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DIE UNABHÄNGIGE WOCHENZEITUNG FÜR ELEKTRONIK

trend guide

2018 | E
ePaper

RUTRONIKER

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Motor driver ICs based on 32-bit MCU in tiny 7x7 mm QFN

New STSPIN motor driver ICs integrate an advanced BLDC controller and a 32-bit MCU in a 7x7 mm footprint

KEY FEATURES & BENEFITS

Three-phase gate driver
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- Real-time programmable over-current
- Integrated bootstrap diodes
- Interlocking, under-voltage and over-temperature protection

Integrated STM32F0 MCU with ARM® Cortex®-M0 core
- 48 MHz, 4-Kbyte SRAM and 32-Kbyte Flash memory
- 12-bit ADC
- 1 to 3 shunt FOC supported
- Communication interfaces: I2C, UART, and SPI
- Complete development ecosystem available

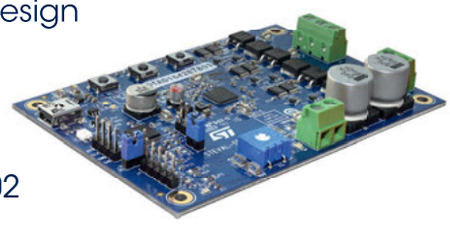
Operational amplifiers and comparators
- Suitable for the signal conditioning of current sensing or analog Hall-effect sensors

In the field FW bootloading capability (STSPIN32F0A)
- Flexible FW upgrade as per application needs

On-chip generated supplies for MCU, driver and external circuitry
- For maximum efficiency and flexibility

7x7 mm QFN package
- For a compact design

Evaluation board
STEVAL-SPIN3201/02



Editorial

Markus Krieg, Managing Director Marketing, Rutronik Elektronische Bauelemente

Vision and expertise are the be all and end all

The distribution market for electronic components continues to grow steadily by single-digit percentages. Demand for passive components is particularly strong, with lead times of one and a half years not unusual for certain product groups. This requires considerable advance planning on the part of all those involved in the supply chain, as the shortage situation will continue to impact the industry in 2019. Although the major manufacturers are already expanding their production capacities, it will be another two years before these expansions have any effect on the market. The imminent introduction of the 5G mobile communications standard with compatible end devices and the new network infrastructure will certainly exacerbate the shortage situation further. This is a typical example in the market, where high demand for components in Asia significantly influences the supply situation in significantly smaller markets such as Europe. These are enormous challenges that we are facing and that Rutronik has prepared for well.

Compared to the previous year, shipments rose by 30 percent in 2018 – a significant increase that the company is managing through additional personnel and process optimization. This is another reason why Rutronik, as a broadline distributor, is a reliable partner, especially in times of challenging supply situations – thanks to its 360-degree product portfolio, its capable employees, and innovative, highly automated logistics solutions. With a team of product managers and field application engineers, Rutronik also supports customers from the initial idea to the final product and ensures that everything runs smoothly.

Digitization is also facing new challenges, with both the automotive sector and the Internet of Things (IoT) sector seeing new technological innovations every day and successful start-ups growing from a single idea. We are witnessing not only exciting trends in this regard in the electromobility segment but also clear decisions and the implementation of mild hybrids (48 V), hybrids, and fully electric drive technologies thanks to newly defined emissions guidelines. In this context, an important key factor is battery management. Rutronik shares its expertise through battery management seminars, workshops, and technical articles and offers completely new solutions that are geared to the needs of customers and future markets.

Worldwide process standards and a consistently high level of quality are absolutely essential in this respect. The motto here is “think globally, act locally.” This is why Rutronik continues to pursue its global expansion strategy. The sales organization for Southeast Asia in Singapore is the latest element of this strategy; in addition, branch offices have been established in Malaysia and India.

As an independent, owner-operated company, Rutronik is laying the foundations to be able to respond even better to customer requirements in the future. Thanks to its highly qualified employees, the company actively helps find innovative and, in particular, sustainable solutions and shares its knowledge. In the latest issue of “Rutroniker”, you will find combined expertise directly from our employees. In-depth technical articles, practical applications, and the latest from the worlds of science and research – all in one trade publication.

I hope you have a great time reading it!

Best regards,

Markus Krieg

Contents

RUTRONIKER 2018

Epcos goes Rutronik

Rutronik expands distribution agreement with TDK

Rutronik Elektronische Bauelemente GmbH and TDK Europe GmbH have significantly expanded their distribution agreement for the European market. In addition to the TDK-Micronas and TDK-Lambda brands, in the future, Rutronik will also offer TDK's Epcos brand of products. The agreement is in effect since April 1st.

Under the Epcos brand, TDK offers aluminum electrolytic and foil capacitors, transformers, varistors, thermistors, piezo components, and actuators for haptic feedback.

Until now, Rutronik's portfolio has included TDK inductors, MLCCs, and TMR sensors as well as Hall sensors from TDK's Micronas brand and power supplies from TDK-Lambda. The major target markets are Industrial, Automotive and IoT.

Broad portfolio offers customers significant benefits

"By expanding the range of TDK products we offer, we can now more comprehensively support our customers in the implementation of their projects – and all from one source," says Gerd Fischer, Senior Line Manager at Rutronik. "We are delighted to be expanding our outstanding partnership with TDK Europe as well as entering new markets and acquiring new customers with the products we have added." TDK Europe is also very optimistic about the expanded partnership. "Rutronik is a well established distributor in Europe and, thanks to its infrastructure, logistics, and highly qualified team, is able to support its customers with expertise and suitable components from the design stage all the way through to implementation. For TDK Europe, expanding our partnership with Rutronik was a logical step," says Dietmar Jäger, TDK Vice President Distribution.

Rutronik24's latest feature

CAD visualization of components

The e-commerce platform www.rutronik24.com has launched a new feature: developers can now choose between different CAD models of the components available on the site and download them for use in their own design programs. To achieve this, Rutronik24 has partnered with UltraLibrarian.

A milestone on the path to increased user-friendliness

Rutronik24 is working with UltraLibrarian, a platform that offers development engineers access to an extensive library of various CAD formats, to display the components in 3D. To implement the feature on Rutronik24, a button that is visible to logged-in users labeled "CAD Models" was added to each component's product page. Clicking on this button opens a menu that allows the user to choose between different formats and display methods and then download the desired model via UltraLibrarian. Rutronik´s collaboration with UltraLibrarian is a milestone and makes the e-commerce platform even more attractive for customers. In addition to the existing procurement, PCN, and mass quotation features, the ability to download CAD models is another key element of our range of services. As a result, the Rutronik24 platform offers developers all the tools they need for their projects from a single source – and is fast, easy to navigate, and user-friendly.

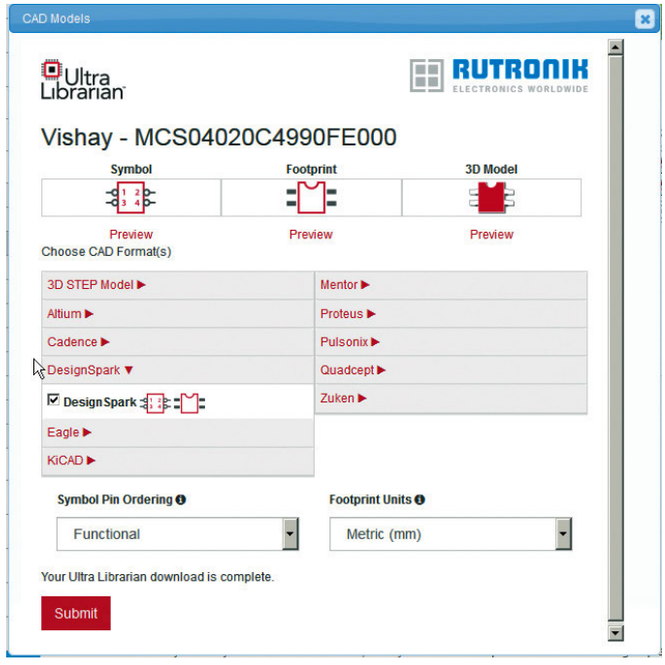
"Global Distributor of the Year 2017"

Yageo awards prize

It's the culmination of a highly successful partnership – in recognition of generating the highest sales of all of Taiwanese manufacturer Yageo's distributors worldwide, the company has presented Rutronik with its "Global Distributor of the Year 2017" award.

"Rutronik is our solution supplier and provides its customers with comprehensive and professional service from a single source. This is precisely why we have worked with Rutronik for over 30 years in an extremely trusting and successful relationship," explained Roger Cheng, Sales Director at Yageo. The award was presented during the EDS summit in Las Vegas.

Yageo's product range includes passive components such as resistors, capacitors, inductors, wireless and automotive components. Rutronik's partnership with the Taiwanese manufacturer dates back to the 1980s and has grown steadily ever since. Markus Krieg, Managing Director Marketing at Rutronik: "We are positive that our work together will continue to be extremely successful in the future."



Credit: Rutronik24

The 3D representation is offered in the formats for common CAD programs.

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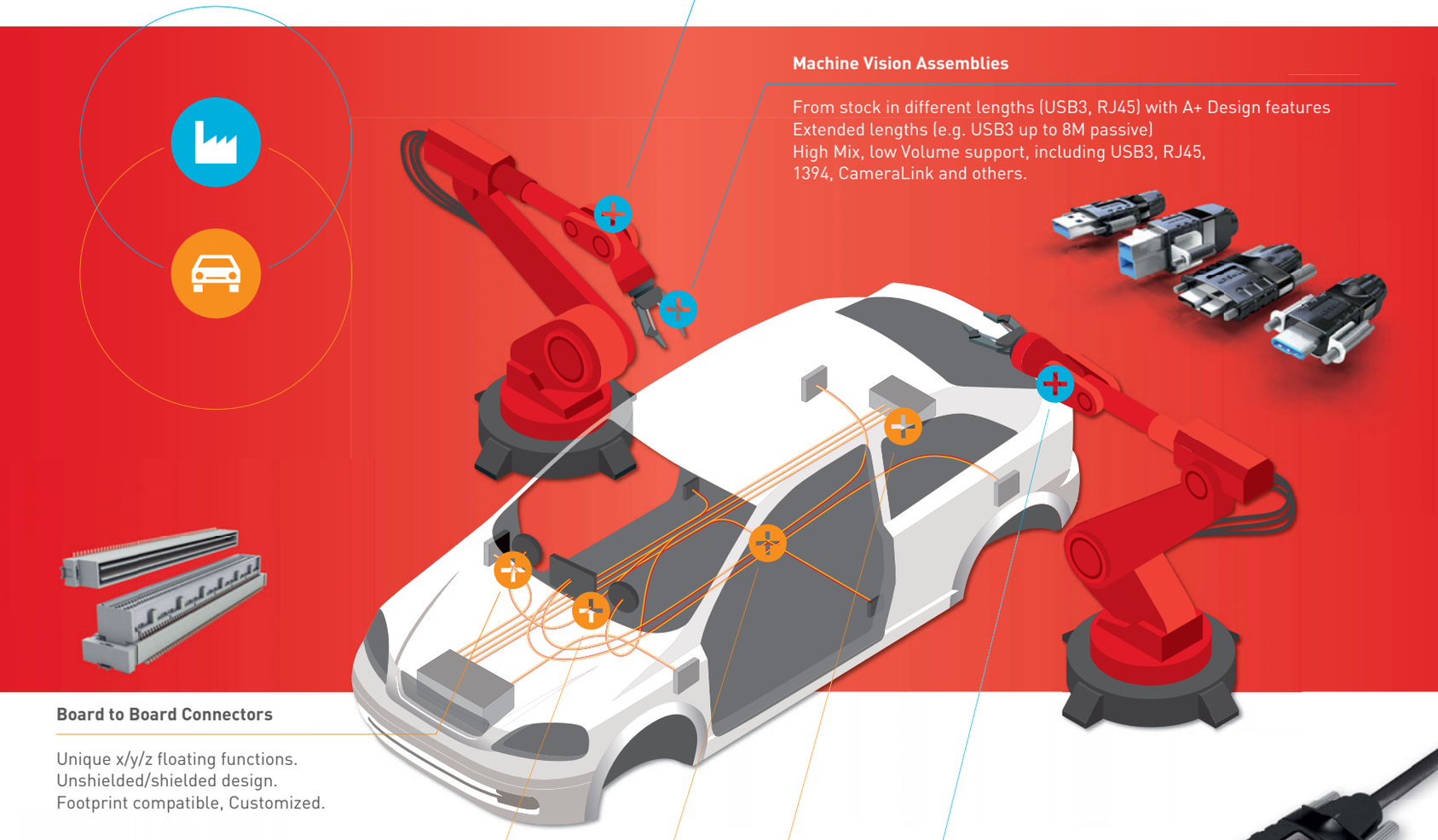

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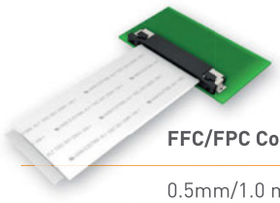

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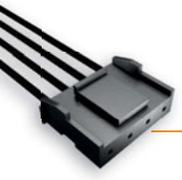

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Bluetooth Low Energy 5

White paper on the real-world performance

Experts at Rutronik have conducted extensive real-world tests on the latest generation of Bluetooth Low Energy and have analyzed the performance of the wireless standard under various conditions. Their aim was to identify new fields of application for the technology and to check the validity of common marketing claims under real-world conditions.

The tests were conducted using a prototype of the Nordic nRF52840 for the hardware and an alpha version of Soft Device S140 for the software. The tests were carried out with two preview development kits (PDKs). Both PDKs were linked and moved further and further apart to measure the power consumption, data throughput, and range of the Bluetooth 5 line.

One of the results of the study was a significant increase in range compared to the previous version, Bluetooth Low Energy 4.2, with a simultaneous reduction in energy consumption. The measurements were carried out in an open field, a forest, an urban shopping mall, and offices in order to simulate different areas of use. In addition, the white paper provides not only the detailed results of the study but also a brief summary of the specifications of the Bluetooth standard and an overview of relevant products.

Rutronik supports young researchers

The white paper is the result of a bachelor thesis written by a Pforzheim University student who interned at Rutronik, where he was responsible for studying the performance of Bluetooth 5.

"Supporting university students is a matter of course for us. Working on projects and the opportunity to contribute their own ideas to academic research not only benefits our students – we as a company also profit from their ideas and can directly pass on the knowledge we gain to our customers as added value at no charge," says Bernd Hantsche, Marketing Director Embedded and Wireless at Rutronik.

The whitepaper is available for download from Rutronik's website: www.rutronik.com/bt5wp ■

Sensirion awards prize for excellent and successful cooperation

„Distribution Excellence Award" for Rutronik

Credit: Sensirion

Glad to work together and reaching success: (from the left) **Nikola Kragleder** (Inside Sales Representative, Sensirion), **Florian Hirsch**, (Director Channel Sales, Sensirion), **Maria Salazar** (Product Manager Enrivonmental Sensors, Rutronik), **Markus Balke** (Product Marketing Director Analog & Sensors, Rutronik), and **Andres Laib** (VP International Sales, Sensirion)

As part of its annual Distribution Sales Meeting EMEA, Sensirion presented Rutronik with the Distribution Excellence Award.

Rutronik and Sensirion – a perfect duo

"We are delighted to receive this award," said Markus Balke, Product Marketing Director Analog & Sensors at Rutronik. "Sensirion distinguishes itself in the field of environmental sensors with its tremendous innovative spirit, making it one of the industry's true pioneers. This results in many joint design-in activities for customers from a wide variety of sectors," explained Balke.

The award was presented at the Sensirion Distribution Sales Meeting EMEA, where the Swiss manufacturer founded in 1998 celebrated "20 Years of Sensirion – 20 Years of Strong Partnership." To familiarize distributors with new products in the field of environmental sensing, more than 50 distribution partners came together for the meeting on the shores of Lake Zurich.

Sensirion is one of the leading manufacturers of digital microsensors and systems. Its product range includes gas and liquid sensors, as well as differential pressure and environmental sensors for measuring temperature and humidity, volatile organic compounds (VOC), CO_2, and particulate matter (PM2.5). ■

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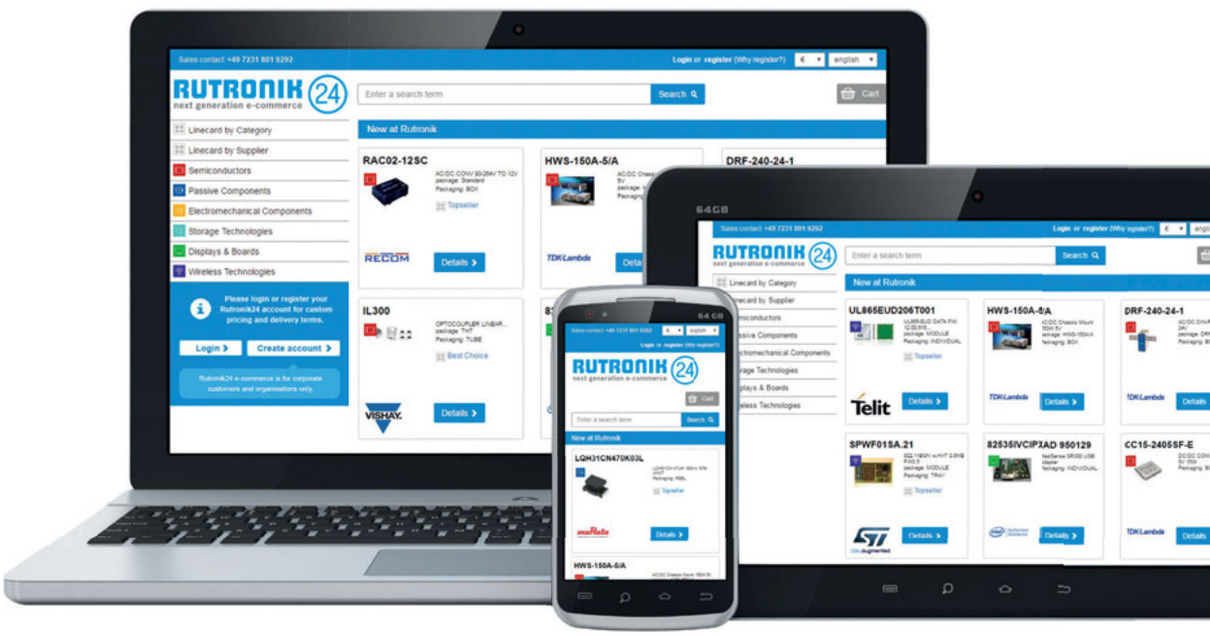

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Interview with Thomas Rudel, Rutronik CEO

"We are exceptionally flexible"

Delivery situation, expansion of the 5G cellular network, electric mobility: Conditions that are constantly changing require companies to react quickly and flexibly. Rutronik, the third-largest distributor in Europe and number eleven in the world, achieves this extraordinarily well. Thomas Rudel, Rutronik CEO, talks about the reasons for this success, Germany's pent-up demand for the digital infrastructure, and analyzes the shortage situation for passive components.

Rutronik's CEO Thomas Rudel

Mr. Rudel, Rutronik will crack the one billion euro mark this year. What are the reasons for this success?

Thomas Rudel: We are of course very proud of what we have achieved. This success was obviously only possible thanks to the exceptional performance of our employees worldwide. The sales mark shows that our strategy is exactly right and spurs us on to continue to give our best. There are several reasons why we were able to achieve this success in 2018: The market for electronic components has been growing continuously in the single-digit range in recent years. In some areas, we have even grown faster than our competitors. By constantly expanding into new markets in America, Asia, and throughout Europe, we have built up a comprehensive sales network that has enabled us to reach this level of turnover. Another aspect is our independence: As a family business, we can make decisions quickly – which makes us exceptionally flexible.

Rutronik offers comprehensive consulting services for all products in its portfolio and other value-added services – free of charge. A year ago, you said that consulting activities had quadrupled. How about today, one year later?

The consulting activities have certainly not decreased. On the contrary: Customer demands are increasing from year to year. We have to face up to this task and of course think about for which products we can afford consulting services in the future. There are components that cost 20 euros ten years ago; today, they are available for roughly 50 cents. In the future, we will certainly no longer be able to provide the same level of service for these items as we did in the past.

The supply situation for passive components is dramatic. How does this affect Rutronik as a distributor and how does the company guarantee its customers security of supply?

We have a top position in Europe for passive components, especially in C component management. In our quantity structure, these components account for around 80% of all deliveries. We see the sale of these products more or less as a service to our customers – because even if we were to increase prices exorbitantly, we would not be talking about a profitable business. Thanks to our strong partners, Rutronik was nevertheless able to supply the market with around 70 billion components even in the allocation year 2017. And the number is rising rapidly: In 2018, we will supply around 100 billion passive components, and the forecast for 2019 is 115 billion. This shows that, due to a strong, long-standing supplier relationship, we were also capable of supplying customers who had not purchased their total quantities exclusively from Rutronik in the past despite allocation. In this context, the priority was clearly to ensure that our existing customers could maintain production so that we could in turn supply them with our other components.

Soon, the 5G wireless standard will be rolled out worldwide, the demand for 5G-

enabled smartphones with over 1,000 capacitors inside them will skyrocket. What effects will this have on the delivery situation?
We assume that applications such as 5G and the further development of security and cloud systems will increase demand worldwide – not only for capacitors but also for other semiconductors. New factories or fabrications will be established in China, or in Asia as a whole, to meet the growing demand for components.

With the first ABU Congress in Pforzheim in June, Rutronik itself launched a top-class event focusing on the future topics of the automotive industry. How do you rate the event and will Rutronik organize further events of this kind in the future?
The congress in Pforzheim was a great success for us! We had top-class speakers on interesting topics that drive and will continue to drive the entire industry. The number of participants and the feedback showed us that there is a great deal of interest and need for exchange in the automotive industry. This confirms that we took the right course by establishing our Automotive Business Unit a few years ago – and we will continue to follow this course in the years to come. At the same time, it means that we will continue to organize our own events on highly interesting topics for our customers – in Germany, but also in Europe, Asia, and North America.

In the last interview, you called for restraint in the diesel debate and did not want to join in the swan song about diesel. How do you feel about this now?
As I have already said many times, the harmful influence of diesel vehicles on the climate and health is overstated. To put this into perspective: The fifteen largest container ships in the world emit as much pollution as 750 million cars. And this problem can only be tackled on a global level. The comparison may seem a little absurd at first glance, but: More than five billion people worldwide are still living on less than two dollars a day. They long for a better life. It is, therefore, important to eliminate the reasons for migration locally – and not through isolated solutions. No country in the world can solve this challenge on its own. And the same applies to the emission of pollutants.

What do you mean exactly?
Diesel is not the demon that is driving the world toward the abyss of climate chaos – but that is exactly how it is being portrayed. This topic has been set in motion by our American friends. Evil be to him who evil thinks and assumes that this has occurred to avoid the assumption that their own suppliers fail to play with open cards when it comes to pollutant emissions. In many countries around the world, more diesel is consumed per capita than in Germany. By the way, the demonization of diesel is happening to the detriment of the German automotive industry, whose technological capabilities are way ahead of companies from other countries. Nobody seems to talk about the pollutant emissions from gasoline engines, which emit large quantities of particulate matter instead of nitrogen oxides.

Always an open ear: Thomas Rudel in conversation with employees at the Eisingen logistics center

Is e-mobility a way out of this dilemma?
e-mobility is a viable alternative for the future, but let us not be naive. Anyone who believes e-mobility is the be-all and end-all should realize that we first need an energy infrastructure which meets the requirements of the technology. That will not be the case for the next 15 to 20 years. We will then also face another problem with regard to the disposal of the highly toxic batteries: If we are unable to find a suitable recycling solution, we will have a new nuclear waste disposal debate.

The future of driving also includes the networked car, and other sectors are becoming increasingly networked, too. At the same time, expansion of the digital infrastructure appears to be slow moving. Will we soon see fully networked factories unable to operate because the cellular network is overloaded or will our "smart" cars simply stop on the highway because we have driven into a cell phone dead zone? How to do you see the future?
The CEO of 1&1, Ralph Dommermuth, told Handelsblatt Deutschland that Germany had sort of "slept through the digital revolution" – and our telecommunications infrastructure resembled that of a banana republic. I do not expect that to change any time soon. Politicians promise year after year that something is really being done about it now. You can forget autonomous driving with the current cellular radio service! A mobile car requires a 6G or 7G data network to accommodate the amount of data that travels from the car to the cloud and back. Not to mention the security concerns: Hackers will always find weak points and ways to overcome countermeasures – a solution for this has not yet been discovered, and the same applies to networked factories. Even the big nations like the USA or China are not immune to such attacks. A possible solution – at least in the automotive sector – are redundant systems that are protected against manipulation by redundancy. Paravan is a prime example here: The company builds disability-friendly vehicles and has developed Space Drive, a vehicle operating system with active multi-redundancy.

Finally, let us look into the crystal ball: How will the distribution industry develop next year?
In my opinion, the distribution landscape will not change a great deal next year – new competitors will not appear on the scene. We are all busy dealing with the allocation of resources and maintaining the production and delivery capability of our customers. In this respect, it is going to be an exciting year. At Rutronik, we will continue to pursue our expansion plans and align our strategies to new future market conditions in terms of suppliers, applications, and technologies.

MPU & memory

A perfect couple

The demands placed by the market on visualization applications are forever increasing. The trend is moving away from microcontrollers toward high-performance microprocessors. The RZ/A and RZ/G series from Renesas are optimized for visualization applications. But which processor suits which memory best?

By Isabell Weinlein,
Product Sales Manager Memories
and
Zibo Su, Product Sales Manager (jun.)
Microcontroller,
Both Rutronik

Highly complex "smart" applications – audio processing, face recognition, gateway, etc. – therefore require high-performance MPU series such as RZ/A and RZ/G. Not only the high level of performance is particularly pleasing: Each series provides a 2D (RZ/A) or 3D graphics controller (RZ/G) and accelerator that supports two high-resolution video channels.

The RZ/A and RZ/G families deliver the ability to incorporate an additional DRAM for data storage. Moreover, the MPU of the RZ/A1 series has an integrated on-chip memory of up to 10 MB SRAM – unlike processors from other suppliers that work exclusively with external RAM and flash. Code and data (including graphical data) can be executed or read directly from the large SRAM or from the external QSPI memory via XIP. It is also noteworthy that the QSPI flash can run in DDR mode, thereby doubling the speed of the NOR flash. The EMI problem between MPU and DRAM is eliminated and fewer PCB layers are required. In addition, the popular QFP package can be used. These factors help to reduce production and development costs significantly. Thanks to the size of the internal memory, developers do not require further power management ICs. RZ/A1LC, RZ/A1L, and RZ/A1IU also offer a

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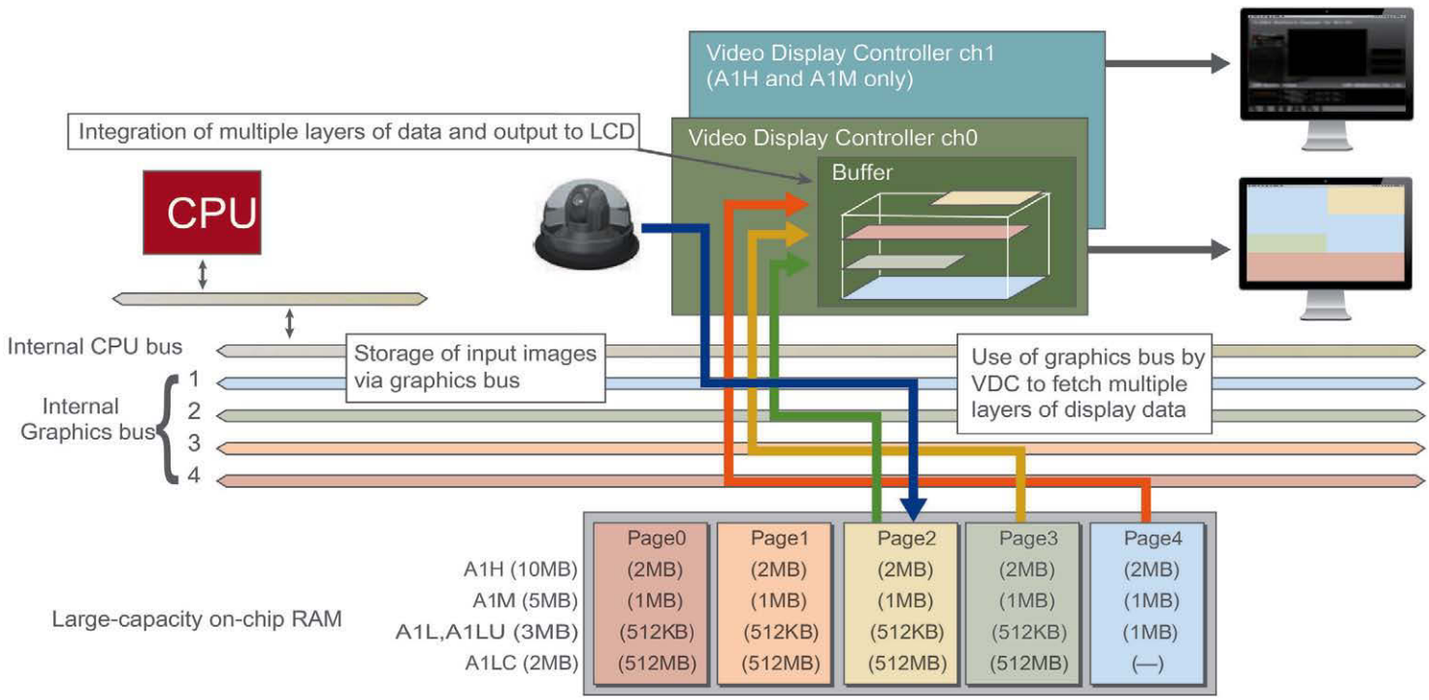

Credit: Renesas

With its own powerful GPU (top center) with four graphics data buses and its own memory, the CPU in the Renesas RZ/A has plenty of room for other tasks.

SDRAM interface in case the customer needs more RAM. The RZ/A is therefore well suited for development engineers who need a powerful MPU, want to switch from an MCU to an MPU while avoiding the drawbacks of an MPU design.

Concentrated graphics power

Thanks to the four dedicated internal graphics buses (AXI), each boasting a width of 32 bits, the RZ/A offers enormous graphics performance. Seeing as the internal SRAM can be used as a frame buffer (with up to 10.64 Gbit/s), the video controller can retrieve the image faster than with an external DRAM solution. The RZ/A supports two independent LCD displays with a resolution of 1280×800 and up to two CMOS camera inputs.

Hardware-accelerated 2D vector graphics (OpenVG) can be used to create a more attractive graphical user interface that is not distorted by image magnification. Processing is thus outsourced from the core to the GPU (graphic processing unit), so that the MPU core can execute more important algorithms. OpenVG is suitable for accelerating flash memories and scalable vector graphics.

If you are planning an application that requires certain graphic properties, Renesas offers three tools to choose from: DISPLAY IT!, STREAM IT!, and the GENMAI CPU board. Hardware reference designs (plans and layout) and demos are also available.

Software – simple, comfortable, powerful

The RZ/A is an easy-to-use MPU product for developers who want high performance without having to acquire full, detailed Linux knowledge. Thanks to the Renesas ecosystem and the corresponding community, developers can focus more on the application layer. Two operating system types can run on the RZ/A: RTOS or Embedded Linux.

RTOS provides customers with four types of development environment: Renesas e^{2}Studio, IAR, ARM DS-5, and Green Hills Multi.

The software stacks with file system, USB stack, and network stack for each RTOS can be selected from Express Logic, Segger, and Micrium. Many different third-party GUI frameworks - Tes Guiliani (based on FreeRTOS, free because it is licensed by Renesas), Crank, Segger, Tara, Altia, and Draupner – can also speed up development work. Tes Guiliani is suitable for highly qualified GUI applications and the 2D effects reach an optical level close to 3D. The mass production license for Tes Guiliani is also based on the license for FreeRTOS and is therefore free of charge.

As when carrying out development work with traditional embedded Linux, the developer can use LTS Ubuntu Linux as the host. Renesas offers a BSP porting guide and a tool to help create the BSP when the customer is develop-

RZ/A tool-chain options

Tool Category	IAR SYSTEMS	ARM	RENESAS	Green Hills SOFTWARE
IDE	IAR EWARM	ARM DS-5	e2studio	Green Hills MULTI
Compiler	IAR	ARM DS-5, GCC	GCC	Green Hills
Debugger SW	IAR	ARM DS-5	SEGGER GDB	Green Hills
Debug Probes	I-Jet, Jlink	ULINK2, DSTREAM	J-Link	Green Hills Probe

Credit: Rutronik

Four available IDEs, compilers, and debuggers

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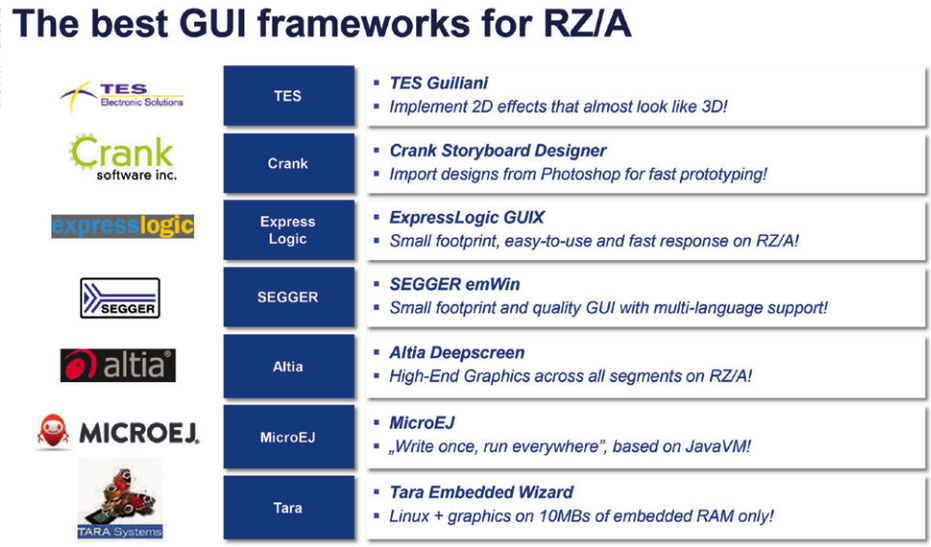
Please visit us, Hall B6 Booth #451

Credit: Renesas



Available GUI frameworks for RZ/A

ing their own board. Additionally, uboot is available on the GitHub platform in order to initially configure a certain part of the board and to start Linux. With the help of buildroot, a cross-compilation toolchain, bootloader, kernel, and image of the root file system can be created. This makes actual application, understanding, and changes much easier. Two different Linux images (Linux 4.9 and 4.14) are available on GitHub for this purpose.

No performance without a memory

However, performance alone is not enough – even with RZ/A and RZ/G, nothing works without a program memory. Additional external flash is required to provide cover for the missing program memory of a microprocessor. Since visualization applications usually require high memory capacities, NOR flash is usually insufficient. In this case, developers need to use a NAND flash memory. These are available in an array of variants – which one is the right choice depends on the requirements of the application.

SLC, MLC or TLC?

According to the structure of the technology, it is possible to differentiate between SLC (single-level-cell), MLC (multi-level-cell), and TLC (triple-level-cell) flash. The SLC technology stores one bit per cell. This means there are only two different voltage levels in the floating gate. Therefore, SLC flash memories are the most reliable but also the most expensive ones.

The MLC technology, which stores two bits per cell, must already represent four voltage levels in the floating gate, the TLC technology achieves three bits per cell and eight voltage levels. It is important to consider the process technology here. Many suppliers rely on more and more die shrinks to increase wafer output. The smaller the process technology (we are currently at 15 nm NAND flash), the fewer the number of electrons in one bit. However, electrons are lost due to influences such as time, EMC (electromagnetic compatibility), and temperature. Due to this decreasing number of electrons - combined with the increasing number of voltage levels - the susceptibility of bit flips, i.e. an unintentional bit change, increases. TLC flash memories are therefore both the cheapest and the most unreliable variant.

The number of possible write/erase cycles (PE cycles), the so-called endurance rate, decreases as the number of bits per cell increases. As a rule, the actual amount of written data differs from the data sent by the microprocessor. Due to the system optimization of the flash, 4 KB of sent data are, e.g., written several times within the NAND. To better estimate the effectiveness with which the data are transferred from the host to the memory, the amount of data can be quantified using the WAF.

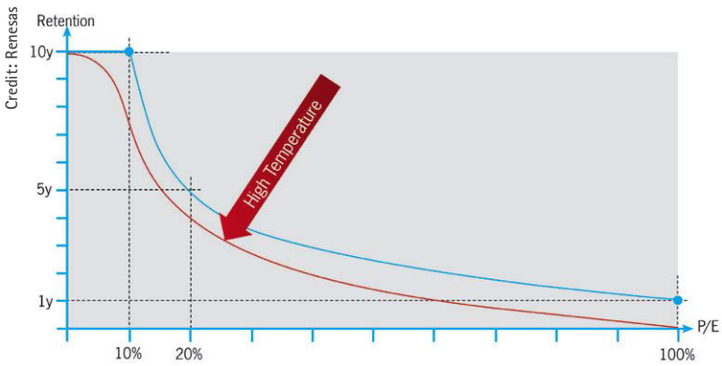
Credit: Renesas

Rutronik offers a system solution with RZ/A1H and Tianma TFT screen with Segger emWin. The kit is immediately available from stock.

The WAF thus also has a negative impact on the endurance, as, in some circumstances, significantly more data were written than were actually stored. This factor goes hand in hand with both wear leveling and garbage collection.

So-called wear leveling ensures that each memory cell is used and deleted equally. The data retention, i.e. the maximum time span in which the data can still be retrieved in the data field after programming, thus increases and prolongs the longevity of a flash device. The more write/erase cycles an application has or the higher the average operating temperature is, the more likely it is to use MLC or even

Credit: Renesas



While an SLC flash memory survives about 100,000 write/erase cycles, an MLC memory and a TLC memory only achieve roughly 3,000 and 500 write/erase cycles respectively. One PE cycle is only reached once the complete density, i.e. capacity, of the memory has been written.

$$\text{Days until 1 year data retention limit is reached} = \frac{\text{Number of write/erase cycles offered by the NAND} \times \text{Total available density in GB}}{\text{GB per write to Memory} \times \text{Number of write per Day} \times \text{WAF}}$$

Result is non-binding

Credit: Renesas

This formula can be used to calculate the relationship between the data written by the host and the data actually stored in the flash.

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SLC flash memory in order to ensure a sufficient life span of the module.

An important instrument for ensuring the longevity of memories is the ECC - an error correction method that compares all the bits with the checksum when reading out the memory and thus identifies and corrects any faulty cells. The amount of errors that can be dictated depends on the size of the ECC (e.g. 8 bits). If the function is assumed by the host, it is essential to check the compatibility between the memory and the processor.

Supplier	Technologies				
	DRAM	NAND Flash	e·MMC	NOR Flash	FRAM
Nanya	✓				
Toshiba		✓	✓		
Alliance	✓				
INSIGNIS	✓		✓		
Fujitsu					✓
ESMT	✓			✓	
Rohm					✓
Swissbit			✓		

Memory makers and the technologies they offer

Older processors, in particular, have an integrated ECC that no longer supports newer memory models. However, in order to be able to support these customers in the future, Rutronik collaborates with two memory suppliers, INSIGNIS and Alliance Memory, which offer older and compatible derivatives. When using Toshiba Flash, it is also possible to apply BENAND™ as an alternative. This SLC NAND has an integrated ECC which assumes error correction directly in the memory, and the host has absolutely no influence on it.

If the microprocessor does not have a NAND interface (as is the case with RZ/A1L), conventional NOR flash or Serial NAND can be used. These memories have an SPI interface that is integrated as standard for microcontrollers and processors. Another variant is already managed NAND memories. Management is provided by a control unit integrated in the memory. The so-called e·MMCs (embedded multi media cards) are mostly manufactured in MLC technology. Functions such as bad block management, wear leveling, and garbage collection are also contained in the memory and do not have to be assumed by the host, i.e. the microprocessor.

Working memory for all requirements

If the RAM integrated in the host is insufficient, it can also be supplemented by an external memory. Internal RAM of between 3 and 10 MB is available for the RZ/A processors. The RZ/G series can be extended with external RAM. The volatile memory types SRAM (static RAM) and SDRAM (dynamic RAM) are available for external RAM. SRAM provides fast access and can preserve stored data for up to several years. However, SRAM only offers small data capacities, requires a lot of space on the PCB, and is much more expensive than DRAM. Although DRAM only offers average access times and needs a cyclical refresh for data preservation, it is characterized by high data density on a small surface at a favorable price.

SDRAM, in turn, is available as a SDR (single data rate) and a DDR (double data rate) model. Compared to SDR memories, DDR memories can transfer twice the data rate, since they use the rising and falling clock edges of the data signal for transmission. Prefetching is used to shorten the relatively slow access time of the SDRAM. The DDR memory accesses several memory cells in parallel. The data written in a buffer is then output at the higher external data rate of the host. While the original DDR technology works with double prefetching, DDR2 uses fourfold prefetching and DDR3 and DDR4 both use eightfold prefetching.

Both types of memory have advantages and disadvantages. A combination of all the advantages seems unrealistic but is actually possible with FRAM. FRAM (ferroelectric random access memory) uses its special technology to combine three important advantages: It is fast (150 ns access time) and ensures very low power consumption and a significantly longer lifetime than flash or SDRAM (10 million read/write cycles). In addition, FRAM – even if the name suggests otherwise – are non-volatile memories and therefore the data remain stored even in the event of power loss. However, Fujitsu offers only small capacities with its memory form – comparable with EEPROM – which can offer the perfect solution especially for metering/energy, point of sales, and IoT applications.

When it comes to choosing the right memory, it is, therefore, important to ask yourself the right questions: What do I want to store and for how long? What will the loss of data cost? Which endurance and data retention rate do I need to achieve my goals?

Once all these questions have been answered clearly, the result is perfect interaction between the MPU and the memory. ■

Glossary

Bad block management: detection of defective data blocks
Buildroot: simple, efficient, and easy-to-use tool for creating embedded Linux systems
BSP: board support package
ECC: error correcting code
Garbage collection: automatic memory clean-up
GitHub: online service that provides software development projects on its servers
GPU: graphics processing unit
PCB: printed circuit board
Prefetching: pre-call of memory contents
RAM: random access memory
uboot: a universal boot loader
WAF: write amplification factor
Wear leveling: memory wear compensation

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Criteria for the right power supply

Making a well-founded selection

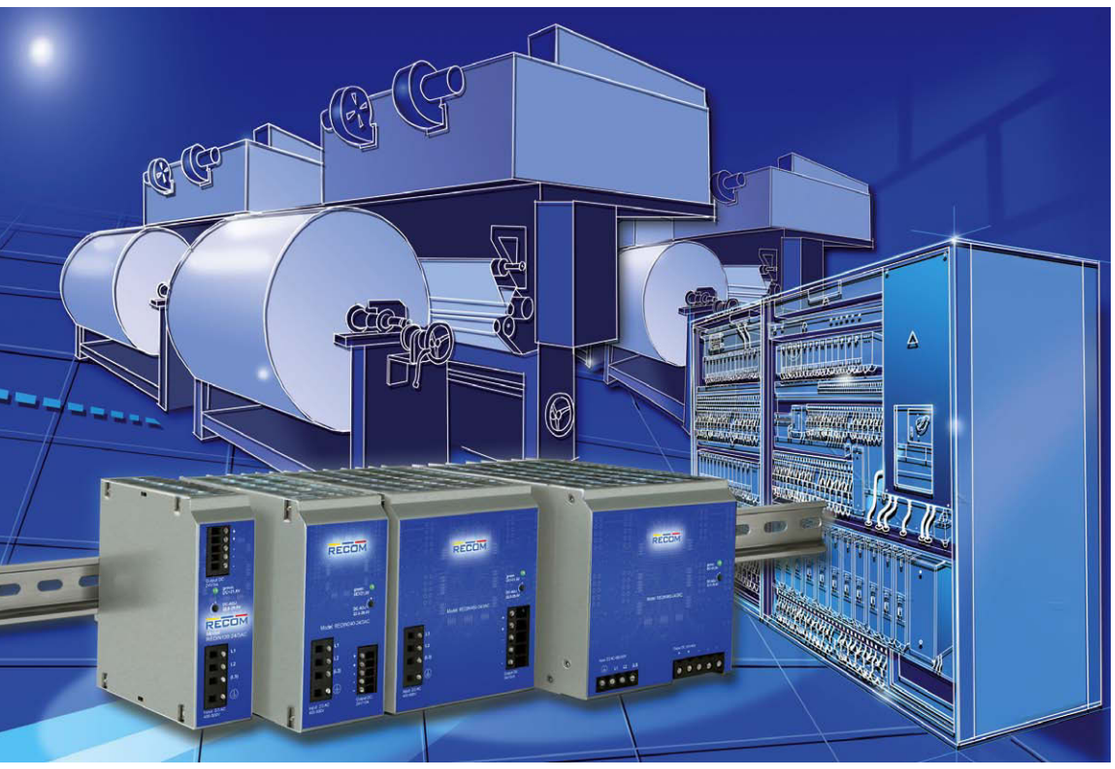
At some stage of every project there comes a point where the developer has to ask which power supply is best suited to the application. Ever shorter development cycles, stricter specifications, and tighter budgets make the selection difficult. This article provides an overview of the details that need to be considered when making that choice.

By Axel Stangl,
Product Sales Manager
Power Semiconductors,
Rutronik

The power supply is the heartbeat of every electrical system and yet it is so often overlooked until the last moment. Choosing the right power supply seems a simple task: You pick a device with the appropriate output voltage and power and at the most favorable price. But in order to have a satisfactory solution in the end, you need to take a closer look.

Wide input range for varying nominal voltages

As a rule, power supplies are supplied from the public mains or an industrial supply grid. In rare cases, a power generator is also used. Nominal voltages from the public mains are usually standardized. While the nominal mains voltage in Europe is 230 V AC/50 Hz ±10%, there are numerous other standards available outside Europe. In the USA, 120 V AC/50 Hz are common, while in China 220 V AC/50 Hz come out of the wall socket. Ideally, the selected power supply should cover all these nominal voltages and their boundary areas. This results in an operating range of 85 V AC to 264 V AC. However, a closer look at the data sheet is well worthwhile here. Even if the selected power supply offers very good efficiency of over 90% at a nominal voltage of 230 V AC, it might only be 70% at 120 V AC.



Credit all pictures: Recom

Influence of efficiency on the service life

When comparing various efficiency figures, one or two percentage points more do not sound like a significant difference. Nor will this figure help to achieve any major energy savings. And yet these few percentage points can make a huge difference. For example, if you compare one device with 90% efficiency and one with 92%, it does not appear to be a large deviation at first glance. But if you consider the resulting losses, however, one power supply has only 8% and the other 10%. The device with 92% efficiency therefore has one-fifth less losses that are emitted as heat. Sometimes this small difference is enough to do without additional forced cooling. And this, in turn, helps to save valuable space.

A much more important fact, however, is that less heat generation has a positive impact on the system's service life. As this has a direct influence on the life expectancy of a system. The Swedish chemist Svante Arrhenius discovered the relationship between chemical reac-

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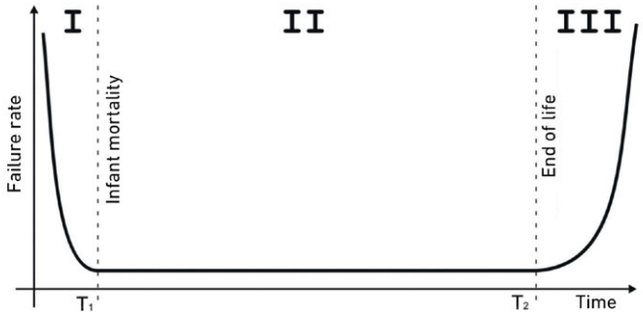


Figure 1: Failure rate over lifetime (bathtub curve)

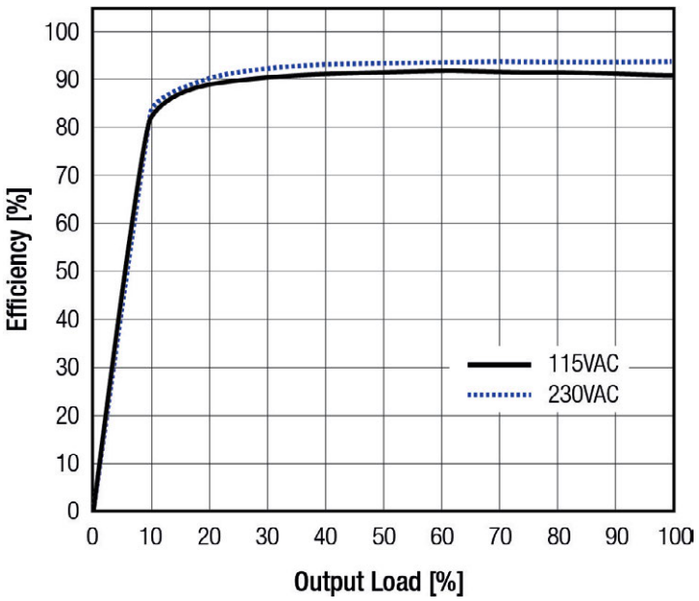


Figure 2: Typical test setup for a life test (e.g. 96-hour test or derating test)

Figure 3: The efficiency of Recom's REDIN480 is not only 93% at full load but also remains stable and high across a wide load range.

Figure 4: Recom's power supplies feature high electrical strength and high reliability; ideal for industrial cabinets operating in harsh environments.

tion rate and temperature back in 1889. The Arrhenius equation provides a rule of thumb that states an increase in temperature by 10°C doubles the probability of failure. In other words: The life expectancy is halved. This means that just two percentage points more in efficiency can contribute to significantly extending the life expectancy of a switched-mode power supply unit.

MTBF – calculated reliability

The reliability of a switched-mode power supply unit is closely related to the MTBF (mean time between failure). The importance of the MTBF is best illustrated by the so-called "bathtub curve" (Fig. 1). This is divided into three sections: early failures, useful life failures, and end of life wear-out failures. The MTBF only covers the middle section; i.e. it does not cover "infant mortality" or the effects of wear and tear. This easily explains why the MTBF for power supplies is often stated in several million hours.

The MTBF can also be determined according to various standards. The most common ones are MIL HDBK 217F, Bellcore TR-NWT-000332, and SN29500, which is also referred to as the "Siemens standard". The results of these calculation methods differ considerably in some cases. Therefore, when comparing MTBF values, it is important to ensure that they are determined according to the same standard and under the same conditions (e.g. ambient temperature).

One thing these methods do have in common, however, is that the MTBF of the switched-mode power supply unit results from the sum of the values of the components. This is why the "component count" also has a decisive impact on the MTBF value. Simple switched-mode power supply units often have a significantly higher MTBF value. Nevertheless, this does not necessarily mean that they are more reliable.

In summary, the MTBF is a good comparison of the reliability of similar devices, but it does not allow you to make any statements on life expectancy. This is only possible through extensive testing.

Tested reliability

A first statement can be made after a 96-hour test. This highly accelerated stress test (HAST) is carried out in a climatic chamber under defined ambient conditions (e.g. +85°C/95% relative humidity) as a so-called storage test (i.e. the test specimens are not in operation). The test specimens are measured according to their data sheet parameters before and after testing.

Based on the differences, a conclusion can then be drawn about the service life. Ninety-six hours under the aforesaid conditions correspond, for example, to 24/7 operation for 7¼ years. In addition, a 1000-hour test, optionally as a storage test (e.g. +85°C/50% relative humidity) or a life test (i.e. the test specimens are tested in operation, at maxi-

mum permissible ambient temperature) is often performed to verify the results.

Stable efficiency even in a low load range

Another important aspect is the behavior under various load conditions. Quite often, only one value under full load is specified in data sheets, if at all. However, this is not very meaningful, as switched-mode power supply units are designed to achieve their best efficiency close to their nominal output. For example, as the load decreases, their efficiency also decreases until it tends to zero when idle. Well-designed power supplies, on the other hand, offer constant high efficiency, especially in the important medium and low load range.

Reliable DIN rail power supplies

Drawing on its experience of producing millions of DC/DC and AC/DC converters, RECOM has developed a series of DIN rail power supplies designed for maximum service life. In order to create appropriate safety buffers, only components of the highest quality were used whose operating temperature is well above the values specified for power supplies.

The DIN rail power supplies of the REDIN series are characterized by their particularly slender design and are additionally equipped with a side mounting system. This is particularly advantageous for switch cabinets with low installation depth. Their wide input voltage range of 85 V AC to 264 V AC ensures they are suitable for worldwide use.

Due to the high efficiency of 93 %, only a slight amount of waste heat is generated, which means the power supplies can be used at operating temperatures of –25°C to +70°C without forced cooling. The modules are equipped with active PFC and the power factor is over 0.95. They are suitable for n+1 parallel operation, either to provide redundancy or to permanently increase the output current. The modules are equipped with intelligent overload and short-circuit protection that switch off the device as soon as the maximum permissible temperature has been reached in order to avoid permanent damage. The power supplies are certified to IEC/EN/UL60950 and UL508.

Furthermore, the REDIN/3AC series is now available for operation in 2 or 3-phase mains environments. It is designed for extreme stability even in the harsh environment of process automation and runs reliably under mains voltages of 320 to 575 V AC even if the third phase fails.

The series supplies 120 W, 240 W, 480 W or 960 W at nominal 24 V DC with a ripple current of just 40 mV; or 22.5–29.5 V DC adjusted by a precision potentiometer. To increase the level of output, the devices can be connected in parallel without any further precautions; the droop-mode control with current limitation ensures a balanced load. ■

Analog front-ends

Flexible from analog to digital

Common topologies for analog front-ends are usually designed for a specific area of application and are, therefore, inflexible. New models offer greater flexibility with integrated programmable amplifiers and MCU interfaces.

By Thomas Bolz,
Product Sales Manager
Analog& Sensors, Rutronik

Analog front-ends (AFE) are used wherever highly sensitive analog signals, e.g. from analog sensors, are amplified and converted into digital signals. The AFE presented here combines several functions in one module: these are a programmable instrumentation amplifier with two fully differential inputs, a sigma-delta-based ADC, a digital interface for communication with the MCU, and a configuration register.

With high differential and integral linearity, the AFE processes almost every analog signal in the µV or mV range with a good signal-to-noise ratio (SNR) and low harmonic distortion and is, therefore, ideal for applications in the embedded and IoT range, e.g. in pressure sensor technology or battery diagnostics with the smallest signal in the AC range, e.g. direct voltage free AC impedance measurement.

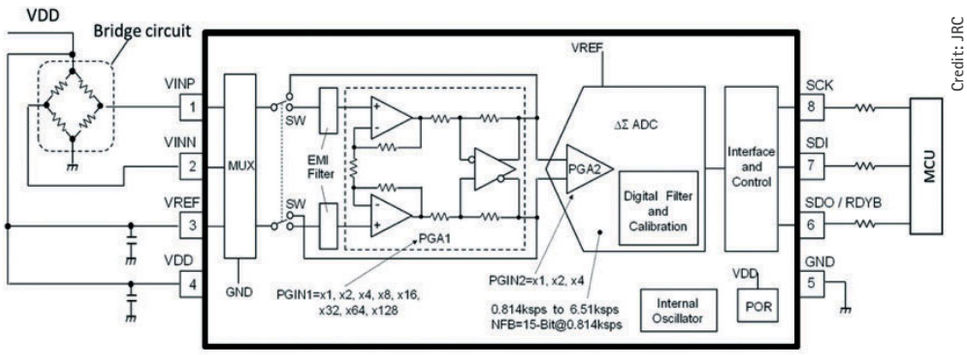
AFE topology requirements for sensor signal amplification

Operational amplifiers (op-amps) used in analog front-ends should always have the following parameters:

- Low offset voltage. Since offset and offset drift amplify non-linear voltage components in the output of the op-amps and thus distort the amplified signal.
- Low voltage noise. The noise voltage per Hertz depends on the bandwidth of the signal (nV/√Hz); it is also amplified by the signal.
- High common mode rejection ratio (CMRR) to suppress electrical interference signals at both signal inputs of the op-amps, so that the measurement signal is not affected.
- Rail-to-rail input and output (RRIO), especially in circuits with small supply voltages, in order to obtain the maximum interference voltage distance, thereby transmitting input signals error-free up to negative or positive supply.

There are basically three different topologies for operational amplifiers:

- The non-inverting amplifier is the simplest type of op-amp. Its simple design goes hand in hand with low component requirements and low power consumption. The disadvantage of the non-inverting amplifier is that common mode signals and noise at the input of the op-amp are also amplified. In the industrial sector, interference and noise can be so significant that they



Credit: JRC

Block diagram of JRC's NJU9103

drown out the desired signal. Therefore, it is recommendable to use a filter that rejects the signal ratios at both op-amp inputs.

- The differential amplifier only amplifies the input signal and – unlike the non-inverting amplifier – blocks the common mode signals. Differential signal processing achieves higher interference rejection, but common mode rejection at higher interference frequencies is not satisfactory. The circuit additionally requires exactly adjusted resistors (tolerance 0.1% and better). If this is not the case, the inputs operate with varying amplification, so that common mode rejection deteriorates significantly.

- The instrumentation amplifier with three op-amps avoids the disadvantages of the other two topologies. High input impedances and the two gain stages provide improved common mode rejection. But even this type of design has its disadvantages: The increased power consumption makes the system unsuitable for low-power applications in particular.

In addition to the choice of the op-amps and the corresponding topology, it is necessary to determine the distribution of the gain stage. It depends on several factors, including the desired gain bandwidth product (GBP), the amplification of the output error of the op-amps used and the limitation of the input and output voltage ranges of the first and second stage. If the circuit operates with high gain or low supply voltage, it becomes difficult to find a good compromise here.

Digitization with A/D converters

After the sensor signal has been amplified analog, it is converted into a digital signal by an A/D converter. Its bit resolution must be selected according to the desired accuracy of the application and the reference voltage. For example, at 4.096 V, a 12-bit A/D converter achieves an accuracy of 1 mV.

Furthermore, the Nyquist-Shannon sampling theorem must be taken into account. This states that the maximum signal frequency should be less than half the maximum sampling rate. As a result, the input signal must be limited in bandwidth through suitable filtering. Quantization errors also occur during quantization of the analog signal frequency. To keep them as low as possible, a high quantization, i.e. a high sampling rate, must be se-

lected. This must be strictly observed with SAR-ADCs, while with sigma-delta ADC this is not critical due to the high oversampling.

Integrated solutions are often the better option

When faced with all these requirements and conditions, it is often better to choose a prefabricated, integrated solution. Since integrated solutions not only achieve higher precision but also contribute to a reduction in development time and costs. This type of solution is usually inevitable, especially in the field of precision sensor signal processing. In this case, precision means achieving maximum gain linearity independent of the gain factor, the common mode ratio of the sensor signal, and the temperature.

A solution with integrated PGA (programmable gain amplifier) is, e.g., the NJU9103 from JRC. The analog front-end can process analog signals with a gain of G=512. Due to its wide input voltage range and high sampling rate, it can also amplify and process very small sensor signals in the µV and mV range as well as signals in the 100 mV range, up to signal frequencies in the kHz range.

Together with its many adjustment options, it offers the optimum amplification for pressure and flow sensors and is also suitable for thermostats, digital displays as well as PLCs and PLC applications. In addition to its large input voltage range, the small package (DFN8/SSOP8) also contributes to overall flexibility.

The front-end internal 16-bit sigma-delta A/D converter from JRC boasts sampling rates of 0.814 kSamples/s to 6.51 kSamples/s, with a single-ended, a differential and a pseudo-differential input. One of the great strengths of sigma-delta A/D converters is their oversampling architecture. Oversampling means that the sampling rate of the switched integrator (sigma) and the clock frequency of the modulator represent an extremely high level of oversampling.

This has two effects: On the one hand, the noise is distributed over a wider frequency band. And on the other hand, it serves as an alternative to a more complex and expensive anti-aliasing filter, which is typically required for SAR-ADCs. Due to a much higher sampling rate than required according to the sampling theorem, a single-pole low pass is usually sufficient. As a result, these converters achieve excellent noise and accuracy specifications.

The PGA also ensures that the ADC is always within the ideal range. Dynamic range works. For example, if the gain is 128 and the sensor offset is 10 mV, the PGA would operate in the limit. To avoid this, an internal reference voltage generates a compensation voltage which is opposite to the offset voltage of the sensor. This forces the PGA output to return to within the dynamic range. This means the NJU9103 is the only available AFE with sensor offset compensation.

Further advantages result from the high level of HF immunity, which leads to significantly fewer malfunctions caused by high-frequency noise, e.g. from cellphones. Added to this are the simple configurability and the

Practical example applying an analog front-end

High-precision sensor signal processing

NJRC has developed the new NJU9103 analog front-end (AFE) with built-in PGA that can be used to process analog signals. The microcontroller's parameters can be easily adjusted via an SPI interface. A demo board helps getting started.

Qi Zhang,
Technical Support Engineer
Strategic Marketing,
Rutronik

The evaluation kit of the NJU9103 from NJRC was originally designed for a STM32 NUCLEO-F411RE. In this case, an Arduino interface is used together with GUI software. This means that a PC is also required to display the measured values. To simplify the measuring system, NJRC specifically decided against the Nucleo board, which is why the STM32F429 Discovery Board was used for the purpose of a more simple, user-friendly demonstration.

In doing so, a measuring system was implemented for analog signal synthesis and analog signal analysis with a graphical display to show the measured values. In this process, the STM32F429 generates a PWM signal that is connected to the differential input of the NJU9103 via a one-pole low-pass filter and a voltage divider. Afterwards, the digital measured values are sent to the MCU via the SPI interface and shown on the display. This combination of demo boards makes it possible to

fast data rate of more than 1 kSamples/s, which offers many possibilities for processing high-frequency measurement signals. Furthermore, the NJU9103 is the first AFE with a PGA that achieves a minimum and maximum gain of 256 and 512 respectively. Current solutions from other manufacturers only reach a factor of 128.

Cost-effective oscilloscope alternative

Added bonus of the NJU9103: Together with a microcontroller, it can replace an oscilloscope for low-frequency signals: Signal analysis and signal synthesis can be easily achieved with the corresponding evaluation boards of the front-end and the microcontroller and just a few passive components. The sine signal can be visualized with the aid of a connected display. A smart concept at extremely low costs.

A detailed description is available free of charge at www.rutronik.com/processing-analog-signals-with-an-amplification-of-g-512-by-using-a-microcontroller. ■

Credit: Rutronik, ST, JRC

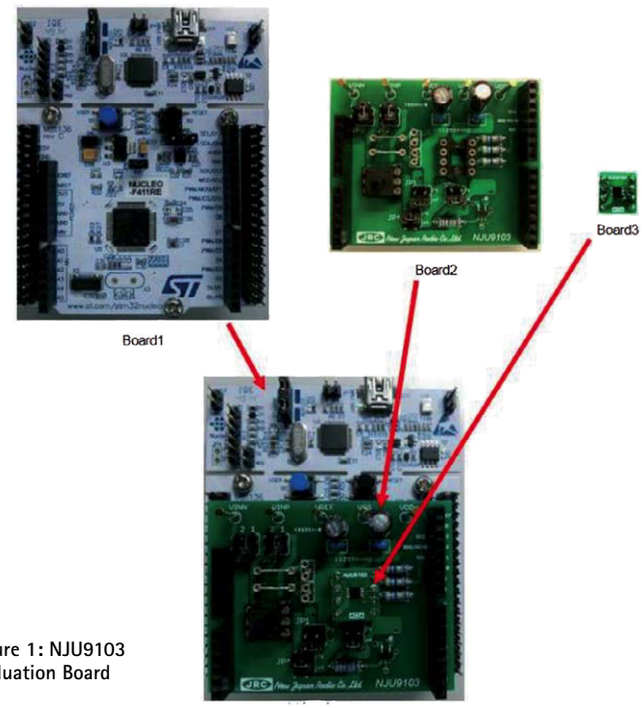
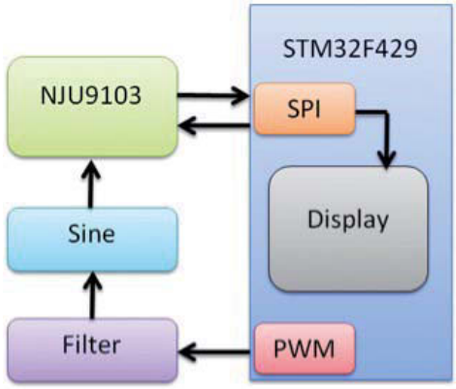


Figure 1: NJU9103 Evaluation Board



Credit: Rutronik

Figure 2: Process block diagram

demonstrate the performance of the analog front-end – consisting of the PGA, ADC, analog switch, and DAC for calibration – with respect to the NJU9103's resolution, precision, amplification, and speed. In this context, the parameters are set via the AFE's programmable register.

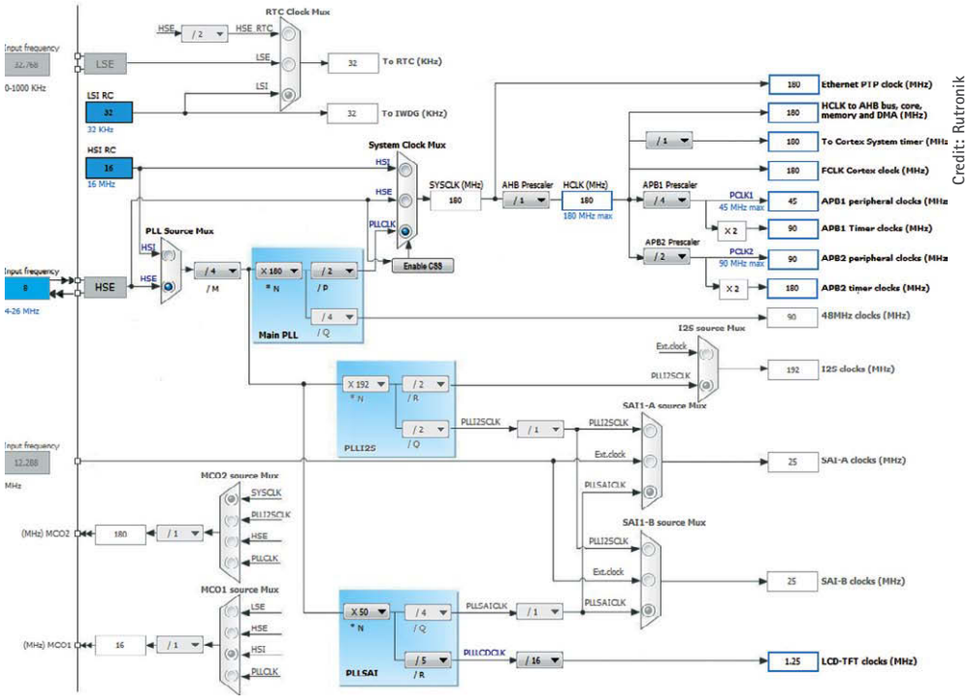
Generation of the sine signal

Configuration is carried out using the PC-based STM32CubeMX software and then the NJU9103 AFE is programmed using the Keil MDK (Microcontroller Development Kit) or Atollic TrueSTUDIO. The commands and data can be transferred via the SPI bus.

Configuring the STM32F429 with the ST-M32CubeMX Software

The software application can be downloaded from the ST website (www.st.com). In addition, the board support packages (BSP) should also be used.

The SPI1 is used to communicate with the NJU9103. The PWM signal is generated using the TIM3 timer, while TIM4 addresses the interrupt in order to show the measured values on a display.



Credit: Rutronik

Figure 4: Clock configuration via STM32CubeMX software

Generation of the PWM signal

In order to generate a precise PWM signal, the counter and prescaler in TIM3 must first be defined and set. The output is configured as a pull-up. The frequency of TIM3 is set via the APB1 (Advanced Peripheral Bus) clock signal. In this context, it's important to note that only the APB1 interface makes the maximum clock frequency available to the timer TIM3.

Generation of the sine signal

In order to synthesize the sine signal, the PWM signal (duty cycle) needs to be generated in an array.

A first-order low-pass filter (1 kΩ//1 µF) with a 3 dB point at 1 kHz was selected to filter and smooth the PWM signal. The ohmic voltage divider can be selected in the NJU9103 under consideration of the PGA's selected gain levels. This results in the output of a sine signal.

In this context, it must be noted that the maximum input voltage of 1 V cannot be exceeded at the AFE's differential input.

```
unsigned char sine[128]=
{
   128,  134,  140,  147,  153,  159,  165,  171,
   177,  182,  188,  193,  199,  204,  209,  213,
   218,  222,  226,  230,  234,  237,  240,  243,
   245,  248,  250,  251,  253,  254,  254,  255,
   255,  255,  254,  254,  253,  251,  250,  248,
   245,  243,  240,  237,  234,  230,  226,  222,
   218,  213,  209,  203,  199,  193,  188,  182,
   177,  171,  165,  159,  153,  147,  140,  134,
   128,  122,  116,  109,  103,  97,   91,   85,
   79,   74,   68,   63,   57,   52,   47,   43,
   38,   34,   30,   26,   22,   19,   16,   13,
   11,   8,    6,    5,    3,    2,    2,    1,
   1,    1,    2,    2,    3,    5,    6,    8,
   11,   13,   16,   19,   22,   26,   30,   34,
   38,   43,   47,   52,   57,   63,   68,   74,
   79,   85,   91,   97,   103,  109,  116,  122
};
```

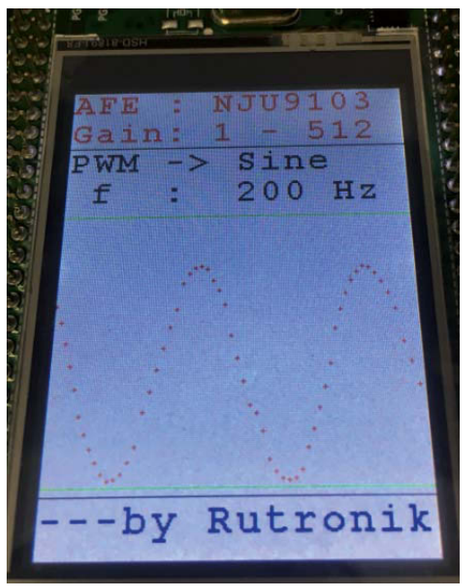
Credit: Rutronik

Figure 3: PWM array

```
/* Configure the system clock */
SystemClock_Config();

/* USER CODE BEGIN SysInit */

/* USER CODE END SysInit */

/* Initialize all configured peripherals */
MX_GPIO_Init();
MX_DMA2D_Init();
MX_FMC_Init();
MX_I2C3_Init();
MX_LTDC_Init();
MX_SPI5_Init();
MX_SPI1_Init();
MX_TIM3_Init();
MX_TIM4_Init();
```

Credit: Rutronik

Figure 5: Initialization



Credit: Rutronik

Figure 6: PWM signal at the MCU output

Credit: Rutronik

Figure 7: BSP functions

Programming the NJU9103

After the demo board has been configured with CubeMX, SPI communication and the TFT display can be directly initialized.

In this context, the board support package contains many useful features that can be used.

When adjusting the register of the NJU9103 AFE via SPI communication, it is important to observe a key point in the data sheet. Only bits 4–7 of the register's corresponding addresses can be set, instead of the whole byte, as is usually the case. The registers can be initialized as explained in the data sheet.

The ADC's sampling frequency is adjusted via timer TIM4. In accordance with the Nyquist–Shannon sampling theorem, the sampling frequency is dependent on the signal frequency that will be measured.

Summary

It is easy to carry out signal analysis and signal synthesis with the two boards and a few passive components. The sine signal can be visualized using the display. In contrast to an oscilloscope, the display can be used to show the NJU9103's slew rate, resolution, and precision. The combination of the two demo boards in this configuration is an ideal platform to demonstrate the performance of the new AFE from NJRC and to launch the development of a new product in the field of analog sensor-signal processing with a variety of areas of application. ■

Passive Matrix OLEDs

A world of contrasts and colors

Passive matrix OLEDs are high-contrast, thin, and energy-saving. They are also being increasingly used in industrial applications. Which advantages and disadvantages do they offer and when does a Design-In-Process make sense?

By Vincenzo Santoro,
Senior Marketing Manager Displays,
Rutronik

Credit all pictures: Raystar

Consumer applications such as smart watches are trailblazers in the use of PMOLEDs.

The term OLED (organic light emitting diode) is becoming increasingly common in everyday life, for example with smartphones, which are often equipped with the currently popular AMOLED technology (active matrix OLED). This displays a maximum resolution on the smallest active area. Retailers and specialist stores are also increasingly advertising OLED equipment – with even sharper images and more true-to-life colors. Smart watches glow in vibrant colors and deliver high contrasts, smart home displays offer aesthetic visualization and touch benefits. AMOLED technology has long since conquered the consumer sector and is now being used in more and more applications. For some time now, passive matrix OLED (PMOLED) displays have also been hugely popular, for example in the industrial sector. Vibrant colors, unique contrasts, and high resolutions as well as a slender design make them interesting for product developers of industrial applications, especially when used as a replacement for a passive LCD display to enhance the application's aesthetic appeal.

Structure and colors of PMOLEDs

A PMOLED consists of several layers. An anode represents the organic layer, the cathode is arranged in rows at right angles to the anode. Both of these layers have a strip-like structure. Actual control is achieved via both the anode and the cathode line, which activates the OLED at the respective intersection points and generates light. PMOLED sizes range from less than 1 inch to 5.5 inches. In addition, they also enable an alphanumeric and graphic dot matrix resolution. The background of the displays is always black, while the pixels can be displayed in yellow, blue, white, amber, sky blue, and green. Unlike AMOLED technology, however, the developer must determine a color when selecting the PMOLED.

Advantages of design-in process

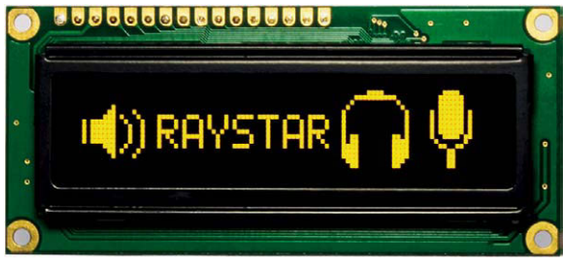
Key points speak in favor of a PMOLED. One factor is the low installation height of the displays. Self-illuminating technology eliminates the need for backlighting of the display module. As a result, it consists only of the front and rear glass, thereby reducing the thickness of the LEDs by a few millimeters. Further advantages are the "around-the-clock" angle of view and the high contrast. The PMOLED displays the same high contrast (2000:1) from all sides, which is why there are no preferential angles of view. This is particularly useful if, for example, a status display is controlled or read out by one or more users from different angles. Moreover, the PMOLED is extremely energy efficient and provides a basis for low-power applications. Only the pixel that is actually intended to light up consumes power, while the non-luminous pixels remain inactive.

PMOLEDs are sensitive

Before deciding whether a PMOLED is suitable for the respective application, it is also necessary to consider the weaknesses of the technology. These include, above all, the lifetime and burn-in effects. The service life of a PMOLED can be severely limited by various influencing factors, as the material reacts very sensitively to oxygen and moisture as well as constantly high temperatures. A PMOLED is therefore not really suitable for use in direct sunlight. Burn-in effects, i.e. the burning of phosphor into the screen, can occur if the display permanently controls the same pixels. A varied and homogeneous control is required to avoid this problem. The cost factor also plays a significant role. Since the production of the display is very complex, a PMOLED still requires higher investment than, e.g., a passive LCD.

More aesthetics for many applications

PMOLED technology is suitable wherever the design should be aesthetically more appealing than that of a passive LCD. It is ideal for metering, as status displays for gas, electricity or water meters only require a selective display. PMOLED technology is also a suitable option for thermostats, white goods or applications with smaller, selective displays. PMOLEDs are not (yet) suitable for 24/7 status displays due to the service life of the technology. Despite the still existing obstacles, PMOLED technology is gaining in popularity. The R&D departments of suppliers are continuously working on ways to extend the service life, minimize burn-in effects, and increase resolutions. The consumer market is definitely an incentive for the development of new OLED properties – be it through flexible OLEDs (e.g. smart watches) or transparent OLEDs (metering), which are also becoming increasingly popular in the industrial sector. To cover the complete PMOLED portfolio, Rutronik works closely with the renowned OLED supplier Raystar. Its extensive standard portfolio includes alphanumeric displays in sizes from 8x2 to 20x4 rows and columns as well as in all color variations. Raystar and Rutronik also offer graphic COG (chip on glass) and COB (chip on board) PMOLEDs in sizes ranging from 0.49 inches to 5.5 inches. All standard products can be customized and open up countless possibilities of the Design-in process that go far beyond the standard functions. In the next few years, the development in the field of PMOLEDs will show what is possible here – from trend technology to the replacement of passive LCDs. PMOLEDs already have a great influence when it comes to developing the design and are a real eye-catcher for all visualization topics. ■



PMOLEDs are an ideal replacement for passive LCDs in order to enhance the aesthetic appeal of displays.

Simulation of temperature sensors

Developing a digital thermometer faster and easier

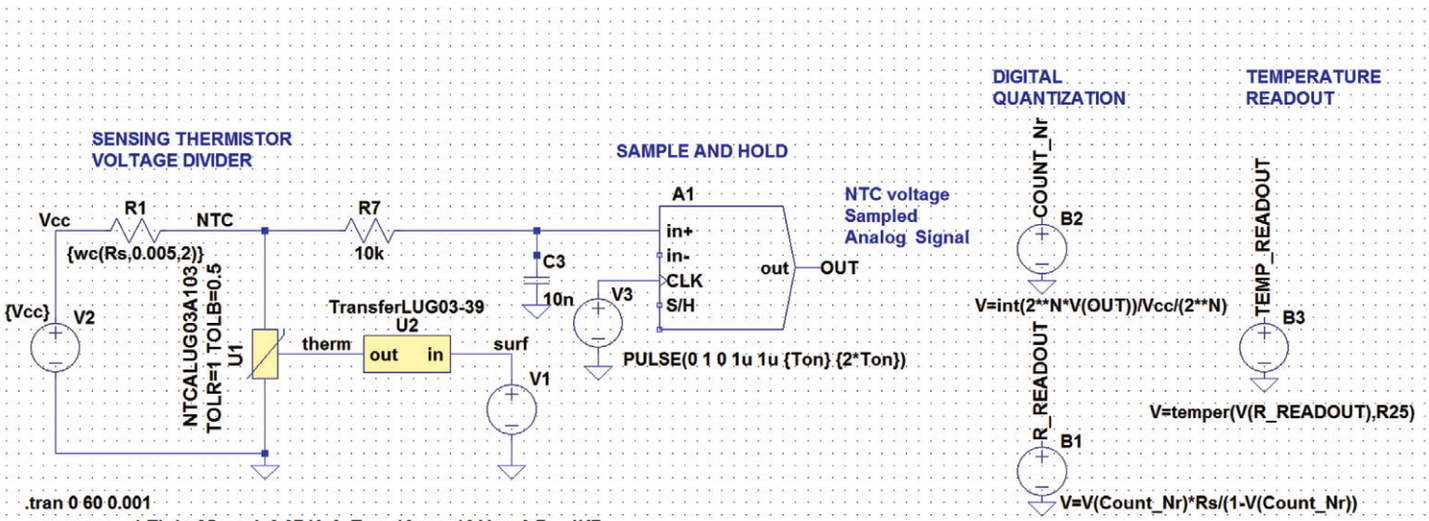
Patients, Sunday roasts, shower or aquarium water – their temperature is increasingly measured using digital thermometers instead of analog ones. The choice of temperature sensor is decisive for their development. A free simulation program makes this task much easier, while helping to save time and money.

By
Bert Weiss,
Technical Support Resistors,
Rutronik,
and
Alain Stas,
Product Marketing Engineer
for nonlinear resistors,
Vishay

When developing a digital temperature measuring circuit, the purely mechanical aspects of the design have to be clarified first; however, these will not be considered here. This is followed by the electro-thermal ones. In this sense, the following questions need to be answered:

- What is the intended temperature range?
- Which level of measuring accuracy is required?
- Which type of temperature sensor is to be used?
- How large are the tolerances of the sensor's electrical characteristics?
- Which minimum bit rate should the A/D converter provide?
- How high does the sensor signal sampling rate need to be?
- How large are the values and tolerances of all other passive components within the application?

It is particularly important to determine the temperature range and measuring accuracy,



Credit all pictures: Vishay

Figure 1: Simplified simulation circuit diagram of a digital thermometer

as they determine the following steps. For example, the temperature range in this case should be from +25°C to +150°C, and the overall accuracy needs to be ±2°C. In this case, two temperature sensors are available: A highly sensitive but non-linear thermistor and a resistance temperature device (RTD), e.g. a platinum sensor that is linear but less sensitive.

Choosing the right sensor: Not an easy decision

When choosing the right sensor, it is important to decide which one can be used to achieve the desired specifications. It is not enough to simply answer each of the questions listed above. Since the various parameters exhibit complex interactions with each other, i.e. they influence one another.

In general: The limiting factor of a system determines the accuracy. If this is unknown, it is of little use to reduce the tolerances of the remaining parameters to almost zero. If, for instance, precision thermistors are used with the aim of measuring the temperature with

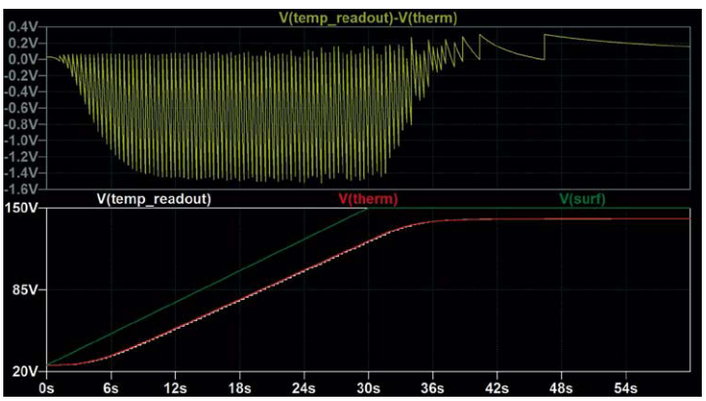


Figure 2: The direct transient circuit simulation shows the temperature profile of the application. Top: External temperature V_{surf}, thermistor temperature V_{therm}, and digitized measured value (t_{on} = 200 ms, n = 10). In the bottom window: Difference between measured value and actual thermistor temperature

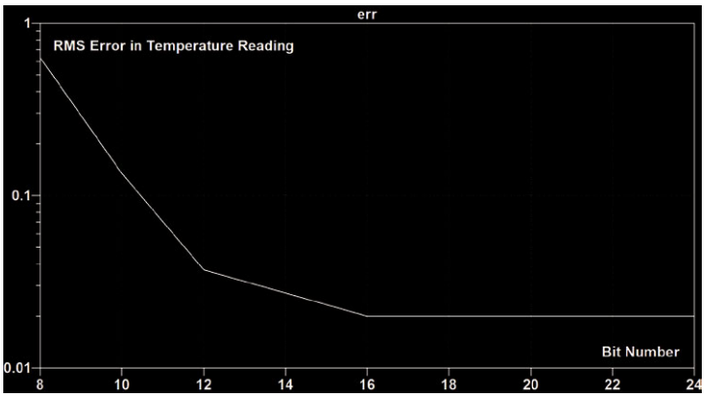


Figure 3: With a resolution above 16 bits, the difference between the readout temperature and the thermistor temperature remains constant.

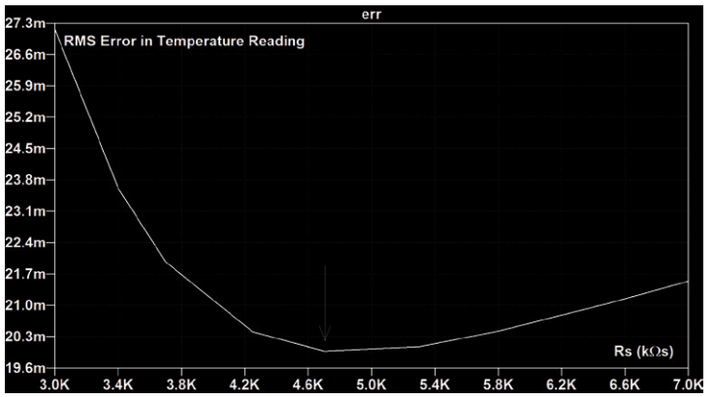


Figure 4: The error function is at its lowest at a series resistance of 4.7 kΩ.

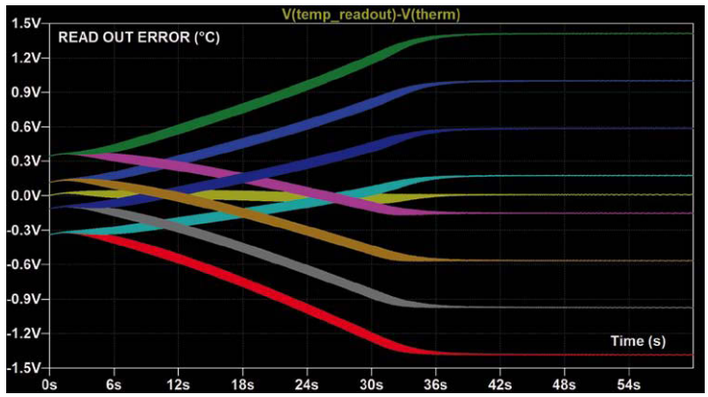


Figure 5: Temperature measurement uncertainty with dR25=±1% and dB=±0.5% for the NTC and ±0.5% for the fixed resistor.

an accuracy greater than ±0.2°C and a simple 8-bit A/D converter is simultaneously used, it would impair the precision of the thermistors significantly. It would be the same the other way round, too: If a moderately precise sensor is used, the application of a 24-bit A/D converter makes only limited sense. If the smallest temperature differences are to be detected, an ADC with high differential linearity in conjunction with calibration algorithms is recommendable.

Another method to achieve the most accurate measurement possible is to use a class A platinum sensor (±0.15°C at 0°C) with a linear temperature characteristic. However, its temperature coefficient is lower than that of a thermistor, i.e. the measurement signal must be amplified. This requires additional hardware and brings further tolerances into play.

Obviously, this makes the selection of components a complex task, which usually demands numerous tests. And it costs time and money. It would be easier and faster if the sensor with its tolerances, the A/D converter accuracy, and the other hardware components could be selected, a "virtual prototype test system" set up, and a simulation carried out that immediately indicates the achievable accuracy. This is exactly what the PSpice-based simulation programs, which are mostly free of charge, do – even though they are analog simulation software. Since PSpice and its well-known "light" versions can simulate any process of the digital thermometer, as shown in Fig. 1 (in this case, a thermistor-based circuit, although an RTD-based circuit would look similar).

Components of the digital thermometer

Whether you choose an NTC (negative temperature coefficient) thermistor or a platinum RTD as your temperature sensor, SPICE models of these components are easy to find. In addition, the circuit contains a voltage divider consisting of a thermistor and a fixed resistor; a low-voltage source supplies the measuring current. The resulting voltage is digitized after amplification and filtering through the appropriate ADC. Ideal components are the new analog frontends from JRC (NJRC9103), which enable direct connection of the temperature sensor. This AFE supplies the digital data directly and also offers various calibration functions for offset compensation. A microprocessor utilizes this to calculate the temperature.

The direct transient circuit simulation (Fig. 2) shows the temperature profile of the application, the response of the sensor with a delay and slope, and the digitization of the signal. The time deviation of the readout temperature can be seen in the lower section. To make the digitization easier to recognize, a low A/D converter resolution of 10 bits and a long sampling time of 200ms were selected for the simulation.

The properties and tolerances of the sensor, in this example a 10 kΩ NTC thermistor of the NTCALUG series from Vishay, and the fixed resistor are easily simulated using Spice. The digitization of the signal and the conversion of the digitized raw measurement data into the temperature are carried out with the aid of analog behavioral modeling voltage sources. Interestingly, the number of bits (n) of the A/D converters is now a parameter of the simulation and can be varied between 8 and 24. The sample time (tone) of the sample/hold module is also a variable parameter.When using Sigma Delta ADCs, the external sample/

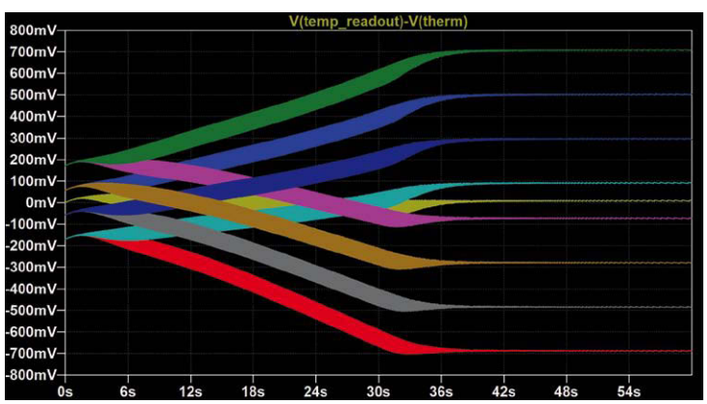


Figure 6: If all resistance tolerances are halved, the temperature measurement uncertainty is also halved.

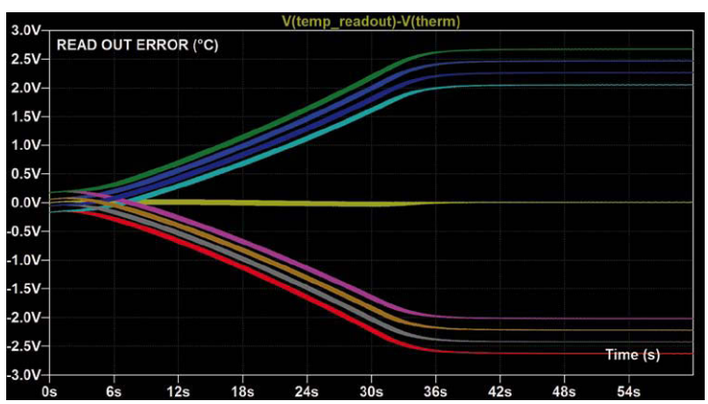


Figure 7: Temperature measurement uncertainty at dR25 = 0.5% for the NTC (but with dB = ±1.5%) and a fixed resistance tolerance of ± 0.25%.

hold can be omitted, especially since the temperature change typically occurs in the range of 100 ms anyway.

In this example, the sampling time of 10ms is the first parameter to be set. The ideal A/D converter resolution can then be determined by entering values between 8 and 24 bits. When calculating an error function as the effective value of the difference between the readout temperature and the thermistor temperature, the error does not decrease further at resolutions of n>16, as shown in Fig. 3.

Alternatively, the series resistor R1 can also be optimized to achieve a minimum error value. Fig. 4 illustrates that the error function for an Rs series resistor reaches its minimum at 4.7 kΩ. The ERR (error) function was defined in the SPICE directives for the simulation (see Fig. 1).

In the next step, the tolerances of the thermistor and the fixed resistor R1 are varied, and a worst-case analysis based on these tolerances is performed for each. Fig. 5 to 7 show three cases: Fig. 5 shows the results for an NTC with dR25/R25 = ±1% and a B25/85 tolerance of ±0.5%, combined with a 0.5% thin-film TNPW series flat chip resistor from Vishay. In this case, the measurement uncertainty increases from ±0.4°C at 25°C to ±1.5°C at 100°C. The simulations apply to a worst-case scenario. Taking into account the R25 and B25/85 tolerances of the NTC and the tolerances of the fixed resistor R1, $2^3 = 8$ cases are obtained; the white curve is the reference curve. The simulation in Fig. 5 shows that the tolerance values are evenly distributed; this means the relative tolerances of the resistors to each other have been chosen appropriately.

Fig. 6 shows that the temperature measurement uncertainty can be halved by halving all resistance tolerances (R25 = 0.5% and B25/85 = 0.25% for the thermistor and 0.25% for the fixed resistor). However, this is a somewhat ambitious undertaking, as it is doubtful whether all resistor suppliers can guarantee a B25/85 value of ±0.25%.

A common value for the B25/85 coefficients is, e. g., ±1.5%. If the same simulation is performed with the same values as in Fig. 5 but with a B tolerance of ±1.5%, the results shown in Fig. 7 are achieved. Due to the relatively large measurement inaccuracies at high temperatures, they indicate a suboptimal design. It can also be clearly seen that the results for the tolerance values of the worst-case analysis are also not distributed ideally.

This shows: A relatively simple simulation circuit can be used to visualize the overall accuracy of the temperature measuring circuit in line with its component dimensioning. This is an ideal starting point for additional experiments in order to reduce time and costs.

The simulation files used here can be requested from edesign.ntc@vishay.com. ■

The colorful world of plug connectors

Standard, individually adapted or tailored to requirements

Number of poles, plating and orientation, soldering technologies, mounting or assembly aids – there are numerous options for plug connectors. More than 1,000 variants thus quickly arise for each product family – no wonder that suppliers do not offer all of them as standard versions. However, custom-made products can be worthwhile.

By Albert Culetto,
Technical Support
Connectors
and Cables, Rutronik

Many plug connector suppliers now design their products in a modular fashion according to the Lego principle, thus enabling them to offer a whole range of product variants that cover many specific requirements. In this respect, there are no tool costs for the customer. The disadvantage is, however: If the tool is used by the supplier for a variant, it is not possible to produce a similar model during this period. The customer should therefore always keep an eye on the minimum order quantity (MOQ) and delivery time.

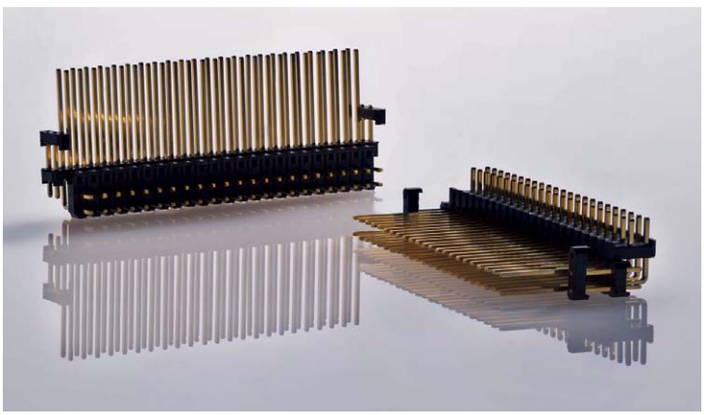
Tailor-made plug connectors

If you decide to make modifications according to your own specifications, the first step is to contact the plug connector supplier. Depending on the order quantity, technical possibilities and utilization of the supplier's machinery as well as the business strategy, the supplier decides whether the customer's requirements can be implemented.

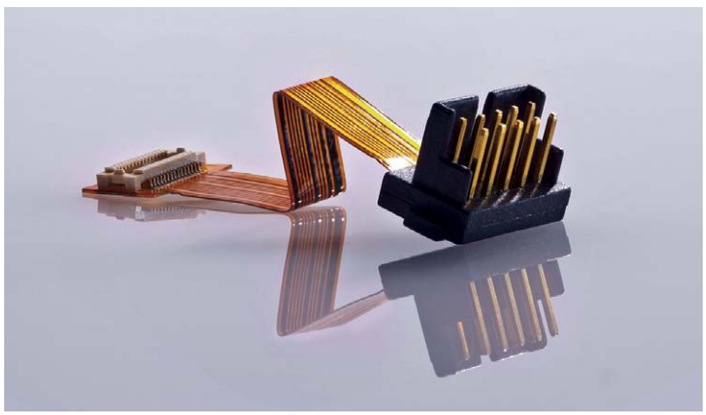
In the course of such a modification, it is worthwhile to think about whether weak points can be eliminated and subsequent processes optimized at the same time. Modifications to the stamped part of the plug connector, e.g. with regard to length, shape, plating or bending, are often sufficient here. Another type of carrier material, such as high-temperature plastic or 2-component injection molding, can also make a clear difference to the design. Snap-in lugs or P&P areas may arise and the package can be adapted with regard to dimensions and shape. Modifications to the packaging, for instance tape & reel or pick & place cap, larger packaging units, load carriers or reusable packaging, etc., can streamline and accelerate the procurement and production process.

Usually, 2D information in a .pdf document is sufficient for these types of modification. Experience has shown that the additional costs range from a few hundred to a few thousand euros. They are only incurred once, the supplier factors the remaining amount in the component price.

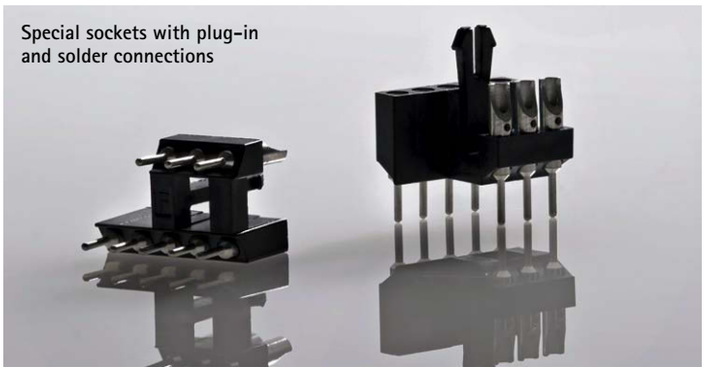
Credit all pictures: mpe Garry



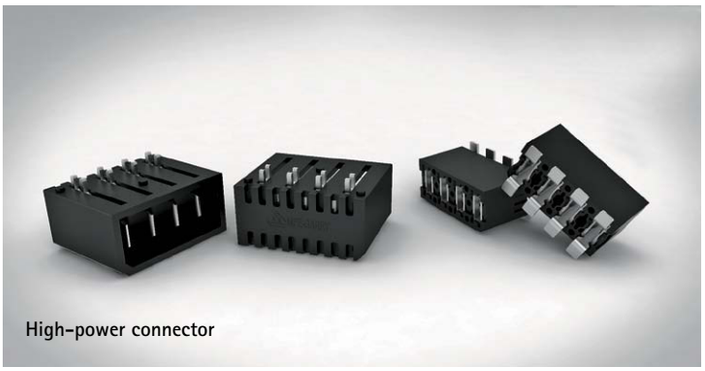
Custom-made pin header with anti-tilt device



Customer-specific programming adapter



Special sockets with plug-in and solder connections



High-power connector

No half measures

When a company decides in favor of a tailor-made plug connector, the question arises: Why not go for a truly individual plug connector? Today, many special requests can be implemented quite easily, e.g.:

- Complex packages in which the package seal has already been integrated using 2-component injection molding
- Packages with a weld-in pressure compensation membrane using ultrasound for guaranteed watertightness
- Press-fit contacts that eliminate the soldering process
- Combinations of various technologies, e.g. IDC and press-fit
- Connector faces that become part of the application package
- Two or more connector faces that are combined
- Connecting bridges integrated into the contacts (power range)
- Additional products, e.g. an electrolytic capacitor or a coil, which are already contacted in the package
- Implemented bus bars
- Ground connections, mounting brackets, spacer bolts or screw bushes, which are already molded on

These difficult-to-process components and processes are simply integrated.

Laser direct structuring for miniaturization

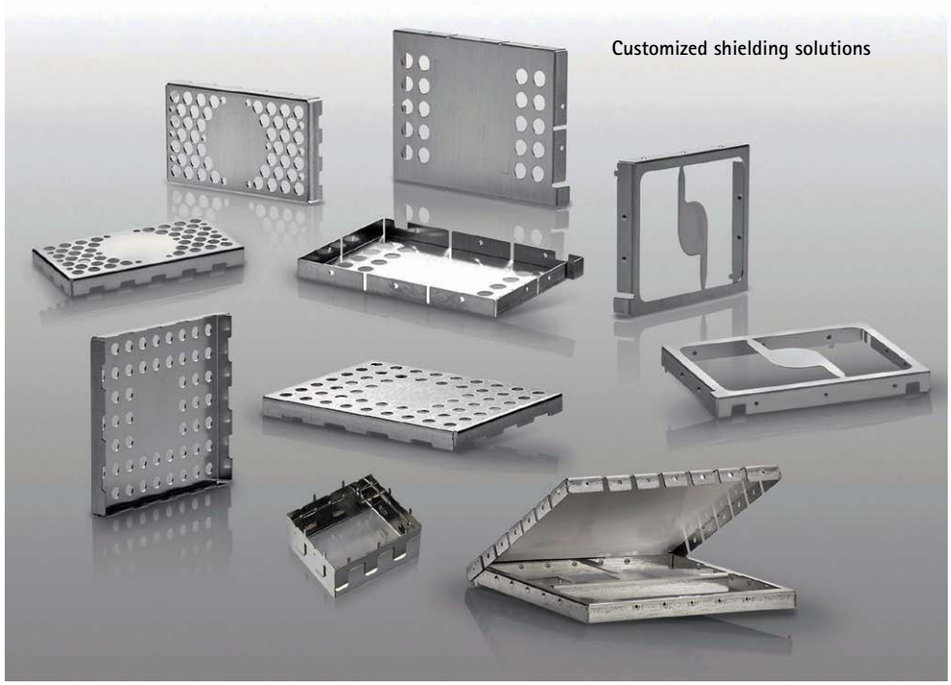
LDS (laser direct structuring) is a good choice when "miniaturization" is the main objective of the design. Thanks to this technology, circuits can be drawn on a variety of RoHS-compliant plastic materials with circuit diagram modification using a 3-axis laser. Cables and spacings as thin as 0.10 mm as well as circuit grids of 0.35 mm are possible in large series production. Furthermore, versatile design functions are also available. LDS enables the integration of connections with fixed contacts, laser-drilled holes, and tiny deflection holes measuring just 50 µm in diameter, structural elements, such as cantilever contacts and integral switching contacts, as well as antenna designs. Effective heatsinks or EMI shielded connections can be developed due to the thicker copper plating.

The processes for plug connector production are fully automatic. LDS and the aforesaid modifications require tools that may cost several hundred thousand euros. The customer is expected to share some of the costs in this situation. . The tool usually remains the property of the supplier in order to protect the know-how that has been incorporated into it.

To meet such complex requirements, the plug connector supplier requires a 3D file as soon as an inquiry is received, preferably in one of the common formats (.stp, .igs, .dwg, etc.). Usually, the developments and designs of the plug connector are not the responsibility of the supplier but of the customer. However, suppliers offer advice in this respect.

A cost-benefit calculation will show the profitability of this decision. As savings on other components and production processes can exceed the additional costs for your own plug connector. Moreover, companies can utilize this to create applications with unique selling points and competitive advantages. The question of whether this can be achieved in individual cases cannot be easily answered and requires individual consideration. A complete analysis of the total costs of ownership is particularly important here.

The time frame for this type of project, from the idea to PPAP (production part approval process) capable sampling, is estimated to be around six months. It is thus essential to choose the right partners from the start. Rutronik supports its customers in this respect: The distributor knows the product portfolio, the manufacturing facilities, technologies, and machinery of its suppliers and can assess whether the respective plug connector supplier is suitable to meet to the customer's product requirements. This saves customers from losing time chasing an unrealistic solution and allows them to receive the ideal plug connector for their design as quickly as possible. ■



Customized shielding solutions

Solutions fit for the street

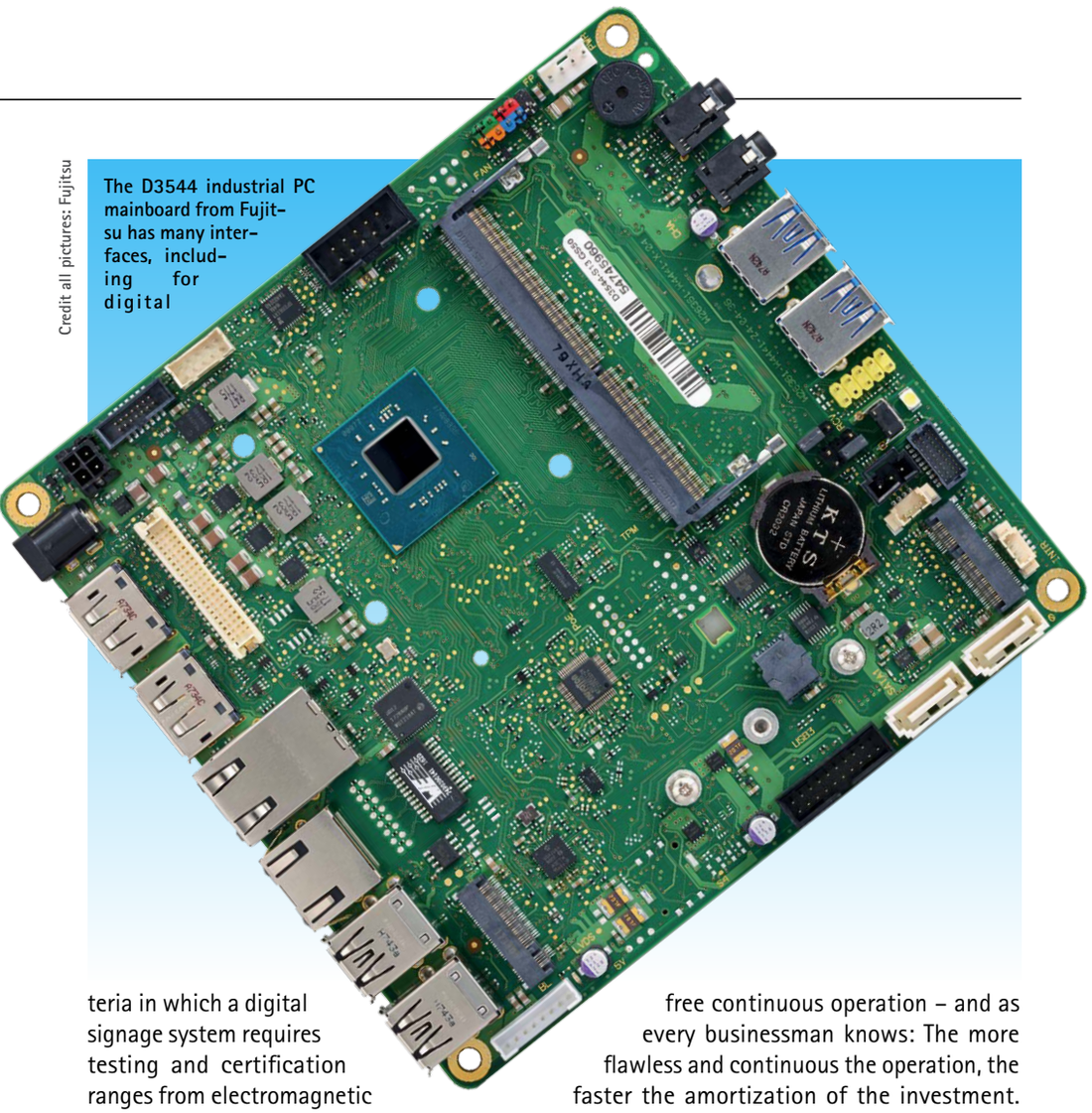
Industrial mainboards for amazing digital signage

Today, digital signage has become a kind of icon of public life: It can be found on squares and at traffic junctions, in schools, medical practices, and hospitals, in stadiums and pedestrian zones. However, the installations need an efficient and reliable power supply to fulfill their various tasks.

By Thorsten Engel,
Product Sales Manager
Boards & Systems,
Rutronik

Digital signage redefines the visual language, as it lets images do the talking – seemingly both effortlessly and tirelessly. And this offers an array of opportunities: The contents can be controlled in such a way that they always reach the right target group, information and entertainment can be easily combined with each other – and, last but not least, digital signage also performs design tasks as "cityscape furniture".

As minimalistic as the installations may look on the outside (after all, people usually only see a large frame around the moving content): The technology behind it is as complex as it is sophisticated. At its core is an industrial PC – i.e. a computer that must meet the highest standards – in conjunction with a number of other components. The entire ensemble has to pass many official tests before it can be used indoors or outdoors. The spectrum of cri-



Credit all pictures: Fujitsu

The D3544 industrial PC mainboard from Fujitsu has many interfaces, including for digital

teria in which a digital signage system requires testing and certification ranges from electromagnetic compatibility, product safety, and energy efficiency through to vibration and extreme temperature resistance.

If you want to save yourself time and effort, you can use a pre-certified kit solution – for example from Fujitsu. In this case, all the components have not only been officially approved as being suitable but are also precisely coordinated to each other. The necessary performance is provided by industrial mainboards "Made in Augsburg", e.g. the D3544-S. It offers an output of 2 × 4K at 60 Hz via DP, while many others still rely on HDMI 1.4 with 30 Hz. The mainboard is thus ideally suited for higher quality and particularly demanding digital signage applications.

A kit solution saves time-consuming preparatory work

The board offers unrestricted use for industrial settings and can therefore be applied in continuous 24/7 operation, even at extreme temperatures. An important equipment feature is passive cooling. There are no moving parts such as fans or the like that can swirl up dust and become clogged with dirt. This also makes a decisive contribution to trouble-free continuous operation – and as every businessman knows: The more flawless and continuous the operation, the faster the amortization of the investment. Since advertising companies sometimes spend a lot of money on advertising clips, reliable broadcasting with outstanding quality is mandatory. Overall, the passive design makes the solution more robust without compromising performance.

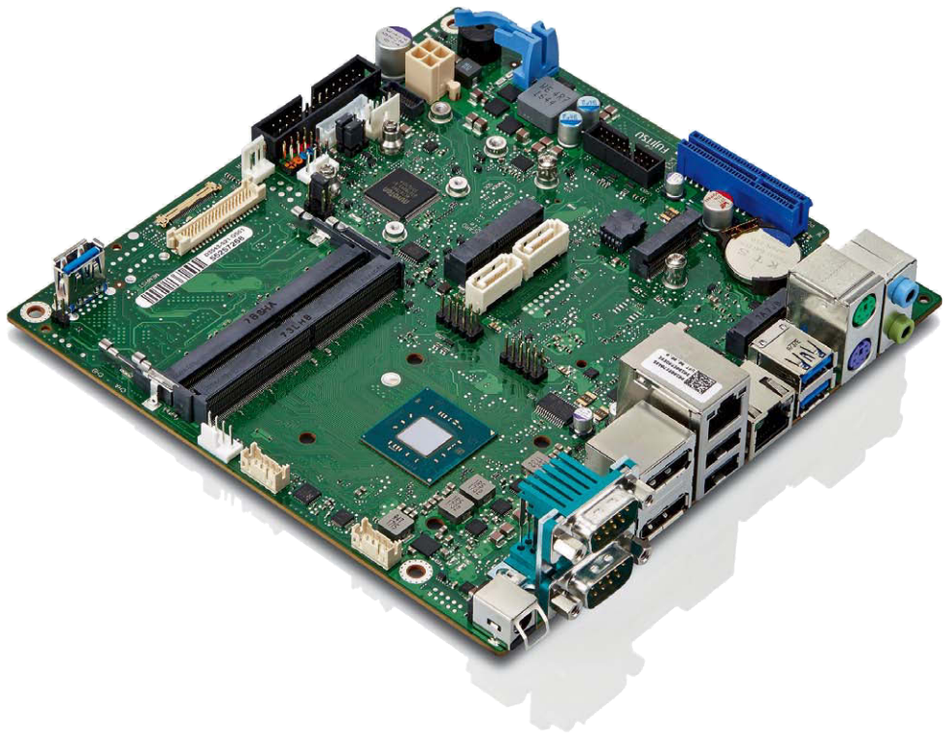
The package – or more accurately: The Fujitsu Smartcase – with a volume of just 0.87 liters is extremely compact, thereby ensuring it can easily be attached behind smaller monitors or integrated in the restricted structural space of a totem using the VESA mount.

CPU scaling for maximum flexibility in use

Maximum flexibility is also a key factor for operators in terms of computing power – Fujitsu therefore offers three different CPUs on the same platform and thus a uniform software load: For price-sensitive solutions, the variants S1 and S2 with Intel Celeron J4x05 CPU are available for Dual or Quadcore as required. The S3 is equipped with an Intel Silver Pentium J5005 for high-performance applications. All the processors boast low power consumption (TDP – thermal design power) of just 10 W.

With this type of equipment, what the viewer perceives as a visual miracle is, in fact, not such a big deal: The smooth presentation of HD clips with commercial content combined with fade-ins – even tickers – with up-to-the-minute, important information or even urgent requests, a common sight at airports.

Serious entertainment, reliable information, clear presentation – or simply an eye-catcher: The digital displays at airports and museums, in schools and medical practices or in a city center fulfill many tasks, quite often with a "rolling changeover" and in all kinds of weather, day and night. The only reason they can do this is because they utilize a technology that combines robustness with complexity – and in the case of Fujitsu's solutions based on the D3544-S mainboard this is also possible with an extended kit and at great value for money. ■



Multilayer ceramic chip capacitors

Capacitance loss due to DC bias in MLCCs

Thanks to extreme further developments, MLCCs are being used in an increasing number of applications. However, one thing is often neglected in the designs: The DC bias behavior that influences the capacitance of class 2 ceramic capacitors. This can lead to the capacitance exceeding the tolerance range of the application for apparently inexplicable reasons and possibly cause technical problems. However, there are ways to counteract this.

By Jürgen Geier,
Field Application Engineer
Ceramic Capacitors, Rutronik

Multilayer ceramic chip capacitors (MLCC) are one of the most widely used types of ceramic capacitors today. And not without reason: They have been optimized significantly with regard to their maximum nominal C values and also ever lower ESR values (Equivalent Series Resistance). However, this is accompanied by ever greater drifts, especially with respect to DC voltage, temperature, and time (Fig. 1).

Class 2 ceramic capacitors have now reached such high capacitances which repeatedly leads to miscalculations of their actual capacitance during operation. It is often not known how the components behave in the real application and why they vary so much as soon as voltage is applied. An important electrical parameter responsible for this is the DC bias.

DC bias effect

The DC bias effect can best be demonstrated in the laboratory. TDK used a 3216 X7R 1µF capacitor with a nominal voltage of 25V for the tests and connected it to an LCR meter. This displayed 1µF at 0V. If 25V was applied,

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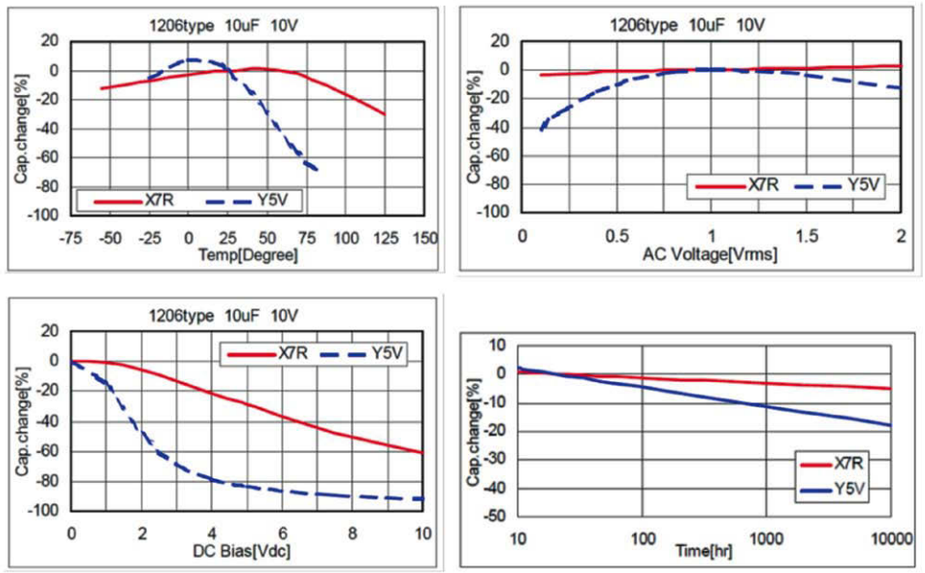


Figure 1: Due to the ferromagnetic base material barium titanate of the type 2 ceramic capacitors, the C-value varies due to the temperature, the DC and AC voltage, as well as the age of the parts.

a capacitance loss of more than 40% compared to the nominal capacitance values could be detected.

The reason for this is the actual structure of the ceramic capacitors: Their dielectric material is obtained from barium titanate, a ferromagnetic material whose molecules adhere to the structure barium2+, oxygen2-, titanium4+. In this case, titanium is in the middle. This molecular structure has a cubic crystal structure above the Curie temperature (approx. +125°C) and changes into a tetragonal crystal structure below the Curie temperature. This generates a polarity known as dipole, where one side of the axis is more positive and one is more negative than the other.

Without the application of a DC voltage, there is no electric field and the dipoles arrange themselves randomly in the entire crystal structure (spontaneous polarization). Meanwhile, the dielectric constant is high, which also results in high capacitance.

If a low DC voltage is now applied, the electric field influences some of the dipoles due

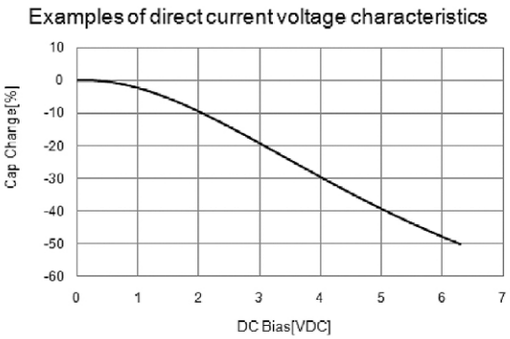


Figure 2: C-value change due to DC voltage

to the polarization. These start to align themselves parallel to the electric field, which reduces the capacitance.

If a higher DC voltage is applied, several dipoles align themselves parallel to the electric field and the capacitance decreases continuously. When the nominal voltage is applied to the capacitor, the capacitance level may drop by up to 50% or more from the nominal capacitance level (Fig. 2).

The effect of DC bias on the capacitance of class 2 ceramic capacitors cannot be avoided. However, there are ways to cope with it.

Improving circuit designs

The comparison of several DC bias curves of class 2 capacitors shows which possibilities

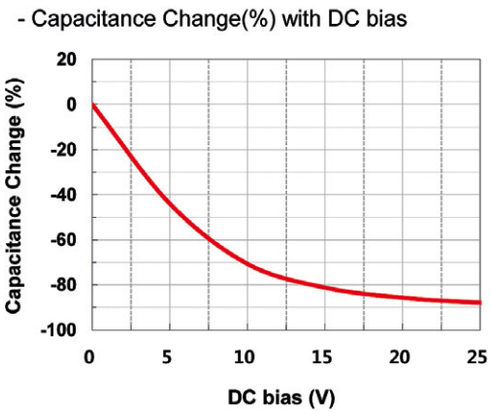


Figure 3: Characteristic data of the 0805 4,7µF capacitor

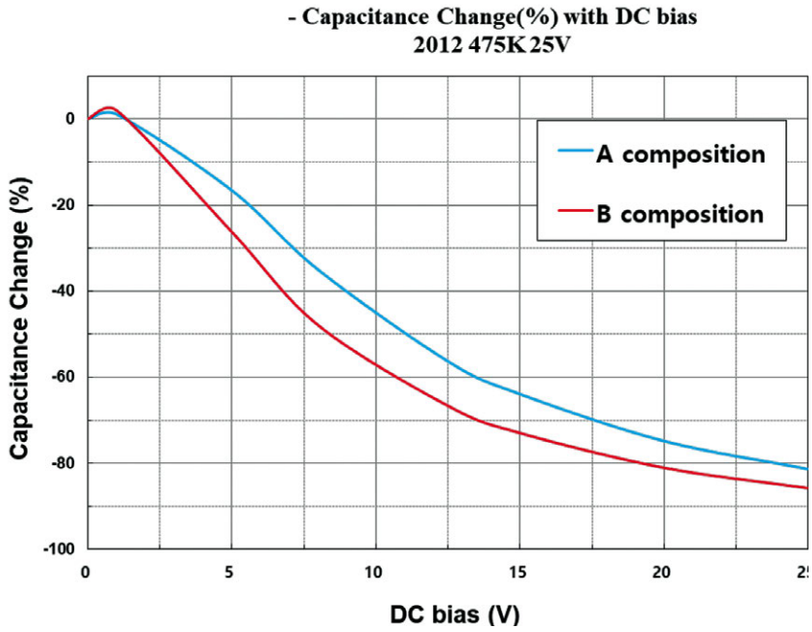


Figure 4: Various base materials in MLCCs display different DC bias behavior.

exist in order to reduce the effect in the application:

With a capacitor featuring 1nF and a nominal voltage of 16 V, the capacitance decreases by almost 9% at 10 V and by 21% at 16 V. This could already be unacceptable for some designs. With the same capacitor featuring a nominal voltage of 25 V, the capacitance at 10V only decreases by 2%.

This is due to the fact that the dielectric layers in ceramic capacitors are thicker at higher nominal voltages. A thicker dielectric means a weaker electric field that affects fewer dipoles.

The capacitance change for a 470 pF capacitor of the same package size at 10 V is only 0.6%. If the design allows two of these capacitors to be connected in parallel, this would be a possible solution for the DC bias effect. Since lower capacitance values allow thicker dielectric layers.

Sometimes capacitors with the same capacitance value are also available in a larger package. They also usually have thicker dielectric layers and thus better DC bias behavior.

Practical example: DC bias not considered

What can happen if the DC bias is not considered in an application is shown by a practical example: One customer used a 0805 4.7 µF X5R multilayer ceramic capacitor with 25 V and a nominal tolerance of 10% as well as measuring parameters of 1 kHz at 1 V eff. The customer complained that the components were defective, as their C-value at 14.5 V was only approx. 1 µF and not approx. 1.5 µF as with the 'golden' sample. This resulted in a ripple signal at 15 V, which in turn led to an undervoltage at the IPM driver power supply and poor MOSFET commutation, which ultimately resulted in an overcurrent at the motor windings.

It turned out that the capacitor manufacturer had used two different raw material mixtures to maintain the reliability of supply. At 14.5 V, one mixture displayed values of approx. 1 µF, the other approx. 1.5 µF; in other words, both met the characteristic data (Fig. 3 and 4). The customer's argument was made by basing his sample on the components with the higher values without examining the reason for the difference or taking into account the corresponding general diagram. The threshold value in the application was approx. 1.25 µF. Initially, the customer just happened to receive the components with lower DC bias. When the customer finally received the ones with the more pronounced DC bias, it manifested itself in misbehavior of the circuit.

Conclusion

The example shows that it is particularly important in shortage situations to know and consider the real requirements of the individual functions in an application and the behavior of the MLCCs. It is essential to note: Which actual voltage is necessary? Which temperatures need to be considered in practice? Where are the threshold values of the effective capacitance value? In case of doubt, developers should seek the advice of the capacitor manufacturer or the distributor, especially if there are relatively clear deviations from the characteristic data and diagrams, as these are not guaranteed in contrast to specification data.

In this case, in particular, it is recommendable to check in advance, using the DC bias curve of the capacitor, whether the capacitance is acceptable for the actual operating voltage. If this is not the case, capacitance loss can be minimized in three ways:

1. Through parallel connection of two or more capacitors with a lower capacitance value

2. Through selection of a capacitor with a higher nominal voltage

3. Through a capacitor with a larger package.

All three methods usually have thicker dielectric layers that help minimize capacitance loss due to DC bias. This avoids technical problems and provides developers with more alternatives to choose from. ■

Water-based electrolytic capacitors

From plague to indispensable component

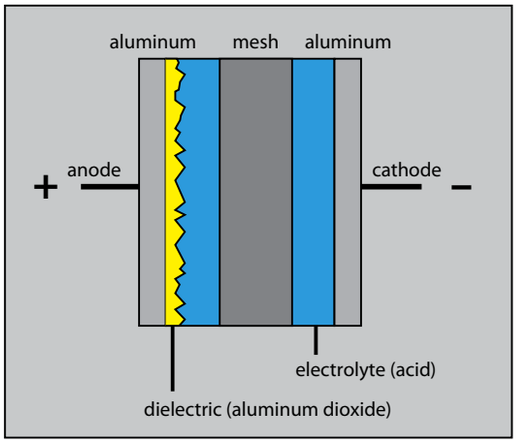
Water-based electrolytic capacitors have had a bad image ever since the well-known "capacitor plague". And wrongly so, because they now meet key requirements in modern-day electronics – and there are new alternatives in the form of polymer hybrid capacitors.

By Christian Kasper,
Technical Support
Electrolytic & Polymer Capacitors,
Rutronik

At the beginning of this century, water-based electrolytic capacitors were often manufactured with the wrong blend of inhibitors or passivators. The result was electrolytic capacitors with an open vent, a pushed-out rubber plug or components fully destroyed by an explosion - the so-called "capacitor plague". These problems no longer exist. Understanding the advantages of these capacitors and their benefits for modern-day electronics requires fundamental knowledge of the components.

How does an electrolytic capacitor work?

Compared to other capacitor technologies, the aluminum electrolytic capacitor offers a major advantage: an attractive value-for-money option guaranteeing high capacitance in the smallest of spaces. Moreover, it is insensitive to overvoltage, a fact underlined in the data sheet by the surge voltage. Disadvantages are its higher impedance, a tendency to dry out over time, a strong impedance increase at low temperatures, and its dependency on the operating temperature. This is determined by the stipulated component parameters, which in turn are defined by the electrolyte used.



Credit all pictures: Rutronik

Design of an electrolytic capacitor

An electrolytic capacitor with a liquid electrolyte (or e-cap) essentially consists of two strips of aluminum foil separated by a separator paper. The effective contact area of the anode foil is enlarged by electrochemical

etching. When applying voltage (forming), a thin layer of aluminum oxide develops on the surface which acts as the dielectric. The liquid or solid electrolyte forms the cathode, which is contacted to the outside via the second aluminum foil. Both aluminum foils are stitched together at the intended point and then wound together with the separator paper and soaked in a liquid electrolyte for impregnation purposes. Finally, a rubber plug seals the capacitor can with the impregnated winding. When designing the capacitor, the subsequent ESR (equivalent series resistance) is determined by the stitching, the electrolyte used, and the separator paper.

Comparison of electrolytes

Various liquid electrolytes are used in electrolytic capacitors today. Electrolytes containing ethylene glycol (EG) or boric acid are used mainly in medium to high-voltage electrolytic capacitors at temperatures of up to 85°C. In this case, the water content in the electrolyte is approx. 5-20% and inhibitors (chemical inhibitors) are used to prevent the aluminum oxide layer being negatively impacted by the water.

Organic electrolytes such as dimethylformamide (DMF), γ-Butyrolactone (GBL), and dimethylacetamide (DMA) allow for a wide temperature range from –55 to +150°C. They have stable parameters, such as low leakage currents and good long-term properties, thus enabling long operating periods. Their water content is extremely low.

The water content of aqueous electrolytes can be up to 70%. This high concentration offers advantages: Water with a permittivity (dielectric conductivity) of ε = 81 has the excellent property of binding an extremely large number of salt ions. This results in outstanding conductivity, which is reflected in an extremely low ESR. Conversely, significantly higher ripple currents can be achieved than with conventional, almost water-free electrolytes. In addition, the material costs of the electrolyte filling are significantly lower due to the high water content.

They, nevertheless, also have a major disadvantage, as water reacts through hydration when in direct contact with aluminum. However, the robust aluminum oxide layer protects the aluminum. To prevent hydration or corrosion even in case of a damaged layer, e.g. due to a production error or prolonged storage, inhibitors or passivators are added to the electrolyte. If this step is not taken, a significant amount of heat and gas (hydrogen) can form when water and aluminum come into contact. The capacitors will be damaged considerably and can even explode in extreme cases.

Even today, component specifications still state that water-based electrolytic capacitors should never be used. However, this specification is not specifically defined, e.g. by the maximum permissible water content. In addition, the negative effect of adding additives is no longer present, making the capacitors ideal for applications with a long service life or high load factors. Electrolytes with a higher water content are frequently found in today's low ESR types with high ripple current resistance and a service life of at least 10,000h at 105°C.

Special hybrid type with polymer

If the primary goal is not simply capacitance but a very low ESR, a liquid electrolyte can be partially or completely replaced by a conductive polymer. These hybrid types are fully AEC-Q200 certified. They combine the liquid, anhydrous electrolyte with the high conductivity of a solid polymer. For this purpose, the liquid electrolyte is also partially polymer based. The aluminum oxide layer and the opposite cathode foil are coated with a conductive polymer, which is subsequently present in the capacitor as a solid state medium. The high conductivity of the polymer significantly improves the contact resistance of aluminum oxide to liquid electrolyte and to cathode foil.

The result: A very low ESR and the possibility of high ripple currents. The improved ESR reduces self-heating during operation, while the solid polymer reduces the proportion of liquid components that can dry out. This is why hybrid electrolytic capacitors have a significantly longer basic service life than the water-based low-ESR standard variants. As with the standard type, the Arrhenius formula (–10°C temperature = double the service life) is used as a rough guide to estimate the service life at various temperatures.

Particularly important when designing hybrid capacitors in the circuit is their behavior with regard to service life, frequency, and temperature curve, which is completely different to the previous one due to the new electrolytes. While the ESR increases with an electrolytic capacitor in the negative temperature range and during its service life, it behaves absolutely stable with hybrid types. Further, strong dependence of the capacitance on the frequency is not given with hybrid capacitors, as there is hardly a change up to 100 kHz here. An electrolytic capacitor, on the other hand, breaks down by at least 40% at 20 kHz.

In nominal terms, it is possible to reduce the overall capacitance significantly while still improving its efficiency when designing a circuit with hybrid capacitors. Miniaturization is also possible, as hybrid technology enables higher ripple currents in a smaller structural shape.

Solid polymer with even better properties

Solid-polymer electrolytic capacitors can be used if you want to do without a liquid part

Electrolytic capacitor with open valve and leaked electrolyte

completely. In this case, the liquid component is replaced by a solid, conductive polymer. This leads to an even better ESR and ripple current while eliminating the possibility of drying out. The service life can be roughly stated as a –20°C temperature = 10 times the service life.

The disadvantages are the price, a considerably higher leakage current, and moisture sensitivity. As the solid polymer attracts moisture, the components are supplied in dry packs and are subject to strict processing requirements as soon as they are opened. These types are only available with AEC-Q200 certification in exceptional cases. In addition, this technology always requires a decision between voltage and capacitance in terms of the actual structural shape. A good mixture, as is possible with electrolytic capacitors or with the hybrid type, cannot be achieved to the same extent here due to the solid electrolytes.

In addition, the residual current is more pronounced in the solid types than in the hybrid ones, since free oxygen is missing for self-healing of the production-related defects in the dielectric. The liquid electrolyte of the hybrid type contains oxygen, which enables self-healing and keeps the residual current at the level of standard electrolytic capacitors. In addition, the solid electrolyte does not completely penetrate every pore of the etched aluminum foil. This has a negative effect on the achievable capacitance and at the same time increases the leakage current. In terms of stability of frequency, temperature, and service life, solid-polymer electrolytic capacitors are on a par with hybrid capacitors.

Conclusion

With increasing requirements being placed on ESR, structural shape, long-term stability, and component price, water-based electrolytic capacitors have become indispensable. If the technology fails to meet your needs, polymer capacitors offer you an alternative. The hybrid variants, in particular, represent an excellent compromise between performance and price and are subject to constant further development by suppliers. In terms of miniaturization and efficiency, they offer new options for designing the circuit. ■

Polymer hybrid capacitors

Tapping into expertise at its source

Polymer hybrid capacitors resemble each other like two drops of water – at least when you look at the data sheets. To find the optimum component, it is therefore advisable to draw on the know-how of manufacturers and distributors. Because there definitely are differences.

By Christian Kasper,
Technical Support
Electrolytic & Polymer Capacitors,
Rutronik

Polymer hybrid capacitors are characterized by their stability in extreme conditions, long service life, low equivalent series resistance (ESR), a specification option of up to 165°C, and certification to AEC-Q200. Due to these properties, they are now used in numerous applications, including in cars, for instance in electric control units (ECU) for oil or water pumps, cooling fans and electric power steering (EPS) systems. Nonetheless, care must be taken when selecting

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	Rated Area					Extended Area	
	Irms @100kHz (A)						
Case temperature °C	0	1	2	3	4	5	6
40	1900000	1800000	1700000	1600000	1500000	1400000	1250000
60	500000	483000	455000	420000	387000	345000	308000
80	125000	120000	109000	104000	94000	87000	78000
90	62000	59000	56000	52000	47000	42000	38000
105	21000	20000	19500	17800	17000	15000	13900
125	5500	5200	5000	4600	4200	3800	3400
145	1300	1250	1150	1100	950	900	850

Figure 1: The lifetime table shows the service life of a polymer hybrid capacitor at different temperatures and currents.

the appropriate capacitor: The data sheets of manufacturers all look roughly the same and it is impossible to detect any subtle differences. They do exist however – but are only shown through testing.

Generally speaking, the production processes for polymer hybrid capacitors are patented. In addition to differences in production, manufacturers choose to use varying raw materials, for example different polymer compositions both in terms of their quantity and substances. The ERS behavior of capacitors may, therefore, vary in a range of 10kHz or 20kHz for automotive applications, although this does not differ at all according to the respective data sheet. There are differences between the components of various manufacturers also in the negative temperature range. It is therefore worthwhile to utilize the know-how of the manufacturer or a "neutral" distributor.

Arrhenius formula

A key aspect is, for instance, the life expectancy of the hybrid capacitor. To determine it, developers like to use the well-known Arrhenius formula. To do so, they require the service life specified by the manufacturer Lb, the maximum temperature Tmax, the temperature rise ΔT0 (6K, maximum permissible value, may vary according to the series and manufacturer) when the ripple current is applied, and the

$$L = L_b \times 2^{\frac{T\max + \Delta To - Tc}{10}}$$

surface temperature of the capacitor Tc during application. The life expectancy is thus calculated as follows:

However, the formula does not do justice to the technology of polymer hybrid capacitors. This is because it roughly describes a quantitative temperature dependence and has the disadvantage that the impact of the ripple current on the capacitor is not taken into account sufficiently, since only the maximum scenario is assumed. Nonetheless, self-heating caused by the ripple current has a significant influence on the service life of the capacitor. In addition, ripple currents in the real application rarely remain constant at any temperature over the entire service life. Working as precisely as possible and using the manufacturer's or expert's know-how in the service life calculation are therefore key to delivering an effective design.

More precise data and certain specific values are not available online or in the data sheet but exclusively from the actual manufacturer. Based on this know-how, available formulas, and in-house measurement data, the manufacturer calculates the service life. In addition, the manufacturer analyzes the greatest possible load on the capacitor and passes this information on to customers for comprehensibility. This provides the customer with a list of which model is best suited for the respective application, which quantity is ideal – e.g. for a parallel circuit – and how long the capacitor will last under the given conditions. After all, this is also the manufacturer guarantee.

Lifetime table and mission profile

In the so-called lifetime tables, manufacturers list the varying values from the test results. This can be used to determine how the service life of the respective circuit can be maximized through the parameters package temperature and ripple current at 100kHz. If a temperature of 125°C at 2A is assumed on the basis of the fictitious lifetime table (Fig. 1), for example, the service life is 5,000 hours. At 145°C and 6A, the capacitor would achieve a service life of 850 hours. The rated area refers to the range determined by measurement results, while the extended area refers to extrapolations based on the measurement results.

The lifetime tables of the manufacturers show that in practice significantly higher values are possible than those stipulated in the data sheet and create confidence in the technology of polymer hybrid capacitors.

A mission profile (Fig. 2) describes the stresses and strains to which a capacitor is exposed in real life use. These include, for example, the changing ambient and operating temperatures, the load duration, and the measured ripple current at a specific frequency. The measurement of such a mission profile costs valuable time in development but is worthwhile if the circuit can be designed more efficiently and the manufacturer confirms, for instance, three instead of four capacitors in the parallel circuit. This obviously provides customers with precise information on the reliability of the capacitor in the respective application.

Overload test for components

In addition, manufacturers carry out overload tests and incorporate the respective findings into their calculations. Seeing as the technology is less than ten years old and thus still relatively new, these tests represent an important source of information for manufac-

Capacitor p/n	35 RX30 220 M[redacted]10X16	
Lifetime	2000	hrs at 125°C
Ripple	1.3	Arms at 125°C/100kHz
Delta Ts	5	°C
ESR	0.067	ohm at 20°C/100kHz
ESR	0.4	ohm at -40°C/40kHz (Typical value)
Capacitor number	1	pcs

Lifetime calculation

Ambient Temperature (°C)	Time (hrs)	RMS current (Arms at 40kHz)	RMS current (Arms/pcs)	*delta Tj (°C)	Lifetime (hrs)	Consumption rate (%)
-40	25	0.87	0.87	2.2	788823.5	0.003
20	25	0.87	0.87	2.2	788823.5	0.003
0	100	0.87	0.87	2.2	788823.5	0.013
100	5438	0.48	0.48	0.7	16023.1	33.9
120	1863	0.48	0.48	0.7	4005.8	46.5
	7451				Total	80.5

*delta Tj : Heat rise at capacitor's core by ripple current.
*Under 40degC condition is regarded as 40degC for lifetime calculation.

Figure 2: The mission profile enables the calculation of the lifetime of the capacitor.

turers regarding the quality and further development of capacitors.

For a test, for example, a 25V capacitor in a 10mmx10mm design, which is specified for 2A ripple current, 100kHz, 20mΩ ESR, and 4,000h at 125°C ambient temperature, was exposed to considerably higher ripple currents. This was carried out at two locations at a constant ambient temperature of 125°C using 200 components at each site. When testing with 6A, i.e. a triple overload, the capacitors achieved over 19,000 hours and operated for even longer. The capacitance drift stabilized at approx. -18%, while the end-of-life definition is -30% according to the data sheet. The ESR remained constant (start at 18mΩ, data sheet value of 20mΩ, leveled off at approx. 22mΩ).

The experts at Rutronik came to a similar conclusion: The ESR did not change even when capacitors were frozen to -55°C. For this purpose, the product marketing engineers cooperated with the laboratory engineers at RUTRONIK to develop a portable demonstration tool that freezes a Low ESR SMD capacitor and a polymer hybrid capacitor within a few seconds while constantly measuring the ESR. It can be observed live how the ESR of the polymer hybrid capacitor remains absolutely stable while that of the electrolytic capacitor increases more than five times.

At the highest overload of 14A per capacitor, which corresponds to a core temperature of roughly 150°C in the capacitor, only one of the four lots failed in the test after 4,300 hours. However, the reason for this was not the technology itself: The heat led to the rubber stopper becoming porous. To eliminate this weak point, manufacturers are already looking for other sealing mechanisms and new designs.

Such tests show that the possibilities of hybrid technology are far from exhausted. All manufacturers are still working hard to further optimize their polymer hybrid capacitors, thereby maximizing performance. The aim is to achieve higher capacities, voltages, and temperatures over a longer service life as well as further SMD cap dimensions to deliver greater miniaturization under higher loads.

It is already often worth replacing other types of capacitor with a polymer hybrid capacitor. For example, if two or even three aluminum electrolytic capacitors in a circuit can be replaced with a hybrid model, it equates to significant savings in terms of size, installation height, and PCB space. In addition, due to its specific properties, the hybrid guarantees greater stability than the aluminum electrolytic capacitor with regard to increasing ESR, drift during the service life, frequency, and temperature as well as changes in capacitance.

Capacitance	470µF		150µF
Size	18x25 (63.6cm³)	-75%	10x20 (15.7cm³)
ESR (20°C)	43mΩ/10kHz	Lower ESR	12mΩ/10kHz (measured value)
Ripple[1] (Tc=125°C)	11.1Arms/10kHz	Same Ripple	12.0Arms/100kHz
Useful life (125°C)	4000 hours		4000 hours

[1] Maximum ripple current at 125°C capacitor case temperature Tc (measured at case surface), when mounted to a heat sink

Figure 3: Example of the replacement of axial capacitors with polymer hybrid capacitors: The reduction in space, weight, and costs is clearly visible.

Replacing capacitors in a circuit

In one specific application, for instance, axial capacitors could be replaced (Fig. 3). The actual choice was between a traditional axial aluminum electrolytic capacitor and the hybrid capacitor, both with a leaded design. The ripple current for each cap was similar for both, only the total capacitance of the hybrid was lower. This factor occurs in most polymer hybrid capacitor solutions but does not usually affect how they work in the circuit. Since the use of these capacitors is defined by the ESR and ripple current, a range in which even large axial or SolderStar capacitors have strengths but also demonstrate the typical weaknesses of aluminum electro-

lytic capacitors. Apart from this fact, the hybrid capacitor required much less installation space, had a significantly lower ESR, and provided stability during its entire service life. Besides space and weight savings in the circuit, the hybrid capacitor also ensured cost savings.

Customers who also want to benefit from this should utilize the know-how of manufacturers and, in particular, that of the experts at Rutronik, who are able to assess the technology from a neutral viewpoint. The FAE team supports developers on-site in their selection by providing manufacturer-independent advice on products and technology. To guarantee the ideal circuit design, Rutronik is the intermediary with direct contact to the various experts employed by the manufacturers.

Operational amplifiers

EMI immunity reduces RF disturbances

Operational amplifiers must offer the best performance and work reliably even in harsh operating environments. Therefore, stray high-frequency interference radiation and the resulting unwanted DC offset in operational amplifiers must be reduced. But how is this achieved?

By Thomas Bolz,
Product Sales Manager Analog,
Rutronik

The immunity of systems with analog signal processing to radiated high-frequency radio signals has become an important design criterion and is nowadays just as relevant as PSRR (power supply rejection ratio), CMRR (common mode rejection ratio), THD+N (total harmonic distortion plus noise), and SNR (signal to noise ratio). Since interference radiation is constantly increasing – a glance at the everyday environment in which systems and devices operate is sufficient: Bluetooth connections are increasingly replacing serial cable connections for headsets and microphones in audio equipment.

WLAN, using the IEEE 802.11b/g protocol, is integrated as standard in laptops, tablets, and PCs, as the 2.4 GHz band can be used without the need for a license in most countries. A

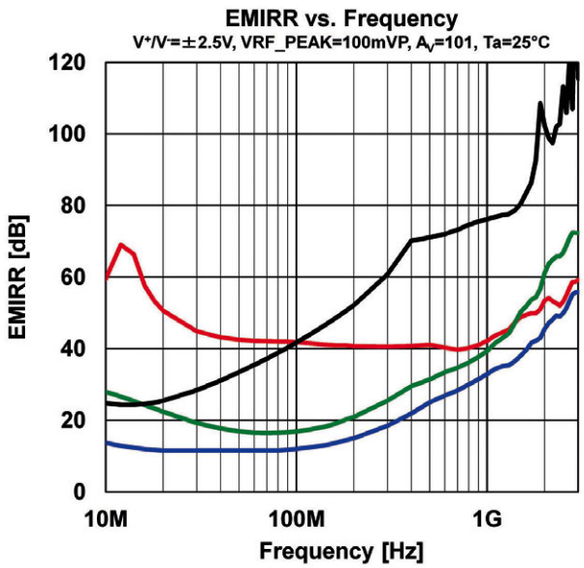


Figure 1: At 1.8 GHz, the NJU7755X from NJR (blue) delivers a 40 dB better EMIRR value than comparable products.

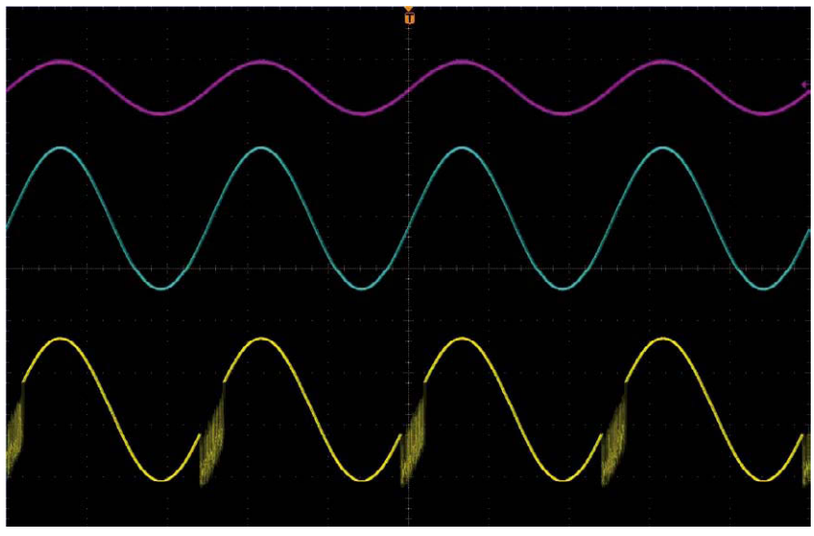


Figure 2: At a radiation of 1.8 GHz, the offset caused by this decreases without any glitches (transient voltage peaks). Upper characteristics (violet): Input signal. Middle characteristics (blue): Output signal of the NJU7755X. Lower characteristics (yellow): Industry standard product shows glitches.

Credit all pictures: NJR

popular variant is the IEEE 802.11a specification with transfer rates of up to 54 Mbit/s in the 5 GHz band.

This also adds to the requirements placed on developers with regard to RF immunity of current op-amp (operational amplifier) designs. They must be able to provide excellent values in terms of EMI strength. This is essentially achieved by equipping op-amps with active filters. Moreover, efficient common mode rejection also combats in-phase RF noise voltages present at both inputs of the amplifier. In this context, each supplier relies on its own processes.

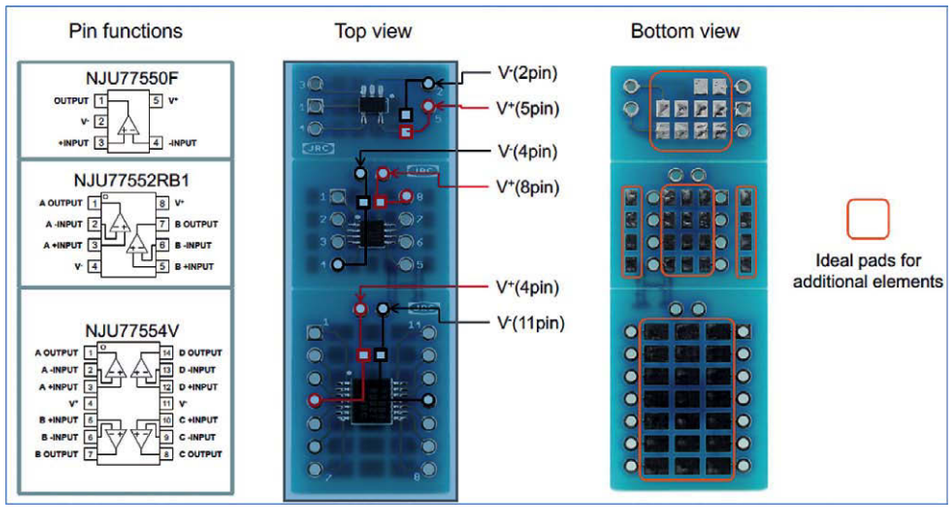


Figure 3: Connection assignment of the NJU7755X

EMI effects

A typical mobile radio device as an EMI generator can emit radiation with a field strength of up to 100 V/m (peak value) in a range of 1.8 to 2.0 GHz, measured at various distances and orientations. Even if these signals are way outside the bandwidth of an operational amplifier affected, they can still induce RF disturbances in this amplifier. Since the RF signals are rectified at the amplifier input via electrostatic discharge diodes (ESD) and other non-linear switching elements. These RF signals converted into a DC offset voltage add up to the input offset of the op-amps. This causes a shift in the DC offset at the output of the amplifier depending on the interference radiation.

EMI disturbances penetrate a system as radiation or via conduction. They then propagate via the conductors on the PCB and the connections of the components – including the op-amps. The physical length of these conductor sections can turn them into effective antennas for high-frequency disturbances.

An example is a 2.4 GHz WLAN disturbance source: At this frequency, a conductor length of 3 cm corresponds to a quarter of the corresponding wavelength and thus forms a very effective antenna as part of a dipole. For other frequencies, this can be easily converted according to the formula

$l = c / (4 \cdot f)$

l = length in m, $c = 3 \cdot 10^8$ m/s, f = frequency in Hz

A practical indication for the design of data devices is therefore: The conductor sections for inputs and outputs, bias voltages, and power supplies should be shorter than 1/4 of the wavelength of the interfering RF signals.

The meaning of the EMIRR characteristics

The EMIRR value (EMI rejection ratio), expressed in decibels, is one of the most important parameters for identifying the EMI immunity of an op-amp:

$EMIRR = 20 \log (U_{RF,peak}/|\Delta U_{IO}|)$ dB

$U_{RF,peak}$: Peak value of the RF voltage applied to the input

ΔU_{IO}: DC offset shift in the output due to the RF voltage

When aiming to achieve the best EMI performance of an applied operational amplifier, you only need to look at its EMIRR characteristics. A comparison with the EMIRR curves of other products provides the most suitable op-amp for the application in question.

In the respect, the Japanese supplier New Japan Radio (NJR) has launched a highly developed op-amp product: The broadband rail-to-rail input/output operational amplifiers of the NJU7755X series feature high immunity to radiated RF signals, which NJR has exclusively protected with three patents.

Compared to other op-amp products on the market, the NJU7755X series delivers a 40 dB better EMIRR value at 1.8 GHz and a smooth

Standards for EMI tests

The severity of the performance losses of op-amps caused by radiation or conducted RF disturbances is shown by the extremely detailed specification of the globally introduced standards for testing and measurement techniques for electromagnetic compatibility (EMC) and immunity to disturbances.

In Germany, the measurement of conducted EMI disturbances is defined according to EN 61000-4-6 (in accordance with the identical IEC standard) in the frequency range of 150 kHz to 80 MHz. The standard EN 61000-4-3 applies to radiated EMI fields between 80 MHz and 6 GHz.

The testing and measurement techniques in accordance with DIN EN 61000-4-39 apply to radiated fields in close proximity (over distances of less than 500 mm for frequencies <26 MHz, or 200 mm for frequencies >26 MHz). They concern the immunity of electrical and electronic equipment, devices, and facilities at frequencies between 9 kHz and 6 GHz. This includes the use of cellphones and RFID systems in the near field of devices affected by interference radiation.

waveform without glitches, i.e. without transient voltage peaks (Figures 1 and 2).

Features of the NJU7755X op-amp series

The NJU7755X is available as a high-efficiency op-amp in four versions with single, dual or quad input/output. With a gain bandwidth product of 1.7 MHz, the new op-amps offer a sufficiently wide bandwidth for numerous applications.

Current consumption is 50 µA per channel. This makes the op-amp ideal for battery-driven low power applications. In addition, there is a slew rate of 0.8 V/µs and a voltage noise of only 24 nV/√Hz.

With its rail-to-rail characteristics, the op-amp targets a wide range of applications, including audio amplification, low-side current measurement, active filters, buffer circuits, and much more. Thanks to the low input bias current, the NJU7755X series is ideal for photodiode amplifiers, piezoelectric sensors, smoke detectors, and other applications where high input impedances are required.

The operating voltage range covers 1.8 to 5.5 V, wherein the overvoltage protection allows input voltages to exceed the positive supply voltage (+5.5 V). This definitely pays off in robust industrial applications. This overvoltage resistance of 5.5 V also applies to a 1.8 V single supply voltage supply.

Operating temperatures range from –55 to +125°C. ■

3D NAND flash architectures

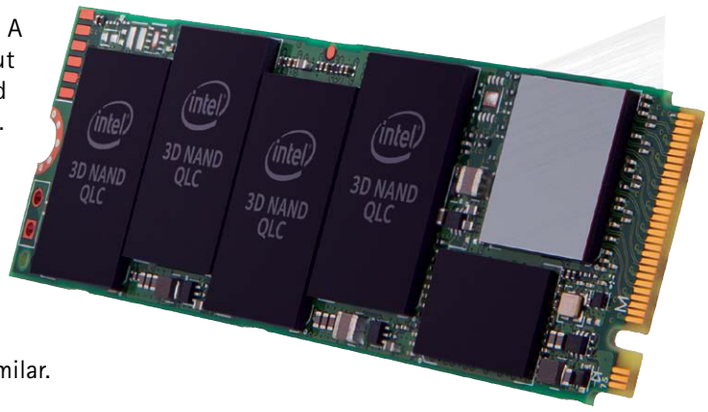
Triple level cell is followed by quadruple level cell

3D NAND flash is about to make a breakthrough. The new memory technology has made enormous progress in recent years and offers an interesting alternative to the established 2D NAND memories used in SSDs. Next-gen memory architectures, such as QLC NAND, show the direction of development.

Conventional 2D NAND flash is impressive due to its extremely fast access times, low latencies, energy efficiency, robustness, and small form factors. The greatest technical advances were aimed at reducing costs through structural downsizing. However, a physical limit has now been reached at 15 nanometers. Even smaller structures would lead to more errors when reading out data and to endurance and data retention being reduced – ultimately the long-term "integrity" of the data would not be guaranteed. Innovations are, therefore, going in the direction of three-dimensional NAND (3D NAND) and increasing the number of bits on a cell.

Current solutions: Charge trapping and floating gate

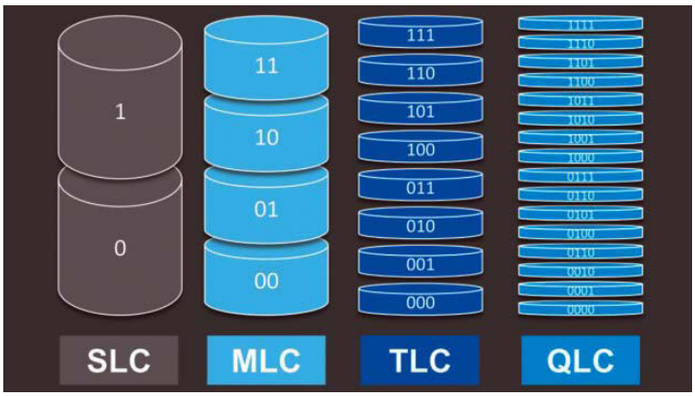
With a 3D NAND flash memory, multiple layers of flash cells are stacked – similar to a high-rise building, thereby enhancing the capacity significantly. A simple comparison, but the technology behind it is far more complex. Today, two approaches have become standard: Floating gate and charge trap. Although they differ completely in the way they are manufactured, the idea is similar.



Intel's first QLC-based SSD is the Intel 660p.

With the floating gate method, the charges are stored with a floating gate on an electronically isolated gate between the channel and the control gate. In the charge trap approach, on the other hand, the charges are held at trapping centers, a silicon nitride layer that is separated from the channel by a thin tunnel oxide layer. In both cases, the defined CG layers are selected via the lines of the control gate or the wordline (WL). The string is selected via bitlines (BLs).

The 3D NAND memory technology offers numerous advantages for suppliers and customers alike. The higher memory density ensures that flash suppliers can produce greater capacities and more gigabytes per silicon wafer at similar rates of yield. Customers benefit from a noticeable reduction in price while enjoying the same shelf life.



Overview of the different NAND flash technologies and their possible states per memory cell

However, a supplier has yet to unveil a 3D NAND product with high temperature resistance, as is often required in industry. The first 3D NAND products that are suitable for industrial temperatures should be launched in 2019.

QLC NAND flash

Increased memory density is not only achieved by stacking memory cells but also by increasing the capacity of the actual cells. When NAND technology was first introduced, only the single level cell (SLC) architecture was available. In other words, one bit could be stored per memory cell. The multi level cell (MLC) and the triple level cell (TLC), which can store two or three bits respectively, were subsequently added. Now, QLC NAND flash, the next generation of 3D NAND architectures, is just around the corner. QLC stands for "quadruple level cell" or "quad level cell" and thus for four bits per cell. This architecture currently enables up to 96 layers. The fourth generation from Micron and the fifth generation from Samsung, SK Hynix, and Toshiba should allow up to 128 layers.

More capacity, lower shelf life

The major advantage of the QLC flash is the considerably higher memory density and thus greater capacity. As a result, smaller footprints are possible, data racks can be up to 7.7x smaller than when using HDDs, thereby saving valuable space in data centers.

Nonetheless, the QLC architecture also displays certain weaknesses. There are 16 different voltages per memory cell, which makes writing data a more complex and slower task. Furthermore, the reliability of the memory decreases. The validation of individual bits is more demanding and the cells degrade over several write cycles, making it difficult to determine individual bit values. This may result in data errors. ECC (error correction code) is helpful in this case but not sufficient to compensate for this effect. This also negatively impacts the shelf life of the QLC memories: With 500 to 1,500 P/E cycles (program/erase, write and erase cycles), it is significantly lower than with a 3D TLC architecture and substantially lower than with an SLC architecture.

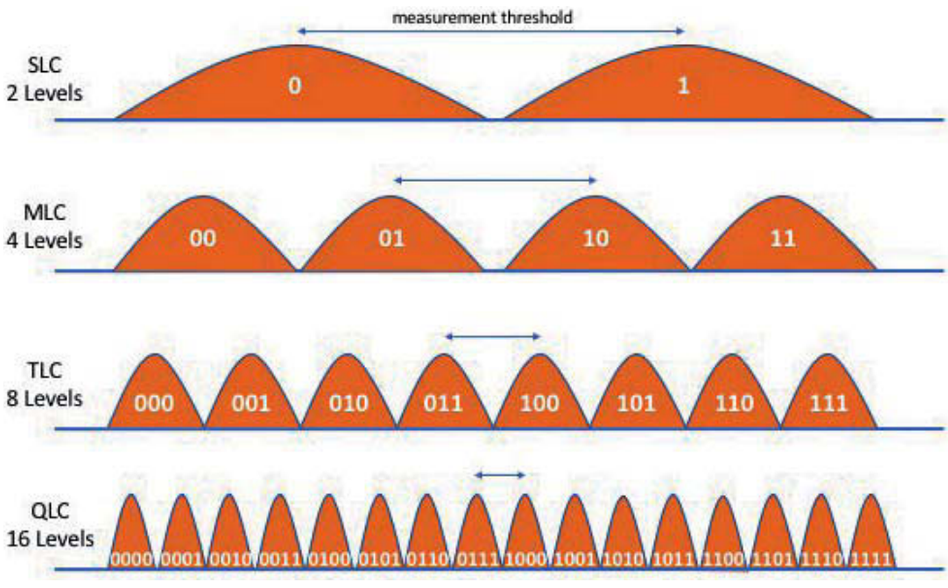
Ready for big data applications

Nevertheless, the use of QLC flash is recommendable in many areas of application.Due to the low P/E cycles, the memories are primarily designed for read operations (90%+). QLC memories can be used wherever large amounts of data need to be read quickly, but only a few write processes are required. This includes, for example, real-time analyses of big data, data inputs for artificial intelligences, the provision of media for on-demand services, NoSQL databases, and user authentication. For these types of application, the TCO (total cost of ownership) is also significantly lower than with HDDs, as the total number of memory units required is much lower, less power is consumed, and more IOPS are processed. Due to the high memory density, applications in the embedded and mobile market are also conceivable.

The first QLC-SSD

In cooperation with Intel, Micron has launched the first product with QLC: The Enterprise SSD series 5210 ION, which is based on SATA. The SSD uses four bits per cell with a total of 64 cell layers. Between 1.92 and 7.68 terabytes can be stored on just 2.5 inches. The sequential data rates are about 500 Mbit/s for reading and 340 Mbit/s for writing. The 5210 ION series is basically designed to meet the demands of reading-intensive clouds.

With the third generation of 3D NAND memories that is still under development, Micron wants to offer the highest density of gigabit per millimeter with a total of 96 layers. Other suppliers will soon also be in a position to launch their first QLC solutions: Intel, which now develops its own 3D NAND memory independently of Micron, recently announced the production of the first PCIe-based QLC SSD and Toshiba Memory plans to start mass production of the BiCS4 QLC NAND in 2019. As a partner of Apcacer, Intel, Swissbit, Toshiba, Transcend, and Wilk, Rutronik is in close contact with the leading suppliers of data memories. The Rutronik Storage Team provides developers and purchasers with comprehensive support and advice when selecting the right memory technology. ■



Graphical display of voltage levels depending on NAND Flash technology and the possible states per memory cell

OTA updates in the automotive area

Smart updates for smart vehicles

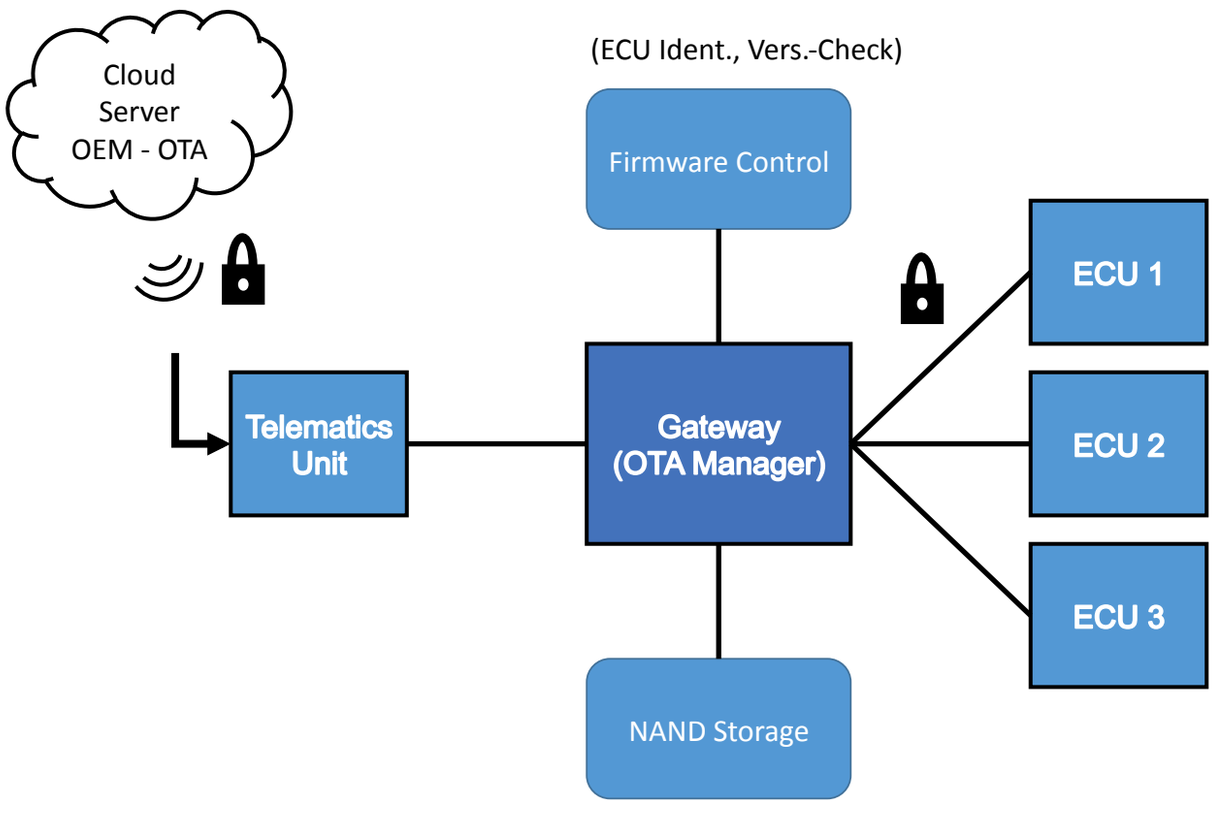
Regular updates of firmware and software also increase the level of functionality, security, and safety in cars. The problem: Vehicles usually have to be taken to a workshop for updates. Over-the-air updates should put an end to this. Similar to smartphones, customers can flexibly upload the latest builds anytime, anywhere.

By Bernd Wondratschek,
Field Application Engineer
Automotive Business Group,
Rutronik

Over-the-air (OTA) means that updates for firmware and software are no longer performed via cable but wirelessly. This can be achieved using various radio standards, including cellular radio and WLAN, but Bluetooth and NFC are also conceivable, for example, at charging stations. In a car, the updates affect the engine control units (ECUs) and the infotainment system. While updates for engine control units usually close security gaps and improve performance, an updated infotainment system contributes to enhanced comfort and personalized use.

As more and more new vehicles come to the market place with software-intensive ECUs, software maintenance requirements will also increase: According to a study by the US National Highway Traffic Safety Administration (NHTSA), 15% of all vehicle safety recalls in the USA in 2015 were down to software errors. The elimination of such errors is much more complex for vehicles than it is for smartphones, for example. If a bug or critical vulnerability related to the software is detected in the vehicle, it needs to be repaired in a specialist workshop. This is the only place where experts are able to provide updates from the

Credit: Rutronik



Presentation of the OTA process in a car

software suppliers, usually OEMs, via a cable connection. This not only costs time and frays nerves but is also fairly expensive for the OEM.

Prerequisite: Networked vehicles

Cellular radio equipment is the key feature to enable OTA updates for ever smarter vehicles. An important milestone for establishing cellular radio in cars is the "eCall" regulation of the EU: All new vehicle models in the European Union have been fitted with the "emergency call function" since March 2018. This special function automatically calls the emergency services, using the European emergency number 112, in case of an accident, but also offers vehicle suppliers a basic option for communication via OTA. Therefore, costs can be saved and money possibly made, as the OTA interface enables new functions and applications – if the hardware permits it – to be purchased and activated via an app store.

The advantages of OTA updates are wide ranging: Users no longer have to visit a workshop for updates and benefit from the latest software and firmware and related improvements, as well as constantly updated maps and new apps. Suppliers can gain more knowledge about vehicle users and vehicle configurations, avoid the costs of software-related recalls, and ensure their vehicles are much safer.

Transfer and distribution

The aim of the OTA method is to replace the transfer of updates via a cable, which has to be performed in a workshop, with a mobile connection between the OEM's server and the vehicle's telematics unit. However, the "eCall" system is not suitable for this, as it cannot transfer data except for emergency calls. The vehicle therefore either requires a separate SIM card or must access a connection via a smartphone hotspot or WLAN network. If a connection has been established, the OTA Manager, which acts as the gateway, can initiate the update process.

Essential: Safety and security

In addition to the many advantages, OTA updates also present a considerable risk potential. It is essential to protect the transfer of the data packets; otherwise, third parties may gain access to important vehicle functions or data.

Safety and security are therefore essential aspects for the success of OTA. Security describes how secure the transfer route is, while safety refers to the safe implementation of the update process. Security includes securing the transfer route using various mechanisms such as TLS (SSL transmission), HTTPS, user identification, VPN, and E2EE. If these are not secured sufficiently, man-in-the-middle attacks, electrical system spoofing, theft of intellectual property, spying on the driver or even the shutdown or manipulation of vehicle functions may occur.

Storage and execution of the update are generally relevant in terms of safety. To prevent manipulation of the software and to ensure the authenticity and integrity of the data, the software package needs to be signed cryptographically. Within the hardware structure, a hardware security module (HSM) can assume this safety feature.

No annoying waiting for the installation of updates

There are also a few points to keep in mind when it comes to the time and duration of updates. The vehicle's ECUs can only receive updates in the safe state, i.e. when the engine is switched off. Furthermore, users do not want to have to wait for an update process before they can drive again. Therefore, the update process should take place as conveniently and inconspicuously as possible, thus avoiding longer vehicle downtime.

Possible solutions include the introduction of redundant memory systems in which both the new firmware and a back-up of the old firmware are stored. If the update process is not successful, the functionality of the vehicle is still maintained. A further measure is planned update processes that take place at a desired time, usually at night.

Name/Device	Smartphone	Car
(S)OTA	Update of the operating system (IOS, Android, etc.) – to close security gaps and to improve performance	Update of engine control units (ECUs) – to close security gaps and improve performance
	Installation of apps – to enable personalized use	Installation of apps and update of the infotainment system – to enable personalized use

Description of (S)OTA in a smartphone and car

To guarantee a faster upload, the size of the data packets should be as small as possible. The software size varies considerably between ECUs and infotainment systems: If the entire code has to be replaced, several gigabytes of data may be generated. This can be remedied, however, by compressing the data packets using delta coding. Instead of the entire software code, it only contains the changes to the old version. This reduces the amount of data to just a few hundred megabytes.

Possible solutions from Rutronik

Rutronik already offers a range of solutions to implement an OTA update of the vehicle, including cellular radio modules (BT, NFC, 3G, 4G, WiFi). In addition, security microcontrollers with integrated HSMs are available, including Infineon's AURIX family and the SPC58 family from ST Microelectronics, as well as security chips and chips for cellular network access from both suppliers.

From a software perspective, Rutronik also offers its customers solutions such as the cloud-based management software Telit IoT Portal. It is especially designed for the distribution of software to a large number of clients. The platform can be "branded" for different purposes and suppliers and enables individualized messages to be sent to clients. When using the "Geofence" function, the software transfer can be limited to a certain area and the normal limitations and typical staggers of a software roll-out are also provided.

Customers who utilize Rutronik's ever increasing portfolio are already prepared for a future with OTA updates. ■

Not all electric motors are the same

Controlling electric drives

Electric drives can be realized in many different ways. This article reveals what else is needed to bring the motor to the desired speed and keep it there.

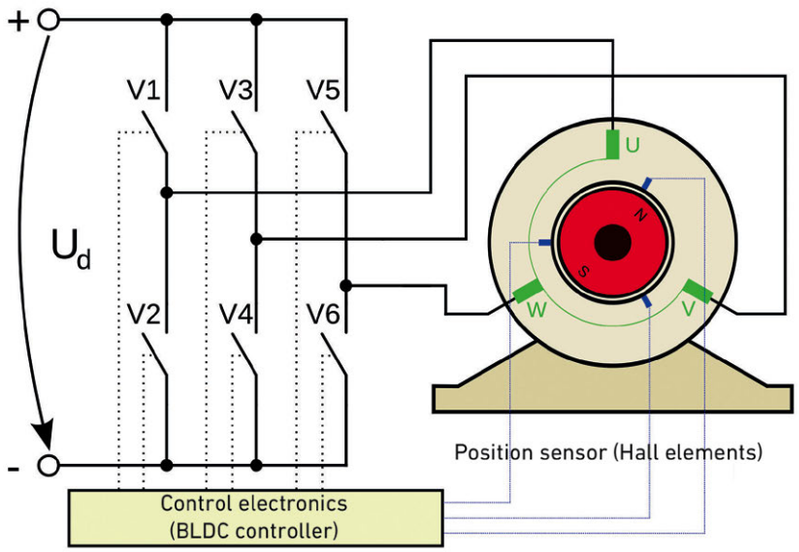
By Walter Hagner, Product Sales Manager Microcontroller, Rutronik

Electromobility is one of the hottest topics in the automotive industry right now due to the diesel emissions scandal. However, the idea of using clean electricity from renewable sources instead of internal combustion engines is not new: Streetcars, for example, were electrified at the end of the 19th century. In contrast, electromobility is just beginning its triumphant march on our highways and streets: Since July 2016, the German government has been subsidizing electric cars; with the target of bringing one million electric cars onto German roads by 2020. But not all electric motors are the same, and electric automobiles therefore differ greatly. There are many different drive concepts and microcontrollers ideally suited for each of these concepts.

Of all electric motors, the brush-commutated DC motor is the oldest and best-known one. In principle, this motor consists of a stator which generates a homogeneous magnetic field by means of a magnet. The rotor consists of a coil of wire through which a current flows, thus creating a dipole field like that of

a bar magnet. Due to the differing polarity, the rotor starts to rotate until the different poles are opposite each other and the movement comes to a standstill. In order for the rotor to rotate permanently, the commutator reverses the current direction every 180 degrees in the rotor coil. As a result, the polarity of the rotor magnet changes, meaning the magnetic polarities are now the same. The polarities therefore repel each other and the rotor continues to revolve. Steady turning of the rotor is thus achieved.

The minimal motor described here has just one pair of poles in the rotor, whereas the motors used in real-life scenarios have several pairs of poles. This distributes the stator field around the entire motor, ensuring smooth running of the rotor. This also has the advantage that the magnetic flux is higher, which leads to a higher torque that is also more "ripple-free" than the basic design with just one pair of poles.



Credit all pictures: Rutronik

Hall sensors on the coils tell the control electronics the position of the rotor.

Controlling the motor

Since the actual motor commutates entirely mechanically, it is very easy to control via the applied voltage, as the torque of the motor depends solely on the magnetic flux and this in turn depends on the current flowing through the rotor. This is best achieved through a PWM signal, which is output by a microcontroller that actuates a power transistor, for example. Ideally, this is done via an H-bridge consisting of four transistors, as this also allows the direction of rotation to be changed.

As stated at the beginning of this article, the stator field is generated by means of a magnet. Of course, it is also possible that this field is generated by coils that are supplied with power from a separate circuit by means of slip rings. This can, however, lead to higher flux densities and a higher torque.

Synchronous motor

The three-phase synchronous motor consists of three pairs of coils offset by 120 degrees in the stator and a permanently magnetized rotor. This can be achieved using permanent magnets or through electromagnetic independent excitation by means of a field coil on the rotor with current supplied via slip rings. After switching on the motor, the field in the stator immediately starts to rotate in relation to the applied three-phase voltage. However, since the rotor cannot instantaneously follow the rotational field due to its mechanical inertia, a starting aid is required that is implemented as a squirrel cage in the rotor. The motor therefore behaves as an asynchronous machine until rotating at synchronous speed. The excitation field in the rotor is now switched on and the motor runs synchronously with the stator rotational field.

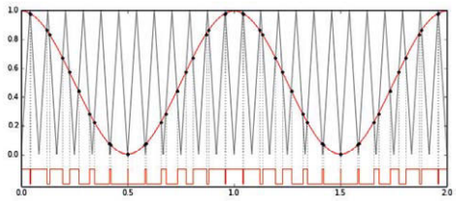
Normally there is no slip (i.e. the difference between the speed of the stator field and the speed of the rotor) with a synchronous motor. However, the rotor magnetic field follows the stator field under load. If the torque angle reaches 90 degrees, the rotor will pull out of synchronism and stop. The lack of brushes in this type of motor is a major advantage compared to a DC motor. This makes the motor much more resistant to wear, and EMC problems do not occur due to the lack of "brush sparking".

Controlling the motor

It is necessary to know the position of the rotor in order to adjust the motor speed when the load changes and in order to control a setpoint change in the speed. An easy way to do this is to attach Hall sensors to the motor coils which transfer the position to the controlling microcontroller. Recording the position without sensors is much more complex as only the currents in the individual phases and the back EMF, which are measured with fast A/D converters, are available as sensor elements. These are transferred to a mathematical model of the motor from which a microcontroller generates the PWM control signals for the six-fold motor bridge.

Since the motor expects sinusoidal control, but the motor bridge can only output pulse-width modulated signals, the sinus is simulated using a corresponding sequence of PWM pulses. A good value is 100 PWM pulses per cycle, as the low-pass effect of the motor coils smooths the pulses.

In order for the motor to run synchronously, the microcontroller must generate three PWM sequences offset by 120 degrees that simulate a sine wave, which requires high computing power of the microcontroller and a sophisticated timer unit for load and setpoint speed changes.



Generation of a sinusoidal signal with pulse width modulation

Asynchronous motor

The asynchronous motor has a very simple mechanical design: As with the synchronous motor, the stator contains three pairs of coils offset by 120 degrees. However, the rotor is a so-called squirrel-cage rotor, i.e. it consists of short-circuited conductors excited by the magnetic field supplied by the stator coils. As long as the rotor does not move synchronously with the stator field, voltage is not induced in the cage and there is no torque present.

When the rotor revolves slower than the stator field, the flux changes, inducing a voltage that leads to a current in the squirrel-cage rotor, which in turn produces a torque proportional to this so-called slip. Due to their simple design, these motors are widely used in drive technology.

If the speed of the motor is to be controlled digitally using a frequency converter, the principle is the same as with the synchronous motor, where the rotor position is determined via the phase currents and the back EMF. The control sequences for the motor output stage are then generated using a mathematical model that is calculated in the microcontroller.

BLDC motor

Although the motor is called a "brushless DC motor", it is not a DC motor but a three-phase synchronous machine, as it also contains three pairs of coils in the stator and the rotor is constructed with permanent magnets. As with the synchronous and asynchronous motors, the motor output stage is achieved through six transistors which are controlled by a microcontroller that generates the sequence.

This so-called commutation sequence consists of six blocks per revolution. Only two bridges are active at any one time, while the two transistors are open at the third bridge. For a better understanding, the individual commutation patterns are graphically illustrated.

If there are Hall sensors in the stator coils, as shown above, commutation is relatively simple, since the position of the rotor is known at all times. If no Hall sensors are available, the back EMF generated in the stator coils is normally evaluated. However, this does not work at very low speeds, as the induced voltage is too low and the pulse too wide to clearly identify the rotor position.

For some time now, methods have been known that are based on sending short test pulses that are too weak to move the rotor into the stator coils. Since the magnetic field of the rotor influences the inductance of the stator coils, the induced voltage (back EMF) can be traced back to the position of the rotor.

Implementation of the drive

The following components are now required to drive the motor: A powerful microcontroller that, in conjunction with a three-phase PWM

Commutation of a BLDC motor

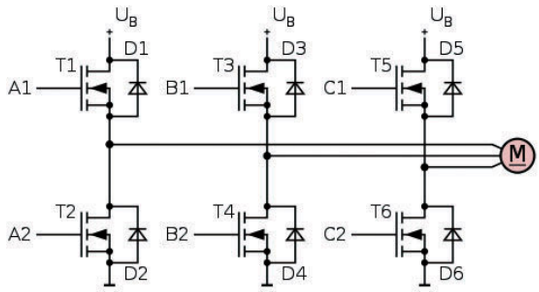
Half bridge	Sequence					
	1	2	3	4	5	6
V1 & V2	–1	both open	1	1	both open	–1
V3 & V4	1	1	both open	–1	–1	both open
V5 & V6	both open	–1	–1	both open	1	1
„1“ upper transistor connected to Vcc „–1“ upper transistor connected to ground						

timer unit, generates the appropriate pulse patterns for the output stage. This output stage in turn consists of six power transistors and the corresponding driver modules. Currently, most suppliers offer corresponding hardware for digital control. Examples of modules from Renesas, STMicro, and Infineon are presented here:

Renesas' Synergy microcontroller family provides innovative modules that offer all the necessary features. The derivatives S7 and S5, two controllers based on Cortex-M4, which run at 120 MHz and 240 MHz respectively, deserve a special mention here. The modules have two 12-bit A/D converters running at 2.5 MHz for measuring phase currents and back EMF. The timer unit can trigger the A/D converters directly via the so-called event link controller, so that no interrupt routine has to be processed. The event link controller is a state machine that relieves the CPU of peripheral interactions. In addition to the triggering of the A/D converter mentioned above, the timers and the DMA can also be activated, and interrupts can be additionally sent to the CPU.

By far the most important function for digital motor control is a powerful timer unit. With the GPT32E, the S7 and S5 offer a high-resolution module consisting of four independent timers with a resolution of at least 8.3 ns and a three-phase PWM generator for controlling the bridge. As already mentioned, the A/D converter can be triggered directly via the ELC unit. In addition, a simplified 32-bit or 16-bit timer is available if additional motors are to be controlled with the same controller. Synergy from Renesas is a concept that also provides comprehensive software for all the most important motors, thereby enabling rapid implementation of the drive.

The timer modules of the STM32 family from STMicro are similar in terms of the functionality. The latest derivate, the STM32H7, contains a so-called high resolution timer unit (HRTIM1), which runs at a clock rate of 400 MHz and reaches a very high resolution of PWM. The module consists of six timers, one master, and five slaves, enabling ten high-resolution outputs for bridge control. This module is particularly interesting for very fast rotating BLDC motors, such as drives running at about 30,000 rpm and outputting more than 100 PWM pulses per cycle. The TIM1 and TIM8 advanced control timers are certainly sufficient for standard drives. They provide a PWM unit featuring six outputs for the motor bridge and the dead time generator for the half bridges. Like Renesas, STM also offers software modules for the various motors.



Detailed view of the motor output stage consisting of six transistors with protective diodes

Infineon's XMC microcontrollers, which are optimized for drives, also feature the CCU8 module, a very flexible unit consisting of four submodules. For instance, the meters can be operated "center aligned" or "edge aligned" and output individual pulses, also known as "single shots". It is therefore relatively easy to generate the PWM signal, including dead time for half bridges.

In short: Depending on the drive concept, different suppliers offer different solutions; the choice of microcontroller therefore depends very specifically on the actual application. This is where qualified field application engineers can give customers advice on the most suitable microcontroller. ■

Power electronics

MOSFETs in BLDC motors

Motors across the industrial and automotive sectors are migrating to BLDCs in order to maximise efficiency and reliability. This article looks at the important MOSFET parameters that should be considered during the design process.

By Mirko Vogelmann,
Product Sales Manager
Power Semiconductors,
Rutronik

With as much as 70% of industrial electricity usage attributed to motors, combined with the rising level of automation, this pushes the need for an overall cost-effective motor. This is further disrupted, with the move away from low-cost brushed DC motors to the more efficient brushless DC motors (BLDCs). As the name suggests, BLDC does not use brushes for energising the coils; thereby it eliminates all the mechanical wear for greater reliability whilst reducing electrical noise as there is no arcing. BLDCs are smaller, lighter and offer a better power-to-weight ratio, with a wider dynamic response and improved torque. These factors are significant in bringing down the total cost of ownership as more motors are deployed to automate processes.

Migrating to BLDC motors

Moving to BLDCs requires more complex drive solutions than brushed DC motors; Diodes Inc understands the challenges and, as shown in the BLDC diagram of Figure 1, has developed products including power management, gate drivers, MOSFETs, IGBTs and Hall effect sensors optimised for BLDC. The control algorithm for the BLDC motor is handled by a microcontroller (MCU), which offer the additional benefit of providing relatively simple integration to a wider system.

In a BLDC, the rotor is a permanent magnet, whilst the stator applies a rotating electromagnetic field to induce the rotor to spin. This means that the rotor position and the timing of the current in the stator coils is critical for the control. Moving to BLDCs is, arguably, more challenging to control compared to a brushed motor as it lacks the switching electro-mechanical contact. In Figure 1, the MCU controls the power by monitoring the rotor's position via the Hall sensors and then the BLDC motor's stator coils are energised by switching the current flow in the correct sequence. When the position sensing is not critical, then further Bill of Material savings can be made by replacing the Hall sensors with sensorless field oriented control.

Improved drive

The switching element in the BLDC is a power transistor, typically a MOSFET (or IGBT), that will switch the drive current to create and collapse electromagnetic fields in the stator coils, rotating around the rotor formed of a permanent magnet. Detecting the position of the rotor in the stator coils is fundamental to generating the correct energizing fields in the coils. In BLDCs that employ sensors it is the magnetic field that is detected, while in sensorless versions the control circuit measures back-EMF to determine the stator position.

Either way, the coils are energized through MOSFETs (or IGBTs) arranged in a half-bridge topology. The selection of the switching element is a major factor in the overall efficiency and performance of a BLDC; figures provided in datasheets are for use under specific conditions, which may or may not coincide with the operating conditions of the actual application. For this reason, it is essential to understand the application before selecting the most suitable switching element whether that is a MOSFET or IGBT.

Similarly, the operating parameters of the MOSFETs (or IGBTs) chosen will have a direct

Credit all pictures: Diodes

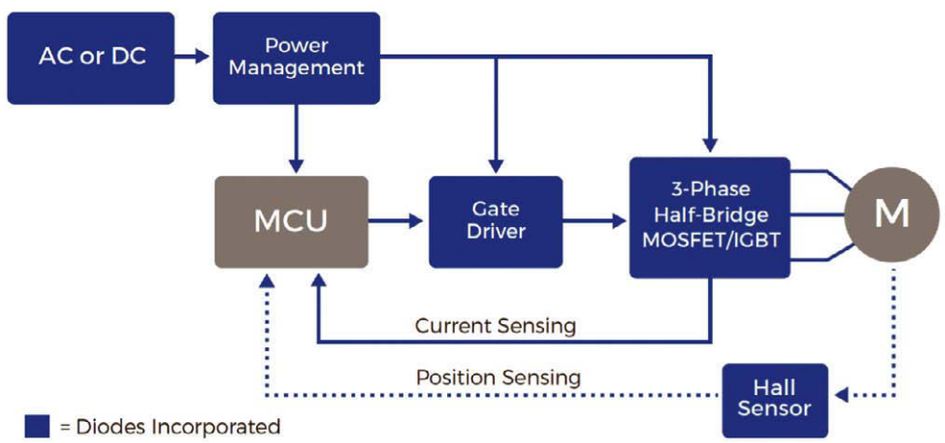


Figure 1: A block diagram of BLDC motor driving.

and significant impact on the total solution. Careful consideration of these parameters will ensure the MOSFETs or IGBTs selected best meet the requirements. This article focuses on selecting MOSFETs for BLDC motors.

Key MOSFET parameters for BLDC

In general, there are three main areas that should be considered: reliability, efficiency and design related parameters. Reliability relates to the extreme limits of a device, and ensuring these limits are never tested during normal operation. Specifically, this relates to selecting a device with a breakdown voltage that provides sufficient protection against transients that may be introduced through other design choices. For example, for a BLDC operating from a 12 V supply, a breakdown voltage of 40 V would suffice. Similarly, in a 24 V or 48 V system, a MOSFET with a breakdown voltage of 60 V or 100 V, respectively, would provide sufficient protection. It is also important to consider the drain current ratings, specifically under pulse conditions. In a BLDC application, a start-up or stall current could exceed the full load current by as much as three times, so a device with suitable drain pulse current capabilities is advised.

For high-power motor drive circuits – typically in excess of 50 W – the channel on-resistance, $R_{DS(on)}$ is an important parameter in terms of reliability and efficiency; a lower $R_{DS(on)}$ will help maximise efficiency (depending also switching frequency), minimise heat dissipation and therefore increase reliability. The 'right' $R_{DS(on)}$ is also dependent on the operating voltage, for example a 400 W (0.5 HP) motor operating at 12 V DC will draw over 30 A, in which case a power MOSFET with an $R_{DS(on)}$ of <2 mΩ (such as the 40 V DMTH41M-8SPS) would be appropriate. The same motor running from a 24 V battery would draw around 16 A, so a power MOSFET with an $R_{DS(on)}$ of <8 mΩ would be more appropriate (such as the 60 V DMTH6004SPS). These figures are calculated on <1.5 W power dissipation in each half-bridge, split across two MOSFETs, and not exceeding the maximum junction temperature of the MOSFET which is typically 150 or 175°C. Further thermal management measures such as heatsinks or forced air flow may be necessary. The $R_{DS(on)}$ has a critical behaviour on the power level that can be achieved, For example, a power MOSFET with an $R_{DS(on)}$ of 1 mΩ (such as the DMTH4001SPS) running from a 12 V supply could drive a motor of >500 W. However, it should also be noted that the $R_{DS(on)}$ has a significant impact on the total system cost, particularly as a 3-phase BLDC motor requires at least six power MOSFETs, so optimisation should cover both cost and efficiency.

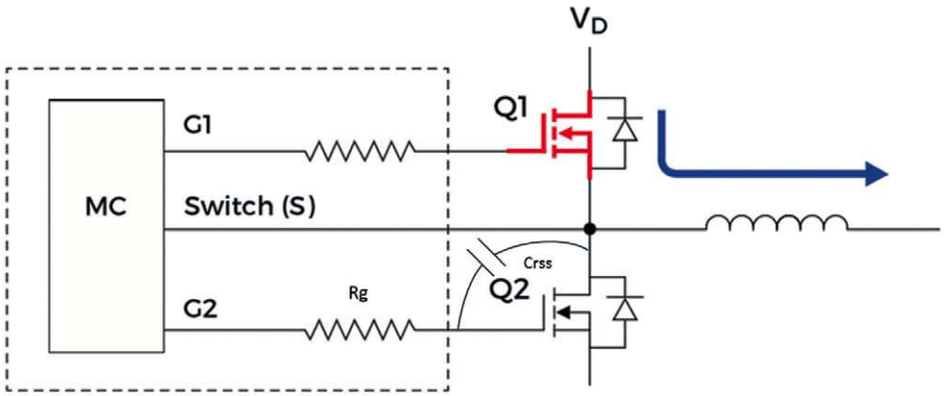


Figure 2: Typical half-bridge circuit for driving the phases of a BLDC motor

Switching performance

In relation to MOSFETs, efficiency is generally an indication of how well a device manages heat dissipation, particularly at the junction. Good thermal design will always be necessary, but there are several other parameters that should be considered when select-

ing a MOSFET. As well as the $R_{DS(on)}$, this includes the gate charge (Q_G). These two parameters are interrelated; as a larger MOSFET of the same cell-pitch structure will have a lower $R_{DS(on)}$, but it will also have a higher Q_G, due to the increasing capacitance of a larger MOSFET structure. This higher gate charge can have a significant impact on switching applications like BLDC drivers.

Avoiding shoot-through

Driving a BLDC with 3-phases (coils) is typically achieved by a PWM (pulse width modulated) signal generated by the MCU for energising each of the phases. Figure 2 shows a typical half-bridge circuit to one coil (1-phase) of a BLDC. If both the MOSFETs are turned on at the same time, it results in a shoot-through from the power supply Vcc to ground return, which will have catastrophic effects on the MOSFETs leading to device failure. To address this, a time period will be designed into the PWM signals, known as dead-time, which ensures only one MOSFET is conducting at any given time. The MOSFETs' switching time will influence the length of dead-time required, a parameter that is also affected by the Q_G of the device. During the dead-time, the body diode of the MOSFET provides a commutation path, this is again not ideal due to the higher power losses of the body diode's I-V characteristic. Hence a good design works with the minimum possible dead-time while avoiding any possibility for shoot-through.

Each of the MOSFETs will exhibit a Miller capacitance between the drain and gate, see C_{rss} (C_{gd}) in Figure 2; this is a parameter that could result in a shoot-through. This Miller capacitance, combined with the gate series resistance (R_g), the MOSFETs' inherent $V_{gs(th)}$ level and switch node dV/dt could result in charge coupling onto the MOSFET gate causing the MOSFET to falsely turn-on, leading to a shoot-through event.

Adequate MOSFET gate drive voltage

Another important parameter is the level of gate-source drive voltage (V_{GS}) that is being applied on the MOSFET gate and how this relates to the zero temperature coefficient (ZTC) point. To ensure a MOSFET is adequately turned on, sufficient V_{GS} needs to be applied and typically this is 5 V (logic) or 10V (standard) MOSFET, depending on the type of MOSFET, logic or standard level $V_{gs(th)}$. Without sufficient V_{GS}, then the $R_{DS(on)}$ can rapidly increase and it can significantly vary from device-to-device and be highly temperature dependent. Graphs for Diodes DMTH6004SPS are used to illustrate this in Figure 3.

The extreme case with a low V_{GS} would be if it goes below the ZTC and into the MOSFET's positive temperature coefficient region causing drain current crowding in the MOSFET cells, leading to thermal runaway as a hot spot forms and then the device fails.

MOSFETs in a full-bridge configuration

For a given size, an N-channel MOSFET will typically feature an $R_{DS(on)}$ half that of the equivalent P-channel device and for this reason it is common to specify N-channel MOSFETs in motor drive applications. Figure 4 shows five stages of a full bridge motor drive circuit using N-channel MOSFETs. It is important to note, also, that such circuits are subject to the effects of reverse current flow due to the body diode of the MOSFETs. PWM algorithms that are able to minimise dead time can reduce these effects, while specifying MOSFETs with a low Vf fast recovery parallel diode is also advisable.

BLDC motors applied efficiently

Brushless DC motors are increasingly being specified for industrial and automotive applications. They offer greater efficiency, higher reliability and increased control in a widening number of functions, including replacing mechanical pumps, fans and to automate industrial processes.

Driving a BLDC requires a combination of an MCU for control, coupled with suitably specified MOSFETs to deliver the power. Thermal management lies at the heart of good design, and this extends to understanding how the unique requirements of BLDC drive circuits can be best met using the right MOSFET design.

By understanding and appreciating the pertinent parameters, engineers can select the right MOSFETs for the task, ensuring the highest reliability and efficiency in even the harshest environments. ■

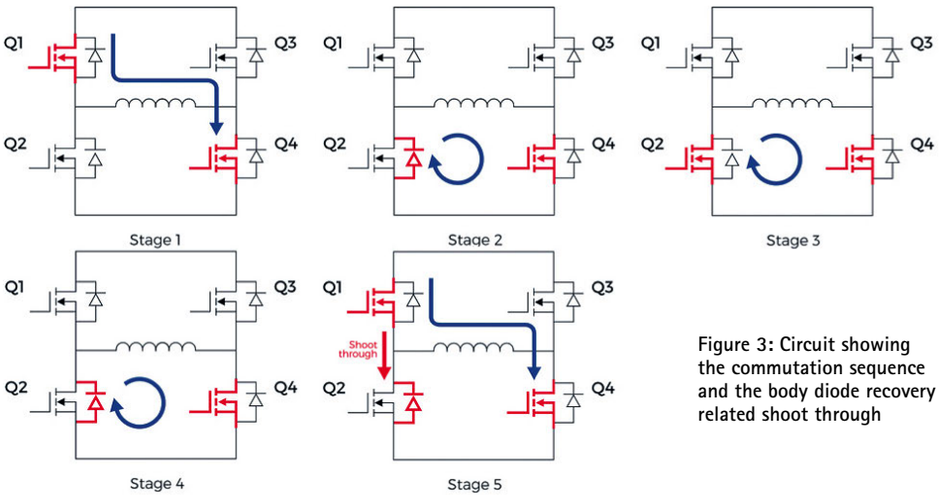


Figure 3: Circuit showing the commutation sequence and the body diode recovery related shoot through

Power supplies

Improved power density

A number of factors, including the need for miniaturization, rising energy costs and consumer expectation are all driving a market trend towards power supplies that are more efficient, smaller and lower cost. In order to achieve these at times conflicting requirements, designers are looking outside their normal design choices and considering other more innovative options.

By Mathias Müller,
Product Sales Manager Power Semiconductors,
Rutronik

The latest member of Infineon's popular CoolMOS™ family is the CoolMOS P7, available in SOT-223 packaging. Infineon engineers chose this package to deliver BOM cost reductions while maintaining direct footprint compatibility with popular DPAK packages – and comparable thermal performance.

Figure 1 shows that SOT-223 package leads exactly match the DPAK footprint allowing it to be used in existing designs to replace DPAK devices. Although footprint compatible, the SOT-223 is smaller than the DPAK – being 25 percent less in height and 35 percent shorter.

A significant amount of testing has demonstrated that the SOT-223 package can be considered a direct replacement for the DPAK, although there are a few important considerations. If the application will dissipate more than 250mW in the package then the addition of copper around the drain pad is required as an additional heatsinking measure.

A standard DPAK package with the recommended copper area will operate at 85°C (point A in Figure 2). On the same PCB, a SOT-223 package will operate at 89 to 90°C (point C). With 20 mm^2 to 40 mm^2 additional copper placed around the drain pad, the operating temperature of the SOT-223 device drops to the same level as the DPAK device (point D).

Mobile phone charger: a practical example

The new CoolMOS P7 technology was evaluated against the earlier CoolMOS CE series in SOT-223 in an 18W mobile phone charger to investigate and demonstrate the benefits of the new technology. The key performance parameters of the charger are shown in the Table on page 59.

Credit all pictures: Infineon

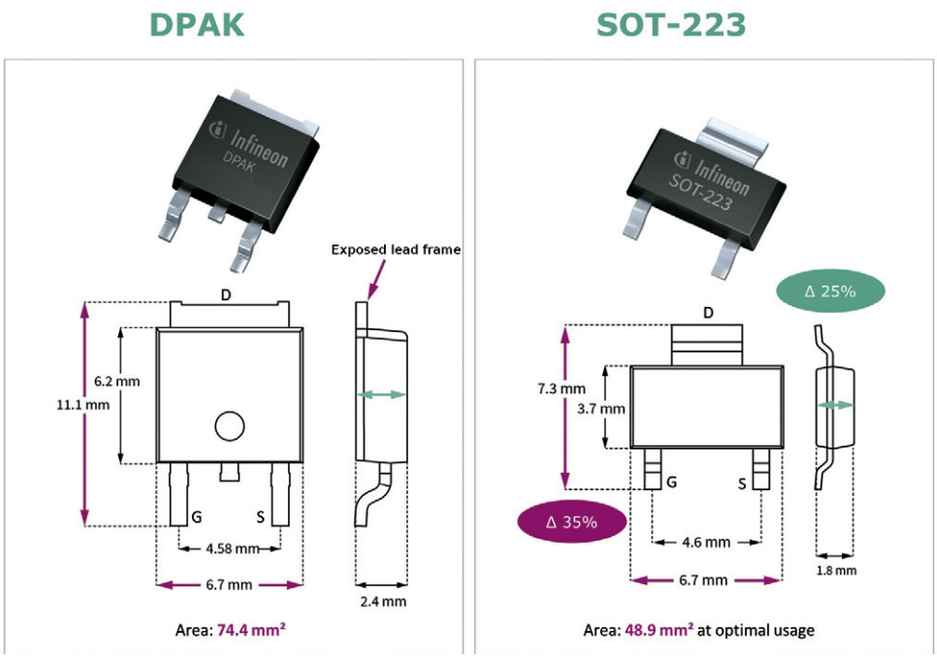


Figure 1: Comparing the size of CoolMOS devices in DPAK and SOT-223

Testing was performed in a stabilized ambient of 25°C with an input voltage of 90 V AC. The temperatures were measured non-intrusively using a FLIR SC645 thermal camera.

Efficiency measurements were measured by using a Yokogawa WT310 to measure input power (Pin). A pair of Agilent 34980A multifunction switch/measurement units were used to measure V_{out} and I_{out} (via a 200Ω shunt resistor).

Figure 4 compares the original CoolMOS CE in SOT-223 (IPN70R1K5CE) with a CoolMOS P7 in SOT-223 (IPN70R1K4P7S). The CoolMOS P7 shows a distinct improvement in efficiency of around 0.25 percent at full load, leading to it running approx. 4.1°C cooler than the CoolMOS CE device.

Test results clearly demonstrate that the CoolMOS P7 in SOT-223 has higher efficiency and improved thermal performance than CoolMOS CE technology.

The second test employed a CoolMOS C6 device in a DPAK package (IPD65R1K4C6) to create a new baseline for comparison against a CoolMOS P7 in a SOT-223 package. Tests revealed that the efficiency is very similar when both devices are operated at full load. The CoolMOS P7 device ran approx. 3°C warmer as a result of the small copper area, although this can be addressed by increasing the copper area.

From this test, it can be concluded that the CoolMOS P7 in SOT-223 is a viable drop-in replacement (from a thermal perspective) for DPAK packages.

The CoolMOS P7 is available in four voltage classes: 600 V, 700 V, 800 V, and 950 V in SOT-223 packaging. The 600V and 700V devices are offered in standard grade and the 800V devices have been completely qualified as industrial grade. The 600V devices are ideal for half-bridge or full-bridge configurations such as PFC, flyback, or LLC stages. The 700V, 800V, and 950V devices are suitable for applications where there is no hard commutation of the body diode, such as PFC or flyback topologies.

Summary

Tests have shown that CoolMOS P7 technology will provide the high efficiency and significant benefits of Superjunction MOSFET technology, even when implemented in a low-cost SOT-223 package that is footprint-compatible with DPAK-based designs.

By meeting minimum DPAK copper area requirements, the thermal performance of the SOT-223 solution is entirely acceptable and,

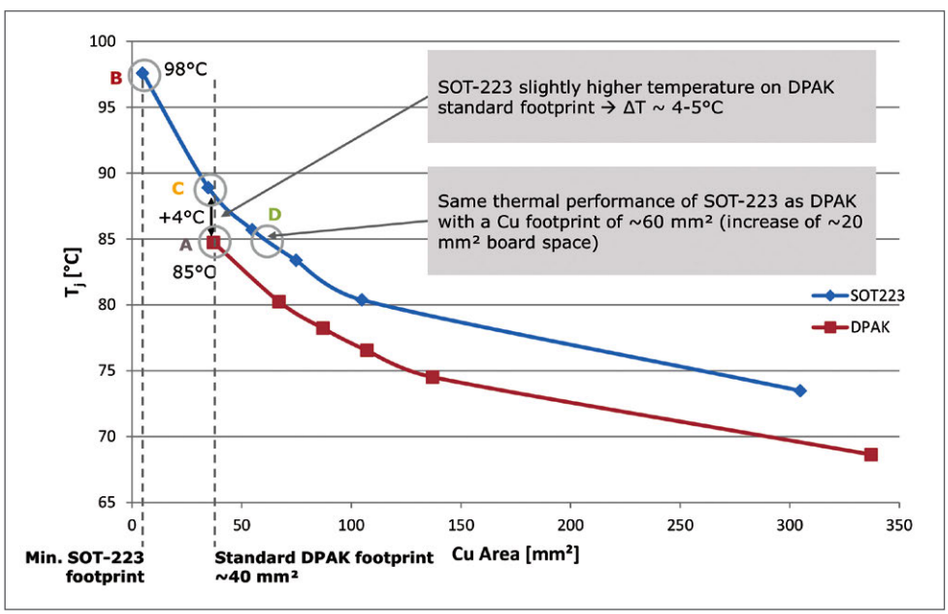


Figure 2: Results of junction temperature thermal analysis @ 250 mW (T_j vs. copper area)

Figure 3: Thermal evaluation was conducted on an 18 W mobile phone charger as shown.

Parameter	Specification
Input Voltage	90–265 V AC
Output Voltage (2.0 A at 18 W)	9 V DC
Configuration	Flyback
Original device	IPN70R1K5CE
Schaltfrequenz (76 kHz @90 V AC, FL, 57 kHz @230 V AC, FL)	25–76 kHz
PCB dimensions L × B × H	45 mm × 35 mm × 13.5 mm
Copper around drain pad	30 mm²

Basic performance parameters for the 18W mobile phone charger

by adding more copper (where space permits), thermal performance very close to a DPAK solution can be achieved.

CoolMOS P7 devices in SOT-223 packages meet many of the requirements of modern power supply design by delivering a good balance between performance, ease-of-use, small footprint, and cost. Further information on Infineon's CoolMOS P7 devices in SOT-223 packages is available from www.infineon.com/sot-223. ■

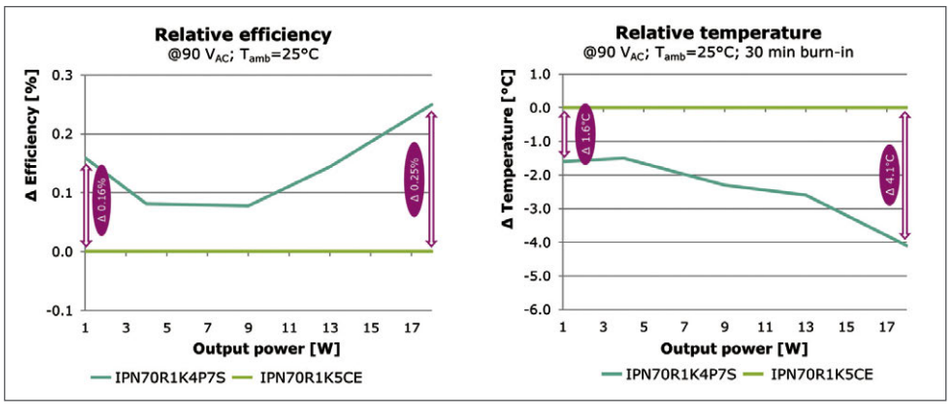


Figure 4: Results of efficiency and thermal testing – CoolMOS CE in SOT-223 vs CoolMOS P7 in SOT-223

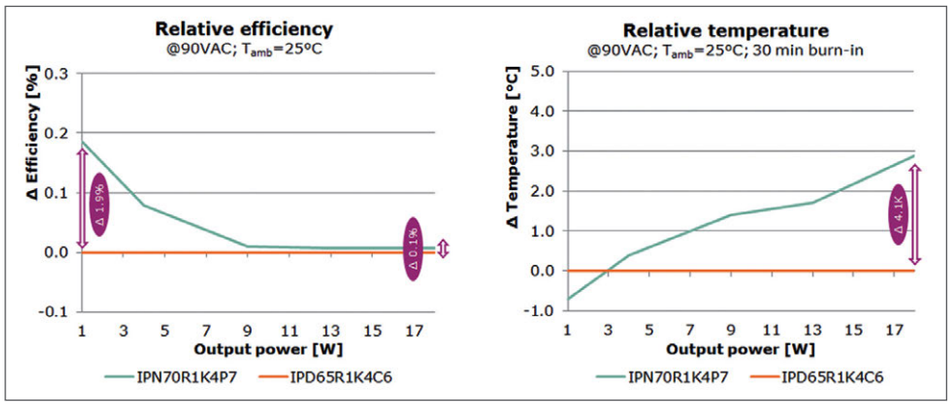


Figure 5: Results of efficiency and thermal testing – CoolMOS C6 in DPAK vs CoolMOS P7 in SOT-223

Optoelectronics

Light in the dark

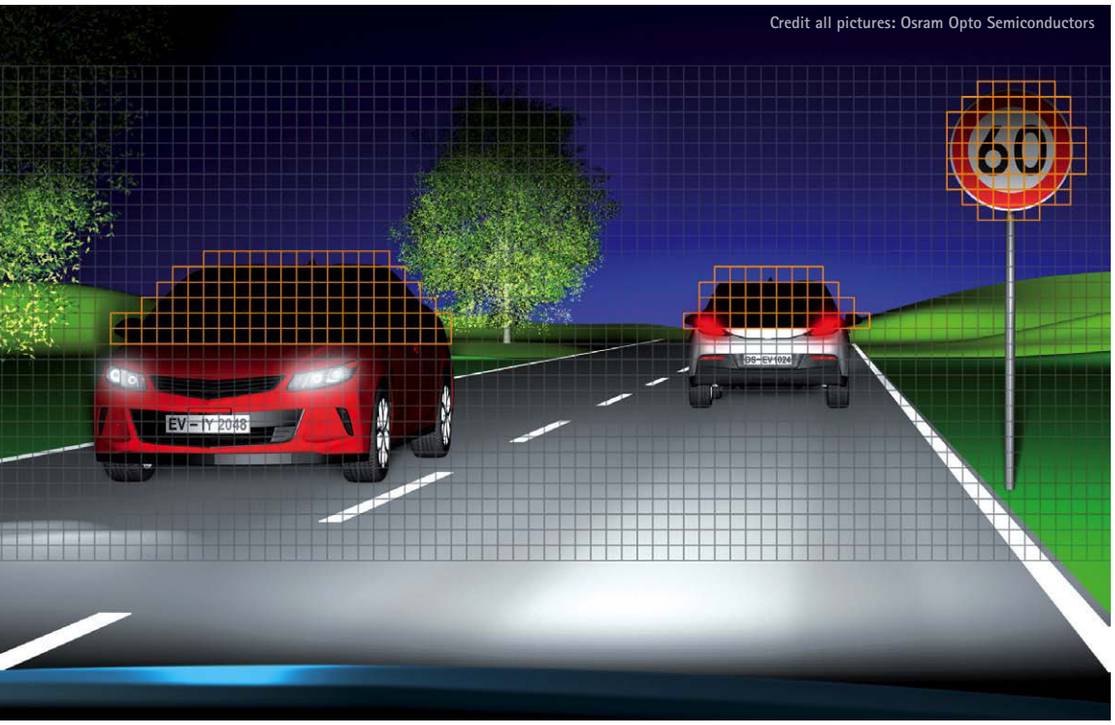
A new hybrid LED solves the traditional problems of automotive lighting: It avoids dazzling oncoming traffic while ensuring ideal illumination of the road ahead. The high resolution of over 1,000 fully electronically controlled LED pixels allows extremely differentiated, active and, therefore, efficient light distribution.

By Julian Eise,
Product Sales Manager,
Rutronik

Every motorist knows the problem: Being dazzled by oncoming and following drivers' headlights at night. This is both annoying and dangerous, as it can take several seconds for the sight of dazzled drivers to clear. Conversely, good illumination is essential for road safety.

Osram Opto Semiconductors has now solved this problem with its hybrid LED Eviyos. It combines two technologies in one component: The light-emitting chip and the control electronics for the 1,024 individual pixels, which ensure ideal illumination of the road. At the same time, the dazzling of oncoming traffic is prevented. In addition to its outstanding illuminating power and compact design, Eviyos is also suitable for use in intelligently controllable headlights due to further benefits, such as its efficiency and scalability. They recognize certain driving situations and react to them automatically. This works through the interaction of a camera and a control unit: The camera captures ambient information and forwards it to the control unit. This processes the information and forwards correspondingly adapted light distribution to the light points in digital form. The technology for the development of Eviyos is based on the findings of the µAFS research project completed in the fall of 2016, which involved various project partners from the industrial sector (including Fraunhofer IZM, Infineon, Hella, and Daimler) under the coordination of Osram Opto Semiconductors. Eviyos generates the desired light distribution fully electronically, i.e. without optomechanical components. The resolution of the system is significantly higher than that of the previous LED matrix headlights. The light distribution can, therefore, be controlled in a highly differentiated manner.

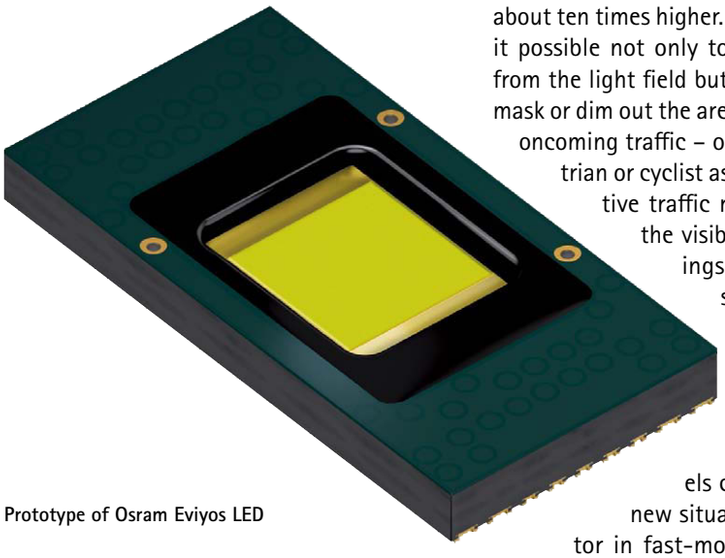
Example of a traffic situation illuminated with the new LED pixel solution. Traffic participants are faded out and important information is displayed.



Less extremes, more flexibility

In the past, the situation with conventional driving lights was always as follows: Drivers had dipped and full beam headlights at their disposal. There was no further differentiation. Even if this is sufficient in many cases, the disadvantages are obvious: When two vehicles are approaching each other, there is a risk of dazzling. However, when driving with dipped headlights, only the area directly in front of the vehicle is illuminated. Quite often they are inadequate to provide sufficient illumination. Conventional light therefore only offers these two extremes and the associated limitations.

The increasing illuminating power of LEDs has made it possible to use them in electronically controlled vehicle headlights since around 2013. Even the first LED modules were intended to provide a remedy for the



Prototype of Osram Eviyos LED

well-known problems of automotive lighting. They already enabled variable light distribution through which certain parts of the light field could be blanked out or otherwise adapted to the driving situation. These solutions delivered great progress, especially in terms of safety but also in terms of driving comfort.

What is the difference between Osram's Eviyos and previous LED matrix solutions for headlights? Basically their resolution. It may sound a little trivial at first, but it is definitely an important aspect: If a current LED headlight works with between eight and less than 100 LEDs, the resolution of the new lighting is about ten times higher. This resolution makes it possible not only to exclude large areas from the light field but also, for example, to mask or dim out the area of the windshield of oncoming traffic – or the face of a pedestrian or cyclist as well as highly reflective traffic road signs. Otherwise the visibility of the surroundings is completely preserved – as if you were driving permanently with high beam headlights. Within just a few milliseconds, individual pixels can be adapted to the new situation – a decisive factor in fast-moving events that are constantly changing. Eviyos not only allows the pixels to be switched on and off individually; moreover, the pixels can be dimmed. For instance, a traffic road sign should not become invisible, it should simply not dazzle the driver. This also enables soft light transitions.

Perfect illumination through image recognition

Needless to say, the right sensors are a prerequisite for correct functioning of the LED in the vehicle headlights. These can be camera systems with appropriate image recognition. The "intelligence" of the system depends primarily on the software users provide for their image recognition and illumination system. Moreover, extended functions are also possible. For example, the light can warn separately of hazardous areas or even project information, such as warnings or direction arrows, onto the road.

For the brightness of Eviyos, Osram currently specifies a luminous flux of at least 3 lm per pixel with a current rating of 11 mA. This corresponds to roughly 3,000 lm per LED – more than twice as much as the luminous efficacy of a halogen headlight. However, according to Osram, an even higher luminous efficacy should be possible. The LED itself measures only 4 mm × 4 mm, control unit included. The comparatively high contrast of at least 300:1 also contributes to the quality and differentiated illumination. In addition to lower power consumption, the LED system is lighter than xenon headlights and, above all, less susceptible to vibrations – a fact that benefits continuous operation.

If required, Eviyos can be supplemented in the vehicle by further LED solutions – according to customer requirements. They can also be used as components for intelligent lighting systems in other applications. LED matrix headlight systems are currently not yet approved for the USA due to the legal regulations in force there. However, it is hoped that the directives will be revised and adapted to the new technical situations. ■

Implementing security solutions in the age of networked vehicles

Security in a vehicle is feasible

Modern vehicles have many functions with external interfaces that make travelling more pleasant. However, these interfaces are also gates for attacks on the vehicle. Hardware-based security functions provide a remedy.

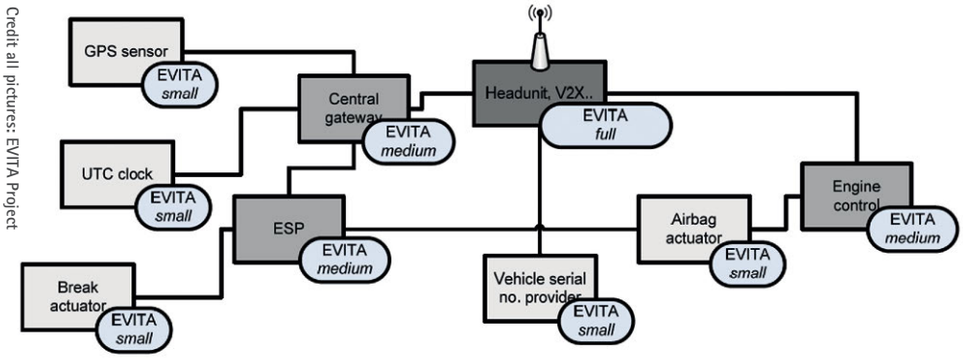
In the future, V2I (vehicle to infrastructure) and V2V (vehicle to vehicle) communication will be combined with V2X (vehicle to everything) – a billion dollar market that is also attracting increasing attention from consumers. One goal of V2X communication is to reduce the number of accidents by exchanging information. Based on an analysis of road accidents between 2004 and 2008, the US Department of Transportation (USDOT) discovered that V2X systems can prevent 4.5 million accidents, i.e. 81% of all accidents.

Threat

V2X has not proven so popular up to now. One reason for this is that there are a lot of negative perceptions surrounding the security of V2X communication. The possibly greatest threat lies in cyber attacks. If the vehicle's computer system or cell phone system is hacked, it can lead to property damage and could even be life-threatening if the car is being driven at the time. In 2015, two security researchers succeeded in remotely hacking into the CAN bus of a Jeep Cherokee, allowing them to take control of the vehicle; they used a weak point in the Linux-based infotainment system. A year later, the two researchers were again able to steer a Jeep Cherokee via a laptop connected to the vehicle's OBD port.

When CAN was developed decades ago, security was not an issue. Accordingly, CAN does not guarantee data confidentiality and signals are transferred in broadcast mode. Modern-day cars exchange messages via the CAN bus, for example to open doors and to start the engine. Messages are exchanged between an ECU inside the vehicle and an electronic key. If this system were to be compromised, a thief could easily steal the car.

In addition, wireless communication standards such as Bluetooth, GPRS or UMTS for mobile Internet functions like email, SMS, video streaming, video calls, etc. have provided hackers with greater "target areas". This would allow them not only to take control of the vehicle but also to install malicious software in order to steal vehicle data such as the location of a vehicle, frequently used routes, and complete calls remotely. Since the so-called T-BOX (Telematics Control Unit) is now responsible for all the aforesaid communication functions, the focus is firmly on security.



Credit all pictures: EVITA Project

Architecture with EVITA

Solution

Which features must a hardware architecture have to ensure that the ECUs meet the highest security requirements and are protected against illegal tampering, unauthorized installations, uploading of malicious software, Trojans, and fake upgrades? Data encryption is an effective way to ensure the integrity, availability, and confidentiality of data within the internal communication bus of the vehicle network. Cryptographic methods can thus prevent cyber attacks.

In recent years, various interest groups have been established to propose guidelines for the design and verification of systems that can withstand hacker attacks and manipulation attempts.

A prime example of this is the EU-funded EVITA research project, in which several companies such as BMW, Continental, Fujitsu, Infineon, and Bosch were involved. EVITA came up with a number of guidelines that describe in detail the design, verification, and prototyping of various security architectures for automotive ECUs. Moreover, EVITA stipulates that all critical ECUs are equipped with a chip that contains not only a dedicated hardware security module (HSM) but also the CPU, wherein three different requirement profiles have been defined for the HSM: Full, medium, and light. These modules encrypt and decrypt all the information exchanged between ECUs.

Based on the EVITA standard, an increasing number of semiconductor suppliers are implementing what is known as a "secure zone"

(also referred to as a "trust anchor") in their microcontrollers/microprocessors. For example, STMicroelectronics has integrated HSMs into both its power architecture-based SPC5 microcontroller family (MCUs) and its ARM core processors, e.g. STA1385 TCU (Telematics Control Unit).

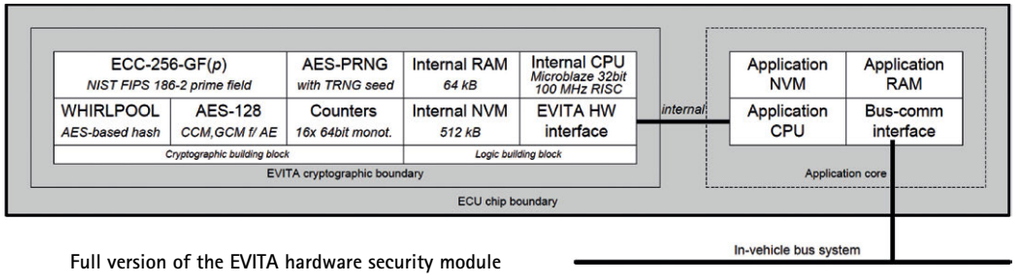
These ICs with HSM offer comprehensive protection against cyber threats. The HSM is an isolated subsystem with its own secure processor core, RAM, and flash memory (code and data). In addition, the HSMs feature hardware accelerators for cryptography. At ST, this is the C3 cryptography accelerator, which also contains a true random number generator (TRNG). Data and interrupt requests are exchanged between the HSM and the application processor via a hardware interface.

The HSM not only assumes access control but can also generate real random numbers for encryption keys and perform all other encryption functions thanks to the integrated TRNG. As already mentioned, the CAN bus does not deliver a high level of security and therefore cannot guarantee the confidentiality and integrity of the transferred data. However, with encrypted data, it can also be used for secure data transfer. Asymmetric and symmetric encryption algorithms with HASH functions, MACs (message authentication code) or CMACs enable data confidentiality, integrity, and availability, digital signature and data authentication. All coding and decoding functions are implemented in the hardware to ensure the host CPU is not overloaded.

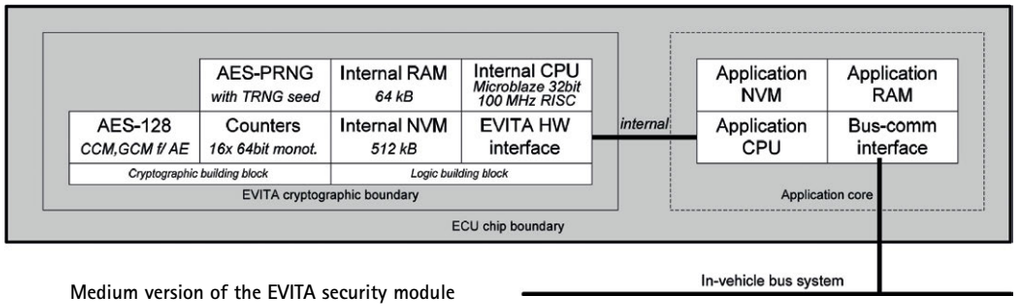
Typical application

Secure boot

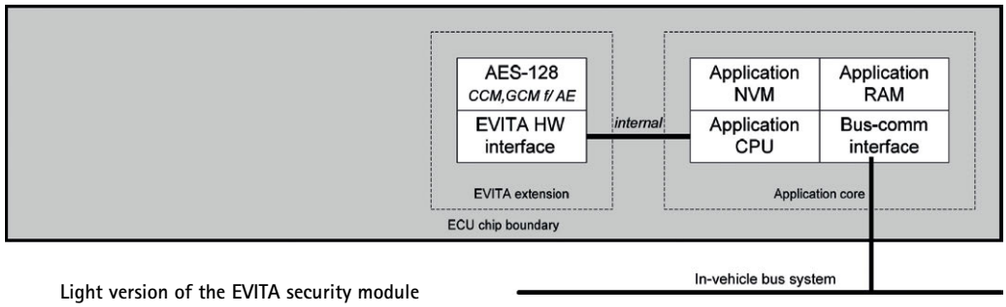
The secure boot function validates the integrity of the boot loader. To do so, the HSM of the MCU first loads the boot loader from the flash via the bus master. Using an agreed secret key, the HSM can calculate an MAC (message authentication code) for the received message; if the calculated MAC corresponds to the stored boot MAC, the integrity of the data is secured and the MCU can use the boot loader.



Full version of the EVITA hardware security module



Medium version of the EVITA security module



Light version of the EVITA security module

Secure communication

The HSM also enables secure communication. The following example shows how this works: A central ECU communicates with a sensor ECU. As already explained, each HSM has a TRNG and a hardware crypto engine. The central ECU generates a random number and sends it to the sensor ECU. The sensor receives the random number, measures its data in parallel and activates its own HSM to encrypt the measurement data with the ECU random number. The sensor ECU sends the encrypted data back to the central ECU. This decrypts the data using its own random number. The transferred random number is then compared with the received random number to verify data integrity and authenticity. The TRNG protects against replay attacks and encryption against "eavesdropping".

Flash memory protection (optional)

Since firmware and security configurations such as passwords and keys are stored in the controller's flash memory, their protection is also critical. The ST SPC5 MCUs are, therefore, equipped with two modules that are exclusively responsible for protecting the memory: The TDM forces the software to write a data set in a specific flash area before one or more blocks can be deleted in a TDR (tamper detection region). The PASS module, on the other hand, performs a password comparison before the flash can be written or deleted.

System security configuration (optional)

To ensure a system startup is carried out securely after a reset, all the stored device configuration formats (DCFs) are checked for integrity before rebooting, thereby preventing unauthorized interventions and changes. In addition, several security features can be checked. This ensures any attempts to change content at specific locations using various attack methods or to load malicious firmware while booting can be stopped.

Conclusion

IT security measures in vehicles are essential. The use of state-of-the-art semiconductors with integrated HSM helps to improve security and make implementation more efficient.

New markets and challenges for Rutronik and its partners

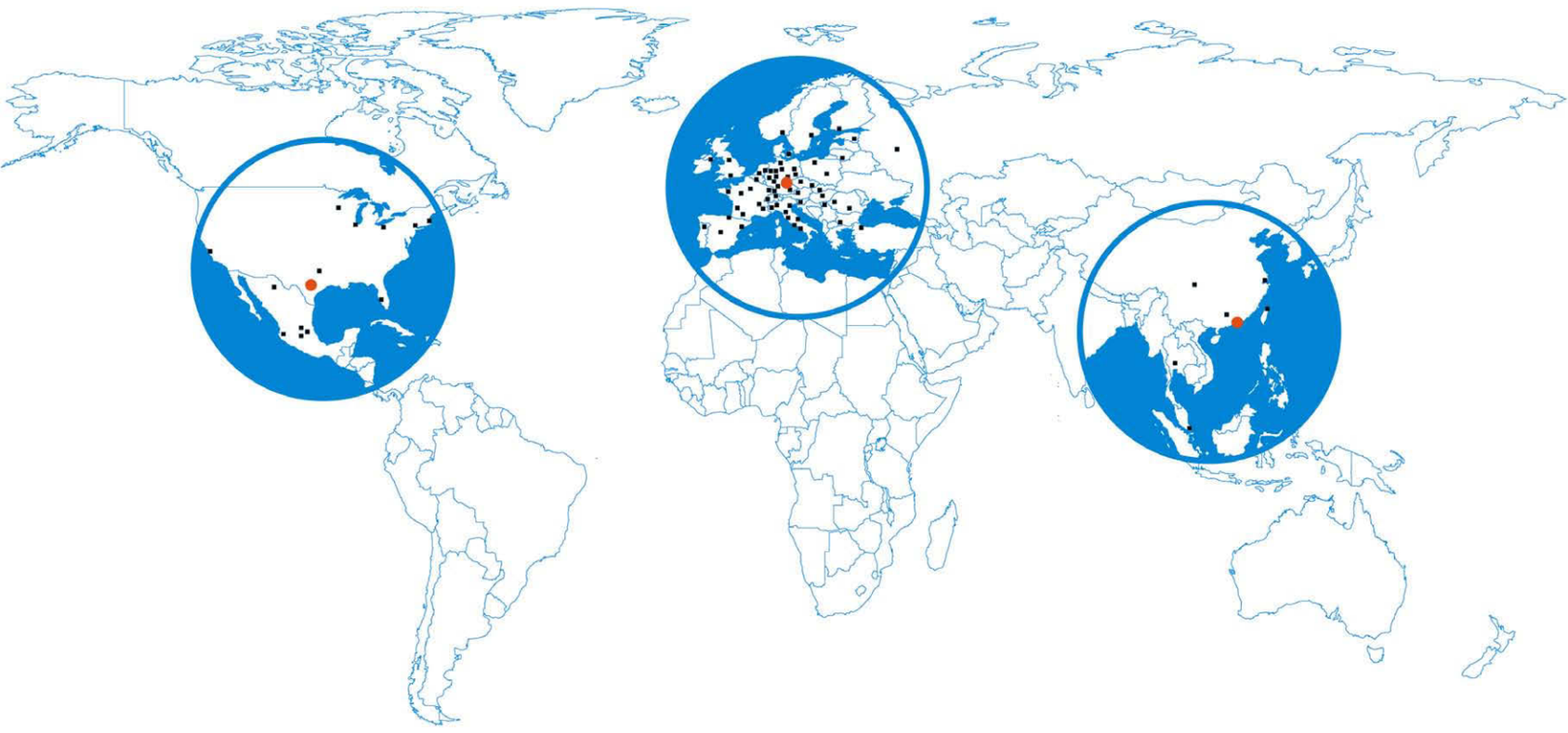
Growing together globally

With the development of the Asian market in 2011 and the North American market in 2015, Rutronik continues to meet the challenges of a global company. Even today, seven years after its launch in Asia and three years after its start in the USA, Rutronik continues to grow and inspires customers and suppliers day after day true to its corporate motto of "Committed to Excellence".

By Gerhard Weinhardt,
Director Global Marketing,
Rutronik

Rutronik's many years of experience in establishing international organizational units in the European market has been of great benefit for the company's global expansion. The initial idea to set up a logistics center with customer service in Hong Kong quickly became a complete organization with sales staff, field application engineers (FAEs), business development managers (BDMs), and local marketing team. Today, Rutronik boasts roughly 100 employees in six offices in China, Taiwan, and Thailand. The Southeast Asia region has developed into a very interesting sales market with enormous potential for Rutronik and its partners. Expansion of Rutronik's global map is, therefore, already planned: A new office and warehouse was recently opened in Singapore. By establishing an independent sales organization covering Rutronik's entire range of services, it is possible to meet the requirements and needs of our manufacturers and customers in full.

Further offices are planned in Tianjin (China) and Penang (Malaysia) as well as in India. Fur-



thermore, another warehouse is planned in mainland China near Shanghai. Rutronik will thus continue to offer short delivery routes and strengthen its local presence with customers.

More than just the US market: North America as a growth factor

Rutronik has established a strong presence in North America since 2015. Delivery times and local presence have been optimized through the relocation of the headquarters to Dallas, Texas, and the construction of a logistics center in Austin. In spring 2018, further offices were opened in Massachusetts and California. Besides enhancing focus on the USA as the primary target market, this step has also resulted in improved access to Mexico and Canada. With a total of 24 employees, including marketing experts, FAEs, and its own sales team, all Rutronik services can be offered.

One of the biggest challenges was and still is the franchise situation. Certain manufacturers view each region as a market in itself, without considering the global customer situation. This is, of course, also reflected in the pricing policy, which is characterized by regional differences. Rutronik is, however, in very close contact with its manufacturers in order to take into account the needs of globally-active customers worldwide and to adapt to changing market requirements. This includes identical logistics systems worldwide and individual technical support through a global infrastructure.

Extensive portfolio, strong brands

Rutronik currently has global franchise agreements and local purchasing agreements in Asia and North America with more than 100 suppliers, including well-known manufacturers such as Infineon, Vishay, Yageo, Rohm, AVX, Osram, Nordic, and many more.

With the excellent support of these manufacturers, Rutronik organized a customer tour of Asia for the seventh time this year. Together with 40 customers from Europe, North America, and Asia, Rutronik spent one week visiting the production sites of Yageo, C&K, Vishay, Chilisin, DLC, and Recom in southern China. To inform customers also on a technical level about the latest news and fields of application, technical seminars, Tec-Days, and workshops have been held in cooperation with Rutronik's franchise partners in Asia and North America with great success for some years now, as in Europe.

Rutronik is therefore continuing its global expansion – for the benefit of its customers.

PCN goes smart

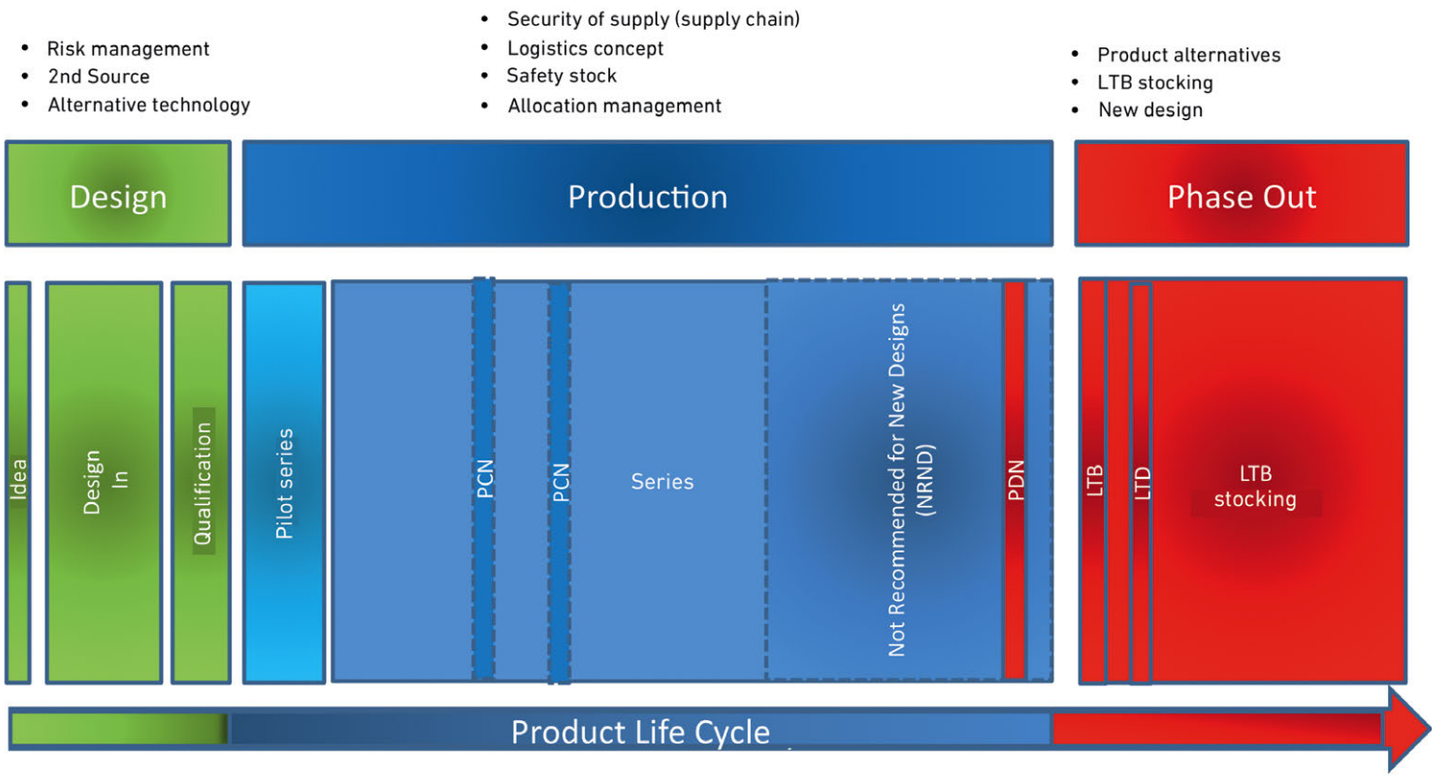
Rutronik relies on digital standard

In a global and digital world with increasingly networked procurement, production, and manufacturing processes, the information process for the materials and components used is also becoming more and more complex. The management of manufacturer information represents a major challenge today.

By Andreas Glaser,
Head of Technical Quality management,
Rutronik

Companies are faced with the task of assigning the innumerable product notifications received to bills of material, products or platforms, evaluating the information, and forwarding it to the appropriate departments within the company or production network. Redundant messages need to be detected and eliminated as early as possible in order to avoid the threat of additional work in terms of double processing.

Today, information is still mainly managed manually. This means that the supplier notifications are processed in local customer databases, if available at all. The majority of suppliers, especially in the field of electronic components, provide the information in electronic form – which simplifies data management - but in non-uniform formats (PDF, Word, Excel, etc.). This means, automated processing of the data is not possible. But this is exactly what is desirable, considering the continuous increase in product notifications over the last few years. In 2017 alone, Rutronik recorded an increase of 30% compared with the previous year. The share of product discontinuation notifications in the total volume dropped slightly to around 19%.



Credit: Rutronik

Component management in the product lifecycle of a device

As a globally active broadline distributor, Rutronik is also increasingly confronted with customer demands for information security, data security, and data automation. Membership in the COG underlines the company's commitment to take obsolescence management and PCN/PDN handling very seriously in order to provide customers with the best possible service. The smartPCN standard plays a key role, particularly with regard to the desired automated processing of change notifications.

Rutronik has initiated an IT project specifically for this purpose in order to set up the interfaces and accordingly to convert the supplier information into the smartPCN format, i.e. to digitize it (XML format). This enables customers to digitally import and process the data using suitable software. Decisive advantages in this context are the automatic import of data and the detection of redundantly received information. Especially when a component is procured from several suppliers, it can happen that the same change notification is received with a time lag from different sources. Annoying and time-consuming multiple processing up to detection of the doublet can be avoided with smartPCN.

Customers have been able to request change notifications in smartPCN format since the third quarter of 2018.

A further advantage of digitized preparation is the simple further processing of the data with regard to a risk assessment of the further availability (life time cycle). A large part of Rutronik's sale revenue is based on the distribution of complex electronic components requiring explanation (Design-In products). Due to their high functionality (integration density), these products can often not be interchanged one-to-one, which makes the use of alternatives in the case of obsolescence much more difficult.

In addition to a systematic information policy, risk assessment of (long-term) availability is fundamentally important, especially for these products. The assessment is the responsibility of the customer and is based, among other things, on the respective application and industry as well as the corresponding requirements and product life cycles. An evaluation to ensure availability should already be taken into account in the early phase of the Design-In activity.

The new standard VDI 2882 – "Obsolescence management from the perspective of users and operators" – is a guideline for avoiding production downtime. It shows concepts for securing and using long-term components or systems and thus supplements EN Standard 62402 ("Obsolescence management - Application guide").

The digitization of the change notification thus enables the user to significantly save time and money and also guarantees a continuous, transparent, standardized, and timely flow of information along the entire supply chain.

Rutronik certified according to ISO 27001

Information security signed and sealed

Although ISO 27001 is not mandatory for all companies, Rutronik has recognized and acted on the importance of data security.

By Marco Nabinger,
Managing Director IT/Security,
Rutronik

Information security begins in the mind: Social engineering – the attempt to obtain information about a company through its unsuspecting employees and to use it to harm the business – is fairly widespread. Despite digital data storage, information continues to be stored in paper form – yet another risk to information security. And last but not least, the IT infrastructure also needs to be prepared for attacks. Rutronik meets these information security requirements – signed and sealed: The company is now ISO 27001 certified.

Rutronik places great importance on the security of its own data and that of its partners – after all, the distributor is committed to its globally uniform IT infrastructure, which is available at all times, as well as to the high quality of its services. Both require a consistently implemented information security concept. In preparation for the provisions of the EU General Data Protection Regulation (GDPR), which came into force on May, 25, 2018, the executive management therefore initiated the ISO 27001 certification project in 2017.

ISO 27001 is currently not yet mandatory throughout the industry – the high standard is prescribed by law only for companies in so-called "system-critical" industries, such as power supply and aviation, and also for important infrastructures such as airports. The standard is complex and consists of several components: Information security policy, organization of information security, staff security, asset management, access control, cryptography, physical and environmental security, operational security, communication security, system acquisition, development and maintenance, supplier relationships, information security incident management, information security aspects of operational continuity management, and compliance/conformity. All these criteria must be met for certification.

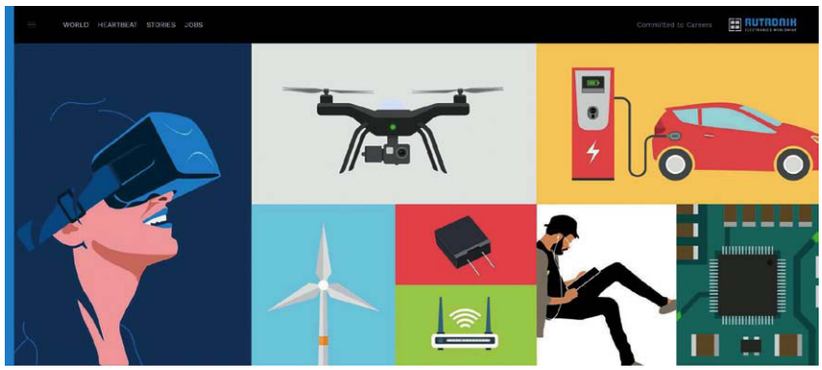
Rutronik has pro-actively implemented the provisions of the ISO standard, as its introduction for all companies is to be expected soon. Since information security was checked anyway when implementing GDPR, implementation of the measures required according to ISO 27001 involved very little additional effort due to the security measures of the Information Security Management System (ISMS) that had already been initiated and were available.

Information security is all the more important in times of digitalization, as cyber attacks are increasing worldwide, Trojans and other malware are becoming more sophisticated, and a huge amount of resources is available to attackers – since one attack now affects everyone. For this reason, the executive management has attached great importance to certification according to ISO 27001 – as it proves that the data of employees, customers, and partners are in good hands at Rutronik.

One company, many aspects

Rutronik launches new career portal

In technical professions the relationship between supply and demand on the labor market has reversed. Employers compete for skilled workers – and are taking innovative approaches to do so. Rutronik has taken various measures to combat this challenge – including a new career portal.



By Sebastian Hör,
PR Referent, Rutronik

An online portal – isn't that old wine in new bottles? "Quite the opposite," claims Dominik Schmidt, Head of Staff Development and Recruiting at Rutronik. "The expectations of applicants have changed. We have responded to this through the new portal rutronik-careers.com. We want to increase the perception of Rutronik as an attractive employer, while at the same time not simply conveying information but managing to give an authentic impression of what we do," Schmidt explains. This also means a different, brighter way of communicating.

"We want to speak the language of the applicants, they should feel addressed. On the new portal, we try to describe directly and in a less formal way what Rutronik is all about, where we want to go, and how each individual employee contributes to the overall goal through their work," says Nicole Maisch, Recruiter at Rutronik. The slogan "Make it work!", which is at the heart of the career portal, is intended to "convey the message that our small components make a big difference. And this is only possible with motivated, qualified employees," Maisch explains.

In cooperation with an external agency, the company has, therefore, analyzed the previous communication policy and worked out how to focus even more on Rutronik's strengths and advantages. "Last year, Focus Money named us as a top employer in three categories," says Schmidt. "This is something we can use to our advantage." At the same time, the Focus Money studies have shown that, in addition to above-average pay, "soft" factors such as training opportunities, work-life spirit, and authenticity are key points when choosing a potential employer.

Authentic, bright, informative

A brand new look and feel compared to the main website Rutronik.com is only the first step. The focus of the new portal is on the so-called "candidate experience", i.e. the impressions and experiences that an applicant associates with a potential employer. This begins with job advertisements and continues with informal chats at exhibitions, corporate web pages, and a transparent application procedure through to being hired by the company and the first days in the new job.

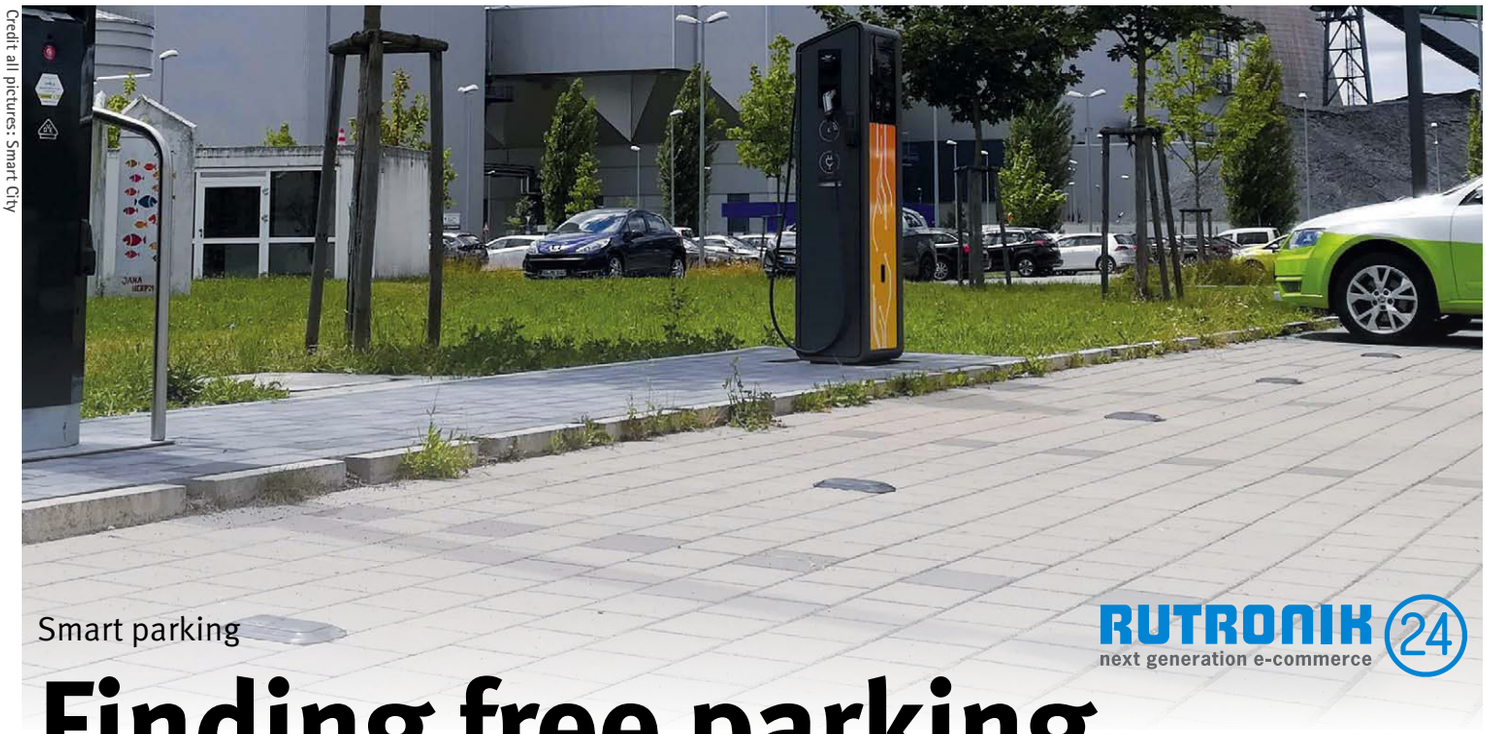
Beyond that, however, a key aim of rutronik-careers.com is to address applicants directly without drowning them in a flood of information. Here, employees will be given a chance to have their say and tell stories, thus providing insights into the work of the third-largest distributor of electronic components in Europe. The most important factor here is to remain authentic. "Needless to say, the videos and texts for the career page will be produced professionally. But at the same time, we want to convey a realistic picture of everyday working life at Rutronik. The colleagues should describe their roles in their own words, there is no such thing as a strict script," explains Gina Freis, Communications Manager at Rutronik.

To give potential applicants a comprehensive view of the company, the career portal offers a multimedia experience with concise text blocks and simple navigation. In the "World" section, interested visitors learn the most important facts about business at Rutronik, the aforesaid employee impressions can be found in the "Stories" section. The "Heartbeat" section deals with topics relating to working at Rutronik as well as additional services, while under "Jobs", as the name suggests, professional opportunities at Rutronik are explained in more detail. A direct link to the job portal with all current vacancies and for unsolicited applications on each subpage enables quick and easy contact.

Ideally, contact is established in this manner and the applicant becomes a member of the Rutronik family.

www.rutronik-careers.com

Credit all pictures: Smart City



Smart parking

Finding free parking spaces with sensors

A startup from Nuremberg, Germany wants to contribute to the smart city of the future by digitally transforming parking spaces. In contrast to other approaches that are either very expensive or time-consuming to install, Smart City System's "Parking Pilot" is based on a small, yet robust, sensor that can be easily attached to parking areas.

By Carlos Ramos,
Field Sales Manager,
Rutronik24

The sensors of the Parking Pilot are simply stuck on, do not disturb and help to use the existing parking space efficiently.

Up to 30% of traffic in inner city areas is people driving around looking for somewhere to park. This not only costs time and frays nerves but also increases the volume of traffic and pollutes the environment. Smart parking, in other words the digital management of parking spaces, could solve this problem and is, therefore, an extremely lucrative market. According to a report from consulting firm Frost & Sullivan, this market segment earned revenues of around $7bn in Europe and North America in 2014; this figure is set to rise to $43bn by 2025.

The race has started

Consequently, a large number of companies are currently working on an intelligent parking system. Speed of development and competitiveness are therefore decisive factors when positioning yourself in the market and establishing a standard. The startup Smart City System has developed its parking sensor in just two and a half years.

The "Parking Pilot" measures 130 mm × 240 mm × 20 mm and can be easily attached to parking areas. The built-in sensor uses a magnetic field to detect whether a car is parked above it or not. This information is then sent to the Smart City System servers using a self-implemented radio protocol. Using API interfaces, the parking lot-specific data is made available live to parking lot operators, enabling them to run their own apps and analysis programs.

The advantage of the Parking Pilot over other solutions is that it is much simpler, more robust, and less expensive. The sensors boast a lifetime of five to seven years and are easy to replace.

While the sensors were still handmade in the beginning, series production has already commenced.

Big advantages even with small quantities

"For our first series production run, we very quickly required a smaller quantity of microcontrollers – and Rutronik24 immediately supplied us with the desired model," explains Stefan Eckart, founder and managing director of Smart City System. The developers had chosen the STM32L0 microcontroller for the Parking Pilot because of its low power consumption and easy programming.

"For us, as a startup, Rutronik24 is a secure source and the perfect partner for our project. The direct and fast communication as well as the uncomplicated advice helped us a lot on the way to market readiness," says Stefan Eckart. Through the sales organization, companies with small and medium-sized requirements can also access the entire product portfolio of the broadliner Rutronik and make full use of numerous value-added services, such as consulting or the supply of samples. For example, Smart City System received samples of a gateway from Advantech through Rutronik24 in order to compare radio standards and further improve its own standards.

The experts at Rutronik24 advised the founding team about the market situation and possibilities for series production and supported them when selecting an EMS service provider. "We were, therefore, able to keep to our tight schedule and bring our first series to market early."

Array of application options

There is so much more potential to be realized in the Parking Pilot than just a guidance system to free parking spaces: Critical zones, such as emergency access points or charging stations for electric vehicles, can be kept clear insofar as the system immediately outputs an alarm when a vehicle attempts to park on them. This relieves not only the burden on parking enforcement officers but also reduces the time between detection and removal of an incorrectly parked vehicle. On supermarket parking lots, the system reliably identifies long-term parkers and, in addition, reservation and navigation services are possible to enhance the customer experience. Precise real-time analyses of parking utilization also make it possible to rent out excess parking areas. In general, every parking facility and parking lot is organized much more efficiently if drivers are able to navigate directly to a free space.

Cities can reduce the amount of traffic on the roads significantly if they monitor public parking spaces via sensors and guide drivers directly to them. The German city of Dresden is already using the Parking Pilot successfully, as are numerous companies, including Aldi Nord, Edeka, VW, and EnBW.

Looking to the future

After the successful start in Germany, the team is already looking to expand into other European countries. If the company remains on its growth trajectory, Rutronik will continue to support it with comprehensive technical, economic, and logistical support right through to tailor-made logistics solutions.

Moreover, Smart City System already plans to extend its offerings: "For example, at some parking lots the power is switched off at certain times of the day. We are currently considering whether solar technology or batteries would make sense for such cases. We rely on the help and support of Rutronik24 in this situation, too," says Stefan Eckart. ■

Processor technology helps protect data integrity

Security first!

The more powerful and all-embracing the Internet becomes, and the more advanced the components that make connected devices "smart" become, the more areas of application are being opened up. In combination with software, microcontrollers form the heart and soul of sensor technology within Industry 4.0 and IoT technologies.Smart factories and smart homes offer immense potential for growth – it also makes them vulnerable to attack.

BY GRADUATE ENGINEER MARTIN MOTZ,
PRODUCT SALES MANAGER
MICROCONTROLLER,
RUTRONIK

Microcontrollers are increasingly becoming the shield against manipulation and cyber attacks in the context of the IoT, Industry 4.0, and robotics. Some microcontroller families already incorporate an array of security features. Microcontrollers are the key control components in connected systems. Suppliers are already employing development processes certified in line with the relevant security standards. Through their secured manufacturing chains, semiconductor suppliers also assure that they can offer their customers a secure end-to-end solution.

Microcontrollers can be categorized in terms of security according to their target applications:

- Authentication solutions and TPMs (trusted platform modules), such as for brand protection and IoT networks

- Banking and identification solutions for classic smartcard companies in the payment processing, personal ID, transport, and pay-TV sectors
- Mobile security solutions for SIM-based solutions in mobile products and machine-to-machine (M2M) applications
- Automotive solutions for near-field communication (NFC, eSE) and secure driving

Integrated data security features

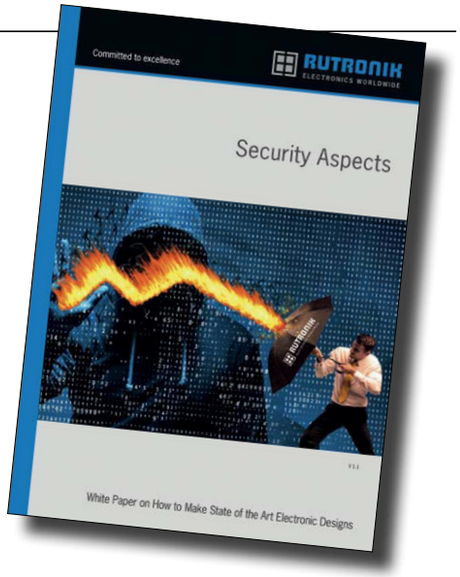
The IoT, Industry 4.0, and robotics mostly use standard microcontrollers for industrial and consumer applications (general purpose microcontrollers). Models with integrated security features are also already available. The STM32 family, for example, has many features offering protection against:

- Identity theft (protection against manipulation, integrity protection, traceability)
- Denial of data service (throttling)
- Data and code spying and manipulation (memory protection, rights management, debug level, protection against manipulation, integrity protection, secure firmware updates)
- Physical/mechanical attack (on-chip manipulation protection)

These features are primarily implemented by on-chip integration. They ensure robust authentication, platform integrity, and throughgoing data security, including the resultant protection of end users' privacy as well as comprehensive data, IP, and branding protection – and as such meet the highest data security demands for standard products. Typical target applications include, e.g., printers, computers, gateways, IoT end points, and sensors.

Hardware-based functions

Integrity and operational safety: The cyclic redundancy check calculates a checksum which identifies errors in data transfer or storage. This not only provides an integrity check, but also means a signature of the software can be calculated during its runtime. Power monitoring is a high-security method (POR (power on RESET)/PDR (power down RESET)/BOR (brown out RESET)/PVD (programmable



This Rutronik brochure provides comprehensive information on the development of safe devices in terms of data protection, depending on the requirements.

voltage detector) flag status) for determining the reason for a reset and thus ensuring that the reset is carried out by authenticated access. It is complemented by the "Read while Write" function for efficient detection of manipulation and logging.

The functionality of the Clock Security System (CSS) is based on the fact that both the clock and the system to restore it, as well as the internal and external clocks, each work independently of each other. The Watchdog and the Window Watchdog likewise monitor the time windows independently of each other.

The integrity and trustworthiness of the memory contents is assured by the Error Correction Code (ECC) and the parity check. They also provide added protection against attack aimed at infecting systems with bugs. A temperature sensor continuously measures the ambient temperature of the IC to ensure it remains within the specified range, thereby avoiding the risk of lasting damage by targeted heating.

Encryption – but done correctly

Encryption techniques protect a source text against unauthorized access by encoding the original plain text. Anyone who cracks the code can thus also decipher the encrypted text. More advanced encryption techniques employ symmetrical or asymmetrical encryption. In the symmetrical method, there is only one key for both encryption and decryption, meaning the sender and recipient use the same key. In the asymmetrical method, each of the communicating parties uses their own key, with which a key pair is created. This con-

sists of a public key with which data is encrypted and a private key to decrypt it.

In some STM32 series, a genuine random number generator is fully integrated into the chip for encryption purposes. The encryption is based on the symmetrical Advanced Encryption Standard (AES). The STM32 F2, F4, F7, L4 series feature keys optionally of 128/256 bits in length, employing various methods (ECB, CBC, CTR, GCM, GMAC, CMAC), while 128-bit AES is implemented in the STM32 L0/L1 series.

Advantage of the symmetrical method: As there is only one key, key management is simpler than with the asymmetrical method. Also, the encryption and decryption is executed much faster. Some STM32 models additionally feature a fully integrated hash function. In this, data is chopped up and scattered, and the function maps a large input volume to a smaller target volume. There is also the Keyed-Hash Message Authentication Code (HMAC). The structuring of this Message Authentication Code (MAC) is based on a cryptographic hash function. The HMACs are specified in RFC (Request for Comments) 2104 and in NIST (National Institute of Standards and Technology) standard FIPS 198.

Preventing manipulation

Protection against manipulation involves defense mechanisms to prevent intentionally or unintentionally launched physical attacks on the hardware system outside the microcontroller. The Backup Domain, linked to various wake-up sources, ensures that protection is also maintained in Low Power mode. The Real Time Clock (RTC) assigns a time stamp to each manipulation event. Some STM32 series also have an RTC register protection function. It blocks illicit writing and works independently of the system reset. This does not, however, include protection when typing a key sequence. When a manipulation has been detected, the protection register ensures that the content written in the course of it is automatically deleted. Additionally, specific communication channels can be closed by a GPIO configuration lock. It blocks selected general-purpose inputs/outputs (GPIOs). The lock can be canceled on the next reset.

Other weapons defending against attack

The debug lock prevents unauthorized access to the microcontroller via a debug interface. The security level is selectable depending on the application and the requirements, though it cannot be scaled back again afterwards.

Access rights authorize users or groups of users to carry out specific actions. To that end, the integrated Memory Protection Unit (MPU) divides the memory into regions with differing rights and access rules.

When a data transfer is carried out, the firewall protects the code or data part of the flash memory, or SRAM, against the code (fragments) running outside the protected sector. The firewall is more restrictive than the MPU; it is only integrated in the STM32L0 and L4.

A read protection function is used to manage memory access control. It might be that this prevents memory dumps, such as backups of user IPs. Write protection protects each sector against unwanted write operations. Proprietary code protection allows each memory sector to be configured as "execute only", meaning code can only be run in it, not written.

The mass erase and secure erase functions enable IPs and confidential data to be deleted safely; the action resets the memory completely to its factory defaults.

To ensure traceability of an end product, many STM32 series feature a 96-bit unique ID. This can also be used to diversify security keys.

Many series additionally incorporate secure firmware update functions. The hardware security functions can be expanded further by software-based measures.

The security of an end product against manipulation by third parties is based on the software solutions implemented and the electronic hardware components used. Microcontrollers and memory chips – where appropriate in combination with sensors and application-specific ICs – are key to IoT applications and Industry 4.0 alike. In connection with the EU General Data Protection Regulation (GDPR) which came into force on May 25, 2018, Rutronik has compiled a set of integrated security features for microcontroller families: It includes tables listing systems for protection against manipulation, encryption modules, permission management, debug lock

level, memory protection, as well as integrity and functional safety.

Evaluation of the security-relevant features listed in a table with regard to integrated data security within the Rutronik microcontroller portfolio provides informative insights: Like various STM32 microcontroller families, selected microcontrollers of the introduced Renesas Rx family and the Synergy S1/S3 family also offer an above-average degree of coverage with regard to security features.

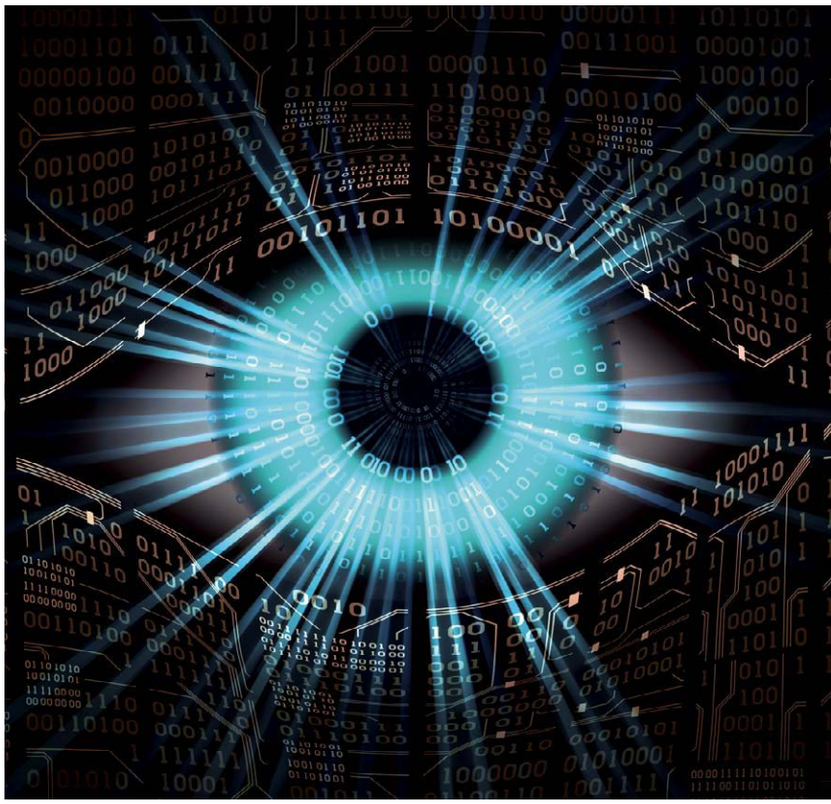
Selected microcontrollers in the Synergy S5/S7 category (Renesas) even meet this requirement fully. In addition, fully integrated support for both symmetrical and asymmetrical encryption methods, including integrated key generation based on AES (128/192/256), 3DES/ARC4 or RSA/DAS or DLP, should be emphasized here. The Rx family can be seen as a pioneer in terms of full coverage of various security features as well as support for integrated mechanisms for symmetric and asymmetric encryption.

Infineon's XMC-1xxx and XMC-4xxx series also offer extensive integrated security data protection, as can be seen in the table on pages 74/75 of the Security Aspects brochure. Within the context of special requirements for symmetrical or asymmetrical encryption, the supplier refers to the Crypto software package. Based on their own assessment of security risks for the end product and its component parts, developers can see at a glance which microcontrollers can potentially be used to ensure compliance with the GDPR in a board design.

If the developer defines security requirements for the end product, the Rutronik product portfolio offers a wide variety of microcontroller families from semiconductor suppliers that meet the challenges of GDPR legislation by integrating security-relevant features.

In summary, the key finding in relation to Industry 4.0 remains that data and services are not a product but a platform business. In the future, it will be less about selling machinery to generate high revenues. Rather, a wide variety of different data-generating machines will be installed on-site, and the platform operator will primarily earn money from the customer through the related data services. This will mark a revolutionary change to business models in the traditional plant and machinery manufacturing industry and its component suppliers. ■

Credit all pictures: Fotolia



Low power cellular

Cellular technologies for the Internet of Things

The LTE categories NB1 and M1 are becoming increasingly popular. Each year, the number of devices with low power cellular standards is growing by an average of over 100 million devices, claims market research company Berg Insight AB in its latest report Cellular and LPWAN IoT Device Ecosystems. Cellular standards with new embedded SIM solutions are experiencing an additional upturn in demand.

BY SARAH BRUCKER,
PRODUCT SALES MANAGER WIRELESS,
RUTRONIK

NB1 and M1, also known as NB-IoT (Narrow Band IoT) and LTE-M1, are simpler versions of normal LTE (Long Term Evolution, 3.9G). This means they use a much lower frequency spectrum and, therefore, consume very little current. Boasting a range of several kilometers and excellent in-building penetration, these standards enable completely new application fields for the IoT. This technology is particularly suitable for energy-efficient applications in which small amounts of data need to be transmitted in individual cases. Since with LTE-M, the downlink and uplink peak value is ~300 kbit/s at a maximum transmission rate of 20/23 dBm; with NB (Narrow Band) IoT, it is just ~30/60 kbit/s at the same transmission rate.

LTE networks as the basis

Since both technologies are based on LTE standards, already existing LTE networks can be used. This is a decisive advantage for the subcategories, as they not only benefit from robust and secure data transmission, but network expansion with worldwide roaming can be carried out quickly and in some cases even through software updates. The MNOs (Mobile Network Operators) organize the frequencies, dimension the dial-in nodes, and expand them according to regional requirements. Network coverage in the USA, Europe, and Asia is already very good, and in most regions even better than with long-range suppliers. This is also due to the fact that the range with NB-IoT is up to seven times greater and with LTE-M up to four times greater than the standard LTE range.

Data transmission even from places that are difficult to access

NB1 and M1 make 2G fallback superfluous. Thanks to the greater ranges, it is not absolutely necessary. In addition, the power supply can be dimensioned more easily because, unlike GPRS, no 2A current peaks have to be absorbed. Low module costs, the external wiring, the Internet provider, and the hassle-free 'everywhere' infrastructure clearly outperform alternative long-range technologies in most applications.

NB-IoT and LTE-M are especially suitable for IoT, i.e. everywhere where small amounts of data occasionally need to be transmitted, also from places that are difficult to cover, such as basements, ducts or wide-open fields. There are a whole host of possible applications, especially for sensors that regularly send small amounts of data to a control station. In the smart metering sector, for example, electricity, water, and other meter data can be transmitted directly to utility companies. Other focus areas are infrastructure, transportation and logistics, agriculture and forestry, wearables, and product-as-a-service with predictive maintenance and repair of machinery.

The most energy-efficient NB-IoT is better suited for applications with a fixed location, where normally no wireless cells are changed during transmission, while LTE M1 is the better choice for mobile applications due to its faster transfer rate.

nRF91: Secure and NB-IoT ready

As a pioneer in the field of ultra-low-power wireless technologies, Nordic Semiconductor is also committed to these new wireless transmission types. Thanks to the nRF91 series, the manufacturer offers a multi-mode module for NB1 and M1. The SiP (System in Package) comes with an ARM Cortex M33 microcontroller for customer-specific programming of the application, sensors, and actuators. ARM TrustZone® and ARM CryptoCell ensure secure storage access, while TLS and SSL guarantee end-to-end data encryption of the data transmission. The rewritable flash memory technology, together with the possibility of over-the-air updates, allows subsequent improvements to the firmware, the stacks, and the application. The module automatically searches for available LTE-M and NB-IoT networks and toggles between them.

Built with integrated assisted GPS or without GPS unit in a package measuring just 10 x 16 x 1.2 mm, the nRF91 SiP requires about four times less space on the PCB and approximately five times less volume than other LTE-M and NB-IoT modules and separate GNSS modules. Seeing as the M33 core enables real edge computing to a certain extent, local information can already be generated from the measured data in the field which can then be efficiently transmitted via the mobile radio unit. This optimizes the overall energy balance and keeps online data consumption to a minimum. The correspond-

ing nRF91-SDK (software development kit) contains all the common stacks, such as MQTT, CoAP, http, LWM2M, IPv4, IPv6, DTLS, TLS, and TCP.

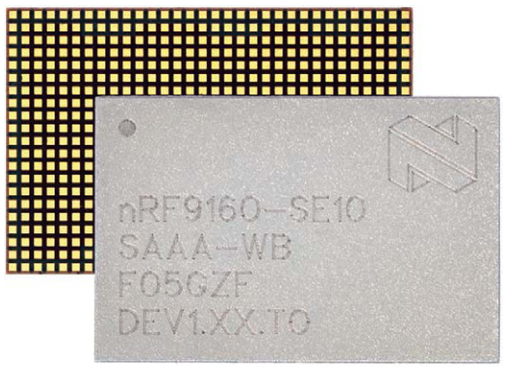
Sensors, LEDs, buttons, and switching relays can be connected via 32 GPIOs. The quartz, SAW filter, and all passive components are integrated – in the SiP, so that only a 50Ω single-ended line is needed as the antenna to complete the edge module.

Sending without SIM

New developments in the field of connectivity continue to drive NB-IoT and LTE-M forward. If you wanted to send or receive data via a cellular network in the past, a SIM card holder and a physical SIM card were necessary in addition to suitable hardware. This means greater space requirements on the PCB and a longer BoM (bill of materials) – and thus higher costs. Added to this is the task of manually swapping SIM cards in the event of changing provider. This is where 'embedded SIM' solutions, such as iUICC (integrated Universal Integrated Circuit Card), can help. They offer the advantage that the SIM functions are already integrated on the hardware module – which means less space requirements, a shorter BoM, and lower costs, since embedded SIM solutions can be controlled and updated remotely.

Customers can obtain precise embedded SIM solutions from the Rutronik partner Telit, a leading provider of cellular hardware, connectivity, and cloud solutions, which markets its 2G wireless modules under the name simWISE. The LTE-M and NB-IoT modules are also to be equipped with simWISE by the end of 2018, for example the ME910C1 LTE-M and NB-IoT combi module.

The simWISE modules are complemented by the Telit IoT cloud platform. This results in a customizable cloud solution with device, connectivity, data, and system management functions. ■



Credit: Nordic

At at size of 10 × 16 × 1.2 mm, Nordic's nRF91 SIP occupies just 20% of the volume or 25% of the area compared to other products in the market.

5G – The future starts NOW

4G now or 5G later?

2020 will be the year when 5G, the fifth mobile generation, is launched commercially worldwide. It is not long until then, but many companies are, nevertheless, currently faced with the question of whether it is wiser to wait with corresponding applications or whether solutions already exist today.

ANJA SCHAAL,
SENIOR MARKETING MANAGER WIRELESS,
RUTRONIK

In order to assess whether developments should better be implemented now or after the launch of 5G, it is necessary to take a closer look at the objectives to be achieved with the new standard. They basically apply to three main topics:

- eMBB – enhanced mobile broadband. Data transfer rates of up to 20 Gbit/s pave the way for the digital lifestyle of end consumers. In addition, eMBB is a prerequisite for applications that have a high bandwidth requirement, e.g. high definition videos as well as virtual and augmented reality.

- mMTC – massive machine type communications addresses the challenges of stable and ubiquitous network coverage in urban areas with a very high connection density of MTC devices. MTC devices are characterized by a battery life of more than 15 years and low hardware costs, as is necessary for smart city or smart agriculture applications. The main objective of 5G is to support one million such connections per square kilometer.

- uRLLC – ultra-reliable and low latency communications. Latency times of below 1 ms are prerequisites for reliable and time-critical applications, such as autonomous driving, car-to-car and car-to-everything communication or predictive maintenance based on cloud computing.

Network slicing

Another fundamental innovation that 5G will deliver is network slicing. This allows the three core areas eMBB, mMTC, and uRLLC with their varying requirements to coexist within the same physical networks without disturbing each other. Network slicing is a type of virtual network architecture that uses the same principles as software defined networking (SDN) and network functions virtualization (NFV). SDN and NFV are both technologies that can already be implemented under LTE to increase flexibility and scalability within a network. The hardware and software are decoupled from each other, thereby enabling further network infrastructures to be programmed. This means that different end devices can enter a network via the same radio access network (RAN) but can then be divided into various virtual networks according to their actual application. They remain in these networks up to the network provider or the data center in which the contents and applications are hosted (Fig. 1). Even if SDN and NFV can already be implemented within LTE networks, only network slicing under 5G really allows all the services to run through one and the same physical network – from the emergency call service, which depends on a robust and time-critical 24/7 network, to the private user sitting in the street café reading the latest news online.

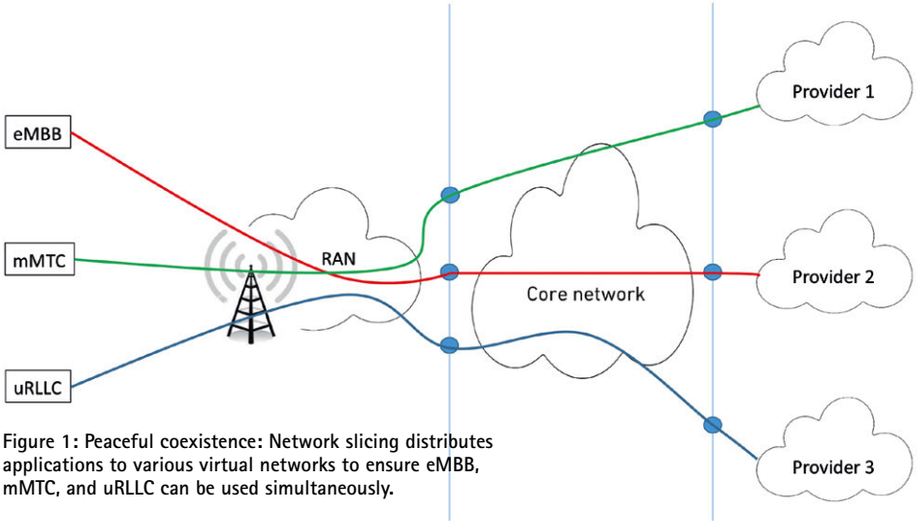


Figure 1: Peaceful coexistence: Network slicing distributes applications to various virtual networks to ensure eMBB, mMTC, and uRLLC can be used simultaneously.

Credit all figures: Telit

Figure 2: One of the first LTE-Advanced Cat. 18 cards in Mini PCI Express format: Telit's LM960.

Many things are already possible today

Under 4G, or with LTE, LTE-Advanced, and LTE-Advanced-Pro, basic technologies have already been created that are fully or partially incorporated into 5G. They form the basis for the introduction of the new mobile radio generation and already support certain 5G targets completely or at least to a large extent.

With regard to eMBB, several carrier components can already be combined under 4G through carrier aggregation (CA) to thus create a broader data line. The multiple antenna method massive-multiple input multiple output (M-MIMO) enables more simultaneous data strings, while license assisted access (LAA) allows for the use of the unlicensed frequency spectrum above 5 GHz.

3GPP release 13/14 with LTE-M (also known as eMTC, enhanced machine type communications) and NB-IoT has already created the

On the home straight to 5G

December 2017: First part of the – 5G NSA (non-standalone) – specification completed. It can be used to extend 5G mobile technology on the basis of 4G core networks.

June 2018: The second part of the 5G NR (new radio) specification – 5G SA (standalone release 15) – is available. Its core consists of a new end-to-end network architecture that enables particularly short latencies of up to less than 1 ms. 5G SA will be anchored on its own 5G core.

Today: Together, both parts create opportunities for new developments and business models that herald a new era of comprehensive networking.

basis for the implementation of mMTC. Both technologies in the LTE Category 0 range offer additional features, such as power saving mode (PSM) or extended discontinuous reception (eDRX). These functions can wake up devices periodically in order to send very small amounts of data and then immediately put them back into sleep mode. This allows the devices to "sleep" most of the time, thus helping to extend the battery life significantly. Maximum coupling loss (MCL) already ensures increased coverage, as is also the aim with mMTC.

The 3GPP release 12 already contains requirements for reducing latency times – a target within the framework of uRLLC. However, considerable improvements can only be expected with the introduction of 5G.

LTE Cat. 18, LTE-M, and NB-IoT as a first step towards 5G

This means: Companies can already start their development of IoT solutions today. The LM960 Mini PCIe card from Telit, for example, is available for implementing eMBB, i.e. higher data transfer rates (Fig. 2). The LTE-Advanced Category 18 solution enables downlink speeds of up to 1.2 Gbit/s with the 4x4 MIMO mode. Thanks to CA, it can support up to five carrier components, while LAA ensures better penetration in buildings. – Telit offers the ME910C1 LTE-Cat.-M1/NB1 family for mMTC applications (Fig. 3). It combines LTE-M and NB-IoT and provides high energy efficiency thanks to features such as PSM (power saving mode) and eDRX. MCL increases the level of coverage.

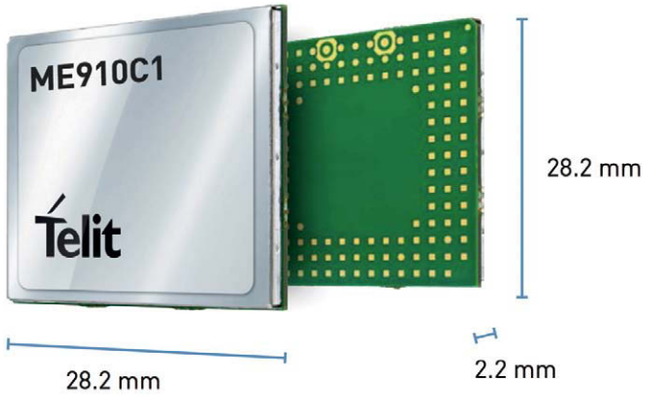


Figure 3: The ME910C1 family combines LTE-M and NB-IoT.

Conclusion

With 5G, it is possible to look forward to many technologies and improvements that are essential for applications in the uRLLC sector, such as connected cars or autonomous driving. For eMBB and mMTC applications, it is recommended, however, to start with development immediately. Suitable solutions are already available from various suppliers. When making their choice, developers receive competent support from Rutronik's wireless specialists. This means that companies will not lose any investments until the start of 5G in 2020, will be able to make their applications IoT-capable today, and will still benefit from 5G tomorrow. ■

Hardware-based security

Taking Industry 4.0 to the next level

Taking security into account, the "trial and error" and "fail fast and early" approaches are incompatible with developing IIoT devices.

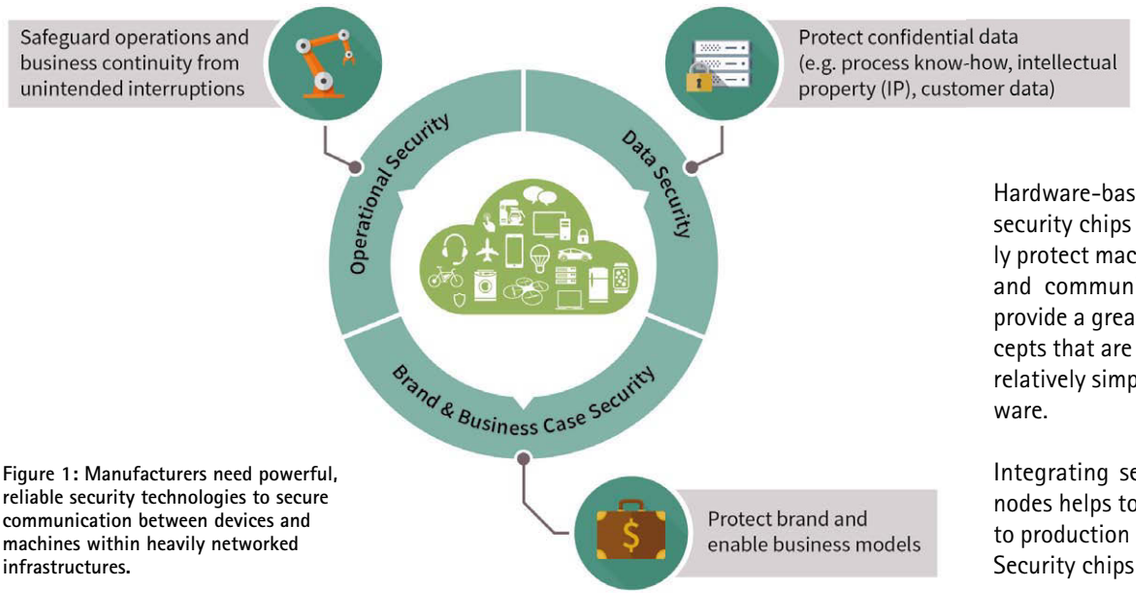
BY DAVID WERTHWEIN,
PRODUCT SALES MANAGER
MICROCONTROLLER,
RUTRONIK

The Internet of Things (IoT) is connecting smart devices and machines to create smart factories (known as Industry 4.0 or Industrial Internet). These highly automated, decentralized factories promise greater efficiency and flexibility across production processes. At the same time they are also exposed to attacks from cyberspace as they rely on Internet connectivity. Software measures alone do not generally provide sufficient protection against these attacks. Hardware-based trust anchors are required to effectively protect smart factories. Infineon's Optiga security controllers provide scalable security for embedded systems, thus protecting machines, data and intellectual property in smart factories.

Smart factories and connected supply chains are presenting many manufacturing companies with new security challenges. Malware, manipulation, sabotage, faulty firmware updates and counterfeit components are examples of advanced threats that can bring entire production lines to a halt and may lead to significant costs and loss of image. The tiniest security gap in a company's infrastructure can lead to theft of data, intellectual property (IP) and process know-how. Safeguarding this sensitive information calls for tailored solutions that deliver end-to-end protection yet also strike the right balance between security performance requirements and financial constraints. Manufacturers need powerful, reliable and scalable security technologies to safeguard communication between devices and machines within heavily networked infrastructures (Fig. 1).

Secured Identities are the anchor

In this context, secured identities for machines provide the anchor for implementing any measures to protect electronic exchange and storage of data. As known from daily life where ID cards or passports are used for identification of humans, secured identities are used by machines to reliably identify each other. But even these secured IDs digitally stored on machines could become the subject of attacks and theft.



Credit all pictures: Infineon

Figure 1: Manufacturers need powerful, reliable security technologies to secure communication between devices and machines within heavily networked infrastructures.

Hardware-based security solutions based on security chips are the best way to efficiently protect machine identities as well as data and communication. Security controllers provide a greater level of security than concepts that are purely software-based as it is relatively simple to read and overwrite software.

Integrating security chips into all critical nodes helps to prevent unauthorized access to production networks and smart factories. Security chips enable

- continuous check of component authenticity as well as data and system integrity to prevent manipulation;
- verification of the authenticity of software updates;
- protection of remote access activities;
- robust protection against low-quality, counterfeit spare parts and repair tools.

Chip solutions also provide cryptographic functionality such as public key cryptography and key management. Although these functions could be implemented in both software and hardware, for industrial applications, a hardware-based solution such as a dedicated security chip has clear benefits and can add real value for manufacturers.

Silicon manufacturers such as Infineon Technologies use highly secured, certified processes to personalize hardware trust anchors, i.e. providing a secured identity to each security chip. This often includes a set of keys and certificates stored on the chip in order to allow other devices in the industry automation system to securely authenticate a remote device, to build up a secured connection, and exchange data in a protected way.

Proper hardware anchors are security-certified components that are also equipped with measures to protect them against physical attacks. As such, they offer protection during transit. In other words, a hardware anchor protection is so robust that it does not need special security measures to be shipped using cost-efficient logistics channels. This not only applies to shipping the security chip itself but, more importantly, also to shipping devices that contain a hardware anchor with customer-specific keys. These physical protection capabilities can reduce costs particularly during installation and delivery processes.

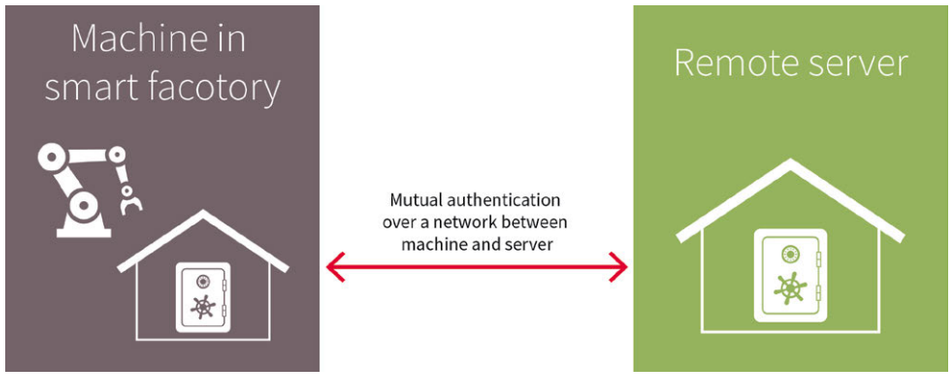


Figure 2: Mutual authentication of machines over a network

Hardware-based security implementations in smart factories

Mutual authentication (Fig. 2) refers to two parties authenticating (securely identifying) each other. In the context of smart factories, this could be a server and a machine authenticating each other before initiating a secured communication or a critical remote maintenance task such as adaptation of critical parameters. In this scenario, the secured identity stored in the machine's hardware anchor is verified by the server and vice-versa. The hardware anchor contains the secret keys and offers functionalities to verify the secured identities of the other parties. It usually does this using a public key infrastructure (PKI) scheme.

When an industrial automation system is set up, the computing and controlling components are equipped with a specific version of the relevant software package. After this point in time, the smart factory must be protected against unintended changes to the software as this could disrupt production, threaten plant safety and enable know-how to be stolen. At the same time, it must still be possible for software to be updated intentionally, for example, for maintenance purposes or to change certain features. Robust trust anchors also support this use case, for example by enabling a secured boot process (Fig. 3). The underlying concept here is that code is only executed after its integrity has been verified in advance by the hardware anchor.

By using state-of-the-art microcontrollers and stand-alone security controllers such as the Optica product family (Fig. 4), it is possible to implement a hardware-based trust anchor that protects the system software against attacks. The key to successful protection lies in the use of open industry standards that allow seamless connectivity across existing and new systems.

Scalable and dedicated security solutions

For many manufacturers, protecting their products against counterfeit is a top priority.

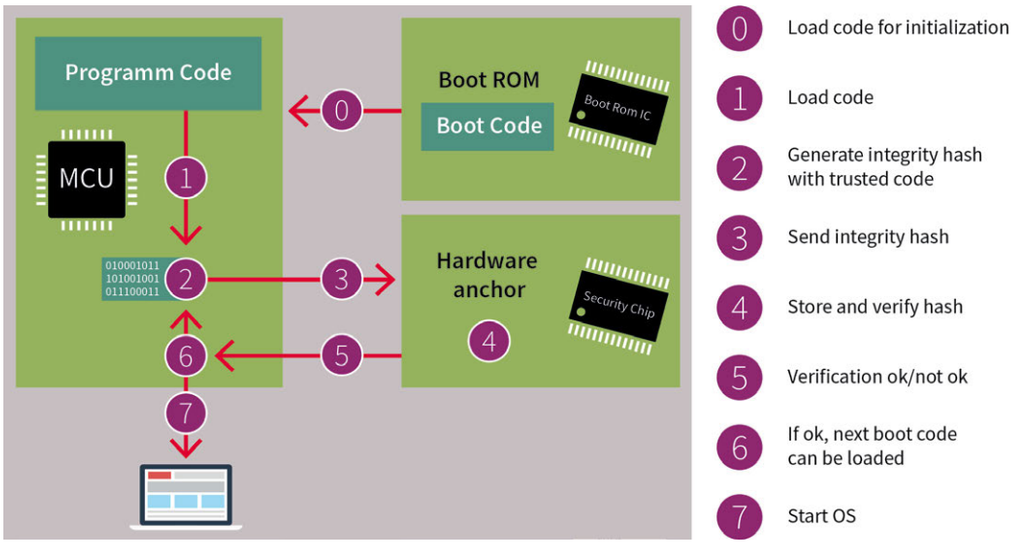


Figure 3: A secured boot process enables platform integrity of computing and control systems in industrial environments.

With its Optiga Trust product family, Infineon offers a complete security solution comprising a chip and software for electronic accessories.

The chip is based on asymmetric cryptography and is easily integrated into electronic accessories thanks to its compact package (2 mm × 3 mm) and turnkey set-up. In order to check whether or not a part is genuine, the host system sends a challenge (essentially a random number) to the chip in the accessory. The Optiga Trust B subsequently generates a response using the chip-individual key. If successfully authenticated by the chip, the accessory or replacement part is accepted by the system and can be used without restrictions.

Following the same principle, the Optiga Trust E was specifically developed for protection of high-value goods in industrial applications. It features an I²C interface as well as an extended temperature range (–40 to +85°C). This would be of benefit to manufacturers of wind turbines, for example, who would want to avoid damage to the overall system caused by counterfeit replacement parts. Both the Optiga Trust B and the Optiga Trust E are delivered with code to simplify integration of the chip into spare parts.

The Optiga Trust X completes the portfolio of turn-key solutions. Based on a Common Criteria EAL6+ certified hardware, this security solutions enables frequently required security use cases including support for secured communication via (D)TLS, secured firmware update. Furthermore Optiga Trust X provides a powerful cryptographic toolbox to efficiently support the growing number of Iot security specifications and protocols.

Comprehensive protection with Trusted Platform Modules (TPMs)

The Optiga TPM (Trusted Platform Module) portfolio covers the broadest range of security requirements. These security controllers are based on the international standard of the Trusted Computing Group, an association of leading manufacturers from the IT industry. TPMs have already successfully proven themselves in computer applications, and this tech-

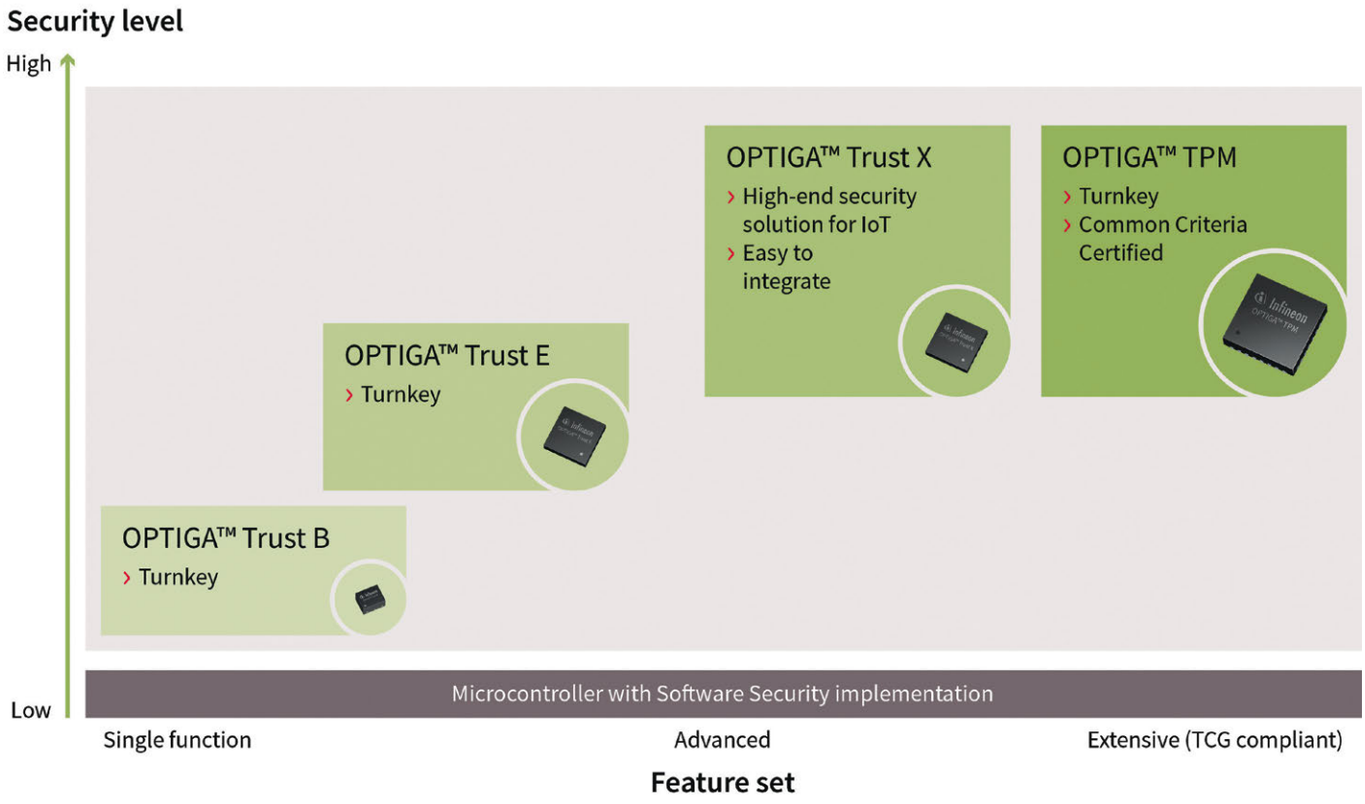


Figure 4: The Optiga product family offers scalable security solutions for a wide range of industries.

nology is now making its way into new networked systems and devices such as routers, industrial facilities and cars.

The members of the Optiga TPM family (Fig. 5) have been validated and security-certified according to the Common Criteria certification process. To permit easy integration into a system, the Optiga TPM family supports commercial and open source code for Windows and Linux, including derivatives and Infineon tools. The Optiga TPM family comprises a broad range of security controllers complying with the TPM 2.0 standard, which, depending on the application area, are available for various temperature ranges and offer different interfaces such as SPI, I^2C and LPC.

One area where Optiga TPMs can be used in industrial applications is secured data transmission or storage. In such an application, the key factor is the combination of secured hardware and software-based security mechanisms. The use of a TPM supports monitoring and/or protection of the system's integrity. This security controller additionally permits reliable component identification, which only allows reliable and trustworthy components to communicate with each other.

For secured remote access, e.g. for system maintenance or software updates, the TPM controls access to the system by means of device authentication. The Optiga TPM also provides secured storage for secret keys and protects cryptographic operations. For typical applications such as for the SSL/TLS protocol, keys are stored in the secured store of the TPM rather than in the memory of the main processor and are only processed internally. This offers the advantage that the secret keys are protected against external security risks. In conjunction with TPM and security mechanisms such as encryption, the system code is also protected against manipulation. As a standardized component, TPMs come with a rich ecosystem of available drivers and software stacks allowing customers to easily integrate security with limited integration effort.

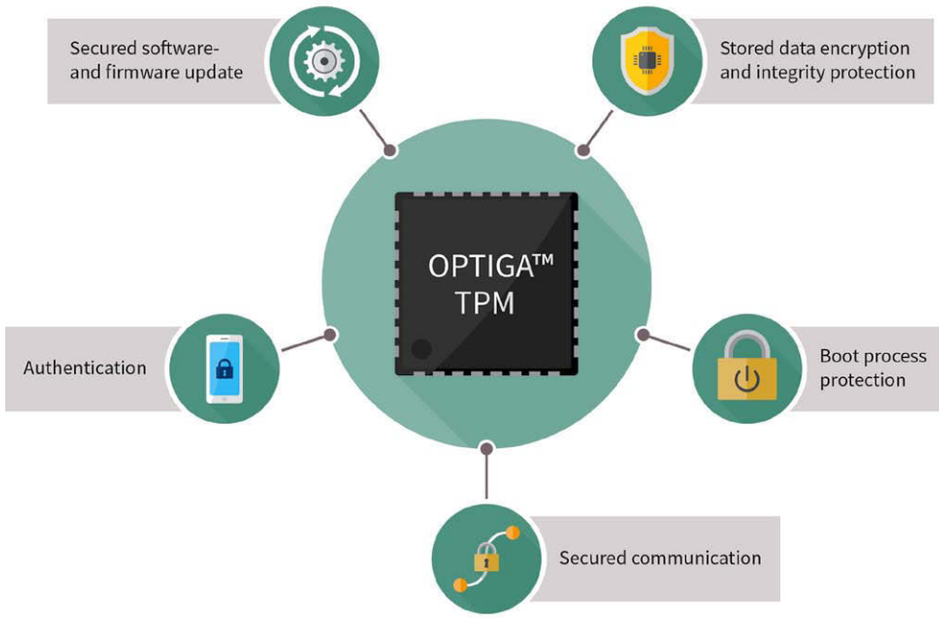


Figure 5: Typical use cases of Optiga TPM

Summary

Security is a cornerstone of Industry 4.0. Secured cryptographic identification of machines and devices protects smart factories against manipulation and data theft. Hardware trust anchors implemented with dedicated security chips provide robust protection for security keys while lowering overall security expenses for device manufacturers. ■

Bluetooth Mesh

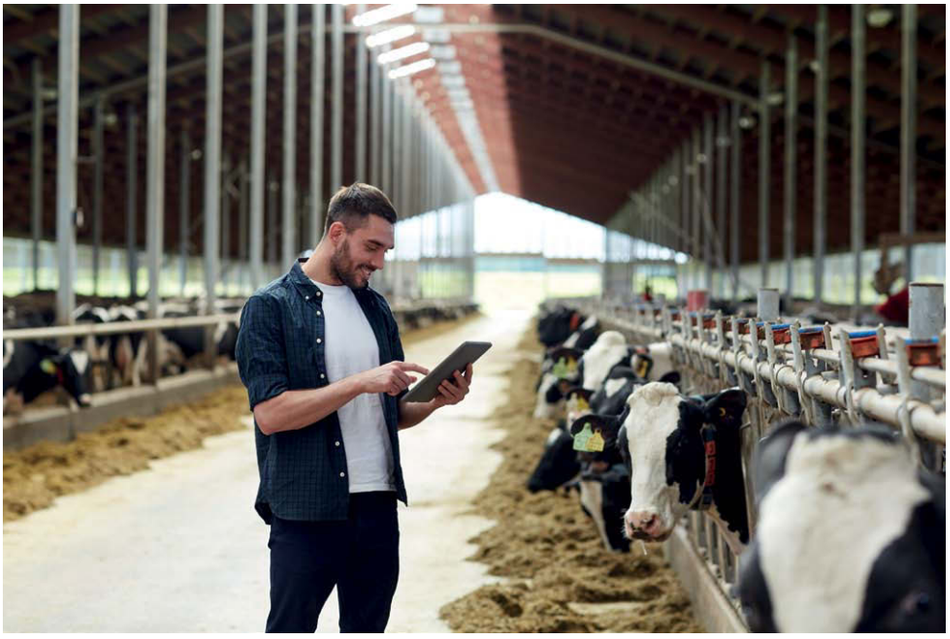
Thinking completely new applications

Mesh technology allows Bluetooth devices to be linked together to form a large network, bridging large distances in an energy-efficient and secure manner. Completely new application scenarios are possible by meeting industry standards in terms of security, reliability, and scalability.

By Kerstin Wagner,
Product Sales Manager Wireless,
Rutronik

The Bluetooth Special Interest Group (Bluetooth SIG) introduced a standard for wireless data transfer in the year 2000: Bluetooth Basic Rate (BR)/Enhanced Data Rate (EDR). In 2010, Bluetooth SIG further enhanced its standard with the definition of Bluetooth Low Energy (BLE), which made data transfer possible with low power consumption.

The demand for this wireless communication technology is high, also because further improvements and developments can be expected. The success of BLE is first and foremost due to its very low power consumption. But the BLE protocol also has its disadvantages. Only three types of communication are possible (Fig.2): Between two individual devices (point-to-point communication, bidirectional, 1:1), between one device and many others (one-to-many communication, bidirectional, 1:m) or communication in which the data from one device is continuously sent to the environment without having a specific addressee (broadcast communication). When broadcasting, all BLE devices in the environment can receive the data but cannot respond to it. The disadvantage of these network topologies is that the entire network fails if the master (star configuration, central role) that is to transfer the data fails.



Credit: Syda Productions – Shutterstock

Figure 1: With the eating behavior in view, diseases are recognized immediately – Bluetooth Mesh connects the sensors efficiently and inexpensively.

The perfect network technology

In July 2017, Bluetooth SIG introduced Bluetooth mesh, a further improved wireless communication technology based on the Bluetooth Low Energy communication protocol which can be used optionally. With Bluetooth mesh, a large network of many-to-many connections (m:m, Fig.3) can be established across a large physical area with up to 32,000 network participants. Transfer still works even if the device that originally sent the message is not in the direct radio range. In addition, Bluetooth mesh 1.0 network technology enables communication between devices from different suppliers, which was not possible with previous proprietary solutions, such as CSRmeshTM. Further advantages are robust and secure data transfer as well as very high energy efficiency.

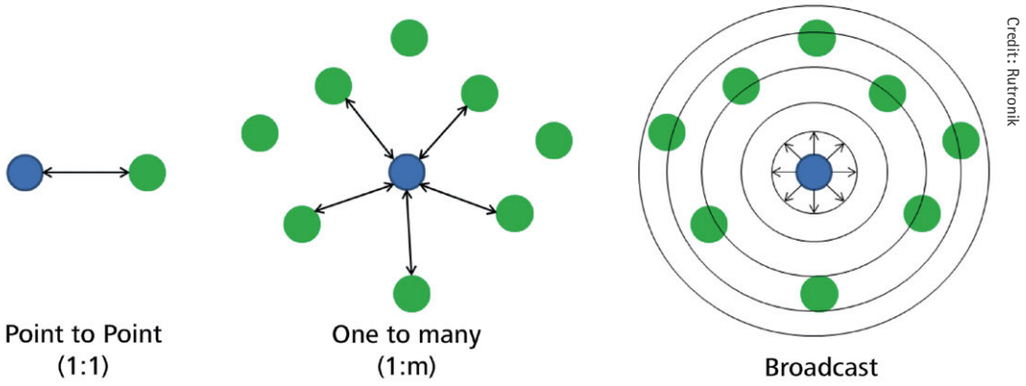
These features make Bluetooth mesh a perfect network technology for many areas of application, such as building automation, sensor networks, industrial manufacturing or goods tracking. Generally speaking, Bluetooth mesh is suitable for all applications that require communication between several devices with a minimum of data.

How does Bluetooth mesh work?

Bluetooth mesh works with a messaging system in which messages are distributed according to the publishing and subscribing principle. Sending messages to a device with a specific address is called publishing. Subscribing is the configuration of devices for which a specific address is assigned to the device. This device can then only receive messages if they have been sent to the specific address. An example: Hall lighting is installed with Bluetooth mesh. All the light bulbs are configured to receive the "hall lighting" subscription. If the "on" message is sent to the "hall lighting" address via a BT mesh switch, all the light bulbs registered under "hall lighting" are switched on.

Data transfer in Bluetooth mesh is referred to as "flooding". This means there is no special route for the message through the entire network to the slave (receiver). The message is sent to all devices within range and then forwarded until it reaches the correct slave.

Due to a dense number of network participants, it is possible to overcome obstacles which previously required the use of slower and not globally standardized sub-GHz technology. Even if the device that originally sent the message (master) is not within radio range, the message still reaches the correct slave. If the network is already narrow enough due to the participant density, connections can be secured redundantly, which is why the data would still find their destination even if a single participant would no longer function as a relay. This self-healing property makes Bluetooth mesh one of the most reliable networks and ensures its wide-scale use in industry for the first time.

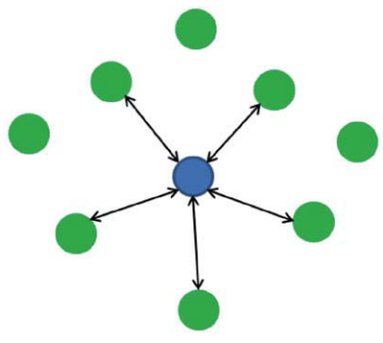


Credit: Rutronik

Figure 2: Conventional communication options in a Bluetooth network with a master

The devices in a Bluetooth mesh network are called nodes. There are four different types of nodes that – in addition to sending and receiving – deliver additional functions:

- Relay nodes: They forward received messages to the next device. Message transfer functions using so-called "hops", with Bluetooth mesh supporting a maximum of 127 hops.
- Low-power nodes: Some devices, such as sensors, need to be extremely energy-efficient. Low-power nodes work in conjunction with one or more other nodes called "friends".
- Friend nodes: Sufficient energy is available here, e.g. through connection to the mains supply. These friend nodes work together with low-power nodes. Friend nodes store



Credit: Rutronik

Figure 3: With Bluetooth Mesh, data in the network is passed from the transmitter to the receiver via the individual nodes.

messages and forward them only when requested to do so by the low-power node.

- Proxy nodes: They provide the GATT interface (generic attribute profile) for BLE devices without the Bluetooth mesh stack. This also enables communication between BLE mesh and a normal BLE node.

Within the access layer of the OSI layer model, it can be determined whether a confirmation message (acknowledgment) should be sent back to the master after receiving the message or not.

Is Bluetooth mesh secure?

Setting up a large network with many devices poses a huge risk to secure data transfer. Security was therefore the top priority when developing Bluetooth mesh. To this end, Bluetooth SIG outlines a strict specification. All security functions within a Bluetooth mesh network are mandatory.

However, the security vulnerability in Bluetooth Secure Simple Pairing and LE Secure Connections identified by researchers at the Israel Institute of Technology also affects Bluetooth mesh, as it is based on the BLE stack. Some suppliers with affected products already offer a firmware update or are in the process of fixing this problem. Rutronik has compiled an overview of the affected Bluetooth products from the line card to record the status of possible firmware updates: rutronik-tec.com/bluetooth-security-vulnerability-status

The key security features are:

- Encryption and authentication: All Bluetooth mesh network messages are encrypted and authenticated.

- Separation of concerns: There are three different security aspects within a Bluetooth mesh network: Application, network, and device security. They are handled independently of each other and have their own security keys:
  1. Application key (AppKey): This secures data relating to specific applications, e.g. lighting or cameras.
  2. Network key (NetKey): Network keys apply to all devices in the network, thereby ensuring secure data transfer.
  3. Device key (DevKey): Each node has a unique device key. This security key can be used to add devices to a network.

- Area isolation: The Bluetooth mesh network is divided into subnets. These subnets are each cryptographically distinct and secure from the others.

- Key refresh: All security keys can be changed in the Bluetooth mesh network during a key refresh procedure.

- Message obfuscation: This data privacy mechanism makes it extremely difficult to track nodes in a network. It is therefore almost impossible to track messages sent.

- Replay attack protection: Security functions protect the network against replay attacks (identity theft: previously collected data is used for authentication and access control).

- Trashcan attack protection: Nodes can be removed from the network securely in a way that prevents trashcan attacks (reading important network information from invalidated nodes).

- Secure device provisioning: New nodes can be added to the Bluetooth mesh network in a secure process.

All these extensive security features make Bluetooth mesh an interesting solution for applications that require low data rate communication between multiple devices. In addition, Bluetooth mesh is ideal for new areas of application such as predictive maintenance or smart agriculture/farming. Implementation of a wireless sensor mesh network in assembly lines can warn maintenance staff in good time before a machine fails. Or, by using mesh networks in agriculture, data such as soil and air humidity or temperature can be transferred directly to a smartphone without a gateway. It also allows more efficient use of water and fertilizers and reduces the use of pesticides: Appropriate measures are only taken if the measured values fall below a certain limit. In the smart home sector, lights could be equipped with sensors that register when someone is nearby, ensuring the lights are only switched on in this case. Bluetooth mesh could even be used for sporting activities: Sensors integrated in the athlete's shoe can record performance data, which can then be transferred via a Bluetooth mesh master from one athlete to the next until they reach the coach, for example, who can then evaluate the data.

Another advantage: The actual environment is not important for BLE mesh technology. Innumerable applications are conceivable due to the industrial requirements fulfilled by mesh specification 1.0 and higher: Be it in hospitals, factories, offices, universities or private homes. Bluetooth mesh is well worth a closer look wherever wireless, secure, and robust communication between a large number of devices enables new applications. ■

Renesas Synergy

Complete solution for IoT development

There are hardly any uniform standards for IoT and embedded development. Writing new software and configuring drivers are therefore time-intensive and costly tasks. Through its Synergy Platform, Renesas has set itself the goal of significantly accelerating and simplifying these developments.

By Zibo Su,
Product Sales Manager (jun.)
Microcontroller,
Rutronik

The Internet of Things (IoT) is one of the largest growth markets. There will be five billion networked IoT devices at the end of this year, and there should already be more than 20 billion by the end of 2020 according to the analysts from the market research company Gartner. They expect an annual growth rate of up to 15%, particularly in the sectors of medical technology, mobile devices, navigation technology, automotive, security technology, and industry. The increased demand for IoT applications in more and more sectors and ever shorter development cycles are putting developers under considerable pressure. In particular, products that interact with a large number of peripheral devices and therefore use complex interfaces, such as Ethernet and USB, often require time-intensive programming of drivers, graphic interfaces, and application software.

Renesas wants to lower these hurdles through its Synergy Platform. The development platform, specially designed for IoT applications, consists of hardware and software components: Four microcontroller series with corresponding evaluation kits are supplemented in the software by the Synergy Software Package (SSP), various development tools, and third-party software add-ons. The Synergy Gallery, a library of already developed solutions, demos, tools, licenses, and much more, completes the offer.

This provides developers with a comprehensive software foundation. They can start directly at the API level, thereby saving valuable development time. Since all the components within the Synergy Platform are fully coordinated, the development process is additionally simplified. Through the integration of numerous peripherals, various middleware components, such as network protocols, WiFi, and PLC, as well as numerous other features, for example the implementation of enterprise cloud interfaces, the

platform supports the realization of countless innovative ideas.

The Synergy microcontroller family

The S1, S3, S5, and S7 microcontroller series were developed especially for the rapidly growing IoT market. Each of the four MCU series is designed for specific applications. Thanks to numerous integrated features, they simplify connectivity and the HMI/GUI design. In addition, they ensure robust security standards as well as high reliability and improved data processing.

The S1 series is extremely power efficient, making it particularly suitable for battery-powered sensors and control applications; the S3 series is primarily designed for efficiency. A 48MHz Arm Cortex M4 processor and a floating-point unit allow DSP operations with minimum CPU clock cycles in order to process data prior to transfer.

Beside good performance thanks to the 120MHz ARM Cortex-M4 processor, the S5 series offers a high level of integration. A 640kB on-chip SRAM eliminates the need for an additional SRAM module and performs tasks, such as buffering graphic frames to control a TFT display. A floating-point unit, integrated encryption and decryption via RSA, and features, such as a capacitive sensor unit, make the all-round MCUs suitable for an array of applications.

The S7 series offers the highest standard of performance, connectivity, and security features within the series. With interfaces for Ethernet, CAN, TFT controllers, USB, timers, A/D and D/A converters, etc., the MCUs can operate multiple secure high-speed channels simultaneously, control a variety of TFT displays up to WVGA resolution, execute precise control commands, and record analog signals precisely. By delivering a performance level of up to 300MHz, an on-chip code flash of 4 MB, and a data flash memory of 64 kB, they can be easily used as the main MCU of a product.

For secure IoT applications with extensive hardware acceleration (Secure Crypto Engine 7), the S7 microcontrollers support a range of symmetric and asymmetric cryptography algorithms, such as AES, RSA and HASH algorithms, as well as secure key generation and storage.

All Synergy MCUs offer drop-in, pin-to-pin compatibility across the same package within each series as well as peripheral and register compatibility across the entire family. High reusability of the software is thus possible during migration from one MCU to another. Furthermore, it reduces PCB layout effort and increases manufacturing efficiency.

The Synergy Software Package

The Synergy Software Package (SSP) uses commercially-tested embedded software that is compatible with all Renesas Synergy microcontrollers. It contains a multitude of programs, connectivity protocols, drivers, and many other features that are indispensable when programming embedded applications.

The main component of the SSP is the X-Ware software from Express Logic. X-Ware includes the real-time operating system RTOS, the NetX middleware, as well as the NetX Duo IPV4 and IPv4/IPV6 TCP/IP stacks, the USBX USB host/device/OTG protocol stack, the MS-DOS compatible FileX file system, and the GUIX run-time graphics library. The SSP is complemented by extensive API interfaces, libraries for security and encryption, CMSIS DSP and Captouch, HAL drivers, and an application framework.

The SSP is permanently supported and maintained by Renesas; further, new content is added and constantly being qualified. This means developers no longer have to create and maintain low-level software for each of their embedded projects.

Development tools and kits

In addition to the provision of coordinated hardware and software, the second main pillar of the Synergy Platform is simplification of the development process. To achieve this goal, it offers hardware support through numerous suitable development kits and software development tools.

The kits support evaluation of the Synergy Platform and configuration of the MCUs:

The starter kit and the promotion kit allow easy entry into the world of Synergy. While the starter kit is based on the S7-MCU, the promotion kit works with an S5 microcontroller. Both boast a capacitive touch sensor, and the starter kit also comes with a Bluetooth LE module.

The development kits enable the evaluation of specific functions through supporting circuits and connections, such as graphics and Pmod plug connectors for third-party peripheral modules. Standard and customer-specific multifunction boards accelerate prototyping even further. Moreover, the kits allow connection to Ethernet, USB, CAN, RS-232, and RS-485 buses, with a modular design also for additional peripheral devices.

Target board kits are the more compact version of the development kits. They also offer access to all the pins of the MCUs but offer fewer connection options.

Development tools

The development tools of the Synergy Platform facilitate file management, software and MCU configuration, code generation, compilation, debugging, and enable intuitive graphical interface design. Available tools include IAR Embedded Workbench for compiling, code analysis, and debugging; E2 Studio ISDE, an Eclipse-based development program; TraceX for the monitoring and graphical visualization of run-time events; GUIX Studio for GUI designs; and the Renesas Synergy Standalone Configurator (SSC), which duplicates the e2 Studio project generator to configure clock, pin, RTOS, and SSP modules. ■

Credit: Renesas

Predictive maintenance

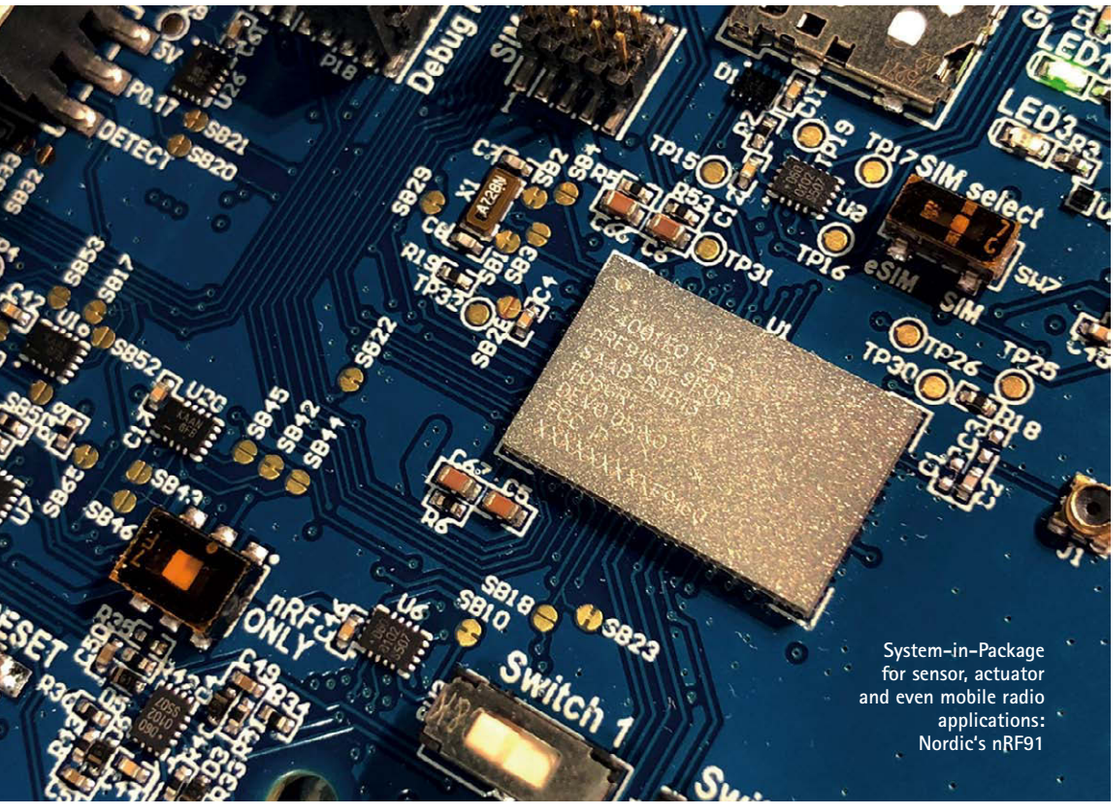
How can predictive maintenance become a success?

Preparing today for tomorrow. If you postpone maintenance, you could well experience sudden machine and belt failure or faulty production. Regardless of whether the delay was due to cost savings, lack of skilled workers or loss of motivation: Thanks to predictive maintenance, this can no longer occur. However, a few points must be observed in order for this to succeed.

By Stephan Menze,
Product Sales Manager
Analog & Sensors,
Rutronik

Each predictive maintenance project begins with the detection of machine characteristics during normal machine operation, such as acoustic or natural frequencies of structure-borne and air-borne noise, which are then digitized and transmitted to a computer or the cloud. In the case of local data processing, we speak of edge computing. This is where local AI solutions such as Intel Movidius can be applied. In terms of cloud computing, an unlimited offering for data analysis is available from third party service providers. The edge solution is able to respond in the millisecond range. An Internet connection is, nevertheless, indispensable for firmware updates and remote monitoring. In principle, however, swarm intelligence is not used for learning and improvement processes and is limited to local computing power and your own experience history. Cloud computing, on the other hand, enables comparisons to be made with all the systems operated in

Credit: Gorodenkoff – Shutterstock



System-in-Package for sensor, actuator and even mobile radio applications: Nordic's nRF91

Creidit all pictures: Noridc

the field and can draw conclusions from changes in individual systems to other systems. In addition to this swarm intelligence, there are no limits in terms of computing power or memory capacity and you can flexibly change the logarithm used – for example, from static data analysis to machine learning or deep learning.

As different as the two implementations may seem, an Internet connection and a local initial analysis of the sensor data are always necessary in a real-life scenario. However, both the scaling of significant components and the ongoing maintenance costs vary accordingly, which makes a precise cost-benefit analysis even more complex.

Positioning of the sensor is a decisive criterion

Whether analyzed locally or in the cloud, it is important to clarify where damage can occur and where it can best be detected. But can the sensor also be installed here? Is the site accessible and is sufficient space available? Is there excessive or loud ambient noise? Is it constant or does it occur only at irregular intervals?

Once the ideal installation location has been clarified, the sensor type is often already determined: If everything speaks in favor of attachment to the device or the machine, it is about detecting structure-borne noise. Thus, a shock and vibration sensor or an acceleration sensor is the implement of choice. When placed outside the device or the machine, airborne noise is detected. MEMS microphone sensors with a specific frequency range are available for this purpose, for example from STMicroelectronics and Infineon. As they always have an opening to absorb the sound waves and to reduce the sound pressure, they are not suitable, without special measures, in humid or dusty environments. In this case, shock and vibration sensors or acceleration sensors can be used.

To answer the question of which frequency range a predictive maintenance system should cover, the following rule of thumb can be applied: The higher the detected frequency, the earlier damage can be registered. In the ultrasonic range above 16 kHz, initial signs can be detected months before the damage would actually occur. When detected in the audible range up to 16 kHz, there may be only a few weeks left before damage happens. This may be sufficient time for some machines or equipment, but too late for others – this must be checked on a case-by-case basis: How serious can the potential damage be? How long does it take until spare parts are obtained and a service technician is available? Is it possible to stop the machine at any time to carry out repair or maintenance work? For instance, detection in the ultrasonic range is highly recommended for a leak test on gas pipes. If a leak generates audible noise, it is already too late for predictive maintenance.

If detection in the audible range is sufficient, the type of machine or machine part determines which frequency range the sensor should cover. The faster the relevant parts rotate, the higher the frequencies to be detected. For example, damage to air guidance systems is usually caused by unbalance, incorrect adjustment or loose connections. This takes place in a range of about 2 kHz. With very slow moving parts, an acceleration sensor instead of a microphone sensor can provide better results.

Microphone, acceleration, shock, and vibration sensors can be combined to increase the number of hits during error detection. Even more information is possible when using other sensor types, e.g. for temperature, humidity or pressure. This type of combination offers the greatest benefits when the sensors are networked with each other. However, this not only pushes up the costs for the sensors and the connection but also results in more data and higher evaluation effort. The combination of several sensors is, thus, only worthwhile if there is a corresponding potential damage, for instance due to belt failure or faulty production, which may even go unnoticed for a longer period of time. This can also be useful for systems in remote areas, e.g. offshore wind

What is predictive maintenance?

In contrast to preventive maintenance, predictive maintenance is not based on fixed maintenance cycles but on demand-oriented maintenance that utilizes measured data collected continuously on site and the respective data evaluation. It registers vibrations or altered noises from machines, systems, and equipment that indicate problems during operation long before actual damage occurs.

The nRF52840 offers different technologies for data encryption before transmission.

farms, as unnecessary engineer call outs result in high costs here. Comprehensive detection of safety-critical systems, such as the braking system in a car, is particularly recommended.

New wireless technologies for data transfer

Depending on the application, individual sensors must first transfer their measurement data to a local data collector. Microcontrollers with integrated radio interfaces and integrated AD converters, so-called wireless SoCs, are ideal for this purpose. Quite often radio stacks are already supplied free of charge and tailored to the microcontroller, so that only the application, i.e. the digitization of the analog values and transfer to the data collector, still needs to be implemented with a few program lines. The data collector can now evaluate the data locally and use its gateway function only for software updates or occasional reporting. In this case, LTE would be a more than sufficiently fast Internet connection, which will also have a secure infrastructure for many years to come. For a time-critical analysis of data in the cloud, where feedback is required within a few milliseconds, 5G will be able to hold its own. The connection of the sensors to the data collector cannot always be achieved with cables. Radio technology is usually cheaper, more flexible, and more durable. With an nRF52840 from Nordic Semiconductor, you can easily choose between Bluetooth mesh, ZigBee or Gazell, a free open source stack for star topologies. NFC enables an uncomplicated connection of the sensors to the respective data collector. For the first time, sensors can be calibrated with a laptop via the integrated USB port. Users who know from the start that they will only use Bluetooth 5 or Bluetooth mesh can also switch to cheaper variants, such as the nRF52810. The latest Bluetooth 5 version enables a range of up to over one kilometer in long-range mode. This makes the technology interesting even where SubGHz technology was previously indispensable.

The new LTE categories are suitable for sensors that do not use data collectors, or data collectors that only need to transfer small amounts of data to the Internet due to strong data compression through edge computing. They make it possible to establish a direct Internet connection from the sensor to the cloud and to transfer the measured values to the cloud without a separate gateway.

The new LTE categories

The latest LTE categories NB1 and M1 – also known as NB-IoT and LTE M1 or LTE-M – are ideal for applications such as predictive maintenance, where small amounts of data need to be transferred in isolated cases. Further information on this technology can be found on page 72 of this issue.

Both LTE-M and NB-IoT are supported by Nordic Semiconductor's nRF91 family. The highly integrated SiP (system in package) comes with an ARM Cortex M33 microcontroller for custom programming of the application, sensors, and actuators. Its computing power enables the application of more complex algorithms for data analysis. This means: The wireless module generates information on site from the measurement data provided by the sensors, so that only a much smaller amount of data needs to be sent. This optimizes the overall energy balance and keeps online data consumption at a low level. In addition to the sensors, LEDs can also be connected via 32 GPIOs, for example as an on-site warning if a sensor detects a value that is too high. It is also possible to connect buttons or switch relays.

For example, the sensor point can switch off entire systems if required or the user can acknowledge machine states.

The nRF91 SiP is still available with integrated assisted GPS. Through the use of NB-IoT or LTE-M, this enables fast position determination during a cold start for monitoring vehicles or other mobile devices.

Protection against data theft

Since the measured values of the sensors can provide a wealth of information on the use of the machines, systems, and equipment concerned, they should be protected against unauthorized access. In this case, the nRF91 also already contains a solution: The host processor with TrustZone uses a trusted execution environment in the CPU and in the system, thereby contributing to the security of application data, firmware, and connected peripherals. ARM CryptoCell ensures secure memory access while TLS and SSL ensure end-to-end encryption of data transmission.

The nRF91 is also perfectly suited for interaction with an nRF52, as implemented on the nRF91 development kit. Thus, both a short-range radio network for sensor connection and a cellular network for Internet connection are available with this multicore two-chip solution. If you choose the nRF52840 from the nRF52 family, it also features ARM TrustZone and CryptoCell technologies.

Factor of success – data analysis

Once the data have been transferred from the sensor, the trickiest task is data analysis. What does it mean when the frequency of a roller bearing has changed? Is it at risk of failing, was the production process simply altered or was the machine shut down for the weekend? Or is an interference factor responsible for the change? Which deviations still belong to normal fluctuations? And finally: How high is the probability of damage occurring, i.e. when does intervention become necessary?

This results in specific profiles, which are stored in the software by corresponding parameters and threshold values. Readjustments may be necessary after the first practical test. The predictive maintenance system also needs to be adapted in the event of production alteration, changes to machinery or similar.

If you take all these points into account, you are on the right track to: Never again experiencing unexpected machine damage, downtime or belt failure due to undiscovered aging systems. The expenditure for maintenance work can be better planned in advance and only the spare parts actually required can be kept in stock automatically. This benefits not only users but also machine manufacturers. If they integrate a predictive maintenance system into their products, they offer customers real added value through greater machine availability. In addition, they can use evaluated field experience for further product development. ■

Secure payment thanks to memory card with Secure Element

E-wallets for smartphones

PBV Kaufmann has developed a system for secure payment by mobile phone. It offers security and still lowers the requirements on the customer side and thus the inhibition threshold.

By Matthias Frei,
Product Sales Manager Switzerland,
Rutronik

Photography and games, appointment management, fitness tracking, weather forecasts, and navigation – the smartphone has become the established feature for all these functions and more. Only purchases are still preferably paid for in cash or by card. This is also due to the requirements of mobile solutions: Customers need a suitable cell phone, Internet connection, credit card, and accepted POS (point of sale). PBV Kaufmann Systeme wants to change this and has therefore developed an electronic wallet for smartphones in cooperation with Rutronik.

The special thing about Scoop e-money from PBV Kaufmann: The system can work fully offline and is not dependent on credit or EC cards. It uses the connectivity of smartphones, accesses the device via NFC, BLE (Bluetooth Low Energy) or another channel and treats it like a prepaid credit card. A server monitors the transactions.

Customer smartphones additionally function as a swarm network: Transaction data of the individual Scoop e-money POS (points of sale) are transferred to the Scoop servers and confirmed from there. The servers monitor all the transactions and thus ensure the integrity of all individual wallets in the mobile devices. Blacklists can also be distributed within the system via the swarm network.

The core: Secure micro SD card

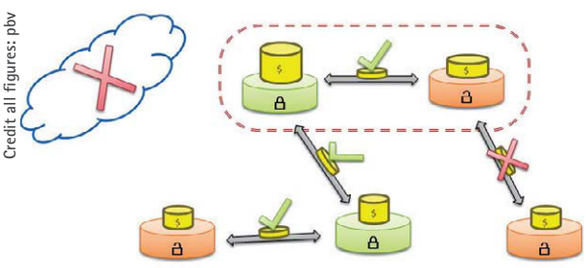
The money is stored at the payment terminals in the form of hash chains on the smartphone. The core of the terminals consists of a micro SD card with a powerful secure processor. It signs the hash chains and checks whether their signatures are valid or have been forged. If necessary, it rejects users with manipulated monetary values. The terminals can thus detect and block fraudulent attempts fully autonomously. This creates the security that other solutions provide through the Secure Element in the smartphone.

The hardware requirements were correspondingly high: To obtain the necessary certifications from the respective financial supervisory authorities in the countries of operation (FINMA, FCC, CE, etc.), the entire system must be demonstrably secure and non-manipulable.

Compatible with any smartphone

PBV Kaufmann uses a special memory card from the Swiss supplier Swissbit for its project. "When presented by Rutronik at an event, we were quickly convinced that it was the perfect solution for Scoop e-money," says Stephan Wullschleger, Technical Managing Director of PBV Kaufmann. "As it meets the highest cryptographic standards, has a reliable mass memory, and is available for a long time."

Thanks to Swissbit's secure micro SD card, the system does not require a Secure Element on the cell phone. This has several advantages: Customers can pay with any conventional smartphone because there are no special hardware requirements for the device. The



Credit all figures: pbv

Devices with Secure Element (green) can always exchange e-money with devices without Secure Element (red) in the absence of the cloud. Devices without Secure Element cannot exchange e-money with each other in the absence of the cloud.

Hash chains

A hash chain is the repeated application of a cryptographic hash function to a particular data object. Over a series of sessions, these individual hash inputs generate a hash chain that authenticates a single user input in greater depth. The hash chains used for Scoop e-money are similar to the blockchain ledger approach for bitcoin and other crypto currencies in that entries are authenticated with previous hash key lists.

only thing the cell phone should have is an NFC module for encrypted communication with the terminal. Alternatively, the smartphone and terminal can also connect via a secure BLE connection or another channel. This makes Scoop e-money independent of network operators and smartphone suppliers and an interesting solution for organizations with a decentralized structure and for globally active companies.

The future is cashless

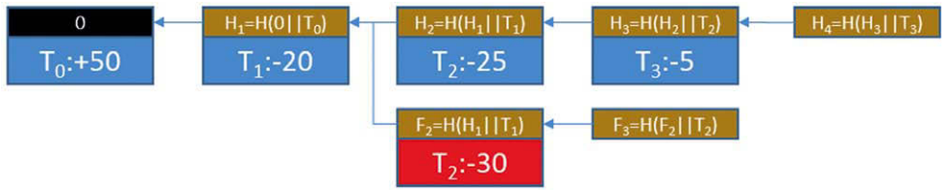
Stephan Wullschleger believes in the system's success: "It offers some unbeatable advantages with which suppliers can convince their customers: Instead of having to search for change, they can pay with transaction times of less than three seconds – and always keep track of all their payment transactions thanks to the concise app. The hash chain technology excludes loss or capital slippage. Another plus for sellers: All cash flows are transparent at all times and usage behavior can be observed live. This enables real-time fill level estimations, reducing unnecessary service effort. In addition, value-added services, such as initial credit or vouchers, can be used as a customer loyalty tool."

Competent support

Rutronik supported PBV Kaufmann not only with the micro SD from Swissbit but also with other components for the Scoop payment terminals. The choice fell on the Bluetooth Low Energy (BLE) modules from Nordic and Murata, the displays from Yeebo, lithium polymer batteries from EEMB, microcontrollers from Renesas, and numerous other components. "Since we received so many components from Rutronik, we were able to coordinate them particularly well and easily," says Stephan Wullschleger.

When faced with challenges or questions to be answered during the implementation of individual components, Rutronik acted as a mediator between suppliers and developers, thereby contributing to the success of the rapid solutions. The PBV Kaufmann team was supported by a total of five product managers and field application engineers from Rutronik. "The partner-like competent advice and the detailed knowledge of Rutronik's experts saved us a great deal of work and time during the development process," confirms Wullschleger and continues: "It also helped us great deal that Rutronik provided us with

A "clean" hash chain with a cryptographic hash function H. T_x represents the user data and H_y the corresponding hash value.



An "unclean" hash chain with a main chain A_y and a branch chain B_y. The chains share the elements T_1 and T_3, and a validating authority can distinguish the right chain from the wrong chain through hash and signature alone.

samples, development material, and supplier documentation at an early stage."

Embedded World in Nuremberg serving as test environment

At the Rutronik booth at Embedded World 2018, PBV Kaufmann presented the solution to the public for the first time. The exhibition presentation simultaneously served as a test of the Internet connection under real conditions. The system passed this test with flying colors.

Four years of development preceded the exhibition presentation: Scoop e-money started as a student idea with initial testing back in 2014. One year later, the project started to take shape with a business plan and initial specifications and the Commission for Technology and Innovation (CTI) began promoting Stephan Wullschleger and his team. The Scoop protocol was finally researched and developed together with the Institute for Mobile and Distributed Systems at the University of Applied Sciences Northwestern Switzerland in Windisch. The first hardware samples, application tests, and the presentation of research results followed in 2017.

PBV Kaufmann is currently working on final market readiness and product branding as well as preparing the product's market launch. Extensions for the app and cloud server are already planned. Thanks to customized terminals and modularizations, developers already have the next steps in mind. ■

Functional demonstrator with a standard coffee machine, a scoop terminal with Secure Element, and a conventional "insecure" smartphone as the e-money source.

Battery management system

Managing lithium-ion batteries

Batteries are the new oil. The key factors of range, operating time, and charging time depend to a large extent on them. However, lithium-ion battery cells have a relatively narrow specified operating range and require a sophisticated battery management system that allows them to be operated safely and their energy used to maximum effect.

Lithium (Li) ion batteries are mostly used in electric and hybrid vehicles as well as in the industrial market. Compared to other energy storage devices, they offer considerably higher energy density and voltage with smaller dimensions, more charge cycles, and a longer service life – at least if the overall battery system remains in its comfort zone.

Li-ion batteries are usually used as battery packs. They basically consist of several battery cells and a battery management system (BMS). The cells determine the parameters and specifications with which the system can operate and which components are required to ensure top system performance.

Tasks of the BMS

The primary purpose of the BMS is to ensure that the cells stay within their specified operating range and that all the cells are charged and discharged as evenly as possible (balancing). This requires highly accurate measurements of the charge and discharge currents, cell voltage, and temperature. These parameters must be carefully adjusted, both to each other and to the battery cells and the respective application. The BMS then guarantees the functional safety of the battery, prevents any lasting damage, and ensures optimum utilization and a long battery life.

Extensive research

In recent years, Rutronik has carried out extensive research on the behavior of battery cells and battery packs and their optimum use, both through its own research activities and in collaboration with universities and higher education institutions:

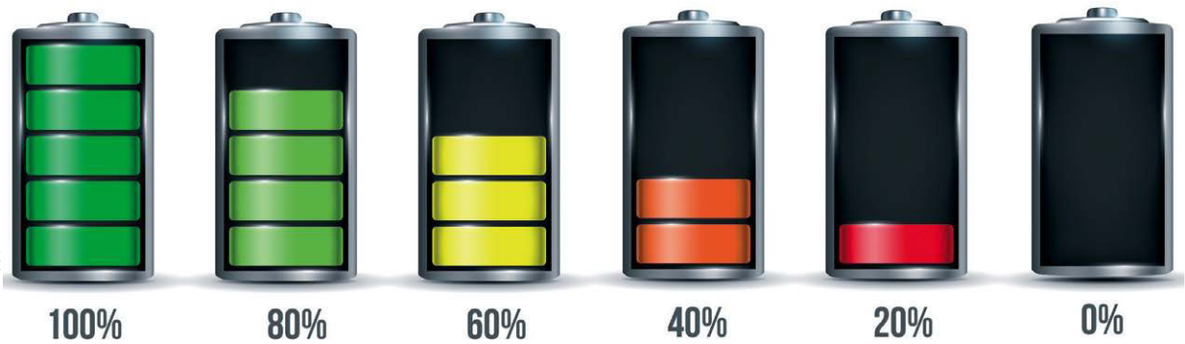
With the support of Rutronik, the Professorship of Measurement and Sensor Technology at Chemnitz University of Technology has developed a procedure that allows precise battery diagnostics not only in the laboratory but also during operation within a few minutes or even seconds.

Rutronik has developed a completely digitally controlled hybrid energy storage system (HESS) in collaboration with the University of Applied Sciences in Zwickau. Through the intelligent combination of Li-ion batteries and supercapacitors (supercaps/EDLC), it considerably extends the battery life.

Know-how transfer

The distributor readily passes this expertise on to its customers as part of the Design-In process and supports them when selecting the battery cells and all other components required for a BMS. Furthermore, Rutronik provides information on the subject in numerous talks and workshops. At nine locations throughout Germany, interested parties have already received comprehensive information at seminars focusing on the technology of Li-ion batteries, thermal management of the battery pack, BMS software requirements, current distribution in parallel-connected cells, and modeling algorithms for battery analysis.

Numerous aspects of battery management systems will also be explored on the following pages. ■



Credit: happyvector071 – Fotolia

BMS components

Best-fit products for battery management systems

The battery management system (BMS) performs numerous indispensable tasks. This demands a whole range of different components. An overview.

By Ralf Hickl,
Product Sales Manager
Automotive Business Unit, Rutronik

The typical design of a battery cell management system is shown on page 93: The energy cells are arranged here in series. For balancing purposes, a resistor with switching transistor is connected in parallel to each cell. These switches are controlled by balancing ICs that communicate with each other via a serial interface. A superordinate microcontroller monitors and controls the cell management functions. A bidirectional electronic fuse also controls disconnection of the battery from the load or the charger on demand or in the event of a fault. Located at the top left is the current sensor technology, designed here as a shunt resistor with signal processing; alternatively, magnetic field-sensitive sensor ICs can assume this role.

Energy cells

The energy storage element itself can be designed with Li-ion cells or ultracapacitors, also known as electric double layer capacitors (EDLC).

Samsung SDI is a world leader in Li-ion cells, especially in automotive applications, such as electric and low-emission vehicles (LEVs). The round cells in the common 18650 design (18mm in diameter, 65mm in length) offer the highest energy densities, mechanical stability, and efficient assembly options. In the future, the new 21700 format (21mm in diameter, 70mm in length) will play a decisive role in the market.

The ultracapacitors of the Chinese-Swiss manufacturer Sech SA are characterized by a nominal cell voltage of 3.0V. The energy density peaks at 8Wh/kg. Thanks to their low internal active resistances, they do not usually require active cooling. According to the manufacturer, they meet the requirements of standards ISO 16750-3 and SAE 2464.

Core attributes of both systems can be found in Table 1.

Current and voltage sensor technology

Current and voltage sensor technology forms the basis for all higher-level functions such as undervoltage and overvoltage monitoring, energy meters, calculating the residual battery capacity, measuring the level of power, short-circuit monitoring, and measuring the charging current.

Manufacturer	Type	Series	Description/Properties
Samsung SDI	Li-ion cell	INR18650-29E EV	High energy cell of 18650 design with 2.5 Ah @ cut-off 4.125 V, discharge current 1C and 80% nom. cap. after 1000 cycles
Sech SA	Ultracapacitor	CxxW	cylindrical or pouch, 3.0 V, up to 3200 F

Table 1: Energy cells

Manufacturer	Type	Series	Description/Properties
Vishay	Shunt resistor	WSBS	Power Metal Strip®, up to 36 W, 50 µΩ … 1 mΩ
KOA	Shunt resistor	PSG4	Metal plate power shunt, 10 W (0.5 mΩ) and 8 W (1 mΩ)
Panasonic	Shunt resistor	ERJM	Metal plate technology, 0.5 mΩ … 1 Ω, up to 5 W
ROHM	Shunt resistor	PSRxxx	bis zu 5 W, 0.2 mΩ bis 3 mΩ
ST	Current sense OpAmp	TSC201	bidirectional, 300 kHz
Melexis	Hall sensor IC	MLX912xx	bidirectional, DC up to 250 kHz
TDK-Micronas	Hall sensor IC	many variants available	

Table 2: Current sensor technology

Current sensor technology

Current measurement can be achieved with the aid of shunts or magnetic field sensors. They must be bidirectional in order to cover both motor and regenerative operation of the drive unit (recuperation) as well as external charging from a measurement perspective.

Current measurement using a shunt is characterized by the following features:

Power dissipation in the shunt increases quadratically with the current according to $P_{tot} = R\ I^2$.

- In order to cope with the power dissipation, the shunt requires a certain mechanical size. It ensures heat dissipation and a minimum of thermal capacity.
- It is robust against magnetic interference fields.
- The measurement is non-isolated, which in many cases requires galvanic isolation for the further signal sequence.
- It enables broadband measurements.
- The measuring accuracy is basically determined by the properties of the shunt, above all by its tolerances and temperature coefficients.
- Calibration is simple.

Current measurement using magnetic field sensor technology offers the following features:

- It has low power dissipation.
- System-dependent galvanic isolation is available.
- The development effort is greater than with shunts, since mechanical and magnetic integration of the magnetic field sensor is incorporated into the overall performance of the measuring system.
- It requires production and assembly skills; a magnetic field simulation saves experimental resources.
- Depending on the actual structure, a sensitivity to magnetic stray fields is exhibited.

Some typical representatives of the two types of current measurement are listed in Table 2.

Manufacturer	Type	Series	Description/Properties
Renesas/Intersil	Balancing IC	ISL786xx	Balancing IC for up to 12 Li-ion cells
Infineon	Balancing IC	TLE8001	Balancing IC for up to 12 Li-ion cells, active or passive balancing possible
ST	Balancing IC	L9963	Balancing IC for up to 14 Li-ion cells
ROHM	Balancing IC	BD14000	Balancing IC for 4-6 EDLC
DIODES	Balancing MOSFET	DMN1xxx/DMN2xxx	Single/Dual N-channel, miniature package
DIODES	Balancing MOSFET	DMPxxxx/DMGxxxx	Single/Dual P-channel, miniature package
Littelfuse	Fuse	885 Nano²®	SMD, up to 500 V DC, 1…5 A

Table 3: Cell balancing

Cell balancing for Li-ion cells

Cell balancing levels out production tolerances and the individual aging of the battery cells connected in series. For this purpose, the voltage of each cell is monitored and the charging current is distributed in such a way that all the cells have the same charge state.

With passive balancing, a resistor is temporarily connected in parallel to a cell with a charging lead via a semiconductor switch (e.g. MOSFET). This causes a discharge current to superimpose the charging current until the other cells have caught up. However, this is accompanied by undesired power dissipation in the resistor. The IC ISL78600 from Renesas/Intersil, for example, is suitable for passive balancing.

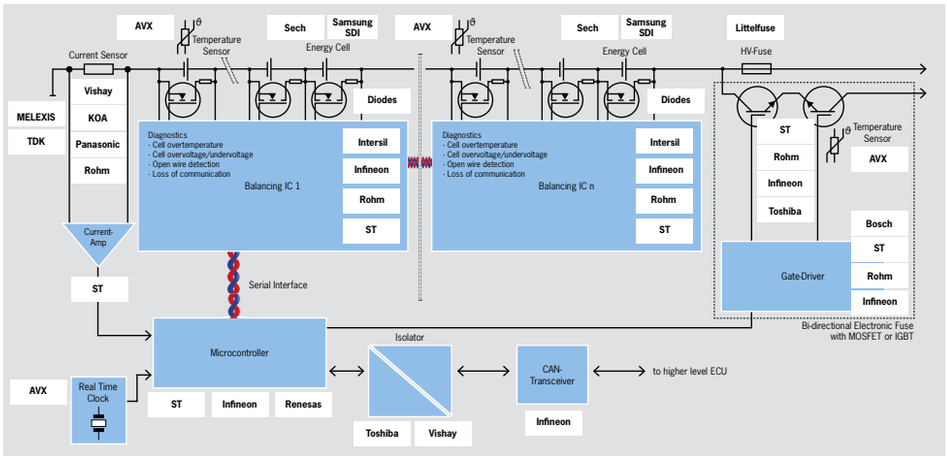
In more complex active balancing, the excess charge of individual cells is distributed to the other cells with the aid of a DC/DC converter circuit with as little power dissipation as possible.

The new TLE8001 Balancing IC from Infineon supports both passive and active balancing. Also new to the market is the L9963 from ST, which stands out due to the number of its channels. Balanced switches are either internal MOSFETs or, for higher switching currents, external MOSFETs in a simple design or as a pair in one package.

Cell balancing for ultracapacitors (EDLC)

Ultracapacitors are sensitive to overvoltages, therefore balancing is also recommended for them. A special balancing IC also ensures the even distribution of the total voltage to the individual ultracapacitors. See Table 3 for examples of relevant components for cell balancing.

Credit: Rutronik



Microcontroller in the control and monitoring device

The control and monitoring device fulfills several functions:

- It works as an energy meter and calculates the remaining charging time and the residual capacity or range.
- It increases security by merging data as part of a multi-layered monitoring system and checking it for plausibility. It monitors the functionality of subordinate controls and interrupts the charging process or the energy extraction from the battery, if necessary.
- It is the diagnostic computer for impedance spectroscopy (DC and AC impedance measurement) and provides information on the state of charge, the temperature, and the general condition of the battery.
- It hosts the operating system.

Due to the multitude of requirements, including functional safety and data security, only high performance microcontrollers with multiple cores in lock step mode and hardware security modules (HSM) are considered; see Table 4.

Galvanic isolation

Optocouplers are suitable for galvanic isolation between signals with high voltage potential and the low-voltage side. The Toshiba models TLX93xx and TLX92xx listed in the table are well established on the market. In early 2018, Vishay also introduced a solution for the automotive market with an initial AEC-Q101 qualified optocoupler with phototransistor at the output (VOMA617A). Due to the dielectric strength of the collector-emitter path of 80V, both are also suitable for use in 48V electrical systems. Inductive transformers from Pulse are another alternative for potential separation at high common mode voltages.

Interfaces, interface drivers

CAN transceivers for twisted two-wire lines as the physical layer of the CAN bus are available in a wide variety of models. Infineon offers a particularly broad portfolio of bus transceivers that have been approved by many automotive OEMs. They are characterized by data rates of up to 5Mbps for CAN-FD (Flexible Data Rate) and the support of partial networking. They are available in a small TSON8 package (3mm x 3mm) with and without bus wake-up. Suitable CAN chokes complete the interface and ensure interference-free transmission of signals.

Fuse disconnectors

Conventional fuses, pyrotechnical disconnectors, and semiconductor switches can be used for electrical protection of the battery circuit.

The semiconductor switches consist of power transistors connected in parallel and their gate drivers. An interesting component is Infineon's TLE9180D. Developed as a motor control IC for 3-phase BLDC motors in electrical systems up to 48V, it has three high-side gate drivers as well as analog amplifiers for current measurement via shunts. Originally developed for applications such as electric steering and starter generators, it has protective mechanisms and diagnostic functions, making it ideal for use in functionally safe applications. When applied in a three-channel electronic fuse, its three low-side gate drivers are not used.

Manufacturer	Type	Series	Description/Properties
ST	Microcontroller	SPC56, SPC58	32-bit PowerArchitecture™, Safety & Security
Infineon	Microcontroller	TC2xx, TC3xx	32-bit AURIX™, Safety & Security
Bosch	Power & Safety Companion	CY32x, CS600	ASIL to D, Q&A WDG
Infineon	Power & Safety Companion	TLF35xxx	ASIL bis D, Q&A WDG

Table 4: Microcontrollers & power/safety companion ICs

Manufacturer	Type	Series	Description/Properties
Toshiba	Optocoupler	TLX93xx	IC output, 1 Mbit/s up to 20 Mbit/s, 125°C
Toshiba	Optocoupler	TLX92xx	Transistor-Ausgang, 3750 V rms, 80 V U_{CE}, 125°C
Vishay	Optocoupler	VOMA617A	Transistor-Ausgang, 3750 V rms, 80 V U_{CE}, SOP-4

Table 5: Galvanic isolation

Manufacturer	Type	Series	Description/Properties
Infineon	MOSFET	OptiMOS™-5	100 V, N-channel, R_{DSon} up to 1,5 mΩ, package: TOLL
Infineon	MOSFET	OptiMOS™-5	80 V, N-channel, R_{DSon} up to 1,2 mΩ, package: TOLL
ST	MOSFET	STripFET™-F7	80 V, 100 V, N-channel, PowerFLAT™ package
Toshiba	MOSFET	UMOS8	100 V, N-channel
ROHM	IGBT	RGSxxx	650 V, 1200 V, short-circuit proof up to 8 µs, up to 90 A
Infineon	IGBT	TRENCHSTOP™ 5 AUTO	600 V, 650 V, 1200 V, up to 400 A
ST	IGBT	STGxx	600 V, 650 V, 1200 V, up to 120 A

Table 6: Power transistors for electronic protection (48 V and HV)

Pyrotechnical disconnectors are disposable products. The control unit generates an ignition with a corresponding cause of deployment. The power dissipation of a live heating wire in a squib causes a small propellant to explode, thereby separating a predetermined breaking point inside a conductor. Detailed treatment of the squib drivers goes beyond the scope of this article.

Li-Ion cells are specified for a relatively narrow temperature range. If this is exceeded, the service life of the battery may be shortened or even irreparably damaged, in extreme cases a thermal runaway is created. All the energy stored in the battery is released within milliseconds, so that the cell catches fire or explodes. To avoid this, sensors are needed for recording temperatures that detect a temperature increase quickly. AVX offers temperature-dependent resistors (thermistors) with a negative temperature coefficient (NTC) in various designs. They are available for surface mounting and as wired or unwired panes for customer-specific installation. ■

Manufacturer	Type	Series	Description/Properties
Infineon	Gate driver	EiceDRIVER™	HV single/dual channel, isolated with diagnostics
ST	Gate driver	STGAP	HV single channel, isolated with diagnostics
ROHM	Gate driver	BM6xxx	HV single/dual channel, isolated with diagnostics and DC/DC
Bosch	Fuse ASSP	iFuse	up to 48 V, 4-channel, current sense, DC/DC, V_{reg}
Infineon	BLDC-ASSP	TLE9180D	up to 48 V, 3-channel, current sense, diagnostics & safety

Table 7: Gate driver for electronic protection (48 V and HV)

Manufacturer	Type	Series	Description/Properties
Littelfuse	Fuse	LC-HEV	450 V/425 V, up to 30 A/40 A

Table 8: Fuses

Manufacturer	Type	Series	Description/Properties
AVX	NTC	NC12, NC20	SMD, sizes 0805, 1206
AVX	NTC	NP30, NJ28, NI24	wired, high accuracy
AVX	NTC	NR, NK20	customer specific pane, plates

Table 9: Temperature sensors

Real time clock modules for BMS

Efficient recording and processing of measured values

If an electric or hybrid vehicle stands in the summer heat or is charged at a fast charging station, there is a risk of the battery being permanently damaged by overheating, overcharge or deep discharge. The continuous real time measurement of the battery parameters is a must. In this case, low energy consumption is particularly important. Real time clock modules help to keep it as low as possible.

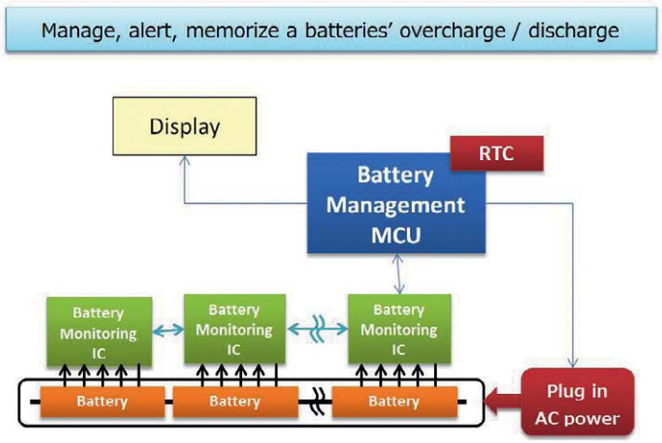
Credit all pictures: Epson

By Jochen Neller,
Technical Support
Inductivities & Timing Devices,
Rutronik,
and Stefan Hartmann,
Department Manager QD,
Epson Europe

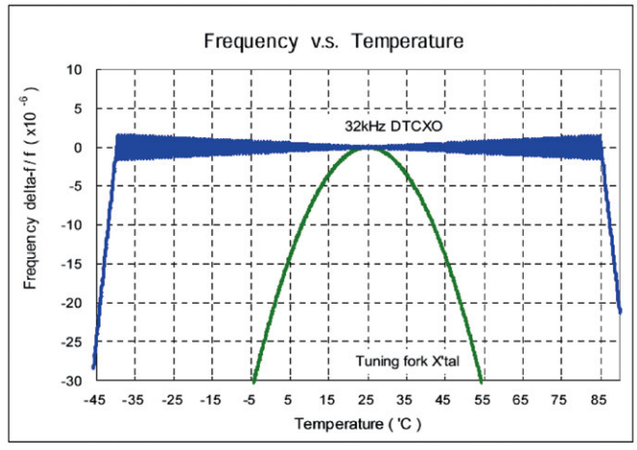
Real time clocks wake up the microcontroller from power-down mode at specified intervals, so that a battery management system (BMS) can regularly measure the voltage and temperature of the battery cells and the battery pack and then evaluate the data.

Integrated or discrete solution?

This can be achieved through real time clock modules (RTC modules) or through microcontrollers with integrated real time clock function plus external quartz. There are an array of arguments in favor of modules with integrated quartz. These are primarily their greater reliability, more precise clock accuracy, and lower power consumption, as well as their simpler design. The latter is of particularly importance when an alternative energy source maintains the supply voltage in the event of a primary supply failure.



Real time clock modules (RTC) ensure that a real time stamp is assigned to each event when monitoring and managing the battery cells. And that as little energy as possible is consumed.



Comparison of the temperature response of an uncompensated kHz quartz (green) and the temperature-compensated RA8900CE real time clock module from Epson (blue)

Looking at the design, the complexity of an oscillator design, especially for watch functions, is often underestimated. This not only means that the desired accuracy is not achieved but also leads to higher failure rates, usually due to insufficient oscillation build-up reliability. Quite often only the initial tolerance of the quartz, i.e. the maximum accuracy deviation at room temperature, is taken into account. This often leads to problems, as kHz quartz crystals have a frequency-temperature response that follows a downward open parabola. This means: Any change in temperature will cause the clock to slow down. This effect can be reduced considerably through integrated temperature compensation, which not only compensates the parabolic temperature response but also compensates the initial tolerance, thereby improving the clock accuracy significantly.

When using an RTC module with integrated quartz, the component supplier is responsible for the oscillator design and integrates the semiconductor and the quartz in a hermetically sealed package. RTC modules are available in various versions and with varying special functions, such as integrated EEPROM or a temperature sensor.

The RTC modules of the RA8900CE series from Epson are equipped with this type of integrated temperature compensation. This allows them to reach temperatures above the operating temperature range of –40°C to +85°C at a clock accuracy of ±3.4ppm. The modules consist of a semiconductor with I2C interface and an integrated quartz in a small 3.2 × 2.5 mm package. They are AEC-Q200 specified for use in electric or hybrid vehicles. In addition, they have a circuit for automatic power supply switching to an alternative voltage source (e.g. a super capacitor) in the event of the primary supply failing. The modules of the RA8900CE series operate in back-up mode with typically 700 nA at a supply voltage of 3 V.

If a high level of accuracy is required for an extended temperature range, the RA8804CE series from Epson is recommendable. It functions at between +85°C and +105°C with an accuracy of ±8ppm and between –40°C and +85°C with ±3.4ppm. The modules are AEC-Q100 specified and consume just 350 nA typically at a supply voltage of 3 V and with switched off I/O ports. Moreover, they also have an event input that can be used to time stamp external events.

Item		RA8804CE(XA)	RA8900CE(UA)
Frequency		32.768 kHz	32.768 kHz
IC		EPSON IC	EPSON IC
Operation Temperature Range		–40…+105°C	–40…+85°C
ftol	@–40…+85 °C	±3.4 ppm	±3.4 ppm
	@85…105 °C	±8 ppm	
Current Consumption (Typ.)		0.4 µA @VDD = 5 V	0.72 µA @VDD = 5 V
		0.35 µA @VDD = 3 V	0.7 µA @VDD = 3 V

The key features of the Epson series at a glance

Both series therefore meet the ever increasing demands for higher accuracy in a wider temperature range with smaller packages.

Integration in a battery management system

In order to integrate the RTC modules as easily as possible into a BMS, both series are equipped with what is referred to as a fixed cycle timer. This generates an interrupt pulse in a specified rhythm which can trigger the monitoring function in the microcontroller. Seeing as the timer repeatedly reconfigures itself after initial programming in order to start a new time measurement, the level of communication with the microcontroller is kept to a minimum. This also reduces system energy consumption.

Epson has developed a whole range of real time clock modules with integrated quartz especially for BMS in motor vehicles. They are based on what is known as QMEMS process technology. QMEMS utilizes photolithographic processes to process the quartz blanks, which results in improved characteristics, especially with smaller designs.

Above all, they reduce internal power dissipation and thus the level of current consumption. Due to the efficient production methods, the quartz-based real time clock modules are also very attractive in price and popular due to their low power consumption and low phase jitters. Since Epson not only manufactures the quartz in-house but also the specific semiconductor, the components are perfectly attuned to one another and their availability is guaranteed. ■

BMS in electric and hybrid vehicles

Inductive components for safe working

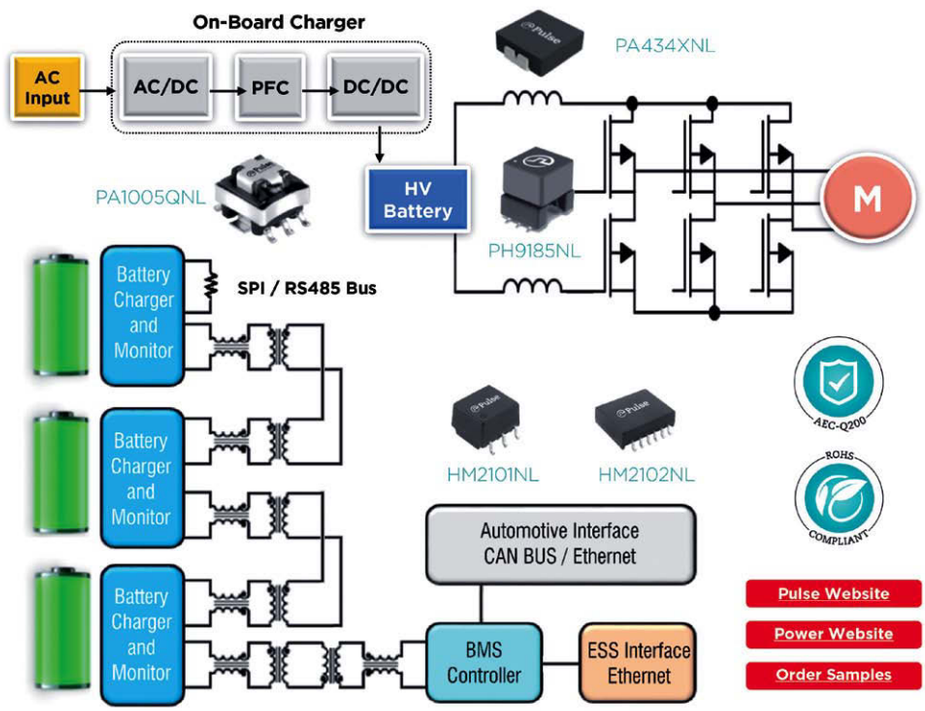
Lithium-ion batteries are explosive charge units that must be handled with care – especially during overcharging and undercharging when the battery cells are operating in a "gray zone". The larger and more complex a battery pack is, the more complicated this task becomes. Inductive components specially developed for battery management systems help to solve this problem.

By Jochen Neller,
Technical Support
Inductivities & Timing Devices,
Rutronik

Many portable electronic devices already use an advanced battery management system (BMS). The BMS in electric, hybrid, and plug-in hybrid vehicles is much more complex, especially in a high-voltage electrical system. The safe galvanic isolation of cascaded battery stacks with high common mode voltages is a crucial central function.

Completely new circuit technologies and more precise detection methods often have to be developed for the cell balancing of large battery packs. Another decisive factor is the isolation of various functional blocks to protect sensitive systems from the high energy of the battery. For this purpose, in particular, suppliers have developed inductive components, such as isolation power transformers and common mode chokes, that improve the safety and overall function of the battery packs – and thus the vehicle – significantly.

Credit all pictures: Pulse



Inductive components developed especially for BMS, for instance, isolate several high-energy cells from each other and thus improve the safety and function of the overall system.

Critical aspects

Two particularly critical aspects need to be considered when designing a battery pack: First, overcharging the battery will cause it to overheat. Battery cells have a relatively narrow specified temperature range, too much heat can damage them or even lead to thermal runaway and thus to a fire or explosion. Excessive heating up must therefore be prevented at all costs.

Second, discharging the battery below a certain threshold value can lead to a permanent reduction in its capacity. This threshold depends on the chemical composition or technology of the battery and is documented in the data sheets of leading suppliers, such as Samsung SDI.

Controlling the energy flow

In cooperation with the on-board charger, the BMS must keep the battery cells in their specified operating range, also in the gray zones of overcharging and undercharging, to prevent malfunctions and damage. In this context, the limits of the permissible charging and discharging current as well as the upper and lower charging and discharging

voltages must be observed. Depending on the respective topology, semiconductor switches control the currents. Due to the high common mode voltages, isolation power transformers are generally used between the low-voltage based cell balancing and monitoring ICs to guarantee consistent communication in the stack through a daisy-chain configuration. Isolation power transformers with high isolated voltages, such as the PH9185.XXXNL series from Pulse, protect the control circuit from high common mode voltages. This series can be configured with various transmission ratios.

Compensating overvoltages and undervoltages

Overvoltages and undervoltages can damage or age the cell. To avoid this, it is necessary to distribute the battery voltage evenly along the battery stack. For this purpose, the BMS measures the voltage of each battery cell, which is adjusted to the overall level by a charge transfer between the cells or a simple discharge of individual cells. In cells with an above-average voltage, the excess charge is distributed to the other cells.

Preventing overheating

Temperature sensors continuously measure the temperature, thus ensuring the battery cells remain in their specified temperature range. If the temperature exceeds the critical level, the control system interrupts the charging or discharging process until the temperature of the overheated cells reaches a safe level again.

Compensating voltages

The BMS typically carries out a so-called Coulomb count in order to determine the state of charge (SoC). It determines the amount of electrical energy remaining in each battery cell and transmits it to the control units via an EMI-protected interface. This stackable architecture can support hundreds of cells on large batteries. Thus ensuring that all cells are discharged evenly and their charge does not fall below the threshold value, which could permanently reduce their total capacity or lead to an impermissible deep discharge.

It is important to note that many cells connected in series have large voltage potential differences through the daisy-chain connections. This requires galvanic isolation between the components. Transformers are suitable for isolating serial communication connections between PCBs from each other. At Pulse, developers can, thanks to the wide range of isolation power transformers, easily find a model that precisely provides the required operating voltage, number of channels, package shape, and package type. For example, the HM11/21xxNL series is available in numerous configurations with different working and isolated voltages, and a suitable transformer is available for every application. The isolation power transformers are approved for many chip sets on the market (Renesas/Intersil, Rohm, and other cell-balancing IC suppliers).

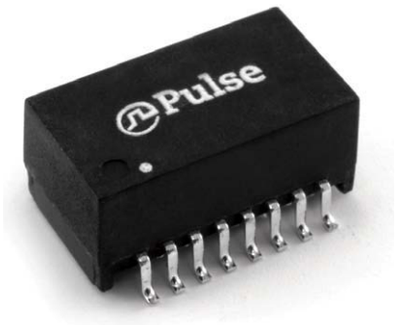
Controlling the current flow

A proven charging algorithm is an alternation of constant current and constant voltage phase. High current inductors are used in the BMS to limit the alteration rate of the current flow and to eliminate the ripple of the charging current. The PA434xNL series from Pulse is, e.g., suitable for this purpose.

Features:
- 5000 V rms isolated voltage
- 600 V rms operating voltage
- 8 mm air and creepage distance as well as reinforced isolation
- UL and TÜV certified, AEC-Q200 qualified

The PH9185.XXXNL isolation power transformers from Pulse can protect a control circuit against excessive battery power.

The PA4334 inductor from Pulse detects changes in the cell voltage quickly and precisely.



At Pulse, developers find a wide range of isolation power transformers.

Worth the effort

When integrated properly, these robust BMS based on innovative magnetic power components are definitely worth the extra effort. Since they can effectively evaluate and control the performance and stability of each battery cell. They enhance the battery life significantly and make the battery system – and thus the entire vehicle – safer. ■

Brake resistors

Krah adds dynamism to the PTC market

Self-protecting PTC brake resistors are often used for frequency inverters in the low power range as well as for servo controllers. Currently, there are very few manufacturers of these special brake resistors. The RXLG-PTC series from Krah means new options are now available.

By Roger Renfordt,
Key Account Manager Industry,
Krah Elektronische Bauelemente,
and Bert Weiss,
Technical Support Resistors,
Rutronik

The RXLG-PTC series is a group of PTC brake resistors for smaller frequency converters and servo controllers. Krah has developed them together with well-known suppliers from the PTC industry and thus offers design engineers a wider range of components with the required dielectric strength.

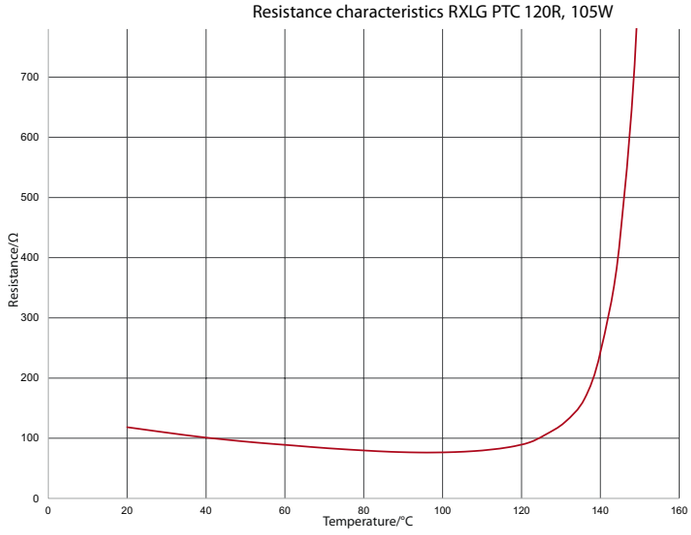
The RXLG-PTC resistors are available for rated loads of 35 W, 70 W, 105 W, and 140 W. The resistance value when cold is 350 Ω for the 35 W type. At higher rated power, the resistance value of this type decreases to 175 Ω (70 W), 120 Ω (105 W) or 90 Ω (140 W). As is typical for PTC, the resistance tolerance is ±35% and the breakdown voltage is only reached at 1100 V DC. The new resistors are assembly compatible with existing systems.

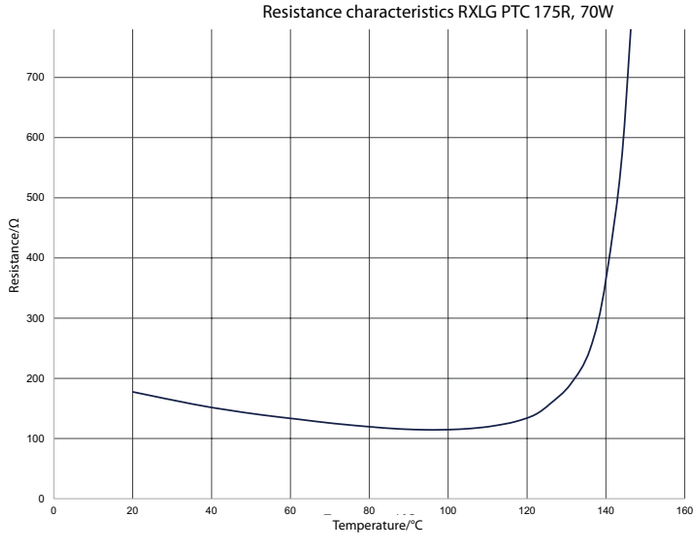
To ensure the PTC resistors can consume as much energy as possible without being damaged, they are made of polycrystalline titanate ceramics. Ceramic as such is not conductive, but if it is specifically doped with foreign atoms, it has the properties of a PTC thermistor with a positive temperature coefficient. The resistance value of these ceramic bodies increases as the temperature rises.

Above a certain temperature, as shown on the resistance characteristic curve as a transition temperature, the resistance value increases almost exponentially. The resistors then no longer consume any more power, thus protecting themselves from overloading. The transition temperature of the RXLG-PTC resistors is roughly 140°C.

Optimized cooling

The focus of development was not solely on the optimum doping of the ceramics. Krah also developed the one-piece aluminum profile body in-house to ensure the real needs of industry are met. Both contribute to the improved performance of the RXLG PTC series compared to existing systems. The compact design enables a reinforced mounting base without exceeding an overall height of 11mm.





The 98 mm × 34 mm mounting base (for the 35 W model) and the cooling profile allow the resistor ceramic to dissipate heat particularly well. Depending on the heatsink used, a further increase in performance is possible. This results in a wide power range and an array of application options for the RXLG-PTC resistors.

The resistors meet the requirements of the certification company Underwriters Laboratories and bear the UL Recognized Component Mark. They can therefore be used in products and systems that demand the UL quality mark.

Residual current circuit breakers

High-precision earth leakage detector

Residual current circuit-breakers can be found in all electrical installations today, either to protect complete systems or individual consumers. Their use is regulated according to the international standard IEC 60601-1 and EN 62020 or VDE 0663.

By Thomas Bolz,
Product Sales Manager Analog,
Rutronik

Current-operated circuit-breakers can be found in all electrical installations today and are designed to protect either complete systems or individual consumers. Their use is regulated according to the international standard IEC 60601-1 and according to EN 62020/VDE 0663. They usually work according to the principle of differential current measurement between the outer conductors of alternating current or three-phase systems. If the leakage current via the protective conductors (PE and N) is too high, they trigger an alarm or immediately switch off the affected circuits at all the poles.

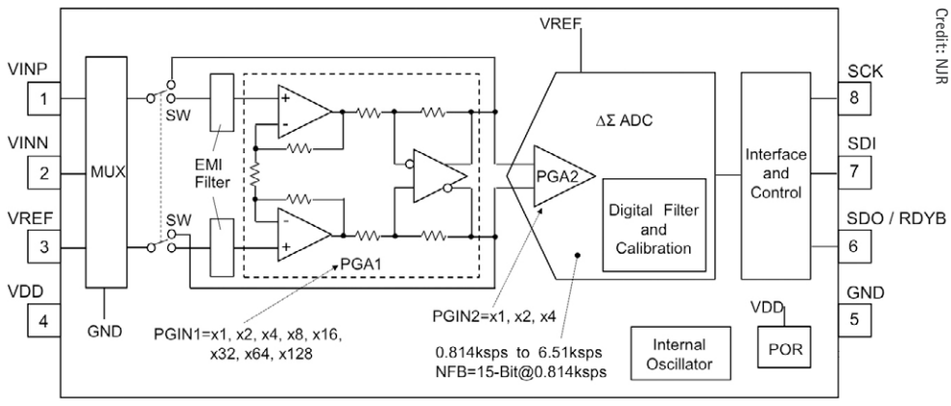
Normally, the current is distributed equally to all the conductors. In the event of a fault due to asymmetrical load distribution on the conductors or damage to the insulation, fault or AC leakage currents can also occur, including harmonics up to the third harmonic wave (for loads with non-linear power supplies, gas discharge lamps, etc.) and/or as DC pulse sequences. A circuit breaker must safely detect this fault condition in order to reliably trigger the shutdown or an alarm.

For these applications, the Japanese IC manufacturer New Japan Radio (NJR) now offers the digital earth leakage detector NJU9102/90102A. It operates according to the principle of differential current measurement and detects both AC and DC residual currents. Its high-precision AD converter digitally processes the differential current measurement signal from a zero phase sequence current transformer (ZCT). When the alarm threshold set for the leakage current of the monitored circuit is exceeded, the NJU9102 emits a short DC pulse at output SCRT (sample counter), which can be used to trigger an external thyristor (SCR) in order to activate the desired reaction.

The NJU9102 offers a unique feature: It gives the trigger pulse only 60 ms after measuring a difference of five times the threshold value. With the NJU9102A, the output signal is delayed by 1.75 ms and the trigger threshold is set to ±8.4 mV. Its AD converter starts the conversion after the PORb (power on reset) signal according to the system clock until an error signal (H) is output at the SRC terminal.

For high-precision measurements, both models use a precise Sinc3 digital low-pass filter with a decimation rate of 64. Its 3dB limit frequency is 150 Hz in order to detect AC interference exactly up to the third harmonic wave. The applied AD converter is a 14 bit delta-sigma converter with a sampling frequency of 146.6 kHz.

When the monitored circuit is switched on for the first time, the detector ignores any inrush currents with a voltage drop of 9.6 V measured via a resistor. The module operates at supply voltages of between 4 V and 5.5 V. Its operating temperature range extends from –40 to +105°C. Both models are available in an 8-port DMP8 package (halogen-free and RoHS II compliant) and are suitable for reflow soldering. Due to its precision and small size, the NJU9102/90102A is suitable wherever local (on-site) protection is required, e.g.: Laboratory tables.



Credit: NJR

Functional diagram of the NJU09102/9102A

Multistage mixed-signal compensation current transformer without loss of resolution

New opportunities for an all-electric society

The market is already full of current measuring systems based on compensation current conversion. However, their measuring range is limited by the system. A research team at Zwickau University of Applied Sciences has developed a multi-stage mixed-signal compensation current transformer. The patent has, in the meantime, been granted and offers enormous potential, as Prof. Lutz Zacharias explains.

Professor Lutz Zacharias, Zwickau University of Applied Sciences

What is the motivation behind your development project regarding precision current measurement using the new current measuring system?

Prof. Lutz Zacharias: Of course, the market already offers n+1 and for many applications well-functioning, mature, and also tried-and-tested current measuring systems which are based on the principle of compensation current conversion. Nonetheless, the use of conventional current transformers is subject to a system-related measurement range limitation. For instance, it has not yet been possible to measure small currents ($I_P \leq 1$ A in the required high resolution using a current transformer designed for a large measuring range (e.g. $I_P = 50$ A).

How do you assess the requirements profile of the industry with regard to precise current measurement? And for which market segments and areas of application is the new current sensor of particular interest?

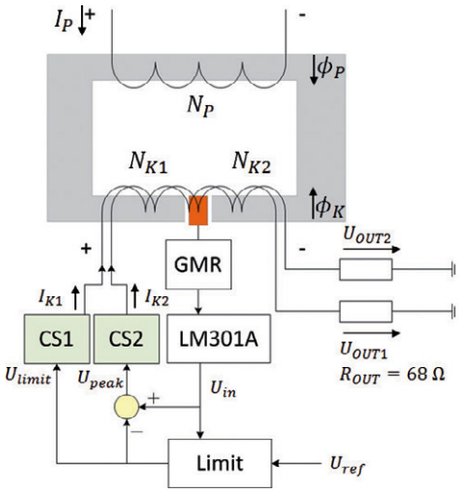
The developed technical solution allows our research team to respond to the ever increasing demands placed on the measurement technology used in a variety of applications to determine current consumption in the wake of the energy revolution. In modern households and businesses, in particular, new consumers with varying power demands, such as electric vehicles or home automation systems, result in both small and very large currents within one application. In order to be able to record electricity consumption correctly, especially with smart meters, and thus also to be able to bill customers accurately and efficiently, developments like the patented measuring method are necessary. The off-the-scale application potentials of the invention, for example in smart meters, electric vehicles, and their charging infrastructure or also in a multitude of modern industrial automation solutions, can serve as a key technology and significant milestone in the technical implementation of the energy revolution.

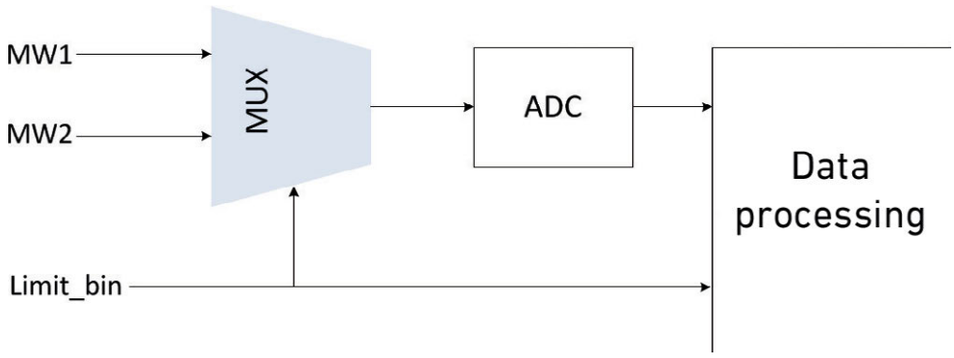
Which improvements will this bring about for the intended application areas?

With a completely new analog circuit principle, the Faculty of Electrical Engineering at Zwickau University of Applied Sciences has succeeded in improving the current transformer measurement methods used so far in such a way that a targeted division into several measurement stages can now be achieved without changing the number of primary transformer windings. Another major advantage of the newly developed measuring arrangement is that a consistently high resolution for each measuring stage can be achieved with very low measuring deviations. Compared to previous solutions, the invention offers the advantage of continuous measurement by quantizing the large available measuring range; in other words, the measuring process does not have to be interrupted to record the measured value. Furthermore, the developed technical solution has the advantage of insulation by dispensing with shunts in the load circuit. The subsequent processing of the measured value and signal output can be carried out digitally, for example using a microcontroller (see diagram).

This all sounds very complex. Can you describe the essence of your invention in a brief and understandable way?

In retrospect, the basic idea (as with so many things) is quite simple really: Firstly, it is a





A basic circuit for a two-stage transformer

compensation current transformer method in which the output signal of a GMR measuring bridge is routed to special evaluation electronics. By cascading such transformer stages as described above, an application-specific scalable measuring arrangement is obtained both with regard to the required resolution and with regard to the desired measuring range along with the advantages previously mentioned. The fundamental innovation of this measuring arrangement is the fact that (according to the current instantaneous value being measured) only the current range transformer stage of the cascade responsible for this needs to be active and that this can happen "without interruption" if "switchover" between the transformer stages is required. For all those readers who want to deal with this subject matter in more detail, reference is made here to the primary source – the patent specification.

How precise is this measurement actually? How much better does the new sensor system measure?

The accuracy class of the active transformer stage responsible for a defined current range is decisive in this context. Let me try to illustrate this with the aid of an example and to pick up on the application mentioned at the beginning:

It was assumed that both high (I_{Pmax} = 50 A) and very low currents to be measured (I_{Pmin} ≤ 1 A) occur during operation of a measuring arrangement. Standard single-stage current transformers on the market are offered with a typical accuracy limit of, for example, 1%. This often proves to be insufficient for certain applications. However, if you divide the total measuring range of 50 A into four equal individual stages, that means Stage 1 ranging from 0 to12.5 A, Stage 2 from 12.5 to 25 A, Stage 3 from 25 to 37.5 A and Stage 4 from 37.5 to 50 A. Each of these individual stages is also tolerated with 1%, an accuracy limit value of 0.25%, in relation to the total measuring range, is obtained when using our measuring arrangement. In absolute terms, the single-stage transformer can, therefore, only resolve 50 A to an accuracy of 0.5 A. With our 4-stage transformer, featuring 12.5 A per stage, it is possible to achieve a resolution of 0.125 A across the entire 50 A range. Formulated dif-

Credit all figures: FH Zwickau

Team of inventors, from left to right, kneeling at front, Lisa Franke, Ringo Lehman; standing, Prof. Lutz Zacharias, Prof. Mirko Bodach, and Kevin Steiner

ferently: When using our compensation current transformer described in the example, 4-fold precision is achieved for the respective individual stage. Basically, the level of precision is thus scalable via the gradation.

We are therefore talking about a multi-stage and, if you want to put a negative light on it, quite complex piece of electronic measuring equipment. Is it worthwhile?
It is definitely worthwhile, especially when the precision of conventional compensation current transformers is insufficient. In this case, the increase in practical value far outweighs any additional circuit technology costs.

Also in order to engage in any possible cost-benefit discussions: How do you rate the possibility of converting to a semiconductor chip?
That is definitely conceivable. The existing wide range of applications contributes to the expectation of high quantities of components. Implementation, e.g. as an SoC, promises a high degree of technical and economic optimization potential within this context.

How would you describe the dynamics of your measuring principle? Which bandwidths can be achieved?
In a direct comparison, the bandwidth is of course initially reduced as a result of the system. Let us assume that a measuring transformer stage of our cascaded system has the same dynamics as the individual stage of a single-stage transformer. With four stages, the dynamics would be reduced accordingly by a factor of four, as the signal rise times per stage add up.

Good single-stage transformers achieve up to 200 kHz. In contrast, a bandwidth of 50 kHz is realistic with the four transformers in our exemplary measuring arrangement. This proves to be fully sufficient in the intended application area. For other applications with more stringent requirements, higher bandwidths are also possible with our measuring arrangement. Desired dynamic increases can be achieved through detailed improvements in circuit technology, such as advances in semiconductor technology, new OPV generations, etc.

Which software would you recommend to industry developers to solve such complex problems? Is standard software sufficient, or can you explain the design tool chain your team actually used in a few words?
In retrospect, all of this is not witchcraft; consequently, the required material-technical basis for this remains modest. Initially, good knowledge of analog and digital circuit development is enough. But maybe there is, at least in the latter case, a challenge that should not be underestimated at this moment in time. In this context, if you would allow me to indulge in a bit of self promotion: These practical skills could be gained by studying electrical engineering at Zwickau University of Applied Sciences - where we continue to train graduate engineers. When it comes to development tools, cutting-edge standard circuit and system simulators fully satisfy the requirements demanded within this context.

Which industry cooperation partner would you like to have for series production? Rather an industrial customer from the field of application technology or rather a manufacturer of circuits or components?
In my opinion, there is no categorical either-or option for this. It is more about weighing up demand in terms of product quantities, also in individual firms in whose products our measuring system is to be advantageously installed. When it comes to large series (such as for smart meters or electronic power supplies), a potential manufacturer might be quite willing and able to design or cost-effectively produce a corresponding functional unit.

Just as interesting is, however, a component with such market potential for a specialized manufacturer of customer-specific ICs and semiconductor components. As already mentioned, an SoC solution is an excellent choice for the system structure being implemented.

Very impressive. How was it possible to advance such a demanding research and development project to patent maturity at a public educational institution? Did it involve German or EU funding programs?
No public funds were applied for or spent on the research project in question, which has now been completed successfully. We are more than happy to show all interested parties the capabilities of the demonstrator that was created as a result of the project.

The secret of our success – if you like – lies rather in the planned and fruitful cooperation of our "multi-generation R&D project team", as this made it possible to combine youthful energy with many years of professional experience and knowledge in a target-oriented manner.

An important guarantee for innovation developed not least from the excellent and unbureaucratic support of our central university administration and our department for research and third-party funding. ■

Registration at the German Patent and Trademark Office for patent

DE 102016110187 B4, Measuring apparatus and measuring method for measuring current

"The invention concerns a measuring apparatus with a primary winding unit that can be fed with a first current to form a first magnetic field, an opposing field winding unit which can be fed with a second current to form a second magnetic field which at least partially compensates the first magnetic field, and a magnetic field measuring apparatus for detecting a total magnetic field formed by the primary winding unit and the opposing field winding unit, the opposing field winding unit n with individual opposing field windings which are connected in series to one another magnetically, n being a natural number and greater than or equal to 2. The invention also concerns a measuring method in which a primary winding unit of a measuring apparatus is fed with a first current to form a first magnetic field, an opposing field winding unit of the measuring apparatus is fed with a second current to form a second magnetic field at least partially compensating the first magnetic field, a total magnetic field formed by the primary winding unit and the opposing field winding unit is detected by a magnetic field measuring apparatus, and the second current is set such that the total magnetic field becomes zero."

Basic considerations on sensor networks in industry

Autarkic sensor systems for IoT applications

Sensor networks can be retrofitted and help to significantly increase the productivity of a plant. However, there is a lot to consider when designing and setting up a system.

By Dr. Christian Viehweger,
Chemnitz University of Technology

Wireless, energy-autarkic sensor systems are among the basic components of a networked world. They enable measuring systems at relevant locations, assume monitoring and control tasks, collect information, and ensure safety. The idea of being able to monitor, control, and analyze processes comprehensively is fascinating. Processes can thus be regulated more efficiently and with less resources. In addition to optimization methods, safety and reliability-critical tasks are also part of a sensor network. For instance, wear and tear can be detected, failure criteria monitored, and alarm conditions detected. A particular advantage of a sensor network is the opportunity to retrofit older systems. Modern functionalities can thus also be used for existing technology. Incompatibilities are also avoided, for example when two machines from different suppliers rely on varying standards.

Challenges when networking systems

In real-world scenarios, the options provided by the systems are restricted only by a few technical limitations and framework conditions. As a rule, integration should be possible without disrupting existing processes. The sensors should be incorporated into their working environment without having to be adapted. Even the routing of cables, for example, can demand structural changes to the equipment and should be avoided wherever possible.

Reliable and continuous operation is also required. Incorrect information or malfunctioning may result in serious consequential damage. This should be avoided at all costs. Confidence in functionality is just as much a part of user acceptance as operability. The systems are often used by people who lack specific knowledge of the technical requirements. They are dependent, for example, on a network functioning automatically. Comprehensive utilization, i.e. the basis for the concept, is only guaranteed through broad acceptance.

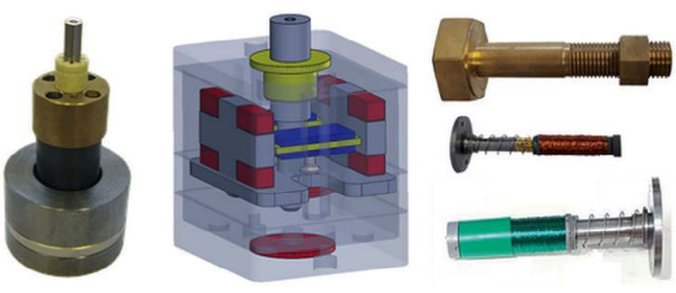
In addition to technical and application-specific challenges, related costs also play a major role. Wireless sensor networks are characterized, above all else, by the use of a large number of individual nodes. To achieve this, both acquisition and maintenance costs must be low. Ideally, the systems can be started and then left to their own devices.

Key technologies for successful implementation

Today, most of the research and development needs for autarkic sensor networks are in the areas of power supply and radio communication. The radio sector, for its part, represents the largest power consumer within the system. The remaining components, for instance sensors or microcontrollers, are often available at favorable prices and with low power requirements. These are usually no longer an obstacle when developing wireless sensor systems.

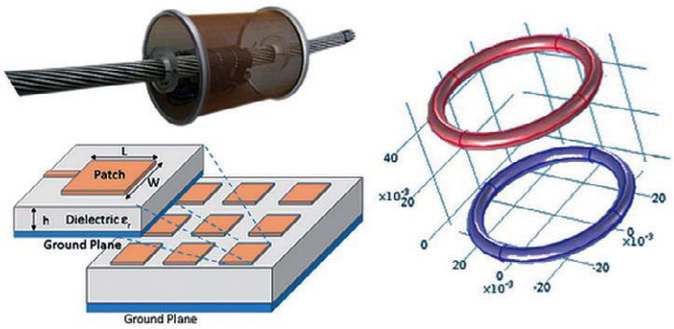
A self-sufficient power supply is the basis for a sensor node. Via energy harvesting, the electronics are supplied with the help of solar cells, thermoelectric or kinetic energy converters, wireless energy transmission, etc. The energy converter can be adapted both to the needs of the consumer and to the source, for example through scaling, the technology

Credit all figures: TU Chemnitz

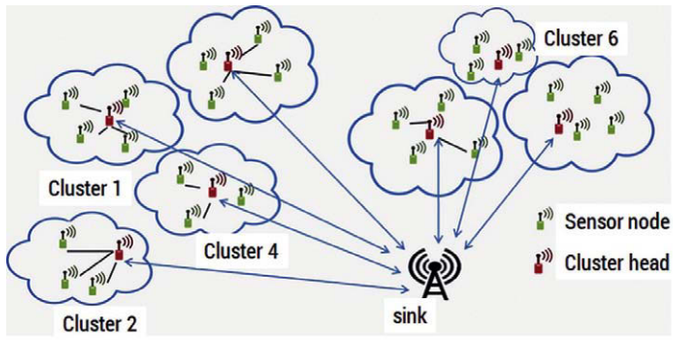


Various designs of vibration energy converters constructed at the Professorship of Electrical Measurements and Sensor Technology of TU Chemnitz. Systems can be supplied reliably by converting kinetic energy into electrical energy. Typically, machines and systems are subjected to vibrations that can be converted. In addition to inductive, piezoelectric or capacitive conversion principles, the Professorship is also researching combined converters, for example with the aid of the magnetostrictive effect, which further enhance the impact.

Energy converters for solar and thermal energy constructed at the Professorship of Electrical Measurements and Sensor Technology of TU Chemnitz. The waste heat from plants, converted with the help of the Seebeck effect, can be used specifically to operate electronics. Solar cells not only provide energy when the sun is shining but can also work under artificial light. Precise adjustment between cell and light source guarantees a high yield. Constant illumination enables a reliable source of supply for sensor networks, especially in production environments.



Special applications for supplying sensor systems. Wireless energy transmission can also be used to reach hard-to-access nodes, moving elements, and encapsulated parts. Inductively coupled coils are ideal for short distances and high power levels. RF transmission is suitable for greater distances. In this case, the level of achievable performance is lower. Depending on the application environment, a boundary field, both capacitive and inductive type fields, can also be used directly.



Cluster-based communication. The network topology determines numerous parameters, for instance the reaction speed, data throughput, energy utilization or the complexity of a single node. If all the sensors communicate with one base station, new challenges arise with regard to collision prevention. A single node also requires more complex hardware. When individually grouped along with local base stations (cluster heads), the load can be distributed and a network utilized more homogeneously.

base or the material. For applications at hard-to-access, encapsulated or moving parts, wireless energy transmission can power the system. In this case, for example, inductive coupling via coils is used. The self-sufficient power supply frees the node from extra maintenance effort or follow-up costs caused by batteries.

Sensor networking in close proximity is generally achieved with state-of-the-art technology such as ZigBee. This energy-saving radio protocol enables different network topologies that can be adapted according to the actual application. The power consumption within the network alters depending on whether star-shaped, meshed or cluster-based connections are employed. Both uniform capacity utilization and concentration on one base station are possible. In addition to the network topology, intelligent data transfer also plays a key role. Depending on the available hardware, data preprocessing can occur or transmission can only take place if a value has changed significantly. This reduces the volume of data; which is of particular interest, as communication usually accounts for the vast majority of power consumed.

Diverse applications

Wireless sensor networks can be used in all areas of activity, e.g. in food cultivation, water management, security systems, traffic systems, health care, and much more. Especially in the industrial sector there are many potential options, for instance in machine and plant monitoring, warehousing and transport systems or materials management. Of particular interest is the possibility of not only equipping new areas with intelligent sensor systems but also of retrofitting existing ones. Radio connection and energy self-sufficiency guarantee the sensors are easy to apply. This opens up completely new horizons. Existing production plants can subsequently be made "intelligent", their efficiency and reliability can be enhanced, process monitoring becomes possible, and much more beside. A company therefore has a powerful tool at its disposal to achieve

Short profile

Chemnitz University of Technology

Chemnitz University of Technology (TU Chemnitz) is a byword for excellent research. Right from today, the pressing overarching social issues of the future are being placed on the agenda with the core competencies of materials and intelligent systems, resource efficiencies in production and lightweight construction, as well as people and technology. Findings of basic research and application-oriented research are hereby leading to promising solutions. TU Chemnitz has been involved since 2012 in the Federal Excellence Initiative with the first and sole Federal Excellence Cluster in the field of lightweight construction research.

The Faculty of Electrical Engineering and Information Technology places the focus of its research on microsystem technology and nanoelectronics, smart systems integration (miniaturization of components and systems, sensors, actuators, control circuits), design, technology, testing and application of components and systems, intelligent sensors based on novel technologies, interfaces between the nano, micro, and macro worlds, not to mention the reliability of components and systems.

The Professorship of Electrical Measurements and Sensor Technology boasts years of comprehensive experience in the field of sensors, system design, signal processing, and embedded systems. The research focuses on the fields of wireless energy self-sufficient sensors, impedance spectroscopy, nanocomposite sensors, and energy storage diagnosis. Thanks to close cooperation with industrial companies, a wide range of differing findings from basic research have already been implemented in products. This has manifested itself, for example, as wireless sensor systems in production monitoring, measuring devices for cable diagnosis, battery management systems or tactile sensors.

Contact:
Prof. Dr.-Ing. Olfa Kanoun
mst@tu-chemnitz.de, www.tu-chemnitz.de/etit/messtech/
Chemnitz University of Technology
Electrical Engineering and Information Technology
Professorship of Electrical Measurements and Sensor Technology
Reichenhainer Strasse 70, 09126 Chemnitz, Germany

a significant increase in productivity without incurring excessive costs.

The future development of autarkic sensor systems in industrial environments will continue to focus on standardizing applications in addition to special systems. This enables a larger number of nodes, thereby cutting costs. The additional integration into cloud systems through the use of new remote transmission protocols, such as NB-IoT, will simplify user interaction and further improve system acceptance. As a result, nothing stands in the way of the permanent availability of status information. ■

Embedded Analytics

Machine learning and sensor fusion on embedded MCU

Many promises of great value are currently linked to machine learning or self-learning algorithms. For sensor applications in predictive maintenance, an ARM®-based microcontroller may be sufficient to implement AI algorithms. This has been demonstrated by Andreas Mangler, Director Strategic Marketing & Communications at Rutronik, together with his engineering team.

Mr. Mangler, you and your team have developed algorithms that require neither a cloud nor a high-performance PC but run on a microcontroller. Why?
Andreas Mangler: We see a clear move in many industrial applications away from having data analyzed and evaluated externally by a service provider (cloud analytics) or a decentralized industrial PC (edge analytics) and toward having everything implemented in an separate protected environment as an embedded MCU-based system (embedded analytics). And all of this ideally with appropriate hardware encryption. IP protection and real-time capability of the system are at the center of decisions in favor of embedded analytics, in particular the protection of the raw data, the algorithms used, and their sequential sequencing in order to finally obtain the desired information from big data. And yet, embedded analytics systems are usually based on mathematical models, patterns, and functions with which a target/actual comparison is carried out using the data already learned and the measured data.

Many tasks therefore not only involve pattern matching, which is not necessarily only available in the image processing of graphic data, but the processing of a large amount of sensor data with varying physical measured variables, which are typically processed time synchronously; the keyword here is sensor fusion.

Credit: Rutronik

Andreas Mangler, Rutronik

"Data can already be reduced through the previous rough estimation of the actual state."

An embedded analytics solution is indispensable, especially in safety-relevant systems or where functional safety is required in real time and quasi ad-hoc decisions have to be made in the microsecond or nanosecond range.

One measure, for example, is the use of stochastic filters, which can be well supported by the MCU's memory organization. Another option is to use IIR filters instead of block-oriented FIR filtering as the digital filters, taking into account the different group delay and transient response of the filter topologies.

This actually sounds quite simple, but most probably it isn't. In a real-life scenario, how can such large amounts of data and algorithms be processed in a small microcontroller?
The problem of sensor fusion is well described by the buzzword VUCA, i.e. Volatility, Uncertainty, Complexity, and Ambiguity. Volatility arises because the system is constantly changing in terms of its data, dynamics, speed, and limits. Uncertainties exist, e.g., due to noise and unforeseeable events. In addition, the systems are typically complex and there are ambiguities, as some states may have different causes. The aim is to assess this "hidden" information in order to better describe the system. Data can already be reduced through the previous rough estimation of the actual state. For example, a heating control system for a gas heater that has to carry out a CO_2 analysis could determine the exact outside temperature in parallel. This way, when used in Norway, the heater can certainly take a winter temperature of -30°C into account when calculating the measured value. In southern Spain, this temperature is extremely unlikely,

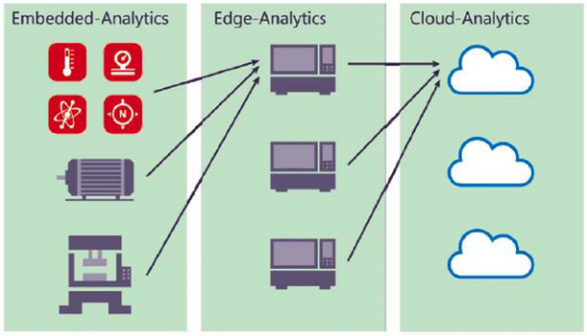


Figure 1: With each step from right to left, less computing capacity and storage space are available, i.e. big data must become smart data and instead of extensive algorithms, lean, self-learning algorithms are required.

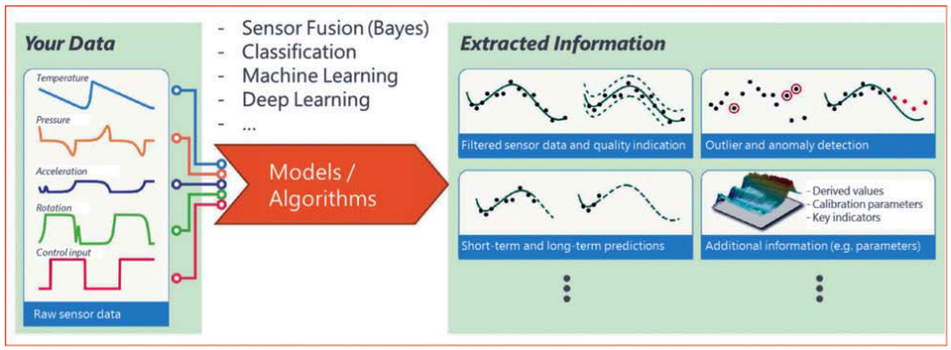


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Figure 2: Principle of sensor fusion and data extraction

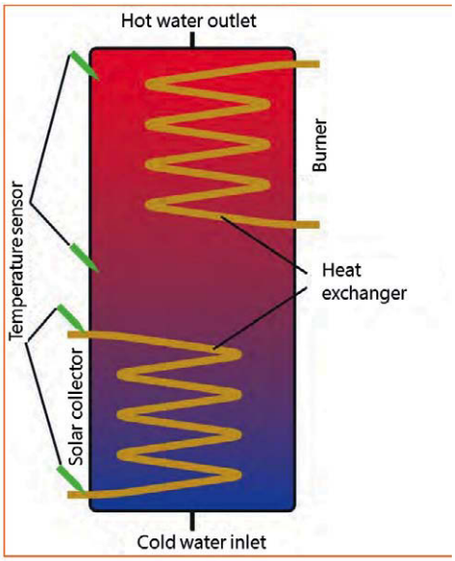

Figure 3: Schematic design of a hot water tank with a PV system and several temperature sensors.

or downright unrealistic, in the winter. Consequently, the GPS location sensor or logistics data of the heater supplier determines the amount of data to be evaluated.

The formula is: Data reduction plus lean algorithms that are combined correctly. This requires four steps: Firstly, sensor deployment planning, i.e. how many sensors of which sensor type are required where? The second step concerns data selection, i.e. the question: Which data is actually required to detect anomalies? This is how "big data" becomes "smart data". Above all, the trick here is to select as much data as necessary and as little as possible, while still managing to pick the right data. In the third step, the algorithms for pre-filtering need to be selected. The parameters required for analysis are then extracted in the fourth step. All the steps have to be precisely adapted to the system and the actual problem. Furthermore, the basic problem of synchronous data processing has to be considered for sensor fusion.

How can this be implemented in the MCU?

The physical system and the possible states in reality are considered and described for this purpose. This then leads to an assessment of the state. These types of model can be defined in advance in the laboratory and stored in the microcontroller's look-up table. The sensor data can then be compared with the model and outliers can quickly be identified as an anomaly. This means fewer measuring points are required, which in turn helps to save storage space.

Can you explain this using a practical example?

Of course; a typical application would be an intelligent hot water tank connected to a photovoltaic system. I start with sensor deployment planning and specify that several temperature sensors as well as pressure and acceleration sensors are needed.

Now the state has to be assessed: Since I know, for example, that the temperature at the solar collector in these parts will only be between -20°C and +50°C, any data outside this range can be omitted. From a purely physical point of view, the water in the tank cannot rise by 30°C from one minute to the next and, as a result, it is also possible to restrict the dynamic behavior over the time or frequency range. Moreover, a temperature difference of one degree does not have an effect on the system. The data therefore only needs to be analyzed down to an accuracy level of one degree.

The next step is to identify the relevant parameters for the task, e.g. protecting against overheating. In this respect, the temperature of the solar collectors, the cold and hot water inflow, the heat exchanger, and the burner plays a key role. Their data must be filtered out from the sensor fusion. Nothing else needs to be included in the analysis. This is followed by other filters to further reduce the amount of data. This means it is primarily about the parameter identification that influences my overall system.

Selected, filtered data are now available. What is the next step?

Certain patterns and anomalies can now be detected via statistical filters, for instance - and these are the interesting points in order to detect overheating at an early stage in our example. By filtering out the anomalies, I am able to limit their data analysis.

In order to describe the anomalies, extreme system values, i.e. the minimum and maximum values and the turning points, have to be explained mathematically. With cloud and edge analytics this is achieved through differential equations. However, these are too extensive for embedded analytics. We have, therefore, replaced the mathematical curve discussion with a self-learning iteration method. In principle, this is not high-level science, but mathematics taught to the first year students on every basic science course. For the extraction and subsequent visualization of data, a two-dimensional representation is helpful, as it allows you to choose a three-dimensional representation in order to place certain identified parameters in the z-axis of the representation. This is basically comparable to a "topological map" of the sensor data.

How did you proceed with this?

We chose a three-dimensional analysis method in order to make the extreme values recognizable and to subsequently compare the sensor model data. It is already possible to see here that some parameters have very little or no influence on the anomalies. This data can then be neglected or filtered out, as deemed necessary.

In order to explain the previously described "topological landscape (Figure 5) mathematically, we divided it into less than 100 subsegments and specified each segment with

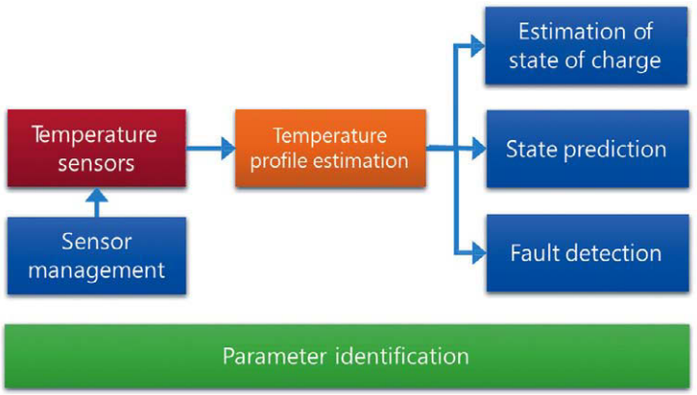

Figure 4: Principle of parameter identification and anomaly detection

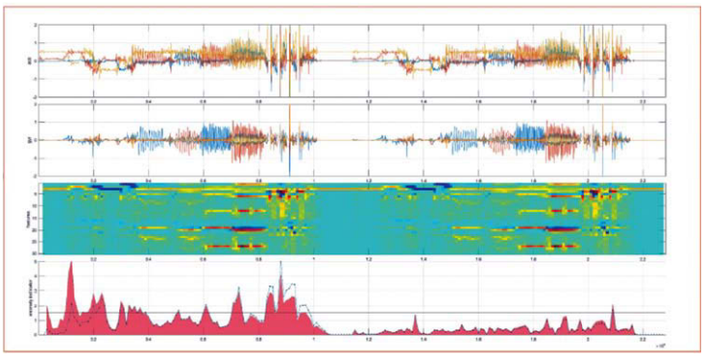

Figure 5: A characteristic curve can be extracted from the raw data of several sensors using various filters, thereby making anomalies visible.

just 10 measuring points for the iteration, thereby limiting the required storage space from the outset. We defined the difference between the model data and the deviating data as +/-1.5%. These are the detection limits of the anomalies.

We then implemented a self-learning iteration method on a STM32 F4 from STMicroelectronics using the so-called dictionary method. This entailed programming iterative queries that determine which mathematical function from the dictionary is to be used to replace which subsection of the sensor function. In just three or four query loops, we arrived at a result that describes the sensor characteristic curve with basic mathematical functions - in other words, an exact modeling of the system that immediately identifies anomalies. The "Sensor Function Dictionary" contains only 5 basic mathematical functions, such as radial basic functions (RBF) or linear functions.

The self-learning approach further reduced the segments and the amount of data, meaning just 30 segments were needed, i.e. 300 instead of 400 data points. This was all achieved in real time.

Can this be achieved with any microcontroller?

In theory yes, in practice no. When processing sensor signals from several sensors (sensor fusion), the real-time capability of the MCU is the main focus of attention. Extremely efficient programming is required for time-synchronous processes, e.g. MEMS sensors with six degrees of freedom. When it comes to time-critical measurements, we discovered that programming on the HAL (high abstraction layer) can lead to measurement errors in the time domain, or that the dynamic changes of the anomalies to be detected were insufficient. The consequence of this was the decision in favor of low-level programming.

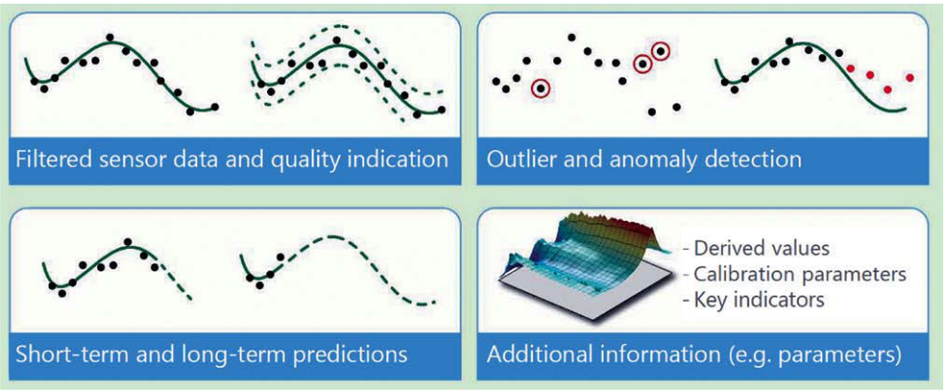

Figure 6: The three-dimensional image of the filtered sensor data enables excellent identification of extreme points.

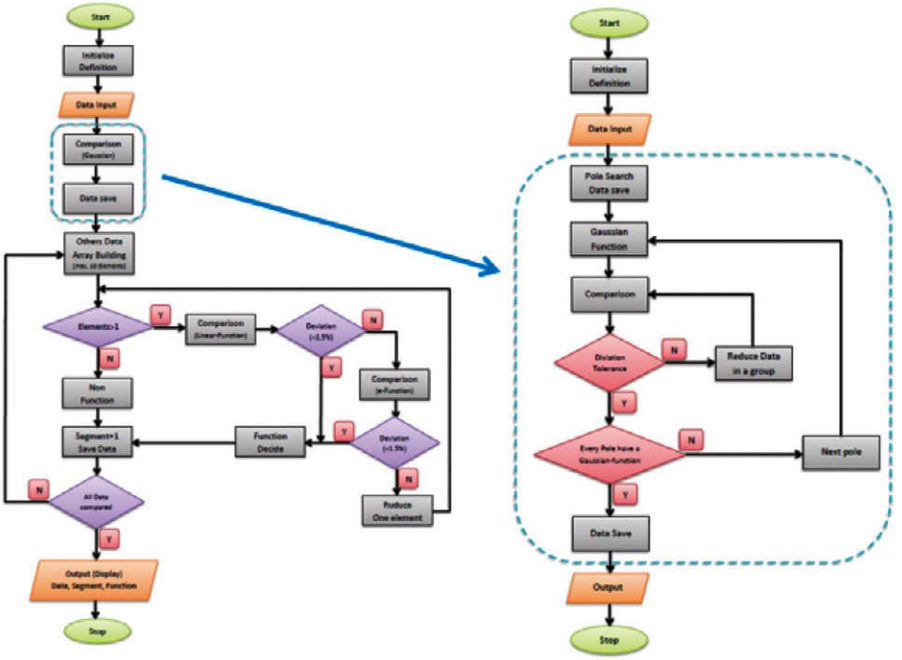

Figure 7: The flow chart of the embedded solution shows the iteration procedure.

The memory requirement depends on the previous sensor deployment planning. We chose the STM32, as the analog and digital peripherals combined with the direct response via the low-level allow assembler-based programming in order to implement sensor fusion with the existing RAM and ROM.

Is this process now tailored to a specific application?

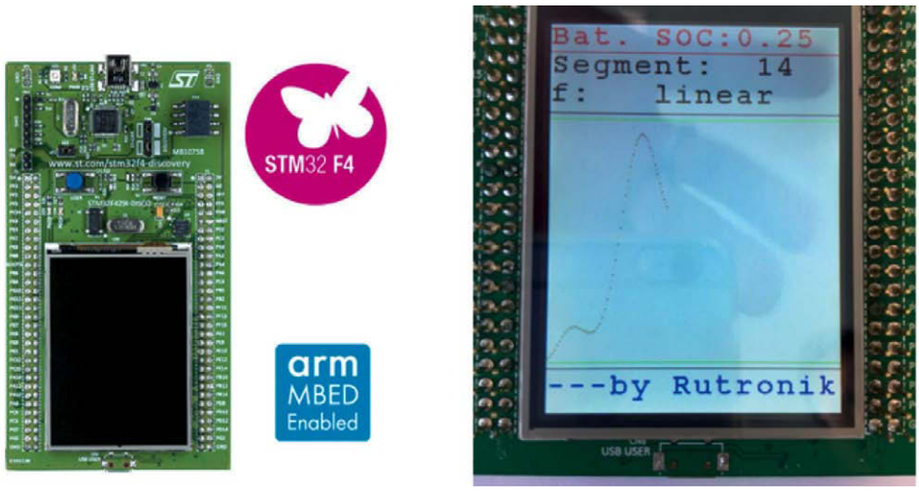

Figure 8: The STM32 has sufficient memory and performance for processing sensor fusion data and enables, for example, predictive maintenance as an embedded real-time system.

No, the self-learning algorithms allow us to map any non-linear system of all sensor types and sensor fusions. In addition, it also meets all other requirements placed on embedded analytics: It works offline, i.e. without a cloud, in embedded real-time systems, runs on a standard ARM MCU, and is both robust and scalable.

What was the biggest obstacle during the development phase?

That it demands comprehensive know-how in various disciplines. And this, in turn, requires a whole team of experts. When selecting parameters and pattern matching or determining anomalies, the physical overall system has to be understood fully. It also requires extensive knowledge of all types of sensors and how they work in order to select the appropriate higher mathematics and self-learning algorithms. We have the big advantage of having in-house sensor specialists, analog specialists, and MCU embedded specialists. In addition, we benefited greatly from the previous research carried out by our partner universities and the specialists in our third party hardware and software specialist network, for example at Knowtion, which specializes in sensor fusion and automatic data analysis.

We can summarize this Rutronik proof of concept development as follows: Artificial intelligence and machine learning at the embedded MCU level is not simply a software task. A comprehensive physical and electrochemical understanding of the sensors and how they function with regard to process anomalies is absolutely necessary in order to implement predictive maintenance. The RUTRONIK engineering resources required for this are available to our customers and provide the necessary support for selecting perfectly coordinated products. ■

Publishing details

Editorial staff:
Sebastian Hör – Rutronik, Press Officer (Editor-in-Chief, responsible for all contents), Tel. +49 7231 801 1679
Ralph Kühn – Rutronik, Journalist, Tel. +49 7231 801 0
Frank Klemmer – Rutronik, Marketing Communications Manager, Tel. +49 7231 801 0
Andreas Mangler – Rutronik, Director Strategic Marketing & Communications, Tel. +49 7231 801 0
Markus Krieg – Rutronik, Managing Director Marketing, Tel. +49 7231 801 0
Christine Schulze – Agentur Lorenzoni GmbH, Tel. +49 8122 55917 14
Sabrina Hausner – Agentur Lorenzoni GmbH, Tel. +49 8122 55917 11
Nikolas Maier – Agentur Lorenzoni GmbH, Tel. +49 8122 55917 15

Advertising Manager: Ipek Baskurt – Rutronik, Media Coordination, Tel. +49 7231 801 0
Final editing: Achim Grolman, Markt&Technik
Layout and Design: Wolfgang Bachmaier, Markt&Technik; Alexander Zach, Markt&Technik

Print: L.N. Schaffrath Druck Medien, Marktweg 42–50, 47608 Geldern, Germany

Herausgeber und Anschrift: Rutronik Elektronische Bauelemente GmbH, Industriestr. 2, 75228 Ispringen, Germany, Tel. +49 7231 801 0, Fax +49 7231 82282

Circulation: 37,000 copies (German) + 10,000 (English)

Special thanks to:
Prof. Dr.-Ing. Olfa Kanoun, Chemnitz University of Technology
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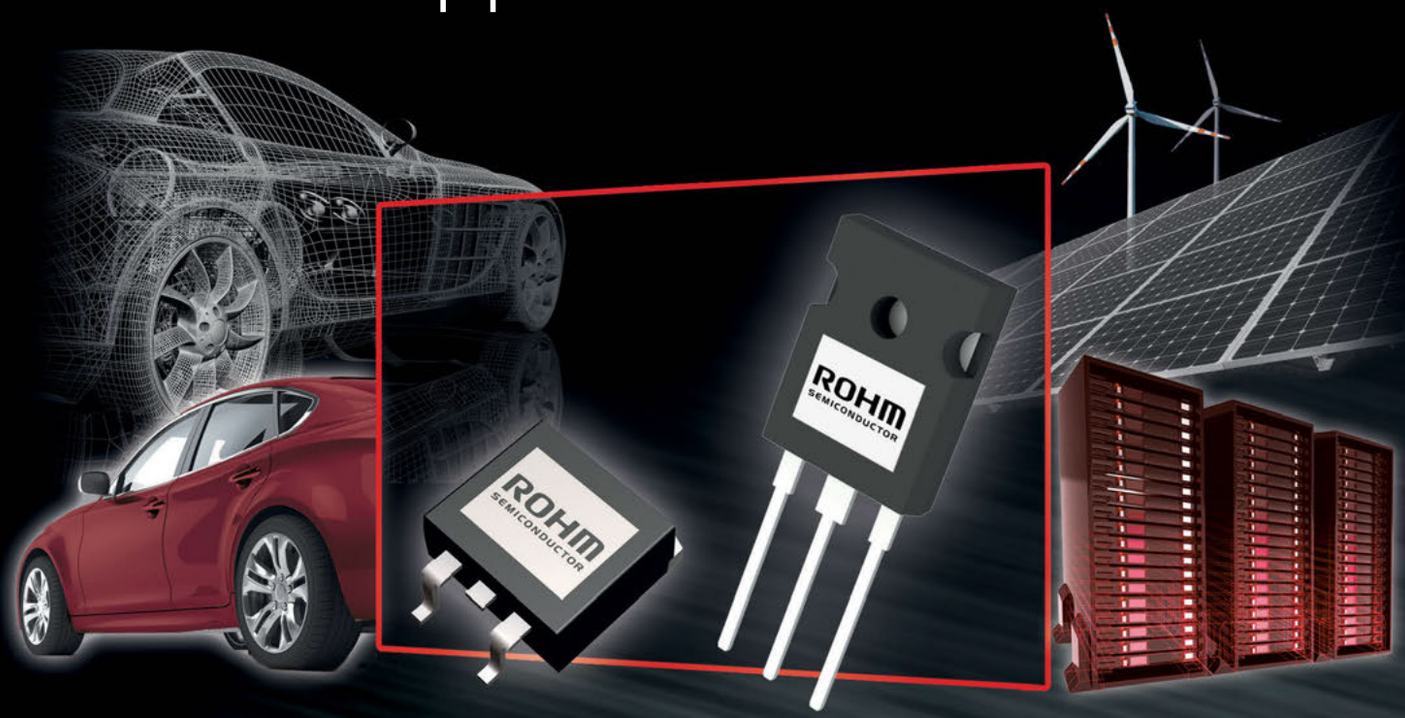

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*Tj=100°C

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