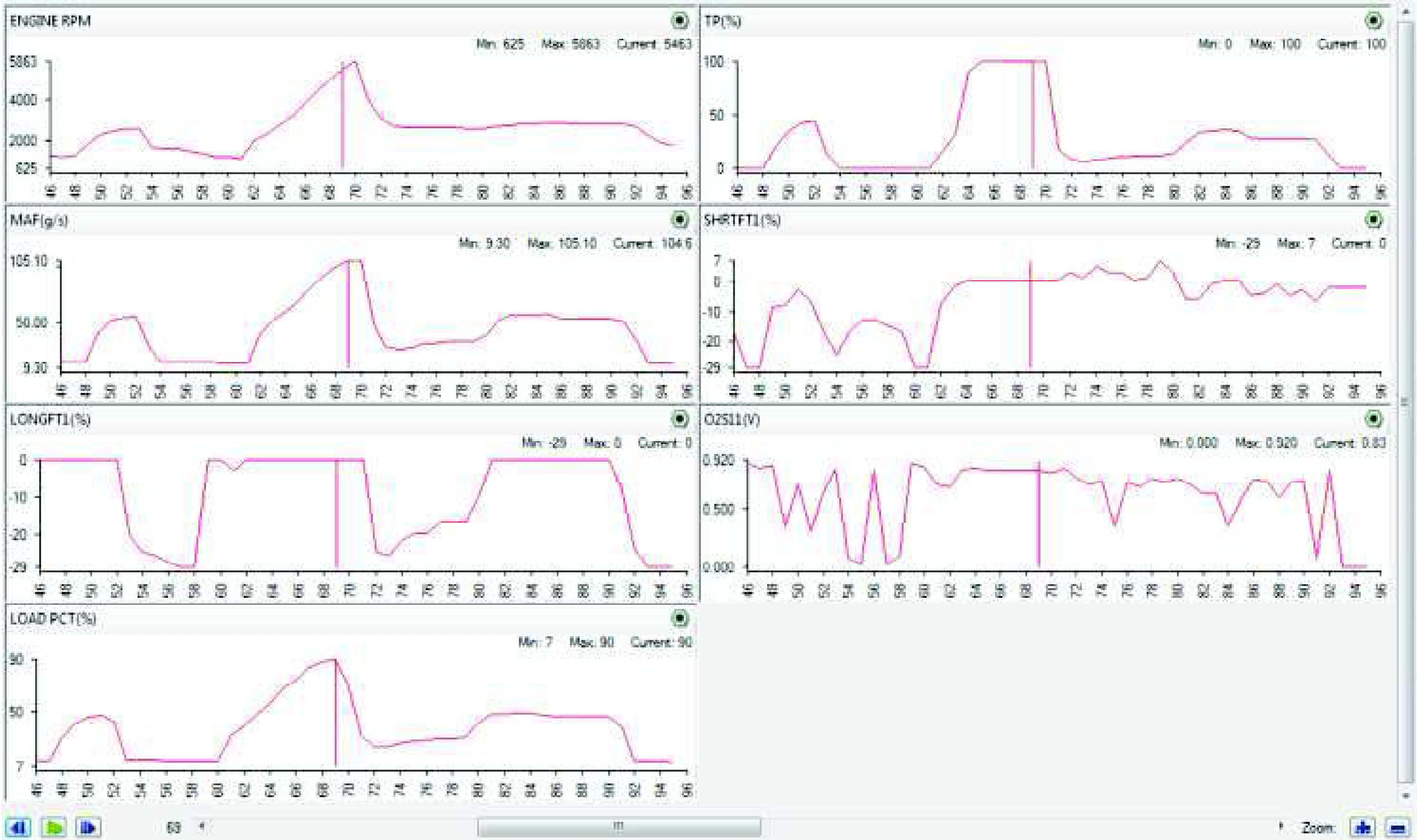
There are only six distinct Parameter Identifiers (PIDs) that will be used (though you may have more than one of each depending on engine design). These PIDs are engine rpm, throttle position, calculated engine load, loop status, short-term trim for both banks, long-term trim from both banks and the oxygen sensor voltage for all oxygen sensors. Set your scan tool to record only these PIDs. On most scan tools that will keep the data rate up faster and make the data graphs more useable.

When using this diagnostic system, think about the cause and effect of the data. You move the throttle (cause) you expect the engine RPM to increase (effect). With the throttle wide open, (cause) you expect to see the oxygen sensors show a rich condition (effect) and the calculated load PID to increase (effect). Watching this data and how the different PIDs relate to one another and how the data trends is an easy and accurate way to get a direction on the problem at hand.



To get a good feel of how this data works, take some test drives on known good cars, using the same test drive route. Capture the data and save it. You'll have a reference library of known good information. With this great resource, you will not only have some great study material, you'll also have a place to go when you need some known good data. You'll learn that different makes and models of vehicles react differently, you'll see how the calculated loads react and how the long term and short term react to a wide open throttle.

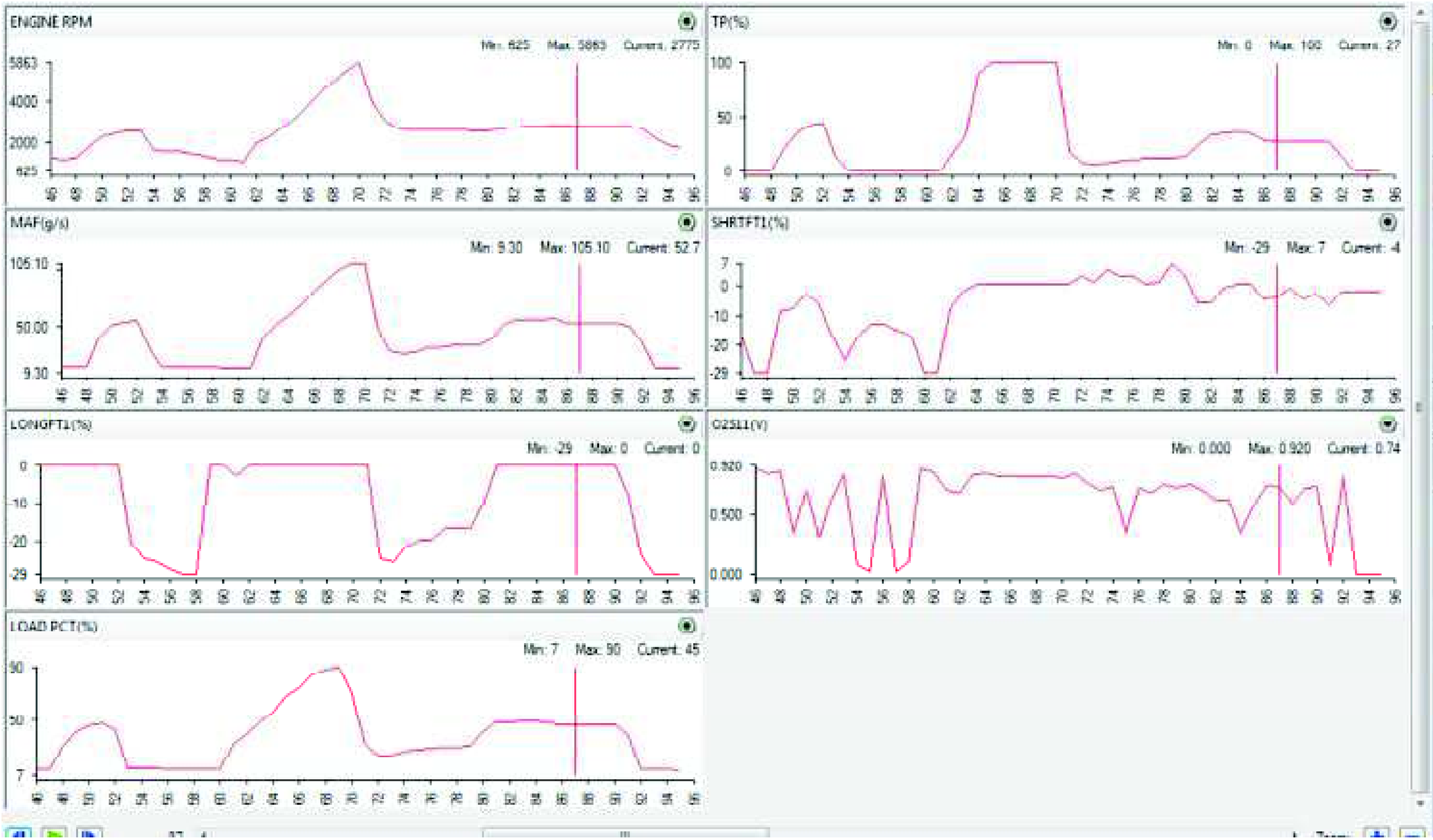
The test drive should start with the engine at idle; accelerate at wide open throttle to a speed of 60 mph if possible. You will need to go through at least one full throttle shift to see how things work at full engine speed, then steady cruise for a minute or so. With this data, you will be able to analyze the operation of the MAF, verify proper fuel supply to the injectors, test the operation of the oxygen sensors, check for proper air flow through both engine banks (dual bank engine) and check for any misfires. Isn't that a lot of great information to be gathered in such a short time?

Applying What You Learn

Using scan data allows you to test the fuel/air management system in its own working conditions while watching how the different parts of the system react with each other. When setting a vehicle up for a test, make sure that all electrical accessories are turned off since we will want to see the engine at idle with no loads. If the vehicle has daytime running lights, turn them off if possible.

Let's apply what we know so far to a 1999 Subaru Forester with a 2.5 engine, automatic transmission and 128,649 miles on the odometer. The customer complained that when setting at a stoplight, the engine would surge as if the gas pedal had been quickly pushed and released.

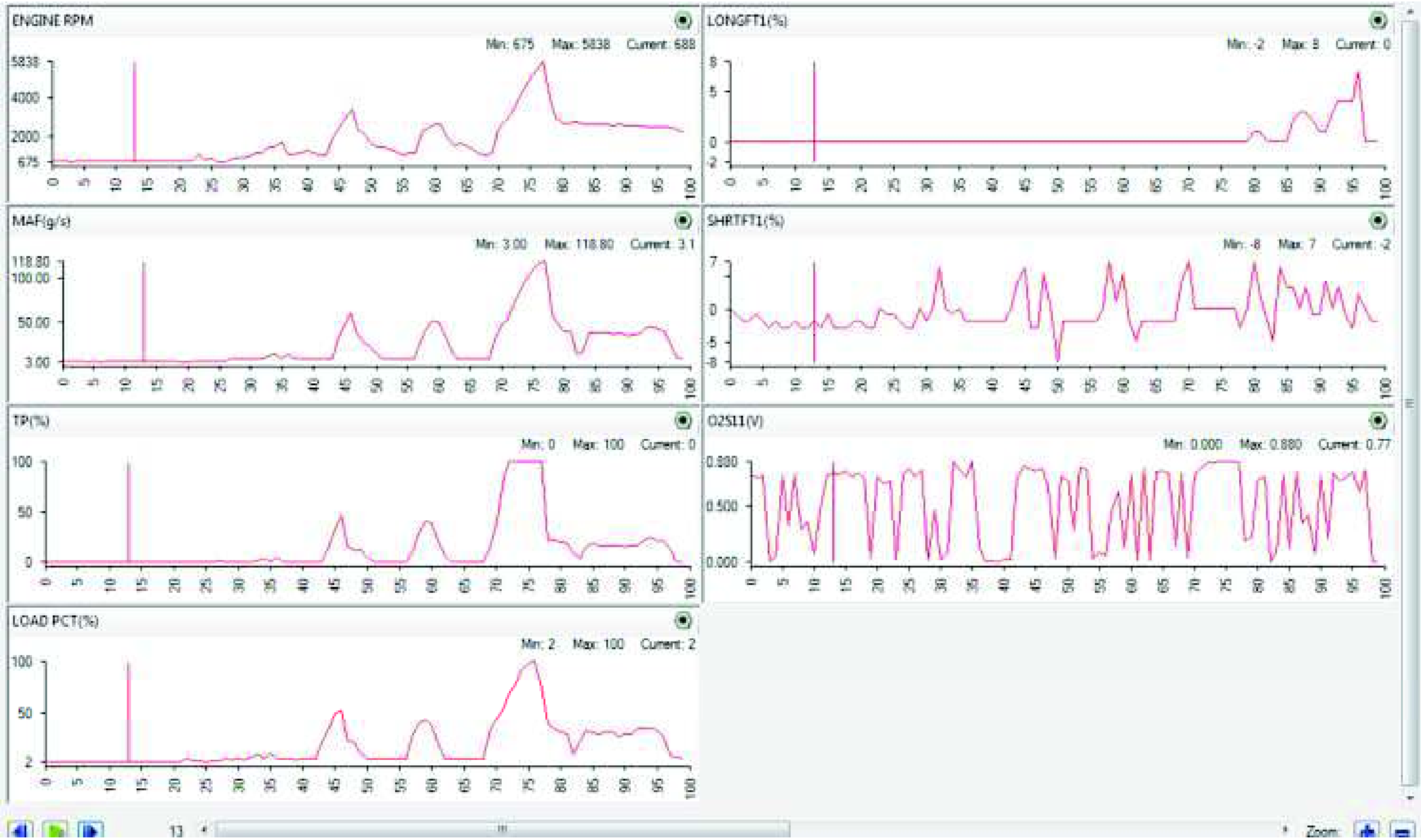
The check engine light is not on, and there are no codes stored in memory. The Subaru vehicles of this era used both the MAF method and the speed density method for fuel management. A visual inspection of the engine found this particular vehicle had a MAF sensor bolted to the air filter box.



The PIDs selected for this test are engine rpm, throttle position, calculated engine load, front oxygen sensor, mass air flow and long-term and short-term fuel trim. The engine was idled for a few minutes, then the vehicle was backed out of the shop. While backing out of the shop, the engine surged like I had tapped the gas pedal hard and fast. I first thought the ECM had commanded the Idle Air Control (IAC) open. As I drove out of the parking lot, the engine surge happened again. The scan tool was capturing data, so I continued on my test drive.

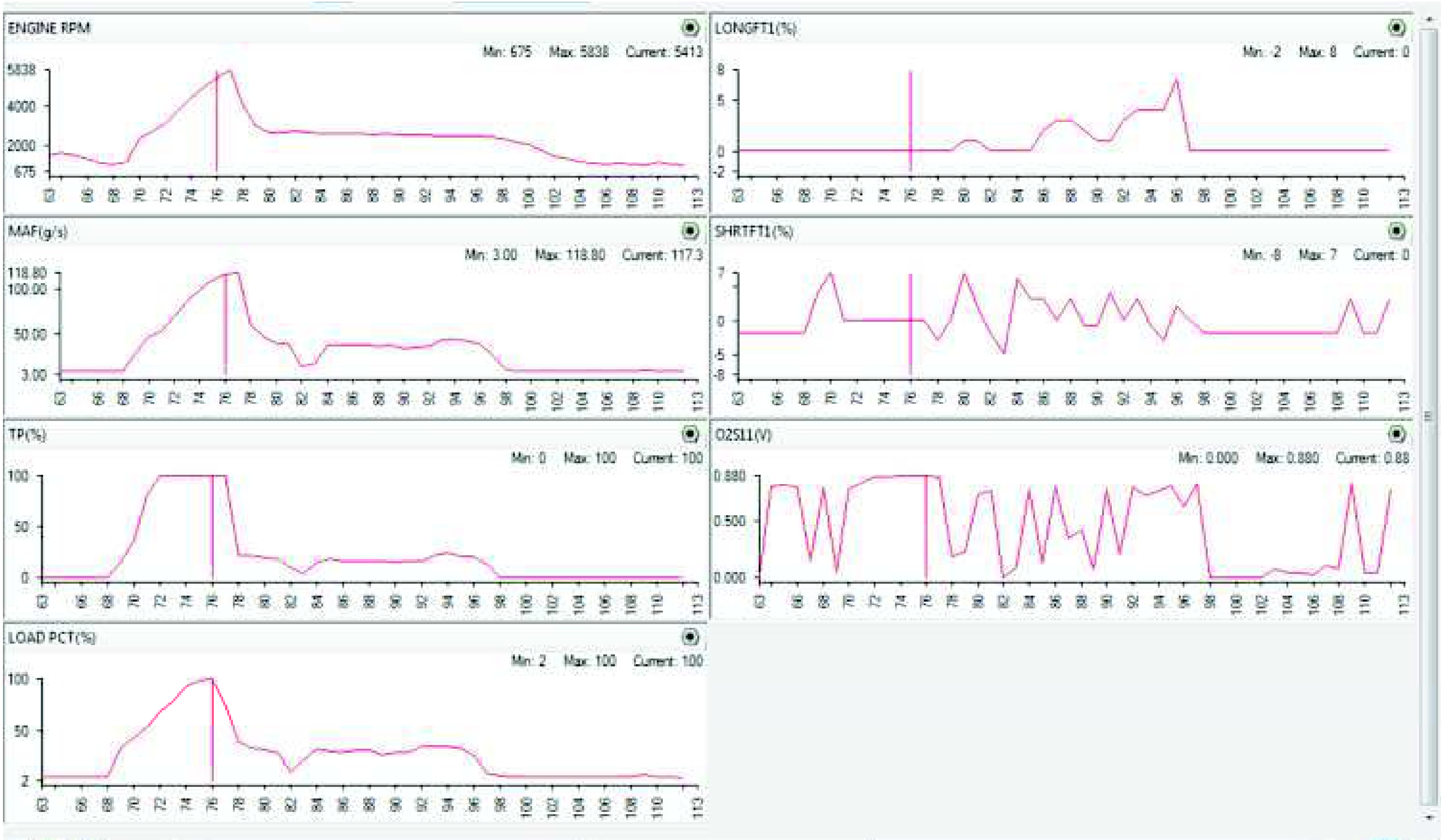
My test route takes me about a quarter of a mile before I am on a four-lane highway where I can make a full throttle acceleration up to 60 mph. This is done to be able to test the volumetric efficiency of the engine and to test for proper fuel supply to the fuel injectors. The test drive continues up a 4 percent grade then across one-quarter mile of flat road. With these different driving conditions, the engine can be put in several different power and load conditions while capturing the data.

On the test drive, I noticed the engine was short on power and would surge lightly if the throttle was held steady. Back at the shop, we can use this data to analyze the airflow and fuel systems of this engine. Starting at the left side of the data graphs I noticed the engine is idling at 1,000 rpm. This is a little higher than normal, and it is a clue to our problem. The MAF data looks a little higher than it should be. A rule of thumb on a MAF's air flow rate at 500 rpm is 1 gram per second per liter of engine displacement. This engine is idling at 1,000 rpm and the MAF data is showing 12.5 grams per second. Consider this to be another clue to our problem.



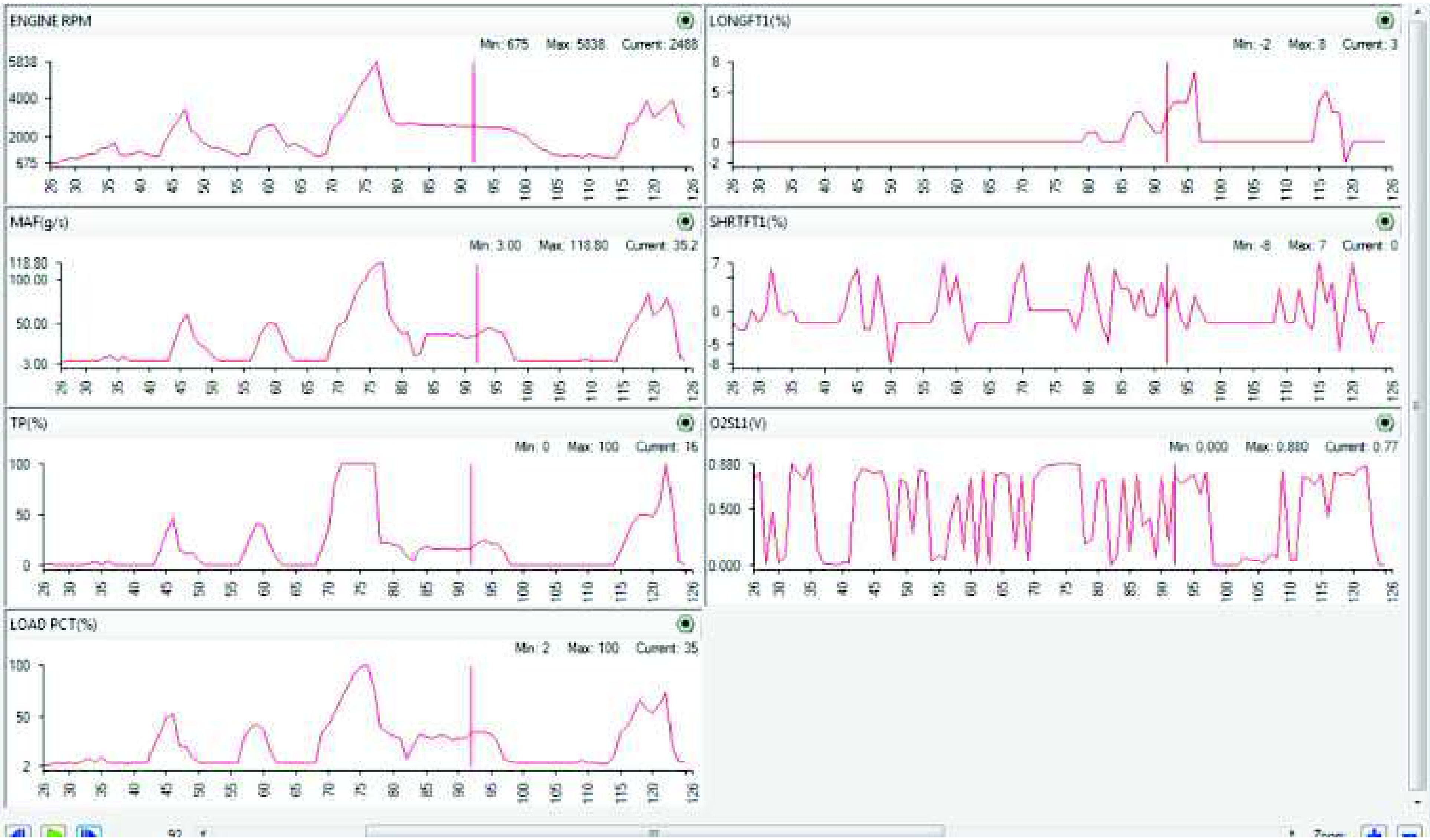
Moving on, I see the oxygen sensor voltage at 900 millivolts (0.900 volts) and both the long term and short term fuel trims at zero percent correction. At this point, I have made one mistake: I have not included the loop PID in my scan data so I do not know if the engine is idling in open loop or not. I can only guess it is running in open loop at idle. I also notice that the engine speed momentarily has increased, the MAF data has increased and the engine load has shown a slight increase, but the throttle has not been opened. This is a third clue to the problem.

As the throttle is opened, the engine speed increases and the engine load increases, while the long-term fuel trim has taken a big dive. As the throttle is moved and the engine load changes, the long-term fuel trim will jump from zero to a -24 percent. The short-term fuel trim, though, is moving up and down as the throttle is moved. When the engine was at full throttle, the oxygen sensor was pegged high at 900 millivolts (0.900 volts), but the oxygen sensor voltage does not move up and down smoothly between 200 and 800 millivolts (0.200 and 0.800 volts) with the vehicle at cruise. Is this oxygen sensor getting lazy? This is the fourth clue to the problem. Looking the engine load data over, I noticed that it peaked out at 90 percent load. Consider this as the fifth clue.



Now it is time to put all of the clues together and settle this mystery. Let's start with the data at idle when the engine speed flared slightly. This was caused by the MAF misreporting airflow that triggered the ECM to momentarily give the fuel injectors an extra pulse or two of fuel. The MAF was actually over-reporting the air entering the engine. The ECM commanded the fuel injectors to inject the correct amount of fuel for the air the MAF was reporting, yet the reported air was more than what really entered the engine. That caused too much fuel for the actual amount of air and resulted in the 900 millivolt (0.900 volts) at the oxygen sensor.

If you study the long term and short-term fuel trims, you will notice that most times, the total fuel trim is -29 percent. Sometimes this is shown in long term and sometimes it is in short term.



Pay close attention to the way the fuel trim graphs trend from low to high. I call this trend “digital,” because the movement from -29 percent to zero percent is almost vertical, and the short term is also following the throttle movement. Here is a case where the information found in the trend of the fuel trims is of great value.

The last PID to examine is the load PID. The scan tool has recorded 90 percent engine load. This load PID is calculated from the MAF data and is a very good indication of the volumetric efficiency of the engine. Here is yet another clue to the mystery. It has been my experience that a known good Subaru load PID will display 100 percent at WOT and a shift point. Ninety percent is a good number for many vehicles, but not for this one.

Solving the Problem

We installed a new MAF sensor, reset the keep-alive memory and cleared the computer of any codes that might have been set during the diagnostic process. We test drove the vehicle a few miles to allow the fuel trim memory to relearn, and then hooked up the scan tool to record the after the repair test data.

The engine idle speed is now 675 rpm with 3 grams per second of air flow. This is the expected data. The engine speed flare is gone as the vehicle is backed out of the shop, and the slight engine speed fluctuation is gone at a steady cruise. The long-term and short-term fuel trims trend nice and smooth between -2 and 8 long term and -8 and 7 short term. The oxygen sensor has gone back to swinging smoothly between 200 and 800 millivolts (0.200 and 0.800 volts) and the calculated engine load PID went to 100 percent at the WOT shift point. Examining the oxygen sensor data shows that on the WOT run, the voltage was pegged above 900 MV, which tells me that there is a good fuel supply to the fuel injectors.

Fuel trim data graphs hold a wealth of information about what is happening with air measurement, fuel supply, engine breathing, cam timing and even misfire problems. The data is quick and easy to get and over the years I have found it is a quick, easy and accurate way to get a direction on engine drivability problems. It also can be used as a great tool to sell service. So start graphing fuel trim data on every car you service, and you too will soon be using it to fix those stubborn drivability problems.