

BASIC TRAINING



K-Lambda Watchdog

Basic Fuel Injection

In recent issues, we have covered the K-Jetronic or CIS fuel injection system in great detail. From the basic version we've already discussed, K-Jetronic evolved into a feedback system called K-Lambda. This article discusses the basic operation of the Lambda version of K-Jetronic.

Remember that everything you learned about basic K still applies to the Lambda-equipped systems. You may even want to review the K-Jetronic material in our April and May issues before you dive into the Lambda system.

Lambda Sensor

The Lambda story begins in the exhaust manifold

where the exhaust gas watchdog lives. The watchdog is an oxygen sensor that sniffs the oxygen content of the exhaust gases. This watchdog barks voltage signals to a system control computer (the ECU) according to the amount of oxygen he sniffs. Here are the ways the watchdog reacts:

- RICHER MIXTURE → LOWER OXYGEN → HIGHER VOLTAGE SIGNAL TO THE ECU
- LEANER MIXTURE → HIGHER OXYGEN → LOWER VOLTAGE SIGNAL TO THE ECU.

Tricking The Dog

Any exhaust leak ahead of the oxygen sensor can

drive the system RICH. A cracked EGR pipe, cracked air injection manifold, or a leaking exhaust manifold gasket not only lets exhaust gas leak out, but these leaks, in turn, allow negative exhaust backpressure pulses to draw in additional oxygen. Our watchdog will assume that this intruding oxygen is a LEAN condition and he'll bark LEAN to the ECU. Then the ECU will incorrectly RICHEN the mixture.

A defective spark plug wire or fouled spark plug will fail to fire the air/fuel charge in a given cylinder. This incomplete firing means that raw fuel (hydrocarbons) and oxygen have not combined in combustion. This means we have a lot of leftover oxygen and leftover hydrocarbons. Our watchdog will ignore the hydrocarbons, but the extra oxygen will make the dog howl that the mixture is LEAN! So the ECU will send a RICH command to correct what it thinks is a LEAN condition. Richening the mixture on an engine that's already dumping unburned fuel could cause a Chernobyl-style meltdown of the catalytic converter.

The presence of leaded fuel will put a muzzle on our exhaust puppy. The oxygen sensor's voltage signal will be much lower-than-normal or nonexistent, depending upon the amount of lead present. This causes the ECU to issue a RICH command.

The exact opposite happens when silicone vapors hit the sensor. The vapors turn our puppy into a mad dog and the mad dog really howls. It sends a higher voltage (RICH) signal that causes the ECU to LEAN the mixture out too much.

A normal oxygen sensor also responds quickly to changes in exhaust mixture. Just as a dog gets old and may take longer to wake up to an intruder, the tailpipe puppy may get lazy too. He barks loudly enough for the ECU to hear him, he just doesn't bark often enough to keep the mixture properly adjusted. On some domestic feedback systems, the sensor's responsiveness (how often the dog barks) is called cross-counts.

The Lambda system can't detect when the watchdog gets lazy. You have to test the oxygen sensor with your volt-ohmmeter (VOM) to be sure that the puppy barks instantly when the need arises and keeps barking often enough to alert the ECU.

Lambda Control Unit (ECU)

Every time the exhaust gas becomes RICH, the oxygen sensor sends a voltage signal greater than about .5 volt to its master, the ECU. When the voltage signal is less than about .5 volt, the signal means LEAN. Just remember:

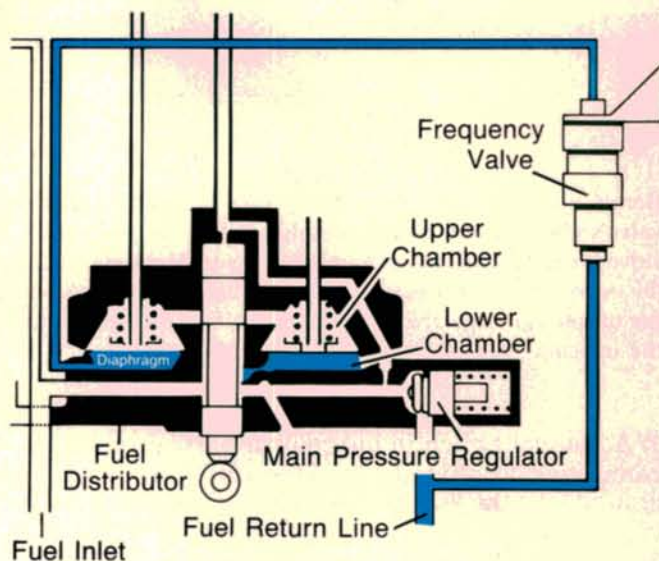
- LEAN = LOW VOLTAGE SIGNAL (less than .5 volt);
- RICH = HIGH VOLTAGE SIGNAL (as high as 1 volt).

The oxygen sensor signal usually enters the ECU at pin connector number 2. This is where you want to take your voltage measurements. Use a high-impedance voltmeter or you'll get inaccurate readings.

Measuring at the ECU lets you check both the sensor and its wiring up to the ECU. Checking voltage down near the sensor pigtail won't identify any unwanted resistance (a broken wire or a dirty connection) between the sensor and the ECU.

The oxygen sensor wire's connection at the ECU can become a problem once corrosion sets in. The connections at the ECU must be clean, dry, and tight. Many a computer has been unplugged and another one plugged in to correct a problem. The R and R process itself—not the new computer—cured the car. That is, unplugging and plugging the connector wiped the connections clean.

The ECU listens to the voltage message from the tailpipe puppy and then makes a command to correct the condition. Remember: command corrects condi-



This schematic shows how the frequency valve is tied into the normal K-Jetronic fuel distributor plumbing. When the ECU grounds one terminal of the frequency valve, the valve opens. With the valve open, some of the lower chamber fuel pressure vents back to the fuel tank.

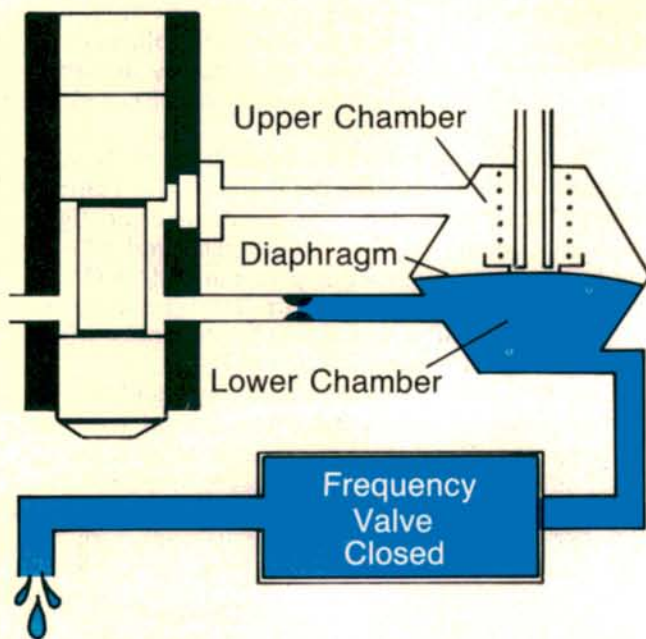
tion. The command the ECU makes is always opposite the signal sent by the oxygen sensor. If the exhaust is LEAN, the ECU makes a RICH command. Therefore:

- LEAN EXHAUST causes a RICH COMMAND;
- RICH EXHAUST causes a LEAN COMMAND.

A part called the frequency valve carries out the ECU's orders to richen or lean out the mixture. We'll explain the frequency valve in a moment.

Open Loop/Closed Loop

When the engine is first started, the ECU allows the fuel system to act like a non-Lambda system. This is called open loop. In open loop, the ECU won't listen to the oxygen sensor's signals. In fact, the ECU won't listen to the exhaust watchdog until three things happen:



Here's a closer, more simplified look at the frequency valve's effect on the fuel distributor. When the frequency valve is closed, the lower chamber pressure is greater than the upper chamber pressure. This greater pressure pushes the diaphragm upward, restricting the fuel outlet port to the injector.

- 1) A thermal switch in the coolant passage opens its connection to ground. Breaking this connection to ground tells the ECU that the engine's warm enough to go into closed loop.
- 2) The oxygen sensor gets hot enough to begin generating voltage signals. The watchdog has to wake up before he can begin barking!
- 3) A certain amount of time passes by. Once the puppy wakes up, the thermal switch opens, and a few minutes go by, the Lambda system goes into the closed loop phase of mixture control. Then the ECU takes the controls and steers the air/fuel mixture toward stoichiometry.

The Lambda system uses a *feedback* loop to closely control the mixture during closed loop operation. Feedback loops have been used for years in home heating systems. The room thermostat senses the temperature of the room and sends a message to the furnace. Too cold? The thermostat calls for more warm air. Too warm? The thermostat turns the furnace off for a while. The process is repeated as necessary to maintain the desired temperature.

The Lambda feedback loop, or closed loop, is essentially the same. The oxygen sensor is the thermostat; the furnace's controller is the ECU. Instead of controlling the amount of warm air produced, we're controlling the amount of fuel that's injected.

Then what would typify an open loop system? Think of the air conditioner from some 1960s'-vintage

cars. There was an ON button and an OFF button. The air conditioner did the best it could do with only two settings, but sometimes it got too cold. Other times, it didn't cool well enough. This is exactly the way a fuel system works in open loop. Sometimes it gives too much fuel, other times it doesn't give enough.

Think about the home heating example again. Now imagine that the house is old, and that all of the window and door weatherstrips are shrunken, cracked, and leaking. Lots of cold air is leaking in. Even though the furnace is running full blast on HOT, the room still doesn't warm up. The heating system just can't provide enough heat to overcome the cold drafts.

This is exactly like an engine with leaking injector seals, leaking manifold gaskets, etc. The oxygen sensor is telling the ECU to richen the mixture. The ECU is keeping the frequency valve turned on as much as it can, but it still can't overcome all the air leaks. The Lambda system is buried at its full-rich position (90 percent duty cycle), but the engine is still too lean.

The opposite happens when the leaks are fuel instead of air. Leaking injectors can bury the system at its lean limit (15 percent duty cycle) and the engine will still be too rich. These air/fuel problems are outside the window or range of the ECU's control!

Frequency Valve

The frequency valve is nothing more than an electrically controlled injector with a hose connected to each end. One hose connects the frequency valve to the lower chamber of the fuel distributor. The other hose connects it to the fuel tank return line.

Think about that K-Jetronic fuel distributor again. The amount of fuel delivered to the injectors depends upon the pressure imbalance between the upper and lower fuel distributor chambers. Anything that changes this pressure imbalance changes the amount of fuel flowing to the injectors and out of the injectors.

If we use the frequency valve to bleed off some of the pressure in the lower fuel distributor chamber, a spring in the upper chamber pushes a diaphragm downward. As the diaphragm flexes downward, it exposes more of the fuel distributor outlet ports and more fuel flows to the injectors.

Unlike some other feedback fuel systems you may have seen, the longer the frequency valve remains open, the richer the Bosch Lambda system runs. The greater the duty cycle (dwell) of the frequency valve, the longer the frequency valve is open. The longer the valve is open, the more lower-chamber fuel pressure it vents off to the tank. The lower the lower chamber pressure becomes, the more fuel sprays from the injectors. To sum up the results:

- HIGHER DUTY CYCLE results in a RICHER MIXTURE;
- LOWER DUTY CYCLE results in a LEANER MIXTURE.

Note that this is *opposite* the reaction on domestic feedback fuel systems.

Remember that the duty cycle is the on/off ratio of the frequency valve. Battery voltage constantly feeds one frequency valve terminal. The ECU pulses the other terminal—the ground terminal. If you compare this to a set of conventional ignition points, the ECU acts like the points. That is, it operates a coil by making and breaking the coil's ground circuit.

In closed loop phase, the ECU controls fuel mixture by changing the dwell of the frequency valve.

Duty Cycle and Dwell

Think of conventional ignition theory for a moment. Dwell is the number of degrees that the points stay closed. The longer the points stay closed compared to total distributor rotation, the greater the dwell. The points still open the same number of times per engine revolution. But points-closed duration (also called primary ignition "on" time) is what we measure when we measure dwell.

The same holds true for the frequency valve. It opens 10 times per second, but its duration—how long it's open—is what changes. Frequency valve duration is similar to primary ignition "on" time or points-closed time.

A dwell meter is really a duration meter. It does the same thing a duty-cycle meter does. As long as you remember to put the dwell meter on the 90-degree/four-cylinder scale, it is interchangeable with the duty-cycle meter. A 50/50 duty cycle reading on the 100 percent duty cycle meter equals a 45-degree reading on the dwell meter. This midrange setting is critical. This is where we set the Lambda mixture adjustment when we turn the mixture-adjusting screw.

To use a dwell meter on a Lambda system, just remember that:

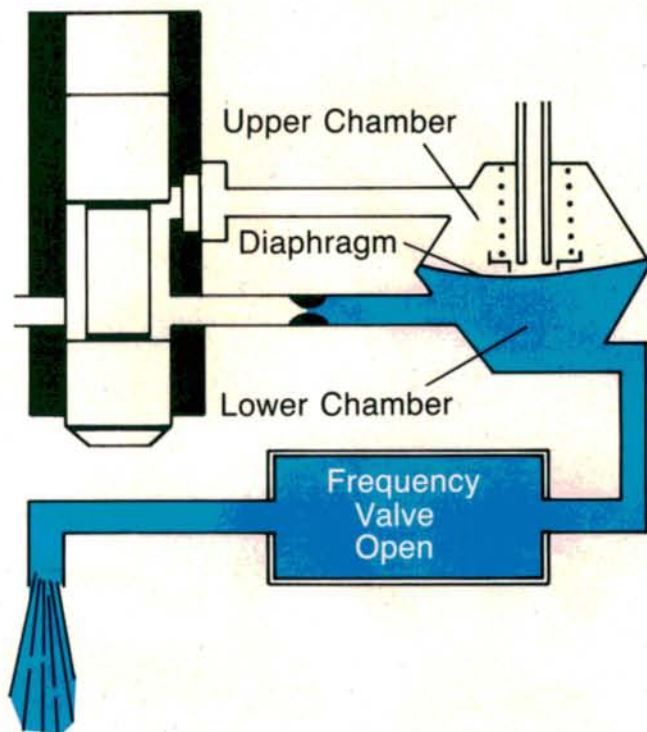
$$\text{DUTY CYCLE} \times 90 \text{ percent} = \text{DWELL.}$$

When the system is in open loop, the duty cycle or the on time to off time of the frequency valve is 50/50. Once the system goes into closed loop, we want the mixture to remain in that window or range of 50/50. That's why we adjust the mixture screw to keep the on/off ratio at the 50/50 mark. By doing this, we let the ECU have enough space in its mixture adjusting range to properly control minor imperfections that occur in the air/fuel ratio. If we connect the duty meter to the system and read 65 percent duty, we know that the ECU is holding the frequency valve open (grounding it) 65 percent of the time. The ECU is closing the valve 35 percent of the time. Look back over what you've already read so far. Can you see that the mixture is lean? Can you understand that the Lambda ECU is driving the system rich to compensate?

Let's assume that you don't find any mechanical problems that are causing a lean condition. You can remove the adjustment plug and turn the CO adjusting screw clockwise to richen the mixture back to the 50-percent duty mark. If the meter was reading 40 percent and you didn't find any problems, turn the screw

counterclockwise to lean the mixture. Remember to:

- turn the screw **CLOCKWISE TO GO RICHER**;
- turn the screw **COUNTERCLOCKWISE TO GO LEANER**.

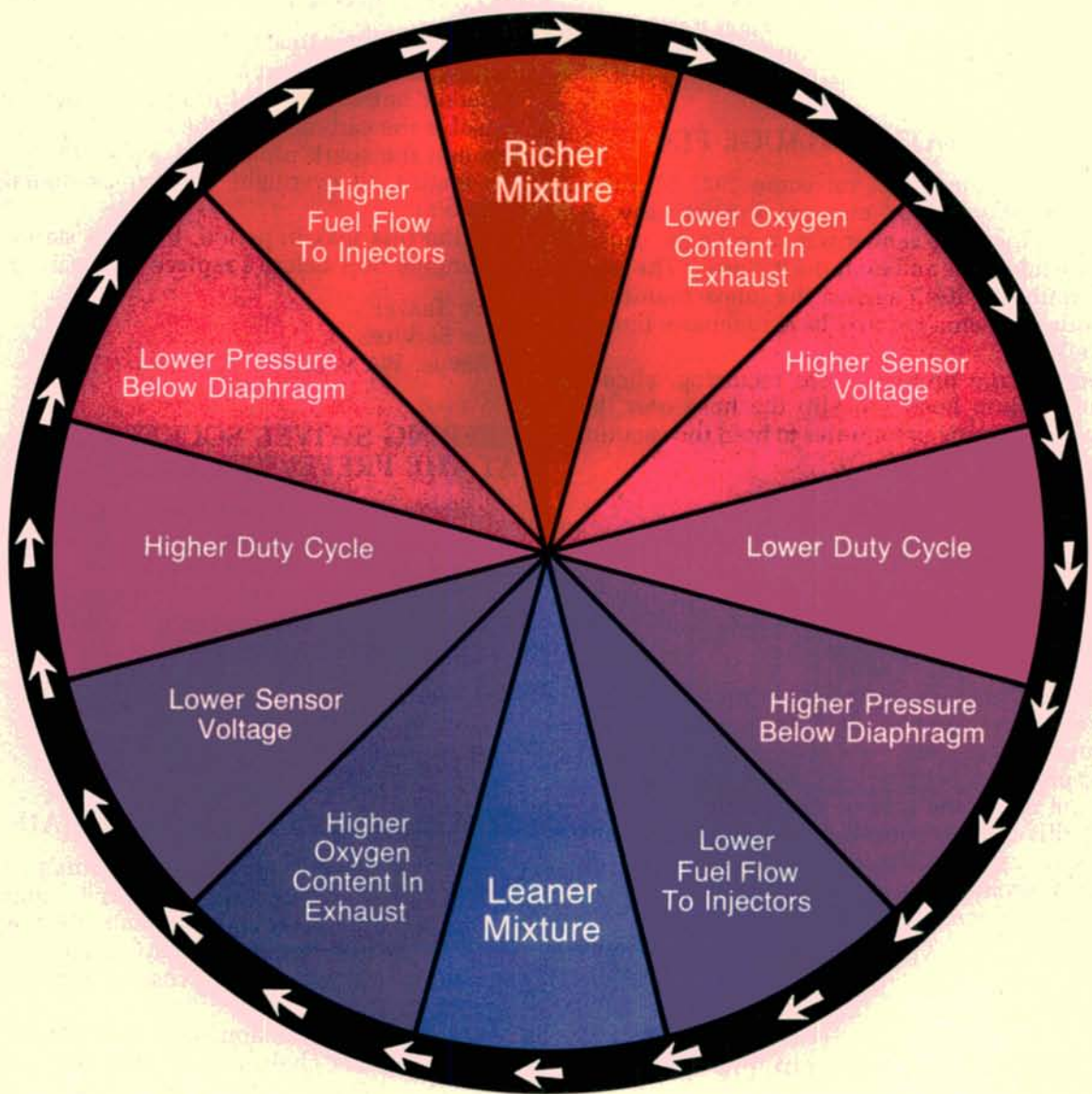


When the frequency valve opens, it reduces pressure in the lower chamber. Then the spring in the upper chamber pushes the diaphragm downward and increases the opening at the fuel outlet port. This increases fuel flow to the injector. The more fuel the injector receives, the richer the mixture becomes.

CO Adjustments

To check the basic CO setting, we need to eliminate the oxygen sensor and put the system into open loop. Connect an infrared exhaust analyzer to the exhaust test port. The engine oil must be warm, the idle speed must be correct, the air injection must be disabled, and all electrical accessories must be off. Don't forget to disconnect and plug the charcoal canister purge hose.

After correcting the idle speed, make your final adjustment as you would on a non-Lambda K-Jetronic car. Reconnect the oxygen sensor when you're done and check for proper oxygen sensor response. If the specs call for setting the duty cycle, connect a duty cycle meter to the car's test connector. Or you can use something such as Thexton's test harness P/N 391 to tap right into the system at the frequency valve connector. Leave the oxygen sensor hooked up. If you're using a duty cycle meter, look for a reading of 50 percent. With a dwell meter set to its 90 degree/four-cylinder scale, you'll want a 45 degree reading.



Remember that once the ECU gets a signal from the oxygen sensor, the ECU makes a command to correct the mixture condition. If you follow the actions and reactions around this chart, you'll get a feeling for how a closed loop feedback fuel system works.

If the meter reads greater than 60 percent, the mixture is set too lean. Turn the adjustment screw clockwise to richen it. If the meter reads less than 40 percent, turn the screw counterclockwise. Remove the 3 mm adjusting tool, cover the access hole, and rev the engine slightly between adjustments. The idle speed will have to be right on the money for your adjustments to work. These adjustments bring the mixture within the range that the ECU's capable of controlling.

If the duty cycle or dwell reading is fixed and the reading isn't oscillating around the 50/50 mark, the

system is stuck in open loop. The reading should fluctuate about 15-20 percent above and below the 50/50 mark. If it doesn't fluctuate—or if you can't adjust the mixture—check the oxygen sensor and the thermal switch. One or both of them is keeping the system in open loop. If they both test okay, then there's a problem in the wiring or in the ECU.

That covers the basic operation of the Lambda version of K-Jetronic fuel injection. For an in-depth look at troubleshooting this system, tune in to next month's **Basic Training!**

—By Dré Brungardt