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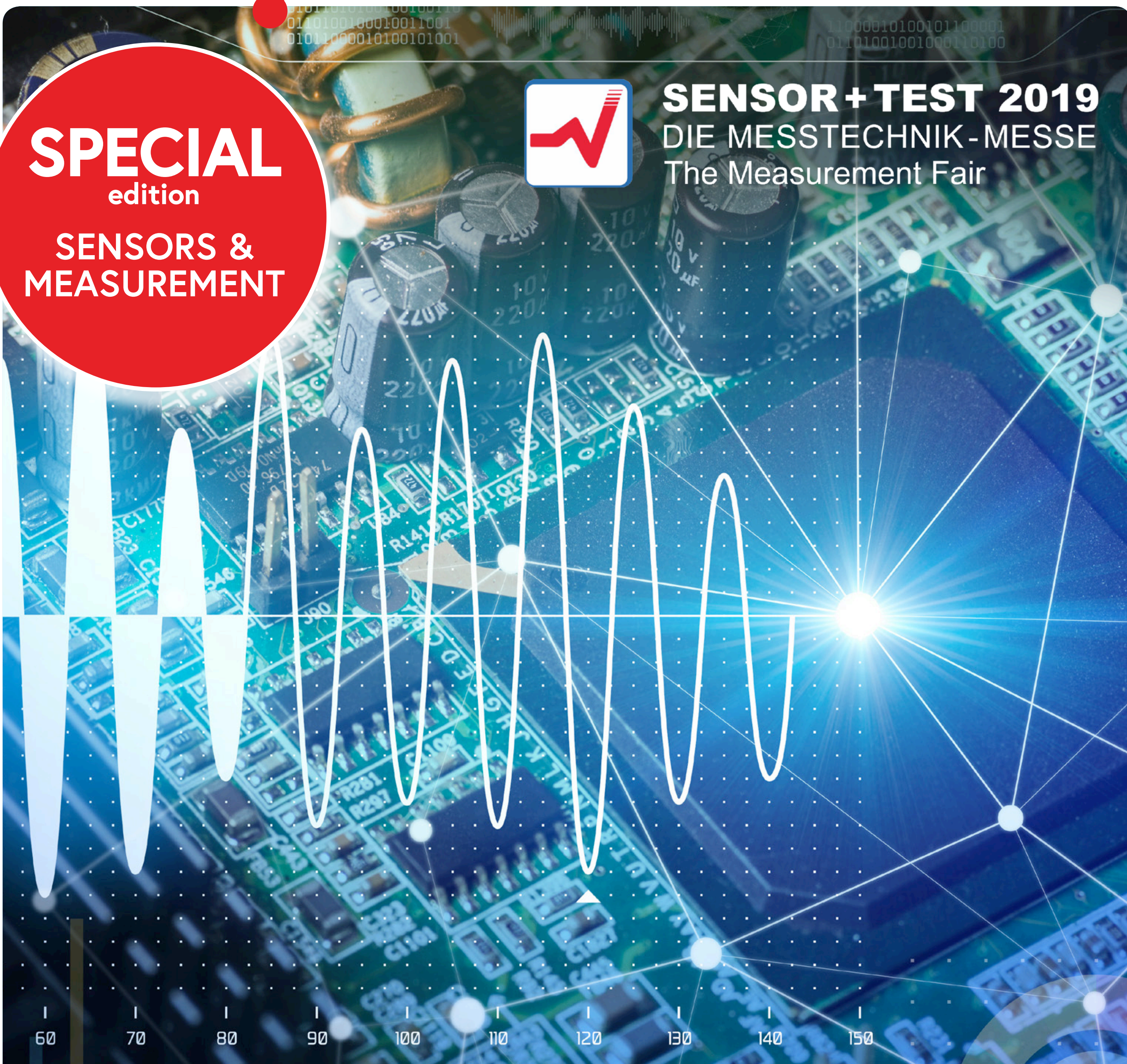

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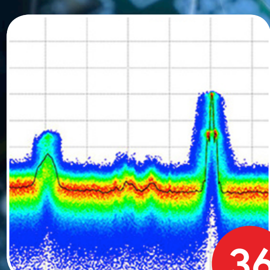
Using the Bode plot



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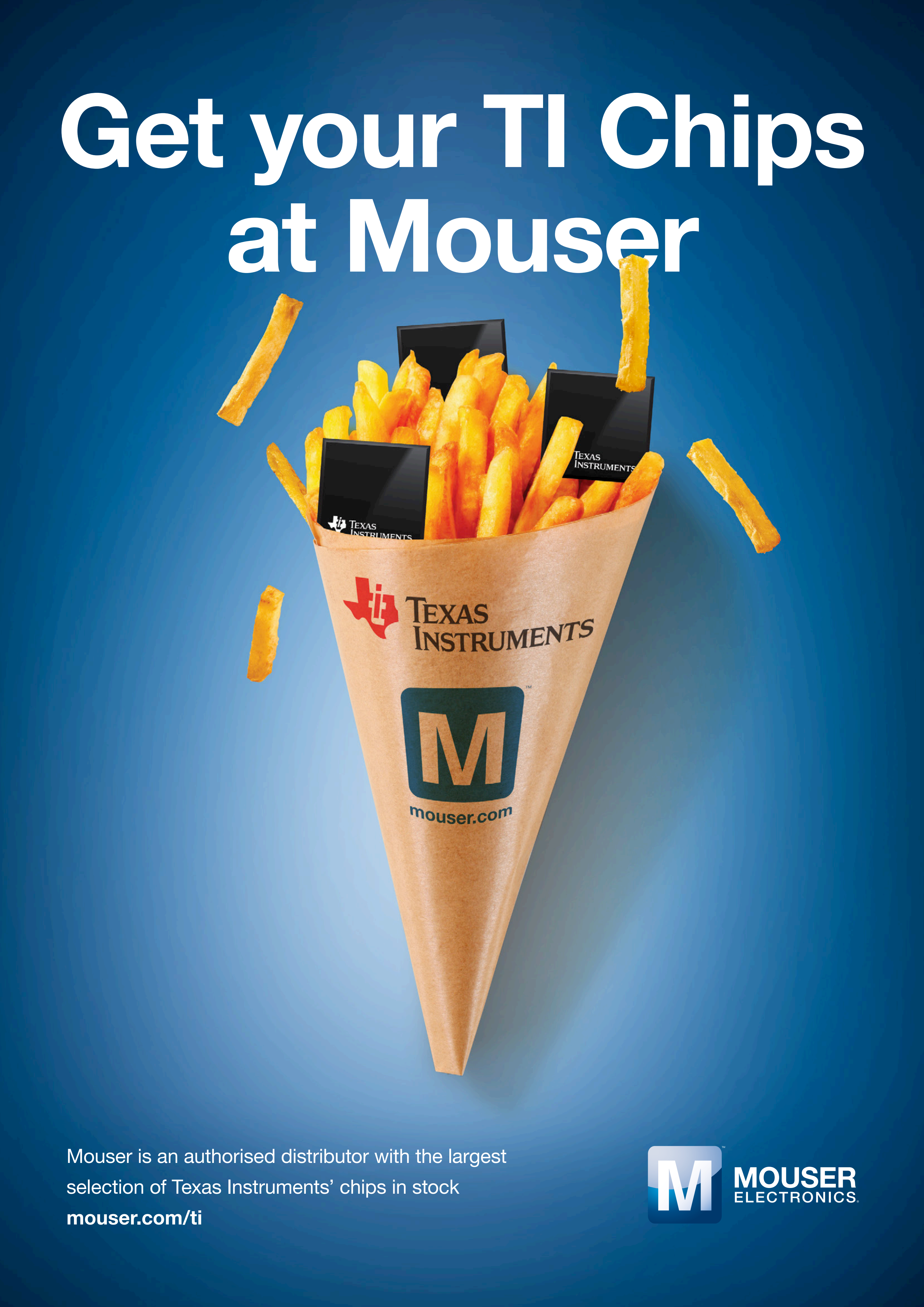
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Foreword

What Better Specialism than Sensors & Measurement

With IoT now firmly established but still a challenge to get right especially in terms security, many in the industry and in small labs are totally occupied with programming and finding common ground for the largest number of interconnected devices on the planet. At first blush, the 'giga' companies rule the roost in terms of IoT development but those with a keener eye will be able to spot at least one force active "underground" where a lot is happening, and ingenuity abounds. I mean the rising number of young engineers who work "analogue" because their expertise is badly needed by hordes of IoT programmers, product and sales managers breathing down their necks.

Sensor design and analogue technology in general have been wronged these past 25 years when it was claimed that anything can be programmed, "embedded" or "app'ed". At the same time, the old hands at analogue test and measurement were either let off or signed up by their managers to courses in 0/1 thinking.

On a more cheerful note, I was delighted recently to overhear a few under-25s discussing "nano-amps", "ADC monotonicity" (wow!), and googling "√Hz". Given their age I was expecting IP stack conflicts, ARM code and software hacks. These budding engineers are sure to get jobs as the industry is crying out for expertise in sensor design and measurement — exactly the subjects of this edition and very much in the spotlight at the upcoming Sensor + Test show in Nuremberg which I strongly recommend visiting. No probe needed, I'm sensing I will be there.

Jan Buiting, Editor-in-Chief

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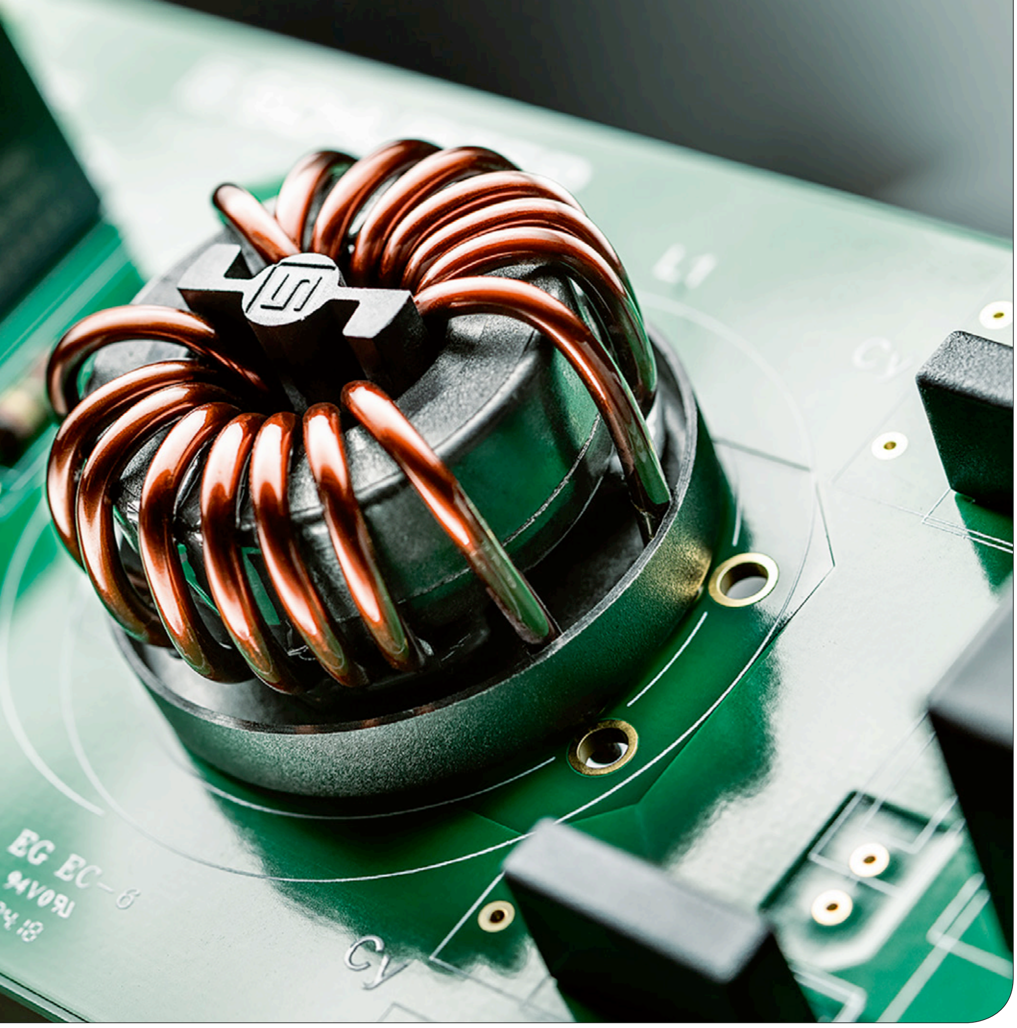

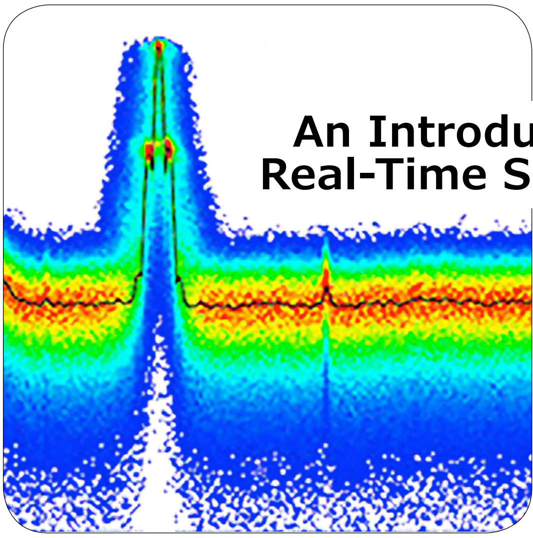

Colophon

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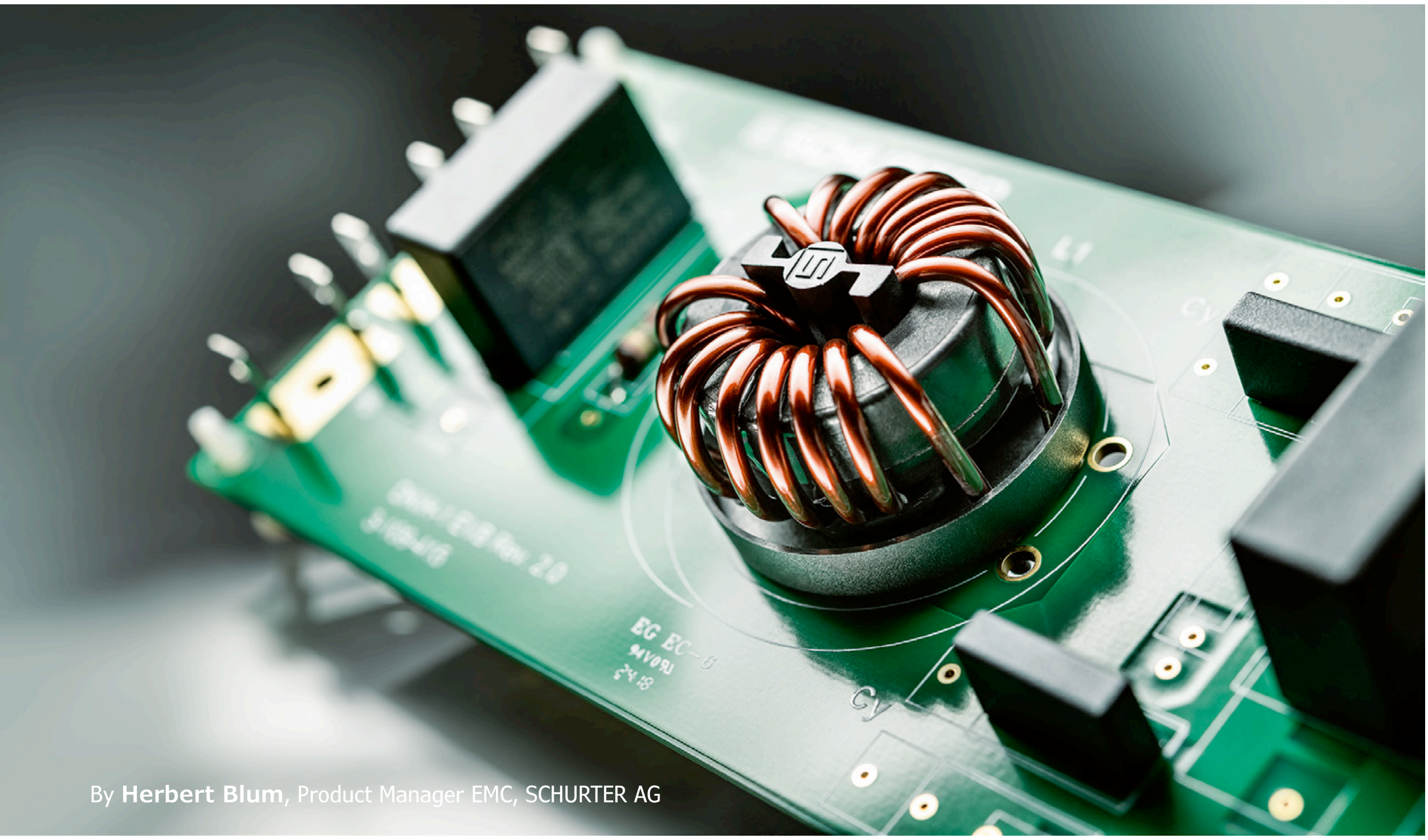
The Ideal Filter In Just Six Steps



By **Herbert Blum**, Product Manager EMC, SCHURTER AG

The causes of EMC interference can be of various kinds. Therefore, standard filters are not always the simplest and best solution. SCHURTER now offers an “Evaluation Board” with which an almost ideal filter for the specific incident can be built within a short time in an iterative process.

Every developer of an electrical or electronic device is faced with the same problem: in the end, the device must comply with international EMC guidelines regarding emissions and immissions. In the age of the substitution of mechanical and mechatronic systems by purely electrical ones, EMC is becoming increasingly important.

Origin

EMC problems, often of an unpredictable nature, mostly arise in the power section. Like most electronic assemblies, the power section is also increasingly being mounted on printed circuit boards with discrete components. Due to the high integration of components to achieve a compact design, thermal problems can arise due to high currents on the printed circuit board. The resulting EMC interference can affect adjacent components due to the lack of spatial separation. Therefore, a compact filter directly on the PCB with discrete components is often the best solution. And a current compensated choke with capacitors is the most efficient measure in EMC Suppression.

Nothing goes without measurements

First of all: Nothing goes without measurements. The ones who can carry out EMC measurements themselves according to EN 55011 should take a closer look at the DKIH Evaluation Boards. Variants of the boards are available for 1-phase and 3-phase systems. These evaluation boards are suitable for systems up to 50 ampères.

Filter Design

An EMC filter should bring the emissions

Company

SCHURTER is an internationally leading innovator and manufacturer of electric and electronic components. The company focuses on safe power supply and easy-to-use equipment. Its extensive product portfolio comprises standard solutions in the fields of circuit protection, plugs and connectors, EMC products, switches, input systems and electronic manufacturing services. SCHURTER's global network of representative offices ensures reliable delivery and professional customer service. Where standard products are unsuitable, the company develops client-specific solutions.
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below the limits specified for the application. Most product standards require measurements in the range from 150 kHz to 30 MHz conducted and 30 to 1000 MHz radiated. Line filters are often required to ensure EMC-compliant operation. Classical LC filters consisting of a combination of interference protection capacitors and Suppression Chokes. The choke is typically designed as a current-compensated choke with two opposing windings and

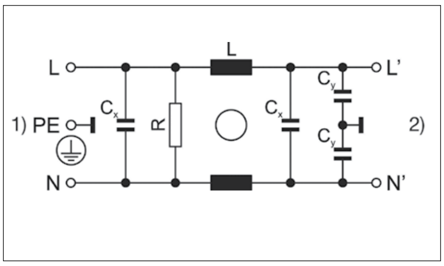

Figure 1: Typical 1-phase filter (FMAB NEO).

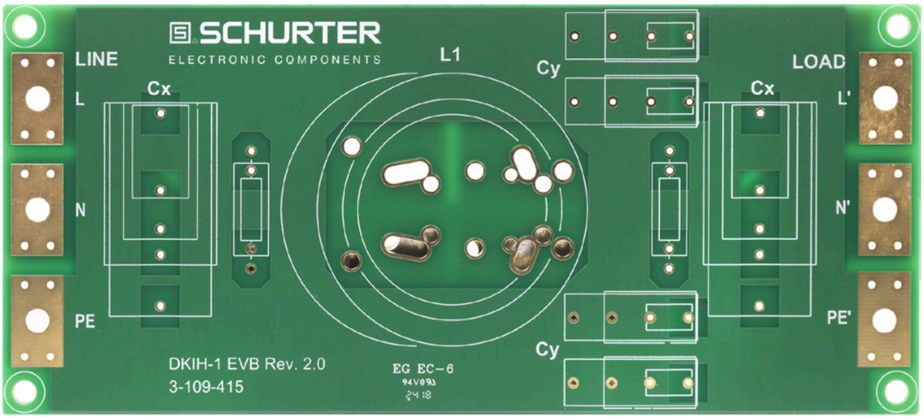

Figure 2: DKIH-1 EV.

the same number of turns. This compensates the magnetic fields, which means that the normal operating current does not see any inductance. A diagram of a typical 1-phase filter can be seen below. With a current compensated choke and two X capacitors between L and N and two Y capacitors to ground. This circuit as shown in **Figure 1** is very effective with low power dissipation but provides good noise attenuation over a wide frequency range.

Measurement at the real interferer

The universal design allows the construction of a classic LC filter circuit, see **Figure 2**. Two X capacitors of various sizes can be installed before and after the choke and a total of four Y capacitors. Leakage resistors are provided to protect against electric shock. The connection is made via two 6.3 x 0.8 mm tabs, a 4 mm hole or direct soldering of the cables to the large-surface pads. It is recommended to make the earth connection as flat as possible using copper tape or wide copper strands. The effect of the Y capacitors is considerably influenced by the connection.

If no previous measurements or simulations have been made, it is usually not known whether we are dealing with a high asymmetrical (L to PE) or symmetrical (L to N) interference.
It is always advisable to make a measurement first without filter components on the device. It must be ensured that the maximum interference level is found. This is decisive for EMC conformity.

Step 1
Measurement without filter components, conducted between 150 kHz - 30 MHz.
- The limit values are clearly exceeded, see **Figure 3**.

Step 2
Configuration of the Evaluation Board DKIH1-EVB with 0.8 mH choke (10 A ferrite) and capacitors of 2 x 470 nF and 4 x 2.2 nF. Viewing the results in **Figure 4**, we notice:
- Insufficient suppression, especially in the lower frequency range
- Larger X capacitors can be used to increase suppression in the lower range

Step 3
Configuration of the evaluation board DKIH1-EVB with choke 0.8mH (10 A ferrite) and larger X capacitors of 2 x 1.0 µF and 4 x 2.2 nF. **Figure 5** shows the results.
- Still slightly insufficient suppression despite larger X capacitors.
- A replacement of the choke with ferrite core by a choke with nanocrystalline core with much higher inductance (6.9 mH instead of 0.8 mH) is required.

Step 4
Configuration of the evaluation board DKIH1-EVB with nanocrystalline choke 6.9 mH (10 A NK), capacitors remain at 2 x 1 µF and 4 x 2.2 nF. The improved results are noticeable in **Figure 6**.
- Only slightly insufficient suppression due to the higher inductance.
- Filter effect not yet optimal.

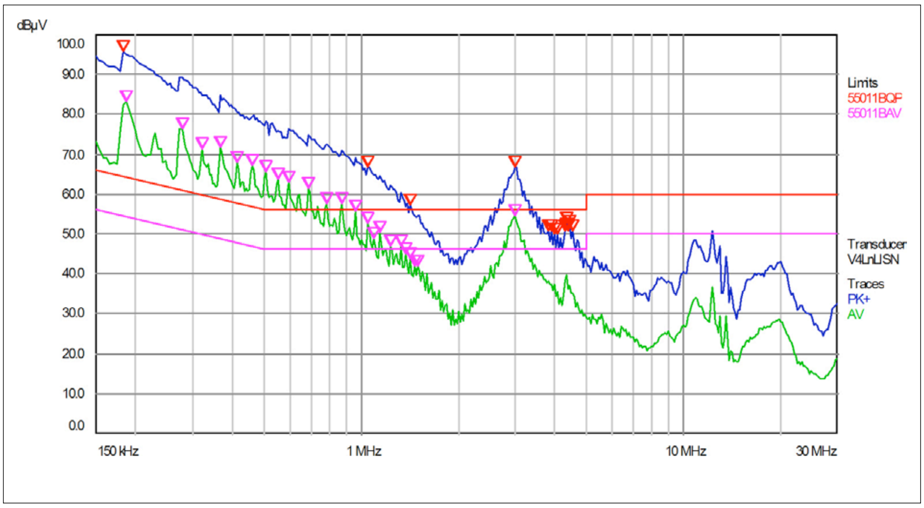

Figure 3: Measurement without filter components, conducted across the frequency range 150 kHz - 30 MHz.

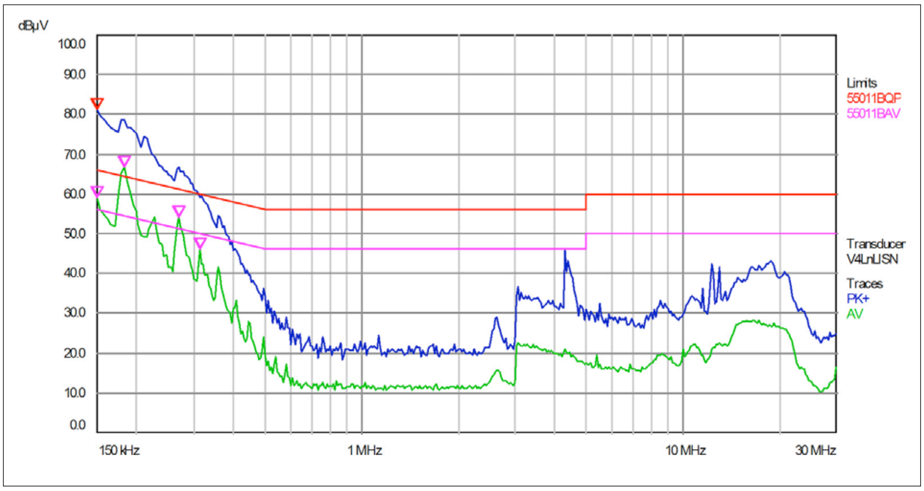

Figure 4: Response of DKIH1-EVB Evaluation Board with 0.8 mH choke (10 A ferrite) and capacitors of 2 x 470 nF and 4 x 2.2 nF.

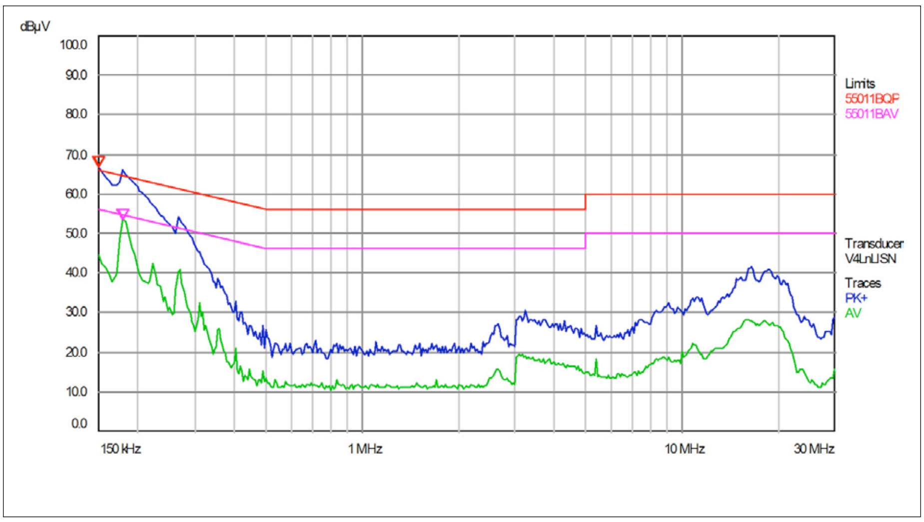

Figure 5: As Figure 4, but with larger X capacitors of 2 x 1.0 µF.

Step 5

Configuration of the Evaluation Board DKIH1-EVB 6.9 mH (10 A NK), X capacitors increased to 2 x 2.2 µF, Y capacitors remain at 4 x 2.2 nF. The results from the change are seen in **Figure 7.**

- Very good suppression thanks to larger X capacitors.
- Circuit can still be cost- and space optimized.

Step 6

Configuration of the evaluation board DKIH1-EVB with 0.8 mH ferrite choke (10 A ferrite), capacitors remain the same at 2 x 2.2 µF, 4 x 2.2 nF. Good results: see **Figure 8**.

- In this example, the amount of asymmetric interference is not very large, so that the inductance can be reduced.
- Cost-optimized circuit with large X capacitors instead of expensive nanocrystalline chokes.

Before implementation

If a suitable circuit is found on the evaluation board, some questions have to be considered before the circuit is implemented on the device board:

- Ground connection of the Y capacitors?
- Leakage current of the Y capacitors?
- Heating of the choke (measure temperature at critical load current)?
- Space requirement of the components?
- Is the temperature rating of the components sufficient?
- Are the voltage ratings of the capacitors sufficient?
- Do the capacitors meet the common safety requirements for the mains voltage used? The IEC standards generally require the use of safety capacitors of at least class X2 and Y2 for 250 VAC applications.
- High voltage requirements on the capacitors?

Especially the leakage currents are often critical due to application or standard requirements. It is recommended to measure the currents of the entire system with a built-in filter circuit.

The normal leakage currents of the capacitors used can easily be calculated from:

$I_L = 2\pi \times f_n \times U_n \times C_y$

Conclusion

Thanks to the SCHURTER DKIH Evaluation Boards, various filter configurations can be quickly measured without changes to the PCB layout. With high L and C component values, the vast majority of interferences can be adequately attenuated.

But the art of optimal filter design is to find the right component combination. Often somewhat smaller C and L values are sufficient, if they are combined optimally.

It is recommended to remeasure the finished application with the final filter design on the circuit board. An EMC measurement of the finished system or device is indispensable for the declaration of conformity.

In case of questions and measuring problems our EMC-Service is at your disposal.

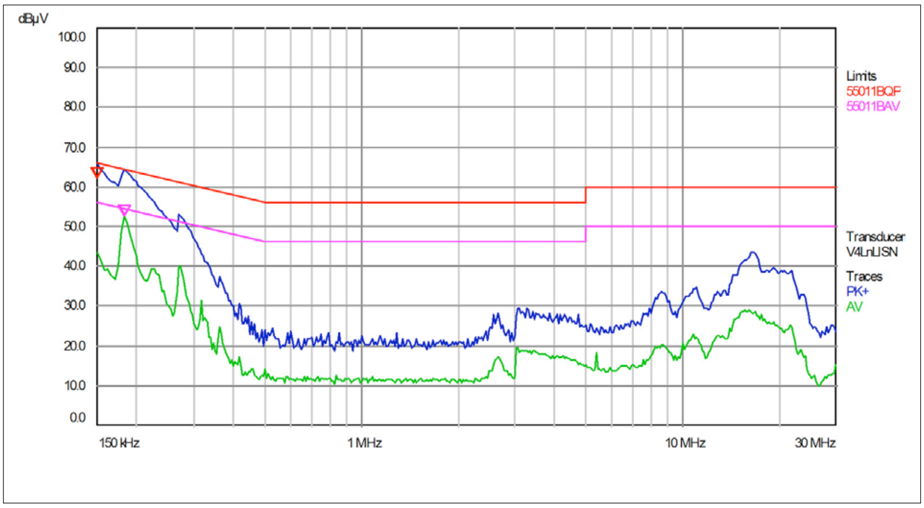

Figure 6: Further improvement thanks to the use of a 6.9 mH nanocrystalline choke.

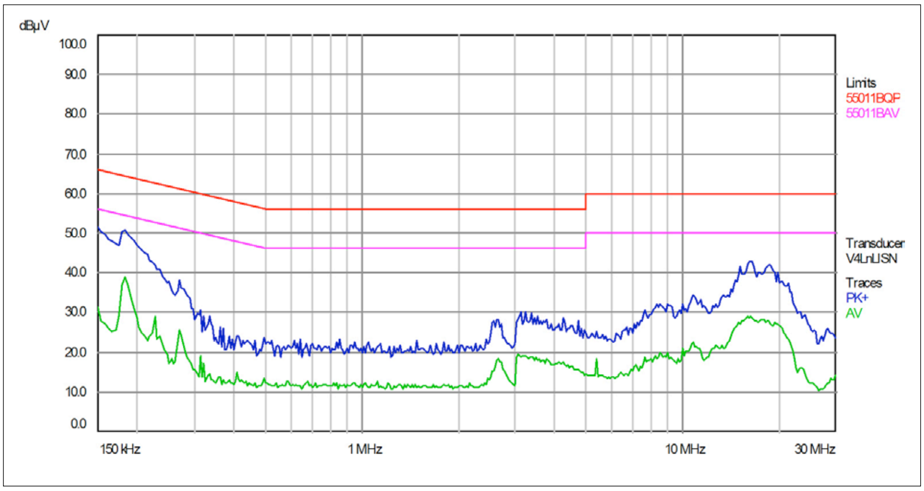

Figure 7: Response with X capacitors increased to 2 x 2.2 µF.

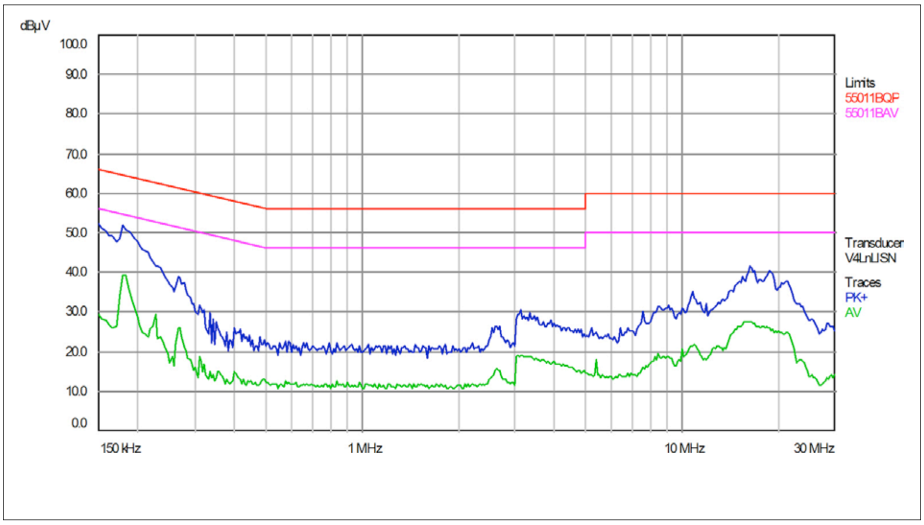

Figure 8: Acceptable, if not good, results from the use of 0.8 mH ferrite choke.

The Author

Herbert Blum is product manager for the entire EMC product range of the SCHURTER Group. Prior to that, he worked for over 10 years as a project manager in the development engineering of filters. Herbert Blum holds a degree in Electrical Engineering and a Master in Business Administration.

Reliable & Secure IIoT Wireless Sensor Networks for Industry 4.0

By **Mark Patrick**, Mouser Electronics

The fourth industrial revolution (or Industry 4.0), is now upon us — made possible by the Internet, cloud computing, data analytics and the roll-out of Industrial Internet of Things (IIoT) infrastructure. Although prior industrial technology deployments had enabled the monitoring and control of various systems in factories, power plants, oil refineries, gas pipelines, rail transportation and suchlike, IIoT has the potential to bringing about the next phase in the progression of automation, through employing industrial wireless sensor networks (WSNs).

Supplementing data from the control system with what is acquired by IIoT nodes provides a more comprehensive dataset that will allow companies to optimize their entire value chain. For example, understanding the health of critical factory equipment can help predict when/where issues might occur, thus avoiding downtime and saving companies huge amounts of money annually. It can also reduce the frequency with which maintenance work needs to be carried out, thereby curbing operational costs, especially when items of equipment are in hard-to-reach places.

By 2023, *On World* forecasts there will be 3.4 billion WSN chipset units shipped worldwide each year (up from 1 billion during 2018). Short range technologies such as 802.15.4, Bluetooth, Wi-Fi, and proprietary protocols currently make up over 90% of all shipments, but low power wide area (LPWA) networks (including Sigfox, LoRa, and NB-IoT) are increasing at much faster rates. The report also expects annual revenues for WSN equipment and associated services (for industrial automation, agriculture, and construction) to surpass $13 billion within the next five years.

The IIoT Nervous System

The industrial sector generally places a higher priority on security and reliability over the cost of systems that help ensure the smooth and efficient operation of manufacturing or processing sites, because any failures, delays, or accidents will cost a lot more in terms of lost revenue or worse, human lives. Advancements in wireless communication, power efficiency, miniaturisation and smarter embedded computing technologies, as well as more robust, ultra-low power designs that can last for several years on button cell batteries, have led to the development of reliable and secure wireless sensor nodes that meet stringent industry requirements and can operate in the most extreme of application settings.

The lower cost of WSN technology makes it relatively easy and also quite economical for companies to deploy hundreds (or even thousands) of sensor nodes across an entire facility — creating an IIoT approximation of a human nervous system. This scalability, combined with the capacity to support multiple wireless networking protocols, further increases the reliability of ecosystems — with an extensive network of sensor nodes, repeaters, and gateways all enabling both the spatial and channel redundancies that are essential to Industry 4.0.

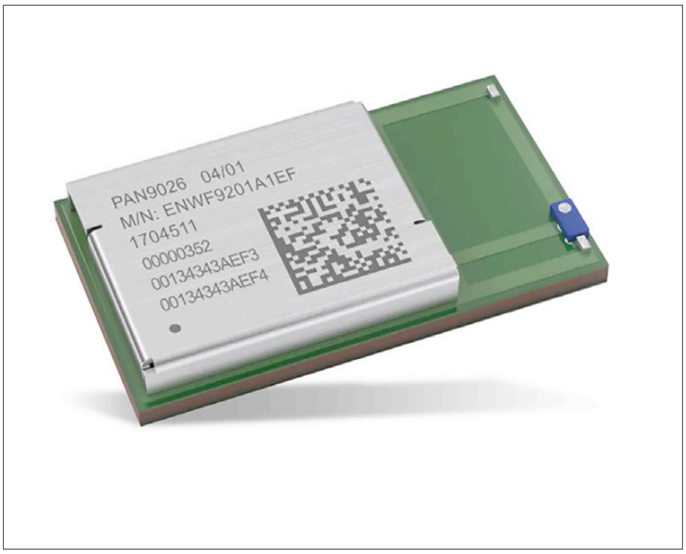

Figure 1: The Panasonic PAN9026 module.

Support for IIoT Wireless Protocols

In addition to harsh or remote operating environments and the sheer size of industrial facilities, designers should also take into consideration the interference brought about by all the metal, concrete and equipment, as well as electromagnetic interference from other electronics in and around the site. All these determine what type of IIoT nodes to implement or which combination wireless protocols should be supported, depending on the application. Bluetooth Low Energy (BLE), ISA-100.11a, WirelessHART, and Zigbee are all valid options.

Microchip's 2.4 GHz transceiver modules [1] boast extremely low receive currents for longer battery life. The IEEE 802.11 module firmware has an easy-to-use API driver interface to the company's free TCP/IP protocol stack and its popular PIC microcontroller units (MCUs). These low-power embedded Wi-Fi modules remove the complexity and cost of developing RF circuitry from scratch and obtaining agency certifications. The RN1810 model incorporates an onboard TCP/IP networking stack, cryptographic accelerator, power management subsystem, real-time clock, 2.4 GHz transceiver, and RF power amplifier.

Panasonic's PAN9026 module shown in **Figure 1** [2] combines IEEE 802.11a/b/g support with Bluetooth BDR/EDR/LE functionality for flexible connectivity options in smart energy, home gateways, and IIoT applications. It features dynamic rapid channel switching (DRCS) for simultaneous operation in 2.4 GHz and 5 GHz. The independent operation of these two standards enables data rates up to 150 Mbps to be reached, plus low power consumption of 400 mA (transmit) and 70 mA (receive). With integrated power management, a fast dual-core central processing unit (CPU), 802.11i security standard support and high-speed data interfaces, it delivers the speed and reliability needed in IIoT deployments.

The Author

Mark joined Mouser Electronics in July 2014 having previously held senior marketing roles at RS Components. Prior to RS, Mark spent 8 years at Texas Instruments in Applications Support and Technical Sales roles and holds a first class Honours Degree in Electronic Engineering from Coventry University.

Next, there is the MRF24J40MA from Microchip [3]. This is an FCC-certified RF transceiver product that provides a complete wireless networking solution serving the 2.4 GHz unlicensed industrial, scientific and medical (ISM) short-range wireless frequency band, as well as ZigBee and proprietary wireless protocol systems. The surface-mount module is designed for use with a variety of 8-bit, 16-bit, and 32-bit PIC MCUs. When combined with the MiWi peer-to-peer software-protocol stacks or other free development tools, it allows design engineers to implement low-power wireless networks quickly and inexpensively.

Smarter WSN Solutions

The Silicon Labs Ember EM35x series [4] is comprised of fully integrated system-on-chips (SoCs) that have a 2.4GHz, IEEE 802.15.4-2003-compliant transceiver, 32-bit ARM Cortex-M3 microprocessor, flash, and RAM, plus numerous peripherals of value to designers of ZigBee-based systems. The transceiver element uses an efficient architecture that exceeds the dynamic range requirements imposed by the IEEE 802.15.4-2003 standard by over 15 dB. The integrated receive channel filtering allows for robust co-existence with other communication standards in the 2.4 GHz spectrum, such as IEEE 802.11-2007 and Bluetooth.

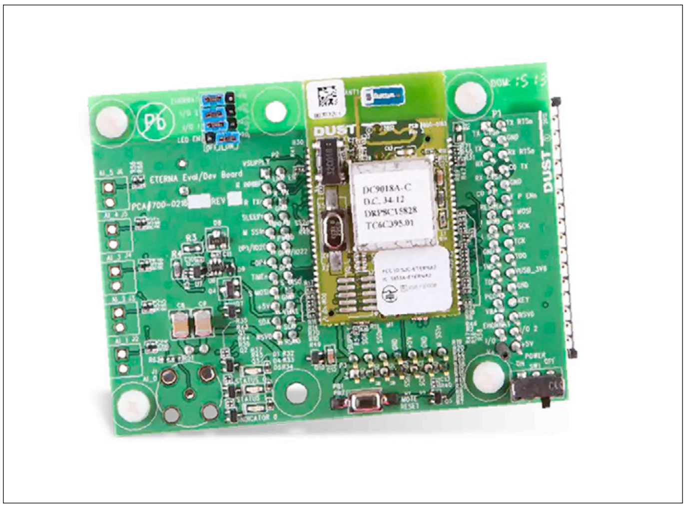

Figure 2: SmartMesh IP Technology from Analog Devices.

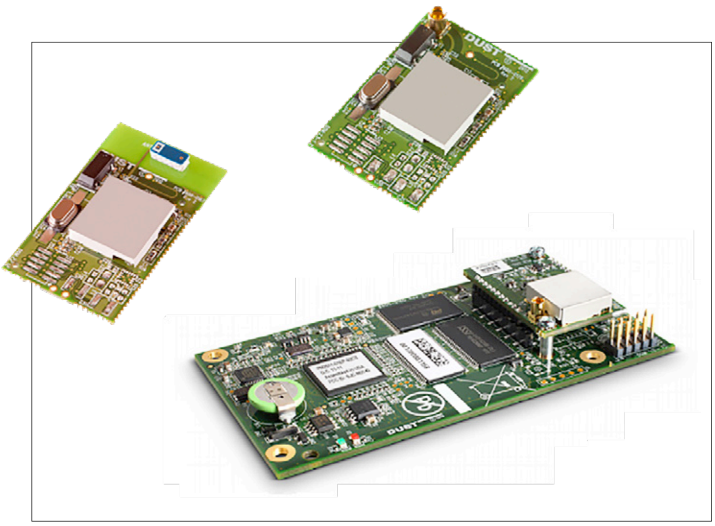

Figure 3: Motes and Network Manager Boards Supporting SmartMesh IP Technology.

NXP Semiconductors' JN5148-001 ultra-low power, high-performance wireless MCUs [5] target ZigBee PRO networking applications. They each feature an enhanced 32-bit RISC processor, offering high coding efficiency through variable width instructions, along with a multi-stage instruction pipeline and low-power operation with programmable clock speeds. These MCUs also incorporate a 2.4 GHz IEEE 802.15.4 compliant transceiver, 128 KB of ROM, 128 KB of RAM, and a rich mix of analog and digital peripherals. The large memory footprint allows them to run a network stack and an embedded application or in a co-processor mode. The operating current is below 18 mA, permitting direct powering from a coin cell. Enhanced peripherals include low power pulse counters running in sleep mode designed for pulse counting in automatic meter reading (AMR) equipment and a unique time-of-flight (ToF) ranging engine to support accurate location services over WSNs.

Texas Instruments' CC2530, CC2531 and CC2533 are SoC solutions for 802.15.4, ZigBee and RF4CE applications. They combine the performance of a leading RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory and 8kB of RAM. The CC2531 enables USB dongles or USB upgradable network nodes to be built with low total bill-of-material costs. It has various operating modes, making it suitable for systems where ultra-low power consumption is required. Short transition times between operating modes further ensure low energy consumption. With its large flash memory of up to 256 kB, the CC2530 is designed for ZigBee PRO applications. 64 kB and above versions support the RemoTI stack for ZigBee RF4CE, which is the industry's first ZigBee RF4CE-compliant protocol stack. Larger memory sizes will allow for on-chip, over-the-air-download to support in-system reprogramming. The CC2533 has up to 96 KB in-system programmable flash memory, and up to 6 KB of RAM.

Analog Devices' SmartMesh IP wireless solutions shown in **Figure 2** [6] (from the Dust Networks product group) consist of embedded chips and pre-certified PCB modules. The modules come complete with fully developed, field-proven, intelligent wireless mesh networking software (**Figure 3**). SmartMesh WSNs are capable of delivering strong data reliability (>99.999%) over ultra-low power, secure wireless communications. This enables sensors to be placed in uncompromising IIoT environments. At the heart of the SmartMesh motes and their related network manager boards is the Eterna IEEE 802.15.4e SoC, which features the company's highly integrated, low-power 2.4 GHz radio design. It also features an ARM Cortex-M3 32-bit microprocessor running SmartMesh networking software.

Conclusion

The WSN hardware needed to support the widespread proliferation of Industry 4.0 technology is getting there. ICs and modules can now be found on the market that attain the performance levels required, while also coping with power budget constraints, challenging operating conditions and an array of different security threats. Consequently, in the coming years, the many benefits that can be derived from increased automation will begin to be realized globally. ◄

Weblinks

[1] Microchip 2.4 GHz transceiver modules : https://bit.ly/2ZMIpzL

[2] Panasonic PAN9026: https://bit.ly/2Wj1ZkX

[3] Microchip MRF24J40MA: https://bit.ly/2GTCeRE

[4] Silicon Labs EM35x: https://bit.ly/2Y50Ii7

[5] NXP Semiconductors JN5148-001: https://bit.ly/2XX4rht

[6] Analog Devices Smartmesh: https://bit.ly/2WpmPis

“Conformable Electronics” sensors from the textile industry are suitable for industrial applications

(Munich, May 31, 2019) As one of the leading companies in the field of “conformable electronics”, Teiimo GmbH offers textile-integrated solutions to measure body and position data. The core of each solution is an intelligent system of sensors, conductors and electronic units. Due to its robustness and ease of integration, it is well suited for applications in industry and robotics.

Intelligent, robust and easy-to-integrate solution for industry and robotics

The garment industry is a harsh environment for technology. 3-dimensional deformation of a garment during wear and cleaning in the household washing machine forces stringent requirements and tests. „Due to these requirements our self-developed system solution consisting of sensors, conductors and electronic units is extremely robust. It is well suited for applications in the industrial environment. Today it is used by workers, for example in accident prevention in production facilities,“ explains Markus Strecker, CEO and founder of Teiimo GmbH. To measure strain, deformation and pressure, Teiimo develops customized sensor solutions. The sensors can be connected to electronic units thanks to their robust, thin and strechable cable solutions. „Our technology can therefore also be integrated in moving parts, for example into a grappling arm of a robot. Captured data will be communicated wireless, reliable and in real time,“ Strecker stats. For data transmission, state-of-the-art radio technologies, including NB-IoT (Narrowband Internet of Things) or CAT M1, can be used and complemented by local wireless networks if required (such as LoRaWAN). Data security will be mainly guaranteed with cloud solutions from German Telekom. „Powerful miniaturized electronics and cloud structures enable the use of artificial intelligence. Our sensors help industrial and robotic companies to make their specific applications of tomorrow more robust and more intelligent,“ Strecker says.

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About Teiimo

Teiimo GmbH unites the world of electronics and textiles ‘seamlessly’: a system of sensors, ladders and electronic units developed on demand is integrated into a textile and is used to acquire and transmit body and position data - cost-effective, robust, easy to use operate, versatile with communication in real time.
Our customers come from sports, medicine and health and safety at work. These we help to improve the quality of life of people. More information at:

www.teiimo.com

Enabling Display Measurement within Augmented & Virtual Reality

Optical components replicate human vision for accurate display testing

White Paper contributed by **Radiant Vision Systems, LLC**

The application of augmented and virtual reality (AR/VR) devices is growing rapidly in industries as diverse as gaming, military, education, transportation, and medicine. According to the International Data Corporation (IDC), the AR/VR headset market is expected to reach 81.2 million units by 2021, with a compound annual growth rate (CAGR) of 56.1 percent. [1] Every AR/VR device manufacturer takes a unique approach to integrating displays within these headsets, and display technology and hardware environments vary greatly.

This market growth fuels an increasing need to measure AR, VR, and MR (mixed reality) displays viewed near to the eye—together referred to as near-eye displays (NEDs) (see **Figure 1**) using methods that are adaptable to the geometries of each device and the different display specifications.

The increasing importance of AR/VR technology demands control solutions that ensure visual performance. However, achieving a quality, seamless visual experience poses a challenge for device designers and manufacturers due to the limitations of measurement systems. The power of displays viewed as near to the eye as possible — like those in AR/VR devices—is their ability provide immersive visual input. However, as images in these displays are magnified to fill the user's field of view (FOV), defects in the display are also magnified. These defects not only detract from the user experience, but ultimately can damage a company's brand image in this increasingly competitive new marketplace. Effective display testing, therefore, is an emerging necessity.

To help manufacturers ensure display quality, Radiant's AR/VR Lens paired with a ProMetric® Imaging Photometer or Colorimeter provides unique optics engineered for measuring NEDs, such as those integrated into virtual, mixed, and augmented reality headsets. The innovative new geometry of the lens design simulates the size, position, and binocular field of view of the human eye. Unlike traditional lenses where the aperture is

located inside the lens, the aperture of the AR/VR Lens is located on the front of the lens to enable the connected imaging system to replicate the location of the human eye in an AR/VR device headset and capture the entire FOV available to the user.
This paper discusses the challenges of NED measurement, introduces Radiant's integrated AR/VR Lens solution, and outlines the solution's advantages for evaluating the human visual experience in NED applications.

Challenges of measuring NEDs

Market trends in AR/VR indicate a need to measure more displays that are:

1. Viewed *extremely close up*
2. *with a wide field of view (immersive)*
3. Viewed *within head-mounted devices (goggles, glasses, and headsets)*

Figure 1: Examples of head-mounted NED designs including immersive headsets and transparent augmented reality glasses.

1. Displays viewed close up

Viewed as close as possible to the eye, NED projections are magnified to create the immersive experience (see **Figure 2**). This proximity also magnifies potential display defects. For example, light and colour uniformity issues, dead pixels, line defects, and inconsistencies from eye to eye become more apparent to the user when viewed close up. The closer a display is to the eye, the more important display testing becomes.
Another characteristic of displays viewed at this proximity is their resolution. To create visual realism of projections across the display, NEDs must have more pixels per eye.
However, this poses a challenge for display measurement as high display resolution and pixel density in turn require higher-resolution measurement devices.

Figure 2: With the display in a fixed position within AR/VR devices, an extended horizontal FOV is leveraged for an immersive experience.

2. Displays viewed with wide FOV

Depending on the device, images in AR/VR displays are projected across a range of FOVs. With human binocular vision covering approximately a 114-120° horizontal FOV, several leading commercially-available AR/VR NEDs (primarily VR) achieve FOVs ranging between 100-120° (see **Figure 3**).
The wider the FOV of the display, the more challenging it becomes to comprehensively capture all areas of the display using an imaging system for measurement.

Figure 3: FOV comparison of VR headset displays. Source: VRGlassesHeadsets.com. Source: [2]

Figure 4: An NED measurement system positioned within the headset at the same location as the human eye can accurately capture the display FOV as it is meant to be seen by the device user.

3. Displays in head-mounted devices

NEDs are typically integrated within a head-mounted device (HMD), such as a headset or goggles. To measure a display as viewed by a human user wearing such a device, the measurement system must be positioned within the headset hardware at the same position as the human eye (see **Figure 4**). The measurement system's entrance pupil (the optical aperture) must emulate the human pupil position within the headset in order to capture the full FOV of the display through the viewing aperture of the headset.

Additional unique measurement criteria

Display testing in AR/VR applications demands unique image characterization data and analyses. For instance, luminance (brightness of the projection) and colour uniformity are critical when combining images from eye to eye, or when images are overlaid on top of the surrounding ambient environment (as in AR).

Image sharpness and clarity are important when displays are viewed near to the eye, and testing for these characteristics is performed using an MTF (modulation transfer function) test method. Characterizing image distortion caused by the viewing goggles or display FOV is key to improving spatial image accuracy and projection alignment.

An AR/VR measurement solution should include analysis functions for these common criteria, as well as repeatable, consistent data to ensure device-to-device accuracy.

Measurement approaches

Emerging AR/VR technologies require an innovative approach to display testing, including new methodology, software algorithms, and—most critical for in-headset measurement—optical geometries. Many technologies exist that attempt to meet the unique testing criteria for AR/VR devices, but have significant limitations when it comes to comprehensively addressing all of the measurable AR/VR display characteristics. Some traditional measurement approaches are outlined below.

Machine vision cameras

The key limitation of machine vision is that it is not appropriate for absolute luminance and colour measurement (see **Figure 5**). Traditional machine vision systems capture relative data only—they do not provide metrological data to measure absolute luminance or colour as visualised by the human eye in an illuminated display. To perform a true qualification of AR/VR displays as they are experienced by a human user, the measurement system should provide photometric values. Imaging photometers and colorimeters capture luminance and chromaticity values as they are perceived by the human eye. This is achieved using integrated optical filters that expose specific wavelengths of light to the camera's CCD. This process replicates the human photopic response. Photometric imaging systems are commonly used for display testing, as they capture a complete display FOV in a single two-dimensional image to analyse photometric data in a spatial context. This context is critical for evaluations of uniformity, distortion, clarity (MTF), contrast, and image position. Testing pixel-dense displays like NEDs also requires a measurement system with high resolution and signal-to-noise ratio. Machine vision is typically employed to accomplish extremely fast, repetitive measurement of visual characteristics that are identified based on clearly discernible contrast differences. Many traditional machine vision systems therefore sacrifice resolution for speed, offering low-resolution sensors that capture a high ratio of image noise compared to the signal they receive. Display defects, however, may occur at a level of detail as precise as a single display pixel. If a measurement system cannot discern a defect in a high-resolution display from one pixel to the next, it may miss defects that would appear obvious to a human viewing the NED. Systems with high resolution and signal-to-noise are imperative for measuring displays in neareye applications with the same precision as the human eye (these systems may include scientific-grade CCDs that are electronically cooled and temperature stabilized to further reduce noise received per CCD pixel).

Limited-resolution cameras

As discussed, measurement solutions that use low-resolution sensors are a poor fit for testing the high-resolution displays that are used in near-eye viewing applications. The human eye is one of the highest-resolution "imaging" mechanisms there is—estimated to be around 576 megapixels (MP). For this reason, low-resolution imaging systems (even photometry-based systems) will never catch all of the defects that a human user would notice at the proximity of an AR/VR display.

Figure 5: Machine vision cameras are imaging solutions that locate and measure features using relative data only.

Low-resolution cameras

Low-resolution cameras are inadequate for measuring displays used in AR/VR devices. They may miss dots, particles, dead pixels, or other small defects that would be apparent when viewing the display close-up. These systems are also incapable of MTF measurement to evaluate image sharpness.

Low-resolution cameras are inadequate for measuring displays used in AR/VR devices.They may miss dots, particles, dead pixels, or other small defects, and are incapable of accurate MTF measurement, which indicates the NED device's ability to project images at a certain sharpness or clarity. In order to acquire MTF measurements with accuracy, images captured for analysis must be unaffected by the imaging system's resolution. A high-resolution imager isolates image clarity (MTF) issues of the NED device

Standard optics

Standard optical solutions are not designed for measuring within NED environments (headsets, goggles) from the vantage point of a human user. This is a limitation of traditional optical hardware design. For example, a traditional 35 mm lens has an internal aperture. This aperture position causes occlusion of the full FOV of the display due to obstruction by the lens housing and NED device's entrance aperture (see **Figure 6**). Additionally, standard lenses are typically too large to fit inside NED headsets and goggles at the eye position. The length and width of these lenses prohibits the connected imaging system's entrance pupil from being positioned where a human user's eye would be, preventing measurement of displays as they are viewed in use.

Custom optics

A custom-built optical solution is generally not viable for NED display testing within headsets due to expense, long development time, and minimal scalability to meet future applications. Relying on in-house design also limits product support through the lifetime of the solution.

Custom software

To accomplish the unique image analysis functions required for AR/VR display testing, some manufacturers may elect to customize a software component in-house. This has similar downsides to customizing the optical hardware component, including increased expense and time to implement, along with minimal scalability for future requirements, limited product support, and inability to apply software for other display test applications.

Replicating the human visual experience

Human visual perception of display quality should provide the standard for opti-

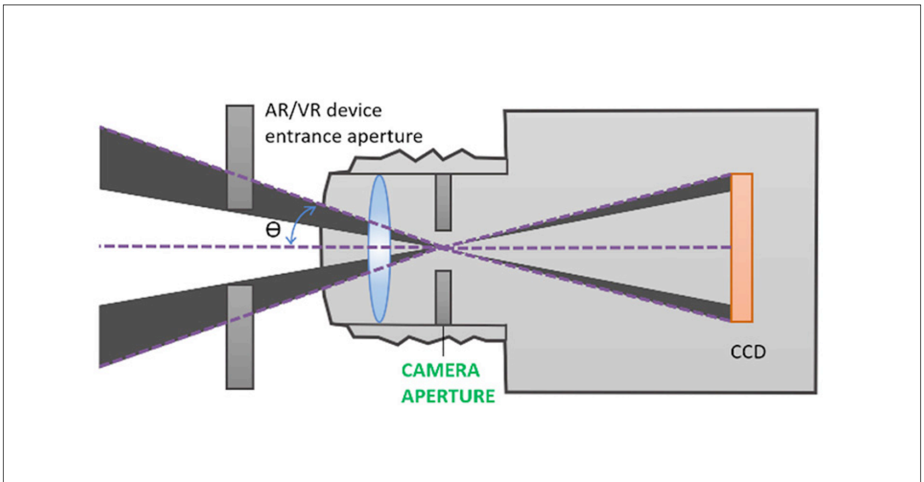

Figure 6: Standard lens with an internal aperture.

cal performance measurement of NEDs. Like the human eye, a NED measurement solution should address the range of display characteristics that can be seen. Measuring a display integrated within an immersive or head-mounted system relies on accessing the display at the appropriate visual position to capture the full FOV that is meant to be viewed by the human user. To replicate human vision for NED measurement, there are several key elements that must be addressed by the display test equipment.

Photometric measurement. Most essential to the visual quality of any display is the appearance of light and color. Imaging photometers and colorimeters are best suited to evaluate visual display qualities

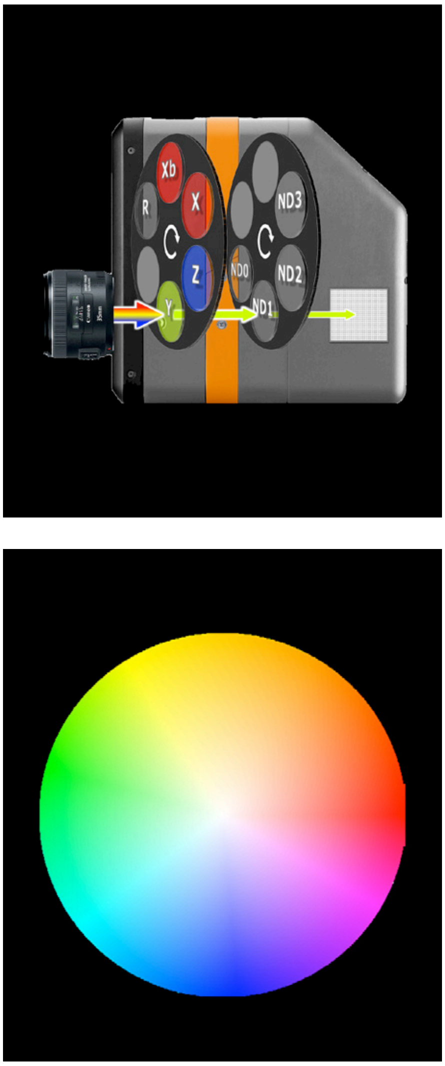

Figure 7: Imaging photometers and colorimeters capture luminance and chromaticity values as they are perceived by the human eye, using integrated filters to expose each wavelength of light at a different duration to the CCD to replicate the human photopic response.

because they are engineered with special tristimulus filters (see **Figure 7**) that mimic the response of the human eye to different wavelengths of light (the photopic response curve). An NED measurement system should employ photometric technology using filters to evaluate light values as they are received by the human eye.

Full field of view. Within the NED headset, the user is meant to have visual access to the entire FOV projected by the display—and therefore may notice defects at any point on the display. CCD-based imaging photometers and colorimeters need only one image to capture the display in full. Like the human eye, an imaging system can see all details in a single view at once. Using wide-FOV optics, an imaging system can capture a wide-FOV display even as it is viewed close up—simulating human binocular vision. Photometric imaging systems paired with wide-FOV optics are therefore recommended for the most accurate and comprehensive NED measurement.

High resolution. AR/VR displays are meant to be viewed extremely close to the eye, which is itself a high-precision imager. Therefore, NEDs are some of the highest-resolution displays, fitting the most pixels in the smallest form factor for a seamless visual experience of images close up. The system used to measure an integrated AR/VR display should have sufficient resolution to capture all details in pixel-dense displays that may be visible to the human eye at close range. Given sufficient resolution of the imaging system's CCD, each display pixel can be imaged across several CCD pixels, enabling pixel-level defect detection (see **Figure 8**).

Aperture. One of the greatest challenges in measuring near-eye displays within headsets is positioning the measurement device in such a way as to view the entire display FOV beyond the goggles. If the measurement system can obtain an image of the full display FOV as the user sees it, tests can be applied to evaluate any defects that may be visible to the user during operation of the device. The challenge is that the human eye is at a very particular position within AR/VR headsets. A display measurement system that replicates the size, position, and FOV of human vision within the headset is necessary for capturing an image

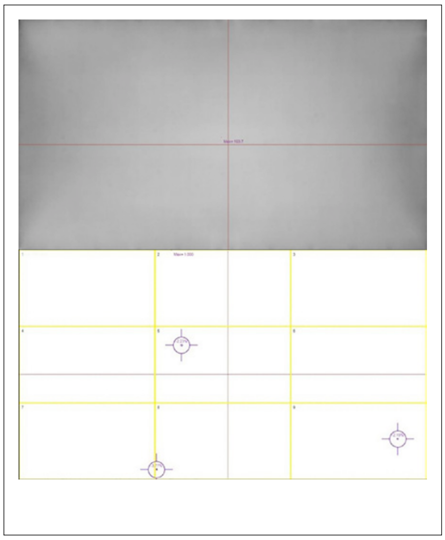

Figure 8: The top image shows the raw image captured by a high-resolution photometric imager. On the bottom, an analysis has been applied to detect tiny pixel-level defects. Close-up viewing in the AR/VR headset may make such defects apparent to the human eye.

of the display for evaluating all qualities that the user may see.
Unique optical parameters that enable imaging systems to capture the full visible FOV include the lens aperture position and geometry. In an optical system, such as the lens on a camera, the aperture or "entrance pupil" is the initial plane where light is received into the lens. A similar point exists in the pupil of the human eye.

Aperture size

Replicating the human entrance pupil in NED measurement systems by achieving the appropriate aperture size is important for several reasons:

1. An aperture that replicates the size of the human entrance pupil captures equivalent light (equivalent detail) of the display as the human eye.
2. If the measurement system aperture is smaller than the human pupil size, the imaged display appears sharper, with fewer/less severe aberrations than what the human observes. (Display qualification may yield false positives.)
3. If the measurement system aperture is larger than the human pupil size, the imaged display appears to have more aberrations than what the human observes. (Display qualification may yield false negatives.)

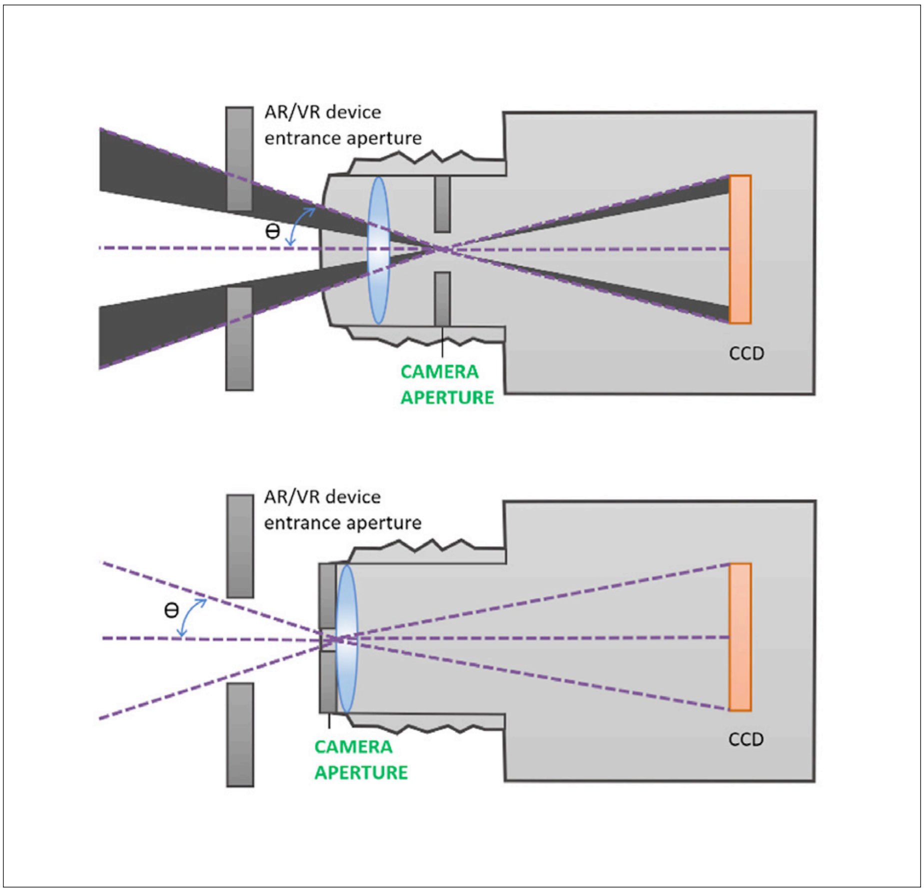

Figure 9: NED measurement requires a unique optical design that positions the camera aperture at the front of the lens, at the same location as the human eye, enabling visualisation of the complete FOV of displays as viewed through headsets or goggles.

Replicating the size of the human entrance pupil enables the imaging system to capture images equivalent in detail and clarity to those viewed by the human eye and make the same determinations of quality.

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Replicating the size of the human entrance pupil enables the imaging system to capture images equivalent in detail and clarity to those viewed by the human eye and make the same determinations of quality.

Aperture position

Simulating the human eye position within AR/VR headsets is a critical objective for integrated NED measurement. A traditional 35 mm lens has an internal aperture, which cannot capture the full FOV of the display due to obstruction by the lens housing and the NED device hardware (the edges of the device's entrance aperture) (see **Figure 9**). Optical components designed with the aperture in front of the lens replicate the intended position of the human eye inside the headset. Combined with wide-FOV optics, an imaging system with aperture at the front of the lens can capture the full display FOV and test for all visible characteristics that will be seen by the human eye.

This effect is like viewing a scene through a knot hole in a fence (see **Figure 10**) — when the eye is position at the hole, the full FOV can be seen beyond the fence. As the eye moves away from the hole, the view becomes occluded by the edges of the fence.

Radiant AR/VR measurement solution

Radiant developed an AR/VR Lens to address the unique challenges of qualifying integrated NEDs under the same conditions as they are visualized by human users. The AR/VR Lens is designed to be paired with high-resolution imaging photometers andcolorimeters, in 16-, 29-, or 43-megapixel models (see **Figure 11**). By capturing displays at this detail, the

Figure 10: "Knot-hole" example: Top, the entrance pupil is far from the opening (knot hole), providing a limited view of the image. Bottom, the entrance pupil is at the opening providing a fuller view.

Figure 11: The Radiant AR/VR Display Test Solution includes (left to right): AR/VR Lens, ProMetric® Imaging Colorimeter or Photometer (16, 29, or 43 MP options), and TrueTest™ Software with optional TT-ARVR™ module.

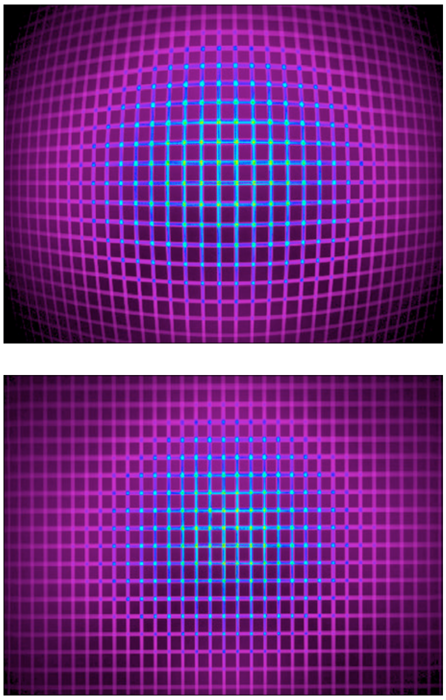


Figure 13: Top, an image captured by an uncalibrated wide-FOV system; bottom, image captured by a system with distortion calibration applied.

measurement system can evaluate the entire display FOV at once with the precision to capture any defects that might be noticeable to the human eye.

In-headset display measurement

Radiant's AR/VR display test solution is specially designed for in-headset display measurement. What separates the AR/VR Lens from other optical components is the lens's ability to replicate the FOV and entrance pupil of human vision. The AR/VR Lens product specifications include:

1. Aperture (entrance pupil) located at the front of the lens.
2. 3.6 mm aperture size. The average pupil will contract to 1.5 mm in diameter in bright light and dilate to 8 mm in diameter in darkness. Radiant uses 3.6 mm for two reasons: 1) it is in the mid-range of pupil dilation; 2) the 3.6 mm aperture allows a high MTF for the lens.
3. Wide FOV to 120° (±60°) horizontal.

Figure 12: Radiant's AR/VR Lens replicates the human eye position in headsets for wide-FOV NED testing.

Importance of calibration

Each Radiant AR/VR camera/lens system is factory calibrated to ensure the most accurate images for absolute light and colour analysis. Calibration processes include factory distortion calibration to remove lensing effects of the wide-FOV lens, ensuring accurate spatial analysis of the display by the camera software. may appear distorted (see **Figure 13**). Because the AR/VR solution uses a fish-eye lens, an uncalibrated image exhibits barrel distortion. Radiant's camera/lens solution is calibrated to process out distortion effects before applying display tests. This ensures accuracy of spatial measurements to detect defects where they occur on the display.

Solution software

Radiant TrueTest™ Automated Visual Inspection Software applies analyses to all images captured by Radiant's AR/VR measurement solution. This platform includes a suite of display tests with standard tests for luminance, chromaticity, contrast, uniformity, and defects like dead pixels and lines. In addition, unique tests for AR/VR projections are available in the pre-configured TT-ARVR™ software module (see **Table 1**).

TT-ARVR™ Software Module Tests	
• Uniformity	• Points of Interest
• Line Defects	• MTF Slant Edge
• Particle Defects	• MTF Line Pair
• ANSI Brightness	• Distortion
• Sequential Contrast	• Focus Uniformity
• Checkerboard Contrast	• Pattern Mura
• Chromaticity	• Field of View (Device FOV)

Table 1: Display tests in Radiant TT-ARVR™ software module.

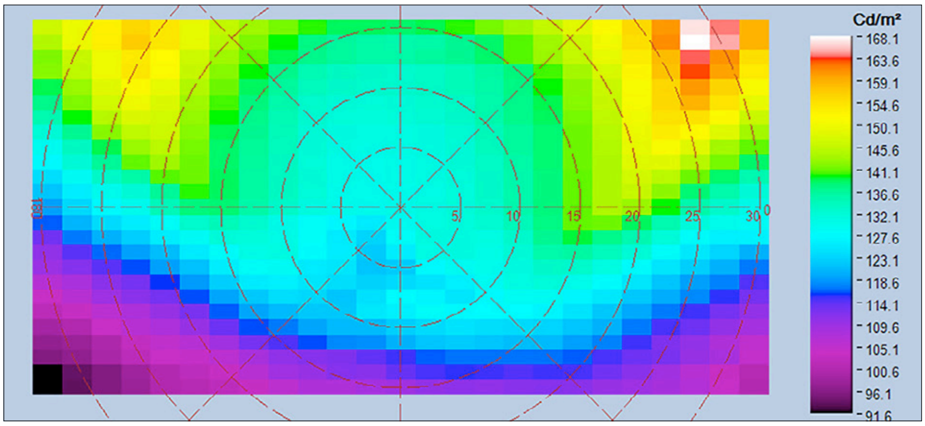


Figure 14: Uniformity analysis (shown in false colour) characterises display quality.

Weblinks

[1] International Data Corporation (IDC). (2017, March). IDC's Worldwide AR/VR Headset Tracker Taxonomy, 2017.:
https://www.idc.com/tracker/showproductinfo.jsp?prod_id=1501

[2] VRGlassesHeadsets. (2017, March). VR Headset Comparisons: Field of view. The Top VR Headsets Compared.:
http://vrglassesheadsets.com/vr-headset-comparisons-field-of-view

Some examples of TT-ARVR software analyses are shown in Figures 14-16. These analyses are performed on the AR/VR display to test the manufacturing specifications of the AR/VR device. These specifications can also be published for consumer use (for instance, on an AR/VR headset specification sheet) to help them evaluate the device and compare with competitive products.

Uniformity analysis (see **Figure 14**) determines areas of low or high luminance across the display, which may indicate a defect in the display. This analysis can also be used to characterise the uniformity against design specifications.

A checkerboard contrast analysis (see **Figure 15**) is performed by projecting a checkerboard pattern on the display within the AR/VR headset. Once the pattern is imaged by the AR/VR test system, the checkerboard contrast test evaluates luminance levels in the image to determine the display system's ability to project distinct light and dark values—a

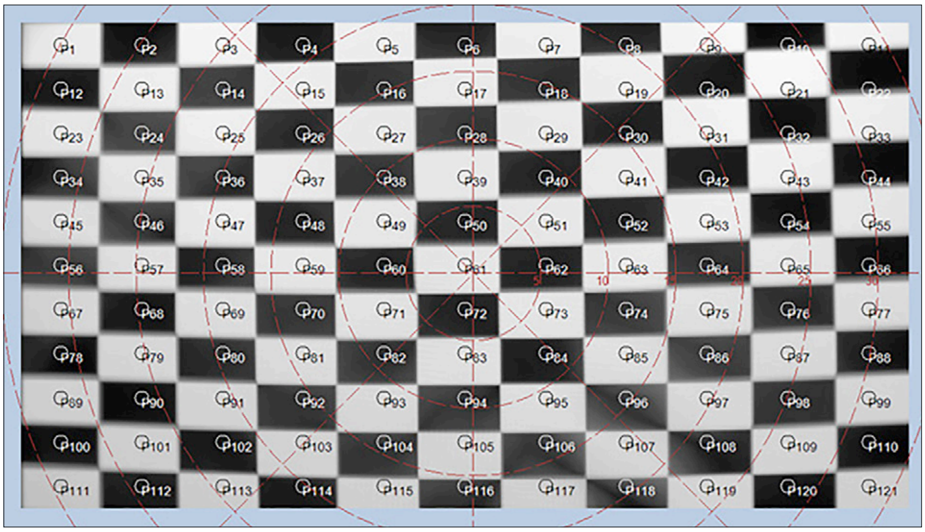
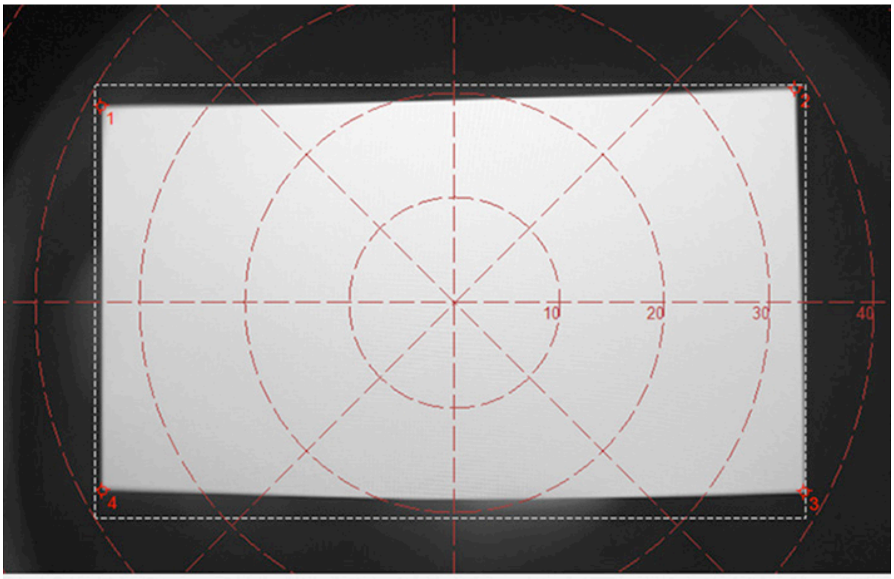


Figure 15: Checkerboard contrast analysis evaluates the contrast ratio of the display.



Result	Value	Unit
Horizontal FOV	66.504	Degrees
Vertical FOV	37.488	Degrees
Diagnol FOV	76.342	Degrees

Figure 16: Field of view analysis measures the display FOV within the NED device.

performance parameter that can be indicated on a specification sheet.

A Field of View test (**Figure 16**) measures the actual field of view of the display is imaged within the headset, ensuring that the horizontal, vertical, and diagonal dimensions are correct to design specifications. These measurements can also be reported on a specification sheet for an AR/VR headset.

Conclusion

New display integration environments—like AR/VR and other head-mounted devices — require designers and manufacturers to implement effective methods to test the optical quality of displays that are viewed close-up, from a fixed position, within headset hardware. Standard display measurement equipment lacks the optical specifications to capture displays within headsets to evaluate the complete visible FOV as experienced by the human user.

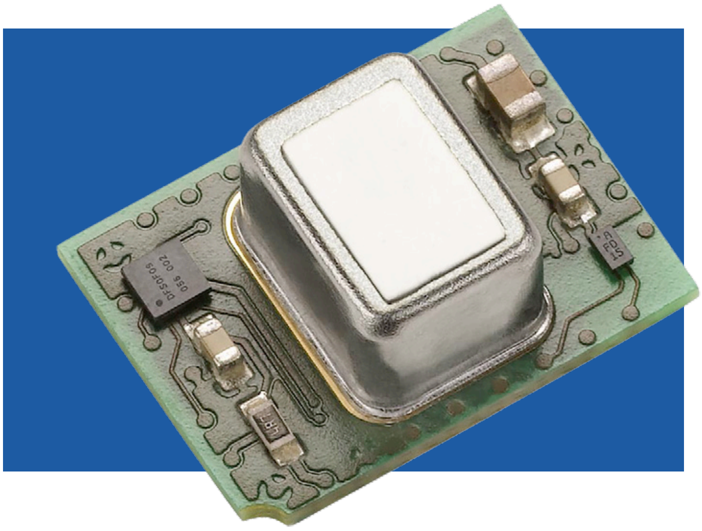
Radiant's AR/VR display test solution is the only commercially available measurement system with unique optical components that replicate the human pupil size and position within AR/VR goggles and headsets to capture a display FOV to 120° horizontal.

The system offers the high resolution and efficiency AR/VR device makers require, employing a compact camera/lens solution to capture all details visible across the NED in a single image to quickly evaluate the human visual experience. ◄

190237-01

Breakthrough in CO_2 Sensing:

First Sensirion Miniaturized CO_2 Sensor



Once again, Sensirion trailblazes innovation in environmental sensing to create healthier and more productive environments for people. At this year's Sensor+Test 2019 in Nuremberg and SensorsExpo 2019 in San José, the expert in environmental sensing, Sensirion, is announcing the SCD40 – the first miniaturized CO_2 and RH/T sensor that fits in a space of just one cubic centimeter. This disruptive innovation is based on the photoacoustic sensing principle and combines minimal size with maximum performance to open up numerous new integration and application possibilities. Due to its unprecedented price-performance ratio, the SCD40 is especially well suited for high-volume and cost-sensitive applications.

Sensirion's profound expertise in miniaturizing sensors has enabled a breakthrough step in CO_2 sensing: with dimensions of just 12 x 12 x 7 mm, the SCD40 footprint has been miniaturized by a factor of 5 compared to its predecessor, the SCD30. Using the photoacoustic sensing principle, the dimensions of the optical cavity are drastically reduced without compromising on sensor performance. Moreover, the SCD40 CO_2 and RH/T sensor leverages Sensirion's outstanding environmental sensing expertise by incorporating a best-in-class humidity and temperature sensor that delivers two additional sensor outputs. Because of its unmatched size and its unprecedented price-performance ratio, the SCD40 is the sensor of choice for today's and future CO_2 sensing markets such as IoT, automotive, HVAC, appliances and consumer goods.

Thanks to new energy standards and better insulation, buildings have become increasingly energy efficient, but at the cost of accelerated deterioration in air quality. Since high CO_2 levels compromise human health and productivity, CO_2 is a key indicator for indoor air quality. Air exchangers and smart ventilating systems in the commercial and the residential sector use CO_2 sensors to regulate ventilation in the most energy-efficient and human-friendly way. Furthermore, CO_2 sensors play an essential role for indoor air quality monitoring and can therefore be integrated in IAQ monitors, air purifiers and smart thermostats. The SCD40 miniature CO_2 and RH/T sensor solution will revolutionize product design approaches and create the foundation for a vast array of new applications.

Visit Sensirion at the **Sensor+Test 2019** at booth no. 316 in hall 1 as well as at the **SensorsExpo 2019** at booth no. 324 in hall M2 to experience the new sensor solution live in action. Furthermore, there will be an exclusive meeting with a live demonstration for selected customers at both events, offering a deeper insight into the upcoming innovation and its availability.

SENSOR+TEST
DIE MESSTECHNIK - MESSE
The Measurement Fair
Nürnberg, Germany
25. – 27.6.2019

www.sensirion.com/environmental-sensing

Everything You Need to Know about 5G Technology

By **Michael Jakal**, General Manager of Central and Southern Europe, Distrelec Group

Within tech circles, 5G technology has been all anyone's been talking about ever since the very first 5G broadband service launched last year. Promising incredible speeds, almost non-existent lag and the ability to transfer vast amounts of data across a significant amount of devices, it is only a matter of time before the wider adoption of this technology – both in the private sector and in many industries. Designed specifically to meet the growth in digital connectivity and data usage of today's society, industry experts will realise that 5G also goes hand in hand with another exponentially growing tech trend – the Internet of Things. In this article, we'll talk you through everything you need to know before 5G hits industries, and the manifold opportunities it provides for engineers.

How does 5G work?

The 5G network makes use of a much higher frequency to send its signals than that available to the 4G network. At 5G frequencies between 24 and 100 GHz, also called millimetre wave, 4G, which uses frequencies between 2 and 8 GHz, can barely compare. In this case, higher frequencies mean higher speeds — but also a decrease in wavelength and hence distance of signal coverage. Another downside of millimetre wave signals is that they are more affected by obstacles like walls, trees or even rain. This means that, for comprehensive 5G coverage to become a reality, a large amount of smaller mobile transmitters will need to be implemented closer to the ground.

Initially, however, 5G will operate together with the existing 4G network until sufficient coverage has been achieved. As 5G is not exclusively bound to millimetre wave signal but can also use the full 4G spectrum — a type of signal called Sub-6 — coverage can still be ensured, however, at the cost of 5G perks. Implementing more transmitters is a project that will be slowly completed over time as it is connected with massive infrastructure costs, and rural areas in particular may never be covered by the 5G network.

5G applications

As already mentioned, 5G provides faster, more reliable downloads and a significant reduction in lag. Just what that means for its applications, though, cannot be overstated. 5G opens up a world of futuristic technology that now does not seem so far away. Connected, self-driving cars that are coupled with both augmented and virtual reality and can seamlessly communicate with other vehicles, pedestrians or infrastructure will be closer than ever before, with the necessary speed and ability to process high data volumes finally enabling a safe experience. And, by integrating security into its core network architecture, 5G can also provide an extremely reliable and secure network for IIoT applications, much to the benefit of industrial facilities. In healthcare, it is primarily the lack of latency that can make a real difference, for example by transforming the industry with the possibility of performing remote surgeries, or even just providing live transmissions that can be monitored remotely. It is important to keep in mind, however, that 5G is still in its infancy, and it is going to be a while before real applications for the IoT based on 5G start to be deployed. It also remains to be seen whether LoRa, SigFox and NB-IoT will be supported by 5G. Currently, they are very much being framed as competing services, and engineers will have to consider this when planning for the future.

True M2M communication

There is a lot of talk about M2M communications in the industry, but the matter of fact is that true M2M communication has not been possible so far. That changes with the introduction of 5G. Where restrictions were previously in place regarding the connection between machines, and where networks acted as an intermediary, 5G's low latency allows for direct communication without the involvement of a network step.

The most important takeaway from this development will be efficiency, eliminating human intervention in the network and reducing the cost of interactions. On top of that, this new M2M communication also opens up the possibility of a higher degree of AI within the network. Addressing again the already mentioned application for self-driving cars, a benefit of this better way of communication between machines would be seen in the communication between cars while monitoring other vehicles, the road and the environment. All of the information gathered can then seamlessly be shared between all connected cars on the road, making driving safer than ever before.

Going even further, the traffic information thus collected could then be integrated into a complete smart city relying on the 5G network to keep all its parts connected and communicating with each other. Engineers have realised this potential – it's estimated that over 25% of cellular smart city devices and applications will operate over 5G networks by 2022.

Developing with 5G — and the future

Beyond the different applications we already know 5G will be used for and was developed to support, there is still everything to play for when it comes to how engineers will take the capabilities of 5G and run with them once it is fully introduced. The opportunities are incredibly varied and extensive – for instance, 5G introduces new opportunities for maintenance management within large machines like planes or mining equipment. Inbuilt sensors can monitor the state of parts within a machine and alert when something needs replacing or fixing. This can now be implemented at the design stage, where integration previously wasn't possible due to the extreme bandwidth requirements and the low latency that is needed.

However, it is difficult to say just now how exactly development engineers will make use of 5G. Development for this new network is still in its infancy, with so much remaining to be discovered and learned. Without the actual 5G network to work on beyond limited trials, we can only speculate on the way innovation will take shape once engineers start working with it – on their own, and also, more importantly,

as a collective shaping each other's projects and ideas. With time, it will become much clearer what exactly can be done with 5G — and whether it lives up to the high expectations placed upon it.

190222-01

The Author

Michael Jakal, General Manager of Central and Southern Europe with Distrelec, has a wealth of experience and industry knowledge across all of Europe. Michael is equipped with the skills, resources and technical insight required to champion new technologies and assist a range of professionals to find the technical solutions they need.

Power Supply Control Loop Response Measurements (Bode Plot)

With a Rohde & Schwarz oscilloscope

By **Andreas Ibl**,
Oscilloscope Product Manager, Rohde & Schwarz

Oscilloscopes are the primary measurement tools used today by engineers to test and characterize their power supply designs. The R&S®RTx-K36 frequency response analysis (Bode plot) option provides a low-cost alternative to low frequency network analyzers or dedicated stand- alone frequency analyzers.

Your task

To ensure the stability of voltage regulators and switched-mode power supplies, the control loop behaviour must be measured and characterized. A well compensating voltage controller enables stable output voltages and reduces the influence of load changes and supply voltage variations.

The quality of this control circuit determines the stability and dynamic response of the entire DC/DC converter.

Rohde & Schwarz solution

Easily and quickly analyze low frequency response on your oscilloscope with the R&S®RTx-K36 frequency response analysis (Bode plot) option. Characterize the frequency response of a variety of electronics, including passive filters and amplifier circuits. Measure the control loop response and power supply rejection ratio of switch-mode power supplies. The R&S®RTx-K36 frequency response analysis (Bode plot) option uses the oscilloscope's built-in waveform generator to create stimulus signals ranging in frequency from 10 Hz to 25 MHz. Measuring the ratio of the DUT signal input and output at each test frequency, the oscilloscope plots gain logarithmically and phase linearly.

The R&S®RTx-K36 frequency response analysis (Bode plot) option allows you to quickly determine the gain and phase margin of switched-mode power supplies or linear regulators. These measurements help determine the control loop stability.

The R&S®RTx-K36 frequency response analysis (Bode plot) option displays the system response to changes in operating conditions, such as supply voltage changes or load current changes.

Measurement setup

Power supply control loops compare reference voltage (V_{ref}) and feedback volt-

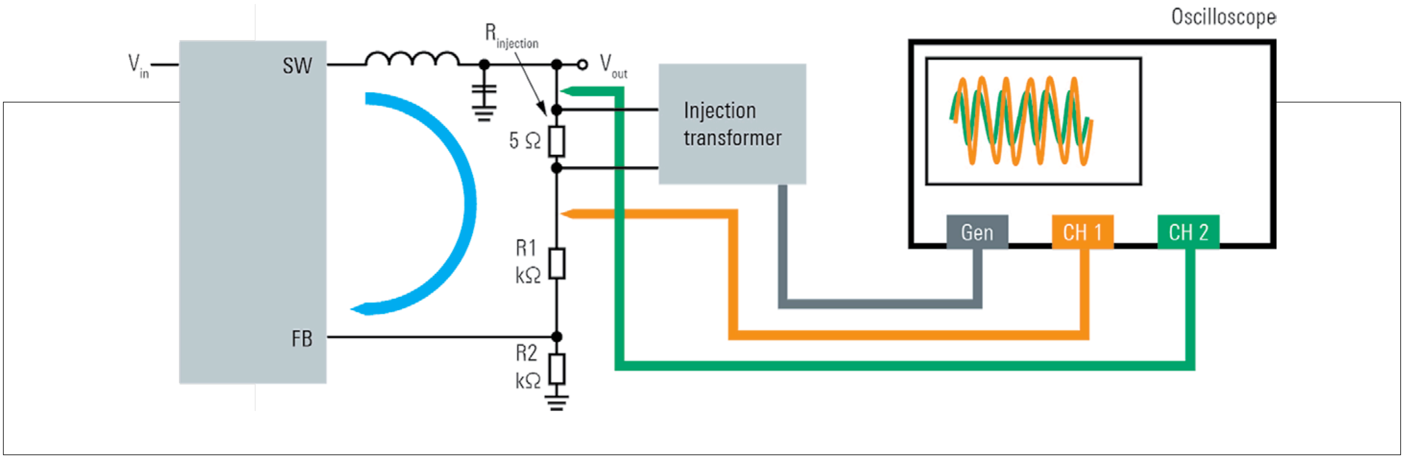


Figure 1: Choosing the correct injection point.

age ($V_{feedback}$) and create a negative feedback to ensure a stable output voltage.

Control loop response testing requires injecting an error signal over a band of frequencies into the feedback path of the control loop. To inject an error signal, a small resistor must be inserted into the feedback loop. The 5 Ω injection resistor shown in the figure on the next page is insignificant in comparison to the series impedance of R1 and R2. Some users choose to permanently design in this low-value injection resistor ($R_{injection}$) for test purposes. An injection transformer, such as Picotest's J2100A, isolates the AC distortion signal and eliminates any DC bias.

Injection point and probing

To measure the loop gain of a voltage feedback loop, the loop needs to be broken at a suitable point. A distortion signal is injected at this point. The distortion signal will be distributed in the loop circuit. Depending on the loop gain, the injected distortion signal will be amplified or attenuated and shifted in phase. For the R&S®RTx-K36 option, the generator of the oscilloscope generates the distortion signal. The oscilloscope measures the transfer function of the loop.
To ensure that the measured loop gain equals the real loop gain, choose a suitable point as illustrated in **Figure 1**:

- Find a point where the loop is restricted to one single path to make sure that there are no parallel signal flows.
- Ensure that the impedance in the direction of the loop is much bigger than the backwards impedance at this point. The backwards impedance equals the output impedance of the converter, a very low value in the range of several mΩ. The impedance in the direction of the loop is formed by the compensator and the voltage divider and is in the range of several kΩ.

Accurate control loop response characterization depends on good probing. Peak-to-peak amplitudes of both V_{in} and V_{out} can be very low at some test frequencies. These values would be buried either in the oscilloscope's noise floor and/or in the switching noise of the DUT itself. This is why increasing the SNR of your measurements will significantly improve the dynamic range of your frequency response measurements. Most oscilloscopes usually come with 10:1 passive probes that have more noise. Using low-noise 1:1 passive probes will reduce measurement noise and improve SNR. Rohde & Schwarz recommends the R&S®RT-ZP1X 1:1 passive probes with 38 MHz bandwidth for this application.

Reducing the length of your probe's ground connection minimizes inductive ground loops. The standard ground lead of your probe can sometimes act as an antenna and amplify unwanted switching noise. Find a ground post near the V_{in} and V_{out} test points. Use the provided ground spring of the R&S®RT-ZP1X probe to shorten the ground connection (**Figure 2**). This will provide a good low-noise ground for your measurement.

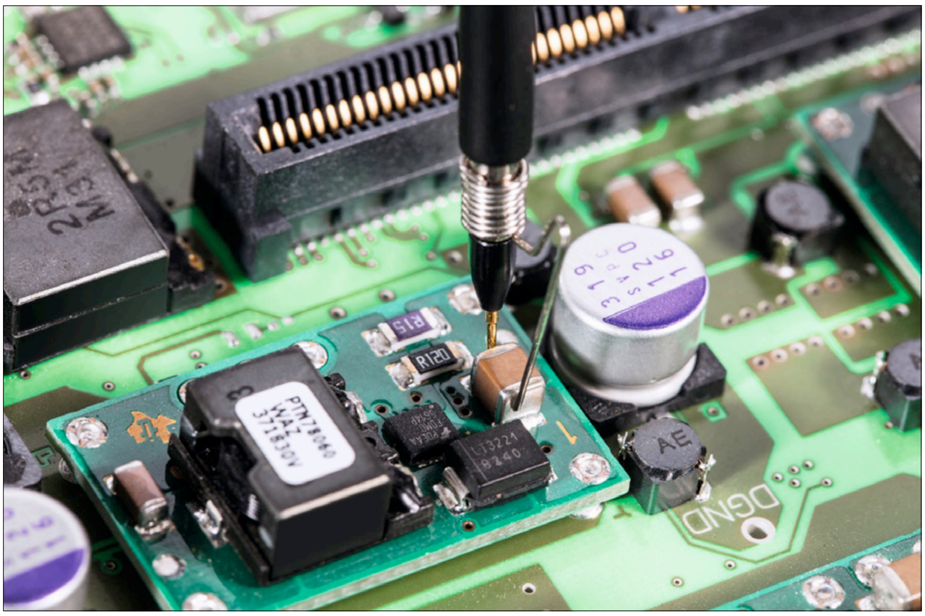


Figure 2: Using a ground spring will provide the best signal-to-noise ratio for your power supply rejection ratio measurement.

Figure 3: Measurement of the stability of a DC/DC converter (blue trace: gain; orange trace: phase; green trace: amplitude profiling of the stimulus signal)

Index	Frequency	Gain	Phase	Amplitude
917	6.79kHz	0.32dB	36.45°	100mVpp
918	6.82kHz	0.22dB	36.44°	100mVpp
919	6.85kHz	0.16dB	36.36°	100mVpp
920	6.89kHz	0.09dB	36.30°	100mVpp
921	6.92kHz	0.02dB	36.29°	100mVpp
922	6.95kHz	-0.05dB	36.33°	100mVpp
923	6.98kHz	-0.13dB	36.28°	100mVpp
924	7.01kHz	-0.20dB	36.21°	100mVpp
925	7.05kHz	-0.28dB	36.16°	100mVpp
926	7.08kHz	-0.34dB	36.14°	100mVpp
927	7.11kHz	-0.42dB	36.09°	100mVpp
928	7.14kHz	-0.49dB	36.00°	100mVpp
929	7.18kHz	-0.56dB	35.93°	100mVpp
930	7.21kHz	-0.67dB	35.98°	100mVpp
931	7.24kHz	-0.74dB	35.89°	100mVpp

Samples: 917–931 / 2350

Marker	Frequency	Gain	Phase
1	6.92 kHz	0.02 dB	36.29 °
2	2.12 MHz	-52.68 dB	-2.54 °
Δ (1→2)	2.11 MHz	-52.71 dB	-38.84 °

Figure 4: Measurement table.

Device setup

After connecting the oscilloscope to the circuit under test, start the application:

- Set start and stop frequency between 10 Hz and 25 MHz and determine the generator output level.
- Set the points per decade to improve and modify the resolution of your acquisition. The oscilloscope supports up to 500 points per decade.
- Profile the amplitude of the generator output (up to 16 steps) to suppress the noise behaviour of the circuit under test.
- Press run to start your measurement. The measurement results are plotted as gain/phase over frequency. Set your markers to your point of interest.

Measurement results

The curves displayed in the Bode plots represent the transmission function of your circuit and help verify the stability of your system (**Figure 3**). One graph displays the amplitude behaviour over the frequency range in dB, while the second plot displays the phase characteristics over frequency (measured in degrees). Drag markers to the desired positions directly on the plotted trace. A legend displays the coordinates of the markers. To determine the crossover frequency, set one marker to 0 dB and set the second marker to −180° phase shift. Now you can easily determine the phase and gain margin.

View the results in a table, as in **Figure 4**. The measurement results table provides detailed information about each measured point (frequency, gain and phase shift). When using markers, the associated row of the result table is highlighted. For reporting, quickly save screenshots, table results or both to a USB device. ◄

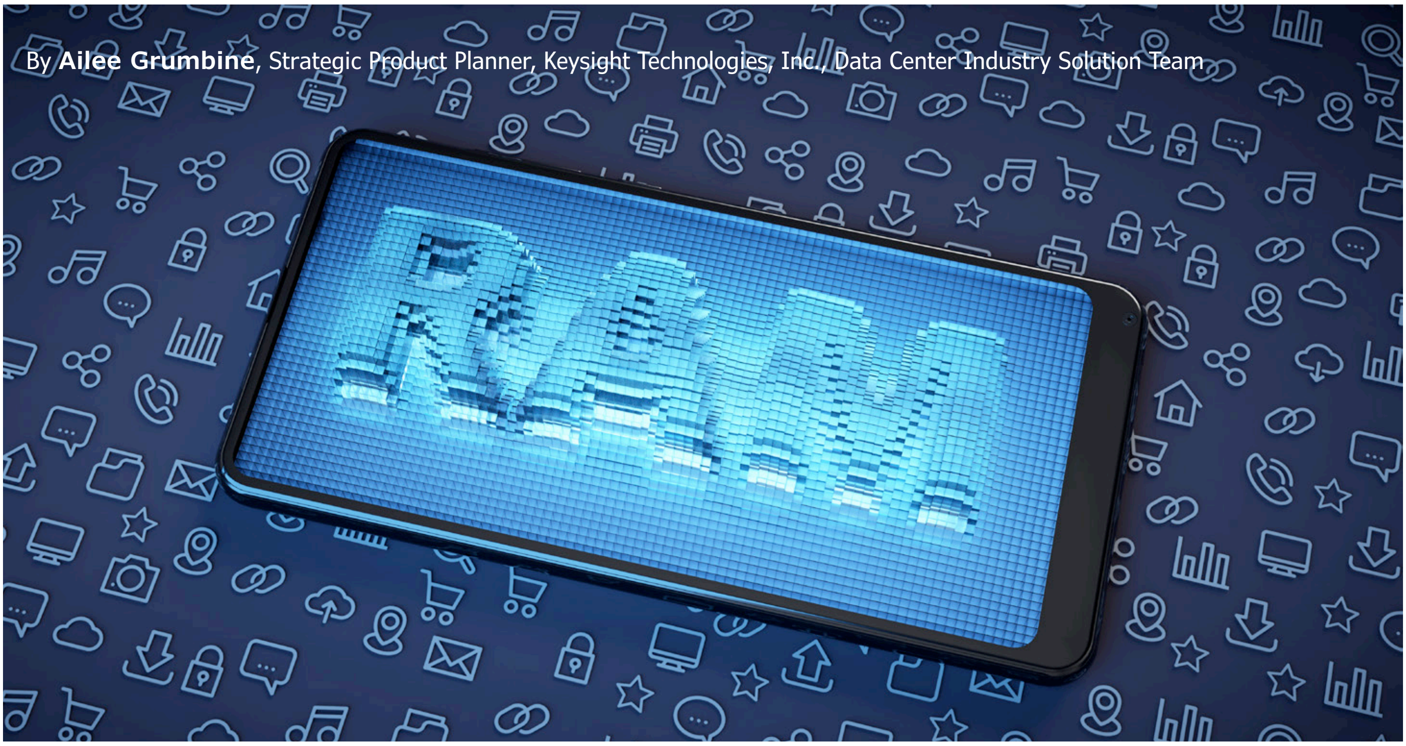
190245-01

The Author

Andreas Ibl is a Rohde & Schwarz oscilloscope product manager. He is responsible for the RTC1000, RTB2000, RTM3000 und RTA4000 oscilloscopes. Andreas completed his engineering Masters degree at the Landshut University of Applied Sciences. In addition to stability measurements, his subjects of special interest include power electronics and power integrity test.

Understanding Ramifications of DDR5 Transmitter Test

By **Ailee Grumbine**, Strategic Product Planner, Keysight Technologies, Inc., Data Center Industry Solution Team



DDR5 is a game changer in DDR memory technology. DDR5 is designed to satisfy large performance demands for data centers. Several key drivers for this technology are smart mobile technology and exascale computing. CPUs in the server and high computing industries are each fueled by GBs of memory. Technologies such as IoT, 100/400GBE and 5G are now connecting the world in real time. Storage architecture has been redefined with nonvolatile memory moving closer to the CPU. Also, the rise of new technology spaces like artificial intelligence and machine learning are defining the role of memory today.

DDR5 uses an explicit full rate clock. The clock signal clocks the command signal and the strobe signal clocks the data. The bus is wide and single ended. A server blade may contain over a thousand parallel data lanes. The read and write commands are bidirectional. This means that read and write data overlaps. Unlike other serial bus signals, the strobe and data can be bursty with idle states. DDR5 will operate at a much higher speed in comparison to its predecessor. It is known that DDR5 will be at least double the speed of DDR4. This means there are several characteristics of the signal that need to be tested and verified differently than DDR4. DDR1, DDR2, and DDR3 operate up to 2133 MT/s.

Hyper speed

The signals use high speed transmission lines where timing and impedance are problematic for designers. DDR4 technology is where the big change happened. DDR4 operates up to 4200 MT/s and is considered a high-speed serial bus. Validating the data valid window with eye diagrams and receiver masks is a key task for the designer. Now with DDR5 operating at the hyper speed of 6400 MT/s, the big question is: can an open eye be achieved? If so, the tests used for the design stage of DDR4 will also apply to the design stage of DDR5. If not, we may need to use techniques like equalization to open the DDR5 eyes, as is often done with serial buses.

Signal integrity is a big issue in characterizing DDR5 DRAM transmitters. The number one challenge when it comes to testing a DDR5 design is the ability to separate read and write data. Legacy methods, such as using strobe and data signals or identifying the read and write pre-amble pattern, may no longer be applicable. Since signal integrity is going to be a major challenge, new test parameters may be required in addition to legacy timing and electrical and eye diagram tests. Jitter may also now become an important component for characterization in the design. Faster data rates especially at speeds higher than 3600MT/s may cause the eye to close.

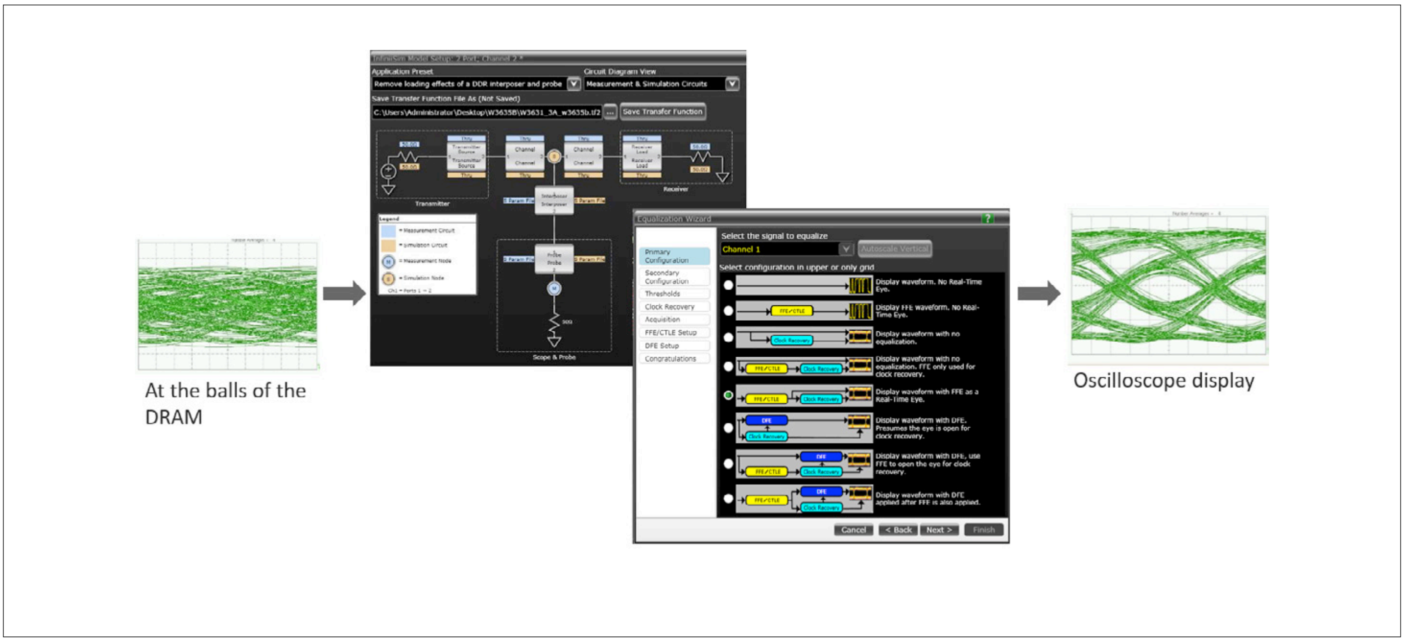


Figure 1: Equalization method being used to open the closed eye at the balls of the DRAM.

The Author

Ailee Grumbine specializes in data analytics and high-speed memory technologies such as DDR and SD UHS interfaces. She graduated from the University of Science Malaysia in 2001 and completed a Masters of Business Administration from the University of Colorado, Colorado Springs. Prior to her current position, Ailee was a regional applications engineer with expertise in high-speed bus applications which include DDR memory physical layer and protocol testing.

This means that every little bit of margin counts. Great consideration should be placed on noise and jitter performance when choosing any test equipment. New methods to characterize the data will also be required if there is no eye. It may be that an equalization method, such as decision feedback equalization, is needed to open the eye for making any eye diagram measurement.

Access to the signals

Before we can do any characterization work, however, we first need to gain access to the signals of interest such as clock, strobe, data, and command. If there are vias available, they are the best place to access these signals because you can probe directly at the balls of the DRAM. However, via access is limited, especially when boards are loaded with multiple devices with as little keep out volume as possible.

The next option would be to use a BGA interposer. The interposer routes out all signal of interests for testing. It is soldered using a BGA rework station to the board and the DRAM is soldered onto the interposer with a BGA rework station. ZIF or micro probe heads are used to provide the connections to the oscilloscope. It is very important to not break the bus when you load the interposer.

Data eye testing

The designer must make sure the interposer is designed to handle the speed of the signal with very minimum loading. Even if the interposer doesn't break the bus, you would probably need to de-embed the signals. Use the S parameters files in the de-embedding software to build a transfer function file, which would correct the frequency response of the signal. At higher data rates, above 3000 MT/s, eye collapse at the ball of the DRAM is anticipated due to inter-symbol interference. DDR5 will probably require equalization, such as decision feedback equalization, to improve the data eye after being latched by the receiver. The equalization method used needs to be able to open the up the eye without amplifying the noise due to reflection (**Figure 1**).

Figure 2: N-unit interval jitter measurement setup on an oscilloscope to measure random and deterministic jitter.

Margin is going to be much tighter in DDR5. This means that we need to do characterization of timing and signal integrity to make sure timing is met between the key signals, such as clock, strobe, data, and voltage requirements. In LPDDR4, JEDEC introduced the tDQS2DQ test, which measures write cycles timing to the DRAM. The test tells the DRAM designer how much skew is allowed by the controller so that the controller doesn't have to deal with huge variations in the DRAM.

It is one of the more critical DRAM compliance tests, which will be critical for DDR5 as well. For jitter characterization, it is important to be able to separate random and deterministic jitter components (**Figure 2**). This allows the designer to identify the source of any potential noise, crosstalk, or duty cycle distortion. A data eye test is a standard method used to verify the data valid window.

A data eye test makes eye height and eye width measurements. If the eye is closed, an equalization method will need to be used to open the eye. Eye width and eye height measurements need to account for noise of the instrument. This is true for jitter measurements as well.

DDR5 design complexity warrants design cycles that include simulation, analysis, and debug and compliance testing. The design workflow will need to allow data analytics capability to perform measurement correlation between simulation, design of experiments, and compliance. Modern simulation tools allow output of waveform files to be used in the compliance test software for early testing before a real device under test is available.

If any of the tests fail, early redesign or optimization work can be done with the help of a data analytics tool to find the optimization point. Then when an actual device under test is available, measurement correlation can be performed to further refine the performance and margin of the design.

Conclusion

In summary, the key to successful DDR5 transmitter testing depends on what tools you use to perform the measurements. A complete DDR5 transmitter solution consists of a probe, an oscilloscope, and a compliance or validation software which will cover all the test speed and test parameters.

When choosing an oscilloscope, make sure it has the lowest jitter and noise performance. You want to use an automated software package for compliance or validation work to ensure interoperability and repeatability. You can perform the measurements manually with an oscilloscope but translating the test parameters into measurement steps can be tedious and will take up more test time. ◄

190239-01

Particulate Matter Sensing for Air Quality Measurements

By **Livio Lattanzio**, PhD, Product Manager Particulate Matter Sensors at Sensirion

Sensirion's dust resistance and advanced binning technologies provide added value to applications in several industries, including air quality monitoring, air purifiers and HVAC. A sensor that works over the whole lifetime of a device guarantees good air quality to the final user and increases energy efficiency and sustainable operation. Advanced binning and higher accuracy help to trigger specific actions based on the detected particle composition and improve the monitoring of filter lifetime based on the contaminant type information collected over the device's operation.

Particulate Matter, abbreviated as 'PM', is a mixture of airborne solid particles and liquid droplets that can be inhaled and may cause serious health problems. PM includes particles with different characteristics — i.e. shape, optical properties, size and composition — but it is most commonly divided into sub-categories based on the particle size information.

Different PM categories are usually reported under the common nomenclature of PMx, where 'x' defines the maximum particle diameter in the airborne particle mixture or 'aerosol'. For example, PM2.5 defines inhalable particles with a diameter of generally 2.5 micrometers and smaller, PM10 particles with a diameter of 10 micrometers and smaller, and so forth. The specific PM categories of PM10 and PM2.5 have been historically identified by national governments as important monitoring levels in order to assess the quality of the air we breathe [1][2], because PM10 particles irritate exposed mucous such as the eyes and throat and PM2.5 particles travel all the way through the lungs into the alveoli. New categories like PM1.0 and PM4.0 are also finding their way into air quality monitoring devices as these new outputs provide additional information to the traditional PM10 and PM2.5 levels, enabling a better particle pollution analysis and the development of new device-specific actions based on the detected aerosol type (e.g. house dust vs. smoke).

The common definition of PM includes particles that are no smaller than 100 nanometers in size. Particles smaller than 100 nm are instead reported as 'ultrafine particles' or 'UFPs' and are not covered in this article. Within the above-mentioned PM definition, which thus includes particles from 0.1 to 10 micrometers in size, the smaller the particles are, the deeper they can penetrate through our respiratory system and into our bloodstream, posing a higher hazard to our health. The World Health Organization (WHO) reports airborne particulate matter as a Group 1 carcinogen [3] and as the biggest environmental risk to health, with responsibility for about one in every nine deaths annually [4]. **Figure 1** shows the size range of common pollutant sources, including filtration technologies used for the removal of such contaminants (adapted from John Wiley and Sons, *Best Practices Guide to Residential Construction*, 2006).

Historically, PM values are measured as 'mass concentration' in µg/m³. The reason behind this is that the traditional and most accurate way to measure PM is the gravimetric method.

This procedure makes use of a pre-weighed filter to collect ambient particles that are physically pre-sorted based on their size (e.g. all particles below 2.5 µm are let in). At the end of the sampling period, usually 24 hours, the filter is weighed to determine the total accumulated PM mass in µg. Mass concentration is then obtained by dividing the mass increase of the filter by the 24-hour total volume of air that passed through the filter, resulting in a value in µg/m³ [5]. Although gravimetric methods are long established as the most accurate way of determining mass concentration, they have some practical limitations to their diffusion in everyday applications: these instruments are bulky, very expensive, they process only one PM size per measurement (e.g. PM2.5), real-time sampling is not possible, and they cannot output the particle number count. For these reasons, real-time optical particle counters (OPCs) have progressively found their way into the air quality monitoring market. These instruments are based on different optical principles, typically scattering or absorption, with light scattering being the most commonly used. In these OPCs, the particle passes through the light source (usually a laser beam) and causes scattering (or absorption) of the incoming light, which is then detected by a photodiode and converted into real-time particle count and mass concentration values.

Currently, optical detection is the most widespread technique due to its ease of use and unbeatable cost-performance ratio. In recent years, OPCs have become small enough to be integrated into air conditioners, air quality monitors and air purifiers, and are used to regulate and control air quality in households, cars and outdoor environments.

Although the basic principle of OPCs might seem simple at first from an implementation point of view, not all OPCs perform in the same way and the quality of their measurement depends greatly on the engineering and design of such devices. The optical principle works very well in terms of particle counting, but as these devices are used mainly for the estimation of the PM mass concentration, they will be susceptible to estimation errors due to the different optical properties of the particles (e.g. shape and color) and different mass densities. The quality of the mass estimation will thus vary highly depending on the manufacturer algorithm used to convert the measured optical signal into PM mass concentration. In addition, the internal airflow engineering has a high impact on the accuracy and drift of these sensors as particles can accumulate easily on their optical elements (laser, photodiode, beam-dump) and degrade their output over time if they are not properly engineered.

Working principle

The working principle of the Sensirion SPS30 is based on laser scattering. A controlled airflow is created inside the sensor by means of a fan. As shown in **Figure 2**, an internal feedback loop between the microprocessor and fan stabilizes the fan speed and therefore the airflow through the sensor. Environmental PM travels inside the sensor from inlet to outlet, carried by the airflow (black dots in **Figure 3**). In correspondence with the photodiode, particles in the airstream pass through a focused laser beam, as indicated in red in Figure 3, causing light scattering. The scattered light is then detected by the photodiode and converted to a mass/number concentration output through Sensirion’s proprietary algorithms, which run on the SPS30 internal microcontroller.

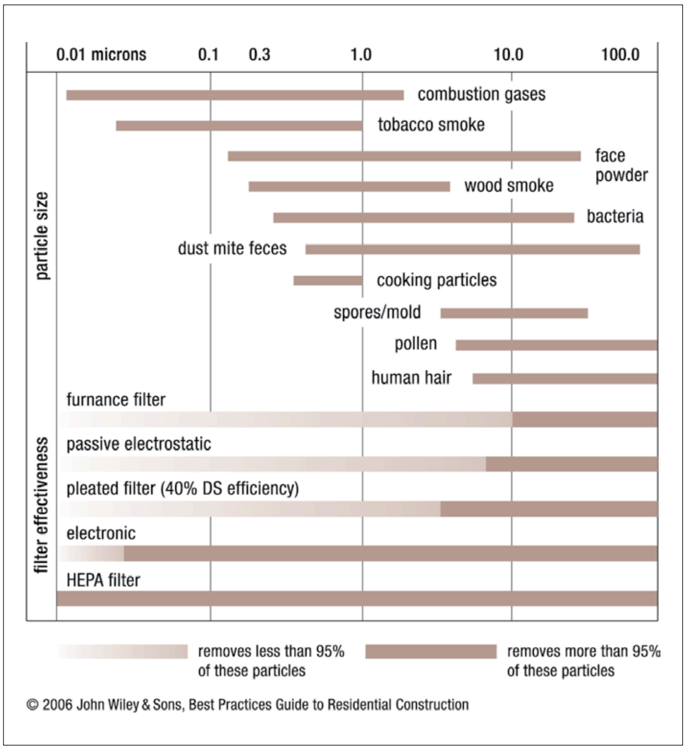


Figure 1: Size range of common pollutant sources (adapted from John Wiley and Sons, Best Practices Guide to Residential Construction, 2006).

Web Links

[1] AQI levels as defined by the China Ministry of Environmental Protection (2012): : http://bz.mep.gov.cn/bzwb/dqhjbh/jcgfffbz/201203/W020120410332725219541.pdf

[2] AQI levels as defined by the US Environmental Protection Agency (2013): : www.gpo.gov/fdsys/pkg/FR-2013-01-15/pdf/2012-30946.pdf

[3] International Agency for Research on Cancer (IARC) list of classifications : https://monographs.iarc.fr/list-of-classifications-volumes/

[4] Ambient air pollution: A global assessment of exposure and burden of disease, WHO, 2016 : http://who.int/phe/publications/air-pollution-global-assessment/en/

[5] Measurement of Particulate Matter, California Air Resources Board : www.arb.ca.gov/aaqm/qa/qa-manual/vol4/Chapter5.pdf

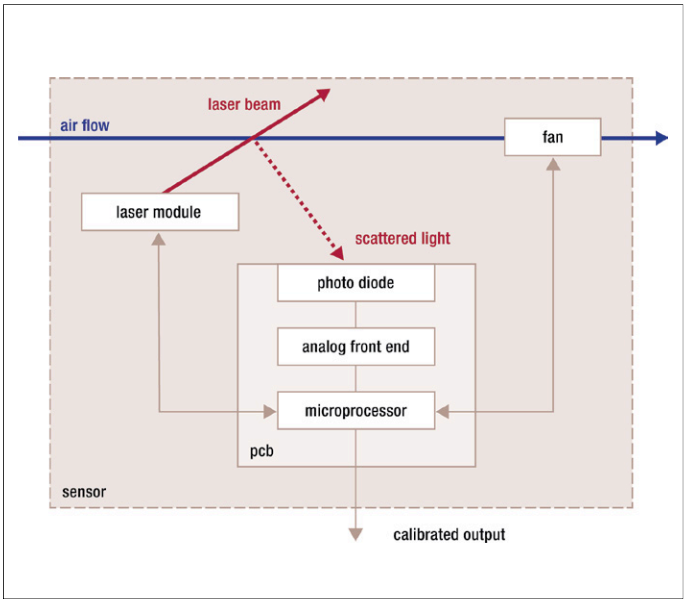


Figure 2: SPS30 block diagram. (Source: Sensirion)

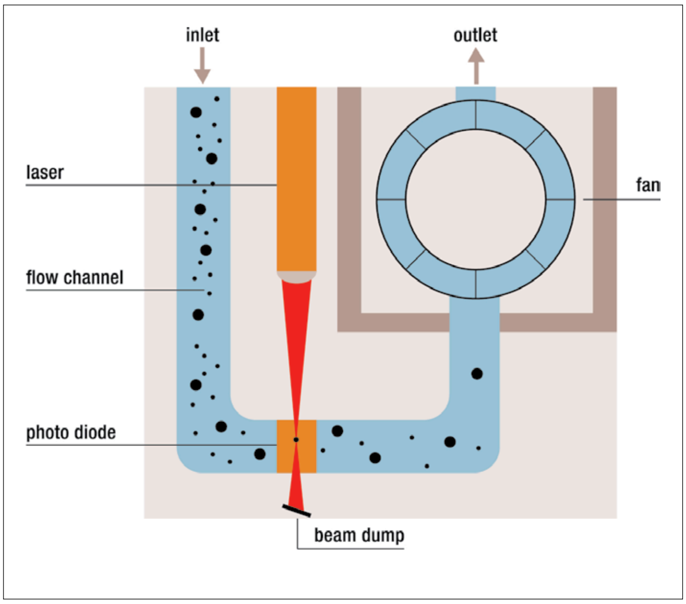


Figure 3: Working principle. (Source: Sensirion)

Particle composition recognition

As mentioned above, the manufacturer's algorithms, together with a proper front-end electronics design, make a fundamental difference in the estimation of mass concentration from the detected scattered light. Most low-cost PM sensors on the market assume a constant mass density in calibration and calculate the mass concentration by multiplying the detected particle count by this mass density. This assumption only works if the sensor measures a single particle type (for instance, tobacco smoke), but in reality we find many different particle types with many different optical properties in everyday life, from 'heavy' house dust to 'light' combustion particles (see **Figure 4**). Sensirion's proprietary algorithms use an advanced approach that allows a proper estimation of the mass concentration, regardless of the particle type measured. In addition, such an approach enables a correct estimation of the size bins. Also, an additional bin output is provided in contrast to most state-of-the-art consumer PM sensors on the market — PM4.0. The increased accuracy for different aerosols and the higher resolution on the number of bins allows users to develop new use cases based on particle composition recognition. **Figure 5** shows a practical demonstration of such a feature, using Sensirion's Control Center software. The bar charts show the real-time measured mass concentration bins, measured with an SPS30. The left

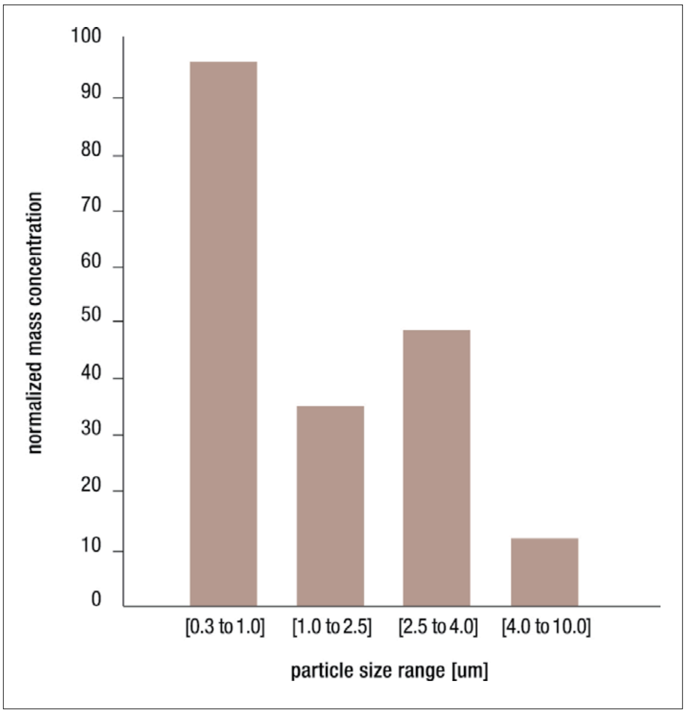


Figure 4: Particle composition of smoke. (Source: Sensirion)

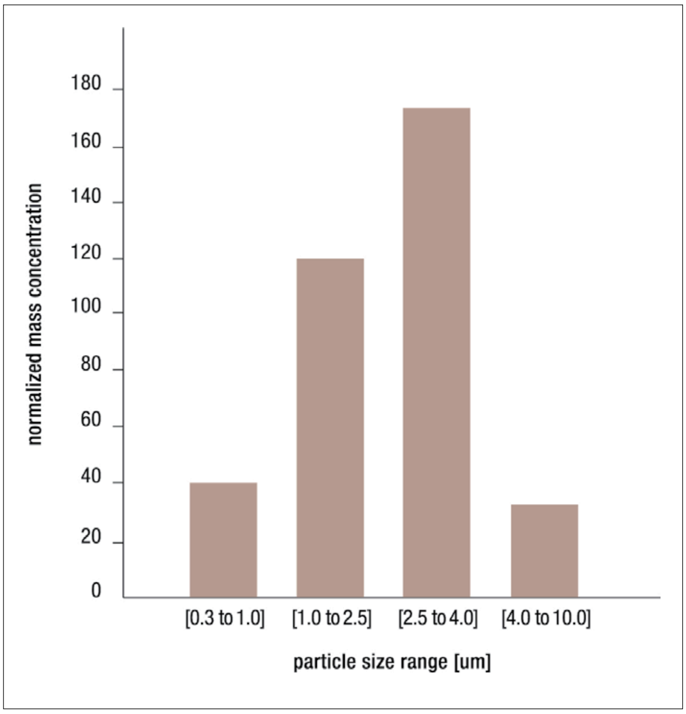


Figure 5: Particle composition of heavy dust. (Source: Sensirion)

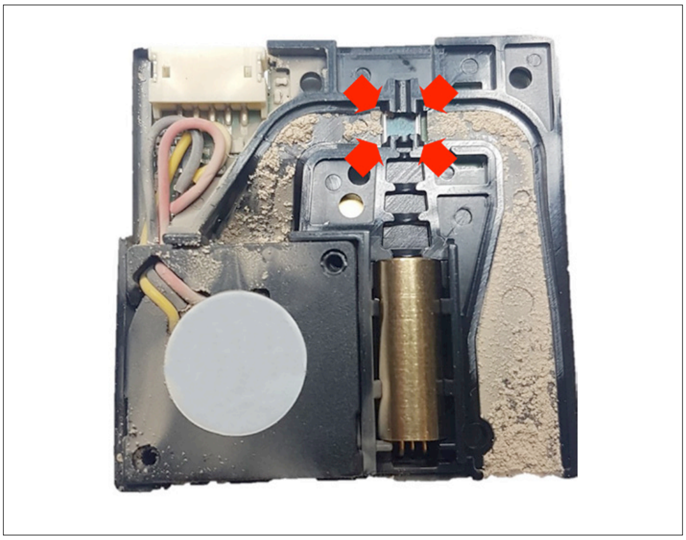


Figure 6: Clean photodiode after stress test. (Source: Sensirion)

chart shows a live measurement of match smoke, clearly richer in smaller particles. The right chart shows a measurement from Arizona dust, clearly richer in bigger particles. This simple but effective experiment highlights the value of the SPS30 advanced binning feature and the potential for the development of new applications based on particle composition detection.

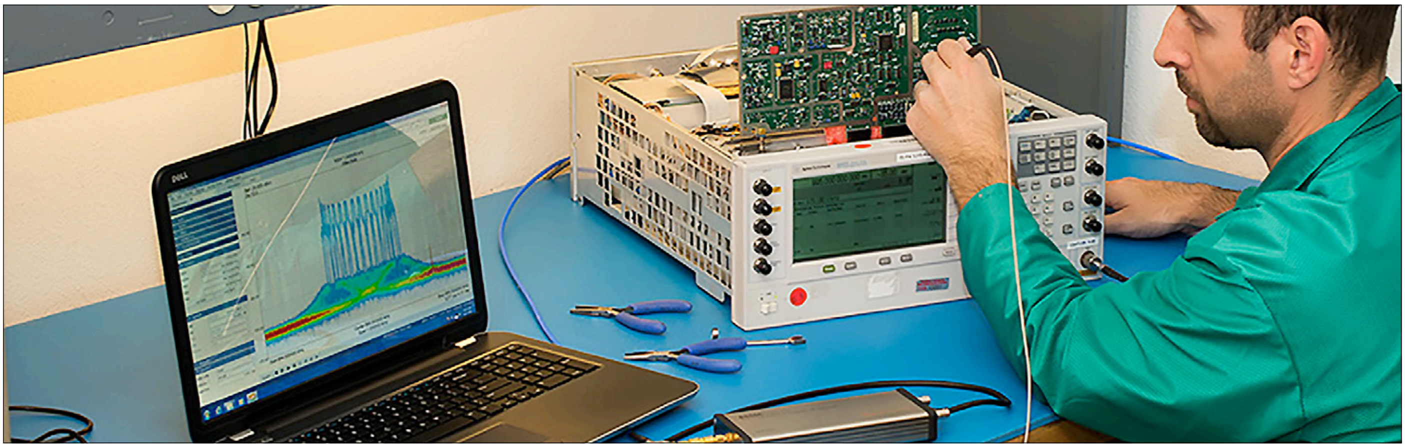
Dust resistance

As mentioned previously a PM sensor is in principle very susceptible to output drift due to the accumulation of dust on the crucial optical parts of the device, namely the laser, the photodiode and the beam-dump (used to absorb the laser light and avoid parasitic scattering). Based on more than 20 years of experience in flow sensor design for several demanding markets and applications (e.g. automotive, medical, industrial and smart energy), Sensirion's engineers have developed and integrated an innovative and proprietary flow path technology in the SPS30 that prevents dust and dirt accumulating on the optical components. The result of a stress test, where a sensor is exposed to the equivalent of five years' dust exposure in Beijing, is shown in **Figure 6**. The picture clearly shows that the flow path protects the crucial optical elements from dust exposure, and that the laser and photodiode are completely clean even after the stress test (the beam-dump, which is also protected from dust accumulation, is not visible in the photo). ◄

190241-01

An Introduction to Practical Real-Time Spectrum Analysis

Technical Brief contributed by **Signal Hound Inc**.



The electromagnetic spectrum (EM) is filled with complex continuous wave (CW) and modulated RF/Microwave signals, with many of these signals carrying important information such as digital information or location signals (radar). The ability to sense and analyze these signals aids in identifying interference causes and deducing component, device, and system behavior. Real-time spectrum analyzers enable on-the-go sensing and analysis of these signals and can put powerful software analysis tools at an engineer's fingertips.

Real-time spectrum analyzers (RTSAs) deliver the information contained in RF/Microwave signals in a convenient format for engineers to view and interpret. Backed by powerful software analysis tools, the frequency-based spectrum information gathered by a RTSA can reveal important information about the performance of RF/Microwave components, track down sources of interference, and monitor the spectrum for activity and security threats. If a RTSA is used in product development or security operations, understanding the EM spectrum and the methods used in RTSAs can provide a valuable perspective in the strengths and limitations of one of the key test and measurement equipment tools in an RF/Microwave engineers arsenal.

What is the EM spectrum and why is spectrum analysis helpful?

Radio Frequency (RF) technology leverages photonic, or electromagnetic (EM), energy from hundreds of kilohertz to tens of gigahertz in frequency for carrying information as analog or digital data. The EM energy acts as a carrier for the information, which is used to modulate the carrier signal. Methods have been devised to modulate and demodulate this information on RF carrier waves, so that security, military, commercial, or consumer data can be cost-effectively conveyed.
This could be over short or long distances, and at high data rates or at low data rates with energy efficient transmission (**Figure 1**).
As the components, devices, and systems that enable the transmission and reception of communication technology signals require several design, prototyping, production, verification, and maintenance stages, equipment that can measure the RF signal energy and provide tools to analyze these RF carrier waves and their modulated signals is extremely valuable. Test and measurement equipment, such as RTSAs, are necessary in characterizing components, verifying device behavior during manufacturing, and ensuring proper performance when operating in the field. For instance, security and interference hunting applications also make use of RTSAs for locating disruptive devices and phenomenon. Otherwise, these factors could pose a security

threat or hinder the operation of normal communications traffic in protected frequency bands.

How does spectrum analysis work?

A spectrum analyzer leverages RF energy capture technology that
 digitizes the frequency domain and modulation information of a RF signal and prepares the digital data for further analysis. As a spectrum analyzer is composed of non-perfect devices, there are limitations on the range of frequencies, bandwidth, power levels, and complexity of RF signals that any given spectrum analyzer can effectively capture and analyse.

Figure 1: RF and microwave signals carrying useful communication information.

The signal chain of a spectrum analyzer generally consists of an antenna or RF input, a RF attenuator, a pre-selector or low-pass filter (LPF), a mixer, an IF gain amp, and an IF filter (**Figure 2**). Then, the conditioned signal reaches an analog-to-digital (ADC) converter that digitises captured signal (see Figure 2). Once the RF signal is digitised, time slices of the RF signal are processed by Fast Fourier Transform (FFT) calculators—the time slices of RF signals prepared for FFT analysis are also known as FFT bins—and converted into concatenated frequency domain sweeps.

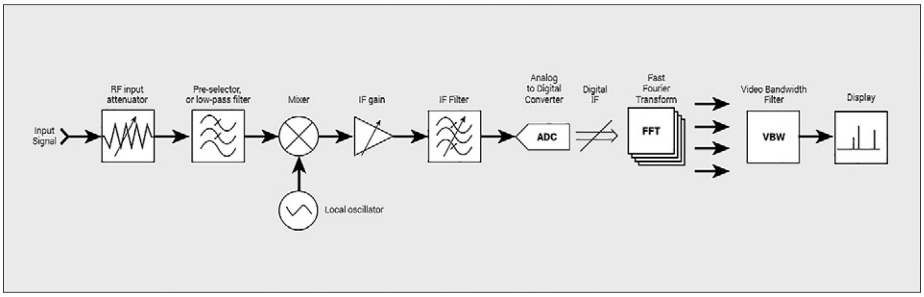


Figure 2: Simplified spectrum analyzer block diagram.

How is a spectrum analyzer configured to measure?

As spectrum analyzers can sweep a finite minimum and maximum number of frequencies, an initial range of frequencies should be identified (**Figure 3**). The greater the sweep frequency range, the longer a measurement may take, and the harder it will be to discern and analyse details in the frequency range. So, the minimum sweep frequency should be chosen. The sweep frequency is selected through start and stop frequencies, or the centre frequency and span bandwidth.

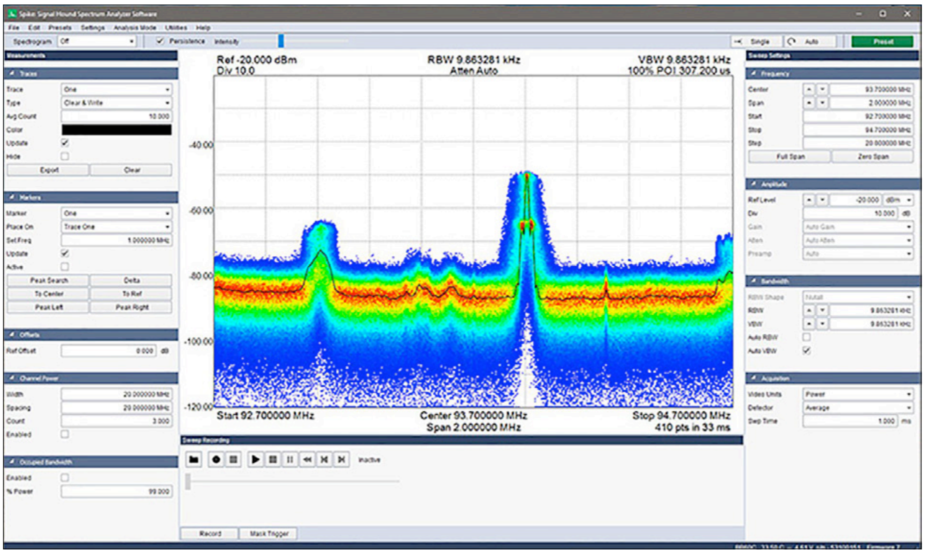


Figure 3: Spectrum analyzer software running on a PC.

Additionally, the bandwidth of frequencies an ADC can convert at a given time is finite—also known as the instantaneous bandwidth — and the smaller conversion bandwidth may provide greater measurement accuracy at the cost of viewable spectrum. However, if a measurement

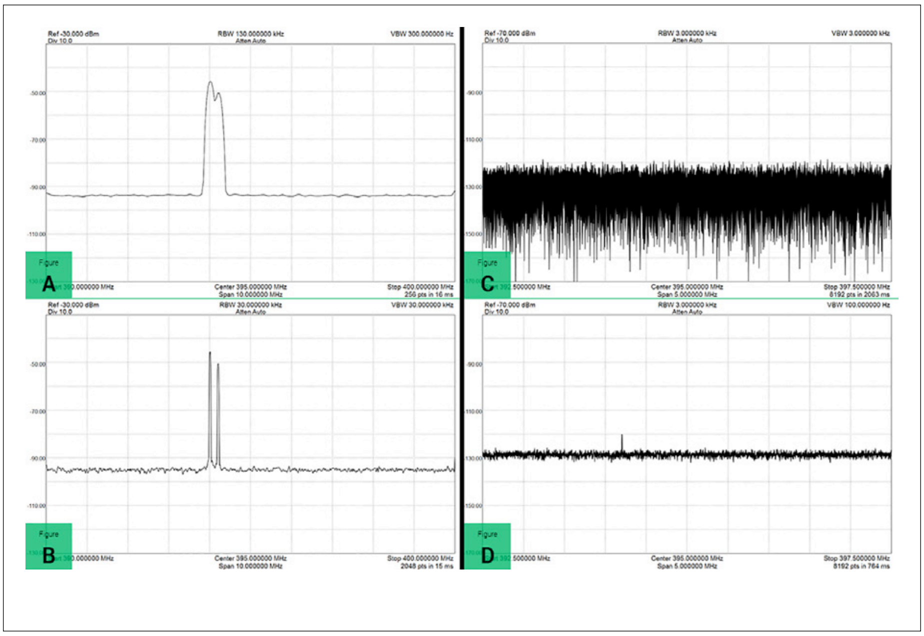


Figure 4: Image A: Large RBW does not reveal two distinct tones. Image B: Lowering the RBW reveals two distinct tones. Image C: Noise floor with VBW equals RBW. D: Lowering VBW reduces the peak-to-peak noise revealing tone.

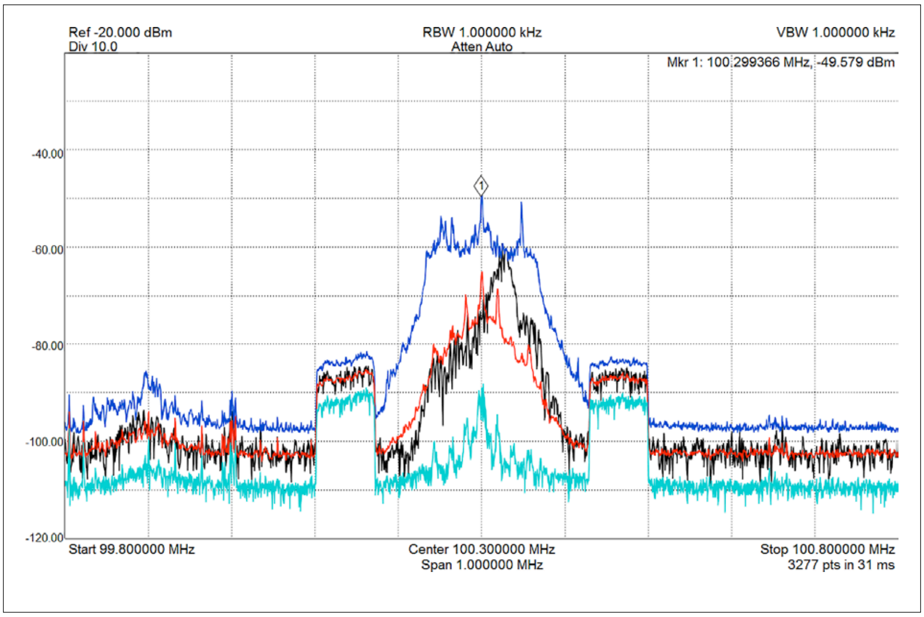


Figure 5: Configuring multiple traces to monitor an FM broadcast transmission.

sweep range is beyond the instantaneous bandwidth, there will be a delay in updating each section of the sweep.
For CW signals that are constant and unvarying this may not be an issue. Yet, this may pose a challenge for modulated communication signals, random signals, or pulsed signals.

What is resolution and video bandwidth and how do they impact spectrum analyzer measurements?

The size of the FFT bins in the frequency domain, or the bandwidth of the resolution bandwidth (RBW), determines the frequency resolution of the signals that can be discerned and analysed by the spectrum analyzer. For instance, if larger FFT bins, or a smaller RBW range, is used, greater signal detail can be observed and analysed by the spectrum analyzer (see **Figure 4**). On the other hand, decreasing the RBW also reduces the speed of each frequency sweep. So, there is a trade-off between the resolution of the frequency sweep and the speed of test.

In addition to the RBW, the video bandwidth (VBW) filter provides a smoothing of the amplitude of the signals by digitally filtering and processing the signal output from the FFT engine. The VBW can provide log, power, or voltage detection signal processing that can, for example, act as a power detector and smooth the frequency sweep without affecting the channel power. The log detector emulates a traditional spectrum analyzer output, while the voltage detector function can aid in deciphering certain amplitude modulated signal information. The VBW filter can also provide video averaging, that averages several frequency sweeps to reduce random noise factors, or peak-to-peak noise.

Lowering the VBW, or increasing the resolution of the VBW, also increases test times, similar to decreasing RBW. In cases when low-level continuous wave (CW) signals are being measured in close frequency proximity to large signal powers, slower sweep times may be a necessary sacrifice for measurement fidelity. For instance, if spurs from a phase-locked-loop (PLL) or intermodulation distortion products could overpower a signal of interest, and reducing the RBW would lower the noise floor and lowering the VBW would further smooth out the remaining noise, the spectrum analyzer could then reveal an accurate measurement of the previously hidden signal.

What is spectrum analyzer RF gain, IF gain, RF attenuation, and power level?

The power level of the RF signal to be measured may influence the settings of the RF attenuation, IF gain, RF gain, and displayed power level. The RF attenuation level can be increased to enable high power RF signals to be measured with better linearity, or reduced to enable low-level signals to be measured with sensitivity. As some noise generators

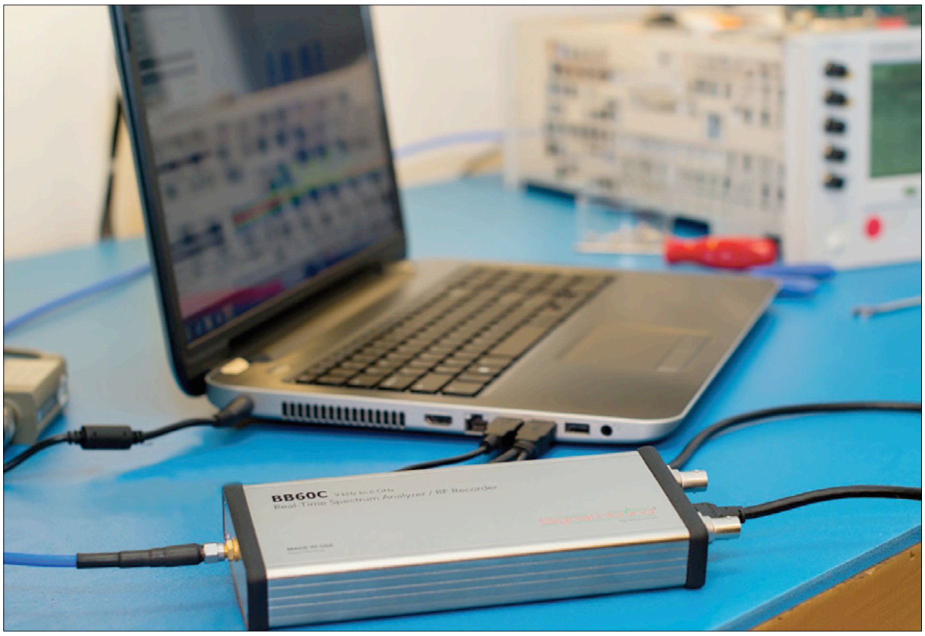


Figure 6: USB-powered real-time spectrum analyzer connected to a PC.

tend to scale with RF input power level, minimizing the RF input power level to the maximum signal power of interest is often recommended.

If a signal is of such low power, that it may not be adequately processed by the ADC after pre-selecting, or the IF filter, increasing the RF preamplifier gain may enable adequate signal levels. Nevertheless, increasing the RF gain will also reduce the linearity. Also, after downconversion by the mixer, the IF signal strength can be manipulated with the IF gain amplifier setting.

As balancing the various attenuator and gain stages may be confusing and time consuming, many spectrum analyzers enable automated optimisation of the sensitivity and linearity based on the reference level of a signal. Depending upon the complexity of the measurement and the experience of the user, many spectrum analyzers provide manual override options for these automatically controlled settings.

What else can a spectrum analyzer do?

Generally, a user is interpreting the data from a spectrum analyzer, which has led the software developers of spectrum analyzer interfaces to incorporate many software tools, both simple and complex. Being able to customize frequency sweep trace colours, develop frequency markers, and manipulate triggers aid in solving many of the basic measurement challenges (**see Figure 5**). Traces can be analysed, averaged, and customized for better viewing and understanding of the EM energy in the frequency range being monitored.

Markers can be placed as several frequencies of interest and marker data can be algebraically manipulated with other marker data to give greater comparisons and insight.

As triggers may also change the method in which data is collected, there are many more features capable with trigger solutions. The concept of a trigger is that the trigger conditions are applied to incoming signals and will "trigger" a data capture even—or any other programmable actions—if EM energy follows the trigger conditions.

For example, if a trigger is based at 0 dB and a signal is increasing in strength and crosses the 0 dB threshold, a trigger event can be programmed for that instance.

Additionally, some triggers, such as a configurable limit lines, can be used to create a boundary condition at each frequency point, where an event can be programmed based on any signal energy violating that boundary. Lastly, an external trigger can also be provided through the trigger input. These triggers can be initiated by external software routines or other equipment triggers to create synchronized testing systems.

What's the difference between real-time spectrum analysis and spectrum analysis?

Real-world signals, especially for communications and radar technology, are not as easily interpreted and measured as CW signals. The majority are modulated signals with signal energy that is non-recurring, sporadic, or even random. Simple spectrum analysis cannot capture and analyse these signals, unless a user happens to be lucky enough to trigger on the event. Capturing and interpreting these modulated signals requires a real-time analyzer, which use modern signal processing technology such as overlapping FFTs and high-speed memory storage (**Figure 6**). These analyzers are capable of capturing any signal that is within the instantaneous bandwidth of the ADC, and that has a duration long enough to be correctly measured.

Another advantage of RTSAs over standard spectrum analyzers, is that the signal information in an RTSA is already digitised and the information can be digitally controlled, filtered, and further analysed readily. Having digitised frequency data also enables rapid storage and playback features without missing slices of time, so deep analysis and security features are enabled.

What limitations for RTSAs exist?

Ultimately, a user will need to be able to see and engage with the signal data provided by an RTSA. As a user cannot necessarily make decisions and observe data at the rate that it happens, RTSAs have built in display and analysis functions to aid a user in observing trends and even record/playback functions for analysis at a later time.

Modern communications applications, such as Wi-Fi, Bluetooth, Zigbee, GPS, and cellular technologies, all leverage techniques that produce non-CW signals that are difficult to observe. Some even hop around or operate in a wide range of frequency bands. Moreover, military and defense applications especially for electronic signal intelligence (ELINT) and

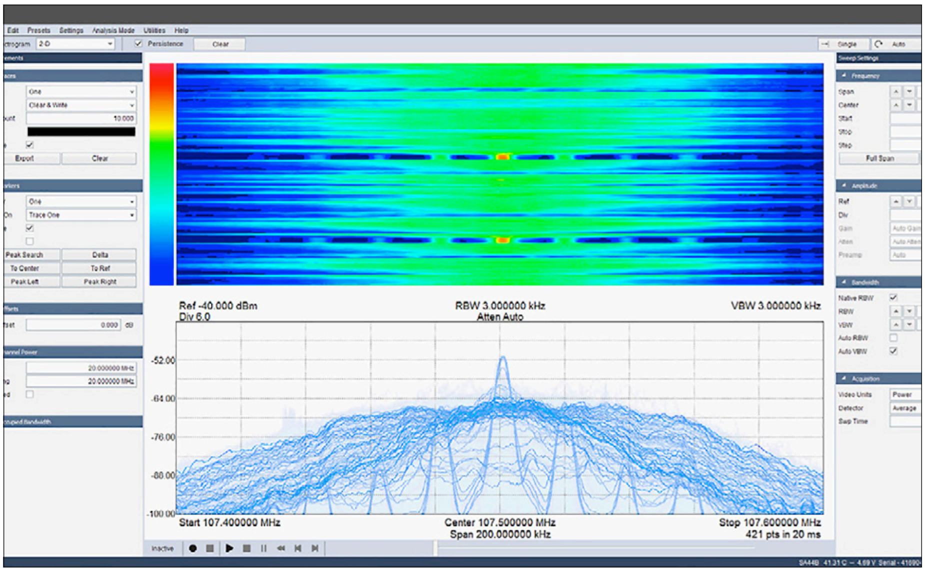


Figure 7: A persistent waterfall display in spectrum analyzer software.

electronic warfare (EW) applications — are often observing and relying upon complex pulse signals to carry important tactical information. Intentionally, these signals are inconsistent and of very short duration, so that they are essentially impossible to observe in real time. Hence, capture, record, and playback technology can be used to later analyse these signals with advanced signal processing and computational engines.

An RTSA has finite limits in the length of duration that can be accurately captured. This feature is known as probability of intercept (POI), and is rated as a percentage and a length of time of an event that can be captured at that percentage of probability. For example, some modern PC-Driven RTSAs can capture RF events with 100% probability as short as 1μs of duration.

POI is dictated by the window bandwidth of the RTSA. For 50% overlapping FFT RTSAs with a window bandwidth of about 2, the length of duration at 100% probability of intercept can be calculated by 3.0/RBW. For instance, for an RBW of 300 kHz, or ~150 KHz FFT bins, a signal of 10 μs, or more, can be captured successfully with adequate resolution. For signals that are shorter than 10 μs, the signal energy from the event may be captured in more than one FFT bin. This would lead to a misrepresentation of the signal amplitude at any given frequency in which that signal contains energy.

As the instantaneous bandwidth, frequency range, and RBW of an RTSA is limited, the speed and complexity of signals that can be observed by a given RTSA will also be limited. Furthermore, there may be commerce regulations and security regulations that limit the performance of RTSAs in terms of instantaneous bandwidth and the length of signal duration with 100% POI.

How are modern signal modulation techniques and infrequent/inconsistent signals observed by RTSA?

For communications signals that leverage frequency hopping, spread spectrum techniques, are low-duty cycle, or are inconsistent, being able to visually observe and make judgements on these signals can be challenging in a rapidly changing display. Moreover, military/defence, ELINT, EW, interference hunting, and security applications may need to observe minute trends and changes in the spectrum over a long length of time to hone in on signals of interest interest.

A method to enable this with a RTSA, is a display technique that combines the signal energy at any given power and frequency point on the analysis display with color coded variations with persistence (see **Figure 7**).

Known as persistent displays, this technology enables a user to see the time domain variations of fast moving signals. Furthermore, this persistent display can be reconfigured for showing captures of the display as time slices that steadily stack to create a "waterfall" of successive frequency sweeps with intensity colour differentiation. Especially useful for analysing disruptive signals and signals that rapidly change frequency, a persistent display can provide a large amount of insight into the dynamic environment of the spectrum being observed.

An added benefit of a RTSA, is that the frequency sweep data, as it is already digitized, can be recorded in high speed memory and further analysis can be performed when greater computational resources are available. So, for a test done in the field, full analysis and troubleshooting may not be available. Instead of having to share limited value screenshots, an RTSA with RF Recording capability can play back the measured signal information.

Though these abilities enable direct observation of the spectrum in highly useful ways, just like a security video, panning through time to search for a specific event can be time consuming and error prone. Another RTSA feature that enhances a user's ability to capture events of interest are configurable limit lines. Limit lines allow the user to create a trigger based upon frequency power invading a boundary that can be configured for each frequency point at different power levels. When spectral energy violates the high/low limit, or logic event, a trigger can be activated that captures the event, or even begins recording for deeper analysis over time. ◄

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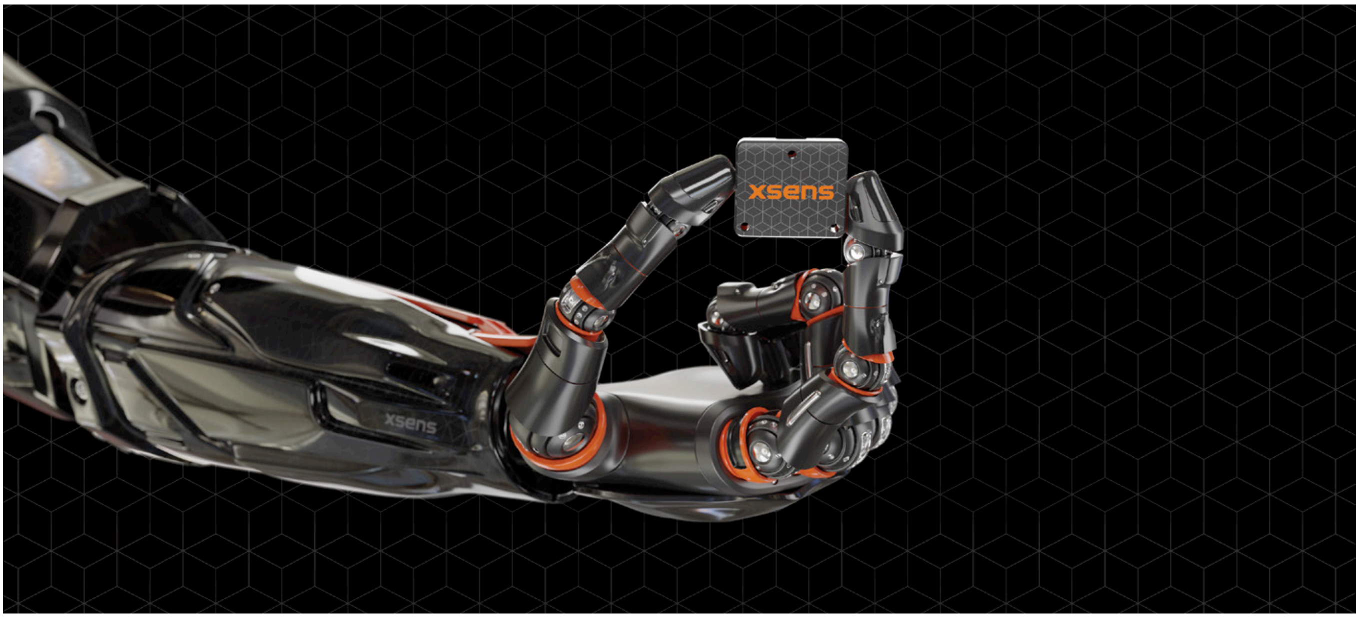
Miniature New Industrial-Grade Inertial Sensor Units



Xsens recently announces the introduction of a generation of inertial motion sensors which set a new standard in the market for their small size, industrial-grade performance and competitive pricing.

The all-new MTi 600-series of inertial sensors, supplied in a 31.5 mm x 28.0 mm x 13.0 mm IP51-rated case, produce roll and pitch readings accurate to ±0.2 °. GNSS-assisted heading (yaw) measurements are accurate to ±1.0 °. Among the products' new features are a CAN bus interface and NMEA compatibility.

To achieve this performance, Xsens has applied numerous innovations in its latest sensor fusion algorithms, which optimize the output from new accelerometer, gyroscope and magnetometer components. This has allowed it to bring the performance-optimized MTi 600-series to market at unit prices below €300 for production volumes of the MTi-610 IMU.

There are four products in the MTi 600-series:

- MTi-610 IMU, which provides fully calibrated sensor data outputs
- MTi-620 VRU offering roll and pitch measurements accurate to ±0.2°
- MTi-630 AHRS offering roll and pitch measurements accurate to ±0.2° and yaw measurements accurate to ±1.5 °
- MTi-670 GNSS/INS with GNSS support offering roll and pitch measurements accurate to ±0.2 °, yaw measurements accurate to ±1.0 °, and global positioning data supplied by an external GNSS receiver

The MTi 600-series modules offer the same core benefits that users of existing Xsens modules will be familiar with:

- A choice of standard interfacing options, now including for the first time support for CAN bus alongside RS-232 and UART interfaces.
- Comprehensive, free MT Software Suite, a software development kit for easy integration into host system designs. This includes the XDA open-source application programming interface for use with any hardware development platform.
- All production units comprehensively tested and calibrated before shipment to the customer.
- Global technical support 24/7 from dedicated applications engineers.

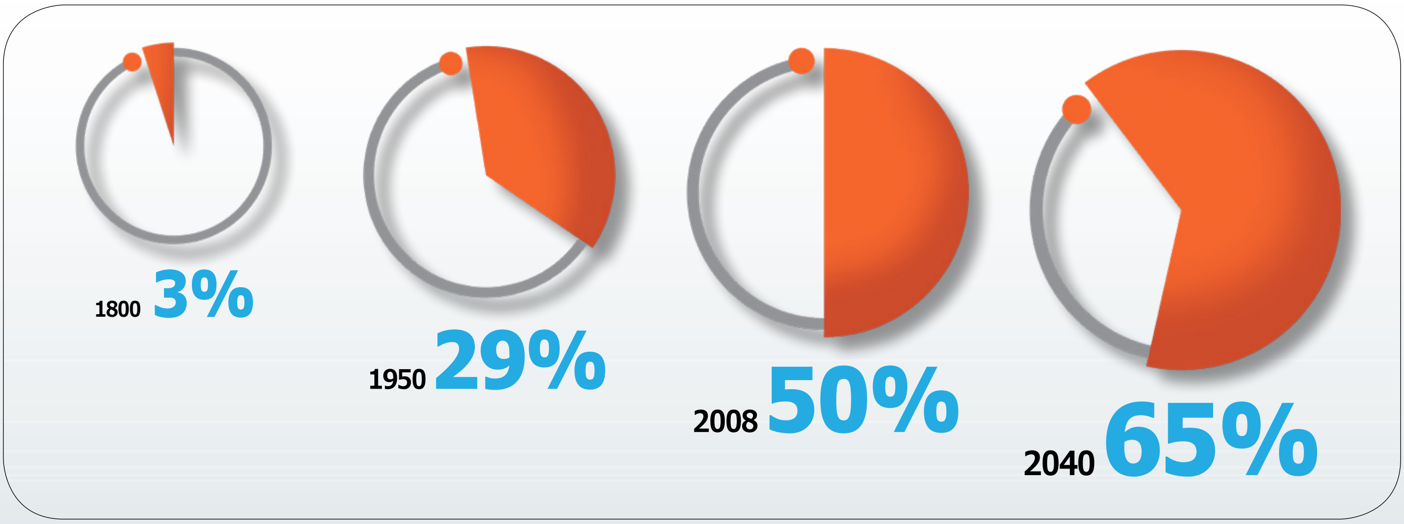
The MTi 600-series modules are the first from Xsens to include an NMEA-compatible interface for GNSS receivers. This means that users can choose any GNSS receiver chip, module or system to work alongside the MTi-670, a GNSS/INS device which supplements the pitch, roll and yaw outputs available from other MTi 600-series products with global positioning information.

The MTi 600-series modules are available for sampling on request. Mass production is expected to begin in July 2019. Developers can pre-order the MTi 600-series Development Kit online at shop.xsens.com.

https://content.xsens.com/mti-600-series#/

What Drives the Market for Sensors (I)? People Living in Cities

According to a UN study and other studies brought together by IoT company Postscapes, the increase in people living in (mega)cities will continue for some time to come. Whereas in 1800 only 3% of the population lived in cities, nowadays that percentage is more than 50, with a tendency towards 65% in 2040. What does this mean in economic terms? An ever increasing demand for sensors to monitor traffic, parking space, waste, leakage and so on and so forth.
(Primary source: *Postscapes, for additional sources see www.postscapes.com/anatomy-of-a-smart-city*)

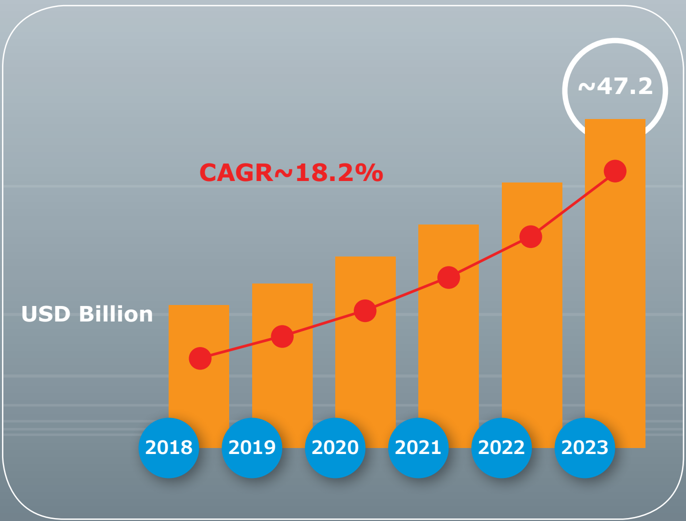


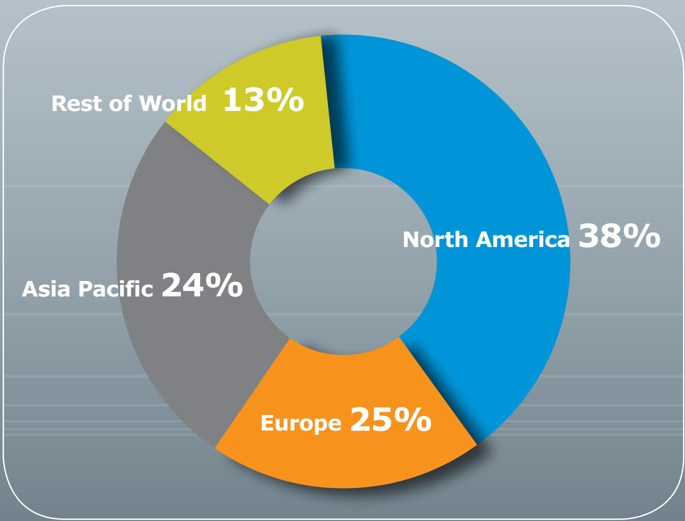
Sensors Market Is In for Very Solid Growth

Research by Market Research Future shows a very solid growth for the intelligent sensors market, roughly doubling its size in 2023 when compared to the current year 2019. Intelligent sensors are capable of self-testing, self-identification, self-validation and self-adaptation. These sensors are highly reliable, very compact and low in power consumption. They (will) do well in smart cities, but also in sectors like defence and healthcare. (Source: *Market Research Future*)

Sensors: North America Leads the Way

When it comes to intelligent sensors, the North American continent is most eager to start the sensors revolution. Europe comes in second, with the Asian Pacific region in its trail. The rest of the world seems to be a little bit timid. These 'RoW' countries will undoubtedly catch up: during the next decade, demand will probably be so high that extra supply will enforce price cuts. (Source: *Orion Market Research*)





What Drives the Market for Sensors (II)? More (Mega)Cities

It is not only that a higher percentage of people are living in large (mega)cities. Also, cities are growing in size rather spectacularly. In 1900, there were only 12 cities with more than 1 million inhabitants. In 1950, there were already 83. Even more telling are developments since 1950: in 2011 500+ cities went beyond and above 1 million people. What's more: by 2025, China alone will have 221 cities with more than 1 million inhabitants. This triggers extra demand for intelligent monitoring, ranging from sensors checking water quality to sensors checking street lighting.

(Primary source: *Postscapes, additional sources see www.postscapes.com/anatomy-of-a-smart-city*)

By **Robert van der Zwan**

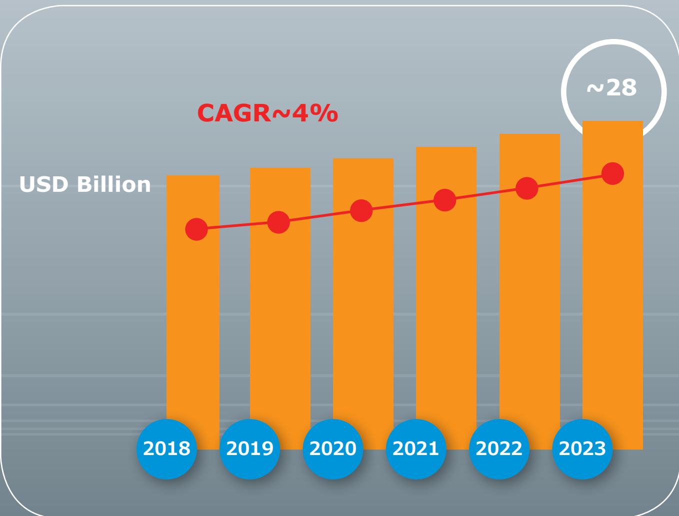
T&M Market: Solid Growth Indeed

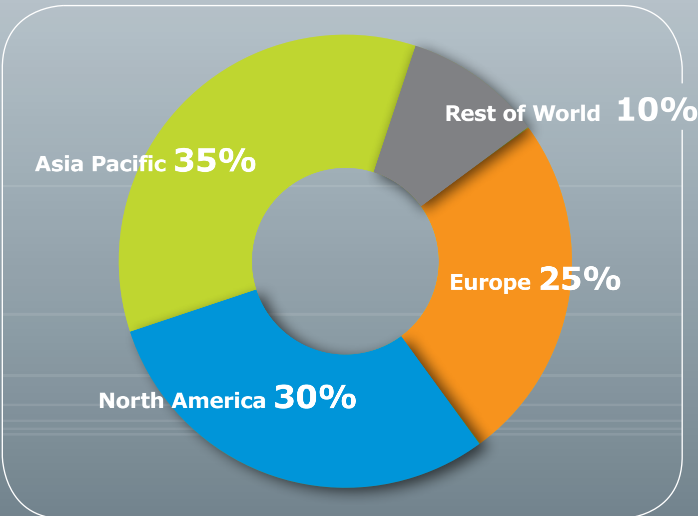
(But More of a Follower than a Trendsetter)

The global T&M market will show solid growth the coming years, albeit not so impressive as the sensors market. The growth rate for T&M will be around 4%, whereas the intelligent sensors market will grow annually at a rate of at least 18%. Nevertheless, players like Rohde & Schwarz and National Instruments face a rosy future. More sensors lead to more networking. More networking leads to more communication, which in turn leads to… more demand in T&M equipment. (Source: *Market Research Future*)

T&M: Asia Pacific Leads the Way

During the coming decade, the Asian Pacific region represents the most promising market for T&M vendors. This mainly has to do with the potential of the economies in 'APAC', especially China and India. Due to its sheer size, Japan is also a major player to reckon with. During the coming five years, the global market for T&M will roughly be divided as follows: APAC 35%, North America 30%, Europe 25% and the Rest of the World 10%. (Source: *MarketsandMarkets Research*)





The Art of Low Pressure Sensing and Finding the Right Sensor

By **Ian Bentley**, Engineering Fellow,
Honeywell Sensing and Internet of Things

Don't let the wide range of available low-pressure sensors be intimidating. Because of the range, there will likely be a sensor, or combination of sensors, to meet most application requirements. The key is to know your requirements and constraints first.

Consider just two industries, and see the wide range of possible applications:

- Medical: Airflow monitors, anesthesia machines, blood analysis machines, gas chromatography, gas flow instrumentation, hospital room air pressure, kidney dialysis machines, nebulizers, pneumatic controls, respiratory machines, sleep apnea equipment, spirometers, ventilators
- Industrial: Barometry, drones, flow calibrators, gas chromatography, gas flow instrumentation, HVAC clogged filter detection, HVAC systems, HVAC transmitters, indoor air quality, life sciences, pneumatic control, VAV (Variable Air Volume) control, weather balloons; energy management systems

Recently when Surrey Sensors Ltd. needed more accurate, smaller, and cost-competitive pressure sensors for use in their pressure measuring systems, they found that the Honeywell TruStability™ RSC Series and HSC Series Digital Board Mount Pressure Sensors were the only solution that met their list of strict requirements, especially at ultra-low pressures.
Honeywell low- and ultra-low pressure sensors are manufactured and rated to help account for application design considerations that affect output readings:

- Overpressure – how high a pressure can go without damaging a sensor.
- Burst Pressure – how high a pressure can go without bursting the sensor diaphragm.
- Resolution – how small a pressure change can be measured by the sensor.
- Stability – innate characteristic of sensor readings and output to drift over time.
- Total Error Band – a measure that combines all of these considerations into a value that helps you apply sensors for your application.

All Honeywell pressure sensors bring high accuracy, durability, and design flexibility required by engineers. For medical applications alone, measuring tiny changes in the pressure of human breath can be lifesaving.

A good place to start when applying pressure sensors is to be aware of even unexpected, sources of pressure changes in your application. Being aware of application constraints can remove confusion when selecting appropriate sensors. That allows you to accommodate the constraints with additional sensors, or even change the application to remove the constraints.

High pressures are easier to measure and require less robust sensors. On the other hand, measuring lower pressure ranges require more robust and sensitive sensors that are also more susceptible to unexpected higher pressure bursts. A good cough in a breath monitor can suddenly cause 80 times or more the expected pressure, and damage a sensor.
Measuring small pressure changes in a small diameter plastic tube may seem easy. But also consider small how pinches in that tube, caused by tube movements, or mechanical wear at connection points, can throw readings off.

One solution is to measure for anomalies before they cause problems. You could measure for higher pressure bursts upstream before they reach, and potentially ruin, sensitive low-pressure sensors downstream. Have additional sensors before and after potential constrictions to identify anomalies before they become problems and contaminate results.

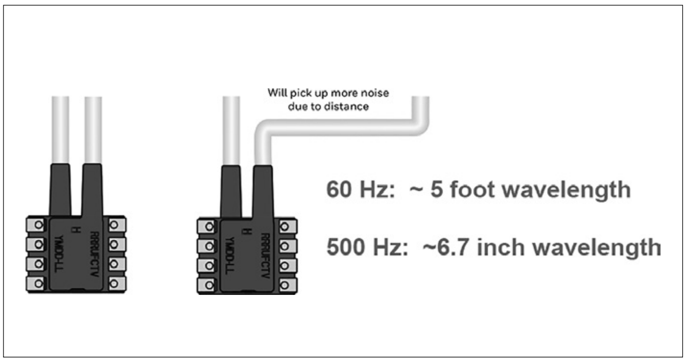
Be aware of potential issues in your manufacturing process to avoid problems. Vacuum pick-up tools, used when placing sensors on circuit boards, creates low pressures that can negatively affect, or even rupture, sensitive pressure sensors. Inadvertently blocking sensor inlet or outlet ports with debris can cause major problems when sensors make it to the end user application. Even post-manufacture cleaning done incorrectly can leave debris that clogs or enters sensors and contaminates results.

Even unexpected sound waves cause differences in pressure. HVAC or box cooling fans turning on, or doors opening and closing, can cause unanticipated pressure changes by the noise alone.

If you can't eliminate the possibility of noise, you can at least mitigate the impact by using various techniques. Keep both sides of your pressure sensor physically close to each other. Minimize pressure tube runs to minimize noise on one side.

Use pneumatic filters to remove physical contaminants, and dampen noise contaminants. Just remember, any physical filter can also affect the pressure difference between the ports and must be cleaned or replaced as they clog so they don't affect readings. You can use additional pressure sensors to proactively measure the condition of those filters.

You can also filter out errors by digitally accounting for drift over time. Good sensors minimize long-term drift - most of which occurs over years rather than days. In fact you may decide your application is not affected by drift.
If drift is important in your application, you can apply offset correction by taking a reading when you are in a known zero condition, like at application start-up in the morning or on a weekend. Then subtract that value from real-time sensor readings until the next time you can officially provide a zero condition. You can also obtain that zero value by directly connecting input and output ports and take that as a zero reading for the calculation. This process can provide a correction for offset to within a quarter percent error, and provide a major improvement in the quality of the output.



In summary, know your design considerations and constraints first. That makes applying the correct sensors easier. Honeywell helps by providing Total Error Band values for each sensor that combines the considerations and constraint characteristics in one value that makes it easier for you to apply the right sensors.

The Author

Ian Bentley, Engineering Fellow, Honeywell Sensing and Internet of Things.
Ian Bentley is an Engineering Fellow at Honeywell with 34 years of experience in sensor design and manufacturing. Over the years, Ian has lead design teams working with several different pressure sensing technologies, airflow sensors, humidity sensors, magnetic sensors and accelerometers.

Time Sensitive Networking

An Introduction to TSN

By **Dr Andreas Weder**, Fraunhofer Institute for Photonic Microsystems (IPMS).

Ethernet has been equally established as a dependable wired solution in both computer and automation networks. The open standard allows terminals to be quickly and simply connected as well as easily scaled to exchange data with relatively inexpensive hardware. Ethernet was, however, not originally designed to meet the requirements posed by automation technology, particularly in regards to guaranteed and real-time communication. Therefore, various bus systems in automation have evolved using Ethernet on a physical level while implementing proprietary real-time protocols on top. These systems often lead to the exclusive use of the network infrastructure as well as vendor dependencies.

Such networks handling time-critical data traffic are today separated from networks directing less-critical data traffic in order to eliminate reciprocal negative interference. In the future, Industry 4.0 applications will require increasingly more consistent Ethernet networks. Such networks can only be produced at great cost with the traditional structure. Time-Sensitive networking (TSN) provides a solution aiming to change these current conditions.

Real-time Communication

Guarantees regarding cycle times and fluctuations in cycle times are prerequisite for a range of application fields in automation, including, for example, drive, control-, and conveyor technology. The data transfer times demanded in these application fields are significantly less than 1 ms. In addition to these applications requiring “hard” real-time capability, other applications such as process automation implement “soft” real-time capability with longer cycle times. Nevertheless guaranteed latencies are required

for these applications as well.
Various real-time communication methods such as EtherCat or Profinet IRT have been specially developed to provide guaranteed cycle times. Although they are based on conventional Ethernet, they are not compatible with each other. This incompatibility has resulted in fragmented networks.

Why TSN?

In most cases, traditional Ethernet networks involving automated sectors such as manufacturing are based on the hierarchical automation pyramid which separates information technology (IT) from operational technology (OT). IT includes classic office communication with typical end devices such as printers and personal computers. OT is made up of systems, machines and software used for process control and automation. The two areas are fundamentally different in how they communicate, with IT dependent on bandwidth and OT focused on high availability (**Figure 1**). Data traffic at the IT level is therefore often classified as non-critical while data traffic is designated (time-) critical at the OT level. As a result, each level uses a particular communication standard. While the Ethernet bus system with TCP/IP has largely prevailed at the IT level, various bus systems, also known as fieldbus systems, that particularly meet requirements for guaranteed latency times are widespread at the OT level. Each control vendor usually promotes a specific fieldbus system. For the user, this means that selecting the controller basically also determines the selection of the bus. The end user is thus often in a manufacturer's dependence, since the different bus systems are incompatible with each other.

In the beginning, there were hardly any connections between IT and OT. Today, the continuous transmission of data is a fundamental necessity for digitized enterprises of all shapes and sizes. Consistent communication is essential to fulfil requirements demanded in operational data acquisition, remote access, or machine connection in the cloud. More importance will be placed on convergent, uniform networks in the future. Industrial automation is already undergoing a phase of restructuring based on the establishment of flexible and intelligent manufacturing, often described or already implemented in the context of Industry 4.0 or the Internet of Things (IoT). Smart production includes component parts, machines, and factories that are constantly communicating with one another in order to optimize and support processes in an automated way. These changes are also having an effect on the established automation model.

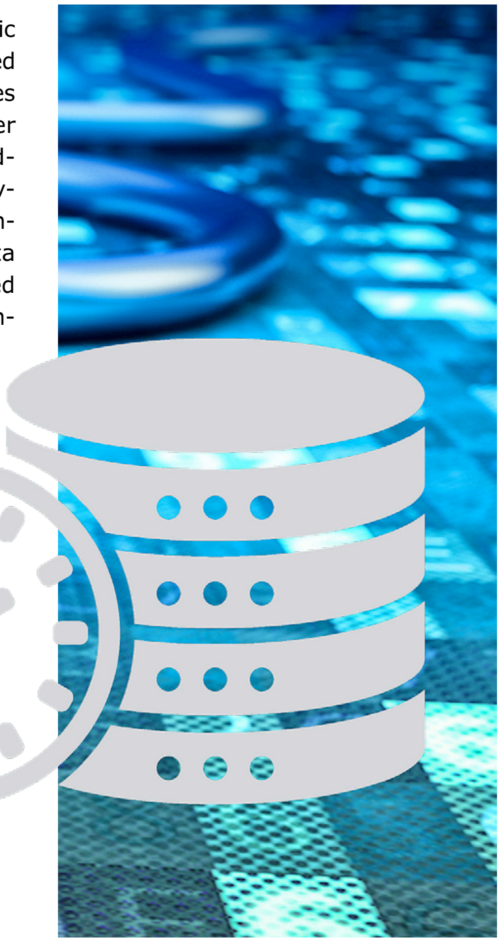
For the benefit of integration, the classic automation pyramid is being transformed into a broad network, which also includes sensors directly connected with higher control levels. The separation of field- and control levels is increasingly dissolving, creating the need for a uniform, convergent network in which critical data traffic can be simultaneously transmitted along with non-critical data traffic without negative reciprocal effects. The existing Ethernet must be adapted in order to meet these requirements. Sub-standards intended to enable converged critical and non-critical data traffic over a shared Ethernet infrastructure are therefore currently being defined and improved.

Advantages of TSN over traditional Ethernet include:

- Guaranteed latency times of real-time critical data throughout the network
- Critical and non-critical data traffic can be transmitted over a converged network
- Higher-level protocol layers can share a common network infrastructure
- Real-time control can also be applied outside of the OT area
- No vendor dependence

What is TSN?

Time-Sensitive Networking is a set of Ethernet sub-standards defined in the



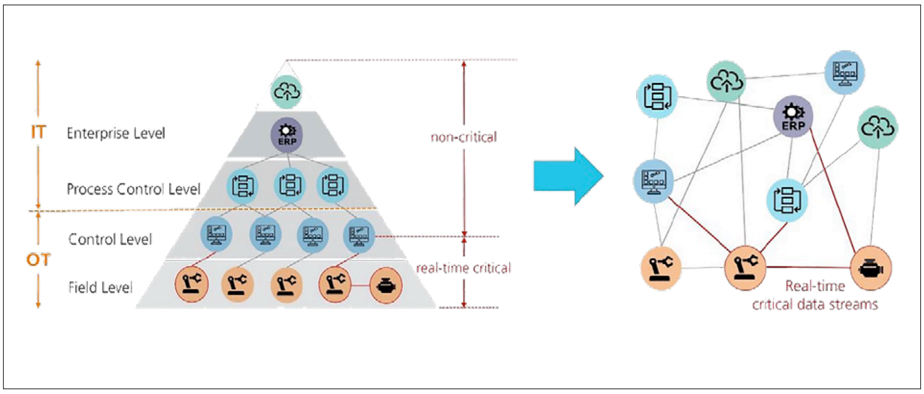


Figure 1: Conversion of the automation pyramid.

Standard	Title
IEEE 802.1AS-Rev	Timing and Synchronization for Time-Sensitive Applications
IEEE 802.Qav	Forwarding and Queuing Enhancements for Time-Sensitive Streams
IEEE 802.1Qbv	Enhancements for Scheduled Traffic
IEEE 802.Qbu & IEEE 802.3br	Frame Preemption
IEEE 802.1Qca	Path Control and Reservation
IEEE 802.1Qcc	Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
IEEE 802.1Qci	Per-Stream Filtering and Policing
IEEE 802.1CB	Frame Replication & Elimination for Reliability

Table 1 – Overview of TSN Standards

IEEE 802.1 TSN Task Group. TSN focuses on creating a convergence between information technology (IT) and industrial operational technology (OT) by extending and adapting existing Ethernet standards.

TSN technology aims to standardize features on OSI-Layer 2 in order that different protocols can share the same infrastructure. The challenge lies in configuring critical and non-critical data traffic so that neither real-time characteristics nor performance is impaired.

Important Core Elements

It is an essential prerequisite that all network equipment have the same understanding of time. All switches and terminals on the network must be time synchronized. Two different approaches to facilitate these functionalities are selectively used. (**Table 1**).

IEEE 1588-2008 - Precision Time Protocol

Using an algorithm within the network, the IEEE 1588-2008 standard prompts the provision of the clock with the most accurate time to be designated to serve as Grandmaster Clock.

IEEE 802.1AS-2011 - Time

In addition to the general IEEE 1588 specification, the TSN Task Group adopted a special profile that stipulates the use of IEEE 1588 specifications in conjunction with IEEE 802.1Q. The profile was developed to facilitate implementations into applications that do not require the full functionality of the 1588-2008 standard. Because the profile did not meet all automation requirements, it was redesigned and is now known as IEEE 802.1AS-rev.

A second core functionality deals with the transmission of critical and non-critical data traffic within a converged network. Critical data traffic is guaranteed for delivery at a scheduled time while non-critical data traffic is usually given lower priority. Eight traffic classes already established according to IEEE 802.1Q are used to prioritize different types of data traffic. However, the standard's defined quality of service (QoS) was not designed for sending critical and non-critical data traffic in parallel. Due to buffer mechanisms in Ethernet switches, a low-priority Ethernet data packet can delay even those data streams with the highest priority along the transmission path. New prioritization mechanisms have been introduced to allow and regulate this coexistence. Depending on the application requirement, additional traffic shaper or scheduling mechanisms can be implemented. Below, two of these mechanisms are explained in more detail.

IEEE 802.1Qav — Credit Based Shaper

This standard defines an algorithm for data streams with real-time requirements to be prioritized over best-effort traffic. The Credit Based Shaper (CBS) was developed in 2009 by the IEEE 802.1 working group for the TSN Audio/Video Bridging (AVB) predecessor technology. The shaper assigns send credits to data streams. Data packets with reserved bandwidth are preferably transmitted as long as credit remains in the positive range. Send credits are spent during transmission until declining to a negative. Once a preferred transmission reaches a negative value, the best effort data packets next in line are transmitted. If this delays the forwarding of data packets with reserved bandwidth, credit is increased accordingly to allow prioritized Ethernet frames to be transmitted in succession following the best-effort traffic.

IEEE 802.1Qbv - Time-Aware Scheduler

The basic function of the scheduler is to create equal discrete time periods (cycles). These cycles or time-slots are then assigned traffic classes. Time-aware shaping provides a fixed timetable for different data traffic classes to predetermine start and arrival times. This makes it possible to comply with defined transmission times and synchronize multiple data streams. Because the scheduler requires synchronization, all network participants know when which priority may be sent and processed. In addition to the time synchronization and various traffic shaping and scheduling mechanisms, other sub-standards have been or are currently in the process of being developed. These different standards are more a construction kit than an all-in-one solution. Modules can be combined in different variations to fulfill certain requirements of differing application scenarios, making it possible to adapt TSN networks to each particular one.

The Fraunhofer IPMS IP Core has currently implemented IEEE 802.1Qbv, IEE 802.1AS, IEEE 802.1Qav, and a real-time capable Media Access Control (MAC).

TSN IP Core on FPGA-Basis

Due to the broad range of TSN functions, integration can best be realized on the basis of a field programmable gate array (FPGA). In comparison to integrated circuits (ICs) where many functionalities are predetermined, FPGA can be flexibly programmed. The logic gate (gate array) can be configured to generate complex digital functions. FPGAs advantages over ICs include:

The Author

Dr Andreas Weder completed his studies in Electrical Engineering with a focus on CommunicationsEngineering at the TU Dresden in 2006. He received his doctorate in 2013 at the TU Dresden 2013 in the field of wireless sensor networks. Since 2006 he has been working at Fraunhofer IPMS, where he has been head of the Module Integration Development Group since 2016.

- Significantly lower development costs
- Shorter implementation times
- Flexibly expandable and re-programmable

Because some TSN standards are currently still being revised and changed, the possibility to expand and re-program is a critical factor in implementation.

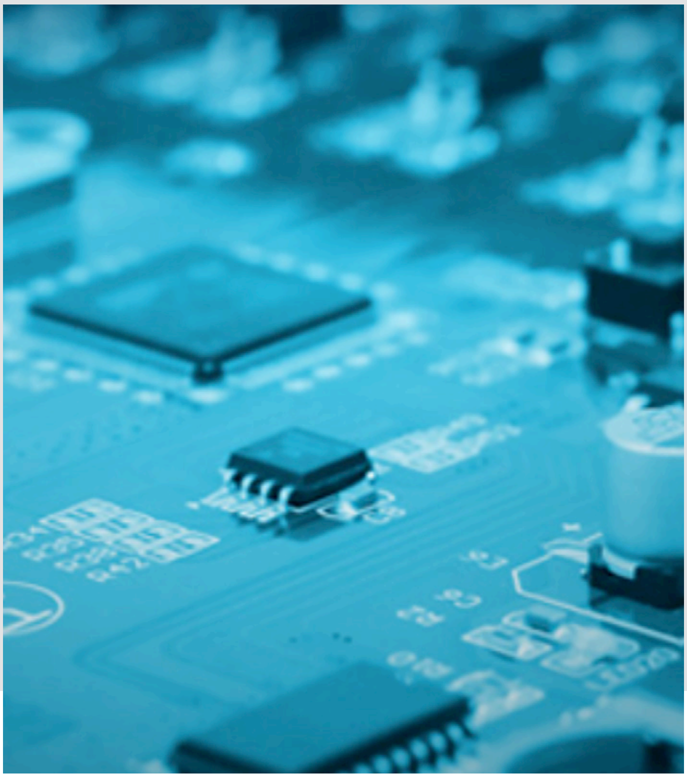
Summary and Outlook

Different real-time requirements demand different approaches. TSN lays the foundation to meet these requirements and the spectrum makes it possible to fulfill various latency, jitter and reliability requirements. Although the standardization process is not yet complete and the implementation of various standards is still in progress, core features can already be integrated into products. Changes or upgrades can be implemented subsequently with corresponding IP Core support services. A TSN network achieves its full potential when all components and devices within the infrastructure are TSN compatible. Numerous manufacturers of industrial devices and switches are now working to make TSN-compatible products. During so-called "Plug Fests", products from all manufacturers are tested for standards-compliant interoperability. Fraunhofer IPMS is currently testing its own TSN_CTRL IP-Core at the Industrial Internet Consortium (IIC) and Lab Network Industry 4.0 (LNI) Plug Fests.

190267-01

Introduction of SMT Assembly and Its Significance for Electronics Manufacturing

Pcbcart



As the centering core in electronics products, PCBs (Printed Circuit Boards) are responsible for carrying all the functions products have to implement in the whole system. The combination of bare PCBs and components leads electronic products to be smaller in size and weight and to better perform in electrical connection. Since the advent of assembly technology to logically and solidly stick components to bare boards, THT (Through-Hole Technology) assembly has been widely applied to make electronic components with leads directly going through holes on boards and make the other end of leads soldered on board back.

When people have higher requirement on performance and appearance of electronic products, THT assembly becomes increasingly far away from people's expectations. Specifically, electronics products are currently expected to run faster, to be smaller and lighter, which arouses for the advent of SMT (Surface Mount Technology) assembly. Up to now, SMT assembly has been used in almost all electronics products serving for numerous fields such as medical care, transportation, military, aerospace, telecommunication etc. Therefore, it's of much necessity to get more aware of SMT assembly procedure, attributes and its significance for electronics manufacturing.

Definition of SMT Assembly

SMT assembly is a type of technology for PCBA (Printed Circuit Board Assembly), which refers to the process during which SMC (Surface Mount Component) or SMD (Surface Mount Device) can be permanently fixed onto PCB surface through reflow or wave soldering.

Different from THT components, SMCs feature little leads that are hidden under component body and they are connected with board through melting solder that'll be cooled down and hardened.

Attributes of SMT Assembly

a. Smaller size and lighter weight

Compared with through-hole components, SMCs/SMDs are much smaller in size since they are in chip shape while through-hole components' combination with bare board is achieved through leads so that THT-assembled PCBs are thicker and heavier than those through SMT assembly.

b. Higher Performance

The connection way SMT assembly conforms to leads SMCs/SMDs to be capable of better performing in terms of vibration resistance, lower rejection rate and high performance.

cvv v The electronic products using SMT assembly feature high frequency and suffer from less EMI (Electromagnetic Interference) and RF (Radio Frequency) interference.

Procedure of SMT Assembly

SMT assembly procedure mainly covers solder paste printing, chip mounting, reflow soldering, visual inspection and AOI (Automated Optical Inspection).

a. Solder Paste Printing

Solder paste printing is completed through the application of stencil whose openings should be filled with appropriate amount of solder paste. After solder paste printing, each pad on board surface should be covered by solder paste that plays a role as adhesive. The performance of solder paste printing depends on some elements including scraping speed, scraping blade angle etc.

b. Chip Mounting

Chip mounting is done on chip mounter whose parameters determine assembly level and efficiency. For example, when the size of a board is lower than the smallest board size a chip mounter can deal with, SMT assembly in panelization will be considered as a solution.

c. Reflow Soldering

The soldering type used in SMT assembly is reflow soldering that should be implemented after four temperature phases: preheating, temperature rise, peak temperature and cooling down. The solder paste between component lead and PCB pad has to suffer from high temperature, be melted and be cooled down. As it becomes hardened, reflow soldering is completed. Temperature parameters should be rigorously set in order to obtain top quality and characters of different components should be carefully considered since RH (Relative Humidity) and temperature matter a lot for some components, especially those humidity and temperature sensitive ones.

d. Inspection

Inspection plays such an essential step in SMT assembly that it determines the quality and performance of assembled PCBs. Inspections can be implemented through a couple of methods: visual inspection, AOI and X-ray inspection among which the former two are mostly applied in every workshop. Visual inspection aims to make obvious defects exposed, appearance for example. AOI, however, aims to make soldering defects exposed through rapid picture shot, such as cold soldering, bridging etc. X-ray inspection is actually upgrading of AOI since it is capable of indicating the internal situation of solder joints.

The Significance of SMT Assembly

As is discussed above, SMT assembly is so compatible with current expectations on electronics in terms of size and function that it has been widely applied in almost all products. Another leading edge of SMT assembly lies in its high manufacturing efficiency since SMT assembly can be completed through partial automation and the latest chip mounter features a mounting speed of 28 points per second that is definitely able to meet the demand of high efficiency.

PCBCart's Efforts on SMT Assembly

PCBCart has been in the business of SMT assembly for more than ten years during which new records have been constantly broken and new ones established. Based in China, PCBCart is accessible to advantages on resources, environment and talents that are dramatically important as far as an electronics manufacturer is concerned.

PCBCart's Efforts on Capability

Up to now, the smallest size of a component PCBCart is capable of dealing with is 01005 that is similar to a pencil tip, meeting some demands of miniaturized electronics assembly. When it comes to manufacturing standard that has been stuck to, IPC-TM 650, ISO9001 and IATF16949 have all been achieved so as to meet different demands from numerous fields.

PCBCart's Efforts on Quality

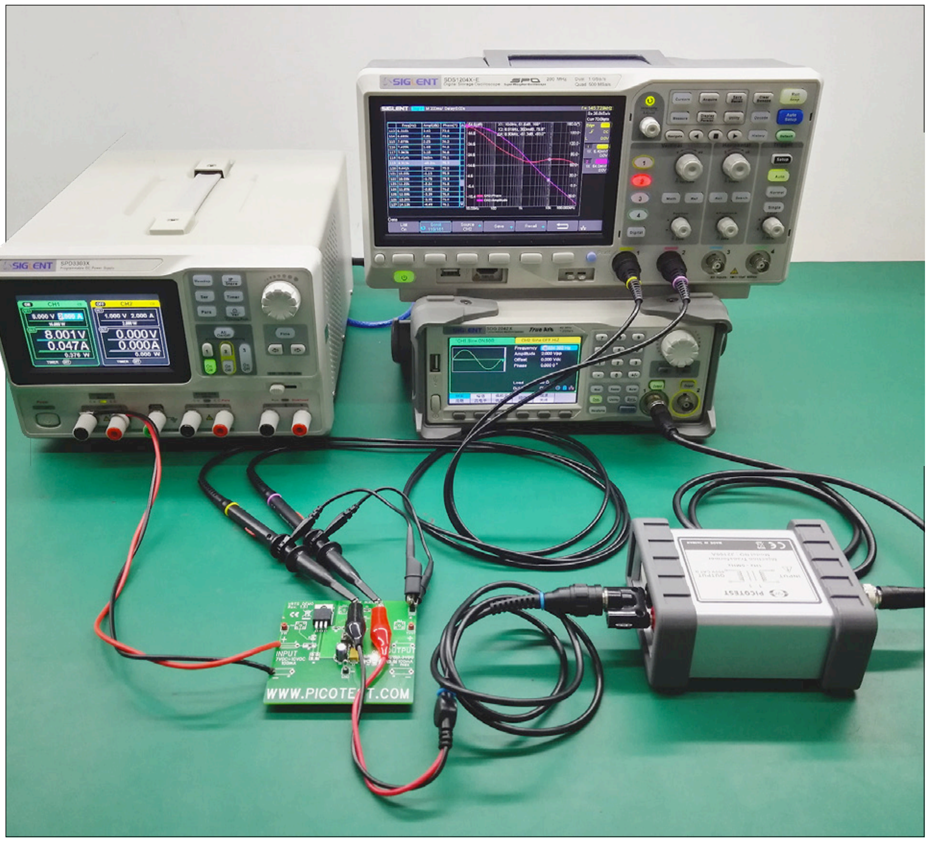
Products' quality has been PCBCart's focus since its establishment and it'll be a permanent running direction. To provide top quality to customers, on the one hand, rigorous quality standard is followed in PCBCart's workshop, ISO9001. On the other hand, numerous inspection measures are appropriately made during the whole procedure of SMT assembly, including visual inspection, AOI test, X-ray test, Flying probe test and function test all of which contribute to excellent performance of assembled PCB prior to market entry. In addition, PCBCart supports lead-free reflow/wave soldering, compatible with environmental protection requirement.

PCBCart's Efforts on Service

PCBCart believes customer service as a shortcut to further development for a cooperation striving for business around the globe. For more than 10 years' development, PCBCart customer service team has been capable of knowing customers' needs at top speed and knows how to react within seconds, which is why PCBCart has won a customer's satisfaction rate of 99%+.

Measurement and Analysis of Integrated Power Supplies

By **Thomas Rottach**,
SIGLENT Technologies Germany GmbH



Looking at today's world of electronics, a handful of topics dominate the headlines. These include digitization, artificial intelligence, electrification of transport, autonomous driving, renewable energies and 5G, the next generation of mobile radio. From a higher perspective, they are all interconnected in some way.

Autonomous driving, for example, is linked to digitisation, artificial intelligence and 5G. Electrification of transport is hardly conceivable without the constant expansion of renewable energies and smart cities. All the topics listed together have given an unprecedented popularity to a sub-sector of electronics: power electronics and the development of power supplies. Efficient use of the available energy is crucial for the success of the technologies. Battery life, range and reduction of cooling costs are the keywords here.

Power electronics

What does this mean for the development of power electronics? First and foremost, the design must be stable. Every conceivable oscillation represents energy loss and worsens EMC behaviour. The classic way to determine the stability of feedback control loops is to measure the phase and amplitude span. This can be determined using Bode diagrams with various load scenarios. Modern oscilloscopes, such as the Siglent series SDS1004X-E or SDS2002X-E, permit creating Bode plots as a standard. The oscilloscope controls the function generator and records the curves. The phase and amplitude spacing can be read out from the plot using markers. The **introductory photo** and **Figure 1** show a possible setup and measurement results.

A further requirement for integrated power supplies is compliance with residual ripple tolerances. One effect of the ever smaller semiconductor sizes is that the supply voltages of microcontrollers or FPGAs are becoming smaller and smaller. For example, with voltages of 1.1 V and tolerances of 3%, the ripple must not exceed 33 mV. On the other hand, the currents are increasing and the dynamic requirements are also increasing constantly. Non-compliance with the tolerances leads to errors, and system failure in the worst case. This means that the determination of residual ripple and noise is increasingly important. An appropriate measurement setup consists of a clean power supply, an oscilloscope with an appropriate probe and an electronic load (**Figure 2**). The load should not only consume static current but also offer the possibility to generate fast load changes. The AC mode should not be used to measure the ripple, as a slow drift of the absolute voltage level cannot be seen and problems may occur even though the ripple is smaller than the tolerance. Siglent oscilloscopes offer up to 2 V offset with small vertical settings (500 µV/div — 100 mV/div). This permits users to keep a constant eye on the voltage level.

Fast load changes

In this context, the measurement of the regulation behaviour at fast load changes is a crucial part of the test procedure. How abruptly does the voltage break down at sudden, high current load? How long does it take for the voltage to be regulated again?

Often, it is necessary to integrate a combination of highly efficient switching rules and less efficient linear regulators (LDO — Low Dropout Regulators). Linear regulators are well suited to compensate for small voltage differences, and they also have the advantage of providing an appropriate filtering effect. An important measurement in this context is the determination of the PSRR (Power Supply Ripple Rejection Ratio). In this measurement, a sinusoidal signal with a varied frequency is artificially superimposed on a DC input voltage. Subsequently, for each frequency, the ratio of the level of the sinusoidal output to the input signal is formed and plotted logarithmically. This measurement can also be performed with an oscilloscope with Bode Plot functionality and a signal generator. An injector module is required to apply the sinusoidal signal to the input DC voltage.

In addition to optimizing the circuit and its behaviour, developers today can also rely on new, more efficient semiconductor switches. Semiconductor types with wide band gap characteristics, such as silicon-carbide (SiC) or gallium-nitride (GaN), afford increased efficiency due to their lower switching losses. Furthermore, the switching frequencies can be increased and the switching edges are steeper. In this context, the control speed can be increased. Another advantage is that external components such as energy storage coils or capacitors can be smaller in size. This also saves space, weight and costs. With all the advantages, there is always at least one disadvantage. Faster switching frequencies and steeper edges are sources of electromagnetic radiation. The higher dielectric strength of modern components enables higher [delta]U/[delta]t and [delta]I/[delta]t. High [delta]U/[delta]t generates strong electric fields which can lead to increased radiation due to capacitive coupling via heat sinks. High [delta]I/[delta]t generates magnetic fields which can be inductively radiated via the coils (like a frame antenna).

To avoid major EMC problems, attention should be paid to a clean ground connection of the heat sinks and to minimizing current loops and the use of shielded coils. A radiation analysis can easily be performed with a spectrum analyzer and Siglent H-field or E-field near-field probes.

Conclusion

In summary, it can be said that the measurements themselves do not differ much from „earlier“ measurements. However, the general conditions and tolerances have changed considerably. The new requirements and the pursuit of maximum efficiency are the reasons for the renaissance of power electronics.

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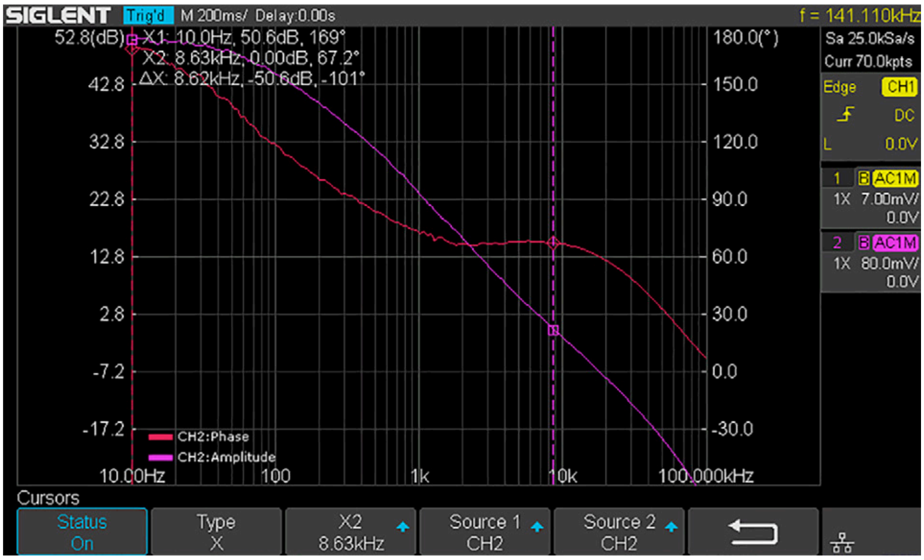


Figure 1: Phase distance measurement.

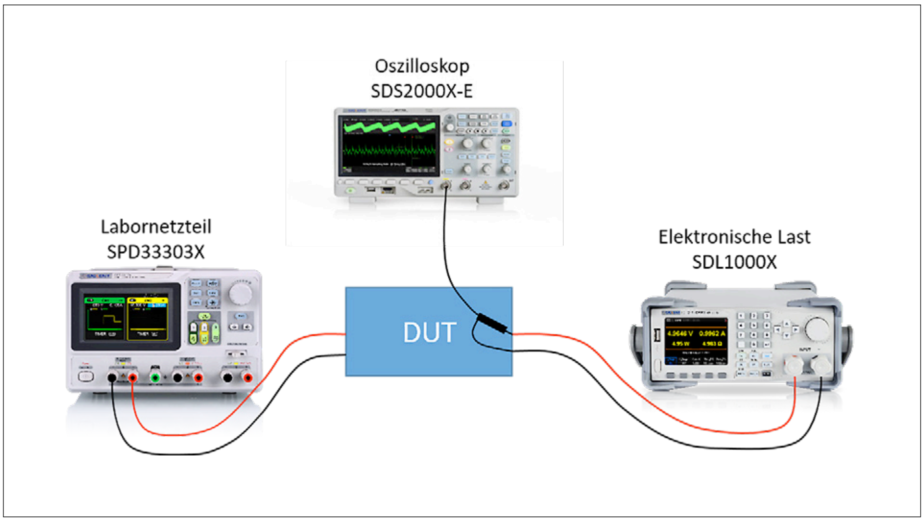


Figure 2: Three test instruments are used to determine ripple response.

When the sparks fly: ESD at Bürklin Elektronik

By Dipl.-Wirtsch.-Ing. **Kai Notté**, Produktmanager Bürklin Elektronik

Each of us has experienced at some point what electrostatic discharge means: You touch a metallic object and it sends a tingle through your finger or even your whole body.

From a physics point of view, an electrostatic discharge is a potential equalization of two differently charged bodies. This potential difference is caused, for example, by friction, which electrostatically charges the body - its potential is increased. If the charged body approaches or touches another body with a lower potential, the potentials are suddenly balanced out, causing a tingle, shock or even a spark. These are by no means small voltages: At a relative humidity of 10%, a person can be charged to over 35,000V by walking on a carpet alone.
In everyday life these spontaneous discharge are largely harmless to humans. However, if this voltage is machine generated, for example, in production, there is a danger to life. The difference in potential is much greater than a charge in everyday life. Physicians therefore classify the danger to humans as the same as an electric shock.

But even the comparatively low voltages of everyday life charges can have great effects: many electrical, electronic and optoelectronic components can be damaged or destroyed by the sudden discharge. However, you cannot see this in the components. It is therefore essential that you can trust your supplier to ensure that your goods are being handled appropriately in accordance with ESD guidelines.

To live up to this trust Bürklin Elektronik and ESD-Protect entered into a partnership in spring 2019. As part of the certification process according to IEC 61340-5-1 and ANSI/ESD S20.20, all goods movements and the associated processes were reviewed and adjusted where necessary.

For you as a customer, this means that you can rely on the fact that your goods have been treated and packaged in accordance with ESD guidelines throughout their entire life cycle. As a result of the certification we are no longer dependent on the original manufacturers packaging. Our newly acquired expertise enables us to offer smaller quantities of ESD sensitive products in protected packaging. In doing so, we can take into account your individual requirements and specifications.

To do this, we train our employees in ESD-safe handling practices for electronic components. In addition, new storage and packaging facilities with continuous monitoring of the relevant

measured values were set up, a process that spanned several months, bringing benefits across the board.

If you use ESD-sensitive components, you know it is not only the packaging that counts. Therefore we offer together with our partner ESD-Protect, an extensive range of ESD-compatible products up to and including individual consulting services for you and your employees. The services range from general seminars on the subject of ESD-safe handling of electronic components to individual consulting and auditing at your premises.

Bürklin Elektronik can also support you in equipping your ESD-sensitive areas. Did you know, for example, that there are not only special grounding/earthing systems and tools, but also office chairs for ESD protection?

Bürklin electronics has a certified ESD control program in accordance with IEC 61340-5-1 and ANSI/ESD S20.20. The shipping and packaging of your ESD-sensitive electrical and electronic components is in safe hands with us.

About Bürklin

Year of foundation: 1954
Employees: 160

Bürklin Elektronik is a distributor specialized in high quality electronic components.

For our commercial and private customers we have more than 75,000 articles from over 500 manufacturers in stock. We are continuously expanding this range and can currently offer more than 1,500,000 items. In addition, we are happy to procure other products from all renowned manufacturers worldwide. We sell our products via our online shop and in our retail outlet at our company headquarters in Oberhaching near Munich. For more than 65 years, our family-run company has stood for first-class service and a high level of specialist trade competence.

We are a classic distributor. Bürklin Elektronik focuses on the customer.
Therefore we attach great importance to professional customer management. Here our customers receive advice over the telephone and incoming orders are swiftly processed. Our customer service team is also responsible for fulfilling customer-specific requests. Our goal is to always satisfy our customers, who are at home all over the world. To this end, we are also broadening our customer relationship and key account management activities.

Our main markets are
- Industrial automation
- Automotive
- Consumer
- Data/Computing
- Instrumentation
- Medical technology
- Transport & Infrastructure

Our services at a glance

Online Shop
Availability display in real time, Order list import, ordering usually possible from a single piece upwards, Optimized filter and comparison function, Product search using the most common product references, Mobile version

Retail Shop
On-site in Oberhaching near Munich; Product purchases in real time collected directly from our warehouse.

eProcurement solutions
EDI via closed networks, which allow an automatic Transfer of all Order documents; OCI interface, allows direct Access to our Webshop via your ERP system; BMEcat with eCl@ss and UNSPSC, with integration option in your preferred B2B platform/marketplace

Internal sales force, External sales force, Field Application Engineers.
Personal contacts for all matters relating to orders, enquiries and questions about our services and also for any questions regarding strategic topics and on-site project support.

Product-related services
Cable assembly via external partners, customer-specific set assembly, 3D printing, calibration of measuring instruments, reeling service (from 100 pieces, free of charge without delivery delay)

Order-related services
No surcharge for small quantities, procurement of articles outside our range, parts list processing, quotation service, delivery on the requested date, blanket orders, project support

Using Precision Current Sensing to Optimize System Performance

By **Khagendra Thapa**, ACEINNA Inc.

Current sensors are used in a wide range of control, protection, and measurement circuits to measure the power flow within the system.

There is a tremendous amount of pressure on the embedded electronics community for higher efficiencies and better system performance. This is due to multiple factors - from thermal management issues, to increased power densities, to battery life, and more. This pressure to improve is driving development in many areas. Much of the focus today is on advanced materials, topologies, and advanced software-defined architectures.

There are other factors to consider in the pursuit of increased efficiency, like good old-fashioned feedback. The more you know about the performance of your system, the better you can manage it. You can have the best semiconductors, in the latest circuit designs, driven by the most advanced software, and unless you know exactly what the system is doing, you cannot optimize it. There is no precision without feedback, and the more accurate the information, the more precise your system can be.

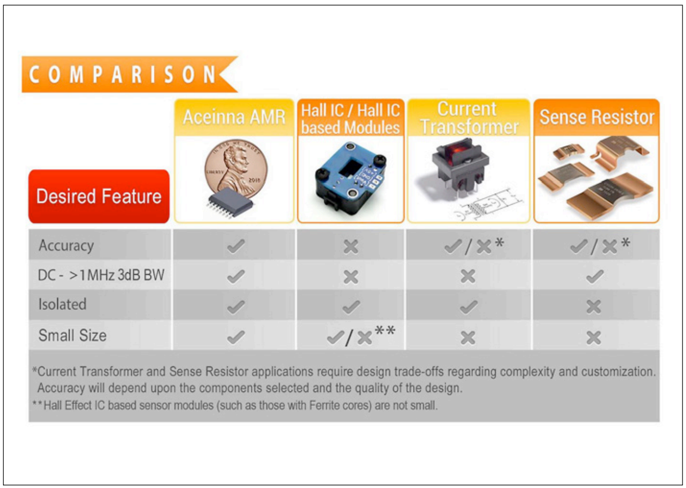
One of the things to look at in high-performance computing is how you manage the power to it, to either optimize performance, or monitor processor workloads. One can measure the current flow into a system as a proxy, to see whether it's running at optimal level, or you can load more computations, or workload, onto the processor. In addition to optimization, accurate current sensing also empowers revenue generation from servers and data centres, charging clients based on the workload or computational power used.

Current sensing

Current sensing in a circuit is an important way to get precise performance feedback, giving you an insight into how efficiently the system is operating. Used in control, protection, and measurement circuits, current sensors measure the power flow within the system, and is often used to dynamically control switching frequencies to minimize losses. Accurate and fast current measurement is key to reducing loss in zero-current and zero-voltage switching systems, as any current or voltage across a switching transistor during the switch phase is wasted energy.

AMR technology

Anisotropic Magnetoresistive (AMR) isolated current sensors offer high accuracy and bandwidth in a small SMT package. **Figure 1** shows that, in comparison to sense resistors, Hall-effect devices, and current transformers, an AMR-based current sensor like the ones from ACIENNA are drop-in devices made from an NiFe thin film that exhibits a very high-sensitivity and high-bandwidth response to magnetic fields.



Desired Feature	Aceinna AMR	Hall IC / Hall IC based Modules	Current Transformer	Sense Resistor
Accuracy	✓	✗	✓/✗*	✓/✗*
DC - >1MHz 3dB BW	✓	✗	✗	✓
Isolated	✓	✓	✓	✗
Small Size	✓	✓/✗**	✗	✗

*Current Transformer and Sense Resistor applications require design trade-offs regarding complexity and customization. Accuracy will depend upon the components selected and the quality of the design.
**Hall Effect IC based sensor modules (such as those with Ferrite cores) are not small.

Figure 1: Compared to sense resistors, Hall-effect devices, and current transformers, AMR-based current sensors exhibit a very high sensitivity and high-bandwidth response to magnetic fields.

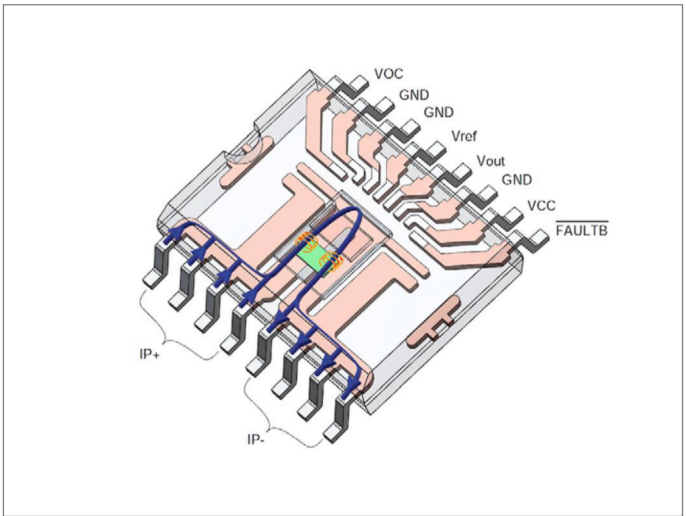


Figure 2: To ensure high accuracy, the two (GREEN) AMR current sensors measure the field from both current directions, essentially cancelling out external magnetic fields.

An AMR based sensor is especially valuable for applications where isolation is needed, due to its construction, compared to legacy methods. For example, one of the simplest ways to manage current is to use a shunt resistor, measuring the voltage dropped across it, but this solution is inherently not isolated. If you need to add isolation, which is the case for higher voltage and/or current applications, the component count goes up, increasing cost and all the problems associated with an increased number of components om the board.

Another approach is to use a current transformer, but that solution can be bulky. In addition, current transformers only work with to AC. A current transformer also has a saturation effect. A third way is to put a Hall-effect sensor in the gap and use it to measure the current through the wire. As there are numerous ways to measure current, the kind of sensor you specify in your power design, will impact the cost, size and effectiveness of your efforts.

ACEINNA's AMR technology is a compact, single-chip solution. Compared to a shunt register, AMR tech uses an insulating substrate, with 4.8 kV isolation, and does not require additional components other than a decoupling capacitor. Compared to a transformer, it's not only the size, AMR tech can respond to both DC and AC bi-directional current. Compared to Hall-effect-based solutions, AMR tech offers a bandwidth of 1.5 megahertz, and has a lower offset and noise, which leads to better accuracy and lower phase shift. That, combined with AMR tech's very fast output step response, provides an accurate and compact solution that can perform critical measurements for protection and control of power systems.

How it works

As illustrated in **Figure 2**, within the ACIENNA sensor, four pins take the current in from one side, and on the same side, it returns through another four pins. As the current flows through the lead frame it flows in a U bend through the device, with the current going in one direction and returning on the bend. As the current flows through the lead frame it generates the field to be measured. When the current reverses, it has a reverse field. There are two separate AMR current sensors in the device, that measure the field from both current directions, cancelling out external fields and offsets which might be present.

This dual-sensor configuration gives an AMR sensor the ability to ignore external fields perpendicular to the current flow, thereby the ability to ignore other components on the board. An AMR sensor is only sensitive to horizontal fields in the silicon. Whereas, if you were using a Hall-effect sensor, they also sense fields which are perpendicular to the silicon. This AMR based design's resistance to stray magnetic fields gives developers much more flexibility in component placement in an AMR-based system.

The dual-sensor construction of an ACIENNA AMR sensor, the high level of integration, and the materials used, provides not only a high accuracy and bandwidth, it also enables a high step response, the ability of a sensor to rapidly react to changes in the magnetic fields it is measuring. This high level of precision reduces phase differences in the signal, and other artifacts of slow and inaccurate measurements.

AMR sensor features

When it comes to power flow in applications like power supplies in servers and telecom, where you have a front-end AC-DC PFC converter feeding a DC-DC bus converter driving DC-DC Point-of-Load converters on the board, an AMR sensor is the best choice.

For example, ACIENNA's recently-released MCx1101 family of ±5 A, ±20 A, and ±50 A current sensors for industrial and power supply applications are fully integrated, bi-directional current sensors, with (at ±20 A) a typical accuracy of ±0.6%, and an offset of ±60 mA, or ±0.3% of FSR (max) over temperature, ensuring accurate operation over a very wide range of currents.

Additional advantages of an AMR-based integrated single-chip solution include a reduced offset voltage, the undesirable voltage representing the difference between the actual output and the specified value under various conditions, affecting the accuracy of the measurement. There is also less noise due to the high level of integration, which can impact the accuracy of any system. A highly accurate sensor can help optimize how much the processor is being used, especially for applications involving AI and the Cloud, using power tracking for performance monitoring's sake.

Application advantages

Knowing how much energy each proxy server is using can help determine whether there's still room for more power, so they can put more number crunching into the system, or find out if it's already running at a limit. The other side of knowing how your power is consumed is so you can charge your customer based on how much processor time or processing power is being used. Accurate current measurement can therefore empower (pun intended) system performance.

Beyond power supplies and data centres, there are a myriad of other applications that can benefit from AMR sensing, like motor drives and inverters. Inverter and motor drives are very similar circuits, but instead of a motor at the end on the load, you get a grid being connected with the inverters. Another application that can benefit is in uninterruptible power supplies (UPS), from the front AC-DC converter to the battery management to the final stage DC-AC inverter, and where it connects to the grid.

On the output side, you'll have a synthesis of the sine waves to connect to the grid. On the power factor correction, if you use a totem-pole type, an AMR sensor will give you a measurement of the current, for the control and protection. On the battery management side, it's about charge and discharge current management in the middle. There are other applications like home appliances, especially those with motors, like refrigerators and dishwashers.

Looking forward

So, overall, when it comes to power supplies, variable motor control inverters, UPS, and electrical vehicles, AMR sensors are often the best choice for applications involving power transfer or motor control. Because of the construction and materials used, these sensors have an inherently high sensitivity, fast response, and wide bandwidth. This makes AMR-based current sensors the logical choice for advanced power management in next generation power systems, for a plethora of reasons.

190244-01

The Author

Khagendra Thapa, VP of Business Development of ACEINNA's Current Sensing business, has over 21 years of business management and leadership experience in the electronics equipment and semiconductor industry. With a strong engineering background, he excelled as a Senior Design Engineer and Principle System Engineer, then moved on to take various senior roles as a WW Strategic Marketing Manager, Business Unit Director and Senior Director of Business Development in the past both in UK and USA.

Powerful Package for
Lock-in Thermography

Solution includes thermographic camera, trigger unit and special software

Today many manufacturers of electronic components and assemblies use thermographic cameras during product development. InfraTec is opening up a completely new range of opportunities to such users. A package for Lock-in Thermography gets you off to a successful start in such challenging measurement tasks at an exceptional attractive price. This includes the VarioCAM® HDx thermographic camera — as a stationary or handheld model — together with the IRBIS® 3 active thermography software, the appropriate trigger unit and corresponding connection cables.

Lock-in Thermography is used nowadays as a variant of active thermography in connection with scientific issues as well as in numerous research and development departments. The focused induction or generation of a heat flux is a way of examining test objects non-destructively for concealed material defects, cavities, cracks, joint flaws or delamination. In electronics, developers use the method for detecting faults and anomalies in the development of electronics, since a focused input of heat can usually be attained easily by means of electrical excitation. Even in the case of the slightest power losses, errors can be reliably detected and localised.

The centrepiece of the package impresses with a large detector and precise lenses

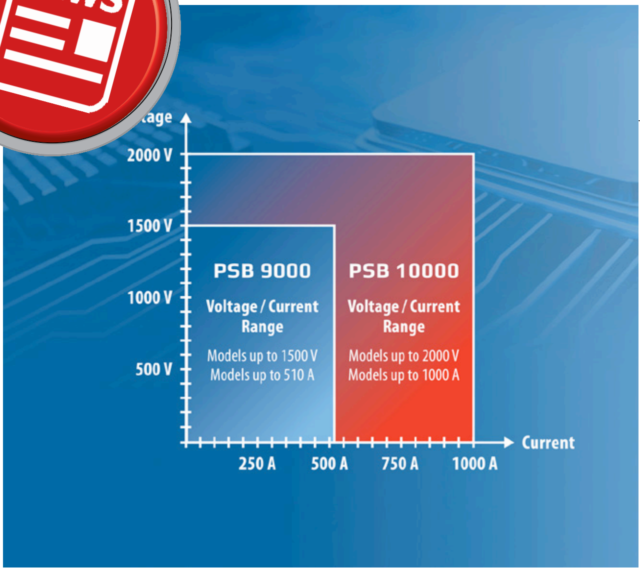
This effectiveness is directly linked to the qualities of the VarioCAM® HDx. Its large microbolometer detector offers (640 × 480) IR pixels. The available range of light-intensive precision interchangeable lenses includes the standard lens, a macro lens as well as a high performance microscopic lens, which enables to depict structures with a pixel size up to 17 µm. In view of the extensive range of lenses, users can operate individually at varying working distances and adapt tests conveniently to different measurement objects and tasks. The GigE interface ensures that a transmission of very detailed images is possible in real time. Optional interfaces to LabVIEW and MATLAB as well as a software development kit facilitate the integration of the thermographic camera into existing system environments.

Special software for identifying the slightest differences in temperature

A second key component of the packages is the thermographic software IRBIS® 3 active. This modern and all-purpose tool is specifically tailored to active thermography. It supports analyses, in which the temperature differences between defective and intact structures are extremely small. Complex evaluation algorithms form the basis for gaining conclusive results. The large data volumes that frequently occur here can be processed automatically with the software.

In all, the package constitutes a powerful solution for basic analyses using Lock-in Thermography. The emphasis here is the integrated use of the thermographic camera. The basic equipment enables users to already achieve convincing results from the start. Upon request, they can configure the entire thermographic system even more flexibly with regard to their specific needs. The modular design ensures long-term flexibility and the certainty of being able to respond to new challenges at any time.

www.InfraTec.eu
www.Infratec-infrared.com



Maximum Performance Concentration: EA Presents PSB 10000 30kW Bidirectional Power Supplies

eMobility is booming so that short time-to-market cycles play an increasingly important role. At the same time the delivery agreement LV 123 poses new challenges for manufacturers. The consequence: the need for high voltage test systems is climbing, similarly the requirements for the performance and functionality of individual devices.
EA Elektro-Automatik is revolutionising the market with the bidirectional power supply type EA-PSB 10000 30kW. This effective unit with an efficiency of up to 96% in both source and sink operation, offers the current highest performance range of all suppliers in 4 rack units. The seamless change from source to load mode allows complex voltage patterns to be modelled. In interconnected operation these space saving products may provide a total power of up to 1,92 MW in parallel operation. EA also offers an additional new feature with battery simulation software. This enables the user to use the EA-PSB 10000 devices to test their hardware under practically real conditions.
The efficiency of the EA-PSB 10000 30kW devices leads to a meaningful reduction in heat generation. Depending on the customer requirements the latest products can be provided with an optional water cooling. Up to 95% of the power loss can be dissipated. Thanks to the robust and closed housing design the units can be used in harsh industrial conditions without concern. The investment costs per Watt are approx. 25% lower than the previous EA-PSB 9000 series.
Integration of digital interfaces offers further application flexibility. In addition the user can make adjustments directly on the device using the generous 5" touch display. With the EA Power Control software the user can also remotely control up to 20 devices.

https://elektroautomatik.com

With the Demo Board Visible LEDs, Würth Elektronik offers customers the possibility of seeing their LEDs in action even before they have been integrated into an application.

For Sophisticated Lighting Solutions

Würth Elektronik presents the WL-SFTW and WL-SFTD series of new RGB LEDs that are ideal for accent and decorative lighting, optical displays as well as industrial applications. Thanks to their PLCC contacting design, the two series of individually controllable LEDs are ideally suited for SMT assembly and reflow soldering. The WL-SFTW series offers three different standard packaging designs. The WL-SFTD series in 3535 package is characterized by its IPX6 protection class.

RGB LEDs can be used to create any colour by additive colour mixing. This makes these components interesting for a variety of decorative applications. With the WL-SFTW series LEDs, Würth Elektronik offers compact components with high light intensity. The 5050 package is ideal for applications in areas with bright ambient light.

The IPX6 protection class of the WL-SFTD series stands for outdoor applications. The encapsulation resin of the RGB LED with diffuse lens also contains UV inhibitors to minimize the effects of long-term exposure to direct sunlight. A wide beam angle and high intensities make these LEDs ideal for outdoor and indoor full colour displays.

www.we-online.com

PEAK-System's Free App

for Calculating Register values for CAN and CAN FD Controllers

PEAK-System, specialized in classic CAN and modern CAN FD, has released the Bit Rate Calculation Tool for iOS, Android, and Windows. The cost-free tool determines the register values of a CAN, CAN FD, or SJA1000 controller for user-defined CAN and CAN FD bit rates.

In addition, the result list can be adjusted using various parameters such as clock frequencies and sample point. In order to include near-by results in the evaluation, a tolerance of up to 5% can be set. Furthermore, the bit timing values contained in the results (BRP, TSEG1, TSEG2, and SJW) can be stored and loaded across platforms. In addition, Android and iOS users can send results via e-mail. On the other hand, Windows users can easily transfer bit timing values into the PCAN-Basic API and applications based on it.

The professional app from PEAK-System is a useful tool especially for engineers when planning and optimizing classical CAN and modern CAN FD networks. The Bit Rate Calculation Tool can be downloaded free of charge from the Google Play Store, the Apple Store, and the Windows version from the download area at PEAK-System's website.

www.peak-system.com/Bit-Rate-Calculation-Tool.496.0.html?&L=1

Capacitive ceramic sensors for vacuum applications.

Advantages of Capacitive Ceramic Pressure Sensors in Vacuum Technology

The quality of industrial processes often depends on the exact measurement of the vacuum. Ceramic pressure sensors offer advantageous properties compared to metal sensors.

The differences to piezoresistive sensors start with the diaphragm. With their thickness of 50 µm, steel diaphragms are very sensitive to mechanical forces. Ceramic diaphragms have at least ten times the thickness and more, depending on the measuring range. This makes them much more robust against mechanical influences. In addition, ceramic has more favourable elastic properties than steel.

In contrast to metallic materials, ceramic is stable until shortly before the breaking point and returns to its original position again and again after relief. This prevents any deformation of the diaphragm after an overload and the associated zero point shifts.

Another positive aspect is the joining of the materials used by an active solder ring with the same coefficient of expansion as the ceramic. This has a positive influence on the long-term stability of the reference vacuum inside the sensor. Due to the dry measuring system, there is also no danger of contamination for the product and the system if a defect of the membrane should occur.

The ceramic Ceracore pressure sensors from Endress+Hauser offer the best conditions for use in vacuum applications due to their design. They can be individually adapted, have 40 times the overload resistance and are insensitive to corrosive and abrasive media.

www.sensoren-komponenten.endress.com

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JUNE

Elektor International Media is proud to present its 2019 Wall of Fame! We partner with top electronics companies – from global parts suppliers to device manufacturers – to promote exciting products and services that power high-tech innovation. The companies listed on this month's Wall of Fame offer electrical engineers, makers, and students a wide range of indispensable tools and solutions for developing next-generation electronics projects and products.

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Selected Products for Innovators and Start-ups

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Weller WT 1014 Digital Soldering Station

The Weller WT 1014 soldering station set includes the WT 1 supply unit, the WSP 80 Robust soldering iron and the WSR 201 safety rest. It is stackable and thus guarantees more space at the workplace. With an integrated usage sensor, the soldering tool switches off automatically.

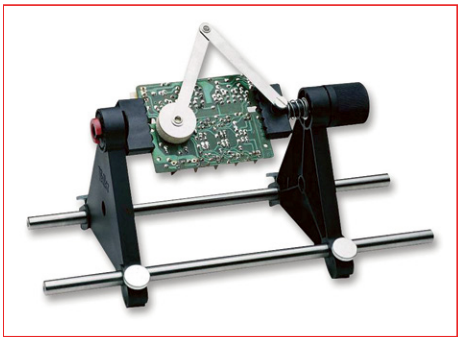
Features:

- 1-Channel Soldering Station digital 90 W (95 W)
- WT1 1-channel power supply unit
- Safety rest WSR 201
- Soldering tips LT
- AUTO OFF time
- Lock function
- And more

price: €389 rrp • €350.10 mp

www.elektor.com/weller-wt-1014

Weller ESF-120 ESD-safe PCB Holder



The Weller ESF-120 ESD PCB-holder is a mounting frame that satisfies all requirements made when mounting, soldering and removing printed circuit boards, without the need for additional tools.
The tool has a spring clamp, rotates through 360° in increments of 15° and has a cushioned pressure arm for keeping components in place when you flip the board upside down for soldering.

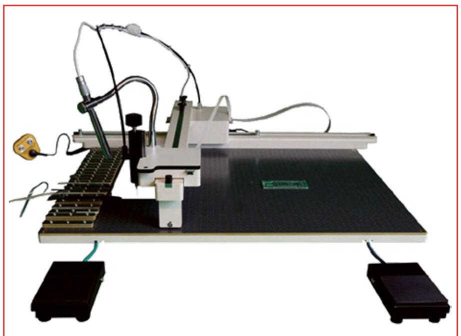
- Max. size: 160 x 235 mm
- Rotates through 360° in 15° increments
- Spring clamp
- Cushioned arm for component fixing
- ESD safe

price: €129.95 rrp • €116.96 mp

www.elektor.com/pcb-holder

Products can be ordered at www.elektor.com. Prices are including Dutch VAT, excluding shipping and handling.

eC-placer



The eC-placer is an innovative camera-assisted manual pick and place device designed and priced for prototype and small series assembly. eC-placer's robust construction ensures long-term accuracy and repeatability. The machine is fast to set-up with 23 adjustable feeders included for component tapes and sticks. The combination of clear imaging from the high-definition camera and ergonomic design enhances productivity and minimizes operator fatigue. Two special placement modes boost speed and accuracy. The Array mode provides a fast solution for placing a row of components. The Copy-paste mode uses a standard steel stencil to accurately locate BGAs, FPGAs and other complex components which are difficult to place by eye alone.

price: €2,399 rrp (also mp)

www.elektor.com/ec-placer

Siglent SDS1204X-E 4-channel Oscilloscope (200 MHz)

The Siglent SDS1204X-E is a powerful 200 MHz four-channel oscilloscope that is built on the same platform as the very popular SDS1202X-E but with several significant improvements, including two 1 GSa/s ADCs and two 14 Mpt memory modules. Waveform capture rates are up to 100,000 wfms/s in normal mode and 400,000 wfms/s in sequence mode. The SDS1000X-E scopes feature a large 7" 256-level color display with intensity grading and color temperature features.

price: €829 rrp (also mp)

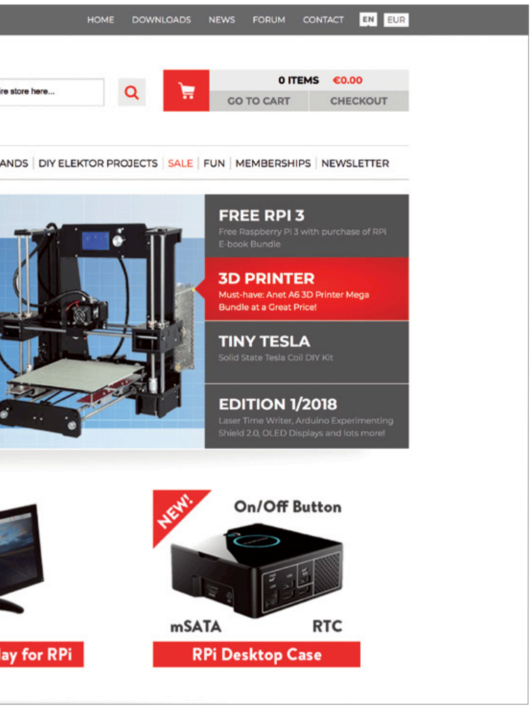
www.elektor.com/siglent-sds1204x-e

Siglent SDG1025 Arbitrary Waveform Generator (25 MHz)

The SDG1025 features maximum output frequency of 25 MHz and is capable of generating several different wave types that can be output using the dual-channels integrated into the device. Siglent's SDG1000 range of function generators also come with a full-colour built in screen that can be used to accurately track waveforms generated and make adjustments as necessary using the large selection of function buttons to the right of the screen. The full colour of the screen makes it easy to track two waveforms being output at the same time as different waves are assigned different colours.

price: €399 rrp (also mp)

www.elektor.com/siglent-sdg1025



Item descriptions are subject to change, errors and omissions. rrp =recommended retail price; mp = member price.

HDMI/AV Digital Microscope ADSM302

Precise optics and HD image sensor provide amazingly crisp images on HDMI display. Ideal for SMD soldering.

- 5" adjustable LCD monitor with adjustable tilt angle
- High resolution video & photo capture
- Wide table with comfortable headroom
- Heavy-weight stable metal stand
- Tall lifting stand (26 cm)
- Smooth adjustment wheels for focus and height
- Buttons on the monitor + remote control
- AV, USB, HDMI outputs

price: €299.95 rrp • €269.96 mp

www.elektor.com/adsm302

MonoDAQ-U-X – Multifunctional USB DAQ System

MonoDAQ-U-X is a fully isolated USB test & measurement device with full software support in DEWESoft data acquisition software. At the core of the measurement chain is a sigma-delta ADC with a maximum sample rate of 50 kS/s (16 bit) and a maximum resolution of 20 bit (100 S/s). 8 multifunctional front pins can be configured as analog or digital inputs or outputs.

price: €489 rrp • €440.10 mp

www.elektor.com/monodaq

PeakTech 3442 True RMS Digital Multimeter

The PeakTech 3442 is a new digital multimeter for heavy duty use with a high variety of useful measurement functions.

- Bluetooth 4.0 interface for data transfer to Android smartphones
- Windows software for data transmission and remote control
- 4 5/6-digits measurement value display (max. 59999)
- LCD-Display with Relative-value measurement
- 42-segment bargraph
- Continuity and diode-test
- Auto-Hold, Min, Max and AVG function
- 4-20mA% current loop measurement
- Duty Cycle (Hz / %)
- Low Pass filter function
- Safety: EN 61010-1; CAT III 1000 V / CAT IV 600 V; TÜV/GS

price: €149 rrp • €134.10 mp

www.elektor.com/peaktech

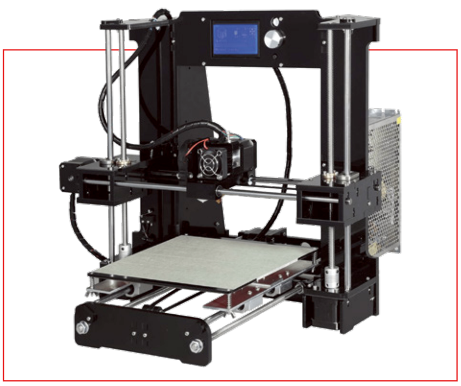
Handheld Thermal Imaging Camera HT-02

This thermal imaging Camera combines the functions of surface temperature measurement and real-time thermal imaging. To improve its recognition this product is equipped with a vision camera. It can not only show the thermal image and the thermal variation but also blend visible and infrared image too. The thermal image and the actual image can be stored on a PC which is used to generate a report or for printing.

price: €259 rrp • €233.10 mp

www.elektor.com/ht-02

Anet A6 3D Printer



What strikes first with the Anet A6 3D printer is its price. If you are seeking quality and if you are convinced that price and quality are necessarily in direct proportion to each other, this price could have a repulsive effect on you. Leave all preconceived ideas behind. This well designed and easy to assemble kit has a robust frame with excellent rigidity. The thread of its silver steel rods is trapezoidal, guaranteeing high accuracy. From the very first tests, this 3D printer was adopted in Elektor's lab, especially for its flexibility and ease of use.

price: €299 rrp • €269.10 mp

www.elektor.com/anet-a6

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When the sparks fly: ESD at Bürklin Elektronik | *Kai Notté*

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Fraunhofer IPMS
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