## *The Purpose of Fuel Trim*

The internal combustion engine is not 100% efficient. There will always be some byproducts of combustion such as HC, CO, O2, CO2, and NO. The least amount of leftover emissions occurs when the mixture is at 14.7 to 1 air fuel ratio. Even at this ratio, there are too many harmful pollutants.

Auto makers created a device that would clean up the byproducts of internal combustion. This device is called the catalytic converter. The catalytic converter works on the theory of oxidation and reduction. The term oxidation means to add oxygen. The term reduction means to take oxygen away. More specifically, oxidation means oxygen (O2) is added to the HC and CO to make it H20 and CO2. Reduction is when the oxygen is removed from the nitrogen (NOX) which reduces NOX to N2 and 02. The catalytic converter must perform both of these functions. It is necessary to utilize a fuel metering system that can continuously switch from rich to lean.

This fuel system is called the closed loop system. By switching the mixture rich and lean, the catalytic converter can efficiently perform oxidation and reduction at the appropriate times. When the mixture is slightly rich, reduction occurs and NOX is converted to N2 and 02. When slightly lean, oxidation occurs. CO is converted to CO2 and HC is converted to H20. The auto makers had this in mind when they created the O2 sensor. The job of the O2 sensor is to tell the PCM when the mixture is rich so the PCM can deliver a lean command (shorter pulse width.) Conversely when the mixture is lean, the PCM will deliver a richer mixture (longer pulse width). The PCM constantly changes the mixture from rich to lean based on the input from the O2 sensor. This process is what allows the catalytic converter to work. Note: when rich= reduction; when lean= oxidation.

This is where fuel trim comes in. Fuel trim is the internal mechanism within the PCM that switches the fuel mixture from rich to lean. It has to do this a minimum of 2 to 5 times a second. Fuel trim is broken down to two types, short term and long term. Since the standardization of OBDII, fuel trim is found on most cars.

# *Fuel Trim*

## *How It Works - Short Term*

Short term fuel trim monitors the O2 sensor and makes live corrections based on O2 sensor voltage. It has the ability to quickly change the mixture when it sees low or hi voltage from the O2 sensor. It can only correct over a short period of time. The starting point is 0. 0 represents the cleanest air fuel mixture 14.7 to 1. The objective of the PCM is to keep short term fuel trim averaging 0. Not right on 0 but an average of 0. An average of 0 would represent a slightly rich and slightly lean mixture. Therefore the average air fuel mixture would equal 14.7 to 1. While averaging 14.7 to 1 the combustion process is clean and the catalytic converter does not have to work hard.

Here is an example of how it works. You remove the vacuum line to the fuel pressure regulator. The fuel mixture will go rich. The O2 voltage will move high towards 900MV. Short term fuel trim will see the high voltage from the O2 sensor and command a lean correction. You will see short term fuel trim go to a number lower than 0. Negative numbers represent the PCM removing fuel from the system. If you create a vacuum leak, O2 voltage will go low. PCM will command a rich command. Short term fuel trim will move higher than 0 adding fuel. It is this correction that makes the O2 sensor go up and down under normal running conditions. Any voltage higher than 450MV from the O2 sensor is considered rich and below 450MV is considered lean.

This switching voltage from the O2 sensor is what gives us the cross count reading on our scan tools. Cross count represents the amount of times the voltage switches above and below the 450MV threshold in 1 second. It is the job of short term fuel trim to make this happen. When this happens a minimum of 2 to 5 times per second the catalytic converter will be most efficient.

Short term fuel trim has limited capabilities. It can only correct for short term problems. If the problem with the fuel system is a long term problem, PCM will have to make a correction for a longer period of time. Thus this is where long term fuel trim helps out.

# *Fuel Trim*

### *How It Works - Long Term*

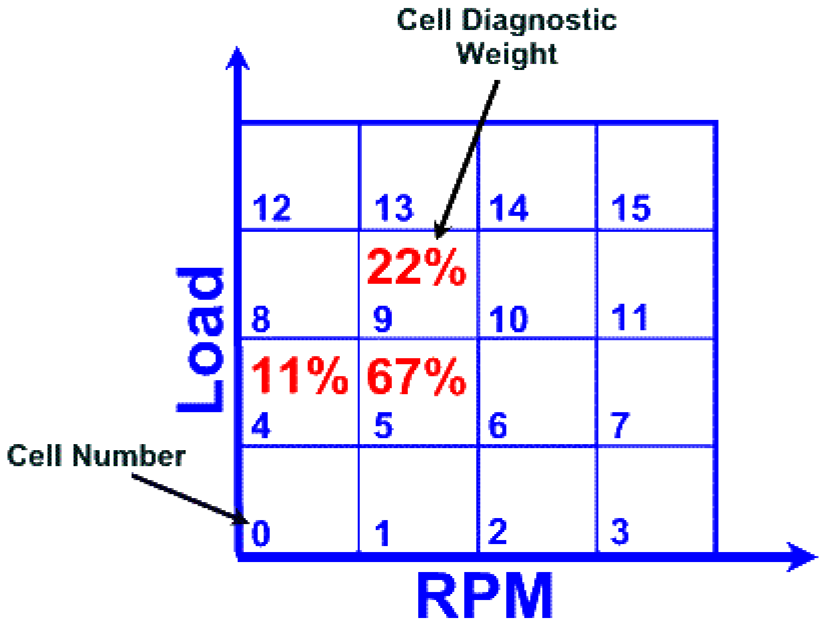
Auto makers knew that over time cars would wear out. Injectors would leak, engines would suffer from compression loss, normal wear and tear would occur, and everybody drives differently. Trying to control the mixture with STFT would be insufficient. That's where LTFT comes in. LTFT has the ability to correct the fuel over the long term. Its job is to monitor the short term fuel trim. It will move in either direction of 0 to lean or richen the mixture.

Here is an example of how it works. The fuel system return line has become restricted. The fuel pressure is 15 psi higher than specs allow. This has created a long term rich problem. STFT would have come way down to correct the problem, below 0. Since this is a long term fuel problem the STFT fails to control the mixture. O2 sensor voltage stays high. Since the O2 sensor voltage stays high STFT will remain low below 0. It will stay low because it will be continually trying to correct the rich mixture problem. Note the STFT only looks at the O2 sensor voltage and tries to correct anything above and below 450MV. With this example, the PCM will determine that a long term fuel correction is needed. The long term fuel trim's job is to monitor short term fuel trim and keep it averaging 0. It has the ability to add or subtract large amounts of fuel over a long period of time. With this example, the LTFT will come down a notch at a time until it sees the STFT move back to an average of 0. With the STFT back to 0, the PCM has successfully corrected the fuel mixture. Once the LTFT has successfully corrected the mixture, PCM will lock this parameter in memory.

This memory is known as block cell. Also known as adaptive strategy. One thing to remember, if the PCM is successful in keeping the STFT averaging 0, the car would most likely pass the smog test. The only way you would know there is a problem is by the low number on LTFT. Another point to remember, if LTFT can't make the correction than PCM will give up and set a rich code. Once it has set the code for rich, STFT will go back to base number of 0 and stay there in open loop condition.

## *Fuel Trim*

### *What Is Block Cell*



Block cell is the adaptive strategy of the PCM. It's the PCM's ability to learn and to correct for fuel imbalances.

During a rich mixture problem, the PCM will have lowered the LTFT to correct the problem. If it is successful then this information would be saved in the block cell memory of the ECM.

There are 15 cells that it could place this information in. Each cell represents a specific load and rpm range. Whatever cell it had to make the correction in would now represent the LTFT that was able to get the mixture right.

When the battery is disconnected then this memory is erased and it has to relearn itself.

All cells will start off at 0 when the memory is erased. These cells would change as the car is driven to reflect the adjustment the long term fuel trim had to make to keep the short term fuel trim averaging 0.

Each cell represents rpm and load. With 15 cells every rpm and load will be represented in block cell starting from idle to WOT.

You can use the block cell to look for rich or lean conditions that only occur under specific rpm or load ranges. If you see a cell with a very high or low number than there is a problem in that area. Now think of the components that could only affect the mixture in that area. You may be able to better pin point the problem.

Note: after repairing a problem make sure to clear the block cell memory. Remember, it will still be in the corrected mode after a repair unless the memory is cleared.

# *Fuel Trim*

## *How to Diagnose Using Trim I*

Finding vacuum leaks is easy using STFT. Simply start the car, let it go into a closed loop, monitor the O2 sensor voltage and the short term fuel trim, then use propane and run it around possible vacuum leak areas. If O2 sensor voltage goes up and the STFT goes to a negative, you have found a vacuum leak. NOTE: always be careful when working with propane.

Let's say that there is a severe rich condition. One the computer can't control. The PCM will try to lean out the mixture, which will be evident with a high negative STFT and LTFT. At this point, the PCM will realize that it cannot repair the problem and turn on the MIL code for rich running. Before the PCM sets the code, it will look at all the contributing circuits/ sensors and determine if they are okay. If so, it will set the rich condition code. If one of the sensors was found to be outside of operating range, it would set the sensor code, then a rich code. The same is true for a lean condition.

Remember if we had a bad load sensor such as a MAF, and it is generating a signal voltage to high load of the engine, it might move into the wrong block cell. This in turn would create a wider pulse width causing it to fail a loaded mode smog test.

# *Fuel Trim*

## *How to Diagnose Using Trim II*

Fuel trim can be a great diagnostic tool. It can help you narrow down the problem. Be careful when looking at STFT. If the PCM was able to correct the fuel mixture with the LTFT, then the STFT will be normal around 0. Even if the STFT is normal, it doesn’t mean there isn't a problem with the fuel metering system. A high negative or high positive LTFT will be the indication that there is a problem with the fuel metering system, but the problem is controllable. When I say it’s controllable, that means the problem isn't out of the computer’s ability to correct. If the problem falls outside of the computer’s ability to correct, it will set a code and fall into open loop. When in open loop we cannot use the fuel to diagnose.

Let’s say you have a rich running problem that the computer can control. The STFT will be normal around O, but the LTFT should be a negative number. If you see this condition you can determine the PCM is ok, and the O2 sensor is sending the right signal. Since this is not a major problem, look for parts of the fuel system that the PCM can’t control like leaking injectors, canister purge, fuel in the crankcase, and high fuel pressure. Sensors are also on the list of items to check. If a sensor is sending a slightly higher signal than it should, the PCM would see this as a rich command. This would cause the PCM to widen the injector pulse width to force a rich command. The O2 sensor would see the rich mixture and send a high voltage signal to the PCM. The PCM would see this as a rich mixture and respond by leaning it out with a negative fuel trim. It will not set a code for the sensor because it’s still within the sensor limits. MAF sensors commonly cause high negative or high positive fuel trim numbers.

NOTE: if you get the proper response by the PCM to a particular problem of rich or lean, then you can safely say the PCM and O2 are good. The response should always be opposite of the problem. If you have a rich condition followed by a rich command of high positive fuel trim then look to the O2 sensor as the problem. Remember fuel trim only corrects from the O2 sensor signal. Let’s say you have a lean condition, the PCM can control the STFT to be normal around 0.The LTFT will be positive adding fuel to correct for the problem. Areas of concern would be a small vacuum leak, resurrected injectors, low fuel pressure or possibly a sensor out of calibration sending a lean signal.

# Fuel Trim

## Graphical Representation of Fuel Trim