Enhanced Fuel Trim by Rick Escalambre

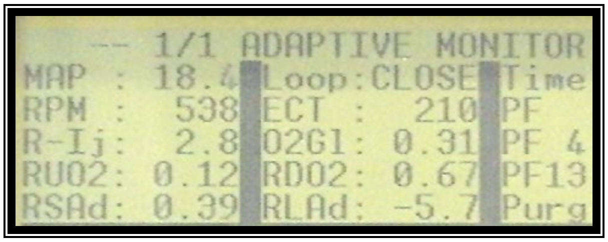
Fuel trim is a technician's most important diagnostic tool available for an air/fuel-related problem. Air/fuel-related problems will always lead to fuel trim regardless of the type of oxygen sensing device: oxygen sensor, air-fuel sensor, broadband sensor, or planar sensor. It can also assist with misfire-related problems because misfires can have an adverse effect on fuel trim.

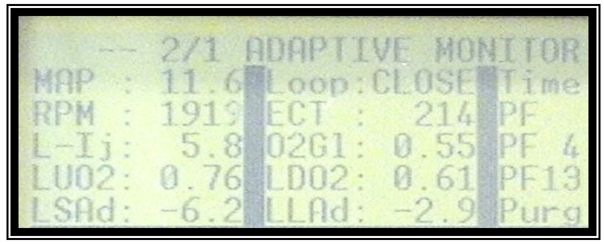
Generic OBD II uses Long-Term Fuel Trim (LTFT) and Short-Term Fuel Trim (STFT) to identify fuel trim trends. It is important to note the word "trend" because the processing of information by the PCM and its refresh rate of data to the scan tool will vary. Depending on the system, the PCM refresh rate using a generic scan tool can be as slow as 2.5 seconds. If you use a global scan tool's aftermarket (OEM) side, the refresh rate will be faster, but the fuel trim will still be a trend.

When looking at fuel trim as a diagnostic tool, always identify if one, two, or three fuel trim readings are available. This means LTFT (1) and STFT (1), LTFT (2) and LTFT (2), or Total Fuel Trim. Using LTFT and STFT 1 and 2 allows the system to be looked at by engine banks. Looking at both banks can help identify if the problem is common to both sides of the engine or a particular problem to one bank. This will alter the diagnostic strategy used.

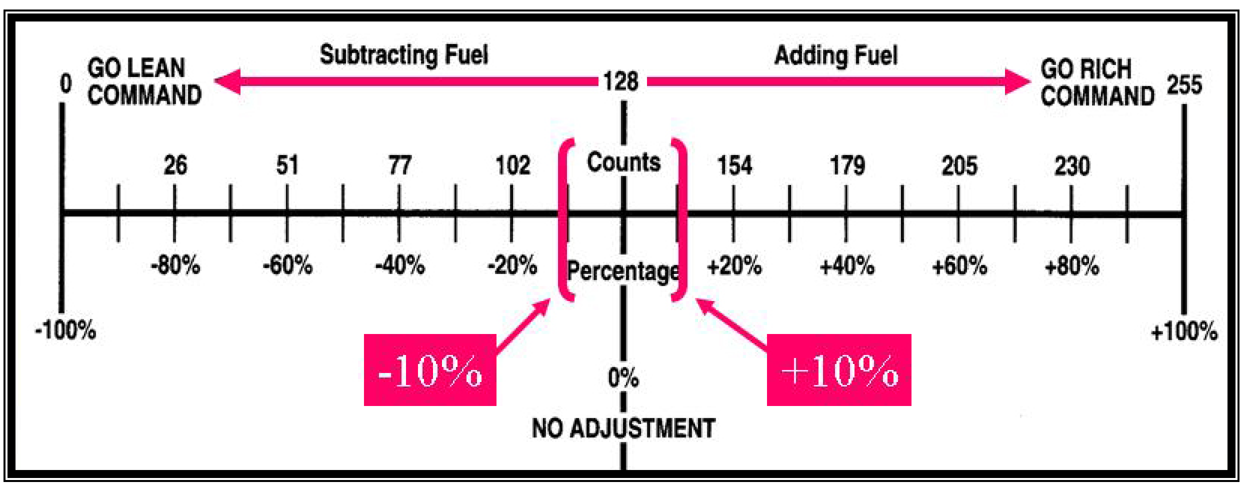
The following pictures were captured from a Chrysler using the DBR III factory scan tool to demonstrate this point. The photo on the left shows a 1/1 Adaptive Monitor, which represents Bank 1 – Sensor 1 Right Short Adaptive (RSAd) and Right Long Adaptive (RLAd). The picture on the right shows a 2/1

Adaptive Monitor, which represents Bank 2 – Sensor 1 Left Short Adaptive (LSAd) and Left Long Adaptive (LLAd).





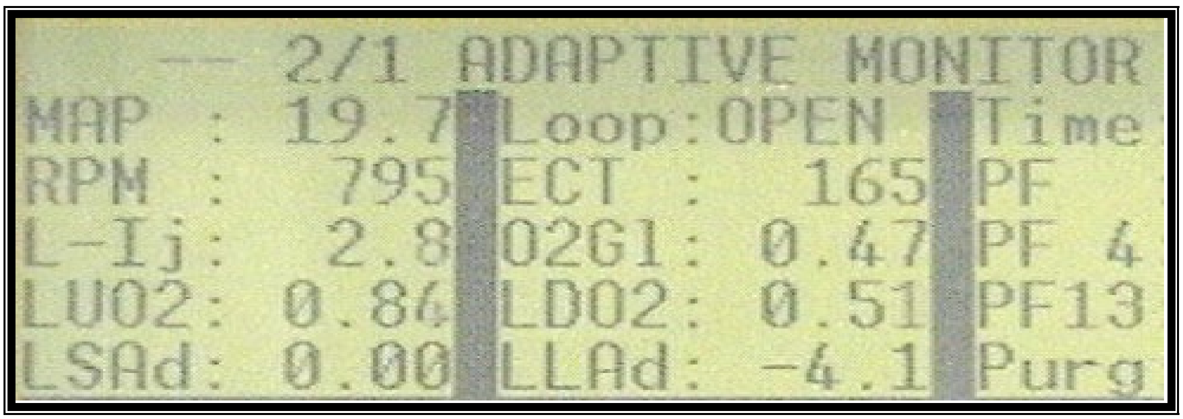
Using an OEM scan tool will generally provide the most fuel trim information, but it may use different terminology from a global scan tool. Fuel trim values can be displayed by Chrysler as Adaptive Fuel; Nissan uses A/F Alpha, Base Fuel Schedule, or Long/Short Term Alpha, and General Motors still uses 0-255 as well ± percentage. The following chart shows the relationship between binary numbers 0-255 and the rate of change the PCM makes to the fuel trim, which is ultimately reflected in the injector pulse width.



Regardless of the terms used for fuel trim, the PCM is always attempting to bring Short Term Fuel Trim as close to 0% as possible. In the real world, it is not expected that LTFT and STFT will both be near 0% because of the many engine operating variables, such as speed, load, temperature, fuel quality/volatility, etc.

In general, there are some basic principles to remember when using Long Term Fuel Trim:

- Long Term Fuel Trim works to bring STFT as close to 0% as possible by modifying the injector pulse width (IPW).
- Long Term Fuel Trim adjusts the fuel mixture once STFT approaches its maximum limits.
- LTFT (LLAd) can be applied in Open Loop.



- LTFT is adjusted when Fuel Trim Learn is Enabled. This occurs once the ECT reaches approximately 140-160°F.
- LTFT adjusts faster after a Fuel Trim Reset.
- LTFT may not adjust during high Purge Flow.
- LTFT is stored by cells in a MAP sensor equipped with Speed Density and Mass Air Flow systems. Some systems use as few as two cells, while others may use up to 96 cells. This will be discussed in more detail in this section.
- Whenever components that affect engine operation are replaced, the Fuel Trim should be reset and relearned. If not,
  - ✓ The engine returns to Open Loop on initial startup, utilizing the LTFT stored when the component malfunctioned.
  - ✓ This could lead to a rough running engine on warm-up after repairs.

- After cleaning a throttle body for sludge and carbon buildup, the fuel trim should be reset and relearned. A dirty throttle body usually forces the LTFT to subtract fuel and increases Rpm through idle air control.

In general, there are some basic principles to remember when using Short Term Fuel Trim:

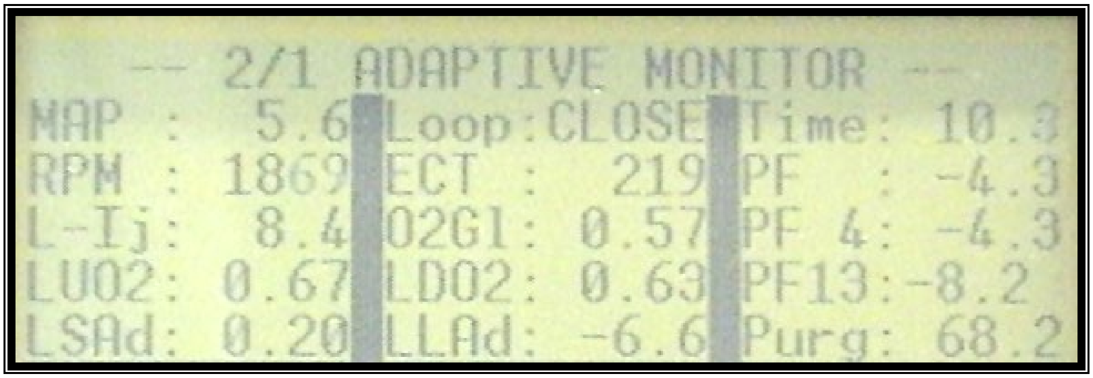
- Short-Term Fuel Trim (STFT) begins to operate once the system enters Closed Loop.
- Short-Term Fuel Trim is based on the upstream Oxygen Sensor (O2) voltage. It makes immediate corrections to the A/F mixture.
- STFT follows the O2 and changes as O2 voltage crosses the rich/lean voltage threshold. Once O2 voltages cross this threshold, STFT rapidly changes pulse width and remains steady until the O2 sensor voltages cross again in the opposite direction.
- STFT values are not learned, and they are reset to 128 or 0% each time the ignition is turned off, load and/or Rpm changes to another cell, or the system reverts to Open Loop.

How does the PCM arrive at the initial fuel delivery/injector pulse width?

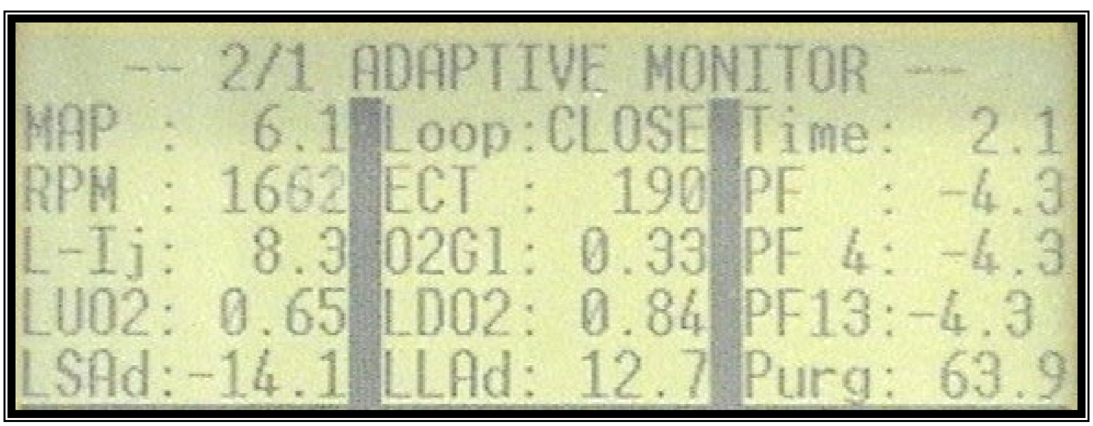
1. Base Pulse Width (BPW) = MAF or MAP & Engine RPM.
2. Modified BPW (Open Loop) = TPS, ECT, IAT, BARO, Battery Volts, and Learned Long-Term Fuel Trim.
3. Corrected BPW (Closed Loop) = Oxygen Sensor(s), Air/Fuel Ratio Sensor(s), rear Oxygen Sensors).

Once the system enters Closed Loop, how does the PCM use fuel trim to correct the injector pulse width?

1. If the total Fuel Trim (LTFT + STFT) is 10% or less, the PCM continues making minor corrections using Short Term Fuel Trim; the following picture shows a total fuel trim of -6.4% (-6.6+.20). In this case, the PCM makes a minor adjustment using the STFT (.20%).



2. If the total Fuel Trim (LTFT + STFT) is more than 10%, the PCM begins changing Long Term Fuel Trim, attempting to bring Short Term Fuel Trim back to 0%. The following picture shows the PCM making a significant correction to the total fuel trim, now -1.4% (-14.1+12.7). This condition could occur immediately following a repair to the vehicle.



Time should be spent trying to relearn the PCM, performing a PCM reset, or disconnecting the battery to clear skewed information from the PCM. Later in this section, we will show how fuel trim cells operate, making it clearer how this affects PCM fuel trim operation.

Ever wonder why global OBD II includes a freeze frame? It is because this is the information the technician might need to duplicate the conditions under which the code was set. Usually, the most critical information in a freeze frame is engine coolant temperature, Rpm, calculated load, and vehicle speed. The following will show how this fits into fuel trim, a failed ASM test, or an OBD II drive cycle. I am sure many technicians have filled in a work order and said they could not duplicate the customer's concern!

Since the inception of fuel trim, technicians have heard about fuel trim cells but have not had the opportunity to see them as they exist and operate. LTFT and STFT are usually seen as two numbers only. From this point forward, fuel trim should be visualized as two numbers times the number of Rpm and Load cells available on the vehicle being tested. Unfortunately, this must be imagined because the information is unavailable to the scan tool. Remember to think outside the box and think in three dimensions, and fuel trim diagnosis will become easier.

<u>Fuel Trim Cells</u>

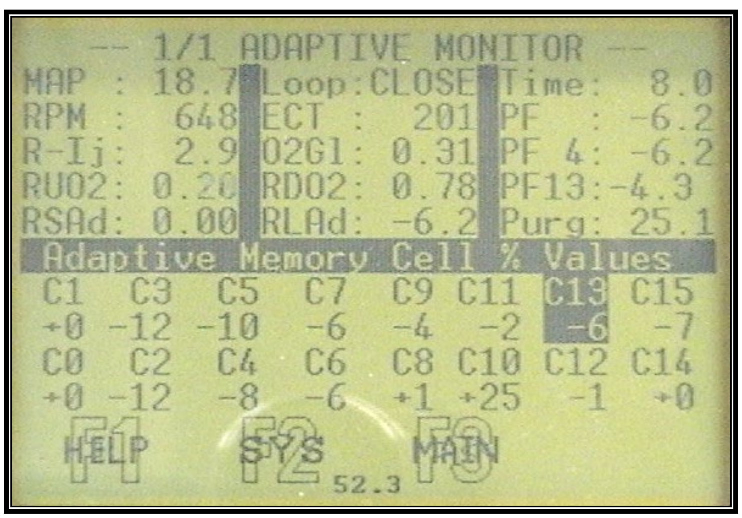
A speed density system has a manifold absolute pressure (MAP) load sensor. It maps an engine in conjunction with engine Rpm and Load. Other fuel trim variables were mentioned earlier in this section, and now the focus will be on the actual fuel trim cells.

The fuel trim cells below allow the PCM to quickly fine-tune the A/F ratio to prevent spikes in vehicle emissions. Fuel trim cells store LTFT-learned values based on the last time the driving condition put the vehicle into that cell. While the vehicle can only be in one cell at a time, the dark boxes simulate driving the vehicle through the different fuel trim cells.

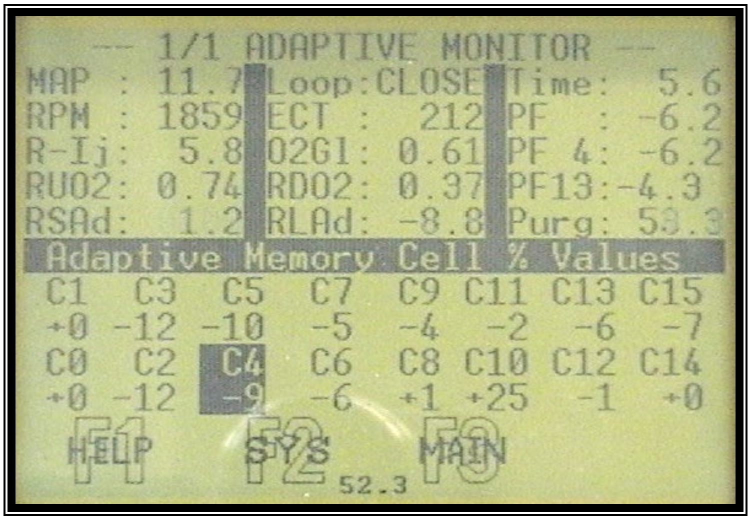
	Open Throttle						Idle	Decel*
Vacuum	20	17	13	9	5	0		
ABOVE 1984 RPM	1	3	5	7	9	11	13 Drive	15
BELOW 1984 RPM	0	2	4	6	8	10	12 Neutral	14
MAP Volt.	0	1.4	2.0	2.6	3.3	3.9		

• If equipped. Increased Load →

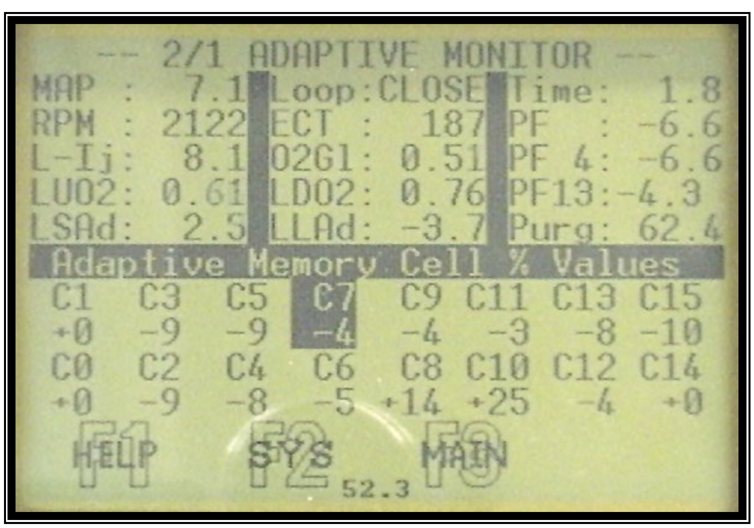
What do the fuel trim cells look like with real-world values in them? The following information was collected from a 2000 Dodge Intrepid, 3.5L engine using a Chrysler DRB II factory scan tool. Matching cell C13 (right) to cell 13 (above) indicates the vehicle is stopped and in drive. The PCM is subtracting fuel by trimming LTFT by 6%.



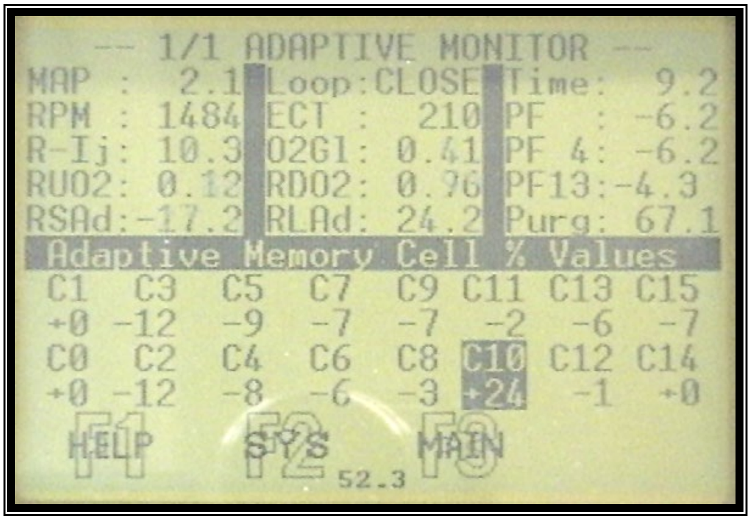
As the vehicle is accelerated, the load/RPM changes and the PCM moves to another cell (C4), which trims LTFT by -9%. This load/Rpm is typical of an ASM test, which might use two cells at best. So, only one (C4) or two (C10) fuel trim cells might be used during an ASM test. The vehicle could easily pass an ASM test but have a driveability problem during other load/Rpm ranges. The same thing is true of an OBD II drive cycle because it uses two cells at best.



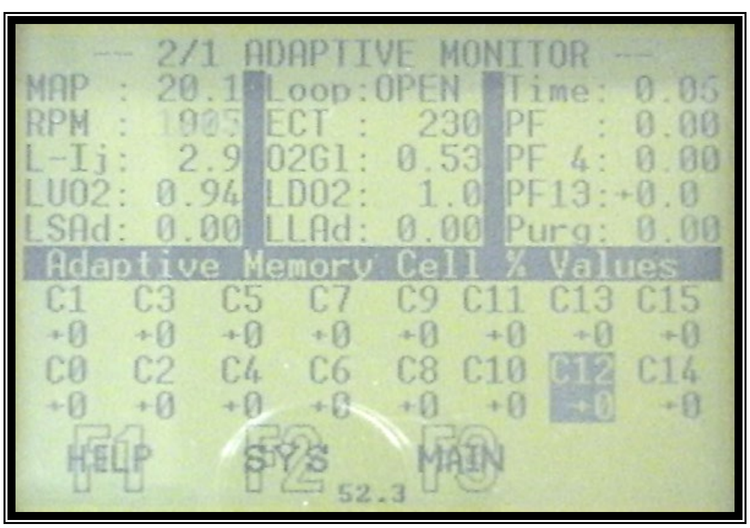
As the vehicle is accelerated, the Rpm/Load changes again, the PCM moves to another cell (C7) and trims LTFT by -4%. The PCM has moved to an upper cell because the engine Rpm is above 1984, and the load has increased.



In the next picture, the Rpm has decreased, but the load has increased, the PCM is now using cell C10, and the learned LTFT is +24%. This means the last time the PCM entered this cell, it added 24% more fuel. This might explain a “could not duplicate customer concern” response because this may not be a typical driving cell when conducting a “road test.”

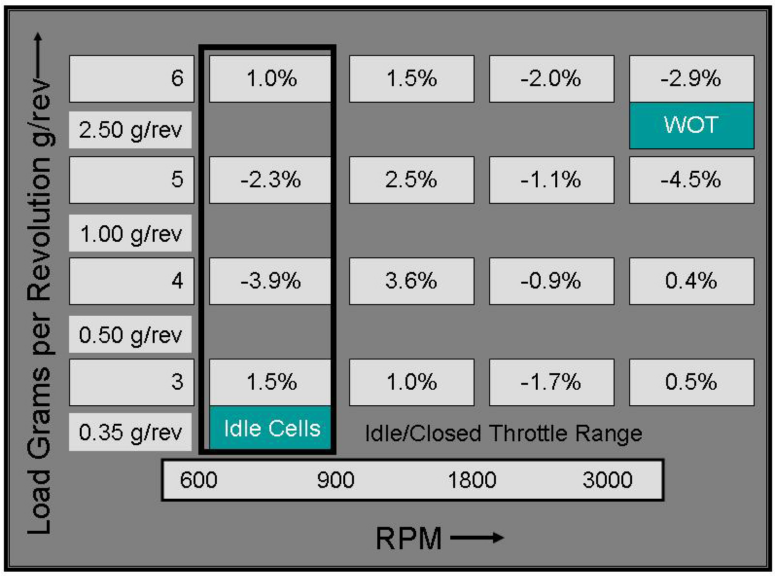


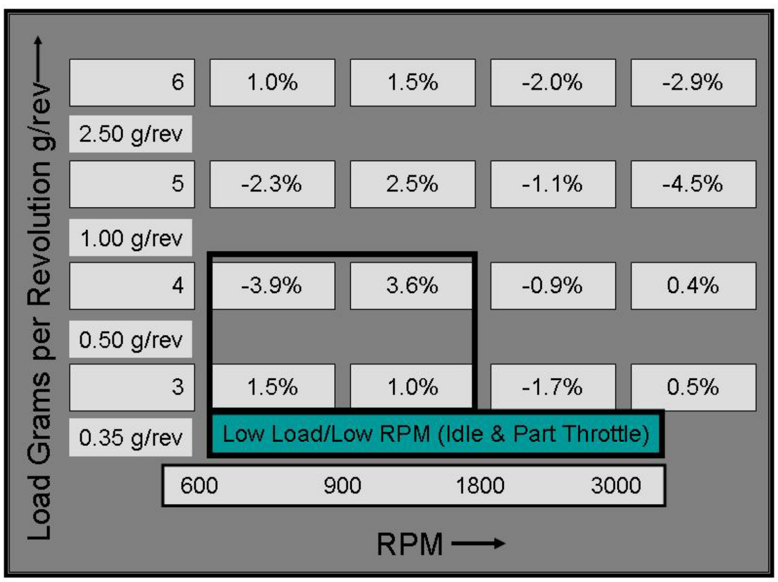
Finally, the problem was repaired, so a PCM reset or battery disconnect was performed. All fuel trim cells below have been reset to a factory setting of 0%. Until the vehicle is driven and cells are relearned, the vehicle might appear sluggish or not perform as well as it did before the work was performed. Be aware of the multiple cells and zero settings when going on a “road test.”

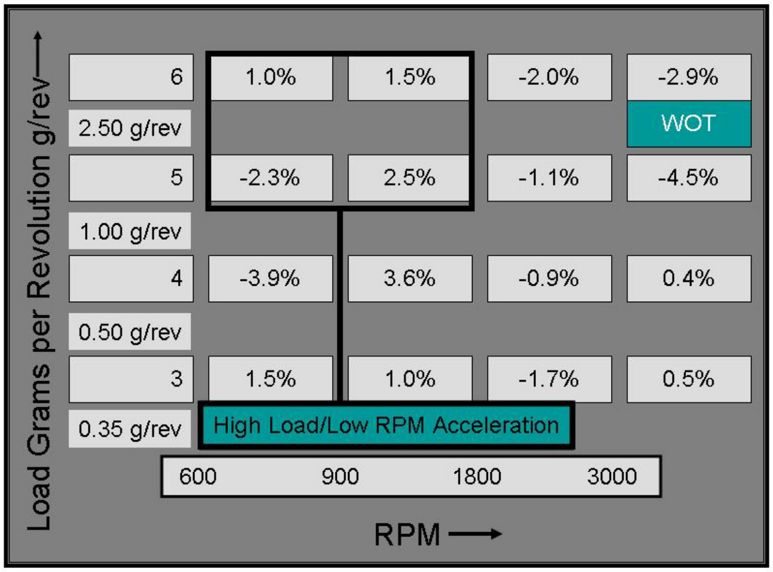


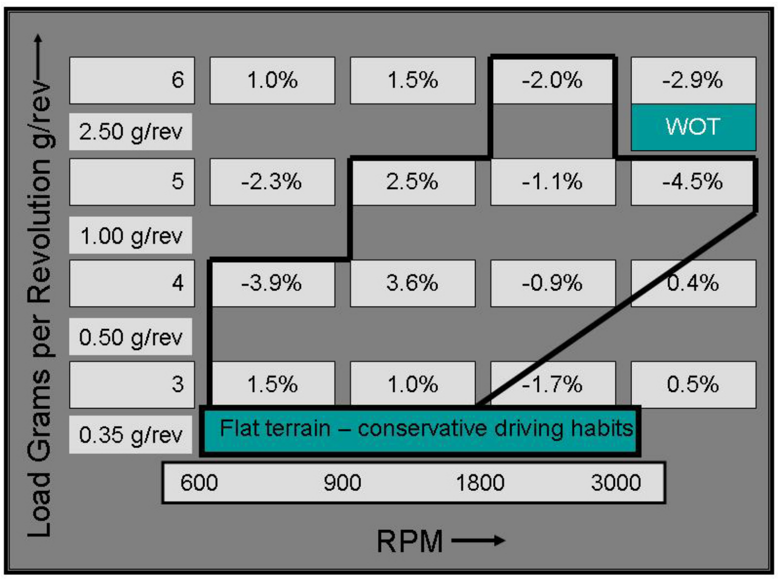
Mass Air Flow Cells

Mass Air Flow (MAF) systems measure actual air mass entering the engine. MAF is more accurate than MAP under stable engine conditions. In a MAF system, load/RPM cell mapping is a linear process and is based on grams per engine revolution (g/rev). As airflow increases the system will move upward to a higher cell. The higher cells equal more load and fuel delivery. The following pictures demonstrate some examples of MAF Fuel Trim Cell operation.









The important thing to remember here is that each cell is programmed with a formula to calculate injector pulse width under a variety of driving conditions. Long-term fuel trim values are learned for each load cell. Once a value is stored in a particular cell, then that fuel trim value will be applied the next time the vehicle enters that cell. The principles covered under Speed Density MAP fuel trim cells can be used for MAF fuel trim cell operation.

Lambda

The PCM must be able to quickly respond to and satisfy a wide variety of operating conditions as they relate to both MAP and MAF fuel trim cells. In the fuel trim cells, 0% correction is the goal of the PCM, but what does that mean for the air/fuel mixture?

The ideal air/fuel mixture is referred to by the Greek letter λ (Lambda). Robert Bosch defines Lambda as the excess air factor as it relates to the actual mix of air and fuel that enters the combustion chamber. It is calculated from exhaust gas and indicates an air/fuel mixture independent of engine controls and combustion efficiency.

Maintaining $\lambda = 1$ on an engine at normal operating temperature is essential. This allows for optimal catalytic converter operation (although in actual practice, λ factors between 0.980 and 1.020 provide the best overall engine operation for all operating conditions).

Listed below are several common λ operating ranges:

- $\lambda = 1$: mixture is optimum in the range of 0.980 to 1.020 (Stoichiometric).
- $\lambda < 1$: the mixture is rich (lacking air), typically in the range $\lambda = 0.85$ to 0.95.
- $\lambda > 1$: mixture has an excess of air; a lean mixture typically in the range $\lambda =$ 1.05 to 1.30.
- $\lambda > 1.30$: The mixture has too much air to support consistent combustion.

Using a five-gas analyzer and the Lambda calculator, Lambda can be used to confirm that the overall mixture entering the combustion chamber is correct.

Knowing that the air/fuel mixture is correct tells a lot about fuel delivery, intake system integrity, PCM fuel calculations, and feedback.

When using Lambda as a diagnostic tool, remember to disable the air injection system before using a gas analyzer, and be sure the exhaust system has no leaks. Any unmeasured air entering the system will affect Lambda calculations.

Summary

Abnormal fuel trim values or codes do not necessarily mean the engine runs lean or rich. Changes in fuel trim mean the PCM had to make corrections to bring the system back into proper fuel control. OBD II systems cannot be repaired with a screwdriver. Understanding how fuel trim is calculated can help narrow down the root cause of the problem.

Fuel Trim Diagnosis is a logical thought process:

- ✓ Determine the conditions when the problem exists,
- ✓ Duplicate the condition,
- ✓ Check fuel trim in multiple cells,
- ✓ Logically determine what causes are possible,
- ✓ Eliminate causes that aren’t possible,
- ✓ Test the remaining possibilities.

Ask yourself, do fuel trim numbers match reality? If the answer is no, then test-retest the feedback fuel control system. Return to the basics!