HAND-HELD TESTER STRATEGIES

There are some marvelous hand-held testers out there. Deciding which one to use depends on the type of test you have to perform, the type of information you seek and which particular meter works best in a given situation.

By Jorge Menchu

Bottle rocket to Space Shuttle, test light to DSO. In technology, things never do stay the same. The automobile and the tools we use are certainly no exceptions. While this might seem like a drawback at first, in fact, it's a blessing, because it opens the door of opportunity for the motivated and technically minded.

One of the keys to success in this business is being able to identify what we know and what we need to know. One discipline often overlooked is the understanding of the tools we use for diagnosis. The chart in Fig. 1 on page 24 shows the relationship these tools have to the other disciplines of automotive repair. Basically, it says that technology is the foundation of an automotive system, the strategy operates the system and the tools allow us to see into this technology and strategy. Our ability to perform a professional diagnosis depends on our understanding of these elements individually and as a whole.

The ideal starting place is to focus on the strategy. But if we don't consider the other elements, we eventually stall because our strength is limited by our weakness. For example, if we fail to understand what our test equipment offers, then how can we validate or rely on the data it gathers?

This article will look at an evolution in electronic test equipment, starting with the basic test light and ending with the latest in lab scope technology. This evolution is based on the features the equipment offers as opposed to when the equipment was introduced. The goal is to point out the characteristics we need to be aware of when we gather data.

The Test Light

When I started as a technician, one of my first diagnostic tools was a simple test light. A test light is just what the name implies—a light that tests for current flow. One characteristic that governs the use of a test light is the format in which it offers information—the light is either bright, dim or off. Another characteristic, often referred to as the *loading effect,* is its low input impedance. The term *impedance* as defined in an electronics dictionary is "the total opposition offered by a circuit or device to the flow of alternating current." For our purposes, we can substitute the word *resistance* for *impedance,* resulting in a definition of "the opposition to the flow of current." Most test lights have low resistance, meaning they allow what could be considered a lot of current to flow, especially in the case of delicate electronic circuits.

The word *delicate* refers to a circuit's ability to supply current to a load (such as a test light) without affecting its voltage. What would you expect to happen if we connected a test light to

Illustrations: Jorge Menchu

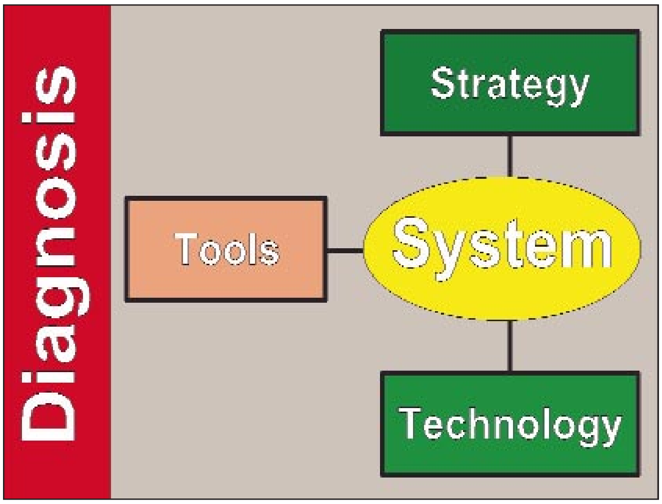

Fig. 1

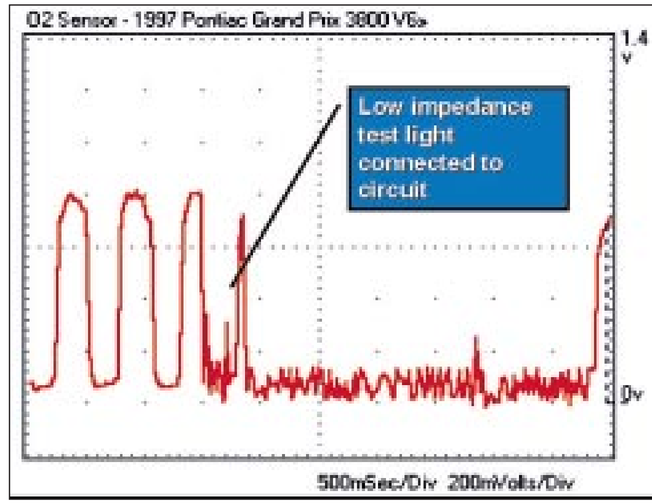

Fig. 2

an oxygen sensor? The O_2 sensor circuit works with low voltages and certainly small amounts of current, right? Because it can't supply enough current to turn on the light, it instead acts as a path to ground, resulting in a shorting of the circuit (Fig. 2).

Because of this low-impedance characteristic, test light usage should be limited to those circuits that draw lots of current, such as headlight and taillight circuits, system power and ground circuits, etc.

The Digital Multimeter

The next step up the test equipment evolutionary ladder is the digital multimeter (DMM). Most DMMs are high-impedance devices that have a 10-megohm rating. Using a high-impedance meter allows us to connect to delicate circuits without "loading" the circuit, which can result in an unwanted change in the signal.

The multiple measurement features of a DMM also take us to the next level in information gathering. We can now read the pulse width of an injector or the duty cycle of a feedback carb solenoid, things a common test light can't do.

Another strength of the DMM is the format of the display, which is easy to read and understand. But it's important that it not update too fast. If it did, the numbers would become an unreadable blur. Most DMM screens, therefore, update one to four times per second. This can be somewhat limiting, especially when you're trying to measure faster signals. Some DMMs have analog bar graphs to help overcome the limitations of a slow screen update.

Another interesting fact of DMMs is the way the meter arrives at the value that's displayed; it averages the signal. In the case of the Fluke 88, for example, the signal is continuously measured up to 40 times per second. The display, on the other hand, updates from one to four times per second, depending on the type of measurement. The value used for the display, therefore, is an averaged value, as opposed to one from an individual measurement.

In many test situations, this is not a concern, but when considering high-speed circuits and intermittent glitches, it can be. For example, Fig. 3 shows a

Fig. 3

screen capture from a Fluke 97 in DMM mode. The signal it's reading is the digital output from a Snap-on signal generator board. The output was set to 147 Hz with the intermittent glitch feature turned on, which causes two consecutive cycles to drop out every two seconds. In this case (DMM mode), notice how the meter was not capable of detecting the glitch. Considering that fewer than a third of the cycles are being analyzed, this is not surprising. And even if the problem were measured it would probably be lost in the averaging.

To counteract this, some DMMs offer a Min/Max feature. Min/Max recording is a very powerful feature that stores the highest and lowest measured values in memory. There are many situations where Min/Max is ideal, such as when you wish to determine the operational range of a signal or when testing a steady signal such as a power or ground where you suspect a glitch. Unfortunately for many meters, the values stored in the Min/Max memory buffers are based on the averaged value used for the regular display. An exception is the Fluke 87, which offers a 1mS Peak Hold feature.

Another characteristic is what I call the *Min/Max window,* which is defined by the actual Min/Max values. Any change that takes place in a signal that falls in between these values is ignored by the Min/Max. For example, if you're reading the frequency of a crank position sensor from idle to cruise, the Min will reflect the frequency at idle and the Max the frequency at highest rpm the engine reached. If a glitch occurs at cruise speed and is measured at a value higher than that recorded at idle and lower than that recorded at the highest speed of the engine, it will be ignored.

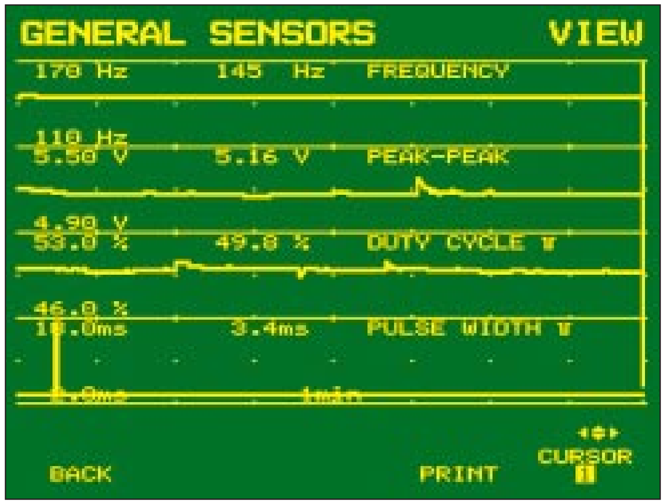

Fig. 4

The Graphing Multimeter

The next step up in the evolution of hand-held test gear is the graphing multimeter (GMM). The graphing meter operates on the same principles as a DMM and has the same limitations; about the only difference lies in the display. The GMM display charts out the measured values on a two-dimensional graph, where the changes from left to right represent time and the changes top to bottom the actual measurement values. The chart offers the history and trends of a signal. Fig. 4 is a screen capture from the Fluke 98 Series II in the Plot Readings (GMM) mode. While this screen offers much information by displaying multiple parameters of an input signal, it's not really adept at capturing that fast or seldom-occurring glitch.

The Power Graphing Meter

The power graphing meter (PGM) is next up the evolutionary ladder. The first PGM offered for automotive applications was the Snap-on Vantage, with other meters now also offering PGM features. The PGM is a much-needed bridge between the DSO and DMM.

The power graphing meter overcomes the limitations of the digital multimeter and the graphing multimeter. To display information, it uses a chart similar to a GMM. What sets it apart is the way it arrives at the values used for display, which are not "averaged." Here's how it works: First, the PGM measures a signal very rapidly. (In the case of the Vantage, it analyzes every cycle of a repetitive signal up to 20 kHz.) The measured values are then stored into memory, representing the minimum, maximum, average and now (current) values. When it's time to plot the next value to the chart on the display (don't mix this up with screen refresh), the most significant is selected from the min, max, and now memory registers. At this point, the registers are reset and the process is repeated. Since the Min/Max is reset every time a plot is made, this minimizes the Min/Max window effect. The result is a meter that is extremely accurate for glitch detection on repetitive signals.

The screen in Fig. 5 was captured with the Snap-on Vantage hooked up to a signal generator board with the glitch feature enabled, as in the previous example. Notice how the Vantage captures the signal dropout every time!

So have we found the ultimate diagnostic tool? We're getting closer, but there are still characteristics we need to be aware of. For example, when testing repetitive signals, there is what I call a *reaction window*—the minimum values a signal has to maintain to be measured. This holds true for all meters discussed so far. When these meters are used to measure frequency, duty cycle, pulse width, etc., they actually react to the signal in a similar way the PCM reacts to the crankshaft position sensor.

Figs. 6 and 7 are two examples from the Fluke 97 set in DMM mode. In this mode, the meter also displays a waveform. The expected signal should

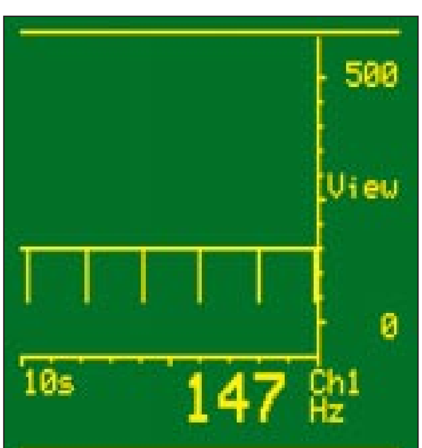

Fig. 5

Fig. 6

Fig. 7

have a peak voltage of 5 volts, as shown on the left. At right, a load was added to the signal, bringing the peak voltage down to 2.4 volts. Note that the frequency is basically the same! It was not until the voltage reading went below 2.4 volts that the frequency reading became unreliable. So in this case, the reaction window is from 2.4 to 5 volts. Be forewarned, the reaction window (or trigger point) the signal has to reach can vary among test instruments, and even test functions.

At this point we still don't have an instrument capable of showing a true *picture* of the signal—there's still some uncertainty as to whether the signal is working as the design engineer intended. We could try to develop a picture by reading multiple parameters of the signal such as voltage, duty cycle and frequency, or we can simply go to the next step.

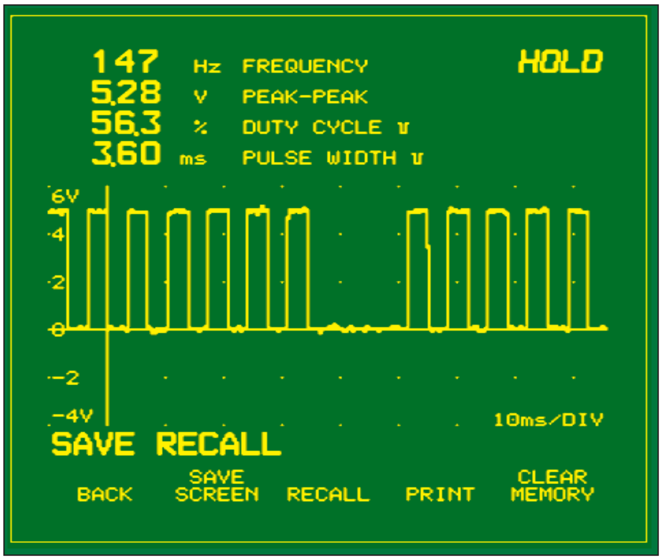

Fig. 8

The Digital Storage Oscilloscope

The digital storage oscilloscope's main role is to take a picture of the electrical voltage in a circuit, resulting in a two-dimensional graph called a waveform. As with the GMM and PGM, the DSO's horizontal axis represents time, but in this case, the vertical always represents voltage levels.

The DSO is a voltmeter and performs voltage measurements similar to the other meters mentioned so far. The difference is the amount of control the user has over the acquisition of the waveform and the speed at which the DSO can sample the signal. For example, the user has control over the voltage and time resolution of the display and the trigger settings used to initiate the waveform capture and display. This type of control is extremely helpful when there's a need to analyze complex signals or to view into extreme detail. Some scopes offer up to four channels, which makes them indispensable for analyzing the relationships of many signals.

Fig. 8 is a good example of the detail a waveform offers. This signal is from the Snap-on signal generator board that was used to capture the screens in Figs. 3 and 5. In this case, we can actually *see* the dropout of the signal that the DMM, GMM or PGM could only indicate, at best. It's interesting to note that if this were an actual repair, the DMM, GMM and PGM would offer only enough information to determine that there *is* a problem, and any repairs based on that information without further testing would be based on experience.

From Figs. 3 and 5 there is no way to tell if the signal dropped high or low or did something else. With a waveform, we can see it and take our analysis to the next step. For example, if this were a typical three-wire Hall sensor and the signal went high instead of low, I would know, based on the way Hall sensor circuits are configured, that the circuit was good from my test point all the way to the pull-up resistor inside the PCM. Since this was not the case and the dropout did go low, the circuit from my test point to the PCM, including the pull-up resistor, is suspect and added to the "possibilities" list.

This all sounds very powerful and it is, but again, there are drawbacks. To take advantage of the true power of a lab scope, you have to learn how to control it and have a decent understanding of electricity. I'm not looking to scare anyone away from DSOs, because, fact is, you don't have to be an expert to use one. Many DSOs offer automated setups to get you started and waveform libraries to give you a starting point or at least let you work

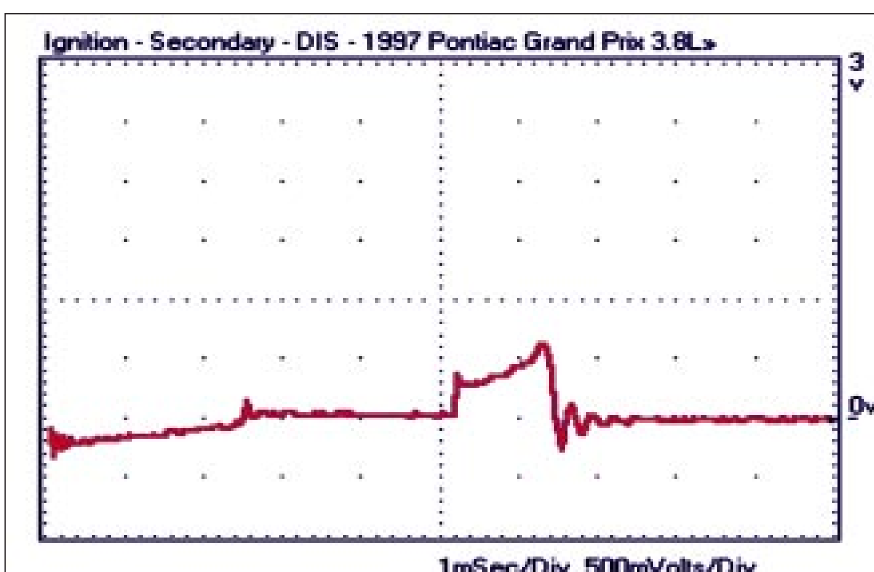

Fig. 9

Fig. 10

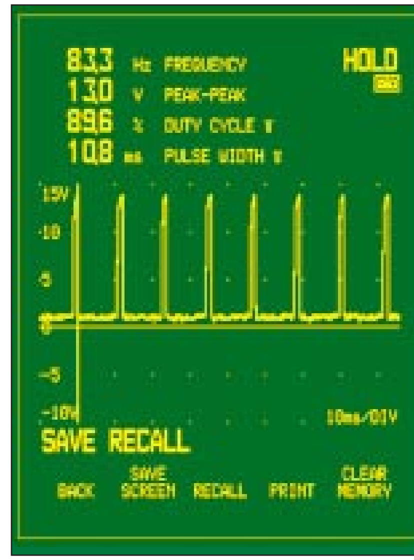

Fig. 11

in a "go/no-go" mode. But regardless of your ability, there are aspects that you need to be aware of.

I've already stated that the DSO offers a voltage picture of electrical signals. The major concerns are how often the picture is taken and displayed (screen update), and in what detail each picture is presented.

Most DSOs update the display two to seven times per second. This means that any event that takes place between the updates is completely missed! In Fig. 8, there are about 14 cycles of the signal on display (including the two dropped cycles). Multiply this by a screen update of four times per second and the scope is displaying 56 cycles every second. Problem is, this signal is occurring at 147 cycles a second. So at this rate, the DSO is displaying fewer than half of the cycles that occur, opening the door for your missing important data.

The next concern is the detail of each picture. Most DSOs use an LCD display. These are similar to a grid of lights, called *pixels.* To fill the display, the DSO will have to sample a signal at least once for every column of pixels. Now what would you expect to happen when a signal event such as a spike occurs in between the samples? Right, it will be completely missed! Fig. 9 shows a good secondary ignition pattern that's missing the inductive kick. We know it must be there because the rest of the signal is good. In this case, the spike occurred—the scope simply missed it.

Many DSOs offer special features to overcome these limitations. In the case of the missed spike, some scopes have a Min/Max feature, sometimes referred to as *glitch detect.* With glitch detect, the highest and lowest signal values are stored in memory. When it's time to plot to the display, the DSO uses these Min/Max values. Then every time a new plot is made, the Min/Max is reset and the process repeats itself. Instead of sampling the signal once for every column of pixels, the DSO samples it at a very high rate—in the case of the Fluke 97, for example, 25 million times per second.

To overcome the slow screen update rate, some DSOs offer the ability to continuously record the signal in memory for playback. In the case of the Fluke 98, 128 screens worth of data can be recorded in memory in which no data is missed. But this feature is good only with a time base setting of 20mS or slower.

The Power Graphing Scope

The next logical step in the evolution of hand-held test equipment—and the latest addition to our tool arsenal—is the power graphing scope (PGS). OTC and Mac Tools have both introduced a new meter (called Perception by OTC and ET2025 by Mac) that promises to combine the benefits of both the PGM and DSO by using the analysis power of the PGM to determine when to take a picture of the signal. In other words, the signal is constantly analyzed for changes that could signify a glitch. When this occurs, it triggers the meter into taking a picture of the signal at that very moment for immediate analysis.

In a Nutshell

Fortunately, most automotive problems are repetitive enough that most meters will easily capture a problem. But this report isn't about those situations; it's about seldom-occurring glitches and the tools needed to nail them. Considering this, then, there is no question about the value of the digital storage oscilloscope and power graphing meter.

What many techs have found is that tools like the PGM are going to be ideal for finding circuits whose signals indicate that a problem occurred. The lab scope will be used when there's a need to truly analyze that signal, and to prove it's working as the engineers intended. Figs. 10 and 11 clearly show this difference. In Fig. 10, we see a PGM chart of a timing control pulse as the engine is revved. It looks fine and the engine is running smoothly, but it doesn't offer much detail about the actual activity of the circuit. Fig. 11 is the same signal captured using a DSO. Notice that the signal does not reach ground! A developing problem? Perhaps.

I hope this article makes you aware of the importance of understanding the equipment you use. Since technology is not going to slow down, we can't, either! I encourage you to look on the increasing complexity we're faced with as a challenge that motivates you. After all, motivation *does* open the door to opportunity. M

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