Power Systems Design
EUROPE
Power Control Intelligent Motion
January/February 2006

Pursuing the Power Paradox

PowerLine
PowerPlayer
Marketwatch

Power Systems Design EUROPE

Power Systems Design Europe

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Two Years Young and Stronger than Ever

This issue marks the beginning of Power Systems Design Europe's third year in publishing.

We are very pleased with the success our publication has achieved and the support we have received from our industry partners, friends, families and loyal readers.

2005 was a banner year for Power Systems Design Europe as within our ten issues; we published a total of 584 pages of content directed at the design and applications needs of European engineering professionals dealing with power electronics, power management and intelligent motion control.

As you are acutely aware, power has become a major issue in all product design spanning all sectors of the electronics industry and across all regions of the world. Power Systems Design Europe is solidly entrenched as the number one trade journal serving Europe's power electronics community.

We are firmly committed to lead the trends in power electronics, not follow them. To this end we have made several proactive enhancements to our publishing efforts. Specifically we have expanded our publishing efforts into China with the launch of Power Systems Design China, both in print and online during 2005. Under the direction of our Editor-in-Chief Liu Hong, powersdc@126.com, we will publish Power Systems Design China six times during 2006. Additionally, with Liu Hong working from our Beijing office, we now have a direct line to editorial from China's power electronics engineering community.

Our next geographic move, which takes place this month, is the Launch of Power Systems Design North America in an online format only, which will publish 10 times a year and be distributed to 32,000 power electronic engineering professionals.

On the editorial side, we have made several enhancements since we launched Power Systems Design Europe in February 2004. Specifically we established an "Editorial Steering Committee" to insure that we are editorially leading the community and have added five new columns which enable us to give you a broader peek into global power electronics industry. These departments are:

1. PowerLine—A feature product announcement column for significant new products launches.
2. PowerPlayer—Contributed each issue by one of our esteemed "Editorial Steering Committee" members. This is a platform for them to speak their mind about the power electronics industry. This is a no-holds-barred column on the topic of their choice.
3. TechTalk—A column which will debut in our March 2006 issue, TechTalk is a forum to interview senior level executives in the power electronics community about technical issues of significance.
4. MarketWatch—Contributed by Chris Ambarian, Senior Power Analyst for iSuppli Corporation. MarketWatch gives you a peak into the internal workings of our industry and what the future might bring.
5. Focus Series—Where we focus our editorial in that specific issue on a significant segment of power electronics, such as Automotive, industrial and portable power.

In case it is not painfully obvious; we are all about power, and support global power associations and events. Specifically, we are a member of PSMA (Power Sources Manufacturers Association) and "Official Media Partners" for PCIM Europe 2006—Nuremberg, Germany; PCIM China 2006—Shanghai, China and APEC 2006—Dallas, Texas USA.

If your travels take you to one or more of these events, please stop by our stand and say hello. Please see page 6 of this issue for dates and details.

Cheers!

Jim

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ON Semi Named Jean Marie Doutrewe Director

ON Semiconductor announced the appointment of Jean Marie Doutrewe as director of Sales, Marketing and Services operations in Europe, the Middle East and Africa (EMEA). Mr. Doutrewe takes over the responsibilities held by Sergio Levi, vice president of EMEA sales. Mr. Levi decided to leave the company at the end of 2005.

Mr. Doutrewe brings a wealth of semiconductor industry experience to the position, having held leadership roles in planning, logistics, customer service, distribution, and OEM sales. Most recently, he held the position of Director of ON Semiconductor's service operations in EMEA, and site manager of Piestany, Slovakia. In 2002—when the company decided to relocate its European and North American customer service operations to Piestany—Mr. Doutrewe led the centralization efforts.

Prior to ON Semiconductor's spin-off from Motorola, Mr. Doutrewe worked for Motorola's EMEA sales organization. Joining Motorola in 1987, he headed up the discrete product group planning team in Toulouse, France. During his career, Mr. Doutrewe has also worked as Business Director for General Electric's south Europe semiconductor division and held several management positions with RCA in Europe.

In this new role at ON Semiconductor, Mr. Doutrewe will dual report to Bill Bradford, senior vice president of the company's global Sales and Marketing, and to Charlotte Diener, vice president and general manager of Global Supply Chain Management.

www.onsemi.com

Zetex Named Hans Rohrer CEO

The Board of Zetex plc announces the appointment of Hans Rohrer as Chief Executive Officer to take over from Bob Conway who has decided to retire from the business.

Hans Rohrer brings a wealth of experience and a proven track record in the semiconductor industry to Zetex. Hans began his career in R&D at Diehl Data Systems before moving on to Texas Instruments where he held engineering and marketing positions. He has worked for the bulk of his career (1980-1998) at National Semiconductor. During his seventeen year tenure at National Semiconductor, Hans held several management positions amongst them vice president and general manager Europe and vice president for VLSI/mixed signal products. Under his seven year leadership as vice president and general manager, National Semiconductor Europe's revenues grew to well above a quarter of its worldwide revenues – the highest of any major US semiconductor company- and was ranked among the top three suppliers by all of its major customers.

Hans then became President of TSMC-Europe, the world's largest independent semiconductor wafer foundry where, in addition to being responsible for the day to day operations, he was instrumental in bringing about a far–reaching technological development project between TSMC, Philips and ST Microelectronics. Latterly he has been CEO of Acuid, a venture backed technology business specialising in semiconductor solutions for automated test equipment. Hans holds a master's degree in electronics and received business and management education from Stanford University, California and INSEAD, Paris.

Hans joined Zetex on 30th of December 2005, and will join the Board on February 1st 2006.

www.zetex.com

Silica Wins Demand Creation Award

Silica, an Avnet company, won the European Demand Creation award for being the clear leader with the highest number of new design opportunities within the first half of 2005. The award reflects the importance that Freescale places on the distribution channel in supporting demand creation growth.

"The success has been due to the way we interact with the customer, every project has very individual demands and it is essential that all aspects of the project are considered before designing in a product," said Miguel Fernandez, President of Silica. "We put great emphasis on supporting customers with application based design-in support and thereby create greater demand for products."

Silica markets the entire Freescale product range and supports customers with in-depth technical workshops on a European base.

www.silica.com

STMicro Among Top Ten Green Companies

Already Successful with its iSim Tool for PSTMicroelectronics has been named at the top of the Best Management Practices category and ranked among the Top Ten Companies of the Decade in the inaugural Low Carbon Leader Awards presented by The Climate Group and published with a recent survey on greenhouse gas emissions by BusinessWeek, on December 12, 2005.

The Climate Group and BusinessWeek have recognized and acknowledged ST's best-in-class management practices, initiated by ST's former CEO, and Honorary Chairman Pasquale Pistorio, and carried on by the Company's current CEO, Carlo Bozotti. Pistorio, who believed environmental initiatives in making chips should come from the top, issued ST's Environmental Decalogue with measurable, time-defined goals for environmental performance in 1995. With its aggressive Carbon Roadmap as a top executive priority, ST has succeeded in reducing its CO_2 emissions by 50% over the past ten years, targeting carbon neutrality and total accumulated energy savings of $900 million by 2010. Last year alone, the Company saved $173 million in energy, water, and chemical costs, relative to its 1994 per-unit benchmarks.

Apart from reducing total emissions of CO_2 by at least 5% per year, ST's carbon neutrality programs include aggressively trimming emissions of perfluorinated compounds, adoption of renewable energy sources, such as wind and water, and reforestation as a means of compensating for the remaining CO_2 emissions.

The jury has also rated ST's Honorary Chairman Pasquale Pistorio as one of the most influential individual achievers in the fight against global warming.

www.st.com

National Power Design Courses

National Semiconductor will hold a tour of advanced technical courses on power management design, starting on February 23rd. Design engineers will receive an in-depth training in power supply design and analysis from the industry leader in power management ICs. The course will be presented by experts from National, with guest speakers from Coilcraft and the University of Salerno (Italy). It will cover techniques, topologies and tools to address real-world design needs. Design engineers are invited to participate in free, day-long courses in seven cities in Europe and Israel.

Each of the 1-day courses will consist of five training segments:

- High current buck switching power supply design
- Forward active clamp design
- New power supply solutions
- Practical design considerations
- Optimising magnetics selection and design for power supplies

All courses are free of charge. Pre-registration is required to guarantee a place, which includes lunch and presentation handbook. For detailed information and registration, see www.national.com/see/powercourses

www.national.com

Maxwell Expands Distributor Network

Maxwell Technologies announced that it has added eight new distributors in Europe and the Middle East to serve growing demand for BOOSTCAP ultracapacitor products and related technical and customer support. "These new channel partners will help us to ensure the best service and technical support and fast, local language response for customers in their respective geographic regions."

The newly signed BOOSTCAP distributors are:

- Alfatec – Germany,
- Alphatron – Netherlands, Belgium, Luxembourg and Denmark,
- BLL – Israel,
- Dimac Red – Italy,
- Inelec – Spain,
- OEM Components – Sweden, Norway, Finland and Poland,
- Williamson – France
- Young ECC – United Kingdom.

BOOSTCAP ultracapacitors are an innovative energy storage technology ideally suited for applications needing repeated bursts of power for fractions of a second to several minutes. Ultracapacitors provide up to 100 times the energy of conventional capacitors and deliver up to 100 times the power of ordinary batteries, require no maintenance, and operate safely and reliably in extreme temperatures.

www.maxwell.com

Power Events

- ***EMV 2006,*** *March 7-9, Düsseldorf www.mesago.de*
- ***ECPE 2006 SiC User Forum,*** *March 14-16, Nuremberg, www.ecpe.org/news/news_e.php*
- ***APEC 2006****, March, 19 - 23, Dallas TX, www.apec-conf.org*
- ***PCIM China 2006,*** *Mar. 21 - 23, Shanghai www.pcimchina.com*
- ***PCIM Europe 2006,*** *May 30 - June 1, Nuremberg, www.pcim.de*
- ***SMT/HYBRID 2006****, May 30 - June1, Nuremberg, www.mesago.de*
- ***SENSOR/TEST 2006,*** *May 30 - June1, Nuremberg, www.sensor-test.de*
- ***EPE-PEMC 2006,*** *Aug 30 - Sep 1, Portoroz, Slovenia, www.ro.feri.uni-mb.si/epe-pemc2006*
- ***MICROSYSTEM,*** *October 5 - 6 , Munich, www.mesago.de*
- ***ELECTRONICA 2006,*** *Nov. 14 - 17, Munich, www.electronica.de*
- ***SPS/IPC/DRIVES 2006,*** *Nov. 28 - 30, Nuremberg, www.mesago.de*

National Semiconductor Introduces Industry's First Single-Chip, Power over Ethernet Device Controller Designed for Low-Voltage Auxiliary Power Sources

ILM5071 offers designers better flexibility to operate PoE powered devices from AC adapters as low as 9.5V or from the power sourcing equipment

Billed as the industry's first single-chip solution specifically designed for Power over Ethernet (PoE) devices that operate from alternative power sources or the PoE-enabled network. The LM5071 is a Powered Device (PD) interface and DC-DC converter IC that simplifies the design of a variety of PoE applications that require an auxiliary power source such as an AC adapter.

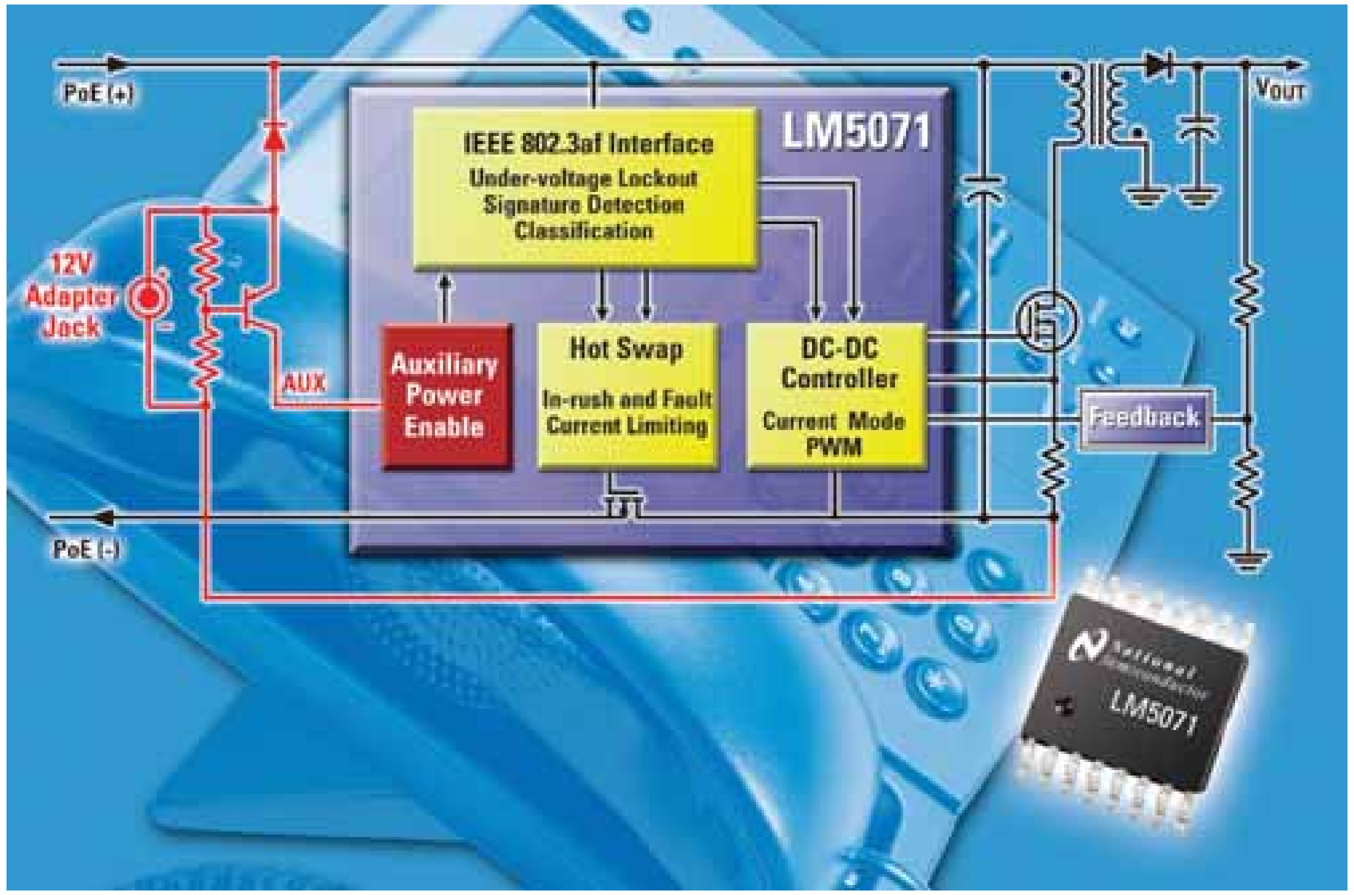
Devices powered by a PoE network include IP phones, security cameras and wireless local area network (WLAN) nodes connected through Ethernet networking cables and ports. Operating these PoE devices from alternate power sources is often necessary to relieve the burden on the Power Sourcing Equipment (PSE) or to operate the device on a network that is not PoE-enabled. Current solutions limit the choice of auxiliary power sources, which can drive up overall system cost or complexity.

National's LM5071 is the industry's first single-chip, IEEE 802.3af-compliant PD interface port and pulse-width modulator (PWM) controller specifically designed to accept power from external AC adapters. The LM5071 integrates a PD front end that accepts power from the PSE or auxiliary power to a single chip with a DC-DC controller that steps down the input voltage to power various PD loads.

Powering the device from an AC adapter can be tricky and requires forethought by the IC designer. The LM5071 solves the auxiliary power interface problem encountered by many PoE equipment designers with an elegant, integrated PD solution. This new addition to National's PoE power product family accepts a wide range of AC adapter voltages, giving equipment designers the flexibility to optimise total system cost.

Key technical specifications

The LM5071 is fabricated with National's ABCD150-XV1 high-voltage analogue bipolar/CMOS/DMOS technology and offers advantages such as an integrated, high-frequency, current-mode DC-DC controller, user-programmable under-voltage threshold and hysteresis, and a highly accurate fault current control loop. It features a maximum input voltage of 80V, user-programmable oscillator frequency up to 1 MHz and over-temperature protection, plus a voltage reference and high-performance error amplifier for non-isolated applications.



Compelling features and benefits

National's LM5071 has a number of unique characteristics that make it easy to design in:

- Auxiliary power interface: Accepts a wide range of auxiliary power source voltages (12V to 48V) and activates the DC-DC converter to efficiently supply the various loads of the PD.
- UVLO threshold and hysteresis: Designers can program the under-voltage lockout (UVLO) trip-point and hysteresis completely independently. This allows precise control of start-up line currents and the start and stop voltage points as desired in a variety of system applications.
- Controls isolated or non-isolated DC-DC converters: Integrates the precision voltage reference and error amplifier for DC-DC feedback in non-isolated converters, including the simple Buck topology. Provides internal pull-up for opto-coupler transistor in isolated designs.
- Signature resistor disconnect: The 25 kiloOhm signature resistor is disconnected after PD detection to reduce power loss.
- Programmable oscillator frequency: The oscillator for the switching regulator controller is fully programmable, allowing the user to optimise regulator performance.
- 50 percent or 80 percent maximum duty cycle: Available with either 50 percent or 80 percent maximum PWM duty cycle to support a variety of DC-DC converter topologies and permit operation over an extended input voltage range.

http://power.national.com

Striving for the Universal Power Management Solution

By Davin Lee, VP, General Purpose Power, Intersil Corporation

In today's ever changing world of hardware technology, the one thing that remains constant is the need for more sophisticated power management. Driven by power hungry processors, FPGAs and other semiconductors, today's power management solutions deliver increased power, greater efficiency, programmability and higher integration while residing in smaller packages.

These advances in power management did not take place overnight. It has taken greater than 20 years to get to this point. Evolution, not revolution, has defined the progression of power management in the semiconductor space since its inception.

Just a few years back, linear regulators were the choice of many board level designers as they were simple to use and required little to no power design expertise. This combined with the low cost of linear solutions made them the voltage regulator of choice. Switching regulators were relegated to higher output loads which require higher efficiency.

Today, switching regulators are prevalent due to numerous factors. First, better power dissipation results in the elimination of special power packages and heat sinks, thereby reducing the complexity and cost. Second, power budget management has become extremely important to system designers and, as a result, efficiency has become the main factor in selecting the optimal power solutions. This is the area in which switching regulators excel, particularly when higher loads are required. Third, the cost of switching regulators has decreased over the past few years as better process technologies have allowed higher integration and resulted in smaller die sizes. Many of today's switching regulators have PWM controllers, FET drivers and the power FET(s) integrated into a single package. Fourth, higher integration has allowed higher switching frequencies, leading to smaller size of external inductors and capacitors and consequently a smaller footprint. Fifth is the increase in the "ease of use" factor. With internally-compensated regulators, a designer is no longer required to perform tedious complex calculations to determine the optimal external components to achieve an efficient and stable control loop. Today, he or she can simply select the input and output capacitors and output inductor from a table based on a set of parameters. With this simplification in implementing switching regulators, the average designer can now take advantage of the higher efficiencies achieved with switching regulators to minimize heat dissipation and maximize power budgets. Better heat dissipation, higher efficiency, reduced cost, higher integration, higher switching frequency and consequently smaller footprint, as well as ease of use have made switching regulators an attractive alternative to linear regulators. There remain certain cases in which linear regulators are still the optimal choice, but switching regulators are now the preferred solution among system designers.

Another evolution in power regulation is the adoption of wide input voltage (Vin) multiple output power solutions with highly programmable features. Today, more and more systems are requiring numerous voltage rails to support the various semiconductors that reside on the board. Multiple output power solutions have risen to address this demand. Products such as the ISL6442 contain two PWM controllers and a linear controller in one package with a wide Vin range of 4.5V to 24V. The switching frequency is programmable from 600 kHz to 2.5MHz to allow usage of smaller output inductors with all three outputs being programmable.

With the advent of digital power, we are one step closer to arriving at a universal programmable switching regulator. Although digital control loops remain unproven in the mass market, they are on the verge of delivering the stable performance found previously in analog control loops in addition to providing access to programmable parameters digitally. By utilizing a digital interface such as PMBus, a power designer can quickly and easily modify the digital power integrated circuit's digital coefficients to adjust and fine tune parameters related to loop compensation, advanced fault protection and monitoring, sequencing and startup, thereby increasing performance of the regulator and increasing protection and reliability. Software GUI-based tools make the task of digital programming easy and accessible to power designers. Before digital power, this flexibility and control was only accessible to a chip designer during the design stage or to those exceptional power engineers that fully understand external compensation schemes.

www.intersil.com

Want a Bigger, Greener Power Market? Learn to Lobby

By Chris Ambarian, Senior Analyst, iSuppli Corporation

There is a certain soundness to the logic proposed by several folks in the industry that says that if you make green-ness and power efficiency cost-neutral to the customer, then the market for those efficient products will expand rapidly. Sounds reasonable enough on the face of it. But today I'm going to question both the premise and the implication in this assertion. I would like to suggest that this thinking over-simplifies and/or misjudges the market in two dimensions—both the supplier side and the customer side—and in doing so we unnecessarily reduce the adoption of higher efficiency electronic equipment. This has the doubly negative effect of both unrealized revenues for suppliers, and the prolonged use in the world of low-efficiency electric equipment.

First, let's ask ourselves a leading question. Why do we even have the occasion to be talking about ways to expand the high-efficiency power electronic equipment market? I would suggest that the reason is that we intuitively know that efficient electronic replacements for traditional electric equipment are already cost effective, and that market adoption of these technologies could be much, much higher. But if efficiency is already cost effective and market adoption is low, then there must be more to the story. To just pursue cost effectiveness may overlook some other inertia, purchase barrier, or irrationality on the part of the consumer.

In my own examinations of the market success of high-efficiency power technologies in various applications, my findings are that there is a non-exclusive priority ranking of four key factors that drive adoption rates. To jump right to the conclusion of this discussion, that ranking is:

1. Legislative mandates for efficiency
2. Cost of energy
3. Elimination of cost barriers to purchase
4. Voluntary efficiency guidelines

Now to flesh out our discussion and justify this list, let's take a look at each, from the bottom up.

Voluntary guidelines

Here we have things like EnergyStar from the US Environmental Protection Agency (EPA). This is a non-legislated guideline, designed to help policy makers more easily make or encourage certain buying decisions. The great thing about them is that such guidelines are simple; they can be created relatively quickly and, with the proper bit of networking and private lobbying, retailers can be pressured into pressuring their suppliers (and their suppliers in turn) to comply with the guideline. The downside is that in searching for something achievable without having any authority whatsoever, compromises must be made and the guidelines very rarely push efficiency to levels that are at all technically challenging—essentially, they are a lowest common denominator efficiency approach.

In summary: consumers get non-aggressive efficiencies; adoption rate limited to that mandated by retailers. Thus far, that's probably 40% of the market, max. Market examples:
1) The PC market. Monitors are EnergyStar compliant. Peripherals are often not. Power adapters are most often not. 2) The Kyoto Protocol. Voluntary, and yet fleet fuel-efficiencies have actually decreased since its adoption by over 100 countries.

Eliminated initial cost barrier

I worded it this way because I think this is a more universal phrase that covers not only cost reduction, but actually any means by which we can mitigate a potential consumer's reaction of "I would like to buy it, but I won't pay that much extra for it." Thus, if you lower the price of that super-efficient water heater down to the same price as that cheap, inefficient one, yeah, I'll buy it. OR, if the energy utility company will give me an incentive payment that makes the price differential almost nothing, I'll also buy it. Why? Because you eliminated my cost barrier!

In summary: Consumers get as much efficiency as you'll provide them for the same immediate or initial cost. Market adoption is limited only by how many people have access to the lowered barrier, as well as by replacement life cycle and customer inertia (or laziness). Note that the customer needs to have no barrier at the time that they go in to purchase—which in the case of refrigerators or air conditioners may be a replacement cycle time of 5 to 20 years. The subtleties and interactions between cost, efficiency, government policy, and market development can be the subject of an entire paper; suffice to say for today that in fact, lowering the price to the customer of an efficient solution to

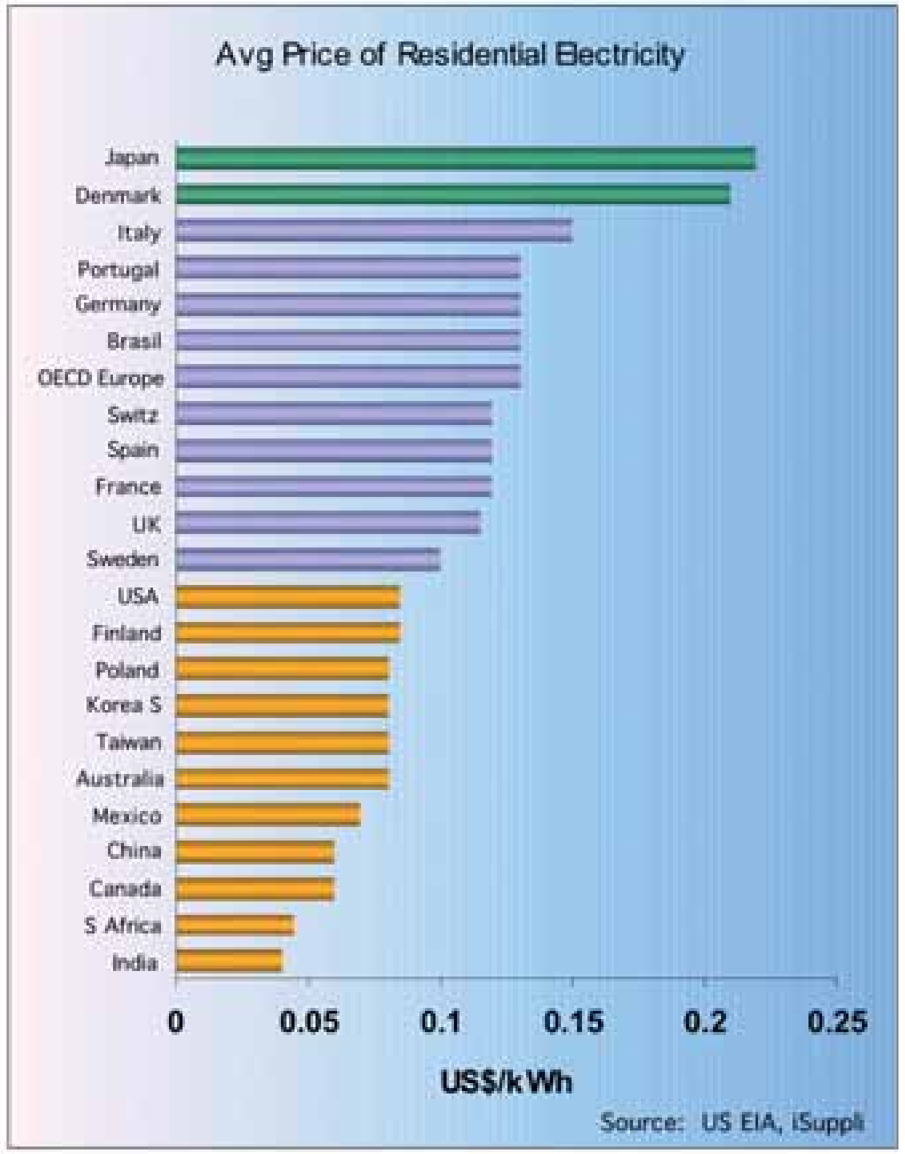


Figure 1. Average worldwide cost per kWh of residential electricity, by country, 1992-2002. The cost for industrial usage is roughly 50-60% of these amounts in every market. (Source: US Energy Information Administration, iSuppli)

the point where it's cheaper than an inefficient solution is a great, consistent way to effect market adoption—but it's not always possible to do. That fact that it may not be possible for a particular product does not necessarily invalidate the overall cost savings of that product—it simply may mean that other ways of eliminating the initial-cost barrier should be considered. And note that even if this barrier is reduced or eliminated, total conversion of the market is not ensured. Example: rebates from electric utilities given for purchases of more-efficient models of refrigerators or fluorescent lights.

Cost of energy

I took a look at the cost of electricity in countries around the world for the several years period leading up to 2002. Most of the world has been paying a fairly stable price for electricity for the last decade, at prices that fall into 3 main groups, as shown in Figure 1. Group 1 is Japan and Denmark at over US $0.20/kWh; Group 2 is Most of Europe, at US $0.12-.15/kWh, and Group 3 is the Rest of the Industrial World, at roughly US $0.07-.09/kWh.

I noticed a striking correlation between this graph and the penetration of high-duty cycle fractional motor drives: The higher the cost of electricity, the higher the penetration rate of electronic controls on motor drives. For motors with a high duty cycle (i.e., appliances that spend a high percentage of their time on), the correlation is remarkable. There is a strong correlation between the cost of electricity and the ratio of motor drive penetration. In markets where the cost of electricity is high, there is a very high rate of adoption of motor controls. In Japan, virtually 100% of air conditioners have inverter drives, while China, the world's largest producer, uses inverters on less than 10% of their production. Similarly, China employs inverters on less than 1% of refrigerators, the US about 5%. 9% of Chinese washing machines have inverters, versus 17% in the US, versus 30% in Europe. In Europe (very obviously in Denmark), a consumer chooses an appliance on the basis of how "green" it is (class A, class B, class C), while in the US, there is merely "efficient" (which is not very efficient at all by electronic standards), and non-efficient.

Could it be that consumers aren't so dumb? Yes.

In summary: Consumers get as much efficiency as they can afford—a decision driven by the cost of energy. Market adoption is paced over time by the cost of energy, and the amount of savings that the efficient technology option offers. Example: hybrid electric vehicles. The price of fuel goes up, and people begin doing the calculations. (HEVs also demonstrate that consumers can even be counted upon to do rather complex, application-specific calculations to evaluate different types of equipment!)

Legislative mandate

Finally, what if the consumer no longer gets the option of using an outdated (but cheap) inefficient technology? We bristle to even think that our "freedom" of choice may be removed – but just for a minute, let's think about it. Imagine we no longer have a choice; as of today, we have to buy an appliance that costs $50 more. Will we simply not buy? No, we need to wash our clothes,

	Extent of Conversion (Market Growth)	Rapidity of Conversion	Potential Efficiency / Consumer & World Benefit	When? (Proactive vs. Reactive)	Supplier Ability to Affect	Action Required by Suppliers
Legislative Mandates	The extent mandated (~100%)	As immediately as chosen	Highest	Proactive	Good	Learn to Lobby
Cost of Energy	Can be driven to 100%, depending on cost of energy	Moderate, <life cycle	Moderate (due to delay)	Reactive	None	n/a
Elimination of Initial Cost Barriers	Low to Moderate	Slow, ~life cycle	Moderate to Low	Proactive	Good	Aggressive Cost Reduction
Voluntary Efficiency Guidelines	Varies; usually low	Slow, ~life cycle	Moderate to Low	Varies	Little	Supply Data

C. Ambarian, iSuppli

Figure 2. A summary of market adoption drivers for efficient electronic solutions. Legislation is ranked highest, due to largest potential impact on growth and environment.

or to stay cool in the summer, or to keep our food cold. So we buy… and then we save $25 or $50 per year in energy costs. The appliance lasts 10 years—so we have 8 years with an extra $25 to $50 to spend elsewhere in the economy—not to mention that we lowered our energy use and its impact on our environment. And as an added benefit, the appliance is functionally more sophisticated! So what is the problem?

The challenge here is really the same as it is with any legislative activity: groups from both sides of an issue lobbying for legislation that will serve their interests. In general, we have in the past been able to count on someone among our government representatives to propose excellent laws—and, we have not been able to count on the entire body of representatives to ratify those proposals. Ratification is generally determined by the side that does the most effective lobbying.

As an example of the challenges, in the USA a few years ago we passed laws requiring greater efficiency in home central air conditioning units. This was a superb opportunity for a market expansion for electronic motor speed controls. Instead, what got passed was weaker legislation that measured system efficiency at 2 fixed operating points, rather than across a range of values you might see in real world operation. It was a simple business for manufacturers to avoid using a variable speed drive by using a cheap start capacitor and relay and by optimizing for those 2 set operating points—even though that optimization didn't substantially increase efficiency at all in normal use, the way an electronic speed control would have. (The good news is that with subsequently passed regulations going into effect this year, virtually the only way to meet the efficiency ratings is to use an electronic control).

On the other hand, by requiring all new homes to be outfitted with a minimum number of compact fluorescent lamps, governments significantly drove the adoption of electronic ballasts. There was intense lobbying by builders to not have to invest the extra $15 per home—but once the regulations were passed, the builders went whimpering away, and just complied. No one suffered.

In summary: Consumers all must buy the efficient solution (at least as efficient as is mandated), and market adoption is paced only by how quickly the laws take effect, and on how quickly consumers have to replace their existing solutions. Example: electronic ballast fluorescent lighting legislation in California that required all new buildings to be outfitted with a minimum number of electronic fluorescent lamps. Becoming effective in the late 90s, virtually 100% of new buildings began containing compact electronic fluorescent lighting almost overnight.

So what are the strategic implications of this multi-faceted model of consumer adoption of green technology?

First, it strikes me that in countries where the cost of energy (be it electricity or petrol) is high, the job of suppliers of high-efficiency equipment is as simple as making the potential customer aware of the savings available. Consumers will figure out what to do—though it may take some years, and the conversion will be less than complete (there are always those who can afford to buy the fuel for a Hummer).

In countries where the cost of energy is low, the challenge is more complex. Low cost of energy has a nearly 1.0 correlation with consumer indifference to efficiency (examples being the USA, China, and Russia). The good news here (at least for semiconductor and electronic equipment manufacturers) is that the cost of both electricity and of petroleum products has risen sharply since 2002, taking them above the historically constant prices they were at for many years, and this should accelerate growth without any further action on our part. But still, even with higher energy costs, those costs are still not in line with those in the middle-tier countries in Europe where after many years there is still a significant portion of the market yet to be converted to electronic solutions.

In those applications and especially in those geographies with low adoption rates, the market can still be aggressively grown by a combination of tactics that play on the other market drivers in the list.

The easiest (but lowest impact) action is to encourage voluntary guidelines. Such actions are already taking place, with various organizations working to create standards and encourage their adoption. From our standpoint in the industry, this doesn't really require much of us except to help provide efficiency data to those organizations to assist them in crafting their messages.

But the real terra incognita for the power management industry is to become heavily involved 1) in the public policy side of the elimination of the initial cost barrier, and 2) even in the drafting of laws that would require high-efficiency electronic solutions in all those applications that would provide the consumer enough benefit to result in a net return on their extra investment.

On the issue of the initial cost, one way to do this is to just make the more efficient approach cost the same or less, as some suggest. The other is to encourage governments and/or public utilities to subsidize the consumer's initial investment in highly efficient technologies to the point that the subsidy overcomes the consumer's hesitation. The subsidies can end when costs come down to a point of parity, or when mainstream consumers realize that in fact the higher efficiency technology is the way to go.

The second area even more uncharted for suppliers in general would be to actively lobby for mandatory requirements for compliance with aggressive but achievable efficiencies. This is not such a farfetched notion: in the face of the failure of consumers and suppliers alike to adhere to the targets set by the (voluntary) Kyoto Protocol, the EU is already strongly considering mandatory compliance for fleet-average fuel efficiencies that will effectively require a significant percentage of passenger vehicles to be hybrid electrics. California has done the same. And both of these, when enforced, will be a big boon the power semiconductor industry.

Admittedly, the analysis above is multi-faceted, and probably beyond what's marketable to a consumer—but the consumer never has to see this. These suggestions are certainly not too complex for suppliers to just go off and do. But to put it even more simply, there are two independent questions as to how the market for efficient electronic products can (and should) play out. The first is whether or not the consumer must purchase a truly efficient product, and the second is whose efficient product they will buy. Certainly, it won't hurt a company to work diligently to cost-reduce their product as much as possible, purely from a competitive standpoint relative to other suppliers of similar products. But it wouldn't hurt either to devote some resource to lobbying for the doubling or tripling of the available market, either. And that is my call to action.

What are the suppliers' lobbying options? Among them will be for individual companies to try to lobby alone, which would be expensive for any one company to take on, and the results would might also end up being a bit self-serving. Alternatively, the power management industry (or various application-specific groups therein) could band together into consortia to do the job; this would certainly be more objective, but the challenge there would be logistics, politics and/or bureaucracy. But the benefits would be worth the effort. Some existing groups (e.g., PSMA) are searching for most effective ways to add value to their industry—perhaps this would be a productive direction in which to move, and an expedient means for doing so. Or perhaps it would make sense to form a more comprehensive power management suppliers' association.

In closing, there is ample evidence and historical experience in the power management market to clearly illustrate the positive role that incentives, voluntary guidelines, government policies, and legislated standards can have in the simultaneous growth of the market and the improvement of efficiency across the consumer base. That experience also illustrates a couple of potential pitfalls—that we should work intelligently to avoid and to do this, we will need to become not merely lobbyists, but excellent, aggressive lobbyists.

Some would argue that we're taking away the consumer's choice. This is the statesman's dilemma of ages: do I do what the populace wants, or do I do what's right?

We can extend the argument to power factor correction. PFC will NEVER be initial-cost neutral to the consumer. So using the cost-neutral logic, we'll never have widespread adoption of PFC. Is that what's best for the world and for the consumer? Of course not. Now, we could spend the next 20 years trying to explain to every person out there the virtues of a zero phase angle—or we could just legislate it and be done with it.

Now, *that's* efficiency.

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Pursuing the Power Paradox

Lightly loaded standby or no-load modes

After July 1, 2006, new products with external power supplies sold into California must meet new mandatory active efficiency and no-load limits. Several other US states as well as Australia, Europe and China have either implemented mandatory regulations or are considering such moves.

By Peter Vaughn, Product Applications Manager, Power Integrations

Engineers are constantly challenged to reduce the cost and size of the products that they design and to achieve this in ever-shorter design cycles. Power supply designers, 'enjoy' the added challenge of new energy efficiency regulations that mandate high efficiency even in lightly loaded standby or no-load modes.

Although mostly voluntary, there is new trend towards regulations with mandatory limits. For example, after July 1, 2006, new products with external power supplies sold into California must meet new mandatory active efficiency and no-load limits. Several other US states as well as Australia, Europe and China have either implemented mandatory regulations or are considering such moves. Even voluntary standards enable the opportunity to label a product Energy-Efficient, resulting in a competitive advantage. And many manufacturers simply choose to work to the most stringent limits to ensure that a single design will be acceptable worldwide, eliminating design variants.

The challenge for semiconductor companies is to create solutions that provide a lower system cost, better energy efficiency, and safe and reliable performance, whilst simplifying the design process and increasing design flexibility in order to reduce the engineering effort required to create a new design. Merely reducing the cost of the last generation of products is not enough.

It was this challenge that shaped the development of the new TinySwitch-III integrated switching power supply IC family from Power Integrations. As with previous power conversion IC families for the company, TinySwitch-III integrates a 700 V power MOSFET, oscillator, high voltage switched current source, current limit (user selectable) and thermal shutdown circuitry into a single IC and uses On/Off control to regulate the output.

Important new features and enhancement have been added to the latest generation of the TinySwitch family, resulting in higher power capability and improved performance. Power capability of up to 28 W for 85-265 VAC and 36 W for 230 VAC input compared to the 15 W and 23 W previously achieved (Fig. 1). The revised pin-out enables improved creepage distance and heatsinking.

OUTPUT POWER TABLE				
PRODUCT	230 VAC		85-265 VAC	
	Adapter	Pk/Open Frame	Adapter	Pk/Open Frame
TNY274P	5.5 W	9.2 W	4 W	7.5 W
TNY275P	8.5 W	14.5 W	5.5 W	11.5 W
TNY276P	10 W	19 W	6 W	15 W
TNY277P	13 W	23 W	8 W	18 W
TNY278P	16 W	27.5 W	10 W	21.5 W
TNY279P	18 W	31.5 W	12 W	25 W
TNY280P	20 W	36 W	14 W	28 W

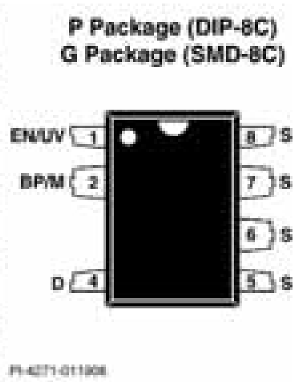

Figure 1. TinySwitch-III power table and package outline.

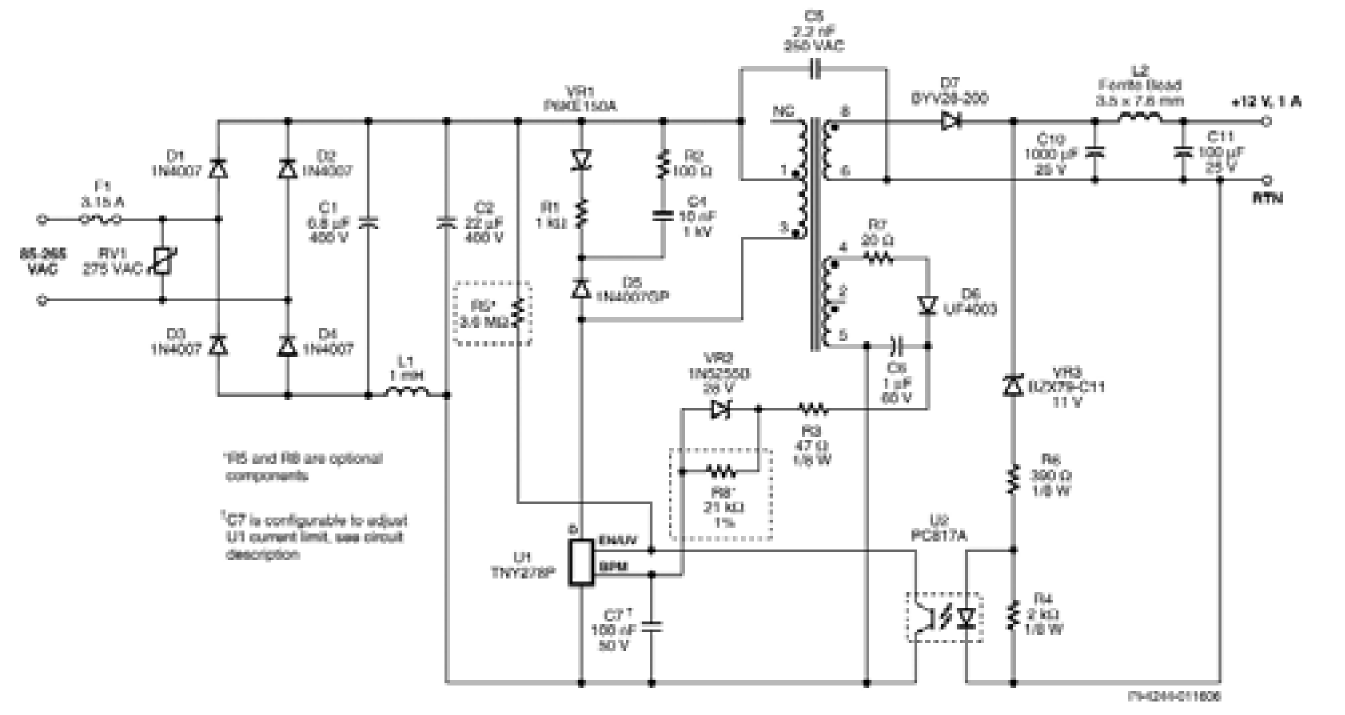

Figure 2. TinySwitch-III schematic implementing a 12 V, 1 A design.

Design Example

To illustrate the new features and enhancements in detail figure 2 shows a 12 W, universal input flyback power supply using a TNY 278 device. This design meets all current energy efficiency and no-load input requirements plus is production worthy meeting CIPR22/ EN55022 B conducted EMI limits with >12 dB margin and EN1000-4-5 Class 3 line surge.

When power is first applied the incoming AC is rectified and filtered creating a DC voltage across C2. The BYPASS/ MULTI-FUNCTION (BP/M) pin capacitor C7 is charged via a switched high voltage current source connected internally between the DRAIN and BP/M, removing the need for external components. Once the IC begins normal operation MOSFET switching transfers energy to the secondary where it is rectified and filtered by D7 and C10.

An optional under-voltage lockup resistor, R5, can be used to program the start up voltage. TinySwitch-III senses the presence of the resistor and inhibits switching until a current of 25μA flows into the pin. This ensures that the input voltage is high enough for the output to reach regulation at startup and prevents the output glitching at power down, as the input capacitors discharge. The value of 25 μA minimizes the steady state dissipation in the resistor to about 10 mW at 375 VDC, important to achieve low no-load consumption.

TinySwitch-III devices are self-powered and therefore do not require an auxiliary bias winding on the transformer to provide the IC supply current. Instead, a local decoupling capacitor (C7) is charged from the DRAIN pin during the off-time of the internal MOSFET. By minimizing the power consumption of the IC, a no-load input power of <140 mW at 265 VAC input was achieved when no auxiliary/bias winding is present (R8 removed).

However, the addition of a bias winding allows the IC to be supplied from a lower voltage. In figure 2, the bias winding is rectified and filtered by D6 and C6 and fed into the BP/M via resistor R8. This disables the internal high voltage current source after startup and the no-load input power is reduced down to less than 45 mW at 265 VAC.

A bias winding also allows the configuration of the output over-voltage shutdown protection feature via the BP/M pin. A current into the BP/M pin that exceeds 5 mA for greater than 30 μs triggers an internal latch and disables the internal MOSFET. This protects the load should an open loop fault condition occur, for example due to failure of the optocoupler, removing the cost of external components. The 30 μs filter prevents false triggering due to noise.

The output over-voltage is sensed on the primary side via the bias winding which tracks the output voltage according to the turns ratio between the windings. Once the output voltage exceeds the threshold set by VR2, current flows into the BP/M pin and triggers shutdown. To reset, the AC input must be removed for long enough for the input capacitors (C1 and C2) to discharge. In the design shown, the over-voltage triggers at an output voltage of 17 V.

Selectable Current Limit for Design Flexibility

As well as being the VCC pin and latching shutdown input, the BP/M pin also allows selection of the internal

DEVICE	CURRENT LIMIT (mA)		
	BP/M cap 1 uF (I_{LIM}-1)	BP/M cap 0.1 uF (std I_{LIM})	BP/M cap 10 uF (I_{LIM}+1)
TNY274	210	250	210
TNY275	250	275	350
TNY276	275	350	450
TNY277	350	450	550
TNY278	450	550	650
TNY279	550	650	750
TNY280	650	750	850

Figure 3. Selectable current limits give design flexibility.

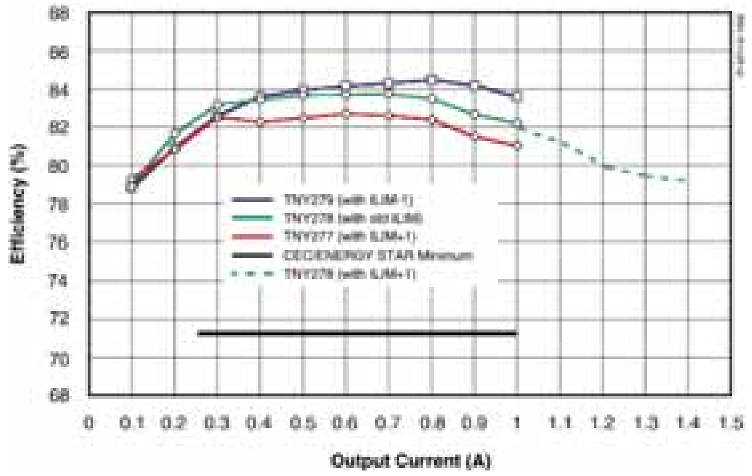

Figure 4.Trade off between device size, current limit, efficiency and power delivery.

current limit value. Figure 3 shows a table of current limit values vs. BP/M pin capacitor. By selecting one of three values of capacitor, one of three current limit values can be selected, providing greater design flexibility. The standard current limit (std I_{LIM}) is optimized for applications in enclosed adapters where dissipation has to be limited due to thermal rise. If lower dissipation and higher efficiency are required, then the lower current limit (I_{LIM-1}) can be programmed to reduce MOSFET conduction losses. The selection of the higher current limit (I_{LIM+1}) allows the design to deliver greater power. This can be continuous where the thermal environment allows (such as open frame supplies) or where short-term peaks are required to start up motors (such as DVD players or DVRs).

Figure 3 also demonstrates the matching of current limits value between adjacent family members; this allows the next smaller and larger family member to be used in the same design by selecting the same current limit. This is useful during development, allowing different devices to be evaluated and the optimum device to be selected without the headache of a transformer redesign.

If the transformer is initially designed for the next higher current limit level, as is the case in the design example, a single platform can be used to cover a wide range of output powers. Figure 4 illustrates the impact of current limit on efficiency, showing that this design easily meets the California Energy Commission/Energy Star external power supply requirement of an average efficiency of above 71.3%.

The output is regulated using On/Off control. When the output voltage exceeds the voltage determined by VR2, R6 and the LED in U2 turns on and current is pulled from the ENABLE/UNDER VOLTAGE (EN/UV) pin. The EN/UV pin current is sampled, just prior to each switching cycle. If the pin current is < 90 μA, the next switching cycle is enable, terminated when the current through the MOSFET reaches the internal current limit. To evenly spread switching cycle, preventing group pulsing, the EN pin threshold current is modulated between 50 μA and 90 μA based on the state of the EN pin during the previous switching cycle.

On/Off control eliminates the need for loop compensation components while providing a high loop bandwidth and excellent transient response. The current through the feedback zener is essentially constant, set by R4. This allows a zener to give good load regulation, as the zener voltage is not being altered by variations in feedback current, as would be the case in PWM control.

Depending on the load, the internal controller selects one of 4 current limit levels, the highest being the specified current limit. This ensures the effective switching frequency stays above the audible range until the transformer flux density, and hence audible noise generation, is low. This, together with standard production dip-varnished transformers, practically eliminates audible noise.

By optimizing the switching frequency based on the load, TinySwitch-III offers constant efficiency operation, maintaining high efficiency even down to very low loads. This is ideal when trying to meet active mode average efficiency or to maximize available output for a fixed input power limit in standby conditions.

The switching frequency of 132 kHz is jittered by +/-8 kHz to spread EMI energy over a wider frequency range and thereby reduce EMI emissions. This reduces the size, number and cost of EMI components. Frequency jitter combined with innovative techniques in the transformer design, allow conducted EMI limits to be met with a simple pi filter on the input (C1, L1 and C2) and Y class capacitor, C5.

Auto-restart limits the output power during a fault condition. If no feedback is received due to an output overload, short circuit, or open loop fault for >64 ms, the IC enters auto-restart, alternately disabling the MOSFET for 2.5 s and enabling it for 64 ms and limiting the output power to <3% of maximum.

This reduces the dissipation of the output diode, clamp components and transformer during fault conditions. It also reduces the power rating and cost of the zener needed to provide very accurate clamping of the output voltage during open loop conditions.

Thermal shutdown provides overload protection by shutting down the supply once the IC temperature reaches 142 C. This function can be use to protect the whole supply by sizing the heatsinking of other key components to be acceptable at point that the TinySwitch-III reaches thermal shutdown. Unlike most thermal shutdown functions, which are either latching or hysteretic with only a few degrees of hysteresis, TinySwitch-III has a hysteresis of 75 C. This avoids the problem of latching thermal shutdown where the end user may return a good power supply that latched off due to being under a pile of clothes, or in the sun (real examples). It also prevents excessive device temperature, as is the case when there are only a few degrees of hysteresis. Here the package essentially sits close to the shutdown temperature and may cause permanent damage to low cost PC board material. A 75 C hysteresis ensures the average board temperature is <100 C while still providing automatic recovery when the overload is removed or the supply moved out of the sunlight.

During normal operation the peak primary current is terminated by current limit. However during brownout conditions or on removal of the AC input, the current limit may not be reached and the cycle is terminated by maximum duty cycle. As power delivery is a function of the peak primary current squared, small reductions in the peak primary current significantly reduce the power delivered to the load. TinySwitch-III detects this condition and enables the on-time extension feature. This enables current limit to be reached independent of the DC bus voltage, maximizing power delivery and improving holdup time. Figure 5 shows the impact of on-time extension on hold-up time.

On-time extension has a second benefit. In a design that operates in deeply continuous conduction mode, it may take several cycles for the primary current to build and reach current limit. This creates a stronger audible component at the frequency cycles are being skipped. On-time extension prevents this by allowing the current to ramp to current limit within one cycle. This becomes especially important in higher power designs where the larger cores required create higher levels of audible noise.

TinySwitch-III features a single, tight tolerance I^2f power delivery term. This eliminates the need to design for the worst-case combination of current limit and switching frequency and dramatically reduces the design effort needed to tolerance a design. This allows up to 6% more power from a given core size, reduces device conduction losses by up to 3% as well as reducing overload power when compared to individual tolerance for current limit of +/-7% and +-6% for switching frequency for TinySwitch-II.

TinySwitch-III offers a significant step forward in reducing the complexity and cost of a switching power supply, meeting the need for a lower component count, lower system cost, higher efficiency, and lower no-load input power solution. Selectable current limit levels offer design simplicity, flexibility and reduced time to market. Built-in protection features reduce component cost and offer enhanced product safety.

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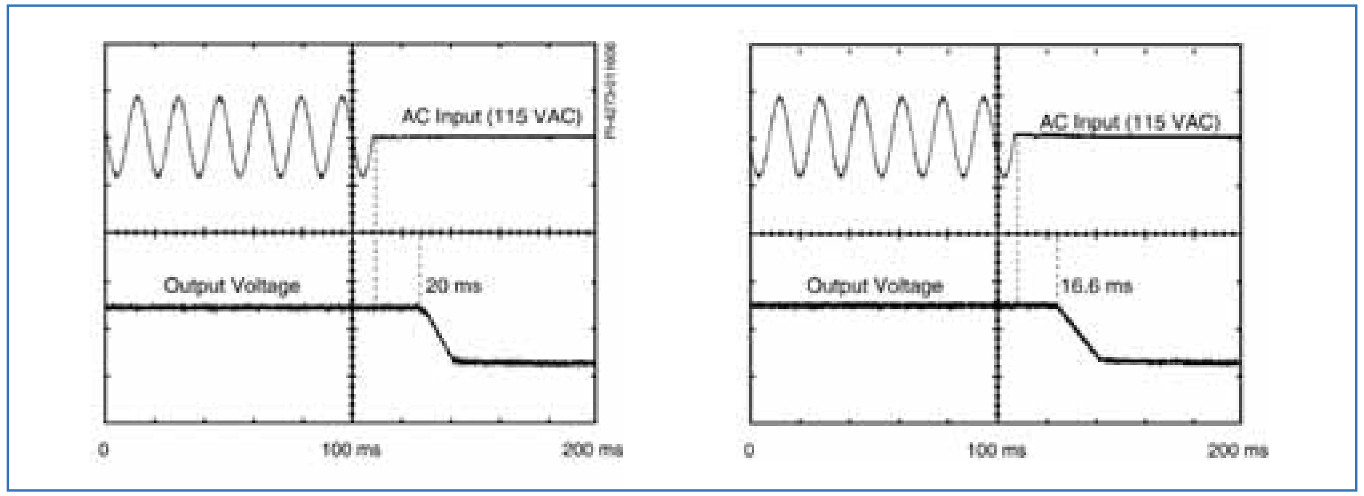

Figure 5. Comparison of a design with and without the on-time extension feature, showing 20% improvement in hold-up time.

HiPak Modules with Next Generation SPT+ IGBTs

The 3300V module will be followed by the 4500V class

ABB introduces HiPak modules utilising the new SPT+ IGBT chips with voltage ratings up to 4500V and current ratings up to 3600A. The SPT+ IGBT HiPak modules achieve the same desirable switching characteristics as the current SPT generation, while exhibiting lower over-all losses for increased current ratings.

By Eric Carroll and Munaf Rahimo, ABB Switzerland Ltd, Semiconductors, Switzerland

The power electronics community has a long wish-list of improvements for the IGBT in terms of losses, ruggedness and controllability. A trend towards the use of Trench cell designs and thinner base structures, seen as the only options for reducing losses, has overlooked the need for greater Safe Operating Area (SOA) and smooth switching behaviour. Recent SPT IGBT developments at ABB have, in fact, resulted in major improvements in ruggedness and softness.

Furthermore, the recent launch of the SPT+ enhanced planar technology has finally combined solutions for the reduction of losses and the dramatic increase of SOA while bucking the former trend utilising Trench cell designs. In 2005 ABB introduced the SPT+ IGBT technology and here we present SPT+ HiPak modules, shown in Figure 1, which set new standards in both efficiency and ruggedness.

SPT+ IGBT Planar Technology

The next generation SPT+ IGBT platform has been designed to substantially reduce the on-state voltage while maintaining low levels of switching losses. This approach combines a carefully

Figure 1. HiPak modules.

selected trade-off for high immunity to cosmic ray failures and smooth switching behaviour while maintaining the high turn-off ruggedness (RBSOA) already achieved by the current SPT technology. The new SPT+ platform exploits an enhanced carrier profile through planar cell optimisation, which is compatible with our advanced and extremely rugged cell design. The new technology leads to a significant increase in plasma concentration at the emitter and thus, a lower on-state voltage is obtained for the same turn-off loss. In addition, an optimised base region combined with the Soft-Punch-Through (SPT) buffer allows the collector current to smoothly decrease during the turn-off transient thanks to the progressive and controlled manner in which the depletion layer is established. The new SPT buffer and an optimal anode design, further ensures good short-circuit controllability with a high Short Circuit Safe Operating Area (SCSOA). Thanks to the combination of an enhanced cell design and the SPT concept, the SPT+ IGBT technology platform has enabled ABB to establish a new benchmark in the technology curve over the whole IGBT voltage range.

Figure 2 compares SPT+ with the current SPT technology for the voltage range 1200V to 4500V. The values for $V_{ce,sat}$ are obtained at the same current densities and for similar turn-off losses, for each voltage class. Therefore demonstrating that SPT+ technology with an optimised planar structure can match the carrier profile of trench-gate cathode designs. It is also important to stress that the reduction in on-state loss is achieved exclusively through enhancement of the carrier profile near the cell (emitter) while maintaining the same drift region thickness of the standard design. This is essential for ensuring controllable and "soft" switching behaviour, which in turn is necessary for very high current modules. The reduction in $V_{ce,sat}$ due to SPT+ cell

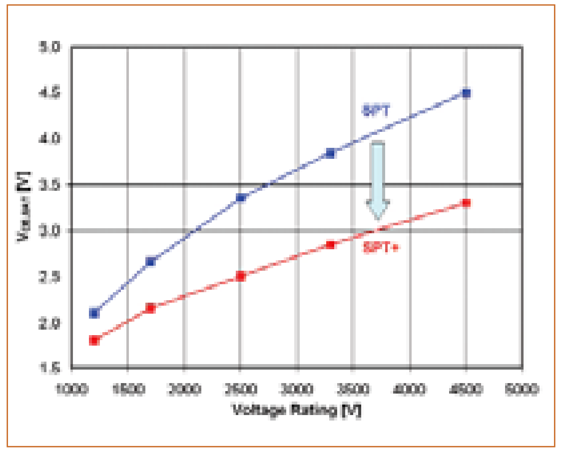

Figure 2. SPT and SPT^{+} IGBT on-state voltage vs. rated blocking voltage at 125°C.

Table (1) 1700V HiPak2	ABB SPT I_{CN}=2400A	ABB SPT^{+} I_C=2400A	ABB SPT^{+} I_{CN}=3600A
V_{cesat} (V)	2.6	2.1	2.6
E_{off} (J)	1.0	0.9	1.7
E_{on} (J)	0.7	0.4	0.7
E_{sw} (J)	1.7	1.3	2.4
Conditions:			
I_c (A)	2400	2400	3600
V_{cc} (V)	900	900	900
$R_{g\ on/off}$ (Ohm)	0.56/ 0.56	0.39 / 0.47	0.39 / 0.47
L_s (nH)	60	60	60
T_j (°C)	125	125	125

Table 1. Comparison of SPT and SPT^{+} IGBT 1700 volt HiPack2.

enhancement ranges from 15% for a 1200V IGBT up to 30% for a 4500V device, allowing corresponding increases in current ratings. In this article, we will briefly demonstrate some of the key electrical characteristics of the new 3600A/1700V and 1500A/3300V SPT^{+} HiPak modules.

3600A/1700V SPT^{+} HiPak Module

We will first discuss the results obtained for the 3600A/1700V SPT^{+} HiPak module. The SPT^{+} technology retains all the desired SPT characteristics while simply reducing conduction losses. Thus the new module is now rated at 3600A using same-sized chips or alternatively, the present 2400A module can be made with 30% smaller chips. Table (1) compares the current densities and losses of the standard SPT HiPak with those of the new SPT^{+} module. It can be seen that for the same Vce,sat (at rated current), the module rating is increased from 2400A to 3600A. The SPT^{+} module has an on-state voltage drop (at chip level) of 2.6V at 125°C. The new IGBT exhibits the same strong positive temperature coefficient of Vce,sat as the present types, which is essential for ensuring good current sharing in demanding paralleling conditions.

The 3600A/1700V SPT^{+} modules were subjected to a series of dynamic tests to demonstrate their electrical capability. In Figure 3a and Figure 3b, the turn-on and turn-off waveforms under nominal conditions (900V/3600A) at 125°C can be seen respectively. The IGBT and the diode both exhibit soft and controlled switching characteristics as well as short current tails. This behaviour is the combined result of the SPT buffer design and silicon specification used in SPT+ technology leading to fast switching, low losses, low overshoot voltages and low EMI levels. The RBSOA turn-off waveforms are shown in Figure 4a. The device was tested at a DC-link voltage of 1200V and 8000A at 125°C. A self-clamp overshoot voltage of 1900V can be observed during the turn-off period. The high SOA obtained under such extreme conditions confirms the module's robustness. The short circuit test at 125°C and at a DC-link voltage of 1300V can be seen in Figure 4b.

1500A/3300V SPT^{+} HiPak Module

Due to the significant challenge in the design of high voltage devices regarding ruggedness and softness, the main goal of the new technology development was to achieve loss reductions without sacrificing either soft switching behaviour or the benchmark robust performance of the current SPT generation. With the same silicon specification, SPT buffer and enhanced planar design, these goals were met or even exceeded for RBSOA despite the lower saturation voltages. Compared to current 3300V SPT IGBTs, the new SPT^{+} IGBT offers 25% lower on-state losses while maintaining low turn-off losses and thus sets a new benchmark for 3300V IGBT performance. Table (2) compares 3300V HiPak modules and shows that despite an increase in current rating of 20%, the SPT^{+} module still allows reductions in conduction losses from 3.8V at 1200A to 3.0V at 1500A.

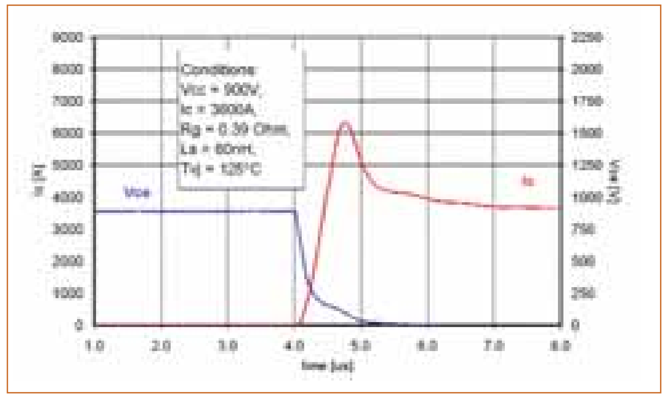

Figure 3a. Turn-on waveforms 3600A/1700V HiPak switching characteristics at 125°C.

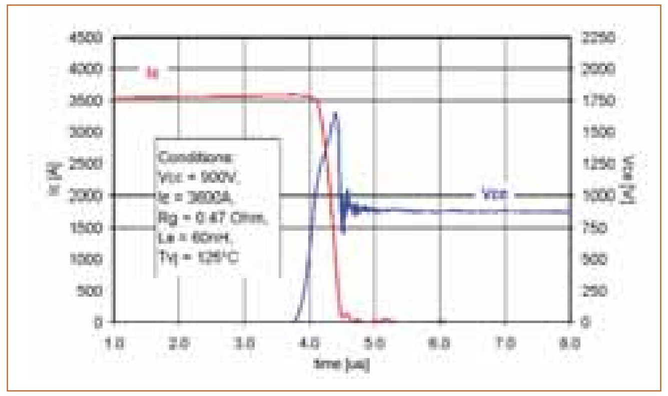

Figure 3b. Turn-off waveforms 3600A/1700V HiPak switching characteristics at 125°C.

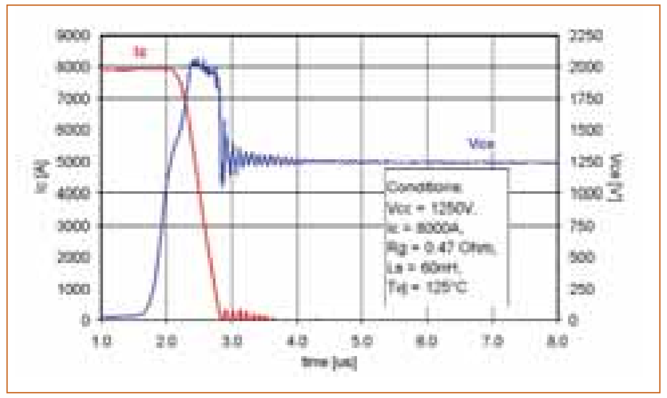

Figure 4a. RBSOA 3600A/1700V HiPak switching characteristics under SOA conditions at 125°C.

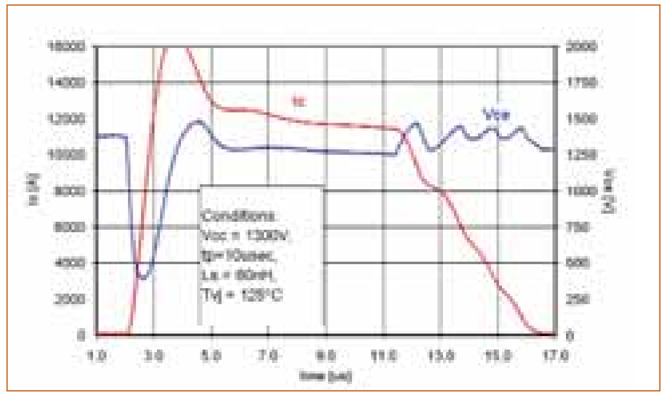

Figure 4b. SCSOA 3600A/1700V HiPak switching characteristics under SOA conditions at 125°C.

Table (2) 3300V HiPak2	ABB SPT I_{CN}=1200A	ABB SPT^{+} I_C=1200A	ABB SPT^{+} I_{CN}=1500A
V_{cesat} (V)	3.8	2.7	3.0
E_{off} (J)	2.0	2.0	2.4
E_{on} (J)	1.9	1.5	2.0
E_{sw} (J)	3.9	3.5	4.4
Conditions:			
I_c (A)	1200	1200	1500
V_{cc} (V)	1800	1800	1800
$R_{g\ on/off}$ (Ohm)	1.5	1.5	1.5
L_s (nH)	120	120	120
T_j (°C)	125	125	125

Table 2. Comparison of SPT and SPT^{+} IGBT 3300 volt HiPack2.

Figure 5a and Figure 5b show the turn-on and turn-off waveforms respectively at 125°C at the rated current of 1500A and a DC-link voltage of 1800V. The current switching transients maintain very smooth waveforms and a short current tail with no "snap-off". Due to the tail duration being short, the turn-off loss is limited to only 2.4 Joules. The 3300V SPT^{+} IGBT and freewheeling diode were also optimised for low IGBT turn-on losses, E_{on}, through a combination of low IGBT input capacitance (for faster V_{ce} fall times) and low diode reverse recovery charge. The turn-on losses have typical values of 2.0 Joules under nominal conditions at 125°C.

The RBSOA test at 125°C was carried out at a current level of 4800A (>3 times nominal) against a DC-link voltage of 2600V as shown in Fig. 6a. The device clearly exhibits a high capability for strong dynamic avalanche under these extreme conditions. Successful operation in Switching-Self-Clamping-Mode SSCM was also obtained with a self-clamp voltage of 3450V for approximately 1μsec. By enabling the IGBT module to withstand SSCM, the device exhibits a square SOA capability up to the self-clamp voltage level. The high dynamic ruggedness, combined with smooth switching behaviour gives users the greatest freedom possible in designing systems without dv/dt or peak-voltage limiters such as snubbers or clamps. Another major advantage of an extremely rugged IGBT is that it allows operation with much lower gate-resistance than that required by conventional technologies. This results in shorter delay times during device turn-off, which not only lowers the turn-off losses but also improves current sharing between individual IGBT chips in the module and ultimately, between parallel connected modules. The short circuit test result of Figure 6b at 125°C demonstrates controllable and "clean" current and voltage waveforms, which exhibit no parasitic oscillations. The waveforms show the 1500V/3300V SPT+ HiPak in short-circuit mode at a DC-link voltage of 2600V for an extended current pulse of 14μsec. The current waveform shows an average short-circuit current of approximately 6500A.

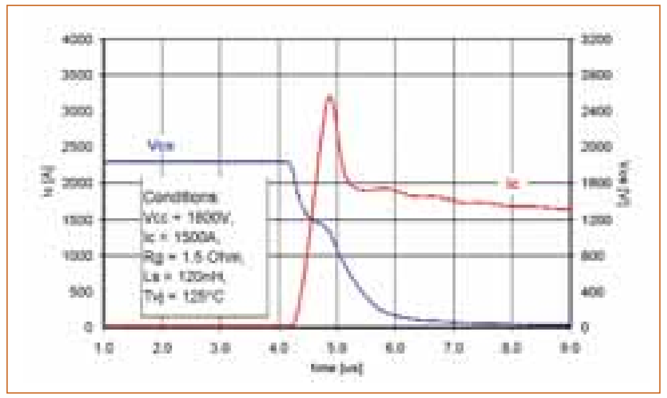

Figure 5a. Turn-on waveforms 1500A/3300V HiPak switching characteristics at 125°C.

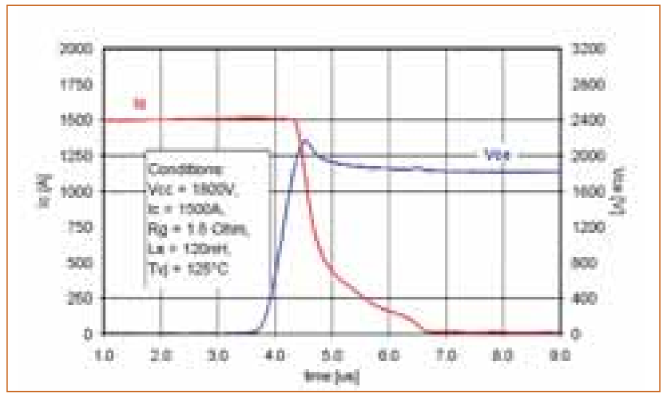

Figure 5b. Turn-off waveforms 1500A/3300V HiPak switching characteristics at 125°C.

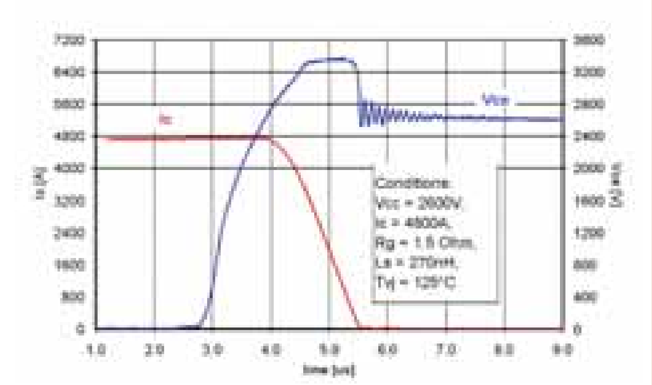

Figure 6a. RBSOA - 1500A/3300V HiPak switching characteristics under SOA conditions at 125°C.

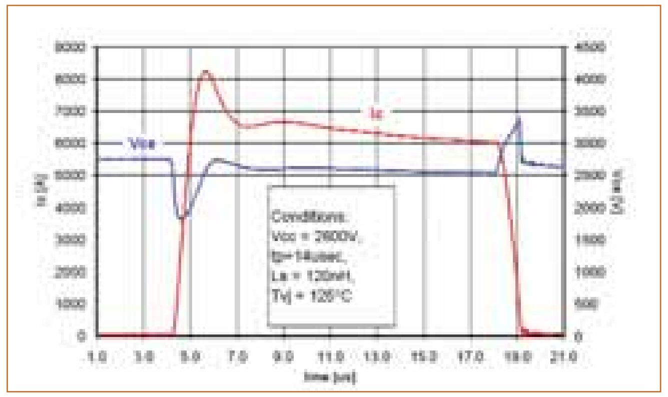

Figure 6b. SCSOA - 1500A/3300V HiPak switching characteristics under SOA conditions at 125°C.

The presented SPT+ HiPaks will give system designers greater freedom in achieving higher power and better efficiency for their applications. HiPak products with SPT+ IGBT chips will become commercially available in 2006 in voltage classes ranging from 1200V to 4500V. This will coincide with the introduction of the smaller HiPak1 in the industry standard 130 x 140 mm footprint. Along with the current single-switch and chopper configurations of the 190 x 140 mm housing (HiPak2), the Hipak1 will also offer dual IGBT and dual diode configurations in both standard isolation and high isolation housings (V_{ISOL} = 10.2 kV). The 3300V module now being sampled will be the first commercially available 1500A version of this popular voltage class. It will be followed in mid-year by the 4500V class accompanied by the general release of the HiPak1 family.

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Intelligent Hot Swap Control

Evolution step of inrush current limiting

High availability systems must operate continuously without interruptions in service. To achieve this level of reliability in large systems with many circuit cards in a chassis, you must be able to add new cards and replace obsolete or damaged cards without powering down the system.

By Chris Umminger and Todd Nelson, Linear Technology

However, removal and insertion of cards into a live backplane is fraught with potential problems. Backplanes often have significant inductance between the card connectors and the power supply capacitance. Disconnecting a card that is still drawing load current can induce ringing and high voltage spikes along the backplane, potentially disrupting or even damaging nearby boards. In higher voltage applications, such as 48V distribution systems, the removal of a card can draw an arc that damages connector contacts. Even worse, when a new card is inserted and the power rails first mate, unlimited backplane currents charge the card capacitance and induce ruinous transient surges. A variety of circuits have evolved to safely “hot” swap cards in these systems.

Evolution of Hot Swap Solutions

Placing a switch M1 between the backplane and the card's bulk capacitance as shown in Figure 1 addresses several hot swap problems. Turning this switch off and on in a controlled manner minimizes the disturbance to the backplane supply voltages. During insertion, the switch is initially held off by R1. After the power rails have made contact, the short pin connects and charges C1 through R2 to turn on the switch. Clamp Z1 limits the gate voltage of M1 to a safe value. When the card is extracted, the short pin disconnects first, allowing R1 to slowly turn off M1.

This simple circuit has several weaknesses. First, although a slow rising waveform appears at the gate of M1, the large gain of the power transistor causes the output voltage to rise at a much faster rate. Thus, unrealistically large values are required for R1, R2, and C1 to achieve a satisfactory turn-on rate. Second, the turn-off of M1 via R1 is very slow, perhaps longer than the time taken to extract the card. Thus, the switch could still be allowing current to flow when the long pins break connection. Third, if the card should short circuit or overload, the only protection is slow acting fuse F1. Finally, in a positive voltage system, this circuit must use a P-type MOSFET for M1, which is generally not as cost effective as using an N-type device.

Early integrated hot swap controllers such as the LT1640 illustrated in Figure 2 address many of these problems. When the short pin makes contact, the controller turns on the switch with a fixed 45uA current source. Initially this charges the MOSFET gate until the MOSFET turns on.

When the output voltage starts to change, the current is diverted to charge the gate-to-drain capacitor C2. The choice of C2 accurately sets the output voltage slew rate and hence the inrush current. During extraction, the controller quickly turns off the MOSFET switch

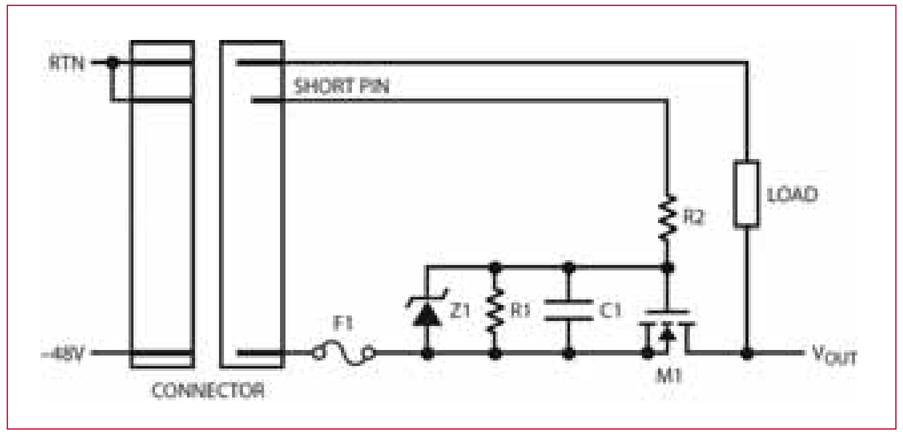

Figure 1. A passive hot swap circuit softens the connection of power to a card.

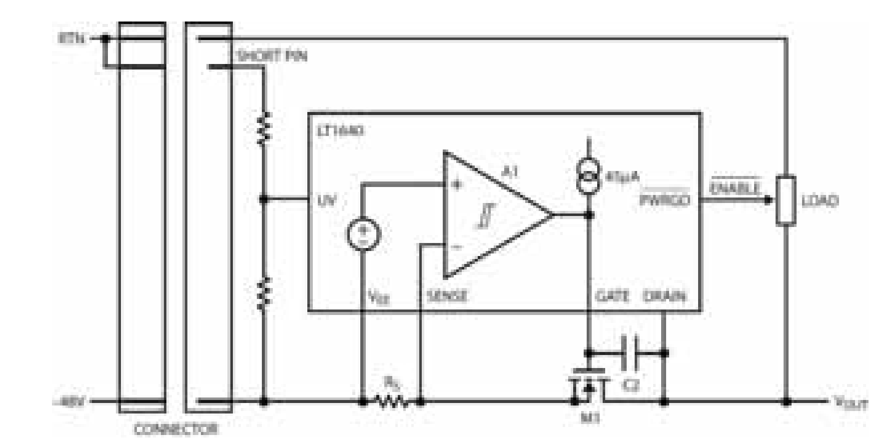

Figure 2. Early hot swap controllers limit inrush current more accurately, turn off faster when disconnecting, and include an electronic circuit breaker.

before the connector contacts open. Additionally, the current sense resistor Rs combined with comparator A1 form an electronic circuit breaker that turns off the switch if the load current exceeds a set limit. For positive voltage systems, devices like the LTC1422 also provide a charge pump to drive less expensive N-type MOSFETs for the high side power rail.

Many systems have short duration supply transients that are part of normal operation. For example, telecom systems may switch over between redundant supplies resulting in a several volt step in the card input voltage. In systems with motors, such as disk drives, there can be large, short duration currents as the motor starts. These events may cause the load current to exceed the circuit breaker threshold momentarily and falsely shut off the switch. The second generation of hot swap controllers evolved to distinguish between real faults and operating transients and provide appropriate fault protection. Converting the comparator shown in Figure 2 into an amplifier that actively limits current solves this issue. Devices such as the LT4250 limit the current to a safe value and then shut off the switch if the fault persists beyond a set timer period.

Further improvements simplify the hot swap circuit by actively limiting current during both inrush and output overloads. This allows you to eliminate the capacitor C2 and bring up the output voltage more quickly. Often the current limit timer is adjustable, so you can match the duration of overload with the specific needs of the system and the ruggedness of the MOSFET. Examples of such parts are the LTC4252A for -48V systems and the LT4256 for positive voltage systems.

Digital Monitoring—A New Era for Hot Swap Controllers

Adding Intelligence Improves Reliability. In complex high availability applications, it is increasingly important to monitor system power for a couple of reasons. First, you can watch for anomalous trends over time that indicate abnormal operation and anticipate impending failures. Second, it is common today for systems to allocate power between different card types to economize on total power supply capacity. Power monitoring ensures that the cards stay within their allotment. Residing at the power connector, the hot swap circuit is a natural place to monitor the power entering a card.

The latest generation of hot swap controllers, such as the LTC4260 and LTC4261, make power monitoring easy. In addition to the core hot swap functions of inrush current control and electronic circuit breaker, the LTC4261 (illustrated in Figure 3) incorporates a 10-bit analog to digital converter, multiplexor, preamplifer circuitry, and digital interface that enable an unprecedented level of monitoring and control. This device

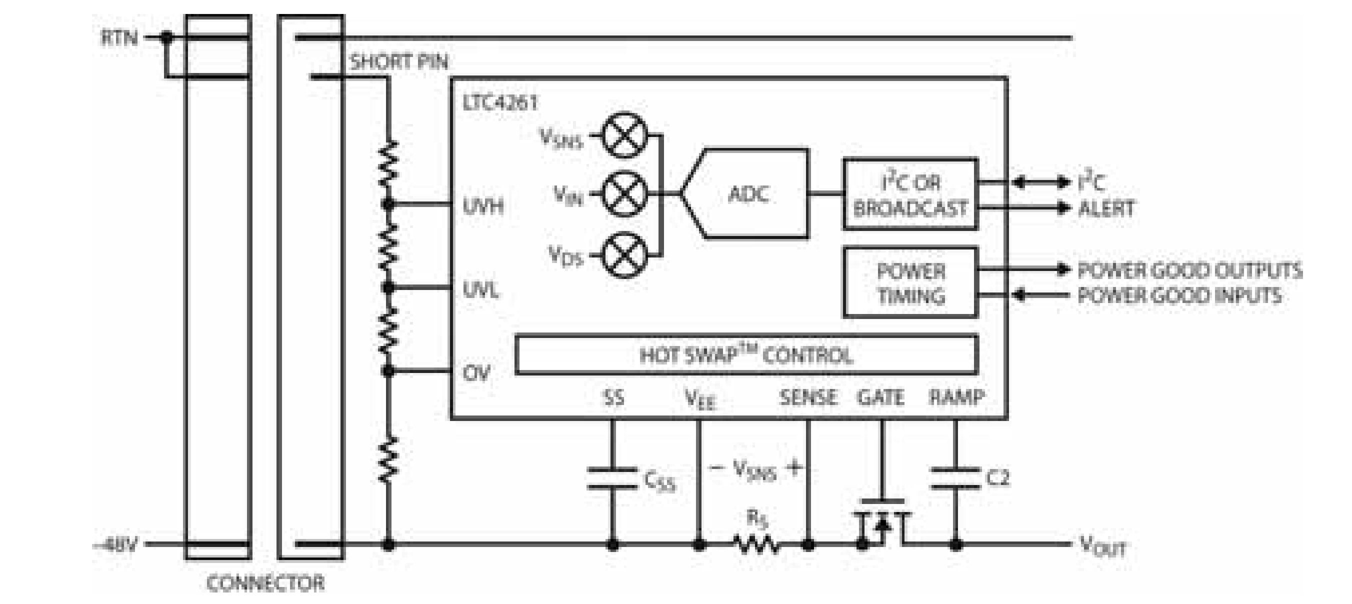

Figure 3. The latest hot swap controllers include digital interfaces to measure current and voltage along with improved current limiting, fault monitors, and power good signals.

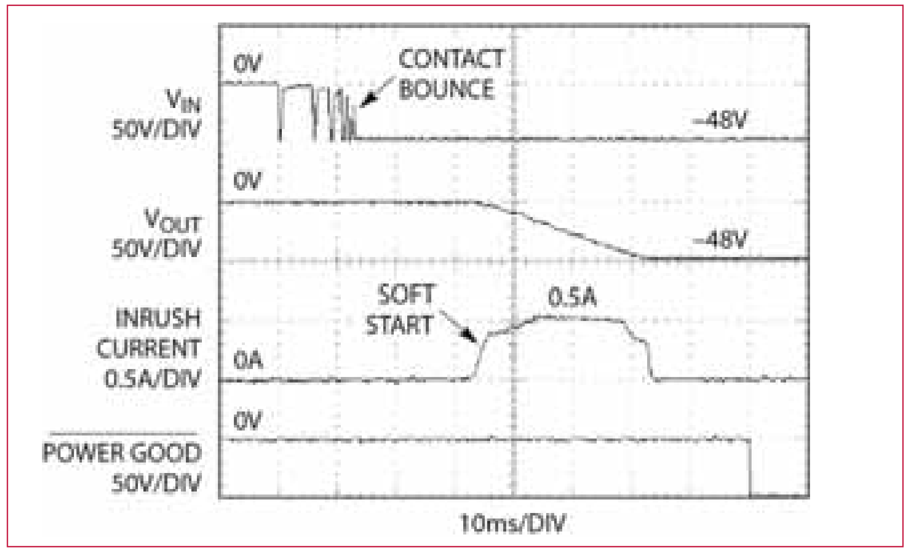

Figure 4. Oscilloscope waveforms show the LTC4261 waits until connection bounce is complete before smoothly powering up the load.

measures input voltage and voltage across the current sense resistor. Knowing voltage and current lets you determine power in the card and observe trends. Furthermore, you can use an additional free data converter input for additional measurements such as the voltage across the MOSFET or the status of the input fuses.

Incorporating a digital interface adds features far beyond monitoring card power. You can issue instructions to the device to control power as well as configure and report a variety of fault behaviors. For example, the switch might be turned off due to a fault such as an undervoltage condition on the backplane. In this case, a flag is set that you can later read to determine the cause of failure. It is also possible to generate an "alert" that will pull an interrupt line low to inform the system of a fault. Additionally, you can configure which faults will cause the card to turn off permanently or attempt to power up again automatically. For example, systems that are remote or difficult to service may prefer to allow a card to restart on its own when an undervoltage situation has ended.

This information is accessible in two ways. First, you can use the popular I2C bus to read and write to the registers. In –48V systems this often means transmitting the data across an isolation barrier to the I2C master. The LTC4261 separates the transmit and receive data pins (SDAO and SDAI) to simplify the isolation circuitry. Second, you may choose to reduce costs further by taking advantage of the single wire broadcast mode. In this case, a single output pin and external optoisolator transmit a repeating datastream that divulges the contents of the registers and the voltage and current measurements.

Monitor a Wide Variety of Faults

Modern hot swap controllers monitor a wide variety of faults in addition to overcurrent. In -48V systems there are often stringent requirements for the allowed operating voltage to protect the load. The two undervoltage inputs UVH and UVL let you independently select a turn on voltage, such as -43V, from a turn off voltage, such as -38V. The overvoltage input OV turns off the switch if the input voltage is too high.

The LTC4261 simplifies and ensures the proper start-up of power to the load. It generates delayed power good signals that start loads in sequence after the MOSFET switch has brought up the card power supply. Subsequently, a power-up timer is started. A system monitor must come back and stop this timer to indicate normal operation. If the timer finishes without receiving this signal, due to system start-up failure, the power is turned off.

Soft Start and Separate Inrush Current Limit Improve Connection

In addition to the many new monitoring features, improvements continue in the basic inrush control function. In certain applications with significant backplane inductance, you must not only control the inrush current but also limit the rate of rise (dI/dt) of inrush current to minimize disturbance to the backplane. Current limit circuits now incorporate a soft start function to limit dI/dt controlled by the choice of an external capacitor, Css.

Another improvement separates the inrush current limit during insertion from the active current limit used by the circuit breaker. In systems with high load currents, a large amount of load capacitance may be present. Charging this capacitance to 48V, for example, stores a considerable amount of energy. An equal amount of energy is dissipated in the MOSFET switch during start-up, which is its most significant stress. The LTC4261 lets you define the circuit breaker current limit, set with Rs, independent of the inrush current, which you set with the value of C2. Thus, you can power up large load capacitances while minimizing MOSFET power dissipation and size. Figure 4 shows the LTC4261 starting up a -48V card after insertion.

Safely managing power during live insertion of cards is a critical feature of high availability systems. A variety of circuit improvements have been made over the years to ensure this occurs reliably. Early hot swap circuits crudely limited inrush current. Later improvements added an electronic circuit breaker to isolate faults, comparators to monitor voltage levels, and power good signals to safely start the load. Today, these circuits have digital interfaces with on-board data converters that allow systems to continuously monitor and manage the power. With this information, you can design systems to reach the next level of reliability and durability.

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Advanced Precision Power Analyser

To find use in many types of power measurement applications

This article describes a new precision power analyser which features the world's highest measurement accuracy (±0.02% of reading) and a measurement bandwidth of 0.1 Hz-1 MHz as well as DC signals.

By Iwase Hisashi, Itou Osamu and Tachibana Katsuya, Yokogawa

The instrument can be equipped with four input elements, and it is possible to measure the efficiency of a DC-input 3-phase invertor with a single unit, thereby enabling highly accurate measurement of the efficiency of invertors installed on electric vehicles, for example. A large-format LCD enables the analyser to display measured values in various forms, including waveforms, for greater operability.

In recent years, the demand for energy-efficient machinery and equipment designed to address global environmental problems and to effectively utilise energy resources has been increasing. In Japan, for example, the law concerning rational use of energy was revised in response to the Conference of Parties III (COP3) conference on global warming, which was hosted by Kyoto in December 1997. The Japanese Government ratified the Kyoto Protocol in June 2002. Internationally, the Energy Star Program was launched in 1995. The energy efficiency standard of this program applies to home appliances and office automation equipment. Now that hybrid automobiles, invertor-driven refrigerators and air conditioners are widespread, greater accuracy is needed in power measurement.

The instrument described in this article meets the demands of the high-accuracy power measurement market by offering the world's highest accuracy for power measurement (Figure1).

Key features of the new instrument include:

High accuracy and bandwidth: The basic accuracy, i.e. the accuracy of measurements at commercial frequencies of 50/60 Hz, is ±(0.02% of reading and +0.04% of range). The frequency bandwidth covers 0.1 Hz-1 MHz as well as DC signals.

Maximum of four input elements: Since the analyser can be equipped with a maximum of four input elements, one unit can measure the inputs and outputs of a three-phase invertor. With two units, multi-channel power measurement can be performed on a synchronized basis.

Common-mode voltage of 1000 V: Earlier power analysers have used photocouplers to insulate the input circuit, which has limited the common-mode voltage to 600 V. The new instrument employs a newly developed pulse

Figure 1. The Yokogawa WT3000 precision power meter.

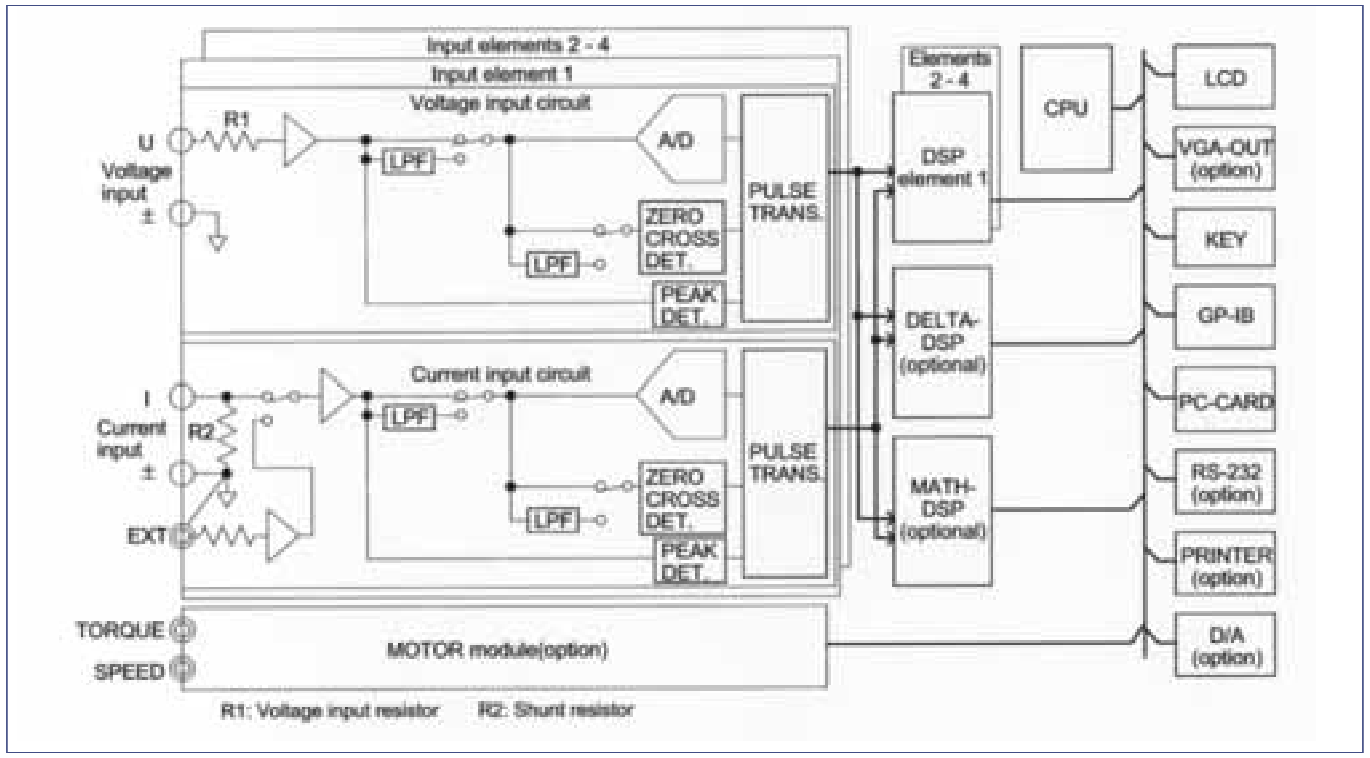

Figure 2. Schematic of the WT3000 precision power meter.

transformer for input circuit insulation. By maintaining a sufficient insulation distance, a common-mode voltage of 1000 V has been achieved, enabling measurement of the ever-increasing drive voltages in modern invertors.

High-speed data update: The maximum data update period of the new analyser is 50 ms: five times the speed of earlier instruments. This feature is useful in evaluating the characteristics of motors such as torque and speed of rotation. It is also effective in measuring phenomena that tend to change in a relatively short period of time or at high frequencies (e.g. ramp currents and secondary voltages in lighting systems).

Motor evaluation: A motor evaluation function is available as an option on the analyser. This allows the analogue or pulse output of the torque and the rotation speed to be input directly from a torque meter into the instrument. Torque and rotation speed readings as well as motor output, synchronous speed, sliding, motor input/output efficiency, and invertor-input/motor-output efficiency are then calculated to measure the total efficiency of the invertor and the motor.

Instrument configuration
Figure 2 shows the basic configuration of the power analyser. The main components are the DSP, the CPU, and the four input elements, which include voltage and current input circuits. Other components include the LCD display, the keypad, and the GP-IB for communication.

The voltage input circuit is a resistance-voltage-division configuration, while the current input circuit is of the shunt-resistor type. Inputs into each are normalised and in turn entered into the A/D convertor by the operational amplifier. The conversion rate is approximately 5 μs.

The input resistance of the voltage input circuit is 10 MΩ, which is five times larger than that of earlier instruments. As a result, losses in the instrument are reduced, and the effects of self-heating caused by high-voltage input are minimised. To increase the measurement bandwidth while maintaining the input resistance at 10 MΩ, input resistor shield cases are used so that capacitors are formed between their terminals.

The shunt resistor of the current input circuit employs a coaxial structure to increase the measurement bandwidth. The shunt resistance of such a structure tends to fluctuate greatly with changes in applied power, so development efforts have been aimed at minimising changes in shunt resistance.

The outputs from the A/D convertor are insulated by the pulse transformers and input into the DSP, which calculates measurements of voltage RMS, current RMS, effective power etc. These calculations are carried out in real time, which reduces any dead time during power measurement. The 'delta' DSP performs the calculations for Δ/Y conversion in 3-phase measurements, while the 'math' DSP carries out the calculations for harmonic wave analysis.

The values measured by the DSP are processed by the CPU for display, communication and D/A output purposes.

Figure 3 shows voltage and current error curves with respect to frequency, while Figure 4 shows a power error curve with respect to frequency.

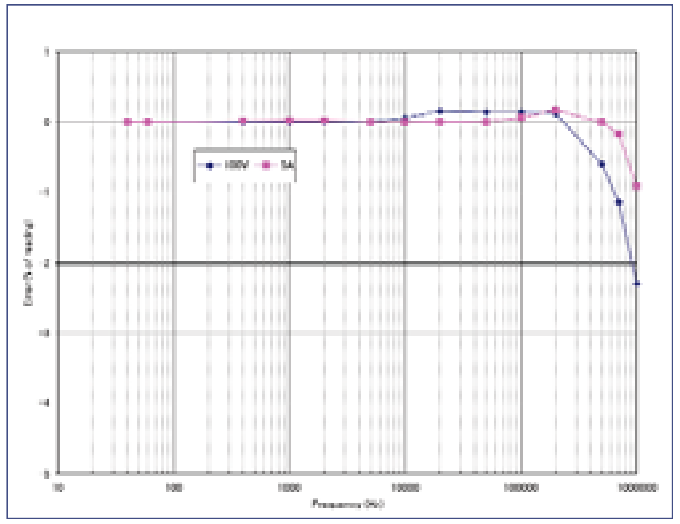

Figure 3. Voltage and current error curves with respect to frequency.

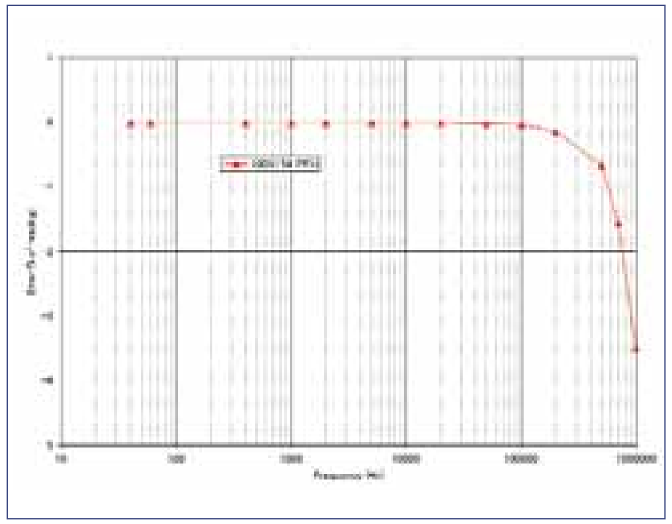

Figure 4. Power error curve with respect to frequency.

Measurement function
The key measurement functions of the new analyser are as follows:
Simultaneous measurement of normal and harmonic waveforms: To measure harmonic waves on earlier instruments, it was necessary to change to a dedicated harmonic wave measurement mode. For users who wish to acquire measurement data related to harmonic waves such as THD (distortion factor) in addition to voltage, current, and power, changing measurement modes not only lowers throughput but also causes a loss of the synchronicity of measured data. New instrument overcomes these constraints by using the 200 kHz sampling clock which is normally used for

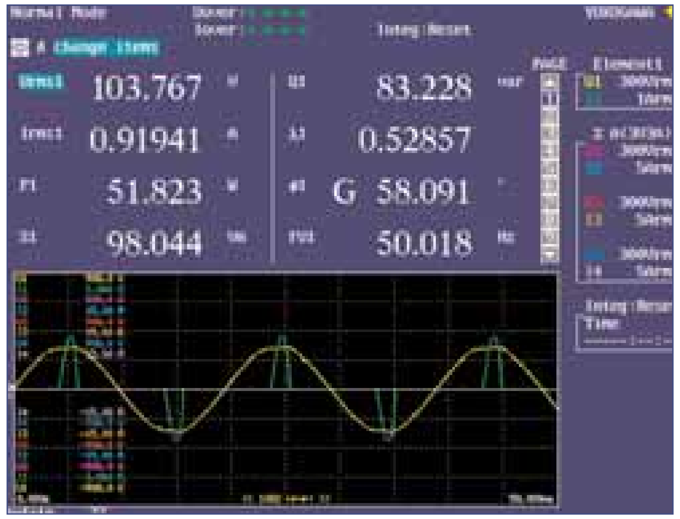

Figure 5. Waveform display.

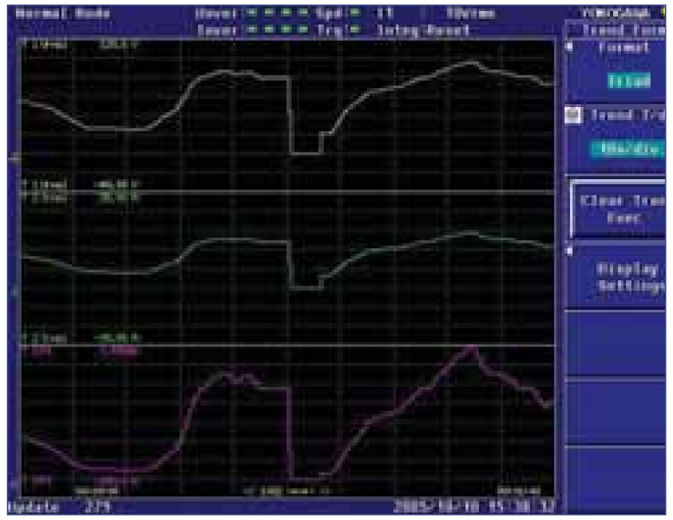

Figure 6. Display of measured data trends.

measurement. For data acquisition, the number of pulses generated by the sampling clock is reduced, so that the generated signals are nearly equal to the PLL (phase-locked-loop) clock signals of the input sources. The FFT (Fast Fourier Transform) calculation is executed using the dedicated DSP concurrently with data acquisition.

Combined use of digital filtering and total averaging: Previous power analysers have used a digital filtering method in which multiple exponential averaging is executed for sampled instantaneous values. The accuracy of this method is greater than that of the total-averaging method, in which instantaneous values in the measured section are summed for averaging. However, the accuracy of digital filtering is low for data update periods below 250 ms when the frequency of data input is mainly in the commercial frequency range.

Data update periods of 50 ms and 100 ms are difficult to achieve with digital filtering. Therefore, the new analyser uses the total-averaging method for these periods to meet the needs of users who require high-speed responses, even if the accuracy must be compromised to a certain extent.

To enable measurement at frequencies above 0.1 Hz, the maximum data update period is set at 20 sec. Thus the data update periods of the analyser are 50 ms, 100 ms, 250 ms, 1 sec, 2 sec, 5 sec, 10 sec and 20 sec.

Display formats: The analyser incorporates a large LCD display, on which a maximum of 104 data points can be displayed at any time. The number of parameters to be selected can be 4, 8, 16 or all, and the number of parameters and the quantity of data to be displayed can be arbitrarily combined by the user.

The instrument can display a waveform of an input signal (Figure 5) and the trends of measured data in a time series (Figure 6). It can also display a list, bar graph, and vector of harmonic waves. In addition, for the first time it can display a waveform during integration.

Communications interfaces: The analyser is equipped with a GP-IB interface as standard, while RS232C, Ethernet, and USB interfaces are optional. For the Ethernet interface, in addition to a control function using the IEEE-488.2 command, an FTP server/client function is also provided.

Measured data can be stored in a PC card and transferred to a PC using the interface function. USB communication enables measured data storage, keyboard connection for file name typing, and outputting to the printer.

Applications software
A number of dedicated PC software applications are available for use with the new power analyser:

- **WTViewer software:** This makes it possible to read measured numerical values and waveform data into the PC via the communications interfaces, display numerical data and waveforms, and convert them into a specified data format and store them.
- **LabVIEW driver:** A library that can be used with the National Instruments LabVIEW software.

Applications
This instrument should find use in many types of power measurement applications, ranging from standard power measurement and calibration systems to high-accuracy measurement for invertors and motors the evaluation of transformers.

This article is based on a paper in Yokogawa Technical Report No.39, 2005: http://www.yokogawa.com/rd/TR/rd-tr-o00000-000.htm. Detailed information on WT3000 power analyser is available at http://www.yokogawa.com/tm/WT3000/

For inquiries within Europe, please contact Yokogawa Europe BV (The Netherlands) at info@nl.yokogawa.com

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Power Amplifiers Proof-Test Equipment

Operation at various on-board vehicle voltages

The discussion regarding on-board vehicle voltages, for example 12, 24, or 42V DC, or even AC, for avionics or automotive applications continues vigorously.

By Dipl.-Ing. Helmut K. Rohrer, Rohrer GmbH, Munich

The argument for higher voltage stems from the reduced current required by all components, and above all from the reduced cable thickness. This cuts the weight quite enormously, and helps to save space. Additionally, efficiency is improved as a result of reduced losses at various intermediate resistances.

All components for higher voltages need to be newly developed and tested. But it is not only higher voltages that give rise to the need for equipment and components testing. Existing systems need to be tested following modifications, to ensure their continuing functional reliability, for example ABS and airbags. Matters will become even more critical if and when new drive-by-wire functions are introduced, such as steer-by-wire and brake-by-wire, meaning the driver will control only an electronic panel and all else, steering, braking, and motor control, will be done electronically. This article explains what tests are necessary and how these can be carried out with a power amplifier.

The on-board vehicle network, as a freely floating network, offers by no means a clean constant DC voltage. It is a DC voltage with various alternating voltages superimposed. These alternating voltage components originate mainly from the generator and the rapidly changing loads. Load changes can be resistive, inductive or capacitive. Rapid load changes can therefore lead to sharp voltage drops or even over voltages. Thus before putting equipment into operational use it is important to carry out a realistic network simulation.

Certainly there are vehicle network components which can fail without critical results. But attention must be focussed on the critical components. Most manufacturers do not just rely on giving recommendations, but have house standards which define the limits applying to their specifications. Understandably, a vehicle network simulation must be able to reproduce all conceivable voltage events, extending from over- and under-voltage right up to sudden short circuits.

Vehicle network simulation with power amplifiers
Power amplifiers are well suited for testing all possible eventualities in a vehicle network. They can generate the various voltages and currents required to test all components under all the conditions that may actually arise. For this purpose the new PA207X series of HERO POWER amplifiers is ideally designed. The amplifiers are linear regulated power amplifiers, with output voltages that can be repeated as often as desired, which have been proven as onboard network simulators, either as source or drain. They can be used in testing batteries equally as well as in providing any desired network voltage.

These network simulators operate from 0 to 60V with flank rising and falling rates of about 8 V/μs at full output power. The dynamic internal resistance is particularly important. In voltage use it is <1 milliohm for DC, and in current use about 100 kiloOhms for DC. In order to reduce power loss arising at small output voltages, over the B2 region from 0 to 30V, the output voltage can be switched in increments. The user can choose the unit he needs for his power range from a range of amplifiers covering different power outputs.

Programmable ranges
Power amplifiers must be able to emulate almost all events that can happen in the real environment. The power amplifier should be programmable accordingly (figure 1). A model with this capability is the PA2073-82-S amplifier. It has two symmetric and two asymmetric (switch able) outputs for currents up to 50A (150A, 200ms), through which it can be optimally adapted to different requirements.

POWER AMPLIFIERS

Figure 1. Operation of the power amplifier is made much easier by an intuitive interface, here in conjunction with a 3-phase equipment.

The asymmetric regions +60/-5V and +30/-2V serve for on-board network simulation. In point of fact networks are unipolar positive, but for simulation of precise and rapid discharge processes a negative voltage is necessary. This should be small, to keep the losses under load conditions as small as possible. At the same power, the advantage of a higher current is obtained. For other purposes symmetric outputs are necessary, ±50 or ±30V. No other power amplifier currently offers this multifunctional and cost-saving facility. When a load is switched into the network, the voltage drop will be insignificant; the HERO power amplifier reacts to load changes in <1μs, so that virtually no voltage drops occur.

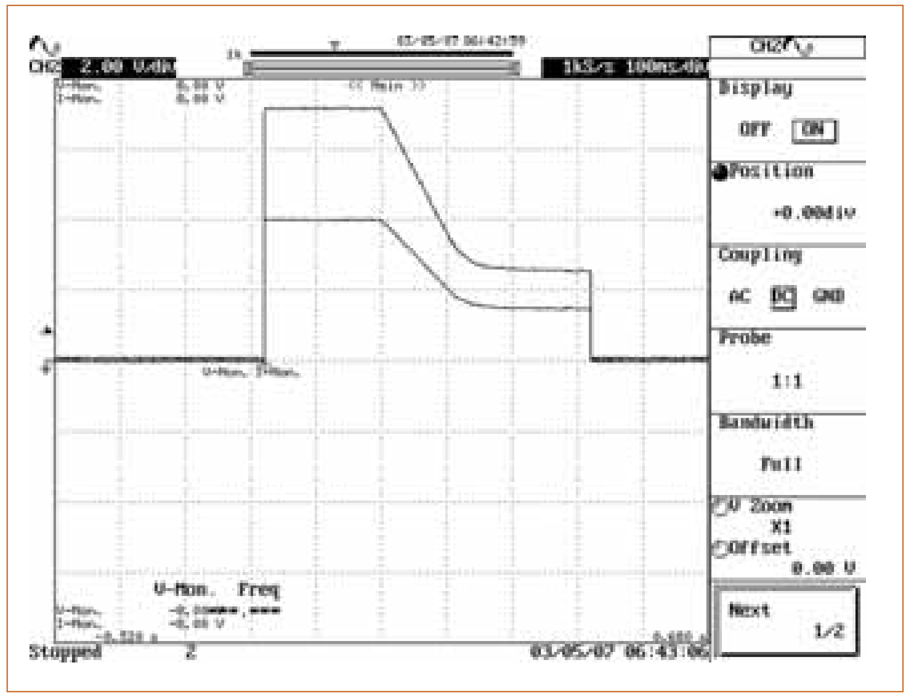

Figure 2. For safe operation, the curve of overload performance must be investigated in every case. After 200ms of a 3-phase overcurrent the power amplifier automatically reverts to the nominal value.

For documentation purposes isolated measurement inputs are offered over the range ±500V. These are differential inputs, enabling a real-time signal to be captured at any desired point. They are available for appraisal on a monitor, or to provide indication for example on an oscilloscope. The danger of false connection from earthed means of measurement is thus excluded. To ensure no difficulties arise with the indication of measured signals, all monitor and measurement inputs are floating, so that simultaneous potential disturbances can have no effect.

But not only the measurement inputs are potential free, the entire power amplifier is built to be potential free, with a common reference potential for input and output. With galvanic separation between input and output, these can have different reference potentials, enabling earth loops to be avoided.

For investigating various forms of interference, the PA2073-82-S power amplifier has two control inputs for two signal sources. Both signals are added; for example for harmonic modulation. With the 150 kHz modulation frequency, high frequency interference can be well simulated. For actual testing of the connected equipment, a continuously adjustable current and voltage limitation can be programmed (without load), in order to protect the equipment from overload and also for protection in fault servicing.

With the help of a pulse generator with TTL input, steep switching flanks can be generated, the level of which can be rapidly changed. With all testing, the operation mode can be switched from regulated voltage output to regulated current output, enabling testing to be performed with constant voltage or constant current.

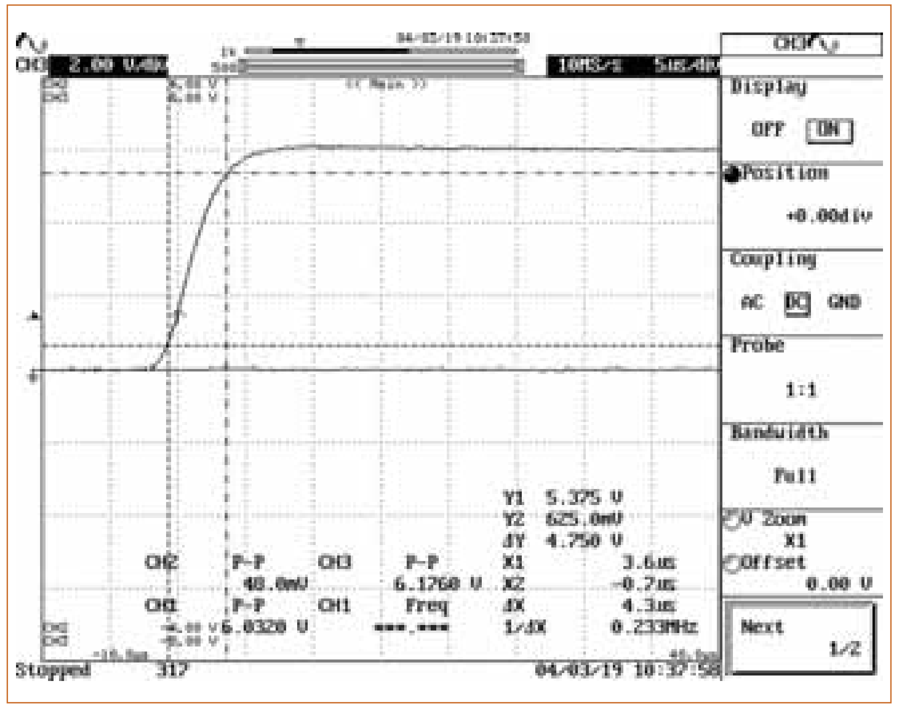

Figure 3. After a rise time of 4μs, the test curve is continuously run through.

For flexible installation the power amplifier is built into a robust 19-inch mini-rack, with rollers. For operation it needs to be supplied from a three-phase supply voltage 3 x 400V/50Hz, but can be adapted for every other operational voltage as necessary.

For safe operation of components it is indispensable for all conceivable fluctuations of an onboard supply to be investigated, so that under all circumstances safe use is guaranteed. The consequences can only be too well imagined if in a braking manoeuvre the brakes, or with an aircraft the controls, do not function, or do not function properly, on account of an on-board network fluctuation. In order to guarantee the highest level of operational security, all connections of the power amplifiers (input/output/output voltage monitor/output current monitor) are galvanically isolated.

At the same time accuracies of 0.1% are attained. The power amplifiers are manufactured in Munich, so that for the user's actual application the manufacturer's know-how is readily available. Various battery simulators and other HEROPOWER power amplifiers are also available for test purposes.

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Mobile Electrical Generator Sets

Variable speed and powerlectronic converter

Contemporary trends of future development in mobile electrical generator sets (EGS) show, that the new generation of EGS will be based on new technologies. Constant speed mobile electrical power sources with combustion engines driving brushless field excited synchronous generators will be replaced by optimally controlled variable speed diesel engine, driving robust permanent magnet generator equipped with power electronics frequency and voltage control.

By Jan Leuchter and Otakar Kurka, University of Defense (Czech Republic)
By Pavol Bauer, Delft University of Technology (The Netherlands)

Mobile Electrical Power Sources, initially developed and produced mainly for military purposes, gradually found their use as power supplies for various machines and appliances to increase their mobility, in mobile workshops, lighting systems, in communication and control systems. EGS enable the independence on the common electrical power network and create an essential part of Uninterruptible Power Sources. They are used in building industry, in agriculture, in ground and air transport, in health service and in other branches of industry and economy. Quite indispensable are the EGS in civil defense, crisis management forces, and naturally in armed and security forces. Sophisticated weapon systems, including aircraft and air defense, artillery systems, transport means, logistical structure and training systems based on computer simulation and virtual reality concepts require also modern and reliable EGS, corresponding to new conditions and requirements.

Mobile electrical power sources of the 1 and 2nd generation, based on improved classical engine - generator sets, are gradually introduced in the course of last two decades. These EGS are operating with constant speed corresponding to the required fixed frequency (50, 60 or 400 Hz), as shown in Figure 2. The 1st generation of EGS (EGSG1) is based mainly on the classical motor-generator principle with a common electromagnetically excited synchronous generator driven by petrol or diesel engine at a constant speed corresponding to the required frequency of output voltage. EGSG1 are very heavy, difficult to handle, noisy and low efficient.

Figure. 1 Mobile electrical power sources.

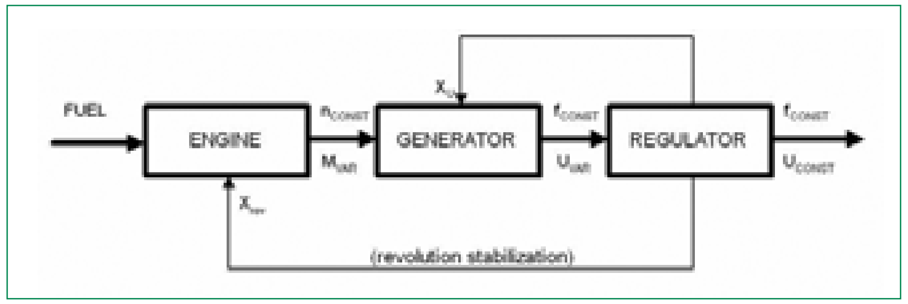


Figure 2. Concept EGS with constant speed of engine.

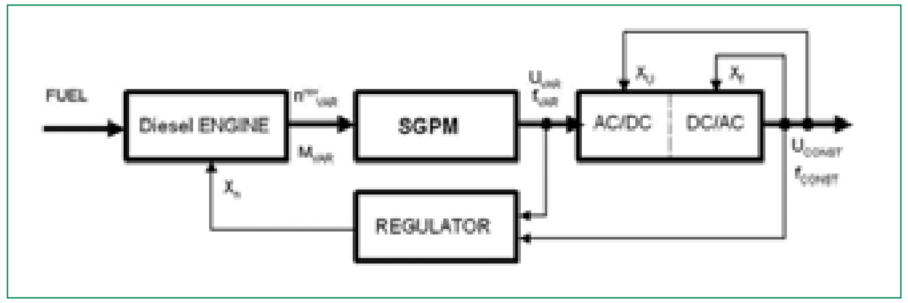


Figure. 3. The concept EGS with optimum variable speeds according load.

The 2nd generation of EGS (EGSG2) is characterized by using modern diesel engines, new types of generators (brushless, asynchronous, and synchronous with permanent magnets) and higher efficiency than EGSG1. Nevertheless these 2nd generation EGS operate still on the classical engine-generator concept with constant speed engine as EGSG1.

The investigations of EGS operation in last years have shown that the majority of sets operate under low load, which does not exceed more than 20 % of rated permanent load. In these conditions both the engine and generator operate with low efficiency, affecting unfavorably the pollution and fuel consumption. An optimal control of engine-generator set speed in the dependence on the instantaneous EGS load (Figure 3) can decrease the fuel consumption namely at low and middle loads, as shown in Figure 4. The optimum speed is hereby calculated according to the EGS load with the optimality criterion the minimum fuel consumption. The consequence of varying engine speed both the output voltage and the frequency of the generator are variable and must be converted to the constant value required by the load (usually 3 x 400V, 50Hz). Therefore it is necessary to introduce a power electronic voltage and frequency converter to the new EGS structure (EGSG3).

New generation of EGS brings some primary benefits:

- the fuel consumption savings for low and middle load;
- decreasing the amount of harmful air and acoustic emissions;
- longer lifetime and higher reliability of EGS;
- increasing versatility of output electrical parameters EGS (voltage and frequency);
- increasing of the quality of output energy.

The main handicap of new concept EGS creates higher initial costs EGS then EGSG1 and EGSG2. These initial costs can be higher by 30 % according to kind of power electronic converter that stabilize output voltage and frequency. The initial costs will be compensated by decreased operating costs. The desire for future EGS is that they be portable, lightweight quiet systems that are electronically controlled and capable of operating on fuels in extreme environmental conditions.

Power Electronics of EGS with optimum variable Speed

The simplified block diagram of EGS with variable speed of engine was shown in Figure 3. The photo of 6 kW experimental EGS consisting of the chosen driving Diesel engine, synchronous generator with permanent magnets, indirect-type converter (AC/DC/AC), output filter and control speed unit can be seen in Figure 5. The output voltage of synchronous generator varying in the range of 200 to 400 V at the frequency 100 to 300 Hz is to be converted to the constant value 3x 400 V/ 50 Hz by means of AC/DC/DC converters (Figure 6).

Synchronous generators with permanent magnet without electromagnetic exciting system are used in many modern applications with variable speed concepts. They have high efficiency; high reliability and high speeds can be reached. Variable speeds of diesel engine correspond to the output voltage and frequency of a synchronous generator with permanent magnets. Voltage source type converters (AC/DC/AC) are usually used on the whole applications range of power converters up to a hundred kW of power. The function of DC/DC converter is to stabilize the output DC voltage to the required level of UDC=570V for an inverter output equal to 3x400 V. The DC/DC converter is designed as STEP-UP chopper (FORWARD) with two switches connected in serial with the diode AC/DC rectifier. If the output voltage of the diode rectifier is less than 570 V then the STEP-UP chopper increases the link voltage (Figure 6).

The output three-phase voltage 400V of AC/DC/AC converter is adjusted to the required constant output frequency 50 Hz by means of DC/AC converter and the voltage control unit.

The measurements show that the real drawback of this concept of EGS with variable speed is the dynamics at sudden transient from the low load to high load. Dynamic behavior of the driving

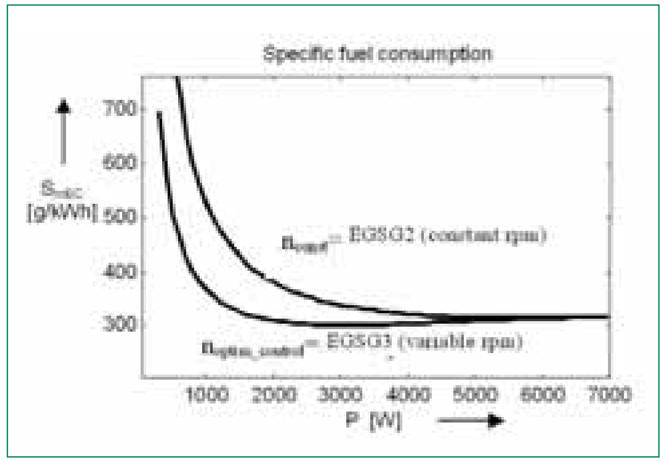


Figure 4. Fuel economy of EGS with constant and optimum variable speeds.

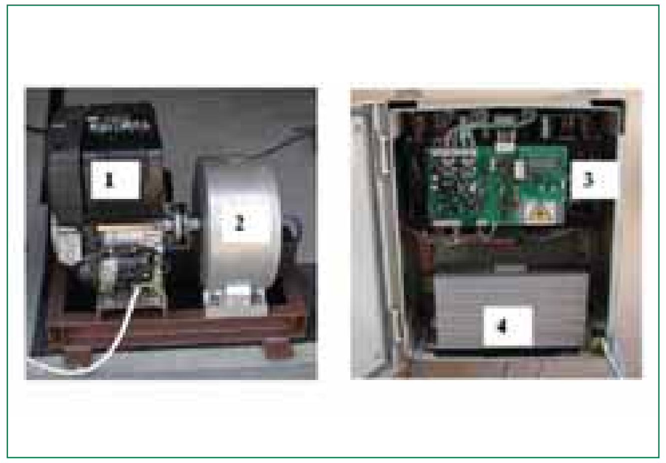


Figure 5. The photo of experimental model (1-diesel engine; 2-SGPM; 3- AC/DC/AC converter; 4-filter).

engine in the case of sudden power output increase requires the time of few seconds to change the speed of engine from the low to higher speed. During this time, the power required by the load is not available and diesel engine can by high load on the low speed stop undesirable. The measurement record of dynamic behavior of EGS with variable speed is shown in Figure 8. After sudden change of the load (A), the feedback control system sets a new optimum speed of diesel engine (B) according to the characteristic. Delay between power output increase and reaction of diesel engine is about 1-5 s in dependence on the speed, load (inertia) and control mechanism.

The photo detail of speed control unit of experimental diesel engine HATZ 1D40 is shown in Figure 9. The required speed of the engine is adjusted by actuating lever and instantaneous speed is calculated from position sensors, which measure the instantaneous position of actuating lever. Servo unit is controlled by microprocessor and adjusts required speed by means of actuating lever.

Electronic converter can improve the dynamic behavior of whole EGS system by means of inserting accumulated energy to the DC link (see Figure 10). This concept is based on the delivery of peak power from energy storage to the

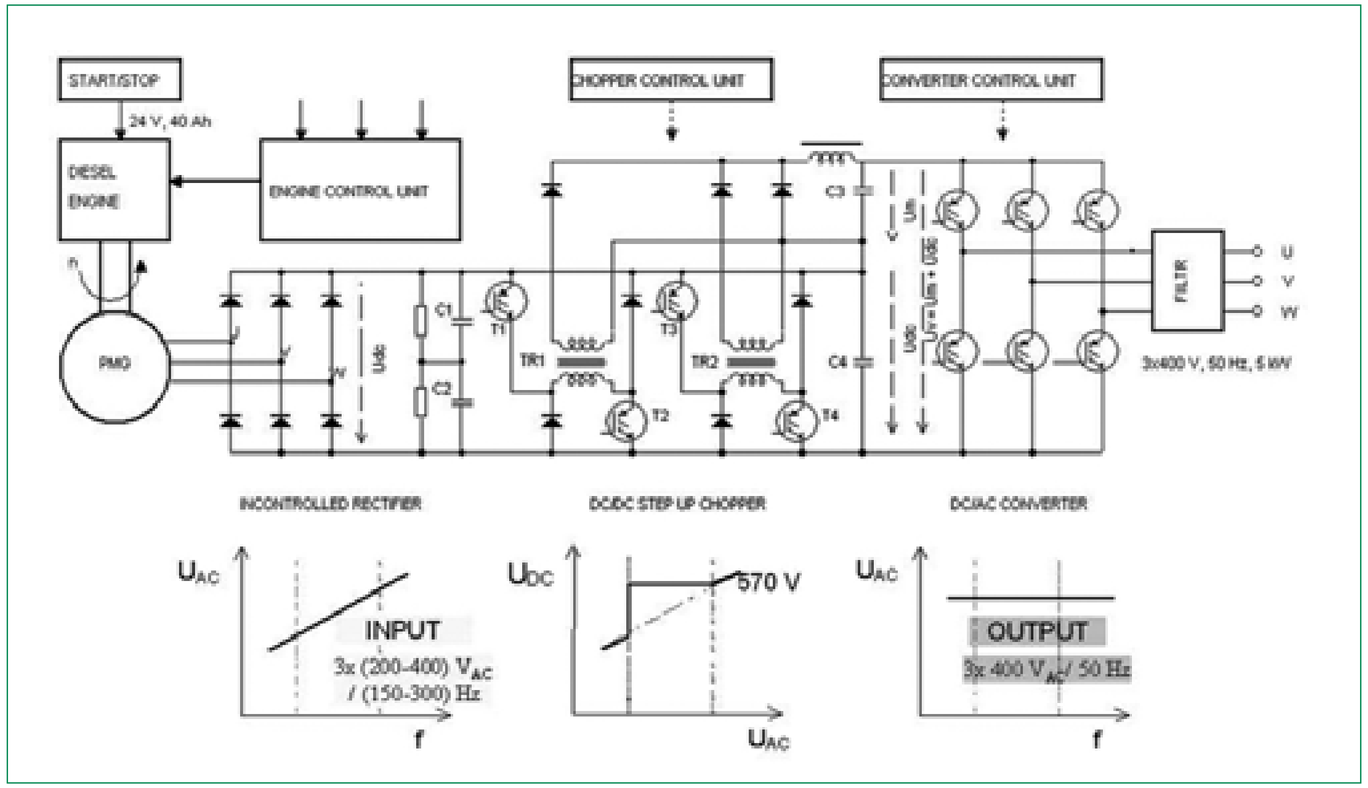


Figure 6. The schematic circuit of experimental model with AC/DC/AC converter.

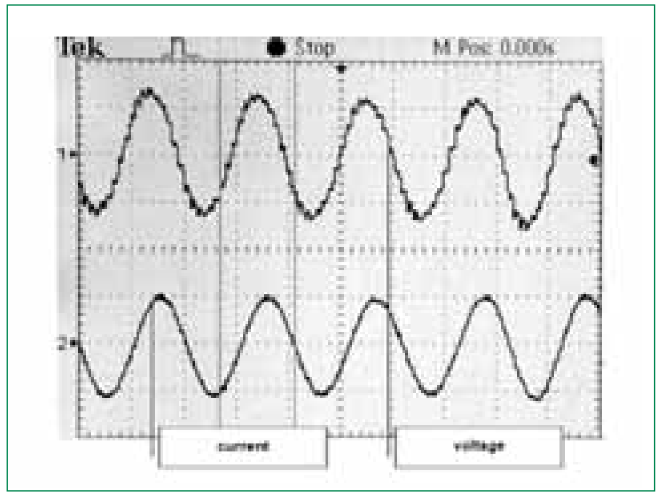


Figure 7. Output voltage and current of EGS.

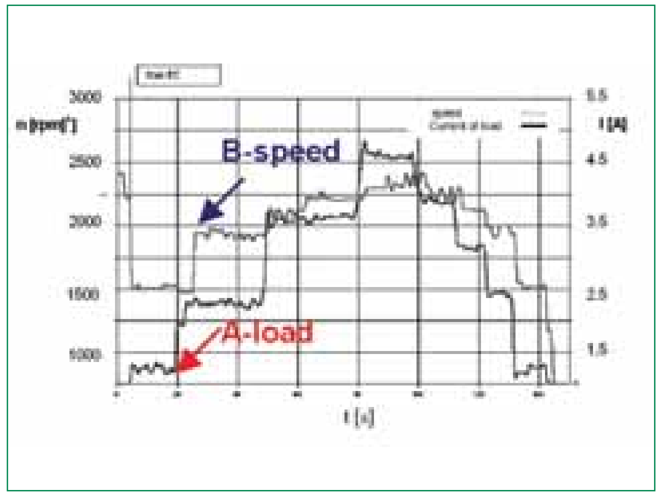


Figure 8. Experimental result of dynamic behavior of EGSG3.

DC link during the regulation time of engine from low speed to high speed. For example: the regulation time from low speed (1000 rpm-low load) to high speed (3000 rpm-full load) take about 2s and so for 6kW EGS about 12 kJ is required. This energy is too high for classical solution with electrolyte capacitors. Solution with accumulators can bring enough storage energy but increases the weight of EGS to unacceptably. Solution of converter with accumulators brings weight increasing of EGS as much as 60kg.

The optimal way of energy storage can be achieved by usage of super-capacitors, although they are relatively new and rather expensive. The efficiency of charging and discharging is much higher than in previous solution with accumulator and can bring better relationship between stored energy storage, dimensions and weight then accumulators.

The 1st and 2nd generation of EGS operates with constant engine speed corresponding to the required output voltage frequency. Both engine and generator operate often with low efficiency at the low and middle load. Higher efficiency and lower operation costs may be achieved by using new concept of EGS with optimum variable speed according to the EGS load. The optimum speed is hereby determined according to the EGS load with the minimum fuel consumption optimality criterion. Both the generator output voltage and frequency are variable and are to be converted to the constant values by power electronic converter.

The main handicap of new concept EGS is higher initial costs EGS then EGS wish constant speed. These initial costs can be higher by 30 % according to kind of power electronic voltage and frequency converter. Other drawback of EGS with variable speed is the engine-generator dynamics at sudden transient from low load to high load. Power electronic converter can improve the dynamic behavior of whole EGS system by means of inserting accumulated energy from super-capacitor.

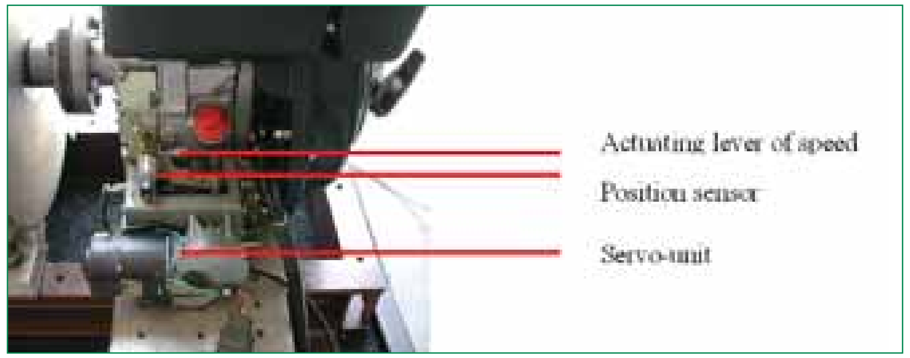


Figure 9. The detail photo of speed control system of EGS.

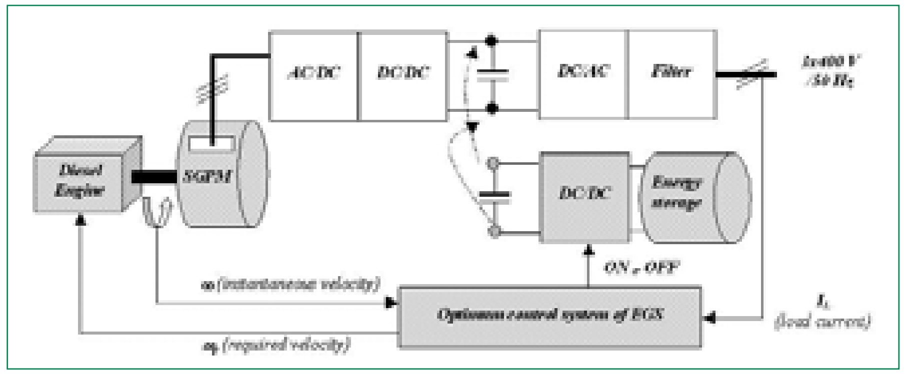


Figure 10. The EGS system with peak power energy to DC link of AC/DC/AC converter.

www.unob.cz/en/

http://ee.its.tudelft.nl/epp/

Integration of Power Devices

Transfer-mold packaging technology

With the transfer-mold package Mitsubishi has developed a novel module packaging concept utilizing a new thermal dissipation structure. This allows a reduction in package size and weight. Consequently the new package will save resources of packaging, logistics and energy for transportation.

By Toru Araki, Mitsubishi Electric Corporation and Robert Wiatr, Mitsubishi Electric Europe

The RC-IGBT will have a significant impact on the power module market due to a more efficient use of resources such as less silicon, lower production energy and reduced packaging materials. Moreover, with these semiconductors, Power Control Systems such as AC Matrix Converters with no need for large DC link capacitors come within reach.

High Voltage ICs (HVIC) are already used to realize a simple gate drive circuit in the low power area. By employing HVICs, a single gate power supply is sufficient for driving all six inverter switches.

With the transfer-mold package Mitsubishi has developed a novel module packaging concept utilizing a new thermal dissipation structure. This allows a reduction in package size and weight. Consequently the new package will save resources of packaging, logistics and energy for transportation.

This new power module, whose key concept is "Environmental Compatibility", will be a combination of RC-IGBT (or RB-IGBT), HVIC and new packaging technologies. The Key Word "Environmental Compatibility" is indicating the new power device's direction: saving resources.

Environmental Compatibility Concept

The "ease of use"-strategy is very important in order to enlarge the market of power devices. The particular items "Small Size" and "Light Weight" are key points in the "ease of use"-strategy. They also contribute to the saving of resources in packaging, logistics and energy for transportation. The most important topic today is the reduction of hazardous substances in order to meet

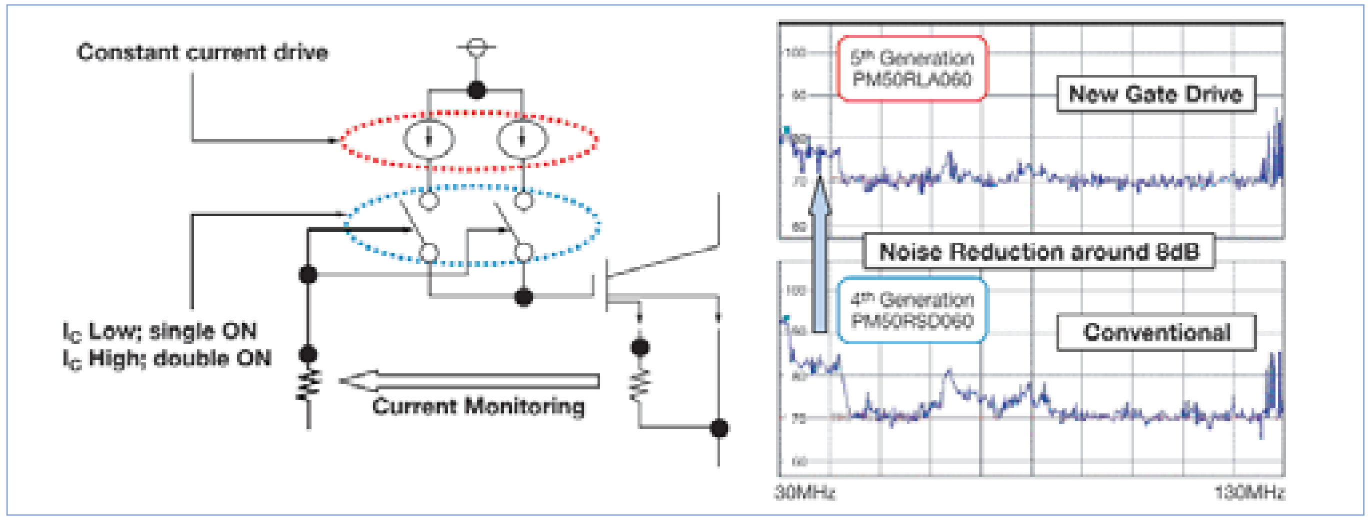


Figure1. New Gate Drive Concept to Reduce Switching Noise.

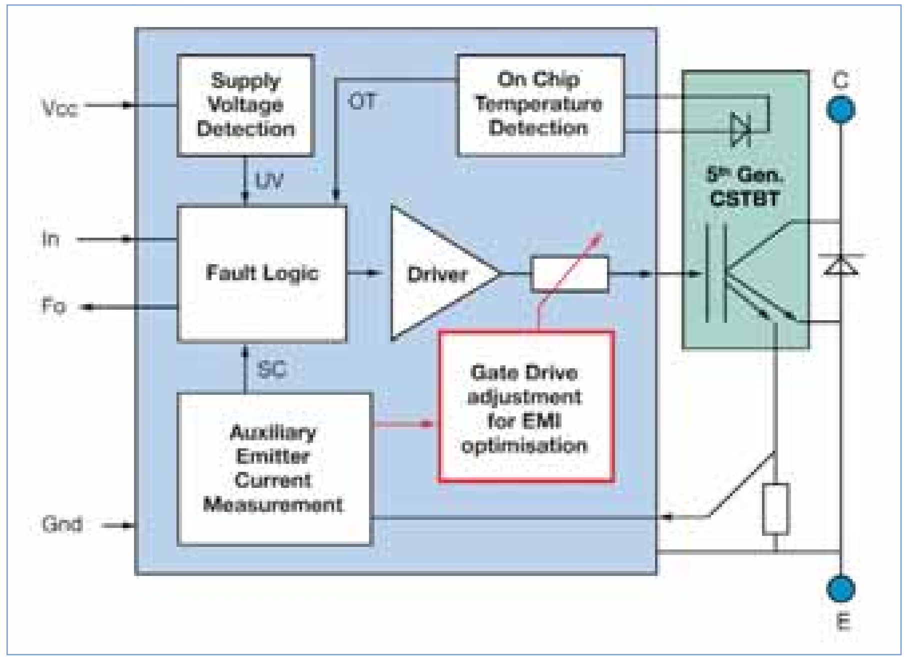


Figure 2. New Gate Drive Conce.

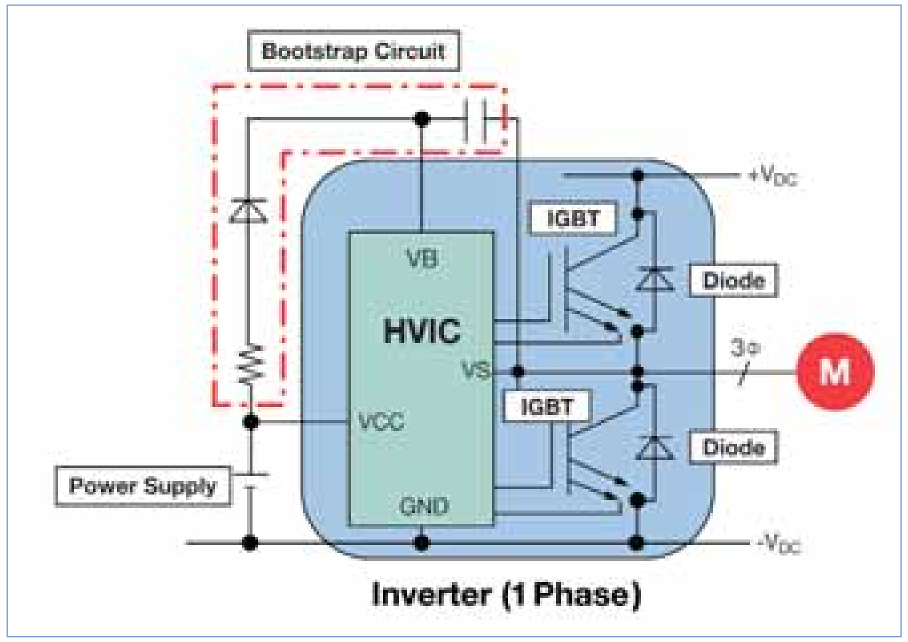


Figure 3. HVIC with Bootstrap Circuit.

the RoHS directive. By using the new transfer-mold packaging technology, it will be simple to realize lead-free packages without additional cost.

Gate Drive Technology

Since EMI noise and surge voltage issues have become major problems in power management system design, gate drive circuits and power chips have recently reached the same level of importance in power modules. Sometimes the size of noise filters is bigger than the inverter drive system itself. Therefore reducing EMI noise and surge voltage to the smallest possible values remains a universally valid request.

Soft switching technology is also a way to solve EMI noise and surge voltage problems. Intelligent Power Modules (IPM) are committed to this. IPMs include special gate drive ICs that have a soft switching circuit for EMI noise reduction. Moreover, these have integrated protection functions for the power elements, IGBT and diode. Customer benefits from IPMs since an easy inverter system design can be realised with practically no risk or trouble.

Figure 1 shows the special gate drive concept for reducing switching noise. The basic concept is that the gate of the IGBT is driven by constant current instead of the conventional constant voltage source. This current value is switched by the emitter current level of IGBT that is detected by the sense emitter cell. At turn-on, when the emitter current level is low, the gate drive current, and with it the output dV/dt, is small. Hence, the output noise is reduced. When the emitter current reaches half the value of the rated IGBT current, the gate current doubles. This current increase takes less than 1 s. This very fast complex operation is realized by high speed Bi-CMOS IC technology.

Figure 2 shows the newest gate drive circuit for the 5th generation IGBT, the Carrier Stored Trench Gate Bipolar Transistor (CSTBT). This gate driver employs soft switching technology to reduce switching noise and a special soft turn-off function to decrease the surge voltage when the CSTBT faces irregular conditions such as over-current or short-circuit operation. This special gate driver IC is also made by a high speed Bi-CMOS wafer process.

The reduced number of power supplies for the gate drives is more important for small power inverter systems, such as white goods applications where the developer aims for the smallest possible inverter system design. For the single power supply concept, High Voltage IC (HVIC) technology is very useful.

Figure 3 shows a HVIC with bootstrap circuit consisting of one resistor, diode and capacitor. By using this topology,

POWER MODULES

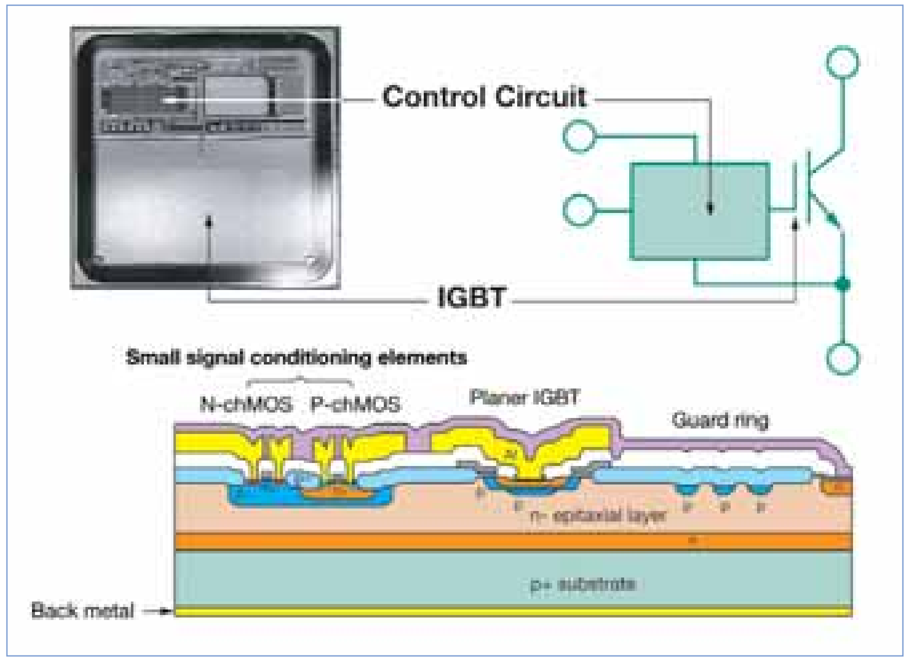
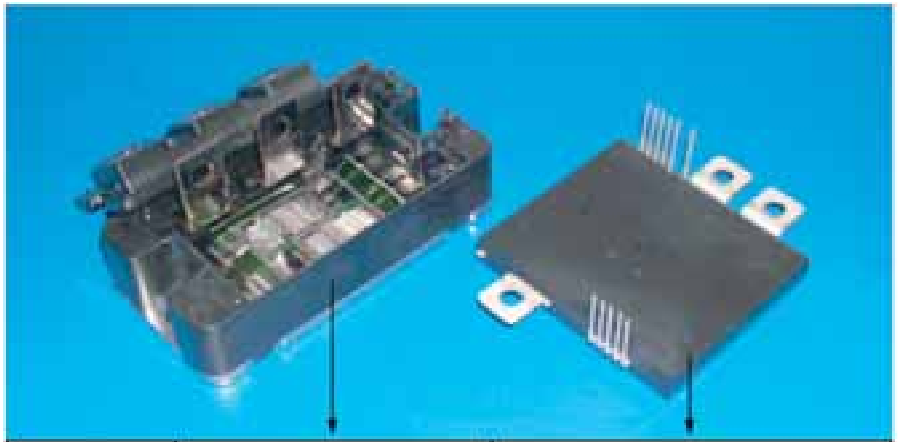


Figure 4. Top View and Structure of Intelligent Power Device.



	Case type	Transfer molded type
weight	1 (310g)	1/3 (100g)
volume	1 (48x94x29mm)	1/5 (64x56x7.5mm)

Figure 5: Comparison of Case Type and Transfer Mold Type.

one single 15V power supply for both high side and low side gate drive function is sufficient.

The integration of the IGBT with gate drive and protection circuits is still important. This topic is addressed with the development of an Intelligent Power Device (IPD). Figure 4 shows the top view and structure of IPD.

Structure

The small signal conditioning circuits, which are constructed in CMOS, are combined with planar IGBTs in this IPD. The combination with CMOS is so important, because it facilitates the design of the signal conditioning circuits. The gate drive technologies are based on IC technology, such as the soft switching technology to reduce surge voltage and EMI noise. HVIC technology decreases the number of power supplies and enables easy usage on customer side. The gate driver technologies become an important point to realize the "Environmental Compatibility" concept.

Packaging Technology

Our newest packaging technology is based on transfer-mold techniques. The transfer-mold packaging technology has often been used for IC packages. It was also used for low power range IPMs, the "Dual-In-Line IPM". Such DIP-IPMs are very suitable for home appliance use, such as air conditioners, refrigerators and washing machines.

Recently the transfer-mold packaging technology has also been extended to middle and high power applications. A first example is the 300A/600V 2in1-package as shown in Figure 5. Figure 6 shows the cross-section of a new transfer-mold package. A key technical point is an insulating sheet that is made of epoxy resin with filler securing a high thermal conductivity. By using a copper heat spreader for a lower thermal resistance, the same thermal resistance value as with the conventional case type structure (about 0.1deg/W) can be realized. Furthermore, lead-free solder for the die bonding is used, so that the package is entirely realized without any trace of lead.

The advantages of these transfer-mold power modules are small size, light weight and longer power cycle lifetime. Figure 5 shows a comparison of the conventional case type and the transfer-mold type. By using transfer-mold packaging technology, the weight is reduced to one third, and the volume to one fifth. This fact exactly complies with the core idea of "Environmental Compatibility" in middle and high range power modules.

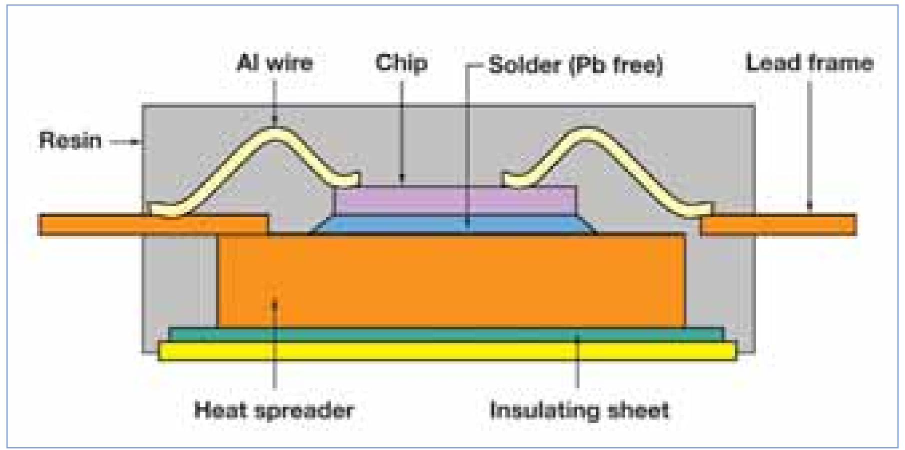


Figure 6. Cross-Section of the New Transfer Mold Package.

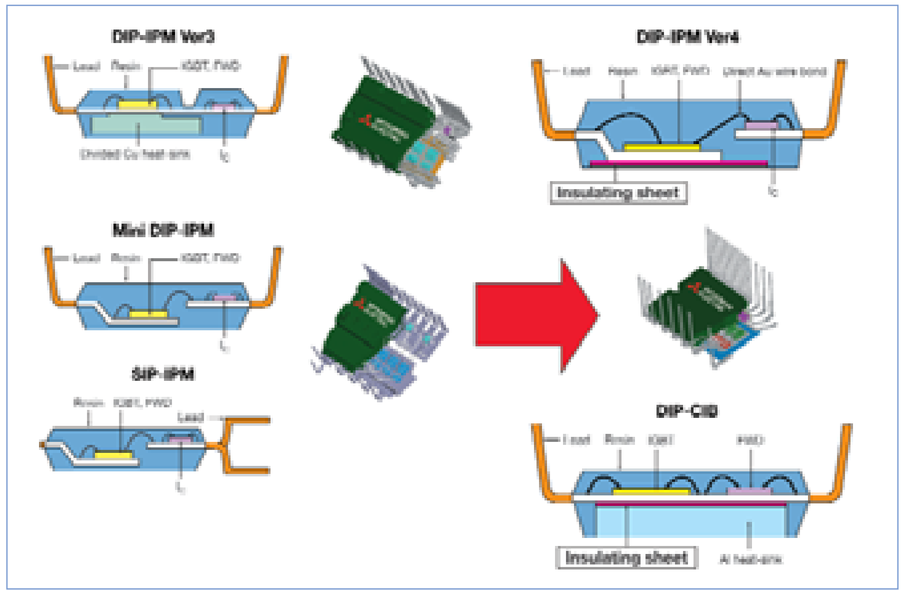


Figure 7. Trends in Package Structures of DIP-IPM.

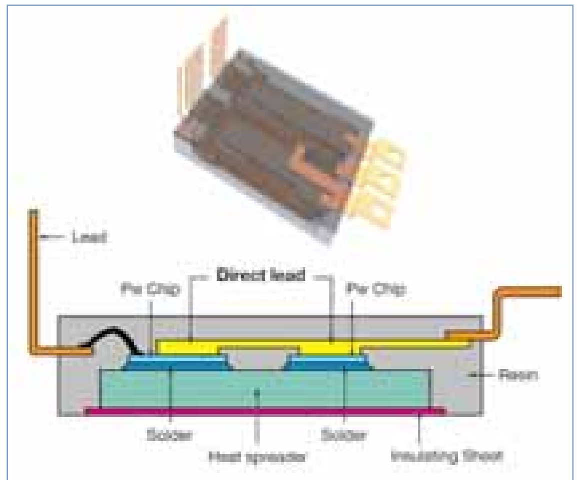


Figure 8. Cross Section and Internal Architecture of Direct Lead Bond.

On the other hand, the same thermal dissipation structure as for the new transfer-mold package, i.e. the employment of an insulating sheet, is used to optimize low power DIP-IPM packages. This new structure is named "Version 4 DIP-IPM".

Figure 7 shows the trend of DIP-IPM packaging structures. By using the Version 4 structure, the thermal resistance will reduce to 60% of conventional full-mold package structures. It is planned to prepare the Ver. 4 structure for all package line-ups, such as SIP, super-mini DIP, mini DIP, large DIP, and to cover 3A to 75A current range.

Another direction of future package technology will be the direct lead bond structure. Figure 8 shows its cross-section and internal architecture.

The first feature of direct lead bond structure is increased current density. This results in reduced chip size for the IGBT. The second feature is low resistance of the emitter wire thus reducing on-voltage. The third feature is an improvement of power cycling capability. Compared to conventional Al wire bond structure it has been extended more than ten times. By using the new transfer-mold package technology and direct lead bond structure, a higher reliability, lower cost, smaller size and lighter weight for the power module package can be realized. All these features contribute to the "Environmental Compatibility" concept.

Conclusion

Mitsubishi's "Environmental Compatibility" concept is based on a new power chip, a new gate drive and new package technologies. The goal is to combine all these technologies to save resources, energy and time. This will lead to further cost reductions for both - manufacturers and customers, and will contribute to a further propagation of power control systems.

www.mitsubishichips.com

DC-DC Converters Designed for UMTS

Tyco Electronics Power Systems announced the release of its EQD075A and EQD020A0F series DC-DC converters, part of a new generation of open-frame DC/DC power modules designed for UMTS and CDMA base stations and wireless IP routers applications. These units support a 3:1 input voltage range that will allow for operation in both 24V or 48V nominal input voltage systems, eliminating the need for separate power modules to handle the two input voltage ranges, and therefore resulting in significant cost and logistics savings for OEM customers.

EQD075A and EQD02A0F series converters operate over a wide input voltage range of 18 to 60Vdc and provide a single precisely regulated output. The EQD series converters are designed to deliver up to 75W of output power in an industry standard eighth brick package measuring 57.9 mm x 22.8 mm x 8.5 mm (2.28 in. x 0.90 in x 0.335 in). The output is isolated from the input, allowing versatile polarity configurations and grounding connections. Built in filtering for both input and output minimizes the need for external filtering.

EQD series converters employ half-bridge conversion topology with highly optimized synchronous rectification and incorporate patented edge-plating with innovative packaging techniques to deliver superior thermal performance. EQD075A offers a programmable output voltage range of 3.0V to 5.5Vdc with industry standard trim equations and can deliver 15A at 5Vdc output with full load efficiency of 90% (48Vin). EQD020A0F is optimized for 3.3V output and can deliver 20A at 3.3V with full load efficiency of 89% (48Vin).

www.power.tycoelectronics.com

Three Phase PWM with DirectFET

International Rectifier has launched a three-phase PWM control IC with integrated drivers for DC-DC converters. The IR3094MPbF enables up to 40% circuit size reduction when used with International Rectifier DirectFET MOSFETs. The smaller footprint makes the IR3094 ideal for space-constrained applications like DDR memory in rack servers and point-of-load (POL) modules used in high-density data systems.

A typical 80A, three-phase synchronous buck solution would require as many as 13 devices including one control and three drivers in addition to three MOSFETs per phase. A chip set made with the IR3094 plus IRF6637 and IRF6678 DirectFET MOSFETs reduces the silicon component count to seven devices for the same output current. Three pairs of these DirectFET MOSFETs can be placed directly next to the IR3094, creating a solution that minimizes printed circuit board trace parasitics and enables optimum switching performance.

The IR3094 is designed for applications requiring a 0.85V to 5.1V output. The new IC is housed in a compact 7mm x 7mm MLPQ package, and features 3A gate drive capability, a 1% accurate reference voltage, adaptive voltage positioning and programmable switching frequency up to 540kHz. The IR3094 provides system protection with programmable soft start, hiccup over-current protection, over-voltage protection, and a "power good" indicator.

The IRF6678, an ideal synchronous MOSFET, features a very low typical device on-resistance of 1.7mOhm at $10V_{GS}$ and 2.3mOhm at $4.5V_{GS}$. The IRF6637 is best suited as a control MOSFET, with very low Miller charge of only 4nC and typical device on-resistance of 5.7 mOhm at $10V_{GS}$ and 8.2m Ohm at $4.5V_{GS}$. Both MOSFETs are housed in the medium can DirectFET package, occupying the same board area as a SO-8 with only a 0.7mm profile, and improved thermal performance through double-sided cooling.

www.irf.com

Chomerics Conductive Gap Fillers

High volume applications adopt pre-cured thermally conductive gap fillers as the preferred solution

Chomerics T630 and T630G dispensable form-in-place gap filling materials are finding a growing number of applications in high volume automotive and consumer equipment. With the ability to be applied quickly with excellent repeatability using automated dispensing equipment, the economical materials provide a valuable option for engineers looking to solve thermal problems in high volume applications.

THERM-A-GAP T630 and T630G are fully cured silicone based materials that enable effective heat transfer between electronic components and the chassis or enclosure wall of a piece of equipment. They can be dispensed directly onto the target surface and do not require a post-application curing cycle. This means that mating components can be assembled immediately after the application of the material; a characteristic that is valuable in high volume, automated production environments.

Being able to achieve 50% deflection with just one psi of applied pressure allows the material to be used with delicate components and in applications where high assembly pressures are difficult or expensive to achieve. The materials are able to fill gaps ranging from 0.020 inches to 0.120 inches. An additional benefit of T630 and T630G is the vibration dampening effect they can provide; this is especially useful in automotive modules.

Both T630 and T630G are UL 94V-0 compliant and have an operating temperature range of –50°C to +150°C. Shelf life is 18 months.

www.chomerics.com

SMBus Battery Charge IC

Texas Instruments announced its first integrated battery charge controller with a System Management Bus (SMBus) interface aimed at multi-cell, multi-chemistry battery packs used in portable applications.

TI's highly accurate and power efficient bq24721 charge management device easily interfaces to a system's host controller through an SMBus communications interface. The charger offers 0.4 percent accuracy on charge voltage regulation and two percent accuracy on current amplifier outputs. Using a synchronous NMOS-NMOS rectifier, the easy-to-design device can achieve power efficiencies up to 94 percent.

The bq24721 integrates several high-performance features, including the system power selector function, which automatically selects the AC adaptor or the battery to properly manage the system load. The device's dynamic power management (DPM) function controls the charge current depending on system load conditions, avoiding AC adaptor overload. In addition, high accuracy current sense amplifiers enable accurate measurement of either the charge current or the AC adaptor current, allowing termination of the "non-smart" packs and monitoring of overall system power.

www.power.ti.com/battman

Tektronix DPO7000 Oscilloscope Eliminates Trade-Offs

Tektronix announced the introduction of the DPO7000 Digital Phosphor Oscilloscopes (DPOs). These breakthrough instruments are based upon a new generation hardware platform that eliminates the trade-offs found in all other oscilloscopes between sample rate, record length and waveform capture rate. With technology innovation, unmatched features and specifications, the real-time DPO7000 is the world's first uncompromised performance oscilloscope.

Design engineers are increasingly working with embedded systems that present a variety of challenges in serial data, power design, video and other applications. In addition, faster signalling speeds are becoming more prominent in mainstream applications. To meet the needs brought about by increasing speed and complexity, engineers need greater real-time signal acquisition and instrument intelligence for design validation, debugging and compliance. This requires the fast sampling rates, long record length (deep memory), fast waveform capture and analysis capabilities uniquely available in the DPO7000. Ranging from 500 MHz to 2.5 GHz, the new DPO7000 models are ideal for engineers and technicians wanting to more efficiently debug their devices, reduce time to market, obtain higher quality products and lower development costs.

The 500 MHz DPO7054, 1 GHz DPO7104, and 2.5 GHz DPO7254 models share a new generation platform that makes broad use of IBM 7HP silicon germanium (SiGe) technology to provide higher performance for demanding applications. The DPO7000 provides fast sample rates of 10 GS/s on four channels and real-time oversampling on four channels; up to 16X oversampling on one channel and 4X on four channels simultaneously. The DPO7054 and DPO7104 support 40X oversampling on one channel and 10X on four channels simultaneously when configured with option 2SR. The DPO7054 and DPO7104 support deep record lengths to 200M while the DPO7254 supports 400M. All models include a 12.1 inch XGA display enabling engineers to see more information at once, and all models provide vertical accuracy of +/- 1%.

DPO7000 models include the unique Pinpoint trigger system, the world's only complete A/B triggering system to rapidly discover and capture intermittent faults or events in complex signal structures.

www.tektronix.com

LeCroy WaveRunner Xi Series Oscilloscopes

LeCroy launches a new line of WaveRunner digital oscilloscopes that eliminate the tradeoff between high performance, display size, and bench footprint.

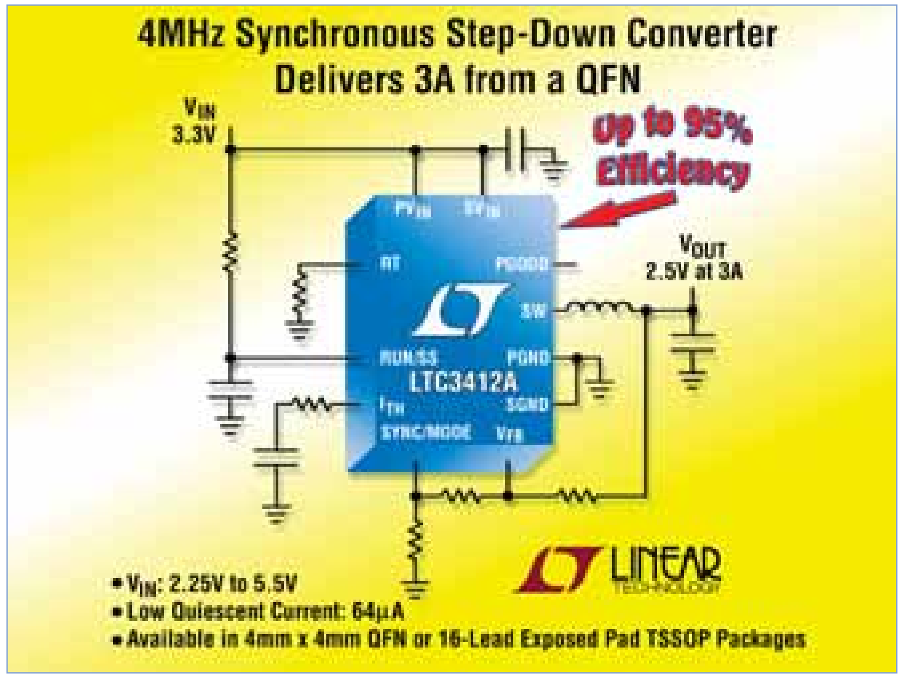
Like WaveSurfer, these oscilloscopes boast big, bright, 10.4" displays and only 6" (15cm) of depth, making them perfect for a crowded bench, and great for engineers who appreciate a big display to better understand their circuit. The WaveRunner oscilloscopes boast of sample rates up to 10 GS/s (interleaved) on the 600 MHz unit, and standard 2 Mpt/Ch memory (with optional memory up to 24 Mpt/Ch interleaved). These high sample rates (at least 10X oversampling) result in significantly better signal fidelity for fast edges or high frequency signals, and ensure accurate timing measurements when using all channels. In fact, these sample rates exceed those of most competitive scopes that are rated at 1 or 1.5 GHz bandwidth (and also have a correspondingly higher price). Thus, the WaveRunner Xi Series is the highest performance oscilloscope in this bandwidth class with the most desirable form factor?an unbeatable combination.

In addition, LeCroy offers a mixed-signal option (MS-32) that allows you to add 32 digital channels, each with 1 Mpt/Ch (32 Mpts total) to a 4 channel WaveRunner Xi to expand 4-channel scope capability to 4+32, which significantly enhances mixed signal and embedded controller debug.

Simply put, the WaveRunner Xi Series provides 2.5-5X the sampling rate, 2X the viewing area and half the footprint of any competitive oscilloscope—no compromises!

www.lecroy.com/europe

4MHz, Synchronous Step-Down Regulator



Linear Technology announces the LTC3412A, a high efficiency, 4MHz, synchronous buck regulator using a constant frequency, current mode architecture. It can deliver up to 3A of continuous output current at voltages as low as 0.8V from a 4mm x 4mm QFN (or a thermally enhanced TSSOP-16) package. It operates from an input voltage of 2.25V to 5.5V, making it ideal for both single cell Li-Ion, or NiMH applications, as well as more general purpose fixed rail systems. Its 4MHz switching frequency allows the utilization of tiny low cost capacitors and inductors with less than 1.5mm profile. High frequency operation also keeps switching noise out of critical wireless and xDSL frequency ranges, making it ideal for xDSL modems, cellular base stations and automotive applications.

The LTC3412A uses internal switches with RDS(ON)s of only 0.065 Ohm and 0.077 Ohm to deliver efficiencies as high as 95%. It also utilizes low dropout 100% duty cycle operation to allow output voltages equal to VIN. No load quiescent current is only 64uA, and less than1uA in shutdown, making it ideal for applications such as automotive power systems that require ultra-low supply currents. For optimum efficiency at light loads, the LTC3412A utilizes selectable Burst Mode® operation to reduce gate charge losses. The current at which the Burst Mode operation initiates is user programmable, enabling the designer to optimize light load efficiency. If the application is noise sensitive, the SYNC/MODE pin can also be configured to provide forced continuous operation to reduce noise and RF interference. Additional features include a Power Good voltage monitor, external synchronization capability, and thermal protection. The LTC3412A is an ideal, for applications requiring 3A of output current, and where a small solution size and low supply current are critical.

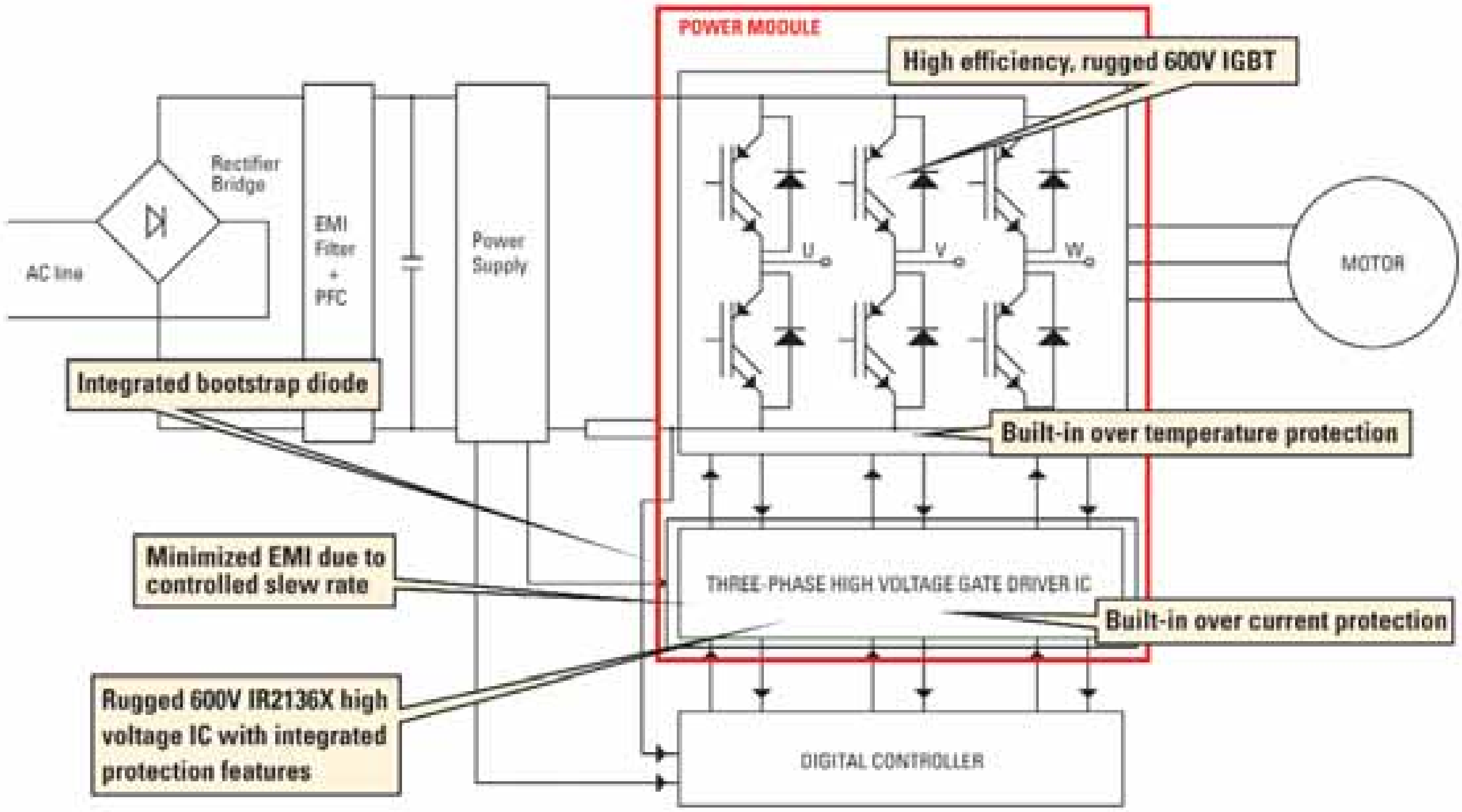
www.linear.com

Companies in this issue

Please note: **Bold**—companies advertising in this issue

MOTOR POWER STAGE PROTECTED WITH RUGGED 600V ICs

High Voltage Power Stage Delivers a Dedicated, Reliable Appliance Solution



INTEGRATED DESIGN PLATFORM

Part Number	HVIC	Current Rating @ TC=25°C	Current Rating @ TC=100°C	Over-Current Trip (typ)	V(trip)	Package
IRAMS06UP60A	IR21365	6A	3A	user defined	4.30V	SIP1
IRAMS06UP60B	IR21363	6A	3A	9.8A	0.49V	SIP1
IRAMS10UP60A	IR21365	10A	5A	user defined	4.30V	SIP1
IRAMS10UP60B	IR21363	10A	5A	14.8A	0.49V	SIP1
IRAMX16UP60A	IR21365	16A	8A	user defined	4.30V	SIP2
IRAMX16UP60B	IR21363	16A	8A	27.1A	0.49V	SIP2
IRAMX20UP60A	IR21365	20A	10A	user defined	4.30V	SIP2
IRAMY20UP60B	IR21363	20A	11.5A	28.8A	0.49V	SIP3

Sinusoidal modulation at 400V, Tj=150°C, FPWM=20kHz (16kHz for SIP2, SIP3), modulation depth=0.8, PF=0.6
A version is open emitter, B version has internal shunt on negative bus

FEATURES

- Utilizes proprietary three-phase monolithic gate driver IC matched with highly efficient IGBT power switches
- Insulated metal substrate technology for reduced EMI
- Optimized for power up to 2.2kW
- Web-based design tool at www.irf.com/design-center/ipm
- Replaces more than 20 discrete parts to deliver complete power stage solution

IR brings digital controllers, analog stage and power modules together in one easy to implement, integrated design platform.

Elektra 05
European Electronics Industry Awards
WINNER
Environmental Award

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