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Power Systems Design: Empowering Global Innovation

SPECIAL REPORT: SUPPLYING THE POWER GRID (PG29)

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COVER STORY
Smart Components for Smart Grids (pg 13)

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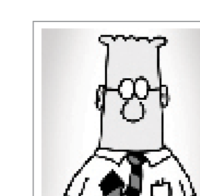

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POWER GRID VULNERABILITY

Welcome to this issue of PSD where we carry a feature section 'Supporting the Power Grid'. The power grid is becoming more sophisticated as governments and utilities try to prop up and renew the systems that have been in place for years without keeping up with modern demands. In addition, the awareness of dependency on fossil fuels and resulting pollution has prompted the proliferation of alternative energy sources such as solar and wind, all of which need to be grid connected.

In addition, the control of power and the metering of electricity and indeed, energy in general has become a science in itself with the high dependency on technology and importantly communications.

Apart from the general infrastructure upgrades and replacement, the 'new' approach to distributed generation and the explosive growth of home solar systems – accelerated by generous feed-in tariffs – has given the power industry a further set of challenges.

European investments in smart grid technologies will reach 56 billion Euros between 2010 and 2020, according to a new report from cleantech research and consulting company Pike Research. And smart meter deployments will hit 240 million in the same time period. However, the European smart grid vision extends far beyond metering. Smart grids here are a significant part of the effort to achieve a low-carbon Europe by 2050, meaning dramatic reductions in greenhouse gas emissions and the goal is to almost eliminate fossil fuels from the energy portfolio.

With the high dependence on communications and electronics systems, there is a high risk of hacking and tampering costing utilities billions of Euros. Here engineering comes to the rescue to develop secure and dependable systems to protect against this. And in the United Kingdom, it was reported earlier this year that criminal gangs have fraudulently made £7 million using hacked recharge keys for pre-payment meters, which will no doubt end up being paid for by the pre-payment customer down the line.

Losing control of our grid power systems could prove not just costly through petty theft but at worse, a compromise to national security - a target for terrorist organisations. Bringing down a power network would be a real catastrophe. The point can not be emphasized strongly enough and companies such as Renesas are developing security systems to minimize this daunting prospect.

In all, this is a complex and fast growing sector of our industry and it will be fascinating from an engineering perspective to see the significant challenges overcome.

There is much more in this issue. Please keep your feedback and opinions coming in, and check out Dilbert at the back of the magazine.

All the best

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DIALOG INNOVATES

Dialog semiconductor has an enviable proven track record with leading OEMs in high volume, high growth portable devices including; smartphones & tablet PCs, portable media devices, digital cordless and short range wireless.

The company's Acquisition of SiTel Semiconductor was crucial to add short range wireless connectivity and VOIP to its technology portfolio which adds best in class technology, expertise and leadership in digital cordless ICs which are shipping to top brand manufacturers.

Dialog has launched its new SmartPulseTM wireless sensor network technology which is based on a derivative of the proven DECT technology called DECT ULE (DECT Ultra Low Energy).

DECT ULE is a Local Area Network (LAN) technology ideal for low power applications within 300 meter range providing sustained longevity for battery powered consumer equipment such as door locks, burglar alarms, security cameras, etc.

There is no need for network planning; the signal can cover the whole household with no interference issues, using one technology for voice, sensors and data.

The DECT Forum has agreed that ULE applications are of relevance not only to current vendors already in the DECT business, but any vendors who can address their own market segments such as home automation, tele-health or smart metering with DECT technology.

A key trend in telecom industry today is the merging of tele-communications with info-communications. IP Connectivity plays a major role here and CAT-iq, the next generation of DECT, has enabled DECT to cater to this market trend.

Unlike solutions such as Zigbee, this technology works straight out of the box with no complex programming or lengthy fine tuning to get the system working. Developers are not interested in rigid standards, which take endless time to develop and ratify, most just want something that is easy to get going and works seamlessly.
Dialog launches the World's first family of DECT ULE devices as a suite of system-in-package encapsulated modules. SmartPulse opens up new markets in home automation / security, personal healthcare, and remote web management via smartphone / tablet PC enabling communications with many existing DECT IP gateways.

Three new devices launched: Wireless data sensor, Wireless data sensor with voice and Wireless base station unit. Dialog follows up in October with an IP base gateway reference design and development kit to simplify and speed-up product time to market.

SmartPulse delivers short design cycle, faster time-to-market, Low R&D investment, optimized design, low BOM cost and economy of scale, plus TBR-6 and FCC certified and qualified. Getting high value end equipment

SMART GRID CHALLENGE

Reported by Cliff Keys, Editorial Director & Editor-in-Chief, Power Systems Design

Guillaume d'Eyssautier, CEO, ADD semiconductor. Guillaume joined ADD semiconductor as CEO in May 2009.

ADD is specialized in the design of System on Chip solutions for narrow band communications using the low voltage electric grid. Powerline communications is applicable in multiple fields such as Residential Automation, Control Systems, Tertiary Buildings, Telemetering, Lighting, Security and Protection.

One of the main challenges for the smart grid is the need for a good communication network to receive information and control the loads of each customer in real time. The most proven and robust solution for this is the use of Power Line Communication (PLC) technology that uses the grid as the communication medium. Comparing the traditional narrow band single carrier FSK modulation with the new solutions based in OFDM, known as PRIME and G3, all grids are not made equal in the international landscape, posing specific communications issues to be overcome.

The contribution of solar and wind energy is increasing. For the majority of this green energy the regulator normally has a limited control. Also it is a volatile source in terms of output, whereas traditional hydroelectric power is more constant. To help level this out, solar panels are becoming more sophisticated with motorized tracking, PLC and, because of the high cost, security systems against theft are required to be implemented.

The electric vehicle (EV) is fast becoming a reality and will, change the scenario. The predicted massive deployment will potentially double the energy consumption in the grid and will as a by-product introduce a large capability to store energy in a distributed structure. The solution to control all this is a combination of embedded intelligence and real time communication and control capability with enough capillarity to control and communicate to any of the millions or hundreds of millions of users in real time.

PRIME is an open and multi provider solution promoted by the PRIME Alliance which includes more than 30 companies such as utilities, meter manufactures, and silicon providers such as ADD Semiconductors, FUJITSU, STM, and TI.

IBERDROLA was the company that started the deployment of 100,000 meters in 2010, and the company is now planning a new tender for 1 million meters by the end of 2012 and to complete the full deployment of 10 million meters in Spain within 3 to 5 years. Other utilities are also starting to introduce PRIME.

G3 and PRIME are both OFDM solutions but with a different history. G3 initially used a chip designed by MAXIM that provided the PHY layers and some available software layers, but this has proved troublesome to implement and the PRIME Alliance is cooperating with EDF to develop a common OFDM standard.

www.addsemi.com

THE SMART GRID DOESN'T WORK - WITHOUT ENERGY MEASUREMENT

By Tom Hackenberg

You can't manage what you don't measure. This applies equally to the smart grid, and in this context the point of measurement is electricity consumption.

IMS Research defines the smart grid as "a utility supply infrastructure with the inherent ability to match and manage generation and consumption efficiently, while obtaining maximum benefits from the available resources." So the first stop along the way to "match and manage generation and consumption efficiently" is to measure the demand.

Energy measurement today is primarily taking place between the distribution and consumption portions of the grid in the form of a utility meter. It is to be expected that utility metering is a sizeable market; utilities are motivated to install energy measurement devices as that's how they get paid.

Utilities are leveraging the smart grid to motivate consumers to share in the responsibility of managing electric power consumption. Companies and consumers are realizing that to identify problem areas of energy consumption within factories and homes they need many interconnected devices that perform this function. We're early into a two-step process that we are predicting will ultimately see energy measurement functionality being integrated into a wide variety and large volume of devices. The first step involves placing dedicated communicating measurement devices such as power meters, sub-meters, home panel meters and home plug meters, alongside targeted equipment. Once this starts happening to a greater extent, and benefits are observed through centralized analysis of the data obtained, demand will be created for equipment with integrated power measurement.

Currently, the progress being made towards integration of metering type functionality within actual devices is mostly limited to industrial/commercial type applications.

Within grid infrastructure we're seeing solid state protection & control IEDs containing this functionality replacing traditional electromechanical equivalents; similarly in datacenter applications "dumb" rack-level power distribution units are being replaced with intelligent ones capable of providing kWh analysis. Other areas show long-term promise: outdoor/street lighting, often tied directly to the grid without a meter. Similarly, motors consume more electricity than any other device in industry, and to minimize and measure motor energy consumption today two devices are needed; a motor drive and a power meter.

POWER SUPPLY DEVELOPMENT DIARY PART XV

By Dr. Ray Ridley

This article continues the series in which Dr. Ridley documents the processes involved in taking a power supply from the initial design to the full-power prototype. Initial testing on a new five-output design shows the cross-regulation achieved.

Five-Output Coupled-Inductor Design

With the second turn of the printed circuit board, the specifications were modified as follows:

1. Output 1 – 32.5 VDC @ 7A isolated
2. Output 2 – 32.5 VDC @ 7 A isolated
3. Output 3 – 32.5 VDC @ 7A isolated
4. Output 4 – 32.5 VDC @ 7 A isolated
5. Output 12 – 12 VDC Bias power and regulated output, primary referenced
6. Maximum power 350 W (only one output fully loaded at a time, application is for audio.)
7. Input – 180 – 265 VAC
8. Power Topology: Two-switch forward

Notice that the voltage levels are adjusted somewhat from the original design with three outputs. As a power supply designer, it is always a good idea to be flexible to system changes that come from the power supply users. This almost always happens during a product development cycle.

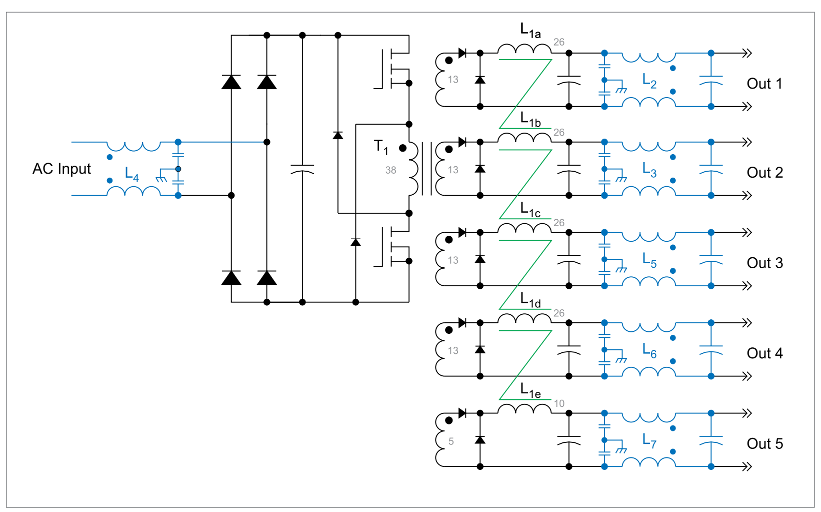

Figure 1: Forward Converter with Five Coupled-Inductor Outputs

Figure 1 shows the schematic of the five-output forward converter. A single core inductor, L1, is used with five windings, one for each of the outputs. This coupled-inductor approach provides the best cross-regulation between each of the outputs. There are two major advantages of coupled inductors – firstly, all of the outputs are tied together through the transformer action of the inductor, preventing them from having individual resonant frequencies. Secondly, regardless of individual loading on each of the outputs, the coupled inductor forces all of the outputs to be in either continuous or discontinuous mode concurrently, greatly improving the regulation.

As shown in an earlier part of this series, excellent regulation was achieved with a wide variation of output loading for three outputs. With the new design, it is important to establish the cross-regulation with the two extra outputs.

Notice that Figure 1 shows common-mode filters on all of the power outputs. These filters are essential for proper testing of the converter, as discussed later.

Short-Circuit Testing

The new revision of the power supply design had substantial changes, including new specifications, transformer, inductor, layout, gate-drive transformer and current transformer. Before testing for steady-state operation and cross-regulation, it is very important to make sure that the new power stage design remains rugged under all conditions.

Most designers are often reluctant to subject their new board to stress testing, but it is very important that this be done in order to confirm the viability of a new design. High-line, short-circuit testing verifies that the current-limiting circuit is working properly, and that the circuit is well protected.

Figure 2 shows the primary current waveform under start-up conditions at high input line and with a short-circuited output. Refinements were made to the current-sensing gain and filtering to make sure the circuit was well protected under these conditions. Once this testing is done, you will find that you have a much higher confidence level in your circuit, and subsequent testing proceeds more smoothly.

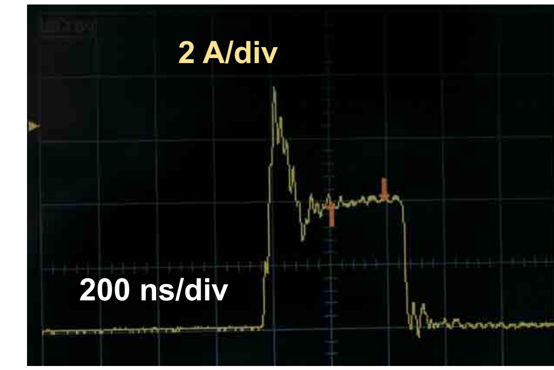

Figure 2: Primary Switch Current During Startup and Short-Circuit

The peak current observed in the power switch was 8 A under these conditions. A 20 MHz ringing was also seen on the waveform, and this was found to be a result of the new board layout which introduced some additional inductance in the primary traces. While not destructive, this ringing needs to be removed later with either a bypass capacitor, or changes to the layout. It was not seen in the earlier breadboard since a bypass capacitor was connected in a very short loop to the primary circuit.

Regulation Testing

Figure 3 shows the regulation data for the five-output converter. The 12 V output was tightly regulated with a feedback loop, and Output A was loaded from 10% to full load. With this loading, the output dropped approximately 2.5 V as shown by the red curve. The other three outputs were minimally affected, dropping by only about 0.5 V. Output B, which was wound on the same layer as Output A showed the most variation.

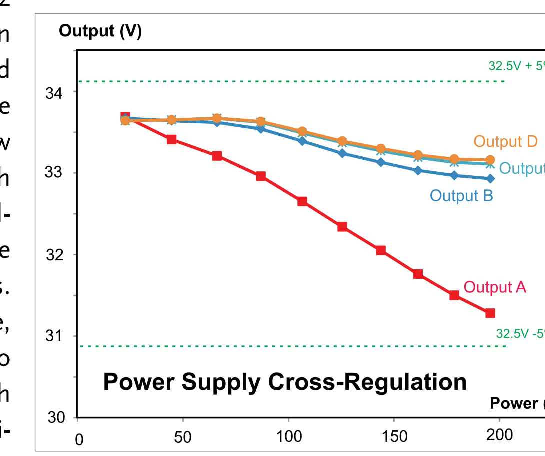

Figure 3: Output Regulation Data.

Most of the drop in output voltage was due to resistive losses which were considerably higher with the new design of the magnetics. Overall, it is expected that this power supply could maintain 5% regulation on each of the main outputs with loading over a ten-to-one range. This is a fairly typical result for cross-regulated converters that have been well designed. It is very important to maintain consistency in the magnetics design to ensure this quality of regulation.

Each of the other outputs was subsequently loaded over the same range, and very similar results were achieved for each. These results are not presented here since they essentially repeat the curves of Figure 3.

Voltage Measurements and Noise

When the cross-regulation results were first measured, results were very erratic. Fluke 79 meters were used on each of the outputs, and it was observed that these would not give accurate and repeatable measurements until high-frequency EMI issues were resolved. For example, holding onto the cables near the meters introduced more than 1 V variation in reading.
Engineers experienced with power supply design will be familiar with this problem. Sometimes solutions involve putting bypass capacitors at the input of the meters, but this is not always effective. The best solution is to provide proper EMI filters at the outputs of the power supply, as shown in the schematic of Figure 1. Once the common-mode filters were put in place, the measurements from the Fluke meter were accurate and repeatable.

Summary

Initial testing on the new revision of the power supply design and board layout properly established current limiting circuitry to ensure a rugged design. A nondestructive issue was detected with 20 MHz ringing in the primary current waveform, and a third iteration of the PCB will be required to fix this.

Initial testing of cross-regulation showed erratic measurements due to EMI noise pickup by the digital voltage meters. Once common-mode filters were placed on each of the outputs, the readings became reliable.

The five-output converter was found to have excellent cross-regulation, each output regulating within 5% over a ten-to-one load range.

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President
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SMART COMPONENTS FOR SMART GRIDS

Quality is the key for reliable supply

By Helmut Doenges

Energy efficiency with advanced magnetic alloys – the quality of smart grids starts with the quality of their materials

The famous English social reformer John Ruskin (1849 - 1900) was already well aware that a bargain-hunter mentality was the road to ruin. "There is hardly anything in the world that some man cannot make a little worse and sell a little cheaper, and the people who consider price only are this man's lawful prey."

Today, however, the truisms that 'quality has its price' and 'a chain is only as strong as its weakest link' need to be re-established in many areas of modern life. One such area is energy supply. Our present age is about to experience enormous change: in the near future, power supply systems will be compelled to metamorphose into 'smart grids', and buzzwords like 'energy efficiency', 'renewable energy' and 'energy management' will move into the limelight - generally focusing on grid operators and utility companies. In all of this, producers of passive components such as resistors, capacitors or inductors - the role of which should not be underestimated in the quality of the overall smart grid system - are largely ignored. Since both energy supply companies and manufacturers must apply an array of perspectives when considering the quality of generated energy and of all levels of the power supply, passive components - primarily soft magnetic components - are taking on growing significance in efficient power supply systems. Utility companies require increasingly precise information concerning the distribution grid, the method, scope, quality and sources of supply and the way in which different sources can be intelligently connected. The prerequisites for this vital information are not only the use of high-performance meters, but also the existence of efficient power supply systems. Smart grids and their components are thus facing enormous challenges, and we would do well to seek out the highest possible quality for all their elements, from power electronics components upwards, to ensure the smart grid of the future has a foundation of consistent efficiency at all levels.

The term 'sensing and measurement' is often used as a catch-all for important aspects such as grid stability, electromagnetic capability or energy theft prevention; however, it is rarely linked with the need for efficient devices in fields such as power electronics. High levels of precision in the information or identification of efficiency potential are only rarely called for, if at all. But the issue here is not only measurement precision; it also extends to minimum-loss generation of electric power. Furthermore, sustainable long-term development of efficient devices and systems can only be successful if developer and designer are familiar with the benefits of modern magnetic materials and aware of their wide-ranging potential applications.

What the smart grid of the future must deliver - onwards and upwards, more and more

And efficiency is the be-all and end-all: understandably given rising energy prices, calls for higher energy efficiency are growing louder. The goal is to make use of low-cost, or even cost-neutral components with minimum losses. However, a recurring problem in practice occurs when there is little or no knowledge of the right low-loss materials and when developers are often unfamiliar with the potential that can be harnessed by using the correct material to develop low-loss, grid-capable power supplies and converters - to name but two concrete examples. Expert knowledge of appropriate materials, the smallest building-block in the structure of a smart grid, is thus fast becoming a premium commodity.

Above all, smart grids must cope with the fact that power will no longer be sourced from a small number of central suppliers, but will come from a diverse range of decentralized sources - including consumers themselves, who generate power from solar plants, wind turbines or CHP plants and feed it into the grid, causing power fluctuations. These fluctuations are likely to increase as the numbers of feed-in sources and new forms of energy grow. In 2010, the proportion of renewable energy sources in the overall electricity balance rose year-on-year by almost ten per cent to 17 per cent, to give Germany as a concrete example. However, the inconsistency of the eco-power supply is a problem; wind is followed by calm, sunshine by clouds. And the challenges will only increase in the future. The German government has declared its minimum target of electricity from renewable sources as 80 per cent by 2050. Many countries throughout the world - particularly after the nuclear meltdown in Fukushima - are following suit.

Changes will develop not only in the form of power that must be fed into the grid and transported, but also in its sheer volume: power from the increasing numbers of wind turbines, especially in Europe's coastal regions, will be joined by power from countless solar roof panels in southern climes, and the need for all this power to be transported represents an enormous new burden for the grid. Here too, there is no lack of examples of the significant role played by the correct highly efficient components; the power density of today's power supplies is increasing and the operating temperatures generated by solar inverters are rising, forcing the designers of devices to address the issue of managing thermal problems. The current load of active components in power electronics has continuously increased to the present day, even doubling in many cases. However, this gain is often offset by the underestimation of thermal problems in the selection of suitable passive components. Optimization of passive components is evidently moving up to join that of active components as a major priority.

In addition to the thermal properties of passive components, the material used in them must assure adequate long-term stability. A lifespan of ten to twenty years is common for power supplies in smart grids; wind turbines, particularly offshore turbines for which maintenance procedures are difficult and complex, often have even stricter requirements.

eMobility - the new consumer on the grid

The grid of the future is also facing new challenges from the consumer side. The automotive industry is also advancing by leaps and bounds, embarking on the exploration of new trends. Concepts from hybrid drives to full electric-drive vehicles are currently in experimental phases - and herein lies the problem; the capacity of existing power distribution grids is far below that required for this additional power consumption by the electric vehicle sector. Future-oriented industries, particularly such as electric mobility, require the involvement of new centres of competence and stronger targeted collaboration that overarches technologies and industries. A few examples are new vehicle concepts, electric drive technologies, power electronics components, high-performance batteries and integration into the energy infrastructure, extending to the development of innovative mobility concepts. The development of chargers for electric vehicles, to give another concrete example, is primarily aimed at achieving high power density and efficiency exceeding 97 per cent. And once again we end up facing passive components: a specification of this magnitude can only be achieved through ultra-low conduction losses from new types of semiconductors and the simultaneous use of low-loss magnetic materials.

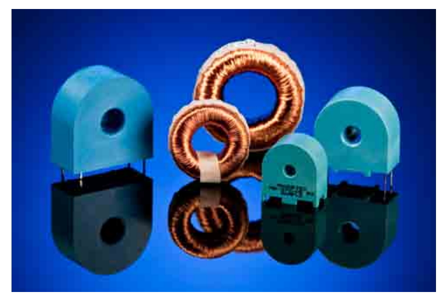
Still plenty to do

Little time remains to upgrade today's power grids to smart grids in readiness for the challenges described. Rising raw materials prices, the imminent exhaustion of fossil fuels, the recently revived nuclear debate which has already led to concrete plans for nuclear phase-out and the accompanying growth of support for renewable energy sources are transforming new forms of energy management into a top-priority issue at many levels. In addition to the essential acceleration of the processes of grid conversion and upgrading, corresponding regulations

Material	alloy composition	losses (20kHz, 200mT) [W/kg]	saturation B_{sat} [mT]	magneto-striction λ_s [10^{-6}]	permeability (50Hz) μ_4 - μ_{max}	max. working temp. [°C]
grain oriented **Silicon steel**	$Fe_{97}Si_3$	**> 1.000**	**2.000**	9	2.000-35.000	appx.120
standard crystalline permalloy I	$Ni_{45}Fe_{55}$	> 150	1.550	25	12.000 – 80.000	130
standard crystalline permalloy II	$Ni_{54}Fe_{46}$	> 100	1.500	25	60.000-125.000	130
advanced Silicon steel	$Fe_{93,5}Si_{6,5}$	40	1.300	0,1	16.000	130
Fe- amorphous alloy	$Fe_{76}(Si,B)_{24}$	18	1.560	27	6.500 – 8.000	150
high performance **ferrite**	MnZn	**17**	**500**	21	1.500 – **15.000**	100/**120**
advanced crystalline permalloy	$Ni_{80}Fe_{20}$	> 15	800	1	150.000-300.000	130
Co-amorphous alloys a	$Co_{73}(Si,B)_{27}$	5,0	550	< 0,2	100.000-150.000	90/120
Co-amorphous alloys b	$Co_{77}(Si,B)_{23}$	5,5	820	< 0,2	2.000 – 4.500	120
Co-amorphous alloys c	$Co_{80}(Si,B)_{20}$	6,5	1.000	< 0,2	1.000 – 2.500	120
nanocrystalline alloys I	FeCuNbSiB	**4,0**	**1.230**	0,1	18.000 - **500.000**	**120/180**
nanocrystalline alloys II	FeCuNbSiB	**< 10**	**1.230**	0,1	1.500 - **15.000**	**120/180**

The right soft magnetic material for the right Grid Technologies

and standards will soon be implemented to govern the extension and optimization of existing distribution grids and the introduction of efficient, high-precision monitoring.



Current transformers for monitoring and remote control in Smart Grids

Monitoring involves the use of control instruments that enable grid operators to draw up, say, wind and solar forecasts as a basis for short-term addition of power station capacities. What is required is thus a meaningful interaction of hardware and software components, complemented by a blanket rollout of smart meters in an advanced metering infrastructure (AMI) for the launch of remote metering. This sector in particular will require high-precision and durable components for electricity metering which deliver reliable and stable measurements. Current transformers with soft magnetic cores are particularly suitable.

The aim must be to convince all those involved in creating the smart grids of today and tomorrow - such as, to take examples of components already mentioned, the manufacturers of inverters, those key 'translators' between power generators and grid, or of grid components - that they should use correct and suitable components from the outset in building their products, to eliminate later risks of unpleasant surprises from asymmetry and interference.

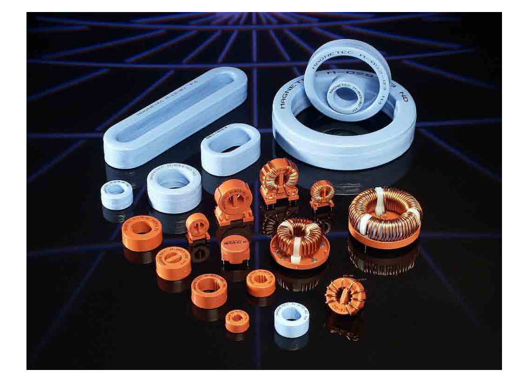
It is actually the case that measures designed to increase the efficiency of on-grid inverters for solar plants or wind turbines are currently being prioritized by the relevant manufacturers. Every tenth of a percentage point is more than welcome in reducing losses or boosting efficiency. The issue is to replace widespread standard components with efficiency-optimized specialist solutions, especially where inductive components such as chokes in the essential EMC filters are concerned.

Ferrite cores have to date been the most widely used standard components in common-mode chokes for EMC filters. Replacing them with higher-quality nanocrystalline tape-wound cores could increase permeability up to fivefold - while enabling more compact designs to be produced. The result is a dramatic fall in choke losses, typically of up to 50 per cent. And nanocrystalline material need not be more expensive than ferrite cores. Calculated in simple terms, the extra costs of purchasing these energy-efficient components can be recouped from the feed-in payments from a 3x25A/1.5mH common-mode choke after only a few months.

Nanocrystalline materials step up to the plate

The raw materials shortages already noted are resulting in soaring prices for many basic metals used in soft magnetic alloys. However, nanomaterials - 90% of which are produced from the significantly cheaper raw materials, iron and silicon - are almost unaffected by this development. They can often represent a lower-cost alternative yet also offer technological benefits, as described in the example of the choke above.

Trends in modern power electronics are moving towards higher frequencies and more compact designs or greater power density. As a result, recent years have seen an increase in the number of industrial power electronics applications using nanocrystalline cores, accompanied by a rise in demand which is slated to continue. A wide variety of cores, transformers and chokes are used in applications including



Current transformers for monitoring and remote control in Smart Grids

the following, all of which are also found in smart grids:

- Power electronics (EMC filters for inverters and all forms of pulsed power supply)
- Installation technology (RCCBs; triggering transformers for protective relays or line protectors and electronic electricity meters)
- Renewable energies (solar inverters and wind turbines)
- Stationary and mobile charging devices for electric vehicles

The soft magnetic nanocrystalline alloy FeCuNbSiB has been available for some years under brand names such as NANOPERM®, FINEMET® and VITROPERM®. A relatively simple yet revolutionary production method is used to produce ultra-thin strips from low-cost materials such as silicon and iron. The result is a new generation of materials offering a unique combination of outstanding soft magnetic properties. For the first time, a single material offers roughly the same high induction swing as silicon iron ('transformer blanks') together with better high-frequency characteristics than those of ferrite (low loss, high permeability). This nanocrystalline alloy also offers a significantly more competitive price-performance ratio than the amorphous co-alloys that broke new ground at the end of the 1980s, with comparable or even superior characteristics. Today amorphous co-alloys are generally used only rarely in special applications owing to their high cost and environmental impact.

Present and future areas of application

A primary area of application for the new material is in the manufacture of common-mode chokes for EMC filters, used in all types of pulsed power supply including variable speed drives (frequency converters). In this area it offers significant benefits in volume, since both its relevant material properties (permeability and saturation inductance) are significantly higher than those of ferrite, otherwise the traditional choice for these applications. The new Cool-Blue® cores serving as protection from harmful motor bearing currents are also growing in popularity, particularly in inverter systems with high and highest outputs such as wind turbines with 1 - 3 MW or printing and paper industry plants.

Further major applications already realized include power transformers for switched-mode power supplies with an output range from several hundred watts to several hundred kW, current limitation cores, magnetic amplifier chokes, drive transformers for IGBT transistors, mains-independent RCCBs, current sensors and current transformers for the new electronic electricity meters. More will follow - particularly in connection with the continuously advancing field of switching topologies or new systems currently under development in the automotive industry.

High-tech manufacturing processes

The manufacturing process uses rapid solidification technology. A charge of liquid metal weighing 50-200 kg with a temperature of approximately 1,300°C is poured

Cool Blue-cores avoid destructive bearing currents

through a specially shaped ceramic nozzle directly onto a rapidly rotating water-cooled copper casting wheel, where it solidifies within a thousandth of a second. As this happens, a continuous metal strip, initially amorphous and only 20 µm thick, is extruded from the liquid metal at speeds of over 100 km/h. In other words, this product is manufactured in a single process step involving a relatively compact production facility, eliminating the need for costly cold or hot rolling plants. The tape-wound cores produced from the metal strip are then annealed under inert gas within magnetic fields in longitudinal or lateral orientation to the tape direction. Under this irreversible heat treatment, the originally amorphous structure of the material finally forms microscopic crystallites with typical grain size of 10 nm – hence the name 'nanocrystalline'. When precise control is applied to the parameters of heat treatment (temperature, time, rate of heating or cooling), the required properties of the material (e.g. form of hysteresis loop or permeability level) can be extensively varied and precisely set.

MAGNETEC is one producer of these nanocrystalline elements, such as filter chokes for power supplies and power electronics inverters. By using extremely compact EMC chokes with tape-wound NANOPERM® cores, MAGNETEC is able to significantly improve EMI filtering in e.g. solar inverters and frequency converters in drive technology. MAGNETEC filters have been the technologically state-of-the-art choice for many years - particularly for extremely small designs requiring maximum attenuation.

Conclusion

This short excursion into the world of nanocrystalline materials clearly reveals the potential still to be exploited in the area. Smart grid assemblies constructed of components as described here which have, so to speak, a hidden impact, play a significant role in completing the intelligent power grid of the future in compliance with the host of requirements posed by current and future developments, and thus in ensuring reliable, stable energy management.

By Helmut Doenges
Marketing Director
Magnetec

PCB LAYOUT

For switching regulator designs

By Frederik Dostal

Switch mode power supplies convert one voltage to another. Such supplies are generally very efficient and thus replace linear regulators in many applications.

Switching frequency versus switching transitions

Switch mode power supplies operate with a certain switching frequency. This switching frequency may be fixed as in PWM type control or it may vary depending on certain factors as in PFM or hysteretic type control. In any case, the principle which makes switch mode power supplies work is that there is a certain on-time period, Ton, and a certain off-time period, Toff. Figure 1 shows a typical switching cycle with 50% duty-cycle. This means that 50% of the length of the complete period T we have a certain current flow in the converter and during the other 50% of the time we have a different current flow.

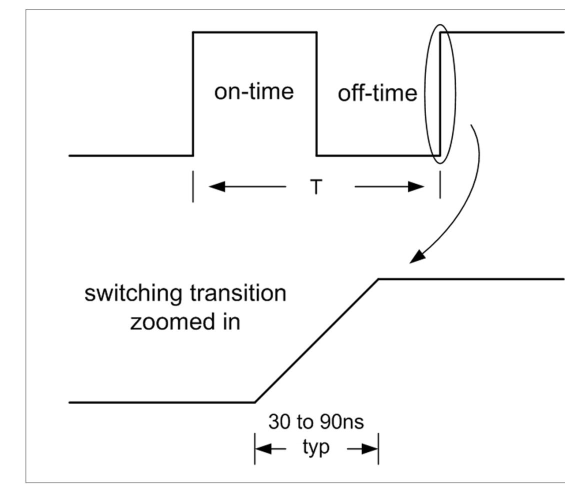


Figure 1: Switching frequency vs. switching transitions

The actual switching frequency, in other words length of the period T, is not so important when we consider system noise. This switching frequency or its harmonics may hurt us if it is in the range of a delicate signal frequency in the system. But generally this frequency is not what hurts us the most.

What is really critical in switch mode power supplies is the speed of the switching transitions. In the bottom part of figure 1 we can see the switching transition zoomed in the time scale. At a time scale of 2us per period T, with 500kHz PWM switching frequency, the transitions look like vertical lines as shown in the top part of figure 1. Zoomed in, as shown on the bottom part of figure 1, we can see that switching transitions are typically between 30 to 90ns.

Why good printed circuit board layout is so important

Every 2.5cm of board trace has about 20nH of trace inductance. The exact inductance does depend on the thickness and the width of the trace as well as its geometric layout but generally 20nH / 2.5cm is a good rule of thumb. If we look at a buck regulator for 5A of output current, we will see current switching from 0A to 5A. The following formula calculates how much voltage offset tiny trace inductance generates if the switched current is large and the switching transition time is short:

$$V = L \times \frac{di}{dt}$$

With 2.5cm of trace (20nH), 5A output current (5A of switched current in a buck) and a transition time of a MOSFET power switch of 30ns we get a voltage offset of 3.33V.

$$V = L \times \frac{di}{dt} = 20nH \times \frac{5A}{30ns} = 3.33V$$

This voltage offset resulting from only 2.5cm of trace inductance is quite significant. Often this offset even yields to switch mode power supplies not working at all. Putting the input capacitor a few cm away from the input pins of a switching regulator will usually prevent the power supply from working. If a power supply happens to still work with a poor board layout, it will generate excessive EMI.

The only parameter we can influence in the formula above is the inductance of our traces. We can lower it by making the traces as short as possible. Thicker copper also helps reduce the inductance. The current is a parameter we cannot change since the power required by a load is fixed. The transition time is something we can but don't want to change. Slowing down the transition times will decrease the generated voltage offset and with this reduce EMI but our switching losses go up and we are forced to operate at lower switching frequencies with expensive and bulky power components.

Finding AC current traces

The most important rule in switch mode power supply board layout is to keep the AC traces as short as somehow possible. If this rule is followed diligently, 80% of a good board layout is already implemented. In order to find these AC traces which change current flow from 'full current' to 'no current' in short amounts of time, the transition time, we draw down the schematic three times. This is shown in figure 2 with a simple buck type switch mode power supply. On the top schematic, we draw a dotted line to where the current flows during the on-time. In the middle schematic we draw with a dotted line the current flow during the off-time. The bottom schematic is the interesting one. Here we display all the traces where current flow is changing from the on-time to the off-time.

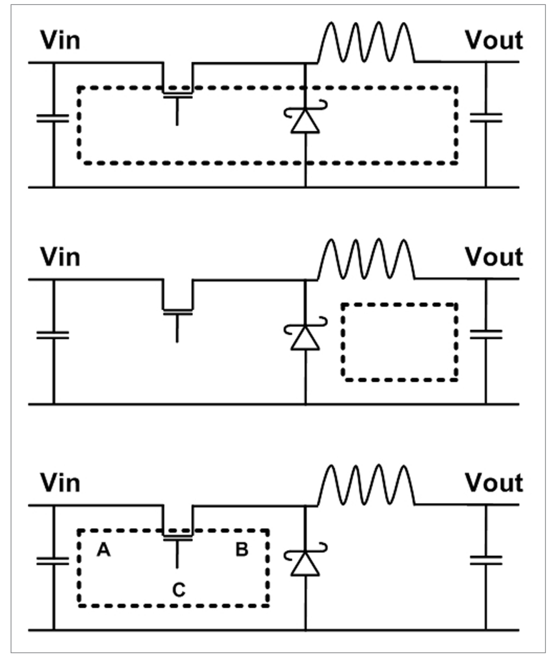


Figure 2: Finding AC current traces in a switching regulator

These traces in the bottom schematic of figure 2 are the AC traces and these have to be kept as absolutely short as possible to reduce parasitic inductances.

This exercise can easily show us for any switch mode power supply topology where the AC current traces are.

When evaluating existing board layouts, it is often a good idea to print them on paper, put a see through plastic sheet on top of them and use different color pens to indicate the current flow during the on-time, off-time and the resulting AC traces. Though we tend to believe that we can do this relatively simple indication process in our heads, very often we make slight mistakes in our thought process so that it is strongly recommended to do this with paper.

Implementing a good board layout

Figure 2 shows the AC traces of a buck regulator. It is important to note that also some ground

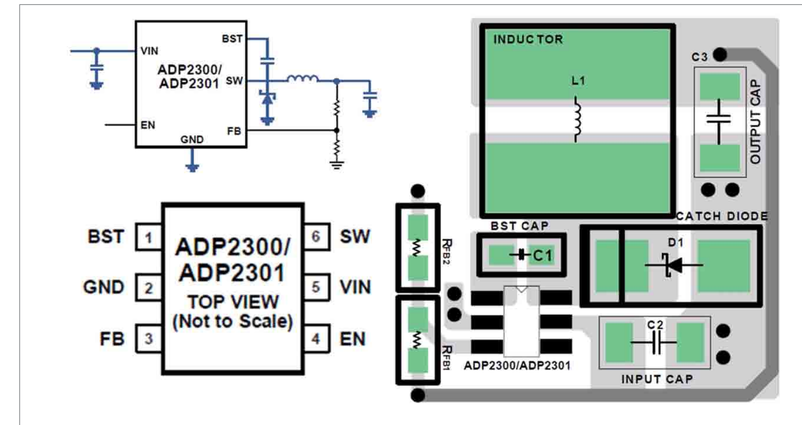


Figure 3: Example of an optimized buck regulator layout

traces are AC traces and need to be kept as short as possible. Also it is recommended to not use any vias for these AC current paths. Vias also have quite high inductance. There are only very few exceptions to this rule. In cases where avoiding vias in the AC path would actually cause more trace inductance than the via itself, it is suggested to use vias. Multiple vias in parallel are better than one single via.

Figure 3 shows an example board layout with Analog Device's ADP2300 step down regulator. Let's check if the AC traces are routed in the absolute shortest way possible. Figure 2 indicates AC current connections with the letters A, B and C:

- Connection A in figure 5 is routed as short as somehow possible since the high side connection of C2 has the shortest trace possible to the switching MOSFET which is pin 5, Vin pin, in the ADP2300.
- Connection B is the trace between pin 6, SW pin, and the cathode side of diode D1. Again in figure 5 we can see that this trace is as short as possible to reduce trace inductance.
- Connection C is the trace between the anode of diode D1 and the ground connection of C2. These two component pads are right next to each other and have the lowest trace inductance possible. Also it is good for this AC current to avoid going through the silent ground plane. A ground plane should be used as reference voltage only and ideally no currents should flow through a ground plane, especially no AC currents. The vias next to C2 connect the ground area of the PCB top layer to the ground on the bottom layer, but no AC currents flow through these vias.

Special considerations for inductors

Regarding electromagnetic interference, EMI, we also have to consider the inductor. The actual component is not as symmetrical as many people think. It has a core and wire is wrapped around it. There is always one start of winding and one end of winding connection. The start of winding is connected to the inner windings of the inductor and the end of winding connection comes from the outer windings of the inductor. Figure 4 shows the sketch of a typical drum type inductor. Often the start of winding is marked with a dot on the component. It is important to connect the start of winding to the noisy switch node and the end of winding to the silent voltage. In case of a buck regulator this is the output voltage. Then the fixed voltage on the outer windings will shield the AC switch node voltage on the inner windings electrically and the EMI of the power supply will be lower.

By the way, this is also the case for so called shielded inductors. They do use some shielding material on the outside which has a certain permeability. This material will pull in most magnetic field lines on the side of the package. However, this material is only containing magnetic fields and not electric fields. AC voltages on the outside winding are mostly a problem due to electric or capacitive coupling which is not contained by the shielding material of shielded inductors. Thus also shielded inductors should be

Figure 4: Start of winding and end of winding in an inductor

placed on the board so that the noisy switch node is attached to the start of winding for lowest EMI.

Basis for a good board layout for switch mode power supplies

How to do a good board layout is often not taught in engineering classes. In high frequency, RF type classes, the importance of trace impedances are studied but engineers having to build power supplies to power their systems often do not look at the supply as a high frequency system and often neglect the importance of the board layout. Most problems resulting from poor board layout can be traced back to not keeping the AC current traces as short and tight as possible. Understanding the reasons behind the presented board layout rules and following them will minimize any PCB related problems in switch mode power supplies.

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NOTEBOOK DC-DC CONVERTER DESIGN

Using eGaN® FETs to increase efficiency and reduce size

By Johan Strydom, PhD

In the competitive world of notebook computers, the key performance attributes are battery life, weight, and size (particularly height) for a given level of performance.

Recent advances in power transistor technology enable significant improvements of the POL converters used to convert the battery and charger voltage (Approximately 19 V in a four-cell system) down to the 1.2 V needed for the microprocessor and graphics processors. Enhancement mode gallium nitride (eGaN®) FETs have been in the commercial market for over two years and have begun to make significant inroads into the territory dominated by the aging power MOSFET. One of the primary benefits of this new technology is that these FETs are capable of much higher switching speed with lower power losses. Pushing frequency higher to reduce the size and cost of energy storage and transmission elements such as capacitors, inductors and transformers has been discussed for many years but, with traditional silicon power devices, the tradeoff between frequency and efficiency has been too costly to implement. eGaN FETs now make it possible for designers to reduce the space occupied by their DC-DC converters in 4 cell and industrial systems by increasing frequency while still exceeding the efficiency of converters based on conventional power MOSFETs.

eGaN® FET Performance

To drive frequency higher in a Buck Converter, especially at a high input voltage, power devices must have very low dynamic losses. The dominant component to the dynamic losses is the classic hard switching "event" where current commutates to the device turning on before the voltage across that device collapses. The energy of each switching period is approximated by ESW = VIN x IOUT x t where t is determined by the various components of the device gate charge (QG), device series gate resistance (RG), driver impedance, drive voltage, and device transfer characteristics. Due to eGaN FETs requiring much less die area and having a lateral structure, they have ultra-low gate and 'Miller' (QGD) charges. This, combined with a gate electrode designed to have low RG, switching times for these devices are very short, and energy dissipated due to classical hard switching is very low.

There are four additional components that contribute to dynamic losses. These include, (1) diode recovery charge (QRR) where the energy loss (ERR) is equal to the recovery charge times the input voltage, (2) output charge (QOSS) which has an energy loss (EOSS) determined by multiplying one-half of the output charge times the input voltage, (3) the energy loss (EG) associated with the gate charge (QG) is

	Q1		Q2					
	V_{DS} (V)	$R_{DS(ON)}$ (max) High Side	Q_{GD} (typ) High Side	$R_{DS(ON)}$ (max) Low Side	Q_G (typ) Low Side	Q_{OSS} (typ) Low Side	Q_{RR} (max) Low Side	V_{SD} (typ) 10A, 25°C	Total Package Area (nom)
eGan FET	40	16 mΩ	0.55 nC	4 mΩ	11.6 nC	18.5 nC	0 nC	2.15 V	8.5 mm^2
MOSFET	30	15 mΩ	1.5 nC	4.3 mΩ	27 nC	32 nC	20 nC	0.76 V	21.8 mm^2

Table 1 - Switching Components

calculated as the gate charge times VGS, and (4) the reverse conduction voltage (VSD) which is determined by the following equation: ESD = VSD x IOUT x tR (where tR is the total reverse conduction time).

To determine the total power loss, the sum of these four components is multiplied by the frequency.

PDYN = f x (ESW + ERR + EOSS +EG + ESD).

eGaN FETs , unlike standard power MOSFETs, have no minority carriers to be stored in a junction, and therefore no QRR. QOSS , VGS , and QG are low compared with a MOSFET, so EOSS and EG are much lower. Finally, due to the reverse current conduction mechanism, eGaN FETs have a high VSD when compared with the body diode forward voltage of a MOSFET. This condition has the potential to increase the energy loss ESD and is influenced by the total reverse conduction time; a condition that can be controlled by the time the rectifier switch is acting like a diode.

Component	Reference Designator	Part Number	Characteristics
Input Filter Capacitor	C1, C2, C3	Taiyo Yuden, UMK-325BJ475M	4.7 µF, 50 V, 1210, Ceramic
Output Filter Inductor	L1[1]	Wurth, 7443340068 or Vishay, IHLP2525CZ-R47-01	0.68 µH, 19 A, 1.72 mΩ, 8 mm x 8 mm / 0.47 µH, 17.5A, 4 mΩ, 6 mm x 6 mm
Output Filter Capacitor	C4, C5[2]	TDK, C3216X5R0J476M	47 µF, 6.3 V, X5R, 1206, Ceramic
	C6[3]	Sanyo, 2R5TPE470M7	PosCap, 470 µF, 2.5 V, 7 mΩ

Table 2 - input and Output Filter Components

eGaN FET – power MOSFET Comparison in a Buck Converter
The devices compared were EPC1014 (40 V, 16 mW) on the high side and EPC1015 (40 V, 4 mW) on the low side, and Infineon MOSFETs BSZ130M03MS (30 V, 15 mW) on the high side and BSZ035N03M (30 V, 4.3 mW) on the low side of a Buck Converter. In all cases, a single device was used for each socket. The MOSFETs were chosen as they are state of the art and similar RDS(ON). 40 V eGaN FETs were compared with 30 V MOSFETs because higher overshoot can be expected with the much higher switching speeds of the eGaN FETs. Table 1 shows important characteristics of the switching devices.

The converters were run open-loop with the duty cycle adjusted for the appropriate output voltage. The output filter was kept small to take advantage of the space savings enabled by high frequency conversion (See Table 2). For 800 kHz testing, only one output filter capacitor was used, and for 300 kHz testing, a 470 µF PosCap was added.

Experimental Results
The tests show that the circuit with eGaN FETs running at 500 kHz was comparable to the MOSFETs at 300 kHz, while the MOSFET circuit saw an efficiency decrease of roughly 1.5% through most of the current range at 500 kHz.

At low current, the efficiency decreases for the eGaN FET solution because the fixed dead-time was minimized for optimal high current operation. This resulted in the loss of the zero-voltage switching advantage at light loads. However, when the dead-time was increased, as an adaptive type driver would do, the 500 kHz efficiency of the eGaN FET system became comparable to that of the 300 kHz MOSFET system under all load conditions. At these frequencies the eGaN FET system saves 36 mm2 of board space (about 20%) with no efficiency penalty.

The frequency was then increased to 800 kHz on the eGaN system, and output filter reduced to maximize board space savings. Even with the higher switching speeds, overshoot was limited to 33 V, and ringing was mostly damped in only a few cycles.

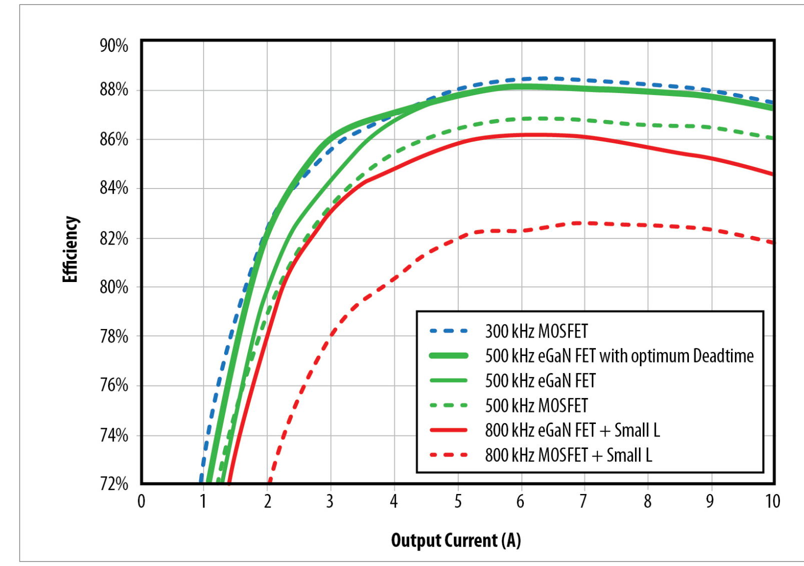

Figure 1: Efficiency comparison between state-of-the-art MOSFETs and eGaN FETs at various frequencies for VIN = 19 V and VOUT = 1.2 V

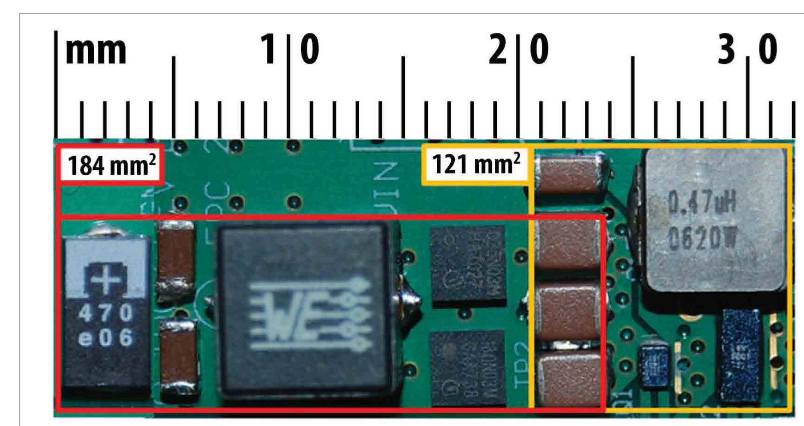

Figure 2: Size comparison between 300 kHz MOSFET Buck (Red) and a 800 kHz eGaN FET buck (Orange)

The result was impressive. Efficiency over most of the current range stayed within 1% of the 500 kHz MOSFET system. The peak efficiency was over 86%, and the board space saved was 30 mm2 (an additional 20%). Board space requirements are compared in Figure 2. This 33% space savings can be translated into a reduced size and price for the multi-layer printed circuit board, or into increased system performance by using that space for processing power and memory.

Conclusions
We have demonstrated significant space savings while maintaining high efficiency by driving frequency from the traditional 300 kHz all the way up to 800 kHz. By using eGaN FETs, power conversion system designers now have a new opportunity to reduce system size and enhance efficiency while reducing overall system cost.

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VIDEO SECURITY BENEFITS

Deploying virtual remote sense controllers

By Bruce Haug

Even before the heightened awareness brought on by threats of terrorism, many public and private institutions had already began to incorporate video security into critical infrastructure.

Video security provides the visual images necessary to improve situation awareness, deter vandalism, theft or other crime, accelerate response and management decisions and increase overall staff and public safety. From airports to bridges, refineries to pipelines, seaports to highways, all have benefited from including video security equipment in their preparedness plans.

One of the most demanding video security installations is a casino, where the sleight of hand and the quickest of movements must be captured, reviewed and archived to meet stringent regulations. The strategic placement of "eye in the sky" cameras supplements a security staff's physical resources, helping to better manage crowds and deploy personnel in a timely and effective manner. High-quality video of gaming areas provides security professionals with the detailed information needed to prevent cheating and to catch cheaters. Surveillance cameras can also help deter crime while aiding authorities in identifying criminals during their investigations.

Retail stores benefit from video surveillance systems by serving as a visual deterrent to potential criminal acts and provide managers and security professionals with tools for dealing with liability claims, employee theft or other management issues. As a result, shoplifting and employee theft can be dealt with more easily when the perpetrator is caught in the act on video. Furthermore, slips, falls and liability claims can be more accurately understood and processed when caught on video.

Contraband, violence, inmate and officer safety are just a few of the issues that must be dealt with on a routine basis in the management of today's correctional facilities. And so, video security has never played a more important role in maintaining order and ensuring a safe working environment. These systems provide 24/7 monitoring of remote locations. As a result, some of the monitoring cameras need to be several hundreds of feet away from the base control system or available power outlet.

As healthcare facilities grow larger and provide around-the-clock care, they become more vulnerable to a wide array of security risks. While industry guidelines mandate a growing reliance on security under its "Environment of Care" standards, it is the responsibility of each individual hospital and healthcare organization to decide on the right tools to meet their needs for protecting patients, visitors, staff and intellectual property.

Camera Deployment

To get complete surveillance coverage at certain sites, somewhere between 200 to 300 cameras may needed. These cameras could potentially be from up to 1000 feet from the base control system or an AC outlet. Each camera requires its own power for operation and typically needs 24V DC at about 20W unless it is mounted in an open environment, where it is subjected to the elements and needs to be heated to prevent ice from forming. In this case, the power demand can approach 70W.

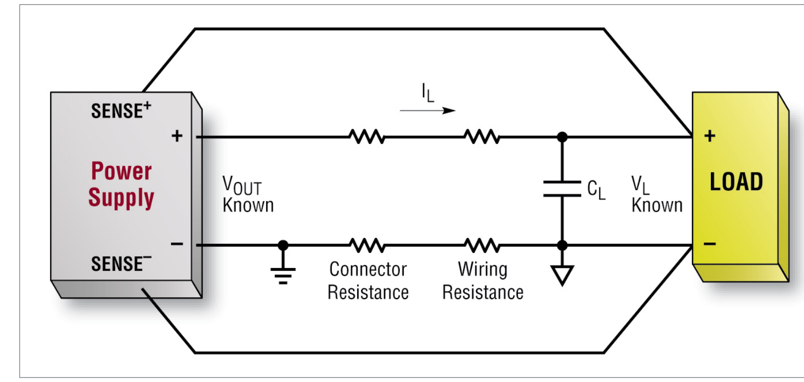

Figure 1: Traditional Approach of Remote Voltage Sensing

Therefore, the system integrator needs to either have an electrician install an AC outlet box close to the camera or power the camera through a long run of wires. Long wire runs can produce a large voltage drop causing considerable load regulation errors. As the load current increases, the voltage drop in the wiring increases due to the line impedance and the voltage delivered to the load drops. System integrators have routinely increased the wire size from 22 AWG to 16 AWG to maintain regulation even though the cost delta between these wires sizes can be as high as $250 for a 1000 foot wire run.

Alternatively, the traditional approach to solving this problem has been to sense the output voltage with a pair of sense wires that run from the regulator's feedback network to the load. While this approach works well, the additional pair of low gauge wires, typically 26 AWG may not be practical due to the cost, weight or logistic considerations. Figure 1 shows a remote sense block diagram with one wire sensing the voltage drop in the positive voltage wire and the other wire sensing the drop in the negative voltage wire.

A New Solution

Linear Technology has developed the LT®4180 Virtual Remote Sense™ (VRS) controller, eliminating the need for remote sense wires to compensate for the IR losses in cables and wiring. This device continuously interrogates the line impedance and corrects the power supply output voltage to maintain a steady voltage at the load regardless of current changes.

The block diagram in Figure 2 shows the LT4180 VRS controller's basic operation.

How VRS Works

VRS works with a small modulation on the output of the regulator to compute the correction. This modulation is filtered by an output capacitor at the load that is always present anyway. The LT4180 works with nearly any conversion topology, isolated or non-isolated power supplies, DC/DC converters including bricks, modules and adjustable linear regulators.

The LT4180 operates in conjunction with a power supply or DC/DC converter and forces the output current to change from 95% and 105% of the nominal output current at a pre-determined dither frequency. In other words, the LT4180 forces a square wave current with a peak-to-peak amplitude equal to 10% of the DC current on top of the regulators output current (IL). A decoupling capacitor at the load filters out the dither current from the VRS square wave. This decoupling capacitor is sized to produce an "AC short" at

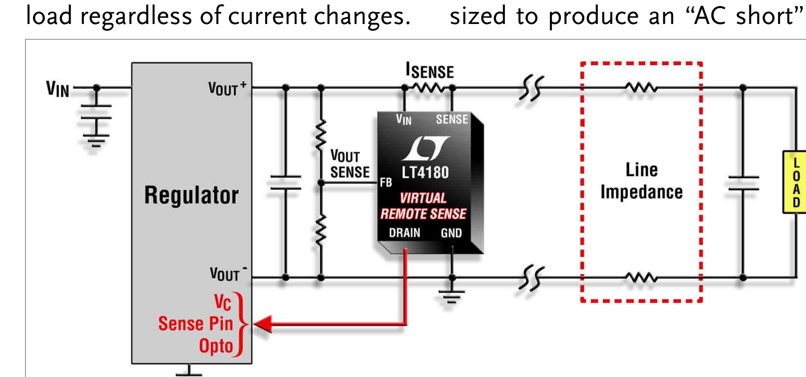

Figure 2: New Approach of Remote Voltage Sensing without Wires

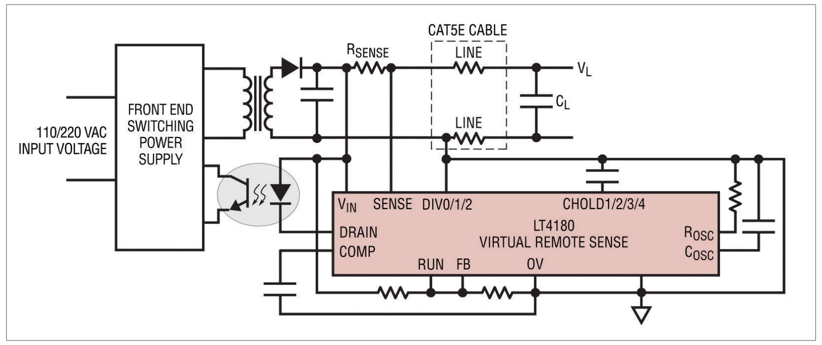

Figure 3: Simplified Off-Line Application Circuit Using the LT4180

the current square wave frequency, resulting in a voltage square wave at the power supply with peak-to-peak amplitude equal to 1/10 of the line impedance. The LT4180 continuously monitors the line impedance and corrects the regulators output voltage to provide accurate load regulation.

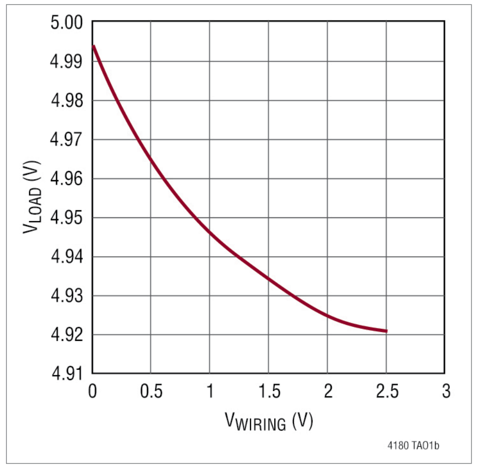

Figure 4: Load Regulation Curve for a 5V Output Using the LT4180

Off-Line Design Example

The simplified circuit in Figure 3 shows how the LT4180 can be designed into an off-line power supply to deliver 24V @ 0.7A with a 3A peak output through a CAT5E cable to power a video surveillance camera. The LT4180 continuously monitors the line impedance of the CAT5E cable and its DRAIN pin drives the diode in an optocoupler to change the duty cycle of the power supply in order to maintain tight regulation at the load regardless of load current changes.

The curve in Figure 4 shows the load regulation of a LT4180 line loss compensation circuit for a 5V output voltage. The load current is increased from zero until it produces a 2.5V drop in a cable. With the LT4180 correcting the power supplies duty cycle results in only a 73mV change in voltage at the load over the entire load range.

Additional Benefits

The LT4180's 3V to 50V input voltage range covers a variety of applications. Its output driver has a 5mA sink capability to drive an opto-coupler for isolated designs. A programmable fixed dither frequency or spread spectrum frequency determines the sampling rate of the line impedance. The soft-correct function insures an orderly start-up. When the run pin rising threshold is first exceeded (indicating VIN has crossed its undervoltage lockout threshold), the power supply output voltage is set to a value corresponding to zero wiring voltage drop (no correction for wiring). Over a period of time (determined by the CHOLD4 pin on the LT4180), the power supply output ramps up to account for the wiring voltage drop, providing best load-end voltage regulation. A new soft-correct cycle is also initiated whenever an overvoltage condition occurs. The LT4180 is available in an SSOP-24 package with three temperature grades. An extended grade version from -40 to 85°C, an industrial grade version from -40°C to 125°C and a military grade from -55°C to 125°C.

Conclusion

The LT4180's VRS provides a new function for power supply designers and system integrators. Excellent regulation is obtained without sense wires for long wire runs to cameras and eliminates the need for additional power outlets or much heavier gauge wires. VRS opens up opportunities previously unavailable in surveillance equipment installation and works with nearly any type of power supply or regulator: switching or linear, isolated or non-isolated, providing maximum flexibility.

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Special Report: Supplying the Power Grid

PSD NORTH AMERICA
Power Systems Design: Empowering Global Innovation

Inside:

CUTTING UTILITY BILLS

Cost-effective dimmable CFL ballasts

By Tom Ribarich

Legislation mandating adoption of energy-saving lighting, such as the EU Lighting Directive, can help governments meet CO2 reduction obligations while also helping reduce end users' utility bills.

As a consequence, Compact Fluorescent Lamps (CFLs) are becoming widely adopted, but their growing popularity is bringing demands for improved performance; in particular, the ability to dim CFLs easily and cost effectively. This article examines how software-based ballast design can help to meet these objectives.

The Resonant Dimming Ballast

Owing to the unique electrical behaviour and specification of CFLs, a dimming fluorescent ballast must integrate several important functions to manage start-up, running and dimming of the lamp. Figure 1 illustrates the main functional blocks.

The EMI filter, rectifier and smoothing capacitor convert the AC line input into a DC bus voltage and prevent ballast-generated noise entering the AC line. The half-bridge ballast-control IC produces a high-frequency square-wave voltage, which drives a resonant tank circuit for preheating, igniting and dimming the fluorescent lamp. This resonant half-bridge circuit allows a high voltage, up to several kilovolts, to be generated to ignite the lamp, and also ensures energy-efficient operation with low EMI through soft switching of the MOSFETs.

Dimming is achieved by combining the fed-back current-sensing signals with the user-controlled dimming input to achieve the desired level of lamp dimming by adjusting the half-bridge frequency. The dimming input is usually galvanically isolated from the circuit.

Figure 2 illustrates the operating points of the system during start-up and throughout the dimming range of the lamp. The circuit starts up at a high frequency, and then sweeps down towards the resonant frequency of the under-damped resonant curve, as described by the blue line. As the frequency sweeps down, the voltage across the lamp increases as the gain of the under-damped resonant curve increases. When the frequency reaches the calculated ignition frequency the voltage across the lamp will be approximately 750Vpeak and the lamp will ignite. This sequence helps avoid lamp flash by starting the lamp at a high frequency, and also allows for preheating of the lamp electrode, which extends lamp life.

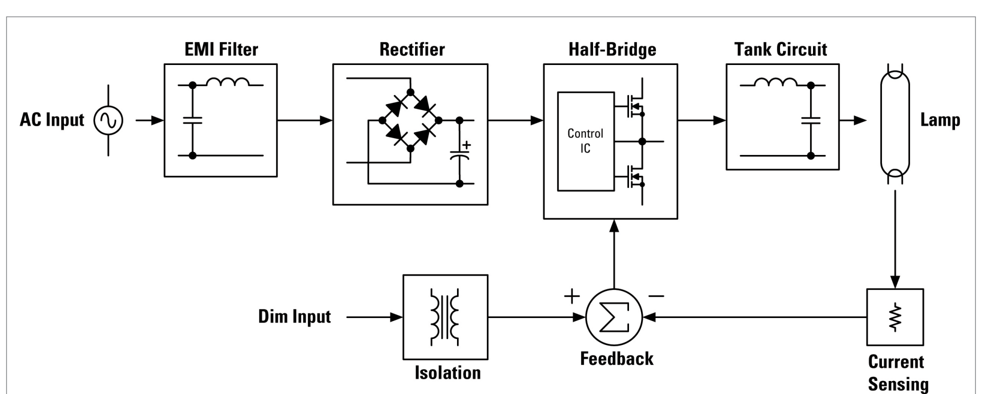

Figure 1: Dimming ballast block diagram.

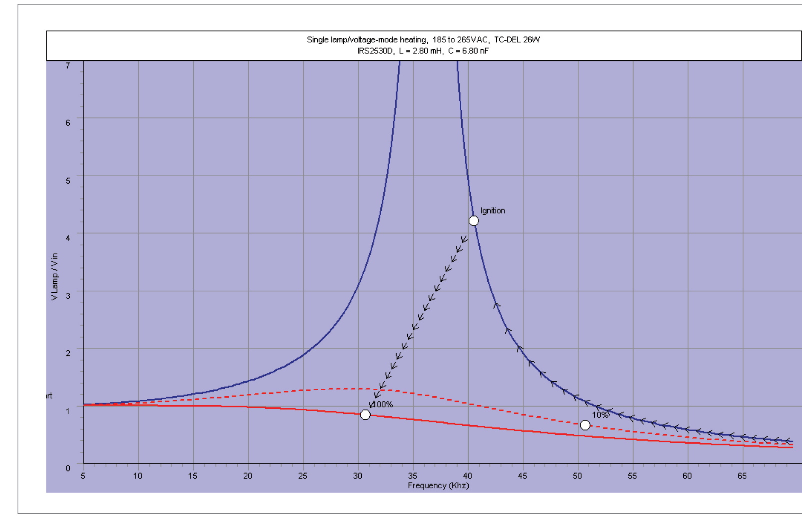

Figure 2: Operating points of the resonant half-bridge dimmer

After ignition the resonant tank becomes damped due to the lamp resistance present in the circuit, and the system's behaviour follows the red line. The half-bridge controller IC closes the feedback loop and adjusts the frequency to somewhere between the 100% frequency and the 10% frequency depending on the desired dimming level. The resonant tank will become more or less damped as the lamp resistance increases or decreases during dimming (solid red line and dashed red line).

Speeding-Up Ballast Design

PC-based design software such as IR's Ballast Design Assistant, IRPLBDA4, reduces the design time for electronic ballasts by helping to select a control IC, create a schematic, calculate component specifications and generate a bill of materials. The BDA also includes advanced simulation and analysis tools that enable designers to understand and optimise important parts of the ballast, such as the resonant tank circuit, to fine-tune ballast performance.

The designer can quickly generate all the documentation needed to build the ballast by following a simple five-step procedure. This is readily accessible via the BDA's home screen, which presents clickable menu options that guide the designer through selecting the target IC, input circuit configuration, lamp type, and lamp circuit configuration. The fifth step is to click on the Design button to generate the schematics, bill of materials and inductor specifications.

Advanced System Analysis

This easy to use tool significantly reduces the time to design a dimmable CFL ballast. The key to improving ballast design, however, lies in knowing where the system's operating points are at all times. To assist with this, the BDA has advanced features that allow the designer to see, edit and fine tune the ballast and lamp input specifications, calculate the resonant tank components and view the circuit operating points graphically. This will give the designer a better understanding and feeling of how the circuit is working - in particular with respect to the resonant tank behaviour during the different modes of the lamp.

Using the ballast and lamp data provided, the advanced screen shows values for the resonant tank components, displays the various operating frequencies that correspond to each lamp mode, and generates a Bode plot similar to that shown in figure 2 presenting a graphical view of the system's operating points.

The BDA software also provides a 'time domain' waveform viewer, which allows the designer to simulate switching waveforms to

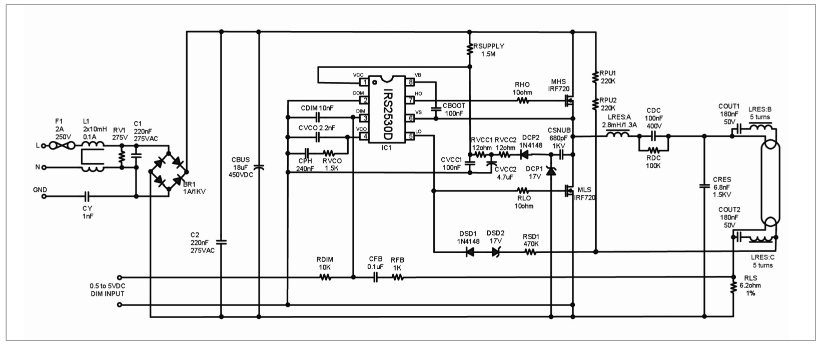

Figure 2: Operating points of the resonant half-bridge dimmer

make sure the circuit is working as expected before building the actual circuit on the bench.

When the input and output circuit parameters are acceptable, the designer can instruct the tool to generate a specification for the resonant inductor - including core type, core size, air gap, number of turns, and wire gauge - and to calculate the various programming resistors and capacitors around the chosen control IC. Clicking the Design button finalises the design and generates the complete set of output files for the ballast.

Ballast Performance

Figure 3 shows a complete schematic for a 26W ballast, as generated using the BDA. The half-bridge (MHS and MLS) is controlled by the IRS2530D dimmable ballast controller IC for preheating, igniting and dimming the lamp. Resistor RSUPPLY provides the micro-power start-up current for the VCC supply of the IC, and the charge pump (CSNUB, DCP1 and DCP2) takes over as the IC supply once the half-bridge begins to oscillate. CVCC1, CVCC2, RVCC1 and RVCC2 are used to filter VCC against high current spikes from the charge pump that can occur during hard-switching or inductor saturation.

The resonant tank circuit (LRES and CRES) provides the necessary transfer function for generating high voltages for lamp ignition and low-pass filtering for dimming. A DC blocking capacitor (CDC) ensures that the lamp current is always AC to prevent mercury migration which can cause lamp-end blackening and shorten lamp life. Secondary windings from the resonant inductor (LRES:A,B) are used to heat the lamp filaments during preheat and dimming, and also separate the lamp current from the filament current. This allows for a single current-sensing resistor (RLS) to be used to sense the lamp current.

The AC lamp current measurement across RLS is coupled to the DIM pin through a feedback capacitor and resistor (CFB and RFB). A DC dimming reference voltage is also coupled to the DIM through resistor RDIM. The resulting voltage at the DIM pin is the DC reference with the AC lamp current superimposed on top. As the DC reference is increased or decreased for dimming, the feedback loop of the IC keeps the valley of the DIM pin voltage regulated to COM by continuously adjusting the half-bridge frequency. This loop will then automatically increase or decrease the AC lamp current amplitude depending on the DC reference input voltage level.

Finally, resistors RPU1, RPU2, RSD1, DSD1 and DSD2 are used to detect if the lamp has been removed and to restart the ballast automatically when the lamp is re-inserted. Protection against all other ballast fault conditions such as failure to strike, open filament, and low AC line/brown-out, are included internally to the IRS2530D. This further reduces component count and increases reliability.

Conclusion

This article has shown how software tools such as IR's Ballast Design Assistant simplify design and evaluation of dimmable fluorescent ballasts. BDA can be freely downloaded from the International Rectifier website at: www.irf.com

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POWERLINE COMMUNICATIONS

Automating street lighting

By Scot Robertson

Street lighting in its many forms - roadway lighting, tunnel lighting, car park lighting and urban lighting - is a major consumer of grid electricity.

All outdoor lighting is, in fact, estimated to comprise 19% of world-wide electricity usage today. For municipalities and businesses with large facilities, street lighting is a significant portion of operational expenses. Street lighting is also a vital part of public safety. Ensuring that street lights are reliably on and at the optimal illumination level for pedestrian and vehicle traffic is critical to public safety and the operators' liability. As a result, any improvements to energy usage, operational reliability, and maintenance costs provide significant payback for the organizations responsible for that street lighting. There are, of course, obvious added benefits to the environment as energy usage is lowered.

Powerline communication (PLC) is the natural choice for automating street lighting networks. PLC enables companies and municipalities to reduce operational costs and improve safety. G3-PLC Is a new OFDM-based PLC system designed for grid automation which dramatically extends the range, data rate, and performance of powerline communications. This article discusses the benefits of a G3-PLC-based automation system and presents a real-world example of a system for reducing energy usage and lowering maintenance costs in tunnels. The basic system design is explained and key performance parameters discussed. A transceiver optimized for PLC automation is presented.

PLC System Promises Benefits to the Environment and to Operators

The G3-PLC system provides a simple solution for adding communication to networks of street lights. This two-way communication enables advanced automation:

- Precision on/off times based on location, the astrological calendar, and weather conditions Power-saving dimming during dawn/dusk and deep night
- Traffic control through dimming
- Traffic monitoring
- Lamp failure notification
- Lamp maintenance notification based on temperature, current, PF, or operational hours
- Emergency on/off/intensity control
- Real-time monitoring of energy consumption

PLC delivers a range of advantages over wireless communication systems. Like wireless, no new wires are required. But with PLC, communication is maintained even underground, through walls, and around corners. The communication channel is owned by the operator or utility, so the risks of sharing bandwidth are eliminated. PLC has no line-of-sight limitation and is not affected by weather. Additionally, since PLC

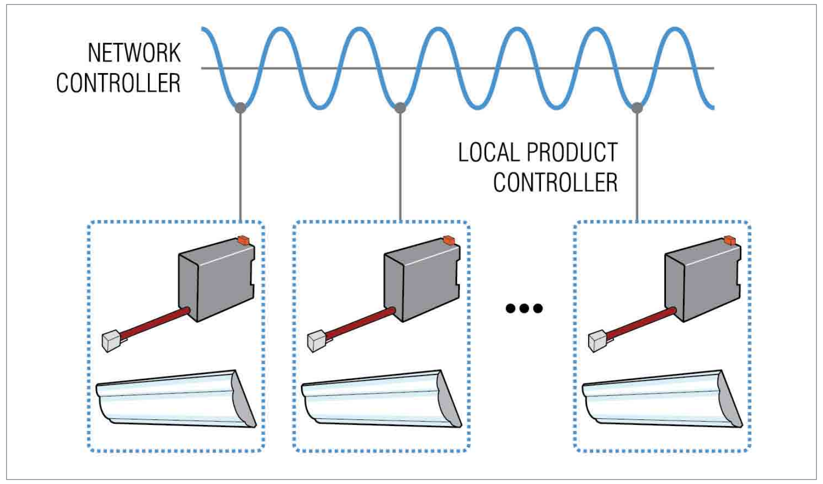

Figure 1: Scheme for PLC technology. In a TLACS system from Nyx Hemera Technologies a local controller integrates PLC to communicate with the network controller over the AC line and controls each lamp using a standard DALI interface

uses the powerline, it can detect when there is a line break and its approximate location.

Tunnel Lighting: a Real-World PLC Example

The savings with PLC are seen in reduced energy usage and operational costs, which can be substantial. Consider an example a new PLC system. The technology is currently used for tunnel lighting by Nyx Hemera Technologies. Their Tunnel Lighting Control System (TLACS) is delivering energy savings of 25% for fluorescent lighting and reducing maintenance cost by 30%. It greatly improves safety by matching the illumination level to the outside at the entrance and exit of tunnels.

The TLACS system is based on the OFDM PLC products from Maxim Integrated Products, which receive signals heavily attenuated by long powerlines even if the signal level is below the noise. The addressability and high data rates of Maxim's solution enable Nyx Hemera Technologies to support up to 1022 lights in a single system. The TLACS system supports wire lengths to 3km, and since it uses the powerline, is modular and easily installed on existing lighting systems (Figure 1).

Optimizing the Lighting Automation System

The performance and capacity of a lighting automation system are determined by the range, data rate, noise immunity, and routing capability of the PLC system. A typical street lighting topology is illustrated below (Figure 2). A concentrator modem with a WAN connection, such as fiber or 2G/3G wireless, communicates with a network of modems, or nodes, which control each lamp. The range of the PLC modem determines the number of nodes with which the concentrator can directly communicate. The greater the number of nodes, the more efficient the system is.

The range of communication on a powerline is impacted by several factors: branches, which divide the power of the signal; attenuation, which varies with frequency; and interferes, such as switching power supplies, motors, and other power consumers on the line. Since noise on powerlines is dynamic (i.e., noise sources are turned on/off over time), noise immunity is crucial for the automation system to maintain its essential features. By incorporating routing capabilities in the nodes, a mesh network can be established to allow nodes connected with the concentrator to extend the network by forwarding messages to/from the concentrator and more distant nodes. Although mesh networks can greatly extend the network that a single concentrator can service, the powerline data rate determines the size which can be maintained for the desired services. Since mesh networks for street lighting have only one channel from the network to the concentrator, all of the forwarded messages must travel through one or more shared links which become the system bottleneck.

The MAX2992 is a G3-PLC-compliant transceiver. It provides leading performance for street-light automation through advanced features that meet the PLC

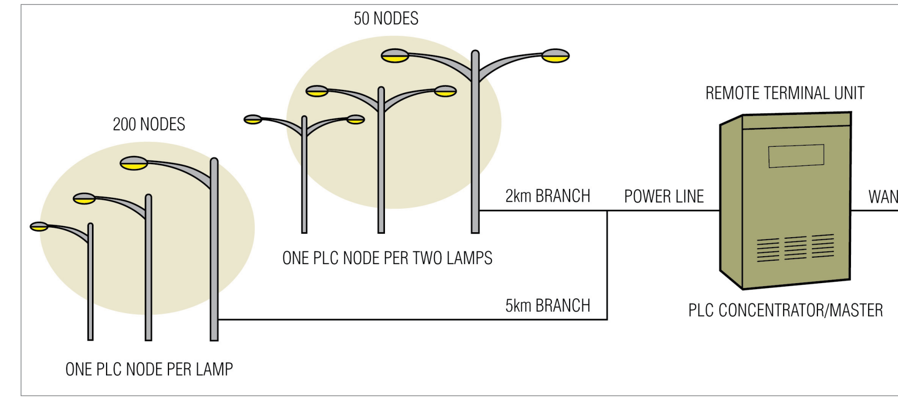

Figure 2: Example of a typical, automated street-light network topology

system's range, data rate, noise immunity, and routing requirements. The MAX2992 implements the IEEE P1901.2 pre-standard for low-frequency PLC. Modulation using DBPSK, DQPSK, and D8PSK enable data rates up to 300kbps for the FCC band (10kHz to 487.5kHz). A robust mode maintains communication even when the signal-to-noise ratio (SNR) is -1dB. The transceiver employs dynamic link adaptation to automatically select the optimal modulation scheme and data rate based on the channel conditions. Further, adaptive tone mapping avoids interferers by selecting the sub-bands with the least noise. This, in turn, allows higher-order modulations to automatically achieve the highest data rate. An automatic association mechanism configures a mesh network when nodes are added or removed. As messages are communicated, a dynamic routing mechanism identifies and updates the best routing path across the network.
The capacity and performance of a street-lighting network are determined by the powerline topology, including the number and location of transformers, conditions on the powerline, the frequency band selected, and the message frequency. The MAX2992's data rate is up to 300kbps for the full FCC band (10kHz to 487.5kHz) when using DB8PSK modulation. FCC band is used in the U.S. and many other countries. When communicating through powerline transformers or over long distances (e.g., 10km), the SNR is reduced due to attenuation. The MAX2992 automatically switches to DQPSK with a typical data rate of 150kbps. In Europe, CENECLEC® BC band (95kHz to 140kHz) is often used for street lighting and supports a typical data rate of 38kbps.

The topology for the street-light network impacts the range of the communication and the mesh network configuration. Branches on the powerline both divide the PLC signal, thereby reducing the range, and create additional branches in the mesh. Additionally, management of the network is fundamental to the network's performance. Networks where nodes are polled by the concentrator have predictable message latencies; networks where each node transmits as needed are subject to contention which creates variable latencies. Topology and line conditions impact network performance significantly, so estimating the capacity and performance of a particular network is difficult. As a result, provisioning specific networks should be based on data collected in trials using the desired message frequency and network management system.

In street-lighting applications predictable message latencies are generally preferred over variable message latency. In this case, polling of the nodes by the concentrator is recommended. When using a round-robin polling scheme, the larger the number of nodes per concentrator, the longer the interval between messages to any one node becomes. Lighting automation such as controlling light dimming or checking traffic levels are scheduled events, allowing predictable message latencies to be compensated for in the schedule.

Realizing the Benefits

The benefits of the G3-PLC system for large networks can be seen in the following calculation. Using G3-PLC for the FCC band of 10kHz to 490kHz, the point-to-point message time is .017 seconds during which approximately 180 Bytes of payload data are transmitted. For a large network of 1000 lamps with

Total Lamps	Forwarders	Message Time (s)	Time to Send One Message to Each Node (s)
1000	7	0.017	588 (10 min.)

Table 1: Time to Poll 1000 Lamps in Mesh Network with Seven Forwarders

average spacing of 80m, the total line length would be 80km.

Because of the distance or transformers which attenuate the PLC signal, the concentrator cannot communicate with each node directly. In this case, the mesh networking features of G3-PLC enable the nodes to become forwarders to route messages to/from the concentrator to each node. Seven forwarders are used in this example (Table 1). Using an average forwarding delay time of .005 seconds and a single concentrator which polls all nodes, the total time for the concentrator to send one message to each lamp is ten minutes. This interval allows the operator to activate lamps or change dimming levels specific to each lamp's location (e.g., high on a hill, in an underpass, or in a valley). There is a maximum delay of 10 minutes even if all lamps must be accessed. If the same command needs to be sent to all lamps, such as an emergency "on" command, a broadcast command can be used which requires less than .2 seconds to reach all lamps.

Conclusion

Streetlamp manufactures, automation integrators, and communication OEMs are developing solutions that use PLC to deploy automated street-lighting systems to conserve power, reduce maintenance costs, and provide rapid pay back to operators and the environment. The MAX2992 PLC transceiver can automatically associate, choose the best routing path, communicate through transformers, and support IPv6 networking. These optimized capabilities greatly simplify deployment of an automated street-lighting system. The device delivers leading-edge performance to enable larger networks, additional savings, and greater safety.

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LOADS ON THE GRID

Brushless motor control; design considerations

By Klaus Schweizer

There are many applications today where the prevailing brushed DC motors continue to represent high demand on the power grid.

In most cases, these durable motors, based on proven technology, meet customer application requirements and failure rates are low. But brushless DC (BLDC) motor applications are now emerging and their extended functionalities are becoming increasingly attractive. Regardless of whether DC-brush or brushless DC motors are used, the challenge in electronic motor control is to design for new functionality while maintaining reliability and high performance.

Brushed DC Motors – Advantages and Disadvantages

Brushed DC motors are a proven technology offering several advantages. In addition to low initial cost, brushed DC motors also stand out for their reliability, the high volume of production possible with this technology, and the ease with which motor speed can be controlled.

The low initial cost involved is perhaps the most important benefit, being preferred for brushed motor control in price-sensitive applications.

However, this technology has its drawbacks. One disadvantage is that carbon brush wear can reduce the motor's useful service life. Additionally, DC motor brush fire may cause EMI (Electro-Magnetic Interference).

While the low effort and cost of electronic control with brushed DC motors is associated with the use of relays, a trend is underway to use transistors instead. Relay control is still the simplest method of controlling brushed DC motors, and arguably performs better for certain applications with unidirectional operation. So, while relays have sufficient reliability in most cases, particularly when motors are rarely switched on, transistors are increasingly preferred when the following variables are considered: mechanical stress and vibration; switching frequency; high coil current; speed control; size and space; and clicking noise.

Brushed DC Motors – Predriver Control in an H-bridge

Typically, half-bridge drivers are employed for brushed DC motor control. In reversed DC motor applications, for example, the DC motor is typically an H-bridge configuration with four power MOSFETs forming the bridge. Currently available H-bridge driver ICs are often simple 'predrivers', which activate and deactivate the gates of discrete power MOSFETs. While Atmel takes a more integrated and complex approach, what is most important is to use the right combination of microcontroller and driver.

For example, Atmel's ATA6836, which is a fully protected hex half-bridge driver, designed in the company's smart power SOI (Silicon-on-Insulator) technology, can be used by a microcontroller to control up to six different loads. Up to a current limit of about 650mA, the ATA6836 can be used to drive up to 5 DC motors directly in H-bridge configuration.

An example circuit showing the case for DC motors with higher wattage (say 10W to 800W) is shown (Fig 1) with an integrated gate driver (the ATA6823), a microcontroller, and discrete N-channel power MOSFETs selected according to the DC motor's wattage.

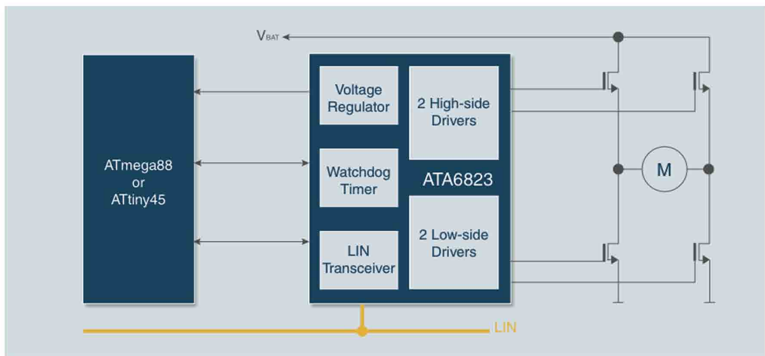

Figure 1

Brushed DC Motors - Further Design Considerations
When designing brushed DC motor control systems, high-temperature is another consideration. However, the ATA6824, for example, has been specifically designed for the demands of engine compartment applications where electronic control units are specified for ambient temperatures of 150°C or higher. However, a system-basis predriver with an integrated 100mA 3.3/5V linear regulator will needs to be qualified for a junction temperature of up to 200°C.

Protection is another important consideration. Discrete power MOSFETs, for example, need to be protected against overcurrent conditions. This is typically achieved by monitoring the drain-source voltage that is fed to a comparator integrated in the predriver. A high short-circuit current will flow if a high-side and a low-side power MOSFET are activated simultaneously within the same branch. System basis gate drivers should feature integrated protection to counter this event.

In choosing a motor driver, designers also look for good speed and direction control. Characteristically, the architecture of system-basis chips involves the integration of all necessary peripheral functions into the driver IC. In this specific case, speed and direction control are made extremely easy. The microcontroller needs only two command lines to set the speed and direction of the DC motor: the direction pins (clockwise or counter-clockwise) and the PWM pin. The moment the PWM signal is low, the system basis predriver activates both high-side drivers so that the freewheeling current can flow without any additional microcontroller commands.

Brushless DC Motors
BLDC motors are now emerging in many applications, although they have been popular in disk drives and industrial applications for many years. According to the latest available market data, around 80% of DC motor applications are still equipped with brushed motors. However, brushless applications are growing at the fastest rate and are expected to take the lion's share of new motor control electronic design.

The advantages of BLDC motors over brushed motors are reasonably obvious: improved speed vs. torque characteristics; high dynamic response; high efficiency; noiseless and interference-free operation; extended speed ranges; and long operational life.

BLDC B6 Predrivers
Currently applications mainly incorporate highly efficient three-phase brushless DC motors, which typically need a B6 bridge to control three 'high-side' and three 'low-side' power MOSFETs. As with the system-basis H-bridge predrivers, the ATA6833/34 high-temperature B6 bridge predrivers include all the elements needed to form a complete system. The system shown (Fig 2) comprises a pin-programmable linear voltage regulator (100mA, 3.3/5V); a LIN transceiver; and a window watchdog, in combination with six push-pull stages, required to control the six discrete N-channel power MOSFETs that operate three-phase brushless DC motors.

Flexibility is a must concerning the control of the power MOSFETs in three-phase brushless DC motors. In a B6 predriver, because flexibility control is mandatory for different kinds of commutation, it does not make sense to use a two-pin motion control. Therefore, the MOSFETs should be controlled from the microcontroller separately via the high-side and low-side driver inputs of the ATA6833/34.

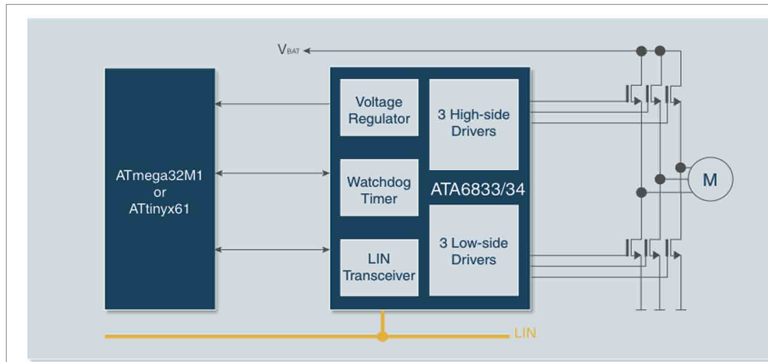

Figure 2

New Generation of BLDC Motor Predrivers
To enable new BLDC motor applications that take advantage of extended functionalities, Atmel has developed a new generation of advanced system-basis B6 predrivers. They comprise six push-pull stages combined with a 100mA, 3.3/5V pin-programmable linear voltage regulator, a watchdog timer (with a time base independent of the microcontroller), and a LIN transceiver.

Unlike the standard-temperature version Atmel ATA6843, the warning threshold of the ATA6844 is set to 150°C, and its excess temperature switch-off threshold is set to 200°C. This makes this IC able to cope with the demands of high temperature environments experienced in some manufacturing, heavy industrial or automotive environments.

Functionalities of the next-generation ATA6843 and ATA6844 (Fig 3), include:

- Expanded overvoltage detection threshold (up to 30V). This is an important feature for all applications requiring full functionality during jump-start conditions, such as fuel pumps.
- Adjustable and very low short-circuit-detection threshold for increased compatibility with low-impedance power MOSFETs. The drain-source monitoring can be adjusted by feeding a voltage in the range of 0.5V to 3.3V to pin SCREF. An internal voltage divider sets the detection threshold to 2.5V if the pin is left open.
- A digital input at pin COAST connected to the logic control. If this input is activated, all power MOSFETs are switched off, allowing the motor to coast. In some situations, the motor is asked to coast until it stops. Also, the coast function may be used in the case of overvoltage or to reduce speed before reversing the BLDC motor.

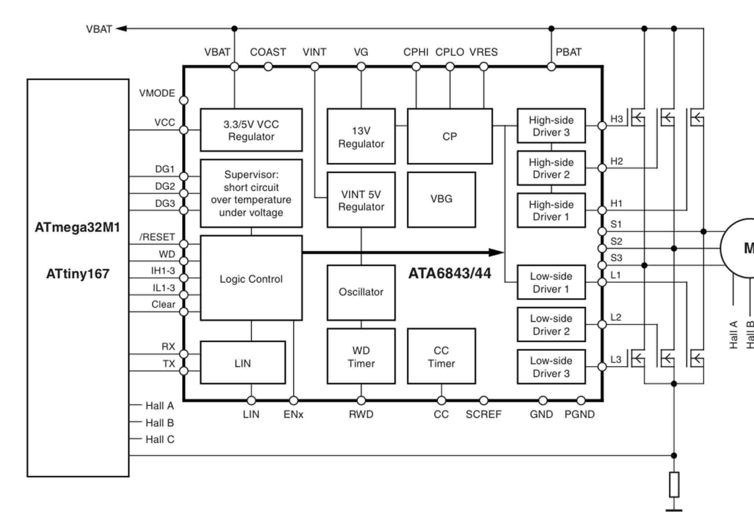

Figure 3

Finally, the predrivers include 6-pin control providing freedom to control discrete power MOSFETs for sinusoidal commutation, and also allow simple and cost-effective MOSFET control via the microcontroller's three command lines.

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SMART GRID PROGRESS

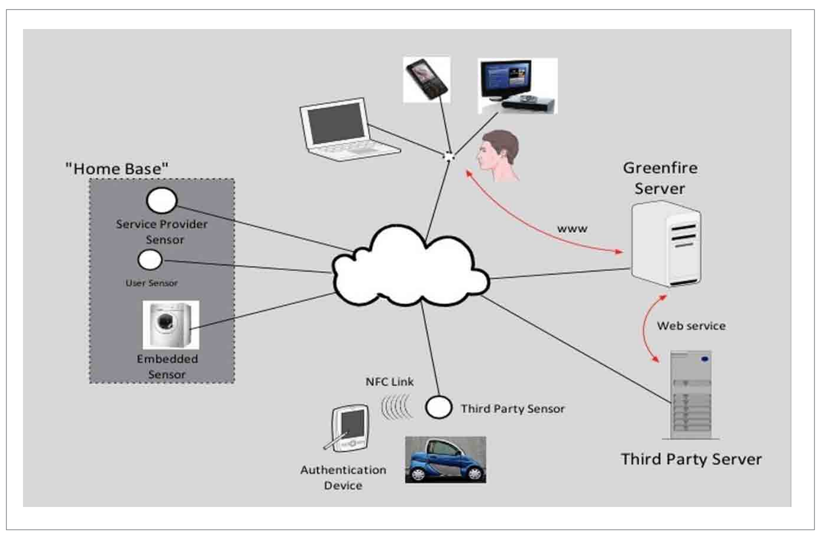
Why you need a personal energy account

By Rich Newell

The Smart Grid will bring massive changes to the way energy is delivered to homes. If the intent is to make everyone aware of and responsible for their personal energy usage, the Smart Grid is only the start.

The new energy infrastructure must take account of usage not just at home but wherever the user is. As an example, the UK radio program "Electric Ride" was broadcast in 2010. A four-man team drove a THINK electric vehicle 4,000 miles across Europe and managed to complete the journey. The problem they faced was finding charging points at regular intervals that would keep their car—which has a range of 100 miles—on the road. Official charging points were few and far between, so the radio had to find ways of keeping the vehicle topped up with the generosity of farmers, restaurant owners and householders.

For an electric car, there is as yet no standard way to account for charging away from home or specialized for-pay charging points. As the Electric Ride team discovered, there is not even a standard way of buying energy from a charging point.



Cars need not only be net energy consumers. They may and probably will be fitted with solar panels to augment grid-based charging. Parked up for long periods they could contribute energy back to the grid in small amounts. Hydrogen fuel-cell vehicles could generate enough energy in their own right to provide energy to the grid.

Similarly, there is no systematic way of tracking our personal energy usage away from home, in a hotel room for example. As a result, most individuals and organizations do not have a clear idea how or where they use energy. By analogy with the financial world, they know the account totals but cannot trace individual transactions. Without this knowledge it is very difficult to identify how energy usage can be reduced or modified with any degree of accuracy.

What is needed is a new type of energy accounting system that deals with all the generating capacity and consumption for which an individual, family or company is responsible. This new approach has the name Virtual Energy Account and uses Internet technologies to integrate all the diverse types of information needed. Servers collect the information to identify how energy is consumed and generated, pinpointing each individual energy transaction.

As well as making it possible to analyze energy information at home, the system can be used to support energy roaming—usage at different geographic locations—whether it is at a hotel, a leisure center or serviced office. All usage or supply can be identified, metered and charged to the Virtual Energy Account using secure devices to authenticate and authorize energy transactions away from home.

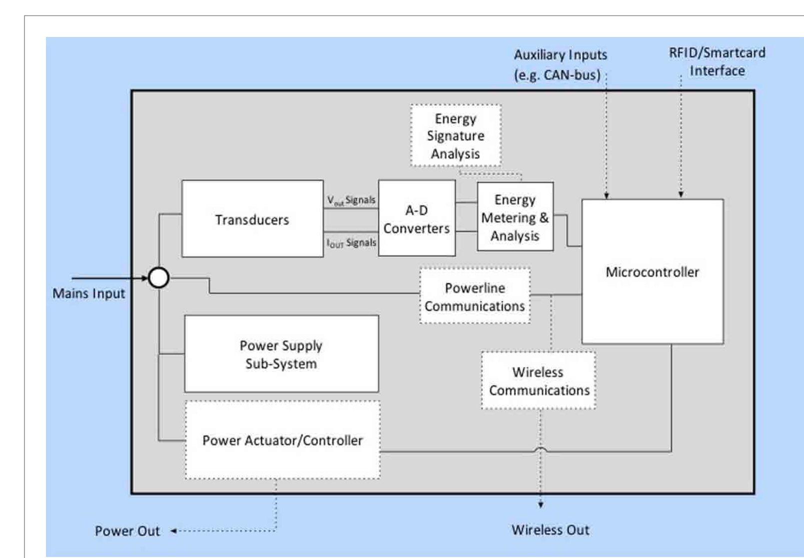
By integrating many different energy transactions, the Virtual Energy Account makes possible radical extensions to billing systems. Using modern, Internet-based technologies, it is possible to enable any energy-consuming or generating technology for dynamic tariffs. Electricity distributors can advertise online the availability of tariffs. Sensors and software on the energy appliances pick up the advertisements and, based on programmed rule sets, respond to them.

Such sensors can provide another degree of control. An unknown with any scheme today is the condition and efficiency of each appliance. Many are protected by fuses and circuit breakers but these only guard against catastrophic failures, such as short circuits. Many appliances work well enough never to trigger these protection circuits but often provide signs of wear that an appropriate sensor can detect.

The energy signature is a concept that can be used to help control these appliances. An energy signature is the combination of measurements taken by an energy sensor. Associated with each signature is a set of rules that define behavior that is acceptable and signals that the equipment should be repaired if it is consuming more energy than it should or, if the signature is a long way out of line, about to fail.

The GreenFire system accommodates these new Virtual Energy Accounts. Two elements make up the GreenFire system: a sensor and a server, which collects the data and provides a real-time energy signature from all of a user's energy flows. The sensor is responsible for measuring power flows and the parameters used to form the energy signature for the attached appliance. It has no display but communicates with the outside world over the Internet. The sensor can take many different forms but is always based on the same underlying architecture.

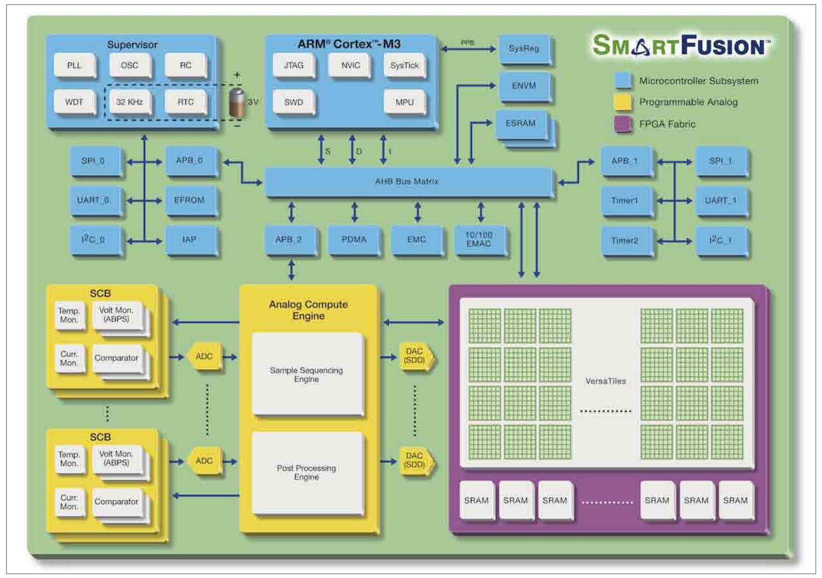
The sensors can be owned by energy service providers, owned and fitted by the consumer or embedded within electrical appliances. A further class, the third-party sensor, provides public energy access points where energy can be downloaded to anyone with the correct authorization. Charging posts and other installations that need a third-party sensor can have a smart card reader input fitted. This enables authentication of the user, as well as transfer of usage data or parameters to a smart card or mobile device.



The sensor must be physically small and unobtrusive, potentially able to fit into an electrical socket or be embedded inside an electrical appliance. Although physically small, it must contain physical transducers and analog-to-digital converters, digital signal processing (DSP), logic and cryptographic circuitry, and a microcontroller to handle communications and general processing.

The device must achieve a low cost point in order to achieve high market penetration. This implies not just a low piece part cost, but also low non-recurring engineering cost (NRE). Low cost of operation is also important, with power consumption kept to a minimum to prevent the sensors from being significant consumers within the network.

Security is mandatory. GreenFire sensors make a tempting target from a security point of view and so must be well protected from hackers. There are many candidate technologies for the GreenFire sensor hardware design, but the SmartFusion™ family of components from Microsemi's SoC Products Group (formerly Actel) provides an ideal substrate. By combining three key pieces of electronic hardware, SmartFusion devices can deliver the high integration necessary to put sensors inside plugs and appliances. A fourth element—security—is inherent in the way the SmartFusion device is designed and manufactured.



First, each SmartFusion device contains an ARM® Cortex™-M3 microcontroller subsystem that includes on-chip memory and hardwired peripherals. Second, there is a built-in, tightly-coupled field-programmable gate array (FPGA) fabric with additional static random access memory (SRAM) blocks. The third main subsection in SmartFusion devices is a programmable analog block that can be used to implement front-end sensor functions. It contains a sequencing engine to reduce the load of retrieving samples, providing more horsepower for dealing with GreenFire rule sets.

SmartFusion intelligent mixed signal FPGAs are based on a flash architecture, unlike most other FPGAs, which are SRAM-based. This means that SmartFusion devices retain their configuration once programmed—even after power is removed—and boot almost instantly once power is reapplied. They do not require an external ROM to reconfigure them each time power is applied, helping to maintain high integration and low board space. The flash architecture also helps reduce the power budget; flash cells intrinsically leak less current than SRAM cells.

To cope with the much greater emphasis on efficiency that government policies will encourage, the grid must evolve, become smarter and embrace the concept of the Virtual Energy Account. Internet technologies coupled with a secure, high-integration hardware platform can provide the intelligence needed to take maximum advantage of low-carbon energy sources, optimize consumption and reduce consumer costs. Based on Microsemi hardware, the GreenFire system can provide the basis for this new smarter grid and make sure people can get around on electric power.

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SAFE PHOTOVOLTAIC SYSTEMS

Over-current protection

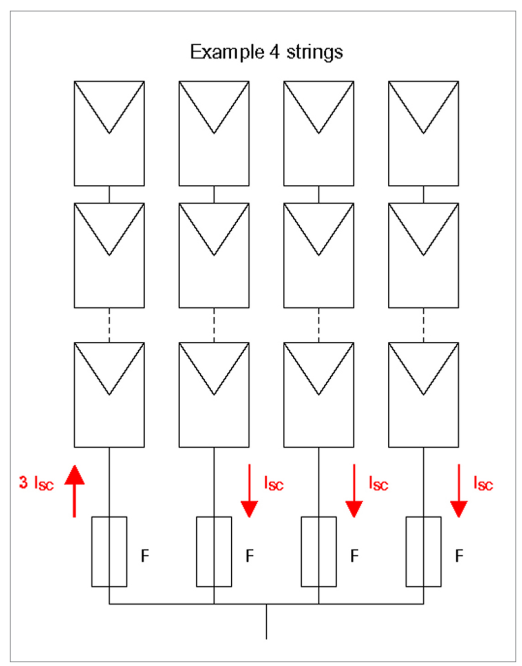
By Frank Ageron

Electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) are building a viable market of mobile electrical energy consumers. New relationships between electricity providers (the utility companies) and automobile owners are emerging.

The photovoltaic market is growing at a tremendous rate all around the world as indeed is renewable energy in general. To manage this trend and ensure safety around the solar technology in particular, manufacturers of solar components and equipment, designers of installations, engineers, etc., have to follow specific regulations and standards edited by international and national committees.

The fact that a solar device is both a dc environment and a non-interruptible source of current whenever the sun is shining makes things pretty complicated compared to our customary ac world. Ensuring the safety of solar power generating facilities is a tricky business, because there are very specific risks inherent to this kind of electrical equipment.

One of the most important safety components is the fuse. Installed in series, its purpose is to conduct normal current and to protect equipment and people from the potential effects of overcurrent, like overheating / fire / external arc / etc.



A new specific standard for fuses was published in 2010: IEC 60269-6 Ed 1 Low–voltage fuses _ Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems.

This new type of fuses is currently called "gPV": general purpose fuse for photovoltaic applications.

The requirements of that standard apply to fuse-links protecting PV strings and PV arrays in equipment for circuits of nominal voltage up to 1500Vdc. They define, for example, the minimum breaking capacity (mbc), rated breaking capacity, and conventional times and currents.

Why a dedicated fuse?
gPV Fuses are designed and tested specifically for DC applications.

When a fault occurs in a DC circuit, the absence of natural voltage zero crossing makes the interruption of DC faults more difficult than the interruption of AC faults because only the arc overvoltage generated by the fuse will force the current to decrease to zero.

For direct current, the correct interruption depends on three parameters:

- Value of the DC voltage,
- Value of the ratio L/R (time constant) of the fault path and
- Magnitude of the prospective fault current.

The short circuit current depends on the number of strings and the Isc of the solar panels. The possible low level of overload to be eliminated in photovoltaic equipment is a very arduous condition for a fuse. No fuse is required for PV installations with number of strings lower than 3 because the short circuit current is too low to melt the fuse.

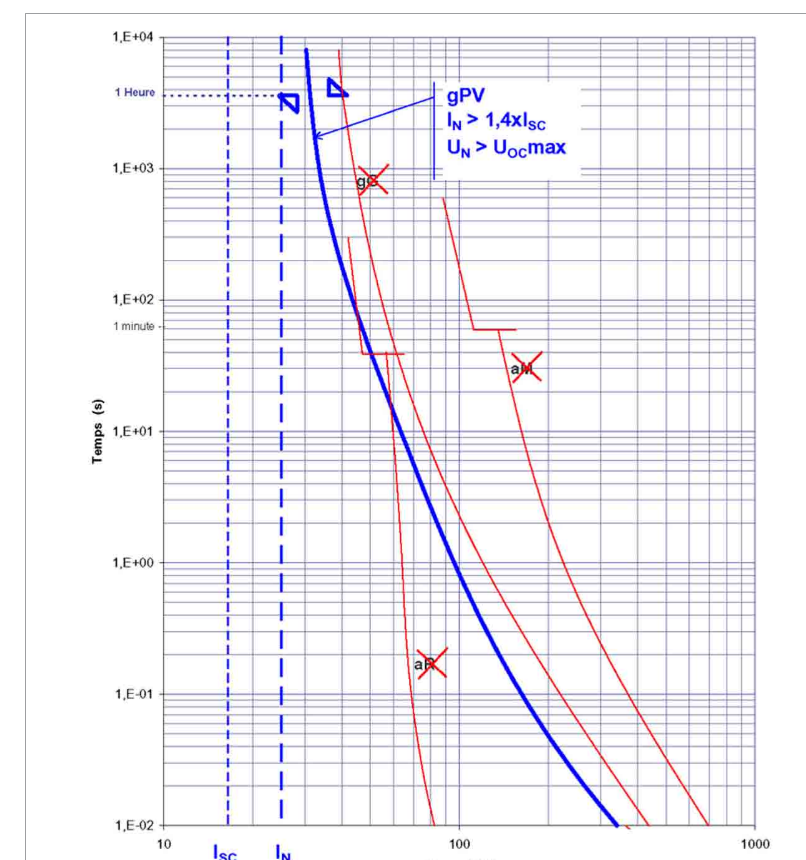
Conventional times and currents for gPV
Despite globalization, there are still some differences between standards. The first example is conventional times and currents. Between an "IEC" gPV fuse and a "UL" gPV fuse, non-melting gates and melting gates are not the same: cf table.

	gPV fuses 0-30A @1h	
	Inf	If
IEC standard	1.13*In	1.45*In
UL standard	In	1.35*In
MERSEN	**1.13*In**	**1.35*In**

To follow our customers on all markets: Mersen's HP6M and HP10M photovoltaic (PV) fuse series were engineered and designed specifically for the protection of photovoltaic systems in compliance with both standards. Their enhanced fuse construction makes them ideal for continuous temperature and current cycling withstand, adding to system longevity.

The 600VDC rated HP6M and the 1000VDC rated HP10M, designed for low minimum breaking capacity capabilities of 1.35 times the fuse's rated current value, allow for safe circuit interruption under typical low fault current conditions produced by PV arrays. Protect off-grid or on-grid PV system from unexpected ground faults and line faults using Mersen's HelioProtection fuse line.

In conclusion, dedicated photovoltaic fuses have to be designed and tested in accordance with the "gPV" standards for PV applications to ensure people's safety and



photovoltaic circuit protection.

Mersen: Safety & reliability for electrical power

At Mersen Safety & Reliability for Electrical Power, we integrate our product expertise into the customer's application to make it safe, reliable and profitable. Our product expertise includes:

- Overcurrent protection (fuses and fuse gear)
- Surge protection
- Cooling of power electronics
- Low voltage and high power switches
- Power transfer for rail vehicles

A trusted team member, Mersen invests early in the projects of customer with research and design support. Our experts offer experienced, attentive and responsive applications support in power low voltage distribution, power controls, power electronics and power transmission & distribution, from the initial design stage, through system implementation and to well after the sale.

We bring our expertise to you with products designed to meet your standards. Thousands of local sales representatives & distributors, around the globe, provide experienced and attentive customer service.

As a global partner, Mersen has an outstanding reputation for helping our customers do more, achieve more and grow more. At OEMs' in terms of increasing system lifetime, reducing costs and improving lead times, improving electrical performance and reliability, developing technical solutions that increase the competitiveness, increasing the global capacity and seizing opportunities in emerging markets. At after market in terms of reducing system downtime, protecting electrical systems, people and investment and improving electrical performance and reliability in energy, transportation, electronics, process industries and chemical/pharmaceutical markets.

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HVDC SYSTEM DESIGN IS QUEST FOR EFFICIENCY

By David G. Morrison, Editor, How2Power.com

Power converters rated in the hundreds or even thousands of megawatts. Overhead lines and undersea cables running as long as a couple thousand kilometers. Equipment operating lifetimes measured in decades. Billion dollar budgets.

Such figures suggest the enormous scale of high-voltage dc (HVDC) power transmission systems. Although conceptually this technology goes back many years, the pace of deployment has recently quickened and the projects have grown bigger as energy needs have grown.

HVDC technology started mainly as a means of transmitting power via undersea cables from power grids on the mainland to remote islands. This development is rooted in a basic limitation of using cables in ac power systems. At distances up to about 70 km, ac power transmission is feasible. However, once the cable runs become longer than that, losses grow to unacceptable levels due to charging of the cable capacitance. Since these losses are eliminated with dc power transmission, much longer cable lengths are possible.

Commercial HVDC projects connecting islands to the grid began as far back as the 1950s. Then, hydropower created another requirement for HVDC technology since power plants located on mountains were often great distances from their loads. More, recently the development of wind power has created demands for HVDC since windfarms, particularly those placed offshore requiring undersea cables, are frequently too far from the existing grid for ac power cables.

But not all applications of HVDC technology are in undersea cables. It's also being used to extend the reach of overhead lines, which employ bare conductors rather than insulated cables. Although ac power can be transmitted further across overhead lines than via cables, ac losses are still a distance-limiting factor. By reducing cable losses, HVDC systems extend the distances that can be spanned with overhead lines even beyond what can be achieved using another advanced technology called FACTS (flexible ac transmission systems.)

The caveat with HVDC power transmission is that it is generally point to point whereas ac systems allow power to be tapped off in multiple locations. However, at least one system has used HVDC technology to feed two grids from one source, and there is work being done to extend the use of HVDC power transmission in multi-point applications.

These trends illustrate the enabling role that HVDC power plays in the development of renewable energy. HVDC technology has yet another use in overcoming siting issues. For example, when new power lines are needed in densely populated areas, rather than facing the difficulties of obtaining permits for new overhead lines, utilities may opt to run subsea cables along a coastline.

Over time, all of these requirements for HVDC power transmission have expanded the opportunities for power electronics engineers within the typically large, global companies that manufacture power transmission equipment and execute turnkey solutions. These opportunities are expected to grow as the number of HVDC projects that are commissioned rises, and as application requirements become more challenging. As the HVDC deployments increase in scale (higher power levels transmitted across longer distances), and as demands for efficiency rise, the equipment manufacturers are likely to need more engineers to perform the necessary research and development, as well as to support the implementation of the HVDC systems.

To get a better sense of the HVDC design challenges encountered by power electronics engineers in the power equipment industry, I recently spoke with two executives from ABB, a company with a long history in this field.

Losses Are Key Design Driver

In many power electronics applications, the cost of the power converter weighs heavily on the minds of the power designer. But in HVDC systems, despite the substantial costs of the power converters (usually one at each end of the cable (or overhead line), the capital costs need to be viewed in conjunction with the energy costs associated with power losses.

"If we look at the calculations in most of these projects, one of the biggest items to consider is the losses multiplied by around 30 years," says Claes Rytoft, the global head of technology for the Power Systems Division of ABB. "Therefore, losses are a key factor impacting the competitiveness of an HVDC system design. So, the additional investment in the converters to minimize losses is more than offset by the savings in energy costs during the lifetime operation of the power transmission system."

To illustrate the point, Rytoft cites the example of an HVDC system ABB developed in China to transmit over 6700 megawatts of power from a hydropower plant in Xiangjiaba to Shanghai, a major load center 2000 km away. According to Rytoft, this distance represents the longest span of any HVDC system installed so far by ABB.

Rytoft estimates that in this system, the losses are less than 7%, and most of these losses are in the 2000-km transmission line. The power converters have efficiencies of 99% or better efficiency, says Rytoft. Even so, the need to optimize converter efficiency is paramount because, as Rytoft notes, "even 0.1 percentage difference in losses can have a big impact on 7000 MW over 30 years. So of course, it's very important for us to have very efficient converter topologies."

System availability is another key design requirement. In terms of the converter station, the customers allow that maintenance will be required on an annual basis. This essentially goes back to the issue of operating costs since downtime costs the utility money as does servicing the infrastructure.

The requirement for minimum downtime translates back to the power converter design, which includes power semiconductor modules connected serially to generate the hundreds of kilovolts needed on the converter output. "In the converter topology we have a design that allows for a short-circuit failure mode. We can continue to operate the converter even if we have a short circuit in the individual semiconductor package and thereby guarantee 12 months of operation between maintenance periods."

Although the size of the power converter is generally not a key design driver, the situation is different with offshore wind farms. "When we talk about offshore applications, size is important because that's a decisive factor for the design of the platform," says Rytoft. "It's a dedicated offshore platform for the converter. So if we can reduce the space or the weight, it has an impact."
To give a sense of scale here, consider an HVDC project in which ABB installed a 400-MW converter station on a platform 120 km out to sea. Dimensions for this converter are on the order of 30 by 50 meters, says Rytoft. Together with the required transformers, the converter occupies two stories on the platform.

To read more about how ABB addresses power electronics challenges in the development of HVDC systems, and about the job growth in this field, see "Advancing HVDC Technology" and "HVDC Creates Career Opportunities," in the online version of this article.

About the Author

David G. Morrison is the editor of How2Power.com, a site designed to speed your search for power supply design information. Morrison is also the editor of How2Power Today, a free monthly newsletter presenting design techniques for power conversion, new power components, and career opportunities in power electronics. Subscribe to the newsletter by visiting www.how2power.com/newsletters.

PV GOES GLOBAL

By Cliff Keys, Editorial Director & Editor-in-Chief, Power Systems Design

Despite a very weak start to the year, IMS Research has recently increased its forecast for the full year by more than 1 GW and predicts more than 22 GW of new PV capacity will be added in 2011.

IMS Research's latest Global PV Demand report, which analyses installations rather than registrations or connections in more than 60 downstream markets predicts that despite a weak Q1 and Q2, demand will grow rapidly in the second half of 2011 due to rapidly falling module prices, incoming incentives in new markets and planned end of year cuts in existing markets. Although installations grew just 13% in Q2 from Q1 the results of our latest report show that there will be a huge surge in installations in the second half of the year. Several mid-sized markets like the USA are growing massively whilst markets like Germany and Italy are starting to pick up too.

According to the new report, several European markets, including Germany are predicted for a major slowdown or even a fall in 2011. However, Europe overall will be only 1% down this year due to geographic diversification, with high demand coming from a number of new countries such as Slovakia and the UK. The report revealed that 11 countries in Europe will install at least 100 MW this year, with 20 countries globally installing this amount or more – up from just 13 the previous year. This increasing diversity in the market is helping to support demand and provide stability to a market that was once dependent for growth on just one or two countries.

It's important to remember that Europe will still account for close to 70% of global installations this year and in fact the next five largest markets are all European.

The market research firm is now also more optimistic about the mid-term future for the PV industry and has also raised its projections for 2012. Despite many still predicting doom and gloom, our latest research, which analysed more than 60 downstream markets and surveys hundreds of participants through the industry and supply chain, presents a very different picture. The decision by the Chinese Government to introduce a national FIT to boost flagging demand, as well as a diversifying global market and the introduction of new incentive schemes globally presents a much more optimistic, but still very challenging future for the industry.

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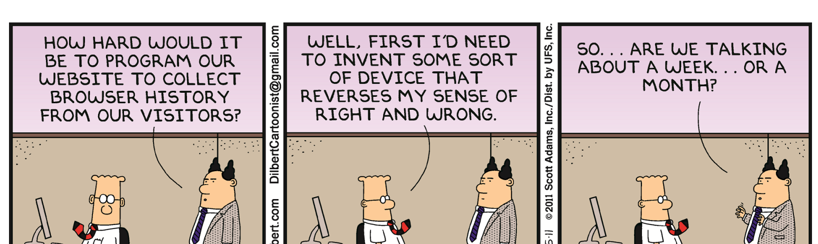
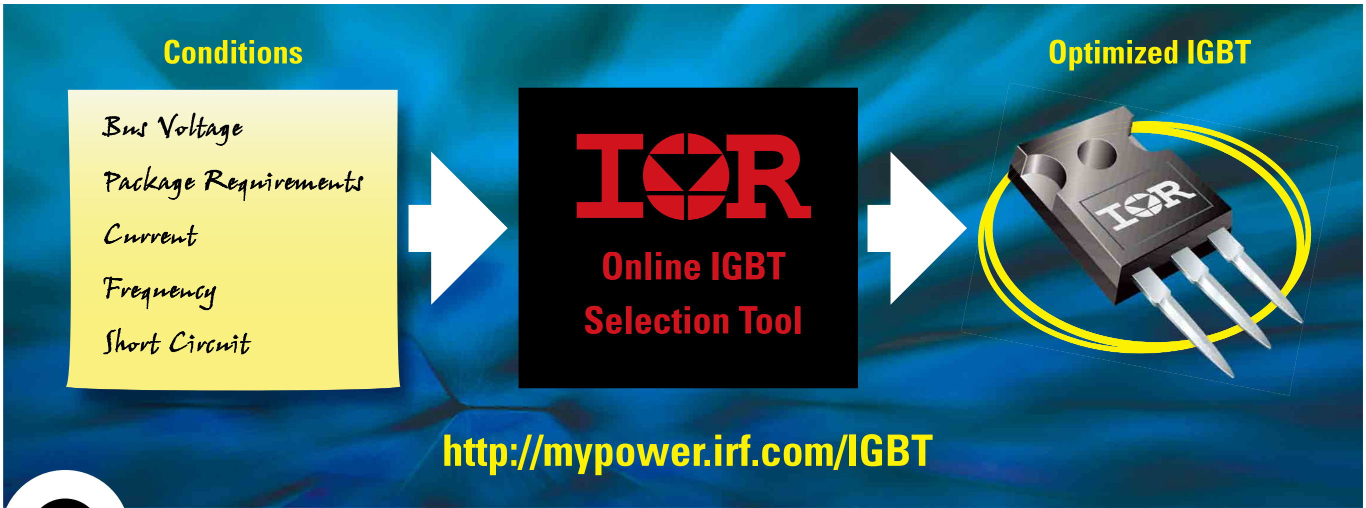
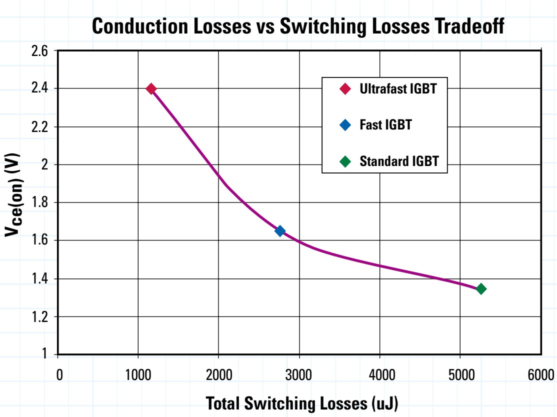
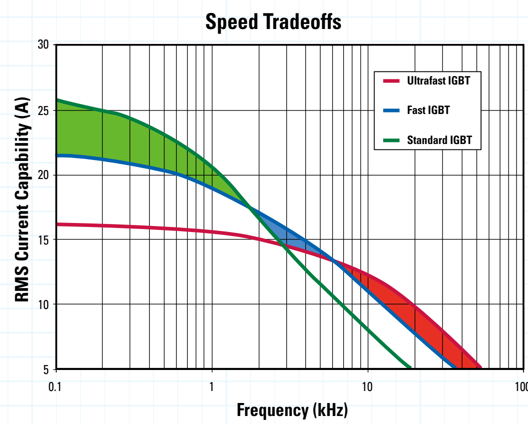
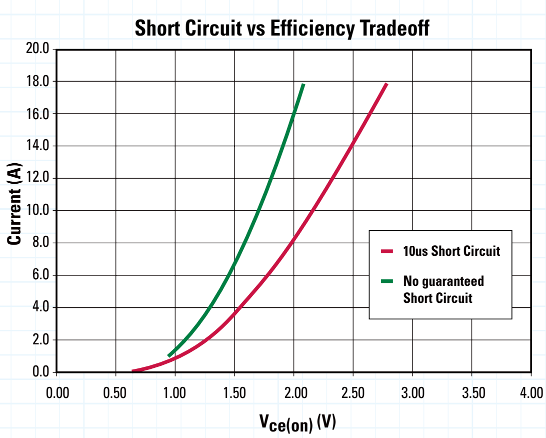




Simplify IGBT Selection with IR's Online Selection Tool







- Use application conditions
- Calculate conduction losses
- Calculate switching losses
- Provide MSRP to show cost implicactions of design choices

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