access to the connector is pretty much non-existent when the engine's fully assembled
- So what's the easiest place to test?

Work Smart

- Regardless of whether the engine is hot or cold when testing, access the easiest point of entry into the sensor circuit initially
- This can save time and headaches
- If the measurements are not what you expect at that location, then it’s time to get as close to the sensor as possible

Click, Snap

- Plastic connectors and harness split loom get very brittle over age and heat cycles
- Slightest touch to a connector locking tab release and you get the dreaded “click” of a tab that just broke
- Begin moving the wire harness around and soon you find a pile of crumbled plastic loom all over the place and section of wiring that’s now exposed to potential damage/abrasion

Look Out

- You may find that you were missing signal at the module but the signal was fine at the component
- Time to start working back toward the module and pay extra attention to the harness for rub points, damage, missing loom, etc.
- Some plastic loom is rigid enough to actually rub thru wiring in high vibration areas

TECH UPDATES

2005 Jeep Wrangler 4.0L

- **Concern:**
  - Check Engine light on
  - Poor Fuel mileage
  - Heavy fuel odor from exhaust at all times
  - No misfires
- **Will need:**
  - DTC scan report
  - Scan data capture
  - Scope capture if sensor fault

2005 Jeep Wrangler 4.0L

- DTC report shows:
  - All 4 O2 sensor heater circuit low faults
- Is that possible?
  - Vehicle already has 4 new O2 sensors installed
  - Clear codes and they return immediately after a key cycle
- What information can we get from scan data?
- What do they all have in common?
- Will need a wiring diagram

Pre Scan
Vehicle System Report

2005 Jeep Wrangler 4.0L L6 MPI
VIN 1J4FA44S95P358698
Odometer
License

CODE SCAN RESULTS
Systems Analyzed: 4

Systems w/ Codes

Engine - Codes
P0057 2/2 O2 Sensor Heater Circuit Low
P0051 2/1 O2 Sensor Heater Circuit Low
P0037 1/2 O2 Sensor Heater Circuit Low
P0031 1/1 O2 Sensor Heater Circuit Low

Engine - 1 Trip
P0057 2/2 O2 Sensor Heater Circuit Low
P0051 2/1 O2 Sensor Heater Circuit Low
P0037 1/2 O2 Sensor Heater Circuit Low
P0031 1/1 O2 Sensor Heater Circuit Low

Transmission - Codes Only
P1684 Battery was Disconnected

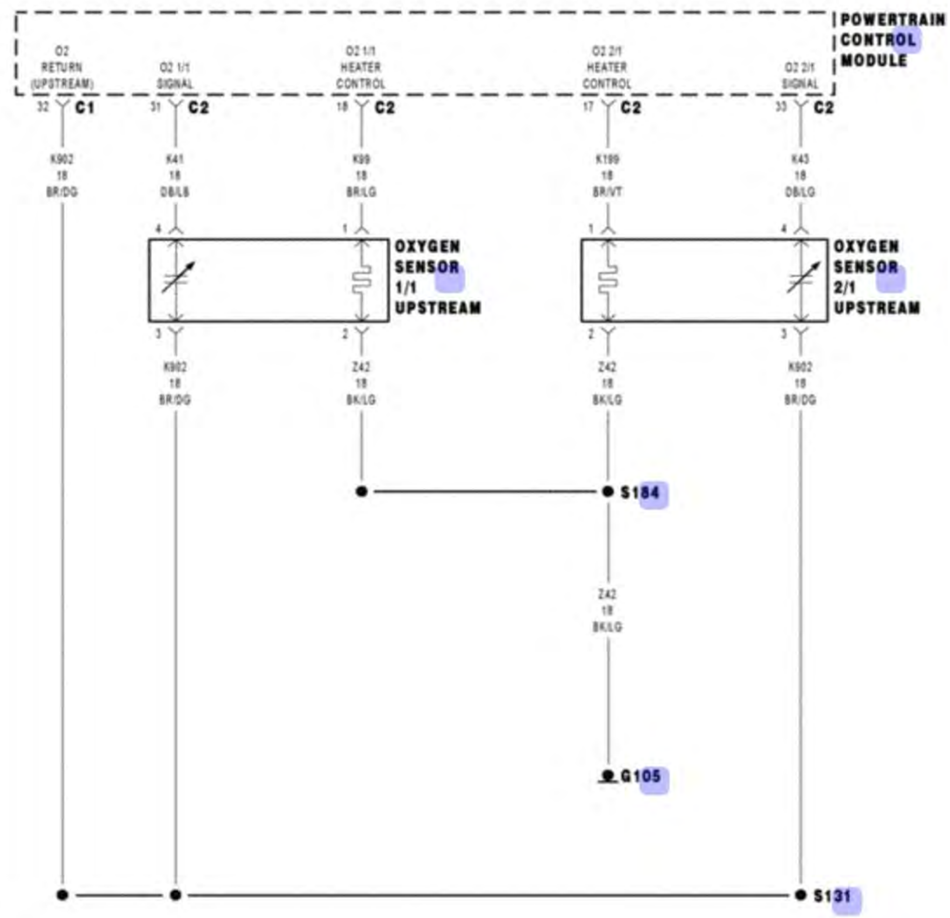
Instrument Cluster - CODES
Panel Dimmer Open

OBDII Codes ($03)
P0031 HO2S Heater Control Circuit Low Bank 1 Sensor 1
P0037 HO2S Heater Control Circuit Low Bank 1 Sensor 2
P0051 HO2S Heater Control Circuit Low Bank 2 Sensor 1
P0057 HO2S Heater Control Circuit Low Bank 2 Sensor 2

TECH UPDATES

2005 Jeep Wrangler 4.0L

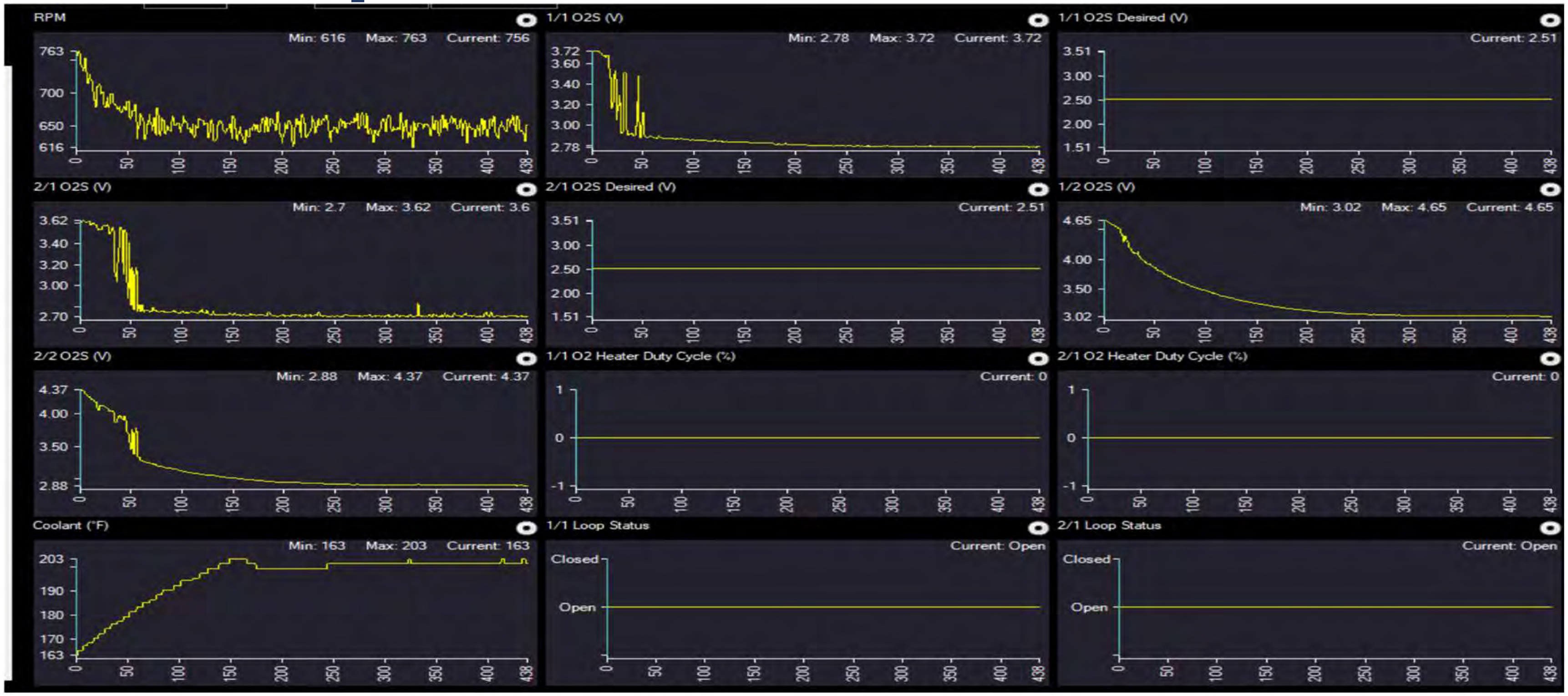
- Wiring diagram shows that all O2 heaters are high-side driven by the PCM and have a constant ground
- Can an open ground cause a “heater circuit low” code?
- If not, what can?



TECH UPDATES

2005 Jeep Wrangler 4.0L

- Scan data shows the sensors are operational
- Can the sensor voltages fall into the normal range without heater operation at idle?

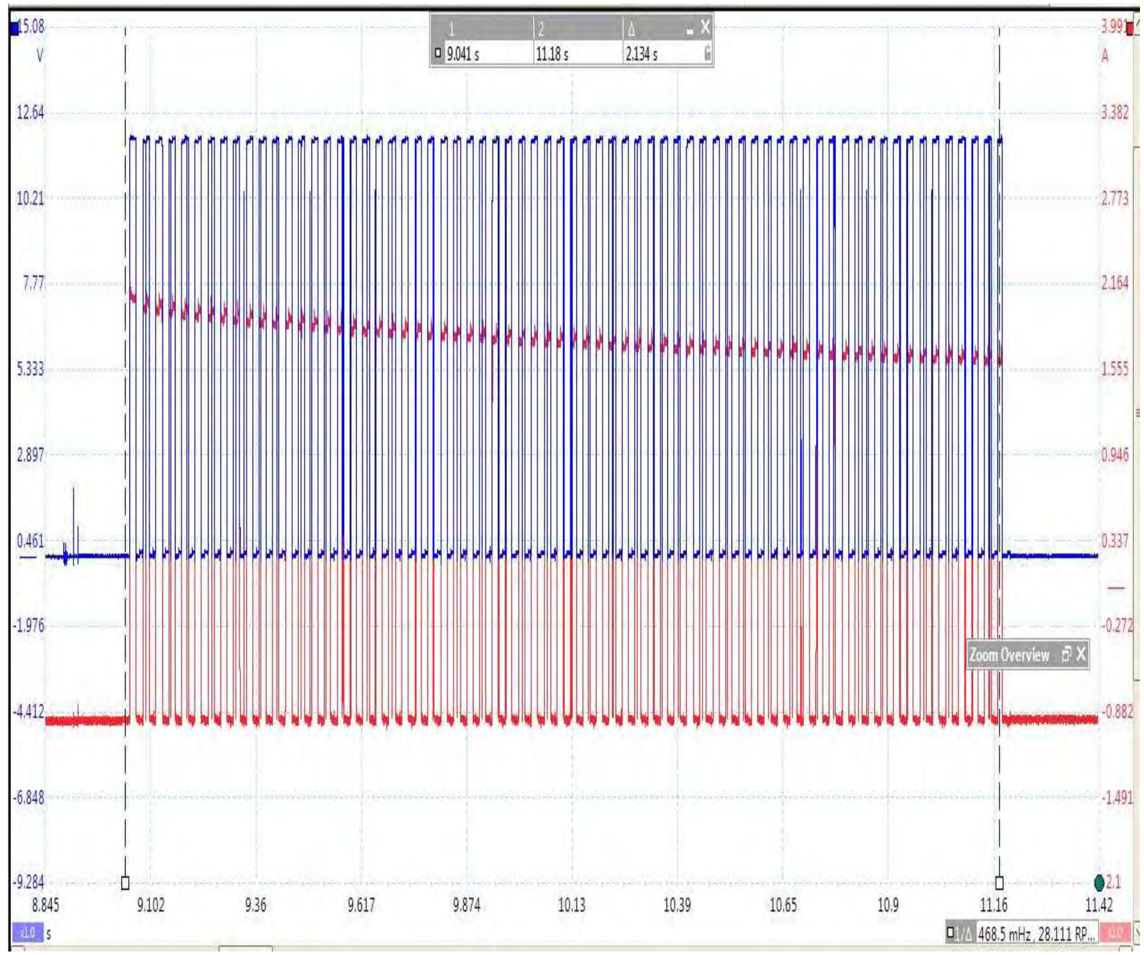


TECH UPDATES

2005 Jeep Wrangler 4.0L

NAPA AUTOTECH

- Scan tool has an O2 heater test for each sensor
- Test was run and each of the 4 sensors were able to reach the target 2.5-2.6v in the normal amount of time
- With the scope, verified the high-side driver is operational and neither the sensor or circuit are shorted to ground
  - Blue is high side driver
  - Red is O2 heater current
  - Measured @ PCM



TECH UPDATES

2005 Jeep Wrangler 4.0L

- After seeing that there were no harness or sensor issues, the call was made of a faulty PCM
- After install and programming, no fault codes returned after several vehicle starts and the fuel smell concerns were gone

Post Scan
Vehicle System Report

2005 Jeep Wrangler 4.0L L6 MPI
VIN 1J4FA44S95P358698
Odometer
License

CODE SCAN RESULTS
Systems Analyzed: 4

Systems w/ Codes

Systems w/o Codes

Engine
Transmission
Airbag
Instrument Cluster
OBDII Codes ($03)
OBDII Permanent Codes ($0A)

READINESS MONITORS

TECH UPDATES

Confidence In Your Call

- In Diagnostics, Our Goals are:

- Prove the Good and Bad
- Document Your Findings
- Avoid Swapping New Parts for Testing
- Avoid Comebacks

Proving Good and Bad

- What are some things that need to be known before calling a sensor good or bad?
  - Does the sensor have all it needs to operate?
  - Are all the circuits complete and healthy?
  - Has a sensor waveform measurement been taken?
  - Has the waveform been compared to a known good?
  - Where can I find a known good waveform?
  - What if I cannot find a good waveform example?

Known Goods

- Let's take a look into those last 3 questions:

- Having a known good example can have enormous value when diagnosing a sensor concern
- Several resources are available today including service information, scope companies, social media, free and paid websites, etc.

TECH UPDATES

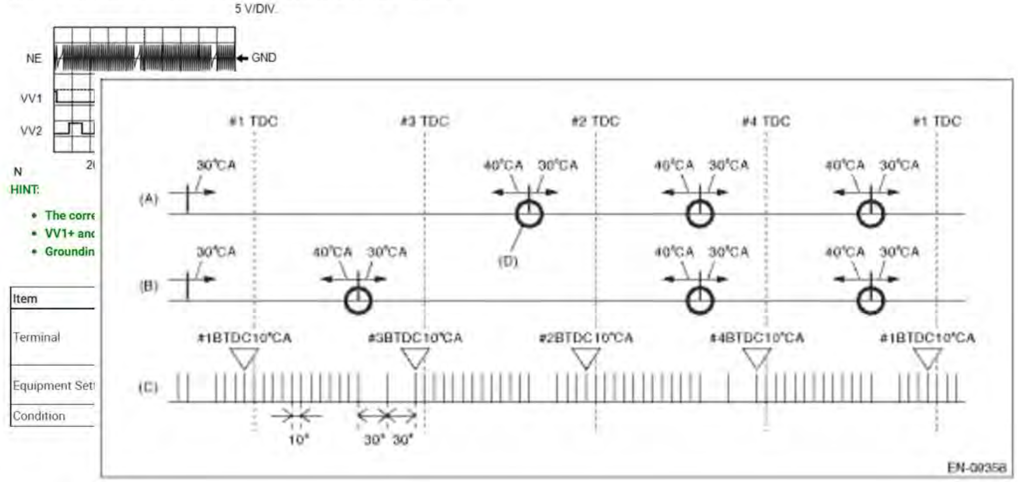
Service Info

- Some OE's have been publishing oscilloscope patterns in SI for many years and others following in recent years
- This example by Toyota is something they've offered for a long time
- This one is found by searching DTC P0335 – CKP circuit
- They even provide the scope settings to use
- Also here is an image from Subaru related to a P0340 setting on a 2015 Crosstrek 2.0 DOHC engine

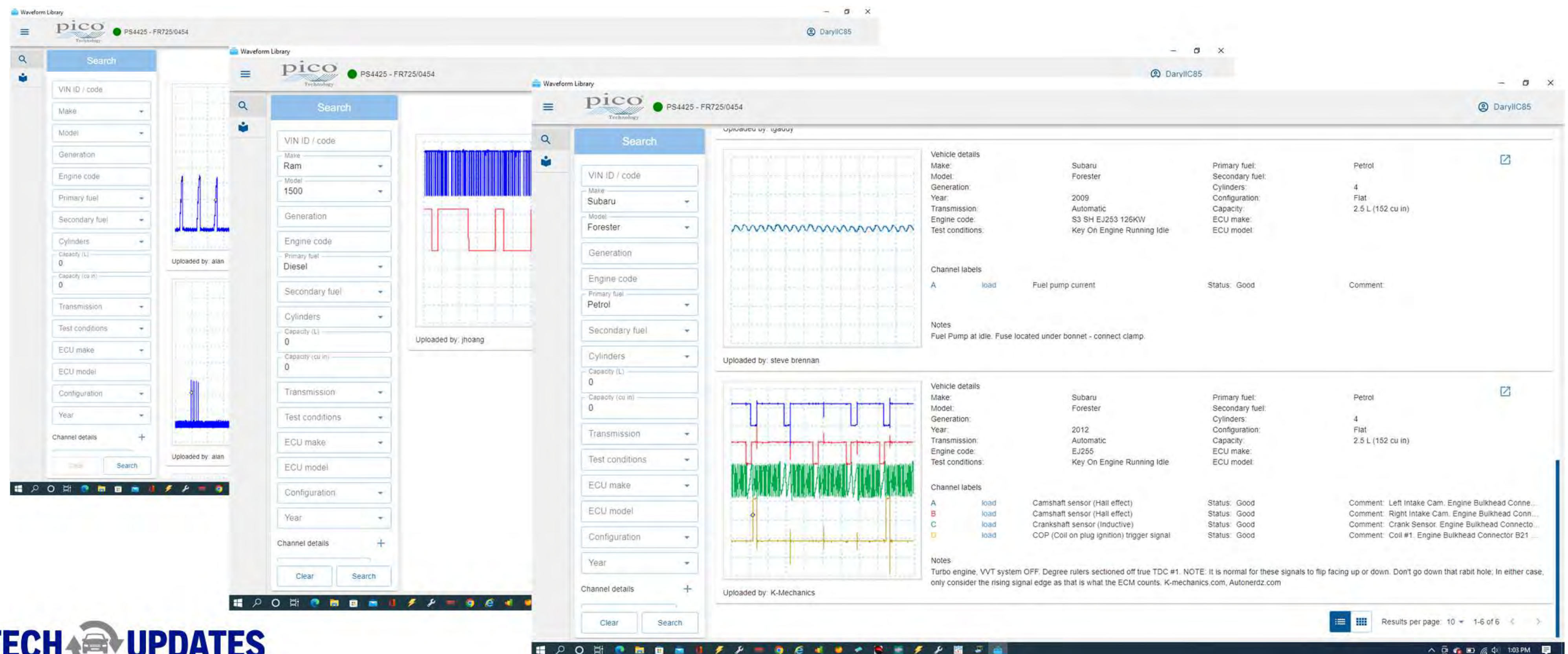
2017 Toyota Truck 4 Runner 4WD V6-4.0L (1GR-FE)

DTC No.	DTC Detection Condition	Trouble Area
P0335	Either condition is met: • No crankshaft position sensor signal to ECM while cranking (1 trip detection logic). • No crankshaft position sensor signal to ECM while engine running (1 trip detection logic). • Missing crankshaft position sensor signal despite VVT sensor signal inputs normal after engine cranked (1 trip detection logic).	• Open or short in crankshaft position sensor circuit • Crankshaft position sensor • Crankshaft position sensor plate • ECM
P0339	Under conditions (a), (b) and (c), no crankshaft position sensor signal is sent to the ECM for 0.05 seconds or more (1 trip detection logic): (a) Engine speed is 1000 rpm or more. (b) Starter signal is off. (c) 3 seconds or more have elapsed since the starter signal switched from on to off.	• Open or short in crankshaft position sensor circuit • Crankshaft position sensor • Crankshaft position sensor plate • ECM

Reference: Inspection using an oscilloscope (VV1, VV2 and NE Signal Waveforms)



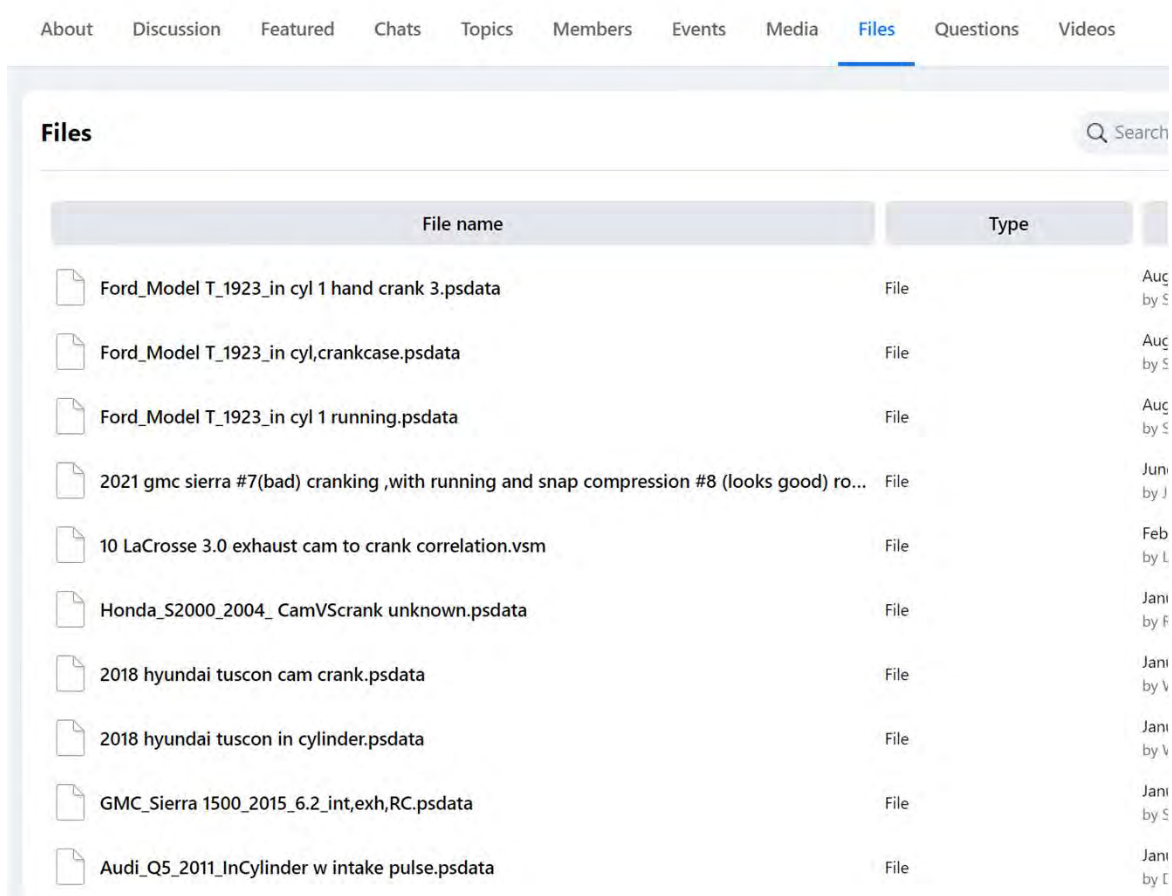
Pico Waveform Library



TECH UPDATES

Social Media

- Social media is loaded with diagnostic discussion groups today
- These can be a great resource, at 0 cost, to look for a waveform to aid in diagnostics
- Here under “Files” there are several thousand files that users have taken and uploaded to help others



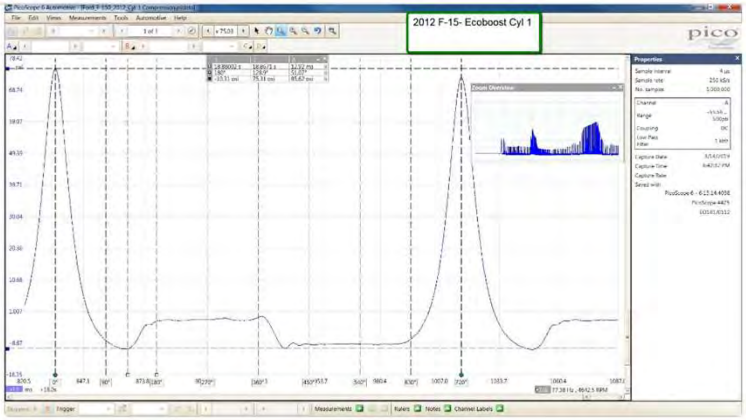
TECH UPDATES

Websites and Paid resources

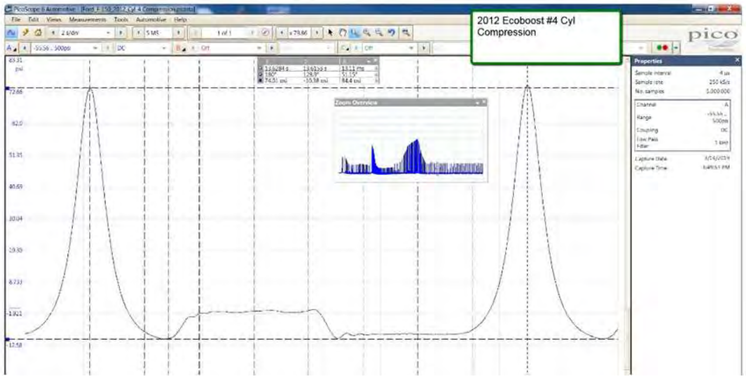
- There are many sites with waveform libraries available
- These typically have very wide vehicle coverage
- If a file is not available, you can submit a post looking for a particular file and

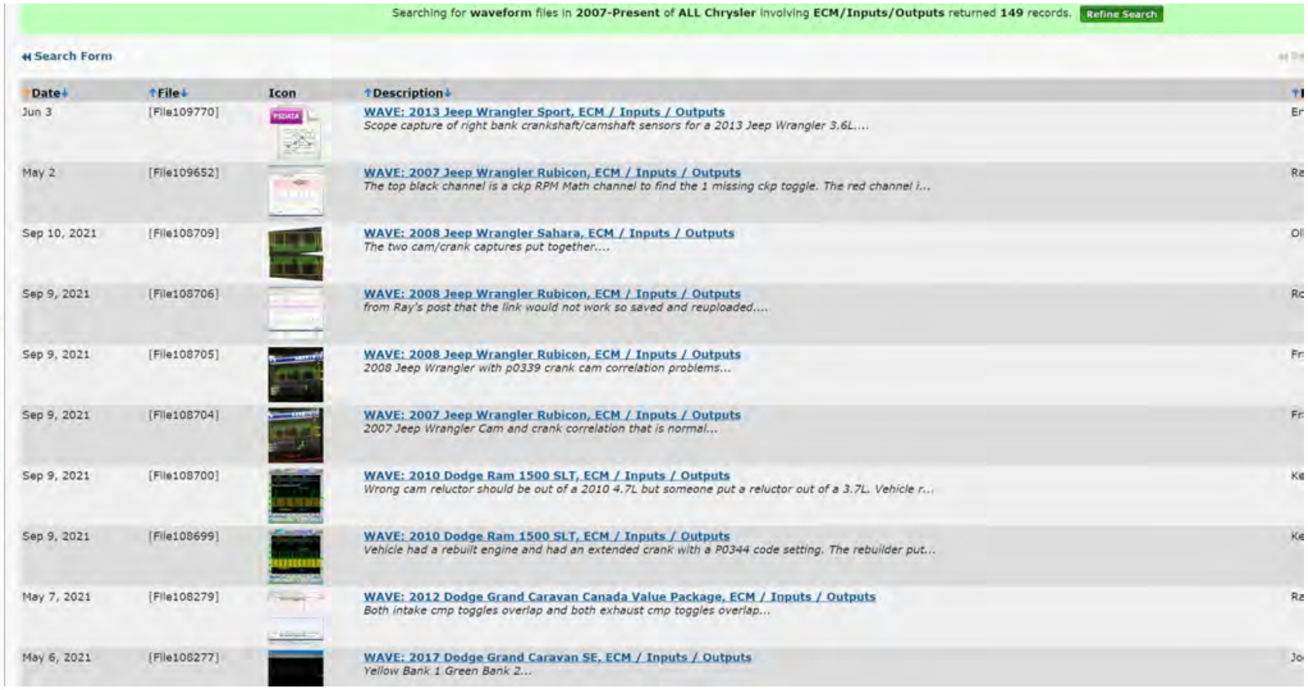
TECH UPDATES

Access from Paid Sites examples



Bank 2





Searching for **waveform** files in **2007-Present** of **ALL Chrysler** involving **ECM/Inputs/Outputs** returned **149** records. Refine Search

Search Form

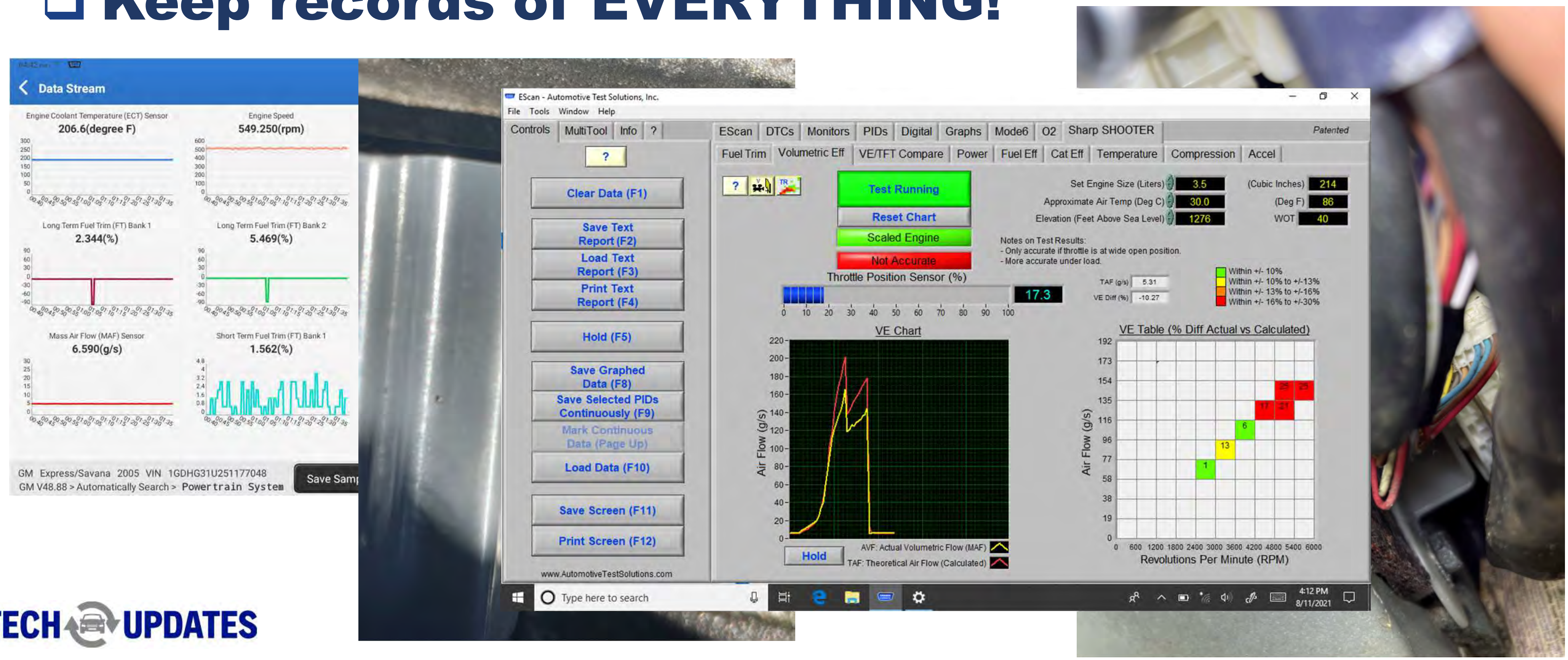
Date	File	Icon	Description
Jun 3	[File109770]		WAVE: 2013 Jeep Wrangler Sport, ECM / Inputs / Outputs *Scope capture of right bank crankshaft/camshaft sensors for a 2013 Jeep Wrangler 3.6L....*
May 2	[File109652]		WAVE: 2007 Jeep Wrangler Rubicon, ECM / Inputs / Outputs *The top black channel is a ckp RPM Math channel to find the 1 missing ckp toggle. The red channel i...*
Sep 10, 2021	[File108709]		WAVE: 2008 Jeep Wrangler Sahara, ECM / Inputs / Outputs *The two cam/crank captures put together....*
Sep 9, 2021	[File108706]		WAVE: 2008 Jeep Wrangler Rubicon, ECM / Inputs / Outputs *from Ray's post that the link would not work so saved and reuploaded....*
Sep 9, 2021	[File108705]		WAVE: 2008 Jeep Wrangler Rubicon, ECM / Inputs / Outputs *2008 Jeep Wrangler with p0339 crank cam correlation problems...*
Sep 9, 2021	[File108704]		WAVE: 2007 Jeep Wrangler Rubicon, ECM / Inputs / Outputs *2007 Jeep Wrangler Cam and crank correlation that is normal...*
Sep 9, 2021	[File108700]		WAVE: 2010 Dodge Ram 1500 SLT, ECM / Inputs / Outputs *Wrong cam reluctor should be out of a 2010 4.7L but someone put a reluctor out of a 3.7L. Vehicle r...*
Sep 9, 2021	[File108699]		WAVE: 2010 Dodge Ram 1500 SLT, ECM / Inputs / Outputs *Vehicle had a rebuilt engine and had an extended crank with a P0344 code setting. The rebuilder put...*
May 7, 2021	[File108279]		WAVE: 2012 Dodge Grand Caravan Canada Value Package, ECM / Inputs / Outputs *Both intake cmp toggles overlap and both exhaust cmp toggles overlap...*
May 6, 2021	[File108277]		WAVE: 2017 Dodge Grand Caravan SE, ECM / Inputs / Outputs *Yellow Bank 1 Green Bank 2...*

Document Your Findings

- In the world of documenting, too much is never enough
- This includes:
  - Visual inspection and notes
  - Pre-scan
  - Test drive data capture (if needed)
  - Pictures/video
  - Service information
  - Scan data & Scope captures

Document Your Findings

❑ Keep records of EVERYTHING!



TECH UPDATES

Avoid Swapping New Parts for Testing

- It’s often tempting to swap in a brand new part “because it’s quicker”
- Even OE diagnostic procedures mention “replace with known good part and retest”
- Not only can this be a waste of time, but if nothing changes then all you’ve learned is what part isn’t the problem

Avoid Swapping New Parts for Testing

- Depending on what part where the part came from, it may not be returnable
- Treat the diagnostic procedure the same whether the part cost is $20 or $2,000
  - Follow test procedures thoroughly
  - Verify circuit integrity
  - Prove that every other component and parameter involved is correct before calling for replacement

Avoid Comebacks

- Gather as much data as possible and document
- Clearly communicate your results
- NEVER replace a part based on a code alone!
- Repeat same tests after repair to verify that results have changed and are correct

Summary

- The goal of this class was to make sensor diagnostics easier by giving a better understanding of the various types and uses
- By using all of the resources available and being diligent in your process, there will be far less guess-work
- Understanding what part of test that the module is failing is also key to having a diagnostic approach

Summary

- With today's vehicle technology, and it's continuing to grow, specialized tooling is a must
- Between scan tools, multimeters, scopes, and other testing equipment, you can get the data you need to ensure a successful diagnostic
- Thank you for your time and attention

Top 5 Reasons to Invest in Training

1. Increase Job Satisfaction Levels
2. Stay Ahead of the Competition
3. Improve Customer Satisfaction
4. Maintain and Increase Employee Knowledge and Skills
5. Keep Up With the Latest Technology

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