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Opinion: Your logic analyzer *can* probe those forgotten signals!

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Logic analysis is a powerful tool. However, the most powerful logic analyzer is useless without a sound probing connection to a system under test. If you approach the problem carefully, you'll find that you can even probe "forgotten" signals.

By Brock J. LaMeres and Kenneth Johnson, Agilent Technologies Inc., Palo Alto, Calif.

Logic analyzer probing can be classified into two groups. The first group consists of the signals that were "designed in." This means that signals that are to be observed were intentionally routed to a logic analyzer connector. These signals are then easily probed using a standard logic analyzer probe.

The second group of signals consists of the "forgotten signals." These are signals that weren't brought out to a connector---but still need to be probed for a successful logic analyzer measurement. Until recently, these forgotten signals were a headache.

In most cases, a messy rework was needed to gain accessibility to them. If that was impractical, elaborate work-arounds were created to make measurements without these signals.

In either case, compromises had to be made in either bandwidth or triggering, and the measurement that was ultimately taken wasn't necessarily what the designer wanted.

There Is Another Way

Today, differential flying leads make probing forgotten signals easy. Not only can signals be probed effortlessly, but full-bandwidth measurements can be made.

The key is to use flying leads such as Agilent's *E5381A* leads. Let's see how they can contribute to ease-of-connection to seemingly impossible-to-probe signals, looking at real world examples of electrical loading and performance.

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Some Basics

A differential flying lead set normally consists of 17 channels, with both differential and singled-ended capability. The probe has 17 individual cables, each containing the probe tip network.

This topology provides the maximum probing flexibility while still achieving full bandwidth measurements. This type of probe exists for use with today's modern logic analyzers.

Each of the 17 probe tips contains a *P* and an *N* node. For a differential measurement, each side of a signal pair is connected to the appropriate node. A standard differential measurement can then be performed by the probe (*i.e.*, P-N).

The probe is capable of measuring a differential signal swing of 200-mV at the tip network ($P=100\text{-mV}_{pp}$, $N=100\text{-mV}_{pp}$). Also, a typical probe tip has a DC loading of about 20-kohms. Capacitive loading depends on which accessory is used to connect to your target, but it can be as low as 0.9-pF.

Single-Ended Measurements

Single-ended measurements can also be performed with these flying leads. You only need to connect the *N* node of the probe to ground. At this point, a user-defined threshold in the analyzer can be set to the middle of the signal swing, and a single-ended measurement can be taken.

The probe is capable of measuring a 250-mV_{pp} single-ended signal. It should be noted that the *N* node of the probe tip must be connected to ground when using the *P* node for a measurement.



This is different from previous flying lead sets in which one ground could be used across all 17 channels. The reason for this constraint is to enhance the performance of the probe. The figure above shows an example of a differential flying lead probe.

Hands-Free Probing of BGAs

One of the most common problems you can run into is trying to probe ball grid array (BGA) packages. As systems become denser and circuit board layer-counts increase, more and more signals are only accessible at a breakout via pattern of a BGA package.

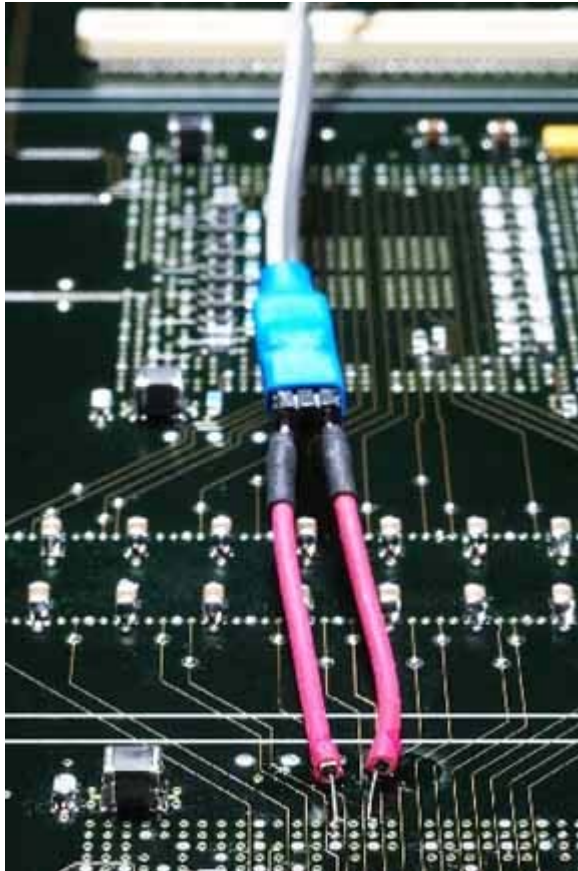
The conventional approach to probing these signals is to manually hold the probe tip on the via. This is very difficult, and not well suited for logic analyzer measurements that tend to be run multiple times. Using a damped wire solder-down accessory is the solution to this problem.

The damped wire accessory provides the most connectivity flexibility of all other flying lead accessories. It can easily

provide a probing connection to extremely small features on the target.

The damped wire consists of a damping resistor at the tip of the accessory. This isolates the target from the capacitance of the 1-in. wire. It also damps any reflections that occur from adding additional trace length to the logic analyzer probe.

The damped wire is flexible so that it can be easily handled during positioning and soldering. It's capable of probing highly dense signals, such as soldering to vias and exposed traces. In addition, it can take measurements at 1500-Mt/s with loading as low as 1.3-pF.



The figure above shows a damped wire accessory soldered to the breakout vias of a 1-mm-pitch BGA. The accessory (red) simply slides into the receiving socket of the probe tip (blue).

Hands-Free Probing of SMT

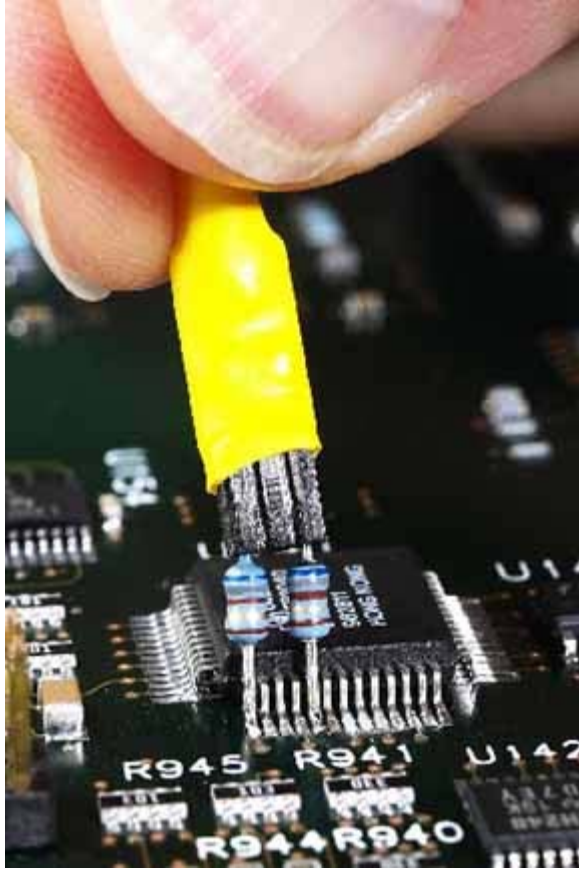
Another problem you can face when performing logic analyzer measurements is probing SMT (surface mount technology) components.

Again, the most common technique is to manually hold the probe on the component. But, this is difficult and requires that the probe be held on very small features.

A possible solution to this problem is to use coaxial resistors as the probing interconnects. The coaxial resistors (82-ohms) are inserted into the sockets of the flying lead tip after the resistor leads are trimmed to the appropriate length. The resistors are then soldered to the SMT components on the board.

The resistor isolates the target from the capacitance of the flying lead tip socket and presents a load as low as 0.9-pF on the target (depending on the quality of resistor used).

The figure shows an example of an application of the coaxial tip resistor as an interconnect. In this example, the coaxial tip resistors are soldered to the leads of a 52-pin QFP (quad flat pack), with leads on 0.025-in. centers.



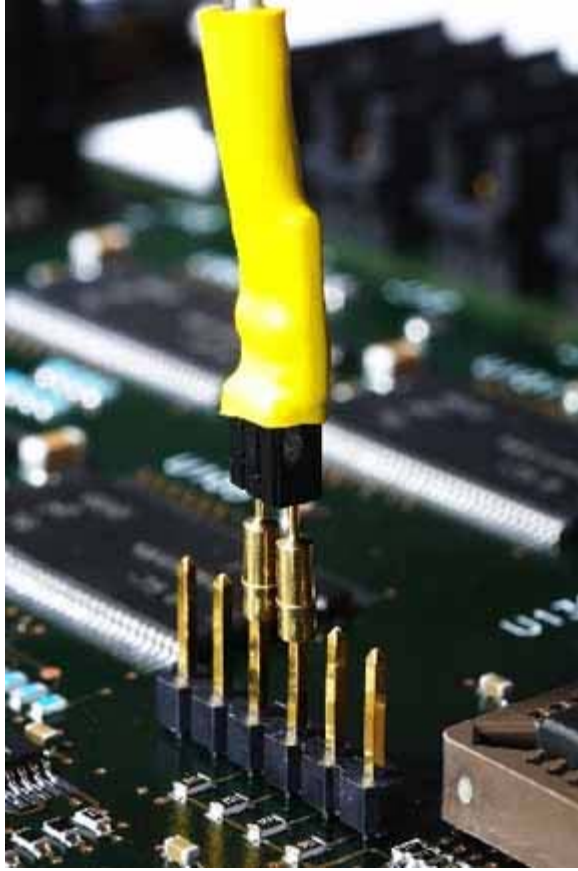
The coaxial resistor is able to make contact with an individual package lead without bridging over to adjacent pins. The illustration shows a closer view of the electrical connection.

Legacy Logic Analyzer Headers

Modern differential flying lead sets have a different sized socket as their tip receptacle. This socket provides the capability for higher bandwidth measurements. However, there will be situations in which an existing design has a traditional socket header on the circuit board that's used with legacy model flying lead probes.

For this case, an accessory exists that will convert the diameter of the older style pin (0.025-in.) to the new diameter (0.020) of the socket on the differential flying lead probes.

The figure below show an example of using a socket adapter accessory. It shows how the socket adapters are inserted into the flying lead tip socket. They're then placed over the existing 0.025-in. pins on the target.



Electrically, this connection (including the original 0.025-in. pins) presents only a 1.1-pF equivalent capacitive load on the target.

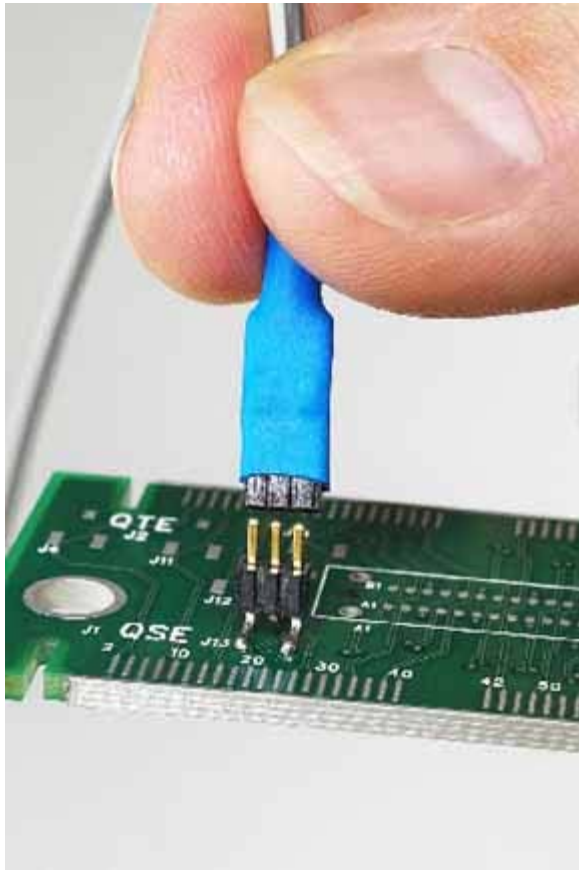
Designing-In Single Node Testability

The differential flying lead set can also be used when probing "designed-in" signals. This lets you design-in single node test points around your circuit board. To accomplish this, a 3-pin header exists that fits into the tip socket of the differential flying lead set.

The 3-pin header is for use as a conventional SMT connector. It's loaded on the target board at various locations around the board. The differential flying lead can then be plugged directly onto the header.

The 3-pin header provides a more mechanically robust connection over the solder-down approaches. However, it still gives the flexibility of spreading individual probing points across a large area on the target.

The figure shows an example of using the 3-pin header. You can see the 3-pin header on the target board, and how the probe tip connects. Electrically, the 3-pin header accessory (including the surface-mount pads) presents only a 1-pF equivalent capacitive load on the target.



So, there you have it. Logic analysis is a powerful tool that can assist you with system validation and speeding time-to-market. However, the most powerful logic analyzer is useless without a sound probing connection to the system under test.

In the past, when signals weren't routed to a standard logic analyzer connector, you were left with few options. If the signal was needed in the measurement, it was usually observed through a sub-bandwidth connection. This limited the measurement to lower speeds. If the signal could not be observed at all, you were left with a subset of the measurements that were needed.

With the invention of modern differential flying lead probes, all of these problems are solved. Logic analyzer users now have a full-bandwidth probing approach that's flexible and easy to connect. Digital designers no longer need worry about connecting to and achieving a full-bandwidth measurement of the forgotten signals.

About The Authors

Kenny Johnson received his BS in Mechanical Engineering from Kansas State University. He has been with Agilent Technologies (Hewlett-Packard) for 18 years as a manufacturing development engineer and an R&D project manager for logic analyzers and logic analyzer probing.



Today he's the product marketing manager for the company's logic analyzer probes. He holds six US patents related to probing. Kenny enjoys volcano watching, running marathons, mountain biking, skiing, and travel.

Brock LaMeres received his B.S.E.E. from Montana State University and his MSEE from the University of Colorado. He is currently a hardware design engineer for Agilent Technologies, where he designs high-speed printed circuit boards used in logic analyzers.



He is also a part-time instructor in microprocessor systems at the University of Colorado in Colorado Springs. His research interests include modeling and characterization of transport systems and high-speed digital design.

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