WELLS Counter Point

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THE ELECTRONIC, DIAGNOSTIC AND DRIVEABILITY RESOURCE.

Fuel System Fuel Trim

Fuel trim refers to the PCM's ability to add or subtract fuel in response to changing engine operating conditions.

Perhaps you are familiar with what a conventional oxygen sensor waveform looks like. The oscilloscope trace repeatedly travels upward to a peak then downward to a valley, as the oxygen sensor reports the amount of oxygen present in the engine's exhaust. The peaks indicate a rich air-fuel ratio (high oxygen sensor voltage and low oxygen content), while the valleys indicate a lean air-fuel ratio (low oxygen sensor voltage and high oxygen content). When the oxygen sensor reports a rich mixture, the fuel system powertrain control module (PCM) responds by commanding a lean mixture. And when the oxygen sensor reports a lean mixture, the PCM responds by commanding a rich mixture. This is classic "closed loop" fuel control, with the PCM always a step behind in its response to the rich or lean voltage signal from the oxygen sensor.

This would seem to be an inefficient means of controlling the air-fuel ratio. Why not find an air-fuel mixture that is close to ideal (stoichiometry) and keep the mixture as near to that point as possible? Why must the fuel system constantly overshoot its goal as it moves from a too-rich to a too-lean air-fuel mixture and back again? The answer can be found in the design of the catalytic converter. The three-way catalytic converter needs a rich exhaust mixture (low oxygen content) to reduce oxides of nitrogen (NO_X) emissions. However, it also needs to receive a lean exhaust mixture (high oxygen content) to oxidize hydrocarbons (HC) and carbon monoxide (CO) into carbon dioxide (CO_2) and water (H_2O) vapor. If the exhaust stays rich, the catalytic converter can't reduce CO and HC emissions. And if the exhaust stays lean, the catalytic converter can't reduce NO_X emissions. Alternating between rich and lean allows all three goals to be reached.

Why Fuel Trim Is Needed

The closed loop setup described above would do a pretty good job of controlling emissions if the engine operated in a narrow RPM range at all times. However, due to changes in vehicle speed, load and many other variables, engine speed frequently changes through a very wide range. The PCM needs ways to make adjustments for these changes. One of these adjustment capabilities is called fuel trim, which refers to the PCM's ability to add or subtract fuel in response to changing engine operating conditions.

The PCM contains a set of preprogrammed maps which tell it how much fuel the engine *should* need under specific conditions of load, manifold absolute pressure (MAP), engine revolutions per minute (RPM), engine temperature (ECT), throttle position (TP), etc. If the PCM determines that the engine needs more or less fuel (based on the exhaust oxygen content information received from the oxygen sensor), it "trims" the mixture by adding or subtracting fuel. Fuel trim is expressed in terms of short term or long term corrections. GM has also used the terms *integrator* and *block learn* to describe the measurements that express fuel trim when viewed on a scan tool.

The GM system assigns a number between 0 and 255 to define fuel trim, with 128 being the middle point. A short term fuel trim (integrator) reading of 118-138 is considered normal. Fuel trim can also be expressed as either a positive (+) or negative (-) percentage. The percentage reading represents the difference either above or below the anticipated amount. So a short term fuel trim reading of +20 percent indicates 20 percent more fuel had to be added to achieve the proper air-fuel mixture. A -20 percent short term fuel trim indicates that fuel had to be removed by shortening the injector pulse width to achieve the proper air-fuel mixture.

When the engine is operating in closed loop, the oxygen sensor signal is the main influence on the PCM's short term fuel trim (SHRTFT) decisions. For example, the oxygen sensor will produce a lower voltage signal if the engine has a small vacuum leak. The PCM interprets this as a too lean air-fuel mixture and the injector pulse width is increased slightly to compensate. The amount of additional fuel that is added is seen on a scan tool as a positive SHRTFT.

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Fine Tuning

***Fine Tuning** questions are answered by Mark Hicks, Technical Services Manager. Please send your questions to: Mark Hicks c/o **Wells Manufacturing Corp., P.O. Box 70, Fond du Lac, WI 54936-0070** or e-mail him at **technical@wellsmfgcorp.com.** We'll send you a Wells shirt if your question is published. So please include your shirt size with your question.*

Q: I have a problem with a 1997 Ford Explorer Truck 4.0L VIN E that I've been working on for the past few days. When the truck first came into the shop, it had a diagnostic trouble code (DTC) P0402 stored in the powertrain control module (PCM). I followed the Ford diagnostic tree for this DTC which recommended replacement of the Delta Pressure Feedback Exhaust Gas Recirculation (DPFE) sensor because the sensor was not within specifications.

The local dealership delivered a replacement sensor, but it didn't look the same as the original that was on the truck. The original sensor was aluminum and the replacement was plastic. I called the dealership and they assured me the part I received was the correct replacement, so I installed it. I took the truck for a road test and the malfunction indicator lamp (MIL) came on before I could get out of the driveway.

After returning to the shop, I checked voltage levels at the PCM. I found 5 volts on the DPFE sensor signal pin at the PCM, so I replaced the PCM. I still have the same problem: the MIL illuminates and the PCM stores a code P0402. Is the 5 volt DPFE sensor signal normal? Where do I go from here?

Al Oliverez
Firestone
Dallas, TX

If a replacement part does not look like the original equipment (OE) part, verify whether any design changes have been made, before you install it. Refer to the diagnostic tree for DTC P0402. Note under step HE23 that one of two DPFE sensors may be installed on this vehicle. One sensor has an offset voltage of 1.0 volts and the other has an offset voltage of .55 volts. Offset is the amount of voltage the sensor puts on the signal wire to the PCM with the key on engine off (KOEO). Installing the wrong sensor will cause symptoms similar to those produced by a part that is not within OE specifications.

The 5 volt signal to the PCM on the DPFE sensor signal wire is incorrect. A DPFE sensor functions very similar to a manifold absolute pressure sensor. It is nothing more than a voltage divider. After looking at the wiring diagram for the PCM pin outs, I believe you have been testing at the wrong pin at the PCM. The pins for reference voltage and DPFE sensor signal are very close together in the connector. The wire colors are as follows: the DPFE sensor signal wire is brown with a light green trace, and the 5 volt reference wire is brown with a white trace. This is a very difficult connector to back probe, and I'll admit I've made my share of wire color identification mistakes.

Results: After talking with another parts house, Al determined that the sensor he got from the dealer was indeed the wrong part. He installed the correct sensor and the MIL has stayed off since.

The "Fine Tuning" question from the last *Counter Point* concerned a 1992 Chevrolet K-1500. The problem began with a no-start, which lead to an ignition module and pick-up assembly replacement. A couple of weeks later the engine started running rough and dying out. The base timing was off, but the ignition, engine management computer and engine mechanical systems checked out okay.

On this vehicle, check the base timing by first disconnecting the connector on the tan/black wire located under the battery junction block cover. Disconnecting this wire takes any influences from the powertrain control module out of the picture. This is where the "base" in base timing comes from. Knowing the PCM has no influence on the timing can be a very useful diagnostic tool. In this case, the base timing had changed without rotating the distributor or having the PCM involved.

On this vehicle, the position of the distributor housing/pickup assembly in relationship to trigger magnets that are attached to the distributor shaft determine the base timing. It is a fairly common failure for the magnetic trigger to crack and move on the distributor shaft. When it moves, the base timing will also change and disturb the timing curve.

To check for this failure, remove the distributor cap and try to rotate the trigger on the shaft. If you are able to move it in any way, the splines are rounding off and the shaft or distributor must be replaced.

This is not what happened on this particular vehicle. The distributor shaft bearings at the top of the housing began to seize due to a lack of lubrication. The distributor shaft became twisted when the camshaft attempted to turn it. The first sign of either of these problems is an unexpected change in base timing. Either answer is correct.

Results: The distributor was replaced and the base timing returned to normal.

The first correct answer received by e-mail or fax was from:
Dan Baumhardt
Auto Diagnostics, Inc.
West Allis, WI

The first correct answer received by post was from:
Eric White
EWOO Automotive
St. Louis, MO

Diagnose The Problem Win A Shirt

Q: "I have been working on a 1999 Ford Escort with a 2.0L engine that has a number two cylinder misfire. The fuel system is operating within specifications, but a quick check with a spark tester revealed there was no spark on the number two cylinder.

"I had the same problem with this vehicle about two weeks ago. At that time, the number two cylinder started firing and the engine ran great after I replaced the ignition coil. Now it is back in the shop with the same dead cylinder problem. The PCM controls the spark on this vehicle. Could this be the source of the problem, or is there something else I should check?"

Mike Metz
H.J. Biebold Garage
Buffalo, NY

The first reader to respond with the most accurate answer via e-mail or fax, and the first reader to respond with the most accurate answer via snail-mail, will receive a Wells golf shirt. The answer will appear in the next issue.

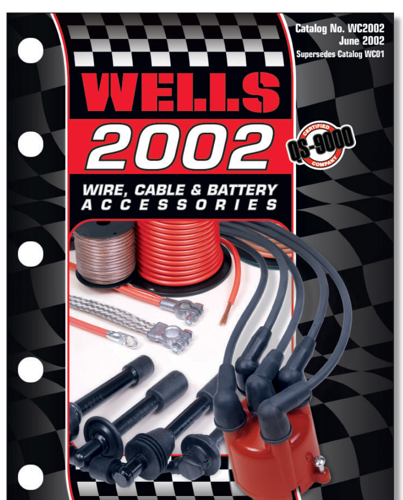
Hot off the Wire

Wire, Cable & Battery Accessories Catalog

Wells Manufacturing Corp. has released its 2002 Wire, Cable & Battery Accessories Catalog. Over 100 new part numbers have been added since the publication of the 2001 catalog. New catalog product categories include Electrical Tape and Nylon Loom Clamps.

Tape is offered in several varieties, including Vinyl Electrical Tape, Professional Grade Electrical Tape, Amalgamating (Cold Shrink) Electrical Tape and Self-Fusing Silicone Tape. Nylon clamps are tough, resilient, lightweight and resistant to aging and most chemicals.

For more information about the Wells Manufacturing Corp. line of products, contact your Wells parts supplier.



continued from page 1

Fuel System Fuel Trim

Long Term Fuel Trim

SHRTFT adjusts the air-fuel ratio in response to brief changes that normally occur during engine operation. Long term fuel trim (LONGFT) is designed to add or subtract fuel over a longer period of time. If the vacuum leak in the previous example were to continue or grow larger, fuel delivery would have to be further increased and continue for a longer period of time. The PCM incorporates LONGFT for this purpose.

SHRTFT continues to add fuel to compensate for the vacuum leak. But if the leak continues for longer than a few seconds, the PCM also adjusts LONGFT to compensate for the lean mixture. When the PCM makes an adjustment to LONGFT, SHRTFT continues to be used to make quick changes in the air-fuel mixture as needed to provide the catalytic converter with an alternating rich and lean exhaust.

Fuel Trim Diagnostics

A scan tool can be used to read both SHRTFT and LONGFT data. LONGFT data has more value for diagnostic purposes because it records what has occurred over a longer period of time and represents a greater amount of mixture correction. For example, if a reading of +20 percent LONGFT is indicated, we know the PCM has commanded the delivery of 20 percent more fuel than the calibrated amount as it attempts to achieve the proper air-fuel mixture. The LONGFT number will always indicate what the PCM had to do to achieve the proper mixture.

Three examples of scan tool fuel trim readings and possible diagnostic explanations follow. Examples of real vehicle readings are shown in **Figures 1 and 2**.

Vehicle 1
SHRTFT = +5%
LONGFT = +20%
Explanation: The PCM is responding to a lean condition. LONGFT indicates the programmed amount of fuel had to be increased by 20 percent to achieve the proper air-fuel mixture. At this point, SHRTFT could "toggle" the mixture rich and lean to achieve the best catalytic converter efficiency. Possible causes for this condition are a manifold vacuum leak, misfire or low fuel pressure.

Vehicle 2
SHRTFT = -10%
LONGFT = -30%
Explanation: The air-fuel mixture is rich because LONGFT is removing 30 percent of the anticipated amount of fuel to achieve the proper air-fuel mixture. Even after removing 30 percent, SHRTFT still has to make a further adjustment of 10 percent to attempt to lean out the mixture. This is not a normal condition. Look for a defective fuel injector, a defective fuel pressure regulator or a restriction in the intake air passage.

Vehicle 3
SHRTFT = +10%
LONGFT = ±2%
Explanation: These readings are normal. It is normal for SHRTFT to add or subtract up to 20 percent of the anticipated amount of fuel to achieve and maintain the proper air-fuel mixture. LONGFT is ±2 percent, indicating no large long term adjustments are necessary.

Figure 1: *With moderate engine load, SHRTFT responsds by adding fuel. LONGFT is also adding fuel.*

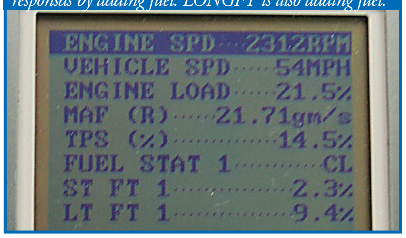
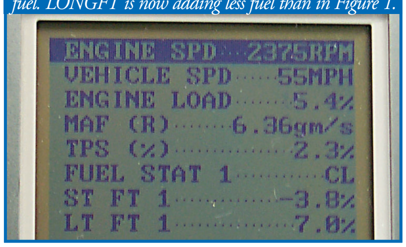


Figure 2: *At low engine load, SHRTFT is subtracting fuel. LONGFT is now adding less fuel than in Figure 1.*



Computer Fuel Trim Strategies

Under normal conditions, SHRTFT is what keeps the engine near the best overall air-fuel ratio of 14.7:1 (stoichiometric). SHRTFT values are retained in the PCM's volatile memory and are erased as soon as the ignition key is switched OFF. These values "start from scratch" each time the engine is restarted.

LONGFT is a learned value that is determined by trends in short term fuel correction. LONGFT values are stored in the PCM's Keep Alive Memory (KAM) and stay there unless they are reset with a scan tool or erased when the PCM's power source is disconnected. After an engine management problem has been corrected, always clear the codes. This also erases the PCM's long term fuel correction information, allowing it to start fresh.

The PCM constantly monitors both SHRTFT and LONGFT to determine if the fuel system is operating normally. If SHRTFT goes beyond its limit in an attempt to control the mixture, LONGFT will also be affected. If SHRTFT correction continues, LONGFT will experience a major change. Both SHRTFT and LONGFT can compensate for a rich or lean condition, but they can only take it so far. When the combined SHRTFT and LONGFT corrections exceed their adaptive limit, the PCM recognizes they are "maxed out" and a diagnostic trouble code (DTC) is stored. The maximum allowable combined fuel trim adjustment varies from one vehicle manufacturer to the next, but a DTC will usually store when the combined SHRTFT and LONGFT are greater than 25-35 percent. On OBD II vehicles, a freeze frame of SHRTFT and LONGFT data is stored at the moment of a fault that results in a DTC being stored.

Fuel correction problems will often be caused by a component failure that sets a separate DTC. For example, a failed oxygen sensor will probably set its own DTC on a late model fuel system. When it does, the fuel system may be out of range but will not set an additional fuel system rich or lean code, because the fuel system monitor won't run until the oxygen sensor fault has been corrected. There are many other possible causes for excessively rich or lean fuel mixtures. Problems with the mass air flow sensor (MAF), MAP or ECT may also trigger a component DTC when they fail. However, there are quite a few components that are not directly monitored by the PCM that can also cause a fault. Some of these include:

- Leaking or plugged fuel injectors,
- Clogged fuel filters,
- Weak fuel pumps and faulty pressure regulators,
- Fuel line obstructions,
- False air leaks between the MAF sensor and throttle body,
- A contaminated MAF sensor,
- Fuel dilution in the crankcase,
- Faulty PCV valves or plumbing,
- Plugged air filters or other air intake obstructions,
- Low compression,
- Improperly adjusted valve or ignition timing,
- A restricted exhaust,
- Exhaust or vacuum leaks that trick the oxygen sensor.

A thorough understanding of how the system receives and processes information may help you to determine which of these failures is behind the system's inability to properly control the air-fuel ratio.

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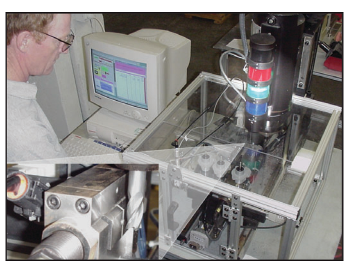
Quality Points

EGR Position Sensor Calibration System

Due to the many sophisticated onboard systems on today's vehicles, components matching the latest original equipment manufacturers' (OEM) specifications must always be installed when replacement becomes necessary. If a poorly calibrated component is installed, it may trigger the malfunction indicator lamp (MIL) or cause the vehicle to fail an emissions test. One of the ways Wells Manufacturing Corp. ensures that all of its components match OEM specs is during the final calibration phase of the manufacturing process.

For example, after a Wells exhaust gas recirculation position sensor is manufactured, it is placed in a custom-designed calibration and test machine cradle. Next, it is electrically connected to the computer using the OE connector. Using the same type of connector that will be used when the component is installed in the vehicle ensures a good connection. The component's position shaft is then depressed until it reaches a predetermined calibration voltage. The computer processes this information to determine the amount of shaft milling that is required. The sensor is then slid into position and the mill does its job. Returning to the original position, the shaft is again operated through its entire range. The computer subsequently graphs and records the voltage versus sensor shaft distance traveled, and the data is compared to OE specs. The critical shaft dimension, output voltage and connector pin integrity are all tested and calibrated. An exact match turns on the green light and the component passes.



Mike Syms monitors the operation of the Wells exhaust gas recirculation position sensor calibration and test machine. Shaft mill in inset.

This calibration and testing is performed on 100 percent of the exhaust gas recirculation position sensors Wells manufactures. We are proud to say this calibration system was entirely envisioned, designed and built by Wells personnel.

Publisher's Information

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