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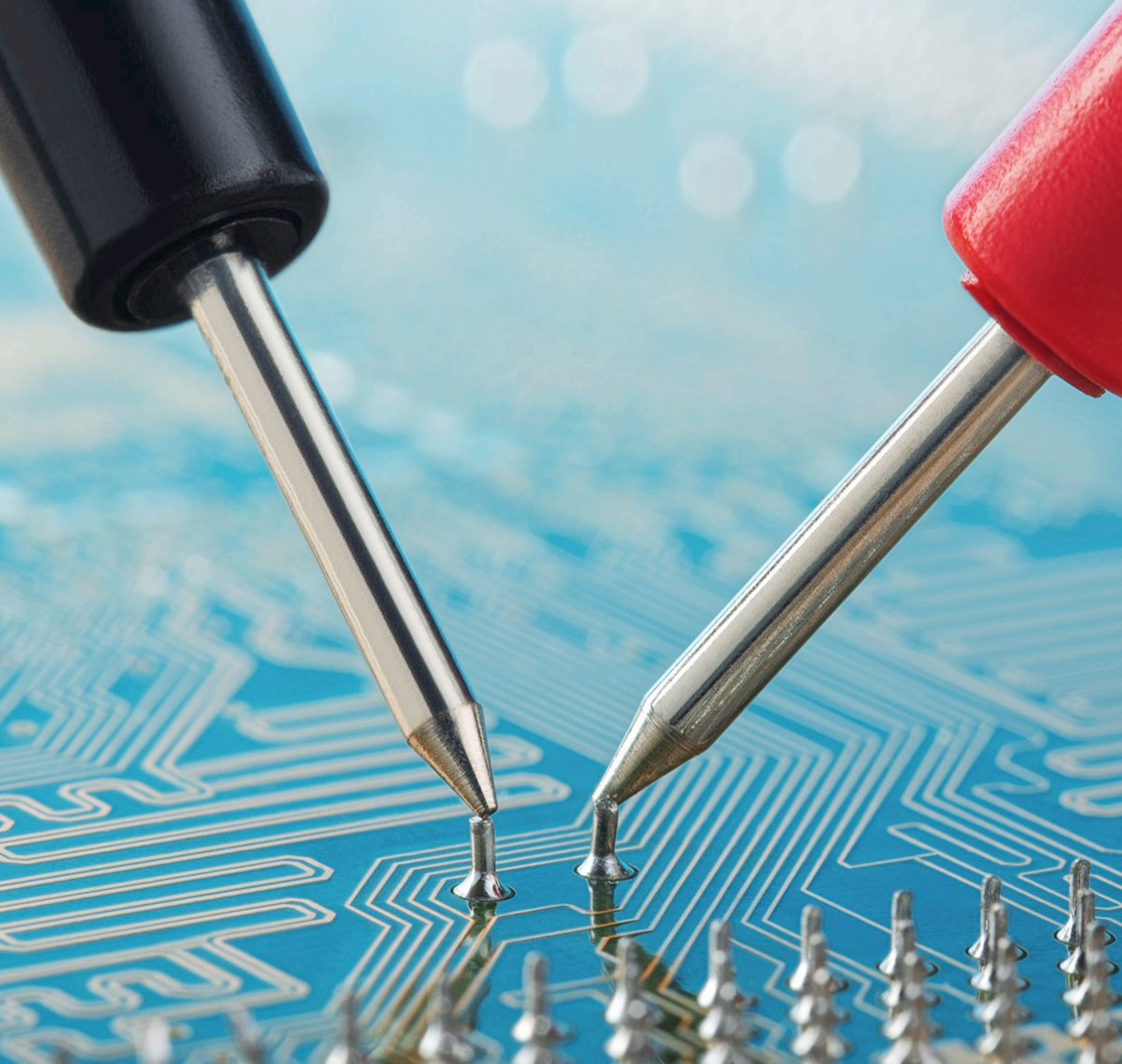

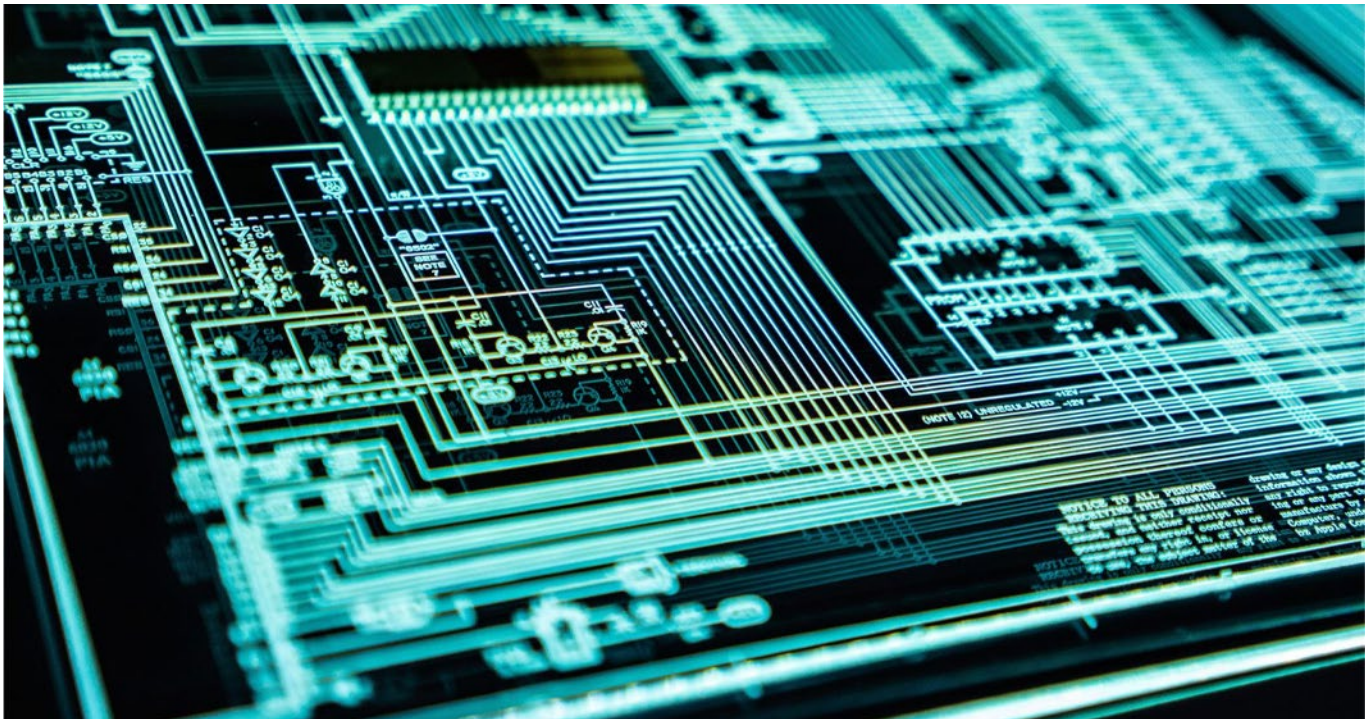

Test and Inspection: Far Beyond Opens and Shorts

Feature Interview by Andy Shaughnessy and Happy Holden
I-CONNECT007

Gardien Vice President Todd Kolmodin talks about test and inspection market drivers from his perspective as a test service provider. Andy Shaughnessy and Happy Holden go down the "microvia rabbit hole" with Todd, as well as explore how OEM design requirements are driving test and inspection functionality and processes. When board layer counts and feature densities force longer test times, the tradeoffs to profitability for manufacturers become time and accuracy. Minimizing time while maximizing accuracy calls for new methods, which Kolmodin explains.

Andy Shaughnessy: Todd, will you give us an overview of test and inspection?

Todd Kolmodin: We're seeing that the way to compete right now is bundling. In test and inspection, you have requirements from a customer now that are far beyond just what I need to test the board for opens and shorts.

When the requirements now come in, we want the open and shorts. That's the "throw it on the table" given. But then they say, "We have some buried passives, some impedance, then some buried inductives, and HiPot; we have all these things that are added on there. Maybe they've moved into high voltage design. They want 4-wire Kelvin high-resolution testing. They want buried resistive testing because the Ohmega™-ply layered technology has really matured, and a lot of people are doing it. We test both in sub part innerlayer or final and we can figure out internal matrices of buried series resistance, parallel resistance, and combinational resistance.

We have integrated multiple tests into the same equipment and it's a way we can stay competitive and provide a one-stop test service or quality assurance service without having to buy all kinds of equipment. There are people buying grid testers and flying probes and then you're buying TDR equipment and machines for doing inductions and such like that. That's how we're seeing it.

Shaughnessy: What do you see going on with test and inspection? The good, the bad, the challenging?

Kolmodin: We're seeing more requirements from some of the manufacturers and that has forced us to invent ways to do things differently. Some of our equipment now can provide the TDR, the standard test, the buried inductance testing, buried capacitance testing, and buried resistive testing all on one machine so you don't need a lot of other equipment. You have to go this way to stay competitive because you can only cut your margins so far; after a while you won't compete anymore and you still need to pay your employees.

We are seeing some onshoring again. We are seeing a lot more of the hotshot stuff under ITAR agreements, and some of the military applications. Overall, I think we're getting stronger again but the function for success is definitely automation. I'm speaking for test in general, not just us.

Happy Holden: Todd, are you testing bare boards or assembled boards?

Kolmodin: With very small exceptions, it's all bare board level.

Holden: So, the test is getting more complex because the printed circuit itself is getting more complex with newer technologies?

Kolmodin: Exactly. Your standard 8-, 10-, 12-, 16-, and 20-layer boards—we see them up to 30+ when you get into backplane. These engineers figured out some time ago how they can bury certain components in the board using different types of material.


Todd Kolmodin

The problem is when you have some of it buried in the board and some buried components behave like electrical faults. As a resistive network, it could be higher than the continuity threshold required. Similarly, if you have capacitance built in, you could get charge time and leakage which will screw up the results of a standard test. You must be able to provide both tests in one session. It gets tricky.

Holden: I don't think a lot of designers realize that the very fast opens and shorts testers are not necessarily measuring any kind of resistance. They have a relatively large window to differentiate an open from a short.

Kolmodin: The standard electrical testers, be it a fixture tester or a flying probe, have metering systems and you tell them this board generically—for the basic opens and shorts test to make it easy—is I have this many networks and an endpoint-to-endpoint resistive value that should not exceed 10 ohms. It then measures, and if it's over 10 ohms, you fail. It's the same thing with leakage; no networks or adjacent networks should have any leakage. The isolation between the two should be 10 megohms or higher. If it's less, that's considered a leak.

We're adding different metering systems. You might have one machine that has three different meters—one for doing standard opens and shorts, one to do inductance, and one to do capacitance. Right now, you can't buy a machine off the shelf that can do all that. We're working on integrating that into a machine so all the meters are there and it does it all. As an equipment supplier, you've got to be there because otherwise you're going to have problems competing later.

Shaughnessy: Do you typically start off working with the OEM or an EMS provider?

Kolmodin: Usually the OEMs are going to contract to the manufacturers. I'm not saying that we don't interface with the OEMs but a lot of times we're the third one down the line. There's always a strong communication line between us and the manufacturer.

Shaughnessy: Interesting. Some companies just don't really have a test strategy. They think it's expensive but the potential is there to save you from blowing a lot of money downstream. How do you convince someone of its value?

Kolmodin: The question is: Are you adding value to the board? We're not necessarily a value add but an insurance policy. Nowadays nobody wants to skip tests because there's too much involved in the manufacture. We're not talking double-sided or four layers anymore so it's really not cost effective to skip test because rolling the dice can be extremely painful.

When we talk to a customer, we ask them about their cost of test, and it's remarkable to discover that some have no idea. They have a test department, but they have no idea what it costs, or they have a very incorrect idea of what they're doing. That is a challenge for us to make our case for value add or ROI.

It's important for manufacturing products such as plating lines, presses, and drills to stay current with the technology. I'll see someone force a board into an antiquated or semi-obsolete test department and wonder why it stays there for three days because they can't get it tested. It's a good argument for paying someone to take that headache away, someone who already understands it. It's about outsourcing vs. not outsourcing. Some manufacturers love the idea because it takes all that capital and headache away. Others feel they can do it better internally, so that's just the way it works.

Shaughnessy: We hear in our surveys and interviews that, especially the designers, are being told you should own the design. Others say, "Well, not really; it's not my problem necessarily."

Kolmodin: That's the challenge electrical test has had for years because what happens is the designers prepare to design a board, they have a system and components, and they lay it out. But they don't have a sense for what will happen, what pain points the manufacturer will have, or what costs will be associated with their requirements. And then there's test as well.

My argument is this: "The technology is available to improve your design. It may have some finite restrictions on it and may impact the cost of your final board or the ability to perform all the requirements that you have." The disconnect has been between designing at the OEM side and manufacturing and test. I think a test strategy needs to have multiple groups involved. Obviously, the ultimate solution is to have the test guys and OEMs in the same group so there's that understanding of manufacturing and test and measurement; otherwise, you have those disconnects as you go forward.

Shaughnessy: What advice would you give designers regarding tests? What are some of the common problems, and what should they do or not do regarding DFT?

Kolmodin: If they have a manufacturer, they definitely should get feedback on capability.

From the manufacturing side, they need to have information from their test and measurement group on how to feed that back to the OEM so the OEM knows, "We can't put 10.5 micro packs in this area back-to-back because there's no way in hell we're going to be able to test it." That type of feedback is the most difficult.

You would have to create a test pass one and a test pass two which gives you 100% coverage, but the drawback is time. Instead of four hours in tests, now we need a day as each board needs two passes because they are not designed to test quickly. Meanwhile, downstream processes want the board "right now."

If designers want a signature analysis from a buried resistive value in an innerlayer, they need to port that signal on the surface of the board where it's accessible. Otherwise, it either must be tested at the innerlayer level or sub-part level, which then increases the cycle time of manufacturing. If they put an IO to it on the outside of the board, it can all be tested at final, which can be a very good time saver, but the drawback is that when you wait until the end and you have a problem with a buried network or something similar, you can't fix it.

Shaughnessy: Are you seeing AI in the tools? Do you think it's going to have a bigger role in test and inspection?

Kolmodin: I see it with robotics—load, unload, things like that. But I think there's a place for that in there. It's still rudimentary, but the way our flying probers measure and remember—it's not so much a science-fiction world anymore. It's not just the PCB industry, but other industries also going in that direction. I do see a place for it in the future.

Holden: Have you seen more requests for high voltage, especially where we're thinking about the automotive prototypes in electric vehicles in which the boards are going to be under 800 volts or higher?

Kolmodin: Yes. The military has a high-voltage test which represents much of their power supply stuff. We see insulation resistance test which is basically a high-voltage test on certain networks or planes on the board. It's usually high-voltage networks.

It's similar to HiPot, but not the same. HiPot test applies a voltage, ramps it up to 500 to 1,000 V or higher, then holds it at that voltage and looks for leaks. Insulation resistance test is where we look at two planes, maybe two networks, and we do the same thing. We ramp it up to 500 or 1,000 V, or we see 3,000. It's doing the same thing—holding that voltage high—but it's also making sure that the insulative resistance between the two networks is at a value or higher, just like an isolation test in circuits. It's just a very high-voltage isolation test called IR. If you had asked me the same question five years ago, I would have said we don't see that too much, but we are seeing it now. HiPot has always been around, but this high-voltage insulation stuff? We see it a lot and we should incorporate that into a test where we're doing our standard opens and shorts test.

Holden: Have people been requesting micro-ohm measurements when they have stacked vias?

Kolmodin: That's the 4-wire Kelvin test that we do. The theory behind it is easy. You put a probe on two sides of a via and you measure it. The problem is when you've got stacked vias and sub parts; copper will give you a resistance per inch, like 9.81 ohms per inch or so, theoretically. But we're dealing in micro- and milli-ohms for resistive values if it's a microvia stack.

Holden: Are you seeing increasing requirements for tighter TDR measurements? Some of the military guys, because of the new ICs, want TDR measurements within 2% of the window, rather than 10%.

Kolmodin: Ten percent is standard for us, but we see it down to the 5% range at times. Even the standard 10% is not really sufficient. We see some of the big OEMs come down to 5% tolerances. For us, it's not a big thing. The machines can do it, but the real challenge is at the manufacturer. For example, the military

guys say, "We want it 5%," and the manufacturer can't get there. For print and etch, it must be right on the money, or you won't get that impedance.

For every percent change it's an order of magnitude of accuracy you have in the process. You're getting down to micro-pixel strength on your photoplotting and etching. You're probably having to get down to laser etching to get 2%.

Holden: Have they solved the problems with OSP so that it doesn't foul up the probe tips?

Kolmodin: OSP is one of the most difficult finishes out there; the main way to get around that is to test before OSP. Otherwise—even before flying probes, even with grid testers or fixture testers—trying to probe a pad with organic coating on it is an absolute nightmare. Usually, you won't get through it and you will have overflow opens and all that. The best thing is to get it from the process prior to OSP in the test, and back into organic coat before you start oxidizing the pads. If the organic coating is to be applied, the best way to test is after your critical process or measurements are done. I don't know a way around that one, really.

Holden: When I was at HP, we were not getting test probes on the surface or test pads, so we came up with a bead probe, which is just expanding the trace and putting solder paste on it so your probe could have a place that wasn't covered with solder mask and didn't affect the electrical impedance. If you have accurate flying probe or bed of nails, you could probably hit these small pads in traces.

Kolmodin: It was a challenge back then. But now that you mention it, when designers decide to use wire bond, direct probing is out of the question. You can't do it. Tell a prober to hit it but after that you've basically destroyed the bonding surface no matter how light you hit it.

You must come up with another way. You must short out the wire bond area, and test somewhere else to check for continuity and shorts. But they would fan out something in the design level if you got wire bond, test IOs. Wire bond is common in some of that product nowadays, especially high-speed and flex, and that is something I would recommend to designers.

Holden: There's a potentially big uptick in electronics, which is good news for young engineers because there is plenty of job security. But the uptick means more complexity from the semiconductor guys and that doesn't necessarily make it easy for us.

Kolmodin: I agree. It has grown leaps and bounds in the 35 years that I've been in this industry. With the acceleration of that curve, I imagine the next five or 10 years will be pretty amazing.

Holden: Especially with electric vehicles. With electronics replacing all those mechanical transmissions, axles, and differentials, that's good news for fabricators and assemblers. But if you don't have the capital budget to keep up with it, that's bad news.

Kolmodin: That's where I ask about the value of in-house vs. outsource. Do you want to keep investing in capital, or do you want to bring in an expert team that's always on top of it all? It might be a few extra pennies here and there, but it sure saves you having to put multiple millions of dollars into equipment every three years, because the acceleration of this technology curve in ICs and printed circuits is faster than what you can amortize your equipment.

Holden: I had a testing challenge with some innerlayers using gold wire bond showing some shorts. Then we would laminate them, mark the boards, and send them out into assembly. Eventually these boards would be tagged and rejected, and we would run over to look at the card. They all said, "Too much time," which meant testing could not find the bad component and the time being spent on it exceeded the value of board. If we have a whisker short on the bare board and it's been laminated in, the tester can't discover it. To the test department, it's too much time. And too much time doesn't point to the actual problem on printed circuit board. It's a profit center decision.

Kolmodin: Right. We call that whisker a micro short. We developed an algorithm and technology with our equipment called micro short detection, which is basically those slimmer shorts on an innerlayer from a clearance to a plane or something like that. If you do your normal voltage test you will actually fry that thing. The tiny whisker will pop like a fuse but won't be detected as a short because it was gone so fast. The problem is that it leaves a metallurgical signature that could actually cause a latent short down the road, which is what Happy was saying.

Holden: Yeah, the data said that was just passing the problem down.

Kolmodin: Especially with the density and spacing that you have on these innerlayers. You've got metal there and you might burn it open for the moment but, left over time, heat, shrinkage, expansion, and some funky metallurgical stuff goes on in there where you can actually grow that short back. It's expensive from an assembly side when you have a $3,000 board out there that fails.

Getting a return is always bad news but a lot of times OEMs aren't going to spend the time to destructively analyze the board or remove a component to say, "Okay, we have to actually go down to a bare board level problem." They'll just send the board back to the manufacturer, marked as failed, and let the manufacturer's lab deal with it. But we do see some of the bigger OEMs and assemblers wanting root cause of analysis.

Holden: I think test will become a bigger thing with EV because I've found automotive to be far more critical about reliability and performance. If you have a single failure, you really have to jump through hoops to the root cause because they're worried about the warranty costs.

Kolmodin: Oh, sure.

Holden: If these things come back under warranty, that's a big expense.

Kolmodin: Just from a mechanical standpoint, we saw the horrors of the Takata airbag recall and that was huge. We're right at the time of year where the new model year comes out, so if they've got a component problem in a car, that's a huge recall, and that's big money.

Shaughnessy: Todd, thanks for speaking with us today. It was a good discussion.

Kolmodin: You're welcome. PCB007

Todd Kolmodin is an I-Connect007 columnist. To contact Kolmodin or read past columns, click here.