Automotive Electronics for Today's Vehicles

The "Magic" to Electrical Diagnostics

What is Wrong with This Picture?

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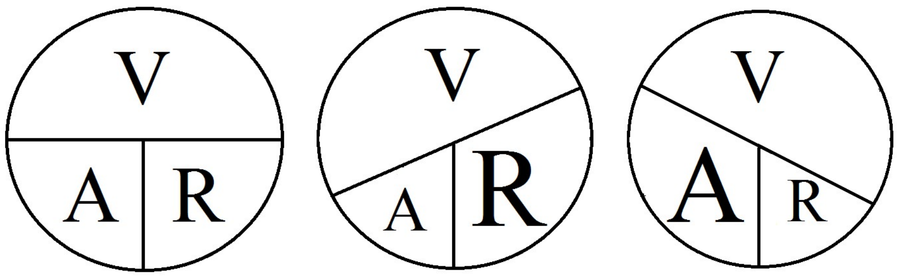
← 2 →

The Basics Mathematically

- What?
  - Victory Over Auto repair
- How about - Ohm's law
  - Either way, it confuses many people



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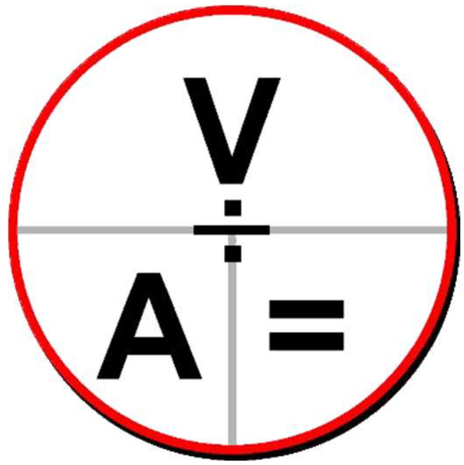
So, we draw the familiar Ohm's law pie chart. Remember to get the letters in the right spot: **V**ictory over **A**utomotive **R**epair.

Because of the basic truths of the law, we know that if **voltage** remains a constant value – if **resistance *drops***, **amperage** will ***increase***. If **resistance *increases***, **amperage** will ***decrease***.

Simplified Ohm's Law Formulas

- To find voltage:
  A x R = V
- To find current:
  V ÷ R = A
- To find resistance:
  V ÷ A = R

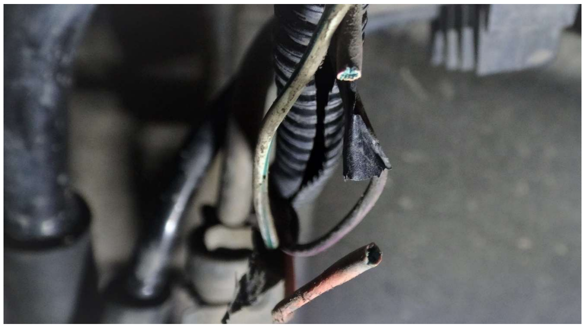


The simplified mathematical formulas are also written the way we tend to read, left to right.

Let's see if we can apply Ohm's law to some actual values.

Voltage Drop Issues a Very Common Overlooked Problem

- Loss of voltage to a component or voltage drop affects
  - Electric motor damage
  - Dim lights
  - Solenoids and actuators not working properly
- It is important to check for proper voltage/volt drop
- Voltage drop testing finds hidden resistance within the circuit



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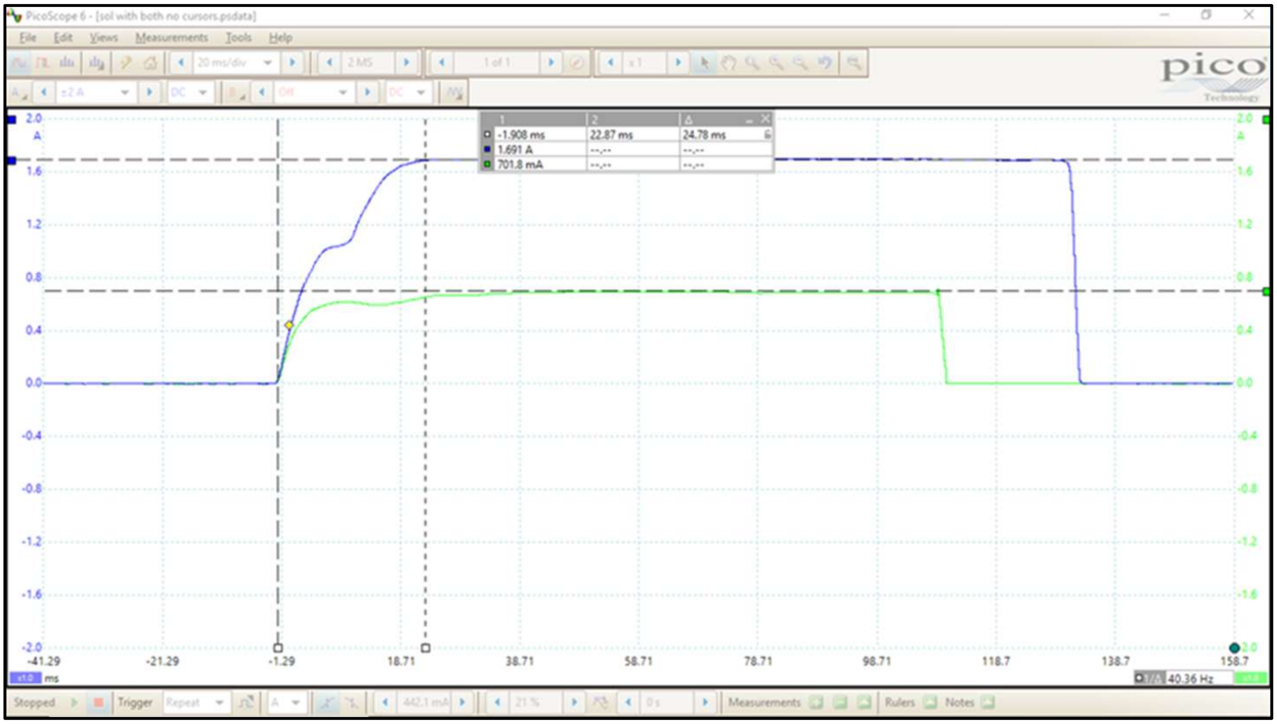
5

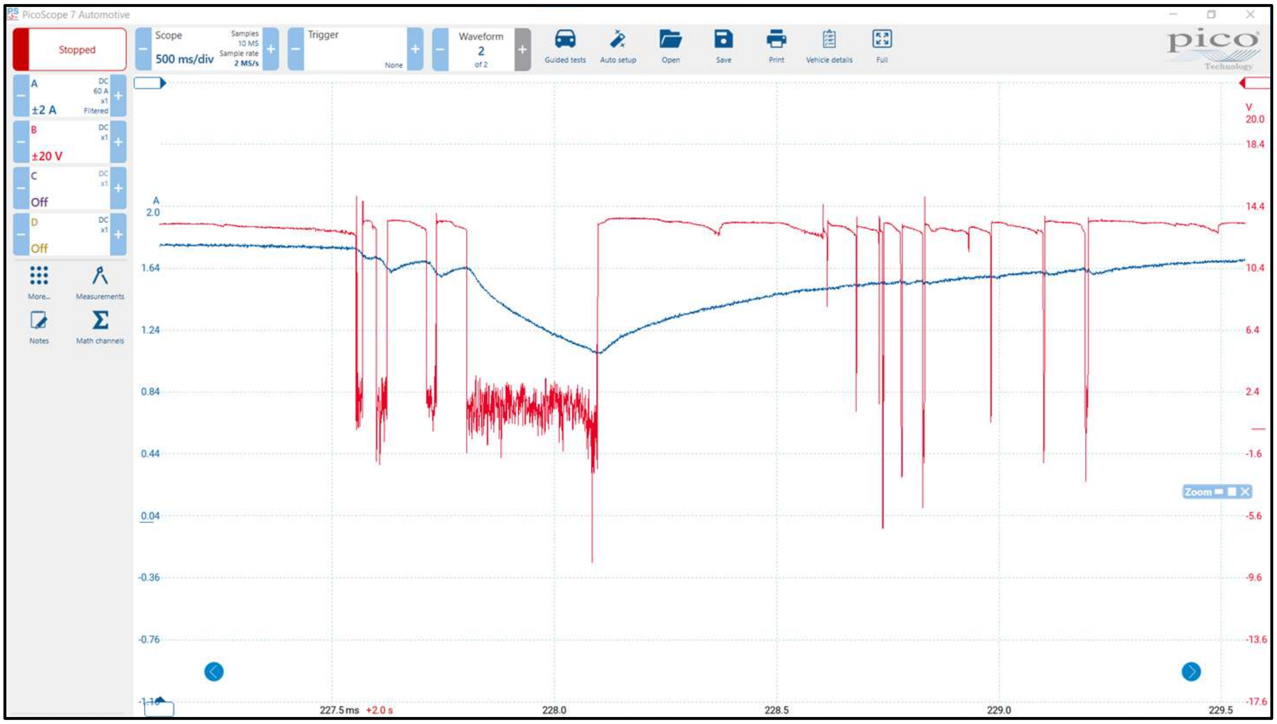
Voltage drop issues can affect components in different ways. A low operating voltage to an electric motor can damage the brushes and commentator contacts. On lighting circuits, lower voltage will result in dimmer than normal lights. When voltage drop occurs on a solenoid or actuator circuit, slow reaction time or no reaction time issues may surface.

Proper voltage is critical for electrical components to work properly. If the voltage is ***lower*** than the system voltage when measured at the component, a technician will need to determine which side of the circuit has **unwanted resistance**. The first voltage test is to **check** the voltage across the component while the component is energized. If the voltage is ***lower*** than desired at the component, separating the system into the power and ground side of the circuit will provide diagnostic direction to the location of the voltage drop. Volt drop testing starts at the source voltage and goes to the component. The measured difference between the two points (source and component) is the **total voltage drop** in the power wire. The next step in voltage drop testing is the **ground side test**. The **ground side voltage test** is performed from the battery ground to the ground side of the component. Any resistance in a live circuit will drop voltage across it, even on the ground side.



In this picture we're looking at the effect a voltage drop on a solenoid circuit. In blue on the top is normal green on the bottom is a higher-than-expected amount of resistance (VVT solenoid). Because the inductive clamp is measuring the magnetic field created by the movement of electrons through a conductor, the polarity of the inductive clamp is important to understand. Many inductive clamps will be marked with a polarity indicator. If the clamp is installed ***backwards***, you have three choices:

1. If your scope has an **invert** function, you can use this to correct the image.
2. You could simply turn the clamp around.
3. You could just live with the reversed image and move on. In many cases, you are only looking for a current level, and whether or not the image is right side up or not, is not an issue.



Here is an example of voltage and current with an intermittent connection. With the scope it makes it very easy to see the impact of voltage drop/bad connection on current flow.

How Inductive Probes Operate

- Measures magnetic field
- Probe outputs a voltage ***proportional*** to the magnetic field
  - Transformer (iron core)
  - Hall effect
  - Rogowski coil (designed for AC)
- Test equipment reads this voltage and *converts* it to an ampere reading

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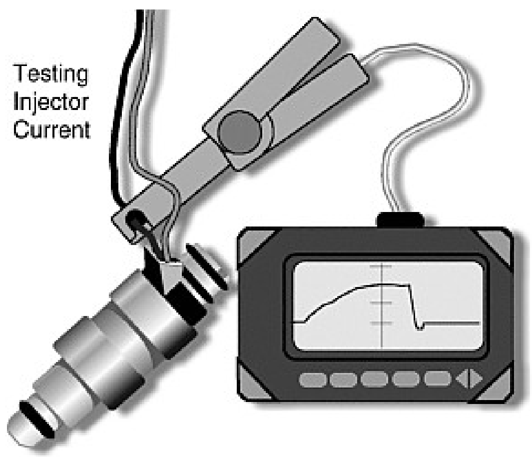
← 8 →

The current probe works by measuring the magnetic field around the wire through which current is flowing. Hall effect circuitry in the probe will output a voltage ***proportional*** to the magnetic field. This voltage is what the test equipment reads and ***converts*** to an ampere reading.

The current probe uses a Hall-effect circuit like a crank sensor to output a voltage ***proportional*** to the field strength, which is an indicator of **current flow**. Many scopes and meters will ***convert*** the voltage reading into an ampere reading on the screen. On scopes that do not have this function, the current can be calculated from the voltage reading.

Hooking Up A Current Probe, 1 Side of the Circuit



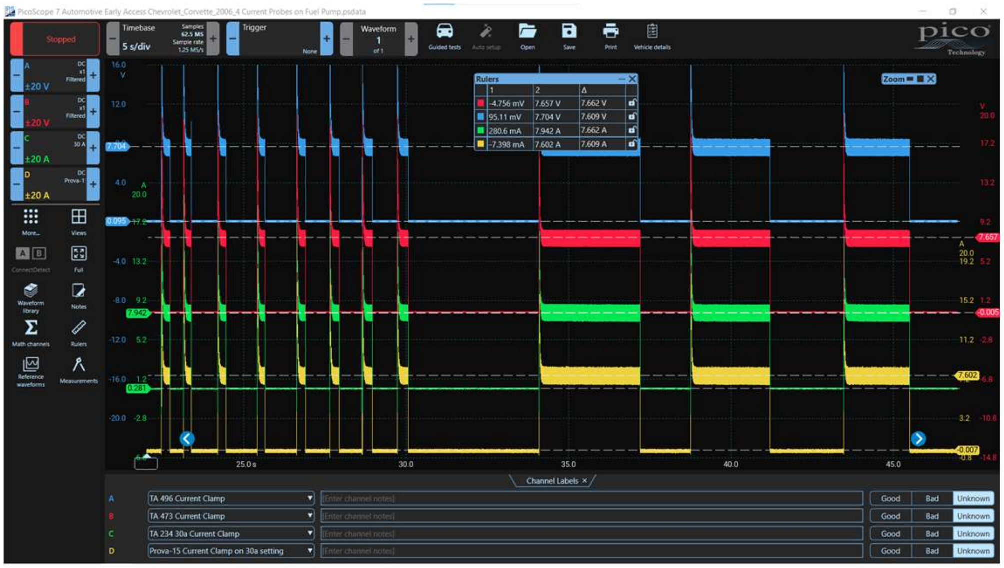
- When using a current probe, it is *not* necessary to **open** a circuit
- The probe clamps ***around*** the wire for the circuit being tested
  - *Ground or power*
  - *Kirchhoff's law*
- The leads of the probe ***attach*** to the test equipment at the voltage test terminals
- In series or just a branch

← 9 →

The great thing about current probes is that they are **non-intrusive**. A circuit does not have to be ***opened*** to use the probe. The probe simply clamps around the wire being tested. Test locations on simple series circuits can be anywhere in the circuit because the current flow is the same throughout the circuit. In a parallel circuit, the probe can be put at a shared power feed source or a shared ground to ***view*** current in the entire circuit; or it can be clamped around a single branch to view just that branch's load.

Gustav Kirchhoff produced many elegant methods of solving any kind of circuit problem. The laws (rules) he produced are named Kirchhoff’s laws. The law we are using here states that at any junction in a circuit, charge is neither created or destroyed, so that as much current flows into a junction must therefore flow away. In our terms, current is the same throughout the circuit.

Although the Zero is Off a Bit the Overall Amperage is the Same

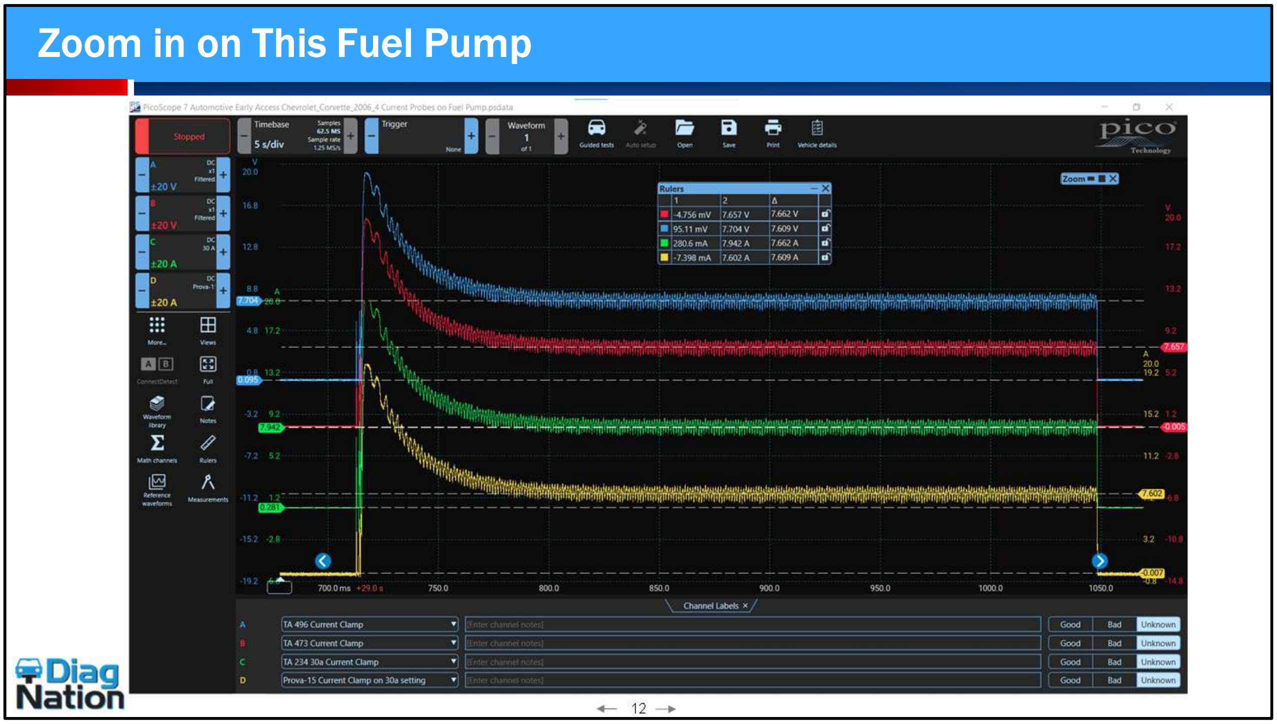


← 11 →

Here is just an example of utilizing four different low amp current probes at the same time. This circuit is a fuel pump circuit off a 2006 Corvette and I'm just utilizing it to show how even different brands of current probe can show the same quality picture.

Notice that channels A and B options show these as voltage leads not amperage leads. Both of those probes were Pico PNC+ and the software did not pick them up properly, yet it did apply the 20 kHz hardware filter as you can see in the probe selection box. This is something I have run into on several occasions, and I will just caution you to unhook your probe hook it back up so it will be picked up properly because otherwise it may not understand to auto zero either.

This is also a good screen capture to show you the channel labels on the bottom where I have labeled each channel's probe and could add notes if necessary and condition good, bad, and unknown.



In this capture, we've just zoomed in to show the quality of each of the probes against each other once again very similar in their operation.

Polarity Labels

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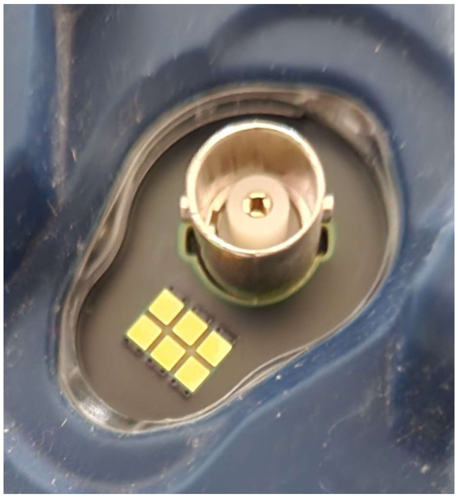
Current probes have polarity labels/stamps on them. They typically point towards the positive battery terminal. If they are hooked up backwards your current picture will just be upside down, you can either use the invert functions of your lab scope or just turn the probe around.

This is just a collection of what we consider low amp current probes. It should be noticed that they all have a switch to change the resolution and either use a button or a knob for zero set. These are typically of the hall effect design.

PicoScope BNC+ Current Probes (self calibrating and scope powered)



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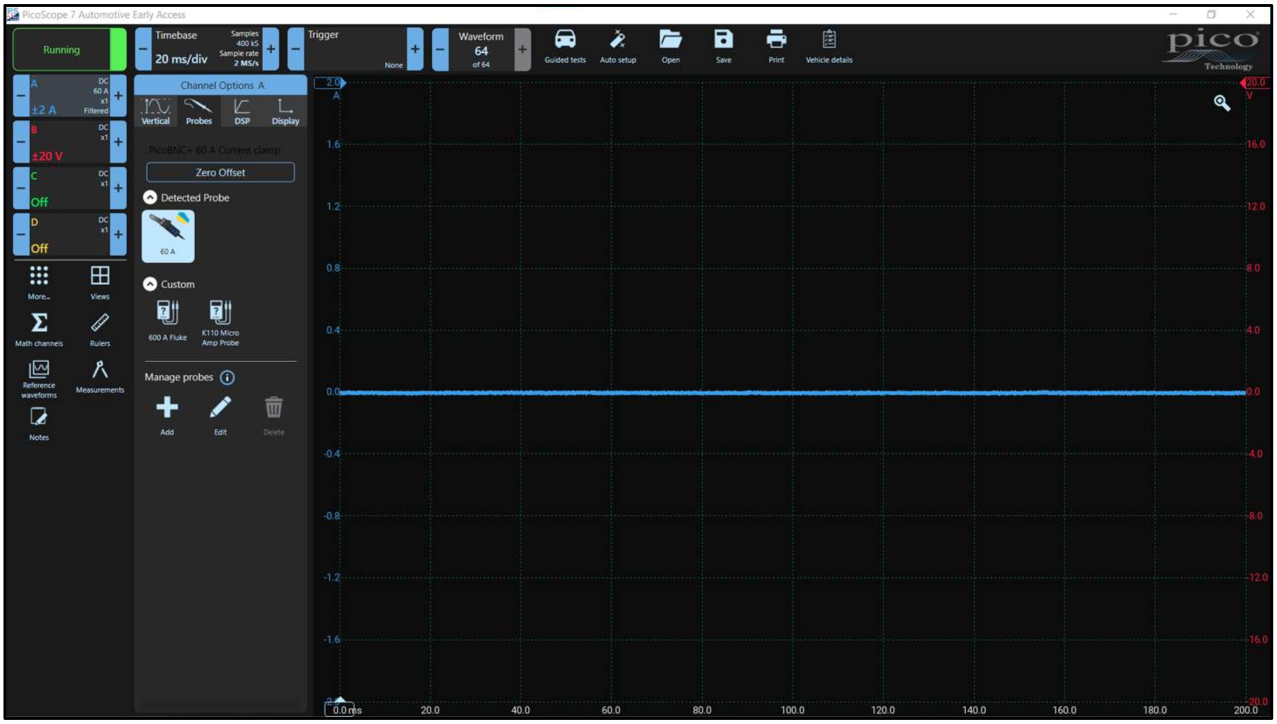
← 15 →

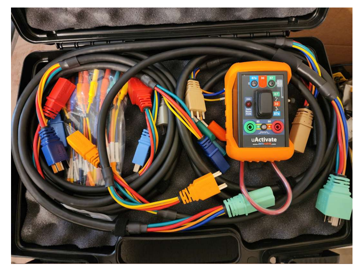
If using the BNC+ designed current probes whether low amp or high amp on the 4225A and 4425A series scopes, the probe will be self calibrating (zeroing) and self powered through the scope therefore no batteries are necessary. It is also important to realize that when plugging these probes in you must pay attention to make sure your Pico software recognized them properly as a current probe. The scope software will automatically switch to hardware filtering from 20 megahertz to 20 kHz and you cannot adjust that with these probes installed.



All current probes are going to “0” a little bit differently my advice is to have it hooked up to the scope when you 0 it to make sure there's reaction from the probe. Some probes and scopes like the picture above have automatic “0” settings and “0” offset functionality.

Using Specialty Testing Equipment

- Power Probe
  - w/open and short location detection
- PWM Power Pro
  - 0-100% up to 40a
- U-activate
  - Relay circuit tester
  - w/testing ports for all terminals
  - Loop for current ramping



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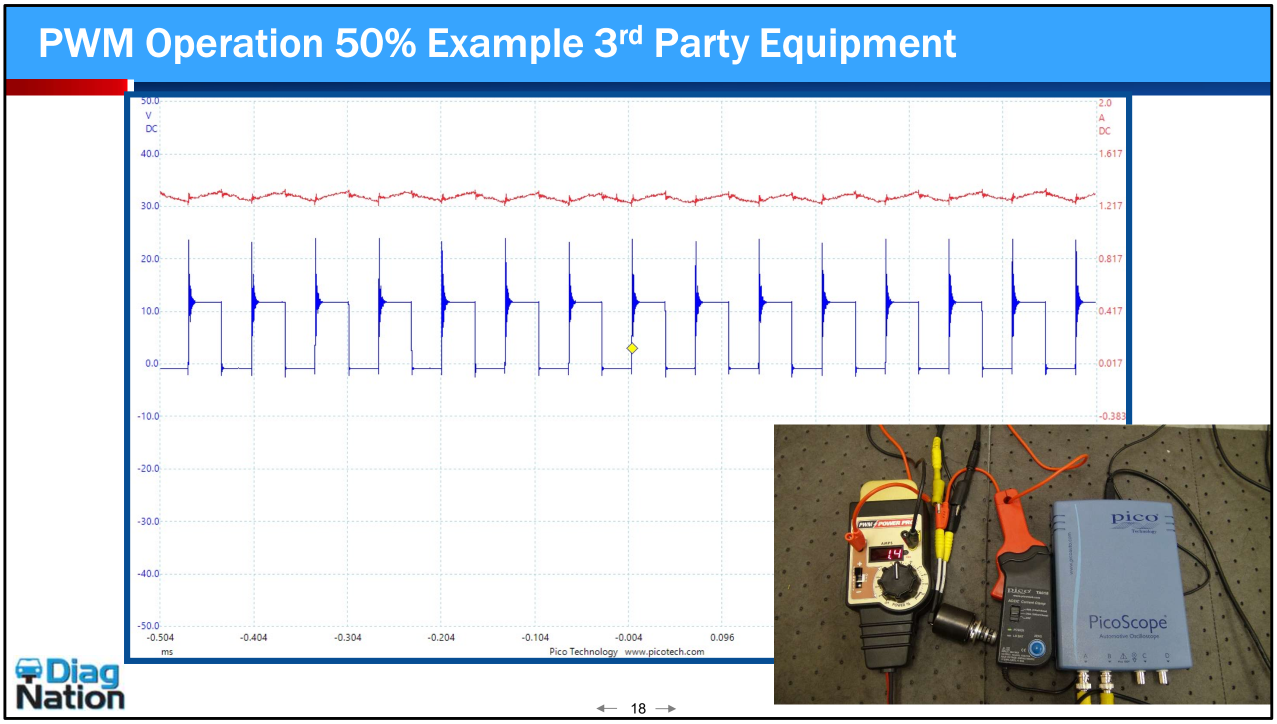
17

This series was never designed to be a sales pitch but there are tools that I've learned to use over the years in conjunction with my lab scope that have been made my diagnostic life easier and more efficient. In the picture above I've listed a few of them we've got the PowerProbe, the Pulse Width Modulated Power Pro and the U-activate relay circuit tester. These three tools are obviously not all of what's available to us out there, but these are some of tools that I use in conjunction with my lab scope to test circuits. As our series continues you will see tools like this being utilized in real diagnostic situations.

One point that I made here is that I use these in conjunction with my lab scope. The reason for this is when operating a circuit with these tools I like to see a picture on my lab scope of what's been accomplished.



PWM tool is increased to a **50% duty cycle** and the waveform confirms that the circuit is correctly energized **50%** of the time and **off 50%** of the time. The **1.4 amps** displayed on the PWM tool is ***not*** exactly the amperage measured by the low amp current probe attached to the PicoScope. A difference of approximately **.1 amp** is considered **minimal**. The amperage at **50% duty cycle** is slightly ***higher*** than the powertrain control module outputs. The powertrain control module usually will only command approximately **1-1.2 amps** at the most. **High line pressure** is achieved at **0% duty cycle**. The line pressure control circuit is designed this way to ensure the transmission has enough line pressure if power is lost to the line pressure solenoid. A duty cycle ***over*** **50%** would cause too high of an amperage draw and line pressure would be well ***under*** **80 psi** at this point. Keep this in mind with PWM commanding solenoids.

There may be cases when it is advantageous to **command** a line pressure control solenoid with the PWM tool and **compare** its amperage with the line pressure measurement PID on a scan tool or with a gauge. The command wire to the solenoid needs to be removed from the transmission connector or TCM (or PCM) before substituting the command with the tool. For the most part, PWM solenoids are tested for flow ***after*** being removed from the transmission and placed in a special flow rate cabinet to make flow measurements at specific duty cycles. Line pressure in the transmission relates directly with amperage flow at the pressure control solenoid.

Variable Circuit Breakers (5a-30a)

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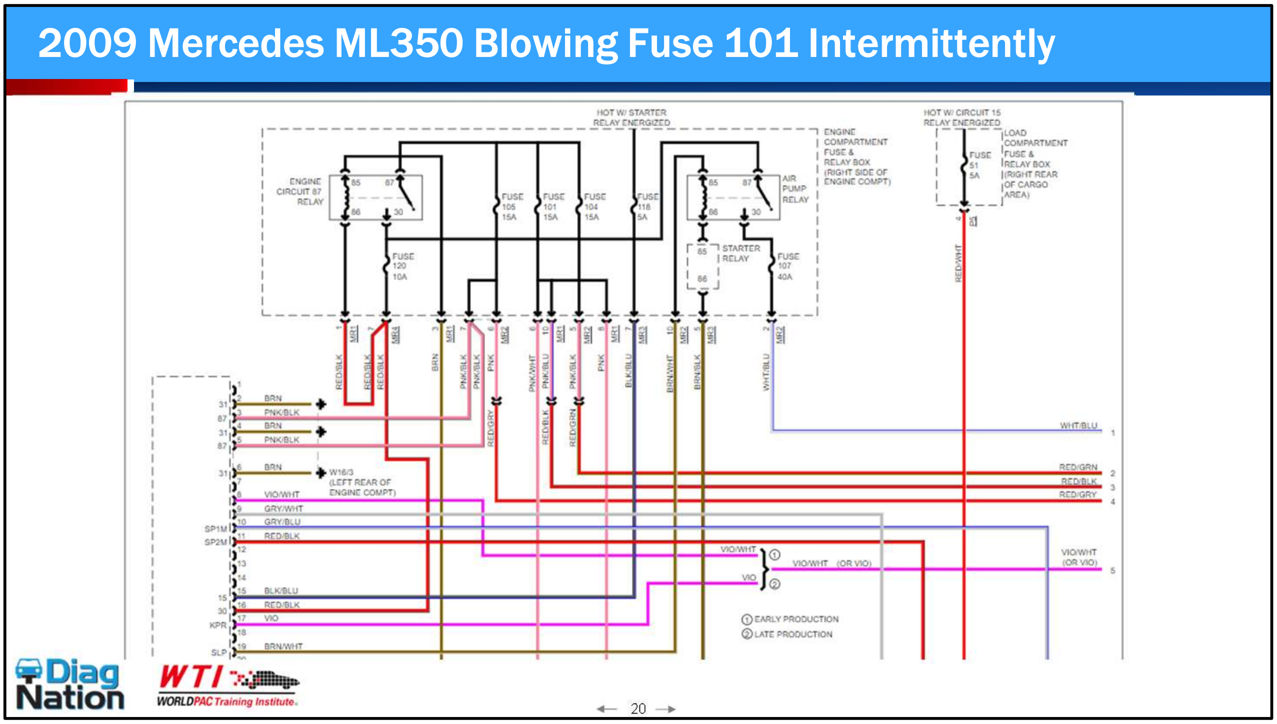
Here is a great example of how I used third party testing equipment and my Pico lab scope together. Obviously, these are variable circuit breakers that are typically utilized to help us to diagnose circuits that are blowing fuses. They are great tools however; they only tell part of the story if we add our lab scope to this it sometimes can give us the clues necessary to find what part of the circuit is causing our issue.



We are going to apply this testing method to a 2009 Mercedes ML350 that blows fuse 101 intermittently. We will remove fuse 101 and place our test equipment like the previous page in its place. One of the problems that we had with blown fuses is that some fuses can branch off into many different circuits in the car and finding the place where a short to ground happens could literally be somewhere between the front bumper and the rear bumper. What the current probe will do is draw us a picture of how and when the current flows and if it flows too high, we can see if there's any consistency, rhyme, or reason to what the current is doing. We may even be able to wiggle the harness and move the car while watching our lab scope to see if we have spikes of current that were too high but not long enough to blow the fuse.

Blown Fuse Circuit Testing with Scope and Current Probe

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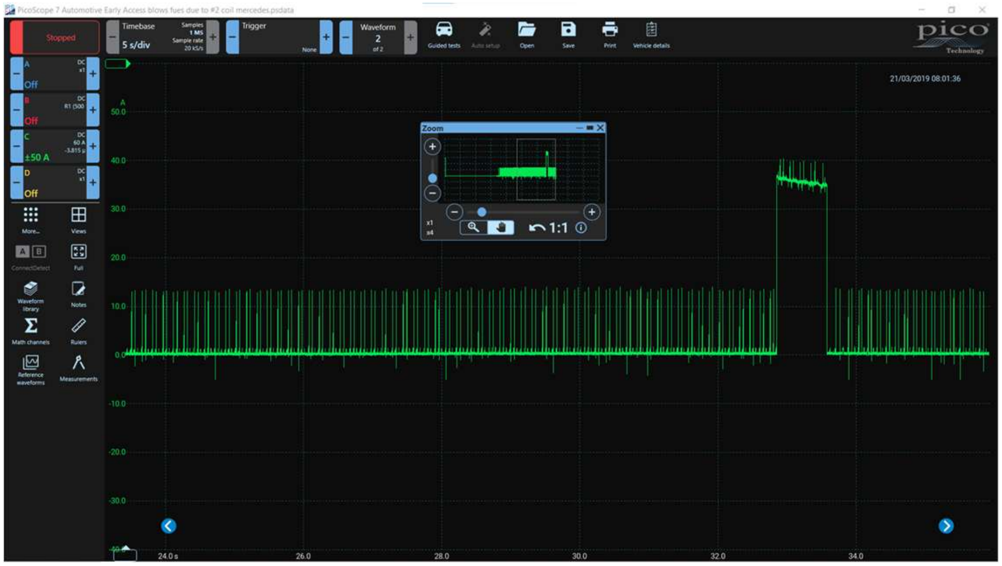
If you look at the picture I placed on the screen, you should be able to tell that I'm using a loop and circuit breaker to be able to power the circuit of a fuse that blows while simultaneously monitoring the current that goes through the circuit. This is an incredible setup that I use on many occasions when dealing with a circuit that blows a fuse that is either consistent or intermittent it works for both.

Fuse 101 w/Circuit Breaker Installed and Current Probe



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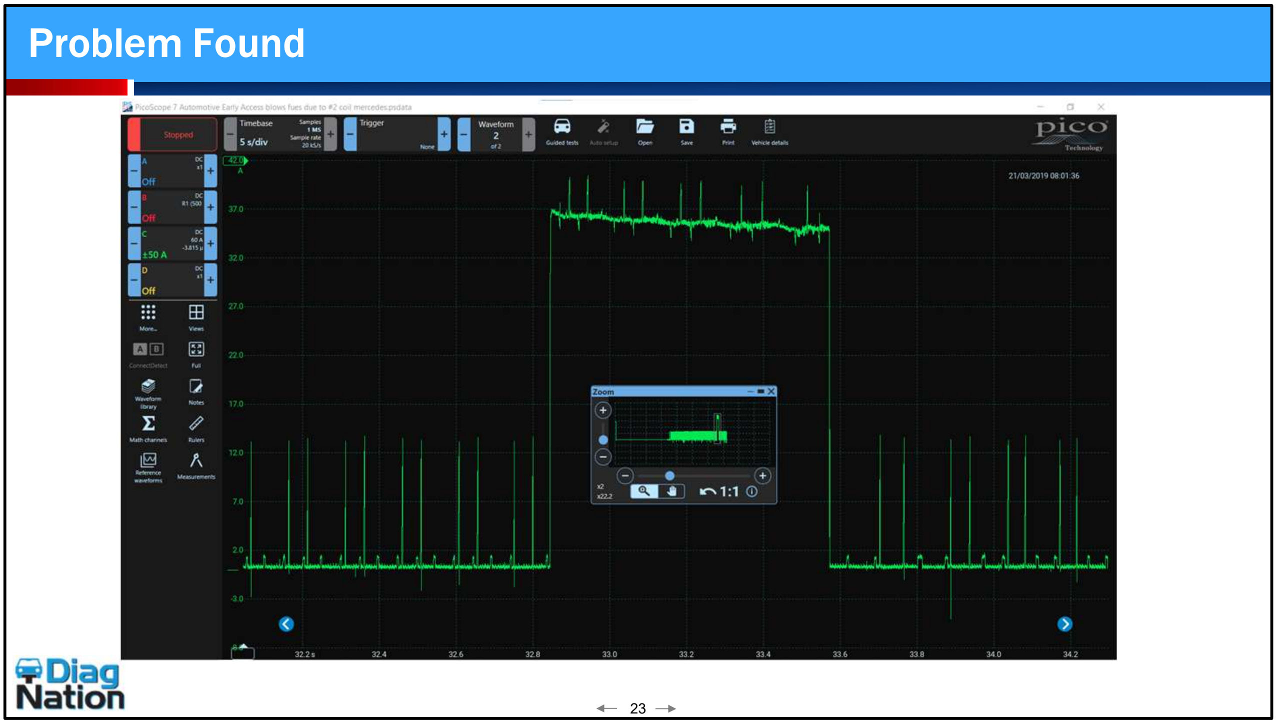
← 22 →

Here is a great example of where the combination of my circuit breaker and low amp current probe and lab scope have shown me where a massive surge in current (about 40a) has happened on this car. Now what we need to do is zoom in on the waveform and see if there's any consistency or rhythm to where this obvious burst of current happened.



This is awesome because when we zoom in on this picture there are a few details. When the current displaying is operating properly, we have a rhythm of injectors of about 1 amp each in perfect rhythm and the higher spikes (about 13a) are our ignition coils firing in perfect rhythm except we are missing 1. But when our spike of current happens to 40 amps it is at the exact time that that coil should have been firing which leads us to a coil that's bad and it doesn't blow the fuse until it intermittently tries to fire.

Ignition Coil Blowing the Fuse

Here is our culprit.

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Starter Current & Relative Compression

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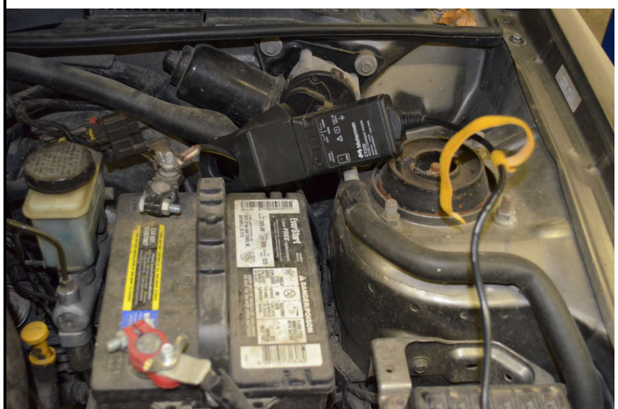
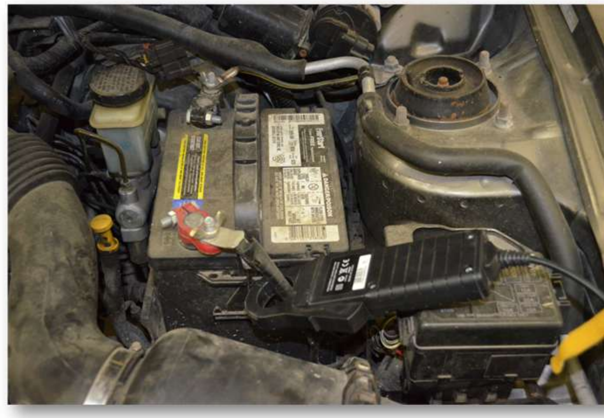
Current Probes – High Amp Clamps

Here is a small selection of high amp current probes. These are typically of the hall effect design.

Adam Robertson www.diagnation.com
775-438-3424 (775) GET.DIAG

Connection Options for Current





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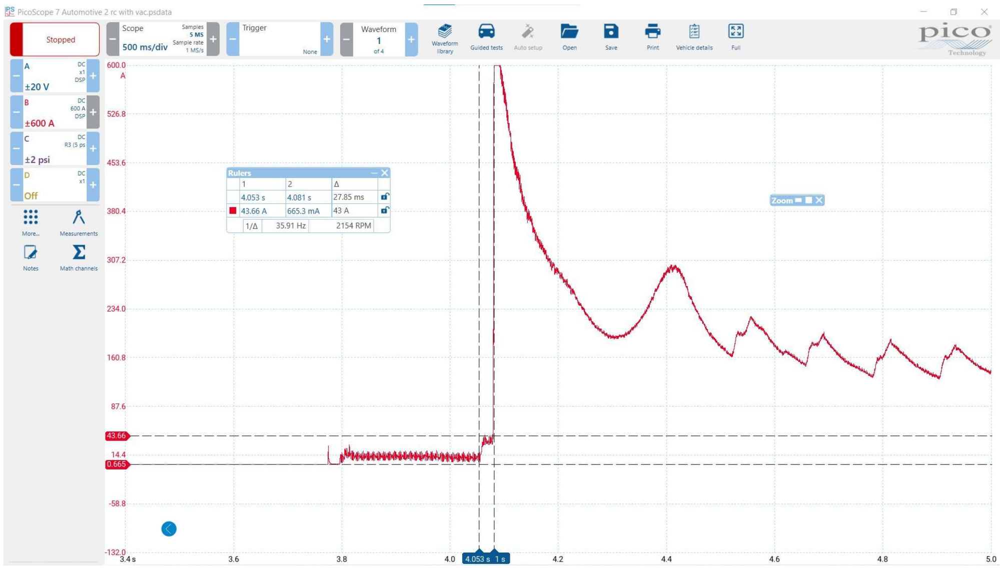
27

How does that ***law*** go? Current is what?

Known Good “Rush-in Current and Solenoid Operation



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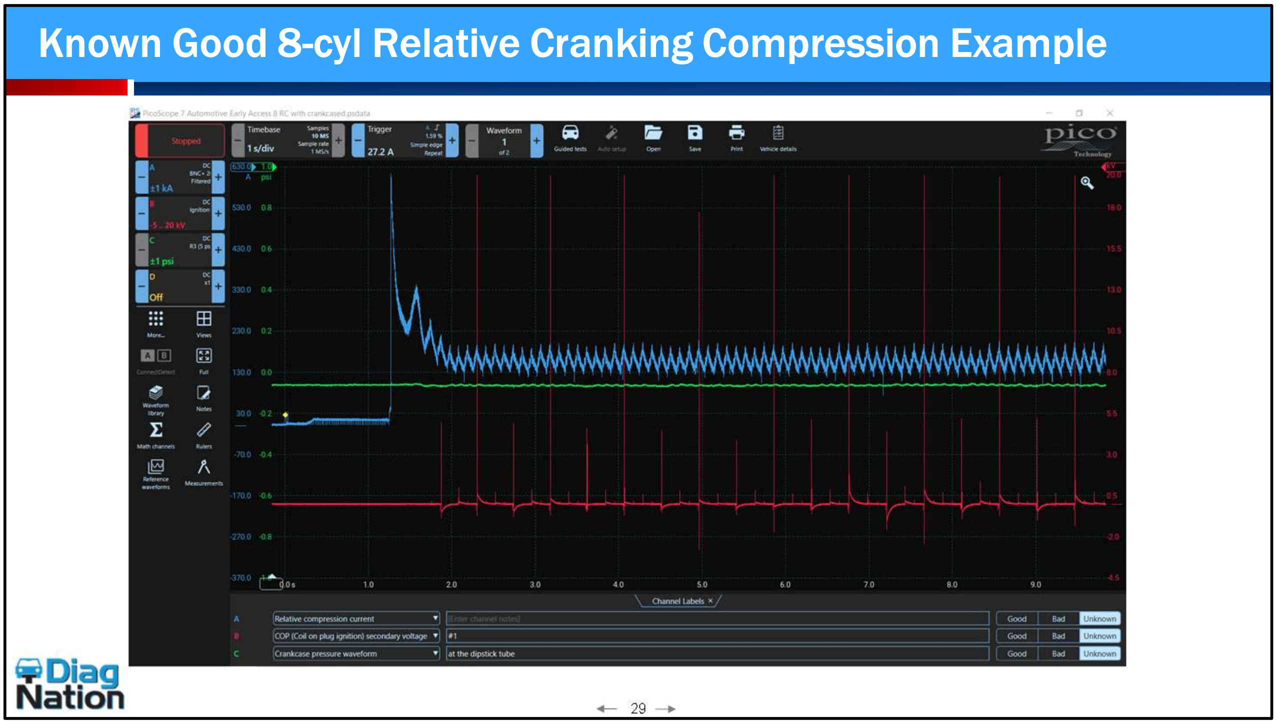
← 28 →

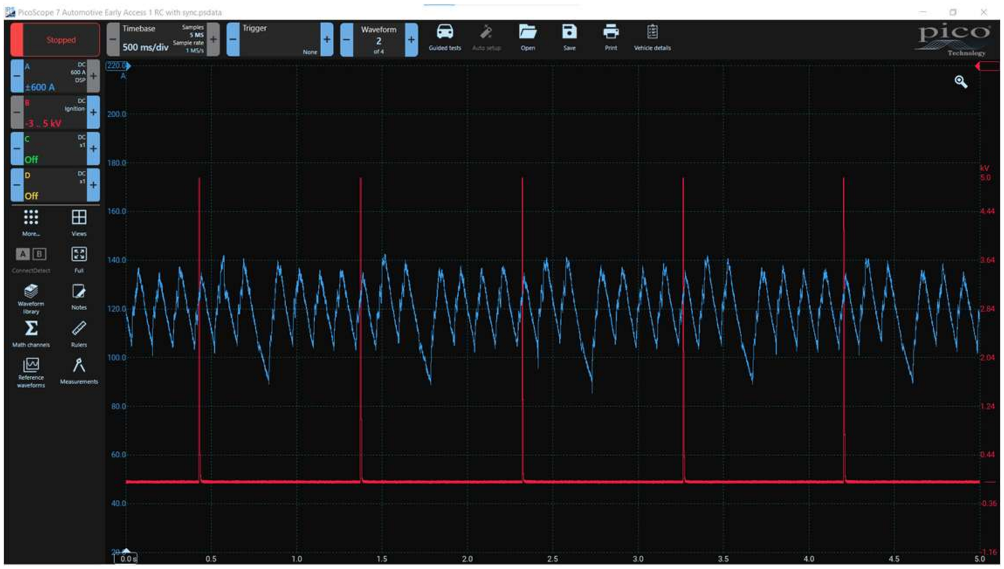


One of the most common uses for high amp current probe and the lab scope is a relative cranking compression test. Once again, we have written classes on this topic so the description of this is a little out of the scope of this class. The basics are this, every time a piston comes up on the compression stroke there's extra load placed on the starter it slows down a little bit and the current climbs. The idea here, is that the amount of current rise for each compression stroke should be relatively the same if all the cylinders have the same mechanical compression.

This type of testing like many others that you will perform with your scope is only limited by your imagination and study. In this snapshot I am not only looking at the relative compression current in blue channel A, but I am also looking at an ignition sync on channel B red and crankcase pressure through the oil dipstick tube on channel C green. As noted above this is a known good reference.

One last thing to notice in this picture is the placement of the trigger. It appears that the drawing of the waveform it's not accurate as to the trigger placement but if you look closely, you see there was some small noises that the trigger picked up and began drawing this picture. In most cases this would not be considered proper trigger placement, but it worked fine.

Typical Relative Compression with Dead Hole V-8



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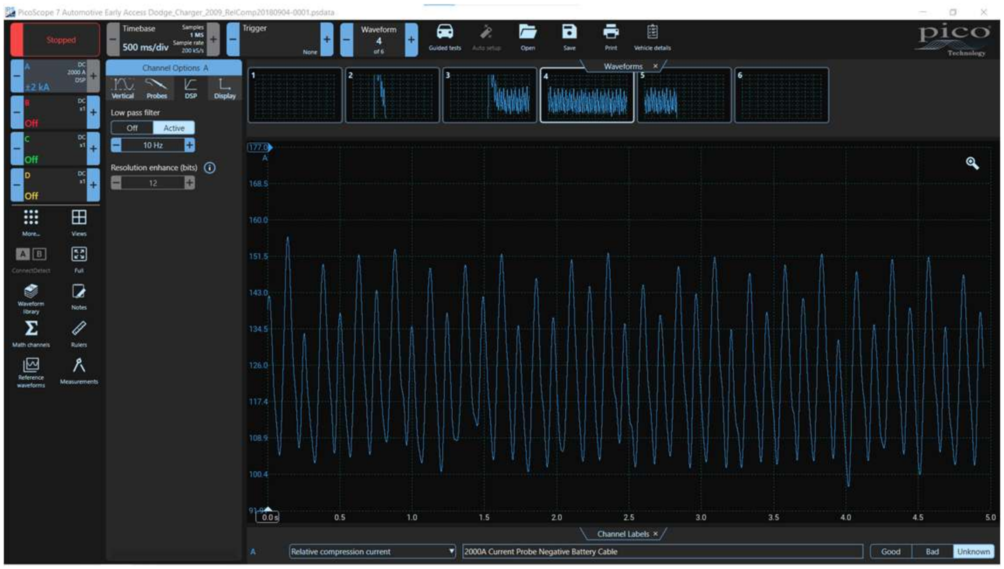
← 30 →

This snapshot represents one of the more common failures found with a relative cranking compression test. As you can see in this V8 engine, we have one cylinder who is not producing the correct amount of amperage when his compression stroke has come around. If my sync was on ignition signal for 1, and my firing order is 18436572 then my low compression cylinder would be cylinder 3.

Heavily Filtered/Zoomed 2.7L V-6 Jumped Timing Chain



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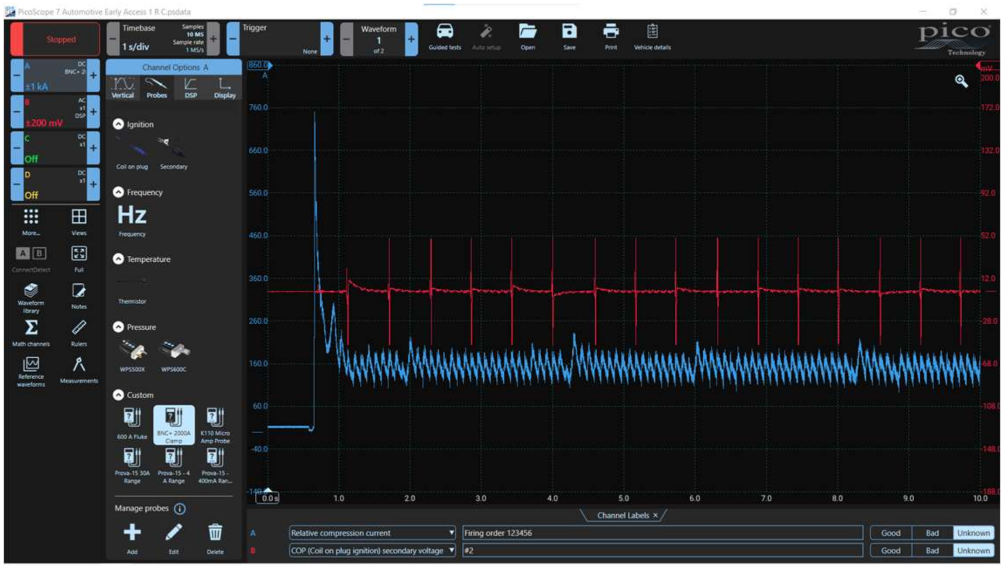
31

Here is another view of a relative cranking compression test with a lot of low pass filtering and zoom level increases. This is to show the detail of the unevenness of the compression cycles in this six-cylinder engine. If you look closely, you can see that there's a rhythmic pattern to where one bank seems to have more compression than the other bank. This has been a great tool to find issues like in this case where the timing chain has jumped. As you can see with this picture learning to manipulate your waveforms with filtering and zooming it can yield results that you could not see with other scopes.

High Current Probe Example Chrysler 3.6L Pentastar



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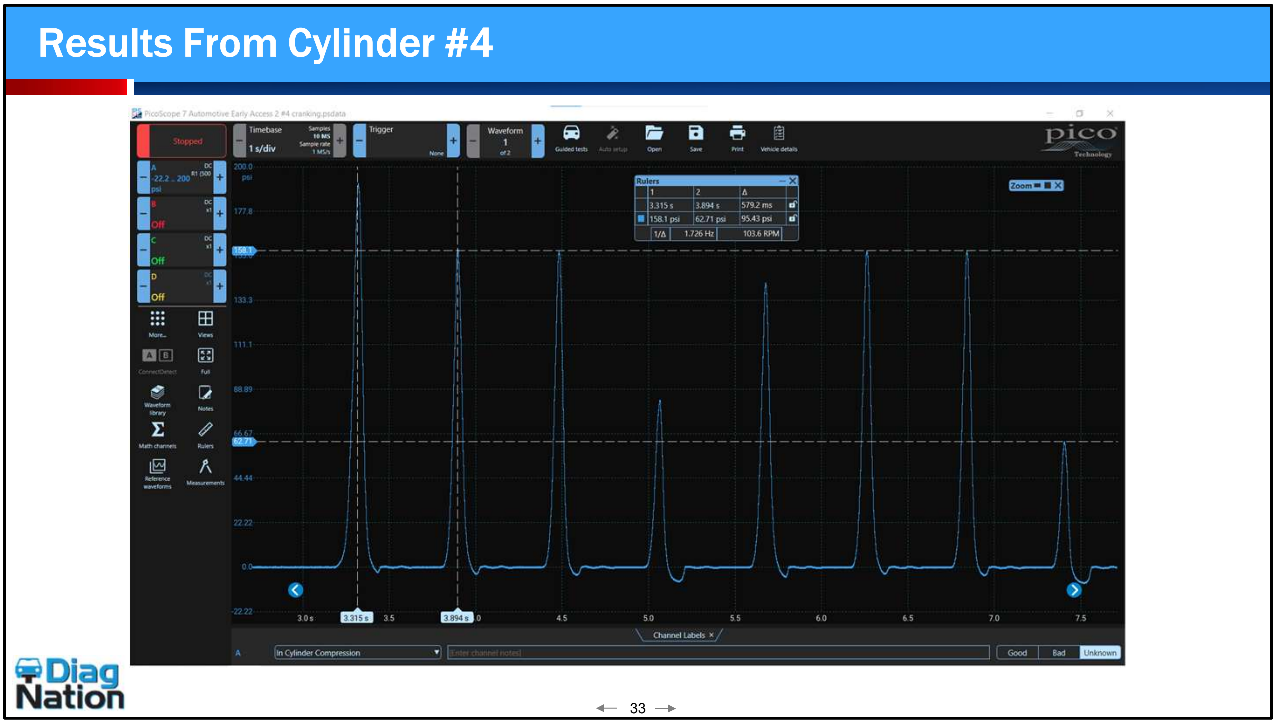
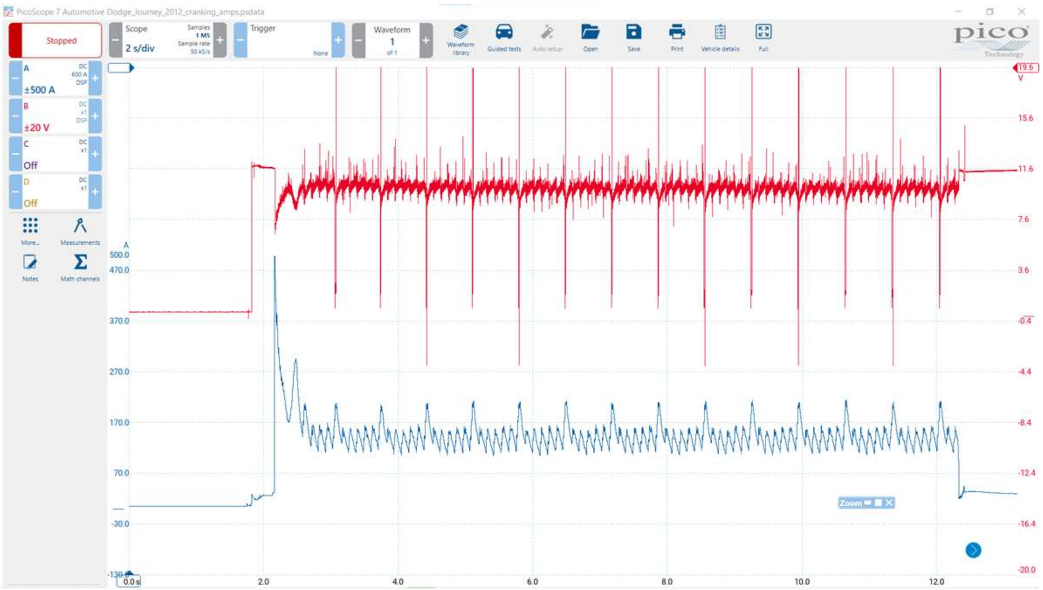
← 32 →

In this example we are using a high amp current probe for relative cranking compression on channel A in blue and ignition sync in red channel B. We also get the opportunity to see that I have built a custom probe for this high amp clamp under the custom column option. Although this is beyond the scope of this class, I think it's important to realize that having enough information on the screen can be critical like in this capture where our compression issue was not happening every 720 degrees. This is definitely an odd picture for relative cranking compression, but it proves that we must get enough detail on the screen to see the consistency or lack of consistency per each 720 degrees. So, time-based adjustment is going to be a critical feature for you to practice with and as you can see in this picture it is set to 10 seconds.

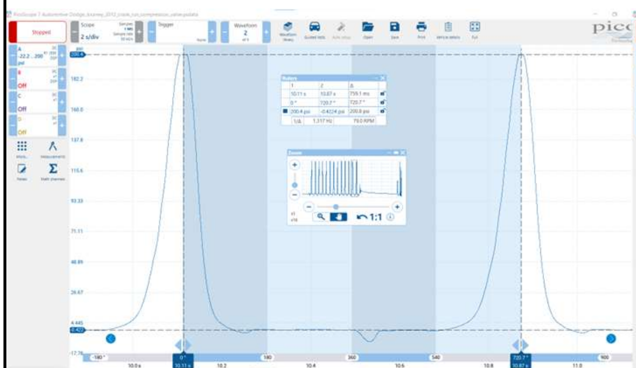


Here are the in-cylinder compression waveform cranking results from cylinder #4. With practice it will be easy to see that we have a varying lift issue with the intake valve which will be due to most likely a combination of bad Cam lobe and follower.

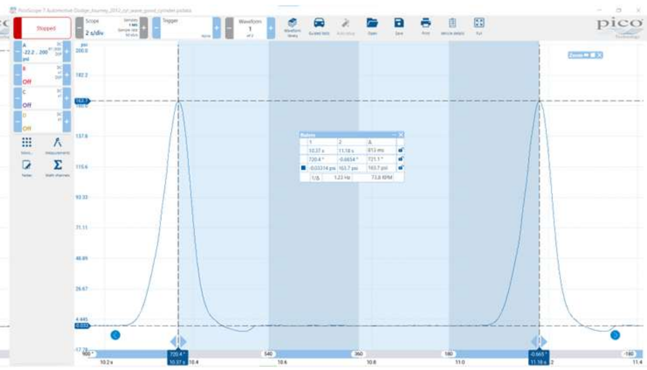
2012 Dodge Journey 3.6 Pentastar



Cranking In-Cylinder Compression Presumed Good and Bad



Bad Cylinder 200psi



Good Cylinder 163psi

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← 35 →

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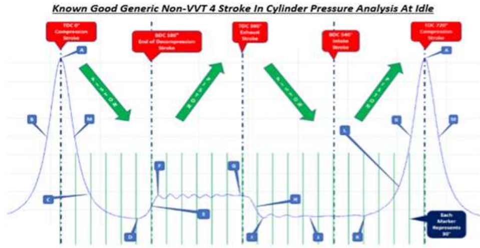
Known Good Generic Non-VVT 4 Stroke In Cylinder Pressure Analysis At Idle



This is a generic in-cylinder compression waveform, captured using a 0-500-psi pressure transducer at ***idle***. It is important to realize that VVT (variable valve timing/lift) and forced induction engines can produce significantly different pressure timing signatures (primarily affecting the timing of points ***D,E,F,G,H,I and K***) and will require some extra thought on your part as to the logical changes. In many cases the actual cam timing specifications can be found in service information and used for reference. ***Note:*** cranking, snap throttle and deceleration captures will add significant diagnostic capabilities and should be utilized in most cases.

The piston reaches the top of its travel at point ***A*** (top dead center of the compression stroke). As the pressure starts downward, we would usually call this the "power stroke". In this case however that's not true due to no "true firing" of the cylinder so we will call this the "decompression stroke" to more accurately represent what is happening. Dual spark plug engines may produce "true" firing but will create excessive heat on the transducer.

Points ***B*** and ***M*** are the midway (50%) points of the compression and decompression strokes. Point ***B*** should be ~30° before TDC, and Point ***M*** should be ~30° after TDC. These points should be very similar in time base to each other if no volume loss has occurred. ***Note:*** with a little practice, a difference in time base between the 2 (***B and M***) is easily seen as a "leaning tower" ***when*** a mechanical problem/leak exists. This time change or "leaning tower" can also be cause by piston speed changes so be careful.

Points ***C*** through ***D*** show on the downward stroke of the piston the vacuum that is being reproduced from the intake event of ***I***, which at Point ***D*** should equal the vacuum depth produced at Point ***I***. ***Note:*** this is a key measurement for valve adjustment issues and volume losses.

Point ***D*** represents the opening of the exhaust valve and should be ~30° to 45° before BDC (bottom dead center). At Point ***D***, exhaust pressure starts to build toward Point ***E*** which represents atmospheric pressure. This seems odd as the piston is still traveling downward yet pressure is rising towards "0" or atmospheric pressure. This is because the exhaust valve is now open and the vacuum that was created during Point ***I***, is being filled by the pressure in the exhaust. ***Note:*** that pressure at Point ***E*** will be near "0-psi" but may continue to rise in the event of restricted exhaust.

Points ***F*** through ***G*** represents the "exhaust" plateau which at idle should be near "0-psi" (or whatever pressure is represented as "0 atmosphere" by your transducer) in a good engine. ***Note:*** that some oscillations due to exhaust pulses created by the other "running" cylinders are normal.

Point ***G*** represents the area that the exhaust closing and the intake valve opening events are in "overlap". In a properly timed and mechanically sound engine, this should not show any visible pressure changes. ***Note:*** that it is common to have visible pressure increases here with cam timing, lobe damage and/or sunk ***exhaust*** valve issues (typically causing "early closing") are present.

Point ***H*** represents the drop into vacuum that is created by the combination of the opening of the intake valve and piston traveling downward. ***Note:*** somewhere during this ramp, the exhaust valve would have completely closed.

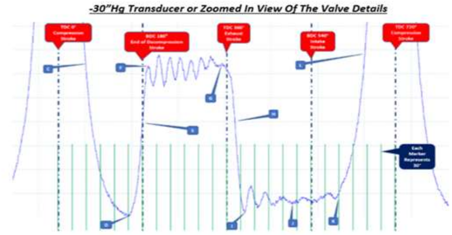
Point ***I*** is when maximum vacuum is achieved inside the cylinder (exhaust valve is completely closed). Point ***I*** should be achieved ~30°- 50° after TDC. As stated earlier, Point ***I*** and ***D*** should represent the same amount of pressure/vacuum. ***Note:*** that simple valve adjustment issues or problems as severe as volume losses will affect this comparison (between ***I and D***).

Point ***J*** represents the "intake" plateau. This pressure/vacuum is combination of the pressures in the cylinder and intake manifold (due to the intake valve being open). ***Note:*** that the difference in pressure between the exhaust plateau (***F through G***) and the intake plateau (***J***) will equal the pressure/vacuum in the intake manifold.

Point ***K*** is the point that the intake valve completely closes. This should happen ~50° to 60° after BDC. ***Note:*** due to the "fluidly" movement of air it is difficult to see the exact point but is close enough for diagnostic purposes, especially when cranking. Point ***L*** beginning the next compression stroke.

It is important to understand that there will be minor differences between engine platforms. Always compare between "known good" and "problem" cylinders when possible, at which point even the slightest differences will point to breathing errors. When comparing cylinders, 2 identical transducers/hoses used simultaneously is the best option. If dual transducers is not possible, then piston speed must be identical during the capture analysis points.

-30"Hg Transducer or Zoomed In View Of The Valve Details



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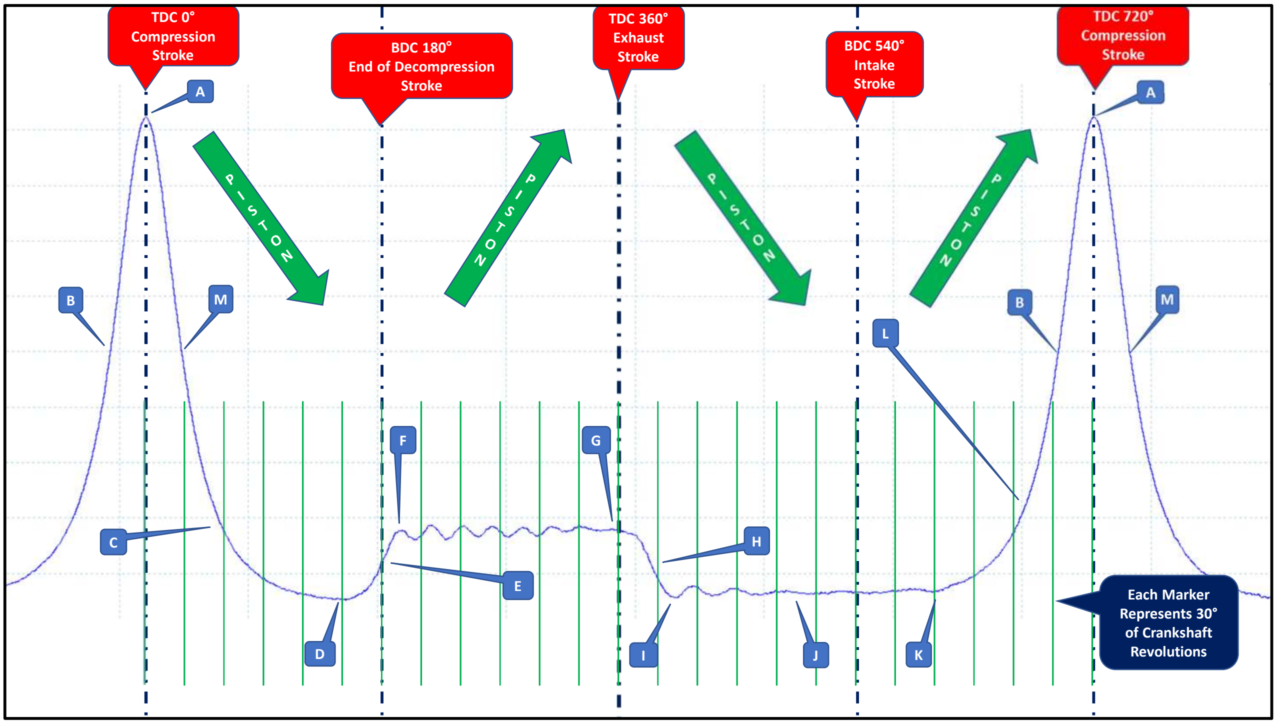
775-438-3424 (775) GET.DIAG


TDC 0°
Compression
Stroke
BDC 180°
End of Decompression
Stroke
TDC 360°
Exhaust
Stroke
BDC 540°
Intake
Stroke
TDC 720°
Compression
Stroke
PISTON
PISTON
PISTON
PISTON
A
B
C
D
E
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K
L
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A
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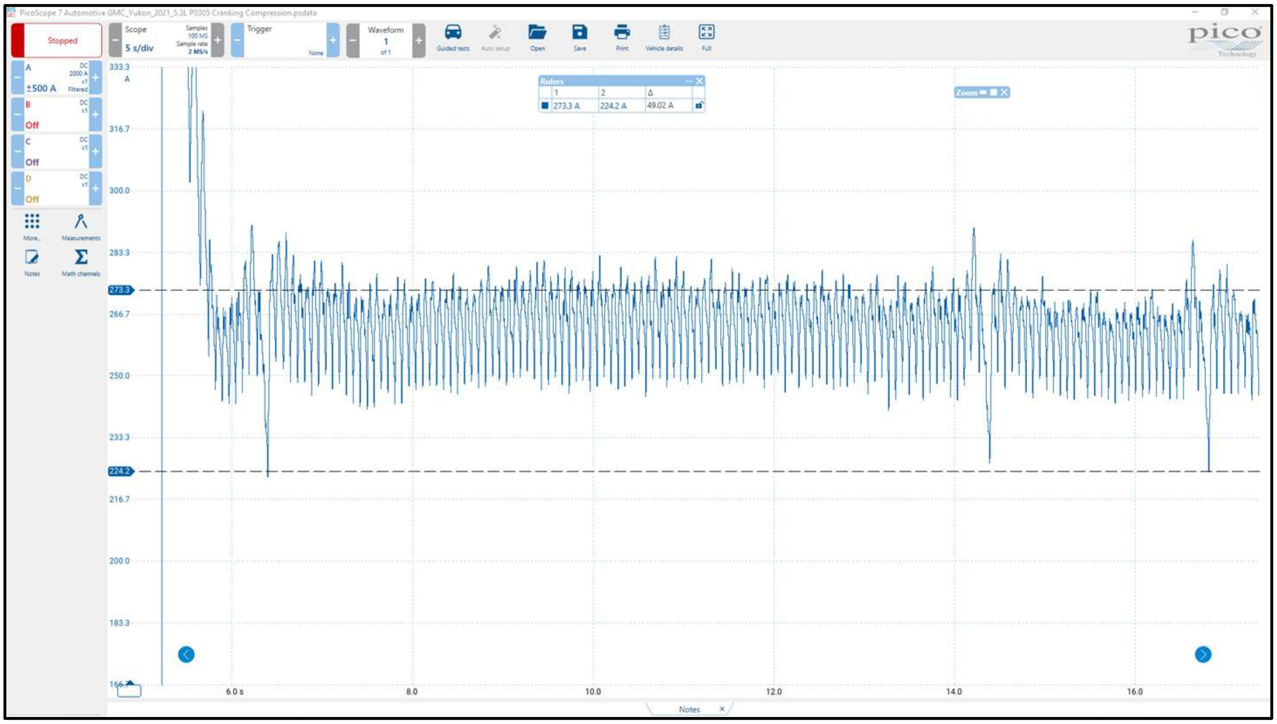
M
Each Marker
Represents 30°
of Crankshaft
Revolutions

Intake Lobes


PicoScope 7 Automotive GMC_Yukon_2021_5.3L P0305 Cranking Compression.psdata
Stopped
Scope
5 s/div
Samples 100 MS
Sample rate 2 MS/s
Trigger
None
Waveform
1
of 1
Guided tests
Auto setup
Open
Save
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Vehicle details
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A
DC
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x1
±500 A
Filtered
B
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C
Off
D
Off
More...
Measurements
Notes
Math channels
Rulers
1
2
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273.3 A
224.2 A
49.02 A
Zoom
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316.7
300.0
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273.3
266.7
250.0
233.3
224.2
216.7
200.0
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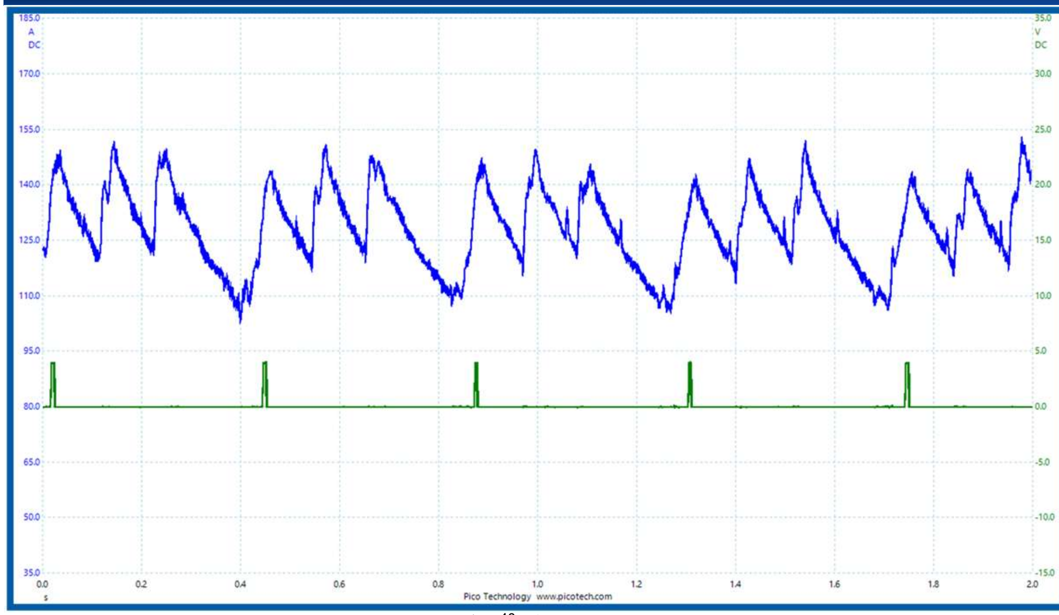
6.0 s
8.0
10.0
12.0
14.0
16.0
Notes

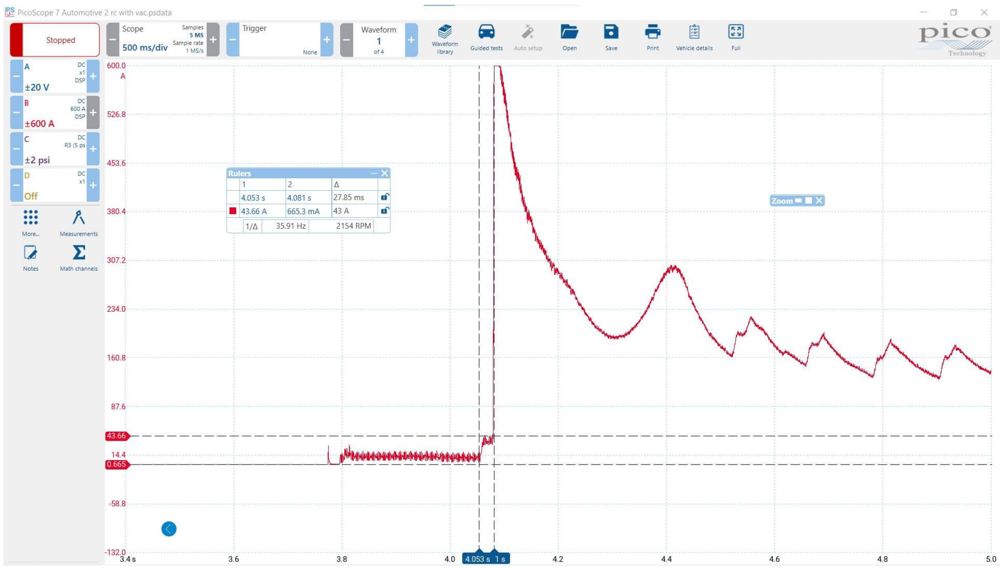
2007 Mazda GDI 4cyl



40

Mazda Example High Fuel Pressure Leak and Low Compression

Remember This?



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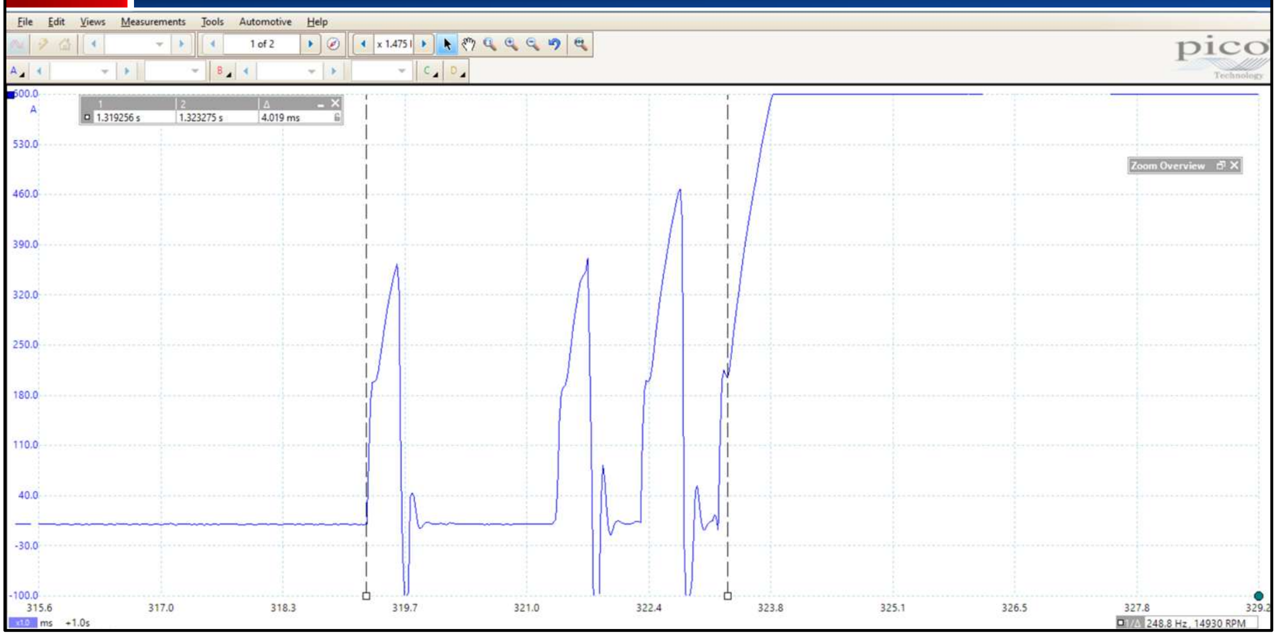
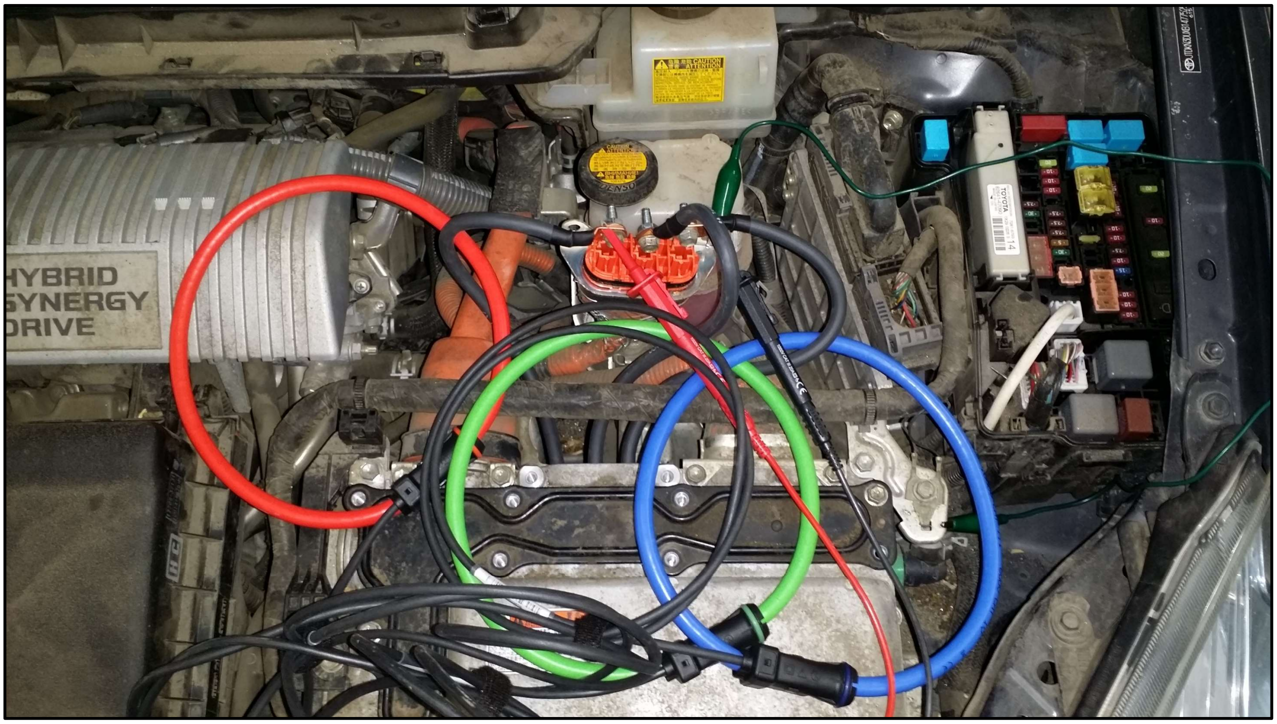
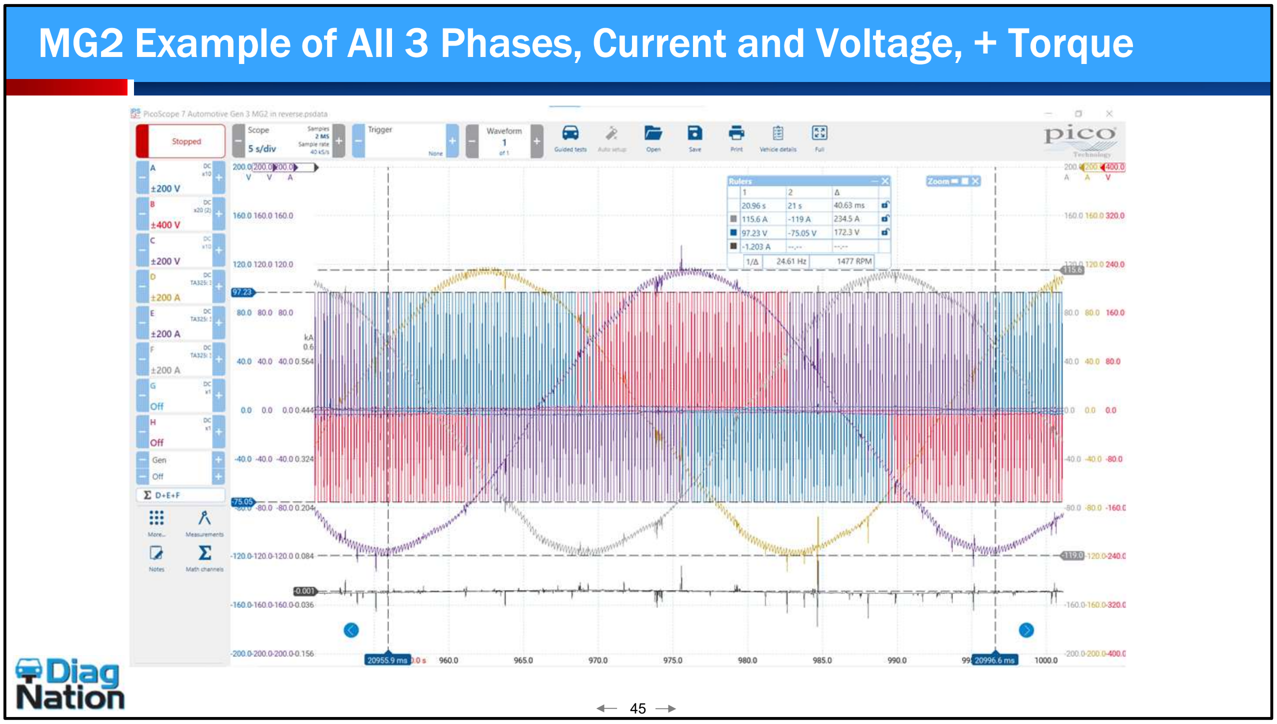
Bad Starter Solenoid





This is a unique set of three current probes that we use when working on three phase electrical motors. These current probes are Rogowski design. It is not necessary to use this type of current probe for this testing these are just a selection of what I have.



There is quite a bit of detail in the waveform above. As explained in class the math channel in the bottom in black is the addition of all three current probes equaling the “0” total current sum.

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Parasitic Draw

A few Tips 'n Tricks

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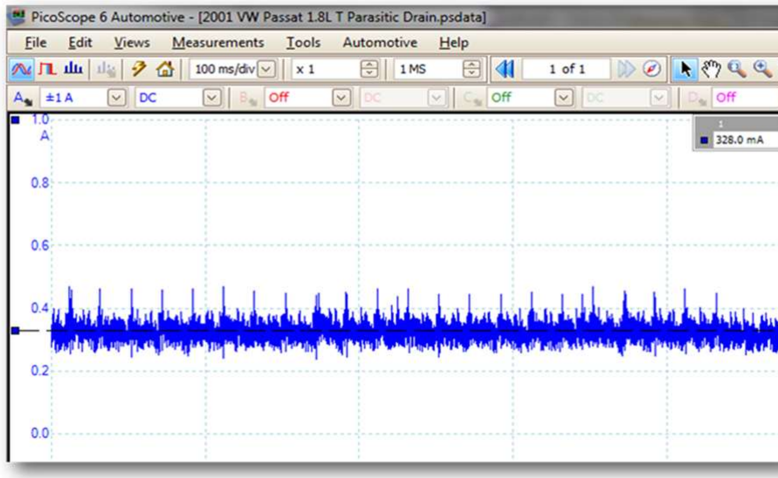
2001 Audi 326mA Draw

- Battery is dead almost every morning
- Various electrical concerns



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← 47 →

We will start our look at current probes, or clamps, by taking on a straightforward case study. We have a 2001 Volkswagen Passat with a customer complaint of the battery going dead overnight. The owner also complains of a variety of electrical concerns from the intermittent flashing of warning lights to alarm buzzers sounding for no apparent reason.

2001 Audi Transmission Module (If Only it Was Always This Easy☺)

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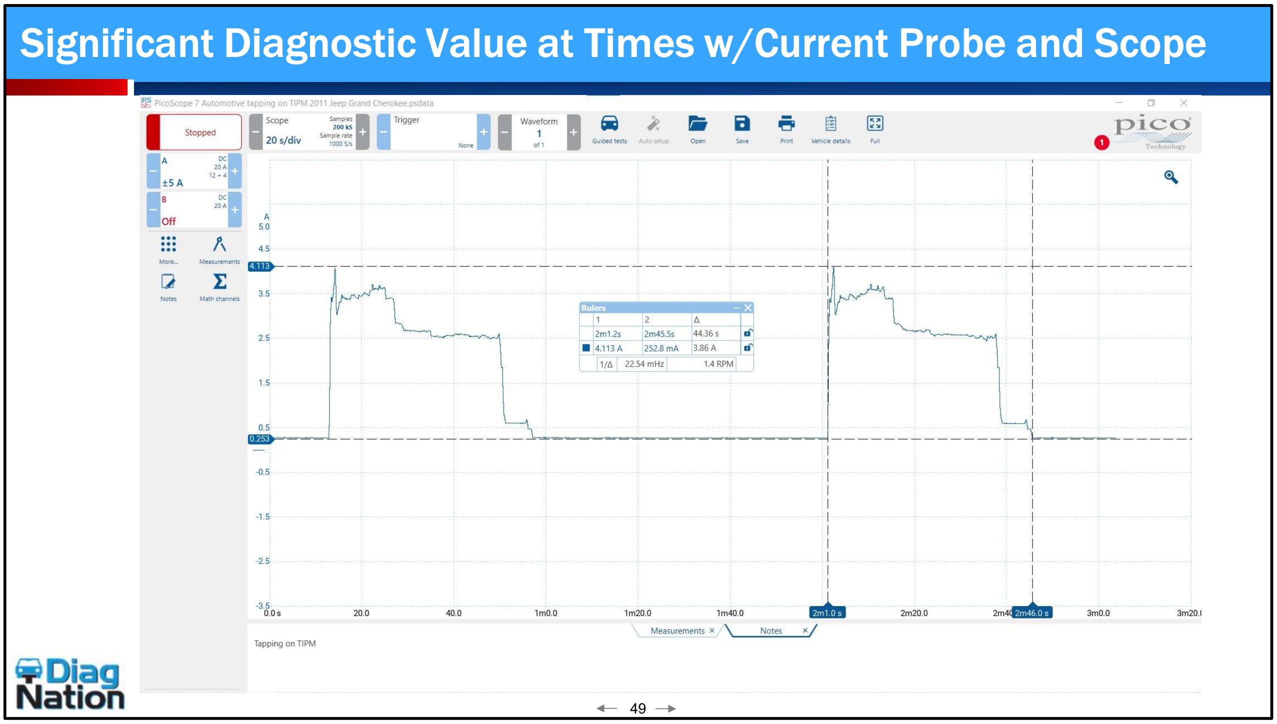
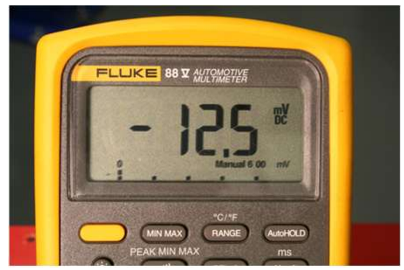
This 2001 Audi Allroad transmission module is located under the passenger's seat. In vehicles that have modules located under the seats on the floor, you should naturally expect this type of thing. If the vehicle has a sun or moon roof, make sure the drains are not plugged. Things like this can take down an entire bus (or two ☺).



There can be significant diagnostic value using a current probe in a scope to watch the pattern of a current draw. This is an example of a bad TIPM out of a Jeep. It had a very repetitive current draw that produced the same pattern as it turned on and off modules.

Current Probes and DVOM

- Also, a great combination
- Typically read on the mv Scale
- Be very careful with switch settings and decimal placements



Actual value 125ma

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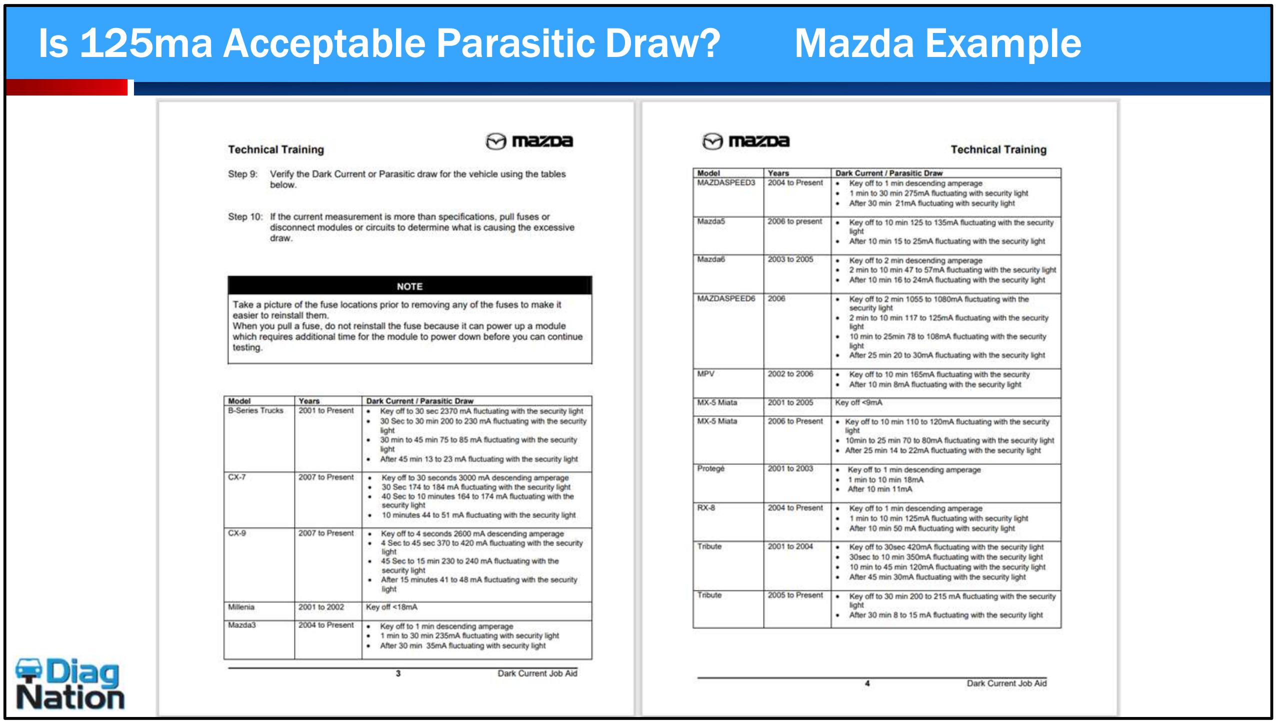
The modern method for detecting parasitic draw is with an **inductive low amp probe**. Before the probe can be installed on the vehicle, the probe must be **zeroed** to the multimeter to avoid false readings.



Technical Training

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Step 9: Verify the Dark Current or Parasitic draw for the vehicle using the tables below.

Step 10: If the current measurement is more than specifications, pull fuses or disconnect modules or circuits to determine what is causing the excessive draw.

NOTE

Take a picture of the fuse locations prior to removing any of the fuses to make it easier to reinstall them.
When you pull a fuse, do not reinstall the fuse because it can power up a module which requires additional time for the module to power down before you can continue testing.

Model	Years	Dark Current / Parasitic Draw
B-Series Trucks	2001 to Present	• Key off to 30 sec 2370 mA fluctuating with the security light • 30 Sec to 30 min 200 to 230 mA fluctuating with the security light • 30 min to 45 min 75 to 85 mA fluctuating with the security light • After 45 min 13 to 23 mA fluctuating with the security light
CX-7	2007 to Present	• Key off to 30 seconds 3000 mA descending amperage • 30 Sec 174 to 184 mA fluctuating with the security light • 40 Sec to 10 minutes 164 to 174 mA fluctuating with the security light • 10 minutes 44 to 51 mA fluctuating with the security light
CX-9	2007 to Present	• Key off to 4 seconds 2600 mA descending amperage • 4 Sec to 45 sec 370 to 420 mA fluctuating with the security light • 45 Sec to 15 min 230 to 240 mA fluctuating with the security light • After 15 minutes 41 to 48 mA fluctuating with the security light
Millenia	2001 to 2002	Key off <18mA
Mazda3	2004 to Present	• Key off to 1 min descending amperage • 1 min to 30 min 235mA fluctuating with security light • After 30 min 35mA fluctuating with security light

3 Dark Current Job Aid

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Technical Training

Model	Years	Dark Current / Parasitic Draw
MAZDASPEED3	2004 to Present	• Key off to 1 min descending amperage • 1 min to 30 min 275mA fluctuating with security light • After 30 min 21mA fluctuating with security light
Mazda5	2006 to present	• Key off to 10 min 125 to 135mA fluctuating with the security light • After 10 min 15 to 25mA fluctuating with the security light
Mazda6	2003 to 2005	• Key off to 2 min descending amperage • 2 min to 10 min 47 to 57mA fluctuating with the security light • After 10 min 16 to 24mA fluctuating with the security light
MAZDASPEED6	2006	• Key off to 2 min 1055 to 1080mA fluctuating with the security light • 2 min to 10 min 117 to 125mA fluctuating with the security light • 10 min to 25min 78 to 108mA fluctuating with the security light • After 25 min 20 to 30mA fluctuating with the security light
MPV	2002 to 2006	• Key off to 10 min 165mA fluctuating with the security • After 10 min 8mA fluctuating with the security light
MX-5 Miata	2001 to 2005	Key off <9mA
MX-5 Miata	2006 to Present	• Key off to 10 min 110 to 120mA fluctuating with the security light • 10min to 25 min 70 to 80mA fluctuating with the security light • After 25 min 14 to 22mA fluctuating with the security light
Protegé	2001 to 2003	• Key off to 1 min descending amperage • 1 min to 10 min 18mA • After 10 min 11mA
RX-8	2004 to Present	• Key off to 1 min descending amperage • 1 min to 10 min 125mA fluctuating with security light • After 10 min 50 mA fluctuating with security light
Tribute	2001 to 2004	• Key off to 30sec 420mA fluctuating with the security light • 30sec to 10 min 350mA fluctuating with the security light • 10 min to 45 min 120mA fluctuating with the security light • After 45 min 30mA fluctuating with the security light
Tribute	2005 to Present	• Key off to 30 min 200 to 215 mA fluctuating with the security light • After 30 min 8 to 15 mA fluctuating with the security light

4 Dark Current Job Aid

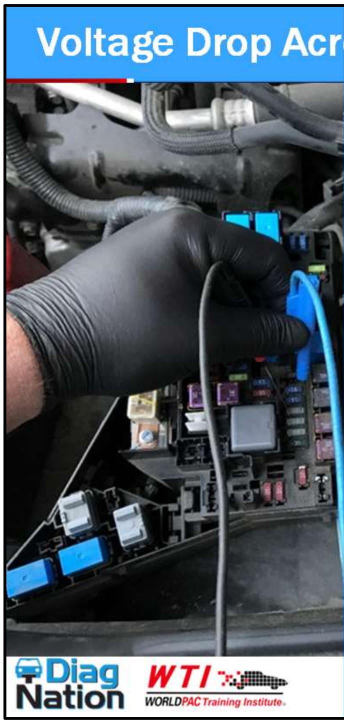
Most manufacturers do not print specifications for parasitic draw. Here is an article found put out by Mazda that gives us an idea that even within one manufacture there can be several different acceptable values.

Reserve Capacity (Automobile)= 25a Load Until 10.5v in Minutes

80 x .25 = 20ma

120 x .25 = 30ma

General rule of thumb, divide the RC by 4 and this is the maximum amount of parasitic draw



Fuse Color	Grey	Violet	Pink	Tan	Brown	Red	Blue	Yellow	Clear	Green
Measurement mV	Mini 2 Amp	Mini 3 Amp	Mini 4 Amp	Mini 5 Amp	Mini 7.5 Amp	Mini 10 Amp	Mini 15 Amp	Mini 20 Amp	Mini 25 Amp	Mini 30 Amp
0.1	2	3	4	6	9	13	22	31	42	54
0.2	4	6	9	11	18	27	44	62	85	108
0.3	5	9	13	17	28	40	66	93	127	162
0.4	7	12	17	23	37	54	87	125	169	216
0.5	9	15	21	28	46	67	109	156	212	270
0.6	11	18	26	34	55	81	131	187	254	324
0.7	13	21	30	39	65	94	153	218	297	378
0.8	14	24	34	45	74	108	175	249	339	432
0.9	16	27	38	51	83	121	197	280	381	486
1	18	30	43	56	92	135	218	312	424	541
1.1	20	33	47	62	101	148	240	343	466	595
1.2	22	36	51	68	111	162	262	374	508	649
1.3	23	39	55	73	120	175	284	405	551	703
1.4	25	41	60	79	129	189	306	436	593	757
1.5	27	44	64	85	138	202	328	467	636	811
1.6	29	47	68	90	147	216	349	498	678	865
1.7	31	50	72	96	157	229	371	530	720	919
1.8	32	53	77	101	166	243	393	561	763	973
1.9	34	56	81	107	175	256	415	592	805	1027
2	36	59	85	113	184	270	437	623	847	1081
2.1	38	62	89	118	194	283	459	654	890	1135
2.2	40	65	94	124	203	296	480	685	932	1189
2.3	41	68	98	130	212	310	502	717	975	1243
2.4	43	71	102	135	221	323	524	748	1017	1297
2.5	45	74	106	141	230	337	546	779	1059	1351
2.6	47	77	111	146	240	350	568	810	1102	1405
2.7	49	80	115	152	249	364	590	841	1144	1459
2.8	50	83	119	158	258	377	611	872	1186	1514
2.9	52	86	124	163	267	391	633	903	1229	1568
3	54	89	128	169	276	404	655	935	1271	1622
3.1	56	92	132	175	286	418	677	966	1314	1676

Charts have been developed to help technicians determine the level of amperage flowing through a fuse that is creating a measurable voltage drop. These charts can be obtained from the **Power Probe website** or other information systems. The charts reference **amperage draw** versus **voltage drop** at the fuse. Multiple charts are available for each fuse type and amperage rating. The chart for our mini fuse ranges form a **.1 mV** drop to a **10 mV** drop across the fuse. The charts convert **measured millivolt voltage drop** to the **approximate milliamp current flow** in a circuit.

Thermal Imaging for Finding Draws, Resistance, etc.

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54

With technology increases in capabilities, infrared temperature sensing is one of the fastest ways to locate a parasitic draw.

Draw Measurement for Long Monitoring Periods

Shunt Resistor Current Measurements

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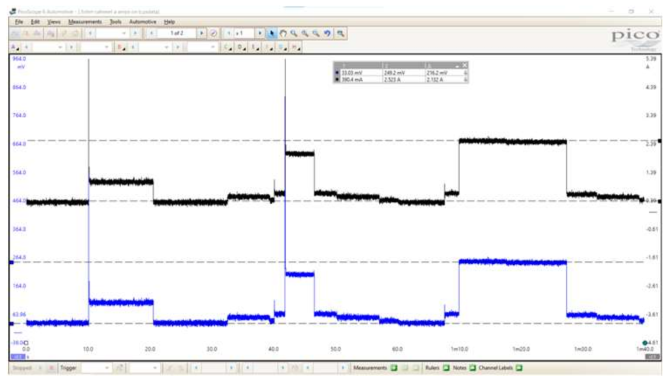
← 55 →

Here is a way to do extended time parasitic draw measurements. In this case we're installing a shunt resistor and utilizing ohm's law we can measure the voltage drop across the resistor to determine the amount of current flow.

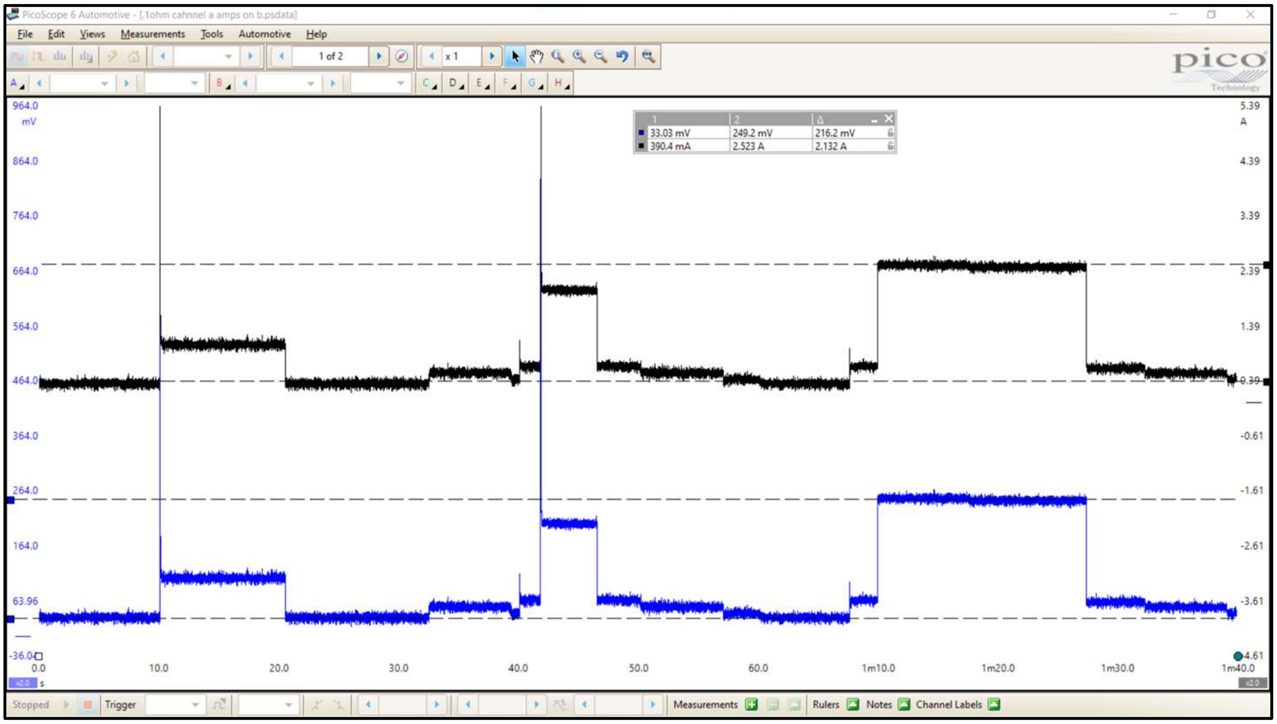
0.1 Ohm 100w Resistor Results w/Math Channel

- Channel A in Blue
  - Voltage drop
  - Resistor 100w 0.1 ohm
  - +/- 5% accuracy
- Math Channel in Black
  - Voltage drop/resistance = amps
  - .249v/0.1 = 2.5a

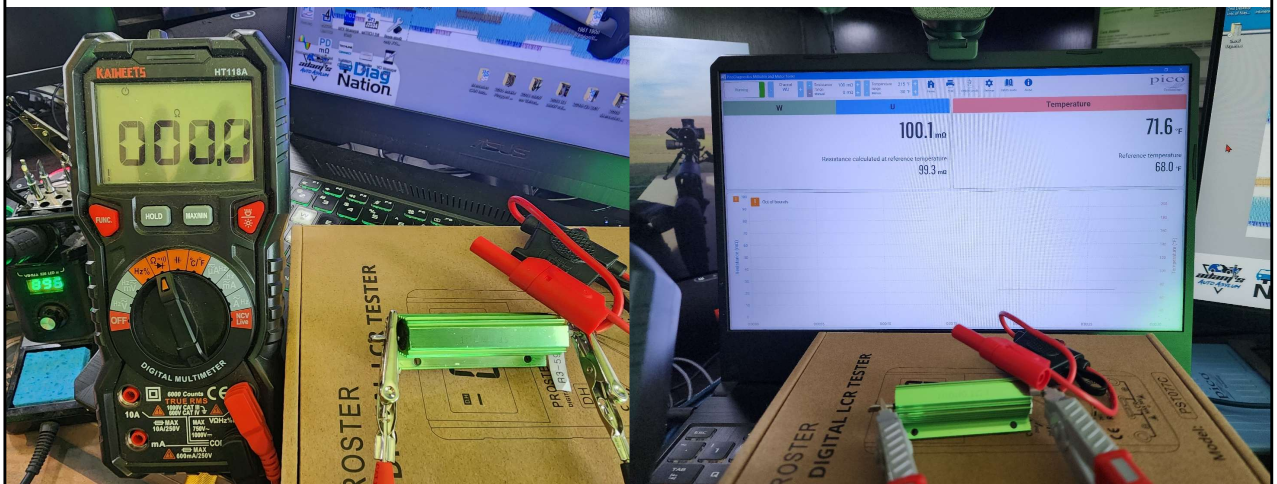


56

In the picture above you can see the value of our resistor and the math channel equation to turn voltage drop into current flow.

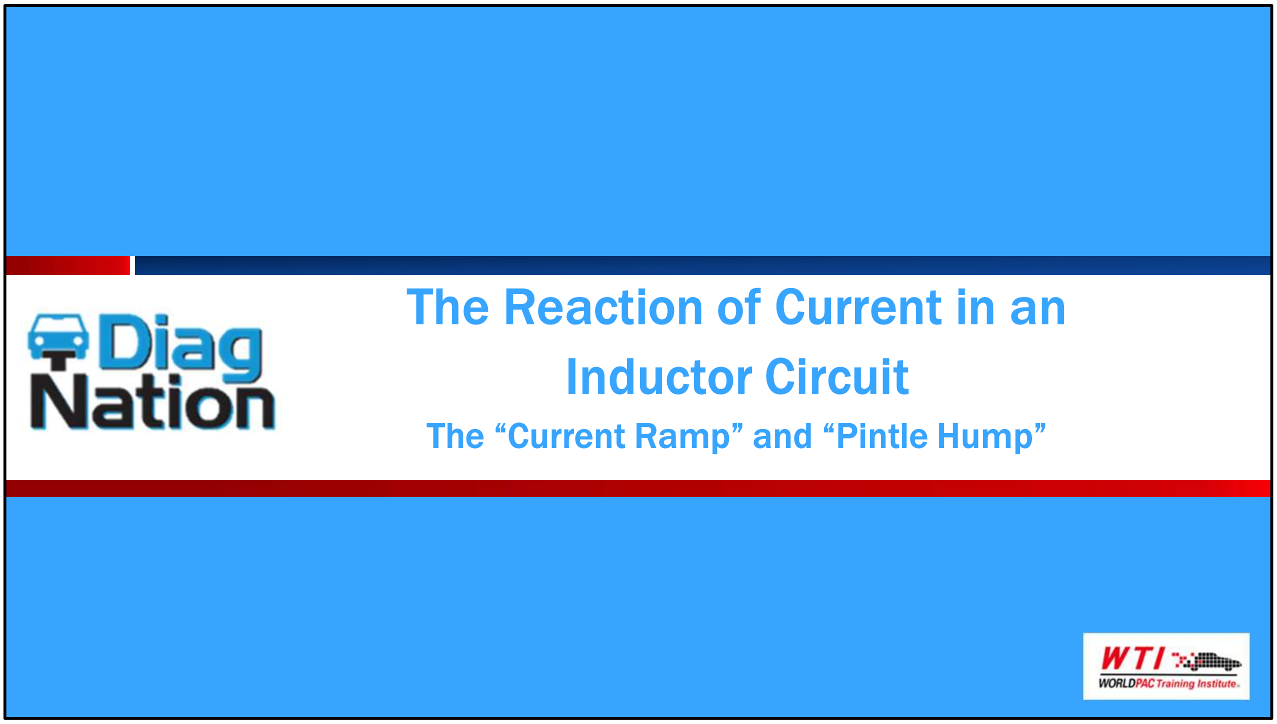

File Edit Views Measurements Tools Automotive Help
1 of 2
x 1
pico
964.0 mV
864.0
764.0
664.0
564.0
464.0
364.0
264.0
164.0
63.96
-36.0
5.39 A
4.39
3.39
2.39
1.39
0.39
-0.61
-1.61
-2.61
-3.61
-4.61
33.03 mV 249.2 mV 216.2 mV
390.4 mA 2.523 A 2.132 A
0.0 10.0 20.0 30.0 40.0 50.0 60.0 1m10.0 1m20.0 1m30.0 1m40.0
s
Stopped Trigger Measurements Rulers Notes Channel Labels

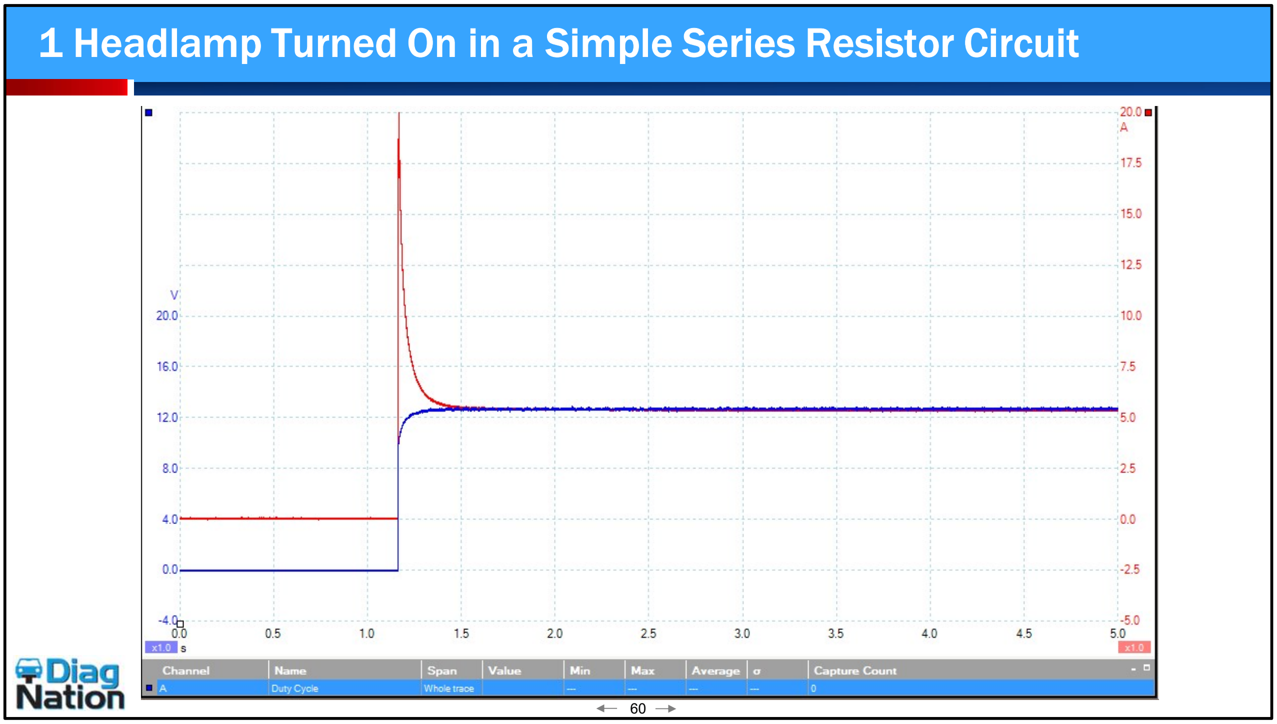
Equipment Challenges Ohm Meter Example



58

This is an example of using a standard ohm meter and the milli ohmmeter to measure the static resistance of our .1-ohm resistor. This demonstration does a good job of showing the accuracy difference between the two meters.

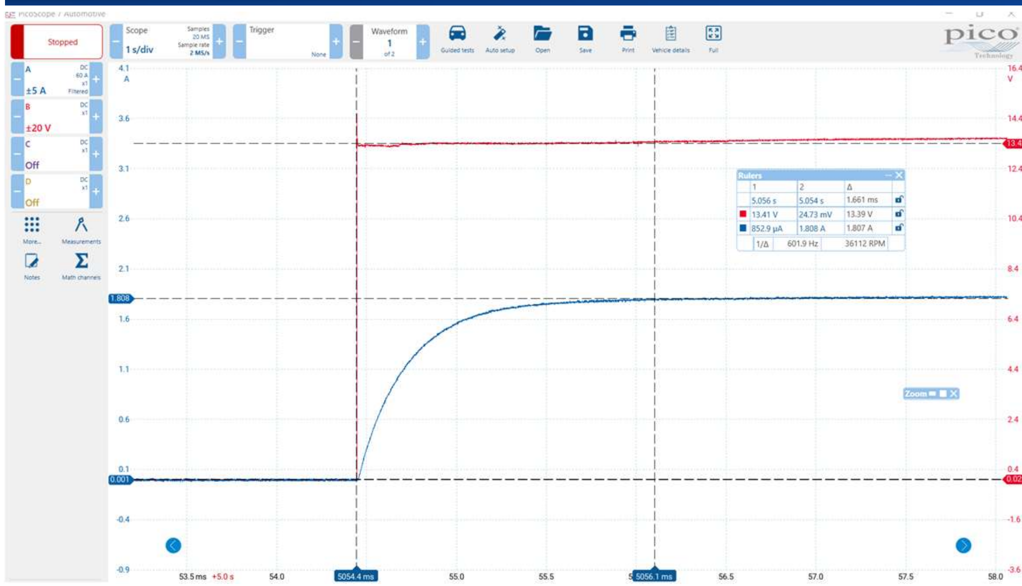

The Reaction of Current in an Inductor Circuit
The “Current Ramp” and “Pintle Hump”



This is a waveform from a single high beam headlamp when it is turned on. A practical usage of Ohm’s law tells us that as the bulb heats up and begins emitting light, the resistance of the bulb increases. 12.2 volts and 6.2 amps tells us that this bulb is drawing 75.6 watts once fully lit. Remember that for a little bit as we are going to go back to that.

Most of use don’t think about the initial amperage draw on a light when it gets turned on, only if the circuit shorts out. This is probably going to get the question as to why the fuses don’t blow because 2 bulbs is going to be a 40 amp pull. The answer is that the fuse won’t blow in such a small amount of time.

The Reaction Of Current/Voltage in an Inductor Circuit “On”



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← 61 →

This is the reaction of current and voltage in an inductor circuit when turned on. It looks significantly different than the last picture of the resistor circuit. Current is on the bottom in blue in this picture with voltage on the top and red.

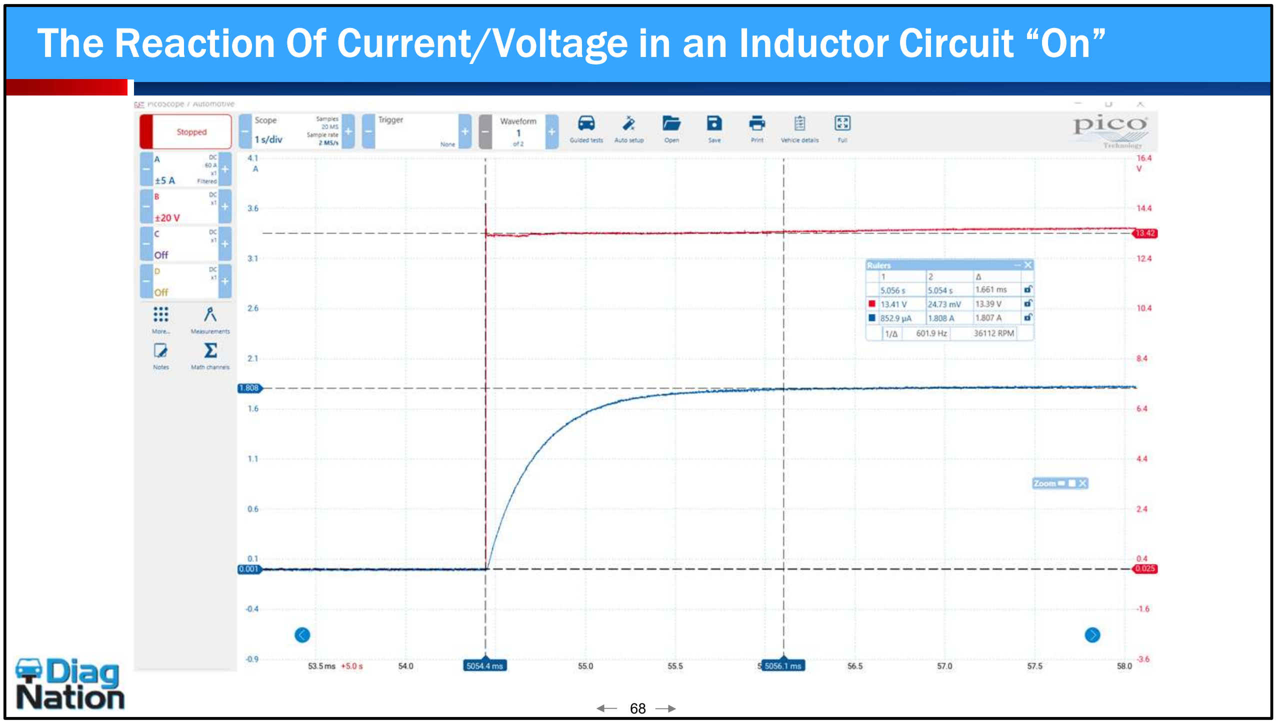
Now, we will use a **digital storage scope** (**DSO**) to look at the same measurements. Because the DSO shows us voltage ***over time***, it appears as a simple waveform straight across the screen.

With the DSO, we see the voltage ***as it falls***, and there is very little potential between reference ground and where we are placing our **RED** lead.

When the ground is removed and the circuit opens again, we see just the ***opposite*** happen. The potential between where we are measuring, and ground reference has a ***larger*** difference. This waveform shows how fast voltage responds. The last two slides captured the change in voltage as a solenoid was turned **on** and **off**.

We will turn the solenoid **on** and **off** exactly like the last test when we were using a DVOM to watch voltage. This time we will use a **low amp current probe** or **LACP** and watch current.

The LACP is connected where the positive voltmeter lead was placed and shows no current is flowing through the open circuit.



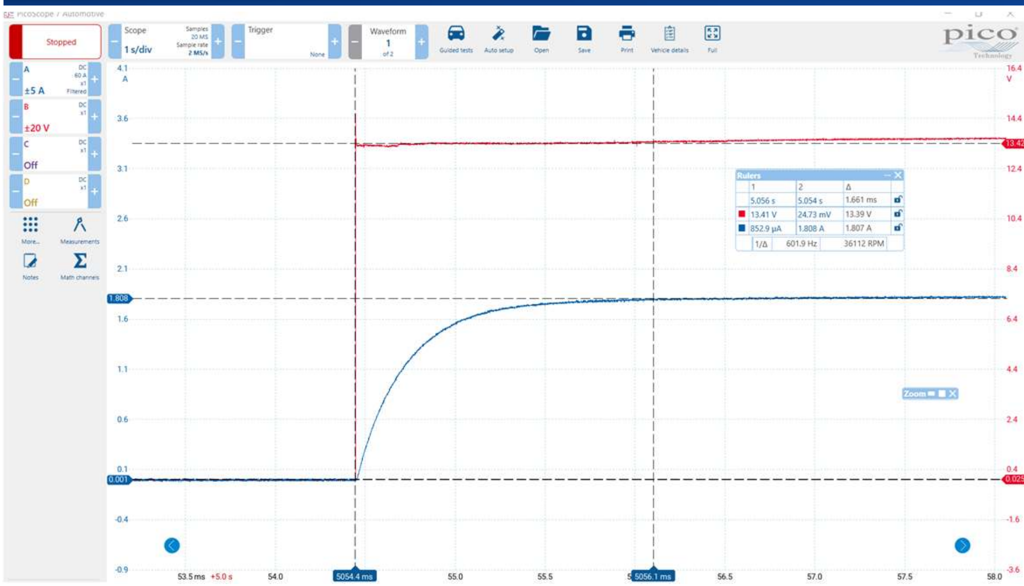
As we turn the circuit on, we can see that the voltage reacted very quickly, but the current seemed slow to achieve full saturation.

If current passes through a conductor, a ***weak*** magnetic field is created. The magnetic flux lines are at right angles to the conductor. The strength of the magnet field ***decreases*** as the lines move further away from the conductor. The strength is also affected by the overall power flowing through the conductor.

You can dramatically increase the strength of the field by creating a coil with the conductor. The lines of force will interact and reinforce each other dramatically increasing the strength of the magnetic field. The number of turns of the conductor determine the strength of the magnetic field. A coiled conductor is called an **inductor**.

This coil is also called an **inductor**. An inductor is a coil of insulated wire wound around a common core. The core may be iron or any other magnetic material. It could be a cardboard tube filled with only air. The image is an ignition coil that I took apart.

This Counter Electromotive Force “Slows” The Current Build



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← 71 →

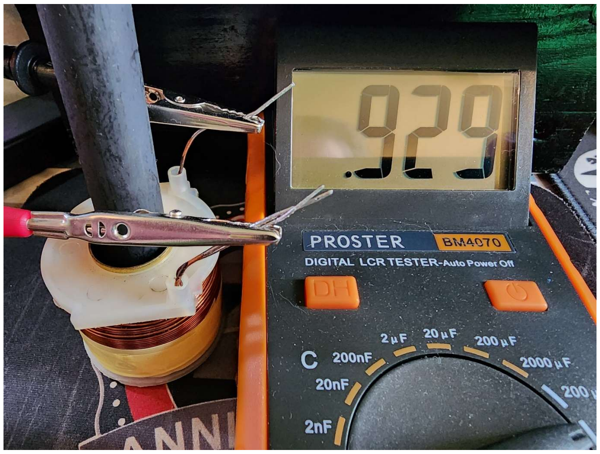
This coil is connected to the battery of the vehicle, and we are measuring the current through it.

We placed an iron core (extension) into the coil windings. Inserting an iron core ***increases*** the magnetic field strength, or **inductance**, another form of energy.

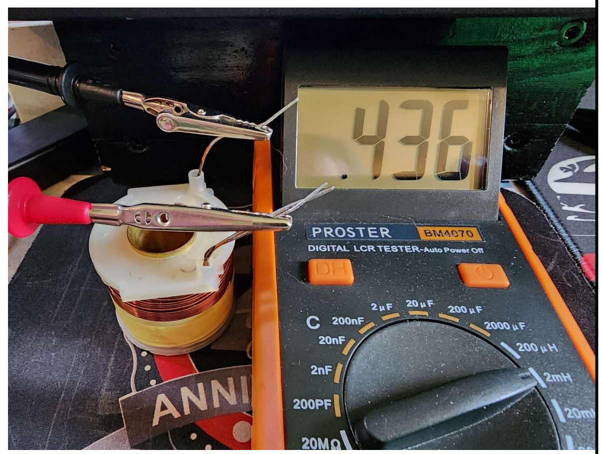
The inductance of any coil will be determined by different things:

- The width of the core
- The diameter of the conductor
- The number of turns
- The material of the core

Inductance/Henry Measurement Example



Iron/ferrous core installed 929 millihenries



No iron/ferrous core 436 millihenries

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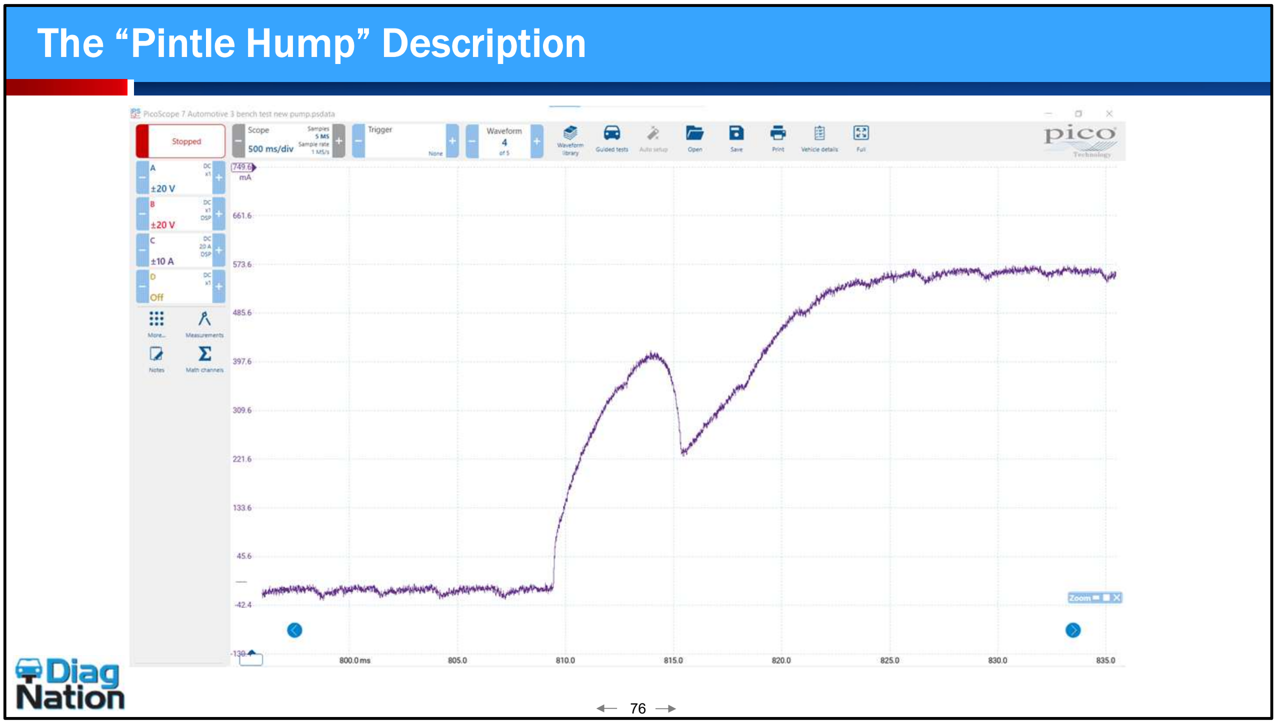
← 74 →

Here we are using an LCR tester to measure the inductance of our test inductor/solenoid.

The current flow ***decreased*** with the iron core in place.



This increase in Henries causes the current to momentarily drop. This allows us to see a ferrous material entering into the magnetic field. It proves mechanical work was achieved.

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The "Pintle Hump"

Non-Intrusive Diagnostics

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Solenoid & Actuator Operation

- A **solenoid** uses a magnetic field to move a center core
  - The core movement can be used like an **on/off** switch
  - The core may be **duty-cycled** to position the core in a certain spot within its travel

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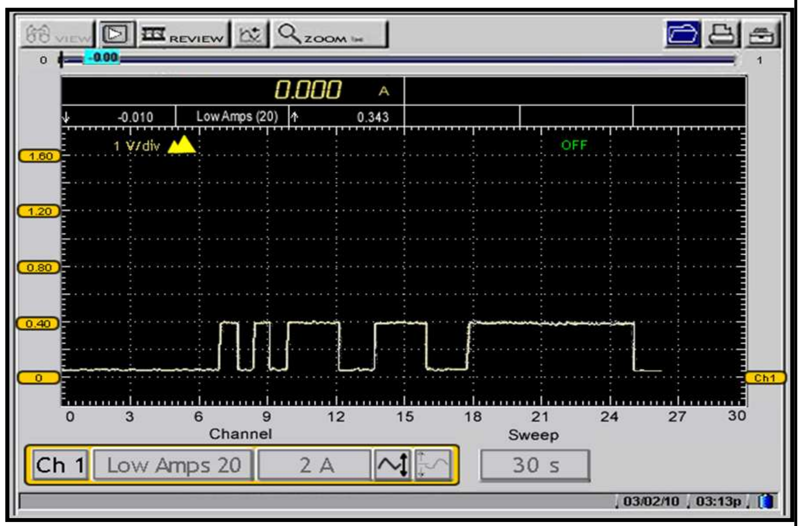
← 78 →

A **solenoid** uses a magnetic field to move a center core. The core may be used to **open** a valve, make electrical contacts, etc. The core movement can be used like an **on**/**off** switch like a starter solenoid, or the core movement may be ***duty-cycled*** to position the core in a certain spot within its travel like an EVAP purge solenoid.

2-3 Shift Solenoid Command On/Off

- Using the scanner bi-directional controls
- Turn the circuit on/off



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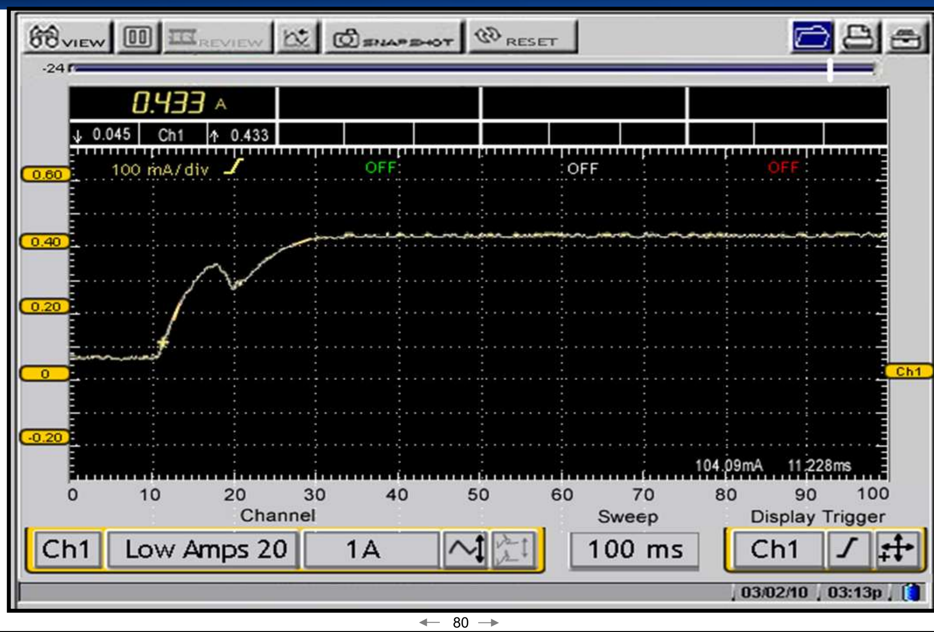
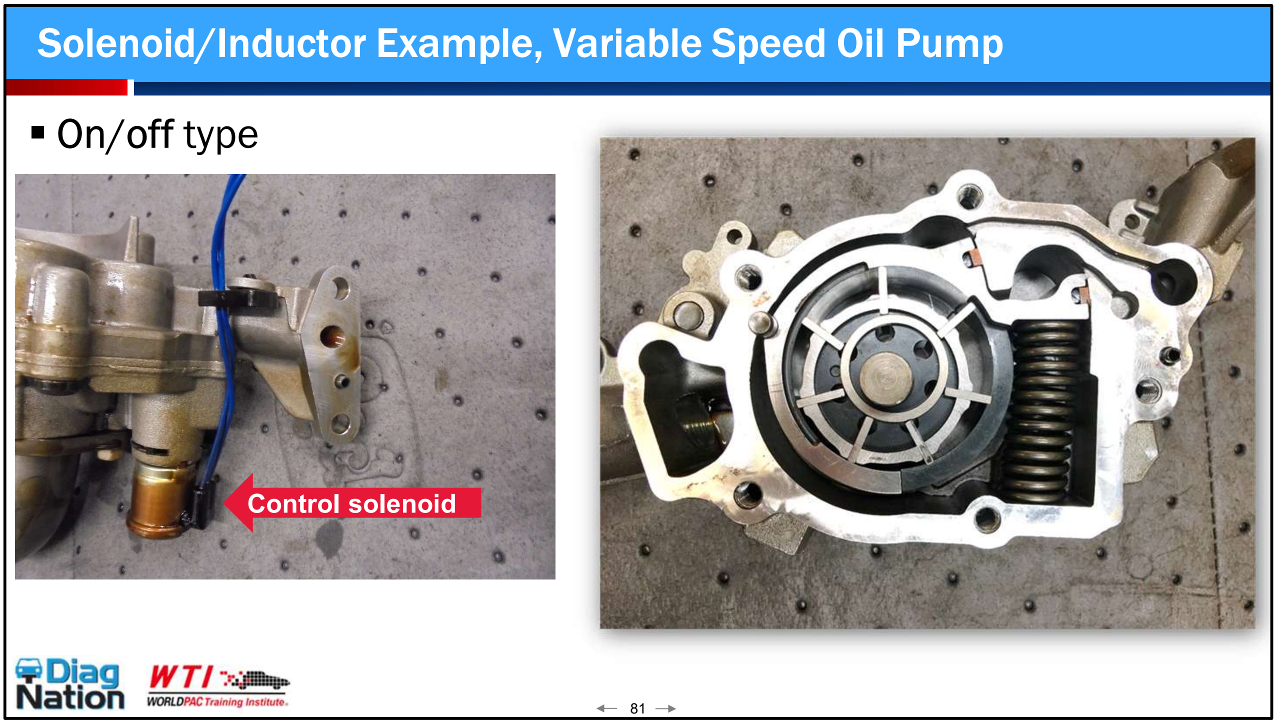
79

The solenoid was being turned **on** and **off**.
The current is starting at **0** and ***increasing***. This test is also good for getting a nominally weak solenoid to fail by keeping it energized. Scanner bidirectional controls were used to turn the 2-3 solenoid **off** and **on**.

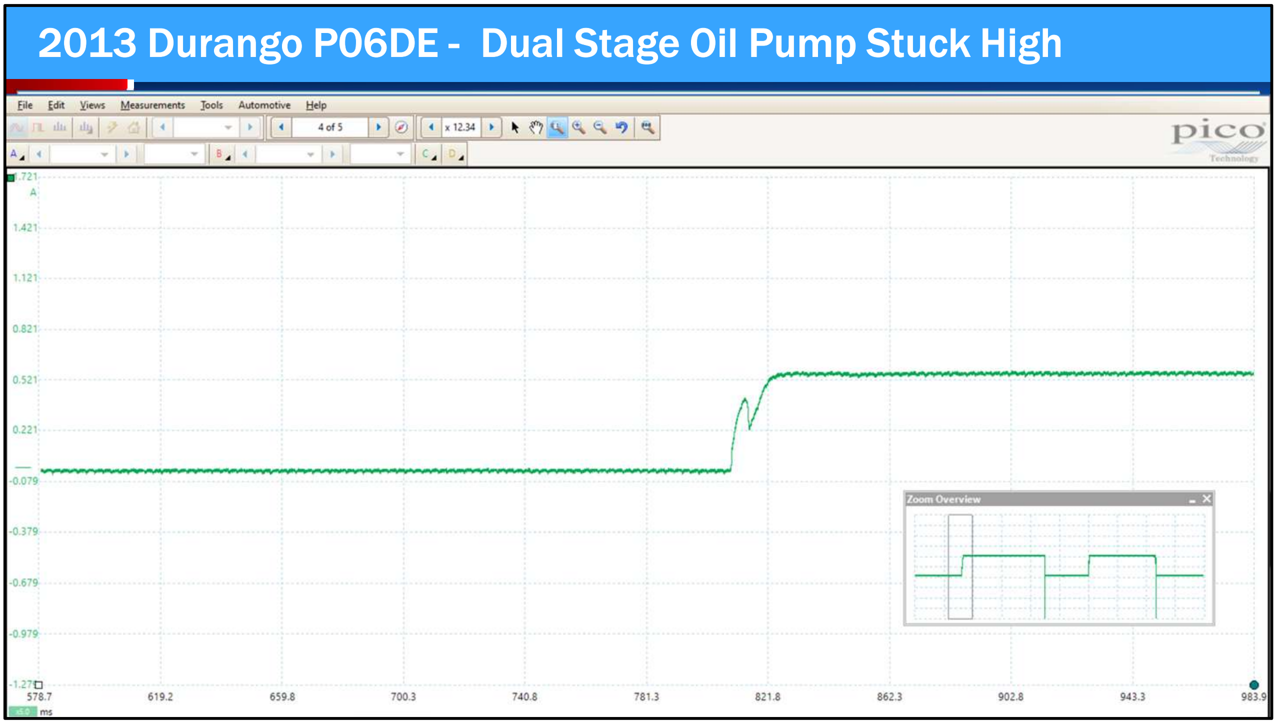
2-3 Shift Solenoid Commanded on 100 ms Screen Time



- We used the scan tool to command 2-3 **on** and capture this waveform.
- The solenoid is commanded **on** at about the 10 ms mark and the current starts to ***rise***.
- The current continues to ***rise*** and at about the 20 ms point, suddenly dips indicating that the valve in the solenoid ***moved***.
- This test proves that movement took place in the solenoid when the circuit is ***closed***.
- Using Ohm's law, calculate the solenoid resistance if the battery voltage was 14 V and the current was .4 A. (You should get about 28 ohms.)



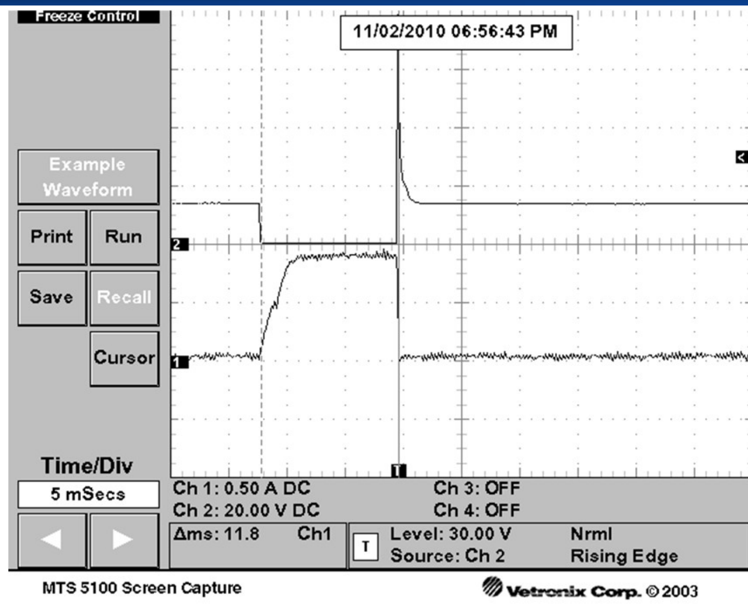
We are going to use an example off a charge 3.6-liter variable speed oil pump. This is a circuit that is simply commanded on and off. When in the off position the oil pressure defaults to high pressure.



Here is just a quick demonstration of a solenoid that is mechanically stuck but electrically fine. And its replacement part working perfectly.

So, after all the discussions we should be able to determine what happened in the picture above. We have a steady voltage but now a positive increase in current flow.

Injector #2 At Idle Voltage and Current



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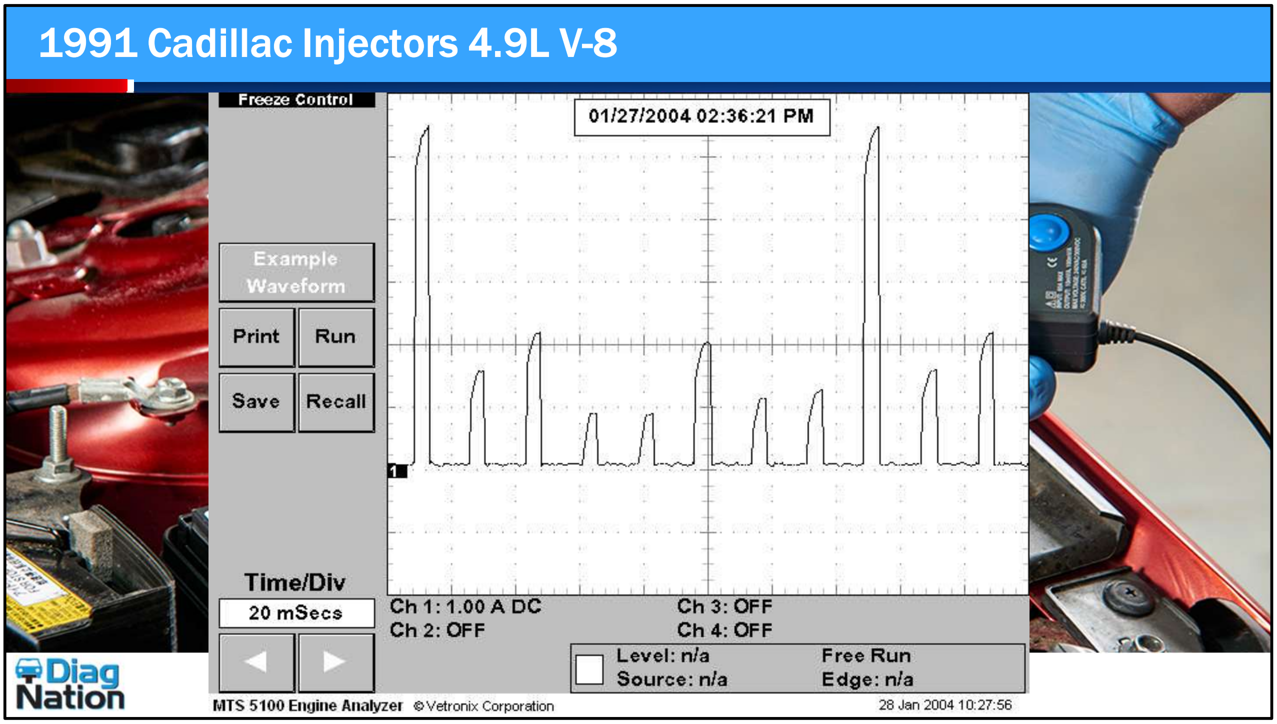
84

This is the injector waveform from **cylinder #2**. This style of injector control is referred to as a **saturated circuit**. The injector has a good constant power supply, and the ECM pulls it to ground and ***holds*** it (**saturates**) until the desired pulse width is achieved.

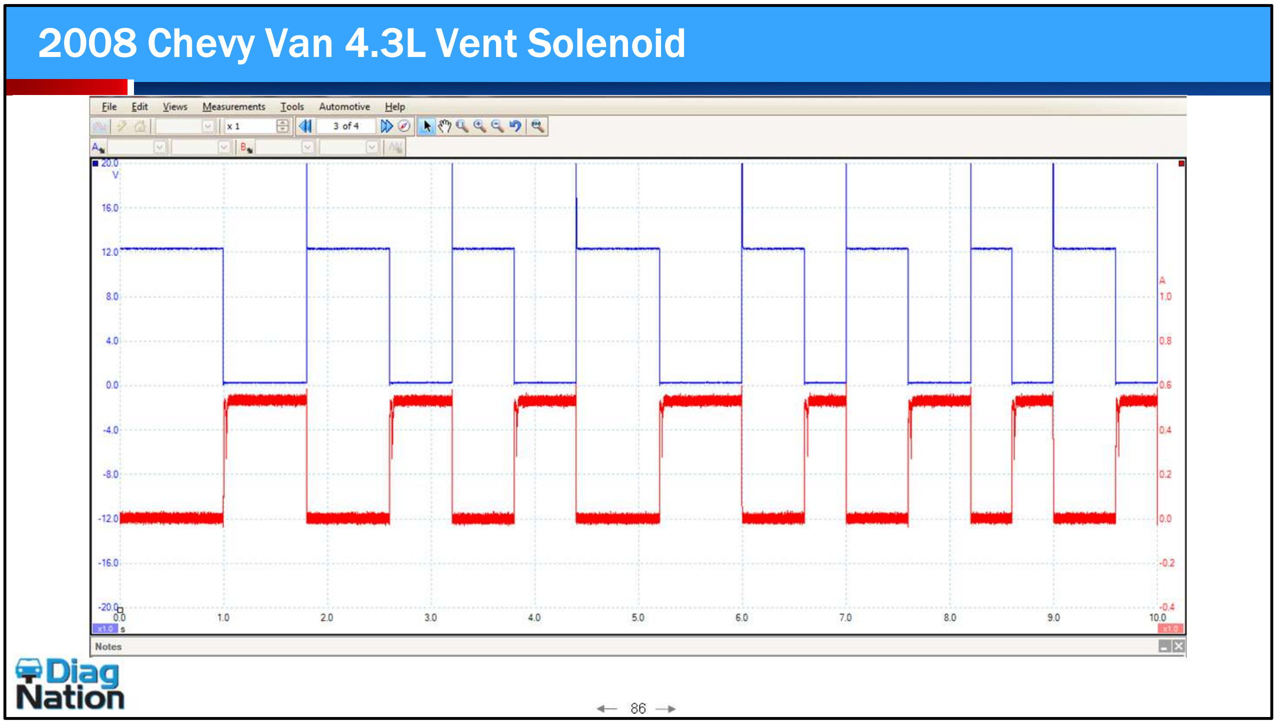
Channel 1: low amp current waveform
Channel 2: voltage signal on the control side

How does the pattern look?
What is the pulse width?
What is the ***bump*** in the ***rising*** ramp on the current?
What is the ***bump*** on the ***closing*** ramp of the voltage?



This is a waveform from a Cadillac 4.9L engine that runs ***rough*** and occasionally dies. All tune-up parts have been replaced. This waveform was taken at the fuse box. There are two fuses, one for each bank to control the power to all of the injectors. We pulled the fuses and installed two jumper wires and hooked a low amp current probe around both wires simultaneously. These are also saturated circuit injectors that typically have a resistance value of 12 - 16 ohms. If we performed the Ohm's law calculations with this data, we would see that they should draw just under **1 amp** each.

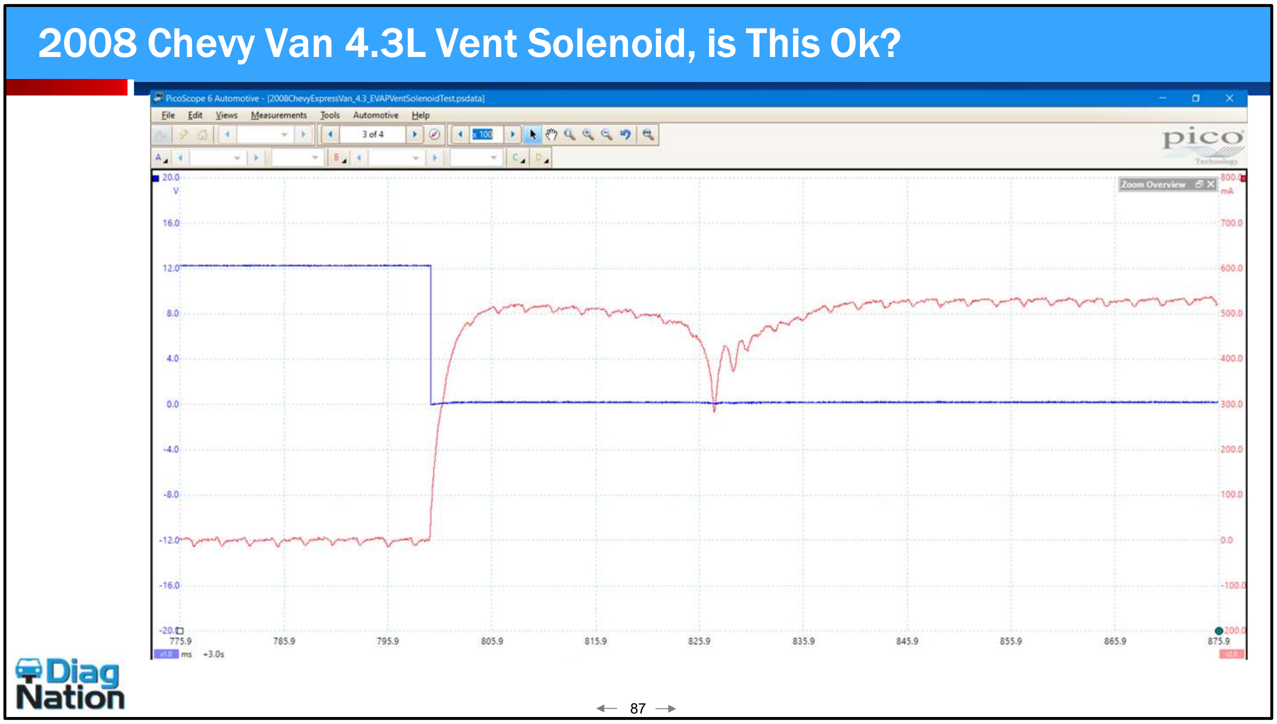
In this case, only two injectors are ***normal,*** all of the others are shorted to different levels. You should also note that the ***turn on*** ramps are very sharp and steep on the shorted ones; this will cause a late and weak building of the magnetic field. In most cases, the injector still **opens**, but with a reduced time. The other problem here is that the PCM cannot properly handle the excessive current draw and will do strange things like: stalling, codes, no-starts, communications issues, high emissions, rough running, etc. This is extremely common with Rochester Products and Multec injectors from GM.



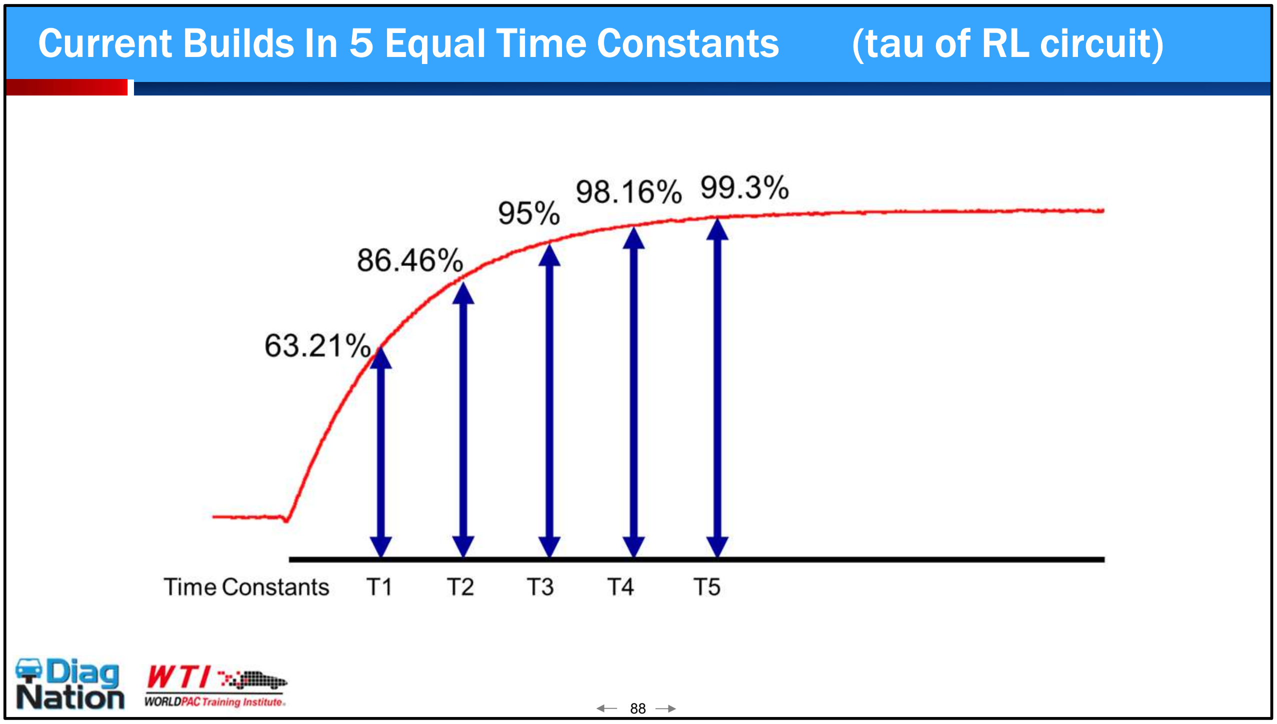
2008 Chevy Express Van 4.3 V6 (Vin-W) with DTC **P0446**

The vent solenoid moves, as you can see, but the vent still leaked on this vehicle even when ***closed***.

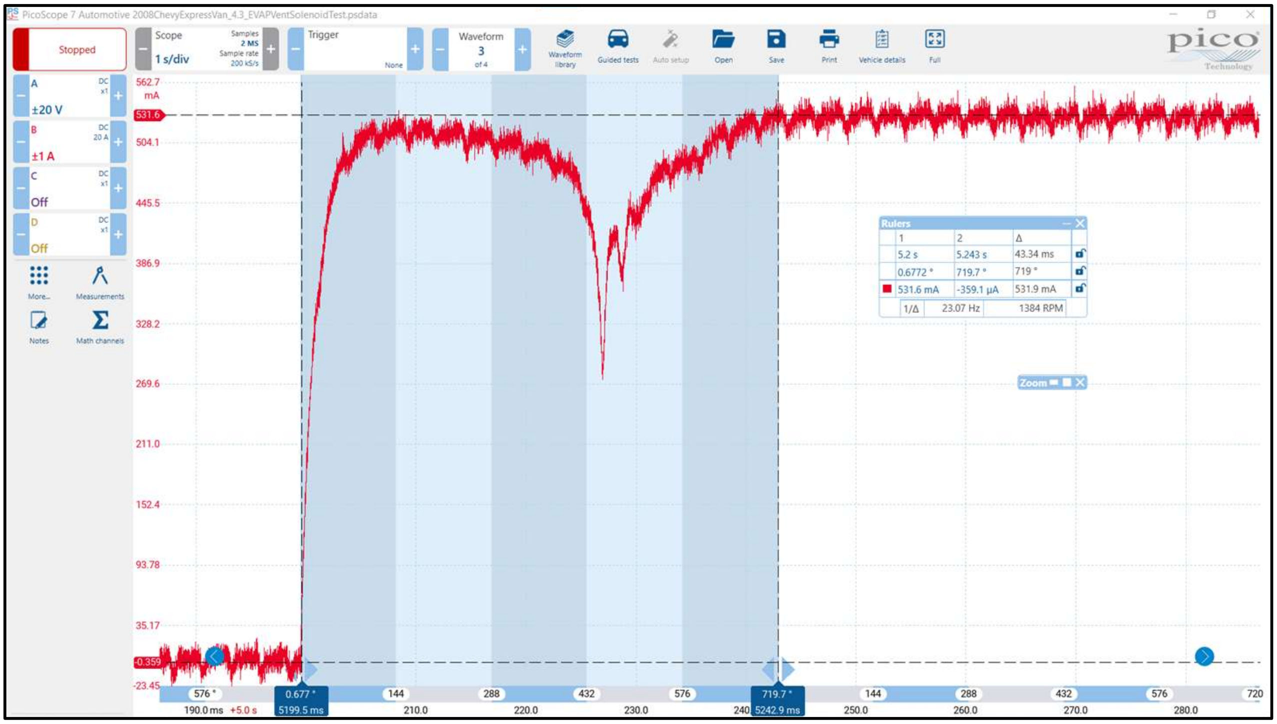
Channel A - BLUE (top): Voltage command to the vent solenoid control from PCM
Channel B – RED (bottom): Low current probe on the vent solenoid power wire



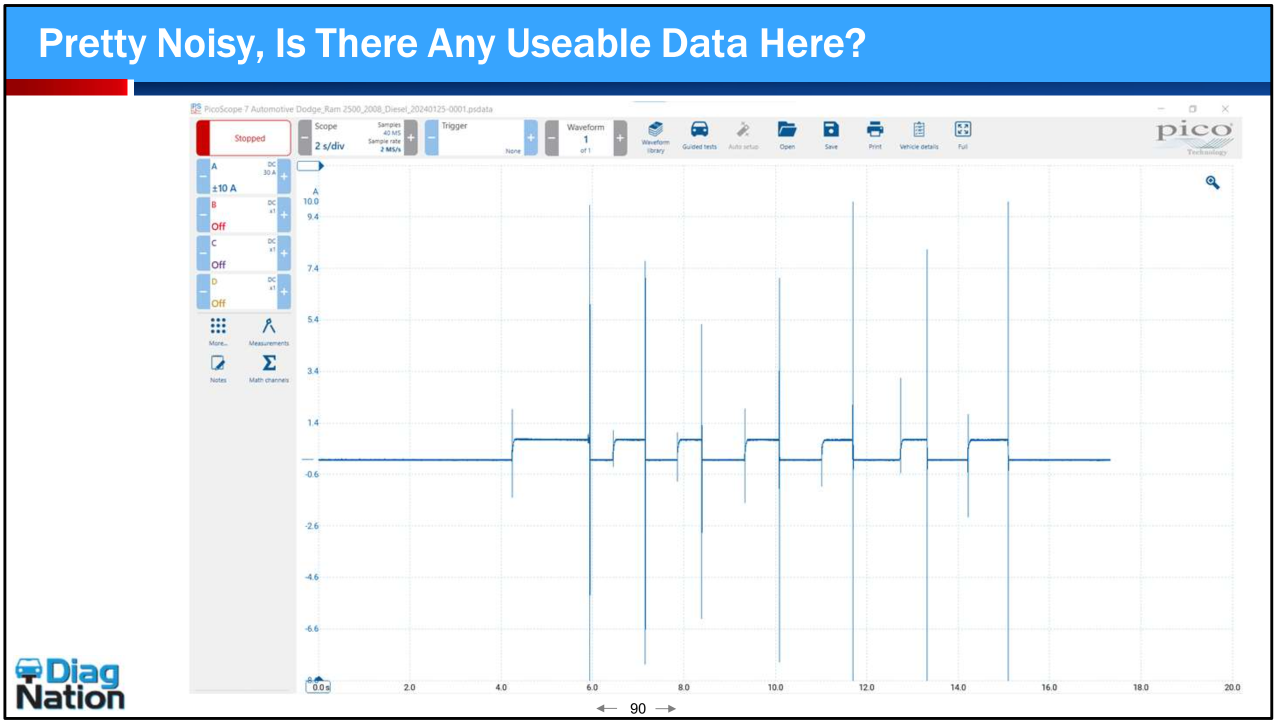
Here we are looking at a zoom in on one event. Now, we can see the ***pintle hump*** of the solenoid performing mechanical work. Even though we could prove that it physically moved, the valve still leaked. In this case there was a little more detail because the movement of the pintle was very late in accordance with the building of the magnetic field.



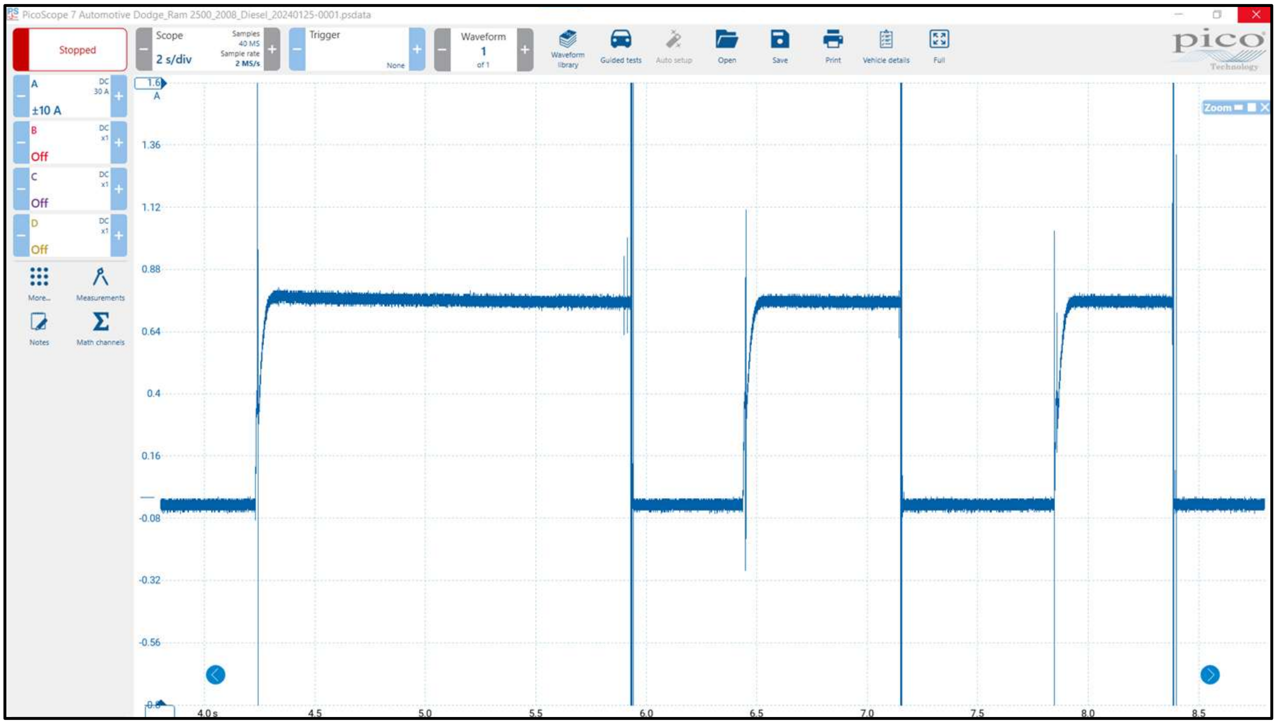
Current builds in five equal time constants. This is an example of a resistor inductor circuit. One of the most common controlled circuits (solenoid) on our vehicles.



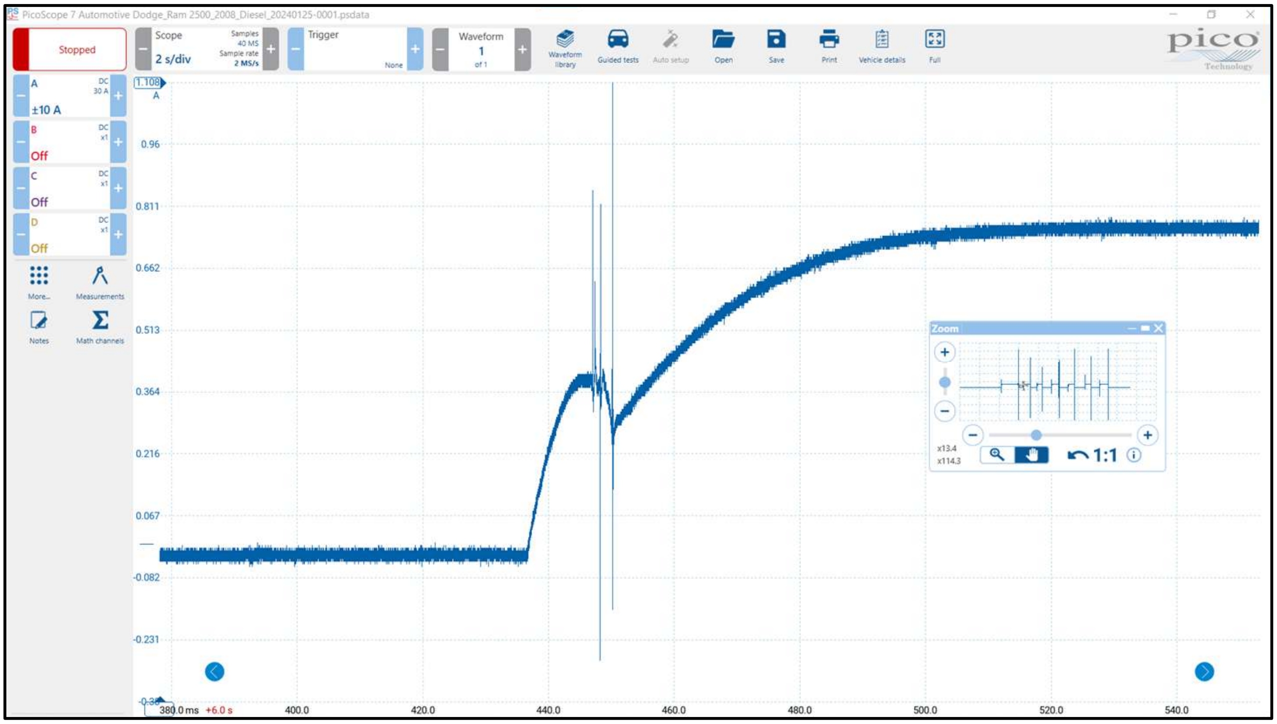
This is a zoomed in view of our event solenoid on our previous vehicle. It should be noted that the pintle did not physically move until the 4th time constant. Although we have seen things like this before that is typically very late for movement. We will look at a few more examples.



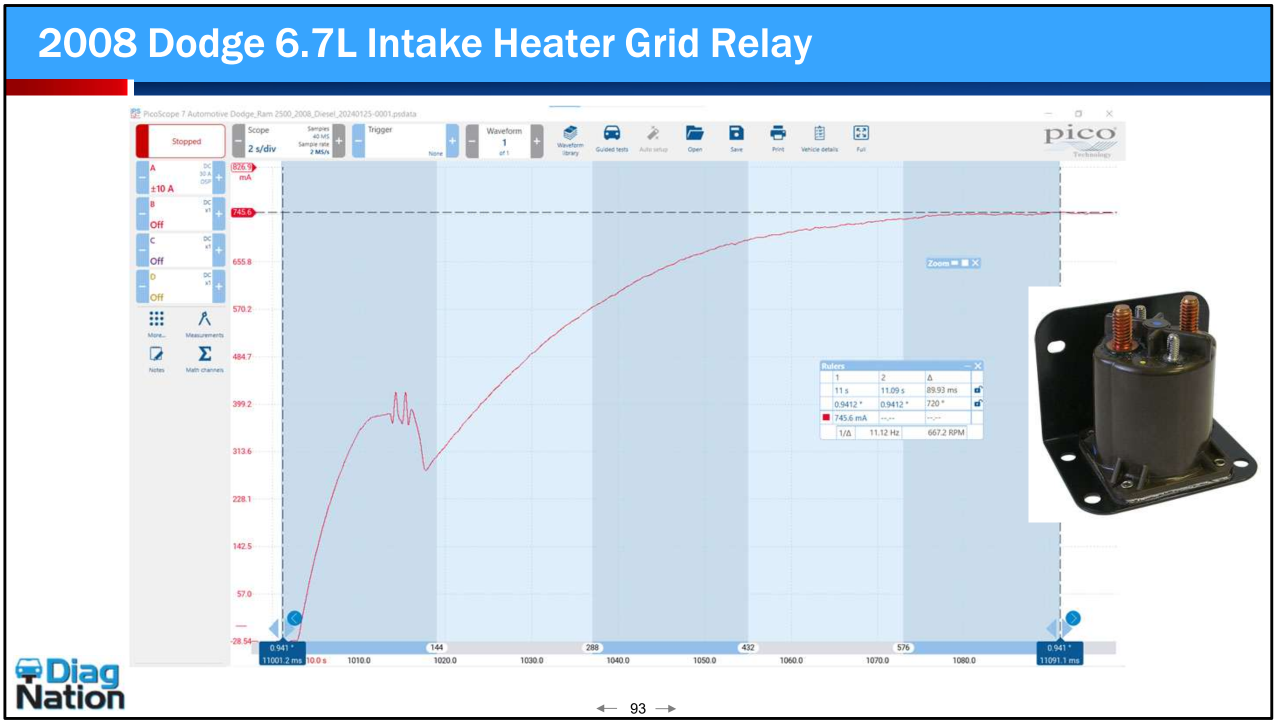
Typically, current probes do not produce a lot of scope noise. In many cases this noise does have a real story to tell.



Here we are zooming in on our events to take a closer look at this noise to see if it has any details diagnostically.

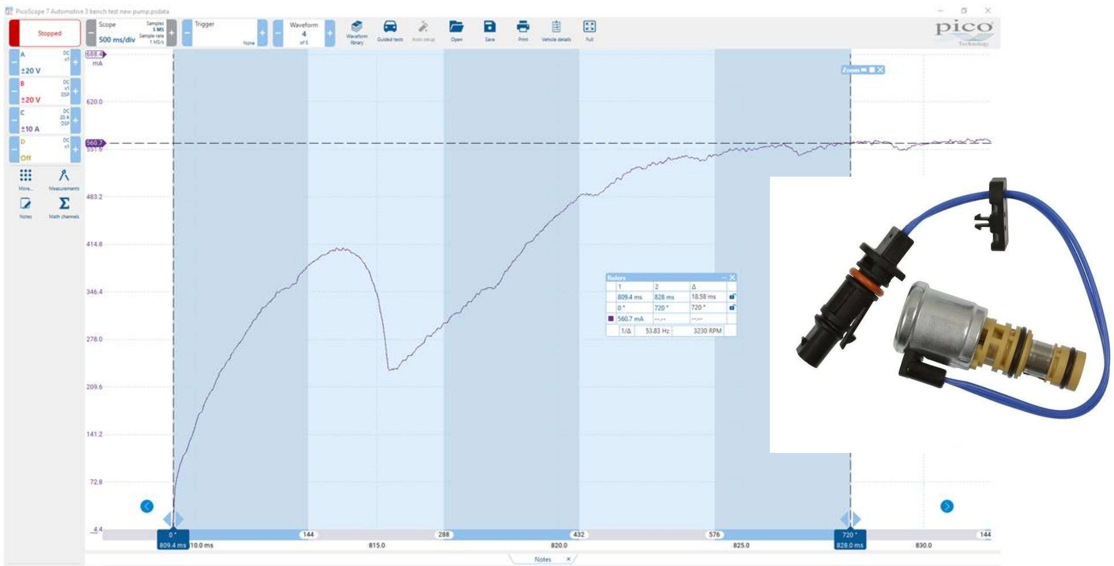


It should be noted that appears that most of the noise is happening just prior to the pintle hump.



And here we see a clear and filtered view of this noise. We also show the component that created this noise on the right side of the picture above. In this case the noise does show a vibration of movement in the contact wafer inside the solenoid. It is not a problem it is very normal for something of this size to produce noises like this.

Oil Control Solenoid Example



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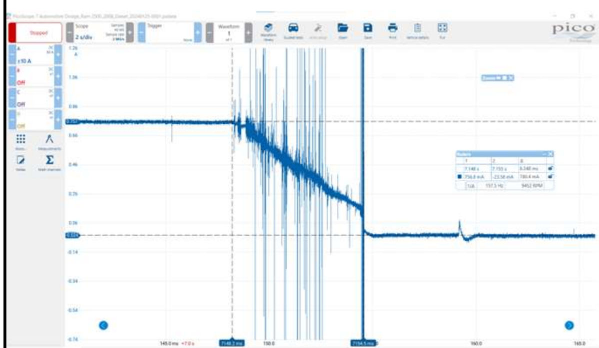
94

Here's a solenoid that has far less mass and a much clearer crisper pintle movement.

Shut-Off Speed, Inductive Kick and Noise (Tail Effect)



- The speed at which the circuit turns off affects the shape/voltage level of the "inductive kick"
- The mass of the "pintle" also affect this
- This a very important detail when using inductors for transformers
  - Ignition coils (<40us)
- In most solenoid circuits these are not an issue
  - "necessary evil"

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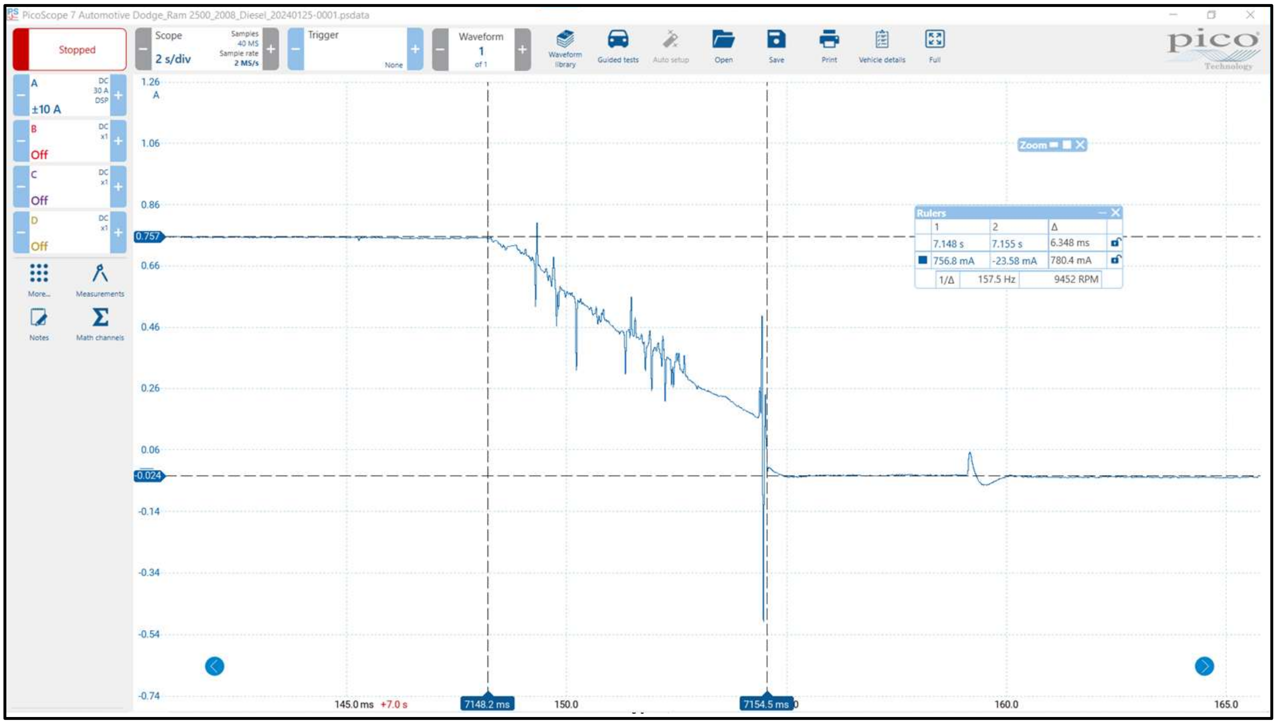
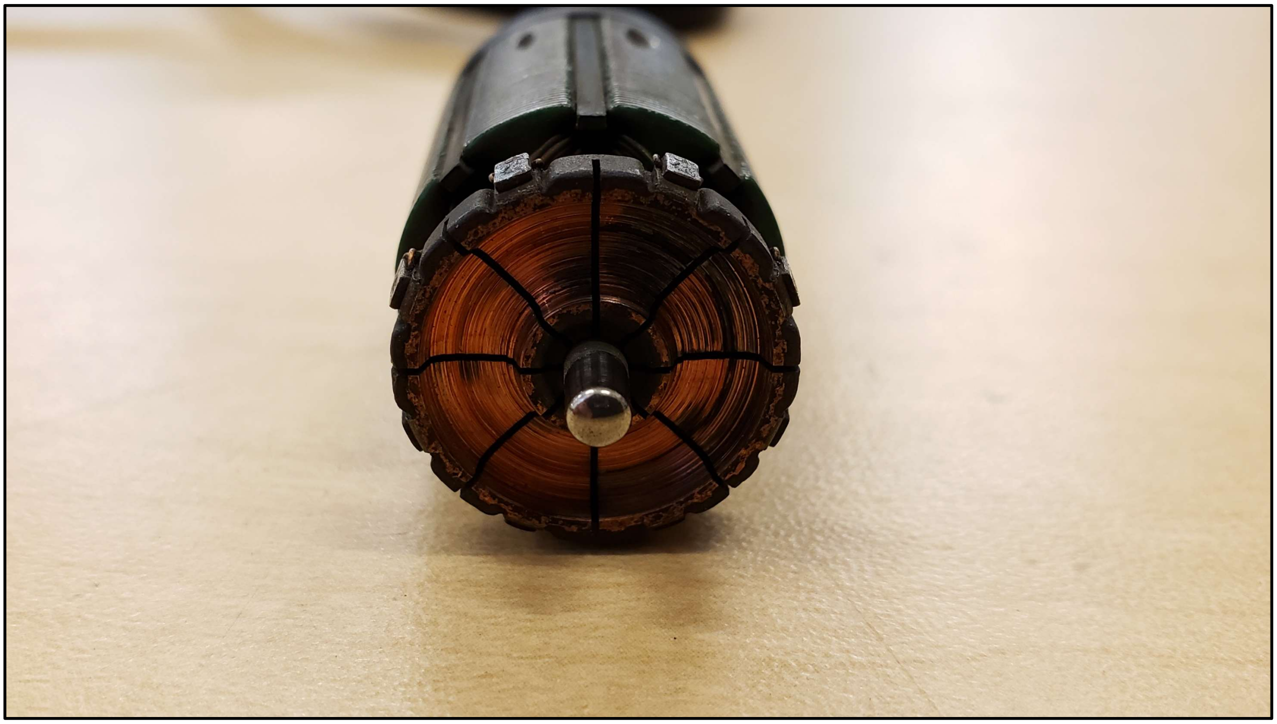
The shut off speed inductive kick and tail effect all can tell stories about the circuit integrity. In most solenoids this is a necessary evil and we do what we need to control the inductive voltage spike. In other cases, like ignition coils this is the primary goal of what we're trying to achieve.



This is a zoomed in and filtered view of the shut off portion of our glow plug relay. It should be noted that the shutoff time is quite long it's over six milliseconds. This is perfectly acceptable for a solenoid control what would cause issues if it were an ignition system.

Fuel Pump/Electric Motor Testing

Waveform Acquisition & Analysis



A lot of information can be gathered from a fuel pump current waveform. The digital storage oscilloscope allows us to look at the brush to commutator bar contact within the fuel pump and watch current flow through each commutator bar. Burnt or worn contacts will show up as a drop in current flow during pump rotation. The mechanical health of the fuel pump can be assumed by observing the RPM of the operating fuel pump. The three things we will start with are: the overall amperage of the fuel pump, the waveform consistency and the RPM of the pump.

Fuel Pump Hook Up at Relay

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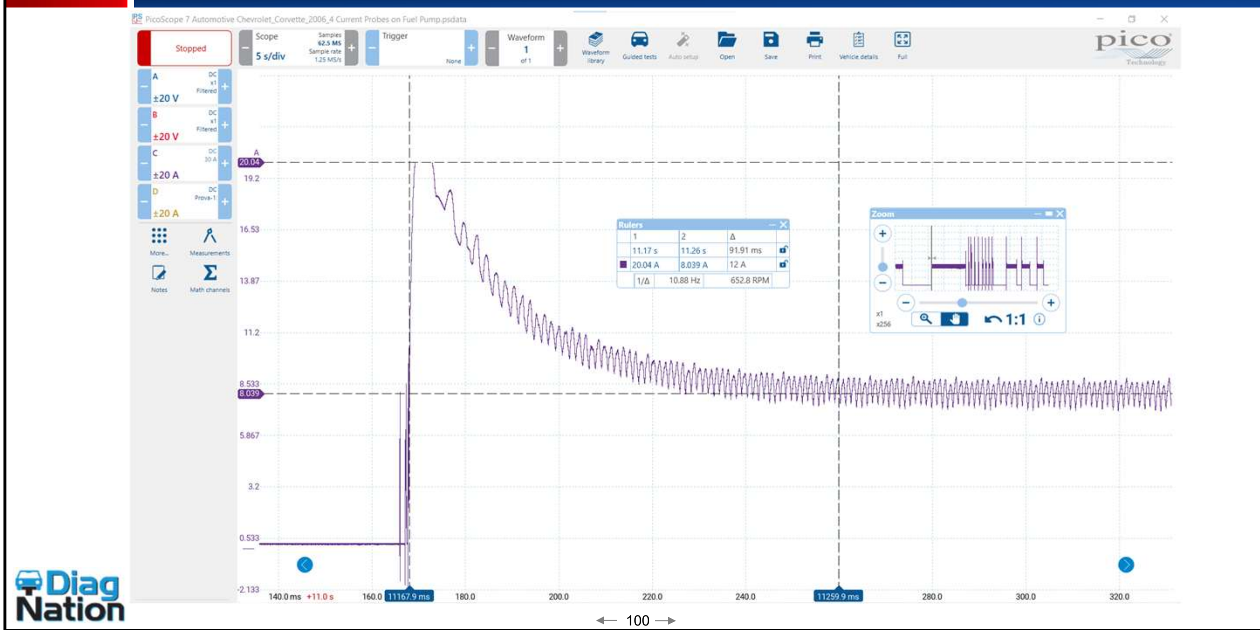
← 99 →

In this photograph, we have removed the fuel pump relay and jumped across **pins 30** and **87**. A fused jumper wire is preferred in case terminal selection is confused. New innovative tools include relays with an external wire for this very test that the probe can be placed around.

Fuel Pump Rush-in Current



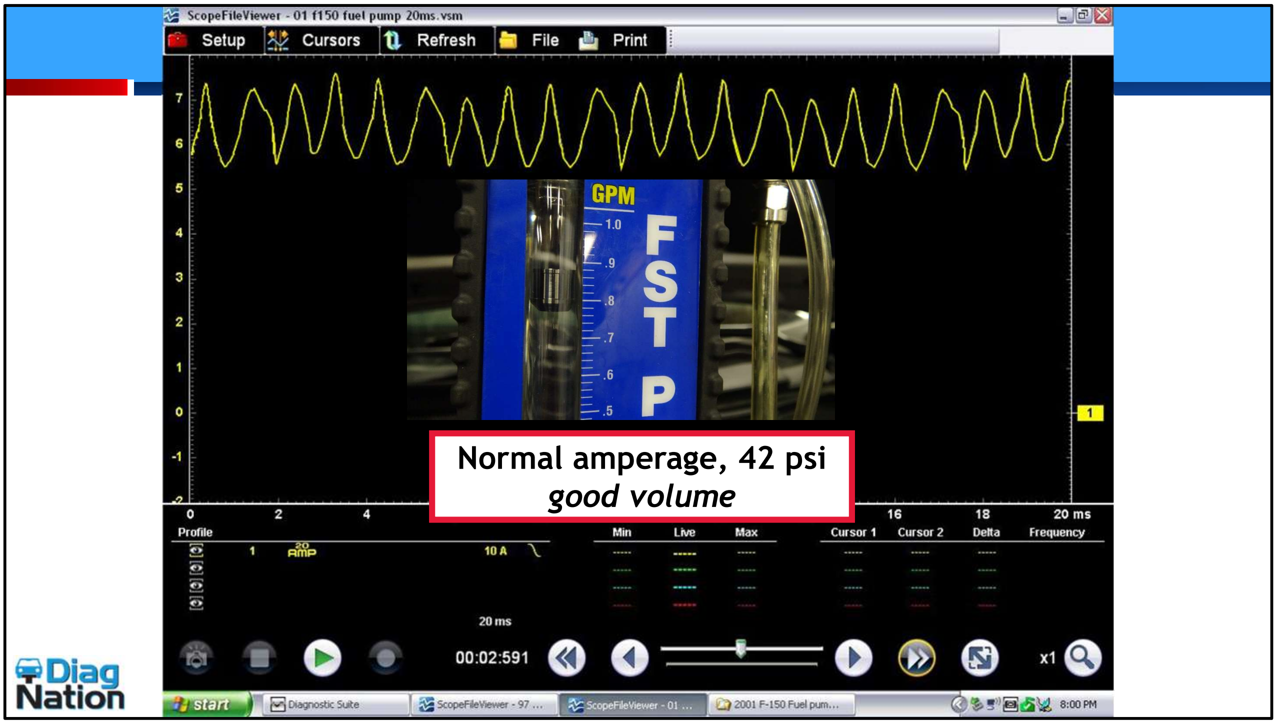
A fuel pump, like any motor, has predictable characteristics that will aid in diagnosis. At startup, when the motor is not yet spinning, there is plenty of time for current to build up in the low resistance windings that comprise the core of the motor. As the core spins, different core windings are energized. By the time the motor is up to a steady speed, current flow has dropped and leveled off because there is less time for current build up in each winding. We can see each winding get energized by examining the ***humps*** in the waveform.

Overall current flow through the motor is determined by the amount of voltage supplied, but also by motor speed which is, in turn, related to how much load is on the motor. With respect to fuel pumps, ***higher*** fuel pressure systems will generally have ***higher*** fuel pump current because of the load on the motor, although the design of the actual pumping mechanism attached to the motor factors in as well.

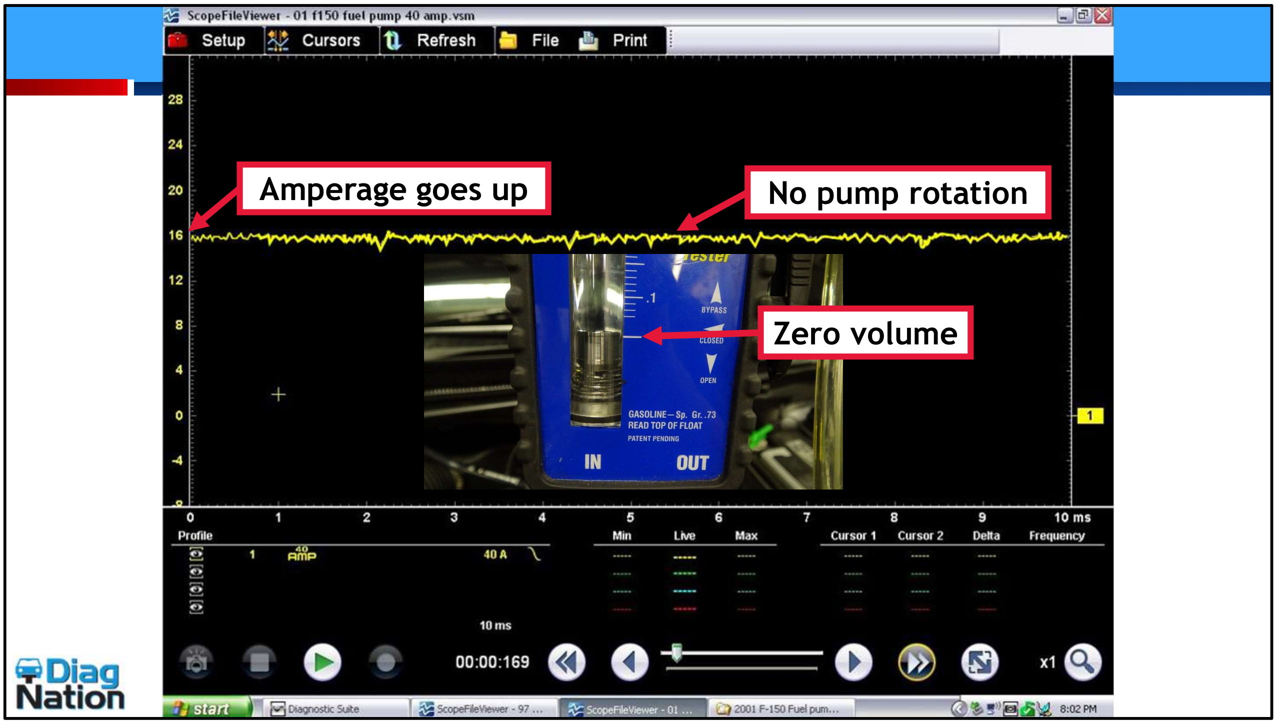
Automated Fuel Pump RPM Calculation (60,000/ms = RPM)

← 101 →

By utilizing the cursors as and a little bit of vertical zoom on channel A, you will notice the software automatically calculated out the time it takes for one revolution (8 commutators) and dictates the RPM of this fuel pump. These type of calculations save us time as we used to have to calculate them manually with most scopes.



Let’s look at an example of a typical fuel pump waveform obtained from a port fuel injection system on a 2001 Ford truck. No abnormalities are seen here as the pump runs at **idle**, drawing an average current between six and seven amps. The pump is able to create plenty of fuel volume which is pictured with the FST Pro volume tester reading: **.9 GPM** (**gallons per minute**).

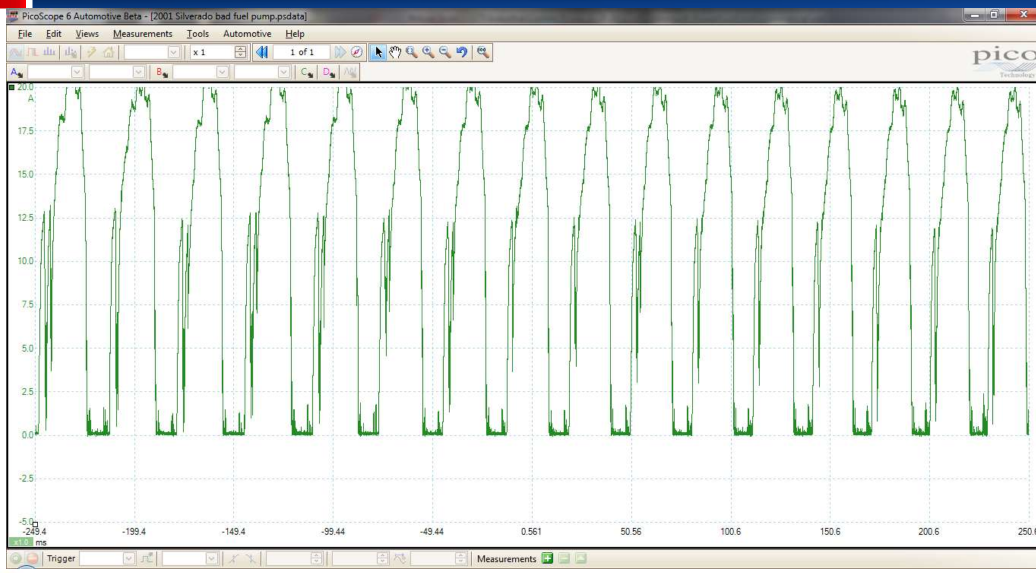


This same Ford truck stalled in the service bay. Stalling was the symptom under diagnosis–the vehicle was towed in, but then started and ran until it stalled in the bay. Note that now; while attempting to restart, the amperage has changed to sixteen amps during cranking. Volume has dropped to zero at the same time.

What do you think happened? Do you see any indication that the pump motor is turning? The absence of humps in the waveform indicates the pump is ***not*** turning.

Intermittent problems can waste a great deal of time waiting to catch the problem actually occurring. In this case, the technician may have to watch fuel pressure and volume until the motor stalled unless a more innovative way of testing is used. One creative way to use the DSO in this situation would be to set a trigger above the normal amperage level of the pump. This would allow the technician to perform other shop tasks while testing the vehicle.

Fuel Pump current



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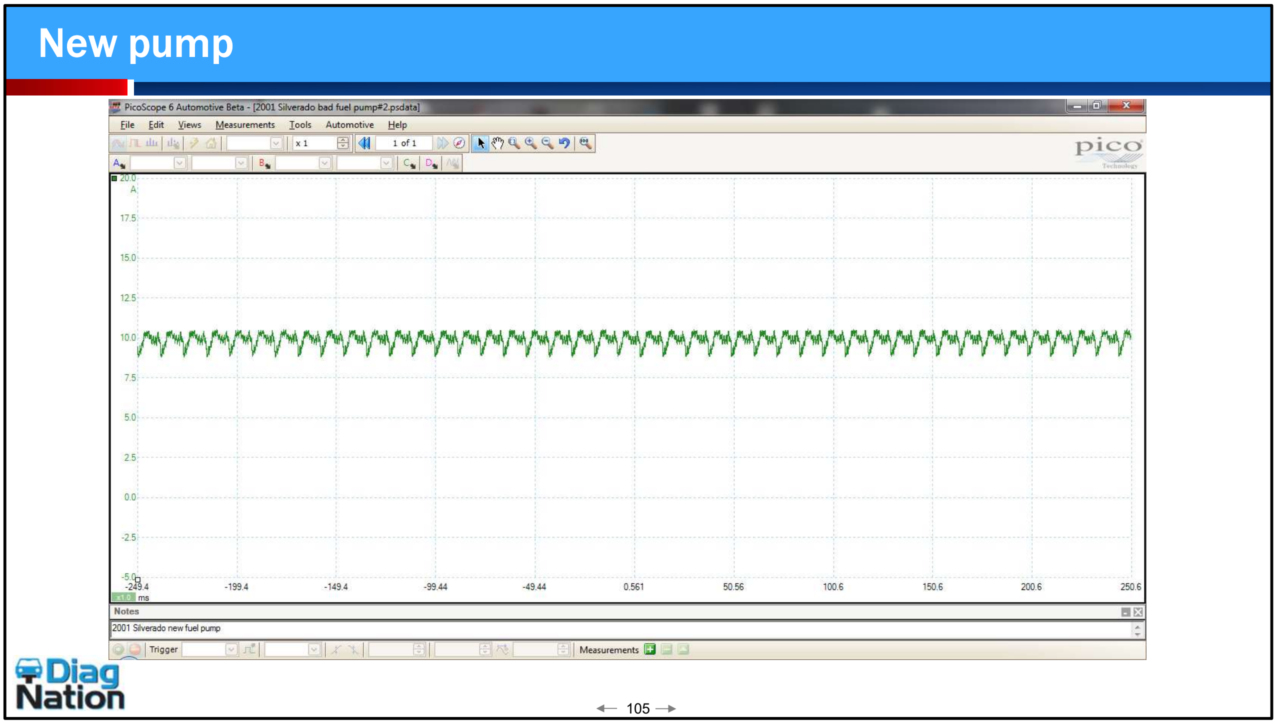
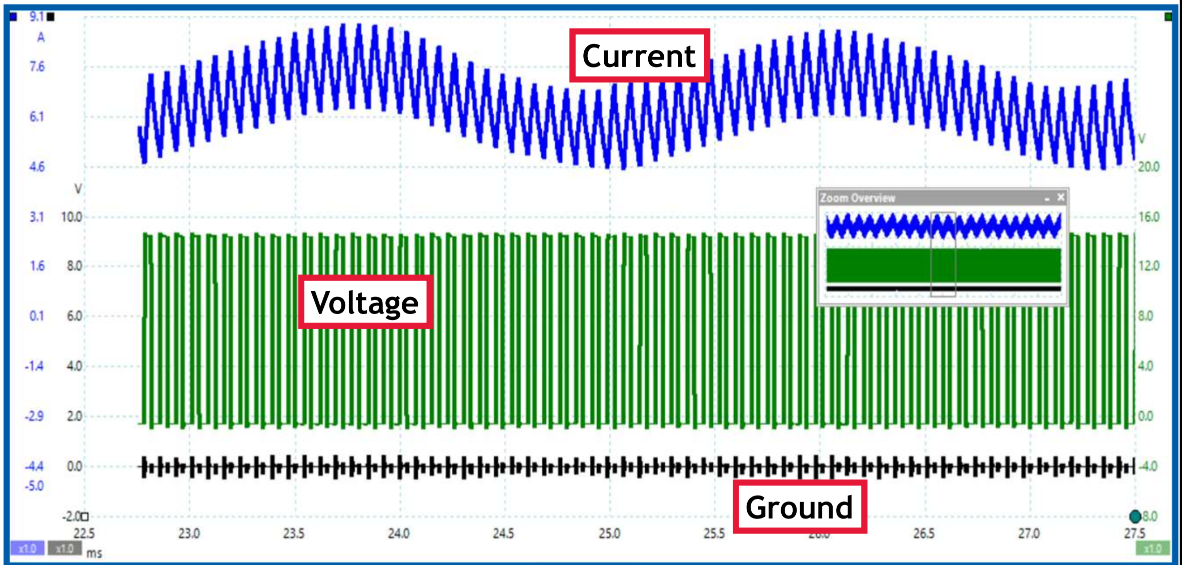
← 104 →

This vehicle was a pre trip inspection with no complaints from the customer on drivability. It should be obvious in this picture that with the brush contact issue that if the pump stopped in the correct position it would not start again until we banged on the tank.

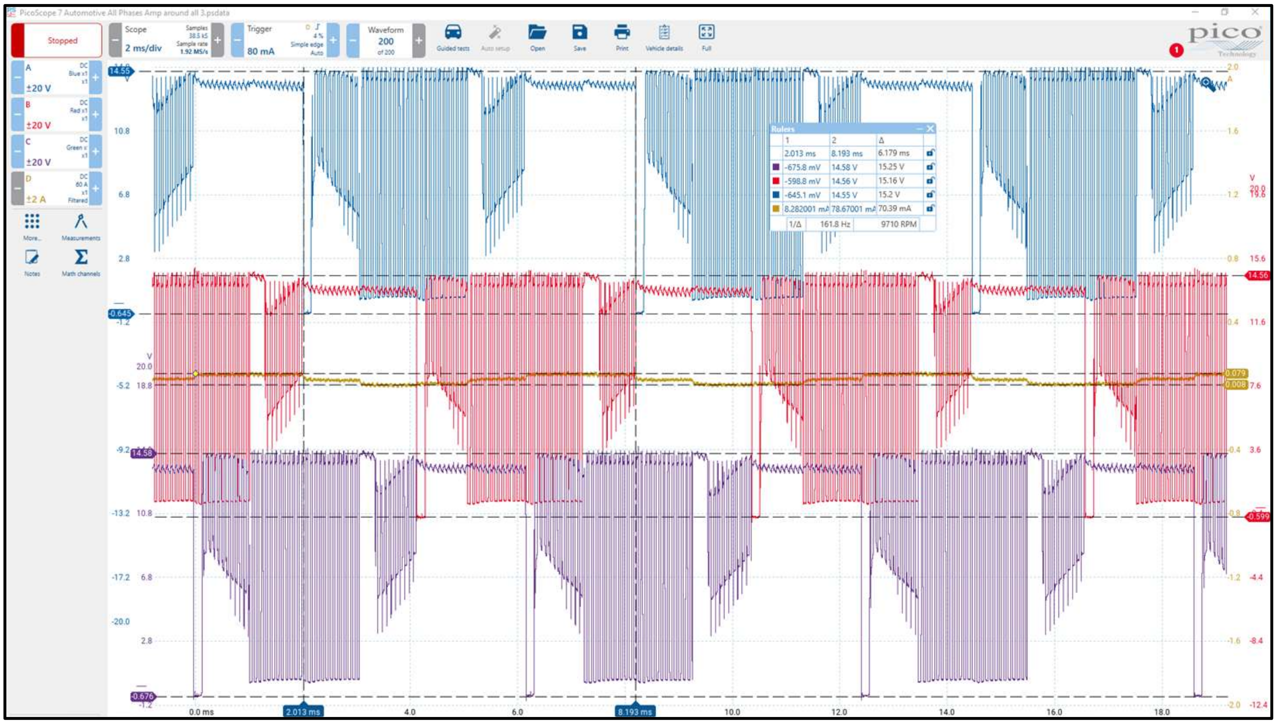


Here is the same vehicle after new fuel pump was installed.

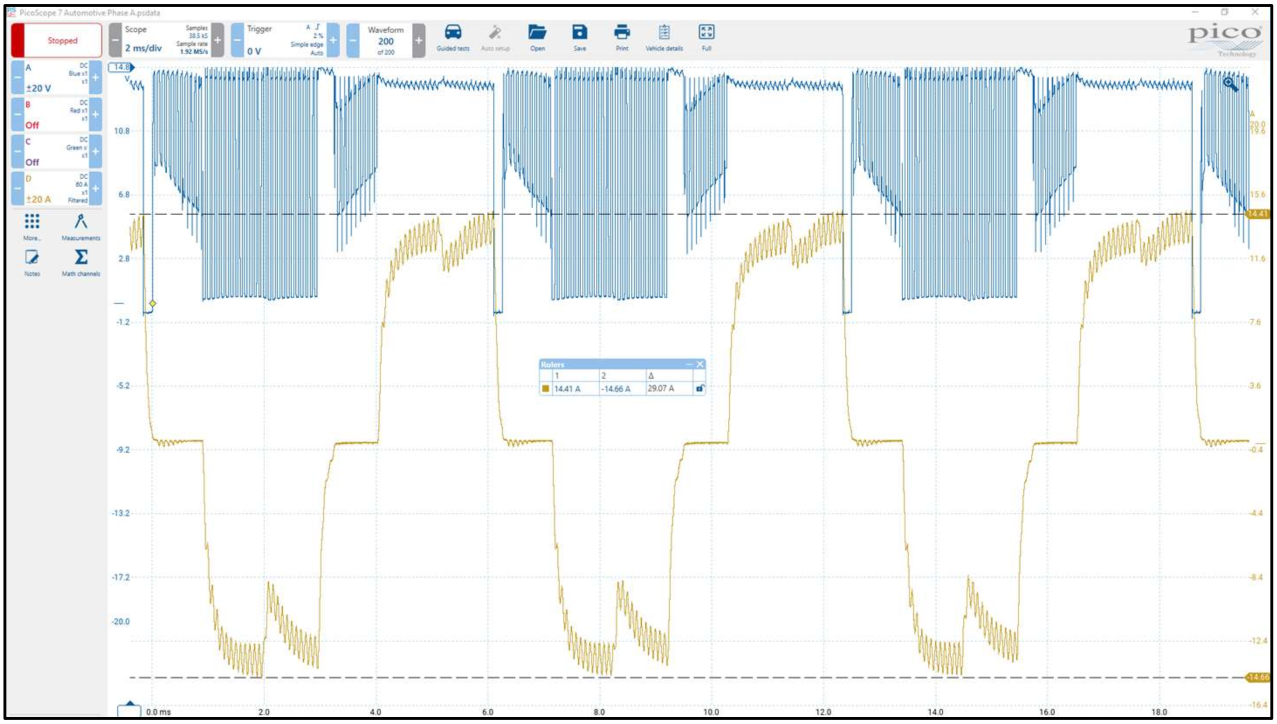
Fuel Pump Drivers/Variable Speed Pump Diagnostic Warning

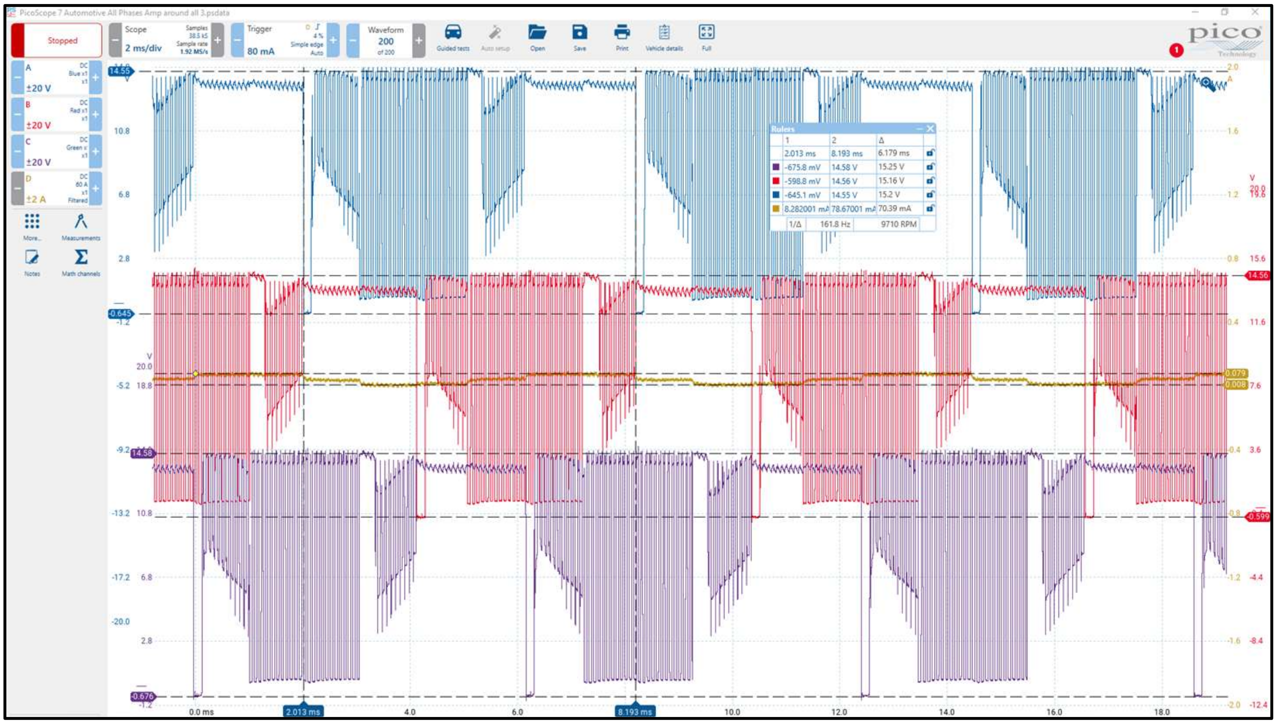


In this screen capture, we have ***zoomed*** in far enough to see the pulsing of the control voltage and we also removed the filtering from the top and bottom waveforms. Now, we can see that the current flow ***pulses*** right along with ***pulsing*** applied voltage. Even the ***noise*** on the ground path is just a reaction to the circuit being pulsed.



Although this is beyond the scope of the class here, we are looking at some brushless three phase controls on a BMW fuel pump. These patterns will be discussed in class live.




Stopped
Scope
2 ms/div
Trigger
80 mA
Waveform
200
of 200
Guided tests
Auto setup
Open
Save
Print
Vehicle details
Full
pico
±20 V
±20 V
±20 V
±2 A
More...
Measurements
Notes
Math channels
Rulers
1
2
Δ
2.013 ms
8.193 ms
6.179 ms
-675.8 mV
14.58 V
15.25 V
-598.8 mV
14.56 V
15.16 V
-645.1 mV
14.55 V
15.2 V
8.282001 mA
78.67001 mA
70.39 mA
1/Δ
161.8 Hz
9710 RPM
0.0 ms
2.013 ms
4.0
6.0
8.193 ms
10.0
12.0
14.0
16.0
18.0

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Imagination Time

Efficiency with Technology

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2005 BMW 325i

- Customer states passenger window *pauses* while trying to roll it up or down
- It works, but sometimes when the button is pushed, it waits up to a few seconds *before* moving
- We tried the operation and it seems fine to me
- What is the best way to approach this?
  - This is a *multiple module controlled circuit*

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← 111 →

2005 BMW 325i

We are now going to diagnose a bad power window regulator with a high amp current probe. Note that the door is **open** and the ignition is **on**.

Current Probe Connection at the Battery

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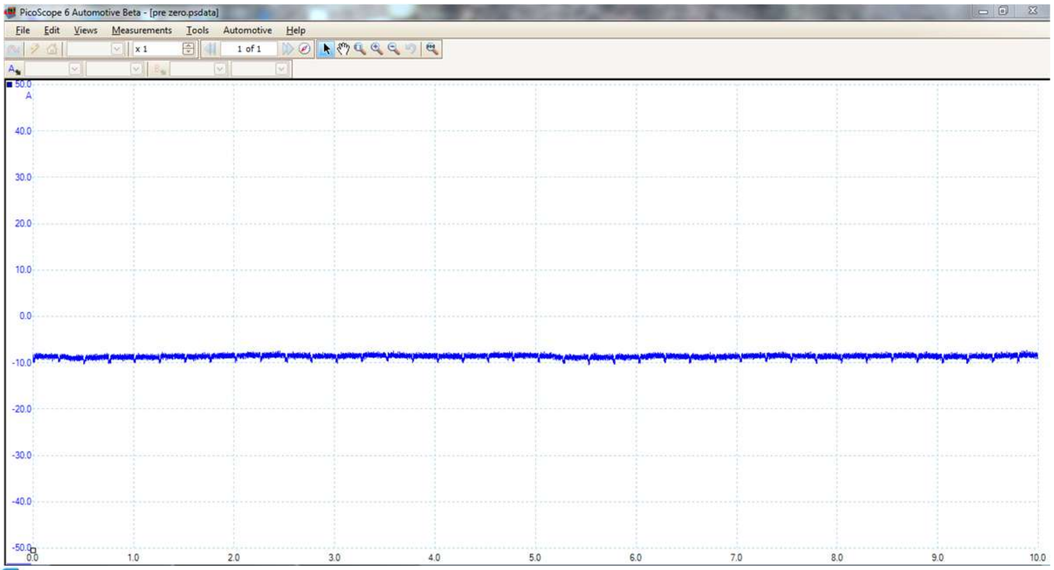
← 113 →

We are hooking to the battery because it is so easy to do. I will not zero the probe until the probe is connected, so I can leave the ignition **on** and see only the window motor current draws.

Ignition On & Driver’s Door Open



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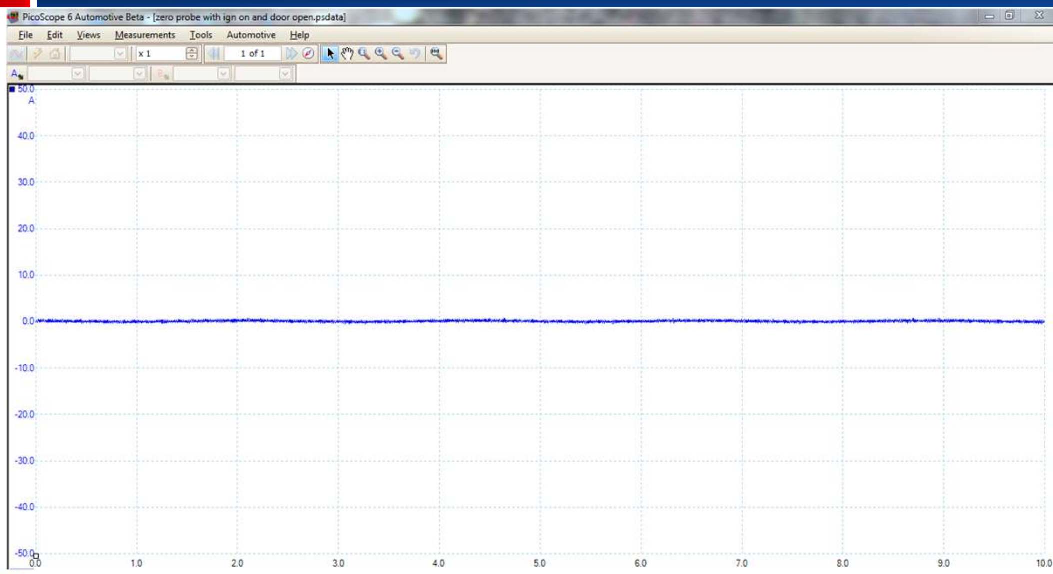
← 114 →

After The Current Probe Zero



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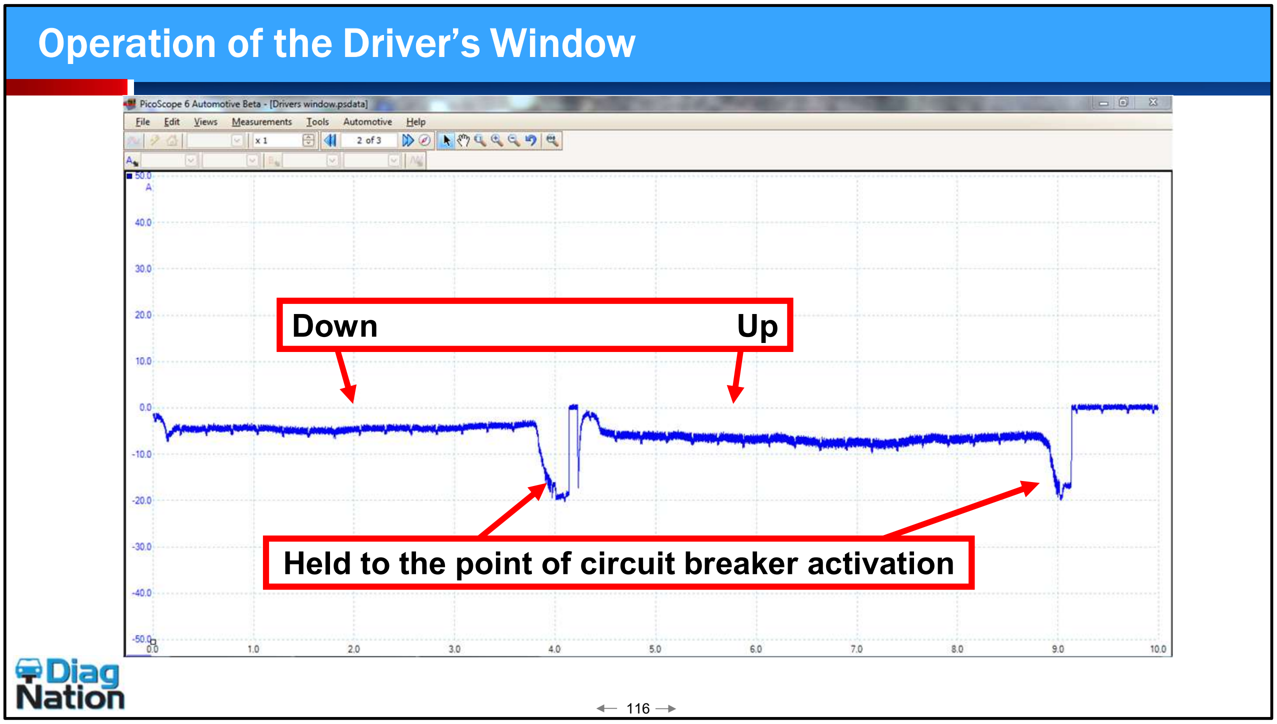
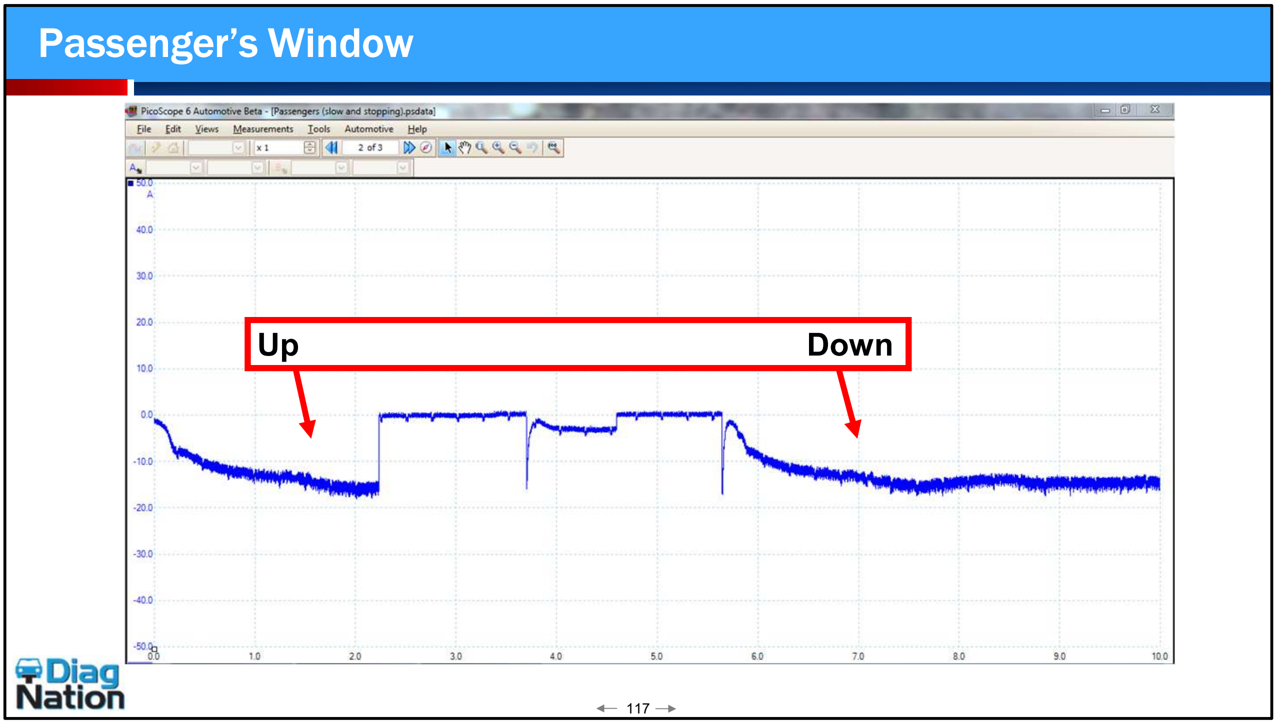
← 115 →

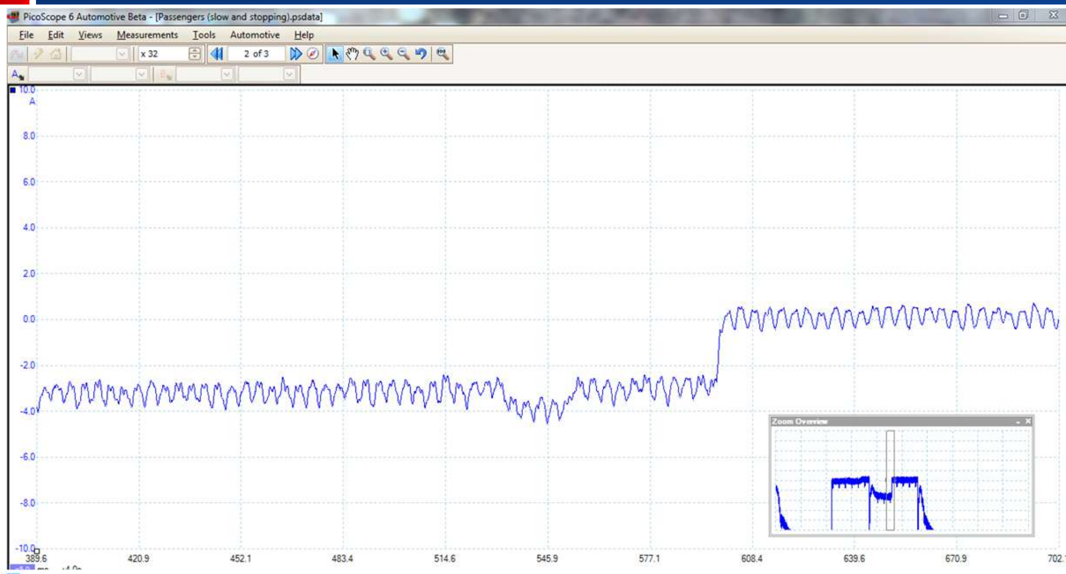


Why did we operate the driver's window first?



What you should see here is that the overall current flow is much ***higher*** on this window than our ***known good*** one. It is also getting very close to the point that the circuit protection system kicks in. This could help to explain why the customer feels the ***pause*** at times.

Zoom In On Brush Quality



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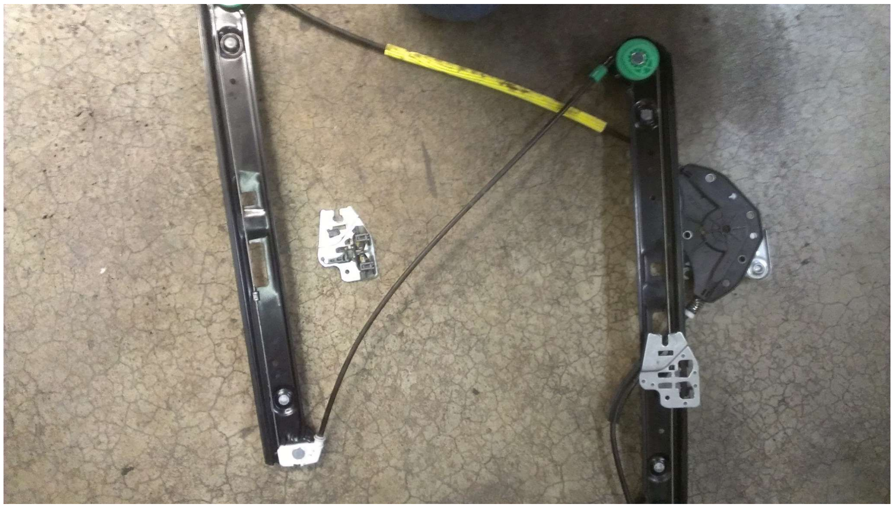
← 118 →

We have now zoomed in on the brush quality to help determine if the regulator/binding or the motor is causing the excessive current flow. In this case, the motor appears ***good*** and the regulator has ***failed***.

Regulator With Misaligned Window Mount



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← 119 →

This is the regulator from the passenger's window and as you can see, the window mount is bad.

Alternator Testing

DSO Current Testing Tips

Alternator Theory

- Electromagnetic induction
- Output depends on:
  - Number of windings
  - Strength of magnetic field
  - Speed
  - Winding type

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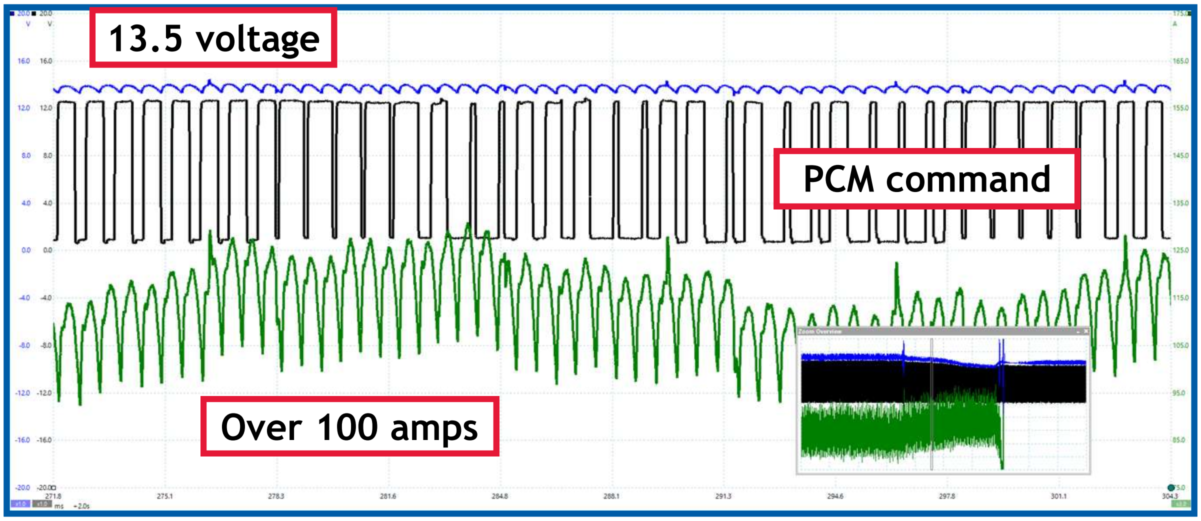
121

The main components of an alternator are the: **rotor**, **stator**, **diodes**, **fan** and **bearings**. A **field circuit** and **regulator** controls the strength of the magnet which are the poles that help make up the rotor. The engine, via a belt, rotates the magnetic field inside the stator windings. This magnetic field induces alternating current into the stator windings producing three phase **alternating current** (**AC**). The diodes convert the alternating current to **direct current** (**DC**) which is used to charge the battery and run the vehicle's accessories. Our job as technicians is to be able to test the field circuit, diodes and alternator output.

BMW Known Good Alternator



Here is the same BMW with a replacement alternator. We see normal system voltage patterns and levels, as well as a current pattern that is responding appropriately to the load placed on the system for testing.

Gasoline Direct Injectors (GDI)

A Few Examples

GDI Injectors Come in 2 Flavors (Magnetic Solenoid and Piezoelectric)

- Boost capacitors in the PCM/injector driver module are used to create higher injector control voltage
  - *~65v for magnetic inductor and ~100-150v for piezoelectric*
  - *Typically shared (power) between 2 injectors*
- High voltage is used to quickly **open** the fuel injector
  - *Typically twisted pair wiring*
  - System voltage (12v) is used to *hold* the injector **open**
- Injectors are *duty-cycled* to reduce current
- It produces a unique looking waveform

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← 124 →

All **gasoline direct injected** (**GDI**) engines use a high voltage signal to control fuel injector operation. Most GDI engines set that voltage at approximately **65 volts** peak to **open** the injector and then drop the supply voltage to a modulated charging voltage level. This controls the current level in the injector. Both the ***power*** and the ***ground*** side of this circuit originate from the PCM with few exceptions. Hyundai, as an example, uses a separate injector driver module to control injector current. The challenges for technicians testing these circuits is similar, no matter what the vehicle.

1. Injector access is very limited requiring testing to be performed from an available connector in the wire harness.
2. DVOM testing is limited to **circuit resistance**. Voltages are quickly turned **off** and **on** making voltage measurements with a DVOM useless.
3. Traditional noid lights ***cannot*** support the voltage on this circuit. Unfortunately, they are unable to provide effective diagnostic information anyway.
4. Swapping fuel injectors for diagnosis is ***not*** practical on a GDI vehicle.

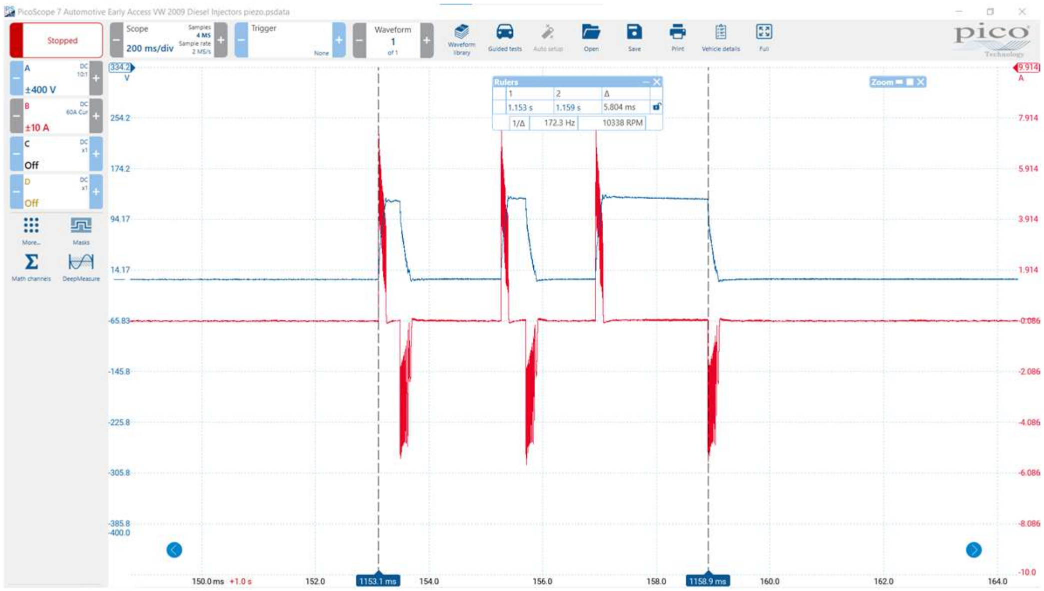
Using a current probe in conjunction with an oscilloscope provides technicians with the most reliable diagnostic information while allowing for a wide selection of access points to the injector circuit. Since current is the same throughout a series circuit, the pattern on the oscilloscope screen will be the same no matter where the current probe is clamped in the circuit harness. The current probe can be attached on a single injector wire, either positive or return, or around all of the positive or return wires to view control of all of the injectors at once.

2016 BMW X5 Known Good GDI Solenoid Injector Current

← 125 →

The next few pictures are of known good injectors this picture is of a gasoline direct injected solenoid style injector. This measurement is in current and shows the peak and the modulated hold section.

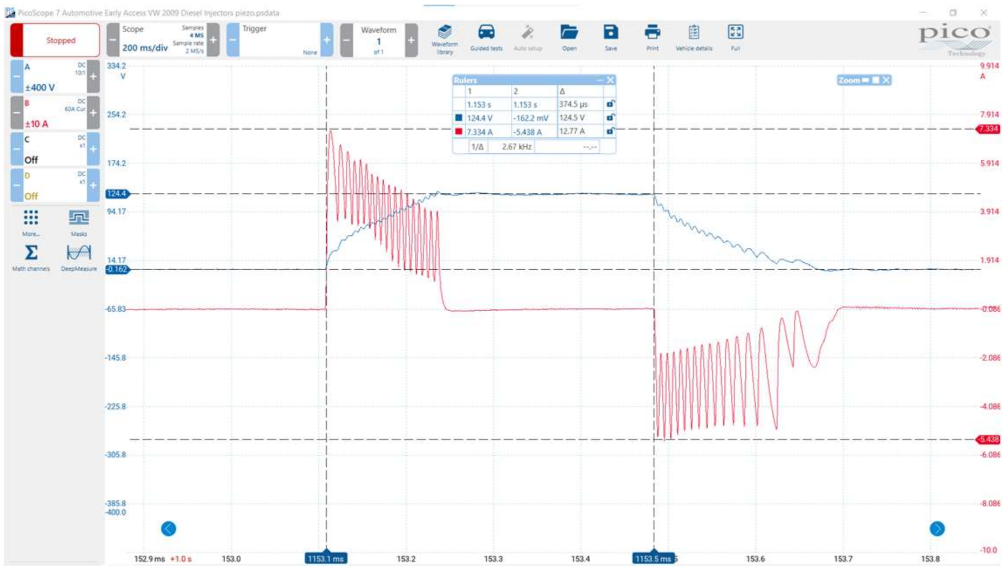
2009 VW Diesel Piezoelectric Injection



← 126 →

We are now looking at one compression event with three individual firings of a piezoelectric injector in a 2009 Volkswagen diesel. We have voltage in blue on the top and current in red on the bottom. It should be noted that this is 3 individual firing events for one power stroke. Each of the 1st 2 events are of a fixed pulse width while the last one is the adjustable for full fuel delivery. The next two pictures are just zoom-ins on various parts of this event.

2009 VW Diesel Piezoelectric Injection



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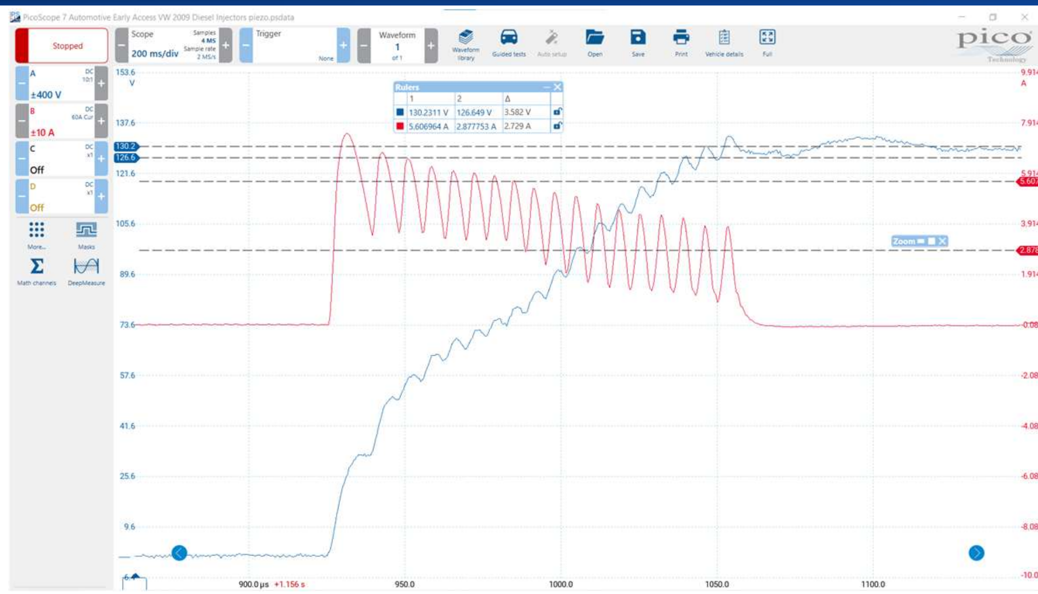
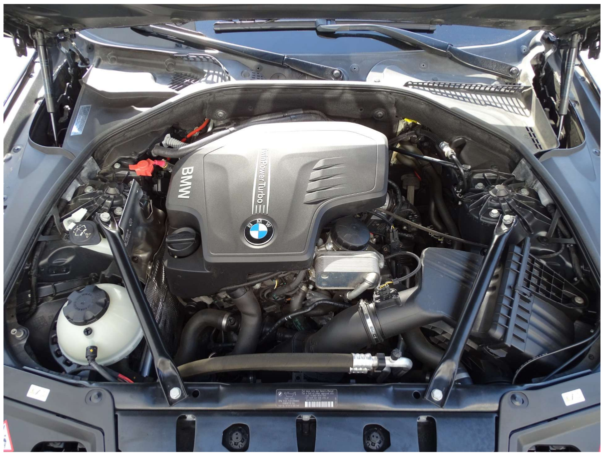
2009 VW Diesel Piezoelectric Injection

128

2009 VW Diesel Piezoelectric Injection



2013 5 Series BMW, Cranks No-Start



- Cranks no-start
- Fouled spark plugs
  - Looks like fuel
  - Has low compression
- Smoke check, no leaks
- Many parts replaced
  - Plugs and coils
  - Injectors
  - List is too long to fit
- Inspected for carbon issues
  - Wasn't too bad

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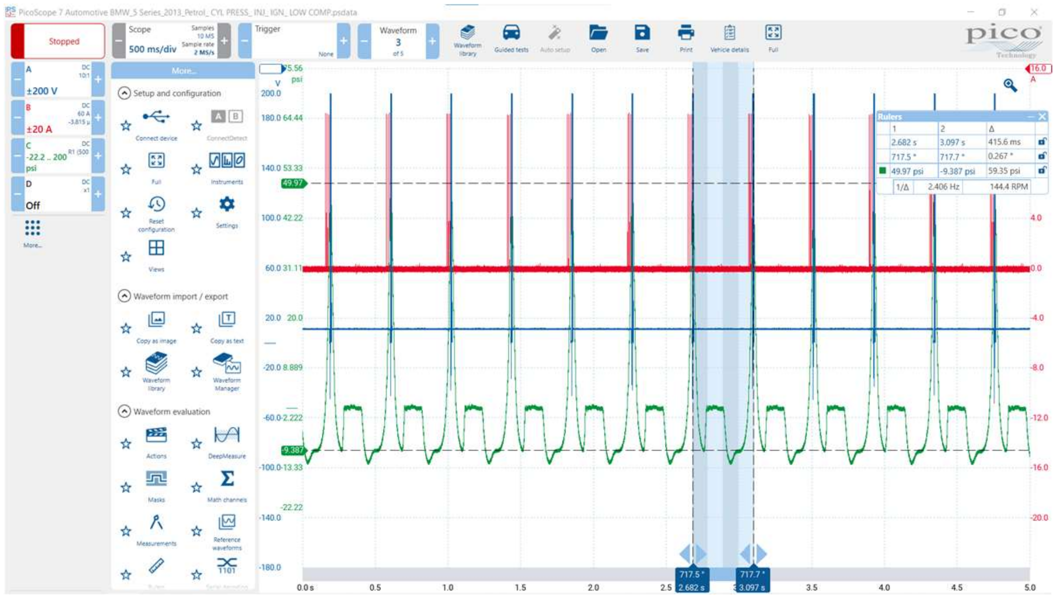
130

Here's a 2013 five-series BMW that is a crank no start. It fuel fouls the spark plugs quite quickly and the technician's thought is that the fuel fouling is causing the low compression that you will see on the next page. Because of this all the injectors were replaced and properly programmed. The number of parts replaced, and time involved in this is too long to list but I think we all get the picture. The real issue here in our opinion, is that the wrong diagnostic procedures were used. Had this vehicle been looked at with the proper equipment in the beginning this monumental waste of time and money would not have happened.

Cranks No Start, Fuel Fouls Spark Plugs 2013 BMW



Diag Nation

← 131 →

The first thing to notice in this cranking compression waveform is that we have a plateau for the exhaust points “F” – “G”. During cranking this is not normal. In order, to see an exhaust plateau there must either be a restricted exhaust or a restricted intake causing a vacuum. During normal cranking there should not be much difference between the intake pressure and the exhaust pressure both relatively close to atmospheric pressure. It is true that the cranking insider compression waveforms do look different in a variable intake lift engine but not to this extreme. The other two channels being used here are looking at the ignition and the direct injector for this cylinder. This was important to make sure that the injector and spark timing are correct. After all this vehicle is fuel fouling the spark plugs.

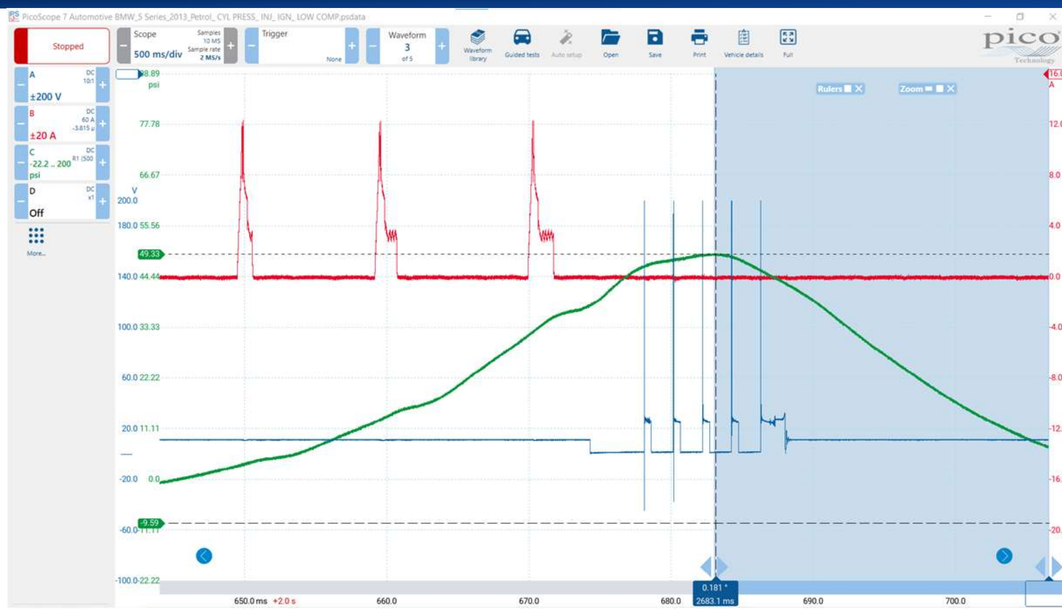
Cranking at 289rpm

132

In this zoom of a 720° event, we can see in red on the top a beautiful triple spike of the GDI injector happening during the compression stroke which is normal. In blue we see an ignition event happening near top dead center with five individual spark events also normal and in the correct time (so pretty we will look deeper on the next page). The exhaust plateau is at atmospheric pressure, but the intake is drawing into a vacuum of approximately 9.5PSI or 19.3 inHg. It is even deeper vacuum in the beginning of the intake pull. This vacuum that's created during the intake pull is restricting volume from getting into the cylinder therefore the overall compression only reaches about 49 PSI.

This is not a rinsed down cylinder this is a lack of air volume getting into the engine. So, the engine is not over fueling it is “under airing”, thus the fuel fouled spark plugs. The intake control of this engine is obviously not proper.

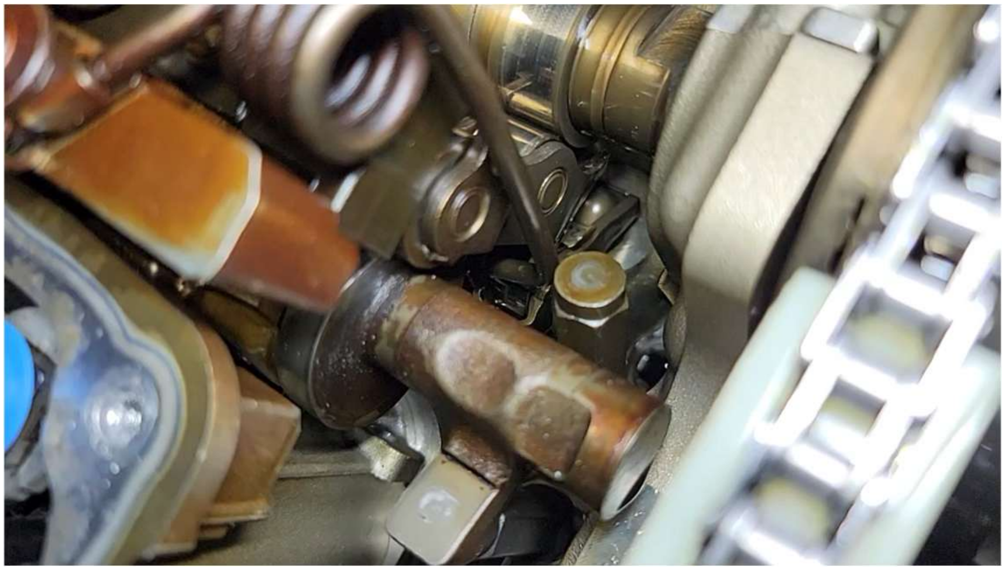
Beautiful Injector and Ignition Control and Timing



← 133 →

We felt we needed to zoom in closer to look at this beautiful control of the gasoline direct injection (red current on top) and spark (blue in the middle). Once again this is normal control. If we added air to it, we would have gotten this engine to start.

Cranking Video Valvetronic and Intake Cam



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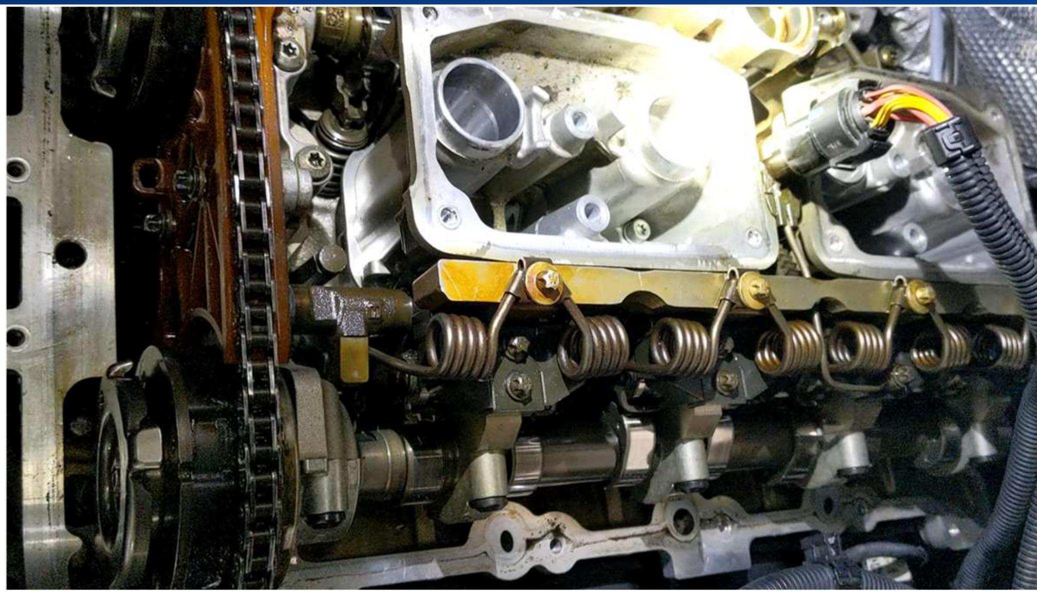
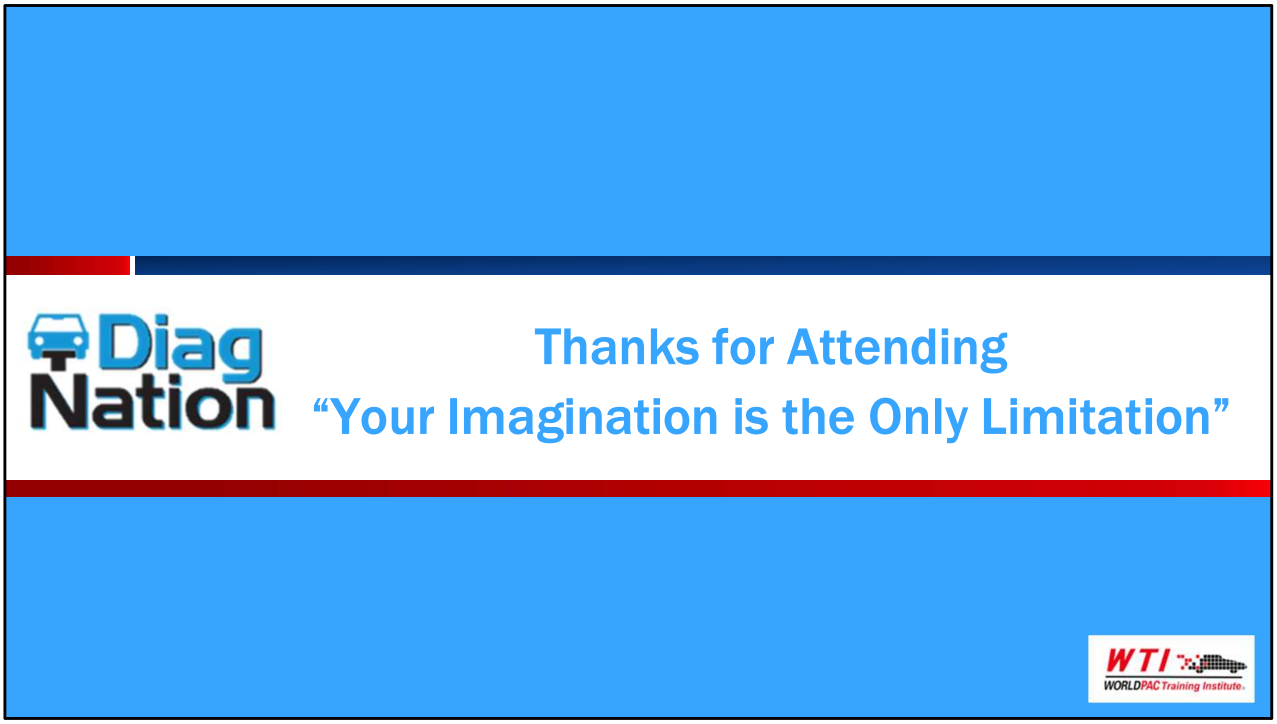
← 134 →

In the live version of this presentation, you would see this video run. In this manual you will just need to realize that the valvetronic system was out of adjustment and was not allowing the intake valves to open properly. Sometimes when this happens on a BMW product a simple flashing of the DME and relearn of base valvetronic settings will fix this problem. And that is what repaired this BMW. Well, and a set of spark plugs.

Key-on Valvetronic Operation Video



This also is a video shown in the presentation of proper key on valvetronic operation, it runs the valvetronic motor from stop point to stop point. During actual cranking the valves are commanded to open to the full position and in our last few pages that was not happening. Yet there was just enough intake valve opening to get a small amount of volume into the cylinder.



Thank you for taking the time to read our materials. After completing this manual and practicing these techniques, it should seem apparent that "your imagination is the only limitation".

REMEMBER: ***"YOU'RE JUST GUESSING WITHOUT PHYSICAL TESTING"***

If you have any questions or would like more information, please don't hesitate to contact us:

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