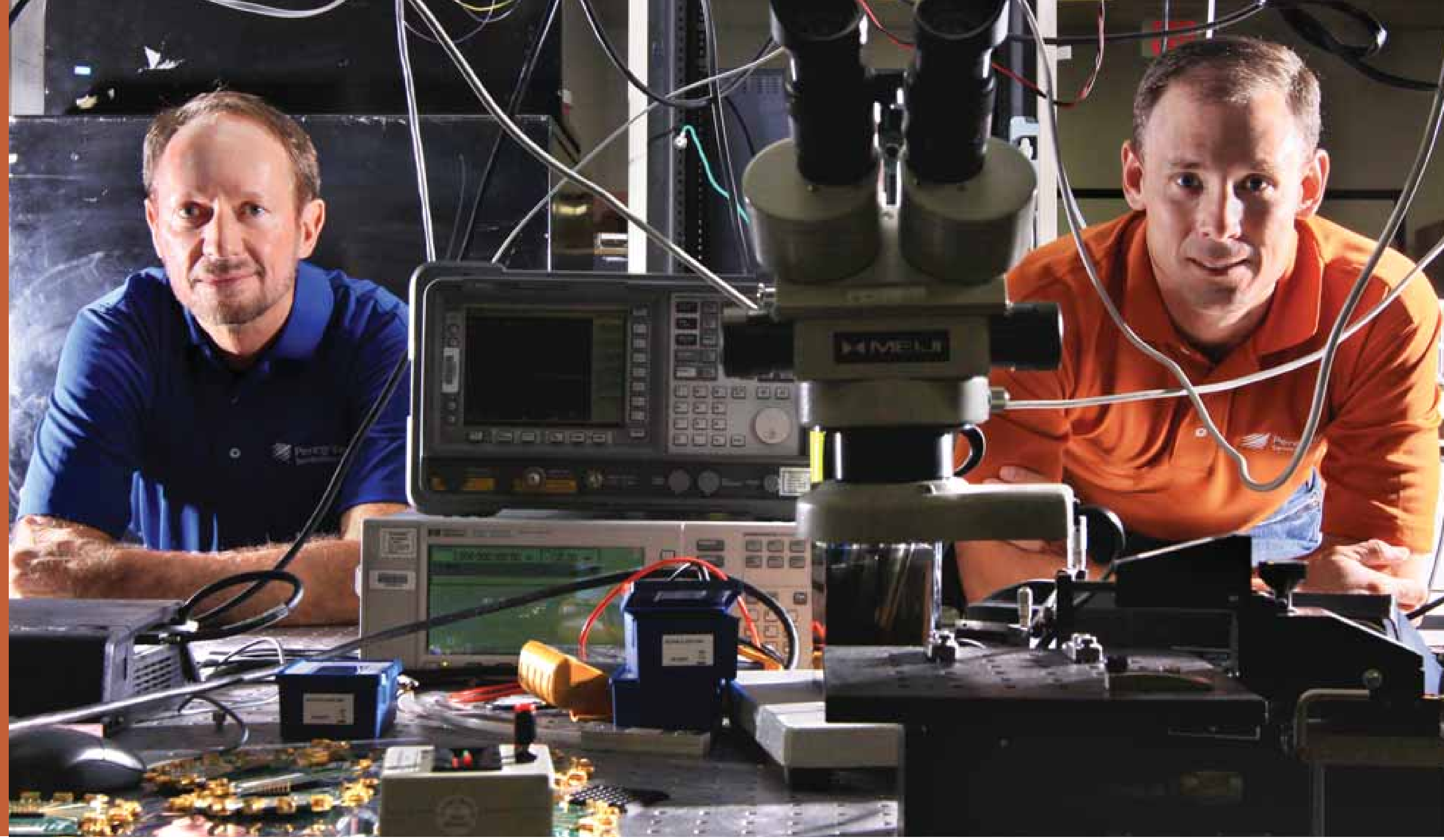
Engineers at Peregrine Semiconductor have developed unique measurement approaches to test the firm's line of RF switches, whose performance might surpass that of the test equipment in which they might ultimately find use.

BY RICK NELSON, EDITOR IN CHIEF



Bill Jasper, senior test engineer (left), applies his previous experience at a contract test operation to help meet his production test responsibilities at Peregrine Semiconductor. He is joined here in the engineering laboratory by Christian Steele, product development section manager at Peregrine, who is responsible for the characterization of Peregrine's UltraCMOS SOS switches and other RF components.

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TESTING THE TESTER COMPONENTS

San Diego, CA—Peregrine Semiconductor builds a range of RF switches and other devices based on its UltraCMOS solid-state SOS (silicon-on-sapphire) process, which integrates ultra-thin silicon CMOS circuitry on a dielectric sapphire substrate. The company's SOS devices operate beyond 10 GHz and at power levels greater than 40 dBm. They target applications ranging from high-volume consumer electronics to high-reliability test-equipment and military and aerospace systems.

For consumer electronics, Peregrine's devices find use in digital-TV, cable and satellite set-top-box, game-console, and cellular-handset applications. For these applications, Peregrine complements its switches with PLLs, prescalers, and mixers, thereby allowing Peregrine parts to make up a significant portion of an RF transceiver signal chain, for example (**Figure 1**). Rodd Novak, VP of sales, marketing, and business development at Peregrine, said the handset market offers significant high-volume opportunities, with the company's nine-throw switches going into pentaband phones. He added that the company ships 2 million of the devices per week.

In addition to making parts for consumer electronics, Peregrine offers a high-reliability lineup that meets the needs of test equipment, telecom infrastructure, and military and aerospace systems. The company also provides foundry services, offering process design kits as well as standard-cell libraries and IP.

The test-equipment market is a key one for Peregrine. And because the company's switches can be used in test equipment, the switches must deliver levels of performance that exceed that which can be economically and accurately measured by commercially available test systems. To overcome this limitation, Peregrine's engineers have developed unique approaches to perform device characterization and high-volume production test.

Christian Steele, product development section manager at Peregrine, said the company's parts can appear to be deceptively simple ones that would be seemingly easy to test. The parts tend to be low-pin-count, 6- to 20-lead devices, but he pointed out that when it come to measuring specs like linearity, the challenges immediately become apparent. "When we try to measure harmonics or IP3 [third-order intercept point] or the 1-dB compression point," Steele said, "it's very challenging and can't easily be done using traditional test techniques." Similarly, he said, insertion loss might be guaranteed within a 0.1-dB or 0.2-dB range from part to part. "If a typical max variation is 0.1-dB wide, the test equipment we are using to collect a distribution of data has to be very repeatable. That challenges our test capabilities and makes us rethink how we perform functions like de-embedding."

Mark Schrepferman, director of communications and industrial products at Peregrine, explained that the test challenges that Steele's team faces help Peregrine develop parts for the test-equipment market. Those parts include the PE42552 absorptive SPDT (single pole, double throw) switch, which operates to 7.5 GHz with a 1-dB compression point of 34.5 dBm and exhibits an insertion loss of 0.65 dB at 3 GHz (**Figure 2a**). Also for test-equipment applications, the company complements the PE42552 switch with the PE43703 7-bit digital step attenuator (**Figure 2b**).

Working with test vendors

Schrepferman said Peregrine gets valuable input on the evolving needs of the test market by working closely with ATE (automated test equipment) vendors as well as by sounding out

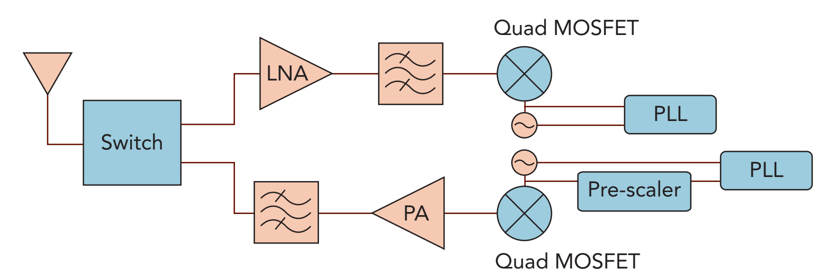
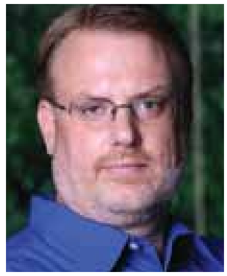


FIGURE 1. Peregrine Semiconductor complements its switch products with prescalers, PLLs, and a MOSFET quad array for mixer applications. The combination can make up a substantial portion of an RF transceiver front end.

Peregrine's test engineers. "Basically, with the current devices out there," Schrepferman said, "whether GaAs or standard bulk CMOS or mechanical switches or even MEMS [Ref. 1], there are a lot of limitations, and the more we interact with the test-and-measurement folks, the better we understand the limitations they've been up against for many years."

There are a lot of topnotch engineers in test companies trying to deliver a set of resources that can source and measure RF test signals (perhaps with a DC offset), and that requires a lot of switching and multiplexing, Schrepferman said, adding that the test-vendor engineers are able to design workarounds to compensate for the limitations they face, perhaps stripping out the DC component of a signal and then adding it back in. He explained that those engineers are very forthcoming in what their needs are, and this enables Peregrine to evolve its roadmap and develop the parts that can make such workarounds unnecessary. Peregrine, he said, works with its test customers on issues such as ground-placement layouts that can facilitate load-board design. Added Steele, "We see [engineers at test-equipment vendors] as strategic allies who put our devices through their paces."



Mark Schrepferman works closely with engineering teams at test-equipment vendors and finds that "Basically, they are all saying the same thing: They want higher-linearity, lower-loss parts that are repeatable and reliable and that settle quickly."

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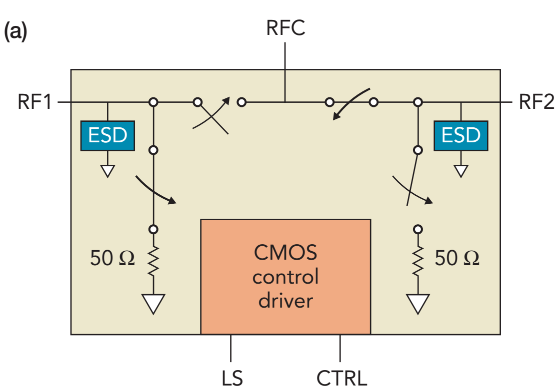
As for what these engineers want, Schrepferman said, "Basically they are all saying the same thing: They want higher-linearity, lower-loss parts that are repeatable and reliable and that settle quickly." That last point shouldn't be minimized. Test engineers, Schrepferman said, resort to hot-switching to avoid settling-time delays. "We found that with our technology, two of the things we do very well are high linearity, which is great because you don't want the components in your lineup tainting the signal you're trying to measure, and our settling time is much faster than GaAs."

When testing its own products, Peregrine faces different test challenges in characterization and production test. Steele focuses on characterization, and he noted that many people perform characterization with a big-box ATE system, a relatively quick approach that can simplify the development of production test programs. But, Steele said, "A big-box tester is not going to offer anywhere near the performance and repeatability we need to measure our parts. So, what we have had to do is design individual automated test systems that will measure one or two parameters in a very accurate, repeatable manner. Each part that gets characterized may go through four different stations as we measure harmonics, S-parameters, switching time, IP3, 1-dB compression point, and so on, with each station giving us the highest performance we can possibly get for one or two specific parameters, without being limited by ATE."

The multiple-station, multi-insertion approach to characterization is not practical for high-volume production test, but Steele said, "My group of characterization engineers works extremely closely with the production test group, because we have to understand what parameters to directly test in production and which ones we have solid characterization data on so we can guarantee them statistically."



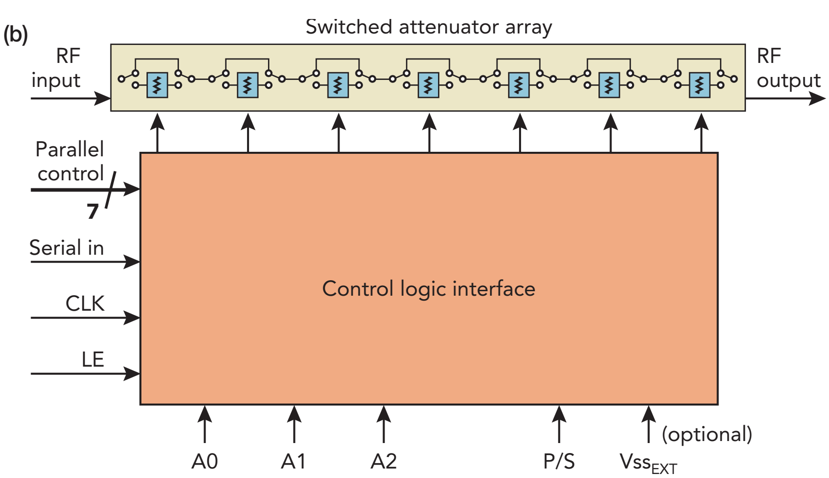


FIGURE 2. **(a) For test-equipment applications, Peregrine offers the PE42552 absorptive SPDT switch, which operates to 7.5 GHz with an insertion loss of 0.65 dB at 3 GHz. (b) Peregrine complements the PE42552 with the PE43703 7-bit digital step attenuator.**

Switching and production test

Steele said that when Peregrine started testing its products in production volumes, it needed to test parts with four to six outputs. But the expensive commercial big-box test systems that were available would have one or two sources and one or two receivers and would use electromechanical switches to route signals between the limited number of instruments and the many ports of the DUT (device under test).

"A lot of those mechanical switches have a reliability of very few switching events," Steele said, "often less than 2 million, and at the volumes we are shipping our handset switches we would be replacing very expensive mechanical switches every month, and that is a very expensive proposition." He cited a related problem: "Before a switch breaks, you also see a degradation in its performance with respect to its return loss and

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insertion loss. And that's bad for us because we are trying to measure low insertion loss in a very repeatable and consistent manner, and we don't want a test system to color our data.”

Bill Jasper, senior test engineer, worked for a contract test operation before taking on production test responsibilities at Peregrine, and he has a thorough understanding of the switching issues involved in implementing a production test system. “In a typical RF test problem,” he said, “You have a component like an LNA [low-noise amplifier] or mixer, and you've got a suite of tests to perform on it. But those tests often have contradictory requirements. For a noise test, for example, you don't want filters in the signal path, but IP3 or intermodulation tests require filters in the signal path. So you face this dilemma, and when you start building an interface to the DUT, you are invariably stuck with relays because of linearity issues. But relays are slow and unreliable, and I was always keeping an eye out for an alternative. And I eventually came across Peregrine. It made switches and step attenuators with linearity specs better than the parts I was testing, so I could easily mix those components in and switch in different filters and attenuation settings and get a very fast, reliable test out of it.”

The next-generation fixture

Steele said that while a few mature products are tested on big-box ATE, the majority of Peregrine's products run on the company's custom solution. He explained,

Rodd Novak says test requirements are becoming more challenging. “Four years ago,” he said, “we guaranteed 0.2-dB insertion-loss performance variations across devices. Our next-generation technology is pushing 0.05-dB variation.”

“Today, with our SP9T [single pole, nine throw] device, we have 10 RF ports on the product. If we want to do a dual-site test, we have 20 RF ports. What we have had to do is look at test solutions from a custom standpoint, and we decided to customize our own solution and build it for the testing we need to do, eliminating any mechanical devices and implementing a completely solid-state solution that lets us do a fair amount of parallel testing.”

Steele described the production test system, which serves for both package test and wafer probe to deliver known-good devices, as essentially a rack-and-stack configuration that includes an assortment of DC supplies, current meters, power amplifiers, signal analyzers, and signal generators. But at the heart of the test system, he emphasized, is a Peregrine-designed test fixture (**Figure 3a**) that routes signals between test-system instruments and DUT ports. He noted that the company has developed various fixtures through the years.

Building on Jasper's experience at his previous job, Peregrine has just designed its next-generation test fixture, which, Steele said, uses upwards of 50 Peregrine parts (**Figure 3b**). He emphasized that the Peregrine products are easy to use, requiring very few supporting components, unlike, for instance, GaAs devices, which require blocking capacitors, or PIN diodes, which require DC bias circuitry. The new fixture, Steele said, “will enable us to leverage faster test equipment, because our solid-state parts minimize settling time and switching time.”

The test fixture delivers amplified power to the DUT and provides return channels from the DUT back to the measurement instruments. “If you are measuring a nine-throw switch,” Steele said, “you don't want any switching events to interfere with your measurements—you want all dedicated measurement paths. But we also want to save the expense of power meters and spectrum analyzers, so we did a lot of custom design work inside that fixture to enable parallel measurement without switching events.”

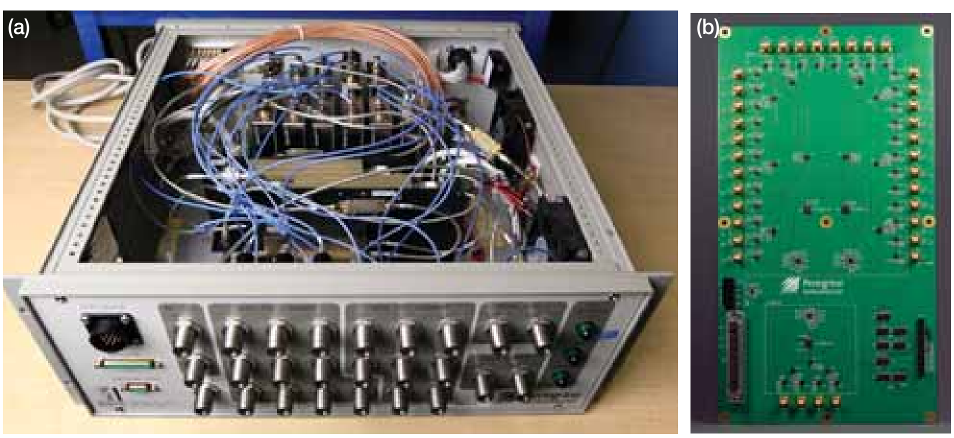

FIGURE 3. A Peregrine-designed test fixture is at the heart of Peregrine's test solution. (a) A hand-wired fixture will be replaced in the company's next-generation test system by (b) a board that uses upwards of 50 Peregrine components. Peregrine's engineers received the first new board in August and are integrating it into the next-generation test systems.

“We make switches”

In fact, Jasper said that when he arrived at Peregrine, the company was using a test fixture that employed a “very clever method of testing parts that required no switches.” The problem with this approach, he added, was that it didn't scale well as the company moved on to introduce nine-throw switches and 7-bit attenuators.

Steele elaborated, “When you've got 18 output ports to measure, it gets pricey to use 18 spectrum analyzers or power meters or downconverters, so we have to get creative.” Added Jasper, “The only way out of that was to use switches, and fortunately we make switches that offer the necessary performance.”

Test challenges are only increasing as frequencies increase and modulation schemes become more complex, Steele said. Novak added that test requirements are getting tougher as the technologies advance. For example, he said, “Four years ago, we guaranteed 0.2-dB insertion-loss performance variations across devices. Our next-generation technology is pushing 0.05-dB variation."

Furthermore, the tests have to take place at high power levels. Said Steele, "A lot of our products operate at high power—our mobile products are operating up around 35 dBm, and some of the commercial switches are going up to 40, with the 0.1-dB compression point around 45 dBm. So when we go to test those, we need to be able to hit them with their data-sheet power, and in a lot of cases in the lab, we need to go up beyond that data-sheet power. So, it gets challenging on how do you route these high-power signals to your DUT and make sure the test system won't inject harmonics that interfere with the measurement. How can we build a system that's got very pure signals going in and out of the DUT?"

To ensure accurate, correlated measurement capability throughout its test-equipment line-up, Peregrine has implemented six-sigma methodologies and performed extensive gauge R&R (repeatability and reproducibility) studies (Ref. 2). Those studies, Steele said, help to establish calibration procedures and ensure correlation among test systems and fixtures at Peregrine's headquarters and the many systems deployed at its Asian contractor. And the results of those studies, he said, have contributed to the development of the next-generation fixture and test system.

Steele said that to ensure R&R, the Peregrine engineers minimize test-system interconnects, keep load-board designs simple, carefully choose their instruments, and pay close attention to instrument programming to get accurate results fast. "Depending on how you set the equipment up, you'll get different answers," he said, "so we have to spend a great deal of time understanding the best settings for the measurement we are making, and then we will code that up" for use in the production test program. He added that they typically avoid using an instrument's preset measurement functions, saying, "A lot of times we don't let the machine use its own brain. I once had a mentor who taught me never to use preset. It will get you the answer, but it's not necessarily the answer you want. To understand how your equipment really works, you have to set it up yourself."

Steele said that Peregrine's engineers have developed fast, efficient test-execution techniques that have driven average test times down to under 1 s, adding that it's not uncommon to run off 50 or 60 different DC and RF tests in that time period. Jasper said the next-generation test system will reduce that time further, especially for the RF tests. And because test time is money, the pressure will be on, he said, to reduce DC test times as well. T&MW

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