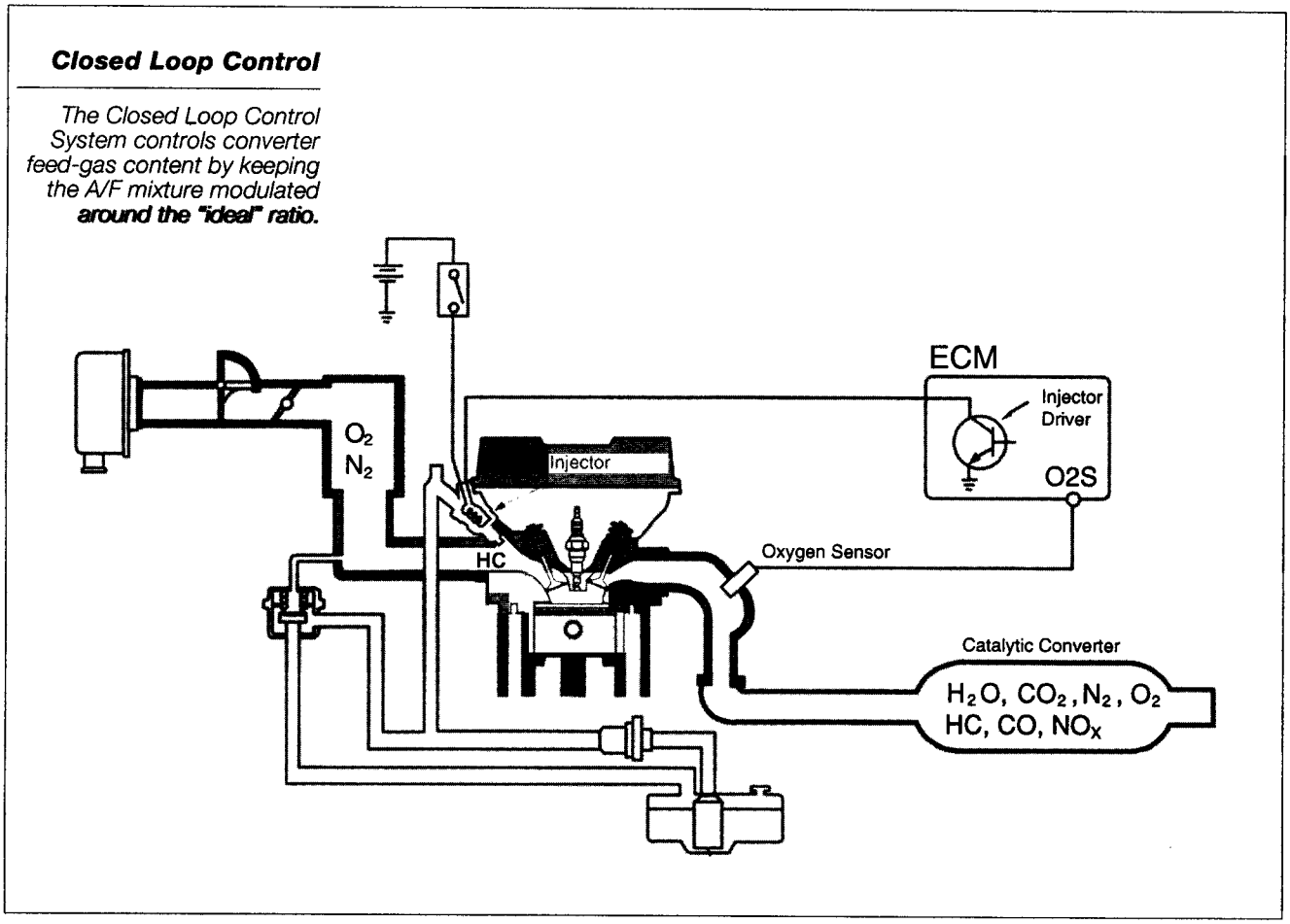
Emission Control Sub-Systems



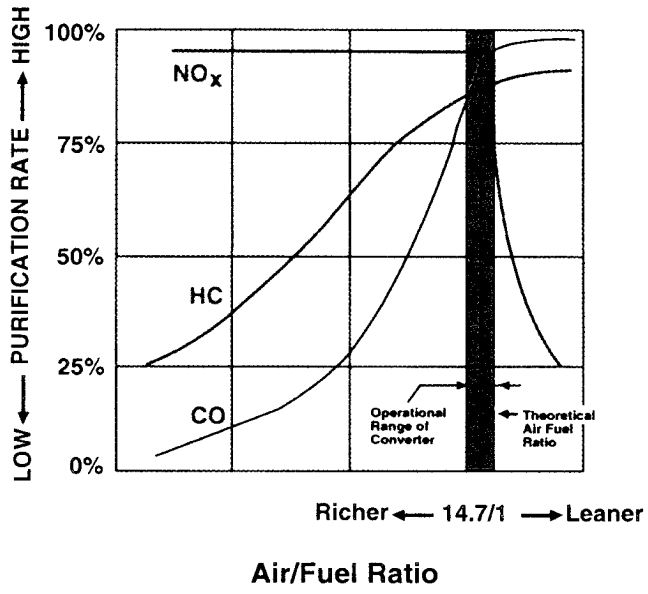
Closed Loop Feedback Control System

The heart of the emissions control system is the closed loop fuel feedback control system. It is responsible for controlling the content of the catalytic converter **feed gas** and ultimately determines how much HC, CO and NOx leaves the tailpipe. The closed loop control system works primarily during idle and cruise operations and makes adjustments to injection duration based on signals from the exhaust oxygen sensor.

During closed loop operation, the ECM keeps the air/fuel mixture modulated around the ideal 14.7 to 1 air/fuel ratio (stoichiometry). By precisely controlling fuel delivery, the oxygen content of the exhaust stream is held within a narrow range that supports efficient operation of the three-way catalytic converter. However, if the air/fuel ratio begins to deviate from its preprogrammed swings, catalyst efficiency falls dramatically, especially the reduction of NOx.

Catalyst Efficiency

As you can see, Closed Loop Control is needed to keep A/F mixture modulated around the "ideal" range, where catalyst purification efficiency is high.



Closed Loop Operation

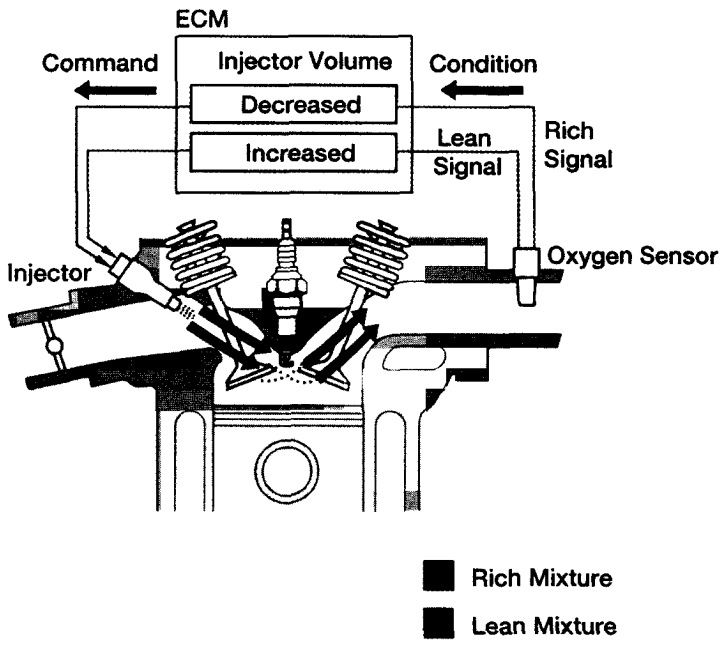
When the ECM has determined conditions suitable for entering closed loop operation (based on many sensor values), it uses the oxygen sensor signal to determine the exact concentration of oxygen in the exhaust stream. From this signal, the ECM determines whether the mixture is richer (low 02) or leaner (high 02) than the ideal 14.7 to I air/fuel ratio:

- If the oxygen sensor signal is above 0.45 volt, the ECM determines that the air/fuel mixture is richer than ideal and decreases the injection duration.
- If the oxygen sensor signal is below 0.45 volt, the ECM determines that the air/fuel mixture is leaner than ideal and increases the injection duration.

During normal closed loop operation, the oxygen sensor signal switches rapidly between these two conditions, at a rate of more than 8 cycles in 10 seconds at 2500 rpm. Small injection corrections take place each time the signal switches above and below the 0.45 threshold voltage.

Closed Loop Operation

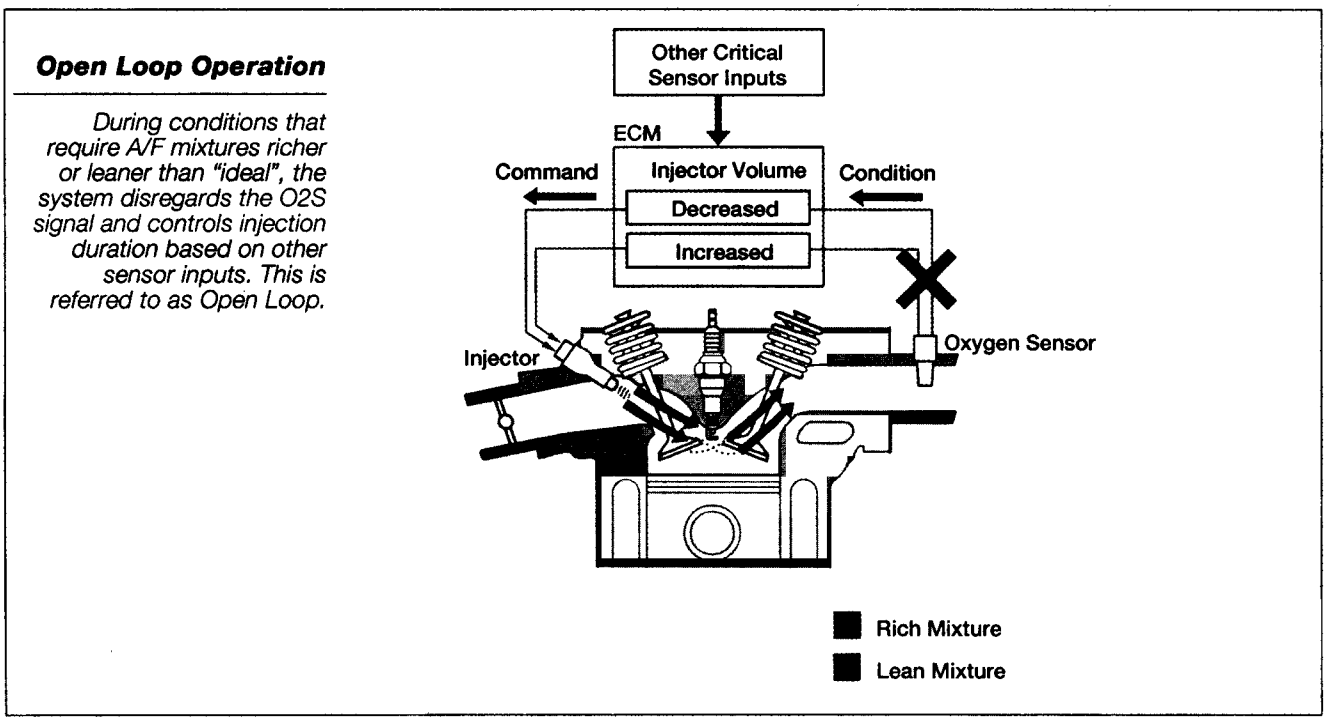
The Closed Loop Control System continuously monitors the oxygen content in the exhaust and then makes minor adjustments to injection duration.



Closed loop control works on the premise of the command changing the condition and can be summarized as follows:

- 02S indicates rich = ECM commands leaner injection duration
- 02S indicates lean = ECM commands richer injection duration

In short, the oxygen sensor informs the ECM of needed adjustments to injector duration based on exhaust conditions. After adjustments are made, the oxygen sensor monitors the correction accuracy and informs the ECM of additional adjustments. This monitor/command cycle occurs continuously during closed loop operation in an effort to keep the air/fuel mixture modulated around the ideal ratio.



Open Loop Operating Conditions

There are certain operating conditions that require the mixture to be richer or leaner than ideal. During these conditions the ECM ignores the oxygen sensor signal and controls fuel duration using other sensor information. This operation, called Open Loop, typically occurs during engine start "clock out", cold engine operation, acceleration, deceleration, moderate to heavy load conditions, and wide open throttle (WOT).

Effects of Incorrect Closed Loop Control on Emissions and Driveability

Generally, incorrect fuel control affects emissions and driveability as follows:

- Air/fuel ratio too rich may result in emissions failure for CO and HC, rich misfire, engine stalling, rough idle, hesitation, overheated converter, etc.
- Air/fuel mixture too lean may result in failure for HC and NOx, lean misfire, engine stalling, stumble, flat spot, hesitation, rough idle, poor acceleration, etc.

Closed Loop Control System Functional Checks
If you suspect that the closed loop system is not properly controlling fuel delivery, one of the first checks you should perform is an Oxygen (02) Sensor signal check. Since the ECM relies on the 02S signal to fine tune injection duration during closed loop operation, an accurate check of the 02S signal is crucial in diagnosing problems that you suspect are the result of improper closed loop control.

Remember, the engine (and engine control system) must meet certain conditions prior to checking the 02S signal or your results may be inaccurate. This usually means that the engine and 02 sensor must reach operating temperature, the feedback system is in closed loop, and engine speed is maintained at a specified rpm. 02S signal checks can be performed on OBD/OBD-II vehicles by using the Diagnostic Tester. Older vehicles may require you to backprobe the 02S signal wire using the Autoprobe or digital multimeter.

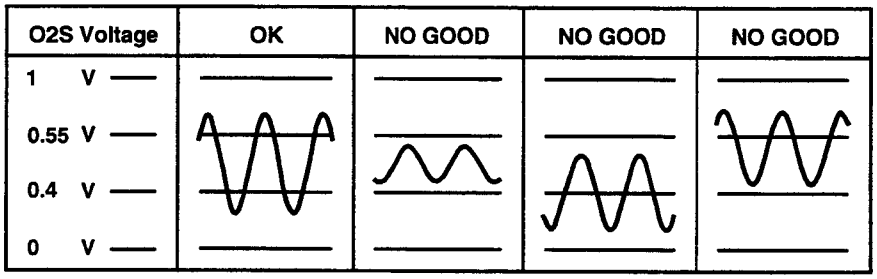
Oxygen Sensor (02S) Signal Checks
Monitoring oxygen sensor signal switching frequency and amplitude is the key to a quick functional test of the entire closed loop control subsystem. The check can be performed as follows:

- Start engine and allow it reach operating temperature
- Make sure all accessories are off
- Run engine at 2500 rpm for at least two minutes to ensure 02 sensor is at normal operating temperature
- 02S signal frequency should be at least eight cycles in ten seconds (0.8 hz) in order to ensure efficient catalyst operation.
- Also, signal amplitude should consistently exceed 550 mv on the rich swing and fall below 400 mv on the lean swing. If the sensor is degraded, either signal frequency or amplitude or both will be effected.

O_2S Signal Patterns

Examples of acceptable and unacceptable O2S signal patterns. Note: O2S signal amplitude exceeds 550 mv on rich swing and 400 mv on lean swing.

Oxygen Sensor Signal Characteristics

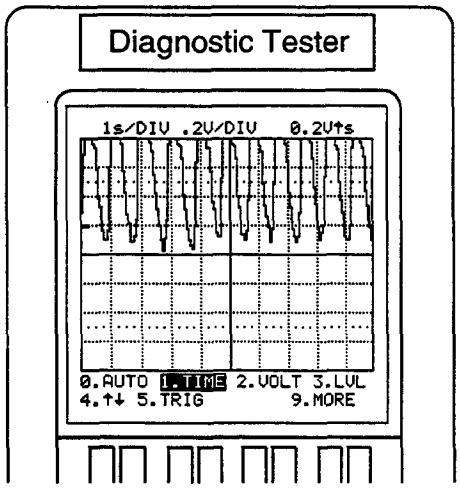


02S Check Using Autoprobe
If the Autoprobe feature of the Diagnostic Tester is used, set up the oscilloscope to read the 02S signal. Follow these steps:

- Calibrate the Autoprobe
- Set time to 1 sec/div (use 0.2 sec/div when measuring switch time)
- Set volts to 0.2 v/div
- Set trigger to automatic
- Use the single shot trigger to capture and freeze the signal

02S Check Using Autoprobe

In addition to O2S signal amplitude, signal frequency should be at least eight cycles in ten seconds (0.8 hz)



02S Check Using a Digital Multimeter
If a digital multimeter (DMM) is used, like the Fluke 80 series, set up the meter as follows:

- DC volts
- Select the MIN/MAX feature
- Press the MIN/MAX button to toggle between maximum, minimum, and average signal voltage

Tests can be performed by connecting your test instrument to the OX1 / OX2 terminal of DLC1, or by back probing directly at the oxygen sensor connector.

Many factors can contribute to the degradation of the oxygen sensor including age and contamination. Since this topic relates closely with catalytic converter operation, it will be discussed in detail later.

Closed Loop Control Quick Check

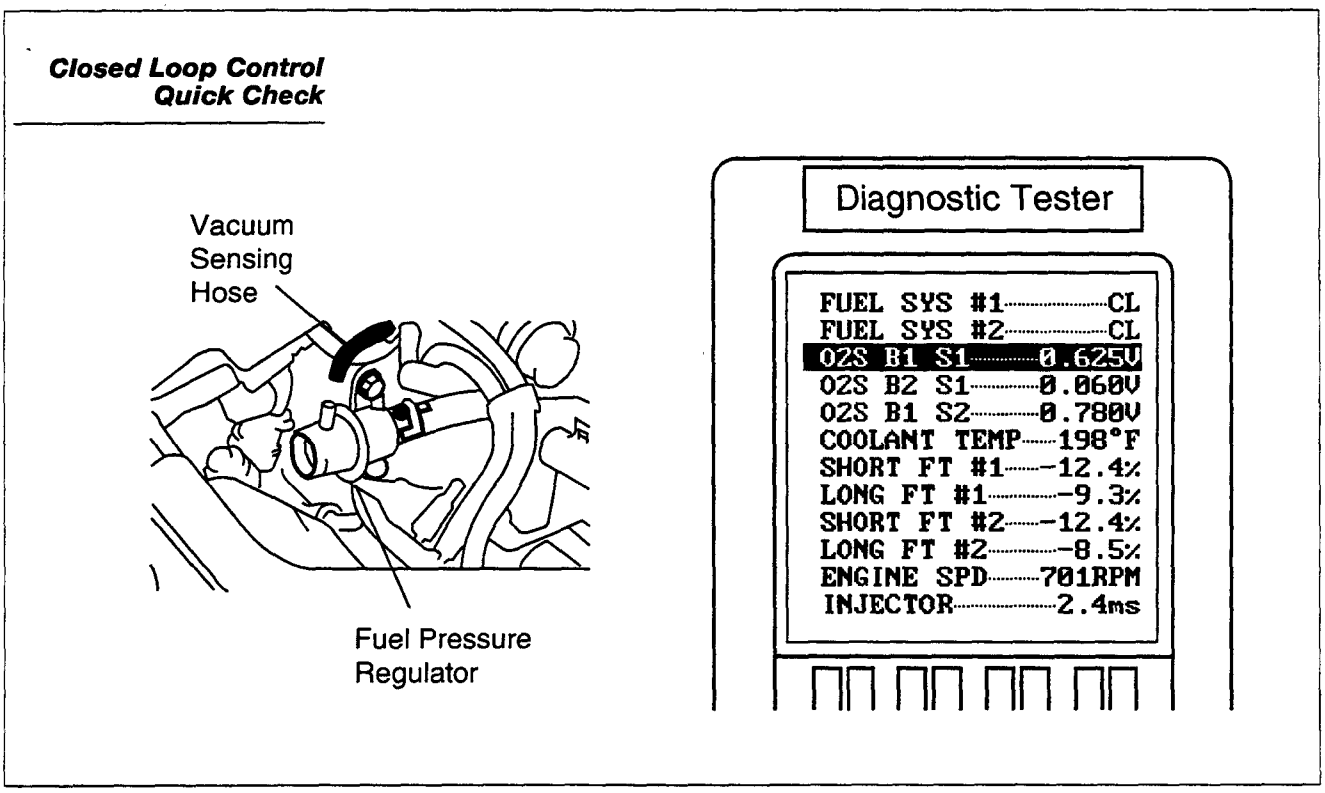
If you suspect that the ECM is not responding correctly to the oxygen sensor signal, a quick check of the closed loop system can be made by artificially driving the system rich or lean and observing the corresponding change in closed loop fuel control. This check can be performed as follows:

- Temporarily remove the fuel pressure regulator signal hose and plug it, to create a rich condition. The ECM should respond by commanding the injectors to lean the mixture.

- Temporarily create an intake manifold vacuum leak to make a lean condition. The ECM should respond by commanding the injectors to enrich the mixture.

On vehicles with serial data, changes to 02S signal, fuel trim, and injection duration can be observed using the Diagnostic Tester.

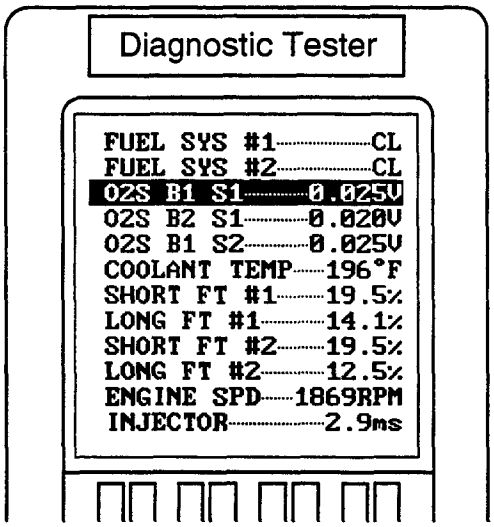
CAUTION: When performing this type of check, avoid prolonged mixture imbalances (both lean or rich) for any extended length of time, as this may cause the catalyst to overheat and permanently damage the converter.



Closed loop control has the ability to provide approximately ± 20% correction range from the basic fuel calculation. This allows the system to easily compensate for small mixture imbalances; however, **major air/fuel imbalances** (such as large vacuum leaks, leaky fuel pressure regulator, etc.) may push its correction abilities to the limit without bringing the air/fuel mixture back to the "ideal" ratio. If this occurs, whether the mixture is driven too rich or too lean, increased emission levels and driveability problems may result from the systems inability to correct for these problems.

Major A/F Imbalances

Major A/F imbalances, like this vacuum leak, may go beyond the correction abilities of the Closed Loop Control System. Check the adaptive fuel correction factors, O2S signal, injector, etc., for indications of a major A/F imbalance.



Check For Major Fuel Correction

A quick check of the **adaptive fuel correction** will show the ECM's intentions of correcting this condition. Depending on the model, this adaptive correction factor may be called VF Voltage, Target AN, or Long-Term Fuel Trim, and on serial data equipped vehicles may be checked using the Diagnostic Tester.

