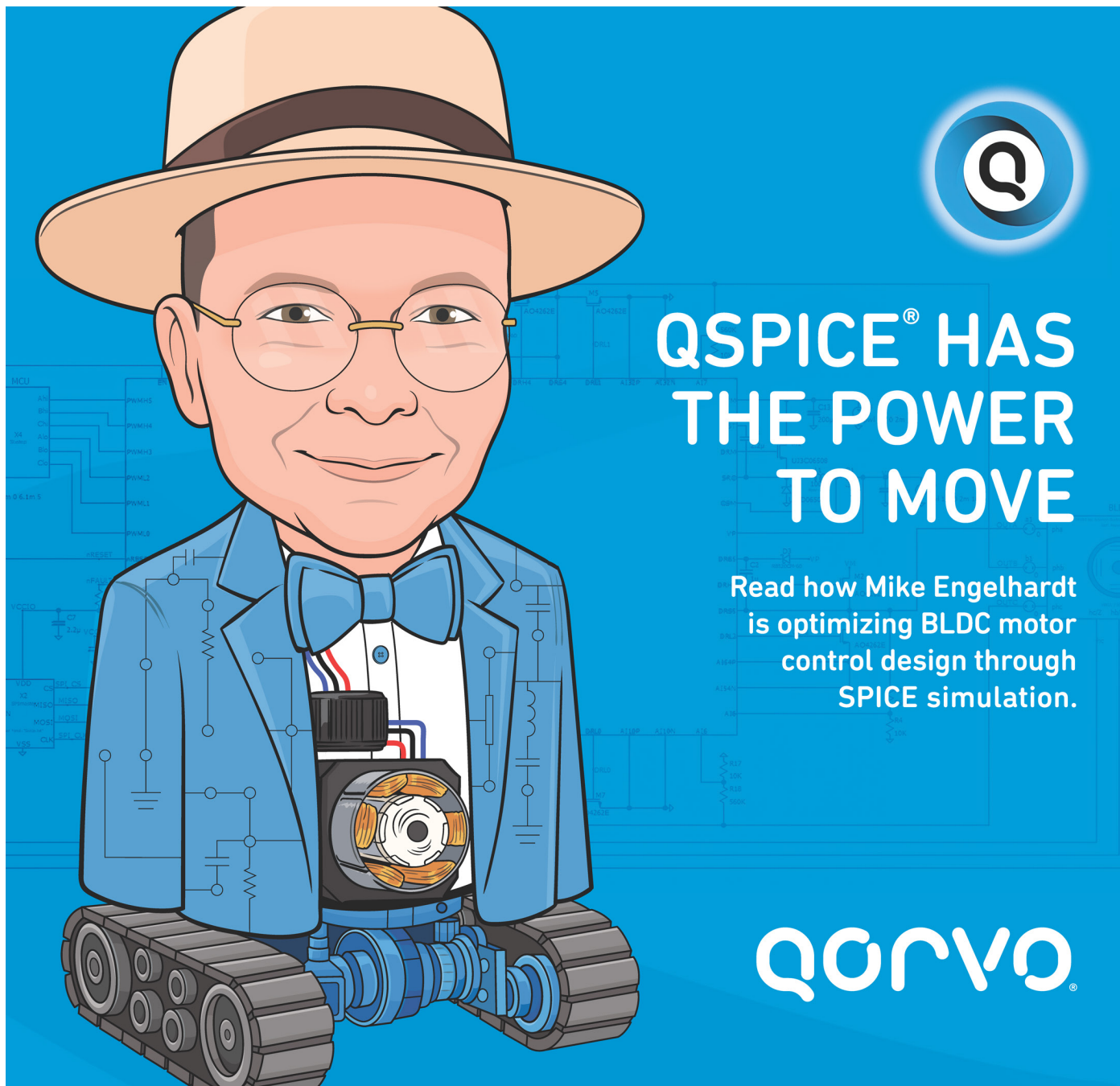




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4 VIEWpoint

Larger and More Reliable Batteries and the Means to Charge Them
By: Jason Lomberg, NA Editor, PSD

6 MARKETwatch

Batteries and Energy Storage
By: Kevin Parmenter, Director, Applications Engineering, TSC, America

7 DESIGNtips

PassThru of a Voltage Using Buck-Boost Regulators
By: Frederik Dostal, Field Applications Engineer, Analog Devices

COVER STORY

9 Optimizing BLDC Motor Control Through System Simulation

By: Siddharth Mohan, Sr. Design Engineer, Qorvo

TECHNICAL FEATURES

14 Military Electronics

Emerging Electrification of Military Ground Systems
By: Andreas Heldwein, Marketing Director for the Defense Segment at Infineon Technologies' HiRel business unit

19 AI + LiAR + Utilities

Smarter Infrastructure: AI-Driven LiDAR Classification for Electric Utilities
By: Lisa Stannis, Director of Customer Development at Sharper Shape

23 AI

The Hidden Bottleneck in AI: How the Network Can Make or Break Your LLM Strategy
By Allison Freedman, Product Manager at Keysight

SPECIAL REPORT: BATTERIES + OTHER STORAGE DEVICES

28 DC/DC Converters Bring Fuel Cell Solutions to Life

By: RECOM Technical Marketing Team

32 Automotive Functional Safety and ISO 26262

By: Timothy Hegarty, Texas Instruments

35 EV Charging Levels from Residential to Commercial

By: Wayne Liang, senior segment manager at Microchip Technology's E-Mobility business

38 BMS transformers in Energy Storage Systems

By: Samuel Lamprecht and Gerhard Stelzer, Würth Elektronik

POWER SYSTEMS DESIGN JULY 2025



COVER STORY

Optimizing BLDC Motor Control Through System Simulation (pg 9)



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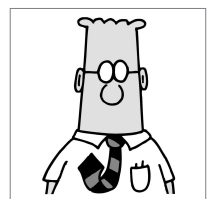
42 PSDcast

The latest audio interviews on relevant topics to the power electronics industry

44 FINALthought

LMR Battery Cells – Powering the Future
By: Jason Lomberg, NA Editor, PSD

44 Dilbert



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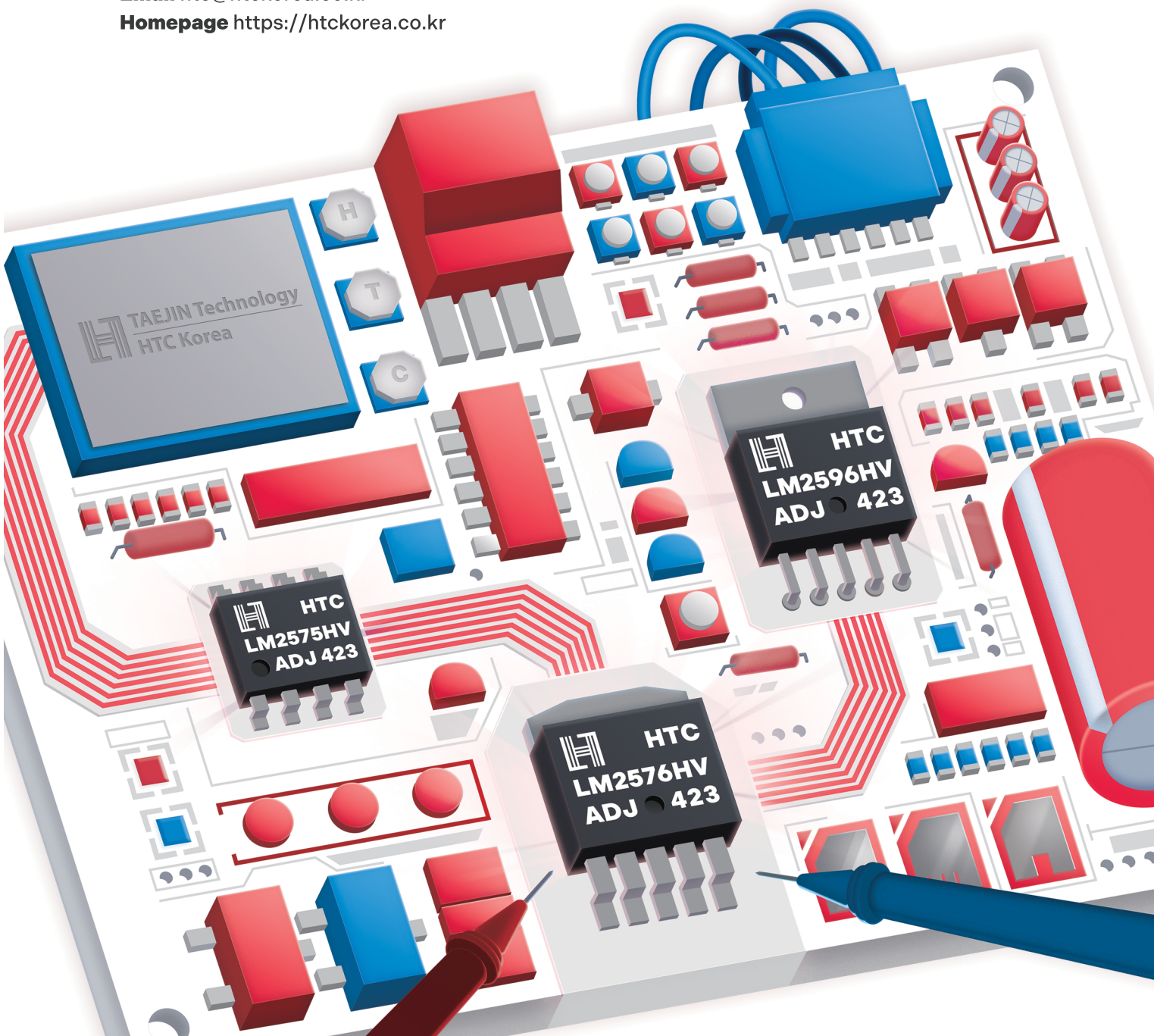
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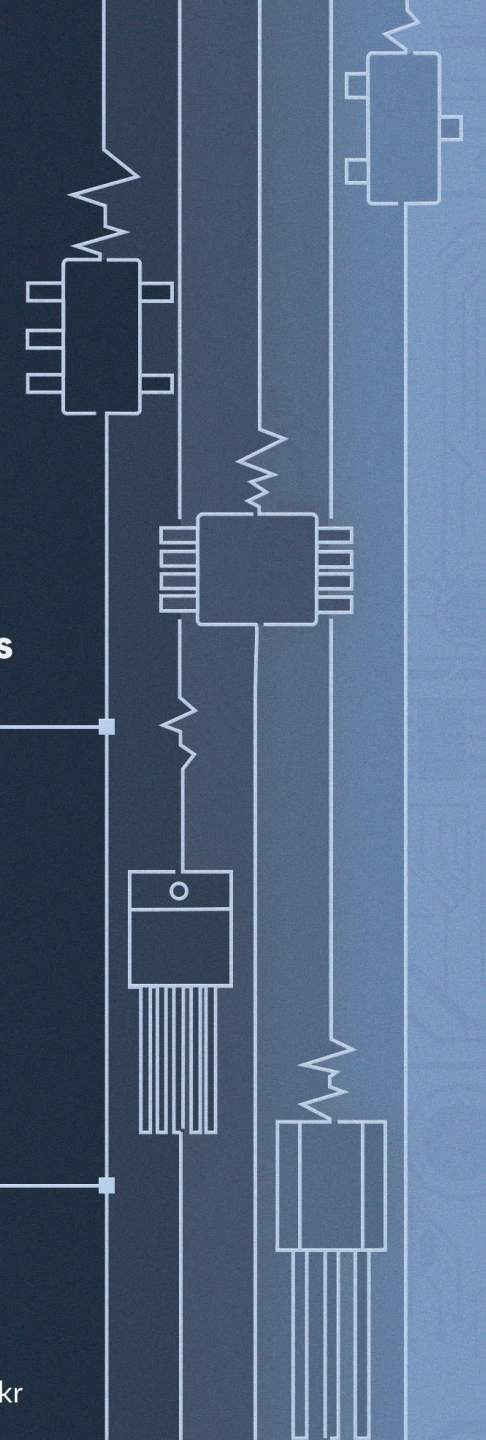
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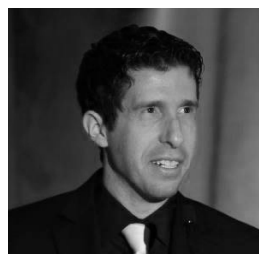
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Volume 18, Issue 7



Larger and More Reliable Batteries and the Means to Charge Them

Welcome to the July issue!

We've just passed the official start of summer in the Northern Hemisphere (sorry, Antarctica!), and with kids home from school and the weather considerably less treacherous, we hope you're able to enjoy the outdoors, and pull yourself away from the workbench long enough for an honest-to-goodness vacation!

Perhaps you'll go for a road trip, and if so, you're probably concerned with energy density and how far your EV can get on a single charge (and where you can stop along the way for a recharge).

Appropriately enough, the July issue covers "Batteries + Other Storage Devices," and given how red hot the topic is, it's seen no shortage of coverage in every corner of our publication, from product releases to technical features, and of course our blog section and PSDcasts (podcasts).

For example, we recently spoke to WiBotic regarding their collaboration with Astrobotic and NASA on flight testing of a wireless lunar charging system. Lunar explorers – especially long-term denizens – will have to contend with rough conditions and be mostly self-sufficient (swap "mostly" for "entirely" once we design to send humans to Mars), and that includes power.

And I probably don't need to explain the logistical and practical advantages of wireless over wired charging, especially on a completely different planetary body.

We also recently interviewed Mathworks about using modeling and simulation – which the company has ample experience in – to help develop more robust battery management systems.

Moving laterally to our blog section, we detailed a development where Chinese researchers have developed a method to recover 99.99% of the lithium, 96.8% of the nickel, 92.35% of the cobalt, and 90.59% of the manganese in spent lithium-ion batteries.

China leads the globe in rare earth element extraction (and are in the top 5 for lithium production), but they also hold a rather dubious distinction – the world's biggest polluter.

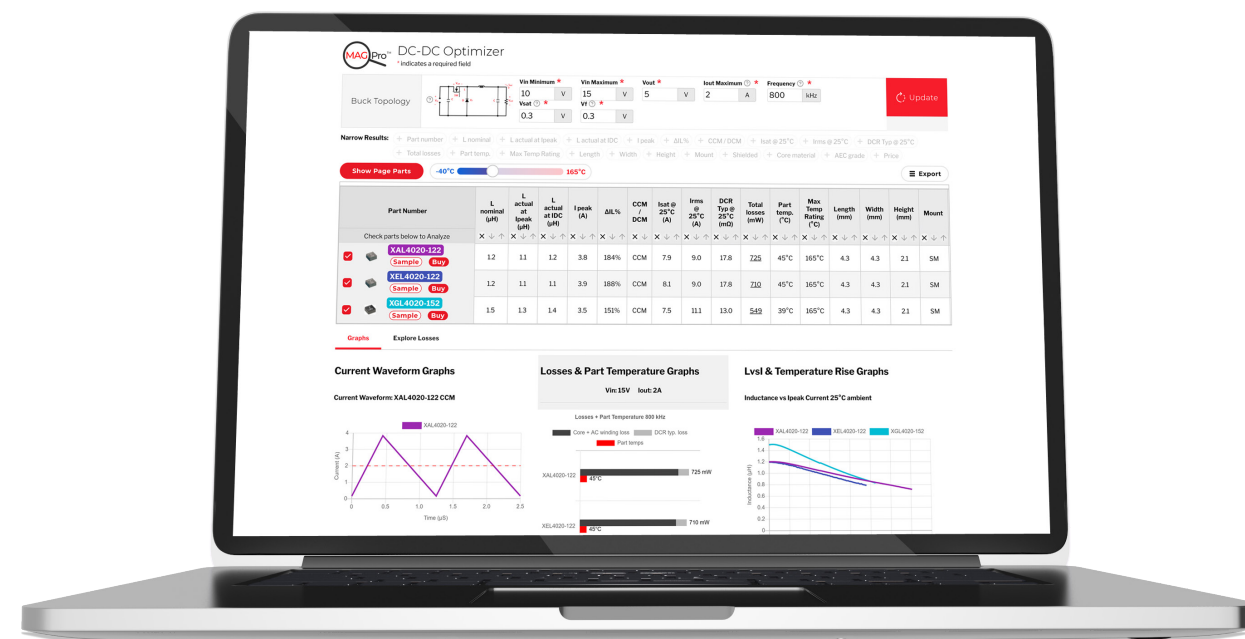
So, the fact that this new method allows China to recover rare minerals from spent batteries in an environmentally - conscious manner is huge! They apparently do so using an amino acid (glycine), which cuts out harsh chemicals in the recycling process plus toxic byproducts.

Finally, I'd like to briefly mention one of several articles in this month's Special Report, this one dealing with battery management system (BMS) transformers in energy storage systems.

Renewable energy sources like wind and solar are making larger energy storage systems a top priority. And as Samuel Lamprecht and Gerhard Stelzer from Würth Elektronik point out, larger energy storage systems "require a sophisticated battery management system (BMS) for reliable operation. BMS transformers can be used to insulate the components and improve the EMC properties."

Best Regards,
Jason Lomberg
North American Editor, PSD

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Batteries and Energy Storage

Kevin Parmenter, Director, Applications Engineering, TSC, America

There are many types of energy storage technology approaches, each suited to different applications based on their ability to deliver capacity, safety, performance, power output, lifespan, cost, and efficiency. Storage applications range from portable electronics and electric and hybrid-electric vehicles to backup systems for grids and AI server farms.

The market for batteries alone is growing dramatically. According to a recent Fortune Business Insights report, the global battery energy storage market size was \$25.02 billion in 2024. The estimated size of the global TAM (total available market) for 2025 is \$32.63 billion, and it's projected to be \$114.05 billion by 2032, exhibiting a CAGR of 19.58% during the forecast period.

In addition to traditional non-rechargeable primary batteries like alkaline and Li MnO₂, there are rechargeable secondary technologies like lead acid, NiCad (NiCd), nickel metal hydride, lithium-ion, lithium-iron phosphate (LiFePO₄) and solid-

state batteries. (For UPS system designs, I've been using newer lithium iron phosphate batteries to swap out lead acid batteries. They reduce weight and last longer and, with their integrated charge/discharge protection circuitry, they can emulate an SLA battery. This works well in a semi-controlled temperature environment, assuming you don't exceed four cells in series or 48-volt stack usage.)

Other energy storage methods include flywheel technology, which stores energy in a rotating mass for grid stabilization, as well as UPS-like backup. These systems typically have a sophisticated motor-generator and control electronics that elegantly control and monitor the operation of the devices. There is also thermal storage (molten salt, phase change materials), hydrogen fuel cells and flow batteries (vanadium redox), plus pumped hydro storage systems and compressed air storage.

There always seems to be a new breakthrough energy storage chemistry ready to go mainstream. Some technologies will forever

be on the horizon, eating up VC and government funding as they are proven to work safely and repeatably over a wide range of temperatures and for an extended lifetime.

These approaches all depend on power needs, energy delivery rate requirements, cost, complexity, lifespan and environmental impact. But regardless of the technology used, the good news is that power electronics are needed to make any technology work reliably in the applications.

The great news is that any rechargeable battery technology requires power electronics to not only measure temperature, current, voltage and time but also to control all these so the chemistry is maximized for long life and performance. The wrong charge profile, for instance, will damage the cell and shorten the application's lifespan. Since monitoring and control is necessary for any energy storage approach, power electronics designers will always be in high demand.

PSD

PassThru of a Voltage Using Buck-Boost Regulators

By: Frederik Dostal, Field Applications Engineer, Analog Devices

This article will illustrate how special converters equipped with PassThru™ mode can be useful when the circuit's input voltage is too high or too low to power a load. It will give examples of how PassThru mode is used with buck-boost regulators and boost regulators to increase power supply efficiency and improve EMC behavior.

In some applications, an existing supply voltage can drive a load directly without the use of an additional voltage converter. At certain times, when unusual operating states occur, the supply voltage may be too high or too low to supply a load directly. In these cases, special voltage converters that have been optimized for this type of operation can be used. An example of an application is an industrial 24 V system. Let's assume a load requires a 24 V supply voltage, but the available 24 V voltage rail can sometimes go up to 38 V or drop to 15 V. These voltages fall outside of the permissible supply voltage range of the load. For these applications, classic boost regulators or buck-boost regulators can be used.

Figure 1 shows a system diagram

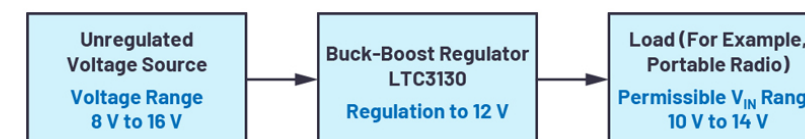


Figure 1: A system in which the permissible voltage range of a load is narrower than the possible voltage range of the energy source

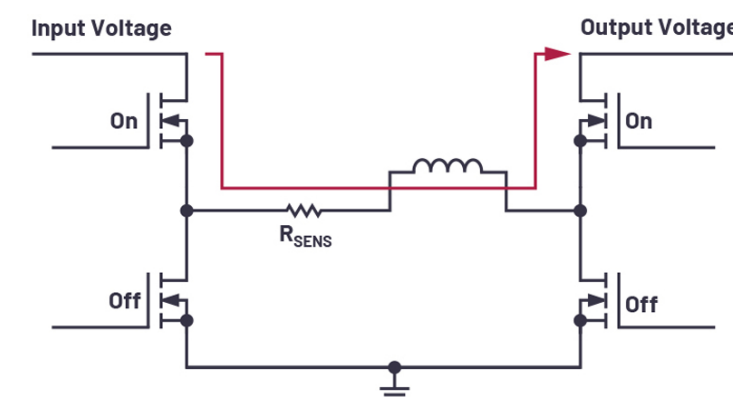


Figure 2: An LT8210 buck-boost regulator with PassThru mode for passing a voltage in standard operation

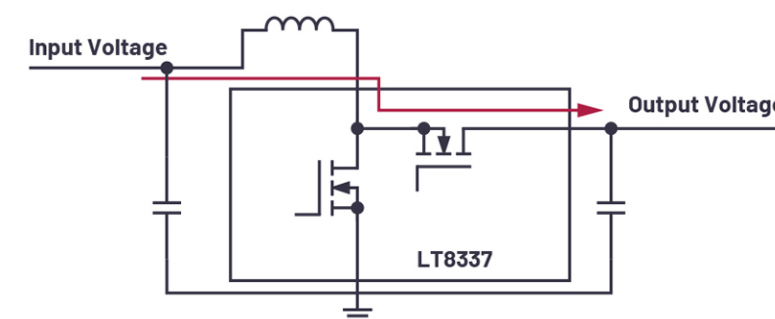


Figure 3: An LT8337 boost regulator with Silent Switcher technology that also offers PassThru mode

of such an application. A portable radio device is supplied with voltage by a battery. The load can handle between 10 V and 14 V, but the voltage source has a possible output range of 8 V to 16 V. An

interposed buck-boost regulator can thus convert the voltage to 12 V at the output. If the supply voltage is somewhat lower than 12 V, the converter works in boost mode, and if it is above 12 V, it



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works in buck mode.

Achieve Improvement with PassThru Mode

A system such as the one shown in Figure 1 works well—however, improvements can be made. If the voltage source is at a voltage that can directly supply the load for most of the time, a buck-boost regulator can be used in PassThru mode. Here, the circuit designer defines an input voltage range within which the input voltage is passed directly to the output of the buck-boost regulator. The advantages of this are that there are no switching losses whatsoever and the circuit efficiency is very high. In addition, the circuit is operated with extremely low electromagnetic emissions because there is no pulsing of currents in this operating mode.

Figure 2 shows the power stage of a new LT8210 buck-boost controller circuit with PassThru mode. In this mode, the two high-side switches of the H-bridge are permanently on and the two low-side switches are permanently off. Through this, depending on the currents and voltages, efficiencies of just below 100% are possible.

Besides a buck-boost solution (LT8210), boost regulators are also available with PassThru mode. The new LT8337 Silent Switcher® boost regulator from Analog Devices has an integrated PassThru mode. **Figure 3**

illustrates the concept behind the LT8337 boost converter. When PassThru mode is active, the high-side switch is permanently on and the low-side switch is permanently off.

In boost regulators, the high-side switch is usually executed with a flyback diode. Through this, an increased regulator supply voltage lying above the set output voltage is automatically passed through the inductor and the flyback diode. A dedicated PassThru mode, however, helps strongly reduce the voltage drop losses of the diode by actively switching on a high-side MOSFET. The PassThru mode also takes care of switching off all unnecessary functions of the LT8337. As a result, the IC itself can reach a current consumption of just 15 μ A. This is very useful, especially for battery-operated applications.

PassThru mode increases the efficiency of a power supply and improves the EMC behavior. These advantages especially come into play in applications in which the available supply voltage is usually within the permissible voltage range of the load. However, it must also be clear to users that in PassThru mode, regulation of the output voltage does not take place within the defined voltage thresholds. In many applications, though, this is not necessary.

Analog Devices

Optimizing BLDC Motor Control Through System Simulation

Get your design moving with the power of QSPICE®

By: Siddharth Mohan, Sr. Design Engineer, Qorvo

Why BLDC motors? Electric motors are responsible for roughly 50% of the world's total electrical energy consumption, according to the European Commission¹. Improving motor efficiency not only reduces operational costs but also plays a vital role in lowering global CO₂ emissions. Among available motor technologies, brushless DC (BLDC) motors stand out for their high efficiency, typically between 80% and 90%, compared to 75% to 80% for traditional brushed motors.

This efficiency, along with their durability and low maintenance requirements, has made BLDC motors a popular choice in both battery-powered and mains-powered applications. Driven by an inverter that regulates their speed and torque, BLDC motors are widely used in everything from power tools and household appliances to electric vehicles and industrial automation. Their popularity has also been helped by advances in microcontroller algorithms, which have made it easier to implement the precise

control these motors require.

Unlike brushed motors, which use mechanical contacts to switch current, BLDC motors operate electronically. This eliminates the sparking and wear that contribute to maintenance issues and performance degradation in brushed designs. BLDC motors also produce less electrical and audible noise.

In terms of construction, a typical BLDC motor features permanent magnets mounted on the rotor shaft, with three field windings arranged around the stator. Rotation is achieved by sequentially energizing these windings. Fine control over motor behavior—such as speed, torque, and acceleration—is accomplished by adjusting the pulse width and frequency of the current applied to each coil.

To achieve such dynamic and precise control, feedback on the rotor's position is essential. This can be done using position sensors (encoder or Hall sensors), or employing a sensorless method by measuring the back electromotive force

(EMF) induced in the stator windings by the rotating magnets. This method is central to field-oriented control (FOC).

Extracting the best performance from a BLDC motor while maintaining efficiency requires careful tuning and dynamic control across a wide range of operating conditions. This is where system simulation becomes invaluable. By simulating the motor, control algorithms, and load conditions together, engineers can optimize the entire system—balancing performance, efficiency, and robustness long before hardware is built.

Qorvo's ACT72350 BLDC integrated driver

To streamline the design of BLDC motor-based applications, Qorvo introduced the [ACT72350](#), a 160 V standalone three-phase BLDC motor driver with integrated power manager and Configurable Analog Front-End (CAFE).

By integrating bootstrap diodes and all the analog blocks needed to measure current and protect

the device, the ACT72350 allows for smaller solutions and replaces up to 40 discrete components in a BLDC motor control system, significantly reducing the BOM.

The CAFE allows customers to precisely configure their own sensing and position requirements, while the wide input voltage range from 25 V to 160 V allows the same design to be reused for a variety of battery-powered motor control applications.

The ability to drive up to 20S battery power makes the ACT72350 ideal for battery-powered applications between 48 V and 120 V, including:

- Power tools
- Garden tools
- Motor controllers
- Drone/RC
- E-bike
- E-vehicle
- Ped-electric bikes
- Light HEV

QSPICE® simulator

QSPICE®, introduced in 2023 by Qorvo®, marks a new era in circuit simulation software—offering power and analog designers a substantial boost in productivity through faster simulation speeds, enhanced functionality, and improved reliability.

Beyond pushing the boundaries of traditional analog simulation, QSPICE empowers engineers

to model complex digital circuits and algorithms with ease. Its innovative blend of modern schematic capture and high-speed mixed-mode simulation makes it the go-to solution for addressing the growing hardware and software challenges system designers face today.

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Model generator

Qorvo® has introduced a powerful new enhancement to its QSPICE circuit simulation software. This latest update streamlines the process of generating highly accurate models for semiconductor components—enabling electronic designers to complete tasks in just minutes rather than hours, all through a new tool ('model generator') now included in the free QSPICE software package.

This newly integrated feature supports the creation of simulation models for discrete components such as Junction Field Effect Transistors (JFETs), Metal Oxide Semiconductor Field Effect Transistors (MOSFETs), and diodes—using standard parameter data commonly found in datasheets. According to Mike Engelhardt³, the creator of QSPICE, this addition represents the most significant advancement in circuit simulation since the platform's debut in 2023. This feature enables designers to create models for the power MOSFETs they want to use

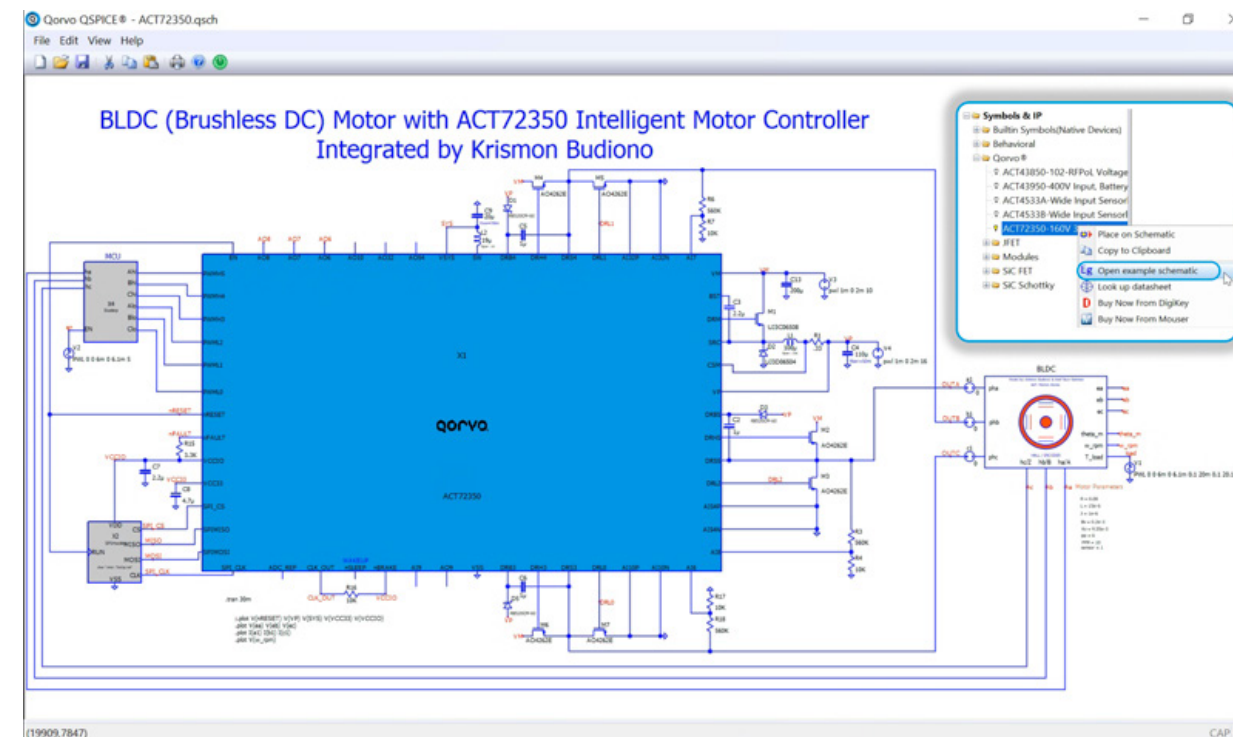


Figure 1: How to run the ACT72350 BLDC motor example

in their BLDC motor circuit simulations.

A full BLDC motor simulation in QSPICE

Krismon Budiono, an electronic circuit simulation enthusiast, recently developed a BLDC motor model in QSPICE⁴. To achieve this important result, Krismon made use of the concepts provided by Professor Marcos Alonso, who has created and posted nearly 100 power electronics design lessons on YouTube (<https://www.youtube.com/@MarcosAlonsoElectronics/videos>). Professor Alonso switched from LTspice to QSPICE to illustrate these lessons, after developing a BLDC motor model in LTspice a

couple of years ago^{5,6}.

To run and test the behavior of the BLDC motor, Krismon used a six-step commutation control he created in Cblock, using a hall sensor model as a practical sensor. Six-step commutation, also referred to as trapezoidal commutation, is a switching technique used to control three-phase BLDC motors. It consists of switching energy between the three phases in sequence, creating a rotating field that rotates the motor.

QSPICE now features a full BLDC motor example that includes the BLDC motor model developed by Krismon (together with the six-step commutation control) and the simulation

of the ACT72350 BLDC motor driver IC⁷. As shown in **Figure 1**, the example can be found by right-clicking on ACT72350 and selecting “Open example schematic”. All files required to run this schematic are included in the latest version of QSPICE.

Trapezoidal waveforms are used to drive a BLDC motor because this type of signal allows for higher system efficiency and because it maximizes the motor torque. The trapezoidal technique employs Hall-effect sensors to determine the position of the rotor; this information is essential for the drive, as it allows the speed and torque of the motor itself to be controlled. **Figure 2** shows the waveforms of three trapezoidal

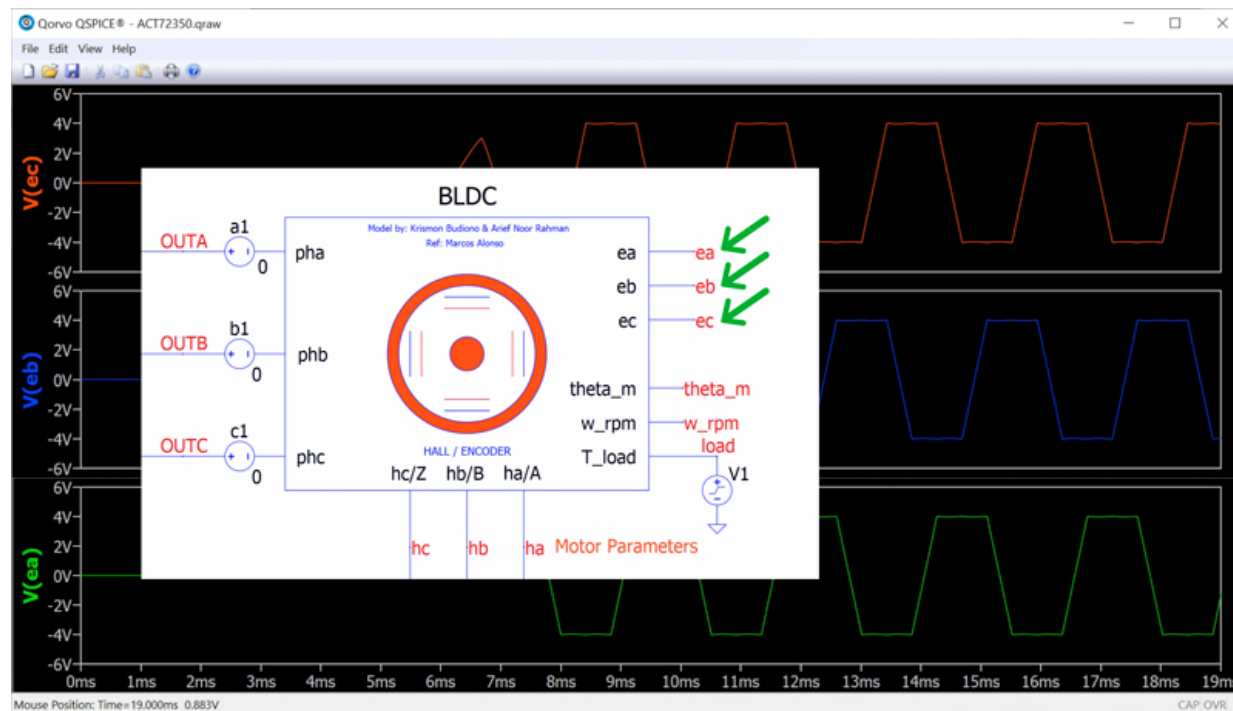


Figure 2: Visualization of trapezoidal back EMF waveforms in QSPICE

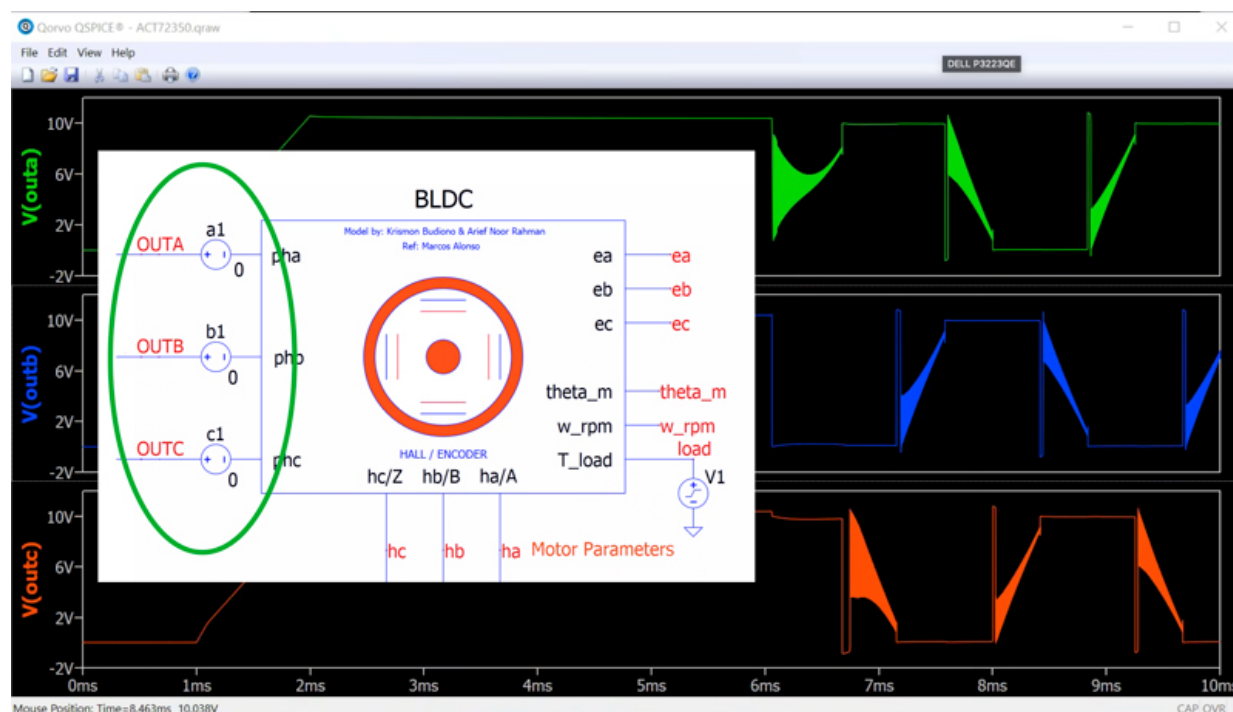


Figure 3: Waveforms corresponding to the motor inductors' response

back EMF of the BLDC motor taken from the “ea”, “eb”, and “ec” nodes of the motor simulation.

It is also interesting to look at the response of the motor inductors, characterized by high-frequency elements at the “OUT A”, “OUT B” and “OUT C” nodes. As shown in **Figure 3**, the model perfectly simulates the real conditions of the system.

The signals involved in the BLDC motor model, six-step commutation control, and inverter, are shown in Figure 2 and Figure 3³. As can be seen, the motor model also provides the angular velocity (“w_rpm”) and can simulate variable load conditions through the “T_load” terminal as well.

While the BLDC motor example included in QSPICE uses the ha, hb, and hc signals (Hall sensors) to detect the rotor’s position, sensorless applications can be developed with the ACT72350 motor driver simulation using techniques such as FOC.

When using a half-bridge configuration, the ACT72350 inserts a 100 ns dead time, or break-before-make (BBM), between each of the half-bridge drivers. The BBM timing can be programmed by accessing the SOC.CFGDRV1, SOC.CFGDRV2, and SOC.CFGDRV3 registers

via the SPI interface. These registers are fully implemented in the model.

In addition to break-before-make, many motors also require control over the dV/dt of switching transitions, as high displacement currents associated with rapid voltage changes can degrade magnet wire insulation. Therefore, users will likely want to add gate resistors to slow down these transitions. The BBM behavior can also be adjusted using diodes and resistors to apply different gate resistor values for turn-on and turn-off events. However, inverter-grade motors may not require such dV/dt control.

Among the advanced features offered by the ACT72350 is gate driver fault protection, which involves sensing the source current of the bottom FET. The trip threshold and the blanking time used to filter out the leading-edge current spike are programmable via SPI-controlled registers. These features, including the thresholds and blanking times, are fully implemented in QSPICE.

While the proposed BLDC motor example uses a sensed control technique, sensorless motor control can also be simulated. In that case, the original schematic shown in Figure 1 should be modified by

replacing the six-step block with an alternative control logic.

Krismon Budiono developed a working example that uses a block with two inputs: one for amplitude (Amp) and another for speed ($d\Phi/dt$). This approach functions similarly to a Class D audio amplifier, where the outputs are switched at a high frequency and the motor serves as a low-pass filter.

Conclusion

The combination of QSPICE and ACT72350 is a perfect example of Qorvo's integrated approach to reducing power consumption in BLDC drives. Additionally, the controller can be paired with a wide variety of commonly used microcontrollers.

Qorvo

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Emerging Electrification of Military Ground Systems

The path to electrify military ground systems is ripe with advantages: quieter and harder to detect vehicles, reduced project cost, diminished dependency on fossil fuels, and more

By Andreas Heldwein, Marketing Director for the Defense Segment at Infineon Technologies' HiRel business unit

While the implementation of electric components in the military will require time and intention, emerging technology in the semiconductor industry, coupled with recent strides in the commercial automotive sector, simplify such efforts.

This article will explore the various options of electrification in military applications, providing examples of projects along the way. Starting with current trends and future predictions, the electrification of military systems is both an attainable and necessary goal of the 21st century.

Background

The U.S. military began using electrified systems, such as electric servos, before exploring electric propulsion systems, like hydraulic drives. From weight saving advantages to faster and more accurate adjustments (e.g., gun turret), simplified maintenance, and streamlined logistical support,



Figure 1: BAE 155 MM M109A7 self-propelled Howitzer

this transition proved both tactically and financially beneficial to the military. But it's not the only advancement the military has made: more recently, the military increased test and evaluation of electric vehicles (EVs), like electric traction motors to drive tracks and wheels, as part of its effort to change and enhance operational capabilities.

In addition to improved performance, another benefit

of electrified military systems is efforts to combat climate change. For example, as climate change continues to impact extreme weather events, military vehicles can be used to power a field hospital or an emergency landing strip for natural disaster aid. Furthermore, this approach would eliminate the necessity for towed or airlifted generators and the fuel required to power them reducing the logistical demands required in disaster situations.

Latest trends and future predictions

Diesel

Diesel – or the military version, JP-8 – has been the fuel of choice for decades when powering military ground vehicles and auxiliary power units, such as generators and A/C systems. Back in the 1980s, the U.S. military and NATO nations released the Single-Fuel Concept (SFC), reducing the number of fuel variations and trimming the need for multiple fuel storage and distribution systems.

Diesel comes with its own set of drawbacks and advantages. For example, diesel contains about 10% more energy per volume than gasoline. Diesel in vapor or liquid form does not ignite as easily as gasoline, greatly reducing accident risk and simplifying handling during transport, fluid transfer, and refueling operations. For reference, the US Army planning estimates for one division are up to half a million gallons of diesel fuel per day (see figure 2). The cost of one gallon of diesel can be as high as \$400 per gallon (Pentagon “fully burdened cost”). U.S. military operations in Iraq and Afghanistan consumed around 68 million gallons per month.

While diesel engines have fewer moving parts than modern gasoline engines, allowing them to be more reliable and durable, they are also heavier than gasoline engines, increasing overall vehicle or equipment weight.

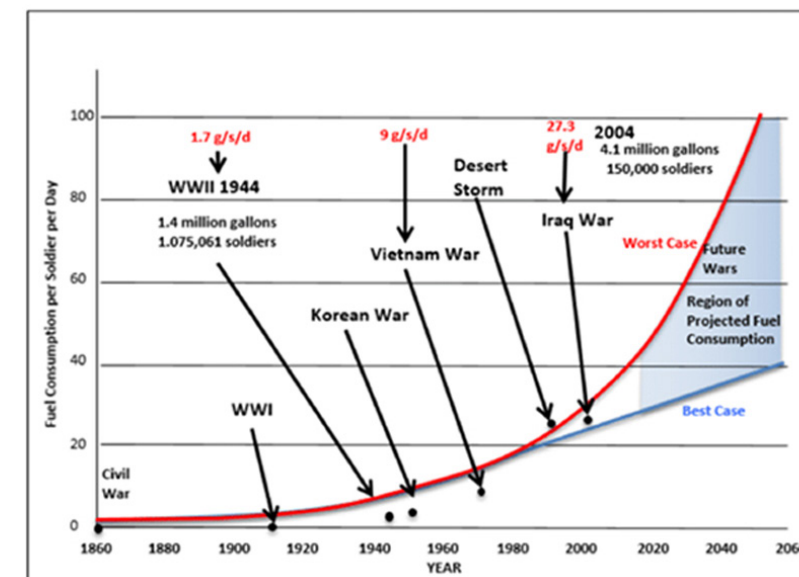


Figure 2: Projected military fuel consumption

The increased weight can create increased logistical challenges when moving individual equipment or entire brigades or divisions.

Trade-offs between temperature and power are also another factor in running diesel engines. While diesel engines can produce more power (especially low-end torque needed for towing) than gasoline engines given the same amount of fuel, they also run hotter. Exhaust gas can easily reach 200°C at the tip of the exhaust and 600°C or more at the engine. Hot engines and exhaust gases make detection through thermal imaging and turning vehicles into targets very easy. While there are efforts on the way to camouflage and reduce heat signature of an internal combustion engine, not generating one would be the preferred option. Electric motors, batteries and power circuits run at peak temperatures around 100°C, and

cooling can lower temperatures further.

A final consideration of diesel engines is noise signature. Diesel engines in military ground vehicles are around 100dB at 50 meters, put simply, they are loud (see Figure 3). In extreme cases, noise levels can reach over 120dB at 50 meters. Mufflers on generators can reduce the noise down to about 70dB, which is about as loud as a TV. However, mufflers are not always an option for large military vehicles as their engine's performance depends on getting exhaust gases and heat out of the engine as fast as possible.

Hydraulic systems

Hydraulic systems have been the backbone of actuators on heavy equipment, tanks, armored fighting vehicles, artillery and any other system that has rugged and very heavy moving

parts. Hydraulic systems have proven reliable over decades but, like any mechanical system, require proper maintenance. The number of components to build a hydraulic system to perform a certain task can be significantly higher than that of a comparable electric system. To name a few components, think about pumps, hoses, fittings, pressure regulators, pipes, hydraulic rams, and hundreds of gallons of fluid. These components are all made from high-strength materials such as steel and reinforced rubber to handle several thousand PSI pressures.

The case for electrification

"Electric vehicles are quiet. They have a low heat signature and incredible instant torque, and because they tend to be low maintenance with fewer moving parts, they have the potential to reduce logistics requirements," said Deputy Defense Secretary Kathleen Hicks in a statement in November 2021 at Wayne State University in Michigan.

Compared to diesel powered drive systems, electric drive systems operate almost silently. The only audible noise they generate is the occasional humming from the inverters in the power supply. Power semiconductors in the inverters, which turn on and off thousands of times per second, naturally emit this audible hum. However, they also emit an electronic signature, which an intelligence, surveillance, target

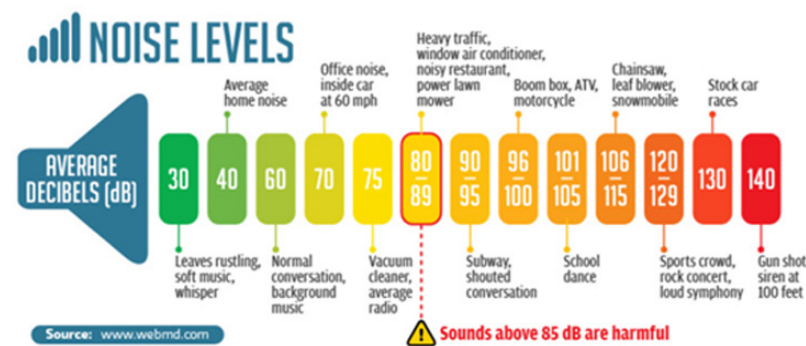


Figure 3: Noise level comparison

acquisition, reconnaissance (ISTAR) system can detect.

Electrification of military vehicles can take place in several stages. For systems on vehicles or ground systems that can convert to electric actuation, one starting point could be simpler auxiliary systems before eventually implementing fully electrified propulsion systems. Breaking down the vehicles by type, there are more than 242,000 wheeled tactical and 170,000 non-tactical vehicles. There are thousands of diesel generators and environmental control units in service around the globe, demonstrating a wide market for electrification.

The global auto industry has shifted to electrified subsystems since the mid-1990s. Motivated by stricter emission laws, engineers and scientists have researched how many watts a system on a car uses and have consequently developed solutions to move them from the mechanical to the electric domain. Examples are electric cooling fans, power steering, and breaking. Implementation took place in

incremental steps. One example is electric steering, which first used an electric hydraulic pump, eliminating the belt driven pump, while actuation of the wheels was still done via hydraulics. Now electric power steering means just that: an electric motor moves the drag link and steers the wheels.

Hybrids, Electric Vehicles (EV), and mild-hybrids are all well established in the commercial space. They all use electric power and may still have an internal combustion engine. Hybrids are broken down into several sub-groups, outlined below:

1. **Mild-hybrids** are the simplest implementation and have been around more than 20 years. They simply turn off the internal combustion engine when the vehicle idles, which is also called the "Start-Stop" feature. This feature requires the vehicle to know the state of charge of the 12V battery as to not stop the engine with a weak battery, preventing a restart.
2. **EVs** are fully electric and no longer have an internal

combustion engine. The high-voltage batteries (600V to 800V) require external charging. The dependency on external charging now limits the range of the vehicle (beyond its initial battery range) to any charging network that is available. This is very likely the one factor that will limit military EVs to specific applications rather than broad implementation across the force. The second factor that limits EVs as tactical options may be the lack of redundant of power systems. "What if the batteries or the electrical motor fails?" may be a question on your mind right now. However, given that today's ground vehicles or generators also lack redundancy, this should be a minimum to no concern.

EVs make sense where their main strengths – silence, no heat signature – make the biggest difference: reconnaissance and security. Ultra-light tactical vehicles in crewed and uncrewed versions powered by electric motors and high-voltage batteries could be the optimal equipment to approach an objective with a much-reduced chance of detection.

3. **Hybrids** combine an internal combustion engine with an electric drive. Both supplement each other: the electric drive's high-torque supports acceleration and acts



Figure 4: Oshkosh, General Motors electric Infantry Squad Vehicle (eISV)

- as a generator to recharge the high-voltage batteries while the internal combustion engine does most work at cruising speed.
4. **Plug-in hybrids** add external charging in case the engine or regenerative braking cannot keep the high-voltage battery pack topped off. Hybrids have smaller battery packs than EVs. They also have extended range capabilities: there still is an internal combustion engine and a fuel tank that can be topped off at a gas station or tactically at a Rearm, Refuel, and Resupply Point (R3P).

The hybrid vehicle traction system is categorized into series and parallel architecture. In a series architecture, electric motors power the wheels either directly or through a transmission. The internal combustion engine operates a generator to charge the batteries, without any mechanical connection (such as a drive shaft) between the engine and the wheels. In parallel architecture, both the internal combustion

engine and electric motors have the capability to propel the vehicle. Although this provides redundancy, parallel architectures are inherently more complex due to the inclusion of both mechanical components (such as differentials, driveshafts, and transfer cases) and electric drive systems connected to the wheels.

Military hybrid EVs

Examples of currently tested military hybrid EVs include: ProPulse® diesel-electric hybrid system by Oshkosh, General Motors eISV (Infantry Squad Vehicle) (see Figure 4), or an electrified version of the Bradley fighting vehicle featuring BAE's HED (Hybrid Electric Drive) and QinetiQ's Modular E-X-Drive® technology.

Oshkosh has implemented the ProPulse® technology in HEMTT A3 and MTRV and claims significant fuel efficiency advantages: around 35% fuel efficiency improvement at 20 mph cruising speed and 25% at 60 mph, respectively (ProPulse®

Hybrid Diesel-Electric Systems, Oshkosh Corporation). General Motors eLSV is powered by a 400V 3-phase permanent magnet motor in combination with a 400V GM BEV2 lithium ion battery with a 66kWh capacity (GM Defense, LLC).

The U.S. Army's Rapid Capabilities and Critical Technologies Office (RCCTO) awarded BAE a \$32 million prototype agreement in 2020 (BAE Systems, July 16 2020), demonstrating the value of electric and hybrid vehicles in the military's near future.

Semiconductor technology as an enabler for military electrification

Semiconductor companies like Infineon have enabled the commercial automotive sector to engage in the design, development, and sale of millions of electric vehicles (EVs) and hybrids for more than a decade. Extensive customer feedback, billions of miles driven, and millions of engineering hours have contributed to making commercial electrified vehicles highly reliable for both urban and highway use. Furthermore, EVs and hybrids have become increasingly affordable as advancements in technology and manufacturing techniques have matured. Car companies have perfected electric vehicle designs, while semiconductor companies have supported and co-developed the necessary technology, anticipating needs a decade into the future.

Power semiconductor devices,

including silicon (Si), silicon carbide (SiC), and gallium nitride (GaN) technologies, are now highly reliable and in mature production. Silicon-based products like IGBTs typically operate up to 700V. Si is cost effective for systems in the EV's power domain that are not always on. For instance, an EV's traction system may primarily power the rear axle motors and to a lesser extent, the front axle motors during hard acceleration. In this case, the inverters for the front axle may be built with Si components to optimize cost efficiency.

Wide BandGap (WBG) materials like SiC and GaN support the high-power and long-range needs of electric vehicles. Both SiC and GaN can switch at high frequencies when powered with high voltages. Switching high voltages (e.g. 400V - 600V) in EV inverters allows for a more efficient use of available battery power. Moreover, SiC has higher thermal conductivity than GaN, allowing the inverter or on-board charger (OBC) to run at higher temperatures. This reduces the need for cooling, in turn reducing the system's overall power consumption, complexity, and weight. Especially in systems greater than 50kWh, SiC has the power and cost advantage over Si (IGBT) and GaN.

Semiconductors are available as discrete components, such as individual transistors, or as modules that include transistors and diodes prepackaged by the semiconductor supplier. SiC discrete devices are

suitable for use in inverters or on-board chargers with power ratings of approximately 1,200V and 50A, whereas SiC modules can accommodate applications requiring several hundred amperes. Certain semiconductor companies provide SiC modules up to 3,300V. SiC is also the most robust technology of the three based on its avalanche current and short circuit capability.

GaN combines voltages in the 600 - 1000V range with high switching frequencies in the megahertz range. This based on GaN having the lowest $RDS(ON) \times Q_g$ (>90% lower than Si). Switching at high frequencies and inherent low parasitic capacitance, GaN designs greatly reduce electromagnetic interference (EMI). The reduction of EMI or electro-magnetic signature is of particular interest for tactical vehicle applications as it reduces detectability. However, while GaN allows for higher switching frequency, GaN is less resilient to high operating temperatures than SiC.

Conclusion

As the military continues to explore and integrate electrification in its ground systems, it paves the way for a future where operational effectiveness, logistical efficiency, and environmental responsibility converge. This progressive transition not only enhances mission readiness but also aligns with broader global efforts toward sustainability and innovation.

Infineon

Smarter Infrastructure: AI-Driven LiDAR Classification for Electric Utilities

As power grids age and climate threats increase, electric utilities are under mounting pressure to modernize their infrastructure

By: Lisa Stannis, Director of Customer Development at Sharper Shape

Meeting today's demands for resilience, safety, and efficiency requires accurate, timely, and scalable data about physical assets. One technology that is rapidly redefining how utilities manage infrastructure is LiDAR (Light Detection and Ranging).

LiDAR captures millions to billions of high-resolution, three-dimensional data points—called point clouds—that precisely map utility networks and their surrounding environments. From power lines to substations to surrounding vegetation, LiDAR offers detailed visibility

that supports planning, maintenance, and emergency response.

But capturing LiDAR data is only half the job. The true value lies in how it's classified—turning those raw, unstructured points into actionable insights.

Why LiDAR Classification Matters for Utilities

Raw LiDAR point clouds lack semantic meaning. Each point represents a location in space but doesn't inherently say whether it belongs to a power line, a tree, a pole, or the ground. Classification is the process of assigning these

labels, making it possible to analyze assets, assess risk, and make decisions.

For electric utilities, classification enables critical operations:

- **Vegetation management:** Identifying and quantifying trees encroaching on lines before they cause outages or fires. This enables utilities to prioritize and address the most critical threats first, enhancing grid reliability and safety.
- **Asset inspection:** Monitoring pole lean, wire sag, and equipment condition.

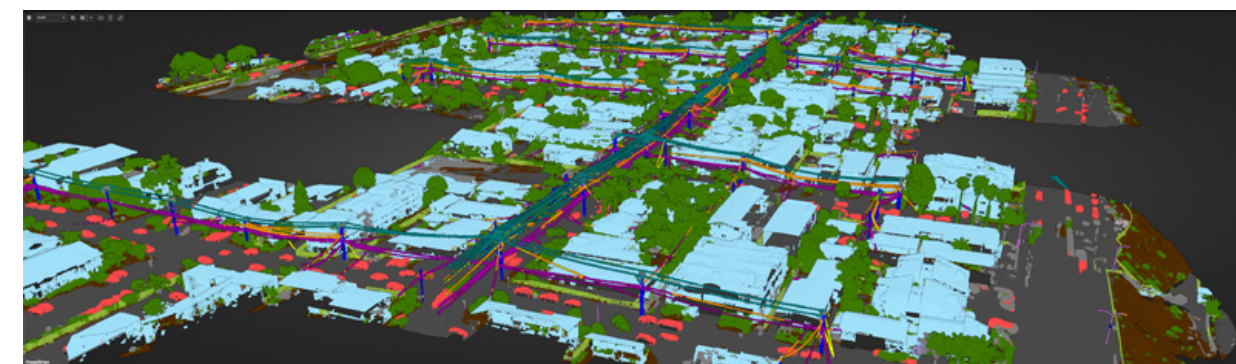


Figure 1: High accuracy LiDAR Classification excels in dense distribution network areas



Figure 2: State of the art, best in class ML point cloud classification

- Regulatory compliance: Ensuring proper clearances and safe infrastructure placement.
- Disaster preparedness: Modeling risk zones for wildfires, storms, and floods.
- System design and upgrades: Informing infrastructure layout in new projects.

Without accurate classification, even the highest-resolution LiDAR data is just a cloud of points.

The Traditional Approach—and Its Limits

Historically, classification has relied on rule-based algorithms, statistical models, and manual annotation. Analysts apply

filters and heuristics to segment terrain, detect structures, and label features. While this works for smaller datasets or simple landscapes, it doesn't scale well to high-density, multi-terrain utility environments.

Traditional methods rely heavily on manual processing, which can take several months to complete. To reduce costs, this work is often outsourced overseas, introducing potential cybersecurity risks associated with transferring sensitive data across international boundaries.

Today's LiDAR acquisitions often span hundreds of square miles and include billions of points. Manually classifying this data is not only time-consuming—it's cost-prohibitive. Even

semi-automated tools require extensive human review and correction, especially in cluttered or variable terrain.

In short, traditional workflows are hitting their limits. That's where artificial intelligence (AI) steps in.

AI-based LiDAR classification, especially through deep learning, has significantly improved both the speed and precision of point cloud analysis. Instead of relying on hard-coded rules, AI models learn patterns directly from labeled data, identifying subtle geometric and reflectivity-based features across vast datasets.

Deep learning models offer significant advantages in LiDAR classification by distinguishing

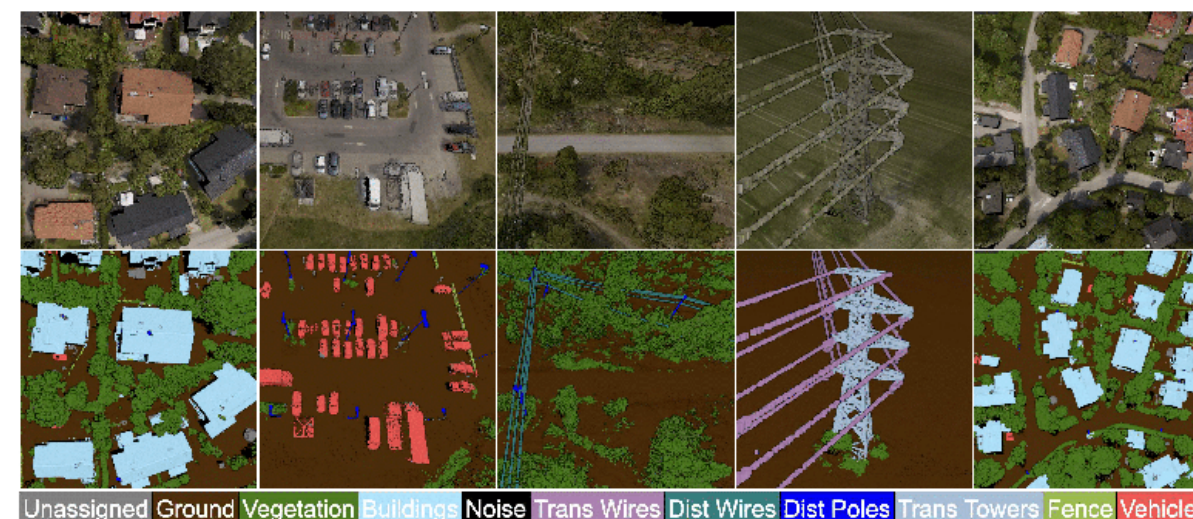


Figure 3: Network infrastructure focused classes detect multiple types of wires, buildings, ground, vegetation, and much more

between overlapping or similarly shaped objects—such as wires and branches—detecting small or partially obscured infrastructure elements and adapting to diverse environments with minimal reprogramming. These models also scale efficiently, enabling the processing of massive datasets in a matter of hours rather than weeks, making them ideal for large-scale utility applications.

Choosing the Right Classification Tool: Key Considerations

LiDAR classification tools vary in how they process and interpret point cloud data—differences that can impact how electric utilities manage assets, assess risk, and plan infrastructure. Some tools use automated algorithms, including AI, to quickly classify features like power lines, poles, and vegetation. Others offer manual or semi-automated options,

allowing for greater control in complex environments but take a significant amount of time to classify. Choosing the right tool depends on the utility's specific needs—such as data volume, terrain complexity, and the level of precision required. Understanding these options is key to making classification workflows faster, more accurate, and more cost-effective.

When selecting a LiDAR classification tool, it is essential to prioritize features that enhance both efficiency and accuracy. AI-driven algorithms that automatically classify points—such as ground, vegetation, and infrastructure—are crucial for processing large datasets quickly. While manual or semi-automated methods offer greater control, they are often too time-consuming for large-scale projects. Tools that include advanced feature

extraction capabilities provide deeper insights into the data and enable more sophisticated classification. Additionally, the ability to segment point clouds into meaningful categories like buildings, vegetation, and ground is vital for ensuring classification accuracy.

Accuracy verification is another key aspect, as automated tools, while fast, may struggle in complex environments. A hybrid approach that combines automated classification with manual corrections helps maintain both speed and precision. Visualization features are also critical, allowing users to transform raw LiDAR data into interactive 3D models that are easier to interpret. This enhances analytical capabilities and improves decision-making based on the data. As AI continues to advance, its integration into

LiDAR classification tools is revolutionizing the field by improving automation, enabling semantic segmentation, and expanding the scope of LiDAR applications across industries.

Challenges of AI in LiDAR Classification

AI is a powerful tool for LiDAR classification, but it comes with its own set of challenges. One major hurdle is the need for large volumes of accurately labeled training data. For utility-specific applications, this data is often scarce and costly to annotate. Additionally, AI models trained in one type of environment—such as urban areas—may not generalize well to others like mountainous or forested regions, often requiring retraining to maintain accuracy. The complexity of developing, validating, and maintaining these models also presents a barrier, as it typically demands specialized expertise that may fall outside the capabilities of many utility teams.

Another challenge is some feature classifications (e.g., custom infrastructure types or rare anomalies) still require manual workflows or expensive custom software. While off-the-shelf AI tools are becoming more accessible, industry-specific applications still demand tailored solutions.

Despite these challenges, AI-driven innovation is rapidly

transforming how LiDAR data is processed. Modern workflows now include automated quality assurance and quality control (QA/QC) systems that can flag anomalies or inconsistencies during data processing, significantly improving reliability. Point cloud alignment and registration are also handled automatically, reducing setup time and minimizing manual intervention. Additionally, dynamic model updates allow new data to be integrated into existing models without the need to reprocess entire datasets, enabling faster, more efficient updates and continuous improvement in classification accuracy.

The result? Utilities get clean, actionable data faster—with fewer manual bottlenecks.

Future Outlook: AI + LiDAR + Utilities

AI is reshaping LiDAR's role in utility operations. As models become more accurate and tools increasingly user-friendly, the process of classification is transitioning from a manual task to a fully integrated, automated workflow. Future developments are expected to include predictive modeling, where historical point clouds are used to forecast vegetation growth, structural fatigue, or fire risk. Edge processing will enable AI models to run directly on drones or mobile platforms, allowing for real-time classification in the

field. Additionally, integrated asset systems will allow classified LiDAR data to seamlessly sync with GIS, inspection, and maintenance platforms.

As sensor costs continue to decline and AI tools mature, LiDAR technology will become more accessible to a broader range of utility providers—from large transmission operators to smaller municipal services. This democratization of technology will support the development of smarter, safer, and more resilient energy networks, enabling proactive infrastructure management and improved service delivery across the utility sector.

Conclusion: Smarter Data for a Smarter Grid

AI-powered LiDAR classification is no longer a luxury—it's becoming a necessity for modern electric utilities. With growing infrastructure demands, increasing environmental risks, and limited field resources, having a fast, accurate, and scalable classification process is critical.

By understanding the tools available and embracing intelligent automation, utility companies can move beyond reactive maintenance to predictive, data-driven decision-making. That's not just an upgrade — it's a transformation.

[Sharper Shape](#)

The Hidden Bottleneck in AI: How the Network Can Make or Break Your LLM Strategy

In the rapidly evolving world of artificial intelligence (AI), performance is paramount—and not just for compute

By: Allison Freedman, Product Manager at Keysight Technologies

The network infrastructure connecting GPUs, switches, and servers in modern data centers is under enormous strain. As AI models scale into the hundreds of billions of parameters, the spotlight is shifting toward one of the most critical, yet often overlooked, components of AI training performance: the network. Historically, benchmarking and optimizing AI networks required live workloads running on expensive, power-hungry GPUs. But GPU availability is limited, and provisioning large-scale test environments takes time and capital. As a result, network validation is often delayed until real workloads are running—far too late to catch design flaws or performance bottlenecks.

That model no longer works in the age of hyperscale AI. The scale of today's AI models makes clear the infrastructure challenges ahead. When OpenAI



Figure 1: Keysight AI Data Center Builder is the foundational solution for validating AI data center performance across compute, interconnect, network, and power

trained GPT-3, its landmark 175 billion parameter model, it consumed an estimated 3.14×10^{23} FLOPs and required thousands of NVIDIA V100 GPUs over weeks of runtime.¹ This kind of workload pushes not just the limits of compute, but the very fabric of the data center. AI training jobs generate extreme east-west traffic across GPUs, storage, and parameter servers. Any congestion,

latency, or imbalance in traffic patterns can have significant effects on throughput and power efficiency. At hyperscale, even small inefficiencies cost millions.

Despite its criticality, the network layer is still rarely tested with realistic AI workloads prior to deployment. Most data centers are forced to use traffic generators, micro-

benchmarks, or best-guess synthetic models that fail to reflect real-world training dynamics. That's a risky proposition in an era where new workloads are constantly redefining performance expectations.

To meet the needs of large-scale AI, forward-looking organizations are now embracing AI workload emulation—a methodology that uses simulated training data to recreate the traffic patterns and demands of LLM training, inferencing, and other AI tasks. Rather than waiting for GPUs to become available, engineers can use emulated workloads to:

- Recreate realistic AI training scenarios
- Measure performance across the entire network fabric
- Identify congestion, jitter, buffer pressure, and routing inefficiencies
- Test alternative topologies, load-balancing methods, and queue configurations

This simulation-based approach lets teams benchmark and debug data center networks before GPUs arrive, drastically reducing costs and accelerating deployment. It also allows engineers to replay past

workloads to test how their network would respond under different traffic mixes or congestion control policies. This isn't theory—it's already happening.

Juniper Networks, for example, recently published a white paper outlining how it uses AI workload replay and emulation to validate switching architectures for AI data centers. By replicating actual LLM training traffic across its network fabrics, Juniper can test for congestion scenarios, analyze fabric scalability, and optimize queueing policies—without waiting for actual GPUs to be deployed. Juniper's engineers also emphasized

the importance of validating network behavior under “future load conditions.” Using workload emulation, they're able to simulate training workloads that haven't yet gone live, helping them build networks ready for the next generation of AI demand.

Meta, known for operating some of the most advanced AI infrastructures on the planet, has invested heavily in internal testbeds that emulate AI training environments. These testbeds allow Meta's engineers to validate topology decisions, switching algorithms, and congestion-handling policies using training-like traffic patterns.

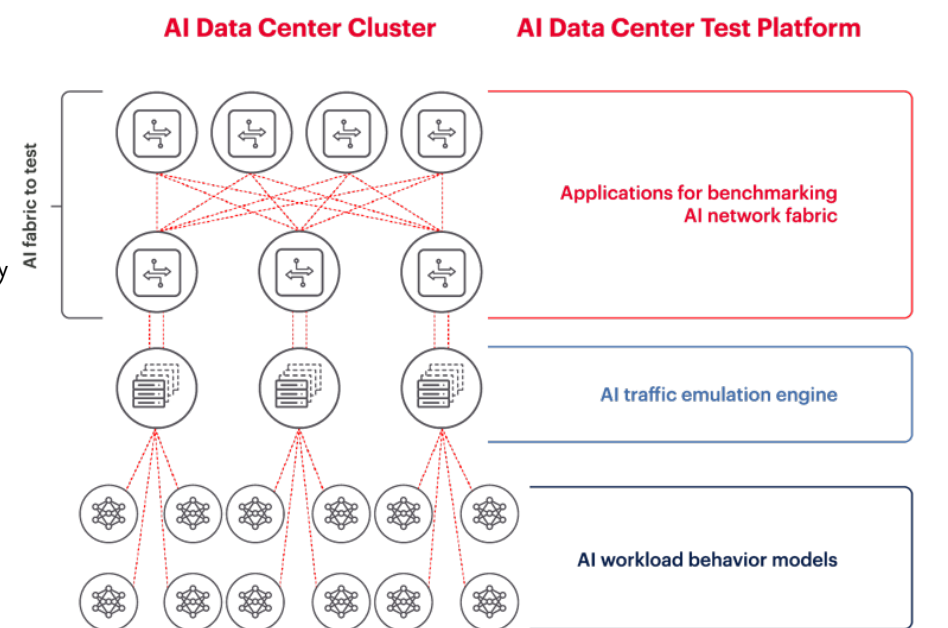


Figure 2: This diagram illustrates an AI data center cluster and a corresponding AI data center test platform. The test platform utilizes applications for benchmarking AI network fabric, an AI traffic emulation engine, and AI workload behavior models to simulate and validate network performance for AI workloads

Microsoft is fundamentally redesigning its data center architectures to meet the demands of large-scale AI workloads. This transformation spans custom AI accelerators, innovative rack-scale systems, and high-bandwidth network fabrics tailored for AI training. To support these changes, Microsoft invests in advanced modeling and emulation tools that replicate the intense traffic patterns of large language model (LLM) training. These tools enable engineers to evaluate new topologies, test load-balancing strategies, and validate congestion control mechanisms in controlled environments—long before deployment. For all these industry leaders, the motivation to simulate realistic AI workloads is clear: eliminate guesswork, reduce time-to-validation, and ensure the network can scale at the pace of AI innovation.

AI workload emulation provides several critical advantages over traditional methods:

1. **Cost Reduction** eliminates the need to reserve expensive GPU infrastructure solely for network testing. Emulation can be done on commodity hardware or virtual environments.
2. **Speed** accelerates development by allowing performance testing in

parallel with hardware procurement or deployment phases. No need to wait for full racks of GPUs to become available.

3. **Realism.** Emulated workloads can replicate real training patterns (e.g., bursty traffic, collective operations, synchronization phases) far more accurately than synthetic traffic generators.
4. **Reproducibility.** Workloads can be captured, saved, and replayed repeatedly to test the effect of different topology designs, queueing algorithms, or configuration changes.
5. **Scalability** allows testing of future “what-if” scenarios—such as validating how a current network would handle double the traffic from next-gen models. This methodology enables network architects to move from reactive performance tuning to proactive optimization—ensuring every layer of the AI infrastructure is tuned for throughput, latency, and cost-efficiency before launch.

As LLMs continue to evolve—heading toward trillion-parameter scales, multi-modal architectures, and low-latency inferencing—data center networks will face unprecedented pressure. East-west traffic in AI clusters is

expected to grow by 10x or more over the next five years and in this context, the old model of “wait for GPUs, then test the network” simply won't scale. Organizations that fail to validate their networks early and often will face performance bottlenecks, cost overruns, and delays in time-to-market.

By adopting AI workload emulation, companies can shift from expensive trial-and-error to informed design, ensuring their networks are future-proofed for the demands ahead. In the race to build faster, more intelligent AI models, infrastructure matters—and the network is just as critical as compute. The organizations that win will be those who can simulate, test, and optimize their networks under AI-scale workloads long before production traffic hits the system.

As companies like Juniper, Meta and Microsoft have shown, workload emulation is more than a tactical advantage—it's becoming a strategic necessity. For hyperscale's, network equipment manufacturers, and any company building data center networks for AI, the message is clear: to stay competitive, embrace simulation-first design and make your network AI-ready from the start.

[Keysight Technologies](#)



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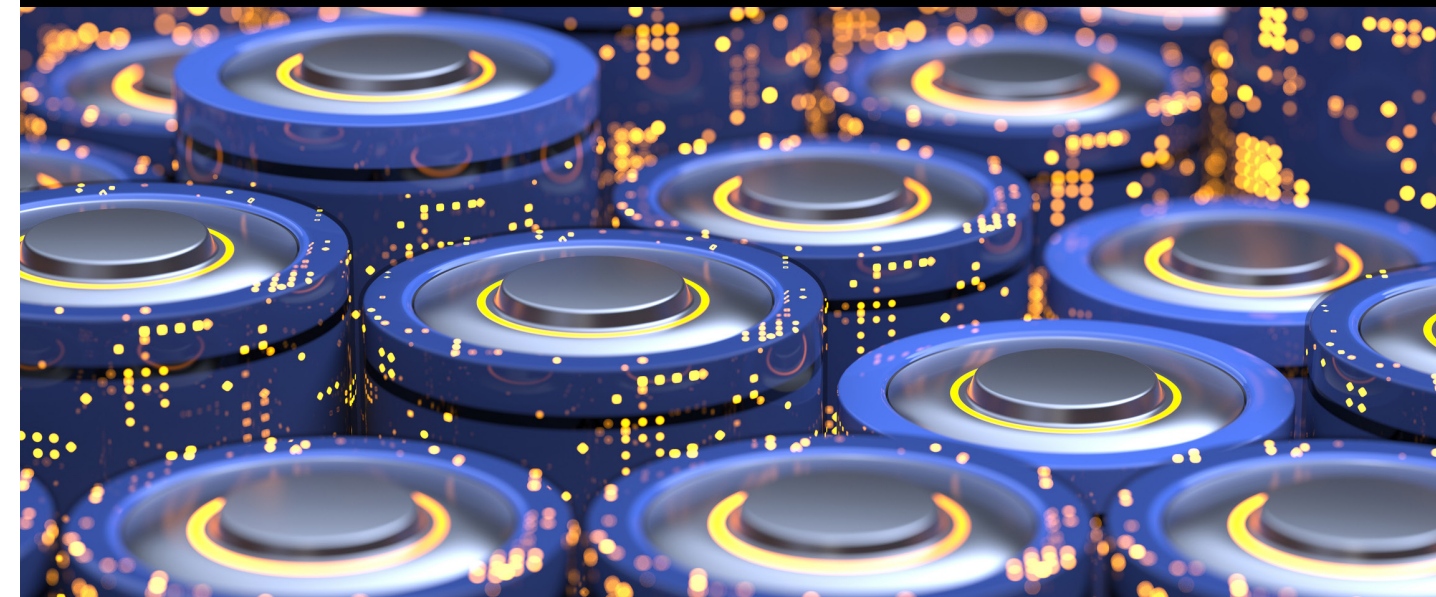
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INSIDE:

- DC/DC Converters Bring Fuel Cell Solutions to Life... 28
- Automotive Functional Safety and ISO 26262... 32
- EV Charging Levels from Residential to Commercial... 35
- BMS transformers in energy storage systems... 38

DC/DC Converters Bring Fuel Cell Solutions to Life

When paired with programmable kilowatt DC/DC converters, fuel cells offer practical solutions to sectors that are hard to electrify

By: RECOM Technical Marketing Team

Fuel cells are electrochemical devices that convert the chemical energy from a gaseous fuel, often hydrogen, directly into electrical energy. This process occurs in a reaction chamber, or "cell" (**Figure 1**). When hydrogen serves as the fuel, the process resembles electrolysis in reverse. In electrolysis, electricity splits water into hydrogen and oxygen, producing hydrogen at the cathode and oxygen at the anode in a 2:1 ratio (H_2O). Conversely, hydrogen combines with oxygen (from air or pure sources) in a hydrogen fuel cell to produce an electrical

current, with water and heat as the only by-products.

While fuel cell technology is often viewed as being modern, it dates back to the first prototypes built by the scientists Sir Humphrey Davy and Sir William Grove in the early 19th century. In the 1960s, practical hydrogen fuel cell technologies were developed to power welding equipment, agricultural tractors, and even space missions. A significant hurdle to their further development was designing durable interface technology to separate the gases from

the liquid electrolyte in the cell. The interface needed to be gas-permeable, electrically conductive, and resistant to both electrolyte corrosion and the heat generated. Today, constructions using proton exchange membranes (PEM) have largely addressed these issues, making stacked fuel cells a viable option for clean, efficient power across multiple sectors like transportation and residential energy.

Fuel cells are an increasingly attractive option in transportation, offering an

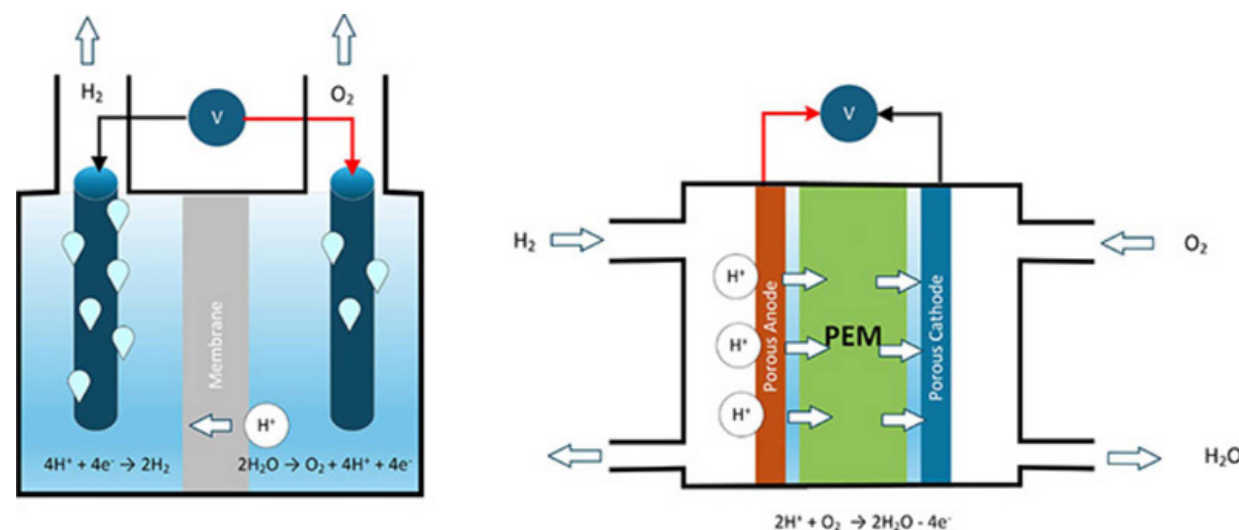


Figure 1: Electrolysis Cell vs Fuel Cell Schematic

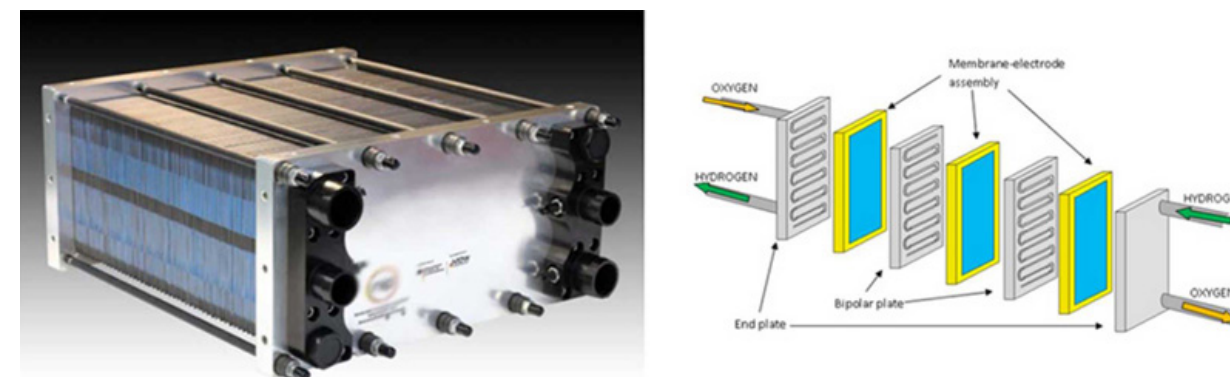


Figure 2: Fuel cell stack construction

alternative to fossil fuels and helping reduce greenhouse gas emissions. Fuel Cell Electric Vehicles (FCEVs) powered by hydrogen are now being produced by many major automakers, such as BMW, Toyota, Honda, and Hyundai. FCEVs offer certain advantages over Battery Electric Vehicles (BEVs), particularly for long-distance travel, due to quicker refueling and greater range potential.

High-pressure hydrogen refueling stations operate similarly to traditional fuel pumps, whereas BEVs often require lengthy charging stops or larger, heavier batteries. This makes fuel cells ideal for applications in long-haul trucking, buses, and other heavy-duty transport, where rapid refueling, lighter weight, and extended range are key factors. As a result, FCEVs are increasingly focused on trucking and railway applications, while clean fuel cell-powered buses and trams can already be found in many urban areas. Additionally, small scale FC units can be

easily retrofitted to refrigerated containers and trailers, avoiding the need to have a continuously running diesel engine to keep perishable goods cold.

Hydrogen fuel cells are also being applied in stationary power systems, powering buildings, industrial sites, and even entire communities. Fuel cells are inherently scalable: adding more cells increases voltage, expanding cell surface area increases current, and connecting multiple stacks in parallel boosts power. However, as individual cells generate relatively low voltages (0.5-0.8V), fuel cells are typically stacked together to deliver useful output voltages of 200V-300V with high current (hundreds of amps) to simplify the

construction (**Figure 2**).

Portable power applications are another promising use for fuel cells, particularly in the military, medical, and consumer electronics fields. Fuel cells provide longer operational times than traditional batteries, an advantage in remote, off-grid, or emergency situations. The U.S. military, for example, is exploring small-scale fuel cells to power field equipment, reducing soldiers' dependence on heavy battery packs.

Despite recent advances, fuel cell energy still faces inherent technical challenges that hinder widespread adoption. Addressing these challenges is essential

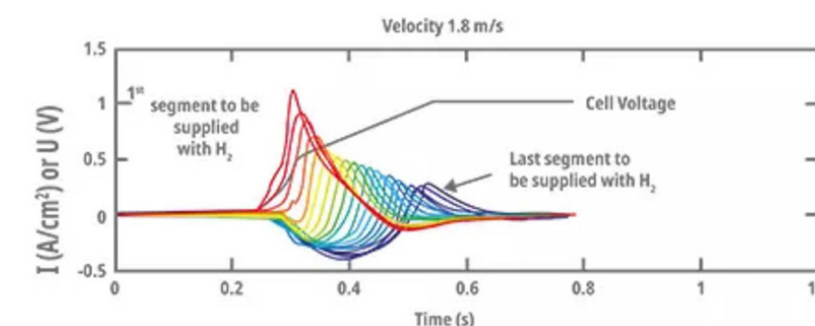


Figure 3: Fuel Cell Stack Reaction Time (Source: LEMTA - University of Lorraine)

for hydrogen fuel cells to play a significant role in our energy transition.

The Reaction Time Problem

Since fuel cells generate power through a chemical reaction involving two gases, there's a delay between gas supply and power output as the fuel permeates through the stack (**Figure 3**). For fixed stationary applications, this delay is manageable. However, for hydrogen fuel cell vehicles, even a brief reaction delay is unacceptable, so fuel cell-powered vehicles also use high-voltage (HV) batteries for immediate power and acceleration. These HV batteries can, however, be relatively small as they are continually recharged by the fuel cell stack.

Another challenge is an emergency stop. Unlike fuel-burning engines that can be quickly turned off, fuel cells need to be flushed out to remove the reaction gases to stop producing power. This makes shutdown a relatively slow process.

The Role of DC/DC Converters in Fuel Cell Systems

DC/DC converters address both the reaction delay and shutdown issues while managing the interface between the fuel cell and battery pack.

They:

- Act as boost converters, converting the fuel cell's low-



Figure 4: RECOM's Modular 5x15kW (75kW) Fuel Cell DC/DC Converter

voltage, high-current output to a higher-voltage, lower-current battery charging output.

- Stabilize the startup and shutdown ramps and mitigate any load transients, providing the stable charging voltage required by the battery pack.
- Track the fuel cell's maximum power point (MPP), adjusting it based on load, time, and temperature to maintain optimal efficiency.
- Disconnect the fuel cell stack abruptly in emergencies.
- Monitor battery voltage and current, preventing overcharging or deep discharge, and safely handling any battery faults.
- Integrate with the vehicle's CAN-bus communication system for centralized

monitoring and control.

The modular 15kW DC/DC solution from RECOM offers up to 75kW by connecting five modules in parallel, making it suitable for heavy-duty applications like trucks, marine vessels, railway rolling stock, and high-power off-grid EV charging stations. This converter has a nominal 150VDC input, but it operates across a 46 to 275VDC range with peak efficiency of around 94%.

The output voltage can be set between 200V and 800V to match the traction battery, with a maximum input current of 500A and a maximum output current from 85A to 220A. An onboard microcontroller manages input and output voltage monitoring to within $\pm 2\%$ of the set voltage

and $\pm 5\%$ of the set current. The solution is also shock and vibration ECER100 conform, while integrated ECER10 EMC filters allow for drop-in installation in automotive applications.

Liquid cooling enables a compact design and wide operating temperatures, with the 75kW unit measuring just 750 x 400 x 200mm. The DC/DC converter operates at full power between -40°C and $+50^{\circ}\text{C}$ ambient temperatures, with built-in short circuit, output overcurrent, output overvoltage protection, and automatic shutdown if the cooling system fails.

Each 15kW module employs a two-stage, four-phase interleaved

boost converter, allowing efficient operation across a wide range of input and output voltages. Digital control ensures accurate monitoring of all currents and voltages, maintaining peak performance under all load conditions and ensuring a rapid response to any faults.

The architecture is modular and versatile, allowing for optimization for different output voltages or power requirements from 15kW up to 75kW. Parallel connections between units also allows scaling, enabling configurations up to 225kW, ideal for high-power off-grid BEV chargers.

The J1939 CAN-Bus interface connector provides a wired

emergency shutdown and alarm signal as well as the digital interface.

Conclusion

Fuel cells offer a versatile and promising pathway toward a cleaner, more sustainable energy landscape representing a crucial step toward the decarbonization goals required to address climate change. When paired with programmable kilowatt DC/DC converters, fuel cells offer practical solutions to sectors that are hard to electrify, and hydrogen fuel cell vehicles can help reduce our over-reliance on BEVs and excessive stress on the electrical grid.

RECOM



PolarFire® FPGA Ethernet Sensor Bridge for NVIDIA® Holoscan

Flexible Integration Assists AI-Driven Sensor Processing from Edge to Cloud

PolarFire® FPGA Ethernet Sensor Bridge for NVIDIA® Holoscan delivers flexible integration for AI-driven sensor processing from edge to cloud. This solution supports multiple protocols, power efficiency, security and reliability in one seamless package. NVIDIA approves this solution for use in its popular Holoscan ecosystem.

Key Features

- Power-efficient protocol conversion
- Highly secure
- Single event upset (SEU) immune for high reliability

Automotive Functional Safety and ISO 26262

Achieving functional safety compliance in automotive off-battery buck preregulator designs

By: Timothy Hegarty, Texas Instruments

Any influential technology emanates a set of risks, which can be especially serious in automotive safety-related systems. The purpose of the International Organization for Standardization (ISO) 26262 series of standards, Road vehicles – Functional safety, is to mitigate risks in road vehicles by providing guidelines and requirements for the functional safety of automotive electrical and electronic systems. Published in 12 parts, ISO 26262 was updated in 2018 to acknowledge evolving automotive technologies, and

the standard now includes specific requirements for semiconductors. ISO 26262 details an automotive-specific, risk-based approach for determining risk classes – known as Automotive Safety Integrity Levels (ASILs) – established by performing a risk analysis of potential hazards based on three variables: severity, probability of exposure, and controllability by the driver.

Automotive manufacturers require various classifications of ASIL system-level ratings

when developing functional safety-compliant platforms. As examples, surround view, driver monitoring, and radar and LiDAR for advanced driver assistance systems (ADAS) require a system-level rating of ASIL D. Meanwhile, end equipment such as digital cockpit and infotainment systems only need an ASIL B rating. An overarching theme in such safety-critical systems is the need to reliably power high-current system-on-a-chip (SoC) and multicore processor loads from an automotive battery source.

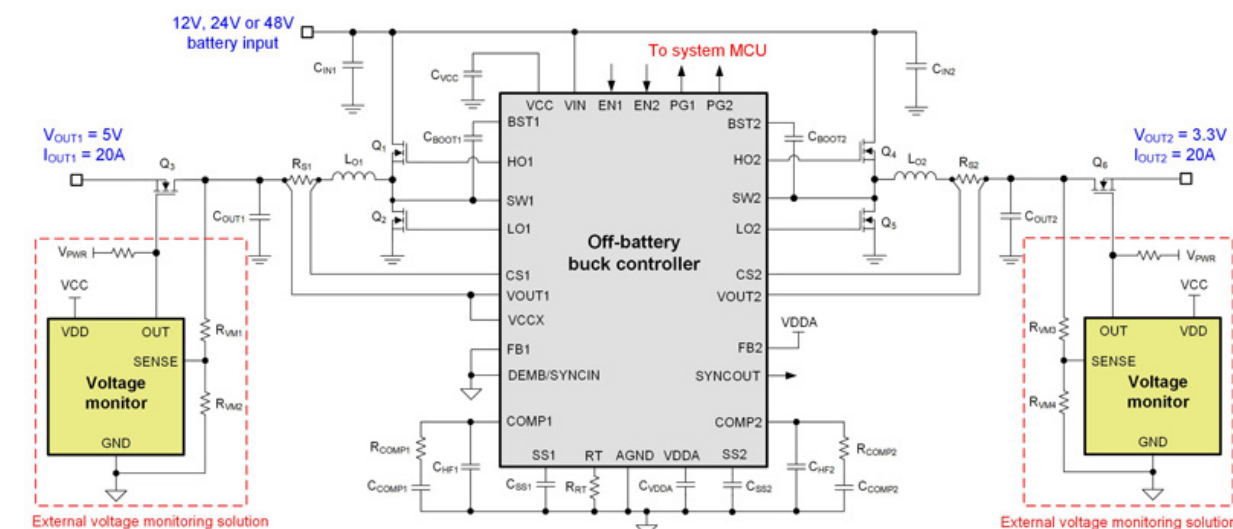


Figure 1: Off-battery dual-output buck preregulator with output voltage-monitor ICs

Functional safety-compliant designs with external voltage monitoring

Synchronous buck controller integrated circuits (ICs) enable DC/DC conversion in automotive designs with 12V, 24V and 48V battery inputs to meet the demands of high-current processor loads, with current specifications often

exceeding 100A. Figure 1 shows a dual-output configuration, which incorporates a voltage-monitor IC on each output for the system to achieve ASIL D functional safety compliance.

Q3 and Q6 in Figure 1 designate the output disconnect switches that open during an output fault condition. A legacy dual-output buck controller as shown in Figure 1 provides rudimentary diagnostic information back to the system microcontroller (MCU) using the power-good (PG1/2) pins.

Functional safety-compliant designs with a synchronous buck controller

The 80V LM5137F-Q1 dual-channel DC/DC buck controller includes all of the functions necessary to implement a high-efficiency synchronous buck regulator for high-power SoC core and I/O rails. The device is offered from a controller

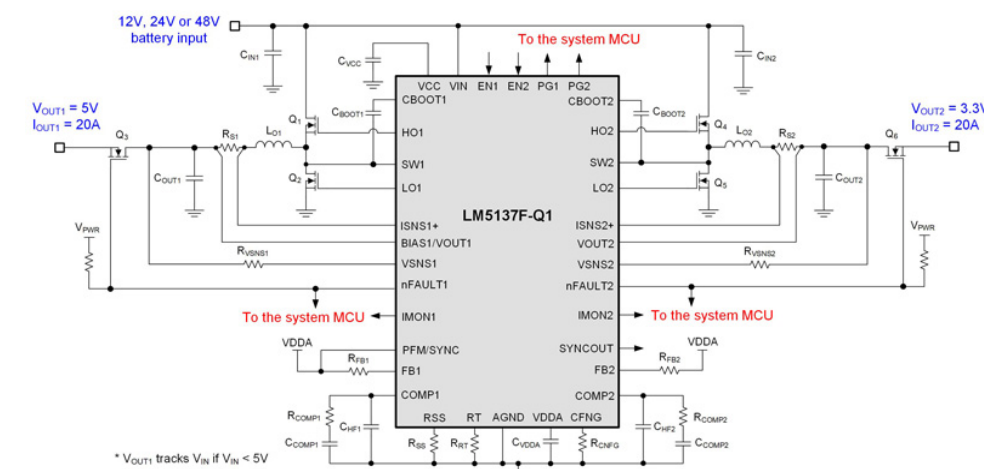


Figure 2: Off-battery dual-output buck preregulator using the LM5137F-Q1 buck controller to achieve ASIL D

family with three categories for functional safety: T1 Functional Safety-Capable, ASIL B or ASIL D, with the latter two options designated by an “F” suffix in the device part number.

The family also offers voltage scalability to support 12V, 24V and 48V battery inputs with a switching frequency range from 100kHz to 2.2MHz. An integrated charge pump gate driver offers 100% duty-cycle capability and true pass-through mode operation. The LM5137F-Q1 also features ultra-low quiescent current for extended battery life and high light-load efficiency, along with dual random spread spectrum (DRSS) to successfully address electromagnetic interference (EMI) across a wide range of frequencies.

Figure 2 shows the full circuit schematic of a preregulator design in an ASIL D system using the

LM5137F-Q1 buck controller. This design has essentially the same operating specifications and power-stage components as Figure 1 but does not require external voltage-monitoring ICs. For added flexibility, you can configure the buck controller as a single-output implementation with two interleaved phases (or stack to four phases for especially demanding high-current loads).

The LM5137F-Q1 incorporates safety mechanisms to help achieve ISO 26262 systematic capability and hardware integrity functional safety requirements up to ASIL D. Such safety mechanisms include analog built-in self-test (ABIST) to verify the health status of the LM5137F-Q1 controller and surrounding components before allowing the outputs to start up. The device also has redundant output voltage monitoring that eliminates external circuitry

and saves on hardware cost, size and complexity. Additional safety mechanisms include advanced fault reporting, overcurrent monitoring and reporting, output undervoltage and overvoltage protection, and redundant thermal shutdown.

As implied by Figure 2, the system- and circuit-level advantages of the functional safety buck controller are:

- Integrated diagnostics, including ABIST before startup and per-channel current monitoring during normal operation.
- Integrated redundancy, including advanced fault identification and tolerance for reduced failure-in-time (FIT)-based failure rates.
- Reduced component count and space savings, achieved by obviating the need for supplemental voltage- and current-monitor ICs.

Functional safety compliant designs with synchronous buck converters

Offering voltage and current scalability, buck converters with integrated switches represent another option for the preregulation stage. For example, the 65V, 8A LM68680-Q1 and 65V, 4.5A LM68645-Q1 buck converter families can sustain input transients to 70V while meeting requirements in systems that must reach at least ASIL C. Scalable to 12V, 24V and 48V inputs, these converters provide

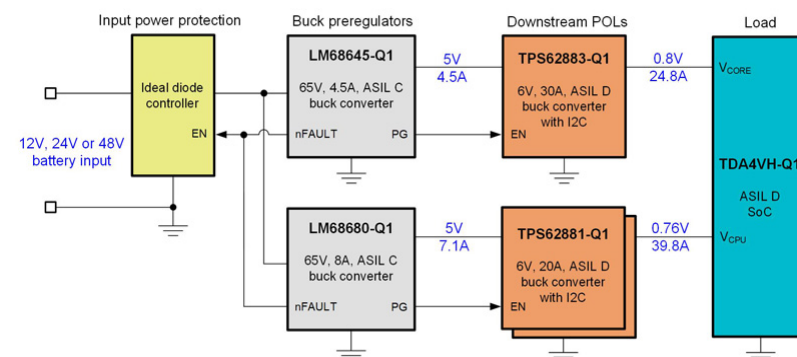


Figure 3: System block diagram with buck converters to power an automotive SoC

functional safety features similar to the LM5137F-Q1 controller described above.

Figure 3 is a system block diagram using the LM68680-Q1 and LM68645-Q1 as preregulators that feed the 30A TPS62883-Q1 and 20A TPS62881-Q1 stackable two-phase point-of-load (PoL) buck converters. With differential remote sensing of the output voltage and ultra-fast load transient response, these PoLs provide tight voltage regulation to a Jacinto TDA4VH-Q1 automotive SoC used in an ADAS domain controller application.

Irrespective of the chosen architecture with controller or converter options to power the various SoC voltage rails, TI provides industry-standard reports and additional resources – including IC-level documentation such as functional safety FIT rate and failure-mode effects and diagnostic analysis (FMEDA) – to help streamline your functional safety system-level certification.

Conclusion

As automotive power electronics moves toward functional safety-compliant designs with higher densities, smaller packaging, improved performance and lower cost, rethinking controller and converter selection for the buck preregulator power stage becomes mandatory. Within this context, achieving functional safety compliance up to ASIL D is one of the primary challenges when designing systems that require high-density buck preregulators.

A buck controller such as the LM5137F-Q1 offers several inherent benefits when benchmarked against legacy controller designs that require supplementary supervisory and monitoring components to accomplish functional safety compliance. Furthermore, TI Functional Safety-Compliant 65V-rated buck converters provide an alternative for lower-power designs.

Texas Instruments

EV Charging Levels from Residential to Commercial

The arrival of electric vehicles (EVs) has ushered in a revolution in the automotive industry with a fundamental shift toward sustainability and a reduced carbon footprint

By: Wayne Liang, senior segment manager at Microchip Technology's E-Mobility business

At the center of our societal-wide EV transformation lies an intricate network of chargers, a critical infrastructure that defines the usability and practicality of EVs. To increase the adoption of EVs, understanding the types and nuances of chargers is important.

Electric vehicle chargers come in diverse forms, ranging from home-based solutions to high-speed public charging stations strategically positioned along highways and inner-city streets. The simplest form, Level 1 charging, utilizes standard household outlets (120V) and is suitable for overnight charging. For faster charging at homes or workplaces, Level 2 chargers (240V) are popular, which significantly reduces charging times. These home-based charging options provide the convenience of daily charging routines, ensuring that the EV is ready for regular commutes.

Public charging infrastructure plays a pivotal role in the



Figure 1: Residential EV charger

widespread adoption of EVs. Level 2 chargers in public areas offer quicker charging, making them suitable for various environments like shopping malls and workplaces. DC Fast Charging stations, a common sight along highways, provide rapid charging by directly supplying DC power to the vehicle's battery, making them advantageous for long road trips, which minimize charging stops.

In the quest for even higher charging speeds, ultra-fast charging stations with outputs of

350 kW are emerging, promising shorter charging durations and enhanced convenience. Wireless charging, using inductive charging technology, eliminates the need for physical connections, allowing for a more seamless charging experience. The transition to electric mobility also involves innovative solutions like battery swapping stations and solar-powered charging. These innovations contribute to the overall sustainability and efficiency of EV usage.

Home Charging Systems: Level 1 and Level 2

The majority of EV drivers, including those with hybrids, most often charge their vehicles overnight at home using Level 1 or Level 2 equipment. Level 1 provides charging through a 120 V AC outlet, and most EV manufacturers will provide a compatible cord set (with J1772 connector) with the purchase of an EV, so no additional charging equipment is required. Most mid-sized EVs require 8 hours of charging at 120 V, which can replenish about 40 miles of electric range depending on weather and road conditions.

Level 2 provides charging via 240V (residential) or 208V (commercial) AC electrical service. Given the prevalence of 240V service in most homes, Level 2 equipment is another popular choice among EV owners for overnight charging. It can also be found in public and workplace charging stations, operating at amperages ranging from 40 to 80 Amps. While most residential Level 2 chargers operate up to 30A, delivering 7.2 kW of power, the adaptability of Level 2 equipment accommodates various charging needs. Level 2 charging also provides around a 25-mile range per hour of charging.

Both Level 1 and Level 2 come outfitted with advanced hardware to monitor and power EVs safely and efficiently, including microcontrollers (MCU), power management systems, wireless and wired connectivity options,

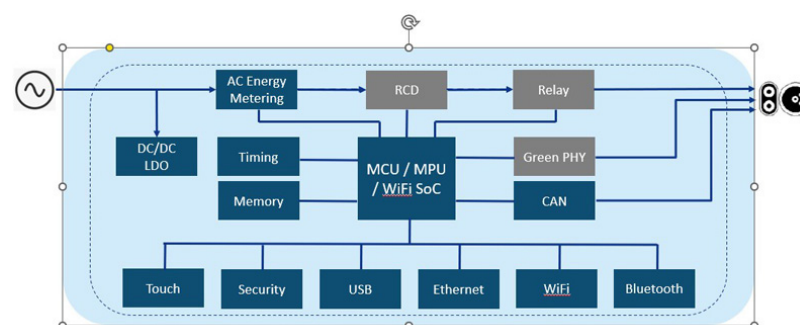


Figure 2: Level 1 and Level 2 charging systems are commonly used for overnight charging at home and use 120V to 240V, depending on the requirements

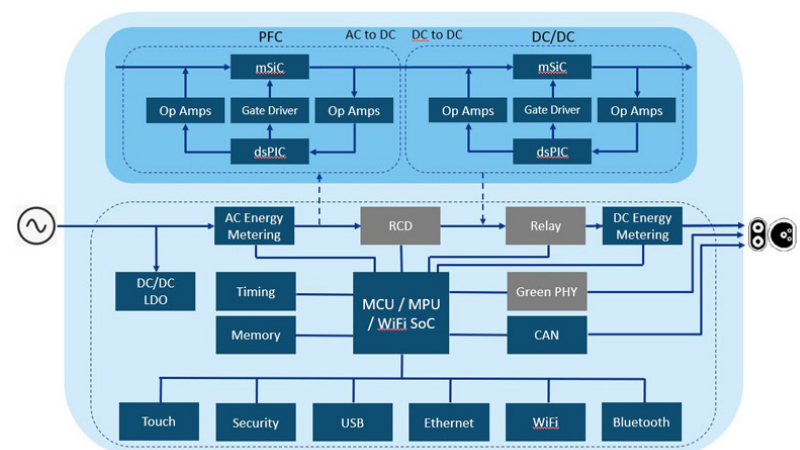


Figure 3: Public or commercial charging stations are similar to Level 2 platforms but offer higher currents to handle multiple vehicles and larger batteries

temperature sensors, energy metering, Human-Machine Interfaces (HMIs) and security features. Most also come equipped with an auxiliary power supply, DC-DC regulators, PMICs and additional hardware to ensure safe and stable power when charging.

Public Chargers

Public charging stations are similar to home-based platforms and rely on Level 2 or DC fast charging systems. They are typically located where vehicle owners are highly concentrated and parked for long

periods. Unlike home setups, these stations are equipped with Power Distribution Points (PDUs), which are responsible for managing the allocation and distribution of electrical power to multiple EVs, ensuring each connected vehicle receives the appropriate power level based on its charging specifications. These will also often integrate intelligent load management systems to optimize power distribution, preventing grid overload while providing a seamless charging process for multiple vehicles simultaneously.

Charging connectors and cables are another crucial component, as different areas and manufacturers adopt various charging standards, such as CHAdeMO, CCS (Combined Charging System) and NACS, to accommodate different vehicles. Other essential components are metering and monitoring devices to accurately measuring energy consumption during charging sessions. Integrated smart meters and sensors monitor and record the electricity delivered to the EV, enabling precise billing and consumption analytics. The monitoring hardware also supports real-time tracking of station usage, identifies potential faults, and assists in preventive maintenance, providing optimal performance and reliability.

Communication is another integral part of public charging stations, which can utilize several technologies such as GSM, Wi-Fi or Ethernet and provide seamless data transfer between the charging station, backend management systems and the EV. They also allow a number of helpful features, including remote monitoring, software updates and user authentication, contributing to the overall efficiency and effectiveness of the charging infrastructure. Safety is a high priority with public charging, so stations are outfitted with a number of mechanisms to prevent damage to both vehicles and drivers. Ground fault protection, overcurrent protection devices, and emergency shut-

off mechanisms are integrated to mitigate those hazards.

Rapid/DC fast chargers

As the name implies, rapid or DC chargers are designed to deliver a substantial amount of energy in a short time. These chargers typically operate at power levels exceeding 50 kW, with the latest installations reaching 350 kW or more. The primary characteristic of rapid chargers is their ability to provide DC directly to the EV's battery, bypassing the vehicle's onboard charger and allowing for a more efficient energy transfer. The integration of sophisticated power electronics, such as rectifiers, transformers, and inverters, enables the rapid charger to convert that AC power from the grid to the DC power required by the EV.

Connectors also play an essential role in the rapid charging ecosystem, with the standards mentioned earlier, such as CHAdeMO, CCS, and NACS, to provide broad compatibility. Thermal management systems are another critical element in rapid charging systems and are designed to ensure the charging cable, connectors and vehicle components do not overheat during high-power charging sessions. Communication modules play a vital part in rapid charging systems as well, enabling seamless communication between the charger, the EV, and backend management systems. The integration of robust safety

systems, including thermal sensors, overcurrent protection, and emergency shutdown mechanisms, keep both the vehicle and driver safe.

Conclusion

EV charging infrastructures mark a critical phase in the widespread adoption of EVs, and those stations are expected to grow along with EV demand. The continued technological advancement in hardware, including home-based solutions and commercial and fast charging platforms, underscores the industry's commitment to enhancing convenience and reducing charging times. The latest innovations in connectors, power electronics and safety systems are the foundation to support the EV charging infrastructure.

The future of EV charging infrastructure is on track for exciting developments. The ongoing expansion of fast-charging networks, coupled with increased power levels and more comprehensive standardization, promise even faster charging speeds and greater accessibility. Advances in battery technology, such as solid-state batteries, may help to redefine the charging landscape by enabling higher energy densities and quicker charging without compromising safety. In the end, EV charging infrastructure holds the key to making EVs more practical and accessible.

Microchip

BMS Transformers in Energy Storage Systems

Improving the reliability of BMS systems with transformers

By: Samuel Lamprecht and Gerhard Stelzer, Würth Elektronik

The conversion of electric grids to renewable energies, especially wind power and photovoltaics, which are not always available, is fueling the need for larger energy storage systems. These require a sophisticated battery management system (BMS) for reliable operation. BMS transformers can be used to insulate the components and improve the EMC properties.

Two key pillars of the energy transition are the widespread use of wind power and photovoltaic systems. In principle, wind and sunshine are free and inexhaustible, meaning that these forms of energy can be used to generate electricity in a climate-friendly way. Unfortunately, there is one drawback: both forms of energy are not continuously available and are subject to major fluctuations. Therefore, if you don't want the lights to go out when it's dark, you need either power plant capacity or buffer storage that can at least temporarily replace the energy missing from the power grid. A case study by the Federal Environment Agency [1] and an

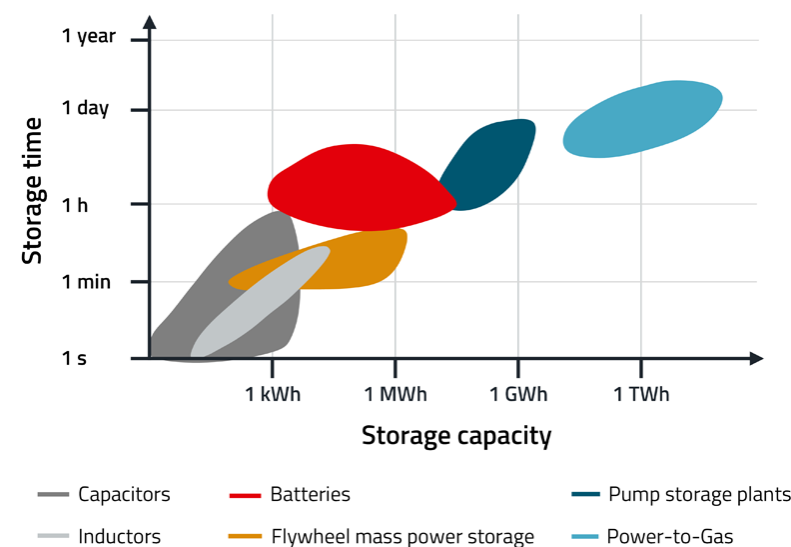


Figure 1: Method for storing electrical energy in terms of storage duration and capacity

article on the "energie-experten.org" portal [2] provide an overview of the various methods of electrical energy storage.

Figure 1 shows the most common methods for storing electrical energy in terms of storage duration and capacity.

Advances in battery technology are now making large battery systems increasingly attractive as buffer storage systems. These energy storage systems then have the task of balancing out the fluctuating energy supply and changing energy demand as

well as cushioning feed-in and consumption peaks.

If the company Kyon Energy, which specializes in storage technologies for the energy transition, has its way, the storage capacity for large battery storage systems in Germany will increase by a factor of 40 to 57 GWh with a total capacity of 15 GW by 2030. This is the conclusion of a study commissioned by the company together with BayWa, Eco Stor, enspired and Fluence Energy from the consultancy firm Frontier Economics [3]. The study also



Figure 2: The range of energy storage systems extends from small battery systems (3 to 20 kWh, left) for households to large ones (100 kWh to 5 MWh, right) for grid operators (Source: Adobe Stock, right: phonlamaiphoto, left: xiaoliangge)

assumes that large-scale battery storage systems can generate €12 billion in economic added value by 2050 by shifting the availability of electricity from times of surplus to times of shortage. At the same time, the study shows that large-scale battery storage systems have a price-reducing effect on wholesale prices and reduce the wholesale price by an average of around €1/MWh between 2030 and 2050. If there is no possibility of using stationary battery storage instead of additional gas-fired power plants, the wholesale price could be expected to increase €4/MWh on average between 2030 and 2050.

Which types of battery storage systems do exist?

The energy storage systems considered here typically work with electrochemical battery cells. There are various electrochemical battery cells that differ in their respective properties and areas of application. One prominent example is the

widely used lithium-ion battery cells. Depending on the area of application, these systems can be differentiated according to their capacity and performance. The physical mode of operation is identical. Although there is no direct correlation between capacity and maximum charging or discharging power, it can often be assumed in practice that the greater the capacity of a battery, the greater its maximum charging or discharging power can be.

First, it makes sense to divide batteries into three size ranges:

- Energy storage for households and small businesses, 3 to 20 kWh
- Energy storage for communities and businesses, 20 to 100 kWh
- Energy storage for electricity grid operators 100 kWh to 5 MWh

How is a battery storage system constructed?

A battery storage system essentially consists of a battery pack with individual battery cells in which reversible electrochemical processes take place for charging and discharging. However, due to various influences such as manufacturing tolerances, ageing, etc., the individual battery cells generally do not behave exactly uniformly, but are characterized by deviations in charging and discharging behavior and the state of charge.

This is where the battery management system (BMS) comes into play, which is designed to compensate for these differences in the charging behavior and state of charge of the individual battery cells in such a way that reliable and safe operation of the battery is guaranteed. For this purpose, the BMS has a charging and monitoring unit that monitors the current, voltage and temperature of the individual battery cells and

is controlled by a BMS controller (**Figure 3**). The BMS controller in turn communicates with higher-level control units via bus systems and controls the power flow to and from the battery. The BMS is basically the brain of the battery. The state of charge (SOC), the state of health (SOH) and the remaining capacity are three important metrics that are tracked and calculated by the BMS. It makes decisions based on the information it collects that affect the performance and longevity of the battery. The BMS actively protects the battery from risks such as deep discharge, overcharging and overheating.

Typical functions of a BMS:

- Protecting the battery from operating outside its safe operating range
- Monitoring the state of charge and health of the battery
- Calculation and reporting of secondary data
- Control of its environment
- Authentication and/or balancing of the battery cells

Which role do BMS transformers play?

The individual battery cells of a battery pack are connected in series, as are the downstream BMS controllers. Voltage differences and electromagnetic interference can occur between the components or circuit boards connected in series. Transformers can be used to isolate the components between the high-

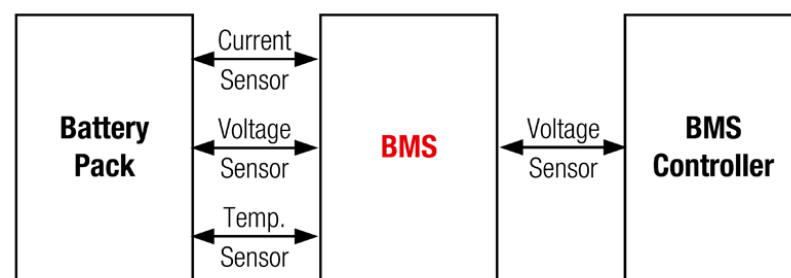


Figure 3: Structure of a battery management system. The BMS block in the center monitors the battery cells and controls charging and discharging processes

voltage and low-voltage sides and suppress EMI interference. This is particularly important to ensure that no dangerous voltages are transmitted to touchable parts or the BMS. The WE-BMS transformers fulfill this function and provide BMS insulation and EMI interference suppression for safe and reliable operation. **Figure 4** shows the use of WE-BMS transformers in a battery management system.

What characterizes the WE-BMS transformers?

The WE-BMS transformers from Würth Elektronik are designed for high robustness and

reliability. They have reinforced insulation in accordance with IEC 60664-1 and IEC 62368-1. These standards define safety requirements for transformers and for audio/video, information and communication technology equipment. With regard to electrical energy, requirements for high-voltage tests, insulation resistances and creepage and clearance distances are described, among other things. They are equipped with a triple-insulated wire on the primary and secondary sides for the highest operating voltage. To ensure the longevity of the insulation, the WE-BMS transformers are

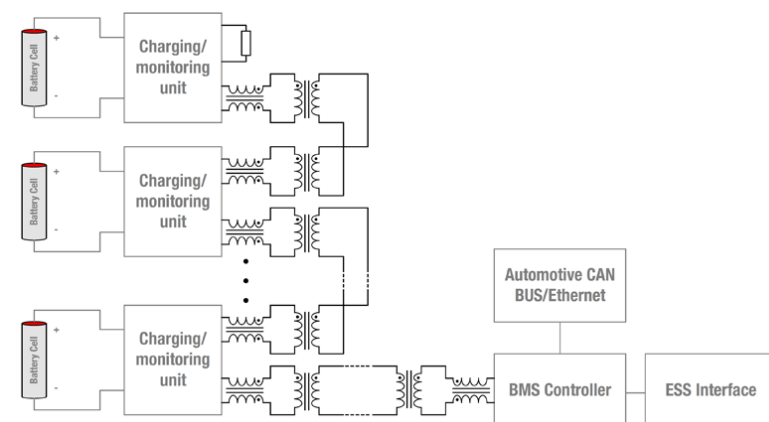


Figure 4: The WE-BMS transformers from Würth Elektronik provide galvanic isolation of the BMS and common mode chokes suppress EMI interference

subjected to a partial discharge test in accordance with IEC 60664-1.

The operating voltage of the latest addition to the WE-BMS transformer range has been increased from 1000 to 1500 VDC. The test voltage was also increased from 4300 to 6400 VDC. The transformers are specified for an operating temperature of -40 to +125 °C and are UL-certified in accordance with the UL standard UL 62368-1 in document E507007.

Insulation, creepage and clearance distances

Important aspects in the design of a BMS transformer according to IEC 62368-1 are the creepage and clearance distances as well as the selection of suitable insulation for the wire. A distinction is made between functional, basic, supplementary and reinforced insulation. The differences in insulation can be seen in **Figure 5**.

Functional insulation is the minimal level required for functionality. However, this type of insulation does not prevent electric shock. Basic insulation provides the user with simple protection against electric shock. The supplementary insulation goes beyond the basic insulation and provides further protection. Reinforced insulation provides an additional layer that works in a similar way to supplementary insulation. Even if the basic

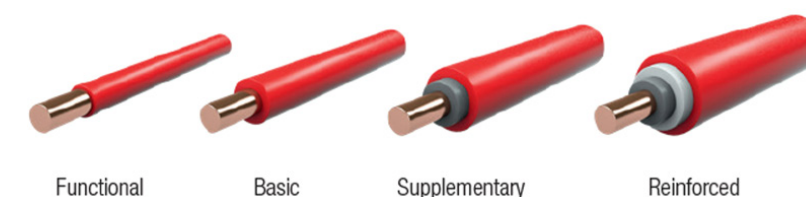
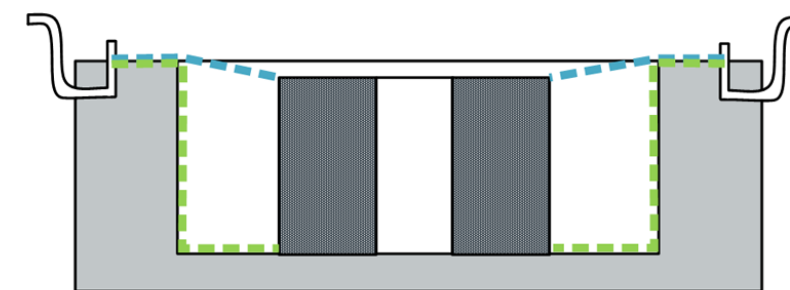


Figure 5: A distinction is made between functional, basic, supplementary and reinforced wire insulation



--- Creepage - - - Clearance

Figure 6: Creepage and clearance distances in the BMS transformer

insulation fails, the supplementary insulation remains effective and protects the user.

The clearance distance is the shortest distance between two conductors through air. It is important to ensure sufficient clearance distances in order to protect people and systems from the effects of electrical operating voltages. The required clearance is determined by determining the overvoltage category, the degree of contamination and the operating voltage. The minimum clearance distance can then be determined using Table 14 of the above standard.

The creepage distance is the shortest distance along the surface of an insulating material

between two conductive parts. The creepage distance is determined in a similar way to the clearance distance but includes the material's comparative tracking index (CTI). By determining the overvoltage category, the degree of contamination and the working voltage, the minimum creepage distance can be calculated using Table 17 of the standard.

The difference between clearances and creepage distances is illustrated in **Figure 6**.

In summary these specialized transformers from Würth Elektronik improve the safety and reliability of battery management systems.

Würth Elektronik



PSDcast – Getting Closer to a Viable Fusion Power Plant

Nuclear fusion – the power of the sun. We’ve been tinkering with the idea for nearly a century – and in fact, we’ve been working towards fusion reactors since the 1940s, roundabout the same time as the Manhattan Project (take that as you will), though as of yet, we haven’t reached net power. But Type One Energy feels they’re right on the verge of a breakthrough. And on the line to discuss this is Chris Mowry, CEO at Type One Energy.

Chris Mowry, CEO at Type One Energy | [Listen To PSDcast](#)



PSDcast – Why Autonomous Public Transit Could Solve Problems that Robotaxis Can’t

We’ve been hearing a lot about the possibility of robo-taxis – be they ground-based or vertical take-off and landing. And one would assume these autonomous robo-taxis would help alleviate urban traffic and congestion, but do they really? Imagry, an autonomous driving software company, has a different solution, and on the line to discuss it is the company’s CEO, Eran Ofir.

Eran Ofir, Imagry CEO | [Listen To PSDcast](#)



PSDcast – Active Suspension Systems in Electric Vehicles

One of the more interesting trends to emerge in the automotive landscape is the broader availability of active suspension systems. While the idea, itself, was tossed around as far back as the 1950s, it didn’t become a thing until 80’s, though it was cost-prohibitive. And even today, being able to adjust suspension in real-time is mostly a luxury feature, though Hongfa and Vicor aim to change that.

Patrick Wadden, Global VP of Vitor's Automotive Business Unit | [Listen To PSDcast](#)



PSDcast – Wide Band-Gap Devices Support Power Density in EV and Hybrid Vehicles

Today, we’re discussing power density in vehicles – specifically, hybrid and electric vehicles. As EVs and hybrids get ever more sophisticated, we’re starting to see the serious limitations of traditional silicon-based power devices and packaging...which is where wide band-gap devices come in. And on the line to discuss that is Pradeep Shenoy, the manager of power design services over at Texas Instruments.

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PSDcast – AI for Disaster Response

AI is poised to transform society, and one of the greatest benefits is disaster response. And here to discuss that is Hari Vasudevan, founder and CEO of KYRO and Think Power Solutions.

Hari Vasudevan, found and CEO of KYRO and Think Power Solutions | [Listen To PSDcast](#)



PSDcast – Power Interconnects for EVs

With hybrid and electric vehicles growing in complexity, every component within them must also evolve. Power interconnects, for instance, and how power busbars have become preferable over traditional wiring systems. Ennovi recently wrote an article for us addressing this very topic -- Power Interconnects from Hybrids to Electric Vehicles – and on the line to discuss it is Ennovi’s Dominik Pawlik.

Dominik Pawlik, Ennovi | [Listen To PSDcast](#)



PSDcast – Have We Become Overly-Reliant on Gigafactories?

As electric vehicles and batteries have become more sophisticated, we’ve witnessed the emergence of gigafactories. The term was first coined by Tesla CEO Elon Musk in 2013, and it’s since been adopted by other manufacturers involved in EVs and their associated parts and components. But have we become overly-reliant on gigafactories, and is this really the best path forward for the industry?

Alex Stapleton, CCO of Alexander Battery Technologies | [Listen To PSDcast](#)



PSDcast – Modeling and Simulation for Battery Management Systems

As we’ve seen the increased electrification of...well...everything, battery density and reliability has become of paramount importance. And thus, battery management systems have also become a critical tool. And on the line to discuss this is Tony Lennon from Mathworks, which has experience developing battery management systems using modeling and simulation.

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LMR Battery Cells – Powering the Future

By: Jason Lomberg, North America Editor, PSD

Perhaps the most critical factor for our electrified future is energy density – who ever boosts the lifeblood of tomorrow’s EVs stands at the bleeding edge of innovation. And General Motors is aiming for that spot, partnering with LG Energy Solutions to commercialize lithium manganese-rich (LMR) prismatic battery cells, an industry first.

LMR would supplant the undisputed king of batteries, lithium-ion – a \$130 billion+ juggernaut found in everything from laptops to cell phones and even electric vehicles.

Lithium-ion and its variations – NMC (Nickel-Manganese-Cobalt), NCA (Nickel-Cobalt-Aluminum), LFP (Lithium Iron Phosphate) – sport high energy density, long cycle life, fast charging, and more. But they’re also susceptible to thermal runaway, they’re relatively pricey, and not only does their disposal present environmental concerns, but their core components -- cobalt, graphite, and lithium, amongst others – are rare minerals.

The whole rare mineral supply is, in part, what keeps us tethered to China commercially. If we can cultivate our own key mineral allotment, our domestic markets could skyrocket. Even better is if we don’t need those key minerals

at all (or only the most plentiful ones).

That’s where lithium manganese-rich (LMR) prismatic battery cells come in, combining high energy density – 33% higher compared to the best-performing lithium iron phosphate (LFP) based cells – with affordability and more abundant supplies.

Traditional battery cathodes use minerals like cobalt, nickel, and manganese, with two of these being in short supply (and hence, pricey). But according to GM, which is teaming up with LG to produce next-gen batteries for the former’s Ultium vehicle platform, LMR solves a lot of the supply issues.

Typical high nickel battery cells break down to roughly 85% nickel, 10% manganese, and 5% cobalt, while LMR is only 35% nickel, 65% manganese, and almost no cobalt. Manganese is far more common than the other two.

GM is also building “prismatic” cells – vs “pouch” cells in high nickel packs

– which will make them a better fit (literally) for full-scale trucks and SUVs. These cells will also reduce battery module components by 75% and total pack components by 50%.

Of course, commercializing these batteries won’t be easy, as LMR has traditionally suffered from a short lifespan and “voltage attenuation.” But GM feels they’ve sidestepped those issues.

They’ve endeavored to “optimize the materials in our LMR cells, adding proprietary dopants and coatings, along with particle engineering, process innovations, to achieve the right energy density and arrangement of battery materials inside the cell to keep them stable.”

None of this will happen overnight – GM has been working on LMR batteries since 2015, but they’re aiming to produce the first cells from a pilot line in 2027, with full-speed ahead by 2028.

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