POWER ELECTRONICS NEWS

MAR 2018

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Addressing thermal management of GaN semiconductors

POWER ELECTRONICS NEWS

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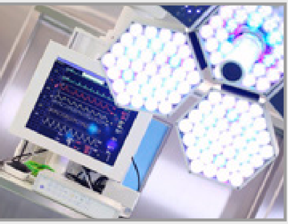

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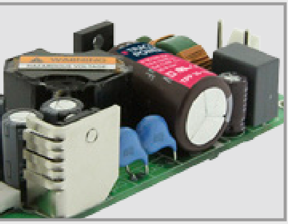

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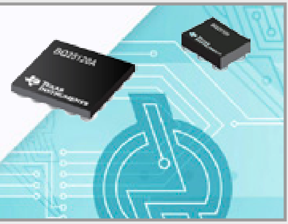

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VIEWPOINT

The increasingly powered world

The growth in the Cloud, IoT, and their related infrastructures have expanded the vistas of design engineering tremendously, providing cost-effective intelligent solutions to application spaces both legacy and novel. Since there can be no electron-

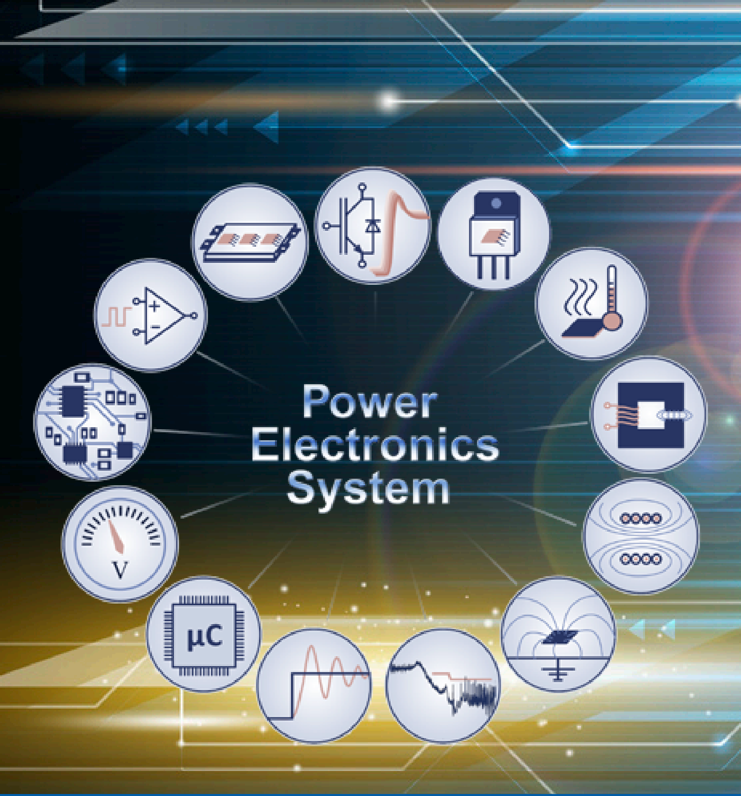
ics without electricity, this expansion of application solutions also means an expansion of power engineering into more and more places.

This month Janice Escobar over at Texas Instruments writes about charger specifications in small battery applications, an area exploding as more and more personal/portable/wearable products are released requiring excellent battery management with safe and fast charging. Charger ICs directly impact the technical attributes of the chargers , which directly impact the user experience. The effort paid in understanding how to design-in the most optimum solution pays off well at the end.

We also have an item on power in the medical environment, an area always under regulatory and customer pressure, from Tim Taylor at Stadium Group. The demand for precision, small size, high efficiency, low noise, and ease of use and maintenance from the customer are made more difficult by regulatory requirements on emissions, electronic noise, isolation, and the other needs of the expanding variety of healthcare environments. Knowing the regulatory factors such as location, operator and patient concerns, and what other equipment factors are important to designing in this space.

Yours Sincerely,

Alix Paultre
Editor Power Electronics News



It took me closer to 5 hours, but it wasn't terrible.

Addressing thermal management of GaN semiconductors

By Alix Paultre based on a technical Paper of Dr. Marvin Tannhaeuser, Siemens

Wide-bandgap semiconductors like Gallium Nitride (GaN) have been hot topic recently, with almost revolutionary claims of high switching speeds, small size, potentially competitive cost, and high reliability. These claims, which turned out to be facts, are enabling GaN transistors to threaten Silicon in power-conversion applications.

Of course, there will always be innovation barriers which make it quite hard and complicated to use these novel technologies and materials like GaN. It's totally independent of which company you work for, discussions about reliability and price for new technologies will come up in every case.
At this point, let's assume that all of these obstacles can be overcome. Which brings us to the next question, which is "What are the major challenges using this GaN power semiconductors?" For an application engineer, what makes it so hard and complicated to use these technologies in a real system?

POWER ENGINEERING

In power electronics one has to master a quite wide range of different engineering disci-

plines, from the power semiconductor, to the electrical connection, to the mechanical connection, and then to the thermal design. Each power semiconductor needs an appropriate gate driver circuit and auxiliary circuits like power supply, isolators, protection circuits and so on. In addition, we also need measurement circuits to finally control the whole power electronics system. One also has to integrate these low-level power electronics systems to some kind of embedded platforms, which realize the digital control concepts also for complex multilevel circuits or other topologies.
Of course you have to address these topics in each power electronics system, especially for grid applications. One needs to consider from the beginning the whole concept, and for component design, like inductor design, but also for the thermal design. Another major element in each power electronics system is always the power inductor, its own engineering field where you need some fundamental knowledge about electromagnetic materials as well core and winding design, and their related issues.

THERMAL DESIGN

Thermal design should always be considered in combination with the whole system concept, the application, and whether or not you can use active or passive cooling methods. Bringing gallium nitride into that game changes the whole system. If you just replace a silicon MOSFET with another GaN device, you will see a small change in system performance in an already given design. But if you use all the performance advantages and their very high switching speed, you will see novel and new challenges which we have to handle in a complete system design.

Because GaN devices enable a very fast and very efficient switching, you can increase the frequency of the power circuit, which reduces the size of the inductors as well. At that point, you need power semiconductor packages with very low stray inductance to address these high switching speeds, and the control algorithm needs to address these challenges as well.
There needs to be improvements in SMT packaging as well, to use the high-switching speed capabilities to design power circuits and power cells with very low stray inductance. Another benefit is that a discrete SMT package can take better advantage of automated manufacturing processes (Figure 1).

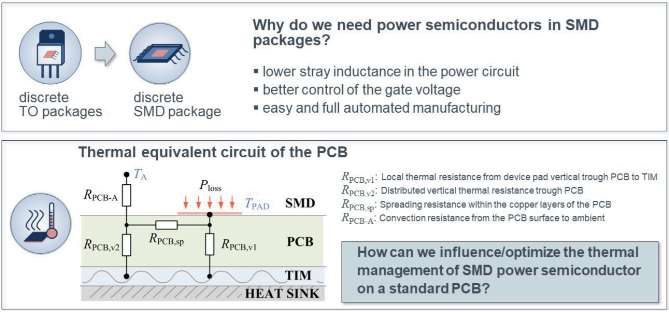


Figure 1: optimizing the thermal management of SMD power semiconductor

On the other hand, there needs to be new approaches for the thermal management of these devices. Therefore one should have a closer look to the PCB, not as an element for electrical connection, but more as an element for thermal management, for heat spreading and dissipation.

In a steady-state equivalent circuit of the PCB one can consider two different thermal paths. One is the local thermal path directly under the device put through the PCB into the thermal heating. Another thermal pass, which is always available, is a kind of spreading resistance into the PCB in combination with the distributed vertical resistance, and resistance from PCB surface to ambient.

All these thermal elements can be influenced by different design formations from the PCB. For example, the amount of copper on the surface, the copper thickness in the inner layers, or the substrate material, the sheer density, and of course the whole geometry of the layout (Figure 2).

Figure 3 compares different setups to compare overall thermal performance from the device path to the heat sink, which is the thermal resistance through the PCB. The first setup reaches 5.8 kelvin per watt, and in the second thermal path, the spreading thermal path, without any kind of local thermal VIAs under the device path. In the second setup it's 8.2 kelvin per watt, but if you see with all the standard versions like 70 or 105 micrometer of copper thickness, you can

Analyzing passive cooling and a variation of the PCB parameters

PCB parameters	Value	Symbol [Unit]
Given (fix) design parameters		
PCB size	50x50	A_B [mm²]
PCB substrate material	FR4	-
Amount of layers	4	n [-]
VIA diameter	0.70	d_V [mm]
PAD size	8x8	A_{PAD} [mm²]
Parameters to be analyzed		
PCB thickness	{1, 2, 3}	d_B [mm]
Copper thickness	{35, 70, 105}	d_C [µm]
VIA plating thickness	{20, 30, 40}	d_P [µm]
Simulation parameters		
Ambient temperature	25	T_A [°C]
Power losses	4	P_{loss} [W]
PCB orientation	vertical	-

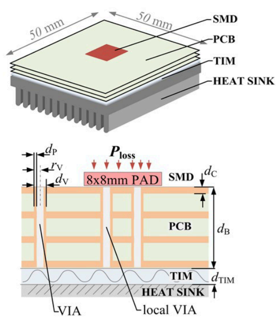
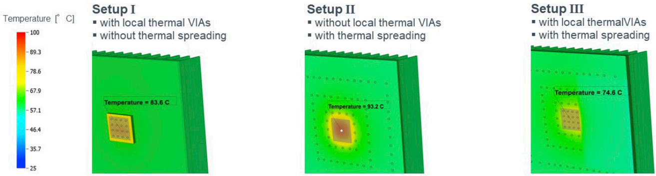


Figure 2: the different PCB parameters



	Setup I	Setup II			Setup III
$R_{th,PAD\text{-}HS}$ from device pad to heat sink	5.8 K/W 100 %	8.2 K/W 141 %	4.8 K/W 83 %	3.4 K/W 59 %	3.5 K/W 60 %
Copper layers (4 layers)	35 µm	35 µm	70 µm	105 µm	70 µm
Design guide	Amount of local thermal VIAs should be chosen by considering the whole thermal resistance	Thermal spreading is important to reach good thermal properties. The copper thickness has a major influence			With the combination of local VIAs and thermal spreading a good performance can be reached with a standard PCB

Figure 3: copper and the thermal resitance

decrease the thermal resistance to approximately 60% of the initial value.

Setup III is a more realistic case where both thermal paths were combined, with local vias also spreading into the PCB. Using 70 micrometers as the copper thickness for the PCB, one can reach a value of 3.5 kelvin per watt as a thermal resistance through the PCB. In addition to PCB design setup, different cooling methods can be used to address the application needs. In general, to handle these losses from the package, a major element must be the PCB design. The thermal spreading within the PCB is as important as the use of the local thermal vias, and can reduce the thermal resistance of the PCB by nearly 40%. An optimized thermal PCB designs also depends on the cooling method. The use of a heat sink and/or fans are normally defined by the boundaries of the addressed application.

In the case of GaN, one can use a cheap and easy cooling method due to its high efficiency and performance. A GaN converter prototype was built to show the feasibility of that thermal concept (Figure 4). The prototype targeted DC/AC conversion, with a three-phase connection on one side, and a DC connection on the other. The prototype was tested at 175 kilohertz, and no additional fans or heat sinks were used for thermal management, just passively by the PCB's four copper layers, at a standard 70 micrometers of copper layer thickness, and standard FR4 material. The input voltage was 700 volts, and the output voltage was a little more than 230 volts.

The prototype exhibited a very high efficiency of 98.5%, which shows the excellent performance of GaN devices The two pictures at the top of Figure 4 show the power cell at the power semiconductor, in a little bit more in detail. At this operation it was 1 kilowatt. The transistor reaches a maximum temperature at the case of just 57 degrees, which is a very good value considering the lack of heat sinks and fans, and a power of one kilowatt.

Measurement conditions
Power: 1 kW (single phase)
Switching frequency: 175 kHz
Cooling: Passive (no fan, no heat sink, $T_A = 25°C$)

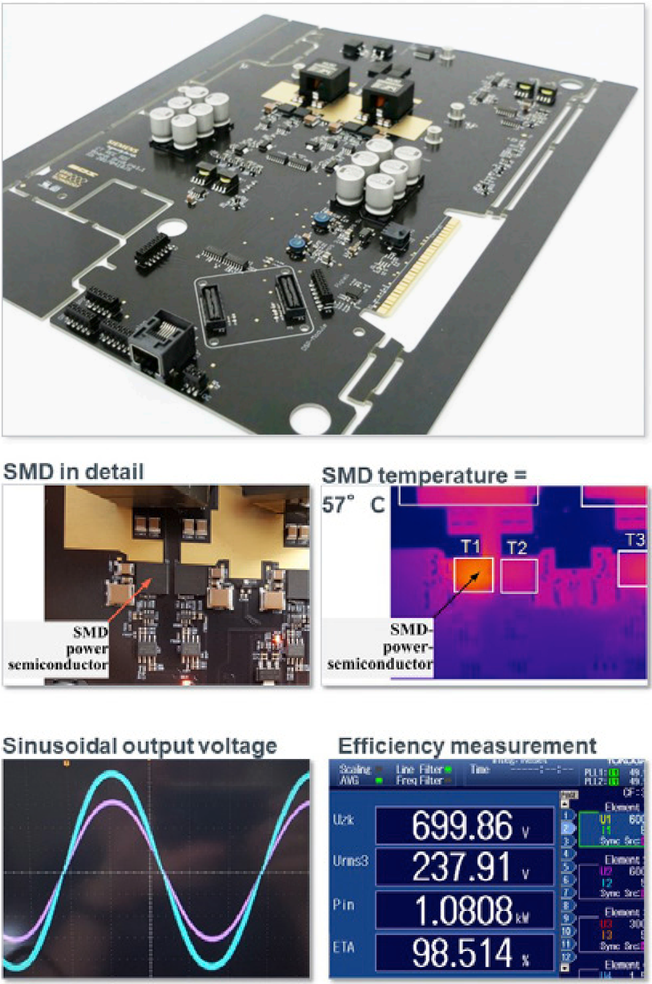


Figure 4: GaN converter Prototype

LOOKING FORWARD

GaN power semiconductors enable a very high switching speed and very efficient switching. Therefore, the power electronic systems can become more efficient, but can also work with higher switching frequency, which allows you to use smaller passive components. In addition, GaN power semiconductors can also enable multilevel converters with much higher system efficiencies than existing comparable solutions. GaN will lead us to smaller and lighter converter systems with a much higher level of integration.

Considering the increasing demand of power electronics in the growing markets for renewables, electromobility, factory automation, and other spaces, one could address all these markets in the future with smaller, lighter and cheaper systems, which are ready for automated high-volume manufacturing. ■

i More info

- Presentation Power Electronics Conference

De facto Standard Tester to specify

HIGHLIGHTS

- *power magnetic component*
- *low permeable soft magnetic material*
- *like powdered core, gapped ferrite core or stress annealed nanocrystalline tape wound core*

Supported by DIN-Connect

Bs&T Thyristor Pulse Technology provide the highest discharge current among same power class to excite the magnetic component under text bipolar into saturation the most accurate inductance value for didt method. Magnetic component, like solide state transformer, harmonic and sinus filter for DC grid of mid voltage till 1000 V, can be finally specified. ■

More info

www.powerlosstester.de

Microchip's XLP PIC® MCUs

As more wearables, wireless sensor networks, and other Internet of Things (IoT) enabled smart devices are getting powered from battery, energy conservation becomes paramount. Today's connected applications must consume little power and, in extreme cases, last for up to 20+ years while running from a single battery. To enable applications like these, products with Microchip's eXtreme Low Power (XLP) technology offer the industry's lowest Run andSleep currents.

XLP PIC MCU APPLICATION EXAMPLES

Internet of Things

- Remote controls
- Security systems
- Portable meters
- Wireless sensors
- Electronic locks
- Asset tracking

Wearables

- Fitness monitors
- Wearable sensors

Smart Energy

- Energy meters
- Flow meters
- Smart plugs
- Energy management

Connected Home

- Bluetooth® Low Energy devices
- Security
- Thermostats
- Smoke detectors

Energy Havesting

- Solar harvesting
- RF-powered devices

Medical

- Glucometers
- Blood pressure meters
- Patient monitors
- Pulse oximeters

Low Sleep Currents with Flexible Wake-Up Sources

- Sleep current down to 9 nA
- Brown-Out Reset (BOR) down to 45 nA
- Real-time clock down to 300 nA
- Watch-Dog Timer (WDT) down to 200 nA

Battery-Friendly Features

- Enable battery lifetime greater than 20 years
- Low-power supervisors for safer operation (BOR, WDT)
- Core Independent Peripherals (CIPs) take the load off the CPU and perform extremely complex tasks in self-sustaining mode at lowest possible energy requirement

VBAT Battery Back-Up

- Automatic switch-over upon loss of VDD
- Maintains Real-Time Clock/Calendar (RTCC) and user registers
- Powered seperately from 1.8–3.6V source (coin cell)

Large Portfolio of XLP MCUs

- 8–121 pins, 4 KB–1 MB Flash
- Wide selection of packages
- Active mode currents as low as 30 µA/MHz with efficient instruction set with over 90% single-cycle instructions

Equipment power supplies in the medical environment

AC-DC and DC-DC power supplies can be used in different ways in institutional and home healthcare environments. The international standard for safety compliance IEC 60601-1 addresses many factors including location, access to operators and patients and what other equipment is potentially connected. The classes of equipment and their use are explained in this article.

THE STANDARDS

It's common knowledge that power supplies intended for the medical environment have to meet particular standards but the actual end application demands different levels of approval for the power supply. If the intended application is in equipment used by operators away from the patient, the requirements are very different to those for supplies in monitoring equipment with direct patient connection.

The international standard that's relevant for general requirements for basic safety and essential performance is IEC 60601-1-2, currently in its 4th edition. In the US it is ANSI/AAMI ES60601-1 and in Europe, EN 60601-1. Canada has its version CAN/CSA C22.2 NO. 60601-1 with some differences, significantly the earth bonding test current. Historically, edition 2 of 60601-1 standard applied to all products in a medical environment but with the explosion of home healthcare applications, the environment dramatically widened.

Also, electronic systems in hospitals now extensively use commercial equipment for economy, and applications vary widely from entertainment systems to automated bedside drug administration.

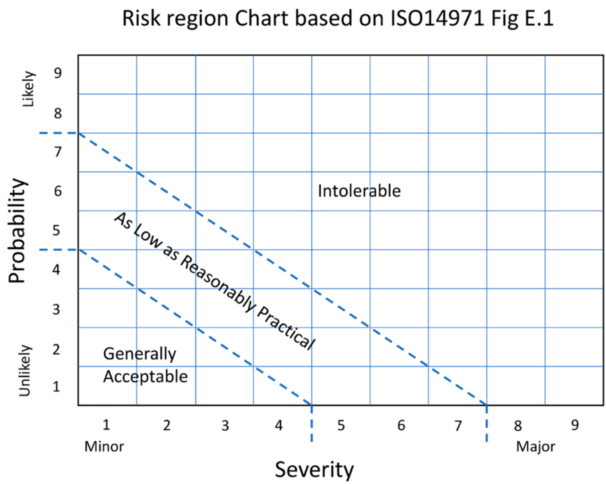


Figure 1. Risk analysis

To ease compliance difficulties, edition 3 of 60601-1 standard took a more pragmatic approach, splitting the applications into operator environment and the riskier patient environment. Risk analysis requirements based on ISO 14971 were also introduced, which mandated that equipment suppliers should not just rely on 'box-ticking' for approvals but should consider ways that the equipment might fail and produce a hazardous situation. The manufacturer must identify risks according to severity and probability of occurrence and decide on acceptability. Figure 1, derived from IS0 14971, shows how risks might be categorized.

For component power supplies, it has been established that they are not separately subject to a reportable program of risk management, but purchasers will certainly want assurance that their end equipment is not compromised by inadequate power designs.

MOOPS AND MOPPS

Edition 3 introduced the concept of 'means of protection' varying in requirements depending on environment. Means Of Operator Protection, (MOOP) correspond in requirements to the IT safety standard IEC 60950, one MOOP being equivalent to basic isolation and two MOOPs equivalent to reinforced insulation or basic + supplementary. This practically means that a power supply certified to IEC 60950 may be used in a non-patient medical environment, opening up the market for lower cost commercial products. A proviso, however, is that both AC lines must be fused for class I equipment and the fuses should meet a high breaking capacity of 1500A.
Where the equipment operates directly in the patient environment, higher Means Of Patient Protection (MOPPs) are required. These levels are similar to the original, more stringent IEC 60601 2nd edition requirements.

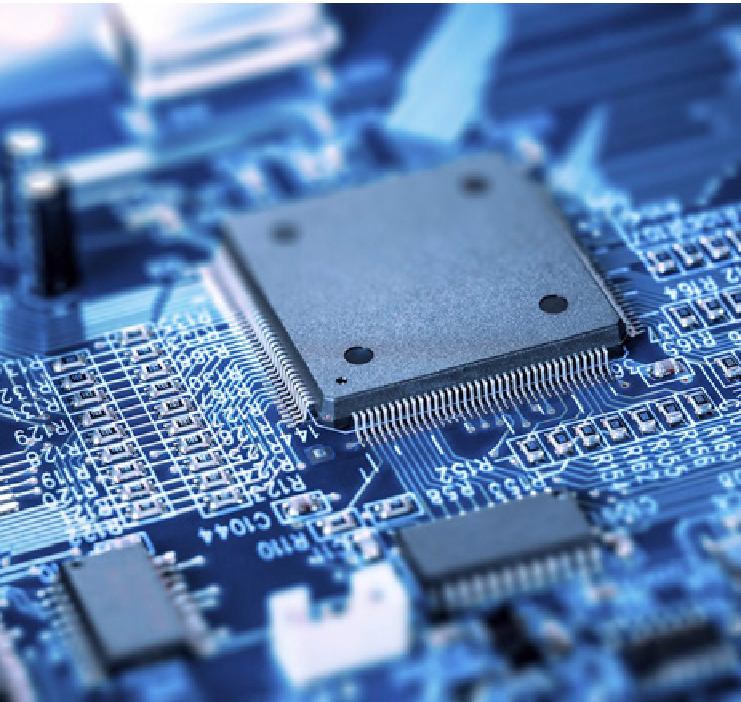
Creepage and clearance values increase, as does the production insulation test voltage; for 240 VAC system voltages it's 4kVAC compared with 3kVAC for MOOPs. Solid insulation also increases to 1mm minimum as opposed to 0.4mm. There are many other detail-enhanced requirements including levels of leakage current.

NEW TOPICS INTRODUCED IN IEC 60601 3rd EDITION

In the 3rd edition IEC 60601-1 new strictures were introduced. We've mentioned risk analysis but here the standard included consideration of altitude for clearance distances, interpolation between voltages for creepage/clearance distances, material tracking indices and environment pollution degree. In fact, this brought the standard into closer harmonization with modern industrial and IT standards such as IEC 62368, the successor to IEC 60950. At the same time, anachronisms were deleted such as allowing wire enamel as a level of insulation. As in other safety standards, IEC 60601 gives different requirements for materials and insulation levels based on the overvoltage category of the system voltage, and pollution degree of the environment.

EMC IN IEC 60601-1-2 4th EDITION

The 4th edition of IEC 60601-1-2 saw significant changes to the EMC requirements for medical equipment. Again, two environment levels are specified named as 'Professional Healthcare Facility' and 'Home Healthcare' with the latter often more stringent reflecting the uncontrolled nature of the location. The EMC level test methods called up are in the IEC 61000 series of standards and are in some cases much more stringent that in the 3rd edition. For example, ESD air discharge



susceptibility increases from 8kV in the 3rd edition to 15kV in the 4th and new requirements for testing of signal input/output and patient coupling ports are included.

LEAKAGE, TOUCH AND AUXILIARY CURRENTS

In the medical standards, there is a differentiation made in the patient environment between the leakage current that flows through earthed metal to ground (leakage current), from non-earthed material to the patient (touch current) and between all possible combinations of patient connections (patient auxiliary current). Limits are set for normal conditions but also for single fault conditions, putting the onus on the equipment supplier to identify and test for those conditions. Single fault conditions include those likely to occur such as reversed polarity of supply mains and also less likely events such as failure of individual circuit components. Multiple failures at once however are not evaluated.

The limits also depend on the detailed application. For applied parts, that is, equipment with intended direct connection to the patient, there are two levels: BF and CF increasing in severity. The higher level, CF, which might

be an electrical connection to the patient's heart, has the lowest allowable current for an individual piece of equipment, of 10μA under normal conditions and 50μA with a single fault. Allowance is made for the real possibility of multiple equipment connections to the patient with an overall maximum leakage current of 50μA allowed or 100μA with a single fault.
At the other end of the spectrum, for non-applied parts, 5mA leakage current is allowed in normal operation and even 10mA under single fault conditions.

FAILURE OF OTHER EQUIPMENT HAS TO BE CONSIDERED

The medical standard specifically includes consideration of other routes for dangerous patient current apart from the connection through the AC supply of the equipment in question. For applied parts, it is assumed that unspecified equipment could fail and connect a dangerous voltage to the patient. Lethal current could then flow from the patient into the outputs of other patient-connected equipment unless prevented. For this reason, medically rated, applied part equipment needs at least one measure of protective isolation between outputs and

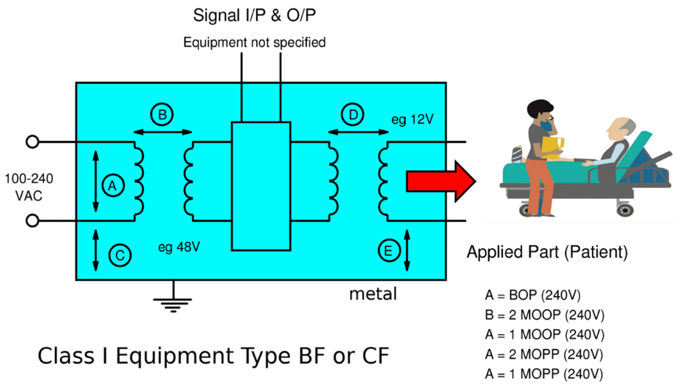


Figure 2. A typical equipment scenario

ground, rated for the system voltage, typically 240VAC. Figure 2 shows the condition of a class I equipment with unspecified input/output connections and the different measures of protection needed between the different elements of the system. In the figure, BOP is basic level of protection between parts of opposite polarity.

Use of class II construction with no earth and plastic enclosures mitigates the requirements. The plastic does have to be 1mm thick minimum, however.

SIGNALS ARE DANGEROUS TOO

Another route for potentially lethal patient current, also shown in Figure 2, is through

any signal input or output connections to the equipment. It is common now for Ethernet or other connections to be made to medical equipment for data logging and monitoring. If the signal connection is with unspecified hardware, measures of protection have to be included equivalent to two MOPPs between signals and applied part.
If the signal connections are known to incorporate approved isolation with two MOOPs, perhaps through a transformer, a further single MOPP must be included between signals and output.
Often a high isolation DC-DC converter is used to provide this function for power along with suitable rated data isolators for signals.

ONE + ONE = TWO

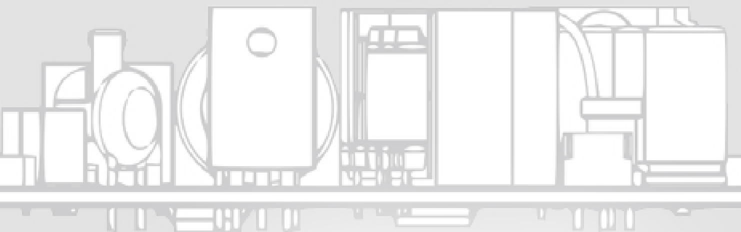
Incorporating multiples levels of isolation in equipment is a useful way to get an overall high level of safety. For example, MOOPs and MOPPs can be added through series connected AC-DC and DC-DC converters. The equipment manufacturer, however, has to provide for methods to individually verify the isolation of each stage. An end-to-end hipot test, for example, will not stress the isolation stages equally. Take the case of a

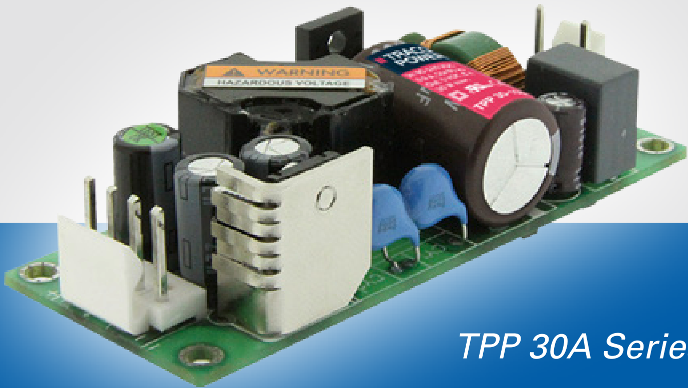
2 x MOOP AC-DC converter followed by a 1 x MOPP DC-DC converter intending to achieve overall 2 x MOPPs. The DC-DC is likely to have a much lower input/output capacitance than the AC-DC so, when 50/60Hz hipot AC is applied, most of the voltage is dropped across the DC-DC. It may be unduly stressed and weakened and the AC-DC barrier may not be adequately tested. The production and routine testing regime needs careful thought. AC-DC power supplies suitable for 'Professional Healthcare Facility' and 'Home Healthcare' environments meeting the latest standards are available from Stadium with a range of desktop and open frame products, some meeting the highest 2 x MOPP - CF level of performance in standard products or available for custom development. ■

Tim Taylor, VP Sales Stadium Group Inc.

More info

www.stadiumgroupplc.com





TPP 30A Series

Compact 15 and 30 Watt Open Frame Power Supplies for Medical Applications

The new TPP 15 and TPP 30 series extend the range of TRACO POWER AC/DC power supplies for medical applications.

TPP 15A Series

These 15 and 30 Watt AC/DC power supplies feature a reinforced double I/O isolation system according to latest medical safety standards IEC/EN/ES 60601-1 3rd edition for 2 x MOPP approved for an operating altitude of 5000 m.

The earth leakage current is below 100 µA what makes the units suitable for BF (body floating) applications.
The excellent efficiency of up to 91.5% offers a high power density in the packaging format 1.0″ x 2.6″ (15 Watt) and 1.36″ x 3.34" (30 Watt). The full load operating temperature range covers –40°C to +60°C while it goes up to 85°C with 50% load derating.

The units operate in compliance to the medical EMC emission and immunity levels according to latest standard IEC 60601-1-2 4th edition.

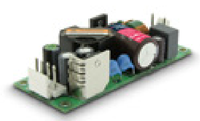
More info

- TPP 15A Series
- Datasheet: TPP 15A Series
- TPP 30A Series
- Datasheet: TPP 30A Series

TRACO POWER

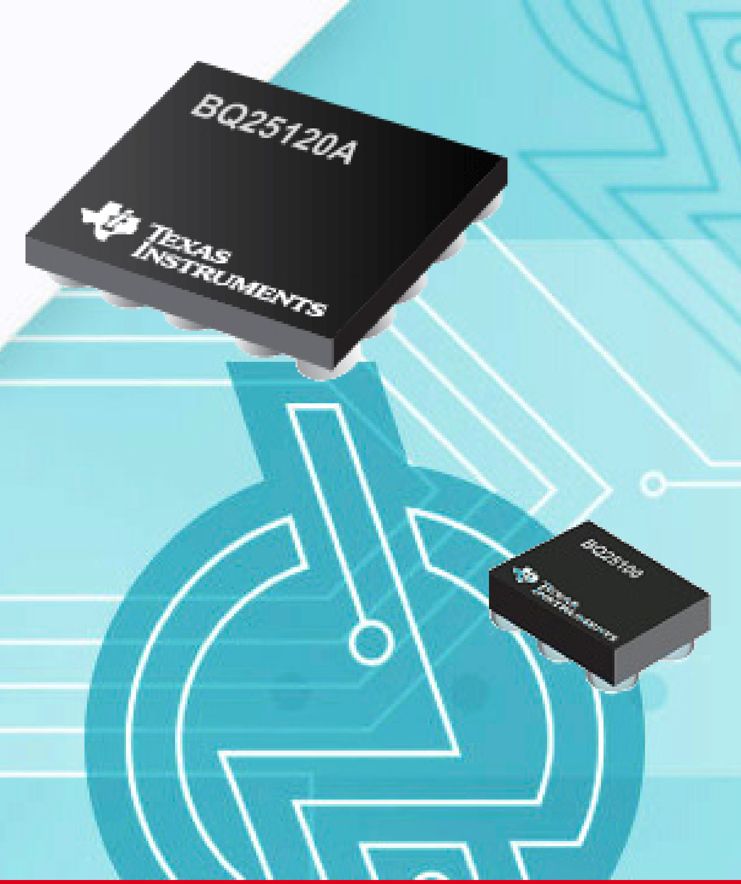
AC/DC Medical Power Supply | **TPP 30A Series, 30 Watt**

- **High power density power supply (open frame)**
- **Certification according to IEC/EN/ES 60601-1 3rd edition for 2×MOPP**
- **Low leakage current <100 µA rated for BF applications**
- **EMC emission an immunity to IEC 60601-1-2 edition 4**
- **Risk management process according to ISO 14971 including risk management file**
- **Acceptance criteria for electronic assemblies according to IPC-A-610 Level 3**
- **Protection class I and II**
- **Operating up to 5000m altitude**
- **Ready to meet ErP directive, no load power consumption**
- **5 year product warranty**



ES 60601-1
UL 60950-1

The TPP 30A AC/DC power supplies feature a reinforced double I/O isolation system according to medical safety standards IEC/EN/ES 60601-1 3rd edition for 2 × MOPP approved for an operating altitude of 5000 m. The earth leakage current is below 100 µA what makes the units suitable for BF (body floating) applications. The excellent efficiency of up to 91.5% offers a high power density in the packaging format 1.36” x 3.34”. The full load operating temperature range covers −40°C to +63°C while it goes up to 85°C with 50% load derating. The units operate in compliance to the medical EMC emission and immunity levels according to latest standard IEC 60601-1-2 4th edition.



5 charger specifications to consider for your small battery applications

Whether you realize it or not, you interact with lithium-ion (Li-ion) batteries every day. You depend on them to survive, well, at the very least, you depend on them to be entertained. Charger ICs interface directly with the battery and manage the power in your everyday portable electronic devices. The technical attributes of chargers can directly impact user experience.

In this article we will take a look at critical electrical characteristics for small battery applications ranging from 30mAH – 450mAH. These include voltage and current accuracy, termination current, over voltage protection and quiescent current.

Let's start with battery chemistry. Li-ion batteries became popular because, compared to nickel- and lead-based batteries, they are much lighter. The density of lead is 17 times greater than lithium; imagine trying to get a drone off the ground with something that heavy inside. Li-ion batteries also provide more energy than lead or nickel and can be packaged into small form factors, ideal for space-constrained applications. From your fitness tracker, to the cordless screwdriver you purchased for that do-it-yourself project you still haven't started, Li-ion batteries are the best choice for portable, rechargeable, battery-powered devices.

With Li-ion batteries powering some of your favorite products, it's important to understand how to care for these power sources. The charger is a close component to the battery, and depending on how charging is implemented, the charger will have a great impact on battery health. Let's go through some 101 basics of lithium battery charging. Figure 1 shows an ideal charging curve for a Li-ion cell. This charging profile is referred to as "CC/CV," which stands for constant current/ constant voltage. When your fitness tracker's battery is low, that means the voltage on its battery is low, so the battery cannot provide enough energy to power your device. Once plugged in, the charger applies constant current or ICharge to the battery until it reaches the desired voltage – let's say 4.2V. At this desired voltage the charger moves

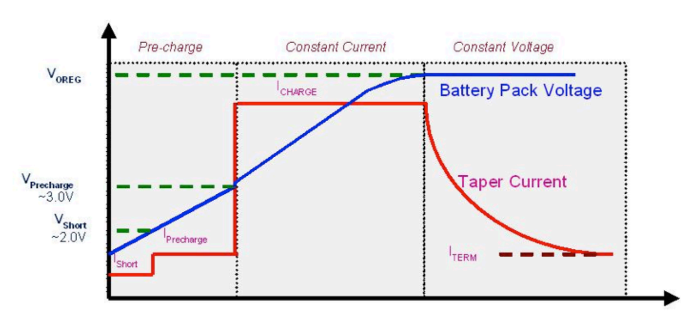


Figure 1: Charging profile for Li-ion batteries

into constant voltage mode so that the battery does not exceed its rated voltage of 4.2V. In constant voltage mode, current is reduced until it is almost zero, this is known as Iterm; once the current has tapered down the charger has reached the end of its charging cycle.

Lithium-ion batteries do not like to be fully discharged. Many vendors recommend that Lithium-ion batteries shouldn't be used below 3V. The cell can be shorted or defective at very low voltages, so you would not want to just provide the maximum current into it, as it could cause more damage. At these low voltages, only a small test current is applied to the battery to ensure the internal protection circuit has opened, this current is known as Ishort. For batteries that are about the short threshold in Figure 1, we apply a current known as Iprecharge. This current that is typically 10% of the normal ICharge current. Once the cell is above 3.0V, it is considered safe to charge at the ICharge current.

Now that you have a bit of background on the CC/CV curve, let's dig deeper into the importance of voltage accuracy Figure 2 shows an example of how overcharging shortens a battery's cycle life. The image reflects a different battery capacities in mAh where mAh stands for milliamp hour and is a unit that measures power (electric power) over time. It is commonly used to measure the energy capacity of a battery. In general, the more milliamp hours, the larger the battery capac-

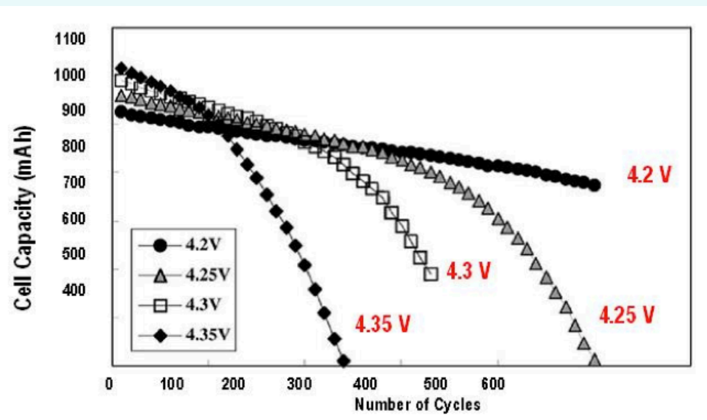


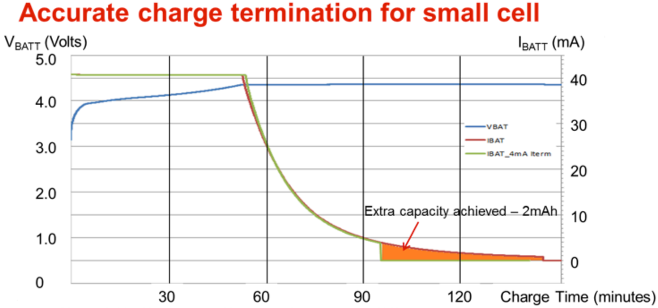
Figure 2: Battery Capacity Variances over Charging Cycles

ity or battery life. If a battery is considered full at 4.2V, the number of times you can charge and discharge that battery is directly connected to the actual voltage at which the battery charges. With 100% accuracy, a battery with a capacity of 900mAh charges to exactly 4.2V every time. The battery can deliver about 800mAh after about 500 recharge cycles, decreasing only 100mAh.

However, if you charge just 100mV over the battery's rated voltage after 500 recharge cycles the battery decreases from 1,000mAh to 450mAh, that's a 550mAh decrease. That 55% decrease is like having a brand new pair of earbuds give out after a year, when they should have lasted for three years. This illustrates why the accuracy at which you charge the battery is critical to maintaining battery performance and extending the battery's life.

Once the battery reaches its "full" voltage, 4.2V, the current begins to taper as seen in the constant voltage section of Figure 1. This termination current is usually about a tenth of the ICharge used when charging the battery to its rated voltage. The smaller the Iterm current is, the closer you can get to filling up the battery without overcharging it. In small capacity batteries, the accuracy of the Iterm current is key.

Figure 3 shows two tapered current profiles, colored red and green. The green terminates at 4mA and the red terminates at 1mA. The shaded area shows the extra 5% capacity restored on every charge by terminating at 1mA instead of 4mA. With this extra capacity in a very small battery, you could potentially use your smart watch a bit longer before having to recharge it again. At such low currents it is difficult for the charger to be accurate; cut off charging before Iterm threshold will prevent you from maximizing the amount of capacity resorted to the battery and cutting off after the threshold will increase your charging time. So why terminate at all? It is important to have an Iterm cut off threshold to ensure the charger indicates to the system that charging is completed.



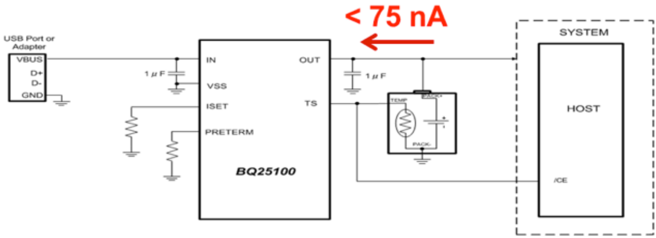
- Charged 41mAh battery at 40mA fast charge current (1C)
- Termination at 4mA (10%) or 1mA
- Shaded area represents additional 5% capacity restored on each charge

Figure 3: Extra capacity gained from lower termination current

Another important battery-charger specification for small battery applications is quiescent current. Also known as Iq, this is the current drawn by the IC with no load. If the Iq is too high, the battery can discharge to a point where the device cannot start up right out of the box without charging it first. Because many manufacturers are unsure how long their products will be sitting on the shelf, it is important that electronics draw minimal current so customers have the option to use their new electronics right out the box. Chargers can completely detach from the battery from the system through the internal battery FET until they are ready for use to improve the IC current draw; this feature is known as "ship mode."

Iq also contributes to how many hours of battery life a product can sustain. Take for example you are designing very small simple rechargeable medical health scanner that needs to run off a 50mAh battery. Its sensors have an average Iq of 25µA and the average processor power is 12µA. Using a charger IC with an Iq of 26µA would get you 33 days of battery life, however, an Iq of 75nA would get you 70% more, equaling 56 days of battery life.

Lastly, but most importantly, is the integrated protection the charger provides. In a small battery application, you are usually deal-



bq25100 application schematic

ing with a 5V input source. When connecting the adapter to the portable device it is possible to see up to 8.6V or more on the input to the charger due to inductive ringing, the oscillation of a signal in response to a sudden change in input. You could also be in a situation where you purchase a cheap gas station adaptor to charge your devices. If the USB adaptor fails, you could see the full car battery voltage spike at the input of your device! If your charger does not have enough headroom to tolerate these voltage spikes it could damage your entire device. Now you could use external means of protecting the input of your charger, but for small battery applications it would take up precious space, potentially heat up your device, and cost more. Integrated solutions that include chargers might not put as much emphasis on these specifications, as that is not it's primary function, so make sure to check the devices electrical characteristics to ensure these considerations are met.

Considering the charger has the most intimate relationship with the battery; you should choose it carefully to produce a robust product. Charger accuracy, termination current quiescent current, and overvoltage protection all play major roles in the longevity and health of a battery; understanding the technical specifications for a charger helps paint a picture of the user experience, especially for small portable electronics.
The bq25100 and bq25120A are two charger ICs that feature these specifications and are targeted for small battery applications. Remember the charger does more than just charge: it maintains and protects the battery, and the brand. ■

Author: Janice Escobar, Product Marketing Engineer Battery Charging Products

More info

- BQ25100
- BQ25120A

Power and safety to healthcare facilities at altitude

The OBR04 Power Supply designed for medical and high altitude applications, but also suitable for other types of applications such as radio-transmitters and also observatory stations equipment installed at the top of mountains.

Powerbox introduces a new series of power supplies for medical applications requiring BF (Body Floating) class insulation and full, reliable operation up to 5,000 meters altitude to power medical healthcare facilities and equipment. Complying with the latest EMI coexistence standard IEC 60601-1-2: 2014 (4th edition) and specifically designed with patient and operator safety in mind, the OBR04 series delivers an output power of 650W. The OBR04 is available in 12 different voltages from 12V to 58V with an efficiency rating up to 91%. With a strong focus on 'no interference and radio coexistence', the prod-uct meets conducted and radiated EN55011 class B without requiring any additional components.

Built to ensure patient and operator safety, the OBR04 has an input-to-output isolation of 4,000 VAC (2xMOPP), an input to ground of 1,500 VAC (1xMOPP) and a 1,500 VAC output-to-ground, when many conventional products offer only 500 VDC isolation. In order to guarantee full operation up to an altitude of 5,000 meters, the OBR04 has been designed in respect of required creepage distances and additional isolation barriers.

DESIGNED WITH HIGH ALTITUDE APPLICATIONS IN MIND

Many countries such as China or those in South America are bringing healthcare to mountainous region based populations, and it is very common in those countries for healthcare centers and hospitals to be located at altitudes higher than 3,000 meters. Medical equipment must be designed to guarantee the highest level of safety up to 5,000 meters. The base design altitude for power supplies is 2,000 meters but as the altitude increases, the insulating qualities of the thin air diminish and the clearance distances have to be increased from 8 mm at 2,000 meters, up to 11.84 mm at 5,000 meters, thus requiring power supplies to be designed in accordance with the needs of such physical requirements and in some cases to comply with local approvals such as the CCC (China

Compulsory Certification). The Chinese Safety Standard GB 4943.1-2011 mandates strict rules for clearance distances and since December 1, 2012 - the primary-to-secondary clearance has increased by a factor of 1.48 to qualify the power supply for operation up to 5,000 meters. Designed with high altitude applications in mind, Powerbox's PRBX OBR04 withstands an isolation voltage of 4,000 VAC (2MOPP) from the input to the output, 1,500 VAC (1MOPP) from the input to ground and 1,500 VAC from the output to ground, when most products currently available are offering only 500 VAC.

The OBR04 leakage current is 300 µA maximum, and the touch current is 100 µA maximum at 264 VAC and 63 Hz.

GROWING DEMAND FOR HIGHER ISOLATION VOLTAGES

"Designed for medical and high altitude applications, the OBR04 is also suitable for other types of applications such as radio-transmitters and also observatory stations equipment installed at the top of mountains and requiring similar performance levels in term of clearance distances" said Martin Fredmark, Powerbox's VP Product Management. "Also, we see a growing demand for industrial applications requiring higher isolation voltages and for equipment that is designed equally as good as those for altitude applications in order to make their final equipment none sea-level depending."

Powerbox's OBR04 is available as standard in twelve output voltages; 12, 15, 18, 24, 28, 30, 32, 34, 36, 48, 57 and 58 VDC, covering a large range of applications from 12 VDC intermediate bus voltages through to point-of-loads up to 58 VDC to power the latest generation of power amplifiers. Depending on the output voltage the maximum output power starts at 600 W and rises to 650 W with a peak power level of up to 720 W. An auxiliary 12 V output is provided for an additional fan, as well as a standby 5 VDC supply at 200 mA. ■

More info

- Medline 650 – OBR04 Series
- Powerbox Medical Brochure EU005

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