NEWS FOR THE ELECTRONICS INDUSTRY

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TAKE CONTROL OF YOUR POWER

+

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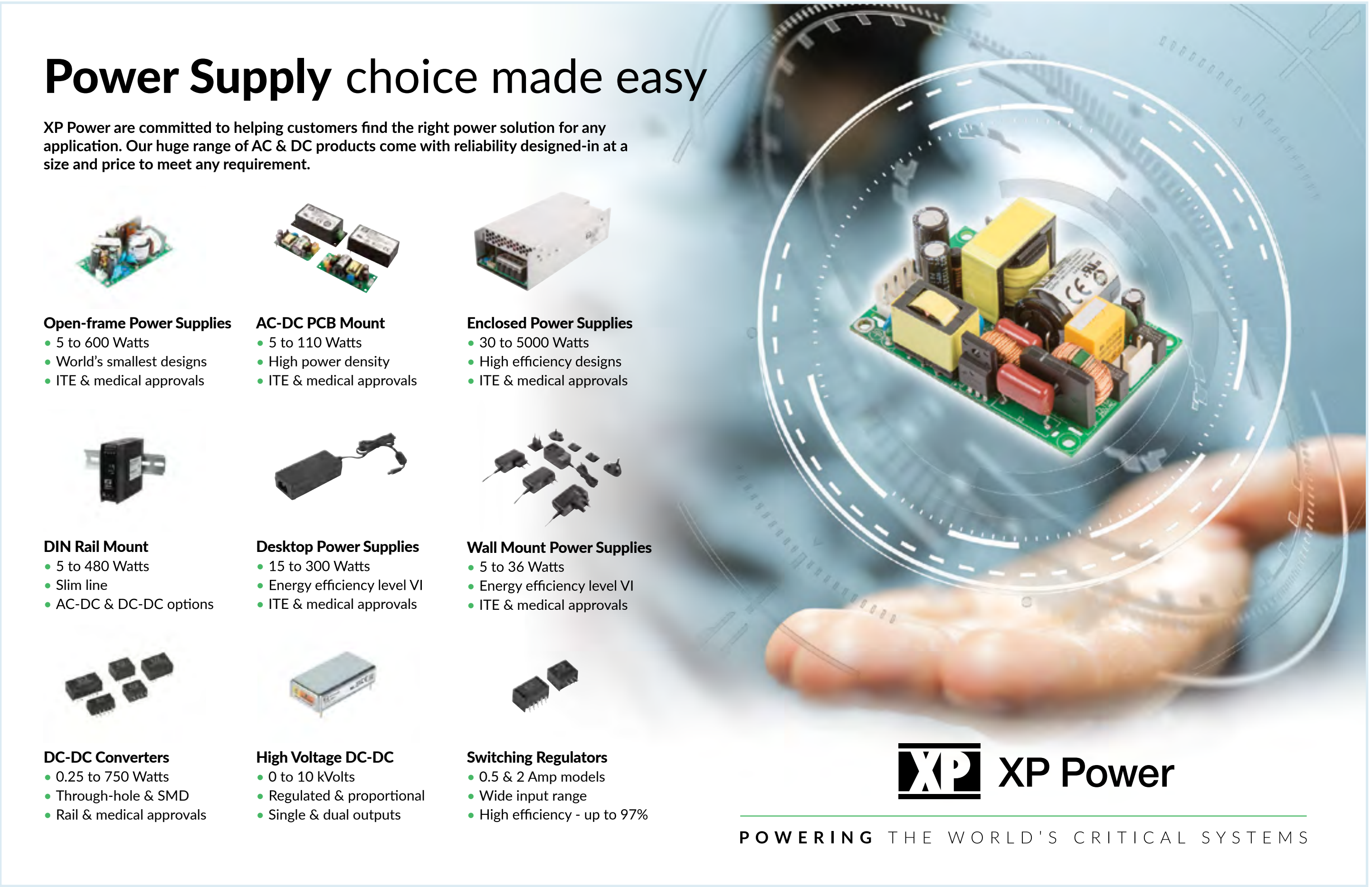

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WELCOME

Every designed product requires power and includes on-board power-saving features that allow them to turn elements on, off, or standby based on need and efficiency. With the rise of the Internet of Things (IoT), energy management and low-power operation have become critical issues in nearly all designs.

Designers are focusing their attention and efforts on system energy usage more than ever before, and power management is all about understanding power requirements and the trade-offs required to unlock innovation. Excellent power management extends battery life, improves device efficiency, and enables applications to run more intelligently.

Delivering power safely, reliably, accurately, and efficiently is a test many engineers face. The latest edition of eTechjournal, "Take Control of Your Power," provides an in-depth look at power system design. In this publication, industry power experts discuss some of the challenges and solutions that engineers face.

Learn how to choose the best battery for your next wireless application, how to overcome battery-life challenges, the advantages of 4th generation SiC MOSFETS, circuit protection solutions, design considerations for auxiliary gate drive transformers, and how to beat the space-constrained challenges for power management applications.

Discover how the latest low-power, energy-efficient devices and system designs have transformed power management, allowing for the use of fewer devices, resulting in more reliable and cost-effective solutions.

We hope you enjoy this edition and welcome your comments and suggestions. Please feel free to drop us a note."

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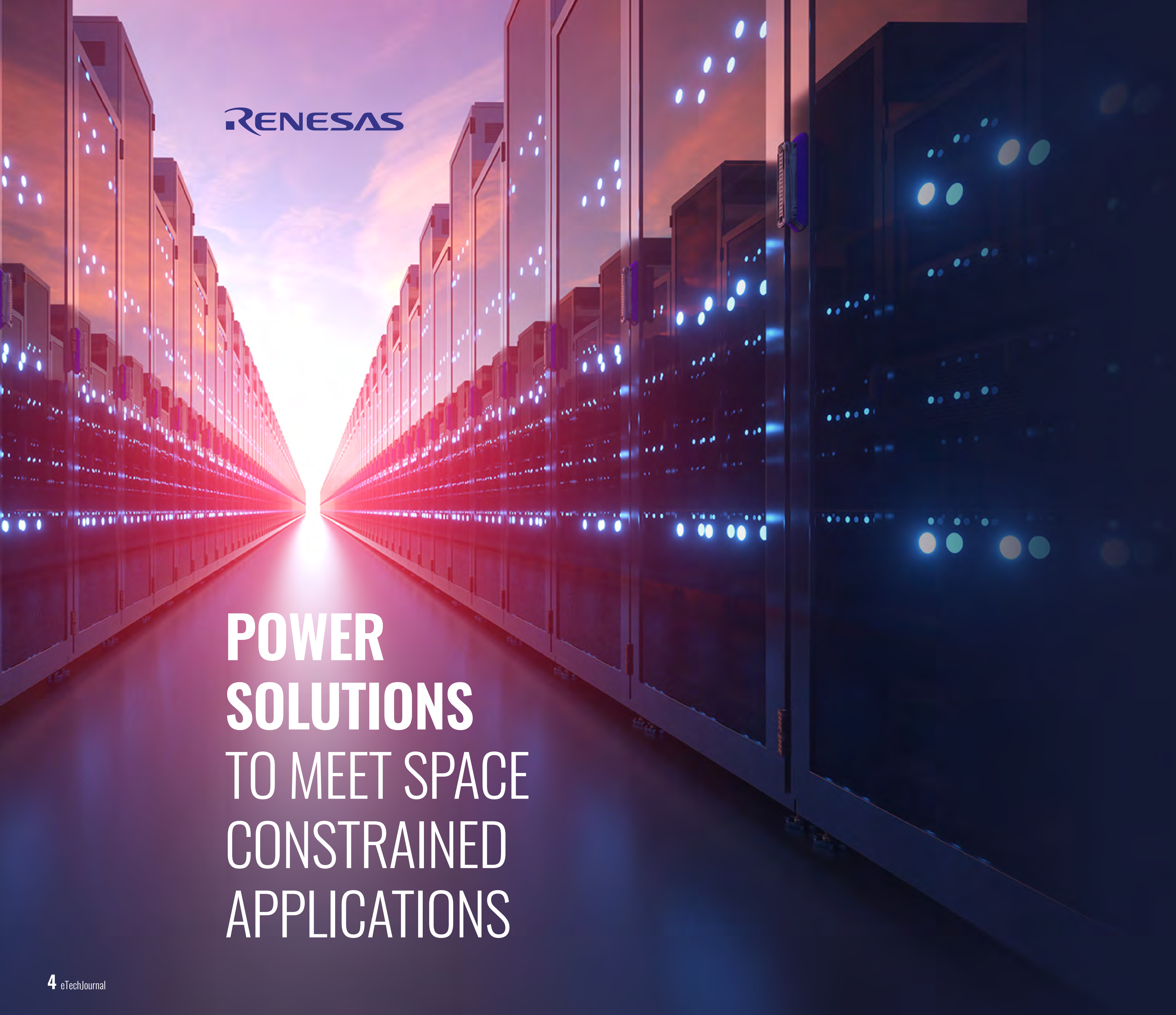


POWER SOLUTIONS TO MEET SPACE CONSTRAINED APPLICATIONS

Power density requirements and increased focus on protection features make digital power modules a great option in space constrained applications.

High performance computing, storage, networking equipment, industrial and automated test equipment are migrating to digital power modules due to space constraints and demands for higher currents. The currents levels required by custom ASICs, FPGAs, DSPs and memory continue to increase due to increased functionality required in these applications. Designers are also expecting more protection features from their power delivery network to insure a robust system level design. This article highlights the benefits of using a digital power module in your next design.

The currents levels required by custom ASICs, FPGAs, DSPs and memory continue to increase due to increased functionality required in these applications. Designers are also expecting more protection features from their power delivery network to insure a robust system level design. This article highlights the benefits of using a digital power module in your next design.

While power modules are not new to the industry, its use is getting more widespread as systems strive to decrease in volume and footprint. As a result, board space allocated to power circuitry diminish as systems strive for greater integration. **Figure 1** shows an illustration of moving from discrete power supply to power module implementation.

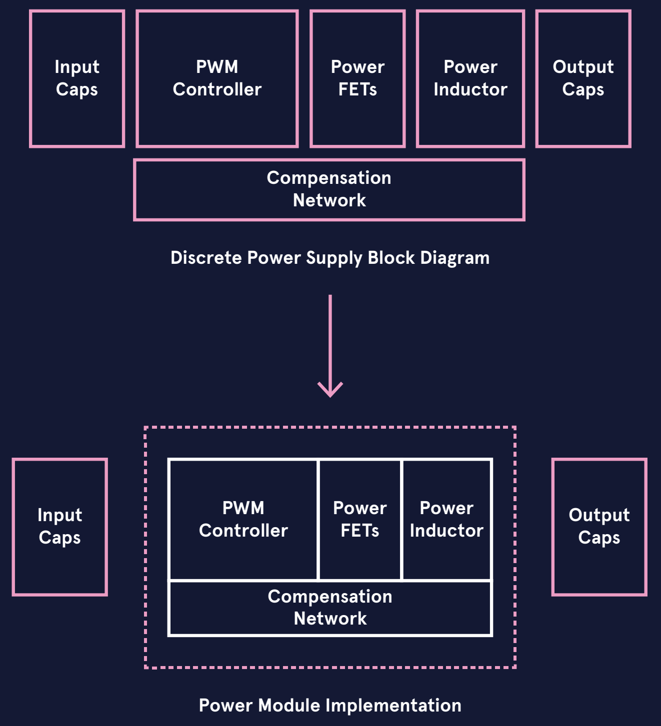


Figure1 : From discrete power supply to power module implementation

Some application areas of power modules include circuitry of high complexity, stringent space limitations and high current designs where power density is of utmost importance.

By integrating the various components of a power supply design into a single compact product, a simple, easy to use solution can be very attractive and helpful in such applications. Besides a small compact design, there is a shift in preference towards PMBus enabled products, where output voltage, switching frequency, loop compensation parameters can be easily changed through the GUI.

In addition, the product should also contain the various protection features that protects itself as well as the circuitry downstream. Some of the protection features include overvoltage and undervoltage protection, positive and negative overcurrent protection and over temperature protection. All these should also be easily accessible to be modified by the user in the GUI through PMBus.

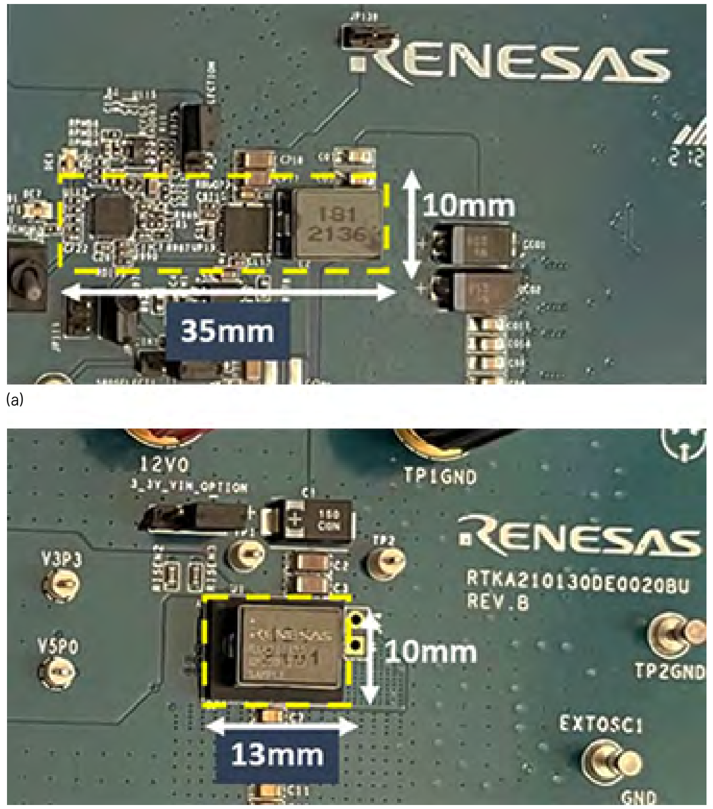
As an example, the RAA210130 as a fully PMBus enabled 4.5V-to-15V DC-DC step-down power module is capable of delivering up to 30A of current from a compact 10mmx13mmx7.8mm thermally enhanced BGA package. The module comprises of a full digital controller, a Smart Power Stage (SPS) with both top and bottom MOSFET, internal power supplies to power the controller and SPS, and a filter inductor, making this module a robust and self sufficient power supply.

The module implements the proprietary Renesas digital synthetic current modulation scheme to achieve excellent transient response, ease of tuning and efficiency across the full load range. This achieves a smaller total output voltage variation with less output capacitance than traditional PWM controllers.

With minimal external components, simple configuration, robust fault management, and highly accurate regulation capability, implementing a high-performance regulator has never been easier.

A standard PMBus interface with PMBus V1.3 compatibility facilitates device configuration, addresses sequencing and fault management, provides real time full telemetry and point-of-load monitoring, and detailed fault reporting.

All of these features are conveniently accessible through the PowerNavigator™ software tool. A fully customizable cycle-by-cycle current, voltage and temperature protection scheme is capable of latching off or restarting the output in response to system faults.



(a)

(b)

Figure2 : Comparison between (a) discrete solution and (b) power module implementation

1

PERFORMANCE

The RAA210130 offers excellent efficiency over the entire load range. **Figure 3** show the efficiency vs. load current at VIN = 12V, with (a) internal and (b) external 5V and 3.3V supply where the peak efficiency is 95.5%. Besides excellent efficiency, RAA210130 also provides impressive transient response.

Figure 4 shows the outstanding transient response at VIN=12V, VOUT = 0.8V, with a step load of 30A, where the VOUT undershoot/overshoot of less than ±2.5% can be achieved. **Figure 5** shows the transient response at VIN=12V, VOUT = 3.3V, with a step load of 15A, where the VOUT undershoot/ overshoot of less than ±1% can be achieved.

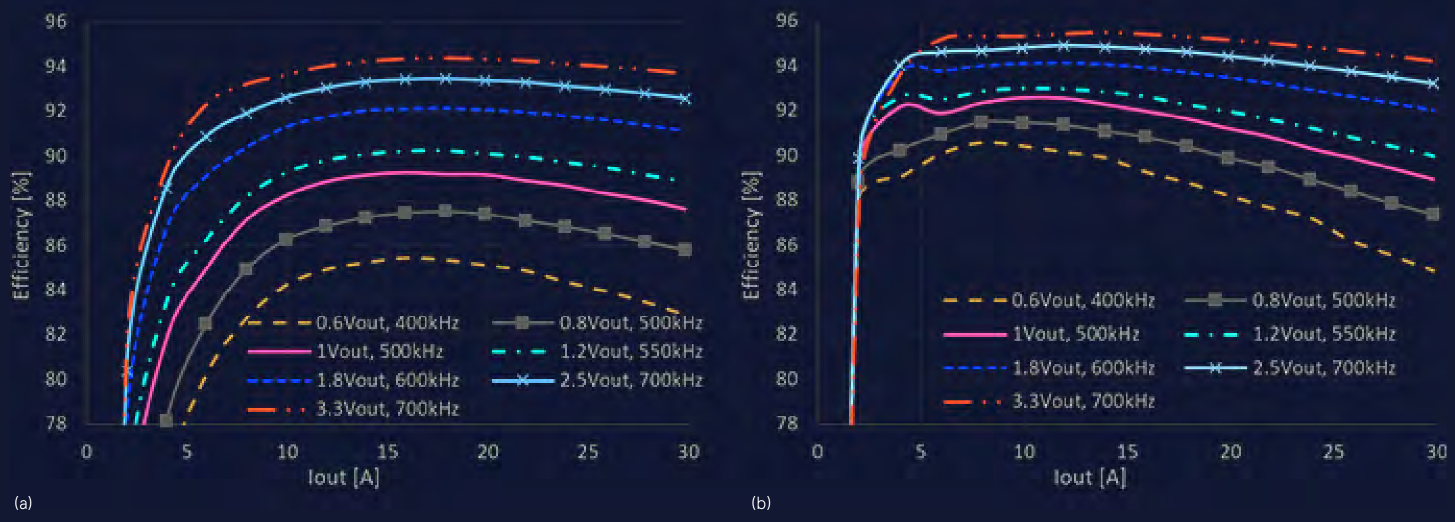


Figure3: Efficiency vs Load Current at VIN = 12V, with (a) internal and (b) external 5V and 3.3V supply

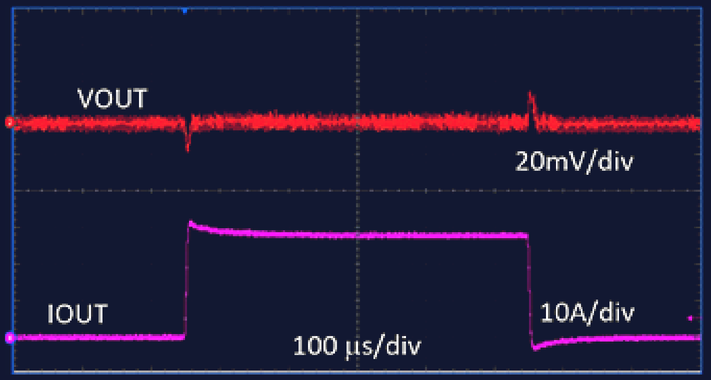


Figure 4 : Transient Response, VIN=12V, VOUT = 0.8V, 0-30-0A, 5A/us step load

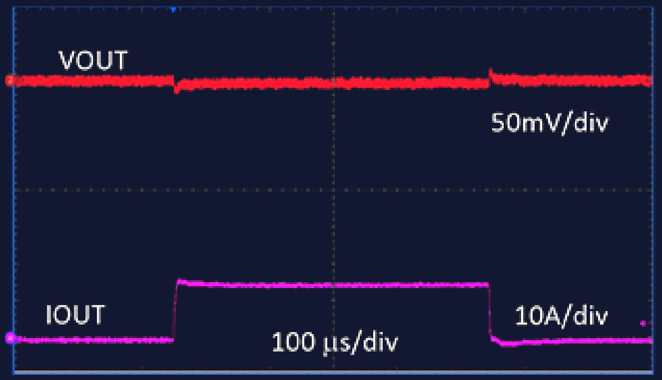


Figure 5 : Transient Response, VIN=12V, VOUT = 3.3V, 0-15-0A, 5A/us step load

2

PROTECTION FEATURES

The RAA210130 includes an extensive fault management system that integrates with high performance host controllers, supporting unprecedented remote system management and debugging capability. If a fault condition occurs, the controller de-asserts the PG pin and alerts the host using the nPMALERT pin. The Catastrophic Failure Protection (CFP) can be optionally configured to assert on select faults for additional protection measures at the system level. The RAA210130 also provides a Black Box, which is a recorder with extensive fault logging to support system level debug. Fault controls are independently enabled and associated fault responses are user configurable.

2.1 Power-Good signal

The PG pin is an open-drain, power-good output that indicates completion of the soft-start sequence and output voltage is within the expected regulation range. If a fault occurs or when the rail is disabled, the PG pin is pulled low.

2.2 Overvoltage/ Undervoltage Protection

Output voltage is measured at the load sensing points differentially for regulation, and the same measurement is used for OVP and UVP. **Figure 6** shows a simplified OVP/UVP block diagram.

The output voltage comparisons are done in the digital domain. The device responds to an output overvoltage or undervoltage condition by disabling the output, declaring a fault, setting the PMALERT pin, pulling the PG pin low, and then pulsing the LFET until the output voltage drops below the threshold. The output does not restart until the EN pin is cycled (unless the device is configured to retry).

The RAA210130 also features open-pin sensing protection to detect an open of the output voltage sensing circuit. If this condition is detected, module operation is suspended.

2.3 Output Overcurrent Protection

The RAA210130 offers a comprehensive overcurrent protection scheme that monitors the total output current, peak phase current, and the valley phase current.

The scheme allows the user to eliminate inductor saturation and limit the total output current. Shutdown and retry response types for OC faults are supported. The response configuration applies to all output current fault mechanisms such as phase peak overcurrent and total output overcurrent.

Figure 7 shows the block diagram of the output overcurrent protection scheme.

The module is protected from both overcurrent and undercurrent using a pulse-by-pulse scheme that acts instantly on a PWM signal if a detected inductor current reaches its threshold.

Thresholds for overcurrent and undercurrent (negative inductor current) allow the user to precisely limit the phase current to prevent inductor saturation. Current limiting behavior can be configured to either shut down the device after a user-determined number of consecutive events or continue indefinitely. If configured to continue indefinitely, the converter behaves much like a current source.

Figure 8 and **Figure 9** show the OC and UC current limiting when the device is configured to shut down after a finite number of consecutive events.

The RAA210130 also supports total output current limits that have user-adjustable response delay. The two sum current limits, fast and slow, allows the user to permit high maximum output current for a shorter period of time and lower output current for a longer period. The response delay for the limiting mechanisms is also adjustable. These mechanisms do not restrict the maximum output current until the current has exceeded a threshold for the response delay time. **Figure 10** shows the total output current protection scheme.

Figure 6 :
OV/UV Comparators

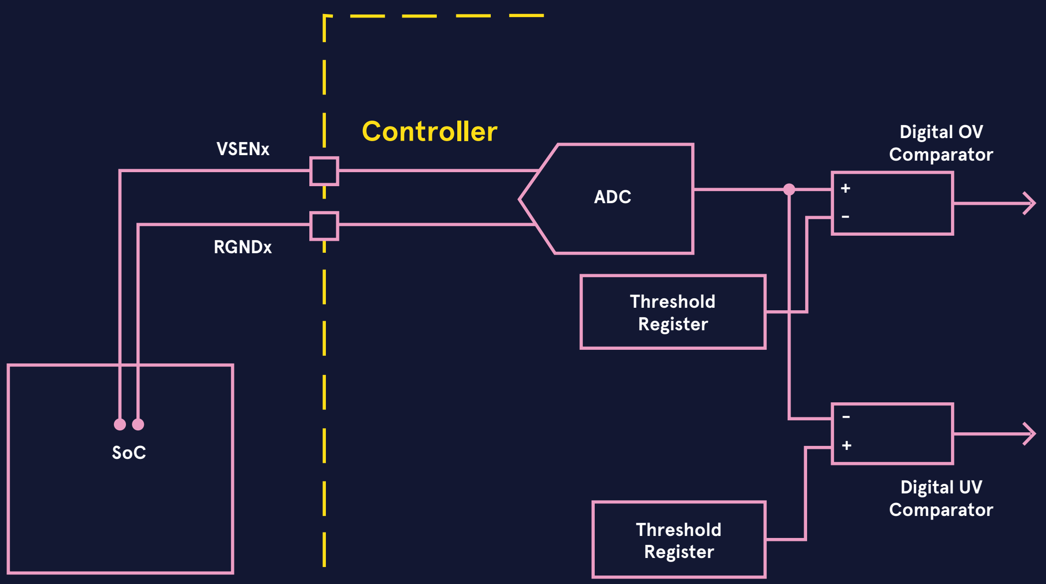
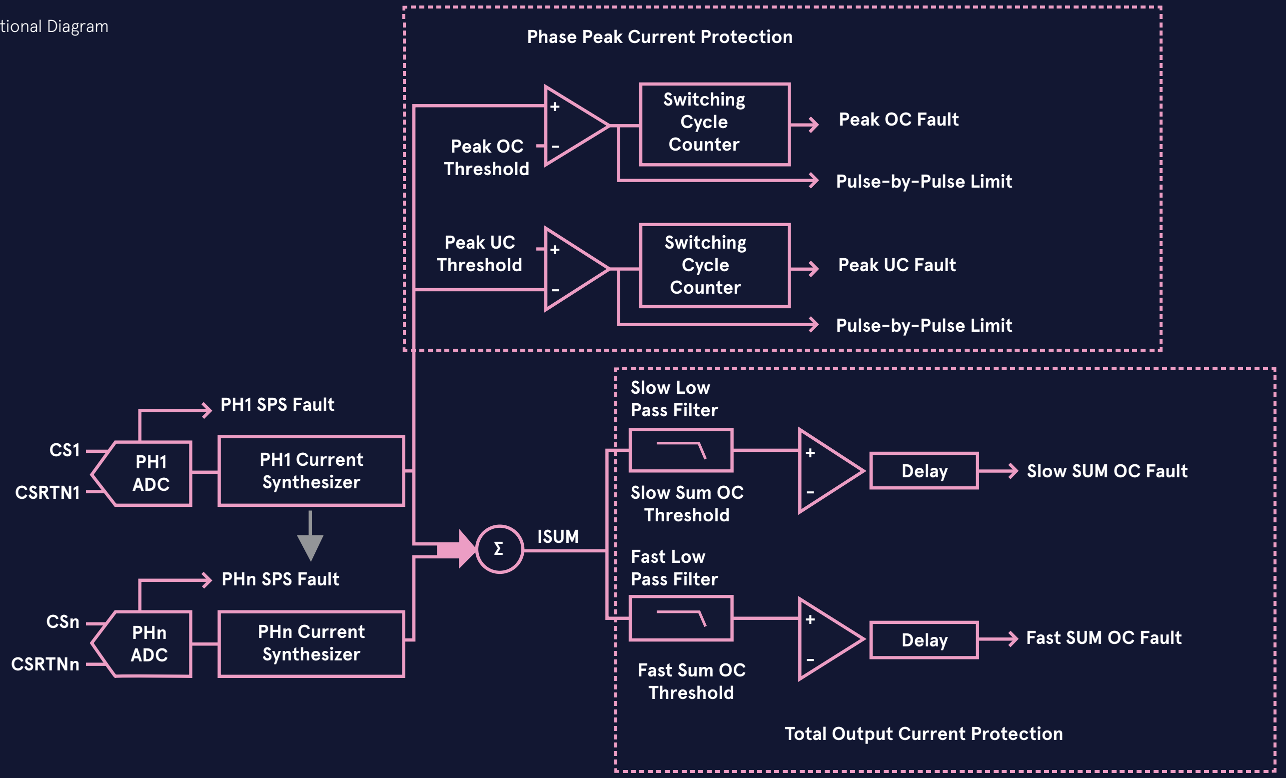


Figure 7 :
OCP Functional Diagram



2.4 Thermal Protection and nVRHOT

The RAA210130 supports a comprehensive scheme for thermal alerting and protection. It monitors SPS temperature and supports over-temperature and under-temperature faults in addition to over-temperature warning. The controller temperature is monitored to support telemetry and thermal shutdown. Shutdown occurs at approximately +130°C. The nVRHOT pin is used at the system level to inform the powered device to reduce its power consumption. nVRHOT is an open-drain output; an external pull-up resistor is required. This signal is valid only after the controller is enabled. nVRHOT is pulled low when the sensed temperature reaches the PMBus OT_WARN threshold, providing the powered device with an advance warning of the controller thermal status.

Figure 11 shows the behavior of nVRHOT and an over-temperature fault shutdown.

2.5 Catastrophic Failure Protection

The CFP pin supports Catastrophic Failure Protection (CFP) functionality. The pin can be configured to activate in the event of a catastrophic fault detection. The function is typically used to immediately disable the input supply to protect the entire system. The CFP function can be configured to respond to output overvoltage, input overvoltage, and/or output overcurrent faults.

2.6 Black Box Recorder

Black Box is a powerful diagnostic tool that captures all telemetry and status information when any fault occurs. The RAA210130 continuously monitors rail information along with the time duration for which the rail has been regulating, and the tool captures that data when a fault is registered. The tool reports the first fault bit that occurred to cause the shutdown. This diagnostic data is stored in RAM, and Black Box can be configured to additionally write to NVM for retrieval when the system loses input power and a fault occurs. The RAM record is updated every time a fault occurs. Black Box can write to NVM up to 10 times and provides an option to limit NVM writing to once per power cycle to avoid filling up the available NVM space inadvertently.

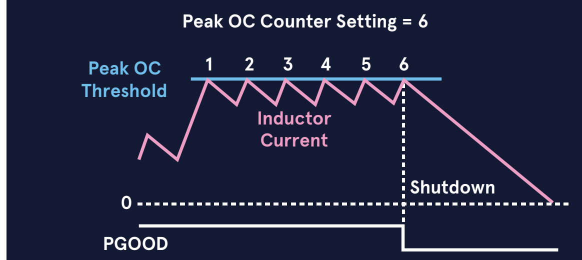


Figure8 : Peak OC Operation

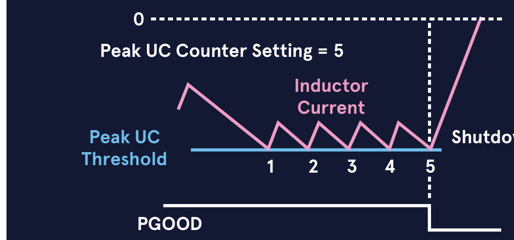


Figure9 : Peak UC Operation

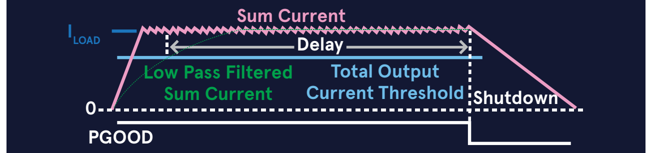


Figure10 : Total Output Current Protection

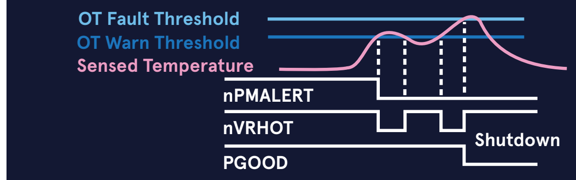


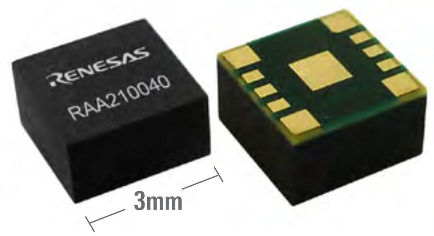
Figure11 : nVRHOT and Over-Temperature Shutdown

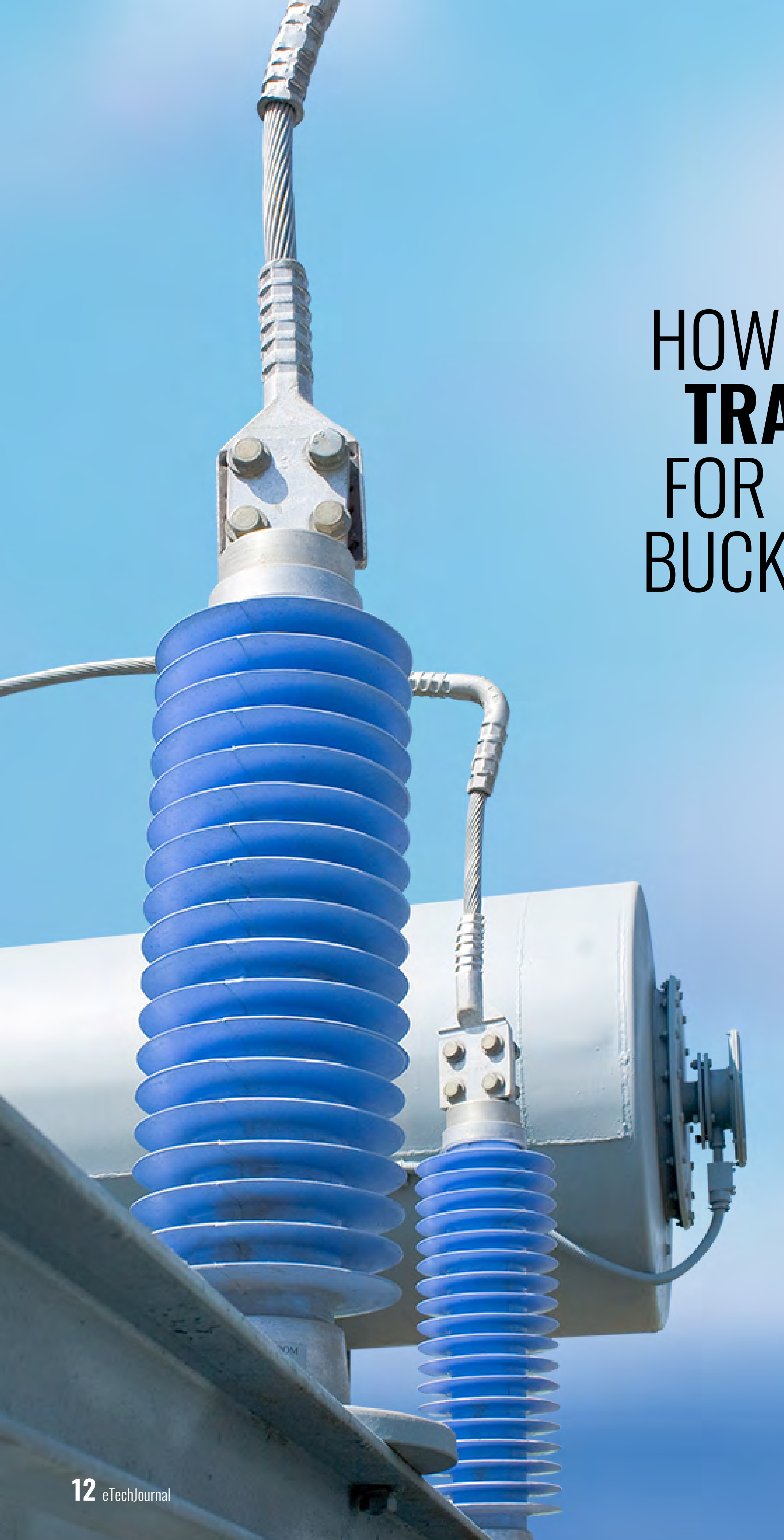
CONCLUSION

There is a growing trend in preference towards a small footprint, ease of use and fully PMBus enabled DC-DC step-down converter. Whilst being capable of achieving excellent transient response and maintain good efficiencies across the full load range, compatibility with the standard PMBus interface helps simplify device configuration, address sequencing, fault management and reporting, full telemetry and point-of-load monitoring. In terms of protection, it is necessary for the product to offer a fully customizable cycle-by-cycle current, voltage and temperature protection scheme. RAA210130 is an embodiment of all the above-mentioned features for your application needs.

To learn more about Renesas RAA210xxx single channel digital interface power modules

CLICK HERE





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HOW TO SELECT A **TRANSFORMER** FOR AN ISOLATED BUCK CONVERTER

Selecting a transformer can be a pivotal process for designing isolated buck converters. This tutorial discusses how an isolated buck converter works, which parameter to focus on when choosing a transformer, how these parameters influence the choice of transformer, and how the transformer influences a circuit parameter.

HOW DOES AN ISOLATED BUCK CONVERTER WORK?

Just like a buck converter, **Figure 1** shows an iso buck topology. By replacing the inductor in a buck circuit with a transformer, the result is an iso buck converter. The transformer secondary side has independent ground.

During on time, the high-side switch (QHS) is on, and the low-side switch (QLS) is off, the transformer magnetizing inductance (LPRI) is charged up. The arrow in the block diagram (**Figure 2**) shows the current flow direction. The transformer primary current increases linearly. The current ramping slope depends on (V_{IN} - V_{PRI}) and LPRI. The secondary-side diode (D1) is reverse-biased during this time interval and loads current flow from C_{OUT} to load.

During off time (**Figure 3**), QHS is off and QLS is on and the transformer primary-side inductor is discharged. The primary current flows from QLS to ground, D1 is forward-biased, and the secondary current (N_{SEC}) flows from the second-side coil to C_{OUT} and load. C_{OUT} is charged up during this time. (Turning off QHS and turning on QLS cannot change the current direction, it only changes the current slope. Positive current decreases until 0A, then the negative current increases).

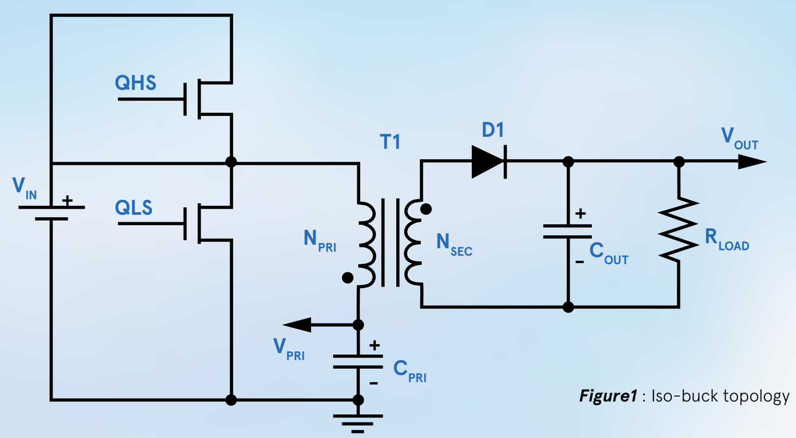


Figure1 : Iso-buck topology

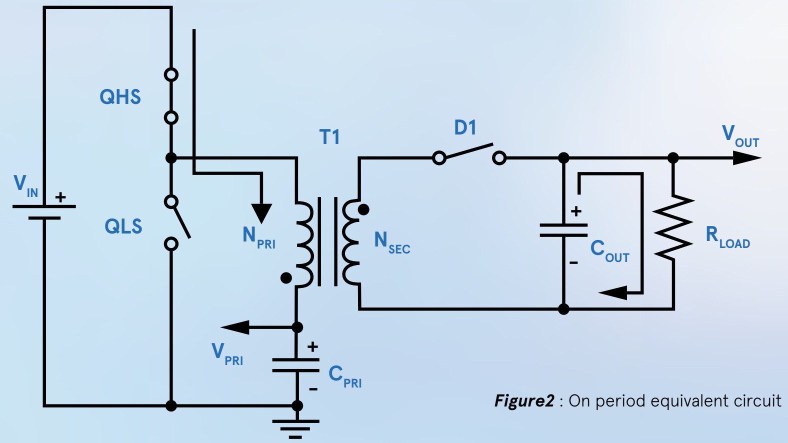


Figure2 : On period equivalent circuit

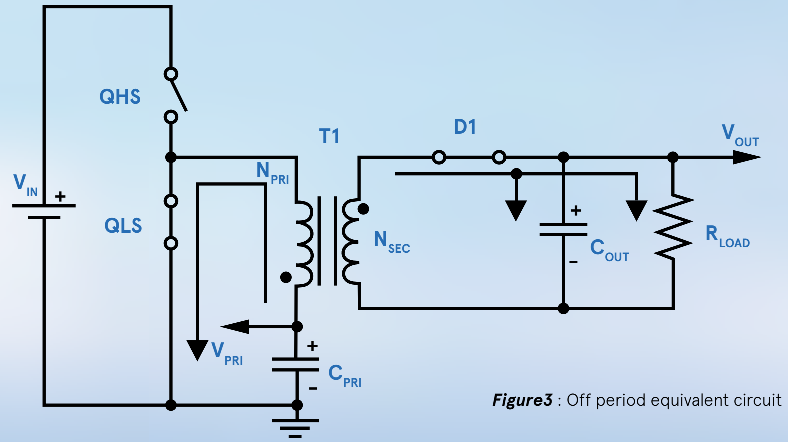


Figure3 : Off period equivalent circuit

WHICH SPEC WILL INFLUENCE THE TRANSFORMER?

When designing a converter, some specs should be declared and defined as it will determine which component will be used, especially in a transformer.

- > **Input Voltage Range**
- > **Output Voltage**
- > **Max Duty Cycle**
- > **Switch Frequency**
- > **Output Voltage Ripple**
- > **Output Current**
- > **Output Power**

Maximum duty cycle (D) is typically assigned in the range of 0.4 to 0.6. The minimum input voltage (V_{IN_MIN}) and max duty cycle determine the primary output voltage (V_{PRI}). The primary output voltage and output voltage (V_{OUT}) determine the transformer turns ratio.

Output current (I_{OUT}) and output power (P_{OUT}) are key parameters that influence transformer selection. Output current helps determine the thickness of the copper wire and output power determines which transformer skeleton is used. The permeability of the skeleton indicates how much energy it can store, and how much power it can put out. Generally, the DC output current multiplied by a coefficient is assigned to the inductor's (transformer's) ripple current.

Duty cycle and switch frequency are used to calculate the T_{ON} time, while V_{IN}, V_{PRI}, and ripple current decide the primary inductance. The assigned coefficient must not be too large or too small since a large coefficient can lead to a large ripple current. Large ripple current may result in half the H-bridge current limit, which may damage the MOSFET.

A large ripple current will lead to a large ripple voltage on the output capacitor due to its ESR and ESL. On the contrary, when an extremely small ripple current is needed, use a large inductance inductor (transformer). It will be a big skeleton with a large size of the transformer winding. The large inductance will limit loop bandwidth and the loop response performance.

CHOOSING A TRANSFORMER

Obviously, energy was transferred to the secondary only in T_{OFF} time. The turns ratio can be decided by the following equation:

$$\frac{V_{OUT} + VD}{V_{PRI}} = \frac{N_{SEC}}{N_{PRI}} \quad \text{EQ 1}$$

Where VD is the diode (D1) forward-bias voltage. For V_{PRI}, assign a maximum duty cycle in the range of 0.4 to 0.6. The V_{PRI} can be calculated by the following equation:

$$V_{PRI} = D \times V_{IN\_MIN} \quad \text{EQ 2}$$

Where D is the maximum duty cycle and V_{IN_MIN} is the minimum input voltage. From **Equation 2**, calculate the turns ratio. Since the inductor is following volt-second balance low, the required inductance is calculated by the following equation in T_{ON} time:

$$L = \frac{(V_{IN\_MIN} - V_{OUT})}{f \times \Delta I} \times D \quad \text{EQ 3}$$

Where f is the switching frequency and ΔI is the ripple current.

As discussed before, ripple current equals the DC output current multiplied by a coefficient:

$$\Delta I = I_{OUT} \times K \quad \text{EQ 4}$$

Where K is the coefficient. But in iso buck converter topology, there is a transformer not an inductor. How do we deal with this? The current ratio equals the turns ratio inversely:

$$IPRI_{toff} = I_{SEC} \times \frac{N_{SEC}}{N_{PRI}} \quad \text{EQ 5}$$

Where $IPRI_{toff}$ is the secondary current, which is converted and transferred to the primary side during T_{OFF} time. The sum of the primary and secondary-side current can be considered as an equivalent inductor current.

$$ILeq = I_{PRI} + I_{SEC} \times \frac{N_{SEC}}{N_{PRI}} \quad \text{EQ 6}$$

Where ILeq is the equivalent inductor current. If the transformer has three more windings, this is the following equation:

$$ILeq = I_{PRI} + I_{SEC} \times \frac{N_{SEC}}{N_{PRI}} + I_{THI} \times \frac{N_{THI}}{N_{PRI}} + \cdots \quad \text{EQ 7}$$

But is this correct? Let's verify it with the simulation result based on the MAX17682.

Figure 4 shows a screenshot of the MAX17682 typical circuit drawn in SIMPLIS. Current probes, IPRI and ISEC1, were placed on both sides of the transformer T1.

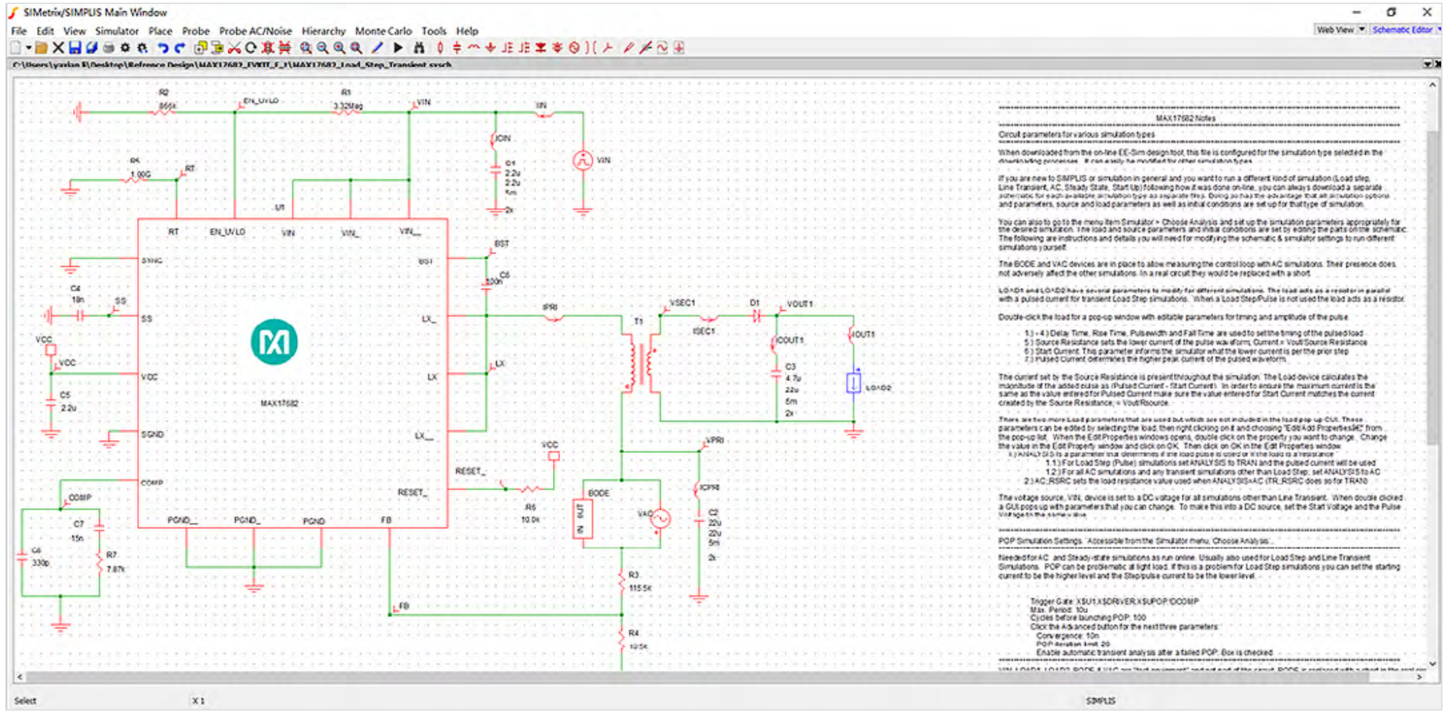
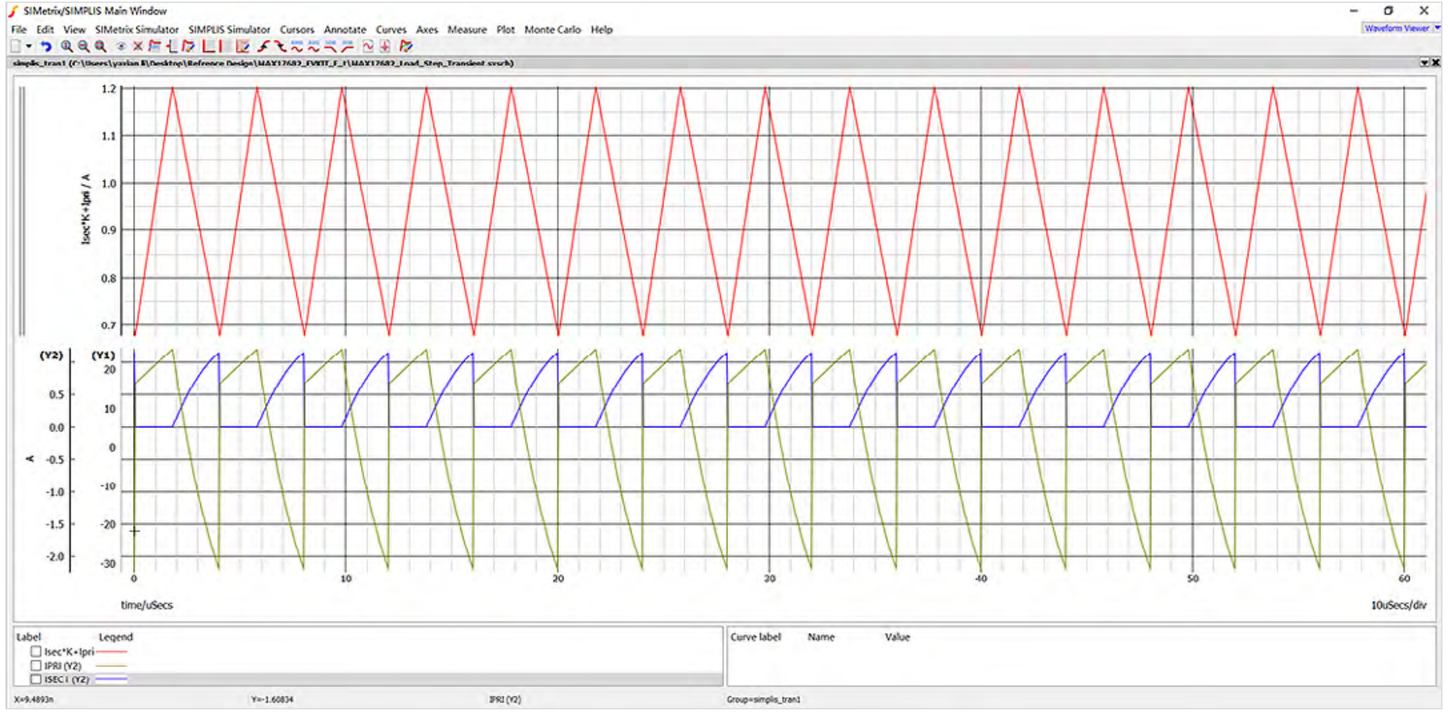


Figure 5 is a screenshot of the transient simulation resulting from two probes. Two current waveforms were added by using the above equations.



Clearly, the added current (cyan) results in a triangle wave, just as the inductor in a non-iso buck converter. The transformer primary ΔI can then be easily calculated:

$$\Delta I = \left(I_{PRI} + I_{SEC} \times \frac{N_{SEC}}{N_{PRI}} \right) \times K$$

EQ 8

Typically, an assigned load current ripple is 0.2 times the DC output current. K can be assigned to 0.2 times Nsec/Npri. At the same time, the primary peak current should be guaranteed less than the limited switch. Where Ipk is:

$$Ipk = ILeq_{dc} + \frac{\Delta I}{2}$$

EQ 9

The transformer primary inductance can be easily calculated as:

$$L_{PRI} = \frac{(V_{IN\_MIN} - V_{PRI}) \times D}{f \times \Delta I}$$

EQ 10

By using the turns ratio, primary inductance, output power, output current, and isolation voltage parameters, a decision can be made on the inductor design.

WHY DOES THE SIMPLIFIED EQUATION WORK?

There may be some uncertainty using the MAX17682 data sheet **(Figure 6)** when selecting inductance. Let's see how we can better understand it and use it for our application.

Primary Inductance Selection

Primary inductance value determines ripple current in the transformer.
Calculate required primary inductance using the equation:

$$L_{PRI} = \frac{V_{PRI}}{f_{SW}}$$

where, V_{PRI} and f_{SW} are nominal values.

Figure6 : MAX17682 datasheet equation

According to the above example, **Equation 10** can be rewritten to follow this equation for T_{OFF} time.

$$L_{PRI} = \frac{V_{PRI} \times (1 - D)}{f \times \Delta I}$$

EQ 11

Assume D is 0.6, if and only if ΔI were 0.4A, the polynomial (1-D) and ΔI is reduced.

Then **Equation 11** and the equation from **Figure 6** are the same. The equation in the datasheet already selects the primary ripple current. If we assign D as 0.6, the primary ripple current is 0.4A. In quantity, the T_{OFF} duty cycle equals the primary ripple current.

$$\Delta I = 1 - D$$

EQ 12

By using the simplified equation shown in **Figure 6**, the user ensures a faster design with a primary ripple current that equals the Toff duty cycle. If you want to modify primary ripple current or use another parameter, this tutorial discussed how to implement that.

To learn more about MAX17682 Iso-Buck DC-DC converters CLICK HERE

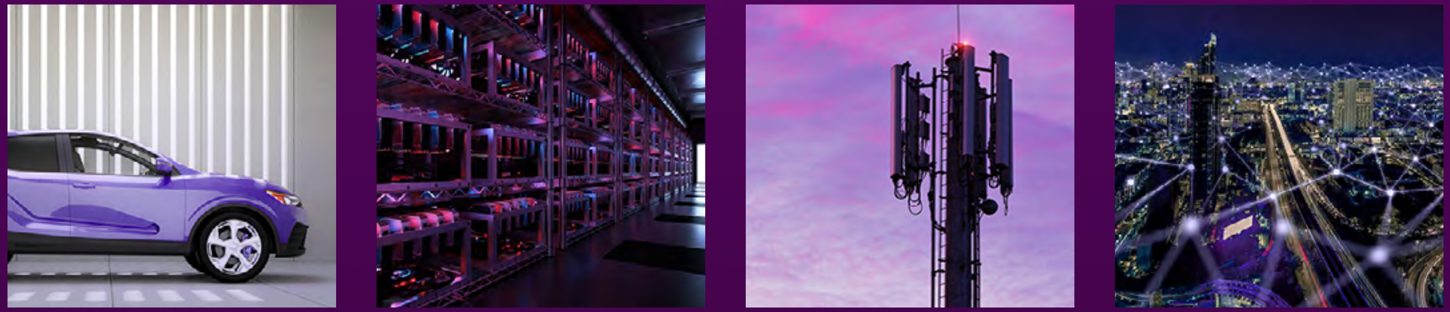


Figure 1

APPLICATION BENEFITS OF USING 4TH GENERATION SIC MOSFETS

ROHM SEMICONDUCTOR

VISIT ROHM

ROHM has released the 4th generation of SiC MOSFETs. It has achieved a 40% reduction in on-resistance and a 50% reduction in switching loss compared to the 3rd generation.

This article describes an experimental test using a step-down DC-DC converter with 500V input voltage and 7kW power, a simulated running test using an EV traction inverter with 800V input and 100kW, and an experimental test using a Totem-pole PFC circuit.

Today, applications such as electric vehicles (EVs), data centers, base stations, smart grids, etc. are progressing toward higher voltage and higher power levels (**Figure 1**).

The reason for this is that it can enhance the convenience of each application. In the case of EVs, for example, higher voltages (400V or 800V) and higher power (up to 350kW) can extend the cruising range and shorten the charging time through quick charging, which will greatly enhance the convenience of people's lives.

However, as the world is currently strengthening its efforts to protect the global environment, simply improving comfort will not be enough to gain acceptance in the global market.

In the future, in addition to improving convenience, it will become increasingly important to reduce energy loss and use it effectively.

The key point to focus on is power conversion. In all the above-mentioned applications, power is supplied from the power grid, batteries, solar power generation systems, etc., and converted to the optimal voltage for effective use. To reduce energy loss and increase power conversion efficiency, SiC power semiconductors are currently attracting attention for their ability to operate at high frequency, high voltage and high current density with low energy loss.

ROHM has already commercialized SiC power semiconductors, which are used in a variety of applications.

ROHM has released the 4th generation of SiC MOSFETs.

By further evolving the trench gate structure established in the 3rd generation SiC MOSFETs already in mass production, ROHM has reduced on-resistance by approximately 40% and switching loss by approximately 50% due to high-speed switching characteristics compared to the 3rd generation. This evolution is shown in the trend of normalized on-resistance (Ron-A: on-resistance per unit area) shown in **Figure 2**.

In contrast to the 3rd generation SiC MOSFETs, the 4th generation offer improved switching speed, which contributes significantly to lower switchin g losses. **Figure 3(a)** shows the block diagram of the buck converter and **Figure 3(b)** shows the general switching waveforms of the converter.

As shown in **Figure 3(b)**, power device losses in a converter consist of switching losses, conduction losses, body diode losses, recovery losses, and Coss losses. (Coss loss is omitted from the figure because it is small.)

As for switching loss, it is generally described in the datasheet as energy per Eon and Eoff pulse, which is a useful for loss estimation in the initial design stage. In detailed design, it is necessary to strictly determine the power dissipation at high voltage input and high frequency. The gate driving circuitry has a large impact in the device losses, so optimizing the gate drive design is necessary to take advantage of the high-speed switching characteristics of SiC devices.

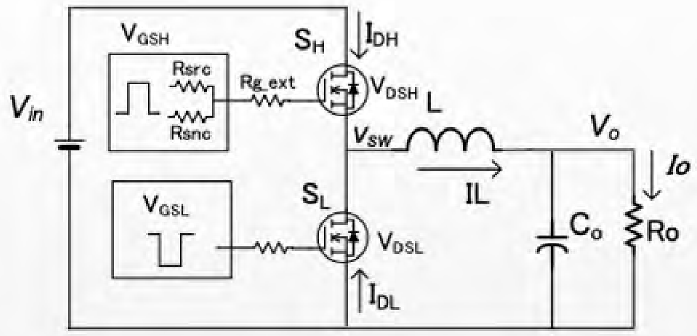


Figure 3a Block diagram of the buck converter

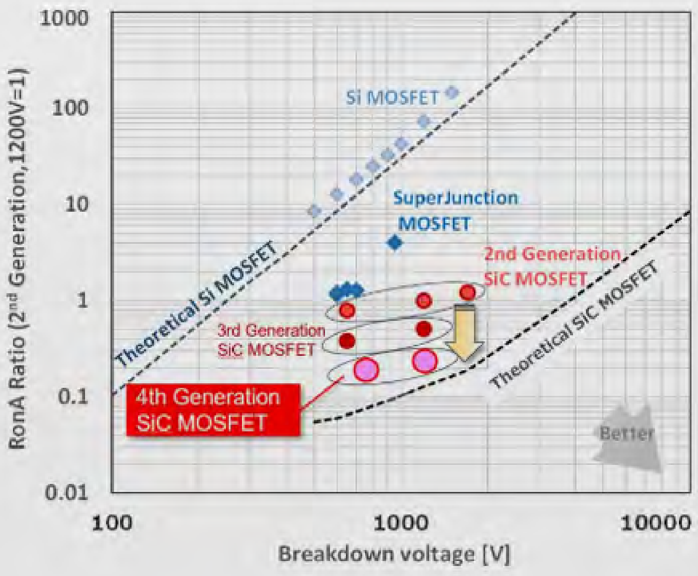


Figure 2 Trend Graph of Normalized On-resistance

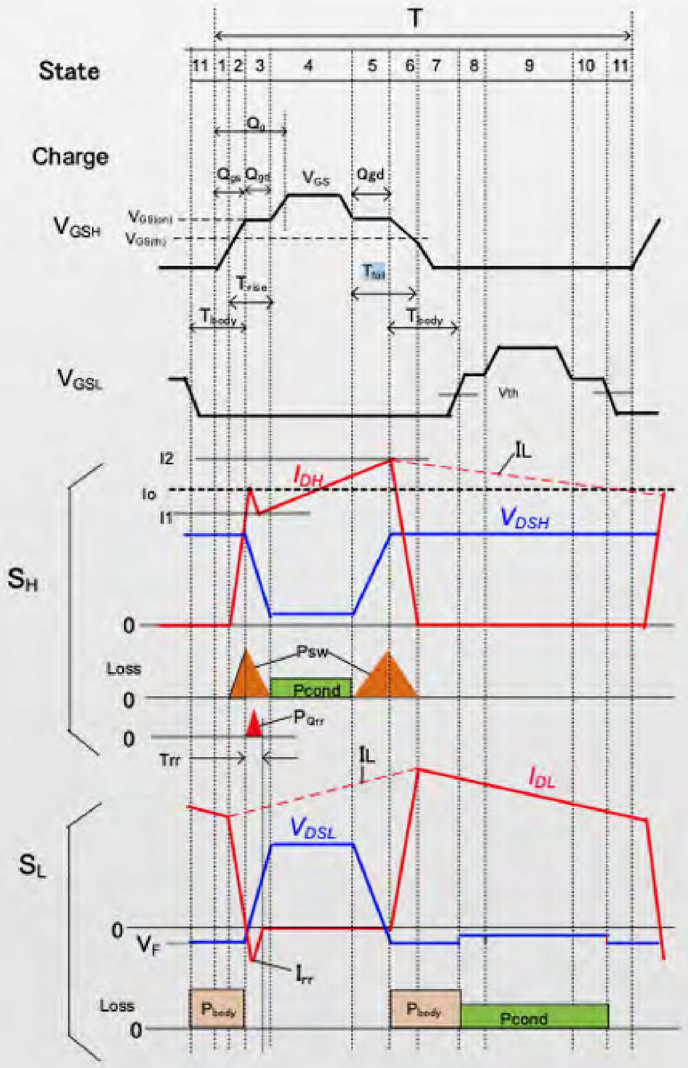
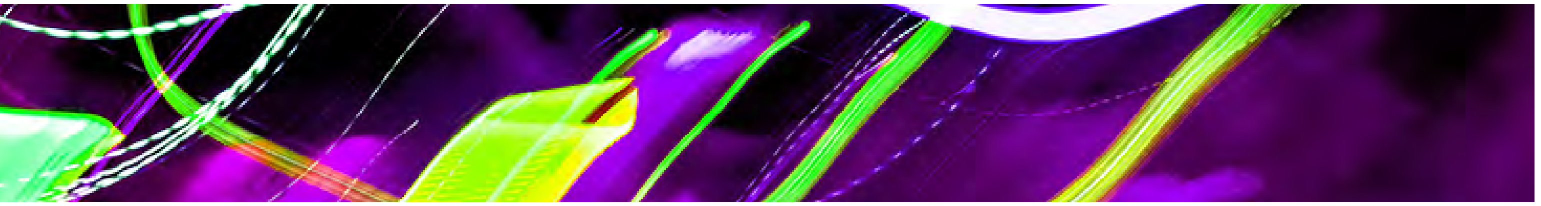
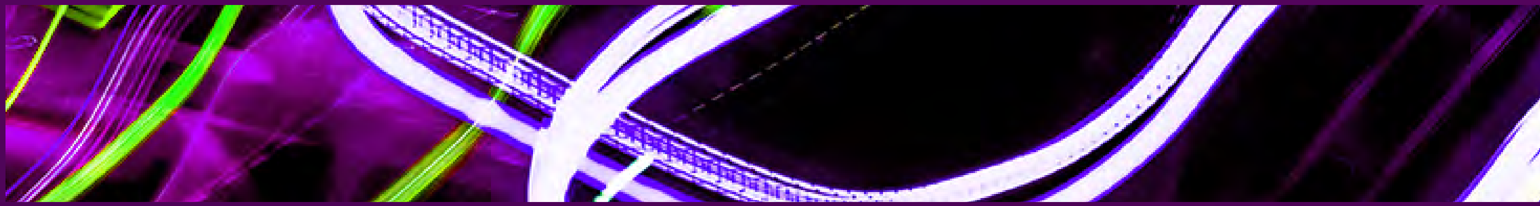


Figure 3b The general switching waveforms of the converter





EXPERIMENTAL VERIFICATION OF DC-DC CONVERTER

In order to confirm previous analysis, the 4th generation SiC MOSFETs was incorporated into a step-down DC-DC converter with the following specifications and verified it experimentally with an evaluation board (**table 1**).

Vin	500V
Vo	250V
Po	7kW
fsw	50kHz
L	500μH
Rg_ext	3.3ohm
4th Generation SiC MOSFETs	SCT4036KR 1200V/36mΩ
3rd Generation SiC MOSFETs (as a reference)	SCT3040KR 1200V/40mΩ

Table 1

Figure 4 shows (a) the DC-DC converter circuit and (b) the evaluation board for the 4th generation SiC MOSFETs used in the half-bridge section with built-in decoupling capacitor. The inductor L, output capacitor Co, and input bulk capacitor are external.

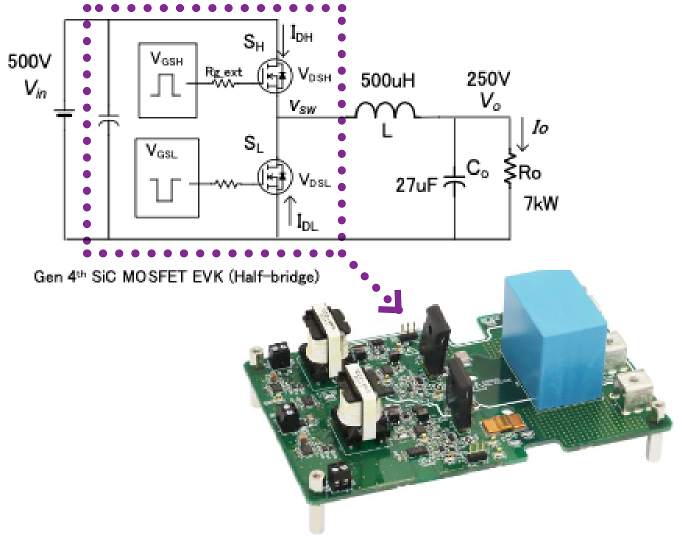


Figure 4
DC-DC Converter Block Diagram for Test
and 4th Generation SiC MOSFET EVK

Figure 5 displays the VGS, VDS, and ID waveforms at 50 kHz during turn-on and turn-off. The turn-on waveform is enlarged on the left. From the waveform observation, we can see that the turn-on rise time Trise is about 20ns, which is very fast.

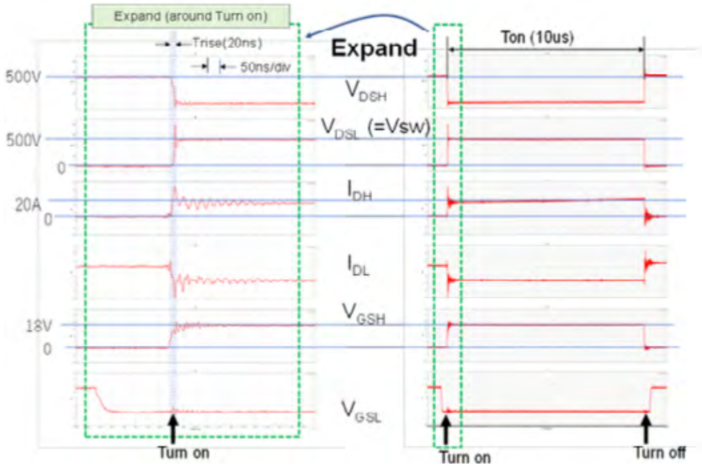


Figure 5. Observed Switching Waveforms (500Vin, 250Vo/20A(5kW), 50kHz)

Figure 6 shows the measurement results of efficiency and power dissipation of this DC-DC converter as well as the efficiency and loss of the DC-DC converter. At light loads (around 1kW), the low switching loss, which is a characteristic of the 4th generation SiC MOSFET, is presented.

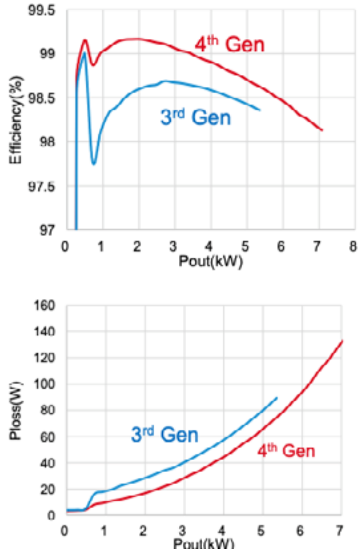


Figure 6. Mearued Efficiency and Losses (500Vin, 250Vo/7kW)

EV APPLICATION

There are various types of EVs, such as BEVs, HEVs, PHEVs, and series HEVs, with different power architectures for different applications. Among them, the power architecture of BEVs with 400V or 800V battery voltage supporting bi-directional and fast charging has been attracting attention recently.

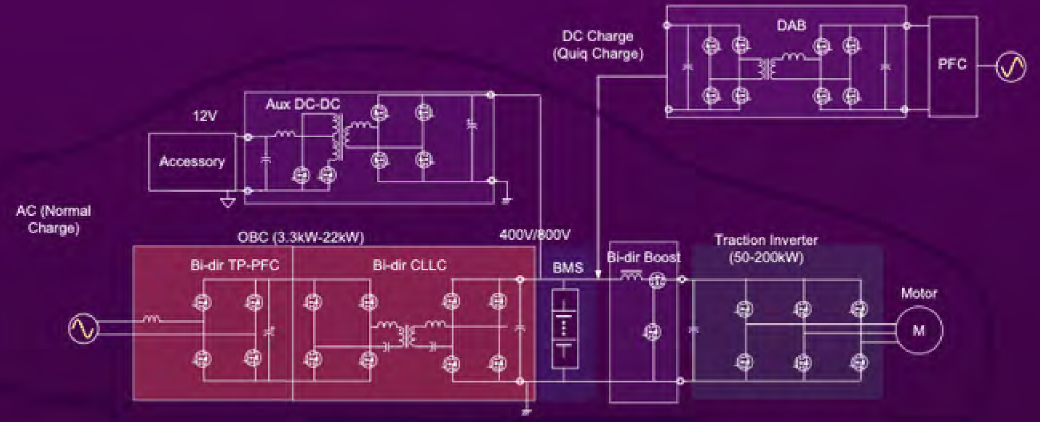


Figure 7. An example of BEV Power Architecture

Figure 7 illustrates a block diagram of the BEV power architecture as an example: the OBC (On-Board Charger) is a hot topic topology with bi-directional Totem-pole PFC and bi-directional CLLC (Symmetric LLC), assuming V2G (Vehicle To Grid).

From the output of this OBC, power is supplied to the auxiliary DC-DC converter, the battery, the boost converter to the inverter and the motor traction inverter.

SIMULATED DRIVING TEST WITH TRACTION INVERTER

As the integration of mechanical and electrical components (motors, reduction gears, and inverters) continues to progress, the importance of reducing losses to achieve high voltage, high output, compact, and lightweight inverters is increasing. This is because it directly affects the cost performance of EVs.

As shown in **Figure 8**, the traction inverter converts the DC power provided by the battery into 3-phase AC power to drive the motor in the powertrain. The three-phase AC waveform is set by a signal wave (reference sine wave) with a frequency synchronized with the motor speed, and a triangular wave (modulation wave) with a carrier frequency that determines the switching frequency. The voltage supplied to the motor is determined by changing the levels of the 3-phase AC and triangular waves when generating the PWM signal.

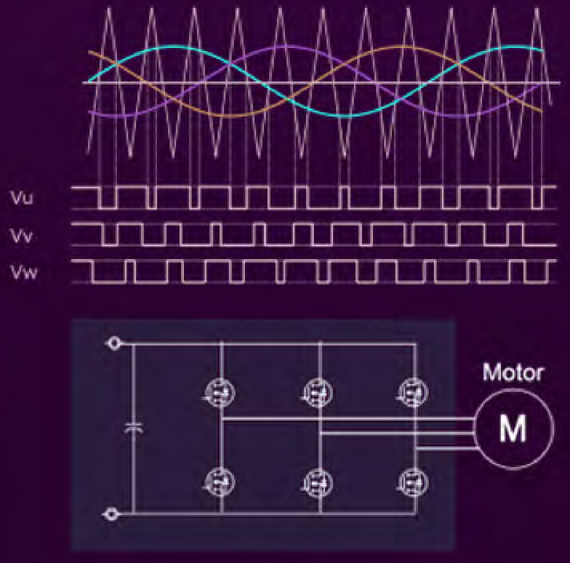


Figure 8. Inverter Circuit Configuration and Drive Signal

MOTOR TEST BENCH ENVIRONMENT

Table 2 shows the main specifications of the SiC devices installed in the motor test bench and the DUT inverter. The DUT inverter consists of a 2-in-1 power module with a 4th generation SiC MOSFET bare chip.

DC Power Supply	Capacity	**100kW**
	Output Voltage Range	**0 to 850V**
	Output Current Range	**±500A**
Test Motor	Type	**PMSM**
	Rated Output	**100kW**
	Maximim Torque (1 minute)	**350Nm**
	Cooling Method	**Water Cooling**
Test Inverter	Power Module	**4th Generation SiC MOSFET 1200V/400A**
	Switching Frequency	**10kHz**
	Cooling Method	**Water Cooling**
Cooling Water Circulation Device	Cooling Temperature Range	**20 to 90 deg.C**
	Refrigerant	**Ethylene glycol aqueous solution**

Table 2. Main specifications of motor test bench and test inverter

Figure 9 illustrates the control system block diagram. The test motor is driven from the DUT inverter through a 3-phase uvw power line. The test motor is connected to the load motor, and the load motor is controlled by the load torque according to the running resistance calculated from the vehicle parameters, which enables the simulated running experiment with the desired vehicle parameters.

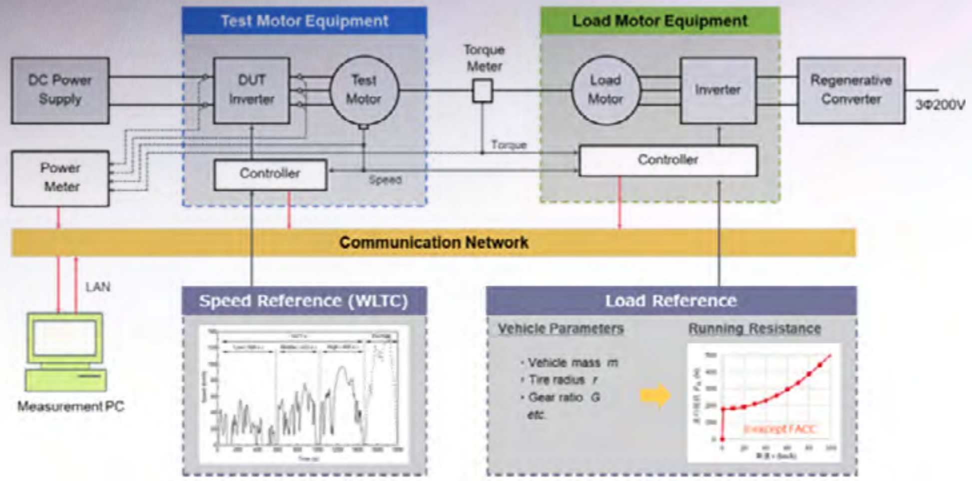
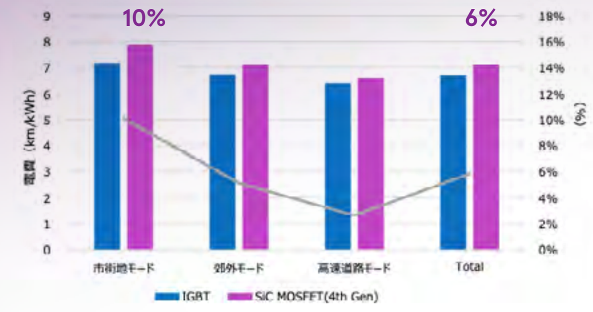


Figure 9. Motor Test Bench / Control System Block Diagram



The cost in urban mode by 10% improvement compared to IGBT

Total electricity cost improved by 6%

4th Gen SiC MOSFET

Figure 10. Electricity Cost Test Result

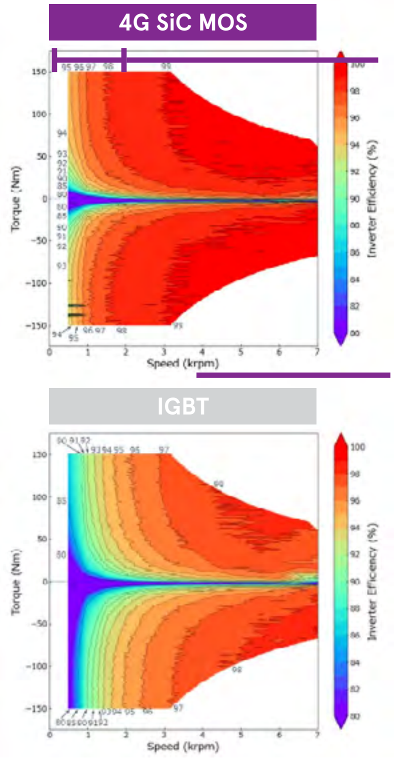
INTERNATIONAL STANDARD WLTC MODE FUEL EFFICIENCY TEST FOR SIMULATED DRIVING

The Worldwide Harmonized Light Duty Driving Test Cycle (WLTC) is a driving cycle specified in the Worldwide Harmonized Light Vehicles Test Procedure (WLTP).

This cycle consists of Low, Middle, High, and Extra-High-speed phases. In Japan, test vehicles are driven in the driving cycle except for the Extra-High phase to measure exhaust emissions and fuel consumption.

Using the mentioned motor test bench, ROHM conducted a driving cost test using 4th generation SiC MOSFETs and IGBTs in the inverter by inputting the conditions of a simulated WLTC driving cycle.

Figure 10 shows the results of the cost test assuming a C-segment class EV, demonstrating that replacing the conventional IGBTs with 4th generation SiC-MOSFETs can improve the cost in all speed phases of the WLTC driving cycle. The total power cost was improved by about 6% compared to the IGBTs, and by about 10% in the urban mode. For reference, **Figure 11** shows a graph of the inverter efficiency map (based on the NT curve, with information on efficiency added). From this result, we can see that the efficiency in the high torque and low RPM range, which is frequently seen in urban driving, has been greatly improved.



Greatly improved efficency in the high torque and low rpm range

Expanding high efficiency area

Driving pattern: WLTC Class 3b, assumed vehicle: C segment, motor: permanent magnet synchronous 100kW / 800V

Figure 11. Inverter Efficiency Map in WLTC Electric Cost Test

EVALUATION OF TOTEM-POLE PFC

Totem-pole PFC is a topology that has attracted a great of attention in recent years as a PFC converter that can target high efficiency. In addition, V2G is being considered worldwide to stabilize the microgrid system and contribute to balancing supply and demand, and bidirectional operation has become important.

Figure 12 illustrates the circuit block diagram. The left leg (S1, S2) is for high frequency switching, and the right leg (S3, S4) is for commercial frequency (low frequency) rectification.

Figure 13 shows the operation diagram by state. During the positive half cycle of the commercial AC, the totem pole low side FET (S2) performs high frequency switching as a boost converter (Figure (a): period D). SiC MOSFETs have a very fast recovery time, and the effect of this power loss is small, so they are a good match for Totem-pole PFC power devices. Next, during the negative half cycle of the commercial AC, the totem-pole high-side FET (S1) acts as a boost converter, switching at high frequency (Figure (c): period D), while S2 acts as a rectifier (Figure (d): periods 1-D). S3 and S4 switch every half cycle of the commercial AC.

To verify the contribution of the 4th generation SiC MOSFETs to the loss reduction of the Totem-pole PFC, an experiment was conducted using the actual board. Table 3 shows the evaluation conditions of the PFC and the specifications of the SiC devices used. When the output voltage is 400V, a SiC MOSFET with 750V breakdown voltage is matched. In this case, SCT4045DR is used. As result, the measured efficiency is over 98% at 1.5kW half load and 97.6% at 3kW full load.

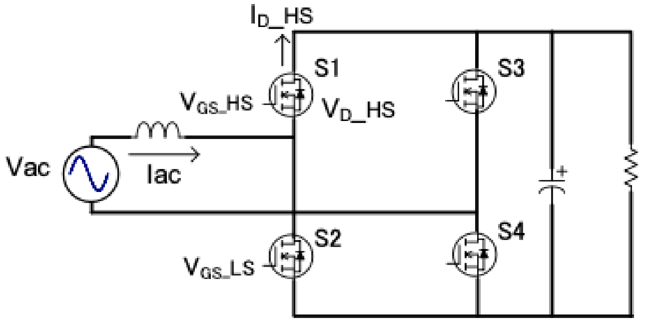
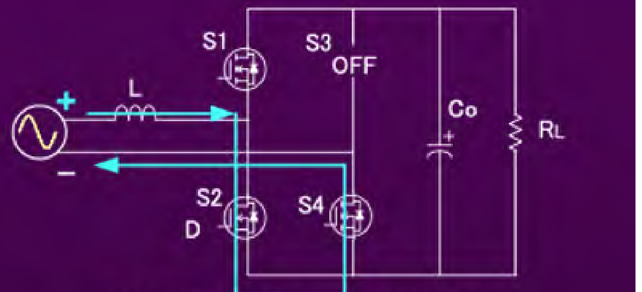
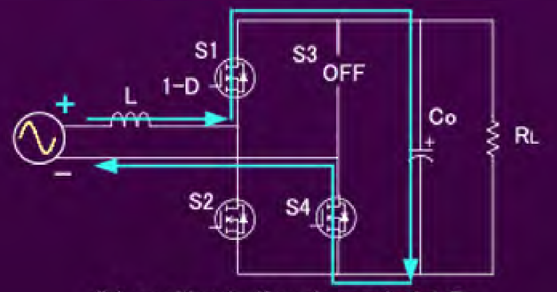


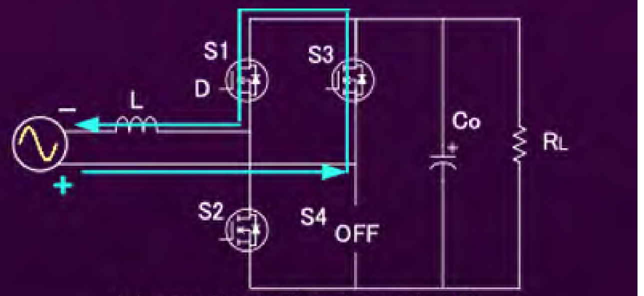
Figure 12. Totem-pole PFC Block diagram



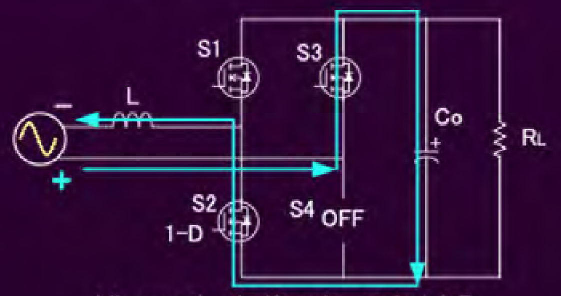
(a) positive half cycle: period D



(b) positive half cycle: period 1-D



(c) negative half cycle: period D



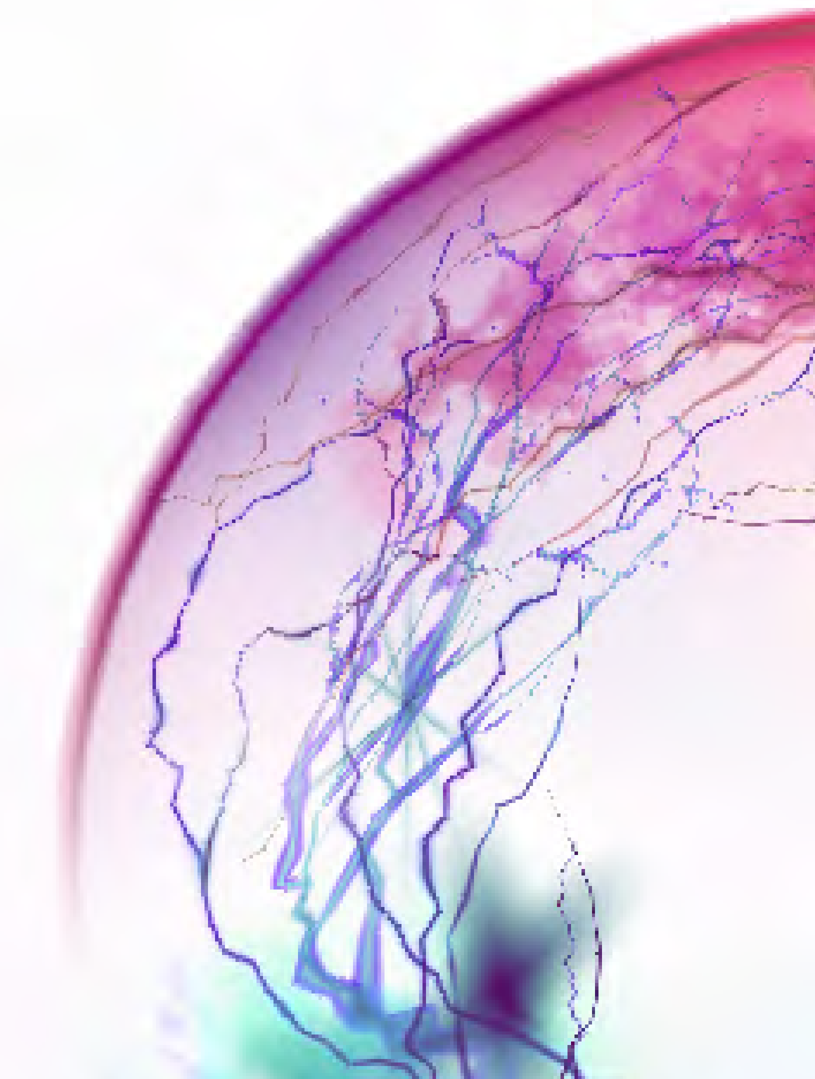
(d) negative half cycle: period 1-D

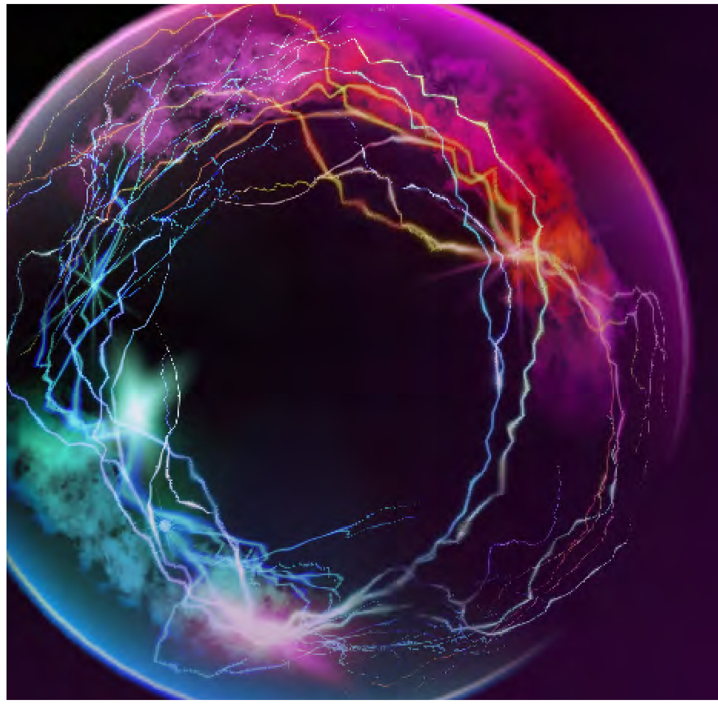
Figure 13. Operation Diagram by State

To verify the contribution of the 4th generation SiC MOSFETs to the loss reduction of the Totem-pole PFC, an experiment was conducted using the actual board. Table 3 shows the evaluation conditions of the PFC and the specifications of the SiC devices used. When the output voltage is 400V, a SiC MOSFET with 750V breakdown voltage is matched. In this case, SCT4045DR is used. As result, the measured efficiency is over 98% at 1.5kW half load and 97.6% at 3kW full load.

Input Voltage	230VAC
Output Voltage	400VDC
Output Power	3kW
Inductance L	500μH
Switching Frequency	65kHz
4th Generation SiC MOSFET	SCT4045DR 750V/45mΩ
3rd Generation SiC MOSFET (as a reference)	SCT3060AR 650V/60mΩ

Table 3. PFC Evaluation Condition





SUMMARY

SiC power semiconductors are key power devices for increasing the convenience and power conversion efficiency in applications where high voltage and high current density are progressing, such as EVs, data centers, base stations, and smart grids.

In the 4th Generation SiC MOSFET, the trade-off of the trench structure has been greatly improved, and the normalized on-resistance has been further reduced.

The high-speed switching performance and low on-resistance of the 4th Generation SiC MOSFETs will greatly contribute to the improvement of power conversion efficiency.

To learn more about ROHM SiC power semiconductors

CLICK HERE

INTRODUCTION TO **STARPOWER**, REVOLUTIONIZING IGBT TECHNOLOGY

Figure 1 StarPower Automotive Campus in Shanghai

The company was founded in 2005 as an independent producer of power modules specializing in the design and manufacture of IGBT modules for industrial and automotive applications. With two main manufacturing locations in the Greater Shanghai area, the company has been continuously investing in extending its capabilities both in terms of technology and capacity. In 2020, the company celebrated its IPO in Shanghai by opening new resources to secure future growth opportunities. Today, a multinational team of leading industry professionals ensures that the company is prepared for the opportunities and challenges of the next decade.

DREAM IS DRIVEN BY QUALITY

When MIT graduate Dr Hua Shen set up the company near his former hometown, he made quality the key distinguishing factor from other domestic manufacturers of power modules; a central principle that has been guiding the company ever since. This process is ensured by constant investment in automation and state-of-the-art production equipment as well as the acquisition of expertise from within the power industry.

StarPower has set out a clear path for future annual growth in order to benefit from the great market trends of energy transition from fossil fuels and further electrification across all aspects of daily life. In China, we are a leading domestic module manufacturer, and in Europe we work with a wide range of multinational customers who value trust and whose trust we have earned.

FOCUS ON IGBT(INSULATED-GATE BIPOLAR TRANSISTOR) TECHNOLOGY

Our strategy is to be an independent second source supplier for a wide range of automotive and industrial applications. This has so far been achieved by firstly, scaling up a reliable and high performing trench IGBT technology in 650 Volt, 1200 Volt and 1700 Volt. At the same time, we continue to support our fast NPT IGBTs, which we ship in large volumes for use in welding applications and other large markets. Supporting our customers across the entire spectrum of industrial applications, we offer a wide range of industry-standard packages and topologies for markets such as industrial motor drives, solar and wind inverters, welding and UPS.

In 2021, StarPower opened a brand-new production facility specially designed for discrete IGBTs and since then, have launched an initial range of TO-220 and TO-247 IGBT devices. Further extensions of this product range, including SMD packages, are expected to follow over the course of 2022 and beyond.

GROWTH MARKET EV

The second growth pillar for StarPower is within the rapidly expanding segment of E-mobility. We have a substantial number of modules already being successfully utilized by the automotive industry today ranging from standard solutions to bespoke, customized packages. Our manufacturing hub in Shanghai is specially designed to accommodate current and future automotive business and lies within a local competence cluster around E-mobility that offers valuable synergies for future expansion. Also our European R&D Centre based in Nürnberg plays a pivotal role here in developing the next generation production processes vital for the automotive market as well as providing technical support to our European customers.

VALUING LOCAL SUPPORT FOR OUR CUSTOMERS

In addition to our sales and FAE team in China, StarPower Europe was founded in 2015 in order to support our ever-growing European customer base. Our expanding team of experienced sales engineers together with our specialized distribution partners is dedicated to support the requirements of the European market.

For further details, please feel free to contacting us at **info@starpowereurope.com**

THE INTERVIEW WITH MARCUS LIPPERT

Business Development Manager
StarPower Europe

Editor: Mr Lippert, as Business Development Manager for StarPower Europe, how are you finding the current market situation?

Joining the chorus of many of my colleagues across the industry, I must say that I have never experienced anything like the current allocation through the course of my career. Such a prolonged period of sustained high demand across all industry segments combined with shortages in production capacity as well as materials is truly remarkable. On a positive note, however, shortages often spark creativity and force us to look for different opportunities, sometimes even trying out what had been considered unthinkable before. For StarPower Europe, the shortage has opened up a lot of new opportunities with many more in the pipeline.

Editor: Does that mean you are filling the gaps where your competitors cannot supply?

It is true to say that we have been able to help out a number of customers to keep their production going and the list of established European manufacturers putting trust in our modules has grown significantly. It is, however, not as simple as that as the power module plays a pivotal role in our customer's applications and changes often require lengthy test and approval procedures to ensure performance and the utmost system reliability. This was clear to us from the start and our strategy is definitely not to act as a firefighter while supply is short, we are in this for the long run.

Editor: What is your long-term strategy for the European market?

When setting up StarPower Europe in 2015, our management was clear that gaining customers' trust in our products and technology is not achieved overnight. At the same time, we always believed that the current dependencies on a small number of IGBT suppliers was not sustainable for the market in the longer term, especially as we live on the verge of a full transition from a fossil-fuel based economy to a new system based on renewable energies. The first impacts of Climate Change and not least the war in the Ukraine are likely further speed up this process, which will lead to rapidly increasing demand for power electronics across all industry segments. In that environment, the market needs competition, diversity and above all alternatives and that is what we are here to offer. Europe is a strategic growth market for us and we are here to stay.

Editors: What local support does StarPower offer in Europe?

We have a growing team of experienced sales engineers supported by our sales office in Cadenazzo/ Switzerland that handles all orders and logistics for our European clients. In addition, our European R&D centre in Nürnberg/ Germany helps us to provide technical support to the local market. Further, we work very successfully with several distributors, most of them specializing in power electronics who help us to extend our offer to SME customers and supply the market from stock. A key pillar here is our relationship with Farnell as our strategic catalogue distribution partner that has brought substantial benefits to our growing customer base and significantly shortened the time between test and approval.

Editor: How is StarPower preparing for the challenges of the coming years?

StarPower was founded in 2005 with a clear vision to become an independent manufacturer of power modules with a focus on IGBT technology. We have been enhancing our capabilities ever since and, based on our rapid growth in the Chinese market, expanded our production capacity continuously and in significant steps with further expansions already under way.

On the product side, we are working on a new generation of IGBT modules in 750V and 1200V targeted at growth markets such as EV drivetrain applications, high efficiency industrial drives and solar converters. First product launches are planned over the course of 2022 and will open up a lot of new opportunities for existing and new customers.

PRODUCT SNAPSHOTS

FAST NPT-IGBT

Quick facts

- *Available in 1200V as half bridge and single switch*
- *Fast NPT technology for ultra-low switching losses*
- *10 us short circuit capability*
- *Fast and soft-recovery anti-parallel FWD*
- *Isolated copper base plate using DBC technology*

Applications

- *Welding*
- *Inductive heating*
- *Switch mode power supply*

DISCRETE IGBT

Quick facts

- *Available in 650V and 1200V*
- *Low V_{cesat} trench IGBT technology*
- *Low switching losses*
- *Fast and soft-recovery anti-parallel FWD*

Applications

- *Motor drive inverter*
- *AC and DC servo amplifier*
- *UPS*

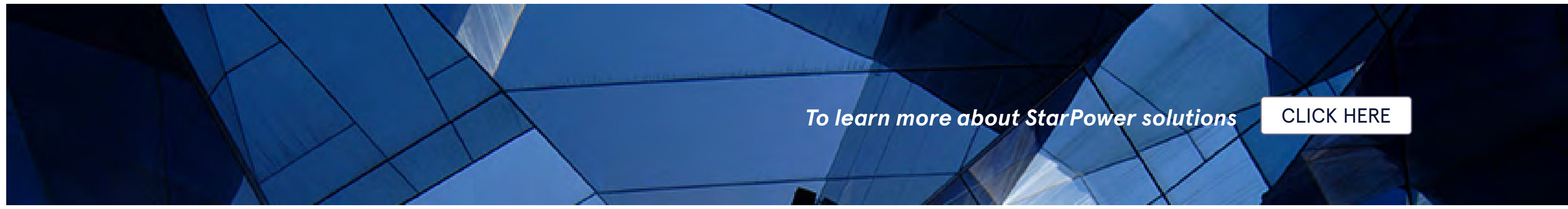
HIGH POWER IGBT

Quick facts

- *Available in 1200V and 1700V*
- *Half bridge up to 1400A, single switch up to 3600A*
- *Low V_{cesat} trench IGBT technology*
- *Fast and soft-recovery anti-parallel FWD*
- *Isolated copper base plate using DBC technology*

Applications

- *High power converters*
- *Motor drives*



To learn more about StarPower solutions CLICK HERE

Author
Bob Zollo,
Keysight Technologies, Inc.

HOW TO CHOOSE THE **RIGHT BATTERY** FOR YOUR NEXT WIRELESS APPLICATION

Finding the right battery to achieve the right runtime for your wireless device is not a simple topic. By no means does this article claim to be an exhaustive treatment of every detail of every step, but this article will provide an overview to the entire subject so that you can use it as a template for your selection process.

First, you must consider the power demands of the device and the desired runtime.

By taking the average current you expect to draw from the battery and multiplying it by the number of hours of desired runtime, you can calculate the capacity of the battery you will need.

Note that this is only a rough estimate. Actual performance conditions, such as operating temperature, peak current, and duty cycle (ratio of peak current to quiescent current), will impact how much total energy (i.e., capacity) the battery will deliver to the device and therefore impact runtime.

In other words, even though a widely varying dynamic current can be represented by a single average current, the capacity that the battery delivers in response to a widely varying dynamic current will not be the same capacity that the battery delivers in response to a constant current equal to the mathematical average of the dynamic current.

For example, if your device requires 180 mA average current, and you want it to run for 10 hours, you would need a 1800 mAH (milliamp-hour) battery. If you device pulls 1.7 A peak currents for 10% of the operating time and 10 mA for the remaining 90% of the time, while this averages to 180 mA, you may not achieve that same 10 hours of runtime from an 1800 mAH battery (depending on the battery chemistry and discharging duty cycle timing).

The next step is to select a candidate battery based on the manufacturer’s data sheet for the battery.

Then, you would need to evaluate how well a battery performs relative to its data sheet. Depending on the battery and the manufacturer’s quality control processes, you may find that there are inconsistencies within and between batches of batteries. The manufacturer may not specify this spread in performance, so you may have to set up a standard suite of tests to verify the battery spec sheet for a sampling of batteries. From this statistical data, you can determine the range of variation. You should select a battery based on the worst case capacity out of the samples analyzed. Any battery you receive with greater than worst case capacity will just mean extra runtime for your device.

In addition to testing across batches, you will probably want to test at various conditions (discharge rates, recharge rates, and temperatures) to create profiles of how the battery will respond under different operating conditions. It is relatively easy to find test equipment to implement a standard suite of tests on a battery. Specialized battery test systems provide turnkey software that allows you to set up typical tests to measure battery performance and capacity. (See **figure 1**.)

The test data is stored in a database that allows you to generate the statistics needed to look at variation within and across samples. This testing will yield your own verified version of the manufacturer specs.

TYPICAL BATTERY TESTS PERFORMED BY TURNKEY BATTERY TEST SYSTEMS

Voltage vs state of charge

This is typically a family of curves with each curve generated at various discharge rates while holding temperature constant
-OR-
with each curve at a specific temperature while holding discharge rate constant

Capacity vs temperature

This is a family of curves at various temperatures holding discharge rate constant

Capacity vs discharge rate

This is a family of curves at various discharge rates holding temperature constant

Capacity vs number of charge-discharge cycles

This is also known as a cycle life chart and is a curve generated at a given charge rate, discharge rate, and temperature

Internal resistance vs number of charge-discharge cycles

This is a curve generated at a given charge rate, discharge rate, and temperature

Internal resistance vs state of charge

This is a curve generated at a given temperature

Figure 1 List of typical battery tests performed by turnkey battery test systems

> What is most important is how the battery will operate under the real world conditions that it will experience when it is used in the final device as it is operated in the user's real use case.

Of course, there may be multiple use cases for the wireless device. For example, if the device is a smartphone, the real use case will vary by user, so it is up to the device designer to create one or more appropriate use cases. Each case would include a sequence of talking, texting, accessing webpages, streaming video, playing games, and listening to music. The amount of time spent on each task would vary between use cases, resulting in some use cases that have high current demand and some that are less demanding.

This kind of testing to see how the device will really deplete the battery is known as a battery rundown test. This is the most difficult test to implement. To perform a battery run down test under real world conditions, you have two options.

1 You can test the battery in the real operating environment while it is providing power to the wireless device. In this test, the wireless device is operated in the desired use case and the battery is run down starting with a fully charged battery. During the test, you continuously measure and log current flow between the battery and the wireless device and continuously measure and log voltage across the battery. With these two measurement waveforms, you can see the real dynamic current flowing from the battery and you can see the resulting battery voltage as it runs down during wireless device operation. This will give you the most realistic assessment of battery runtime.

2 Similar to option 1, except in this case you can test the battery using a simulation of the wireless device to run down the battery. The wireless device is simulated by an electronic load that is continuously reprogrammed to draw the same dynamic waveform as the wireless device would draw during the specific use case that you are trying to test. While this is just a simulation and may not give the most realistic assessment of runtime, this method gives you the most flexibility as the simulation can be easily reprogrammed to simulate different use cases.

See **figure 2** for an example of an instrument that can perform either of the above battery rundown test options.

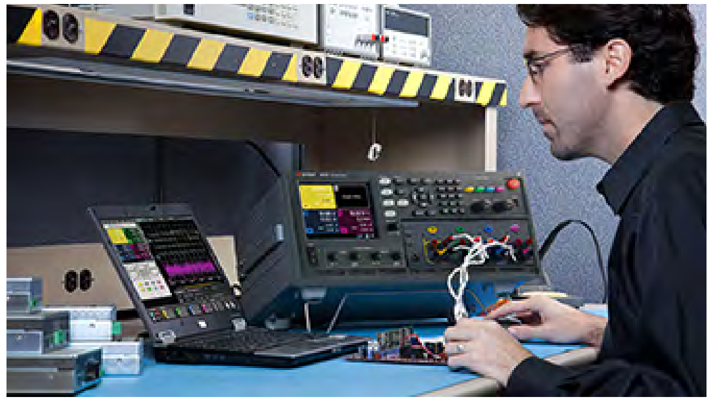


Figure 2 The Keysight N6705C DC Power Analyzer, outfitted with a Keysight N6781A Battery Drain Analyzer module and BV9201B PathWave BenchVue Advanced Power Control and Analysis Software, provides a complete instrumentation solution for performing battery rundown tests.

In summary, battery selection consists of finding the right battery, verifying its specs to understand variability within and across batches and across manufacturers, and finally measuring its actual runtime under real world conditions.

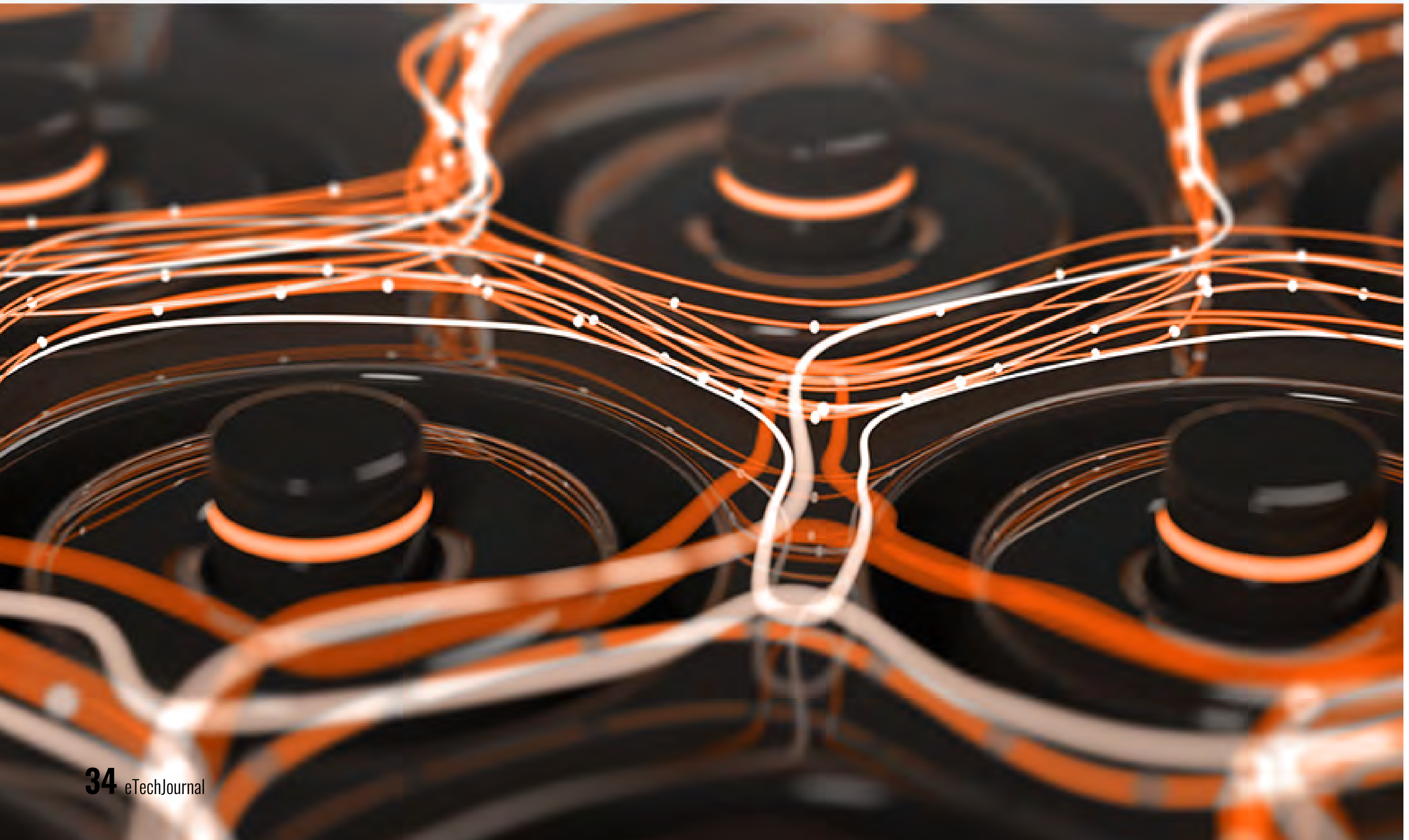
To learn more about Keysight N6705C DC Power Analyzers and N6781A Battery Drain Analyzer

CLICK HERE

Author
Brian Whitaker,
Keysight Technologies, Inc.

HOW TO OVERCOME **IOT BATTERY LIFE** CHALLENGES

Why IoT Battery Life Does Not Meet Expectations and How To Fix



Battery life can contribute significantly to the cost and reliability of Internet of Things (IoT) infrastructure.

While for consumer electronic devices, battery life is often a critical purchase consideration. Therefore, the fact that the calculated battery life of IoT devices is often inaccurate is a significant issue for manufacturers.

One method to measure battery life is to divide the battery capacity in amp-hours by the average current drain in amps which gives you a time in hours. However, in the real world, this calculation is overly simplistic.

This formula can generate inaccurate results because devices use different power modes, including active, sleep, and hibernate.

Additionally, operating modes such as constant power and constant resistance will draw current from the battery differently and change the battery lifetime.

It is essential to fully understand how a battery responds to these different scenarios and the typical usage patterns of the device to predict battery life accurately. In addition to varying current drain, battery capacity is variable, depending on the average discharge current and usage patterns.

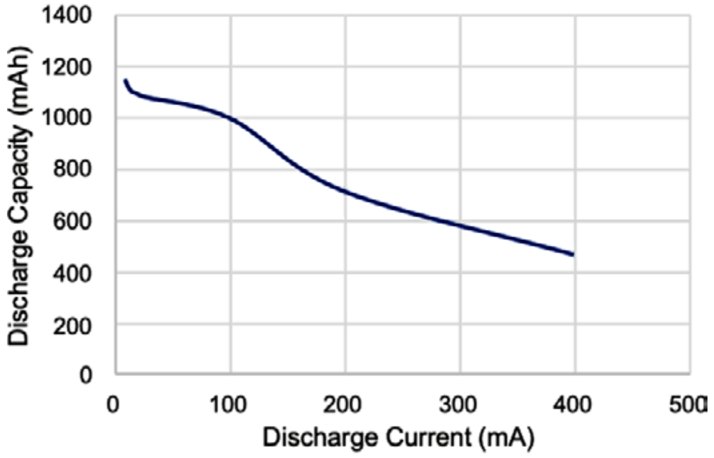


Figure 1 1,100 mAh alkaline cell, 0.9V cutoff voltage - discharge capacity variation

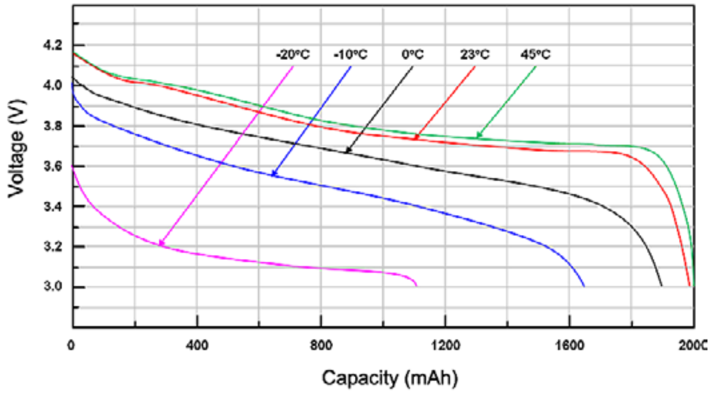


Figure 2 1,000 mAh Li-ion cell, 3 V cutoff voltage – temperature variation

You can see in **Figure 1** that there is a considerable variation in discharge capacity based on the discharge current level for an alkaline cell. Furthermore, temperature can affect battery life, so it is critical to consider this. **Figure 2** shows how temperature can affect the capacity curves of a battery.

The following are additional factors that can lead to a longer computed battery runtime as compared to real-world usage:

- Battery model / profile is not available to the engineer.
- Battery profiles are not generated with accurate device operating conditions.
- Current consumption measurements are not accurate.
- Voltage drops such as a device shutting down when the voltage reaches a cutoff range are not considered.

A solution to accurately predict real-world battery life is the use of battery emulation and test software. It can profile batteries through charging / discharging to create unique battery models. Test software can also emulate charge states to reduce test time, improve safety, and gain insight to extend battery life.

Another critical capability of test software is the ability for engineers to visually track charging / discharging batteries to determine capacity.

Finally, test software can cycle batteries to assess loss of capacity and reduction of battery life.

Batteries and Power Management

Alan Wadsworth

Business Develop

SUMMARY

Keysight's ***Batteries and Power Management Webinar*** provides more detailed information on the capabilities of battery emulation software, including a demonstration of ***BV9210B PathWave BenchVue Advanced Battery Test And Emulation Software***. The whitepaper ***Measuring IoT Battery Life with Test Software and Hardware*** also discusses options for measuring battery life, including utilizing battery emulation software.

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- 3 year warranty

Models	Power (W)	Peak Power (W)	Output Voltage (V)	V_{ADJ} Range (V)	Efficiency (typical)
TIB 080-112	80	120	12	11.8–15.0	88.0 %
TIB 080-124	80	120	24	23.5–28.0	90.0 %
TIB 080-148	80	120	48	47.0–56.0	90.0 %
TIB 120-112	120	180	12	11.8–15.0	94.0 %
TIB 120-124	120	180	24	23.5–28.0	94.0 %
TIB 120-148	120	180	48	47.0–56.0	94.0 %
TIB 240-124	240	360	24	23.5–28.0	95.0 %
TIB 240-148	240	360	48	47.0–56.0	95.0 %
TIB 480-124	480	720	24	23.5–28.0	95.0 %
TIB 480-148	480	720	48	47.0–56.0	95.0 %

WÜRTH ELEKTRONIK
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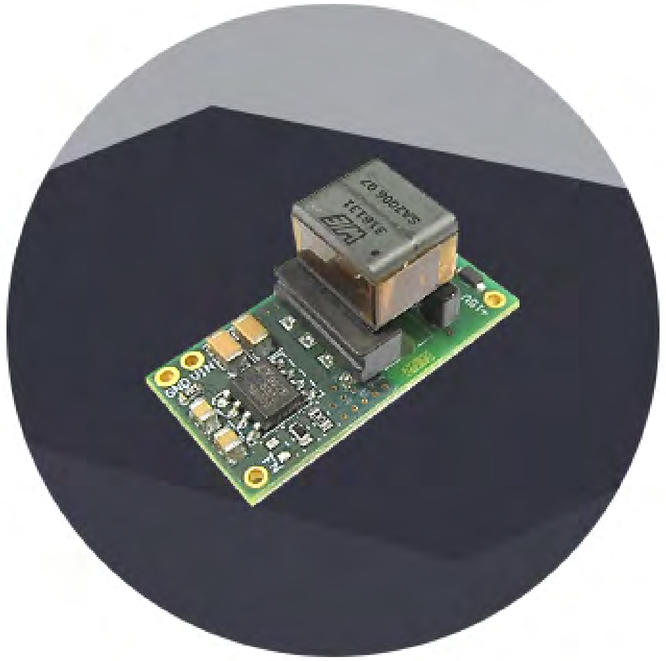
Author
Andreas Nadler, Eleazar Falco, Emil Nierges
Editor: Gerhard Stelzer

POWER SUPPLY DESIGN AUXILIARY GATE DRIVE TRANSFORMER

SiC and GaN MOSFETS enable efficient and space-saving power supply designs with higher switching frequencies. With the new transformer series WE-AGDT designers can easily implement a compact and efficient gate driver supply with up to 6W output power capability.



Wide bandgap power semiconductor devices like Silicon Carbide (SiC) MOSFETs are enjoying growing popularity in many modern power electronic applications like E-mobility and renewable energy.

Their extremely fast switching speed helps to increase efficiency and reduce the overall size and cost of the system. However, fast switching together with high operating voltages and increasing switching frequencies present important challenges to the gate driver system.

Rugged galvanic isolation, compliance with safety standards, control signal noise immunity and EMI performance are just some of the most important aspects to consider. An optimal design of the isolated auxiliary supply providing the voltage and current levels to drive the SiC/GaN device is critical to help the full gate driver system meet the many requirements set by state-of-the-art applications.

REQUIREMENTS FOR SIC/GAN GATE CONTROL

In applications using SiC/GaN high-voltage semiconductor devices operating under hard-switching, galvanic isolation is a common requirement for safety and functional reasons, where depending on the application, basic or reinforced insulation will be required. The operating voltage, insulation material, pollution degree and the applicable regulatory standards set the minimum creepage and clearance distances as well as the dielectric isolation voltage requirement affecting the components placed across the isolation barrier.

The high-speed isolated gate driver IC (e.g. TI UCC21520) and the transformer in the isolated auxiliary power supply (DC/DC Block in **figure 1**) both ´bridge´ this isolation barrier, thus having to meet stringent safety and functional requirements.

Some of the latest SiC-MOSFET devices require typical gate voltages between +15 V and +20 V for full turn-on and between 0 V and -5 V for reliable turn-off. For a GaN-FET usually only +5 V and 0 V are required respectively, although a small negative voltage can also be applied to ensure turn-off in presence of excessive gate voltage ringing. Please note that these values vary depending on the manufacturer.

In **figure 1**, a half-bridge configuration is shown, and several of these stages are typically required in an inverter circuit to drive AC-motors in the kW range. Each SiC/GaN-FET requires an independent gate driver stage with its own isolated auxiliary supply. This not only enables individual control of each SiC/GaN device, but also helps to keep the gate current loop small and local to the device, minimizing the adverse effects of parasitic loop inductance and ground bounce caused by the very high $\Delta I/\Delta t$ generated during the switching transition (**figure 2** and **figure 3**).

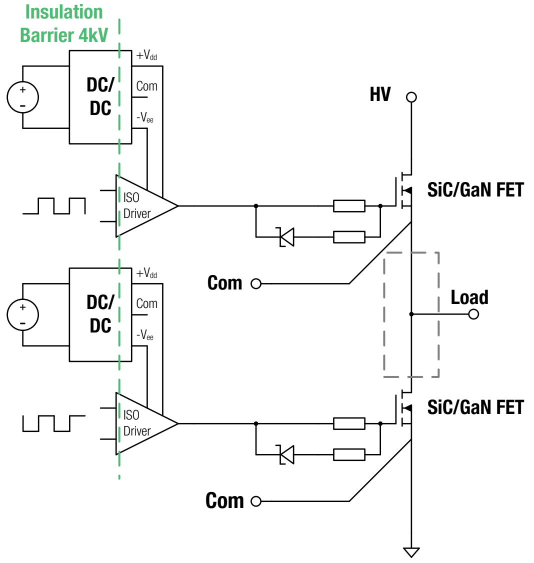


Figure 1 : Overview of a HV half-bridge control of the High-side & Low-side SiC-MOSFET.

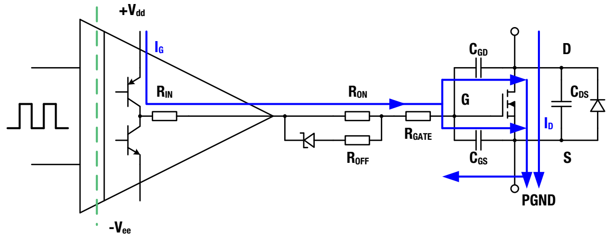


Figure 2 : High $\Delta I/\Delta t$ current paths on turn-on of SiC/GaN FET.

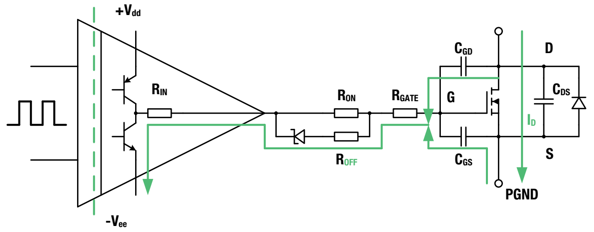


Figure 3 : High $\Delta I/\Delta t$ current paths on turn-off of SiC/GaN FET.

If ignored, this may lead to uncontrolled turn-on/off of the MOSFET and thermal issues. Some SiC MOSFETs are designed with an additional low impedance Kelvin source connection (**figure 4**) for a gate current return path. This connection does not carry the high switching current and therefore has a lower interference potential than the source connection, which significantly improves gate driving (e.g. Infineon IMZ120R045M1 1200 V / 52 A).

Regarding the auxiliary supply, it should be compact with its output capacitors (with minimal ESL and ESR) placed very close to the gate driver and SiC/GaN device to minimize the gate current loop and associated parasitic effects.

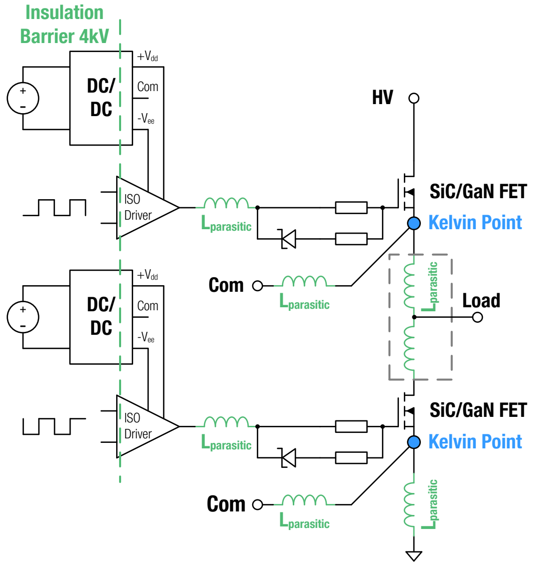


Figure 4 : Kelvin connections and critical parasitic inductances in a half-bridge configuration.

DRIVING SIC-MOSFETS

There is currently a large selection of compact, isolated 1 – 2 W DC/DC converters available on the market. For a SiC-MOSFETs like the Infineon IMZ120R045M1 1200 V / 52 A, up to 1 W power requirements per device can be estimated (example calculation (1)). However, an application with over 5 kW load power would require the use of either a SiC-MOSFET module (e.g. ROHM BSM600D12P3G001 1200 V / 600 A) or alternatively several discrete SiC-MOSFETs in parallel (current sharing). In a module solution, several semiconductor dies are paralleled to form the final SiC-MOSFET.

This technique reduces the effective RDS(ON) but results in a higher total gate charge, QG, requiring more drive power from the gate driver system power supply (example calculation (2)). Above 2 W of power, there is only a very limited selection of off-the-shelf isolated DC/DC converter modules, which despite their convenience, they often come at a premium cost while being larger than discrete solutions and with efficiencies under 79%.

The total power to drive a SiC gate is given by equation 1:

$$P_{GATE} = P_{DRIVER} + (Q_G \text{ X } F_{SW} \text{ X } \Delta V_{GATE}) \qquad \textbf{(Eq. 1)}$$

With,
P_{GATE}: Total power required to drive the SiC device gate
P_{DRIVER}: Power loss in the gate driver section (approx. 0.3 W)
Q_G: Total gate charge value (from datasheet)
F_{SW}: Maximum switching frequency
ΔV_{GATE}: Maximum voltage swing at the gate from –Vee to +Vdd (e.g. -4 V to +15 V = 19 V)

Example calculation (1) with Infineon IMZ120R045M1 1200 V / 52 A:

$$P_{GATE} = 0.3 \text{ W} + (62 \text{ nC x } 100 \text{ kHz x } 19 \text{ V}) = 0.42 \text{ W}$$

Example calculation (2) with ROHM BSM600D12P3G001 1200 V / 600 A:

$$P_{GATE} = 0.3 \text{ W} + (1900 \text{ nC x } 100 \text{ kHz x } 19 \text{ V}) = 3.91 \text{ W}$$

The SiC-MOSFET modules currently available can feature a total gate charge from as little as a few hundred nC up to 3000 nC. The higher their blocking voltage and power ratings, the higher their gate capacitance.

With an increase in the switching frequency or load power (requiring more paralleled SiC devices with the corresponding increase of the total gate charge), 6 - 10 W of driver system power can be expected for the most demanding present and near-future applications.

> Efficiency, size and especially the parasitic coupling capacitance are important parameters in high-performance SiC-based systems.

As the switching speed increases, with the resulting very steep switching edges, the harmonics couple capacitively between the converter output stage/gate driver (high-voltage side) and the low-voltage control side.The parasitic capacitance (CP) between primary and secondary sides in the auxiliary gate driver supply is mainly set by the interwinding capacitance of the DC/DC power transformer. With the latest SiC-MOSFETs switching at ΔU/Δt slew-rates of 100 kV/us, 10 pF parasitic capacitance would cause a peak displacement current of 1 A across the isolation barrier. A high displacement current can degrade the insulation barrier in the long run (dielectric stress), disturbs the control signals and leads to common mode currents, which are a typical source of EMI issues.

$$IP = CP \text{ x } \Delta U/\Delta t \qquad \textbf{(Eq. 2)}$$

With,
IP: electrical displacement current
CP: parasitic coupling capacitance

It is generally recommended to keep CP in the auxiliary supply below 10 pF. Note however that the maximum capacitance tolerated by the system will depend on the switching speed and the common-mode transient immunity (CMTI) capability of the gate driver IC used.

Würth Elektronik has addressed these challenges by presenting suitable solutions with its new SiC gate driver power supply reference designs. These designs are built around the new WE-AGDT transformers featuring very low interwinding capacitance down to 6.8 pF. They provide different well-regulated bipolar as well as unipolar gate drive voltages with an output power capability of up to 6 W, while keeping an extremely compact form factor (27 x 14 x 14 mm (L x W x H)). (figure 5).

Figure 5 : Würth Elektronik reference design for a compact, isolated DC/DC converter for HV SiC/IGBT Gate Driver.

SIC GATE DRIVER POWER SUPPLY REFERENCE DESIGN

The bipolar reference design (RD001) has the following features:

- Input voltage range: 9 - 18 V
- Output voltage variants:
  +15 V / -4 V, +19 V / -4 V and +20 V /-5 V.
- Peak efficiency of up to 86 % (83 % @ 6 W)

The unipolar reference design (RD002) has the following features:

- Input voltage range: 9 - 18 V
- Output voltage variants: +15 V, +18 V and +20 V
- Peak efficiency of up to 88 % (86 % @ 6 W)

In addition to the LT8302 controller (Analog Devices), the key component in these reference designs are the new WE-AGDT transformers, built on a compact EP7 bobbin package, and with the following specification:

- Wide Input Voltage Range: 9 - 36 V
- Very low interwinding capacitance typ. 6.8 pF
- Very low leakage inductance for highest efficiency
- SMD Pick & Place ready
- Safety Standard IEC-62368-1, IEC-61558-2-16
- Basic Insulation for 800 V (peak)
- Dielectric Isolation min. 4 kV AC
- Temperature Class B 155 °C
- AEC-Q200 Qualification

The reference design documents RD001 [1] and RD002 [2] provide detailed information and are available for download on Würth Elektronik website, alongside with the corresponding PCB layout files (Altium Designer) as well as PCB fabrication files.

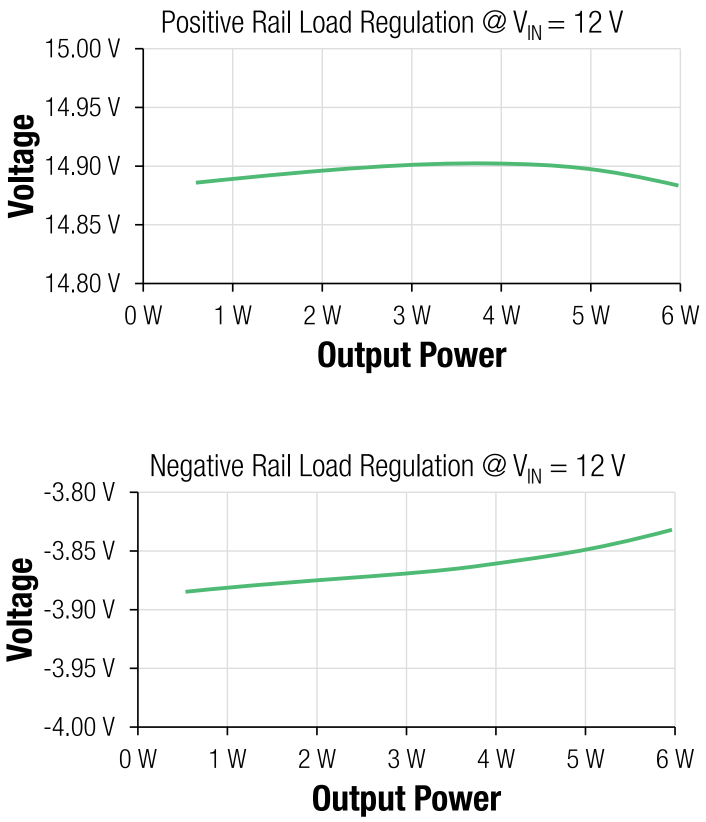


Figure 6 : Voltage of positive and negative rails versus load power for +15V/-4V variant (@ VIN (nominal) = 12 V)

Please note that the power capability of these designs can easily be scaled to 10 W with an EP10 bobbin and appropriate uprating of some components. Würth Elektronik engineers offer support for specific requirements.

The new WE-AGDT Auxiliary Gate Drive Transformer series [3] from Würth Elektronik features eight different transformers, each of them optimized for different specifications and their own reference design. They offer design flexibility and ease of use while providing the gate-drive voltage levels, drive power and low parasitic capacitance required to drive state-of-the-art SiC-MOSFETs, silicon IGBTs and power-MOSFET devices.

AUTHORS

Eleazar Falco
holds a degree in Electrical Engineering from the University of Elche in Spain. In 2014, he joined Dyson in the United Kingdom, where he worked in electronics hardware development of home appliances, focusing on offline power supply and motor control. Since 2018, Eleazar is an Applications Engineer for switching power supplies at Würth Elektronik in Germany.

Andreas Nadler
graduated from the Kempten Technical School as a state-certified electrical engineer. He then worked for several years as a hardware engineer in the field of switched-mode power supplies and analog circuit technology. Since 2015, Andreas has been a Field Application Engineer at Würth Elektronik eiSos GmbH in the business unit for passive and active components. There he specializes in the design of EMC-compliant power supplies and interfaces, as well as the overall interference suppression of electronic assemblies.

Emil Nierges
studied electronics, telecommunications and information technology at the Technical University of Cluj-Napoca, Romania where he graduated with a degree in Electrical Engineering. After graduation he moved to Canada and worked in the hardware development of telecommunication testing products. In 2012 he relocated to Germany to join Wurth Electronics Midcom as a Product Applications Engineer supporting leading IC manufacturers with custom magnetics for reference designs. Since 2019, Emil is a Product Manager with a focus on developing standard magnetic components.

To learn more about Würth Elektronik WE-AGDT Auxiliary Gate Drive Transformer series CLICK HERE

Reference design RD001
www.we-online.com/rd001

Reference design RD002
www.we-online.com/rd002

WE-AGDT Auxiliary Gate Drive Transformer series from Würth Elektronik
www.we-online.com/catalog/WE-AGDT

BOURNS®

CIRCUIT PROTECTION SOLUTIONS FOR POWER MANAGEMENT APPLICATIONS

To help enhance reliability and fulfill regulatory requirements in power supplies, it is recommended that engineers include circuit protection in their designs. Areas where circuit protection may be needed include the power input port, the power output port, or control/sensing ports.

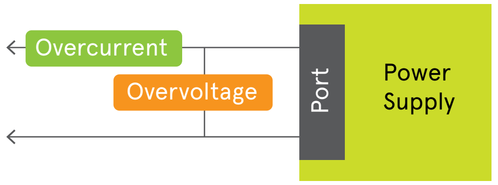


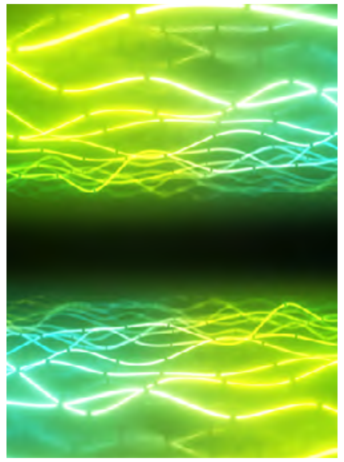
Figure 1

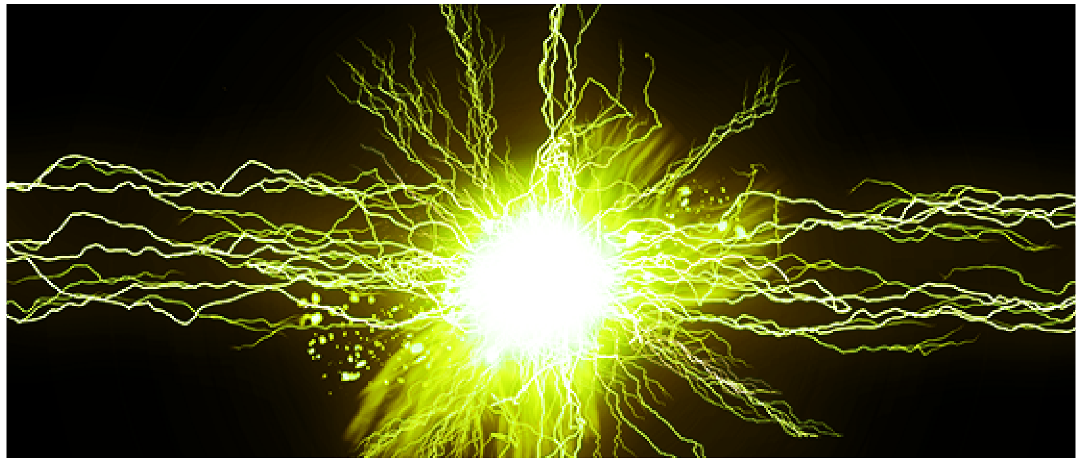
Circuit protection encompasses both overvoltage and overcurrent protection. Overvoltage protection works to limit the voltage applied to the supply to levels that can be tolerated without damage. Overcurrent protection is used to limit the current when it exceeds a specified maximum level chosen by the designer.

The typical circuit protection arrangement at the power supply input is shown in Figure 1.

The overcurrent device is first so that it protects against failures of the overvoltage element as well as the rest of the power supply.

This can pose a challenge to designers because lightning and other surge events will activate the overvoltage element and the resulting surge current will be passed through the overcurrent device. Therefore, a minimum overcurrent trip value will need to be specified to allow this surge current to pass without permanently taking the power supply offline.





OVERCURRENT PROTECTION TECHNOLOGIES

The most common overcurrent technology found at the power input port is a conventional fuse.

Bourns offers a wide range of SinglFuse™ surface mount fuses. These are available in fast-acting, slow blowing and high inrush current tolerant reaction time profiles to allow designers the ability to tailor the fuse response to meet their overcurrent protection needs. For designs that can benefit from circuit protection that offers series resistance to limit inrush currents, Bourns offers a range of fusible resistors.

In various power supply applications, occasional overcurrent events at the input may be expected due to accidental temporary shorts and overloads. To eliminate nuisance fuse blowing in these applications, Bourns offers self-resetting polymer and ceramic PTC (positive temperature coefficient resistor) devices.

OVERVOLTAGE PROTECTION TECHNOLOGIES

Bourns also has a broad portfolio of overvoltage product technologies. Metal Oxide Varistors (MOVs) are popular overvoltage protection solutions where designers select the proper voltage rating to match their line voltage rating.

Designers will typically add a suitable safety margin to the power supply rated voltage input to allow for temporary line voltage swells. It is also important to choose the surge rating of the MOV to make sure the voltage does not exceed requirements during a surge of a certain intensity. Larger diameter MOV devices can handle higher surge currents and better limit the surge voltage allowed into the power supply.

To reduce the stress on the MOV, designers can place a GDT in series with the MOV. This effectively keeps the MOV disconnected until a significant voltage surge occurs at which point the GDT triggers and reconnects the MOV for the duration of the surge which virtually eliminates the aging of the MOV and greatly enhances reliability. Correctly designed, this arrangement also allows designers to reduce the voltage margin as temporary overvoltage events will not trigger the GDT.

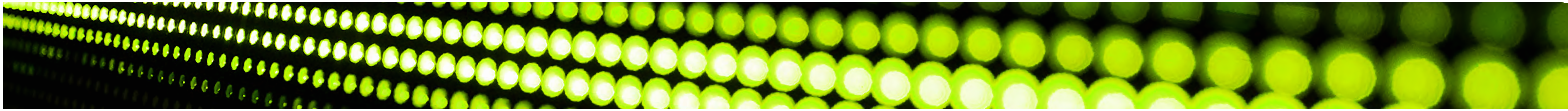
Bourns has innovatively designed two product lines that integrate the GDT/MOV functionality into a single device with matched MOV and GDT ratings.

- ***The Bourns® GMOV™ helps developers save board space and reduce placement costs.***
- ***The Bourns® IsoMOV™ hybrid protector offers the further advantage of enhanced surge ratings for the same diameter MOV or GMOV.***

Bourns has two other product line solutions that may be suitable for power management protection. An AC Transient Protector (ACTP) is effectively a solid-state version of a GDT that, when paired with an MOV, allows for precise voltage triggering.

The Bourns® Model ACTP250J1BJ bidirectional thyristor is an optimal solution to protect a power supply from damage due to an overvoltage condition on its AC input lines. Power TVS (PTVS) devices are another premium option that deliver the inherent reliability a silicon solution with lower, precisely controlled clamping voltages.

For ultra-fast and efficient in-line overvoltage protection, Bourns offers a protection circuit that combines its IsoMOV™ protectors, Bourns® TBU® (Transient Blocking Unit) devices and TISP thyristor technologies together. This solution can not only offer assured limits to voltage let through to the power supply, but can also protect against sustained overvoltage events without damage and often without interrupting the operation of the power supply.



BOURNS CURRENT SENSE RESISTORS FOR POWER MANAGEMENT

For power management applications, current sense resistors from Bourns give designers a simple and cost-effective direct method of accurate current measurement.

These resistors detect and convert current to an easily measured voltage, which is proportional to the current through the device.

New model series feature Bourns' metal foil technology construction that provide low TCR, low inductance, low noise, excellent reliability and very low resistance values for long-term stability.

These attributes make it possible to achieve best-in-class measurement precision delivering an optimal current sensing solution for power supply, stepper motor drive, and input amplifier applications.

Plus, Bourns also offers new smaller package sizes that are particularly well-suited to meet space-constrained requirements.

With extensive expertise in current sense resistor development, Bourns continues to design products with low TCR, which is determined by characteristics such as the materials used in the resistive element, power rating, and physical size of the component. Bourns has leveraged metal foil technology to achieve lower resistance values, ranging from 5 to 40 milliohms, and still provide power ratings of 0.25 to 1 W in components small enough for mobile applications.

Bourns offers efficient, reliable, cost-effective and accurate measurement solutions for battery management system (BMS), industrial control and other high current applications that feature:

WIDE FREQUENCY RANGE

Enables reliable AC and DC current measurement. Limitation mainly by lead inductance depending on shunt style. Can be compensated for MHz measurements.

LOW DRIFT OVER TEMPERATURE AND LIFETIME

Delivers repeatable measurement at cold start, system working temperature range and under overload conditions.

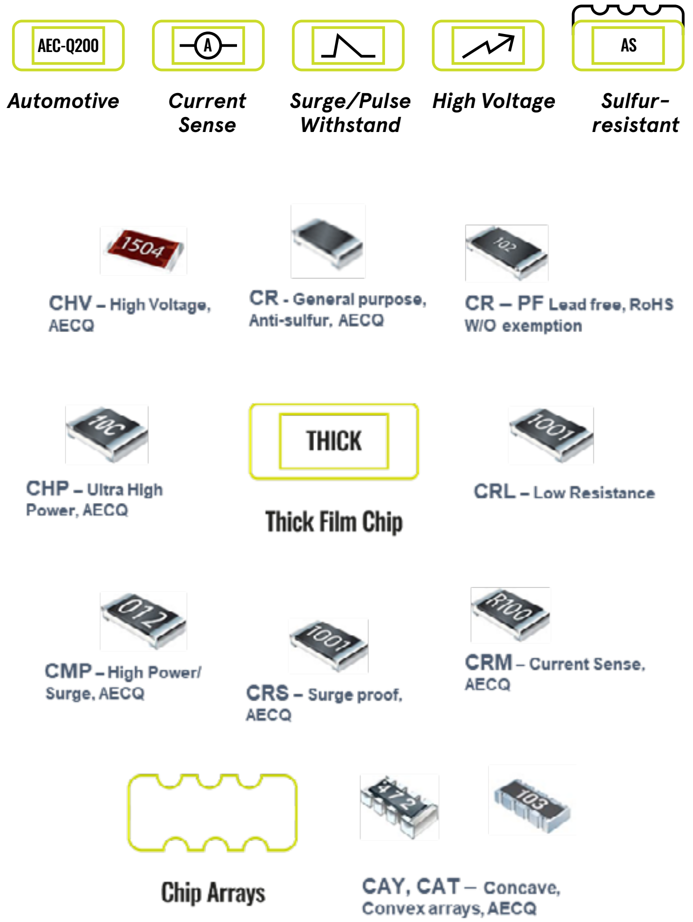
LINEAR BEHAVIOUR

Makes signal conditioning simple and offers compatibility at different operating points.

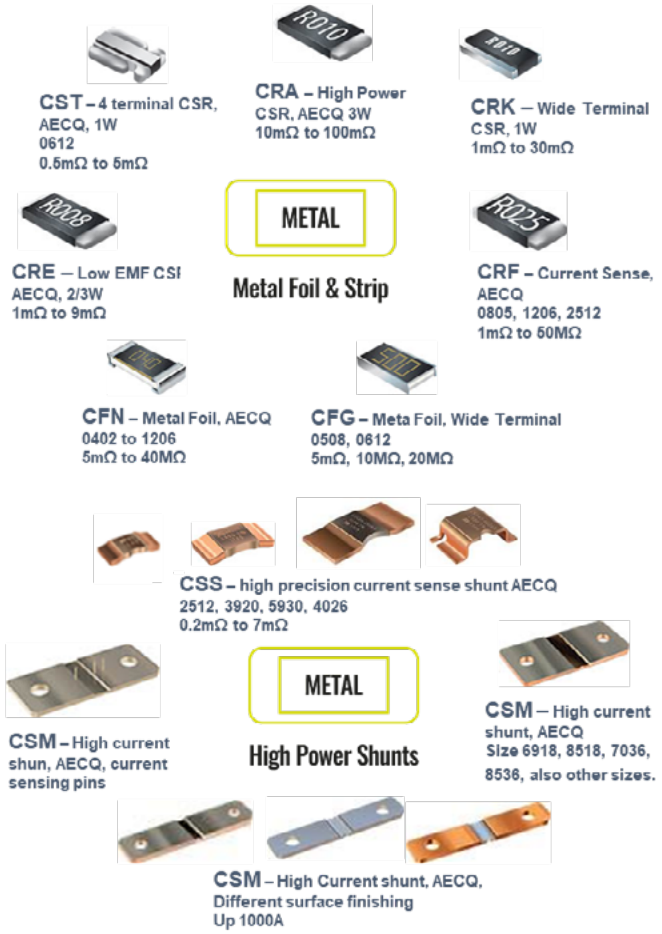
AEC-Q200 COMPLIANCE

Ideal for harsh environmental designs.

BOURNS THICK FILM CHIP RESISTOR PORTFOLIO

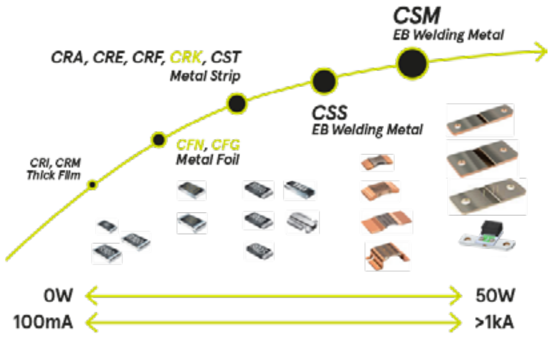


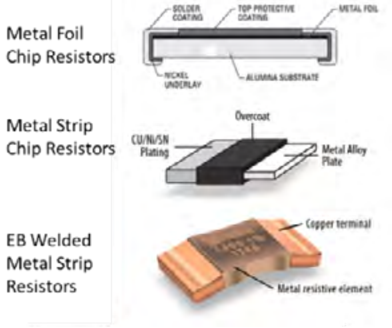
BOURNS CURRENT SENSE RESISTORS PORTFOLIO



BOURNS CURRENT SENSE RESISTORS TECHNOLOGIES

From chip to high power customised welded metal type





BOURNS ADVANCED MAGNETICS SOLUTIONS FOR POWER, EMC & SIGNAL LINE DESIGNS

The global semiconductor industry continues to significantly advance its integrated circuits (ICs) designs to meet increasing power conversion application requirements.

Because these new ICs offer higher switching speeds and reduced switching losses, they are driving demand for equally significant power, signal and EMC magnetic component advancements.

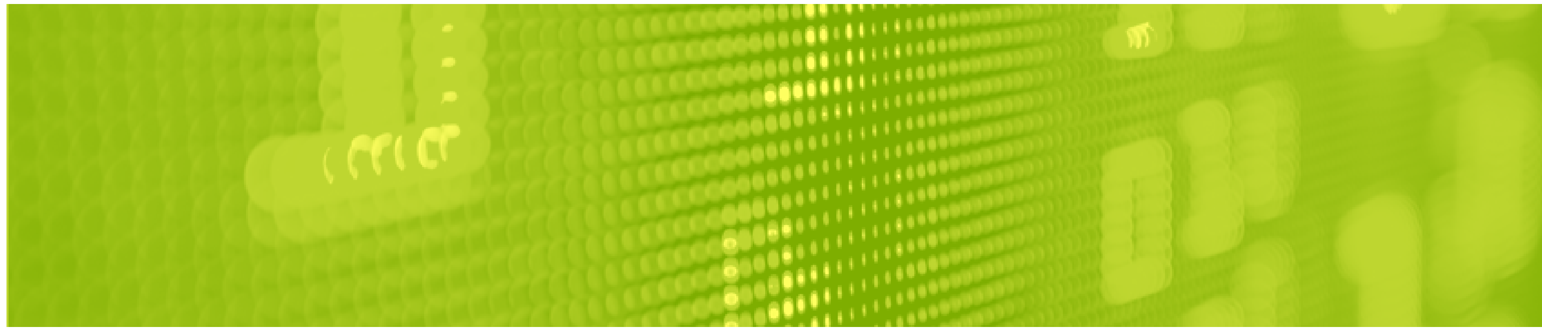
Helping to ensure efficient and safe, highly reliable power, magnetics solutions are necessary elements in many of today's breakthrough electric vehicle, high power battery charging, e-mobility, renewable energy, energy storage, Internet of Things (IoT) and industrial infrastructure designs.

Magnetics for Efficient Power Management

Meeting this demand, Bourns has more than 50 years of magnetic components development experience and continues to innovate and expand its portfolio of advanced magnetic components. By offering one of the industry's most comprehensive lines of magnetic components gives circuit designers the breadth they need to select the right components to meet their increasingly complex and demanding customer requirements.

Bourns advanced magnetics components are designed to meet essential power application requirements for superior power conversion efficiency, isolation, EMC compliance, signal integrity, increased power density, low noise, miniaturization and excellent thermal management.

And, Bourns automotive grade components are manufactured in accordance with the International Automotive Task Force (IATF) 16949 standard in ISO 14000 certified factories.



SOURCING ADVANCED MAGNETICS FEATURES& SIGNAL LINE DESIGNS

Today's power management applications require magnetics that support higher switching frequencies and ever-more performance in more compact designs.

Engineers need to consider sourcing components that offer:

- **Miniaturization** – Smaller form factors for space-constrained designs
- **Low EMI noise** – Inductors that mitigate EMI noise while maintaining high efficiency
- **Thermal management** – For temperature stability
- **High robustness and reliability** – To help maximize product lifespan
- **Advanced materials and construction (advanced metal alloy powder cores/ molded techniques)** – Provide highly efficient and ultra-low DC resistance

Meeting Application-specific Requirements

From design to spec and build to print – all the way to volume production, Bourns' custom Magnetics team can design and manufacture transformers and inductors for almost any power level. Customers are able to leverage Bourns' engineering expertise and advanced software design tools to expedite the development of an optimized design. Custom capabilities include ferrite cores, designs for EMI reduction, high frequency power topologies, custom bobbins and cores, aluminium housing, flat wire windings, Litz wire and support for finite element analysis and simulations. In addition, Bourns' engineering lab can provide fast turnaround prototype samples and can support volume production manufacturing goals.

Leading Power Conversion & Energy Storage Solutions

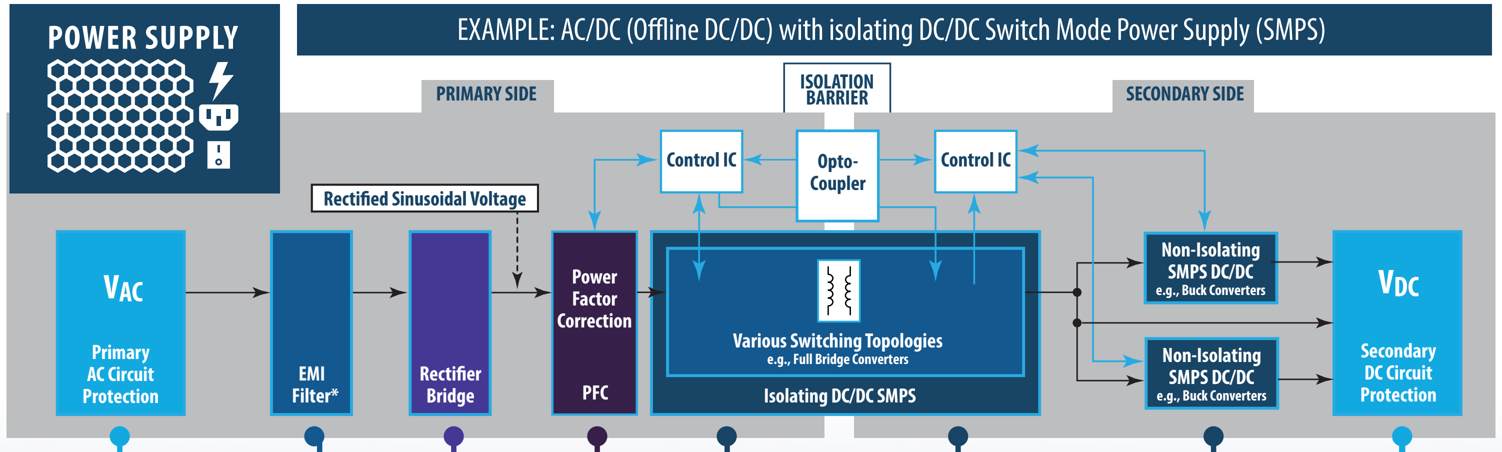
With a strong and growing product portfolio that matches increasingly complex and demanding application needs, look to Bourns for power conversion and energy storage solutions. The company's high creepage and clearance isolation transformers, BMS signal transformers, chip LAN transformers, power inductors, and high current common mode chokes are backed by Bourns' in-house AEC-Q200 testing and are all produced in the company's IATF 16949 and ISO 14000 certified factories.

These solutions plus its ongoing magnetics innovation, Bourns helps engineers satisfy their high reliability, safety and isolated communications requirements in broad range of power management applications.

Bourns has partnerships and reference designs with all the major power electronics IC providers such as Texas Instruments, ADI and PI helping customers save time and minimize risk. Strict automotive grade requirements including AEC-Q200 and PPAP are also supported. Plus, Bourns designs for compliance with UL and IES safety standards for isolation and creepage and clearance.

To learn more about Bourns solutions for Power Management applications CLICK HERE

Power Conversion Flowchart



CIRCUIT PROTECTION DEVICES

Part	Description
	Power TVS Diodes
	AC - Transient Protector (ACTP)
	IsoMOV™ Protectors
	GMOV™ Components
	Metal Oxide Varistors (MOVs)
	Gas Discharge Tubes (GDTs)
	PTC Resettable Fuses: Multifuse®
	Fusible Resistors

RECTIFIER DIODES

Part	Description
	Bridge Rectifier Diodes
	Bridge Rectifier Diodes

POWER TRANSFORMERS (High Frequency)

Part	Core Type	Power (W)
	EP5, ER7.5	20
	EPC10, EFD10, EPC15	50
	EP7, EPC20, EE10, EE13	100
	EE16, EE19, EE20, EE25, EPC24	150
	EPC125, EPC30, PQ26/20	500
	EC35, EC29A, EC28B, FED28A,EC40B, RM14	700

CIRCUIT PROTECTION DEVICES

Part	Description
	TVS Diodes
	PTC Resettable Fuses: Multifuse®
	Thyristor Surge Protectors: TISP®
	SinglFuse™ SMD Fuses
	TBU® High-Speed Protectors (HSPs)

INDUCTORS

Part	Description
	Inductors
	Common Mode Chokes

*EMI filters can be used on power and signal lines

INDUCTORS & RESISTORS

Part	Description
	Power Inductors
	Snubber Resistors *(Wirewound, Thick Film, Metal Strip)*
	Current Sense Resistors *(Thick Film, Metal Strip, Metal Element)*

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Part	Description
	Power Inductors
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	Current Sense Resistors *(Thick Film, Metal Strip, Metal Element)*
	Variable Resistors: Trimpot® Trimming Potentiometers

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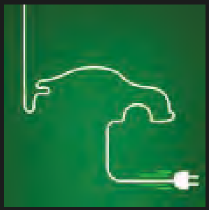
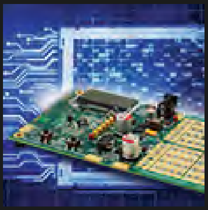
DC Power: High Power Conversion & Wide Bandgap Technology



What You Need to Know about DC Power Today



The Benefits of Digitally Controlled DC Power

10 Ways Silicon Carbide Can Improve Circuits

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