Smart Mobility

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RUTRONIKER

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STM32 MP1

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- 3D GPU OpenGL ES 2.0
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Staying on course for success

Following the recent record years which in part saw the market overheating, component distribution in Germany and around Europe is now returning to somewhat calmer waters. According to a survey by the German electronic component distributors' association FBDi, sales in Germany fell by two percent in the second quarter of 2019, while European semiconductor distribution market analyst DMASS reported a one percent decline in the same period.

In both cases, however, trends in the individual electronics sectors were quite inconsistent: sensor sales, for example, grew 22 percent in Germany. Among the losers were electromechanics and power supply, while the large-volume semiconductor and passive component product segments remained at the previous year's level. Across Europe, analog products and sensors achieved growth, for example, whereas optoelectronics and LEDs performed worse.

All in all, this does not yet represent grounds for panic, but it is a scenario in which the choice in favor of a particular distributor is considered more carefully than it would be in times of unchecked growth. As an owner-managed broadline distributor, Rutronik relies particularly on comprehensive technical support in this context: field application engineers, business development managers and sales engineers work together as part of a dedicated consulting function to provide customers with sound comprehensive technical and commercial support, ranging from brainstorming and concept design, through prototyping and mass production, to phase-out at the end of the product lifecycle.

The new issue of *Rutroniker* reflects the company's broad spectrum of technical know-how, covering a wide range of topics. Whether tips on downsizing and replacing MLCCs as a solution to component shortages; security for connected systems; intelligent displays; or a gesture-controlled positioning function for camera systems with facial recognition: the numerous specialist articles, application examples and features presenting useful information from the science and research sphere provide real support to developers and decision makers. They are all aimed at helping Rutronik's customers to focus on their most important task: staying on course for success with innovative and sustainable solutions, even in somewhat more turbulent times.

Yours,

Ingo Kuss,
Editor-in-Chief
of Markt&Technik

IKuss@markt-technik.de

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RUTRONIKER
2019

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• Research and Success Stories

Interview with Thomas Rudel, CEO of Rutronik

"We still have significant potential"

Brexit, the trade war between the US and China, the carmakers in crisis: 2019 was not an easy year for the economy. The situation faced by distributors is no different. In this interview, Rutronik CEO Thomas Rudel talks about overall societal challenges and a tough twelve months for the industry, but nevertheless looks to the future with optimism.

Rutroniker: The ifo Business Climate Index is falling steadily and German companies are viewing the macroeconomic developments with concern. What is your take on the current situation?

Thomas Rudel: Naturally, we share those concerns. The USA and China are imposing punitive tariffs on one another and the situation is continuing to escalate. In addition, China is attempting to exert a powerful influence on Hong Kong and Taiwan, which also gives us cause for concern. This in turn is having a highly unsettling effect on the economy. Added to this are challenges of our own making, which are also contributing to the growing feeling of uncertainty.

What do you mean exactly?

Along with the challenges alluded to above, other factors are leading to added economic uncertainty. These include the climate debate, for example: the 'Fridays For Future' movement has shifted the topic of environmental protection back into the focus of social debate. At the same time, I believe that the CO_2 debate and the way that it is focused solely on passenger cars is disingenuous: what about cruise ships, for example? And how will phasing out coal help us when we simultaneously subsidize coal-fired power plants elsewhere around the world? By confining the problem to "those evil passenger cars," all we are doing is damaging our automotive industry – and putting jobs at risk in the process.

But why shouldn't Germany set a good example when it comes to protecting the climate?

Naturally, Germany should lead the way as an innovative country. But CO_2 is not the only problem, it is merely one of many problems. Pollution of the environment in general must be addressed – collectively by all nations. It is not acceptable, for example, to have privately funded initiatives removing plastic waste from the North Sea and politicians simply patting themselves on the back. This is where I expect politicians to deliver non-bureaucratic solutions – to the refugee crisis as well,

**RUTRONIK CEO
THOMAS RUDEL**

The priority for us is to see a rapid resolution of the trade disputes. It is the US that stands to lose out in the long term.

which also presents major challenges for Germany and all of Europe.

You mention the challenges presented by the refugee crisis. To what extent does this impact on the economy and how can one counter this challenge?
Over the next 20 to 30 years, the global population is likely to grow to more than ten billion people. However, the available space on our planet is limited – and if parts of the planet offer no prospects due to climate change, civil war or abject poverty, people will simply migrate to wealthier countries. The result will be that our social systems will no longer be able to cope. Indeed, they are already pushed to their limits. Therefore, we must combat the causes of migration. A total of 3.4 billion people in the world live below the poverty line and more than 700 million people live in extreme poverty, surviving on less than 1.90 dollars per day. That is shocking. We must find solutions on the ground that will enable these people to remain in their home countries – which would be preferable to setting off on dangerous migration routes. There is an interesting study on this topic that puts the investment cost of creating the infrastructure for a city of five million inhabitants, which would allow them to produce something there and live under conditions similar to those of industrial nations, at a total of 50 billion euros. This is almost exactly what the refugee crisis has cost Germany to date. This approach would establish sensible and sustainable conditions that would enable people to remain in their own countries.

Returning to the actual economic impact of the US–Chinese trade war on the business climate: what does the conflict mean for the electronics sector?
Automotive sales in China have declined dramatically over the last few months, and are down by around 15 percent. If you consider that electronic components account for some 40 percent of the purchase price of a new car, this offers a clear answer to your question regarding the significance for the electronics industry. Of course, the demand for electronics remains strong, but I believe that a medium to long-term consequence of the trade war will be that China will rely increasingly on its own suppliers. For the US, where China has been the most important sales market up to now, the outlook is not good. At the same time, it opens up opportunities for us Europeans to position ourselves in Asia and to acquire new trading partners in China. This is one reason why Rutronik has positioned itself globally: both Asia as well as America are

large and important sales markets. The priority for us is to see a rapid resolution of the trade disputes. It is the US that stands to lose out in the long term.

During the past year, the allocation situation for passive components was one of the revenue drivers; in the meantime, the situation has eased noticeably. Against the backdrop of a slowing economy, what does this mean for the revenue targets of the coming years?
At present, we anticipate the next allocation in the second half of 2020, especially with regard to ceramic capacitors. The major suppliers such as Samsung and Yageo are predicting a fivefold increase in worldwide demand over the next five years due to the triumphant progress of the IoT, the 5G standard and the automotive market. The same applies to batteries because products with higher voltages are required – sales of batteries will increase from 79 billion dollars in 2018 to 190 billion dollars in 2025.

You mention the automotive market. Following the great success of the ABU (Automotive Business Unit) congress in 2018, Rutronik has hosted two further events in Pforzheim and Milan this year. How important do you think these congresses are for Rutronik?
Rutronik is the only distributor that has established a dedicated department – under the leadership of Uwe Rahn – and pursues an integrated approach in order to offer automotive customers a complete solution comprising active, passive, electromechanical and wireless components. The 2018 and 2019 congresses in Pforzheim attracted more than 200 registrations, including the who is who of the industry, and were a great success. This points to enormous demand on the part of our customers. This year also saw us hold a highly successful ABU congress in Milan. The Automotive Business Unit is an immensely important department for us and one that is actively breaking into new markets!

At the same time, German carmakers are in crisis. They are forced to invest billions in electric drive systems, battery technology and networking while reliable sales markets like China are currently collapsing. In addition to this, competitors from the Far East and the technology giants from the USA are catching up. How can the German automotive industry change course and what assistance can Rutronik provide?

This is why we are collaborating with Paravan, with which Schaeffler has a joint venture. The steer-by-wire technology originally developed for people with disabilities is the only system to have secured international approval for use on public roads. Our cooperation with Paravan makes us pioneers in this field; the system is currently being tested in motorsports – and we are right in the middle of this development. It is also important that we are because the trade dispute already mentioned has a direct impact on the automotive sector. This is one of the reasons why Germany is investing heavily in electric vehicles.

However, given the insufficient charging infrastructure and the lack of clarity surrounding the disposal of used batteries, I do not consider this to be a farsighted decision. While it is certainly a smart idea for the environment in major cities, I don't see it as being a feasible solution in rural areas. Hybrid vehicles, which already consume no more than three to four liters of diesel, are a better solution here. We need to realize that the Chinese automotive industry has now caught up with our 15-year lead. This is why it is immensely important for our automotive industry – and therefore for us at Rutronik – to compete in the market with logical, well thought out, sustainable concepts – that is, with German engineering skill.

Finally, let us take a traditional look into the crystal ball: how will the distribution industry develop next year?
The distribution sector has suffered major losses in the second half of the year. I expect the next twelve months to be very tough and we must manage our resources accordingly. Listed competitors have already made thousands of employees redundant. We do not want to get to that stage. Comparing the current situation to the economic crisis of 2009, I believe that 2019/2020 is much more critical – due to the massive problems faced by the automotive industry, which in turn are largely attributable to the trade war and Brexit. However, there are also grounds for optimism: Rutronik now operates in all markets and can grow in Southeast Asia and in America. We still have significant potential given that we started there from nothing. What's more, our integrated product portfolio gives us a competitive edge because customers need products from all areas. If we are prepared to confront the situation using all available means, we will be successful. ∎

Overvoltage and overcurrent protection components

A well-equipped protection force

Overvoltages and current spikes must be avoided in many areas of electronics; numerous laws and regulations in the various destination countries specify product safety in explicit terms. The corresponding overvoltage protection components can also lower the failure rate as well as maintenance and repair costs.

By Gerd Fischer, Line Manager at Rutronik, and Oliver Steidl, Business Development Manager at Yageo Europe

Static discharges and overvoltages (transients) can destroy circuits. If a surge voltage that exceeds the permissible operating voltage of an IC is applied to a circuit, it can permanently damage the IC.

To clamp these damaging transients, that is, to deflect them to ground potential, thereby protecting the IC, various components for overvoltage protection are available. These include MOVs (Metal Oxide Varistors) and TVS (Transient Voltage Suppressor) diodes, GDTs (Gas Discharge Tubes) or ESDs (Electrostatic Discharge Diodes).

Image 1 provides a schematic overview of the various types of protective equipment and levels for electronic circuits. The principle required here is the use of multiple protective elements to deflect transient overvoltages and overcurrents. Components such as MOV, GDT, SPG (Spark Gap Protectors) and TSS (Thyristor Surge Suppressors) serve as the primary form of protection against overvoltage. TVS and ESD components provide the secondary protective effect. PPTCs (Polymeric Positive Temperature Coefficient Thermistors) act as overcurrent protection and as decouplers, while NTCs (Negative Temperature Coefficient Thermistors) are used in order to suppress overcurrents.

Varistors score highly thanks to their short response time

Due to their very short response time, varistors are used in numerous applications for clamping transient overvoltages of below 20 ns. The best-known of these are Metal Oxide Varistors (MOV). That is because they are capable of absorbing overvoltages – and significantly higher voltages than TVS diodes.

MOVs are manufactured primarily from zinc oxide. They offer a wide voltage range from 18 to 1800 V, and for surge currents of up to 70 kA, in some cases even more. The MOVs by Yageo are available with safety certification according to UL/TÜV/VDE(CSA/CQC) and for operating temperatures from −40 to +105°C and −40 to +125°C. Their I_{pp} values range from several hundred amperes up to several dozen kiloamperes, and they have pulse forms of 8/20 μs. In this case, the V_{BR} value is bidirectional and symmetric.

For this reason, these MOVs are widely used in AC current supplies, signal lines and circuit breakers, LED drivers or smart-metering systems. Rotor diameters of 5 to 53 mm enable the simple selection of the correct component for each of these applications. Yageo also offers TMOV varistors as a special solution. By combining a Metal Oxide Varistor and an NTC, they can effectively limit both currents as well as overvoltages.
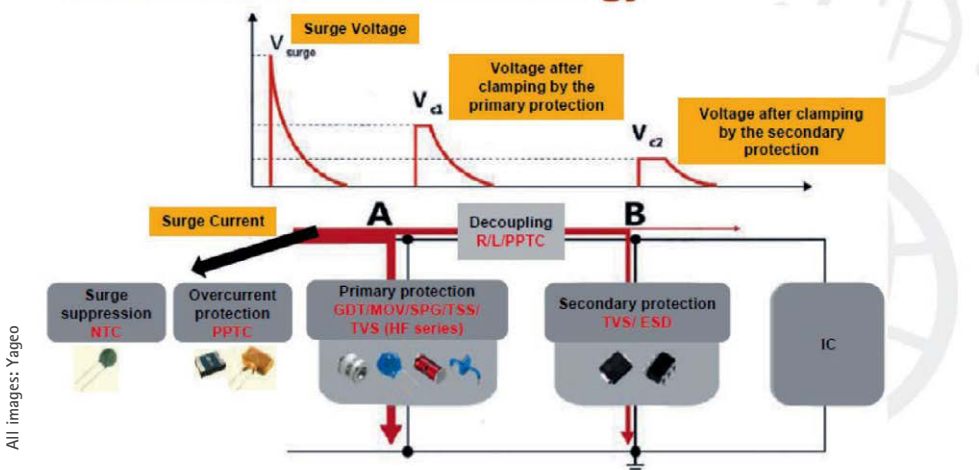

Circuit Protection Methodology

Image 1: Methodology of overvoltage and overcurrent protection

All images: Yageo

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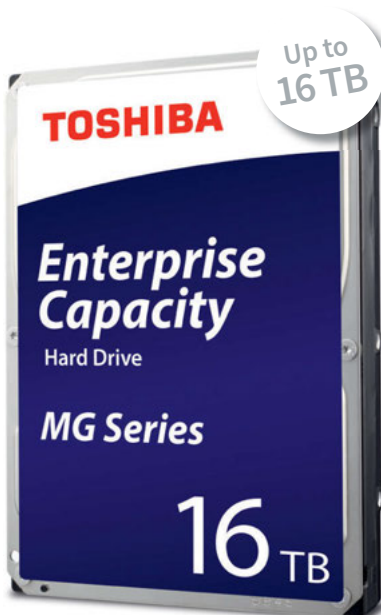
· Industry Standard 3.5″
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Applications		TVS	MOV	ESD	GDT/SPG	TSS	PPTC	NTC
Power	DC power lines	V	V		V		V	V
	AC power lines		V		V		V	V
Telecom/ Network	Ethernet interface			V	V	V		
	PoE interface	V	V		V			
	BNC interface			V		V	V	
	USB 2.0/3.0			V			V	
	RS485 interface	V			V	V	V	
	CAN (Controller Area Network)/ LIN (Local Interconnect Network) interface			V				
	Antenna/ RF interface			V	V			
	HDMI interface			V				
	Base station	V	V		V			
LED driver			V		V		V	V
Automotive		V	V	V	V		V	V
Mobile phone				V				
Computer		V	V	V			V	V
Consumer electronics		V	V	V	V	V	V	V

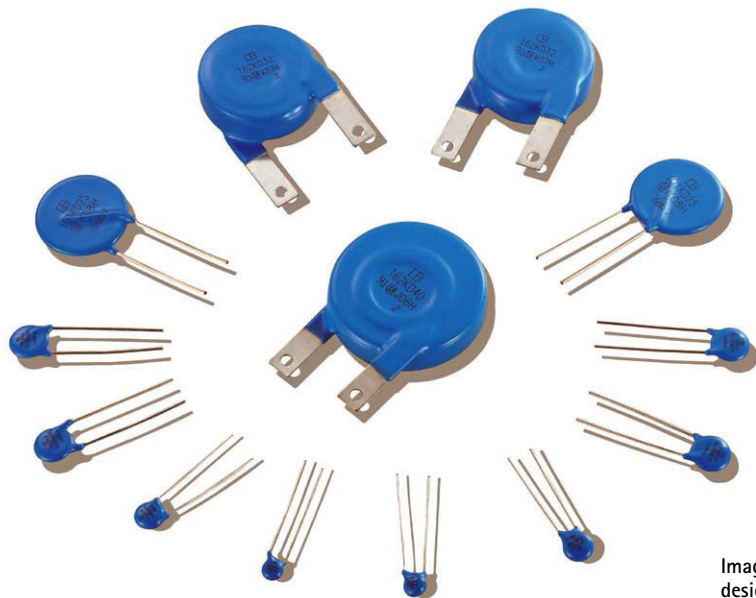Use of protection components in key applications (source: Yageo)

Image 2: Typical varistor designs

The disadvantage of MOVs is that, unlike TVS diodes, they can age. This means that they only have a limited service life, depending on the transients that they absorb. To mitigate this effect, they are typically used in series with GDTs or SPGs.

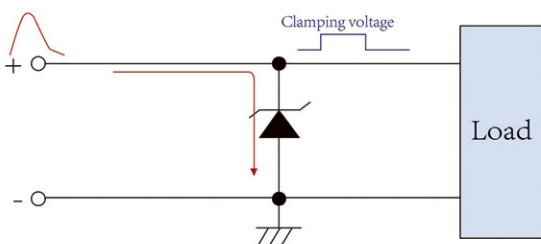## TVS diodes guarantee rapid unidirectional or bidirectional blocking

TVS diodes, also referred to as suppressor diodes, TVPs (Transient Voltage Protectors), ABDs (Avalanche Breakdown Diodes) or BODs (Break-Over Diodes), can clamp overvoltage peaks within a safe range of picoseconds and restrict them to a safe value to protect the circuit from damage. These are the components with the best clamping behavior among

Image 3: The operating principle of a TVS diode parallel to the load

the protective diodes and are connected parallel to the load to be protected (Image 3).

The primary advantages of TVS diodes are their short response time and low capacitance and their ability to provide unidirectional and bidirectional protection. As such, they are ideally suited for DC current supplies, security and surveillance systems as well as in the telecoms and automotive sectors.

TVS diodes by Yageo are supplied with UL safety certification. They are also available with automotive-grade qualification (AEC-Q101) and stand out by virtue of their low dynamic internal resistance and rapid response characteristics. They are available for a P_{ppm} of 200 to 30,000 W for 10/1000-μs pulse forms and I_{pp} values of 6/10/1620 kA in 8/20-μs pulses. V_{rem} is specified as 3.3 to 600 V (or higher). Enclosure shapes SMAJ, SMBJ, SMCJ, DO-41, DO-15, DO-201 and others are available.

Image 4 shows a comparison of the protective properties of MOVs and TVS components.

The growth market of electric mobility

Although the TVS diodes are relatively recent additions to the Yageo portfolio, the supplier has drawn up a dedicated road map for TVS products with a focus on automotive, high power and high surge applications. By further expanding the road map and adding new enclosure designs for future applications, Yageo is pursuing the stated objective of capturing further market share in the protection component segment, above all in the growth market of electric mobility. Due to the stricter CO_2 limits that will take effect starting in 2020, suppliers are under pressure to reduce the CO_2 emissions of their vehicle fleet substantially. As a result, the development of electric vehicles has picked up speed noticeably and is set to accelerate further. Protection against overvoltage is essential both for electric vehicles themselves as well as in the area of the charging infrastructure. This is where TVS diodes with their specific characteristics are particularly suitable for use as circuit protection components.

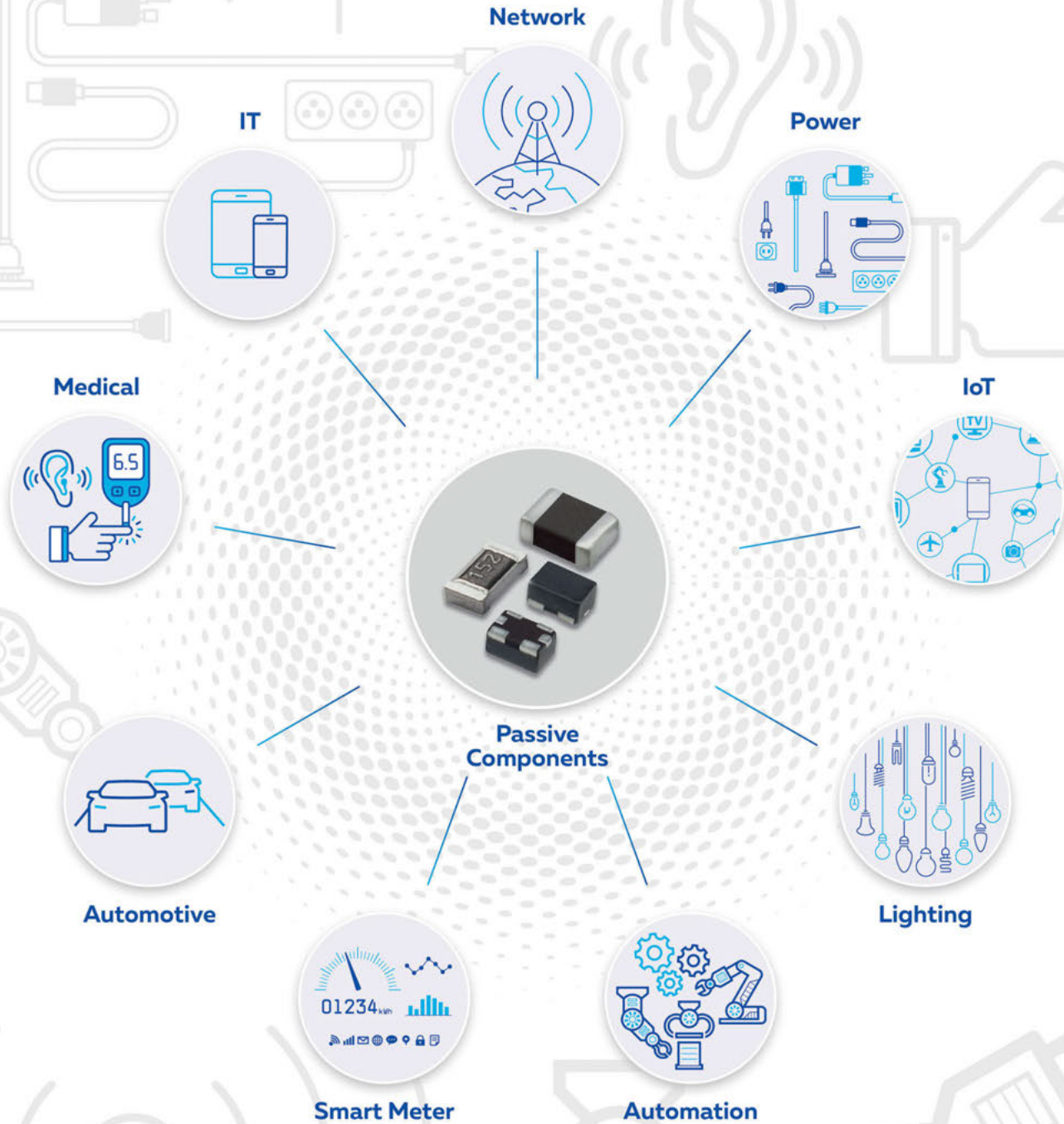## Additional protection components

TVS arrays are offered as electric-discharge protection devices with operating voltages in accordance with the applicable values of

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MOV:

+ Hi Current
+ Single Pulse
- Voltage Tolerane
- Weak Clamping (V_{br}/V_c)
- Parameters Change

Part Number		Maximum Allowable Voltage		Varistor Voltage	Maximum Clamping Voltage		Withstanding Surge Current		Maximum Energy (10/1000 μs)		Rated Power	Typical Capacitance (Reference)
Standard	High Surge	$V_{AC}(V)$	$V_{DC}(V)$	$V_{1mA}(V)$	$I_P(A)$	$V_C(V)$	I (A) Standard	I (A) High Surge	(J) Standard	(J) High Surge	(W)	@1KHz (pf)
180KH05	180KH05J	11	14	18(15~21.6)	1	40	100	250	0.4	0.6	0.01	1400
220KH05	220KH05J	14	18	22(19.5~26)	1	48	100	250	0.5	0.7	0.01	1150
270KH05	270KH05J	17	22	27(24~31)	1	60	100	250	0.6	0.9	0.01	930
330KH05	330KH05J	20	26	33(29.5~36.5)	1	73	100	250	0.8	1.1	0.01	760
390KH05	390KH05J	25	31	39(35~43)	1	80	100	250	0.9	1.2	0.01	640

TVS:

+ Precision Component
+ Tight Clamp
+ Multiple Pulse
+ Keep Parameters
- Smaller Currents

Part Number		Device Marking Code		Reverse Stand-Off Voltage	Breakdown Voltage @I_T	Test Current	Maximum Clamping Voltage @I_{PP}	Peak Pulse Current	Reverse Leakage @V_{RWM}
Unidirectional	Bidirectional	UNI	BI	$V_{RWM}(V)$	$V_{BR}(V)$	$I_T(mA)$	$V_C(V)$	$I_{PP}(A)$	$I_R(\mu A)$
SMBJ16A	SMBJ16CA	LP	BP	16.0	17.80~19.70	1	26.0	23.1	1
SMBJ17A	SMBJ17CA	LR	BR	17.0	18.90~20.90	1	27.6	21.8	1
SMBJ18A	SMBJ18CA	LT	BT	18.0	20.00~22.10	1	29.2	20.6	1
SMBJ20A	SMBJ20CA	LV	BV	20.0	22.20~24.50	1	32.4	18.6	1
SMBJ22A	SMBJ22CA	LX	BX	22.0	24.40~26.90	1	35.5	16.9	1
SMBJ24A	SMBJ24CA	LZ	BZ	24.0	26.70~29.50	1	38.9	15.5	1

Image 4: Comparison of functional characteristics of varistors (MOV) and protective diodes (TVS)

the IC supply voltage (2.8 to 36 V). They are supplied with low capacitance (below 1 pF) for high-speed data interfaces such as HDMI and USB 3.0 in various compact enclosure shapes.

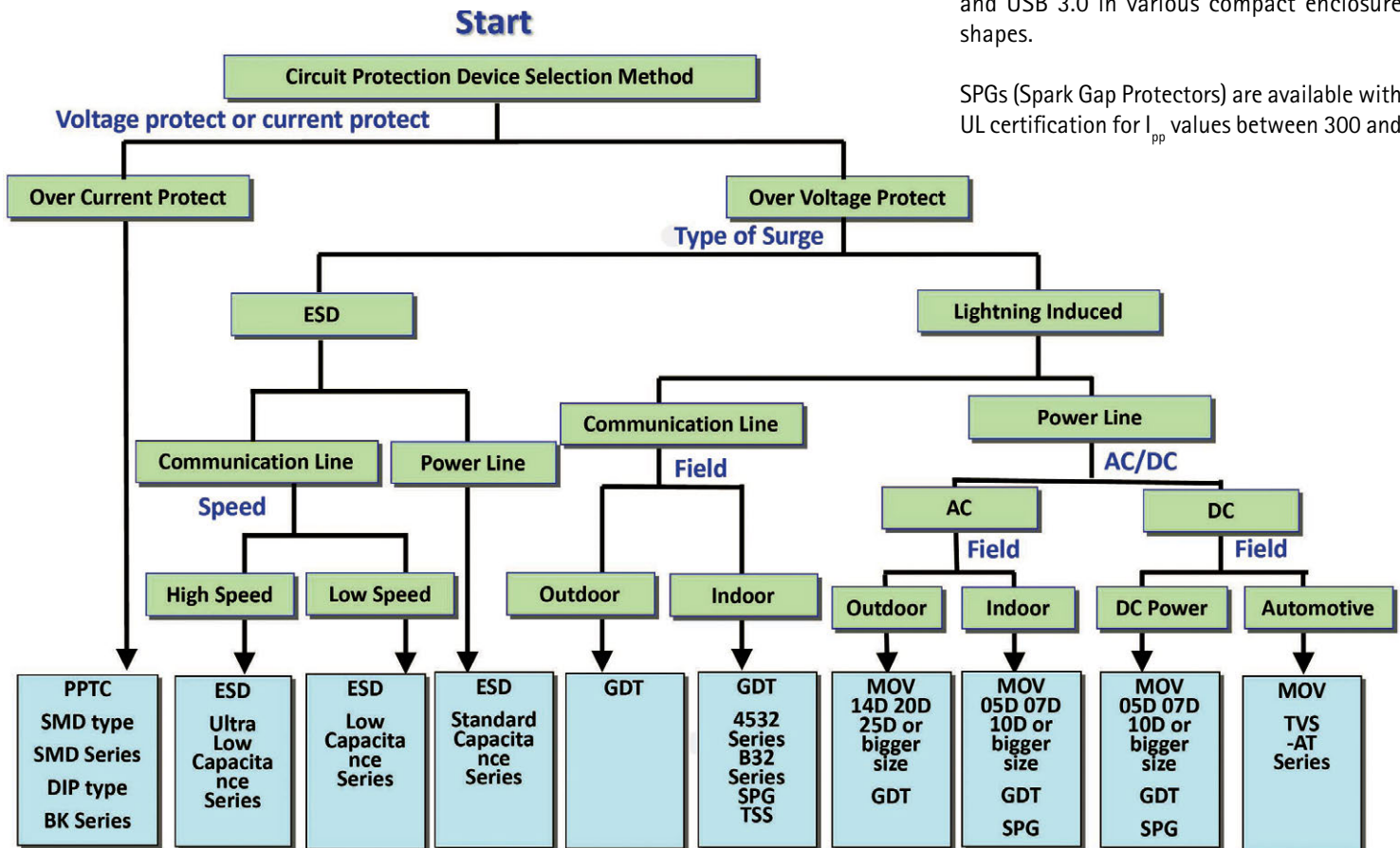SPGs (Spark Gap Protectors) are available with UL certification for I_{pp} values between 300 and

Image 5: Decision guidance for selecting protection components

From passive specialist to leading component supplier

Known as a leading provider of passive components, Yageo recently acquired BrightKing Holdings Ltd. with a complete portfolio of overvoltage and overcurrent protection devices. As a result, Yageo covers almost 100% of the market in the area of diodes and MOVs. This step brings Yageo closer to its objective of offering a pallet of electronic components that is unrivaled in scope as well as innovative services at a high level of quality worldwide from a single source. Thanks to the one-stop shopping approach, customers profit from cost benefits and the rapid, local service across the globe.

Yageo currently operates 23 sales offices, nine production sites in Asia, North and South America and Europe, eight logistics hubs and two R&D centers. Two UL-1449 test laboratories in Taiwan and China offer a pretest service in relation to overvoltages for the purpose of UL certification. In 2019, Yageo will expand its production capacity by 35% to realize a production volume of 522 million units.

Applications	Applied CPC type & CPC BOM Usage	Potential of Demand Growth	Design trend
5G base station	➤ MOV, TVS, GDT, PTC ➤ 20pcs/set	5G small cells in 2025: 30M sets CPC demand in 2025: 600M pcs	➤ High surge ➤ High power
Automotive	➤ TVS, ESD, PTC, NTC ➤ Traditional car: 50 ~ 70pcs/ Ecar: 60 ~ 80pcs (mainly increased in BMS)	Ecar in 2025: 40M cars CPC demand in Ecars: 2.4B ~ 3.2B pcs	➤ High surge ➤ High power
Smart phone	➤ ESD ➤ 35pcs/set	Keep flat	
IOT	➤ TVS, ESD, MOV, TSS, PTC ➤ Demand varies by different communication port (POE, HDMI, USB…etc.)	Increasing, e.g. video-surveillance demand in 2018 is 180M sets and CAGR is 5%.	➤ Down sizing ➤ Ultra low junction capacitance ➤ Integration of protection device and

The biggest growth markets for Yageo

3000 A for 8/29-µs impulses as well as a DC spark-over voltage from 140 up to 5000 V. They offer an isolation resistance of >100 MΩ combined with a low aging effect and are not polarized.

GDTs (Gas Discharge Tubes), likewise with UL/VDE certification, are available for I_{pp} values between 500 and 100 kA (8/20-µs impulse) and DC spark-over between 75 and 6000 V (impulse spark-over up to 7800 V). These GTDs offer isolation resistance of around 1 GΩ. Typical applications are in coaxial cables and Ethernet connections.

TSS components (Thyristor Surges Suppressors) for telecoms and surveillance systems, smart meters, etc. offer an I_{pp} of several hundred amperes (8/20-µs impulse) and a low leak current of between 1 and 5 µA at a precise spark-over voltage (V_{DRM}: 6 to 620 V).

PPTCs (Polymeric Positive Temperature Coefficient Thermistors) are suitable for the same applications as TSS. Under normal operating conditions, they have a very low resistance and have no effect on the circuit to be protected. Consequently, they are operated in series to the circuit. The response speed of several milliseconds is quite low, and is proportional to the current value. I_{hold} is between 30 mA and 14 A, and V_{max} can be 5 to 600 V.

NTCs (Negative Temperature Coefficient Thermistors) with their exceptional, long-term stable thermal cycle behavior are ideal for power supplies (UPS) and power adapters. They are supplied with diameters of between 5 and 25 mm (5D to 25D). ∎

Simplifying power supplies and saving costs

SiC works

Silicon carbide technology can offer many advantages besides greater efficiency, enabling designers to increase power density, enhance reliability, and economize on the overall bill of materials, even in a relatively simple circuit such as a flyback converter.

BY WOLFGANG SAYER,
LINE MANAGER AT RUTRONIK, AND
ALY MASHALY,
ROHM SEMICONDUCTOR

Silicon carbide (SiC) power semiconductors are understood to enable greater efficiency in power-conversion applications where energy is extremely precious, such as solar generators and high-end electric vehicles.

In fact, they have many more advantages to offer, including increasing power density and reliability due to their increased temperature capability, simplifying circuit design, reducing reliance on external components, and allowing the use of smaller and lower-cost passive components. We can see how these benefits can be unleashed in ordinary applications by comparing several designs for the flyback converter of an auxiliary power supply using both SiC and silicon technologies.

The root of the SiC advantage

In the form used for fabricating power semiconductors, SiC has a bandgap of 3.2 eV between the valence and conduction bands technology, which is about three times that of ordinary silicon. In addition, its dielectric breakdown field strength is about ten times that of silicon. Together, these two characteristics endow SiC devices with superior properties, including faster switching, higher efficiency, greater stability over temperature, and a higher maximum operating temperature. For equipment designers, this can relieve demand for thermal management without compromising device reliability.
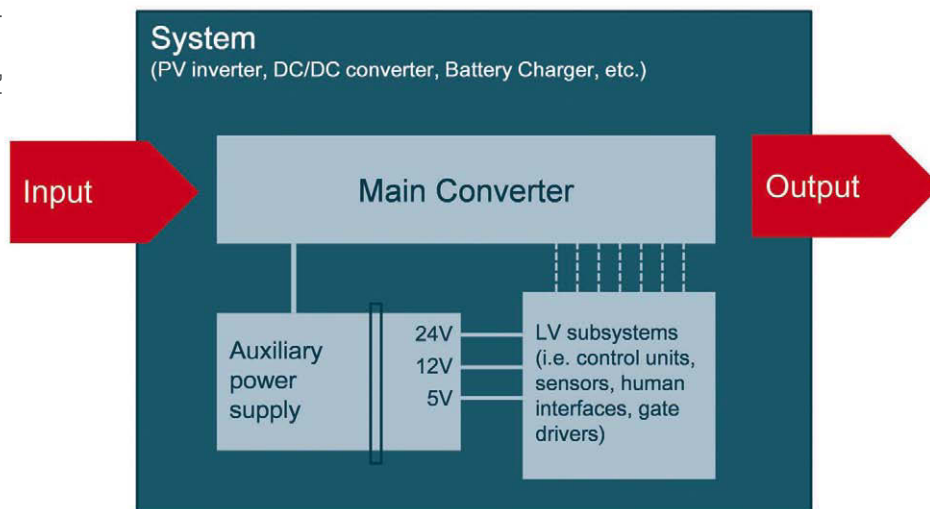
Images: Rohm

Image 1: Positioning and purpose of auxiliary power supply

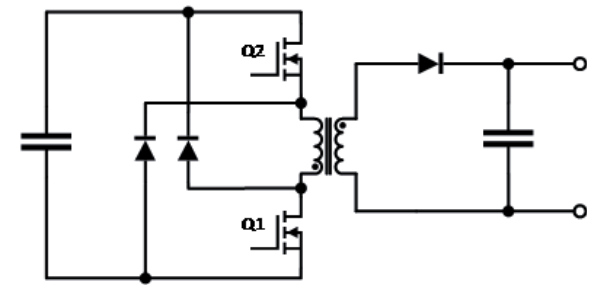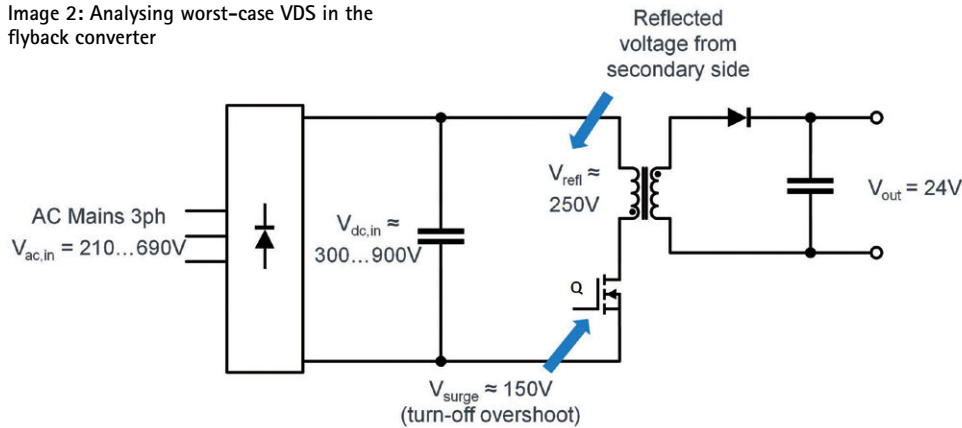Image 2: Analysing worst-case VDS in the flyback converter

Image 3: Conventional silicon MOSFETs in a two-switch flyback converter can provide the required voltage capability.

Sic's higher breakdown field strength allows MOSFETs to be designed with a much thinner drift layer, resulting in lower on-resistance, $R_{DS(ON)}$ relative to the die area, for a given breakdown voltage. To achieve high breakdown voltage in ordinary silicon, the MOSFET has higher $R_{DS(ON)}$ leading to greater conduction losses. SiC also permits lower MOSFET gate charge, Q_g, enabling faster switching with lower energy loss, concurrently with low $R_{DS(ON)}$ and high breakdown voltage.

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Auxiliary power supply design challenges

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Equipment such as solar inverters, industrial DC/DC converters, battery chargers, and others often contain an auxiliary power unit running off the main input to supply subsystems such as sensor modules, a display, and other control units or drivers (Image 1).

For simplicity a flyback converter is typically used. The main power switch must be able to withstand the worst-case drain-source voltage due to the reflected voltage from the secondary side, maximum turn-off overshoot, and DC input voltage (Image 2). The sum of these voltages can exceed 1300 V.

A variety of design approaches can be considered to ensure the power transistor is able to withstand worst-case voltage applied across the drain and source terminals. Each has its own advantages and disadvantages.

One approach is to choose a power transistor that has high breakdown voltage, say 1500 V. However, ordinary silicon high-voltage transistors come with relatively high on-resistance ($R_{DS(ON)}$) thereby incurring undesirable conduction loss and heat dissipation. They also tend to have high gate charge (Q_g), which causes high driving losses, as well as high

leakage current, especially at high temperatures.

An alternative is to connect a pair of 800 V silicon MOSFETs in series. This calls for more complex gate-driving circuitry, and a voltage-balancing circuit is also needed. In addition, both devices require a heatsink, therefore adding to the space consumed.

Another solution is to use a two-switch flyback topology (Image 3), at the expense of greater circuit complexity. An isolated gate driver and power supply is needed to control the high-side switch and, again, a heatsink is required for each device.

Instead, a single SiC MOSFET such as the SC-T2H12NZ, which has 1700 V breakdown volt-
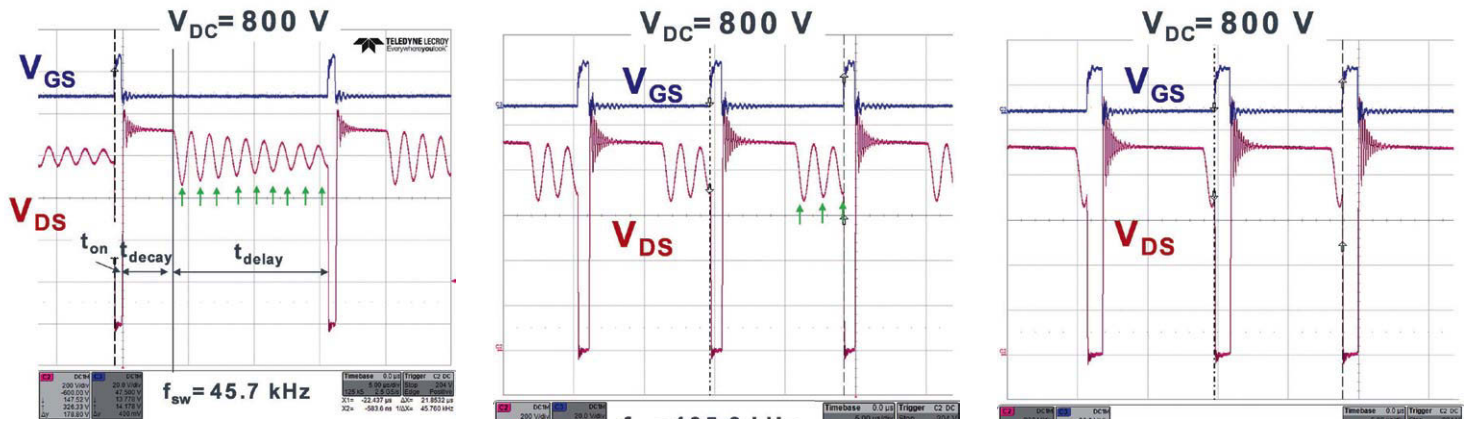
Image 4: MOSFET switching waveforms at light, mid, and full load

age and 3.7A current rating, can be used. This device combines high breakdown voltage with $R_{DS(ON)}$ ranging from one half to one eighth that of comparable 1500 V silicon MOSFETs. In addition, Q_g and input capacitance are greatly reduced, hence permitting higher switching frequency and so allowing for smaller external components. Moreover, SiC's ability to withstand higher operating temperature relieves heatsinking requirements.

By allowing a single-FET flyback circuit to achieve the required breakdown voltage with minimal conduction losses, and operate at higher switching frequency, turning to SiC can yield BOM savings that result in a more economical solution overall.

A dedicated flyback controller IC, the BD7682FJ, is featured for driving SiC MOS-FETs. In addition to generating a gate-drive signal in the recommended 14–22 V range for SiC devices (typically about 18 V), it incorporates a 14 V Under-Voltage Lockout (UVLO) to avoid thermal problems as well as an output clamp to prevent overvoltage on the SiC gate. The controller implements quasi-resonant switching to minimize dynamic losses and achieve low noise, and features a burst mode to enhance light-load efficiency. Protection functions, such as soft-start, over-current limiter per cycle, over-voltage protection

function, and overload protection are also built in.

Performance evaluation

Rohm has built a 100 W auxiliary power supply evaluation board featuring the SCT2H12NZ and BD7682FJ, which is able to operate with an input voltage from 210–480 V AC or 300–900 V DC.

Image 4 shows the transistor V_{GS} and V_{DS} waveforms at light load (left), 50% load (center) and nominal load (right). The light-load waveforms show how the controller waits for several valleys before turning the MOSFET on, resulting in a lower operating frequency than the nominal 90–120 kHz range. As the output power increases, the delay time is reduced and operating frequency increases. At nominal power, turn on occurs in the first valley. Measurements taken across the load range have shown that efficiency rises to 88–92% at the nominal power output for input voltages of 300–900 V DC.

By creating this auxiliary power supply evaluation board, Rohm demonstrated that system-level cost savings can be achieved if the advantages of SiC devices are fully utilized.

Full integration for maximum advantage

Rohm has now taken things a step further by creating the BM2SCQ121T-LBZ quasi-resonant AC/DC converter that combines a fully integrated 4 A, 1700 V SiC MOSFET with the functionality of the BD7682FJ including UVLO, voltage clamping, and burst mode. Conveniently packaged in TO-220-6M, the converter makes it easier than ever to design with SiC and maximizes savings in part count and board real estate.

Conclusion

By enabling a combination of high breakdown voltage rating with low $R_{DS(ON)}$, as well as high switching speed, low switching loss, and high temperature capability, silicon carbide MOS-FETs enable designers to simplify circuit design and lower materials costs in a wide range of applications including simple flyback converters.

A new, fully integrated, flyback converter IC containing gate-driving and control circuitry with a 1700 V SiC MOSFET built in now encapsulates these advantages in an easy-to-use industry-standard power package. ◼
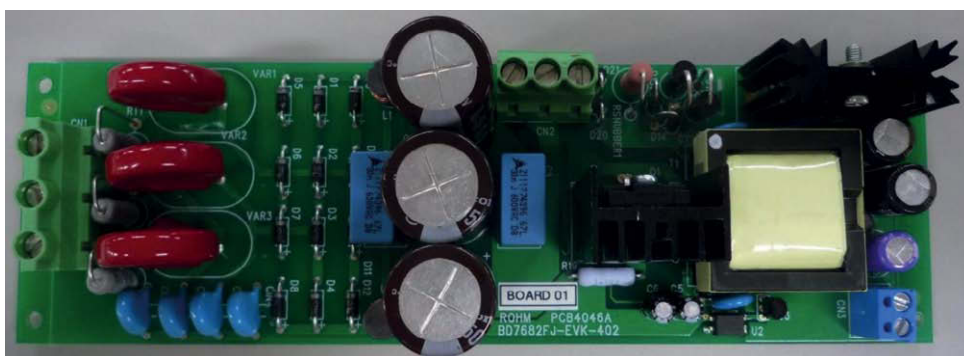

Image 5: Evaluation board for the BD7682FJ

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Thermal protection

Thermal fuse with that special extra

In modern highly compacted electronic devices, safety in operation is increasingly threatened by excessively high temperatures. As a rule, thermal fuses are used to counter this risk. But only in combination with a shunt resistor is it possible to provide fail-proof protection.

BY MICHAEL BAUMANN, PRODUCT SALES MANAGER MECHANICS AT RUTRONIK, AND MARKUS HÄCKI, PRODUCT MANAGER AT SCHURTER

In order to achieve ever greater power densities, modern electronic devices need to accommodate more and more components and functions within a very tight space. As a result, new products – small, but offering extremely high performance – are being produced, but nevertheless bring with them the risk of thermal runaway. Thermal runaway means overheating within a technical device caused by heat-producing and self-energizing processes. With a power semiconductor such as a MOSFET, in connected status, the drain-source forward resistance increases as temperature increases, resulting in an increasing power dissipation in the barrier layer. If the cooling system is insufficient, this power dissipation, which is released in the form of heat, cannot be fully discharged, thus raising the forward resistance and the process very quickly becomes increasingly unstable. That can result in the component or the device being destroyed and, in the worst situation, cause fires or explosions.

Adding a current measurement sensor

When designing components and circuits, engineers need to consider the temperature dependency of the component's electrical resistance. This current measurement property can be a specific benefit. Because abnormal temperature protection only triggers in heat conditions, it is often a good idea to combine a thermal fuse with a current measurement sensor in the form of a shunt, so that current flow can be sufficiently taken into account. This combination means that the thermal fuse can identify a creeping temperature increase while the shunt will identify a rapid onset malfunction (excess current).

A shunt is a low-ohm resistor with as low a temperature dependency as possible, which enables accurate measurements to be made of the current flow inside the component without being influenced by the ambient temperature. The small voltage present at this resistor is measured in order to calculate the current intensity. The lower the voltage, the less the circuit is influenced by the measuring device. A controller processes the measurements taken and if the current is too high, it

Image: timothyh/stock.adobe.com

separates the circuit. The permitted current intensity depends on the system and can be configured accordingly.

Clever combination for fail-safe protection

Thermal Switch) with shunt, Schurter is supplyingbetter fail-safe protection to prevent thermal runaway. It is not a replacement for the conventional overcurrent protection but rather an extension to the safety chain to provide functionality that safety fuses have not been able to provide previously. The RTS is located as close as possible to the component it is protecting. As soon as the ambient temperature of the power semiconductor exceeds a certain threshold, the thermal fuse separates the components from the circuit. If thermal runaway is detected, galvanic separation occurs. Because it is enhanced with the addition of a shunt measuring resistor it is also possible to measure the extent of the current flow and correct it with control electronics.

Adding an overcurrent fuse to the RTS combines three functions into a single reflow soldered SMD component inside the space-saving RTS housing with its small 6.6 mm ×

8.8 mm footprint: abnormal temperature protection, overcurrent protection and current intensity measurement. This way costs are reduced while operational safety is greatly increased.

Standard parameters and customized variants

The RTS from Schurter copes with operating currents up to 130 A and rated voltages up to 60 V DC. The standard version has a measuring sensor resistance of 500 µΩ and a tripping temperature of 210°C. The current design of the standard RTS with shunt is designed especially for the 12 V power electronics sector within the automotive industry and is particularly suitable for cooling fans, ABS, servo steering, PTC heaters, HVAC, glow plugs and diesel heaters. But it can also be deployed in industrial applications, particularly in fields such as battery protection, power adaptors, control-gear lighting, H-bridge circuits and motor drives.

Besides the standard products, customized designs with adapted parameters (e.g. resistance level or tripping temperature) are also available to provide effective protection for individual needs. ■
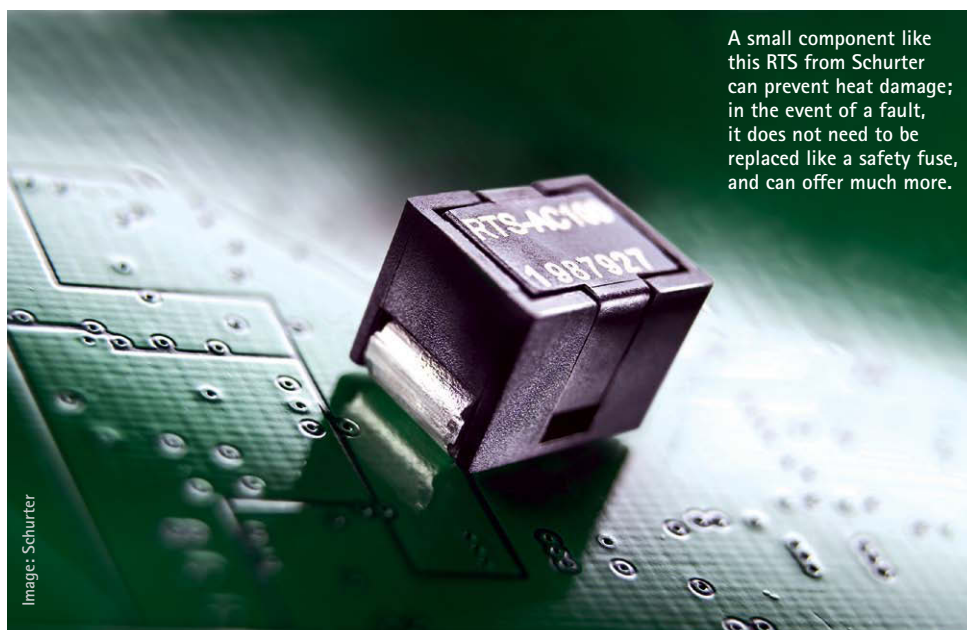
Image: Schurter

A small component like this RTS from Schurter can prevent heat damage; in the event of a fault, it does not need to be replaced like a safety fuse, and can offer much more.

Horticulture lighting

En route to the high-rise farm with LEDs

Vertical agriculture will be taking on an increasingly important role in the agricultural sector. Thanks to the latest LED technology it is possible to cultivate an extremely wide variety of plants, saving space and positively affecting their growth, completely without sunlight. Efficient lighting solutions are needed here.

By Safa Demir,
Product Sales Manager Opto at
Rutronik

The world is facing two major challenges – rising population and climate change – which, if no appropriate solutions are found, will result in food shortages. One outstanding response to the challenge is vertical agriculture in the horticultural sector.

With the latest LED technology, which emits very little heat, light sources can be provided close to the cultivated plants without burning them. This enables multilevel cultivation. Compared with conventional farms or standard greenhouses, space and water are used much more efficiently with vertical agriculture, and, what's more, it can take place in urban areas.

It is also interesting for high-demand commercial plant cultivation such as cannabis for medical use. The efficiency and reliability of the lighting plays a crucial role in all these fields.

Optimum photosynthesis with the appropriate light spectrum

To optimally promote the plants' photosynthesis in artificial light the correct combina-

Image: zapp2photo/stock.adobe.com

tion from a wide wavelength spectrum is required. Only wavelengths of 450 nm, 660 nm, 730 nm and some green light in 520 to 550 nm affect photosynthesis. Depending on the phase – whether the plants are at the germination, vegetative or fertilization stage – a different light composition is ideal. This is particularly the case in a vertical agriculture facility where no natural sunlight is present. Moreover the wavelengths must be adapted to the purpose of the cultivation. This is dependent on whether the plants need to grow quickly or slowly, whether the flowers are the focus or whether particularly large or abundant fruit is required.

When applied individually many color spectra do not contain a particularly high proportion of photosynthesizing light waves. But when combined in the correct proportions with other wavelengths, the rate of photosynthesis goes up. The mixing proportion must relate to the wavelengths found in natural light during the day. For example, as evening draws in, the optimum wavelength is 730 nm (far red) to prepare the plants for their nighttime rest, while 450 nm (deep blue) and 660 nm (hyper-red) are required for photosynthesis. Different compositions of the light spectrum can be achieved simply by varying the number of LEDs in the relevant wavelengths, without changing the design of the PCB or the luminaries. However, a controller is required to be able to accurately control the LEDs, altering the mix ratio as the day goes on.

*LEDs for
efficient horticulture lighting*

There is a wide variety of LEDs of many different wavelengths that can be combined, as necessary, to assemble an individual horticulture board.

High-power LEDs give maximum brightness. The Oslon product range by Osram comprises high-power LEDs with varying illumination angles (80°, 120° and 150°) and a wide selection of color spectra. Osram has developed, particularly for use in the horticulture lighting sector, the Oslon-SSL-Color LEDs in wavelengths of 450 nm (deep blue), 660 nm (hyper-red) and 730 nm (far red) along with the Oslon Square in wavelengths of 450 nm (deep blue) and 660 nm (hyper-red). The SSL range also provides color spectra such as blue, true green and red for special light combinations. The Oslon Square, with its beam angle of 120°, achieves an efficiency

of up to 3.779 µmol/J, while the Oslon SSL product range even achieves 3.91 µmol/J.

Rutronik also offers a wide portfolio of mid-power LEDs. They are not as bright as the high-power version, but, for that, are less expensive. That means they are of interest for consumer applications. The efficiency values are sufficient to promote photosynthesis corresponding to the needs. The Duris-S5 series by Osram and the 2835 and 3030 packages by Everlight are suitable mid-power components.

The Duris S5 series is also suitable for domestic use horticultural applications. The compact Duris S5 purple LED provides a space-saving combination of the photosynthesizing 450 and 650 nm wavelengths.

In addition to the LEDs providing visible light, there are also components from Stanley, emitting ultraviolet wavelengths in UV-B (280–315 nm) and UV-A (315–400 nm). They kill germs and thus extend storage time. In addition, they can improve the taste and color of the fruit.

*Increased efficiency with
the correct power solutions*

Once the optimal LEDs have been selected for the application in question, the next thing is to tune the LED drivers. Because there are large numbers of LEDs on the horticulture boards, efficient energy supply is required. The OT FIT 380/230-400/1A4 from Osram, with its wide voltage range of 200 to 400 V and large breadth of current intensity from 400 mA to 1400 mA, allows for the flexible layout of the board design and a good variety in the number of LEDs. It also has an NFC adjustable current intensity and optimized surge and burst capability at 4 kV.

If the LEDs are also fitted with a secondary optic, the color spectrum and the illumination angle of the light can be better controlled. Depending on the density of the LEDs the light can be focused or scattered. This achieves different light intensities to deal with the specific needs of the particular plants. Ledil, for one, has a good range of lenses with various illumination characteristics. They are compatible with many of the standard LED packages, such as the Osram Oslon range. ∎

A solution to the short supply of components

Downsizing and replacing MLCCs

With some passive components, very long delivery lead times are creating production bottlenecks. A creative way out of shortages of MLCCs is to use smaller sizes or to replace them with suitable tantalum or hybrid capacitors.

By Jürgen Geier,
Technical Support Ceramic Capacitors
at Rutronik

The demand for multilayer ceramic capacitors (MLCCs) has increased tremendously in recent years. These days each and every smartphone contains an average of 750 to 1,000 MLCCs, and a car can contain as many as 3,000 – and the trend is upward. At Murata, the demand for MLCCs has risen by a factor of 2.5 over the past four years. Many manufacturers are continually expanding their production capacity, but on their own, they cannot cover the constantly increasing demand.

One remedy is to downsize. Because smaller sizes allow much greater production output in comparison to larger sizes. Compared with 1210 MLCCs, alone from the pure surface of the same wafer, it is possible to obtain around 16 times as many 0402s and 44 times as many 0201s. In terms of volume, the production output increases by a factor of 80 (0402) or of 400 (0201) (Image 1).

That is why it is recommended to use smaller-sized MLCCs, provided the required value combinations are available. This applies in particular to new product developments and redesigns too. So valuable production capacities can be maintained for high-capacitance MLCCs that cannot be produced in smaller sizes, but they are not straightjacketed by having to make parts that are available in smaller sizes.

Downsizing offers other benefits

Other areas also benefit from component downsizing. This is because smaller components make it possible to cut costs beyond the low component price, by requiring less PCB space, weighing less, needing less solder and, above all, requiring less storage space (Image 2).

In order to fully exploit the potential, it is necessary to consider a few things. Starting by not simply looking at existing value combinations, but by examining the application's actual requirements and ultimately even the MLCCs' function. This is particularly true for the capacitance and voltage values, but also for the necessary temperatures and impedance/ESR values. To this is added the DC bias, especially with HiCaps, i.e. capacitors with capacitance in the µF range. DC bias is an effect whereby the MLCCs' capacitance is reduced in accordance with the voltage applied. That means it is necessary to check that in operation it does not fall below a particular C-value threshold.
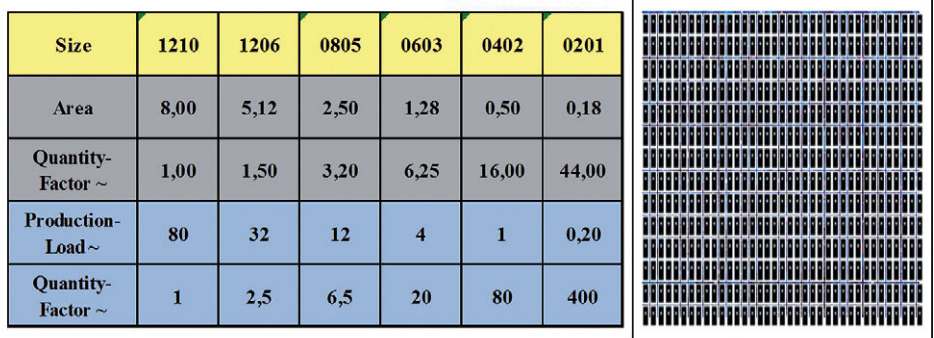
Image: Rutronik

Size	1210	1206	0805	0603	0402	0201
Area	8,00	5,12	2,50	1,28	0,50	0,18
Quantity-Factor ~	1,00	1,50	3,20	6,25	16,00	44,00
Production-Load ~	80	32	12	4	1	0,20
Quantity-Factor ~	1	2,5	6,5	20	80	400

Image 1: The smaller the size, the more pieces from each wafer

Image: Vishay
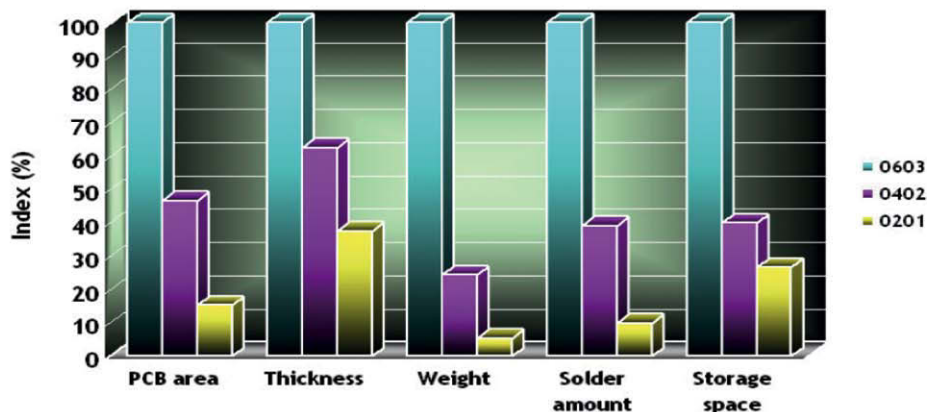
Image 2: Smaller design MLCCs provide many benefits.

Image 4: The capacitance of the 0603 MLCC in 4.7 µF (in red) lies well above the capacitance of the 0805 MLCC in 1.0 µF.
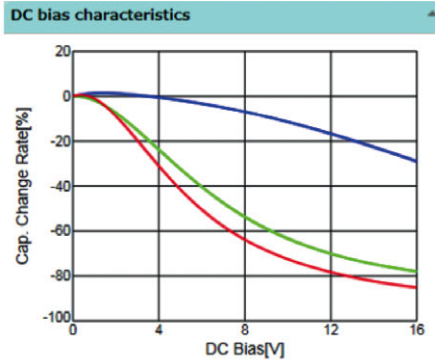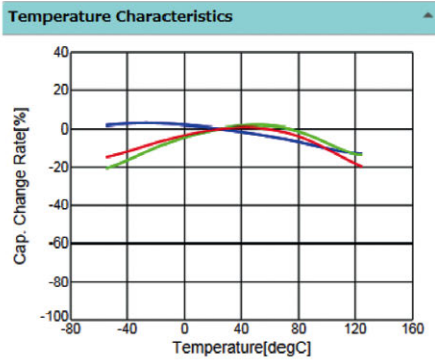
Image 3: Comparison on temperature and DC bias characteristics for three high-capacitance MLCCs GRM21BR71C10SKA01 (blue), GRM188C71C225KE11 (green) and GRM188C71C475KE21 (red)
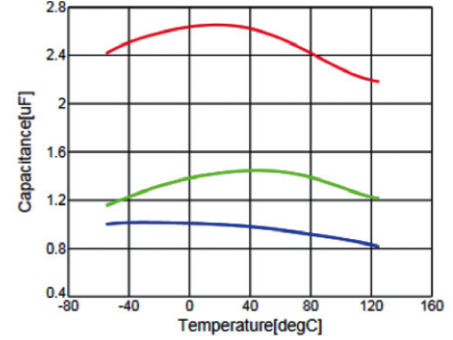
With low capacitance MLCCs, such as interference bypass capacitors in the 100 nF range at 16 V, the impedance curve barely differs for the 0603, 0402 and 0201 designs. In general, the smaller the design, the better the impedance properties (Image 3).

For high capacitance MLCCs, such as buffer capacitors in the range of a few µF, the smaller designs indicate a similar wider capacitance drift with temperature but a more pronounced DC bias (Image 3).

If higher nominal capacitance values are used, we achieve even higher actual (residual) capacitance values throughout in real operating conditions (Image 4).

For ceramic capacitors, such as those with 100 pF and 50 V, the electrical properties of the 0603 and 0201 sizes are almost identical.

Interesting alternatives

In general, ceramic MLCCs are beneficial where the ESR values are especially important and the operating frequencies are higher. The cost-effective 1:1 replacement of ceramic for tantalum of equivalent size is sensible only for capacitances of up to 2.2 µF. Moreover, further options to improve availability are opened up for capacitance values from approximately 10 µF. This is best done by means of a replacement, i.e. by using other technologies. Here, polymer tantalum capacitors come to the fore, along with polymer aluminum electrolytic capacitors. However, we need to consider and agree on a few things, in particular whether functionally, the capacitance or the ESR value (which is better in ceramic designs) and current carrying capacity (ripple) are the focus.

Rutronik offers a dedicated service for MLCC replacement with comprehensive materials and aids, for example a solder-pad design comparison. Moreover, users are given an "MLCC Replacement Sheet", into which they can enter full details of their MLCC spec requirements (nominal voltage, capacitance, size and height, temperature characteristics, etc.) and their application (working voltage of capacitors, number of MLCCs connected in parallel, ripple current, ESR value, operating frequency).

To consider further alternatives to MLCCs, the real minimum capacitance values, specific operating conditions such as DC bias, temperature drift and ageing are crucial. If these are taken into account, there is a very good chance of finding a replacement that meets the requirements of the application at least as well. ■

MOSFETs with a fast body diode

Using the LLC topology and FREDFETs to boost efficiency

In view of the global energy crisis, the current focus of electronic equipment is to achieve high power combined with lower energy consumption. Consequently, many electronics companies are increasing their standards for the efficiency of numerous products in their specifications. These can scarcely be met using conventional hard-switch converters. Developers of power supply units have therefore turned to soft-switch topologies such as the LLC resonant converter in order to improve the efficiency and enable operation at a higher frequency. However, there are a couple of aspects that must be considered.

By Gerald Zipfel,
Technical Support Power at Rutronik,
and
Antonino Gaito,
Senior Application Engineer
Power MOSFET at STMicroelectronics

A resonant LLC half bridge guarantees zero voltage switching (ZVS) in the entire switching device before it switches on (or zero current when it switches off). As a result, energy losses can be avoided by overlaying the switching current and voltage during each transition. With this circuitry, switching losses can also be kept low at high frequencies and the size of reactive components therefore reduced. Of course, lower losses also allow the use of smaller heat sinks. The zero voltage condition results from the intrinsic conduction of the MOSFET body diode. During extremely fast load changes, the MOSFET can transition from a zero-voltage to a zero-current switching condition. In this case, high dv/dt values could switch the intrinsic bipolar transistor to the conductive state, which generally results in the destruction of the MOSFET.

LLC topology

The basic circuit of a half bridge in LLC topology comprises two mechanical switches: the high-side mechanical switch (Q_1) and the low-side mechanical switch (Q_2). They are connected by an inductor L_r and a capacitor C_r to the transformer (see Image 1). The mechanical switches are bridged by their intrinsic body diodes (D_1 and D_2) and the intrinsic capacitive output resistance (C_1 and C_2). To clarify their role in the general operating principle, these are shown separately in Image 1. In addition, another inductor, L_m, can be seen. This is the leakage inductance of the transformer, which plays an important role in the LLC topology.

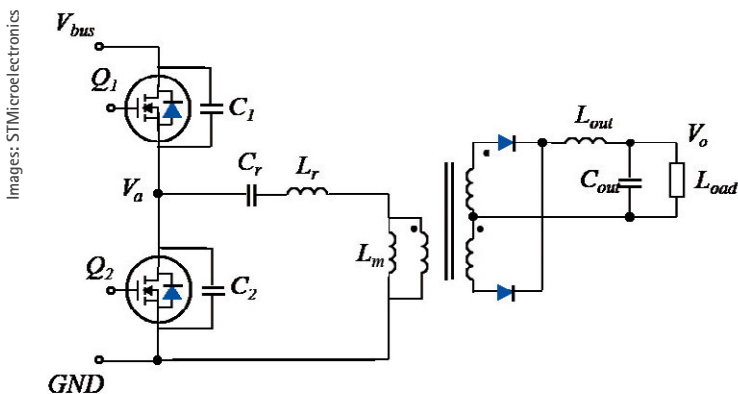If one assumes that the primary inductance value L_m of the transformer is so high that it
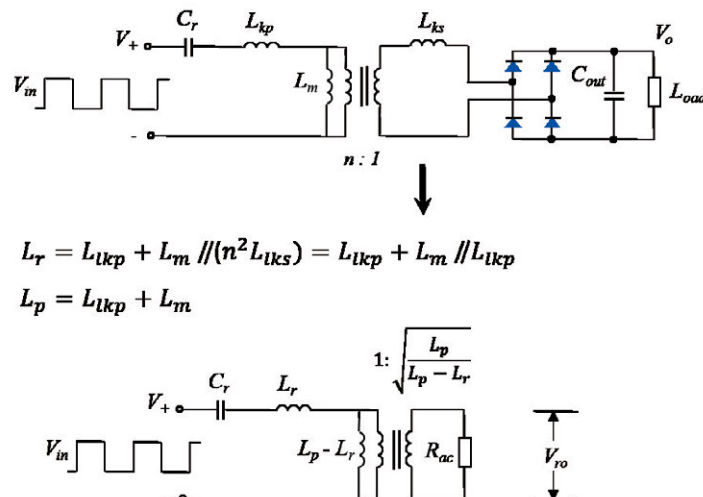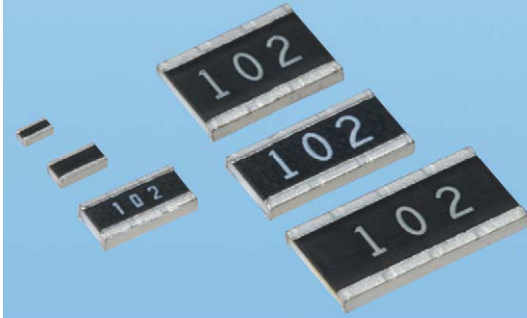
Images: STMicroelectronics

Image 1: LLC bridge circuit

$$L_r = L_{lkp} + L_m /\!/(n^2 L_{lks}) = L_{lkp} + L_m /\!/L_{lkp}$$

$$L_p = L_{lkp} + L_m$$

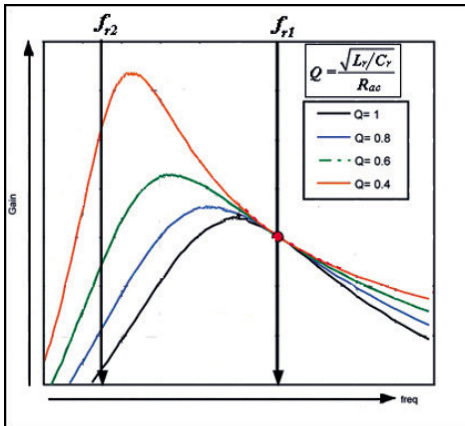Image 2: Parasitic electrical equivalent circuit

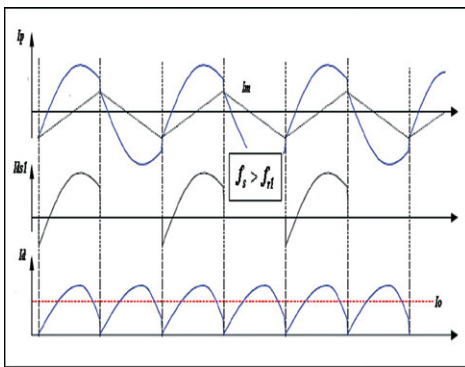Image 3: The amplification of the resonant cell changes depending on Q

Image 4: Typical waveforms of an LLC converter

has no effect on the resonance network, then the converter shown in the figure above acts as a series resonant converter.

In a resonant cell, the maximum amplification is achieved if the frequency of the input signal (f_i) is equal to the resonance frequency (f_r), that is, if the LC impedance is equal to zero. The converter used operates in a frequency range that is limited by two specific resonance frequency values. These values are dependent on the circuit. The LLC controller sets the switching frequency (f_s) of the MOSFET equal to the resonance frequency of the switch to guarantee the valuable advantage of the resonance.

During a load change, the resonance frequency changes from a minimum value (f_{r2}) to a maximum value (f_{r1}):

$$f_{r2} = \frac{1}{2\pi\sqrt{(L_r + L_m)C_r}}$$

$$f_{r1} = \frac{1}{2\pi\sqrt{L_r\,C_r}}$$

For $f_s \geq f_{r1}$, LLC acts as a RC series resonant circuit. This operating principle applies at high load, that is, if L_m is faced with a low impedance. Conversely, for $f_s \leq f_{r2}$, LLC acts as an RC parallel resonant circuit, which is the case at low load. This does not normally occur because the system would then operate in ZCS (zero current switching) mode. If the frequency f_i is in the range $f_{r2} < f_i < f_{r1}$, these two operating principles are combined.

If the amplification of the resonant cell is displayed in graphic form, we get the curves shown in Image 3. This shows how the curve shape changes depending on the quality Q.

The operating range of the LLC resonant converter is limited by the maximum amplification. Bear in mind that the maximum voltage amplification is not available at f_{r1} or f_{r2}. In fact, the frequency at which maximum amplification is achieved is between f_{r2} and f_{r1}. As the quality Q reduces – that is, as the load decreases – this maximum amplification frequency shifts to f_{r2}, and a higher maximum amplification is achieved. With increasing quality Q – that is, increasing load – the maximum amplification frequency shifts by contrast to f_{r1}, and maximum amplification decreases. Therefore, full load is the least favorable case for a resonance network.

With regard to the MOSFET, as mentioned above, there is a key advantage of resonant converters with LLC when it comes to soft-switching MOSFETs, while the sinusoidal output current reduces the emitted interference (EMC) for the overall system.

Image 4 illustrates typical waveforms for an LLC converter. It also clearly shows that the drain current I_{ds1} oscillates into the negative before becoming positive. The negative current value signifies that the body diode is conducting. In this phase, the drain-source voltage of the MOSFET is very low because it is dependent on the drop-out voltage at the diode. If the MOSFET switches while the conductivity of the body diode is practically zero, a transition to ZVS takes place, which reduces switching losses. As a result, the size of the heat sink can be reduced, thereby boosting the efficiency of the system.

If the switching frequency f_s of the MOSFET is less than f_{r1}, the current at the converter takes on a different shape. If this continues long enough to produce an intermittent current at the output diodes, the current on the primary side deviates from the sinusoidal waveform.
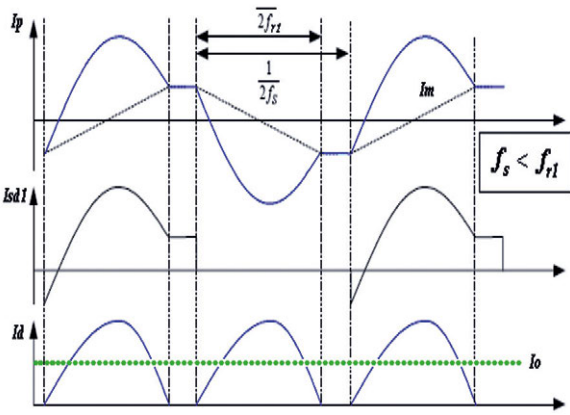
Image 5: Typical waveforms of an LLC converter if $f_s < f_{r1}$

Furthermore, if the intrinsic output capacities C_1 and C_2 of the MOSFET have a value comparable to C_r, the resonance frequency fr is also dependent on the component. To avoid this and to make the f_r value independent of the components used, it is important to select a C_r value greater than C_1 and C_2 at the design stage.

Freewheeling and the ZVS condition

Analysis of the equations relating to the resonant frequencies shows that the input impedance of the resonance network is inductive above the maximum amplification frequency and that the input current of the resonance network (I_p) remains below the voltage (V_d) applied to the resonance network. Below the maximum amplification frequency, the input impedance of the resonance networks is capacitive by contrast and I_p is greater than V_d.

During operation in the capacitive range, a polarity reversal of the body diode in voltage terms takes place during the switching operation, while the body diode is still carrying current. This subjects the MOSFET to a very high risk of failure. As highlighted in the yellow circle (Image 6), the reverse recovery time (t_{rr}) of the internal body diode is extremely important.

In accordance with this point, during a transition from low to high load (see Image 8), the control circuit (LLC controller) should be able to cause the MOSFET to switch to ZVS mode and to a positive shutdown current range. If this is not guaranteed, the MOSFET could operate in a hazardous range.

At a constant low load, the system operates close to the lower resonance frequency f_{r2}. In this case, ZVS mode and a positive shutdown drain current are guaranteed. After the load change (from low to high), the switching frequency should follow the new resonance frequency. If this is not the case (as shown by the green line in Image 8), the system status is in range 3 (ZCS range). This means that ZVS mode and a positive shutdown drain current

are not available. If the MOSFET is switched off, current therefore also flows through its body diode. If one analyzes the transition from low to high load in the amplification diagram, the following can be established:

The black dotted line plots the ideal course during the transition, whereas the green line corresponds to the actual course. As one can see, the system operates in the ZCS range during the transition from low to high load. The performance of the internal body diode then becomes extremely important. Therefore, the trend with the new LLC concept is moving toward the use of circuit breakers with a very low recovery time in the body diode.

Evaluation and reference boards

In order to develop a switch-mode power supply, we recommend gathering experience using an evaluation or reference board. They can also be used to test MOSFETs with a fast body diode and evaluate their advantages. These are also available for LLC topologies in different variants from Rutronik.

The STEVAL-ISA132V1 evaluation board can supply a continuous output of 170 W (V_{IN} = 190 V to 264 V AC, V_{OUT} = 24 V) and a peak output of over 300 W for a limited time. Its architecture is based on a single-stage LLC
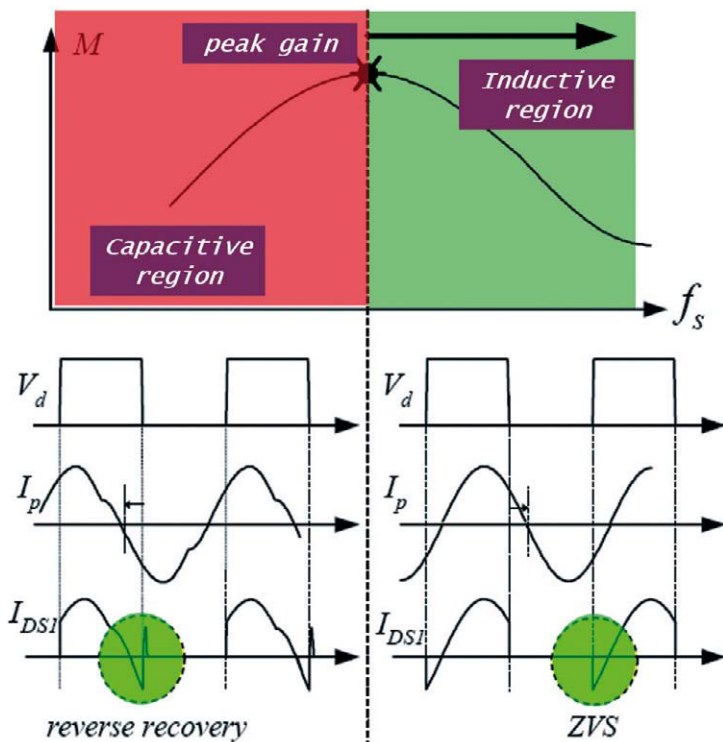

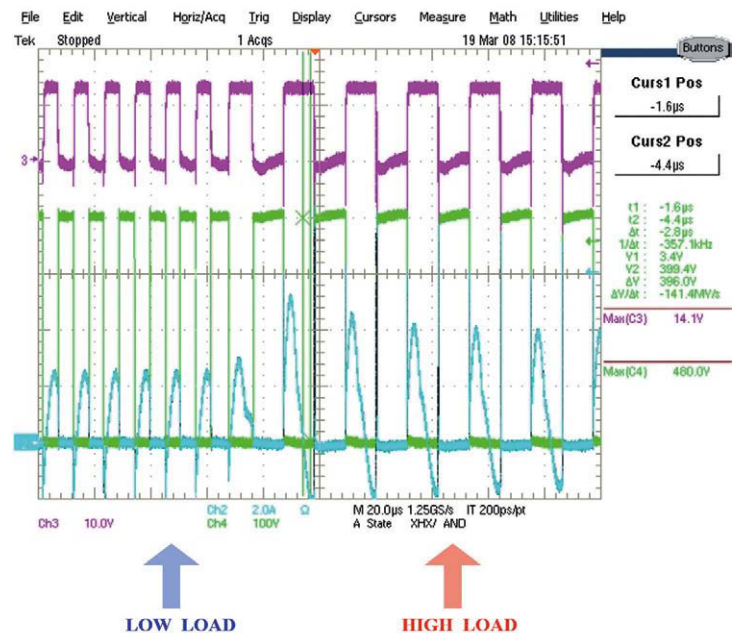Image 6: Time response of the currents with capacitive or inductive input impedance

Image 7: Transition from low to high load

Background of FREDFETs

FREDFETs (Fast Recovery Epitaxial Diode Fet) are MOSFETs with a fast body diode. Siemens introduced them in the late 1980s as better alternatives to standard MOSFETs for hard-switch bridge topologies (half bridge, full bridge, 3-phase bridge) and especially for frequency converters. Common high-voltage MOSFETs are scarcely suitable for bridge circuits when operated at higher switching frequencies because their body diodes have relatively long disable delay times. Rapid switching generates high reverse currents, which cause high losses, particularly in the opposing mechanical switch. Added to this are high interference voltages, which must be reduced again with the help of additional filtering.

Meanwhile, IGBTs (Insulated Gate Bipolar Transistor) have largely eclipsed FREDFETs in frequency converters, motor controllers and similar because they are often the better option in terms of price and in technical terms.

Despite this, FREDFETs continue to play an important role in specific switch-mode power supply topologies. One of these, which is becoming increasingly popular, is the 'LLC converter'. Ideally, LLC converters operate in the resonant mode, which is also referred to as 'soft switching'. For this topology, STMicroelectronics offers MOSFETs with characteristics that are precisely optimized for this purpose as well as LLC controllers (analog and digital), including integrated 600 V half-bridge drivers.

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resonant converter without PFC and the L6699 resonant controller. This incorporates some innovative functions such as self-adjusting, adaptable dead time, anticapacitive protection of the operating mode and a proprietary Safe-Start process that prevents hard switching during start-up.
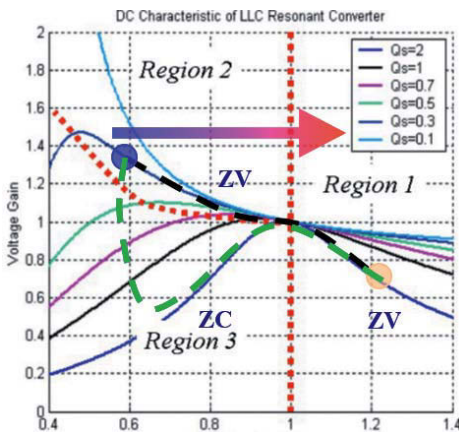

Image 8: Gain with zero-voltage (ZV) and zero-current (ZC) switching areas

The EVLSTNRG-170W evaluation board opens up the possibility of gaining experience using digital control of both the PFC stage as well as the LLC converter based on the STNRG388A digital controller. In this case, the upstream PFC stage operates in what is called "Enhanced Constant ON Time" mode (DCM-CCM boundary), and the LLC converter in "time-shift-controlled" mode (TSC). The board is designed for a continuous output of up to 170 W. The application supports multiple output voltages: 24 V (6 A) for the main application, 12 V (2 A) e.g. for a controller and 5 V (2 A) for stand-by operation (always-on).

Another interesting board for smaller outputs is the EVLCMB1-90WADP. This is a 19 V/90 W converter that is specially designed for the typical specification of an AC/DC adapter for laptops and notebooks. Naturally, the board can also serve as the basis for further applications provided that the output voltage is adjusted accordingly in the target design. It has a wide mains input range (90 V to 264 V AC at a frequency of 45 to 65 Hz) and very low power consumption at low load.

Once again, its architecture is based on a two-stage approach: a transition mode PFC preregulator and a downstream LLC half-bridge resonant converter. Both controllers, for the PFC stage as well as that for the LLC converter, are integrated in the STCMB1 Combo IC. ■

Microprocessors, microcontrollers and their periphery

Process or control?

Every new application design requires a microcontroller or microprocessor. And when making a decision between the two, there are a few factors to consider. An overview of the microprocessor and the microcontroller, and heterogeneous architectures.

By Hao Wang,
Product Manager Digital at
Rutronik

When deciding between a microprocessor (MPU) and a microcontroller (MCU), the type of application is often a critical factor. The final selection, on the other hand, depends on criteria like the operating system and memory. However, sometimes a combination of the two makes sense, and this is referred to as a heterogeneous architecture.

Operating system

For extensive, computer-intensive industrial and consumer applications that are based on operating systems like Linux or Android and require numerous high-speed connections or user interfaces with a broad functional scope, a microprocessor is the best choice. This is because, instead of an operating system, most microcontrollers have only bare metal programming which runs programs almost without any human intervention thanks to sequential processing loops and state machines. Many high-performance microcontrollers, however, can support a real-time operating system (RTOS) such as FreeRTOS in order to respond to processes in real time in a deterministic manner for applications that require hard real-time behavior.

As a universal operating system with a lot of free software, extensive hardware support and a growing ecosystem, Embedded Linux has enjoyed great success. A further plus point: there are no user or licensing fees due. However, an application that runs with Embedded Linux requires at least 300 to 400 DMIPS (ARM-Dhrystone MIPS) which makes a microprocessor the better choice. In this application, a microcontroller does not generate enough computing power nor is it equipped with sufficient memory.

If it is a complex or a time-critical control system, then an RTOS is useful, but requires a high-performance microcontroller that offers at least 50 DMIPS. This is much less than is required for Embedded Linux; the traditional RTOS are designed to be lean so that they run on a microcontroller. This makes sense when it concerns real-time computing hardware, such as an antiblocking system for vehicles where too much latency in the response can have deadly consequences. Even if a larger number of functions, interrupt sources, and standard communications interfaces have to be supported, a microcontroller with RTOS is recommended.

Memory

Another main difference between microprocessors and microcontrollers is normally due to the fact that microprocessors rely on an external memory for saving and executing the program and not – as in the case of microcontrollers – on an embedded flash memory. In microprocessors, the program is normally stored on a nonvolatile memory such as eMMC or Serial Flash, to name a few. During the start, it is loaded into an external DRAM
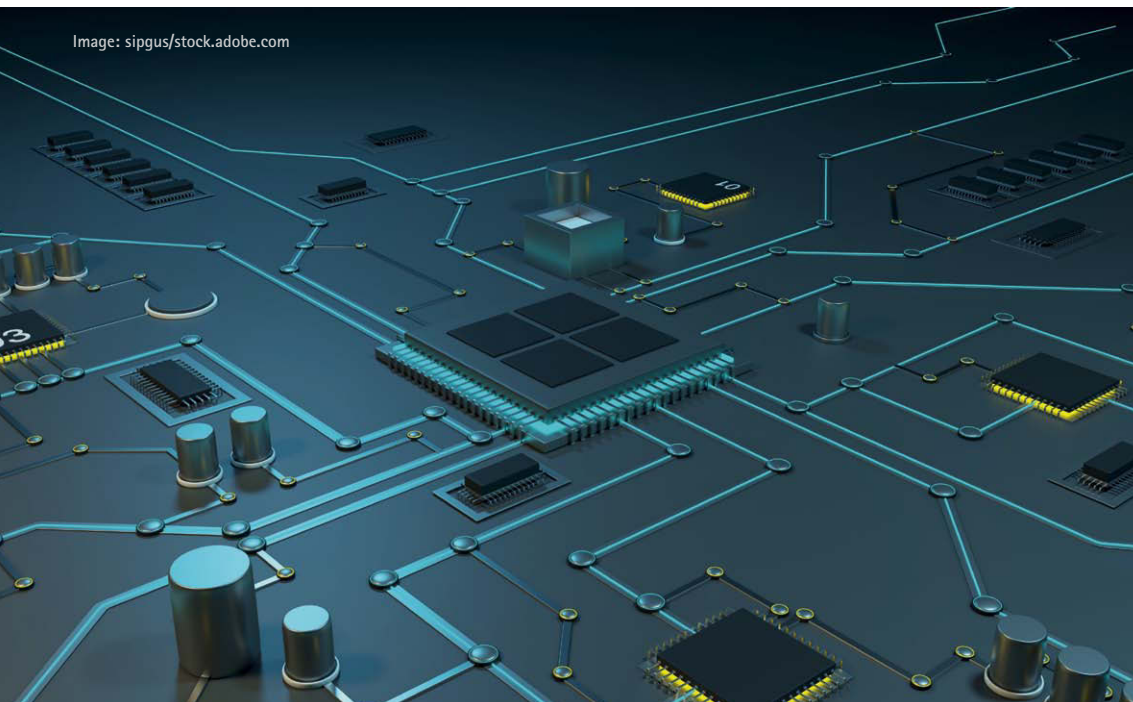
Image: sipgus/stock.adobe.com

and executed here. Both the DRAM as well as the nonvolatile memory can have several hundred megabytes or even gigabytes. This means microprocessors are almost never limited with regard to memory capacity. One potential disadvantage is that the design of the PCB layout can be more complex due to the external memory.

Current high-performance microcontrollers, such as the STM32H7 produced by STMicroelectronics, offer a maximum of 2 MB program memory which can be insufficient for many applications. Because the program lies on an on-chip memory, its advantage is that it carries out start-up and reset processes considerably faster.

Computing power

Computing power is a classic selection criterion. However, the lines between microprocessors and microcontrollers have become fuzzy in this regard. This becomes obvious, for example, if you look at the ARM architecture as one of the most broadly distributed in the microcontroller and microprocessor market. ARM offers different processor architectures for various requirements:
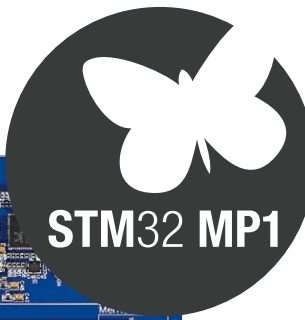
Cortex-A offers the highest performance of all of them and is already optimized for comprehensive operating systems. They are mainly deployed in powerful devices like smartphones or in servers.

Cortex-M are smaller with a more on-chip periphery, however, with lower energy consumption – and thereby optimized for embedded applications.

Dhrystone is used as a benchmark to compare the performance of different processors. Based on this benchmark, the difference between a typical inexpensive microcontroller with 30 DMIPS and a microcontroller with the highest currently available performance, including an embedded-program flash memory, is 1027 DMIPS. In contrast, microprocessors do not start until almost 1000 DMIPS.

Energy consumption

Microcontrollers score highly when it comes to energy consumption, which is quite a bit lower than that of microprocessors. Although microprocessors have an energy-saving mode, their consumption is nevertheless considerably higher than that of a typical microcon-

troller. Moreover, the external memory makes it harder to switch the microprocessor to an energy-saving mode. For ultralow power applications in which a long battery runtime is critical and which have only an infrequently used or no user interface, the microcontrollers are the better choice, particularly for consumer electronics or smart meters.

Connectivity

The majority of the microcontrollers and microprocessors come equipped with all the conventional peripheral interfaces. However, if ultrafast peripheral devices are required, then users will not find the relevant interfaces, such as the Gigabit Ethernet, in microcontrollers. However, they have become practically a standard feature in microprocessors. This makes complete sense because microcontrollers can barely process the data volume incurred. One key question to ask is: are there sufficient bandwidth and channels available to handle the emerging data traffic?

Real-time performance

If it is all about real-time performance, a microcontroller is definitely the component of choice. Thanks to its processor core, the embedded flash memory, and the software (RTOS or Bare Metal OS), the microcontroller does an outstanding job meeting its real-time tasks. Because the Cortex-A microprocessors are masters at pipelining, users can expect an increasing depth of the pipeline with higher latency times during jumps and interrupts. Hard real time is difficult to realize due to the fact that the OS multitasks with microprocessors.

System base ICs

Since a power supply is already integrated in microcontrollers, they only require one single voltage rail. Microprocessors, on the other hand, require numerous rails to supply the core and the other components. Power is supplied, for example, by special ICs, so-called system basis chips, that only have to be configured.

Heterogeneous architecture

Nevertheless, the line between microprocessor and microcontroller is becoming visibly fuzzier. With the introduction of the STM32MP1 with one or two Cortex-A7 cores typical for a microprocessor and a Cortex-M4
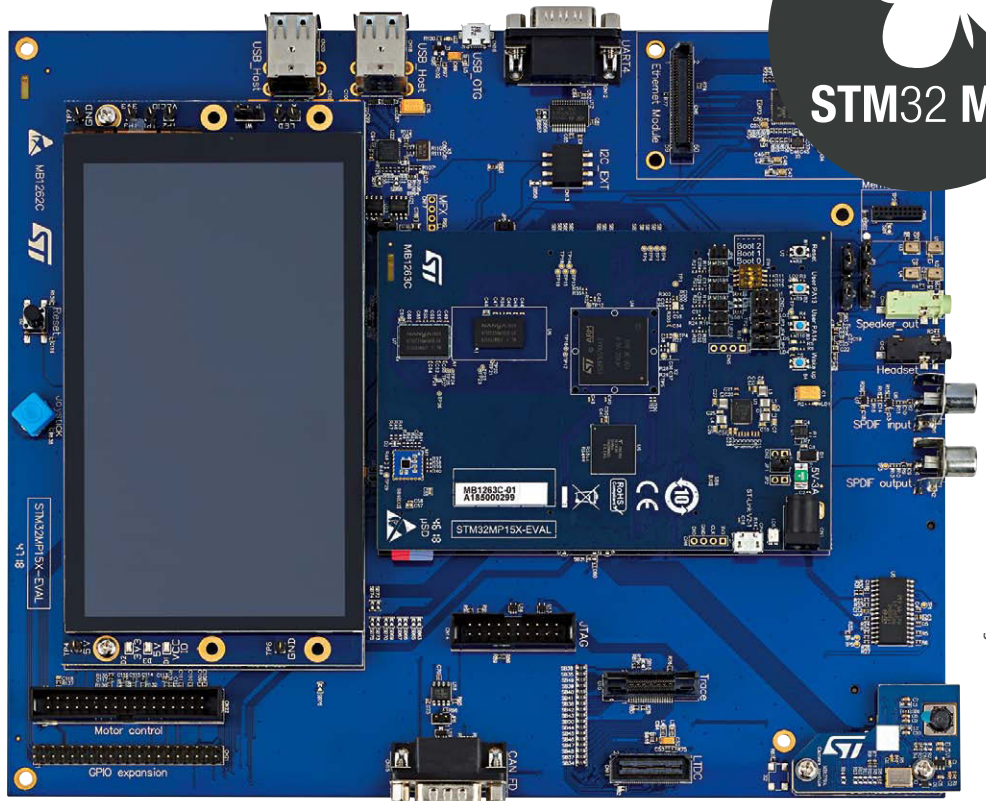

Image: STMicroelectronics

The evaluation board STM32MP157A–EV1 is equipped with many interfaces and a display.

core as a representative of the microcontroller class, STMicroelectronics has added to its portfolio a powerful microcontroller for high-performance and resource-hungry applications based on open-source software. This opens up the option of combining the advantages of both worlds. For example, an OpenST Linux can be run on microprocessor cores while the M4 core runs a FreeRTOS in order to meet the real-time and safety requirements, as needed in process monitoring. Due to this separation, all of the operating system features, such as HMI with touch control and network communication, can be used without going into the safety requirements of the entire application. Heterogeneous architectures also have an advantage when it comes to the latency time during system start or energy consumption because the more suitable processor can be used any time. For example, with the help of its retention RAM, the M4 can wake up in milliseconds while the A7 takes up to one second in latency time to wake up.

Reference design for the STM32MP1

The STM32MP1 is available with the Evaluation Board (STM32MP157C-EV1) and Discovery Kit (STM32MP157C-DK2) as a reference design. Developers benefit from the support with the system design.

It is based on the combination of STM32MP1 and the technologies from proven partners like Nanya. It consists of a 4-Gbit DDR3L SDRAM, a 4 GB e-MMC from Kioxia (previously Toshiba) and an optimized power management IC STMPIC1 as a support chip.

Conclusion – MCU or CPU?

It is hard to say when a microprocessor or a microcontroller is the better choice, but the rule of thumb is that you should always weigh the various pros and cons against one another. The following can be used as a rough guideline:

Microcontrollers are ideal for more inexpensive and mobile applications in which energy consumption is a main concern, as well as for applications with real-time requirements.

Microprocessors are perfectly suited for intense computing applications that run with an operating system and require the high-speed interfaces. Games and other graphic-intensive applications are networked using special microprocessors. ■

Acoustic components in medical applications

Make it sound right

To dimension a small loudspeaker for an industrial or medical application, you don't have to be a hi-fi expert. Nevertheless, the engineer should keep an eye on some basic principles.

BY ANNE SANTHAKUMAR,
PRODUCT SALES MANAGER ACOUSTIC
COMPONENTS & TIMING DEVICES AT
RUTRONIK, AND
MIKE VAN DEN BROEK,
SENIOR APPLICATIONS ENGINEER AT
PUI AUDIO

Transmission of information from a machine to the end user is of great importance in a large number of applications. It allows rapid feedback based on visual or acoustic stimuli and provides the necessary input for further processing by the user. Especially in the medical industry, where very short reaction times can make the difference between life and death, a high degree of attention must be paid to signal transmission.

Acoustic signals are particularly suitable for this purpose, since, unlike optical signals, they do not require permanent monitoring and, if the speaker is dimensioned accordingly, can also function across several rooms. This includes not only the transmission of audio signals by the application, but also the recording of information by microphones.

Focus on safety requirements

Special safety and testing regulations apply to technical applications in the medical industry and are specified by the DIN standard DIN EN 60601-1-8 or the ISO standard IEC 60601-1-8. The regulation is an essential part and required. In terms of acoustic warnings, the regulations highlight two aspects in particular:

- Differentiation between individual devices based on their different tones
- A harmonic component in the tone that audibly helps the operator to locate the device

Manufacturers of medical devices should therefore consult the DIN standard as early as possible in the design cycle, as it may prescribe a specific set of tones and a specific sound pressure level (SPL) that must be reproduced in the finished application.

Choosing the right speaker

There are several components that are capable of processing audio signals. Speakers, buzzers and microphones are the predominant elements of acoustics-based human-machine communication. The components to be used in the medical application are selected primarily according to the specifications of EN 60601-1-8. Buzzers are only suitable for reproducing a single, fixed tone frequency, whereas speakers are capable of playing many different tones at once across a specific frequency band. Due to their wider range of use, speakers are used in most applications.

When choosing a speaker, it is advisable to focus on the lowest tone you need to reproduce and the respective SPL requirement. In most cases, the frequency will be lower than 500 Hz. The values are indicated in the specification sheet of the respective speaker. However, the way in which these were measured must be taken into account. For example, the SPL depends to a large extent on the input power provided by the speaker and the distance at which the microphone was spaced to capture the SPL. However, there is no set standard specifying at which distance the SPL should be measured. Many speakers are listed at 10 cm or 50 cm away from the measuring device.

In addition to these basic values, the conditions of use must also be taken into account: for instance, the measurable sound pressure changes depending on the distance away from the speaker. A speaker with a listed SPL of 86 decibels (dB) at 50 cm will only output 80 dB when the distance away from the speaker is doubled.

Doubling the input power from 1 W to 2 W, for instance, generates an SPL gain of 3 dB,

which represents a sound pressure level of roughly 89 dB at a distance of 50 cm.

When dimensioning the speaker, it is therefore important not only to pay attention to the rated values in the data sheet, but also to consider the everyday conditions of use of the finished device. PUI Audio recommends a few basic steps that may help here:

- Invest in a low-cost SPL meter or download a suitable SPL app.
- Perform multiple measurements of the environment to minimize inaccuracies.
- Create a use case to determine the actual operating conditions, thereby making a realistic assessment of the speaker dimensions.
- Target a value of about 15 dB to 20 dB above the specified SPL in order to achieve the prescribed characteristics even at a certain distance.

Interpreting a speaker's power rating correctly

In addition to the performance data, the operating conditions represent another important characteristic value. All PUI Audio speakers are specified in the data sheet with the rated input power and the maximum input power.

The *rated input power* is the level at which the speaker was designed to play at continuously. In contrast, the *maximum input power* describes the ability of a speaker to sustain instantaneous peaks.

If a speaker is intended to reproduce a continuous pure tone (a sine wave), it is important not to exceed the rated input power, as otherwise there is a risk of the component being destroyed.

Use the peak voltage applied to determine how much power a speaker can dissipate. When using a multimeter that displays RMS voltage, multiply the measured value by 1.414 and then square the result. Then divide the resulting value by the speaker's impedance. Example: According to the formula, a 2 V rms pure tone signal applied to an 8 Ω speaker dissipates 1 W of power.

Voice and music signals do not consist of pure sine waves since a constant tone is not reproduced. The calculation can, nevertheless, be carried out using the aforesaid formula. It is, however, a good idea to check the signal us-

ing an oscilloscope to ensure the peaks of the signal do not exceed the maximum input power of the speaker.

Selecting the right amplifier

An amplifier is essential when using a speaker. Amplifier selection is pretty straightforward as long as you pay attention to certain specifications. – The key criterion is how much power an amplifier can create with a given input voltage condition and impedance load. At the same time, the level of distortion must remain below 1% to prevent any component damage. This is referred to as Total Harmonic Distortion (THD).

Besides causing an unpleasant sound, distortion can also destroy the speaker. Exceeding 1% distortion with an amplifier drives it into a 'clipping' condition. In this case, the amplifier sends DC voltage to a speaker instead of AC voltage, forcing it to its outer mechanical bounds. This causes the leads that con-

nect the input terminal to the voice coil to break.

The clipping effect can also occur to a certain extent with an oversized speaker whose power reserves are insufficient. It is possible to destroy a speaker rated for 5 W with a 4 W clipped signal. As a rule of thumb, PUI Audio recommends selecting an amplifier that has double the power capacity of what you need to prevent components being destroyed by clipping.

PUI Audio is the leading manufacturer of speakers, e.g. in the medical industry. The company's experience and expertise come from decades of business relationships with medical technology firms, delivering effective client consulting and participating in product developments. Rutronik's qualified team of application engineers supports customers when selecting the right components for their projects and provides comprehensive support throughout the entire design cycle. ■
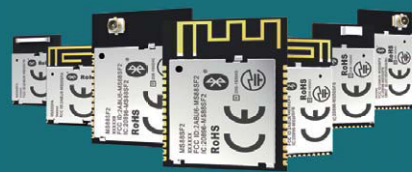
How the STM32L5 Series helps to overcome IoT challenges

Security for networked devices

Based on the principle of hardware isolation, ARM TrustZone technology provides a CPU-based security philosophy in a system-on-chip approach that encompasses a variety of systems. This allows for the creation of secure IoT end nodes and a trustworthy device core. The ARMv8-M architecture expands TrustZone technology to Cortex-M-based systems.
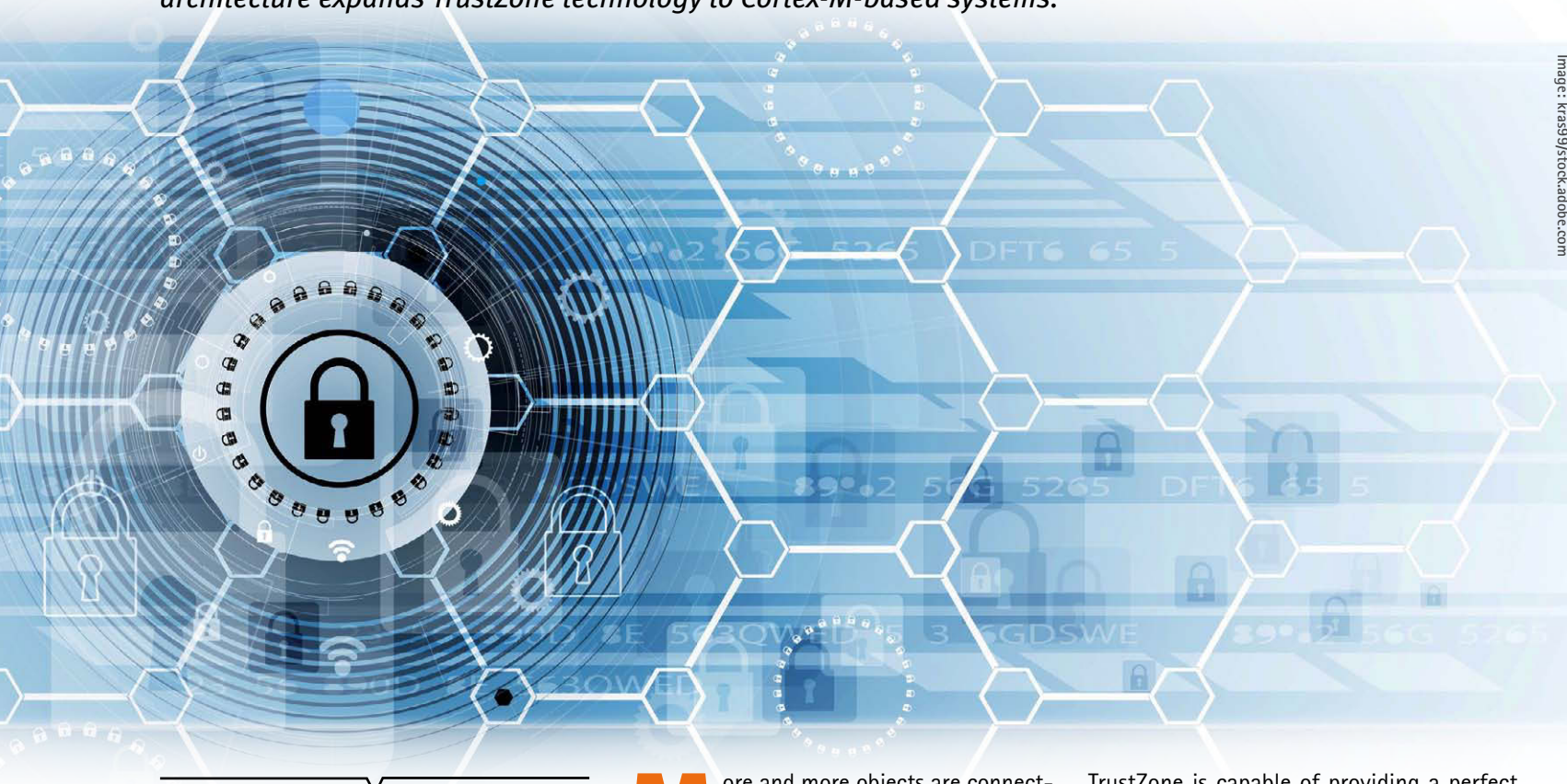

Image: kras99/stock.adobe.com

BY DIPL.-ING. MARTIN MOTZ, PRODUCT MANAGER DIGITAL AT RUTRONIK

More and more objects are connecting to one another wirelessly via the Internet. This has increased the need for reliable security features in IoT nodes, especially for consumer products, industrial devices and home appliances within the home, because such Internet connections provide an attack vector for attacks by hackers – from DDoS attacks (distributed denial of service) to unauthorized access to internal networks.

Priority is given to measures that provide anti-tampering security in system-integrated hardware – namely networked, embedded devices. First and foremost, however, systems at the physical level should have secure boot processes, as hackers frequently target systems' reboot mechanisms. To counter this threat, a variety of software solutions are used that employ hardware security mechanisms. One of these is ARM's TrustZone technology. Like any currently available technology, not even

TrustZone is capable of providing a perfect and everlasting defense against attacks from outside, but TrustZone makes it substantially more difficult to penetrate a system.

Reliable security features at chip level

The heart of the TrustZone approach is made up of two areas isolated at a hardware level: a "secure world" and a "nonsecure world". These can be implemented simultaneously on a single core. This prevents secure software from directly accessing insecure resources. The isolation of the two areas within a system-on-chip (SoC) encompasses not only the processor but also the memory, bus activities, interrupts and peripheral devices.

This is the foundation on which TrustZone technology establishes a basis for system-wide security and creates a trustworthy plat-

form on which any part of the system can be flexibly conceived as part of the secure world. Creating a security subsystem allows assets to be protected from software and hardware-based attacks.

TrustZone can secure both a software library and an entire operating system for execution in the secure world. Nonsecure software is not accessible when accessing the secure page and resources located therein.

TrustZone technology for Cortex-M

The ARMv8-M architecture expands TrustZone technology to Cortex-M-based systems and provides robust protection with lower costs than with a dedicated IC.

It substantially reduces the costs and development workload for processor-based security, thus ensuring that security hardware is no longer a relevant cost factor.

Cortex-M and Cortex-A processors have the same security concepts in principle, but also have key differences. The key advantage of the Cortex-M is that context changes between the secure and nonsecure worlds are performed at a hardware level, which allows for faster switches and greater energy efficiency. Unlike the Cortex-A, absolutely no secure monitoring software is required. The level of security achieved in the Cortex-A processors is much greater, however.

TrustZone is based on the principle of granting the absolute minimum of permissions required. This means that system modules such as drivers and applications are only granted access to a resource where necessary. Software is generally executed in both secure and nonsecure environments. Content is transmitted between the two environments via a routine referred to as "core logic" (Cortex-M processors) or the "secure monitor" (Cortex-A processors).

TrustZone for ARMv8-M is an ideal technology for a Platform Security Architecture (PSA), as the hardware between the normal code and the trusted code basis is isolated. It provides a flexible basis on which SoC designers can select certain functions with the secure environment, allowing for the development of cost-effective and low-energy solutions. TrustZone includes procedures that provide trustworthy hardware for hardware-based secure storage, random number generators (RNGs) and a reference clock for secure time configuration.

The Cortex-M23 low-power microcontroller is the smallest yet also the most powerful microcontroller in this category with Trust-Zone technology implemented. The Cortex-M33 series is optimized in terms of cost and power consumption. The Cortex-M33 series is designed for mixed-signal applications, especially those that require efficient security and – where relevant – digital signal control.

Standardized rules for software development

However, TrustZone is only used to its full potential if recognized data security rules are adhered to during the software development process. This is where the C CERT standard, which specifies "good coding practice", comes into play, ensuring that, for example:

- Variable lifecycle conventions (local, global, auto, etc.) are adhered to
- Preprocessor instructions are unambiguous (e.g. by using include guards)
- Value limits for variables are adhered to,
- Memory limits (e.g. for arrays) are monitored and adhered to

It is implemented by integrating a tool into the development environment that verifies compliance with rules during software development each time it is compiled. Retroactive implementations in existing code can, much like MISRA-C (C programming standard from the automotive industry), be complicated, as violations of the standard necessitate the re-design and recoding of large portions of the program.

In both C CERT and MISRA-C the code undergoes static analysis and is checked against certain coding rules. The difference between the two is that the MISRA-C rules serve to provide functional device security, while C CERT provides data protection and data security.

The STM32L5 family is the successor to the STM32L4+ Cortex-M family and is the first ST product family that is based on the AR-Mv8-M architecture with TrustZone. This makes it much easier for developers to create trustworthy devices based on the PSA Framework with the Cortex-M33 processor, TrustZone technology and enhanced SoC security features. With its wide range of integrated digital and analog peripherals and interfaces, among them CAN FD, USB Type-C and USB Power Delivery, the STM32L5 microcontrollers provide an ideal platform for products such as industrial sensors, controllers, home automation devices (such as smart home), smart meters, fitness trackers, smart watches, medical engineering applications such as pumps and measurement devices and much more.

An upgrade to the Cortex-M33 processor and a cache for internal and external program memory improves the STM32L5's performance compared to its predecessor. An optimized power supply reduces current consumption to 33 nA in shutdown mode and offers maximum energy efficiency for long operating periods.

The STM32L5 also satisfies the need for more security thanks to additional safety features which are typically not present on microcontrollers such as a cryptographic coprocessor and external-storage media encryption. Further improvements include software isolation, secure boot and a specially secured storage area for cryptographic keys.

Specific explanations are provided below on various examples of peripherals (integrated functional units) and their implementation in connection with the TrustZone security concept in the microcontroller series.

Bus interfaces

Configurable Secure Attribute Units (SAUs) support up to eight memory ranges, optionally as secure or nonsecure ranges. The Cortex-M33 processor supports System AHB (S-AHB) and Code AHB (C-AHB) bus interfaces. The S-AHB is used for each instruction call and each access to data in memory-mapped SRAM as well as for instruction calls and accesses to SOC peripherals, external RAM and external hardware. The C-AHB is used with each instruction call and data access in the code range of memory.

Real-time clock

TrustZone provides a completely securable real-time clock (RTC) for a wake-up timer Alarm A/Alarm B as well as customizable time-stamping for secure/nonsecure configurations.

Overview of Global TrustZone Controller

The Global TrustZone Controller (GTZC) encompasses three subblocks:

- The TrustZone Security Controller (TZSC) defines the secure, privileged state of the master/slave peripherals and determines the size of a nonsecure area in the Watermark Memory Peripheral Controller (MPCWM). It notifies selected integrated peripheral units in connection with shared usage of RCC and I/O logic about the secure status of "securable peripherals" such as the RCC and GPIOs.
- The block-based memory protection controller (MPCBB) controls the secure state modes of all blocks (256-byte pages) of the associated SRAM.
- The TrustZone access controller for illegal access events (TZIC) collects all illegal access events in the system and generates a secure interrupt to the NVIC (Nested Vectored Interrupt Controller). Using the subblocks the TrustZone and privileged attributes are configured throughout the entire system.

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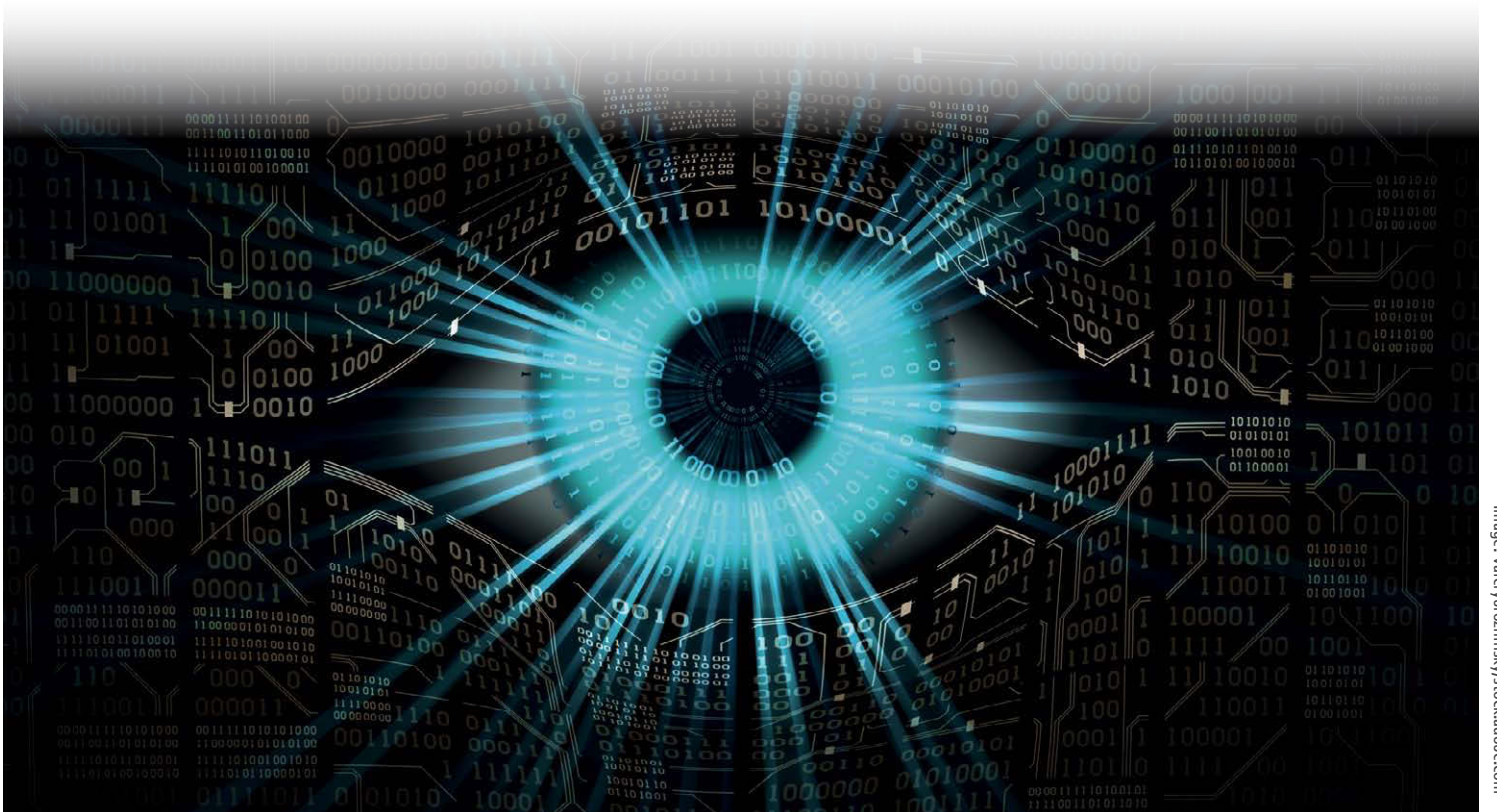
The most important features of the GTZC are:

- Three independent 32-bit AHB interfaces for TZSC, MPCBB and TZIC
- MPCBB and TZIC are only accessible with secure transactions
- The private and non-private area in the TZSC is supported in terms of secure/non-secure access

TrustZone support in the Tamper and Backup Register (TAMP)

For tamperproof/nonsecure configurations TAMP offers backup register configuration in several configurable memory areas as follows: a secure read-to-write area, a secure write-to-read area, a nonsecure read-to-write area and a monotonic counter.

TrustZone in integrated flash memory

TrustZone in the embedded flash memory accounts for 512 kB for storing programs and data and allows for "single/dual bank" operating states and the "read-while-write" (RWW) mode in dual bank mode.

Four security levels are available for the flash memory.

- **Level 0.5** is only available when activating TrustZone. All read/write operations from and to the nonsecure flash memory area are possible on the condition that TrustZone is activated and read-only access is not set. Debug access to the secured area is not possible, although it is still possible to access nonsecured areas.
- **Level 0:** No read protection
- **Level 1:** Memory read protection – the flash memory cannot be read or written to while debug functions are linked or "Boot in RAM" or the boot loader are enabled. If TrustZone is activated, "nonsecure debug" is possible, but booting in SRAM is not.
- **Level 2:** IC read protection

TrustZone Security mode

If the TrustZone Security mode is activated, the entire flash memory is secure following reset, and the following security measures are available:

Nonvolatile, secure flash area with integrated verification (watermark-proofed): the secure area is only accessed in "secure mode" here. In terms of addressability, a memory bank can only be addressed in single bank mode with jumps of 1 kB or the entire memory bank is divided into 4 kB blocks.

Proprietary Code Read-Out Protection (PCROP): this is a part of the flash secured area that offers protection from unauthorized read and write operations by third parties. The protected area is referred to as an "execute only" area and can only be addressed by the STM32 CPU by instruction code. No other access method (DMA [direct memory access], debug, CPU data read, write or erase) is possible. In single bank mode two areas with both secured areas can be selected. In dual bank mode one area per memory bank can be selected alongside the secured area.

The "secure hide protection area" is part of the secured flash area and can be protected to prevent read operations, write operations or access to data in this area.

In a volatile block-based secure flash area, each page can be programmed in real time as secure or nonsecure.

Activation and access permissions

The security architecture is based on ARM's TrustZone technology with the ARMv8-M Main Extension.

TrustZone Security is activated by the TZEN option bit (Trust Zone Enable) in the FLASH_OPTR register. In this case the SAU (Security Attribution Unit) and IDAU (Implementation Defined Attribution Unit) define the access permissions relating to secure and nonsecure status.

SAU is an attribution unit relating to security and is used for the management of hardware security attributes. Up to eight configurable SAU areas are available for security attribution.

IDAU is an attribution unit that relates to access permissions. It covers a first memory partition for nonsecure/not securely accessible attributes where code or data can be stored. These are then combined with the results of the SAU security attribution and the higher security status is selected. IDAU duplicates the memory for flash, system SRAM and peripherals to enable secure and nonsecure states. This process is not performed for external storage, however.
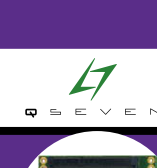
Using the mechanisms specified here, Trust-Zone also affects other areas in the microcontroller in keeping with the principle of a hardware solution.

An extensive yet concise summary of security information (tampering, attacks) in microcontrollers is provided in the Rutronik white paper "Security Aspects" (pp. 74–75): www.rutronik.com/security-aspects ■

Protocol-independent device development in the age of Industry 4.0

IPC speaks the language of the field

In automation technology, industry PCs or IPCs are networked for the most diverse applications with varying field devices. Due to the plethora of industrial networks and protocols, that makes this a huge challenge, yet the Ixxat-INpact PC card family offers an elegant solution.

By MARIO KLUG,
SENIOR MANAGER PRODUCT MARKETING
BOARDS AT RUTRONIK,
AND THILO DÖRING, MANAGING DIRECTOR
AT HMS INDUSTRIAL NETWORKS

Solving complicated tasks independently falls into the domain of IPCs in many automation fields. They run mostly using standard operating systems (Linux or Windows), but are being more and more frequently connected using standardized communications systems with higher-level controllers. That is why there is an increasing need for the devices to support different OT protocols, like production protocols such as Profibus or Profinet. The PC cards from the Ixxat INpact family from HMS Networks offer a flexible and inexpensive option because these cards support numerous protocols. The multi-network capability of the INpact is based on the multi-network processor Anybus NP40, also produced by HMS Networks. The network processor processes all the communication between the IPC and the industrial network. It also facilitates a simple connection from the PC-based or embedded slave applications to the EtherNet/IP, EtherCAT, Powerlink, Modbus-TCP, Profinet IRT, Profinet IRT Fiber Optic and Profibus.

Moreover, the Ixxat INpact allows different hardware solutions to be integrated simply

and flexibly. It is just as easy to connect devices or subsystems as a slave to higher-level networks as well as to display process data in control stations or to record even the largest data volumes in test systems. At the same time, the solution is so flexible that the protocols can be just as easily switched out. The program interface remains the same. Regular firmware updates that also contain product improvements ensure interoperability with the respective current network standards.

INpact, the flexible interpretation family

Cards come in three versions that support the PCIe, Mini-PCIe, and M.2 interfaces which are intended for most products. The card version is equipped with a preinstalled network protocol. Alternatively, for the CE version (Common Ethernet), the respective desired protocol can be flashed by users themselves. This makes the simple exchange between all available industrial Ethernet protocols possible. Currently, EtherCAT, EtherNet/IP, Modbus TCP, Profinet and Powerlink as well as Profibus are supported. At the

same time, each of the functionalities are implemented as a slave for the respective protocols. CC link and DeviceNet add-ons are in the works. All cards function on the standard Windows and Linux operating systems as well as the INtime real-time operating system.

The C programming interface permits the software development of the devices, regardless of the network protocol. Should the device be used in an environment with a different bus protocol, the development effort is minimal. The application bandwidth for the new protocol translator is large and ranges from operator panel manufacturers, complex measurement equipment, high-quality analysis and handling systems to test systems. The following illustrates a few examples.

....

Networking automation devices

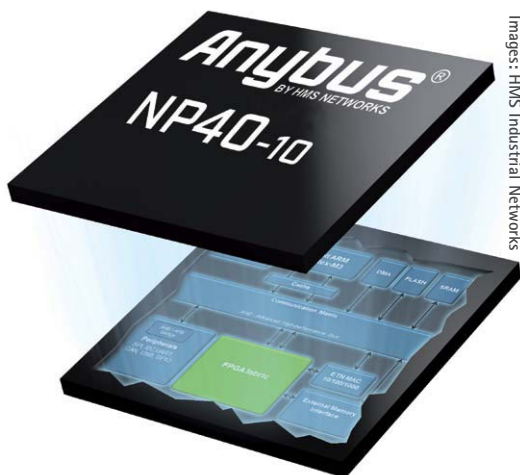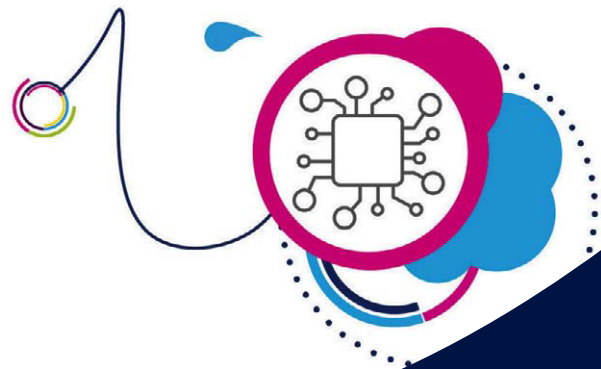..

Complex calculations, e.g. for complicated motion applications, are often performed on site by powerful IPCs at the command of a PLC. Even measurement processes with complex analyses of incoming data performed by the powerful IPC are standard nowadays. The IPC then reports the recorded results or measured value back to the PLC. Standard IPCs, however, often lack the necessary powerful interface to the industrial networks. Depending on the hardware and fieldbus requirement, the INpact cards enable suitable interfaces to be integrated for the respective application. The high-performance INpact cards thereby allow for a higher data transmission rate. Depending on the application, cyclical I/O data with very low cycle times have to be handled, for example to sensors with high scanning rates. Even acyclic data such as algorithms or

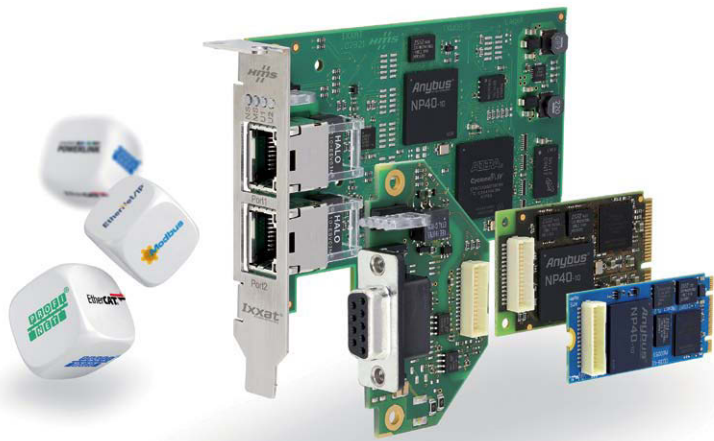**The Anybus NP40 is a multi-network processor that independently processes all communication with the industrial network.**

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The IXXAT INpact family from HMS offers a flexible and inexpensive solution for implementing several industrial communications protocols via PCIe, Mini-PCIe or M.2 card.

The Ixxat INpact is a flexible communications solution for manufacturers of IPCs, operator panels and edge gateways.

audit information are quickly transmitted in this manner.

Operator panels

Nowadays, panel PCs are the tool of choice for machine operators in many areas of automation technology. Usually, an IPC works for this. It takes over the operation and display of machine data. In many cases, it can be necessary for the panel PC to directly access sensor and actuator process data, which requires considerable development time and effort. In this case, too, the INpact cards free the manufacturer from having to provide special network hardware and the associated protocols. The required compatibility with the network on site can be simply established using a plug-in card. This enables device manufacturers to offer a broad product portfolio with low development time and cost.

Edge gateways

Edge gateways function as powerful links in the Internet of Things (IoT) and take on the role of the intermediary between the IT and the OT world, in other words, the production sector with the field devices. They record information on the production process and the devices involved. After preparing and analyzing the data accordingly, the data is then made available to the intended applications in the IT world.

The edge gateways act as key elements that deliver the data basis for all further operations, such as complex calculations for preventive maintenance. That is why the edge

gateway itself has to be robust, reliable and able to be diagnosed and maintained remotely – requirements that an IPC brings with it as a basis from home. What is missing is the option of flexible integration in existing and future OT structures. INpact cards close these

gaps because they offer the option of also transferring large data volumes via different protocols with any preferred PC hardware. Querying diagnosis information via the available API permits seamless integration into the corresponding maintenance solutions. ■

Anybus NP40

The Anybus NP40 multi-network processor from HMS Networks targets manufacturers of automation devices that place great value on a deep technology integration. The NP40 is particularly designed for device manufacturers with medium to high unit volumes. This network processor is a flexible and inexpensive option to integrate automation devices into the most diverse industrial networks. Because it processes all of the network communication independently, it relieves the host processor in the automation device from having to perform this task. The Anybus NP40 is designed to meet the high requirements of the real-time Ethernet protocols as well as the TCP/IP communication with high data volumes. It offers high-performance, extensive flexibility, and low power consumption.

The Anybus NP40 is a flash-based single-chip network processor consisting of a

high-performance ARM Cortex-M3 and an FPGA. The FPGA is used to implement the different physical Ethernet interfaces, including the integrated real-time switch while the ARM core is used to play back the protocol and application stack. Because the NP40 is flash based, automation devices with NP40 implementation for different industrial Ethernet networks can be reprogrammed. This means that a single hardware platform can support several networks simply by loading the new firmware.

For high-performance real-time networks, the processor architecture makes data exchange possible with practically no delay. The Anybus NP40 supports the following industrial Ethernet protocols: Profinet, EtherNet/IP, EtherCAT, Modbus-TCP, Powerlink, CC-Link IE Field and BACnet/IP as well as the fieldbuses Profibus, DeviceNet, CANopen, and CC-Link.

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Protect data with Swissbit

Memory cards for data protection

Where data storage solutions are required for industrial applications, the key selection criteria must include robustness, durability, safety against failure and long-term availability of the flash storage media. Noteworthy too: demanding security requirements can be addressed with special versions that feature WORM (Write Once Read Multiple) or cryptography functionality.

BY ADRIAN ELMS, SENIOR MARKETING MANAGER AT RUTRONIK, AND HUBERTUS GROBBEL, HEAD OF SECURITY PRODUCTS BUSINESS DIVISION AT SWISSBIT

Our increasingly networked world in the age of the Internet of Things (IoT) is, at the same time, increasing the threats of misuse, sabotage, data theft, counterfeiting etc. Cybersecurity has become a key concern for a wide range of applications – from the automotive industry to the Smart Factory. Here, the attack vector is through vulnerable software. For all-round full protection, hardware solutions can also complement pure software solutions. Here, a Trusted Platform Module (TPM) is used for encryption, for example, or a secure element as a tamper-proof memory and security anchor. To ensure secure operation of a system, booting should already be monitored seamlessly as a Trusted Boot.

This concept ensures that software can only be launched on specific hardware or hardware classes. The boot loader uses an authentication secret that is only available within the boot environment (BIOS/UEFI). Swissbit's approach: essentially every system requires memory, for example as boot media or for data collection, and this is where the solution comes into play. The secure element isn't fixed to the hardware but provided as a removable component like a dongle for example. This makes security solutions retrofitable!

This opens up a variety of new approaches for security solutions for secure boot, data protection, license protection and secure identification of connected devices within a M2M communications network. At the same time, since only standard interfaces for SD memory cards or USBs are needed, systems designers can be flexible in their selection of hardware. TPM functionality can be implemented by the smart card in the Secure Storage Card as a Java Card Applet.

Copy prevention and authentication

In 2015, Audi, the BMW Group and Daimler paid 2.8 billion euros to take over Nokia's geo-data company Here – indisputable evidence of the significance of navigation systems at the dawn of autonomous driving. Commonly, SD memory cards are used to load map data into a navigation system. Swissbit cards with hardware encryption enable data image protection.

The use of flash memory devices with secure element offers direct benefits such as navigation-system data control and ensuring compliance with license terms.

Special flash memory products by Swissbit allow for diverse solutions for data and counterfeit protection as well as cryptography.

Image: Swissbit

Memory cards with integrated smart cards make it possible to assign vehicles with tamper-proof identities as the basis for authentication applications. In the future, infotainment systems within vehicles will become increasingly important as an interface to ITC devices and the Internet. The secure element makes it a secure platform that can be used to provide paid services, obtain media content, or pay tolls for example. New functions can be retrofitted and protected to the highest cryptographic standards.

Data protection and functional safety

In recent years, increasing connectivity within and outside the car, i.e. Car2Car Communication, has made protection and defense against cyber attacks a much-debated key concern, mainly with regard to possible consequences for functional safety. Communication of ECUs via bus systems can be encrypted if, for example, at certain nodes an eMMC (embedded Multimedia Card) with Secure Element serves as a TPM. Thanks to this authentication feature, the risk of tampering with in-vehicle communications can be averted.

Tamper-proof recording

Demand for security solutions will increase significantly. Not only for embedded systems for the Industrial Internet of Things (IIoT), but also for ordinary everyday applications, where safeguarding of recordings or events is required. These include, for example, smart meter readings or log files in industrial systems, and of course current fiscalization of cash registers. E-mobility charging stations will no doubt need similar solutions in the near future to safeguard billing processes. As soon as a drop in fuel tax calls for consumption-led taxation of e-mobility, fiscal processes will also need to be implemented. The solution: an audit-proof record can be achieved using WORM (Write Once Read Multiple) memory functions that ensure that data is written only once and can no longer be deleted. For export, data within the WORM memory is linked to a digital signature to ensure its authenticity and integrity.

Design

Swissbit's secure memory cards consist of a flash memory chip, which, beginning at wafer level, are produced and tested to industrial

standards and powered by a special version of the durabit firmware with integrated AES 256-bit encryptor. With the DP (data protection) version, all data is encrypted and protected in various ways (CD-ROM mode, PIN protection, hidden memory, WORM mode). The standard edition for authentication and PKI applications, the voice edition with elliptic curve cryptography for mobile applications, and the premium edition with symmetric and asymmetric encryption all feature an Infinion/NXP smart card chip CC EAL 5+/6+. For applications subject to FIPS (Federal Information Processing Standard) requirements, an option with NXP smart card chip FIPS 140-2 Level 3 as a secure element is also available. Swissbit memory cards as described above are also available as various flash types – MLC (Multi Level Cell), pSLC (pseudo Single Level Cell) and SLC (Single Level Cell) – and in various sizes. An SDK and a PKCS#11 library for using the

API are available for the development of applications.

Conclusion

These examples are just a snapshot of the diverse applications, where data storage and provision as well as access and communication protection can be simply achieved with a single solution. Swissbit's extremely robust and durable flash memory devices with security features make them particularly suitable for challenging applications with long life and maintenance cycles. The use of standard interfaces has the advantage that retrofitable and upgradable applications can be developed. Considering cybersecurity is still a constant battle between attacker and defender, a replaceable security device can even be an insurance for the future for new products. ■

Wireless protocols in automation technology

What are the wireless standards that make Industry 4.0 work?

As Industry 4.0 is implemented, besides gigabit lines, wireless technology will increasingly be taking its place on the industrial scene. The question is no longer if, but how and when will wireless technology take hold. Here are the most important answers.

BY BERND HANTSCHE,
DIRECTOR PRODUCT MARKETING EMBEDDED & WIRELESS AT RUTRONIK

Avoid broken cables between sensors and industrial robots by equipping them with a wireless interface.

Image: phonlamaiphoto/Fotolia

S tandards for the wireless transmission of measurement and control data have developed a great deal, which is causing even the most recent critics to rethink their stance of "our system must operate – wireless is not secure enough." But deciding which standard is the most appropriate depends on the application.

Field level I: Close to the workpiece, but must be flexible, self-sufficient, and maintenance-free

On newer production lines, one is struck by the first sensors and actuators that manage without cables and sliding contacts. They are flexible to install and they enable totally new motion sequences in production processes. Previously, a flat battery, which causes a production stoppage, has been the most frequently cited reason for not installing such solutions. But now, self-powered sensors and actuators are standing the test. With their energy-harvesting modules they are able to convert ambient-light energy or heat differences into sufficient electrical power to be able reliably to send data packets over short-range wireless connections, up to a few hundred meters away. A local energy storage unit ensures failure-free functionality for weeks, if at any time it is not possible to harvest sufficient energy from the environment. Besides the Sub-GHz protocol EnOcean, Bluetooth 5 and ZigBee 3.0 on the 2.4 GHz band are also available to network the sensors and actuators.

The ZigBee Alliance appears to have learned from the mistakes of the past. So version 3.0 is proving popular not just in the Amazon Echo, Philips Hue, Ikea Trådfri and Osram Lightfy, but also – due to its specifications – in the industry sector too. A compatible En-

Ocean module combination takes care of the energy harvesting with ZigBee. The wireless unit – like the wireless stack – is based on a semiconductor supplied by Nordic Semiconductor.

For straightforward P2P connections or for interaction with a smart phone, tablet or laptop, Bluetooth can likewise be used and is fully self-powered.

If a wider range is required or if, due to the frequency plan, it is not possible to use the 2.4 GHz band on the site, the EnOcean protocol from the EnOcean Alliance offers a proven alternative. This too deploys EnOcean modules for energy conversion and wireless communication. As a distributor, Rutronik is working together with EnOcean GmbH and the EnOcean Alliance, as well as with Nordic Semiconductor. It means that developers throughout the industry can find a solution even for software-specific adaptations and for more complex problems.

Field level II: Always on receive – cross-linking inside the factory building

In larger and more complex networks, where connections make use of sensors or actuators to the gateway, hub or to an edge computer, what looks like the perfect solution – because it is maintenance-free and self-sufficient – soon reaches its limits. Particularly with non-time-synchronized mesh topologies each wireless node must be permanently on receive in order to receive incoming data packets and ensure that they are processed immediately. This requires a supply of permanent and more intense energy. In the case of stationary wireless nodes, wired power sources are available, while for "floating" wireless nodes Airfuel charging technology is the mobile alternative that allows a lot more movement than Qi charging technology. The best compromise to meet different requirements is generally the traditional battery.

Many wireless standards, such as Bluetooth Mesh, Wi-Fi Mesh and ANT Blaze, have a history based on a star topology and for a few years have also been supplying mesh topologies. ZigBee, Threat and some others were designed from the start for mesh networking communication. While Wi-Fi Mesh manages with practically zero power supply, all the other mesh systems mentioned can operate for months on one battery charge. Compared with the home sector, where ZigBee controls the LED light sources, it is apparent that unrouted

Bluetooth Mesh sets the standard for industrial lighting systems in warehouses and production halls, open-plan offices and hallways. Unlike the conventional method of specifically routing data packets, with these, the data flow ensures particularly rapid reaction and throughput times. Despite this, smartphones and similar can be integrated into the network, providing another huge advantage over other wireless standards which have to find their way to the IT equipment via a router.

Bluetooth Mesh is an intermediate layer which can in theory be placed on any Bluetooth 4.0 hardware. However, due to the latest pricing system set by the Bluetooth Special Interest Group, when designing a new system, it is a good idea to use more up-to-date Bluetooth 5 or 5.1 hardware. Rutronik supplies semiconductors with the relevant stacks from STMicroelectronics, Redpine Signals, Nordic Semiconductor and Toshiba. If you prefer a solution with integral high-frequency circuitry and certification, you can choose Bluetooth Mesh modules from Insight SiP, Garmin, Panasonic, Murata, Telit, Fujitsu, Minew and Redpine Signal.

Field level III: Outside visual range, but closely connected

At transshipment points such as logistics centers, railway stations and ports, long-range wireless is the method of choice. Of the technologies using public and license-free ISM bands, LoRa has become established in most central European countries. France and the Netherlands have mainly settled on Sigfox because of its good network expansion.

However, 2019 saw a changing trend: the Cat M1 and Cat NB1 4G standards for narrowband IoT have experienced strong growth, depending on the region and the application. The initial test phases have already moved into series production. While the LTE-M is available for tracking applications with cell changing, the LTE NB1 uses even less energy.

Nevertheless, in many countries the network is undergoing expansion and low-power mobile wireless technology is being deployed. German mobile wireless suppliers are clearly concentrating primarily on the metering market. Since an installed electricity, gas or water meter does not move, there is no need to change mobile wireless cells during a connection. Providers in other countries prefer to opt for tracking applications for moving objects and have focused on expanding category M1. Most mobile wireless module manufacturers
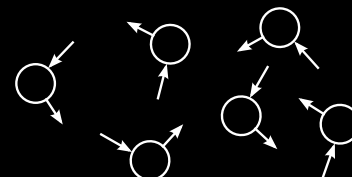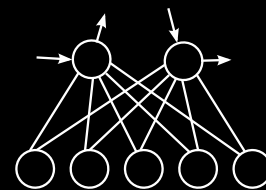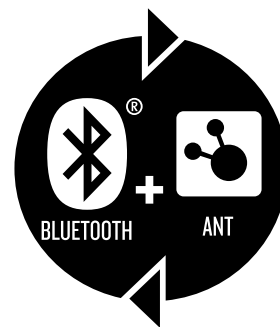
"Innovation in Automation"

The latest wireless technology

The "Innovation in Automation" series of online seminars provides informative videos on demand from the leading manufacturers of electronic components for Industry 4.0. They demonstrate solutions for the industrial plants of the future; subthemes are artificial intelligence, robotics and networks. The seminars also include a presentation by Telit as a supplier of mobile wireless, M2M sim solutions, IoT device management and short-range wireless, and by Intel, producer of Wi-Fi 6 solutions. Simply register at www.rutronik.com/iia to view the seminar videos.
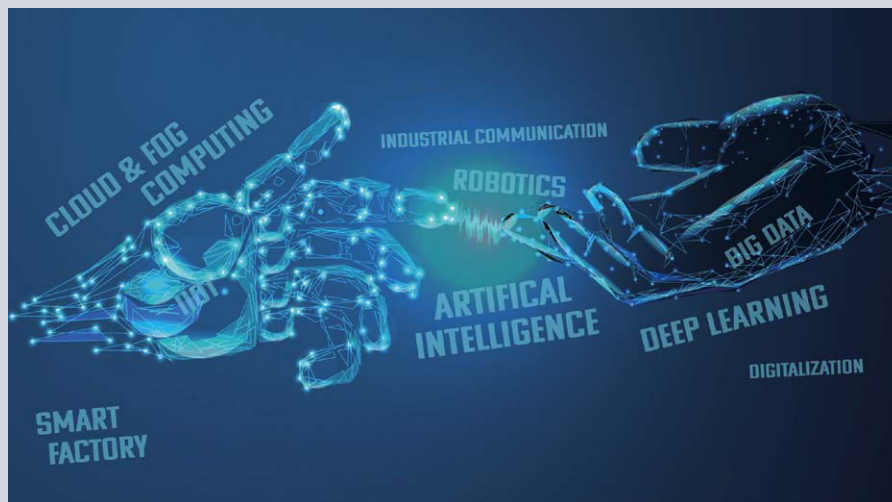
Image: Rutronik

support both networks; Rutronik has solutions from Telit, Nordic Semiconductor, Murata, Telic, Advantech and, soon, from other partners.

Like 2G, 3G and conventional 4G modules, LTE M1 transceivers are also often combined with GNSS (Global Navigation Satellite System) into a single housing because they are intended to track and monitor the position and motion of containers, vehicles, high-end goods, people and animals. The position has to be defined and transmitted via the mobile wireless network. A few years ago, GPS was a navigation system that was almost without competition. But GNSS alternatives were made available in the form of the Russian Glonass and the Chinese Beidou systems, although they are not quite up to the standard of the American system. In 2019 the European Galileo made its breakthrough; it has been operating successfully in millions of smartphones for some time now. In mid 2019 the decision was made to make greater tracking accuracy available free of charge, so that Galileo is now ahead of the GPS system with regard to free use of layer 1 data. In addition, Galileo is the only system to provide an authentication function. This ensures that the received signals actually come from Galileo and not from a counterfeit transmitting station. And Galileo

is the only civilian system operating within a democratic country. Nevertheless, almost all users would be best advised to install as many systems in parallel as possible. Because the more satellites that are used, the faster, more energy efficient, and more accurate can most modern multi-GNNS receivers work. However, we should be ready for future changes and be able to react if one of the systems should fail. The NB1 or M1 modem available in the module can be used to change the firmware settings.

For applications using GNSS with LoRa, Sigfox, Wi-Fi or Bluetooth, it is necessary to ensure a corresponding option to access the GNSS unit's operating mode in the host controller. Usually it is sufficient to create an NMEA control command, to tell the receiver which systems it should use, and which it should ignore. This remote functionality must always be implemented manually and in the worst case it could prove disastrous for the application but could also be a life or business saver.

Process level:
Welcome to 6th generation Wi-Fi

At processing level all the data from the individual workstations are collected together. Of-

ten the data collected at the field-level sensor has not been prepared at all. To obtain information from it, a minimum of a preliminary processing of the data takes place. For many applications it is advantageous to be able to use this to compare several field data received in parallel. Elaborate pattern-matching algorithms can be set up that not only compare against both static patterns but which constantly need to adjust their reference as well. To cope with this and with similar computing-intensive tasks, heavier-duty x86-based systems are used as a general rule.

Here the trend is towards interconnection and in the direction from system-level to wireless technologies. However, the 6th Wi-Fi generation is not just faster than the earlier ones, but is also distinctive for better connection management for subscribers, which scores particularly well in professional installation scenarios. Another plus point is its improved frequency assignment with the soon-to-be-introduced 5G network. With Intel as its technology partner, Rutronik has been able to provide its customers with market-ready Wi-Fi 6 solutions from the start. m.2 PC cards in particular were in great demand for industrial PCs, Panel PCs and NUCs.

System level:
It is down to the location

The choice of technology at system level is heavily dependent on the complexity and the local circumstances, such as the extent of the factory site or the operational frequency plan. For smaller dynamic operations, Wi-Fi 6 can be a solution, while for larger companies with very static installations, a cabled solution would – still – be a solution. Yet as soon as 5G is available and affordable, it will be necessary to rethink these installations too.

Operative level:
Here, the earlier generation is still an option

When communicating between different plants, the information is so heavily condensed beforehand that conventional LTE is fully sufficient to cope with the data throughput and latency periods – even in major international corporations. Those wishing to ensure their cabled on-site Internet connections can already transmit important key operational data by mobile wireless via an LTE router.

Where users opt for field level, where it is a matter of individual sensor data, usually for

the lower LTE categories, it is possible at operational level to opt for LTE category 6 or higher. Power consumption and the price of the modem are negligent because the computers always operate from the mains, and only a very few LTE modems or LTE routers are used. Telit, Telic, and Advantech supply solutions such as PC cards, external modems and routers. For example, an individual total solution might combine them with an Intel or Asus server, configured with an LTE modem from Telit and a Wi-Fi 6 card from Intel.

More wireless trends in automation

Following its success in end-customer smartphones, a further technology is also making headway in industrial environments.

13.56 MHz technology enables secure exchanges between active reader and passive transponder as well as between two active readers. Since it is compatible with almost all modern tablets and smartphones, economical standard hardware is available; there is often no need to deploy more expensive special devices such as an RFID Gun. Besides the cost of the hardware, this provides software programming benefits too.

Those wishing to use RFID for longer distances or to scan several transponders at once still either need to use another frequency or look around on active systems. In this case the transponders are not supplied from the reader's electromagnetic field, communicating via load back coupling, but they have their own power supply (usually a battery or solar pow-

er) and communication in 2.4 GHz band based on Bluetooth or a similar proprietary wireless protocol.

Where neither fixed cabling nor energy harvesting are options, and even economical wireless connections such as Bluetooth Low Energy deplete the batteries too quickly, increasing numbers of industrial applications are choosing the ANT protocol. For example, the first Time-of-Flight sensors will soon be available for high-accuracy distance mapping, which require very little power.

In addition, ANT is available ex works in most Android smartphones, and with multiprotocol SoC solutions that can transmit data traffic in Bluetooth networks without incurring further hardware costs. ■

Bluetooth 5.1

New direction finding function aimed at industrial applications

The Core Specification 5.1 for Bluetooth and the direction-finding function that it contains now allows for direction detection and improves location tracking accurate to just a few centimeters. Thanks to numerous improvements in automation scenarios and indoor location tracking services, Bluetooth will be a serious option for hard industrial applications in the future.

By Felix Graf,
Product Sales Manager Wireless at Rutronik

With the latest generation of Bluetooth Low Energy, Core Specification 5.1, the Bluetooth Special Interest Group (Bluetooth SIG) has paved the way for even more precise location tracking services based on the widespread Bluetooth standard. ABI Research expects up to 431 million products supporting Bluetooth location tracking services to be sold in 2023.

In addition to the known distance tracking functionality using RSSI, the new Core Specification also offers a direction-finding function that allows the direction from which a signal is coming to be determined. This also allows for very precise position tracking, accurate to just a few centimeters, and offers a wide variety of new potential applications, both in the consumer segment and in industrial applications.

Proximity-based solutions and positioning systems

Bluetooth-based location tracking services may take the form of proximity-based solutions or positioning systems (Figure 1). The former are frequently applications that are used to approximate the distance between two Bluetooth devices within range of one another – often smartphones. Typical applications for proximity-based solutions already in use include point-of-interest solutions (POI), for example in retail or museums – when a visitor approaches a POI, they receive detailed information about the object being viewed. Many functions for everyday objects are also based on the proximity-based solution concept. In these applications a beacon tag is placed on the object to be located (keychain, pallet, etc.) that can then be found using the smartphone.

The second type, the positioning system, determines the location of individual objects in a closed system – a defined spatial area such as a warehouse, museum or airport lobby. The most common applications are real-time location systems (RTLS) and indoor positioning systems (IPS).

RTLSs enable multiple persons or objects equipped with appropriate tags to be tracked within a closed system. This makes it suitable for applications such as locating and tracking equipment, pallets or personnel in a warehouse.

Indoor positioning systems are comparable to GPS, but unlike these, they also work in enclosed spaces. Permanently installed locator beacons regularly transmit signals that can be received by devices such as smartphones, which calculate their relative position based on the distance to the individual beacons. This allows passengers or visitors at airports or shopping malls to better find their way around.
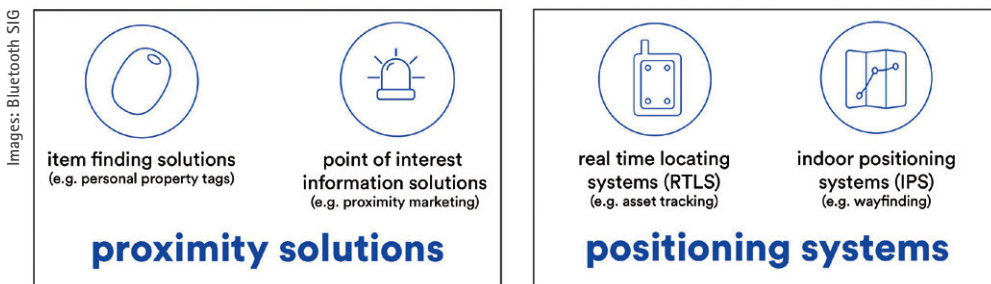
Images: Bluetooth SIG

Bluetooth Location Services

item finding solutions
(e.g. personal property tags)

point of interest
information solutions
(e.g. proximity marketing)

proximity solutions

real time locating
systems (RTLS)
(e.g. asset tracking)

indoor positioning
systems (IPS)
(e.g. wayfinding)

positioning systems

Figure 1: Bluetooth–Based Location Tracking Services

Previously, all Bluetooth-based location tracking systems were based on estimated distances calculated using the Received Signal Strength Indicator (RSSI). Using a reference value and the actual measured signal strength, the receiver calculates its distance from the beacon to just a few meters accuracy (~1 m to 10 m).

Antenna mesh enables direction finding

Direction finding is a new function in Bluetooth 5.1 that allows not only the distance of a signal but also the direction of its source to be determined. Traditional proximity-based solutions also benefit from this, as the direction of a signal is essential information that for example makes looking for an object much easier.

To determine the direction of a signal, either the receiver (angle of arrival, AoA) or the transmitter (angle of departure, AoD) of a location signal must have a permanently installed antenna mesh (Figure 2). In both versions, the receiver determines the direction from which the signal is coming.

However, the direction-finding algorithms are not part of the Bluetooth 5.1 Core Specification. These can be determined by triangulating one or several angles measured using AoA or AoD along with the distance measured using RSSI. This allows location determination that is accurate to just a few centimeters.

AoA for tracking, AoD for navigation in enclosed spaces

In an AoA-based application the transmitter is a beacon with a single antenna, such as a smartphone or a simple tag. Multiple permanently installed receivers (locators), each equipped with a complex antenna mesh, determine the direction from which they receive the signal. AoA applications are especially well-suited to tracking objects (RTLS), such as in automated production or warehouses. They also enable enhanced accuracy when using beacons at points of interest.

AoD-based applications use antenna meshes on the transmitter of a beacon signal to send the signal via the different antennas in sequence. In this case the receiver – probably often a smartphone in the future – will have an antenna to receive the sequential signals. If the position of the beacons is known, the
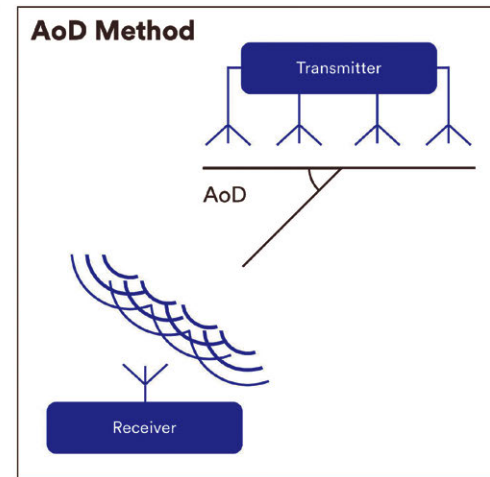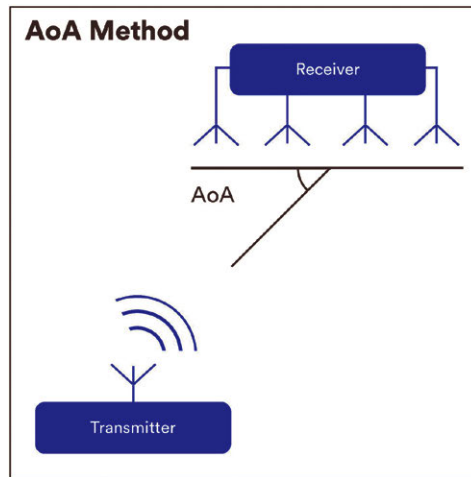
Figure 2: Left: The antenna mesh is in the receiver. Right: The antenna mesh is in the transmitter.

receiver can determine its position relative to the transmitters. This makes AoD-based applications especially well-suited to indoor positioning systems (IPS) for simple navigation in enclosed spaces such as airports. Unlike current IPSs, the user now receives not only their position, but also information about the direction of their destination. Unlike AoA-based applications, the AoD-based method is better suited to situations that rely on connectionless communication.

Design of the antenna meshes

Regardless of the method used, one of the most important success factors for the direction-finding function is the number and arrangement of the antennas. A series of antennas arranged simply in a row allows only the angle to be determined. More complex arrangements in three-dimensional space allow both horizontal and vertical angles to be determined. The Bluetooth SIG has not yet provided any specific requirements or recommendations regarding the arrangement of the antennas, although it is likely that this will change when more profiles on the new location-tracking services are published.

Bluetooth 5.1 has great potential

With the introduction of the latest-generation Core Specification 5.1 for Bluetooth and its direction-finding function, the Bluetooth SIG has taken a major step towards greater precision in location-tracking services, which may enable significant improvements in a variety of application scenarios. However, there are a number of aspects to be considered if this po-

tential is to be leveraged. For example, an ideal application scenario must minimize reflections and multipath interference. The ideal constellation is a closed system with enough permanently installed locator beacons that have the tag in view at all times. For indoor navigation using a smartphone to work throughout the entire area, Bluetooth 5.1 must be integrated into all readily available smartphones. Polarization must also be taken into account when using smartphones, as its direction is almost impossible to control. The limited space in smartphones makes it likely that only one antenna will be available, even in the future, which is why smartphones will only be usable as transmitters in AoA-based applications or as receivers in AoD-based applications.

Forward-looking

Nordic Semiconductor is one of the first manufacturers to offer a multiprotocol SoC (system on chip) with support for the new Bluetooth Core Specification 5.1. The nRF52833 supports not only Bluetooth Direction Finding and Bluetooth Long Range but also Bluetooth Mesh, 802.15.4, Thread and Zigbee as well as proprietary 2.4 GHz protocols, allowing for applications involving distance measurements accurate to a matter of centimeters and direction information. The SoC is based on a 64 MHz ARM Cortex-M4F processor with 512 kB flash memory and 128 kB RAM. Other features include full-speed 12 Mbit/s USB, high-speed 32 MHz SPI and +8 dBm output power. Its analog and digital interfaces include NFC-A, ADC, UART/SPI/TWI, PWM, I²S and PDM. Its supply voltage range is 1.7 V to 5.5 V. The nRF52833 is operable in an expanded temperature range from –40°C to +105°C. ◼

Intelligent displays

Getting to market faster with modules

The demands placed on displays have altered dramatically. Even in industrial applications, users now expect attractive user interfaces with touchscreens and interactive displays as well as intuitive operability. Consequently, it is worth thinking about display modules.

BY NIKOLAI SCHNARZ, PRODUCT SALES MANAGER PROFESSIONAL MONITORS & APPLICATIONS AT RUTRONIK

So-called intelligent displays already contain an integrated controller board including a graphics processor. They can thus be used without additional components such as PCs or single-board computers, both for display and device control with bidirectional communication. Especially for low or medium production volumes, they offer significant advantages over traditional displays. If all components have to be integrated individually, this takes a great deal of time and involves high development costs. The developers have to carry out every step of the design-in process themselves, from selecting suitable microcontrollers, graphics controllers and drivers, to board design, programming, testing and GUI (Graphic User Interface) development. Especially with smaller quantities, the costs and effort can quickly exceed the benefit or even the resources of a company.

For example, use of a TFT display with a 4.3" diagonal (cost approx. €40) including an in-dependent design requires the deployment of two engineers for six months. A TFT display module (cost approx. €59), on the other hand, can be integrated into an application by a developer within about a month. Thanks to reduced development costs, the overall costs are reduced in this case despite higher unit costs for the display module. As many of the time-consuming development steps are eliminated, the time to market is drastically reduced.

All-in-one solution with corresponding software

With its intelligent display modules, manufacturer 4D Systems offers such one-stop solutions for the embedded display sector. With their existing interfaces alone they enable countless extensive applications – without PC boards, which cause additional license costs for operating systems and whose functional

4D Systems display modules can be used to realize a wide variety of applications in almost any size.

Images: 4D Systems

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scope exceeds requirements, especially for simple applications. For example, an intelligent display without an additional controller is sufficient for a fully automatic coffee machine.

However, if the application is to perform complex calculations with database queries, use Internet-based data streams or contain high-performance sensors or actuators, a single-board computer (SBC) or host controller is required. For the connection of SBCs such as Arduino, Raspberry Pi or BeagleBone Black, 4D Systems display modules offer an adapter. In addition, they are compatible with microBus (M-Bus) boards and support microelectronic compilers and microSDK as well as MPLab and Atmel Start.

In order to use the display modules and create applications, 4D Systems offers the free "4D Workshop" software with four different modes: Designer mode allows 4DLG codes to be generated to program the display, while Serial mode allows the module to be converted to a slave device and controlled using any microcontroller host with a serial port. The ViSi and ViSi-Genie modes offer simplified visual programming with accompanying automatic 4DGL code generation.

Seamlessly scalable

Even after the initial creation of an application, the decision between simple displays and intelligent display modules has an effect on the development processes, because other processors are often used in new product generations. For traditional development with a chipset solution, this usually means that the GUI also needs to be adapted. In order to significantly reduce the amount of work this involves, 4D Systems has designed its development environment in such a way that the GUI is also fully supported by subsequent processors.

The same applies when the production volume increases. Manufacturers then often change display suppliers – for example, because they receive more favorable conditions. This generally means, however, that the previous programming has to be adapted to the chipset of the new display. With 4D Systems display modules on the other hand, increasing production volumes without having to invest in new software development is easy. This is because both small and large order quantities are possible and the chipsets remain compatible with the existing software.

Standard modules and customer-specific adaptation

For large displays (1.38" to 7.0") – whether with or without touchscreens – 4D Systems uses TFT technology. For smaller displays without a touch function (0.96" to 1.7"), OLED technology is used because it allows a much thinner structure. The TFT displays are optionally available as open frames or with a cover glass (cover lens bezel). If the display is to be mounted on the inside of the housing, an open-frame version with side mounting brackets is available. If on the other hand the display is mounted on the outside, the glass frame (cover glass) model can simply be glued into the housing.

All 4D Systems display modules are connected via an interface board (USB, 5 V) and require a micro SD card to store the graphic content. In order to ensure the smooth functioning of the application, especially if data from the memory needs to be processed not only temporarily but permanently, it is strongly recommended that industrial memory cards be used. These have higher-quality underlying technology and thus offer more read and write cycles than basic consumer cards. This increases the reliability of the entire application. Such cards can be obtained from Swissbit or Apacer, for example.

With these features, the intelligent displays are particularly suitable for low-volume applications such as fully automatic coffee machines, medical scales, dispensing systems, info displays for smart pedelecs, control panels for soldering and welding equipment in the jewelry sector, 3D printers and timing devices.

In conjunction with other embedded and wireless products, the display modules enhance a wide range of applications, e.g. air-conditioning systems with temperature displays that can also be used for touch control. The display modules are equipped with the serial interfaces I^2C and SPI or RS-232 and RS-485.

The standard modules, which achieve a resolution of up to 800 × 480 pixels, already cover a wide range of applications. In addition, 4D Systems also meets customer-specific requirements, such as a certain brightness level or the antireflective coating of the display, as well as specific certifications for applications in medical technology or the automotive sector. ■
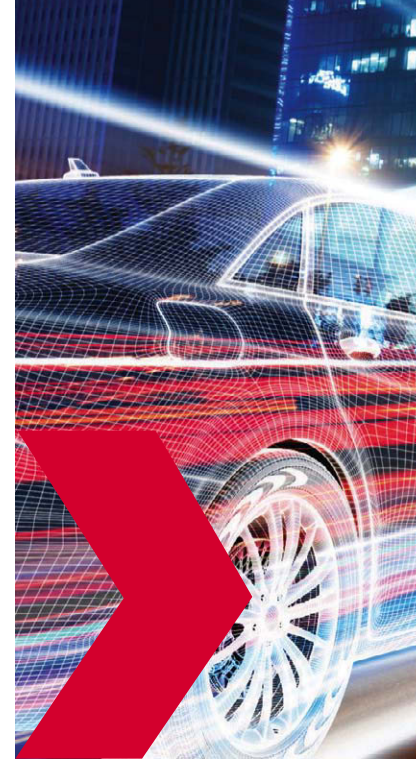
Gesture-controlled positioning function for camera systems with facial recognition

Everything from a single source

Rutronik stands for supporting with system concepts instead of just components. In this example, a face recognition system with a swiveling camera was required.

BY THOMAS KEPCIJA,
PRODUCT SALES MANAGER
ANALOG & SENSORS, AND QI ZHANG,
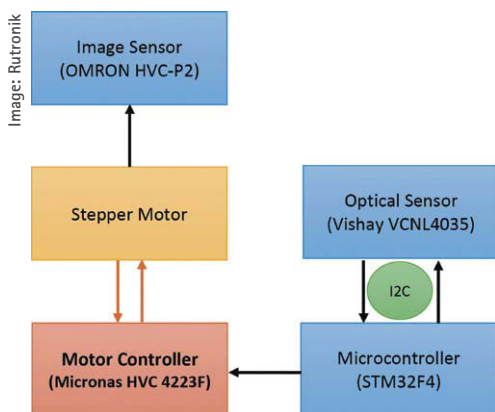TECHNICAL SUPPORT ENGINEER
AT RUTRONIK

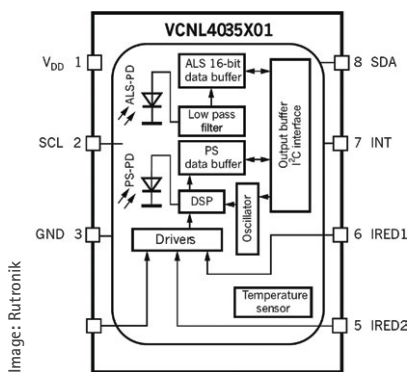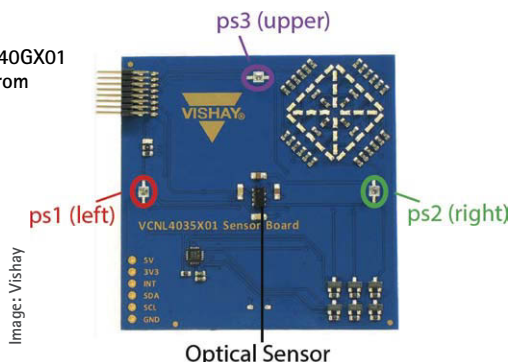Image 1: Schematic of the demonstrator's construction

Image: Rutronik

Image 2: VCNL4035X01 block diagram

Image: Rutronik

Image 3: VSMY2940GX01 Evalkit from Vishay

Image: Vishay

In the city of Hasselt in Belgium there is a parking garage named Q-Park. At the gate, the vehicle's license plate is read by an imaging camera and recorded on the magnetic strip of the ticket that the driver takes. The data is stored on a server, possibly in the cloud. The vehicle is parked so that the occupants can pursue private or business interests. Payment can be made at a machine in the parking garage or, if the occupants are staying overnight, in the hotel. They then get into the vehicle, drive to the exit, and the gate opens automatically once another imaging camera has read the vehicle's license plate and compared it against the data stored in the database. A very convenient concept that eliminates the need to wind down the driver's window or to stand at payment machines to pay parking charges (if staying overnight), as there is a partnership with the parking garage operator and the ticket can be paid at the hotels when checking out.

Put simply, the system consists of two fixed cameras, software algorithms for vehicle license plate detection, a database (in the cloud) and a control system for the exit gate.

This intersystem concept is consistent with Rutronik's strategy of tackling the challenges of system solutions involving many manufacturers and partners and developing a modified version as a pre-study to provide our customers with a proof of concept. The modified version here is one that uses facial recognition instead of license plate recognition. The system consists of a camera with a software algorithm for facial recognition and a motor to turn the camera based on gesture controls.

Rutronik leverages its major strength here – the use of synergies. This means that specialists from the various departments, among them Power, Microcontroller, Analog & Sensor, Wireless, Embedded, Mechanical, and Passive, were called upon to define the components and assign the tasks. This saves time and allows an overarching interdepartmental con-

cept to be presented to the public, in keeping with Mr. Rudel's slogan: "all from a single source."

Functional description for the demonstrator and applications

The task: a maximum of three participants standing next to one another; use a camera to capture one image of each person, and store the image under an identifier in the form of a number or name. The camera head is aligned using a stepper motor to allow the participants to be photographed. The stepper motor is controlled using a high-voltage controller. The motor controller receives instructions via a gesture sensor. A second run is then performed where the position of the participants is switched to verify whether the participants can be recognized using the OKAO Vision technology algorithm provided by the image sensor manufacturer.

Our example application here is granting employees access to company premises, buildings or internal zones within the company. The company takes a picture of each of its employees and stores it in its database or on its cloud server with the appropriate permissions based on the position within the company. Once a live camera image is compared against the database, employees are granted access to the company car park, building and internal zones within the building. Persons who are not employees of the company are denied access and must register through reception or an intercom system. Visitors may be granted corresponding rights so that they can move around within certain zones. Visitors that regularly visit the company may also be stored in the database and avoid the need to register at reception if they are approved beforehand by their contact for their scheduled visit. For employees, the system can also be expanded to encompass the clock-in/clock-out system and eliminates the need for old-fashioned systems such as badges, cards or IDs. It can be
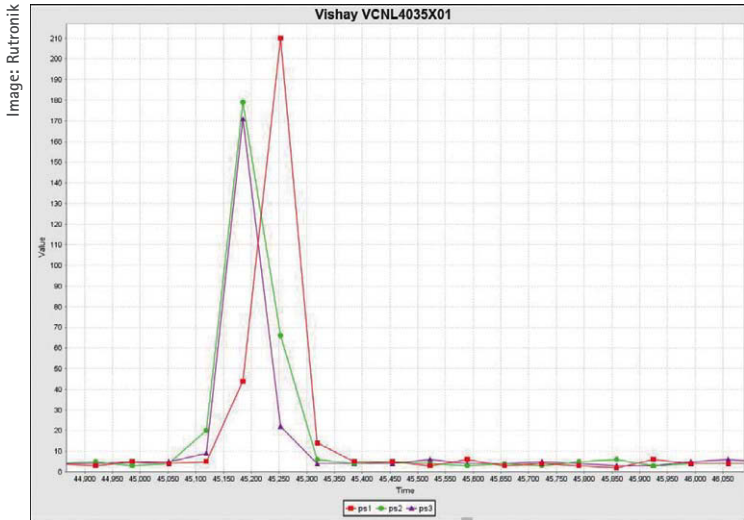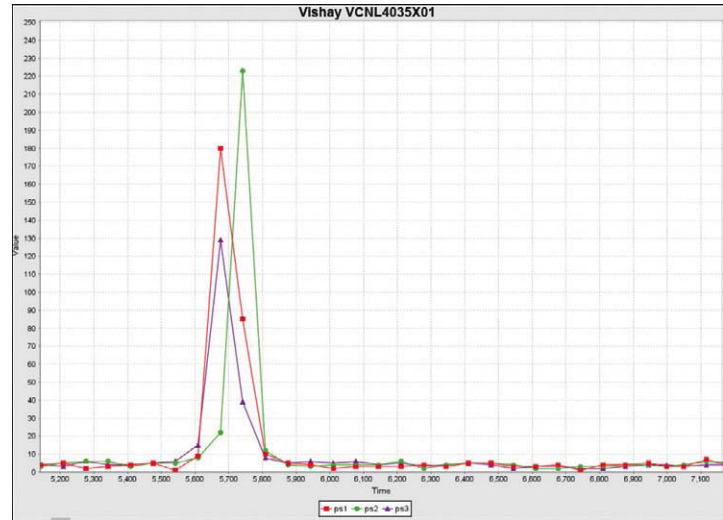
Image 4: Right-to-left gesture: ps2 -> ps1

Image 5: Left-to-right gesture: ps1 -> ps2

used not only by businesses but also by hospitals and other public institutions.

Considering another approach, the camera can also be replaced with fin blades that can be opened or closed by means of gesture control or other sensor technology, for example to control a car's wing mirrors or to control the air intake of a vehicle. There are many other potential applications in which the basic principle of the demonstrator can be used.

Construction of the demonstrator

The demonstrator consists of a high-voltage controller of the HVC 4223F family from TDK, a stepper motor (14HS17-0504S), a proxim-

ity and ambient light sensor (VCNL4035X01) from Vishay, a STM32F4 board and a camera module (image sensor) from Omron (HVC-P2).

The system concept is kept very simple by having it constructed almost entirely from evaluation kits in order to ensure its reproducibility. The Small Demo Board SDB-I from TDK-Micronas includes the HVC 4223F motor controller, while the gesture controller uses a VCNL4035X01-GES-SB board, a Nucleo board from STM with the STM32F4 microcontroller, and the B5T-007001-020 kit, comprising a camera head and mainboard.

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Gesture sensor from Vishay

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The potential applications mentioned at the start are based on a motor drive for the alignment of the camera or fin blade, with control performed in our case via a gesture sensor. The optical sensor from Vishay used here

(VCNL4035X01) is a compact (4.0 × 2.36 × 0.75 mm), multifunctional sensor.

A proximity and ambient light sensor, multiplexer, two 16-bit ADCs, an I²C interface, a programmable interrupt for the proximity and ambient light sensor, a power-on and a shutdown function are integrated. The sensor does not include an integrated IR emitter, but does feature a driver that allows for the connection of three external IR emitters. Vishay's gesture sensor board is shipped with demo software featuring a detection algorithm and display of measurement data. The software can be used to modify certain parameters.

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Gesture detection algorithm

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As previously mentioned, the VCNL4035X01-GES-SB sensor board from Vishay is used, featuring three VSMY2940GX01 IR emitters arranged in a triangle and the VCNL4035X01

LGPIO3	LGPIO4	Motor rotation
0	0	Left
0	1	Right
1	0	---
1	1	---

Table 1: Emulation of LGPIO Pins
(0: low level; 1: high level)

sensor on the board, as shown in Image 3. A red LED shows whether gesture detection is available if the Upper/Lower parameter has triggered the lower/upper switching limits.

To detect which IR emitter the reflected light is coming from, the three emitters are controlled via a switch. This means that they are triggered in sequence and the corresponding reflected signals are measured at the proximity sensor.

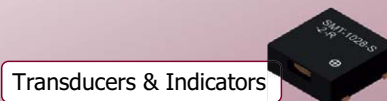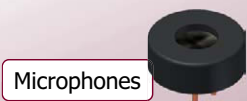Image 6: HVC 4223F Small Demo Board SDB-I

Image: TDK

8-pin motor connector

HVC4223F SDB-I v1.1

I/O test field

23 mm

Power LED

Power Supply 8 to 18 V DC

Stepper Motor

Image: TDK
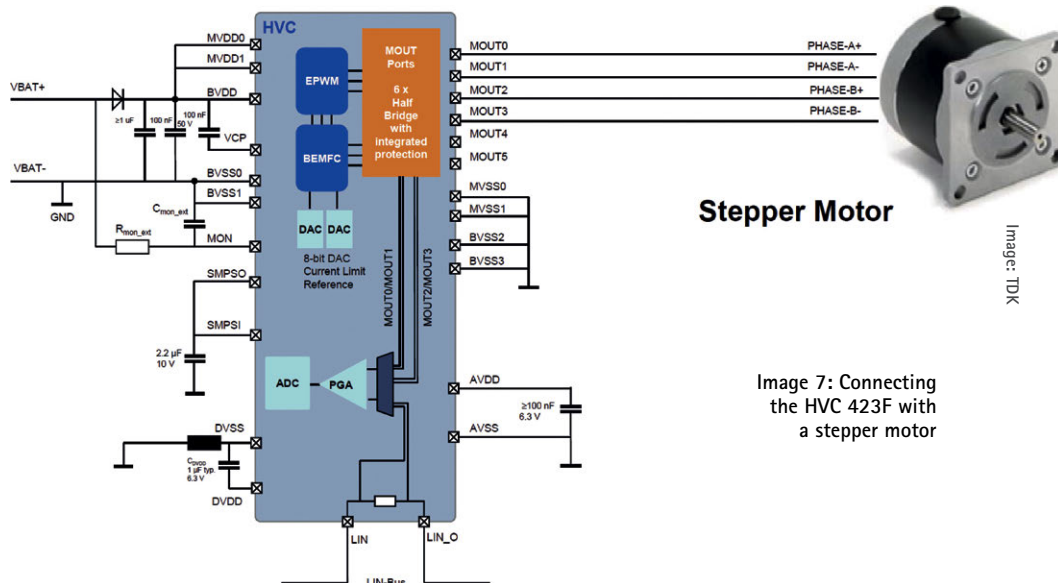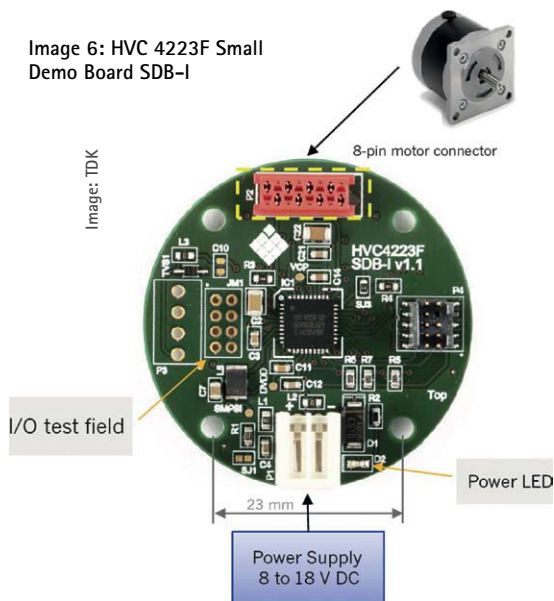
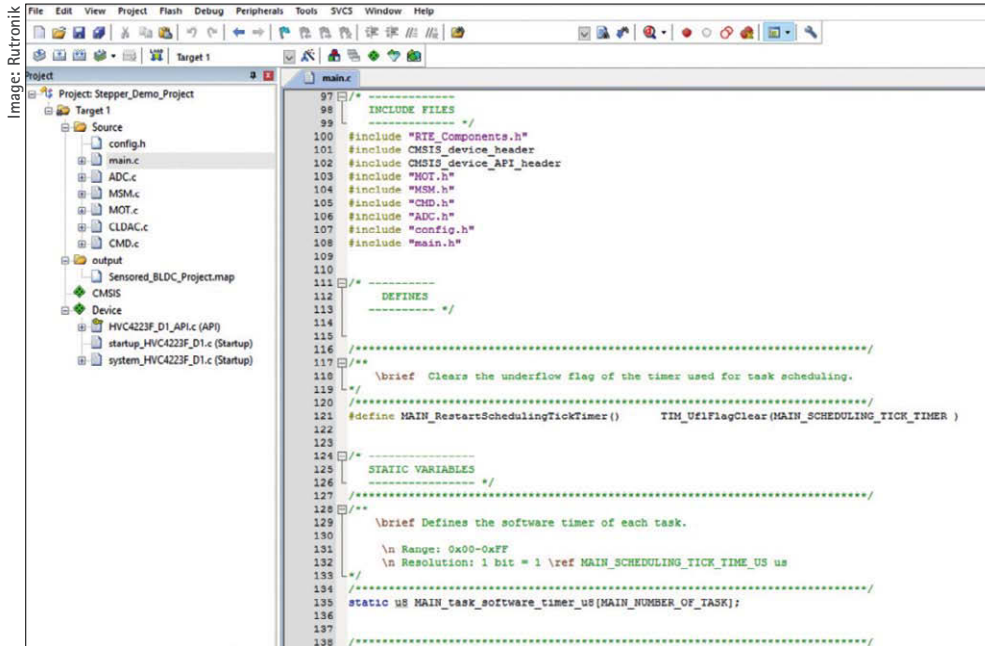Image 7: Connecting the HVC 423F with a stepper motor

Image 8: Keil MDK-ARM v5.14 software environment

A right-to-left gesture causes an event (object) to be detected if the detected signal from IR emitter ps2 falls within the defined switching limits (Upper/Lower parameters). The detected value is stored in a variable, IR emitter ps2 is deactivated and IR emitter ps1 is pulsed, the detected value is stored in another variable, IR emitter ps1 is deactivated and the process is repeated. – A custom-defined algorithm is used to interpret whether a gesture is from right to left or vice versa. The algorithm used by us is called "insertion sort". With a right-to-left motion, a peak value is first expected in the measured values from IR emitter ps2, then in the values from IR emitter ps1. When observing how the values from both emitters develop over time, IR emitter ps2 exhibits a continuously increasing measured value up to the maximum, and then transitions to a continuous decline. The value from IR emitter ps1 is initially constant, but transitions to a continuous increase. Once it

Position feedback from the motor driver

A remark regarding the demonstrator: no position feedback is used, so the microcontroller cannot know in which position the motor is upon power-on. The motor or camera is manually aligned when powered on. This behavior has been implemented for the motor controller. Upon power-on, it is assumed that the motor (or camera) is in its center position. From this center position (0°), the camera can be moved to the left (–30°), and from this position it can only be moved to the right to the center position (0°). From this position, the camera can be moved to the right (+30°), and from this position it can be moved back to the center position (0°).
The following options with position feedback are available by having the motor perform a calibration sweep after power-on using mechanical limit points. Using the software's blockage detection, this position can be detected as a limit position (+X). A mechanical limit position should therefore be established for each rotational direction. There is an additional expense for mechanical design and minor software adjustment. Sensor method: The motor performs a calibration sweep upon power-on and a sensor detects the limit position. When using a Hall effect sensor, two sensors should be used to create a limit position for both rotational directions. Additional expenditure for mechanical design, attachment of a magnet and sensors, plus wiring and software adjustment should be considered.
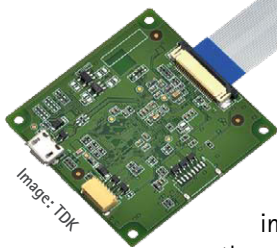
Image 9: B5T HVC–P2 Sensor Module Kit

Image: TDK

has reached its peak value, the value transitions to a continuous decline. The algorithm compares the measured values to determine if the measured signals from an IR emitter are continuously increasing ($Xps2_n > Xps2_{n-1}$); if they are, this value is compared against the value from the other IR emitter by way of subtraction. If $Xps2_n < Xps2_{n-1}$, the previous value ($Xps2_{n-1}$) is compared against the result from the other IR emitter. If subsequent measures from IR emitter ps2 confirm that the value $Xps2_{n}1$ is greater, the maximum measurement has been found. If the subtraction of the values of the two IR emitters always shows IR emitter ps2 to be the minuend and IR emitter ps1 to be the subtrahend, the direction of the gesture is determined by the negative/positive nature of the difference; >0 is a right-to-left motion and vice versa. Variables are used with time stamps. A time window of 300 ms is defined for gesture control with a sample rate of 10 ms and a lower threshold value of 50 mA for an event to have occurred. This means that an event is only deemed to have occurred from a certain height between the object and sensor.

The gesture sensor does not directly provide information about the detected gesture – it simply shows the raw data. The raw data is interpreted in an external microcontroller using an algorithm. The analysis is performed by

Image: TDK
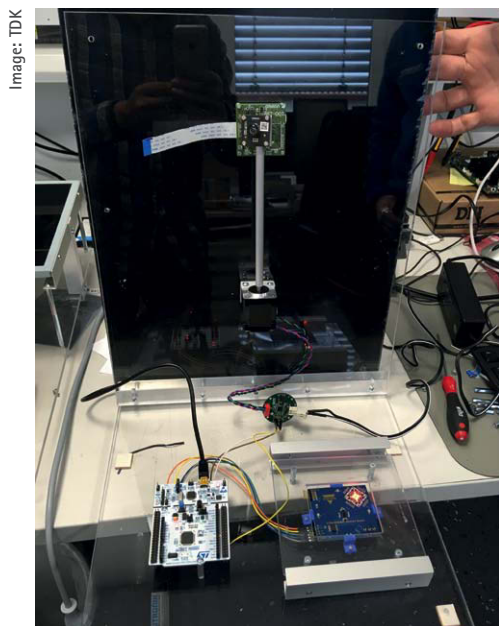
Image 10: Assembled demonstrator comprising the components described

a Nucleo board (STM32F401) to control the motor controller.

Motor driver from TDK Micronas

The HVC 4223F motor controller from TDK, marketed under the Micronas brand, does not possess a hardware I²C interface, but the performance capacity of the integrated ARM Cortex-M3 (T) allows for software emulation of the signals from the Nucleo board on one of the 11 available LGPIO pins. In our construction the first two free pins LGPIO3 and LGPIO4 are used.

The HVC 4223F is distinguished by its optimum integration with components in a compact QFN40 housing (6.0 mm × 6.0 mm). The target applications are smart actuation solutions, both with brushed DC motors and with brushless DC and stepper motors. With integrated half bridges; voltage supply for direction connection to battery voltage, LIN interface and 32 kB flash storage enable integration while largely eliminating the need for external modules. To control a bipolar stepper motor in our example application, four of the six available n/n-channel half-bridge FETs were used.

The HVC 4223F offers hardware support for controlling a bipolar stepper motor by means of current or voltage control. Where current control is used, the measured phase current is compared against a predefined threshold value from the programmable 8-bit DAC. When this value is exceeded, a comparator in the enhanced EPWM module automatically disables the corresponding MOUTx output until it falls below the defined normal operating value again.

Overvoltage, overcurrent and overtemperature monitors are integrated into the IC for diagnostic functions. The chip can be connected directly to the 12–18 V car battery and also has a LIN interface (LIN 2.2 transceiver) for direct communication with the outside. The 32-bit ARM Cortex-M3 processor and 32 kbit flash memory provide enough computing power to support even complex algorithms for controlling devices such as permanent-magnet synchronous motors. TDK-Micronas recommends the Keil MDK-ARM v5.14 software environment, which requires no license for memory up to 32 kbit.

Libraries and source code in the form of application notes are provided by TDK-Micronas as examples for controlling motors, the LIN

Current per phase	0.50 A
Resistance/phase @25°C	15.00 Ω ±10%
Inductance/phase @1 kHz	26.00 mH ±20%
Holding torque	0.23 Nm (2.03 lb.-in)
Step angle	1.80°
Step accuracy (non-accum)	±5.00%
Rotor inertia	18.00 g·cm²

Table 2: Extract from the stepper motor specifications

interface or other general applications. For cases where eventually production software is to be used in the course of development, TDK-Micronas has had an A-Spice-compliant firmware developed by a system vendor that also meets functional safety requirements.

In summary, the HVC 4223F is a versatile motor controller for controlling a variety of small, electric, smart actuator motors. The ARM Cortex-M3 processor offers a sufficient level of performance to implement even complex algorithms for controlling motors. Complete integration of all required components for controlling BLDC or stepper motors reduces development time and thus also development costs and significantly cuts the adaptation workload for other applications following an initial familiarization process. TDK-Micronas supports users with libraries and source code and offers contact with a system vendor that developed production software/firmware for the HVC 4223F module.

Image sensor from Omron

The facial-recognition image sensor from Omron, B5T-007001-020, is connected to the stepper motor via a shaft to enable it to be turned 30° to the right or left. The B5T HVC-P2 sensor module kit used comprises a camera head (1600 × 1200 pixels) and a mainboard that are connected together by means of a ribbon cable.

Omron's OKAO Vision technology is used to provide ten detection functions to choose from. The available functions include facial recognition, human-body detection, gender estimation, age estimation, eye tracking and blinking detection and hand detection. The expression estimation function recognizes five facial expressions (neutral, happy, surprised, angry, sad). Three image output formats are available: no image output, 160 × 120 pixels and 320 × 240 pixels. The kit is available with two different camera heads for wide-angle capture and long-distance capture. ■

Robust and precise barometric pressure sensor

Ideal for wearables

Smart watches and wearables are often used in harsh environments and their features like motion and activity tracking demand the highest precision, fast read-out and low power consumption. For accurate elevation gain, vertical speed and motion detection, barometric pressure sensors are integrated.

By Ralf Kern,
Line Manager at Rutronik, and
Theresa Möhrle,
Product Marketing Manager
Pressure Sensors at
Infineon Technologies

The new DPS368 is ideal for these applications as it saves up to 80% space compared to other waterproof pressure sensors, and offers a precision of ±2 cm and up to 50% power savings compared to piezoresistive technology. The digital barometric air pressure sensor is robust against water, humidity and dust as the pads and membranes are protected by gel (Image 1). It is IPx8 certified and can withstand being 50 m under water for one hour. The pressure sensor element of the DPS368 uses a capacitive sensing principle that guarantees high precision during temperature changes. It is based on the proven DPS310, but comes with a very robust and waterproof package. This combination makes the DPS368 ideal for a variety of applications (Image 2) in harsh environments. Target applications are smart watches, wearables and smartphones (e.g. fitness tracking,

step counting, fall detection, navigation, altitude detection); home appliances (e.g. air flow control in HVAC/vacuum cleaners, water level detection in washing machines, intruder detection); drones (e.g. flight stability, height control), and health care (e.g. fall detection, air flow monitoring).

Robust and sensitive

The DPS368 offers superior resolution, temperature stability, energy efficiency and high robustness. This combination of benefits makes it particularly attractive in battery-powered applications where sensing very small pressure changes is needed – even in harsh environments. The sensor integrates both barometric pressure and temperature sensing (Image 3) into a single, extremely

All images: Infineon

Gel

Package

Package Substrate

MEMS & ASIC
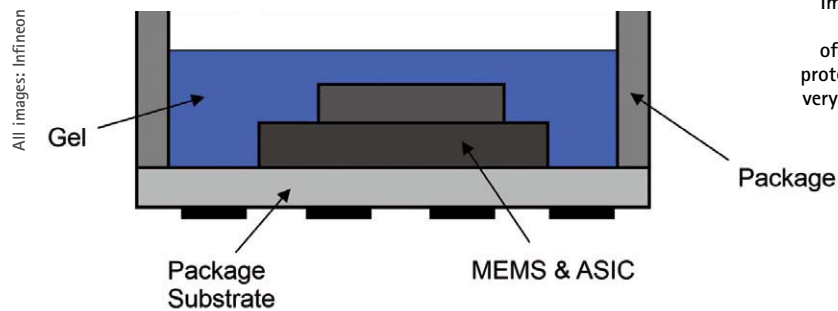
Image 1: The ASIC and MEMS chip of the DPS368 are protected by gel in a very robust package.

Image 2: The DPS368 is ideal for precise pressure sensing in various mobile devices and wearables that are often used in harsh environments.
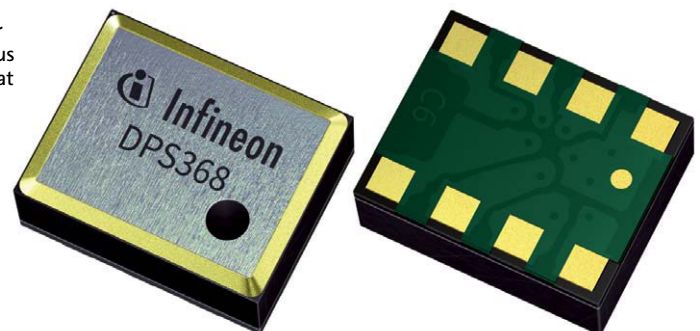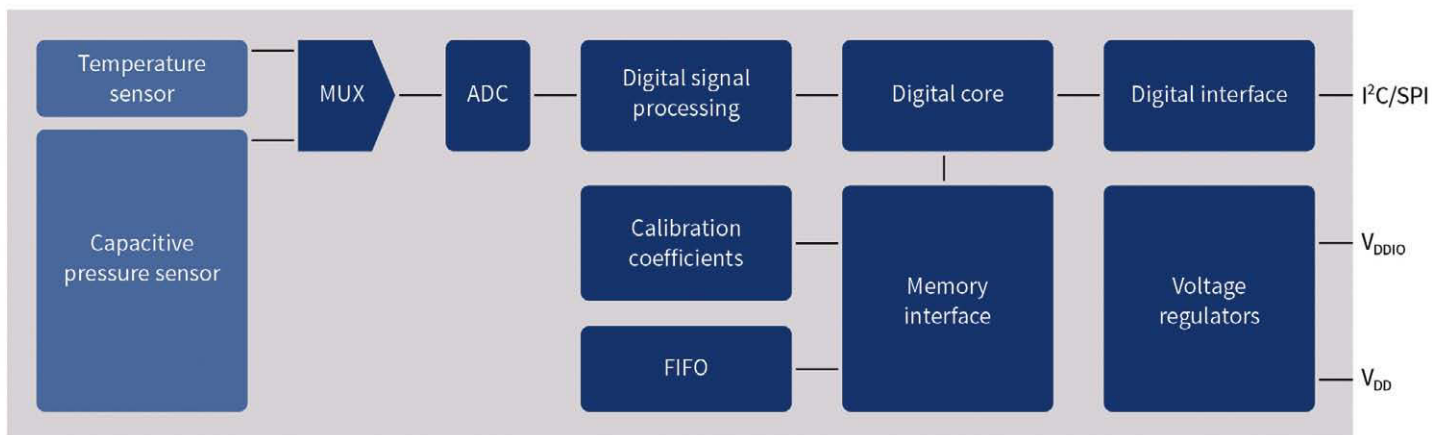
Image 3: Block diagram of the DPS368 architecture

compact 8-pin LGA package that measures just 2.0 mm × 2.5 mm × 1.1 mm. Average current consumption is 1.7 µA for pressure measurement (only 0.5 µA in standby mode).

Capable of precision to ±0.002 hPa (equating to ±2 cm), the device can measure air pressure between 300 hPa and 1200 hPa at a temperature of −40 to +85°C and has a pressure temperature sensitivity of less than 0.5 Pa/°C. The temperature reading is accurate to ±0.5°C. The sensor is able to detect single stairs, body motions or gestures. Every single component is individually calibrated during production with the calibration coefficients stored in one-time programmable (OTP) memory. Raw data can be transferred using an I2C or SPI interface, with compensated pressure values being calculated in the host device.
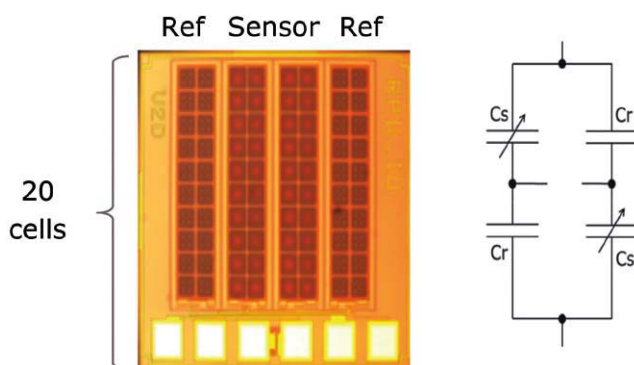
Image 4: The cell structure of the capacitive sensor enables differential measurements with very low temperature drift.

The device provides up to 50% less power consumption than competitor products when running at full speed due to its capacitive technology (AC biasing), which leads to longer battery life. An integrated FIFO that can store 32 measurements and allows the host processor to remain in sleep mode for long periods between readings provides further system power savings.

The high measurement rate (up to 200 Hz) and fast reading enable a quick sensor feedback.

Fast prototyping

Infineon supports quick evaluation and prototyping with comprehensive IoT solutions, evaluation boards and software. The sensor board Shield2Go can either be used together with the microcontroller board XMC2Go or with popular IoT hardware platforms such as Arduino and Raspberry Pi for fast and easy development using the DPS310, DPS368 or DPS422 sensors. A free, ready-to-use Arduino library is also available through GitHub (github.com/Infineon). This allows fast and cost-effective evaluation of applications and speeds up the production of prototypes.

Furthermore, the Sensor Hub Nano is available for developments with the barometric sensors. The standalone board, measuring just 30 mm × 15 mm × 10 mm (including battery), incorporates a pressure sensor that can be evaluated for a variety of applications. Bluetooth connectivity is used to transmit the data to the host.

As an alternative to using the SES2G sensor evaluation software, the Infineon Pressure Sensor Android app is available free of charge.
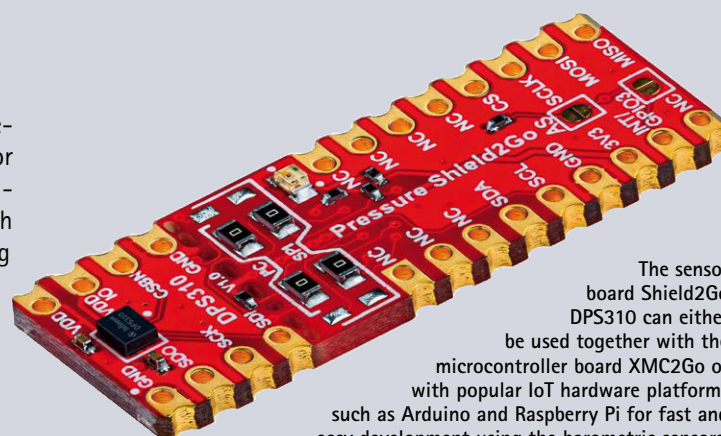
The sensor board Shield2Go DPS310 can either be used together with the microcontroller board XMC2Go or with popular IoT hardware platforms such as Arduino and Raspberry Pi for fast and easy development using the barometric sensors.

Compatible with the related sensor hubs, this app connects via Bluetooth and provides access to key sensor functionality to speed up the evaluation and testing of sensor performance in a target application.
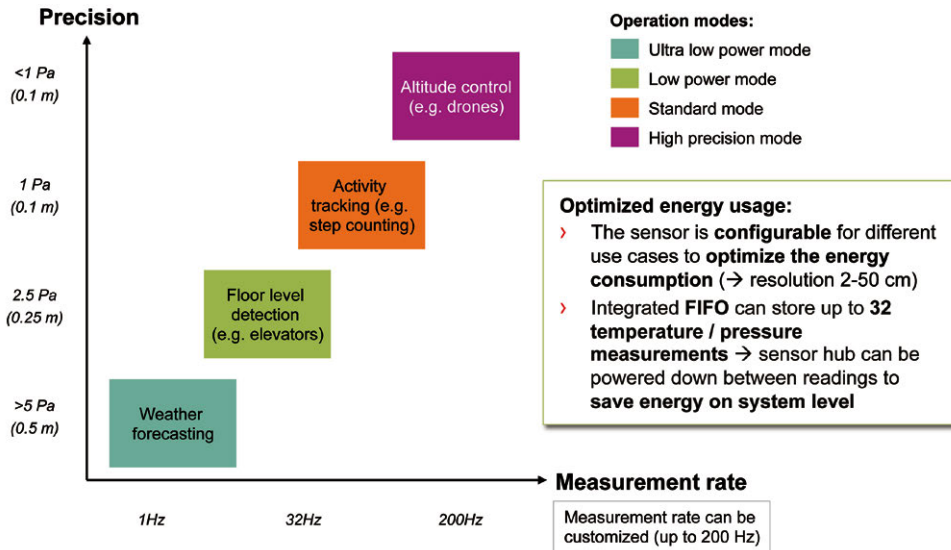
Image 5: Different operation modes enable optimized energy consumption and precision, depending on the related application.

Capacitive technology

Typical small form factor MEMS (Microelectromechanical System) pressure sensors are built around piezo-resistive measurement techniques. In these cases, the flexing of a diaphragm in relation to changes in pressure is sensed via a strain sensor. However, piezo-resistive sensing elements are particularly susceptible to variation with temperature changes and they do not respond linearly to temperature. For this reason, these sensors have a need for more complex calibration compared to a capacitive element. In addition, resistive measurement comes with a relatively high current consumption – a particularly important consideration when the target application is battery-powered and operating lifetime is critical.

Because of the limitations of piezoresistive technology, Infineon developed a capacitive MEMS technology for its pressure sensors. The cell structure and capacitive bridge configuration developed is illustrated in Image 4. The barometric pressure sensor consists of four arrays of sensing and reference cells. The sensing cells have a flexible membrane that reacts to pressure change and provides the air pressure measurement. The reference cells have a stiff membrane which does not react to pressure changes and provide a stable measurement reference. The benefit of this type of structure is that the pressure measurement can be differential, and both sensing and reference cells are exposed to the same temperature changes negating temperature drift effects. The cell size is optimized for high sensitivity and mechanical reliability. Based on the small MEMS cell there is no gravity effect. Other key features besides the very good temperature stability over wide temperature and pressure ranges are low noise and low power consumption.

Optimized system design

For flexible system designs the sensor is configurable for different use cases to optimize the resolution in balance with the energy consumption. Different operation modes (high precision, standard, low power and ultra-low power) coordinate with different precision (2 to 50 cm) and measurement rates (single shot and up to 200 Hz). For example, one-time measurement can be configured for GPS altitude accuracy, while the option to take several measurements per second will address the needs of gesture recognition or fall detection. The configurable modes (Image 5) also lead to optimized efficiency, as the power consumption is directly proportional to the measurement frequency. ∎

LSM6DSOX by STMicroelectronics

Machine learning helps make motion sensors energy efficient

Inertial measurement units comprising an acceleration sensor and gyroscope have gained widespread acceptance in applications for capturing movements, determining spatial orientation and stabilizing images and objects. To reduce power consumption and to improve the quality of data capture, ST has integrated machine-learning technologies into its latest sensor.

BY
MARIA ALEJANDRA SALAZAR MARTINEZ,
PRODUCT SALES MANAGER ANALOG &
SENSORS AT RUTRONIK,
AND WERNER NEUMANN,
TECHNICAL MARKETING AT
STMICROELECTRONICS

Up to now, reducing the power consumption of inertial measurement units (IMUs) has been an unsolved dilemma. That is because it involves either sending vast quantities of captured raw data – an energy-intensive process – or preprocessing this data in the host microcontroller, an operation that is no less power hungry.

With the new MEMS sensor LSM6DSOX from the iNEMO family, ST has provided an elegant solution to this Gordian knot: Here, a machine-learning core works with finite-state machines (FSMs) and classifies motion data based on known patterns along a decision tree. As a result, the main processor no longer needs to perform this first level of activity tracking. The result? Power consumption is reduced while at the same time detection is improved, which increases the processing speed of apps such as fitness trackers, apps for wellness monitoring, navigation or the fall detection function in smartphones, wearables or game controllers.

*Decision-tree logic
for quick and
efficient processing*

A decision tree is a tool that supports mathematical differentiations. It consists of multiple configurable nodes. At each node, a statistical parameter is compared with a

Images: STMicroelectronics

threshold value and the next node is selected based on the result. If this ultimately reaches a leaf – one of the last nodes of a tree – the decision tree generates a result that can be read by a specific device register.

With the help of the decision tree, the sensor processes an inductive algorithm with a fraction of the normal power consumption. The system can not only detect movements such as walking, running, jogging and cycling or immobility, but can even count bicep curls, squats, push-ups and other movements during a workout, for example – all on the basis of learned patterns.

The choice of data is critical in order to achieve a highly accurate result: data that characterizes the required class of a movement must be collected. Since it is highly complex to describe these classes manually in software, machine learning tools are used here, which greatly simplify the programming. ST uses the publicly available machine-learning tool Weka and a dedicated development environment that converts the acquired parameters into register settings of the sensor. This means that the developer can simply concentrate on the functionality without first having to evaluate the collected data.

The LSM6DSOX can be configured to process up to eight decision trees simultaneously and independently of one another.

....
*Programmable
interrupts*
....

In addition, the LSM6DSOX can issue an interrupt for specific user-defined movements. For this purpose, the finite-state machines can be independently programmed for specific motion detection types, such as a glance at a display, a turn of the wrist, a shake, double shake or picking up the device. Each of the 16 finite-state machines has its own memory area and is executed independently from the others. The interrupt is triggered once the final movement state has been reached. Other configurable functions are predefined to trigger interrupts for free falls, motion detection, 6D/4D orientation as well as clicks and double clicks.

The LSM6DSOX can also be used for closed-loop control applications, for example, for stabilizing moving industrial controllers. Special cases of this application are optical and electronic image stabilization (OIS and EIS) in camera systems.

WE CONNECT

VISION & REALITY

The number of hybrid and fully electric cars will increase dramatically over the next few years. To enable existing and new visions for a sustainable electric mobility quickly and successfully you need a strong and reliable partner, combining innovative technological capacities with the highest quality awareness. JAE connects vision and reality: With connector solutions for charging technology all from one source, we help you to shape the electric mobility of tomorrow today.

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Low efforts, high quality

Wide charging options
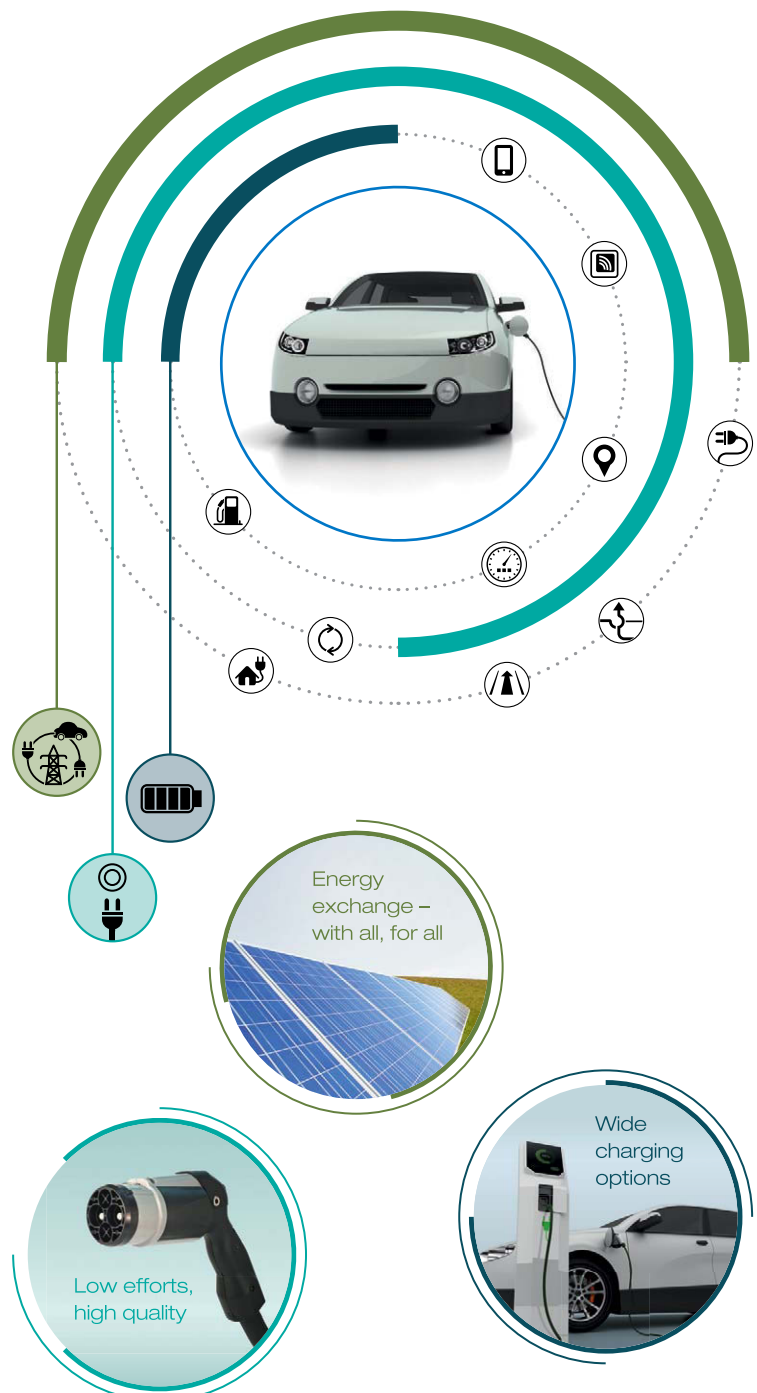
Connect with JAE – and profit from innovative, reliable and responsible electric mobility solutions. Don't wait for the future, but shape it!

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JAE
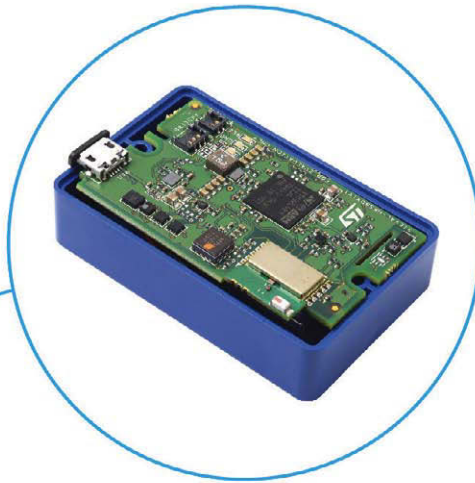
ST offers plug&play-enabled modules for testing and prototype development.

Always-on user experience with low power consumption

The LSM6DSOX is a System-in-Package (SiP) with a combined mechanical 3D acceleration sensor and 3D gyroscope together with a low-power CMOS-ASIC for evaluation in a small plastic land-grid array enclosure (LGA-14L). Its acceleration range of ±2/4/8/16g and the angular rate range of ±125/250/500/1000/2000 dps are dynamically selectable. The high-performance mode ensures high performance at a power consumption of just 0.55 mA. With its extremely low-noise acceleration sensor and gyroscope, the sensor combines an always-on user experience with low energy consumption and outstanding measuring accuracy.

With all of these features, the LSM6DSOX opens up a vast spectrum of applications – not only for motion detection but also for managing user interfaces, protecting laptops, detecting motion patterns and vibration for robots, machine controllers and forklift trucks all the way to the detection of aircraft movements such as takeoffs and landings. ∎

Part number	Description
STEVAL-MKI197V1	LSM6DSOX adapter board for a standard DIL24 socket
X-NUCLEO-IKS01A2	Motion MEMS and environmental-sensor expansion board for STM32 Nucleo
STEVAL-MKI109V3	Professional MEMS tools board
STEVAL-MKSBOX1V1	Ready-to-use box kit with wireless IoT and wearable sensor platform to help customers to use and develop apps based on remote-motion and environmental-sensor data, regardless of the level of expertise.

Evaluation tools for the MEMS sensor LSM6DSOX

SPICE models for platinum temperature sensors

Simulating more precisely

For decades, SPICE models have been available for active components – but not for passive ones. For a temperature sensor circuit based on an RTD resistor, Vishay provides a precise SPICE model that enables much more precise simulation than generic models.

By José Angel Iglesias Mazuelos,
Product Manager Resistors at Rutronik, and
Alain Stas, Product marketing Engineer
for nonlinear Resistors at Vishay

With the advent of IoT applications, electric mobility and increasing industrial automation, the precise simulation of passive components, such as temperature sensors, is becoming increasingly important. Complex mechatronic problems require powerful software to perform difficult calculations, and efficient simulation models for electronic components. Since there are hardly any realistic models available for passive components, generic models are often used. Such simulations provide qualitatively correct results, but their accuracy is limited.

For a temperature sensor circuit based on an RTD resistor, however, Vishay provides a precise SPICE model that enables much more precise simulation than generic models.

The active part of the measuring circuit consists of an operational amplifier NJU7098A by New Japan Radio, which is characterized by an extremely low current consumption of just 2 µA.

If this setup is to be used for temperature measurement, the circuit diagram can be described as shown in Image 1.

An SMD platinum sensor (PTS1206) from Vishay with accuracy class 1B serves as the input signal for the temperature measurement. This type of linear temperature sensor has become increasingly popular in the automotive industry since attaining its AEC-Q200 standard qualification, as it provides a good alter-native to conventional SMD NTCs for applications involving high stability and temperature requirements. Another key advantage of the PTS over NTCs is the linearity of the electrical characteristic. Although NTCs are more sensitive than RTDs, they are not nearly linear enough over the wide temperature range from −40°C to +85°C, even after linearization.

Analog Devices does of course provide a usable LTspice model for this circuit, which is available to download from its website. In this, the PTS sensor is represented by a variable resistor.

Engineers who are familiar with simulations will notice a particular detail in this model: although this is a temperature measurement circuit with a specified overall accuracy of ±1°C, the variable temperature (global ambient temperature) does not appear anywhere – neither in the SPICE directives nor in the definition of the PTS.

To save users of New Japan Radio's NJU7098A models from having to delve into the PTS data sheets, Vishay has explicitly included the SPICE model for DC temperature sweep. This extended model enables the following features:

- Adjusting/passing through the temperature
- Visualizing the influence of the TC tolerances of the PTS
- Fine-tuning/determining the feedback resistance

All images: Vishay

Low IB, Zero-Drift Operational Amplifier
Quad Matched Resistor Network
RTD Sensor Circuit with ±1°C Precision
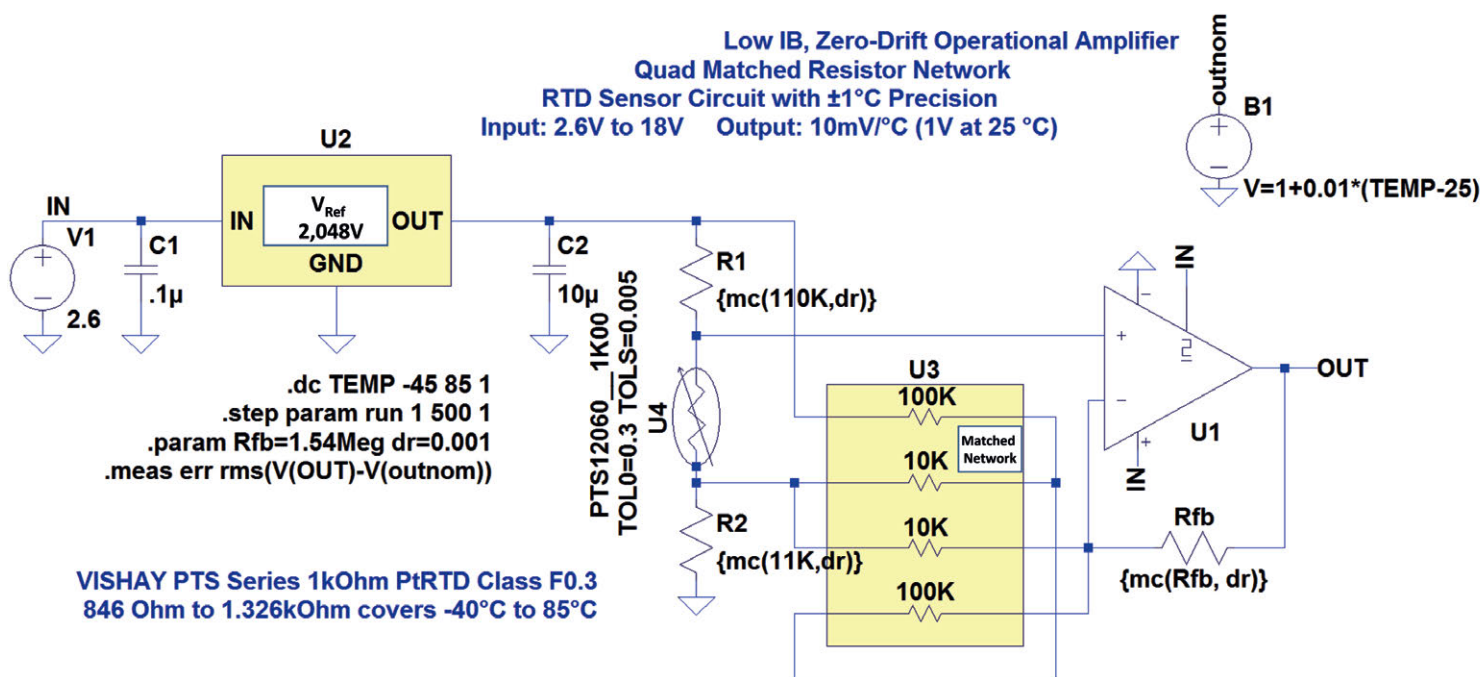**Input: 2.6V to 18V   Output: 10mV/°C (1V at 25 °C)**

Image 1: Measurement setup for Ltspice simulation

- Testing the circuit with Monte Carlo tolerances of all passive components (fixed resistors, PTS)
- Calculating the effective output voltage accuracy of the NJU7098A as a measure of temperature in °C (Image 2)

Image 2 shows that the circuit itself, including all component tolerances, has a linear temperature characteristic (top window) with a total accuracy of mostly ±1°C (bottom window) – which had to be proven.

The analysis could be taken deeper, such as with a dynamic temperature change over time for the PTS sensor. This would require a different SPICE model for the sensor however. This could be used to demonstrate an important effect: the response of the sensor over

time. If the sensor turns out to be too slow for the planned application, a smaller sensor – such as in the 0805, 0603, or even smaller format – is a good alternative.

The example shows that a SPICE model provided by the sensor manufacturer complements the simulation model for the IC outstandingly well. It also shows that there are numerous possibilities for developments in the field of temperature sensor simulation.

The simulation described in this article can also be found in [1].

References:
[1] www.vishay.com/videos/resistors/hands-on-electronic-simulation-of-an-optimized-linear-output-temperature-sensing-circuit.html

Image 2: Left window: Linear output voltage of the NJU7098A as a function of temperature.
Right window: Linearity deviation of the temperature readout (referred to an output voltage of 1 V at 25°C and a sensitivity of 10 mV/°C).
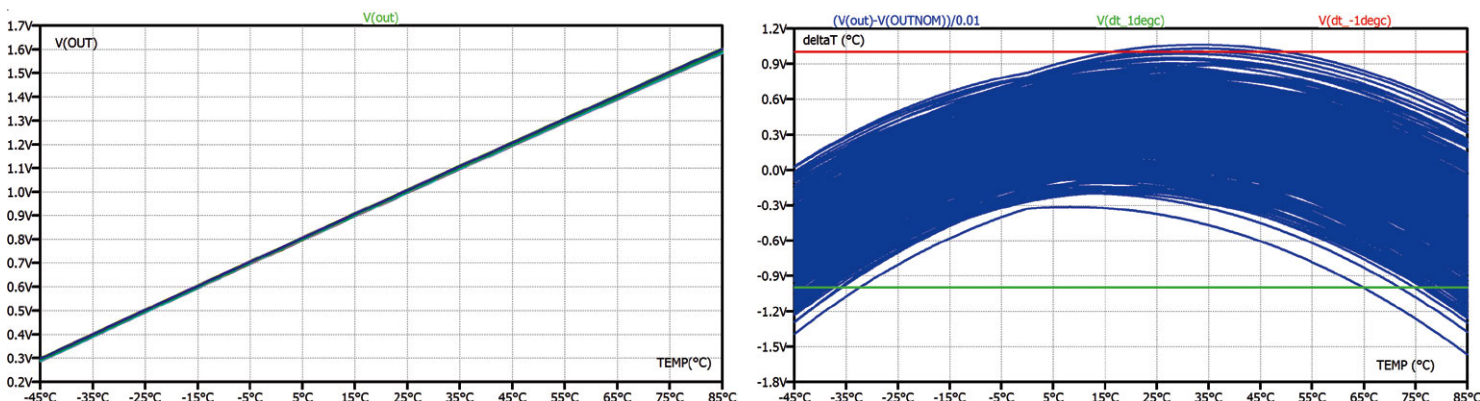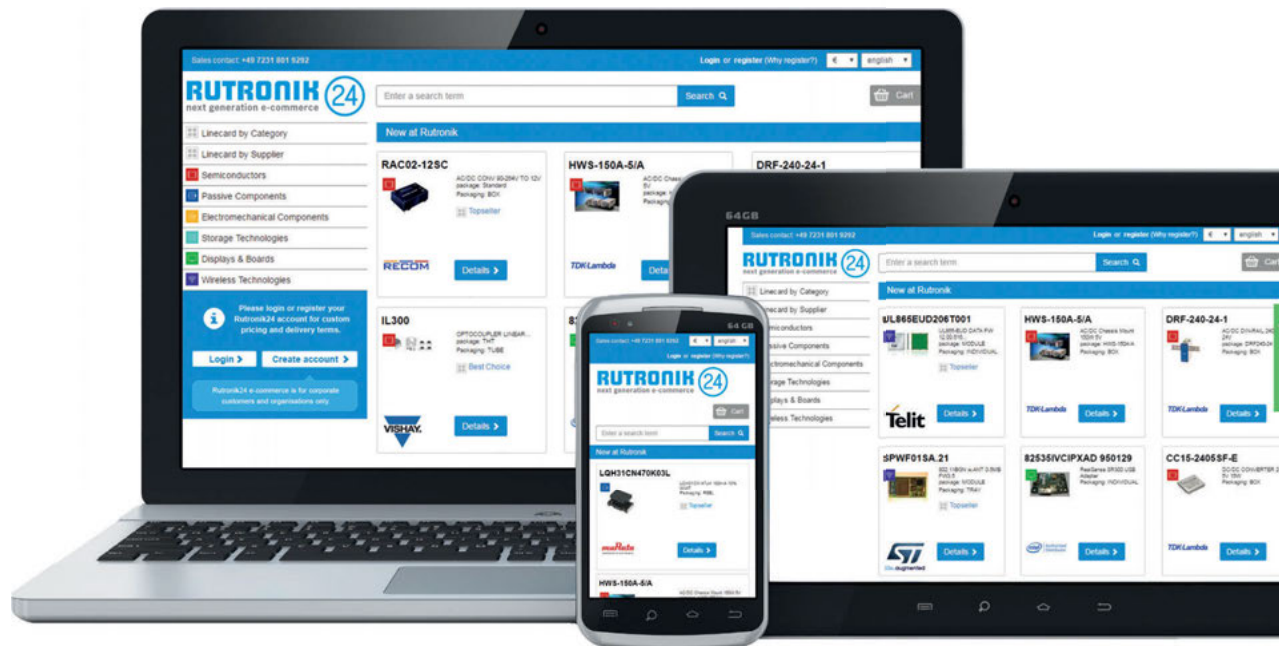
Recom turns its attention to battery management systems for the automotive industry

Need electricity?

From very small to very big: the (automotive) industry requires power supplies in many different designs and of a particular quality. Recom covers almost all high-end areas. An overview.
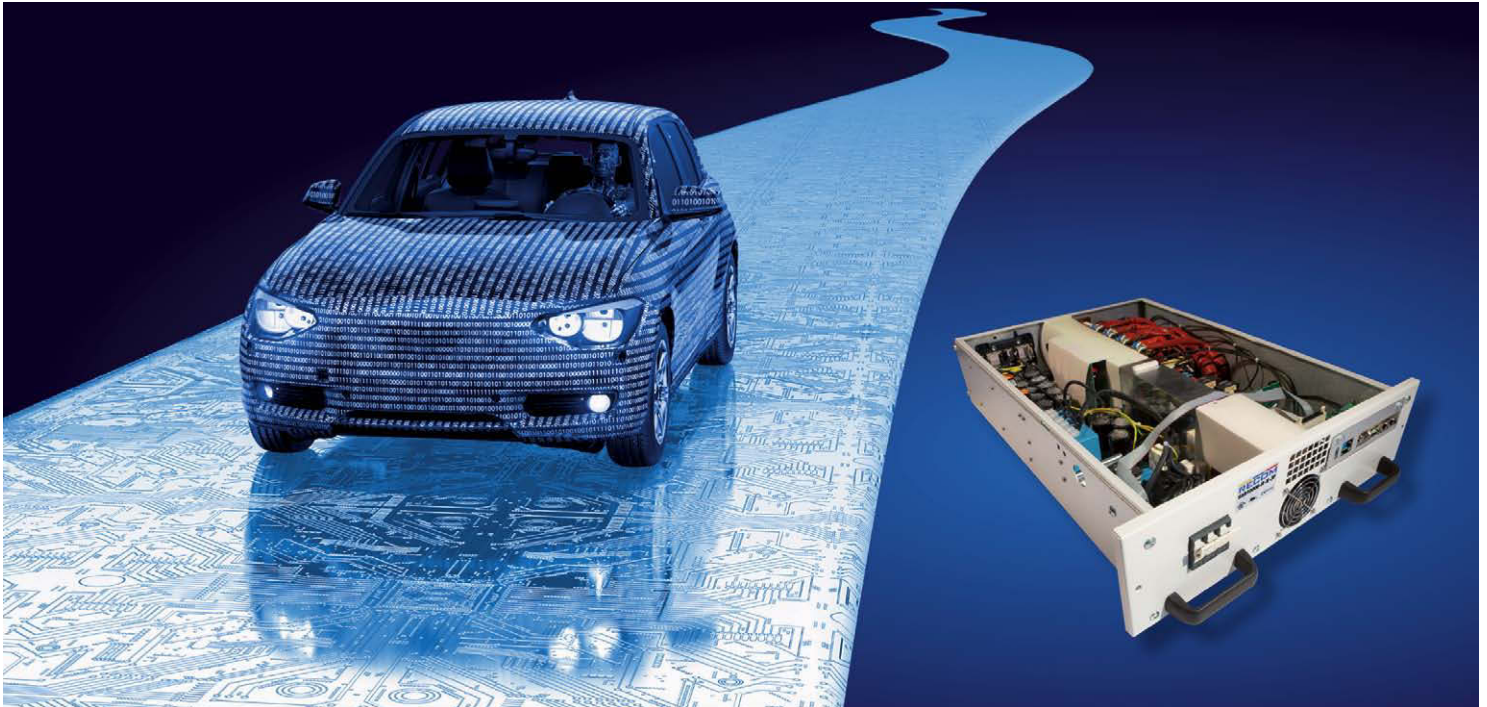
By Axel Stangl,
Product Sales Manager Power at Rutronik, and
Steve Roberts,
CTO at Recom

Automotive electronics comprises various systems ranging from entertainment and communication electronics to driver assistance systems and traction control in conventional, electric and hybrid vehicles. A common element of all vehicle electronics is the conversion of battery voltage, whether from a 12 V lead-acid battery or a 400 V lithium-ion battery to a stable lower voltage for powering the electronics. An electric vehicle (EV) also has a current transformer on board for charging the battery from a domestic power supply or a charging station while on the road. In EV/HEV ecology, there are also various upwards and downwards converters within subsystems and charging points for high-power fast-charging stations for fast charging using three-phase AC/DC converters. Bidirectional AC/DC converters are increasingly used, allowing energy from the batteries to be returned for off-grid AC supply or to the grid for load control, or for the efficient conditioning of high-voltage battery packs for maximum performance at high voltages.

Power supply characteristics in the automotive area

12 V batteries are still required in all types of vehicles, including electric cars, as many safety systems (airbags, belt tensioners, automatic braking systems, etc.) are only certified for a 12 V supply. The voltage of a 12 V lead-acid battery can vary over a wide range, from starting conditions in a cold environment to high overvoltages during load shedding. The LV124 (also known as VW80000) standard defines the values for systems with a 12 V nominal voltage, and the LV148 standard for systems with 48 V, as present in hybrid vehicles (HEVs) (Image 1). These are the voltage levels that can exist from high-power sources, but there are also fast low-energy transients at higher voltages, positive and negative, which can be present as per the ISO 7637-2 and ISO 16750-2 standards for power supply lines.

In addition to various failure situations and slowly changing voltages, the LV standards
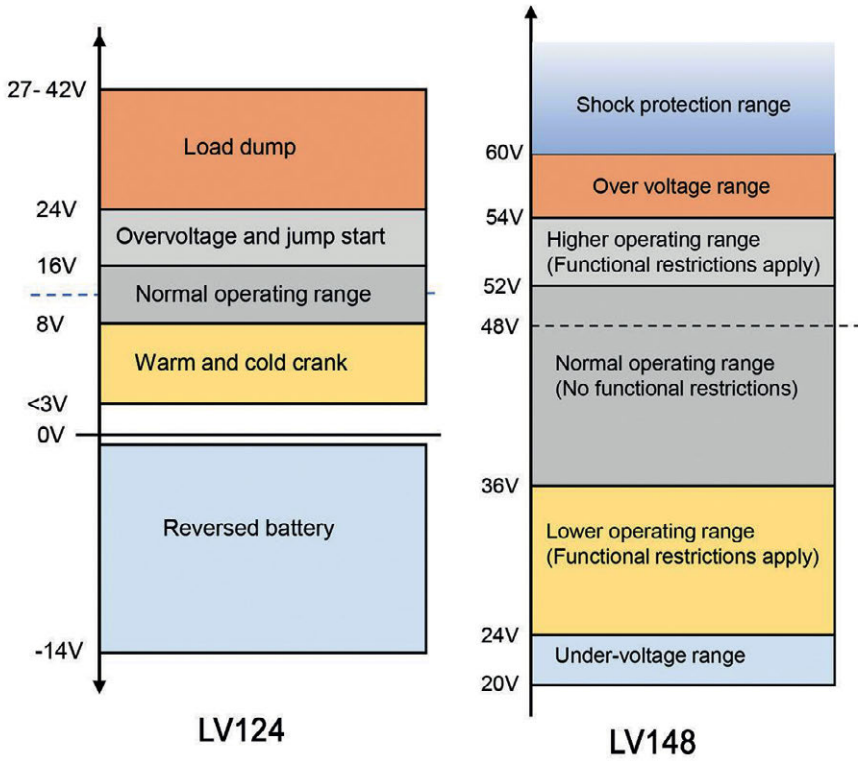
Image 1: Vehicle voltages defined by LV124 and LV148

also specify AC voltages superimposed on the nominal values with up to 6 V peak-to-peak amplitude and frequencies from 15 Hz to 200 kHz.

Additional filtering and protection

In order to comply with the LV standards and strict EMC emission limits in the automotive area (typically CISPR25), all current transformers intended for connection to the vehicle electrical system require additional filtering and reverse polarity protection compared with conventional commercial or industrial components (Image 2). Depending on the classification of the converters, an overvoltage limiter may also be necessary, which reduces all high overvoltages and causes only a minimal voltage drop during normal operation.

Current transformers for critical applications such as engine control and safety systems are often discrete, embedded in the host electronics and manufactured from components cer-
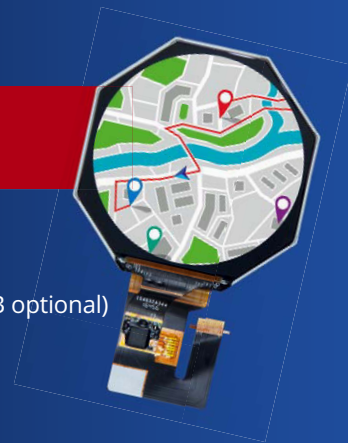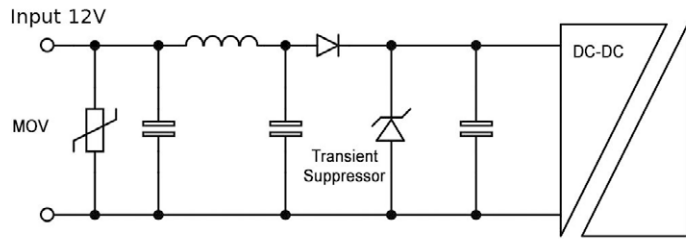
Image 2: Typical additional filtering and protection for DC/DC converters in the automotive area

tified as compliant with the corresponding stress tests and automotive specifications. Important standards are issued by the Automotive Electronics Council AEC-Q: AEC-Q101 for semiconductors, AEC-Q200 for passive components and AEC-Q400 for multichip modules with different operating temperature classifications for the respective automotive environment, from high temperatures in the engine compartment to the relatively benign environment of the vehicle interior. The companies supplying these components have been certified according to IATF 16949:2016 for the automotive sector, thereby proving that their quality meets the required standards. The supplier may also establish a Production Part Approval Procedure (PPAP) to ensure the release and control of components and assembly procedures before, during and after manufacture.

Product example for the automotive industry

The RAQ-0505S is an isolated DC/DC convert-
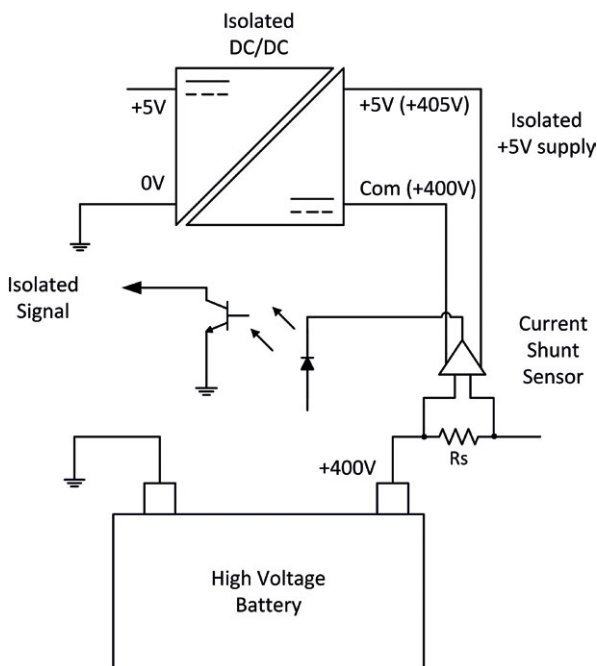
Image 3: Power supply of a battery current sensor on the high-voltage side with the RAQ-0505S

er for general automotive applications where a filtered 5 V DC power supply is already available to provide an isolated 5 V and 1 W output with full and permanent short-circuit protection.

The insulation rating of the SMT converter is 5 kV DC/1 s (2.8 kV AC/1 min) with >4 mm creepage distance. A typical application for the component is the generation of an isolated 5 V for the CAN bus data system used in most vehicles. Another primary application is the power supply of current sensors on the high-voltage side in battery-management systems in EVs (Image 3). Here the sensor circuit needs a local 5 V power supply, which must be isolated from the system ground around the 400 V battery voltage due to its offset. Such isolated power supplies also enable the use of a modular battery where each cell can be independently monitored and controlled so that the battery voltage is not compromised in the event of a single-cell, multiple-cell or cluster failure. This means that many locally isolated 5 V supplies are required in one unit, isolated from both the low-voltage supply and from each other.

The RAQ-0505S operates from −40°C to +105°C without derating, is manufactured in Recom's IATF 16949:2016-certified factory in Taiwan and has PPAP documentation. DC/DC converters do not have their own AEC-Q category for stress testing, so the design of the component has been verified according to AEC-Q200 for service life, shock and vibrations, board flex capability, ESD, terminal strength and temperature change (1000 cycles). The AEC-Q104 tests are also applicable for board level reliability, low temperature storage, drop test and temperature steps. The design of the DC/DC converters is also tested according to ISO 16750 and certified for safety approval according to IEC 60950-1. With a basic external filter, the EMC complies with CISPR25 Level 3 and EN 55032. Reliability is an impressive 1000 hours at the maximum operating temperature of 105°C according to MIL-HDBK 217F.

DC/DC converters in production applications

Other Recom products undergo similar environmental, accelerated service-life (HALT) and production tests for the RAQ part and are manufactured in the same automotive-approved facility, making these high-quality modular DC/DC converters suitable for use in a wide range of manufacturing, industrial automation, automotive test and measurement, and noncritical automotive applications. CAN bus isolators used in robot manufacturing are a popular application for the RKE series, RB components are built into circuits for automotive leakage current detectors, and RP and RKE components are found in onboard chargers, to name just a few examples.

DC/DC converters with a wide input voltage range such as the REC15E-Z for 6–36 V or 18–75 V are suitable for automotive supplies with 12 V and 48 V rated voltages. Interphase AC/DC converters have established themselves in automotive charging circuits as auxiliary power supplies for access-negotiation circuits.

Bidirectional AC/DC applications

Power Control Systems, now part of the Recom Group, recently introduced a 10 kW bidirectional AC/DC converter. The initial version uses a three-phase current input/output and has a short-circuit proof output of 20 V and 500 A. With the bidirectional current flow, the model is used in controlled charging and discharging for battery conditioning so that battery packs can be fully charged, discharged and recharged to reach full capacity. During the discharge process, the energy is not lost but fed back into the supply. The product has a digital interface for controlling and monitoring the charging and discharging cycles.

Modular converters – save development time

Modular current transformers from qualified manufacturers can be a cost-effective solution for automotive applications with competitive unit prices and savings in development and certification time. Together with the newly acquired Power Control Systems, the Recom Group offers products from 1 W to 10 kW with a growing portfolio of AEC-Q-verified components. ■
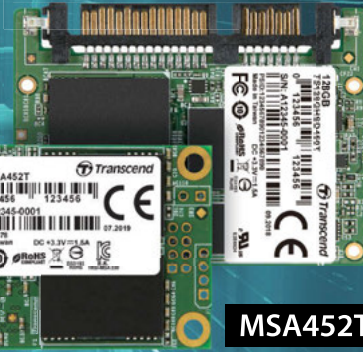
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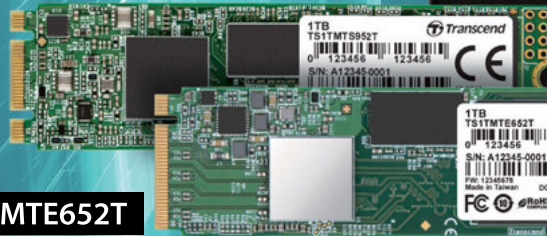

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HSD450T

MSA452T

SSD452K

MTS952T

MTE652T

SSD450K-I

MTS550T-I

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Film capacitors for DC intermediate circuits

Smoothing out power modules

Power inverters with rapid-switching transistors need capacitors with low series inductance in the DC intermediate circuit. This applies to all circuits that regenerate AC voltage from DC voltage via a semiconductor switch. But not every capacitor is suitable for the job.

BY RALF HICKL,
PRODUCT SALES MANAGER AUTOMOTIVE
BUSINESS UNIT AT RUTRONIK

Capacitors on a DC intermediate circuit serve as buffers for power spikes in motor- or generator-actioned drive unit operation. They cushion system perturbations, i.e. line-conducted EMC, and as a snubber they function as filter components to protect the switching transistors from voltage peaks and high dU/dt (voltage gradient).

Significant characteristics of intermediate circuit capacitors

A low ESL (equivalent series inductance) and a small ESR (equivalent series resistance) are advantageous for the filter function against steep gradient impulses. In the data sheets, the quality is expressed as loss factor tan δ. The power dissipation, which in the capacitor falls away on the ESR, is proportional to tan δ and results in undesired self-heating.

For the snubber function, due to parasitic line inductance, the capacitor is best positioned with a short cable length to the switching transistor. The unavoidable losses in the transistors at the final stage likewise cause an increase in temperature that shortens the service life of neighboring components. Here, film capacitors are robust and more long-lasting because, in contrast to capacitors with

Image: WIMA

liquid electrolyte, they do not dry out.

Electrolytic capacitors were mainly used for power supplies with commutated line voltage. With the arrival of active power factor correction or battery power and faster switching IGBTs and MOSFETs, film capacitors or ceramic capacitors are being increasingly used – depending on the voltage situation. Film capacitors offer some advantages over electrolytic capacitors.

- High dielectric strength, so no need to arrange the series connection of individual capacitors with additional voltage balancing
- High temperature resistance with solid-state dielectric
- Low ESR and thus high pulse power
- Low self-inductance, effective at high frequencies, and suitable for a high di/dt (current gradient)
- Self-healing in segmented metallized plastic film design, therefore robust and secure ("films fail open")
- Long service life, calculable and gradual ageing with accompanying loss of capacitance. With the self-healing facility, no sudden failure caused by a short circuit can occur that could result in consequential damage.

Self-healing prevents a sudden failure

Self-healing is the capability of the capacitor to microscopically burn small internal short

Image: Rutronik

Image 1: Diagram of a segmented metallization for controlled self-healing

circuits free, leaving behind a high impedance spot. To keep the internal short-circuit areas small, most manufacturers of power film capacitors turn to the controlled self-healing technology which has been proven for some decades now. The film metallization is segmented. Each metallized segment is connected to the neighboring segments by just a thin fusible link (Image 1). In the event of a local breakout in the dielectrics these links to the neighboring segments melt, thus isolating the damaged segment. So the damage remains local and the capacitor only loses a tiny proportion of its capacitance.

Polypropylene (PP) or polyester (PET) are often used as dielectrics. PP provides a low loss factor and is well suited to cope with pulse stress. PET has a high specific capacitance and low volume requirement.

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Capacitors for smaller outputs

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For smaller outputs, standard single capacitors are sufficient as intermediate circuit ca-

Manufac-turer	Series	Voltage range	Capacitance range	Properties	Consistent with semi-conductor end-stage housing
AVX	FHC1	410…900 V	510…140 µF	Standard products	HybridPack 1
AVX	FHC2	410…900 V	900…260 µF	Standard products	HybridPack 2
AVX		customer specific	customer specific	customer specific	HybridPack Drive, ACEPACK Drive
WIMA	DC-Link HY, DCHYH06500JG00x	450 V	500 µF	Standard product	HybridPack 2, customer specific
Rubycon	HVC	250…2000 µV	100…2200 µF	customer specific	HybridPack 1, 2; customer specific
TDK Epcos	PCC LP, B25655J/M/P	200…900 V	50…3000 µF		HybridPack Drive, ACEPACK Drive
WIMA	DC-LINK MKP4	400…1300 V	1.0…400 µF	AEC-Q200	THT PCB mounting
Vishay	MKP1848 DC-LINK	450…1200 V	1.0…400 µF	AEC-Q200	THT PCB mounting
Murata	FH	500 V	10…20 µF	125°C	THT PCB mounting

Capacitor ranges and power modules for power semiconductor

pacitors. They are interconnected on a PCB or via copper rails to the required capacitance. Due to the mechanical size and mass of the capacitors it is necessary to pay attention to the long-term stability of the soldering points, screws and the PCB. Manufacturers help here by making capacitor housings with more than just two solder pins (Image 2). The advantages of using standard components for PCB assembly is that they

are easy to mount and users can scale the overall system.

Suitable semi-conductor modules for use in combination with PCBs are Infineon's Easy-PACK 1B and 2B, and also CIPOS or modules such as in the ACEPACK housing by STMicroelectronics.

With the arrival of electric vehicles, Infineon has introduced semiconductor modules into
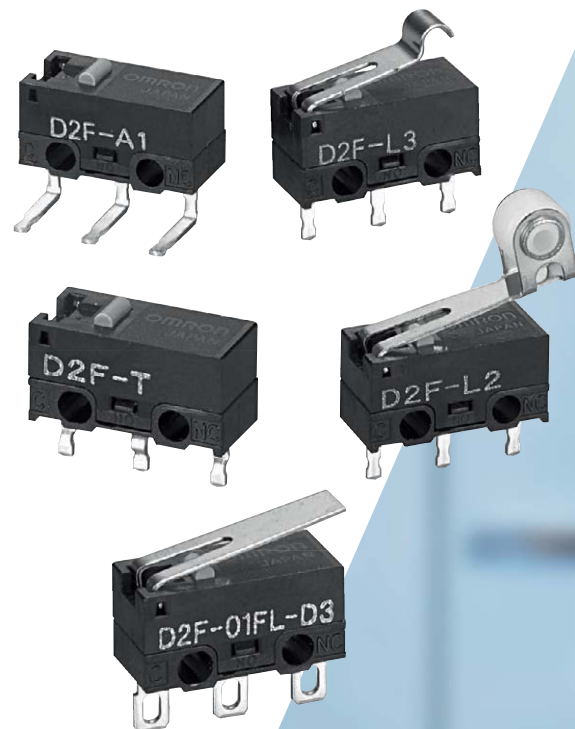
Image 3: WIMA's DC-LINK MKP4 series is mechanically custom fit for Infineon's HybridPack 2.

their HybridPack 1, 2 and drive housings as a power stage for traction inverters in vehicles. Due to the amount of load current flow, contact is no longer made via pins, but via power rails. Made to fit to Infineon's housings, manufacturers of film capacitors have developed appropriate molded power capacitor modules; these include AVX, TDK Epcos, Rubycon and WIMA. Examples of suitable modules are shown in the table.

Internal design of the capacitor modules

Since the modules consist of individual windings that are parallelly switched via rails, they provide good scalability of the overall capacitance where individual elements from stable series production are used. By parallelly switching the individual elements in the capacitor module (Image 3, Image 4) they simultaneously achieve low ESL and ESR values.

Besides the standard modules, customer-specific designs of capacitors and transistors are also possible, such as can be found in Tesla's inverter for the model 3 rear axle. So design, electrical values, and mechanical assembly can be optimized.

Engineering support

Nowadays, however, the technical parameters taken from the data sheet and the manufacturing process cannot alone determine the quality of design components. For power components the manufacturer's support during the selection stage and during development play an important role. Because this prevents late changes, thus reducing the time to market.

Thermal simulation

For rewarding projects AVX supplies thermal simulation of its power film capacitors as a special service. So, for example, with customer-specific capacitor modules, it is possible, at an early stage of the development process, to optimize internal material use and set out the measures to dissipate heat. The results of the thermal simulation (Image 5) can also be used to estimate its service life.

Where the project is appropriate and on request AVX also encapsulates temperature sensors inside the capacitor housing. The measurement results allow for verification and optimization of the thermal model.

Estimating service life by means of an application profile

In order to estimate the service life of the capacitor modules in the application, the manufacturer needs the anticipated operating data during the system's lifetime – in other words a histogram stating how long the capacitor will be exposed to specific current, voltage and ambient-temperature combinations. From that, with the aid of the computed or measured temperature inside the capacitor, the manufacturer can calculate lifetime consumption. The service-life model for the capacitor in question forms the basis of this, such as AVX, TDK Epcos, Rubycon and WIMA have for their products. The principles are well described, for example in Rubycon's technical notes – see www.rubycon.com.

Equivalent electrical circuit diagram and 3D CAD data

Inserted into a simulation model, and with the equivalent electrical circuit diagram, it is possible to simulate the dynamic behavior in operation of the electrical quantities and in special situations with high di/dt, such as emergency inverter cutouts. Developers can dimension their protection against voltage spikes with no hardware structure.

In the most straightforward case, a film capacitor is modeled as a series connection of ESR, ESL and the calculated end-of-life capacitance.

Where capacitor manufacturers supply CAD data for their products, the capacitor can simply be included into the CAD design drawing for the overall mechanical system. This also saves valuable development time. ■

Bibliography:
AVX: energy.sandia.gov/wp-content/gallery/uploads/Ritter-AVX_CapacitorRel.pdf
Rubycon: www.rubycon.co.jp/en/products/film/technote.html#10

Image 4: WIMA's DC-LINK MKP4 series is mechanically custom fit for Infineon's HybridPack 2.
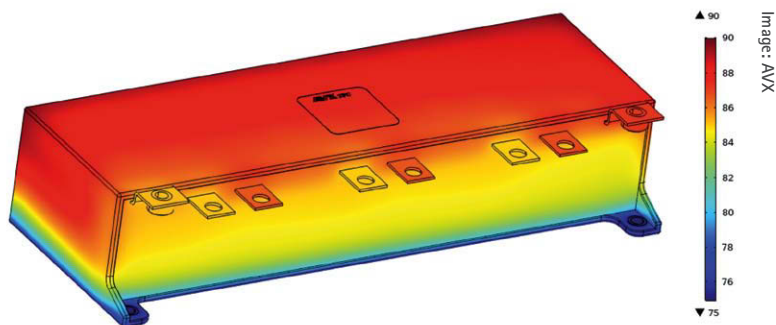

Image 5: Result of a thermal simulation on a FHC2 series capacitor from AVX

Interview with racing driver Carrie Schreiner

Motorsport is a test laboratory for production vehicles

Carrie Schreiner is currently the most successful woman in German GT racing. The 20-year-old from Völklingen in Saarland took up karting at the age of ten, was immediately successful, and has been working her way upwards ever since. In the Rutroniker interview below she talks about the importance of the sponsorship by Rutronik, the future of motorsport, and the clichés that the women involved with it still encounter.

Since 2018, she has been competing successfully for the Rutronik-sponsored team HCB-Rutronik Racing, and is currently the only woman to compete in the ADAC GT Masters series. Carrie Schreiner is not only a racing driver, however, but is also concerned with the significance of motorsport for innovations in production vehicles and more.

Rutroniker: **In the context of the climate debate and the Fridays for Future movement, motorsport is increasingly subject to criticism. Why is motorsport better than its reputation?**

Carrie Schreiner: I think it's right and important that young people should be thinking about the future of the planet. But it's not the case, as is often presented in motorsport, that we simply burn gasoline senselessly – quite apart from the fact that, worldwide, motorsport only accounts for a minimal share of total global pollution compared to shipping and aviation. Car manufacturers have been working for some time on alternatives to make our sport more environmentally friendly. Formula 1 is now opting for hybrid engines, and that's not the end of the story. However, motorsport is playing a leading role not only in this respect, but also in terms of possible innovations for the automotive industry.

Why is motorsport so important for the development of production vehicles?
In motorsport, vehicles are exposed to extreme conditions and high stresses that cannot be simulated and that do not occur in normal road traffic. Consequently, manufacturers can use it to gather a large amount of empirical data. Motorsport essentially serves as a test laboratory for production vehicles. I drove in the Lamborghini Supertrofeo for two years, and the production vehicle was very similar to the racing car. The same applies to racing series for compact cars with front-wheel drive – Audi, Hyundai and VW and others are all testing their developments under the extreme conditions mentioned.

Which existing motorsport innovation or one that is currently being tested do you consider particularly interesting for production vehicles?

Motorsport racing driver Carrie Schneider in conversation with Sebastian Hör, Rutronik

Images: Dirk Pommert/Rutronik

Much of what is taken for granted in our cars today was first tested in motorsport. One of the hot topics for the future is autonomous driving. I find the steer-by-wire concept particularly exciting, and it has already been tested in racing by Rutronik partner Paravan. The electric steering takes over the complete torque for the steering angle. The only feedback given to the driver at the steering wheel concerns the effort required for the steering angle – if there is still a steering wheel. The signals may also come from a joystick or the onboard navigation, providing not least a much higher level of safety. After all, the steering column holds huge risk potential for the driver, especially in the event of a frontal collision. In addition, steer-by-wire technology is one of the technological prerequisites for autonomous driving, and enables completely new vehicle concepts since the driver's position is no longer restricted. Another example of an innovation that has been tested in racing and that has now found its way into production vehicles is lighting technology, i.e. LED and laser systems.

Carrie Schneider:
"We test innovations, and the findings help Rutronik to provide customers with the best-possible advice."

Rutronik as a distributor of electronic components sponsors HCB-Rutronik Racing. What is the biggest advantage of working with Rutronik?

With the Automotive Business Unit (ABU), Rutronik has a department that explicitly focuses on industry innovations – from autonomous driving and networking, to digitization and e-mobility. In racing, these new technologies are tested under extreme conditions, and if they prove worthwhile, are used in production vehicles. To put it more simply, we test innovations, and the findings in turn help Rutronik to provide customers with the best-possible advice. With the two-time winner of the 24 Hours of Le Mans, Manuel Reuter, ABU has also created a brand ambassador who acts as an interface between both sides and provides valuable input thanks to his network and know-how.

In August, Stéphanie Frappart was the first female referee to oversee a European final in men's football, thereby proving that women can also succeed in a so-called male domain. In motorsport they have been proving this for many years. To what extent do you still encounter clichés about women in motorsport, and to what extent has this changed since you became a racing driver?

There are still people who say stupid things, but in recent years the level of acceptance has risen significantly. Nevertheless, as a woman you still have to prove yourself a bit more –

you have to show that you can drive quickly and aggressively if necessary. In the next few years men will continue to enjoy a number of advantages, and that won't change overnight. But I can live with that.

To what extent do you as a woman in a male-dominated sport see yourself as a role model for young girls and women?

For a long time I wasn't even aware that I had a role-model function. Then this year I met a young girl at the Hockenheimring who takes part in regional kart championships and also wants to compete in the German Kart Championship. Her father told me that last year at the Hockenheimring they both saw me win a race. That showed her she could do it, too. That touched me quite a bit.

Finally, I would like to ask you a personal question: if you hadn't become a racing driver, what would you have done?

I always knew that I wanted to be a racing driver, and never really thought about alternatives. But if my career hadn't worked out, I probably would have joined my father's company selling table-tennis equipment. Apart from that, I'm also interested in fashion, which could possibly have been another area for me. But being a racing driver is still my favorite thing to do! (laughs) ■

Semiconductor switches for electronic fuses

Safe is secure

Fuses are used in many fields of power electronics. Until recently, cables, consumers and voltage sources were generally protected by safety fuses. Using semiconductors brings advantages.

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

Fuses protect the components in electrical circuits. If an overload or short circuit occurs, the fuse triggers and opens the circuit. This prevents damage and keeps the cost of repairs down. Ideally, the shut-off characteristic is designed in such a way that the current is cut off before other components, such as the cables, semiconductors or passive components on the circuit are damaged.

It follows therefore that a correctly dimensioned fuse is the weakest link on the circuit. The thermal characteristic of the protected object is crucial; for example the electric cable, the wiring harness or the semiconductor switch in the connected control unit.

Instead of safety fuses or electromagnetically triggered mechanical contacts, electronic fuses contain semiconductor switches along with their control logic including protective and diagnostic functions.

The characteristics of fuses

Safety fuses are single-use products. They conduct, protect, and separate in both directions of current. This bidirectionality is an advantage in circuits with loads that – depending on the operating status – are motor or generator actioned. This includes, for example, traction inverters, which are also able to brake regeneratively (recuperate).

On the other hand, electronic fuses can be triggered and reset any number of times. Due to the body diode, designs with a single MOSFET as the switch disconnect in only one direction of current. So, for bidirectional disconnection, two antiserial MOSFETS need to be switched, which means a higher cost. Unlike safety fuses, electronic equivalents have their own power requirement. This needs to be taken into account for battery-driven devices in particular.

Conventional fuses as disposable products

Cutout behavior

Conventional safety fuses are characterized by stipulating the rated current and trigger behavior (sluggish, agile, superagile, etc.) In the case of electronic fuses it is possible to set flexible cutout criteria. This includes:

- Pt spec (maximum load integral or melting integral)
- overcurrent
- overvoltage or undervoltage at the fuse input
- overload (power)
- overtemperature – ambient or in the fuse

The fuse manufacturer can also set the trigger behavior for an electronic fuse. So for example, it is possible first to limit the current and then cut out, or cut out immediately and wait for a reset.

Because an electronic fuse already contains a switch, it can also be used for this function. So any further switch is superfluous and other functions such as a soft start can take place by controlling the switch with pulse width modulation (PWM).

Switch-on behavior

Safety fuses are typically a single-use product. Once they have fulfilled their function they are unusable and must be replaced.

With an electronic fuse, a soft start can be made using a configurable edge steepness on

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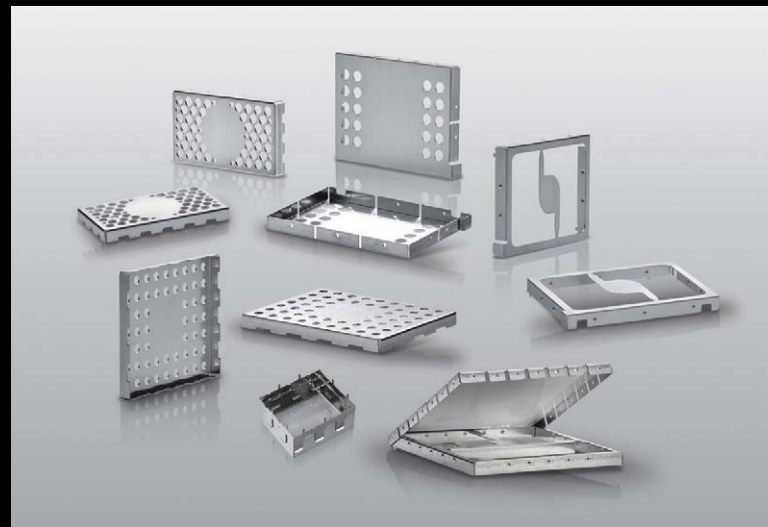
Manufacturer	Family/Type	Type Designation	Features	Voltage Range / Current Range	Promoted as
DIODES		ZXCT1032	single channel linear soft start OC detector OC disconnect Flag pin (diagnosis) external P-channel MOSFET	current range adjustable via control voltage and shunt resistor 9.5 V … 21 V	High-side inrush controller and electronic fuse
Infineon	PROFET™+2	BTS70xx	single or dual channel protection against OC, UV, thermal protection, absolute and dynamic diagnosis for open load in on and off state, short circuit to GND and battery proportional load current sense	automotive specification of 12 V boardnet 3 A … 15 A, depending on type	Automotive smart high side switch
STMicroelectronics	VIPower™ M07E	VNx7ExxxAJ	single, dual or quad channel, current limitation, power limitation protection against OC, OT flexible latch-off functionality on and off state diagnostic capability multiplexed current sense	automotive specification of 12 V boardnet R_{DSon} from 10 mΩ …100mΩ	Automotive high side driver
STMicroelectronics	VIPower™ M09		single, dual or quad channel, current limitation, power limitation protection against OC, OT flexible latch-off functionality diagnosis multiplexed current sense	automotive specification of 12 V boardnet R_{DSon} from 4 mΩ … 80 mΩ	Automotive smart high side switch
STMicroelectronics	STEFxx	STEFxx	protection against output OC and OV programmable linear soft start time current limitation thermal protection status feedback on some STEFxx	STEF01: 8 V … 48 V, programmable STEF033: 3.3 V / up to 3.6 A STEF04S: 3.3 V / 5 V / 5 A STEF05: 5V / up to 3.6 A STEF12: 12 V / up to 3.6 A	Electronic fuse
STMicroelectronics		STPW12	protection against excessive input power thermal protection adjustable power limit short circuit limit	10.5 V … 18 V 10 W … 16 W	Electronic power breaker
Vishay	SiP324xx	SiP32419, SiP32429	single channel protection against OC, OT fault output pin auto restart after 150 ms (SiP32429) latch off (SiP32419) slew rate control	6 V … 28 V 0,75 A … 3,6 A	Load switch with programmable current limit and slew rate control

Product examples of semiconductors for use in electronic fuses

the semiconductor switch or by controlling it with a PWM. Once triggered, it can switch back on automatically, and cyclically with a previously defined repeat number of reset attempts. Alternatively it is possible to reset only on request. Here a network connection is advantageous.

Particularly in systems that must meet a Safety Integrity Level (ASIL), an essential product characteristic is a diagnostics capability. Here too, electronic fuses provide advantages because it is possible to integrate the diagnostics directly. Moreover, the constant current metering can create and analyze a load profile. The result can be used as an early warning as well as a means to take preventative measures such as preventative maintenance and replacing worn parts.

Other characteristics of electronic fuses

In the event of an overload the electronic fuse scores highly with additional features.

In the event of a shortcircuit the cutout is faster, which means that the voltage dip on the rest of the onboard power system lasts for a shorter time. This is important for the electronic circuits installed there, which, after a protracted power dip and subsequent power-up will need a reset and reboot before they are operational again. On critical assistance systems, which could fail if a reboot were to occur during a journey, this could be extremely dangerous – the key phrase here is "secure power supply".

An electronic fuse can be designed so that the current is limited to a defined maximum before it cuts out. Even where there is a short circuit, the onboard power system voltage does not dip so much that other control units go to reset. In addition, the leakage inductance energy charge is restricted. This keeps voltage spikes low when oscillation occurs.

With no spark gap there is no arcing on switching/cutout. This makes an electronic fuse more suitable for use in explosion-protected areas.

Product examples

The table shows a selection of semiconductors for use in electronic fuses. Some components were developed for very specific applications, a smart high-side driver for example still requires additional logic before it can be used as a fuse in practical use. The STEF01 by ST-Microelectronics is well regarded everywhere. Its overcurrent (OC), overvoltage (OV), undervoltage (UVLO), and the slew rate are configurable by means of an external passive component (fully programmable). An external FET can be installed to implement a reverse-current blocking circuit. ■

Energy management strategies for telecommunications and telematics

The digital world of the future promises greater comfort and safety. But autonomous driving, automatic detection of traffic signs, and many other features demand permanent data connections for example. They in turn necessitate a stable, safe and uninterruptible power supply.

By Vanessa Jakob,
Product Sales Manager Capacitors
at Rutronik, and
Jürgen Auer,
Vice President Sales & Marketing
at Sech

Most uninterruptible power supply (UPS) applications in telecommunications and telematics at present are based on battery technology. It is even currently used to buffer peak loads. In such applications the battery offers advantages thanks to its relatively high energy density, maturity, and years of familiarity in use. So the architectures are designed specially to match the properties of the available battery technology.

For almost 20 years now, ultracapacitors have been successfully used as peak and standby power solutions in numerous applications, including wind turbines, mobile base stations, industrial robots, and a variety of other electronic devices and industrial machines. In recent years, due to the rising demands in a

Images: Sech

Ultracapacitors have established themselves as peak and standby power solutions in many applications.

wide range of high-volume applications, they have developed into energy storage devices which – in terms of both cost and performance – are also an interesting alternative for use in large and small UPS systems as standby power supply for data centers, hospitals and high-tech manufacturing facilities. Typical system sizes start at a few kilowatts, and can easily be expanded to megawatt-scale systems with modular solutions. In those solutions, single ultracapacitor cells are linked to form modules or even systems.

Perfect for peak power and short-term backup

All of these applications – regardless of the required power class – demand power quickly in order to either provide the required peak power or to bridge the mostly very short outages that occur nowadays. In the event of a prolonged power outage, the plant or system is set to a safe state (graceful powerdown). Peak power and bridging times typically range from a few milliseconds to 20 seconds. Ultracapacitors are ideal for these applications in particular. They are able to release, and recover, most of their stored energy within seconds (or fractions of a second), countless times, without being damaged. They are designed for a service life of ten years and more in such applications. They are also easy to handle. No maintenance or servicing is required, and they are very simple to monitor. The voltage curve can be used to easily evaluate and monitor the health status of the ultracapacitor. Lead-acid batteries – the predominant method of energy storage at present – have a short life even under ideal conditions, and unexpected failures occur due to their electrochemical composition. They are much more complex and costly to moni-

tor and health-check than ultracapacitors. Additionally, they are difficult to manufacture in an ecologically sustainable way.

Ultracapacitors are different: their properties are based on an activated carbon material with an extremely large electrical surface area. The material is used as an electrode, and an electrolyte impregnated in the cells ensures the necessary exchange of charge.

Ultracapacitor design

Depending on the state of charge, the ions of the electrolyte accumulate on the activated carbon (carbon electrode) at a distance in the nanometer range. Since the capacitance is directly proportional to the surface area, and indirectly proportional to the charge gap, ultracapacitors can store several hundred times more energy than conventional capacitors. The charging and discharging process takes place electrostatically, without chemical reactions as happen in batteries. Ultracapacitors can therefore capture and release the stored energy much faster, and with no degradation. This makes them ideal for applications with high power output and energy requirements and large numbers of cycles. While batteries can store up to 20 times the energy, ultracapacitors offer up to 20 times the power density of batteries thanks to their very fast charge/discharge characteristics.

Batteries provide high energy availability – ultracapacitors ensure high power output

If high energy availability is a prerequisite, a battery storage system is the first choice – despite its known weaknesses, and regardless of the battery technology it employs. However, combinations of batteries and ultracapacitors are increasingly being used. It is important to note that the two storage technologies have different potential characteristics: batteries store and supply their energy via redox reactions (i.e. Faraday or mass transfer processes), and so maintain a virtually constant potential until the re-

action mass is consumed. With ultracapacitors, on the other hand, the voltage changes with the stored charge.

Dream-team battery and ultracapacitor

For applications in telecommunications and telematics, however, benefits can be gained with a direct parallel combination. If, for example, individual lithium cells (~4 V) are connected in parallel via two series-connected ultracapacitors (~2.5 V), the ultracapacitor delivers a large part of the peak power required during transmission due to its very low internal resistance. The lithium-ion cell provides all the reserve and standby power. The combination leads to a significant improvement in operating time. Similar examples can be found in the power supplies of telecommunications base stations. They require local energy storage in case of voltage dips in the supply line and outages lasting from milliseconds to several seconds.

The active parallel combination requires a power processor that is as efficient as possible and a bidirectional DC/DC converter that is comfortable handling wide voltage fluctuations at the input and allows immediate power reversal without loss of control. With their very low internal resistance, today's ultracapacitors offer the possibility of achieving the efficiency rate of over 90% demanded for an efficient system (ultracapacitor plus DC/DC converter). Cost must of course also be taken into account. Nevertheless, an overall cost-benefit analysis reveals the advantages of a combined solution. Lifetime tests have shown that combining with ultracapacitors can massively extend the service life of battery storage systems, and significantly enhance power availability. Many companies all over the world are currently focused on combination solutions, and have developed the necessary power electronics. ■

Activated carbon is used as the electrode material in ultracapacitors.

New technology stops mosquitoes biting

No more itching and scratching

If you think you are too small to make a difference, try sleeping with a mosquito in the room." This quote from the Dalai Lama expresses not only that everyone can bring about changes but also just how annoying mosquitoes can be. Now, however, a start-up company has developed a wristband that prevents mosquitoes from biting you in the first place.

BY BERND HANTSCHE,
DIRECTOR PRODUCT MARKETING
EMBEDDED & WIRELESS AT RUTRONIK

We learn the principle of action and reaction at a young age. An action, for instance, is a mosquito bite. The reaction is unpleasant itching and scratching. Many remedies are therefore designed to relieve the itching sensation. nopixgo takes a different approach. In the form of a wristband, it prevents an action – a mosquito bite – from happening at all.

At the heart of the nopixgo wristband is the module with biopulse technology. It works with weak electromagnetic pulses and waves that block a mosquito's interest in biting. The insects perceive these natural pulses through their sensilla, which are hair-like sensory organs. A natural instinct deeply rooted in their

DNA then activates a protective reaction, ensuring the mosquitoes either lose interest in biting or flee the situation. The wristband therefore drastically reduces the risk of a mosquito bite within a radius of two meters.

Effective without chemicals and tricks

Compared to other mosquito repellents, the nopixgo wristband offers many more advantages: Unlike chemical substances, mosquitoes do not become used to the electronic signals emitted by the wristband. Since they activate an instinctive protective response from the insect. This repellent effect is not based on chemical solutions such as those

found in creams and sprays – and which are sometimes harmful to your health. There is no unpleasant film on your skin or nasty odors.

Risks of electromagnetic radiation

However, there are also many reservations about electromagnetic pulses such as those employed by the wristband. And not without good reason. In June 2018, the World Health Organization (WHO) recognized electrohypersensitivity (EHS) as a disease and included it in the classifications of environmental diseases. And debates about the risks of radiation have been in full swing again since the 5G spectrum auction.
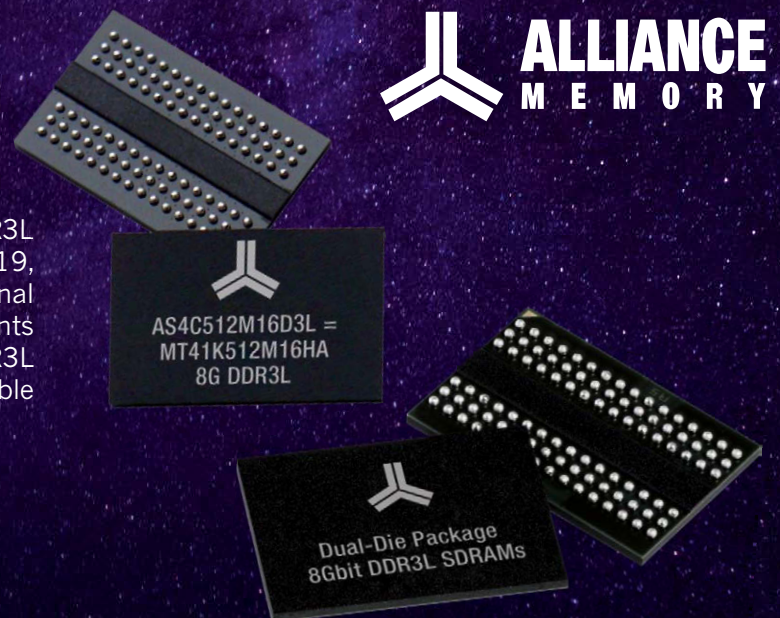
At the same time, scientists have been further investigating the sensitivity to electromagnetic radiation. For example, the biologist Prof. Dr. Alexander Lerchl and his team from Jacobs University Bremen have shown in mice that carcinogenic substances cause more tumors when the animals are exposed to a lifetime of electromagnetic fields, such as those produced by cellphones. The result is particularly astonishing since Prof. Dr. Lerchl had previously been convinced that mobile radiation posed no risk to health in principle.

Effect of radio waves on mosquitoes

A completely new indication of electromagnetic sensitivity was provided by studies conducted at the University of Zaragoza, Spain, in May 2019. Female Aedes albopictus – a species of mosquito in which the females feed on blood – were bombarded with a sub-GHz ISM frequency band and a species-specific broadband modulation in the kHz range. The result: The radio waves blocked the mosquitoes' interest in biting.

Kurt Stoll, an electronics and high-frequency scientist from Switzerland, had discovered this long before anyone else did and has been continuously improving the modulation of frequencies ever since. In cooperation with insectologists at the University of Tübingen in Germany, he has also adapted these signal frequencies to other types of mosquito. He never doubted that his work would be confirmed by the Spanish researchers. In the meantime, the frequency patterns have been patented and are now available as biopulse technology in a radio module. Initial application of this module is in the nopixgo wristband. After completing various field tests with a small number of wristbands and continuously optimizing the respective firmware, logistical support from Rutronik and other partners ensured the finished product hit the market in time for the 2019 'mosquito season'. You can purchase nopixgo from numerous trade partners worldwide.

Hazardous and safe radiation

Although the risks of electromagnetic radiation should not be taken lightly, they are definitely not something to worry about in relation to nopixgo. Since 5G networks use about four times higher frequency waves and much greater transmit power than the mosquito repellent wristband. This also applies to the WiFi router in your home. WiFi generally still relies on the 2.4GHz band and usually makes full use of the legally permitted 100 mW (20 dBm) to achieve the greatest possible range and a robust communication link.

By way of comparison: A microwave oven emits waves of the same frequency as a WiFi router to heat up food, while a smartphone typically requires 600–800 W of transmit power in the waves. If you place a glass of water next to your WiFi router, you will notice t h a t

the   m a x i - mum 0.1 W emitted by the router is insufficient to heat up the water. But opinions tend to differ when it comes to the 2 W required by a smartphone to access GSM base stations. During longer calls and with poor network coverage, regional and temporary warming of the skin tissue around the ear has been measured. Therefore, a Bluetooth headset (2.4 GHz, typ. 10 mW, limited by law to 100 mW) is always the healthier alternative for frequent callers.

The signal strength of the pulses employed by nopixgo is less than one percent of that of a smartphone. The SAR level of the wristband – Specific Absorption Rate, which refers to the rate at which, e.g., the human body absorbs electromagnetic fields – is 0.1 W/kg. According to the German Federal Office for Radiation Protection (BfS), the various models of the Huawei P20 achieve SAR levels of 0.73–0.76 W/kg (next to the ear), or 1.21–1.26 W/kg (worn on the body), while the iPhone Xs boasts an SAR level of 0.99 W/kg next to the ear and when worn on the body. The maximum recommended limit of the World Health Organization (WHO) is 2.0 W/kg.

Using heat to prevent itching

Another start-up company is taking a completely different approach. Under the brand name 'Heat It', it has developed a heat source to treat insect bites. This carefree treatment stops mosquito bites itching, and speculators are currently joining the crowdfunding campaign in the hope of seeing a return on their investment after the product's launch in 2020. While the 'Heat It' gadget reacts to the swelling, pain and itching from bites, the nopixgo wristband prevents a bite occurring in the first place – and without a bite, there is no need for pain relief.

Mosquitoes – the world's most dangerous animal

Moreover: 'Heat It' does not protect against the transmission of diseases by mosquitoes. However, this was definitely the main incentive for Kurt Stoll, the inventor of the biopulse technology. His aim was to alleviate the suffering of children in Africa who have contracted malaria as well as other vector-borne diseases such as dengue fever or zika, which are also transmitted by mosquitoes – making the mosquito the world's most dangerous animal. As a result of global warming, people in so-called industrialized or affluent countries also increasingly face the risk of being infected by these diseases.

Like many inventions based on completely new scientific findings, nopixgo is also having to overcome the prejudices that exist against other mosquito repellent gadgets on the market. They, however, are all based on completely different modes of operation. As an electronics distributor, Rutronik is able to assess the functionality of the underlying biopulse technology and is convinced of the positive effect – and success – of the nopixgo wristband. Rutronik is therefore supporting the flow of materials and capital of the Swiss start-up: On the one hand, the electronic components are provided for PCB assembly, and, on the other hand, the dispatch of the wristband to dealers worldwide is organized by Rutronik's Central European logistics center. So far, there have been no returns, complaints or claims, which is not only an indication of the high-quality Swiss production but also of the product's satisfactory performance. ■

API interface

On the way to automated procurement

When ESO Electronic is procuring electronic components, it's often not the days that count, but hours or minutes. That is why the EMS service provider is committed to digitizing – and so automating – the process.

By Andrea Bissinger,
Director Sales Global at Rutronik24

One area of focus for printed circuit board assembler ESO Electronic is rapid prototyping. It is the norm for the company to deliver fully assembled PCBs to its more than 200 customers within five days. Requesting each single component manually from different distributors, comparing prices and availability, and placing separate orders is only possible with lots of man power. A buyer might take several minutes on a single article alone to obtain all the required information from multiple distributors' online shops and clarify details by phone or e-mail as necessary. When a hundred components are involved, the research adds up to many hours. "Not only does that take an extremely long time, manual work adds no value at all, and the time could be much better used on strategic tasks", explains Dominik Ottenbreit, managing director of ESO Germany.

Image: penguiiin/stock.adobe.com

Moreover, ESO Electronic has long-standing business relationships with the vast majority of its suppliers. Such a positive attribute also entails disadvantages in relation to conventional methods of procurement, as buyers tend to immediately think of particular distributors to source specific products or product groups. This has in the past meant that other suppliers were not even requested to provide quotes for the components in question, even if they had in fact included them in their portfolio, and perhaps even with more attractive terms.

Self-developed inventory control system

ESO has developed its own inventory control system so as to largely automate its procurement, enabling it to speed up the process substantially and establish transparency in issuing requests for quotes to all relevant distributors every time. The program contains specially written software for each distributor and supplier that links to their various APIs (Application Programming Interfaces). Information can be transferred 1:1 in machine-readable form via this interface. ESO has thus established the basis for sending automated requests to a selected number of distributors.

The ESO Electronic system is only half the battle however: the data interchange only works if the distributors also provide the relevant data in a machine-readable format, and have an API. Rutronik24 has been offering an API through the rutronik24.com online shop since 2016. After logging in or registering a new account if they have not yet done so, the only

thing that users have to do is download the API manual and request a personalized API key. After entering the key in their browser, they see all the product details displayed in XML or JSON format: the unit and graduated price in various currencies; the daily available stock; the standard delivery time; the minimum order quantity; the packing unit and type (bulk, reel, tube); the housing/construction type; the description text for the product; and the Rutronik match code.

Pioneer in API use

ESO Electronic was one of the first Rutronik24 customers to use the API, and has been actively involved in its ongoing development. "It is very clearly written and kept simple, and the documentation is easy to understand, so we had implemented the connection within just a few days. If we had any technical questions, we always had a contact person available," comments Dominik Ottenbreit.

In the beginning, however, the response times of the API were still relatively slow, at up to 30 seconds. Dominik Ottenbreit addressed the issue on a visit to Rutronik24 in Ispringen. Team Leader Field Sales at Rutronik24 Marek Fuchs recalls: "We received some evaluation reports from ESO, which helped us a lot in optimizing the system. So we were able to cut response times pretty quickly." Today they are usually less than a second. Within a few seconds, the purchasing function is provided with a list indicating pricing and availability from each supplier, showing the cheapest price highlighted at the top and the standard market price next to it for comparison purposes.

This means that complete bills of materials can be priced very quickly, and the system automatically selects the appropriate suppliers. For project-specific and high-cost articles, however, manual intervention is still required, as prices can only be provided when the manufacturer submits the relevant information to the sales department.

ESO Electronic currently issues more than 100,000 API requests on average every three months. And the EMS service provider always automatically gets attractive, individually tailored prices from Rutronik24. "Thanks to the API integration and the outstanding intensive support provided by the field sales and office staff, Rutronik24 has become one of our most important suppliers over the past three years," says Dominik Ottenbreit.

Next step: automatic ordering

Automated request issuing is not the end of the story, however. ESO Electronic already has the next step in its sights. Then the shopping cart generated in the ESO inventory control system will automatically trigger the order to Rutronik24 via the API. Until now, it has had to be entered manually. ■

Standard Products PM unit

Nobody talks about them, but everyone needs them!

Rutronik not only presents innovative new products, but it also renews its internal distribution structures wherever necessary.

By Reza Maghdounieh,
Senior Manager Product Marketing
Purchasing & Standard Products
at Rutronik

Standard products, or commodities, are present in almost every application – whether safeguards to protect the application from overvoltage, operational amplifiers to amplify an analog signal, or transistors to control voltage and currents. A characteristic feature of these products is their broad-ranging portfolio from many different manufacturers with mostly identical technical parameters. The selection of components for a specific application generally does not require intensive consulting by field application engineers (FAEs) or hardware engineers in the development departments, but is in fact sufficiently well known and widespread. Only the distributor with the best performance in terms of price and availability can win.

In 2018, Rutronik decided to bundle its existing expertise in-house, establishing its Standard Products product marketing unit with effect from January 1, 2019. In this technical marketing department, the commercial benefits are consolidated on the basis of the company's volume purchasing, and complemented by the technical expertise of three highly experienced product managers. Rutronik is now looking to pass those benefits on to its customers more widely. The new unit now bundles the company's commodities business, providing customers with local support in conjunction with the sales function. The product managers are supported in their day-to-day work by five operational buyers, who not only bring with them many years of know-how in relation to customers and manufacturers, but have also made a positive contribution to Rutronik's business development in the past through their product expertise and market knowledge.
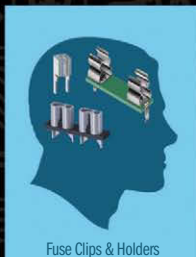
Image: Rutronik

A clear focus on the key manufacturers, combined with a collaborative approach, guarantees direct and prompt access to technical resources and maximum support on commercial matters. This includes not only market-driven prices, but also rapid escalation in the event of delivery delays, which were still a hot topic in the industry last year. Rutronik has further increased the availability of components in order to ensure shipping to customers worldwide at very short notice, meaning that the company is now in a position to also fulfil new requirements within just a few days.

Customers can make initial price and availability checks at www.rutronik24.com. This in

itself provides much greater availability at significantly more attractive costs compared to other e-commerce platforms. Rutronik additionally offers a 24/7 online facility to order samples of new and innovative products, as well as of current products.

Alongside price and availability benefits, the advantage of this is that technical specialists are available at all times to answer questions on standard components and provide customers with expert advice on the challenges they face. So customers enjoy optimum support, since the technically highly trained product managers and FAEs are available to the individual development departments locally in or-

Rutronik24 BaseCamp

More than just a jump start for start-ups

Start-ups seem to be everywhere nowadays – in the headlines, in financial news and even on the TV. At Rutronik, supporting new businesses is nothing new – but only recently has there been a dedicated team available to only them.

BY MAREK FUCHS,
TEAM LEADER FIELD SALES AT RUTRONIK24

The BaseCamp start-up team is part of Rutronik24, which is Rutronik's specialist sales organization for small and medium-sized enterprises (SMEs) as well as larger companies with small and medium needs, making it ideally positioned for such novel enterprises. BaseCamp's team of three concentrates entirely on providing young
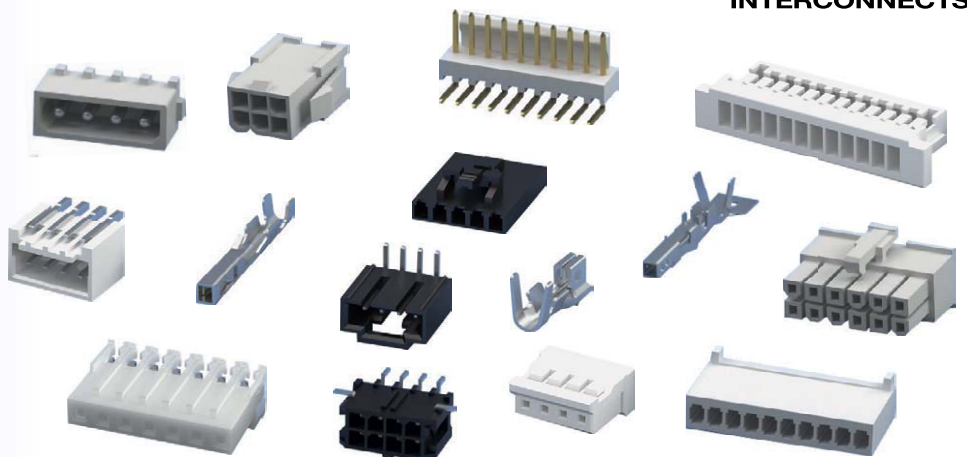
der to provide advice on technical questions at any time.

The extensive linecard with products from market-leading manufacturers not only assures customers of outstanding technical quality, but also offers them long-term security of supply for their application.

In line with the company motto, the staff of Rutronik's new Standard Products unit truly are "Committed to Excellence". Short communication channels, short delivery times, and low prices – that's not just meant as a marketing claim, but is put into practice every day.

■

businesses with long-term support.

Even if the sales structure of Rutronik24 is ideal for start-ups, their support needs are considerably different to those of traditional Rutronik24 customers. This is primarily due to how they are founded – most start-ups are small teams and literally start out from scratch. There are no defined or even automated processes for procurement or production. Partners for activities such as production or sales are often lacking. Many also have no fully developed business plan or watertight financial planning.

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Long-term relationship sought

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The BaseCamp team provides the young businesses not only with a jump start, but also with a potentially long-term partner. Depending on their needs and situation, this starts with a critical review or even joint preparation of a business plan and financial planning, with a balanced scorecard, SWOT analysis, feasibility study and, in particular, technology advice/ assessments. The BaseCamp team then takes a closer look, together with colleagues that specialize in that specific application or mar-
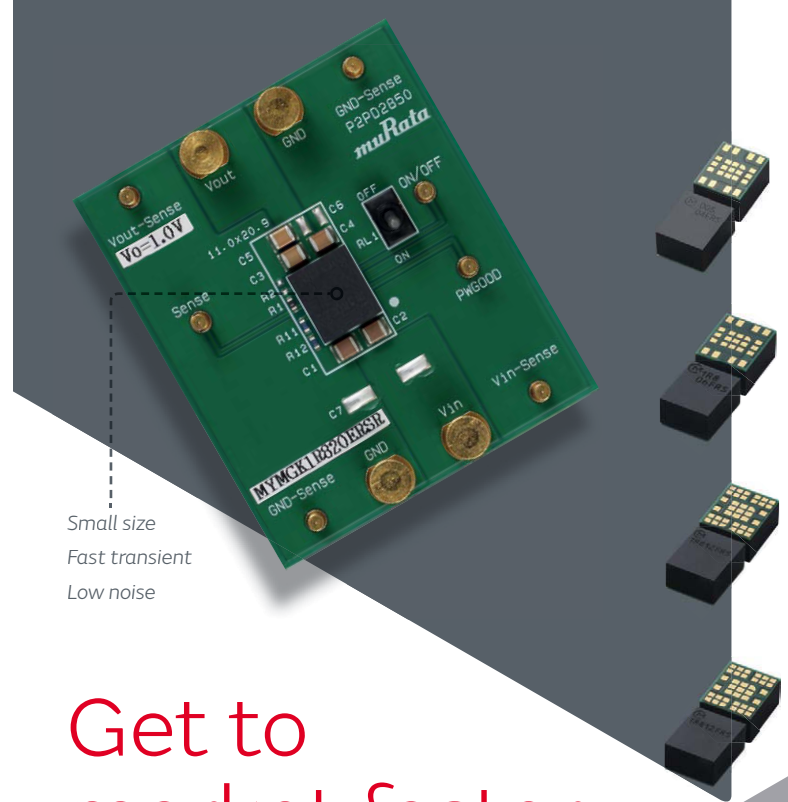
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ket, to see if the new development offers real unique selling points in the market. If this review ultimately concludes in any of these points that there is no compelling concept, the start-up is very unlikely to have a chance on the market. This is why it is not only crucial for Rutronik24 to critically examine these aspects – this also provides the newly founded company with an important assessment of its market potential.

If the initial analysis reaches a positive conclusion, the BaseCamp team decides how to proceed henceforth together with the start-up. This support may consist of advice on matters such as procurement and production routes, on marketing, on go-to-market strategies or on sales and logistics, as well as support on automating as many processes as pos-

sible. For normal consulting regarding the choice of components, the BaseCamp team involves Rutronik's product managers and field application engineers and also makes contact with component manufacturers where necessary. Rutronik has the benefit of a large, worldwide network to draw upon when finding the right production and sales partners. Finally, the roadmap is subjected to scrutiny, because this is the basis for the business' long-term success. Start-ups can make use of all of the consulting services and the Rutronik network at no cost whatsoever.

Evolution of start-ups

Rutronik has a tradition of establishing links with start-ups through its partnerships with universities and other higher-education institutions. The BaseCamp team also maintains contact with various Fraunhofer institutes, chambers of industry and commerce, interior ministries and economic ministries, and is present at many trade fairs and events. In the future a truck specifically purchased for this purpose will serve as an eye catcher and meeting point.

New partners, paths, opportunities

innolution valley is one of Rutronik24's most important partners. The team has created a

robust platform for discussions and collaborations between founders and young entrepreneurs, especially in the B2B segment, as well as with established companies and investors. For meeting people in person, for networking and for learning from one another, the annual innolution valley festival and the innolution night are essential entries in the community schedule. Rutronik24 with BaseCamp has also been involved since 2017, and, since then, Rutronik24 has become a key strategic partner for the Pforzheim region. In 2020, Rutronik24 will be one of the main partners of the innolution valley festival and the innolution night 2020 in Pforzheim. "Rutronik24 is perfectly positioned for collaborations with start-ups, because both parties are able to benefit heavily from it," says Gunnar Gross, founder and host of innolution valley. "Hardware start-ups in the B2B segment in particular not only receive support in their product development and feedback from an established company with a proven track record in the industry, but can also – just like Rutronik – benefit from a long-term supplier relationship. Not only this, but start-ups will find real motivators in the BaseCamp team who are aware of the need for future-proof business models. And without these models, no start-up can be successful." ∎

Aurix microcontrollers

Playing it safe

The importance of safety is growing in all technical areas. Developers are therefore increasingly required to design conclusive safety concepts that take the individual components into account, right down to the smallest detail. At the heart of a system are its microcontrollers.

By David Werthwein,
Product Manager Digital
at Rutronik

In terms of functional safety, IEC 61508 provides the key specifications. It comprises a series of standards for the "functional safety of electrical/electronic/programmable electronic safety-related systems". In addition, there are slightly adapted standards for certain areas of application, which are subordinate to IEC 61508. The respective adaptation to the specific conditions in the automotive sector is the ISO 26262 series.

Numerous safety features

Besides meeting the requirements of ISO 26262 to ASIL-D, Infineon's Aurix 32-bit microcontroller was also developed as an SEooC (Safety Element out of Context). This means that the derivatives of the Aurix range can be integrated into a safety-relevant overall system due to their safety features.

The second generation of the Aurix range is manufactured in 40nm embedded flash technology and is fully automotive qualified. Thanks to six TriCore processor cores with up to 300 MHz, it offers significantly more computing power than its predecessor. The functional safety support also makes the Aurix microcontroller particularly interesting for industrial applications. The following hardware and software safety features ensure the Aurix microcontroller is highly suited for safety-critical applications:

- Checker cores
- Flash & RAM ECC (Error Correcting Code)
- Safe SRI (crossbar)
- Voltage, frequency and peripheral monitoring
- Safety Management Unit (SMU)
- SafeTpack safety manager
- Logic Built-In Self-Test (LBIST)
- Safety characteristics

The checker cores run in the background and monitor the processor. All operations are executed twice. As soon as varying results are achieved, an error message is issued by the SMU.

Both the Flash and the RAM have an integrated ECC function. This error detection procedure determines whether there is an error relating to the storage or transmission of data. If such an error is detected, it can be corrected.

Via SRI (Shared Resource Interconnection), also known as crossbar, data is transmitted back and forth between the cores and the memory. These connections are secured by hardware mechanisms in the form of end-to-end connections.

The second generation of Aurix microcontrollers is based on an operating voltage of 3.3 V and a frequency of 300 MHz. An alarm is generated if the permissible tolerances are exceeded or undercut. Peripheral devices can, for example, be monitored via a CRC (Cyclic Redundancy Check). Checksums are used to check correct data transmission during this procedure.

As an integrated hardware IP in the Aurix microcontroller, the Safety Management Unit is responsible for recording, processing and evaluating all safety-related errors.

SafeTpack is a comprehensive safety manager for the second generation of Aurix microcontrollers developed by Hitex. It coordinates the execution of commissioning and cyclic tests that ensure correct operation of the Aurix processor cores and internal buses through a blend of hardware and software modules.

These hardware and software features create a level of safety that cannot be achieved easily with a standard microcontroller.

Functional safety, however, cannot be achieved with the microcontroller alone; rather, it must be seen as a central component of the overall design. The safety of the overall system can only be guaranteed when developing a safety concept from the outset and pursuing it with intensity. This complex process can be summarized in five steps.

Implementing functional safety

1. Performing a hazard and risk analysis: The risk analysis must determine the extent to which safety-critical applications are taken into consideration and the extent to which they must be complied with in relation to legal functional safety requirements. A variety of methods are available for this purpose. For example, HARA (Hazard Analysis and Risk Assessment) is popular. It can be used to determine whether a system is a safety-relevant system and, if so, how high the degree of safety relevance is.

2. Defining the safety requirement level: Depending on the standard, there are various safety requirement levels. For industrial applications, IEC 61508 defines the so-called "Safety Integrity Level (SIL)", featuring the levels SIL1 to SIL4. Which level is actually relevant can be determined in a matrix using the combination of the parameters 'extent of damage', 'length of stay', 'protection against danger' and 'likelihood of occurrence'. Similarly, ISO 26262 defines the adequate safety criteria for automotive environments, with safety levels ASIL-A to ASIL-D.

3. Determining components and implementing the design: The most suitable component is chosen for implementation of a desired application. To achieve this goal, specific safety functions must be taken into account. It is then possible to design the layout of the board and populate it accordingly. A conclusive safety concept must be developed and put into practice, especially when programming the microcontroller.

4. Validating the safety function: The validation procedure shows whether all safety-relevant functions are working properly – i.e. each individual function, independent of the overall system. If one or more of them do not work according to the specifications, they can be revised during the development phase. This procedure is repeated as often as necessary until all the safety functions meet the requirements.

5. Verifying safety: Verification is the second part of the check that occurs after validation. It involves checking the flawless operation of the system using checklists. In contrast to validation, verification considers the system as a whole. Independent certification authorities, such as TÜV in Germany, support this step and certify safety according to the legal requirements.

Programming an intricate microcontroller such as Aurix is complex, especially when safety aspects are added. To support developers and accelerate programming, Infineon has developed the PDH (Preferred Design House) concept for all customers. The PDH model includes free and paid support services. An overview of all the partner companies included in the PDH and their expertise is listed at www.infineon.com/pdh. ∎

Toughing out any environment

DPS368 – new XENSIV™ digital barometric pressure sensor

Infineon has developed a miniaturized digital barometric pressure sensor that works reliably in even the harshest of environments. Robust against water (IPx8), dust and humidity, this water-resistant package is up to 80 percent smaller than other waterproof pressure sensors. This makes it ideal for space-constrained and mobile applications such as smart phones and wearables, home appliances, drones and healthcare trackers.

Highlights includes best-in-class resolution and stability over time for extremely precise measurement of altitude, air flow and body movements. Fast read-out ensures quick sensor feedback and capacitive technology extends batters lifetime by cutting power consumption by over 50 percent relative to competitor products.

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