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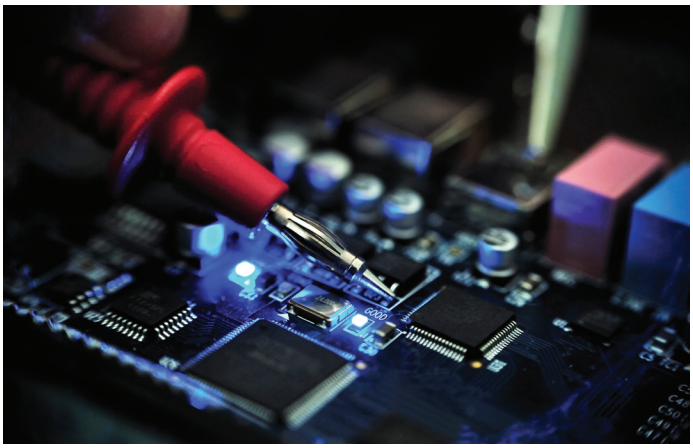
CONSIDERATIONS FOR ADDRESSING THE DEMANDS OF TODAY'S TEST & MEASUREMENT APPLICATIONS

Like other industries, digitalization is transforming the test and measurement field. Advances in technology such as 5G, the Industrial Internet of Things (IIoT), Industry 4.0, cloud computing, advanced analytics and more are driving this quickly growing trend. For example, 5G technology plays an important role in virtualization and automation—two long-term trends in test and measurement. Along with all these factors, increased adoption of modular equipment and consumer electronics make the test and measurement industry more important than ever.



As test and measurement products shift away from bulky and stationary to mobile, handheld and miniaturized, the increasing precision of electronics requires engineers to quickly and accurately measure current, voltage and other parameters to ensure quality along with reliability. Many applications require innovative solutions that can provide reliability such as latching features along with gold plating for more precision and accuracy. Low-profile connectors give designers more space and flexibility to include far more technology into smaller devices.

The overall test and measurement equipment market presents a huge opportunity for growth due to the increasing demand for electronics, automation and connectivity in automotive, aerospace and defense, industrial transportation and manufacturing, IT/telecommunications, and other sectors. In this trend paper, TE Connectivity (TE) will explore test and measurement trends and demands in these areas.

Market Trends in Growth Industries

Companies are always looking for ways to lower capital and operational expenses while at the same time use new and advanced technology to become more dynamic in manufacturing, network capacity, autonomous functionality and more. 5G is specifically geared to deliver greater capacity to transmit and receive large amounts of data, improve responsiveness, and increase connectivity between multiple devices and applications. As more functionality moves to the cloud and networks become virtualized, 5G technology enables automated processing of a huge volume of data from multiple sources across a complex, distributed architecture. This automation and virtualization allows manufacturers and data centers to scale up services and incorporate higher bandwidth technologies such as artificial intelligence and machine learning.

This technology is also becoming more critical for testing and measuring wireless devices and products that incorporate virtualization and automation because OEMs and network operators need to test and measure performance in the environments and conditions in which the devices and products will be used. As 5G technology evolves to greater millimeter-wave (mmWave) frequencies, over-the-air (OTA) measurements may become critical for design validation.

Automotive

As cars become increasingly more connected and autonomous vehicle trends continue to take shape, the demand for complex simulation and test and measurement devices continues to grow. For example, the need for radio-frequency (RF) testing keeps increasing as infotainment systems evolve and wireless communication (LTE and Wi-Fi) needs inside the car expand, and significant responsibility for that RF testing falls on module suppliers. Fast data and wireless networks, like 5G, are required for automotive radar and target simulation and processing the large volumes of sensor and traffic data needed in real-time for autonomous driving and autonomous features on self-driven vehicles, such as automatic braking and collision avoidance.

As more connectivity is integrated into vehicles, data and cellular networks, and infrastructure, the demand for electronic testing devices as well as the number and types of measurements needed keeps increasing. In addition, suppliers are pushed to prototype, develop and deliver products faster so OEMs can speed up their go-to-market timelines. Automotive engineers need to measure more signals with higher complexity at the same time. They need to capture and analyze as much data as possible, as quickly as possible, to maximize the impact of these emerging technologies. The need for high-speed and more bandwidth will keep growing as the need for data analytics keeps increasing.

Aerospace & Defense

The aerospace and defense (A&D) industry is not only one of the most important markets for test and measurement, it can also be one of the most challenging. Accurate and effective testing is required in every part of the end-to-end A&D supply chain. Test and measurement equipment must ensure system reliability and integrity under extremely harsh conditions where failure is not an option. Testing and measurement is essential to ensure safety in aircraft and reliability and efficiency in communications systems, navigation systems, instrument landing systems and more. Testing advanced radar systems found in aerospace and defense requires greater bandwidths, higher frequencies and signal as well as lower phase noise and lower predynamic range.

Trends toward millimeter-wave frequencies and higher modulation bandwidths in ultraband radars and other equipment for signal intelligence and spectrum monitoring haven't been fully realized yet due to the need for cost-effective solutions. Testing these bandwidth-rich millimeter-wave frequencies in mass production remains a challenge but also an opportunity.

Features like surveillance, identification, targeting, control, intelligence gathering, and self-protection systems are becoming ever more complex and integrated. Because of this growing system complexity, the pace of technology change and changing standards and regulations, test and measurement systems in this industry need to be:

- Flexible – to support increasing bandwidth and software-defined instrumentation needs
- Scalable – to handle platform upgrades and changing technology
- Durable – to withstand extreme shock, vibration and temperature ranges in which these systems and vehicles are meant to perform

Upgradability, interoperability and total cost of ownership are also important considerations for this industry. Aerospace and defense customers are looking for smart test systems that are modular and can scale to meet future needs.

Aerospace electronics and avionics will continue to advance, with high-speed, high-bandwidth, data-intensive functions driving demand for advanced test solutions. There is a strong focus on having repeatable measurements and multi-channel solutions as well as adding functionality to existing systems, especially with the adoption of 5G increasing bandwidth, signal and frequency ranges.

Increasing aircraft production and model variations are driving demand for data acquisition (DAQ) systems—engineers want to capture and analyze as much data as possible to maximize their product designs. Mapping and surveillance require massive data collection and analytics underscoring the need for secure, rugged electronics deployments. Test systems are also increasingly important for cybersecurity needs, requiring a high level of flexibility to prevent and defend malicious attacks on secure networks.

Internet of Things (IoT)

The number of connected devices in factories and across industries—like in industrial and commercial transportation, medical devices, consumer devices, appliances and the home—is a rapidly increasing trend that's not likely to stop. This trend is driving a similarly growing need for inspecting, testing and verifying smart products and other equipment to ensure that they work correctly once deployed. Continuous monitoring and IIoT (Industrial Internet of Things) technology collects and analyzes real-time data that drives process improvement, efficiency, profitability and safety.

5G is taking over as the foundation for implementing new innovations in autonomous automobiles, industrial and commercial vehicles, and factory equipment, where a significant amount of data must be received, analyzed and acted upon quickly. The use of highly complex electronics and higher computing power where precise synchronization and shorter development cycles are required is driving a demand for complex simulation, test and measurement tasks and devices.

As you can tell, the IoT market requires high measurement accuracy and massive data collection capabilities. Test and measurement in this space has become increasingly important to ensure reliability, performance, quality of experience and long-time availability. Across industries, there is a need for testing performance (such as power consumption and battery lifetime), radio frequency, coexistence and interference, as well as security and data transfers. Wireless devices need to be tested to adhere to regulatory standards and operator-specific requirements. Factories need optimized test setups to detect and predict manufacturing defects during mass production. Demand for parallel testing and low-cost instrumentation based on USB is increasing.

Test and measurement must take place at the device, wireless communications and network level to ensure performance, interoperability, reliability and security. Engineers must test and measure signal and power integrity, battery drain, EMI, wireless conformance (to standards) and connectivity, network readiness and performance, and more.

Internet of Things (IoT) *continued on next page >>*

Internet of Things (IoT) *continued from previous page*

In a factory, the placement and proliferation of connected devices requires testing for:

- Precision – such as on an assembly line where very fine tolerances are required
- Interoperability – to ensure consistent performance and connectivity where devices of different ages and multiple manufacturers may be integrated
- Security – to protect potential points of vulnerability and access across multiple connected devices on a network
- Scalability – to enable modular growth in system networks that may contain thousands of sensors, components and devices

Data Center

In the data center, there is a growing demand for electronic test and measurement equipment to address trends related to network function and health, product development, real-time analytics and troubleshooting. As the demand for more bandwidth increases, new standards and higher data transmission speeds are resulting in the need for high-speed digital testing equipment.

Likewise, as data centers adopt 5G technology to handle higher data transfer speeds and lower latencies, they are using faster transceivers and Ethernet interfaces, which require superior test, measurement and monitoring capabilities including solutions that can validate FlexE and FlexO technologies.

The continuous increase in data traffic is causing a shift from large data centers to modular, software-defined and virtualized data centers which brings with it a need for testing and monitoring the data center at a component level. This has also given rise to edge computing, in which functions critical to end users are computed closer to the device rather than being sent to the cloud. The resulting reduction in latency enables real-time network analysis, insights and troubleshooting in the end user device.

In Frost & Sullivan's report, "Growth Opportunities in the Data Center Test and Measurement Market, Forecast to 2024," they identified several growth opportunities these trends create for test and measurement equipment manufacturers, including:

- Using software-based solutions that can be easily deployed across the mobile edge and a virtualized network infrastructure
- Offering a complete lifecycle management tool that spans from the device all the way to the network infrastructure
- Developing solutions to cost-effectively bring business-critical Internet of Things (IoT) applications to the cloud environment
- Engineering a common platform that is interoperable with application programming interfaces (APIs) and third-party software
- Partnering with small artificial intelligence (AI) and machine learning firms
- Delivering relevant, software-defined solutions that can be used to validate the hyper-converged infrastructure (HCI)
- Creating solutions to optimize data center infrastructure and check compliance of augmented reality (AR) and virtual reality (VR) devices and applications on the data center networks
- Collaborating with leading cloud computing service companies to offer testing solutions in the cloud environment

What Design Engineers Need

Long-term trends such as virtualization and automation, which are enabled by 5G, present challenges for designers, such as the use of higher frequency bands (24Ghz and above), massive ports (MIMO), higher signal absorption rates, high-density networks and need for over-the-air (OTA) testing.

Engineers need to be able to more cost-effectively test networks and services that support new use cases such as: enhanced mobile broadband (eMBB), ultra-reliable low latency communications (URLLC), and massive machine type communications (mMTC).

As one of the innovative leaders in this space, TE has the following integrated testing solutions for 5G applications:

- 5G mmWave mobile device testing applications – including connectors, adaptors, horn antenna and testing cable assemblies
- 5G sub 6GHz massive MIMO testing applications – including ERFV adaptors, testing cable assemblies and other adaptors

Our ERFV RF coax connectors were specifically designed with the introduction and proliferation of 5G in mind. They enable board-to-board and board-to-filter applications at a lower cost due to their one-piece compressive design and are highly customizable with a range of between-board heights and connector configurations. These RF connectors provide proven reliability with excellent misalignment tolerance, insertion loss and return loss (≥ 22 dB @ 4 GHz; ≥ 20 dB @ 6 GHz).

Signal Integrity

Higher data rates introduce new challenges for test solutions. There are several 20+ Gbit/s high speed standards that are driving the upper end of the test spectrum from 40 GHz all the way up to 110 GHz and beyond. Along with the design trade-offs related to choices of vias, stackups, and connector pins, accurate measurements are needed to better understand new challenges related to conductor skin effects and dielectric losses on printed circuit boards (PCBs). TE's STRADA Whisper cable receptacles help maintain optimized signal integrity at high frequencies and save space on the PCB, which can be essential for dense equipment designs.

High Data Rates

The STRADA Whisper backplane family was designed especially for high-performing, high-bandwidth systems, able to transfer data at speeds of 25 Gbps. Whisper connectors and cable assemblies offer scalability up to 112 Gbps—allowing data center operators to achieve efficient future system upgrades without costly backplane or midplane redesigns. The STRADA Whisper product family operates with extremely low noise, low insertion loss and little to no skew—all of which provide design flexibility and high design margin.

Our broad portfolio of small form-factor pluggable (SFP) connectors are flexible and cost-effective and our I/O interconnects are designed to transfer data at speeds of up to 28 gigabits per second (Gbps) NRZ and 56 Gbps PAM-4. Choose from zSFP+, SFP+, and SFP, depending on PCB space constraints.

EMI Performance

Multiple circuits and components in electronic devices emit electromagnetic fields (which can be conducted or radiated) of varying strengths, causing a potential for interference that can degrade or disrupt performance. Circuits must be designed so that they don't add to or become disrupted by the interference.

With the demand for miniaturization rising, design engineers must create compact circuits that do not generate EMI and RFI and that function properly while surrounded by internal and external sources of EMI and RFI. This makes it crucial for designers to perform EMI/RFI measurements and software simulations during different stages of the design process, measuring EMI and RFI emissions across a wide frequency range. Failing an EMC compliance test can be costly—in time and money. Designers must spend valuable time reworking circuit layouts and without proper testing and measuring during the redesign process, could potentially fail another EMC test.

To enhance signal quality, TE's SFP connector and cable assemblies portfolio focuses on the latch-plate area to reduce EMI and avoid degradation of circuit performance as well as ensuring compliance to standards. Products are offered in both EMI spring and EMI elastomeric gasket versions to meet customer system requirements.

Modular Design

Today's engineering designs often require high performance, signal integrity, EMC compliance, and high speed data transfer with power and signal connections. Connectors must have smaller profiles to use less space, must be lighter in weight and often have to withstand varying environmental conditions. The right interconnects can help design engineers adapt and be flexible to continually push the boundaries of design, allowing engineers to address tough design specs without compromising on connection reliability.

Low-profile flexible printed circuit (FPC) connectors, like our dual-contact FPC connector and others from TE, can give designers flexibility and space-saving capability to include more technology into smaller spaces. Our FPC connectors are useful where small centerline spacing makes larger wire-to-board interconnects impractical. In addition, many applications require connectors that can provide reliability such as latching features along with gold plating for more precision and accuracy.

TE offers a comprehensive portfolio of interconnect solutions to address the needs of customers who are involved in test programs, product research, development, test and evaluation especially those who prefer handheld and mobile T&M devices.

Wireless Connectivity

As engineers across industries—automotive, industrial and commercial transportation, aerospace and defense—design in more wireless communications technologies like 5G, for advanced functionality and self-driving vehicles, the complexity of the communications environment and the likelihood of radio interference increases. Security also has to be tested as the number of network-connected onboard systems also increases the risk of hacking threats, which can impact safety. Testing is needed to verify whether these connected vehicles' RF protocol/application layers are in compliance with industry standards.

TE's broad range of antenna types include standard antennas and custom antennas for use in a wide variety of IoT, industrial, transportation, energy management, smart environment, consumer and medical applications. Our antenna solutions provide high-quality transmissions in wireless devices in a wide variety of frequencies including, but not limited to: Cellular, GNSS, Wi-Fi, Bluetooth, ZigBee, ISM, and LPWAN. We operate antenna design and manufacturing facilities worldwide, with implementation support and testing capabilities in active and passive antenna performance, near and far field patterns, efficiency optimization, throughput optimization, scattering parameters, SAR, environmental testing, acoustic, and industry compliance.

From Manufacturing to Performance — TE Can Address Your Design Needs

Design engineers must address design considerations that go beyond end-user performance to also include manufacturability—clearly one influences the other and vice versa. Interconnects that are challenging to install during manufacturing can compromise reliability and the end-user's experience.

TE understands these challenges. With increasing performance demands across a wide assortment of applications and manufacturing conditions, design engineers likely need a partner who can provide input on the optimal connectivity and interconnect solution for the specific application.

Choosing the right solution is critical to the efficient testing and measuring of connected devices and equipment. As industries like automotive, aerospace & defense, industrial manufacturing, medical devices and consumer devices increasingly rely on high-speed data and data analysis, TE's experience across these businesses combined with our data connectivity expertise offers customers a broader product portfolio and knowledge base to draw from to better optimize their own designs. Our T&M solutions are designed and manufactured to exacting specifications, and are fully configured, shipped with calibration certificates, and ready to use "out of the box."

With sensor solutions that cut across four major categories—Pressure, Position, Vibration and Force—we leverage these technologies to develop customized solutions for a wide range of market applications including:

- Aerodynamic Research and Flight Testing
- Automotive Design Testing
- Automotive Safety Testing
- Environmental Monitoring & Water Monitoring
- Test Equipment & Instrumentation
- Traffic Sensors

TE provides a consultative approach, combining a depth of technical expertise with industry understanding to address specific T&M requirements. We couple this with a commitment to high quality service and helping our customers win in their markets.

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