Waveform of the Month

LEADING YOU ON

Untangling the Confusion Over Test Leads

An article by Jorge Menchu that originally appeared in:

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Leading You On

There are many things to consider when you decide to hook up your lab scope. Just consider a few of the choices and decisions that must be made when we pull the scope out of the cabinet. Is it an AC or a DC signal? What time per division setting should I use? Where should I tap into the system?

In our haste to get connected and start collecting data, one thing is often overlooked—the test leads! The test leads are the only link between the system under test and your test equipment.

I like to compare the test leads to the telephone line between two telephones. We all know that the type and quality of the line used, as well as the integrity of any connections between the two telephones, can all have an effect on the quality of the signals that are sent and received.

Considering their importance, it's about time we started giving them some of the attention they deserve. What follows is a brief description of the basic types of test leads and their connectors, test lead characteristics, and their intended uses.

Basic Leads

When selecting or using a test lead, the most important consideration is whether it is shielded or not. Non-shielded test leads are often identical to the type that are supplied with DMMs. Non-shielded test leads are usually constructed from 18 gauge, multi-strand copper wire.

Because they do not have any shielding, these types of leads are more prone to introduce noise into the signal. This can be a major concern when using special features (such as glitch capture, peak detect, or min/max), or when low volts/divisions and/or fast time/division settings are used.

Shielded test leads are less prone to pick up noises, and are standard issue for lab scopes. The construction of these leads is complex in comparison to non-shielded leads:

- In the center of the cable you will find a multi-strand center conductor.
- The center conductor is surrounded by an insulator material.
- In turn, the insulator is completely surrounded by a braided sheath that forms the electronic shield.
- Finally, all of the cable components are surrounded by an outer insulator (silicone vinyl) that keeps dirt and moisture out, and prevents accidental shorts or groundings.
- The braided sheath is the pathway to ground, which protects the center conductor from noise.

Connector Types

Test leads are connected to the scope in three basic fashions—**banana plugs, BNC and "Lemo" connectors.**

Banana Plugs

Banana plugs are typically used with DMMs at the ends of their non-shielded test leads, even though some shielded test leads also terminate to banana plugs. The meter has the socket and the test lead provides the plug. The test lead plug may be surrounded by a sheath for protection. This sheath is simply a plastic tube that seals the connection to the meter to keep splashes of liquid from reaching the scope's internal parts. The sheath also prevents accidental shorting if the lead slips out of the meter.

BNC Connectors

BNC connectors are typically used with shielded cables. This type of connector is the standard for most scopes sold in the electronics market. Some BNC connectors are fully insulated and have a plastic body. Others are not and have a metal body. The scope has the female side of the connector and the test lead has the male connector. Looking inside the male BNC, you'll see a center pin that carries the signal. On non-insulated BNC connectors, the metal body of the connector is the ground.

When BNC connectors are used, the connector must be installed before a connection to the circuit is made. This extra caution is necessary because it is possible for the center pin to short against the ground tab of the BNC socket!

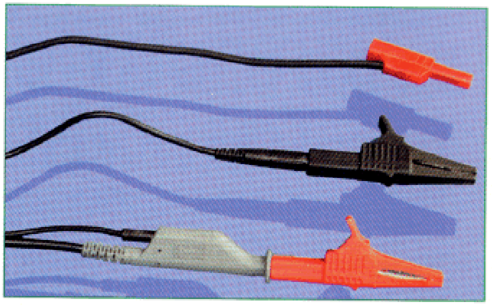
Lemo

Lemo is a brand name for a particular type of test lead connector. They are plastic, keyed, and push in. The ground and signals are transferred to the scope via pins inside the protection of the plastic connector. Lemos can be attached to a wide variety of cables, both shielded and non-shielded.

Picking A Lead

Scope leads for automotive use come in two flavors: 1:1 (one to one) and 10:1 (ten to one). When to chose one lead over the other comes down to:

- your scope's input impedance,
- determining the requirements you wish to perform,
- the scope's maximum input voltage,
- the scope's maximum volts per division setting.



Here are some examples of shielded leads. The top lead utilizes a stacking sheathed banana plug, and is supplied with the Edge PAC scope. The lower lead set is supplied with the Fluke 98, and features a removable ground lead that attaches at the gray connector.

1:1

One to one (1:1) probes do not alter the signal as it passes through, so they have no effect on the signal's amplitude. Most scopes have a one megohm input impedance, so the loading effect on the circuit is minimal. For this reason, 1:1 test leads can be used for almost all testing situations.

10:1

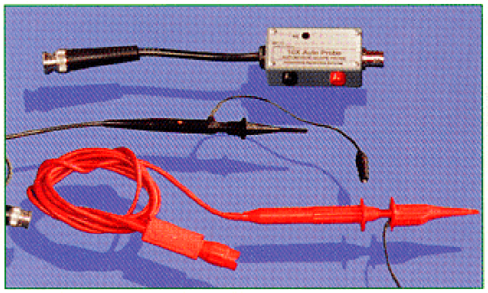
This is pronounced "ten to one," or they may also be called "10X" (ten "X" or ten times). There are a few things to know when using ten to one test leads. 10:1 leads have a built-in circuit that reduces the voltage of a signal by a factor of 10. Therefore if there is 10 volts at the scope's probe tip, the scope will only see 1 volt. This not only reduces the signal, but also increases the scope's input impedance to 10 megohm!

If you're not paying attention, this can throw you off. Follow this example: If you are testing a 10 volt signal with a scope setting of 2 volts per division, the signal will rise 5 divisions (2 X 5 = 10). If you install a 10:1 probe the signal will only rise one half division with these settings. So you actually have a volts per division setting of 2 X 10 = 20. That's 20 volts per division.

Here is where the name 10X comes in. At 2 volts/division and a rise of one half the division, the signal is measured as 1 volt. Adding the 10:1 probe means you need to multiply the values by 10. So you actually have a volts per division setting of 2 X 10 = 20.

The good news is that you can tell some scopes that you are using a 10:1 probe and the scope will make all the conversions for you. See your scope manual to learn how to calibrate your scope for a 10:1 probe. Note that setting the calibration will only change the volts per division setting and measurements values that are displayed. The real work is done by the probe!

There is one final concern with 10:1 probes: Some of these probes have a compensation adjustment that is used to balance the 10:1 circuit with your leads and scope. This is an operation you may wish to perform occasionally. You'll certainly want to adjust it when viewing digital signals that have unusually spiked or rounded edges. See your User's Manual for more information about this.



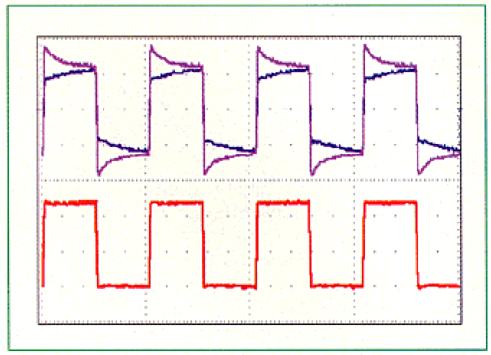
Three different 10:1 probes. The top probe was designed for automotive use. Two probe taps in the side allows you to connect a second set of test leads. The center probe is designed for electronic applications and can be rather fragile, especially near heat. The lower probe is a Fluke product, also designed for automotive use.

When To Use 10:1 Probes

• **If the procedures for the device/circuit you are testing specifies the use of a 10 megohm meter and your meter is only 1 megohm.**

NOTE: Check the User's Manual to determine the input impedance of your scope. For example, the Snap-on/Sun LS-2000 is a 10 megohm input impedance meter when it is used with 1:1 probes.

• **When you expect the voltage to go higher then the scope's maximum voltage rating.** Some scopes have a maximum input voltage as low as 200 volts. Others range around 400 volts. Using a 10:1 probe effectively multiplies the maximum voltage rating by a factor of 10. So a specification of 200 becomes 2000 volts.



Here are some examples of how probe compensation can effect waveforms. This adjustment should be performed periodically.

• **If your scope has an internal circuit that bypasses the signal to ground when the maximum input voltage rating of the scope is exceeded.** This is a very effective method for protecting the scope, but it can cause problems, especially when testing the primary ignition system. If the scope's protection circuit bypasses the signal to ground before the primary ignition spike is complete, this disrupts the clean switching action of the module that is needed to create a strong secondary signal—so the engine dies. Well, what do you do? Use a 10:1 probe!

• **If the maximum volts per division setting of your scope is not high enough to view the signal.** Some scopes have a maximum setting of 10 volts per division with only 8 divisions. This means any signal above 80 volts can not be displayed. Using the 10:1 changes the 10 volt maximum division setting to 100 volts per division.

• **If the signal you are testing with 1:1 probes has a lot of noise in it, use a 10:1 probe.** 10:1 probes have a limited bandwidth. This will sometimes filter out the unwanted high frequency portions of a signal and eliminate the noise.

Grounds

Grounds are certainly important. The ground connection and its lead are the foundation for your measurements, so it is imperative that both be in good condition.

Many shielded test leads include a ground at the probe end of the lead. This is always the best configuration for preventing noise but it can lead to confusion when connecting multiple channels. Many multi-channel scopes do not offer ground access on the probe tips and choose to use a separate ground input called a chassis ground.

The Tektronix 222 had totally separate grounds for each channel. To use both channels, you had to connect both grounds. Most automotive multi-channel scopes do not use this separate ground arrangement, and share the same ground throughout all of the channels.

If you have leads or a setup that allows you to connect more then one ground at a time, caution must be exercised. If one ground is connected and another contacts a power source, something is going to smoke!

Another scenario might occur if you are testing a circuit that has a 'floating' ground, such as some speed sensors. Connecting your scope's ground leads to the system ground and the floating ground ties both grounds together. Tying two floating grounds together can be just as bad. You can really mess things up, especially if the floating grounds are for AC generators, like many speed sensors.

A Note About Noise

The lab scope is a very sensitive device and the automotive environment is extremely noisy. Noise is unwanted electrical signals that appear in a circuit or on your instrument display.

The high voltage of an ignition system is the number one source for noise under the hood. The high voltage produces strong electromagnetic waves that can be "picked up" by other circuits and/or your test leads. It is almost impossible to prevent noise from appearing in all signals.

When noise is a problem, the type of test lead you use can have a direct effect on the quality of your signal. Understanding the characteristics of your test leads can help you answer the big question: Is the noise being picked up in the test leads, or is it in the circuit under test?

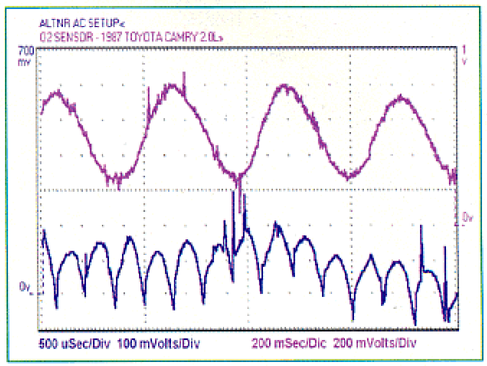
Noise Makers

Environmental conditions and events that help to produce noise:

- Bad connections, especially bad grounds in the circuit under test, or poor connections in the test leads.
- The secondary ignition system, especially when it has bad components such as old wires!
- Mechanical stress. This could be called the knock sensor syndrome.
- Test leads that are run too close to ignition wires.
- The circuit under test is too close to the ignition wires.

The following scope settings make the scope more sensitive to the conditions above, and will make it more likely to pick up unwanted noise:

- Special features like Glitch Capture turned ON.
- Non-shielded test leads.
- Fast time/division settings.
- Low volt/division settings.



It is common to see noise, especially when the scope is adjusted to low voltage and time per division settings. The spikes in these signals represent noise in the ignition system, and have no other significance.

Conclusion

Whenever I perform a diagnostic test that fails, I assume that I have made a mistake. Is the scope adjusted correctly? Are the leads in good working order? Are the connections good?

It is even more important to question your work if you are using a scope that has a record and playback feature. If a "failure" occurs in your recorded waveform, was the failure caused by a bad test lead to circuit connection, or was it really caused by the problem you are looking for? The scope is only capable of capturing problems. It's not capable of telling you whether the failure was an actual component fault, or something you have done wrong. Check your work if you're not sure.

In the next installment of this series, I will cover low pass, AC filters, and ignition leads. After that, we'll finish up with several different types of probes, and special adapters.

—By Jorge Menchu

Related Links

For information or to purchase products discussed in this article, click on one of the following links:

Shielded test leads:
http://www.aeswave.com/products/Products.asp?ci=11&sa=Y&vp=1

Filtered test leads:
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