NATIONAL INSTRUMENTS™

Automated Test Outlook 2018

A GUIDE TO SMART TEST TRENDS

MONITOR PLAN **ACT**

Why should I read this outlook?

We know your time is precious, so we made the 2018 Automated Test Outlook easier to consume. In addition to technology trends, we've given you the insights you need in fewer words with bulleted summaries. You'll also see commentary from industry peers and references to additional resources. Finally, we added an Urgency Meter (like the one above) to help you prioritize implementation of these trends for your organization.

A Note to the Smart Test Leader

From the initial rollout of 5G technologies to the accelerating race to vehicle autonomy, organizations need smarter test strategies to stay ahead of the competition. For more than a decade, NI has collected insights from top test leaders and made them available to you in our annual Automated Test Outlook. The trends, techniques, and information sources we've documented here will help you meet quality, time-to-market, and cost demands now and into the future. Thanks for reading, and don't hesitate to contact us if you'd like to learn more.

Eric Starkloff
Executive Vice President of Global Sales, Marketing, and Support, NI

Securing Your Test System

- Test systems, like other industrial equipment, are vulnerable to cyber attacks
- Apply a phased approach to cyber security, address the most likely threats first
- Communicate with suppliers to understand threats upstream in the supply chain

In today's digital age, a compromised test system can wreak havoc on an organization's reputation and revenue, but securing test systems is not so easy. If you want to secure your test systems but aren't sure where to begin, use the following three-phase approach to get started.

PHASE 1. Carefully Apply IT Practices to Test Systems

First, use data about breach trends to help you decide which IT security measures to adopt for your test system. This data equips you for conversations with IT security staff about the risk of test system compromise. For example, the 2016 Verizon Data Breach Investigations Report (DBIR) says hackers take advantage of the lag time between a vendor's patch release and the installation of the patch on a computer. Your vulnerability begins within two to seven days of a patch release for widely used software, but most test systems can't be requalified within that timeframe. To minimize your risk, remove unnecessary widely used software, enable as many OS security features as practical, and isolate test systems from IT networks.

Second, most test systems were not designed to handle dynamically quarantined files or high packet rates. Carefully assess the behavior of IT security technologies before applying them to test systems.

Third, supplement traditional IT security measures with test-system-specific security features to address risks unique to test systems. For example, given how crucial calibration data, test parameters, and test sequences are to maintaining test quality, you can use technologies such as file integrity and calibration integrity monitoring that are specifically configured for your test system.

PHASE 2. Evaluate Your Supply Chain

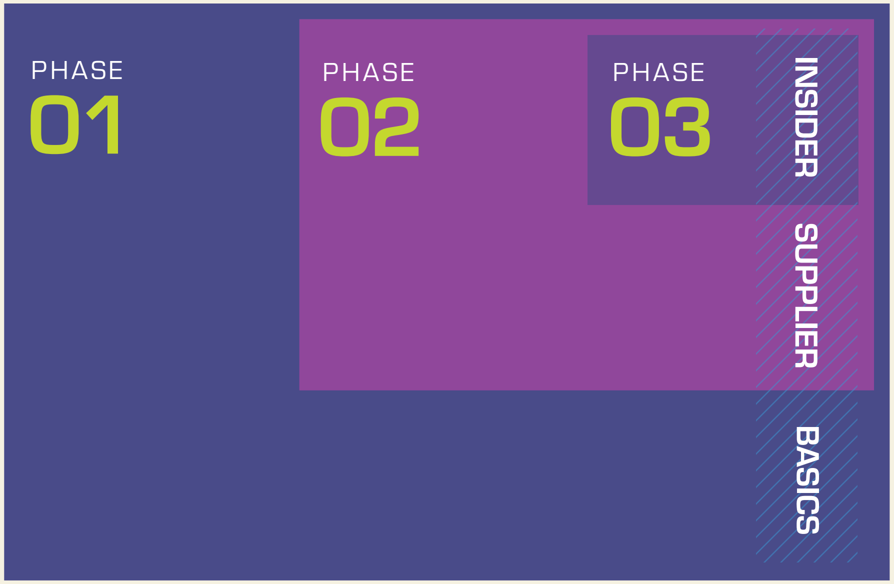
The integrity of a test system relies on the integrity of its components throughout their life cycle. Supplier diversification reduces the risk of system-wide compromise, but this advantage is often outweighed by the sustainability costs for training staff and managing all the supplier relationships.

If you have standardized your supply chain, the most important thing you can do to secure it is talk with your suppliers. Ask them about their supply chains and what they do to protect the integrity of their products throughout their development, manufacturing, and order fulfillment processes. Your insights into any weaknesses in their processes can help reduce your risk of supply-chain compromise and help your suppliers shore up their security. If you find a weakness, make sure your suppliers can detect it and offer clear instructions on how to respond. Without that dialog, both sides may make uninformed decisions.

PHASE 3. Protect Against Insider Threats

Broad media coverage of insider threats makes them seem like a big risk, but the 2016 Verizon DBIR says they are unlikely. Out of over 64,000 reported cyber-security incidents in 2015, only 172 involved a misuse of privilege by an insider. More than 75 percent of the insider incidents were done alone without any external assistance or internal collusion.

Overcoming insider threats is a multifaceted challenge that still needs significant research. You should pay attention to anyone who can access critical test systems, regardless of their status as employees or contractors. Also, clearly identify the most critical aspects of the business, the people involved in them, and the distribution of authority among them. The most important step you can take is to separate authority for critical functions into at least two roles so that a single individual cannot compromise the test system.



Start by addressing higher probability threats before trying to protect your organization against higher impact insider threats.

CASE STUDIES

IT Practices

In 2016, an unnamed multibillion-dollar company's manufacturing systems were crippled multiple times during a three-month period. PLCs kept failing for no apparent reason until the investigation uncovered the root cause. IT had recently expanded security scanning to include test system devices, and the packet rates overwhelmed the PLCs. The economic impact of not understanding the unique needs of test systems was several million dollars.

Supply Chain

In 2014, Energetic Bear hackers attacked three different software vendors who offered their industrial control system software for download on their websites. When the hackers accessed the files on the website, they altered the legitimate vendor software installer by inserting a piece of malware into it and then saved the file in its original location on the website. Then customers downloaded the trojanized software and installed it. The economic impact on both the software vendors and their customers is unknown.

Insider Threat

Timothy Lloyd of Omega Engineering became infamous for his insider activity in 1996. When he was dismissed from his system administrator role at a manufacturing site, he installed a software time bomb that systematically deleted all the manufacturing software from the systems under his control. The economic impact on Omega Engineering was several million dollars and the loss of 80 jobs. It almost forced the company into bankruptcy.

Secrets of High-Performing Test Teams

- Two-thirds of top test teams use a structured software engineering process
- A technical leader is essential to drive change and coach a team
- Centers of excellence provide rubrics and frameworks for team building

Organizational studies show that most teams underperform and miss their real potential. For engineering teams, inefficiency shows up as debug costs, maintenance costs, quality issues, inaccurate project estimates, and missed deadlines.

To determine the characteristics that set apart high-performing test software organizations, NI conducted a five-year study of top performers in the test industry. The study showed that they invest in three key areas: the software engineering process, technical leadership, and a culture of learning.

Software Engineering Process

To have the most effective test strategy, teams must align on best practices for gathering and tracking device-under-test requirements, controlling access to source code, reviewing design and code updates, testing software, and deploying new software versions.

Over two-thirds of the teams in the study consistently invested in architecture design before coding a project, and they wrote code with modularity and code reuse in mind. The best teams differentiated themselves by paying special attention to the enforcement of documenting requirements, tracking software issues and bugs, and ensuring a structured test and software release process.

Technical Leadership

Successful test software teams must have members who are well-versed in programming core concepts, capable in the programming environments, proficient in code module and architecture development, and committed to continuous improvement.

To build technical leadership on undeveloped teams, a technical lead should be designated to drive change and coach the team. The technical lead must have the support of the group manager to conduct activities that may not be immediately billable to a specific project. The lead also should have the drive to excel and the passion to invest in coaching the team to build alignment and execute on process change.

Culture of Learning

Teams that invest in learning, both formal and informal, through local events, user groups, and community engagement are the ones that generally thrive. They empower new team members to have an immediate impact by designing an onboarding program that weaves standard training with the team's unique coding style and process.

Internal user groups that meet frequently enable a team to share skills, introduce new best practices, and build proficiency plans. As teams hone their skills and advance their competency and confidence, the meetings evolve from a learning focus to innovation discussions.

Implementing a Center of Excellence (COE)

Establishing a COE is an industry-proven practice for building teams that are proficient and effective. The three key areas previously mentioned provide a framework for developing a test software COE. Creating a COE requires dedication from the team's leadership. Not making this investment can prove to be costly.

Steps for Success

1. Execute a self-assessment across all team-based proficiency areas to identify gaps in process and skills
2. Undertake an iterative process of learning about new skills and techniques
3. Align on a plan to integrate new techniques into your unique workflow

The LabVIEW Center of Excellence program provides you with the structure to implement each of the best practice areas identified in the study so you can begin your team transformation today. Visit ni.com/labviewcoe to get started with your own improvement program.

"The Center of Excellence provided a forum for all engineers to contribute to the process improvements we were making, as well as a learning opportunity to quickly adopt those improvements. The program also gave us a structure and a platform to go through the change process. We received input and direction on specific topics, which gave us more confidence to make decisions along the way."

—Chris Forristal, *Software Team Leader, Valeo*

CASE STUDY: TEAM PROFICIENCY AT L3 TECHNOLOGIES

↑ 9X IMPROVEMENT IN DEVELOPMENT TIMES

↑ 80% CODE REUSE ACROSS SIMILAR PRODUCTS

↓ 50% REDUCTION OF BETA TEST DOWNTIME

By focusing on developer proficiency, L3 has seen a tremendous improvement in the modularity and scalability of its test code development.

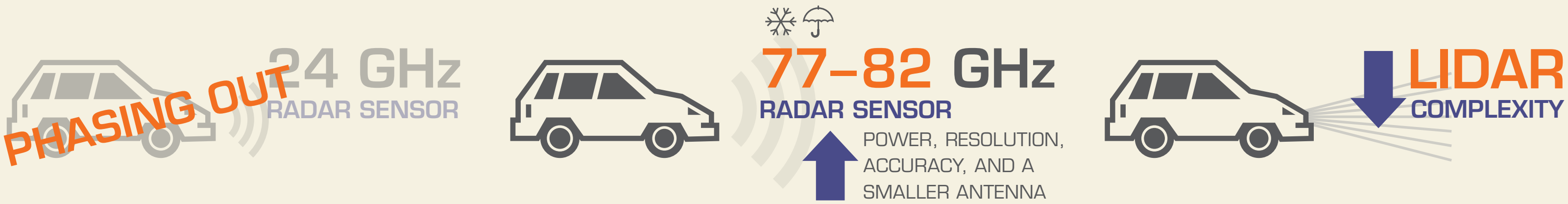
Testing Sensor Fusion for Autonomous Vehicles

- Fusing radar, lidar, and other sensors improves autonomous driving capabilities
- The unique timing for each sensor presents a synchronization challenge for test
- Rapidly evolving technology demands test system flexibility

Autonomous vehicles, once seen only in science fiction, are now a certainty within a matter of years. In June 2017, Honda announced it would join the ranks of many other major car manufacturers and produce an autonomous vehicle capable of driving city streets by 2025. A key enabling technology for this will be sensor fusion, the combining of data from an array of sensors to make decisions. Dating back to the Apollo Lunar Module, sensor fusion today lives in our pockets where smartphones combine GPS with accelerometers and gyros. This fusion allows manufacturers to use cheaper, less powerful sensors and save battery life while offering consumers more comprehensive functionality. What makes this concept novel in vehicles is the pairing of active, smart algorithms with a new mix of sensors. The full potential of sensor fusion technology is not yet known, but as we put this concept into practice for autonomous vehicles, test engineers must overcome two major challenges: evolving sensor technology and difficult synchronization.

Evolving Sensor Technology

From GPS to cameras and radar to accelerometers and gyros, test systems must be ready to handle a wide spectrum of I/O such as video, CAN, and RF. Further complicating this challenge, the sensors themselves are constantly changing. Radar sensors, valued for weather-agnostic obstacle detection, are migrating from 24 GHz to 77–82 GHz allowing for smaller antennas, wider bandwidth, and the ability to transmit higher power. This leads to greater accuracy and object resolution. Lidar, a simpler alternative to radar, has traditionally been expensive and unreliable in suboptimal weather conditions. Today, however, the rise of solid-state lidars is helping to decrease costs. In addition, Ford has released research that uses lidar sensors to differentiate rain from snow, making lidar a compelling option.



The evolution of radar and lidar technology is indicative of the constant change testers must be ready to address across sensor types.

Difficult Synchronization

If data isn't properly synchronized, the vehicle cannot formulate an accurate picture of the environment, and safety becomes a major concern. Synchronization challenges originate with the sensors themselves. Because sensor data is not inherently timestamped, engineers use sensor specifications such as camera frame rate to deduce timing with software, which decreases accuracy. To make matters worse, test engineers using hardware-in-the-loop (HIL) testing must establish a synchronized connection between a mathematical model running in real time and sensors like a camera that may be running on a different GPU-based processing platform where the camera is viewing a simulated scenario.

To properly test self-driving algorithms, the tester must ensure that the camera is seeing images that are synchronous with the model and any other sensors. Ideal test systems provide a common sense of time to all components, which makes synchronizing sensor and test data easier.

Preparing for a Certain Future

At this point, we can count down the days to the arrival of the autonomous car. Sensor fusion is key to the success or failure of these smart machines. Already challenging, the complexity of sensor fusion technology is still evolving. To adapt to future changes, test systems must be modular and flexible enough to incorporate new I/O when necessary while providing a common timebase for synchronization. Some technologies have already forced test engineers to take new approaches, like incorporating realistic over-the-air test for automotive radar instead of cabled solutions. In the future, thanks to rapidly developing machine learning techniques applied to verification, test engineers will determine the most efficient test scenarios based on smart algorithms that can quickly detect failure-triggering patterns. This will allow them to achieve maximum test coverage in less time.

A flexible test solution that expands with new technologies and addresses complex timing and simulation is essential. By using a test system that keeps pace with your cutting-edge technology, you'll be on the road to producing safe, smart vehicles that are ready on time.

Watch our **five-part webinar series** to learn more about autonomous vehicle test.

MONITOR PLAN ACT

Standardizing the Test Lab

- R&D test labs are becoming more automated
- Techniques formerly isolated to manufacturing are adding efficiencies to the lab
- Trends in the semiconductor industry are being replicated in other industries

The days of performing manual measurements as a characterization or validation engineer are numbered; it is simply too inefficient. Instead, leading test organizations are implementing best practices from the production floor in their characterization and validation labs. By investing in the following processes to maximize product quality while shortening time to market, you can achieve the same success as these test organizations.

Measurement Automation

Instead of manually configuring each measurement, you can create a configuration file that lists the settings for all instruments at each desired setpoint and then use automation software to send commands to and receive data from your test system. Nearly every instrument has an instrument driver and can receive commands via PCI Express, USB, serial (RS232/RS485), GPIB (IEEE 488.2), or LAN. The faster you make the measurement, the more corner cases you can explore.

Device Fixturing

Manually connecting your device under test (DUT) to each instrument wastes time and decreases measurement repeatability. Instead, design a universal interface board that connects to your test instrumentation on one side and provides a mezzanine board to connect your DUT on the other side. Calibrate your system to the pin and add probe points for troubleshooting. The less time you spend debugging your test system, the more time you can spend debugging and optimizing your design.

Hardware Abstraction Layer (HAL)

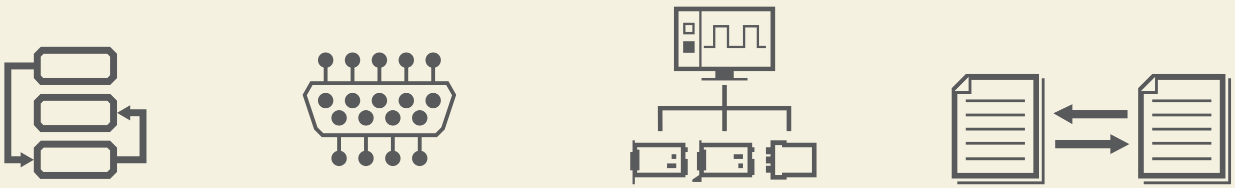
Some hardware vendors provide APIs that make function calls to a family of instruments rather than to only single instrument models. HALs further this concept by creating an API that can make function calls to all instruments, regardless of vendor, for each instrument category (for example, digital multimeters). As long as a comparable instrument is available and incorporated in the API, HALs save test organizations from costly rework if an instrument is unavailable.

Shared Software Libraries

Duplicating development efforts is one of the biggest inefficiencies for large organizations. A shared software library with well-understood code modules allows your team to share and reuse code for common operations across test systems. It also ensures that individuals across your teams perform common tasks, such as logging results to a database, in a consistent way.

"By optimizing our labor pool and capital equipment pool through a centralized engineering test organization, we were able to increase our test output, improve our test efficiency, and lower our capital costs."

—Neil Craig, *Senior Engineering Manager, Qorvo Inc.*



Centralized Test

Though you can implement all these best practices independently for each product group or design team in your organization, leading organizations have taken a different, more consolidated approach to help amortize the upfront investment. Centralizing test engineering requires your organization to evolve. A centralized engineering test organization can accept test plans from product engineers or design teams across your organization, efficiently schedule test jobs based on tester and technician availability, and provide test results in a consistent fashion. This gives you the benefit of quantitative indicators for test engineer and test equipment efficiency across your organization to justify further investment in labor and capital equipment. For example, you can define and track statistics for capital equipment and labor usage such as the number of jobs completed in a given timeframe, perhaps normalized by the size of each job, or track the time that each of your test systems is actively running. Monitoring these statistics helps you serve more product design teams, ensure high product quality, and quickly deliver products to market while minimizing your capital and labor costs.

Curious how Bloomy Controls implemented a HAL to save valuable test development time? Watch the **webcast** for more information.

Testing Before the Standard

- Being first to market requires insight into the standardization process
- Product requirements can change frequently until a wireless standard is finalized
- Flexible design and test tools are required to get a head start on product development

In November 2011, Quantenna launched one of the industry's first IEEE 802.11ac chipsets two years ahead of the standard's ratification. The same thing is happening today with 5G. In South Korea, telecommunications operator KT is planning to conduct a 5G trial at the 2018 Winter Olympics in PyeongChang in February, a full five months before the 3rd Generation Partnership Project (3GPP) intends to finalize the 5G specification.

Today's engineering organizations are routinely asked to build a wireless product long before the wireless specifications are complete. The design and test of prestandard technologies require deep knowledge of the complex process and politics involved. Although these processes often change from one standard to the next, the story of how the 3GPP has created 5G provides insight into how the process generally works.

Within the 3GPP, new ideas and technologies often start as a "study item," or a proposal to conduct further research. Study items are first heard at the plenary meeting and then allocated time units within the various radio access network (RAN) committees. The RAN committees then conduct further research and report on their progress to the plenary. One particular study item might pass through the plenary meeting and various RAN committees several times before finally being ratified and aggregated as part of a comprehensive specification.

For engineers working on components like RF front-end modules, transceivers, and radio modules, technical submissions to standards bodies like the 3GPP provide early insight into future wireless standards. From these submissions, engineers can glean valuable insight into the physical layer including frequency range, modulation schemes, spectrum usage, and other implementation requirements.

However, because politics often determine which submissions are most likely to be accepted, connections with a standards body insider are also critical. Shardul Velapure, senior RF engineer at Qualcomm, said, "When preparing to test a prestandard product, talking to committee members from the standardization body often reveals key details about the physical layer that you might not find in written documentation."

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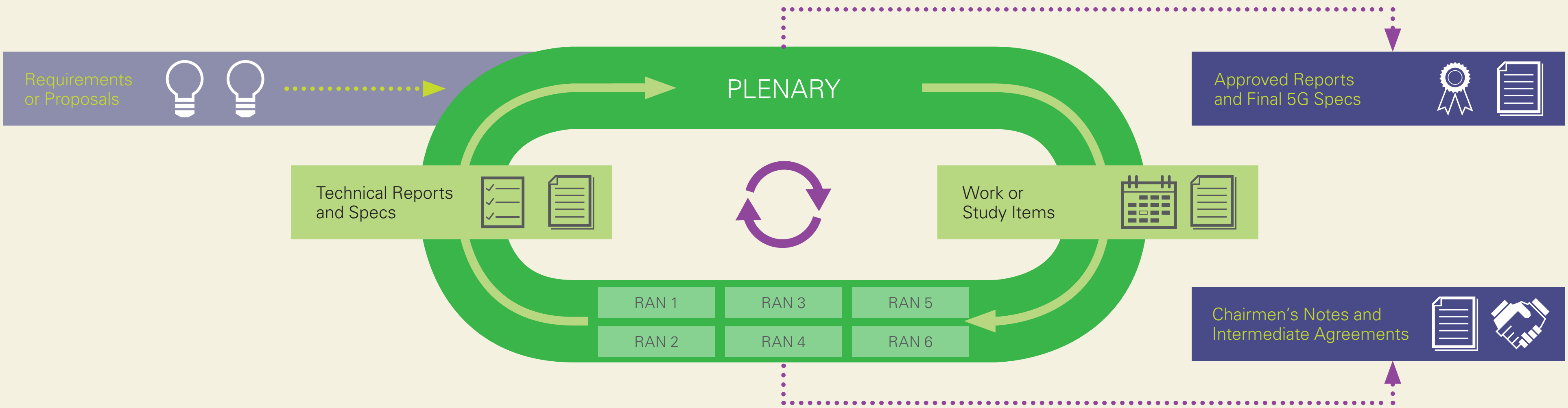
—Shardul Velapure, *Senior RF Engineer, Qualcomm*

Even when an engineer can identify general characteristics of a new standard's physical layer early in the process, some of the finer implementation details that affect measurement results often are determined much later. Dirk Leipold, senior principal system architect at Qorvo Inc., said, "Figures of merit like error vector magnitude (EVM) are highly dependent on yet-to-be-determined physical layer characteristics. Because of this, correlating EVM results from a waveform we developed in house versus waveforms from our customers and test equipment vendors is challenging. We require test equipment that has not only the RF performance needed but also the flexibility to generate or acquire a wide range of IQ data using waveforms from various sources."

Lack of clarity over the final technical details of a standard widens the scope of product development. Leipold also said that early designs must be more flexible and more thoroughly tested. As a result, automated testing of early products like the 5G power amplifier (PA) he designed is important because of the sheer volume of test cases. He said, "We can't just recompile a PA to get better EVM performance, as getting better EVM requires a thorough understanding of the electromagnetics and thermals and requires lots of characterization."

Although waiting for a wireless standard to be completed before beginning work in R&D might sound easier, waiting is a sure way to miss a market window. Instead, getting ahead of the development schedule requires both insight into the standard and flexible design and test tools. These challenges are some of the reasons why NI participates in standards bodies like the IEEE working group and the 3GPP and why its instruments are inherently software-centric. The next time you attempt to be first to market with a wireless product, make sure you have the relationships and products to succeed.

Follow the "**5G and Beyond**" blog featured in Microwave Journal and written by James Kimery, NI director of RF/Communications and 5G, and his team to learn the latest developments in the race to 5G.



The Test Implications of Packaging Innovation

- Packaging technologies combine separate dies into a single chip
- Test and validation approaches must evolve to ensure quality
- Modular solutions allow test organizations to adapt to future needs

"Testing of SiPs can be challenging and design for test is important. SiPs often include multiple functions and features that may not lend themselves well to traditional test approaches."

—E. Jan Vardaman, *President and Founder, TechSearch International Inc.*

System-in-package (SiP) technologies are making a significant impact on the electronics supply chain as the semiconductor industry strives to meet the perpetual demand for higher performance, smaller size, and lower cost. SiPs contain two or more dissimilar dies typically combined with other components such as passives, filters, MEMS, sensors, and antennas, according to E. Jan Vardaman in TechSearch International's "SiP Drivers and Market Trends" presentation at the International Microelectronics Assembly and Packaging Society's SiP 2017 conference. The guaranteed system-level performance and plug-and-play nature of SiPs lower the design burden for companies looking to differentiate based on product style or fashion rather than electronic design.

With the expectations for strong SiP growth, the race is on to meet various challenges ranging from assembly and packaging technologies to test and validation. For example, with the inclusion of RF components, shielding poses a significant challenge for the assembly design process. On the test side, dies integrated into SiPs are tested and generally meet known-good-die criteria, but when multiple dies are combined, often with added active and/or passive components, the performance of the SiP as a system must be verified and warranted.

Implications for Test

In recent years, system-level test (SLT) use has grown more important in guaranteeing the overall performance of SiPs in their end-application environment. An SLT environment emulates the end-application environment in electrical, physical, and software forms and ideally covers 100 percent of the environmental scenarios. Today, finding a commercial off-the-shelf test solution that meets these requirements can be difficult because of the following four challenges.

Device Handling

The potentially long test times required for SLT pose mechanical handling challenges, which typically include the ability to load and unload asynchronously and the capacity to handle many sites (often a few hundred) and ultimately provide high throughput.

High-Level Communication

On the electrical and software side, SLT usually contains elements of both IC test and end-device test. For example, communicating with a SiP may use device-specific protocols, like communicating with an end device such as a smart watch, instead of using digital patterns that are common with automated test equipment, to test at the IC level.

Application Load Boards

SLT load boards may be specially designed to emulate the end-application environment. For example, the load board of a SiP intended for a mobile phone may resemble the reference design of the mobile phone.

Increased Analog and RF

SiPs often incorporate multiple sensors and power management blocks along with two or more RF standards such as Wi-Fi, Bluetooth, GPS, NFC, and 2G/3G/4G cellular radios. Consequently, the tester needs to provide robust analog and RF I/O, which may resemble that of high-performance ATE.

Early Success With the Modular Approach

If you are in the semiconductor industry, then you are likely feeling the stress on your test strategy. Though this seems like an insurmountable challenge, early innovators have already tackled it. Many of today's successful SLT implementations center around a high-performance, flexible test platform that remains open enough to integrate device-specific needs. Look for a flexible, industry-standard platform that readily accommodates additional device-specific requirements to ensure any technology investments you make today will evolve for the future. Whether or not you work in the semiconductor industry, you likely rely on semiconductors every day. Understanding the roadmap of SiP offerings from your suppliers is important because it will likely have a significant impact on your design options.

How We Arrived at the Trends

NI works closely with test organizations to help them build smarter test systems by leveraging a software-centric, platform-based approach to test and measurement. Each year, we interact with more than 35,000 customers, as well as technology suppliers and standards bodies, to understand key trends and technologies impacting test organizations. These efforts are examined at our annual Test Leadership Forum at NIWeek and broadly circulated through this document, the Automated Test Outlook.

Learn about the smarter approach to test at ni.com/smarter-test.

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