K-Lambda Watchdog

PART TWO

Last month, I discussed the fundamentals of the Lambda version of K-Jetronic fuel injection. I'll continue the discussion here and also describe some practical ways to test this system.

His Master, the ECU

Whether you call it the brain, the control unit, Lambda controller, or computer, it's nothing to be afraid of. This computer is really quite dull. It can only respond to voltage-on or voltage-off signals. It interprets these signals as either the number one or the number zero. With this two-number, or binary system, the computer makes calculations with incredible speed. Unfortunately, when something goes wrong in the system, it can make wrong decisions just as quickly. Even worse, it doesn't learn from its mistakes as you and I hopefully do. It will continue making mistakes until you step in and correct the problem.

We call the Lambda brain the electronic control unit or ECU. The ECU is deaf, dumb, and blind without its sensors. The Lambda system's sensors are like watchdogs. These watchdogs are critical to proper engine operation. However, they must live in conditions that would frighten a junkyard dog. The underhood and engine environment is extremely hostile due to heat, vibration, chemical gases, and voltage zaps. In spite of this, the dogs must maintain their positions and bark out reports to their master, the ECU.

By using the information provided by its watchdogs, the ECU can tell what changes are occurring under the hood. Then the ECU is able to make "intelligent" decisions about fuel mixture control. The end result is a smooth running car. If one of the sensor dogs were to die in action, a driveability problem would flare up.

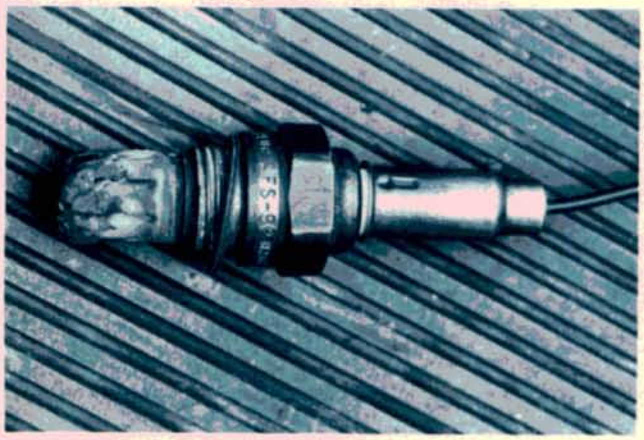
Mad Dogs and Technicians

Last month, we discussed the most important watchdog, the oxygen sensor. But what are the Lambda system's other purposeful puppies? Depending upon the make and model, there are thermal switches, throttle switches, and vacuum switches. With a little bit of obedience training, you can learn how to command these dogs to speak. For test purposes, you can take the commands away from their master, the ECU.

The throttle switch dog tells the ECU when the pedal is to the metal. It does this by grounding the wire that connects it to the ECU. This wire is usually connected to ECU pin number 7. On some cars such as Mercedes-Benz, the throttle switch also grounds a wire (pin number 6) at idle. When this watchdog dies, there will be a performance problem at wide-open throttle (WOT). If the car has a three-pointed star on it, it will also have an off-idle hesitation.

Instead of throttle switches, Peugeot uses vacuum switch watchdogs. A wire from the ECU is connected to one side of each vacuum switch. The other side of the vacuum switch is grounded. The yellow vacuum switch closes (completes the ground) at about 3.3 inches or more of vacuum. The green vacuum switch is open above about 3.3 inches of vacuum and closed (grounded) below 3.3 inches.

To test such a vacuum switch, connect a hand-held vacuum pump to it. Connect an ohmmeter or self-powered test light across its terminals. Keep an eye on the meter or the test light. When you apply 3.3 inches of vacuum to the yellow switch, the meter should show continuity or the test light should light up. When you apply 3.3 inches of vacuum to the green switch, the meter reading should change from continuity to open circuit or infinity. Or, the self-powered light should go out.



Silicone vapors ruined this oxygen sensor. Careless, excessive use of silicone sprays or certain silicone (RTV) sealers can cause this. Silicone contamination makes the sensor send a higher voltage—a false rich signal—to the ECU.

When the complaint is poor fuel economy and/or the system won't go into closed loop, don't overlook a stuck-open or missing coolant thermostat.

Getting Dogs To Do Their Tricks

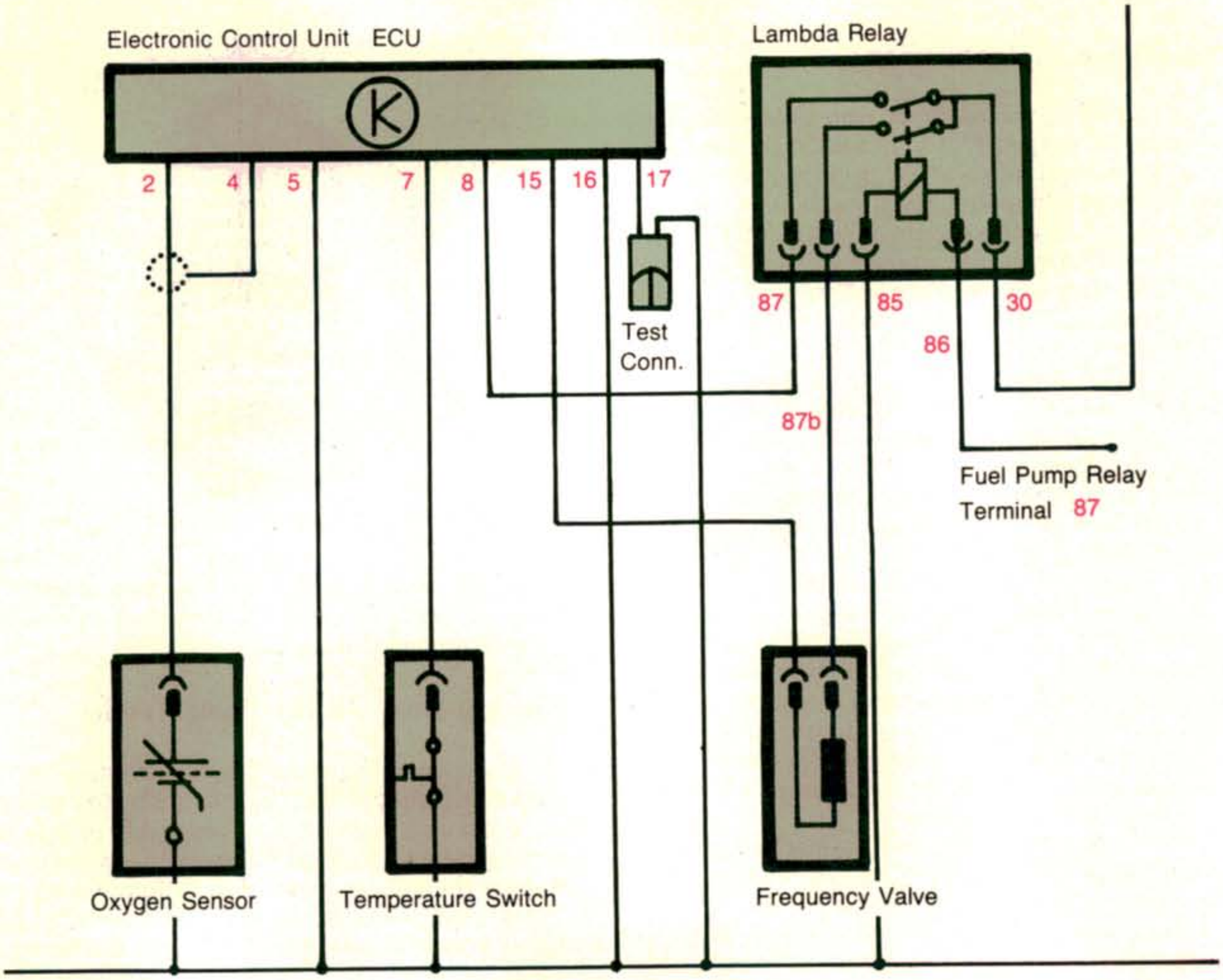
These switches should be tested while in action. This will confirm that their connections to the ECU are good and that the ECU is capable of responding to their signals. To do this, remove the fuel pump relay. Bypass the relay by connecting a jumper wire across its terminals (usually terminal 30 and terminal 87). The ignition switch must be on and you must have a dwell meter or duty cycle meter connected to the car's diagnostic connector. Check your manual to find out where the diagnostic connector is located on that particular car.

As you operate each switch, enrichment should occur. Remember, this is what the master—the ECU—uses its watchdogs for! When a switch grounds a signal wire, the ECU makes a command to richen the mixture. It does this by raising the duty cycle or dwell of the frequency valve.

When a particular switch is closed, the dwell or duty cycle should increase. If it doesn't increase, bypass the switch and ground the end of the signal wire. If the duty cycle/dwell still doesn't increase, check the connections to the ECU. Okay? Then check the ECU's ground. If its ground is good, replace the ECU.

On any Lambda system, one of the top dogs in the pack is the thermal switch. It is grounded when cold and opens up when it's hot. Usually, the thermal switch is wired in parallel with the wide-open throttle switch. This means it has the same effect on the system the WOT switch has when it's grounded. It creates a richer mixture—but only when the engine's cold. Therefore, when you ground the signal wire to the thermal switch, the duty/dwell should rise.

Some makes such as Audi also have a start enrichment relay. It is wired in parallel with the thermal



This is a simplified but "typical" layout of the K-Lambda computer, Lambda relay, frequency valve, sensors, and switches. Always take your voltage readings on this system with a high-impedance voltmeter.

PIN NUMBER DESIGNATIONS

INPUT PIN NUMBERS

2 This pin receives the signal from the oxygen sensor. Check this pin with the engine warmed up and running. The voltage must range or vary above and below the 0.5 volt level.

4 Some oxygen sensors use a shielded cable. The cable should have no continuity to either the sensor wire or to ground.

5 This is the computer ground, so there must be continuity from this pin to chassis ground.

6 This pin connects to an enrichment device. The particular device varies by make and model. This pin should be grounded with the engine idling.

7 This pin is either the thermal switch or the WOT switch, sometimes both. Depending upon the model, this pin should be grounded when the engine's cold or when the engine's at WOT.

8 This is battery voltage from Lambda relay terminal 87.

12 This is the thermal switch on some models such as Peugeot or Volkswagen.

16 This is computer ground, the same as pin 5.

OUTPUT PIN NUMBERS

15 This is the frequency valve signal.

17 This is the test connection wire for a duty cycle meter.

switch. When you crank the engine, it should make the duty/dwell rise—even when the engine's hot.

The thermal switch is also important because the Lambda system won't go into closed loop until it heats up and opens its contacts. If the coolant thermostat is missing or stuck open, the system will stay in open loop and run rich all the time. Before attempting to adjust the mixture, you must verify that the system's in closed loop operation! You can't tune up a dead dog!

Frequency Valve Freaks

After the watchdogs have barked their signals to their master, the ECU, the ECU can only command or control fuel mixture one way. It controls the frequency valve. Last month, we discussed frequency valve theory and operation. Now I'll tell you how to tell if the frequency valve died—and more importantly—what killed it.

On the Lambda system, bad connections are the main enemy. The one terminal on the frequency valve must receive a constant supply of battery positive voltage. The other terminal must have a good connection to the ECU, because the ECU operates the valve by grounding it.

If there is no power to the frequency valve, check the Lambda relay first. Check your manual, because the Lambda relay location varies from car to car. It may be under the hood, under the dash, or inside a kick panel! The Lambda relay has two inputs and two outputs. One input, terminal number 30, is direct battery positive. The other input, terminal number 86, is from the fuel pump relay. The fuel pump relay is also known as the RPM relay. It is powered as soon as the distributor sends an RPM signal to the fuel pump relay. The fuel pump relay then feeds battery voltage to the other input of the Lambda relay. Once this happens, the contacts inside the Lambda relay close and battery voltage goes to the relay's two outputs.

The two outputs of the Lambda relay are:

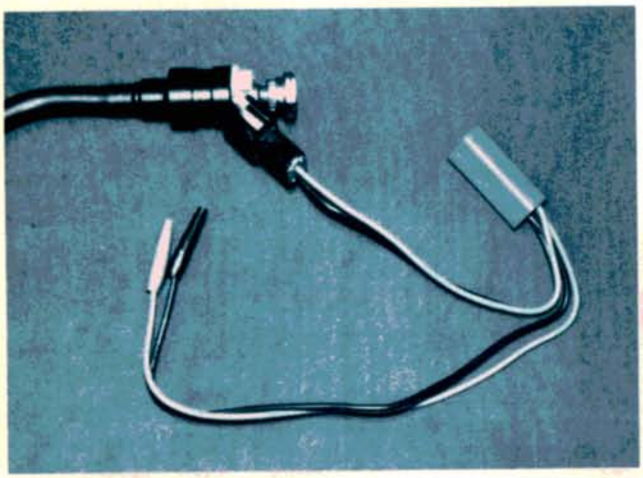
- relay terminal number 87 to ECU pin number 8;
- terminal number 87b to the frequency valve.

Both should power up at the same instant. If not, trouble is afoot! With the engine running, check for power on both of the number 87 terminals. No power? Check for power at both inputs, terminals 30 and 86. Also verify that you have ground at terminal 85. If you have power at 30, power at 86, and ground at 85, replace the Lambda relay.

Remember this detail: if you have power at either of the the 87 terminals on the relay but not at both of them, replace the relay.

What if you've only got power at terminal 30? Then check for power to the warm up regulator or the frequency valve. If either of these units has power, then there's an open in the wire between the fuel pump relay and the Lambda relay.

The frequency valve has battery voltage at one of its terminals, right? You can test for duty cycle with one of those little test lights that are designed to plug into a Bosch two-pin fuel injection wiring harness. Companies such as BWD, Borroughs, Kent-Moore, OTC, and others offer these fuel injection test lights. Pull the two-wire connector off the frequency valve and plug the test light into it.



In order to measure K-Lambda duty cycle with your dwell meter, use an adapter harness such as this Thexton item (P/N 391) to connect the meter to the frequency valve. Put the meter on the 90-degree scale. To convert duty to dwell, multiply duty cycle times 90 percent.

With the engine running, the light should blink as the ECU makes and breaks the frequency valve's ground. If the test light doesn't blink, go to the master himself. Probe ECU terminal number 15 the same way. No blinks? Then touch the ECU ground terminal, terminal 16. If the light comes on when you touch terminal 16, check for power at terminal 8. Got power at terminal 8? You do? Then start playing taps, because the leader of the pack has died! Replace the ECU.

Brain Teasing

Before you try making friends with unfamiliar and sometimes angry doggies, you should have a guide of some kind. Dig out a wiring diagram for the vehicle you're troubleshooting. One of the best strategies is to go directly to the multi-pin harness connector for the ECU and do your dog training there. Testing here allows you to check everything from the switch/sensor doggies back to their master himself, the ECU.

When you take readings at the ECU, be sure to backprobe the harness. Do not disturb the tightness of the connectors! These connectors must latch themselves tightly onto the end board connectors sticking out of the computer.

Finding Vacuum Leaks

Never try to correct fundamental problems by cranking on the mixture screw. Instead of solving problems, this cover-up approach will only cause fuel economy and driveability problems.

The Germans like to call vacuum leaks or air leaks *false air.* This fuel system is so tightly designed that it really can't cope with this unwanted extra air. Think back to our example of the furnace in last month's article. Remember how the furnace couldn't keep up with all the cold air leaking past the shrunken weatherstripping?

As we emphasized in last month's **Basic Training**, vacuum leaks are a major contributor to K-Lambda performance and driveability problems. When you track down vacuum leaks, you must be patient and use a systematic procedure.

First, verify that the problem is lean mixture and not some mechanical malfunction. The easiest procedure is to move the air flow sensor plate. On updraft systems, reach under the plate and push up on it. This may require separating the mixture control assembly from its moorings or separating it from the air filter. On downdraft types, simply push down on the plate. You only have to move it a little bit! If the rough idle smooths out, the engine RPM rise slightly, and the hydrocarbon (HC) reading on your infrared analyzer settles down, you know the engine's extremely lean. Extremely lean usually means vacuum leaks.

The duty cycle is also a good indicator of vacuum leaks. The bigger the vacuum leak, the higher the duty cycle reading will be. As you raise engine RPM to 2500, the duty cycle will become almost normal again. At 2500 RPM, vacuum leaks aren't as pronounced as they are at idle. However, a mechanical engine problem, ignition problem, or even a plugged injector is more likely to show up at *both* idle and higher RPM. This tactic is a great way to separate the men from the boys.

As long as you're comparing idle and off-idle symptoms, remember that a leaking cold start valve will screw up the CO reading at idle but not at higher RPM.

Hunting for vacuum leaks with carburetor cleaner spray is not a good idea because it can damage rubber seals. Because carburetor spray is so volatile, it can make it appear that there's a vacuum leak when there isn't. It can also soak right through good gaskets. The best thing to use is a squirt bottle of a much less volatile substance such as parts-washing solvent. Liberally spray this on all suspected seals and gaskets. MANY COMMON SHOP SOLVENTS ARE FLAMMABLE. IF YOU DECIDE TO USE SOLVENT TO DETECT VACUUM LEAKS, BE CAREFUL!

For leaks down where the sun don't shine, propane is very effective. Sometimes you have air leaks in the duct between the air flow sensor and the intake manifold. If you discharge some propane under that duct, it'll find leaks you might otherwise miss. If you have an old propane enrichment tool that you used on those dinosaur domestic carburetors, dust it off and use it to find vacuum leaks.

Whenever you introduce propane or squirt around with solvent, keep an eye on your infrared exhaust analyzer. Exhaust analyzers can take as long as 10-20 seconds to respond to the raw HC in the solvent or propane. You should also hear the idle change long before the infrared responds.

Watch out for small cracks that cause air leaks in the long plastic duct. This duct connects the air flow sensor to the throttle valve assembly.

Vacuum Leak Checklist

Here are some common places where you'll probably have to tackle vacuum leaks:

- **Injector seals and injector holders.** It's a good idea to replace these o-ring seals every 30,000 miles. These seals harden and leak. Those threaded plastic holders are also nasty leakers. Always coat the new seals/holders with anti-seize compound.
- **Intake manifold gaskets.** Intake gasket leaks are a problem on any car. For added insurance, I like to coat the gaskets with a copper gasket compound.
- **Auxiliary air valve hoses.** Give these hoses a tug and a squeeze. Remember that these hoses can also collapse, causing a poor cold idle condition.
- **Air flow sensor boot.** On updraft models, the boot may not seal tightly or may have tiny cracks in it. Remember that if something causes the engine to backfire, the backfire may blow off this boot. Then the engine won't start again. If this happens, don't just reseal the boot. Find out what made the engine backfire in the first place!
- **Cold start valve gasket.** Don't laugh! Someone who was troubleshooting a hard start complaint may have removed the valve to inspect it. But he didn't notice its gasket flutter away into never-never land.
- **Cracked air duct.** This is the long plastic duct that goes from the air flow sensor to the throttle valve.
- **Decel valve hoses.** If the system's equipped with a decel valve, carefully check the valve's hoses for cracks.
- **Disconnected full-load enrichment hose.** On models fitted with a full-load enrichment warm up regulator, the vacuum hose has a nasty habit of coming off down where you can't see it. Fix this one and you'll slay two dragons at once—rough idle and a WOT hesitation!
- **Other leakers.** Other leakers include the dipstick seal, valve cover gaskets, oil filler cap, EGR valve, crank seals, brake booster and hoses, and the vacuum advance unit.

Throttle Valve Adjustment Procedure

It never ceases to amaze me that people wouldn't think about removing the back cover from their $300 color television set and turning an adjustment screw when the picture is off. But they'll pop open the hoods on their $15,000 cars and turn adjustment screws! No problem!

Fortunately, many important adjustment screws are safely sealed away behind tamper-resistant plugs. But the throttle valve offers the do-it-yourselfer (DIYer) an opportunity to really muck things up. Just because he used to adjust the carburetor on his old car in a similar manner, he thinks the throttle stop screw is the proper place to adjust idle speed today.

Why would this fellow want to try adjusting the idle speed? Probably vacuum leaks, that's why! But this DIYer can't figure out why the idle is still too high after he's turned the idle speed screw all the way in. He spies the throttle stop screw, breaks the lock nut loose, and backs out the stop screw. This allows the throttle blade to rest against the housing. Instead of stopping against the screw, the throttle blade now stops against the soft aluminum throttle housing. Now the destruction begins!

After cutting away at the soft aluminum for a while, the throttle blade cuts out enough metal to allow unwanted air to leak past the blade. Now the idle is too high again. The car may be in for a tune-up—but the complaint really is that the idle is too high.

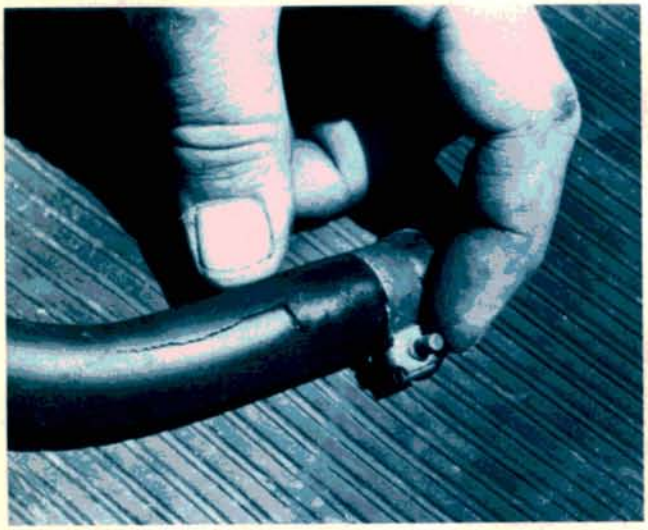
Look for signs of tampering. If the paint seal on the throttle stop screw is broken, the throttle stop must be reset. But first, check for and correct the offending vacuum leaks that started the whole mess in the first place!

Once you have corrected the vacuum leaks, check the throttle valve housing for damage. On some models, you may have to remove the housing in order to inspect it thoroughly. Check for wallowed-out throttle shaft bores, too. If the throttle housing is damaged, you'll have to replace it!

On some models, there's a secondary throttle blade. Be sure this secondary blade isn't sticking open.

Next, check that the bowden throttle cable moves freely. Then loosen the lock nut and back out the throttle stop screw until it no longer touches the throttle lever. Turn the screw back in until it just touches the lever, then turn it in another half turn.

Lock your adjustment with the lock nut. Paint the nut and screw again so the next technician—it could be you—knows the job was done correctly.

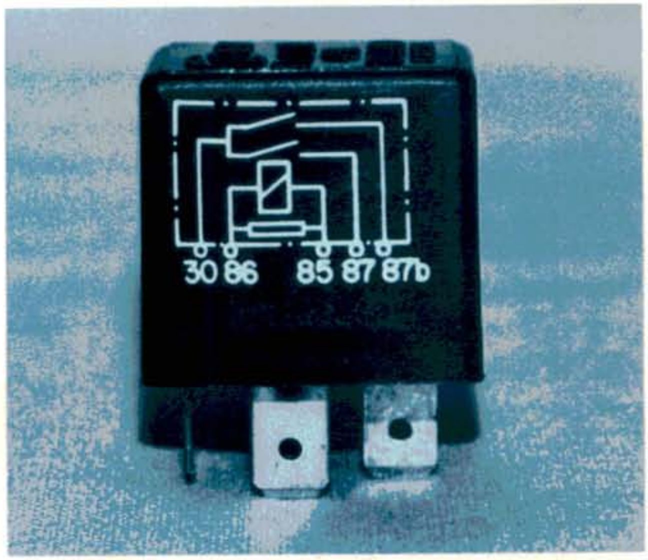


Auxiliary air valve hoses can also crack and cause air leaks. Remember that if an auxiliary air valve hose collapses, the engine will tend to stumble and stall when it's cold.

Quick Lambda Check Out Procedure

To give any Lambda system a quick check-out, follow this procedure:

- Disconnect the oxygen sensor pigtail wire from the system and connect a high-impedance VOM to the oxygen sensor. Ground the negative lead of the VOM. Position the VOM so you can read it easily under the hood.
- Connect a duty cycle meter to the car's test connector or connect a dwell meter to the frequency valve using the Thexton test harness P/N 391 or an equivalent adapter.
- Connect an exhaust analyzer to the test port.
- Start the engine and warm it up.
- Grab the disconnected wire that runs from the oxygen sensor to the ECU with one hand. With the other hand, grab the negative battery post or a good ground point. The readings should go *up* on all three meters. Duty will go up in response to the lean condition signalled through your body to the ECU. CO will go *up* as the ECU richens the mixture to compensate for the lean signal. The VOM connected to the oxygen sensor will read *higher* voltage as the oxygen sensor responds to the richer mixture.



In case you aren't sure which relay you're looking for, this is a typical Lambda relay. Depending upon the make and model, you may find this relay mounted under the hood, under the dash, or inside a kick panel.

Now move your hand from ground to the positive post of the battery (or a suitable system voltage supply point). Your body acts as a big resistor and allows a small voltage to go to the ECU. The meters should all go *down* immmediately.

By moving your hand back and forth between battery positive and ground, you can simulate the signals normally sent by the oxygen sensor. The meters should follow your inputs rapidly as you move your hand back and forth.

If the duty cycle rises but CO doesn't, check the frequency valve. It should buzz. Touch it. It should have constant battery voltage at one terminal and a duty/dwell signal at the other terminal. If not, check the continuity of the frequency valve-to-ECU wiring.

Also, disconnect the frequency valve harness and put your ohmmeter across the frequency valve winding terminals. The windings of the frequency valve coil should measure 2-3 ohms.

Finally, remove the output hose from the frequency valve and check for fuel flow through the valve. Yes, there is a small screen inside the valve that can clog.

When in doubt, cover the fundamentals. Do that and in no time, you'll have those Lambda watchdogs eating out of your hand!

—By Dré Brungardt