January/February 2018

PSD NORTH AMERICA

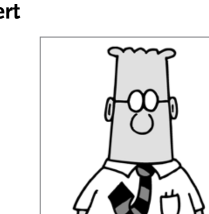
Information to Power Your Designs

Special Report: Power Supplies & Magnetics (pg 27)

PSD NORTH AMERICA
Information to Power Your Designs

WWW.POWERSYSTEMSDESIGN.COM

Visit us online for exclusive content; Industry News, Products, Reviews, and full PSD archives and back issues



PSD NORTH AMERICA

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

Editorial Director
Jim Graham
jim.graham@powersystemsdesign.com

Editor - Europe
Ally Winning
Ally@powersystemsdesign.com

Editor - North America
Jason Lomberg
Jason@powersystemsdesign.com

Editor - China
Liu Hong
powersdc@126.com

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

Publishing Director
Julia Stocks
Julia.stocks@powersystemsdesign.com

Creative Director
Chris Corneal
chris.corneal@powersystemsdesign.com

Circulation Management
Sarah Corneal
sarah.corneal@powersystemsdesign.com

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

Ruben Gomez, North America
ruben@powersystemsdesign.com

Registration of copyright: January 2004
ISSN number: 1613-6365

Free Magazine Subscriptions, go to:
www.powersystemsdesign.com

Volume 10, Issue 1

Automotive Regulations Create Engineering Challenges

Let me know if this works. Sorry for the text file — I'm working from my phone. Also, the previous headline is fine.

Automobiles are simultaneously on the bleeding edge of innovation and a lightning rod for numerous controversies, including anthropomorphic climate change and general environmental concerns. Thus, it's hardly surprising that they've become a focal point of our industry.

Most of us still drive conventional autos with internal combustion engines, but electric and hybrid vehicles are rapidly becoming viable options. Two of the most important considerations for these advanced technology vehicles are battery management and local and federal regulations.

On powersystemsdesign.com, we've talked a lot about rapid recharge times, but new electric and hybrid vehicles will create tremendous demand for large arrays of series/parallel connected battery cells.

Samuel Nork and Tony Armstrong, both with Analog Devices, discuss this growing requirement for large battery stacks in their piece, "Maximize Run Time in Automotive Battery Stacks Even as Cells Age."

"Large battery stacks consisting of series-connected, high energy density, high peak power Lithium polymer or Lithium-Iron Phosphate ($LiFePO_4$) cells are commonplace in ... allelectric (EV or BEV) and hybrid gas/electric vehicles (HEVs and plug-in hybrid electric vehicles or PHEVs)...", the authors note.

But the batteries remain the priciest component of electric and hybrid vehicles, and "even the higher cost, higher quality cells will age and mismatch with repeated use." The authors promote 'active balancing,' "a new technique to recover battery capacity in the pack which is quickly gaining momentum."

Manufacturers are also expending considerable R&D effort to comply with new regulatory CO_2 emissions and fuel economy requirements, and these in turn are driving the adoption of 48V mild hybrid systems. Worldwide OEMs like Audi, Fiat Chrysler, and Hyundai have already announced preliminary 48V systems, with many more to come.

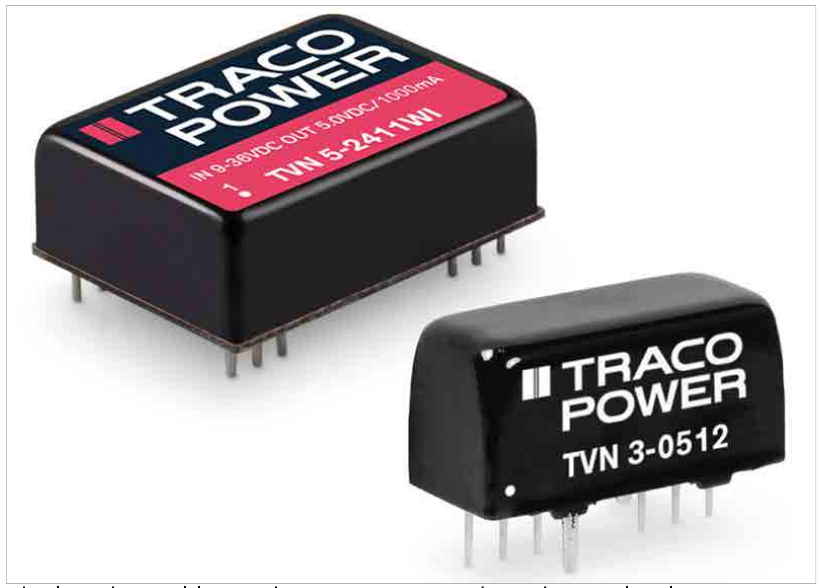
In "Automakers Shift to 48V Mild Hybrid Systems," Ed Kohler, with Intersil Corporation (a Renesas company), notes that "48V subsystems do introduce an incremental vehicle cost, but the widespread acceptance shows that automakers acknowledge it as a means to achieve lower CO_2 emissions, improved fuel economy, and vehicle drivability enhancements." Meanwhile, ON Semiconductor's Matthew Tyler discusses the migration to electric and hybrid vehicles from an electromechanical perspective in "Advances in Substrate Technology Enable Development of Power Modules Optimized for Automotive BLDC Application."

Switching from conventional mechanical systems to ones that are predominantly electrically based will help automakers comply with stringent new regulations.

Jason Lomberg
North America Editor, PSD
Jason@powersystemsdesign.com

TVN Series DC/DC converters combine high efficiency and low output ripple & noise.

Isolated low noise DC/DC converters of high efficiency. For noise sensitive applications, switching regulators tend to be ruled out due to the disturbing output ripple and noise. Linear regulators win over a smoothed output voltage but they work inefficient and produce a lot of heat. If the circuit has to be isolated, linear regulators are out of question. The power supply of a noise sensitive application calls for a compromise in performance or it requires an expensive filtering.



With the TVN 3 and TVN 5WI series TRACO POWER merges the advantages of switch mode DC/DC converters and linear regulators. These 3 Watt and 5 Watt switch mode DC/DC converters have a functional insulation system that provides an I/O-isolation voltage of 1600 VDC. The output voltage is fully regulated (line/load) and filtered for a residual ripple and noise of 10 mVp-p typ. It can even be reduced to 5 mVp-p by a single external 10 µF capacitor. The expenses for an external filtering can be kept down. With an efficiency of 80-89% (depending on model and operating point) the heat dissipation is very low. The low thermal losses have a direct positive impact to the lifetime and reliability not only for the DC/DC converter but also for the components around it.

The TVN 3 and TVN 5WI converters enable a cost efficient high performance solution for analogue circuits and for applications in instrumentation, audio & video, wireless communication, medical instruments, data acquisition systems, etc.

The 5 Watt converters of TVN 5WI series come in a six side shielded DIP-24 metal package and have an internal input filter to comply with conducted noise level EN 55032 class B. Standard features include remote On/Off, over voltage protection, under voltage shut down and short circuit protection. Models are selectable with output voltages of 3.3, 5.0, 12, 15, 24, ±5.0, ±12, ±15, ±24 VDC while the voltage of the single output models can be adjusted with an external resistor to -10% to +20% of nominal. They are available with ultra-wide input ranges of 4.5 – 12 VDC, 9 – 36 VDC or 18 – 75 VDC. The 3 Watt converters of TVN 3 series come in a compact SIP-8 metal package.

TRACO POWER
www.tracopower.com

Magnetics and Power Supplies

By: Kevin Parmenter, PSD Contributor

One of the key design issues of power supplies are the magnetics used in them. The magnetics are core to the safety – compliance, efficiency, thermal performance, de-rating, size and weight – and are therefore linked to the overall viability of the power supply product.

It is my privilege to chair a rap session on this topic at APEC this year, on Tuesday March 6, 2018 at 5 PM at the Convention Center. A panel of technical experts will debate the question, "which makes the most difference in power supply design – magnetics or semiconductor devices?" and take questions from the audience.

As the components industry becomes more commoditized, who is investing R&D dollars in magnetics and/or silicon semiconductors? In many circles, the magnetics are thought of as "how much am I willing to pay for your compressed dirt and sand?" That, of course, is the wrong way to think of it. Other questions the industry is facing are along the lines of:

- Who's waiting for whom?
- Are the wide band gap device makers waiting for the magnetics companies to create new materials or have they been ready all along?
- Are new materials needed for the cores?

Wire is not advancing very much, and design decisions such as whether to use Litz or flat wire and insulated foil have been around for a while. Not much has changed in insulating materials when it comes to tape, varnish and such. That begs more questions: Where are the breakthroughs; where are they needed; and who is willing to invest in them?

Magnetics and semiconductor companies and enterprises in the pharmaceutical industry have a similar problem. Large investments in R&D are needed, however margins are tight and once prototype parts are proven in a design, the production buyers send RFQs to everyone who ever made a magnetic device or component. More often than not, the company that invested sees their time and money go to waste when the production buy goes to a no-name company in a far-off land that simply copies the component design and construction, with absolutely zero investment in innovation. However, it's also true that a power converter can only be as good as the sum of its parts.

Packaging is becoming more of an issue and differentiator. We may see more combined co-packaging of semiconductors and magnetics going forward. There are many unanswered questions as to what makes the most difference between semiconductors, magnetics and/or packaging combinations. Who will be the investors in the components and products needed and commit the time and technology, intellectual property to advance power conversion technologies forward in the future? The answer may depend on which industry has the most influence. Is it high-voltage, lower voltage, higher current, off-line low power, off-line high power, DC-DC, VRM supplies, or inverter designs? Its certainly not the same for each and every power converter design and topology.

PSD
https://www.powersystemsdesign.com

Cool Running, 144W, 4 × 40A μModule POL Regulator

By: Afshin Odabaee & Yan Liang, Analog Devices, Inc.

The LTM®4636 is a 40A-capable μModule® regulator featuring 3D packaging technology, or component-on-package (CoP) to keep it cool - see Figure 1. The body of the device is an overmolded 16mm × 16mm × 1.91mm BGA package with an inductor stacked on top to expose it to cooling airflow. The total package height is 7.16mm.

In addition to dissipating heat from the top through the exposed inductor, the LTM4636 efficiently disperses heat to the PCB via 144 BGA solder balls dedicated to GND, VIN and VOUT—where high current flows.

A single LTM4636 is rated for 40A loads; two parallel converters can support 80A; four support 160A. Upscaling a power supply by paralleling LTM4636s is easy: simply copy and paste the single-regulator footprint, as shown in **Figure 1**.

The current mode architecture of the LTM4636 enables precision current sharing among the 40A blocks. Precise current sharing, in turn, produces a power supply that spreads the heat evenly between devices. **Figure 2** shows that all devices in the 4-μModule 160A regulator operate within 1°C of each other, ensuring that no individual device is overloaded or overheated. This greatly simplifies heat mitigation.

Figure 3 shows the complete 160A design. Note that no clock device is required for the LTM4636s to operate out-of-phase to each other—clocking and phase control is included. Multiphase operation reduces input and output ripple current, reducing the number of required input and output capacitors. Here, the four LTM4636s run 90° out-of-phase.

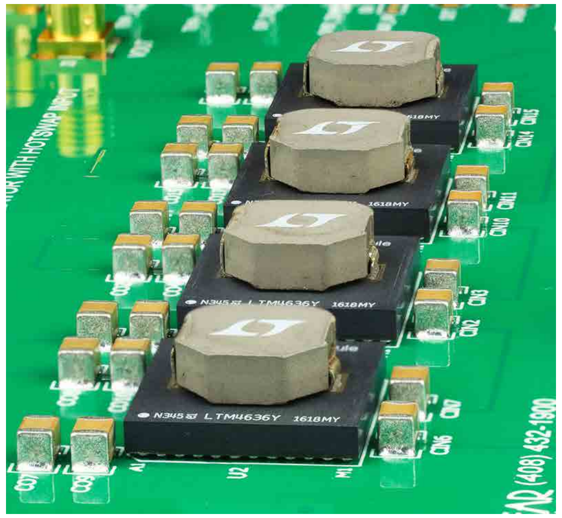


Figure 1: 3D Packaging of the LTM4636 Puts One of the Hottest Components, the Inductor, on Top, Where Significant Surface Area Is Exposed to Airflow. It Is Easy to Lay Out Parallel LTM4636s to Scale Power Capability—Simply Duplicate the Layout of One Channel and Multiply. The Clean Layout Here Shows Four Channels at 40A Each.

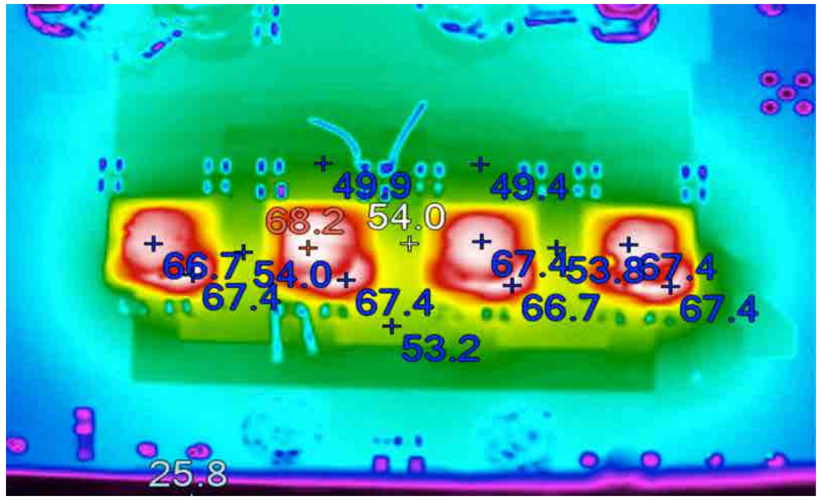


Figure 2: Precision Current Sharing Among Four LTM4636s Running in Parallel, Resulting in Only 40°C Rise in Temperature for 160A Application.

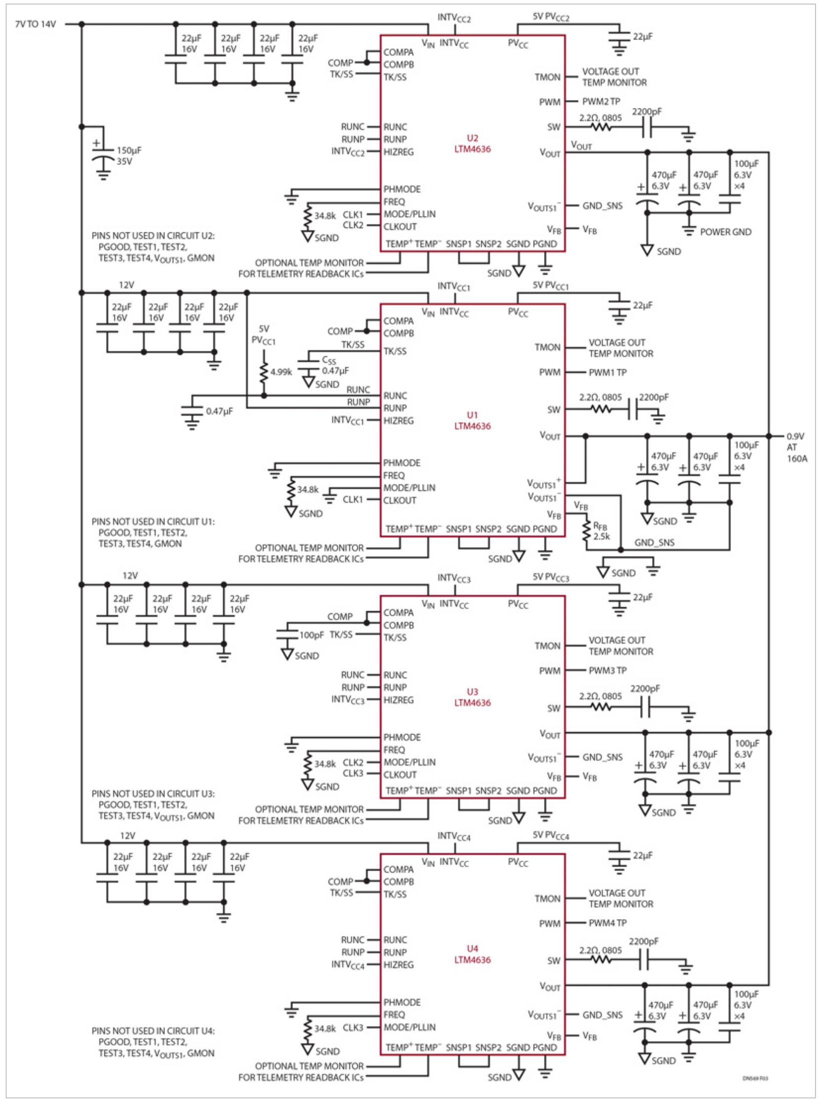


Figure 3: 140W Regulator Features Four LTM4636s Running in Parallel with Precision Current Sharing and High Efficiency 12V Input to 0.9V Output at 160A.

Conclusion

Choosing a POL regulator for a densely populated system requires scrutiny beyond voltage and amperage ratings of the device. Evaluation of package thermal characteristics is essential, as it determines the cost of cooling, the cost of the PCB and final product size.

Analog Devices
www.analog.com

Addressing Differential and Common Mode Noise With Dual-Mode Choke Technology

Circuit designers must deal with many types of noise

By: Lazaro Rodriguez, Standard Product Engineering Manager, Triad Magnetics

Circuit designers must deal with many types of noise: internal, external, RF, line frequency and more. Noise can be a limiting factor in system performance and so must be addressed and minimized. The question is "at what cost and effort?" Is it better to sacrifice performance or cost? In either case, the trade-off is not very appealing in today's competitive electronics industry.

Even the ubiquitous switched-mode power supply (SMPS) has noise issues. SMPS units are subject to differential mode (DM) noise and common mode (CM) noise, both of which must be suppressed.

Noise Mechanisms and Solutions

DM noise and CM noise have different causes and thus different solutions. Differential mode noise is noise that is conducted on the line and neutral in opposite directions (**Figure 1**). Common mode noise is conducted on the line and neutral in the

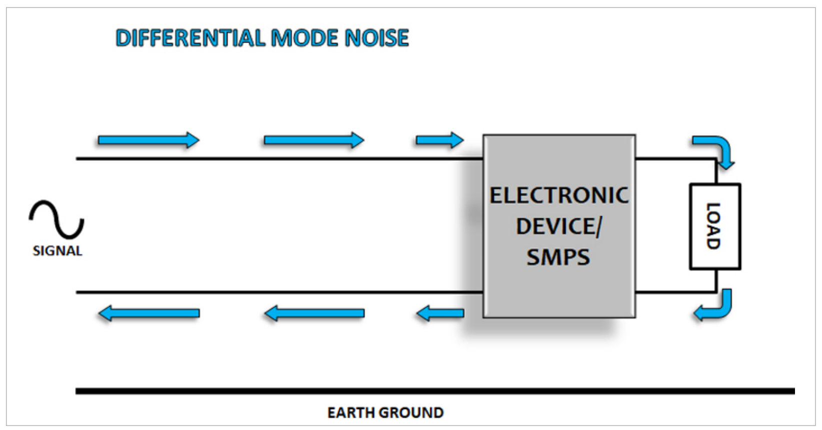


Figure 1: DM Noise

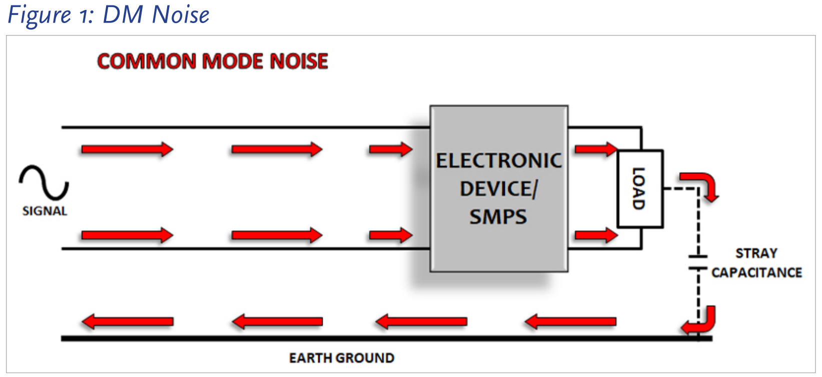


Figure 2: CM Noise

same direction returning through ground (**Figure 2**).

The basic DM filter uses a single-winding choke (inductor) inserted in series with the line path, along with a capacitor from line to neutral, thus blocking noise propagation through the system. Since the DM inductor is in series with the line path, it handles the noise and DC offset current being supplied to load. Therefore, it must be designed to provide the needed inductance, but do so with low DC resistance to handle the RMS current and peak line current without saturating (**Figure 3**).

The basic CM filter uses a dual-winding inductor in the line and neutral paths, plus a capacitor from line to ground (**Figure 4**). The current that flows in one winding (line) creates a magnetic field that is opposed by the flux created by the current flowing on the other winding (neutral); thus cancelling most of the flux in the core, preventing any saturation and allowing differential current to flow unimpeded. Conversely,

Common Mode noise flows on both the line and neutral lines in the same direction, creating equal in phase flux in each winding which adds together. This acts as a high impedance to the common mode noise to help attenuate it. Although typically not stated, all common mode chokes have some leakage inductance.

This leakage inductance can be used to attenuate differential mode noise. The problem with this leakage inductance is that it exists as a byproduct of the mechanical separation of two coupled windings and not as a designed parameter. The CM filter choke needs only to have the required inductance along with a sufficiently low DCR for the RMS current.

Solving DM and CM Noise Issues

Through advanced technology and applications expertise, Triad Magnetics has developed a new, better solution to the problem of differential and common

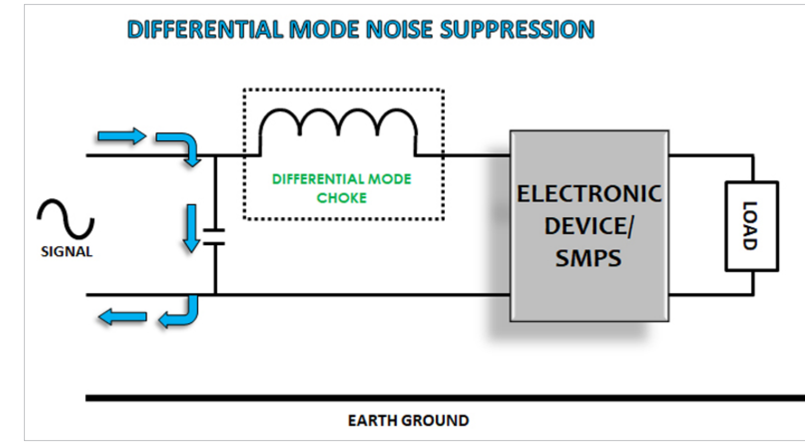


Figure 3: DM Noise Suppression

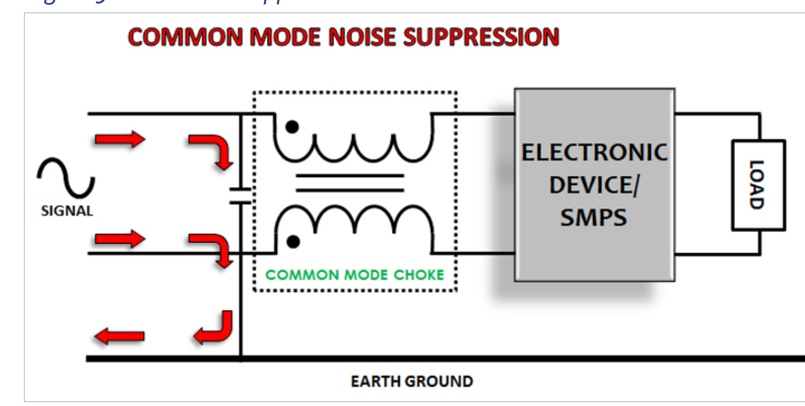


Figure 4: CM Noise Suppression

mode noise. As the DM and CM noise mechanisms are largely unrelated, their solutions typically require two different chokes (inductors).

It would be fortunate and much more convenient if the two noise-suppressing approaches could be implemented by one choke. Such an approach would save space and increase reliability by reducing component count, would simplify the bill of materials (BOM) and lower overall cost. Fortunately, this

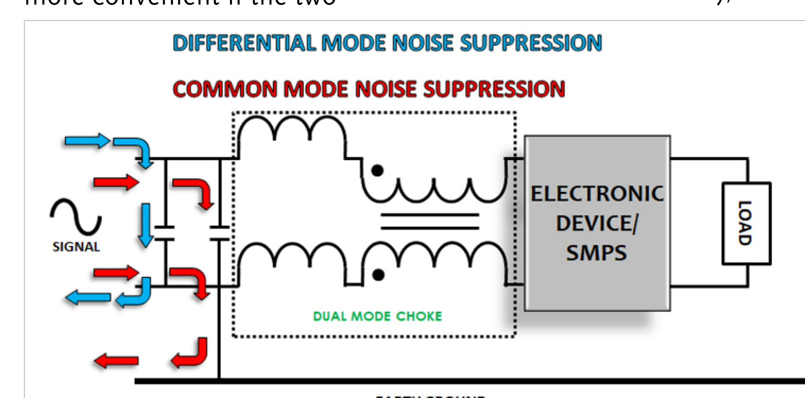


Figure 5: DM and CM Noise Suppression

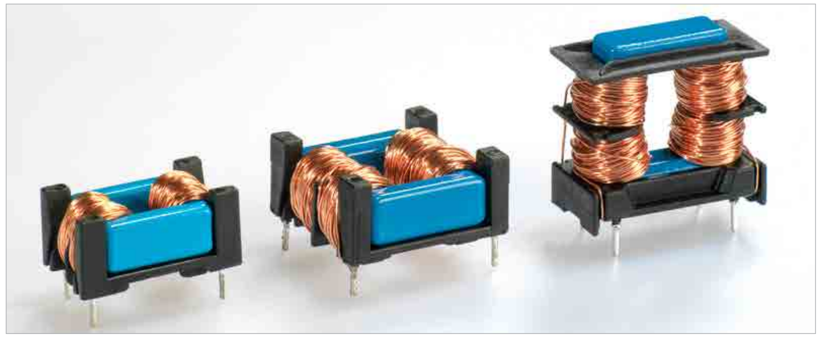


Figure 6: CMF Series Dual Mode Chokes

new solution from Triad Magnetics combines both chokes into a dual-function, open-frame design that provides the features of both chokes in a single, smaller, more cost effective package.

The CMF Series Dual Mode Chokes (**Figure 5**) from Triad are more than a simplistic co-packaging of two distinct devices into a single package. Instead, their design has been delicately balanced between differential and common mode noise inductance. Too much differential mode noise inductance and the core can saturate and not provide any common mode filtering benefits. On the other hand, too much common mode inductance, no differential mode inductance will be available for filtering differential mode noise. The CMF Series Dual Mode Chokes provide both exceptional common-mode noise suppression and are highly effective in suppressing differential mode noise.

The two-in-one CMF Series Dual Mode Chokes solve both the DM and CM noise problems. They are ideal for suppressing both types of noise in a wide range of applications that includes switch mode power supplies, LED lighting, electronics ballast and other devices (**Figure 6**). They are compact in size and come in either a horizontal package (where height clearance is a concern) or a vertical package that requires minimal board space.

There are 21 CMF models designed with precision wound coil bobbins in an open frame package. The current ratings range from 0.45 to 2.3A; inductances are from 10 to 100mH; differential inductances from 200 to 2100mH. DC resistances are 188 to 2930mΩ, depending on the model.

They're available in horizontal packages (13.5h × 15 × 24.5mm to 14h × 25 × 29mm) and vertical packages (27h × 15 × 29mm) to fit tight clearance situations. Their compact package makes them especially useful where higher density circuit boards are desirable to create smaller, more compact end products (**Figure 7**).

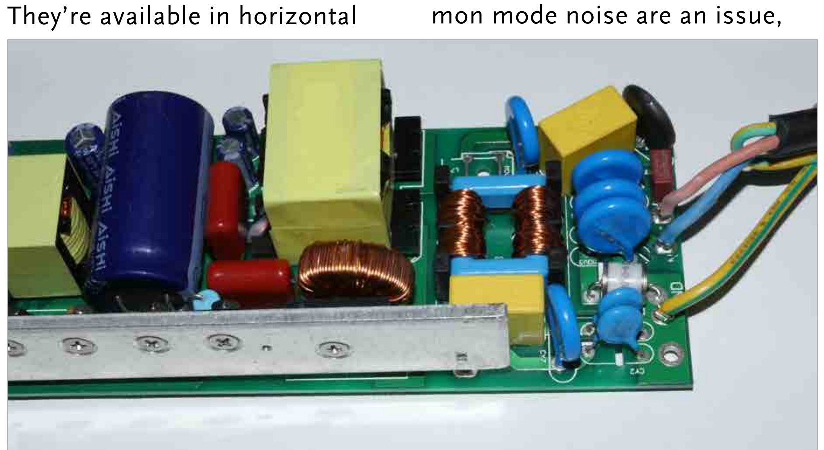


Figure 7: CMF Installed On Circuit Board

Despite their small size, the creepage and clearance spacing is greater than 3mm, and they are rated for 300VAC operation. They're an excellent solution for most designs, including switch mode power supplies, LED lighting, electronic ballast and more.

Designed for general purpose applications, the CMF Series Dual Mode Chokes operate over a temperature range of (-40 to 105°C). They are also RoHS compliant to the 2011/65/EU standard, which is intended to prevent lead contamination of the environment.

Conclusion

When both differential and common mode noise are an issue, there is a new technology solution available from Triad Magnetics. With over 70 years of electronics industry experience, Triad's engineers have solved some of the industry's most difficult filtering and power issues and the CMF Series Dual Mode Chokes are another example of this dedication to innovation. If you're experiencing a design dilemma that requires magnetic components, chances are that the engineers at Triad have already solved the problem for someone else.

In addition to the CMF Series, Triad Magnetics offers more than 1,000 standard part numbers to help electronics designers find the right magnetic component solution available off-the-shelf. If not, the creative thinkers of Triad Magnetics can offer powerful custom solutions. Whether it's switchmode/high frequency, wall plug-In, power transformers, inductors or audio transformers, each product is backed up by the industry's most resourceful and organized magnetic supplier organization.

Triad Magnetics is dedicated to quality and reliability. Producing products for long-run reliability requires a higher level of personal commitment. For example, each manufacturing team is empowered with the responsibility for quality and reliability through a highly-evolved system of critical self-inspection. The Triad Magnetics system of in-process inspection, pre-ship audits, and failure analysis has allowed many of our customers to eliminate their incoming inspection process while our continuous improvement protocol provided the highest levels of product quality and reliability.

The global manufacturing and distribution system capabilities of Triad Magnetics supports responsive customer service. Our manufacturing facilities in the U.S., China and the Philippines support just-in-time delivery capabilities, as well as our large network of distributors with thousands of part numbers ready to ship overnight.

Triad Magnetics
https://www.triadmagnetics.com

Thermal management of hot spots in IT equipment

Electrical current running through semis create thermal losses

By: Sonja Brown, Director of Product Marketing, EPCOS, a TSK Group Company

It is no surprise that electronic equipment can get hot. This is because electrical currents running through semiconductors and other components create thermal losses. Especially in IT equipment the losses in the form of heat dissipation can be quite significant. As much as 40 percent of the power used by data centers is for temperature control – mainly in the form of cooling the equipment to extend hardware life and increase uptime and efficiency. And multiple companies have recalled notebooks due to poor thermal management.

While the cooling of a notebook or data center is important, thermal management of IT equipment can be assisted through the use of PTC thermistors during the design of the equipment itself, allowing for increased efficiency of the semiconductor and proper heat dissipation.

PTC sensors

Due to the non-linear characteristics of PTC thermistors, their resistance is low at low and ambient temperatures. However, their resistance increases sharply as temperature rises. The type of ceramic material used determines the different threshold values based on the reference or limit temperature. Many of the newer temperature sensors based on PTCs use a more homogeneous ceramic material, which improves reliability while permitting processing by reflow soldering. This helps cover a wider range of temperatures and threshold values.

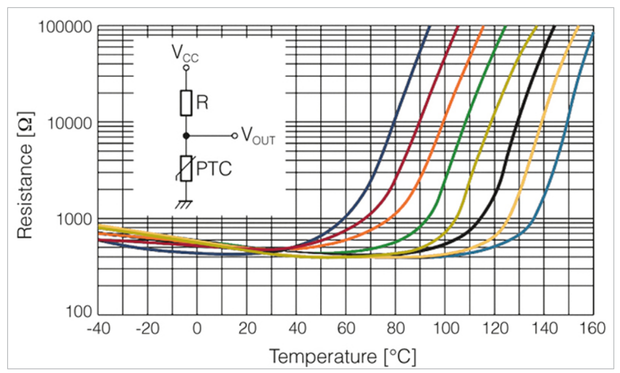


Image: Typical characteristics of PTC thermistors: The different limit temperatures and resistance curves of PTC thermistors are determined by the ceramic mixture of the PTC thermistors.

At normal temperatures resistance is typically less than 1 kΩ. Although different PTC sensors have different limit temperatures, resistance typically approaches 4.7 kΩ as the specified limit temperature is reached. The PTC resistance increases to 47 kΩ as the temperature increases an additional 15 K, providing an exponential upsurge compared to temperature rise. This is predictably accurate within ±5 K.

Due to the dependability of the sudden increase in resistance as temperature rises, PTC thermistors make the best and most accurate limit temperature sensors for sensitive electronic components. PTC thermistors should be mounted as close as possible to the component they are protecting to ensure the proper thermal contact and fastest response time. When this is done, they can quickly sense the critical temperature, ensuring efficiency and reliability of the components and thereby the equipment.

PTC sensors are usually coupled with a fixed resistor in voltage division circuits to create a temperature-dependent output voltage. In this case, the voltage changes promptly according to the characteristic of the PTC sensor. This directly controls a component such as a switching transistor or comparator and triggers corresponding functions that help avoid overheating and other temperature-related damage. For example, as temperature rises, a fan can be triggered, or other components can be switched off quickly and cost-effectively.

The design of PTC thermistors is such that there is only a very low resistance of a few ohms at their rated temperature. If the current exceeds the defined limit temperature, the thermistor heats up and power dissipation increases, increasing resistance and limiting the current. When the component has cooled down, it returns to its low resistance state.

Controlling temperatures

Thermal monitoring of system components in data center equipment and other IT equipment is essential because convective cooling is insufficient. Most notebooks utilize DC/DC converters – known as points of load (POLs) – instead of a central power supply to provide one or more supply voltages via a bus system. As a result, POLs are distributed across the entire board to generate the required voltage which is needed to close the load.

POLs are highly efficient, however, they generate thermal losses

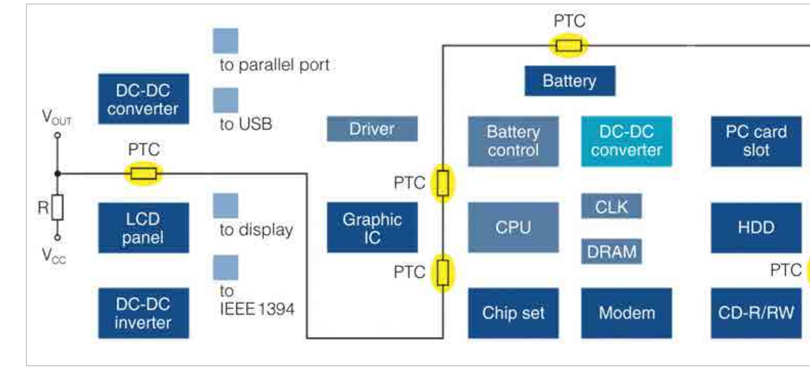


Image: A circuit of PTC sensors in series can be used to monitor the hot spots in IT equipment

that can lead to local overheating. As a result, POLs need thermal monitoring to circumvent this overheating. Processors, drives, batteries, RAM and other chipsets and system components also require the monitoring of potential hot spots on the board.

The exponential resistance change of PTC sensors allows the monitoring of multiple hot spots with a single, simple circuit with sensors in series. When multiple points on a circuit board need simultaneous thermal monitoring, a single PTC is located at every point that needs to be monitored. The PTCs are connected serially and thereby ensure reliable monitoring of each individual hot spot. The series circuit does not negatively affect the reliability of over-temperature measurement at each hot spot.

Circuits with serially-connected PTC sensors are not only simple and reliable, but certain PTC sensors, such as the EPCOS Superior Series from TDK are available for limit temperatures from 75 to 145 °C in increments of 10 K, so each hot spot can be monitored with a reference temperature specific to it. In this case, as long as each of the PTC sensors in circuit remain below the limit temperature, the resistance of each of the sensors will remain below 10 kΩ. If any of the PTC sensors exceeds its limit temperature, the resistance will exponentially rise.

Aside from notebooks and servers, this type of PTC sensor circuit can be used for other systems such as power supplies, UPS, frequency converters, light controllers and automotive electronics.

Conclusion

Thanks to their characteristic resistance curve, PTC thermistors have multiple uses as limit temperature sensors and current limiters. Whether they are used in IT equipment such as servers and notebooks, they can not only help control temperature, but improve the efficiency, reliability and lifespan of the products in which they monitor.

EPCOS
www.epcos.com

Self-Balancing Supercapacitor Reliability Testing Performance

There is now greater demand for supercapacitor reliability testing data

By: Eric DeRose, Field Applications Engineer; Bob Knopsnyder, Senior Development Engineer and Bharat Rawal, Contractor/Retired Manager, BestCap® Technology, AVX Corporation

Supercapacitors are increasing in popularity amongst board-level components. In turn, there is now greater demand for supercapacitor reliability testing data, as sub-ppm component failure rates are critical for minimizing and eliminating PCB rework.

The following case study addresses basic supercapacitor reliability testing and application guidelines, and then delves into test conditions and long-term reliability test data for AVX's SCM and SCC Series supercapacitors tested at 85°C and at various applied voltages — both at and below rated voltage — for more than 4,000 hours to demonstrate the impact of voltage on supercapacitor reliability, reveal performance characteristics that are currently unique to this series, and boost overall confidence in supercapacitor reliability.

Supercapacitor Reliability Testing Guidelines

Extensive testing is required to achieve a comprehensive understanding of an electronic component's device physics, degradation behavior, and failure mechanisms, and to accurately establish its long-term reliability. Such detailed part characteristics and performance data also help engineers recommend optimal, application-specific component solutions based on operating conditions, including voltage, temperature, relative humidity, and equivalent series resistance (ESR).

Electrochemical devices, like supercapacitors and batteries, are not well suited to typical electrostatic capacitor testing techniques, which use higher voltages and temperatures as acceleration factors. One of the primary requirements for the effective use of voltage and temperature acceleration is that their corresponding mechanisms should stay the same, and that is not the case for electrochemical devices. Using higher voltages and temperatures than a supercapacitor is rated for will cause hastened degradation of capacitance and a significant rise in ESR, so these conditions are not representative of normal operating conditions.

Due to these limitations, supercapacitors should only be tested at or below the maximum rated voltage and temperature, but for a longer span of time than electrostatic capacitors. It is also possible to test these devices at or below the rated voltage and temperature, ensure that the mechanisms do not change, and then use that data to estimate the failure rates over time; however, verifiable, long-term testing is preferable whenever possible.

Supercapacitor Application Guidelines

Supercapacitor lifetimes are a function of both voltage and temperature. So, operating conditions in excess of their rated voltage and outside of their rated temperature range can cause accelerated supercapacitor failures and can permanently damage entire circuits. As such, it is critical to define an application's operating conditions before attempting to specify or estimate the lifetime of a supercapacitor.

The rated voltages of standalone supercapacitors are generally lower than other energy storage devices, like batteries, so supercapacitors are often placed in series to attain desired voltage values. However, using capacitors in series tends to create a voltage imbalance during the charge and discharge cycle, which can threaten the maintenance of operation at or below rated voltage and negatively affect the longevity of all components in the circuit. There are several circuit balancing techniques that can effectively surmount this issue (e.g., passive balancing with a resistor across a capacitor or with a diode, active balancing with an IC chip, using a buck-boost converter with a single large capacitor to scale up the voltage, etc.), but each requires the addition of nonessential components that could infringe upon space-constrained device footprints, negatively affect load current, and create yet another potential point of failure.

Test Conditions

The following case study provides extensive, 4,000-hour reliability test data about the lifetime characteristics of supercapacitors. It investigates both capacitance and ESR over time under several different test voltages and temperatures varied to simulate harsh-environment operating conditions, such as high and low temperatures and relative humidity.

It also employs some general rules of thumb established through 12 years of electrochemical device testing experience and verified by crosschecking the results for validation. For instance, failure rate (F) has been shown to follow the relationship:

$$F \propto V^n \cdot e^{\frac{-Q}{kT}}$$

in which "V" is voltage, "n" is the voltage exponent, "Q" is the activation energy (measured in electronvolts [eV]), and "k" is the Boltzmann constant.

SCM Series Long-Term Reliability Test Results

The following test procedures were conducted on AVX's SCM Series supercapacitor modules, which, unlike other supercapacitors in series, do not require balancing circuitry. Introduced to market in October 2016, SCM Series supercapacitor modules are comprised of SCC Series cylindrical, electrochemical, double-layer supercapacitors connected in series and produced using a core-matching technique that combines capacitors with similar capacitance, ESR, and leakage current values (assuming that leakage current values were measured when the charging current reached an asymptotic value, i.e., after approximately 72 hours of test time).

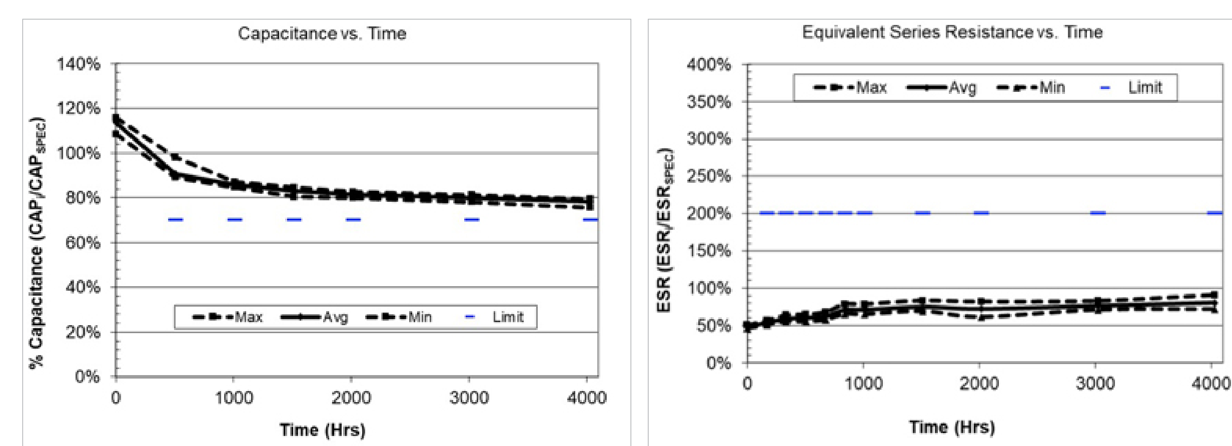


Figure 1: This graph pair represents Capacitance vs. Time and ESR vs. Time for the SCMT22C505MRBA0 at rated voltage (5V) for 4,000 hours at 85°C.

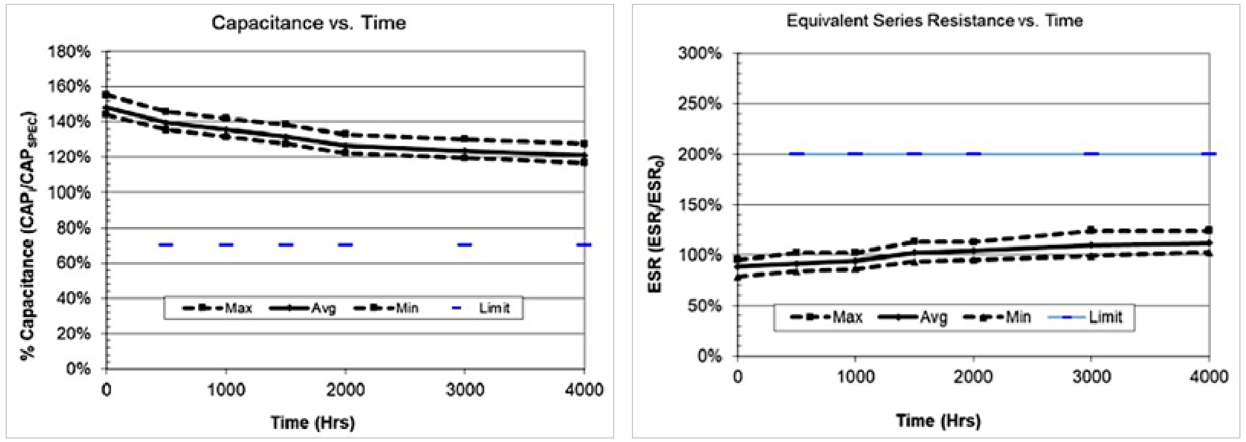


Figure 2: This graph pair represents Capacitance vs. Time and ESR vs. Time for the SCMT22C505MRBA0 at 90% rated voltage (4.5V) for 4,000 hours at 85°C.

Backed by over 4,000 hours of data, this technique imbues the series with exhibit optimal hold-up, energy harvesting, and pulse-power handling characteristics, including: very high capacitance (0.47–7.5F ±20% tolerance), extremely low ESR, (4–300mΩ at 1KHz), low leakage (2–1,000µA), and high energy density (1–5.6Wh/kg), and long-lifetime performance (500,000+ cycles), and is responsible for its unique ability to operate effectively without balancing circuitry.

SCM Series parts rated for 5V/5F (SCMT22C505MRBA0) were tested at various applied voltages at 85°C, and the results clearly demonstrate that the parts exhibit a decreasing rate of change in capacitance as the voltage drops and that ESR values become stable with time.

At rated voltage, all SCM Series parts are rated for a maximum operating temperature of 65°C. So, the part under test suffered catastrophic failure at rated voltage and 85°C (**Figure 1**), which verifies the critical nature of operating supercapacitors within their rated voltage and temperature range.

Derating to 90% (4.5V) of rated voltage drastically improved the longevity of the part (**Figure 2**). In this test, the 5F part lost 30% of capacitance after a little more than 3,000 hours, and ESR began exhibiting a slow rise at the same mark. As such, it can be safely concluded that this part would survive 85°C operating temperature for 3,000 hours at 4.5V operating voltage.

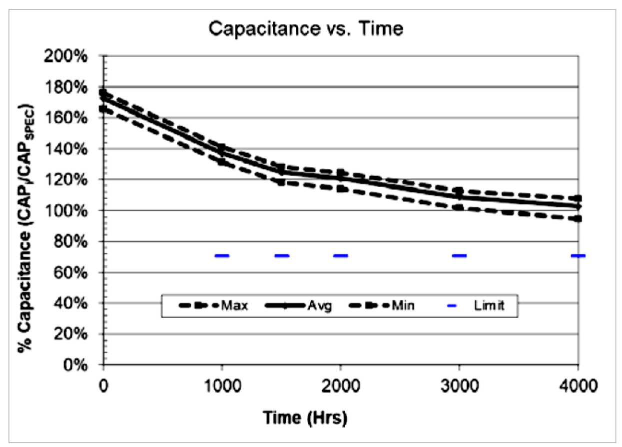


Figure 3: This graph pair represents Capacitance vs. Time and ESR vs. Time for the SCMT22C505MRBA0 at 80% rated voltage (4.0V) for 4,000 hours at 85°C.

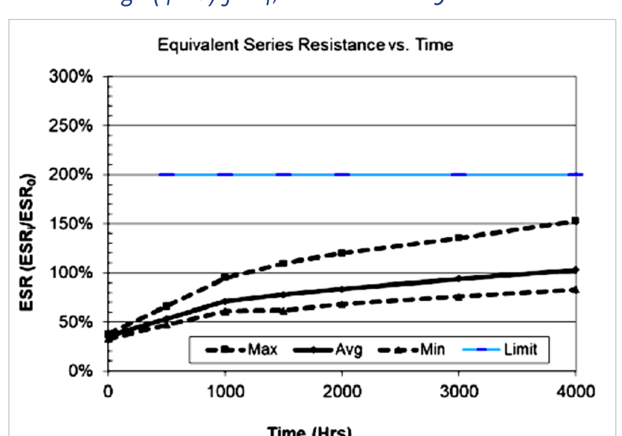


Figure 4: This graph pair represents Capacitance vs. Time and ESR vs. Time for the SCMT22C505MRBA0 at 70% rated voltage (3.5V) for 4,000 hours at 85°C.

At 80% of rated voltage (4.0V), the part almost passed 85°C testing conditions for 4,000 hours. The ESR curve was encouraging — demonstrating a slow, lethargic rise — however, the capacitance dropped off after 3,000 hours of testing (**Figure 3**).

At 70% of rated voltage (3.5V), capacitance reached an asymptotic curve and ESR remained stagnant (**Figure 4**). The 5V/5F SCM Series part (SCMT22C505MRBA0) easily passed 4,000 hours of testing at 85°C operating temperature.

The curve in a Capacitance vs. Time plot of an unbalanced 5V/0.47F module tested at rated voltage and 70°C for 4,000 hours (**Figure 5**) also illustrates that capacitance reached an asymptotic value, which indicates slow degradation of capacitance.

Similarly, when an unbalanced, 5V/1F, two-capacitor module (SCMR18C105MRBA0) was tested at rated voltage, 40°C, and 95% relative humidity for 4,000 hours, it easily passed both Capacitance vs. Time and ESR vs. Time tests, proving its suitable under said conditions (**Figure 6**).

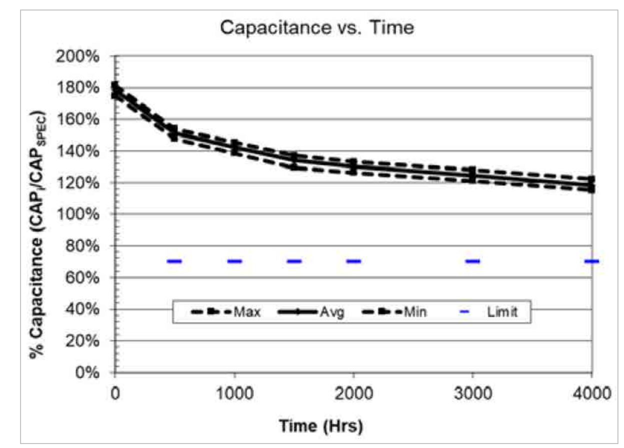


Figure 5: This graph represents Capacitance vs. Time for the 5V/0.47F SCMR14C474MRBA0 at rated voltage for 4,000 hours at 70°C.

SCC Series Long-Term Reliability Test Results

The following test procedures were conducted on AVX's SCC Series cylindrical, electrochemical, double-layer supercapacitors — the building blocks for the SCM Series modules. Produced using the same core-matching techniques as described above, the SCC Series currently offers the industry's smallest 2.7V/1F supercapacitor (SCCR12B105SRB) and also exhibits optimal hold-up, energy harvesting, and pulse-power handling characteristics, including: very high capacitance (1–3,000F), extremely low ESR (0.16–200mΩ at 1KHz), low leakage (6–5,800µA), high energy density (1.2–5.6Wh/kg), and long-lifetime performance (500,000+ cycles).

At rated voltage, all SCC Series

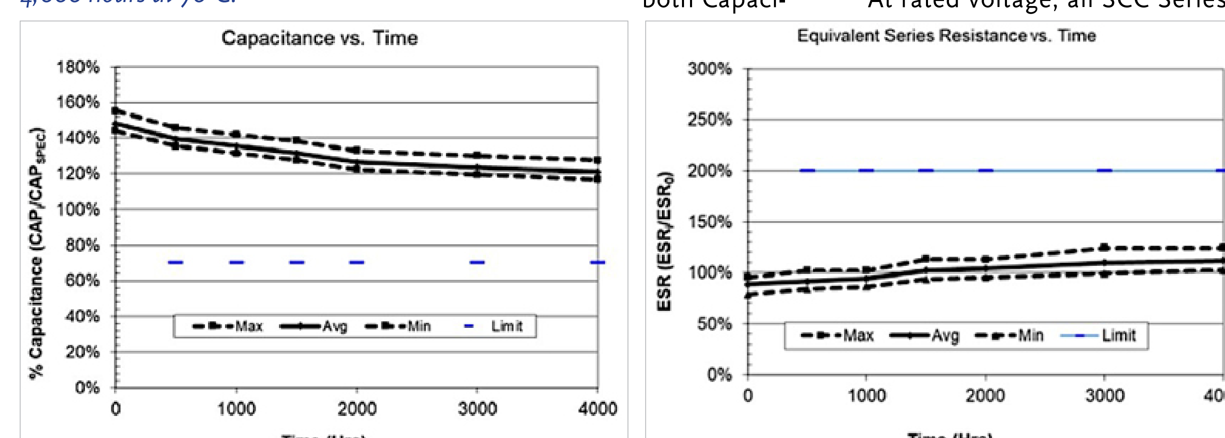


Figure 6: This graph pair represents an unbalanced, 5V/1F SCMR18C105MRBA0 at rated voltage (5V), 40°C, and 95% relative humidity for 4,000 hours.

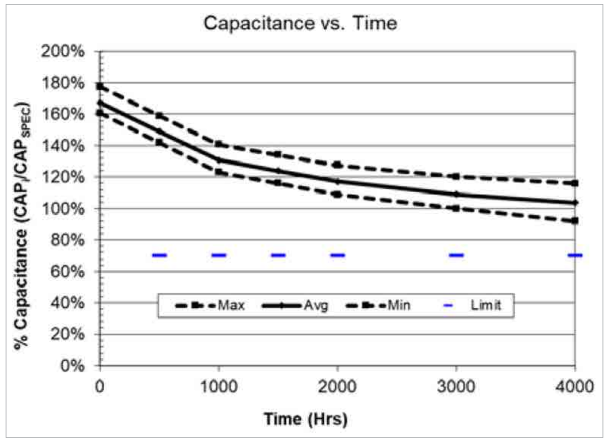


Figure 7: This graph represents Capacitance vs. Time for the 2.7V/1F SCCR12B105SRB at roughly 77% rated voltage (2.1V) for 4,000 hours at 70°C.

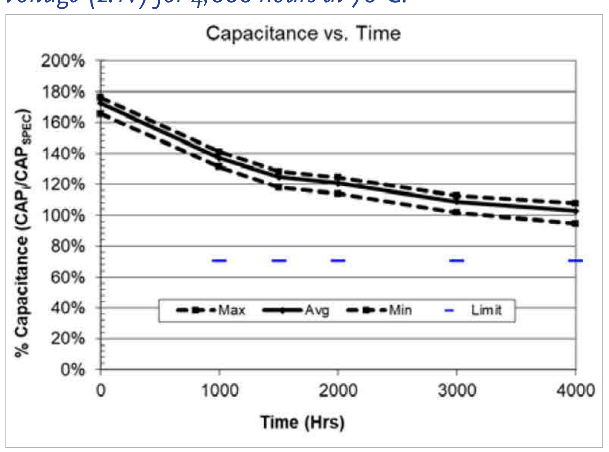


Figure 8: This graph represents Capacitance vs. Time for the 2.7V/1F SCCR12B105SRB at rated voltage (2.7V) for 4,000 hours at 70°C.

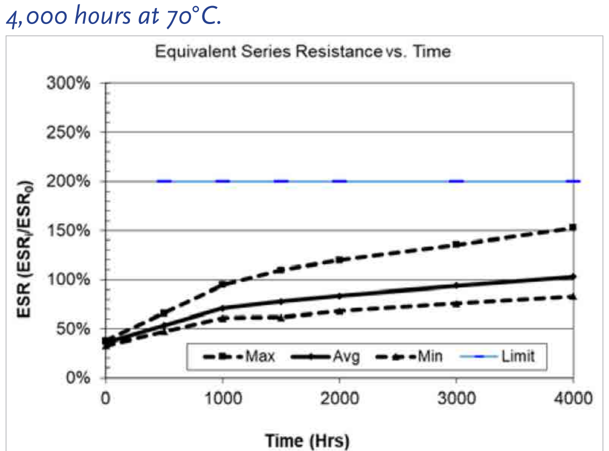


Figure 9: This graph represents ESR vs. Time for the 2.7V/10F SCCS30B106SRB at 70% rated voltage (1.9V) for 4,000 hours at 85°C.

parts are rated for a maximum operating temperature of 65°C. Long-term testing of a 2.7V/1F (SCCR12B105SRB) part at 70°C and a derated voltage of 2.1V demonstrated that capacitance reached an asymptotic value as testing neared the 4,000-hour mark (**Figure 7**).

When the same part number was tested with rated voltage applied and held at 70°C for 4,000 hours, capacitance easily withstood the test conditions (**Figure 8**).

When, similar to the SCM Series test depicted in Figure 4, a 2.7V/10F (SCCS30B106SRB) part was tested at 70% of rated voltage (1.9V) and held at 85°C, it also easily passed performance requirements regarding ESR over time (**Figure 9**).

Conclusions and Implications
The results of this case study clearly indicate that AVX's SCM and SCC Series supercapacitors operate well within rated specifications at elevated temperatures and exhibit unique qualities that enables their use at ≤4V and 85°C. These proven performance capabilities are important because they provide long-term evidence of the technology's suitability for use in parallel with lithium ion (Li-ion) batteries — a feature that is not currently offered by any other supplier in the industry.

When derated to typical operating temperatures spanning 25°C to 45°C, long-term reliability testing data indicates that these parts are expected to last more than 20 years. As such, testing supports that these unique supercapacitors offer ideal solutions for hold-up, energy harvesting, and pulse-power circuits in industrial and consumer applications including: smartphones, uninterrupted power supplies (UPS), wireless alarms, remote meters, global systems mobile (GSM) and general pocket radio service (GPRS) transmissions, camera flash systems, scanners, drones, toys, and games.

AXV
www.avx.com

Train Your Fitness Monitor to Deal with Any Lighting Conditions

Is the data produced by these always accurate and reliable?

By: Maxim's Wearable Health Team

With the proliferation of wearable health monitors among fitness enthusiasts, it may be worth posing the following question: Is the data being produced by these devices always accurate and reliable? In the same way that automobiles encounter real-world driving conditions vastly different from the laboratory environment used to generate performance figures on fuel economy, wearable health and fitness monitors can encounter environments not anticipated when they were originally designed. In this design solution, we consider the challenges in designing accurate, reliable wearable health and fitness monitors for a wide variety of user conditions.

We'll review the conventional approach to their design and introduce an innovative solution that enables a higher level of accuracy while consuming less power and space than has been possible until now.

Heart-Rate Detection
Heart-rate (or pulse) detection is an almost ubiquitous feature of wearable health and fitness monitors (**Figure 1**). This reading is useful because heart rate is a vital sign that provides a good indication of heart rate variability (HRV). HRV is used to assess stress levels, sleep quality, and overall well-being, among others. This measurement is based on a technique called photoplethysmography (PPG). A PPG signal is obtained by illuminating skin using a light-emitting diode (usually green) and detecting changes in the intensity of the reflected light (**Figure 2**) using a photodiode which generates a current proportional to the amount of received light.

As the heart pumps blood, the amount of light returned to the photodiode from the skin registers a small change in amplitude (AC signal). This small change is superimposed on a large static amplitude (DC signal), which represents absorption through tissue along with ambient (background) lighting conditions in which the measurement is being made. The current signal is digitized and sent to a microprocessor within the device which then uses an algorithm to calculate the heart rate.

There are two major challenges in making accurate heart-rate measurements using wearable devices. The first challenge is the variation in lighting conditions the user encounters either during exercise or in normal living conditions. Rapidly varying lighting conditions can introduce "artifacts" into the measurement process. Artifacts are large changes in the received signal, which effectively mask the small AC signal, causing problems for the microprocessor to correctly calculate the pulse rate. Wearable devices must be able to compensate for large variations in ambient lighting to prevent spurious readings. While ambient light compensation is a feature of many modern health and fitness devices, the

Figure 1: Wrist-Worn Health and Fitness Monitor

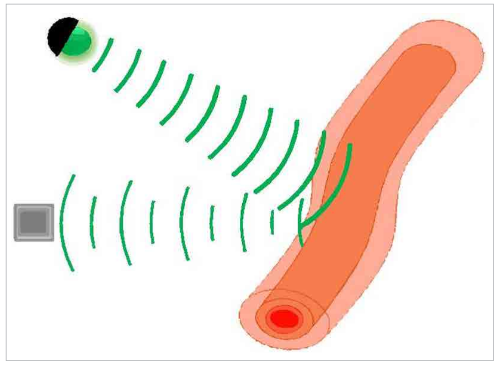


Figure 2: PPG Using LED and Photodiode

magnitude (ambient range) and quality (ambient rejection) widely varies. Currently available solutions have an ambient range of up to 25μA and an ambient rejection of up 55dB (at 120Hz).

The second challenge is the motion of the user, particularly during periods of high-intensity training, which can also cause artifacts. Currently available solutions use digital filtering techniques to attempt to compensate for motion artifacts, but these are not always successful.

Apart from the challenges associated with artifacts, wearable devices need to consume as little power as possible (to prolong battery life) in the smallest possible form factor. Available solutions use several photodiode detectors that operate sequentially at high frequency. Since the LEDs are the most power-hungry component in the device, operating them at the high frequency required for accurate readings can place a large drain on the battery powering the device. This typically consumes more than 450μW of power (at 25 samples per second).

Dual-Channel Approach

The MAX86141 optical pulse oximeter and heart-rate sensor (**Figure 3**) offers an alternative solution for the detection of optical heart rate, oxygen saturation (SpO2), and muscle oxygen saturation (SmO2 and StO2). It uses two photodiode detectors simultaneously (instead of sequentially) which provides a two-fold advantage. First, operating two channels in parallel results in lower power consumption (184μW at 25 samples per second) since the LEDs only need to be turned on once rather than the multiple times for sequential sampling.

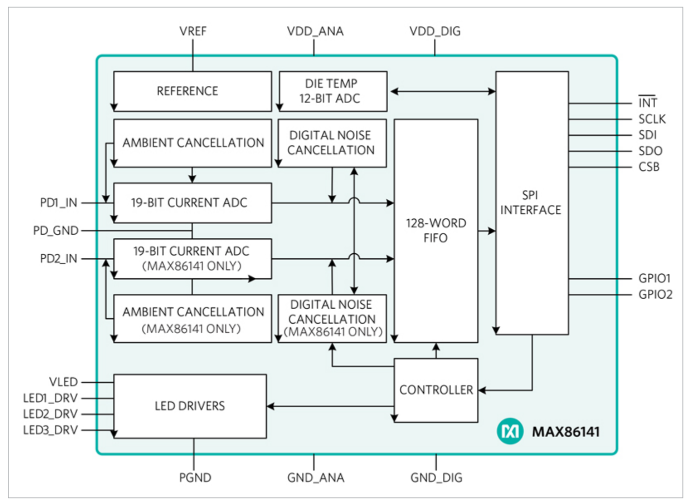


Figure 3: Functional Diagram of MAX86141

Second, the use of two photodiode detectors allows the creation of correlated (in time) differential signals. This is a new form of optical motion detection in which the signals are used by the downstream microprocessor for improved motion compensation. The MAX86141 also includes a "picket-fence" algorithm that can detect and replace rapid changes in ambient lighting such as when a car has direct sunlight exposure passing under a bridge or passing through a woodland area with alternating sunlight and shade. The ambient range is 100μA and ambient rejection is 84db (at 120Hz), far exceeding that of other solutions. It has a very low system power of 120μW and is available in a miniature 2.048mm x 1.848mm, 0.4mm pitch WLP.

Conclusion

Having considered the challenges facing designers of wearable health and fitness monitors, as well as the limitations of current solutions, we can conclude that the MAX86141 optical pulse oximeter and heart-rate sensor for wearable health provides lower power operation and higher accuracy measurements while requiring minimal space. It is well suited for use in wearable devices for fitness, wellness, and medical applications, such as those worn on the wrist, finger, and in the ear.

Maxim Integrated
www.maximintgrated.com

Safety of Household and Similar Electrical Appliances – How EN 60335 Compares

EN 60335 Part 1 defines how household and similar electrical appliances can meet the overall requirements of the 'Low Voltage Directive' and other legislation

By: Gary Bocock, Technical Director, XP Power

When designing to meet the requirements of EN 60335, engineers have to adopt a different mind-set. Compared with the familiar IT and medical standards, not only are some design limits different but also the potential users and end products are much more varied. Unusually in safety evaluation, multiple faults have to be considered simultaneously with the effects of EMI.

The scope of the standard

EN 60335 part 1 is a safety standard for household and similar electrical appliances that defines how these categories of products can meet the overall requirements of the 'Low Voltage Directive' LVD 2006/95/EC and others such as the 'Machinery Directive' 2006/42/EC or even the 'Construction Products Directive' 89/106/EEC, as relevant. This variety is in recognition of the fact that a typical household will have all sorts of electrical equipment, intended for many different uses.

Because the products can vary in type and use so much, unusually, EN 60335 includes currently 114 'Part 2' standards which relate to the requirements of particular products ranging from toys to insect killers to 'scissor type' garden shears. For this reason, the relevant 'Part 2' document also has to be consulted and takes precedence over the 'general requirements' of Part 1. Standard EN 60664-1, 'Insulation coordination for equipment within low-voltage systems. Principles, requirements and tests' is also often referenced.

A modern kitchen might have 'professional' grade appliances which are covered by the standard. Equally, commercial premises can also have equipment intended for the domestic market; examples would be hotels, shops, offices and anywhere with a 'house-keeping' function such as care homes. The standard covers these areas as well, with the increasingly blurred distinction between office, home and medical. Even outdoor equipment such as electric fence controllers are covered.

Another layer of applicability is the expected user. EN 60335 covers equipment handled and operated by the general public but specifically excludes provisions for very young children up to three years, young children three to eight years without supervision and very vulnerable people with extensive and complex disabilities. Generally, EN 60335 covers rated input voltage not more than 250 VAC single-phase and 480 VAC 3-phase as well as battery operated equipment but some specific household products such as power tools are covered by their own separate standards. The standard specifically does not apply to audio, video and similar electronic apparatus, appliances for medical purposes, hand-held motor-operated electric tools, personal computers and similar equipment or transportable motor-operated electric tools.

Practical implications for Power Supply design

EN 60950, EN 60065 and their successor EN 62368 have been common standards applied to Information Technology and audio-visual equipment. EN 60601 is the equivalent for medical. Power products meeting these standards would not necessarily meet the requirements of EN 60335 although in some areas EN 60335 is less stringent.

Examples are that EN 60950 allows solid insulation of >0.4 mm for reinforced insulation to accessible parts with little conditionality but EN 60335 defaults to >2 mm unless specific evaluation of the material is done along with 48 hr dry heat tests and subsequent high voltage dielectric tests. Even after that, the standard still requires > 0.6 mm for equipment subject to over-voltage class II environments and >1.2 mm for class III. Another example difference is creepage and clearance; EN 60335 refers to IEC 60664 when the working voltage across isolation has periodic waveforms imposed greater than 30 kHz as would normally be the case with switched-mode power supplies. The IT standard EN 60950 and medical IEC 60601 are less prescriptive on this, just using 'actual rms or dc' whereas the newer standard EN 62368 also refers to IEC 60664. The difference this makes in creepage distances is a minimum overriding value as shown in the graph for a pollution degree (PD) 1 environment for any level of isolation basic/reinforced. The values are multiplied by 1.2 and 1.4 for pollution degrees 2 and 3 respectively.

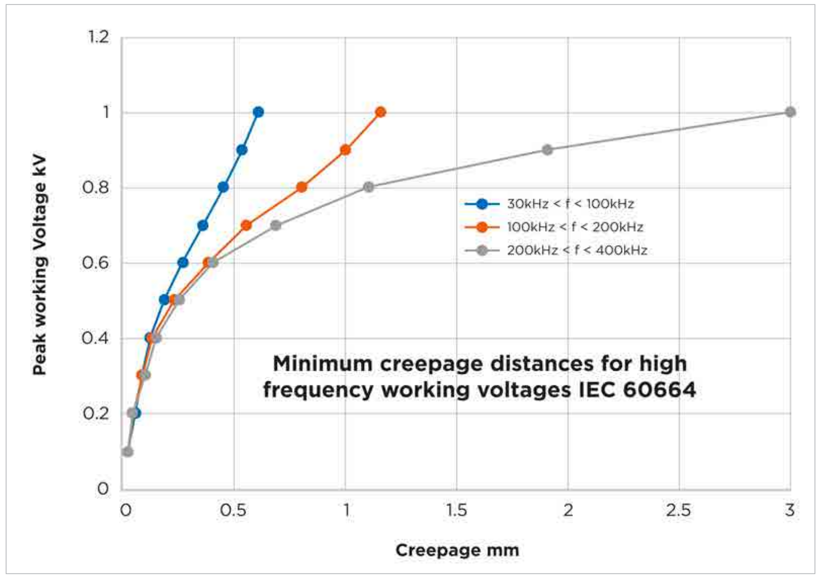


Figure 1: Creepage distances depend on frequency, not just voltage

In practice, the minimums only override the EN 60335 default values for higher frequencies and voltages. For example, EN 60335 requires 2.4 mm PD1 at 1 kV working voltage, basic insulation. In this case above 200 kHz, the high frequency peak value for creepage of 3 mm applies.

Otherwise, EN 60335 is less stringent in some areas. For example, compared with EN 60950, the 'basic' level hi-pot test is 1250 Vrms compared with 1500 Vrms, clearances distances are a little less and the ground impedance test current is 25 A rather than 32 A. SELV for EN 60335 is however lower at 50V with no load compared with 60 V for the IT standard. EN 62368, the replacement for EN 60950 does away with the concept anyway and refers to Energy Source (ES) limits where the maximum voltage deemed safe depends on prospective current and frequency.

Test	Standard	Values
ESD	IEC 61000-4-2 Severity level 4	+/-15 kV (air) +/- 8 kV (contact)
Radiated susceptibility	IEC 61000-4-3 Severity level 3	10 V/m
Electrical Fast transients and bursts	IEC 61000-4-4 Severity level 4	+/- 4 kV (AC) +/- 4 kV (DC) +/- 2 kV (I/Os)
Surge	IEC 61000-4-5 Severity level 3/4	+/- 2 kV (line to line) +/- 4 kV (line to ground)
Conducted RF	IEC 61000-4-6 Severity level 3	10Vrms
Voltage Dips/Interrupts	IEC 61000-4-34 Severity Class 3	20% Dip, 5 secs 30% Dip 500 ms 60% Dip 200 ms 95% Interrupt 10 ms 95% Interrupt 10 ms

Table 1: Severity levels of typical EMC tests are high

Two-fault protection

In the latest edition, the writers of EN 60335-1 standard have come right up to date with the realities of modern household equipment. It is likely to be 'smart' and have electronic controls and may even be Internet connected. The electronics may now be part of the inherent safety provisions of the equipment, for example many ON/OFF controls are now digital inputs to a processor putting the product into a 'standby' mode. If the electronics is monitoring temperature and relies on that ON/OFF control to disconnect the device, the electronics is certainly part of safety. In a break from history, the standard therefore considers failures in the electronics in conjunction with another single fault elsewhere, effectively two faults.

The electronics fault could simply be that a coin cell battery keeping a processor alive during power dropouts is not replaced routinely – something we are probably all guilty of. To test for this, the standard requires equipment with Protective Electronics Circuits (PECs) to be subject to a slowly reducing input voltage to the level where functionality is lost but with any back-up battery disconnected. The product has to remain safe. Other hard faults in the PEC are imposed along with a 'first' fault such as bridging of basic insulation, again checking for no hazard. As can be imagined, the combination of possible faults multiplies up requiring careful engineering judge-

Figure 2: The 3 Watt VCE03 series from XP Power meets EN 62368 and EN 60335

ment as to what to test.

This contrasts with the IT and medical safety standards which look for safe operation only after imposed single faults.

EMI induced faults
Equipment meeting IT and medical standards for example have to meet the provisions of the EMC directive 2014/30/EU which mandates compliance with the appropriate standard defining EMI and its severity in the EN 61000-4 series. The product is categorised as to whether it continues to function, interrupts or fails. However, failing in a way that compromises other safety protection features in the equipment is not evaluated. In EN 60335 this is considered, again in recognition of the fact that the environment is not well controlled and equipment may not be routinely maintained. Consequently, a failure is imposed in any PEC and then the EMC tests conducted to check for safety hazards. The severity levels of EMI according to EN 61000 are typically set high (see **table 1**) and significantly, surge arrestors on mains power supply inputs are disconnected during the tests. The rationale for this is that these components can have wear-out mechanisms and cannot be assumed to be effective after periods in service. We now have three 'abnormal' conditions, a failed PEC, a worn-out surge arrestor and an EMI surge or transient.

Integral power supply products therefore have to be designed to withstand these stress levels without surge arrestors and not fail or induce failures in a hazardous way. They must also not respond to the EMI stimulus and PEC failure by switching into an operating condition from a safe standby or off condition set by the first PEC failure.

Software and Safety
A specific requirement in household equipment meeting EN 60335 is that any software or firmware control of the product should be robust under single fault conditions and with EMI applied. The software should not have any systematic 'bugs' and be subject to a program of verification and validation in development to ensure that safety is not compromised. The hardware comprising the program electronics needs to be evaluated with Failure Mode and Effect Analysis (FMEA). All this with an existing first fault and EMI and at any identified critical point in the program execution.

For comprehensive protection, redundant hardware may need to be added or effective self-test and reporting schemes.

The latest technology in power supply products will often include digital processing and control with field updatable firmware. This of course is affected as well. EN 60335 is certainly addressing the reality of modern household equipment – perhaps future editions will need to address safety implication of their wireless connectivity as well.

Working with a power designer and manufacturer, experienced in integrating power products into EN 60335 applications eases the end equipment EMC and safety approvals processes benefitting time to market and costs for new domestic appliances. XP's products are being successfully used in heating applications, pumps, hand dryers, heat exchangers and many other products requiring EN 60335 approvals with power ratings ranging from three to hundreds of Watts.

XP Power
https://www.xppower.com

Essential performance, voltage dips and medically certified power supplies

How to minimise the risk of performance drops or loss of functionality in medical devices

By: Robin Jeffery, TDK-Lambda EMEA

Although essential performance is covered in IEC 60601-1 2nd edition, the 3rd edition defines it in greater detail as "the performance necessary to achieve freedom from unacceptable risk". It is up to the manufacturer to determine if a loss of performance or functionality will result in an acceptable risk or an unacceptable risk. This is analysed by determining the probability or the frequency of an event happening and the severity of that event. If a medical device loses performance or functionality in a way that it harms a patient, the operator or the environment, that is classed as an unacceptable risk.

As an example, if a handheld battery-operated meter that measures blood glucose levels was to stop working due to a defective part, it would be an acceptable risk. This is because they are usually readily available in a hospital or clinic, and a replacement could be easily found. If a failure caused the device to display an incorrect reading, it could result in harm to a diabetic patient if too much or too little insulin was then administered. That failure would certainly be an unacceptable risk.

Although medically certified power supplies are not classed as medical devices, their (EMC immunity) performance under IEC 60601-1-2 can affect the medical device it is powering, particularly with the stricter IEC 60601-1-2:2015 4th edition levels now published.

IEC 60601-1-2 is based on the IEC 61000-4 standard, and for input voltage dips IEC 61000-4-11 applies. This standard covers "Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests".

There are five key tests indicated in **Table 1**. 100Vac input and 50Hz conditions are shown as they could represent the worst case.

AC Input Voltage	Actual Voltage Dip for 100Vac nominal	Voltage Dip by AC Input Cycle (50/60Hz)	Voltage Dip Time Period for 50Hz	Suggested Performance Criteria Level
Dip down to 0%	0Vac	0.5 of a cycle	10ms	A
Dip down to 0%	0Vac	1 cycle	20ms	A
Dip down to 40%	40Vac	10/12 cycles	200ms	B
Dip down to 70%	70Vac	25/30 cycles	500ms	A
Dip down to 0%	0Vac	250/300 cycles	5000ms (5s)	B

Table 1: IEC 61000-4 standard, and for input voltage dips IEC 61000-4-11

Tests are made against four performance criteria levels:

Performance Criteria A – 'Performance within specification limits'

This is the most acceptable result. A small voltage transient on the output may be similar to that seen for a step load change and is unlikely to cause the end equipment to malfunction.

Performance Criteria B – 'Temporary degradation which is self-recoverable'

Criteria B would probably be acceptable in most cases. This could occur during a short interruption to the AC input.

Performance Criteria C – 'Temporary degradation which requires operator intervention'

This performance criterion would generally be classified as unacceptable from a user point of view, without even considering a risk analysis. If the AC power dropped out for a few cycles and the power supply had to be reset by a nurse or doctor, it would be too inconvenient.

Performance Criteria D – 'Loss of function which is not recoverable'

Criteria D is a "fail" recording on the test result in that the power supply had suffered damage and no longer functions. It is highly unlikely that any manufacturer would place a product with this performance level on the market.

Referring to **Table 1**, most power supplies will pass the first two tests with a Performance Criteria level A with some output derating to increase the hold-up time.

The third and fourth tests require the power supply to continue to operate for 200ms when the input drops to 40% of nominal or for 500ms at 70% of nominal. This would be 40Vac with an AC supply voltage of 100V. There is a way to still achieve Criteria A though. Modifying the product's low voltage input protection circuitry would allow the power supply to operate at the low input voltage for a short time. As the AC input current will be higher, the user must ensure that the power supply is not operated at full load, which many users already do to improve product life. As hold-up is related to the actual output power drawn, operating the power supply at 50% load will result in a significant increase in the hold-up time.

All of the above tests are of course much easier to comply with if the medical device is operated with a 208/230Vac input.

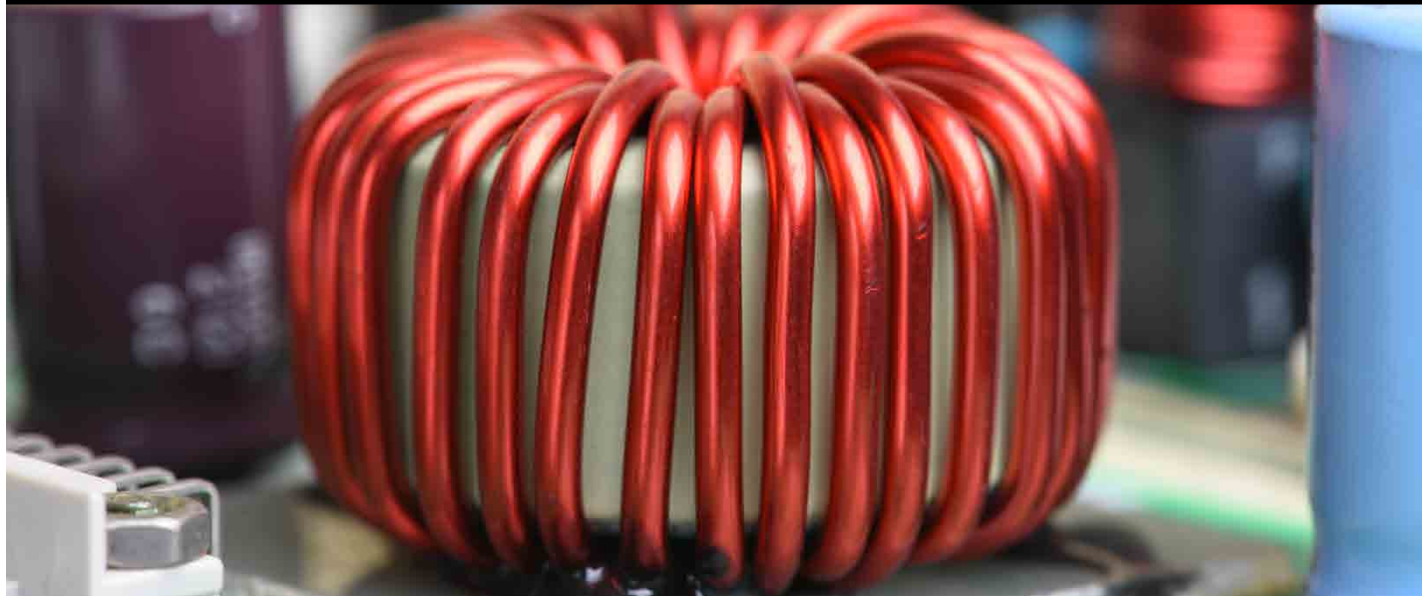
The last test of a 5 second interruption to the AC supply is usually met by the medical device manufacturer, with the installation of battery back-up or a UPS (Uninterruptable Power Supply). Adding sufficiently large energy storage electrolytic capacitors inside the power supply would result in a significant increase in size.

As mentioned, the risk analysis has to be conducted by the medical device manufacturer. Accepting Criteria below level A will depend always upon the end application, and if harm will occur.

TDK-Lambda
www.uk.tdk-lambda.com/medical

Special Report: Power Supplies & Magnetics

PSD NORTH AMERICA



Inside:

No Inductors Required

Switching power supplies must not generate a lot of noise

By: Tony Armstrong, Director of Product Marketing, Power Products, Linear Technology

A fundamental axiom for switching power supplies is that they must not generate a lot of noise. Accordingly, quiet, well-regulated power supplies are important for optimum performance in many circuit applications. In order to attain this level of performance it is critical to be able to mitigate any noise generated as part of this conversion process. An obvious way to attain this is to simply use a linear regulator. However, although they supply quiet power supply rails, their conversion efficiencies are poor at high step-down ratios and this can lead to thermal issues with the design in high output current applications.

Of course, magnetic-based switching regulators can alleviate the usual thermal issues since they generally have high efficiency of conversion, leading to simpler thermal design when high output currents are required by the end application. It is well understood that component selection and circuit board layout can play a significant role in determining the success or failure of virtually all power supplies. These aspects set their functional EMI and thermal behavior. For the un-initiated, switching power supply layout may seem like a "black" art, but it is in fact a basic aspect of a design often overlooked in the early stages of the process. Since functional EMI requirements always have to be met, what is good for functional stability of the power supply is also usually good for its EMI emissions, too. Furthermore, good layout from the beginning does not add any cost to the design and can actually provide cost savings by eliminating the need for EMI filters, mechanical shielding, EMI test time and numerous board revisions.

Moreover, the potential problems of interference due to noise can be exacerbated when multiple DC/DC switchmode regulators are used in a design to generate multiple rails or if they are paralleled for current sharing and higher output power. If all are operating (switching) at a similar frequency, the combined energy generated by multiple regulators in a circuit is then concentrated at one frequency. Presence of this energy can become a concern, especially if the rest of the ICs on the printed circuit boards (PCBs), as well as other system boards are close to each other and susceptible to this radiated energy. This can be particularly troubling in industrial and automotive systems that are densely populated and are often in close proximity to electric noise generating sources, such as mechanically switched inductive loads, PWM drive power outputs, microprocessor clocks and contact switching. Furthermore, if switching at different frequencies, intermodulation products can alias into sensitive frequency bands.

Switching Regulator Emissions

Switching regulators usually replace linear regulators in areas where low heat dissipation and efficiency are valued. Moreover, the switching regulator is typically the first active component on the input power bus line, and therefore has a significant impact on the EMI performance of the entire product design.

Conducted emissions ride on the wires and traces that connect up to a product. Since the noise is localized to a specific terminal or connector in the design, compliance with conducted emission requirements can often be assured early in the development process with a good layout or filter design. Radiated emissions are a different matter altogether. Everything on the board that carries current radiates an electromagnetic field. Every trace on the board is an antenna and every copper plane is a resonator. Anything, other than a pure sine wave or DC voltage, generates noise all over the signal spectrum. Even with careful design, a power supply designer never really knows how bad the radiated emissions are going to be until the system is tested. And radiated emissions testing cannot be formally performed until the design is essentially complete.

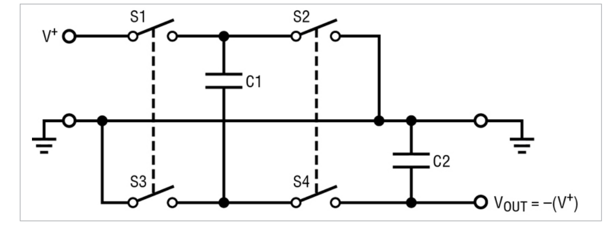


Figure 1: Simplified Charge Pump Block Diagram of a Voltage Inverter

Filters are often used to reduce EMI by attenuating the strength at a certain frequency or over a range of frequencies. A portion of this energy that travels through space (radiated) is attenuated by adding metallic and magnetic shields. The part that rides on PCB traces (conducted) is tamed by adding ferrite beads and other filters. EMI cannot be eliminated but can be attenuated to a level that is acceptable by other communication, signal processing and digital components. Moreover, several regulatory bodies enforce standards to ensure compliance in both industrial and automotive systems.

Modern input filter components in surface mount technology have better performance than through-hole parts. However, this improvement is outpaced by the increased demands created by today's high frequency switching regulators. The low minimum on and off times required at higher operating frequencies result in higher harmonic content due to the faster switch transitions, thereby increasing radiated noise. However, these high switch edge rates are needed to get higher conversion efficiencies. A switched capacitor charge pump does not exhibit this behavior since it operates at much lower switching frequencies and most importantly can tolerate slower switching transitions without degradation in efficiency.

Savvy PCB designers will make the hot loops small and use shielding ground layers as close to the active layer as possible. Nevertheless, device pin-outs, package construction, thermal design requirements and package sizes needed for adequate energy storage in decoupling components dictate a minimum hot loop size. To further complicate matters, in typical planar printed circuit boards, the magnetic or transformer style coupling between traces above 30MHz will diminish all filter efforts since the higher the harmonic frequencies are, the more effective unwanted magnetic coupling becomes.

Switched Capacitor Charge Pumps

Charge pumps have been around for decades, and they provide DC/DC voltage conversion, using a switch network to charge and discharge two or more capacitors. The basic charge pump switch network toggles between charge and discharge states of the capacitors. As shown in **Figure 1**, C1 the "flying capacitor" shuttles charge, and C2 the "reservoir capacitor" holds charge and filters the output voltage. Additional "flying capacitors" and switch arrays enable multiple gains.

When switches S1 and S3 are on, or closed, and switches S2 and S4 are off, or open, the input power supply charges C1. During the next cycle, S1 and S3 are off, S2 and S4 are on, and charge transfers to C2, generating VOUT = - (V+).

However, until recently, charge pumps have had limited input and output voltage ranges, which has limited their use in industrial and automotive applications where inputs up to 40V or greater are commonplace.

A recent introduction in this area is Linear Technology's LTC3256. It is a highly integrated, high voltage low noise dual output power supply, which takes a single positive input and generates 5V and 3.3V step-down supplies with high efficiency and no inductors. The device features a wide 5.5V to 38V input voltage range and includes independently enabled dual outputs: a 5V 100mA supply, and a 250mA 3.3V low-dropout (LDO) regulator, for a total of 350mA output current. This combination of regulators offers much lower power dissipation than a dual-LDO solution. For example, with a 12V input and a maximum load on both outputs, power dissipation is decreased by over 2W with

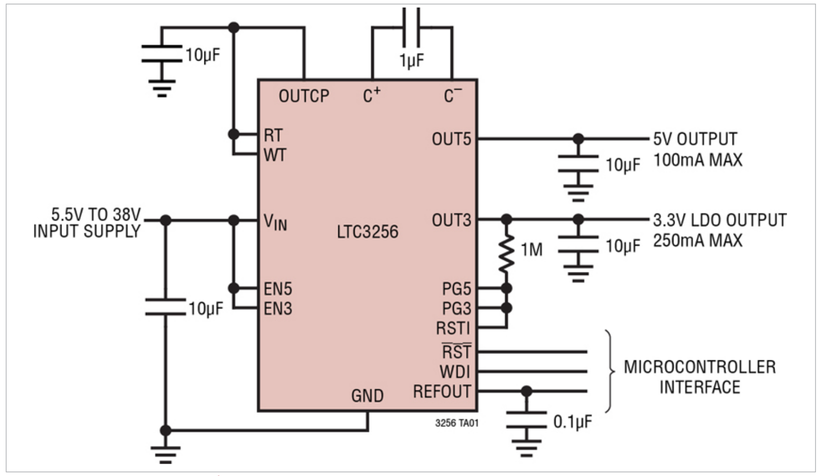


Figure 2: LTC3256 Schematic Has a 5V/100mA Output & a 3.3V/250mA Output

the LTC3256 vs. a dual LDO, thus reducing the heat loss and input current. See **Figure 2** for its complete schematic.

The LTC3256 has been engineered for diagnostic coverage in ISO26262 systems and incorporates numerous safety and system monitoring features. The device is well-suited for a variety of applications requiring low noise, low power rails from high voltage inputs such as automotive ECU/CAN transceiver supplies, industrial/telecom housekeeping supplies, and general-purpose low-power conversion.

The LTC3256 maximizes efficiency by running the charge pump in 2:1 mode, over as wide an operating range as possible, and automatically switches to 1:1 mode as needed, consistent with VIN and load conditions. Controlled input current and soft switching minimize conducted and radiated EMI. The device offers low quiescent current of only 20µA with both outputs in regulation (no load) and 1µA in shutdown. The integrated watchdog timer, independent power good outputs and reset input ensure reliable system operation and enable fault monitoring. A buffered 1.1V reference output enables system self-testing diagnostics for safety critical applications. The LTC3256 also has additional safety features including overcurrent fault protection, over temperature protection and tolerance of 38V input transients.

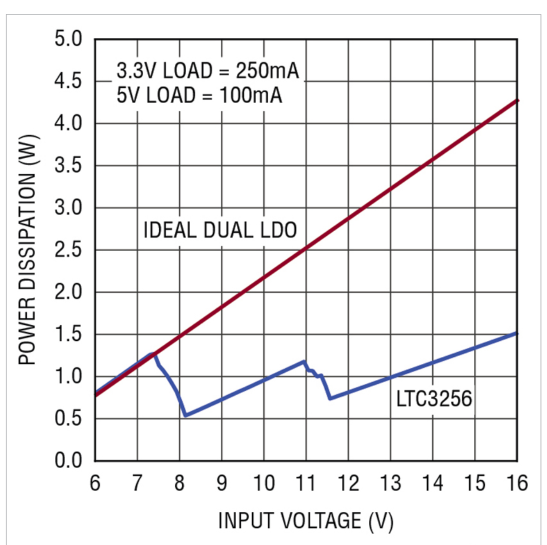


Figure 3: Power Dissipation Characteristics of the LTC3256 vs. a Dual LDO

The graph of **Figure 3** below highlights the LTC3256's good power dissipation characteristics. At 12VIN, the LTC3256 with 3.3V @250mA and 5V @100mA outputs dissipates about 750mW, while under these same conditions, a dual LDO would dissipates almost 3W. That's 2.25W less for LTC3256, which is a huge benefit for the thermal aspect of the design.

Conclusion

It is well known that EMI considerations require careful attention during the initial design process in order to ensure that they will pass EMI testing once the system is completed. Until now, there has been no sure fire way to guarantee that this could easily be attained with the right power IC selection for all but very low power systems. However, with the recent introductions of low EMI regulators, such as the LTC3256 high voltage charge pump, an alternative choice is now available. It provides much higher efficiency and lower power loss when compared to linear regulators and do not require the compensation, layout, magnetics and EMI issues associated with a switching regulator.

Linear Technology
www.linear.com

Forced Air Cooling: Sourcing an Appropriate Fan

Putting an effective thermal management system in place to ensure operational reliability

By: Mark Patrick, Mouser Electronics

Dissipating the heat generated by certain components is a key part of electronics design. Consequently engineers need to be sure that they put an effective thermal management system in place in order to ensure that operational reliability is maintained. There are a variety of different technologies that can be employed for heat dissipation purposes. These will be based on the principles of either conduction, convection or radiation. By having a good understanding of the thermal path for removing unwanted heat from their respective systems, engineers will be able to decide on the best optimised technology to achieve desired results.

Though conduction represents the easiest way of removing heat from a system, if the electronic components involved are placed inside an enclosure (such as a rack-mount), this will impinge on the efficiency with which heat removal is carried out. Therefore, the vast majority of systems where an enclosure is being utilised, will rely on forced air cooling (for which some form of fan will be needed) to tackle the build-up of heat. There are a broad array of fans on the market, so proper consideration should be given to which option is most suitable for the application in question.

When looking to implement a thermal management solution, engineers are advised to create a detailed thermal profile of their electronics system, so that they have complete visibility of where heat is being generated and what are the quantities involved. This should cover every possible operating condition. By distributing temperature sensors around the PCB and within the enclosure itself, all the necessary data can be acquired. Once this is done, the engineer can look at the positioning and the extent of the thermal management needed to attend to the system. In addition to compiling information on the heat generated by the constituent electronic components, this profiling can also provide engineers with valuable insight into the airflow around the system and where there might be impedance.

By knowing the system impedance (in terms of the drop in air pressure witnessed between air inlets and outlets), is pivotal when it comes to accurately estimating the overall airflow that the specified fan will need to produce. It is possible to derive the system impedance through measurement of the pressure drop using sensors. Alternatively, by placing the whole system in an air chamber, better quality results can be achieved. When larger systems are involved (like modern high density data centres), more sophisticated computational fluid dynamics are employed. Through this technique thermal profiles can be determined to a higher degree of precision.

Implementing a thermal management mechanism that is effective, while respecting both budgetary and space constraints can be a difficult balancing act. Key to this is knowing how much the internal temperature of the system can rise without the risk of operational failure being increased. Assessing the system and identifying the 'most critical' component in relation to its operating temperature will enable the maximum ambient temperature to be obtained. The combined power dissipation for all relevant components (such as MOSFETs, microprocessor units, etc.) will result in a total power dissipated by the overall design. Power dissipated (in W) directly equates to energy (Joules/s), which manifest itself in the form of heat. Equation 1 describes the relationship between temperature rise that stems for the operation of the electronic components in the system and the airflow.

Equation 1:

$q = w \times Cp \times \Delta T$

q - amount of heat absorbed by the air (W),

w - mass flow of air (kg/s)

Cp - specific heat of air (Joules/kg • K)

ΔT - temperature rise of the air (°C)

By knowing the maximum temperature that is permissible within the enclosure and the amount of heat generated (based on the cumulative power/heat dissipated by the components), an exact calculation of the amount of airflow required can be made - as shown in Equation 2.

Equation 2:

$Q = [q/(\rho \times Cp \times \Delta T)] \times 60$

Q - airflow (m3/min),

q - amount of heat to be dissipated (W)

ρ - density of air (kg/m3)

Cp - specific heat of air (Joules/kg • K)

ΔT - temperature rise of the air (°C)

By substituting constants for Cp and ρ at 26°C, the following general equation for calculating airflow can be arrived at.

Equation 3:

$Q = 0.05 \times q/\Delta T$

The airflow figure that corresponds to the system can now be compared against fan specification, so that a suitable product can be sourced. Fan manufacturers will characterise their fan units by providing a performance graph that plots airflow against static pressure - as shown in in **Figure 1**. The fan described in Figure 1 is from CUI's CFM-120 offering. These 120mm x 120mm frame axial fans have a dual ball bearing construction and support speeds of 4600 RPM.

It must of course be acknowledged that Equation 3 gives an idealised representation, with effects such as back pressure from the enclosure not taken into account. In reality there will always be some system impedance (as discussed earlier) to allow for. To determine the real-world requirements of the fan, it is important that the system impedance is calculated. This can then be plotted on the fan's performance curve, taking where the lines cross as the operating point for the fan - as seen in **Figure 2**.

Measuring the airflow through an enclosure, as previously mentioned, can be done via use of an airflow chamber. If that is not feasible, then an alternative approach is to settle on an operating point that is comfortably above the figure derived from Equation 3 so that some headroom is allowed for in terms of the airflow supported.

During the design phase effort should be made to keep the system impedance to a minimum, as this will have clear knock on effects when it comes to sourcing a fan - since a lower spec unit can then be chosen. It is advised that, whenever possible, the areas close to air inlets and outlets remain fairly clear of components. Component placement on the PCB should encourage airflow to and around critical components, using guides to accentuate this when needed. Furthermore, due consideration should be taken if the system will be deployed at altitude (such as in aerospace applications). The equations previously cited assume for air density at sea level. As air density reduces with altitude, a significant increase in the airflow will be required accordingly.

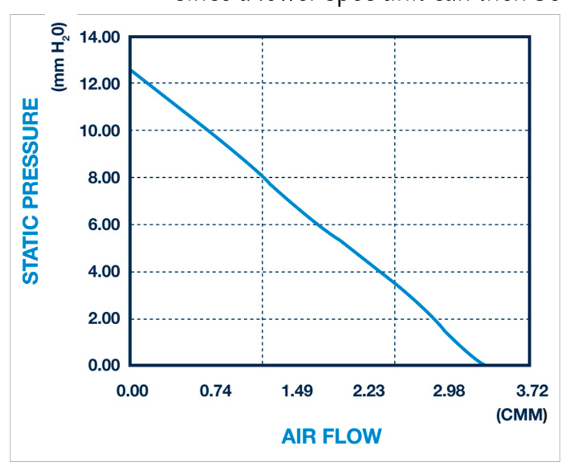


Figure 1: Example of a manufacturer's fan performance curve

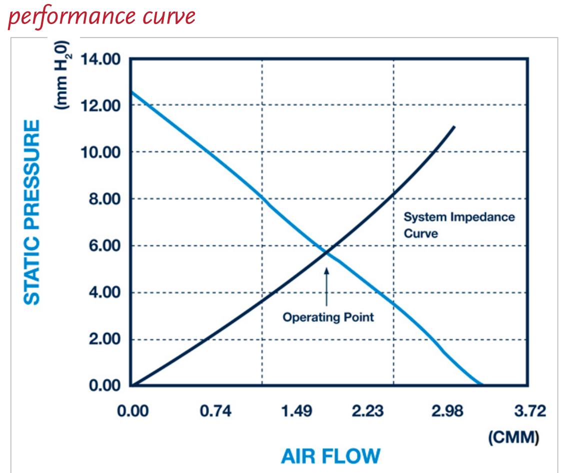


Figure 2: System impedance plotted on fan performance curve to determine operating point

Fan selection

In addition to being offered in both AC and DC configurations, fans are generally categorised by the way in which air enters and leaves the unit. For axial fans air will exit in the same plane that it entered (drawing air in from one side then expelling it from the other), while centrifugal fans (or blowers) are constructing so that the airflow is redirected and leaves on a completely different plane. The latter can effectively compress the air, allowing it to deliver a constant airflow under different pressures. The volume of airflow needed and the static pressure of the system will dictate which is the most suitable type of fan to meet given application requirements. Axial fans are suited to systems where high airflow is mandated and there is low static pressure. Conversely, centrifugal fans offer lower airflow, but can deliver it against higher static pressure levels.

Thought should also be given to issue of noise (both of an audible and electrical nature). DC fans may exhibit impressive specs, but the audible noise that is associated with them could be a problem for some system designs. Generally axial fans will have lower audible noise than centrifugal fans. As already noted, reducing system impedance, will lower the airflow needed by the system and this will, in turn, will curb the audible noise. DC fans will also generate electromagnetic interference (EMI) and this needs to be negated. Ferrite beads, shielding or filtering can be used to do this.

Active control technology

Due to there combination of low power operation, compact size

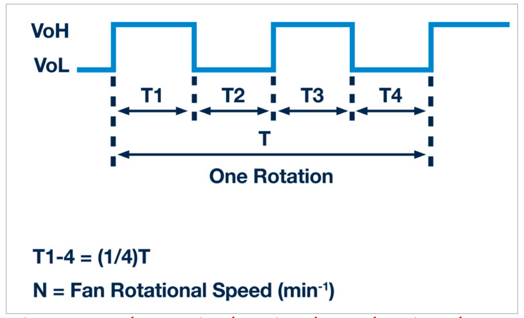


Figure 3: Schematic showing how the signal supports speed detection

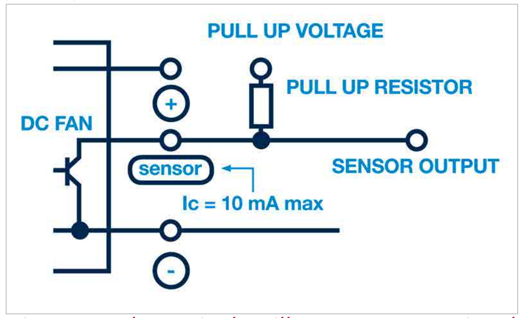


Figure 4: Schematic that illustrates output signal indicating stall/lock fault

and high airflow, axial fans are widely used in rack-mount enclosures. In many cases additional features are incorporated to further boost performance parameters by providing greater control over the speed of operation. This means that their impact on the overall power consumption of the system can be minimised. As already described, calculating the minimum airflow rate required to adequately cool a component-laden PCB inside an enclosure will enable engineers to select a fan capable of delivering the cooling needed under all conditions. This makes the assumption that the fan will run constantly, even when maximum cooling is not required. While this is not likely to result in failure, it does adopt worst-case conditions at all times and is clearly therefore quite inefficient from a system point of view, with the operating lifespan of the fan being significantly shortened as a result. Because of this it has become common practice to monitor the temperature within an enclosure and only turn the accompanying fan on when required. While this approach will improve the fan's lifespan and reduce audible noise, it can lead to problems in relation to thermal lag. It may also introduce a fault condition if, for some reason, the fan is unable to start because there is an obstruction.

To address this, modern DC axial fans, like the CFM series from CUI, have auto-restart protection functionality built in. This detects when the fan motor is prevented from rotating and automatically cuts the drive current. Models in this series, which include the popular CFM-60 fan, also offer optional controls such as tachometer and rotation detection sensors. The tachometer gauges the rotational speed of the fan motor and provides a pulsed output that can be used within control circuitry (as shown in **Figure 3**). If the motor stops, the output stops pulsing and stays at either a logic high or logic low state. The rotation detection feature doubles as a lock sensor, so that if the fan motor stops the output is driven to a logic high state and remains at a logic low during normal operation (see **Figure 4**).

In summary, with semiconductor devices exhibiting high degrees of complexity and PCBs becoming more densely populated, thermal management is proving to be an ever-greater challenge. Forced air cooling is a highly efficient method via which to dissipate heat from PCBs situated inside enclosures. By correctly specifying and subsequently sourcing a fan that is well matched to the requirements of the system, a long and trouble-free operational lifespan can be benefitted from. Contrary to this, if the level of forced air cooling is insufficient for the system's needs, the fan will almost certainly be responsible for the resulting failure - even though that failure will typically arise from some other critical component failing. Care and attention must be given to the fan selection process, so that the right fan for the system design is quickly and cost-effectively sourced. Mouser and CUI work closely together to offer the engineering community highly advanced forced air cooling products that are optimised for their particular needs.

Mouser Electronics
www.mouser.com

Connectors boost the efficiency of wind power plants

More modularity, more flexible handling

By: Norbert Weiss and Carsten Edler, HARTING ELECTRIC GmbH

Germany's roughly 30,000 wind turbines currently produce a good 50,000 megawatts of electricity for households and companies. The expansion of wind energy both onshore and offshore is helping determine the pace and success of the shift in energy policy introduced at the beginning of the decade – a move away from nuclear power (NPP) towards renewable energies and reduced energy consumption.

For installers and operators, profitability and efficiency are of paramount importance when it comes to site preparation, installation, operation and the maintenance of wind turbines. These factors determine the level of investment and operating costs (CAPEX/OPEX) – and ultimately determine the economic impact a wind power plant can provide. Plants which are down produce no energy, receive no feed-in tariffs, and leave their potential to generate revenue untapped.

The HARTING Technology Group is one company that is heavily involved in accompanying the transformation under way in the energy sector. The company's product portfolio ranges from single components through complete customer-specific solutions and digitisation strategies. These offerings also include consulting and services, thus providing the basis for long-term and secure investments in this sector.

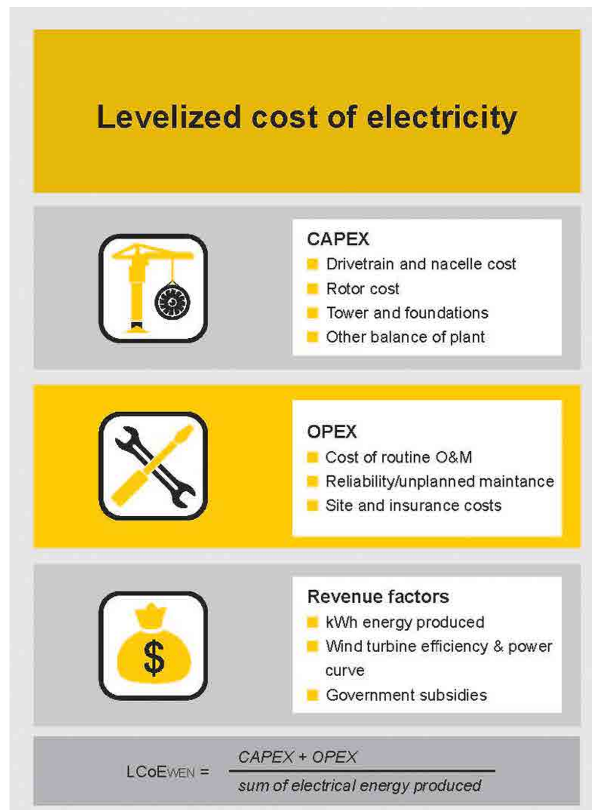


Figure 1: Levelized cost of electricity

Wind turbines are subjected to extraordinary stresses both onshore and offshore due to the particularities of the respective location, climate, corrosion and other environmental influences. Creating the foundation for maximum value retention of these systems takes optimal reliability, the best materials, high mechanical robustness of the components that are used, rapid assembly, optimal maintenance cycles and servicing that is simple to perform.

Connectors help reduce the costs of erecting and operating wind turbines. Modular wind turbines are characterised

Figure 2: Slip Ring

by flexibility of design and rapid component switch-out. Connectors can significantly increase the modularity of these facilities – and more and more wind turbines are being designed accordingly. The pre-assembly of individual units makes the modular concept possible. Components are quickly and easily joined together only at the final location of the wind turbine, meaning that flexible and reliable connectors are of vital importance to their design.

Using connectors to bridge wind turbine modules can limit the monetary and personnel costs accrued during installation and operation of wind turbines. A good example is connectors at the interface between the slip ring body and stationary nacelle. The slip ring is used to e.g. transmit the signals for the pitch systems that determine the angle of incidence of the rotor blades. A pluggable design – for example HARTING's Han-Modular contact inserts and the Han-Modular hinged frame – offers many advantages over permanently attached wiring. For example, the slip ring can be replaced more quickly, thereby reducing downtimes and minimising revenue loss. In addition, if servicing is required, the slip ring can be replaced without intervention in the pitch system and without dismantling the connecting cables.

Figure 3: Slip Ring Coupling

The drives for rotor blade adjustment, blade heating, lighting systems and yawing, as well as the generator brakes, can also be connected simply. Complex wiring is no longer required. In the event of maintenance, worn parts can be quickly and easily replaced in plug & play fashion. Connectors also facilitate the work of the assemblers, which sometimes need to install components in difficult-to-reach angles on the gondola and tower.

Many types of wind turbine employ a gearbox to tune the speed and torque between the rotor and the generator and thus optimise efficiency. Connectors speed up installation here as well: pre-assembled cables and connectors with a high degree of protection, for example the connectors from HARTING's Han Eco, Han HPR or Han M quickly make the necessary connections between the gear units.

Using HARTING connectors also offers advantages for tower lighting. The energy bus elements for the lighting can be pre-installed in the tower segments. At the construction site, fitters only need put the segments together. Electricians do not necessarily need to be used for this activity. Other areas where connectors can simplify handling include the interior areas of wind turbine power cabinets. Instead of the usual fixed wiring, plug-in solutions, such as Han B, Han Eco, Han Com, Han E and Han Modular from HARTING's offerings are good solutions for this application.

In all scenarios, using plug-in connectors provides a convincing case to users in the form of a reduction in costs and time expenditure. Connectors speed up installation and increase the modularity of a wind turbine, reduce investment and operating costs, and provide options for the optimisation and modularisation of the power cabinets. In addition, without a modular design the on-site logistics of onshore plants with an average output of 3.3 MW – including connectors – would quickly reach their limits. As a rule, the cost associated with the use of plug-in connectors is usually amortised within just a few years in the form of cost and time savings.

In addition, HARTING produces LED lighting systems as turnkey system solutions with pluggable device connection, pre-assembled cables, distribution units and, if required, uninterrupted power supply. Lights can be sited in a plant in such a way that their total number remains low and energy costs decrease.

HARTING also offers high-precision current transformers for metering for wind turbines which can be used to connect display devices such as current meters and voltage meters. On request, HARTING can also have its current transformers for metering specially calibrated by a state-approved body in order to further boost the precision of a metering and billing process that employs the devices.

HARTING ELECTRIC GmbH
www.harting.com

2018: The Year of Wireless Power?

By: Jason Lomberg, North America Editor, PSD

At CES 2018, Powercast unveiled a consumer version of its RF-based wireless charging system, and considering the technology and its implications, we could finally have one of the true Holy Grails of power.

Back in August of last year, we interviewed Powercast's COO/CTO, Dr. Charles Greene, and he elaborated on the state of wireless charging and what to expect in the near future. At that point, "wireless charging," as a consumer application, only satisfied the strictest sense of the term – inductive chargers lacked wires, but they couldn't account for distance.

"Inductive charging relies on coils, a transmitting coil and a receiving coil, said Dr. Green. "You have to have near-physical contact."

The biggest limiting factor with inductive charging is distance, and that defined the leading consumer applications. That includes Powermat's solution, previously adopted by the Power Matters Alliance and such luminaries as Duracell, General Motors, and AT&T, and the Qi wireless standard, which attracted bigwigs like Apple, LG Electronics, Motorola Mobility, Nokia, Samsung, BlackBerry, and Sony. In a recent press release, Powermat dropped a bomb – they'd jumped ship from the PMA to its sworn enemy, the Wireless Power Consortium, throwing their weight behind Qi and unifying a certain segment of the wireless charging market.

But because inductive charging requires a short gap between the transmitting and receiving coil – 4 cm for the Qi standard – it's still not radically different from wired charging. A leading OEM touted the benefits of wireless power – specifically inductive power – which includes the following:

- Reduced cost associated with maintaining mechanical connectors

That's right – with inductive power, you can save money on charging cables. Not exactly an evolutionary advantage ...

But Powercast's brand of long-range RF power – which received FCC approval in December – has the ability to send energy in the 915MHz ISM band to devices up to 80 feet away.

Energous Corporation announced similar certification for its WattUp Mid Field transmitter. The downside? Efficiency. Wired and inductive chargers naturally boast higher efficiency in the same way Ethernet cables beat Wi-Fi in the speed department.

And mobile phones will feel a tad lonely....

"We do know that people are going to want to recharge their phone," said Dr. Greene. "The primary focus of the PowerSpot today is ... peripheral devices, and for the short term we see Qi as the solution to go with for charging the phones."

But the convenience of long-range, RF-based wireless power should pacify a consumer market that increasingly values expediency over efficacy. Indeed, 2018 could be the year of wireless power.

PSD
https://www.powersystemsdesign.com