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Special Report: Electric + Hybrid Vehicles (pg 33)

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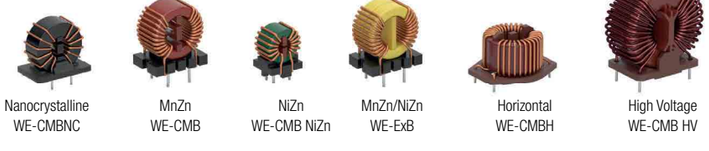
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Power Systems Corporation
146 Charles Street
Annapolis, MD 21401 USA
Tel: +410.295.0177
Fax: +510.217.3608
www.powersystemsdesign.com

Editorial Director
Jim Graham
jim.graham@powersystemsdesign.com

Editor - Europe
Ally Winning
Ally@powersystemsdesign.com

Editor - North America
Jason Lomberg
Jason@powersystemsdesign.com

Editor - China
Liu Hong
powersdc@126.com

Contributing Editors
Kevin Parmenter, PSD
kevin.parmenter@ieee.org

Publishing Director
Julia Stocks
Julia.stocks@powersystemsdesign.com

Creative Director
Chris Corneal
chris.corneal@powersystemsdesign.com

Circulation Management
Sarah Corneal
sarah.corneal@powersystemsdesign.com

Sales Team
Marcus Plantenberg, DACH-Region
m.plantenberg@pms-plantenberg.de

Ruben Gomez, North America
ruben@powersystemsdesign.com

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Volume 15, Issue 10



On the Road to Success for Electric Vehicles

Welcome to the December issue of PSD. This year seems to have gone faster than a Tesla in ludicrous mode. We all wondered when the year started if this would be the year that SiC and GaN technologies made the breakthrough into the mainstream, and turned out that, yes it was. GaN especially looks to have taken a major leap forward and we'll hopefully see the benefits of the technology in a much wider range of products next year. SiC didn't get quite as much attention, but in the areas that it excels, it has been making strong inroads, predominantly in power generation, distribution and automotive applications.

That doesn't mean that SiC is having things all its own way in these areas. Developers of silicon solutions are also innovating to provide solutions for their industries. In this issue of PSD, we will focus on the automotive industry and look at some of the technology that has been introduced this year. The internal combustion engine has had well over a century of refinement to get to where we are today. Electrically driven automobiles were actually invented around the same time as the internal combustion engine, but lost the race to become the dominant technology. As such, very little work has been done on the electrical automotive vehicles until fairly recently. But, because of the pressure to go carbon neutral, manufacturers are developing both purely electrically driven vehicles, and hybrid vehicles that use both electrical power as well as burning fossil fuels.

This demand has put a lot of pressure on designers of electrical equipment to innovate quickly to improve the performance these vehicles. Led by Tesla, technology has come on leaps and bounds over the last decade, and this trend is set to continue as manufacturers try to meet stringent demands placed on them by national governments. Electrical vehicles don't have the same range as combustion engineered vehicles, and until they do, their adoption will be limited at best. Automotive manufacturers are looking for innovation from suppliers in all areas of vehicle design – from better batteries, to a more efficient conversion and drivetrain system and making the vehicle lighter while retaining full performance and safety. It's not just on the vehicle that electric vehicle manufacturers are looking for savings, they also need faster charging so that when the vehicle reaches its range limit, it can get back on the road quickly. Again, Tesla has led in charging technology with the company's superchargers, but even though they have pretty good specifications, they still require drivers to wait for quite long times at the charging station. In the issue, we'll look at how some manufacturers see how savings can be made with different power topologies and more efficient components.

Next year is set to be another major year for the power electronics industry, and we'll be here to update you all the way. I hope you all have a lovely Christmas break and I wish you a happy new year.

Best Regards,

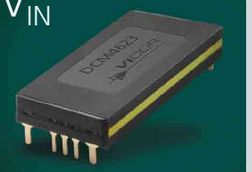
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Active Balancing Solutions for Series - Connected Batteries

By: Samuel Nork, General Manager, ADI Boston & Tony Armstrong, Marketing Director, ADI California

Large, high voltage rechargeable battery systems are now common sources of power in applications ranging from electric vehicles to power grid load leveling systems. These large battery stacks are typically comprised of series / parallel arrays of lithium polymer or $LiFePO_4$ cells due to their high energy density and peak power capability. As in single-cell applications, careful control of the charging and monitoring of the cells is essential to ensure safe operation and prevent premature aging or damage to the battery. However, unlike single-cell systems, series-connected battery stacks need cell balancing.

No Active Balancing (30%-70% SoC Limits)

	Initial		Post-Discharge		Post-Fast Charge	
Cell #	Capacity (A-hrs)	SoC (%)	Capacity (A-hrs)	SoC (%)	Capacity (A-hrs)	SoC (%)
1	110	100	47	43	77	*70*
2	100	100	37	37	67	67
3	100	100	37	37	67	67
4	100	100	37	37	67	67
5	100	100	37	37	67	67
6	100	100	37	37	67	67
7	100	100	37	37	67	67
8	100	100	37	37	67	67
9	100	100	37	37	67	67
10	90	100	27	*30*	57	63
		NO BALANCE		NO BALANCE		
Stack Capacity	1000		370		670	

Usable Stack Capacity: 670A-hrs – 370A-hrs = 300A-hrs
(75% of 400A-hrs theoretical max capacity → 100A-hrs "lost")

Figure 1: Stack capacity loss examples due to cell to cell mismatch

All Series-Connected Cells Need to be Balanced

The cells in a battery stack are "balanced" when every cell in the stack possesses the same state of charge (SoC). SoC refers to the remaining capacity of an individual cell relative to its maximum capacity as the cell charges and discharges. All battery cells must be kept within a SoC range to avoid damage or lifetime degradation.

The relative SoC for cells connected in series will diverge over time due to temperature gradients or differences in impedance, self-discharge rates or loading cell to cell. A passive balancing scheme is a simple and inexpensive way to force all cells to match the lowest SoC cell. However, passive balancing is slow, generates unwanted heat, and does not address SoC differences due to capacity mismatch cell to cell. All cells lose capacity as they age, and they do so at different rates. Since the stack current flows into and out of all cells equally, the usable stack capacity is determined by the lowest capacity cell in the stack. Only active balancing methods can compensate for "lost" stack capacity due to cell to cell mismatch.

Cell to Cell Mismatch Reduces Run Time

Cell to cell mismatch may severely reduce the usable battery stack capacity unless the cells are balanced. As shown in **Figure 1**, a 10-cell stack comprised of 100A-hr cells with a +/- 10% capacity error is charged and discharged until 30% and 70% SoC limits are reached. If no balancing is performed, the usable stack capacity is reduced by 25%. Passive balancing may eventually equalize SoC during the charging phase but cannot prevent cell 10 from reaching 30% SoC before the others during discharge. **Figure 2** illustrates how "ideal" active balancing enables "lost" capacity to be recovered. When the stack

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100% Efficient Balancing (30%-70% SoC Limits)

	Initial		Post-Discharge		Post-Fast Charge	
Cell #	Capacity (A-hrs)	SoC (%)	Capacity (A-hrs)	SoC (%)	Capacity (A-hrs)	SoC (%)
1	110	100	33	30	77	70
2	100	100	30	30	70	70
3	100	100	30	30	70	70
4	100	100	30	30	70	70
5	100	100	30	30	70	70
6	100	100	30	30	70	70
7	100	100	30	30	70	70
8	100	100	30	30	70	70
9	100	100	30	30	70	70
10	90	100	27	30	63	70
	ACTIVE BALANCE		ACTIVE BALANCE			
Stack Capacity	1000		300		700	

Usable Stack Capacity: 700A-hrs – 300A-hrs = 400A-hrs
(100% of 400A-hrs theoretical max capacity)

Figure 2: Capacity recoveries due to ideal active balancing

is discharging, charge is added the lowest capacity cell(s) such that all cells reach 30% SoC at the same time. Similarly, charge is removed from the lowest capacity cell(s) during charging to allow all cells to reach 70% SoC together. Over the operating life of a battery stack, variations in cell aging will create capacity mismatch. Only active balancing provides "capacity recovery" by redistributing charge as needed to maintain SoC balance throughout the stack.

High Efficiency Bidirectional Balancing Provides Highest Capacity Recovery

The LTC3300 (**see Figure 3**) is designed specifically to address the need for high performance active balancing. The LTC3300 is a high efficiency, bidirectional active balance control IC that is a key piece of a high performance BMS system. Each IC can simultaneously balance up to 6 Li-Ion or LiFePO4 cells connected in series.

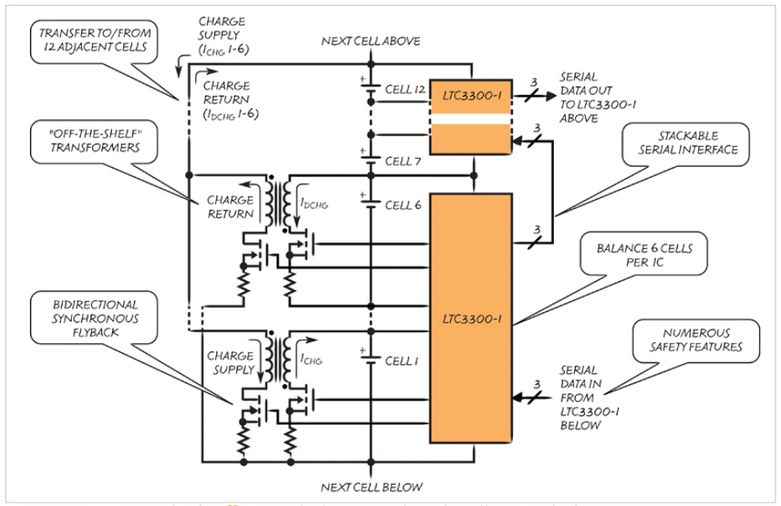


Figure 3: LTC3300 high efficiency bidirectional multicell active balancer

SoC balance is achieved by redistributing charge between a selected cell and a sub-stack of 12 or more adjacent cells. Balancing decisions and algorithms are handled by the BMS that controls the LTC3300. Charge is redistributed from a selected cell to a group of 12 or more neighbor cells to discharge the cell. Similarly, charge is transferred to a selected cell from a group of 12 or more cells to charge the cell. All balancers are controlled via stackable SPI interface.

Each balancer in the LTC3300 uses a nonisolated, synchronous flyback power stage to achieve high efficiency charging and discharging. The "primary" side of each transformer is connected across the cell to be balanced, and the "secondary" side is connected across 12 or more adjacent cells. The number of secondary cells is limited only by the breakdown voltage of the external components. Sequencing and IPEAK/IZERO current detection depends on whether a balancer is charging or discharging. If any type of fault is detected, balancing will automatically stop.

Balancer Efficiency Matters!

One of the biggest enemies faced by a battery pack is heat. High ambient temperatures rapidly degrade battery lifetime and performance. Unfortunately, in high current battery systems, the balancing currents are also high. The LTC3300 achieves >90% efficiency in both the charging and discharging directions, which allows the balance current to be more than doubled relative to an 80% efficient solution.

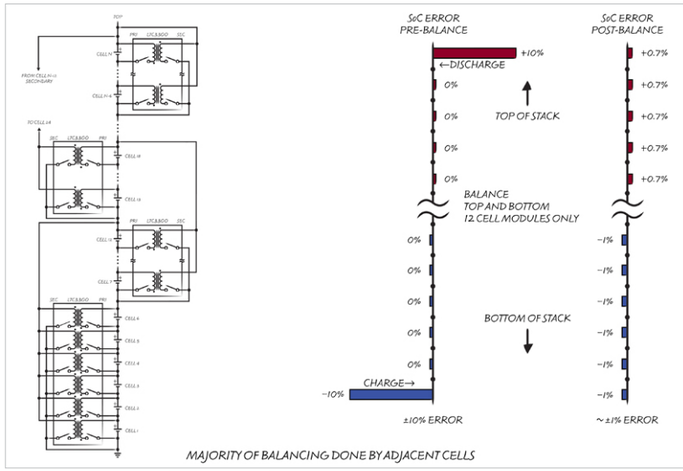


Figure 4: Interleaving connections and charge transfer performance

Local Cells Do Most of the Balancing Work

Transferring charge throughout the stack is achieved by interleaving the secondary connections. Interleaving in this manner allows charge from any group of six cells to be transferred to or from a group of adjacent cells either above or below in the stack. This flexibility helps optimize the balancing algorithm. As shown in **Figure 4**, it is not necessary to move charge via multiple conversions all the way from the top of the stack to the bottom – most of the balancing work is done by the local neighbor cells.

Safety is Key

In addition to providing excellent electrical performance, the LTC3300 provides numerous safety features to maintain the highest possible reliability. Data integrity checks, programmable volt-second clamps, cell over- and undervoltage checking, as well as secondary side overvoltage detection prevent data or wiring faults from causing damage. These characteristics enable the LTC3300 to provide high performance and reliable active balancing in series-connected battery systems. With the LTC3300, mismatches in cell capacities are compensated without compromising run time, charge time, or the lifetime of the battery pack.

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Challenges for EV's Growth

By: Kevin Parmenter, Field Applications Manger, Taiwan Semiconductor

The Last model year sales of new electric vehicles passed a milestone of one million units. According to McKinsey's Electric Vehicle Index at the current growth trajectory, "EV producers could almost quadruple that achievement by 2020, moving 4.5 million units or around 5 percent of the overall global light-vehicle market." This is great and a challenge to the power electronics industry. The Auto industry is planning to release more than 350 new, feature-laden EV models by 2025, with ranges that increasingly top 200 miles. So, why would someone NOT buy an EV? Ranked in terms of objections Price is # 1, driving range is #2 and #3 is access to charging infrastructure. EV prices are declining as volumes increase and driving range is still a limitation so much focus in on battery and charging technologies. So much so, that approximately 53 battery conferences are held every year. You could attend one a week and not see them all. Hopefully out of all that activity comes greater EV range, so let's assume the cost and range are solved by innovation and capitalism. Are EV's more energy efficient and less polluting than a conventional automobile if you factor in the non-renewable energy sources to create the EV itself including the batteries and the disposal issues of the finite life batteries and is the operating cost to the consumer less or does it just make us feel good for going green? I'm not sure we have all that data yet. As I have stated in other articles, for something to become mainstream in adoption other innovations must take also take place. To compensate for there being no clear Moore's law in the battery industry how do EV's keep up. Grabat in Spain have reportedly developed a graphene battery that can provide electric vehicles with 500-mile driving range – now things are getting interesting assuming manufacturing cost, reliability, safety, environmental issues as well as other concerns are met. Once we overcome the remaining obstacles our real issue is infrastructure. The latest figures show there are approximately 375,000 filling stations globally. So, let us assume conservatively we need to replace the equivalent of the global gas stations in terms of energy transfer capability. According to my local utility adding an EV is like adding an additional household or in the US say a 200-amp service for each EV added (assuming long-term – overnight charging rate). To replace all that infrastructure, we need more reliable renewable energy because if we burn coal and oil to recharge electric vehicles then what's the point? We need charging not just inside our homes and offices but where we need it –grocery stores, parks, restaurants, shopping malls, places of business, hotels, churches, Schools, gyms, where people want to drive to and from at the point of need. The other upside could be the holy grail of power generation, which is energy storage on the grid. This is going to take work on the smart grid, IoT (think smart charging), Bidirectional converters, solar and wind generation efficiency improvements and more. Think of the power electronics opportunity to replace all the gas station infrastructure and solve all the needed issues to mainstream electric transportation globally – it may be the largest power electronics market we have ever known.

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Precision Power Analysis: Meeting the Challenges of Today's Applications

Engineers need a test and analysis platform that delivers reliable measurements for today and challenges of tomorrow

By: Anoop Gangadharan, Yokogawa Europe

In the rapidly evolving area of power electronics, the need for reliable testing to enhance safety, efficiency and performance has never been greater. In sectors as diverse as renewable energy, electric vehicles and energy-efficient technologies, changing application needs and evolving industry standards call for custom measurements and consistent accuracy. Engineers need a test and analysis platform that not only delivers reliable measurements today but is also ready for the challenges of tomorrow.

For example, in the automotive sector, meeting consumer demands for greater charging capacity, shorter charging times, and greater travelling range requires thorough positive and negative cycle evaluations of battery charge and discharge characteristics. Similarly, the evaluation of inverter signals needs to account for the harmonic superimpositions from switching circuits. Minimising the interference from this switching noise requires isolated inputs, high-speed sample rates, and long-term observations (**Figure 1**).

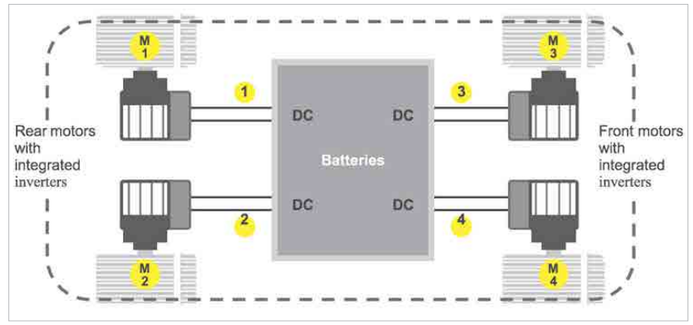


Figure 1: Measuring power-train efficiency in an electric vehicle, showing four DC measurements (1 to 4) with the corresponding mechanical power measurements (M1 to M4)

With the forthcoming advent of contactless charging, such evaluations will need to be conducted at lower power factors and frequencies with hundreds of kilohertz; areas that are outside the scope of traditional test instruments. In addition, motor-drive technology has become more complex in recent years, with pure sine-wave PWM signals becoming less common.

Similarly, in the area of power transmission and distribution, new developments such as renewable energy stations, energy-positive buildings and infrastructures mean that electricity no longer has a unidirectional flow from the power station to the consumer (**Figure 2**). With a multitude of renewable and non-renewable power stations feeding the grid, engineers in charge of ensuring a balanced grid need robust testing and accurate measurements to reduce the impact of noise, distortions and harmonics from multiple

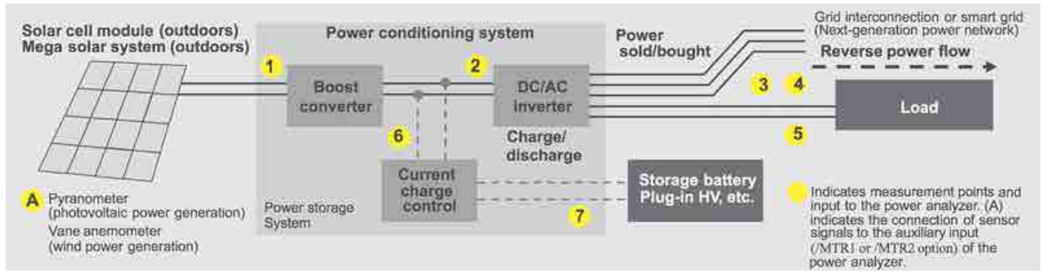


Figure 2: A precision power analyser helps engineers in renewable energy grids to improve conversion efficiency by offering precision insights in charging, discharging, storage and overall efficiency

sources. Power generation stations and large consumers also need to evaluate the effects of their power outputs and usage levels on the grid and on other users.

These high-accuracy measuring instruments will need to include the ability to carry out high-frequency measurements. With mean voltages increasingly differing greatly from the fundamental voltage waveform, harmonic measurements are needed to establish the values of derived measurements such as active power. Similarly, addressing the challenges of measuring parameters such as energy efficiency, harmonic content and power factor will require both progressively greater accuracy and consistency in measurement over the specified ranges and conditions.

The simultaneous measurement of normal values with harmonics is also needed for overmodulation analysis of PWM waveforms and the high-speed measurement of power fluctuations.

Addressing the challenges

These challenges are now being addressed in a power analyser that sets new standards in terms of precision and accuracy, as well as being based on a flexible modular architecture that allows customisation to meet the needs of different applications (**Figure 3**).

This instrument offers a high degree of isolation, noise immunity, current sensing and filtering in a modular architecture that provides an extensible measurement platform.

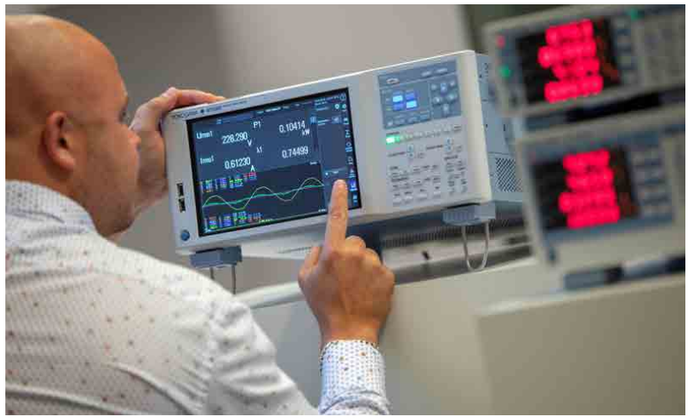


Figure 3: The Yokogawa WT5000 combines measurement accuracy of 0.03% with modular flexibility. Here, a WT5000 is configured for simultaneous synchronised measurements from four torque and rotation sensors to determine the overall efficiency of four motors

It combines an industry-leading basic power accuracy of ±0.03% with a frequency range of 5 MHz and a sampling rate 10 MS/s (18-bit). Current measurements are available via 5 mA to 5 A or 0.5 A to 30 A modules.

Seven built-in slots for user-swappable power input modules and diverse mainframe options enable users to expand or reconfigure the instrument as their applications and requirements change. In addition to measurements on power parameters, the torque and speed from four separate motors can be measured.



Figure 4: The WT5000 has seven built-in slots for user-swappable power input modules and mainframe options that enable users to expand or reconfigure the WT5000 as their requirements change

Other key features include the ability to use 5 A or 30 A input modules in conjunction with the split-screen touch display to compare multichannel measurements; carrying out measurements under highly fluctuating input and/or load conditions with an autoranging integration function and automatic data update rates and custom measurements for added flexibility, with user-defined triggers and computations, as well as functions such as dual-motor evaluation. The instrument performs harmonic measurements, including comparisons of two simultaneous measurements up to the 500th order.

A full touchscreen interface, supported by hardware hotkeys and powerful software for remote measurements, make connecting, configuring and measuring easier than ever before.

High-speed A/D convertor

This analyser achieves the world's highest measuring accuracy: ±0.03% of total at 50/60 Hz - by using an 18-bit analogue/digital converter with a sampling frequency of 10 MS/s. This makes it possible to accurately capture waveforms from the latest high-speed inverter devices.

Noise immunity

Very high-speed power devices using semiconductor materials such as silicon carbide and gallium nitride are increasingly being used in power-conversion products such as invertors and

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drives. As a result, common-mode voltage effects can create noise problems that can affect the performance of measurement systems. The design of the new instrument minimises the effects of high-frequency common-mode voltage, resulting in an excellent CMRR (common-mode rejection ratio) characteristic.

Storage
The analyser incorporates optional internal memory of up to 32 Gbyte for storing large quantities of measurement data in field applications. This is achieved without the need for any external storage media, whilst at the same time enabling high-speed measurement.

Motor evaluation
In addition to the swappable 30 A and 5 A modules, the WT5000 offers multi-motor evaluations for applications in electric or fuel-cell vehicles, robotics, pumps etc. where developers are increasingly required to evaluate a number of different motors. Using the optional motor evaluation function, it is possible to evaluate up to four motors simultaneously with one unit (**Figure 4**).

The dual harmonic measurement function makes it possible to measure the carrier frequency component from the rotational speed of the motor in an inverter drive whilst checking the influence of the carrier frequency on the motor drive.

High-current measurements
An increasing number of applications require the evaluation of larger-current devices, typical examples being electric vehicles and large-scale solar installations. Since an external current sensor input function is fitted as standard in both the 30 A and 5 A input modules, the instrument can measure up to 30 A or 5 A with direct input. For much higher currents (up to 2000 A RMS) dedicated high-current sensors are available.

Automotive: Powertrain tests: From R&D to manufacturing and compliance testing, measurements on powertrains in electric vehicles not only require progressively greater accuracies but also consistency in measurement over the specified ranges and conditions.

Key requirements here are DC and multiphase AC measurements from the battery, inverter and motor; as well as mechanical motor characteristics such as torque, rotation speed and direction. In addition to harmonic evaluations of inverter signals, it is also important to account for superimpositions from switching circuits. In this context, the seven modular input elements of the WT5000, make it easy to evaluate total power and efficiency, whilst its ability to evaluate multiple motors on a single unit, allows the testing of two sets of torque and A/B/Z phases or four sets of torque and rotation speed.

Conclusion
The precision power analyser described in this article offers an unmatched 0.03% accuracy and modular architecture, helping engineers to innovate their power testing and analysis with precision, flexibility and confidence. Whether it is for the development of energy-efficient devices and appliances, plug-in hybrid/electric vehicles or renewable energy technologies, this instrument helps engineers to solve design challenges, improve productivity and ensure quality through reliable power measurements.

The accuracy and precision of the instrument are backed up by tests carried out at Yokogawa's European standards laboratory at its European headquarters in The Netherlands. This facility is the only industrial (i.e. non-government or national) organisation in Europe to offer traceable power calibration, to national and international standards, at frequencies up to 100 kHz: A requirement for higher harmonic measurements specified in quality standards such as ISO 9000.

Yokogawa Europe
https://tmi.yokogawa.com/eu/solutions/products/power-analyzers/wt5000/

When Configurable Power Supplies are the Best Solution

Factory or field configurable power supplies are cost-effective solution time to market

By: Hector Garcia, Power Specialist, Avnet Abacus

It is often assumed that in any product design, if you can use a standard 'off-the-shelf' power supply it will be the lowest cost option compared with a full custom or configurable part. It's true that with today's fast-paced product launches and upgrades, if a custom part is commissioned, the Non-Recurring Engineering (NRE) costs may not be recoverable, risks are high and the time for development could be way too long. Even in military development programs, which can be measured in decades, Commercial off-the-shelf (COTS) parts are often preferred. Configurable parts should not be dismissed though.

Power supply manufacturers do concentrate their marketing on particular standard models and try to specify them to capture the largest share of applications. When a manufacturer can sell most of its product as a single configurable style though, the cost on the market can be surprisingly close to a 'standard'.

An argument often put forward is that a 'standard' part is shipped to many customers and therefore manufacturers benefit from economy of scale. If you believe that the savings are always passed on to customers then this is surely a good thing. But there's a fallacy here: each power supply manufacturer needs to have hundreds if not thousands of 'standards' to meet market demands. Just look at the power product listings boasting a multitude of variants available from typical suppliers. For them, this means huge approved vendor lists and mountains of documentation. If they could sell fewer types that fit more applications, real savings could be made and passed on to the end user. This is where 'configurable' products can score for both manufacturers and their customers.

Does the power supply have to fit in the 'space that's left' anymore?
With energy and cost saving constraints, system designers are now acutely aware that their power system cannot be an 'afterthought' as in the bad old days. This has the unfortunate effect though that the power supply specification must be set early on in development with guesses at power rating, size, voltage rails and even safety compliance levels.

Then there's the monitoring and control features to anticipate. The result can be that product designers have to work around the pre-determined power specification, chosen from standard offerings, severely limiting the scope of their designs.

No responsible designer would compromise too far, so there is the very real risk that the power supply and its specification would need to change mid-program with consequential disruption to mechanical arrangements. Even if the designer works around his power specification constraints, could marketing change their requirements during development? Surely not. Have circuit designers never been asked to 'just add an extra interface' or 'just add in a medical version'? That decision to fix the power supply as a standard gets thrown out of the window and the search

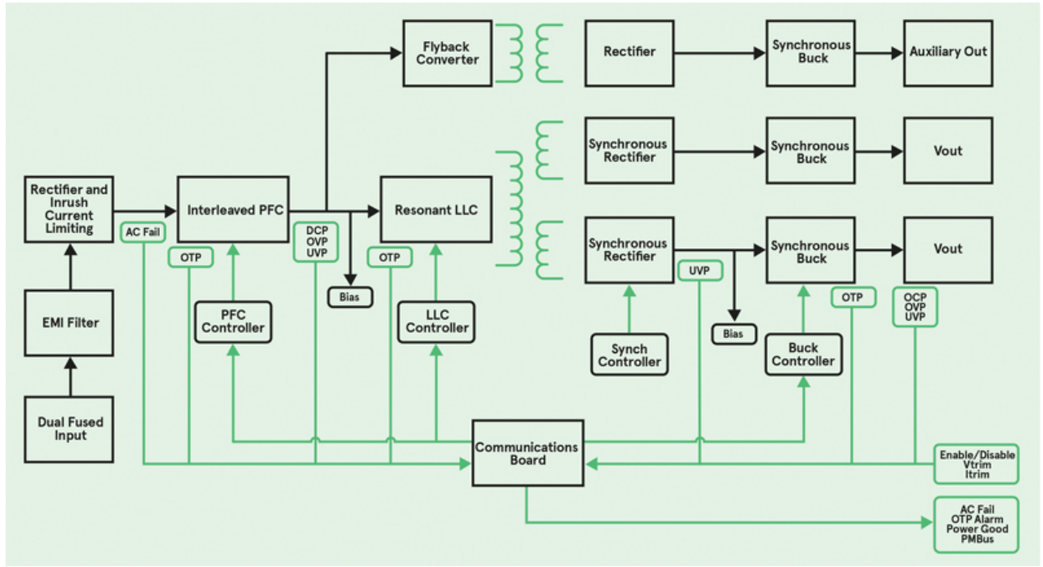


Figure 1: Typical configurable power supply architecture

starts again with all the costs and uncertainties involved.

The alternative solution is to specify a configurable or programmable power supply from the outset. These typically are a base unit with mains filtering and a power factor correction stage followed by plug-in modules for individual output isolation and regulation. Now, any specification changes can be accommodated with, at worst, a module swap and sometimes no more than an adjustment of a potentiometer to a different voltage. Many configurable supplies for example can adjust a single output from 5V to 3.3V with no effect on other outputs.

Module power ratings can be chosen up to a maximum for the base unit and outputs can be put in parallel or series to increase current and voltage levels respectively. Usually effort is made by the manufacturer to make the configurable supply meet worst case specifications. As such you can expect them to meet the most stringent EMC performance and medical safety specifications, even patient-connect type (2 x MOPP).

You might say that the argument for specifying a configurable supply at some extra unit cost relies on the assumption that a standard power supply choice will always change during program development with its associated disruption, necessitating choice of another standard part. No one wants to anticipate failure so the argument would not be a popular one, especially with the financial guys. However, that's not the whole story.

Liberating designers

There are positive advantages to going the route of a configurable supply from the start. As long as the right footprint is allocated in the end product, power supply selection can be left to the later stages of product development when actual voltages, power levels and signalling requirements are known. The product designer is then freed up to optimise their part of the design without power constraints. And more, the inherent flexibility can be used to tailor the end product for its application. Those marketing guys might also want a bare-bones version – just remove or downsize power modules. They might want a fully featured option – just add or upgrade power modules. Time to market for variants is minimised by having that configurability.

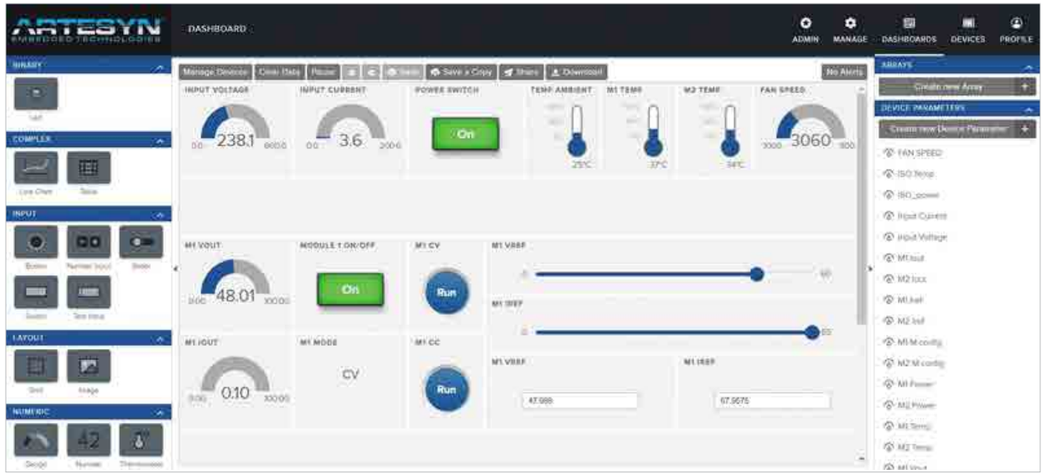


Figure 2: Artesyn iHP series monitoring software GUIe

Configurable power supply designers know that for their product to be attractive, flexibility is the key so they will often feature all-isolated outputs, for example.

Typical standard power supplies will have a common ground for multiple outputs constraining grounding systems from being optimum for EMC and functionality. Standard multioutput supplies will also often require a minimum load on a specified 'main' output, below which other outputs fall out of specification.

Configurable supplies, with their individually regulated outputs don't suffer from this restriction. The typical way individual outputs are controlled is shown in **Figure 1**, an example from the Excelsys CoolX range.

Programmability gives flexibility and 'future proofing'

Perhaps the biggest potential advantage of configurable and programmable supplies is that because of their modular nature with individual output regulation, they will often incorporate comprehensive signalling and control. Recent programmable power supply products incorporate multiple microcontrollers for full digital loop control. Opening up the internal control bus to users via a Graphic User Interface (GUI) gives the possibility of adding factory and field programmability and extra functionality to the end product. **Figure 2** shows an example of the monitoring features of the free software supplied for the Artesyn iHP configurable product.





Figure 3: Example configurable power supplies from Artesyn, Excelsys and MEAN WELL

Now, power supplies can be set in the factory to a particular configuration for an end-product variant, field service is facilitated by hooking up to portable diagnostics and end users can fine-tune power supply performance to match their load characteristics.

Using the manufacturer-supplied GUI, some programmable power supplies can even be dynamically and automatically adjusted – for example in battery charging where voltage might need to change depending on cell temperature and mode change from constant current to constant voltage might be required.

Your choice of configuration and suppliers

So, what are the choices on the market today? Leaders in configurable supplies are Artesyn, Excelsys and MEAN WELL. Artesyn has two ranges, µMP configurable and iMP/iVS, fully configurable and programmable. All are compliant to EN60601-1 medical specifications, the µMP can have up to 12 outputs while the iMP can have 21 and the high-power iVS 24. A free downloadable GUI is available for the µMP and iMP and the iVS can be controlled by standard PMBus commands over an i2C interface. The high power iHP series can be expanded with modules up to 24kW in 3kW increments with up to eight outputs. The system holds industrial safety approvals with additional compliance to SEMI F47 for semiconductor processing equipment.

Excelsys has gone down the route of convection cooling, with leading efficiency designs that still give high power in small form factors at high temperatures. Its CX06M, for example, provides up to eight outputs at 600W combined up to 40°C with derating to 85°C. The package size is 1U x 4.5 x 8 inches (1U x 114.3mm x 203.2mm). The parts are particularly suitable for medical applications where the lack of fan noise is often appreciated.

MEAN WELL has recently introduced its NMP series of configurable 2 x MOPP medical grade supplies at 650 and 1200W. The fan cooled NMP650 is just 1U x 6.3 x 3.5 inches (1U x 160mm x 88.9mm) and the NMP1K2 1U x 6.3 x 5 inches (1U x 160mm x 127mm). Like the Excelsys offering they include a 5-year warranty. All the products offer monitoring and programmability to some degree, typically able to report on voltage levels, output currents and temperature by PMBus signals. Fault threshold monitoring can be set and protection is comprehensive. Even mode of operation can be set in some models, changing from constant voltage to constant current with foldback as required. **Figure 3** shows some examples.

Flexibility from stock

With the extreme flexibility of configurable supplies available at keen prices, they can realistically compete with the rigidly specified 'standard' parts and enable system designers to pass on that flexibility to end users. Specifications can be tailored for their exact application along with 'future-proofing'. There is also the possibility of easy upgrades and output specification changes through exchangeable modules and remote programming through friendly GUIs. Programmable power supplies from Artesyn, Excelsys and MEAN WELL are available through Avnet Abacus from stock.

Avnet Abacus
www.avnet-abacus.eu/ac-dc-power-supplies

IPM, Battery Chemistry & Charging Algorithms for Wearables

Without silicon, new batteries and new charging algorithms have no way to acquire customers, and without customers

By: Keith Curtis, Microchip

The greatest challenge faced by both new battery chemistry and charging algorithm developers is obtaining an Application-specific Integrated Circuit (ASIC) design. Without silicon, new batteries and new charging algorithms have no way to acquire customers, and without customers – or at least potential customer - they can't entice ASIC manufacturers to spend development money to create an ASIC. It's the classic the chicken or the egg problem. As a result, many battery chemistries and charging algorithms never see the light of day.

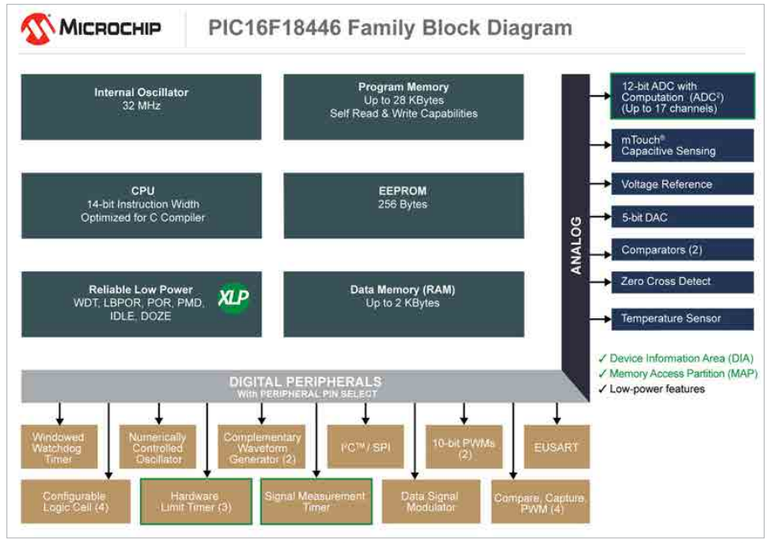


Figure 1: A block diagram for Microchip's PIC16F18446, which features high resolution Intelligent Analog peripherals such as an integrated 12-bit ADC2

However, the recent introduction of several new microcontroller families with intelligent analog on-chip, such as the PIC16F18446, may represent an alternative to the ASIC battle. These microcontroller families can include a long list of analog and mixed-signal peripherals such as voltage comparators, op amps, Analog-to-Digital Converters (ADCs), Digital-to-Analog Converters (DAC), voltage references, ramp generators, digital Pulse Width Modulations (PWMs), and even logic blocks. Using these blocks, it is then a reasonable leap to build an intelligent charger to show off the new battery or algorithm.

Let's take an example: A simple charger that first charges constant current, and then switches over to constant voltage (i.e. a standard LiPoly charger profile). Now we have a couple of options, either a DC system, or switched mode. Let's stick with the DC system for simplicity. So, we need a current source, a voltage source, and a switch to transition from one to the other. **Figure 1** shows a classic current source on the left and a voltage source on the right.

Now if we look closely, we can

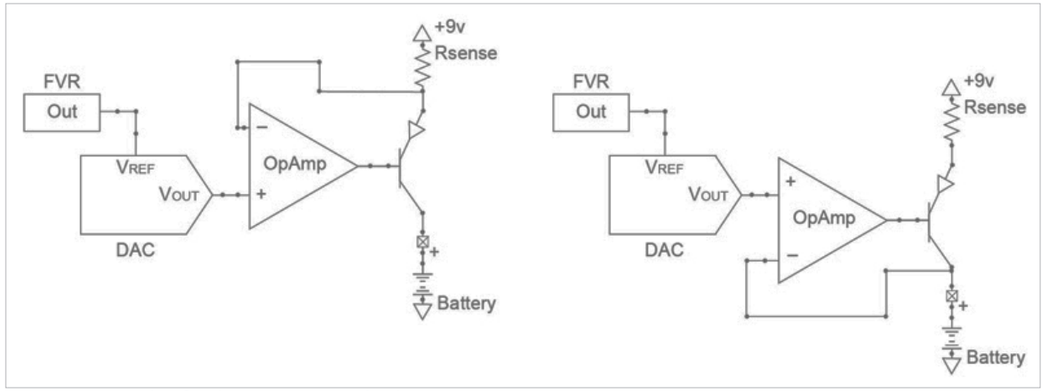


Figure 2: Example of a classic current and voltage source

see that they are pretty much the same. The only difference is the inverting input to the op amp and the value out of the DAC. If we put a comparator on the battery voltage and generate an interrupt when the battery voltage exceeds 4.1V (see **Figure 2**), then all the firmware needs to do is change the setting for the inverting input on the op amp and load a new value into the DAC.

Now, it may not be as simple as this; the charger may be pulsed, or it may require a switch mode charger for efficiency. Well, as far as pulsing the charge voltage/current, the typical op amp peripheral has an enable bit in its control register, so all that is required for pulsing is a periodic interrupt to turn the op amp peripheral on and off. Implementing a switching converter is a little more work, but still doable using on chip peripherals. This is shown in **Figure 3**.

The shown circuit is a switch mode voltage source. To make it a switch mode current source, simply change the output feedback from the battery to a current sense resistor between the battery and ground. One thing to note is that the compensation loop will probably also need to change, but even that can be done with two networks and a simple firmware routine to change which input drives the inverting input. Even the switcher can be pulsed in a similar manner to the DC circuit

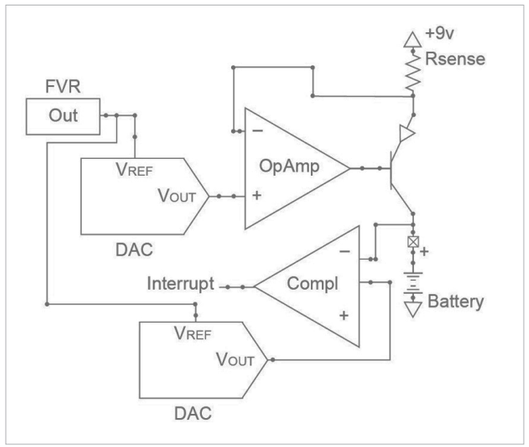


Figure 3: Example of a battery Voltage Switch

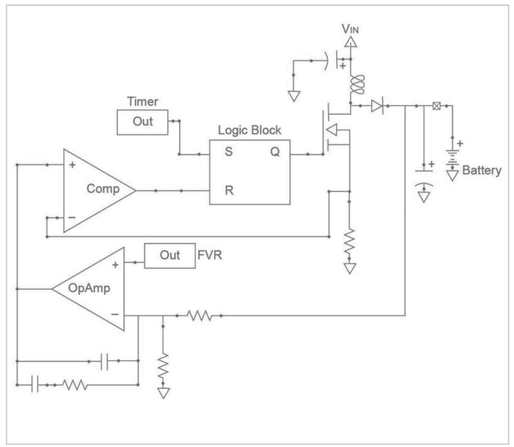


Figure 4: Example of a switch Mode Boost Converter

by simply turning off the timer and op amp in the switch.

The end result is that a combination of firmware and peripherals can implement almost any charger function:

1. Constant Current
2. Constant Voltage
3. Pulsed Current
4. Pulsed Voltage

Plus, adding additional features, options, algorithm tweaks, supervisory functions, or even emergency shutdown functions to a design is as simple making a firmware change.

So, using these new microcontrollers, both battery and charger developers can develop proof-of-concept chargers that they can demonstrate for their customers. In fact, for small to medium production runs, the microcontrollers can be preprogrammed, marked with a unique part number and delivered directly to their customer, making the device look and feel just like a custom charger ASIC.

Another point to consider is some customers' desire to combine multiple power management functions into a single device. These devices can include chargers, backlight drivers, fan controls, and even gas gauge functions, all within a single chip. By generating a microcontroller-based design initially, the battery / charger designer can further boost industry acceptance by licensing their intellectual property either to the customer, or a third party, to design the required composite power device. Customers can then take advantage of preprogramming, and customer part number marking, to further hide their design work from competitors until their design reaches sufficient production numbers to justify the creation of their own composite ASIC design.

Microchip Technology
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The Power and Evolution of GaN:

Part 3 of a 6 part series

By: Alex Lidow, CEO and Co-founder of EPC

In the first article in this series, how gallium nitride (GaN)-on-silicon low voltage power devices have enabled many new applications, such as light detection and ranging (LiDAR), envelope tracking, and wireless power was discussed. In this article, more detail on one of these leading applications, LiDAR, will be explored. How GaN is being used to make LiDAR systems that see farther, with higher resolution, and at lower cost will be shown.

Application

Light Detection and Ranging (LiDAR) is a remote sensing technology which transmits pulses of light from the sensor and measures the reflection to determine the location and distance of objects. If a laser is used as the optical source, the distance of a small spot even at a long range can be measured. When combined with steerable optics, it is possible to sweep the spot distance measurement and map objects in 3-D space, as shown in **figure 1**.

For applications such as autonomous and assisted driving, where the LiDAR system provides the 'eyes' for the vehicle, short pulses are needed to achieve the necessary distance resolution – as short as a few nanoseconds or even less. These pulses are typically generated using a laser diode. To get sufficient range, the peak optical power must be high, which means laser diode current peak values of 10s to 100s of amps. Until recently, this required the use of complex circuits and unusual, expensive semiconductors.

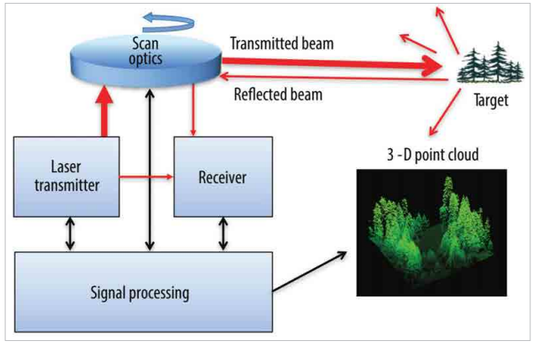


Figure 1: Overview of a typical LIDAR system

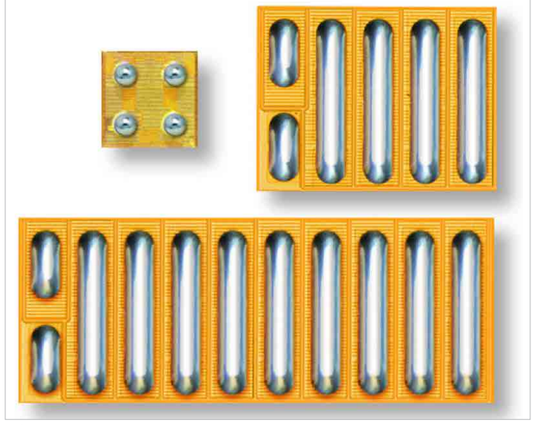


Figure 2: The EPC2036, EPC201C and EPC2001C are popular autonomous vehicle LIDAR systems

Why GaN?

A typical pulsed laser driver for LiDAR uses a semiconductor switch in series with the laser and an electrical energy source. Performance is limited by stray inductance and the speed of the semiconductor power switch. Within the last decade, cost-effective gallium nitride (GaN) power FETs and ICs have become commercially available, with significantly lower inductance and switching figures of merit (FOMs) up to 10x better than comparable silicon MOSFETs.

With the advent of eGaN® FETs and ICs, the desired performance becomes possible with simple, small circuits at low costs. Three of the most popular FETs for LiDAR are the EPC2036, EPC2016C and EPC2001C, shown in **figure 2**. The greatly improved performance of eGaN FETs versus older silicon MOSFET technology translates to much faster switching for a given peak current capability, enabling currents >100 A and pulse widths <2 ns with a laser load, although these cannot be met simultaneously (yet!). The extremely high performance of GaN and the ultra-low inductance of the chip-scale package make eGaN FETs the ideal switches for pulsed laser drivers.

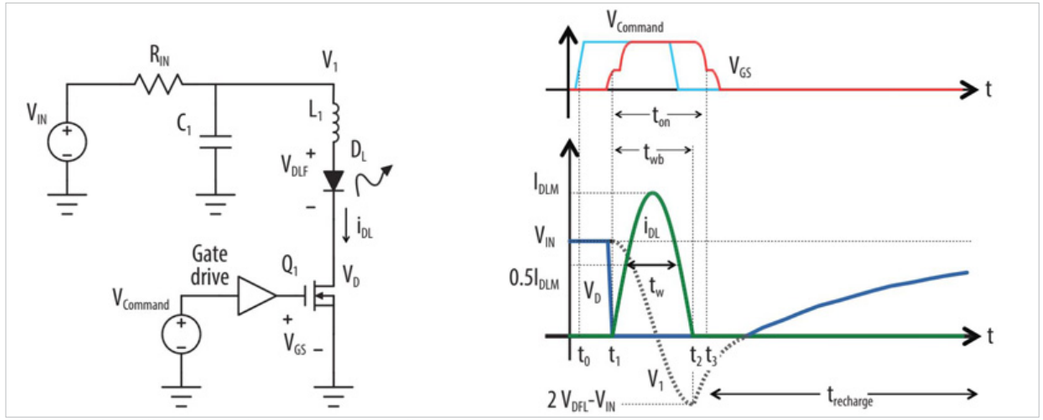


Figure 3: Simplified laser driver with key waveforms

How to Build an Ultra-Fast High-Power Laser Driver

The simplest and most common laser driver is the resonant capacitive discharge driver, shown in **figure 3**. FET Q1 discharges C1 resonantly through the stray inductance L1 and laser DL. To overcome inductance L1 and achieve the fast current rise-time desired, C1 is charged to a relatively high voltage (usually 25 V to 150 V). FET Q1 must be able to withstand the voltage, conduct the peak current, and turn on in 1 ns or less. The eGaN FET is the only readily available, cost-effective semiconductor switch that can meet these requirements.

The EPC9126 and EPC9126HC laser driver demonstration systems are designed to minimize inductance using the same basic optimal layout principles recommended for EPC power conversion applications. The EPC9126 comes populated with the EPC2016C and generates 35 A pulses less than 4ns wide into

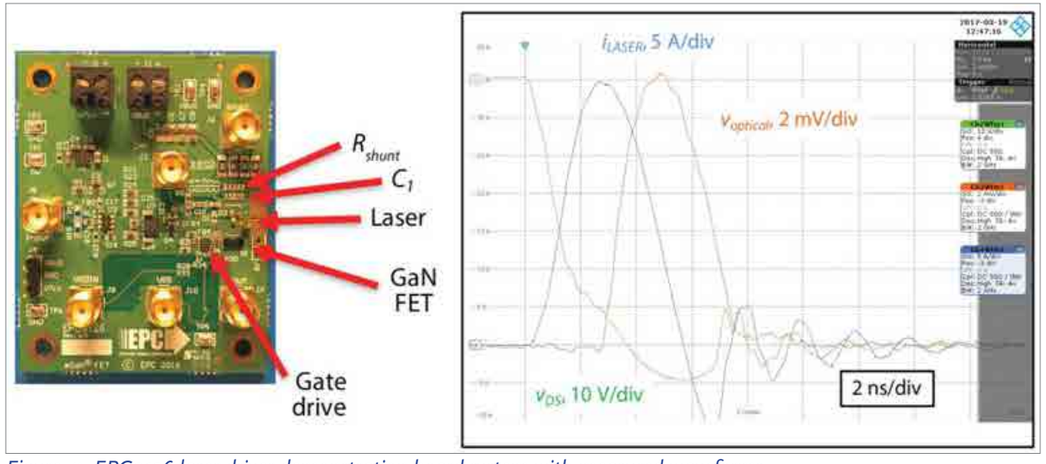


Figure 4: EPC9126 laser driver demonstration board system with measured waveforms

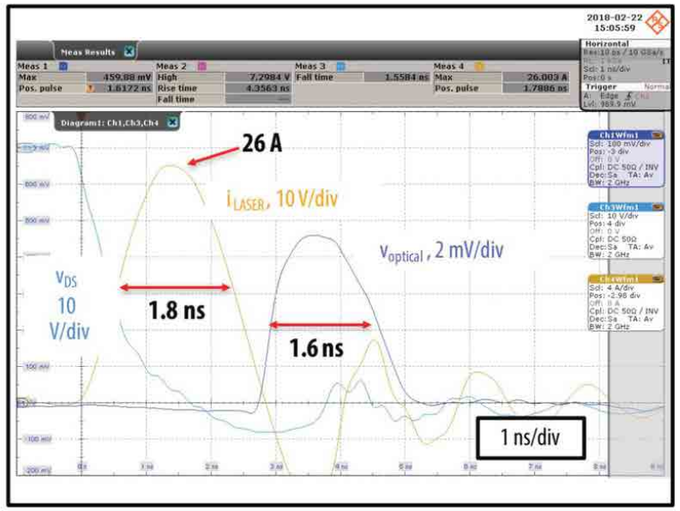


Figure 5: EPC2016C FET and Texas Instruments LMG1020 driving Excelitas TPGAD1S09H surface mount triple junction laser

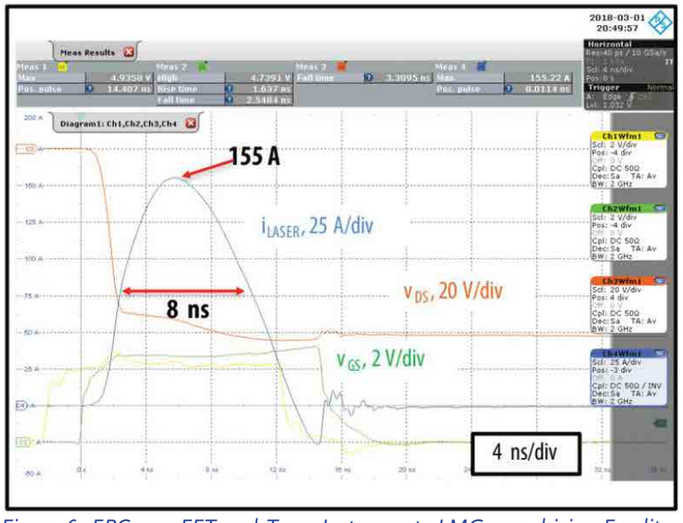


Figure 6: EPC2047 FET and Texas Instruments LMG1020 driving Excelitas TPGAD1S09H surface mount triple junction laser

a triple junction laser. Its high current companion, the EPC9126HC, can generate pulses of 65 A that are less than 8 ns wide. Both drivers have built-in sensing of key waveforms and can accommodate multiple laser packages. **Figure 4** shows the EPC9126/HC.

For the utmost in performance, the PCB can be optimized for a particular laser and paired with a high-performance gate drive such as the Texas Instruments LMG1020.

Using a low inductance surface mount laser such as the Excelitas TPGAD1S09H, the EPC2016C can achieve 26 A, 1.8 ns pulses (**figure 5**). For very high peak power (> 4 kW), the 200 V EPC2047, with a pulse current rating of 160 A, can achieve 8 ns, 155 A pulses with the same driver and laser (**figure 6**).

Automotive qualified parts

For automotive LiDAR applications, EPC has released the AEC-Q101 qualified EPC2202, rated at 80 V with a 75 A pulse current capability, the EPC2212 at 100 V with 75 A pulse current capability, and the EPC2203, rated at 80 V with a 17 A pulse current capability. The EPC2202 and EPC2212 have the same footprint as the EPC2016C, and the EPC2203 has the same footprint as the EPC2036. More transistors as well as integrated circuits designed for LiDAR are proceeding with automotive certification.

Conclusion

The superior performance of GaN power transistors enable groundbreaking laser driver performance. The ability to generate single digit nanosecond, high current pulses to deliver hundreds of watts from a few square millimeters is truly remarkable. It is one of the main factors in making affordable, high performance LiDAR possible in a small form factor thus fueling the LiDAR revolution.

Efficient Power Conversion (EPC)
http://epc-co.com/epc

IoT Devices Are Hot . . . But They Still Need Thermal Protection

Currently, more than seven billion IoT devices are in use worldwide, and the number of active IoT devices is expected to grow

By: Todd Phillips, Global Market Manager, Electronics Business Unit Littelfuse, Inc.

Of all the "hot" electronics markets, none is hotter than the market for devices designed to interact with the Internet of Things (IoT). Currently, more than seven billion IoT devices are in use worldwide, and the number of active IoT devices is expected to grow to 22 billion by 2025. Virtually all of those devices need to be powered or recharged in some way, often with USB cables in the case of portable or wearable objects. Consumers' desire to recharge their wireless IoT devices quickly and the higher levels of power required to do that raise the risk of thermal damage for both the charging cable and the device itself. As these devices get smaller and more transportable, their ports are increasingly exposed to debris in pockets, bags, and the atmosphere itself. These contaminants, when trapped between the device's or connector's power pins, can produce faults that lead to over-heating, especially at the higher power levels being used to charge the latest devices.

Chargers with various versions of USB cables and connectors have been used for years to recharge mobile and wearable devices. The challenge for manufacturers is to provide effective over-temperature protection for both USB charging cables and IoT devices. Polymeric Positive Temperature Coefficient (PPTC) devices (**Figure 1**) are among the devices traditionally designed into the connectors of USB cables to provide over-temperature protection. However, the development of USB Type-C™ and USB Power Delivery

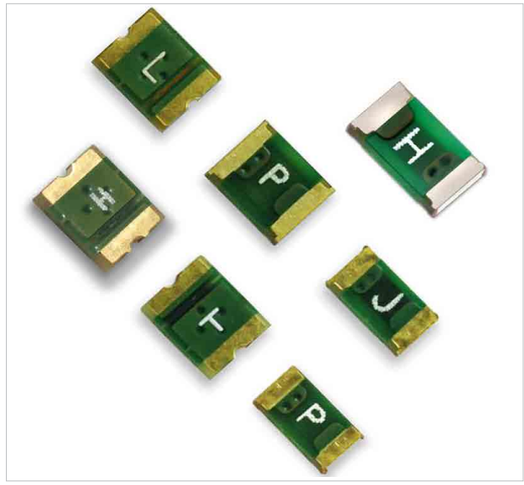


Figure 1: Devices like these Low Rho SMD Series PPTCs have long been used for over-current and over-temperature protection in USB connectors



Figure 2: Typical USB-C application with AC plug and captive USB-C cable

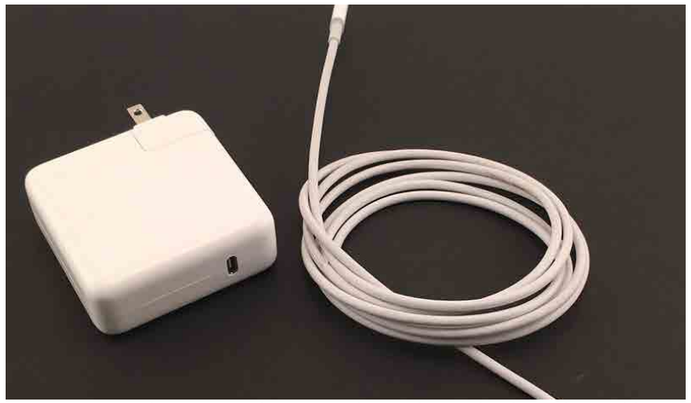


Figure 3: Typical USB-C application with AC plug and independent cable



Figure 4: Resistive faults in USB-C connectors can damage both cables and the IoT devices being charged.

(USB-PD) specifications and the higher levels of power they support (up to 100W) are driving the development of innovative protection solutions.

Charging Essentials

USB Type-C (often shortened to USB-C™) cables are equipped with one or more symmetrical (and therefore, reversible) 24-pin connectors with a low-profile 8.4 mm × 2.6 mm form factor. USB-C chargers have an AC plug on one end and either a cable with a USB-C connector on the other (for plugging into the device to be charged) as seen in **Figure 2** or a USB-C output port that allows plugging in a USB-C cable as seen in **Figure 3**. When recharging a device, the cable, the charger, and the device being charged must all work together.

From a protection standpoint, USB-C cables must be capable of carrying appropriate voltages and currents. For chargers with captive or fixed cables, the cables must be capable of handling the charger's maximum voltage output. Cables with Type-C connectors on each end must be capable of handling 21V and at least 3A. Those that include special e-marker ICs can carry 5A of current. Any device placed in the path of power, especially protection devices, must also be capable of withstanding these voltage and current levels.

USB-C cables are susceptible to damage from two different factors. The first factor is the connector's susceptibility to contamination and the associated risk of uncontrolled overheating. The pin pitch of USB Type-C connectors is 0.5 mm—much tighter than the 2.5 mm pin pitch in USB Type-A connectors. This tighter pitch significantly increases the risk of a fault that could cause a thermal event When dust, metal particles, hair or other debris gets stuck in a USB Type-C cable connector or the connector pins become deformed, it can create a resistive fault from the power line to ground. These resistive faults can cause a dangerous temperature rise while increasing current by only a minimal amount. The result can be damage to both connectors and device ports (**Figure 4**). The second factor is the higher level of power these cables are being tasked with carrying today—some as high as 100 W. When this level of power flows through a fault, it can produce significantly more damage than a lower level of power through the same fault.

As mentioned previously, the traditional approach to protecting USB cables from overheating damage involves locating a protection device on the VBUS power line. The protection device would be placed on a printed circuit board inside the connector to sense the temperature rise created by the resistive fault. However, when attempting to protect up to 100W of power, using this approach can challenge power supply design engineers.



Figure 5: PolySwitch® setP™ digital temperature indicators combine a compact 0805 footprint with a rigid design that can stand up to automated assembly and molding processes.

One of the drawbacks of adding a protection device in the path of power is that its resistance, even if it's just milliohms of resistance, can contribute to meaningful power loss, making it more difficult for power supply manufacturers to meet mandatory efficiency requirements. It also can be difficult to fit the device into the close confines of a USB-C connector. For example, the PPTCs suitable for protecting 60 W chargers typically have a 1210 (3.2 × 2.5 mm) footprint. A PPTC needed to protect a 100 W charger would be even larger. Although locating a PPTC on the VBUS line remains a reasonable option when designing cables for power levels up to 20 25 W, a new generation of digital temperature indicators combine a compact 0805 footprint (2.0 × 1.2 mm) with a better over-temperature protection solution for higher power charging.

Compact digital temperature indicators like the PolySwitch® setP™ (**Figure 5**) employ a different method for over-temperature protection for USB Type-C cables and IoT devices than earlier solutions. Instead of being placed on the VBUS line, they are designed to be placed on the communication channel (CC) line (**Figure 6**). They comply with USB-IF's USB Type-C specifications and can help protect even the highest levels of USB Power Delivery (100W).

A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2−	VBUS	SBU1	D−	D+	CC	VBUS	TX1−	TX1+	GND
GND	TX2+	TX2−	VBUS	VCONN			SBU2	VBUS	RX1−	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

Figure 6: Functional signal plan for a USB Type-C plug

When a damaged connector pin or debris caught between the connector pins creates a fault that causes the cable's temperature to rise higher, setP switches from a low resistance state to a very high resistance state, causing the voltage on the CC line to rise higher than the "vOpen" value defined by the USB-IF. This vOpen value is used to determine if the source and sink are detached. Once the system thinks the source and sink are disconnected from each other, power on VBUS is turned off, thereby preventing the device from overheating. Once the user disconnects the cable and removes the debris, normal charging can resume.

This approach offers a variety of benefits to the charging system designer and the end users. The setP indicator is not only about half the size of other solutions, but it also has a rigid structure that can stand up to typical cable assembly and molding operations. That makes it suitable for use in USB Type-C charging cables, USB Power Delivery charging cables, and chargers with captive USB Type-C cables.

Conclusion

USB-C cables offer IoT device owners a fast, uncomplicated way to charge their devices and transfer data. Now, with the development of a new approach to over-temperature protection, they can be confident that the process will remain safer as well.

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The Basics & Benefits of Tantalum & Ceramic Capacitors

A comparative selection guide

By: Brian Brunette, AVX Corporation

Tantalum (Ta) capacitors and multilayer ceramic capacitors (MLCCs) are two widely accepted capacitor technologies that can be employed in a wide range of electronics applications. Although both technologies perform the same basic function, they are very different in terms of their construction techniques, materials, and performance under various conditions, so it's important to understand the potential impact of selecting one over the other. Understanding the inherent characteristics of both tantalum capacitors and MLCCs, including their reliability and behavior with temperature and voltage, typical testing capabilities, and the latest developments for each will help ensure sound selections.

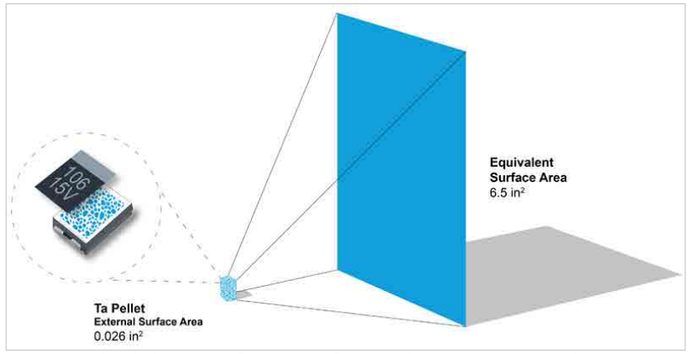


Figure 1: The dielectric surface area of a tantalum capacitor anode compared to its finished size

Capacitor Basics

The basic formula for capacitance is C = εr * ε0 * (A/d), in which

- C = capacitance, in Farads (F)
- A = the area of overlap between the two plates in square meters (m2)
- εr = relative static permittivity or the dielectric constant
- ε0 = the electric constant (ε0 ≈ 8.854×10–12F/m)
- d = the separation between the plates in meters or, essentially, the dielectric thickness.

Tantalum Capacitors

Tantalum capacitors achieve high capacitance values through a combination of factors, including a tantalum pentoxide (Ta_2O_5, εr = 27) dielectric, a large plate area (A), and a very thin dielectric thickness (d). The positively charged dielectric plate of a tantalum capacitor is formed from pure elemental grade tantalum powder that is pressed and sintered into a pellet. These pellets are extremely porous and, as such, allow the surface area of each individual particle to collectively comprise the area of an equivalent capacitor plate. In addition, the Ta_2O_5 dielectric layer is formed at a rate of 17 Ångströms per volt, with the thickness proportional to the applied voltage, which results in a very thin dielectric layer and contributes to large capacitance values.

Tantalum Capacitor Styles

For surface-mount applications, AVX manufactures two styles of tantalum capacitors, both of which incorporate an MnO_2-based cathode to take advantage of its self-healing characteristics and are shown in Figure 2. The molded style (top) is the more traditional configuration and utilizes a tantalum wire embedded in the pellet to create the positive connection to the circuit. The newer, smaller, microchip-style configuration (bottom) was introduced to market more recently and is used in applications with high component density and minimal available board space. The microchip-style configuration has a tantalum wafer with tantalum powder pressed and sintered onto its surface and defines individual anodes using a high precision sawing operation. Both types of capacitors have the same basic elements and both have been proven suitable for the highest reliability applications over decades of production and testing.

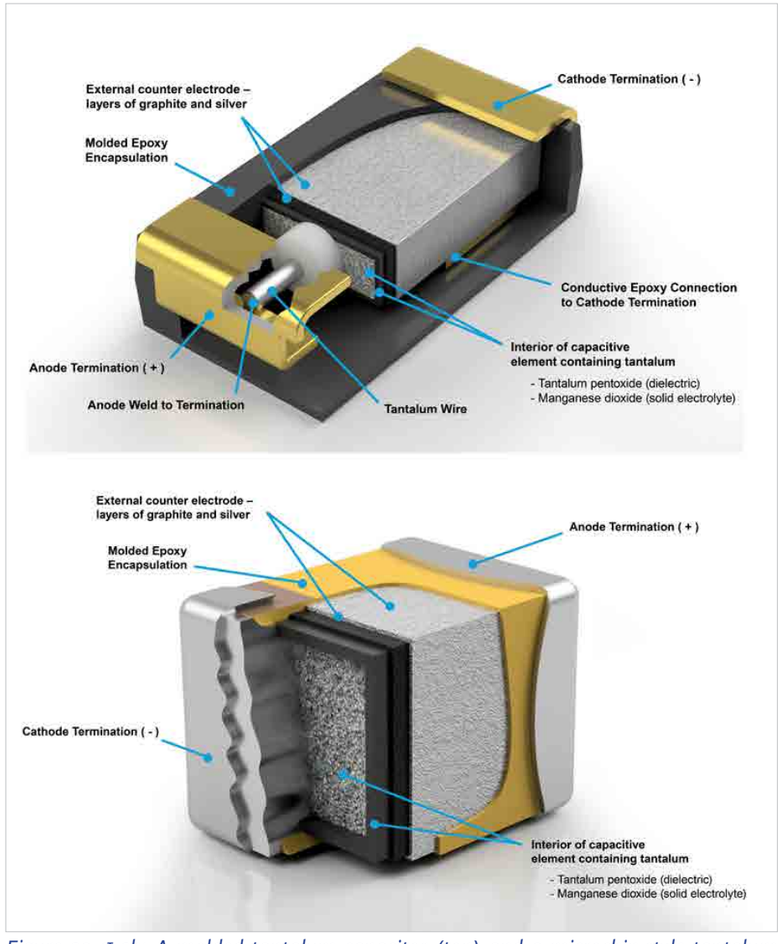


Figure 2a & 2b: A molded tantalum capacitor (top) and a microchip-style tantalum capacitor (bottom)

Ceramic Capacitors

In contrast to tantalum capacitors, ceramic capacitors have less overall plate area and significantly thicker layers, but compensate for such deficiencies by using dielectric materials with a much higher dielectric constant. Titanium dioxide (εr ~ 86–173) and barium titanate (εr ~ 1250–10000) are two of the most popular dielectric materials used to make MLCCs, and each material comprises its own class of capacitors.

Class 1 and Class 2 Ceramic Capacitors

Class 1 ceramic capacitors offer the most stable capacitance with respect to applied voltage, temperature and, to some extent, frequency. The basic elements of Class 1 ceramic capacitors are composed

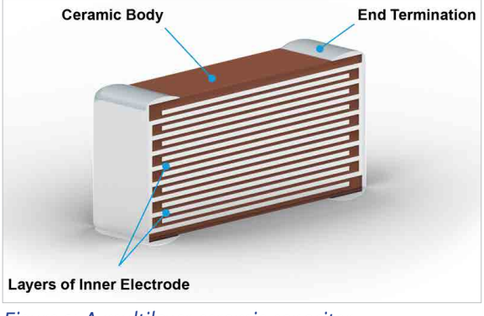


Figure 3: A multilayer ceramic capacitor compared to its finished size

EIA CODE PERCENT CAPACITY CHANGE OVER TEMPERATURE RANGE	
RS198	**Temperature Range**
X7	-55°C to + 125°C
X6	-55°C to + 105°C
X5	-55°C to + 85°C
Y5	-30°C to + 85°C
Z5	+10°C to + 85°C
Code	**Percent Capacity Change**
D	±3.3%
E	±4.7%
F	±7.5%
P	±10%
R	±15%
S	±22%
T	+22%, -33%
U	+22%, -56%
V	+22%, -82%
Example: A capacitor is desired with the capacitance value at 25°C to increase no more than 7.5% or decrease no more than 7.5% from -30°C to +85°C. EIA Code will be Y5F.	

Figure 4: EIA code table for ceramic capacitor dielectrics

of paraelectric materials, such as titanium dioxide, that are modified by additives including zinc, zirconium, and niobium in order to achieve the desired linear capacitance characteristics that are inherent to tantalum. Class 1 ceramic capacitors also have the lowest volumetric efficiency among ceramic capacitors due to the relatively low permittivity (εr ~ 6–200) of the paraelectric materials used and, as such, offer capacitance values in the lower range.

Class 2 ceramic capacitors utilize ferroelectric dielectric materials, such as barium titanate (BaTiO), and are modified by additives including aluminum silicate, magnesium silicate, and aluminium oxide. These materials have a higher permittivity than Class 1 capacitors (εr ~ 200–14,000 depending on field strength) and achieve better volumetric efficiency, but exhibit lower accuracy and stability. Class 2 capacitors also have nonlinear capacitance values that are dependent on both operating temperatures and applied voltage and will age over time, which can affect performance.

Ceramic Capacitor Dielectric Codes

Ceramic capacitor dielectrics are defined by a three-character EIA code that specifies the material's capacitance stability over a specified temperature range. For instance, ceramic capacitors made using X5R dielectric materials have an operating temperature range of -55°C to +85°C with an allowable variation in capacitance of ±15% over that range and exhibit non-linear capacitance value stability over that range.

Similarly, any material that allows a device to meet or exceed the X7R temperature characteristics, ±15% capacitance variation over a temperature range of -55°C to +125°C, can be called X7R. There are no voltage coefficient specifications for X7R or any other type of dielectric. A vendor can call a capacitor X7R, X5R, or any other

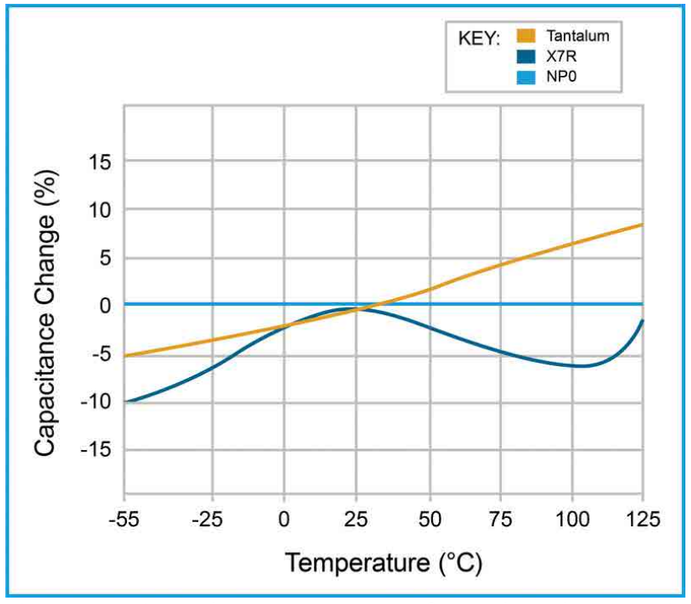


Figure 5: Capacitance change over temperature for tantalum, Class 1 ceramic, and Class 2 ceramic dielectric materials

of dielectric code as long as it meets the temperature coefficient specifications, regardless of how bad the voltage coefficient is.

Tantalum vs. Ceramic Capacitor Performance

Tantalum vs. Ceramic Capacitor Temperature Response

Figure 5 illustrates the typical capacitance response over temperature for tantalum capacitors, Class 2 ceramic (X7R) capacitors, and Class 1 ceramic (NP0 or C0G) capacitors. The tantalum capacitor exhibits linear capacitance change with respect to temperature: -5% capacitance change at -55°C to 8+% at 125°C. Class 2 ceramic capacitors demonstrate the most non-linear response to temperature, but can be made to achieve similarly desirable linear performance in applications with narrow operating temperature ranges (e.g., medical implantable devices) by accounting for the temperature response when designing the circuit.

Tantalum vs. Ceramic Capacitor Voltage Response

In addition to providing linear performance over temperature, tantalum capacitors do not demonstrate capacitance instability with respect to applied voltage. Unlike tantalum capacitors, the capacitance of Class 2 ceramic capacitors changes with applied voltage because the permittivity of the dielectric shrinks in response to higher applied voltages. These changes are

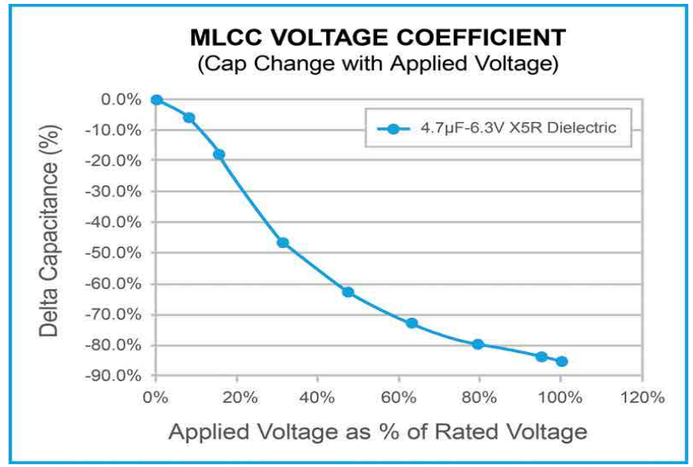


Figure 6: Capacitance change over voltage for a Class 2 (X5R) ceramic capacitor

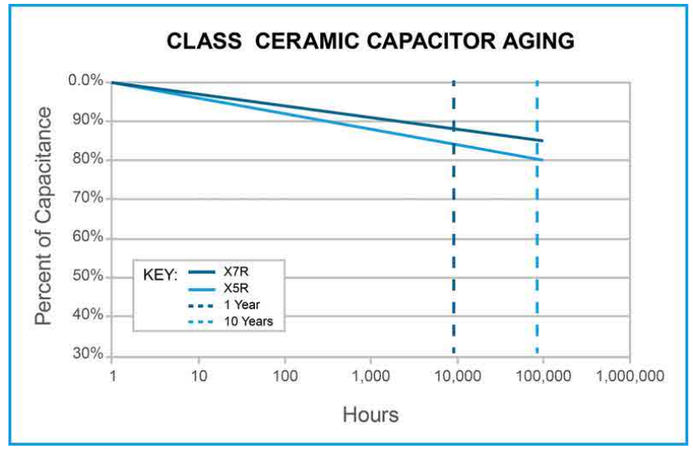


Figure 7: Capacitance change over time for Class 2 X7R and X5R dielectric capacitors

relatively linear and thus easy to account for in circuit designs, but some higher permittivity dielectrics can lose as much as 70% or more of their initial capacitance when operated at or near rated voltage.

Tantalum vs. Ceramic Capacitor Aging

Class 2 ceramic capacitors also exhibit a logarithmic decrease in capacitance over time, which is referred to as aging. Degradation of the polarized domains in these ferroelectric dielectrics decreases permittivity over time, causing the capacitance of Class 2 ceramic capacitors to decrease as the component ages. Tantalum capacitors do not experience similar aging and have no known wear-out mechanism.

Tantalum vs. Ceramic

MANUFACTURER	PRODUCT	DIELECTRIC	INSULATION RESISTANCE	EQUIVALENT DCL/CV
AVX	—	X7R	1,000Mohm-µF	0.001 x CV
AVX	—	X5R	1,000Mohm-µF	0.002 x CV
B	COTS	X7R	1,000Mohm-µF	0.002 x CV
B	Commercial	X7R	1,000Mohm-µF	0.002 x CV
B	Commercial	X5R	1,000Mohm-µF	0.002 x CV
C	Hi- Rel	X7R	1,000Mohm-µF	0.001 x CV
C	Hi- Rel	X5R	1,000Mohm-µF	0.001 x CV
C	Commercial	X7R	1,000Mohm-µF	0.002 x CV
C	Commercial	X5R	1,000Mohm-µF	0.002 x CV
Typical Tantalum	Commercial	Ta_2O_5	—	0.01x CV
AVX Hi-Rel Tantalum	HRC5000/HRC6000	Ta_2O_5	—	0.0025 x CV

Figure 8: A comparison of the IR of ceramic capacitors to DCL of tantalum capacitors

MANUFACTURER	DIELECTRIC	LIFE TEST CONDITIONS	INSULATION RESISTANCE POST LIFE TEST	EQUIVALENT DCL/CV
AVX	X7R	125°C, 2 x Rated Volts, 1K Hours	0.3 x Initial Limit	0.003 x CV
AVX	X5R	85°C, 2 x Rated Volts, 1K Hours	0.3 x Initial Limit	0.006 x CV
B	X7R	125°C, 2 x Rated Volts, 1K Hours	0.1 x Initial Limit	0.020 x CV
B	X5R	85°C, 2 x Rated Volts*, 1K Hours	0.1 x Initial Limit	0.020 x CV
C	X7R	125°C, 2 x Rated Volts**, 1K Hours	100hm-F	0.1 x CV
C	X5R	85°C, 2 x Rated Volts**, 1K Hours	100hm-F	0.1 x CV
Typical Tantalum	Ta_2O_5	—	0.01 x CV @ 2K Hours	—
AVX Hi-Rel Tantalum	Ta_2O_5	—	0.0025 x CV @ 1K Hours, 0.005 x CV @ 2K Hours	—

* *1.5 x Rated Volts for 0603 ≥ 1µF, 0805 ≥ 4.7µF, 1206 ≥ 2.2µF*
** *1.5 x Rated Volts for 0603 ≥ 1µF 10V & 16V, 0805 ≥ 4.7µF 10V*
** *1.5 x Rated Volts for 0603 ≥ 4.7µF 6.3V & 10V, 0805 ≥ 22µF 6.3V, 1206 ≥ 47µF 6.3V*

Figure 9: Life test variation between ceramic and tantalum capacitors

PARAMETER	TANTALUM	CERAMIC
ESR	—	X
Volumetric Efficiency	X	—
Temperature Range	X	—
Low Inductance	—	X
DC Bias Dependency	X	—
Microphonic (Piezoelectric)	X	—
High Frequency Filtering	—	X
Aging Performance	X	—

Figure 10: A comparison of tantalum and ceramic capacitor parameters

Capacitor IR and DCL

Insulation resistance is the resistance measured across the dielectric of a capacitor. As capacitance values (and hence the area of dielectric) increases, the IR decreases. So, the product (C x IR or RC) is often specified in Ohm Farads or, more commonly, megaohms. Leakage current is determined by dividing the rated voltage by IR (per Ohm's Law).

Ceramic capacitors typically specify insulation resistance, whereas tantalum capacitors are graded by direct current leakage (or DCL). These units are equivalent and conversion from one measure to the other is made using Ohm's law.

Tantalum vs. Ceramic Capacitor Testing

Tantalum vs. Ceramic Capacitor IR Life Test

Figure 9 depicts the life test conditions for various types of ceramic and tantalum capacitors made by several different manufacturers and the allowable change in insulation resistance and/or DCL/CV. As shown, the conditions for life testing are not standardized, so direct comparisons between ceramic capacitors made by various manufacturers are difficult to make with a high degree of certainty and direct comparisons from ceramic to tantalum capacitors is virtually impossible, save for the exception of a few very high capacitance ratings.

Due to the notable differences between most of the test methods used to evaluate tantalum and ceramic capacitors, a direct comparison of their relative performance isn't easily obtained via product literature and specification data. As such, AVX conducted the following testing to provide a more direct comparison of their respective performance.

Tantalum vs. Ceramic Comparative Testing

The AVX team selected samples of ceramic and tantalum capacitors that represent common ratings for both technologies and commonly used values for medical and other high-reliability applications.

- Tantalum Capacitor (TBCR106K016CRLB5000)
- 10µF, 16V
- 0805 case size
- Ceramic Capacitor (MQ05YD106KGT1AN)
- 10µF, 16V
- 0805 case size
- X5R dielectric

The team submitted all parts to the same test plan to ensure that special testing requirements (e.g., capacitance test frequency and DC Bias, hold times after environmental testing, etc.) could be accurately observed, collected, and compared for both basic product types.

- Temperature Stability (MIL-PRF-55365) – 13 units
- Thermal Shock (MIL-STD-202 Method 107) – 40 units
- Moisture Resistance (MIL-STD-202 Method 106) – 40 units

A majority of the test results showed similar performance between the ceramic and tantalum capacitors. For example, temperature stability showed that ceramic capacitors are more stable with regard to equivalent series resistance (ESR) and DCL, while tantalum capacitors are more stable for capacitance value over temperature. Tantalum capacitors also exhibited a capacitance increase at elevated temperature, while ceramic capacitors exhibited capacitance decreases at the same condition. In addition, both moisture resistance and thermal shock testing resulting in stable performance for both technologies.

In conclusion, both tantalum and ceramic capacitors offer several advantages and benefits that aid in the manufacturing of efficient, high-reliability electronics across a wide range of markets. However, since both capacitors differ significantly with regard to their composition, materials, and performance, the choice between specifying one technology over the other comes down to specific application considerations and requirements. So, it is important for engineers to take the potential effects of component selection into account early on in their design phase.

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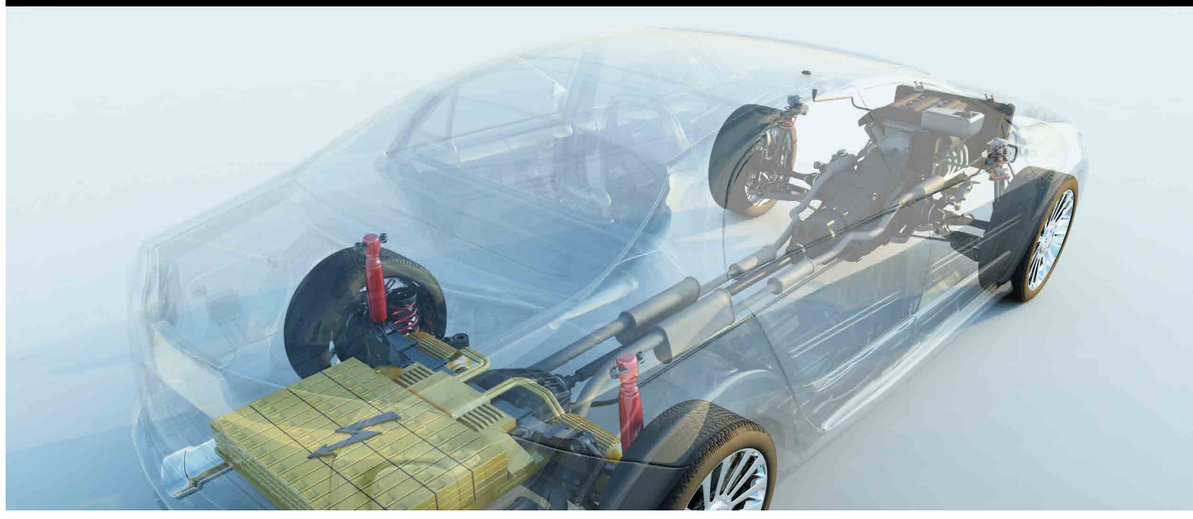
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Mild Hybrid Vehicle Solutions Address Emissions Challenge

The addition of 48V systems to 12V and Full Hybrid Vehicles provide opportunities for fuel efficiency and reduce emissions.

By: John Grabowski, EV/HEV Systems Applications Manager, ON Semiconductor

With the very recent reassertion by scientists that the current trajectory for reducing the rate of global temperature increases is simply not good enough, there is now even greater pressure to reduce vehicle emissions of CO_2 gasses. The best way of achieving this is through a reduction of the average vehicle's fuel consumption. The use of hybrid engineered vehicles, as opposed to pure internal combustion engine (ICE) variants, is one method of reducing fuel usage.

The powertrains of all vehicles must be able to operate over a very wide range of power and speed conditions typically referenced as a torque-speed range. The use of a hybridized powertrain allows system designers the freedom to optimize the two power sources at different points of the torque-speed range.

The electrical power source is able to provide a very large amount of torque, useful for acceleration, but it is only available for limited periods of time. The specific time is dependent on both the size of the battery and the torque output of the electrical machine itself. With the availability of the high torque producing power source, the ICE can be significantly downsized resulting in improved fuel efficiency. However, the addition of this hybrid power source is certainly not a straightforward engineering task and necessitates an approach that has a knock-on effect for many other vehicle systems.

To-date, electrification has been achieved by adding a high-voltage (in the region of 350V) battery and a high-performance electric machine directly coupled to the ICE powertrain. These 'Full' Hybrid vehicles (HEVs) have set the standard and have strong appeal from an enhanced efficiency standpoint. However, they tend to add a considerable amount of cost and weight to the vehicle.

Recently, 48V vehicle system architectures have received a significant level of attention. These systems can be thought of as a partial step towards a full HEV. Typically, they are referred to as 'Mild' Hybrid Electric Vehicles (MHEV). They are based around a relatively compact 48V battery, a high performance electric machine, and multiple 48V electrified subsystems. The lower cost of 48V systems makes them attractive to automotive OEMs, and they look set to become part of most vehicle manufacturers' ranges.

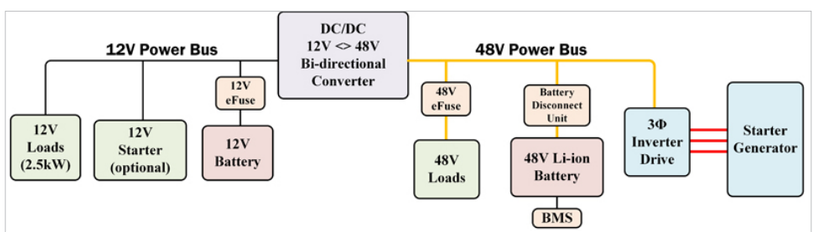


Figure 1: A Typical 48V Mild Hybrid System Electrical Topology

The MHEV Dual-Voltage Architecture

Currently, there are a large and increasing variety of 48V architectures. Most include a battery, a starter-generator, a voltage converter, and typically at least one 48V load. Since 48V vehicles still retain a 12V battery and multiple 12V loads, it is likely that these systems will exist as dual voltage architectures for the foreseeable future. See **Figure 1**.

With the use of a 48V dual-voltage architecture, many new vehicle electrical configurations are possible. Because the 48V system is fundamentally capable of higher power levels, the use of new higher powered sub-systems is possible. With the inception of the 48V system, the integration of 48V E-Compressor and 48V E-Roll stabilization systems, in 12V topologies, are now possible. In addition, the higher power availability will encourage the higher powered 12V loads to migrate to the 48V bus taking advantage of the increased efficiencies.

Initially, the 12V side of the dual voltage system will remain as is, without the 12V alternator. Since the only power generating source is the 48V alternator, the system will require a converter that will transfer the 48V generated power to the 12V battery. This converter needs to be compact, lightweight, and highly efficient. It is designed to be bi-directional, which enables the combined use of both batteries during periods of high current demand, required in situations such as cold starting. The bi-directional converter is able to convert power from either battery and transfer the power between them.

On the 48V side, the starter-generator is the primary component. It is responsible for generating all of the vehicle's electrical power and start the vehicle. In addition, the starter-generator performs regenerative energy recovery during vehicle braking. In this mode, the machine acts as a generator providing negative torque to the powertrain which slows down the vehicle and recovers electrical charge for the battery. Starter-generators come in many configurations and power levels, each with very specific vehicle implementation goals.

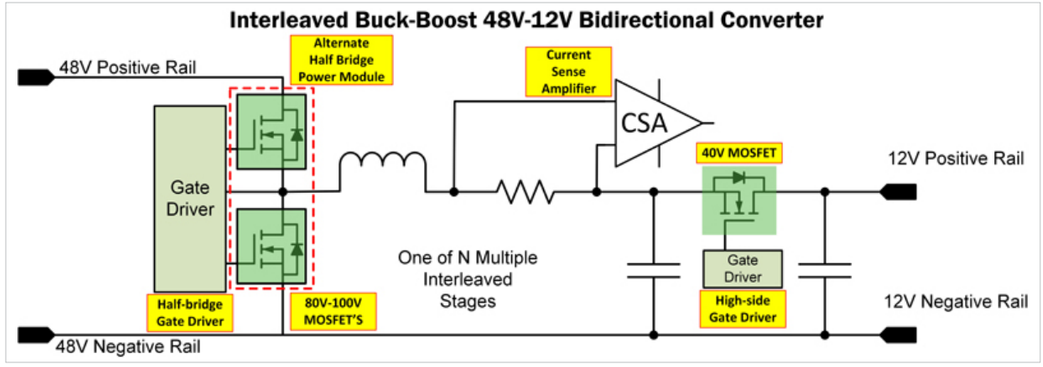


Figure 2: A Single Stage of a Multi-stage DC-DC Converter

48V MHEV DC-DC Converters

The bidirectional power converter is required to share charge between the two battery systems and typically has power ranges in the 1kW to 3kW range. The most popular topology utilized to maintain high efficiency over this large power range is the multi-stage buck boost converter. The buck topology permits power to flow from the higher voltage side down to the lower voltage side. The boost topology permits power flow in the opposite direction. A multi-stage design permits the sharing of many individual converter sub-circuits combined into a single high-power converter. This multi-stage design permits the shedding of some of the stages during light load conditions. The multi-stage shedding function is facilitated by the use of an output MOSFET's that can be switched on or off to enable each particular stage. A typical converter design is shown in **Figure 2**. The highlighted boxes indicated areas where ON Semiconductor has significant product offerings.

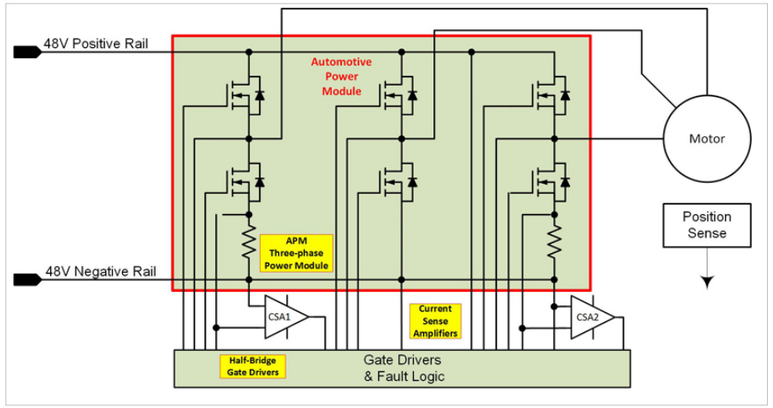


Figure 3a: 48V Sub-systems Summary



Figure 3b: An APM Based 48V Three-phase Auxiliary Motor Drive

MHEV Sub-Systems

The MHEV has a wide variety of conceivable 48V sub-systems, more than are possible with 12V only systems. The highest power load on the MHEV is the electrically controlled supercharger known as the E-Compressor. Since a supercharger needs to accelerate to extremely high speeds in fractions of a second, it requires large amounts of transient power. A typical supercharger drive consists of a low inertia three-phase motor driven by a three-phase power inverter. Peak power levels can reach upwards of 8kW, even though it has a relatively low average power. These wide power range profiles are a perfect match for 48V systems that generate large amounts of power for relatively short periods of time.

80V Discrete MOSFET's		
Part Number	Package	$R_{DS(on\text{-}max)}$ (mΩ)
FDBL86361_F085	TOLL	1.4
FDBL86363_F085	TOLL	2
NVMFS6H800N	SO8FL	2.1
NVMFS6H801N	SO8FL	2.8
FDB86366_F085	D2PAK	3.6
NVMFS6H818N	SO8FL	3.7
FDD86367-F085	DPAK	4.2
NVMFS6H836N	SO8FL	7
FDD86369-F085	DPAK	7.9
NVTFS6H850N	u8FL	9.5
FDMS86380_F085	SO8FL	13.4

APM19 Power Modules		
Part Number	Rating	Description
FTC03V85A1	80V/180A	3-Phase Interleaved DC/DC
FAM08V13DB1	80V/130A	3-Phase Inverter
FAM08V19DB1	80V/190A	3-Phase Inverter
FAM04V16DB1	40V/160A	3-Phase Inverter

Current Sense Amplifiers (CSA)		
Part Number	Gain	Description
NCV210RSQT2G	200	Current sense amplifieres
NCV211RSQT2G	500	Current sense amplifieres
NCV213RSQT2G	50	Current sense amplifieres
NCV214RSQT2G	100	Current sense amplifieres

Table 1: 48V MHEV Solutions Application Devices

Many other vehicle sub-systems are also ideally suited to the 48V architectures for both single and three-phase configurations. A listing of potential 48V sub-systems can be seen in **Figure 3**.

Other 48V Systems

Many 48V sub-systems consist of low power three-phase motor drive systems. These motor drives are most conveniently realized by use of a module design. The ON Semiconductor line of Automotive Power Module (APM) three-phase modules are a perfect choice. These modules are a compact and efficient choice for the construction of a three-phase auxiliary motor drive system. The module has a six-device power bridge, internal current shunt, snubber capacitor and is constructed on an isolated ceramic substrate. A 48V inverter reference design has been built for evaluation of our 80V APM devices. The system configuration and picture is shown in **Figure 3**.

It has the following features:

- FAN08V19DB1 three-phase power module
- Optical input isolation
- FAN7393 half-bridge gate drivers
- Inverter DC link current shunt amplifier
- Module temperature conversion circuitry
- NCV213RSQT based over current protection
- NTS based over temperature protection
- Optional three channel current sensor board (typ. 2-Phase plus DC Link)
- Reverse battery & voltage transient protection circuitry

This three-phase motor drive system is in the final testing stage at the ON Semiconductor power laboratory in Ann Arbor, Michigan. ON Semiconductor will provide additional details when the testing is finished.

48V System Component Offerings

ON Semiconductor offers many components that are applicable to 48V electronic system design. A brief subset of these devices are shown in **Table 1**. We offer MOSFET's in various discrete and modular packages. Our line of current sense amplifiers are capable of converting current shunt voltages, even in designs which have large common-mode voltage, into logic level signals. In addition, we are constantly developing new devices to expand our already world class portfolio. New device packages are also in the final stages of AEC qualification and will soon be released for production.

48V Sub Sub-system Proliferation

One possible consequence of the 48V revolution, will be the generation of wide varieties of 48V peripherals. This proliferation will likely reduce the cost of 48V sub-systems and make them a more attractive addition to other high-voltage based vehicles. If these peripherals are included in Full- Hybrid or electric vehicles they will need to be powered by a 48V source, thus introducing the need for a triple voltage architecture. This architecture will generate a new solution component requirement for xEV vehicles, called the "the triple voltage converter".

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Overcoming Poor Power Quality in Small Spaces

Electric vehicles (EVs) are commercially viable and several design challenges are needed for next generation EVs

By: Steve Hughes, Managing Director, REO UK



For years, the adoption of electric vehicles (EVs) has been marred by a slow diffusion of innovation among consumers. Probably the most obvious problem is that buyers have been apprehensive of the high initial cost of buying EVs, as well as the total cost of owning an electric vehicle over the course of its lifetime compared to traditional petrol and diesel-powered vehicles.

However, in its annual Electric Vehicle Outlook 2017 report, Bloomberg New Energy Finance (BNEF) brought to light recent data showing that this is changing faster than ever before. According to the report, in the third quarter of 2016, global sales of electric vehicles rose 63 per cent compared to the same period last year, and it projects that total annual sales will exceed one million units for the first time.

Government policy aside, one of the truest indications that we are experiencing a paradigm shift towards clean transport is the response from big oil. Traditional bastions of fossil fuel such as BP, Shell and ExxonMobil are making moves to alter the fundamental make-up of their oil-heavy portfolios. Whether it's investment in straightforward alternative energies such as wind and solar, or research into microalgae-based biofuels, it's clear that EVs are inspiring far-reaching changes.

Soon, all cars will need to be capable of zero-emission driving. Battery-electric and hybrid cars are leading the way to more efficient and sustainable driving, but automotive manufacturers are under significant pressure to design components as robust as those designed for internal combustion vehicles.
This is greatly down to the modern motor vehicle being a far cry from the crude, greasy and heavy electromechanical systems of old. Yet, despite the advancement in nearly every other area of engineering, sitting in a car today, you would be unlikely to tell that the vehicle is being propelled by largely the same internal combustion technology that was invented 159 years ago.

Internal combustion engines (ICEs) as we've known them for the past hundred years have been chosen over alternatives like the steam engine because they're relatively well-suited to powering automobiles. Now that the environmental cost is clear, however, the UK Government has announced plans to stop sales of pure ICE vehicles from 2030, with The Road to Zero Strategy.

While sales of electric vehicles are rising, manufacturers are profiting and governments are considering the burgeoning EV market, there are still various challenges that could hamper innovation and development in the market.

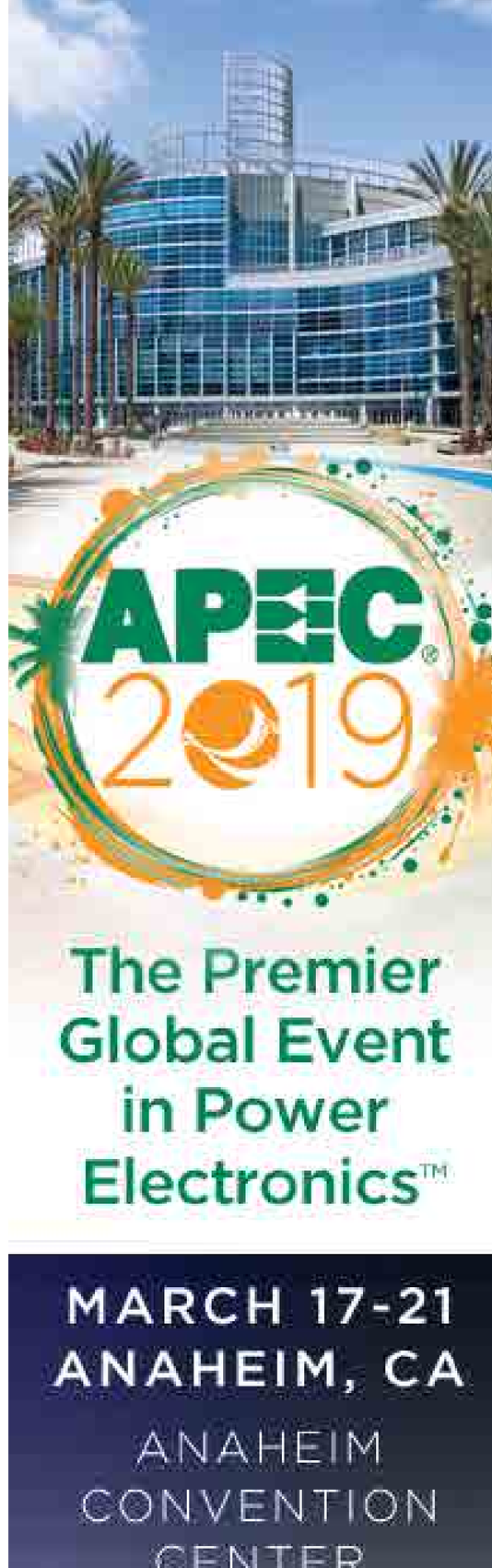
According to Toyota, the average car is made up of 30,000 components. In EVs, the number of components is a great deal less, especially when considering the number of moving parts.

To explain more clearly, for an internal-combustion engine (ICE), there is typically the crankshaft, fuel pumps and fuel injectors. In addition to this, there will be two valves per cylinder, or at least four valves per cylinder in the latest more economic engine designs. Outside of the engine, there are even more moving parts including a multiple-speed manual or an automatic transmission.

In comparison, EVs have been created to have the simplest architecture possible. Take the Nissan Leaf for example, which has been manufactured with no clutch or torque converter, but features a simple reduction gearbox, with a single gear ratio and the motor itself has just one moving part.

While the number of components may differ, the design principles for these components are virtually identical. For example, each of these parts must be able to withstand repeated bouts of acceleration and braking, as well as low and high-speed driving over smooth and rough areas. The same parts must be able to perform in a variety of extreme environmental conditions, from hot and humid to cold and wet.

At REO UK, we've identified one of the key constraints for EV components to be poor power quality because of issues like electromagnetic interference (EMI). While electrical and electronic components provide a much more efficient transfer of energy, having



so many parts operating in close proximity makes the vehicle susceptible to electrical noise.

EMI, if unaddressed can result in overheating, efficiency losses and even interference with the vehicle's data communication systems. When looking to integrate features that can mitigate issues like EMI, design engineers are also faced with the problem of having the limited space of fitting more electrical components into a vehicle that already has high component density.

This is compounded by the fact that the same lines used to deliver power to the electric vehicle are also used for data signaling to provide the battery management control system with information on variables like charge status, temperature and voltage. A failure to address EMI can result in overheating, efficiency losses and potential radio frequency issues that interfere with the vehicle's data communication systems.

To meet this challenge, REO has built on its extensive experience in railway electrification and developed a variety of inductive and resistive components for electric vehicles and their charging systems. EVs have some equivalent subsystems to those found in their internal combustion counterparts. The powertrain consists of batteries combined with an electric motor to generate propulsion and the drivetrain uses electric motors to drive the wheels.

For the EV charging systems, this takes the form of a single-phase transformer and electromagnetic compatibility (EMC) filter. As transformers get bigger for higher frequency applications, the proportion of losses and eddy currents rises. To keep these at bay, it's preferable to keep the size of the transformer small. REO achieves this by using better core materials such as amorphous cores, nanocrystalline cores and ferrite cores.

Automotive manufacturers should also look to integrate inductive and resistive components to supress EMI. EVs, much like petrol ICE vehicles, feature an inverter and a DC-DC converter, using high frequency switching, to manage power conversion. By using high frequency components like REO's transformers, filters and choppers, engineers can protect any sensitive semiconductor power electronics in the vehicle.

For example, our chokes have been designed to eliminate electrical noise in the inverter and can effectively store and discharge magnetic energy from the core. This is regardless of whether its core is made from a ferrite, amorphous or nanocrystalline material.

According to the Department of Energy, petrol or diesel cars can only convert between 14 to 26 per cent of the battery's energy. EVs, however, can convert up to 80 per cent of the battery's energy. This is because vehicles traditionally use friction to convert mechanical braking energy into heat and wear on the brake pads. In an EV, braking choppers are responsible for converting any energy created as a result of high speed changes.

Components like inverters are also at risk of overheating. As we've discussed, design engineers are already limited on space and so traditional air-cooling methods, that involve using a fan to dispel any heat generated, are not viable. Instead manufacturers must integrate liquid-cooling systems to manage the thermal properties of the electrical components while allowing them to meet the space constraints in the vehicle.

As EVs become increasingly mainstream, it's important that design engineers and automotive companies keep pace with consumer demand and not at the cost of reducing efficiency, by using poor quality or the wrong components. Instead, automotive manufacturers should look to assemble their future models with the latest components that address prominent issues for EVs, like poor power quality.

REO UK
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SPECIAL REPORT : ELECTRIC + HYBRID VEHICLES

Ultra-Compact Secondary Automotive Buck DC/DC Converters

High-efficiency, reliability and low power consumption makes new converters suitable for sensors used for assisted driving.

By: David James, EU Design Centre, ROHM Semiconductor GmbH

ROHM has recently launched the BD9S series of secondary synchronous Buck DC/DC converters qualified to AEC-Q100 for automotive applications. These offer high reliability and low power consumption in a compact form factor. This makes them very suitable for applications like radars, cameras and sensors which can be used for assisted driving.

The growing demand for safety requires a higher number of subsystems and at the same time, it is necessary to decrease the component size and quantities to reduce vehicle weight. Secondary converters must generate safe low voltage supplies from the output of a primary DC/DC (such as Rohm's new BD9V100 device) with the highest possible efficiency and reliability. **Figure 1** and **Figure 2** shows a typical application and key features.

Key Features
The key, user friendly, features offered by this lineup of devices can be summarized as :

- Multiple safety functions
- Fixed Frequency operation
- Compact and Space Saving
- Broad Line-up
- High efficiency

Multiple safety functions
The BD9S series devices include a range of safety functions to protect the device, especially against external faults, and to ensure safe and successful operation in any application.

If the input voltage falls too low for safe operation the BD9S series will stop switching and RESET itself using a Under Voltage Lockout (UVLO) circuit. It always re-starts with a soft start, where the time can be set be external capacitor, to suit different system applications.

If the feedback voltage (which is derived from output voltage by the resistor divider) falls below a threshold for long enough, the BD9S series will stop operation and then restart. This Short Circuit Protection (SCP) is intended



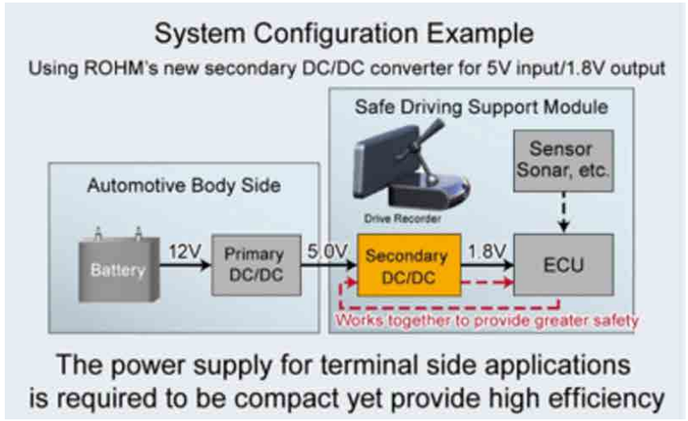


Figure 1: Example System Configuration

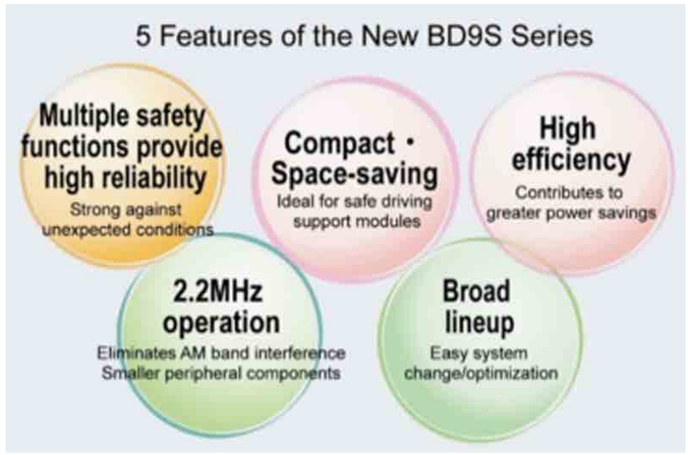


Figure 2: Key Features of BD9S Series

to protect against temporary external shorts.

To minimize the output voltage overshoot when recovering from strong load transients or external fault conditions, the BD9S series includes an Over Voltage Protection (OVP) which monitors the feedback voltage and will turn OFF the output MOSFET.

To protect the high side MOSFET, and to avoid saturating the inductor (which would reduce the efficiency), the Over Current Protection (OCP) circuit limits the current every cycle.

For any power management device handling high currents over heating can be a risk. A Thermal Shutdown (TSD) circuit will disable the BD9S series if the junction temperature is too high. The BD9S series will restart automatically when the temperature falls.

When a fault (UVLO, SCP, OCP or TSD) occurs or the device is disabled, the BD9S series will stop supplying current. To ensure the output voltage discharges quickly, so that any connected device will RESET correctly, there is an integrated output voltage discharge switch.

Fixed (2.2MHz) Frequency Operation

The BD9S series switches at a fixed 2.2MHz frequency (tested and set during manufacturing), to reduce the size of the external components and prevent interference in the AM radio band.

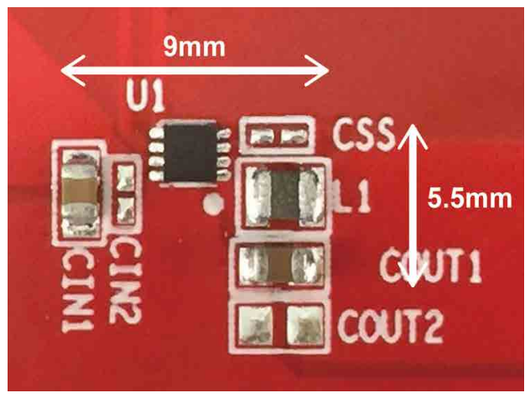


Figure 3 : PCB footprint of BD9S11x with essential components

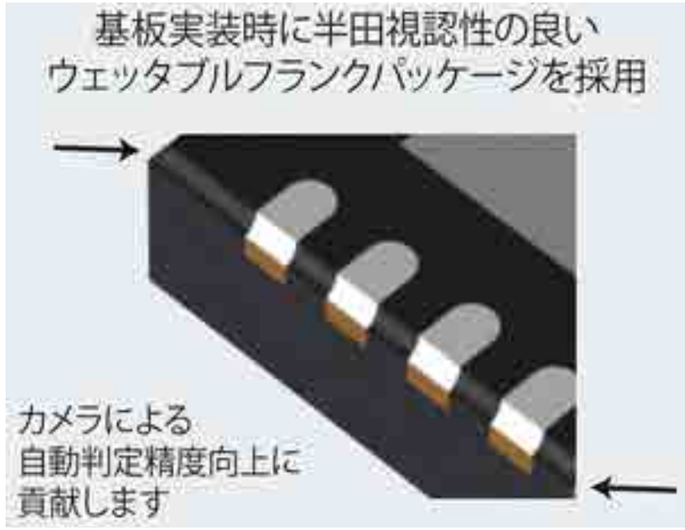


Figure 4 : Structure of 'Wettable Flank' pins

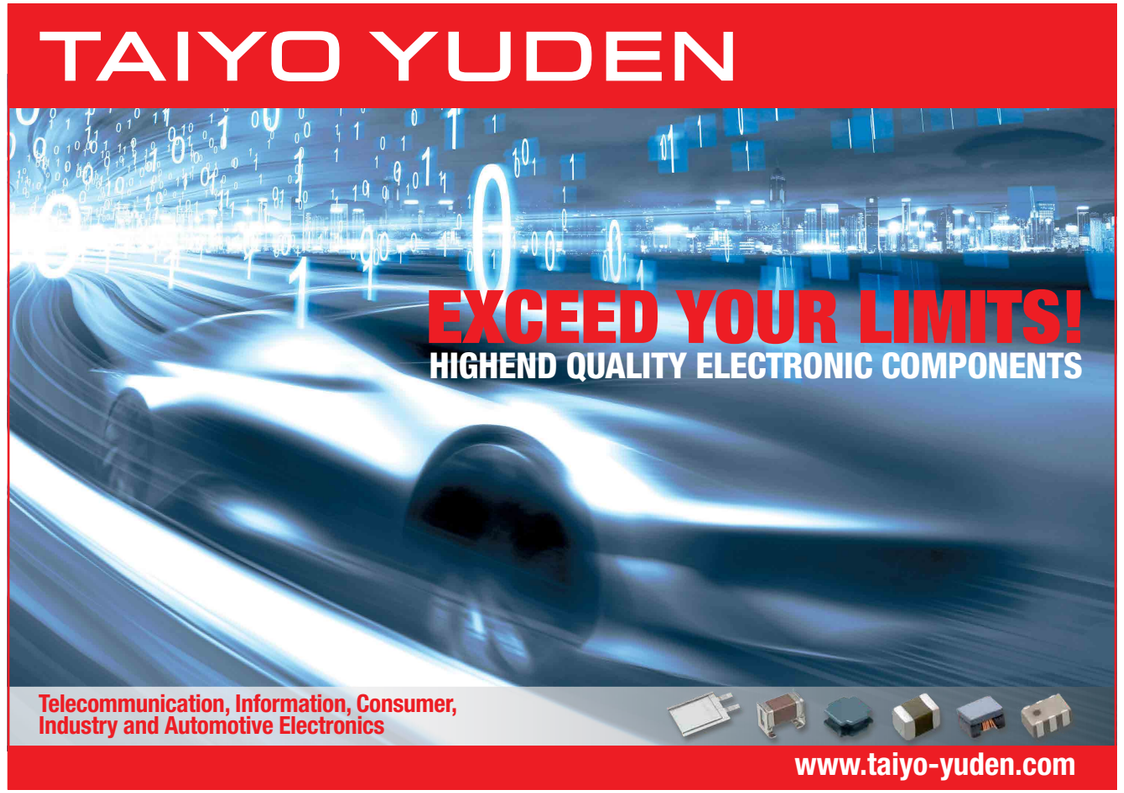
Board Space ('footprint') Reduction

In many applications PCB space is extremely limited. The BD9S series switches at a high enough frequency to reduce the size of the external components and integrates the output power switches and compensation network to reduce the required 'footprint' to a compact 9mm x 5.5mm area (see **figure 3**) making it very competitive.

Rohm can also offer a 3mm square VQFN package with 'wettable flanks' (see **figure 4**), significantly improving visibility during solder mounting, which is a known quality issue with conventional QFN packages.

High Efficiency

For DC/DC converters efficiency is critical both to reduce power consumption but also to avoid over heating of the device itself. The BD9S series achieves 90% efficiency (depending on operating conditions) see **graph 1**, using a current control loop to



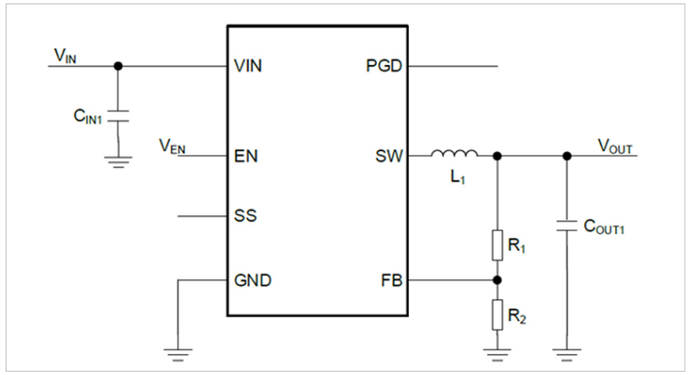


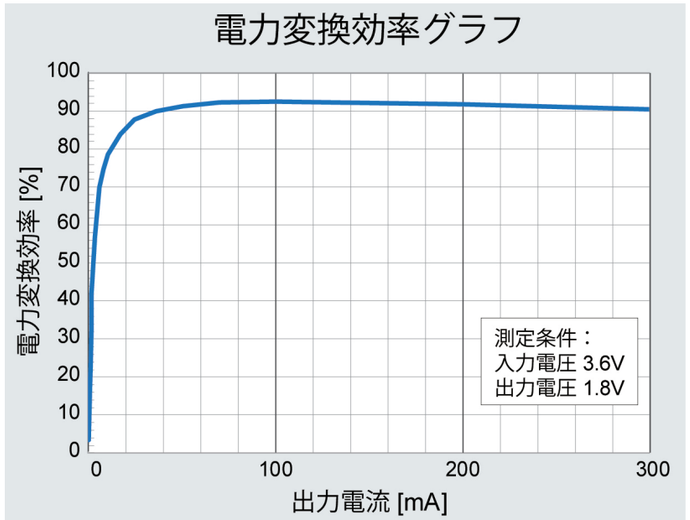
Figure 5 : Example Application Schematic of a BD9S11x

ensure rapid response to changes in the load.

The heat generated will depend upon input voltage, output voltage and load currents. For all DC/DC converters, the efficiency is reduced at lower load currents. The packages used in BD9S series include exposed heat sink to maximize heat dissipation. The practical thermal dissipation will depend upon many factors, such as the ambient air temperature and the PCB layout. A larger ground plane connected to the exposed heat sink will help to dissipate more thermal energy.

Broad lineup

To fulfil a range of applications and provide flexibility, the BD9S series has been implemented as a range of devices covering different output voltages (either programmed during production or set by external resistive network) with maximum output current from 0.6 to 4A in two different ultra-compact packages: VQFN16FV3030 (3.0 x 3.0 x 1.0mm) and VSON008X2020 (2.0 x 2.0 x 0.6mm). These packages are leadless with wettable flanks. The suffix 'xxx' indicates the derivative.



Graph 1 : Power Conversion Efficiency vs Output Current

Other Features

The BD9S series has an enable pin to reduce current consumption. After enable, the device always starts using a soft start where the duration is set by external capacitor.

There is a Power Good open drain output to indicate when the feedback voltage reaches the target. The open drain output allows connection to different power rails using a pullup resistor so it can act as a RESET signal for other devices.

Application

Rohm's has designed the BD9S series devices to be easy to use in any automotive application, with a minimum BoM to reduce PCB area and save costs. See typical application diagram of the BD9S11x (**figure 3**). The correct method to select these components is carefully described in the datasheet, and an application note is under preparation.

ROHM Semiconductor, GmbH
www.rohm.com/eu

Enhancing EV ecosystems through efficient power conversion

Efficiency, ruggedness & adaptability of SiC devices will give them a part in innovation robust, efficient EV ecosystem.

By: Anup Bhalla, VP Engineering and Zhongda Li, NPI Manager at UnitedSiC



Today's hybrid and fully electric vehicles (EVs) are still in the early stages of the iterative process of innovation. Several generations of hybrid vehicles have been introduced to market and improved through a combination of technology advances and user feedback. A number of vendors now market competent EVs and although their ranges are limited, the reviews now tend to focus on when they'll catch up with fossil-fuel cars, not whether or not they can. Analysts are now forecasting that perhaps 25 percent of all vehicles will be electrified by 2025, and that there could be up to a quarter of a billion EVs in use by 2040 (see **Figure 1**).

What's interesting about the current EV market is that the development focus is largely upon the vehicles themselves, and to some extent their charging networks. But a successful EV ecosystem, with the credibility and robustness to supplant our century-long fossil-fuel habit, will demand systemic thinking

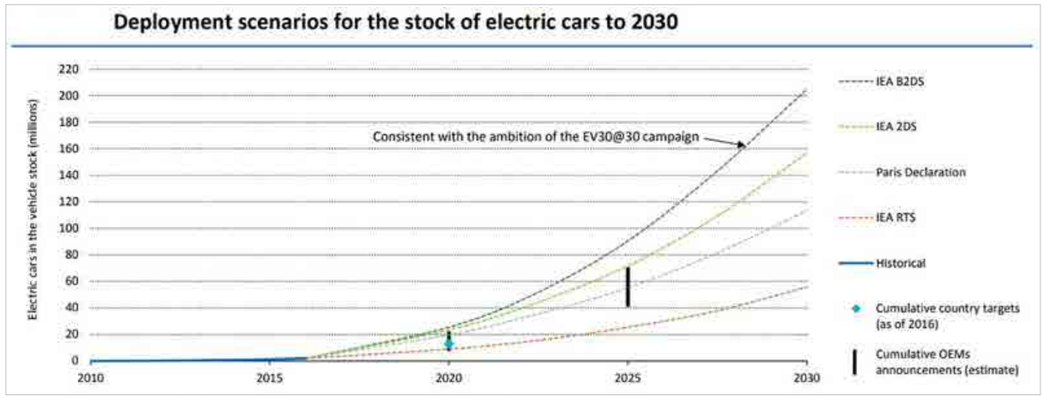


Figure 1: Electric vehicle predictions (source: International Energy Agency)

and constant optimizations at, and between, every level of that ecosystem. Many of these optimizations will be enabled by a shift to more efficient power-conversion electronics, which will offer wide-ranging benefits.

More efficient vehicle electronics

The most obvious application for this technology is in vehicle electronics. Many EVs are being designed with well-established silicon IGBTs and switching devices, sometimes even in discrete packages rather than the module format that has become popular for standard sub-circuits. There are lots of these devices in today's EVs – perhaps up to 66 of them in a single Tesla vehicle – providing the powertrain inverter, and power switches for on-board battery chargers, inductive charging converters and auxiliary converters for driving legacy 12 V vehicle systems.

Using discrete IGBTs gives certainty, at the cost of excess circuit complexity and the loss of potential efficiency gains that could be made from moving to a more modern switch such as wide band-gap silicon carbide (SiC) devices.

Finding the sweet spot

Taking on a new technology such as SiC switches means making a systemic tradeoff between their performance advantages, the inevitable price differential with established technologies, and the cost savings made possible by the new device's characteristics.

For example, as EV battery voltages rise to 800 V, designers may introduce SiC diodes and MOSFETs. If they push the switching frequencies of these devices to their theoretical maximums, the resultant circuits may be up to five times smaller and lighter than silicon alternatives, at the cost of higher switching losses at these high operating frequencies. Backing off the switching frequencies to around 50 kHz, and using the SiC devices in cascode arrangements, could deliver both a switching efficiency gain and enable the use of fewer, smaller components than an equivalent conventional silicon design.

The systemic optimization opportunity here is to consider all the gains possible from shifting to a device technology that is initially slightly more expensive, but which is expected to rapidly descend the price learning curve.

The greater efficiency of SiC devices at reasonable switching speeds will reduce the size of the supporting inductors, transformers, capacitors and other passive components, as well as their related heatsinks, relative to those used in a high-power IGBT automotive drive. This could mean, for example, a shift from using bobbin-wound inductors with fly leads that have to be hand-soldered onto circuit boards for the IGBT-based circuits, to small planar inductors, with windings formed from stamped metal or PCB traces, that can be surface-mounted for the SIC-based approach.

The extra cost of one type of component will soon absorbed by lower-cost manufacturing, smaller circuit sizes, greater reliability and repeatability of the resultant circuits, and so on. Moving the SiC parts from discrete packages into modules will create opportunities for further economies, in terms of lower mechanical and electrical connection costs and simplified cooling schemes.

More efficient chargers

Another place where more efficient devices can create opportunities for systemic optimizations is in charging circuits. Charging EV batteries from the mains means having to make an efficient conversion between AC and DC. This demands the use of complex conversion-circuit topologies and power-factor correction (PFC) techniques to enable the most effective transfer of energy to the battery.

One way to achieve PFC is to put 50 Hz or 60 Hz inductors in series with the power converters, at the cost of increased losses and larger circuit boards. An alternative is to use an active switching circuit that takes a rectified mains voltage and boosts it to a fixed DC level, while controlling the line current to be sinusoidal. This basic approach can lead to losses at high power because the ¬circuit topology puts

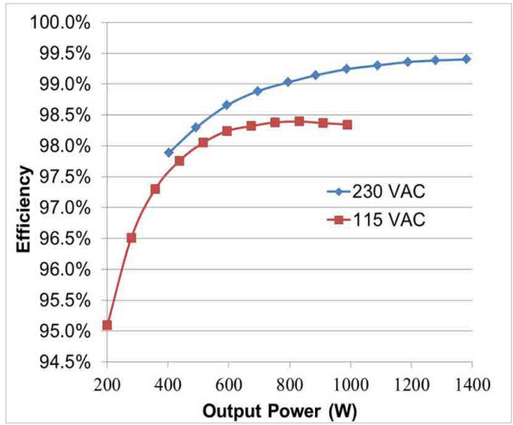


Figure 2: Using SiC cascodes to achieve high power conversion efficiencies

three diodes into the current path, each of which dissipates energy.

Replacing these diodes with silicon MOSFETs can reduce conduction losses, and further efficiency gains can be made by swapping out other diodes in the circuit topology for synchronous switches.

As ever in circuit design, though, there are further trade-offs to be managed. The MOSFETs have inherent body diodes, which can act as a rectifier during certain phases of the power conversion cycle and end up conducting the full output current. When the device is reverse-biased by the next phase of the switching cycle, a large reverse-recovery current flows, causing power dissipation and electromagnetic interference that cancels the efficiency gains made by replacing the original diodes.

The next optimization is to shift to SiC MOSFETs, which have low channel-conduction losses, operate at high speeds, and have a fast body diode. However, the forward voltage of the body diode can be 2.5 – 3 V, leading to high conduction losses.

One way around many of these issues is to use the SIC devices in a cascode arrangement, in which a high-voltage SiC JFET is coupled with a high-performance, low-voltage Si MOSFET in one package. The resultant device has low switching losses, due to its extremely low input, output and Miller capacitances and stored energy ratings. In addition, the body diode voltage drop is 1.5-2V,leading to lower conduction losses.

All these tradeoffs and more go into applying SiC cascodes in power-conversion circuitry. The systemic optimization question, though, is how good the SiC cascodes are in an onboard electric vehicle charger?

One way of assessing this is to see whether a SiC converter can meet the 80PLUS Titanium power-supply efficiency standard, which says it must exceed 96 percent efficiency at high line and half load. Meeting the standard demands that, if the mains-conversion stage is to achieve 97.5 percent efficiency, the PFC stage must exceed an efficiency of 98.5 percent. UnitedSiC makes a 1.5 kW demo board, using UJC06505K SiC cascodes switching at 100 kHz, which achieves this requirement with some margin (see **Figure 2**).

The EV ecosystem optimisation opportunity

SiC devices, on their own or in hybrid cascode modules, can increase the efficiency of individual aspects of today EV ecosystem, such as in-vehicle electronics or charging circuitry. Once all these efficiency gains have been made, there will be other opportunities for systemic optimizations within the EV ecosystem.

For example, the uptake of EVs will create a large estate of highly distributed energy-storage units (i.e. the vehicle batteries) which could be used to sink, as well as source, energy. If EV owners can be persuaded to allow their vehicle's batteries to be used in this way, perhaps nuclear power stations will be able to use them to absorb the energy they have to generate overnight at their base loading, which might otherwise go to waste. And perhaps grid operators will find more efficient ways to distribute energy by drawing on these localized energy stores, rather than having to install extra capacity just to service peak loads.

UnitedSiC
https://unitedsic.com/

An Alternative to the Alternator

The case for replacing alternators with DC-DC converters in road transport

By: Frank Vondenhoff, eMobility/HEV, Bel Power Solutions

With innovative manufacturers developing and expanding their range of solutions, engineers have more reasons than ever to replace alternators with DC-DC converters in road transport applications.

Today's eMobility and hybrid and electric vehicle manufacturers emphasize the efficiency, reliability and practical advantages of a DC-DC converter over an alternator – not just in powering DC auxiliary components but in battery charging. To meet every engineering need, these products are available in a wide variety of standard configurations and, importantly, there is no limit to the scope for custom modifications.

Many global manufacturers have committed to the electrification of transport by establishing specialized eMobility units within their businesses (Bel Power Solutions, Eaton, etc.) by focusing on creating and improving industrial EV power components. Technology design centres are currently located throughout the world and in many countries throughout Europe, Asia and the United States, which cover the whole spectrum of electric and hybrid vehicle types, sizes and power levels.



Figure 1: The Bel Power Solutions 350DNC40 is a 4 kW DC/DC Converter that creates DC voltages in hybrid and electric vehicles suitable to power low voltage accessories. Features include very high efficiency, high reliability, low output voltage noise and excellent dynamic response to load/input changes.

As well as road-going buses, trucks and all kinds of cars, from taxis to luxury sports models and even ground support equipment and heavy construction vehicles, DC-DC converters can be used in every form of off-road and workplace transport. That includes construction equipment, airport ground support vehicles and the marine sector. The list is endless, embracing such unusual fields as rollercoaster operation.

Why DC-DC conversion is superior

The benefits of DC-DC converters, compared to alternators, stem largely from the fact that they draw power directly from an HV battery pack rather than from the rotation of an engine or motor. Not only is this more efficient, but it dispenses with the need for various moving parts, like belts and pulleys, and so reduces maintenance needs and potential sources of failure. A DC-DC converter also scores more highly in terms of reliably regulating an output voltage.

On top of these inherent advantages, technology leaders within eMobility have used their expertise in this vertical market to build superior design, specification and support into their DC-DC converters, offering to maximize the positive effect on customers' businesses. By incorporating the latest advances in CAN communication and other technologies, the products are reliable with high performance – and each can be customized for specific applications and requirements. Furthermore, prices are increasingly competitive, with shorter lead times, and are backed by excellent customer service, expert technical advice and engineering support.

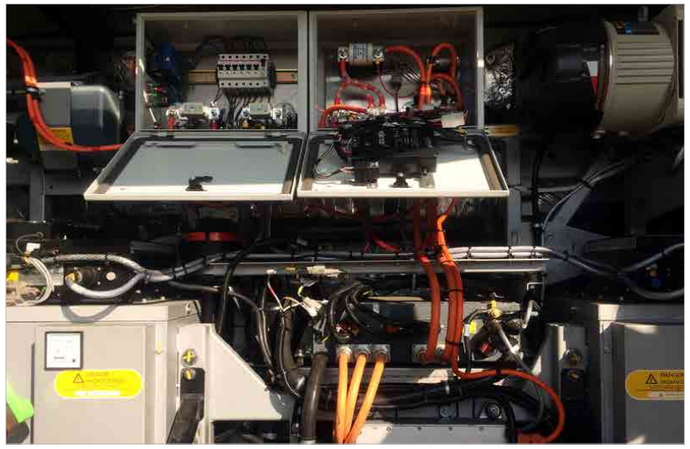


Figure 2: For an electric bus in Europe, Bel Power Solutions was selected to power all the auxiliary DC peripherals, as our product had the right current to power it. It turned out to be so successful that this unit is now being used in a fully electric double deck bus.

For example, Bel Power Solutions has both liquid cooled 350/700 DNC40-12/24-8G and convection cooled 350/700 DNC40-12/24-CG models. These down-converters deliver up to 4 kW of power when liquid cooled or 3.3 kW with convection cooling. Depending on the model chosen, they handle input voltages ranging from 240 to 850 VDC.

Along with very high efficiency – typically up to 93% – users can expect robust, highly dependable performance, low output voltage noise and excellent dynamic response to changes in load or input. Nominal output voltage is either 14.4 V or 28 V, but this is adjustable as required via CAN bus. Input and output are fully isolated, galvanically, from each other. Communication and control are optimised via a CAN bus serial interface according to SAE J1939.

There is a choice of liquid or convection cooling. Liquid cooled models have an operating temperature range between -40° and +85°C. For those with convection cooling, the range is -40° to +45°C. In addition to over-temperature, output over-voltage and over-current protection, each model is protected in relation to input and output polarity. Ingress protection is rated at IP65 and IP67, and there is also the confidence of E-mark compliance.

Customization can be key

While the varying standardized specifications have been designed to cater for most situations, today's manufacturers understand that every customer's needs are unique and their engineering teams welcome requests for modified solutions. Output voltage is just one of the factors which can be tailored to precise requirements, but there are many more possibilities. Customers are strongly encouraged to ask about these services when doing their research.

For example, Zurich Airport has implemented a DC-DC converter to enhance the supply of auxiliary power while airplanes are being serviced at the gate. Previously, a ground support vehicle carried a diesel generator to charge the planes' auxiliary power units. The generator has now been replaced by a 300 VDC battery pack and a DC-DC converter, for cleaner and more convenient charging.

At its simplest, a DC-DC

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converter is an easy way of supplying DC power at the right voltage to things like dashboard instruments, lights, radios and other low-powered accessories. More unusually, one eMobility manufacturer was asked to provide DC-DC products for a roller coaster project in which power needed to be maintained in 20 carts.

Electrifying trends

Electric and hybrid manufacturers anticipate growing demand for DC-DC converter solutions as the electrification trend continues and customers seek to optimise their conversions. Major drivers of change include consumer interest in sustainability, business recognition of electric cost-effectiveness and legislators' increasingly strict emission limits.

Current EU regulations are pushing many cities into replacing highly polluting diesel buses and even petrol-powered vehicles with clean electric alternatives. By 2025, it is likely that the switch to fully electric buses will be complete in many city centres.

For the logistics industry, urban emission restrictions and extra congestion charges are not the only reason for moving toward electric power. Businesses in that efficiency- and reputation-conscious industry are increasingly attracted by the cost-cutting potential and PR rewards it offers.

After buses and trucks, the next-largest growth area for eMobility is large off-road vehicles as used in military operations and in the mining and construction industry. Then there is the marine market, including ferries and pleasure boats. It is expected, for instance, that within the next few years all canal boats in Amsterdam will be electric powered.

Time to change

It has taken a relatively short time for electric cars and industrial EVs to grow from a very small interest area into one with a significant market presence. Now that the trend has achieved real momentum, it is time for more businesses to get on-board and start electrifying their vehicles.

With its advanced technology and deep knowledge in this area, Bel Power Solutions is ideally placed to help customers replace their alternators with efficient, reliable DC-DC converters. Better still, Bel Power will work with companies to ensure the right model choice – and modify its specification, if necessary, for a perfect fit with the application. Whatever new electric power demands an industry faces, Bel Power is ready to tackle those challenges and provide customers with the ideal solution.

Bel Power Solutions & Protection
www.belfuse.com/power-solutions

Simple Battery Charger ICs for Any Chemistry

Battery-powered devices to require a wide variety of charging sources

By: Steve Knoth, Senior Product Marketing Engineer, Power by Linear Products, Analog Devices

It is common for many battery-powered devices to require a wide variety of charging sources, battery chemistries, voltages and currents. For example, industrial, high-end feature-rich consumer, medical and automotive battery charger circuits demand higher voltages and currents as newer large-battery packs are emerging for all types of battery chemistries. Furthermore, solar panels with wide-ranging power levels are being used to power a variety of innovative systems containing rechargeable sealed lead acid (SLA) and Lithium-based batteries. Examples include crosswalk marker lights to portable speaker systems to trash compactors and even to marine buoy lights. Moreover, some lead acid batteries found in solar applications are deep cycle batteries, capable of surviving prolonged, repeated charge cycles, in addition to deep discharges. A good example of this is in deep sea marine buoys, where a 10-year deployment life is a pre-requisite. Another example is "off grid" (i.e. disconnected from the electric utility company) renewable energy systems such as solar or wind power generation, where system up-time is paramount due to proximity access difficulties.

Even in non-solar applications, recent market trends imply a renewed interest in high capacity SLA battery cells. Automotive or "starting" SLA cells are inexpensive from a cost/power output perspective and can deliver high pulse currents for short durations, making them an excellent choice for automotive and other vehicle starter applications. Embedded automotive applications have input voltages >30V, with some even higher. Consider a GPS location system used as an anti-theft deterrent; a linear charger with the typical 12V input stepping down to 2-in-series Li-Ion battery (7.4V typical) and needing protection to much higher voltages, could be valuable for these applications. Deep cycle lead-acid batteries are another technology popular in industrial applications. They have thicker plates than automotive batteries and are designed to be discharged to as low as 20% of their total capacity. They are normally used where power is required over a longer time constant such as fork lifts and golf carts. Nevertheless, like its Li-Ion counterpart, lead-acid batteries are sensitive to overcharging, so careful treatment during the charging cycle is very important.

Current integrated circuit (IC)-based solutions cover just a fraction of the many possible combinations of input voltage, charge voltage and charge current. A cumbersome combination of ICs and discrete components has routinely been used to cover most of the remaining, more difficult combinations and topologies. That wasn't until, in 2011, when Analog Devices addressed and simplified this market application space with its popular 2-chip charging solution consisting of the LTC4000 battery charging controller IC mated with a compatible externally compensated DC/DC converter.

Switching vs Linear Chargers

Traditional linear topology battery charger ICs were often valued for their compact footprints, simplicity and low cost. However, drawbacks of these linear chargers include a limited input and battery voltage range, higher relative current consumption, excessive power dissipation, limited charge termination algorithms and lower

relative efficiency (efficiency ~ [VOUT/VIN] * 100%). On the other hand, switch mode battery chargers are also popular choices due to their flexible topology, multi-chemistry charging, high charging efficiencies (which minimize heat to enable fast charge times) and wide operating voltage ranges. Nevertheless, some of the drawbacks of switching chargers include relatively high cost, more complicated inductor-based designs, potential noise generation and larger footprint solutions. Modern lead acid (LA), wireless power, energy harvesting, solar charging, remote sensor and embedded automotive applications have been routinely powered by high voltage linear battery chargers for the reasons stated above; however, an opportunity exists for a more modern switchmode charger that negates the associated drawbacks.

An Uncomplicated "Buck" Battery Charger

Some of the tougher challenges a designer faces at the outset of a charging solution are the wide range of input sources combined with a wide range of possible batteries, the high capacity of the batteries needing to be charged, and a high input voltage.

Input sources are as wide as they are variable but some of the more complicated ones that deal with battery charging systems are: high powered wall adapters with voltages spanning from 5V to 19V and beyond, rectified 24VAC systems, high-impedance solar panels, car and heavy truck/Humvee batteries. Therefore, it follows that the combination of battery chemistries possible in these systems, Lithium based (Li-Ion, Li-Polymer, LiFePO4), and lead-acid based – increases the permutations even more, thus making the design even more daunting.

Due to IC design complexity, existing battery charging ICs are primarily limited to step-down (or buck) or the more complex SEPIC topologies. Add solar charging capability to this mix and you open a variety of other complexities. Finally, some existing solutions charge multiple battery chemistries – some with onboard termination; however, up until now no single-IC charger has provided all of the necessary performance features to solve these issues.

New, Feature-Rich Compact Chargers

A buck IC charging solution that solves the problems discussed above would need to possess most of the following attributes:

- Wide input voltage range
- Wide output voltage range to address multiple battery stacks
- Flexibility - ability to charge multiple battery chemistries
- Simple and autonomous operation with onboard charge termination algorithms (no µP needed)
- High charge current for fast-charging large, high-capacity cells
- Solar charging capability
- Advanced packaging for improved thermal performance and space efficiency

When ADI developed the popular LTC4000 battery charging controller IC (which works in conjunction with an externally compensated DC/DC converter to form a powerful and flexible 2-chip battery charging solution) a few years ago, it greatly simplified the existing solution which was quite convoluted and cumbersome. To enable PowerPathTM control, step-up/down functionality and input current limiting, solutions consisted of a buck-boost DC-DC switching regulator or a buck switching regulator charger controller paired with a front-end boost controller, a microprocessor plus several ICs and discrete components. Key drawbacks included limited operating voltage range, no solar panel input capability, inability to charge all battery chemistries, and no onboard charge termination. However, fast forward to the present and now some simpler, and much more compact monolithic solutions are available to solve these problems. The LTC4162 and LTC4015 buck battery chargers from Analog Devices both provide single-chip step-down charging solutions, with varying charge current levels and a full feature set.

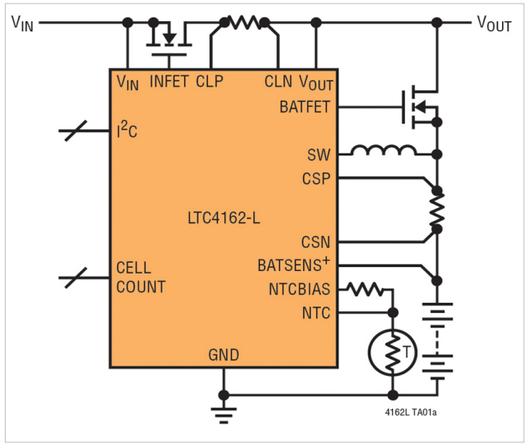


Figure 1. Typical Application Circuit for the LTC4162-L

The LTC4162 Battery Charger

The LTC4162 is a highly integrated, high voltage multi-chemistry synchronous monolithic step-down battery charger and PowerPath™ manager with onboard telemetry functions and optional maximum power point tracking (MPPT). It efficiently transfers power from a variety of input sources, such as wall adapters, backplanes and solar panels, to charge a Li-Ion/Polymer, LiFePO4 or lead acid battery stack while still providing power to the system load up to 35V. The device provides advanced system monitoring and PowerPath management, plus battery health monitoring. While a host microcontroller is required to access the most advanced features of the LTC4162, the use of the I2C port is optional. The main charging features of the product can be adjusted using pin-strap configurations and programming resistors. The device offers precision ±5% charge current regulation up to 3.2A, ±0.75% charge voltage regulation and operates over a 4.5V to 35V input voltage range. Applications include portable medical instruments, USB Power Delivery (USB-C) devices, military equipment, industrial handhelds, and ruggedized notebooks/tablet computers.

The LTC4162 (see **Figure 1**) contains an accurate 16-bit analog-to-digital converter (ADC) that continuously monitors numerous system parameters on command, including input voltage, input current, battery voltage, battery current, output voltage, battery temperature, die temperature and battery series resistance (BSR). All system parameters can be monitored via a two-wire I2C interface, while programmable and maskable alerts ensure that only the information of interest causes an interrupt. The device's active maximum power point tracking algorithm globally sweeps an input undervoltage control loop and selects an operating point to maximize power extraction from solar panels and other resistive sources. Further, it's built-in PowerPath topology decouples the output voltage from the battery, thereby allowing a portable product to start up instantly when a charging source is applied under very low battery voltage conditions. The LTC4162's onboard charging profiles are optimized for a variety of battery chemistries including Li-Ion/Polymer, lithium-iron phosphate (LiFePO4) and lead acid. Both charge voltage and charge current can be automatically adjusted based on battery temperature to comply with JEITA guidelines or be customized. For lead acid batteries a continuous temperature curve automatically adjusts the battery voltage based on the ambient temperature. For all chemistries, an optional die junction temperature regulation system can be engaged, preventing excess heating in space constrained or thermally challenged applications. See **Figure**

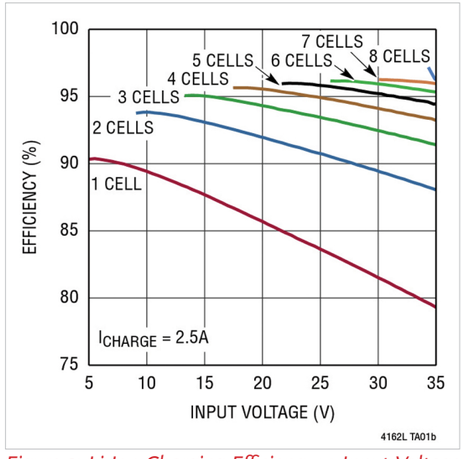


Figure 2: Li-Ion Charging Efficiency vs Input Voltage by Cell Count

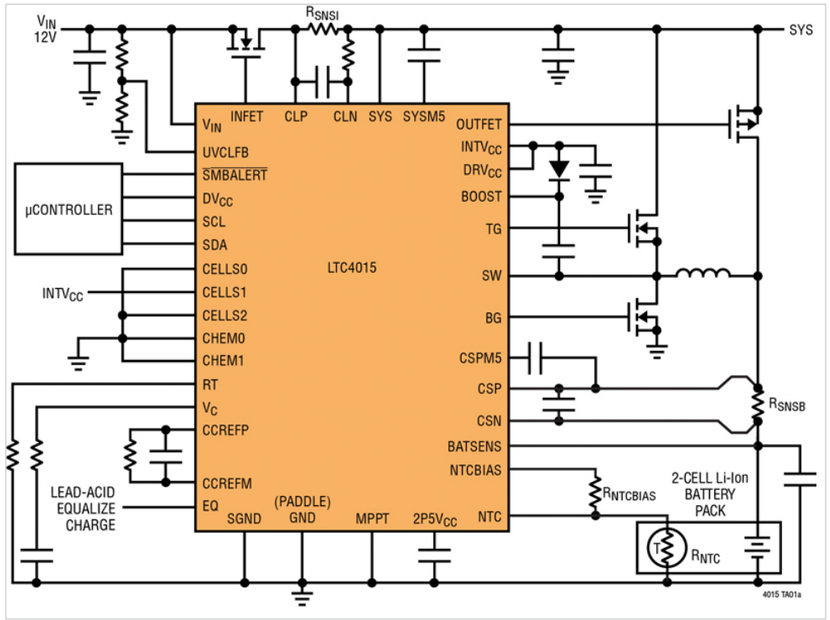


Figure 3: 12VIN to 2-Cell Li-Ion 8A Buck Battery Charger Circuit

2 for Li-Ion charging efficiency performance.

Finally, the LTC4162 is housed in a 28-lead, 4mm x 5mm QFN package with an exposed metal pad for excellent thermal performance. E- and I-grade devices are guaranteed for operation from –40C to 125C.

What if Higher Current Is Needed?

The LTC4015 is also a highly integrated, high voltage multi-chemistry synchronous step-down battery charger with onboard telemetry functions. However, it features a controller architecture with offboard power FETs for higher charge current capability (up to 20A+ depending on external components chosen). The device efficiently supplies power from an input source (wall adapter, solar panel etc.), to a Li-Ion/Polymer, $LiFePO_4$ or lead acid battery. It provides advanced system monitoring and management functionality, including battery coulomb counting and health monitoring. While a host microcontroller is required to access the most advanced features of the LTC4015, the use of its I2C port is optional. The main charging features of the product can be adjusted using pin-strap configurations and programming resistors.

The LTC4015 offers precision ±2% charge current regulation up to 20A, ±1.25% charge voltage regulation and operation over a 4.5V to 35V input voltage range. Applications include portable medical instruments, military equipment, battery back-up applications, industrial handhelds, industrial lighting, ruggedized notebooks/tablet computers, and remote powered communication and telemetry systems.

The LTC4015 also contains an accurate 14-bit analog-to-digital converter (ADC) as well as a high precision coulomb counter. The ADC continuously monitors numerous system parameters, including input voltage, input current, battery voltage, battery current and reports battery temperature and battery series resistance (BSR) on command. By monitoring these parameters, the LTC4015 can report on the state of health of the battery, as well as its state of charge. All system parameters can be monitored via a two-wire I^2C interface, while programmable and maskable alerts ensure that only the information of interest causes an interrupt. The LTC4015's onboard charging profiles are optimized for each of a variety of battery chemistries including Li-Ion/Polymer, $LiFePO_4$, and lead acid. Configuration pins allow the user to select between several predefined charge algorithms for each battery chemistry, as well as several algorithms whose parameters can be adjusted via I^2C. Both charge voltage and charge current can be

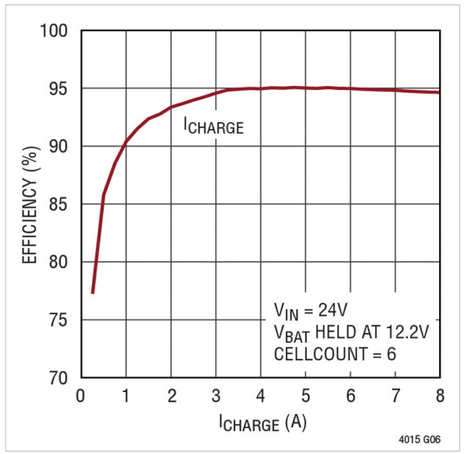


Figure 4: Lead Acid Charging Efficiency with the LTC4015

automatically adjusted based on battery temperature to comply with JEITA guidelines, or even custom settings. See **Figure 4** for lead acid charging efficiency performance.

The LTC4015 is housed in a 5mm x 7mm QFN package with an exposed metal pad for excellent thermal performance.

Space Savings, Flexibility, and Higher Power Levels

At equal power levels (for example, 3A), because it is a monolithic device with integrated power MOSFETs, the LTC4162 can save up to 50% of the PCB area compared to the LTC4015. Since their feature sets are similar, the LTC4015 should be used when output currents are >3.2A up to 20A or more. None of the industry competing IC battery charger solutions offer the same high level of integration, nor can they generate the same power levels. Those that approach the charge current (2-3A) are limited to only a single battery chemistry (Li-ion) or are limited in battery charge voltage (13V maximum), and therefore do not offer the power levels nor the flexibility of the LTC4162 or LTC4015. Furthermore, when you consider the number of external components required for the nearest competing monolithic battery charger solution, the LTC4162 offers up to 40% savings in PCB area footprint, making it an even more enticing choice for designs.

Solar Charging

There are many ways to operate a solar panel at its maximum power point (MPP). One of the simplest is to connect a battery to the solar panel through a diode. This technique relies on matching the maximum output voltage of the panel to the relatively narrow voltage range of the battery. When available power levels are very low (approximately less than a few tens of milliwatts), this may be the best approach. However, power levels are not always low. Therefore, the LTC4162 and LTC4015 utilize Maximum Power Point Tracking (MPPT), a technique that finds the maximum power voltage (VMP) of a solar panel as the amount of incident light changes. This voltage can change drastically from 12V to 18V as the panel current changes over 2 or more decades of dynamic range. The MPPT circuit algorithm finds and tracks the panel voltage value that delivers the maximum charge current to the battery. The MPPT function not only continuously tracks the maximum power point, it is able to select the correct maximum on the power curve to increase power harvested from the panel during partial shade conditions, when multiple peaks occur on the power curve. During periods of low light, a low power mode allows the charger to deliver a small charge current even if there is not enough light for the MPPT function to operate.

Conclusion

Analog Devices' newest powerful and full-featured battery charging and PowerPath manager ICs, the LTC4162 and LTC4015, simplify a very difficult high voltage and high current charging system. These devices efficiently manage power distribution between input sources such as wall adapters, backplanes, solar panels, etc., and the charging of various battery chemistries, including Lithium-Ion/polymer, Lithium Iron Phosphate ($LiFePO_4$) and sealed lead acid. Their simple solution and compact footprints enable them to achieve high performance in leading-edge applications where only more complicated older technology switching regulator-based topologies such as SEPIC were once the only option. This greatly simplifies the designer's task of medium-to-high power battery charger circuits.

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Surface-Mount Fuse Tech. Steps Up to EV Reliability Demands

The rapid emergence of (EV) and (HEV) underscore the necessity for highly reliable circuit protection

By Mike Roach, AEM Components (USA), Inc.

Electronic systems for automotive applications are subjected to among the harshest of environments – wide temperature variations, shock and vibration, exposure to humidity, water chemicals and salt. Traditionally, blade-type automotive fuses have provided the necessary fault protection, but as cars get "smart" and "connected," more and more embedded and distributed electronics have started to turn to pc board-mounted circuit protection. The rapid emergence of electric (EV) and hybrid electric vehicles (HEV) in particular, have underscored the necessity for highly reliable circuit protection to help protect against catastrophic failures and this has in turn placed increased emphasis on improving surface-mount fuse technology.

This article describes the common types of one-time, wire-in-air surface-mount fuses, and compares the alternative fuse structures for each type. It presents the results of comparison tests simulating real-world application scenarios to demonstrate the dramatically better performance offered by latest generation of these type surface-mount fuses.

Need for Surface-Mount Fuses

Historically, it is typically an industry's need for technology advances that ultimately drives adoption in a wide range of applications. For example, brighter, more-efficient and lighter displays – first developed by the television industry – now are integral part of consumer, commercial, industrial, military and aerospace applications. In a similar way, it would appear the demands of the automotive industry are driving advances in circuit protection technology.

Resettable devices are the ideal choice where overcurrent conditions are the result of a transitory fault condition, but in many applications, particularly where fault currents can result in serious damage to other circuits or systems, the traditional one-time fuse is still the best choice for protection. While traditional clip-mounted glass tube fuses are found in a host of applications and blade-type fuses are ubiquitous in automotive applications, the move toward smaller, distributed and embedded electronic functionality has elevated the demand for high-performance, space-saving surface-mount fuses. In a similar manner as chip inductors and multi-layer ceramic capacitors (MLCCs), surface-mount fuses are packaged in a variety of EIA standard sizes determined by the technology uses and the rating.

While other surface mount, solid body fuses exist, this article focuses primarily on higher voltage applications that would generally utilize surface mount, wire-in-air fuses. In addition, information related to etched fuses is also presented, as they have garnered interest due of their low cost and limited use of board real estate.

Wire-in-Air Fuses

Wire-in-Air fuses are typically found in higher operating current applications where fast-acting and superior arc-suppression are required. Applications include battery chargers, battery packs and circuits subject to very high fault currents and higher voltages. The common construction for this type of fuse has the fusible wire element housed inside a ceramic tube and connected to the endcaps with solder.

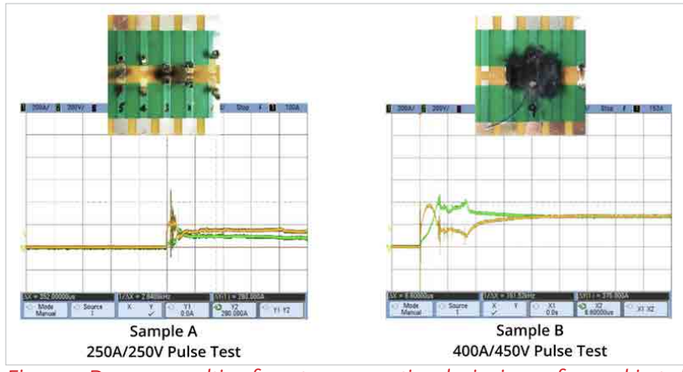


Figure 1: Damage resulting from two conventional wire-in-are fuses subjected to extreme overload conditions - simulating a catastrophic EV battery short circuit

There are several disadvantages associated with these conventional ceramic wire-in-air fuses. Endcap detachment can be a common failure mode in the conventional construction. In addition, here is also a lack of uniformity in performance due to the variability in the placement of the wire element inside the ceramic tube. Even worse is the fact that under worst case, high current-fault conditions, the solder in the ceramic tube can vaporize and build up pressure to the point where the fuse explodes. If this happens, solder is redeposited across the trace, which can result in a secondary conductive path with potentially serious consequences.

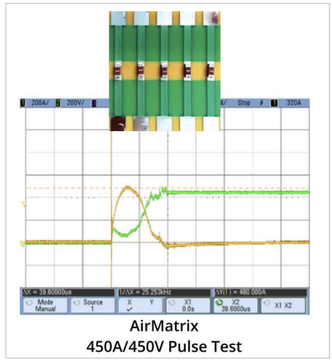


Figure 2: AirMatrix fuse sustains no damage after being subjected to extreme overload conditions – simulating a catastrophic EV battery short circuit

In comparison, the fuse element of advanced AirMatrix wire-in-air fuses use a proprietary, hermetically-sealed structure that assures repeatable and consistent electrical performance. The AirMatrix's fuse element is uniformly straight across the cavity and externally bonded to the endcap. Unlike the conventional square nano type fuse, with its ceramic body and solder connect design, the AirMatrix fuse uses a fiberglass-enforced body and solderless direct connect construction.

Figure 1 shows two conventional wire-in-air fuses subjected to an EV short circuit condition. Sample A at 250V/250A (left image) and Sample B at 450V/450A exhibited significant damage to the fuse and collateral damage to the surrounding circuitry. In the waveforms, the current flow (yellow trace) through the fuses each display secondary arcing that ultimately resulted in pc board damage.

When subjected to the same EV battery short circuit conditions as the square nano tube fuses, the AirMatrix fuse's advanced construction withstood 450V/450A conditions without experiencing any external damage (**Figure 2**). Note how in the waveforms, the current flow (yellow trace) through the AirMatrix fuse drops to zero, with no secondary conduction and the voltage potential across the fuse (green trace) shows an open circuit.

Etched Fuses

One other approach being given consideration as an option for circuit protection in BMS sensing lines is etched fuses on flexible printed circuit boards. Given the lack of board space needed for these fuses and their comparative low cost, it is easy to see why they would be attractive, but a lack in consistency in response time from fuse to fuse, and their open-air construction, can present a considerably safety risk, especially in worst case overload conditions.

To determine the suitability of etched fuse technology for this highly demanding automotive application, samples of a 1 amp



Figure 3: All etched fuse samples exhibited some degree of overheating, burning or fire after being subjected to overload conditions, whereas all the AirMatrix fuse samples passed the overload conditions with no external damage or damage or indication of overheating

etched fuse and 1 amp advanced wire-in-air AirMatrix fuse were subjected to overload test conditions of between 7 & 50 amps and 50 & 125 Vdc and monitored closely throughout the test for performance.

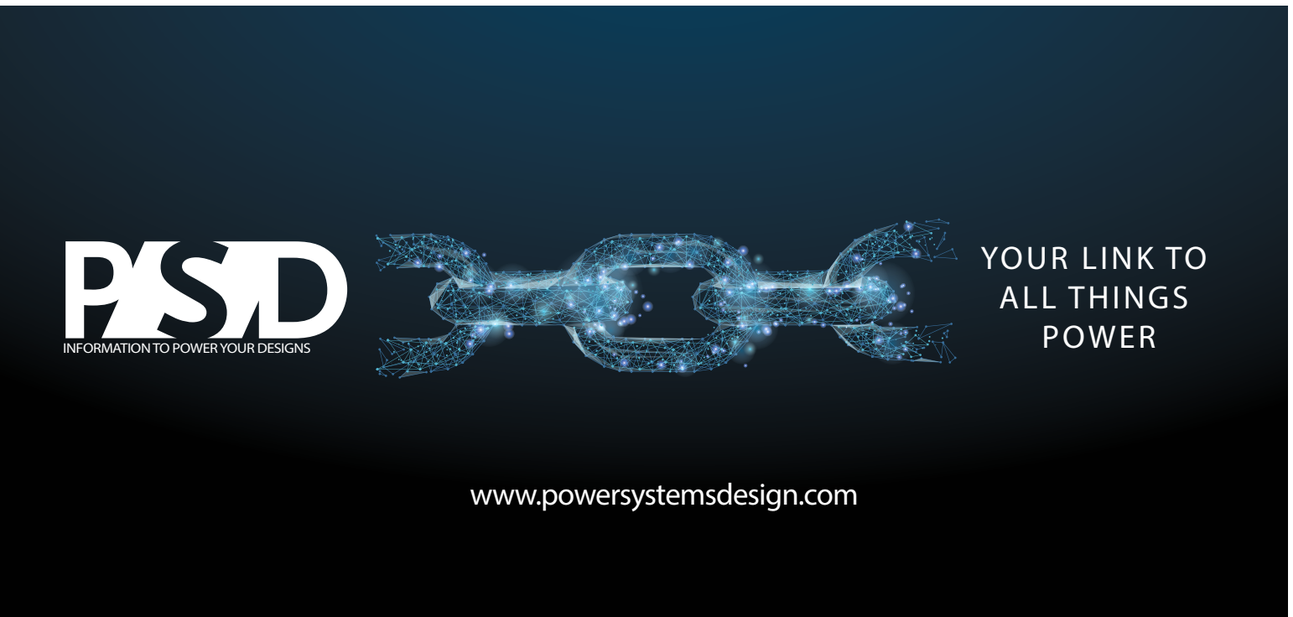
In all cases, the etched fuse exhibited some degree of overheating, with the degree of damage being further pronounced at more extreme conditions. At higher current values, the amount of energy present was sufficient enough to cause combustion.

As with earlier testing performed on the AirMatrix fuses, these samples exhibited no external damage and no evidence of overheating, while maintaining their mechanical integrity, even at the highest test level of 50 amps and 125 Vdc. (See **Figure 3**)

Meeting Automotive Standards for Performance and Safety

As demonstrated by reliability testing, new structures being utilized in both solid body and wire-in-air surface-mount fuses offer significant advantages in performance and safety over the more traditional fuse approaches. The SolidMatrix multi-layer ceramic chip fuse and the AirMatrix wire-in-air fuse are specifically designed to help automotive applications engineers qualify their devices for the AEC-Q200 automotive standard. These advanced surface-mount fuses are manufactured in a IATF16949-certified facility and are specifically designed for reliable performance in highly demanding automotive applications.

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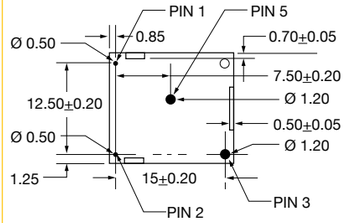


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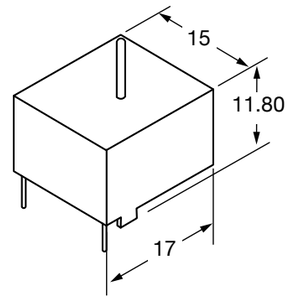
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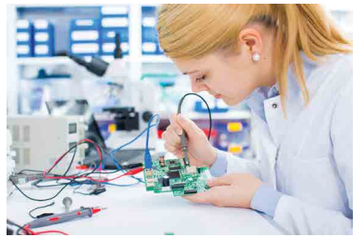
The advanced CST25 Series is designed with a unique built-in sensing winding feature. This capability allows the versatile CST25 Current Sense Transformer to be installed directly on the printed circuit board without any additional wires or jumpers.



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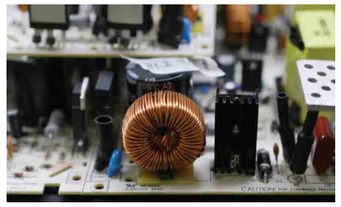


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info@holystonecaps.com www.holystonecaps.com

Holy Stone (Europe) Limited
Henderson Business Centre, Unit 32 & 33
Ivy Road, Norwich, NR5 8BF, United Kingdom
Tel: +44-1603-251780 Fax: +44-1603-251785
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New Test Equipment May Not Need a High Outlay

By: Ally Winning, European Editor, PSD

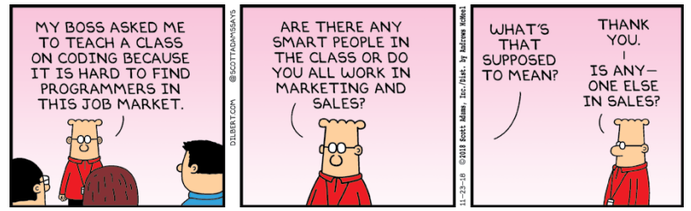
Innovation comes in many shapes and forms. Mostly when we think of innovation, we think of component specifications, or unique ways to use components in a new product. But, sometimes innovation comes in other forms, such as business practices. I was reminded of that a few weeks ago when I attended an event hosted by Microlease, a company that rents our test equipment. The event was held to announce that Microlease had signed an agreement to stock Fluke's thermal imaging equipment for rental. Although the partnership was interesting itself, it set me thinking about the value of leasing.

Test equipment is ideal for leasing for a number of reasons. For instance, the latest equipment can get very expensive to purchase outright, especially equipment intended for testing the latest wireless technologies, such as 5G telecommunications, which can cost up to $500k. If the equipment is used in a production line, it may be in use pretty much all of the time, but if it is intended for prototyping or individual projects, it may be see much less use and provide lower overall value for money. It may be difficult to get a company to loosen the purse strings for a piece of equipment that sits on the shelf for much of the time, even more so as test is often looked at as not adding direct value to the product. Every company tries to cut down on non-essential externalities whenever possible.

At first look, this may not seem to affect power designers directly, as power design doesn't really need the same ultra-expensive equipment as communications applications, but this is changing. Power designs now have much higher switching speeds and today's products require much higher tolerances. Specifications, such as slew rates and ramp-up sequences need to be very tightly controlled and this requires more accurate measurement from a higher standard of equipment than has previously been available to designers. Also, more and more customers involved in mission-critical designs are seeking assurance from suppliers that the components they buy will behave exactly as they require, meaning each individual component needs proven and certified before dispatch.

Extra testing requires extra equipment, and in these times where the bottom line is more important than ever, an outright purchase may not be the ideal way to acquire equipment, especially if the equipment is only needed to certify a batch of products for a single customer. Renting could be better than buying for jobs like these and allow the cost of test equipment to be accurately quoted in the initial job estimate. In some cases, engineers may be required to wait to a new financial year before new capital purchases, but leasing could allow them to start the job before the current year finishes. Leasing may not be the ideal solution for every company, but it is nice to know there could be another option available, and the more options the better for everyone.

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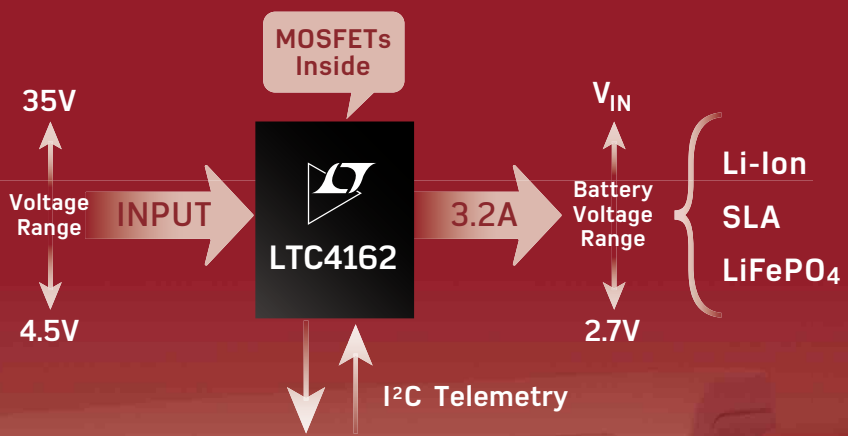
EASY TO USE MULTI-CHEMISTRY CHARGER

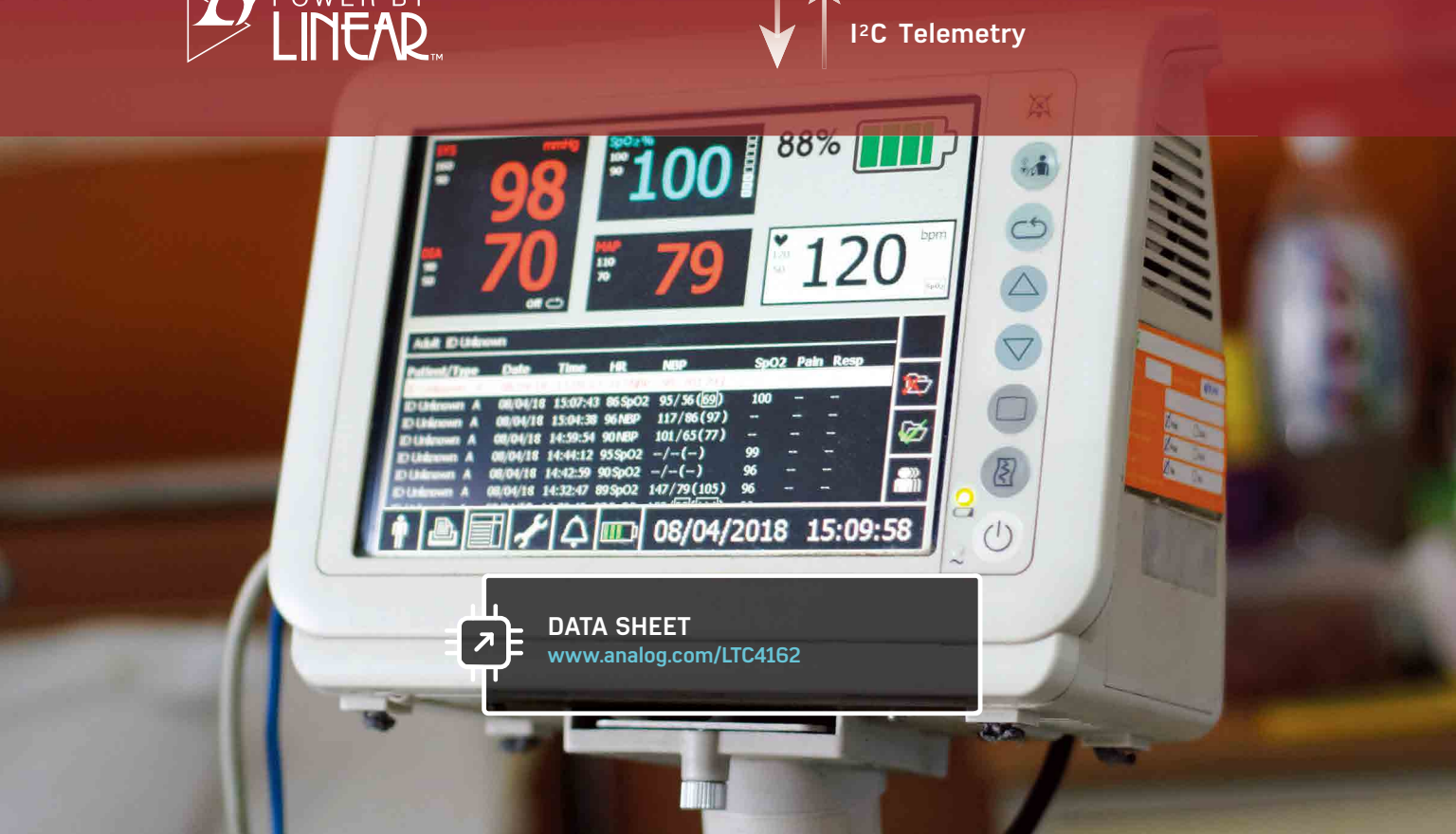
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35V/3.2A MULTI-CELL STEP-DOWN BATTERY CHARGER

- Built-in Termination
- Wide Charging Input Voltage Range: 4.5V to 35V
- 95% Charging Efficiency
- Advanced Solar Panel MPPT Algorithm
- 16-Bit Digital Telemetry Monitors V_{BAT}, I_{BAT}, R_{BAT}, T_{BAT}, T_{DIE}, V_{IN}, I_{IN}, V_{OUT}

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