CONNECT AND PROTECT

New Challenges for Test and Measurement Systems

Approaches to protecting sensitive electronics

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1. Abstract

Technological improvements are having an impact on test, measurement, and simulation systems. Environmental conditions and system architecture place a wide variety of requirements on equipment for testing and measurement. This article describes the value of test and measurement systems based on examples from various real-world applications. The most important requirements and criteria for everything from system architecture and mechanical systems to enclosures with a small form factor and 19" systems with electronics cabinets are explored.

2. Test and Measurement Device Industry – Trends and New Challenges

The new 5G mobile communications standard is an important foundation for implementing new technologies such as IIoT and autonomous driving. In the area of Industrial Internet of Things (IIoT), a wealth of data is received and processed by millions of connected devices. Edge data centers arise near applications to process the IIoT data in real time. This data is also connected to industrial systems using 5G to optimize latencies. The application data itself is stored in the cloud. Autonomous driving also requires fast data networks and real time processing of large volumes of sensor and traffic data. 5G and edge computing are critical for the development and introduction of autonomous driving and driverless transportation.

These trends are expanding the global market for electronic test devices, which is already significant and continuously growing. The required use of highly complex electronics, increased data traffic, higher computing power, shorter development cycles and precise synchronization is changing the resulting demand for complex simulation, test, and measurement tasks. Some examples include:

- Increasing amounts of digital data to be tested
- More complex electronic test objects
- Greater time pressure for product launch and routine testing
- Higher and new frequencies for test applications
- Greater focus on tests for improving product quality and reliability
- Increased analysis and evaluation of sensor data so that the end product's reliability, safety, and functionality can be assessed as early as the development phase.
- Increasingly, integrated manufacturing tests complex electronic devices for large-scale production as well as test and measurement applications along the production line for quality assurance.
- Test solutions for traditional, digital, RF, analog, and protocol-based tests are also now required for performance tests for controlling hardware, sensors and software and recording and analyzing user data.

The increasing number of various test and measurement tasks requires greater modularity of the test equipment so that the different requirements can be represented in an application. Manufacturers of test and measurement equipment are striving to develop modular systems as base devices that can be easily adapted to the required tasks.

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3. Reference Examples

Simulation, test and measurement systems can take very different forms. Some are relatively small test and measurement systems that test only dedicated signals or connections such as WiFi and Bluetooth in a device or that record and evaluate stress tests of individual components. Conversely, there is test and measurement equipment that consists of larger units and is used for function tests on complex products in manufacturing or other applications. These trends and new challenges can be clearly illustrated using examples from the automotive, digital communication, and aircraft construction industries

3.1 Simulation and testing of autonomous driving

Autonomous driving and the networking of vehicles bring new challenges for test and measurement systems, both in vehicle development and simulation of processes as well as in real operation. Sophisticated onboard infotainment systems, wireless communication via LTE and WiFi, and safety systems such as vehicle radar and target simulations are becoming more and more convenient to implement. This is also increasing the demand for corresponding test and measurement devices for developing these functions and for routine tests.

Vehicle development and simulation

Before test vehicles hit the road, extensive simulations are run to ensure the safety and reliability of the software developed for autonomous driving, namely, through identifying and correcting errors at an early stage. This reduces the development time associated with autonomous driving and prevents prototypes that are not yet safe from participating in traffic. Test vehicles record the data for the simulation. Sensor data is recorded during these test drives so that it can be subsequently loaded into the simulation. High-performance storage systems are installed for this purpose and store the mass quantity of data. Software errors can then be identified and corrected during the simulation. Afterwards the same point in the simulation can be checked to see if the correction provides the desired response. Such storage systems must be installed in rugged, yet compact enclosures that are placed in special mounting frames, for example in the luggage compartment, so that they are roadworthy and easy to replace.

Real driving mode

Once the hardware and software have proven themselves in the simulation, prototypes are required to drive on the road to demonstrate their reliability in real-world conditions. Test systems are then installed in these prototypes to measure all the sensor data simultaneously. The keyword here is sensor fusion; signals from multiple sensors (e.g. radar, camera, LIDAR, video, and laser sensors) must be recorded during autonomous driving, linked, and made available to the vehicle, synchronized and in real time. Testing whether this functions reliably in real-world traffic requires having small scale test solutions that can be installed in the vehicle but are still able to process all the sensor data. A space-saving and compact system solution also requires having a compact, yet very powerful system controller. Section 4.1 provides more details on how such a system controller can be built.

„ One of the biggest challenges for autonomous driving is the storage and processing of all sensor data as well as the data transfer speed of that data. Modular solutions such as COM or PXI Express can be beneficial for these applications.“

Christian Ganninger, Product Manager, Embedded Systems, nVent SCHROFF

Mountains of data for better safety

Vehicle developers record and analyze as much data as possible to ensure maximum safety during autonomous driving. This results in very large amounts of data that have to be forwarded and processed very quickly. Measurement and test systems are developing into highly complex IT systems. The greatest challenge here is determining the bandwidth sufficient for storing and processing all the sensor data as well as the data transfer rate for the overall amount of data. A system architecture such as COM or PXI Express is particularly well suited for this, both of which are explained in greater detail in sections 4.1 and 4.2.

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3.2 Test and Measurement Equipment in Manufacturing Technology

The digital transformation is increasing the demand for connected devices and more powerful control systems. In this regard, the IIoT also has an impact that is continuously growing in importance. It pertains to interconnected sensors, instruments, and other devices that are networked with industrial computer applications. IIoT can be used to more easily record machine values over the entire production process as well as monitor and control them to contribute toward improving operating efficiency and quality.

In-process tests

In many manufacturing areas, the strategy known as the zero defects concept is followed. The basic idea behind this strategy is that there is no acceptable defect rate and there should be no wasted work. To achieve the lowest possible defect rate (target values range from 10 to 20 ppm) and the least possible amount of wasted work, it is essential to create optimum requirements. This also includes optimized testing design in mass production so that manufacturing defects are quickly detected and remedied.

„Especially in production lines, robust, compact and cost efficient systems that can be flexibly configured are in demand. The right partner should have experience in EMC protection, cooling and adaptation to application interfaces. “

Waldemar Schulz, Product Manager EMCA, nVent SCHROFF

Powerful test and measurement equipment in smartphone manufacturing

For example, if you look at how smartphones are manufactured it is clear just how powerful in-process test and measurement equipment has developed. The smartphone has become a very complex product systematically developed into a powerful computer. The manufacturing of these devices is subject to very high demands regarding product reliability and quality. Often, even minute manufacturing fluctuations can have an adverse effect on the quality of the products. When such a mass product is manufactured, in-process tests have to check many functions in a minimum amount of time. Examples of essential tests are checking for HF as well as power (power consumption and battery life), coexistence and interference tests, carrier sense, security tests and data transfer tests. Here, there is also a large amount of measured data that has to be recorded, forwarded, and processed quickly. The real-time availability of data measured from the production lines makes it possible to be proactive instead of reactive, and product defects can be remedied immediately. This requires durable, compact systems that can be used in production lines with cost efficiency and flexibility. EMC protection, cooling, and adaptation to application interfaces play a special role, particularly for the mechanics of such systems.

3.3 Comprehensive Test and Simulation for Quality Assurance in Aviation Technology

Aircraft engineers are being subjected to the pressure of shorter development times for new aircraft series. The requirements imposed by new technologies, societal trends, new customer requirements, and commercial pressure are driving new developments in this area. Aircraft keep getting more complex and diverse, and they are being equipped with more electronics and electronic systems. Demand is growing for state-of-the-art test solutions that advance the development and testing of aircraft better and faster than before. The test methods have changed fundamentally—both on the ground and in computer simulations. In both cases, the goal is to minimize the number of flight hours needed for testing the aircraft. State-of-the-art commercial aircraft start out by running through a series of comprehensive tests and simulations to make sure they are as safe as possible.

Ensuring product quality

Components used in aviation technology are subjected to high loads and have to function reliably at extreme temperatures, in humidity, while vibrating or even in salt-laden air. Accordingly, these components are put through stress tests beforehand.

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These tests simulate the actual operating conditions to ensure that the components function reliably. Test and measurement equipment that is suitable for this must be performance oriented in order to record and evaluate all the necessary parameters and ensure product quality. This includes tests such as environmental simulations, mechanical-technical tests, vibration tests, tests on the fuel system, engines, hydraulic systems, landing gear, aircraft frame, wings, and avionics and control systems, as well as testing of electromagnetic compatibility (EMC) and electromagnetic interference (EMI).

Test and measurement equipment for flight operation

Furthermore, highly complex test and measurement systems are also required during operation of an aircraft. Take the engine, for example: sensors collect an abundance of data such as atmospheric density and pressure in the engine, sometimes more frequently than once per second. Based on this data, a digital engine control monitors and regulates the fuel flow, speed and reverse thrust so that the engine is always operating optimally and consumes the least possible amount of fuel. Tests that are carried out range from validation and verification of prototypes and qualification tests in the development phase to acceptance tests in production or in the field. This leads to a demand for scalable and flexible test applications based on the test platform. In turn, this leads to a demand for scalable and modular system architectures and/or scalable and modular mechanical systems. This is where the PXIe standard is used with a flexible 19" subrack and a modular electronics cabinet platform.

„ In aircraft technology, a large number of different tests are carried out - in order to save costs, efforts are made to use the same test platforms. This means that the mechanics must also be scalable. This applies to everything from flexible 19" subracks to modular cabinet platforms.“

Bhowmick, Pradipto, Product Manager Schränke

nVent SCHROFF

4. Requirements for System Architecture and Enclosure Solutions

These growing requirements for simulation, test, and measurement tasks are also changing the requirements for enclosure and cabinet solutions. This concerns the system architecture with factors such as high computing power, fast data transfer, more accurate synchronization of individual components (clock and trigger functions), etc., as well as requirements for mechanical properties such as improved EMC shielding, superior signal integrity, improved cooling, and suitable configurations and platform-based developments for the modularity of test and measurement systems.

Depending on the application, it is important to choose a system architecture that provides the desired properties and interfaces. In the area of test and measurement applications, there are multiple standardized system architectures acceptable for building corresponding systems. In addition, corresponding mechanical requirements have to be taken into account, depending on the application.

4.1 Versatile Applications of PXI Express

PXI Express systems are suited for the tough requirements in simulations for autonomous driving, on test stands for function tests in the area of civil and military aviation technology, and for product tests of consumer electronics during the production process. Such complex products require test systems with a high data throughput and extremely precise clock and trigger signals for synchronizing the functions of the test object. These devices can be easily integrated into IIoT networks and offer sufficient data bandwidth to connect and synchronize the test devices to and with the rest of the production line. Additionally, detailed data is transferred for quality management as well as for documentation. Thanks to its fast data transfer rates with PCIe, paired with the implemented high-precision clock and trigger architecture which synchronizes the cards with each other, PXI Express is very suitable for such test, measurement, and simulation tasks.

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System architecture and mechanical systems

PXI Express is an updated PXI platform and provides the user with the widely adopted PCI Express bus. PXI Express is based on the widespread 19" form factor and offers backwards compatibility with the proven PXI. PXI Express has PCIe Gen3 with up to x8 links and supports a system bandwidth of up to 24 GB/s for acquiring and evaluating simulated and measured data. A sophisticated clock and trigger architecture supports synchronization of the measured data. Backwards compatibility with PXI-1 enables access to a variety of dedicated measurement and test cards. The PCI Express bus is expanded by one or more PCI Express switches to enable a larger measurement system with more than four slots. A PCIe-to-PCI bridge is required to operate the older PXI cards on the parallel 32-bit PCI bus in addition to the PXI Express cards in the chassis. If the required clock and trigger signals or the synchronization are designed to customer specifications, then CPCI serial systems can also be used.

Modular design of PXI Express systems

Any PXI Express system is subdivided into two areas. One area includes the plug-in cards (processor cards, measurement cards, I/O cards, etc.), which are selected in a wide variety of combinations specific to the application. These represent the actual target functions of the system. The second area consists of the PXI Express chassis. It provides the infrastructure required for operating the plug-in cards such as the mechanical enclosure, backplane, cooling system, power supply, etc. Since a test application finds a variety of uses, manufacturers of test devices prefer enclosure solutions such as the nVent SCHROFF PXI Express chassis, which is modularly built upon the proven RatiopacPRO platform and requires only minor adaptations for various areas of use.

nVent SCHROFF PXIe system – Modular Design

Backplane

To ensure that the backplane can be quickly adapted, it is designed to be as passive as possible, and the PCI bridge, PCIe switch, and clock functions are executed as separate modules and arranged on the rear side of the backplane between or above the slots. As a result, a more compact structure is possible in comparison to active backplanes. Thanks to the modular concept, standard components can be used, and any PXI Express backplane configuration can be easily implemented.

Cooling

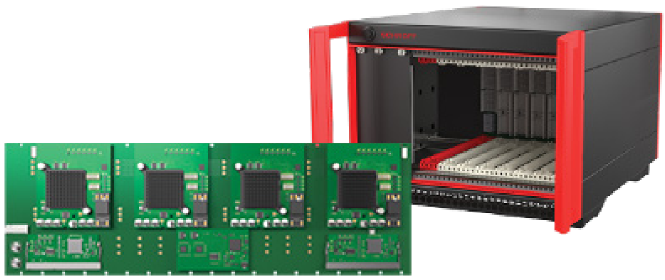
Depending on the area of use, there are different requirements for the cooling system. In general, attention should be given to providing uniform system cooling with a view to maximizing the permitted thermal power loss per slot. The loss depends both on the permitted temperature difference and the achievable air flow. In general, the greater the air flow and permitted temperature difference, the greater the thermal power loss that can be dissipated within the system. When used, for example, as a desktop enclosure in a laboratory environment, the resulting noise emissions should also be taken into consideration. The cooling system for a PXI Express system is usually designed for the maximum power per slot to be installed. However, due to the varying power values of the individual cards as well as the varying air impedance, the actual air distribution can differ. The cooling system can be adapted to the respective test or measurement task by running a simulation or testing the real system in advance. For applications outside of the lab, an air filter should also be installed to protect the electronics from dust and other dirt.

Power supply

It is necessary to ensure that the power adapters being used will be available, if possible, over the entire anticipated product life cycle. This prevents costly recertification of the systems. For nVent, corresponding industrial-grade power adapters with the conventional PC voltages (3.3 V, 5 V, ±12 V, and 5 V standby) are used. Unlike the ATX power adapters used in the commercial area, such industrial power adapters are typically available for more than 10 years. The switch-on behavior and correct switch-off behavior of the various output voltages are also very important. Firstly, to ensure that the cards are in fact initiated correctly and all functions are detected by the system controller during the boot process. Secondly, it is also necessary to prevent data loss or, in the worst case, damage to a card caused by uncontrolled switch-off of the voltages when the device is shut down. In the best case, this is ensured by a separate controller in the system that switches on the voltages in the correct sequence, monitors during operation, and maintains the specified times and sequences when the device is shut down.

Hardware management

In addition to controlling and monitoring the voltages, this controller can also assume other functions. To ensure the right balance between cooling output and fan noise in every state of the system, the fans are controlled by temperature sensors. The controller uses an I²C interface to transmit the system status to the system controller, the CPU board. Here, too, it is possible to secure a number of advantages through a modular design. By taking the approach of building the system controller from a COM module and a carrier, you can flexibly replace the standard COM module with processors of varying capacity while using the same carrier. It is even possible to transition to the next generation of processors here without redesigning the carrier.



Configuration of a PXI Express backplane

Mechanical systems: enclosures, subracks, and cabinets

Depending on the area in which the PXIe systems are used, for example, as test and measurement applications in production engineering, in the automotive field, or in aeronautical engineering, there are different requirements for modularity, durability, and EMC characteristics. It is therefore advantageous when you can rely on a broad product portfolio of enclosures, subracks, and cabinets that are established in the market and satisfy these requirements.

At the mechanical level, then, modular platforms such as those of the EuropacPRO subrack and the RatiopacPRO enclosure from nVent SCHROFF satisfy the test and measurement application requirements for modularity, stability, EMC protection, and unique customer branding or customized aesthetics. They flexibly adapt to the modular system infrastructure of PXIe and, by having a broad standard product range, enable an enclosure solution to be implemented quickly and easily. This means every PXI Express chassis can be implemented quickly and with little risk. PXIe systems are used in various form factors - as a desktop unit in a lab and in the development department or as a subrack, e.g. installed in the modular nVent SCHROFF Novastar electronics cabinet, when multiple systems are combined.

4.2 COM Modules in a Small Case

Test and measurement applications are typically not mass products, but complex, dedicated devices manufactured in short runs or medium-sized runs. In the modular area, such special devices can be custom built for the respective application with the corresponding cards available on the market. If just a single-board computer is needed, however, it is often difficult to find a suitable mainboard with the corresponding interfaces and functions for the desired test or measurement application. Computer-On-Module (COM) technology provides an attractive option here for creating a suitable solution with short development times and low costs.

System architecture

The actual computer (processor, chipset, integrated graphics, and main memory) is installed entirely on a small board; all of the usual interfaces such as Ethernet, PCIe, and USB, are routed to the connectors on the carrier. Such modules are available from countless manufacturers as standard modules with all types of embedded processors. The carrier is then developed—preferably by a signal integrity specialist—specifically for the corresponding application. Application-specific interfaces with the test object, circuits for generating clock and trigger signals or other special functions can be implemented on the carrier. A widespread standard for this is COM Express, a PICMG standard. The COM Express specification is very broad and primarily geared toward high-end applications with fast data transmission, high processor performance as well as demanding cooling and power supply.

Modular mechanical design of COM solutions

The enclosure also has to be appropriate for the modular design of the COM module in conjunction with the carrier. On the one hand, it protects the electronics from environmental factors such as vibration, dust, moisture, heat, and EMC radiation. On the other hand, it also protects operating personnel from getting injured or causing damage through unintended contact.

An enclosure platform with a parametric model, such as Interscale from nVent SCHROFF, can easily be adapted to any space-saving height, width, and depth desired for the COM module and carrier with its interfaces. Various fastening accessories for mounting additional modules and electronic components within the enclosure are available and allow for the flexible configuration of an individual solution. An interlocking tabbed design creates stability and provides integrated EMC protection for versatile application options, such as installation in a test device or in a control cabinet, mounting directly on a machine or as a portable application. In addition, the enclosure consists of only a few individual pieces that are easily fastened with two screws, which makes for fast integration and assembly time and minimal maintenance outlay.

The cooling solution also varies, depending on the environment. If a fanless cooling system is required, a flexible heat sink on the processor is used and the heat that is created is transported outward via the enclosure as well as a heat sink integrated into the enclosure. If higher cooling capacities are required, it is also possible to use fans and perforated enclosures. The electronics used remain the same; only the cooling solution is adapted. A high degree of flexibility for individual enclosure requirements is ensured by a toolkit of compatible options for various dimensions, cutout profiles and positions, powder coating and labeling, as well as a broad range of accessories and fastening options (wall mounting, top-hat rails, feet, etc.).

Depending on the application in which the COM module/COM carrier is used, various voltages are available: in the automotive area, 9 to 36 VDC, in telecommunications, 48 VDC, in railway applications, 16.8 to 150 VDC, etc. To cover the multitude of potential applications, the power supply and its management system for the COM carrier are designed as a separate module and can thus be flexibly adapted to the respective conditions. This means the COM carrier manufacturer provides a variety of power modules with different input voltage ranges, and these modules can be swapped at any time if the application changes, potentially altering the voltage range as well.

nVent SCHROFF COM system with heat sink

4.3 VPX Systems for the Most Stringent Environmental Requirements

Examples of typical measuring applications for VPX systems are test flights of prototype aircraft equipped with corresponding measurement equipment. A great deal of sensor data and other flight data is synchronously recorded and processed at this time. Similar measurement equipment is also sometimes subsequently installed in the production aircraft. VPX is primarily used by the military, in the aerospace industry, and in rail technology.

System Architecture and Mechanical Systems

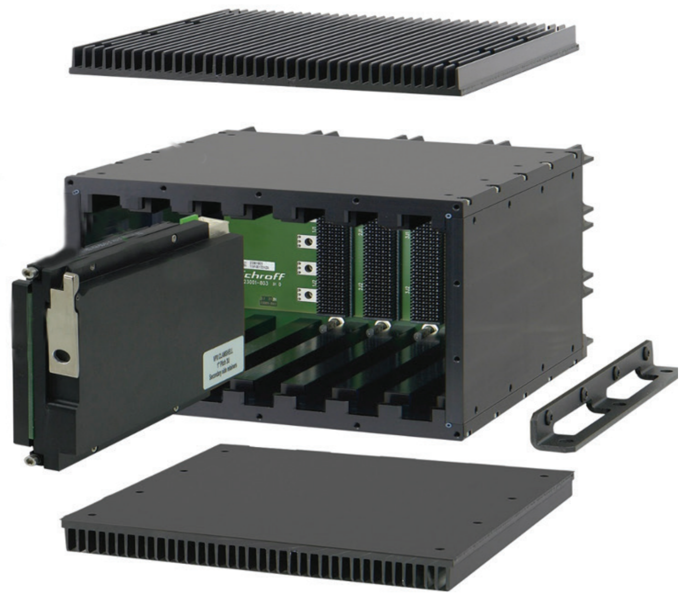
VPX (the VITA 46 specification) allows for a wide range of software protocols; in addition to the parallel PCI bus and VMEbus, this also primarily includes fast serial data transfer. During the specification work, great emphasis was placed on the durability of the VPX system. The VITA 48 REDI (Rugged Enhanced Design Implementation) specification provides additional definitions of particularly rugged mechanical solutions for the harshest environmental conditions.

Rugged mechanical systems

Harsh environments place special requirements on mechanical systems with respect to shock and vibration loads. In this case, users rely on a corresponding system platform with a broad range of standard components for modular subracks that satisfy the increased load requirements. With nVent SCHROFF, for example, you can put together standard systems with shock and vibration resistances of 2 to 40 *g*. Depending on the requirement, side panels of different thicknesses (screwed or tox-cold welded), 19" brackets and corner profiles as well as various versions of module rails such as a rugged module rail attached at three-points are used to ensure the required stability of the system. Cover plates and rear panels or rear hoods as well as other accessories complete the system. Additionally, the systems are provided with corresponding EMC gaskets to establish contact between the components and ensure EMC sealing. Modifications for cutouts, paint and printing as well as surface treatment, can be flexibly implemented for these subracks.

Cooling system and power supply

The VPX specification offers a wide variety of cooling options ranging from convection and conduction to liquid cooling. Redundancy and hardware management are options that can be implemented to realize a fail-safe system for the most extreme conditions. Special VPX power adapters equipped with clamshells are typically used for conduction-cooled systems. VPX systems for which standard air cooling is sufficient are generally operated using commercially available CompactPCI power supplies.



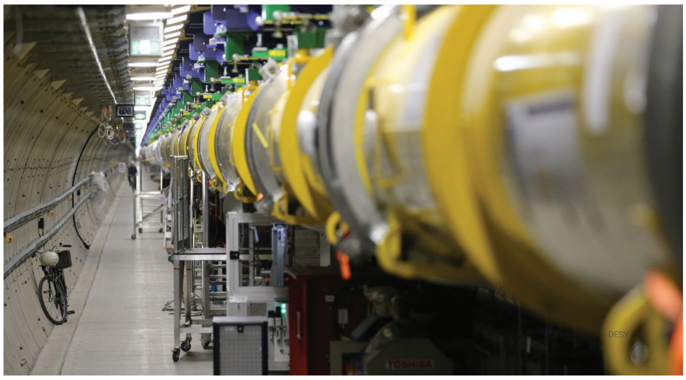
nVent SCHROFF Titan system

4.4 MicroTCA for Complex Test and Measurement Systems

MTCA.4 is used particularly for high-end test applications that place special value on synchronization, rear I/O, high availability, redundancy, and remote maintenance, as is the case, for real-time motion control, in medical technology, and in the physics community. Compared to the other solutions described, components in an MTCA.4 system can be replaced while the device is operating. Wherever downtime is critical or expensive, it makes sense to consider relying on a highly available technology such as MicroTCA. In addition, thanks to built-in hardware management, all operating states can be viewed and monitored. The integrated carrier and shelf management makes it possible to monitor the status of all components in the system at any time and to respond to error statuses.

At present, MicroTCA.4 is used primarily by the physics community for controlling particle accelerators for high-energy physics, but it is also applicable in other areas as well. Operation of particle accelerators requires highly accurate synchronization of all machine parts. Clocks in the femtosecond range are created and distributed on cards in the RTM section of the MicroTCA systems. To be able to generate such precise signals, it is an important prerequisite to have a constant temperature in the system. This is achieved by electronics cabinets fitted with air/water heat exchangers, such as the nVent SCHROFF Varistar LHX. By maintaining a constant water temperature, the temperature in the cabinet can be kept constant to within +/- 0.1 °C. Clocks in the femtosecond range can play a role in test and measurement applications, so it is also necessary to maintain stable temperature specifications here. This means that corresponding electronics cabinets with air/water heat exchangers should be used.

nVent SCHROFF MTCA.4 systems



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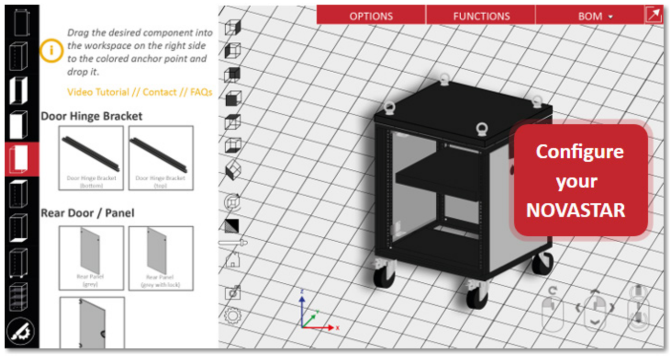
5. Flexible Branding for Corporate Identity

For test and measurement systems, it is important not only to adapt to the technical requirements, but also to have the option of giving these systems their own design and branding. Thanks to the platform-based modular design of nVent SCHROFF enclosures, subracks, and cabinets, the design can be adapted even for small quantities. Consequently, entire series of test and measurement devices from a manufacturer can also provide a uniform appearance with high recognition value from the front panel through to the entire cabinet. This plays a particular role when the systems are visible to end customers, for example, as in a factory building with a requirement for uniformity.



nVent SCHROFF 3D Configurators

6. Fast Project Start-up

In the case of customer-specific project requirements, it is necessary to provide for design recommendations and technical collaboration with a specialist as early as the request phase and to support the customer during this phase as well as preparation. Particularly when the system architecture suitable for the desired application is being defined, it is often necessary to receive additional support and advice from specialists. This ensures from the outset that all essential parameters are taken into account, which in turn keeps the development time as short as possible. If the project concerns a standard product or the mechanicals only, then manufacturer websites and online 3D configurators are the first place to go. Here, it is helpful to have configurators that are easy and intuitive to use (drag and drop) so that a compatible enclosure solution can be identified quickly. nVent SCHROFF offers configurators for subracks, front panels, and electronics cabinets. These configurators include a real-time plausibility check so that the user's individual requirements can be implemented in a product without any errors. A bill of materials with the currently installed components is created automatically. In addition, 2D or 3D CAD data can be generated directly from the configurator and imported into a CAD system. It is also possible to create a 3D PDF data sheet that includes graphics and the bill of materials.

7. Summary

Further developments in areas such as communication, production engineering, and the automotive industry are leading to increasing use of highly complex electronics with increased data traffic, higher computing power, etc. This results in an increasing number of test and measurement tasks that require not only more powerful systems, but also better modularity of the test and measurement equipment to minimize development outlay. The correct system architectures as well as modular and flexibly adaptable product platforms for a customized mechanical system enable fast project starts, shorter development times, and the building of entire series of test and measurement devices with a uniform appearance and high recognition value.

About the author:

Christian Ganninger studied electrical engineering at the Karlsruhe University of Applied Sciences. Afterwards, he worked as a developer and technical coordinator for backplanes and subsequently as a project manager for backplanes and systems in a company developing and producing 19" systems and backplane units. Since May of 2005, he has been an employee of Schroff GmbH and was initially product manager for backplanes. Later on, he took over product management for MicroTCA, power supplies and rugged enhanced systems. Since 2011, he has been responsible for the Systems product category in EMEA, and in 2014, he assumed the role of Global Product Manager for Systems.

Waldemar Schulz, studied industrial engineering at the University of Applied Sciences in Pforzheim. Since 2015 he has been an employee of Schroff GmbH and initially worked as a production analyst on process optimisation in project management systems. Later he became part of the global nVent ERP team and as (certified SAP) Inhouse Consultant/ ERP Analyst he supervised ERP implementations in several international production facilities. In 2019 he took over the role as global product manager for the EMCA product category (subracks, enclosures and front panels).

About ENCLOSURES

Electrical systems are available in all shapes and sizes—from large industrial control systems to individual components. nVent provides a comprehensive range of enclosures that accommodate these important systems. Our enclosures are marketed under the nVent HOFFMAN and nVent SCHROFF brands and offer double protection. They protect electrical devices from the operating environment and people from the hazards posed by electrical systems. The nVent SCHROFF brand offers server cabinets, cooling solutions for data centers, energy supply solutions, subracks, and enclosures.

About nVent

We at nVent strongly believe that reliable systems also make the world a little safer. Through innovative electrical solutions, we connect and protect our customers. nVent is a global enterprise with an annual turnover of approximately 2 billion dollars and nearly 9,000 employees worldwide.

More information

You can find more information about nVent SCHROFF at https://schroff.nvent.com/en/schroff

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