

Impact of Switching on ATE Measurements

White Paper

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When designing an automated test system, there are few things other than the instrument selections which will have a more profound effect on the System's overall performance than the switching selection. One of the biggest obstacles in correcting switching problems is that it is so integrated into the design of the system that once a problem is discovered, it's so time consuming and costly to fix, that more often than not it is left in place and the test system never lives up to its true potential.

Below is a list of some of the most important considerations when designing or implementing a ATE switching system. It's equally common for a group to put together a great switching plan, only to have someone implement it incorrectly in the test programming. The latter problem is more addressable than the first, but cost and schedule will surely be impacted.

Noise – one of the more insidious problems in test system design. ATE test benches are electronically filthy environments. There are instruments from a variety of manufacturers, each having its own internal power supply. If it's a high performance instrument like a spectrum analyzer, then it probably has a high quality electrically quiet power supply. On the other hand if the device is something low cost like an Ethernet switch, then it may come with a cheapie wall mount power supply with no ground connection and a very noisy internal design. There are also rack cabinet fans and instrument fans. Then the big power consumers like AC and DC power supplies. Some are quieter than others. The list goes on and on.

A wise old test engineer told me long ago that you should do your best to make the device you are testing believe that it is operating in the environment it was designed for. There's a lot of truth in this advice that applies to many aspects of testing. Here's a simple example to illustrate my point. The test engineer needs a 28 VDC supply, so he goes out and finds the quietest supply on the market and uses it to test his device. The device will later be placed in an aircraft with an extremely noisy 28 VDC supply. It turns out the device had a fault in the filtering circuit which was not found in the ATE because it was never stressed. In this case, a noisier power supply in the tester might have uncovered the problem.

The same goes for the wiring and cabling. It's best to match the type of wiring that the Unit Under Test (UUT) will be connected to while in service. Giga-tronics ASCOR founder Jeffrey Lum correctly points out that the switching system becomes part of the cable assembly. Think about any particular path from the UUT through the switching system to the measurement instrument. Would you build a connection path that starts out as coaxial cable, then transitions to single conductor wire for a few feet and then back to coax cable again? Of course you wouldn't, but many engineers bring coaxial cabled signals to a switch card that isn't shielded and the familiar problems result.

Many of the Giga-tronics ASCOR switching cards have shielded relays on them and it's important to use shielded switch cards for shielded cable applications. Yes, you may need several different types of switching cards in your test system, but that's why we make so many available. Switch cards are not "one size fits all".

Bandwidth Limitations – this can be particularly important, and also poorly understood. We are seeing many customers with high speed serial data needing to design a switching system. The really tricky thing here is to ignore the data rates. Wait, did he say ignore the data rates? Well, let me explain. The really high bandwidth components of these digital signals are in the edges. It takes very high frequency components to create a fast rising edge. If you were to run your signal through a low pass filter, the edges would all slow down.

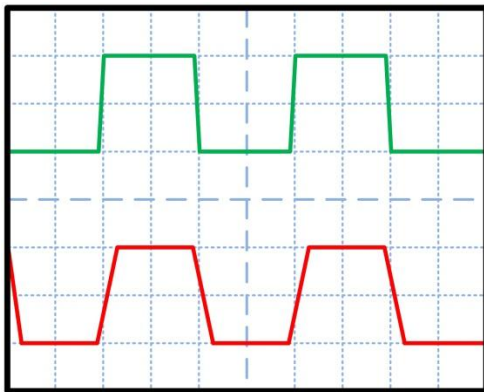


Figure 1

Let's look at an example. Suppose you have a data signal with a 10 MHz PRF, and 100 ps rising edges. To find the required bandwidth we use the formula:

$$BW = 0.35/T_r \text{ (where } T_r \text{ = the speed of the rising edge)}$$

In our example then, the required BW is $0.35/100 \text{ ps} = 3.5 \text{ GHz}$. That's a lot of bandwidth for a 10 MHz signal and those microwave switches are really expensive. My boss will not be happy because I didn't include this in my cost estimate. Suppose I ignore this problem and use a 50 MHz switch. After a little algebraic magic, the formula

becomes $T_r = 0.35/BW$ or $0.35/50 \text{ MHz} = 7 \text{ ns}$. This is the fastest rising edge that will pass through the switch card. This is quite a bit slower than the 100 ps you wanted to measure. Don't forget the cables either. They need to be able to pass the higher frequency or the same effect takes place. It's like passing your signal through a low pass filter. The data is still there, but the edges look a lot different.

Measurement Uncertainty – isn't this an instrument function? How can switching add to measurement uncertainty? Well, everything in the path adds to measurement uncertainty to some degree. The question is: is it negligible or not? I would say in many cases it is. The fact is that switches have contact resistance and that contact resistance is different every time you close the switch. Sometimes that matters and sometimes it doesn't.

In the situation where you are using high impedance DMM to measure a voltage through some switches, then it probably doesn't matter very much. However, in the case where you have a power supply passing through some high current relays and you are measuring a voltage drop to calculate current, then the closed resistance value of those relays can have a significant effect on your measurement. If that amount is not included in your test tolerances, then you are probably going to have a test that becomes intermittent at some point or another.

The most glaring example and one often ignored is in high frequency RF & microwave switching. Ironically RF & microwave engineers are very used to dealing with insertion loss, because at those frequencies everything has insertion loss: the switches, the connectors and even the wire itself have measurable insertion loss. They are so used to it, they assume that they can just measure it and

subtract it out. This works if the insertion loss is consistent, but what if it isn't? Some RF & microwave relays have good insertion loss specifications, but have variations in insertion loss each time you close them while others give very consistent results. Suppose your switching path goes through five of the non-repeatable switches. This could cause an uncertainty of an additional dB or so. Probably something you will want to account for.

Grounding – often misunderstood and critically important. Shielding, ground loops and power grounds are different. Here's the important point for switching systems: Never connect your signal grounds to the other ground connections on the switch card. Remember, the switch needs to emulate the cable assembly, right? Do your cables have ground wires sticking out the middle? Of course not. Now let me qualify what I just stated about the switch card ground. If the ground on the switch card is connected to the switching system's ground, then don't connect it. All of the noise and voltage offset on that system ground plane will now be flowing through the shield of your cable. If the switch card has an isolated signal ground plane, like the Giga-tronics ASCOR cards all do, then it will be electrically quiet and you can connect your shield to it and carry the shield through the card. Then connect the next cable's shield to it and you have a nice continuous shielded system.

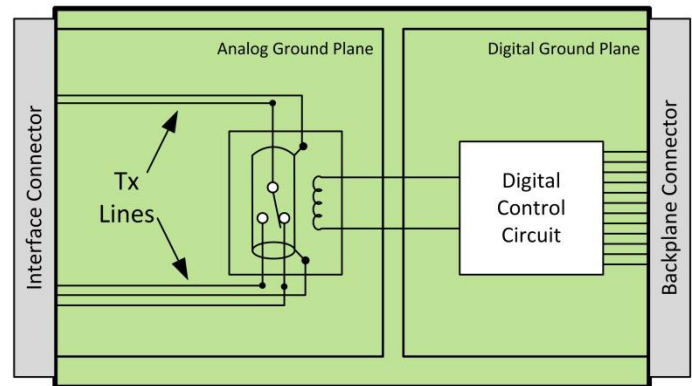


Figure 2

I also just skipped over a good illustration of ground loops. Suppose the switch card system ground is not isolated and you have connected your signal cable shields to it, even though I asked you not to. Now suppose there is some sinusoidal noise on that system ground plane with respect to the

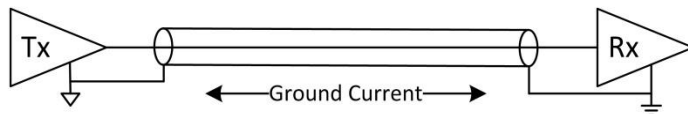
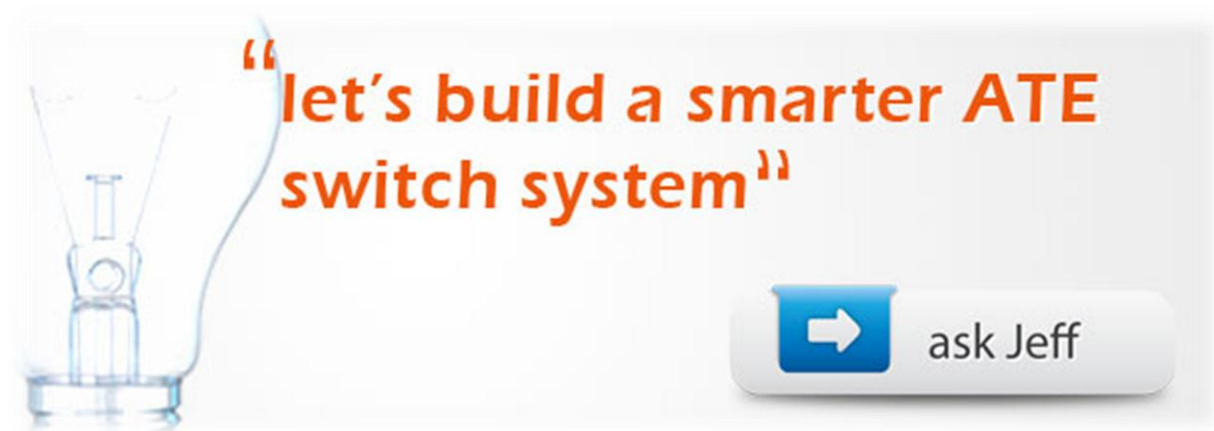


Figure 3 - Ground loop diagram

signal ground of your UUT. Well, now you have this sinusoidal current flowing up and down your signal cable and since it runs nicely parallel to your test signals, guess where it couples? Right into your signal which was supposed to be protected by the shield in the first place. Just like I mentioned earlier, consider the switch as part of the cable and don't create any new ground points that weren't in the UUT's natural environment.

Accuracy – While measurement accuracy is an instrument characteristic, accurate measurements can be compromised by the switching system. All of the issues we have discussed up to this point will affect your ability to make accurate measurements. You must guard against the tendency to think of the switching system as this black box where signals go in one end and magically come out identical at the other end. The switch becomes part of your UUT's environment. Remember my earlier statement about making the UUT believe it's in its operating environment? You can't do that effectively if your switching system doesn't deal with the preceding issues. In order to effectively cancel out the errors, you need to know what they are, and what their repeatability is likely to be. Do your best to eliminate the ones you can, and compensate for the ones you can't.



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