Frequently asked questions — Controlled Impedance

Controlled impedance traces have started to move from purely specialist applications into more common-place use during the last few years. Here are some answers to questions most frequently asked of us.

1. Why do designers increasingly specify controlled impedance?

Telecommunications and computing equipment are operating at ever increasing speeds and switching rates. Because of this some of the laws of physics which could be ignored at lower frequencies now have to be given serious consideration. At high speeds PCB traces act as transmission lines and the electrical energy can reflect back and forth similar to a wave on a lake when it meets an obstruction. Controlled impedance traces are designed to minimize electrical reflections and ensure an error free transition between the PCB track and interconnections.

2. I have some PCBs where differential impedance measures 8 to 10 Ohms higher than predicted.

Closely spaced differential traces on woven glass reinforced substrates such as FR4 may have a resin rich area between the traces. This resin rich area has a lower E_r than the bulk material. When using glass reinforced laminates you will need to compensate the E_r possibly reducing it by 0.4 to 0.8 depending on trace separation and laminate composition.

Remember in FR4 Glass, E_r is around 6 and resin E_r around 3.

Non-woven and aramid reinforced substrates will reduce or eliminate this effect. See AP139 for more details.

3. Si6000b has a bug in the stripline structure — when I invert my structure the impedance changes.

You most likely omitted to take trace thickness into account! For example If H is 15 and H1 is 10 and T is 1, a common arithmetical error is to assume that by inverting H1 is 15 – 10 = 5. The correct answer is when you invert H1 is equal to 15 – 10 – 1 = 4. Take this into account and the Si6000b gives you the correct value either way you model the structure.

4. How do I calculate dimensions of controlled impedance tracks?

IPC D 317 has some basic equations and a number of calculators are available on the Internet. Polar's Si6000b controlled impedance design system has been designed to extend the usable range of dimensions to suit modern fine line designs. Si6000b software uses advanced field solving methods to achieve this.

5. My customer says I need to test their PCB's at 900MHz. Can I do this with a TDR based test system?

Yes, a TDR based impedance test system is suitable for testing over a wide range of frequencies. The parameters that determine impedance (laminate E_r) do not vary significantly below 3 to 5GHz. So it is unnecessarily expensive and time consuming to do a single frequency test using a network analyser. You can see how impedance is likely to vary by plotting E_r against Z_o using laminate manufacturers tables for E_r vs Frequency.

6. Some impedance test systems are available with different impedance probes. Do I need a probe to match each impedance that I am asked to make?

When using a TDR you need to test on the flattest part of the test trace. It is perfectly acceptable to use a 50ohm probe in all cases and allow enough distance for the trace to flatten before setting the test limits. In cases where you are forced to use a short test coupon, i.e. you do not have enough length to allow the trace to flatten out, try using a probe with an impedance value close to that of the track under test.

7. Why is it important to test on a coupon? Surely it is best to test on the actual pcb track?

Test coupons are ideal for production testing. They have convenient ground points close to the track under test and, importantly for stripline constructions, the coupons should be fabricated with internal planes interconnected. (Planes on the actual board are isolated and this will affect the TDR reading.) You can only get a true reading on the board itself when it is fully assembled with supply decoupling capacitors in place.

8. Why is the interconnection between test probe and coupon so important? And would it be possible to use a test lead to allow the ground to be connected more easily?

Controlled impedance measurements are only accurate when the test system is itself a controlled impedance system — right up to the end of the probe! Poor interconnection i.e. long ground leads or coils of wire will cause reflections which will reduce or invalidate the reading from the track you are attempting to measure. A wide variety of probe footprints are available, and for occasional use there is an adjustable probe IP 50-V.

9. A small but increasing number of boards use differential structures. How do these differ from ordinary single ended structures such as a microstrip?

Differential structures are sometimes used to interface to telecoms cables, for example "twisted pair". The differential configuration of cables and structures is used because of its ability to maintain excellent signal quality in areas of high electrical noise — without the need for excessive amplification. Explained simply, at the start of the cable the signal is transmitted into one side of the pair and at the same time it is inverted and transmitted into the other side. As the signal travels along the pair of cables (or traces) any electrical noise which appears on the cable is identical on both sides (i.e. not inverted). The receiver simply subtracts the incoming signal from the PCB or cable and the noise cancels out and the remaining signal is a high quality reproduction of the original.

10. My customer has asked me to produce boards with 100 ohm tracks at a tolerance of ±0.5 ohm. Is this a realistic request?

Not really — measurements at high frequency are not as easy to make as those you would using a DMM for DC conditions. RF engineers are pleased to achieve a match to within a few ohms. Typically 50 Ohm traces have a tolerance of around 5%, 75 Ohm around 15% and 100 Ohm as much as 20%.

11. How is an impedance test system made traceable?

Reference impedance standards are not commonplace. Polar uses Maury precision microwave air lines — in effect a highly accurate mechanically stable coaxial "pipe". These precision air line standards are regularly calibrated by a national standards lab (NIST or NPL). The lab calculates the impedance by measuring the internal dimensions using air gauging techniques and then mathematically calculating the true impedance.

12. What is the frequency of the pulse on the CITS?

The CITS500s uses the technique of Time Domain Reflectometry (TDR) which involves measuring the electrical reflections from a very fast step pulse. In practice a sequence of fast pulses and samples is used to build up a waveform.

The fast step can be shown by Fourier Analysis to consist of a range of frequency components. Therefore when you perform a TDR measurement, with a CITS500s or any other TDR instrument, it is not done at a particular frequency but over a range of frequencies. On PCBs the main frequency related influence on Z_o is the E_r of the laminate; Z_o varies as 1/root E_r, so you can see how Z_o is likely to change with frequency by graphing Z_o vs E_r using the Si6000b (you can do this on the Si6000b demonstration edition using a surface microstrip field solver).

13. My CITS occasionally has a lot of ripple on the test trace. If I test again the ripple has disappeared. What can cause this?

Check that you don't have a mobile phone or other wireless device close to your CITS or RITS.

Microstrip test coupons are a similar dimension to a mobile phone antenna and will 'receive' signals from your phone. Even when you are not making a call, mobile phones will regularly transmit and sign on to the nearest base station. This will cause a CITS (or any other RF test system) to make erroneous readings.

14. Stripline traces measured on a coupon are always a few ohms high — why is this?

Check that your fabricator has remembered to short the V_{cc} and Gnd planes on the coupon (NOT ON THE BOARD!)

If the trace is differential see also Question 2.

Shorting the planes on the coupon simulates the actual RF conditions on the finished assembled board.

15. When measuring differential traces there is a significant difference in the reading if the coupon is measured from the opposite end — why?

Measure each line as a single-ended line. Do the impedance of the lines differ? They shouldn't — differential lines need to be matched in impedance, sometimes this is not easy on fine line traces. CITS500s V7.90 and above software allows you to make an automatic check for line imbalance.

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