Serial Data Interpretation

Using and interpreting serial data may seem confusing at first because there is so much data. Some of the data uses unfamiliar names, and some of it is displayed in unfamiliar units. To help you become familiar with the new terminology and what each data parameter means, refer to appendices A & B of this handbook. They provide detailed definitions, specifications, and an explanation of each data parameter available on OBD, OBD-II, and V-BoB data streams.

ECM Strategy for Fuel and Spark Control

Troubleshooting driveability problems can be complicated, especially when there is so much diagnostic data available. You may sometimes find it difficult to decide which information is important and which information you should ignore. The key is getting back to the basics. That means the basic theory and the basic data.

As you have learned, fuel and spark calculation are, for the most part, affected by only a few input sensors. In fact, basic injection and spark calculation are a function of just two sensors; the engine speed and engine load sensors.

There are only four other sensors which have significant effects on injection (and to a lesser degree on spark advance corrections); those are engine coolant temperature, intake air temperature, throttle angle, and oxygen sensor feedback.

Data analysis is much easier once you are familiar with these six input parameters, their units of display, and their nominal values.

Six Important Sensor Inputs

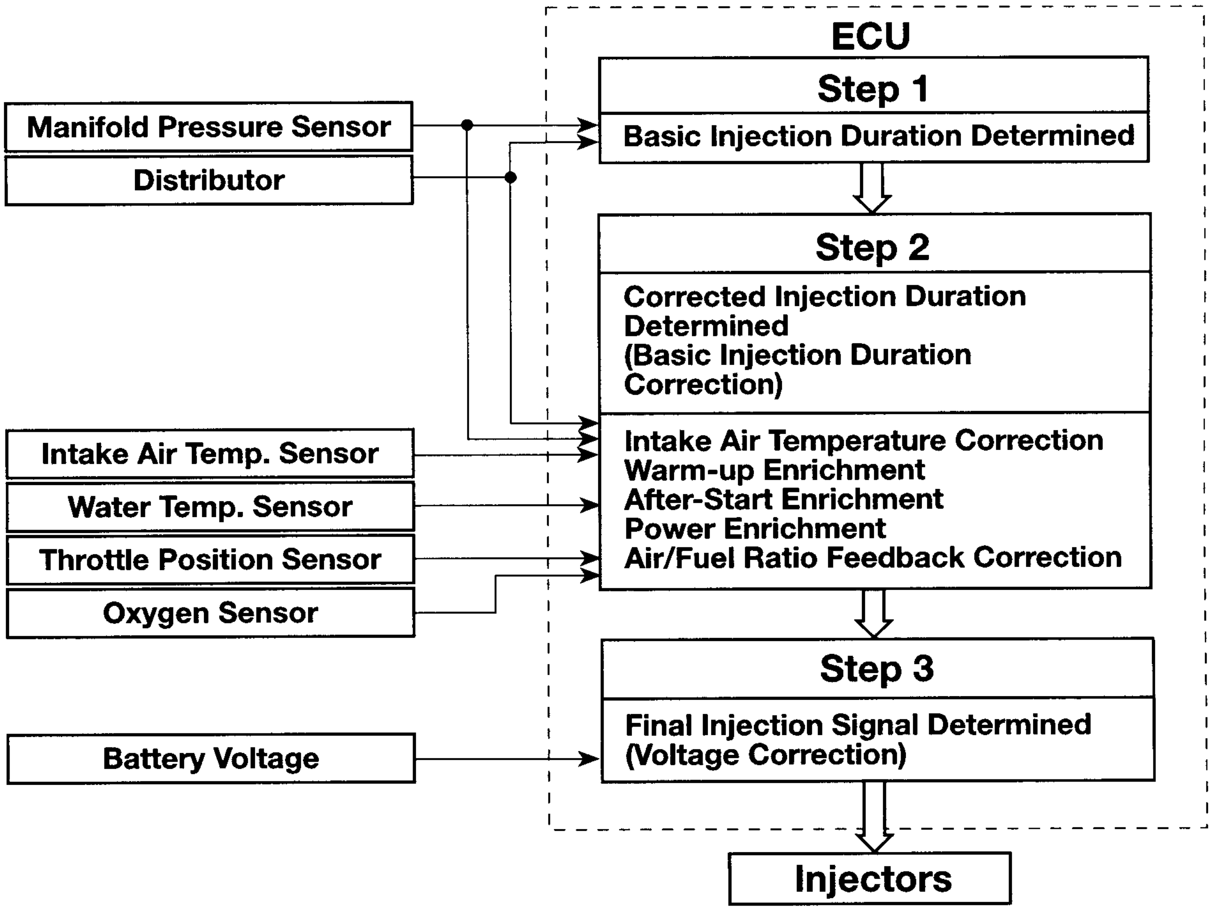
The six major sensor inputs which have the most impact on fuel and spark calculations are, in order of importance:

- **Engine Load**
  - Vane Air Flow meter
  - Karman Vortex Air Flow meter
  - Mass Air Flow meter
  - Manifold Absolute Pressure sensor
- **Engine Speed**
  - Engine rpm (Ne) sensor
- **Engine Coolant Temperature**
  - Engine Coolant Temperature sensor
- **Throttle Position**
  - Throttle Position sensor
  - Closed Throttle Position switch
- **Intake Air Temperature**
  - Intake Air Temperature sensor
- **Exhaust Oxygen:**
  - 02 Sensor

Major Inputs Affecting Fuel and Spark

These six sensor inputs account for practically 100% of the fuel and spark calculation.

Fig. 5-39



Fuel Trim
To better understand how oxygen feedback and learned corrections are determined, a brief review of injection theory is in order.

Review of Injection Duration Theory
Final fuel injection duration is a function of three steps:

- Basic injection duration
- Duration corrections for operating conditions
- Battery voltage correction

Basic injection duration is based on engine load, speed, and a correction factor called fuel trim. Duration corrections for operating conditions are based on the sensors listed below. These are adjustments to the basic injection duration based on changing operating conditions.

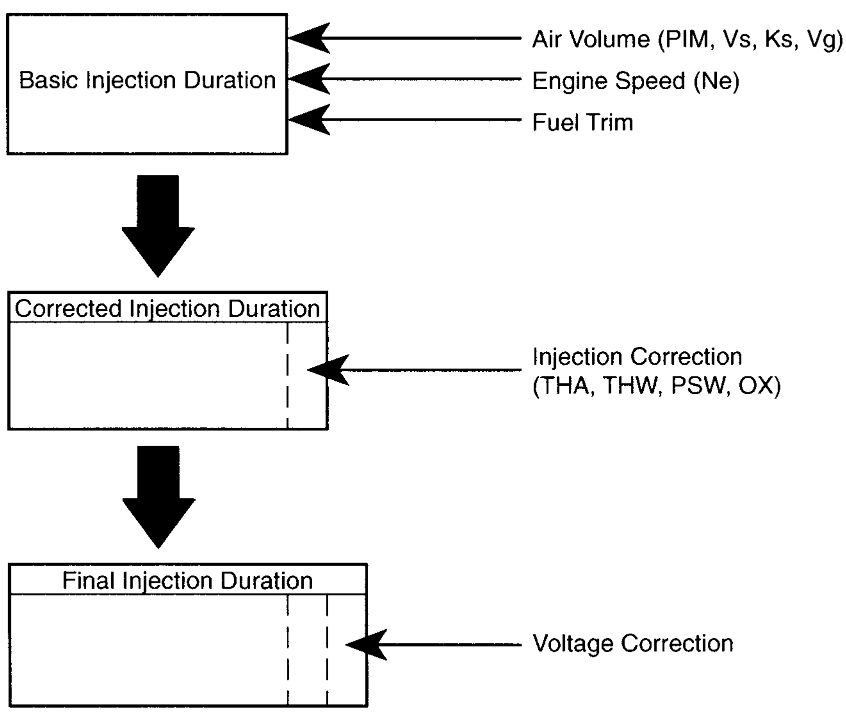
- Engine Coolant Temperature (ECT)
- Throttle Position (TP)
- Intake Air Temperature (IAT)
- Exhaust Oxygen (02S)

Battery voltage correction is an adjustment to the final injection duration to account for variations in injector opening time caused by changing operating voltage.

Injection Duration Calculation

Basic injection is a function of engine load, speed, and a long fuel trim correction factor. Basic injection is also corrected for changes in battery voltage.

Fig. 5-40



Calculation of Basic Injection Duration
The first step in determining how much fuel to deliver to the engine is calculation of basic injection duration. Basic injection duration is a function of:
- Engine load (VAF, MAF, or MAP)
- Engine speed (Ne)
- Long fuel trim (LFT) correction factor

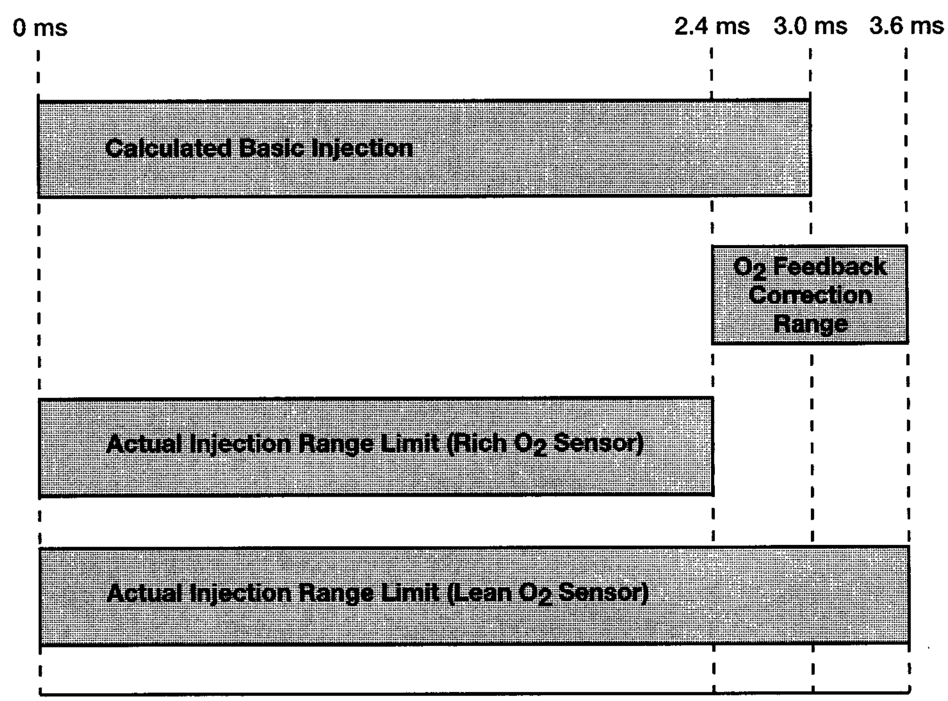
This basic injection duration value is the ECM's best guess at the actual injection time necessary to achieve an ideal air/fuel ratio. Generally, this basic injection calculation is very accurate, typically within ± 20% of what actual injection needs to be. Once within this range, the ECM can trim the air/fuel ratio to stoichiometry based on oxygen sensor information.

Oxygen Feedback Correction
Depending on many different factors, the amount of correction required for 02S feedback will vary. If the amount of necessary correction remains relatively small, for example less than 10%, the ECM can easily adjust the mixture. As 02S feedback correction approaches the ± 20% limit, the ECM fuel correction range becomes limited.

Oxygen Sensor Correction

The ECM can make oxygen feedback corrections of up to ± 20% of basic injection. If the engine requires fuel delivery outside of this range, a long term correction is necessary.

Fig. 5-41



Oxygen Feedback Correction Continued
When the amount of necessary correction becomes excessive, the ECM has a "learned memory" to adjust or "trim" the basic injection calculation. By increasing or decreasing basic injection duration, 02S corrections can be held within an acceptable range, maintaining the ECM ability to correct over a wide air/fuel ratio range.

Fuel Trim Impact on Injection Duration
Fuel trim is a term used to describe the percentage of correction to injection duration based on oxygen feedback. There are two different fuel trim values which affect final injection duration; long fuel trim (Long FT) and short fuel trim (Short FT).

Long FT is part of the basic injection duration calculation. It is determined by how closely the fuel system achieves the design air/fuel ratio.

Long FT is a learned value which gradually changes in response to factors beyond the control of system design. For example, fuel oxygen content, engine wear, air leaks, variations in fuel pressure, and so forth.

Short FT is an addition to (or subtraction from) basic injection duration. Oxygen sensor information tells the ECM how close it comes to design air/ fuel ratio and the Short FT corrects for any deviation from this value.

How Short FT Works
Short FT is a temporary correction to fuel delivery which changes with every cycle of the oxygen sensor. Under normal conditions, it fluctuates rapidly around its ideal value of 0% correction and is only functional during closed loop operation.

Short FT is a parameter on the OBD-II data stream, that can be displayed on the Diagnostic Tester. Its normal range is ± 20%, but under normal operating conditions, rarely goes beyond ± 10%.

Short FT responds to changes in 02S output. If basic injection duration results in a lean air/fuel ratio, Short FT responds with positive corrections (+1% to +20%) to add fuel or enrich the mixture. If basic injection is too rich, Short FT responds with negative corrections (-I% to -20%) to subtract fuel or enlean the mixture.

When Short FT is varying close to ± 0%, this indicates a neutral condition where the basic injection duration calculation is very close to stoichiometry, without any significant correction for 02S.

How Long FT Works
Long FT is a data parameter on the OBD and OBD-II data streams. It is a more permanent correction to fuel delivery because it is part of the basic injection duration calculation. Long FT changes slowly, in response to Short FT. Its normal range is ± 20%, positive values indicating rich correction and negative values indicating lean correction.

If Short FT deviates significantly from ± 10% for too long, the Long FT shifts, changing the basic injection duration. This shift in basic injection duration should bring Short FT back to the ± 10% range.

Unlike Short FT which effects injection duration calculation in closed loop only, the Long FT correction factor effects the basic injection duration calculation in open and closed loop. Because Long FT is stored in a nonvolatile RAM (NVRAM) and is not erased when the ignition is switched off, the fuel system is able to correct for variances in engine and fuel conditions even during warm-up and wide open throttle conditions.

On OBD data streams, Long FT is displayed as Target A/F. On non data stream equipped engines, Long FT is referred to as Learned Voltage Feedback (LVF) and can be accessed from the check connector VF1 terminal.

To gain a better understanding of Long and Short fuel trim, use the example given below. Referring to the graphic on the opposite page:

Condition #1
shows a fuel system operating within normal design parameters. Based on engine load and speed, basic injection is calculated at 3.0 ins. The short FT is varying ± 10% and oxygen sensor voltage switching is normal.

Condition #2
shows effects of air leak into intake. Basic injection remains at 3.0 ms because none of the inputs effecting basic injection duration have changed.

- Extra air causes engine to run lean, causing oxygen sensor to go lean.
- Short FT tries to correct but reaches +20% limit without bringing oxygen sensor back to normal switching.
- ECM learns that it will need to increase basic injection duration so that oxygen sensor can return to normal operating range.

Condition #3
shows what happens after ECM shifts Long FT to +10%. Although MAF and rpm remain the same, basic injection increases by 10% based on shift in Long FT. Basic injection is now 3.3 ms.

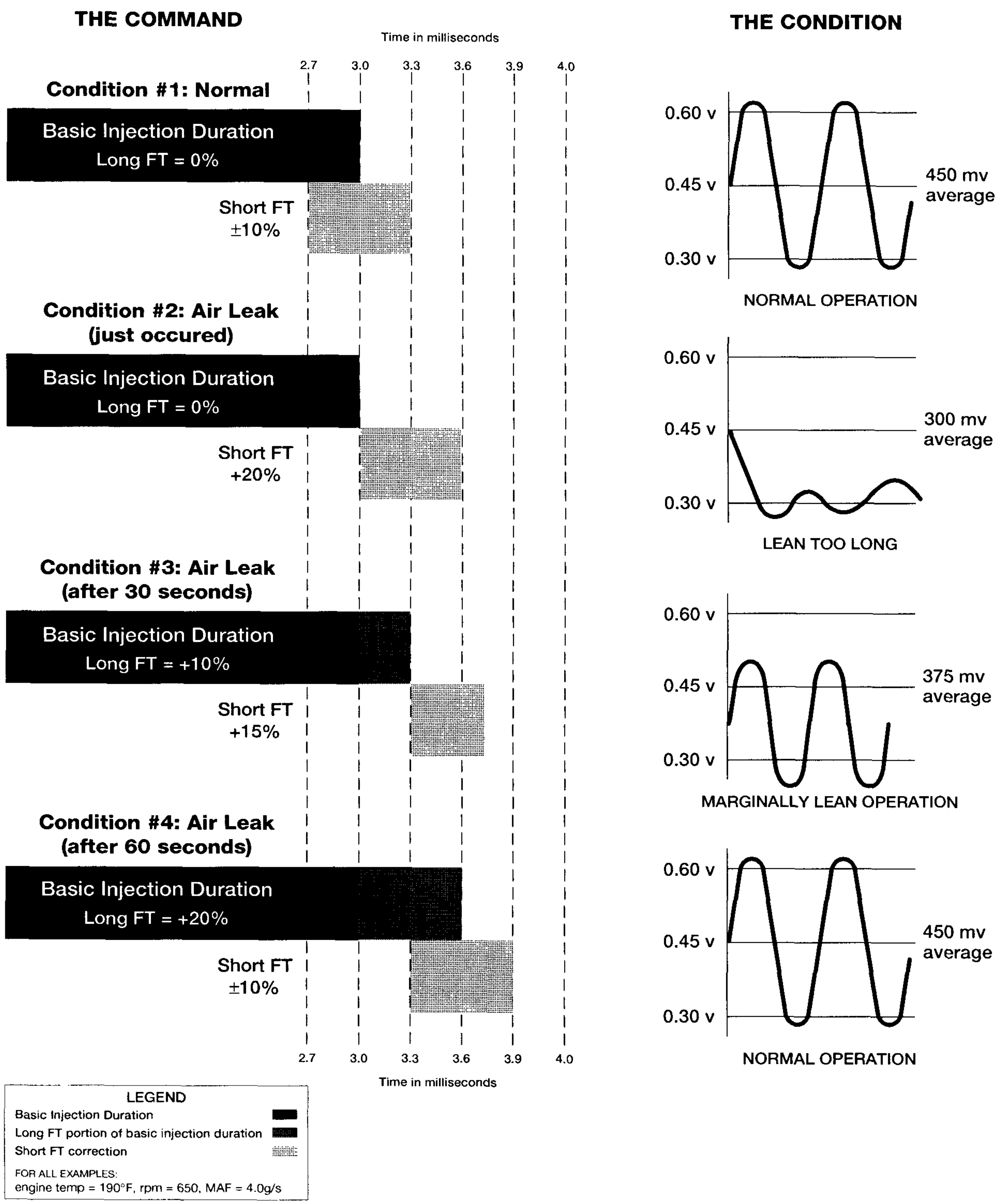
- The fuel system is now supplying enough fuel to restore nearly normal oxygen sensor switching. Switching is taking place but the voltage swings are lower than normal. Short FT is still making an excessive correction (+15%) to achieve this.
- ECM learns that it must continue shifting Long FT to get Short FT back to ±10%.

Condition #4
shows the result of another shift in Long FT. MAF and rpm are still the same as in condition #1, however, basic injection duration has increased by 20% to 3.6 ms.

- Basic injection is now back within ± 10% of required injection.
- Normal oxygen sensor switching is accompanied by Short FT switching ± 10% of basic injection duration.

Fuel Feedback Correction

Fig. 5-42



Learned Voltage Feedback and Target Air Fuel Ratio

Although Long FT, Target A/F, and LVF (Learned Voltage Feedback) are essentially the same, there is a difference in how this data parameter is displayed on OBD engines. LVF and Target A/F are displayed as a voltage signal with a range of 0 to 5 volts. The signal, which varies in fixed 1.25 volt increments, has a nominal value of 2.50 volts.

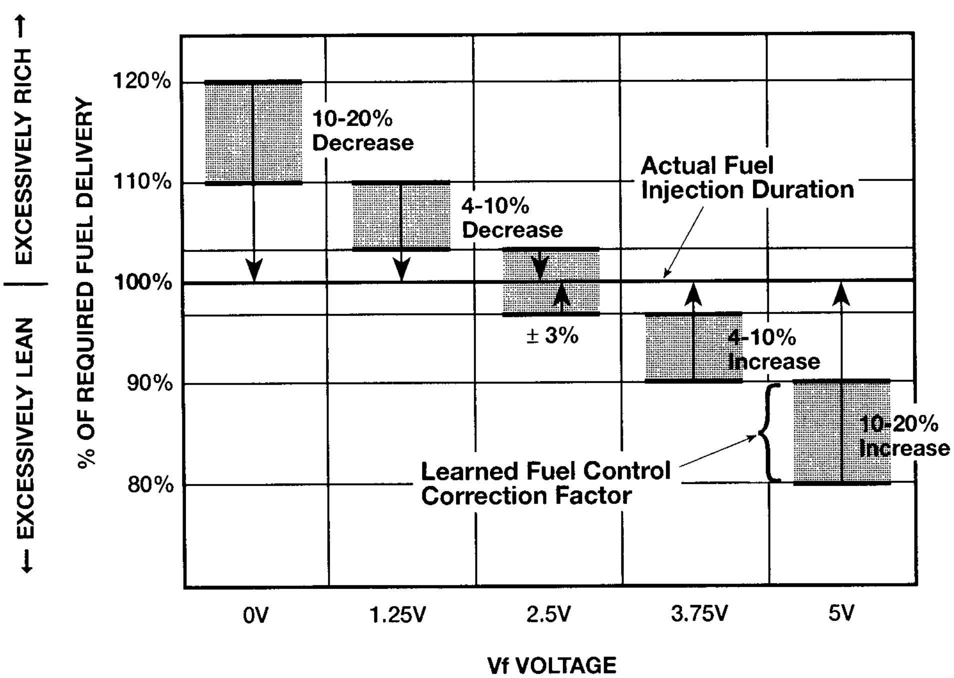
When LVF is at 2.50 volts, it indicates that basic injection duration calculation is within ± 10% of required injection duration (to achieve 14.7 to 1 AFR). If basic injection duration deviates more than ± 10% of required injection, LVF will shift to correct the excessively lean or rich condition.

Lower voltage indicates decreased injection duration to correct for a rich condition. Higher voltage indicates increased injection duration to correct for a lean condition.

Learned Voltage Feedback

LVF is essentially the same as Long Fuel Trim. On OBD serial data, it is represented by the Target A/F data parameter. OBD vehicles without serial data have the LVF voltage on terminal VF1 of DLC1.

Fig. 5-43



Using Fuel Trim in Diagnosis

When troubleshooting driveability problems, one of the first checks to make is a quick inspection of the oxygen feedback system. Determine if the vehicle is operating in closed loop and if the fuel system is correcting for an excessively lean or rich operating condition.

When to Use Fuel Trim Data

Fuel trim value outside of prescribed operating range is not a problem in itself. This condition is typically an indication that other problems exist. Fuel trim data can help lead you to the cause of these problems. Typically you will use fuel trim data to:

- Perform a pre-diagnosis quick check of feedback control
- Troubleshoot the cause of emissions system failure (I/M test failures)
- Troubleshoot cause of driveability problems, particularly when these problems occur during open loop operating modes (i.e. starting, warm-up, power enrichment)
- Perform post-repair quick check of feedback control

Where to Find Fuel Trim Data

The easiest way to perform a fuel trim inspection is to use your Diagnostic Tester. Fuel trim data is available on all OBD-II and most OBD data streams. The following chart indicates what fuel trim data is available for diagnosis:

Fuel Trim Data Interpretation

Fig. 5-44

Diagnostic System	Long Fuel Trim Data Parameter	Normal Operating Range* *Possible problem indicated outside of this range	Diagnostic Interpretation
OBD (w/o serial data)	Learned Voltage Feedback (LVF)* *Accessed at VF1 terminal of check connector, TE1 off	2.50 ± 1.25 volts	LVF represents command to injection system 5.0 volts = lean condition 0 volts = rich condition
OBD (with serial data)	Target A/F	2.50 ± 1.25 volts	Target A/F represents command to injection system 5.0 volts = lean condition 0 volts = rich condition
OBD-II	Long FT	0% ± 10%	Long FT represents command to injection system > 10% = lean condition < -10% = rich condition

How to Determine Fuel System Loop Status
Long FT and LVF only "learns" during closed loop operation. Therefore, the engine must be operating in closed loop when performing tests involving fuel trim data. To confirm closed loop operation, refer to the following chart:

Determining Fuel System Loop Status

Fig. 5-45

Diagnostic System	Loop Status Data Parameter	Normal Operating Range	Diagnostic Interpretation
OBD (w/o serial data)	Voltage Feedback (VF)* * Accessed at VF1 terminal of check connector, TE1 on, IDL/CTP off	Varying or Fixed	• Varying between 0 and 5 volts indicates closed loop • Fixed voltage indicates open loop operation
OBD (with serial data)	A/F FB	On or Off	• On indicates closed loop • Off indicates open loop
OBD-II	Fuel Sys	Open or Closed	• Closed = closed loop • Open = open loop

An alternate method of determining closed loop operation on all vehicles with DLC 1 (Check Connector) is to use your Diagnostic Tester to perform the 02S/rpm test. This test allows you to monitor the oxygen sensor(s) signal frequency and amplitude directly from the OX1 and OX2 terminals of DLC 1.

Sub-systems and Conditions Affecting Fuel Trim

Once you know the driveability symptom and are able to confirm that the air/fuel ratio is excessively lean or rich, it is a fairly easy task to identify all of the sub-systems which can effect the mixture. Check each sub-system to confirm proper operation.

The following chart lists sub-systems and other factors which can cause the oxygen feedback system to make rich or lean corrections and, in some cases, cause fuel trim data to approach its correction limits:

Sub-systems and Factors Affecting Fuel Trim

Fig. 5-46

Negative fuel trim % (low LVF, < 2.5v) **Lean Command** **(Rich AFR Condition)**	**Positive fuel trim % (high LVF, > 2.5v)** **Rich Command** **(Lean AFR Condition)**
POSSIBLE CAUSES:	POSSIBLE CAUSES:
High altitude operation (except HAC equipped)	Lower than normal fuel pressure
Fuel contamination in crankcase	Air leak into intake system
Loaded or malfunctioning evaporative emissions system	Air leak into exhaust, upstream of O2S
Excessive EGR flow rate	Throttle body/shaft wear
Leaking fuel pressure regulator	High oxygen content in fuel
Higher than normal fuel pressure	Restricted fuel injector or faulty spray pattern
Leaking fuel injector	Water contaminated fuel
	Secondary air system improperly routed upstream

NOTE: OBD vehicles without High Altitude Compensation operating at high altitude (> 5000 feet) may operate at the lean fuel trim correction limit. This is a normal condition.

