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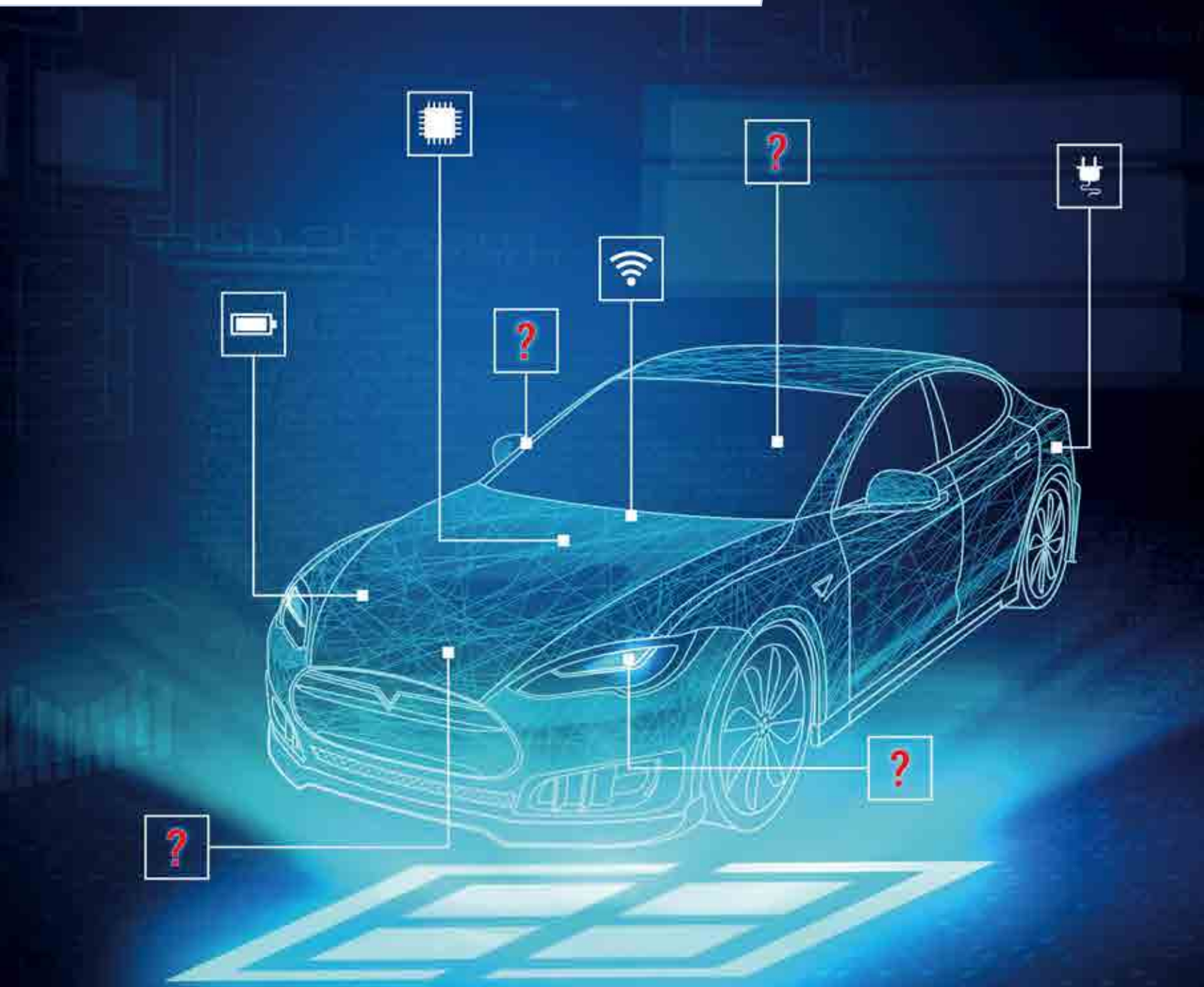
DIE UNABHÄNGIGE WOCHENZEITUNG FÜR ELEKTRONIK
2/2021 | E



- *Know-how*
- *Application*
- *Automotive*
- *Rutronik innovative*
- *System technology*
- *Latest components*

RUTRONIKER

YAGEO Group

KEMET YAGEO Pulse

YAGEO Group Automotive Solutions

Anti-Sulfurated Chip Resistors | Shunt Metal Current Sensors | Circuit Protection Components
Automotive High Frequency MLCC | Polymer Tantalum Capacitors | BMS Transformers

Rutronik is global partner of YAGEO Group

Editorial

Stephan Menze
Head of Global Innovation Management

Crisis is no protection against innovations!

After a year and a half of the COVID-19 pandemic and the associated lockdowns, we are now – at least in Germany – starting to see the light at the end of the tunnel.

This is great news, but it doesn't mean that all the challenges – including those in the electronics industry – have just disappeared. COVID variants continue to cause concern, shortages of microchips is something that we will have to deal with for years, and the question of how we can get autonomous and electric vehicles onto the roads is anything but trivial.

Rutronik is tackling these challenges with German inventiveness. Our proprietary Lisa app enables companies and test centers to manage the entire process from booking an appointment to managing test results in compliance with the GDPR through to billing and documentation for the health and financial authorities.

In terms of microchip shortages, we will be supporting our customers with long-term planning and predictive procurement based on the second-source principle, helping to prevent stoppages due to a lack of components. But even we cannot perform magic. That's why we are advising our partners to focus their planning as far as possible into the future – and to use suppliers that are less well-known here in Germany, as outlined in the article on page 26.

The question of how to achieve the most efficient use of batteries is one that Rutronik has been working on for years. Partly because of the transport revolution and the concentration on electric mobility, we are thinking about how batteries can be optimally utilized and how safety can be improved. This includes the issue of how the high-voltage vehicle electrical system can be quickly and reliably disconnected from its auxiliary units to guarantee safety even in the event of a short circuit, as well as that of increasing the lifetime of a battery.

As a result, not only have we worked with a technology partner to develop a reference design for an intelligent, resettable, and low-loss SiC-based high-voltage circuit breaker with a breaking capacity of up to 40 kW (more details on page 63), but we have also collaborated with researchers at the University of Applied Sciences Zwickau on the HESS hybrid energy storage system. Read all about it in our article on p. 56.

These are just a few examples of what Rutronik is doing to address current and future issues with innovation and a passion for new solutions. You can find out more in this issue of Rutroniker. Happy reading!

Yours truly,
Stephan Menze

Contents

WE CONNECT

THE NEW MA01 SERIES

BtB HIGH SPEED TRANSMISSION FLOATING CONNECTORS FOR AUTOMOTIVE

- Perfect alignment
- High speed data transmission
- High contact reliability
- Multiple mounting options
- Tailored to automotive market requirements (–40 °C to +125 °C)

Technology to Inspire Innovation

JAE

Smart lighting

The basis for the central nervous system of buildings

Modern building management systems can make a decisive contribution to greater energy efficiency and comfort. Smart lighting systems form the basis for a kind of central nervous system. Bluetooth usually forms the "neural pathways," but other wireless standards also offer advantages.

By Kerstin Naser,
Product Sales Manager Wireless
bei Rutronik

Smart lighting is one of the largest market sectors for Bluetooth: according to the "2021 Bluetooth Market Update" by Bluetooth SIG (Special Interest Group), 27% of shipped Bluetooth devices are already used for smart lighting. This puts them in second place behind smart appliance applications (35%), but they are growing faster than them.

There are good reasons for this: connected lighting with a smart control can reduce energy costs by around 70 to 75%. At the same time, comfort levels are increased, for example by allowing users to change the colors of the light as desired or by automatically adapting the light to natural daylight (Human-Centric Lighting, HCL). This lighting concept provides a light spectrum that transitions from high blue components in the morning, which have an invigorating effect, to more red components in the evening, which have a calming effect.

Furthermore, presence detectors can be used, for example. Depending on whether someone is in the room or not, the light can be switched on or off automatically. Automatic switching based on the existing intensity of illumination or ambient light in a room is also possible.

Lighting is everywhere

Lighting is utilized virtually everywhere in a building. This makes it the obvious foundation for the infrastructure of new building management approaches, since the wireless technology integrated into the lighting control devices can also be used for numerous other applications. Bluetooth SIG predicts that by 2029 commercial connected lighting will generate $19.1 billion in global revenue.

Together with the DALI (Digital Addressable Lighting Interface) Alliance, Bluetooth SIG has defined a gateway that allows D4i-certified luminaires to be monitored and controlled via Bluetooth Mesh. This way, lighting components from various suppliers can understand each other and interoperate smoothly.

Going beyond illumination, indoor location asset tracking or indoor navigation can, for example, be implemented using smart lighting. Objects that are to be tracked must be equipped with a beacon. The wireless transceiver in the luminaires receives its data signal as soon as the object is within range. The position of the object can then be derived using the building floor plan. This is particularly useful in warehouses or large factories, where it significantly reduces search times. Processes can thus be optimized and costs reduced. In hospitals, tracking can substantially contribute to increased speed and quality by easily locating mobile health-care equipment or hospital beds.

Networked via Bluetooth

Bluetooth Mesh is used by most smart lighting systems for reliable and secure communication. This allows the low power consumption rate and the low latency of Bluetooth Low Energy (LE) to be used for sys-

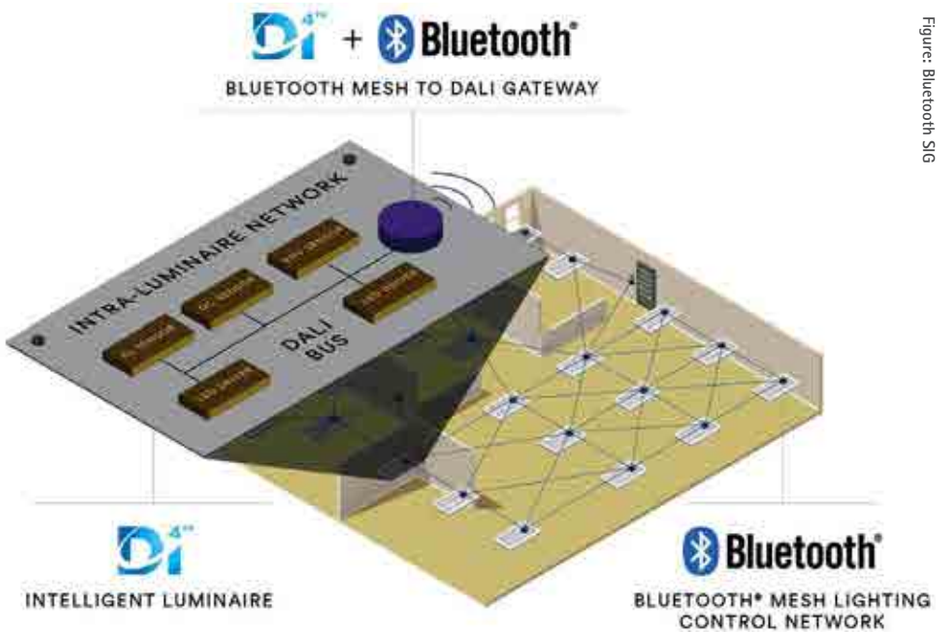


Figure: Bluetooth SIG

Figure 1: Bluetooth SIG and DALI have defined a standardized gateway for controlling D4i luminaires via Bluetooth Mesh.

WE CONNECT

MA01 CONNECTORS AT A GLANCE:
GREAT FEATURES AND STRONG BENEFITS

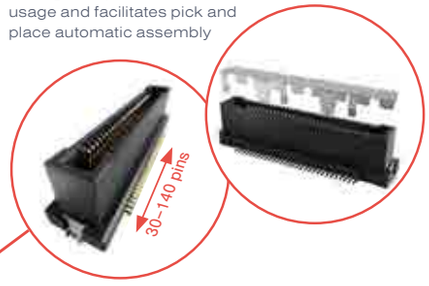
JAE`s cutting-edge MA01 BtB floating connectors combine perfect alignment, compact design, high data rate and wide temperature range with high reliability, excellent durability and great variability.

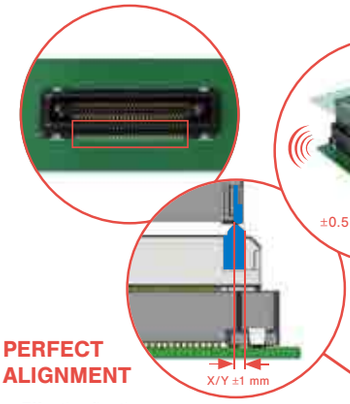
HIGH CONTACT RELIABILITY

- Double contact structure
- Rolled surface connection (lower insertion force, higher wear resistance)

SMALL, COMPACT DESIGN

- Various pin counts (30–140 pins)
- High pin density (0.635 mm pitch)
- Easy to assemble due to alignment pegs
- A special cap protects the connector's mating area prior to usage and facilitates pick and place automatic assembly



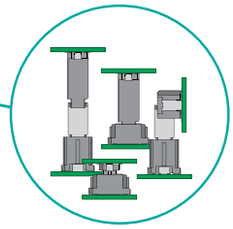


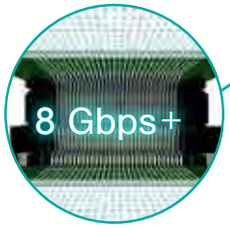
PERFECT ALIGNMENT

- Effective floating range: X/Y ±0.5 mm movable
- Special mating guide construction (X/Y ±1 mm) prevents misalignment at PCB assembly
- Easy fitting during manual assembly due to special guiding form
- Excellent optical controllability and a production friendly structure: JAE connectors have visible SMT contacts

MULTIPLE MOUNTING OPTIONS

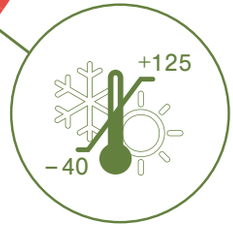
- Different stacking heights (8 to 30 mm)
- Multiple BtB PCB mating connections (parallel and vertical, in low and high versions)





HIGH SPEED DATA TRANSMISSION

- High data rate transmission: 8 Gbps+
- Equivalent to 10GBASE-KR, PCIe Gen3



WIDE OPERATION TEMPERATURE RANGE

- –40 °C to +125 °C
- Tailored to automotive market requirements

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Technology to Inspire Innovation
JAE

tems where hundreds or thousands of devices from various suppliers need to communicate with one another. Bluetooth Mesh uses the so-called flooding principle, which ensures messages reach their destination. This is possible as all the network participants can communicate directly with one another – and if one participant should fail, the message is transferred on via another route. In addition, smartphones can also be integrated into a BLE or mesh network with a corresponding app, thus enabling the switching of luminaires without a gateway or an Internet connection.

Bluetooth Mesh is supported, for example, by powerful multiprotocol SoCs from Nordic Semiconductor's nRF52 and nRF53 series. In combination with the nRF21540, users can enjoy a 16× range extension. The nRF5340 is equipped with two Arm Cortex-M33 processors. The application processor is optimized for performance and can be clocked at either 128 or 64 MHz, has 1 MB Flash, 512 kB RAM, a floating-point unit (FPU), an 8 kB two-way associative cache, and DSP instruction capabilities. The network processor is clocked at 64 MHz and is optimized for low power and efficiency (101 CoreMark/mA). It has 256 kB Flash and 64 kB RAM. In addition to Bluetooth LE and Mesh, the nRF5340 also supports NFC, Thread, and ZigBee. It offers high-speed SPI, QSPI, USB, and an operating temperature of up to 221 °F (105 °C).

Numerous suppliers offer modules based on these SoCs from Nordic Semiconductor. Many already have integrated antennas and are pre-certified for the key markets (CE, FCC, IC). As such, they help to shorten development time and reduce costs. This applies, for example, to the ISP series from Insight SiP, the PAN1780 and PAN1781 modules from Panasonic, the MBN52832 from Murata, and various modules from iVativ and EnOcean.

The ISP family from Insight SiP is characterized by its small form factor, which makes it particularly suitable for use in lighting applications. The modules are based on various Nordic ICs and can be exchanged easily thanks to pin compatibility.

The Panasonic PAN1780 module is based on the Nordic nRF52840-IC. Due to the integrated Arm Cortex-M4F with 1 MB Flash and 256 kB RAM, the module can be used in stand-alone mode, which helps to save costs and space. The PAN1781 is based on the Nordic nRF52820, which has 256 kB Flash and 32 kB RAM, and supports angle of arrival (AoA) and angle of departure (AoD) of version 5.1 of the Bluetooth Core Specification, so-called direction finding. This Bluetooth standard thus enables even more precise positioning.

The SX-ULPGN-BTZ module from Silex is based on the Qualcomm QCA4020 System-on-Chip (SoC). With dual-band 802.11a/b/g/n Wi-Fi, Bluetooth LE and 802.15.4 connectivity (ZigBee, Thread Pro R21), it is also ideal for lighting and many other applications.

The supplier Cypress/Infineon also offers Bluetooth Mesh chips and modules suitable for lighting applications, for example the CYW20706 IC or the CYBT-343026-01 module, which is based on the CYW20706 IC.

Other wireless standards

In addition to Bluetooth LE and Bluetooth Mesh, other wireless standards are also common for smart lighting applications, such as the EnOcean standard, Thread, ZigBee, or Wi-Fi.

The advantage of Wi-Fi compared to Bluetooth is its significantly higher range. However, the resulting higher power requirement is perhaps also the biggest disadvantage of this technology. In addition, integrating luminaires into a Wi-Fi network is somewhat more complex, as a password and SSID (Service Set Identifier) must be entered for each luminaire. And a Wi-Fi network can reach its limits when lots of luminaires are connected.

ZigBee can be used to create a large, robust mesh network. If a participant in the network fails, the information can be forwarded via an alternative route and is thus not lost. To set up the network, a bridge or hub is also required, which is connected to the WLAN router. The bridge or hub sends the (on/off) command to the luminaires via ZigBee. Unlike Bluetooth Mesh, data transmission is routed as varying tasks are assigned to the individual devices (coordinator, router, and end devices). This means that a certain path is specified for the data through the network.

Thread works in a similar way to ZigBee: here too, data distribution is routed, i.e. via a predefined path. Thread is a mesh protocol based on IPv6. This makes it relatively easy to integrate it into larger IP networks. The Thread protocol is also supported by the Nordic ICs and forms a perfect basis for Thread-based application layers such as Matter, HomeKit, DALI+, KNX IoT, OCF, etc.

Figure 2: The multisensor STM 550 from EnOcean for home automation and IoT applications is self-powered thanks to energy harvesting.

The EnOcean sub-GHz wireless standard (868 MHz according to RED specification, 902 MHz according to FCC/IC specification, 928 MHz according to ARIB specification) offers high reliability by sending short telegrams. There is little collision probability within a network, thus enabling a large network of sensors. Further, there is no interference with DECT or WLAN. The use of a rolling code and 128 AES encryption ensures advanced data security. Inside buildings, the EnOcean wireless standard achieves a range of up to 30 meters.

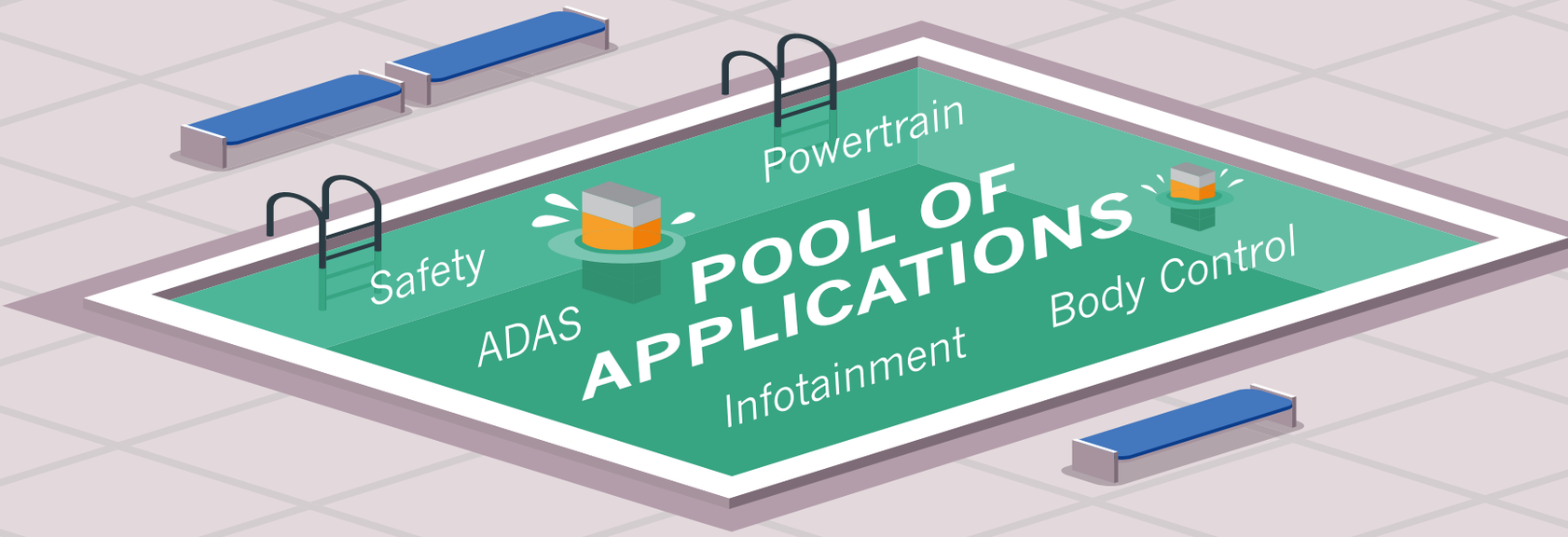
The supplier EnOcean is particularly well known for its energy harvesting technology. It offers maintenance-free wireless sensors based on the EnOcean wireless standard as well as with Bluetooth and ZigBee. The new STM 550 IoT multisensor (Fig. 2) provides status information (open/closed) thanks to a magnetic contact and can measure temperature, humidity, acceleration/orientation, and illumination. The integrated solar cell produces enough energy for the measurements and to transmit the measurement data via Bluetooth, ZigBee, or the EnOcean standard, for example.

Conclusion

Be it Bluetooth, Bluetooth Mesh, EnOcean, WLAN, Thread, or ZigBee – all wireless standards have their specific advantages and disadvantages and which one is best suited for the relevant application needs to be decided individually. One thing applies to all though: they form the central nervous system for smart home lighting and thus for greater efficiency, convenience, comfort, and extensions, e.g. to include a navigation and tracking system. ■

AUTOMOTIVE HIGH CAP. MLCC

SAMSUNG ELECTRO-MECHANICS



AEC-Q200 — **PREMIUM QUALITY** — **VW80808**

Voltage	Application	Size	X7R/X7S - Bis zu 125°C Standard - PN Serie	X7R/X7S - Up to 125°C 5mm Bending - PJ Series
100V	xEV 48V Battery Line	1210” 1206” 0805”	**4.7µF:** CL32Y475KCIVPNE **2.2µF:** CL31Y225KCHVPNE **1µF:** CL21Y105KCYVPNE	**4.7µF:** CL32Y475KCIVPJE **2.2µF:** CL31Y225KCHVPJE **1µF:** CL21Y105KCFVPJE
50V	ICE 12V Battery Line	1206” 0805” 0603”	**10µF:** CL31Y106KBKVPNE **4.7µF:** CL21Y475KBBVPNE **220µF:** CL10B224KB8VPNC	**10µF:** CL31Y106KBKVPJE **4.7µF:** CL21Y475KBBVPJE **220µF:** CL10B224KB8VPJC
25V		1210” 0805”	**22µF:** CL32Y226KAVVPNE **10µF:** CL21Y106KABVPNE	**22µF:** CL32Y226KAVVPJE **10µF:** CL21Y106KABVPJE
16V	DC Block EMI Filter Power Supply	1210” 1206” 0805”	**22µF:** CL32B226KOJVPNE **10µF:** CL31B106KOHVPNE **10µF:** CL21Y106KOQ4PNE	**22µF:** CL32B226KOJVPJE **10µF:** CL31B106KOHVPJE **4.7µF:** CL21B475KOQVPJE
6.3V		1210”	**47µF:** CL32Y476MQVVPNE	**47µF:** CL32Y476MQVVPJE

Voltage	Application	Size	X8L - Up to 150°C High Temperature Standard - PN Series
25V	ICE 12V Battery Line	1206” 0805” 0603”	**2.2uF:** CL31E225KAH4PNE **470nF:** CL21E474KAF4PNE **220nF:** CL10E224KA84PNC

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Cloud platforms

Out of the cloud trap and into a new business model

"America First" was a favorite political slogan of the last US President. And it certainly rings true with cloud platforms: US providers are leading the way in this field. However, European alternatives are now available for many data processing tasks. They provide data sovereignty and the opportunity for a new business model.

By Bernd Hantsche,
Director Product Marketing
Embedded & Wireless at Rutronik

Windows and Office have been the software of choice on most computers around the world for decades. Despite this, another division at Microsoft has been growing rapidly in recent years and will soon be responsible for half of the technology company's operating profit: the Azure cloud platform.

But you would be wrong to think that Microsoft plays the same leading role in the cloud business as it does in operating systems and office software. A company founded as an online book retailer back in 1994 has likewise expanded its business to offer Amazon Web Services (AWS), an even larger cloud platform. According to Statista, a leading provider of market and consumer data, AWS is responsible for about one third of cloud services, while Microsoft's Azure accounts for around one fifth. Search specialist Google follows in third place with GCP and holds a market share of just over 9 percent. Another player in the market for B2B cloud solutions is IBM, with a share of the market of roughly 6 percent.

But cloud offerings are not just a US phenomenon: Chinese company Alibaba has also set up a platform. However, due to fears about the Chinese government's access to data, the company is having trouble gaining the trust of users in the West and its market share is still small. After all, data is the new gold, and people are somewhat reluctant to transfer their gold to someone under the control of a government where conflicts of interest in terms of data protection, economic growth, knowledge advantage, and leadership are inevitable.

Two approaches for more data sovereignty

All that said, US providers also need to retain or regain sovereignty with regard to data and information. That, however, is not 100 percent feasible since Azure, AWS, GCP, and the IBM Cloud offer unique services for which there are few alternatives. Nevertheless, for the majority of data processing tasks, such as data archiving, the use of VM (virtual machines), SaaS (Software as a Service), PaaS (Platform as a Service), IaaS (Infrastructure as a Service), or the use of containers (e.g. Docker), companies will, in the near future, be able to switch to solutions that technically speaking offer the same level of security, and even a higher one when it comes to data protection and political influence: Gaia-X and the Internet Computer Protocol (ICP).

They are based on very different technical concepts: Gaia-X focuses on the creation of policies, standards, federated identity, and access management, meaning users do not have to rely on specific software or hardware. In contrast, ICP is a closed network that is not (!) based on previous protocols such as TCP/IP. It is rather a fully independent software approach that even has its own programming language. Despite this, both initiatives have the same goal: to provide an independent framework of solutions and services based on international standards and European values, which is available to all providers. Further, both approaches require immense processing power.

DFINITY

The Dfinity Foundation is focused on defining and introducing the Internet Computer Protocol.

Gaia-X connects elements via open interfaces and standards

As goddess of the earth, Gaia is one of the first deities in Greek mythology. She is also the namesake of the project for a high-performance, competitive, secure, and trustworthy data infrastructure for Europe. The European project is still in its infancy: it was presented to the general public at the Digital Summit 2019 in Dortmund. The Gaia-X European Association for Data and Cloud was first founded in February 2021 and has its official headquarters in Brussels.

The intention is to use Gaia-X to interconnect various elements via open interfaces and standards in order to link data and create an innovation platform. For instance, it uses the rulebook of the IDSA (International Data Spaces Association), meaning customers do not have to set up all the security concepts from scratch for each new project.

An example of an innovation based on the Gaia-X infrastructure is Catena-X, which was specifically created for the automotive industry and its supply chains. It is intended to enable the fully automated and secure exchange of traffic-related data à la car-to-car and car-to-infrastructure, as well as production-related data throughout the entire supply chain from semiconductor supplier to vehicle supplier. The Catena-X Automotive Alliance was founded in May 2021. According to Oliver Ganser, Chairman of the Board and Head of Consortia Catena-X Automotive Network, the plan is to develop data concepts and to ensure they become binding for the industry within just three years.

In addition to Catena-X, various other consortia from a range of industries are likely to form soon, building on the Gaia-X infrastructure and specifying similar blockchain solutions for their value chains. The key drivers in this respect are not only the new supply chain law and a detailed carbon footprint throughout the entire value chain, but also improved traceability of legal and technical production data of the individual product finishing steps.

Internet Computer Protocol banks on distributed processing power

The Internet Computer, or Internet Computer Protocol (ICP), is being promoted by the Swiss-based Dfinity Foundation.

ICP is a distribution of data processing tasks based on blockchain technology. This means: the data is not entrusted to a cloud company but distributed in small units within a partner network depending on the available computing capacity. When processing these smart contracts, the relevant server operator receives corresponding ICP tokens. ICP tokens are the digital currency of this data processing network; they are traded on a crypto exchange like Bitcoin. The data processing of smart contracts is, therefore, decentralized and also completely encrypted and anonymous. If you want to earn ICP tokens and then exchange them for euros or dollars on a crypto exchange, you need servers that are as powerful as possible to process the smart contracts.

While the Internet Computer Project with its highly innovative – possibly disruptive – protocol as well as the corresponding programming language for customer applications has been around for many years, the ICP token only went public in May 2021. In Insights – Digital Assets: Beauty Is Not in the Eye of the Beholder, Goldman Sachs stated: "Recently, a still more ambitious blockchain-based platform, the Dfinity Internet Computer, proposes replacing the current Internet with a new paradigm in which all data and applications are hosted in a cohesive manner. Decentralized applications are already being launched with the goal of replacing centralized technology platforms such as Facebook, Google and LinkedIn." Just two months after the launch, more than 500 developers have created applications, such as DSCVR, a decentralized social content aggregation platform similar to Reddit, but where users control not only the content but also the actual platform. Fleek is a decentralized web hosting system with numerous websites deployed, while OpenChat provides real-time decentralized, blockchain-based messaging.

Cloud 3.0 business model

Despite all their differences, the two projects also have a lot of similarities: they want to offer the highest levels of security, data sovereignty, and speed. Their ecosystems are still emerging, but their purpose makes them promising in the fight against the centralized data sovereignty of just a handful of US companies. They also offer companies that still have a bit of space left in their data centers a lucrative business model opportunity. Especially as storage space, computing capacity, and servers are in great demand for both cloud models.

When selecting and procuring energy-efficient servers or server components, it is definitely worth taking a closer look at the portfolio of a distributor. It provides a chance to compare several product providers in the same setting – and not simply on the basis of data sheets, but also with regard to soft yet essential characteristics such as long-term availability, complaint rate, goodwill behavior, and roadmap.

The next crash is a matter of when, not if

The shares of the largest cloud providers Microsoft, Amazon, IBM, and Alphabet (Google) have recovered faster after the most recent stock market crash than most financial experts had predicted. Cloud growth is likely to have played its part in this development – and it has increased more than ever before due to the COVID-19 pandemic. Which crash is on the cards? Economic war, including a trade embargo? Damaged submarine cables to overseas destinations? Crashed satellites? In any case, Europe and European companies would be well advised to (also) focus on alternatives in order to reduce their dependence on US corporations. Major US firms that dominate the top sales rankings include not only cloud-based services, but also semiconductor suppliers and distributors – and the European industry is heavily dependent on them. To regain more sovereignty, some European countries are investing in the development of advanced microprocessors and semiconductors and have launched initiatives such as the "Electronic Components and Systems for European Leadership (ECSEL) Joint Technology Initiative (JTI)." Rutronik welcomes this move and, as an internationally active broadliner with European roots, is committed to strengthening local companies while promoting global exchange in an open and cooperative manner.

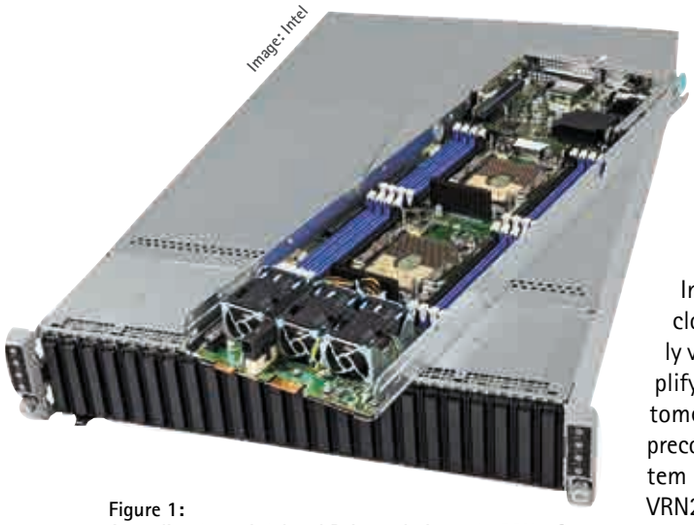

Figure 1:
According to an Intel and Bain analysis, up to 80% of workloads will run on a cloud architecture by 2024. Intel Data Center Blocks for the cloud help accelerate and simplify the transition to the cloud.

High-performance servers and components

Rutronik offers ready-built servers from Advantech, Asus, Calmo, Kontron, and Intel, as well as individual components for building custom mainframes to play a high-performance role in the networks of GAIA-X or Internet Computer Protocol. For example, when generating a 3D simulation of a car accident and its impact on the individual assemblies, you need an extremely graphics-intensive server. Rutronik offers special barebone servers and very powerful graphics cards for such applications. The portfolio also includes housings, fans, CPUs, mainboards, memories, and data storage units, as well as AI and graphics accelerators.

Intel Data Center Blocks (DCB) for the cloud (Fig. 1) are pre-certified and fully validated to help accelerate and simplify the transition to the cloud. Customers can select from a number of preconfigured servers or customize a system for their unique needs. The Intel VRN2208WFAF84R server system, for example, has been designed for VMware Virtual SAN (Storage Area Network) and is based on scalable Intel Xeon processors and the Intel R2208WF0ZSR server system mainboard. It is available as standard with 1 TB of raw memory (384 GB DDR4 RAM, 1 TB DCPMM) and 24 TB of raw storage (0.48 TB boot device, 1.5 TB cache tier, 24 TB capacity tier).

To guarantee a powerful power supply for server parks and data centers, Rutronik offers, for example, the online UPS (Uninterruptible Power Supply) solution FSP EPOS (Fig. 2). It includes various models between 10 kVA and 200 kVA with true double conversion technology. Reliable output power is ensured by DSP technology and active power factor correction in all phases of the 50 Hz / 60 Hz frequency converter mode. The N+X battery redundancy function reduces power failure and optimizes the charging and usage behavior of battery networks. The easy-to-configure products of the EPOS series range offer users plenty of flexibility when it comes to meeting the ever-increasing power demands of IT and network environments.

FSP also offers power supplies, redundant power supplies, and UPS to ensure that smaller power consumers can also be supplied effectively and efficiently.

In contrast to traditional IT distributors, Rutronik also has many years of experience in the embedded segment, i.e. in sophisticated and robust industrial computers, and in-depth knowledge of the electronic component market. Thanks to close partnerships with suppliers of semiconductors, plug connectors, or LEDs, for example, Rutronik's experts know how long the voltage converter chip on a mainboard will be around, how many mating cycles the M.2 interface will survive, or why there is often a tenfold difference in prices for SSDs offering exactly the same capacities, and how the controller chips of the SSD ensure the perfect balance between data security, longevity, and speed. As such, companies receive a reliable and future-proof solution. ■

Figure 2:
The online UPS solution FSP EPOS protects server farms and data centers against all conceivable disturbances, such as noise, lightning, and leakage current.

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The DNA of tech.™

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Find out more about what our power inductors can offer your designs

INDUSTRIAL APPLICATIONS

- Laser equipment
- Solar inverters
- High end embedded / industrial computing
- Industrial control units
- Construction vehicles
- E-bikes

ADDITIONAL BENEFITS

Vishay's invention of the composite inductor created a fundamental component that designers rely on to drive innovation in electronics. Continuous product advancements have brought the benefits of Vishay's shielded inductors to nearly every application for commercial and industrial electronics.

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Voice control

How smart devices are sounding and hearing better

Global sales of smart speakers rose from 99.8 to 134.8 million units between 2018 and 2019; analysts are predicting growth to 205.9 million devices by 2025. The more impressively they can deliver top-quality sound and reliable voice control, the higher this growth will turn out to be. A few design guidelines are useful in this context.

By Anne Santhakumar, Product Sales Manager Acoustic Components & Timing Devices at Rutronik,
Jeff Hsieh, Senior Manager of Acoustic R&D Dept.I, and
Sam Cheng, Director of Acoustic R&D Dept. II, both at Kingstate Electronics

Playing music, reading the weather forecast, and controlling smart devices – smart speakers do all this and more. They normally consist of a cylindrical housing with a speaker pointing downwards. This is designed to emit sounds evenly with a 360-degree spatial effect so that it can be heard optimally from anywhere. To receive voice commands by users from anywhere, array microphones with a corresponding algorithm are normally integrated.

A diffuser distributes the sound as evenly as possible in the surroundings. How the sound waves propagate is determined primarily by its geometry and the distance between the diffuser and the speaker membrane. Kingstate, a supplier of acoustic components and sound solutions, uses finite element analysis to optimize the sound quality and performance of its products. It enables Kingstate to produce a simulation model that predicts the polar diagram of the propagating sound. (Figure 1).

Advanced microphones for better understanding

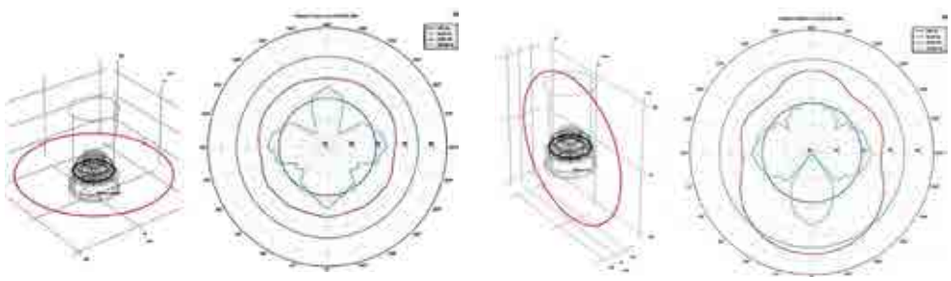
For a long time, a major hurdle preventing the breakthrough of voice-controlled devices and house control systems was deficiencies in voice recognition – users too often got the response "I didn't understand you. Please repeat." Current, more advanced microphones are providing a way to solve this problem. They optimize recording of voices and simultaneously reduce unwanted background noise. They thus ensure improved voice recognition and more convenience for the operator.

Microphones are highly sensitive acoustic components, but they pick up not only minimal sound signals in the air but also the conductive resonance and the harmonic distortions caused by oscillations of the speaker and the mechanics of the product. Due to these nonlinear signals, the DSP (digital signal processor) is unable to effectively process the AEC (acoustic echo cancellation) signal and the user hears an echo. The audio quality deteriorates and hissing occurs. But there are several options for designing the microphones in conjunction with the speakers to obtain a higher sound quality:

1. Microphone array: A microphone array made up of two to eight microphones can be combined with DSP and beam-forming algorithms to improve voice quality (Figure 2). The individual microphones are placed at different angles (the distance to the relevant microphones is important in preventing phase problems) in order to localize and evaluate the signals from various sources.

2. Microphone sensitivity and frequency: The microphones in the array should have frequency responses that are as identical as possible and ideally differing from one another by no more than 1 dB. This allows the deviation of the calculation by the DSP to be reduced. The total length of the sound tunnel, i.e. the distance that the sound travels between the microphone and the upper edge of the screen (Figure 3) should not be more than 5 mm and the resonant frequency of the microphone channel should not be less than 12 kHz.

3. Microphone phase: The phases of the microphones should be as close as possible to one another, ideally at ±5°. This reduces the deviation time during the DSP calculation and



Images: Kingstate

Figure 1: The polar diagram shows how the sound will be propagated.

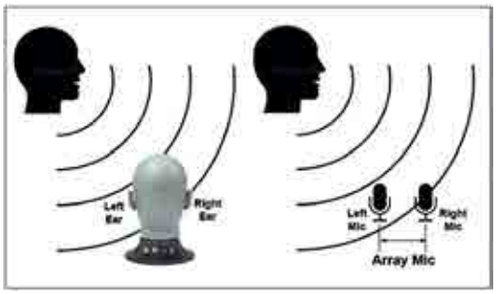


Figure 2: Humans can localize the sound direction by combining the information from the left and right ear. Exactly the same principle can be applied with two or more microphones.

guarantees a high accuracy of the sound and the directional characteristics.

4. Sealing of rubber microphone holder: Another issue that can distort the sound quality is the sealing of the rubber microphone holder. To prevent the sound from the internal speaker on a device getting through a gap in the microphone's sound tunnel (Figure 3), the rubber holder and the screen on the microphone must be smoothly sealed. In addition, the sound insulation should be a minimum of 20 dB SPL (decibels sound pressure level).

5. Positioning and impact resistance: Because of the amplification of the speaker and the AEC signal processing of the microphone, the speaker is normally positioned in the center of the device. The microphone should be located as far away from the speaker as possible. To ensure it is impact resistant and airtight, the microphone must be covered with rubber. The speaker housing and screw holes should be secured with a foam or rubber holder to prevent vibrations. Otherwise, the microphone will pick up an interference signal from the speaker, impairing the quality of the AEC.

These guidelines enable reliable acoustic designs to be created – and there is no longer anything preventing the advance of smart speakers. ■

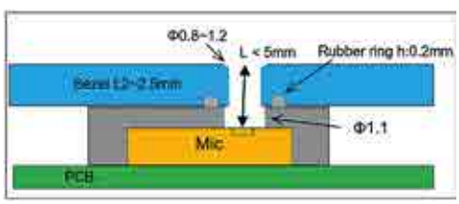


Figure 3: Design of rubber microphone holder and screen

UV-C LED modules

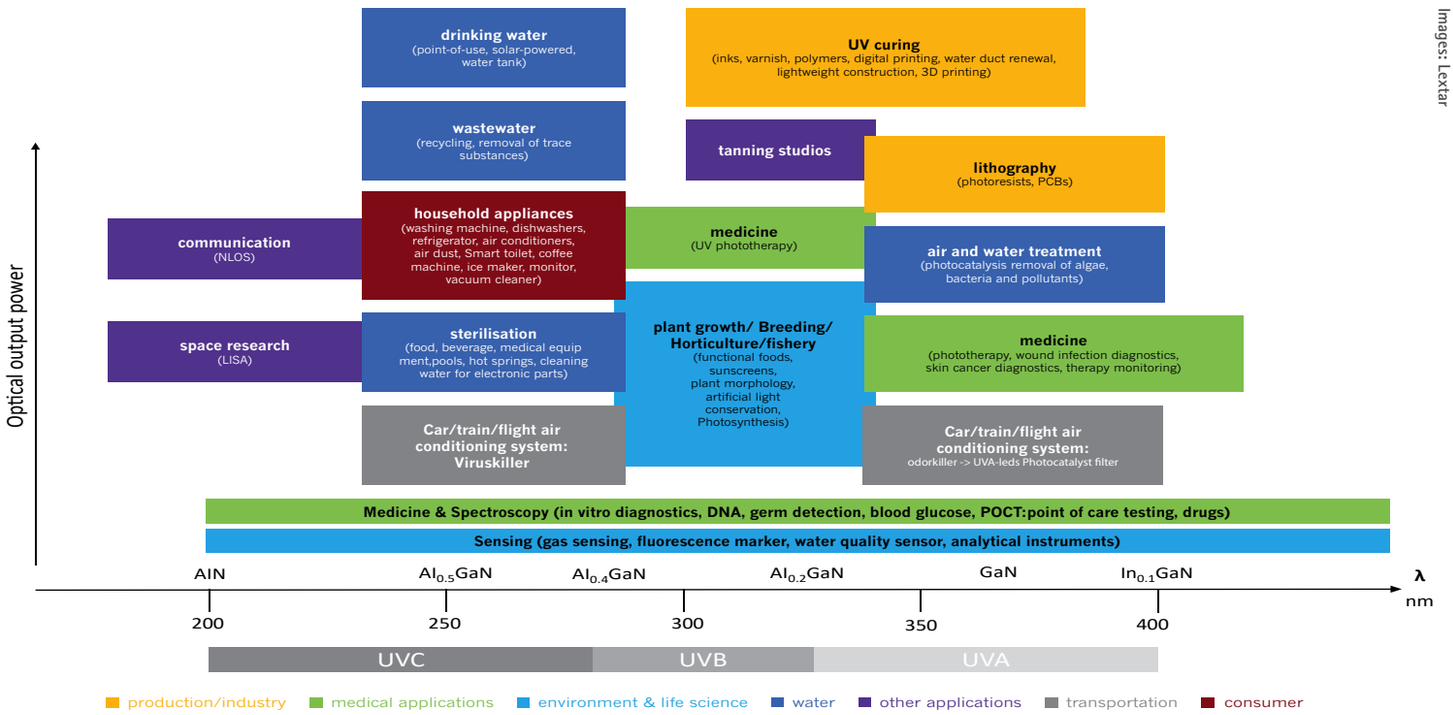
Purifying air and water with light

The invention of the mercury lamp roughly one hundred years ago revolutionized medical sterilization. To this day, UV rays play a key role in the disinfection and sterilization of interior spaces – even more so since the outbreak of the COVID-19 pandemic. UV-C LEDs open up numerous new possibilities.

By Alain Bruno Kamwa, Product Sales Manager Opto at Rutronik, and Nancy Yang, Sales Marketing at Lextar

Respiratory droplets, contact, and aerosols are the main routes of transmission of COVID-19. The sterilization of air – along with vaccination, testing, and general COVID-19 safety rules – is therefore a key contributor to slowing the spread of the pandemic.

A variety of methods are available for this purpose. One of the simplest is direct irradiation using UV lamps, such as those used in hospitals. It offers good sterilization efficiency, but also has a few shortcomings: firstly, nobody can stay in the room during sterilization, as the UV rays are liable to cause various health issues if they hit the body. Secondly, a large amount of UV energy is required for effective sterilization. This is because the UV-C rays suitable for sterilization (Figure 1) are greatly attenuated during transmission: the dose rate on a given area decreases with increasing distance from the radiation source inversely proportionally to the square of the distance (Figure 2). Thus, this method is not really suitable for public places.



Images: Lextar

Figure 1: Overview of UV-A, UV-B, and UV-C rays and their technologies, target markets, and applications

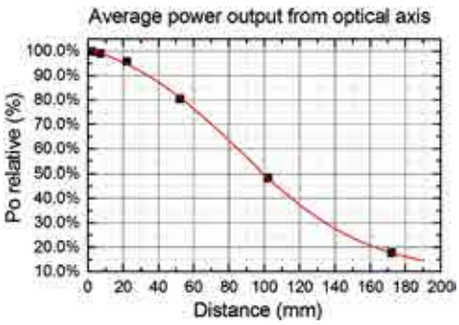


Figure 2: The UV-C radiation decreases with increasing distance from the light source.

Hidden air purification

Modern UV-C LED light sources are opening up new possibilities, as compared to mercury lamps, they guarantee higher energy density and lower power consumption with exactly the same volume characteristics. And seeing as they are very small, they are easy to integrate and allow "hidden" UV sterilization products. They take up very little space and do not need to be cleaned separately. On the downside, there are higher costs and limited luminous efficacy. The light output of a single LED is usually still in the milliwatt range. Therefore, it is unable to purify the air by irradiating a large area like a mercury lamp tube can. As a result, UV-C LEDs are combined with other methods to kill airborne bacteria.

Current methods include air recirculation, a photocatalyst, UV-A LEDs, a high-efficiency HEPA filter, and a UV-C LED sterilization system. A fan is usually used to generate air circulation, which circulates the room air and drives the bacteria and viruses suspended in it to the filter element in the disinfection chamber. They accumulate on the surface of the filter element. Unlike traditional air purifiers, they not only collect here, but are also rendered harmless by the UV-C LED. With this particular method, the radiation remains inside the device; meaning people do not have to leave the room during sterilization.

Figure 3: With three reflectors per UV-C LED, the matrix generates particularly high-energy UV-C radiation.

Figure 4: The automotive UV-C LED sterilization module can be integrated into the air conditioning system of a vehicle.

The Lextar LBM2101 UV-C LED air sterilization module can be integrated into air purifiers, air conditioners and other compact end devices as it measures just 1.06 in. (27 mm) in diameter and 0.5 in. (12.7 mm) in height (Figure 3). Its special design concentrates the UV rays emitted by the LED inside the device. This increases the effectiveness of UV-C radiation and ensures that the radiation does not escape. After just one hour, the sterilization rate reaches more than 99%, i.e. more than 99% of the airborne viruses and bacteria are rendered harmless. The aluminum housing ensures excellent heat dissipation, thereby extending the service life of the LED.

Driving without the risk of infection

Coronavirus survives in the air for up to three hours, and longer indoors than outdoors. To reduce the risk of infection in vehicles, such as taxicabs, car-sharing vehicles, buses, and trains, Lextar has developed an automotive UV-C LED air sterilization module. It can be combined with the vehicle's air conditioning system without impacting its operation and destroys 99% of the SARS-CoV-2 pathogens.

The module consists of a UV-C LED matrix in which each of the 20 LEDs is equipped with three reflectors, thus generating particularly high-energy UV-C beams (Figure 4). Further, there is a nanoscale filter that removes 99.53% (tolerance ±10%) PM2.5 from the air, improving indoor air quality immensely. The module is compatible with current auto-filter systems, meaning it can be replaced without modification and adapted according to customer requirements.

Sterilizing water with light

As well as air, UV-C LED sterilization and disinfection modules can be used to disinfect surfaces and water. When it comes to the latter, a distinction needs to be made between

flowing and standing water. In tanks for water purifiers or in water tanks for humidifiers, the purified water usually stands for a long period of time, thus allowing bacteria from living organisms in the air or on surfaces to multiply significantly. Lextar's static water sterilization modules (Figure 5) regularly irradiate the water in the tank with sufficient radiation power to kill the bacteria.

The best sterilization rate can be achieved if the module is installed at the bottom of the water tank and the UV-C rays hit the water directly through a window in the waterproof module housing. However, the sterilization module can also be placed on the side or on top of the water tank.

The sterilization of running water is quite a different proposition: it flows relatively quickly through the pipeline – and also through the sterilization module. So there is obviously only a very short space of time to completely destroy the bacteria. This requires a very high level of radiation power, which also leads to higher costs than for standing-water sterilization modules. This is the reason why such modules are currently found mainly in high-quality household water dispensers and in commercial machines.

The installation location of the module is not as critical here as it is with standing water. But what should be considered is the length of the water outlet pipe. Since secondary contamination can occur in the water pipe, the shorter the distance from the water outlet of the module to the water outlet of the unit, the better.

Why LEDs do not generate ozone

When using air purifiers, there have been repeated warnings about the formation of ozone, which is harmful to health. Ionizers generate ozone to break down airborne molecules that are perceived as unpleasant odors, thus eliminating the odors. Equipment based on electrostatic precipitators or electrostatic filters, or that operate with nonthermal plasma, can also form ozone.
However, this does not apply to devices based on the effect of UV-C LEDs. Ozone consists of three oxygen atoms. To produce the gas, the chemical bond of oxygen must be broken. To do so, the binding energy generated by the light source must be greater than that of oxygen, which is 5.1 eV (electron volts). A mercury lamp generates a binding energy of 6.7 eV. This obviously allows it to generate ozone. Conversely, the binding energy of a UV-C LED is only 4.5 eV, i.e. it is not capable of forming ozone.

UV light, a true all-arounder

Thanks to their sterilizing effect, UV-C LEDs have experienced a huge surge in demand as a result of the COVID-19 pandemic. But there is more to UV light than just sterilization. For example, it can be used to neutralize unpleasant odors, enable fruit and vegetables to grow without natural sunlight, and keep produce fresher for longer after harvesting. It can accelerate the drying and curing process of plastic coatings or paints, for example, and detect the composition of pharmaceutical drugs via spectroscopy.

For such applications, Rutronik offers all the necessary components – from UV lamps, modules, lenses, and LED drivers to fans for thermal management and control sensors, e.g. for UV, VOC (volatile organic compounds), and PIR (passive infrared sensors). Further, Rutronik has developed two boards: the first is an evaluation board that uses a VOC sensor to detect odors and neutralizes them with UV-A LEDs plus a photocatalytic filter. The second board enables the sterilization of air, water, and surfaces with the help of UV-C LEDs. ■

Figure 5: The water treatment module can be used for running water with a flow rate of between 0.6 and 12 l/min.

Figure 6: Germ-free water straight from the faucet: the Lextar faucet UV-C sterilization module, with a power consumption of 10 to 30 W, cleans at a flow rate of between 2 l/min. and 12 l/min.

ToF lidar

3D detection like a plane

Three-dimensional detection of the environment is gaining in importance in an increasing number of usage scenarios, from smartphones and cars to industry. One method is the time of flight method using lidar systems.

By Alain Bruno Kamwa, Product Sales Manager Opto at Rutronik

The time of flight (ToF) method enables the position, shape, and movement of people and objects to be detected. The fundamental principle is simple: a light source emits light beams that are reflected by the environment. A corresponding ToF camera captures the reflected light and the distance is calculated based on the known speed of light and the measured travel time of the light.

There are two different approaches. For indirect ToF (iToF), the light source is modulated and the phase shift of the reflected light is detected. As this method is relatively insensitive to drift in the internal time measurement, it is primarily suitable for shorter distances.

With direct ToF (dToF), the sensor measures the time directly as described above. Lidar is a key method for dToF. Like radar, it is a process for detection and ranging (DAR), with lidar using light waves to do this and radar radio waves. A pulsed laser diode in lidar sensors emits a light pulse, which is used to determine the distance between the sensor and the obstruction. This is done using a very precise time base. Minimal changes would have a significant impact at short distances, which is why lidar is mainly suitable for medium or long ranges of over 100 m.

Larger field of view, higher resolution

A laser diode is used as the light source in a lidar sensor. As it generates a very small, extremely focused light beam, only the distance to an equally small point can be measured. This is not sufficient for 3D detection as is necessary for facial recognition, driver assistance systems, or even autonomous driving. There are various solutions for enlarging the detected area, known as the field of view (FoV).

With flash lidar, the light beam is scattered by optics, thus enlarging the emission angle. However, this creates diffuse and significantly weaker light. Scanning lidar technology eliminates this shortcoming. It uses moving micro-mirrors to direct the light beam over the FoV to be detected in a kind of scanning process. However, scanning lidar sensors are unsuitable for use in vehicles. With dimensions of around 10.5 cm × 6 cm × 10 cm, they are very large, while the moving mirrors are also susceptible to vibrations, impacts, dust, and extreme temperatures, which cannot be avoided on vehicles.

Solid-state lidar sensors are smaller and more robust. They use semiconductors instead of mechanical components to direct the light beam. In lidar with MEMS-based mirrors, there is a matrix of micro-mirrors that switch back and forth between two positions several thousand times per second due to electrostatic fields.

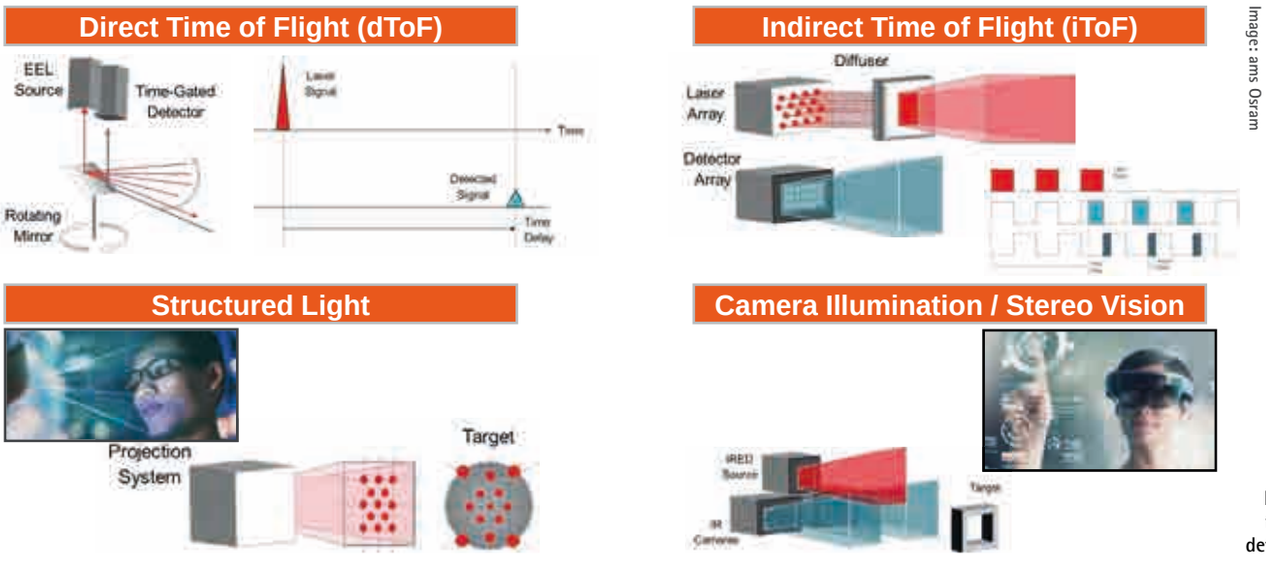
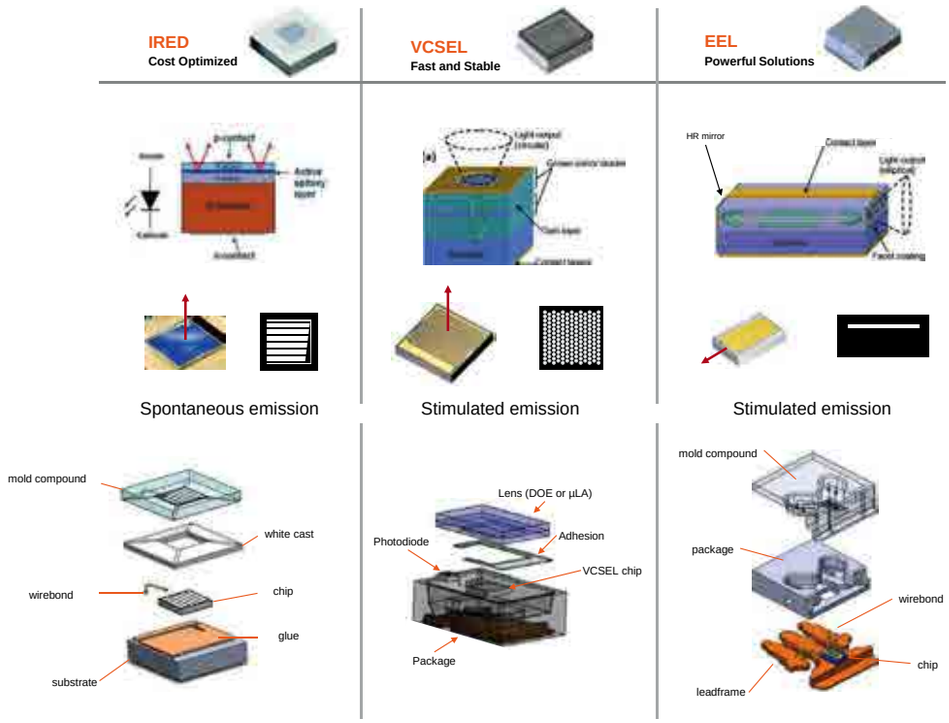


Image: ams Osram

Different measuring techniques for light detection and ranging

Image: ams Osram



Comparison of chip technology and package for high-performance infrared LED, VCSEL, and edge-emitting laser (EEL)

Light source IRED, EEL or VCSEL

The light source itself takes the form of either infrared LEDs (IREDs), edge-emitting lasers (EELs), or vertical cavity surface-emitting lasers (VCSELs).

IREDs and EELs have established themselves in many applications. The main advantages of IREDs are their homogeneous light and high power density. In addition, they are relatively low cost and offer easy packaging. By contrast, EELs provide a higher luminous intensity, higher power, and greater efficiency – leading to longer ranges.

VCSELs offer a combination of the easy packaging of IREDs and the spectral width and speed of an EEL. Their power density is currently between that of an IRED and an EEL. Although VCSELs require slightly more space than EELs, this is compensated by their advantages for certain applications. Their emission characteristics qualify them for flash lidar systems and they also have good wavelength stability with rising temperatures.

The resonator in a VCSEL, where the laser beam is generated, is made up of two Bragg mirrors arranged parallel to the plane of the wafer. The mirrors themselves consist of multiple layers, achieving reflection of over 99% and – in conjunction with the planar technology of the mirrors – an outstanding circular beam quality with low divergence and a low threshold current. This means that neither secondary nor external optics are necessary, unlike with conventional edge emitters. Furthermore, this construction makes VCSELs insensitive to mechanical vibrations. Despite this, they achieve good focusing capability and provide easy fiber coupling and low power consumption.

For dToF applications that require a high power density for distance measurements over 200 m, EELs are generally the lasers of choice. A wide range with different package designs (TO, plastic, SMT) and power classes is available from ams Osram. These EELs deliver the highest average powers on the market and are easy to use in pick and place and reflow soldering (SMT) assembly.

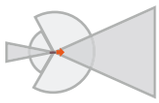
For 3D sensor applications covering shorter distances, ams Osram has developed the infrared laser modules in the Bidos series. The series includes VCSEL components up to 100 W and a wavelength of 850 nm or 940 nm.

The 940 nm VCSEL power array provides an optical output power of 3 W with typical rise and fall times of 0.5 ns. The integrated monitor photo diode allows both calibration of the optical output power and automatic power control, along with detection of laser safety problems such as lens fall or skin contact, which is always to be avoided in laser applications.

Powerful lasers for autonomous driving

In autonomous vehicles, safety is the number one priority. This requires lidar systems with a long range and high speed – which in turn means very powerful lasers. With two brand-new EELs, ams Osram now enables 3D systems to have a higher resolution and thus improved measuring signals, which are critical for autonomous vehicles. The two new SPL S4L90A_3 A01 and SPL S1L90A_3 A01 lasers have power of 125 W at 40 A per channel. Thanks to their low thermal resistance of only 30 K/W on the single-channel version (SPL S1L90A_3) and 17 K/W on the four-channel version (SPL S4L90A_3), they can easily be cooled even at high currents. The four-channel version (SPL S4L90A_3) consists of a chip with four emission ranges, which provides an exceptional optical power of 480 W. With

Image: ams Osram



	Short Range 0 m – 40 m City Traffic, Freeway lane change	Mid Range 1 m – 90 m City Traffic, Interurban road crossing Freeway rear view	Long Range 1 m – 250 m Freeway, long distance view
Flash LiDAR	EEL VCSEL	EEL VCSEL	
TSS LIDAR	VCSEL	VCSEL	VCSEL
MEMS ToF LiDAR	EEL	EEL	EEL
Mechanical Scanning LiDAR	EEL VCSEL	EEL VCSEL	EEL VCSEL

Depending on the lidar architecture, an edge-emitting (EEL) or surface-emitting laser (VCSEL) is suitable (the fuller the circle the more appropriate the laser for the relevant application). However, the specific applicability depends to a large extent on the system design.

dimensions of just 3.35 mm × 2.45 mm × 0.65 mm, the component is only slightly larger than the single-channel version (2.0 mm × 2.3 mm × 0.65 mm), yet covers a wide detection range. In collaboration with Efficient Power Conversion (EPC) and GaN Systems, ams Osram is developing an evaluation kit for each laser version.

ToF applications

Based on the infrared VCSEL technologies from ams Osram and the patented depth-processing algorithms from Chronoptics, the two companies have jointly developed a 3D ToF camera system that features better power than the latest iToF cameras. The Chronoptics KEA 3D ToF camera system is outstandingly well suited for applications such as autonomous driving, biometric identification systems, and unlocking mobile devices. With its compact dimensions of only 100 mm × 40 mm × 35 mm, the camera is designed for a working distance of 0.2 to 15 meters and has external light insensitivity of up to 120,000 Lux. It is equipped with the Bidos P2433Q VCSEL from ams Osram. It has a compact form factor, market-leading output power, and module efficiencies of 38%, with future modules expected to reach as much as 50%. Its package concept is suitable for large-scale serial production.

Vishay supplies a proximity sensor with high-performance VCSEL. The VCNL36687S with a detection range of up to 20 cm also integrates a photo diode, a signal processing IC, and a 12-bit A/D converter in a small 3.05 mm × 2 mm × 1 mm LLP (leadless package) SMD package. Thanks to its relatively small detection range, no mechanical barrier is necessary to optically isolate the detector and transmitter. This enables a proximity detection function to be implemented and used very easily. Because of the VCSEL's extremely narrow directional lobe of ±3°, the sensor is suitable for a narrow detection range and does not require any lenses. The VCNL36687S is designed for industrial and consumer applications in smartphones, tablets, virtual-reality / augmented-reality (VR/AR) headsets, and other battery-operated devices, e.g. to minimize the risk of unwanted touch input or to detect whether or not the user is wearing the VR/AR headset. ■

ams Osram and Chronoptics have developed a 3D ToF camera system that exceeds the power of modern iToF cameras.

Image: Chronoptics Limited

Interview with CEO Thomas Rudel

"Of course, face-to-face meetings remain very important"

The world has been in the grip of the COVID-19 pandemic for a year and a half now. And this has impacted the electronics sector in various ways. But there are still plenty of reasons to look to the future with positivity, as Rutronik CEO Thomas Rudel explains in this interview.

Thomas Rudel, Rutronik CEO

"I don't expect there to be a return to traditional trade fairs as we had before the pandemic. There will be a mixture of real-world and digital trade fairs."

COVID-19 has been part of our everyday lives for a year and a half now. How do you see things now overall compared to last year? How has Rutronik adapted to the changed situation?
Thomas Rudel: We have dealt very well with the effects, both in terms of our order situation and on a personnel level. We have retained jobs and have not even had to announce reduced working hours. We have not been dependent on government support, which some other companies – including much larger ones – have unapologetically taken advantage of. That's something we are very proud of.

Speaking of jobs: how has Rutronik protected its employees?
From day one, we tackled the situation proactively and did everything possible to protect our employees as effectively as possible. They are tested for the virus twice a week here onsite and we offer vaccination by our company doctor. In addition, 25% of our staff continue to work at home. Of course, there are employees who remain skeptical about the vaccine and I think this is partly down to an inadequate educational campaign by politicians. It's important to recognize that not everyone who isn't vaccinated yet is an anti-vaxxer or a COVID denier. People need to be convinced, not stigmatized.

On the subject of vaccinations: are vaccines allowing a return to "normal" operations with face-to-face meetings and appointments with customers?
Of course, face-to-face meetings remain very important – particularly for our sales team – and we continue to move back towards normal operations in this area. No site visits at all just isn't feasible, even though we have had very positive experiences with virtual consultations. Suppliers and customers who visit our headquarters or one of our subsidiaries are asked to take a test before they come or do so as soon as they arrive.

There have been no trade fairs for a long time, and instead Rutronik has been taking advantage of online formats, particularly Tech Talks. What have experiences with these events been like, and what is the concept for the future?
We are intending to further expand our TV studio, which we have used for the Tech Talks, as we recognize that it is an absolutely excellent communication channel. I don't expect there to be a return to traditional trade fairs as we had before the pandemic. There will be a mixture of real-world and digital trade fairs. Particularly the trade fairs that previously cost seven-digit sums are very much under review. A positive side-effect of all this is that the number of business trips is reduced. This is a small but welcome contribution to climate protection.

Rutronik has launched a brand-new project with the Lisa test app. What functions does the app provide?
The Lisa app was developed completely in-house by our IT department. It enables companies and test centers to manage the entire process from booking an appointment to managing test results in compliance with the GDPR through to billing and documentation for the health and financial authorities. The convenient QR code function allows users to manage their own results as well as those of other family members. It is linked to the German Electronic Notification and Information

System for Infection Prevention (DEMIS) and can also be linked to the government's COVID-19 warning app. We see ourselves as a top three provider of these kinds of apps.

What was the incentive to develop the app?
As has been widely reported in the press, there was a lot of playing fast and loose with rapid tests. There was no effective monitoring system, so not only were test centers popping up all over the place, but there was all kinds of fraud going on when it came to billing health insurers for the tests. Expired or damaged test kits were also being widely used. It was a nice earner, as you could charge a health insurer 14 euros for the handling and 6 euros for the test itself. Those figures are still 8 and 3.50 euros now. You can make a good return on that. We want the app to put a stop to this by networking all the relevant players.

"We expect the shortages to last for at least another one or maybe even two years."

Increasingly accelerated digitalization is leading to lots of upheaval, including in the electronics sector. To what extent can Rutronik benefit from this and tap into new areas of business?
I don't see any totally new areas of business yet, even though digitalization is changing things – although this still isn't happening as quickly in Germany as it should be. The option of working at home is definitely beneficial in terms of giving employees greater flexibility and is also good for companies. In the past, you had to take a sick day if your child was sick, or you had to take time off to go to the doctor or if you were stuck in traffic. That was particularly difficult for single parents. Working from home means that you can just log off for two hours and then continue working. We really welcome that. However, it does mean that bandwidths have to be able to cope. All the good intentions in the world count for nothing with an antiquated 1 Mbit Internet connection, which many rural areas still have. Politicians need to take urgent action on this.

Allocation of microchips remains a serious issue. Major car manufacturers, including the world's largest manufacturer, Toyota, but also some German companies, are cutting back production, announcing short time, or putting vehicles into storage with dummy electronics. To what extent is Rutronik, whose main area of business is the automotive industry, feeling these shortages?
Of course, we are feeling a bit of the effect as we can no longer keep up with our deliveries because components are not delivered on time – and even if they are, then with only 30% of the advised quantity. We need huge flexibility and currently we are mainly involved in troubleshooting. That's why we are advising our customers to make very long-term orders. We expect the shortages to last for at least another one or maybe even two years. Lots of new semiconductor factories are being planned, including in Europe, but it will be years before they are completed.

The EU wants to have 30 million electric cars registered by 2030, while Norway will not be registering any cars with combustion engines from 2025. How can Rutronik be part of the transport revolution?
I take an extremely critical view of the fixation purely on electric mobility, even though we should do well out of it as a component distributor. The problems start with the disposal of batteries, but there is also the question of whether our energy network can cope with millions of people charging their electric cars every evening, not to mention many other issues like price.

What do you mean exactly?
Batteries are highly toxic and we don't have a solution yet for recycling and final disposal – we don't have a second Gorleben facility in case of doubt. Also, our energy networks are not designed for the huge consumption spikes that would be caused by millions of electric cars being simultaneously charged in the evening. As the power network is linked across Europe, this could mean that the lights will suddenly go out over an entire continent. Last but not least, we have the prices. VW recently presented a design study for a low-cost electric car, but still – how are people in poorer countries in Europe meant to afford it? Despite the subsidies, in its current form electric mobility remains a transport concept for the well-off. And that's not all.

Please continue ...
An electric car's energy balance is only clean if you ignore the aspects surrounding it. The materials for the batteries, such as lithium, come from all over the world, which means that the transportation causes CO2. Then some of them are mined in regions where there is hardly any water. But it is needed to mine them, which makes the situation even worse. And ultimately, how much sense does it make for me to charge my electric car with power generated from coal or nuclear because there's not enough renewable energy?

"I think it's wrong to condemn combustion engines lock, stock, and barrel – a one-liter car is no longer a fantasy, it is actually possible."

What is the alternative?
Looking purely at efficiency, with an electric car you get 11% output from your 100% input. Diesel is around 22 to 24% and a Formula 1 engine around 50%. I think it's wrong to condemn combustion engines lock, stock, and barrel – a one-liter car is no longer a fantasy, it is actually possible. And with reasonable power too. But in any case, I think that a one-dimensional fixation on electric mobility is fundamentally wrong and not really in the interests of the environment.

How do you assess the economic situation and the prospects for the electronics industry, particularly for Rutronik in the USA and Asia?
We want to continue moving the American market forward. It has been very difficult because of COVID-19, as we have been unable to provide such intensive support to our colleagues there, but now this is becoming slightly easier again. Of course, we are keeping a very close eye on the new COVID mutations and what their effects will be. With normal development, we hope that we can achieve our targets – in all markets.

Finally, let's take that dreaded look into the crystal ball. What are your expectations for 2022?
This time I don't want to address the economic trends, but say what I'd like to see. I hope that our employees – especially at the warehouse in Eisingen – who have done incredible work over the past two years, can return to normal working times and also enjoy greater freedoms in their personal lives. Also that we are able to visit our employees in international subsidiaries again. While we always want success, the most important thing is a return to normality, that it's possible to visit friends and acquaintances without fear and to hug them again. And, of course, staying healthy. ■

Electrolytic and polymer hybrid capacitors

Why calculating lifetime makes sense

Electrolytic and polymer hybrid capacitors have many advantages, but also one disadvantage: their limited lifetime. Therefore, it is crucial to determine this with the help of a lifetime calculation.

By Sven Jimenez Rodriguez, Product Sales Manager Capacitors, and Christian Kasper, Technical Support, both employed at Rutronik

Electrolytic and polymer hybrid capacitors have an almost identical design: they consist of a cathode side and an anode side, which in turn are both made of aluminum film. The film for the anode is subjected to an oxidation process, which creates an aluminum oxide layer forming the dielectric. Both films are rolled up with separator paper to form a winding element (Figure 1, Figure 2).

The difference between the two types of capacitor is the material used for the filling process, which also gives them their name: electrolytic capacitors are filled with electrolytes, while polymer hybrid capacitors utilize either polymerized electrolyte or a combination of solid and liquid polymer.

Both types boast a number of advantages, such as high capacitance values despite their small size, low costs, and availability in various designs, e.g. SMD, THT, or snap-in.

Compared to electrolytic capacitors, polymer hybrid capacitors additionally provide a higher ripple current capacity as well as lower internal resistance at low temperatures and more stable capacitance at high frequencies.

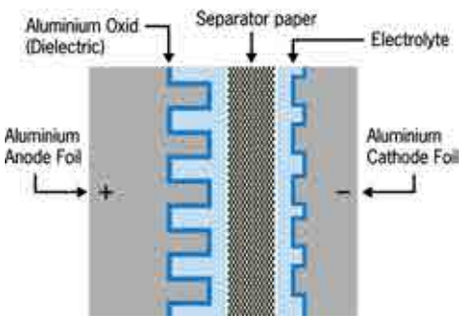


Image: Rutronik

Figure 1: An electrolytic capacitor essentially consists of an anode and cathode film, separator paper, and electrolytes.

The shortcoming of both technologies lies in their limited lifetime. During operation, the electrolyte or the liquid polymer shrinks (Figure 3).

What limits the lifetime

The biggest factor impacting the lifetime of electrolytic and polymer hybrid capacitors is the core temperature of the capacitor. It increases as the ambient temperature and the level of applied ripple current increase. Further, mechanical stress due to excessive ripple current can also damage the oxide layer and cause additional consumption of electrolyte due to self-healing. Self-healing is the ability of electrolytic and polymer hybrid capacitors to restore the oxide layer by means of a chemical reaction between the electrolyte and the aluminum. Electrolyte shrinkage also causes the electrical parameters to deteriorate, for example the capacitance as well as the equivalent series resistance (ESR) and the loss factor.

End of life usually refers to the phase when the data sheet parameters – generally capacitance loss and increase in loss factor percentage – are undershot.

When selecting a capacitor that does not undershoot the electrical parameters during the targeted operating period of the end product, the Arrhenius equation can be used to make an initial assessment. As shown in Figure 4, lifetime as a function of the diffusion coefficient resembles the Arrhenius equation to a large extent. Therefore, as a rule of thumb, the following statement can also be made: a 50 °F (10 °C) reduction in the operating temperature doubles the lifetime.

Image: Panasonic Industry

Figure 2: Basic design of electrolytic and polymer capacitors

The Arrhenius equation provides only a rough guide value, as it fails to take into account the significant impact of the ripple current on self-heating. It reads:

$$Lx = Lo \cdot 2^{(To-Tx)/10}$$

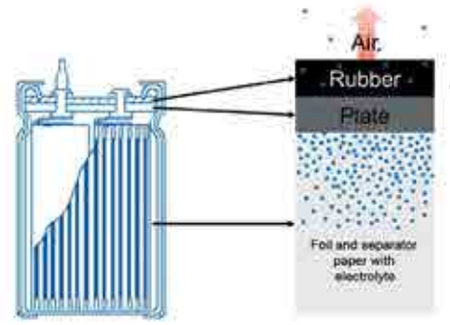


Image: Rutronik

Figure 3: The electrolyte or liquid polymer diffuses during operation, resulting in a limited capacitor lifetime.

where
Lx: Lifetime in a certain application (h),
Lo: Guaranteed lifetime at max. operating temperature (h),
To: Maximum operating temperature (° C),
Tx: Actual operating temperature in application (° C)

Support from capacitor suppliers

To obtain an accurate lifetime calculation, working with the respective capacitor supplier is recommended. This calculation requires a mission profile from the customer. It details the number of actual operating hours in the relevant temperature range.

Each supplier uses individual calculations for their own products that incorporate the temperature profile and ripple current load. As such, the supplier can perform a detailed lifetime calculation using the mission profile provided by the customer.

Using the mission profile, the supplier can evaluate and recommend the capacitor for the corresponding application. This also prevents use of an over-specified – and thus more expensive – capacitor.

Cooling ensures a longer lifetime

Heat sinks that increase the surface area are a good way to improve heat dissipation and thus increase the capacitor lifetime. Active cooling through the use of fans or water, for example, can ensure even better heat dissipation. Such cooling concepts can also be taken into account when validating the component and calculated into the lifetime calculation.

The connection of the cooling elements to the capacitor also plays a key role.

Attaching the cooling element directly to the component is often more effective than placing it directly on the opposite side of the board. Moreover, it is important to also consider the peripheral units of the capacitor, as it both radiates and absorbs heat through its legs. This is especially true if power semiconductors or other heat-generating components are in the vicinity. This heat input can also be included in the lifetime calculation if empirical data, e.g. on temperature, current, voltage, and frequency, is available.

If you use a thermal paste or thermal pads, their thermal resistance is decisive. The lower it is, the more efficient the heat dissipation. If the cooling element needs to be electrically isolated, an insulating thermal paste or suitable pads should be selected.

The thermal resistance model, from the core (winding element) to the legs and the package of the capacitor, can be obtained by customers from the supplier if they wish to perform a calculation or simulation themselves.

If both the heat situation and the thermal resistances from the cap or PCB to the cooling element are fully known, the additional heat dissipation or supply can be inferred. Once possible heat dissipation has been verified, the supplier may allow a higher ripple current for the layout – but only if the maximum ripple current specified by the supplier is not exceeded, since that would result in a mechanical load on the capacitor.

Conclusion

The Arrhenius equation is recommended to determine an initial guide value when selecting a capacitor. Using a mission profile, the lifetime of the selected capacitor in the application can be calculated exactly. This also takes into account the level of self-heating caused by the ripple current. To maximize the capacitor lifetime, it is worth looking at possible cooling concepts and involving the supplier or distributor in the development process. ■

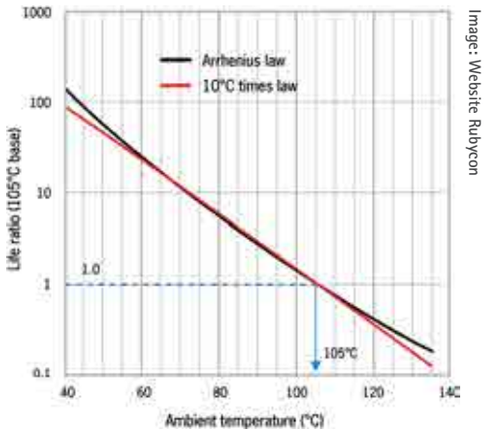


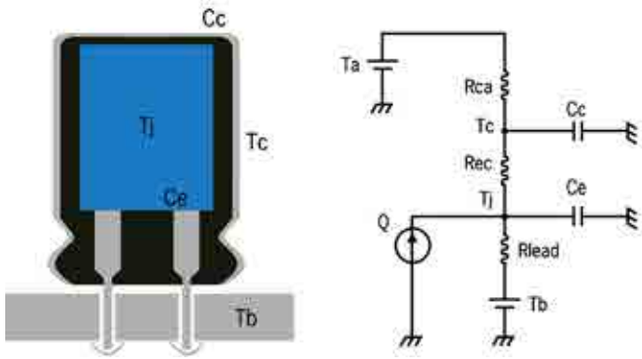
Image: Website Rubycon

Figure 4: The Arrhenius equation and the rule of thumb that states the capacitor lifetime doubles with every 50 °F (10 °C) reduction in the operating temperature offer almost the same results.

Mission Profile Active (operating)			
Ambient temp. [°C]	Time [Hrs]	Ripple current [Arms]	Frequency [kHz]
Operating Time Total			

Image: Rutronik

Figure 5: The example of a mission profile shows which parameters the supplier needs for accurate lifetime calculation.



Ta	Ambient temp.
Tb	PCB temp.
Tc	Surface temp.
Tj	Element temp.
Cc	Al-case heat capacitance
Ce	Element heat capacitance
Q	Power Loss
Rca	Rth (Surface to amb.)
Rec	Rth (Element to surface)
Rlead	Rth (Element to PCB)

Image: Rutronik

Figure 6: Thermal equivalent circuit diagram of the capacitors

Beyond the mainstream world of semiconductors

Diversity instead of monotony

Semiconductors are in much greater demand than their supply; delays are a common issue. The trend toward more diversity also offers a solution to this problem: if you look beyond mainstream suppliers and products and put more focus on diversification when considering the design, you can significantly reduce procurement risks.

By Reza Armin Maghdounieh, Senior Manager Product Marketing Standard Products and Purchasing, and Emilia Mance, Product Sales Manager Standard Products, both employed at Rutronik

A car that parks itself. A truck that maintains both a steady speed and distance from the vehicle ahead on the highway. Both have something in common: they contain more semiconductors than a notebook. And experts predict that the number of semiconductor components will increase quite significantly as a result of autonomous driving, with some even talking about up to 50% more components in the next three to five years.

But it is not only the automotive sector in which demand for semiconductors is rising. In the (industrial) Internet of Things, virtually all objects are interlinked to be able to locate, control, coordinate, or query their status and condition. Physical variables such as temperature, pressure, or acceleration are required, which semiconductor-based components convert into electrical signals.

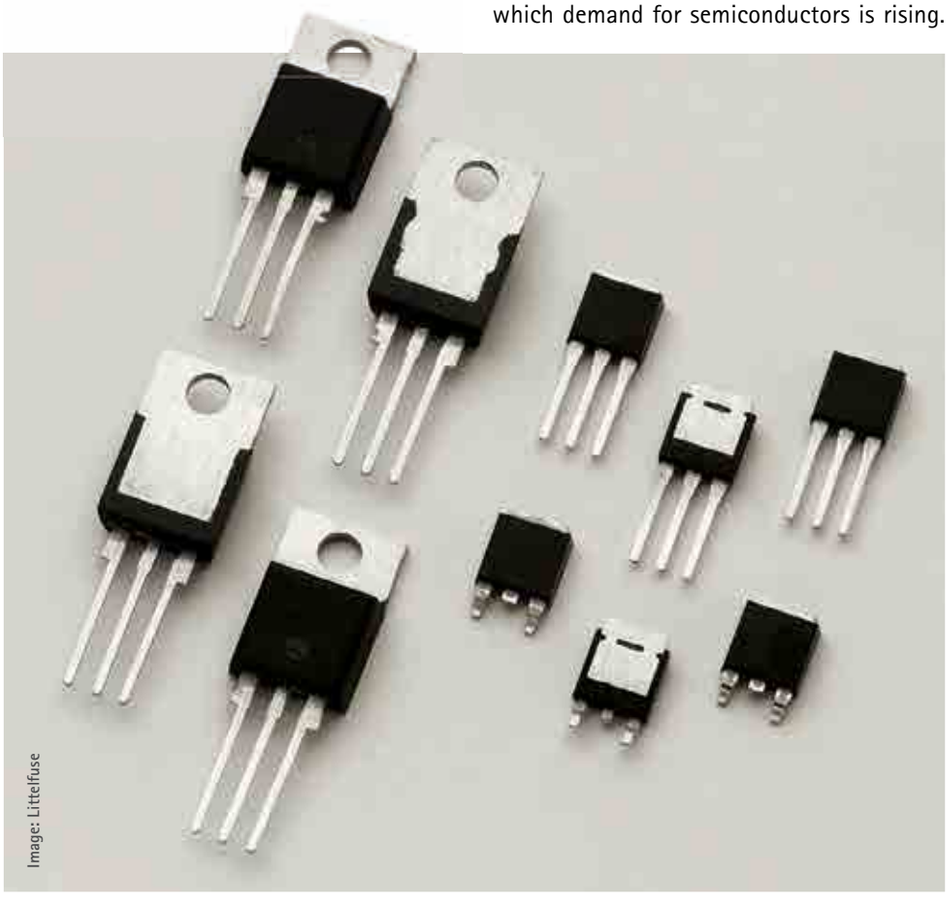


Image: Littelfuse

Even the COVID-19 pandemic was unable to slow down the growth of the microelectronics industry – quite the opposite. New applications in medical technology and home office applications caused demand to sky-rocket within a very short space of time.

While the demand for semiconductors has continued to grow by 4 to 8% annually for many years, more than 100 wafer production sites have closed down since 2009, thus reducing or consolidating production capacities.

As the table shows, the top ten semiconductor suppliers now serve around 66% of the total market worldwide. If the production of just one – or even several – of these suppliers comes to a standstill, for example due to a natural disaster or a fire, customers around the globe face major delays and disruption (Figure 1). It is not possible to compensate for such losses, as capacity utilization of the wafer production sites needs to be above 90% at all times in order for them to cover their own costs.

Reducing risks with hidden champions

But there are more than just the best-known top ten suppliers. Numerous hidden champions develop and produce semiconductors that

are fully compatible with the well-established components of major suppliers. Furthermore, they often offer advantages in terms of availability, price, and technical support. In the event of delays and supply shortages, like those dominating 2021, these suppliers are often more likely to be able to deliver products and avoid production downtime. And this applies not only to large customers, but also to small and medium-sized businesses. The only requirement is that the components have already been taken into account during development.

However, these hidden champions are usually only hidden, i.e. unknown, in Europe. Of the $123.1 trillion generated by the global semiconductor market in the first quarter of 2021, Asia accounted for 63%, North America 18.5%, and Europe just 9.8%. This means many, even very well-known, companies in other parts of the world already rely on the technologies of companies whose names are hardly known here.

For example, diodes: products of the top ten suppliers can be found in almost every conceivable design. Further, there are global players, such as Panjit Semiconductor or Littelfuse, that (still) play a minor role in Europe.

Based in Taiwan and boasting annual sales of approx. $500 million, Panjit Semiconductor is a renowned supplier of rectifiers and diodes and offers a complete portfolio of discrete semiconductors. Panjit's SiC Schottky diodes are suitable for maximum repetitive reverse voltage (VRRM) values of between 650 and 1200 V and current ratings of between 2 and 20 A. The rectifier range includes various models, e.g. general purpose, fast recovery, ultrafast recovery, and superfast recovery. In terms of diodes, self-designed wafers and a specially developed packaging technology ensure excellent transient properties. Major players in the industry and the automotive sector have already approved and successfully used Panjit products in numerous applications.

Littelfuse also offers a broad product portfolio that includes discrete semiconductors. The TVS and ESD protective diodes, as well as triacs are no less effective than their counterparts from better-known suppliers. Thanks in part to their low trigger currents, they can be driven by a microcontroller with minimal effort. Headquartered in the USA, Littelfuse has annual sales of approx. $1.2 billion and currently employs around 12,000 people worldwide.

But only a few supplier names come to mind when you pause to reflect on diodes and operational amplifiers. Quite often the second-highest-ranking supplier in this field of products fails to get a mention: New Japan Radio (NJR). Founded in 1959, the company is part of the Nisshinbo Group, which also includes Ricoh Electronic Devices, and generates annual sales of around $327 million with a workforce of around 1,500 people. Due to their very high EMC immunity, NJR operational amplifiers are ideal for use in industrial environments with high-frequency interference.

Image: Rutronik

Unexpected events frequently cause semiconductor production to come to a halt.

Another company that is largely unknown in Europe and, therefore, underrated is Giantec Semiconductors. The history of the EEPROM supplier reads like a true success story: within just one decade, it has become one of the Big 3 and now dominates the Asian market. Giantec's products are also fully compatible with those of other top suppliers – but usually with more attractive commercial conditions while offering the same or even superior technical parameters. This is particularly true when it comes to the automotive sector. A highlight of the portfolio is the serial presence detect (SPD) series for the automatic configuration of memory modules in computer systems.

Rank	Company	$Billion 1Q21	Reported 1Q21	Guidance 2Q21	Comments on 2Q21 revenue
1	Intel	19.7	–1.5%	–3.9%	supply constrained
2	Samsung SC	16.8	+4.6%	n/a	strong demand for server/PC
3	SK Hynix	7.5	+6.6%	n/a	growing DRAM demand
4	Broadcom	n/a	n/a	n/a	$6.7B in 4Q20
5	Qualcomm (IC)	6.3	–3.9%	–3.7%	supply constrained
6	Micron Technology	6.2	+8.0%	+13.9%	driven by DRAM
7	Nvidia	5.3	+5.9%	n/a	1Q21 is guidance from 4Q20
8	Texas Instruments	4.3	+5.2%	+0.3%	industrial & automotive strong
9	MediaTek	3.8	+12.1%	+14.0%	growth driven by 5G
10	AMD	3.4	+6.3%	+4.5%	driven by data center & gaming
11	Infineon Technologies	3.2	+2.6%	+1.9%	supply constrained
12	STMicroelectronics	3.0	–6.8%	–3.8%	seasonality in personal elec.
13	Kioxia	2.7	+2.6%	n/a	strong SSD demand
14	NXP Semiconductors	2.6	+2.4%	+0.1%	supply constrained
	Total of above companies		+1.5%		
	Memory companies		+3.8%		Samsung, SK Hynix, Micron, Kioxia
	Non-Memory Companies		+0.1%	–1%	companies providing guidance

Semiconductor production is predominantly driven by the top ten semiconductor suppliers.
(Source: Semiconductor Intelligence/semiwiki.com)

Conclusion

Those who focus on diversity instead of monotony when developing their products, and also look beyond the top ten suppliers, can reduce risks and at the same time exploit the strengths of the technical parameters in a circuit more purposefully, as smaller providers in particular generally focus more on specific requirements and offer solutions aimed to meet them. Especially in the current situation where demand for semiconductors is far greater than supply, thinking outside the box definitely aids automotive suppliers and companies that produce highly specialized applications in small quantities. ■

Schmitt trigger

A hallelujah for two switching thresholds

Sharp edges and reduced noise: how Schmitt triggers can be used to generate clean square wave signals, thereby improving signal transmission and the noise immunity of digital systems.

BY THOMAS BOLZ,
PRODUCT MANAGER STANDARD PRODUCTS
AT RUTRONIK

When higher data rates are transmitted by cable over longer distances, noise is generated that overlays the wanted signal and makes it difficult to clearly determine the digital signal. This can result in digital logic elements no longer being able to process the wanted signals. The noise can be reduced by shielding the line, but not completely suppressed. The use of input filters, e.g. RC networks, additionally reduces noise – but also the maximum data rate.

A better way to regenerate degenerated signals is to use Schmitt triggers. They are used, in particular, in devices that establish a connection between an analog and a digital environment – in other words, wherever noise suppression is absolutely essential (Figure 1).

How does a Schmitt trigger work?

A Schmitt trigger is a comparator circuit with hysteresis (Figure 2). It analyzes the analog input signal and converts it into a switching pulse when one of two defined threshold voltages is undershot or exceeded. The difference between the two switching thresholds, the switch-on voltage (V_{on}) and the switch-off voltage (V_{off}), is referred to as hysteresis.

Figure 3 shows how noise is removed from a digital signal using a Schmitt trigger: if the input voltage exceeds the value V_{on}, the Schmitt trigger switches on and outputs a signal. This remains stable despite the noise until the input voltage undershoots the value

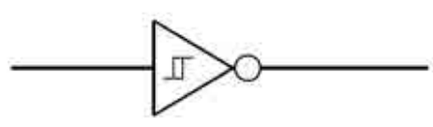


Image: Diodes

Figure 1: A Schmitt trigger reduces noise on binary signals.

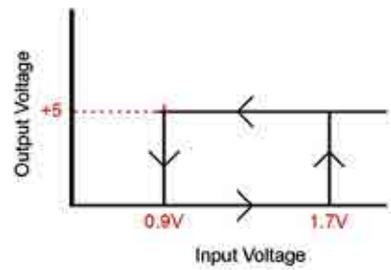


Image: Diodes

Figure 2: The Schmitt trigger outputs a constant signal between two switching thresholds.

V_{off}. The further apart the two threshold voltages, the greater the noise immunity of the system.

Digital inputs do not like analog signals

Schmitt triggers are therefore used for digital signal transmission, as digital circuits require discrete voltage signals at the input. If a continuous signal with a voltage level outside the defined levels is fed into a logic gate, for example, unique signals are not issued at the output. A consequence of this can be oscillations with indeterminate signals, which lead to instability and increased power consumption.

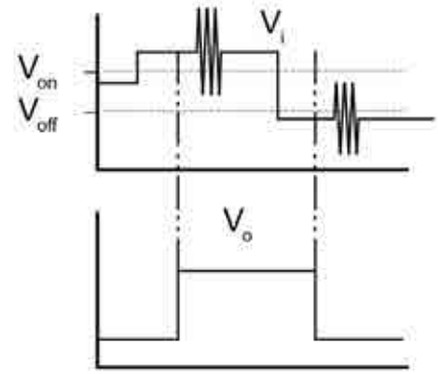


Image: Wilfrid Laurier University Physics Labs

Figure 3: Noise removal of a digital signal using a Schmitt trigger

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A rule of thumb for digital inputs:

- The input voltage must always be higher or lower than the lower or upper threshold voltage limits.
- Switching between the high and low levels must be performed quickly.
- No analog input voltages are permitted.
- If these specifications cannot be met, the use of a Schmitt trigger is recommended.
- Square wave signal as the basis of digital signal transmission

The best-known special case of digital systems is the binary signal. In this case, only the states "0" and "1," for example 0 V and 5 V, exist. A signal of this kind, which switches back and forth between two values and has a rectangular progression over time in a diagram, is called a square wave signal. Square wave signals consist of a fundamental sine wave and odd harmonics. To transmit them in as loss-free a way as possible, you need to know more than just the basic frequencies, which can be read from the amplitude-time diagram. Rather, the actual signal must be analyzed in terms of the frequencies it contains. The relevant amplitude-frequency diagram shows the other frequencies present in the signal, along with their components.

Many factors distort the wanted signal

When transmitting digital signals over large distances at high data rates, various sources of interference impact the wanted signal:

The **low-pass character of the line** distorts the signal linearly, i.e. low frequencies are transmitted while high frequencies are filtered out. This limitation makes it difficult or even impossible to detect the signal unambiguously at the output. The square wave signal is scattered.

Electromagnetic interference comes from fluorescent lamps, power grid switchgear, or inductors (coils or motor drives). They have randomly distributed frequency spectra that interfere with or overlap the line frequencies and thus distort the signal. To ensure the quality of the wanted signal is still sufficient, the signal-to-noise ratio (SNR) must be high enough. However, a simple amplifier does not distinguish between wanted and unwanted signals, but simply increases both equally.

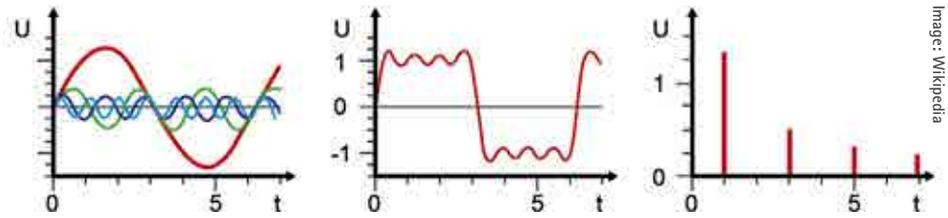


Image: Wikipedia

Figure 4: A square wave consists of a fundamental sine wave and odd harmonics (Fourier analysis).

Other lines or adjacent data channels generate crosstalk due to capacitive or inductive coupling. This is indicated by rapidly rising or falling signals. If a signal of this kind passes through a transmission line, it induces crosstalk noise in an adjacent line, which propagates as a pulsed noise.

The bandwidth of the transmission path also impacts the wanted signal, as the frequency space of real signal transmission systems is limited. The smaller the bandwidth, the more the square wave signal is scattered, since the higher the sine frequency, the lower the amplitude component. And of these frequencies, only those that are within the bandwidth of the transmission path pass through the line. As the gain increases, the usable bandwidth decreases, as the gain bandwidth product (GBP), which is constant, applies to each amplifier. The high frequency components of the input signal enter the output range with a smaller amplitude.

The composition of the signal from several sinusoidal oscillations with varying frequencies becomes increasingly noticeable the more components are in the transmission path. The reason for this is the **time differences** of the various frequencies through these components that prevent them from reaching the receiver at the same time.

Impedance mismatches cause a portion of the transmitted signal to be reflected at both the transmitting and the receiving ends of a line. These reflections cause additional errors. For example, in CMOS logic ICs, they lead to a greater signal delay and ringing, as well as overshoot and undershoot.

With mechanical switches and relays, chattering (contact jump) often occurs: instead of a clean transition from zero to full current, a rapidly pulsed electric current is generated. This causes problems, especially with logic ICs, since they respond fast enough to misinterpret the on-off pulses as data signals. Schmitt triggers filter out these "bounces" thanks to the two switching thresholds. This process is also referred to as "debouncing."

To avoid signal output instabilities, logic components must be controlled by pulses with steep edges. However, external signals often have a finite rise or fall time (slew rate). For example, clock signals from crystal oscillators used to drive PCB devices may have a low slew rate. By reducing the track resistance and/or capacitance on the board or increasing the drive capability of the input signal it is possible to avoid distortion of the output waveform. These methods are, however, usually time consuming and costly. A simple way to eliminate these problems is to use a Schmitt trigger. It converts a slow or noisy signal into a clean signal with sharp edges (Figure 5) before passing it to the logic gate.

Wide range of applications

The examples show that the Schmitt trigger is a versatile component that can be used in servers, network switches, telecommunication infrastructures, test and measurement equipment, robot controllers, industrial stepper motors, power meters, power analyzers, and digital input modules for factory automation. Assembling a Schmitt trigger from discrete parts is a demanding and sometimes time-consuming process; calculation of the individual components is very complex.

A stand-alone product such as the 74LVC14A from Diodes is much more convenient. It provides six independent Schmitt trigger inverter buffers and is designed for operation with a wide power supply voltage range of 1.65 V to 5.5 V. The inputs are tolerant to 3.3 V or 5.5 V, allowing the device to be used in a mixed voltage environment. The CMOS technology guarantees low power consumption.

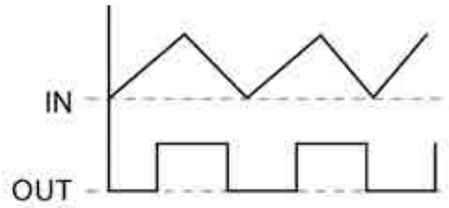


Image: Rutronik

Figure 5: A Schmitt trigger converts slow edges into sharp rising edges.

Image: Diodes

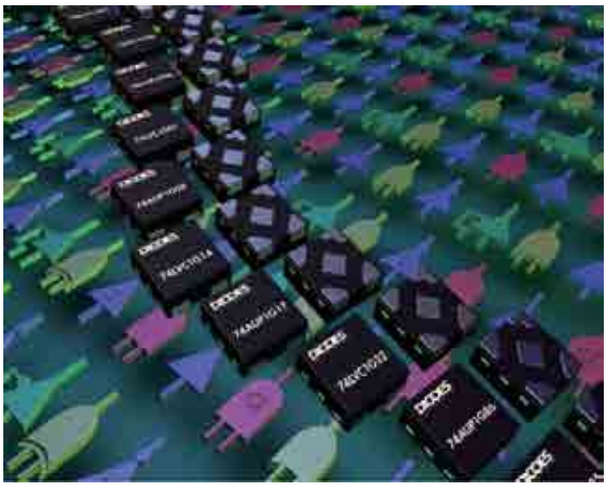


Figure 6: With six independent Schmitt trigger inverter buffers, the 74LVC14A from Diodes is suitable for a wide range of applications.

The 74LVC14A is fully specified for partial power-down applications. This circuitry disables the output, thus preventing damage to the current backflow when the device is powered down. The gates perform the positive Boolean function, i.e. they work as inverters, thus negating the output signal. The 74LVC14A is available in two package options, SO-14 and TSSOP-14, and boasts ESD protection. It is suitable for voltage level shifting, general purpose logic, or power-down signal isolation in PCs, networks, notebooks, and hard drives, for example.

Alternistors

Switching inductive loads in domestic appliances

From coffee machines to refrigerators: triacs are used as robust, easy-to-operate switches for AC applications. High-commutation triacs, also known as alternistors, have improved commutation properties and can switch even inductive loads silently, cost-effectively, and over a long service life.

By Thomas Bolz, Product Manager Standard Products at Rutronik, and Tawade Prasad, Technical Marketing at Littelfuse

Triodes for alternating current (triacs) are part of the thyristor family and can be operated by both a positive and negative voltage. Once triggered, they remain in a conductive state without any further triggering signal until the load current falls below the holding current. When operated with AC voltage, this happens at the zero crossing of the current, at the latest.

Their construction can be viewed as two electrically isolated, antiparallel thyristors that share a gate electrode, as shown in Figure 1. The control surfaces of the power areas of the two thyristors overlap. There are two methods of controlling triacs.

Burst control involves allowing the switch to conduct for a certain number of half cycles and then keeping it switched off for a few half cycles. This results in an average power on the load depending on the ratio of on and off half waves. Figure 2 represents this for the ratio 2:1.

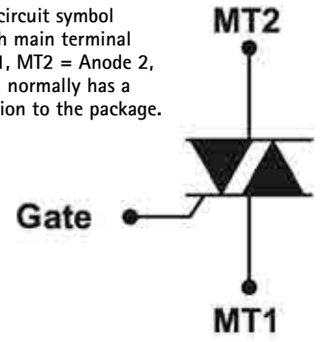


Figure 1: The circuit symbol for a triac with main terminal MT1 = node 1, MT2 = Anode 2, and gate. MT2 normally has a direct connection to the package.

Image: Rutronik

The period length specified by the power grid only allows whole-number ratios to be set, which limits the quantization of the output variable. To obtain a useful chronological av-

Image: Maksym Yemelyanov/stock.adobe.com

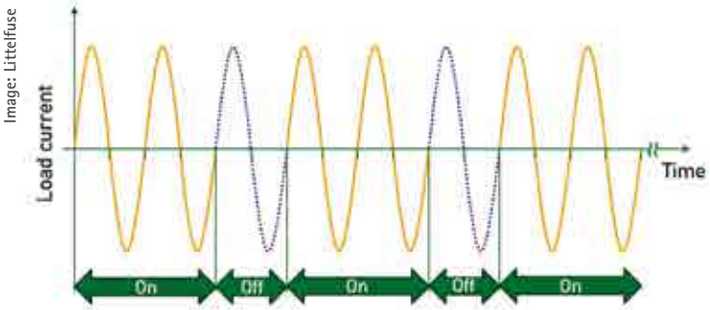


Image: Littelfuse

Figure 2: Schematic view of burst control

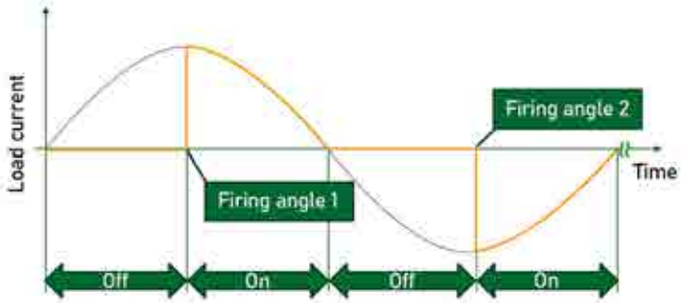


Image: Littelfuse

Figure 3: Phase angle control principle

erage, the on and off periods must be in the range of several half waves.

Burst control is used to control the power of electrical AC voltage consumers. Typical applications include flow heaters and electric heaters. As switching only takes place at the zero crossings, odd harmonics are largely avoided.

With **phase-angle control** the triac is triggered at a defined time after the beginning of each half cycle. Figure 3 shows a schematic view of the functional principle.

The average value is controlled cyclically by varying the time, also known as the firing angle, at which the triac is triggered. The free choice of firing angle permits analog adjustment of the average value from 0 to 100%. Easy triggering, e.g. for a dimmer, is shown in Figure 4.

Silent and durable: triac vs. relay

Unlike electromechanical relays, triacs are solid-state relays, which provides certain advantages. They operate silently. As there is no mechanical wear, they have a significantly longer service life than relays. When using triacs, there is no chatter or arcing and sparks. This means that they can also be used in potentially explosive environments where sparking relays are absolutely taboo. Triacs can also be used for phase control of a load. This opens up a wide range of possible uses in small and large domestic appliances. From coffee machines to refrigerators, triacs control parameters such as temperatures, light intensity, and motor speed.

Phase shift makes the difference

Thyristors and triacs switch off when the main current between the anode and cathode falls below the holding current. By recombining charges after switching off, this switching operation generates what is known as a return current. However, if there is a remaining excess charge in the adjacent areas of the gate, and if the voltage rises again after the zero crossing, this can cause triggering of the second thyristor in the triac.

At power grid frequencies up to around 400 Hz and with a sinusoidal wave form, commutation is not a problem with a purely ohmic load since the current and voltage are in phase. Commutation takes place at the zero crossing of the current as expected, which is at the same time as the voltage zero crossing due to the phasing. Figure 5 shows the resulting current and voltage progressions.

If the triac is used to control an inductive load where a phase shift occurs between current and voltage, the situation shown in Figure 6 arises.

Here, a voltage occurs at the main terminals on the triac during the current zero crossing. The resulting rapid change of voltage dv/dt could incorrectly trigger the sensitive triacs. Therefore, triac-controlled circuits require a very careful design.

One important parameter when selecting the appropriate triac is the permitted voltage increase rate dVcom/dt. If this is exceeded, the component does not switch off. To guarantee switch-off, both the current drop rate dI_{com}/dt during the commutation interval and the subsequent rate of voltage increase dV_{com}/dt after the switch-off operation have to be limited. The data sheets for triacs contain characteristic data for the maximum permitted rate of increase of the commutation voltage depending on the component temperature and the drop rate of the anode current at which the triac is not triggered.

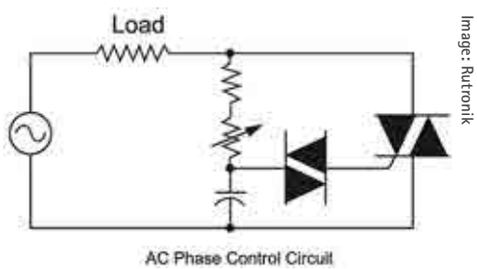


Image: Rutronik

Figure 4:
Easy triac circuitry for phase control

Snubber networks prevent unwanted triggering

If a triac has to be operated in an inductive load circuit where incorrect switching is to be expected, a discharge or RC snubber network is normally connected in parallel to the triac (Figure 7). The snubbers ensure that the triac is not excessively heavily loaded or prematurely triggered by a sudden voltage increase, e.g. caused by voltage peaks in the power grid supply. In addition, the current increase rate dI/dt can be limited by a series inductor, which means that the triac does not trigger despite high changes in voltage.

When choosing the appropriate snubber network, the individual components must be carefully selected. Key factors here are the load inductance, the frequency of the AC supply, and the effective current of the load. The snubber resistance must be high enough to prevent voltage overshoot and to limit the peak discharge current of the capacitor using the triac to the permitted dI/dt limit for the switch. The snubber capacitor must be designed for the full AC voltage of the supply system.

However, a snubber network parallel to the triac increases the complexity of the circuitry and also results in additional power loss in the snubber.

A smarter method of keeping the circuit design simple is to use alternistors. These high-commutation triacs differ from standard tri-

Image: Rutroink

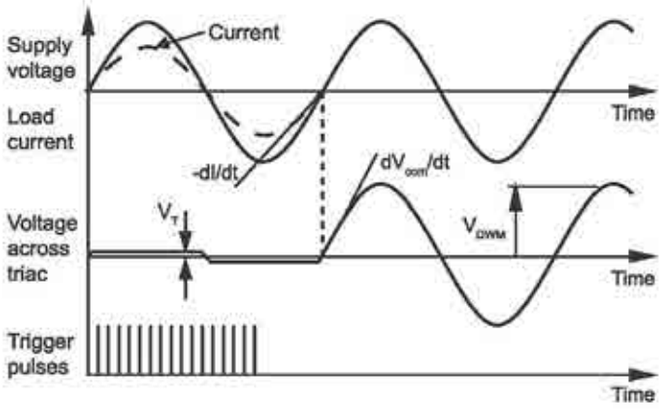


Figure 5: Commutation with purely ohmic load

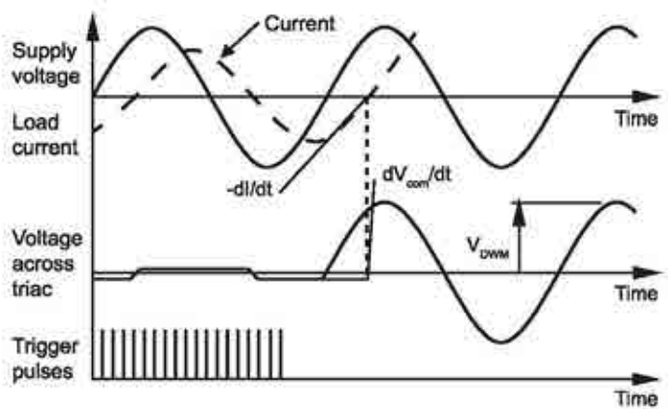


Image: Rutroink

Figure 6: Commutation with inductive load

acs in that they have better separation of the two "thyristor halves," which gives them better commutation robustness. A higher permitted dV_{com}/dt also enables control of inductive loads without snubbers. A higher permitted dI_{com}/dt improves commutation of currents with a higher frequency or a non-sinusoidal shape without requiring additional inductors to limit dI/dt.

This means: the use of alternistors allows developers to create a simpler design thanks to a reduced number of components and considerable savings in terms of both space on the board and system costs.

Options for highly inductive loads

Alternistors from Littelfuse provide high surge current resistance of at least ten times their nominal current. This is important in circuits with an inductive load as the inrush current of an inductor is several times the nominal current. The surge current limit ITSM is the peak value of an on-state current surge in the form of a sinusoidal half wave of 10 ms or 8.3 ms duration (50 or 60 Hz), which the triac can withstand without damage in the event of a short circuit. When a triac is loaded with the surge current limit, increased barrier layer temperatures occur for a short time.

Littelfuse supplies alternistors in different mechanically and thermally robust packages, in insulated and non-insulated versions. The discrete packages allow installation with spring clips to reduce installation work. The clip bonding technology used is widespread in the manufacture of high-performance semiconductor modules and components and guarantees excellent reliability. The clip bonding technology replaces the usual wire bond connection between the die and lead with a solid copper bridge that offers better heat resistance and an ultrafast switching capacity.

The contact surfaces of copper clips are much larger than with wire bonds. This improves the thermal properties as the heat is dissipated from the top of the chip to the lead frame more efficiently. This reduces the maximum barrier layer temperature during operation and thus extends the service life and improves the reliability of the triac. All triac chips have glass-passivated barrier layers and thus guarantee long-term reliability and component parameter stability.

The cooling vanes are internally galvanically isolated up to a voltage of at least 2500 V RMS, and all components are UL-certified (Ref. file E81734). This makes it unnecessary to use and install separate insulators, allowing savings to be made compared to designs with live cooling vanes. The use of ceramic insulation results in better heat dissipation and a longer service life than conventional epoxy insulation.

Four product series of alternistor triacs are particularly worth highlighting. They only operate in quadrants I, II, and III (Figure 8). As typical applications are normally connected to AC circuits, the triacs operate in quadrants I and III. The loss of the fourth trigger quadrant can thus be tolerated.

Qxx10Hx: The 10 A version is available insulated and non-insulated in the TO-220AB packages and in the TO-263 SMD package (D2Pak). The ITSM is 120 A (60 Hz). The 25 A version (**Qxx25xHx**) is available with the following package options: TO-220 insulated and non-insulated; robust, insulated TO-218 and TO218X package with solder lugs; TO-263 SMD package (D2Pak). The ITSM is 250 A (60 Hz).

Image: Maksym Yemelyanov/stock.adobe.com

Image: Rutronik

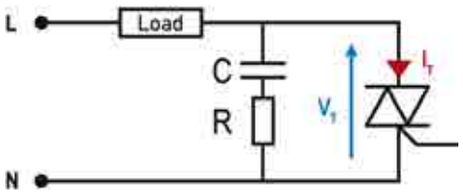


Figure 7: Triac with RC snubber network

The high-temperature alternistors from the QJ series are a particular highlight: the **QJxx16xHx** is a 16 A power triac, which is available in TO-220AB and an insulated TO-220 and TO-263 package with a maximum barrier layer temperature of 302 °F (150 °C) and an ITSM of 200 A (60 Hz). The 25 A version (**QJxx25xHx**) is available in the same packages, and also in robust, insulated TO-218 and TO218X packages with solder lugs. This triac has a maximum barrier layer temperature of 302 °F (150 °C) and an ITSM of 250 A (60 Hz).

The QJ series help to resolve overheating problems in AC power control applications. They enable easier thermal management and have a high surge current resistance. This allows high inrush currents in heating and motor control applications.

Summary

Triacs are perfectly suited for AC voltage switching and phase angle control applications, such as heating, lighting, and motor speed controls. The triac is used wherever current comes out of an electrical outlet – in coffee machines, flow heaters, infrared heaters, kitchen appliances, power tools, heating controls, AC semiconductor relays, dimmers, and motor speed control systems.

Image: Littelfuse

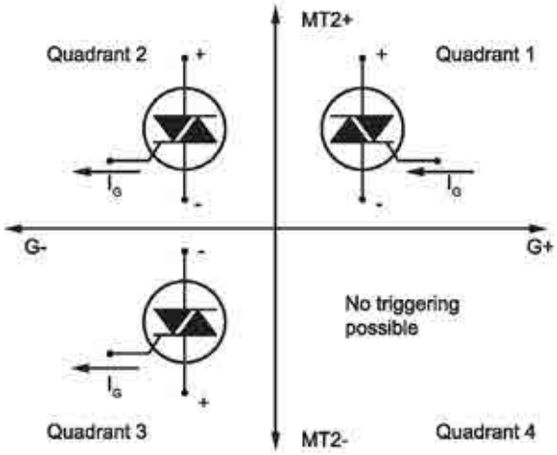


Figure 8: Trigger quadrants of an alternistor triac

eFuse – the electronic fuse

Semiconductor technology for fast protection

Today, fuses are used less to protect against system failure and more to protect against user faults. But it is not only the nature of the faults that has changed – the actual fuses have also evolved.

By Emilia Mance, Product Sales Manager Standard Products at Rutronik, and
Turadj Aliabadi, Senior Marketing Manager for Discrete Semiconductors at Toshiba Electronics Europe

Fuses are based upon a slender section of wire that is designed to melt should excessive current flow into the application being protected. They thus stop the flow of current and protect the application. The fuses are dimensioned according to two units: current and time. The current limit defines the upper limit of allowable current flow before the fuse sacrifices itself. The time element allows naturally occurring current surges beyond the specified current limit to be accommodated, for example as often occurs during the inrush of current when a product is powered on.

The key problem with fuses of this kind is the sacrificial part: when a fuse blows, a service technician, for instance, will need to check the reason for the fuse blowing and then replace it. This is obviously time consuming and can cause process delays. It might also be challenging and costly depending on how the fuse is integrated and the accessibility of the equipment.

Nowadays, an overcurrent situation often occurs due to a user fault, such as a short circuit when inserting a faulty USB device into a PC or laptop. Rather than using fuses, the power supplies for such devices often make use of polymeric positive temperature coefficient (PPTC) components. They are a kind of low impedance resistor. Their resistance rises rapidly due to heating during the excessive current flow conditions caused by a fault, essentially restricting the flow of current. Once the fault has been eliminated, the fuse cools down, returning to its original low resistance. This is how PPTCs provide protection while not requiring a service technician to get them working again after blowing.

Images: Toshiba

Not the fastest protection function

It should be noted that neither device is particularly fast in executing its protection function: fuses typically require a second to blow, while PPTCs respond faster but can take seconds to attain their full current restriction. And while fuses disconnect appliances fully from the power supply, PPTCs still allow a small amount of current to flow even once tripped. Both types of fuse are also dependent on the ambient operating temperature, so a derating at higher operation temperatures must be factored into the design.

The fast fuse

Semiconductor technology has been used to enhance or replace a variety of components over the past decades. This also applies to fuses. Electronic models, also known as eFuses, are increasingly replacing fuses and PPTCs. They offer enhanced protection and the ability to reset them once the fault has been removed using a simple logic interface. Computer mainboards, specifically the tracks supplying SATA hard drives or USB ports, benefit from the improved protection.

eFuses make use of advanced silicon processes. Low impedance MOSFET switches ensure low current loss when electricity is flowing. Integrated analog comparators are

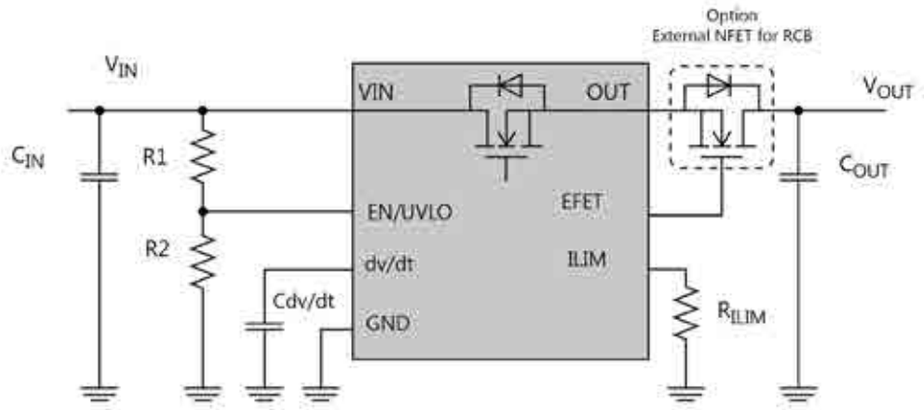


Figure 1: Example of an application circuit for an eFuse protection

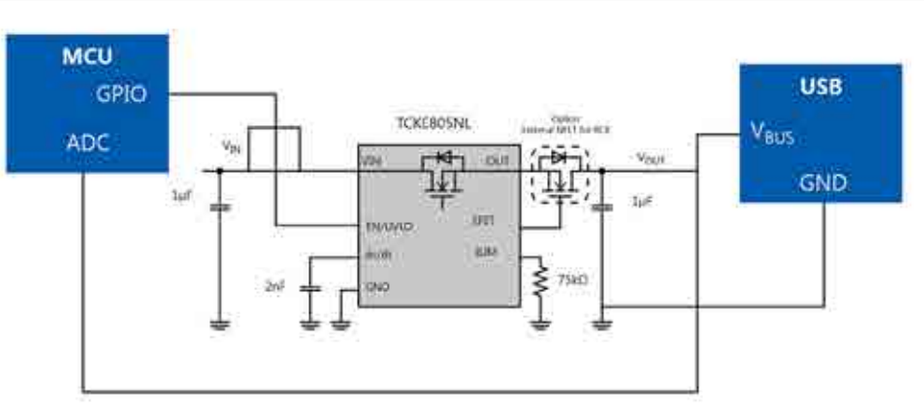


Figure 2: Protection of a USB charging socket using a TCKE805NL

capable of accurately monitoring the flow of current, reacting in less than a microsecond to completely cut off the supply. In conjunction with a host processor, a decision can be made as to the cause of the fault and when to electrically restore power via the eFuse's interface.

Being a silicon product, eFuses of course offer a range of other useful features, including over-temperature monitoring, overvoltage clamping, under-voltage lockout, and reverse current protection.

eFuses in use

Any application that provides power to add-on sub-modules, such as oscilloscope probes or programmable logic controllers (PLCs), can benefit from eFuse technology. Solutions like the TCKE8xxx series from Toshiba are easily integrated thanks to their compact 3.0 × 3.0 × 0.7 mm WSON10B package. The devices offer a short-circuit trip current of 5.0 A with an accuracy of ±11%. Thanks to the integrated fast-trip comparator, the devices remove power under fault conditions within 150 ns. The series also offers a choice of models with auto-retry or latched response. The auto-retry models reengage power automatically as soon as they have cooled by around 68 °F (20 °C), while the latched response variants are locked and have to be reset via the EN enable pin. Certification to standard IEC 62368 simplifies the certification of the entire system for customers.

The on-resistance (R_{ON}) of the integrated switch is a highly respectable 28 mΩ, while the slew rate to control inrush current and the under-voltage lockout can be set using external components. Internal temperature monitoring also provides protection and, once 320 °F (160 °C) has been reached, automatically shuts off the output.

Figure 2 shows how this type of eFuse can be used to protect a charging socket in USB chargers and battery packs. In this case, the TCKE805NL provides the optimal fit, offering latched protection together with an overvoltage clamp fixed at 6.04 V. A 75 kΩ resistor connected to an ILIM pin limits the current to 1.5 A, while a 2 nF capacitor provides a turn-on ramp time of 4 ms. Input and output capacitors of 1.0 µF located close to the VIN and OUT pins reduce voltage overshoot and undershoot during sudden changes in current draw. If required, an N-Channel FET can also be integrated to protect against reverse currents.

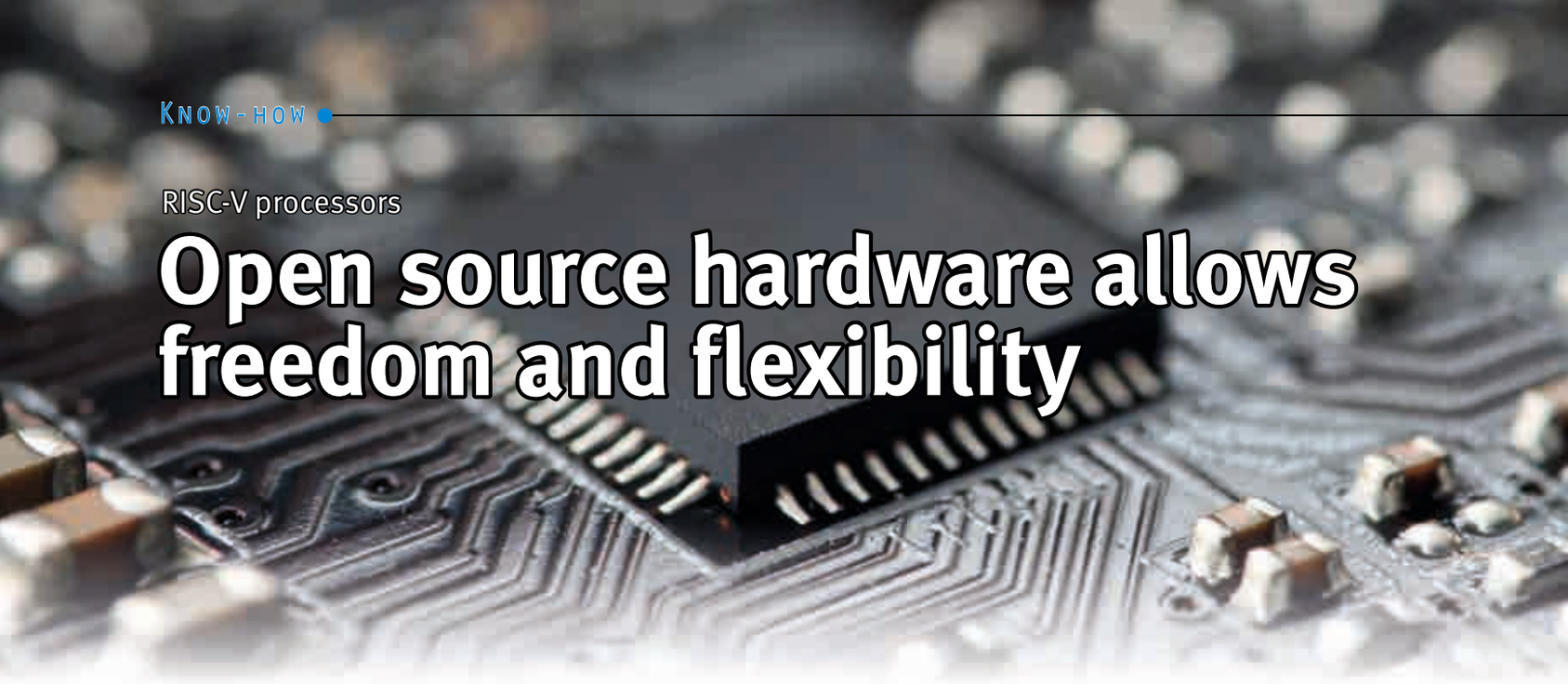
Conclusion

Fuses and PPTCs have been an essential safety element for years. However, the type of protection required today is often against human-induced faults, rather than complete system failure. Configurable eFuses provide applications with reliable, but resettable, protection, helping to extend the service life of applications and reducing the need for support from a service technician in many cases. ■

The history of the fuse

Memories of the German physicist Georg Ohm come to mind when handling resistors. Likewise, the British scientist Michael Faraday when selecting capacitors and the American physicist Joseph Henry when dimensioning inductors. But interest in these three core electrical components was waning by the time people got around to quantifying the characteristics of the humble fuse in the 20th century.

The development of the simple fuse, whose name stems from the Latin word "fusus" (melted), can basically be traced back to Arthur C. Cockburn. Although some of his experimental accuracy was mocked by London's newly formed Society of Telegraph Engineers at their 1888 meeting, he went to great lengths to scientifically determine the factors that came together to create a reliable fuse. A result of his work: a fuse should be rated to blow at around 150% to 200% of the rated current of the circuit being protected. At this time, electric lighting was still in its infancy and telegraph workers additionally needed to be protected from lightning strikes. The fuse thus became a critical safety component for this fledgling industry.



RISC-V processors

Open source hardware allows freedom and flexibility

In response to the increasingly complex structure of standard processors, an open, greatly reduced instruction set architecture was created at the University of California, Berkeley, ten years ago. It is now in its fifth generation – and offers many advantages.

By Walter Hagner and Hao Wang, both Product Sales Managers Digital at Rutronik

One reason for developing a comparatively simple instruction set was to research why most compilers do not even use many of the addressing modes provided by common processors. The new instruction set architecture (ISA) was named RISC (reduced instruction set computer) due to its reduced complexity.

The fifth version, RISC-V, is based on the open source approach and appears to be a major breakthrough moment for RISC. One of the main reasons for this is that the RISC-V Foundation, which now has over 1,000 members and is driving the development of RISC-V ISA forward, does not charge licensing fees for the use of instruction sets. Even commercial use of RISC-V does not require any license agreements or payments. This makes RISC-V very attractive when compared to x86 and ARM processor technologies. In addition to the significantly lower costs, it also means that users do not make themselves dependent on other companies. Anyone can develop their own RISC-V cores and processors without having to disclose them. In view of the fact that processors can also be loaded as soft cores in programmable logic, this is an advantage that cannot be overestimated.

Flexibility and durability

RISC-V defines ISA but not the processor architecture. This provides developers with a great deal of flexibility; as they can combine RISC-V with any architecture they want. Thanks to the fixed instruction set, programs developed today will also be executable in future implementations. This makes RISC-V particularly interesting for industrial applications with long life cycles.

The entire RISC-V instruction set is based on the formats register-to-register, unconditional and conditional jumps, data store, and short and long immediates. The architecture is characterized by its variety of registers, since RISC-V is a load-store architecture that works without complex addressing modes. It also basically has no dedicated I/O area, but only memory-mapped I/O.

Yet another benefit of the RISC-V concept is that there is no need for a large micro sequencer. As such, most of the commands are executed directly by hardware rather than by a micro program. This has the positive effect that generally only one clock cycle is required.

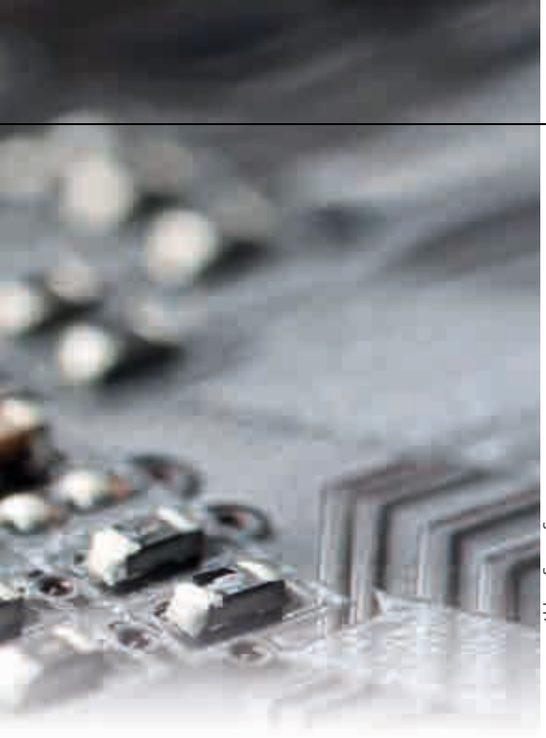


Image: megafloppi/stock.adobe.com

Three basic architectures …

In general, three basic architectures are available with differing integer register widths. Already defined are RV32 with 32 bit and RV64 with 64 bit. The 128-bit version, RV128, is still in the design phase.

… and extensions for specific processors

The basic architectures can be extended to allow specific processors to be developed for dedicated applications. Developers can choose from an array of functions such as floating point, double and quad floating point, atomic operations, and vector instructions.

RISC-V-based microcontrollers

Various suppliers are already offering RISC-V-based microcontrollers. The RISC-V organization comprises numerous members, including strategic members and well-known founding members, leading global universities, and major digital corporations such as Google and Alibaba.

Rutronik pays particular attention to market development, as many of its franchise and technology partners are active members of the RISC-V community; many have already invested large sums in the technology. Rutronik's strategic RISC-V partners include Infineon, Nordic, Gowin, Rockchip, Efinix, Segger and many more. From this it can already be deduced today that, in addition to Arm Cores and their own proprietary solutions, the groups will in future rely intensively on the RISC-V card.

The first RISC-V-based 32-bit microcontrollers were launched by a technologically leading Asian manufacturer, which uses RISC-V cores in addition to Arm Cores. These are cost-effective MCUs with high computing power and low power consumption for the demanding embedded market. The RISC-V Bumblebee Core operates at 108 MHz and supports RV32IMAC, i.e. the ISA variant for 32 bit. The letters after the 32 stand for the extensions integer operations (I for Integer), multiplications and divisions (M for Multiply), atomic operations (A for Atomic) and a compressed 32-bit instruction set (C for Compressed), which makes the microcontrollers very powerful. Typically, these MCUs offer up to 128 kB of on-chip flash memory and 32 kB of SRAM memory. Numerous advanced I/Os and peripherals are connected to two APB buses. These features make these MCUs ideal for networked applications, including most notably industrial control, motor drives, power monitoring and alarm systems, consumer and handheld devices, POS, automotive GPS, and LED displays.

Developers can already find extensive development boards, starter kits and a comprehensive software library in the RISC-V world, as well as IDE support and debugging tools also from Rutronik partners such as Segger. This allows users to quickly implement their projects.

Conclusion

Compared to x86 and Arm, RISC-V primarily offers lower costs as well as more freedom and flexibility – and is enjoying growing popularity. So it is well worth taking a closer look at it. ■

E-mobility

The renaissance of film capacitors

Film capacitors are based on one of the oldest, most tried-and-tested capacitor technologies. However, because they are heavier and larger than other types of capacitors, they were long considered unsuitable for automotive applications. So it might come as a bit of a surprise to some that they are currently experiencing a renaissance due to the high currents at high voltages in electric and hybrid vehicles.

By Marcel Fritz, Product Sales Manager Capacitors, and Christian Kasper, Technical Support, both employed at Rutronik

Film capacitors are characterized by a variety of technical advantages. In addition to low loss factors and the fact that they are suitable for operation with both alternating and direct voltage, film capacitors also allow the highest currents at a high voltage level while offering frequency-stable capacitance. Standard film capacitors are sufficient for voltages of between 50 V and 2,500 V, such as those in current car models. Meeting the demands of automotive standard AEC-Q200 has long been part of the suppliers' repertoire.

Moreover, film capacitors meet the stringent service life and performance requirements set out in the automotive sector: when applied properly, their service life is limited only by material aging. Temperature and humidity are the main contributors to this adverse effect, but the current and the resulting self-heating also promote aging. The latest developments are, therefore, aimed at improving the temperature and humidity stability of the components. Yet another focus of the suppliers is centered on optimizing the capacity/voltage (CV) ratio of the capacitors.

Further developments overcome heat and humidity

In vehicles, heat is generated primarily in the vicinity of the drive motor, but also wherever the current flowing through the components is responsible for self-heating. The first series are now specified up to 275 °F (135 °C) for use in automotive applications. However, users should definitely consider the voltage derating as well as a possible reduction of service life at these high temperatures.

High humidity during operation can attack the vaporized metalized layer on the film capacitors. If the tightness of the plastic case or compound is not sufficient, moisture may penetrate the condenser under certain circumstances. Unwanted air moisture can even be trapped inside during the production process.

Numerous analyses and empirical studies have led to the conclusion that, in practice, the penetration of unwanted air humidity has the biggest impact on the service life of a film capacitor. This fact, along with the high service life requirements in the automotive sector, necessitates accelerated service life testing.

A recognized standard for accelerated service life testing is the Temperature-Humidity Bias (THB) test. It is a reliability test aimed at accelerating the aging process of capacitors and measuring whether the capacitors maintain their capacitance, loss factor, and isolation resistance at a given temperature, relative hu-

Image: Vishay

As THB type Grade IIIB capacitors, Vishay F340 EMI suppression film capacitors can withstand 185 °F (85 °C) and 85% relative humidity for 1,000 hours.

Image: Wima

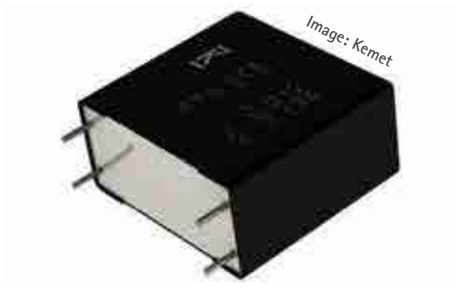
DC link capacitors offer high volume capacitance and excellent healing capabilities. The MKP 4 models from WIMA are AEC-Q200 qualified.

midity, and nominal voltage over a defined period of time (see table). Depending on the testing level, they meet various climatic requirements, e.g. in an electric car. At Grade IIIB, High Robustness under High Humidity, the capacitors must survive testing at 185 °F (85 °C), 85% relative humidity, and 1,000 hours of operation at applied nominal voltage without any damage.

A real space-saver due to customized solutions

It is extremely challenging for film capacitors to meet the space and weight requirements of automotive developers, as the more capacitance the capacitor should have, the more layers the winding needs. And the capacitor obviously becomes larger and heavier with each new layer. However, suppliers are following the ongoing trend toward miniaturization and are busy reducing the size of components as far as physics will allow. Special designs, generally customer-specific, also allow the use of even the smallest spaces in a vehicle.

And just because film capacitors are based on an old, tried-and-tested technology, it does not mean there have not been any developments. Suppliers are constantly optimizing components, adapting them to new requirements and placing innovative products on the market.



The C4AK series DC link capacitors from KEMET offer high capacitance density and DC ripple current capabilities and are designed for continuous operation of up to 1,000 hours at 275 °F (135 °C).

Grade (I) – Robustness under Humidity	
Test A: 40°C / 93% R.H., 21 Days Rated Voltage	Test B: 85°C / 85% R.H., 168 Hours Rated Voltage
Grade (II) – Robustness under High Humidity	
Test A: 40°C / 93% R.H., 56 Days Rated Voltage	Test B: 85°C / 85% R.H., 500 Hours Rated Voltage
Grade (III) – High Robustness under High Humidity	
Test A: 60°C / 93% R.H., 56 Days Rated Voltage	Test B: 85°C / 85% R.H., 1.000 Hours Rated Voltage

THB capacitors must meet firmly defined test criteria.

Use with cars, in cars, ...

In the field of e-mobility, one of the main areas of application for film capacitors is in the DC link of the drive motor. In the corresponding power electronics, their job is to equalize the flow of energy in the DC link. Needless to say, DC link capacitors with their low self-inductance and low equivalent series resistance (ESR) are of particular importance here. Since the drive power consumed increases with the voltage, high voltage values are, among other issues, also an important criterion.

Customized models meet efficiency requirements or provide the necessary parameters, such as special connections (connecting lugs and busbars), specific electrical values, and package shapes and sizes.

Due to their enhanced space efficiency, blocks are usually used in the drive in which several film windings, usually made of polypropylene, are encapsulated.

Further, DC film capacitors are used as filters to attenuate noise and voltage peaks in the battery management system (BMS) branch. In addition to the voltage layer, it must be ensured that the capacitance is adapted to the interference being filtered.

Interestingly, film capacitors are also used in braking system controls (ABS, ESP). The advantages are obvious: they provide constant capacitance and dielectric strength over the expected life span of the vehicle, i.e. for well over ten years. SMD models, in particular, exhibit a particularly constant capacitance and voltage at various voltage levels.

Furthermore, film capacitors are also suitable for applications in vehicle interiors and peripheral units. In the sound system, they are busy at work in the NF filter or in the crossover in the loudspeaker branch. As such, car suppliers can exploit all the advantages for which film capacitors have long been cherished in the high-end hi-fi segment.

... and around cars

Use of film capacitors is, however, not just restricted to electric cars but also extends to charging stations (e-chargers). On the power input side, RFI types such as Class-X and Class-Y capacitors ensure that EMC regulations are met. At the same time, they protect against interference on the network side. Since charging stations are typically located outdoors, the THB Grade X and Y capacitors are recommended.

In some cases, the charger is also integrated into the vehicle (onboard charger (OBC)) to enable charging at home. In this case, RFI types are also used.

In the broadest sense, charging stations are a kind of inverter, meaning AC capacitors can also be found in the power grid input. That said, most of the capacitors are DC link ones. But snubber capacitors, which help to suppress unwanted peak voltages, are also an integral part of charging stations.

Conclusion

The fact that film capacitors were rarely used in cars until recently makes it all the more exciting to see just how many applications this technology now offers. Due to their high dielectric strength and stable electrical properties, they have become an indispensable component in the current shift toward e-mobility. It is, therefore, worthwhile for every developer to take a closer look at the technology and use its advantages for their own projects. ■

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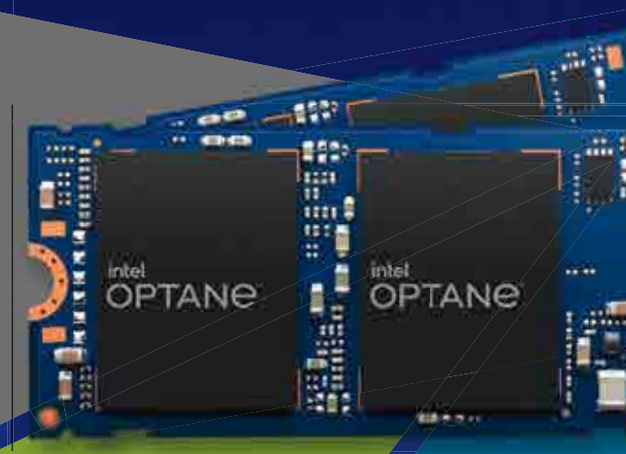

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shown in configurations and may not reflect all publicly available updates. See backup for configuration details. No product or component can be absolutely secure.
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Ceramic safety capacitors

The safe way to get the optimum suppressor capacitor

The dilemma of assigning ceramic safety capacitors begins with the naming. Material classes, ceramic types, noise suppression, and RFI capacitors – who knows about all that these days? An overview and guidelines help to identify the most suitable types.

BY JÜRGEN GEIER,
TECHNICAL SUPPORT AT RUTRONIK

Unlike other ceramic capacitors, safety capacitors are not divided into material classes 1 and 2 and ceramic types such as NP0 or Y5U. Instead, they have designations like noise suppression and RFI (radio frequency interference) capacitors and are divided into X and Y classes depending on the pulse voltage and wiring type.

The main application of safety capacitors is suppression of power grid AC voltages. Therefore, they must meet the safety requirements of IEC 60384-14 and are given the corresponding test mark.

Differentiation by interference types

In principle, capacitors can be divided by differential mode and common mode interference types. Differential mode is where the interference pulses along the wires (L-N) run in opposing directions. Here, the suppression capacitors are connected between the two lines – "across the line" – so that the interference cancels itself out. These are referred to as Class X capacitors.

In common mode, the interference pulses on both wires run in the same direction. In this case, the capacitors are connected between the relevant wire and ground – "line bypass" – to discharge the interference to ground. They are referred to as Class Y capacitors.

These X and Y capacitors are then further subdivided based on the requirements in IEC 60384-14 into the different test/pulse voltages and are differentiated as X2 and X1 or Y2 and Y1 types respectively. The tables show the currently valid distinctions.

The most frequently used types are X1Y2 and X1Y1 combinations. They satisfy both X and Y usage criteria. Because of the relatively low capacitance values generally required, the ceramic capacitors discussed here are primarily used as Y capacitors in the value range 10 pF to 4.7 nF, sometimes also between 10 nF and a maximum of 22 nF.

Further differentiation or mandatory requirements from preceding definitions also result from the different capacitor designs (wired or SMD) and whether they have to meet commercial, industrial, or automotive requirements.

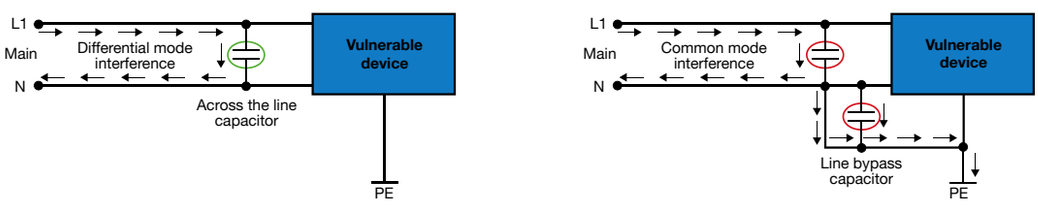

Figure: Vishay

Figure 1: Depending on whether interference pulses run in the same or opposite directions, suppression capacitors between the lines or between the wire and ground are used.

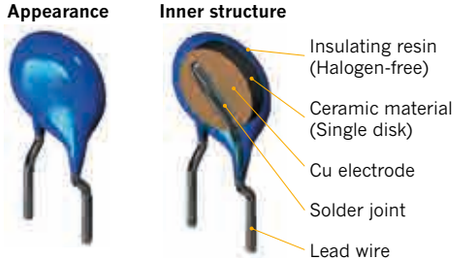

Figure: TDK

Figure 2: The sectional drawing shows the construction of a radial single-layer capacitor.

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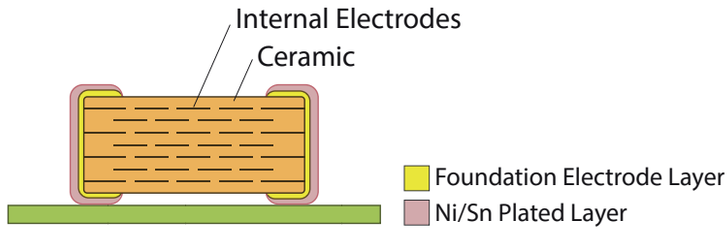

Figure: Murata

Figure 3: Sectional drawing of an MLCC

Different designs for different requirements

The most common and best-known designs are radial, single-layer types, specifically: ceramic single disks with lead wire spacing of 5 or 7.5 mm for X1Y2 and X2Y2, or 10 or 12.5 mm for X1Y1 and X2Y1 versions (Figure 2).

In addition, many SMD types are now also available in X2 and Y2 or X1Y2 versions as MLCCs (multi-layer ceramic capacitors), as well as Y1 or X1Y1 versions as single-layer, plastic-encapsulated with lead frames for SMD installation. Compared to wired radial designs, the advantages of these lie mainly in their volume and height.

By contrast, if the focus is on costs, priority should be given to the smallest possible design and SMD versions are recommended for the best suppression levels.

In some cases, there are also specific requirements for DC voltage or climatic conditions, e.g. "Y1: 1500 V DC (Annex H)" or "Humidity robustness IIB (500 h at 185 °F (85 °C) and 85% humidity with nominal voltage applied)".

Don't specify too much too soon

It is important to ensure that component lists only list the corresponding capacitor type, e.g. X1Y2, with capacitance value and, where applicable, nominal and test voltage. This is the only way to provide a choice of different versions and multiple series from different suppliers. By contrast, if the complete designation of a specific capacitor is stated in the list, every extension will require a new acceptance or certification, e.g. by the VDE.

Even if this kind of overview makes selection easier, the many parameters to be considered mean that it is often not easy to determine the optimum capacitor types. Certain suppliers provide assistance, e.g. Vishay with a decision tree (Figure 4).

In addition to the models from Vishay, the Rutronik range also includes safety capacitors from Murata, Kemet, Samwha, and TDK. ■

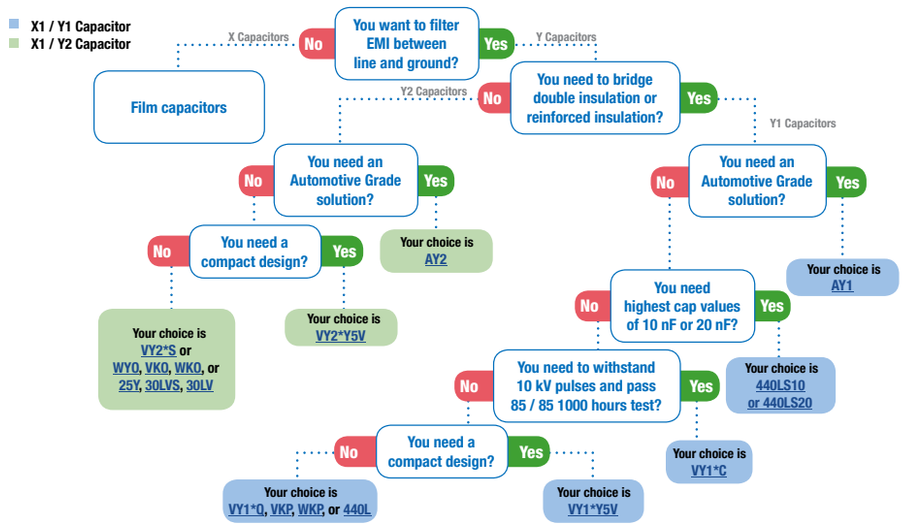

Figure: Vishay

Figure 4: The decision tree from Vishay provides support in selecting the optimum safety capacitor.

Figure: ohms1999/stock.adobe.com

Subclass	Nominal voltage specification (V AC)	Pulse strength (kV)	Test voltages (kV)
X1	275, 400, 440, 760	4	2.5/2.6 (AC)
X2	250, 275, 400	2.5	1.075 (DC); 1.5 (DC)
Y1	250, 300, 400, 500	8	4 (AC)
Y2	250, 300, 400	4	2,5/2,6 (AC)

Overview of safety capacitor classification

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Inductors

Toroidal cores, Kool Mu, and air-core coils

Inductors are used for power factor correction and impedance matching when coupling two circuits. They often function as storage chokes, common mode or differential mode chokes for noise suppression, and filter coils. Discover everything developers should know about inductors right here.

By Jochen Neller,
Technical Support at Rutronik

An inductor, also called a coil or choke, is a passive component with the ability to store energy. It does this in a magnetic field – unlike a capacitor, which stores energy in an electric field. And while a capacitor resists changes in voltage, an inductor resists changes in current. Most of the useful properties of inductors are based on their ability to store energy in their magnetic field through changes in current.

Coils are traditionally manufactured as wire-wound versions, although there are also multilayer and film technology (thin film) variants (Figure 1).

What they consist of – core types and materials

Cores are used as the basis for inductor windings. The most common types are toroidal cores and E cores and their variations. Toroidal inductors are characterized by their good intrinsic shielding effectiveness thanks to a closed magnetic path, and also by good energy transfer and a high degree of coupling between the windings. E cores – like the U, RM (rectangular module), and shell core variants – also have a closed magnetic path, the same as a toroidal core, but without an air gap. However, E cores with an air gap exhibit reduced saturation behavior, i.e. electrical energy can be stored in this gap, thus enabling a higher inductance value (L) to be achieved.

The cores are generally made of ferrite. The magnetic material is composed of an oxide of iron and other elements. Well-known combinations are manganese and zinc (MnZn) for high permeabilities and nickel and zinc (NiZn) for high levels of frequency. A MnZn ferrite (Fi329), for example, is used by Sumida (Figure 2). The material provides the inductors

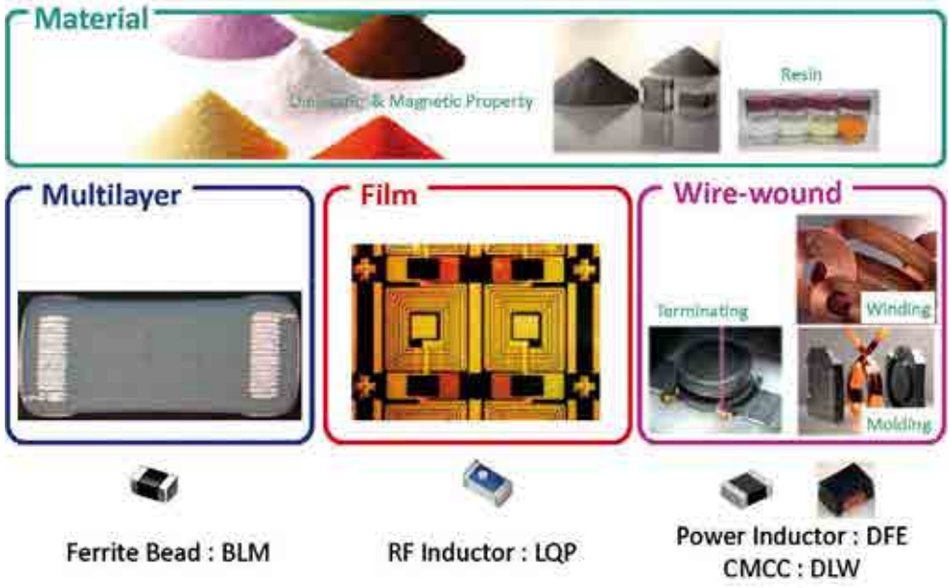


Figure: Murata

Figure 1: There are three types of coils: wire-wound, film, and multilayer versions.

Figure: Sumida

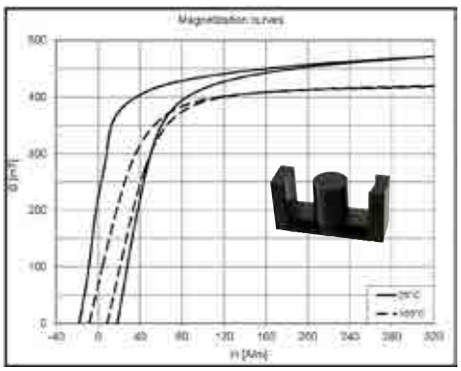


Figure 2: Fi329 is the name of Sumida's ferrite material with a very high saturation flux density and low losses.

with a very high saturation flux density, low losses, and thus high efficiency. They are ideal for green power applications up to 300 kHz, such as solar and wind energy and electric and hybrid cars.

By mixing in a binder (e.g. epoxy), the magnetic iron powder is given an inherent distributed air gap. As a result, the core has greater magnetic flux storage capabilities and generates less heat despite its more compact design. Kool Mu – an alloy mainly made up of iron, silicon, and aluminum alloy powder – and molypermalloy powder (MPP) also have an inherent distributed air gap. The cores are available with several permeabilities, but are more expensive than pure iron powder cores.

Ceramic is also a common material used for inductor cores, despite it having no magnetic properties whatsoever. The ceramic core acts as a carrier for the coil winding; the terminals attached to it ensure defined pinning, i.e. exact spacing between the terminals. These inductors are also referred to as air coils. They are used in the HF range where low inductance values, very low core losses, and a high quality factor are required.

Copper wire is used for the windings around the cores.

What is important – crucial specifications in the data sheets

If you take a look at inductor data sheets, some specifications are crucial:

The **inductance value L** of a coil (often expressed in µH) is influenced by the material, the shape and size of the core, the number of windings, and the shape of the coil.

The **DC resistance (R_{DC})** is the resistance of the coil winding measured without a flow of alternating current. It is specified as a typical and/or maximum rating.

The **rated current** is the level of direct current that can be passed through the inductor, resulting in a defined temperature increase of the inductor (e.g. by 104 °F (40 °C)). The **saturation current** is the level of direct current flowing through the inductor that causes the inductance value to drop (due to magnetic properties) by a specified amount (e.g. by 30%). Figures 3 and 4 show the typical shapes of the saturation and rated current.

The **self-resonant frequency (SRF)** is the frequency at which the distributed capacitance of the coil resonates with the inductance. The distributed capacitance is determined by the turns of wire layered on top of each other and around the core.

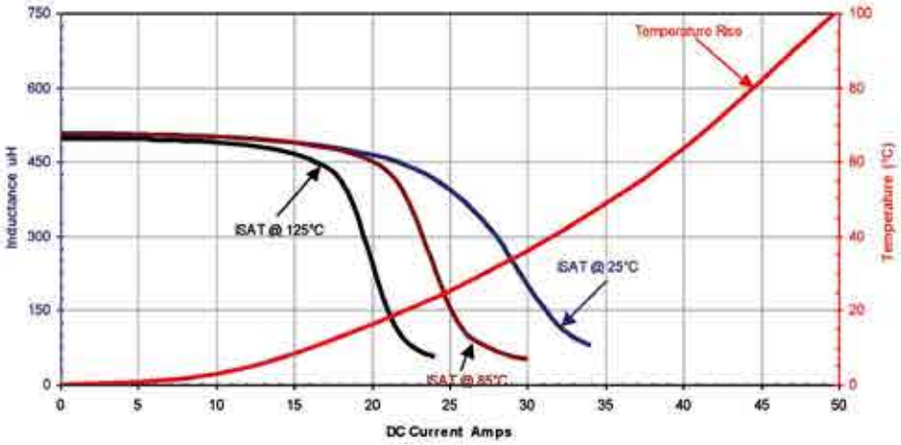
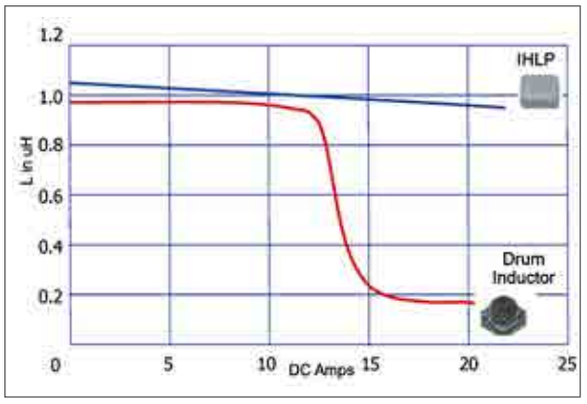


Figure 3: Saturation current and rated current shape of a ferrite inductor from Vishay



Figures: Vishay

Figure 4: Comparison of the saturation current shape of iron powder composite inductors with ferrite inductors from Vishay

The **quality factor (Q)** is technically defined as the ratio of inductive reactance X(L) to effective resistance R. R is mainly composed of the DC resistance of the wire, the skin effect of the wire, and the core losses.

The **operating temperature range** is the ambient temperature in which a component can be operated safely (Figure 5). It is important to note whether the self-temperature rise of the component, caused by the winding loss from a given direct current, is included in the temperature or not.

What they have to offer – performance and applications of inductors

The performance of an inductor is mainly determined by the core and copper losses. The current flowing through the winding causes losses in the copper wire, which are converted into heat. Inductors with stranded wire have lower alternating current losses than comparable models with a fixed wire. The higher the operating frequency, the more important low alternating current losses are.

The core losses are caused by the varying magnetic field in the core material. They vary considerably from one magnetic material to the next. The core must therefore be carefully selected to achieve maximum inductance. MnZn and NiZn are recommended, in particular, for standard applications. In confined spaces where it is important to keep temperatures low, MPP or Kool Mu are preferable.

For HF circuits, inductors with a high quality factor (Q) are usually applied as they can be more frequency selective. A high quality factor generally indicates an inductor that is a more selective filter, meaning it offers low tolerances and losses. These are wire-wound and thin film coils.

To eliminate electromagnetic interference (EMI), multilayer coils are usually ideal. They cost less than the other technologies and have a lower quality factor, meaning they provide attenuation over a wider frequency range. In this case, the Q value is often not even specified in the data sheets. ■

Figure: Vishay

Figure 5: Vishay IHLP-2020CZ-8A inductors are specially designed to operate at very high temperatures of up to 356 °F (180 °C).

Supercaps

Principles and uses of EDLCs

EDLCs, also known as supercaps, boost caps, or gold caps, are electrochemical capacitors, which combine a high capacitance with a low internal resistance. This makes them suitable for a wide range of applications. But what are they and what needs to be considered?

By Julio Gállego-López, Business Development Manager, Christian Kasper, Technical Support, both at Rutronik, and Akos Labady, Senior Field Application Engineer at Eaton

An EDLC (Electronic Double-Layer Capacitor) consists of two aluminum electrodes coated with carbon (Figure 1). Their highly porous structure results in an extremely large surface area, which is primarily responsible for the high capacitance. The separating paper between the electrodes simultaneously acts as a reservoir for the electrolyte. This is mainly made up of acetonitrile (ACN). It is used as a solvent for dissolving salts that increase conductivity. When a DC voltage is applied, the charge carriers collect according to polarity at an extremely short distance from the carbon surface. This effect, known as the Helmholtz layer, forms the dielectric. Because it happens at the positive and at the negative electrode, the components are referred to as double-layer capacitors.

Energy storage systems based on supercapacitors

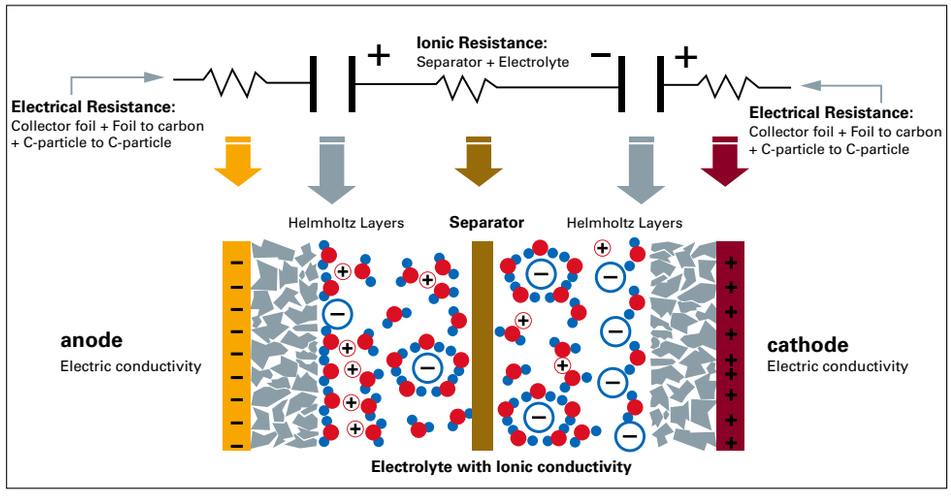
Three applications are relevant for supercaps: energy harvesting, pulse power, and backup. The objective is to develop an energy store purely based on supercaps or combined with a battery, with the supercap as a secondary store to cover power peaks.

Energy harvesting

In energy harvesting, the primary energy source, e.g. a solar module, requires a method of storing the generated energy and retrieving it as required, e.g. in a supercap. However, it is important to consider that supercaps have a higher leakage current or a higher self-discharge rate than batteries. During the harvesting or charging phase, the charging current should be at least ten times as high as the leakage current.

Pulse power or booster

If an application repeatedly requires power peaks, a supercap can cover them, thus extending the life of the primary energy source, for example a battery, by many times (Figure 2). Here, the ESR (equivalent serial resis-



Figures: Eaton

Figure 1: Structure of an electronic double-layer capacitor (EDLC)

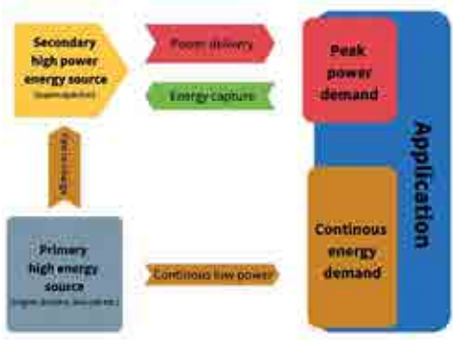


Figure 2: The primary battery constantly delivers a relatively low current, with the supercap covering demand peaks.

Figure 3: If the energy source fails (e.g. the power network), supercaps can act as backup storage to provide the required energy, e.g. to safely shut down servers.

tance) of the capacitor is the most important parameter and is the basis for the choice of supercap. As a rule of thumb, the capacitor's ESR should be around 25 percent of the ESR of the primary battery.

Power failure or backup

Supercaps are capable of supplying energy for a specific period of time (Figure 3). The system does not necessarily have to have an energy source such as a battery. Examples include real-time clock applications that require a few microwatts of power over multiple days or even weeks, but also very power-intensive applications such as trams, which have to cross a short distance with no overhead line. Supercaps are also suitable for running driverless transport systems (automated guided vehicles, AGVs) for a certain distance without the need for a battery.

Important parameters in development of supercaps

Certain parameters have to be taken into account for designs involving supercaps. The most important of these are

- Temperature range
- Service life
- Charge and discharge cycles over service life
- Usable voltage range
- Costs
- Charging parameters
- Balancing

Temperature range: Due to their chemical and physical composition, supercaps have very constant power over a very wide operating temperature range. The curves for capacitance and ESR as a function of temperature are available from the supplier on request.

Service life: Operating voltage and temperature have the greatest influence on the service life of supercaps. If they are stored in an uncharged condition, their service life is almost unlimited. As characteristic service life data in data sheets, suppliers specify the change in performance that typically occurs due to a declining capacitance and increasing resistance.

Cycles over service life: Under typical operating conditions, depending on the cell, a supercap can perform up to a million working cycles with a reduction in nominal capacitance amounting to 20 to 30 percent in most cases.

Usable voltage range: Supercaps have a nominal voltage of 2.7 or 3.0 V (hybrid types: 3.8 V). They can operate until this is 0 V (hybrid types only down to 2.2 V). Hybrid components combine the properties of a battery with those of a supercap. However, their use must be carefully considered due to the required minimum voltage. Some suppliers also specify the surge

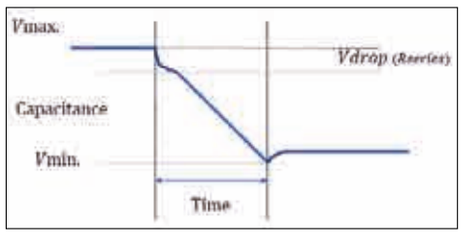


Figure 4: Supercap discharge curve

voltage in their data sheets. This describes the absolute maximum voltage for a maximum of one second. Random voltage peaks above the nominal voltage do not impair the capacitor immediately, but depending on their frequency and duration they can significantly reduce its service life.

Theoretically, the full energy content of a capacitor is $E = \frac{1}{2}\, C \cdot V^2$ (C = capacitance, V = voltage). Since most electronic devices require a particular minimum voltage to operate, this means: the voltage range never stretches from the nominal voltage to zero. Using a voltage range of half the nominal voltage enables approx. 75 percent of the available energy to be obtained from the supercap.

The energy content with partial discharge is calculated using the following formula:

$$E = \frac{1}{2}\, C\, (V^2_{max} - V^2_{min})$$

Costs: The price per watt-hour of a supercap is relatively high compared to lithium-ion batteries, for example, which is why it is advisable to consider very carefully whether development with a supercap makes sense and is feasible. The costs need to be set against the advantages of using supercaps.

Charging parameters: Supercaps do not store energy through a chemical reaction in the same way as batteries, but electrostatically. This enables them to be charged and discharged in the same way and with the same current value. This is possible with constant current or constant power from a DC source.

Balancing: The operating voltage of applications for which supercaps are suitable normally far exceeds the nominal voltage of supercap cells, which is 2.7 or 3.0 V. Multiple capacitors have to be connected in series to achieve the required voltage, e.g. 12, 24, or 48 V. The different capacitance and leakage current tolerances of the individual capacitor cells have to be balanced when charging using cell balancing, so that the individual cells do not fall below their maximum voltage range. Both active and passive methods are available. In simple terms, passive balancing is suitable for applications with a low load, active balancing for those with a high load and faster charge/discharge cycle sequences.

Passive balancing involves connecting a bypass resistor or a Zener diode in parallel to each cell to compensate for the leakage current from the cell and thus reduce the differences in capacitance between the cells. If all parallel-con-

nected resistors are identical, cells with a higher voltage should discharge faster than cells with a lower voltage due to the resistance, leading to balancing of the individual cell voltages.

Active balancing involves integrating voltage comparators either individually or in a circuit combined with other monitoring/charging functions. Active balancing does not continuously regulate the full compensating current, as is the case in passive balancing, but only when the voltage exceeds a predefined threshold. This makes active balancing highly effective and efficient, but also more complex and costly. In general, a supercap module which has most of the balancing already integrated is generally the better choice. In this case, balancing is optimally adapted to the cells.

Scaling of a supercap

At the first stage of a development with supercaps, it is crucial to define the values of the parameters in Figure 4. They determine the operation of the supercap in the application.

V_{max}: Maximum operating voltage

V_{min}: Minimum voltage below which the application will not work

Time: Time for which the supercap must deliver a voltage and a current between the maximum and minimum voltage

V_{drop}: Voltage drop at the capacitor due to the ESR (determined later)

Since most applications require almost constant current, but some also require a varying current, an average current (I_t) should be assumed.

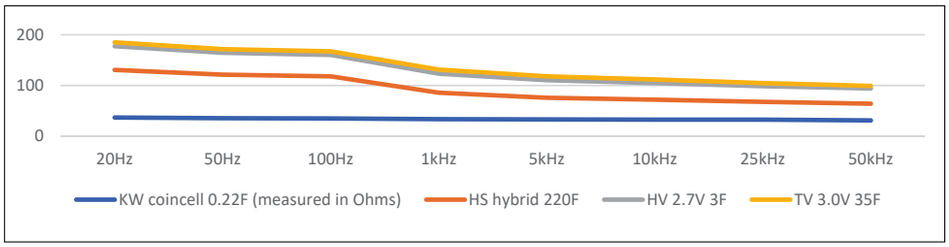


Figure 5: ESR response (in ohms) as a function of frequency

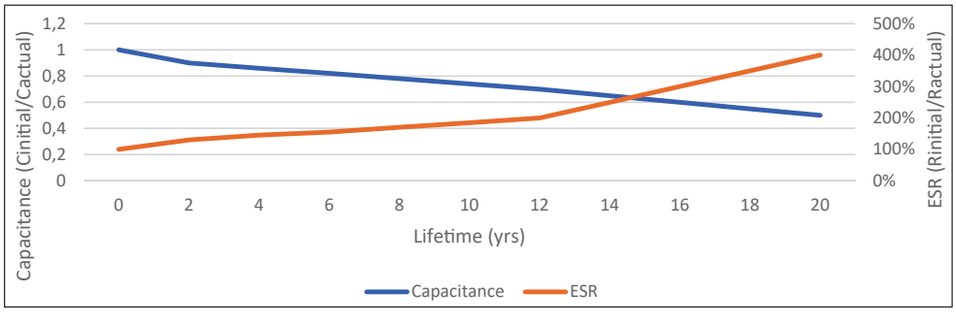


Figure 6: While the typical capacitance declines over the lifetime of a supercap, the ESR increases.

End of life of a supercap

A supercap reaches EOL (end of life) when, compared to the data sheet,

- either the capacitance has fallen by 30 percent (in some applications, e.g. aviation, 20 percent is applicable; in others, e.g. automotive, 50 percent)
- or the ESR has doubled (normally at approx. 30 percent capacitance reduction), in button cells (coins) an increase of 400 percent applies).

The relevant EOL criteria can generally be found under the heading "DC life" in the data sheet.

Capacitance calculation

The following formula (resolved for I_T or C) can be used to determine the required capacitance of a supercap:

$$I_T = C \cdot dV/dT = C \cdot (V_{max} - V_{min} - V_{drop})/T$$

$$C = I_t \cdot T/(V_{max} - V_{min} - V_{drop})$$

However, in the first step the voltage drop (Vdrop) is not taken into account:

$$C = I_t \cdot T/(V_{max} - V_{min})$$

A standard capacitance is then selected, which is above the calculated value. For example, if

the result of the formula is 13.2 F, a 15 F capacitor should be selected.

The next step is a second calculation that takes into account the maximum ESR for DC (or at low frequency). The DC ESR is normally defined in the data sheet; an example is shown in Figure 5.

Voltage drop (ESR drop)

$V_{drop} = DC\ ESR \cdot I_t$

$C = I_t \cdot T/(V_{max} - V_{min} - V_{drop})$

Taking into account the ESR Vdrop results in a higher final capacitance because the usable voltage range is reduced. This new calculated value must be below the previously selected capacitance. For example, if it is 13.8 F, the selected 15 F capacitor is still suitable. However, if the calculated capacitance is above 15 F, a capacitor with a higher capacitance must be selected. It is always important to take into account the degradation of capacitance and the ESR (Figure 6).

For example, if we take 80 percent of the original capacitance as the EOL and if the calculated capacitance value is 13.8 F, the capacitance actually has to be 20 percent above this, i.e. 16.56 F. This means that a 25 F capacitor, for example, should be chosen.

Temperature profile

A crucial factor when using a supercap is the temperature profile of the application, as it has a huge influence on various supercap properties, especially ESR, capacitance, and leakage current. In turn, this has an impact on its service life.

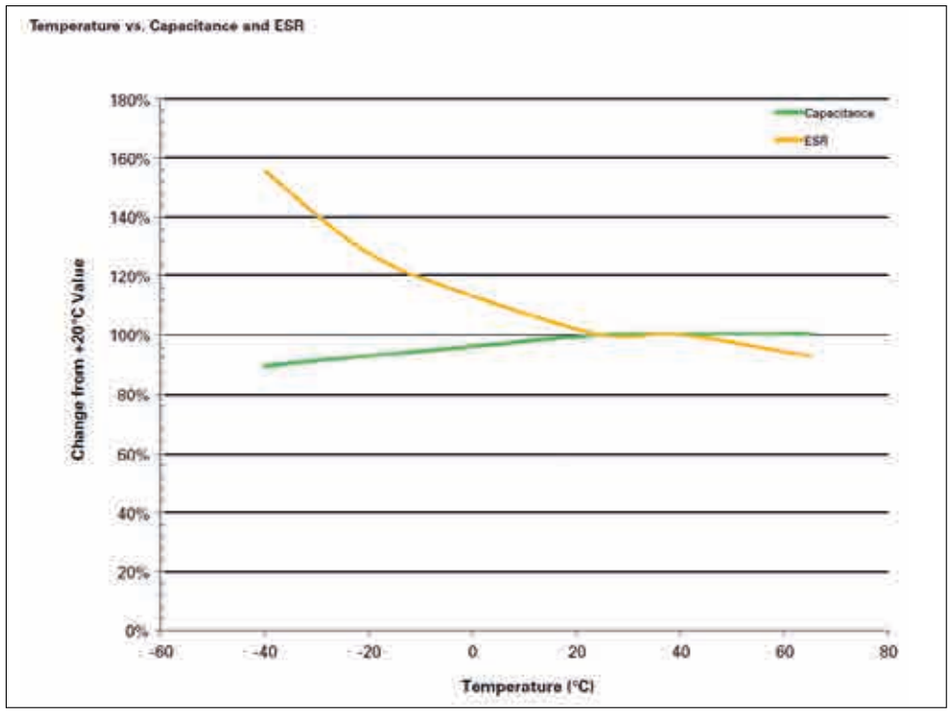


Figure 7: For applications that operate at temperatures below 68° F (20° C), the increasing ESR should always be taken into account.

The internal resistance (ESR) is almost stable in the medium temperature range and even falls slightly at higher temperatures (Figure 7). If the component is operated at temperatures below 68 °F (20 °C), the increasing ESR must be taken into account and incorporated into the calculations. By contrast, the capacitance is relatively stable over the entire temperature progression, only falling slightly at low temperatures.

In simple terms, the leakage current is the minimum current that has to be supplied to a supercap to permanently maintain the same charge or the same voltage level. It depends significantly on the temperature and the applied voltage. With every temperature increase of 50 °F (10 °C), it increases by around two to three times and rises sharply above 104 °F (40 °C) (Figure 8). A voltage reduction by 0.2 V causes it to fall by approx. 50 percent. It is proportional to the capacitance of the capacitor and depends on the electrolyte type. When using ACN (acetonitrile), it is slightly higher than with PC (propylene carbonate).

The leakage current plays a major role in applications where voltage is permanently applied, because the cells always have to be supplied with current to maintain the voltage at a constant level. For capacitors connected in

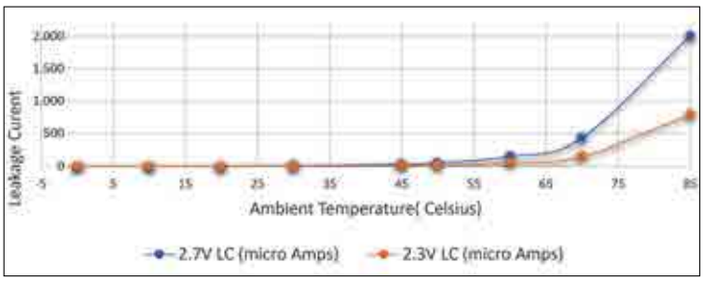


Figure 8: Leakage current from supercaps against temperature

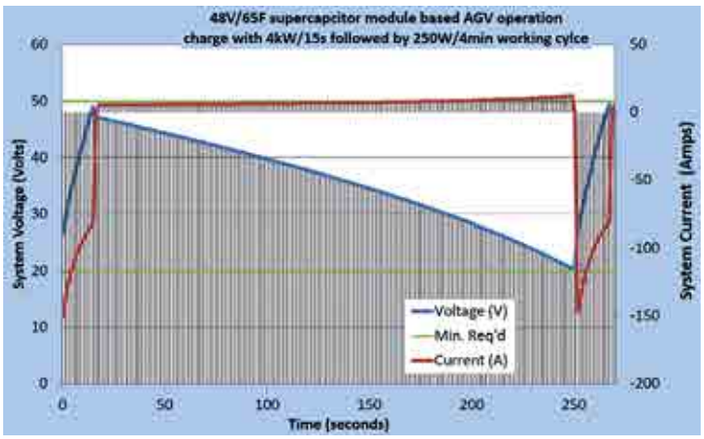


Figure 9: Working cycle of a driverless transport system with a 48 V/65 F supercap energy storage system with a weight of approx. seven kilograms and a volume of nine liters.

series that are permanently connected to voltage, the leakage current is also important. Its change over the service life takes the system out of equilibrium over time. Cells with a lower leakage current are charged slightly, while the cell with the highest leakage current is slightly discharged. This leads to further uneven aging of the cells in the system. Passive balancing would be a remedy here. As a rule of thumb: the balancing current should be ten times the leakage current.

Example of a supercapacitor system

In warehouses for modern e-commerce, the highly automated transfer to stock and picking processes are often performed by driverless transport systems (AGVs). They take boxes or pallets off shelves and convey them to a packaging station. An operation such as this normally takes two to three minutes. The power supply either comes from guide rails or a built-in energy store (battery or supercaps). This energy store can either supply power over the entire area and be charged after the shift or cover only part of the route and be regularly recharged at a charging station between jobs.

Supercaps have progressed to be a popular power supply solution for these kinds of driverless vehicles, particularly in refrigerated warehouses or where maintenance-free 24/7 operation is required. This is because they can be charged up during vehicle operation for two to three minutes of use within 10–30 seconds and thus allow the warehouse operator to achieve almost 100 percent vehicle utilization due to the short downtimes for charging. In addition, they can operate largely maintenance-free for over ten years and do not represent any safety problems, as can be the case with batteries. ■

Digitally controlled hybrid energy storage system

"More power, Scotty!"

A new digitally controlled hybrid energy storage system (HESS) can double the service life of a battery and improve the temperature response of the entire system, for example to support fast charging. Rutronik developed the patented system in conjunction with the University of Applied Sciences Zwickau.

By Andreas Mangler,
Director Strategic Marketing and Communication at Rutronik

HESS consists primarily of a battery and an ultracapacitor, also known as an ultracap or supercap (for more about supercaps, see page 51), along with ultrafast control electronics. This combination allows optimum division of work: with its high energy density, the battery, in this case a lithium-ion battery, constantly supplies the energy for the average power of the application. The supercap covers temporary peak currents. Its high performance enables it to supply high currents for a short time without being damaged. Afterwards, it is fully recharged within a matter of seconds. At ten years and at least 500,000 charge cycles, its lifetime is much higher than that of a battery, while its operating temperature range of –40 to +158 °F (–40 to +70 °C) makes it considerably less temperature-sensitive than batteries. This makes the entire system more robust and allows it to be used even at temperatures below 32 °F (0 °C) with no loss of performance. However, the key to the high-performance energy system lies in the optimized control circuit.

Dynamic load profiles with high peak currents

To understand the functioning of HESS, it is useful to look at the actual load profile, for example of an electric scooter (Figure 1). Here, we see numerous peak currents, particularly when starting the motors. There are also peaks below the zero line, caused by high recuperation currents. They all have a very steep gradient with a short peak. Overall, we have an extremely dynamic load profile with current changes in the microsecond range.

Images: Rutronik

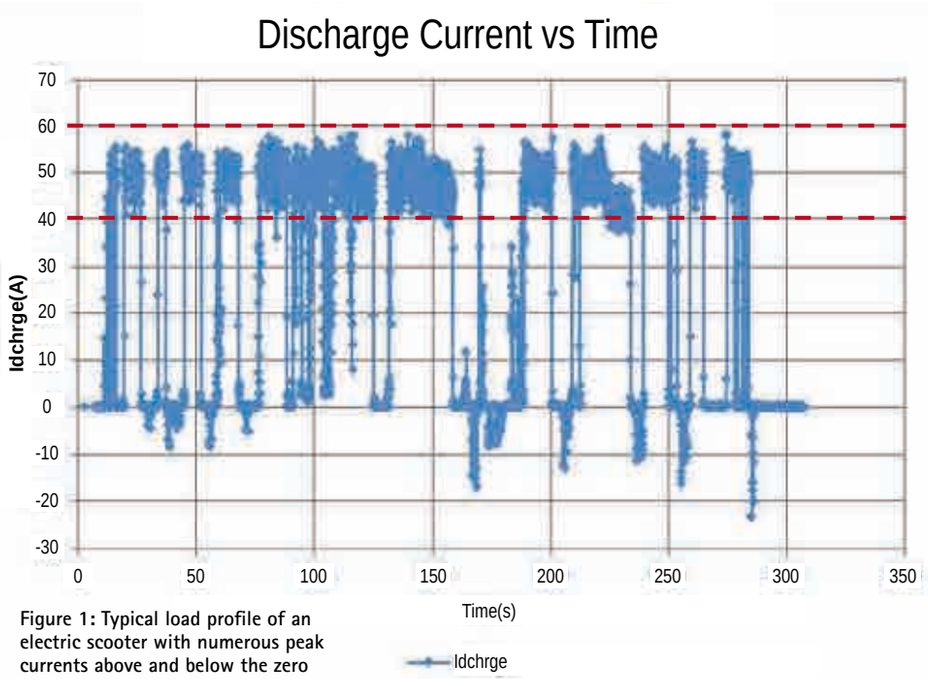


Figure 1: Typical load profile of an electric scooter with numerous peak currents above and below the zero

In a 48 V vehicle electrical system, which is increasingly becoming the standard for small vehicles in particular, there is a significant disequilibrium between the average power and the peak power. For example, the electric power steering requires an average power of between 0.25 kW for a relaxed driving style and 0.46 kW for an aggressive style. At the peak, e.g. due to an electronic steering intervention, a figure of 1.5 kW is reached. Thus, the ratio of the average and peak power is around 1:6 or 1:3. The gap widens further with an electric turbocharger. Here, average powers of 0.53 kW (relaxed driving) and 0.71 kW (aggressive driving) compare to peaks of between 7.5 and 10 kW – a ratio of around 1:16 and 1:12 respectively. Across all applications in the vehicle, on average only between 3.55 and 4.33 kW is required depending on driving style, but the peaks are between 25.3 and 27.8 kW.

For developers, this raises the question of how large the dimensions of the battery should be. If they choose a battery with a relatively low capacity based more on the average power, it has to deal with numerous currents above its nominal current. They permanently damage the battery and thus significantly reduce its service life. A battery with a higher capacity operates within its specified range more frequently and therefore has a longer service life. But the weight, volume, and costs increase.

HESS is the solution to this dilemma. The system limits the discharge current of the battery to its nominal current, e.g. 10 A, which means that it operates exclusively in its optimum operating range. The supercap covers the peak currents. To achieve this, a sensor measures the current increase rate (di/dt) within nanoseconds. The measured data is sent to the digital control circuit, which activates the MOSFET within a few microseconds, before the peak current actu-

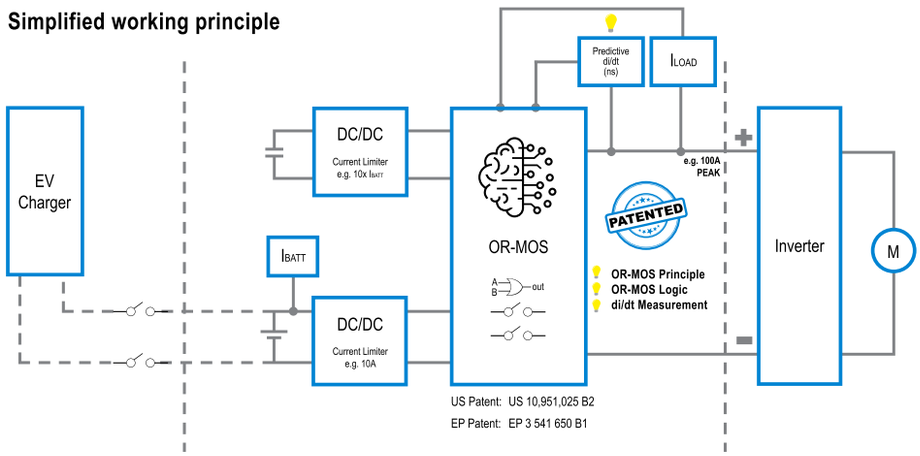


Figure 2: Thanks to ultrafast detection of current increase rates, the patented OR-MOS circuit can predict peak currents and switch between the battery and supercap in a matter of microseconds.

ally occurs. This ultrafast OR-MOS circuitry allows the supercap to cover the peak currents (Figure 2).

Three examples illustrate how HESS functions (Figure 3):

- At a current of 10 A, the entire current flows from the battery to the load.
- If the load only requires 5 A for a particular amount of time, the battery still supplies 10 A. The remaining 5 A is used to charge the supercap so that it is ready for operation when higher currents are needed.
- At a peak current of 30 A, the battery continues to supply 10 A, with the other 20 A coming from the supercap.

Detection in nanoseconds

Figure 4 illustrates the time levels that the processes operate on. Monitoring of the energy status is carried out in the second range. With "power sharing" between two energy stores, as in HESS with the battery and supercap, they are switched within a few milliseconds. The MOSFETs themselves are switched in the microsecond range, with the switching speed only limited by the gate delay of the logic arrays.

To facilitate this, the patented circuitry from Rutronik and the university detects the current increase rate within nanoseconds, enabling it to predict peak currents. This can also be used for reverse and recuperation currents to charge the supercap. In addition, the system has locking logic, i.e. the MOSFET switches lock one another to prevent a flashover in bridge circuits or the parasitic diode in the MOSFET.

To achieve this, the digital control circuit combines an ultrafast logic circuit with the fastest possible control algorithms in the power electronics, developed by Rutronik in collaboration with Prof. Lutz Zacharias and his team from the University of Applied Sciences Zwickau, along with ultrafast sensors. Rutronik calls this the Buck-OR-MOS-Boost topology. This enables HESS to create an ideal balance between energy and power density, capacity, costs, weight, and volume.

Rutronik is currently working on a reference design, which will be available to customers with a complete bill of materials (BoM). All components, from the semiconductors through to the supercaps and Li-ion batteries, are covered by Rutronik in its current range. ■

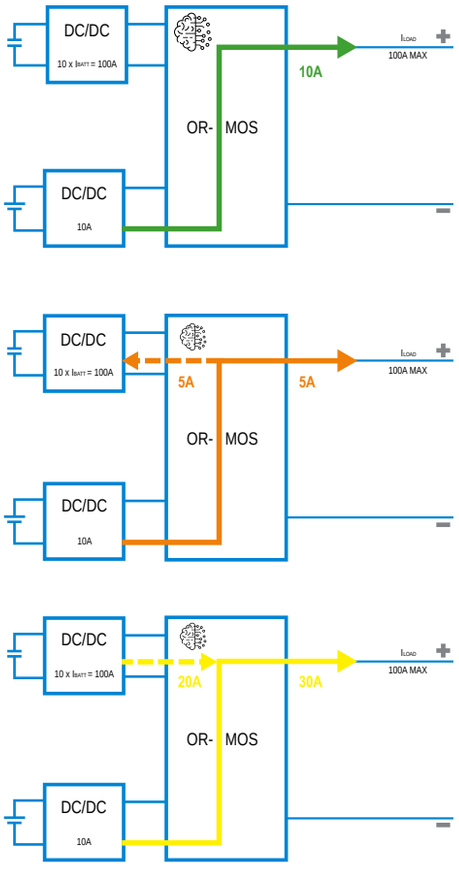


Figure 3: The OR-MOS circuit controls the current flow according to the current required by the load.

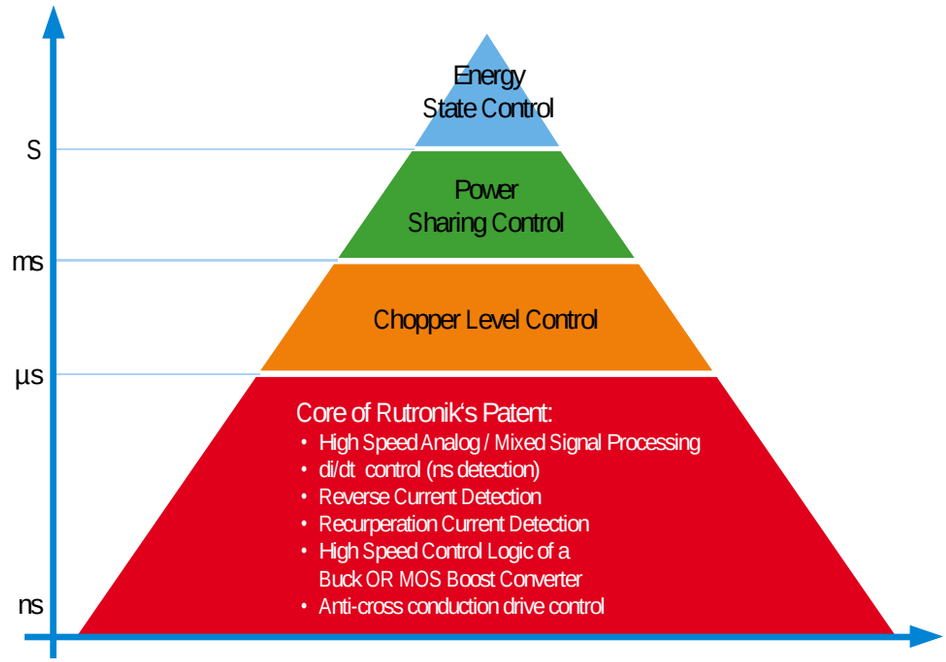


Figure 4: Ultrafast detection in the nanosecond range enables the MOSFETs to be switched in just a few microseconds.

The RutDevKit-PSoC62

Development aid for countless applications

Rutronik has devised the next development kit: the RutDevKit-PSoC62 boasts an extensive range of useful features and interfaces. Further, thanks to Arduino add-ons, it offers developers a modern and easy-to-use hardware platform that can significantly reduce development time.

By David Werthwein, Product Manager Digital, and Gintaras Drukteinis, Technical Support Engineer, both employed at Rutronik

The basis for the RutDevKit-PSoC62 is the PSoC62 (Programmable System on Chip) from Infineon. The ultralow-power microcontroller is based on 40 nm manufacturing technology and combines a dual-core Arm Cortex-M4 and Cortex-M0.

Due to an integrated rotary switch for selecting the switched-mode power supply (SMPS), the RutDevKit-PSoC62 offers a range of power supply options: it can be operated with a standard power supply, via USB-C, or even with a coin battery. The SMPS can also power the Arduino shields that plug onto the board and charge lithium-ion batteries in the 3.2 V to 4.7 V range. Moreover, it also has a current measurement connection.

In addition to the USB interface, the RutDevKit-PSoC62 has an integrated CAN-FD and RS-485 interface for communication between various devices or components, such as sensors or actuators. In combination with external PSRAM (64 Mbit QSPI) or NOR Flash memory (512 Mbit Semper NOR Flash with features for functional safety according to IEC 61508, e.g. Safe Boot or ECC), the development kit is particularly suitable for the development of wearables and sensors. Thanks to the microSD card slot, data can also be stored externally.

For even greater flexibility when using the controller, all general purpose inputs/outputs (GPIO) can be addressed via external pin connectors that can be soldered onto the kit. An integrated potentiometer helps with the first ADC adjustment and can also be used for subsequent applications.

The integrated power management IC (PMIC) is powered by the emergency power supply, i.e. a battery or supercapacitor. It controls the power supply for the controller and for the rest of the system (sensors and actuators or Arduino shields). Activation is via push button or the real-time clock (RTC) alarm. This enables the implementation of energy-saving solutions for applications in the industrial and automotive sectors.

The USB-C plug combined with USB power delivery capability enables more power to be transferred in the same period of time as its USB-A and USB-B predecessors. Charging times can thus be reduced significantly. As such, the RutDevKit-PSoC62 also ensures conformity with the USB-PD specification.

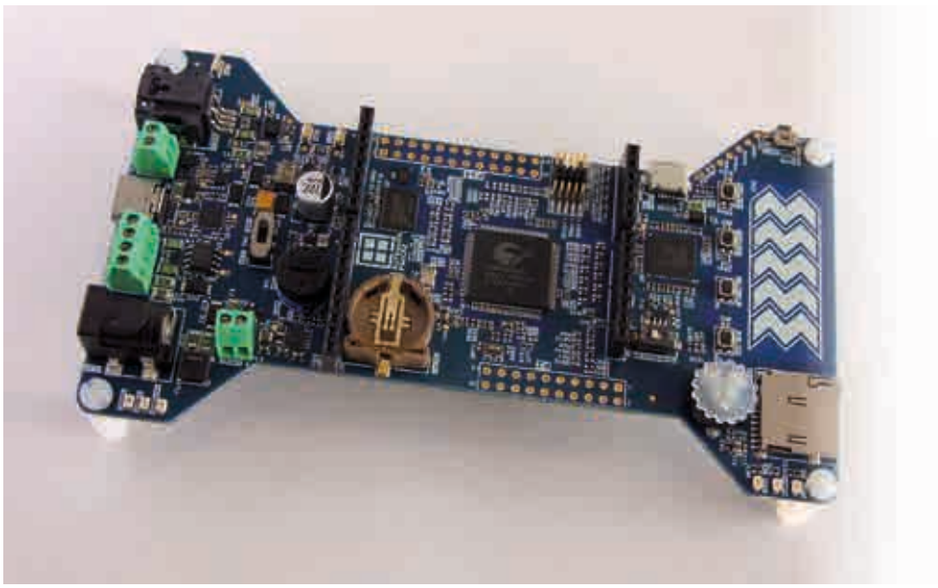
For elegant and reliable touch applications

The CapSense technology of the PSoC62 provides high sensitivity for accurate touch response, even in noisy environments, and fast sensing times for elegant, reliable, and easy-to-use capacitive touch-sensing applications. To do so, it utilizes a patented Capacitive Sigma Delta (CSD) sensing algorithm, which provides capacitive sensing through a switched capacitor technique with a delta-sigma modulator.

With the KitProg3 from Infineon, debugging is possible directly via the board without an external debugger. KitProg is a low-level communication firmware for programming and debugging PSoC microcontrollers. KitProg3 uses the industry standard CMSIS-DAP as the transport mechanism, while USB bulk endpoints provide fast communication.

Infineon provides the IDE "ModusToolbox" free of charge for programming. It includes

Images: Rutronik



The RutDevKit-PSoC62 offers many features to significantly reduce development time for countless applications.

a collection of easy-to-use software and powerful stand-alone tools, e.g. configurators. They can be combined flexibly with any compilers, editors, debuggers, and revision control systems.

Easy to extend with adapter boards from Arduino

The RutDevKit-PSoC62 is designed in the shape of a butterfly. Arduino stackable headers are located in the middle, where users can plug in any Arduino shields. This unique design not only ensures a recognition factor but also high electromagnetic compatibility (EMC). Since the Arduino shields are suspended in the air, the flow of current is not disturbed at high frequencies, e.g. by copper on the board.

Rutronik has already developed two such adapter boards and additionally provides the corresponding software stacks:

- The RutAdaptBoard-TextToSpeech shortens the development time for high-quality speech output. It comes with an integrated speech IC from Epson, which can output freely definable sentences in twelve languages with the help of corresponding PC software from the supplier. For this purpose, Rutronik has developed software for loading the created text files from the PC to the RutDevKit-PSoC62 via an operable graphical user interface (GUI). An audio amplifier and a 3.5 mm jack socket can then be used to control the sentences from the kit and output them via the speaker.
- The RutAdaptBoard-HMS is based on the Anybus NP40 network processor from HMS. It can be controlled serially and output various Industrial Ethernet and fieldbus protocols. It enables the integration of optimized infrastructure components, such as switches for high-performance Ethernet. Additional ASICs and FPGAs are not necessary for communication. EtherCAT applications can be implemented with the TwinCAT PC software from Beckhoff. Add-ons to other protocols are currently under development.

Needless to say, other Arduino shields can also be combined with the RutDevKit-PSoC62. However, users are expected to carry out the necessary software adjustments themselves.

Further, Rutronik provides firmware and demo applications free of charge. All the components needed for custom designs are available directly from Rutronik. The RutDevKit-PSoC62 and the two Arduino shields can be found at www.rutronik24.com. ■

Statement from Infineon

"Infineon welcomes the decision on the part of Rutronik to use the powerful PSoC62 microcontroller as the core of their newly developed RutDevKit. With the PSoC6 microcontroller family, Infineon offers the market a platform for IoT (Internet of Things) applications that enables connectivity, increased computing power and security at low power consumption and cost. To this end, we continue to rely on the service and customer reach of Rutronik, whose RutDevKit can provide customers with a distinct advantage in development."
Susanne Horn, Vice President Distribution Management EMEA, Infineon

From the left: Mathias Roettjes and Susanne Horn, Infineon, as well as Markus Krieg and Thomas Ulinski, Rutronik, presenting the RutDevKit, which is equipped with many components from Infineon. The center piece of the development kit is the PSoC62 microcontroller from Cypress/Infineon.

AIoT – Artificial Intelligence of Things

The electronic nose

The Internet of Things (IoT) often only develops its full potential when the things have a certain level of intelligence – when they are also able to analyze the collected data, for example. Especially in the fields of environment and health, IoT can be a very useful tool for humans: a prime example is the application of an electronic nose.

By Julian Eise, Product Sales Manager Opto at Rutronik

The majority of Europeans and North Americans spend their days indoors. The quality of indoor air has a big impact on our well-being: the lower the air quality, the more difficult it is to concentrate and remain alert. In the long term, it can also lead to health problems. The Chinese government is therefore promoting companies that develop products to improve air quality. But what does "poor air quality" actually mean?

Volatile organic compounds (VOCs) are the main contributors to air quality. They are in a gaseous state at room temperature and are then the smallest air particles. Sources are, for example, construction materials, plastics, and solvents; but microorganisms, humans, and animals also emit VOCs to the air. However, they can be detected when using appropriate sensors. These contain a substrate on which the VOCs can collect and react with the air. As a result, the resistance of the sensor changes. The sensors output the VOC content in ppm (parts per million).

When taking remedial action against a high VOC level, it is often helpful to know the origin of the particles. How a data mining algorithm manages to classify VOCs and assign them to a specific substance is demonstrated here using VOCs from perfume, alcohol, and vinegar. They are ideal for testing since they are common household substances whose VOCs can be harmful to humans in high concentrations and are easily detected by the VOC sensor.

How reference data is generated for the data mining algorithm

The examination is based on measurements. They provide the reference data needed to de-

Images: Rutronik / Eise

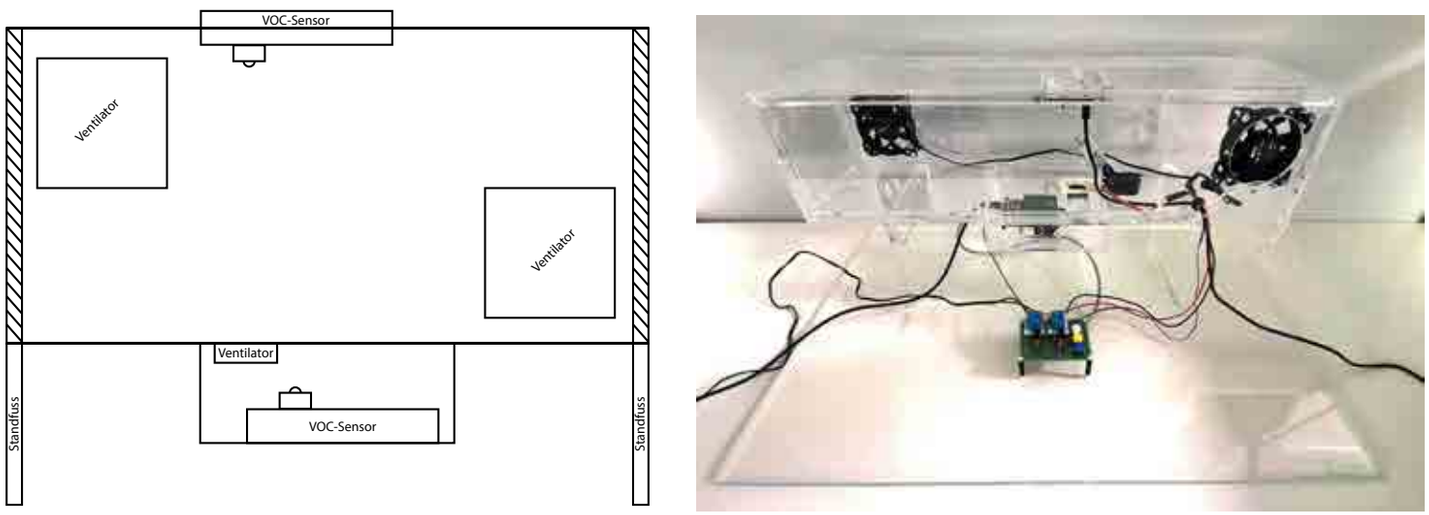


Figure 1: The measurement setup used to obtain reference data is very similar to the natural environment in which VOCs occur.

velop a data mining algorithm. In addition to a VOC sensor, a temperature and a humidity sensor were also used for this purpose. Since both of these values influence the behavior of the VOCs.

With the aid of sensor fusion, i.e. the combination of the measured values of various sensors, it is possible to generate a data set that is subsequently analyzed. Sensor fusion can also deal with the effects of disturbance during measurements, thereby providing a more robust overall system and more reliable detection of individual elements. This is particularly important when measuring VOCs, as even the smallest deviations can negatively influence the result significantly. In addition, the factors influencing the actual sensors had to be taken into account, e.g. long-term drift or signal accuracy.

The measurements were performed in a test setup that mimics a natural VOC environment (Figure 1).

Underneath an enclosed space there was a small chamber. A container of perfume, alcohol, or vinegar was placed inside. During the measurements, the chamber was open at the top, thus allowing the VOCs to escape into the larger space above. A small fan in the chamber was intended to increase the flow rate of the VOCs. Fans in the larger space ensured the VOCs dissipated faster when cleaning between measurements.

Both the chamber and the larger space contained a development board on which a VOC sensor board with a Sensirion Environmental Sensor Shield was mounted. This combined the SGP30 for sensing the atmospheric concentrations of VOCs and CO_2 with the SHTC sensor for humidity and temperature measurements.

Sniffing by the second

During the measurements, a software-generated measured value and a real-time stamp were output every second. To ensure the reliability of the measurements, each one was repeated ten times for each substance. The perfume measurements are shown here as an example. The values from the small chamber (Figure 2) indicate deviating behavior: 550 seconds after the start of the measurement, the VOC concentration was between 22,000 and 60,000 ppm, with 60,000 ppm being the maximum value that the sensor can detect. Results obtained by correlation testing showed that the highest values were measured at the highest temperatures.

The measurements performed in the large test space (Figure 3) showed an almost opposite pattern: in this case, half of the curves displayed a flat rise for more than ten minutes, and only two curves rose sharply, peaking at a VOC value of more than 2,500 ppm. Two others were consistently linear, reaching a maximum value of about 600 ppm. The maximum value of all measurements with this sensor was 7,600 ppm. Again however, the highest VOC concentrations coincided with the highest temperatures. Further, the measurements with high levels of humidity showed a faster increase in the levels of VOCs.

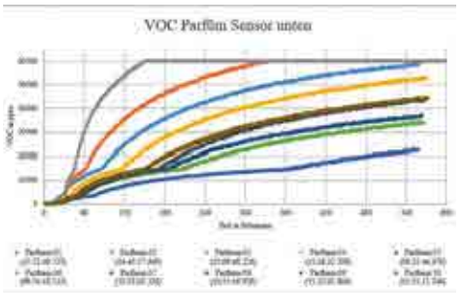


Figure 2: The behavior of perfume VOCs differs during the ten measurements in the small test chamber of the experimental setup.

Figure 3: Progress of the concentration of perfume VOCs in ten measurements in the larger test space of the experimental setup

Typical perfume, typical vinegar?

Once the measurements with alcohol and vinegar had also been completed, the results were compared. At first glance, the VOCs of alcohol (Figure 4, blue curves) and perfume (Figure 4, red curves) behave similarly. One

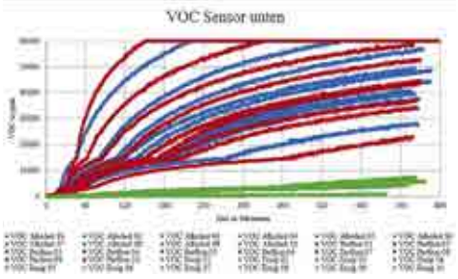


Figure 4: Concentration of perfume (red), alcohol (blue), and vinegar (green) VOCs in the small test chamber

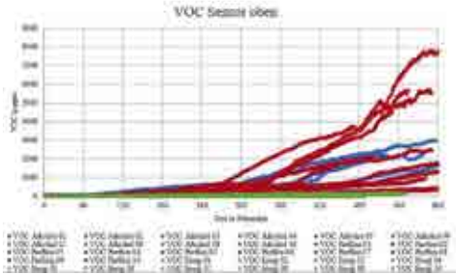


Figure 5: Concentration of VOCs as in Figure 4, but in the larger test space

reason for this is the roughly 80% alcohol content of perfume. But things are very different with vinegar: these VOCs volatilize at a much slower rate than those of the other two compounds. The conclusion drawn from the chamber measurements was therefore that it is possible to draw a physical distinction between vinegar and perfume as well as alcohol, but not between perfume and alcohol.

The measurements in the larger space provided a very different picture (Figure 5): differences between perfume and alcohol are also apparent here. The VOCs from perfume volatilize faster than those from alcohol. Once again, vinegar clearly differed from the other two substances.

Data mining algorithm learns to smell

The basis for the data mining algorithm had thus been generated. The first step of the algorithm is the principal component analysis (PCA). The PCA can be used to simplify and illustrate extensive data sets. In terms of the electronic nose experiment, this means that the data was used to create three color clouds that graphically represent perfume, alcohol, and vinegar, making them clearly distinguishable (Figure 6). The only exception: the measured value "Perfume 01" behaves in a similar manner to the alcohol measured values and is, therefore, located in the blue cloud representing alcohol. Such outliers can be used to train the system and improve distinction between results.

The second step focused on designing the data mining algorithm. This involved using the Orange3 tool, which offers three methods: logistic regression, neural networks, and a decision tree. To obtain the best overall results, all three methods were used on a trial basis and their results compared. According to Orange3, the neural networks produced the most accurate results, boasting an accuracy of 98.1%. For comparison: logistic regression achieved just 74.9%.

The labeled reference data, i.e. data labeled "perfume," "alcohol," or "vinegar," were thus fed into a neural network after the PCA to train it. The labels were subsequently removed from some of the reference data and the data was re-entered into the neural network. This was now the first time that unlabeled data had come into contact with the reference data of the algorithm. The data underwent the same process as the reference data and should therefore be assigned correctly to one of the three substances by the algorithm. The results are always incorporated into the calculations to ensure a constant improvement of the classification.

Successful smell test

Finally, the last step of the data mining process is to interpret and evaluate the findings. This is done by checking the accuracy of the measured VOC values and repeating the measurements to verify the estimates of the algorithm.

For this purpose, new measurements were carried out with perfume, alcohol, and vinegar. As shown in Figure 7, this experiment was successful: the algorithm can distinguish between perfume, alcohol, and vinegar on a mathematical basis, thereby detecting compounds based on VOC measurements.

To be able to use the algorithm in an application, it is first necessary to understand what the algorithm distinguishes and why. As such, the actual findings must be traced and documented with the aid of the reference data. Further steps can then be defined, e.g. triggering a warning signal when high VOC levels of alcohol are detected.

If newly recorded and classified VOCs are added to the reference data, it successively increases the accuracy of the algorithm. This makes sense, as the bigger the database, the better the algorithm results. If it is then used in a customer application, it can also store newly recorded compounds, train them on the basis of further data, and thus also classify foreign compounds. In addition, predictions are possible, so that the application can make a forecast about the source with very few measured values.

Conclusion

A purely physical distinction of VOCs from other substances is not clearly feasible. This is only made possible by a data mining algorithm. Relatively little reference data is sufficient for this purpose, but the reliability of the data and the accuracy of the classification increase with the number of measurements.

In addition: the development of VOC sensors is still in its infancy. Many suppliers are currently working on a better understanding of VOCs. As expertise grows, the sensors will provide better and more reliable measurement results. ■

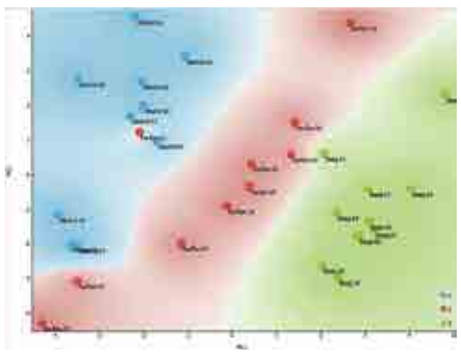


Figure 6: Each compound (perfume, alcohol, and vinegar) is represented as a color cloud in the principal component analysis (PCA).

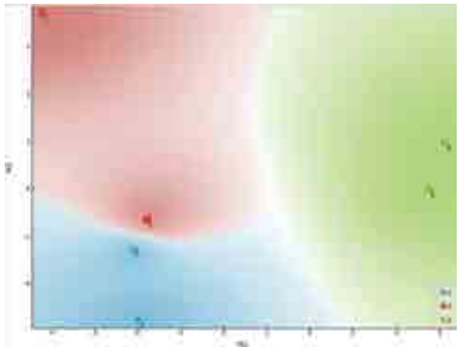


Figure 7: Successful test: the algorithm correctly assigned six new measured values to one of the three compounds.

Reference design for high-voltage circuit breakers

Disconnect the HV electrical system quickly and safely

In modern electric vehicles, it must be possible to disconnect the HV electrical system from its auxiliary units quickly and reliably. Cooperation between Rutronik's Automotive Business Unit (ABU) and Vishay has resulted in a reference design for an intelligent, resettable, and low-loss high-voltage circuit breaker.

By Bernd Wondratschek,
Field Application Engineer ABU
at Rutronik

Next-generation electric vehicles will offer up to three different voltage levels:

- A 12 V electrical system for small actuators and all control units
- A 48 V electrical system for larger power consumers such as water pumps, EPS (electric power steering), and radiator fans
- A 400 V to 800 V electrical system containing the battery pack and the largest consumers, such as the inverter, the high-voltage heater, the OBC, the HV/LV DC/DC converter, and the HVAC

The HV electrical system in particular demands a maximum level of safety and reliability for all the installed components, as disturbances here have a much greater impact on the electronic architecture than at the LV level. A fault, e.g. a short circuit in the HV heater, could place a permanent load on the battery, which is also connected to the HV electrical system, and, in the worst-case scenario, damage it extensively. To avoid this, the large consumers in the HV electrical system must be monitored consistently.

High-voltage circuit breakers instead of mechanical relays

Within this architecture, HV circuit breakers are an indispensable component. In the event of a short circuit, they safely disconnect the impacted auxiliary unit from the HV electrical system and the rest of the vehicle's electrical architecture, thus preventing greater damage.

Until now, mechanical relays have been used for this purpose. However, they have decisive disadvantages: when switching under load, arcs can occur that permanently damage the relays and thus accelerate their aging. The relatively slow switching behavior of the relays also leads to high switching losses. This generates more heat and active cooling may be required if an auxiliary unit should fail.

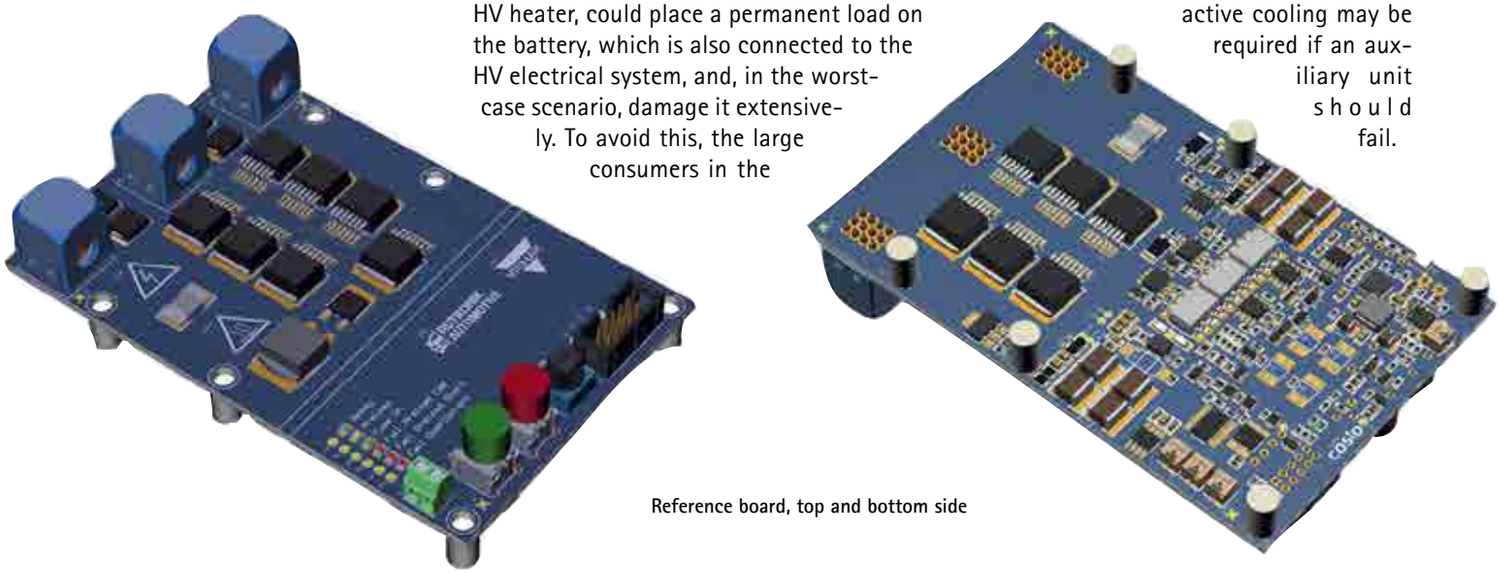


Figure: Rutronik

Reference board, top and bottom side

Figiure: Infineon

Figure 1: The TC375 lite kit from Infineon can be used with a wide range of development tools for motor controls and safety applications.

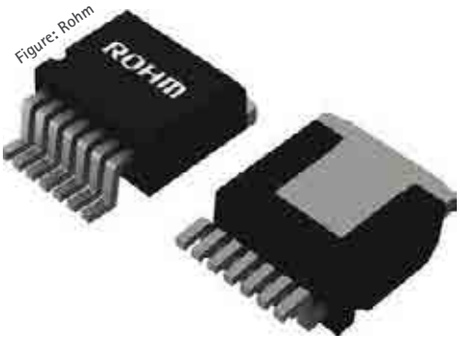


Figure: Rohm

Figure 2: The ROHM SiC MOS dies in the SOT263-7L package do not require additional heat sinks thanks to low power loss.

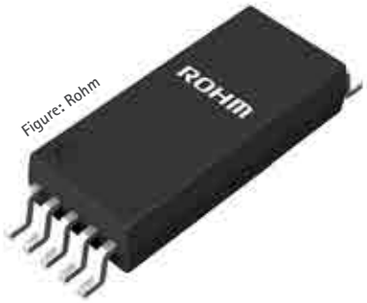


Figure: Rohm

Figure 3: A ROHM SiC-MOS driver with galvanic isolation

As an intelligent, resettable, and low-loss solution, Rutronik's ABU and Vishay's Automotive Division have now developed a reference design for an HV circuit breaker. It derives its "intelligence" from the control via a microcontroller and its ability to record measured values and provide diagnostic functions.

In terms of its circuitry, the HV circuit breaker consists of an isolated 800 V power stage with high-performance measurement and evaluation electronics as well as an Aurix TC375 lite kit with a second generation Aurix microcontroller from Infineon (Figure 2).

The power stage features high-performance semiconductors of the latest SiC generation from ROHM, galvanic isolation of the measuring channels, high-precision shunts, optocouplers, and protective components from Vishay. Control is ensured by the kit, which combines the Aurix TC375 32-bit single-chip microcontroller with an onboard miniWiggler micro-AB USB interface, an external power supply, and numerous connectors.

High switching capacity for the highest requirements

With the fourth generation 1,200 V SiC MOSFETs in an SMD package and precisely tuned control via a SiC gate driver, the HV circuit breaker is able to switch up to 40 kW. The SiC-MOS dies are located in an SOT263-7L-SMD package (Figure 3). This means they do not require an additional heat sink; the dies can dissipate heat directly to the PCB. The power loss is approx. 16 W at maximum switching capacity and the resulting heat can be passively dissipated at room temperature (77 °F/25 °C). The HV circuit breaker thus exceeds the requirements of premium OEMs.

A possible capacitive load is preloaded via a preload path with SiC MOSFET, thus preventing overcurrent at switch-on. Two preload modes (13 ms or 130 ms) are implemented for this purpose. A galvanically isolated optocoupler with phototransistor output (VOMA617A from Vishay) controls the SiC-MOS according to the relevant mode. This makes it possible to achieve the highest possible preloading of a capacitive load at maximum technical utilization without damaging the two series-connected preloading resistors.

The main MOSFETs are controlled by a galvanically isolated SiC driver (BM61S41RFV from Rohm), which is buffered by a new polymer tantalum capacitor (T51 series from Vishay). The capacitor features low self-inductance and high ripple current capability. This obviously makes it ideal for buffering peak currents that arise during the driver switch-on process.

The maximum load current (up to 50 A) of the HV circuit breaker can be set either via the microcontroller or individually via a potentiometer in stand-alone mode.

Two parallel-connected shunts (WSLP3921 from Vishay) in the power stage guarantee the extremely accurate bidirectional measurement of the battery current. Thanks to bidirectional measurement, it is also possible to record the current that is fed back into the battery, for example from auxiliary units equipped with motors.

The voltage is measured using single-chip voltage dividers from Vishay's CDMA series. The current and voltage measurement signals are transmitted in a galvanically isolated manner (floating measurement), processed by measurement signal amplifiers, and forwarded to the microcontroller. The newly developed VOA300 linear optocouplers from Vishay ensure galvanic isolation from the 12 V side. As well as being less expensive, they are characterized by a large coupling factor and a high bandwidth.

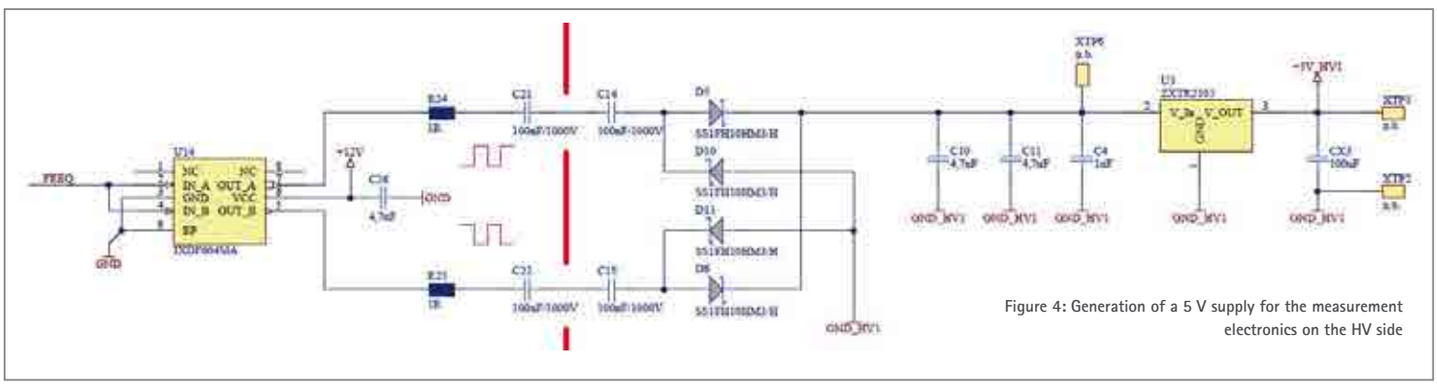


Figure: Vishay

Figure 4: Generation of a 5 V supply for the measurement electronics on the HV side

Galvanically isolated voltage supply

The measuring and evaluation electronics require a 5 V supply. For this purpose, an external 12 V power supply must be connected to the screw terminals on the PCB. The new SICQ464 DC/DC converter from Vishay converts this power supply into the 5 V required to supply the evaluation electronics; another component provides the required 3.3 V reference voltage for evaluation and calibration.

The measurement electronics also require 5 V, but this voltage must be provided in a galvanically isolated way. Eight high-voltage MLCCs of the VJ2225 series from Vishay, two of which are series connected, guarantee the galvanically isolated supply of both the measurement signal amplifiers and the SiC drivers and optocouplers (Figure 4). The MLCCs transmit the supply voltage generated by a 50 kHz push-pull driver stage and downstream diodes to the high-voltage side. The voltages required for the measurement electronics and for controlling the SiC MOS are 5 V and 18 V, respectively.

The Aurix board is connected to the HV circuit breaker via a ten-pin plug connector. It outputs the processed measured values via a CAN bus by means of the software; further, the circuit breaker can also be configured via the software. The software is based on Infineon routines, allowing customers to build their own projects upon this basis and easily implement new features. In this case, the Aurix lite kit works as a control unit that cyclically queries the current, temperature, and measured voltage values. The HV circuit breaker is equipped with a multiplexer (MUX) that transmits the respective signals via an analog connection in the plug connector to the Aurix lite kit for evaluation. The ten-pin plug connector also contains an I2C connection, which is used on the board of the HV circuit breaker to control the channel selection of the MUX and to transmit the status messages.

In addition to the precise current and voltage measurements, the reference design also has a diagnostic function for monitoring all measured values (temperature, voltage, current) and error messages, as well as further protective measures such as overcurrent detection with adjustable threshold, input and output transient protection. Additional TVS diodes are used to safeguard the power supply.

The temperature measurement of the circuit breaker is performed by an NTC, which receives the heat from the power stage via thermal jumpers (galvanically isolated thermal conductors) of the THJP series from Vishay. The input and output voltages are monitored by comparators with ratiometric thresholds, which thus also enables use in 400 V systems.

The reference design has six LEDs for the Ready (green), Preload (green), Fuse on (green), Fail preload cap (red), Fail preload short (red), and Fail overcurrent (red) status indicators. The HV circuit breaker can be turned on and off manually via two push buttons. Equipped with a package that allows access to all measuring points, protection against accidental contact is also guaranteed.

Design and service redefined for distribution

Rutronik provides the innovative reference design for the HV circuit breaker to customers with above-average requirements. This enables them to implement a state-of-the-art, high-quality circuit concept for electric vehicles within a short space of time. ■

Batteries for electromobility

A key element of future business models

Mobility is turning electric, that is for definite. But which battery technology will emerge as the most effective? What should battery management systems look like? What about recycling or second life for the batteries? And how will decisions on these issues impact the business models of those in the market?

By Andreas Mangler,
Director Strategic Marketing and Communication at Rutronik

Image: Samsung SDI

The OEMs' roadmaps are largely a done deal. Many want to have completed the switch to electromobility between 2025 and 2030, at least in Europe (for more information, read the article on page 76). Alongside the actual electric motor, the battery and the battery management system (BMS) are the crucial components.

Raw materials for battery cells

For 2040, Bloomberg is predicting that more than 50 million electric and plug-in hybrid cars will be sold worldwide, which corresponds to over 50 percent of all vehicles sold – a realistic scenario. However, there are limiting factors. Chief among them are generating the required energy, the charging infrastructure, and the raw materials, especially for the battery cells.

Based on the reduction in CO_2 emissions that the EU has set as a target for 2030, according to calculations by McKinsey, the required battery power will rise from 17 GWh in 2018 to 312 GWh in 2030. Thus, the demand for cobalt will increase from 2 to 34 tons, for nickel from 6 to 112 tons, and for lithium from 2 to 38 tons per year over the same period.

Battery chemistry and geometry

However, these calculations are based on the battery technologies currently used. If they were to remain state of the art over the next ten years, there would not be sufficient raw materials to meet the CO_2 targets. This is even more important when we consider that there are not yet any comprehensive concepts, no infrastructure, and no business models for a second life or recycling of batteries.

The chemical composition and geometry of a battery cell are the key factors that determine its properties. Currently, some car manufacturers use LFP (lithium iron phosphate) batteries, most of which come to market as pouch cells. They are relatively robust and allow fast charging over 5C, i.e. five times the nominal current.

However, because of their higher energy and power density, cylindrical NMC (lithium nickel manganese cobalt oxide) cells are the most popular and are set to be in demand for a long time to come. They are also used in other vehicles such as e-bikes and automated guided vehicles (AGVs). This is reflected in the huge demand recorded by Rutronik, the sole distributor of Samsung SDI round cells in Europe.

In addition, other lithium compounds are on the market, such as lithium nickel cobalt aluminum oxide (NCA) and lithium titanate (LTO), along with nickel metal hydride (NiMH). The latter are not relevant for electromobility. Of course, there are alternative batteries with different chemical compositions, but many of these have not yet been developed for series production.

The geometry of a cell is critical in its thermal behavior and thus determines the cooling requirement. Prismatic cells are relatively easy to handle. Although round cells are slightly more demanding in terms of thermal management, a large number of concepts are available due to them being so widely used.

Requirements for batteries

On the other hand, there are different requirements for batteries depending on the vehicle

class and type. For entry-level smaller electric cars where the focus is on low costs, an energy density of around 220 Wh/kg is sufficient. As a result, prismatic LFP cells are often used, although cylindrical NMC cells are also gaining in popularity in this sector. In mid-range and premium vehicles, they are the preferred battery type already. Here, around 300 Wh/kg or even 350 Wh/kg and powers of up to 150 kW are required for the powerful drives and long ranges. However, NMC cells typically only allow charging at a maximum of 5C. Different chemicals and geometries are necessary for higher currents.

The various vehicle concepts also involve different requirements. While 48 V vehicles are normally equipped with battery packs or modules up to 30 kW, significantly higher powers are needed for plug-in hybrids at up to 200 kW and for purely battery-powered vehicles at up to 600 kW.

Due to the diverse requirements, when choosing the ideal battery cell, a compromise between energy and power density, cooling effort, form factor, and costs is practically always necessary. Which cell technologies and chemicals will establish themselves in the medium and long term remains to be seen. But it is certain that battery capacities will have to continue rising to meet the need for higher powers, longer vehicle range, and fast charging. It is expected that solid batteries will make a breakthrough in a few years, significantly changing the world of electromobility. Because of their robustness and better thermal stability, they will become established in some areas in the long term. But in the mass market, suppliers are set to continue with cylindrical cells for some years yet. They are proven and allow outstanding levels of function within systems.

As well as the technical impacts, the battery technology that a supplier of battery cells or modules, a BMS provider or an OEM, chooses to rely on has far-reaching consequences for their business model. Every battery type requires a different kind of battery and thermal management. For example, a company that currently specializes in thermal management for cylindrical NMC cells may need to reposition themselves in ten years – a massive challenge for supplier companies.

We are in a constant transformation and change process. Everyone involved is aware that the current state of battery technologies in vehicles is just the beginning. CO_2 reduction or CO_2 neutrality along the entire value chain, i.e. from raw material extraction and processing to production of the battery cells and modules, has to be the objective – not just local zero CO_2 emissions from vehicles.

Back to the requirements and challenges in terms of battery management systems: one method of remaining sustainable is to use scalable hardware and software platforms, which can be applied to different cell chemicals and geometries, similar to OEMs' platform strategies for the drive train.

Battery integration

Three methods are available for installing battery cells in the vehicle: as a separate battery module, which can be removed relatively easily when optimized for second-life operation, as a complete removal quick-change battery unit, or as a permanently installed, space-saving assembly made up of the battery and chassis. The major advantages of the first option are primarily low costs, along with easy logistics and procurement. Integration into the vehicle chassis brings advantages with respect to volume and weight. This option has to be chosen at a much earlier stage, as OEMs cannot use standard modules or stacks and generally want to establish their own platforms.

In addition, choosing one of the two concepts has a far-reaching impact on the business model. The battery accounts for the largest proportion of value-added on an electric vehicle, around 40 percent, i.e. it makes a huge difference which parts of the battery value chain an OEM itself accounts for. When using battery modules, there are just a few as they are normally purchased almost as a standard component. Furthermore, they can be removed from the vehicle relatively easily, enabling other service providers, for example workshops, to replace individual modules when required. At the same time, they open up much greater opportunities for second-life operation or recycling than when the battery is permanently integrated into the chassis.

Optimum battery management

The battery management system ensures optimum operation of the battery in the vehicle.

To achieve the EU's CO_2 reduction targets, McKinsey calculates that a battery capacity of 312 GWh will be needed in 2030 – and for this 34 tons of cobalt, 112 tons of nickel and 38 tons of lithium per year.

Image: Rutronik

It monitors the charging/discharge currents and other influencing factors, primarily temperature. Based on the measured values, algorithms stored in the BMS ensure that the battery is protected against harmful influences and the degeneration process is minimized.

A Coulomb counter is frequently used for this purpose. It measures the charge supplied and subtracts the charge withdrawn to determine the charge level and capacity and ultimately the state of health (SoH) and the remaining useful life (RUL) of the battery. The SoH describes the performance and available capacity of a battery at the current time. For example, a 100 Ah battery with an SoH of 80 percent has a maximum capacity of 80 Ah. A battery in electric vehicles normally reaches its end of life at an SoH of 70 to 80 percent.

Measures with Coulomb counters provide relatively imprecise figures, which means that the end of life determined can vary considerably from the actual situation, or the battery may no longer have the maximum capacity assumed when it is removed from the vehicle.

The situation with thermal management is similar. In current BMSs, NTC thermistors are normally placed at neuralgic points in the battery pack. The values determined are then fed into thermal models for the battery cell to draw conclusions about the temperature inside the battery cell.

More reliable and precise information about the condition of the battery can be obtained from impedance spectroscopy, which entails measurement of the AC and DC impedance. The battery is excited with varying levels of current, which are combined with the resulting voltage to calculate the impedance. This enables noninvasive measurement and analysis of internal battery processes, e.g. charge transfer, electrode degradation, or diffusion, allowing conclusions to be drawn about the condition of the battery. Because the battery impedance depends on temperature, it also provides accurate figures for the internal temperature of the cells as a basis for configuring the vehicle thermal management system.

In the vehicle and in the cloud

To guarantee the safety of the energy store and the operational safety of the vehicle at all times and in any location, the BMS in the vehicle must function autonomously, even when there is no cloud connectivity – the key concept here is edge intelligence. This is the only way to set the battery to a safe operating condition at any time and prevent a thermal runaway. To achieve this, the measured data must be stored and processed in the vehicle.

In addition, all battery data can be sent to the cloud and used for big data analyses. By evaluating and comparing thousands of batteries, the processes can be better understood in terms of capacity, aging, and the thermal behavior of the battery – allowing genuinely optimum use of the battery. This applies both during its use in the electric vehicle and afterwards. The state of health of the battery determines when its "first life" in the vehicle ends and whether it will then have a "second life," e.g. as an energy store for photovoltaic or wind power plants; in other words, whether it will be recycled or destroyed. The data collected during use of the battery thus provides an opportunity to use the battery for a further business model.

Rutronik supports its customers with extensive know-how and with the appropriate components from Infineon. This provides all the necessary monitoring functions from the Coulomb counter through to DC and AC impedance measurement.

Recycling or second life?

There are currently no concepts, no infrastructure, and no business models that support comprehensive second life or recycling of batteries on a broad scale. This may be because there is hardly any market for this at present, because electronic vehicles are still too new. But it is easy to predict that this will change in a few years. And in view of the increasing demand for battery raw materials, it promises to turn into a very interesting market.

Various players in the market cover just some of the seven main stages of the value chain in battery manufacture – from extraction of the raw material to its refinement into its individual components, pre-production, production of parts such as the electrode and the cell, through to manufacture of modules and assembly to use in the vehicle. There are only a very small number of companies involved in extraction and refinement of the raw materials. They include the battery manufacturer CATL, which covers almost the entire value chain through to the manufacture of battery packs within the company. From the other side, the only vehicle manufacturer in a similar position is Tesla.

Recycling only eliminates two stages of the value chain, namely extraction and refinement of the raw material. And it is a highly complex and energy-intensive process. This means: it is only worthwhile if the state of health of the battery is still good enough. Therefore, second life and recycling is primarily a business model for companies that have the data determined during battery use in the vehicle. Anyone who does not have this can determine the state of health with a good BMS, even retrospectively, especially if comparison data for a new battery is available. However, this involves significantly more work as different data models from the original production have to be maintained to allow an A/B comparison. ■

Current measurements in electric vehicles

Sensor for high currents and voltages

As electromobility increasingly becomes part of daily life, there is a growing demand for sensors that allow the bidirectional measurement of AC and DC currents in vehicles. They need to be efficient, accurate, compact, and flexible to use. A new current sensor meets all these demands.

By Ralf Hickl,
Product Sales Manager ABU
at Rutronik

An increasing number of vehicle applications get their power from a battery, especially if the vehicle in question has an electric drive. At the same time, vehicle batteries and consumers are becoming increasingly powerful. This leads to higher voltages and currents in the vehicle's electrical system. Other standards and safety regulations have emerged in response to higher voltages, such as galvanic isolation from the other voltage layers of the electrical system, as well as higher costs for protection against contact. The high currents lead to greater power loss in cables and anything with an ohmic resistance. So when it comes to current measurements, ultra-low ohmic shunt resistors that can dissipate high power loss are required. They are, however, relatively large, which means a lot of materials, weight, and costs.

To protect the battery and the electrical lines of the vehicle's electrical system from overload, the currents must be measured, as a fire in the wiring harness could quickly turn the vehicle into a write-off. This protective function used to be carried out by fuses. In the future, it will be the job of semiconductor switches to shut down the power supply in the event of overcurrent or a short circuit. A prerequisite for this procedure is accurate current measurement. Precise measurement of the current is also required, above all, by traction inverters to control the drive. (An overview of various concepts for measuring direct current can be found in issue 1/2021 of Rutroniker, page 44.)

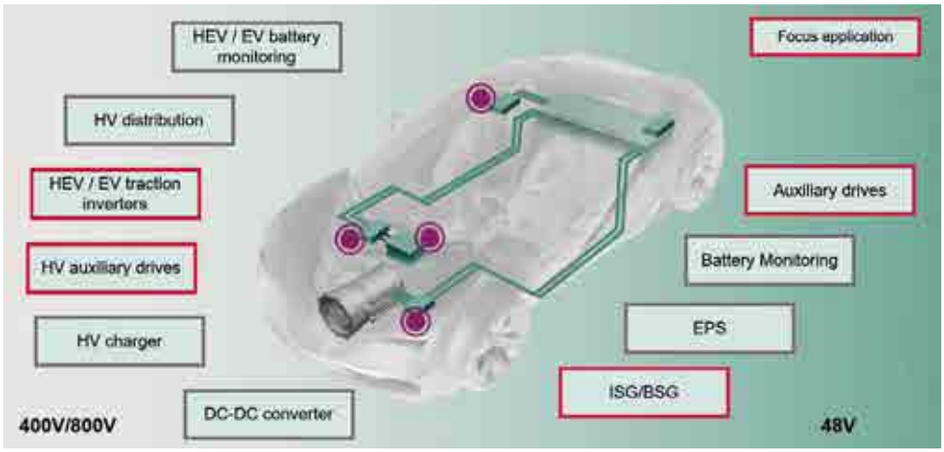


Figure 1: Target applications of the TLE4972 current sensor

Magnetic field sensors for galvanic isolation

As a result of various voltage levels of 12 V, 48 V, and high voltage in vehicles, the demands on galvanic isolation between these levels is increasing. Especially at high currents, sensors that measure the magnetic field generated by the current and transmit it as an analog signal offer great advantages: compared to a resistance-based current measurement using shunts, magnetic field sensors offer significantly lower power loss while at the same time providing galvanic isolation. These are particularly important features for high-voltage and high-current applications, since galvanic isolation ensures protection against contact, while the low power loss guarantees low self-heating.

To meet these challenges, Infineon has now further developed its TLI4971 current sensor specifically for automotive applications: in the new TLE4972, the measurement current does not flow through the IC package as in the TLI4971 with an internal current path. Instead, the sensor is placed on the PCB or power rail close to the live line without contact.

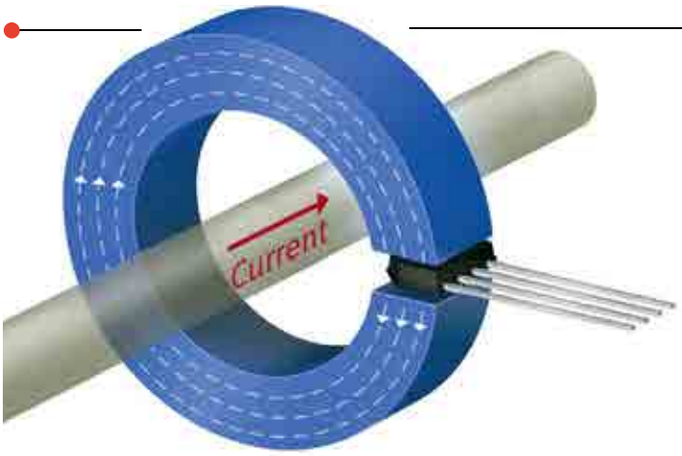


Figure 2: A magnetic field sensor with flux concentrator must be generously dimensioned to avoid permanent magnetization due to a short circuit and distortion of the system's transfer characteristic.

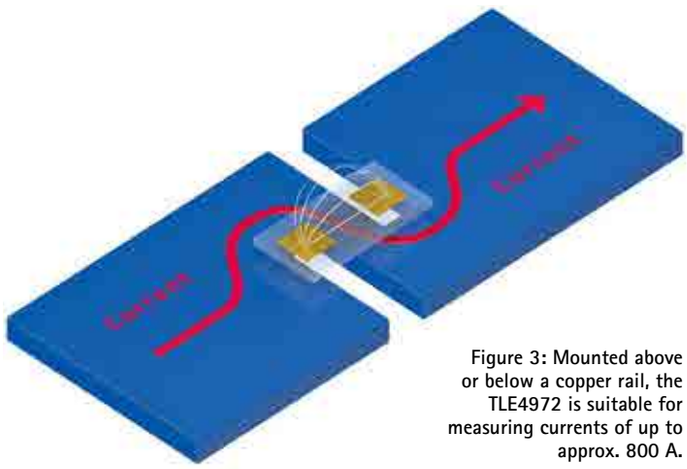


Figure 3: Mounted above or below a copper rail, the TLE4972 is suitable for measuring currents of up to approx. 800 A.

Figures: Infineon

TLE4972 is coreless ...

More powerful battery systems allow higher peak currents in normal operation and in the event of a short circuit. If the current sensor has a flux concentrator with magnetic core material, this must be generously dimensioned accordingly. Otherwise, a short-circuit current could permanently magnetize it, thereby distorting the system's transfer characteristic (Figure 2). Seeing as the TLE4972 is coreless, saturation of a magnetic core with subsequent remanence does not occur even in the event of overcurrent resulting from a short circuit, for example. This supports high linearity, and hysteresis in the transfer characteristic is avoided.

... fast ...

Measurements for fast overcurrent and short-circuit detection are needed, especially for the main battery switch. This is enabled by the TLE4972 thanks to two independent open-drain outputs with configurable trigger thresholds and programmable noise pulse filters. They signal overcurrent, e.g. to a microcontroller or gate driver. The typical response time of the over-current detection (OCD) open-drain output pins is less than 1 µs. The wide frequency range of the TLE4972 from 0 Hz to at least 120 kHz contributes to fast overcurrent detection without software-induced latency.

The differential analog output also provides a high bandwidth and can thus be used for the torque control of drive motors in electric vehicles.

... precise ...

Thanks to the differential measuring method, undesired stray fields, e.g. due to the current flow in neighboring conductors, have no impact whatsoever on the measurement signal. Additional sensors on the chip also compensate for the effects of temperature and mechanical stress. As a result, the accuracy and stability over the component's entire service life is increased. The data sheet states a measurement inaccuracy of less than 2% over temperature and lifetime.

The measurement range of the TLE4972 is scalable via software configuration and the mechanical design of the overall system.

The overall system, i.e. the sensor plus current conductors on the PCB or power rail, can be calibrated after assembly, thus allowing compensation of the production tolerances. Communication is via the Aout pin with power on.

... safe, ...

Infineon has developed the TLE4972 in line with ISO 26262, the international standard for functional safety in the automotive industry. Thanks to the high degree of self-diagnostic capability, the sensor meets the functional safety requirements for a safety element out of context (SEooC) in accordance with ASIL B.

The TLE4972 is, therefore, particularly recommended for use in applications that need to meet a high degree of functional safety. Developers can request the relevant documentation from Infineon. This data can be used to easily calculate and quickly prove the reliability of their overall system.

... and flexible

The TLE4972 outputs measured values in analog form. The output can be configured as fully differential, semi-differential, or single-ended. For the single-ended output mode, the sensor imports its reference voltage from an external source, e.g. from a connected analog/digital converter (ADC). In semi-differential mode, it exports its internal Vref to a pin, e.g. for use with a connected ADC. This counteracts common mode noise as long as it is constant throughout the conversion time of the ADC.

In fully differential mode, the TLE4972 provides two output signals in phase opposition. This mode of operation in conjunction with an ADC that has differential inputs ensures the best suppression of common mode noise signals along the analog transmission path. In this respect, the TLE4972 is ideal for Infineon's Programmable System on Chip (PSoC) series 4, 5, and 6, since they have 12-bit ADCs with differential inputs and share the supply voltage range of around 3.3 V with the sensor.

Two package variants

The TLE4972 is available in two package variants: in the TDSO-16, it is suitable for measuring currents of up to about 400 A flowing through tracks on or in a common multilayer board. For higher currents of up to approx. 800 A, Infineon recommends mounting on a specifically shaped copper rail (Figures 3 and 4).

For currents of between 400 A and 2 kA, the TLE4972 in a TSON-6 package is ideal. Measuring 4.5 mm × 3.5 mm, it can also be installed vertically in a power rail cutout.

Support from the supplier

Infineon supports developments with the TLE4972 through a new simulation tool that is available online via Infineon's Collaboration Platform (activation required). Further, the supplier offers four evaluation boards for various measuring ranges: TLE4972 EVAL STD PCB (up to approx. 200 A), TLE4972 EVAL INLAY (up to approx. 400 A), TLE4972 EVAL LAT BAR (up to approx. 580 A), and TLE4972 EVAL VER (up to approx. 830 A).

Conclusion

The TLE4972 is a component for the potential-free measurement of high bidirectional currents. It additionally signals overcurrent autonomously and meets the requirements of ASIL B as a SEooC. The sensor is, therefore, particularly suitable for motor control. Moreover, it can elegantly implement the electronics for an electronic high-voltage fuse in conjunction with the analog and digital features of a PSoC.

The experts at the Rutronik Automotive Business Unit (ABU) envisage the component in numerous target applications for measuring current in motor phases in BLDC drives for traction, auxiliary drives, e-turbo, integrated starters/generators, belt starters/generators, and in the high-side path of electronic fuses, battery management systems (BMS), and battery or load break switches. ■

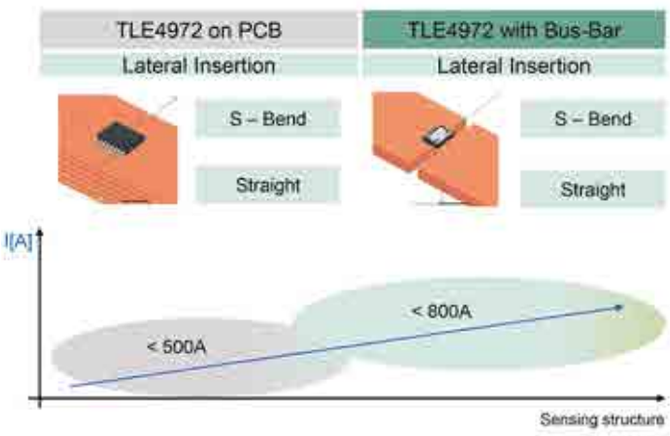


Figure 3: The two package variants of the TLE4972 offer various mounting options. This makes it suitable for measuring currents from 200 A to 800 A.

Voltage protection in vehicles

Keeping voltage levels within limits

High voltages can be present for brief periods in vehicles. And just a few volts above the specified voltage are enough to damage highly sensitive ICs. Adequate protection against electrostatic discharge (ESD), load dump pulses, and transients is, therefore, essential.

By Emilia Mance,
Product Sales Manager
Standard Products at Rutronik

In modern vehicles, all onboard electronics are connected to the battery and the alternator (Figure 1). As a three-phase generator, the alternator produces an alternating voltage that is converted into a pulsed direct voltage via rectifier diodes. Its level fluctuates as it depends, among other things, on the speed of the generator (engine) and the current power requirements of the windshield heating, lights, infotainment system, etc.

Voltage regulators are used to keep the onboard voltage and charging voltage as constant as possible and to protect the electrical system against overvoltages. They essentially consist of high-power Zener diodes.

Depending on the operating state of the vehicle, however, many other electrical faults can burden the electrical system. For example, it is possible that voltage fluctuations of between 8 and 16 V arise at the starter or that the switching of a relay or a loose contact leads to very short transients with significantly increased voltages. If left uncorrected, these transients would be transmitted along the power line, causing individual electronic components and sensors to malfunction or permanently damaging the vehicle's electronic system.

Load dump pulses have very high transient spikes

The biggest threat are load dump pulses, as they burden the network with large transient energy spikes lasting several milliseconds. These occur when the battery is disconnected while the alternator is running or the connection is poor due to corrosion. The alter-

Image: Rutronik

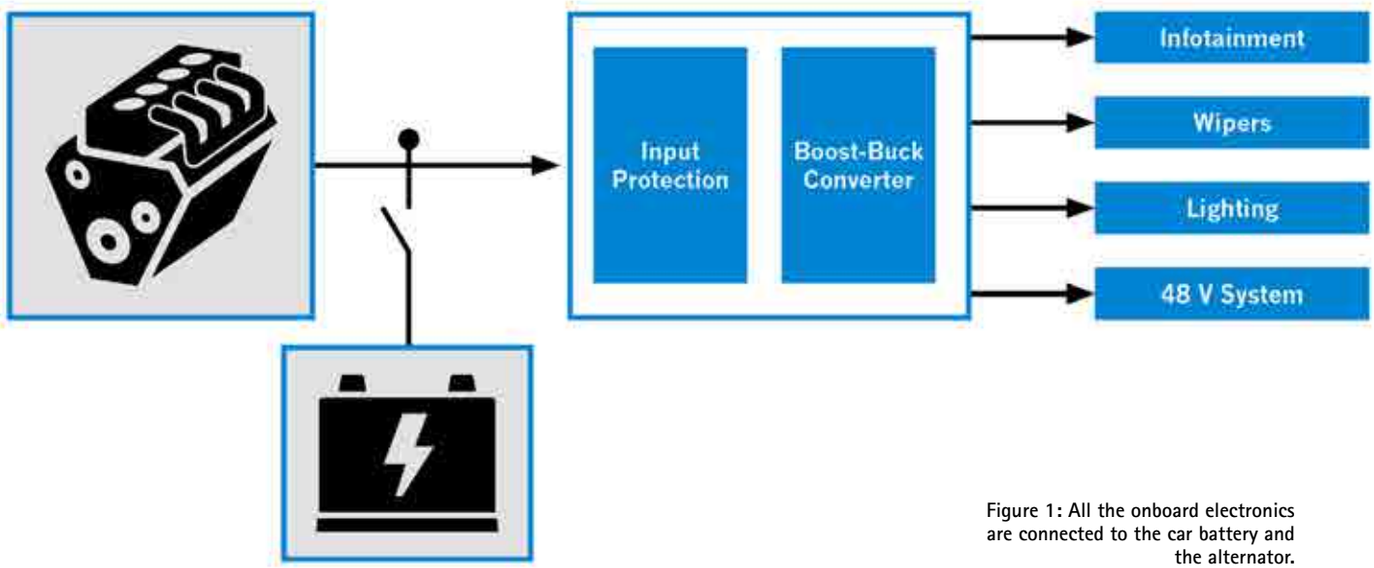


Figure 1: All the onboard electronics are connected to the car battery and the alternator.

Image: Rutronik

Figure 2: Diodes are used in almost all vehicle systems to protect against overvoltage.

nator then pushes the voltage of the vehicle's electrical system up to extremely high levels due to a lack of load. The high winding inductance of the alternator ensures that it takes a relatively long time for the changed load conditions to be regulated again – roughly a thousand times longer than with a Transil pulse.

The ISO 7637-2 standard describes voltage spikes that may occur in the electrical systems of a vehicle. It classifies five types of pulses with varying amplitude and duration (E1 to E5). The load dump pulses belong to category E5. They are further divided into pulse 5a without (Figure 3) and 5b with centralized load dump protection (Figure 4).

To demonstrate their protection against load dumps, electronic systems for motor vehicles must pass the relevant test as specified in the ISO 16750 standard (ISO-16750-2 5b). In this case, use of a TVS (transient voltage suppressor) diode is mandatory. It limits the load dump surge of the ISO-16750-2 pulse 5b to a maximum clamp voltage, thus preventing damage to the vehicle electronics.

Centralized clamp voltage too high for other components

If the centralized, integrated clamp voltage US* of the TVS diode on or in the alternator is too high to ensure adequate protection of the downstream electronic components, a local TVS diode with a lower clamp voltage must be used. The centralized, integrated TVS diode is bypassed or shorted without dissipating any load dump energy. As a result, all load dump energy will be dissipated on the lower clamp voltage TVS diode as clamping starts earlier. The result is a waveform that corresponds to the ISO 16750-2 5a pulse (without centralized load dump protection).

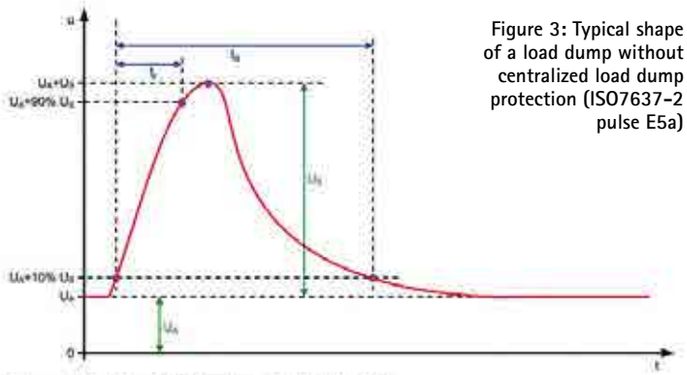
Since the pulse has particularly high energy and can last up to 400 ms, TVS diodes with high energy are needed. Rutronik's portfolio includes a range of TVS diodes from various suppliers for secondary transient voltage protection that comply with the ISO 7637-2 standard (see table). The required energy is supplied, for example, by the SLDXX series TVS diodes from Littelfuse. They are designed especially to protect against damage caused by the switching of inductive loads and generator load dump. The diodes are very impressive, with a fast response time of less than 1 ps from 0 V to BVmin. Their robust P600 axial leaded package conforms to industry standards.

When selecting a load dump protection diode, there are some parameters to be considered, which depend on the particular application: the internal resistance Ri of the alternator results in the short-circuit current Ipp. Ipp multiplied by the clamp voltage Vcl, to which the load dump must be reduced, resulting in the power loss which the protective diode has to cope with.

Centralized clamp voltage within the area of the local TVS diode

On the other hand, if the centralized integrated clamp voltage of the TVS diode in the alternator is within the voltage range of the local TVS diode, pulse 5b applies, i.e. with centralized load dump protection. The lower load dump power surges are then incurred at the local TVS diode. In this case, the operating voltage of the local TVS diode should be slightly higher than the clamp voltage of the centralized clamp voltage. The Littelfuse series TPSMB, TPSMC, and TPSMD, as well as SZ1SMB, SZP6SMB, SZ1SMC, and SZ1.5SMC are recommended for this purpose. ■

Image: www.demvt.de



Parameter	12 V electrical system	24 V	Unit
U_A	65 to 87	123 to 174	V
R_i	0.5 to 4	1 to 8	Ω
t_d	40 to 400	100 to 350	ms
t_r	5 to 10		ms

Figure 3: Typical shape of a load dump without centralized load dump protection (ISO7637-2 pulse E5a)

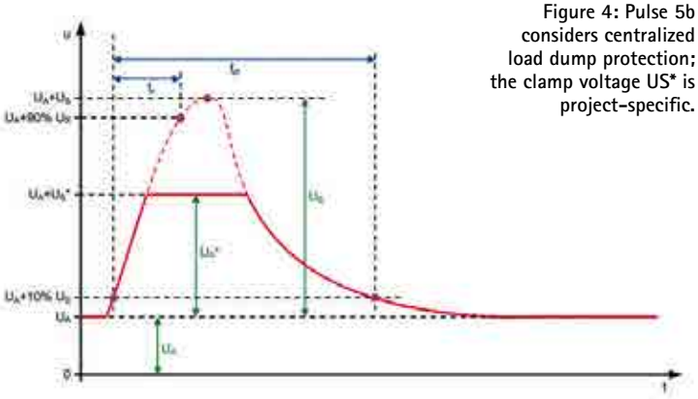


Figure 4: Pulse 5b considers centralized load dump protection; the clamp voltage US* is project-specific.

Image: www.demvt.de

Future mobility

Understanding the requirements of future mobility

In the next ten years, the car market will change significantly; some of the most exciting technologies are now making electric cars possible, with driverless or autonomous vehicles set to be available in the future. This article takes a look under the gleaming bodywork to find out what is driving and shaping future mobility.

By Marko Milosevic, Product Sales Manager Connectors at Rutronik, and
Wolf Martin Neugebauer, Distribution Corporate Account Manager Europe at Molex

The most obvious changes include the new energy source for vehicles. Consumer demand for alternatives to fossil fuels is growing, and the impact of CO_2 emissions caused by transport on the environment is a cause for major concern. Therefore, numerous governments and manufacturers have committed to gradually replacing gasoline-powered vehicles with hybrid and electric cars.

Thanks to the longer service life and shorter charging times of the batteries, they are now taking their place in the mainstream of the automotive industry. But the improved battery power is not the only innovation that is helping to make electric vehicles a reality. For some years, systems to recover kinetic energy have been used in racing cars, utilizing the energy released when braking to charge the onboard batteries. Car manufacturers have now adopted these systems to increase the range of their electric vehicles.

Well networked

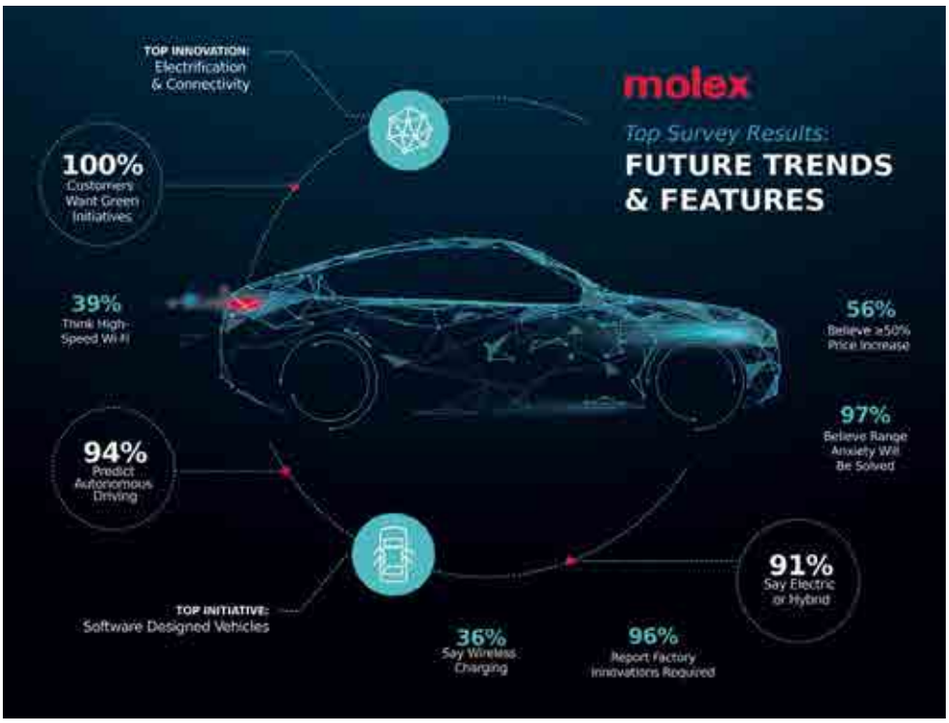
The next generation of vehicles will be part of an integrated network. For years, infotainment systems have been using GPS signals, and in recent times also information from external sources, to provide drivers with traffic information.

But it is the introduction of 5G connectivity that has really made the car a networked object. High-speed communication with a high bandwidth allows vehicle-to-vehicle communication (V2V) and remote software updates, enabling cars to use the latest technology without having to be taken to a service center.

Servicing will also become more targeted and cost-effective. Internal vehicle systems will monitor the condition of the vehicle and communicate with the manufacturer in real time using 5G technology. Preventive maintenance will be carried out precisely when it is needed and potential problems will be detectable before they cause any damage.

This has led to another new concept – the million-mile car. From a mechanical perspective, electric vehicles are much simpler than

Image: Molex



The Molex survey of manufacturers and suppliers in the automotive industry has delivered some fascinating results.

conventional, gasoline-powered cars as they have fewer moving parts and high-pressure systems. As a consequence, they are subject to less wear. According to some industry experts, combined with remote monitoring of servicing requirements, this will give new vehicles a far longer service life than previous models.

Autonomy thanks to sensors

An autonomous vehicle is simultaneously one of the most wanted and most complex developments in the automotive industry. Consumers are not willing to entrust their lives to a technology that is not yet tried and tested.

For a car to be able to drive itself, the technology has to be capable of understanding the external environment and interacting with it. It has to identify all potential hazards and know how to prevent them in order to immediately take the necessary actions.

This calls for a range of different sensors that detect the environment, particularly embedded imaging systems along with radar and lidar. The onboard electronics have to be able to collect a huge quantity of data and process it almost in real time, enabling the vehicle to respond in the shortest possible time.

Thanks to 5G communication, vehicles will exchange this data with other road users or devices – known as V2X communication (vehicle to X, where X could be pedestrians, cyclists, or the traffic control system in a smart city). This is intended to create additional safety for autonomous vehicles by detecting potential hazards and transferring them to the cloud so that other vehicles can autonomously respond to them.

Although the use of cloud-based data services will lead to safer driving, the key prerequisite is the lowest possible latency between detection and decision. This means that every vehicle must have its own intelligence in order to be able to take action quickly. This is where the concept of edge computing will play a role in the automotive world. Edge computing brings processing power close to the point at which it is required – on the edge of the network. This type of onboard processing will be indispensable in the cars of tomorrow.

Not losing the connection

All systems and applications that facilitate future mobility will have to be connected to one another in the vehicle – using intelligent and space-saving solutions. For compact systems with a 2.00 mm or 1.25 mm grid, two series from Molex are particularly interesting: the DuraClik plug connector system with a 2.00 mm grid is suitable for use with significant vibrations and at high temperatures and allows extremely reliable electrical contacts and very durable connectors in a small space. The plug connectors are available with different numbers of poles.

The PicoBlade Standard plug connectors with a grid of 1.25 mm provide easy, yet secure, locking, taking up little space and reducing the risk of accidental breaking of the connection due to vibrations or mishandling. PicoBlade plug connectors are available as wire-to-board and wire-to-wire connections. The Mizu-P24 is one of the smallest waterproof wire-to-wire solutions. The Mini50 has been specially developed for connections inside and outside a vehicle and is available in a choice of sealed or unsealed versions. Because of its small form factor and small connections, the Mini50 series is primarily suitable for low-current circuits. Molex also supplies various compact and high-performance antenna solutions for all standard antenna protocols and frequencies, in a range of form factors.

Understanding future requirements

To keep up to date with the latest trends, Molex has conducted a survey of manufacturers and suppliers in the automotive industry. The results reveal an industry that is utilizing the very latest technologies to create solutions for future mobility. The results of the Molex survey can be found at experience.molex.com/electronic-solutions/whats-next-in-the-automotive-industry/ ■

E-mobility boom

The third revolution of the automotive industry

It has been roughly 135 years since the first car took to the streets. Since then, the automotive industry has already experienced two revolutions and is now in the midst of the third. All the market participants must adapt to the changes. This is best achieved with partners.

By Uwe Rahn, Director Automotive Business Unit at Rutronik

The first revolution of the automotive industry was triggered by Henry Ford: he introduced mass production at the beginning of the 20th century through the standardization of parts and a division of labor. At the end of the 20th century, Japanese production engineer Taiichi Ohno's "lean" production – also known as the kanban system or kaizen – gave carmakers the ability to offer a diversified range of models. Today, it is not possible to identify one person as the leader of the revolution; rather, various technological and social developments are shaking up the market. One of the most important is the trend toward electromobility.

For a long time, suppliers and customers alike were reluctant to make the switch to electric drives. This has now changed fundamentally: the number of hybrid and electric vehicles registered for the first time in Germany has risen drastically within just one year: from 3% (2019) to 13.5% (2020). Roughly 600,000 of these vehicles are now running on German roads.

State-subsidized traffic transition

There are a number of reasons for this e-mobility boom: the German government has announced that e-car buyers will be able to apply for a innovation premium of up to €9,000 until 2025. Further, electric vehicles enjoy a ten-year tax exemption (for vehicles first registered by December 2025 up to December 2030). A 174% increase in funding applications for battery electric vehicles (BEV) and 428% for plug-in hybrid electric vehicles (PHEV) since 2016 shows that the government incentives are working.

This also applies to the company car segment. The non-cash benefit that company car drivers have to pay tax on when a company car is used for personal reasons is 50% less for plug-in hybrid electric vehicles and electric vehicles with CO_2 emissions of up to 50 g/km than it is for a combustion engine model, and 75% less for pure electric vehicles that drive with zero emissions.

Hybrid and electric car drivers also find an additional financial incentive when it comes to charging their vehicles. Rising fuel prices ensure that charging continues to be much cheaper than refueling. This price gap is likely to increase: the price of gasoline and diesel is set to go up by €0.30 a liter by 2024 due to rising CO_2 prices.

Increasing popularity

At the same time, consumer acceptance of electromobility is steadily increasing. Initial skepticism has gradually given way to the idea that it is an innovative contribution to sustainable and climate-friendly mobility. And range anxiety is fading fast thanks to the expanding charging infrastructure.

Similar developments can be observed around the world. According to the German Association of the Automotive Industry (VDA), the percentage of electric vehicles worldwide will rise from just under 5% in

Image: hkama/stock.adobe.com

2020 to over 31% by 2026. The association believes small and micro cars show the greatest market potential in both the short and the long term. Their share of the market is forecast to reach 55% by 2030, while medium-class and luxury cars are expected to account for only 22% and 19% respectively. This also suits automotive companies, which should be able to meet the CO_2 fleet limits with small cars.

Different countries, different speeds

Yet another incentive for suppliers is the ban on new gasoline and diesel cars in the UK, Denmark, Ireland, and Sweden from 2030, as well as CO_2 fleet limits. At the same time, ever more OEMs are setting their own phase-out dates: Ford has pledged that all of its cars on sale in Europe will be electric by 2030, VW plans to go all-electric by 2035 at the latest. Volvo wants to be an electric-only brand from 2030 onward. Audi will launch its final new combustion engine model in 2026. The German carmaker has also decided to phase out hybrids and will then focus entirely on all-electric vehicles.

OEMs are withdrawing from the development of new combustion engines at a correspondingly earlier stage, and their investments are now flowing into electromobility projects: the German Electrical and Electronic Manufacturers' Association (ZVEI) found that 29 global OEMs are investing €300 billion – with more than 45% of that destined for China.

Europe and China still dominate the automotive market, but the greatest level of growth is taking place in China. Work is underway on a brand-new infrastructure there, which will include a charging infrastructure with high-power charging stations in addition to electric vehicles.

Electronics sourcing to be a critical variable

Electromobility, but also other automotive applications, are leading to a growing number of electronic components in vehicles. They are increasingly found in the power train, in infotainment and anti-theft applications, in the chassis and body, and in occupant protection.

Roland Berger has calculated that the proportion of automotive electronics in the cost of all materials and parts will increase from 16% at present in a hybrid electric car to 35% in an all-electric luxury-class vehicle. The global automotive semiconductor market revenue is set to increase from $50.2 billion in 2019 to $65.1 billion in 2024. This means: electronics sourcing is increasingly becoming a critical variable in the automotive value chain. Long-term partnerships are a key to success.

Specific automotive support from the distributor

In such a volatile environment, strong partners are more important than ever. Rutronik recognized the signs at an early stage and founded the Automotive Business Unit (ABU) back in 2015. It focuses exclusively on developments in automotive electronics – which, in addition to electromobility, also include autonomous and connected driving. Utilizing their in-depth product and application know-how, the ABU's experts act as neutral consultants for engineering and manufacturing and as intermediaries between OEMs, suppliers, and service providers.

Together with partners from the semiconductor industry, the ABU develops innovative reference designs for automotive applications to enable customers to achieve short development times and a fast time to market. In this issue of Rutroniker, on page 63, we present a reference design for a high-voltage circuit breaker that the ABU has developed together with Vishay's Automotive Division.

As a platform for even more intensive exchange between decision-makers from OEMs, Tier 1 and Tier 2 companies, engineering service providers, component suppliers, and electronics manufacturing services (EMS), the ABU has launched the Automotive Executive Community (AXC). In personal exchanges or at exclusive events, the focus here is also on finding solutions to overcome new challenges in automotive electronics. ■

Auxiliary power supply for electric vehicle chargers

Converters for electromobility

The electronics in chargers for electric vehicles operate in a harsh environment, which means that all additional power supplies have to be designed for the corresponding overvoltage category and a wide temperature range. In addition, when it comes to the AC/DC and DC/DC converters used here: they have to be efficient and economical.

By Axel Stangl, Product Sales Manager Power and Line Manager for Recom at Rutronik,
and
Steve Roberts, BSc., MSc., Innovation Manager Recom

For a long time, insufficient charging stations was a barrier to the widespread adoption of electric vehicles. A comprehensive expansion of the charging infrastructure is now removing that barrier, in many countries at least. For example, in December 2020 alone China installed 112,000 public charging points – more than the entire public charging network in the USA. According to IHS Markit, this expansion will lead to a 14 billion US dollar market for charging infrastructure for electric vehicles by 2025.

Chargers integrated into the vehicle (onboard chargers, OBCs) will increasingly be customer-specific designs. By contrast, standard modular auxiliary power supplies will be used for charging stations and wall boxes. They run from around 2 kW in a wall box with AC output to 350 kW for a DC quick-charging unit at a public charging station. However, because of their proximity to the AC distribution network they all operate in a very harsh environment with extreme temperatures and sharp voltage drops, overvoltages, and voltage peaks. To meet international standards and thus function as economically as possible, the charging units also have to meet stringent requirements in terms of efficiency and no-load losses.

Images: Recom

The overvoltage category counts

Devices exposed to AC voltage transients should have a wide range input and comply with overvoltage category (OVC) level III (see table). However, most AC/DC products only comply with OVC II, or the OVC class is not even mentioned. For example, Category III includes the 5 W RAC05-SK/480 AC/DC converter from Recom. It has a very wide input range from 85 V to 528 V for a nominal 100 V to 277 V from the line to the neutral conductor in single-phase systems or 208/480 V nominal for connection from phase to phase in three-phase systems. The internal safety distances are wider than in standard modules to meet the stricter requirements of OVC III. In addition, the converter has a series of DC outputs. The converter can be operated at temperatures from –40 °F (–40 °C) to 176 °F (80 °C).

For higher powers, the 10 W RAC10/277 from Recom is suitable, with its input range of 85 V to 305 V (AC). The economical converter is also classified in OVC III and has single and double outputs for a wide range of applications. With a high output surge current value of 140%, it is also suitable for loads with high inrush currents. Both models come in a 2 in. × 1 in. package for PCB installation, have low standby losses and meet Class B EMC standards.

A typical charger also requires DC/DC converter functions for internal DC busbars and for supplying insulated communication interfaces. A high dielectric strength is often necessary here, along with a wide operating temperature range and a compact size. With its AC insulation capacity of 5 kV, the R05CT05S is exceptionally well suited in this case. It provides a 5 V or 3.3 V output voltage from a 5 V input voltage in an IC format package. The operating temperature is up to 284 °F (140 °C) and the components are fully protected against short circuits, overcurrent, excess temperature, and input undervoltage.

A new, slightly more powerful 1 W version was recently launched, with the RxxCTExx series in a tiny SOIC-16 SMT package with a height of just 2.65 mm.

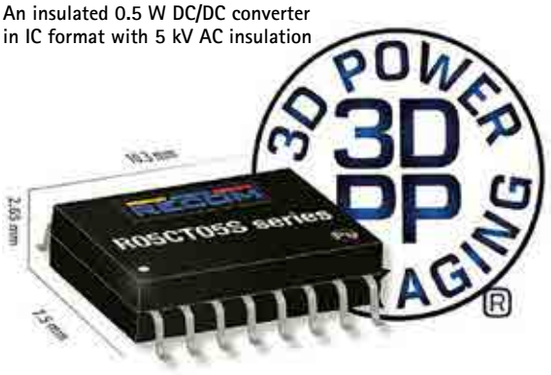
For very cost-sensitive applications, THT components such as the RKE/H series from Recom in SIP7 format are recommended. It has a wide choice of input and output voltages and features a high-efficiency and DC insulation of 4 kV, which is useful for monitoring battery voltage and current, which are often not related to ground.

Non-insulated DC/DCs for 48 V battery chargers

In some electric vehicles, 48 V batteries are used, e.g. in small vans, off-highway vehicles,

Overvoltage Category	Relevant equipment
OVC I	Equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level.
OVC II	Energy-consuming equipment to be supplied from the fixed installation. Examples of such equipment are appliances, portable tools and other similar household loads.
OVC III	Equipment in fixed installations and for cases where the reliability and the availability of the equipment is subject to special requirements. Examples of such equipment are switches in the fixed installation and equipment for industrial use with permanent connection to the fixed installation.
OVC IV	Equipment connected at the origin of the installation. Examples of such equipment are electricity meters and primary overcurrent protection equipment.

DC supply overvoltage categories.
EV chargers are typically in Category III. (Source: Recom)



An insulated 0.5 W DC/DC converter in IC format with 5 kV AC insulation

drones, and plug-in mild hybrid vehicles. Non-insulated DC/DC converters can be used as the main charging source for these, as the voltage is below the SELV (safety extra low voltage) limit of 60 V (DC). This enables the efficiency of the power conversion to be improved. A module such as the RBBA3000 from Recom is well suited, with its rated output of 50 A for a power of up to 3 kW. It is externally programmable from 0 to 60 V DC and the current is monitored, which means that a precise battery charging profile can be created. The DC/DC converter is designed in a base-plate-cooled half-brick format with dimensions of 63.2 mm × 60.6 mm × 13 mm. It has a load current measuring signal, eliminating the need for an external shunt that is susceptible to losses. With an operating temperature range of –40 °F (–40 °C) to 185 °F (85 °C), it is suitable for the charger environment and a variety of other applications. ■

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How digitalization, AI und ML impact the automotive industry

The magnificent seven

Digitalization, artificial intelligence, and machine learning are bringing many changes – including for future vehicles, their production, and their use. Seven trends can be identified in this area, which are set to shape the automotive industry between now and 2030 – with huge impacts on the procurement situation.

By Andreas Mangler,
Director Strategic Marketing and Communication at Rutronik

The automotive industry is set to change massively in the coming years. This is linked to seven megatrends in the automotive and mobility market between now and 2030.

❶ **Networked vehicles:** With connectivity to other vehicles (V2V) and components (V2X) such as a smartphone or parts of the transport infrastructure, e.g. traffic lights or smart parking solutions, they will optimize traffic flow and provide numerous services for users. Networking is also a prerequisite for trend number two.

❷ **Autonomous driving:** This includes all assistance systems, which will ultimately be developed to become the basis for fully autonomous driving. Autonomous driving is primarily of interest for trucks, which will be able to travel on the highway using "platooning," i.e. a series of multiple vehicles, and also for agriculture and other commercial vehicles, as well as vehicles that are not on the road, for example automated guided vehicles (AGVs).

❸ **Electromobility:** You can find lots of information about this on pages 66 und 76.

❹ **HMI:** Including both digitalized control concepts for user/vehicle interaction, such as touch-screen displays, and switches.

❺ **Changed customer structure:** An individual's car will no longer be sacrosanct, with a move away from private car buyers towards

Image: ufotopix10/stock.adobe.com

fleet operators and providers of various mobility-on-demand models.

❻ **New sales channel:** Some vehicle features, such as customer-specific functions, will be enabled for particular vehicle owners by remote access from the plant under a pay-per-use model, e.g. navigation accurate to the meter for courier services.

❼ **Digital industry:** The production process will become increasingly digitalized, based on predictive and self-learning systems**.**

These trends pose immense challenges for component supply. This is particularly true in 2021: After a phase of continuous growth - viewed over a long period of time - there was an extremely declining market at the end of 2019 and then in 2020 due to the pandemic. Production capacities of component manufacturers were scaled down, on the one hand because of the massive decline that had occurred during the first phase of the Corona pandemic, and on the other hand because of the shift to electromobility and the significant expansion of assistance systems.

All manufacturers are currently investing a great deal in making sure they are out in front when the next stage on the road to fully autonomous driving is reached. To achieve this, they require numerous camera and sensor systems, as well as communication components. Furthermore, the complexity of the software in vehicles and the volume of data processed are increasing. Translated into components, this means a sharp rise in demand for storage components, embedded MCUs, and processes – and therefore significant quantities of microchips.

Battle for semiconductors

The necessary elements come from a very small number of semiconductor production facilities worldwide. TSMC holds a key position, alongside just Intel and a few memory manufacturers, headed by Samsung. Against this backdrop, a TSMC production facility in Europe, perhaps in Germany, which has been discussed in recent months, would be an important step despite the huge investment, some of which would certainly have to be covered by subsidies. Without this kind of local partner in Europe, it will not be possible to satisfy the hunger for semiconductors in the future.

The situation is made more difficult by the fact that the same components are needed for infrastructure applications and for consumer electronics in large quantities. This is partially linked directly or indirectly to the automotive market. For example, if we look at the changed customer structure due to mobility-on-demand services and shared mobility, the same electronic components are required for all the elements in this scenario – starting with the smartphone, including the corresponding infrastructure, especially considering the establishment of the 5G network, and then booking and billing, through to the vehicles themselves. The situation is similar for electromobility, with the associated charging facilities and the smartphone for billing.

This applies particularly to China. After the first major COVID-19 lockdowns, the country has recorded a massive upturn due to huge investments in the 5G infrastructure and in

electrification of vehicles. The demand for components is therefore huge, which is having an impact on worldwide availability. There is no sign of a reversal in this trend in the short term.

Electromobility needs SiC and GaN

If we look at electrification of vehicles, for the pure power electronics for the charging infrastructure, the charging components in the vehicle, and the drive components, we are primarily talking about silicon carbide (SiC) and gallium nitride (GaN) components. The former are absolutely essential for the large drives in the vehicle and for fast charging at 150 kW or higher, as even small power losses here result in considerable heat sources. The situation for the SiC dies or modules is very similar to that for semiconductors: just a few manufacturers share the global market. They include two Rutronik partners, which are also investing heavily in SiC technology: Rohm and Bosch Semiconductors.

Bosch Semiconductors has a complex SiC roadmap. Mass production has not yet started, but A and B prototypes are already available. As a tier-one supplier, this almost makes Bosch a SiC self-supplier, but the company will also act as a provider of SiC components. Like Bosch Semiconductors, Rohm produces in Europe, which is not usual in this market scenario and is therefore more important than ever for domestic industry.

During the current period of transition from combustion engines to pure electromobility, Rutronik itself is supporting all concepts from mild hybrid to plug-in hybrids to pure electric vehicles, both with the necessary components and with technical support. The focus of our field application engineers' (FAEs) work is currently on battery and backup systems, charging infrastructure, and the electric drive train.

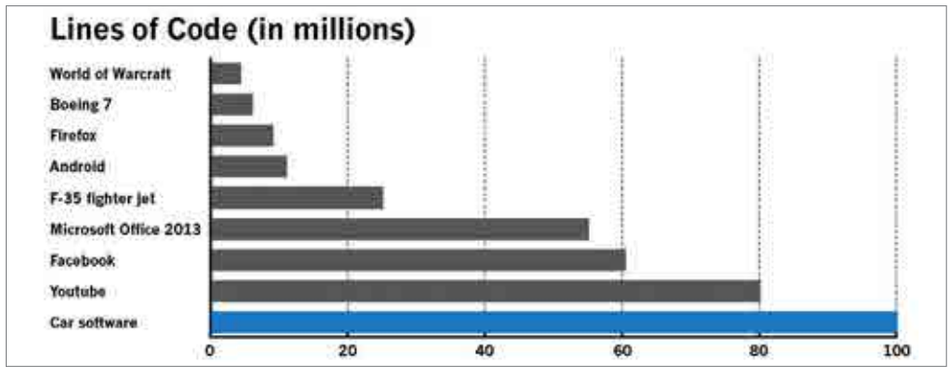

Image: Rutronik

A modern car contains 15 times as many lines of code as a Boeing 787 (onboard electronics and online support tools only).

Autonomous driving calls for different applications

In autonomous driving, another trend is identifiable: commoditization of the systems used. There are now very economical systems that are opening up innovative new opportunities in other applications using the same or similar technology, almost as a by-product of autonomous driving. One example is the Intel RealSense camera, the image quality of which enables autonomous driving in areas other than road transportation. It is available in a robust form for industrial environments, for example for applications in agriculture or in the consumer goods sector, e.g. robot lawn mowers. Software platforms, including open source, and software modules have already been developed for these kinds of applications, supporting numerous complex solutions and making them much easier to implement, e.g. object detection in an enclosed environment.

Data-driven business models

Some mobility trends, such as autonomous driving, networked vehicles, or pay-per-use models, are based on data. This means that new players like Apple and Google have entered the automotive market. Like other major Internet corporations, they have many years of experience in acquisition, management, and utilization of data, while automotive OEMs are having to create these business models from scratch. The latter are primarily relying on platform strategies, in other words a small number of scalable hardware platforms, to which a data-driven business model is added.

Both approaches, top-down – starting with the data – and bottom up – starting with the hardware, i.e. the vehicle – open up a major opportunity for distributors to gain a foothold with components for the data and signal processing in data-driven business models. They include not only the vehicle, but also cover networked cars, charging infrastructure for electric vehicles and shared mobility models, right through to the infrastructure for smart cities. ■

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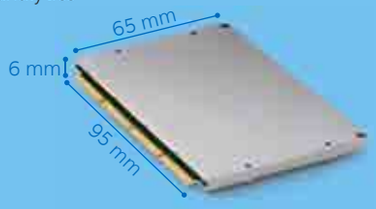

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