Training Manual

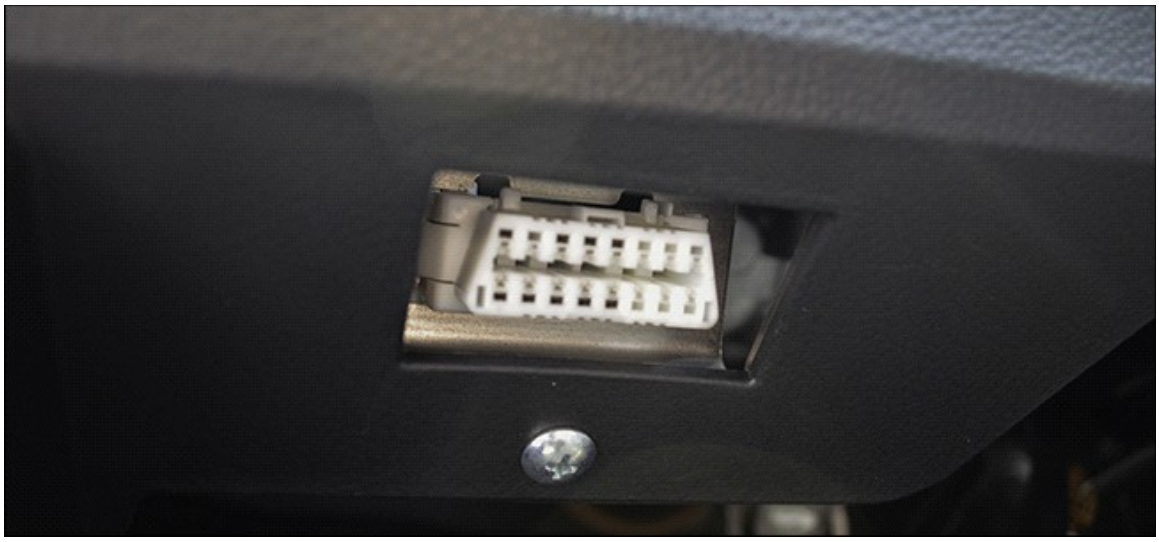
Scanning.

Always scan for codes before working on the vehicle and introducing any new codes!

Don’t sabotage the job for the next person!

It can be very frustrating taking a job over from someone who hasn’t completed it and being the first one to scan it – not knowing if the codes were there when the vehicle came in or if they were introduced by someone swapping parts to try to fix the fault – without ever having scanned it. Do a full system scan first and take note of all the fault codes, then clear them all and see if anything returns right away, then you know where to start looking. Even getting no codes can be very useful information – quite often if a vehicle won’t start and there are no codes it is fuel related, maybe failed fuel pump.

Older vehicles are plain obd "on board diagnostics", they can either have their own special plug or the standard obd plug. Not every vehicle with an obd plug is obd2, but basically it’s the same plug, though the communication wires can be in a different position.



obd2 was introduces in America in 1996 so every American car since 1996 is obd2. Europe introduced eobd somewhere around 2002. Japan went obd2 from around 2006, before that they were jobd [Japanes OBD]. But there are many exceptions depending on what country they are shipped to so don't make decisions based on vehicles of the same year made in the same country. "AU Ford" and "Holden" are often additional features on budget scan tools, they have their own language. For some vehicles this site can show you how to get flash codes by bridging out terminals https://codes.rennacs.com , it will show you which terinals to join together with a piece of wire to get the engine, airbag or ABS light to flash codes with a long pulse being a ten and a short pulse being a one. A long flash followed by 3 short flashes would be code 13.

There are some standards to fault codes

EOBD fault codes[edit]

Each of the EOBD fault codes consists of five characters: a letter, followed by four numbers. The letter refers to the system being interrogated e.g. Pxxxx would refer to the powertrain system. The next character would be a 0 if complies to the EOBD standard. So it should look like P0xxx.

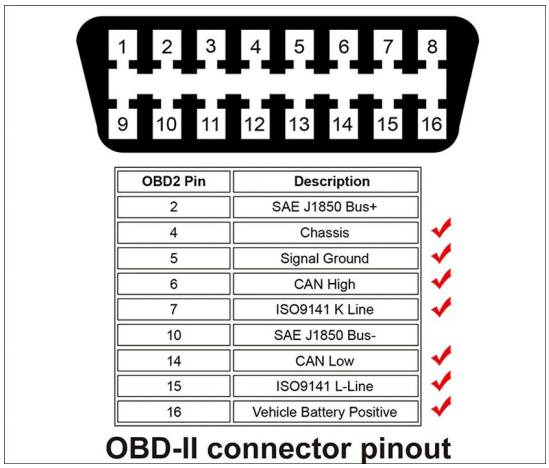
The first letter indicates the family of DTC.

•P: Powertrain, (i.e. engine and gearbox)
•C: Chassis

•B: Body
•U: User network
The first digit indicates if the code is generic or not (green digit):

•0: Generic fault
•1: Manufacturer fault
The next character would refer to the sub system.

•P00xx – Fuel and air metering and auxiliary emission controls.
•P01xx – Fuel and air metering.
•P02xx – Fuel and air metering (injector circuit).
•P03xx – Ignition system or misfire.
•P04xx – Auxiliary emissions controls.
•P05xx – Vehicle speed controls and idle control system.
•P06xx – Computer output circuit.
•P07xx – Transmission.
•P08xx – Transmission.
The following two characters would refer to the individual fault within each subsystem.[24]



Five Protocol Types

- ISO 15765-4 CAN (SAE J2480) ...
- ISO14230-4 (KWP2000) ...
- ISO 9141-2. ...
- SAE J1850 PWM. ...
- SAE J1850 VPW.

Though a budget scantool can get into obd2 on many vehicles it can't access all the live data, only what the manufacturer is obliged to share on obd2. Some emissions related codes can only be cleared in obd2 mode - so try obd2 mode for codes that won't clear when accessing the manufacturers info.

If the test results are strange check your test equipment. No scan tool, [multimeter or load tester] is perfect, sometimes they give the wrong definition for a fault code. The Autoland sometimes gives 7 fault codes for an SRS system on a Holden, the other scan tools show it as being "driver's airbag", occasionally a scan tool can get confused when trying to automatically find a system. If a scan tool gives strange faults try at least two other scan tools and pick the results from the two, or more, that agree with each other. Sometimes the smaller scantools can give the wrong definition for a fault code as well, they assume standard obd2 definitions, when sometimes a manufacturer specific code exists for that particular vehicle and it has a different definition than all the other brands - always double check based on brand, on Google if unsure.

Some fault codes will only clear after taking the vehicle for a drive. A "hard" fault code is one that will only go away once the ECU has tested it during a drive cycle.

Just because a vehicle is newer does not mean it is better at giving fault codes. A 2017 Holden Colorado can't give a fault code for a bad MAF sensor.

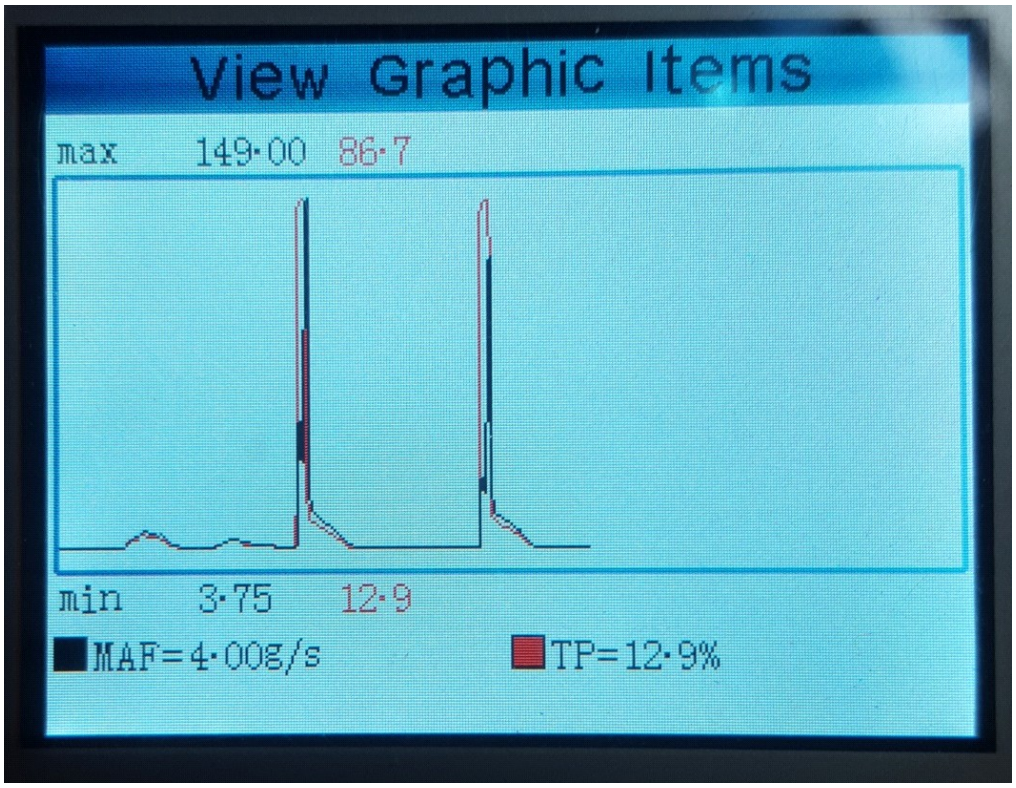
Don't judge the behaviour of one ECU based on a different ECU. Programs change like Windows 7 vs Windows 10.

A computer is as clever as the person who programmed it, and assumes that the wiring and connector plugs are perfect. A VW beetle won't turn off the oil light if the hood switch is faulty - it has been programmed to remain on until there is evidence that the fault has been rectified, the hood needs to be opened first for this to happen. If it doesn't 'see' the hood get opened it keeps the oil light on even if the oil pressure is perfect.

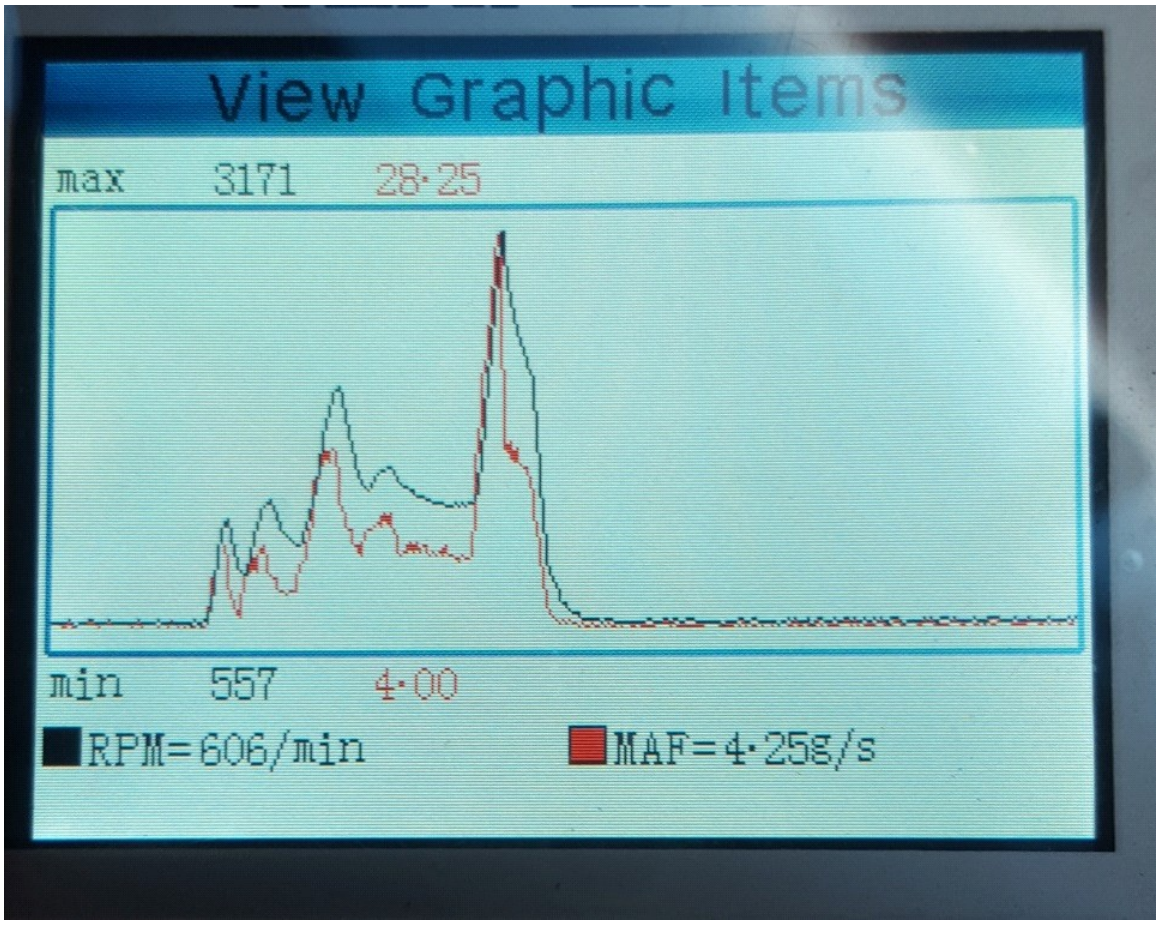
When a vehicle is running familiarize yourself with useful information in live data like the MAP sensor and MAF sensor readings. A small car idles at 3 g/s [grams per second] [MAF sensor], a diesel at 8 g/s. Most MAP sensors are 34kpa at idle with no intake leaks. 100kpa is normal barometric pressure at sea level. [This changes with the weather]. 34kpa is a vacuum that is 64kpa lower than atmospheric pressure.

This picture is from a V6 Holden. At full throttle "TP" we get 149 g/s, but at idle minimum is 3.75 g/s. This is usually around 1v-4v at the sensor itself.

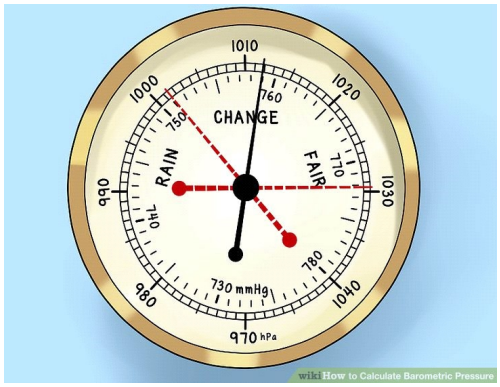
Look at the ‘max’ numbers at the top and ‘min’ at the bottom to see the range of movement. This ECU sees 12.9% when the pedal isn’t being pushed and has learned that this number is ‘idle’ position. The MAF has gone from 3.75g/s to 149g/s with a rev from 12.9% to 86.7% at the throttle.



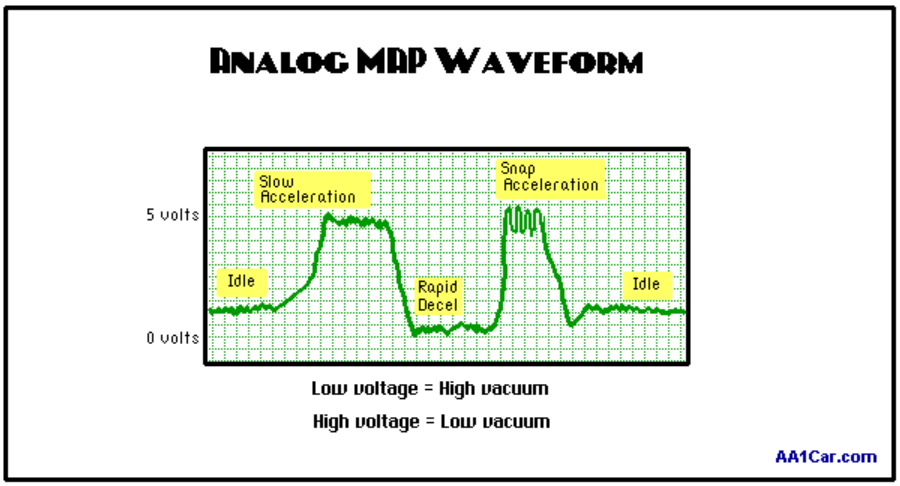
The previous image was with throttle position, the next one is with engine revs. 557 rpm at idle and 3171 rpm at revs.



While a MAP sensor shows intake manifold pressure a Barometric pressure sensor on the vehicle should show around 100kpa [97-104 depending on the weather].



The Barometric pressure sensor lets the ECU know how thick/thin the air going into the engine is. The MAP sensor tells it the load on the engine. Maximum load would be 100kpa when the throttle is fully open and the engine revs haven't increased yet. No load, even at full revs, would be back at 34kpa, cruising with throttle open on a flat road once the desired speed has been reached.

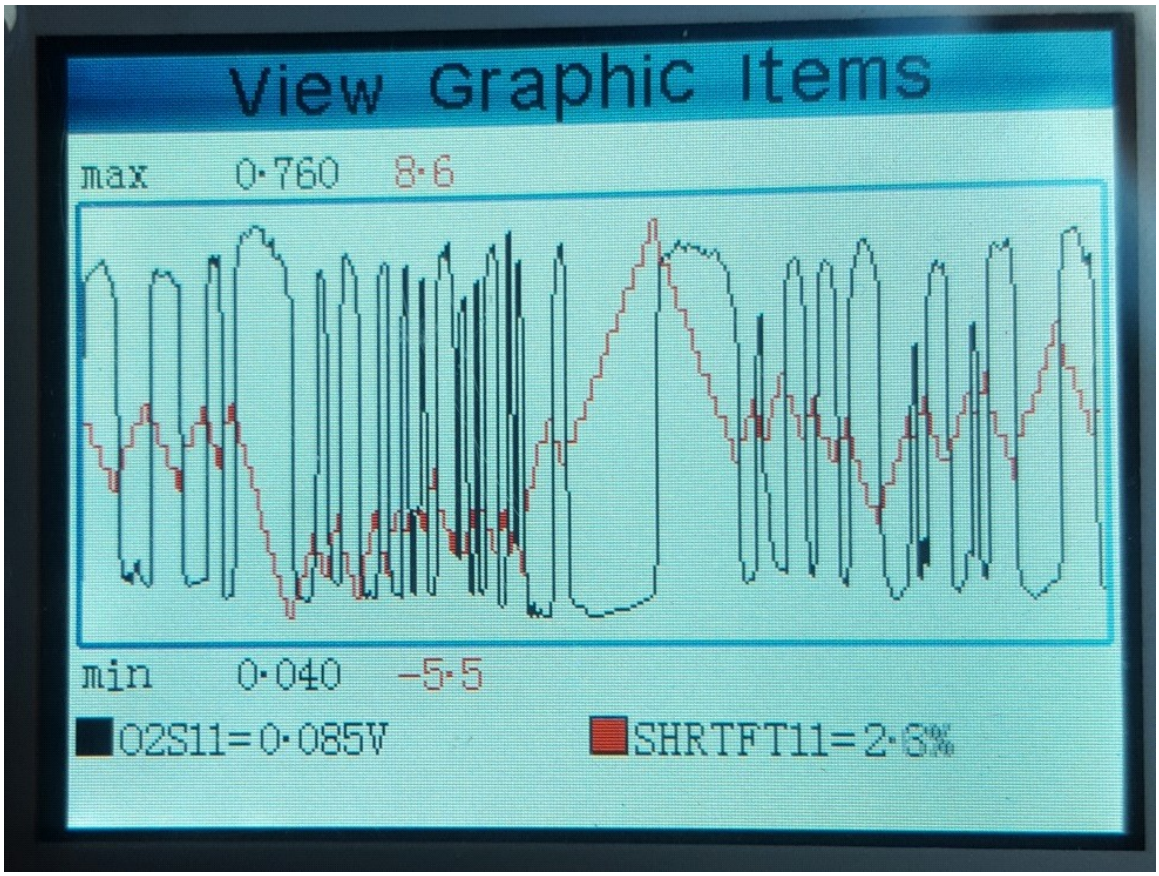


Fuel trims can show you if there is an air leak. The rear O2 sensor can show if the injector or spark is at fault. 650mv at the downstream sensor can mean spark is missing, less than 350mv can mean an injector isn't firing. Fuel trims can change with various engine loads. A manifold leak will cause more problems at idle than under load. The following image shows +25% short term fuel trim at idle plus 10% Long term fuel trim, a total of +35% at idle due to a manifold leak. With the throttle wide open fuel trims are much lower because there is less vacuum in the manifold where the leak is.

Idle Speed		Moderate Load	
VSS	0 MPH	VSS	46 MPH
Engine Load	7 %	Engine Load	55 %
ST FT 1	25 %	ST FT 1	1 %
LT FT 1	10 %	LT FT 1	0 %
ST FT 2	25 %	ST FT 2	3 %
LT FT 2	10 %	LT FT 2	0 %
Light Load		**Heavy Load**	
VSS	27 MPH	VSS	63 MPH
Engine Load	29 %	Engine Load	100 %
ST FT 1	3 %	ST FT 1	-2 %
LT FT 1	0 %	LT FT 1	0 %
ST FT 2	-1 %	ST FT 2	1 %
LT FT 2	0 %	LT FT 2	0 %

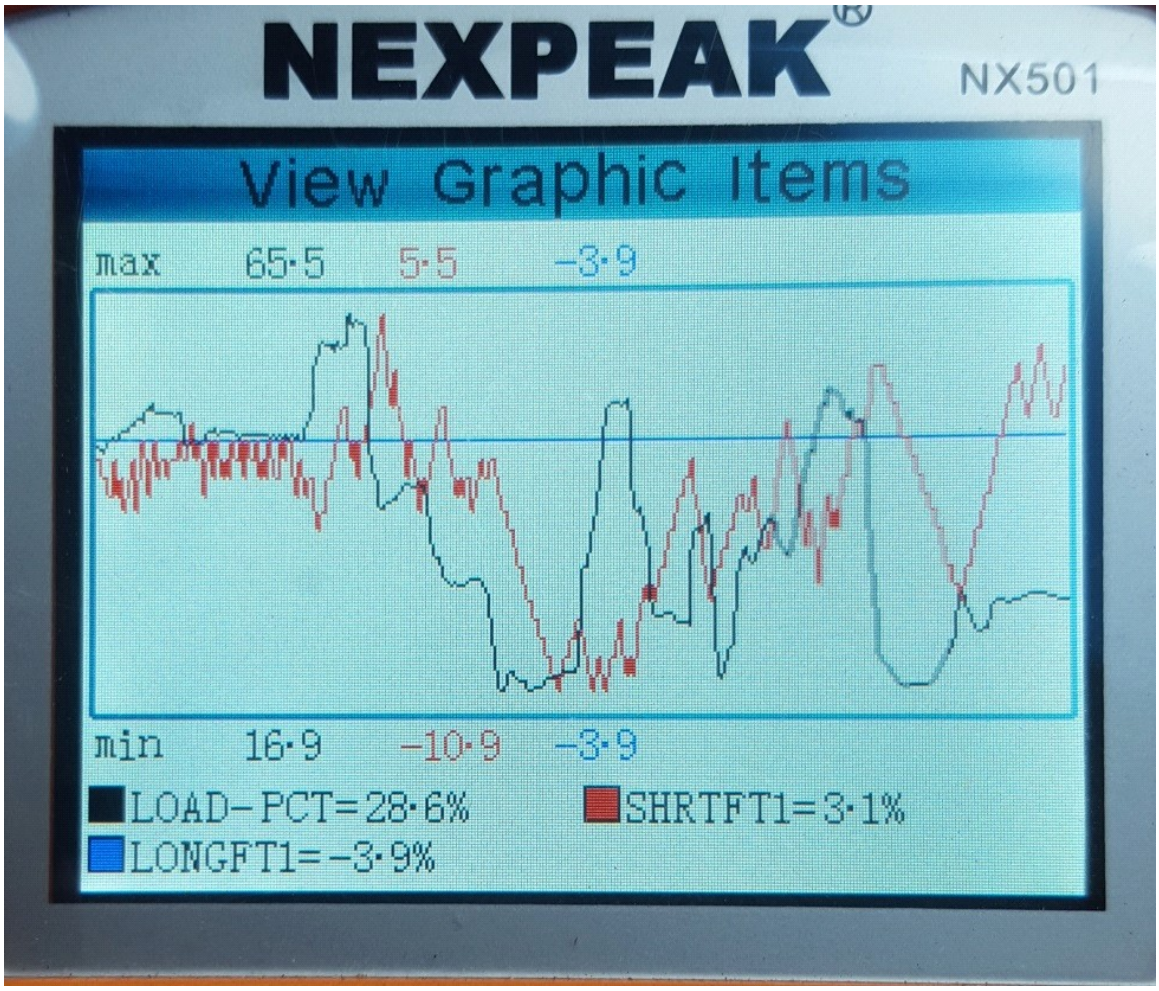
Fig. 3 This screen capture of the four engine management system operating modes is an example of a driveability fault that shows up only at idle speed. The readings under light, moderate and heavy loads appear normal; the idle readings are abnormal.

The short term fuel trim controls injection quantity to make the O2 sensor go from lean to rich and back again to achieve the correct ‘average’ mixture. Short term fuel trim has no memory, it just reacts to the oxygen sensor readings as they happen. When the O2 sensor reaches it lowest allowed voltage the short term trims increase injection time slightly and push it up to the highest allowed voltage then decrease injection time to bring it back down again to the lowest voltage in a constantly repeating cycle.



If all the mechanical aspects of an engine remained perfect- no manifold or hose leaks, the correct fuel was used, injectors never wore out and oxygen sensors never got carbon deposits the ECU would only need short term fuel trims “STFT”. But since this isn’t the case the ECU has long term fuel trims “LTFT”.

Long term fuel trim steps in when short term has reached its limit and the mixture still isn't right. It gives an extra increase or decrease, depending on what is needed, and stores that in long term memory. Next time you start the vehicle the ECU has already set the long term to what it was the last time the engine ran, then short term works normally. When the long term reaches a certain limit, maybe +25% or -25% the ECU throws a fault code for "mixture too rich/lean"



5v sensors usually operate between 0.5v and 4.5v. Either side of that is for showing a fault like short to ground or short to 5v feed.

Two wire speed sensors give a varying voltage depending on engine revs. Low revs = weak pattern. When scoping a crank sensor for signal don't get the pattern confused with voltage drop due to engine compression. There will be a ripple at the sensor corresponding to compression on the cylinders. Magnetic interference can cut square wave cam sensor signals and cause issues. Scope the cam signal at a high frequency to detect magnetic interference.

Some vehicles have more than one diagnostic plug. A 2014 UD Condor has the standard obd plug for the engine ECU and the American style 9 pin plug for transmission diagnostics. Be aware that occasionally you will not be able to get into a system with ANY scan tool – because it simply isn't on the plug you're connected to. Sometimes [read OFTEN] the manufacturers, or previous mechanics on the job, go to great lengths to see how well they can hide really important connectors.

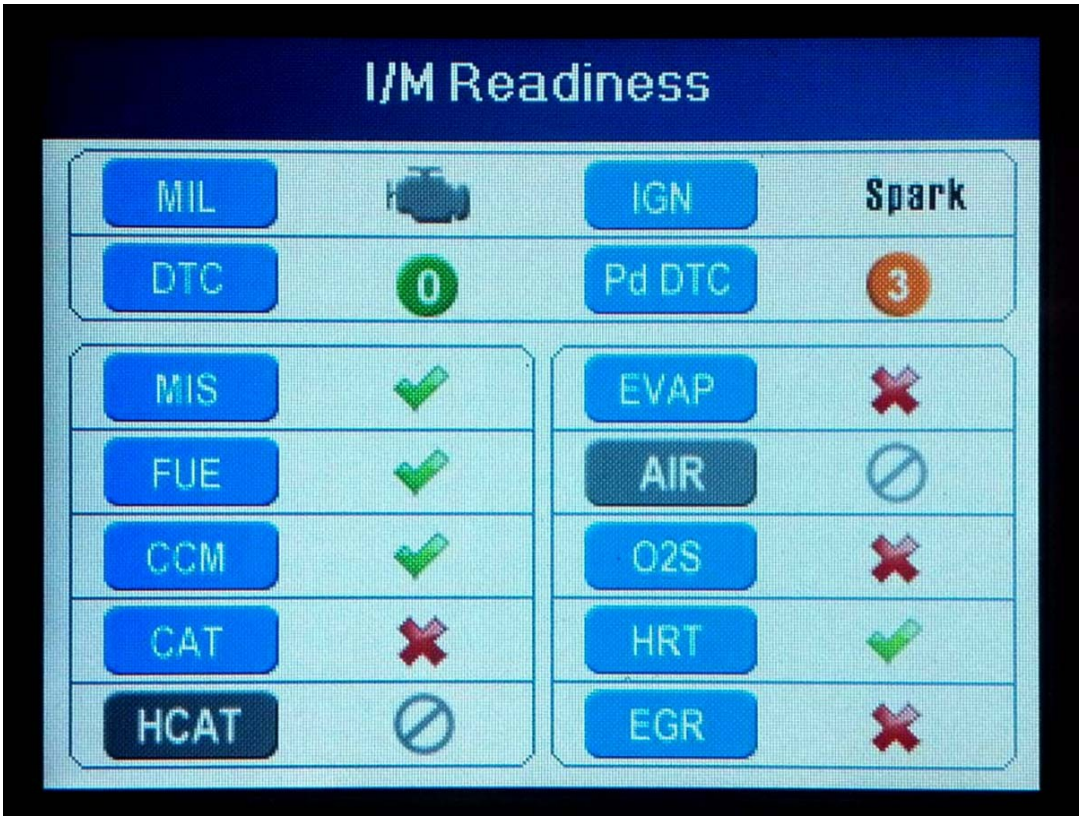
Older Isuzu trucks have a 20 pin diagnostic plug AND a 3 pin plug – besides several connectors to bridge together to get flash codes. Reminder: If you can't get into a system using the manufacturer access on a scan tool try the universal OBD2/EOBD mode, there is some emissions related information the manufacturers MUST share by law, even if they won't give you access to other information in the system.

NOTES:

I/M or “Internal Monitor” Readiness test.

It’s also worth doing an I/M readiness check. This is what the police do in the some countries and states in the USA and Europe when checking emissions. If any of the components aren’t “ready” the vehicle fails its emissions test. It also shows what the ECU thinks is working. Some cars won’t give a fault code for an O2 sensor that isn’t working, they will simply run the injectors on the long term fuel trim in memory without ever throwing a code. Doing an I/M readiness check can save having to find O2 sensor wires and scope them.

Clearing codes resets I/M readiness and it may require a few drive cycles, from cold, before the ECU is happy with all the components again. With most cars after you clear a fault code and start the engine everything but EGR will be ready. After perhaps 3 drive cycles from cold to hot the ECU will declare the EGR “ready” again.



“PD DTC” = “Pending diagnostic trouble code”

A “pending” DTC means that something is disconnected but the ECU hasn’t needed it yet [unplugged solenoid perhaps] so it isn’t an issue yet. When the ECU tries to use it then it will become a “current” DTC.

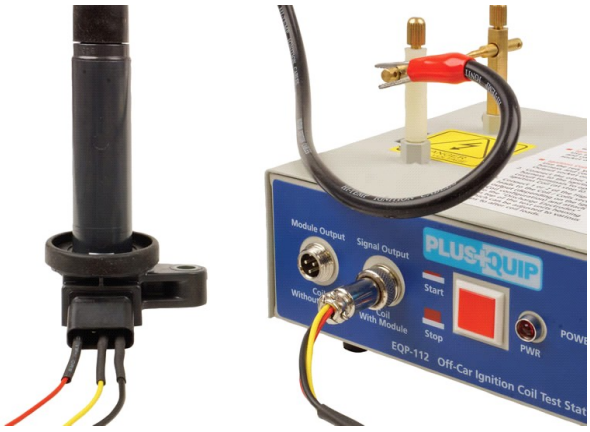
NOTES:

Diagnosing.

1.) Find out what the complaint is. eg: “Engine light on and misfire”

2.) Scan it: Code P0302 “misfire cylinder 2”. This is not the end of the diagnostic process!

3.) Diagnose the fault, don’t just change the parts - backyard mechanics do stuff like that, if you think something is faulty PROVE it [unless it is very time consuming to prove and the part is very cheap, like $3 spark plugs]. Connect the scope to the coil, check it has earth and positive feeds. Check that it has a trigger from the ECU. Check that supply voltage does not fall away when it is triggered [bad connection/voltage drop]. Connect the coil to the coil tester to prove 100% that it is faulty before replacing it.



Gather information. Check operating voltages, Google common faults, talk to the customer about what happens when the fault occurs. Use the forums, asking a question on the forums is no different to asking the

technician next to you if they know anything about fixing the issue. You may end up doing another job and come back and find your question has been answered, saving hours of struggling with the vehicle.

If you don’t know how a module works connect the oscilloscope and measure each wire when operating it to work out what each wire does.

Always look where someone else has been before first - most problems are caused by the nut that holds the steering wheel - and the mechanics before you. Record the evidence - photograph the damage.

Nobody knows everything, ask several people for advice. Some people giving well-meaning advice can be wrong. Ask a mechanic whether you should have the radiator cap “off” or “on” when changing a temperature sensor. Half of them will say “off”, half will say “on”, while the one who has thought about it will tell you to take it “off” first to release the pressure, then put it back “on” to slow down the water leaking out of the head when you remove the sensor. Sometimes the answer is “both”. If a car has a misfire leave it running for a minute with the misfire happening then turn it off and check the spark plugs to see which cylinder is fouled. Driving it when it's not misfiring will clean all the plugs and make it harder to work out where the fault is.

There may not always be a fault code saying which cylinder has a misfire so

another way to check which cylinder is to blame is to use a temperature gun and measure each exhaust outlet as close to the engine head as possible.

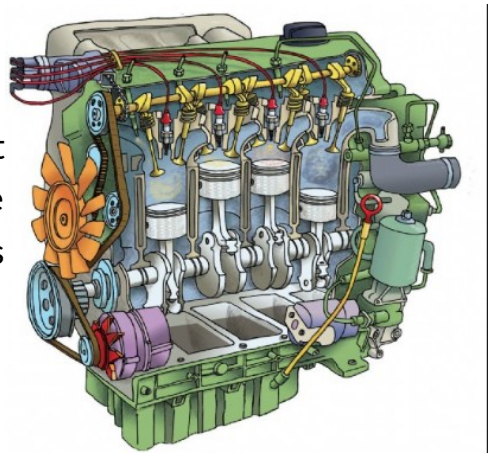
A diesel engine with bad fuel will keep changing which cylinder is hot because it will be a random misfire, a misfire on one cylinder will mean that one outlet is constantly colder than the others.

If an ECU that has the ability to show which cylinder is misfiring throws a “random misfire” code it could be a burned exhaust valve because varying revs will make the interference between cylinders change from one to the other as the pressure pulses change with revs. If it is a burned intake valve then it will throw a code for that one cylinder only since it works with vacuum which doesn’t has as much energy as hot exhaust gasses.

NOTES:

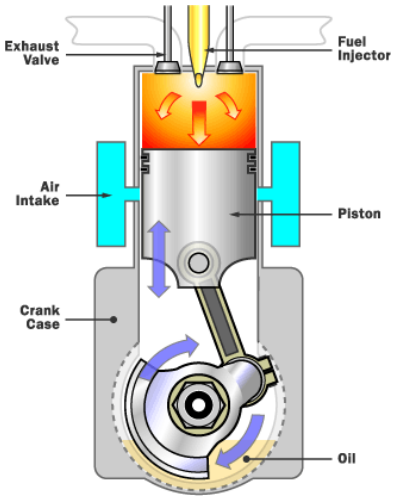
Solving the problem:

Describe how it works and prove it is faulty: To solve a problem try to explain how the system works then prove it: "The engine needs air, fuel, compression and spark" - prove that it is getting each of these.



Is it actually getting air? Check for blocked air filter, check MAF and MAP sensor readings in live data, Is it getting too much air? [use the smoke tester to check for intake leaks], does the air flow slow down? [blocked exhaust]. Is it getting fuel? [check pressure and flow]. is it getting the RIGHT fuel? [recently filled with wrong fuel or contaminated fuel, vehicle sat for 6 months and fuel has gone bad], spray “quick start” AFTER the MAF sensor to see if it will run on that. Is it getting TOO MUCH fuel, pressure too high? [wet spark plugs]. Is it getting spark? Is the spark strong enough? Is the spark plug gap too big for the spark to jump? Does the spark get to the spark plugs?

With a tricky fault break down the explanation further each time to provide more variables to test “the right time” “amount” “quality”[of each variable]. Sometimes a “wet” or “dry” spark plug can determine whether spark or fuel is the



problem - with some cars the ECU will turn off fuel injection for the cylinder if it detects a misfire so this doesn't always work.

Remove assumption from your diagnostics "The distributor turns and generates a cam and crank signal …" Is it really turning? Have you checked? Just because the engine is turning doesn't mean the cam shaft isn't broken. The distributor may not actually be turning. You may see the cam moving through the oil filler cap but it could still be broken halfway.

Don't ASS-U-ME anything. A battery may have a "+" and a "-" post but it is possible to totally flatten a battery and charge it in reverse so the "+" and "-" are actually the wrong way around – customers have done that in the past, and will do it in the future.

A trailer with none of the 16 lights working could still have all the bulbs blown – people plug 12v trailers into 24v trucks occasionally.

NOTES:

Variables:

There are several ways to do some jobs. Do it the way you prefer unless the boss insists it be done his way. If it works his way then just do it that way, if something goes wrong with it then it's not your fault. If you insist on doing it your way it will be your fault.

Make sure your reference source is good – battery earth is safer than a tow-bar bolt for an oscilloscope or test light.

Think of the variables involved. If something isn't playing up in the workshop what is different? It's not outdoors, the doors are unlocked, open windows, bonnet is up, maybe the customer parks next to a room at home that has the spare key which may be transmitting a signal, something not present in the workshop. On some cars the wipers won't work if the hood is open.

In one case a current drain only happened between 12pm and 1am - the

clock was faulty. It never played up in the workshop but a long term recording oscilloscope pattern showed that it happened for an hour overnight.

One Audi model changes over indicator feeds from lower lights to rear door lights when the back is open. When wiring up a trailer module make sure you get the feed that powers up the lower lights, when the door is closed.

When checking an alternator charging check both terminals at the battery, if it is low also check the positive and negative at the alternator to make sure there is no volt drop in the wiring. Check the feeds to the regulator as well before condemning the alternator.

Don't simply be a guessing "parts changer" though sometimes it's cheaper to replace a part than spend hours diagnosing it. You don't want to waste time diagnosing whether a $12 relay is faulty when they are readily available but we also don't want to just replace a $400 oxygen sensor because there is a fault code for the heater circuit – it may be a blown fuse.

When you load a battery to show 600cca on the load tester it is actually half that [check it with a clamp meter]. To get a real 600 amps the battery would have to drop to 7v.

Look at the second bullet point in this picture – where it shows 600 on the CCA scale the needle is actually on 300 on the actual amps scale.

Don't check for power with a bulb test light - airbags can kill if you probe the wrong wire.

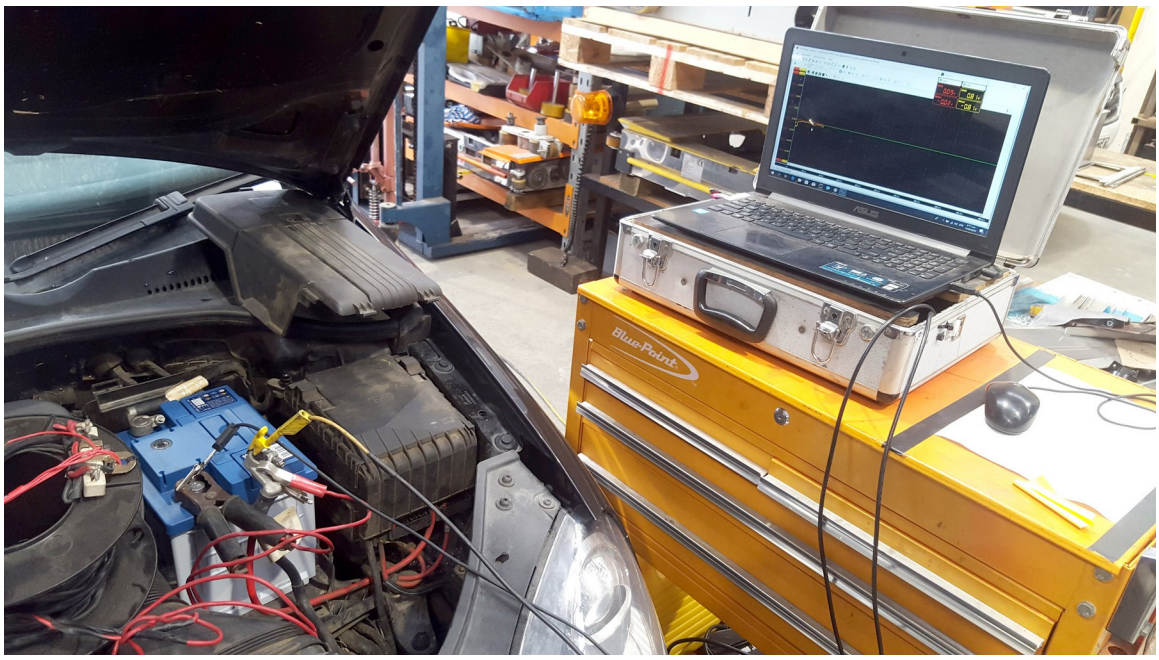
Sometimes simply disconnecting the battery can fix an issue. A Mercedes might disable the HID headlights when they have been unplugged to be safe but give no fault codes in any of the modules. It won't start working again until the battery has been disconnected.

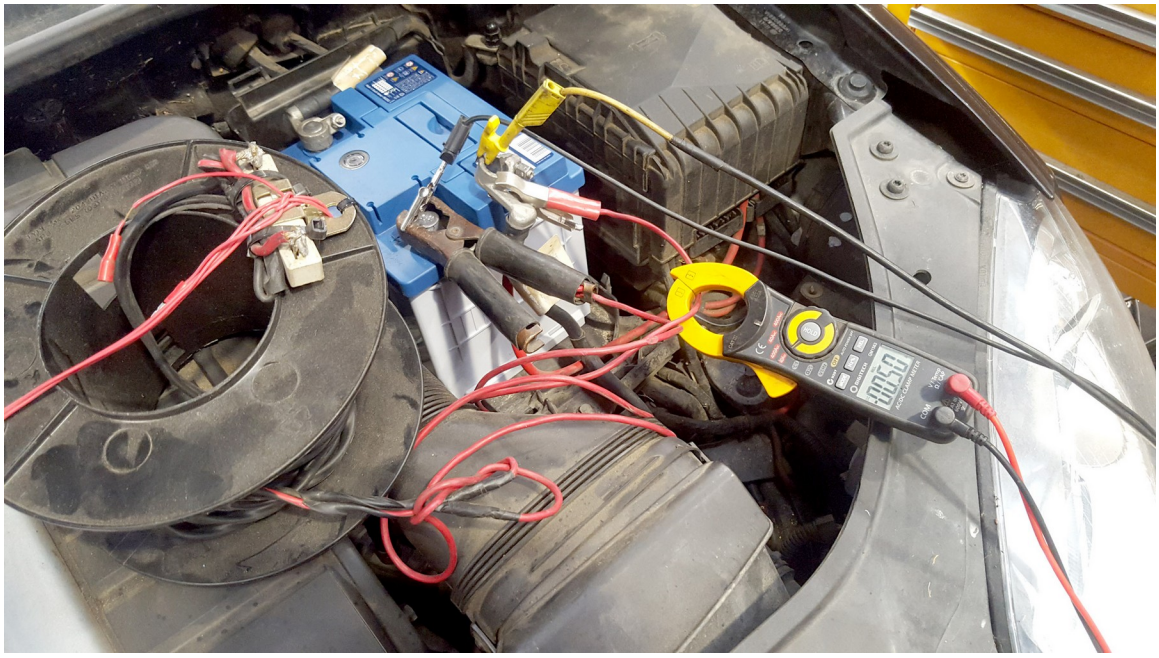
Current draw:

The modules on modern vehicles can take up to 2 hours to go to sleep. If a

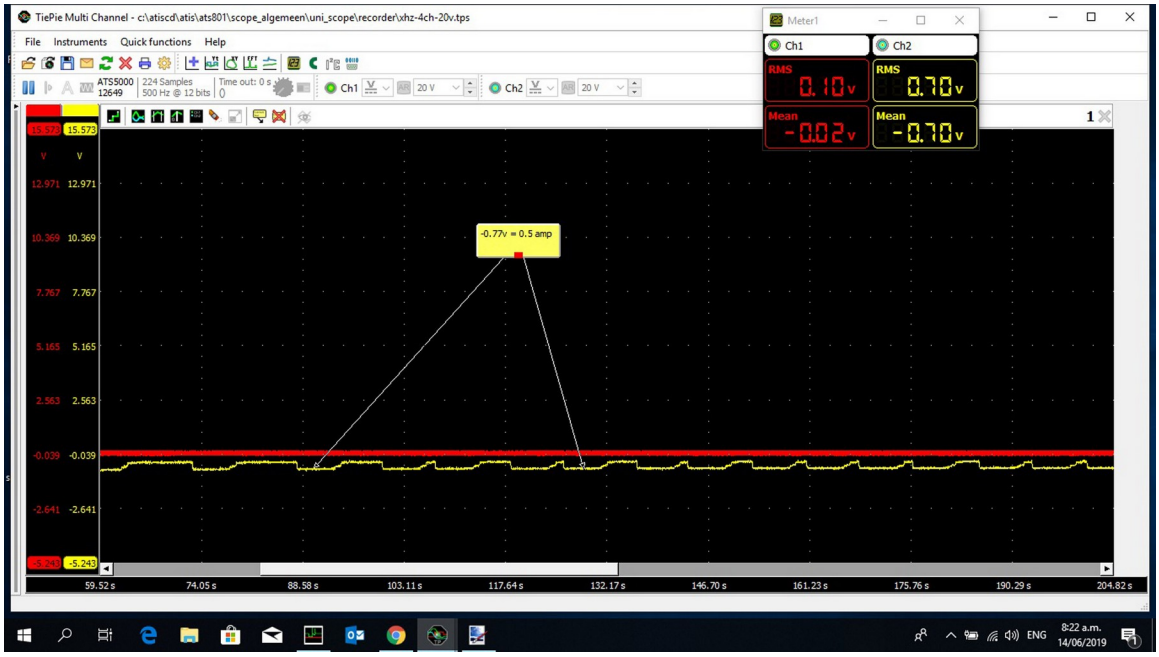
vehicle has a current draw leave the doors open but latch them [tie a rag around the locator so you don't slam it by accident] and make sure any door switches are disabled so everything appears to be closed to the modules, do the same with the hood . That way you don't keep waking the modules up each time you open a door.

Use the oscilloscope to measure the voltage drop across a thin piece of wire in series with the battery and measure the current with a clamp meter so you know what current that voltage represents.





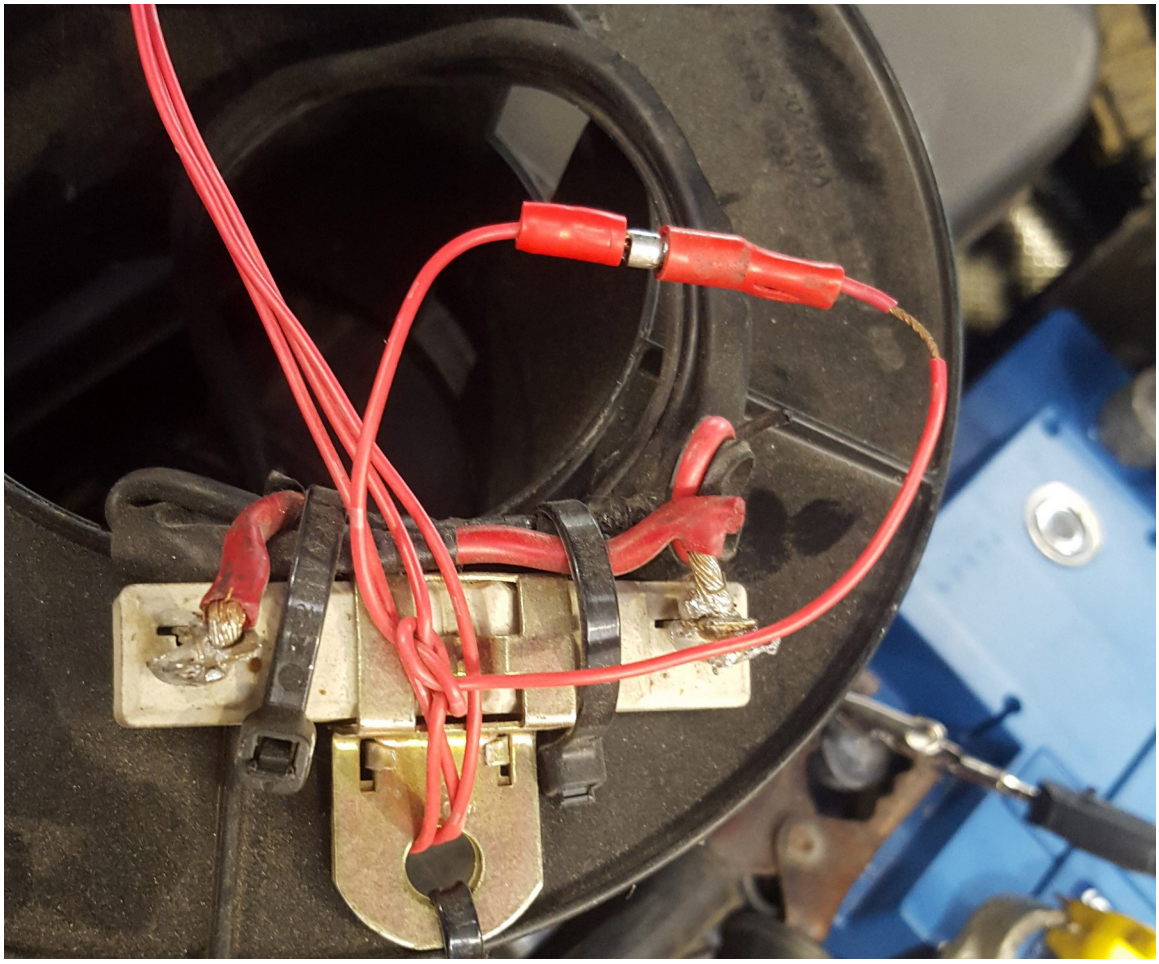
Set the oscilloscope to a 1 hour recording pattern and watch the voltage change while doing something else.



When the fault occurs remove fuses one at a time OR measure the voltage drop across the two contacts of each fuse to see which one has a current draw. If one of them has a current draw there will be a voltage drop across its contacts, that way the modules don’t wake up just because the fuses get plugged back in each time. If several modules are contributing to a current draw do a full system scan to see which ones are awake. Go through the inputs of each module in live data to see why they are awake. A faulty glovebox switch on a Porsche can make all the seat modules and BCM wake up and stay awake each time a door is opened - because it assumes someone must be in the vehicle if the glovebox is open, so the modules stay awake in case they want to adjust the seat.

If the current draw is small you can use a 1 ohm resistor which will make your oscilloscope voltages equivalent to current draw. 1 amp current draw will register at 1 volt drop on the scope.

If the current draw is higher the voltage drop will be too high and relays will start clicking and cause issues, then you will need to bypass the resistor and simply have a thin piece of wire to measure voltage drop across. The voltages will change but you can still measure the current drop with a clamp meter and calculate actual current draw from that.



DPF regeneration

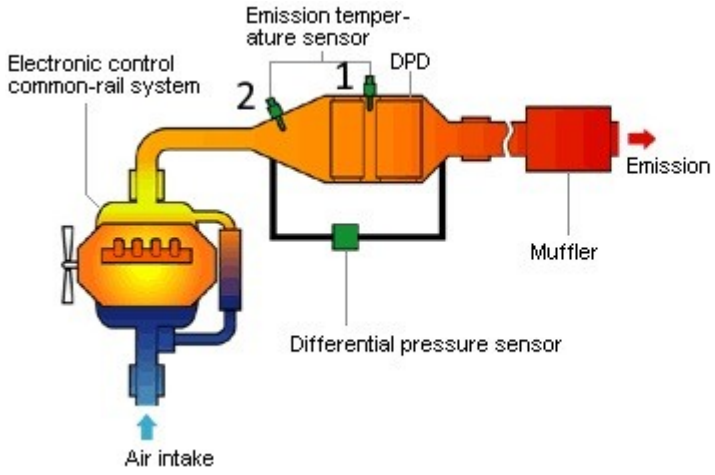
The idle switch must be turned all the way down or the vehicle won't do a burn.

First RESET the dpf data in 'special functions' before doing the burn.

Park in an area with good air flow and make sure the exhaust isn't blowing on anything combustible. Preferably near a fire extinguisher or water.

The exhaust temperature gets up to 500 degrees for 15-30 minutes then goes up to about 600 degrees for 5 – 10 minutes for the final clean. If the engine isn't warm enough when the forced burn is started the vehicle will bring on the exhaust brake for a while to get to the correct temperature.

The exhaust temperature sensors are numbered backwards, sensor 1 [around 600 degrees during a burn] is after the CAT and sensor 2 is before the CAT [around 350 degrees during a burn]. The CAT catches fire and blows flames over the DPF filter to clean it out.



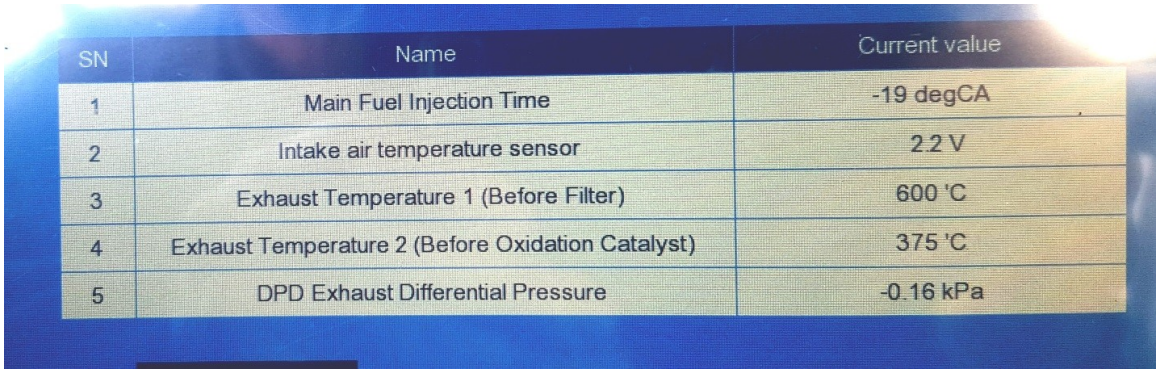
DPD for 4HL1 diesel engine

If one scan tool doesn't show an option for DPF regeneration in 'special functions' try different variations of the engine eg: 4HK1, 4HK1-TC, 4HK1-TC euro2/3, until you find the option. If that doesn't work try a different scantool.

If the temperature starts 'cycling' [going up then dropping back again] the

CAT isn’t efficient enough to do a burn and needs to be replaced.

When the vehicle is doing a burn the exhaust gasses are so hot that you can’t hold your hand half a meter behind the exhaust because of the heat for the first 15 minutes when it’s at 500 degrees. When it gets to 600 degrees it’s too hot about 75cm away.



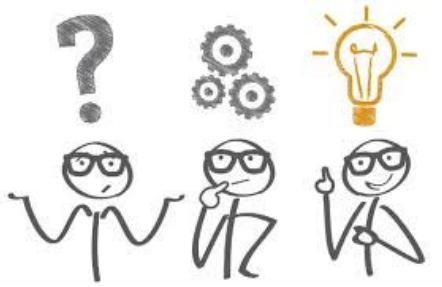
SN	Name	Current value
1	Main Fuel Injection Time	-19 degCA
2	Intake air temperature sensor	2.2 V
3	Exhaust Temperature 1 (Before Filter)	600 'C
4	Exhaust Temperature 2 (Before Oxidation Catalyst)	375 'C
5	DPD Exhaust Differential Pressure	-0.16 kPa

A Toyota Hiace needs the battery to be disconnected for 30 seconds to clear the codes before doing a burn – the codes won’t clear with a scan tool.

NOTES:

Solving problems.

The Halving method.



In computer programming the halving method is the fastest way to do a search. When diagnosing vehicle issues the halving method is also the fastest way to locate a fault.

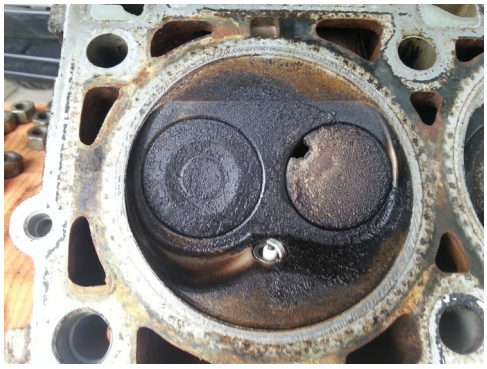
We do this automatically when we pick up a book with some writing in it and don't know where the writing ends, open it halfway, then keep halving the number of pages we open in the direction of wherever the writing stops, until we find the blank page next to the writing. This is something we do naturally when it is something simple like the pages of a book. But when presented with a fault on a vehicle the skill is easily forgotten but just as useful.

As an extreme example if a truck had 16 trailers and there was a short on one of them you would go halfway and unplug 8 of them to halve the problem - then we know which 8 the fault is on. Then unplug 4, then 2 then 1. That would make 4 attempts to find the faulty trailer. Otherwise starting from the back and unplugging one at a time could take between 1 and 16 attempts to find the fault, this would give an average of 8 attempts as opposed to a guaranteed 4 using the halving method. If there was a permanent short this wouldn't make too much difference but if it was an intermittent short which needed an hour's test drive on each attempt to create the short this would be the difference between 8 hours and 4 hours to locate the faulty trailer.

With an intermittent short on tail lights on a truck and trailer fit a weaker fuse at the trailer plug to determine whether it is on the truck or trailer. This halves the problem between the truck and the trailer.

If there is a misfire code for one cylinder on an engine, number the coils and fit them in different cylinders. Also swap the spark plugs around and note where they came from - this will determine whether the fault was with the spark plug or the coil.

The same can be done with injectors - if the misfire moves to another cylinder it can be narrowed down to a spark plug, coil, or injector. If it doesn’t move after everything is swapped over it could be a mechanical issue with valves or cam timing.



Disconnecting the exhaust system can remove it as a possibility for an engine slowly cutting out. If possible removing an oxygen sensor will give the same result. The hole will be big enough for an engine to idle normally if the rest of the system is blocked.

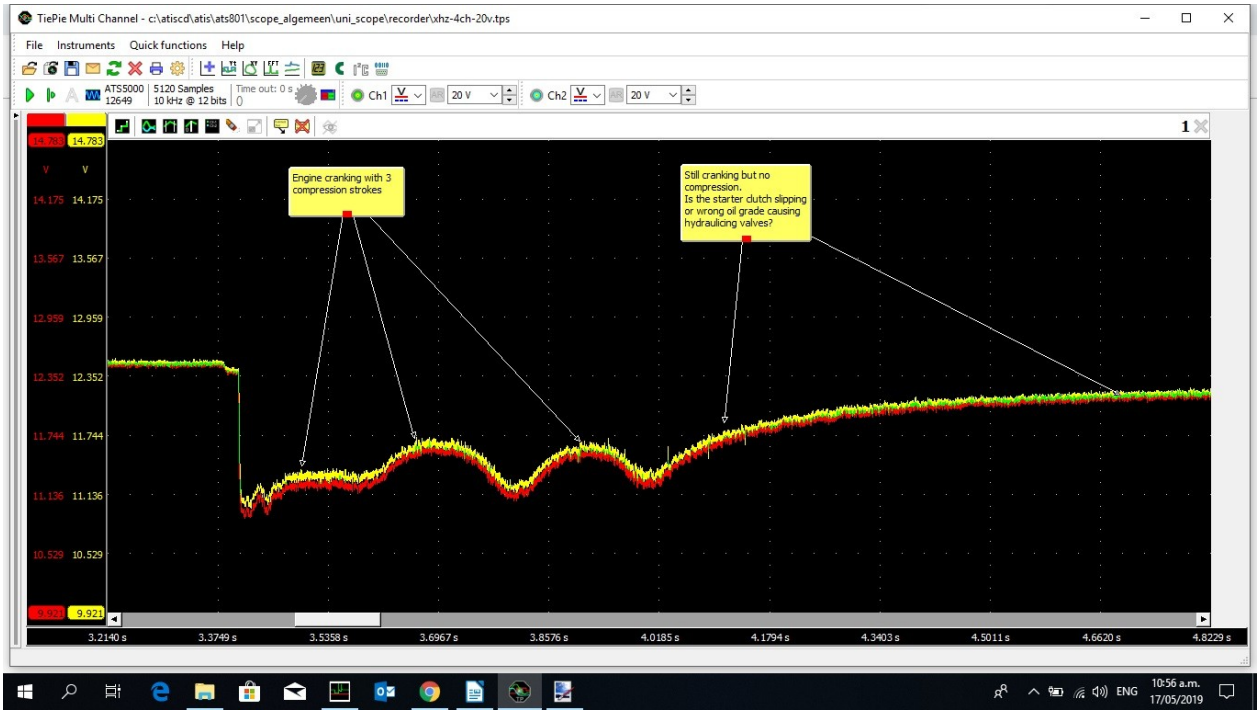
If a fault is too intermittent and time consuming to locate you can still halve the problem by suggesting to the customer that a suspect part be replaced before they take it away. Let them know the fault has not been fixed but we can eliminate a possibility by fitting a new part. Googling the fault may also suggest the most common component to fail that is worthwhile replacing.

Vehicle not starting:

Visual check: water leaks, hoses off – anything obvious before starting?

Scan for fault codes before introducing any new codes!

- Check oil and water for clues of engine damage or oil contamination
- Check battery voltage when cranking – ECU's won't work below 9v



- Do a compression test on all cylinders. One or two lower than the others can also indicate an adjustment problem which can cause timing issues with VVT solenoids.
- Check air filter, smoke test the intake manifold to check for leaks.
- If it starts and dies regularly, and runs longer when left for a while, check exhaust back pressure in case it's blocked. Removing an oxygen sensor is a similar test to see if it will run better with no restriction.
- Check fuel pressure either in live data or with a pressure gauge.
- Is there enough fuel? Fuel gauges can stick so don't believe the gauge, check for yourself.
- Is it the RIGHT fuel? Maybe someone added the wrong fuel or it is old or contaminated. "Diesel bug" grows in diesel and eats the hydrocarbons and can block injectors.
- Check sparks plugs for signs of misfiring. Are they all even [colour and gaps]? Are the gaps the right size?

- Scope the injectors to see if they are getting triggered
- Check for spark. Check the strength of the spark, can it jump a 2cm gap?
- Check injection and coils power supply **when cranking** – some vehicles only provide power to them when cranking and not with ignition on.

Tips:

try to wire something the way you would like to find it if you have to fix it again in a few years.

When adding fuses try to put them close to the fuse box and easy to see – just because you know where they are hidden doesn't mean someone else will be able to easily find an added fuse holder.

Check the basics

Check all fuses, check for MISSING fuses.