Closed Loop Systems

A system that controls its output by monitoring its output is said to be a closed loop system. An example of a closed loop system is the vehicle's charging system. The voltage regulator adjusts the voltage output of the alternator by monitoring alternator voltage output. If voltage is too low, the voltage regulator will increase alternator output. Without the voltage regulator, alternator output could not be adjusted to match the electrical loads. Many systems are closed loop systems. Some other examples are: cruise control, ignition system knock control, idle speed control, and closed loop air/fuel ratio correction control. When the ECM corrects the air/fuel ratio based on the oxygen or air/fuel ratio sensor, the system is said to be in closed loop.

Open Loop Systems

An open loop system does not monitor its output and make adjustments based on its output. The temperature control in a vehicle not equipped with automatic air conditioning serves as an example.

Closed Loop Fuel Control

The ECM needs to monitor the exhaust stream and adjust the air/fuel ratio so that the catalytic converter will operate at peak efficiency, reducing regulated emission gases. Measuring the amount of oxygen remaining after combustion is a means to indicate the air/fuel ratio. A richer mixture will consume more oxygen during combustion than a leaner mixture. The oxygen sensor or air/fuel ratio sensor measures the amount of oxygen remaining after combustion in the exhaust stream. From this information, the ECM will control the injection duration to achieve the desired, ideal air/fuel ratio of 14.7: 1. This is necessary so the catalytic converter will operate at peak efficiency.

Note: The engine operation often requires different air/fuel ratios for starting, maximum power, and maximum fuel economy. The 14.7:1 ratio is for catalytic converter efficiency.

Stoichiometry and Catalyst Efficiency

Catalytic converter efficiency is nearly 100% when the air/fuel ratio is approximately 14.7:1.

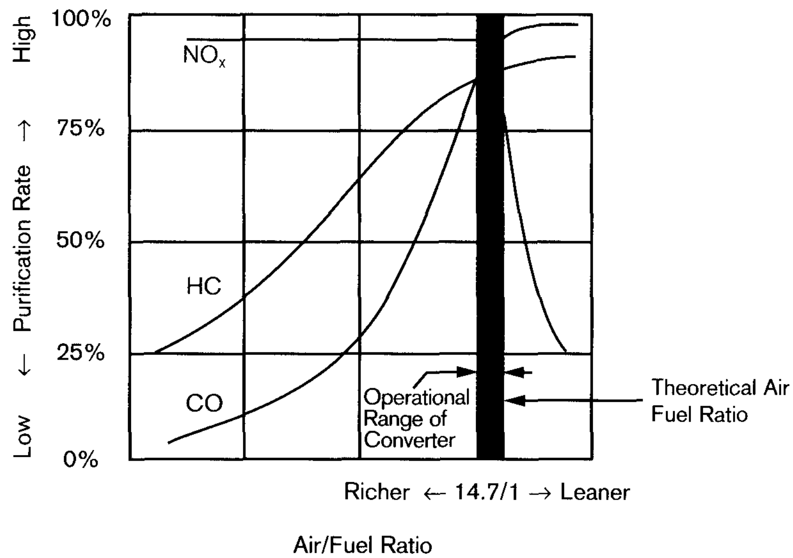

Fig. 4-38

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Stoichiometry and Catalyst Efficiency
For the catalytic converter to operate at peak efficiency, the air/fuel ratio must be at the ideal stoichiometric ratio of 14.7 parts air to one part fuel as measured by weight. This why the ECM tries to maintain a 14.7 to I ratio whenever possible.

Open Loop Mode

When in open loop, the ECM does not use the oxygen sensor A/F sensor to adjust the injector duration.

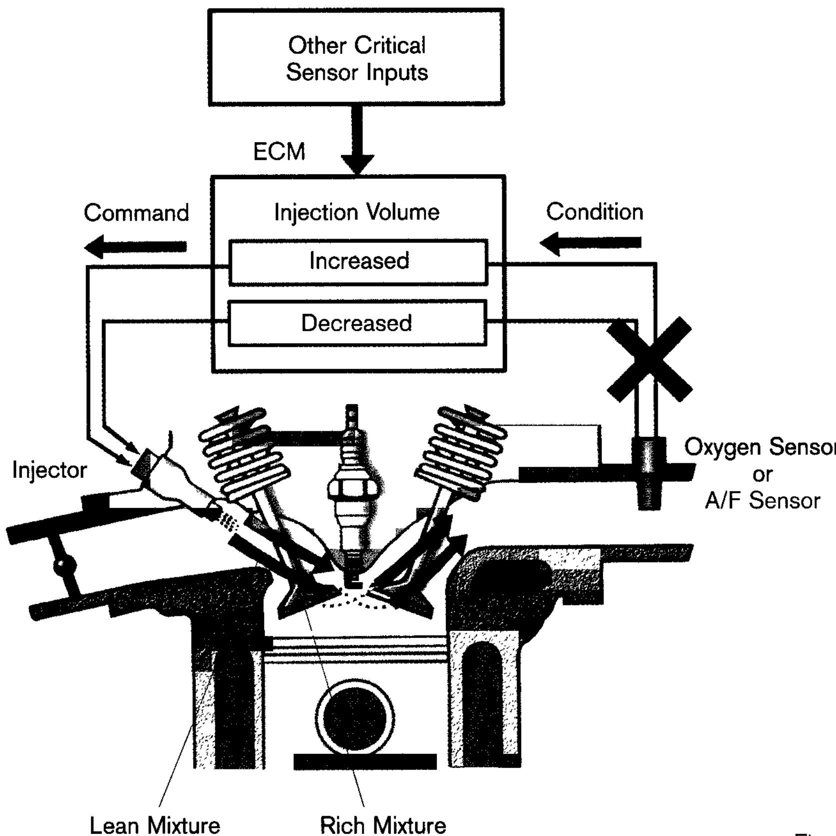

Fig. 4-39

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Open Loop Mode
The ECM will be in open loop mode when:

- starting the engine.
- the engine is cold.
- hard acceleration.
- during fuel cut-off.
- wide open throttle.

If the engine will not go into closed loop mode, the problem may be insufficient engine temperature, no response from the oxygen sensor or air/fuel sensor, or the heater circuit is inoperative. Usually, no response from the oxygen or A/F sensor will set DTC P0125.

If there is a driveability problem only in closed loop, anything that disrupts air/fuel ratio, the oxygen or A/F sensor circuit may be the cause.

Closed Loop Fuel Control

Now, the ECM will adjust injector duration using the oxygen sensor A/F sensor signal.

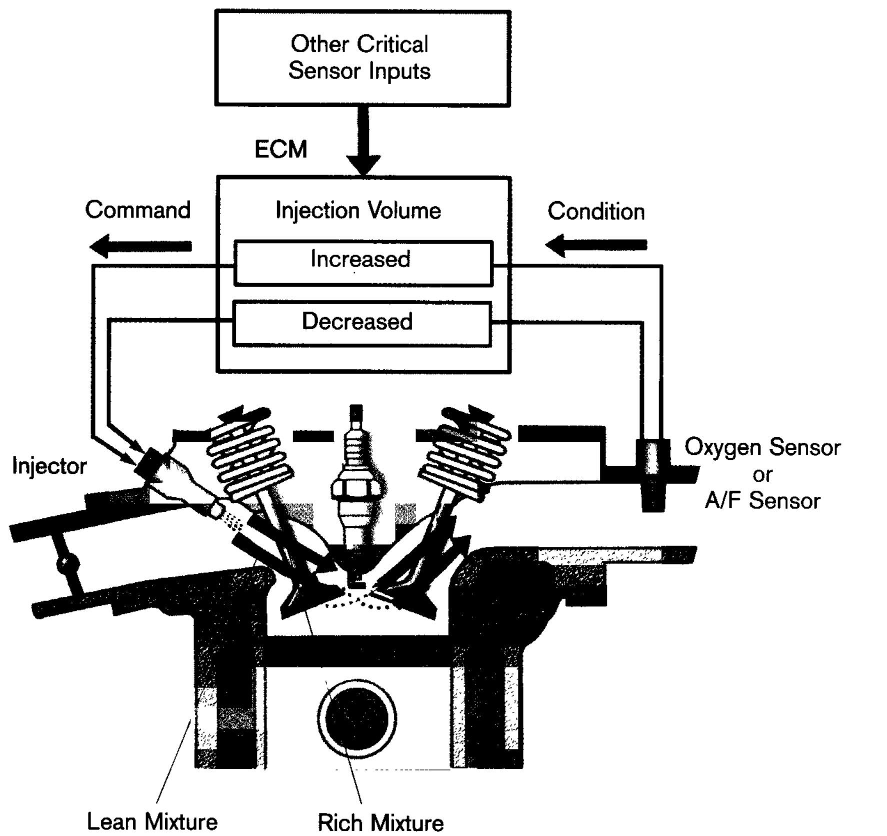

Fig. 4-40
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Closed Loop Operation/Oxygen Sensor
When in closed loop, the ECM uses the oxygen sensor voltage signal to make minor corrections to the injection duration. This is done to help the catalytic converter operate at peak efficiency.

When the voltage is higher than 450 mV, the air/fuel ratio is judged to be richer than the ideal air/fuel ratio and the amount of fuel injected is reduced at a constant rate. The reduction in the duration continues until the oxygen sensor signal switches to a low voltage (lean air/fuel ratio).

Exhaust Oxygen Content	Oxygen Sensor Output	Air/Fuel Mixture Judged To Be:
Low →	High, Above 0.45 volts →	Rich
High →	Low, Below 0.45 volts →	lean

When the voltage signal is lower than 450 mV, the air/fuel ratio is judged to leaner than the ideal air/fuel ratio so the amount of fuel injected is increased at a constant rate. The increase in duration continues until the oxygen sensor switches to high voltage (rich air/fuel ratio). At this point, the ECM will slowly decrease the amount of fuel, therefore the air/fuel ratio oscillates slightly richer or leaner from the ideal air/fuel ratio. The result is an average of approximately 14.7: 1. This produces the proper mixture of exhaust gases so that the catalytic converter operates at its most efficient level.

The frequency of this rich/lean cycle depends on exhaust flow volume (engine RPM and load), the oxygen sensor response time, and the fuel control programming. At idle, exhaust flow volume is low, and the switching frequency of the oxygen sensor is low. As engine speed increases, the switching frequency of the oxygen sensor increases, generally eight or more times at 2,500 RPM in ten seconds.

Closed Loop Operation Air/Fuel Sensor

With an A/F sensor, air/fuel mixture correction is faster and more precise. An oxygen sensor signal voltage abruptly changes at the ideal A/F ratio and changes very little as the air/fuel ratio extends beyond the ideal ratio. This makes fuel control less precise, for the ECM must gradually and in steps change the injection duration until the oxygen sensor signal abruptly switches.

By contrast, the A/F sensor outputs a voltage signal that is relatively proportional to the A/F ratio. The ECM now knows how much the A/F ratio has deviated from the ideal, and thus, the fuel control program can immediately adjust the fuel injection duration. This rapid correction reduces emission levels because the ECM can more accurately maintain the ideal air/fuel ratio for the best catalytic converter efficiency.

Therefore, when observing A/F sensor voltage output, the output is relatively constant because there is no cycling between rich and lean.

Fuel Trim

As the engine and sensors change over time, the ECM needs a method to adjust the injection duration for improved driveability and emission performance. Fuel trim is a program in the ECM designed to compensate for these changes.

When in closed loop, the ECM modifies the final injection duration based on the oxygen sensor. These minor corrections are needed to maintain the correct air/fuel ratio. However, if more correction than normal (as determined by the ECM) is needed, the ECM will use the fuel trim strategy to compensate. Fuel trim allows the ECM to learn and adjust the injection duration quickly by reducing the correction time back to normal. This means that driveability and performance will not suffer.

Fuel trim can be observed on the Diagnostic Tester as a percentage. A positive percentage means that the ECM has increased the duration and a negative percentage means the ECM has decreased the duration.

There are two different fuel trim values that affect final injection duration and can be observed by the technician; short term fuel trim (SHORT FT) and long term fuel trim (LONG FT). SHORT FT is a temporary addition or subtraction to the basic injection duration. LONG FT is part of the basic injection duration calculation and it is stored in the ECM's memory.

SHORT FT
SHORT FT is based on the oxygen sensor, and therefore, it only functions in closed loop. SHORT FT responds rapidly to changes in the oxygen sensor. If SHORT FT is varying close to 0%, little or no correction is needed. When SHORT FT percentage is positive, the ECM has added fuel by increasing the duration. A negative percentage means the ECM has subtracted fuel by decreasing the duration. The SHORT FT value is temporary and not stored when the ignition key is turned off.

SHORT FT is used to modify the long term fuel trim. When the SHORT FT remains higher or lower longer than expected, the ECM will add or subtract this value to the LONG FT.

LONG FT
LONG FT is stored in memory because it is part of the basic injection duration calculation. The ECM uses the SHORT FT to modify the LONG FT. The LONG FT does not react rapidly to sudden changes, it only changes when the ECM decides to use the SHORT FT value to modify the LONG FT. LONG FT is stored in the ECM's memory and it is not erased when the ignition key is turned off. Because LONG FT is part of the basic injection duration, it affects injection duration in closed and open loop. Like the SHORT FT, when LONG FT is at 0% there has been no modification to the basic injection duration. A positive percentage means the ECM is adding fuel; a negative percentage, subtracting fuel.

Fuel System Monitor
The fuel system monitor is designed to set a DTC if the fuel injection system is going to exceed emission standards. This monitor uses the fuel trim correction levels for detection. The amount of fuel trim correction that will set a DTC varies with each engine type and model year.

ASSIGNMENT **NAME: ______________________________**

1. Explain in detail Open Loop Operation?

2. Explain in detail Closed Loop Operation?

3. Explain the relationship between “Stiochometric Fuel Ratio” and “Catalytic Converter efficiency”:

4. List the five engine conditions when the ECM will be in “Open Loop Mode”:

5. Explain in detail how the ECM uses the Oxygen Sensor to control fuel duration:

6. Explain the term “Fuel Trim”

7. Explain in detail both “SHORT Fuel Trim” and “LONG Fuel Trim”;

