

## ScopeCorder – SL1400, DL750, DL750P

### Are you probing high-impedance circuitry or otherwise sensitive circuits and systems?

#### Probing with the Yokogawa ScopeCorder

*Abstract:* For many electrical measurements in the industrial environment, a high-impedance DMM or Recorder is an appropriate tool. These test instruments have a relatively high input impedance ( $>1\text{ M}\Omega$ ), which means that once connected, they don't load the circuit under test. These test tools generally will not affect circuit operation or circuit measurements.

On the other hand, today's test engineer may be faced with making unavoidable measurements on a high-impedance test point, or on a test point which is located within a feedback control circuit. Making measurements in these environments can compromise your measurement as well as the normal operation of the DUT – unless the right precautions are taken.

#### Where to start with the ScopeCorder

Unless you are measuring low-level (less than 10 mV, for example) low-frequency ( $< 1\text{ MHz}$ ), then you should consider using a 10:1 passive probe. Even if you are making low-freq, low-level measurements, you may still want the performance which a 10:1 probe affords you.

Why? Because 1:1 probes create more loading effect than a 10:1 probe. While 1:1 probe may not load most test points, it can load high-impedance test points.

In fact, a 1:1 probe design, can, due to *resistive loading*, have a nearly 35% error on a 500 k $\Omega$  test point! However, on that same test point, a 10:1 probe would exhibit only a 5% error due to *loading effect*. This is error *measurement error* due to *loading effect*.

Measurement error by itself can be enough of an issue alone, but when a probe is connected to the DUT, the DUT may also be affected in some way. In other words, the *loading effect* of your probe may be causing a *side effect*. Special care is also required when measuring test points which are part of a feedback-loop or closed-loop. Feedback circuits often exhibit *high-impedance* nodes. Probing these types of circuits or systems with an inappropriate probe can seriously affect the *phase margin* of the feedback circuit causing *state changes*, *instability*, and / or *oscillations* – or even *downtime*. This effect is usually more pronounced when probing high-impedance nodes or test points and can be minimized by using a high-impedance probe such as a 10:1 probe or even a FET probe and other pre-cautions.

Besides the obvious *resistive loading*, there are other causes, such as *capacitive loading*, and *inductive loading*.

### Capacitive Loading

With any passive probe design, probe input capacitance increases the loading effect as frequency increases – this is unavoidable. However, besides this loading effect and subsequent measurement error, adding a capacitor to a Dot's feedback loop or control line can be the equivalent of adding a low-pass filter to the design – unintended consequences. Think about it like this: Probing with a 1:1 probe can be equivalent to adding a 100 pF capacitor to the DUT while probing with a 10:1 probe is more similar to adding a 10 pF to the DUT or test point – the 1:1 probe is much more likely to affect the feedback circuit than is the 10:1 probe.

Probing a feedback path with the wrong probe can, again, seriously affect the *phase margin* of a feedback circuit causing *state changes*, *instability*, and / or *oscillations*.

### Inductive Loading (ringing)

Probing with a passive probe is equivalent to adding a resonant series L-C circuit from your Test Point to ground. What!?

Now, that series resonant L-C circuit is caused by the probe's input capacitance in combination with the ground lead and exhibits a resonant frequency of over 100 MHz, or as high as 400 MHz if you will simply shorten the ground lead. Staying below this frequency means that we

can keep it simple and use the 10:1 probe which we have recommended thus far.

As rise times on a Test Point increase, this resonant frequency becomes a problem and the series L-C circuit can “ring” adding significant error to your measurement and changing the phase margin in your feedback circuit. Keep this in mind – *even a 10:1 probe may not be sufficient* - above 100 MHz you need time to consider other probes such as active bipolar or FET probes (not the scope of this article).

Also, though it is often tempting to extend probe leads when checking large boards, this can cause ringing on step changes in input – so don't do it whenever waveform integrity matters, especially on fast rise times.

### Grounding, Isolation, and your DUT

Floating measurements are afforded with the SL1400 by using isolated modules. When using an isolated module, your test point's ground nodes are isolated from each other as well as from common ground. This is essential when probing many different test points simultaneously. Why? Because isolation between each of your measurements is just important as the isolation itself. Isolation is *good engineering practice*. And the ScopeCorder's isolated-input modules preserve the grounding system which is already in place in your DUT.

You would never think to tie ground points in a system together with a bunch of test leads – so don't do it inadvertently when connecting your

ScopeCorder – Use isolated modules where it is important and refrain from connecting each of your DUT test points to a common point. Doing so can introduce a host of potential problems within the DUT itself and also discards the advantages isolation made possible by your ScopeCorder.

So, to take full advantage of the isolation which a ScopeCorder offers, use the best probe, and *never* tie all of your ground leads together.

### Rules to live by

In summary, a list of *items to remember selecting and connecting each of your probes*:

1. Do *not* simply tie all of your grounds to one point and then connect one ground lead to your DUT. This practice defeats the isolation which the SL1400 isolation modules provide. Use a ground point *physically near* your test point. One ground per each test point.
2. Do *not* extend your ground leads or probe leads in any way. This is to be avoided. If you see *ringing* on your fast rise-time signals, it is safe to assume that your ground lead is *too long*. Always use a ground- or reference contact on each individual probe and make sure this is as short as possible.
3. Use the manufacturer's probe recommended for your instrument – and accessorize it.
4. Avoid *loading effect* and its effect on your DUT: When probing high-impedance or feedback circuits, avoid using a 1:1 probe. Very often, the

1:1 probe is fine, but the 10:1 probe may be a better choice.

5. Avoid sudden changes with your sensitive circuits: Avoid switching your probe's attenuation switch (1X, 10X) while connected to your test point. Also, if you must use a 1:1 probe, avoid range-switching your test instrument while connected to any sensitive test point or DUT.

### But wait, there's more

*Protect your test equipment investment.* In terms of isolating your test points from each other *and* from the scope input – not only does a 10:1 probe offer less *loading effect* – it offers 9M ohm of isolation between itself and the test point. This serves double-duty: protecting the instrument from inadvertent over-voltage input while at the same time providing an *additional 9 MΩ of isolation* (as compared to the 1:1 probe design) to your Test Point.

### Accessorize for Convenience and Performance

Bottom line: In instances where probing is critical, take advantage of the isolation which a 10:1 probe offers.

However, do you find that passive probes are inconvenient? Perhaps you prefer to connect to your test points using banana-plugs and clips?

For the SL1400, there is the 10:1 Yokogawa 700929 which offers safety, convenience, and performance – to protect your sensitive test points. This probe can be adapted to *virtually any* type test point or connector including safety connectors.

To keep your options open in terms of connecting your instrument, make sure to take advantage of the accessories. The SL1400 has a deep catalog of adaptors and cables to suit virtually every need.

### Conclusion

Take the time to learn more about probing and its effect on your measurements, your system, or DUT. As a rule of thumb, use the best probe that you can – ideally, match your SL1400 with a Yokogawa probe and accessories. Keep your best probing tools handy and organized so that you will not be tempted to take inappropriate shortcuts when making measurements and remember to include *all* probe information into your test procedures, leaving nothing to chance.

### *About the author*

Barry Bolling is an Application Engineer for Yokogawa Corporation of America. During his twenty years in the electronics industry, Barry has served in a number of capacities in the areas of RF-Analog design and verification.