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Editorial

Thomas Rudel,
CEO Rutronik

Be a rationalist, not a reactionary

Dear readers,

The coronavirus crisis continues to grip the world. After early success in fighting the pandemic, infection numbers began to rise again in the third quarter. This presents major challenges for the global economy. Supply chains have been disrupted, there are production bottlenecks in some countries, and this in turn has an adverse impact on the flow of goods. And the pandemic means restrictions for us as individuals too.

Despite this – or perhaps because of this – it is important to remain rational, to maintain a broader perspective, and to avoid decisions taken at a whim at the expense of long-term goals. For Rutronik, this means that our product marketers will continue to work with field application engineerings, sales staff, customers, and partners on the innovations of tomorrow.

Whether it's about charging systems, 48 V on-board networks, or small drives for interior features in the automotive sector, the new 5G mobile communication standard, lighting concepts for agriculture, or new energy storage concepts, these are all topics that were important before the coronavirus pandemic and they still are now.

What is certain is that the global economy will change, and Rutronik will change with it, which is why we as an owner-managed family company have a particular responsibility to quickly identify disruptive technologies, new markets, and potential, as well as to participate in the development of innovations. This allows us to offer our customers and partners the support that they're accustomed to and rightfully expect from Rutronik.

Security of supply is a special asset in terms of disrupted supply chains and production stoppages. We are proud of having managed to preserve our ability to deliver without any limitations, even at the height of the pandemic. This has allowed us to help our customers maintain their own production capacities, which ultimately protects jobs. This is something that should not be understated, especially in such economically perilous times.

Thanks to forward-looking planning and personal commitment, our partners can obtain the right components for their project from us while also receiving the support of our qualified team's expertise – from initial idea to the end of a product's life cycle. This all-encompassing support is what defines us, and this is why our partners depend on Rutronik as their choice of distributor. We employ careful, long-term planning as opposed to relying on short-term gains and quarterly figures.

Let's work together to emerge from this crisis all the stronger – in keeping with our motto: committed to excellence!

Yours truly,

Thomas Rudel

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Power electronics

Si, Si-Schottky, or SiC Schottky?

The growth in the use of silicon carbide (SiC) in power electronics is gaining pace, because it allows for reduced power and switching losses as well as more compact form factors compared to silicon – and falling prices make it an increasingly compelling option for power semiconductor developers.

BY THOMAS BOLZ AND EMILIA MANCE, BOTH PRODUCT SALES MANAGERS STANDARD PRODUCTS AT RUTRONIK

In power electronics, the demand is for ever-greater switching performance at ever-higher voltages. Space requirements, weight, and efficiency also play a key role in choosing components for applications such as industrial motor control systems, renewable electricity generation, and electromobility. The aim is to minimize costs and workload while maximizing the quality of the applications.

While silicon (Si) diodes are usually the standard product of choice here, components based on SiC offer significant advantages, especially from a voltage of 600 V upwards. As high-performance components in circuit applications are always used with pulsed currents, they also need to account for the switching losses as well as the EMI (electromagnetic interference) generated by the reverse recovery currents.

Figure: buffaloboy/Shutterstock

Switching and forward voltage losses

Switching losses are incurred with each switching process – for example, when switching components on or off. As switching frequencies increase, so too do the corresponding losses and thus the overall power loss of the system. This is why, when switching frequencies are high, much of the total power loss of the system is due specifically to that. If Si components are used in these applications, the high power losses and resultant heat generation require the load current to be limited or costly cooling to be implemented.

In terms of network frequency, forward voltage losses play the greater role, while with switching frequencies from a few 100 Hz upward, the switching losses incurred with these are dominant.

With a very high reverse voltage, reverse voltage losses also play a role – especially at high temperatures. SiC Schottky diodes are ideal in these cases, as they offer very low reverse recovery currents and short reverse recovery times, which allows them to heavily reduce the associated energy losses.

To calculate total loss, we apply:

$P_l = P_s + P_t + P_r$ (switching losses + forward voltage losses + reverse recovery losses)

While power loss in the diode increases as the forward current increases with a forward bias, it remains constant with a reverse bias. This is why the leakage current (I_R) of SiC Schottky diode in the booster accounts for a not insignificant share of the total loss with a low output current.

At high currents, on the other hand, the forward voltage (U_F) is the dominant factor. Because the Schottky diode spends most of its time in reverse-bias operation, the reverse recovery current has a significant impact on the diode's power loss, so it is not enough to simply keep the forward voltage of the diode as low as possible. It makes more sense to consider IR and UF in tandem and to evaluate how they both contribute to the total loss of the diode.

The higher the output voltage of the booster, the higher the switch-on time and the longer the Schottky diode remains in reverse bias. Reducing the forward voltage with Schottky diodes increases the residual reverse current, making it necessary to find the ideal diode.

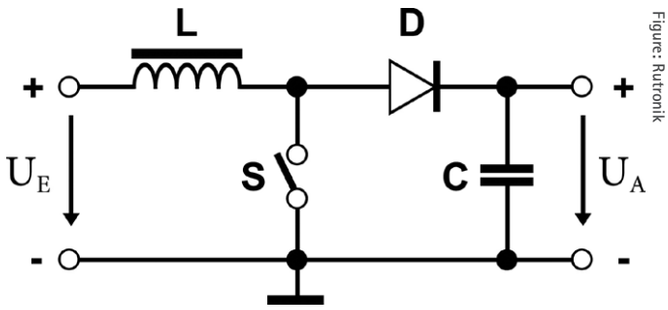

Figure: Rutronik

Boost converter principle

So when choosing diodes, it is essential to minimize forward voltage losses, switching losses, and charge while also maximizing breakdown voltage and soft commutation. To ensure good energy efficiency, considering total power loss instead of individual module parameters is often a more logical approach with Schottky diodes.

Due to their lower switching losses and the absence of reverse current spikes when switching the diode off, SiC Schottky diodes are much more efficient than Si diodes. Radio interference is reduced accordingly, and the EM behavior of the system as a whole is improved.

Operating temperature and thermal design

Thermal design plays a key role in power electronics systems to ensure a high power density, thus enabling the production of more compact systems. At high currents, Si Schottky diodes are susceptible to excessive heat output. The combination of high heat levels and elevated leakage current (I_R) can result in an increase in package and ambient temperature. Improper thermal design therefore might generate heat levels that cannot be dissipated. A possible result of this is thermal runaway, which is an extreme rapid build-up of heat that may damage the component and possibly even the system as a whole.

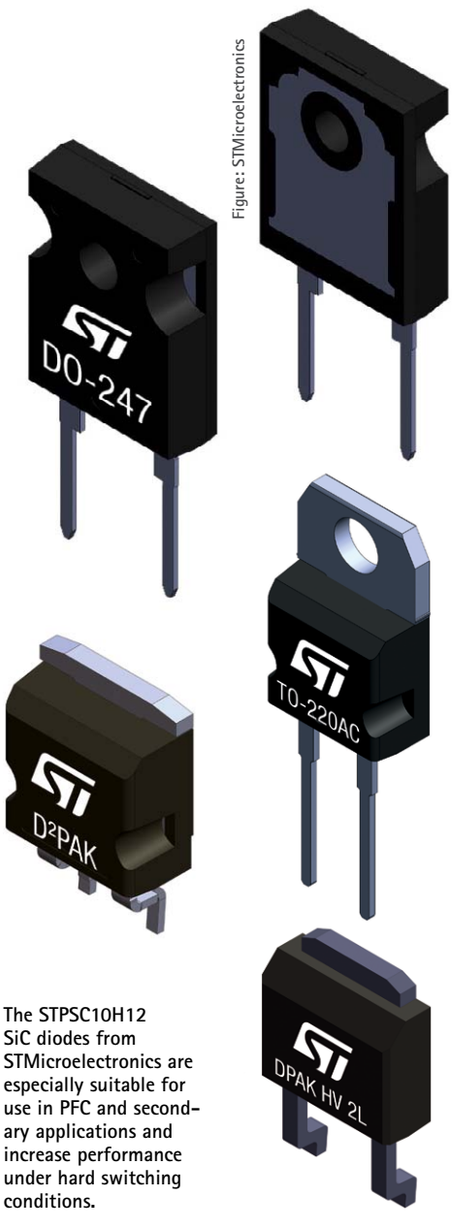

Figure: STMicroelectronics

The STPSC10H12 SiC diodes from STMicroelectronics are especially suitable for use in PFC and secondary applications and increase performance under hard switching conditions.

The temperature relationship of SiC Schottky diodes is massively different from that of Si Schottky diodes. The heat conductivity of silicon carbide is almost three times higher than that of silicon, making SiC ideal for higher operating temperatures. Less heat loss when operating SiC power semiconductors also entails greater efficiency and smaller heat sinks, which reduces the space requirements of the application and its weight.

As the forward voltage (V_f) increases with operating resistance at higher temperatures, this helps to prevent thermal runaway, enabling SiC Schottky diodes to also be connected in parallel. Due to their positive temperature coefficient, they are also more suitable than silicon diodes for parallel circuits at high voltages.

Power factor correction

European standard EN 61000-3-2 defines the limits for the harmonic content of the mains current for devices intended for sale to the general public and having active power. It also defines restrictions and exceptions where 75 W is exceeded. In practice, this means that the use of a bridge rectifier with subsequent filtering is in many cases not permitted for basic AC/DC conversion, as the mains current in this case is pulsed and exhibits a higher harmonic content. A booster known as a power factor pre-regulator or power factor corrector (PFC) is used to keep it roughly sinusoidal.

A CCM-PFC controller (continuous conduction mode) is the preferred active topology for very high performance PSUs. This design imposes the following requirements on the flyback diode:

- low reverse recovery time/charge (t_{rr}/Q_{rr}) in order to reduce the switch-on losses of the MOSFET and the switching losses of the diode
- a low forward voltage (V_f) in order to reduce conduction losses
- a soft reverse recovery curve to reduce electromagnetic radiation (EMI)

The SiC Schottky diode is thus the ideal solution in this case.

The best diode for each application

Si diodes are the first choice for low-voltage applications. In high-voltage applications of 600 V to 1200 V on the other hand, SiC diodes offer significant technical advantages that make the higher costs worth it. In the 200–600 V range, switching frequency and current are the critical factors. SiC diodes are required in various applications, including in charging stations for electric cars and on-board chargers (OBCs), in power converters for electric and hybrid vehicles, switched-mode power supply units and PFC circuits, as flyback diodes for inductors and MOSFETs/IGBTs, and as inverters in DC/AC converters for solar and wind power.

Rutronik offers ultra-fast high-voltage diodes from STMicroelectronics. These are ideal for cost-sensitive applications, and with a low forward voltage (V_f), they are suitable for the input of an AC rectifier bridge. These STTHxx Si diodes are designed for 600 V to 1,200 V with a current capacity of 5 A to 30 A.

The Schottky rectifier diode STPSC10H12 with SiC substrate offers a low forward voltage and a rated voltage of 1,200 V thanks to the large band gap of the material. Due to the Schottky design, it exhibits no reverse recovery time during switch-off and has a negligible oscillation tendency. Their minimal capacitive switch-off behavior is independent of temperature. The SiC diode STPSC10H12 is especially suitable for use in PFC and secondary applications and increases performance under hard switching conditions. It is specified for operation at junction temperatures of between –40°C and +175°C. An AEC-Q101-qualified version for automotive used is also available in the form of the STPSC10H12-Y, which also supports PPAP. ■

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Bipolar junction transistors

A challenger for MOSFETs

Digital switches are usually created using MOSFETs, but bipolar junction transistors have become an alternative to be taken seriously when it comes to models with low saturation voltages. For applications with low voltages and currents, they provide not only superior current amplification but also cost benefits.

By Thomas Bolz,
Product Manager Standard Products
at Rutronik

In load switch applications, the transistor needs to amplify the base current precisely enough for the output voltage to be close to zero or so that only the saturation voltage of the transistor is measurable. MOSFETs are usually used for this purpose because they do not require any underlying controller as voltage-controlled components. On the other hand, bipolar junction transistors (BJTs) are current-controlled components that require an underlying controller capable of continuously carrying current.

Bipolar junction transistors with a much higher current gain (h_{FE}) and a much lower saturation voltage (V_{CEsat}) can get by on a much lower base current, though. Their higher current gain reduces the base current enough to allow it to be directly switched by the microcontroller. For example, if a transistor needs to conduct a 1 A current and has an h_{FE} of 100, the base current needs to be at least 10 mA to ensure that the transistor is saturated. If the transistor provides a current gain of 500, 2 mA is sufficient.

It also significantly reduces the losses via the base bias resistor and the base–emitter voltage (V_{BE}). If the transistor is operated as a low-frequency switch, the low saturation voltage drops reduce the collector–emitter power dissipation and enable higher collector currents (I_C) on a standardized chip surface.

For a fully-on state, the low-V_{CEsat} BJTs therefore require a low base–emitter voltage of just 0.3 to 0.9 V, making them ideal for low-voltage switching applications. This control voltage applies across the entire temperature range.

If bipolar junction transistors are used as saturated switches, they can also affect the conductivity of the collector region, thus reducing the collector–emitter resistance considerably while saturated ($R_{CE(sat)}$). MOSFETs do not offer this conductivity. However, this does increase the reverse recovery time of the base, which means longer switching cycles.

Due to their transit frequency, these transistors can only be used for applications involving up to several hundred kHz. Dividing the transit frequency by the current gain factor produces the cut-off frequency. This is defined as the threshold at which the current gain falls to –3 dB (i.e. a factor of 0.707). It is important to maintain some distance from this cut-off frequency.

Longer service life for mobile applications

Due to their high gain performance, low-VCEsat BJTs are also more efficient than conventional BJTs and MOSFETs, so when combined with a base resistor, they can replace a MOSFET and a Schottky diode. This provides benefits in the form of longer battery charge life and reduced component costs, especially with mobile and/or battery-operated applications such as electric toothbrushes, shavers, or hand mixers. Bipolar junction transistors are also

Figure: IB Photography/Shutterstock

Bipolar junction transistors provide mobile devices with a longer service life.

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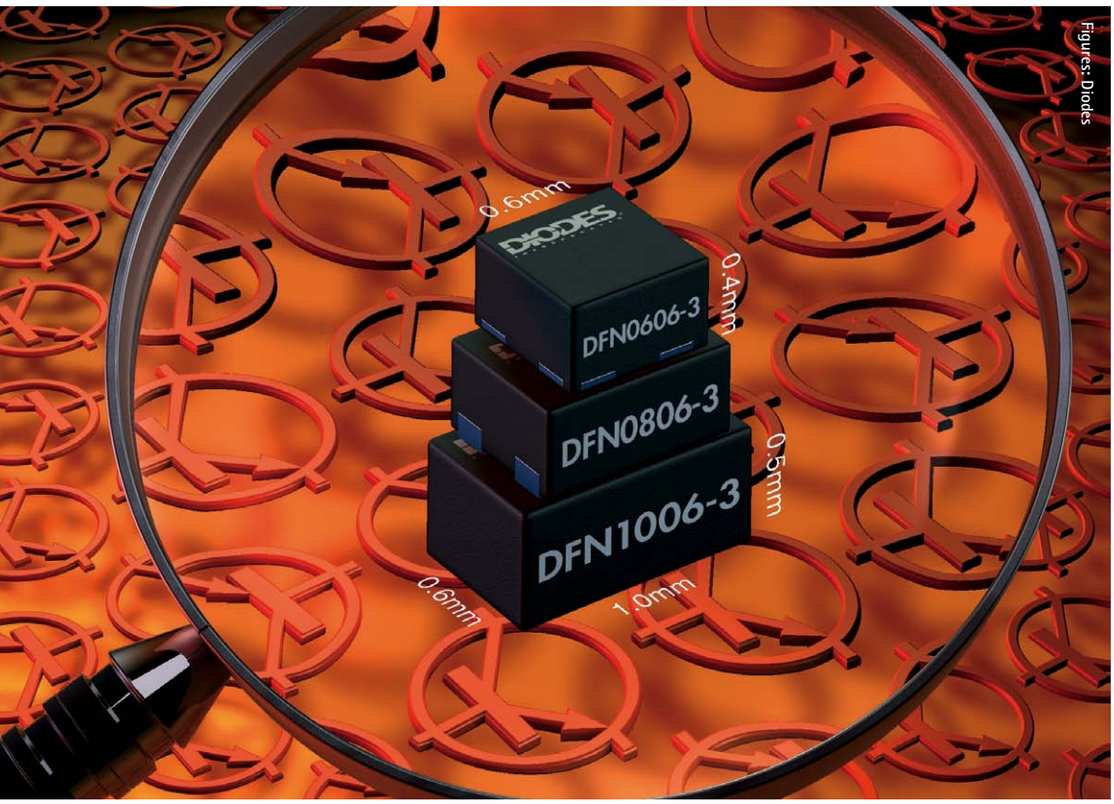

The 45 V NPN small-signal bipolar junction transistor BC847BFZ from Diodes is 40% smaller than comparable DFN1006, SOT883, and SOT1123 components while providing greater performance.

much less sensitive to ESD (electrostatic discharge) compared to MOSFETs with an ESD tolerance of over 8,000 V, and they also offer internal protection against voltage spikes.

The gain of the transistors increases even further with higher temperatures. At the same time, the share of the base–emitter voltage relative to the forward voltage ($V_{BE(sat)}$) present at the maximum permitted base current is reduced. As a result, the collector–emitter resistance at saturation ($R_{CE(sat)}$) is lower for BJTs than the on resistance ($R_{DS(on)}$) of a comparable MOSFET. BJTs also generate less heat at higher current densities and/or under continuous current than MOSFETs with the same chip surface area.

Also, the saturation voltage remains proportional to power loss at a given load current. Low-V_{CEsat} BJTs therefore offer lower power loss, which in turn results in a reduced need for heat sinking. Considering the total power loss, however, it is also important to consider the losses incurred in controlling the base. When using low-V_{CEsat} BJTs with higher gain, these too are lower.

Another advantage of bipolar junction transistors is that they can block in both directions, eliminating the need for an additional anti-parallel MOSFET. They are also cheaper, thus offering a significant cost advantage over MOSFETs.

High switching performance

BJTs can provide a switching performance many times higher than their maximum permitted power loss because a transistor operating as a switch has two stationary operating points. If enough base current flows into the first, this results in a collector current that closes the switch, across which there is only a residual voltage drop. As the base current at the second operating point is therefore zero, the transistor at which the full operating voltage is present serves as a block. The transition between the two operating points is very fast. This allows the load line to be positioned such that it cuts the power loss hyperbola when the transition from conducting to blocked transistor and vice versa is fast enough and does not occur too frequently. The stationary operating points only need to be located below the hyperbola.

Because BJTs enable very fast switching in the linear range and offer a high pulsed current with a high current density, they are suitable for use as drivers for controlling MOSFETs. This allows for reduced dimensions and lower costs compared to specialized IC driver solutions.

Small components, great performance

Low-V_{CEsat} BJTs are typically available with a maximum collector–emitter voltage (V_{CEO}) of 12 to 100 V and collector currents of up to several ampere in SOT packages. The smallest bipolar junction transistors in the world are currently delivered in DFN0606-3 ultra-small packages from Diodes. With a footprint of 0.36 mm² and a height of just 0.4 mm, the 45 V NPN small-signal bipolar junction transistor BC847BFZ is 40% smaller than comparable DFN1006, SOT883, and SOT1123 components and still offers greater performance than comparable transistors with much larger form factors because its leadless package allows higher power densities with a heat resistance of just 135°C/W. Diodes' models allow low-voltage applications to be switched with less than 1 V, enabling mobile applications to be fully switched on with minimal power. With a collector current of 100 mA and power loss of 925 mW, they are especially well suited to wearables such as smartwatches, health and fitness gadgets and other consumer devices such as smartphones and tablets. The corresponding PNP transistor is the BC857BZ (Figure 2).

Conclusion

For many circuit applications, BJTs with low saturation voltages are not only an adequate substitute for MOSFETs but also provide a number of advantages – namely, a low on resistance, working with a control voltage of less than 1 V, offering excellent temperature stability, and being non-sensitive to ESD. As they block current in both directions, they can make a second MOSFET superfluous. Their power loss and the resultant heat output are lower, as is their price. ■

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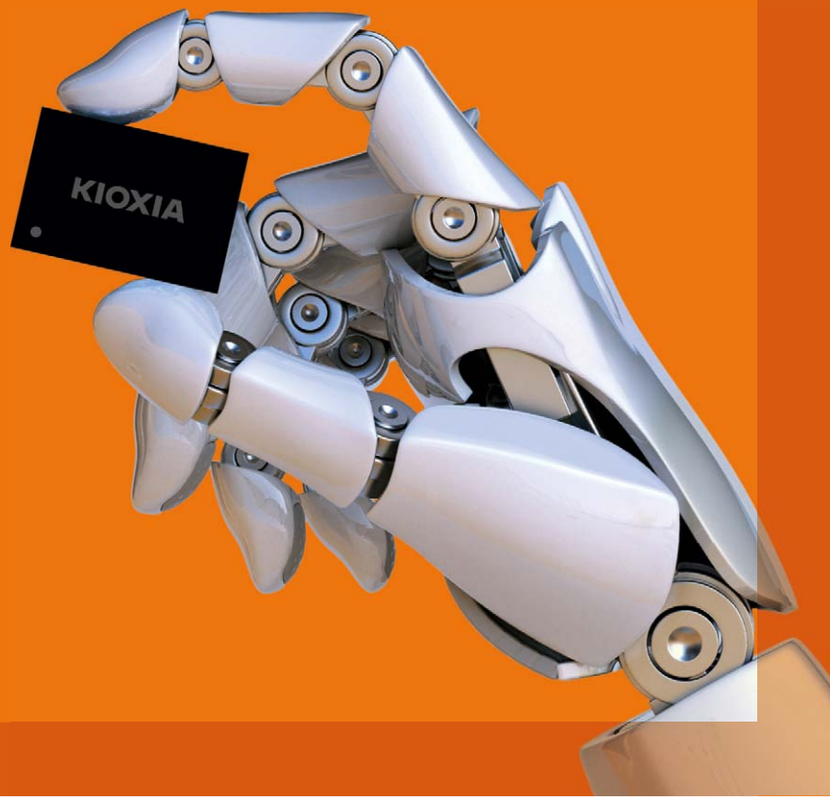

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Intel Atom x6000E processor series

Combining the best of many worlds

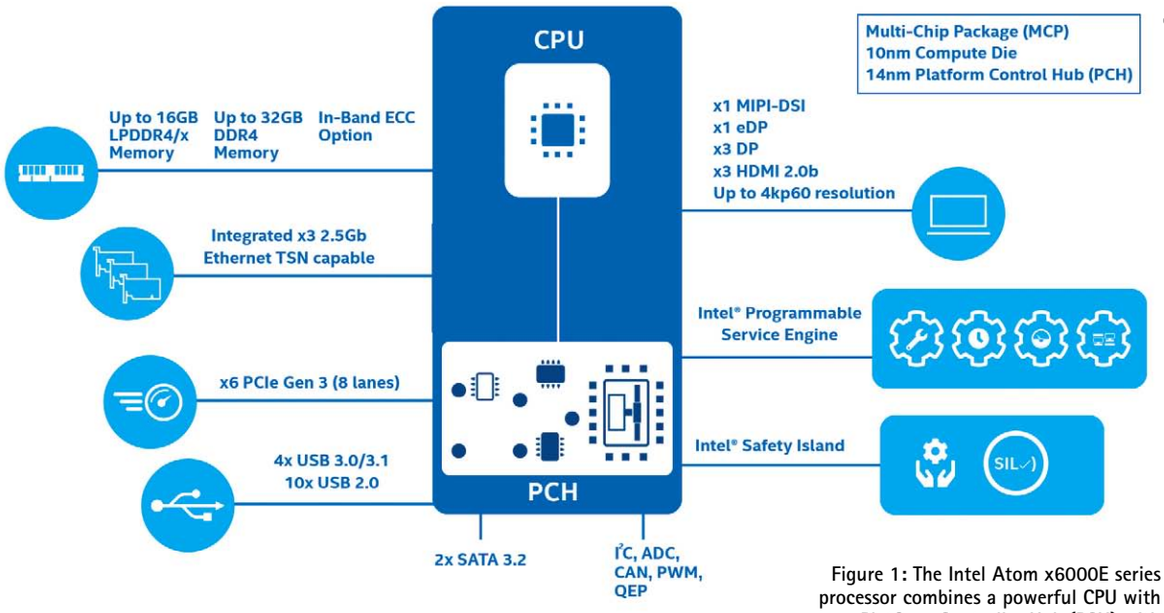
The Intel Atom x6000E processor series, codenamed "Elkhart Lake" (EHL), is the latest member of the processor family and features capabilities for a wide range of industrial applications. As a system-on-a-chip (SoC), it contains numerous I/Os that have never before been available on an Intel SoC.

BY BERNIE ESTERMANN,
BUSINESS DEVELOPMENT MANAGER INTEL AT RUTRONIK

The core of the Intel Atom x6000E series processor is a dual-chip solution integrated into a 35 mm x 24 mm BGA package. The CPU complex is based on Intel's 10 nm process technology with up to four (Tremont) cores with 1.5 MB L2 and 4 MB LLC cache. This results in up to a 1.7x improvement in single-thread performance and up to a 1.5x improvement in multi-thread performance compared to Intel's Apollo Lake architecture, with the same power dissipation. Intel's Ultra High Definition (UHD) graphics engine with twice the graphics performance has the ability to drive a maximum resolution of 4kp60 on up to three simultaneous displays. The memory controller supports DDR4/LPDDR4 with up to 32 GB and 4267 MTs. The Platform Controller Hub (PCH), which is based on 14 nm process technology, is connected to 4 GTs via a powerful on-package interface (OPI). In addition to the usual I/Os for PC compatibility, the PCH offers a wealth of I/Os that have never before been available in an Intel SoC like this: UARTs, SPI, I²C, CAN FD, PWM, Quadrature Encoder Peripheral (QEP), and ADCs. Figure 1 shows the block diagram.

In-band ECC

One extremely interesting feature is the in-band error correction code (IBECC), which improves security and reliability without the need for additional external EEC memory. The IBECC stores EEC correction bits in internal



Figures: Intel

Figure 1: The Intel Atom x6000E series processor combines a powerful CPU with a Platform Controller Hub (PCH) with numerous interfaces.

caches and external reserved memory blocks. The ECC check itself is completely transparent for the user. It can be enabled for memory areas of DDR external memory with high security and reliability requirements and disabled for others. Activated IBECC memory areas are subject to a reduction in bandwidth, but in most cases the overall increase in memory bandwidth balances out compared to Apollo Lake.

Programmable Services Engine

The Programmable Services Engine (PSE) is a dedicated offload engine powered by an ARM Cortex-M7 with 384 kB of tightly-coupled memory (TCM) and 1 MB L2 cache that is located on the Platform Controller Hub. The PSE is fully user-programmable, with Intel offering numerous reference designs in both source code and/or binary:

- Embedded Controller (EC) Light: Relocation of some EC functions from the platform to the PCH, battery management, thermal management
- Out-of-band management (OOB): remote restart, startup/shutdown management
- Network proxy: network response, system wake
- General purpose low-power computing: support for real-time functionality, low DMIPs computing, low-speed I/O for IoT applications (as an alternative to support by an additional external microcontroller)
- Sensor hub: Reduced load on the sensor application and data fusion at low power consumption

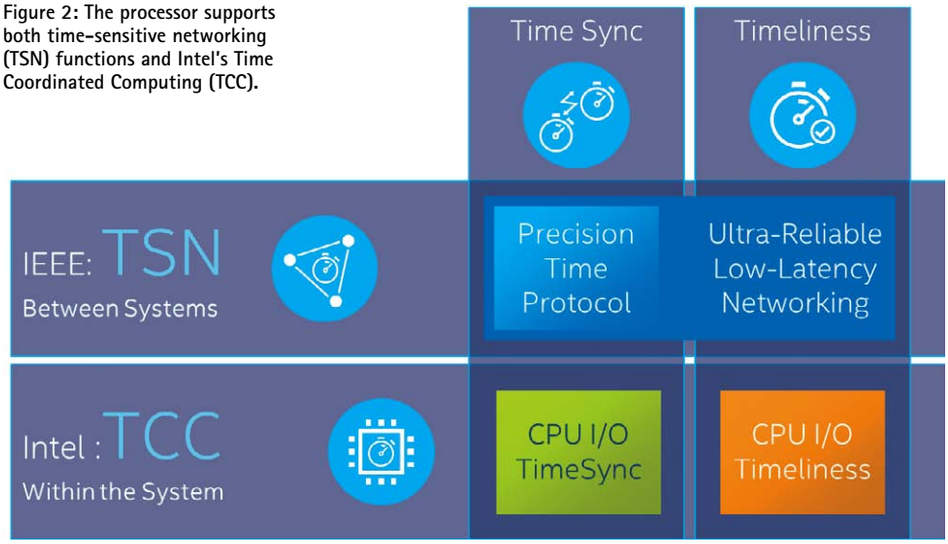
Customers with existing ARM-optimized software can use the Zephyr Software Development Kit (SDK) to generate, compile, and port their own code to the PSE.

Real-time functionality

The Intel Atom x6000E series processor has three integrated 2.5 GbE MACs (media access control), all with time-sensitive networking (TSN) capability. Additionally, the processor supports Intel's Time Coordinated Computing (TCC) Technology (see Figure 2).

Intel TCC Time Synchronization provides a hardware mechanism to coordinate the different clocks in each IP block. Intel TCC Timeliness also provides a hardware mechanism to specify the latency of data packets between IP blocks. TSN refers to a set of standards/specifications and features based on standard Ethernet networks that support time-critical applications.

Figure 2: The processor supports both time-sensitive networking (TSN) functions and Intel's Time Coordinated Computing (TCC).



Functional safety

Intel provides a comprehensive software solution for the Intel Safety Island (SI) engines within the PCH to implement functional safety applications in a timely manner (TTM) with few additional components:

- Performance: Security features for high-performance, multicore systems with low power consumption, a high level of integration, and high performance
- Certification: SIL2/Cat.3 PL d certified, SIL3/Cat.4 PL e capable
- Security package: Complete technical documentation to assist customers with system certification
- Safety Island: Integrated Intel Safety Island controllers to reduce the customer's effort in implementing security mechanisms
- Functional safety software: A range of safety software components to detect hardware failures
- Mixed criticality: Consolidation of both safety-critical and non-safety workloads with mixed criticality on a central computing platform

Boot solutions

One of the challenges of developing a proprietary Intel processor-based system has been the need for a BIOS. This usually meant the use of a standard BIOS solution and a corresponding hardware customization, which resulted in additional costs and licensing fees.

Intel now offers the Slim Bootloader for selected Intel platforms, including the Atom x6000E series. The Slim Bootloader is a Linux-based basic software package with a BSD licensing model, which means that, unlike with GPL, customizations do not need to be recopied.

Fully integrated voltage regulator (FIVR) for simplified design: The Intel Atom x6000E series processor is suitable for a variety of applications beyond the use of the standard SMARC, Qseven, and COMExpress modules. The SoC has numerous I/O functions that cannot be covered by standard form factors. In order to use all of these new functions, customized designs are often required.

Support for functional safety: Industrial automation is increasing the complexity of hardware and software systems and the question of liability in the event of failures is becoming increasingly important.

Security for high-performance computing: Provision of security features for high-performance, multicore modules with low power consumption, a high level of integration, and high performance. Integrated ISI for less effort in implementing security mechanisms.

Shorter certification period: Reduction in total operating costs for the customer and reduction in certification time in accordance with international standards (IEC 61508).

Consolidation and cost reduction: Consolidation of both safety-critical and non-safety workloads with mixed criticality on a central computing platform to reduce costs.

Operating conditions and reliability for industrial use: Intel products are designed for maximum reliability and a long service life. Intel offers a guaranteed availability of 15 years for EHL processors. For IoT devices used in harsh industrial environments, EHL offers an extended temperature range from -40 to +85 °C. Furthermore, IBECC serves to protect against system failures for increased reliability.

Security and controllability: The integrated basic security features are available in all Intel processor series. They help technology vendors protect the platform and data and build standardized trusted applications. From Intel's perspective, most IoT implementations require a combination of intelligent features, excellent performance, and comprehensive, built-in security features. EHL provides a complete IoT security reference architecture that demonstrates how built-in security features can protect intelligent devices based on Intel technology.

AI, DL, and machine vision: Artificial intelligence (AI) opens up a world of new possibilities for manufacturing and industrial companies. AI allows manufacturers to predict yield, quality, energy consumption, and other critical factors. AI can also help to repair systems before they fail, locate oil pockets, prevent crop damage at an early stage, and create safer working environments.

Intel has a complete portfolio of AI products and optimizations for common neural network frameworks that enable technology providers to move into entirely new areas of application. Intel offers a comprehensive range of imaging products and software tools that help OEMs, ODMs, and system integrators scale imaging technologies across the entire infrastructure to meet individual needs at any point in an AI architecture with the right balance of performance, cost, and efficiency.

Conclusion

In addition to standard compatibility with Windows 10, Linux, and many real-time operating systems, the Intel Atom x6000E series offers familiar workload consolidation and virtualization features. The PSE on the PCH, which features numerous industrial I/Os, can perform a variety of functions that in the past required a separate microcontroller. Select SKUs offer functional safety. Together with TCC, TSN precisely controls programmable logic controllers, PLCs, and other time-sensitive tasks that could not be handled by Windows-based systems alone.

Due to the large number of industrial I/Os, this SoC is suitable for price-optimized and feature-optimized solutions beyond the standard form factor. ■

Hall effect-based current differential sensors

A novel solution for current measurement

We're digitalizing, prioritizing green power, and we're gearing towards an Internet of Things and Industry 4.0 – with major projects that a continuously growing world population also needs to have access to. In the future, we will need the right amount of power from the right source at the right place if we are to achieve this.

By Jens Rheinstädter,
Product Sales Manager
Analog and Sensors at Rutronik

With their flexibility and diversity, current sensors help us to monitor and regulate energy consumption, but they do have limitations. Current flows running parallel to one another and electromagnetic radiation create unwanted problems that can distort or interfere with measurements. But if a current sensor were capable of ignoring these stray fields, the potential uses for these devices would expand, opening doors to the applications of the future.

Hall effect-based current sensors with stray field suppression are available in various models from a small number of suppliers. Belgian supplier Melexis has introduced a compact and highly robust current sensor to the market for the precise measurement of DC and AC currents in high-voltage power applications. The focus markets for the MLX91220 include the automotive, industrial, and renewable energy sectors.

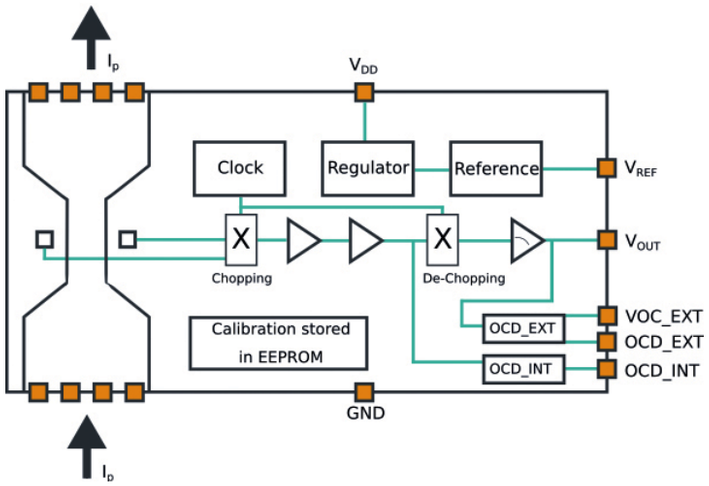
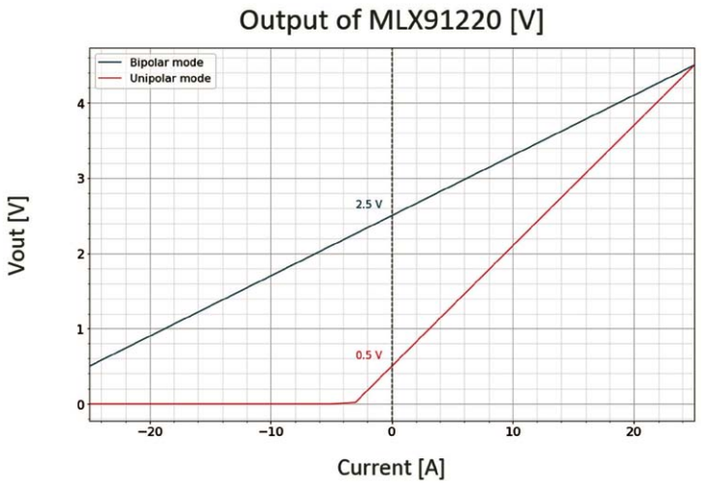


Figure 1: Block diagram of the MLX91220 current sensor (SOIC16 pinout)



Figures: Melexis

Figure 2: Bipolar and unipolar output of MLX91220

The concept

The MLX91220 works on the basis of a proprietary Melexis design – the current sensor measures the differential magnetic field generated by the current flow in the primary copper lead frame of the IC in a standard SMD package. This is how it achieves a very short response time and provides high immunity against external stray fields and crosstalk, making it ideal for compact power electronics projects and high-speed applications. An additional overcurrent detection pin (OCD) with a response time of 2 µs detects potentially destructive overcurrents and/or short circuits so that the power electronics can be disabled or protected as quickly as possible.

Factory-calibrated plug and play solution with basic insulation

The sensor output of any IC is factory calibrated for a specific current range. It compensates throughout its entire life to provide optimum stability, partly in relation to temperature – and therefore ensures precision for the longest time.

The current sensors emit a linear analog signal proportional to the current flowing directly through the IC's lead frame. For applications with unidirectional currents, it can be set to emit only one current polarity, which enables a higher output range with superior resolution.

The MLX91220 is easy to integrate. The evaluation boards are designed for 32 A continuous RMS current and current spikes of 100 A and more. They are a completely plug-and-play application solution with no external shielding or cores required. There is also no ferromagnetically induced saturation or hysteresis involved, and no calibration is required by the end customer. The boards are available both in an SOIC-8 package with a rated insulation of 2.4 kV RMS and in a wide, surface-mounted SOIC-16 package with a basic insulation of 4.8 kV RMS in accordance with IEC/UL 62368.

Current sensors for new microcontrollers

To support more recent microcontroller trends, the new generation of integrated current sensors focuses on additional functions such as OCDs as well as an additional supply voltage option (3.3 V). An increased signal-to-noise ratio (SNR) provides a higher usable resolution and signal integrity for the downstream ADCs in the signal processing chain while also increasing the bandwidth by a factor of more than four compared to the first-generation MLX91210.

Fixed and ratiometric modes

The current sensor can be operated in one of two modes, depending on the application. Both are based on the principle of the output voltage of the sensor being proportional to the current flow – the difference however lies in the output signal.

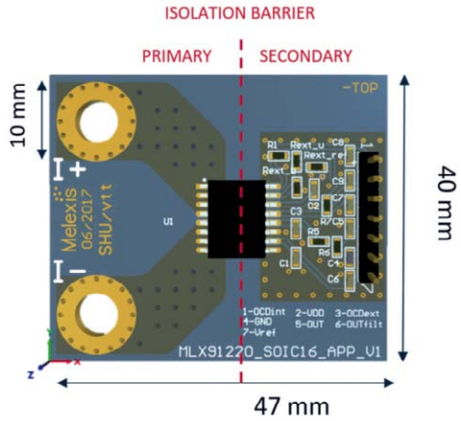


Figure 3: Evaluation board for the MLX91220 SOIC-16

	OCD_{INT}		OCD_{EXT}	
	Min	Max	Min	Max
Typical application	Short-circuit detection		Out-of-range detection	
Overcurrent effect	OCD_{INT} pin to V_{SS}		OCD_{EXT} pin to V_{SS}	
Detection mode	Bidirectional		Unidirectional / bidirectional	
Accuracy	Lower		Higher	
Threshold trimming	EEPROM		Voltage divider on VOC_{EXT}	
Response time	1.4 µs	2.1 µs	10 µs typical	
Required input holding time	1 µs		1 µs	
OCD output dwell time	10 µs		10 µs	

Core parameters for internal and external overcurrent detection (OCD)

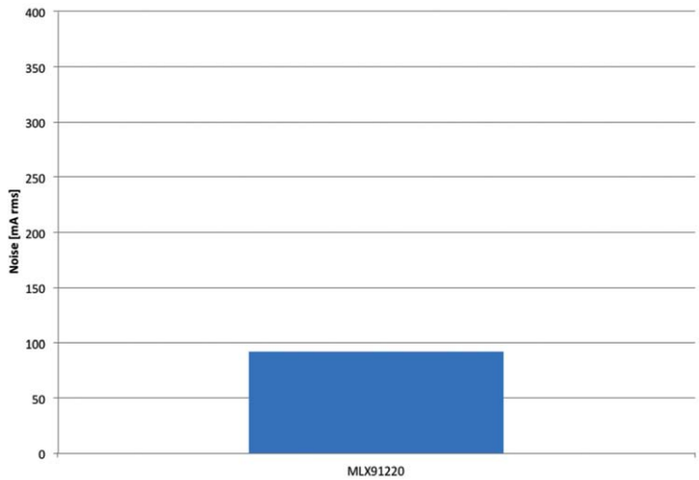


Figure 4: Typical input-based noise for the MLX91220 with 80 mV/A sensitivity at 5 V

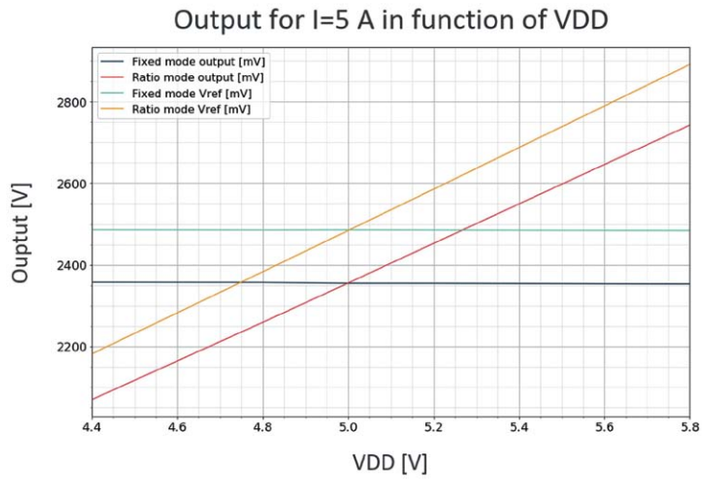


Figure 5:
Fixed and ratiometric modes of the MLX91220, calibrated to 5 V

In ratiometric mode, the output voltage rises in proportion to the supply voltage (V_{DD}). The offset is 50% of V_{DD} with bipolar applications and 10% in unipolar applications.

In fixed mode, the output is immune to supply voltage volatility. The output voltage is always equal to VREF with a current flow of 0 A through the primary conductor. With the 5 V version it is set to 2.5 V, while with the 3.3 V version it is set to 1.65 V in bipolar mode or 0.5 V in unipolar mode, regardless of V_{DD}. However, it is also possible to use an external reference signal from the application for the output signal to be used by the sensor.

Overcurrent detection

For the SOIC16 package, the MLX91220 offers two OCD functions that enable the detection of the presence of overcurrent primarily applied to the integrated sensor. The internal OCD (OCD_{int}) is factory calibrated and can be set to be a limit value of between 20% and 288% of the end-of-scale value on request.

The external OCD (OCD_{ext}) can be adjusted by the customer using an ohmic divider (see R_{ext} and R_{ext_bi} in Figure 4). This threshold is limited by the output range. The most important parameters with both methods are shown in the table.

Figure 6 shows a bidirectional configuration of the external OCD. In this case:

$$VOC_{EXT} = V_{REF} \cdot \frac{R_{ext\_bi}}{R_{ext} + R_{ext\_bi}}$$

Based on $VOC_{EXT,}$ it is possible to derive two threshold values:

$$Lower\ threshold = \text{VOCEXT}$$

$$Higher\ threshold = 2.V_{REF} - VOC_{ext}$$

If V_{OUT} is outside the range defined by the two threshold values, the OCD_{ext} pin with the open drain implementation on the IC is pulled to ground.

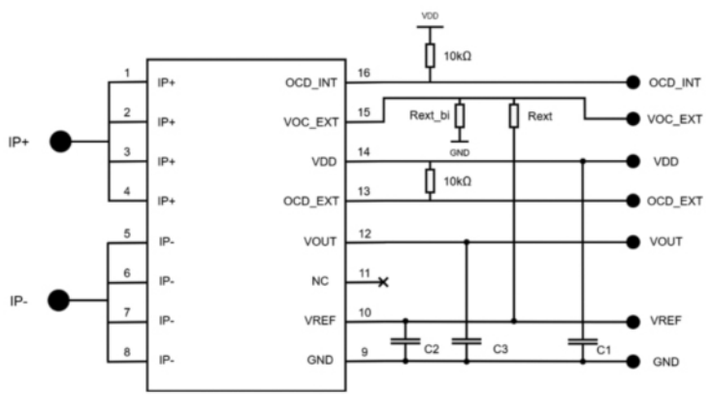


Figure 6:
Application diagram for the MLX91220 current sensor in SOIC-16 package

Conclusion

The MLX91220 is an ideal solution for small, robust, precise, and low-cost current measurement. Its strength lies in the combination of the sensor element, signal processing and insulation on a surface of just a few square millimeters and the very low thermal losses – a significant advantage over conventional shunt-based circuits.

The MLX91220 can be customized as needed in terms of current measurement range, current measurement polarity, ratiometric or fixed out, overcurrent detection level, and power supply values. It is available in both SOIC-8 and SOIC-16 packages for a variety of basic insulation levels (2.4 or 4.8 kV RMS) and is available with the corresponding creep and distance dimensions.

The MLX91220 therefore has a very broad range of applications. In the automotive market, it is superbly suited to high-side current measurement in DC–DC converters and 50/60 Hz phase current measurement at the input of on-board chargers (OBC) – typically part of PFC circuits.

In the industrial market, the applications range from small drives and servos to power supplies, solar applications, DC input current measurement, MPPT converter measurement, and HVAC systems up to 20 kW. The MLX91220 also makes it possible to equip home appliances with more efficient electric motors and allow them to better diagnose and monitor energy consumption – such monitoring is one of the cornerstones of concepts such as predictive maintenance or the Internet of Things. ■

RAM for Internet of Things applications

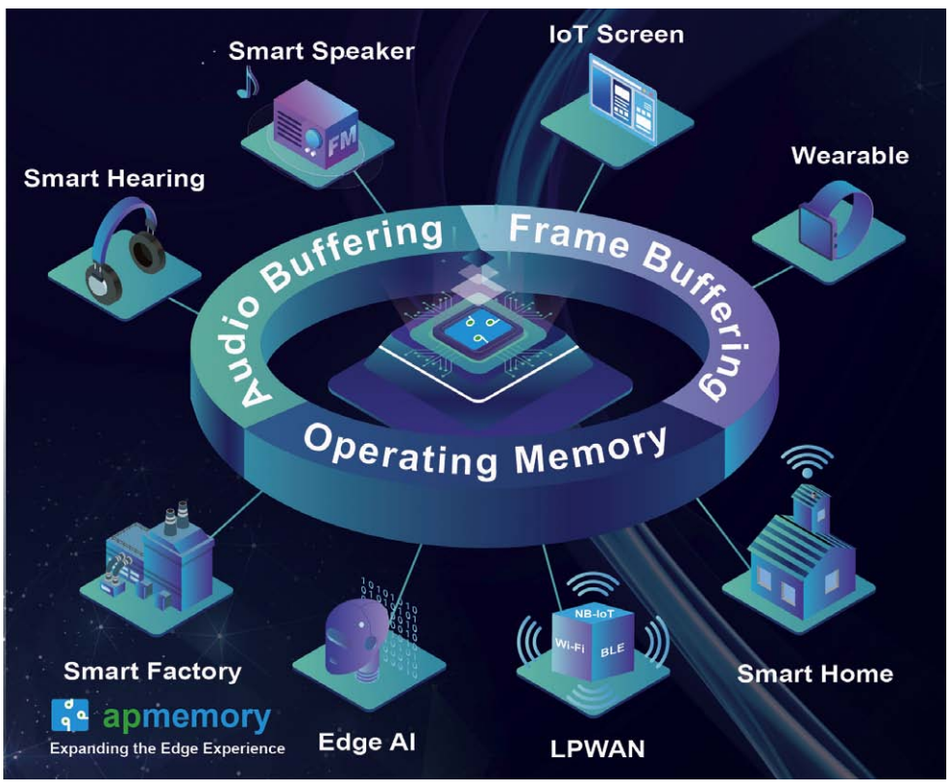
Improving the user experience with IoT RAM

IoT and embedded applications require ever-more RAM with higher bandwidths, smaller form factors, and lower power consumption. For developers, this presents the question of what an ideal memory module should look like for such applications.

By Chen Grace Wang, Product Manager at Rutronik, and Wesley Kwong, Business Development Manager at AP Memory

The user experience benchmark for IoT and embedded applications continues to get higher and higher, which demands more RAM with higher bandwidths, small form factors, lower power consumption, and thus also less power loss while also keeping the component costs the same or lower. This is especially true of applications that use artificial intelligence (AI) and/or machine learning (ML).

SRAM (static RAM) is still the RAM solution that offers the highest speeds and lowest latency and is closest to the processor, but it does have some drawbacks. The regular 6T-SRAM layout topology has not been shrunk to the same proportion as the process nodes. The power loss of embedded SRAM also increases as the CPU consumes more power. This means that it is becoming increasingly difficult to meet the requirements of the latest IoT applications using embedded SRAM due to the limitations in terms of power consumption and their increasing RAM requirements.



Figures: AP Memory

External SRAM modules also require a high number of transistors, which increases memory costs. As a result, it is almost impossible to meet the limited form factor requirements.

External DRAM modules (dynamic RAM) still offer considerable cost advantages over SRAM. With a single transistor and capacitor, they offer comparable performance, allowing for a much denser array. For applications that are persistently or usually attached to a single power supply unit, external DRAM modules may be an acceptable solution. However, they do have a large number of pins, and their update requirements and the ever-increasing complexity of routing mean that they are complicated to integrate.

Older SDRAM modules (synchronous DRAM modules) with low densities are designed for older process nodes, and their size makes them basically unsuitable for compact, energy-efficient systems.

This means that a RAM alternative is needed that offers high performance at lower costs and with lower power consumption, while also meeting the growing requirements of a complete IoT user experience.

IoT RAM combines benefits of DRAM and SRAM

IoT RAM is based on pseudo-static RAM technology (PSRAM). It combines the advantages of DRAM – a small surface area, low product

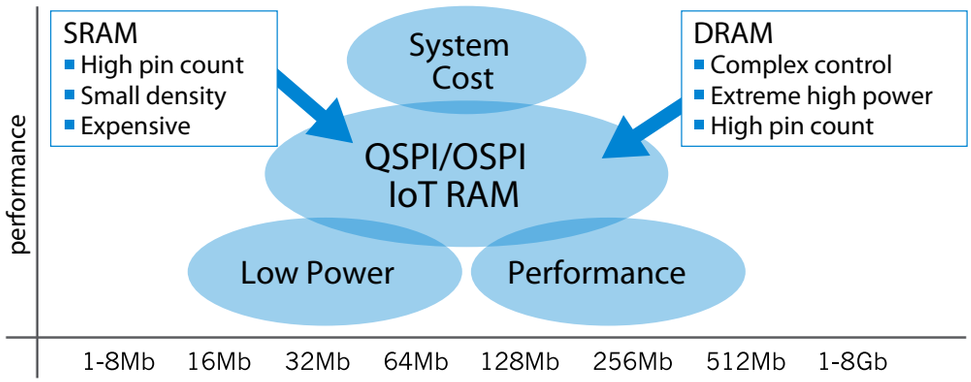


Figure 1: IoT RAM satisfies the requirements of IoT/embedded applications for more memory, lower power consumption, and low costs.

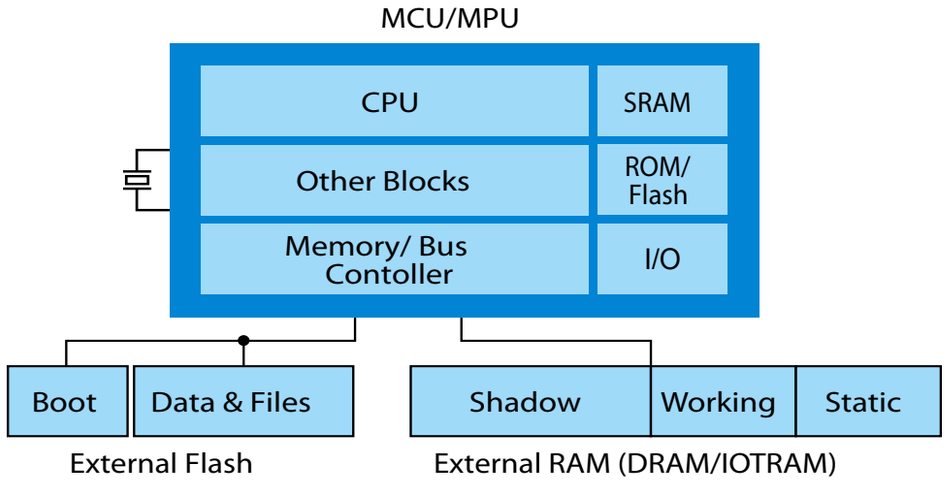


Figure 2: Typical MCU-based system with conventional memory modules

costs of up to a tenth of SRAM and a density ten times higher than that of SRAM – with those of SRAM – namely, high speed, low latency, and ease of control. Internally, PSRAM uses DRAM cells, which consist of just one transistor and one capacitor but behave like ordinary SRAM and the conventional, relatively simple SRAM interfaces.

IoT RAM also offers flash-SPI interfaces with low pin counts that are used by many MCUs and FPGAs. The low-cost IoT RAM solutions from AP Memory are compatible with the SPI interfaces of most MCUs, SoCs, and FPGAs, including Quad-SPI (QSPI) and Octal-SPI (OSPI).

System-in-package (SiP) versions of IoT RAM are suitable for any situation where SoCs require more memory than is possible with the internal SRAM. SiP options, especially those using "known good dies" (KGD), provide all of the aforementioned benefits thanks to the higher system memory, making them "more than Moore."

The low latency of IoT RAM allows for very fast wake-up from modes with very low power consumption, immediate wake-up from standby, and fast switch-on times. IoT RAM operates with very low power consumption, usually 0.15 to 0.5 µA/Mbit depending on the memory density.

Internal refresh

Looking at the example MCU diagram (Figure 2), the spaces for RAM and static memory are continuously growing. If DRAM is used for this, it increases the power consumption of the system and also requires the integration of a refresh controller.

IoT RAM requires no controller, as the entire refresh logic for the DRAM cells – unnoticed by the user – is handled internally. This reduces the complexity of the interfaces and the validation costs that this entails. Older MCU-based systems that still use SDRAM benefit from IoT RAM thanks to lower power consumption and the simplified interfaces (see table).

Fluid video playback in edge computing

Looking at an application using frame buffering, it becomes apparent how external RAM enables superior user experiences. The system does not need to access slower nonvolatile memory as often for read/write activities, which improves the system performance as a whole. This is shown by the Coremark test suite. The user benefits from lower latency, more fluid video playback, and more reliable recording.

IoT RAM solutions from AP Memory already work seamlessly with many existing MCUs, SoCs, and FPGAs in IoT/embedded devices where high performance, low cost, and fast reaction capabilities are needed. To this end, AP Memory maintains close partnerships with a growing number of MCU, SoC, and FPGA providers. IoT RAM solutions offer simplified signal protocols (QSPI, OPI, and ADMUX) and packaging options (KGD, WLCSP, SOP, USON, and BGA) for volatile memory in IoT and edge-computing products. Rutronik offers a large selection of both IoT RAM and PSRAM solutions from AP Memory with a variety of memory densities to meet a range of performance and bandwidth requirements. ■

	64 Mbit SDRAM	64 Mbit ADMUX PSRAM	64 Mbit OPI IoT-RAM
Active IDD – @200 MB/s 100 MHz	60 mA	35 mA	15 mA
Max Standby Current @25°C	5000 µA	200 µA	30 µA
Signal Pin Count	38	35	11

The advantage of IoT RAM over SDRAM and PSRAM lies in its low power consumption and reduced pin count.

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Every day, in every part of the world, millions of people benefit from technologies which are enabled by Murata innovation.

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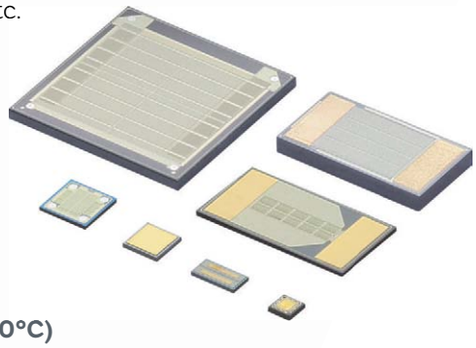
Feature product

Silicon capacitors (SiCaps)

Ideal for automotive sensors and Lidar, servers, optical transceivers up to 100GHz, and medical implant applications. Offering variable connection methods including SMD, wire bonding, embedding etc.



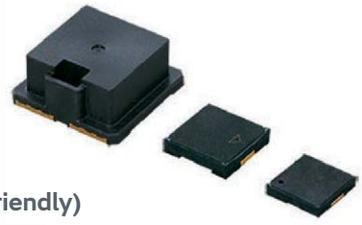
Features:

- Low insertion loss
- Less cross talk
- Miniaturization
- High S/N ratio
- Low profile
- High reliability (250°C)

Feature product

Piezo sounders

High quality, high sound volume piezo sounders. Ideal for a wide variety of applications including automotive, white goods, and more...



Features:

- Small size and low profile
- Low power consumption
- SMD package (& reflow-friendly)
- High sound pressure level (volume)
- Suitable for automotive applications

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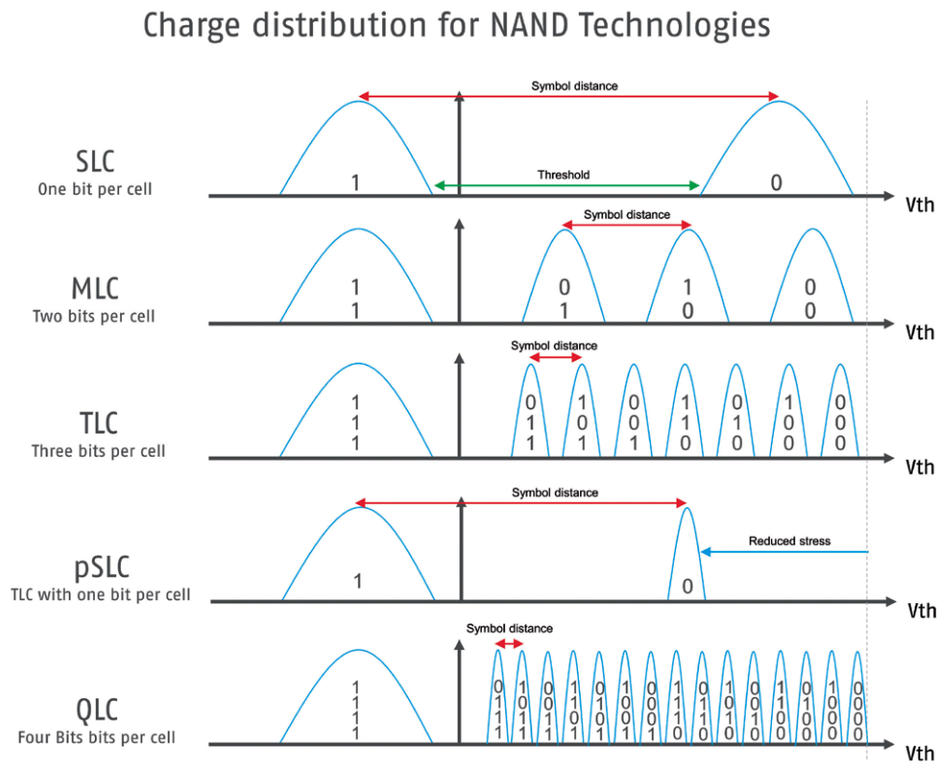
NAND flash architectures

What comes after 2D SLC NAND flash?

Two-dimensional SLC NAND is currently still the reigning champion when it comes to interchangeable storage media. But the 43 nm generation will soon be discontinued, and smaller 24 nm structures will suffer the same fate in the medium term, so developers should start looking at possible alternatives.

BY DANIEL ZAJCEV,
PRODUCT SALES MANAGER STORAGE
AT RUTRONIK

With 100,000 program/erase cycles, extremely fast access times, low latency, energy efficiency, robustness, and the availability of low capacities (e.g., microSD with 128 MB), as well as several form factors, 2D SLC NAND flash is currently still the reigning champion among interchangeable storage medium technologies for industrial applications. But the 43 nm generation will soon be discontinued, and smaller structures will also disappear in the medium term. Because requalification can take months, if not years, developers should already start looking at which storage technology they will be relying on in the future.



Figures: Swissbit

Figure 1: The distribution of charges in SLC, MLC, TLC, and QLC NAND flash memory shows why reliability and program/erase counts suffer – unless there are correction mechanisms and better controller and firmware features to counteract this.

Since NAND flash was introduced in 1987, the focus of development has been on cutting costs by shrinking structures. To meet the need for ever-increasing amounts of data – with 175 ZB of data expected to be generated by 2025 – while also cutting costs, innovation has been looking toward three-dimensional NAND flash memory (3D NAND flash) and also towards increasing the number of bits on a cell with SLCs (single-level cells) with one bit per cell, MLCs (multi-level cells) with two bits per cell, TLCs (triple-level cells) with three bits per cell, and QLCs (quad-level cells) with four bits per cell (Figure 1). The vertical layering of NAND cells increases memory density and thus by extension also memory capacity. But this also goes hand in hand with reduced reliability and fewer program/erase cycles.

Consumer and data centers as primary markets

The flash market is mainly driven by the consumer and data center markets, accounting for around 80% of sales. The fact that the focus is on capacity and not – as with industrial applications – on reliability and service life is reflected in production figures; around 80–90% of NAND flash memory produced today is 3D NAND flash. Supplier roadmaps show that the number of layers increases with each new generation, which in turn allows even greater capacity per NAND chip. Customers benefit from noticeably lower cost, but at the expense of quality. But there are also

AUTOMOTIVE HIGH CAP. MLCC

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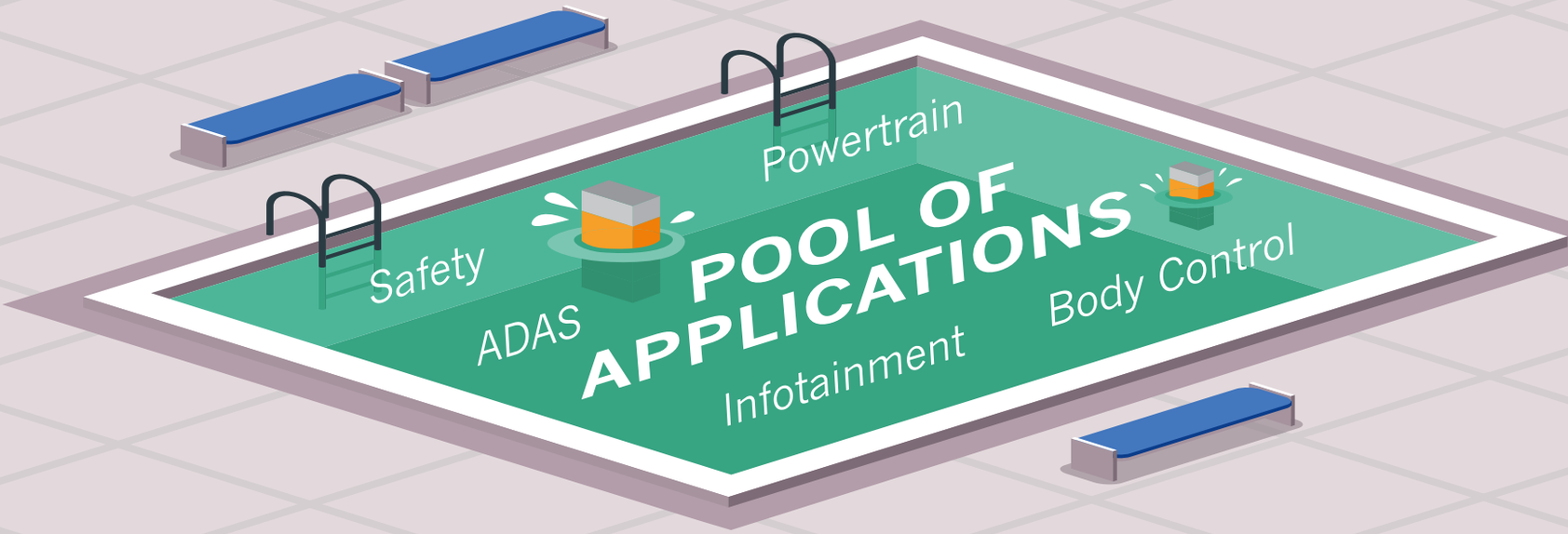

AEC-Q200 — **PREMIUM QUALITY** — VW80808

Voltage	Application	Size	X7R/X7S Standard - PN Series	X7R/X7S 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	1210” 1206” 0805”	**10µF:** CL32Y106KBJ4PNE **10µF:** CL31Y106KBKVPNE **1µF:** CL21B105KBFVPNE	**10µF:** CL32Y106KBJVPJE **10µF:** CL31Y106KBKVPJE **1µF:** CL21B105KBFVPJE
25V		1210” 0805”	**22µF:** CL32Y226KAVVPNE **4.7µF:** CL21Y475KABVPNE	**10µF:** CL32B106KAJVPJE **4.7µF:** Coming Soon
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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models that offer the same durability as 2D NAND flash.

Three-dimensional TLC NAND can enjoy a long service life thanks to Charge Trap Technology combined with smarter controllers, ECC (error-correcting code) and LDPC (low-density parity-check code) methods. However, it is difficult to directly compare the lives of these products against those of 2D SLC NAND flash types. Manufacturers provide entirely different information on endurance, drive waters per day (DWPD), and data retention. The suppliers Intel and Kioxia specify the maximum number of program/erase cycles for their 3D TLC NAND models as 300 to 3,000. By comparison, a 2D MLC NAND flash memory module using a 15 nm process technology can manage a maximum of 3,000 program/erase cycles.

Is 3D NAND suitable for industrial use?

For NAND flash memory to be used in industrial applications, there are other essential criteria. These include long-term availability, PCN handling, and a fixed bill of materials (BoM), as well high endurance, data retention, temperature stability and more. Flash memory suppliers can guarantee some of them, including PCN handling and a fixed BoM – and now also functionality in a wide temperature range.

It took a whole five years from the introduction of 3D NAND flash memory until the first modules with industry-grade temperature stability entered mass production. The different cell sizes and the different charge states that this entails in the upper and lower parts of the die create inconsistencies in how individual bit states are read. External temperatures make this process even harder.

At Kioxia, a wide temperature range is currently approved for BiCS3 memory with 64 layers. The new generation from Kioxia, BiCS4 with 96 layers, is not yet qualified for a wide temperature range. This can also mean that not every generation of 3D NAND flash memory will be approved for industrial use.

Smaller capacities under 8 GB cannot be created using 3D TLC NAND technology – at least not using current technology – because the 3D TLC memory chips are produced with a capacity of 32 GB per die, which means that the minimum capacity available is 32 GB. Customers who require capacities of under 4 GB continue to enjoy price benefits when purchasing and using 2D SLC NAND products because the die is essentially financing the smaller base capacity.

But there are now also solutions available for businesses that require smaller capacities in compact form factors – for example, for applications involving a graphical interface in conjunction with a display.

3D NAND
Endurance vs. Error Correction (P/E cycles)

Technology	BCH 8b/512B	BCH 40b/1KB	LDPC 120b/1KB
SLC	60k	100k	-
pSLC 2D Planar	-	20k	-
MLC 2D Planar	-	3K	-
TLC 2D	-	300	1K
TLC 3D	-	1k	3K
pSLC 3D	-	20K	30k-60K

Figure 2: Program/erase cycle counts are primarily determined not only by the NAND flash technology itself but also by error-correction mechanisms.

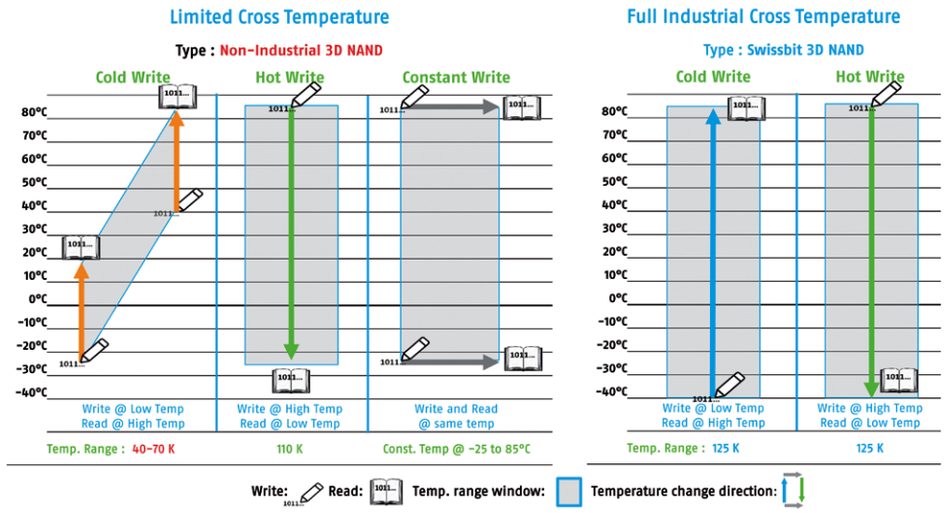


Figure 3: High-quality industrial-grade 3D NAND flash memory can both read and write at very low or very high temperatures.

Optimized firmware and controller

Transcend's 452K series is another sign that 3D TLC NAND flash memory combined with increasingly better firmware and controller features may be potentially suitable for industrial applications in the future.

The TS128GSSD452K in a 2.5-inch form factor with a SATA III interface is fitted with BiCS4 3D TLC NAND flash memory. According to supplier specifications and actual testing, the SSD is expected to last for 100,000 program/erase cycles. This is ensured by the operation of the 3D TLC NAND flash in SLC mode along with massive overprovisioning, where part of the memory is not made available for data storage but instead is set aside for data management.

Conclusion

Even if the final discontinuation of 2D SLC NAND flash memory is still a few years away and last time buy stocking is possible when end of life is announced, early testing of 3D NAND products are recommended given the protracted nature of the process of incorporating new components into a design.

Given the developments and innovations currently being observed from NAND flash memory and controller suppliers, memory products that look to start living up to the quality of 2D SLC NAND flash memory are to be expected. Whether long-term availability can be guaranteed and 100,000 program/erase cycles will be possible remains to be seen.

As a partner of Swissbit, Apacer, Intel, Kioxia, Transcend and Wilk, Rutronik is in close contact with the leading suppliers of NAND flash memory. The Rutronik Storage Team provides developers and purchasers with comprehensive support and advice for selecting the right memory technology. ■

Selection criteria for MLCCs

Don't blindly leave component choices to tools

Miniaturization has long been "en vogue" when it comes to multi-layer ceramic chip capacitors. But downsizing is no trivial process, especially given that there are many marginal conditions to be considered. Digital tools can help, but relying on these can often cause you to lose perspective of key technical issues.

BY JÜRGEN GEIER, TECHNICAL SUPPORT CERAMIC CAPACITORS AT RUTRONIK

Multi-layer ceramic chip capacitors (MLCCs) are small and thus useful for miniaturization. But it is also important to consider aspects such as ESD protection, EM interference, and heat management, as well as the typical characteristics and the drift that go hand in hand with these. Digital tools are increasingly being used to make the process of selecting components easier. Even so, developers still need to keep all of the aforementioned aspects in view to be able to achieve their objective quickly and avoid unnecessary re-design work.

E24 series	10	11	12	13	15	16	18	20	22	24	27	30	33	36	39	43	47	51	56	62	68	75	82	91
E12 series	10		12		15		18		22		27		33		39		47		56		68		82	
E6 series	10				15				22				33				47				68			
E3 series	10								22								47							

Table 1: Capacitance grading

Code	C ≤ 10 pF	C > 10 pF
A	±0,05 pF	
B	±0,10 pF	
C	±0,25 pF	
D	±0,50 pF	
F		±1 %
G		±2 %
J		±5 %
K		±10 %
M		±20 %
S		–20 … +50 %
Z		–20 … +80 %

Table 2: Tolerance codes

NP0	E24	E12 preferred, tolerance: ±0,25 pF or ±5%
X7R	E12	E6 preferred, tolerance: ±10%
Z5U	E6	E3 preferred, tolerance: ±20%
Y5V	E6	E3 perferred, tolerance: –20 … +80%

Table 3: Preferred combinations when selecting MLCCs (capacitance > 1µF: E3 series preferred)

Low Temp. Requirement (a)	Letter Code for Column (a) (b)	High Temp. Requirement (c)	Numerical Code for Column (c) (d)	max (+/-) %ΔC Over Temp. (e)	Letter Code for Column (e) (f)
-55	x	+45	2	±1.0	A
-30	y	+65	4	±1.5	B
+10	z	+85	5	±2.2	C
		+105	6	±3.3	D
		+125	7	±4.7	E
		+150	8	±7.5	F
				±10.0	P
				±15.0	R
				±22.0	S
				±22/-33	T
				±22/-56	U

For example, X5R = ± 15% ΔC over -55°C~+ 88°C

Table 4: Temperature drifts of various MLCCs (source: Samsung)

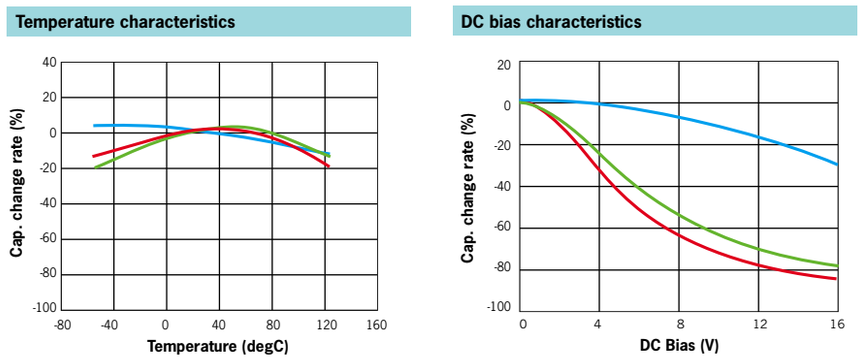


Figure: Murata

Figure 1: Smaller constructions have a higher DC bias rate.

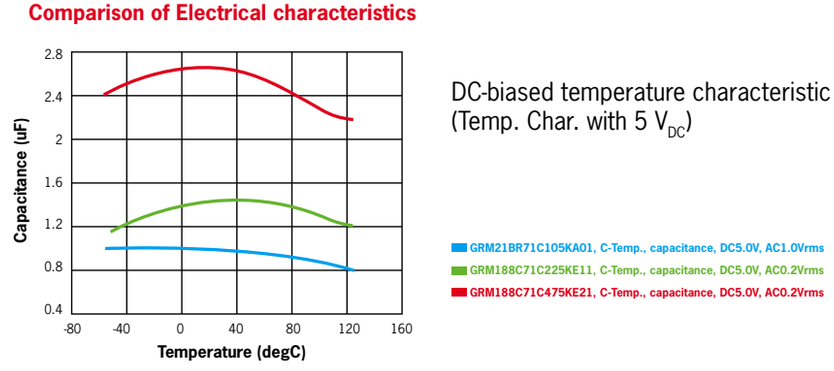


Figure: Murata

Figure 2: Smaller constructions have a higher residual capacitance than larger ones.

First of all, it is recommended to not simply fall back to existing value combinations of MLCCs when downsizing – especially in terms of capacitance (C value) and voltage – but instead to base decisions on the actual needs of the application and even on the function of the individual components. Ideally, the preferred versions of the suppliers should be considered. Alongside the C value and voltage, other important values include impedance and ESR (equivalent series resistance).

Especially with hi-caps, which are MLCCs with C values measured in µFs, the DC bias is also a factor to be taken into consideration. DC bias is an effect that reduces capacitance depending on the applied DC voltage. It can drop to as low as around 20% of the nominal value at the rated voltage, depending on the component, so it is essential to be aware of your absolute minimum C value during operation.

Figure 1 shows a number of examples of DC bias curves. They show that the DC bias rate is much higher with smaller components.

Another factor of influence on DC bias is operating temperature, as illustrated by the graph in Figure 2, which shows that for smaller constructions with higher nominal values, the remaining capacitance over DC bias and temperature is far above that of larger constructions with lower nominal values.

When grading nominal C values, developers should base their choices on the base guide values (Tables 1 to 3), which means that they should ideally only use the preferred values with the standard tolerances. In fact, the Z5U and Y5V ceramic types should be left well alone, as they are increasingly being discontinued, and some are actually already discontinued.

In addition to the issue of DC bias, class 2 ceramic capacitors (such as X7R, and X5R) also have temperature drift and aging to consider.

Temperature drift can be relatively easily determined using Table 4. It shows, for example, that an X5R MLCC has a predictable temperature drift of ±15% in a temperature range of –55°C to +85°C.

MLCCs –
they also age

Aging causes MLCCs to lose capacitance over time. The loss is between around 1% and 6% per logarithmic decade, which means after 1 hour, after 10 hours, after 100 hours, and so on. As a result, the higher the C values and the thinner the internal layers of an MLCC, the more susceptible the MLCC will be to aging. That said, compared to the effects of DC bias and temperature drift, aging is basically a negligible factor, although it can play a key role when measuring C values for testing tolerances.

Unlike with living beings, MLCC aging is a reversible process. Appropriate heat treatment allows the effect to be reversed. The components are usually exposed to +150°C for an hour, then allowed to rest for 24 hours. Soldering also enables de-aging.

Looking at the various C value drifts overall, it becomes apparent that it is not advisable to use class 2 capacitors with a limited nominal tolerance range of ±5% instead of the standard tolerance range of ±10% – even if some suppliers still offer and deliver this. The result is pointless debates on adherence to tolerance ranges. During measurements, compliance with requirements regarding measuring devices and measurement conditions is frequently inadequate. For example, the measurement voltage, usually with a defined effective value of 1.0 V, drops during the measurement, causing the displayed capacitance value to be too low.

Figure: Samsung

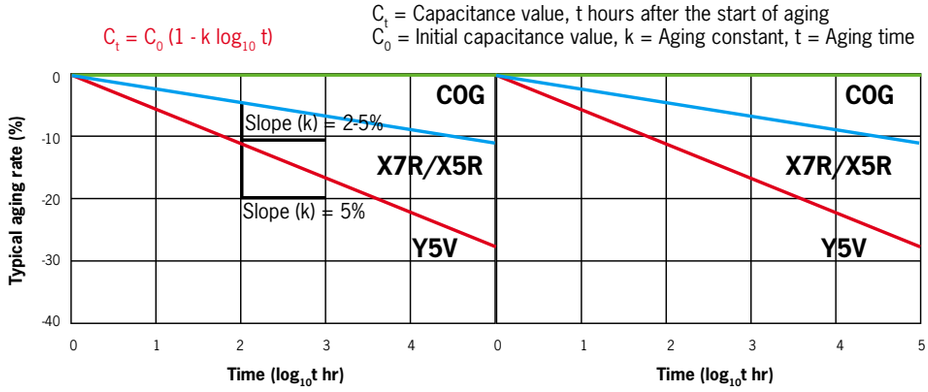


Figure 3: Exposing MLCCs to very high temperatures for a while allows aging effects to be reversed.

Figure: Murata

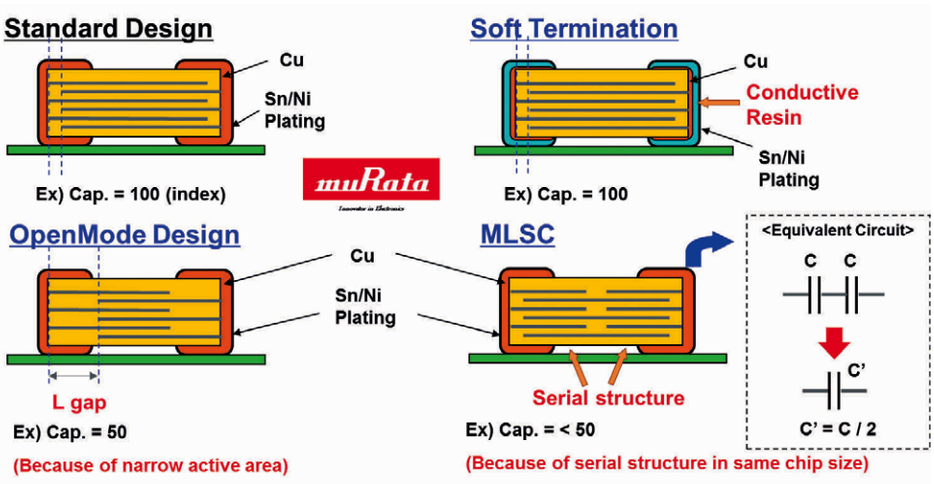


Figure 4: MLCCs with specific properties can also meet special requirements.

Figure: Vishay

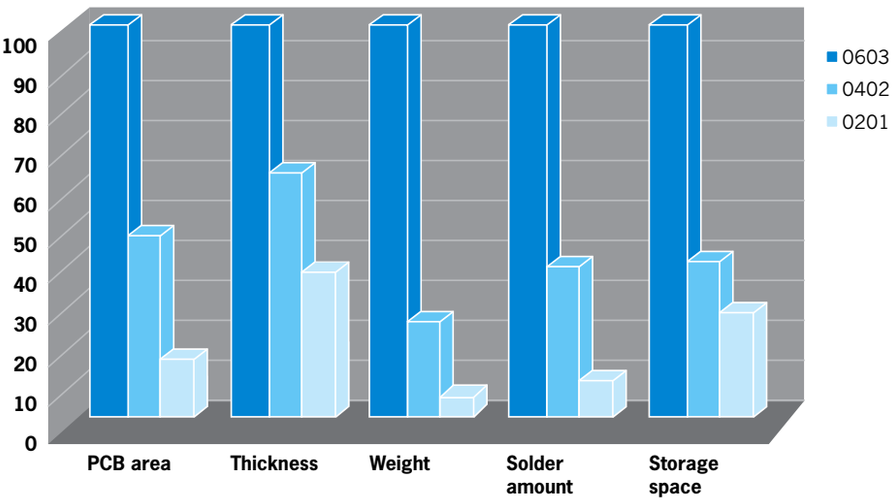


Figure 5: Cost-effectiveness comparison of various construction sizes

Better to leave some breathing space with voltage requirements

The specified voltage is usually a DC voltage – even if it is not explicitly labeled as such. If the value is an AC voltage, this will be declared accordingly (e.g., "250 V AC"). Additional details and information – for example, relating to ripple current, or peak-to-peak – are usually provided by suppliers in their detailed data sheets or in their specification/application information. It is important to note here though that MLCCs that have the same C value but a higher dielectric strength (regardless of predictability or error rate aspects) tend to have thicker interior layers, which results in a less pronounced DC bias.

That said, some suppliers continue to provide lower voltage specifications for capacitors that today support voltages of 50 V, for example.

In either of these two cases, it is ultimately not a problem to exceed voltage requirements – for example, by using a capacitor specified for 25 V or 50 V with a requirement of 16 V.

Alongside the base parameters considered here, there are a number of other aspects that play a role when selecting components – for example, the required quality level or properties depending on the application and field of use. Such properties may include Automotive Grade (usually AEC-Q200-qualified) or soft termination (also known as flexiterm, flexcrack resistant, resin external electrode, and polymer termination, among other similar expressions), which prevents the formation of cracks that notably can occur when bending PCBs (Figure 4).

Motivation for miniaturization

Miniaturization has other implications arising from the motivation behind them. While it may have been driven until recently by the demand for modern electronics to provide more and more performance, which increasingly limited the amount of space on the PCB, the primary factors today are more likely to be availability and cost effectiveness (Figure 5), especially among suppliers. For developers, this means that they increasingly have to adapt to the pace of the suppliers and leave enough leeway for alternatives if they want to stay flexible and cost effective – double sourcing being key to this. This is especially true in the midst of challenging market conditions, which can always arise, even if just temporarily.

Technologies for the mobility of the future

New transformer design with minimal tolerance

Electric vehicles and the future promise of autonomous driving require progress in many key technologies – among them the charging of high-performance batteries. On-board chargers (OBC) may benefit from a novel design for power transformers.

By Jochen Neller, Technical Support at Rutronik, and Gerard Healy, Product Manager at Pulse Electronics

In order to continue achieving good efficiency levels in the high-performance segment, power switches with low switching losses are required. Modern products frequently use resonant converter topologies that offer the advantage of reducing switching losses using the ZVS principle (zero-voltage switching). These are most notably used in LLC resonant converters where the resonant inductance enables zero-voltage switching, making them ideal for high-efficiency multi-kW OBC applications.

The term LLC refers to the fact that the resonant circuit relies on the function of the three components: the transformer's magnetizing

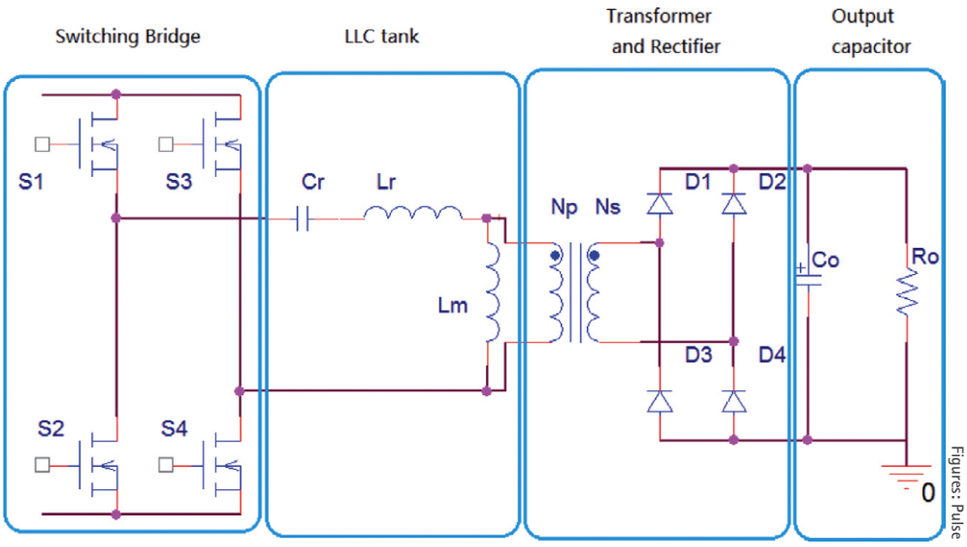


Figure 1: LLC converter with an idealized model for the transformer

Figures: Pulse

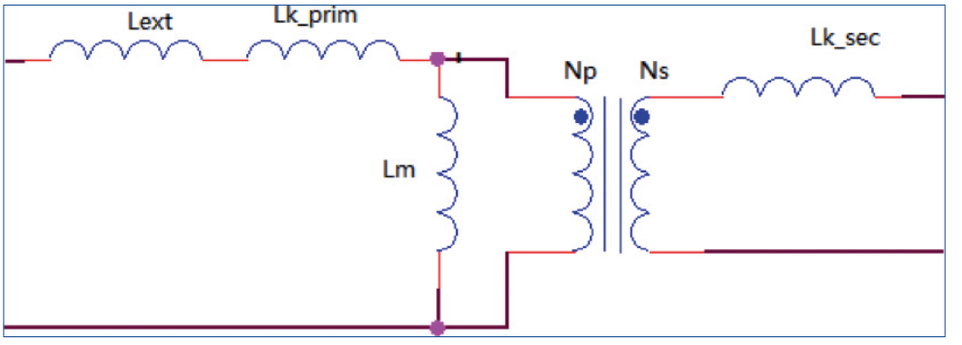


Figure 2: Transformer model including leakage inductance

inductor (L_m), the transformer's leakage inductance (L_r), and the resonant capacitor (C_r). This is a known method of replacing the required resonant inductor with the leakage inductance of the LLC transformer if the value is calculated correctly and the required tight tolerance is adhered to. The supplier Pulse has used finite element modeling to design a 3.6 kW LLC transformer where the high-precision, tight-tolerance leakage inductance of the transformer serves as the resonant inductor of an LLC converter.

Figure 1 shows the LLC block diagram with the highlighted resonant inductor L_r. The resonant circuit is inductively coupled with the output/smoothing circuit. The magnetic coupling is primarily determined by the geometry of the coils and the core air gap.

The amplification of the LLC converter is determined using the following formula:

$$\text{Amplification} = (L_m + L_r) / L_r \qquad \text{(Equation 1)}$$

While the tolerance of the magnetizing inductor L_m can be controlled by complying with the strict tolerance value for the core air gap, the resonant inductor L_r needs further study.

A more complete model that reflects the leakage inductance of the primary (L_{k_prim}) and secondary (L_{k_sec}) coils as well as possibly an external resonant inductor (L_{ext}) is provided in Figure 2.

The following is now apparent:

$$L_r = L_{ext} + L_{k\_prim} \qquad \text{(Equation 2)}$$

As mentioned, the need for the discrete resonant inductor can be eliminated by designing the transformer with a sufficiently high leakage inductance. The challenge here is to properly define a tight tolerance for such a parasitic parameter, which Pulse has achieved with this novel coil design.

Sandwich coil design

One example would be the PQ50/50 platform with primary and secondary coil wires with dimensions that are suitable for the 3.6 kW power level. Taking into account the system requirements that the transformer was developed for, the Equations 1 and 2 that were used to determine leakage inductance revealed that a split primary coil with a sandwich-type secondary coil came closest to achieving the target value.

Figure 3 shows the coil cross-section surface of a patented coil design for fine-tuning leakage inductance. What's unique about this design is the ability to control the distance between the coil segments independently of one another and to achieve the required leakage inductance. The width of each coil sector and the wire bundle size are carefully adapted to the coil precision to fine-tune them to the leakage inductance tolerance requirement.

Finite element method for optimized transformer design

As a finishing touch to the design and to ensure that the leakage inductance is concentrated around the primary coil, it is essential to optimize the design of the primary and secondary coils and the position of the core air gap.

Finite element method

The finite element method (FEM) is used to calculate components on a computer. It is commonly used to simulate mechanical deformations of solid bodies resulting from the effects of factors such as pressure and temperature. This allows design errors to be identified and avoided in advance, thus saving costs. It involves dividing a unit virtually into tiny, finite elements. In this case, FEM is used to simulate how a ferrite core transformer would react to magnetic flux.

This design was developed using finite element modeling, a modern method for analyzing technical magnetic problems and developing effective solutions. It results in a magnetic flux that achieves the desired result. Figure 4 on page 32 shows the finite element model of the individual flux paths of the primary and secondary coils.

A prototype design (Figure 5) and an electrical test confirmed the simulation of the finite element model for the optimized transformer design. The measurement of the electrical parameters shows that the target leakage inductance and tolerance values were met. This shows how this novel design allows the leakage inductance of the LLC transformer to be replaced by a discrete resonant inductor. ■

A detailed report is available at www.power.pulseelectronics.com/hubfs/LLC%20Transformer%20Final.pdf.

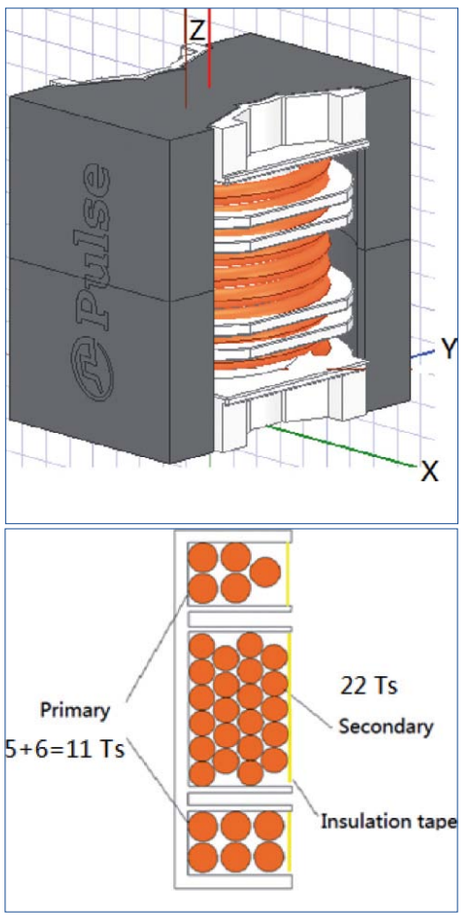


Figure 3: Coil cross-section area of patented coil design for fine-tuning leakage inductance

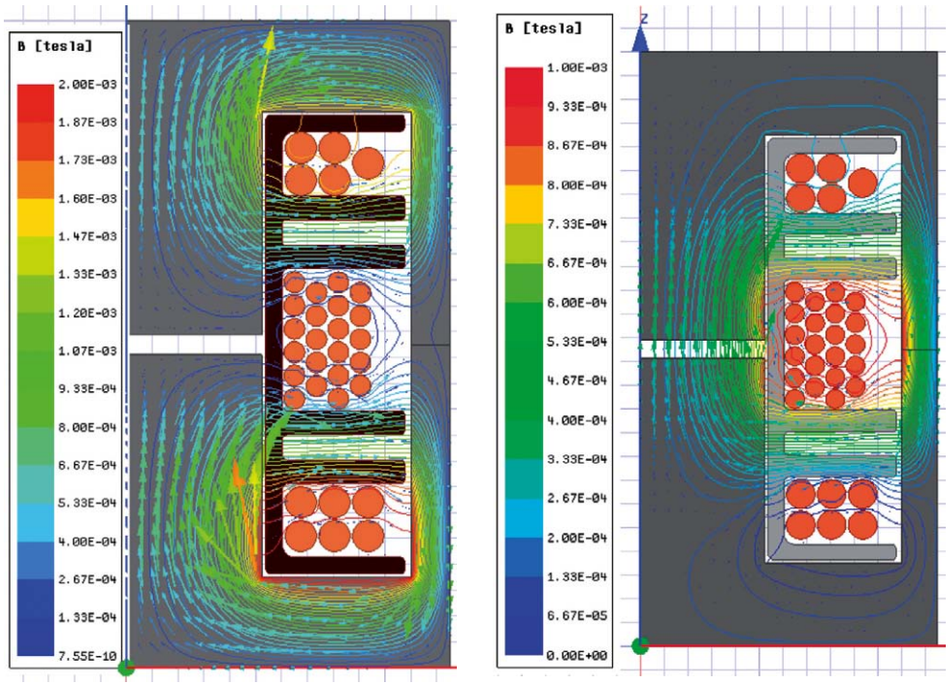


Figure 4: Finite element modeling of the individual flux paths of the primary coil (left) and secondary coil (right)

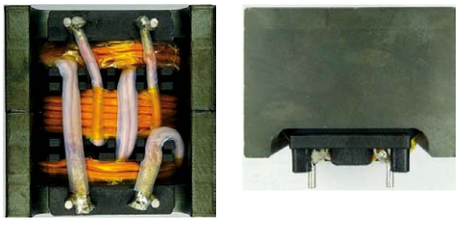


Figure 5: Prototype of optimized LLC transformer

Supercaps

3 volt technology for longer life

Supercaps, also known as ultracapacitors, are still considered to be a newcomer product. Despite only gaining significant attention in recent years, they are a tried, tested, and proven double-layer technology that has seen an encouraging and constant growth in popularity. 3 V technology can only be a boon for their appeal.

By Tobias Baisch,
Product Sales Manager Capacitors at Rutronik

A range of technological advantages makes supercaps or EDLCs (electric double-layer capacitors) an appealing prospect for many applications. These electrostatic capacitors offer superbly low equivalent series resistance values (ESR) and have a stable and effective temperature profile. Their high capacitance and large number of charge cycles allow them to serve as a supplement to batteries (rechargeable or otherwise) and in rare cases to even replace them.

For combining supercaps and Li-ion batteries, Rutronik has specially-patented solutions based on a high-efficiency DC/DC converter topology with ultra-fast switching functions for highly dynamic loads with high peak currents. This involves combining a high-energy store (battery) with a high-performance capacitor (supercap) to essentially emulate a new generation of energy storage facilities while also enjoying the benefits of Li-ion batteries and supercaps. This doubles the life of the battery while offering superb peak currents and reduces the irreversible losses of Li-ion batteries.

Over the past two decades, suppliers of ultracapacitor cells have invested much in their research and development activities. One of the main goals here has been to gradually increase cell voltage from its original 2.3 V. Three-volt technology is currently at the leading edge. This presents a number of benefits when compared to earlier versions with lower voltages – the higher the voltage, the more energy the cell can hold. Depending on the application, it may even be possible to use fewer capacitors, enabling savings in space, weight and cost. When using the same number of capacitors, the increased service life is a major benefit. It also allows for applications that were previously only feasible with caveats when using supercaps due to the low en-

Figures: AVX, Eaton, Maxwell, Samwha, Sech

ergy storage – for example, when recovering braking energy in vehicles.

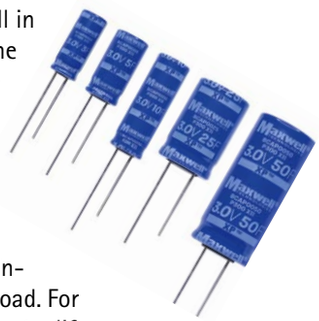
The path to 3 V tech

To achieve a voltage level of 3 V, all of the materials must be perfectly adapted to one another. The surface structure of the activated-carbon layer and the composition of the electrolyte play an essential role here. To achieve as large a surface as possible, the pore size, pore distribution, and pore geometry are improved, as are the chemical surface properties of the carbon material. Adapting the positive and negative carbon layer to the properties of the electrolyte's anions and cations also helps improve voltage potential. This ensures that the proportion of the various charge bearers to one another is optimized to provide the largest electrical surface available.

This ensures that the cell is also perfectly suitable for the current needs of the industry. In other words, taking into account defined end-of-life criteria, which depending on the supplier may be, as an example, 20% capacitance loss and/or an ESR increase of 100%, the 3 V cell must offer at least the same service life as a 2.7 V cell, which is often 1,500 hours at an ambient temperature of 65°C.

Today, 3V technology is considered state of the art, and the benefits that it offers allow for greater progress and optimization in projects and the future use of supercaps in various applications.

Offering longer service lives ...



Swapping a 2.7 V cell directly for a 3 V cell in an existing layout means that you have the same number of components and the same assembly costs, but you also have a significant increase in the life of the supercap. The 0.3 V increase in dielectric strength reduces the voltage in relation to the nominal value of the cell, which results in the supercap's life being increased while retaining the same voltage load. For some applications, providing a modicum of extra life may make the difference in allowing these applications to be achieved in the first place. These may be new developments or redesigns that would not have been feasible with previous technical specifications and that can have their service life requirements met with the newer technology. By fitting a 3 V cell in an existing, functional layout or design that was previously equipped with 2.7 V cells, the application can offer a longer service life than before.

... or less space

On the other hand, it's also sometimes worth investigating how many cells are actually needed – especially in circuits where there are many cells connected in a series. If the higher voltage makes it possible to reduce the number of components, this provides space advantages that help achieve the miniaturization needed in many applications. ■

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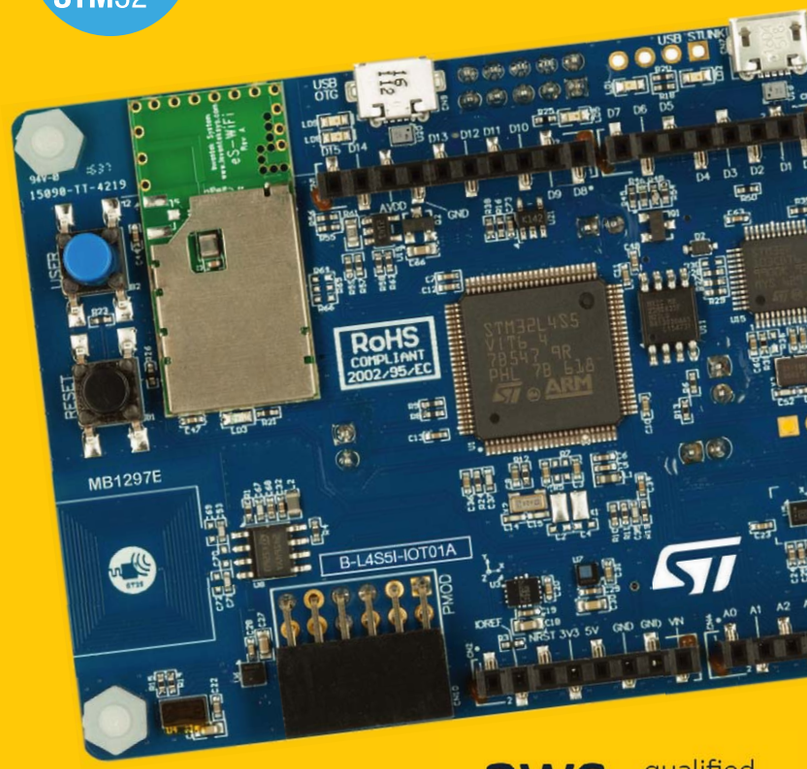

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Miniaturization

Reducing the space consumed by inductive components

Space on a PCB is in short supply, but the demands placed on the technical properties of inductive components continue to rise. Choosing the right technology can make a difference in successfully mastering the balancing act between space and performance.

By Martin Dossmann,
Product Sales Manager Inductors
at Rutronik

Space on a PCB is in short supply, but the demands placed on the technical properties of inductive components continue to rise. Choosing the right technology can make the difference in successfully mastering the balancing act between space and performance.

In the automotive sector, it has long been standard practice to define the available development space for modules before the development using actual components even begins. In industrial applications, there are also increasing size restrictions in the interest of saving space, weight, and costs. At the same time, the modern designs of many applications require higher currents, higher switching frequencies, higher efficiency levels, and better temperature management.

Power inductors

A conventional application for inductors is filtering electrical interference in a conductor. To filter push-pull interference in a current signal, coils with a single winding are used. It is conventional to use a ferrite core to boost the filter effect, although saturation effects can occur with high currents and temperatures. Coils with much higher buffer inductance values than are actually required for the application are often used as a work-around for this effect. The drawback with this over-specification is that components tend to become significantly larger and more expensive as a result.

An elegant approach to avoiding this is the use of coils with a different core material such as iron or metal powder. Figure 2 shows the inductance curve of ferrite and metal powder chokes as the current rises and at different temperatures. The metal powder components exhibit a more stable inductance curve at both 25°C and 150°C compared to the ferrite models.

When selecting products for real applications, this enables the use of coils with a lower-rated inductance. This generally results in a smaller footprint and consequently also a cheaper component.

The technology and production process of metal powder inductors have since adjusted to the needs of the market, satisfying the technical requirements of modern applications and providing a competitive commercial offering.

But it's still worth taking a closer look at the specifications of the application. Instead of comparing the rated inductance values in the data sheets when selecting components, it would be a more pertinent question to ask which inductance is required with a real current at conventional operating temperatures. The consistent behavior of metal powder coils also provides the confidence of passing EMC testing reliably.

Transducers and EMI filters

Transducers and EMI filters (electromagnetic interference) are created relatively rarely using standard products; the requirements placed upon these products are simply too diverse. Manufacturers have made great technological strides in the development of these products in recent years. Especially when it comes to power supply units in the field of power electronics, the specifications are often pushed to their limits with conventional ferrite core designs for high-frequency transducers. The transducer is often the tallest component on the PCB, making its miniaturization

Figure: Chilisin

Figure 1: Inductor using ferrite and iron powder technology

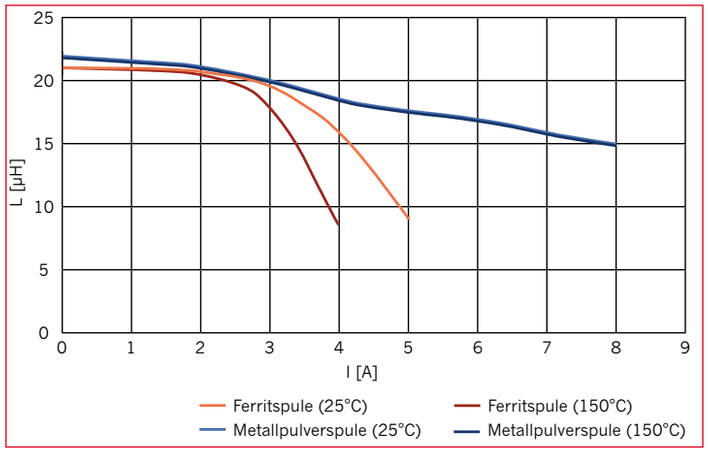


Figure: Rutronik

Figure 2: Typical saturation curve of coils using various technologies with a rated inductance of L_0 =22 µH and a 10 mm × 10 mm footprint.

a matter of some importance. With its large volume, it also plays a significant role in the heating of the system as a whole.

To enable the creation of smaller form factors and more efficient circuits, nanocrystalline cores have been developed. These materials offer much greater magnetic permeability (see table), allowing for the generation of higher magnetic flux densities in the component. They also make transducers with a higher switching frequency possible, which means lower losses.

Another trend is open designs that are not encapsulated by a package but are simply mounted on a base plate to comply with insulation resistance requirements. This saves space and helps to better dissipate heat.

Conclusion

There are inductors available today that use different – sometimes novel – materials and designs to meet all of the key requirements of modern applications – namely, small size, low weight, higher currents and switching frequencies, and optimized heat control. When selecting components, it is essential to take into account not only the rated values of the inductors but also the values arising in real applications. ■

Material class	Magnetic Permeability µ
NiZn ferrite cores	10–3,500
MnZn ferrite cores	300–20,000
Nanocrystalline ferrite cores	700–200,000

Common core materials with their permeability values

Operational amplifiers with EMI immunity

Pushing radio frequency filters to their limits

IEEE802.11, Bluetooth, UMTS, GSM: radio communication protocols that couldn't be more different, and yet they do have something in common – namely, electromagnetic waves that can disrupt how integrated circuits process signals. EMI-immune circuits provide a remedy for radio-frequency interference.

By David Mittbrodt,
Product Sales Manager
Analog and Sensors at Rutronik

Wireless data transfer has many benefits, and a variety of communication protocols have become established in recent years. However, the radio frequency electromagnetic waves that are used to enable devices to communicate with one another wirelessly can cause severe interference in electronic circuits and components.

The frequency range of HF signals can be as low as 3 MHz and as high as 30 THz, depending on the definition. The biggest problem with most analog ICs is their susceptibility to demodulating and intermodulating radio frequency interference outside of their linear frequency range. This effect is especially relevant when signals need to be amplified or adjusted.

In mobile communications, microwave frequencies of between 900 and 2,700 MHz are used. Even if these signals are way outside the bandwidth of a relevant operational amplifier, they can still cause electromagnetic interference (EMI). Interference may be caused if an HF signal with a wavelength of 900 MHz at 33 cm or of 2.4 GHz at 13 cm, for example, is sufficiently longer than the connectors on the housing of the operational amplifier. This results in conductors, PCBs, bond wires, and component connectors acting as effective antennas to receive this radio frequency interference.

A real-life example would be a car radio that uses an operational amplifier to boost its audio signal. If radio frequency signals that go beyond the actual usable bandwidth of the

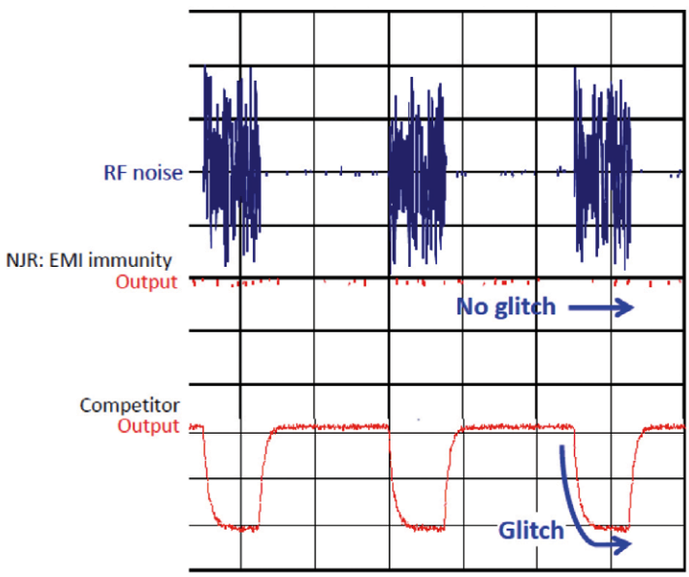
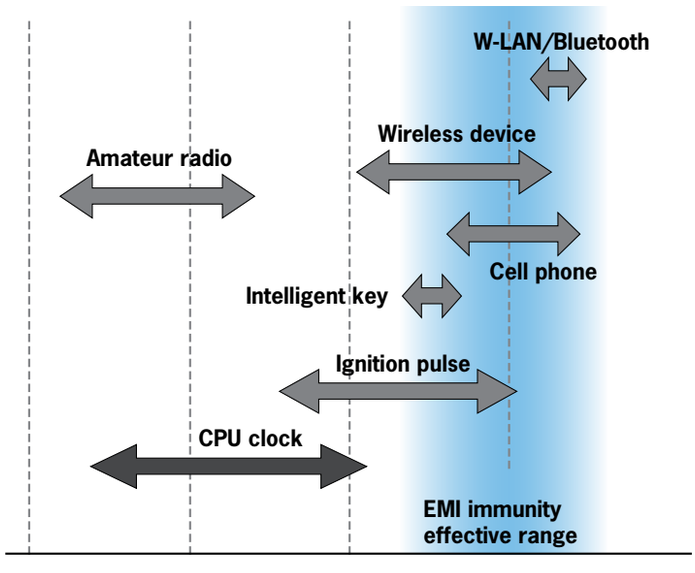


Figure 1: Comparison of the output signal of two operational amplifiers when receiving an HF signal: one with and one without EMI immunity



Figures: NJR

Figure 2: High-frequency ranges of various devices; the range covered by operational amplifiers with EMI immunity is shown in blue

device are introduced into the circuit, this causes the voltage at the op amp input to fluctuate. This in turn has a negative impact on the signal quality at the op amp output. The supply voltage of the op amp spikes suddenly, which causes a shift in the output voltage.

How can interference in circuits be prevented?

With analog low-frequency circuits, it is often possible to install filters and shielding that damp or filter out interference signals, but this often produces large, complicated circuitry that also makes the device more expensive, making it less competitive. Not only that, but there are barely any low-cost filters for circuits with a bandwidth of more than 20 kHz that offer sufficiently good properties without also significantly impairing the functional bandwidth.

Op amps with strong HF immunity may provide a remedy here. Figure 1 shows an example comparison of a signal at the output of two op amps when a 2.4 GHz RF signal is received. The middle of the figure (red) shows the movement at the output of an op amp with installed EMI immunity, while the behavior of an amplifier without RF immunity is shown at the bottom. In the latter case, interference (transient voltage spikes; glitches) is clearly visible upon receipt of the RF signal, which also results in an offset voltage shift at the output. Periodic interference will cause regular malfunctions. With sporadic interference, which commonly occurs in practical applications, malfunctions are often not even noticeable. An example here are the data packets transmitted at non-regular intervals for digital radio. This interference can cause malfunctions in the entire electronic equipment.

Suppliers such as New Japan Radio (NJR) or STMicroelectronics offer solutions tailored to this very problem. NJR's new NJU7755x series is delivered as standard with a supply current reduced by up to 85%, an amplification bandwidth of 1.7 MHz, and strong EMI immunity, making NJR's op amps perfect for precise analog sensor signal processing. Figure 2 shows the various radio frequency ranges; the range with the blue background is where the NJR op amps offer EMI immunity.

Another recommendation is the STPA003 from STMicroelectronics, which was developed for high-performance car radios. It works free of interference even with GSM signals (lower frequency band of 380 MHz to 1,910 MHz, upper frequency band of 390 MHz to 1,990 MHz), which is relevant for use in automobiles.

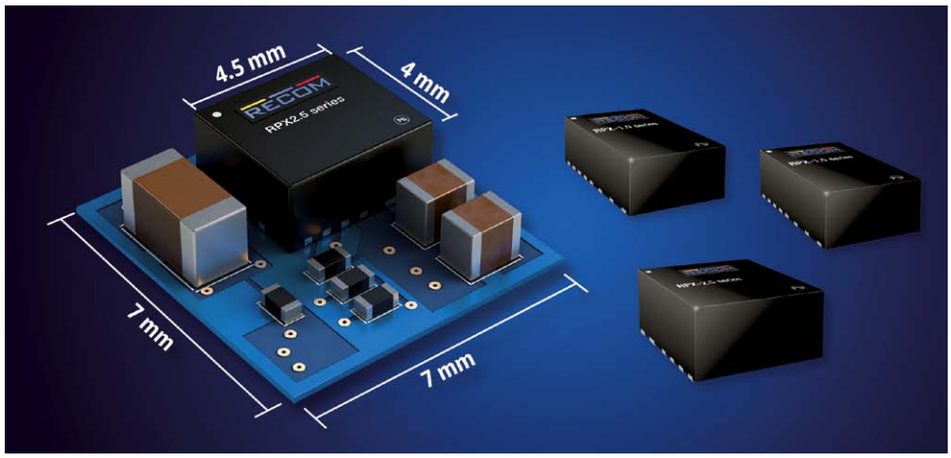
This shows that radio frequency interference is to be expected even in audio frequency bands. Suitable op-amps filter these out without massively driving up the total cost of the circuit. ■

Buck converters

From circuit to fully integrated module

Buck converters have been in use for a century now, and it's impossible to imagine modern electronic circuitry without them. This article shows how a clunky electromechanical component has transformed into a miniature PCB-mounted component that can process hundreds of watts of output.

BY AXEL STANGL, PRODUCT SALES MANAGER POWER AT RUTRONIK, AND STEVE ROBERTS, RECOM INNOVATION MANAGER



Buck converters convert a supply voltage into a lower output voltage. Their basic elements are shown in Figure 1. First, switch SW1 is closed, which causes electricity to flow into coil L1. This causes the current flow to rise continuously until switch SW1 is opened and switch SW2 is closed. This causes a change in the current flow. Capacitor C1 serves as an integrator; the resultant output voltage is therefore a function of the current and the switch-on times of switches SW1 and SW2.

SW1 and SW2 were originally actually mechanical switches that were quickly replaced by silicon – SW1 with a transistor and SW2 with a diode.

Circuits change with technology progress

Over the years as many components as possible have been incorporated into circuits to reduce the cost and size. The ability to integrate the main switch S1 directly into the controller IC was a breakthrough. The coil and diode were still external. To further increase efficiency, newer versions then implemented both switches (SW1 and SW2) using MOSFETs, which enabled switching frequencies of up to 2 MHz.

Now the aim was to take another step toward miniaturization. As a result of the constant increases in switching frequencies, it was now possible to reduce the size of the coil construction. The amplitudes of the currents fell, which affected the size of the basic capacitor. The use of higher-grade capacitors with reduced internal heat generation further supported this advancement.

More efficiency with small size

The current objective is to reduce design sizes while further increasing efficiency. To achieve this, the cycle-switched power circuits must be minimized, and the components on the z-axis must be mounted above one

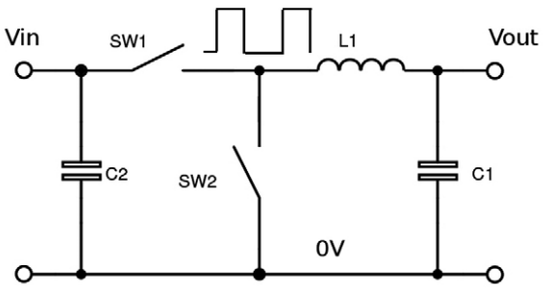
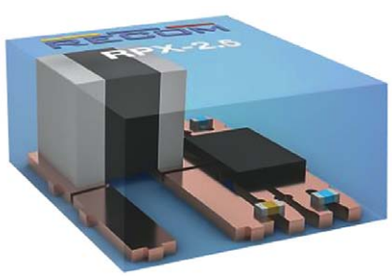


Figure 1: The basic elements of a buck converter



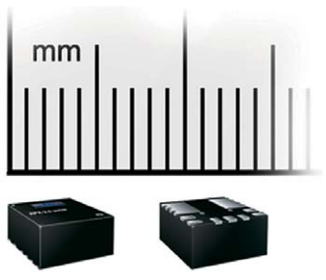


Figure 2: Flip chip on lead frame construction

Figures: Recom

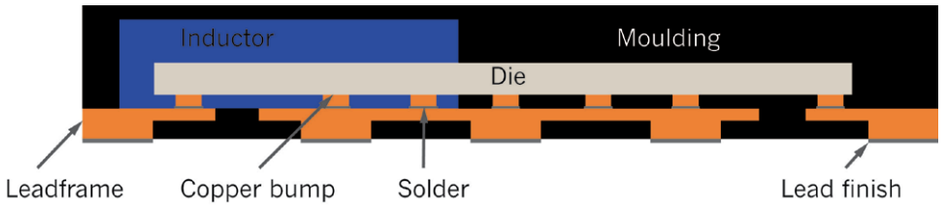


Figure 3: The POL module of the Recom RPX buck converter with an integrated chip inductor and flip chip on lead frame (FCOL) construction

another. This can be achieved most simply using flip chip on lead frame (FCOL) packaging technology, which has the controller IC (with integrated power transistors) vertically connected to the lead frame directly – alongside an SMD choke that is also mounted directly on the lead frame (Figure 2).

This construction enables the fully automated production of highly compact buck converter modules. This shortens the connections of the self-shielding inductor, thus also having a positive effect on electromagnetic compatibility. Products manufactured in this way can also be molded on, which creates a leadless QFN package (quad flat no-leads) with a MSL3 rating and provides full environmental protection. One example of this is the Recom RPX series (Figure 3) with a 2.5 A output adjustable to between 1.2 V and 6 V in a package measuring just 4.5 mm × 4 mm × 2 mm that only requires external input and output capacitors.

These modules are complete solutions that can be mounted on the user's PCB using standard SMD assembly and furnace soldering processes. Recom recently introduced two more RPX series power modules based on FCOL technology. The RPX-1.0 and RPX-1.5 modules can be shipped in ultracompact QFN packages measuring just 3 mm × 5 mm × 1.6 mm with supply voltages of up to 1.5 A at 36 V DC.

Conclusion

Buck converters have evolved significantly over many decades. Innovations from capacitor, inductor, controller IC, and packaging technology have enabled the integration of all components into increasingly miniaturized packages with ever-increasing power densities. The aim of making DC/DC converters with low power consumption akin to an IC is now largely achieved by combining innovative 3D power-packaging technologies for both isolated and non-isolated converters. Further improvements to performance and power density are to be expected in the future. For general use as modules, however, fully equipped buck converters have similar dimensions to those of normal SMT components and will also be used in the final application. ■

NTC sensors

Fast and reliable temperature measurement

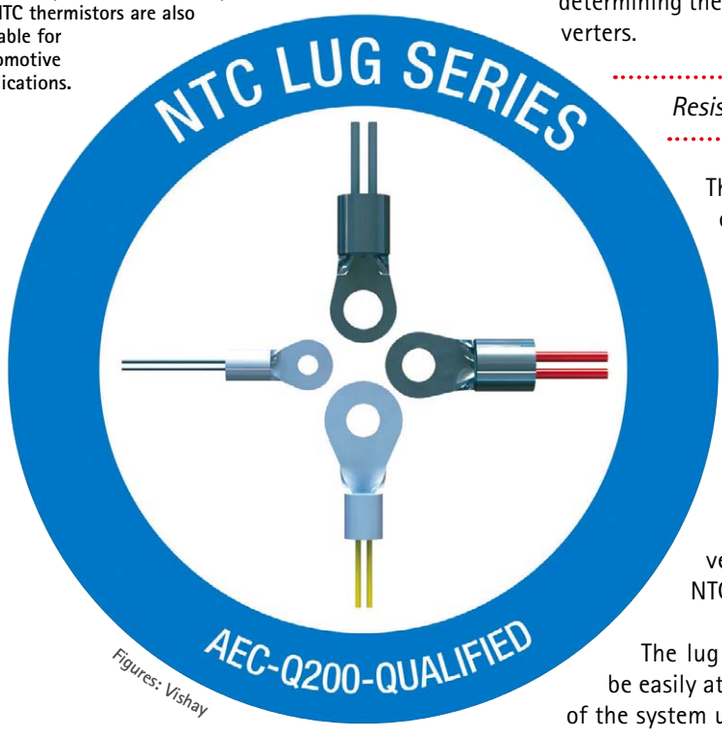
Wherever precise temperature monitoring is needed, NTC (negative temperature coefficient) sensors or thermistors are the ideal choice with their diversity of standard versions and their customization opportunities.

By Jose Iglesias, Product Manager Resistors at Rutronik, and Mandy Maier, Product Marketing Manager Nonlinear Resistors at Vishay Electronic

The technology of NTC thermistors means that they offer the highest sensitivity to temperature changes. They detect changes of –3% to –5% per degree Celsius, while other resistive technologies such as platinum or nickel-based temperature sensors achieve less than just 1% per degree Celsius. NTC thermistors also offer a broad range of resistance values, which produces low voltages, allowing point-to-point measurements with maximum precision.

These properties make NTC thermistors the ideal surface-temperature sensor solution for many electronic devices – for instance, power electronics, cooling-system control, and consumer electronics – as well as numerous other industrial and automotive applications. The thermal reliability and precision in particular play an essential role in determining the lifetime of batteries and inverters.

AEC-Q200 qualification means that Vishay's NTCALUGx family of NTC thermistors are also suitable for automotive applications.



Figures: Vishay

Resistant to mechanical stress

There is an increasing number of applications that involve exposure to heavy vibrations and that need to control high power levels and high voltages in very limited spaces. Robust NTC sensors with specified electrical and mechanical performance values are required here, which is why Vishay has developed a large selection of NTC lug thermistors.

The lug enables the thermistors to be easily attached to the metal surface of the system using a screw. They are usually fitted directly on heat sinks, battery poles, high-voltage rails, high-current plug connectors or housings. The NTCALUGx standard family portfolio includes M2 to M6 lug terminals, and larger versions are available as customized solutions.

The NTC chip itself is located within the lug sleeve, with appropriate heat-conducting and electrically isolating safety mechanisms in place. With insulated wires, NTC thermistors offer a good thermal connection and can durably withstand operating temperatures of up to 150°C.

The electrical properties of the lug and terminals are critical in the final assembly. To satisfy specific design requirements, there is a very large selection of standard sizes and customization options. For example, a nickel conductor in a closed lug ring with a small profile reduces the thermal gradient of the final assembly, which can be important, especially for temperature measurements of heat sinks.

The need to detect temperatures on elements that conduct high voltages and currents requires a higher insulation voltage between the sensor surface or the lug and the NTC's terminals. The NTCALUG series from Vishay, for example, offers insulation voltages of up to 5 kV AC, providing it with a key advantage, especially in applications relating to electric vehicles such as on-board chargers (OBCs), DC–DC inverters, charger plugs and sockets, charging situations, clutch and electric traction motors, batteries and battery management systems (BMS), temperature control of MOSFETs, and DC link capacitors.

These applications usually require superior mechanical strength, which can be achieved by means of larger lugs and thicker wire sec-

tions (NTCALUG01x) when establishing connections to automotive connectors. The NTCALUG03x mini-lug version offers superior reaction times and a lower temperature gradient due to the minimization of the mechanical parameters, making it perfect for modules with limited space – for example, in LED lighting. The effects of mechanical stress, caused by limitations of circuit design and cable management needs, can be mitigated using right-angled lugs and flexible multicore wires.

The NTC is selected not only based on the electrical criteria but also based on a choice of screw sizes and wire thicknesses. It is also possible to make adjustments to cable lengths, to have cable insulation stripped for soldering, to have reinforced cable insulation (such as heat-shrink or silicone tubing), to include cable harnesses, and to integrate any number of plug connectors for easier end-device production or to connect control boards.

Rutronik's broad selection of standard and customizable lug NTC-sensor products offers a wide range of opportunities for temperature reading as well as excellent value for money. These modules with many material options are highly flexible for developers when it comes to integrating them into device designs and optimizing production efficiency. They also provide very reliable performance. Vishay's products are available with AEC-Q200 qualification, UL certification and as lead-free/RoHS-compliant versions (without exception).

EASY MOUNTING MECHANICAL OPTIONS

Mounting screw ->							
Metric screw ->	M2	M3	M3,5	M4	M5	M6	M8
Stud screw ->	#1-2	#3-4	#5-6	#8	#10	#1/4	#5/16
CABLE AWG24			■	■	■	■	■
CABLE AWG26		■	■	■	■	■	
CABLE AWG28	■	■	■	■	■	■	
CABLE AWG30	■	■	■	■			
CABLE AWG32	■	■					

Vishay's NTCALUGx family of lug-mounted NTC thermistors are available in many sizes and versions.

Bridge ICs

A translator for images and videos on any device

Displays are being found in more and more devices – even refrigerators, smartwatches, and automobiles. Users expect crystal-clear playback with zero jerking – on any medium. Bridge ICs are used to make this possible, even with different standards.

BY ZIBO SU, PRODUCT MANAGER DIGITAL AT RUTRONIK

The most well-known differential method for fast transfers of large amounts of data at rates of up to several Gbit/s – and thus for image and video content – is LVDS (low-voltage differential signaling technology). Developed by National Semiconductor, LVDS was standardized as EIA-644 by the EIA (Electronic Industries Association). It is a free and open standard that is used by many IC suppliers.

LVDS is a unidirectional connection that works very energy-efficiently. This technology uses the voltage differential between two copper cables to transfer information. The LVDS transmitter encodes up to 24-bit data based on an input clock over four serial differential pairs (see Figure 1). A terminating resistor prevents reflection back to the signal source.

Because LVDS works with low voltages of under 3.3 V, the technology requires little current and generates only minor electromag-

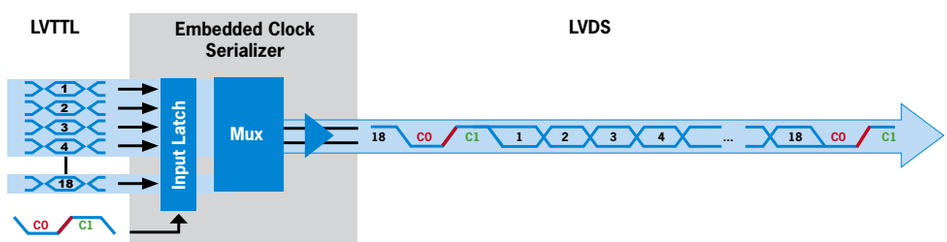


Figure: Rutronik

Figure 1: An embedded clock serializer with a single LVDS channel

netic interference. Common-mode voltages generating an electromagnetic wave are eliminated by the differential.

LVDS only describes the physical level; several other communication standards are based on it, including FPD-Link (flat panel display), FPD-Link II and III, MIPI (mobile industry processor interface) and DVP (digital video port).

LVDS with FPD-Link

When we talk about LVDS, we usually mean the FPD structure. FPD-Link was developed alongside LVDS by National Instruments and remains the standard today for the transmission of graphical and video data between notebooks, tablet PCs, or LCD televisions and their displays.

FPD-Link chipsets consist of transmitters (TTL to LVDS) and receivers (LVDS to TTL) that support 18- and 24-bit color displays. At the TTL level, the RGB data and control data from the graphics controller is transmitted to the inputs of the FPD-Link transmitter. It acts as a multiplexer (mux) for the parallel TTL data and converts it to the serial LVDS standard. The LVDS data is sent to the outputs of the transmitter via the cable connecting the mainboard to the display. At the FPD-Link receiver on the display, they are deserialized (demuxed), which means that they are converted back into TTL signals and sent to the inputs of the timing controller. Multiplexing the parallel TTL signals allows higher-speed data to be transmitted over a narrow-band interface. Even so, the requirements of high-bandwidth communications are met.

Figure 2 shows the structure of an FPD-Link with four LVDS wire pairs. Three of the four cables transmit the graphics and video signal while the fourth conveys the LVDS clock signal. The mux circuit serializes the parallel graphics and video signal and transmits it over the differential pair. Thus, only three cables are needed as opposed to the 22 otherwise needed, and there is also an improvement in electromagnetic compatibility.

FPD-Link chipsets are available with falling and rising edges and programmable data import to provide a convenient interface with a variety of graphics and LCD panel controllers. The 5 V or 3.3 V chipsets support a frequency range of 20 to 65 MHz.

MIPI

The MIPI Alliance has specified six types of interfaces in mobile, networked devices: for the physical level, multimedia, chip-to-chip or interprocess communication, device control and data management, system debugging, and software integration. Each specification satisfies the most important requirements of these devices: low energy consumption, high bandwidth, and low electromagnetic interference.

DSI (display serial interface) and DSI-2 are the MIPI interfaces between one or several displays and the application processor. They define a serial bus and a communication protocol for data transfer between the host, the image data source, and the target application. They were developed to enable lower-cost display controllers for mobile devices such as smartphones, laptops and tablet PCs, wearables, augmented reality applications, and vehicle instrument panels.

The physical layer

MIPI-DSI is based on the physical layer MIPI D-PHY. It is used to connect megapixel cameras and high-resolution displays with an application processor. A clock-forwarding, synchronous link is used here that combines high-speed data transmission with low power consumption as well as high resistance to interference and high jitter tolerance with low costs (Figure 3).

At the physical layer, DSI specifies a serial point-to-point high-speed differential signal bus. It encompasses a high-speed clock lane and one or several data lanes. Each lane covers two wires due to the differential signal use. All lanes run from the DSI host to the DSI device with the exception of the first data lane (Lane 0). It is capable of a bus turnaround operation (BTA) that allows the direction of transmission to be reversed. When several lanes are used, they transmit data in parallel, thus allowing four bits to be transmitted simultaneously when four lanes are being used.

The connection operates either in low-power mode or high-speed mode. The transition between the two modes is done with minimal latency. In low-power mode, the maximum speed clock is disabled and the signal clock information is embedded in the data. The data rate is not enough to control a display, but can be used to send configuration information and commands.

In high-speed mode, the high-speed clock is used at frequencies of several tens of megahertz up to over a gigahertz as a bit clock for the data lanes. The clock speeds vary depending on the requirements of the display. Because only a low voltage is required for the signal output and the data is transmitted in parallel, high-speed mode can operate with minimal power usage.

Further DSI layers

In terms of lane management, the transmitter distributes the transmitted data over one or several of the four lanes, depending on bandwidth requirements. For mapping – the method of determining which bit is transmitted over which lane – the standards from VESA (Video Electronics Standards Association) and

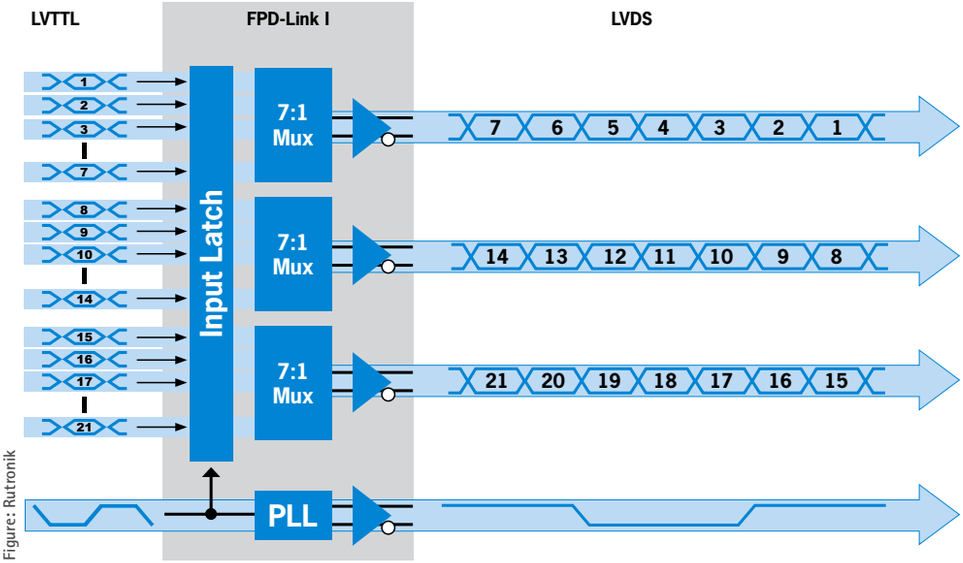


Figure: Rutronik

Figure 2: An FPD system with four LVDS pairs

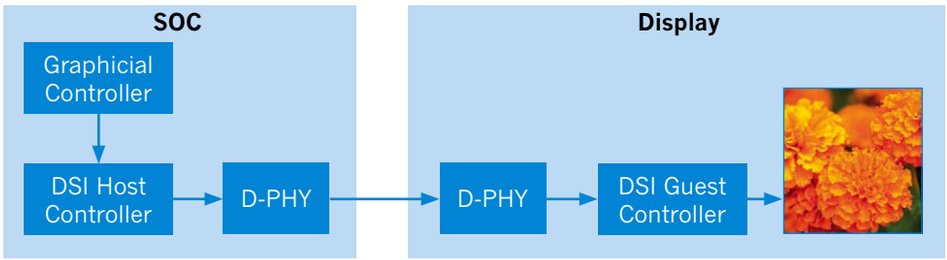


Figure: MIPI Specification for M-PHY Version 2.0

Figure 3: The physical layer D-PHY connects the application process to the display.

JEIDA (Japan Electronic Industry Development Association) are well established.

The low-level protocol layer defines how the bits and bytes are organized into packets and which bits constitute the header and payload. This is also where error checking is performed.

At the application level, data from the layer beneath is finally translated into pixels or commands.

LVDS vs. MIPI DSI

A comparison of LVDS and MIPI DSI reveals only one common factor: both use four lanes. LVDS only transmits the video/image signal, though, for which the RGB-TTL signal is converted into an LVDS signal using the SPWG (Standard Panels Working Group) or JEIDA standard. MIPI DSI on the other hand can transmit not only video/image data but also command signals. Both signals can be controlled in accordance with the specific handshake sequence and rules.

Bridge between DSI and LVDS

If the application process doesn't support a standard or does not have enough lanes to connect to a display module, a bridge IC can create the corresponding interface between the video output of the processor and the input of the display module, the camera, or other peripheral devices. This allows application processes to be connected to various displays without having to re-develop the entire system.

Toshiba offers a range of these bridge ICs. They are suitable for consumer, industrial, and automotive applications such as smartwatches, tablet PCs, ultrabooks, 4K UHD displays, smart TVs, wearables, cameras, gaming accessories, head-mounted displays (HDMs), LCDs, IO port expansions, and POS applications.

The DSI-LVDS bridge enables ICs to control an LVDS-compatible display via a DSI link. These support a pixel resolution of 24 bits. The TC358771XBG and TC358774XBG models enable classic 4:3 (UXGA, ultra extended graphics array) with a resolution of 1,600 × 1,200 pixels over DSI Single Link. The TC358772XBG and TC358775XBG models support WUXGA (Wide Ultra eXtended Graphics Array), which enables displays with 16:10 format and a resolution of 1920 × 1200 pixels over DSI Dual Link. The bridge ICs also support an I2C master controlled by the DSI link that can be used as an interface with other control functions via I^2C.

The bridge ICs operate using the LVDS standard at 135 MHz, while in the DSI standard they transmit at up to 1 Gbit/s per lane. They support the video input formats RGB565/666/888. By optimizing the backlighting of LCD displays based on ambient light, they help to reduce the power usage of mobile devices.

Conclusion

Using bridge ICs such as those from Toshiba, developers can also leverage the advantages of DSI – low power usage, low pixel data rates, and low component costs – for designs that do not support DSI, providing them with the flexibility they need in such a rapidly developing market. ■

No room for traditions

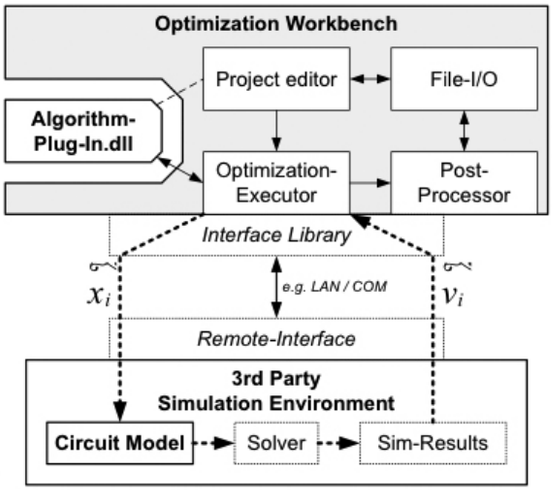
Computer-based algorithms as an alternative to traditional methods

An increasing number of design parameters and boundary conditions constitute a key challenge in the optimization of electronic circuits. Computer-based automated algorithms offer a strong alternative to traditional empirical methods or extensive mathematical efforts.

By Dipl.-Ing. (FH) Christian Pohl, Prof. Dr.-Ing. Lutz Zacharias, Prof. Dr.-Ing. Mirko Bodach, Dipl.-Ing. (FH) Sven Slawinski, Dipl.-Ing. (FH) Ringo Lehmann (all at Westsächsische Hochschule Zwickau) and Dr. Thomas Barucki at Adapted Solutions

The ever-increasing requirements power electronic systems have to meet are leading to circuits and controllers becoming increasingly complex. As a result, engineers are faced with a challenging array of design parameters and criteria. Frequently used methods such as empirical parameter optimization based on experimentally or mathematically determined initial values are uneconomical when a certain degree of complexity has been reached, as in the case of cascaded controllers.

Figure 1: The most important components of an optimization



Figures: Westsächsische Hochschule Zwickau

The use of computer-based optimization algorithms within an automated optimization process on the basis of suitable strategies from systems theory rather than heuristic methods represents an excellent alternative. The "Optimization Workbench" (OWB) framework was developed to run such algorithms within a circuit simulation. It offers a rich and intuitive front end with a number of generic functions as well as a simulator interface, project configuration tools, and extensive post-processing capabilities. Additional algorithms can easily be added as external plug-ins.

Initially, optimization using a genetic algorithm (GA), Monte Carlo (MC) analysis, and parameter sweep/permutation (PSP) are available. While MC merely involves a random search (often referred to as "analysis of statistical experiments") and PSP a simple scan, GA is a highly sophisticated, multi-criteria optimization method. Based on the natural evolutionary process, it applies genetics to a wide range of complex optimization problems where target functions may be irregular and multimodal and information about the extreme values is difficult to find by other means.

There are, of course, a number of other extremely powerful methods for multi-criteria/multi-target optimization. Yet genetic algorithms are so fascinating from an engineer's point of view because these methods combine power and efficiency with user-friendliness, because they are effectively "natural."

The GA implemented in this study is not intended to be a detailed model of biological evolution, but rather to improve the dynamics and power quality of, for example, power electronic devices by iteratively applying basic evolutionary principles such as selection, recombination, and mutation to the parameter vectors of a simulation model.

Beginning with a group of random parameter vectors within a defined search space, recombination and mutation are used to form parameter vectors derived from them. Through the selection process, the suitable candidates for the next iteration are selected on the basis of their individual fitness, which in turn was determined by the simulation.

Highly flexible with minimal programming effort

In addition to the algorithm itself, the process of performing computer-based optimization requires a variety of genetic components. The structure of the OWB according to these requirements is shown in Figure 1.

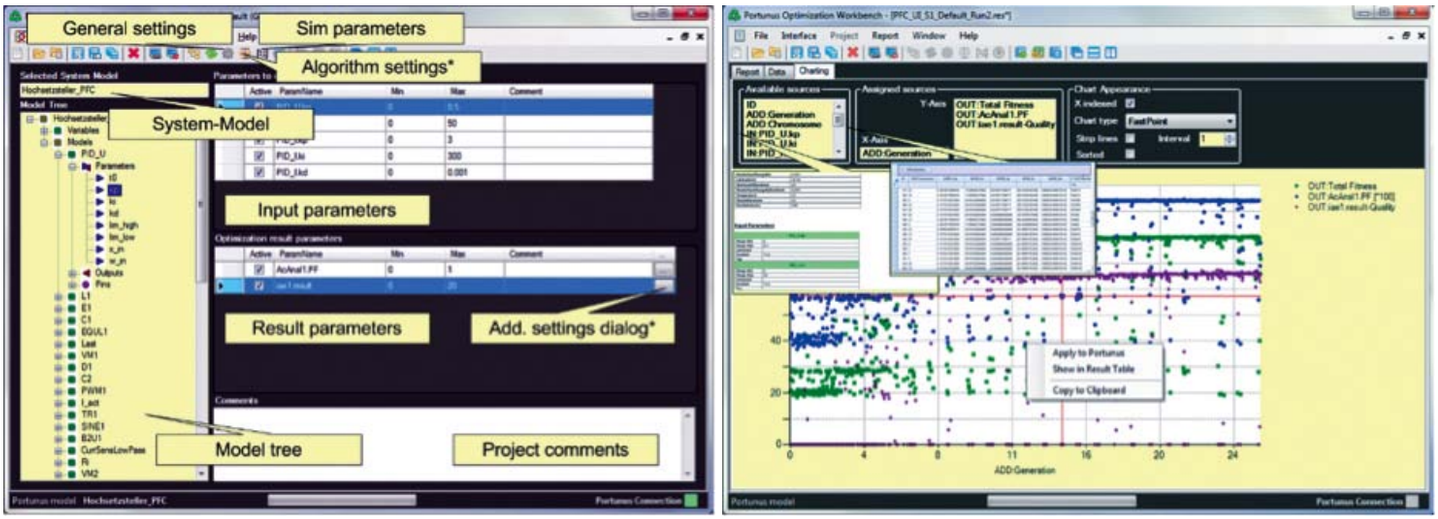


Figure 2: OWB project editor front end (left) and OWB postprocessor front end (right)

The OWB's project editor (Fig. 2a) is used to create a configuration for planned optimization runs. Based on the properties of the selected optimization algorithm, various dialog boxes are presented on the front end in addition to generics such as simulator configuration and report settings.

During the configuration stage, user actions, algorithm-specific dialog boxes, and parameter settings are hosted from the editor environment and can be controlled by the selected plug-in, if required. This approach offers a high degree of flexibility with minimal programming effort.

Once an optimization run is started, the Optimization Executor prepares the simulator and postprocessor before passing control to the algorithm. The plug-in now begins generating parameter sets and captures their results via simulation with a single synchronous method call. The collected results can be transferred to the postprocessor (Figure 2b) by calling another method. The postprocessor uses an internal automated function to dynamically adjust and update its layout based on the reported results.

After and even during an optimization run, the user can examine the archived results in the postprocessor module. It offers three main components: a template-based parameter report, a results table containing the reported values from the algorithm, and a highly configurable 2D result diagram synchronized with the contents of the table for the purpose of graphical analysis. In addition, the user benefits from various options for exporting the archived data to other applications for deeper analysis.

At the present time, three important plug-ins (GA, MC, PSP) are implemented by default. GA, which is based on the open JGAP library, offers a rich set of tuning parameters and is therefore suitable for a wide range of optimization tasks. The MC analysis can be used for exploratory optimization as well as to pre-optimize parameter constraints for more sophisticated algorithms like GA.

The PSP plug-in can be used to sample system properties within an n-dimensional search space by simulating all permutations of the parameter-specific target value vectors.

An important feature of the OWB design concept is the ability to easily define additional plug-ins. Since the OWB performs the genetic tasks itself, a well-documented and simplified interface design allows the user to focus on implementing the optimization algorithms. Should the user have expanded requirements, the interface still makes it possible to influence or interact with most of the OWB's automated functions.

With support for all .NET languages such as C#, VB.net, and VC++, the well-structured GUI, and the ability to use the freely available IDE from Microsoft Visual Studio, implementing and debugging new plug-ins is easy and efficient. In this way, the OWB can be adapted to any optimization challenge that can be solved with computer-based methods.

On a fundamental level, OWB was designed to provide an intuitive and efficient user interface with extensive error reporting in case of incorrect user action. In addition, due to the sometimes long optimization runtimes, the application was written to be stable and highly fault-tolerant to avoid sudden crashes and data loss.

Conclusion

The Optimization Workbench (OWB) presented in this article has proven to be stable and reliable in all of our numerous optimization runs. Designed as a convenient add-on for existing simulation environments, it enables computer-based optimization with minimal integration effort. The system makes it possible to accelerate complex design processes and optimally exploit technical system reserves.

Thanks to the optimization capabilities already implemented in the OWB, but also because of the equally available plug-ins for the design of controllers and power electronics, the software is extremely versatile. With its intuitive user interface, it represents a convenient tool to assist development engineers in this domain.

Consequently, the tool is already structured to be extended for operation in simulation cluster environments in order to reduce the required optimization time by running simulations in parallel. To optimize grid models, an interface to simulators such as ATP and Cerberus is currently being evaluated in order to meet future requirements resulting from smart grid developments. ■

An interview with Rutronik CEO Thomas Rudel

"Coronavirus will remain with us for a long time yet"

The year 2020 is not an easy year for the economy. In an interview with Rutronik CEO Thomas Rudel, he speaks about the impact of the coronavirus crisis on his business and the distribution market as a whole, and also about what gives him hope for the future despite everything.

EXCLUSIVE INTERVIEW

RUTRONIK-CEO THOMAS RUDEL

"We will see the market consolidate; "zombie" companies won't survive the crisis at its worst."

The coronavirus crisis has resulted in unprecedented upheaval in all sectors, and even healthy, well-positioned businesses like Rutronik face major challenges. Supply chains were sometimes disrupted for a while, the international trade in goods suffered, and sales markets declined sharply due to quarantine measures.

Mr. Rudel, the most important question first – how is Rutronik doing right now?
Well, we're in the same boat as many other companies – Rutronik has suffered a strong decline in revenue. This means we won't be able to achieve our objectives for 2020. Agenda 2025, in which our aim was to have doubled our revenue by this year (editor's note: to around €2 billion), will need to be pushed back far into the future. Right now we can't tell how and at what pace the global economy will recover. A serious forecast as to when things will calm down is not possible at this time.

The coronavirus crisis has plunged many a business into a severe crisis. What are your expectations regarding the development of the economy over the coming months?
The issue of the coronavirus pandemic and its consequences will remain with us for a long time yet. There may be effects that we're not even considering right now. It's certainly possible that we can expect a huge wave of businesses going bankrupt. Businesses that didn't have as much public attention – the self-employed in particular who number around two million in Germany – are facing considerable difficulties. This can have serious consequences for the economy as a whole.

The coronavirus emergency funding was mainly dispensed to major companies. Adidas withheld rent payments for its stores despite profits in the billions last year, while TUI and Lufthansa are receiving billions in loans and bonds. How do you see this?
I don't think it's right for such large companies that have generated billions in profits in recent years to benefit so disproportionately more from the emergency funding measures than small and medium-sized enterprises. How can it be that Lufthansa is pocketing nine billion euros in government aid but is still cutting jobs en masse? The very purpose of the funding is to preserve jobs, not to keep shareholders happy. I think it's unacceptable. Major automobile manufacturers are also declaring short-time work restrictions here in Germany, but in China, they're continuing with full production. It's absolutely disgraceful.

On the topic of short-time work, has this been a topic for Rutronik? How are you handling the crisis?
It's not something that concerns us. We developed a pandemic management system and established a task force. Thanks to the superb work being done here, we were able to provide staff with the means to work from home so that we could continue working normally – well, at least as normally as can be in these times. The results show that it worked; as of now (editor's note: mid-August), Rutronik has not had a single Covid-19 case at its headquarters in Ispringen, and the warehouse in

Eisingen was also not affected. And aside from that in general, the team at our warehouse has been doing a tremendous job. The staff there have been working a two-shift system with a requirement to continuously wear face masks to ensure that business could continue normally. Well done to them!

How has Rutronik's global focus been affected during the pandemic?
Of course, we've had to take stock of the situation in each individual country where Rutronik is represented because infections have developed differently everywhere and the situation is also being handled differently. But it has been smooth for the most part.

What changes has the coronavirus pandemic caused to the market environment and how can Rutronik benefit from this?
It's difficult to tell how our customers are doing. We don't know if they can buy goods, and if they can, how many. This means that we need to take a much closer look and check carefully because for us it entails a greater risk in terms of orders.

"Rutronik is generally well-positioned and – relatively speaking – has fared well during the crisis. But it's hard to tell what the coming months will bring."

Which markets or technologies have thrived as a result of the pandemic and will play a bigger role in the future, and which ones have suffered?
I haven't seen any major changes so far. The medical market of course has become more important due to the pandemic. But we can't tell right now how long-term that will be. In the long run, I expect the economy to have to deal with the long-term consequences for a long time yet. We will see the market consolidate; "zombie" companies won't survive the crisis at its worst because banks will be even more reluctant to give out loans. But even healthy companies won't be spared; sectors like mechanical engineering will suffer because orders are declining.

There are fears at the moment of new Covid-19 waves to come. How do you see this scenario and its consequences?
First of all, we know that we are largely left to fend for ourselves in the economy. The

measures taken by governments were usually so spontaneous that it was very difficult to react accordingly – even if we managed to do so. The tit for tat among individual German states when it came to relaxing restrictions was also a chaotic mess that was highly irresponsible of the governments and may yet come to cause businesses to suffer. Just between the states of Rhineland-Palatinate and Baden-Württemberg, there were major differences in terms of hygiene concepts, mask-wearing obligations, and rules for opening retail stores.

What would you specifically like if the crisis intensifies again?
Firstly, for any lockdown measures to be reasonable and have purpose and to have only isolated shutdowns, as was the case with the outbreak in the Tönnies plant. Secondly, to finally pick up the pace of the development of the digital infrastructure. I've been saying for years that Germany is at the level of a developing country in this regard. The coronavirus crisis has been merciless in this regard; it's all very well having people work from home or learn from home, but it's a disgrace when students in video conferences keep having their video streams freezing because the bandwidth isn't enough for uninterrupted transmission. Thirdly, and finally, for each individual to show more common sense!

What do you mean exactly?
I can't believe that people feel like their human rights are being violated because of an obligation to wear a mask for a few minutes while shopping during the day. It shows a lack of responsibility and a lack of solidarity with our society. Just like this obsession with having to fly out on vacation, to hell with the consequences, exposing themselves and their families to unnecessary risks. And they're also putting their own job at risk. What if you come back with a coronavirus infection and spread it to your colleagues? You might end up crippling an entire company. And what then? For two weeks of carelessness, you've put the economic well-being of yourself and your colleagues in jeopardy.

Even so, why do you have an optimistic outlook of the future?
Rutronik is generally well positioned and – relatively speaking – has fared well during the crisis. But it's hard to tell what the coming months will bring. We can't plan for the next year – we just have to wait and see what happens until December. Then we can see where the wind is blowing. But all in all, I remain cautiously optimistic that the economy will recover. We have a strong SME community here in Germany – our Mittelstand. If the government finally gets around to providing them with more support instead of focusing on major corporations, our country will overcome this crisis.

Rutronik Analytics – Business Intelligence & Analytics as a Service

Finding target customers and optimizing how you serve existing ones

"Ten profitable ideas how to win new customers" or "Eight tips on customer acquisition" – advisers have plenty of good ideas on how businesses can acquire new customers. In this age of big data and machine learning, however, there are smarter solutions available. Rutronik is taking a whole new approach with such a service.

By Andreas Mangler, Director Strategic Marketing, and Stefanie Piller, Digital Marketing, both at Rutronik

Rutronik Analytics is the new module of the Rutronik service portfolio. It's based on BIAaaS, an acronym that stands for "Business Intelligence & Analytics as a Service". Business intelligence describes a framework that can be used by businesses to acquire data, information and ultimately, knowledge. Rutronik uses a range of software technologies for this purpose and a multi-dimensional database in which data from various external sources can be aggregated and verified and supplemented with know-how from the product, application and market specialists.

Motivation to use Rutronik Analytics and Challenges

Three questions to Andreas Mangler, Director Strategic Marketing at Rutronik

Mr. Mangler, why is Rutronik taking such a big step into an entirely new segment with Rutronik Analytics?
The main purpose behind Rutronik Analytics BIAaaS is to facilitate Rutronik's own progress. Our main objective is to strengthen our core expertise – firstly, by means of our product portfolio and secondly, with a broader customer base and better penetration among customers and projects. Because 70% of our products require explanations, we need to be able to make optimum use of our limited resources, that is, our FAEs, product managers and BDMs. Rutronik Analytics and BIAaaS provide us with support in all of these aspects. We now want to open up these opportunities to our customers and help them to also grow.

Setting up such an entirely new, complex service must have entailed some challenges. What were they?
One of the biggest challenges was to structure the internal knowledge from the online business and IT division and the specialist knowledge of our product managers, BDMs and FAEs, and to make it usable. We also found that without extensive training of the software, pretty much nothing happened. Regarding the system itself, the challenges with VUCA are fairly well documented, namely volatility as a result of constantly changing data; uncertainty, as the data wasn't always available in a clear structure and was often subject to different interpretations; complexity as a result of complex market scenarios and different dependencies between the data sources; and finally ambiguity of the data and results.

How do you overcome these challenges?
By outlining and structuring the subject matter more clearly with each step. Defining various tools and reports was also very helpful. But of course, without the fantastic team of data mining specialists, IT colleagues and our market and product specialists, none of this would have been possible. This team has created a unique tool in Rutronik Analytics that uses modern technology to create a new dimension in sales efficiency in the electronics market.
To summarize, these new IT tools enable us to create market transparency that facilitates rational management decision-making. And this will be an important contribution in finding new target customers using web scoring and serving existing customers with our services in the best way possible.

Using analytics methods based on machine learning, scoring methods and data mining processes, information can be extracted from the database that can make all the difference for the company in question. The result is that Rutronik Analytics users gain a transparent overview of their own market and that of their target customers. This allows them to make rational management decisions that actually help the company to progress. They can grow their customer base by strategically finding their target customers – including in places where they wouldn't even have expected to. Rutronik Analytics customers can also get to know their customers better, understand how they "tick", address them in their language, and know what each one needs right now, in the medium term, and in the long term.

"As a service" refers to the fact that the software, including the hardware infrastructure, is operated by Rutronik, in accordance of course with all data protection standards as per the GDPR. The customer does not need to install any additional software – they can simply use the service precisely when and as much as they need it.

With the Rutronik Analytics service, Rutronik is offering its customers not only a lead generation service but also insights into the structures and wishes of their newfound target customers. However, the service is not limited to finding new customers – it can also be used to selectively approach existing customers and make more efficient use of the portfolio.

Defining the objective

To ensure that the analysis actually satisfies the expectation of the Rutronik Analytics service customer, the first step is to jointly define the objective. The motivation behind the market analysis and the ultimate objective (e.g. finding new customers, identifying cross-selling potential) are discussed here. There are also other questions to be discussed: Which product, product group or service will be placed on the market? What is the precise function or purpose of the product when used by the customer? What benefits does it provide them with?

And in which business/application field is it used exactly?

This is determined at four levels. The first, top level is the focus market or focus industry, followed by an application segment, then an application, and finally the product or service of the target customer.

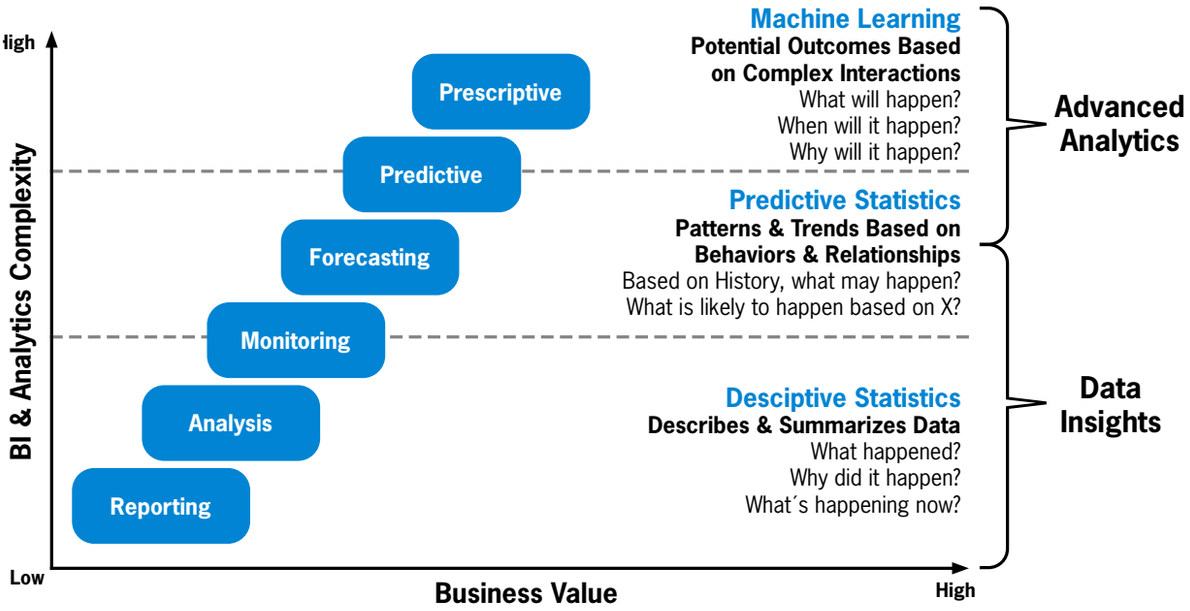
This information allows the algorithms to be trained in such a way that they also provide the desired results. Here's an example – optical object recognition in relation to assistance systems for ADAS autonomous driving systems is subject to entirely different requirements and specifications than optical pattern detection in equipment such as assembly machines, even though the physical measurement principles might be similar or almost identical. It isn't a good idea to mix up these two applications during machine training, even though they're based on the same physical principles. This would essentially cause the system to make wrong assumptions when it is being trained.

Focus, not scatter – modern cherry picking

When it's about acquiring new customers, you need to narrow down your target customer group, because the point of the output of Rutronik Analytics is not to address as many businesses as possible, but to specifically find out which businesses offer the best chances of success and the greatest potential for Rutronik Analytics customers. To do this, successful existing customers or known prospects are pre-selected as reference customers, and selected properties are described, such as the business model, the position in the value chain, and the applications that have been developed or produced with the technological aspects. These form the basis for searching for a statistical twin.

It also draws upon other exclusive data sources that have been generated on the basis of Rutronik's solid market knowledge. This includes knowledge from Rutronik's product managers and field application engineers from every division and country about components, technologies, applications and markets, as well as market data and other selected data sources.

The websites of reference customers (referred to as "customer DNA") are also analyzed and a "tag cloud" is extracted from them. It offers multiple benefits – the Rutronik Analytics customer can in turn improve their communication with existing and new customers in their language, as the tag cloud represents the vocabulary that the target customer uses.



The further you look into the future, the more significant the benefits are from data analysis.

The identified terms can also be used to directly derive demand structures to enable businesses to offer customized system solutions. For example, if "IP55" appears in the tag cloud, this indicates that one of the customer's needs would be for a connector protected against spray water in their systems.

The system uses data mining methods and scoring models to compare the generated profile against millions of websites and evaluate the similarity. The higher this is, the more likely this company is to be a compelling prospect. Thanks to this analysis, the Rutronik Analytics customer already knows plenty about their target customer and can address the right point of contact in their professional language style and offer them exactly the solutions that they need. ■

Rutronik SMART

The IoT partner for trendsetters

The website is reminiscent of Instagram – and that's no coincidence. After all, Rutronik SMART is aimed at developers who want to be trendsetters when it comes to the Internet of Things. Rutronik SMART promises a complete service that allows you to reduce your costs and risks. Markus Balke, Senior Manager Product Marketing Analog & Sensors at Rutronik, explains what's behind it.

Mr. Balke, what is Rutronik SMART all about?
Our hashtag #IoT_enabler explains it fairly succinctly – Rutronik SMART is our umbrella brand for everything needed to enable IoT applications – end to end, from sensor to cloud. It focuses on sensors and wireless, as well as security solutions and cloud services. But it also encompasses displays, mains power supply units, batteries, as well as everything else down to the smallest resistor – basically, everything you need for IoT devices. We also help our customers develop their ecosystem and facilitate contact with software providers for special projects where necessary.

But Rutronik offers all of this already. What's the point of Rutronik SMART?
IoT developers can find exactly the modules here that they need and that are best suited for their projects. The criteria defined for these are a small construction size, a high level of integration, low power consumption and at least three years of availability. So basically,

we've pre-selected components from Rutronik's enormous portfolio. In the Rutronik SMART mission statement, we put it like this – we are the IoT partner that provides its customers with a single source for everything. We allow them to minimize their risk, reduce their costs and gain technological advantages over their competitors.

Sounds good! Can you describe it more precisely?
I already mentioned that it acts as a single source for all of an IoT developer's needs. They're in good hands, because Rutronik as an owner-managed distributor maintains long-term business relationships – and this is only possible when both sides benefit in the long run. To this end, we operate with a top-class service level and high quality standards, offering on-time delivery and continuous availability of around 30 billion components.

Markus Balke, Senior Manager Product Marketing Analog & Sensors at Rutronik

"We are also contacted by companies who previously had barely anything to do with electronics."

Single-source procurement also reduces costs thanks to the need for fewer procurement sources. The well-coordinated logistics systems and standardized EDI systems (electronic data interchange) for automated ordering also help reduce workload and expense.

And where does the competitive advantage come from?
Our specialists provide support for each project based on their extensive product, technology and market expertise as well as their experience from a variety of projects. We are familiar with the roadmaps of leading component suppliers and solution providers, which allows us to help our customers be sure that they are using the latest solutions and technologies. And because we advise the customer for the entire solution without being dependent on any given suppliers, this also allows smart approaches to combining these solutions and technologies.

But IoT projects are about more than just the hardware. The biggest challenge is often with the software, for example when there is a need to filter out noise frequencies in radar measurement technology. For such challenges, and also with production challenges, we establish contact with qualified third-party service providers.

We know that IoT is a broad field. Are there markets or applications on which Rutronik SMART focuses?
We generally cover everything, as many requirements in the various fields are identical. Even so, there are a few markets which we do

focus on. We see compelling applications for digital solutions in the smart health segment. They can offer a way out of the dilemma facing society whereby populations are aging, but there is still a shortage of nursing staff. Examples would be a "digital nurse" for monitoring patients or telemedical solutions where the health and well-being of elderly people is monitored. This allows them to continue living in their own homes for as long as possible, even if they are weak or sick.

We expect a major boom in smart tracking, especially position tracking, which involves the creation of movement profiles. Condition tracking, which involves monitoring goods during transport, also offers considerable growth potential, as well as predictive maintenance, where machinery is monitored remotely to predict how it needs to be maintained.

Retail is also an incredibly interesting market – after all, brick & mortar retailers need to be able to put up a fight against the online giants if they don't want to end up surrendering the market to them. Smart retail solutions, for example, allow them to adjust prices automatically depending on the quality and shelf life of the goods, or to relocate goods between different outlets as necessary.

There is an incredibly large number of applications that fall under the smart home umbrella, and we focus here primarily on building automation and smart control, for example for heating, air conditioning and access control. Our latest project, which we created ourselves at Rutronik SMART and in which we have invested a lot of research effort, also falls under the smart home umbrella.

And what is it?
A deodorizer – but one that is actually worthy of the name and doesn't simply cover up bad smells with other smells. A sensor detects all of the components, a specially trained algorithm identifies them, and a UV LED is used selectively destroy them. This is a minor revolution for any area where unpleasant odors can develop, from toilets to kitchens, from landfills to gyms. (*Editor's note: If you are interested in the details, there is a special article on this on page 60.*)

Looking at the website at rutronik.com/smart, you'd think it was more a social media platform than a corporate website. Is Rutronik SMART targeted specifically at a younger customer group?
We are primarily addressing Generation Y developers, those who were born in the 80s and 90s. Some work in startups, and others are established customers of Rutronik who are now seeking to integrate connectivity into their products. But we are also contacted by companies that previously had barely anything to do with electronics, instead being primarily from mechanical engineering fieldsand now wanting to provide internet support for their devices. They are all familiar with the look and feel of our website from Instagram or LinkedIn. When designing the website, it was also just as important for us to have the functions associated with this: a diverse newsfeed along with hashtag searches to find everything on certain topics quickly, as well as the ability to find anything in our portfolio that is needed for IoT projects. ■

A secure MCU platform for edge intelligence in the IoT

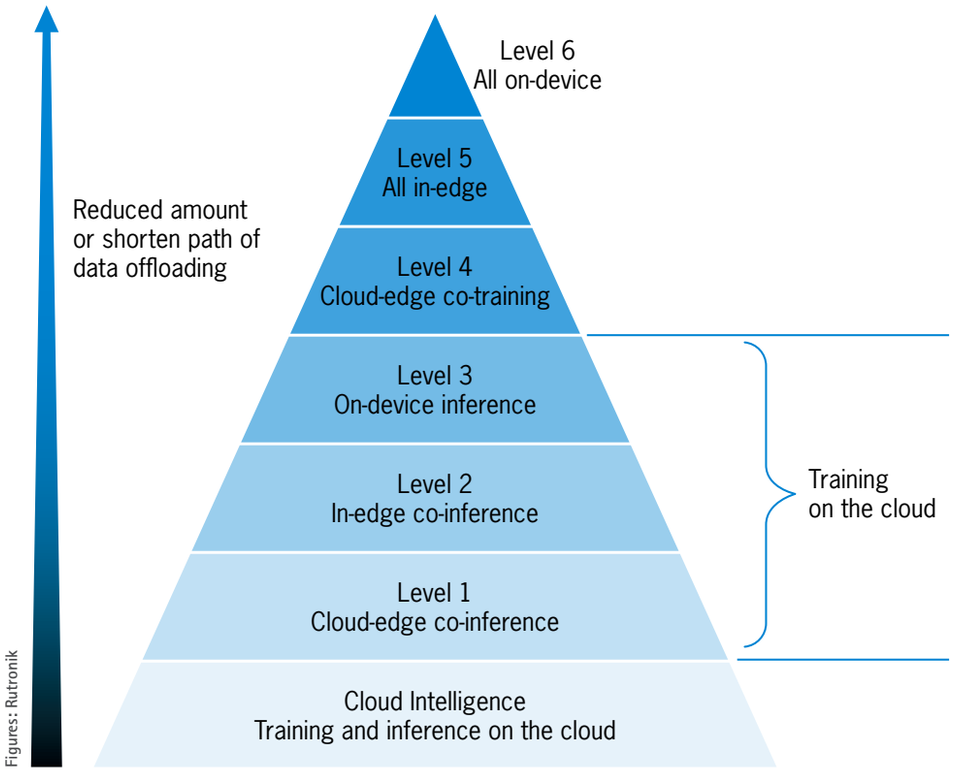
Machine learning and AI-based signal processing in edge computing

AI (artificial intelligence) applications and services are increasingly being integrated into MCU platforms, especially in industrial environments. With an edge intelligence IoT MCU platform from Rutronik, hardware and firmware developers now have a complete edge computing solution for their AI-based applications.

By Andreas Mangler,
Director Strategic Marketing
at Rutronik

End users and end devices at the network edge often generate massive amounts of data, including sensitive data that is governed by data protection legislation such as location data, health records, activity records and production information. Analyzing such data in the cloud or on edge systems entails a major risk of privacy violations – even when complying with legal requirements such as the General Data Protection Regulation (GDPR).

Years ago, real-time automation and control systems were largely developed as independent systems. Today, they are connected with



Figures: Rutronik

Six stages from the cloud to Edge Intelligence

networks through which sensitive data can be leaked or tampered with. In most cases, the system architecture does not provide adequate protection against such attacks. This is why data and algorithm security is very high on the list of priorities for industrial businesses.

Paradigm shift from cloud computing to edge computing

Edge intelligence (EI), a method of independent learning on the end devices themselves, is one way to enable distributed data learning in a way that is consistent with data protection interests. The original data records remain stored on the devices or nodes where they were generated, but the parameters of the edge AI model can be used for multiple end devices.

In Edge intelligence, digital signal processing must be performed by the AI in the (I)IoT ([Industrial] Internet of Things) front end. This entails a genuine paradigm shift from wholly cloud-based intelligence to local smart digital signal processing in the end device.

For the EI services offered by various companies to be considered trustworthy, a decentralized trust model is required. Basic designs of distributed security mechanisms make it possible to ensure the implementation of user authentication, access control, model & data integrity and mutual platform verification. If the risk of both trustworthy and "malicious" edge nodes being present in the network cannot be eliminated, safe routing plans and trusted network topologies are necessary for providing EI services. New security mechanisms with trusted zones and cryptography-based algorithms are needed for all communication processes with the MCU and data storage. This applies to the entire process, from programming to algorithm training to the practical use in the field.

Key criteria for EI-based systems

At least six criteria play an essential role in the performance of EI-based systems. They were also fundamental to the design of the RUT-DevKit-STM32L5 Edge Intelligence IoT MCU platform from Rutronik:

1. Latency

Latency is the time needed for the decision and inference process, including preprocessing, model inference, data transmission and post-processing. Assuming a latency of 100ms for the entire process, elements such as the analog sensor data signal process would have to be much shorter. Strict time limits apply in particular for mobile real-time applications such as robotics, predictive maintenance or sensor data fusion. In this case sampling rates

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of around 100kHz and the associated signal pre-processing are required. In the RUTDevKit-STM32L5, high-speed analog/digital converters (ADCs) for the STM32L05 provide the required latency values.

There are also other factors that affect latency, including the edge device resources and the data transmission method, as well as how the neural network is implemented in the software. In the RUTDevKit-STM32L5, the PSRAM Octo-SPI interface and the NOR flash Quad-SPI interface support the board's real-time capabilities. They help achieve the fastest data transfer rates possible.

2. Precision

Precision relates to the AI training model and thus also to the results of the AI model. It relates to the ratio of the number of data samples that produce correct predictions through inference to the total of data samples. The factors of influence include the speed at which the input data is fed into the AI model. For example, in a video analysis application, the right rate of input may result in data being skipped due to the limited resources of the edge device. This causes precision to suffer. On the other hand, a cameraless system such as blind spot detection in a car that is based on pulsed infrared sensor technology provides faster and more precise decision-making results. It is precisely for such applications with decentralized intelligence that MCU platforms are ideal.

Cameraless, EI-based gesture control with very low latency times has enabled the Halios family from Elmos, for example. Halios stands for High Ambient Light Independent Optical System. Its highly sensitive components detect gestures without any mechanical elements or camera-based systems. These can be superbly combined with the RUTDevKit-STM32L5.

3. Energy consumption

The work involved in calculation and communication when deriving results from an AI model consumes a fairly large amount of energy. This is a problem when implementing the AI model in the end device, because – unlike edge servers and cloud data centers – these devices are usually battery-powered. This is why energy efficiency is an important factor in EI applications. It depends on the size and complexity of the AI model and the resources on the edge devices. Efficient handling of memory space and communication times and a low-power/high-performance MCU reduce energy consumption.

4. Data protection

(I)IoT applications and devices also generate a lot of sensitive data, which is why privacy and data security must be ensured near the data source of an EI application. The method of processing the original data plays a key role here. A "trust zone" in the MCU and data storage – a virtual area with hardware-based access controls – is therefore essential. The management of secure (trusted) and insecure (non-trusted) areas, stringent process planning for programming, and the application of restricted access rights in operation are critical here.

For secure machine learning processes involving quasi big data, the RUTDevKit-STM32L5 has an SD card slot. This allows an encryption-capable SD card to be added in order to protect valuable data.

5. Communication

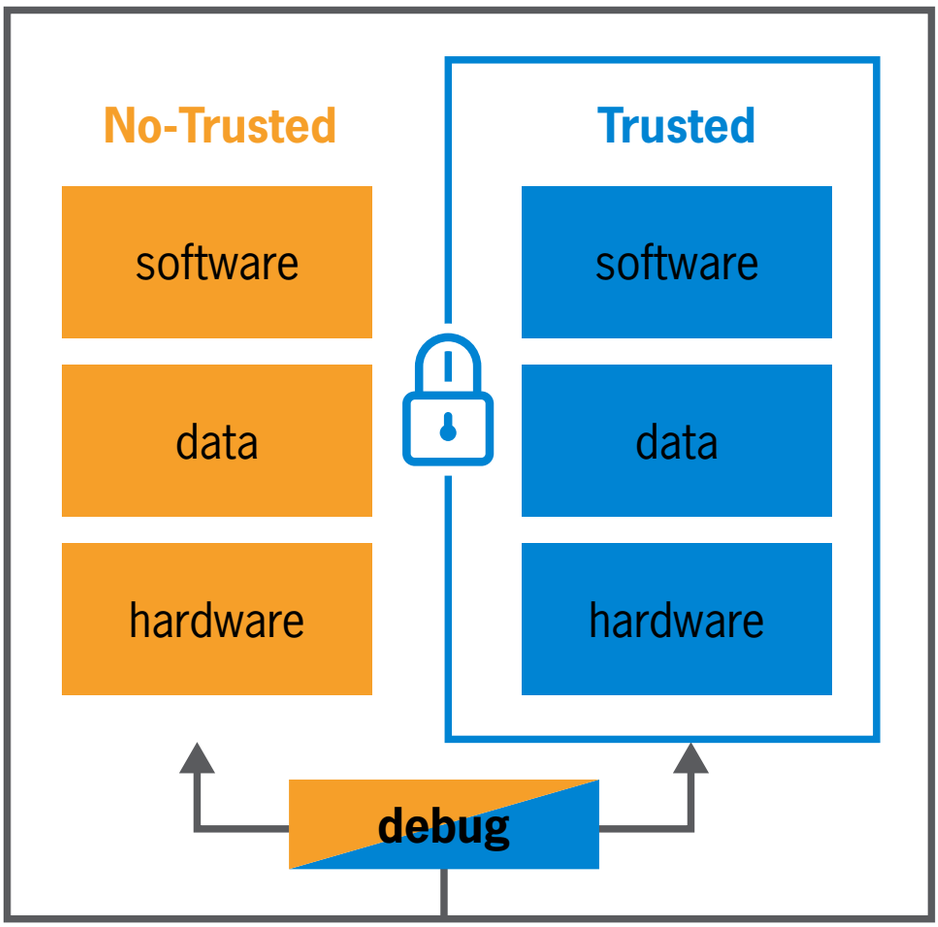
External communication with other EI systems plays an especially large role in a system's real-time capability. To keep latency as low as possible, this communication overhead must be minimized during the inference phase. This is especially true of the heavy usage of WAN bandwidth in the cloud.

An Anybus module is available for the RUTDevKit-STM32L5 that enables communication across all standard fieldbuses and Industrial Ethernet networks, relieving the burden on the MCU's computing performance.

6. Memory

A high-precision AI model is typically based on an extremely high number of data records. However, for mobile and battery-powered devices, the focus tends to be more on reducing storage resources. To be able to store big data and inference data securely on such devices, it is important to optimize storage peripherals for the AI implementation.

The RUTDevKit-STM32L5 features 412 kB flash memory, 64 Mbit PSRAM and 128 Mbit NOR flash memory on the MCU chip, plus a slot for an SD card in the GB segment with a secure area to provide the ideal conditions for machine learning applications.



ARM TrustZone provides a secure and insecure environment on a single core.

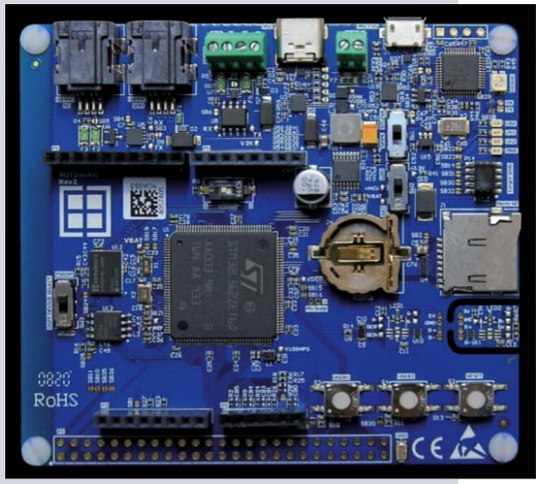
Conclusion

For many applications, it may make sense to run AI models not in the cloud, but on edge devices. Its latest development, the RUTDevKit-STM32L5, is Rutronik's important contribution to ensuring secure, autonomous systems with adequate connectivity. The complete solution for AI-based edge applications run on an MCU platform enables hardware and firmware developers to create proofs of concept in a very short time. They enhance system efficiency and scalability, while reducing development time and cost.

The RUTDevKit-STM32L5 provides a basis for a modular toolkit. Arduino-compatible plug-in boards that enable feasible solution concepts for specific end applications are under development.

The RUTDevKit-STM32L5 – an Edge Intelligence IoT MCU platform

The RUTDevKit-STM32L5 provides hardware and firmware developers with a complete solution for in-house development of AI-based edge applications. The BOM includes only components from the Rutronik portfolio. It can be found at www.rutronik.com/development-stories/rutdevkit-stm32l5 and can be easily adapted for any application. The components at a glance:



The RUTDevKit-STM32L5 – a complete solution for developing AI-based edge computing applications

Hardware

- STM32L562ZET6Q ultra-low power IoT controller (110 MHz), ARM Cortex-M33 TrustZone with 512 kB flash, on-chip PSRAM and NOR flash connected via Octo-SPI, Arduino pin connectors, access to microcontroller IO pins, ST-Link USB debugger
- APS6408L 64 Mbit Octo-SPI PSRAM
- EN25QH128A 128 Mbit Quad-SPI NOR flash
- CAN FD with TLE9251VLE driver
- USB-C power supply with protection IC TCPP01-M12
- RS-485 interface with ST3485EDBR driver
- Micro-SD card slot
- Arduino interface
- 4-layer design

Software

- CAN-FD test mode demo
- RS-485 Modbus demo
- USB power supply demo
- Dual bank flash bootloader demo
- TrustZone demo
- Tamper detection demo

Automotive Business Unit

Network founded, US presence expanded

Electromobility and autonomous driving, connectivity, digitalization and new mobility concepts are the focus topics of the transformation process not only in the automotive industry, but also in Rutronik's Automotive Business Unit (ABU).

By Calogero Avarello, Business Development Manager Automotive Business Unit, and Holger Hartmaier, Senior Account Manager Automotive, both at Rutronik

When the Automotive Business Unit (ABU) was established in 2014, Rutronik was one of the first to help companies not only meet and master the transformation of the automotive industry, but also benefit from it. At the core of this is a focus on modern, cost-effective concepts for the mobility of tomorrow.

The ABU's experts focus entirely on automotive applications. Their in-depth expertise and many years of experience in automotive electronics combined with the know-how of leading component suppliers offers numerous benefits to customers. The combination of expertise, networks, and extensive distribution know-how makes the ABU the ideal partner for all topics relating to the future of mobility.

At the start of 2020, the ABU established an automotive executive community (AXC), which sees itself as a platform for decision-makers at OEMs, tier ones, tier twos, and service providers for discussing current market conditions, trends, and the latest innovations. The focus is always on future challenges in the field of automotive electronics. This provides AXC members with a pool of information on topics such as trends for individual suppli-

Figures: Rutronik

The Rutronik Automotive Congress has become established as a unique industry event for information gathering and networking.

ers. The official AXC kick-off meeting was held on July 8, 2020 in Munich with leading representatives of German OEMs, tier ones, and suppliers.

ABU drives activity in the US

Since March 2020, Rutronik has had another representation office in the US. As the new Senior Account Manager, Holger Hartmeier will be driving and further developing the company's automotive activities in North America from Livonia, a suburb of Detroit, MI, with the support of the ABU headquarters in Ispringen, Germany. Holger Hartmaier reports directly to the Director of the Automotive Business Unit, Uwe Rahn. Via its distribution center in Texas, Rutronik already offers customer-optimized, globally identical and scalable logistics systems.

In addition to technical seminars, roadshows and Tec-Days in close cooperation with Rutronik's franchise partners, plans are also underway for events such as the first automotive congress outside of Europe. It is expected to be held in Detroit in June 2021 concurrently with the NASIC (North American International Auto Show). The agenda will include interesting presentations on current topics and megatrends in the automotive industry held by renowned representatives of OEMs, tier ones and suppliers. The event will also provide suitable opportunities for management-level networking and discussion.

Rutronik in North Amerika

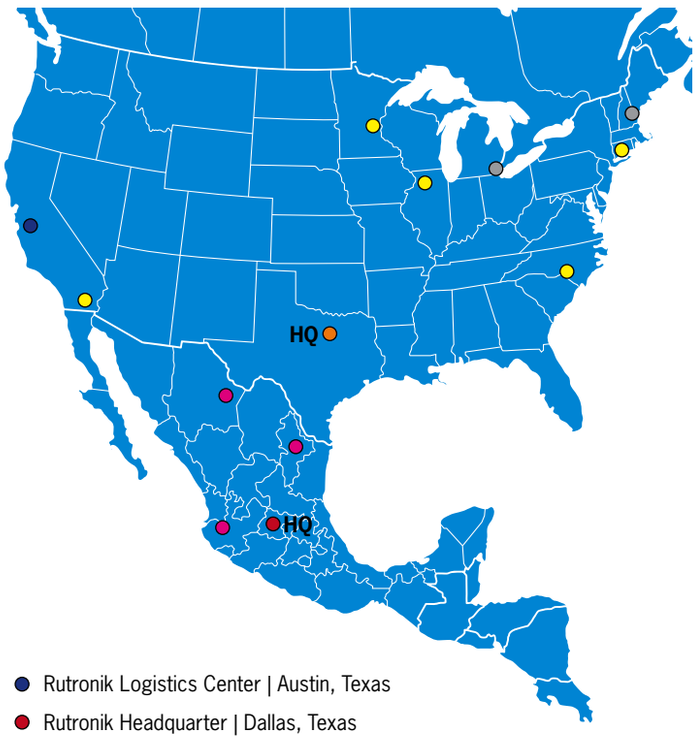
Alongside the U.S. corporate headquarters in Plano and the logistics center in Austin (both in Texas), Rutronik currently also maintains regional offices in the states of Massachusetts, California, and Michigan. The company also has a presence in Connecticut, Illinois, Minnesota, and North Carolina with its own field application engineers and field sales engineers.

Rutronik has been represented in Mexico since 2008 with its headquarters in Querétaro. Since then, there have been three additional representative offices established in the states of Chihuahua, Jalisco, and Nuevo León.

The "Motor City"

The region of Detroit, birthplace of the U.S. automotive industry, currently produces more automobiles than any other federal state. In 2017 alone, more than two million vehicles rolled off the assembly lines in eleven plants, accounting for 18.5% of the total US production. Michigan is home to the headquarters and technology centers of 17 OEMs, while 96 of the 100 largest suppliers also call Michigan their home. Automobile manufacturers and suppliers together operate more than 1,600 facilities and employ more than 117,000 engineers in Michigan alone.

Rutronik's partners in North America include over 70 suppliers.



- Rutronik Logistics Center | Austin, Texas
- Rutronik Headquarter | Dallas, Texas
- Regional Sales Offices | San Jose, Detroit, Concord
- Home Offices | Connecticut, N. Carolina, Illinois, Minnesota
- Rutronik Headquarter | Queretaro. Mexico
- Regional Sales Offices | Chihuahua, Monterey, Guadalajara

Rutronik is represented in the U.S. and Mexico with numerous branch offices and with its logistics center in Plano, TX.

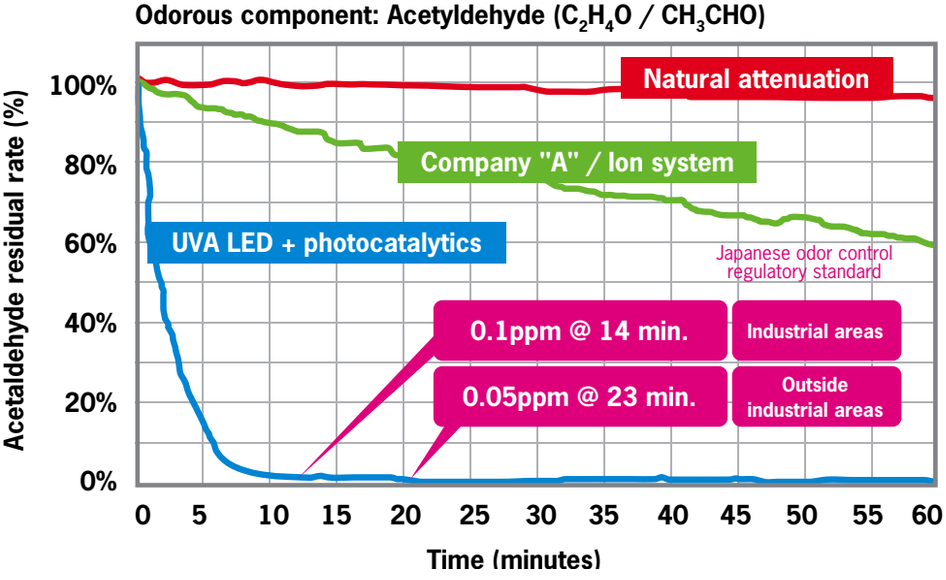
Deodorizers

Rutronik brings a breath of fresh air

Cigarette smoke, sweat, sulfur, rancid fat, burned food – the sort of things that nobody likes to have to smell. If you can't get in some fresh air, then this is where filters become useful. UV-assisted, photocatalytic models are especially effective here. Rutronik's first deodorizer demonstrator is also based on this technology.

By Maria Alejandra Salazar Martinez,
Product Sales Manager Analog & Sensors,
and Alain Bruno Kamwa, Product Sales Manager Opto, both at Rutronik

Many components of odors are volatile organic compounds (VOCs) such as hydrocarbons (such as methane), alcohols (such as ethanol) and organic acids (such as acetic acid). They are present in many objects, cleaning agents and cosmetics, are secreted by living beings, and are produced in various processes, including the anaerobic decomposition of organic substances (rotting). VOCs can not only create unpleasant odors, but also negatively affect our health, well-being and performance. Conversely, air free of such pollutants can be a major boon for our quality of life and health.



Figures 1 and 2: Kanagawa Institute of Industrial Science and Technology (KISTEC)

Figure 1: Many odor components can be quickly neutralized using photocatalysis and UVA light.

Methods for clean air

Where the concentration of VOCs in the air cannot be reduced by simply increasing the supply of fresh air, effective air purifiers are an important tool. Some of them not only filter unpleasant odors and contaminants but also neutralize gases and destroy pathogens. There are different classes of devices that can be categorized based on how they function:

Air scrubbers pass the air through water rollers, causing dust particles to stick to the water film, thus filtering them out of the air. Air purifiers are also known as air humidifiers, as the water molecules are dispersed into the surrounding air as a result of the process.

Ionizers generate negatively-charged particles that bind to positively-charged particles in the air, causing them to increase their mass and drop to the ground. A major disadvantage of ionization is the production of ozone, which is harmful to health in larger quantities.

Filter systems pass the air through several filters. Their large surface enables them to adsorb these undesired particles, pathogens and odors. The most well-known of these right now is the HEPA filter (HEPA: high-efficiency particulate air) and the activated-carbon filter (e.g. in water filters). The filter also acts as a reducing agent to absorb ozone or chlorine.

Photocatalytic filters use titanium dioxide plates that can be exposed to UV light (UV-assisted titanium dioxide photocatalysis,

UVTP), producing free radicals that break down organic materials such as VOCs, as well as bacteria and viruses.

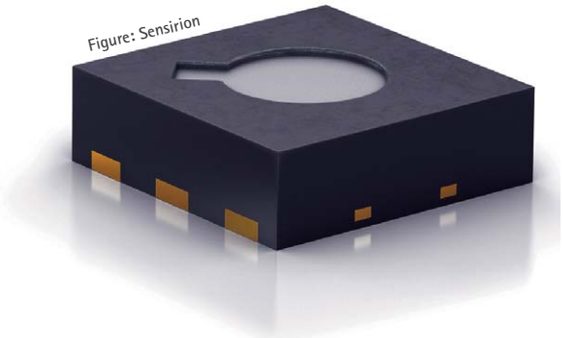
Light against pathogens and odors

UV-assisted titanium dioxide photocatalysis (UVTP) is already an established feature of water and wastewater treatment, most notably for ensuring the quality of drinking water. Their use in air purifiers is less common. They are used in the construction industry and in some urban centers for reducing the toxic pollutant content of the air. The latest findings indicate that UVTP can also guarantee the microbiological safety of foods.

Smell the risk, before you risk a smell

Two studies from the Kanagawa Institute of Industrial Science and Technology (KISTEC) in Japan recently demonstrated using a UVTP-based deodorizer how this method of photocatalysis is extremely effective against odors. The results were confirmed by the Japan Food Research Laboratories. These studies involved acetaldehyde, a gas with a pungent odor, being pumped into a 36-liter tank until a concentration of 10ppm was achieved. The deodorizer was then activated and the concentration was measured over a period of 60 minutes using a photoacoustic multi-gas monitor. The result: after 14 minutes, the share of acetaldehyde was just 0.1ppm, after 23 minutes it was just 0.05ppm. The process was repeated several times, in each case following the same procedure. For a comparison, the institute used an ionizer with the same test construction. This reduced the acetaldehyde concentration by just 40% within an hour. Without any air purification measures, 95% of the acetaldehyde was still present after an hour.

The same tests produced almost exactly the same results with ammonia (smell of urine), methyl mercaptan (smell of feces) and formaldehyde (smell of pungent cleaning agents).



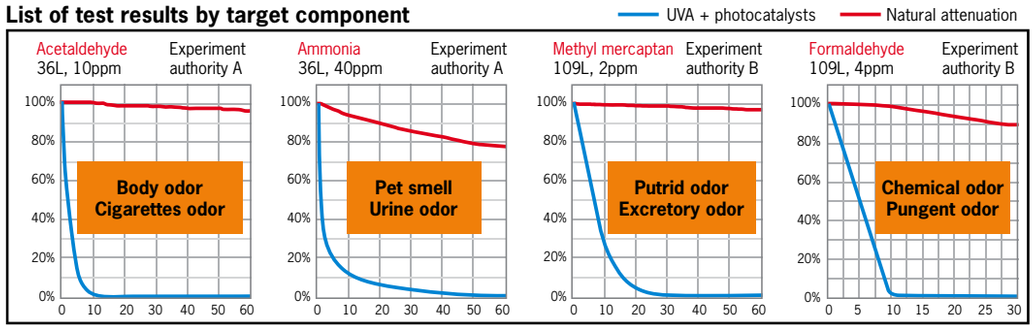


Figure 2: Whether it's the stench of cigarettes, rotting or chemicals – UV-assisted photocatalysis quickly provides fresh air again.

Only in the test series for hydrogen sulfide (rotting and sulfur odor) and trimethylamine (unpleasant fish smell) did the deodorizer need to be used for longer to achieve a comparable result. But after two hours, almost all of these VOCs were barely measurable.

The UVA LED NDU1104ESE-365 from Stanley with a wavelength of 365 nm proved to be the most effective model for the UV source in the studies. UVA-LEDs with wavelengths of 385 nm or 395 nm neutralized much fewer VOCs. Its drive current of 500 mA also makes the NDU1104ESE-365 more effective than other models with lower values, because light output rises with the current (Figure 3).

Deodorizers from Rutronik

Based on these findings, Rutronik has developed a deodorizer demonstrator. At the base of its quadratic housing (48 mm × 48 mm × 60 mm), air flows into the device. A fan ensures that the air moves up from the bottom through the housing, passing through a photocatalytic filter located between two UVA-LEDs with a wavelength of 365 nm and a drive current of 500 mA (Figure 4).

Rutronik used the SGP MOX sensor from Sensirion to determine the VOC content. It is mounted next to the LED and is based on the "chemisorption" of gases in the presence of oxygen, with the doped O_2 atoms of the metal oxide (MOx) bonding with the odor molecules. The electrons that this reaction releases cause a change in the electrical resistance of a film made of metal oxide nanoparticles. This is how the sensor detects a wide variety of VOCs and other gases that play a fundamental role in odors and the quality of a space's air.

If the number of VOCs exceeds a certain value, the LED is activated. The radiation time is based on the type and quantity of the VOCs. Optionally the values measured by the sensor can also be displayed so that users can always read the air quality values.

The rechargeable lithium-ion battery with a charge life of two hours can be charged at any household mains socket or, using a PC or a car charger, making it portable and flexible. This allows businesses to test its effect anywhere, be it in public or portable toilets, trash rooms, industrial kitchens or fitness studios.

The Rutronik deodorizer is still in the test phase – but should it prove to be suitable in practical use, it would be an important step in fighting unpleasant and harmful odors. And that's when air fresheners, paper air fresheners and room sprays will cease to have any purpose. ■

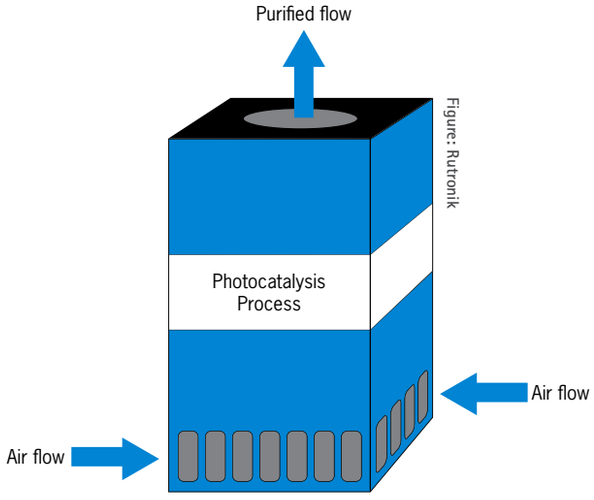


Figure 3: Construction of the deodorizer demonstrator from Rutronik

Rutronik's integrated management system

Quality – is it necessary?

Almost every website and brochure contains a promise of quality from the respective companies. Nearly every product or service is advertised using the word quality. Quality, it seems, is everywhere. But overuse of the term has its downsides, blurring its purpose so that it fades into meaninglessness.

By Patrick Lehn,
Management Systems Representative at Rutronik

Intuitively, we understand quality as a synonym for good and first class, thereby connecting it with positive characteristics, excellency, and a high level. Who wants to produce, acquire, or own something of inferior quality or to be associated with poor quality? In short: quality is worth striving for.

But finding an all-encompassing definition is difficult, which is why it makes sense to approach quality from a different angle. If you do the right things in the right way with the right tools, the result will most likely be right. Generally accepted and tested procedures, documentation, standards and norms can help in this regard.

Although the definition of quality according to ISO 9000 is somewhat rudimentary, it offers sufficient leeway and covers the widest possible spectrum: "Degree to which a set of inherent characteristics of a product, system, or process fulfills the requirements of customers and other stakeholders."

Therefore, the point is not to achieve a poorly-definable result by means of a top-down approach through some kind of "high-quality" work. On the contrary – if precisely specified and reviewed requirements are met, quality essentially follows on its own. Here, every feature of a process or product must meet the quality requirements; exceeding a

Figure: Iurii Motov/Shutterstock

Quality management consists of many components that need to perfectly fit together.

criterion does not compensate for shortfalls elsewhere.

Rutronik's quality building

Quality at Rutronik can be imagined as a building, with the foundations, support structures and roof being the certifications. These guarantee that processes, procedures, and systems meet generally applicable standards. At regular intervals, this level of quality is checked by independent auditors. At all of its locations around the world, Rutronik follows processes and standards that meet the requirements of the relevant ISO standard to guarantee a consistent level of quality worldwide.

First step – standardization and certification

The history of standardization and certification at Rutronik began way back in 1997 with a quality management system in accordance with ISO 9002. The introduction of the environmental management system in 2002 laid the foundations for an Integrated Management System (IMS). With gradual addition to encompass the topics of occupational health & safety (2008) and information security, the company has had a comprehensive IMS in place since June 2018 that is ISO 9001, ISO 14001, ISO 45001 and ISO 27001 compliant. It supports global collaboration between all divisions and departments and serves as the cornerstone of economic and environmental decision-making, the implementation of these decisions, and the monitoring of their success.

Second step – the extension

But the building does not yet meet Rutronik's requirements: "Committed to excellence". The company does so much more than simply fulfill the – admittedly very important – basics. Over the past few years, for example, the protective measures for ESD and moisture-sensitive components have been expanded considerably, services relating to master data management as well as product change notifications (PCN) and product discontinuation notifications (PDN) have been further improved, and complaint management processes have been optimized and supplemented with a workflow-based software solution.

With regard to infrastructure, a completely redundant design of the entire information technology has been established, including comprehensive precautionary measures for possible failures. These are part of an all-encompassing business continuity concept for preserving business processes in the event of operational disruption.

In addition, Rutronik has continued to focus further on communication and information. This ensures that employees are promptly and fully supplied with all relevant information. The Rutronik Academy offers an extensive range of training courses not only for employees but also for customers and suppliers. The newly created Rutronik e-Academy is a web-based learning platform that provides new and important training subjects within the framework of modern workforce development.

Third step – life

With the development of the four-pillar integrated management system (quality, environment, health & safety, information security) and further measures beyond these, Rutronik has created a framework for quality. The continuous improvement process anchored in all areas of the company guarantees the vitality of these actions. Potential for errors is recognized more quickly, and optimizations can be implemented immediately. But there's still one variable left that's needed and is probably the most important one in this entire structure: the men and women who make up Rutronik's workforce. This is why establishing and maintaining a quality culture takes absolute priority, a culture that shows each employee the value of their contribution and motivates them to make that contribution.

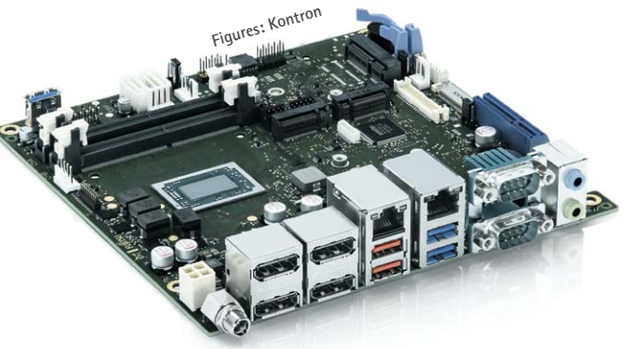
And to finally answer the question in the header: Yes! Quality is absolutely necessary. Because as the Rutronik motto goes, quality isn't everything but everything is nothing without quality! ■

Industrial-grade motherboards of German engineering quality

High processing performance for graphically intensive applications

Since Kontron's acquisition of Fujitsu's Industrial Mainboard Division, the transition process has been now been completed. Kontron is not only continuing Fujitsu's business seamlessly, but is also developing it further with new developments "designed & manufactured in Germany".

By Mario Klug, Senior Manager Product Marketing Boards at Rutronik, and Peter Hoser, Vice President and Head of Product Center Boards at Kontron



The D3713-V/R Mini-ITX motherboard from Kontron, equipped with an AMD Ryzen Embedded V1000/R1000 processor, offers brilliant graphics thanks to the AMD Radeon Vega GPU integrated into the SoC and is optimized for professional gambling systems, medical displays, thin clients and industrial PCs.

At the end of 2019, the first motherboard models were being relocated to Kontron. Since then, the complex process of integrating the motherboard business has been successfully completed – not only the full portfolio and the collected expertise, but also the entire production capacity were transferred to Kontron. The Fujitsu motherboards are produced by Kontron's production partner Katek Mauerstetten, around 40 miles from Fujitsu's previous mainboard production site in Augsburg, with the usual high quality standards.

"Despite the large portfolio of boards and peripheral devices, the transfer of the mainboard production from Fujitsu to Kontron was almost completely smooth," said Mario Klug, Senior Manager Product Marketing Boards at Rutronik. "We were able to maintain support at usual for our customers in particular due to the continuity of having the same points of contact. Kontron managed – despite the challenges of COVID-19 with disruptions to the component supply chain – to serve our backlog without any major delays. That deserves our respect."

Continuity and development

Long-term deliveries, technical support, repairs and the continuation of the product portfolio are in professional hands at Kontron. The company has brought over many former Fujitsu employees with skills in key fields such as R&D, product management, marketing, production, sales and support. This not only ensures that the appropriate expertise that has been established in development in particular since the days of Fujitsu/Siemens continues to flow into new designs, but also allows Fujitsu customers and partners to continue relying on their contacts that they know and trust.

To ensure that production was adapted quickly, that production costs remain competitive and the quality level remains high, Katek Mauerstetten employs the same processes and

The skyline of the new D3713-V/R Mini-ITX motherboards from Kontron with AMD Ryzen Embedded V1000/R1000 processors is densely packed with many interfaces covering almost the entire breadth of the form factor.

The SMARTCASE S711 for Mini-ITX industrial PCs is based on the Kontron D3713-V/R mITX motherboard can be used as a horizontal or vertical installation. The construction kit provides high-flexibility configuration options, consisting of the board, CPU, memory, expansion cards, BIOS, cooling system and case.

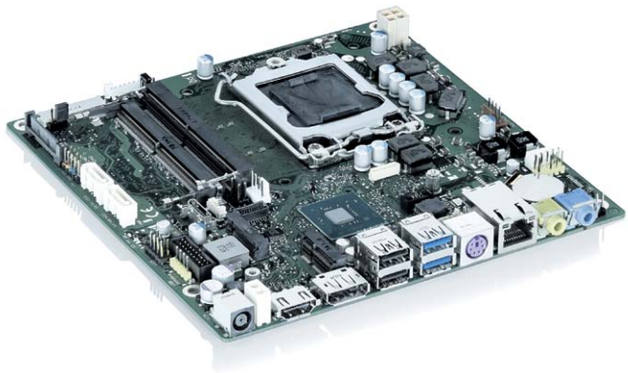
equipment that were previously used by Fujitsu, and in some cases has even improved them, with solder paste printing, wave soldering systems with solder masks for the double-sided SMD process, improved 3D AOI instead of 2D AOI (as was previously used at Fujitsu), in-circuit testing (ICT) and universal function testing (UFT). This enables Kontron to continue offering the full Fujitsu portfolio of motherboards, all-on cards and accessories. The model designations and revisions have remained the same, and existing certifications remain valid or will be renewed. In addition, the product lifecycles were significantly extended. The motherboard portfolio is now being expanded with new products.

New Kontron board "Designed by Fujitsu"

The D3713-V/R mITX marks the start of a new era for high-quality motherboards "designed & manufactured in Germany". The new D3713 motherboards are fitted with powerful AMD Ryzen Embedded V1000 and R1000 processors. Their graphical performance make them among the best products in the embedded market, offering good value for money. This makes them appealing for customers for a variety of industries, for example for graphically intensive applications in kiosk, infotainment, digital signage and professional gambling systems, in medical displays, thin clients and industrial PCs. With a TDP (Thermal Design Power) that currently ranges from 12 to 54 W, the processors are extremely scalable, from motherboards that are cooled entirely passively through to systems with cooling systems precisely tailored for each board that Kontron offers as validated accessories.

Superior performance thanks to new AMD microarchitecture

The "Zen" high-performance architecture from AMD offers an improvement over previous architectures of 52% in terms of instructions per cycle and a 200% improvement in GPU throughput per cycle. For the conventional embedded computing segment, the AMD Ryzen V1000 processors and AMD R1000 processors are especially attractive, with three times the performance per watt compared to



The D3674-B Thin mITX Extended Lifecycle Motherboard offers maximum performance and functionality on an "ultra-thin" form factor. It supports 8th and 9th generation Intel Core i9/i7/i5/i3 processors as well as Intel Pentium and Intel Celeron processors, and offers connectors for HDMI 1.4, DisplayPort 1.2, Dual Channel LVDS, LAN and 9x USB (2.0 and 3.1 Gen1).

the AMD R Series SoCs and four times the performance per euro.

Different industries, different requirements

Each individual target market and each individual application has individual needs. In the kiosk segment, for example, there are strict requirements on robust design, with wider temperature ranges playing a larger role in outdoor applications. Internal LVDS/eDP display connectors are almost more common in kiosk applications than in the digital signage segment. With the ability to connect up to four 4K displays, it is possible to create innovative signage applications or integrate multiple virtual digital signage players in a single system. High reliability in continuous operation is enormously important for all applications.

While infotainment applications also use the high graphical performance on larger displays to be viewed from greater distances, casino gambling and arcade systems place greater value in premium graphical output. In this area, 4K is displayed right in front of the user's eyes, sometimes in connection with ultra-brilliant curved displays. This is where the high graphical performance of the new AMD Ryzen Embedded V1000/R1000 series is especially valuable. For customers in the gambling segment, the fact that a single microarchitecture can be scaled from high-end upright casino systems to low-end video lottery terminal systems, reducing development costs and making servicing easier, is also of interest.

One PCB design for different markets

Fujitsu boards have long been recognized for meeting the requirements of many different applications. The new Kontron D3713-V/R Mini-ITX motherboard is no different. Kontron also now uses a wide-range power input of 8 to 36V instead of supporting ATX PSUs, or offers flexible storage and expansion options by means of two low-height M.2 sockets with Key B (2 lanes) and Key M (4 lanes) support. With its careful choice of LAN controller, Kontron also supports features such as Time Synchronized Networking, which is of interest both for Ethercat applications as well as OPC UA implementations. Dual LAN is also on board for Industry 4.0 installations. The 4×4K DisplayPort, an embedded DisplayPort and the Dual Channel LVDS (24-bit) provide maximum display support.

The new boards are high-quality and offer a wealth of interfaces, with no need to cut corners in terms of cost. The aim is to achieve full connectivity with highly scalable platforms and cost-optimized system designs.

For low-cost and fully certified system designs, Kontron offers a SMARTCASE kit for the D3713. The SMARTCASE S711 provides customers with highly flexible configuration options, consisting of the board, CPU, memory, expansion cards, BIOS, cooling system and case. Extensive tools enable customers to adjust fan curves and BIOS defaults independently or to integrate a customized boot screen logo. ■

E-paper displays

Modern, efficient and reader-friendly

Whether for price tags on supermarket shelves, on displays for heating systems at home or for reading e-books, electrophoretic displays (EPD) are becoming increasingly popular. But what are their strengths, and where can they best exploit these?

By Peter Lama,
Product Sales Manager Displays
at Rutronik

Figures Holitech

The main difference between EPDs—also known as e-paper displays—and conventional display types is that the former operates on a purely passive basis. This means that they have no backlighting like LCD displays and no light-emitting pixels as OLED displays do, instead relying on ambient light. This means that they are still very easily readable even in bright light and intense sunlight—basically just like real, printed paper. They are also extremely energy-efficient, as they need just a single pulse of current to display new information. Any activated pixels or segments then retain their state for as long as they are needed without consuming any energy at all.

They also offer up something special in terms of their viewing angle—content is clearly readable at up to 180° on an e-paper display, so basically from any angle.

Lives of up to 10 years make for a compelling argument for long-term projects in particular. Of course, how long these displays actually "live" for is primarily dependent on how they are used. It is important to observe the specified operating temperatures, which should not be exceeded.

Applications from price tags to thermostats

These features make e-paper displays ideal for electronic price tags. They are an elegant and modern solution that also help to save costs, as they minimize the workload involved in keeping prices up to date. With e-books, the "paper white" displays combined with touch technology provide a comfortable reading experience that is easy on the eyes.

E-paper displays are also best employed wherever low power consumption is needed and display updates are rare, for example in industrial metering applications, for thermostat displays, for receivers, room signage and much more.

How e-paper displays work

An e-paper display consists of many microcapsules, each measuring just a few dozen µm. These microcapsules house microscopic particles in a clear liquid—negatively charged white particles and positively charged black particles. By applying electrical fields externally, these particles can be moved around (Figure 4). The electrodes are controlled by an active matrix, each with a thin-film transistor for each pixel, just like conventional TFT displays. The response time of an e-paper display is usually several 100 ms, so they are too sluggish for displaying moving video footage, but for static displays that rarely change, this is not a problem.

Bringing in color …
albeit slowly

Most e-paper displays that are currently in use can display information in black & white, usually text and figures. Up to 16 shades of gray and various colors are possible. The fact that there are hardly any full-color e-paper displays is due in part to the higher price, and

also due to the color quality still being poor. The suppliers are feverishly engaged in development, but this is no easy task. The technology for color displays is much more complicated than for black & white displays.

E-paper displays on the market support for black & white, black, white & red, and also black, white & yellow as standard, and companies like Holitech have also recently started offering combinations such as white & green and white & blue. This supplier's portfolio includes sizes ranging from 1.54" to 42.0", and the company also provides features on request such as touch support, glass panels or acrylic panels, as well as frontlighting.

Minew offers e-paper displays with cases, wireless modules, batteries and associated electronics as complete electronic price tags. Customers here have a choice of sizes ranging between 1.54" and 11.6". Advantech also offers selected ready-to-use modules with e-paper displays that are available in 2.9", 5.6" and 13.3" sizes with housings, batteries, boards and a wireless module. ■

Cutting operating costs thanks to a broad connectivity spectrum

Ethernet switches for modern industrial environments

Industry 4.0 and the IIoT are becoming increasingly established. The digital transformation has long been underway in manufacturing companies around the world. Analysts from leading market research institutes collectively speak of a market worth billions for components and solutions. Industrial switches play a key role here.

By Mario Klug, Senior Manager Product Marketing Boards at Rutronik, and Reiner Grübmeyer, Director Product Management Systems & Software at Kontron

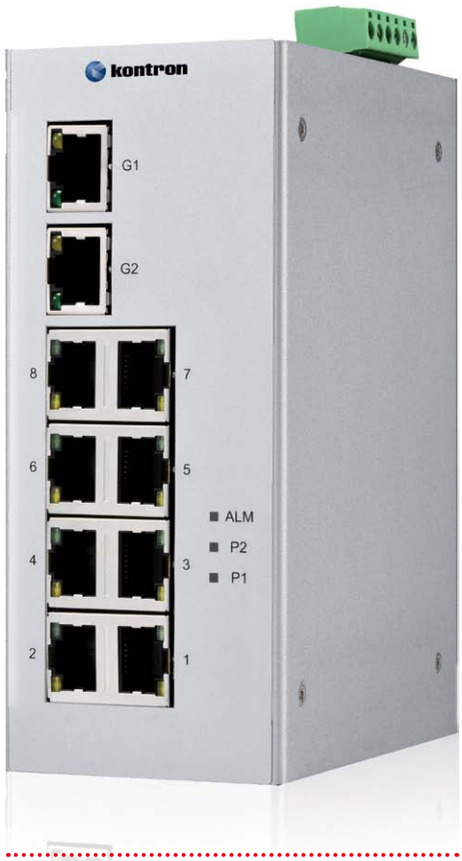
The blinding pace of development of IIoT and Industry 4.0 revolves entirely around the Cloud. Around the world, manufacturing companies are increasingly relocating their IT-based processes to cloud platforms. This is causing an ongoing fusion between formerly strictly segregated production-related operational IT (OT) activities and conventional information technology (IT). Industrial standards are urgently needed to overcome the discrepancies in the standards between these segments.

High expectations in a robust industrial environment

Modern high-performance chips, automation solutions, 5G connectivity and IT – and not least industrial switches – are essential components for successful applications in the fields of Industry 4.0 and the IIoT. Complex solutions used in robust industrial environments demand perfect alignment between hardware, software, and connectivity with production systems. This is the only way that the digital transformation can be successfully achieved in manufacturing industrial enterprises.

Industrial switches for high-speed Ethernet

From 2021, numerous new industrial Ethernet switches suitable for Fast Ethernet, Gigabit Ethernet and in future also 10 Gigabit networks will be launched on the market, meeting the requirements of components for industrial applications, which need to operate perfectly under sometimes critical conditions. This includes a compact construction as well as the option to connect machinery, control systems and other components based on industrial standards and integrate them with one another without any problems. One sup-



The KSwitch D3UM 8F-2GS is an industrial 10-port unmanaged Ethernet switch with eight 10/100BASE-T(X) ports and two 1000-FX-SFP slots, a wider temperature range of -40°C to +75°C, and a double DC power input.

plier looking to establish itself in this market environment is Kontron.

Kontron consistently utilizes a single chip design for its industrial Ethernet switches that combines all of the required components into a single chip as far as possible. The advantage of this is that it results in more reliable and lower-cost products. Data throughput and performance increase while power usage decreases, which has a positive impact on the total cost of ownership (TCO) of an environment. Fewer individual components on the board enables a construction that is lower-cost and more compact, thus reducing the amount of space needed in the switch cabinet or in industrial racks by 35% compared to other solutions. Flexibility is provided by the ability to mount it on a top hat rail in a 19" switch cabinet or to directly install it on the machine using various adapters.

Resistant to environmental influences

All devices in this new product family have a high-quality metal case that is ideal for use in harsh environments. This means that the switches are not sensitive to environmental influences and operate well in relation to temperature. These industrial Ethernet switches are not fazed by vibrations, impacts or falls.

Harsh environments in many applications also mean that devices need to be able to deal with substantial temperature differences without adversely affecting operation and disrupting production processes. The switches can be used in temperatures of –40 to +75°C or –10 to +60°C as standard. Most models also support a wider supply voltage range of 12 to 58 V DC with two redundant inputs.

There are also often strong magnetic fields or unstable supply voltages in production environments, which is why these switches are fitted with robust power supply units as standard and every port features a safety standard with surge immunity of up to 2 kV for EMC purposes.

Ethernet for more connectivity

All of the industrial Ethernet switch models available as of early 2021 offer full bandwidth (wirespeed), enabling the implementation of Fast Ethernet, Gigabit Ethernet and in future also 10G Ethernet without any packet loss. The devices feature RJ45 and optionally also SFP (Small Form Factor Pluggable) slots, providing users with a broad spectrum of standardized, low-cost connection options that are independent of the products of specific manufacturers. SFPs are available as modular,

The KSwitch D4MF 7F-2FS is an industrial 9-port managed Ethernet switch with seven 10/100BASE-T(X) ports and two 100-FX-SFP slots, a wider temperature range of -40°C to +75°C, and a double DC power input.

Figures: Kontron

With the RES2404-PTP, Kontron is offering a managed 19" high-performance switch for industrial use with up to 24 10/100/1000BASE-T ports and four 10G-SFP+ ports for copper or fiberglass lines, a wider temperature range of -25°C to +70°C, and Power-over Ethernet functionality.

optical or electrical transceivers for fiber optics or "direct attach copper" and offer flexibility and scalability for any given application.

Numerous switches will support Power over Ethernet (PoE/PoE+, Ultra PoE), which makes it easier to supply external components with power. Some models will be operable as powered devices, which means that they themselves can be supplied via PoE, reducing the complexity of installation and saving costs. The management functions implemented enable easy creation of virtual local networks (VLAN) in industrial cloud environments, for example. It is also possible to structure networks and isolate them from one another for security reasons.

Customers who opt for the latest generation of switches will benefit from state-of-the-art design, high quality, a large range of functions, and standards-based solutions that can be integrated into any environment without any problems.

Attractive investment and operating costs and the option of modular expansions facilitate the development of a future-proofed environment that can satisfy the current and future needs of Industry 4.0 and the IIoT. ■

Monitors and displays

Putting an end to cable spaghetti

They might look wonderful in the brochure or on the website, but in reality, the cable spaghetti next to the monitors doesn't look quite as appealing. 3-In-1 solutions that only need a single cable for power, touch controls and video now live up to the promise of the picture in the brochure.

By Nikolai Schnarz,
Product Sales Manager Displays
at Rutronik

They're called "Magic Monsters" or "Adapt IQ" and come from an American monitor manufacturer that has become a global industry leader in touchscreen monitors, displays and tablets since it was founded in 2008, not just because of the high quality of the products, but also the development of entirely new features, in particular video over USB. This allows both the video signal and the power to be carried entirely over USB to the display, so there is no need for a separate cable or a separate power supply unit. It also allows board developers to dispense with the HDMI interface, which is encumbered with licensing requirements. This means less cost and also makes the displays an intriguing proposition for applications where space is at a premium. It also makes installing the monitors easier, as the user only needs to connect a USB cable.

Figures: Mimo Monitors

One cable is enough for transferring the video signal, power and touch input signals.

The open-frame displays with and without touch support can be integrated into most housings, for example for shop use.

For video over USB, an appropriate driver is installed on the computer to enable display output and touch controls directly over USB – without additional calibration steps. The driver is available for all currently standard operating systems.

However, some applications still require a video signal over cable, for example when larger distances need to be covered from the source device to the monitor or if a media player, cascaded system or video matrix is being used, so that the drivers for the operating systems cannot guarantee that the signal will reach the display via USB. Mimo Monitors offers models with HDMI connectors for this purpose.

All-in-one solution for limited space conditions

There's also an "all-in-one" solution that is specially designed for digital signage applications – the 10.1" model includes an integrated media player from manufacturer BrightSign, optionally with or without a touchscreen and with the ability to use "Power over Ethernet" (PoE) for the power supply and network connection. The integrated media player eliminates the need to install the cables that would otherwise have been necessary between the display and player, thus reducing the amount of space needed by the solution. It also makes it easier to protect it against unauthorized access or tampering. And thanks to PoE, these all-in-one devices can also be fitted anywhere, even if there is no power available. This makes them ideal for doorsign displays, for shelf systems, and for any applications where there is barely any space for separate data source devices and cables. They are suitable for use in IT infrastructure that needs to be kept scalable.

A separate media player is also recommended if the display needs to be used over as long a term as possible but the content sources need to be flexibly modifiable, e.g. due to other performance or capacity-related requirements. Even if space is no object, a separate solution should still be chosen.

Stretch displays are commonly used for vending machines, shelves, fruit & vegetable stands in supermarkets and also on buses and trains. With a size of 23" x 2", they can show plenty of information without consuming too much vertical space. The shelf-edge stretch display from Mimo Monitors offers a brightness level of 700 nits and is also available with an integrated Android ARM Cortex A35 Core Player.

Broad product range

The Mimo Monitors portfolio encompasses 7" and 10.1" displays with resistive or capacitive touchscreens as well as non-touch versions. There are various installation options available for all displays and touchscreen monitors. These might be stands or standardized VESA mounts on the rear, for which Mimo Monitors offers a whole range of accessories such as mounting brackets and adapters for installations.

These models are also available as open-frame versions for applications such as installation in housings. Mimo Monitors offers the available displays and touchscreen monitors with many diagonal sizes and resolutions, ranging from 7" to 32", from 800 x 480 to 1920 x 1080. The 15.6", 18.5" and 19" models feature VGA, DVI and HDMI interfaces, while the models measuring 21.5" upwards only have VGA and HDMI.

They are used in retail environments as well as hotels, restaurants, medicine and automation, for home entertainment and gaming and for digital signage. ■

Easy and modern touchscreen control

5G offers new opportunities

A quantum leap for high-speed transmission

Everyone's long been talking about 5G, and the first networks have already been built and early tests have been conducted. But what actual benefits will 5G provide? How will cellular infrastructure change? And what about LTE? Do all designs now need to be ported directly to 5G?

By Anja Schaal,
Team Leader Product Marketing
Wireless at Rutronik

To determine whether and when businesses should start adopting 5G, it is worth taking a look at the three key aspects of 5G. Because these cater to different applications, they each offer different improvements:

eMBB (Enhanced Mobile BroadBand) with data transfer rates of up to 20Gbit/s is tailored to digital lifestyle applications as well as high-bandwidth applications such as HD videos, virtual reality and augmented reality. The high-speed data rates allow for ultra-fast

Figure: Liridon/stock.adobe.com

loading of websites and for the uninterrupted streaming of video content.

mMTC (Massive Machine Type Communications) offers stable network coverage everywhere in urban environments thanks to a very high connection density of MTC devices. In the final 5G development stage, a million of these connections will be supported per square kilometer, allowing numerous devices to send and receive data in the same wireless cell at the same time without disrupting one another, making connection problems in a full stadium or festival a thing of the past.

uRLLC (Ultra-Reliable and Low Latency Communications) provides latency of under 1ms to allow for time-critical applications where reliability is important—if not essential. It is essential for making autonomous driving, car-to-car and car-to-everything communication possible in the first place, not to mention cloud-based predictive maintenance.

New infrastructure for 5G

The first eMBB 5G products are already available on the market based on 3GPP Release 15. However, most are unable to provide the target data rate of 20 Gbit/s. The existing LTE/sub-6GHz bands (Frequency Range 1, FR1) are usually unable to provide enough bandwidth for this purpose, which is why new bands are required for 5G—the mmWave ultra high frequency bands from 24 to 100 GHz (FR2).

These require entirely new mobile communications infrastructure, because an LTE radio tower covers an area of several square kilometers around it. mmWave signals only support a maximum range of one kilometer—and this isn't all around like LTE signals, but rather in just one direction.

Even so, many businesses are already launching their 5G eMBB projects, which the 5G n78 frequency band (3.3 to 3.8 GHz) allows them to do. This allows the creation of private or company-specific mobile networks, known as campus networks. These allow businesses to be broadly independent of mobile communication service providers—and lets them gain a headstart in setting up their smart factories.

Long term evolution living up to the name

Does the introduction of the new 5G NR standards (New Radio) make the existing LTE designs obsolete? Such concerns are justified, as many 5G FR1 frequency bands overlap LTE bands. But there's no need to worry—technologies like DSS (Dynamic Spectrum Sharing) allow different standards such as LTE and 5G to share the same frequency band.

5G NR also supports in-band LTE-IoT—which is LTE-M with NB-IoT, so "Long Term Evolution" (LTE) will still live up to its name. The latest LTE-M and NB-IoT solutions are already available and compliant with 3GPP Release 14. Both technologies are undergoing continued development with each new 3GPP Release, until they ultimately—as of today with 3GPP Release 16—become 5G mMTC. This means that LTE-IoT devices currently working using LTE-M and NB-IoT will still work under 5G NR. This is true both for standalone 5G networks (SA) where 5G NR uses a core 5G network, and also for non-standalone networks (NSA), where 5G NR services are provided over a 4G/EPC (Evolved Packet Core) network.

As a result, it is not only possible for existing LTE and LTE-IoT designs to continue operating seamlessly under 5G—it is actually recommended to already start working on an LTE-M/NB-IoT solution for mMTC applications to ensure a smooth transition down the line.

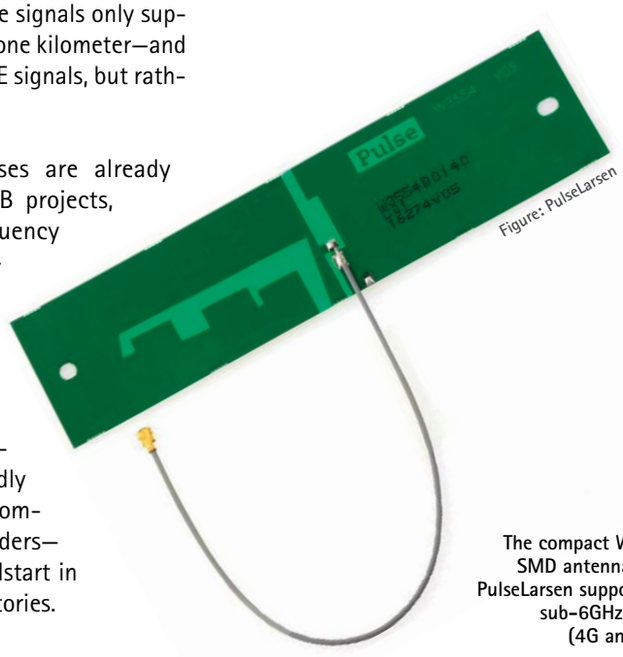


Figure: PulseLarsen

The compact W3415 SMD antenna from PulseLarsen supports all sub-6GHz bands (4G and 5G).

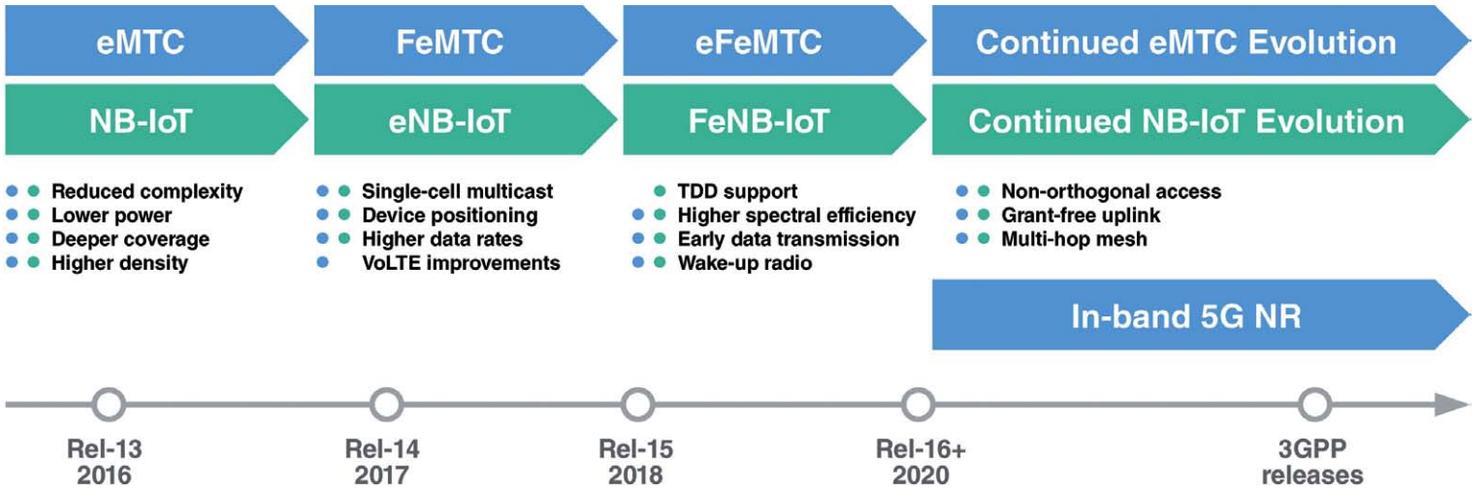


Figure: Markt&Technik

The transition from 4G (LTE-M/NB-IoT) to 5G (mMTC) will be a smooth one—with each 3GPP Release, the technologies will continue to evolve until they ultimately become 5G.

Components for the first steps

If you want to jump right in to 5G, Rutronik already has the right components for it. For eMBB implementations, the FN980m 5G/LTE card from Telit is one of the first to support 5G 3GPP Release 15 with sub-6GHz frequencies FDD and TDD as well as mmWave, LTE, WCDMA and GNSS. 5G therefore offers downlink capacity of up to 5.5Gbit/s and uplink capacity of up to 2.7Gbit/s, while 4G still only allows 2.4Gbit/s in the downlink and 211Mbit/s in the uplink. With the standard M.2 (NGFF) form factor and an operating temperature of –40 to +85°C, it is suitable for wireless fixed network access points with high transmission rates, corporate routers and gateways, indoor and outdoor end devices (Customer Premises Equipment, CPE), video transmission and monitoring. The FN980 card model is also available as a purely 5G/LTE sub-6GHz solution.

Telit has added the ME310G1 module to its xE310 family specifically for mMTC applications. Support for 3GPP Release 14 Cat M1/NB2 with Power Saving Mode (PSM) and Extended Discontinuous Reception (eDRX) allows for IoT applications with low energy consumption and longer battery life. It is ideal for applications involving thousands or millions of IoT devices where not only energy efficiency but also low costs are more important than high-speed data rates (e.g. medical devices, fitness trackers, industrial sensors, smart meters). With a maximum coupling loss (MCL) of up to 15dB/20dB, the module also offers better coverage and thus better penetration into buildings compared to previous cellular LTE standards.

Nordic Semiconductor also offers a solution for LTE-M and NB-IoT (3GPP Release 13) in the form of the nRF9160 SiP (System in Package) module. This extremely compact, highly-integrated SiP is pre-certified for global operation. It provides the application MCU, an ARM Cortex-M33 CPU with ARM TrustZone and ARM CryptoCell security technologies, the LTE modem, and RF front end and power management in an enclosure measuring 10mm × 16mm × 1mm. For asset tracking with precise position detection, there is a version with GPS support. With many digital and analog interfaces as well as peripheral devices, the nRF9160 is ideal for connecting devices to the internet via a mobile network, for logistics and asset tracking, for smart metering, smart city applications, smart infrastructure, smart agriculture, wearables and medical applications.

Ideal for high data transfer rates—Telit's FN980m data card

Figure: Telit

Antennas for 5G applications

5G antennas are also already part of the Rutronik portfolio. With a frequency range of 698 to 6000MHz, the W3554 series ultra-broadband dipole antenna from PulseLarsen is suitable not only for 5G applications, but also 2G, 3G and 4G as well as GNSS, WiFi, Bluetooth, Bluetooth Low Energy, ZigBee and the 868, 915, 2400 and 5000MHz ISM bands. The PCB antenna measures just 30mm × 120mm × 0.2mm.

The compact W3415 5G SMD antenna from PulseLarsen supports all sub-6GHz bands (4G and 5G) with a size of just 40mm × 7mm × 3mm. With multiple antennas on one board, MIMO (multiple input, multiple output) allows for optimum use of 5G. One antenna can be used as the main antenna, while one can be used as a diversity antenna.

Power supply, and computing aspects

For developing an internal campus network, FSP provides special 5G network components.

Figure: Telit

The ME310G1 module enables applications involving thousands or millions of IoT devices.

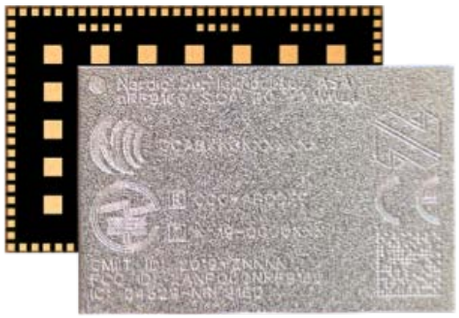


Figure: Nordic

Despite highly compact dimensions, the nRF9160 is highly integrated.

These are suitable for supplying base stations, access networks, data centers or individual network devices. Thanks to the supplier's expanded and revised portfolio, the need to design network components yourself is finally a thing of the past.

Rutronik is also able to develop custom solution concepts for network-based information processing using products from Asus, Advantech and Intel. And if even the distributor's considerable portfolio is unable to meet all of a customer's needs, Rutronik can still call upon numerous partner companies as a member of the 5G Campus Network Alliance.

Conclusion

To provide global 5G network coverage, cellular infrastructure will see major changes, especially through campus networks. The driving force of this change will be the improvements enabled by the 5G application profiles. But those developing on the basis of LTE have no reason to fear—LTE will survive under 5G.

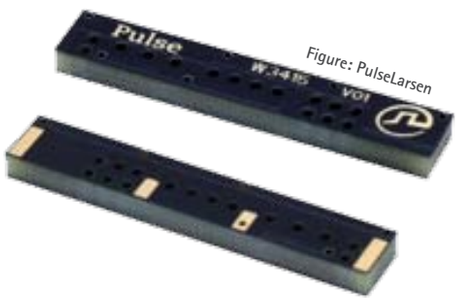


Figure: PulseLarsen

5G, 4G, 3G or 2G, GNSS, WiFi, Bluetooth and more—PulseLarsen's W3554 ultra-broadband dipole antenna can do it all.

IEEE 802.11ah alias WiFi HaLow

The best of WiFi and LPWAN

High data rates and a simple network structure have made WiFi one of the most common wireless standards. But WiFi has a flaw – its low range. This is why the WiFi Alliance developed IEEE 802.11ah for longer-distance wireless. The first module to meet this standard is now appearing on the market.

By Kerstin Naser,
Product Sales Manager Wireless
at Rutronik

Unlike the usual standards, which operate at 2.4GHz or 5GHz bands, the IEEE 802.11ah standard – also known as WiFi HaLow –uses the unlicensed 900MHz frequency band for transmission. This makes it part of the LPWAN group of technologies (Low-Power Wide-Area Networking) along with LoRa and Sigfox. The use of the lower frequency band means that HaLow achieves a range of up to 1.5 kilometers, almost twice the distance of WiFi standards based on 2.4 GHz or 5 GHz. This is a compelling prospect not only for smart home applications but also various IoT scenarios such as industrial enterprises with large premises, in agriculture, in healthcare, and in smart cities.

Passes through walls more easily

WiFi HaLow also establishes a very stable connection – because there is at least 10dB more available in the link budget compared to 2.4GHz WiFi, a wireless signal can pass through walls or other obstacles more effectively. A theoretical maximum of up to 8,191 devices per access point are supported; the first 802.11ah WiFi module for IoT devices from Silex (see more below) supports 1,024 nodes per access point. In a practical test, Silex successfully had data transmitted over 100 connections and 30 fixed devices essentially simultaneously.

This new version of WiFi is also attractive for mobile applications such as wearables and sensor applications – a data rate of at least 150 kbit/s is available when using a 1MHz channel. If the sensors are only active when new data needs to be transmitted, this can be achieved with low power usage in combination with a low-power data modem, making WiFi HaLow ideal for connecting many smaller devices. By combining multiple channels, it becomes possible to increase the data rate a little. Interoperability between 802.11ah devices from different suppliers is ensured, with the WLAN encryption standards WPA2-PSK, WPA3SAE and WPA3-OWE guaranteeing secure data transmission.

IEEE 802.11ah or WiFi HaLow therefore combines the benefits of WiFi and of LPWAN technologies, offering not only greater range but also a higher data rate. However, the technology is still in its infancy, the infrastructure is still under development, and there are gradually more and more devices that support the standard appearing for sale.

First HaLow components

One of the pioneers was Japanese manufacturer Newracom, which developed the first WiFi HaLow chip back in October 2015 for IoT applications. This chip was presented along the standard at the Mobile World Congress 2016. Newracom won the "Best WiFi IoT Product 2019" award in 2019 for the

With 10dB more than conventional WiFi, a HaLow wireless signal penetrates walls and is therefore ideal for smart home applications.

Figure: Andrey Suslov/Shutterstock

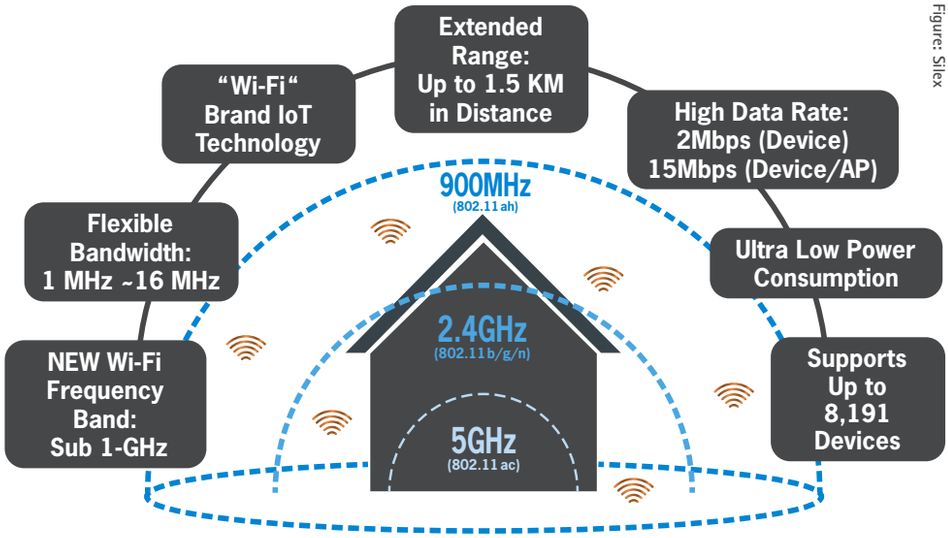


Figure: Silex

The new 802.11ah WiFi standard offers a much greater range than the other WiFi standards.

NRC7292, the first IEEE 802.11ah-compatible WiFi HaLow SoC.

Another pioneer of this new standard is Silex. The SX-NEWAH, the first 802.11ah WiFi module for IoT devices, will soon be available through Rutronik. The US version is already available with Rutronik offering samples. This module is also based on the NRC7292 SoC from Newracom and is the first industrial WiFi module to operate in the sub-GHz band. This means that it offers all of the benefits of the new WiFi technology:

- Greater range and stable connections, including through walls or in adverse environment conditions, with at least 10dB more than with 2.4GHz WiFi
- Low power usage for a battery life of several years
- Data rates of up to 15 Mbit/s with TCP/IP support
- A large number of devices per access point (repeaters and gateways are not needed)
- IP connectivity: The module can be integrated into existing IP networks.
- High security: Enterprise WiFi Security, WPA3
- Interoperability with 802.11ah devices from different suppliers ■

Time Sensitive Networking (TSN)

A basis for Industry 4.0

The Fourth Industrial Revolution is defined by how information is fed into or acquired from production processes. Real-time support plays a critical role in this. Time Sensitive Networking (TSN) provides standardized methods for providing such support.

By Walter Hagner, Product Sales Manager Digital, and David Werthwein, Product Manager Digital, both at Rutronik

industrial production, tools, equipment and machinery needs to be adapted perfectly to one another to prevent damage to the workpiece or machinery. This requires real-time data communication, which means that all devices involved must have an identical time base and it must be guaranteed that responses are received by the recipient within the specified time. Technologies with Industrial Ethernet support such as Ethercat or Profinet guarantee such response times. As each bus system is optimized for certain applications, several standards have become established.

In non-industrial environments at the upper levels of the automation pyramid, on the other hand, Ethernet is broadly established due to its robustness and reliability. But Ethernet cannot meet the real-time requirements of industrial processes.

For implementation in an Industry 4.0 context, it is necessary to merge the two network environments to create seamless, autonomous systems. This is where the idea of "Time-Sensitive Networking" or TSN comes into play. It runs concurrently with conventional communication technologies and enables real-time communication even in heterogeneous environments – in other words, where different bus systems and Ethernet are in use.

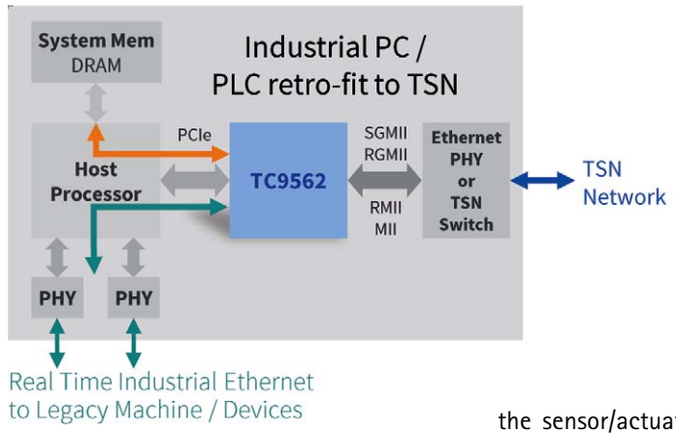
Requirements for real-time

One of the most fundamental requirements for real-time systems is ultra-high-precision clocks in each end device to be synchronized to allow each data packet to be timestamped. This is the purpose of Precision Time Protocol PTP-1588. Packets in conventional TCP/IP or UDP protocols are not timestamped, but with (g)PTP and 802.1Qbv-2015 they can still be used for real-time communication.

Based on the timestamp, each data packet is also assigned a time window (scheduling and traffic shaping) and priorities (selection of communication paths, reservations and error tolerances). TSN provides eight priorities that stipulate the maximum response time for the data packet. Time-critical communication is only possible using these three factors.

An Ethernet frame, which is a record containing data such as the destination and source address, control information, etc. measures 1500 bytes when considering just the payload (without a header, trailer and safe time (time between two data packets). When you add the data link information to this, the total data packet comes to 1538 bytes with a 12-byte safe time (9.59 ns). So, at 100 Mbit/s, such a packet would need 1.23 µs. This means that TSN can be used to achieve precisions measurable in µs. With purely hardware-based solutions, time packets measurable in nanoseconds are possible.

The part of the TSN mechanisms responsible for real-time support is located in the second layer – the data link layer – of the seven-layer OSI model. As the functions of this layer are standardized under TSN, different protocols can use the same network infrastructure. The second layer is divided into two sub-layers in which the real-time support protocols



How existing machinery and devices can be used to develop a TSN network

are implemented and via which the TSN data can be transmitted: the MAC (Media Access Control) and LLC (Logic Link Control) layer.

TSN offers entirely new opportunities in many fields, but two in particular benefit especially from these standards: industrial automation and automotive engineering.

TSN in automotive

A growing number of driver assistance systems are essentially a precursor autonomous driving and require not only higher data rates in the vehicle but also deterministic communication – this means that data needs to reach the recipient in a precise pre-determined time – with low latency and failsafe mechanisms.

This can be achieved with TSN regardless of the communication technology used thus far. As the cables are by definition very short in a vehicle, real-time support is fairly easy to achieve here. With Gigabit Ethernet, TSN can achieve even lower latency times and even less jitter.

TSN in industrial automation

In industrial automation there is currently a diverse structure of different fieldbuses that all need to be migrated to TSN, which is why it will take longer here for the standards to become established than in the automotive sector. There is a strong motivation to use TSN though, as it ensures that significantly less communication hardware is required and that eliminates the need for the masses of protocols in use.

From a current perspective, one of the long-term objectives would be to use TSN down to the sensor/actuator level, as the costs for communication hardware such as MAC/PHY and microcontrollers are still too high.

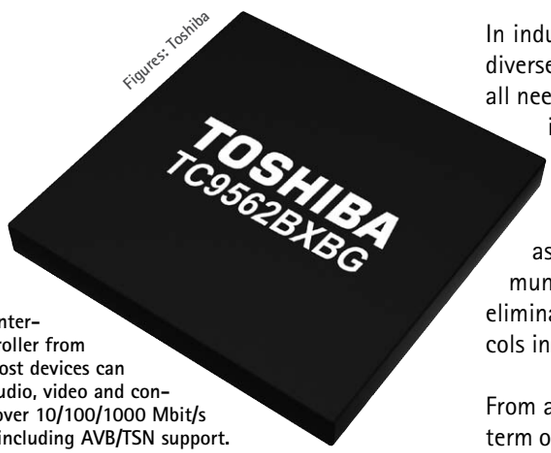
Solutions for TSN

Toshiba's Neutrino family is recommended for implementing TSN at manageable cost. The Ethernet-AVB (Audio/Video Bridging)/TSN bridge solution is based on the TC9562 network interface controller. It supports the standards IEEE 802.1as for time synchronization, IEEE 802.1Qav (Ethernet-AVB) and IEEE 802.1Qbv for traffic shaping (the definition of rules for processing and forwarding network packets), IEEE 802.1Qbu and IEEE 802.3br for frame pre-emption, which is a more efficient method of transmitting non-time-critical data.

If the TC9562 is connected to an application process or another host SoC, the host device can transmit data (e.g. audio, video and control data) over 10/100/1000 Mbit/s Ethernet. On the host, it has a PCIe interface with 5 GT/s. The module features an integrated ARM Cortex-M3 with 187 MHz clock speed, fast RAM and, at its heart, an AVB and TSN-capable MAC that enables real-time transmission and Quality of Service. As this is mostly taken care of by the on-chip controller, the extra workload for the host is minimal. All that's otherwise needed is a suitable PHY. A reference board along with extensive software is provided for development, including Linux drivers.

An interesting alternative is Intel's I225, as it has a combined MAC and PHY and includes the IEEE-1588 feature (timestamp generation) in the hardware. Aside from the real-time clock (1588) implemented in the I225, all real-time protocols required for TSN must be implemented by skilled developers in the second layer and processed by the host processor. ■

Figures: Toshiba



With the Network Interface Controller from Toshiba, host devices can transfer audio, video and control data over 10/100/1000 Mbit/s Ethernet, including AVB/TSN support.

Electromechanical components for medical engineering

For versatile protection and maximum reliability

Developers of medical devices must be in a position to get increasingly complex technologies ready for serial production as quickly as possible. But they also need to meet the highest quality and safety standards – after all, their ability to work flawlessly can literally mean the difference between life and death in a worst-case scenario.

By Burak Duman, Technical Support Mechanics, and Martin Unsöld, Senior Manager Product Marketing Mechanics, both at Rutronik

Medical engineering often requires compact end systems that are easy to clean and sterilize. Electromechanical components help to achieve this, offering protection from usage mistakes, overcurrents and overvoltages as well as overheating. User-friendly design for medical devices requires modern control concepts that minimize human/machine interaction errors as much as possible. But they also need to provide a sterile and easy-to-clean device with IP67 protection.

The ability to easily operate a device manually can be ensured using robust rocker switches, rotary switches and pushbuttons manufactured from high-grade materials, for example using ENC series optical encoder switches from C&K (Figure 1). These components, available with two-channel, 2-bit output, provide robust haptic feedback with clear lock-in feedback.

Tact switches enable reliable operation due to the tactic feedback they offer. C&K's KSC series models (Figure 2) are designed for more intensive usage, offering a long service life of up to 10 million cycles. Their silicone and rubber actuators offer specified haptic feedback and audible reactions depending on the force and actuator hardness, and also enable the switch to be easily integrated.

Customized metal keyboards offer many ways to handle operate medtech devices often equipped with various applications. These keyboards, which are highly resistant to liquids, can also be easily cleaned and sterilized.

Figure: C&K

Figure 1: C&K's optical encoder switches enable reliable operation of medical devices thanks to robust haptic feedback.

Figure: C&K

Figure 2: C&K's KSC tact switches are resistant to even higher stresses.

Figure: Omron

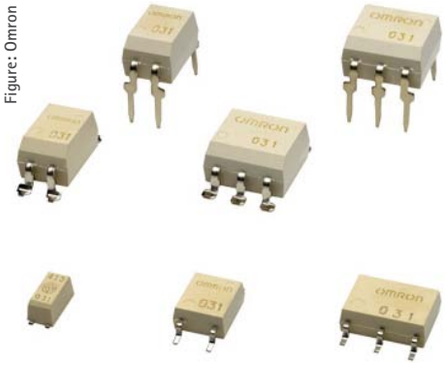


Figure 3: Omron's G3VM-series MOSFET relais warrant a high number of noiseless switching cycles.

Complex, modern devices can make use of human-machine interfaces to enable their control. The corresponding functions are controlled using the control unit via a signal and/or MOSFET relay. MOSFET relays such as the G3VM from Omron (Figure 3) guarantee a high number of silent switching cycles. No light arc is generated when the contacts are switched, which means that there is no failure as a result of contact wear and tear. These components therefore offer the advantage of a long service life.

High-performance power supply

Like any technology, new medical developments and enhancements of these depend on a reliable, custom-built supply of power, which is provided by a power supply unit. However, a safe deactivation mechanism that switches to a backup power supply such as a rechargeable battery must also be ensured for faults such as short circuits. Various fuse mechanisms such as cartridge fuses, 5mm/¼" axial lead fuses and brick fuses are used for this purpose. Brick fuses in particular are defined by their small and compact construction.

The surface-mountable 6125 series brick fuses from Eaton Bussmann are especially recommended for applications where work needs to continue in the event of a fault without resulting in damage to components. They not only protect the power supply from short circuits but also serve as EMI filters. The fast-acting types (6125FF) are specially designed for high switch-on currents. The 6125TD series with time-delay action corresponds to the EIA-IS-722 standard and can conduct rated currents for at least four hours. The 6125FA models guarantee overcurrent protection up to 125 V AC/DC.

The 1025 series from Eaton Bussmann (Figure 4) comes into play when even higher currents are involved. These conventional surface-mounted fuses offer protection from the highest current level. Their higher melting integral also allows for higher switch-on currents. With an operating temperature of –55 to +125°C, they are also suitable for use in harsh environments.

Eaton Bussmann also offers fuse brackets for panel or PCB mounting, with many being suitable for 5 mm and ¼". They are available in a variety of IP protection classes.

Resettable fuses are ideal for difficult-to-access circuits, especially in applications that need to be continuously available or where overcurrents are common. These PTC components (positive temperature coefficient) increase resistance when the temperature rises as a result of excessive current. Once the problem has been fixed and the temperature drops again, the resistance is automatically "reset". The largest selection of PTC components is found at Littelfuse, for example the PolySwitch and Poly-Fuse series. The nano SMD series from Littelfuse also has especially small dimensions that help to save space and cut costs. With the large selection of different models, it also provides versatility in design. Thanks to their high voltage ranges, they can also be integrated into newer applications.

Can't stand the heat

Heat emissions from components during operation present a certain risk for the flawless function and lifetime of the components, which is why thermal management tailored to the application and specific installation conditions is essential. Board-level heatsinks (pin heatsinks) are an established method of cooling PCBs that host not only power semiconductors but also controllers and signal processors. As they are directly mounted on the component in question, they can be used to cool them specifically and efficiently. Fischer Elektronik and Assmann WSW are among the providers with the largest range of aluminum or copper board-level heatsinks with various sizes, form factors and installation mechanisms.

Figure: Eaton Bussmann

Figure 4: Eaton Bussmann's 1025 series can withstand even high currents.

Figure: Panasonic

Figure 5: Thermally conductive foils are thin and still very effective against heat.

Figure: ADDA

Figure 6: There she blows – ADDA's AD12032 series of fans

Figure: Jamicon

Figure 7: Jamicon's JV0620-00 series – quiet and long-lasting thanks to the use of floating bearings

Thermally conductive foils as thin as 10 µm to 100 µm help to save even more space (Figure 5), and also offer a high thermal conductivity of up to 1,950 W/mK. They are simple to handle as they are easy to cut to the desired size. Thermally conductive foils are available on the market from suppliers such as 3M and Panasonic.

Where very large amounts of heat are generated, fans are the method of choice. They are superior to passive cooling both in terms of performance and in terms of cost. If the focus is on maximizing air flow, the AD12032 from ADDA comes recommended (Figure 6). If noise levels are a factor, on the other hand, for example in devices used in patient rooms, models with floating bearings such as the AD12032 series from ADDA or the JV0620-00 from Jamicon are recommended (Figure 7). The dual ball bearing models from Jamicon have an especially long service life. ■

Heat management for horticulture lighting

Cooling an artificial sun

A home or a farm? It's a difficult choice, with population growth and climate change causing ever more arable land to disappear. This is why innovative forms of agriculture and modern technologies are needed. Effective heat management is especially needed when using "LED suns".

By Burak Duman, Technical Support Mechanics, and Martin Unsöld, Senior Manager Product Marketing Mechanics, both at Rutronik

Alternative farming capacity is required to be able to produce enough grain, fruit and vegetables regardless of weather conditions and the location. "Urban farming" involves the repurposing of decommissioned underground tunnels or bunkers as well as buildings' roofs and walls. However, the nature of these locations means that they often lack the sunlight required for plant growth, which is why LED lighting systems are increasingly being used as alternative sunlight sources, allowing for the cultivation of plants as needed. Using appropriately controlled light frequencies, it is even possible to optimize plant growth, resulting in larger plants, larger yields, fewer harmful substances – and this method also allows the color and taste of the crops to be adjusted. UV LEDs can also protect plants against micro-organisms, spores and bacteria.

Heat management for longer LED lives

LEDs are much more efficient than conventional halogen bulbs, using up to 50% of the electrical energy to generate visible light, but this means that they also still discharge

Figure: pipicato/shutterstock

around half of the energy they consume as heat. As LEDs get ever smaller while requiring more and more energy, so too does the heat output. This affects the life of the LEDs in the long term.

Current LEDs have a life of 2,000 to 4,000 hours. Excessive temperatures mean that they can lose up to a sixth of this, so heat management solutions play a major role in prolonging the performance of LEDs as much as possible. This means that they also significantly reduce the need to replace and maintain them during operation.

Customized cooling elements

There is no off-the-shelf solution for heat management, as there are numerous factors to be taken into consideration. Are low-power, mid-power or high-power LEDs being used? What temperatures are to be expected? How much space is available in the application? Is noise output a factor?

Generally speaking, there is a choice of passive and active solutions. Passive solutions include heatsinks and heat-conducting foils from suppliers such as Assmann, Fischer Elektronik or 3M. Active solutions are fans and blowers such as those offered by Adda, Delta and Jamicon.

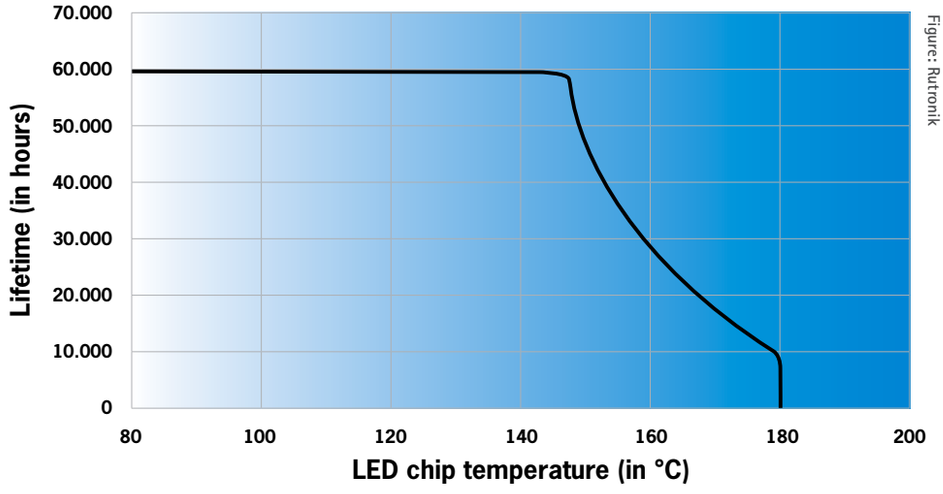


Figure: Rutronik

A temperature in excess of 140°C on the LED chip reduces its life drastically.

Design-friendly heatsinks

Heatsinks differ primarily in terms of their material. Fin heatsinks made of aluminum are ideal when you need to effectively dissipate a relatively large amount of heat. They are also suitable for cost-sensitive applications due to their attractive purchase price. Suppliers also offer them as customized solutions, adapting their size precisely to the heat dissipation needs.

Plastic heatsinks conduct heat, but are electrical insulators and – depending on the plastic composite – can also offer high levels of light reflection. The plastic can be used directly as a housing, eliminating the need for any additional cooling element. The reflectivity of the plastic means that the light rays do not lose any of their brightness. Plastic heatsinks are – like aluminum heatsinks – design-friendly, but much lighter, making them especially suitable for applications where every gram counts.

One plastic that is especially well-suited to heat conductivity and dissipation is boron ni-

tride, also known as "white graphite". This synthetic material with a graphite-like structure is pure white and an electrical insulator.

If the material properties are maintained, boron nitride has a heat dissipation index of up to 15 W/m·K. The cooling fillers of boron nitride are designed to be redirected easily in any direction, making it possible to control which direction heat is dissipated in – vertically or horizontally. Boron nitride is especially well-suited to thin-walled and complex geometric forms – 3M offers heatsinks to match.

Regardless of the cooling method and material used, solutions are practically always custom-developed, as the requirements and local conditions are too specific – this makes professional support all the more important to find the ideal solution for the application at hand. ■

Testing joystick geometries

Fun & games for HMI designers

When C.B. Mirick had his invention patented as a control system for unmanned aircraft in 1926, he could not have foreseen how it would later be used in numerous fields and applications. Several construction designs are available to choose from when it comes to developing a joystick. An overview.

By Thomas Kepcija, Product Sales Manager Sensors at Rutronik, and Philipp Herbst, Head of Application Support & Tools at TDK-Micronas

„Joysticks have quickly become an established feature of control tools in many industrial and medical applications, for trains, ships, agricultural machinery and construction machinery, and also for simulators such as flight simulators. In the entertainment industry, they are used for console and PC gaming as well as radio-controlled aircraft, cars, and ships." Today, joysticks are an integral feature of industrial applications, consumer products and automotive development.

The initial design of a joystick was based on switched contacts, which is considered to be a digital joystick. The simplest design had four contacts and offered 4 bits of information declaring "on" and "off" states, which also made it possible to register diagonal movements.

Analog joysticks measure the direction and angle between the movement and the axes, for which potentiometers or optical or magnetic sensors are used. These are contactless

Figures: TDK-Micronas

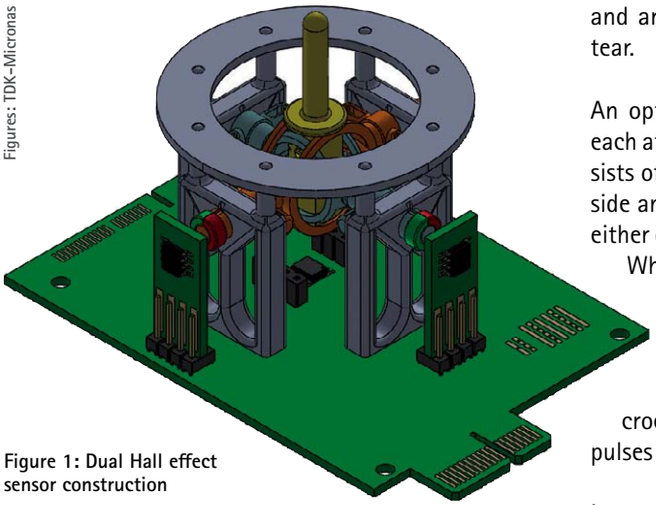


Figure 1: Dual Hall effect sensor construction

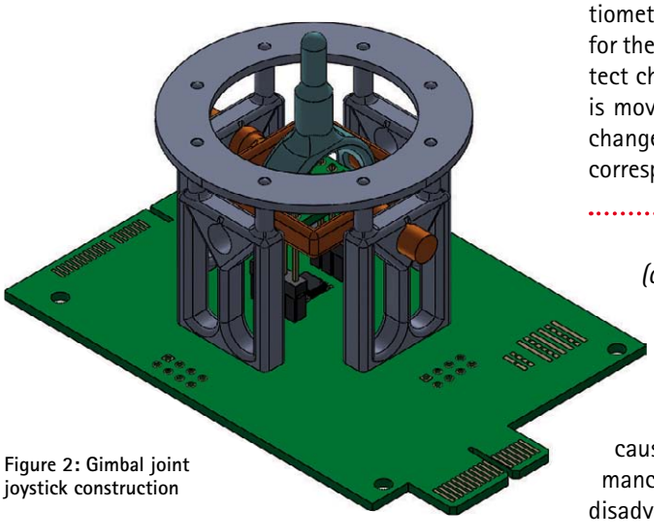


Figure 2: Gimbal joint joystick construction

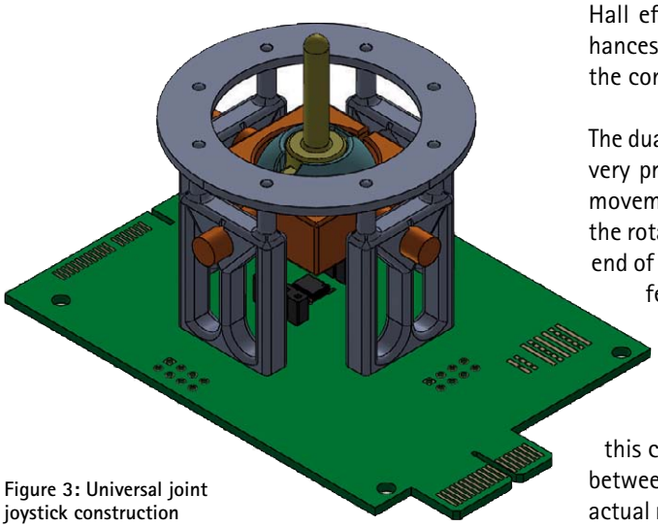


Figure 3: Universal joint joystick construction

and are therefore not subject to wear and tear.

An optical joystick has two encoder disks, each attached to an axial joint. Each disk consists of slots and plates, with a diode on one side and a photo cell on the other. These are either discrete or connected to a light barrier. When light from the diode passes through the slot, the photo cell converts it into a current. If there is no slot, no current will be present at the photo cell's output. An algorithm in the microcontroller uses the number of current pulses to calculate the position.

In a potentiometer joystick, there is a potentiometer on each of the two rotary joints, one for the x-axis and one for the y-axis. They detect changes in resistance when the joystick is moved and the angle of the rotary joints changes. A microcontroller then outputs the corresponding values.

Revolving joints (dual Hall effect sensor construction)

The original mechanical contact joysticks using potentiometers have a disadvantage, namely that friction causes the detection and control performance of the potentiometer to degrade. This disadvantage is overcome by replacing the potentiometers with magnets and contactless Hall effect sensors (Figure 1). This also enhances precision and reliability, and improves the control experience.

The dual Hall effect sensor construction is also very practical—as with a potentiometer, the movement of the joystick handle is read as the rotation of the magnets positioned at the end of the shaft, which is read by the Hall effect sensor. Existing complex mechanical joystick designs only need minimal adjustments—if any.

However, there is one problem with this construction—because the relationship between the Hall effect sensor output and the actual movement of the joystick exhibits nonlinear properties, these need to be converted into linear values using set points.

Gimbal joint joystick

Figure 2 illustrates another construction. In such a gimbal joint joystick, there is a rotating permanent magnet under the handle that is pointed towards the Hall effect sensor. The contact between the permanent magnet and the single Hall effect sensor allows the movement of the joystick to be projected to the 2D detection range. As long as the joystick moves within approx. ±30°, the output signal offers good linearity.

The challenge with such a construction is managing the mechanical system. As the mechanical system ages through wear and tear, the sensor—the centerpoint of rotation—shifts without being noticed, and this cannot be compensated by static means.

Universal joint joystick

A universal joint mount is a good alternative for solving the problem of declining precision caused by frame friction (Figure 3). The mechanism is not only more robust against friction, but also simplifies the production process and reduces production costs. It also benefits from ease of linearization and a simple mechanical construction. The key improvement in this design is that the joystick handle rotates around a Cardan joint and always points to the center of this joint.

Kits—using the "surprise egg" approach

To evaluate the various construction options, an equally versatile joystick platform and a flexible Hall effect sensor are required. Many suppliers offer joystick kits to provide potential buyers with a sensor that they can use to test in their application, providing data for simulations.

The "Joystick Evaluation Platform" from TDK-Micronas (Figure 4) is strongly reminiscent of the "surprise egg" approach—only without the chocolate. The various components can be put together—much like a toy in a surprise egg—to allow for any of the three mechanical joystick geometries.

In addition to the TDK-Micronas HAL 3900 sensors, the kit also contains PCBs, 3D-printed mechanisms, magnets, accessories and detailed instructions. Additional sensor PCBs enable direct integration of the sensors into an application.

The HAL 3900 not only enables precise detection of magnetic fields but also synchronous measurement of all three magnetic field components BX, BY and BZ at a single point. This allows the sensor to detect the direction of

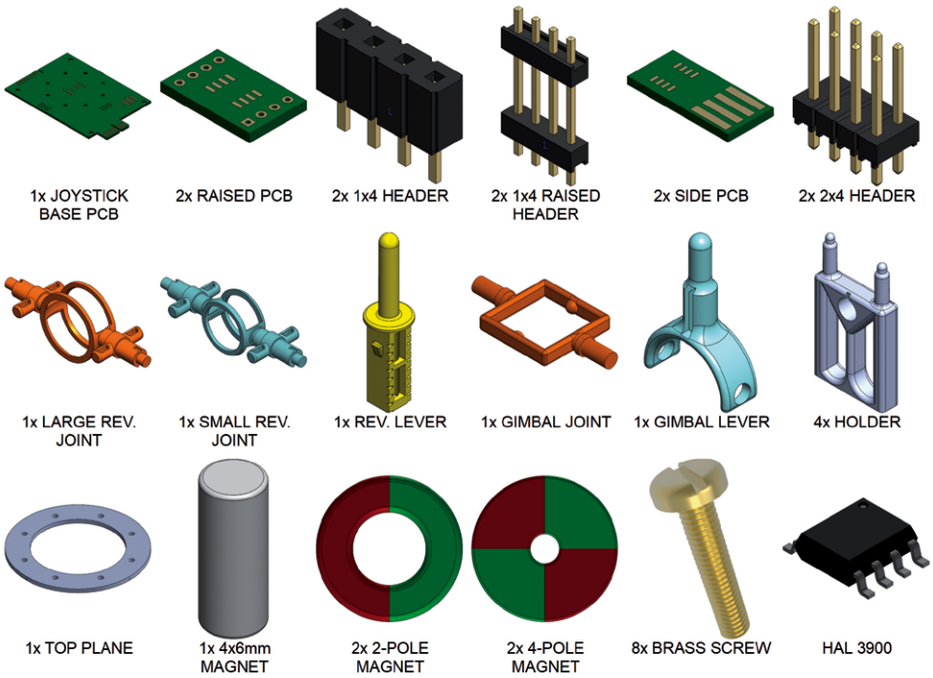


Figure 4: The "Joystick Evaluation Platform" works like a surprise egg toy.

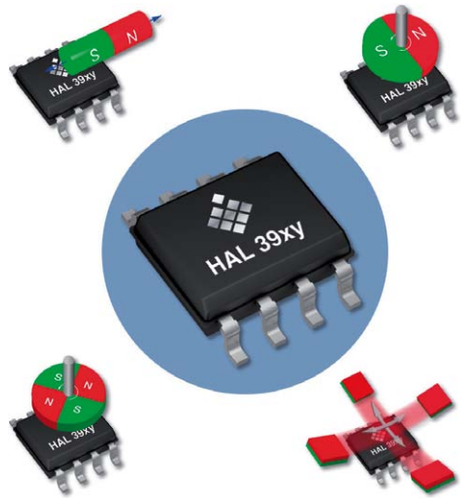


Figure 5: The all-purpose solution—the HAL39xy family is suitable for a wide variety of measurement tasks.

the magnetic field. This unique concept also allows six z-Hall plates and two Hall pixel cells to be fitted to provide 2D stray field compensation. This makes the sensor suitable for a variety of measurement tasks, and for any sensor/magnet geometry that previously required different sensors. Because the HAL 3900 sensor array is highly flexible, design engineers can simply select the best operating mode for any given measurement task. Depending on the measurement mode selected, it is possible for example to output raw temperature-adjusted values for BX, BY, BZ or up to two calculated angles.

To reduce non-linearity errors in the overall system or even in order to generate random output behavior, the sensor offers "fixed set points" at up to 33° with one activated channel, or fixed set points at up to 17° per channel if two channels are activated. If variable set points are required, there are up to 18 set point ranges when using one channel or up to eight ranges per channel when using two channels.

As an SEooC (Safety Element Out of Context) according to ISO 26262, the HAL 3900 is qualified for safety-critical (ASIL) applications. Stray field compensation (in accordance with ISO 11452-8) is already integrated into some measurement modes and is done automatically. An SPI interface handles communication with the sensor.

The digital HAL 39xy does not require external signal processing or complicated compensation algorithms. The measurement modes with three or six z Hall plates and the revolving joint construction can be used to create a stray field-compensated joystick.

The sensor data of the joystick kit can be read using an Arduino or the TDK-Micronas SPI Programmer. Using the downloadable "Joystick Evaluation Platform" software (Figure 6), users have a tool at their disposal that lets them import key RAM registers from the sensor's signal paths, visualize measurements for specific joysticks, and move a rendered joystick to be exported for further analysis as a .csv file.

To achieve the best possible joystick performance, the LabView Programming Environment of the HAL 3900 combined with the TDK-Micronas SPI Programmer allows for sensor calibration and adjustment of the required measurement modes.

For Arduino platforms, TDK-Micronas provides downloadable source code for reading the required HAL 3900 registers. The design platform developed by Rutronik based on the ST-M32L05 with Arduino-compatible connectors is ideal for evaluating the new products. ■

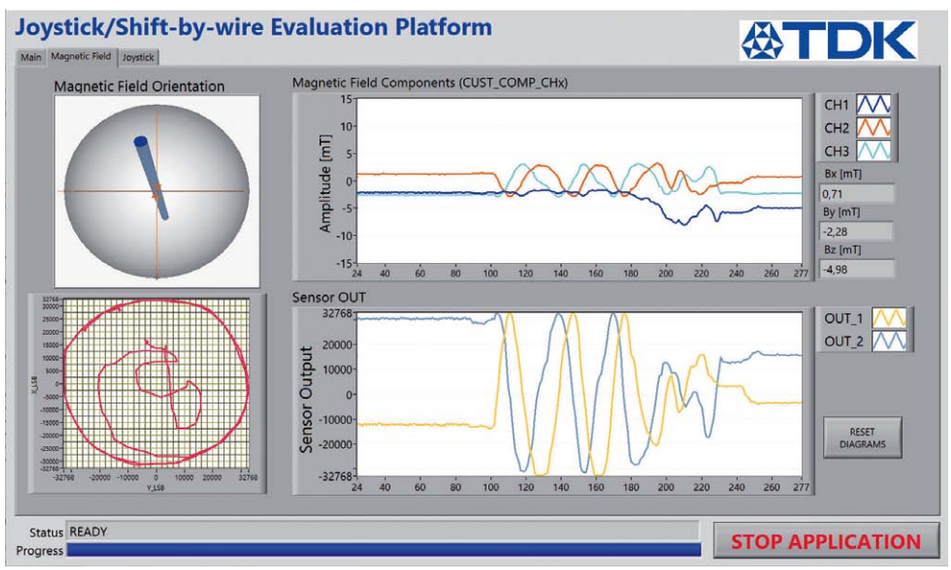


Figure 6: Users can use the "Joystick Evaluation Platform" software to read essential values.

UVC LEDs

Don’t give germs a chance!

The fight against viruses has been a long one. Chemical disinfectants only offer limited benefits against micro-organisms such as viruses and bacteria, as they can become resistant. UV light is a much more effective method for disinfecting and sterilizing water, air and surfaces, which makes it a more effective method against coronavirus.

By Alain Bruno Kamwa, Product Sales Manager Opto at Rutronik

In order to disinfect the protective clothing of the medical staff at the Huoshenshan Hospital in Wuhan, China so as to prevent the SARS-CoV-2 virus from spreading outside of the clinic, a disinfection tent with UVC LEDs was set up as a novel approach. In the 1.5m × 0.75m × 2m room with layered synthetic fabric walls, UVC emitters from American supplier Bolb are fitted to the reflective surfaces of the ceiling, walls and flooring. During the 30-second disinfection process, the UVC LEDs provide a dosage of 6 mJ/cm² with a consistent brightness of 200 µW/cm². The light wavelength of 265 to 280 nm destroys genetic information, ensuring that the virus can no longer spread or infect other cells.

Artificial UV sources

For a long time, ultraviolet light was generated using mercury-based radiation sources, for example using low and medium-pressure mercury vapor (Hg) lamps that generate UV light in a spectrum of 185 to 405 nm by means of gas discharges. UV light can also be generated using UV cold cathode tubes (UV-CCL or UV lamps) in a spectrum of between 185 and 405 nm by means of glow discharge.

UV LEDs emit UV rays in a spectrum of between 227 and 405 nm by means of electroluminescence. The wavelengths are particularly short when using UVC LEDs—between 260 and 270 nm—which provides the greatest sterilization effect. Figure 1 shows this using the example of cryptosporidium, a parasite that spreads in particular through unpurified drinking water. Other pathogens, bacteria and viruses exhibit very similar characteristics.

LEDs also offer a compellingly stable spectral output under specific temperature conditions and an almost limitless number of switching cycles, which makes them ideal for mobile solutions that need to provide full light output without any delay.

A multitude of weapons

UV rays are invisible to the human eye throughout their entire wave range of 100 to 400 nm. Their frequencies are divided into UVA, UVB and UVC bands, and these have different effects on living organisms.

LEDs allow us to pretty much choose the wavelength at our discretion. UVA LEDs with a wavelength of 315 to 400 nm offer greater penetration in dispersed biological tissue such as human skin compared to UVB and UVC rays. UVA LEDs are used in fields such as dentistry and cosmetics, for example in tanning studios and nail studios. In the industrial sector, UVA LEDs are used to cure resins, adhesives and paints.

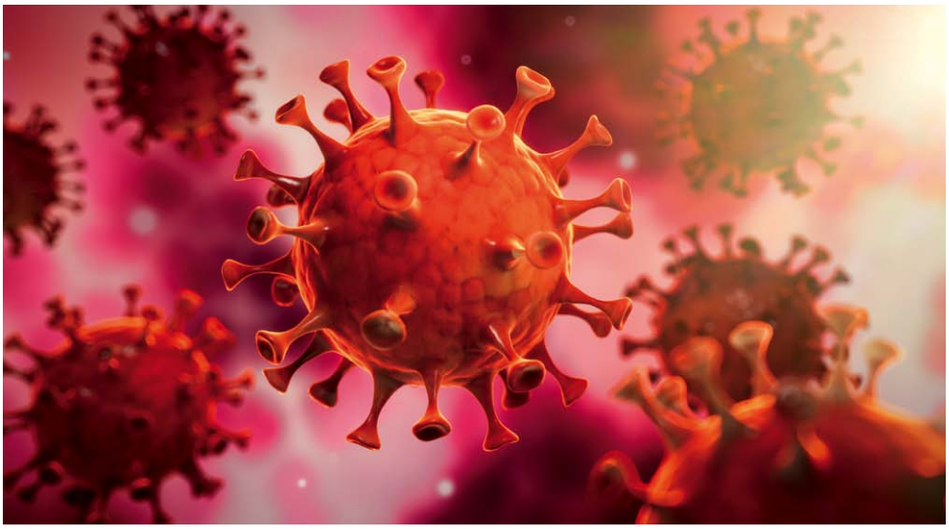


Figure: peterschreiber.media/stock.adobe.com

With a wavelength of 280 to 315 nm, UVB LED rays have comparatively little penetrating power when it comes to dispersed biological tissue, but they are subject to more scatter. UVB rays encourage the formation of vitamin D in the human body, which is why UVB LEDs are mainly used in medicine for phototherapy and dermatological treatments.

No defense against UVC rays

The high-energy light from UVC LEDs is subject to ever more scatter in biological tissue. With a wavelength of 100 to 280 nm, these rays do not penetrate tissue especially deeply, but they can burn unprotected skin. Because the ozone layer in Earth's atmosphere absorbs the natural UVC radiation of sunlight, no earthly organism has developed defense mechanisms against UVC rays, and this is also true of viruses and bacteria. This vulnerability makes irradiation with artificial UVC light an especially effective method of sterilization and disinfection.

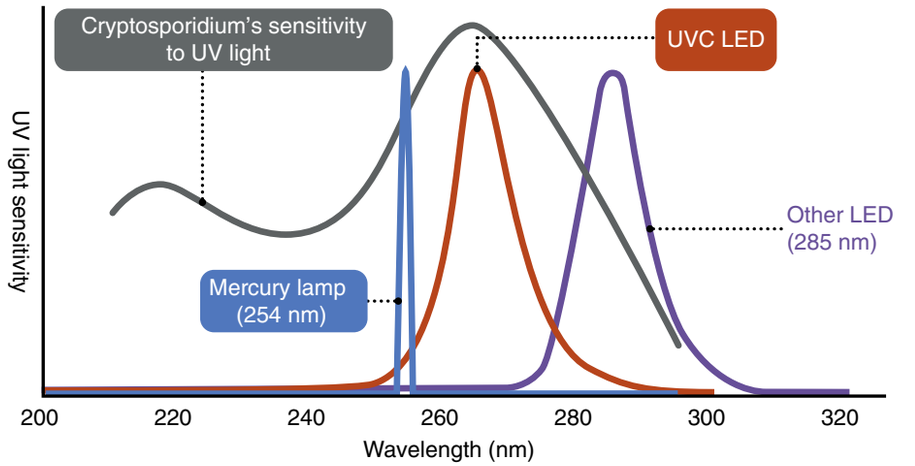


Figure: Stanley

Figure 1: The wavelengths of UVC LEDs are most effective where cryptosporidium—and other bacteria and viruses—react most sensitively to them.

UVC LEDs in practical applications

Each micro-organism reacts differently to UVC radiation, which is why the intensity of the radiation should be geared towards the desired reduction rate, which is the number of killed micro-organisms. The intensity of UV radiation is inversely proportional to the square of the distance, meaning that as the distance from the radiation source increases, the UV radiation very quickly loses its effectiveness, which is why the object to be disinfected should be as close as possible to the emitter.

Viruses, including the SARS-CoV-2 virus, are commonly spread by air, so the use of UVC LEDs in air conditioning systems seems advisable. In addition to the required reduction rate, air flow rates and air flow geometry also have to be considered.

UV light with a wavelength of 254 nm has proven to be especially effective at killing micro-organisms, although when directly applied, it can be harmful to the skin and eyes. On the other hand, "far UVC" light (207 to 222 nm) also broadly disables most pathogens in the air without damaging exposed human tissue.

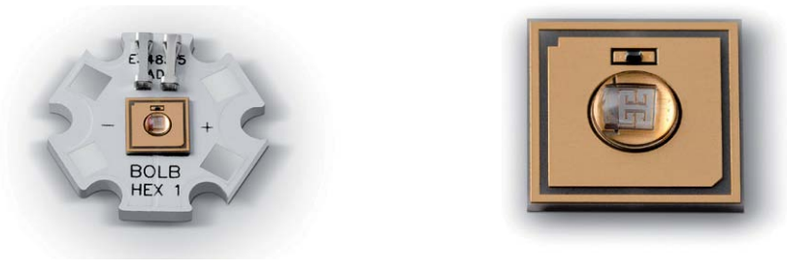
Disinfecting surfaces

Other viruses and bacteria are also transferred via surfaces, including influenza, noroviruses, rotaviruses, streptococcus and salmonella. For sterilizing larger surfaces, a suitable product would be for example the low-power PU35CL1.0 UVC LED from Lextar with output of 2–4 mW and 20 mA, which can also be used to pasteurize drinks, package antimicrobial foods, and sterilize toothbrushes.

For smaller-scale installations, Bolb has introduced the compact mid-power S3535-DR100-W272-P40 UVC LED with dimensions of 3.5 × 3.5 × 0.9 mm³. With DC power consumption of 40 mW and a current of just 100 mA, it stands out as having the lowest energy consumption in the world with the lowest heat output.

Material	Reflectance in %
Aluminum, etched	88
Aluminum, polished, commercial	78
Aluminum, foil	73
Chromium	45
Nickel	38
Stainless Steel	20–30
Silver	22
Tin-plated Steel	28
White-wall Plaster	40–60
White Paper	25
White Cotton	30
White Oil Paints	5–10
White Porcelain Enamel	5
Glass	4
Water Paints	10–30

Different materials reflect UV rays to different levels. This aspect must be taken into account at the design stage.



Figures: Bolb

Figure 2: High output—the high-power UVC LED from Bolb with 100 mW at 250 mA, with and without mount

In the high-power segment, Bolb has introduced the S6060-DR250-W272-P100 UVC LED into its range, the most powerful component with DC power consumption of 100 mW at 250 mA.

Bolb's UVC LEDs are especially well-suited for the treatment of drinking water and disinfection of water in pools or RVs, as well as applications involving stricter irradiation intensity requirements (W/m²) as applicable in fields such as industrial filter systems, air purifiers, medical disinfection boxes and vacuum cleaners.

Selection criteria for UV LEDs

A key selection criteria for UV LEDs is the beam angle, with certain beam angles being required in certain applications. Bolb's UVC LEDs have a beam angle of 150°, which can be further focused using lenses from Ledil as necessary. Because this reduces the irradiated surface, it also increases the radiation energy per square meter, meaning that the exposure time required is reduced when applying the same energy output. Different UV lenses with compatible glasses allow the irradiation output to be easily scaled for different purposes. For its UV lenses, Ledil uses a special grade of silicone that is especially compatible with UVC wavelengths, as well as aluminum reflectors that are highly reflective of all UV wavelengths, making them especially suitable for disinfection applications.

Other selection criteria for UV LEDs include national UV standards, reflectivity on different materials (Figure 3), heat management, drivers, power consumption and the inverse-square law, which dictates how the intensity of a beam diminishes with increasing distance from the light source.

Bolb's Blazar surface emitter satisfies many of these criteria. This UVC module with 25 LEDs (5×5) and a 55° reflector achieves an effective output of 2 W with power consumption of just 1.25 A.

Multi-UV LEDs are currently in development. With a dual wavelength chip, they can provide multiple UV wavelengths, for example UVA and UVC, essentially making them an all-purpose weapon in the struggle against viruses, bacteria and other pathogens. ■

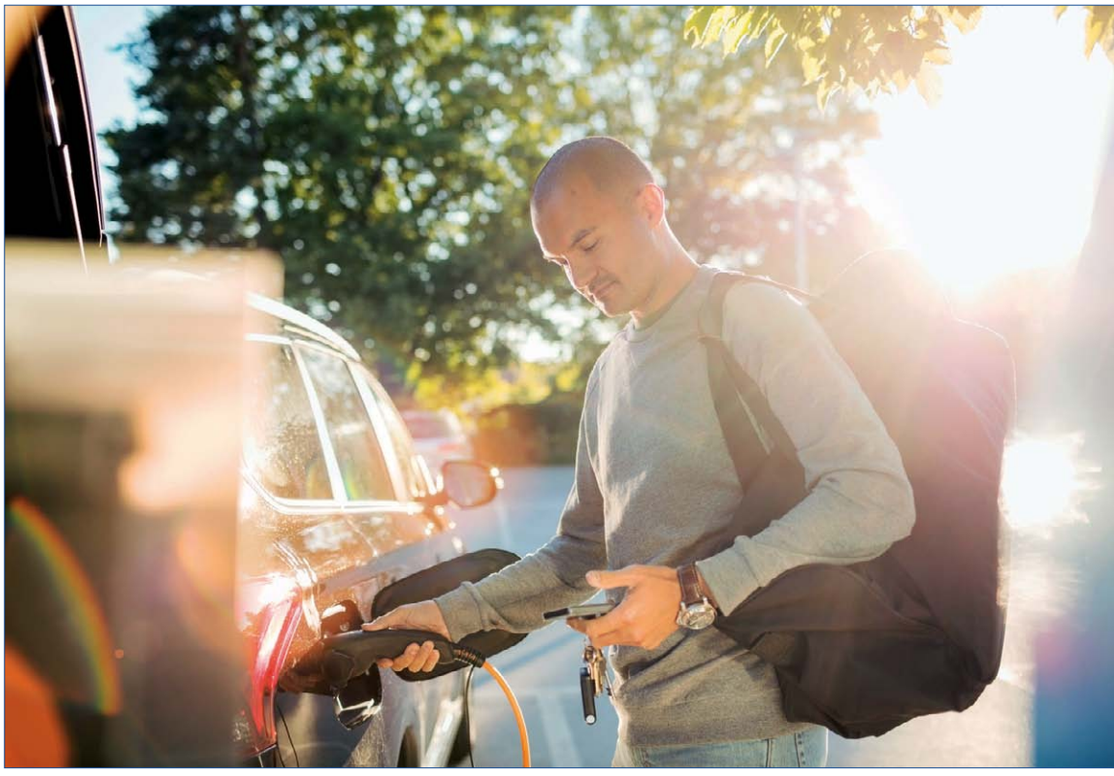
A strategic approach to fighting pathogens

UVC LEDs were originally developed to fight multidrug-resistant micro-organisms such as Methicillin-resistant Staphylococcus aureus (MRSA). Testing is currently underway to determine how UVC LEDs can also be used to fight viruses. Viruses can only reproduce with the aid of a host. They infest a cell and reprogram it using the cell's own ribonucleic acid (RNA). As the newly produced viruses infect other cells, the host cell is destroyed by this reproduction process. High-energy, short-wave UVC light is absorbed by the RNA of the virus, which causes the genetic information to be destroyed, making the virus unable to spread and infect even more cells.

48-Volt on-board network

A transitional technology, or key to the mobility of tomorrow?

Power networks based on 48-V technology enable low-cost mild hybrid vehicles that allow OEMs to comply with current CO_2 limits. However, a trend toward plug-in hybrids and pure electric vehicles is emerging. Is there any point in continuing to invest in 48 V technology?



By Mirko Vogelmann, Product Sales Manager Power at Rutronik, and Dr. Johannes Breitschopf, Technical Marketing ATV DDM RDME at Infineon

Introducing mild hybrid vehicles was the fastest, cheapest, and thus most logical step for many automobile manufacturers to ensure that their vehicles satisfied the CO_2 limits imposed by the European Commission. The 48 V on-board power systems required for this are usually achievable with reasonable investment. It enables features such as regenerative braking, temporary storage of energy in battery packs and capacitors, and subsequent electrical support for a conventional combustion engine. This itself reduces consumption and emissions by percentages in the low double digits.

Figure 1 shows how the market share of electric vehicles would have to develop in order to comply with future limits. It is immediately apparent why the 48 V on-board power system is only seen as a transitional technology

Figure: IHS Markit

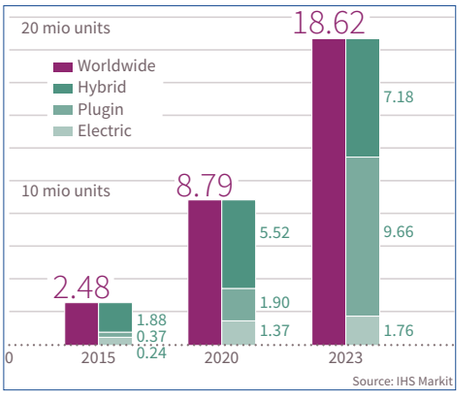


Figure 1: Until 2023, the majority of all hybrid and electric vehicles around the world are likely to be plug-in hybrids if the enforceable limits are to be complied with.

while a sufficiently large fleet of high-voltage (HV) battery electric vehicles (BEVs) becomes established.

The best way to reduce CO_2 emissions

A purely electrically powered car with zero local emissions seems to be the ideal solution for fulfilling CO2 emission requirements that will only get stricter as time goes on, which is why development and funding needs to be provided to this end. Relying entirely on HV electromobility is not the right solution, though. The advantages and disadvantages are already a topic of heated discussion.

There are concerns that focusing on HV electromobility may cause the development of promising alternative concepts such as fuel cells or carbon-neutral synthetic fuels to suffer, resulting in the neglect of potentially key technologies. Also, when you consider the entire value chain as a whole, it becomes apparent that it will be unfeasible to achieve a global shift toward purely electrical vehicles in a carbon-neutral fashion, and this will remain the case for years to come. In particular, the current energy mix of nuclear energy, fossil fuels, and renewable sources and the production and recycling of batteries have a negative impact on our carbon balance.

One of the challenges in the use of batteries is that the requirements placed upon the overall electric vehicle system can vary greatly depending on the conditions it is to be used in. In extreme and/or greatly variable environmental temperatures, efficient heating/cooling solutions that are adapted to such conditions are necessary to guarantee the safety and reliability of the battery and the system as a whole. This too is a new area of development.

The time it takes to create a carbon-neutral electromobility concept and how 48 V on-board power systems can help achieve this will be critical. This will reveal whether 48 V on-board power systems are only a transitional automotive technology or if there is more potential within.

48 V approaches for the future

Regardless of whether a vehicle is powered entirely electrically using a battery or whether it uses a fuel cell or synthetic fuels, 48 V power systems in auxiliary power units can help achieve energy savings compared to 12 V supplies and also in comparison to HV simplifications for the installation and operation of auxiliary power units in vehicles – thereby offering potential for optimization. Typical 48 V applications include e-turbo, electric air conditioning systems with 4 to 5 kW, electric heaters such as eCAT (electrically heated catalytic converters), PTC block heaters or windshield de-icers with 1 to 5 kW, ERC (electrical roll control) with 1 to 5 kW, pumps and fans of up to 1 kW, and other applications involving high power densities and/or continuous usage. Second-generation mild hybrid vehicles are increasingly achieving these using 48 V power systems; 48 V systems are also encountered in HV-BEVs as a third power system.

Urban mobility ideal for 48 V technology

Urban mobility is a promising business field for 48 V technology. Unlike the objectives of current HV-BEV development, which include long distances of more than 400 km and short charging times, the focus with urban mobility is on short trips of between 2 and 50 km, cost, battery weight, and insulation protection. Charging times are irrelevant in urban environments because the vehicle can be charged during working or night hours.

Calculations show that a 30 kW motor is adequate to complete urban and extra-urban driving cycles with small compact cars. In this driving cycle, a 48 V BEV drivetrain is around 25% cheaper than a HV 400 V BEV drivetrain.

Electrically powered commercial vehicles with 48V systems supporting loads of up to 1,000 kg are already available on the market, among them the Streetscooter postal vehicle. Electric motorbikes, scooters, and mopeds using 48 V power systems are also becoming increasingly established. Some of them even have a replaceable battery system.

All of these vehicles can be created with applications that are being or have already been developed for mild hybrid automobiles, including batteries with battery management systems (BMS), inverters, DC/DC converters, and auxiliary power units.

New requirements placed upon semiconductors

As already mentioned, 48 V power systems with any circuit topology already allow for the basic boost and recuperation functions with the combustion engine engaged, and gliding while the combustion engine is disengaged. However, when the engine is disengaged, a fully automated forward clutch is essential. The recovery of braking energy while the engine is disengaged and driving on electrical power alone using the capacity of a 48 V sys-

Figure: Infineon Technologies

Figure 2: To guarantee the safety of the battery and the system as a whole, heating and cooling solutions adapted to the requirements are needed.

tem, on the other hand, place new demands on the performance and robustness of semiconductors.

On-board power systems of 48 V also use sensors and microcontrollers as well as power, supply, communication, and driver semiconductors. They control electric motors, handle power distribution in the inverter, and supply auxiliary power units.

Low-loss MOSFETs are often used as power amplifier ICs and are usually controlled, monitored and – if need be – used to recover a safe operating state via three-phase drivers. Key components other than motor driver ICs include high-performance gate driver ICs that, in combination with MOSFETs, allow for the creation of high-reliability battery switches or safety switches for 48 V/12 V cut-off mechanisms. Electrically, the 48 V system is coupled with the 12 V system by means of a DC/DC converter.

Bridge driver ICs such as the TLE9180 from Infineon are used as communication and power components.

For 48 V applications such as starter generators (belt-driven or integrated), DC/DC converters or main battery switches/cut-off switches, there is high demand for 80 V and 100 V MOSFETs.

Broad portfolio for 48 V

Numerous semiconductor suppliers are investing not only in high-voltage technologies for electric vehicles but also in 48 V technologies and products. They are already offering a broad, scalable portfolio of powerful semiconductors as well as evaluation kits that allow for the creation of all kinds of applications – plus those with high specifications, including complete systems and chipset solutions for voltage controllers, smart power drivers, and very low-resistance MOSFETs that are ideal for use in 48 V systems.

Investment in 48 V technology still worthwhile

This shows that 48 V is not just a transitional solution; it will continue to offer a path to low-carbon mobility in the future and will therefore still provide benefits in numerous application scenarios. This means that investments in and system optimizations for the use of an 48 V on-board power system will remain worthwhile. Appropriate components are already available. ■

Lidar for autonomous driving

How science fiction becomes science reality

It is the dream of many to be brought from point A to point B without any effort on their part whatsoever – a dream that is embodied in Knight Rider's K.I.T.T. or the vehicles in The Fifth Element. Modern cars are increasingly approaching these visions of the future, and various sensor technologies play one of the most important roles here. One of the most promising of these is lidar.

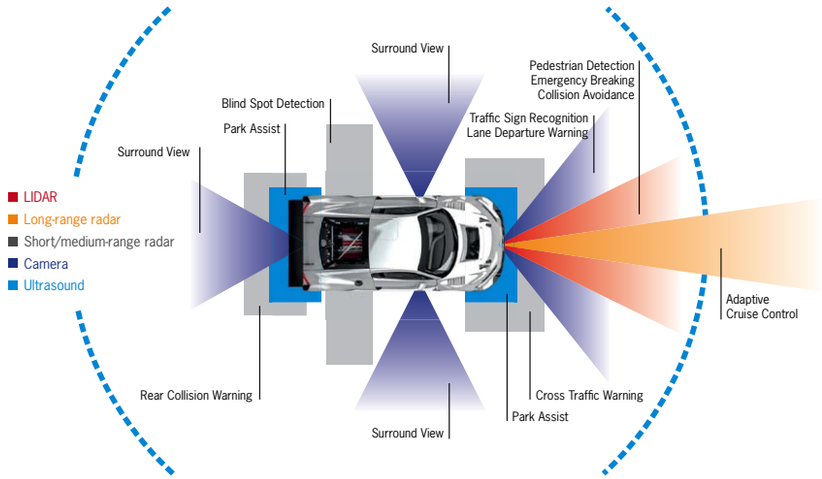
By Alain Bruno Kanwa,
Product Sales Manager Opto
at Rutronik

Like radar, lidar is a method for detection and ranging (DAR). Both use the same method of echolocation as bats: they send out ultrasonic waves and detect where objects or prey are located based on how they are bounced back. While radar uses radio waves, lidar uses light waves.

Lidar sensors use a pulsed laser diode that sends out a light pulse. If it is reflected by an obstacle, the sensor will detect it. The time of flight (ToF), which is the time between the sending and receipt of the light waves, allows the distance between the sensor and obstacle to be calculated.

Highly sensitive detectors

The light waves are dispersed in many directions depending on the distance and form of the reflective object or living being. This is why the broader the detector range, the more precise an image of the environment it produces – because it can detect even more reflections. Current lidar sensors use avalanche photodiode (APD) arrays of 8, 12, or 16 diodes. Each diode represents a pixel of the overall image. This means that in addition to the size of the array, the distance between the diodes (=pixels) is also a factor in the sensor's reso-



Figures: Laser Components

lution. The APD sensitivity also plays a role. Ideally, they should detect as few traces of the reflected beam as possible.

The ideal light beam

The length of the light pulses plays a critical role in the sensor resolution, which is why lidar manufacturers put a lot of effort into developing pulse lengths that are as short as possible. Presently, they measure 5 ns on average up to a maximum of 10 ns. Another factor is the size of the light beam. Because the laser diode sends out an extremely focused light beam, it can only measure the distance of a point that is of the same size. This is nowhere near sufficient for use in driver assistance systems and certainly not in autonomous vehicles. There are various solutions for enlarging the field of view (FOV). The challenge here is to detect even the smallest faces within a large FOV.

Eye and skin safety

One limiting factor in lidar development is eye safety. Given that laser beams may shine into the retinas of people, especially when used for road traffic, it is important to ensure that it does not cause eye damage. Human skin can also be attacked by laser beams. The standard EN 60825-1 defines various classes based on their risk to eyes and skin – both wavelength and pulse length play a role here. These are three examples for laser classes: Class 1 applies to laser radiation that is nonhazardous or is used in an enclosed housing. Class 2 applies to laser radiation in the visible spectral range of between 400 and 700 nm. With a short exposure time of a maximum of 0.25 s, it poses no danger to the eye. Class 4 lasers are highly dangerous for the eyes and skin, even if diffused.

Flash lidar – scattered light

One method of widening the FOV is based on scattering the light beam so that it covers a large FOV with a broad beam angle. Known as flash lidar, the light in this case is diffused, however, and much weaker than a focused light beam. Even so, to achieve a long range and high resolution, laser diodes with a very high output of 1–2 kW are used.

For applications where objects only need to be detected at short distances, vertical-cavity surface-emitting laser diodes (VCSELs) with a wavelength of between 850 and 940 nm are ideal. They can be used to develop powerful 2D arrays. For detectors, highly sensitive sensors that can even detect individual photons – known as single-photon avalanche diodes (SPADs) – can be beneficial.

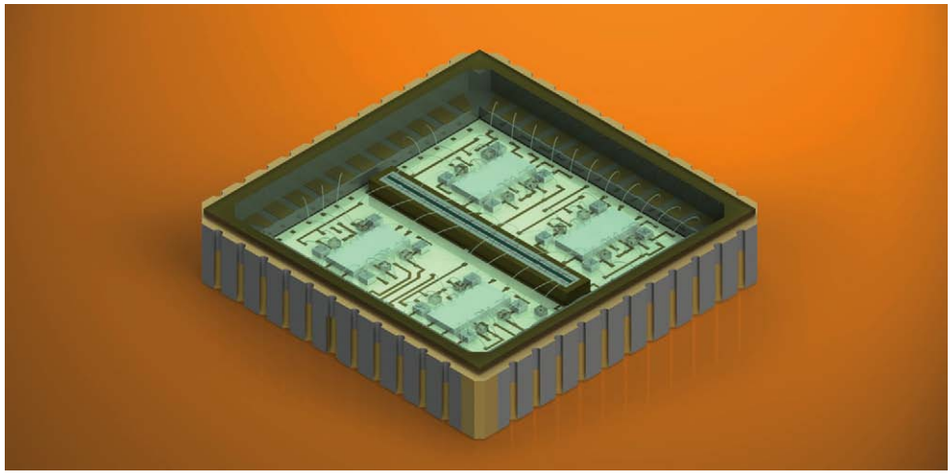
In order to increase range and also for conditions with intense sunlight exposure, the Fraunhofer Institute has developed CMOS SPAD detectors for microelectronic circuits and systems. SPADs are integrated into a CMOS process that is certified for the automotive industry and has been optimized for optoelectronic applications. This produces highly sensitive, very fast avalanche photodiodes with a momentary amplification of up to 10^8, high pulse rates, and low noise.

Laser Components offers a flash lidar sensor with CMOS SPADs; the SPAD2L192 is a 192 × 2-pixel solid-state CMOS sensor for flash lidar applications. It measures distances based on the first-photon, direct ToF principle. Single-photon detectors offer very high sensitivity and high temporal resolution. The pixel-internal time-to-digital converter with a temporal resolution of 312.5 ps and an end-of-scale value of 1.28 µs enables a nominal range of 192 m and a resolution at a distance of 4.7 cm.

Scanning lidar – mobile mirrors

To preserve the intensity of the light while covering a wider FOV, scanning lidar technology employs the principle of scanning the field with a beam of light. Using moving micro mirrors, the light is directed over the FOV to be scanned. Scanning lidar sensors usually use between 1 and 16 laser diodes. Edge-emitting lasers with a wavelength of 905 nm generate the best results here, while high-power laser diodes with over 100 W achieve ranges of up to 150 m.

As only a few diodes with relatively low power are sufficient, scanning lidar sensors offer good thermal properties. This enables very high pulse rates, allowing for eye safety even at a wavelength of 905 nm.



Each avalanche photodiode (APD) in an array represents a pixel of the overall image.

The FOV is normally 145° on the y-axis and 3.2° on the z-axis. Theoretically, a 360° panoramic scan should be possible with this technology, but in practice, there do tend to be blind spots – where the light beam is unable to scan the immediate vicinity – but additional radar and camera solutions provide a workaround for this flaw. However, due to their size and poor robustness, scanning lidar sensors are not suitable for use in vehicles. They measure around 10.5 cm × 6 cm × 10 cm, making them too large to be used in the housing of a spotlight, for example. The moving mirrors are also sensitive to vibrations, impact, dust, and extreme temperatures of the types that cannot be avoided in vehicles.

Appropriate diodes are available from Laser Components – the 905DxxUA series includes pulse laser diodes with single and multi-junction designs with up to a 110 W laser output and a wavelength of 905 nm. The components are absolutely reliable, offer superb thermal stability, and very precise chip alignment in a hermetically sealed package. This makes them suitable for distance measurement and obstacle detection, surveying equipment, laser radars, and many medical applications. The AEC-Q101-qualified models can also be used in automotive applications.

Si-APD or Si-APD arrays are recommended for detectors. The SAHA-series Si-APDs from Laser Components are optimized for wavelengths between 850 and 905 nm. The semiconductor material is especially efficient here, and the pulsed laser diodes also emit at these wavelengths. In a miniature SMD package, Si-APDs offer high quantum efficiency and thus high sensitivity and low noise. The SAH1Lxx array series with 8, 12, or 16 high-sensitivity Si-APDs in an LCC44 package with a protective window offers the same characteristics. They offer an especially low spacing of 40 µm. An array with 12 APDs is also available in a 14-pin DIL package. In addition to the standard array, there are also customized arrays available with specific numbers and sizes of APDs.

Solid-state lidar – semiconductors instead of mechanical components

Solid-state lidar sensors are a smaller, more robust alternative. These rely on semiconductor instead of mechanical components to direct the light beam. There are two versions of these: those with MEMS-based mirrors and those with OPAs (optical phased arrays).

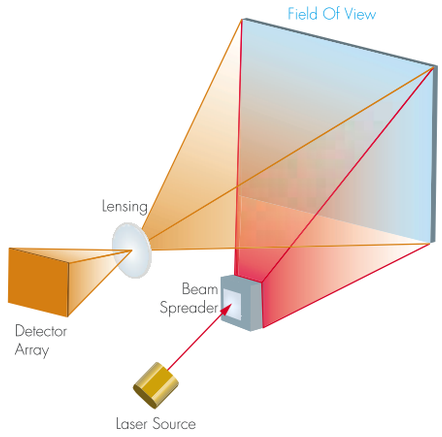
Lidars with MEMS-based mirrors use a matrix of micromirrors, with each mirror having an edge length of just a few micrometers. They switch back and forth between two positions several thousand times a second, moved by electrostatic fields. These kinds of lidars are used in applications such as scanner checkouts or DLP projectors (digital light processing), so they are a proven, tested technology with relatively low production costs.

However, for automotive applications, the sensors need to satisfy much more stringent requirements. For example, they require a wider FOV compared to POS checkout systems or projectors. With a scan frequency of over 100 Hz, current solutions offer angles of 40°; MEMS systems with broader angles are currently under development.

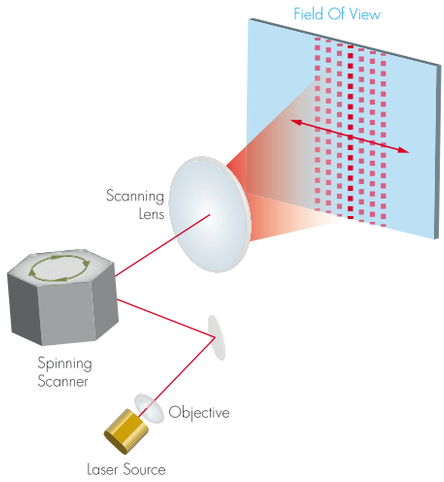
With lidars using OPAs, the phase of the emitted light from each laser diode is modified by a modulator to enable a pulse to cover a larger area. The technology is still currently in the research stage. A variant of this uses a silicon circuit measuring just several square millimeters as a replacement for the rotating emitter and detector unit. For higher outputs and a broad FOV, tests are underway using wavelengths that reach further into the infrared range than the 905 nm currently conventionally used. A wavelength of 1,550 nm, for example, is not harmful to the eyes but could be adversely affected by snow or rain. Other detectors are also required here.

Many technologies turn science fiction into science reality

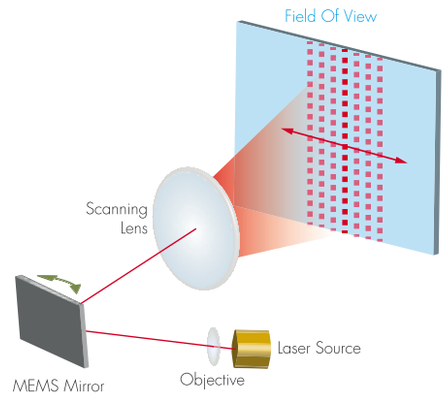
We're still a few years away from achieving autonomous driving as science fiction films depict it, but each assistance system – be it adaptive cruise control (ACC); emergency brake assist (EBA); or lane departure warning (LDW) – is a step toward achieving that goal. For many of these, lidar is an essential component, one that absolutely should be combined with other technologies such as ultrasonic sensors, cameras, and radar solutions – because every technology has its strengths and weaknesses. ■



Flash lidar: scattering a laser beam broadens the field of view. An array of high-sensitivity sensors can detect individual photons.



Scanning lidar: pulsed lasers (pulsed laser diodes or VCSELs) are used to scan the field of view using a rotating mirror.



Solid-state lidar: moving MEMS mirrors reflect the light in different directions to enlarge the field of view.

High-current inductors for automotive electronics

Small yet powerful

New switching transistors – for example, based on gallium nitride (GaN) – increase the operating frequency of switched-mode power supply units, enabling the use of smaller capacitors and inductors. Inductors using high-tech core materials also help achieve high circuit efficiency.

By Ralf Hickl,
Product Sales Manager ABU
at Rutronik

Figure: Vishay

Modern ICs for switched-mode power supply units and switching transistors allow for ever-higher switching frequencies while keeping switching losses low thanks to steeper transition slopes. The increase in switching frequency enables the use of capacitors with low capacitance values and inductors with low inductance values. As electrical values decrease, so does the size of the components, which means less space taken up by the construction, less weight, and less cost for the circuit as a whole. And this also increases the power density of the circuit, which helps the components to contribute toward reducing the CO_2 emission of the vehicle.

In order to achieve good efficiency, parasitic effects also need to be minimized despite miniaturization. In coils, direct current resistance (DCR) and effective resistance are the key factors here, accounting for the core losses in the equivalent circuit diagram. Vishay's IHLP series is a range of miniaturized inductors with excellent electrical properties.

Core material for low eddy-current losses

"IHLP" stands for inductor, high current, low profile. The core in this case is not ferrite but a compressed composite made of a soft-magnetic iron powder with an epoxy resin used as a binder. The iron powders determine the magnetic properties. The composite is a poor electrical conductor that insulates the iron powder particles from one another, thus keeping eddy-current losses low.

Increasing quality with superior EMC properties ...

During production of the component, a coated copper coil is brought into contact with a wire frame embedded in a powder mixture in a press mold, and this mixture is then compressed into its form at a pressure of up to 2.8 t/cm^2. The resultant inductor coil unit provides a magnetic shielding effect and reduces interference from stray electromagnetic fields. This results in a compact, high-performance inductor for surface-mounted devices that offers superb electromagnetic compatibility properties.

Typical applications for such inductors with compressed coil units include LED drivers, switched-mode power supply units, DC/DC converters, and EM filters. They also meet special requirements by varying the mixture proportions of the composite and by using different powder materials and grain sizes. Although the concept is already over 20 years old, Vishay continues to evolve the formula. Even today, new versions are being produced that are optimized for saturation (IHLP...Suffix A1),

time constants (L/DCR), coil quality (IHLP... Suffix 1A), or operating temperature (IHLP... Suffix 5A, 8A).

... and temperatures specified up to 180°C

For use in applications where environments are in play that demand high robustness with more stringent heat requirements, there are some inductors in the IHLP series that are specified for operating temperatures up to 180°C. This provides benefits in heat management or expands the potential uses to applications where actuators are located directly adjacently to the vehicle component to be controlled. The inductor's FIT value (failure in time) falls, and its service life increases.

More features of IHLP inductors:

- Optimum proportion of direct current resistance (DCR) and inductance (L) to housing size (large τ = L/DCR).
- Within the operating range, the dependency of inductance (L) on a superimposed direct current is relatively low, so the differential permeability ($\mu_{r,diff}$ = dH/dB) is almost constant. This makes IHLP inductors especially suitable for use in switched-mode power supply units and as filter components in power supply units.
- The dependency of these inductors on temperature is low compared to other core materials.
- The saturation field strength has comparatively little dependency on temperature.

Design aid

To help developers in their use of inductors, Vishay offers the IHLP Inductor Loss Calculator Tool (www.vishay.com/inductors/calculator/calculator), which supports boost, buck, and buck-boost switched-mode power supply topologies. Three-dimensional models of inductors are available for virtual models of assembled PCBs. Equivalent circuit diagrams are also available on request from Vishay for electrical simulations. ■

Small electrical drives in the vehicle

Improving convenience on the path toward autonomous driving

In the future, autonomous driving will maximize the convenience of mobility. Until that time, many small electrical drives enable easier, more convenient control of the vehicle. But how are they constructed, what requirements do they need to fulfill, and which applications can manufacturers provide to make driving even more pleasurable for their customers?

By Bernd Wondratschek,
Field Application Engineer ABU
at Rutronik

Today, there are over 75 small electrical drives in a mid-size vehicle, and that number is increasing. Electric motors with up to 100 W in power handle functions such as adjusting the side mirrors or closing the trunk door. Other automatic adjustment mechanisms are also possible depending on the user conditions, including not only the seats but also the interior mirrors and headrests, for example, or even gesture-controlled compartment doors, perhaps to open and close the glove box.

As small drives are based on the 12 V onboard voltage, they can be powered directly via terminal 30 (battery) or terminal 15 (post-ignition). They are partly the reason why the 12 V electrical system will not be disappearing from the vehicles of the future; switching to the increasingly popular 48 V technology at this power level would not yet offer any significant benefits right now in terms of lower production and development costs. However, looking at the lower wire cross sections and nominal load currents of a 48 V electrical system, which are just a quarter of those of a 12 V system, these are arguments that need to be considered in the long run.

In drives of up to 100 W, brushed DC (BDC) and brushless DC motors (BLDC) as well as stepper motors are used. The latter are ideal for applications where absolute precision control is required or very fine step adjustments need to be performed – for example, for adjusting the mirrors and moving the dashboard needles. BDC motors are used wherever long service lives and higher efficiency can give way to cost benefits. BLDC motors are the most robust versions, but they are more expensive and sometimes more complex to control.

Construction and function of controllers

Figure 1 shows a simplified circuit design of a small drive with DC motors, featuring the main components: the microcontroller, the system basis chip (SBC), the MOSFET driver (gate driver), and several MOSFETs. The SBC is used to create a communication interface with the vehicle bus, to ensure that the key components are suitably supplied with power, and to be able to perform tasks in the interest of functional safety and reliability (a watchdog function, for example). Each of the MOS-

FETs are arranged as half bridges, forming a full bridge (also known as an H-bridge) together with the motor connected between them. Adding another, third half bridge creates a B6 configuration that allows two DC motors (as shown in Figure 1) or a three-phase BLDC motor to be controlled.

The microcontroller receives the input controller signals via its I/O pins and processes them to control the gate driver. At the same time, it can evaluate the signals of the driver when an error occurs. The MOSFETs are triggered by the driver using a PWM signal.

This full-bridge/B6 arrangement can turn the motor clockwise or counterclockwise.

Controlling BDC motors ...

BDC motors fundamentally consist of the rotor, the commutator with carbon brushes, and the stator (or permanent magnet). The carbon brushes conduct the current to the rotor. The friction that this generates causes the brushes to wear down. The rotary movement is generated by the rotor's magnetic field forming as a result of the current passing through the rotor. The rotor's magnetic field is aligned with that of the stator. Once the opposite pole of the stator's magnetic field has been reached, the commutator installed in the rotor changes the magnetic field of the rotor and generates a magnetic field that is inverted by 180°. This causes the two identical poles to repel each other, and the rotor pole is drawn by the opposite stator pole. The commutation is therefore a purely mechanical process. There is no need to determine the position of the rotor during start-up.

... BLDC motors ...

BLDC motors are constructed like AC synchronous motors and have a purely electronic commutation mechanism, with permanent magnets in the rotor and a controllable winding in the stator. The windings are usually arranged at 120° angles to one another (or divisible fractions of these) and are stimulated in sequence, depending on the direction of rotation. The rotor follows this rotating magnetic field.

To prevent excess load caused by high start-up currents, the rotor position should be determined before start-up to ensure that the right winding is activated during start-up.

With sensor-based position detection, three Hall-effect sensors precisely detect the magnetic field of the rotor's permanent magnet. This method results in higher component costs and requires more space and wiring but is simple to create. Appropriate automotive-qualified (AEC-Q100) Hall-effect sensors from Diodes, Melexis, and TDK-Micronas are available from Rutronik.

FOC (field-oriented control) is a popular sensorless method, even if the implementation of the software algorithm and the management of the motor size transformation are complex. To provide developers with assistance in starting out with FOC implementation, STMicroelectronics offers FOC software tools, the SPC5-MCTK-LIB library, and the associated evaluation kit for its SPC5 microcontroller family. The library works with SPC560P as well as SPC574K and SPC58NN models and therefore supports controllers in a variety of performance classes.

With the TLE9879 three-phase embedded motor driver (e-power IC), including evaluation kit and FOC example algorithms, Infineon has provided an answer for sensorless BLDC control via FOC. The high level of integration of the IC means that only the B6 bridge and the motor are otherwise needed.

... and stepper motors

Stepper motors only have windings in the stator. They are usually constructed as hybrid stepper motors, where the rotor construction's defining feature is a permanent magnet combined with a soft iron core. Selective triggering of the windings allows the rotor to be adjusted by a specific angle. The angle change in each step depends on the number of phases of the motor and the number of pole pairs in the rotor; the angle change is usually 1.8° or 0.9° with two phases (i.e. there are two windings in the stator and a corresponding number of poles in the rotor core). The stepper motor is relatively simple to control; it enables reproducible movements and very high precision. And furthermore, it doesn't require any position feedback.

Property/form factor	Discrete	Medium integration	High integration
Space requirement	High	Medium	Low
Protection options	Medium	High	Medium
Flexibility	High	Medium	Low
Power consumption	High	Low	Medium
Total costs	Low	Medium	High

ICs fulfill different requirements depending on the level of integration.

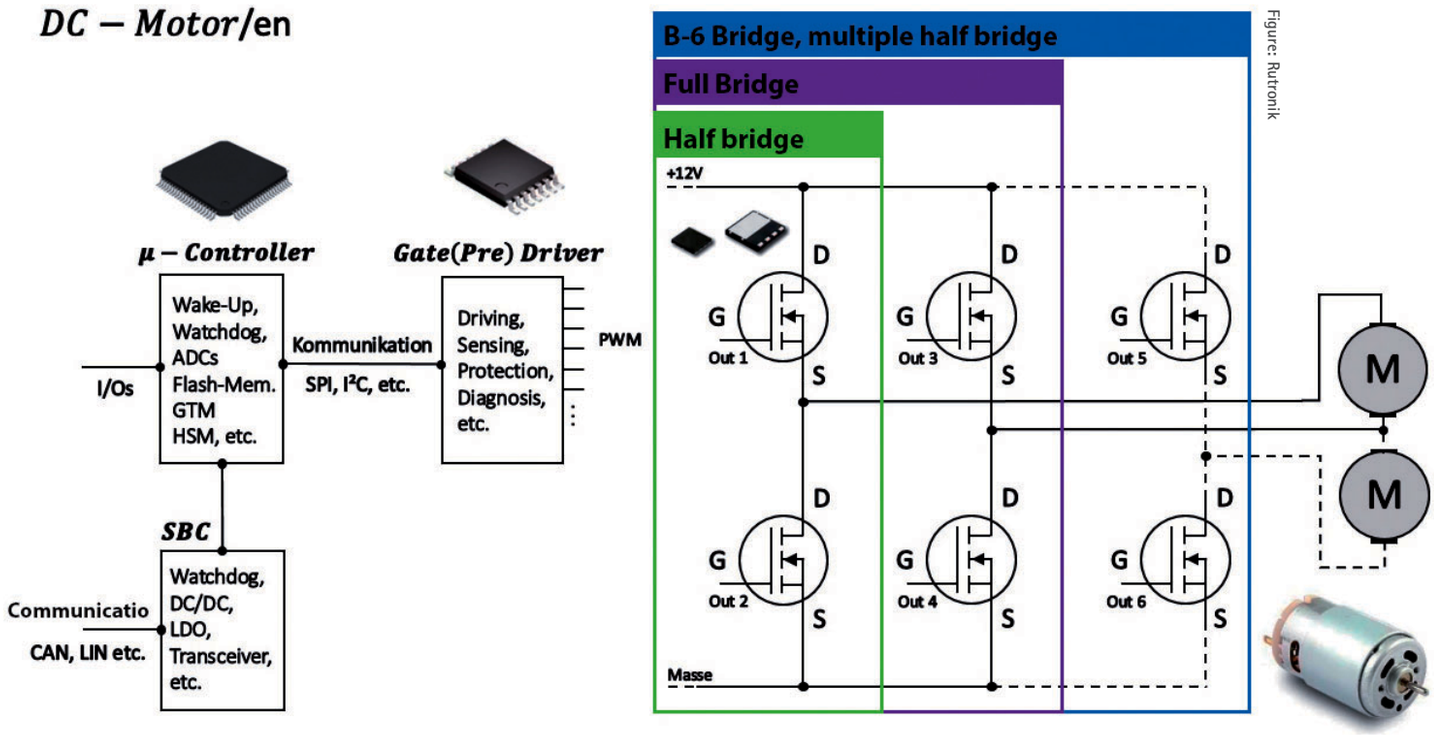
Requirements of small drives

Depending on the application, small electrical drives need to fulfill a variety of requirements. The most important ones are:

- High efficiency
- Low size and weight
- Low noise emissions and silent running
- Resistance to stresses (water, dust, vibration, etc.)
- Different operating modes (continuous operation, periodical operation, and brief operation)
- High reliability, especially with safety-critical drives
- Low costs
- Ease of implementation

Semiconductor suppliers are addressing these requirements with ICs specially enhanced for these purposes. For example, Toshiba's TB9083FTG is designed specifically for functional safety applications as a fail-safe predriver. Optimizations in process technology enable smaller packages and the use of less material – for example, the MOSFETs from Diodes (PowerDI3333-8) with a package size of around 3mm × 3mm at 40 V. Reduced bias currents in drivers and a lower switch-on resistance (R_{DSon}) in the MOSFETs increase efficiency, which reduces power loss and heat output. New packaging technologies with top-side cooling and increased heat dissipation contribute to simpler heat management, which increases the resilience of the IC. To minimize noise emissions and EMI problems, all suppliers implement functions such as PWN and slew rate control depending on the drivers.

More and more system-related functions are integrated into the semiconductor modules to facilitate implementation in the circuit. This includes current measurement and integrated current amplifiers (CSA) as well as protection and diagnostic functions such as data import via SPI for easier status detection and end-



Simplified construction of a small drive with a DC motor

of-life estimation – for example, the L9907 from STMicroelectronics. Functions such as auto-restart and latch-off also allow for testing and restart after an error. Suppliers also provide simulation tools such as Infineon's Toolbox to help developers with implementation.

Different integration levels for different requirements

Depending on the requirements, chips with different integration levels are available to choose from (see table).

In a discrete design, each circuit component is positioned on the PCB. This is often the cheapest option, but it needs plenty of space and results in higher ambient temperatures. To keep space requirements as low as possible, Diodes offers a broad range of dual MOSFETs (N-type) and complementary MOSFETs (N and P-type) in a single package. When it comes to discrete drivers, superb products are available in the form of STMicroelectronics' L9907 and Infineon's TLE9180; these can be used with a variety of electrical system voltages and so are also suitable for small control applications in the truck segment.

For medium integration applications, some components have been combined into modules. These may consist of MOSFETs and the associated drivers, such as Rohm's BD63035EFV-M or Bosch AE's CJ260. Infineon on the other hand combines SBCs (system basis chips) with the drivers in its TLE956x modules. Medium integration offers a good compromise between space and cost restrictions. It requires the least development effort and is currently the best way to implement circuit protection. But if construction space is very limited and PCB cooling can also be achieved with difficulty, it is recommended to take another step toward integration.

High integration combines the microcontroller with the MOSFET driver and the functions of an SBC in a single package. But this usually also makes it very inflexible, as the only way left to make any adjustments is by triggering the MOSFETs. This highly integrated component comes from Infineon and is known as the E-Power IC (TLE98xy). Infineon compensates for the lack of flexibility with a variety of IC models for applications with half, full, or B6 bridge requirements.

TDK-Micronas' HVC4223 embedded motor controller is representative of the highest level of integration. It combines all four components – microcontroller, SBC, gate driver, and MOSFETs – in a single IC, but this also means that it needs to fit the requirements of the application exactly.

The benefit of the medium- and high-integration modules is the integrated diagnostic features. These usually include:

- OC/UC – over-/undercurrent protection
- OT – overtemperature protection
- OL – open-load protection
- SC/SCG – short circuit/short circuit to ground protection
- LD – load dump protection
- Cross-conduction protection
- Reverse polarity protection (usually via external MOSFET)

Discrete MOSFET drivers with protection and diagnostic functions – for example, overcurrent and overtemperature protection – are now also offered, although additional discrete components such as PTC thermistors (PTC: positive temperature coefficient) are often necessary here.

The protection and diagnostic features are currently becoming an essential aspect for electronics developers and OEMs because they allow for easy circuit monitoring. As such, they also represent a step toward fully autonomous self-monitoring vehicles. ■

Hall sensors in automotive applications

Suitable for a variety of parameters

On the road to autonomous driving, cars are being equipped with an increasing number of sensors. Magnetic field sensors based on the Hall effect offer several advantages over other measuring principles and technologies. Current models also meet the more stringent requirements of ISO 26262:2018.

By Edgar Schaefer,
Automotive FAE at Rutronik

Figure: TDK-Micronas

Hall sensors detect the voltage difference that results when a magnetic field is applied to a semiconductor perpendicular to the direction of flow of the electric current. Since this Hall voltage is directly proportional to the strength of the magnetic field, the sensors, together with a permanent magnet, can indirectly measure numerous variables, e.g. rotation, speed, distance, pressure, angle, and fill level. Since the sensor measures the strength of a magnetic field around a conductor with a steady flow of current, it can also measure current without contact. Similarly, it also detects the other parameters without contact, meaning that it operates without any wear and tear and therefore reliably delivers precise measurements, even in long-term operation.

Simple Hall sensors are often used as switches, e.g. in seat belt buckles, windshield wipers, or engine switching systems. In this context, a threshold value for the magnetic field strength is saved in the sensor. If the detected value reaches this threshold, the switching state of the sensor changes. For example, Melexis' MLX92241, with its built-in blocking capacitors, makes a local board-less design possible with operation directly on a cable harness, e.g. for detecting whether the seat belt is fastened. Its EEPROM memory can store customer-specific threshold values for the switching points, output polarity, Ioff current, and temperature compensation coefficient for the magnetic material. The programmable negative temperature coefficient can be used to compensate for the behavior of permanent magnets that become weaker at high temperatures. The Hall sensor elements are equipped with safety mechanisms to protect against electrostatic discharge, reverse polarity, and thermal overload. They meet the requirements of ASIL A.

Linear hall sensors also measure distances and rotation

Hall sensors with linear output signals are necessary to measure distances or rotational movements. They not only recognize the states "on" and "off," but also output an analog signal proportional to the magnetic field strength. The A/D converter, which is either integrated into the MCU or the Hall sensor, converts the analog signal into a digital signal. To control other system components, the MCU then outputs a proportional pulse-width modulated (PWM) signal or a data stream compatible with the SENT automotive sensor bus system. Some of the latest-generation Hall sensors have the PWM interface and the SENT interface built right into the sensor itself.

When using Hall sensors that merely detect the magnetic field perpendicular to the chip plane, large and cost-intensive additional assemblies are often required. More advanced solutions integrate an increasing number of sensors as well as signal processing and calculation functions, often eliminating the need for additional components and allowing additional parameters to be measured.

For example, vertical Hall sensors detect not only the magnetic field perpendicular to the direction of the current, but also that parallel to the direction of the current or to the chip plane. In addition to the amplitude of the magnetic field, 2D sensors also detect its direction. This can be used to determine an engine's direction of rotation, for example. For example, the Hall-based Xensiv TLE4988C from Infineon makes it possible to quickly measure the position of the camshaft. One major benefit for module manufacturers is the reduced dependence on rare-earth back-biased magnets; the sensor is optimized for Fe, SmCo, and NdFe, for example. Automatic in-vehicle calibration takes the tolerances of ferromagnetic wheels and magnetic encoders as well as the mounting tolerances of the sensor takes into account, thereby ensuring extremely accurate sensing in real application environments. The TLE4988C comes inside a PG-SSO-3-52 camshaft sensor package with Sn plating as well as a 3-wire voltage I/F and increased supply/output capacitance of 220/1.8nF for higher EMC robustness.

The Xensiv TLE5501 analog angle sensor from Infineon is based on TMR (tunneling magnetoresistive) technology. It features high detection sensitivity with a high output voltage, eliminating the need for an internal amplifier and allowing the sensor to be connected directly to the microcontroller. In addition, TMR technology features minimal temperature drift, which reduces the need for external calibration and compensation. The TLE5501 uses 360° angle measurement to detect the orientation of a magnetic field by measuring the sine and cosine angle components using TMR elements. It outputs the raw signals as a differential output signal. Due to the high bridge output voltage, additional signal amplification is not necessary. The TLE5501 is available in AEC-Q100 and automotive ASIL versions and is suitable for angular position sensing, steering angle sensing, safety applications, and BLDC motor commutation.

The third dimension

3D Hall sensor technology combines lateral and vertical Hall sensors and as a result, can detect the strength of the magnetic field in all three dimensions. This type of sensor makes it possible to detect the absolute rotary or linear position of each moving magnet. The MLX92256, for example, is equipped with lateral sensing. Designed specifically for use in window lift systems, it integrates a voltage regulator, two Hall sensors – one with IMC (integrated magnetic concentrator) and both with an advanced offset cancellation system – and two open-drain output drivers all in a single package. It is available in two versions. The MLX92256LSE-AAA-000 toggles the pulse signal when there is a change in the lateral or vertical component, while the direction pin only changes in the event of a change in direction. The MLX92256LSE-ABA-000 is equipped with two speed outputs, one for the perpendicular field and one for the lateral field.

The MLX90371/MLX90372 Triaxis position sensors from Melexis are now available in the third generation. They combine a magnetic Triaxis Hall front-end, an analog/digital signal conditioner, a DSP (digital signal processor) for signal processing, and an output stage driver. They are immune to stray fields up to 4 kA/m (or 5 mT) as they occur as a result of the increasing electrification of vehicles, especially electric and hybrid vehicles. Since they can also work with a weak magnetic field, smaller and cheaper magnets are sufficient. This not only results in cost benefits, but also space savings. The MLX90371 is an ASIL-B SEooC (safety element out of context) to ISO 26262 and offers an analog or PWM output. The MLX90372 is an ASIL-C SEooC to ISO 26262 and has a SENT or PWM output. Both meet the EMC requirements of automotive OEMs and are specified for operating temperatures up to 160°C. For applications with particularly stringent safety requirements such as accelerator pedal position sensing, the MLX90372 is also available in a "dual die" (fully redundant) TSSOP-16 package for redundant sensing.

TDK-Micronas offers a programmable 3D sensor family for position sensing. It consists of three members: the HAL 3900 with an SPI interface, the HAL 3930 with a PWM/SENT interface and switch output (configurable as a high/low-side switch), and the HAL 3980 with a PSI5 interface. The sensors can suppress external magnetic stray fields by using an array of Hall plates. Only a simple two-pole magnet is required to measure a rotation angle, ideally placed over the sensitive area in an end-of-shaft configuration. 'The sensors can also be used for off-axis measurements. They can measure an angular range of 360°, linear movements, and a 3D position, making them ideal for steering angle position sensing. Depending on the device, it is possible to transmit temperature-compensated values of BX, BY, BZ, or up to two calculated angles. The HAL-39xy sensors operate in an ambient temperature range from –40°C to +160°C; they are ASIL B-ready and designed as SEooC according to ISO 26262 for automotive applications.

Rugged and reliable

The examples show that not only have tremendous advancements been made in sensor technology to meet the increasing demands in cars, but that their design has also evolved. Many of the latest models also meet the more stringent guidelines of ISO 26262:2018, some as ASIL-C SEooCs. Redundancy and safety functions contribute to this as well as measures to improve EMC. Corresponding packages ensure the sensors are resistant to moisture, dust, and dirt. For use in high-temperature environments, Hall sensors are specified for operating temperatures of up to 170°C. As a result of these features, they play a key role on the road to autonomous driving. ■

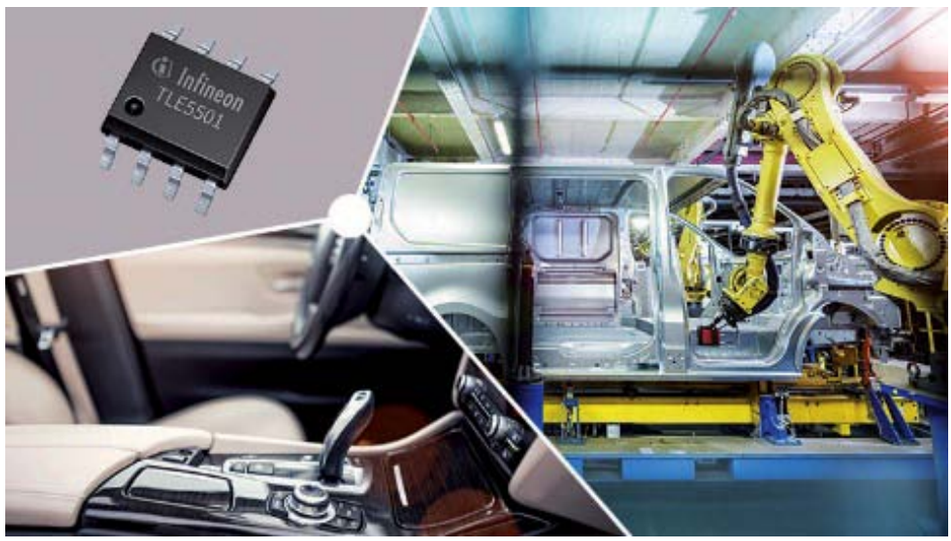


Figure: Infineon Technologies

Automotive motor system IC

A new source of power for automotive aids

Everywhere you look, cars have little devices here and there to make the driving experience more comfortable – window regulators, sunroof controllers, seat adjusters, trunk door mechanisms, automated front-lighting systems, and various flaps, fins, pumps, and fans. The broadness of this field is also apparent in the diversity of electrical auxiliary motors. This means that drive solutions need to be scalable and flexible.

By Ralf Hickl,
Product Sales Manager ABU
at Rutronik

Everything is powered by auxiliary motors, sometimes independently from the primary motor if efficiency demands it. Requirements range from drawing a few watts to pushing the car battery to its limit. Motors also need to be small and cheap. Figure 1 shows a number of components of motor control systems. Micronas' HVC4223F is the market leader in terms of the level of integration. Discrete constructions with separate ICs such as voltage controllers, microcontrollers, bus transceivers, and more are at the other, bottom end of the integration scale.

In the mid-range segment, Infineon's new TLE956x motor system ICs combine the functions of the mid-range system basis chips of the TLE94xx (Lite SBC) and TLE926x (mid-range + SBC) series with two additional functions: an operational amplifier for measuring current using shunt resistors and gate drivers for controlling N-channel MOSFETs. Then there are outputs for anti-reverse polarity MOSFETs and up to four high-side switches for any desired purpose.

The motor system ICs are available in two versions: one to control DC motors with up to four half-bridge drivers and one for operation with BLDC motors with drivers for a six-pulse bridge.

Microcontrollers and MOSFETs must be connected externally to the TLE956x motor system ICs; see the block diagram (Figure 2). Depending on the version of the TLE956x family, the CAN FD transceiver offers partial networking via wake-up pattern (WUP) or wake-up frame (WUF).

Creating a control device with Autosar

Compared to the derivatives of the TLE985x/6x/7x embedded power IC family, the motor system ICs offer flexibility in terms of CPU architecture and greater scalability in terms of processor performance, memory expansion, and bus integration (CAN FD). This allows users to keep using their preferred microcontroller, saving them time and money that they would otherwise need to invest in learning another architecture and in new development tools. Thanks to the extra memory of an external microcontroller and the TLE956x, it is possible to create a control device using a memory-hungry operating system such as Autosar.

Do not disturb!

However, placing the output transistors in the output stage has two undesirable effects. Each switching operation causes switching losses, as the transition slopes are finitely steep.

Figure: Rutronik

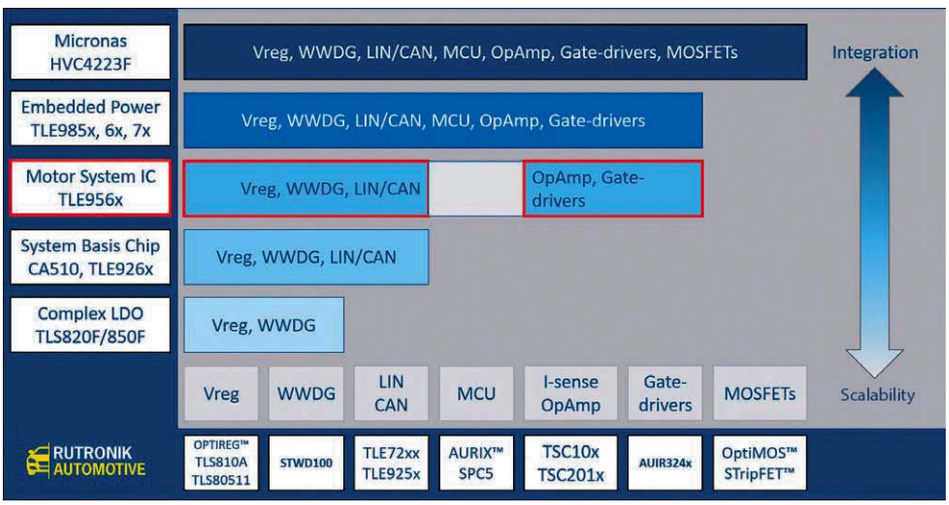


Figure 1: Integration vs. scalability, with example components

These losses increase the system temperature. Also, the steeper the transition slopes, the more electrical interference signals there are. The cable-related proportion of interference can be mitigated using an EMI filter in the power cable, but the filter components do cause extra costs.

The aim is therefore to adjust the transition slope in such a way that the switching operation just about passes the EMC test. A resistor/diode network in the gate cable also often limits the control current. In conjunction with the gate capacitance of the MOSFET, this creates an RC circuit with a time constant that limits the voltage slope. However, this does generate additional cost for the resistors and the diode. When switching to another MOSFET with a different gate capacitance, the resistor network also needs to be adapted.

Adaptive MOSFET gate control

The TLE956x solves the problem more elegantly by having a digital control loop update the actual transition slope steepness values based on the defined set point value. The control value is the current from the gate drivers. This concept, referred to as "adaptive gate control", eliminates the need for the resistor/diode network in the gate cables, which also removes this cost factor, eliminating any issues with switching to MOSFETs with other gate capacitance values. The controller adjusts the gate currents automatically to produce the configured slope steepness.

Further reducing switching losses with active freewheeling

When operating DC motors in H-bridges, a high-side MOSFET is often switched on statically, and the clock cycle of the diagonally positioned low-side MOSFET is regulated using pulse width modulation. If this active

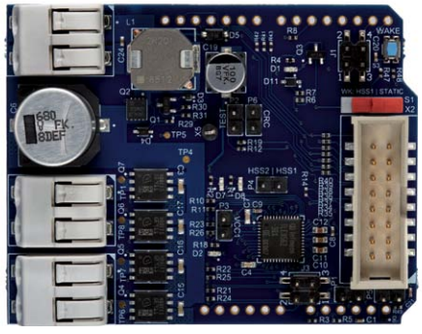


Figure: Infineon Technologies

Figure 3: Evaluation board DC SHIELD_TLE956X for DC motors

Figure 2: Block diagram of a BLDC motor control using TLE9563/4

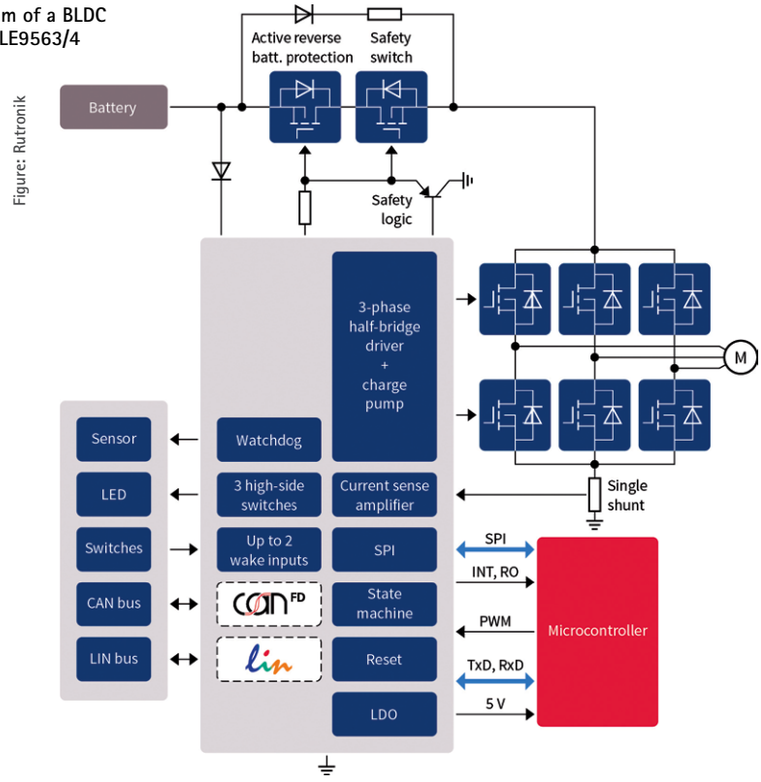


Figure: Rutronik

MOSFET is switched off using a PWM cycle, the motor current commutates through the body diode of the MOSFET in the same branch above.

Active freewheeling involves the half bridge of the active MOSFET following a push-pull circuit design. Triggering the MOSFET causes the freewheeling current to commutate through its channel instead of its body diode. If RDS,on is low, this results in reduced loss compared to body diode commutation.

Brakes even in sleep mode

Electric motors, especially those with permanent magnets, can also serve as generators – for example, if someone applies manual force to open or close a motorized trunk door. Reverse polarity protection (diode or untriggered MOSFET) in the control device ensures that the generated energy cannot be fed back into the vehicle battery. Instead, the voltage is increased in the intermediate circuit using the bypass capacitor connected in parallel to the MOSFETs. In a worst-case scenario, the generated energy can cause a fault due to overvoltage.

Type TLE956x motor system ICs solve this by means of a braking effect achieved using short-circuiting, where all low-side MOSFETs are switched on at the same time. This briefly short-circuits the armature/rotor to enable:

- the generated energy to dissipate as heat by means of the effective resistance of the shorting circuit
- the application of a mechanical counterforce (braking effect)

The braking function also works in sleep mode with the TLE956x, which keeps power consumption low. There are two variations of this: a braking force that is varied depending on the intermediate circuit voltage and continuous braking regardless of the intermediate circuit voltage.

Start now

Now is the right time to start developing using the TLE956x family of components. It is at the leading edge of technology, is commercially competitive, and is at the start of its life cycle. This is a perfect storm promising an end product that offers superb value for money and long availability – for example, for a seat adjuster, sunroof controller, belt tensioner, hand brake, window regulators, or motorized trunk, as well as BLDC applications such as pumps, fans, and sunroofs.

Arduino-compatible evaluation boards for the TLE956x provide an entry-level solution for development (Figure 3 & 4). Suitable controller boards with automotive microcontrollers from Infineon include the Aurix TC275 Shield Buddy and the Aurix TC375 Shield Buddy. ■

EV charging

Electromechanical engineering for charging stations

The development of high-performance charging infrastructure for e-mobility has created a whole new growth field for the use of high-grade electromechanical components, which include not only relays but also fuses, switches, and thermal management components.

By Burak Duman, Technical Support Mechanics, and Martin Unsöld, Senior Manager Product Marketing Mechanics, both at Rutronik

The automotive industry faces the challenge of focusing on the environment – reducing emissions – as one of the most important topics of our society. The only way this is likely to be achievable is with electric motors. According to a study by McKinsey, it is estimated that as many as approximately 120 million electric vehicles will be registered for road use in China, the EU, and the US by 2030. Demand for charging energy will rise from around 20 billion kilowatt hours in 2020 to 280 billion kilowatt hours in 2030, for which around 40 million chargers will be needed, 15 million of them in Europe alone.

Leading automobile manufacturers have already announced an investment plan for the development of 400 charging stations in Europe. The current economic stimulus package of the German Federal Government also has a clear focus on electromobility. Around an additional €2.5 billion is expected to be invested in developing charging station infrastructure.

For the imminent change and the development of high-performance charging infrastructure, manufacturers such as BMW, VW, Mercedes, and Audi are already adapting their production facilities and are preparing their workforces with training and certifications.

Relay types used in charging stations

A variety of electromechanical components are required both for electric cars and for charging stations. IEC 61851-1 defines the various types of charging stations. They are categorized on the basis of power supply criteria and the electronic communication between the charging station and the electric car. The choices of electromechanical components are dependent on the type of charging station in question.

Figure: Hongfa

Figure 1: The HFE18-200 relay from Hongfa is perfect for auxiliary applications.

Mode 1 and 2 charging stations that operate using alternating current (AC) have barely any electronics in them. In these cases, the vehicle's on-board charger (OBC) handles the charging cycle management.

Mode 3 charging stations require a relay to switch the AC current. As with other charging stations that use AC, the OBC limits charging performance here as well. The requirements placed upon the relay include 230 V/400 V (according to IEC 60664-1) and overvoltage category 4. This means that a distance of at least 3 mm must be maintained between the contacts. Some suppliers offer appropriate products – Hongfa for example offers 35 A/3.6 mm (HF170F), 65 A/3 mm (HF176F) and 90 A/3 mm (HF167F) relays through Rutronik, while Omron supplies a 36 A/3.2 mm model (G6QE).

The trend is shifting toward DC fast-charge stations (Mode 4) as a solution to the problem of long charging times. The bulk of the electronics in these cases is located in the charg-

Figure: Littelfuse

Figure 2: The fact-acting PSR-series fuses from Littelfuse provide reliable protection for power semiconductors.

ing station, not in the vehicle. The vehicle's OBC is therefore circumvented. The charging process is handled directly by the charging station, which supplies the DC voltage. Mode 4 charging stations use a variety of relays:

The main relay covers a current range of 80 to 600 A and is usually used to disconnect the battery. Models for this purpose are offered by Hongfa (HFE18V-300, HFE82V-250V) and Omron (G9TB).

The fast-charge relay controls the fast-charge process, with rated currents being between 32 and 600 A. Suitable relays are available through Rutronik from Hongfa (HFE18V-600).

The HV pre-charge relay is used in the pre-charge circuit, for which a product such as Hongfa's HFE80V-20B can be used.

Relays for auxiliary applications (Figure 1) are mainly used for air conditioning systems, heating systems, DC–AC converters, and other applications. They typically have a power rating of between 20 and 40 A, and Hongfa once again has a suitable product in its portfolio for this in the form of the HFE18-200.

Relay requirements

To qualify for automotive use, these relays must have compact dimensions and meet special technical specifications. Electric motors require very high power levels, which involves certain risks, so a reliable switch is essential here, which means that the relay contacts must not be at risk of oxidation. Suppliers have developed relays filled with gas (usually hydrogen) to prevent this, thus maintaining a lower contact resistance, avoiding power loss, and preventing relay failure. The relays from premium suppliers Omron and Hongfa meet these requirements and can be used in almost any application – whether in electric or hybrid vehicles, in 48V battery systems or charging stations.

Fuses

Because the operation of charging stations involves high voltages and currents, it is necessary to protect both people and the components. Surface-mounted, cartridge, and high-voltage fuses are just a few of the components required here.

Depending on the type of charging station, other requirements may apply. Mode 1 to 3 charging stations are usually used in private households. Mode 4 fast-charge stations on the other hand are installed in public spaces such as supermarkets and gas stations and require a high-current connection. Because they transform the AC voltage at the input to a DC voltage at the output, both circuits require fuses.

The fast-charge stations consist of extremely sensitive power semiconductors that can be adversely affected by interference such as voltage pulses and overcurrents. Special high-speed fuses such as the PSR series from Littelfuse (Figure 2) for the DC output have been developed precisely for this. They are extremely effective at limiting current and offer superb cycling capability. The JLLS-series fuses from Littelfuse are ideal for AC input circuits. They also heavily limit current and prevent short-circuit currents faster than other mechanical safety mechanisms. This allows them to protect devices with components that are sensitive to overvoltages such as rectifiers. Both of these types are among the most compact fuses in the over-30 amps segment. Besides Littelfuse, Eaton also offers comparable models.

Efficient thermal management

The high power levels generate plenty of heat within the electronic components, and temperatures on the outside of charging stations can also get very high. This can have a severely negative impact on the function and life of the components, which is why efficient thermal management is essential. For this purpose, Rutronik offers a variety of solutions, including thermally conductive foils, heatsinks and fans from leading suppliers such as 3M, Delta Electronics, Fischer Elektronik, Assmann WSW, Jamicon, and Adda. The product and application specialists provide expert support in selecting suitable components.

Switches and metal keyboards

Suitable switches and metal keyboards for use in automotive applications enable the ease of use of charging stations. For example, a metal keyboard can be used to enter a PIN for authentication, and microswitches can be used to start the charging process on the charger handle.

Because charging stations need to be able to withstand harsh environmental conditions such those as gas stations or supermarkets, they require a very robust metal keyboard that also works in the rain and in a variety of environmental temperatures. IP-Line from Knitter Switch is shipped with up to IP69K protection and IK08 impact resistance. The keyboards are also available with customized designs and offer a great deal of design scope.

To protect them against vandalism, they need vandal-proof push buttons with scratch-resistant actuators and a housing made of robust stainless steel. C&K metallic push buttons for example can resist extreme outdoor conditions and vandalism attempts with IP67 protection and IK10 impact resistance. The switches are also available with lighting in various colors and with labeling on the actuator.

This brief summary shows how electromechanical components in charging stations help to achieve e-mobility through everything from the control unit to the electric car connector to the charger plug – and in doing so, help to reduce CO_2 emissions. ■

Figure 3: Robust metal keyboards can be customized.
Figure 3: Robust metal keyboards can be customized.

E-mobility

The challenges for charging infrastructure

Progress in e-mobility and the development of the charging infrastructure are dependent on a variety of factors. To achieve a sustainable concept, it is important to understand the systems and the relationships between them. These include charging concepts, ranges, financing, resource acquisition, and battery recycling.

By Albert Culetto,
Technical Support at Rutronik

Whether for a wholly battery-powered vehicle or a hybrid solution, the charging concept of an electric car follows a certain pattern. The on-board charger (OBC) of the vehicle handles the charging management. Charging per se is a simple plug-and-play affair, inserting the cable into the socket and observing the charging times, battery capacity, and OBC charging power specified by the manufacturer. To ensure optimum charging and avoid errors, the battery and charger communicate with one another. This is how the car defines how much it needs to charge, while the charging station (Mode 2 or 3) confirms its capacity. This communication provides great flexibility in selecting a vehicle type – all that is needed is for the plug type to be compatible.

Example of charging time

A BMW i3 has a net capacity of 37.9 kWh and an OBC of 11 kW max, which means that a battery should be recharged within 3.5 hours. This is consistent with the manufacturer's specifications that 80% capacity will be achieved with a maximum wall-box charge (Mode 3) after 3.12 hours. If charging is only performed using a normal Schuko wall socket (Mode 2), the manufacturer's specifications claim a charging time of around 15 hours (37.9 kWh / 15 hours = 2.5 kW), which in turn is consistent with the maximum throughput expected of such a socket. In this case, a pure DC charge takes around 42 minutes (50 kW).

Charging connectors and modes

Despite the desire for charging connector standardization, there are various systems that have become established, depending on the country of origin of the car. Because most electric cars around world had been produced in Japan until 2015, the common CHAdeMO standard has proven robust there. Europeans on the other hand insisted on their own standard (Type 2), but have not managed to establish it – the US and China have faced the same problem. This means that car brands around the world currently share four different plug formats.

A charging station (wallbox) can offer different charging modes. Compliance with regional electricity standards (VDE) helps to ensure general safety. Ultimately, there are four different charging modes:

Mode 1: uncontrolled charging without communication, no circuit breaker mechanism (danger), on-board charger (OBC); max. charging current: 16 A/11 kW, 1-phase/3-phase

Mode 2: uncontrolled charging without communication, IC-CPD protection/pilot function built into cable (in-cable control and protection device), on-board charger (OBC); max. charging current: 32 A/22 kW, 1-phase/3-phase

Mode 3: controlled charging, AC charging at type-verified charging stations, protection/pilot function built into charging station, on-board charger (OBC); max. charging current: 63 A/44 kW, 1-phase/3-phase

Mode 4: controlled charging, DC charging only at type-verified charging stations (electric vehicle supply equipment, EVSE), monitoring and safety mechanism/pilot function integrated into EVSE, on-board charger (OBC) is circumvented.

Range

Range is a very controversial subject. It currently varies between 100 and just under 1,000 km of driving distance and also depends on whether the vehicle is purely battery powered or if it is a hybrid solution. There's also the greatly varying needs of the customer to consider; the average route to work in Germany is around 16.9 km (in certain regions as much as 30 km). Any car type can manage this with a daily recharge. But it becomes more complicated when covering longer distances such as during vacation trips, which is where fast-charging stations come into play. A 50 kW charging station can be used to charge a BMW i3 in around 42 minutes, for example.

There are now charging stations of up to 200 kW that reduce the charging time to just under ten minutes (to 80% charge). If the charging connector is also cooled (500–850 A), charging becomes almost as fast as filling up at a normal gas station.

Government subsidies

Financing will substantially dictate how electromobility develops. The economic stimulus package introduced by the German Federal Government in relation to the coronavirus pandemic makes the purchase of an electric car a more compelling proposition. It has increased the net upper limit of the price of subsidized vehicles to € 40,000, while the government subsidy when buying a fully electric vehicle is doubled to € 6,000. Added to this are the VAT savings of 3% on invoices issued before the end of 2020 and the manufacturers' environment bonus (approx. € 3,000). Funds are also earmarked by the federal government and Germany's federal states in the stimulus package for investment in infrastructure.

Fear of mains overload has kept many from having their own charging station or wallbox installed so far – but this worry is unwarranted. A standard family home is supplied with a line that is fused for at least 63 A. By comparison, the largest power consumer in the home is an electric stove, which has a 16 A fuse. Even with larger household consumers such as electric boilers (approx. 16 A or 25 A), there is still enough capacity for a wallbox.

Energy providers are also working on developing infrastructure. They aim to make the network of transformer substations denser and more efficient, and to incorporate charging lots into planning at an early stage. Such concepts also incorporate large-scale garages, and future street lighting concepts feature public charging stations integrated into street lamps.

Lithium – a key resource

Lithium mining, which is currently essential for battery cell production for electric cars, leaves a damaging environmental footprint. The largest reserves in the world are located in Bolivia, Argentina, and Chile, with resources of around nine million tons each. In Europe, the largest reserves are located in Portugal (100,000 tons) and Austria (50,000 tons). According to Statista, around 37.4% of the demand for lithium today is attributable to batteries.

Mining causes the brine in which the lithium is found – a highly salty ground water – to be pumped to the surface, where it is dried in various evaporation steps. The water is not fed back, which results in a drop in groundwater levels, adversely affecting human and natural life in the regions concerned.

Even if data reports vary, these figures provide a glimpse into the scope of the issue –

Figure: Scharfsinn/Shutterstock

in Salar de Atacama, Chile, 21 million liters of water are reported to be required each day for the extraction of lithium. The amount of material mined also varies, with the latest data suggesting 23 tons of pure lithium per day, which translates to consumption of 900,000 liters of water per ton of lithium. If the production of lithium batteries entails such massive consumption, we should handle this raw material with care.

Battery recycling

This also makes recycling batteries as secondary raw material an important subject. Car batteries use not only 10 to 20 kg of lithium but also lots of other raw materials, including manganese, cobalt, nickel, and graphite, as well as liquid electrolyte (in a mid-class vehicle battery).

There are currently two recycling methods available to choose from. The first uses the different melting temperatures of the materials and involves smelting. The second involves crushing the individual components and then separating them chemically. Before either occurs, the connecting elements, safety electronics, insulation materials, and packaging plastics must be removed by physical means. The advantage of crushing is that it can be done locally, and the battery, which is considered to be a hazardous material, does not need to be transported (or at least not far). But recycling is only worth the expense when you're processing larger volumes.

The life of a battery also plays a role in how raw materials are consumed. For electric cars, a battery is already considered dead when it reaches as much as 80% of its maximum capacity. But it isn't fair to write off such a battery so early – it can have a second or third life. Once the battery pack has been checked and the individual cells have been rearranged, its second life as a buffer battery can begin – to be used for temporarily storing solar, wind and hydroelectric energy, output peaks from energy providers, or other surplus energy. There are also opportunities for mobile energy storage facilities for parking garages and much more. This is how the old 80% capacity rule can be redefined as 100% capacity with the same quality properties. Size and weight are secondary here.

Conclusion

The markets and plants for recycling and second-life batteries are not yet fully developed, but it is important to already be thinking about topics such as the mining and use of resour a 50 kW charging station ces and the renaturalization of the earth and to understand the underlying issues. Everyone can decide for themselves what form their mobility will take in the future. ■

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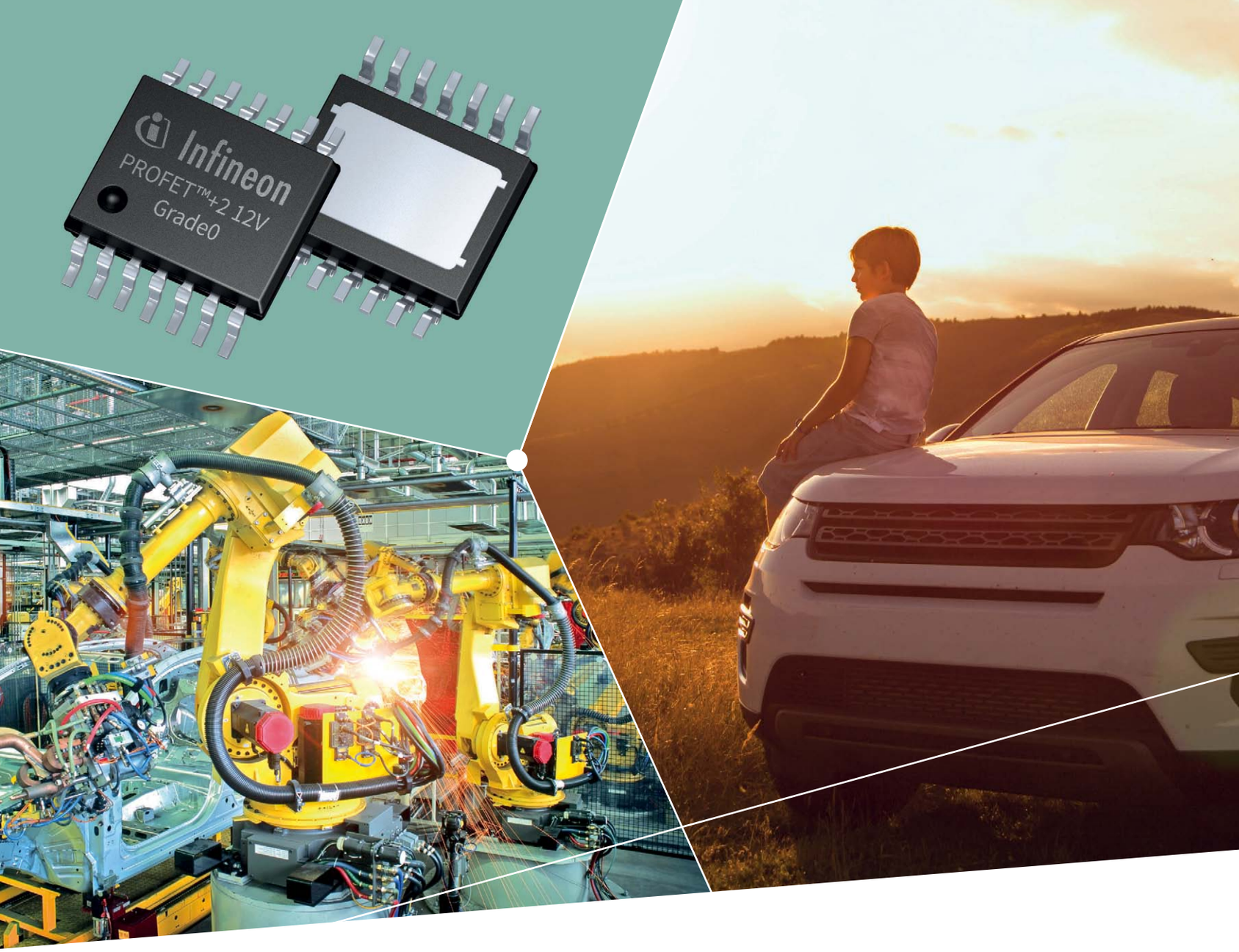

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