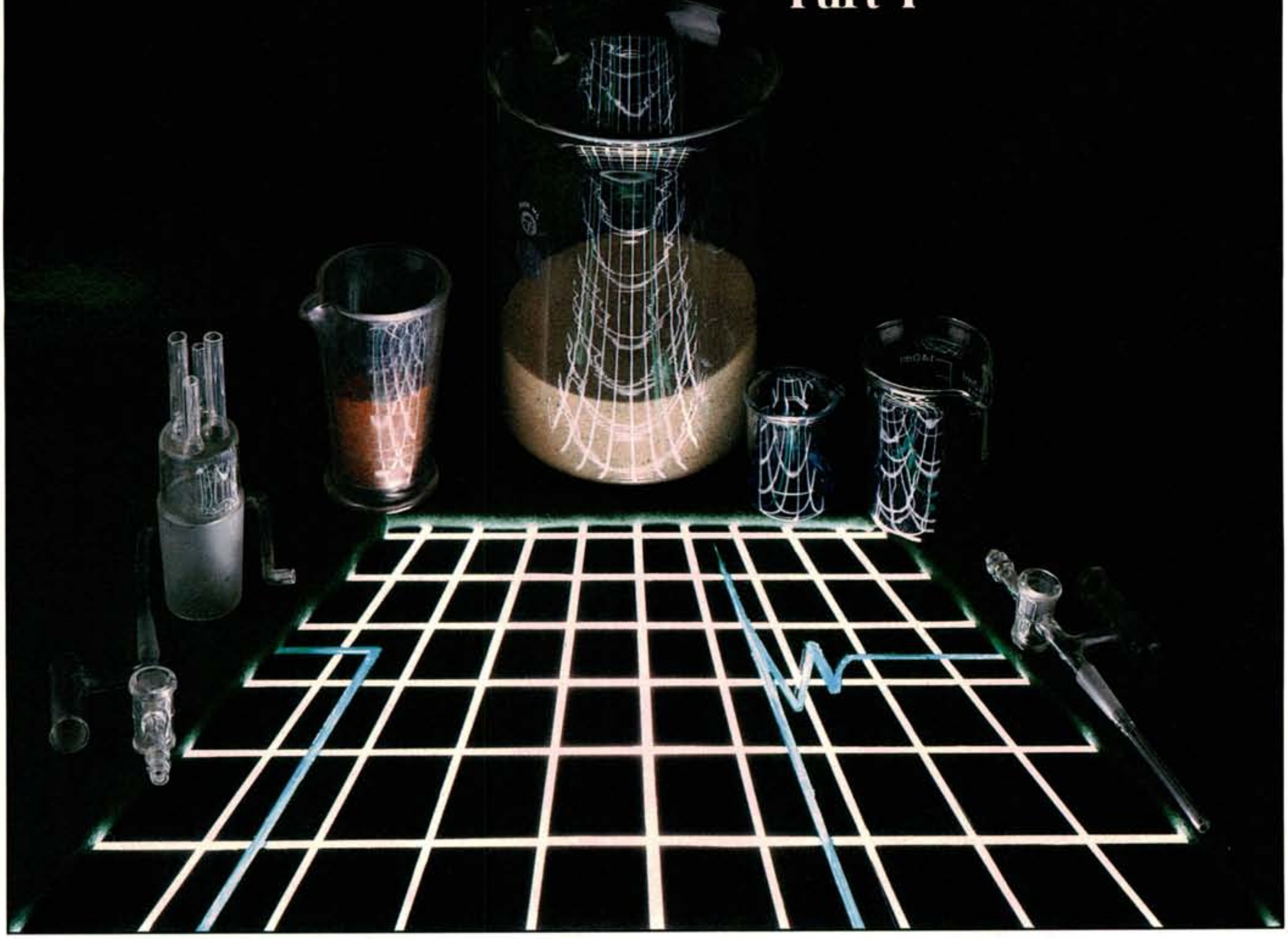
Trace Elements
Part I



This month's **Driveability Clinic** article about a Mitsubishi-built Dodge Conquest with a feeble minded control unit, raises some interesting questions about ways to troubleshoot a car with a complicated driveability problem. When the diagnostic capabilities of the control unit are limited, we need to put on our thinking caps and move on to more sophisticated test procedures.

These types of problems become more difficult to solve in light of the fact that many vehicle manufacturers are tight-lipped with specific information you need to do a thorough troubleshooting job.

Go ahead and grab a typical diagnostic chart listing DC voltage requirements for various signals which enter and exit the control unit. Under "Injector Number One," for instance, you may find a test value of 11-13 volts DC with the key ON and the engine OFF.

Talk about a big help. DC voltage testing with your DVOM is great for locating a voltage drop in a ground, a no- or low-voltage condition, or a simple open circuit. But DC voltage tests alone won't tell you anything about the pulse width or frequency of the signal being sent to the number one injector.

In the Volts/DC setting, your DVOM just isn't capable of responding to the frequency of the signal being sent by some inputs and outputs. Even a DVOM capable of measuring percent or frequency won't tell you if the pattern of the signal is usable by the control unit.

Looking at the Elements of the Trace

Next, we need to identify signals by "type" so we know if we're measuring an analog voltage, a square wave, or a sine wave. (Good luck finding a list of known good patterns or signal descriptions in the shop manual! The shop manual probably tells you to just hook up that dealer-only, $12-million tester, and go for it!)

But you don't have that tester, do you. Well, here you are — stuck in Lodi again: no patterns, no tester, and precious little information to work with. The engine in the car you're working on still runs and sounds like the bilge pump in the hull of the ***African Queen.*** You've already eliminated all the obvious mechanical and electrical problems with no success, and DC voltage tests at the ECU terminals aren't pointing to any clear-cut problems.

What do you do next?

At times like these, you need to take a "look" at both input and output signals with a lab scope so you can identify different signals and measure them. This month we'll take you through some preliminary steps which should help you get started with scope testing of computer signals.

We'll concentrate our efforts in the following areas:

- **How to make preliminary scope adjustments.**
- **How to measure analog signals.**
- **How to identify and measure digital signals from signal generators.**

Next month, we plan to emphasize more advanced troubleshooting techniques, and discuss things like duty cycles, frequency, and ways you can use the scope to isolate faulty control unit inputs and outputs.

Setting Up the Scope

Let's start with a quick review of the set up procedure for our oscilloscope. It's been a while since we did this in these pages, and a fast review seems to be in order.

The settings we offer here are a starting point since we won't always know the type or frequency of a signal being measured until actually sampling it. For instance, some MAP sensors are analog, others are digital.

Later, when we know the nature of the beast, we'll fine tune our scope settings for the best view of the signal. But for now, we need a starting point. We'll be using a dual trace analog scope operating in single trace mode for these tests.

Getting Ready to Sample a Signal

1) Don't turn the scope on yet.

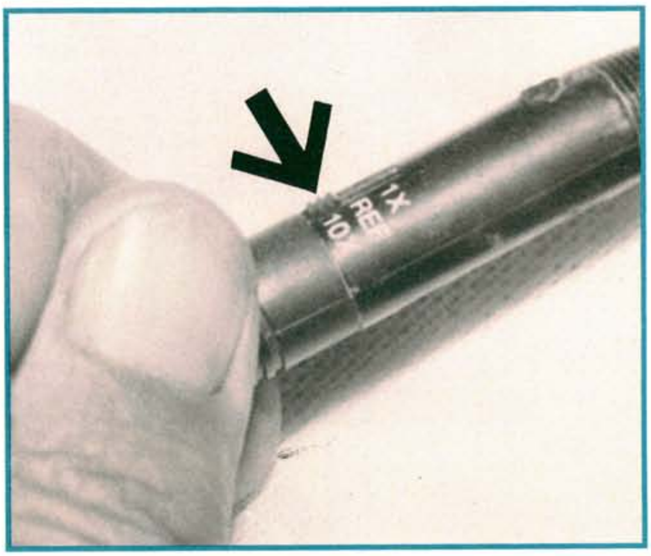
- Set the Intensity and Focus knobs to their mid-range positions. (If the scope has a Scale knob for illumination, set it to the mid-range setting as well.)

2) Adjust the Vertical Scale (Voltage).

- Select Channel 1 (or channel A depending on how your scope is marked).
- Set the AC-DC-GND switch to DC .
- Set the Volts/Div knob on the scope to the 0.2 volt setting.

Setting the Volts/Div Knob to the 0.2 Volt setting.

- The scope probe has a switch too. Set it to the 10X range. The 10X scale magnifies the incoming signal by a factor of 10. The 10X function also has a higher input impedance, which means it will place a smaller load on the circuit being tested than it will if it's set to the 1:1 setting.



Adjusting the scope probe to the 10X setting.

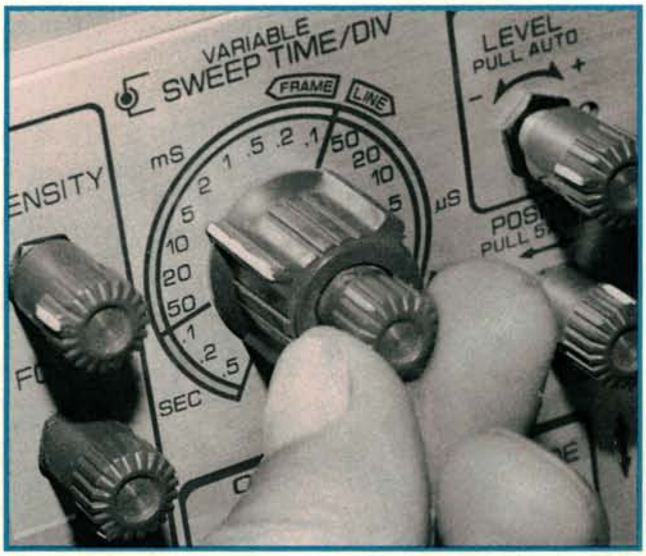
Combining the 0.2 Volt/Div setting and the 10x magnification of the scope probe means that each block on the graticule will measure 2 volts (0.2 x 10 = 2 volts) for each major division on the scope screen, or graticule for those of you who prefer the correct terminology. Since there are eight blocks on the graticule, you'll be able to measure a total range of 16 volts from the top to the bottom of the graticule.

Turn the Variable knob in the center of the Volts/Div knob fully clockwise until it clicks into the lock position.

Now that we have the vertical (VOLTAGE) adjustments set, we can move on to the horizontal adjustments for TIME.

Adjustments for the Horizontal Amplifier (Time)

- Set the Horizontal Position knob to the mid-range.
- Set the Time/Div knob to 5 msec/div (milliseconds per division).
- Turn the variable knob in the center of the Time/Div knob fully clockwise until it clicks into the lock position.



Adjusting the time division knob to 5ms, and locking the variable knob in the clockwise position.

Finally, Adjust the Trigger Controls

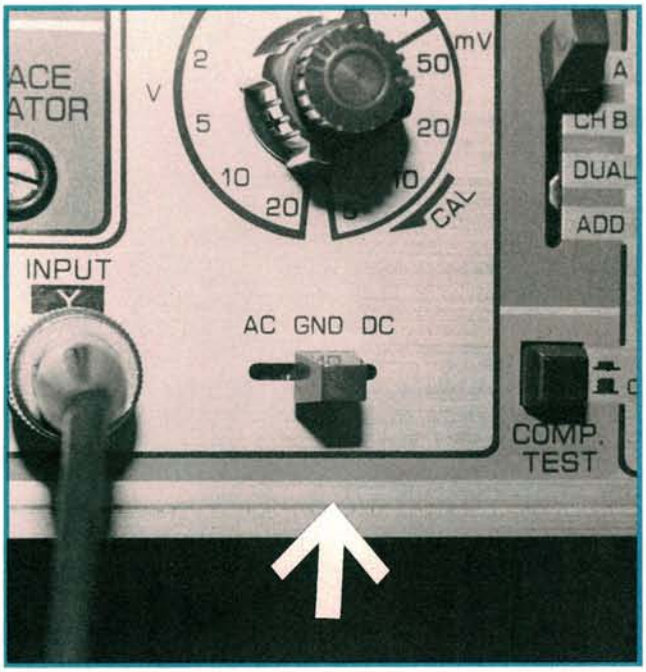
- Set the Trigger knob to the mid-range.
- Set the Mode switch to Auto.
- Set the coupling switch to DC.

Now Turn on the Power

After you turn on the scope, the trace should appear on the screen in about 15 seconds as the Cathode Ray Tube (CRT) heats up. When the trace appears, use the Vertical Position control to move the trace to the bottom line on the screen.

Fine tune the focus and intensity controls as you would with your television set at home. Use the focus knob to establish a thin, crisp trace, and use the Intensity control to dial in only as much brightness as necessary to make the trace visible. Too much intensity can burn spots in the screen phosphors.

Connect the ground wire from the scope to the car's battery ground, and switch the AC-DC-GND switch to GND to verify the baseline for the scope trace. Then switch back to the DC setting.



Location of the AC-DC-GND switch. Check the ground baseline and then switch back to the DC setting to make your tests.

A Look at an Analog Signal

Now we're ready to start poking some fun at those pesky signal wires.

We'll start with an analog signal like the one sent by the Throttle Position Switch (TPS). The trace line across the screen made by an analog signal will move up and down in response to changes in voltage. (To get an even better look at the voltage swing on a five volt analog sensor, zoom in on the trace. Switch from the 0.2 Volts/Div scale to the 0.1 Volts/Div scale. This will magnify the image, and make it easier for you to find those tiny glitches that can develop in the TPS wiper contact.)

Double check the baseline by momentarily switching to the GND setting to recalibrate the ground baseline any time you change the Volts/Div scale. If you don't, you may get inaccurate readings. Remember, an accurate ground reference point is the starting point for all voltage measurements.

When you're done checking the ground reference, switch back to the DC setting.

Now turn the car's ignition key to the ON position, and backprobe the TPS signal wire. Then move the throttle through its entire range of movement, from closed throttle to wide open throttle.

Look for two things:

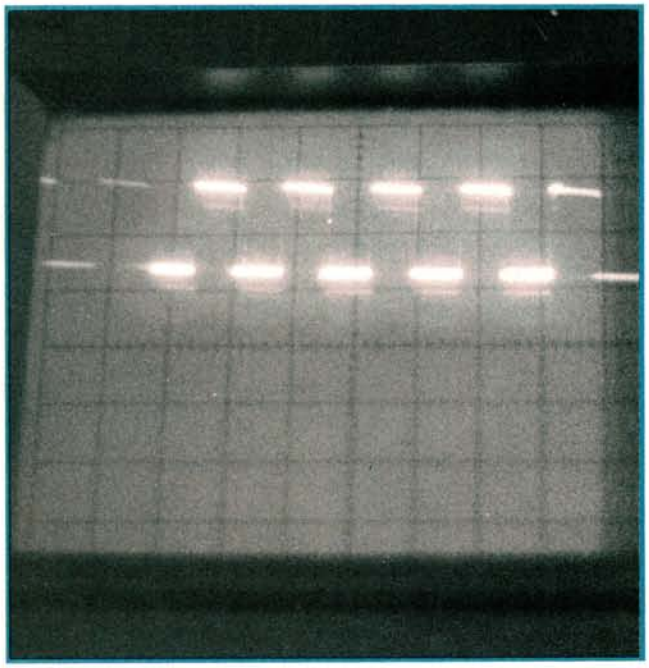
- **Smooth, even movement of the trace through its entire range of operation.** "Static" in the trace caused by dirt or worn contacts will signal a bad TPS. The static will appear as jagged movement of the trace.
- **Correct voltage levels.** Use the lines on the graticule and the Volts/Div setting to calculate the range of voltage. A typical TPS will read between 0.3 volt and 1.0 volt in the idle position.

Sensors Which Generate Signals

We don't want to spend too much time on analog sensors in this article. It's the sensors and control unit outputs which generate ***signals*** that can really drive you nuts without the help of a scope.

Let's start with a common example of a signal generator — a Hall effect generator commonly used in ignition systems to trigger the ignition coil. The Hall effect generator has three wires connected to it: a power supply; a ground; and a signal wire.

The power wire receives 14 volts which is supplied to the Hall effect unit by the charging system in a running engine.



Sampling a square wave.

Make sure you check the ground wire to the Hall unit. Compare the ground signal to the ground baseline by momentarily switching the AC-DC-GND switch to GND. Be sure the baseline stays put as you move the switch back and forth between the DC and GND settings. If it doesn't the ground circuit is probably loose, corroded, or both, and should be repaired before you go on.

Finally, our photo shows us sampling a typical square wave. The frequency of the signal should increase as engine speed increases.

Trace Elements

Frequency

Frequency is the number of times a signal repeats itself in one second. Frequency is measured in Hertz, which is abbreviated as Hz. A signal which repeats itself once every second is said to have a frequency of one Hz.

Two Hz? The signal repeats itself twice each second.

Your local FM radio station, transmitting at 107.5 MHZ (a million Hertz), is repeating its signal 107.5 million times each second!

Lots of Info

The square wave signal we see coming from the Hall effect signal wire is far more than just a pretty picture. It contains a lot of information we can use to evaluate the quality of the Hall sender's signal.

The scope will tell us the following:

- The **Amplitude** of the signal (voltage level).
- The **Duration** of the signal (the length of time the signal lasts).
- The **Pattern** (or shape) of the signal.

Since we're watching voltage in the form of a picture made by the trace, we are also looking for a signal of the correct shape. Tracing a wave form pattern reveals any imperfections in the shape of the wave form. This can be very important, since the control unit may refuse to accept a signal it can't recognize — even if the voltage level is correct.

Imperfections in the shape of the waveform are called distortions or "glitches." In some parts of the country, you may refer to these glitches as "doo-hickeys." That little doo-hickey may mean big problems.

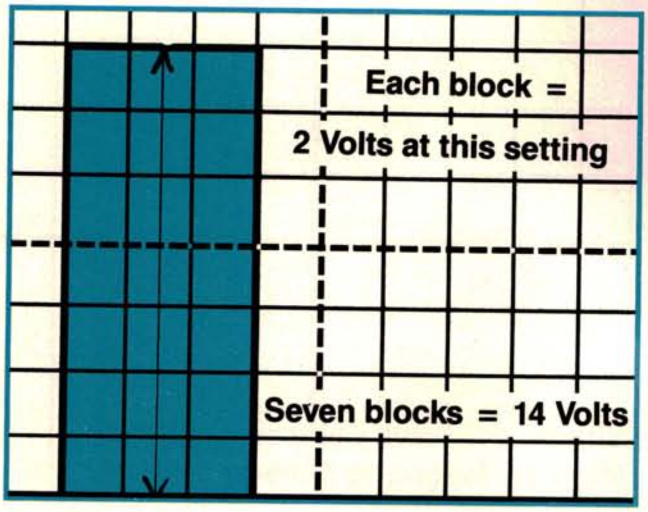
And your DVOM won't know the difference.

Amplitude

Let's take a look at the first thing the scope will measure for you—Amplitude. Amplitude is the voltage level of the signal. We measure amplitude by calculating the height of the signal above the baseline. The height of the trace above the baseline is the equivalent of a voltage reading.

You'll need to keep track of the Volts/Div setting and make adjustments for the setting of the probe amplification as well.

But it's not nearly as difficult as it seems. Here's an example: Let's say a signal rises seven major divisions above the baseline when you touch the probe to the wire. Our scope is set to the 0.2 Volts/Div scale, and the probe is set at the 10X setting. That means that each major division (or block on the graticule) represents 2.0 volts. If the trace rises seven full blocks, the scope is measuring a DC voltage of 14.



Time Duration

All voltage signals are shown on the scope in terms of Amplitude (the height of the trace above the baseline), and the amount of time the signal lasts which is called **Duration.** A constant voltage from our TPS will appear as a straight trace across the entire width of the screen.

The square wave from our Hall effect sender is a different story. It is a changing signal which alternates between a high voltage and a low voltage (or ground). As it drops from a High to a Low reading it should form a pattern which looks like a "square wave."

Time duration, also referred to as a PERIOD, is the total time it takes to form one complete square wave.

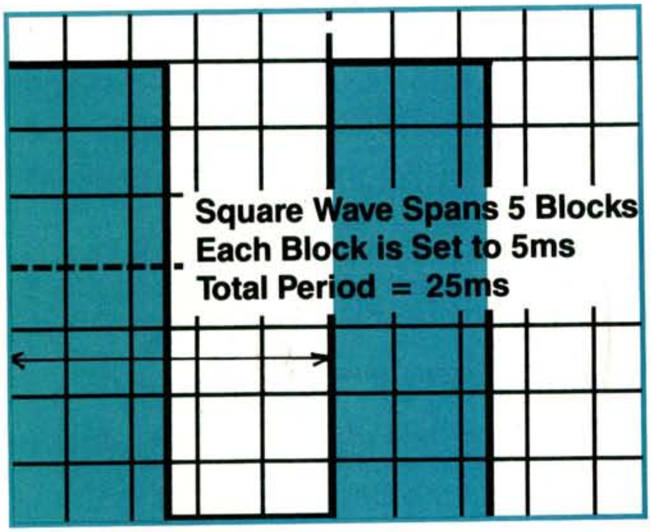
A single complete square wave period contains both the HIGH time (voltage high) and the LOW time (voltage low). If the High time and Low time are the same, the signal is said to be Symmetrical. This is the case with most Hall effect signal outputs.

The total time duration (or Period) of the square wave is measured from the leading edge of one cycle to the leading edge of the next, as shown in our illustration. It can also be measured from the trailing edge to the trailing edge. Either way, the important thing is that you measure one entire Period which includes both the High and Low signals which make up the square wave.

Measuring Time Duration

We'll measure the duration of the square wave just as we did the Amplitude. Our illustration shows a square wave. The square wave spans five blocks of the graticule (counting from left to right). The Time/Div scale is still at the 5ms/Div setting. If we multiply the five block width of the signal by the Time/Div setting, we get a Period of 25ms for the square wave being sampled.

If the manufacturer is kind enough to give you the recommended time duration of the signal in milliseconds, simply compare your measurement to the spec.



Each square wave is 5.0 blocks wide, and each block equals 5ms at this setting. This square wave has a Period, or time duration of 25ms.

But don't count on getting the information. The manufacturer may have decided to give a spec for frequency, not milliseconds. In this case you'll need to do some math to convert time frequency so you can compare the actual sample with the specification. We'll look more closely at this in next month's article, and give you detailed formulas for the conversion.

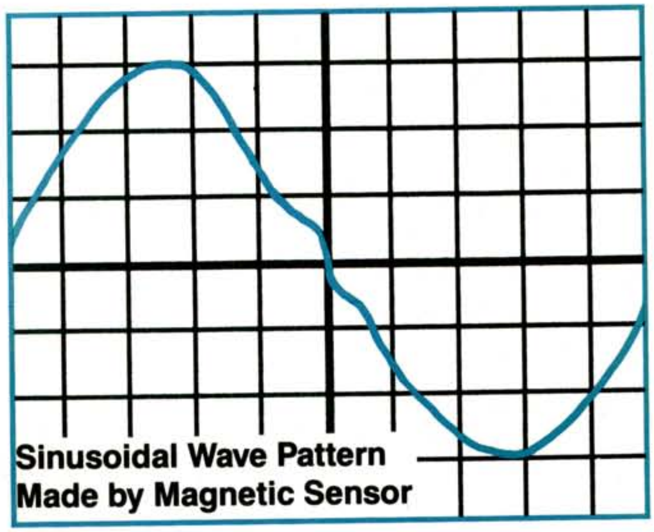
Getting Familiar With Patterns

Magnetic sensor patterns are different from the square wave put out by the Hall sender. The magnetic sensor puts out a ***sinusoidal*** wave very similar in appearance to a sine wave.

A pure sine wave is a smooth, changing signal commonly seen when we measure an AC signal. The wave changes amplitude and periodically changes direction. Each time the sine wave passes through the zero volt line, current reverses direction.

The sinusoidal wave has a little doo-hickey in its pattern. This is a characteristic of magnetic sensors and represents the effort of the sensor to overcome its own magnetic reluctance. In other words, the magnet is "reluctant" to let the current change direction, and puts up a fight. It loses in the end, but creates a little hump in the wave for its efforts.

Our figure shows one complete time period of a sinusoidal wave. We can convert the time duration of the sinusoidal wave into frequency.



A sinusoidal wave pattern. In this case, the doo-hickey is a normal part of the pattern.

Checking a Fuel Injector

A good example of the importance of checking time duration is a test of a fuel injector delivery. If you've eliminated high fuel pressure and leaking injectors as possible causes of an extremely rich fuel mixture, the scope will allow you to measure the duration of the ON signal sent by the control unit. The time the injector is turned on is commonly referred to as its Pulse Width.

The control unit looks at different inputs and refers to it's programmed reference chart to determine how long to open the injectors.

Common inputs to the control unit which determine pulse width include:

- Air and coolant temperatures.
- Throttle position.
- Engine speed.
- Manifold and atmospheric pressures.
- Air flow.

The scope is ideally suited to measure injector pulse widths. Its Time/Div scale allows us to precisely measure the amount of time the injector stays ON each time it is fired. That way, we can tell if the fuel delivery problem we're experiencing is the result of an improper signal coming from the control unit.

Please notice that we said "improper" signal — not "faulty" signal. The control unit may be doing its job even though the pulse width signal to the injector is wrong. Maybe it's getting a bad signal from one of the inputs listed above. Garbage in results in garbage out.

If we determine that the pulse width is wrong, the next step is to check all the inputs to the control unit before condemning it. Once again, the scope will help.

Come back next month for **Part Two** of our article.

—By Vince Fischelli