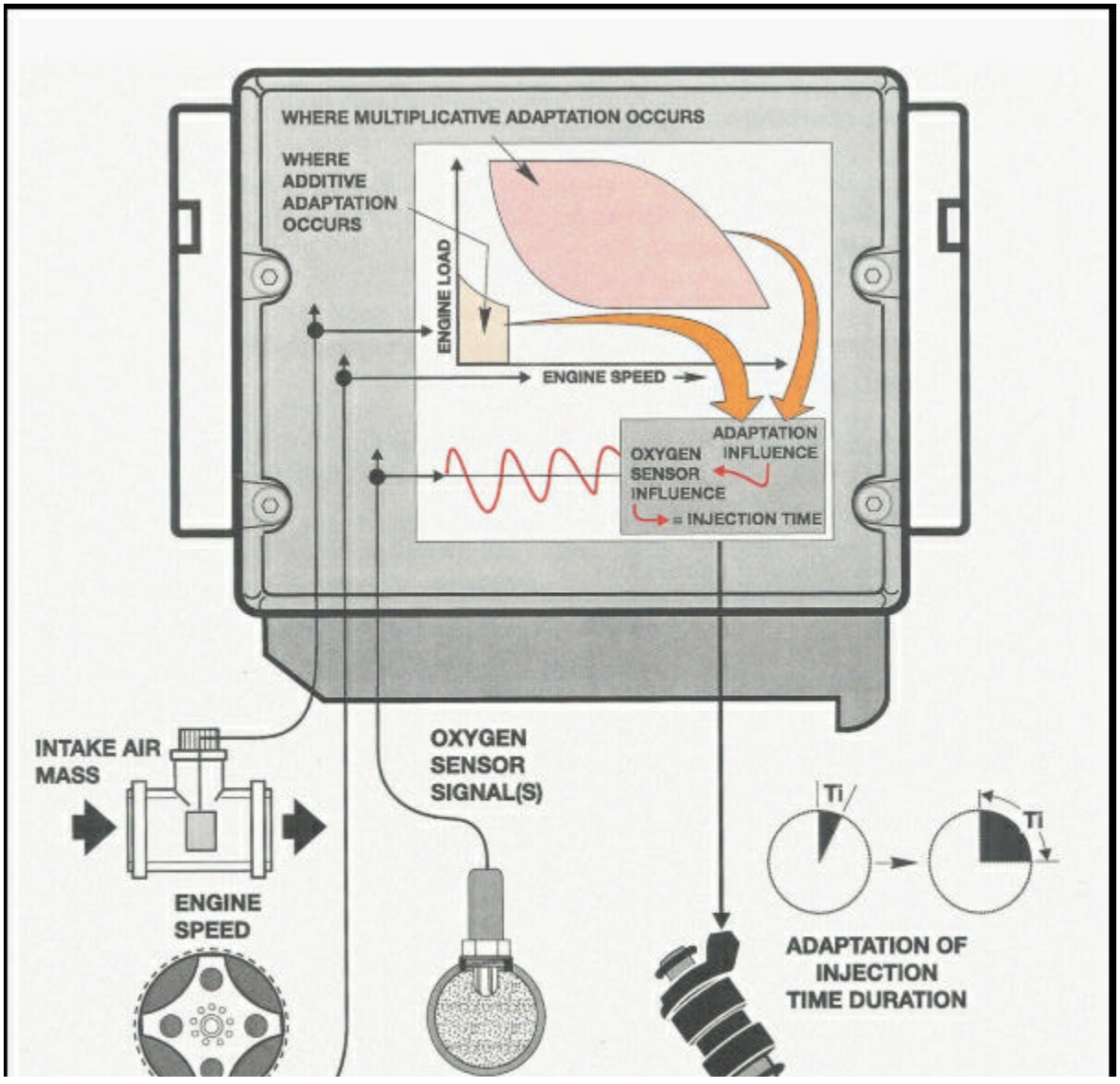
Fuel Trim (Fuel Adaption) Diagnostics

Q: What Is "Fuel Trim"?
A: "Fuel Trim" is the fine tune control of fuel delivery by the ECU. To accomplish this the ECU increases or decreases fuel delivery by increasing or decreasing the time that the injectors are open.

Q: How does the controller know what to do?
A: By monitoring the primary Oxygen sensor(s) (pre catalytic convertor), engine coolant temperature, throttle position, air mass volume, engine speed(rpm) and to a lesser extent changes in altitude, humidity, ambient temperature, fuel quality, etc.

The ECU modifies the injection rate under two areas of engine operation. These areas are the idle or low load mid range engine operation and operation under a normal to higher load when at higher engine speeds. These altered injection rates are known as **Long Term Fuel Trim (LTFT) Additive** and **Short Term Fuel Trim (STFT) Multiplicative**. See figure 1.



Long Term Fuel Trim (LTFT)
This is the control of Injection Pulse Time Open (ti) (also called Injection Pulse Width) over the entire range of engine operation. It is primarily calculated at idle or low load mid range engine operation and is averaged over time.

In these idle/low load conditions the amount of fuel variation is small due to the relatively small amount of air input. The computer monitors the O2 sensor and ADDS or SUBTRACTS approximately 0.001msec to the injection pulse time (ti) in order to maintain a Lambda = 1. This amount of increase or decrease of the injection pulse width is known as the **Adaptation Value**. This is the value output by the ECU when reading the live data stream.

For example: An LTFT of 1 is the factory spec for a new injector's injection pulse width (time open). This corresponds to an LTFT **Adaptation Value** of 0.0.

An LTFT **Adaption Value** of 0.100 would indicate a wider injection pulse width. This corresponds to a LTFT of 1.100.
An LTFT **Adaption Value** of -0.020 would indicate a narrower injection pulse width. This corresponds to a LTFT of 0.980.

The LTFT is also influence by the Short Term Fuel Trim (STFT).

Short Term Fuel Trim (STFT) Multiplicative
This is the control of the Injection Pulse Time Open over the mid to upper range of engine operation. When the engine operates at normal or higher load or at higher engine speeds, larger volumes of fuel and air are needed. In order to maintain a Lambda = 1 in these conditions, the ECU monitors the O2 sensor and calculated load (see figure 2) and compares the values against the optimal value for the fuel injection pulse width stored in the drive map. If this base fuel injection pulse width value does not yield a Lambda = 1 at the O2 sensor for the measured air mass, the computer increases or decreases the pulse width by a percentage (%) determined by the difference in Lambda from optimal. These percentages have been computed by the engineers at the factory from extensive dynamometer testing and are stored in a "weighted STFT value array(1)" in the drive maps. When the STFT reaches the limit of its adjustment it will cause corresponding decrease or increase to the Long Term Fuel Trim. If the correction to the base value exceeds +25% or -25% for longer than 10 seconds a DTC is set for rich or lean stop for STFT.

Calculated Load =	Current Air Mass / Maximum Air Mass	X	Atmospheric Pressure @ sea level / Current Barometric Pressure

Figure. 2

Short Term Fuel Trim in general makes very quick and small temporary changes to the fuel being delivered to the engine. **Long Term Fuel Trim** makes slower more permanent changes. Each change in the Long Term Fuel Trim is equivalent to a change of the Short Term Fuel Trim over it's entire range. The idea of this being that when the Short Term hits it's upper/lower limit, it resets back to the beginning, and moves the long

term TRIM up or down by one count. The Short Term continues to change very quickly, and if it hit's it's limit again, it increments/decrements the Long Term again. This continues until the Long Term has added enough fuel to compensate for the problem or until the long term has hit it's own limit. When the later occurs the Air/Fuel ratio cannot be maintained at Lambda=1 and a "Lambda Control" DTC would normally be set and in later injection systems a "LTFT at rich/lean stop" fault.

Once a LTFT DTC is set, depending on the calibration, the ECU usually defaults to Open Loop (O2 sensor not on line) the ECU determines fuel delivery based on all sensor inputs (except oxygen sensor) and predetermined internal "drive maps".

During Closed Loop, the input from the Oxygen sensor(s) is used by the ECU to calculate fuel delivery adjustments or Adaptations. If the Oxygen sensor(s) indicate a lean condition, the Adaptation values will be above 0. If the oxygen sensors indicate a rich condition, Adaptation values will be below 0. Adaptation values that are between +10% and -10% of the base injection pulse width are an indication that the ECU is maintaining proper fuel control.

If the ECU drops into Open Loop for what ever reason, you will notice that the long term fuel trim adaptation value will show 0.0 ms. This is because the ECU is no longer looking at the O2 sensor, and therefore can't make any adjustments to the fuel delivery. It must rely only on the fuel curve that has been programmed into the drive map. This is a good reason for having the fuel curve as close to perfect as possible.

Let's look at some conditions that will set adaptations faults and there causes.
Intake air leaks
Incorrect Fuel Pressure
Injector valve defective or coked
Engine Temperature Sensor defective
EGR valve defective
Secondary air leak
Fuel evaporation control system defective or leaking.
Air Mass Meter defective
Vacuum leaks
Oxygen sensor aging (slow response)
Clogged or damaged catalytic converter
Contaminated fuel
Fuel tank ran empty
Combustion altered by a mechanical failure (Spark plugs, compression, intake/exhaust valves, ...etc.)

LTFT Adaption Value positive (+), LTFT >1.
Lack of fuel or too much air. ECU is attempting to increase the amount of fuel by increasing the injector open time.

This could be caused by unmetered air leaking past the EVAP, EGR or into the air intake system after the Air Mass Meter or a fuel pump delivery problem or clogged or damaged fuel injector.

LTFT Adaption Value negative (-), 0<LTFT<1
Too much fuel, Lack of air. ECU is attempting to decrease the amount of fuel by decreasing the injector open time.

This could be due to leaking injector or a stuck open pintle supplying too much fuel.

STFT Adaption Value positive (+)
Consistent high positive value can mean low exhaust back pressure, blown TWCC

STFT Adaption Value negative (-)
Consistent high negative value can mean high exhaust back pressure, clogged TWCC.

OBD II Requirements
The OBD-II requirements for fuel system monitoring says that the fuel delivery system must be continuously monitored for the ability to provide compliance with emission standards. The fuel trim monitoring system is considered malfunctioning when it causes the emission levels to exceed 1.5 times the FTP standards. The regulations specifically require a monitor of the long-term fuel trim limits. The operating conditions at the instant of fault detection must be stored in Freeze Frame data for the automotive technician.

BMW monitors LTFT and STFT in all LEV systems.

Fuel Trim Diagnostic Monitoring
The fuel trim Diagnostic monitors the averages of Long Term and Short Term Fuel Trim. If these fuel trim values reach and stay at their maximum limits for a period of time, a malfunction is indicated. The fuel trim Diagnostic compares an average of Long Term Trim values and Short Term Trim values to rich and lean limits which are the calibrated fail thresholds for the test. If either value is within the fail thresholds, a pass is recorded. The closed loop system still has control authority. If both values are outside the fail thresholds, then a failure condition exists. This will cause a DTC to be stored and the rich or lean condition to be recorded. The fuel trim diagnostic also conducts an intrusive test to determine if a rich condition is being caused by excessive vapor from the EVAP canister.

1. The exact method of utilizing the weighted STFT array is held proprietary by BMW, but a good example is that used by GM. See http://members.iatn.net/tech/gm/obd2/obd2-6-3.html .