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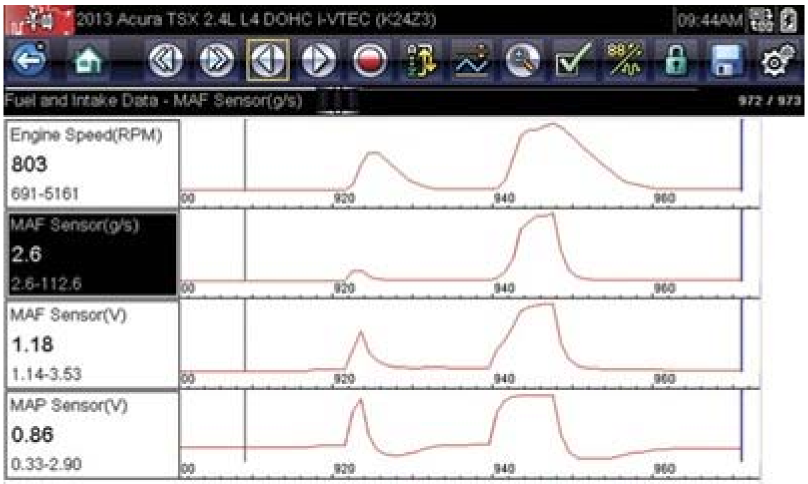
# Failure in Spec: What Happens When a Mass Airflow Sensor Lies




***This Acura engine has both a MAF and a manifold absolute pressure (MAP) sensor. Notice how closely they follow each other. If the MAF sensor stops working completely, the PCM will use the MAP sensor to operate as a speed/density engine management system.***

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Sometimes the hardest part of chasing driveability problems is knowing where to start. It’s tough enough when the trouble codes indicate something vague like “random misfire” or “system too lean,” but it can be even worse when there are no codes at all, with only a driver’s complaint about stalling or sluggish performance. What do you look at first?

Most techs will grab a scan tool right away, but some of us older guys are more likely to start by looking under the hood for something obvious, like a broken wire or severe neglect or (aha!) signs of a recent repair. Once you get snookered by something as simple as a split vacuum hose or a loose ground wire, you’ll start every diagnosis with a quick visual/touch inspection.

OK, there’s nothing obvious, so now it’s time for the scan tool and a test drive. The idle is a bit rough; long-term fuel trim is way negative but short-term is making up for it and the oxygen sensor trace looks normal. There’s a hesitation and not much power off the line, so it certainly feels like it’s not getting enough fuel. After a few minutes at steady cruise, the engine seems smoother but throttle response is still lacking and power is definitely down, especially at wide-open throttle (WOT), almost like the engine has a governor. Both fuel trims are now positive, but the O2 sensor shows a lean air/fuel ratio.

It’s tempting to think these symptoms indicate a vacuum leak or low fuel pressure, but this is an article about mass air flow sensors (MAF), so at this point you already know that’s the problem to be considered. The clue is in the fuel trim numbers and the lack of power at WOT.

Fuel trim is negative at idle, the opposite of what you would see with a vacuum leak, and it changes to positive at higher speed/load but the oxygen sensor readings still indicate it's running lean. That could be caused by low fuel pressure, but the engine continues running smoothly even at WOT. So the question is, if this really is a bad MAF sensor, how can it have such a dramatic affect on fuel delivery and engine performance without setting a code?

Before exploring that question, let's review how a MAF sensor works.

**Description and operation**

Although there are some differences, electronic MAF sensors all work on the same principle. A resistance-calibrated wire is mounted in the engine's intake airflow before the throttle and supplied with a constant voltage. The sensor's electronics control the current flowing through the wire to heat it to a specific temperature. Air flowing past the wire carries away heat, so the current must be increased to maintain its temperature. The amount of current flowing through the wire has a direct correlation to the mass of air flowing past the wire: More current equals higher airflow.

Depending on the sensor design, the signal sent to the powertrain control module (PCM) is either analog or digital, so the sensor is usually called analog or digital.

***This MAF sensor is mounted in the top of the air filter housing. Notice the IAT sensor on the right; it's part of the MAF assembly but it is not used for measuring airflow.***

A typical analog sensor has two elements that measure temperature, a "cold" wire that measures the intake air temperature, and a "hot" wire mounted next to it that is maintained at a specific temperature above the cold wire. Electronics inside the sensor reads both temperatures, controls the level of current flowing through the hot wire and produces a 0 – 5-volt output signal that's proportional to the current applied to the hot wire. The output signal is typically about 0.7 volts at idle and about 4.5 volts at wide-open throttle.

Digital sensors work basically the same way, but instead of reporting the current flow as a voltage signal, the sensor reports the duty cycle of the voltage flowing through the hot wire (that's how current is controlled). On MAF sensors from the 1980s and early 1990s, the duty cycle generally tops out at about 160 Hz, but on more modern sensors the duty cycle is in the kilo-hertz range, generally topping out at about 8,500 kHz.

On many models, the MAF sensor also reports intake air temperature (IAT). On some the PCM simply uses the signal from the "cold" wire for IAT. Other MAF sensors include a separate (non-replaceable) IAT sensor as part of the same assembly. That IAT sensor has its own reference voltage and signal return wires, so these MAF sensors have at least five wires.

***This shows both the "cold" and "hot" wires. Notice the dirt baked onto the hot wire: this one is dirty enough to affect engine performance, but it's easy to clean.***

Regardless of whether the MAF signal is digital or analog, a scan tool will report its reading as "grams per second" (g/s) because that's the data used for fuel control. It might also show the raw voltage or current signal, and you can always back-probe the sensor itself with an oscilloscope if you suspect there's a glitch in the signal. But the generic OBD II data stream will show you how the PCM is using the signal, and that's a clean and easy place to start your driveability diagnosis.

**What goes wrong**

By far the most common MAF failure is caused by accumulation of dirt on the hot wire. Even though the sensor is protected by the air filter (it's often mounted inside the air filter housing), oil mist or fine dust that contacts the hot wire tends to bake onto the wire. This insulates the wire from the air flowing past it so less heat is carried away. The MAF does not report all the air flowing into the engine and the PCM selects the wrong injector pulse width. On some sensors, the hot wire is momentarily heated to about 1,000 degrees when the ignition is turned off to burn it clean.

Performance aftermarket air filters that use oil to trap fine dust particles are a prime source of MAF contamination because people tend to put too much oil on the filter.

Usually with a dirty MAF, long-term fuel trim will be negative at idle and become more positive as rpm (airflow) increases. But we just noted that a dirty MAF under-reports airflow; why is long-term fuel trim negative at idle? Actually, given enough time it might start to increase, but on most models it won't change at idle as long as the short-term trim is able to keep total fuel trim below the code-set criteria (25%).

***This sensor is in the intake duct just above the throttle plate. Cleaning it was easy, but the car came back in just a few months with similar MAF sensor issues.***

So think about what happens when the MAF is under-reporting: As the car cruises down the road, the PCM "sees" less air and calculates a shorter injector pulse width, but the oxygen sensor "sees" a lean air/fuel ratio so the PCM trims the pulse width longer. The engine will cruise smoothly, but when the throttle opens suddenly for acceleration, the sudden inrush of air isn't detected. The result: Fuel delivery doesn't increase as much as it should for acceleration and the engine hesitates or stumbles.

At wide open throttle, the fuel system goes into open-loop to provide maximum power. With a dirty MAF, the engine will run lean because of the under-reported airflow. Fuel trim will become more extremely positive but no code will set because of the (programmed) open-loop condition. Still, the engine will run so lean that it might not accelerate beyond a certain rpm, and this often leads to random misfire.

Dirt accumulates on the MAF gradually, and the PCM is able to compensate well enough to avoid setting codes for thousands of miles. Some drivers may never notice the loss of engine performance, but those who do notice might come to your shop asking for a "tune-up." That's another clue that the mass air flow sensor has failed in-spec, meaning it's not functioning correctly but the malfunction is not bad enough to set a fault code.

### Testing

A faulty MAF will have the same effect on both banks of a two-bank engine. If a fault code or some other symptom shows up only on one bank, the MAF is probably OK.

A dirty MAF can be diagnosed quickly and accurately with a scan tool running in generic OBD II mode. Set the tool to graph rpm, both long- and short-term fuel trims and the oxygen sensor or air/fuel ratio sensor. The fuel trims will show you if the PCM is compensating for inaccurate airflow measurement, and the oxygen sensor readings show you if that compensation is successful.

Watch how the short- and long-term fuel trims change during a test drive. If the PCM is subtracting fuel at idle but adding fuel as rpm climbs, that's a typical sign of a dirty MAF. During a steady cruise, expect the O2 sensor to cycle normally if there are no lean codes. During a full-throttle acceleration, the O2 sensor would normally indicate rich A/F ratio, but it won't if the MAF is dirty.

***Many older-style MAF sensors have a screen in front, not so much for protection but to***

***straighten the flow of air through the housing. If this screen is damaged, the MAF sensor will tend to over-report airflow. Engine performance will actually improve but the driver will probably notice higher fuel consumption.***

Of course, the most accurate diagnostic technique is to read the actual airflow on the scan tool and compare it to a known-good value. The problem is, few auto manufacturers provide airflow specifications in their service/diagnostic information. A volumetric efficiency (VE) calculator will tell you what the airflow should be for any engine at any rpm. There are a several easy-to-use VE calculators on the Web and even a few smartphone apps, but be careful with the results, since a low VE could be caused by a dirty MAF or by mechanical problems in the engine (low compression, etc).

There is also a rule-of-thumb VE that says airflow at idle should be roughly equal to the engine's displacement. That means a four-liter engine should inhale roughly 3.7 to 4.3 grams of air per second at idle. A reading that's significantly different is not enough to condemn a MAF, but at least it will tell you if you're on the right diagnostic path.

Probably the easiest diagnostic technique is to unplug the MAF and then start the engine. It doesn't work on all engines, but on many models the PCM will substitute airflow data if the MAF fails completely, and the scan tool might actually display those numbers so you can compare them to live data. This is a good way to test the MAF on older models if the malfunction indicator light (MIL) is illuminated and lean codes are set (P0171 and P0174). Of course, this test will also set some codes, but if the engine starts easier and/or runs better, you'll know for sure something is wrong with the MAF sensor.

Always to turn the ignition switch off before connecting or disconnecting any sensor to avoid the possibility of sending a voltage spike to the PCM.

***Thanks to proper engine maintenance, the original mass airflow sensor on this Chevy van is still working perfectly after running 20 years and 140,000 miles***

### Cleaning vs. replacement

Most OEM service information will tell you a MAF cannot be cleaned. Sometimes this is true because the hot and cold wires (which look like tiny resistors) simply cannot be accessed. On some models, cleaning the sensor is only a temporary fix because the contamination is a result of potting material leaking out of the sensor assembly itself. But the best reason to replace a dirty MAF sensor rather than trying to clean it is to avoid a come-back.

Even if you plan to replace the part, cleaning a MAF sensor is a good way to confirm your diagnosis before spending the customer's money. If the MAF is dirty enough the cause the driveability problem, even partial cleaning will restore some of the engine's performance.

There are special chemicals available for cleaning a MAF sensor, but many techs are comfortable using any spray cleaner that dries quickly and doesn't leave a residue. Simply spray it on and let the chemical and dissolved dirt drip away from the sensor. The job requires a gentle touch and practiced technique to avoid damaging the fragile wires. Do not use compressed air, and do not install the sensor until it is completely dry.

The best part about cleaning or replacing a MAF sensor is the immediate and sometimes dramatic improvement in engine performance.

The engine will run better, and that will help your customer feel better about the cost of the repair. And, of course, knowing you fixed it always feels good, even if sometimes it really is this easy. ●

**Why is it called 'mass' airflow sensor?**

It's called a "mass" airflow sensor because the PCM needs to know the density of the air flowing into the engine, not just the volume. A liter of air at 90 degrees is less dense (the molecules are farther apart) than it would be at 40 degrees, so there is less oxygen in that liter of hot air.

This hot-wire measuring technique automatically accounts for variations in temperature and humidity that affect the air's density.

How much does that variation matter? On racing engines that use carburetors, the crew chief chooses the main jets after hearing the race-day weather forecast. A cool, moist day means the air is "fat" with oxygen, so bigger jets can be used.

Ever notice how a fuel-injected engine seems to make a bit more power and uses a little more gas in cold weather?