



BY HOWARD JOHNSON, PhD

Differential coupling

The best-performing, highest-quality, and likely also most expensive differential link you will ever encounter appears on the front panel of an Agilent differential-network analyzer. This spectacularly intricate piece of technology measures differential- and common-mode waveforms going through a test circuit in both forward and reverse directions. It is the gold standard for measurement accuracy when characterizing differential-circuit elements.

An ordinary network analyzer needs only two ports. The two ports make in and out connections to your test circuit. In operation, one port at a time emits a standard test signal while the other measures the received-signal level. The recorded gain, after correcting for all known losses in the measurement apparatus, equals the transmission gain through your test circuit.

The same apparatus also measures the input and output impedance of the test circuit. In that mode, one port at a time emits a standard test signal while measuring the level of signals reflected back from the test-circuit

interface. Reflection measurements are quite sensitive to delays and losses in the equipment cables. The cables must be carefully calibrated before making any kind of impedance (S11 or S22) measurements.

A differential-network analyzer works along the same principles, except that each port stimulates the circuit with either a differential- or a common-mode signal. Each port dis-

tinguishes the same types of signals at its point of measurement. Those features give the instrument tremendous flexibility in measuring all patterns of differential-to-differential or differential-to-common-mode effects.

If you expect the analyzer to provide data of utmost precision, the cables connecting the analyzer to the device under test must be of the highest quality. Obviously, they must convey differential signals with extreme clarity.

What kind of cables do you think the engineers at Agilent chose for their differential link? If you had to pick a differential-transmission medium that performed well beyond 20 GHz, what would you pick? Would you use a super-tightly coupled differential twisted pair, a quad configuration, or something more exotic?

Think again. Port 1 on the Agilent differential-network analyzer uses two single-ended coaxial cables. It is that simple. Port 1 stimulates the differential mode of transmission at your test circuit using two completely independent, totally uncoupled, not-even-near-each-other coaxial cables. Port 2 uses a second pair of coaxial cables, making four cables in all.

The coaxial cables are precisely

symmetric. They are also beautifully shielded and have very low loss. The system performance hinges on their extreme symmetry, not tight coupling. The engineers who built this equipment knew what they were doing. Differential links do not need tight coupling to work effectively.

The same theory applies to your PCB (printed-circuit board). The individual elements of a differential pair need not be pressed close together. They do their job, as long as they are symmetric with respect to the nearest reference plane and are precisely the same length.

If layout density is your greatest concern, then pressing the elements of each differential pair close together may make sense. Pressing them close does save space. To save that space, however, you must first determine how skinny to make the lines to attain the correct differential impedance and deal with the inherent manufacturing uncertainties of making tiny, thin PCB traces.

On the other hand, if density is not a great concern, then leave your traces relatively widely spaced, as you would any ordinary traces on the same board. Control crosstalk by pushing other traces far away. When you change reference planes or go through package or connector boundaries, make sure the traces of each pair are skew-aligned with respect to the receiver.

With these simple rules, your traces may not perform as well as the highly vaunted Agilent differential-port interface, but they will do as well as any other differential traces ever laid on a PCB.**EDN**

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