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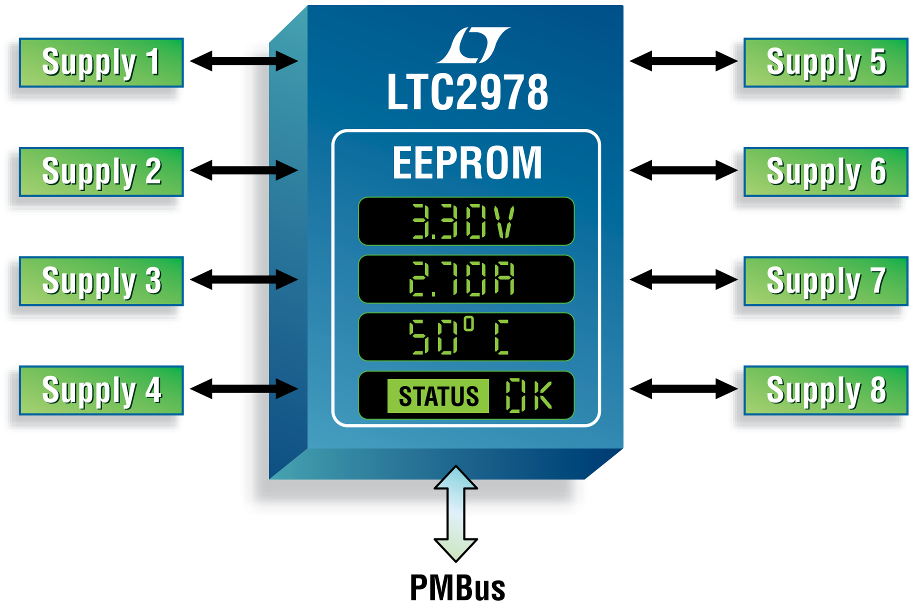

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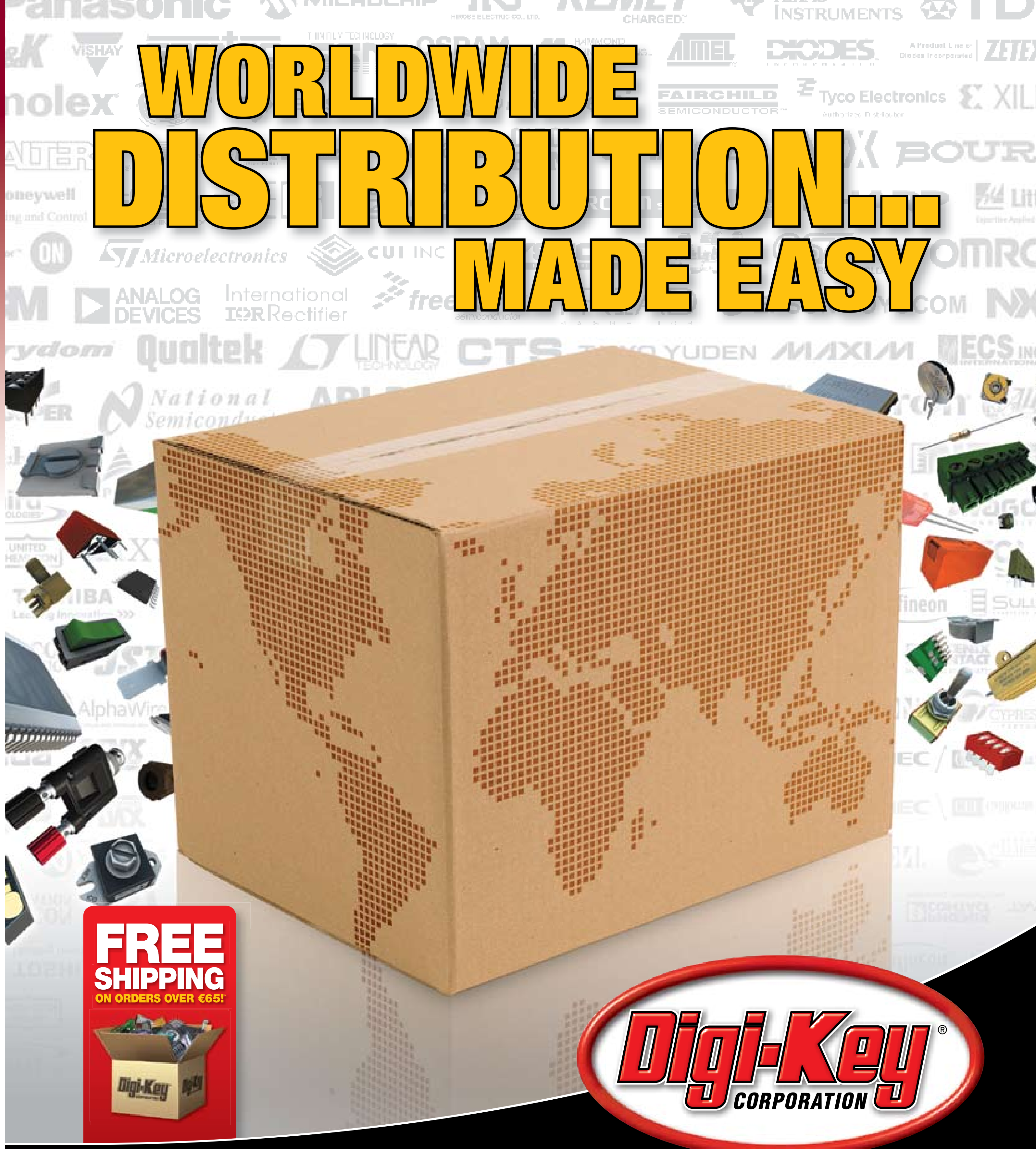

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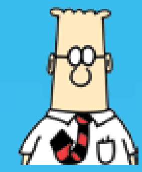

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PSDE Green Power
ENERGY EFFICIENCY

Engineering: The Crucial Component

Having returned from the hugely successful APEC power event in Palm Springs, California, I am still amazed by the number of companies that have been quietly innovating during the recession. It was heartening to see and hear about the new products and technologies about to hit the market. Engineering never sleeps, it seems, even when times are extremely tough.

This APEC was a very special time for us at Power Systems Design too. It was the first anniversary of the launch of our North American magazine (Power Systems Design North America). At the time we took the decision, it was a brave - if not seemingly foolhardy - move, given the financial climate. We did it at the request of the engineering community there. Since that time, we have found that engineers 'across the pond' have accepted it eagerly. Engineering is a truly global community with a hunger for good information.

Now, we have the European top power conference and exhibition, PCIM in Nuremberg, Germany which takes place May 4th – 6th. Looking at the list of conference participants and exhibitors, it promises to be another feast of innovation from the power industry. I would strongly recommend making a date in your diary to come along and see for yourself.

We shall be there participating too. In fact on Wednesday 5th May in Hall 12, Stand 377 for just an hour from 4pm – 5pm, I shall be running a lively forum with key companies on the topic of "**Designing for Energy Conservation and Performance**".

My thinking here is that in today's competitive environment, it's just not enough to design for merely saving energy. Power can be saved for sure, but maintaining peak performance at the same time takes a specialized approach. Customers continually insist on ever higher levels of performance and reliability in a wide range of applications. This is a tough call and requires a special approach to system design and to the components or modules selected. Do try to free up some time to join us all, I'm sure you'll not be disappointed.

I also had a wonderful opportunity to meet with the legendary Bob Dobkin, Vice President of engineering at Linear Technology - and a highly creative engineer - at the company's HQ in California. He gave me a briefing on his latest brainchild, the LT4180, a Virtual Remote Sense™ DC/DC controller that eliminates those cumbersome remote sense wires required to compensate for the voltage drop in cables, wires, and circuit board trace runs. It blew my mind and is reported in this issue.

I hope you enjoy this issue. Please keep the valuable feedback coming for my guidance and do check out our fun strip, Dilbert, at the back of the magazine.

All the best!

Cliff Keys.

Editor-in-Chief, PSDE
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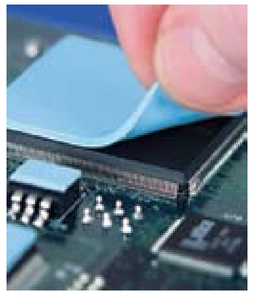

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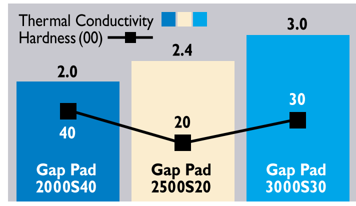

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Simplified Implementation of Vector-Controlled 3-Phase Motor Systems

In the appliance industry, getting products to market can mean the difference between success and failure. New technologies for motor control mean better efficiency and reduced noise and vibration, now becoming a key to the customer.

Toshiba Electronics Europe (TEE) is the European electronic components business of Toshiba Corporation, ranked among the world's largest semiconductor vendors with one of the industry's broadest IC and discrete product lines including development and prototyping of industrial and home appliance applications solutions

The company announced an evaluation kit for the development of embedded systems designed to control three-phase BLDC (brushless DC) motors commonly utilized in appliances.

Based on the company's TMPM370 family of ARM Cortex™-M3 microcontrollers, the kit will speed and simplify the design of motion control systems for pumps, fans, robotics, and other industrial and home appliance applications.

oshiba's new BMSKTOPASM370 Field Oriented Motor Control Kit – which has been developed in conjunction with hardware and software tool specialist Hitex Development Tools - comprises an evaluation board an in-circuit emulator (ICE), an 18V three-phase BLDC motor, a 24V power supply and a comprehensive package of software tools and documentation.

he kit's evaluation board is built around the TMPM370FYFG high-performance, low-power 32-bit microcontroller, which is based on an ARM Cortex-M3 core running at 80MHz. This device combines Toshiba's proprietary PMD3+ programmable motor driver technology, a vector engine (VE), 12-bit ADC functionality and a comprehensive set of peripherals and interfaces to provide accurate, hardware-based field oriented vector control of sensored and sensorless three-phase motors. All of the circuitry and interfaces needed for low voltage motor control are incorporated into the evaluation board, along with safety control functions and a small LCD for stand-alone evaluation.

The software package supplied with the kit includes source code, a board support package (BSP) and a PC-based graphical interface for the quick and easy configuration and control of low- and high-voltage motor control parameters. A Segger J-Link ARM Lite USB-driven JTAG emulator for Cortex-M3 cores further simplifies application development. Comprehensive documentation includes application notes, reference designs and bill of material (BoM) information.

www.toshiba-components.com

Next Challenge for Low Power Drives

By Alfred Hesener, Director Marketing & Applications Europe, Fairchild Semiconductor

It has become an undisputed truth that brushless DC motors see an ever-increasing use in low power drives, such as pumps, fans, or small motion control, as they should – the advantages (such as efficiency, size, features) are strongly outweighing the disadvantages (electronic controls needed). Motors with brushes like the example pictured here are facing extinction!

Engineers trying to implement this have been faced with some challenges. First of all, nobody wants to pay more – the expectations are such that the new features should effectively come for free. Looking at system cost level, a smaller motor (especially given current raw material prices) can compensate for higher electronics cost to some extent. Another challenge is the "traditional" way of implementing electronics, all on one PCB integrated with the host microcontroller, causing EMI issues and adding cabling complexity, since today in many cases sensors are used to detect the rotor position. Plus, the heat generation of the power electronics section (including a larger power supply) is at odds with the signal processing on the same board.

The next challenge for low power drives certainly is to put the smart power module controlling the motor into the motor itself, effectively turning a dumb mass of metal into a smart, agile part of the system that then can be controlled with digital signals effectively. Easier said than done, however – as can be seen from existing solutions on the market, integrating power electronics with a motor is a piece of engineering art, given today' s targets for power density, reliability, and performance.

The first issue clearly is centred around power density. BLDC motors are already smaller than their predecessors of the same power rating, so the electronics to be added into the motor must be small as well, while at the same time meeting creepage and clearance norms, with more high-power signals that need to be routed, and providing good thermals. And, a small motor used e.g. in a refrigerator will see many thermal cycles in its lifetime, so significant reliability aspects must be considered.

The second issue is centred around electromagnetic emissions. With 50Hz that was not a problem, but with modern switchmode electronics operating at 50kHz or higher (in the case of using MOSFETs for lower power drives), significant electromagnetic emissions are being generated. In many larger systems, like fans or pumps, this is not a big problem, since the motor case can also be used as a shield; these emissions can however cause malfunctions inside the system, forcing the designer to add larger design margins, particularly in the case of discrete solutions.

The design margins needed are leading directly to the third issue, achieving a good efficiency. There is no point in moving to a "fancier" motor in many cases if the efficiency that can be achieved is not good. And if larger margins on the power devices, input capacitor or gate drive circuit are needed to yield stable and dependable performance over a larger load and component variation range, resulting in lower efficiency, the cost of operating this motor increases, and that is in nobody's interest.

Using smart power modules in low power drives are a suitable way out of these three issues. Integrating the power devices with the driver circuits not only gives excellent alignment between the drivers and the switches (reducing the source of electromagnetic emissions, which are linked in many cases to fast switching), but also reduces the physical size (and hence the "antennae" for electromagnetic emission), and structures the high power and high voltage layout in a way that makes repeatability of the system performance much easier to achieve. This also helps to increase efficiency, by effectively controlling the power switches much tighter. Last but not least, a smart power module also removes a lot of the creepage and clearance issues from system design, since now many of these connections are internal to the module. And reliability is improved by testing all power devices contained in the module together, different to a discrete solution where the system FIT rate would correlate to the multiplied FIT rates of the individual components , a much higher value.

Going forward, I think we will see many more lower power motors using smart power modules, integrated into the motor housing, enabling the next level of applications of this type of motor with ease and improved time to market.

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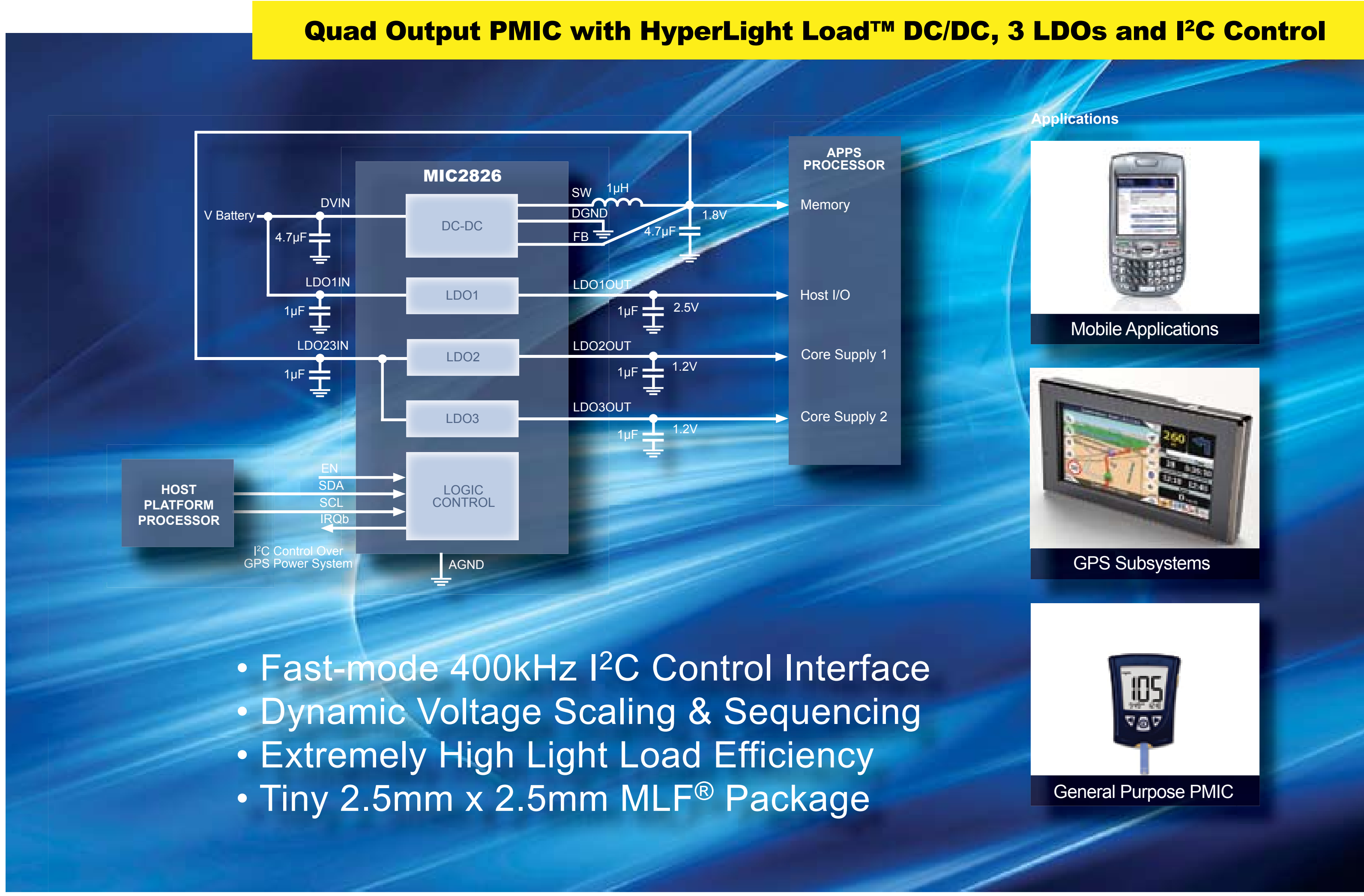
Advanced Portable System Power Management ICs



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A Smart Future for Major Home Appliances?

By Lisa Arrowsmith, Smart Home Market Analyst, IMS Research

Historically, networking in major home appliances has been mainly restricted to lifestyle and convenience applications in ultra high-end products for a niche target market. Examples include Bluetooth¬-enabled fridges that let you transfer photographs from camera-phones, or broadband-enabled appliances for web-surfing or recipe downloads. Remote diagnostics have also played a role in the inclusion of connectivity protocols in home appliances. However, these functions have failed to result in widespread consumer adoption of networked appliances. Appliance makers are betting that all this will change with the introduction of 'smart' appliances.

The term "smart appliance" refers to the ability of an appliance to respond to signals from utility companies (either via an AMI network or parallel broadband infrastructure), with the ultimate goal of reducing energy consumption during periods of peak demand – ideally with little disruption to the consumer. Some of the more sophisticated architectures being touted include fridges that delay the coil defrost cycle during periods of peak electricity demand, and clothes dryers that temporarily deactivate the heating element while retaining spin functionality upon request by utilities.

Two of the leading major home appliance manufacturers – GE and Whirlpool – are being particularly vocal about the launch of smart home appliances, although many of the other leading players are also either developing or trialling prototypes. Whirlpool announced last year that it will make all of its electronically controlled appliances capable of receiving and responding to signals from smart grids by 2015. However, this is dependant on a global standard for home appliance communications being defined by the end of this year. Whirlpool also assumes that purchase incentives will be offered to consumers or manufacturers.

GE has also made a lot of noise about its smart appliance trials and associated partnerships; the launch of a GE smart water heater; and subsequent announcements regarding the opening of a number of smart grid-enabled appliance factories in the coming years.

Tangible volumes of smart appliances could come as early as next year when Whirlpool promises to roll out 1 million smart clothes dryers. While consumers will pay a premium at first for this functionality (the size of which could depend on government incentive programs), once time-of-use pricing becomes more widely adopted consumers would reduce their energy bills.

What does this mean for component suppliers? Lack of interoperability standards and delays in implementing real-time electricity tariffs could dampen the lofty ambitions of Whirlpool and GE. Still, the introduction of smart appliances continues the trend towards more electronics in home appliances. Advanced motor and system control are now found in appliances of all types. To meet stricter energy efficiency standards and improve performance, appliance designers have incorporated inverter-based variable speed motor control into washing machines, dishwashers, refrigerators, and room air conditioners. Displays and system controls are increasingly using higher end microprocessors. IMS Research forecasts that revenues from 16- and 32-bit microcontrollers used in home appliances will more than double by 2014. Smart appliances have the potential to push growth in micros and other semiconductors even higher in the long term.

www.imsresearch.com

Power Supply Development Diary Part II

Introduction

This article continues the series in which Dr. Ridley documents the processes involved in getting a power supply from the initial design to the full-power prototype. In part II, we focus on the interface between the power stage and controller, and getting the gate drive working properly.

Power Supply Development Testing

The results of initial testing are shown in this article for a two-switch forward converter. This was a project for which the initial prototype breadboard was complete, and it was time to apply control and power signals. As mentioned in the first article of this series, there were a total of 85 process steps involved in moving the power supply from the original non-working condition to a full power board. It would take too many articles to present every detail of each of these steps, so I will focus on the events which I have observed many times before in the industry.

Power Supply Requirements

The specification for the power supply was as follows:

1. Output 1 – 35 VDC @ 10A isolated
2. Output 2 – 35 VDC @ 10 A isolated
3. Maximum power 350 W (only one output fully loaded at a time, application is for audio.)
4. Input – 180 – 265 AC
5. Power Topology: Two-switch forward
6. Controller: Digital controller from TI Power Stage and Control Interface Schematic

The full schematic of the power stage is shown in Figure 1, together with the signals for interfacing with the control circuit. The power stage was completely separated from the control so that each could be worked on individually, and layouts for each were independent. This is crucial for a digital power supply controller which needs fine-pitch layout versus the heavy copper suitable for the power stage.

It is quite common to find errors in either circuit that can require a new layout – keeping the power and control separate can greatly speed up the development process. For early testing, it is often a good idea to provide a connector between the two, with two separate boards.

For high power work, using either digital or analog controllers, it is best to have only one ground connection between the control circuit and the power circuit. There should be no overlap of ground planes in order to prevent power currents from flowing near the control parts. A single point ground should be established between the two parts of the circuit.

The drive for the gate of an offline power supply should be galvanically isolated for both of the power FETs using a gate drive transformer as shown in Figure 1. This is much better than using an integrated high-side driver. A gate drive transformer has the advantage of providing negative gate voltage during the off-time which provides superior noise immunity from accidental turn on of the FET. A gate drive transformer is also much better during the development phase when power stage failures are likely to occur. If the high-voltage power FET is destroyed, the damage is usually limited to the secondary of the gate drive transformer, and the control circuit is left intact. This is crucial for finding the root cause of failures.

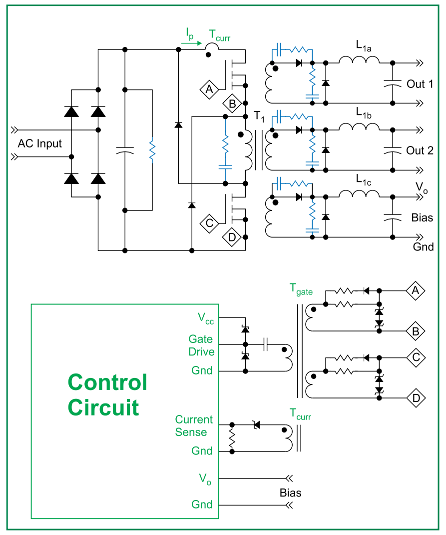

Figure 1: Power Stage and Control Interface Schematic

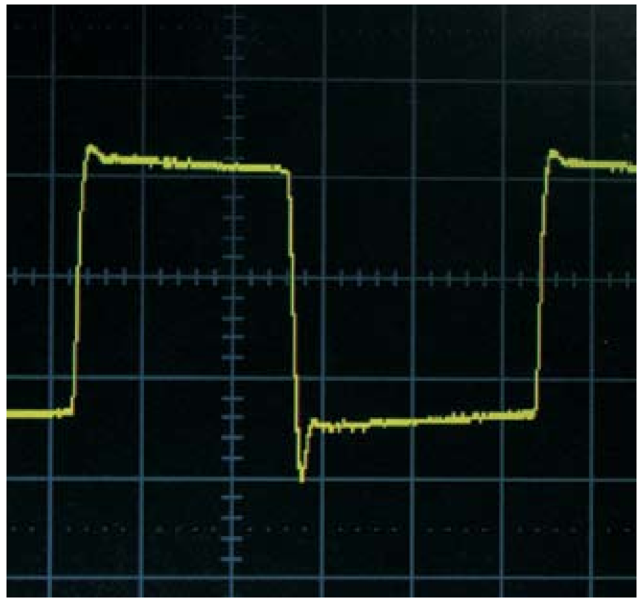

Figure 2: Gate Drive Waveforms with Damaged Gate

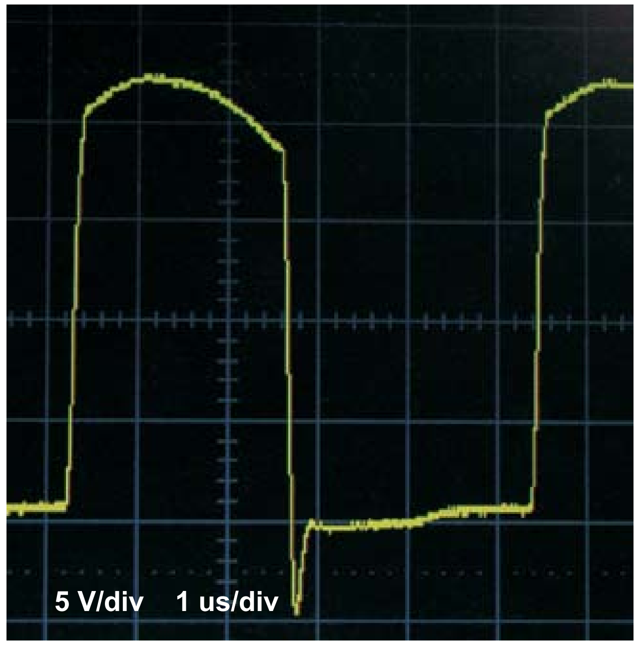

Figure 3: Normal Gate Drive Waveforms

The current-sense network is also galvanically isolated. The current transformer network shown provides the cleanest signal for current sensing, and its wide bandwidth allows for protection of the power devices as we shall see later.

Event #1 Bypass Capacitors

The first problem encountered was that the digital controller simply did not work properly when hooked to the gate driver. The issue was tracked down to the lack of a bypass capacitor in the proper place for the gate-drive chip. The need for this was documented in the data sheet, but deeply buried in other information.

If you haven’ t worked in power supply design before, adding bypass capacitors next to your integrated circuits is often just a formality. Quite often, they can be removed without any detrimental effect. However, they are crucial elements of power supply control circuits, especially when power FETs must be driven. Placement of all bypass capacitors for gate-drive outputs, clocks, references, and supply voltages must be very tight to the integrated circuits.

he lack of a gate-drive bypass capacitor also highlighted the difference in thinking of digital and analog engineers. The digital engineer’s immediate response to the oversight was to make another board before proceeding. The approach from most analog engineers would be to add a bypass capacitor next to the chip with two lengths of hookup wire and move on to the next test. Experienced power designers know there will be many such issues, and it is best to collect as many changes as possible and rework the PCB when the changes become unmanageable.

Event #2 Gate Drive Overheating

Once the bypass capacitors were properly placed, gate-drive waveforms at 200 kHz were obtained from the control chip. However, both the gate driver and the lower power FET overheated significantly, even with no power applied to the input of the power stage. The FETs were able to switch a resistive load, but something was not working properly.

This led to another significant conclusion for me. An overheated and destroyed gate driver for a digital controller is a substantial repair problem. The high density drivers have pads on the bottom which, when surface mounted, remove the heat very effectively. However, this prevents you from mounting the driver in a socket. After many years experience in designing offline converters, you learn that failures of the control chip and the gate-drive chip are common events. When trying to track down failure mechanisms, it is not uncommon to burn through many chips in a day. If they have to be unsoldered, this can be a very tedious process, severely impacting development time.

At this point, the digital controller part of the project was put on hold. Clearly, it did not make sense to continue debugging the power stage at the same time as working with a digital controller. An analog control board from a previous project was substituted for the digital control to allow testing to continue. The clearly delineated separation of the control and power stage made this substation straightforward.

Only one of the FETs was hot with the gate drive applied. The waveforms on this FET are shown in Figure 2. There was a significant drop in the predicted voltage, but the waveform still looked reasonable if you are not familiar with normal FET operation.

One indication that something is not right is that the waveform is very square. Upon being desoldered from the power board, the gate-to-source resistance was measured at 27 ohms when it should be an open circuit. The gate may have been damaged by static when handling or mounting to the board, or it may have been damaged upon arrival. It could also have happened when the power board and controller were connected together.

Notice the use of back-to-back zeners across the FETs. These were added after the failure was found, a normal precaution for offline converters. Figure 3 shows the proper gate waveforms after the FET was replaced. Notice the higher amplitude, and the curve of the top of the waveform. This is characteristic of the gate drive scheme chosen.

Event #3 Driving Inductive Loads

The digital controller was replaced with a 3825 controller, one of the most rugged chips on the market. This is a good choice of controller to use to debug a power stage. In order to test the initial operation, the controller from another power supply design was used with wires jumping between the two boards. This allowed testing to rapidly continue without designing a special board.

The initial operation, however, was very unpredictable, with very narrow or missing gate pulses from the controller when connected to the transformer. This was due to a second common problem. Most bipolar technology control chips cannot provide the reactive current needed by a gate-drive transformer. The solution to the problem is shown in Figure 1 – schottky diodes must be added at the output of the gate signal to supply the reactive part of the current.

Other Early Mistakes

When hooking up the power stage with a substitute controller, several other mistakes were made.

#4.The supply voltage Vcc was mistakenly applied to the output of the controller. The 3825 had to be replaced.

#5.An auxiliary ramp summing circuit for current-mode control was applying a negative voltage to the current sense input. Nothing works according to the datasheet if you do this. This is a more common occurrence than you might think when hooking up low-voltage control circuits to high-voltage power stages.

The first of these mistakes was made after trying to achieve too much in one day. Working on power supplies requires a clear and fresh mind to avoid mistakes. In this case, it was easy to fix the controller since it was in a DIP socket. When power is being applied, though, working while tired can be dangerous, destructive, and often very time-consuming.

Summary

The first phase of this project showed up numerous errors and failures that are difficult to predict and anticipate. This is normal in power supply development, and such events must be budgeted in the schedule. If you are a manager, pushing your engineers to work harder and longer hours is not the path to better results. The development and testing of a power supply must be a deliberate and methodical process with sufficient time allocated to work efficiently with a clear head.

Switching to an analog controller during the debugging process was clearly a necessary step to get the power stage operating properly. This eliminated unknowns of a very complicated component, and made replacement after failures fast and straightforward.

In the next phase of this article, power is applied and the process of debugging continues.

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ON THE ROAD

On the Road

Reported by Cliff Keys, Editor-in-Chief, PSDE

Linear's Latest Masterpiece

I had the privilege of meeting with Bob Dobkin, Vice President of engineering at Linear at the company's HQ in California. He gave me a briefing on his latest brainchild, the LT4180, a Virtual Remote Sense™ DC/DC controller that eliminates the remote sense wires required to compensate for the voltage drop in cables, wires, and circuit board trace runs.

Virtual remote sense controller eliminates remote sense wires

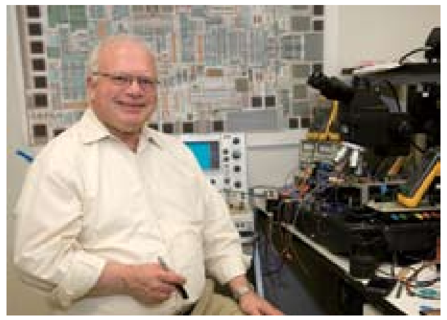
Voltage drops in wiring and cables that cause load regulation errors are usually corrected by an additional set of sensing wires. Bob had the idea that if he could remove the need for these cumbersome sense wires, it would not only greatly simplify system design, for instance where long and complex cable runs are required, but also it would also considerably save cost and increase reliability. Of course, actually achieving it would take much 'out of the box' lateral thinking. But Linear is world famous and universally envied for just this.

The voltage drops in wiring and cables can cause considerable load regulation errors in electrical systems. As the load current increases, the voltage drop (IR losses) in the wiring increases (due to the line impedance) and the voltage delivered to the system drops. The traditional and almost universally adopted approach to solving this problem is to sense the output voltage with a pair of wires that run from the regulator's feedback network to the load. While this approach works well, the installation of an additional pair of wires is certainly not practical or conducive to system high reliability. As is universally accepted, more connections mean greater opportunity for failure.

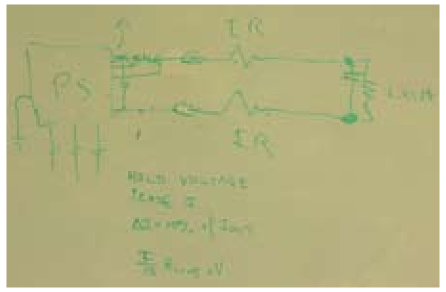
Bob's innovative skills are legendary. It was certainly not an overnight transition from the original idea to practical concept. Bob told me he had wrestled with this for a considerable time and like every good engineer's design, the principle looks simple to the casual observer. But as every engineer knows, the transforming of the initial idea into a credible working product with real solid specifications and rock-solid reliable performance is no easy task.

The LT4180 virtual remote sense (VRS) controller is a new and revolutionary way of eliminating the need for these extra sense wires to compensate for the IR losses in wiring and cables. This device continuously interrogates the line impedance, which may not be constant - as experienced in the real world - and automatically corrects the power supply output voltage to maintain a steady voltage right where it's needed: at the load, regardless of current or even line changes.

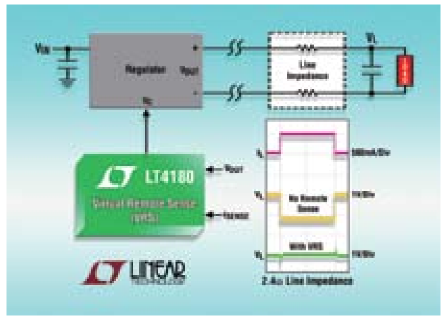
VRS works with a small modulation on the output of the regulator to accurately compute the correction. This modulation is filtered by the output capacitor at the load. The LT4180 works with any conversion topology and isolated or non-isolated power supplies, DC/DC converter including bricks, modules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



Bob Dobkin, Linear's Vice President of Engineering at work



This is how Bob initially enlightened me to the concept



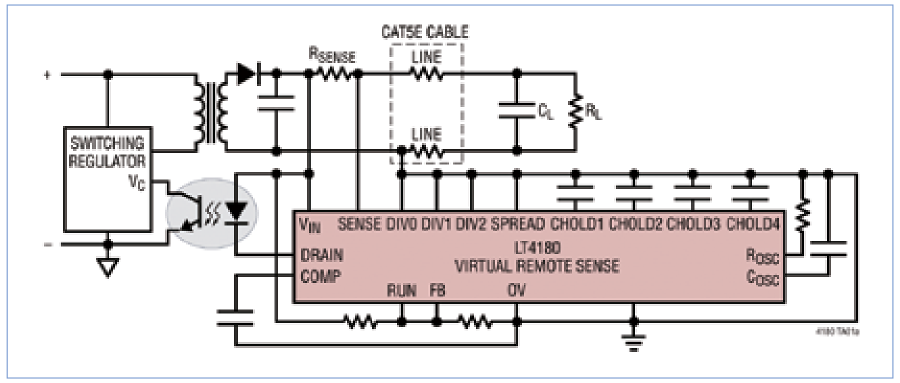
Simplified Virtual Remote Sense Controller

The 3V to 50V input voltage range addresses a wide variety of applications, including remote instrumentation, battery charging, wall adaptors, notebook power, battery charging, surveillance equipment and halogen lighting.

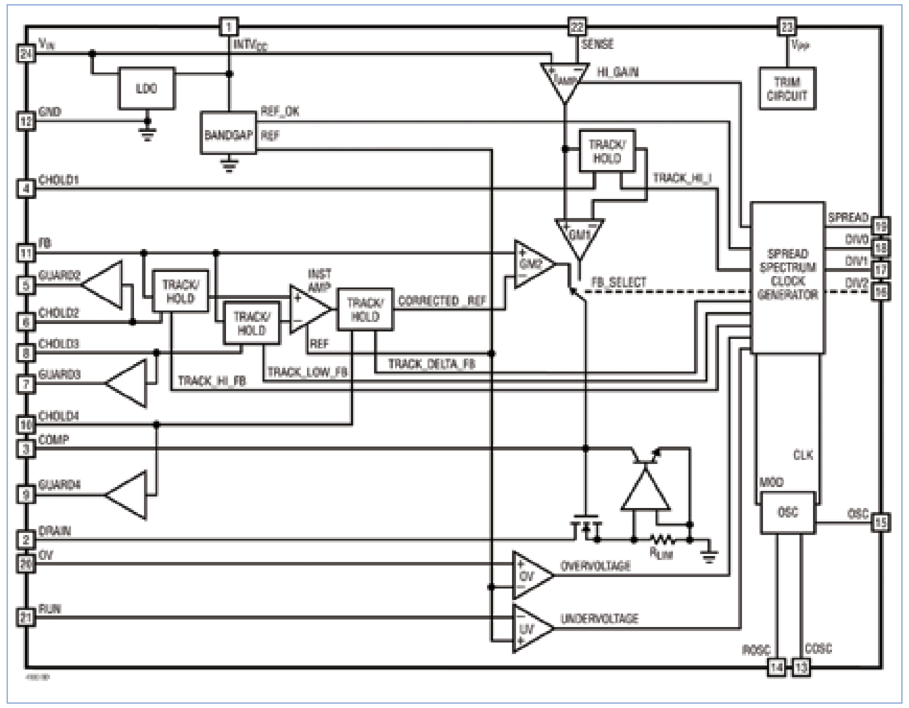
As mentioned earlier, the LT4180 operates with any topology regulator in either isolated or non-isolated power supplies. The output correction is obtained by modulating the output and measuring the incremental change in voltage that occurs with a change in current. The other great benefit which adds to the simplicity is that no specialized filtering is necessary because any modulation noise is elegantly and simply eliminated by the supply bypass capacitor located at the load. Additionally, the capacitor itself does not need to be a specialized or expensive high-performance part.

According to Bob, "The LT4180 provides a completely new function to power supply designers. Excellent regulation is obtained without sense wires, eliminating the need for point-of-load regulators. Difficult regulation problems such as long wire runs or system retrofits can be easily accommodated. For example, with halogen lights, the light output drops more quickly than power, so keeping the correct voltage more than compensates for any additional cost of the power supply."

As with all of Linear's products, full, unambiguous and accurate information is provided. This has over years built the reputation and credibility that the company enjoys today. The LT4180 is no exception to this philosophy and here we show a great deal of detail that is relevant to the discerning engineer.



Typical Application of Isolated Power Supply with Virtual Remote Sense



LT4180 Block Diagram

Bob Dobkin is the prime example of what I often refer to in editorial comment as a talented, creative and tenacious engineer. The ability to think sideways and sometimes turn normal thinking and tradition on its head is what makes a design great. He has without doubt achieved this for Linear with the LT4180.

ABSOLUTE MAXIMUM RATINGS
(Note 1)

V_{IN}	–0.3V to 52V
SENSE	V_{IN} – 0.3V to V_{IN}
INTVCC, RUN, FB, OV, ROSC, OSC, DIV0, DIV1, DIV2, SPREAD, CHOLD1, CHOLD2, CHOLD3, CHOLD4, DRAIN, COMP, GUARD2, GUARD3, GUARD4, V_{PP}	–0.3V to 5.5V
V_{IN} Pin Current	10mA
INTVCC Pin Current	–10mA
COSC Pin Current	3.3mA
Maximum Junction Temperature	125°C
Operating Junction Temperature Range (Note 2)	
E-, I-Grades	–40°C to 125°C
MP-Grade	–55°C to 125°C
Storage Temperature Range	–65°C to 125°C

Linear's Specifications are always credible and real

Here follows Linear's brief performance summary

- Tight Load Regulation without Remote Sense Wires
- Compatible with Isolated & Non-Isolated Power Supplies
- Works with any Topology
- VIN Range from 3V to 50V
- Ability to Drive Opto-Coupler
- Low Turn-On Transients
- Undervoltage & Overvoltage Protection
- Spread Spectrum Modulation Dither
- +/-1% Internal Reference Voltage Over Temperature
- SSOP-24 Package

Three temperature grades are available: an extended grade version from -40 to 85°C, an industrial grade version from -40°C to 125°C, and a military grade option from -55°C to 125°C. The 1,000-piece price starts at $2.95 each. The LT4180 is offered in an SSOP-24 package. All versions are available from stock.

www.linear.com

Dialog Semiconductor Excels Again

Unveils new class of ultra-efficient configurable system power management & audio ICs

Highly featured power management and audio device with complementary Class D speaker driver – combines efficiency with outstanding performance for battery-powered devices

Reported by Cliff Keys, Editor-in-Chief, PSDE

Dialog Semiconductor plc a leading provider of high performance power management and audio semiconductor solutions, has announced its second generation of system level power management ICs, which now include an integrated class G codec.

Called the DA9057, the device's five on-board dc/dc converters optimally support 24bit stereo audio headphone playback on a 5mW power budget. This further extends battery life for music-enabled devices.

The DA9057 combines the industry's most flexible power sequencer with a fully programmable filter/mixer engine to support a wide variety of ARM-based multimedia processors.

Its power handling capability is maximised by the integration of a dual-input switching USB power manager/Li-ion battery charger plus five programmable dc/dc converters. This architecture increases the current available to a system, enables 'instant on' operation and allows handsets to run cooler with less time spent charging.

A dedicated programming graphical user interface empowers OEMs to easily optimise a system's power sequencing requirements; even when additional functionality is added late in the design cycle.

The DA9057's integrated true-ground Class G headphone driver is up to 70 per cent more efficient than a standard Class AB amplifier.

In addition, a standalone filterless Class D speaker driver has also been introduced. The DA7201 is a 3W mono audio power amplifier capable of driving 4ohm speaker loads. The component is typically twice as efficient and has a smaller footprint than its Class AB equivalent.

Designed to interface directly to the DA9057's differential line outputs, its tiny 1.5mm2 footprint allows placement close to the speaker, delivering a peak efficiency greater than 90 per cent, and reduces heat build-up in portable applications with embedded mono or stereo speakers. Both the DA9057 and DA7201 allow direct battery connection.

"Handheld mobile internet devices,such as smartphones, are becoming ever more powerful and the pressure to free board space, manage power budgets and heat build-up within the product casing have become our customers biggest concern" explained Mark Jacob, Dialog's director of marketing for audio & power management. "We've responded by carefully combining the most power-efficient technologies at higher levels of integration and delivered a highly compact yet flexible mixed signal solution for this burgeoning market," added Jacob.

Other functions integrated on DA9057 include a programmable LED backlight driver, backup coin-cell charger, touch-screen interface, voiceband codec with sidetone, ALC (automatic level control), general purpose filter engine and 5-band equaliser.

Engineering samples of the DA9057 are available now in a 7x7mm BGA 169 package. Engineering samples of the DA7201 will be available from April in a wafer level CSP 9 package. Volume production delivery for both devices will begin in Q4 of 2010.

www.dialog-semiconductor.com

PSDE Green Power ENERGY EFFICIENCY

Cool Power from Danfoss

Direct liquid cooled power modules in converter solutions

Modern wind turbines are being designed for a lifetime of 15-20 years. In the special case of wind power, the turbines are expected to run 24 hours a day, 365 days a year when the wind allows. This corresponds to 150-180.000 hours of service which again is 10-20 times the lifetime expectancy for typical automotive applications and 3-5 times the expectancy in Industrial Applications.

By Klaus Olesen, R&D, Danfoss, Schleswig, Germany

To secure sufficient reliability over the expected life of any such critical system, calls for an in depth understanding of the relevant failure mechanisms and mission profiles of the specific application.

Today's major converter systems can from a power-cycle point of view be boiled down to three basic topologies: Doubly Fed Induction Generator (DFIG), Full Conversion with Gear (FC) and without gear known as Direct Drive (DD).

The different topologies are characteristic by the dominating frequency regimes they are operating at. The Grid side again differs as it is operating at rated frequency.

Further, the different topologies depending on control strategies and generator design will result in different sharing between diodes and IGBTs and thereby influence the resulting fatigue effects. The dominant failure mechanism in power modules for wind applications for example, is related to active power cycling of the power semiconductors occurring during operation.

Depending on the converter topology chosen this active power cycling will result in temperature swings of the wirebond - Silicon interface; put simply the size of the temperature swings as well as the absolute temperature levels determine the life time of the power module.

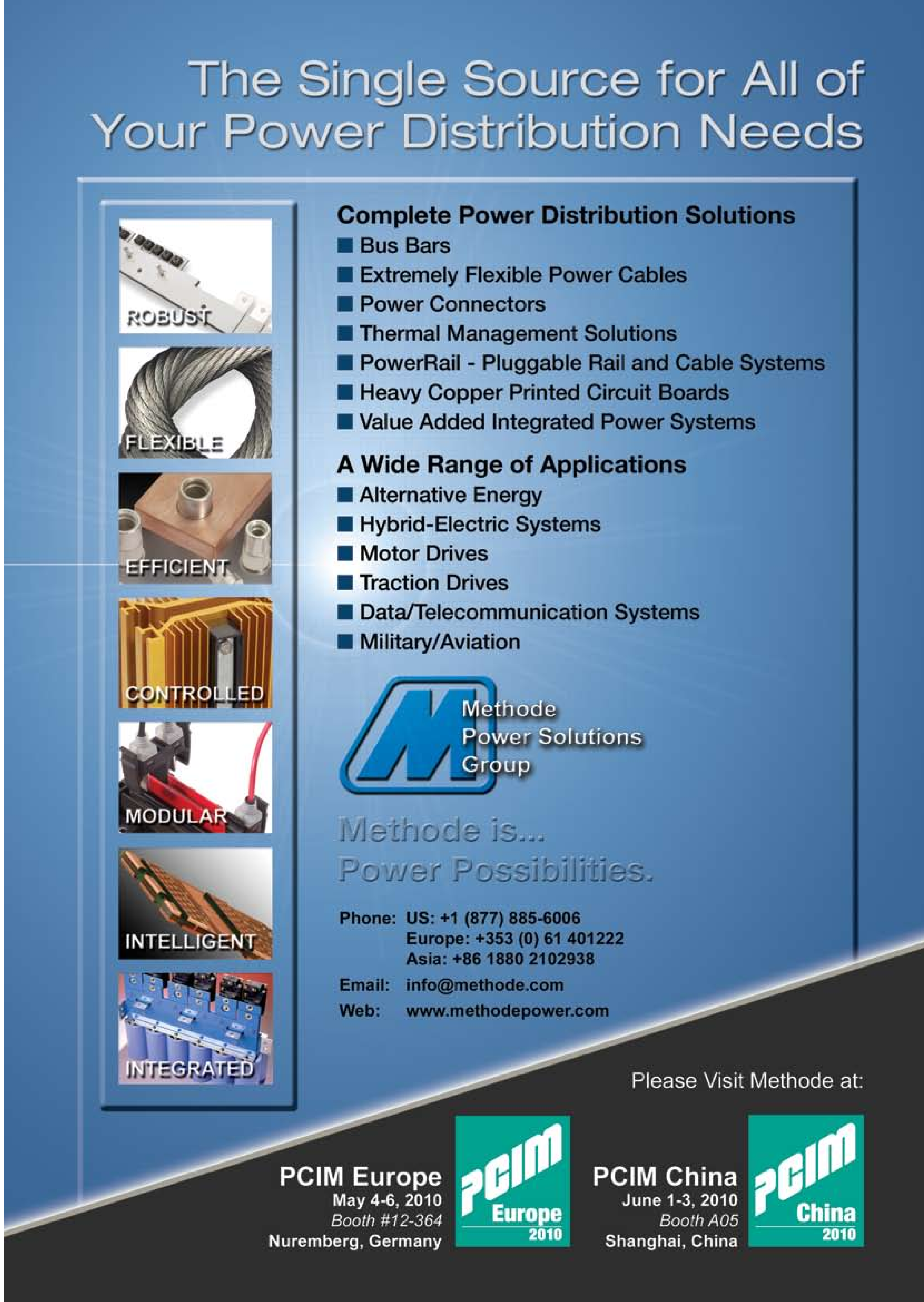
Since the number of temperature cycles seen in wind applications is several orders of magnitude larger than typical seen in industrial- or automotive (e.g. HEVs) power modules it is obvious that an extremely highly efficient cooling of the power modules is needed.

ShowerPower® is a direct liquid cooling concept that ensures homogenous and highly effective cooling across large power modules and of systems of large power modules.

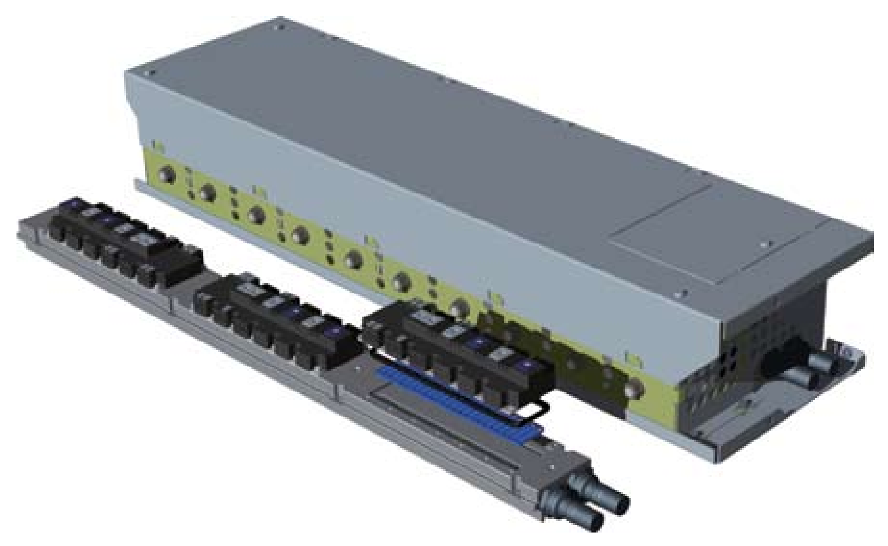
Liquid cooling of power electronics has been around for many years, in some segments more than others. The acceptance for applying liquid cooling varies from business segment to business segment: the automotive industry for example has always used liquid cooling for cooling the combustion engines so the idea of cooling power electronics in an automotive application is not at all un-nerving for these design engineers. In other segments, however, the idea of having water flowing through power electronic assemblies can be disturbing.

The largest obstacle for applying liquid cooling has, in the past, been the high cost and the limitations in performance that confines the usability to more exotic applications where no alternative exists. These limitations being large temperature gradients across the cooling areas and high pressure drops in the coolers that make large/expensive pump systems necessary. Here, the concept from Danfoss for applying liquid cooling is described, combining high performance, very low

Cooling technology is the vital component in power systems



cost and ease of implementation even in thermo-mechanical assemblies with complex geometries.



A power stack based on three P3 modules, the power modules assembly is shown beside the stack

Liquid cooling – still state of the art

Basically two types of liquid coolers exist: Closed coolers, where devices to be cooled are assembled in a dry fashion eliminating the problems associated with spillage of coolant, and open coolers, where the devices to be cooled are assembled on a so-called "bathtub" through which the coolant flows and cools the backside of the device.

Closed coolers - cold plates

Cold plates are often aluminium plates, extruded or machined, and some of them have copper tubes inserted in grooves in the plate. Other versions consist of two metal parts, machined or extruded, that are joined together (normally using welding or active brazing) and the coolant is then guided through channels defined between the two parts.

The first improvement by going the direct liquid cooled route is the elimination of the thermal interface material (TIM) which is responsible for 30-50% of the thermal resistance between junction and coolant. Secondly the inherent reliability problems related to pump-out and dry-out effects of TIMs are gone. Thirdly ShowerPower® enables cooling of standard power modules with flat base plates thus allowing dual sourcing of the power modules, an increasing prerequisite in the wind industry.

Direct liquid cooling of the power modules using ShowerPower® enables more compact, lightweight and cost effective designs compared to traditional cold-plate based solutions, partly due to the higher level of design freedom given to the designer.

As an example, ShowerPower® has been demonstrated to reduce the number of power modules in modern wind turbines converters by up to 50% compared to traditional cold plate solutions. This is due to the improvement in thermal performance over the cold plate.

Temperature gradients

All liquid coolers suffer from the inherent problem of cooling, where the heating of the coolant is reflected back into the power device resulting in a temperature gradient.

The other major drawback of these coolers has been the high cost. Cold plates are still expensive due to the precise machining operations in the manufacturing process while the traditional pin fin coolers also feature high manufacturing costs; a typical pin fin baseplate can cost five times more than the standard flat baseplate.

ShowerPower® – the solution

As previously discussed traditional liquid cooling systems all feature a liquid flow along the surface to be cooled, this will always create temperature gradients in the surfaces to be cooled because the liquid is heated up and this temperature difference is reflected back into the power device.

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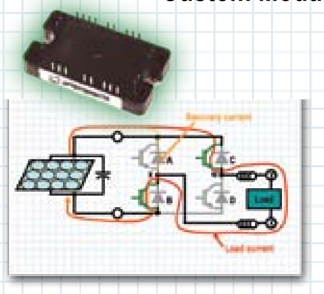

	Part Number	Voltage	Amps
SP3	APTGV30H60T3G	600V	30A
	APTGV50H60T3G	600V	50A
	APTGV75H60T3G	600V	75A
	APTGV100H60T3G	600V	100A
	APTGV15H120T3G	1200V	15A
	APTGV25H120T3G	1200V	25A
	APTGV50H120T3G	1200V	50A
SP4	APTGV50H60BG	600V	50A
	APTGV25H120BG	1200V	25A
SP6-P	APTGV100H60BTPG	600V	100A
	APTGV50H120BTPG	1200V	50A

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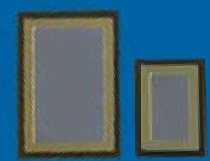

CREE 1700V SILICON CARBIDE JUNCTION BARRIER SCHOTTKY DIODES

PART NUMBER	I_f (A)	V_f (V) TYPICAL	I_R (µA) TYPICAL	Q_c (nC) TYPICAL	T_J (°C) MAX
CPW3-1700S010B	10	1.8 @ 25°C 3.2 @ 175°C	10 @ 25°C 20 @ 175°C	80	175
CPW3-1700S025B	25	1.8 @ 25°C 3.2 @ 175°C	25 @ 25°C 50 @ 175°C	210	175

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Concept

The original idea was to cool perpendicularly to the surface to be cooled, thus the name ShowerPower, but in contrast to existing spraying or jet impingement systems the idea is to get rid of the coolant before it starts creating large temperature gradients along large portions of the device to be cooled where a number of nozzles guide the coolant to the surface to be cooled and a corresponding number of outlet nozzles lead the coolant away before the coolant has travelled large distances on the cooling surface.

The inlet nozzles are supplied from an inlet manifold situated between the two plates and the outlet nozzles are connected to an outlet manifold situated between the bottom plate and the bottom of the bathtub. Inlet and outlet manifolds are connected to the main inlet and outlet connectors of the bathtub. In this way parallel cooling is achieved and identical cooling is achieved everywhere on the surface to be cooled.

The next step in the design has been to simplify the structure of the plastic parts. The double-plate design discussed until now demands at least two plastic parts, which are to be joined, but it is possible to realise the functionality using one plastic part only. The inlet- and outlet manifolds are now interlaced instead of sandwiched, see the figure below.

The areas to be cooled can be of any size and shape. Non-planar geometries and surfaces are easily realized. Tailored cooling is also possible, i.e. if a specific hot spot needs extra attention in a power module, the nozzles are simply tailored in order to cool more effectively locally.

Comparing the thermal step response curves (heating curves) shows why the two cooling solutions perform differently: The two curves are almost identical until roughly one second indicating that for shorter temperature swings the sizes of the swings will be the same (only dependant on the internal thermal capacity of the module), but the average temperature where the swings occur will be much higher for the cold plate because of the much higher steady state thermal resistance for the cold plate. For cycles with periods longer than one second the size of the temperature swing too will be larger for the cold plate. Therefore a coldplate solution requires much more silicon in order to offer the same power cycle capability as direct cooling with ShowerPower®.

Examples of Danfoss power stacks are shown below. Both stack designs are based on the P3, 1700A/1000V, module placed on a ShowerPower® cooler.

The earlier example features three P3 modules placed in a row, here the power module assembly is shown in the foreground; the other example shows a setup having seven P3 modules.

The heat transfer coefficient, or convection coefficient, which is a measure of the cooling efficiency (the higher the better) as function of volume flow-rate (ethylene-glycol/water 50%/50%). The ShowerPower cooler is proven to be the same or even more effective than the pin fin cooler.

The homogeneity of the cooler means all the cells will have the same pressure drop. Additionally, the inlet-outlet manifolds have the same pressure throughout their volumes, thus the hydrothermal performance is indeed homogenous across the whole of the cooling area.

The homogeneity of the ShowerPower cooler has been compared with that of the standard pin fin cooler using thermography. A significant temperature gradient was observed in the pin fin case, whereas there was no detectable gradient in the ShowerPower case

Tailored cooling - eliminating hot spots

As mentioned, it is easy to adapt to special cooling demands e.g. if a power module has components that run especially hot. As a special case of the tailored cooling it is straightforward to cool only at the component positions. In an experiment with a power the temperature gradient across one of the IGBTs was 20K when cooling underneath the whole substrate area.

The RthJA was 0,26K/W. By localizing the cooling the temperature gradient across the chip is reduced to 2K, the trade off was that the RthJA is increased 50% to 0,38K/W.

Optimizing the cooler

Several approaches have been investigated in the quest for improving the performance of the ShowerPower cooling principle to improve thermal performance without increasing the pressure drop. One approach was to introduce small by-pass gaps between the walls of the meandering channels and the baseplate of the power module, allowing fluid flow over the top of the walls of the meander cells.

The result was that the pressure drop was reduced; this was expected since some of the fluid had to travel a shorter distance through the cooler. Another effect though, was more surprising: by introducing the small gap of 0,25mm the thermal performance improved 25-30%. Overall, the effect was extremely positive and improved thermal performance at a lower pressure drop.

Summary

Due to the homogeneity of the cooling all the IGBT chips inside the modules will have the same junction temperature (and all the diodes will have the same temperature), this eliminates the critical lifetime-limiting hot spots, and facilitates the paralleling of the many individual chips. The compact cooler opens up for larger design freedom in the power train to fit the needs of the individual application. ShowerPower from Danfoss is the key to reliability and longevity in the vital high power systems upon which our community is becoming increasingly dependent.

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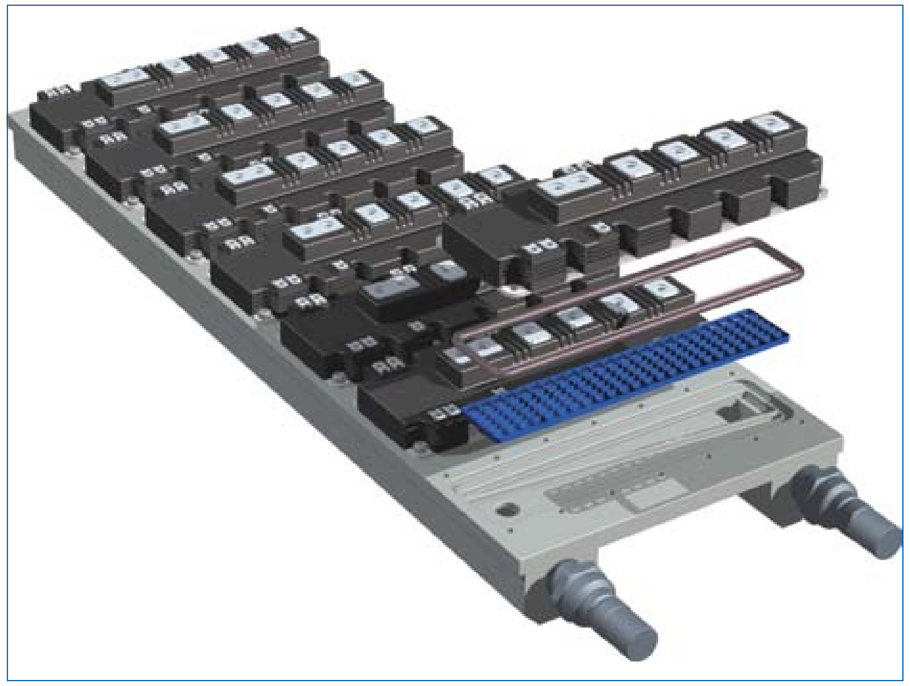
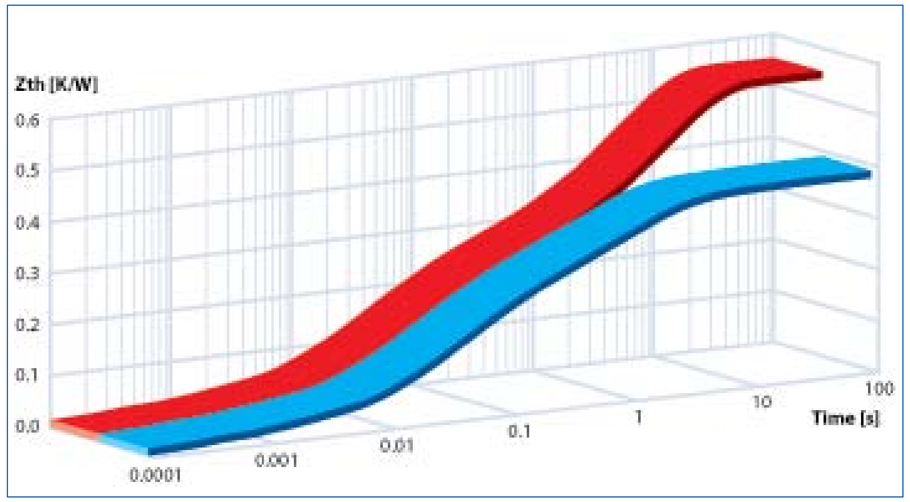
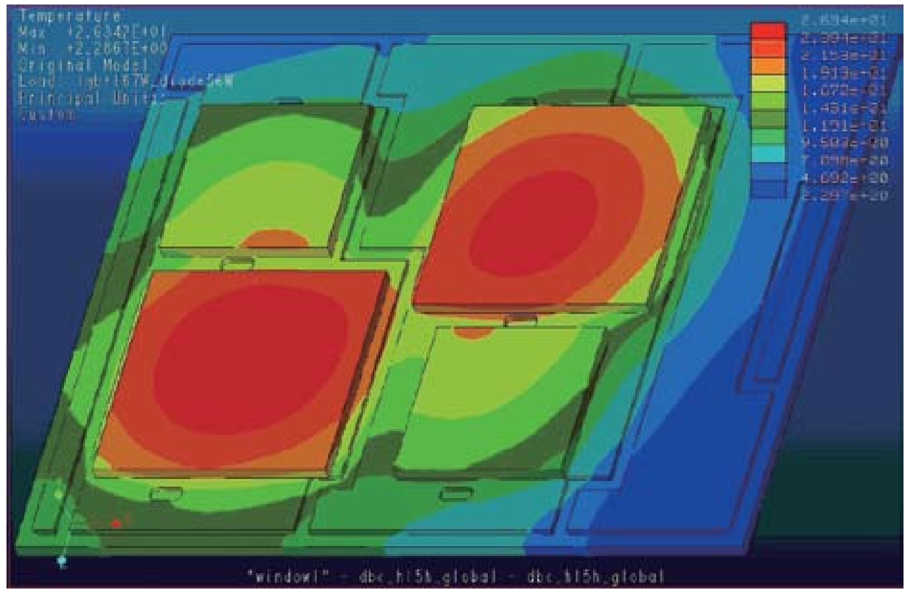


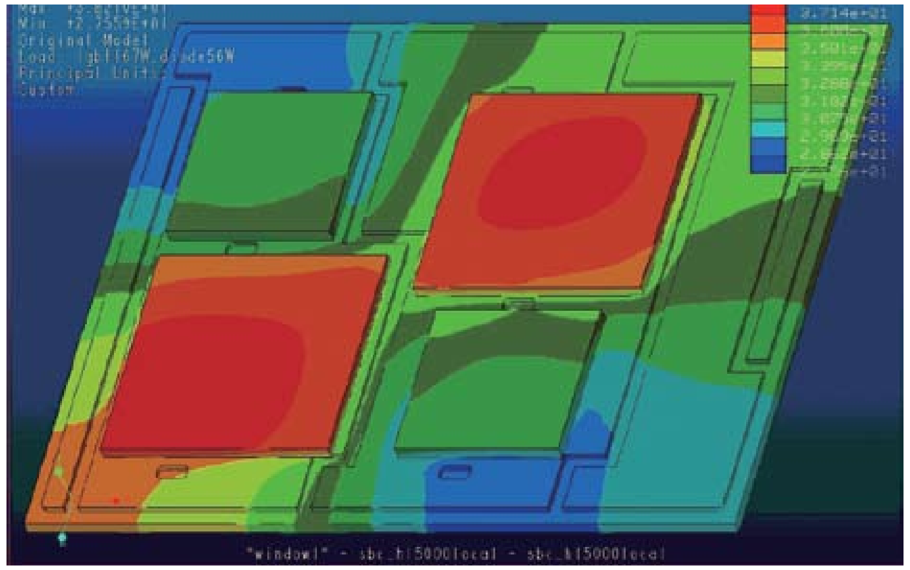
A power module assembly featuring seven P3 modules on a ShowerPower® cooler



Thermal step response curves, cold plate (Indirect) vs. ShowerPower® (Direct)



Cooling underneath the whole area



Localized cooling, cooling only underneath the chips

PSDE Green Power ENERGY EFFICIENCY

The Way Forward for Solar

Evolution of PV solar power architectures

PV modules, or panels, produce direct current (DC) electricity, typically with a peak output up to 250 Watts. With suitable control circuits, they can be used to charge a battery – which also generates DC, or to power DC devices. However, by far the largest market for PV solar installations is so-called "grid connect" applications. Here, the DC generated by solar modules is converted to alternating current (AC) for direct connection to the AC power grid. When solar power is not generated, for instance at night, the grid provides power for the user. When the solar installation is generating power, the user can power electrical appliances with it and any excess is sold back to the power company that supplies the grid.

By Paul Engle, CEO, Enecsys Ltd. Cambridge, England

The conventional PV solar architecture

In conventional PV solar installations, modules are connected in series, like a daisy chain, to form a "string". A central inverter converts the high voltage DC output of the string to AC for connection to the grid. Figure 1 shows the arrangement.

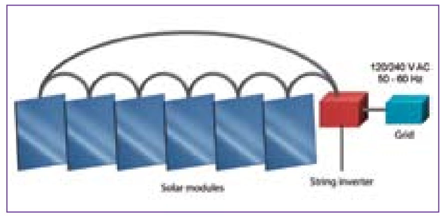


Figure 1: The conventional DC string architecture in a solar PV system

Installation is complex and expensive for these conventional systems, requiring specialist skills and safety procedures due to the high DC voltages and currents that are developed. These can reach up to 900V at 5A – lethal if touched. In systems using DC strings, maximum energy harvesting occurs only when every module is matched exactly for technical performance and the same amount of solar radiation reaches each solar cell in every module. In real world conditions these requirements are often not met and the system performs below its potential, often dramatically so. Shading from any source such as tree branches or even something as small as an antenna or vent pipe can dramatically reduce the energy produced from string systems. Also, dust and dirt that build up unevenly on modules causes some modules or even a few cells of modules to see less solar energy than other modules. Because the modules are connected in series the whole system only performs at the level of the poorest performer in the string so a shadowed module limits the whole system and the higher potential energy of the other modules that are not shadowed is wasted. Under these real world conditions the penalty to the potential for energy harvest is severe. It is not uncommon for a system that has relatively few of its cells obstructed to perform at less than half its peak power capability and even not perform at all if such shadowing occurs on several modules in the system.

Clearly, if the weakest modules have such a dramatic affect on PV solar system efficiency, it is important that modules are closely matched before installation. This adds to both manufacturing and installation costs. In addition, PV systems based on conventional architecture can only be installed on one plane on a roof, with the modules facing in one direction. If multiple planes are used, the whole system output is limited by the performance of the modules that receive the lowest level of light.

Two further disadvantages of conventional PV installations lie in the central string inverter itself. First, it is a central point of failure. When it fails, all power from the solar installation is lost. Second, although very efficient, perhaps converting up to 99% of the available power from DC to AC, string inverters are large units that need to be located in protected environments indoors. Even then, most manufacturers of these inverters will only warrant the products for 5 or 10 years. In practice, a string inverter usually needs to be replaced at least once during the life of a PV solar installation. String inverters are big, expensive units. PV modules, on the other hand, typically perform well for 25 years.

A partial solution – the DC-DC "optimizer"

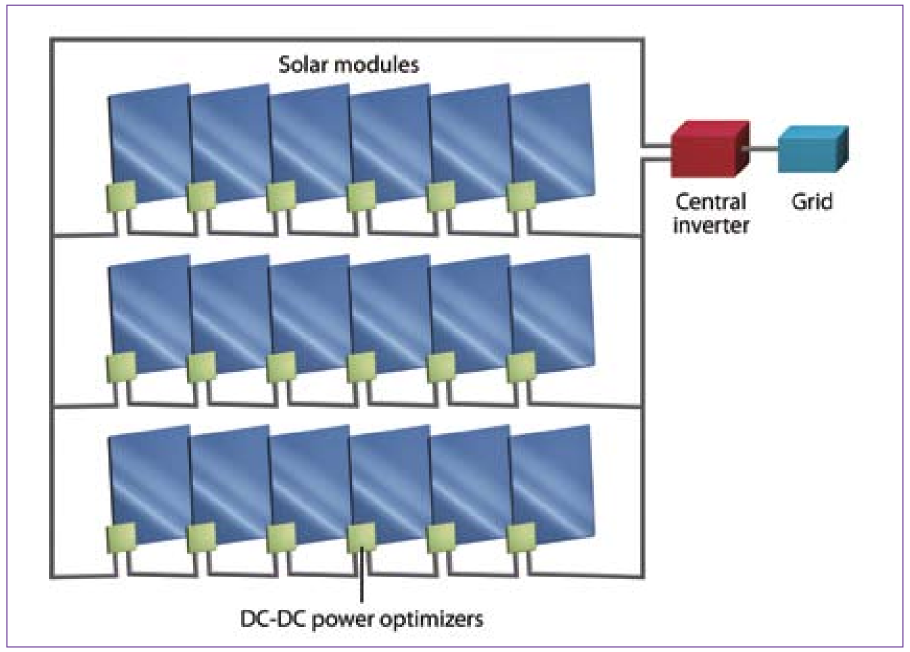


Figure 2: A PV solar installation with DC-DC power optimizers

Installing intelligent DC-DC converters behind each module, then feeding the DC voltage to the central inverter, overcomes some of the problems described above. Figure 2 illustrates the architecture.

Using DC-DC optimizers maximizes the power harvested from each module by enabling per-module maximum power point tracking (MPPT). MPPT is an electronic technique that varies the electrical operating point of each module in order to extract the maximum available power from it. Using this architecture, any degradation in the performance of a module, due to clouds, shadows or other obstructions, does not affect the performance of other modules and has much less affect on the power harvested from the system as a whole. Installers don't need to match adjacent panels for best output and modules can be installed on any available roof space – they don't need to be on a single plane, as they do with a conventional DC string installation. In addition, the system can be monitored on a per-module basis, making it easier to identify the exact location of any problems that might occur over the life of the installation.

Despite the benefits, the disadvantages of this architecture are significant. It adds around $200 to the cost of every module without eliminating the most expensive and weakest link in conventional PV solar strings – the central inverter. Furthermore, there is still high voltage DC to deal with, requiring specialist skills and equipment, with associated higher costs. What's more, the wiring and installation of these optimizers adds complexity and cost.

The way forward – micro-inverters

All of the advantages of DC-DC optimizers, but none of the disadvantages, can be realized by using micro-inverters. One micro-inverter is built into, or attached to, each PV module. This architecture is illustrated in Figure 3.

Each micro-inverter converts the DC from each module to AC, ready for direct connection to the grid. An example of a micro-inverter is shown in Figure 4.

The micro-inverter architecture allows each module to be an independent, standalone, solar AC grid connect system with its own optimized energy production output. Micro-inverters mean faster, simpler and safer plug-and-play installation. There are no high voltage DC circuits to handle and installation time and costs are cut by 15% to 25%. Further, the need for a large, hard-to-install, central inverter, which is the single most common point of failure in conventional systems, is completely eliminated. Installations are flexible and scalable, and modules can be located on any plane, or on multiple planes within a single system.

Micro-inverters deliver between 5% and 15% more power from the installation and such systems are intrinsically safer. By eliminating the central string inverter – or several of them over the life of the system - the additional cost of adding a micro-inverter to each module is mitigated. In fact, it has been calculated that using reliable micro-inverters – those with a realistic operating life in excess of 25 years – enables the cost-per-harvested Watt of PV solar systems to be cut by up to 25%, compared with conventional systems. This dramatic improvement is in stark contrast to the small, incremental advances being made in the efficiency of PV modules over the last few years.

Equally important from the installer perspective, micro-inverter PV systems allow monitoring down to the level of individual modules. Any faults that do arise are easily located, reducing maintenance costs. In fact, these monitoring systems can even be web enabled, so the status of the system can checked from anywhere in the world where there

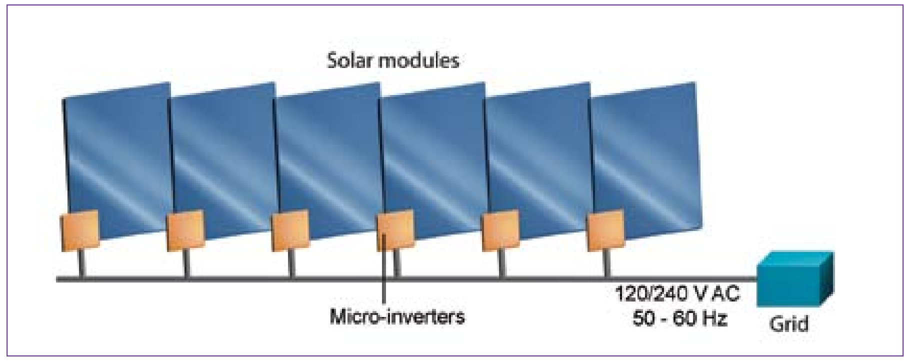


Figure 3: A micro-inverter based PV system reduces the harvested cost-per-Watt by up to 25% over the life of the system

Figure 4: The Enecsys micro-inverter

is Internet access. The monitoring systems also give users real-time and historical data on the performance of their system.

Micro-inverters may not yet be as efficient as large central inverters, but because the overall yield from PV-systems based on micro-inverter architectures is so much higher, it is important not to be misled by headline efficiency figures. Efficiency is important but it's only part of the story. Micro-inverters represent one of the fastest growing parts of the solar-electric industry. The solar inverter market was valued around $2.4 billion in 2009 and is growing fast.

The reliability question

Micro-inverters are not a new idea. The challenge has been to design these products to be reliable in real-world conditions. Temperatures can easily reach +85 degrees C behind a solar module and high temperatures are not good for electronic devices. A rule of thumb used by electronics designers is that every 10 degrees C rise in temperature will halve the mean time between failures (MTBF) of an electronic system.

The MTBF figure is a guide to the predicted failure rate during the so-called "useful life" period of a product. It's a statistical calculation based on the predicted failure rates of the individual components within the product.

However, the concept of MTBF is widely misunderstood, and often misrepresented in marketing material. The inference made by some suppliers in the solar industry is that a high MTBF supports an expectation of a long life for their products. Such statements are wrong. An MTBF of 600 years sounds great but 100% of the products may still fail in an unacceptably short time. This is because wear-out mechanisms determine the lifetime of products, and these failure mechanisms are not predicted by MTBF.

A product with an MTBF of 300 years could actually live 40 years before the wear-out mechanisms lead all of them to break down. By contrast, a product with 600 years MTBF might have wear out mechanisms that limit its life expectancy to 15 years or less. If you know this, you would clearly choose the 40-year life expectancy product over the 15-year life expectancy product. For a solar micro-inverter, this is very important. With a 15-year lifetime product you would have to replace all of them before the modules wear out, in about 25 years. With the 40-year lifetime product, you will only replace a few of them during the lifetime of the modules.

Clearly, an over-emphasis on MTBF as a measure of real-world reliability is dangerous. A company may claim an MTBF of 800 years for its products but only warrant them for 10 years – the warranty is the better indicator of likely operating life.

The safest approach is to select products that are backed by accelerated life test data derived from accepted test methodologies. For the solar industry, IEC 61215 is a recognized test methodology for solar modules and therefore an appropriate guideline for micro-inverters. Two further important indicators of reliability are the temperature range over which the micro-inverter is rated and the warranty offered by the micro-inverter manufacturer. Solar modules are typically rated from -40 to +85 degrees C. Why would you then choose a micro-inverter rated at a maximum temperature less than the maximum temperature for the solar module?

Until now, the reliability of micro-inverters has been limited by the need to use relatively unreliable components in their manufacture. These problems are now being overcome. As a result, demand for micro-inverters currently outstrips supply (Q1, 2010).

Summary

For most rooftop PV solar installations in domestic and commercial premises, there is growing recognition that conventional DC string architectures are underperforming their potential for energy harvest. They are not delivering the efficiency required to enable more widespread adoption of solar-electric technology. The interim step of using DC-DC optimizers greatly improves energy harvesting, but at a cost that is unacceptable. The next few years will see micro-inverter based systems become widely adopted and a growing number of PV module manufacturers will build micro-inverters into their products. The AC module will become an industry standard module and installation time, complexity and cost will be dramatically reduced. At the same time, users will harvest more electricity from their systems and their investments will be paid back over much shorter periods.

www.enecsys.com

Modular UPS Systems

Made to measure protection avoids loss of revenue

A tailored and integrated approach to power protection, comprising modular UPS and fully-matched standby generators, is helping businesses sustain vital uptime and availability.

By Alan Luscombe, Sales and Marketing Director, Uninterruptible Power Supplies Ltd (UPSL)

Changes in the business landscape, the growing risk of nationwide power cuts, and advances in technology are accelerating the uptake of more flexible and efficient UPS systems.

With global 24/7 online trading and customer expectations of immediate, anytime availability, power continuity around-the-clock is often essential: in highly competitive markets even a minor interruption to business systems can cause considerable revenue losses.

Whether due to planned maintenance or unplanned power outages, system downtime is undesirable - and increasingly unacceptable for business critical loads. The UK's ageing power stations and unproven alternatives are a major cause for concern and should spur organisations to urgently review and reinforce their power protection systems, to ensure they can cope with unreliable supply, more frequent interruptions, and the possibility of long term power cuts.

Design for uptime

Transformerless three-phase UPS technology, introduced in the early 1990s and now widely adopted, delivered significant weight and space savings and enabled the development of rack-mounted modular UPS systems.

Compared with traditional free-standing units, these units can reduced the required floor space by 75%, and vertically scalable modules mean that additional capacity for redundancy or load upgrades can be easily achieved at a fraction of the cost of adding an additional stand-alone unit.

Going back just a decade, only 10% of three-phase UPSs were parallel redundant systems but today this configuration accounts for more than 70% of installations. The majority of organisations needing protection for critical loads are upgrading to parallel redundancy, providing a minimum of one UPS over and above that required for capacity and ensuring continuous support of the load if any one UPS shuts down.

When specifying a UPS system, it can be difficult to predict what the power requirement is going to be so installations are often over-sized to provide contingency, creating a wasteful gap between installed capacity and the size of the actual critical load. While this may ensure sufficient UPS capacity, it means inefficient operation, additional expense and inefficient use of energy and costly floor space.

However, rack-mounted modular UPS configurations can be cost-effectively 'right-sized' from outset more easily by inserting or removing 'hot-swappable' modules, enabling power to be added as requirements grow without downtime or increasing footprint. Hot-swap technology, along with significant reductions in repair time, can also achieve six nines availability (99.9999%) - highly desirable in the pursuit of zero downtime.

Modularity improves efficiency by working closer to the load capacity than traditional UPSs but without sacrificing the security of the system. The more a load approaches the capacity of any UPS, the more efficiently the UPS operates. A traditional stand-alone parallel redundant system is typically just 50% loaded while a modular solution typically achieves a 70% or higher loading. This reduces energy use, Co2 emissions and UPS cooling requirements.

Cost benefits

Compare a single stand-alone non-redundant 100kVA UPS solution with a parallel redundant 3 x 50kVA UPS modular solution. While the latter may carry a price premium, the cost-benefit is quickly apparent. The modular configuration provides redundancy if one of the units fails, and modules can be added to accommodate an increase in capacity, in affordable, incremental steps without interruption to the critical load. The stand-alone system provides

Reduced required floor space by up to 75% is achievable

The scalability of modular systems contributes major savings.

no redundancy and the addition of a second parallel 100kVA unit to increase capacity would be more costly, take up twice the space, and would also incur downtime during installation.

Price sensitivity is understandable, especially in the current market where expenditure on capital equipment may be subject to tougher scrutiny. However, while the purchase price of a traditional standalone UPS system can be typically 10% to 15% less than an advanced modular UPS system, Total Cost of Ownership should be considered. The lower purchase price of traditional standalone UPS technology must be offset against significantly higher operating expenses in comparison with a modular system based on technology which reduces energy loss costs. In fact the higher initial price of the modular system can be recovered within the first year of operation, and a comparison of additional long-term costs also favours modular technology.

For example, approximately £150,000 could be saved over five years by replacing a ten year old 400kVA parallel redundant UPS system, running at half of its rated capacity, with a new Decentralised Parallel Architecture (DPA) 200kVA parallel redundant UPS system. This would also reduce CO_2 emissions by over 700 tonnes and cut floor space by 70 percent.

Upgrading a traditional UPS demands extra space, costly cabling and potentially involves taking the UPS system off-line during the upgrade. With a modular UPS, the upgrade is performed by simply inserting the additional power modules into the rack, without any interruption to the load, without increasing the footprint, and with no additional work on site. This flexibility makes upgrading a system very easy, and with little additional cost.

Standby power

There may be situations where organisations can tolerate occasional downtime, and in this case a UPS fitted with a standard or extended autonomy battery may provide the required system integrity. However, where downtime is untenable, a standby generator with automatic mains failure (AMF) detection and changeover facilities will be a vital part of the protected power supply system.

During a mains supply failure, the UPS battery will support the load for the time it takes the generator to start, stabilise and be switched over to supply the UPS. Assuming the generator has been correctly sized for the application, the UPS will accept the generator as a 'mains replacement', start to recharge the battery and continue to supply the critical load for the duration of the interruption.

Round-the-clock dependence on uninterrupted critical loads means that this seamless interaction between UPS and standby generators is an important requirement. Turnkey supply and installation also delivers valuable integration benefits, ensuring fully matched UPS and generator systems, removing the problem of demarcation between different suppliers and eliminating potential points of failure. Individually sourced units can compromise system autonomy and presents a risk of mis-sizing, causing installation and commissioning problems. A packaged solution with fully matched UPS and standby generator ensures a true 'no-break' supply in the event of a mains failure – protecting critical loads and assuring uptime.

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International Rectifier

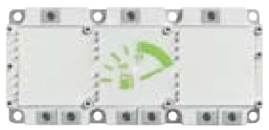
IR Introduces 20V, 25V and 30V MOSFETs in PQFN Package for ORing and Motor Drive Applications

International Rectifier has launched a family of HEXFET® power MOSFETs including the IRFH6200TRPbF that delivers the industry's lowest on-state resistance (RDS(on)).

The new power MOSFETs featuring IR's latest silicon technology are the company's first devices available in a 5x6mm PQFN package with optimized copper clip and solder die. The IRFH6200TRPbF 20V device delivers industry leading RDS(on) of only 1.2 mOhm (max.) at 4.5V Vgs to significantly cut conduction losses for DC motor drive applications such as hand tools.

www.irf.com/whats-new/nr100218.html

Infineon



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White Goods

Special Report – White Goods

Reverse Conducting Drives

Bringing the IGBT into a new dimension

For the low cost / low power consumer drive market, the RC-Drives family of IGBTs from Infineon has been launched. For the first time Infineon's famous "reverse conducting" (RC) IGBT technology of monolithically integrated IGBT and free wheeling diode in a single die is available for hard switching applications like fans, pumps and motors. By integrating the diode a substantial saving in terms of cost and package size is possible whilst performance is not sacrificed.

For the next generation of home appliances, this gives new opportunities to designers in board layout as the new smaller packages offer the chance to reduce PCB area, plus purchasing is kept happy with the savings these products bring.

By Mark Thomas, IGBT Product Marketing Manager, Infineon Technologies

Over the last 10 years, the market forecasts of major home appliances (MHA) sold with variable speed drives (VSD) has been on the optimistic side, with predictions of rapid market acceptance – which never eventuated. High cost has been one of the main reasons for the slow growth with manufacturers selling appliances with VSD as high end products where volumes are not high.

The latest market studies continue to predict rapid market growth by indicating, for example, the VSD market in MHA is set to double over the next 5 years. This time, however, there is more confidence in the accuracy of these latest predictions. Government legislation and China's government subsidy program to stimulate the Chinese economy during the 2009 down turn are two reasons why MHA manufacturers are more actively implementing VSD to fulfill tougher efficiency standards. Manufacturers are also using this as a chance to develop products with "unique" features to differentiate themselves from the competition.

Without doubt, Intelligent Power Modules (IPM) will enjoy market leadership in this segment, but there is a trend evident that discrete solutions will win more of the market share. Due to cost pressure, OEMs and design-houses are looking more closely at implementing discrete solutions. This has been recently seen by a significant increase in requests for technical support to help with optimizing discrete solution designs.

This is the breaking of a new dawn for high efficiency MHA using VSD using discrete solutions.

Part number	Package Type	B_{Vces}	Ic@ 25°C	Ic@ 100°C	V_{ceon} @ 175°C Typical	E_{ts} @ 175C Ic@100°C Typical	T_{sc}	V_{geth}
		[V]	[A]	[A]	[V]	[mJ]	[usec]	[V]
IKU04N60R IKD04N60R	IPAK DPAK	600	8	4	1.90	0.21	5	5
IKU06N60R IKD06N60R	IPAK DPAK	600	12	6	1.90	0.30	5	5
IKU10N60R IKD10N60R	IPAK DPAK	600	20	10	1.90	0.58	5	5
IKU15N60R IKD15N60R	IPAK DPAK	600	30	15	1.90	1.22	5	5

Table 1. RC-Drives product family overview

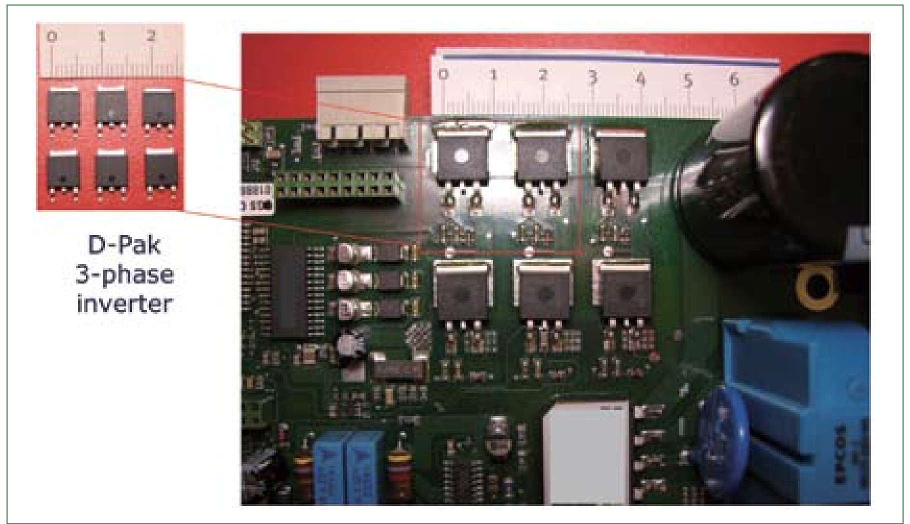

Figure 1: Demonstration of the area saving potential offered by the RC-Drives family

RC-Drives Product Family Overview

In response to customer requests, a new family of discrete IGBTs is now available specifically designed with MHA market in mind. The new RC-Drives family is based on Infineon's Trench Field Stop IGBT Technology (TRENCHSTOP™).

The new family consists of 4A, 6A, 10A and 15A IGBT + free wheeling diode (FWD) as seen in table 1

Since the MHA market is one of the target applications, the device has been optimised accordingly. Price and performance (high efficiency, 5μs short circuit robustness and EMI behaviour) were the key requirements for market acceptance when originally defining the product.

Price is seen as the most important feature for the customer; as they are pushing the price of the modules down to bring models offering VSD into the mainstream market and not just for high-end models. The price advantage offered to the customer by the RC-Drives family comes from the reduction in the package size, a single die solution (less test time and bonding requirements) and cost optimization of the technology. Here a 30% cost improvement was achieved over the previous Infineon products offered for this segment. Additionally, due to the package shrink (75% compared to a D^{2}PAK package), a substantial PCB area reduction is possible, as can be seen in figure 1

Of course, performance is needed and here the advantage of the TRENCHSTOP™ technology comes out on top. Since switching frequencies where VSD is used are rarely seen to exceed 16kHz, the family has been optimised for low conduction losses. This means at low switching frequencies the dominant conductions losses are reduced thanks to the low Vce(sat) (as seen in Figure 2). The resultant high efficiency of the IGBT and diode significantly works towards satisfying the thermal issues when moving to a smaller package.

Easy controllability, via the gate resistor, of the turn on and turn off waveforms further allows the designer

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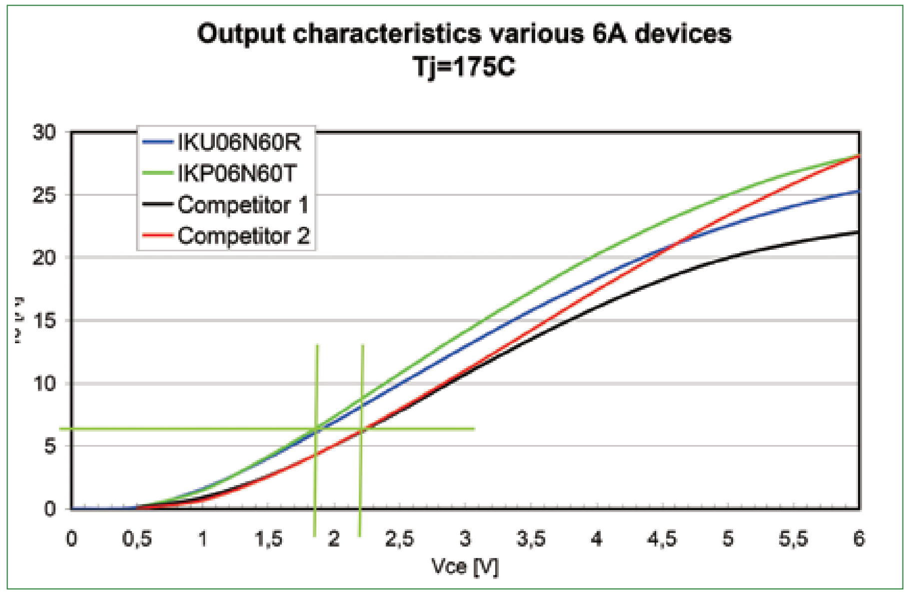

Figure 2: RC-Drives in relation to the conventional 600V TRENCHSTOP™ family from Infineon and competitor devices at Tj(max) of 175°C

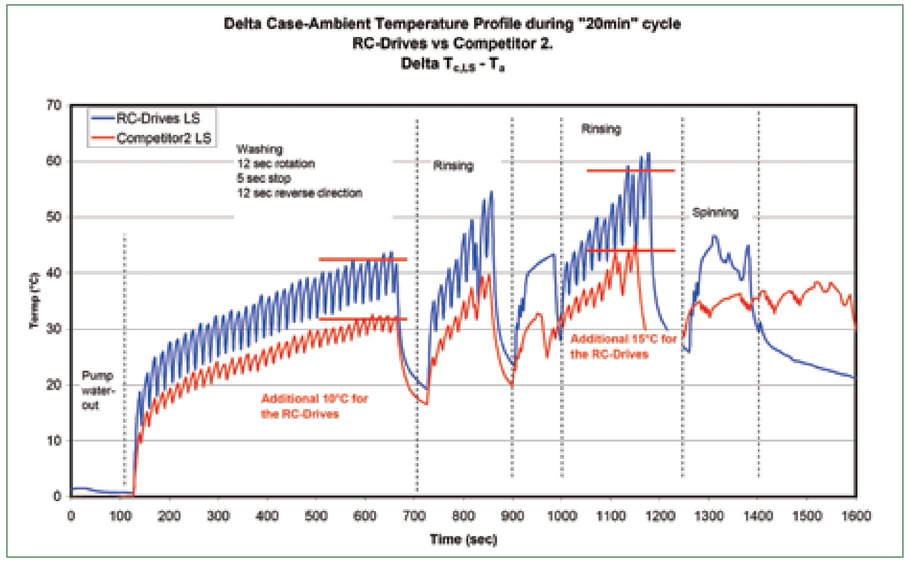

Figure 3: Delta-Ambient Temperature Profile during "20min" cycle RC-Drives vs. Competitor 2. Delta Tc,LS - Ta

to optimise for efficiency. For Infineon IGBTs, low gate resistors (down to 5Ω) are recommended to get the best efficiency. A feature of all Infineon IGBTs is the soft switching nature, which means excellent EMI behaviour is still maintained even with very low gate resistors.

Addressable Major Home Appliances

Starting at the lowest power rated applications, like 30W to 100W air conditioner fans, the 4A device is best suited. Here the 75% footprint reduction over a conventional TO-220 package is the key benefit to the customer whilst being able to operate the devices, when correctly done, without the need for a heat sink.

When addressing VSD refrigeration compressors up to 200W, the 4A DPAK (TO-252) version of the RC-Drives shows itself to be the best suited device. Again here, the MHA manufacturers enjoy the 30% cost savings of the RC-Drives family, plus the space-saving credentials are helping them come up with new ways to implement the power board into the fridge unit.

To support the release of the new family, a 200W demoboard is available for ordering. Details can be found on the Infineon website.

For VSD washing machine motors and inverterised air conditioner compressors up to 800W, when a discrete IGBT solution is preferred, a TO-220 or TO-220 Full Pack package has been used.

Application tests have been performed on a commercial washing machine, where the new IKU06N60R in an IPAK (TO-251) using thermal isolation foil has replaced the competitor TO-220 Full Pack devices on the power board. Thermal measurements taken during operation have seen only a 15°C increase in case temperature (as can be seen in Figure 3). This is with a package that is 75% smaller than the TO-220 Full Pack! Here the low conduction losses play a vital role in keeping the case temperature down, even with the higher thermal resistance of the IPAK (TO-251)

The application test demonstrates the RC-Drives family really brings the IGBT into a new dimension by offering excellent power handling capabilities in a package that is 75% smaller that the TO-220.

Summary

The fully released RC-Drives family specifically targets the price sensitive Major Home Appliance Market that uses Variable Speed Drives. Low conduction losses allow for a 75% package shrink, whilst thermally only a 15°C increase in case temperature is seen during application testing of a commercial washing machine.

For more information about discrete IGBTs from Infineon, please visit

www.infineon/igbt

www.infineon.com

Low Cost Motor Control

For white goods applications

Advanced motor control techniques like: Brushless DC and Brushless AC are already used on large scale in industrial applications as they are offering several advantages compared to universal AC motor control like: better efficiency, higher robustness and lower motor cost. On the other hand, the electronic portion of driving the motor has become more complicated also driving up the total system cost.

By Massimo Incerti - White Goods Application Specialist and Cristian Ionescu - White Goods Marketing Manager, NXP

The White goods market, as an extremely price driven market segment has been very careful in implementing "new" motor control methods in appliances like Washing Machines and Dish Washers. The traditional and well-known control methods have been preferred so far, but since several years, also supported by year over year semiconductors price erosion the technology used in this market has started to change.

NXP as a semiconductors supplier for industrial applications has a very good coverage on various product families like General application (Rectifiers, Zener diodes, etc), Logic and Power (Triac's, Power IC) as well as Interface and Microcontroller products.

Nowadays Brushless DC motors (BLDC) are widely used in many applications replacing the traditional brushed DC (BDC) motors.

BLDC gains popularity in markets like White Goods (WG), HVAC applications and industrial applications thanks to higher performance in terms of efficiency and reliability, reduced noise and weight, longer lifetime, elimination of sparks created by the commutator and overall reduction of Electro Magnetic emissions.

The BLDC control consists of a control unit and a power unit, with NXP offering competitive solutions for both units. This article will focus on a demonstration board developed by NXP, designed for BLDC motors over 300W at 12V to 30V. Rotor orientation feedback is determined using Hall sensors and interfaces to the outside world using a PC using either CAN or UART connection.

The Cortex-M0 core is one of the latest cores released by ARM in 2009. Cortex-M0 is the smallest, lowest power and most energy-efficient ARM processor available on the market able to achieve 32-bit performances at an 8-bit price level

ARM's Cortex-M0 is based on ARMv6-M architecture and uses the so-called Thumb instruction set including Thumb-2 technology.

The Thumb instruction set is able to operate 32 bit operations out of 16 bit instructions thus enabling a smaller code footprint.

Thumb ISA (Instruction Set Architecture) is made by 56 instructions only, all with guaranteed execution time, from this point of view Cortex-M0 has a pure deterministic response; for example Data processing instructions are completed in one cycle, data transfer is done in two cycles and branches take three cycles to be executed. Regarding data transfers, the M0 core can handle 8, 16 or 32bit data in one

Figure1: BLDC demonstration board

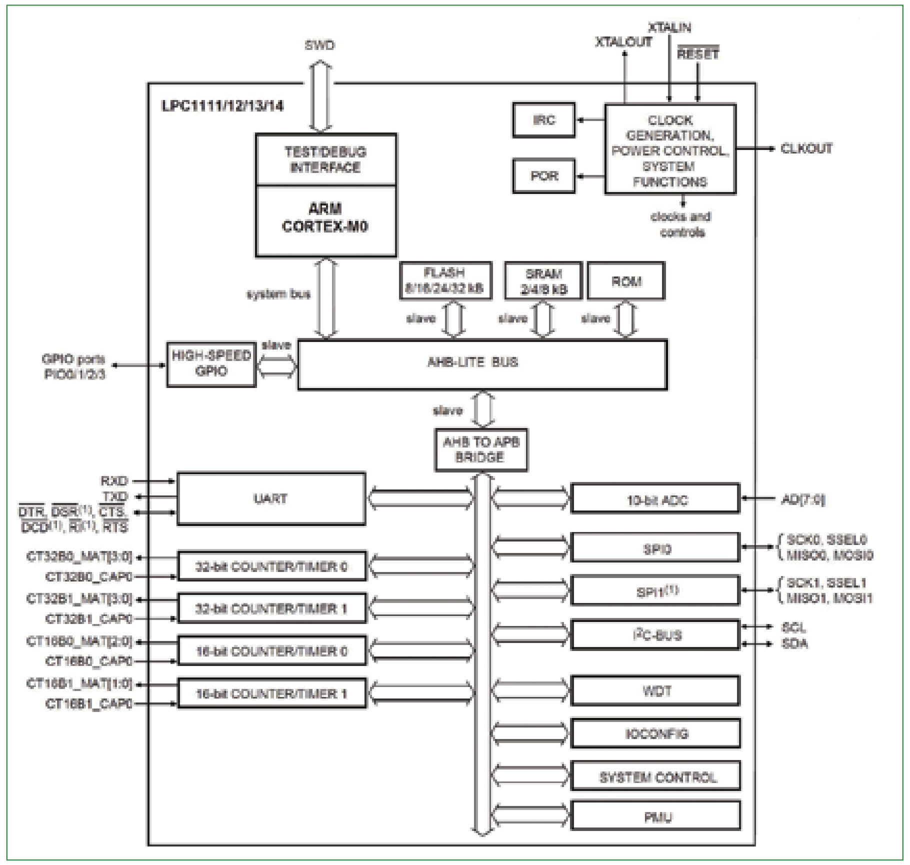

Figure 2: LPC1100 internal block diagram

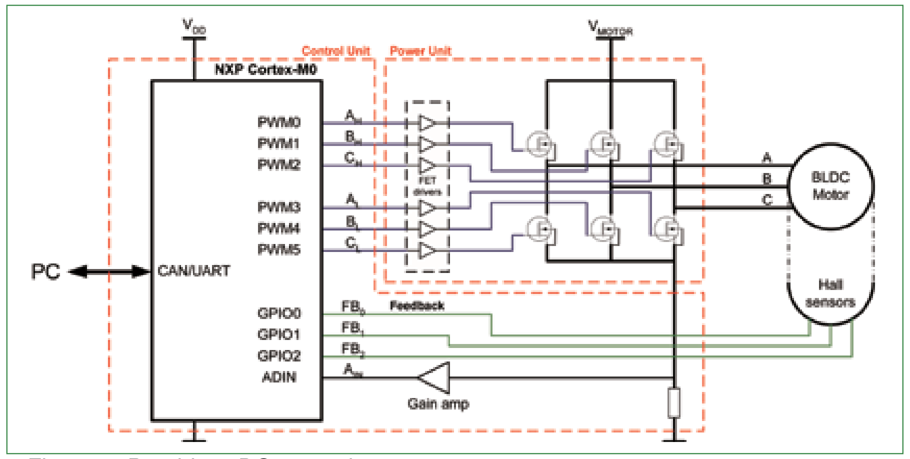

Figure 3: Brushless DC control

LPC1100 BLDC motor control demo application	
Supply voltage	12-30V
Max. power output (safe operation)	over 300W
Code size	6kB
CPU load	~25%
LPC1114 features	
Flash	32kB
RAM	8kB
Clock frequency	50 MHz
PSMN2R6-40YS features	
R_{DSon}	2.8mΩ
V_{DS}	40V
I_D	Up to 100A

Table 1: BLDC board setup and product key features

instruction only.

Apart from the core, Cortex-M0 integrates a NVIC (Nested Vectored Interrupt Controller) that is able to handle both interrupts and system exceptions. The Cortex-M0 core is characterized to have a fully deterministic behavior of the interrupt handling which is 16 cycles by default with no jitter. The maximum amount of vectors the NVIC is able to handle is 32 with prioritization. Tail chaining and late arriving interrupts are supported as in Cortex-M3 architecture.

In 2009 NXP Semiconductors released the first members of the LPC1100 family based on the Cortex-M0 core.

From a computational point of view, LPC1100 family is able to deliver 0.9 DMIPS/MHz according to Dhrystone benchmarks. An additional benchmark (http://www.coremark.org) which is more dedicated to embedded systems performance analysis positions the LPC1100 at 1.4 Coremark/MHz which is extremely high compared to the actual 8 and 16bit Microcontroller solutions. At the same time, the users can save around 40% of the flash memory needed using Cortex-M0 LPC1100.

Thanks to the extremely low gate count, Cortex-M0 based devices can be used in low power sensitive applications such as medical devices, e-metering, motor control and battery powered sensors. ARM's Cortex-M family processors integrates support for multiple power modes; sleep, deep sleep, power down modes.

LPC1100 family supports up to 50 MHz clock speed, it is a zero latency architecture, integrates a simple AHB-Lite interface. The block diagram is shown in the following picture:

The LPC111x integrates all necessary peripherals for embedded control systems in industrial, consumer and white goods applications. The flash content is up to 32KB and the price is starting (for 8K flash based devices) from 0.65$.

For controlling BLDC motors the LPC1100 family incorporates four timers, two 16-bits and two 32-bits, with a total of 13 match outputs where each match output can be configured as PWM. Six PWM signals are used in the demonstration board driving the high and low side MOSFETs.

The general-purpose inputs/outputs (GPIO) on the LPC1100 are highly configurable and can be used as external interrupts triggering on the rising, falling or both edges. Rotor orientation feedback is captured through these GPIO interrupts.

The LPC1100 has an 8 channel 10-bits Analog to Digital Converter (ADC) from which one channel is used as e.g. over-current protection by measuring the motor current through a shunt resistor.

Measuring the voltage on the floating phase during BLDC commutation, the rotor orientation can even be determined without use of any sensors. This requires accurate timing in capturing the floating phase voltage. In the LPC1100, an ADC conversion can be triggered by a match event of two of the four timers. This decreases CPU load and allows accurate capturing of the floating phase at the right moment.

For interfacing to the outside world, the LPC1100 has the UART and/or CAN interface.

On the other hand, NXP has introduced in 2009 a new MOSFET generation (6th) with Trench technology to support various applications such as motor control in industrial segment. The new Trench 6 Mosfet has the following benefits: reduce the Rspec - mΩ / mm2 to lower RDS(ON) and allow fast switching; reduce gate-charge & switching loss; lower QG(tot) & FOM for best efficiency; increase Tj(max) to 175C for reliability and high performance application support. The continuing extension of the product portfolio represents a very good fit into the motor control applications.

In the bellow table you will see an overview of the BLDC board characteristics:

Further developments based on our Cortex-M products will address BLAC with Field oriented control and U/f control. These developments are linked to our microcontroller family concept that has proved its continuity in offering similar peripheral IP, software compatibility and easy migration within various architectures like ARM7, Cortex-M0, Cortex-M3 and the new Cortex-M4.

This strategy allows us to offer for different motor control methods not only the appropriate mix between CPU performance and required peripherals but also tool and software re-use among all the various projects (for example software modules written for Cortex-M0 can be re-used on Cortex-M3/M4 based micros). Our customers can therefore dramatically reduce the time to market and keep the tool investment at a minimum level (same IDE, debugging and programming tools).

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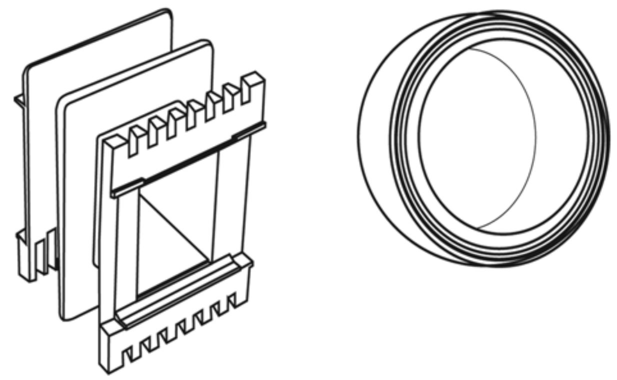
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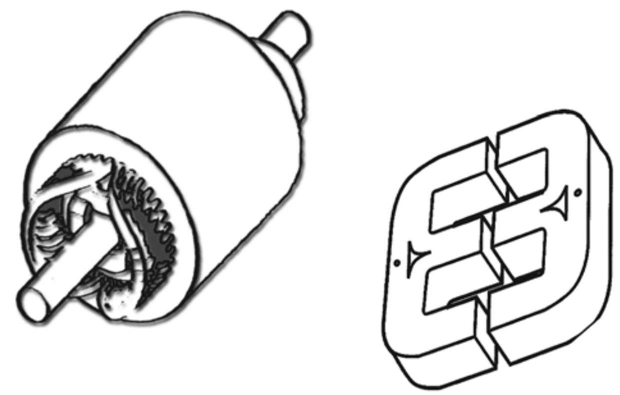
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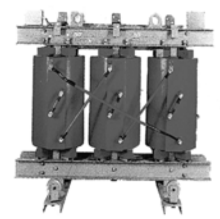
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White Goods Design

Use of thyristors in three phase motor control

Three phase motors are being employed in a growing number of white goods, in order to make them more energy efficient. This means that domestic appliances such as washing machines, dishwashers and refrigerators can run at speeds that best match the application requirements with power being used more efficiently. These motors are generally controlled by magnetic starters based on electromechanical relay devices, but there are certain disadvantages to employing this type of design. In the following article ON Semiconductor's Alfonso Camacho looks at how, by utilisation of thyristors to provide the switching functionality, it is possible to create systems that are less noisy, switch at faster speeds, and have a longer operating life.

By Alfonso Camacho, ON Semiconductor

The rising cost of utility bills, as well as government led programs to curb the impact of excessive electricity consumption, are driving consumers to replace household electrical goods with ones that offer greater levels of energy efficiency. The European Commission has set a target to reduce residential energy consumption by 27% by the year 2020. As a result products that are powered by three phase motors, rather than conventional single phase devices, are gaining in popularity.

In traditional three phase motor designs, the relays used in magnetic starters have three mechanical contacts which control the supply of power to the motor terminals once the coil has been energised. However there are some shortcomings associated with this form of motor control, especially at higher current levels. Larger currents can cause sparking and arcing to take place across the contacts when the relays are activated/deactivated, damaging the contacts and thus having an adverse effect on the overall efficiency of the motor. This will cause noisier operation and shorten the product's operational lifespan. Design engineers are therefore keen to find an alternative to this approach, and are looking to solid state technology, instead of outdated electromechanical technology, for answers. Thyristors can deliver the switching functionality needed in a more efficient, less noisy and more reliable manner. They are also capable of switching at considerably faster speeds.

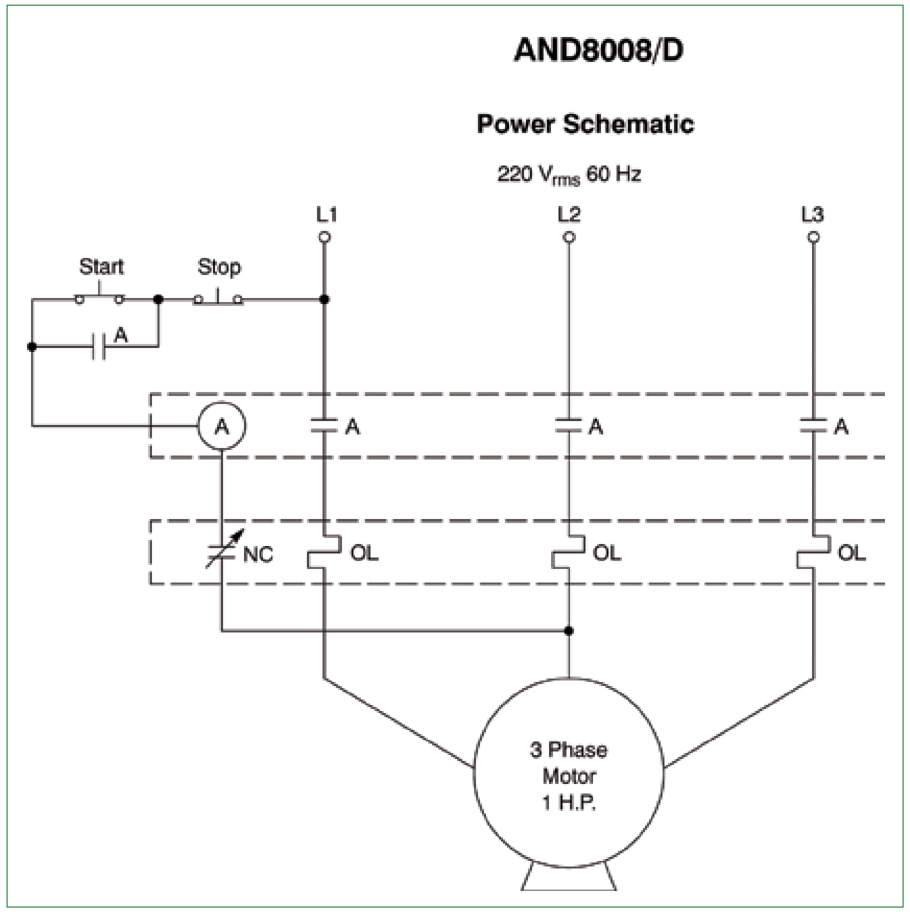

Figure 1: Motor control based on electromechanical relays

A thyristor's construction means that it can withstand high voltage levels not allowing any current to flow unless the thyristor is triggered. Once it has been triggered it presents a low impedance path until the current is removed or it drops below a certain pre-defined level (referred to as the holding current). After the gate current has activated the thyristor it does not need to be maintained, meaning the device will latch in the low impedance state without gate current being continuously applied.

When looking to create a three phase motor control system that incorporates thyristors, the engineer needs to give careful consideration to the various aspects that will influence the finished design. Otherwise the advantages of moving to a solid state approach will not be fully realised.

Comparison between magnetic starter and solid state motor control

Three phase motors are made up of the stator windings and the rotor. The rotor induces the voltages of the stator frequency, and the currents produced correspond to the size of these voltages and the impedance of the rotor. Since they are induced by the rotating stator field, these rotor currents will produce a rotor field with the same number of poles as the rotor and rotating at exactly the same speed.

An example of a traditional three phase motor controlled by a magnetic starter can be seen in Figure 1. The magnetic starter's coil (denoted by A) is energised and the mechanical switch contacts close so that a current flows through the motor. The motor is protected from voltage surges by an overload relay (NC).

By contrast Figure 2 describes a motor control system that is based purely on thyristors. Three thyristor devices (T1, T2, and T3) effectively replace the mechanical contacts utilised in magnetic starter design. A trio of optocouplers (O1, O2, and O3) supply the signal currents to these thyristor. In order to protect the thyristors from voltage transients, an RC 'snubber'

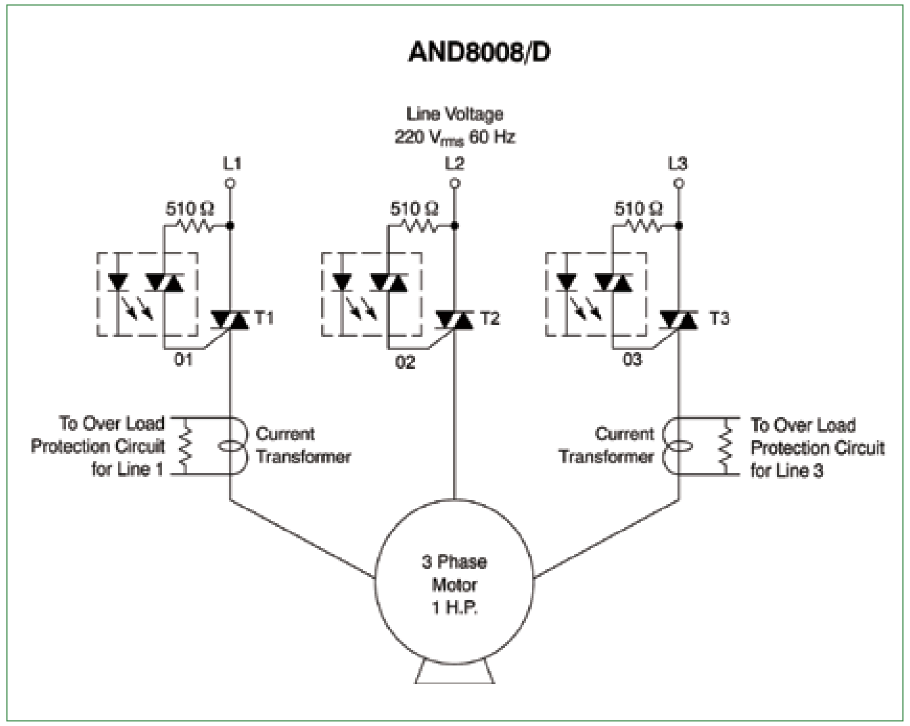

Figure 2: Motor control circuit based on thyristors

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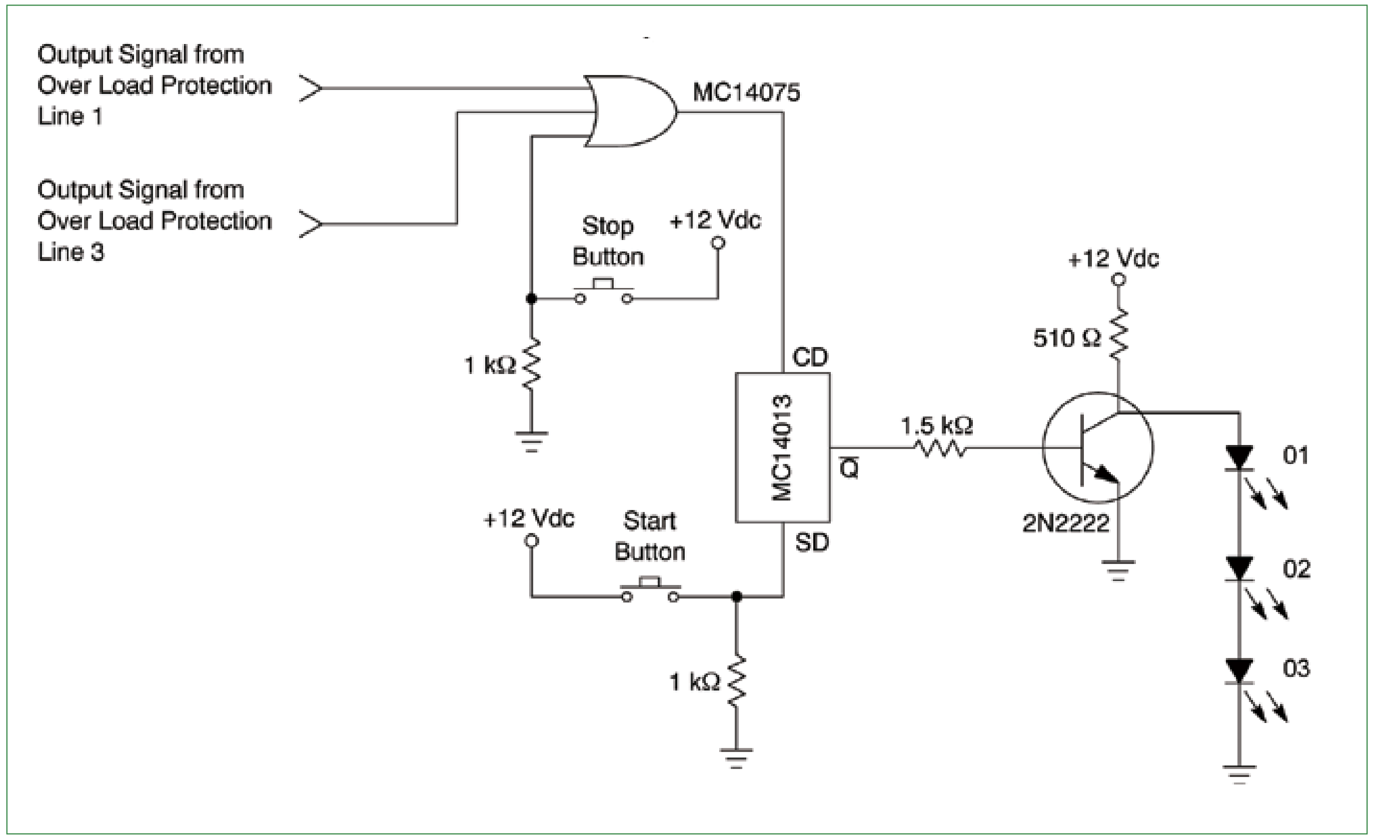

Figure 3: Description of start/stop control circuit

network (made up of a resistor and capacitor in series) is placed across each of the devices.

It is important to note that when looking to protect a circuit against voltage transients, snubbers must be used in the proper manner. Good snubber design relies on compromise. The voltage rate, peak voltage, and turn-on stress must all be taken in to account, and the most suitable balance found, or else unreliable circuit operation will result.

The control signals for the two electronic overload circuits are received from the shunt resistors which are connected in parallel to the current transformers on two of the three main lines (L1, L3) for sensing the current flowing through the motor. The voltage in the shunt resistors will be dependent on the current in each main line. The voltage level will increase, causing activation of the overload circuits and thereby stopping the motor, should an overload condition arise in the motor's power circuit.

Figure 3 shows a schematic of the basic circuit needed for controlling the motor. When the start button is pushed, the flip-flop (MC14013) is activated. This triggers the transistor (2N2222), which turns on the optocouplers' LEDs. These in turn will activate each of the thyristors, which starts up the motor. The motor will cease to operate, when the stop button is pushed or if any overload condition occurs in its power circuit.

Conclusion

The ability to have variable speed control in the operation of white goods results in greater energy conservation. This can give manufacturers a competitive advantage as it means their products will have lower running costs, as well as allowing them to meet government environmental guidelines (such as EnergyStar® in the United States and the EU Code of Conduct here in Europe) before they become mandatory legislation.

It is clear that thyristors can be used as a substitute for magnetic starters in three phase motor control – leading to more sophisticated and streamlined designs that offer longer operational lives and higher immunity to dv/dt. Employing these devices instead of electromechanical relays will bring about quieter operation and faster response, as well as permitting a higher degree of safety to be realised. As bulky permanent magnets will no longer be required, the systems created will also be less cumbersome. These attributes will help to accelerate the pace at which single phase motor appliances in homes are replaced by more efficient three phase options.

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White Goods Get Smarter

Driving permanent magnet synchronous motors

By Dr. Stephan Chmielus, Fairchild Semiconductor, Germany

The European Union has introduced the "EcoDesign of Energy-using Products (EuP)" regulation. The study for circulators revealed that the stringent requirement of energy efficiency can be met with sinusoidal-driven Permanent Magnet Synchronous Motors (PMSM) and variable-speed drives only.
Traditio-ally, sensors are used to detect the rotor position, which is essential for enhanced control techniques like Field Oriented Control (FOC). This article will explore the challenges of sensorless control of PMSM. This article will also examine Intelligent Power Modules (IPM) that are now replacing discrete solutions, enabling highly efficient and cost-effective variable speed drives.

The Key To Meet New Challenges

The new energy-saving standards that are proposed by the EU will impact the design of energy-using products. EcoDesign looks at all energy-consuming steps. It also considers the whole life cycle costs including production and disposal costs. The directive established a framework for setting EcoDesign requirements and will force all manufacturers that have products that are applied from AC line to be energy efficient. As an example, the pilot study for circulators in buildings gives an impressive overview including a detailed life cycle cost estimations for small and large stand alone circulators and circulators integrated into boilers [1]. To meet the EcoDesign requirements, the mandatory technologies for circulators are summarized by the study. The required technologies for large standalone circulators are shown in Figure 1, which is directly from the EcoDesign study. The existing voluntary efficiency classes are mentioned and compared to the proposed revised efficiency classes and to the Energy Efficiency Index (EEI). The A classification of the existing scheme is separated into two new classes (A*, A**) in order to distinguish between best available efficiency. Whereas the EEI describes the ratio of the calculated mean electrical power to the reference power. The study explicitly claims that only PMSMs fed with variable-speed drives are able to meet the energy-saving challenges.

As a result of the EcoDesign directive the Energy+ Pumps project [2] was initiated in 2006 to promote highly

Class (Existing Scheme)	Energy Efficiency Index	Class Under Proposed Revised Scheme	Circulator Type and Control
D-G			
C	0.8	C	450W standard (baseline)
	0.66	C	450W improved
	0.64	C	450W variable speed (induction motor)
B		B	
A		A	
	0.3	A*	450W PM motor (variable speed)
		A**	

Figure 1: Needed technology for 450W circulator to meet existing efficiency classes [1]

Special Report – White Goods

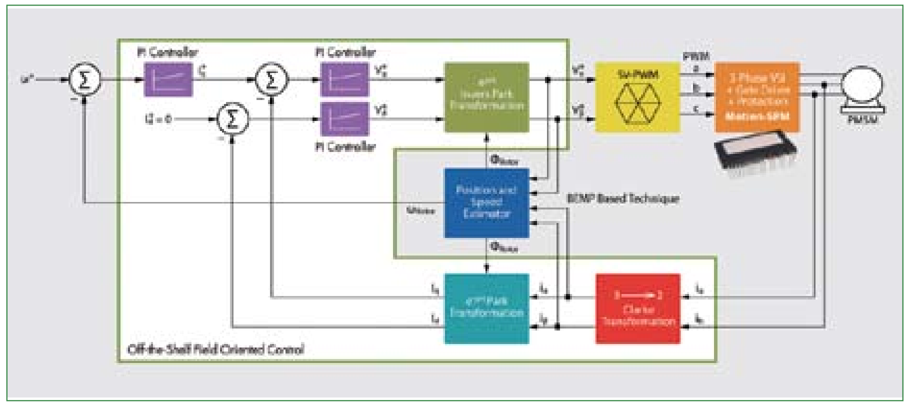

Figure 2: BEMF based FOC

energy-efficient circulators as the European standard. Using the example of low power circulators the final report of this project reveals that despite the higher purchase costs of the PMSM drives, the overall cost in 10 years will drop down to 50% compared to a conventional circulator. The investigation costs are amortized after roughly 2 years.

To enable energy-efficient PMSM drives, adequate voltage/current waveforms as well as frequency have to be supplied to the motor. Adjustable waveforms and speed allow using the drive optimally during any circumstances. Frequency converters enable designers to adjust the speed and current. Furthermore FOC is well popular for 3-phase AC motors to achieve high dynamic response of the drive.

Field Oriented Control of PMSM

The approach of FOC is to imitate the operation of a DC motor. It is based on the decoupling between the current components I_q and I_d. The block diagram of FOC including the needed surrounding components is pictures in Figure 2. The three time-variant output current (i_a, i_b, i_c) are transformed into two time-invariant values (I_d, I_q) using Clarke and Park. Hence transforming the three output phase currents into the stator fixed α, β reference frame and rotor fixed d,q reference frame simplified the required control strategy from a three dimensional AC value to a two dimensional DC value. The resulting two current components in the rotor fixed reference frame are quadrature current Iq and direct current Id whereas the quadrature current is perpendicular to the axis of the rotor flux and therefore it is proportional to the torque. The second current component Id is controlled to zero since a magnetizing effect of the rotor is not needed. Now the constant DC values can be easily controlled. The gap between the measured current components and the desired values which depends of course of the needed speed of the PMSM is the reference values for the PI controller and Inverse Park transformation. The inverse transformation yields in time-variant voltages (V_α*, V_β*) which are the input signals for Space Vector (SV) modulation. Finally the SVM generates the gate signal for the IPM.

Rotor position detection is essential for high dynamic response of PMSM drives. Traditionally the developers rely on mechanical components like encoder or resolver on the motor shaft to observe the rotor position. To remove the dependency of the sensors, to increase the ruggedness and reliability and after all to reduce the cost sensorless control of PMSM is still an interesting and growing research area. At higher speed the rotor position can be indirectly computed from the back electromagnetic force (BEMF), which is the preferred technique due to its simplicity. Modeling the PMSM as series combination of winding resistance, inductance and BEMF enables to estimate the BEMF provided that input voltage and current for each phase is measured (Figure 2). A possible observer afterwards like Luenberger can improve the estimation of rotor position by modeling the drive behavior and adjusting the mismatch between measured position and estimated one. The BEMF technique is superior at medium and high speed due to the speed dependant BEMF but cannot be surely applied to low speed and standstill.

Sensorless Control of PMSM at Standstill and Low Speed

The simplest way to start a sinusoidal driven PMSM is to accelerate the motor with a sequence of sinusoidal voltages until the BEMF-based position estimation can take over the control. However the dynamic performance of such a control would not fulfill the requirement of most of drives. Current research and development activities deal with the handling of industrial demands. Whereas the general specification is to utilize the current sensorless setup of PMSM drives. Enhanced techniques based on the variation of the impedance as a function of rotor position are investigated to detect the position at zero and low speed without mechanical sensors. Among other techniques two fundamental groups has been developed – the injection of a high frequency carrier signal and the transient injection method. Both groups have in common that the saliency presence in the motor is exploited to detect the rotor position, which can be indirectly obtained by the current response of the motor. The High Frequency Carrier Injection (HFCI) can be either realized in the stator fixed α, β reference frame or rotor fixed d,q reference frame resulting in an rotating or pulsating carrier. The rotating carrier injection is shown in Figure 3. The HF signal is superimposes to the time-variant voltages V_α* and V_β*. The resulting voltages modify the switching of the voltage source inverter (VSI) obtaining an HF current with rotor position information. Two orthogonal position signals can be derived from the Clarke transformed time-variant current components i_α and i_β. Afterwards the rotor position can be instantaneous detected by applying narrow bandpass techniques like heterodying filters. Additional sensors are not needed.

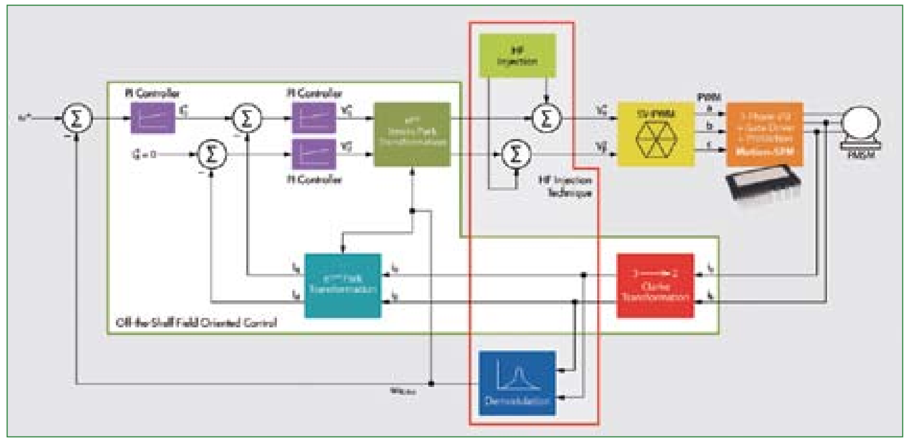

Figure 3: HF Injection (rotating carrier)

A promising transient injection method is the INFORM technique (Indirect Flux detection by On-line Reactance Measurement) developed by Schroedl [3]. A sequence of test voltages is applied to the PMSM via the VSI and the current reaction is sensed at specific times. The current derivation corresponds to the rotor position. The test voltage can either be a special measurement sequence interrupting the current control algorithm or can be integrated into the pulse pattern. This method will not disturb the torque since the test current is only a small portion of the load current. Hence it can be neglected in the phase currents. Combining this technique with an observer yields a stable control structure.

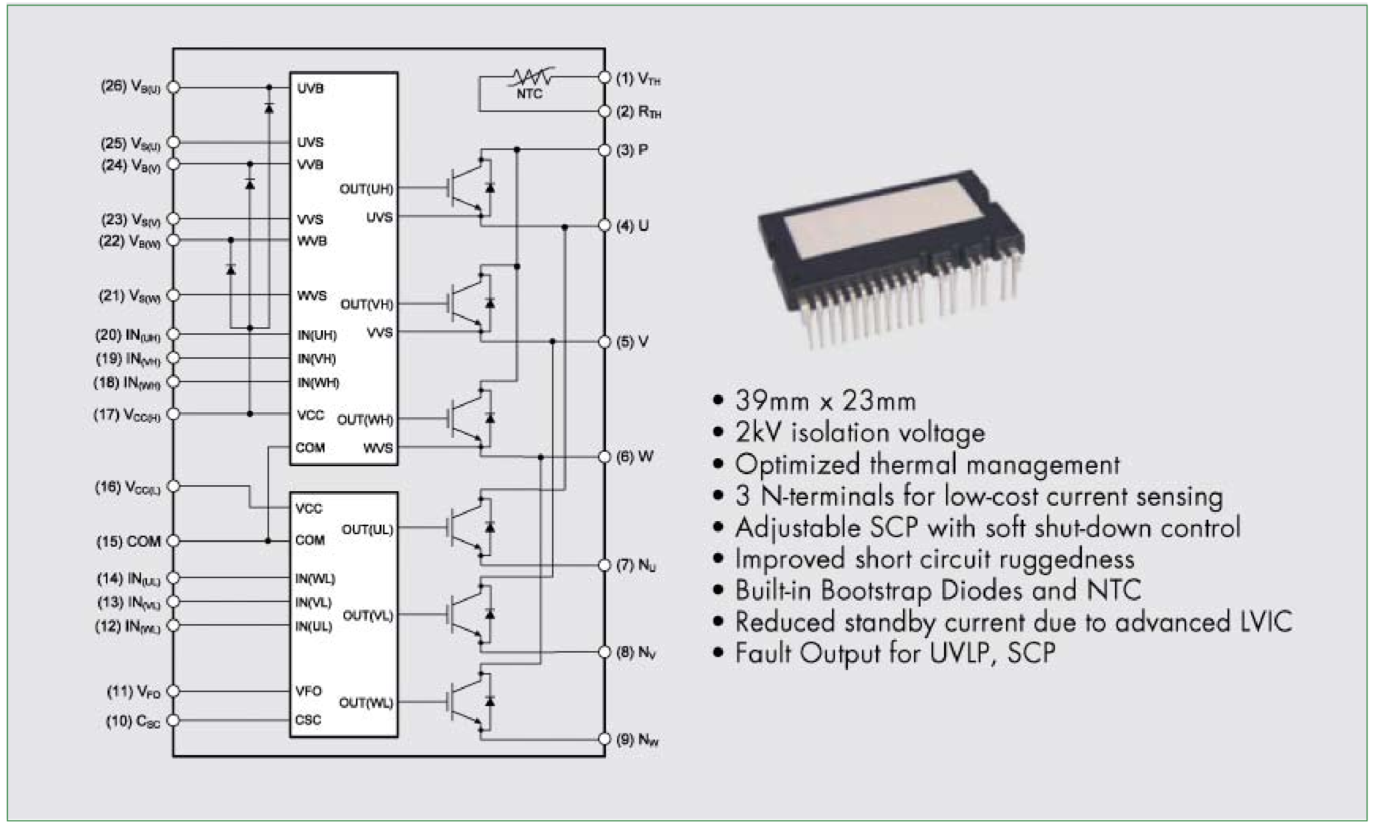

Figure 4: Internal Structure and Package of μ-MiniDIP SPM

Using IPMS for Energy Efficient Drivers

Intelligent Power Modules (IPMs) are increasingly used for frequency converters to meet the stringent requirement of energy efficiency and reliability. To meet the new requirements Fairchild has launched a new class of IPMs called μ -MiniDIP SPM® (smart power module). These modules excel in the package of only 39mm by 23mm containing a 3-phase VSI including bootstrap diodes, NTC, fine-tuned gate driver and additional protection functions as UVLP, OCP and fault output. Its internal structure is shown in Figure 4. The precisely matched IGBTs and drivers ensure higher performance. In addition the fully isolated modules reveal increased reliability, protection functions are close to the power switches and the low thermal resistance of the packages result in lower temperature changes over a load cycle. Using IPMs simplified the design-in phase due to an easier and faster design and higher flexibility.

Conclusion

EcoDesign is the moving power for highly efficient variable-speed drives using PMSM. Moreover, a sensorless-controlled PMSM drive is investigated to increase the ruggedness and reliability and to reduce overall costs. Modern IPMs enable highly efficient and cost-effective variable-speed drives.

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Home Appliance Requirements

Interconnection systems address needs

As the appliance industry becomes more global, manufacturers are placing a higher priority on their cabling and connector decisions when developing new designs produced on one continent and shipped into another. Now more emphasis is being placed on standardisation across all borders, whether it is for components listed on the bill of materials of the same washing machine built in Malaysia and the US or harmonising appliance design to meet the most stringent safety and environmental standards for shipment to Europe, India and China.

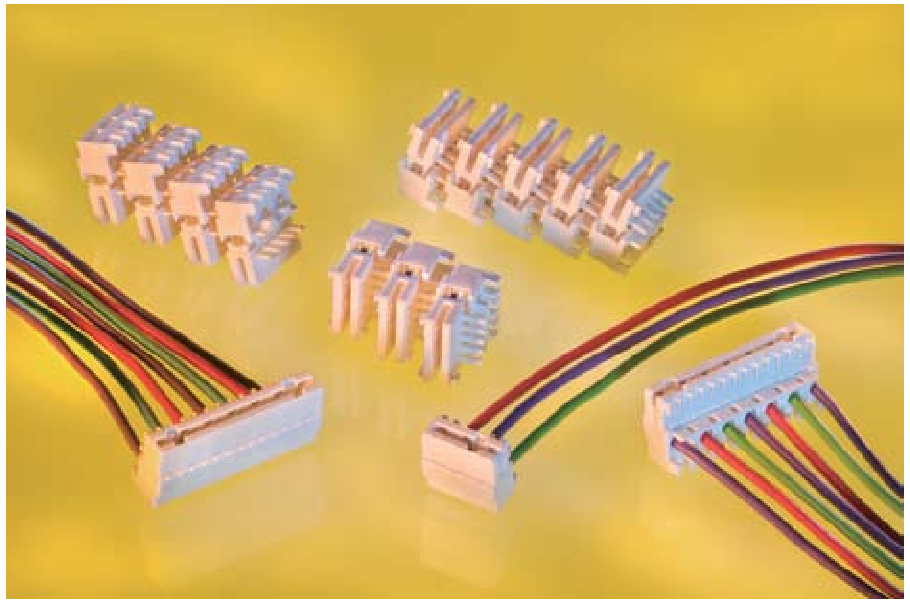
By Lee Thomas, Industry Marketing Manager – Home Appliance, Molex

Global environmental and safety standards

After successfully addressing the issues created by the RoHS and WEEE Directives, the connector industry is migrating it's products to conform to the requirements of IEC 60335-1 for Glow Wire.

The International Safety Standard IEC/EN 60335-1 4th Edition, issued by the International Electrotechnical Commission is a mandatory requirement for certain home appliances sold in Europe, although the signs are that this legislation will expand to other regions.

Connectors are involved in the section "Resistance to Heat and Fire" since they are "parts of insulating material supporting live parts". The Glow Wire test measures ignition resistance of the connector's plastic material. This is different from the UL94 testing. Glow Wire is designed to identify the tendency of a plastic material to resist ignition when wires are overloaded. A connector that is V-0 or V-2 rated does not necessarily meet Glow Wire requirements.



The Molex line-up includes RAST 5 for indirect mating in either 10A or 16A versions

All connectors in unattended appliances carrying a current greater than 0.20A must pass the Glow Wire test at 750°C. A connector passes the test if, during 30 seconds of applying a glowing wire, there is no ignition or any flames self-extinguish within two seconds.

Molex has released Glow Wire compliant versions of its most popular connector ranges used by the home appliance manufacturers and is continuing to do so. In addition to its ongoing work, providing customers with connectors that meet the latest safety requirements, Molex is also looking to the future.

As a leader in connector technology innovation, Molex can mould its connectors using environmentally-friendly, halogen-free compounds which are also Glow Wire compliant. This provides products that are not only safe but also eliminate the use of toxic flame-retardant materials that use bromine, antimony and phosphorus. Working closely with the world's leading resin manufacturers and renowned outside test houses, Molex goes a long way to help designers achieve the approvals they need.

Standard products across the supply chain

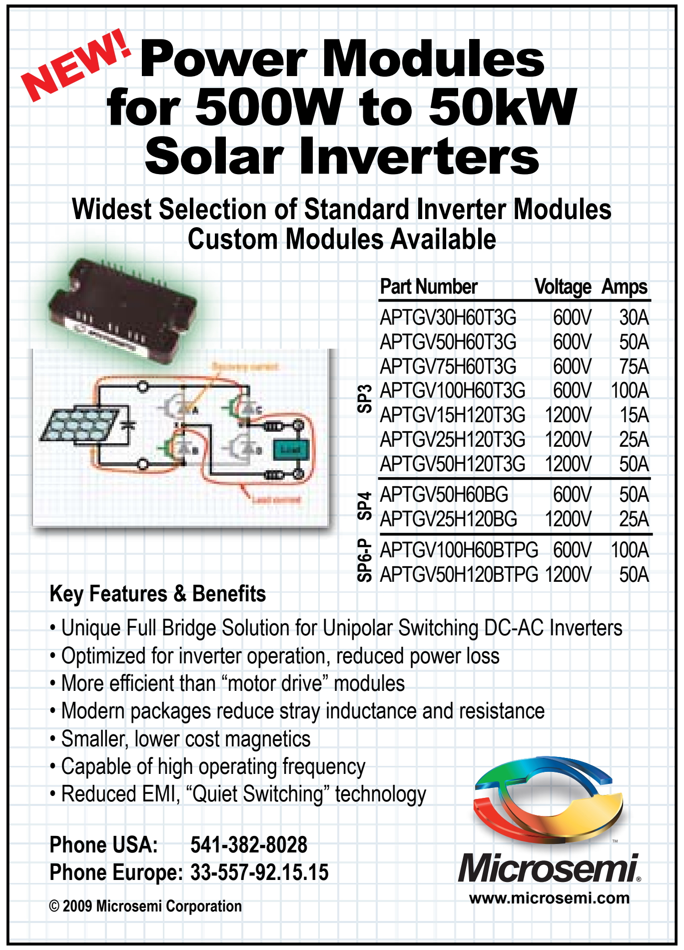
RAST has become the industry standard in home appliance wiring harnesses; originally introduced as a European standard, it is being adopted world-wide. At the same time, apart from crimping technology, insulation displacement technology (IDT) has become established as an alternative connection technique between the connector and cable. In the appliance industry, because of the significantly reduced applied costs, insulation displacement connections are now state of the art technology used not only in Europe but also the US.

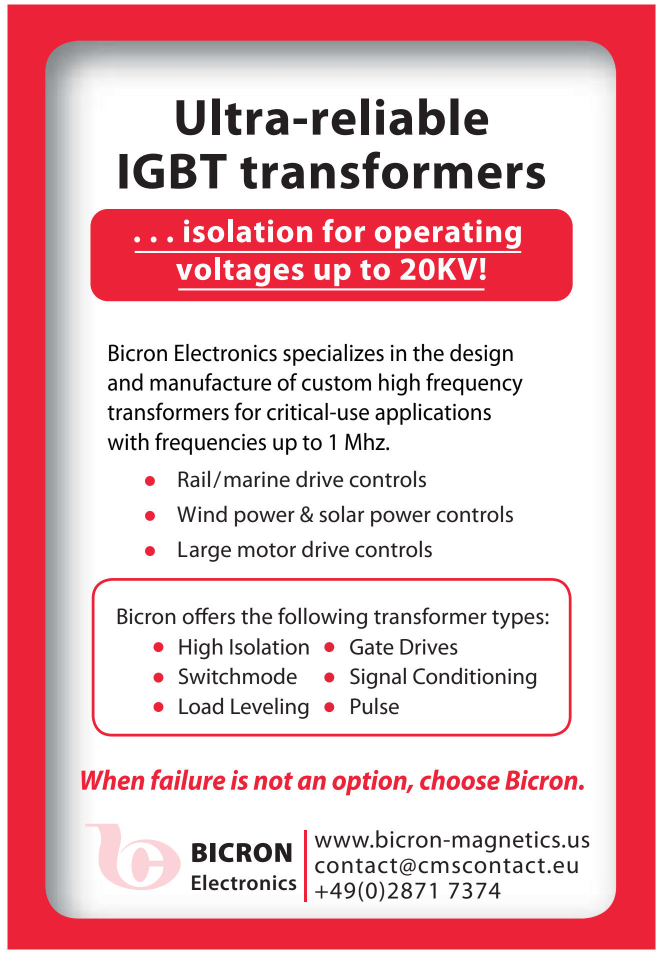
Molex is at the forefront of the design and manufacture of IDT connectors, with all RAST IDT and crimp products being Glow Wire compliant, as well as UL, CSA and VDE approved. The Molex line-up includes RAST 5 for indirect mating in either 10A or 16A versions. RAST 2.5 for direct and indirect mating and RAST Power for direct and indirect mating in both 6A and 10A versions.

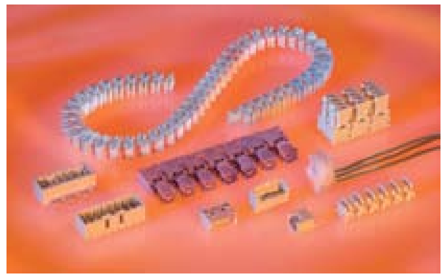
Utilising our experience in innovative connector design and state of the art manufacturing techniques, Molex has developed a new generation of RAST IDT connectors. The R5 connector uses a high conductivity alloy terminal that is designed to achieve the same mechanical and environmental specifications as existing RAST 5 designs. The RAST Signal product is designed specifically to optimise the connector performance when mated with single-sided PCBs. This achieves a greater 'normal force' but with lower insertion force figures than the standard RAST 2.5 designs.

Along with the comprehensive range of RAST IDT and Crimp connectors, Molex offers a full range of mating headers. They are available in vertical and right-angle versions for RAST 5, vertical for RAST 2.5 and RAST 2.5 5.00mm pitch products, with standard or custom polarisation and keying options available on request.

Along with the RAST IDT products, Molex offers a complete range of application tooling, from manual presses through to fully-automatic machines. These machines have a proven track record in the industry and are the tool of choice for major harness makers world-wide. As a global industry leader in interconnection systems, Molex has a team of knowledgeable and







The Molex line-up includes RAST 5 for indirect mating in either 10A or 16A versions

experienced tooling engineers in every region to support these products very cost-effectively.

Application specific custom solutions

Committed to continuous investment in research and development of new products, Molex maintains its position as a technology leader in interconnection systems. For home appliance designers faced with a specific challenge that cannot be met through standard connectors and integrated products, Molex engineers have successfully worked together to develop a tailored solution.

Ranging from 'Foam In Connectors', designed to meet the demands of the refrigeration industry, through connectors designed to mate with industry standard components such as motors and compressors, to custom made ribbon cable board-to-board jumpers and complete electro mechanical sub assembly re-design and manufacture – Molex has risen to the challenge.

Future-proof solutions

As with the consumer electronics market, home appliance manufacturers are continually looking for ways to set their products apart from their competitors. The latest trends include wireless remote control, appliances with built in video / audio streaming, small stackable appliances, RFID scanners, hand-held personal care and of course ultra-efficient appliances. It appears that the next generation of Home Appliances will also be designed and manufactured to be Smart Grid-enabled or at least have demand response capabilities. Such appliances will interact with the Smart Grid and will have the ability to temporarily reduce power or delay some normal operations. As consumers will still be able to override appliance actions, disruption in the home will be minimised. These initiatives will help to reduce overall energy consumption by delaying certain operations such as a refrigerator's defrost cycle until the energy load is lower, or reducing the wattage needed for a tumble dryer's heating elements.

All of these exciting developments require more electronics and hence more connectivity such as IO, docking station, board-to-board, RF and wire-to-board products. As an industry leading manufacturer, Molex is able to offer standard and custom solutions to help designers bring the future into today!

Innovative user interfaces

As well as a global leader in interconnect solutions, Molex has been at the forefront in providing custom user interfaces, membrane switches and flex circuits to the appliance market for over a decade. With manufacturing facilities placed strategically in the US, Mexico and China, Molex has invested in automated processes for screen-printing, surface-mount component bonding, die cutting and tactile element (dome) placement. Secondary processes include final assembly, 100% electrical inspection and testing and packaging. Furthermore, full-service prototype labs at each location can produce designs and qualify products prior to final tooling.

Molex engineers understand the demands and requirements of the home appliance industry and are experienced in finding the right solution for a particular application. Here capacitive touch switches, which are at the leading edge of design, are proving an attractive alternative to the conventional user interface technologies as they are resistant to harsh chemical exposures, contaminants and EMI.

When a finger or conductive object enters the field, the product recognises a change in the capacitance functioning similar to a switch or touch pad. There are no moving parts that can wear out or detract from the reliability of the product. In addition to being more robust and durable, the integration of unique backlighting elements and wide variety of overlay options, enable home appliance manufacturers to achieve an elegant and distinctive user interface design.

The appliance of science

Since 1945, when Molex entered the home appliance market with its moulded terminal block for range cookers, the company has remained at the forefront of connector design. Manufacturing some of the most innovative and reliable interconnect products in the world, Molex offers a broad portfolio of products and, combined with comprehensive expertise, provides unlimited possibilities for applications in the home appliance market.

Committed to following lean management and Six Sigma principles, Molex has developed state of the art manufacturing processes that lead to improved quality, whilst response times for customer specific requirements are greatly reduced. As a result, many of the company's home appliance connectivity products have become the industry standard for the latest technology-led designs.

Molex provides a seamless global service, including design, manufacture and sales. With a broad range of capabilities and strong customer focus, Molex believes it is uniquely positioned to fulfil the needs of the home appliance manufacturer. Whether based on the other side of the globe or just around the corner, Molex can assist home appliance engineers in reaching all of their design goals – with exceptional quality and efficiency.

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Coordinated Circuit Protection

For electronic components in household and professional appliances

Resettable circuit protection devices can be used to help provide overtemperature, overcurrent and overvoltage protection for the electric motors and fans, controllers, touch-pads, displays and interface circuitry required by sophisticated appliances.

By Faraz Hasan, Global Industrial & Appliance Marketing Manager, Tyco Electronics Circuit Protection Business Unit

The motors, controllers and electronic components found in household and professional-grade appliances can benefit from the application of coordinated circuit protection. Polymeric positive temperature coefficient (PPTC) overcurrent protection devices offer low resistance and are compatibly sized with fuse solutions. Like traditional fuses, they limit the flow of dangerously high current during fault conditions. The PPTC device, however, resets itself after the fault is removed and power to the circuit is cycled, obviating the need to replace a blown fuse.

Typical White goods illustration

Protecting increasingly sophisticated and complex control boards from misconnection, power surges or short circuit damage is of particular concern to the equipment manufacturer. Although appliance transformers, their enclosures and connections are capable of withstanding higher voltage transients, the use of sensitive solid-state devices on the board necessitates improved overcurrent, overtemperature and overvoltage control.

Coordinating overcurrent and overvoltage protection can also help designers comply with safety agency requirements, minimize component count and improve equipment reliability. A metal oxide varistor (MOV) overvoltage protection device, used in a coordinated circuit protection strategy with a line-voltage rated PPTC overcurrent device helps manufacturers meet IEC 6100-4-5, the global standard for voltage and current test conditions for equipment connected to AC Mains.

Controller Protection

Traditionally, single-use fuse technology has been used to protect electronic circuits from damage

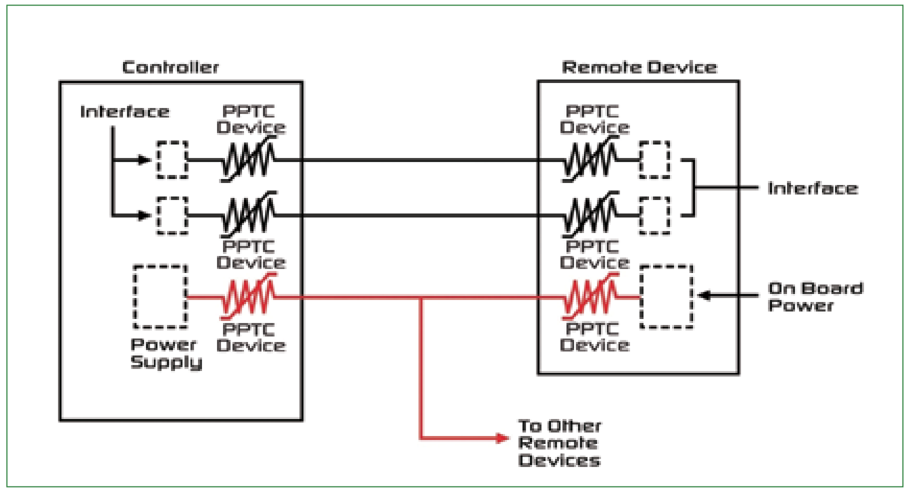

Figure 1: PPTC devices help protect the interfaces between controllers and remote devices as well as power inputs.

caused by overcurrent events. With this approach, the fuse blows when a wiring fault or part failure creates a condition in which excessive currents can flow, therefore breaking the electrical connection and helping prevent the potential for more widespread damage or fire hazards. The problem with this technology is that a failure in one system component can disable other components downstream and throughout the system. When this happens, the fuse must be accessed and replaced on all the affected components before the system can be made operational again.

In comparison, controllers and remote devices that utilize resettable fault protection technology can help minimize the impact that failure has on the system, reduce the number of system components affected, and shorten repair time. In many industrial controller applications, replacing single-use fuses with PPTC devices allows designers to maintain the same level of overcurrent protection on the critical interfaces, while generally eliminating the need for fuse replacement or service when an external fault condition causes high current conditions in the system.

In addition to controllers, any remote sensor, indicator, or actuator that requires a power, analog, or communications bus interface can benefit from the use of PPTC devices (Figure 1). These system components are subject to damage caused by mis-wiring, power cross, or loose neutral connections on AC Mains inputs.

Coordinating protection for ac mains applications

From small countertop appliances to professional grade ovens, increasing complexity and functionality are driving the industry toward circuit integration and board size reduction. Protecting sensitive electronic components from voltage transients, short circuits, and customer misuse is of primary concern to manufacturers.

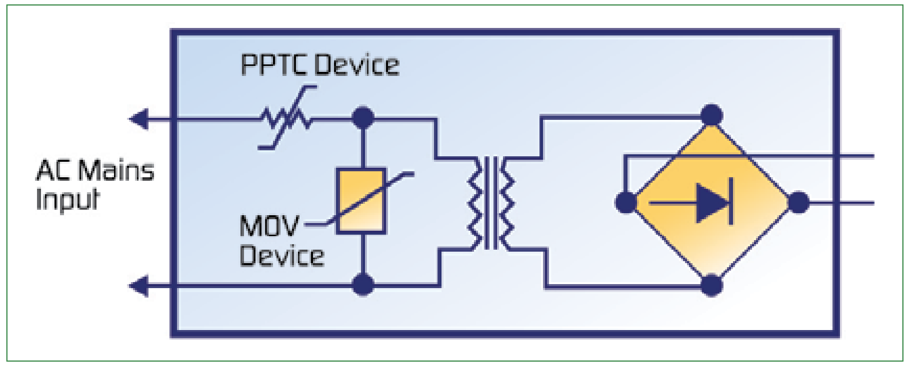

Figure 2: Coordinated overvoltage and overcurrent protection on AC Mains circuit

Electrical equipment can be exposed to potential damage from large voltage or power transients on the AC Mains inputs caused by lightning strikes or power station load-switching transients.

Coordinating overcurrent and overvoltage protection at the AC Mains input can help designers comply with safety agency requirements and minimize component count and cost.

Figure 2 shows how an MOV is used in combination with a PPTC device to help improve equipment reliability in the harsh AC environment, and helps fulfill the IEC-61000 test requirements.

The MOV device's high current-handling and energy absorption capability, fast response and low cost make it suitable for overvoltage protection in power supplies, control board transformers and electric motors. The PPTC overcurrent protection device is also rated at 240 VAC, permitting maximum intermittent voltages of up to 265 VAC, and it can be installed with the MOV device in the AC Mains input lines.

Unlike a single-use current fuse, the resettable PPTC device helps protect against damage from conditions where faults may cause a rise in temperature with only a slight increase in current draw. When installed on the primary side of the circuit, in proximity to potential heat-generating components such as magnetics, field-effect transistors (FET), or power resistors, the PPTC device helps provide both overcurrent and overtemperature protection with a single installed component.

Certain Mains overload conditions may cause the MOV device to remain in a clamped state where it will continue to conduct current. This may eventually result in an overtemperature failure of the device. While not directly applicable to passing IEC 61000-4-5 tests, placing the PPTC device in close thermal proximity to the MOV device can help protect the MOV device in extended overload conditions. It does this by transferring heat to the PPTC device, which causes the PPTC de-

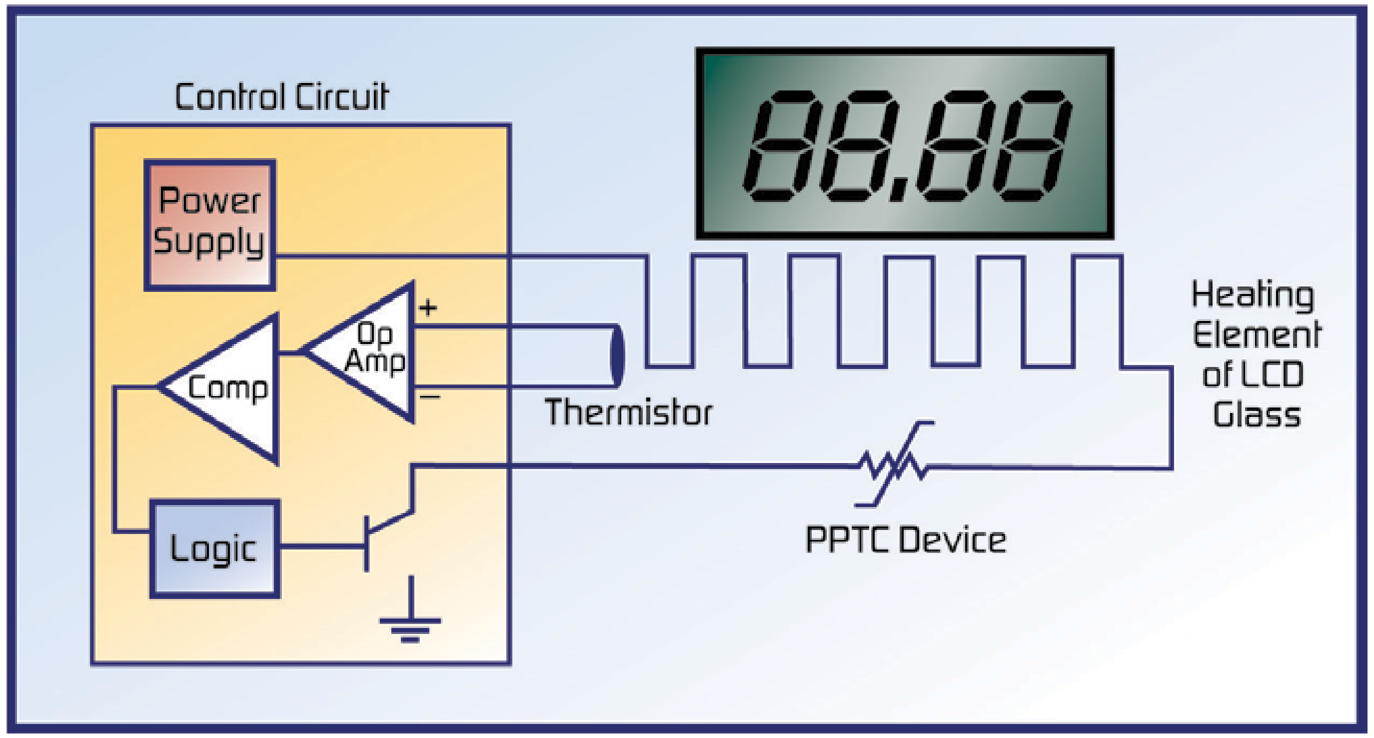

Figure 3: In an overheat condition, the PPTC device thermally trips to reduce current flowing to the heating element.

vice to trip faster, limiting the current through the MOV device.

The PPTC and MOV devices chosen for a particular application depend on the IEC 61000-4-5 class rating for the equipment as well as the operating conditions of the equipment itself. When selecting a PPTC device, the primary consideration is to match the hold current rating of the device to the primary current drawn by the electrical equipment under normal operating conditions.

LCD heater protection technique

Liquid crystal displays (LCDs) are used in a wide range of appliance applications and may be subjected to significant temperature variations. Because LCDs perform poorly at low temperatures, heaters are often employed to raise the display's temperature and improve functionality. Typically, the heaters incorporate temperature sensors connected to a microprocessor-controlled switch that modulates the heater, as well as a high-temperature shut off function that turns the heater off if the LCD temperature exceeds a specified limit.

The disadvantage of this approach is that the overheat control mechanism relies on the same microprocessor that is controlling the heater element. Consequently, if the heater control malfunction is due to microprocessor failure or some other functional control component, the high-temperature shut-off function may also be disabled. If this control circuitry fails, the current flowing through the heater element can increase and may lead to thermal runaway.

Installing a PPTC device, independent of the main heater controller, helps protect the LCD and the heater control circuitry from overtemperature damage. As shown in Figure 3, the PPTC device is typically placed in line between the power supply and the heater, in a thermally conductive relationship with the heated LCD panel. In this way, heat emanating from the LCD is transmitted to the PPTC device. When the LCD reaches a specified shut-off temperature the PPTC device "trips" and reduces the current flowing through the heater element. Once the fault is removed and the power is cycled, the circuit will reset to normal operating conditions.

Summary

Coordinating overcurrent, overtemperature and overvoltage protection can help designers minimize component count and reduce warranty returns resulting from failed motors and control board transformers. The low resistance, fast time-to-trip, low profile, and resettable functionality of the PPTC device helps circuit designers provide a safe and dependable product and comply with regulatory agency requirements.

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When White Goods Go Green

With this issue themed on white goods, it seems to me that this is yet another ideal opportunity for the power industry. Who else but engineers could make these products turn from ‘white’ to ‘green’? In Germany, there has been an interest in ecological cleanliness for well over a decade and I believe that this is now becoming the norm throughout the rest of the industry.

We have seen many advances in the electronic devices creatively engineered into so-called white goods. It’s no longer a motor connected to a power supply. There are advanced cycle timers, motor controllers, safety devices to avoid the once-prevalent failures, all of which minimize risk, noise and use of valuable energy. Once again, engineering is the key. We now see power devices and modules, microcontrollers, DSPs, circuit protection components and significantly improved motors and control to achieve all this. Not just achieve it, but at a viable cost.

Consumers want –and have come to expect - all white goods to be reliable with zero attention and maintenance, possess full functionality, to be environmentally friendly and to run as quietly as possible. This last feature is of particular importance where the appliance such as a washing machine, is located within an apartment. Again it is ‘engineering to the rescue’ - only good electrical/ electronic (as well as mechanical) engineering can achieve all this.

PV Consolidation

Q-Cells International was responsible for close to 150MW of new, non-residential PV capacity in 2009, surpassing many of its rivals. Unsurprisingly it also reveals that Spanish system integrators, who dominated the market in 2008, subsequently slipped down the rankings in 2009 as their domestic market evaporated according to IMS Research.

Despite the research identifying more than 200 active PV system integrators, none were identified as having a dominant market share in any of the segments analyzed highlighting the extremely fragmented nature of the system integration business and the difficulties PV component suppliers face in identifying their largest potential customers.

A number of PV component suppliers, such as Q-Cells and First Solar, have chosen to expand their activities from just supplying cells or modules to also building turn-key PV plants. It is likely this move was provoked by the need to chase margins that had tightened following the module price collapse in 2009, and also by the need to stimulate demand by financing and developing major PV plants themselves.

Although several hundred companies are now active in the non-residential market, industry consolidation looks certain, especially as challenging conditions are expected in the second half of 2010 following Germany’s FIT (Feed in tariff) cut.

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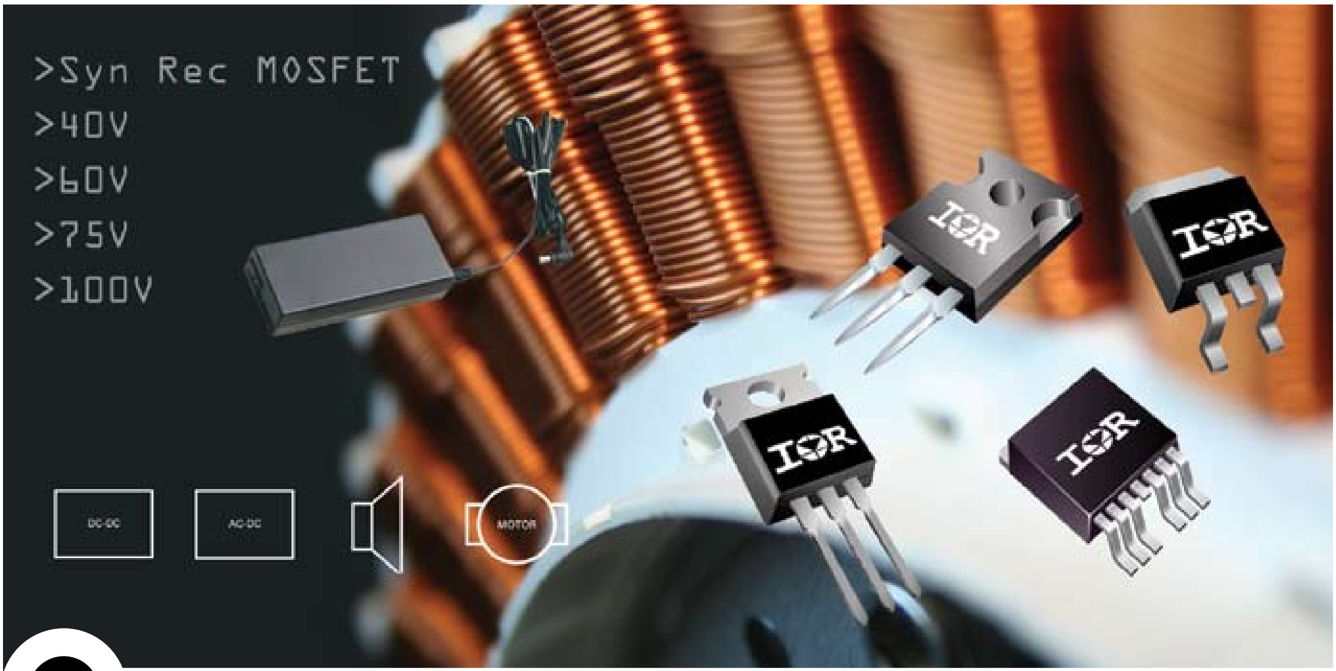

Lower $R_{DS(on)}$ Higher Performance

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Part Number	V_{DS} (V)	I_D (A)	$R_{DS(on)}$ Max @ V_{GS}=10V (mΩ)	Qg (nC)	Package
IRFS3004-7PPBF	40	240	1.25	160	D²PAK-7
IRFP4004PBF	40	195	1.7	220	TO-247
IRFS3004PBF/ IRFB3004PBF	40	195	1.75	160	D²PAK/ TO-220
IRFR4104PBF	40	30	5.5	59	D-PAK
IRFS3006-7PPBF	60	240	2.1	200	D²PAK-7
IRFS3006PBF/ IRFB3006PBF	60	195	2.5	200	D²PAK/ TO-220
IRFB3206PBF	60	210	3.0	120	TO-220
IRFS3206PBF/ IRFP3206PBF	60	210	3.0	120	D²PAK/ TO-247
IRFR1018EPBF	60	79	8.4	69	D-PAK
IRFP4368PBF	75	195	1.85	380	TO-247
IRFS3107-7PPBF	75	240	2.6	160	D²PAK-7
IRFS3107PBF	75	195	3.0	160	D²PAK
IRFB3077PBF	75	210	3.3	160	TO-220
IRFR3607PBF	75	80	9.0	84	D-PAK
IRFP4468PBF	100	195	2.6	360	TO-247
IRFS4010-7PPBF	100	190	4.0	150	D²PAK-7
IRFB4110PBF	100	120	4.5	150	TO-220
IRFS4010PBF	100	180	4.7	143	TO-220
IRFP4568PBF	150	171	5.9	151	TO-247
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