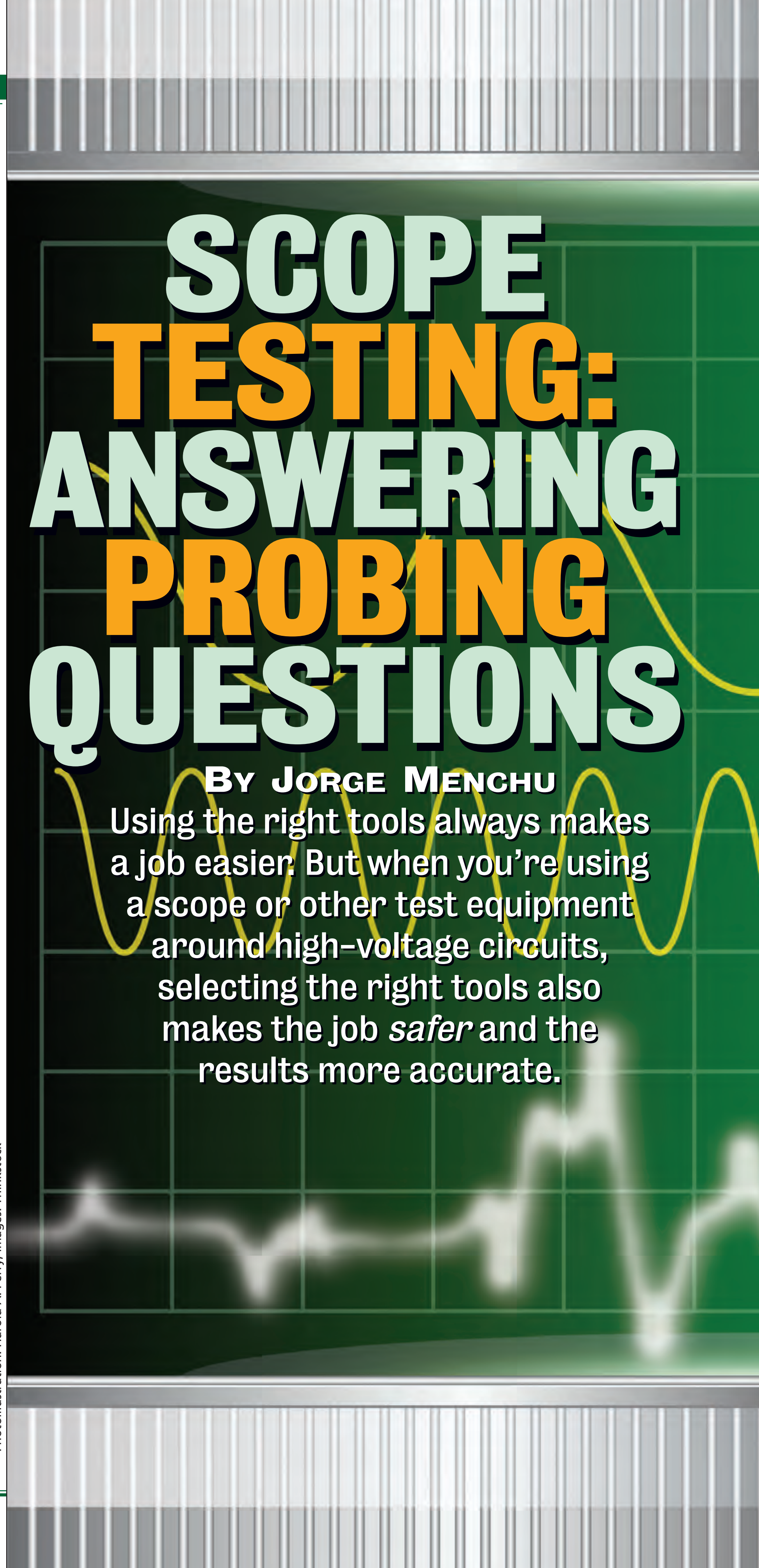


SCOPE TESTING: ANSWERING PROBING QUESTIONS

By Jorge Menchu

Using the right tools always makes a job easier. But when you're using a scope or other test equipment around high-voltage circuits, selecting the right tools also makes the job *safer* and the results more accurate.

Photoillustration: Harold A. Perry; images: Thinkstock

When it comes to our test equipment, we tend to focus on working specs and overall performance with little concern for safety ratings. After all, traditional automotive systems operate at low voltage and are rather safe. However, awareness of the safety ratings, and safety in general, has risen along with the popularity of electric and hybrid vehicles, in which the energy once stored solely in the fuel tank is now in the electrical system.

Regardless of whether you're tapping into high voltage or not, there are a number of important things to know about your probes, probing in general, safety ratings and your test equipment.

Take a look at the most basic piece in your test kit—the pin tip probe (see the photo on page 34). Perhaps you've noticed that most pin probes have some sort of rating stamped into the body of the probe. In this case, there are four safety messages:

1000V CAT III – Implies that the probe's design meets the high-voltage safety standards defined by the International Electrotechnical Commission document IEC/EN 61010 (see the box above the photo).

Max. 16 Amps – Indicates that this probe is capable of safely handling up to 16A.

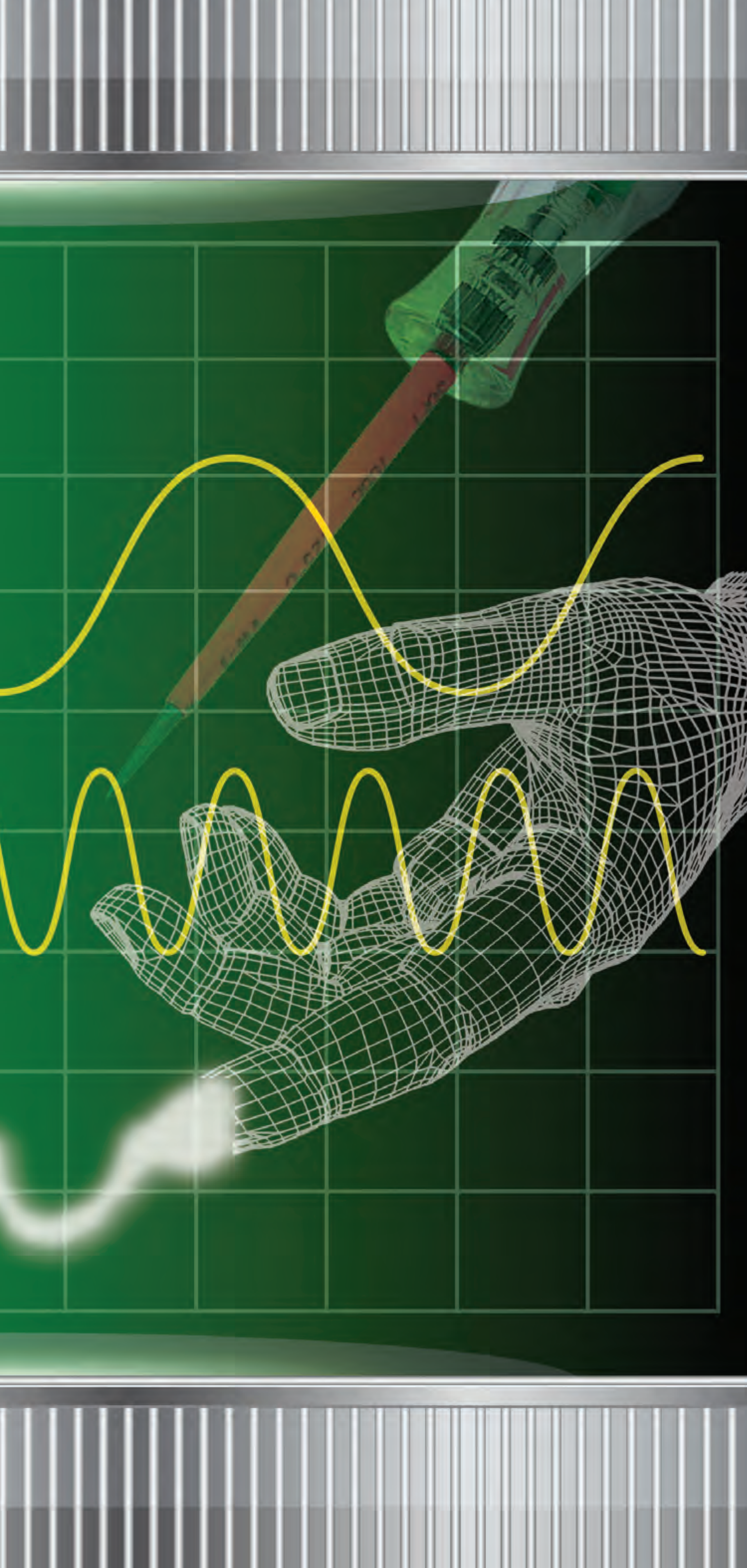
Triangle/Exclamation Point – A *caution* symbol indicating danger; the user should refer to a safety manual for more information.

Double Square – Indicates the device has at least two layers of insulating material or reinforced insulation surrounding the live parts.

Unfortunately, there's an issue here. The probe in the photo does not meet the specifications for a CAT III-rated probe.

To see what I mean, check out the two probes in the photo on page 37. The black probe is similar to the probe in the previous photo but is correctly rated CAT II 1000V. The red probe is correctly rated at CAT III 1000V/CAT IV 600V.

Obviously, the difference is the length of the probe tip—the exposed metal. A probe rated CAT II can have



an exposed tip up to 19mm in length. An exposed CAT III probe tip must be no longer than 4mm. (Some manufacturers provide an insulation sleeve that can be slid over the tip to turn a CAT II probe into a CAT III.)

So, if you know how to safely use a test probe, 19mm or 4mm, why is this a concern? For one, if you're working in a field such as education that requires certain safety requirements to be met.

On the other hand, perhaps the warning for all of us is that this example is indicative of a much bigger problem, one magnified by low-cost bargain and counterfeit electronic products available on the internet from unknown sources. Unlike the probe tip, when it comes to test equipment, "safety marked" or not, we can't see the quality of the components inside and the design considerations it takes to meet a particular safety specification/requirement.

Consider this common DMM mistake/accident in which *you* are in control of the most important internal component—the fuse. The test leads are in the wrong meter inputs or the meter is not on the voltage test; when you connect to 12V DC, pop goes the meter fuse. Replace the blown fuse with a super bargain knock-off that claims to be up to standards or simply replace it with the wrong type of fuse.

Now you want to test the voltage on a hybrid battery pack, somewhere in the 200V range. You're in a hurry and accidentally leave the test leads in the amp input, which has about .1 ohm of resistance between the test leads. This time the fuse actually blows apart and the current shorts across the PC board components, burning everything—the test probes, the meter and you. Let's do the math: 200V/.1 ohm = 2000A. Some newer meters have an input ALERT in the event the test leads are not put in the proper meter inputs.

When it comes replacing fuses, always use manufacturer-specified rated fuses, with the proper amperage, interrupt and voltage ratings.

Most meter fuses, when "blown," are designed specifically not to break apart. This contains the heat and arc inside the fuse, preventing continued arcing across the PC board.

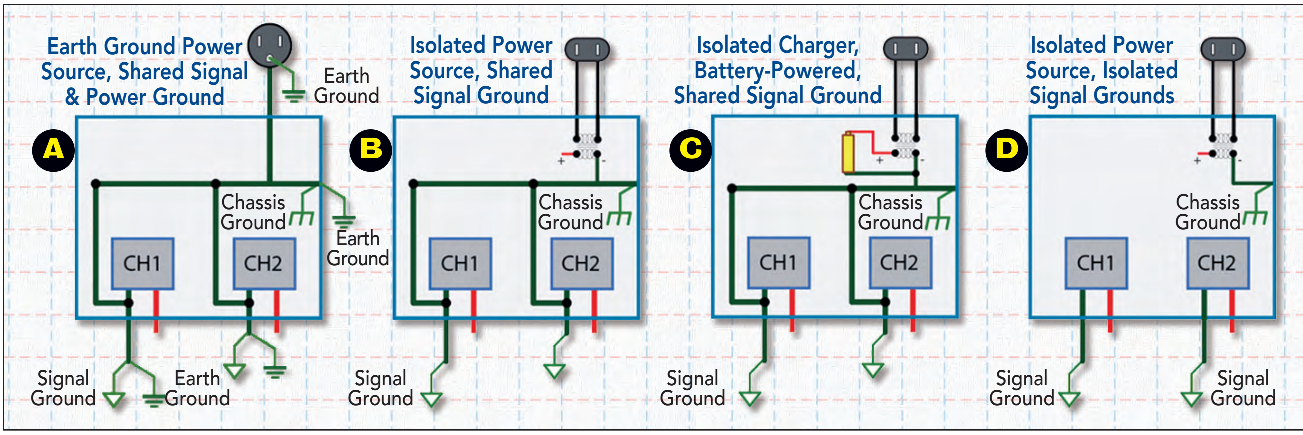


Fig. 1 **The configuration of a scope's internal ground path can have a big effect on its safety and the accuracy of its readings when in use. In some cases, a scope's internal ground configuration may alter the operation of the circuit that's being tested.**

Potentially 2000A pushed by 200V . . . this is serious business. Keep in mind that the goal of safety standards such as IEC/EN 61010 and CAT ratings, which applies to probes, leads and test instruments, is to prevent shorting and/or arcing at the test points, protect from high-voltage transients and surges and minimize the personal shock hazard.

Regarding the CAT ratings (I, II, III and IV), a higher rating indicates a higher danger level, due to a higher total energy from a combination of voltages, current and transients (voltage spikes and/or inductive kicks).

This brings up an important point that's a bit confusing—the difference between a CAT II 1000V rating and a CAT III 600V rating. Simply put, regardless of the voltage rating, CAT III is designed to withstand a bigger energy punch than CAT II. In a worst-case scenario, a CAT III level high-energy arc delivered to a CAT II meter is likely to last longer and do more overall damage.

Okay, now I know why a CAT III probe has less metal exposed than a CAT II: The higher energy level of a CAT III circuit can arc further, increasing the likelihood of accidental shorting. And the overall energy can be more damaging. Bottom line: Less exposed metal in the tip means arcing is less likely to happen in the first place.

Getting back to the question of the safety marks, how do we know when the safety marks are legit? To start, consider the safety marks in four levels:

Level 0 – Some manufacturers display only specifications—for example, 600 to 1000mV.

Level 1 – Self-administered safety marks and compliance. In this case, the manufacturer or the manufacturer's agent makes the determination of conformity. This is the case where terms like "conforms," "complies" or "meets" are used. For example: "The instrument complies with IEC/EN 61010-1:2001-02 and IEC/EN 61010-031:2002, Class 2, double insulation. CAT IV 600V/CAT III 1000V."

Also, some marks such as C E (see the box on page 37) can be properly self-administered or certified by independent testing. If you go as far as asking a manufacturer for a written declaration of compliance, a declaration is the manufacturer's guarantee of testing by an independent lab.

Level 2 – Safety marks which are administered only through independent testing of at least one product sample of applicable standards by an independent testing lab. The box mentioned above gives examples of safety marks applied to the Fluke 88V DMM.

Level 3 – Marks for testing labs that are recognized in the U.S. by OSHA (which includes having to meet the National Electric Code). They're called

CAT Ratings

IEC/EN 61010 specifies general safety requirements for electrical equipment intended for professional, industrial and educational use. Below is a brief outline of the various CAT ratings:

CAT I - Low-voltage, self-contained systems, including traditional automotive systems.

CAT II - Testing on the insides of devices that are powered by AC line voltage; AC outlet more than 30 ft. away from distribution panel.

CAT III - Building power switching and distribution (one- and three-phase); hybrids and electric vehicles fall into this category.

CAT IV - Outside power line.

Photos: Jorge Menchu

Markings on scope test probes should provide an indication of their operating limitations. Use reputable suppliers, as some probes (like this one) include inaccurate rating information.

The red Fluke test probe in this photo can be twisted to lock it into either CAT III 1000V or CAT IV 600V configuration. The black probe has a single CAT II 1000V rating.

"nationally recognized test laboratories" (NRTLs), such as UL, who we are all familiar with. For a list of NRTLs, go to *https://www.osha.gov/* and search "NRTLs."

Unfortunately, whether OSHA is involved or not, the fraudulent application of the marks and misrepresentation and/or misinterpretation of the standards hasn't stopped. On the other hand, just because an instrument is not "independently certified," that doesn't mean it doesn't meet safety standards.

Is this a concern for you? After all, if you have a meter that can test up to 1000V, you can test up to 1000V. Just keep in mind that it's not what you can do, it's about what can go wrong and the effect it has on you and your equipment when it does.

The proper application of the CAT ratings is about minimizing the likelihood of things going wrong in the first place—and if they do, minimizing the damage. Perhaps the best advice is from the folks in the high-voltage world, whose lives depend on the integrity of their test equipment: Purchase equipment only from a trusted manufacturer. And, if you want to be high-voltage hybrid-ready, go certified CAT III.

One final warning: Most accidents with electronic test equipment occur due to user error. To avoid this:

- Learn what some of the dangers are by carefully reading the safety precautions in the manual and supplied by the vehicle manufacturer.
- Make sure your leads are in the correct ports and the meter dial is in the correct test position *before* connecting to the circuit.
- Always use the recommended replacement fuses, not cheap alternatives.
- Wear gloves and safety goggles when working on high-voltage systems.

Safety Symbols From the Fluke 88V

C E (European Conformity) – Products sold in the European Union must conform to the C E directive. It's a self-certify mark not on the OSHA list.

UL (Underwriters Labratories) – Recognized by OSHA; certified to meet applicable U.S. standards.

CSA (Canadian Standards Association) – Recognized by OSHA; certified to meet applicable Canadian standards.

TUV (TÜV SÜD) – Recognized by OSHA; certified to meet applicable European standards.

Check Mark (C-Tick) – Certified to meet applicable Australian standards.

Probing, Grounds & Safety

My first lab scope was an analog two-channel unit powered by plugging it into a wall socket. It didn't take long before I decided to capture an AC waveform by probing another wall socket. I stuck my pin-tip probes in the socket and sparks flew and I

The metal shell of the USB connector connects the instrument ground to a PC. Scopes using this type of connection share common signal and earth grounds.

jumped. Do you think I should have read the manual first?

Why did the sparks fly? Turns out the scope chassis, PC board and test lead ground were all connected to the third prong (earth ground) on the AC plug. What does this mean? By connecting the ground probe into the AC socket, I created a dead short to earth ground through my new scope (see Fig. 1, diagram A on page 34).

I learned an important lesson that day: Anytime I connect my earth grounded lab scope to a circuit, I'm connecting that circuit to an earth ground. Fortunately, for automotive testing, I have not known this to be an issue outside of some ground loop situations resulting in a noisy signal. But I caution, as one gets more confident and adventurous with a scope, it's an important consideration.

So how do you know if your scope and ground inputs are earth grounded? They're not earth grounded if your scope is powered from a built-in battery, or if the charger/power cord has only two prongs for the AC connection. This means it's an isolated power supply.

On the other hand, your scope is likely to be earth grounded if:

•The AC power cord has three prongs (the round prong is the earth ground).

•The scope is connected to a PC powered only by an AC wall socket. The ground connection is made by a standard USB cable through the metal shell of the connector (see the photo above).

•The scope is connected to a PC/TV-type monitor powered only through an AC wall socket. The ground connection is made by the monitor cable.

In the latter two cases, to confirm, with all else connected, unplug the AC cords from the power source and check the resistance between the ground prong of the AC plug and the scope input ground (see the photo below left). Low or no resistance indicates earth grounding.

Note that to maintain the highest level of isolation, some DMMs and scopes use an optically isolated USB to connect to a PC (see the photo below right).

Scopes With Shared Ground

Now let's look at a ground issue that's a direct concern for automotive testing. There are two types of channel ground systems inside scopes. The most common is where all the scope channel grounds are shared (see Fig. 1, diagrams A, B and C on page 34). This means you connect one ground from any channel and all channels are grounded. The second is where the ground for each channel is isolated from the others, meaning each channel needs its own ground connection to get a signal.

On the shared-ground scope there are some safety precautions to consider. Similar to the AC short example mentioned earlier, when you connect multiple channel grounds to different points on the vehicle, you're tying them together via the ground connections and through the scope.

For example, Channel 1 ground is

This simple test will help you determine whether a scope's signal grounds are connected to earth ground. The DMM's low resistance reading indicates a direct connection between the two.

An optically isolated USB charging port on this scope completely separates signal grounds from earth ground. This makes it safer and more accurate to use than a scope that features shared grounds.

connected to the battery ground. Channel 2 ground is connected to the PCM ground. If the PCM ground was floating at .5V above the battery ground due to some resistance problem, you just fixed it. But in doing so, there would be current through the ground system of the scope. This is called a *ground-loop*.

Here's a more dramatic example: You have a car that cranks slowly and is not starting. Connect Channel 1 to the battery terminals, both signal and ground. Channel 2 is backpinnning an injector and is grounded at the engine block. Crank the engine over and your test leads start smoking! Now you know why it was cranking slowly—a bad ground path between the battery and the engine block.

A way to avoid situations like this is to use just one ground connection from the scope to the vehicle, ideally located on a main system ground, such as the battery, chassis or engine block. Doing this also sets things up for doing voltage drop tests on any other ground in the system.

Likely Effects of 60Hz, 120V AC Current

1mA - Barely perceptible.

16mA - Maximum current an average person can grasp and let go.

20mA - Paralysis of respiratory muscles.

100mA - Ventricular fibrillation threshold.

2A - Cardiac arrest and internal organ damage.

Source: NIOSH

Scopes With Isolated Grounds and/or Channels

Not all scopes share a ground among the channels. For example, the Pico 4225 and 4425 have independent floating inputs, which are isolated from the PC/earth ground, meaning each channel is independent of the others (see Fig. 1, diagram D). For the 4425, it's like having four independent scopes that simply share the display. This also means that the channel grounds are not connected to earth ground.

With this setup, we lose the convenience of making just one ground connection for all the channels. But it does open up one very powerful opportunity: You can put your test leads anywhere. For example, all four variable-reluctance wheel speed sensors can be viewed simultaneously. You could even do a voltage drop test across a power-side connector or fuse while another channel is grounded at the battery. On a shared-ground scope, this would result in a short circuit!

When using scope test probes and other test equipment, the biggest danger is in not knowing what the dangers are. Be safe.

This article can be found online at *www.motormagazine.com.*