Power Systems Design

NORTH AMERICA

Empowering Global Innovation

March/April 2009

PowerLine

PowerPlayer

MarketWatch

TechTalk

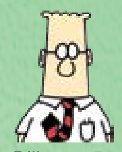
Design Tips

PSDNA Green Power ENERGY EFFICIENCY

Special Report - White Goods

ISSN: Pending

Power Systems Design NORTH AMERICA



Dilbert – 56

Viewpoint
Moving on.., By Cliff Keys, Editor-in-Chief, PSDNA 2

Industry News
New CEO and Company Structure for CT-Concept 4
VEC Technology Announces Government Contract and Entry in Wind Energy Blade Industry 4
TI Projector Development Kit Available from Digi-Key 4
Mouser Electronics Receives Outstanding Sales Achievement Award from Microchip Technology 6
Ametek inc. Acquires Xantrex Programmable Power Supply Business 6

PowerLine
Ultra-Small 3A DC-DC Converter Radically Increases Power Density 7

PowerPlayer
Follow the Value Migration, By Kevin Parmenter, Freescale Semiconductor 8

MarketWatch
White Goods Still Offer Medium Term Opportunities, By Jason DePreaux, IMS Research 10

Design Tips
Frequency Response of Switching Power Supplies- Part 2, By Dr. Ray Ridley, Ridley Engineering 12

TechTalk
Superconductor Power Cables, Reported By Cliff Keys, Editor-in-Chief, PSDNA 16

Cover Story
Energy Efficient White Goods, By Paul Greenland, Semtech Corporation 18

Thermal Management
Die and Board Level Hot Spots, By Dr. Paul A. Magill, Nextreme Thermal Solutions 22

Energy Efficiency
Dynamic & Static Power Management with SmartReflex™, By Christophe Vaucourt, Texas Instruments 25

Power Supplies
Making Sense of Power Specifications, By Gary Bocock, XP Power 30

Powering Transportation
Power in Transit, By Gilles Terzulli, AVX Corporation 33

Current Sources
Solving Current Source Design Challenges, By Robert Dobkin, Linear Technology 35

Power Management
Aggressive Power Management, By Mark Hartman and Joy Taylor, National Semiconductor 38

Special Report: White Goods
Energy Efficient White Goods Need Accurate Control, By Stéphane Rollier, Bernard Richard and David Jobling, LEM 42
Smart Energy Meters in Home Appliances, By Cosimo Carriero, Analog Devices 45
Cooling White Goods, By Bob Knight, Knight Electronics 48
Taking Control in White Goods, By Vincent Mignard, Renesas Technology 50

New Products: Web Exclusive Content – Go to: www.powersystemsdesign.com

GreenPage
Economic and Ecological Energy Prevails, Reported by Cliff Keys, Editor-in-Chief, PSDNA 56

Power Systems Design NORTH AMERICA

AGS Media Group
146 Charles Street
Annapolis, Maryland 21401 USA
Tel: +410-295-0177
Fax: +510-217-3608
www.powersystemsdesign.com

Editorial Director, Power Systems Design China, Europe & North America
Editor-in-Chief, Power Systems Design Europe & North America
Cliff Keys
cliff.keys@powersystemsdesign.com

Contributing Editors
Liu Hong
Editor-in-Chief, Power Systems Design China
powersdc@126.com

Ash Sharma, IMS Research
ash.sharma@imsresearch.com

Dr. Ray Ridley, Ridley Engineering
RRidley@ridleyengineering.com

Publishing Director
Jim Graham
jim.graham@powersystemsdesign.com

Publisher
Julia Stocks
julia.stocks@powersystemsdesign.com

Circulation Management
Kathryn Phillips
Kathryn.phillips@powersystemsdesign.com

Research Director
Meghan Corneal
meghan.corneal@powersystemsdesign.com

Magazine Design
Beata Rasmus, Eyemotive
beata@eyemotive.com

Production Manager
Abby Wang
abbyw@action-new.net

Registration of copyright: January 2004
ISSN number: Pending

Send address changes to:
circulation@powersystemsdesign.com

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

Volume 1, Issue 2

Moving on..

The hard face of our business is biting in with many working short time or finding themselves out of work, tough times indeed. The business has, as expected, certainly not improved since our last issue of the magazine and the news keeps rolling in, albeit not always as gloomy as some forecasters had predicted.

During the period from February 2009 to January 2010, global pricing for commodity components is expected to decline at a relatively moderate pace of 1.1% per month, according to a forecast from iSuppli's Component Price Tracker (CPT) Index. This rate of decline is well within normal decreases as defined by Moore's Law and learning-curve factors.

In contrast, during the last major electronics downturn following the dot-com bust from June 2002 to May 2003, the average monthly price fell by 2.5%.

On a more positive theme, following on the heels of the APEC conference in Washington DC (see the web report featured in the March issue), we are now in deep preparation for the PCIM show in Nuremberg, Germany. The show runs from May 12 – 14th 2009 and is the No. 1 European meeting place for the power electronics, intelligent motion and power quality industry.

Designer's Power Systems Design Forum

PSDE's panel discussion in the Forum, together with vendor presentations will be on offer to visitors to the show. I will run a forum where industry experts from major companies in our industry will provide insight and opinions on the special PSD theme of:

"Power Design for Ecological and Economic Success"

This reflects the need not only for energy efficient designs, but also the realistic requirement today for designers to deliver industry-beating and differentiated designs - on time and within a real-world budget.

This issue of the magazine supports a special feature on white goods. I have selected the best articles from major manufacturers on this topic.

I hope you enjoy the issue. Please send me your valuable feedback, it really helps me deliver what you need, and check out our fun-strip, Dilbert, at the back of the magazine. I'm sure we could all use a smile!

All the best!

Cliff Keys.

Editor-in-Chief, PSDNA
Cliff.Keys@powersystemsdesign.com

New CEO and Company Structure for CT-Concept

CT-Concept Technologie AG, the worldwide market leader in IGBT gate drive units, has reorganized its structure in order to support future growth. The newly formed CT-Concept Holding AG will own the IPR and thus all forms of driver licensing and cooperation. CT-Concept Technologie AG will continue to act as the operational division covering development, production, logistics, sales and marketing.

After presiding over more than 22 years of successful business growth, the founder and chairman of CONCEPT, Heinz Rüedi, is taking a step back from active involvement and will continue as CEO of CT-Concept Holding AG.

The board of directors named Wolfgang Ademmer as the new CEO of CT-Concept Technologie AG who's duties commenced on May 1st.

Wolfgang Ademmer (left) and Heinz Rüedi (right)

Ademmer, 41, was formerly Senior Director at Infineon Technologies AG responsible for power electronics for hybrid vehicle and white goods since 2005. Prior to this position, he directed and handled the IGBT power module business at eupec GmbH as Vice President Sales & Marketing, establishing a solution-oriented strategy to cope with market trends, including a business plan for IGBT drivers.

"In Mr. Ademmer, we have found the ideal candidate to lead us to the next leap in growth. Thanks to his sound experience in the power semiconductor market and the excellent technology base at CONCEPT, he will provide the strategic direction to extend CONCEPTs market position and help us to tap new markets," said Heinz Rüedi, founder of CONCEPT.

"Knowing CONCEPT for more than ten years, I'm excited about our potential to create further success in a healthy market. Stimulated by the macroeconomic demand for more electricity, the market for medium and high-power converter solutions will grow steadily, unlike the purely end-consumer driven markets. With our products we will help to create efficient and reliable solutions in all medium and high-power applications, with an emphasis on a cost/performance ratio that competes with in-house developments" added Ademmer.

www.igbt-driver.com

VEC Technology Announces Government Contract and Entry in Wind Energy Blade Industry

VEC Technology LLC, (VEC), a 92% majority-owned subsidiary of Genmar Holdings, Inc., announced today that it has begun to deliver VEC built containers to the U.S. Army National Guard (USANG).

Over the past decade, Genmar has invested over $150 million in the development and expansion of our patented closed-molded VEC Technology into one of the world's most unique technology companies. Genmar began its research and development in VEC over 10 years ago with its sole intention at that time of developing VEC Technology for the manufacturing of recreational fiberglass boats. Since that time, Genmar has not only successfully manufactured over 75,000 VEC fiberglass boats, but has also expanded VEC's unique patented manufacturing processes and applications into several other industries outside of boating which require large precision-built composite parts. VEC recently received a $1.5 million initial test order from the U.S. Army National Guard to build VEC composite containers. VEC began delivering the first VEC containers contracted by the USANG last week.

VEC also announced today that it is entering the wind energy blade industry. There have been severe cracking and non-performance problems among many of the existing large fiberglass wind energy blades that have been installed throughout several of the existing wind power farms in North America. The majority of the problems with the existing wind energy blades have had to do with the numerous inconsistencies in the traditional fiberglass blade manufacturing technique. Most of the fiberglass wind blades presently being manufactured throughout the world are manufactured through the older traditional process that frequently causes a lack of consistently built blades for precision repeatable performance. In the case of VEC's patented closed-molded processes for manufacturing wind blades and all other VEC built products, VEC offers a precise and consistent manufacturing process which ensures every blade will be manufactured exactly the same.

Through VEC's computer-controlled process, VEC believes blades manufactured with VEC Technology will also produce more energy than any of today's existing wind blades due to VEC's satin finish. Wind energy blades manufactured with the VEC process will be lighter, stronger and have a finish throughout, thus eliminating the need for any sanding or painting.

The VEC close-molded process also creates a cleaner ecologically-friendly working environment resulting in positives to employees and the overall environment.

www.genmar.com/vectechnology

www.vectechnology.com

TI Projector Development Kit Available from Digi-Key

Electronic components distributor Digi-Key Corporation, recognized by design engineers as having the industry's broadest selection of electronic components available for immediate shipment, announced that it is stocking Texas Instruments' DLP Pico Projector Development Kit, a fully integrated and miniaturized light projection solution that can be quickly and easily integrated into the design process for new industrial, medical, and consumer products.

Available now exclusively on Digi-Key's global websites, the Pico Projector Development Kit (Digi-Key part number 296-23836-ND) is a new way of enabling developers to integrate digital projection into their own innovative applications. Potential applications for this kit include simple 3D measurement applications, virtual cosmetics, augmented reality, battery or USB powered display applications, projection of video and images, and miniature applications that do not have space for a large display.

The Pico Projector Development Kit includes an HVGA resolution, DLP projection device with a light engine that uses three solid-state color LEDs as a low power light source. The kit also includes a power supply cable and video cable specifically for connecting to a BeagleBoard, a development board that contains the OMAP35x processor and is supported by an open-source Linux community. The Pico Projector Development Kit is specifically designed to interface with the BeagleBoard to expedite development.

"We are very excited about offering TI's DLP Pico technology to our customers. The Pico Projector Development Kit will enable the development of a wide array of embedded systems in the high-growth medical, industrial and consumer segments, creating flexibility and options on how information and content is shared. With regard to the pairing of the pico projector and the BeagleBoard, it will be fun to see what engineers come up with using these two gadgets," said Mark Larson, Digi-Key president and COO.

www.digikey.com

Mouser Electronics Receives Outstanding Sales Achievement Award from Microchip Technology

Mouser Electronics, Inc., known for its rapid introduction of new products, announced it received an award for Outstanding Sales Achievement for 2008 from Microchip Technology, a leading manufacturer of microcontroller and analog products.

Mouser's sales achievement was a direct result of the cooperative, collaborative relationship between Mouser and Microchip. Microchip's continuous release of new products, combined with Mouser's ability to rapidly launch new products via the web and its quarterly catalog, allowed immediate product availability to the design engineering community. The resulting response from buyers was overwhelming and led to record breaking sales numbers. While Mouser's 2008 sales increased 84%, even more impressive is that Mouser's Microchip customer base

increased 250% over 2007.

Glenn Smith, President and CEO of Mouser, states "The entire Mouser team proudly accepts this award from Microchip. This great achievement is indicative of Mouser's commitment to become the world's most preferred source of components for the electronics design engineer and a confirmation of Mouser's promise to provide the latest, newest products and technologies as quickly as possible."

Mouser Electronics is the only major distributor to publish a new 2,184+ page print catalog every 90 days. In addition, its website with interactive online catalog is updated daily, contains more than a million products for easy online purchase, provides over 1.5 million cross-references, as well as more than 900,000 downloadable data sheets, supplier-specific reference designs, application notes, and other technical design information.

www.mouser.com

www.microchip.com

Ametek inc. Acquires Xantrex Programmable Power Supply Business

TTi Instrument Distribution announced the acquisition of the programmable power business of Xantrex Technology by AMETEK, Inc. for $120 million in cash. Based in San Diego, California, USA, the Xantrex Programmable Power division is a leader in AC and DC programmable power supplies, with annual sales of approximately $80 million.

Xantrex Programmable Power is a leader in programmable AC and DC power sources used to test electrical and electronics products by simulating various input voltages, frequencies and potentially harmful line transients. Its products are used in design verification testing, manufacturing, quality assurance and regulatory compliance by its customers in a wide range of industries including aviation,

military, and general electronics.

Xantrex Programmable Power significantly expands AMETEK's position in the niche market for programmable power sources, and provides further opportunities for growth in the highly attractive electronic test and measurement equipment market.

Xantrex Programmable Power will join AMETEK as part of its Electronic Instruments Group (EIG), a recognised leader in advanced monitoring, testing, calibrating, and display instruments. AMETEK EIG sells its instruments to the process and analytical, aerospace, power and industrial markets worldwide, and had 2007 sales of $1.2 billion.

The existing Xantrex product lines will be rebranded using the Sorenson brand. Sorenson was acquired by Xantrex in 2006 and has a long and respected history in the programmable power market. Distribution of the Ametek Programmable Power, Sorenson and Elgar brands remains with TTi Instrument Distribution in the UK.

www.tti.eu

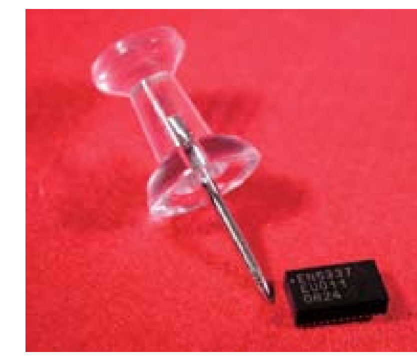
Ultra-Small 3A DC-DC Converter Radically Increases Power Density

Enpirion has just launched its ultra-small 3A synchronous buck DC-DC converter with an integrated inductor, delivering a radical increase in power density over competing solutions. The EN5337QI is a power supply on a chip (PwrSoC) in a tiny 28mm^2 package - less than half the size of Enpirion's previous 3A solutions, and one-third the size of competitor's offerings. With a power density of 149W/in^2 (23 W/cm^2), the EN5337QI sets a new standard for low-power switching regulators.

The EN5337QI features the ability to synchronize to an external clock to eliminate or move beat frequencies out-of-band. It is specifically designed to meet the precise voltage and fast transient requirements of present and future high-performance, low-power processor, DSP, FPGA, memory boards and system level applications in a distributed power architecture.

Advanced circuit techniques, ultra high switching frequency, and very advanced, high-density, integrated circuit and proprietary inductor technology deliver high-quality, ultra compact, non-isolated DC-DC conversion.

The Enpirion solution significantly helps in system design and productivity by offering greatly simplified board design, layout and manufacturing requirements.



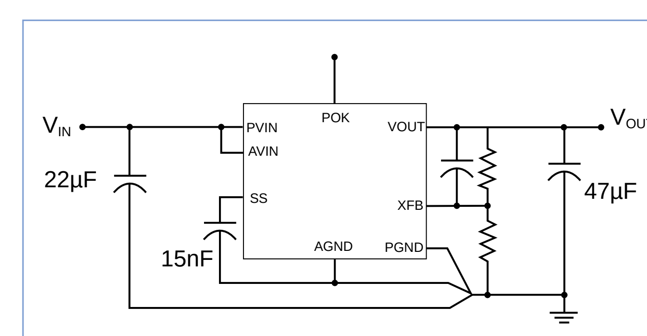
In addition, a reduction in the number of vendors required for the complete power solution helps to enable an overall system cost savings.

"Designers are being challenged to pack more functionality into smaller PCB form factors, while improving overall system power efficiency," said Dr. Ashraf Lotfi, Enpirion's founder and CTO. "To address these challenges, designers need power solutions like the EN5337 that can deliver high-efficiency power in a very small form factor."

Enpirion's 3 A power converters are ideally suited for high-volume, mass-market electronics such as DTV, audio, computing, multi-function printers, set-top boxes/DVRs, and storage. The EN5337QI is an excellent choice for product designs that are space-constrained, noise-sensitive, and require high efficiency and simple, reusable power solutions.

As with all of Enpirion's products, the 3A part was developed using advanced circuit techniques, ultra-high switching frequency, and proprietary integrated-inductor technology. The result is a highly-efficient, low-noise power solution that consists of very few parts and is extremely easy for developers to use – attributes that Enpirion has become well-known for in the industry.

"Enpirion has the technology edge, the flexibility, and the commitment to market solutions with smaller footprint, lower parts count, and higher speed at competitive BOM cost," according to a report by the Power Sources Manufacturers Association (PSMA). "They are leading the industry at providing PwrSoC product. Enpirion has a definite technology-leading edge in designing and developing PwrSoCs, as well as in inductor technology



The EN5337QI is available now, and pricing is set at $2.50 for quantities of 1000 parts.

www.enpirion.com

Follow the Value Migration

By Kevin Parmenter, Applications Engineering Manager, Freescale Semiconductor

We have all heard the term, "follow the money" but this is just not sufficient for today. We face great economic uncertainties and challenges and with this come great opportunities.

Every sector of trade seems impacted by the current economic conditions. If we pay attention to the subtitle signs, we see that within all this there are also great opportunities. Several trends are converging to shift customer's perception of value. Consumer expectations are changing as younger people enter the demographic customer pool.

Our generation expects fuel efficient, easy to use vehicles with the comforts of home. Any time we want to drive, we turn the key and go. The next generation is asking why the car cannot be connected to the internet 24x7, run on something else besides fossil fuel, email you when it needs an oil change (or better yet, make its own appointment), steer itself, avoid traffic and accidents. The convergence of value migration enabled by energy costs and awareness of environmental concerns mean that soon more "things" will be connected to the internet than people - all shaping customer perceptions.

Consumers expect products which enhance health and safety and offer higher value and ROI than ever before. According to the latest PSMA power technology roadmap, last year was the first year that customers were willing to pay for electronics and products which offer energy savings.

Intelligently controlled systems are the way of the future. Adopting design techniques commonly used

in cell phones, laptops and satellites for everything else – finding ways to harness every single milliwatt of power for productive work at a systems level using intelligently controlled power electronics.

When the economy gets tough in our industry, the tough innovate and pay attention to value migration. What does value migration mean during these times? If you are overwhelmed and internally focused and not spending time with customers or doing market research now that business is down – beware. Value migration is the shifting of value-creating forces. Value migrates from outmoded business models to business methods, services, designs and products that are better able to satisfy customers' priorities.

We must beware of those holding onto outdated business models. History tells us that during downturns we must innovate and solve real (and often unexpected) customer needs and wants.

Power electronics is at the right place at the right time with the right products. Customers want high ROI innovative quality products which simplify their lives and lower total cost of ownership. Lots of money is being invested by Google, Greenbox and other companies as well as governments to enable logging into a web browser and find the energy trends for your home or building. Delivering accurate data to that website will take investment in new products and services. By measuring this information consumers will then want to do something about it – replacing lighting, appliances and motors with energy efficient versions.

Pluggable hybrid cars may provide the Holy Grail to the power utilities – a way to store the electrons they generate. Efforts such as gridwise.org are working to update the grid, this will take smart meters and efficient power electronics embedded at all levels of power conversion from generation to consumption.

At the center of all of this are those who will invent and deploy it all. Let's Follow the value migration an innovate our way out of this economic situation and enjoy the new opportunities it presents.

The internet provides power electronics and systems designers a new revenue stream. It can also be a powerful value migration of customer's expectations of new market realities where they will invest their limited funds – will the investment be on your products and services?

www.freescale.com

White Goods Still Offer Medium Term Opportunities

IMS Research has been analyzing the major home appliance (MHA) market in detail for more than a decade, and the situation today is as bad as we can recall. Falling house sales and reduced consumer spending due to the global recession have combined to severely impact market volumes in 2008, and the immediate outlook for 2009 is also bleak. Despite this, we believe a trend towards more efficient and sophisticated appliances will present considerable opportunities to power electronics suppliers in the medium and long term.

By Jason DePreaux, Power Analyst, IMS Research

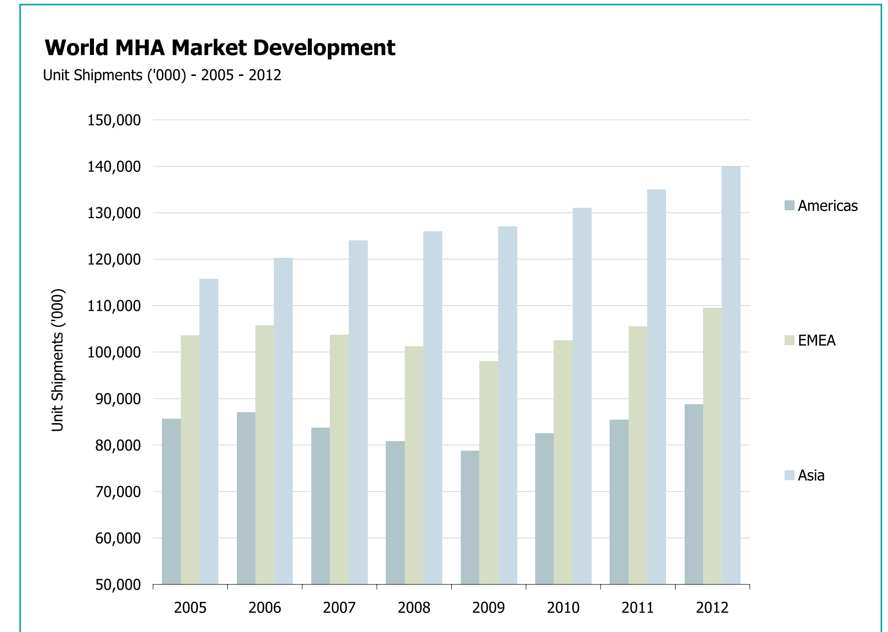
The slowdown in the North American and European MHA markets has been underway for some time. In the US and Western Europe, MHA shipments in 2008 were down around 10% from what were already low 2007 levels. Another fall is predicted in 2009. Even Eastern Europe, which had been consistent in returning positive growth, witnessed a sharp pullback in shipments in 4Q08, contracting 15% year-on-year. While the situation is somewhat more encouraging in Latin America and parts of Asia, where growth is projected to be flat to slightly positive, MHAs sold in these regions tend to be the lowest cost, most basic models, and therefore have much lower electronic content.

In spite of the slump in market volumes, MHAs have seen increases in the amount of advanced technology they are using in recent years. Examples of new appliance technologies include more efficient designs, electronic displays and touch controls, and advanced sensing technology.

The key drivers of higher electronic penetration; namely tougher energy standards and consumer preferences, are projected to persist even as shipment levels drop.

Government action continues to provide momentum for more efficient MHA designs. Mandatory comparative labeling schemes are in place in the US, EU, and parts of Asia. These systems rate appliance efficiency based on a variety of metrics including electricity consumption and water use. Just a few years ago the EU added new ratings (A+ & A++) for cold appliances that have helped drive sales of the most efficient refrigerators. The recently passed American Recovery and Reinvestment Act contains a boon for energy efficient home appliances in the form of rebates for qualifying Energy Star appliances worth $300 million. With governments seeking to reduce energy consumption and consumers becoming more mindful of their environmental impact, MHAs are becoming smarter in the way they use energy. This is good news for power electronics suppliers.

Changing consumer preferences have helped contribute to the growing adoption of advanced features. The United States, traditionally a top-load



Note:The above statistics do not include the cooking sector

Source: IMS Research

washing machine market, has rapidly embraced front-load style. Currently one in every three washing machines sold is a front-loader, up significantly from just a few years ago when the figure was under 10%. The trend is set to continue as stricter Energy Star ratings in coming years will not be met by many current front-load offerings. Other trends like LCD displays, touch controls, and even integrated television in refrigerators are being embraced more by the "IPod generation" of users accustomed to thumbing jog wheels and navigating menus.

The combination of more efficient home appliances and growing consumer acceptance for advanced feature sets has had a direct effect on the amount and sophistication of electronic content found in a typical appliance. Tougher efficiency standards mean that MHA makers are incorporating more complex systems that allow precise control. One example is replacing a traditional on/off motor control with an inverter based motor control; particularly effective in washing machines and room air conditioners where penetration of this feature is greatest.

The increased prevalence of electronic displays means more microcontrollers and possibly also driver ICs. The recent emphasis by governments on developing a "Smart Grid" has also given a new lease of life to developments surrounding "connected appliances." Thus far, the concept has yet to materialize in any tangible volumes, but should standards be established, it could have an enormous effect on the use of electronics in MHAs. The growing electronic content of MHA bodes well for semiconductor companies, and we are predicting that total MHA semiconductor market revenues will grow by nearly 20% by 2012.

In the face of challenging market conditions, there are reasons for optimism as stringent efficiency standards and advanced features become more common in MHA design.

www.imsresearch.com

Frequency Response of Switching Power Supplies – Part 2

Extracting test Signals from noise

In this article, Dr. Ridley continues the topic of frequency response of switching power supplies. Last month's article focused on the broadband noise generation of power supplies. This article shows how we can extract single frequencies one-by-one from the noise with a frequency response analyzer. This allows us to perform control measurements on our switching power supplies.

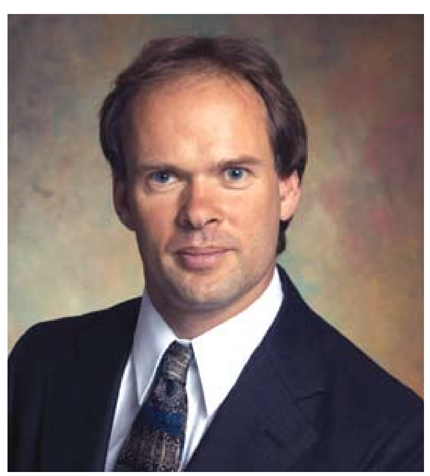
By Dr. Ray Ridley, Ridley Engineering

Single Frequency Measurements for Switching Power Supplies

The previous article in the Design Tips series of this magazine[1] discussed the wide range of frequencies generated by a switching power supply. High noise is unavoidable when working with switchers, and the converter must also be tightly controlled in the presence of this noise.

This presents a challenge in two areas: firstly, the control chip must run reliably with the noise and predictably set the duty cycle of the switch from one cycle to the next. Secondly, measurements must be taken on the power supply once a control loop is closed to ensure that it is always stable.

Analog controllers do an exellect job of managing the first problem through the simple sawtooth ramp and reference technique of a standard



PWM controller. Once the controller is working properly, we use traditional Bode plot measurements to assess performance and stability.

Power supplies are one of the few areas of analog electronics that still make conventional measurements rather than depending on prediction and modeling alone. The loop gain and stability margin can vary tremendously for a converter operating over its full range. Figure 1 shows the range of variation that can exist for a simple buck converter when variations of line, load, temperature, and EMI filter are considered.

These curves show extreme changes in the gain and phase of the converter. The curves, however, assume linearized operation, with small-signal circuit models used to generate the plots. In the real world, the switching power supply may have regions of operation that are not well modeled, and even more variation is possible. Clearly, in the face of such extreme behavior, measurement of the power supply is an essential step in making sure the design of the control loop is rugged.

Figure 2 shows a typical noisy power supply waveform with an injected signal, used to make control measurements. This points out another unique requirement of switching power

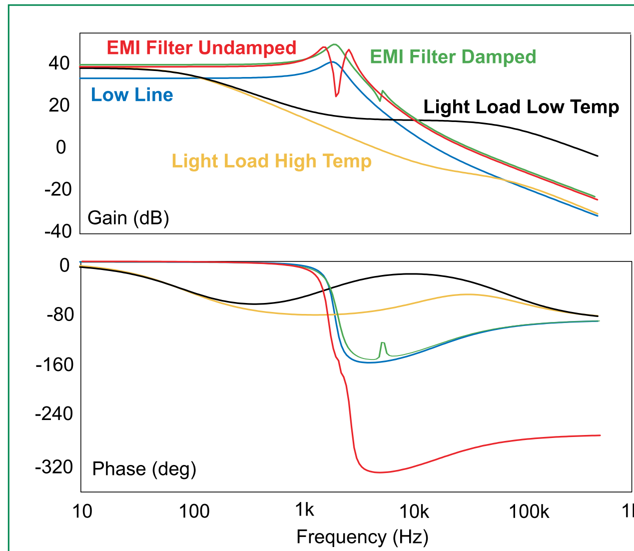


Figure 1: Variability of Bode plots for a "simple" buck converter with variations of line, load, temperature, and EMI input filter.

supplies – specialized equipment is needed to be able to extract the injected waveform in the presence of the switching noise. This is done with a frequency response analyzer.

Frequency Response Analyzer

A frequency response analyzer is a piece of test equipment designed to inject a sinewave into a circuit, and measure the response of the circuit at that single frequency at two different test points in order to generate a gain and phase response. The injected sinewave is swept from frequencies as low as 0.1 Hz, up to the switching frequency of the converter.

The role of the frequency response analyzer is to extract extremely small test signals (sometimes much less than 1 mV) from noisy waveforms, and compare their gain and phase. The technology needed to do this is not new, having been used for decades in our field.

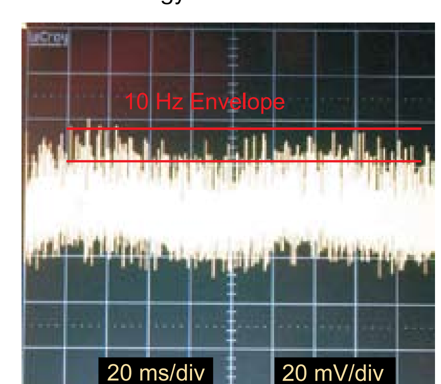


Figure 2: Typical power supply waveform with signal and noise.

Figure 3 shows a block diagram of an analyzer designed for switching power supplies. An oscillator puts out a test signal which is injected into the circuit to be measured. (Techniques for injection will be

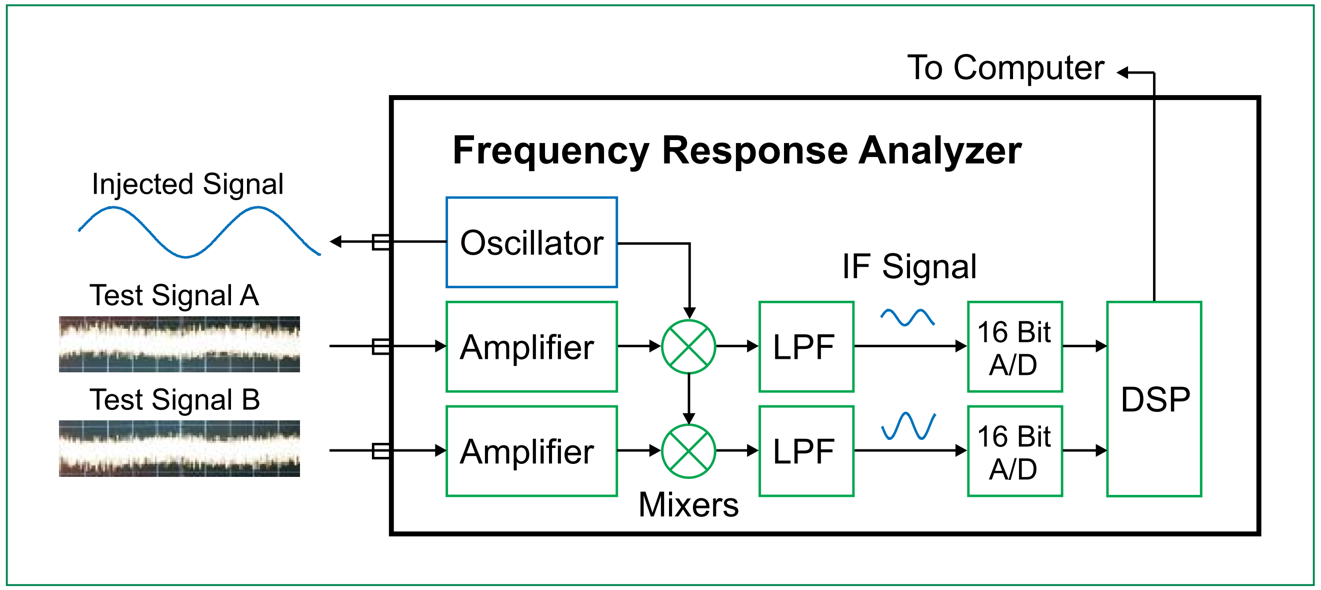


Figure 3: Frequency response analyzer test equipment block diagram.

presented in later articles in this magazine.) Two input channels on the analyzer are used, connected to different test points in the circuit. Each input channel processes a test signal, first with analog signal processing to eliminate noise, then with digital signal processing. The output of the digital processor interfaces with a computer. Early versions of frequency response analyzers used purely analog techniques to create Bode plots.

The analog section of the input channels work in a similar way to radio receivers, using wide band amplifiers, and heterodyning techniques with mixers and filters to isolate the test signal, and reduce the frequency of the carrier down to an easily measurable quantity. Communication theory tells us that the gain and phase of the test signals can be preserved when producing an IF bus in this manner. This greatly simplifies the task of the A/D conversion stage of the system.

After A/D conversion, the data is passed to a microprocessor, and then to a computer to perform further digital filtering and noise reduction. The results can then be presented as a traditional Bode plot to the user.

Using these techniques, extreme values of signal to noise and dynamic range can be obtained, in excess of 110dB. This is essential for reliable measurement of switching power supplies. Further details of the theory are given in [2].

This process cannot be short-circuited with modern “frequency-response analyzer on a chip” products that have recently been introduced. The integrated chips for this have neither the dynamic range, or noise-rejection capability needed for switching power supply measurement, although they may work reasonably well for linear, non-switching circuits where noise levels and gains are low.

Using the frequency response analyzer, individual frequencies are extracted from the noise, and two signals can be accurately compared in terms of gain and phase. This allows us to study the control characteristics of a system and design the feedback loop properly.

Summary

The frequency response analyzer is a highly specialized instrument that we use, and it is essential for stabilizing power supplies quickly and efficiently.

In the next two articles in this series, the essential role of loop gain measurements will be discussed and compared to the technique of trying to design control loops with step-load response measurements.

References

1. “Frequency Response of Switching Power Supplies”, Power Systems Design Magazine, Design Tips Archive, January 2009. http://www.powersystemsdesign.com

2. http://www.apinstruments.com/files/102Bman.pdf. Page 58 shows detailed block diagram of frequency response analyzer functions for a high-performance instrument suitable for measuring switching power supplies.

3. http://www.switching-powermagazine.com/downloads/Measuring Frequency Response.pdf Techniques for using a frequency response analyzer.

www.ridleyengineering.com

TechTalk

Superconductor Power Cables

Fundamental to the smart grid

I talked with Jack McCall, Director Business Development HTS T&D Systems, AMSC Power Systems about the issues concerning the much publicized power grid. Utilities, sometimes already hard-pressed to supply enough power to their customers will face increasing demands for power over transmission lines ill-equipped for today's needs. I fired a few general questions and asked Jack to give me the full picture.

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

What is the real current position of the North American power grid?

The need to modernize electric power grids to meet, and withstand, the rising demand for power in general and renewable power in particular is well documented. The U.S. power grid as it is currently constituted simply cannot support what the Obama Administration has set out to accomplish. Radical changes can – and will – be made. This will entail not only construction of new cross-country transmission systems but must also support the growth of more concentrated urban loads through advanced superconductor technologies.

Superconductor power cables, which are able to transmit up to 10 times more power than traditional copper-based cables, significantly enhance the flow of electricity under city streets and will play a key role in achieving these objectives. Additionally, they can automatically suppress dangerous power surges to create resilient, 'self-healing' grids that can survive attacks and natural disasters and have been identified as a fundamental component of the "Smart Grid" envisioned by the United States Department of Energy (DOE).

Long-haul DC superconductor cables also can significantly reduce the amount of space needed to transport renewable energy from America's heartlands to its load centers on the East and West Coast. Plans for interstate 765 kV overhead power lines are now being considered. According to a recent study published by the American Wind Energy Association and Solar Energy Industries Association, a 200-foot-wide right of way would be required to carry 5 gigawatts of renewable energy to America's cities. Moving this power for a thousand-mile transmission run would require a right of way three times that wide. Of course, this would require significant eminent domain land takings and would threaten wide swaths of conservation lands.

Direct Current superconductor power cables could carry this same amount of power more efficiently for a similar cost in just a 25 to 50-foot-wide right of way. And these underground cables would spare our vistas from unsightly overhead lines.

What exactly are the advantages of superconductor power cables?

At the heart of the superconductor power cable is high temperature superconductor wire that can conduct many times the electrical current of a copper wire of the same dimensions. Stranding superconductor wire onto a cable assembly in a coaxial configuration takes advantage of another unique property of superconductor wires and results in a cable that produces essentially zero Electromagnetic Field (EMF) emissions. The inherently low impedance of this cable enables control of power flows over the surrounding grid network. Liquid nitrogen, the dielectric and coolant of choice to maintain the cable's superconductor state, is inexpensive and environmentally friendly. The use of liquid nitrogen in superconductor cables also replaces the need for oil that is used in many conventional power cables, providing an added environmental advantage. American Superconductor (AMSC) is working in partnership with the world' s leading power cable and commercial refrigeration companies to apply revolutionary superconductor wire to new underground cable solutions to eliminate costly grid bottlenecks.

Most discussions about the U.S. Smart Grid tend to center on intelligent communications and metering technologies. However, the DOE's actual definition is much broader and encompasses grid infrastructure, or the 'brawn', that will be required to support the 'brains' of the Smart Grid. This necessary 'brawn' is in fact a large focus in President Obama's recently approved economic stimulus package. Because of their ability to deliver significantly more power in a much smaller right of way than traditional power cables, superconductor cables can increase the capacity of the grid to enable, for instance, the widespread adoption of plug-in hybrid electric vehicles (PHEVs).

Superconductor power cables and AMSC's Secure Super Grids™ (SSG) technology meet each of the following Smart Grid criteria detailed by the DOE: 1) Accommodate all generation and storage options, 2) Provide power quality for the digital economy, 3) Optimize assets and operate efficiently, 4) Anticipate and respond to system disturbances or "self-heal", and 5) operate resiliently against attack and natural disasters.

High-capacity, very low impedance (VLI) superconductor power cables generate little to no magnetic field and can be located in close proximity to other infrastructure without disturbance. As a result, they can be easily retrofitted into existing ducts or placed in narrow trenches making them much easier to site, particularly in dense, urban areas. At lower voltages, superconductor cables also offer a highly desirable alternative to higher voltage cables or even overhead lines.

AMSC's SSG technology is a "system-level" solution that utilizes customized superconductor power cables to deliver up to 10 times more power than conventional copper cables while simultaneously suppressing fault currents that can result in serious outages including widespread blackouts. SSG additionally allows for the construction of multiple paths for electricity flow in metropolitan power grids to ensure system redundancy when individual circuits are disrupted due to severe weather, traffic accidents or willful destruction. This solution requires the use of AMSC's proprietary second generation (2G) high temperature superconductor wire, branded as 344 superconductors.

Stand-alone fault current limiters based on superconducting materials also offer a new vista in grid security and technical control of system operating parameters. Additional 'brawn' needed to support the Smart Grid will be provided by power electronics (rather than superconductor) technologies such as AMSC's D-VAR® and Static VAR Compensator (SVC) solutions, which regulate voltage, prevent blackouts and relieve congestion on existing transmission lines.

But isn't this just another 'nice-to-have' idea?

No. Superconductor cables are an essential component of our 21st Century power grid. And they are now commercially available. Superconductor cables have been well demonstrated at electric utilities and are now being deployed in the grid. Over the past three years, three of these cables have been energized in the United States. Since April 2008, a 138 kV HTS transmission line has been operating successfully outside of New York City on Long Island Power Authority's (LIPA) primary transmission corridor. At full capacity, LIPA's HTS cable system is capable of transmitting up to 574 megawatts (MW) of electricity, enough to power 300,000 homes, in a right of way approximately one meter in width. It is the longest and most powerful superconductor cable system in the world. Phase two of the project will replace of one of the existing HTS cable system's phases with a 600-meter-long cable employing SSG technology.

An additional project is also underway in New York City at Consolidated Edison, Inc. where the first distribution-voltage (13kV) level SSG solution is being installed in the utility's Manhattan power grid. The full-scale, 300-meter-long superconductor cable system is scheduled for deployment in 2010. The U.S. Department of Homeland Security (DHS) is contributing up to $25 million for the project.

www.amsc.com

Energy Efficient White Goods

Energy costs and environmental issues take high priority

White goods are defined as major appliances, large machines which accomplish routine housekeeping tasks, including cooking, food preservation, or cleaning, whether in a household, institutional, commercial or industrial setting. An appliance is differentiated from a plumbing fixture because it uses an energy input for its operation other than water, generally using electricity or natural gas.

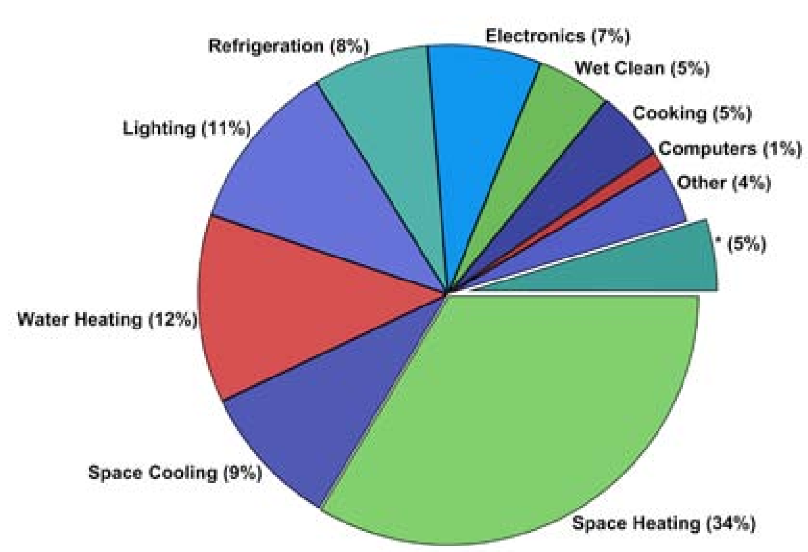
By Paul Greenland, VP of Marketing, Power Management Product Group, Semtech Corporation

In recent years white goods have been the subject of considerable research and development because they represent a significant proportion of the energy consumed in an average household as illustrated in Figure 1. North American designs lagged behind Europe until the mid-nineties, with an emphasis on utility and capacity rather than energy efficiency and reduction of consumables. That is not the case today, energy costs and environmental issues take a higher priority. A quick visit to a store selling domestic appliances will reveal a wealth of information related to the energy efficiency and operating cost of appliances, coupled with frugal use of consumables such as water and cleaning agents. Sophisticated control and power management now have a place in what was once a purchase focussed primarily on simplicity and reliability.

Washing Machine

The average washing machine consumes 44% less energy and 62% less water than one manufactured in the Eighties. This is due to a combination of developments addressing the challenge at the system level. The drive to the motor and motor type, algorithms to address specific materials, sensing of water turbidity and load volume all have a part to play.

The first washing machines used brushed permanent magnet motors. The brushes, which soon became the weak point of the system, used to wear in the forward direction of the drum and frequently broke on reverse. Recently variable speed motion control systems have been adopted in most washing machines. The latest systems target permanent magnet synchronous motors. Instead of using shaft position sensors, such as Hall effect devices, a sensor-less algorithm estimates rotor angle based on measured stator currents and the applied voltages. The stator currents are measured by sampling currents in the dc link shunt. A field-oriented control algorithm allows good dynamic control of torque, which eases load balancing. Field weakening control allows a wide speed range along with additional functions to optimize torque output. As motors become less expensive and more durable, it becomes economical to offer washing machines driven directly by motors instead of by belts, making the washers more versatile and less noisy.



* The pie chart includes 1 quad of energy (5%) that is a statistical adjustment by the Energy Information Administration to reconcile two divergent data sources.

Figure 1: US Domestic Energy Consumption.

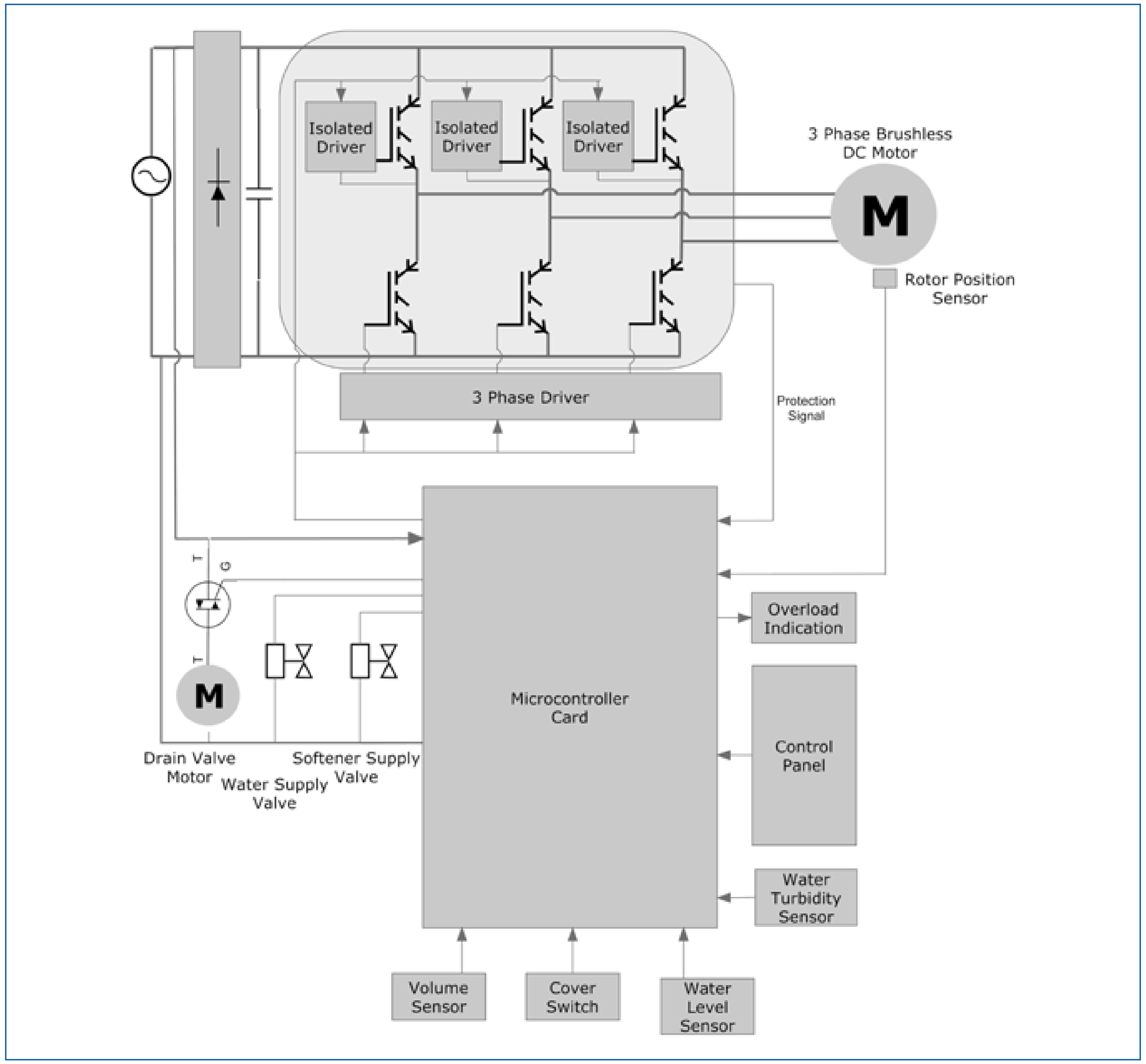


Figure 2: Washing Machine Block Diagram.

Another likely trend will be the gradual displacement of top-load washers by front-loads washers, which, because they require less water, satisfy government restrictions on water use. In Japan, a washer is being tested that cleans with bubbles rather than with an agitator. This machine "senses" how soiled each load of clothing is and then generates the bubble activity necessary to remove that amount of dirt. Further in the future people may use washers that clean using ultrasonic generators to dislodge dirt cutting the use of cleaning agents.

Dishwasher

The dishwasher, almost a luxury in Europe, is ubiquitous in US households; efficiency considerations are predominantly concentrated on reducing water use through the use of softeners and rinse aids. This equates to energy saving as water is often heated prior to dish washing and the load is convection dried. To its credit, the average dishwasher is much more water friendly than traditional hand washing. Using any Energy Star-qualified dishwasher instead of hand washing saves 5,000 gallons of water, $40 in utility costs, and 230 hours of labor per year.

Stove/Hob

Induction Hobs are the latest in eco-friendly cooking technology offering the instant control of gas combined with the convenience and style of a radiant ceramic hob whilst at the same time being significantly more energy efficient than both. Induction hobs are far more energy efficient than any other hob. This is because around three quarters of all the energy consumed is used to heat the pan compared with gas cooking which only uses about 50% of the energy consumed to heat the pan.

The cooking zone also automatically detects the size of the pan base so that heat is only generated through the area in direct contact with the pan. Whilst giving you the flexibility to use smaller sized pans on larger zones this also results in greater energy efficiency – the smaller the pan, the lower the energy consumption. In practice energy savings compared with conventional hobs, including infra-red can be greater than 40%. An induction hob works by creating a very strong electromagnetic field by running current through an electrical coil positioned directly beneath the ceramic surface of the hob.

This field induces an eddy current which generates heat almost instantly in any ferromagnetic cookware positioned on the ceramic plate. The cookware almost instantly reaches the hob temperature selected. The induction coil in the hob is driven by a high frequency inverter; the cooking pan load may be represented as a resistor connected across a secondary coil coupled to the primary in the hob. This technology was pioneered in Japan in small induction ranges and rice cookers.

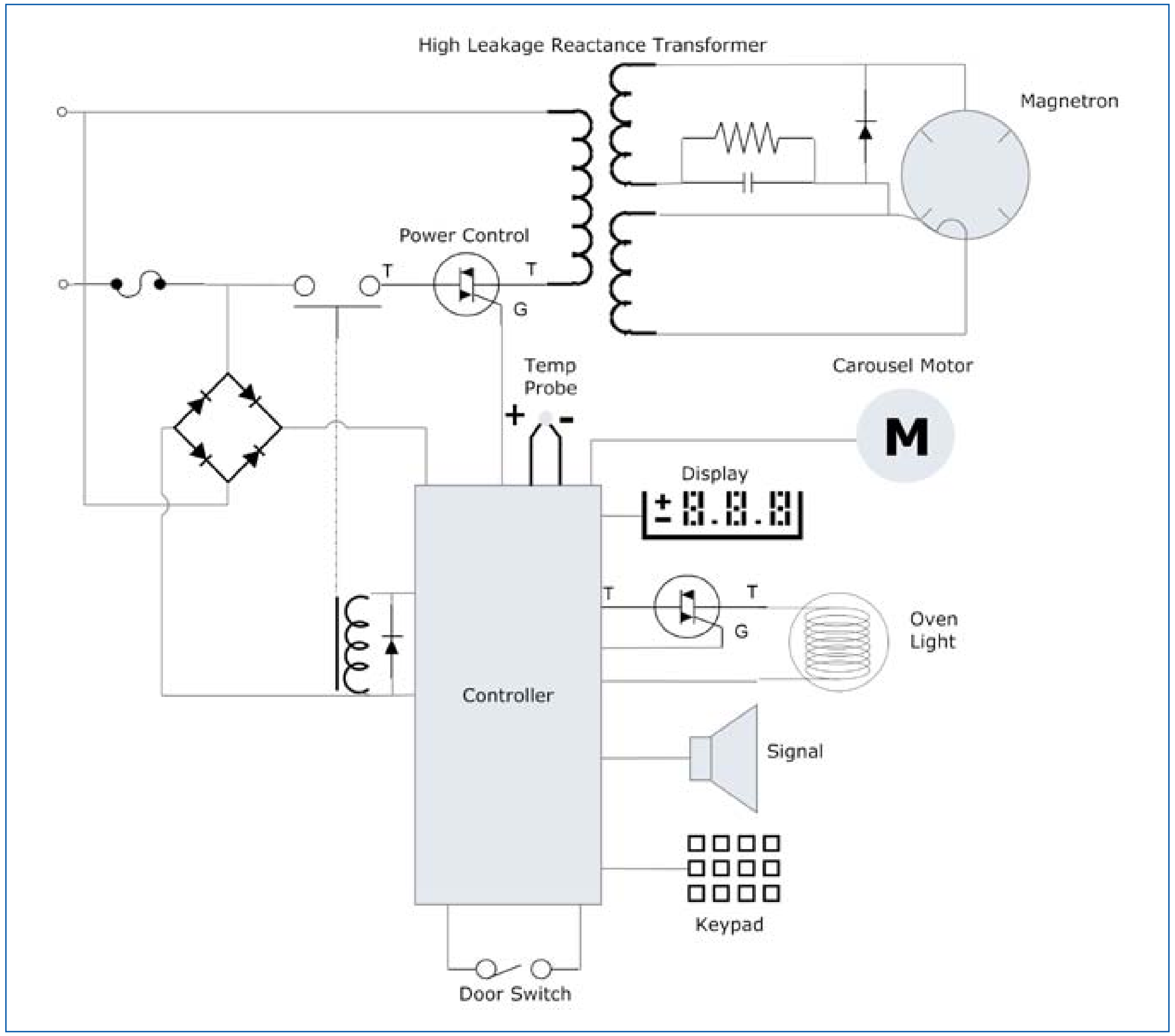


Figure 3: Microwave Oven Block Diagram.

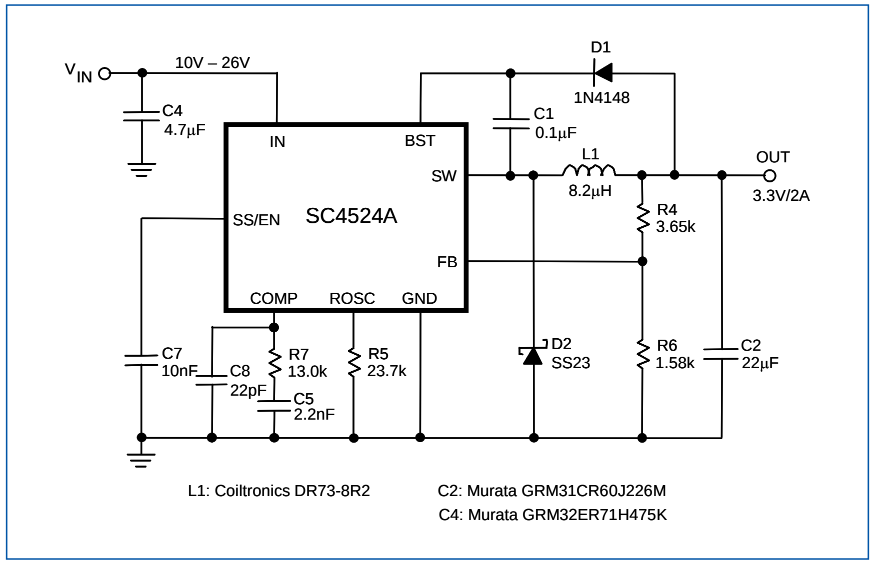


Figure 4: SC4524A Application Example.

Microwave Oven

Shortly after the Second World War, a researcher at the Raytheon Corporation, Dr. Percy Spencer was standing near one of the high power radar units and noticed that a candy bar in his shirt pocket had softened. In the archetypal 'I have to know why this happened' mindset of a true scientist, he decided to investigate further. The Amana Radarange and future microwave oven industry was the outcome. It is fairly easy to guess one influence in more efficient microwave ovens, just pick a new one up.

A microwave oven weighs a fraction of what it did because the bulky line frequency high leakage reactance transformer has been replaced by a high frequency inverter. This is usually a self-oscillating flyback converter, not dissimilar to the flyback/HV supply for a CRT Television. This inverter supplies the magnetron, which emits the microwaves that heat the food. A typical domestic microwave oven uses between 500 and 1000W of microwave energy at 2.45 GHz to heat the load. This heating is caused mainly by the vibration of the water molecules. Thus plastic, glass and paper containers heat only through conduction from the hot food. 2.45GHz was selected for a number of other reasons including Electro Magnetic Compatibility and convenience in implementation. In addition, the wavelength of 12.25cm results in reasonable penetration of the microwave energy into the food. The 3 dB point is about 2.54cm for liquid water, half the power is absorbed in the outer 2.54cm depth, another quarter of the power in the next inch, and so on. The power from the microwave pulsates at line frequency and the inverter frequency controlled by a triac in the primary circuit. 30% to 50% of the power supplied to the microwave is dissipated as heat, which is diverted through the oven cavity augmenting the heating of the food to a minor degree before leaving through vents. Generally speaking a microwave oven is the fastest, most energy efficient way of cooking small food items. However, larger items, such as a Thanksgiving turkey are cooked more efficiently in a convection oven.

Power Management

The power supply in white goods is usually mounted on the control card with the microcontroller. A line frequency step down transformer provides isolation and filtering of noise from load switching. Most resistive loads and solenoid valves are driven by triacs, which are switched at the zero crossing to minimize EMI. Cam timers, used in the earliest models required no low voltage power supply. The on-board power supply is a buck regulator, which accommodates the loosely regulated secondary voltage, usually 12V nominal.

The SC4524A, shown in figure 4 is well suited to this application. It is a constant frequency peak current mode controlled buck regulator with an output current rating of 2A, wide input voltage range and comprehensive overload protection. Current mode control gives excellent rejection of input ripple and simplified loop compensation. This approach reduces transformer and filter cost without compromising efficiency.

Conclusion

Work continues to reduce the energy and resources consumed by white goods. Manufacturers influenced by voluntary commitments, energy labeling, tough competition from overseas and escalating energy costs have reached the point at which some appliances, notably refrigerators and freezers are approaching least life cycle cost. Life cycle cost is the sum of purchase price and running cost over the life cycle of the appliance. Today's best refrigerator consumes less than a quarter of the energy of a refrigerator made in 1990. Power management has its part to play, an efficient on board step down regulator, combined with microcontroller run time control and sampled sensor signal conditioning allows for sophisticated control at minimal operating power overhead. On board line transformer isolated power supplies continue to be preferred over direct off-line because there is minimal power line filtering and hold-up in white goods; consequently costly EMI filtering and surge suppression has to be added to the off-line power supply increasing system cost.

www.semtech.com

Die and Board Level Hot Spots

Thermal challenges need design solutions

For the past 50 years, the thermal management industry has offered only heat sinks, fans, and thermal grease as methods for electronics thermal management. During this same time electronic circuits have been packaged more tightly, generating more heat in a smaller footprint. As a result the electronics industry has reached a breaking point; a sort of thermal overload. The heat generated in these dense electronic systems can be quite large and has led to significant increases in on-chip temperatures that have reduced or limited the performance of components and systems.

By Dr. Paul A. Magill, Vice President of Marketing and Business Development, Nextreme Thermal Solutions, Inc.

The challenge of removing heat from ICs has increased significantly. This problem is no longer just at the chip-level but has grown to include hot spot formation on boards. The emergence of nano-electronics (90 nm feature size process technology going to 32nm by the end of the decade) has led to localized areas of high heat flux that are dominating the performance of electronics at the chip level. This same problem can also be found at the board level where devices such as MMICs, power MOSFETs and other power devices are being placed closer to devices, such as displays, that are very sensitive to high heat fluxes.

This article discusses methods for mitigating the effects of die-level and board-level hot spots through localized cooling of the on-chip heat source and the innovations that are driving new approaches in electronics cooling.

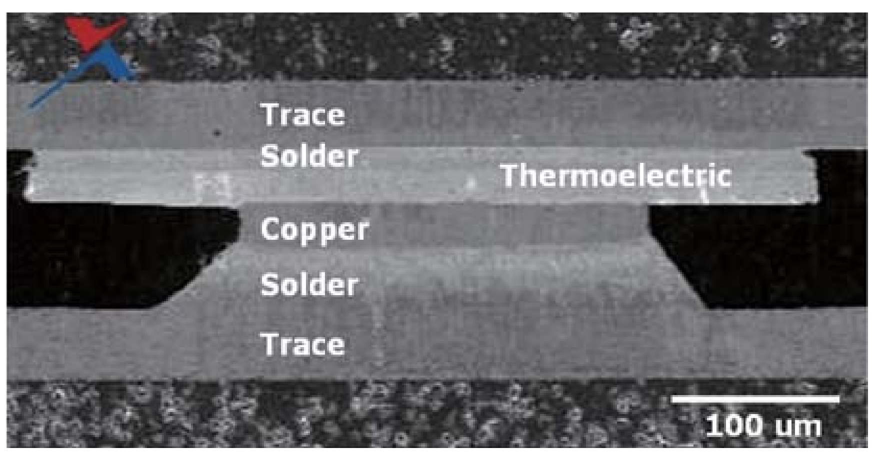


Figure 1. The thermal bump.

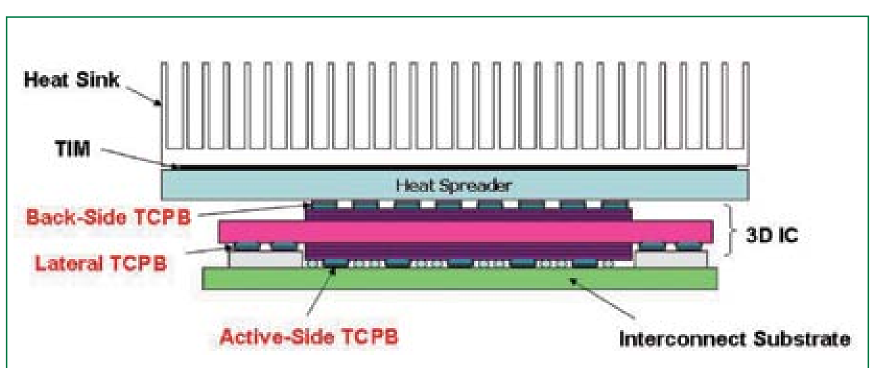


Figure 2. Integrated 3D Thermal Management.

Thin-Film Thermoelectrics

Nextreme has introduced localized thermal management solutions deep inside electronic components using thin-film thermoelectric structures known as thermal bumps. The thermal bump was developed as a method for integrating active thermal management functionality at the chip level in the same manner that transistors, resistors and capacitors are integrated into conventional circuit designs today.

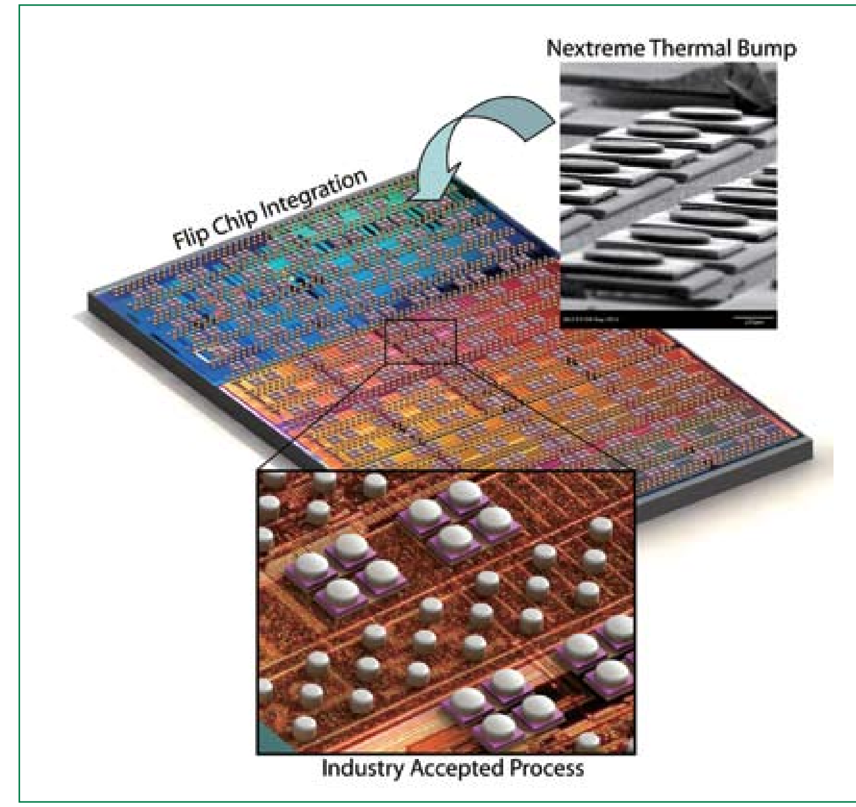


Figure 3. Thermal and electrical bumps integrated on a single substrate.

The thermal bump (Figure 1) is made from a thin-film thermally active material that is embedded into flip-chip interconnects (in particular copper pillar solder bumps) for use in electronics packaging.

Unlike conventional solder bumps that provide an electrical path and a mechanical connection to the package, thermal bumps act as solid-state heat pumps pulling heat from one side of the device and transferring it to the other as current is passed through the thermoelectric material.

The use of thermal bumps in power electronics offers many advantages in terms of size, efficiency and power-pumping capability. Thermal bumps today are already extremely small: 110µm (microns) in diameter by 65µm high and have the capability to be scaled to different sizes for different applications. The bump adds as little as 100 microns of thickness to a heat spreader, enabling unobtrusive integration close to the heat source.

Thermal bumps have been shown to achieve temperature differentials in excess of 60ºC between the top and bottom headers and have power pumping capabilities exceeding 150W/cm^2. This makes thermal bumps ideally suited for applications involving high heat-fluxes.

Today, thermal bumps can be introduced into systems at the chip level or at the board level using discrete modules. Here are a few of the integration possibilities:

Die/Chip Cooling

Thermal bumps can be integrated for heat removal from the back- or, front-side of the die and even laterally, as depicted in Figure 2.

Back-Side Cooling

Back-side cooling can be enhanced by the introduction of thermal bumps either into the heat sink to form an active heat sink or into the heat spreader. Here, discrete devices are used to mitigate hot spots generated on the front side of a die. In fact, while the following example demonstrates the feasibility of hot spot cooling using integrated thermoelectric cooling, it also reveals the limitations of cooling the hot spot from the backside of the die.

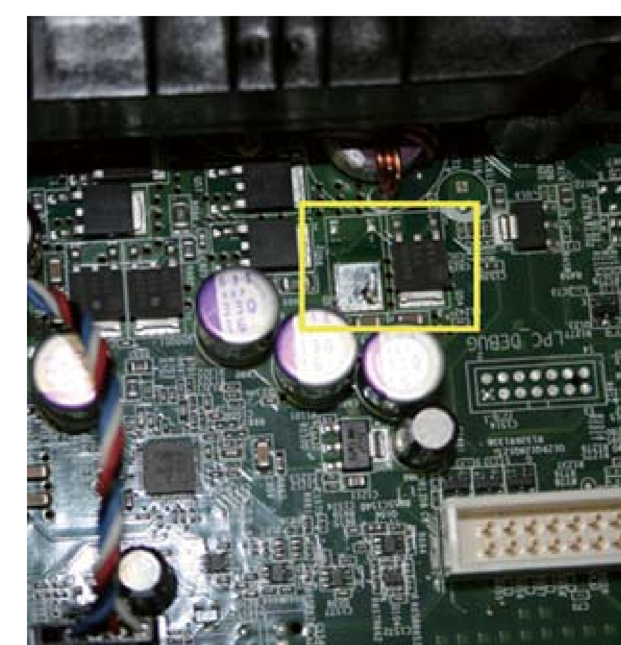


Figure 4. MOSFET replacement.

The hotspot is on the active side of the die while the cooling device is attached to the copper heat spreader. The heat spreader is flipped onto the backside of the die so that the cooler is located near the backside of the die, behind the first level thermal interface material, or TIM1.

Lateral Cooling

In the lateral cooling concept, current flows from left to right but the heat flows from the center of the module outwards. For a 3D chip stack, this lateral heat removal concept can be combined with an interposer through which the heat can be removed. Here the thermoelectric material is underneath the substrate and the heat is pulled from the center segment to the side.

In this example, the center of the platform will cool and the sides will become hotter as is shown. With this approach heat is dissipated laterally into the walls.

Active-Side Cooling

The last approach is active-side cooling. In Figure 3, an artist's rendition depicts the active side of a microprocessor. The smaller structures represent conventional copper pillar bumps next to the larger thermal bump. There could be as few as 10-20 or as many as 600-1200 thermal bumps strategically placed on the chip only in the vicinity of the hot spots. For this application it is not necessary to use a large amount of thermoelectric material – and in fact as little as 1mm x 1mm per hot spot – would be consumed to achieve the desired cooling effect Placement of this material so close to the heat source would lead to a higher TEC efficiency.

Board Cooling

Hot spots on printed circuit boards can be cooled by the introduction of discrete modules strategically placed near the source of the heat. Metal traces, which can be several microns thick, can be stacked or interdigitated to provide highly conductive pathways for collecting heat from the underlying circuit and funneling that heat to the thermal bump. Additionally, adding thermal vias (e.g., copper filled vias) would be required to provide pathways for the rejected heat.

In Figure 4, two MOSFETs were replaced by one eTEC cooled MOSFET. The ~0.5 W input power for the eTEC module translated to a ~3W increase in MOSFET output power.

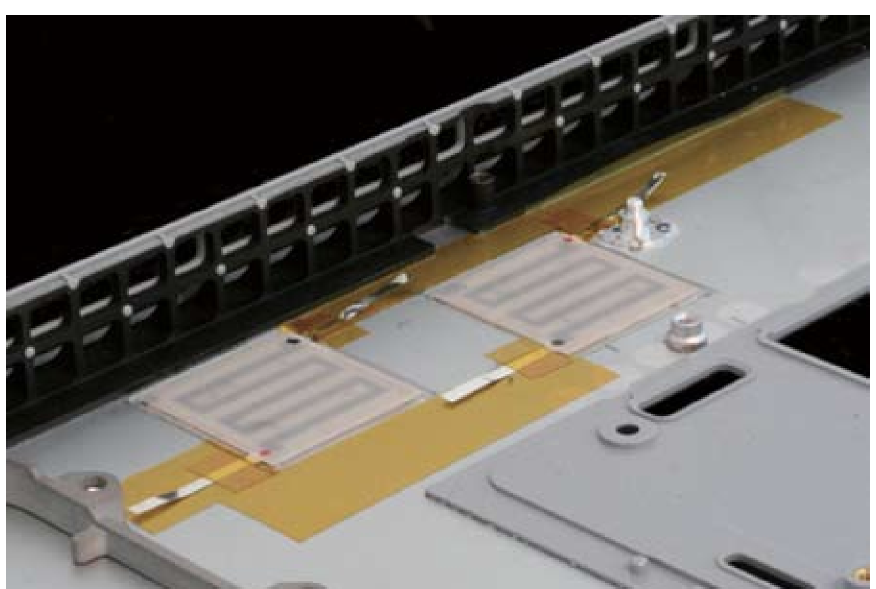


Figure 5: Two thermal barriers integrated into the chassis of a server.

Managing the heat flow in systems is also a problem for many manufacturers of mobile devices. Unlike electro-magnetic energy, which can be isolated or confined, heat is mechanical in nature and hence can flow in any direction. This may include flowing towards sensitive components such as LCD displays. Thermoelectrics may be used to create a thermal barrier to the flow of this energy.

A thermal barrier creates a small temperature inversion that channels thermal energy away from the barrier and in a more desirable direction. A thermal barrier (Figure 5) may be constructed using several discrete thermoelectric devices but loosely spaced and powered only at a very low level.

The overall design, number of modules, their spacing, and the heat spreader materials and dimensions determine the characteristics of the thermal barrier. In most cases, a 3 to 5°C temperature inversion is all that is necessary to cause the heat to flow away from a surface, in essence creating a mirror or thermal reflector. The thermal barrier can be activated when the temperature of the board reaches a critical point, thus creating an "on-demand" thermal management solution.

Summary

The use of thermal bumps and discrete devices to provide a thermal management solution does not obviate the need for syste m-level cooling or for a reasonable means of rejecting heat out of the system. Rather, it offers the system design engineer a new set of tools with which to shape and enhance the performance of their system. Ultimately the focus should be on cooling what you need to cool and nothing else and then manage the removal of this heat in a controlled fashion.

www.nextremethermal.com

Dynamic & Static Power Management with SmartReflex™

High frequency buck converters conserve energy

As cellular phones and other portable electronics become more complex, more power is consumed by systems in both active and standby mode. Consequently, power-management design for portable devices imposes new challenges in the areas of core voltage, energy management and battery lifetime.

By Christophe Vaucourt, Portable Power Systems Engineer, Texas Instruments

Battery capacity simply cannot keep pace with the exciting new functionality on mobile handsets. While consumers demand new applications, they also want smaller, sleeker mobile devices, accelerating the trend toward higher levels of silicon integration and smaller digital submicron process geometries.

Increasing the microprocessor complexity increases its power consumption and with the smaller transistor structures responsible for higher achievable clock rates and increased performance, comes an inevitable penalty, increasing the leakage currents.

Leakage currents are present in any active circuit, independently of clock rates and usage scenarios. This static power consumption is mainly determined by transistor type and process technology. Higher clock rates also increase dynamic power, the power used when transistors switch. The dynamic power depends mainly on a specific usage scenario, clock rates, and I/O activity.

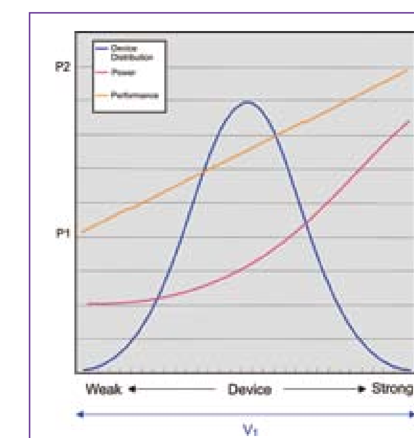


Figure 2: Performance and Power at Constant Core Voltage.

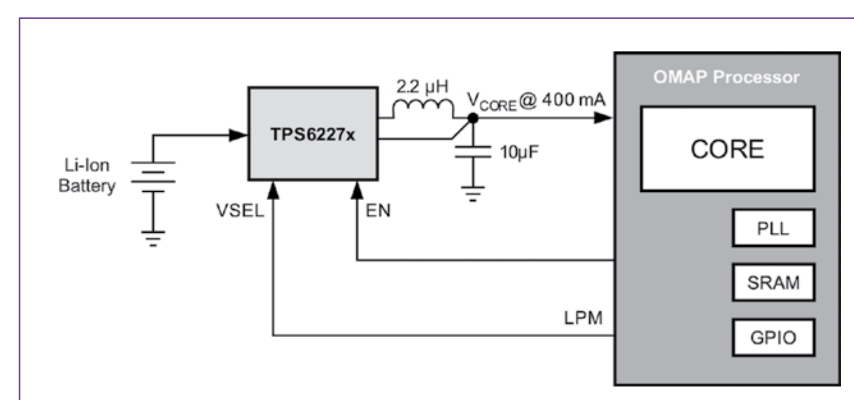


Figure 1: TI SmartReflex- Simple Voltage Scaling System Overview.

Texas Instruments' SmartReflex technology is used to decrease both static and dynamic power consumption while maintaining the device performance. SmartReflex in the OMAP™ devices is a feature that allows the core voltage to be optimized based on the process corner of the device.

SmartReflex 1: Simple Dynamic Voltage Scaling

Power consumption of the processor can be reduced by lowering the internal clock frequency and/or even more by lowering the core supply voltage. Dynamic Voltage Scaling (DVS) is used to reduce core supply voltage to minimize power consumption.

Depending on the operating frequency of the processor, the core voltage can be dynamically and very accurately adapted to its lower limit in order to minimize power consumption. This principle can be used not only to reduce power consumption in active mode but also to extend standby time through a reduction of leakage currents effects in deep-sleep mode.

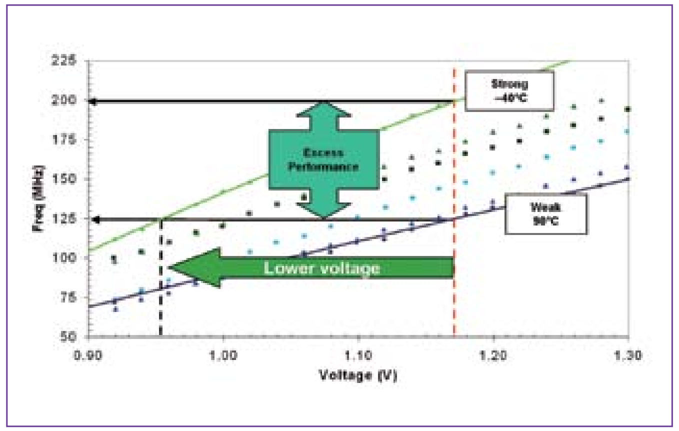


Figure 3: Performance vs. Process, Temperature and Voltage.

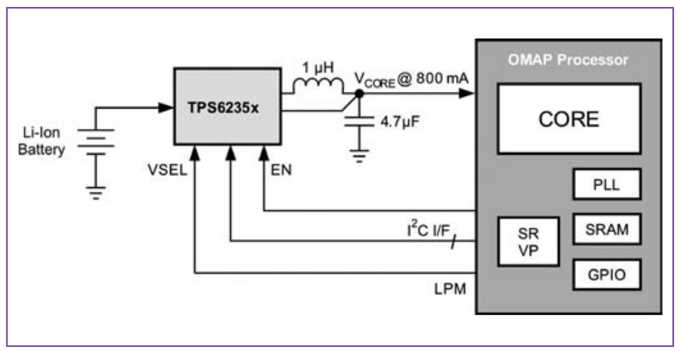


Figure 4: TI SmartReflex 2 - System Overview.

The following relationship describes the power consumption of a digital processor:

$P_C \approx V_C^2 \times f$

P_C: Core Power Consumption

V_C: Core Supply Voltage

f: Core Clock Frequency

As can be seen, the power consumption can be reduced by lowering the clock frequency and even more by lowering the supply voltage.

The TPS6227x device features an output voltage selection input pin (VSEL). The DC/DC output voltage is set internally by the means of a high precision feedback divider network. No further external components for output voltage setting or compensation are required, thereby enabling for smallest solution size.

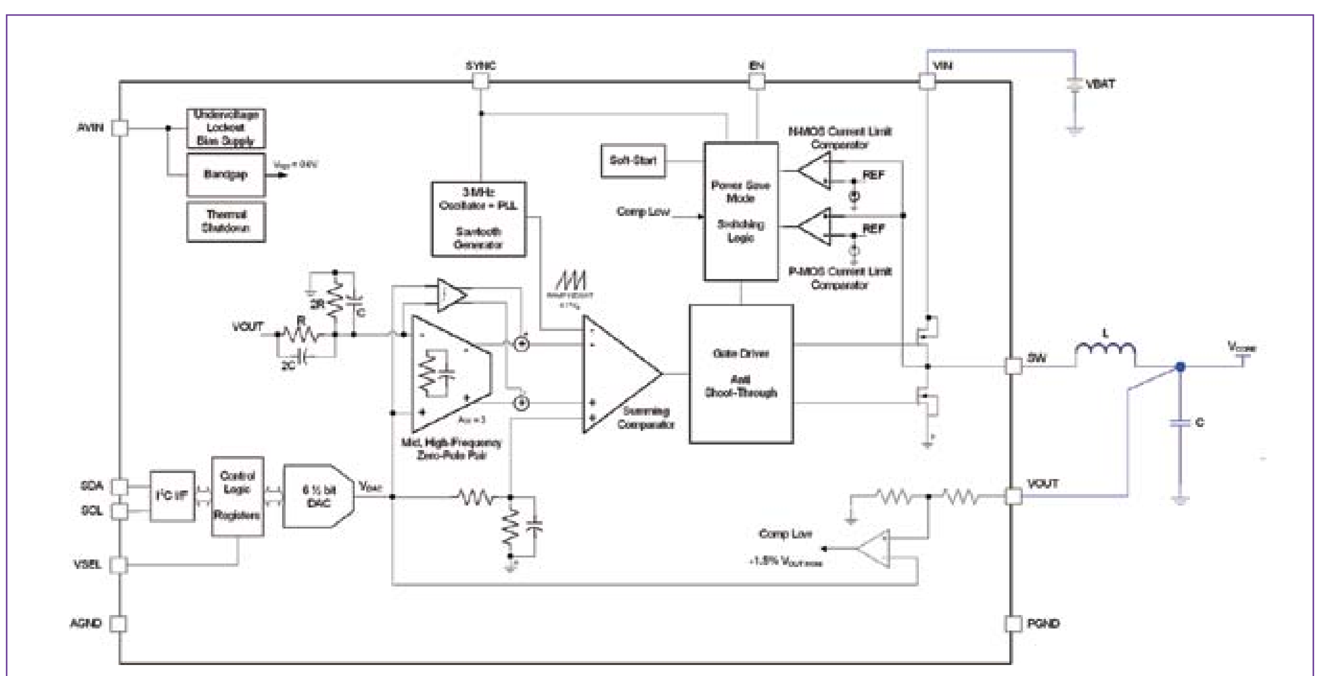


Figure 5: Fast Response SmartReflex 2 Compliant Regulator Block Diagram.

Connecting the VSEL input to an external logic control signal allows simple dynamic voltage scaling for low-power processor core operation. For best performance, the DC/DC output voltage can be changed "*on-the-fly*" without restrictions.

SmartReflex 2: A More Comprehensive System-Level Solution

For high-performance, power-sensitive applications, power reduction is only half the challenge. Providing higher performance while consuming less energy per function is imperative.

In addition to dynamic power (the power that is consumed when transistors switch), modern processors are encountering new standby leakage power challenges caused by shrinking component geometries. Unfortunately, moving down the process scale from 90 to 65 to 45 nanometer (nm) has an exponential effect on leakage power; leakage thus becomes an increasingly significant percentage of a device's total power.

While digital processors are getting more and more powerful, their active power consumption tremendously increases translating into new heat dissipation challenges.

It is desirable to minimize the power consumption while maintaining the target performance. The baseline power is the power consumed independent of the processor activity, and it is dominated by leakage power. The active power is the power consumed by active parts of

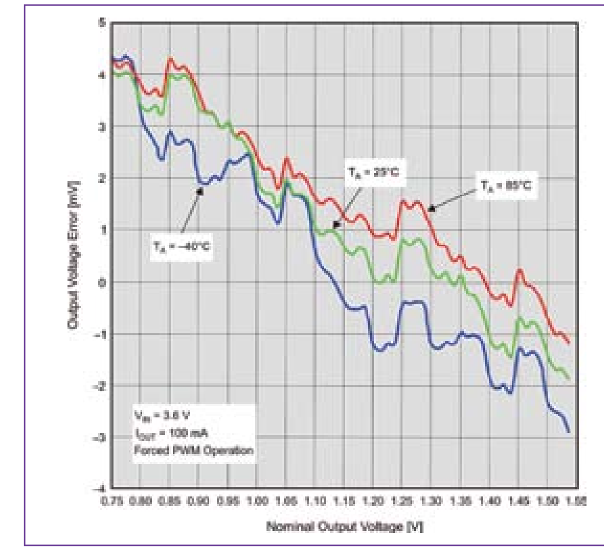


Figure 6: Output Voltage vs. Digital Code.

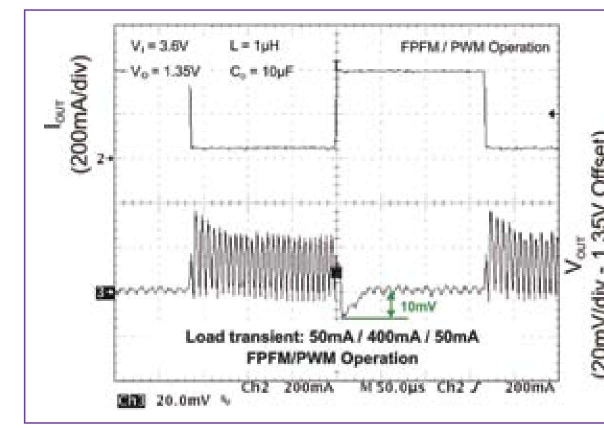


Figure 7: FPFM Load Transient Response.

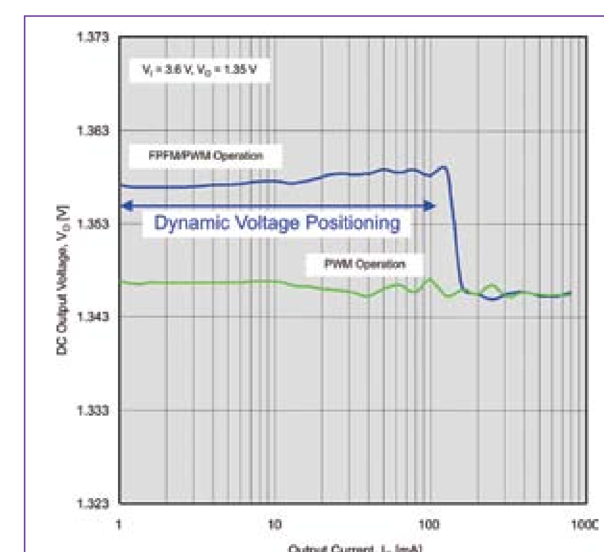


Figure 8: Dynamic Voltage Positioning DC Regulation Accuracy.

the processor; this power can be separated by the major modules within the digital device. If a module is not enabled, there is no active power consumption from that module.

The theoretical performance and power consumption for a general bell-curved manufacturing distribution is shown in Figure 2, with (P1, V1) representing the nominal OPP (Operating Performance Point) and P2 representing the performance for the strong device at V1.

The extra performance margin cannot be utilized and a significant amount of extra power (both leakage power and active power) is consumed for strong devices operating at (P1, V1).

In the case of this particular TI OMAP™ device, the nominal OPP for the core is (125MHz, 1.15V); a strong device is capable of running at the same speed with a much lower supplied voltage or running at a much higher speed with the same supplied voltage.

SmartReflex 2: Hardware Implementation

SmartReflex 2 is a technology that uses adaptive voltage scaling (AVS) to reduce active power consumption. The voltage is adjusted within the defined range and SmartReflex™ voltage processor assures that the voltage applied is sufficient for each device (of different strength) to operate at the nominal OPP frequency.

In the simplest approach (SmartReflex 2 Class-0), the

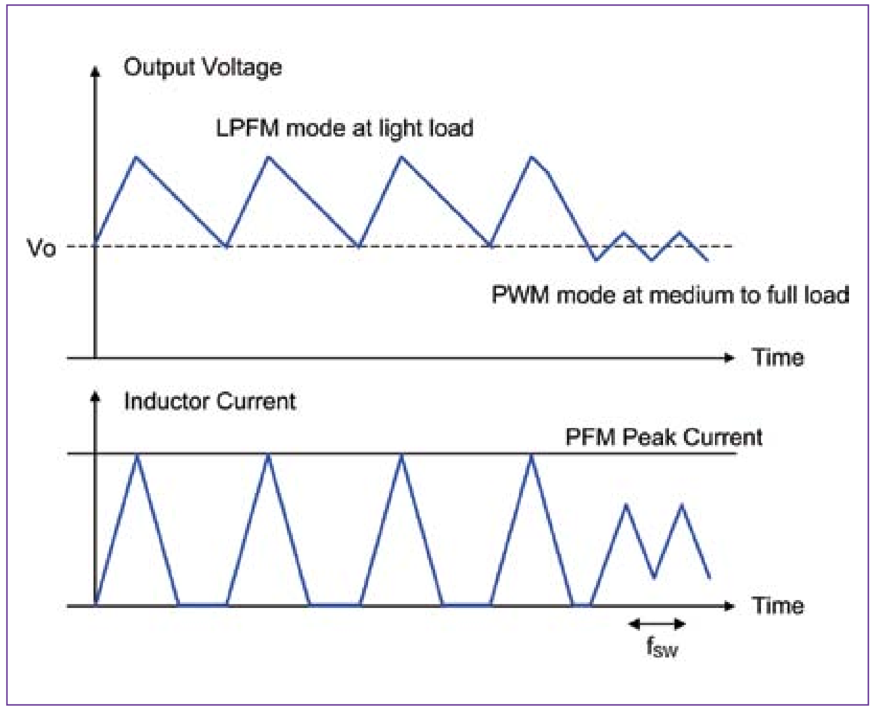


Figure 9: Single Pulse, Variable Peak Current PFM Principle (Light PFM).

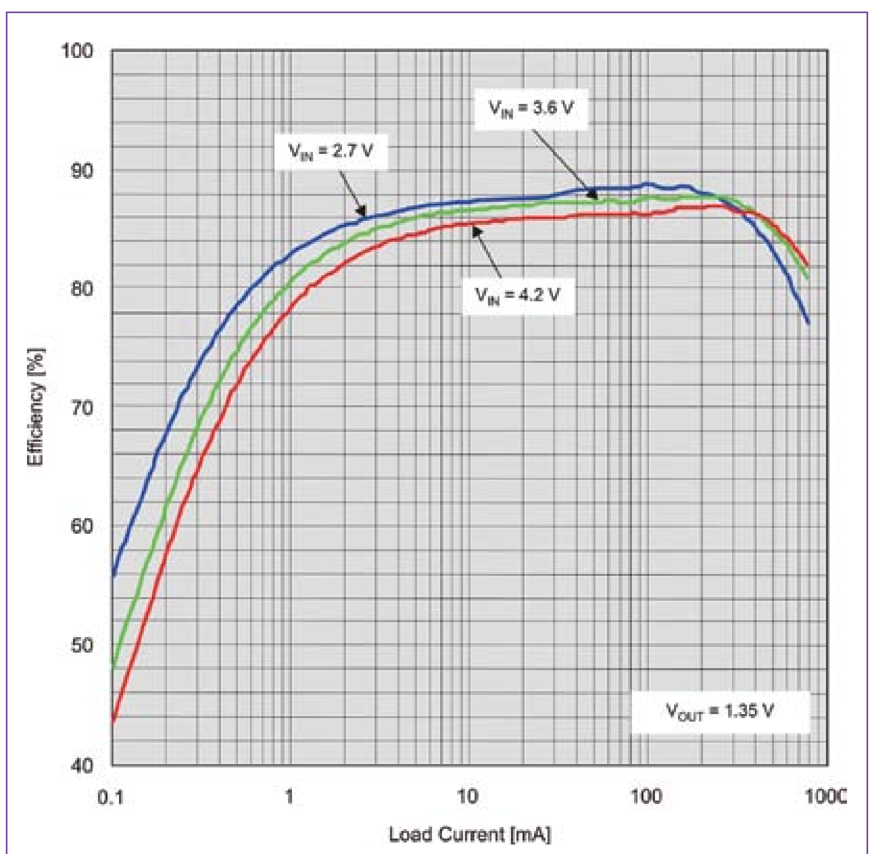


Figure 10: Light PFM Efficiency.

processor performance is measured at manufacturing test and the required operating voltage for that device is determined. This information is permanently stored into the device. During boot-time, the SmartReflex 2 control output (e.g. simple logic signals or I_2C I/F) is sent to the power supply to select the appropriate core voltage level.

Modern regulators aim not only to provide state-of-the art electrical performance but also small solution size. To address TI's SmartReflex requirements, a dedicated high switching frequency converters operating at 3MHz nominal fixed frequency has been developed.

With an output voltage range adjustable via I_2C interface down to 0.6V, the TPS6235x series supports low-voltage DSP and OMAP processor core power supplies in smart-phones and handheld computer. The communication interface is used for dynamic voltage scaling with voltage steps down to 12.5mV, for reprogramming the mode of operation (Light PFM, Fast PFM or Forced PWM) or disable/enabling the output voltage.

With increasing SmartReflex 2 implementation class comes increasing power savings benefits, but also increased system complexity. In Class-2 and -3 implementations, either software or a hardware voltage processor (VP) continuously adjusts the supply voltage to changing environmental conditions.

The AVS system offers optimal voltage scaling for a given processor. By virtue of closed-loop performance regulation, the lowest voltage for a given operation condition is always selected.

The voltage processor contained in the digital processor further reduces system integration complexity by providing an automatic handshaking between voltage scaling and frequency scaling. Through closed-loop control and configurable gains, the maximum system energy efficiency is achieved.

To support closed-loop operation, the TPS62350 device features a 6.5-bit resolution monotonic output voltage response vs. digital voltage code.

To maintain correct functionality on digital processors embedding SmartReflex technology, the power supply must be designed to provide a core voltage with a maximum 5% error (covering DC accuracy and AC transient response).

To address these very tight regulation requirements, the TPS6235x device converter uses a unique advanced summing comparator fast response, voltage mode, controller scheme with input voltage feed-forward. This achieves "best-in-class" load and line response and allows the use of tiny inductors (1μH) and small ceramic input and output capacitors (4.7μF).

During light-load conditions, the TPS6235x converter includes a complementary Fast PFM (FPFM) mode to enhance efficiency without compromising on the transient performance. Fast-PFM mode helps to shorten the wake-up time of the inner regulator circuit. At the expense of larger quiescent current consumption (ca. 90μA), the regulator's activation time can be dramatically reduced thereby transitioning smoothly between FPFM and PWM modes.

"Dynamic Voltage Positioning" regulates the output voltage in PFM mode slightly higher than the nominal value (PWM mode). The output voltage is set higher in the magnitude of 1% typ, thereby giving additional headroom to minimize the absolute voltage sag.

Figure 7 shows the load transient performance of a Fast-PFM scheme. In a nutshell, the Fast-PFM mode reduces the transient voltage drop by a factor of two compared to other switched mode regulators.

Fast PFM mode offers the excellent transient response performance during large load swings, at the expense of the ultra-light load efficiency (i.e. sub 10mA). Light PFM (LPFM) mode features lower quiescent current (c.a. 30μA), reduced output ripple voltage giving-up a bit on transient performance.

In light PFM mode, the converter only operates when the output voltage trips below a set threshold voltage (i.e. nominal output voltage). It ramps-up the output voltage with a single or multiple pulses and goes back into power-save mode. As a consequence in power-save mode, the average output voltage is slightly higher than its nominal value in PWM mode and the light-load efficiency is dramatically improved.

Conclusion

The solid foundation for SmartReflex technologies now extends outward with the second-generation features of SmartReflex 2: adaptive power supply to reduce digital processor leakage and active power consumption.

Each SmartReflex implementation class has different advantages. With increasing SmartReflex 2 implementation class comes increasing power savings benefits, but also increased system complexity.

Each design must choose the class of SmartReflex 2 implementation that best suits its requirements. TI's discrete solutions for dynamic voltage management supports fast and accurate voltage scaling as required by today's and tomorrow's processor cores. The small package of TPS62270, TPS62350 and the limited amount of external components makes them an ideal choice in real estate sensitive applications.

www.ti.com

Power Supplies

Making Sense of Power Specifications

Putting the data into power supply data sheets

Why is it that seemingly similar power supplies have significantly different performance and reliability characteristics? The answer may lie in the specification detail that can be missing from some data sheets, available only in the long-form data/application notes or may even be due to "specmanship".

By Gary Bocock, Technical Director, XP Power, UK

Let's look at typical data for an AC/DC power supply, though many of the issues may equally apply to DC/DC converters.

Input Characteristics

Input voltage range

AC/DC power supplies are typically universal in nature, meaning that they operate over a wide range of input voltages, normally from 85 or 90VAC up to 264VAC. This feature allows a single product to operate world-wide without changes in configuration of the input stage. Some products utilise automatic input voltage range selection giving two operating ranges; typically 90 to 132VAC & 180 to 264VAC. Universal input power supplies provide better immunity to supply disturbances in some circumstances and this may be a benefit.

If the power supply is to be used close to its full power capability within the application it is important to check the specification details on the available output power in the low input voltage area, where some products de-rate by as much as 20 or 30%, meaning that they may be operating outside of specification when operating from nominal 100VAC or 115/120VAC supplies or at the very least may infringe the design margins of the end equipment. Ignoring this de-rating in the available output power will seriously affect the reliability and life time of the power supply and therefore the end equipment.

De-rating the power supply output power at low input voltages is common in lower cost universal input power supplies and is normally due to the limitations of the active power correction boost converters employed.

Earth leakage current

Earth leakage current is a parameter which varies widely from product to product. The earth leakage current is largely a consequence of EMC filtering within the power supply and is normally only a key consideration in medical applications or in installations or equipment using multiple AC/DC products or where external EMC filters are utilised to reduce overall system noise.

Inrush Current

A key consideration affecting the selection of fuses, filters and switchgear is the inrush current at the point of application of the AC power. The maximum inrush current is usually specified in the data sheet however there is more to this than a simple maximum value.

In lower power, lower cost products the inrush limiting is typically via a simple NTC thermistor which will provide protection from a "cold start" but may take a minute or more to return to its initial value following the initial switch on. This results in an inrush current many times the specified maximum during an off/on cycle even with a relatively long delay. The inrush current is also likely be specified at 25ºC and may be significantly higher even for a cold start in higher ambient temperatures.

In products above a few hundred watts, this thermistor is likely to be taken out of circuit once the output voltage is established, to remove unnecessary power dissipation, removing this as an issue.

Inrush current is an important factor to be considered to avoid nuisance tripping of fuses and circuit breakers as well as reliability of switches and filtering. The fuse rating given in some data sheets is usually the rating of the internal fuse which is designed to operate only in the event of catastrophic failure and is not user replaceable. Determining the value of the equipment fuse needs to take into account the normal maximum running current, the inrush current and the effects of aging. The equipment fuse should also only be required to operate under catastrophic failure conditions as the electronic power supply overload protection will cater for any problems on the DC side.

Output characteristics

Overload protection

All power supplies offer overload protection to protect both the power supply and the load tracking and wiring from overheating. This may come in a number of different guises or characteristics.

In low power products a trip and restart or "hiccup" mode is common as this helps to keep costs down by utilising primary control schemes. Trip & restart overload schemes are generally unsuitable for loads involving high start up currents such as electromechanical equipment, lighting equipment or applications which have a high capacitive element, as start up may be unreliable and variable even from unit to unit. This overload characteristic is also unsuitable for direct battery charging applications. With these types of load a constant current overload characteristic is desirable.

Remote Sense

Low voltage high current applications will benefit from products which offer remote sense where the output voltage can be measured at the point of load. This feature is particularly desirable where the load is variable. If the load is relatively constant then a simple user adjustment of the output voltage will be adequate and more readily available though may result in other voltage rails also being adjusted by the same percentage in multiple out supplies where the additional rails are often semi-regulated.

Output accuracy and minimum loads

Output accuracy or regulation is specified in many different ways by various manufacturers. It should encompass line regulation, load regulation, cross regulation (for multiple output supplies), transient response, initial set accuracy and temperature coefficient. These parameters can be specified over differing input ranges, load ranges, load step changes and temperature ranges etc. While these items can be presented in many ways the majority of single output supplies will have comparable performance. Perhaps the most important consideration is for multiple output units where the performance can be very different.

Single output power supplies rarely require a minimum load but multiple output units often require minimum

The 3" x 5" CLC175 AC/DC power supply from XP Power is capable of delivering its 175W full load output with only 10CFM airflow.

loads on one or more outputs and this should be made clear on the product data. Minimum loads are normally specified to reduce the effects of cross regulation between outputs and to maintain the output accuracy within the specified limits. These minimum loads will need to be considered in the system design and where necessary components added to ensure that they are met.

As standby/no load power consumption requirements reduce, the addition of minimum loads is becoming a real system performance issue and other solutions are required, particularly in low power applications where features such as inhibit are rare due to market cost requirements and the primary control systems in general use.

Output ripple & noise

Ripple & noise is one of the product performance specifications which is most open to interpretation, making comparison from the data sheet difficult if not impossible. The main variables are the measurement bandwidth and the use of various external components and measurement techniques. The only real way to compare performance is to measure the products under the same measurement regime.

Efficiency

Most data sheets will offer a figure for efficiency allowing the user to quantify the waste heat generated within the end equipment. The efficiency of a power supply will vary dependant on the load and input voltage applied, so it is important to understand the unit's efficiency under the operating conditions of the application. Efficiency during operation at low line is typically lower than at high line and may vary by as much as 6-7%. The most important parameter is the worst case efficiency in order to understand the maximum waste heat generation by the supply.

The drive in power supply development is to increase efficiency in order to reduce the physical size of the product and reduce power consumption. This is also being driven by the standby/no load power and average active efficiency requirements set out in legislation such as Energy Star, CEC, EISA and EUP.

Power density specifications are being increasingly used by power supply and DC/DC converter manufacturers to convey advancement in power technology & efficiency. If these watts per cubic inch specifications are compared it is essential to ensure that the products have similar specifications and do not require external components to meet various specification requirements.

Reliability, Temperature & Cooling

The normal measure of reliability of power converters is given as Mean Time between Failure (MTBF). The MTBF is normally calculated based on the predicted failure rate of the components utilised within the product, a so called parts count method. When comparing the MTBF of various supplies there are a number of key parameters to check to ensure that the specifications are indeed comparable. Firstly the methodology needs to be identical; typical methods are MIL217 at its various issue levels and Bellcore RPP (now managed by Telcordia Technologies). These two methodologies will give very different results and cannot be compared to one another. Where the MTBF is given to the same specification then in order to be compared it must also be stated under the same environmental conditions to prove a useful tool to the system designer.

The most influential factor in terms of reliability and lifetime is the ambient temperature and effective cooling of the power supply. Convection cooled products need adequate space to cool effectively and forced cooling requirements need to be carefully considered to ensure that the product is adequately cooled in the specific application. Manufacturers are increasingly providing key measurement points within the sub assembly to ensure that the product will be both safe and reliable and to ensure adequate lifetime. Thermal de-rating data is normally provided up to ambient temperatures around 60 to 70ºC. Careful consideration of this data is required since some products de-rate from as low as 40ºC. For example, most power supplies from XP Power de-rate from a minimum of 50ºC, some from 60ºC. Also, be aware that while a unit might be specified to operate at an ambient temperate of, say, 40ºC, when the unit is enclosed within end-user equipment the internal temperature can be much higher than that.

Airflow is another important consideration. Be aware that some products may specify an airflow rate that might be difficult to achieve in practice e.g. 20 – 30CFM. As a guide, look for a required airflow less than 15CFM. Typically, XP's products require 10 – 13CFM.

EMC

Datasheets include EMC specifications. Open frame products include conducted emissions and conducted immunity specifications with some providing information on radiated emissions and radiated immunity, some may require additional components to meet the stated performance so these should be considered when selecting the product for the application. External power supplies must provide specifications for both conducted and radiated EMC performance as these are considered stand alone products. Typically the products are evaluated using passive loads in an ideal test set-up which is unlikely to be replicated in the end application so choosing a supply with local engineering support and test facilities will be an advantage during the end product development.

In summary, power supply and DC/DC converter data sheets contain a lot of information which needs careful consideration when applied to the end application. The data is generated with the power supply or converter in isolation and in some instances additional components are required to meet the various parameters. Cooling and de-rating information may differ significantly between products though this is not always apparent in short form data and efficiency data is normally given under best case rather than worst case conditions. How well the power supply performs in the end application is the key consideration and a study of the long form data and application notes will often provide the detail required to select the best power solution for your system.

XP's Power Supply Technical Guide is a free 148-page guide to power system technology. It is available to download free-of-charge from the XP website.

www.xppower.com

Power in Transit

Power capacitors for electric vehicles

Electric vehicles are in widespread use. Hybrid cars are now a common sight on our roads as people look to find more environmentally-friendly forms of personal transport – and as a reaction to spiralling oil prices - and there are many other commercial and public electric vehicles, such as trains, trams, buses and industrial trucks and equipment in everyday use.

By Gilles Terzulli, Power Film Capacitor Marketing Manager, AVX Corp., St Apollinaire, France

The electronic systems and components that have enabled the realisation of such a wide variety of electric vehicles have all experienced a major evolution, including the DC link power capacitor.

The purpose of capacitors in electric vehicles is to prevent ripple currents from reaching back to the power source, and to smooth out DC bus voltage variations. Capacitors are also used to protect semiconductors – originally thyristors, but now IGBTs.

Metallised film has become the capacitor technology of choice for electric vehicle and other medium and high power applications. There are several reasons for this.

One major advantage is the ability of film capacitors to overcome internal defects. The latest dielectric films used for DC filter capacitors are coated with a very thin metallic layer. In the case of any defect, the metal evaporates and therefore isolates or fuses the defect, effectively self-healing the capacitor. The total capacitance is divided into elementary cells (sometimes several million) protected by fuse gate. If there is a weak point, the particular cell where the weak point is located will be insulated by fuses blowing.

Capacitance decreases as function of the ratio between elementary cell surface and total surface of capacitor, so there is no complete failure and no short circuit, only a minimal capacitance decrease which can be useful as a measure of ageing.

Metallised film has become the capacitor technology of choice.

Metallised film capacitors from AVX are designed to meet CEI 1071 standards. This means they are able to handle multiple voltage surges of up to twice the rated voltage, without significantly decreasing product lifetime. It also means the designer need only account for nominal voltage requirements when specifying the system.

Metallised film capacitors also offer significant space savings when compared to devices manufactured using other technologies - such as aluminium electrolytic - if high RMS current handling is a requirement.

AVX has significant experience in developing power capacitors for automotive application, dating back to 1995. Currently the company offers a range of metallised film devices based on cylindrical (puck) or flat bobbin modular building blocks. This approach has several benefits. Firstly, the arrangement of the capacitors can be optimised to suit the available space, resulting in great volumetric efficiency. Second, the arrays are current- and inductance-balanced by AVX and suffer no expansion problems across a temperature range of -55 to +125degC. Lastly, because the individual capacitor building blocks are manufactured on process-controlled, automated lines, quality and cost-effectiveness are assured.

An application note from AVX discusses some design considerations concerning metallised film capacitors used in electric vehicle applications.

DC link filter: high current and capacitance value design

In an electric car or fork lift truck where energy is supplied by batteries the capacitor will be used for decoupling. Film capacitors are particularly well suited for this use, since the main criteria for DC link application is the device's RMS current withstanding capability.

AVX high energy power film capacitor.

If we take the following typical electric car data:
Working voltage: 120Vdc
Ripple voltage (Uripple) allowed: 4Vrms
RMS current (Irms): 80Arms @ 20kHz

The minimum capacitance value will be determined from the equation:

$$C = Irms/ (Uripple \times 2\pi f) = 159\mu F$$

If we were to attempt the same calculation using electrolytic technology we need to take into account the fact that you need a 1µF capacitor to handle 20mA, so in our example, in order to handle 80 Arms the minimum capacitance value would be:

$$C = 80/0.02 = 4000\mu F$$

Therefore we see it is much better to use a much lower rated film device, saving cost and space.

Overvoltage

If we consider the example of light traction application, such as metros, tramways or electric buses, the DC link voltage wave form is represented in figure X.

In such applications, discontinuities can occur when power is transferred between from the catenary or messenger wire to the train. When contact is not completed, energy flows from the DC link filter, decreasing the voltage. Therefore, as soon as the contact is re-established, an overvoltage appears. In the worse case the voltage change would be equal to twice the catenary voltage, resulting in an overvoltage almost twice the rated voltage. However, film capacitors can handle this level of overvoltage.

In comparison, to do the same task using electrolytic technology the capacitors would need to be significantly larger - around twice the size for a rated voltage of 1000V, reaching a surge voltage of 2000V.

Protection of semiconductors

The first electric vehicle applications used thyristor technology, but subsequently many applications are now based around IGBTs. DC link capacitor development has had to match the evolutions in semiconductor technology not only electrically, but also mechanically to deliver the lowest parasitic inductance. AVX offers several families of film capacitors designed to operate optimally with both thyristors and IGBTs.

As an example of the success AVX has enjoyed with its power film capacitor families, products supplied by the company helped break the world speed record for conventional trains. In April, 2007, a French-made TGV with a 19.6MW (over 26,000-horsepower) capacity and special wheels reached 574.8km/h (357.2 mph), beating the previous record of 515.3 km/h (320.2 mph) set in 1990.

The high energy power film capacitors used in the TGV are part of the Trafim™ family. They offer significantly reduced weight and volume and are specified at 3mF, 1890Vdc (DKTFM546); 2.5mF, 2630 Vdc (DKTFM603); 1.67mF, 4000Vdc (DKTFM537); and 1mF, 4000Vdc (DKTFM538).

More, AVX's metallised film capacitors exhibit exceptional reliability in the field with zero catastrophic field failures over the company's history of over 150,000 large oil-filled DC filter products shipped to customers with over 3 billion hours of operational life in a variety of harsh and demanding applications.

www.avx.com

Solving Current Source Design Challenges

Simple, high performance two-terminal current source

Compared to other analog circuitry, current source design appears relatively easy on the surface, but in reality it is more complicated than meets the eye. While high quality voltage sources are commonplace, current sources, as components, have remained elusive. Furthermore, two-terminal current sources generate a new set of problems, especially if high accuracy and stability over temperature are desired.

By Robert Dobkin, Vice President, Engineering & Chief Technical Officer, Linear Technology Corporation

A current source must operate over a wide voltage range, have high DC and AC impedance when connected in series with unknown reactance and exhibit good regulation and a low temperature coefficient. For optimal two-terminal solutions, no power supply bypass capacitor should be used since it degrades AC impedance.

A new device, the LT3092 from Linear Technology, overcomes the problems of earlier two-terminal current sources. It has better than 1% initial accuracy and a very low temperature coefficient. Output currents can be set from 0.5mA to 200mA, and current regulation is typically 10ppm per volt. The LT3092 operates down to 1.5V or up to 40V. This gives an impedance of 100MOhms at 1mA or 1MOhm at 100mA. Unlike almost any other analog integrated circuit, special design techniques have been used for stable operation without a supply bypass capacitor, allowing it to provide high AC impedance as well as high DC impedance. Transient and start-up times are about 20µS.

Figure 1 shows a basic diagram of Linear Technology's LT3092 current regulator. The architecture is similar to Linear's LT3080 voltage regulator, but it uses a PNP transistor as the output

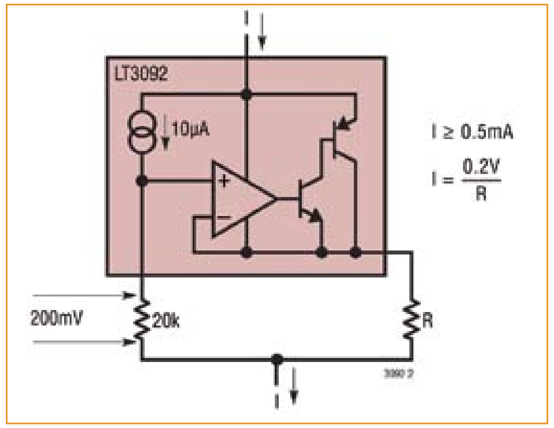


Figure 1: Two-terminal current source.

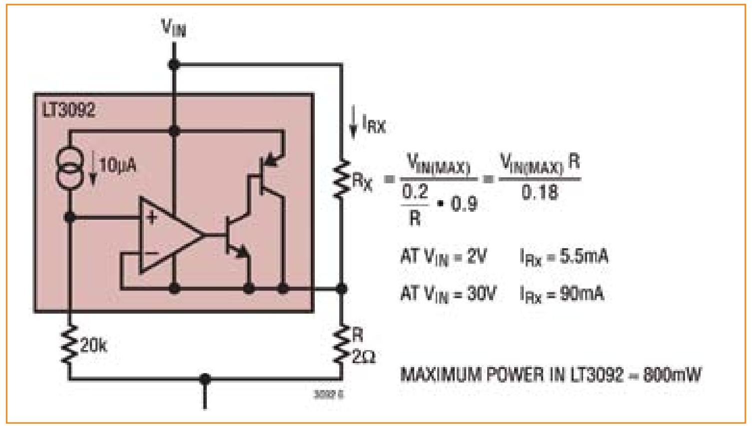


Figure 2: Reduced dissipation.

device instead of an NPN. Internal circuitry is differential and buffered, with a regulator to isolate it from power supply changes. This isolation allows stable operation without bypass capacitors. Additionally, for environments that may have power supply reversal, the LT3092 is immune to damage from reverse power supply voltage and does not conduct current, so it protects the load.

The internal current source and the offset of the amplifier are designed to reject power supply changes by 100dB or better, so the regulation is very good. Setting the RSet down to zero allows the output to be adjusted down to zero.

A small voltage is impressed upon an external set resistor, 20k in this case, to generate a 200mV reference. That forces 200mV across a current-determining resistor R, and the total current is then equal to 0.2V divided by R (plus 10µA). The current regulator works from about 1.5V across it up to 36V, and the current regulation and temperature stability is extremely good. As a two-terminal current source, the load can be either in the positive leg or in the ground leg of the circuit.

The 200mV generated reference is chosen to equalize the errors due to changes in the internal current source and in the offset of the amplifier with supply voltage. With supply changes, the internal current sources change approximately 50pA per volt. The offset of the internal op amp changes less than 5µV per volt. Assuming worst case for both the current source and the offset of the amplifier, a 200mV reference contributes equal error from both the amplifier and the internal current source. If the 200mV is increased to 500mV using a 50k resistor, the contribution of the internal op amp offset declines. This improves the regulation of the current source against supply changes.

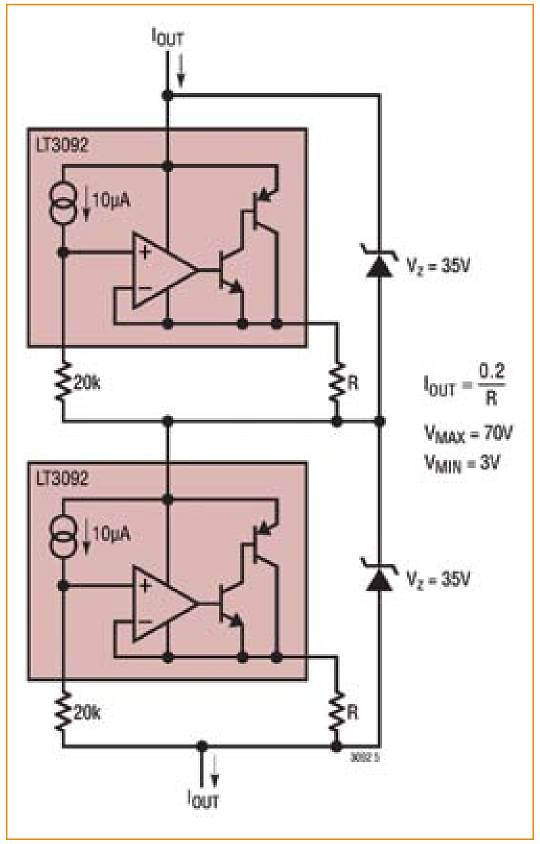


Figure 3: Stacked current sources for higher operating voltage.

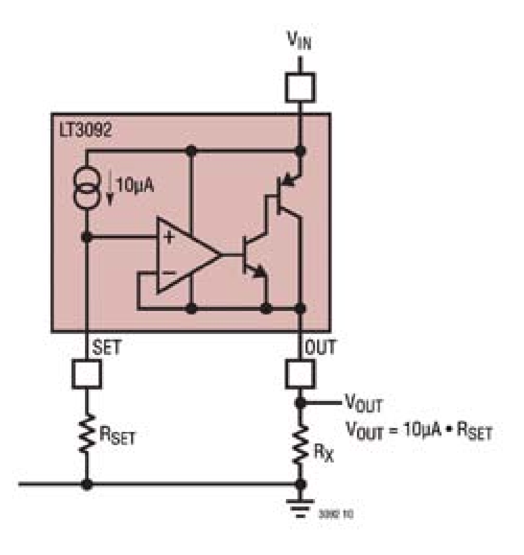


Figure 4: Intrinsically safe regulator—no capacitors needed.

However, the regulation of the loop is so good that in all but the most extreme cases, 100mV to 200mV across the set resistor will be fine.

Reducing power dissipation

For high set currents and high voltage, there is considerable power dissipation in the LT3092. For example, 30 volts and 100 milliamps equals 3 watts of dissipation, which can result in significant temperature rise depending on the thermal resistance of the PC board. An external resistor can shift a portion of the power to the resistor and reduce the power dissipation in the LT3092. Figure 2 shows the basic current source with a resistor RX from the input to the output of the device. As long as the total current is more than the current through RX, regulation is not impaired and the current source impendence does not change.

Current through RX is within the feedback loop and gets compensated as the voltage from input to output changes. The current flows through the internal PNP transistor or the external resistor while the feedback loop keeps the total current constant.

For good regulation and to ensure reasonable margin, the current through RX should not be any larger then 90% of the desired current for the device at the maximum voltage. The formulas in the illustration show how to choose RX so that the current through RX always leaves at least 10% of the current flowing through the LT3092. This drops the maximum internal power down by shifting some power to the external resistor. The result is a significant reduction in device dissipation, as well as a reduced rise in temperature. There is negligible effect on the performance of the circuit by including this external resistor.

Increasing voltage compliance

For higher voltages, current sources can be stacked to operate at a higher total voltage. Figure 3 shows stacked current sources.

Two current sources are set up for the same currents and a voltage-limiting Zener is placed across each of the current sources. At low voltage, whichever current source has the incrementally higher current will saturate and the current will be controlled by the other current source. As the voltage increases, at some point the Zener breaks down and starts to conduct. Then the voltage across the saturated current source starts to increase and it regulates the current as the voltage continues to increase. When the current control goes from one current source to the other, there is a small discontinuity in the output current equal to the error between the two current sources. Typically this is less than 1% and again no bypass capacitors are needed to make the device work.

Intrinsically safe as a voltage regulator

The LT3092 will act as a voltage regulator that needs no output capacitor. "Intrinsically safe" applications are usually designed with low current, and small or no capacitors. Figure 4 shows the LT3092 as a 200mA regulator. As a voltage regulator, the 10µA current that's generated internally flows through an external RSet resistor. This 10µA times the RSet value impresses a voltage on the Set pin. The internal voltage follower provides the same voltage at the output pin as the Set pin. The load is connected from the output pin to ground.

Conclusion

As a new IC, the LT3092 solves current source design, which is a more difficult challenge than a voltage regulator design. Current source values of 1mA up to high currents are achievable using a single unit or paralleled units. Regulation against line, load and temperature is excellent and unique design techniques have made the device operable without bypass capacitors even though there is a complex feedback circuit internally. This device adds a versatile component to a designer's toolbox.

www.linear.com

Aggressive Power Management

Achieving high-performance, low power processing engines for portable devices

With the wave of higher data rate and media content available, media-intensive portable devices are expected to be used almost continuously while relying on battery capacity similar to that of a voice-centric device. The portable devices that make use of these networks must be conscious of both power and performance. Power conversion efficiency today is already over 90%, and any improvement to the DC/DC converter itself would only provide minor impact to the overall system. Therefore, it has become necessary to use new techniques to manage energy at the system level.

By Mark Hartman, Application Manager and Joy Taylor, Marketing Manager – National Semiconductor

The main source of processor power loss comes from dynamic switching and static leakage losses. Dynamic losses increase with operating frequency and number of gates. Static leakage loss increases as process geometry decreases. A simple equation can describe the combined dynamic and static power loss:

$$P_{LOSS} = (\alpha C V_{DD}^2 f) + (V_{DD} I_{LEAK})$$

Where,

α = factor related to effective % of gates switching

C = circuit capacitance, a constant proportional to the number of gates and parasitic routing

f = clock frequency

The dynamic portion of the power loss equation ($\alpha C V_{DD}^2 f$) is due to the charging and discharging of the each transistor and its associated capacitance. The leakage portion of the power loss equation ($V_{DD} I_{LEAK}$) is due primarily to gate and channel leakage in each transistor. Each of the power saving methods discussed below effect one or more of the variables in PLOSS equation. When to use which methods depends on many factors related the device and the application.

Voltage and Frequency Scaling

The energy consumed in a processor is the power loss times the time:

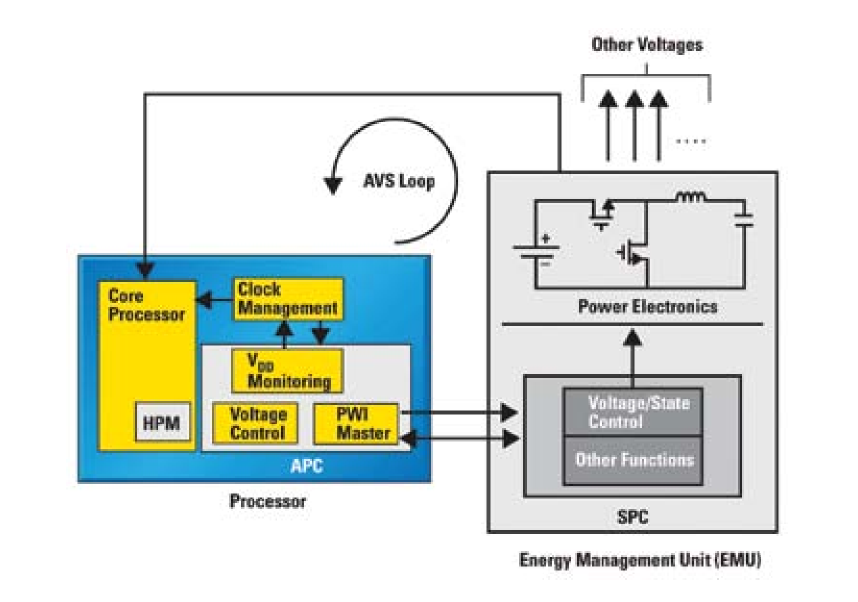


Figure 1: The Adaptive Voltage Scaling (AVS) loop and its components.

$$E = \{(\alpha C V_{DD}^2 f) + (V_{DD} I_{LEAK})\}t$$

The dynamic term includes α(factor related to effective % of gates switching), C (circuit capacitance, a constant proportional to the number of gates and parasitic routing), V_{DD} (supply voltage), and f (clock frequency). Dynamic energy is the energy used to charge and discharge circuit nodes inside the logic, basically when 1's and 0's change state. Dynamic energy is proportional to V_{DD}^2.

It is readily seen why a common energy saving technique employed in digital circuits involves scaling down the frequency (f) and voltage (V_{DD}) of the processing engine to reduce energy expenditure. Note that dynamic energy is independent of frequency and time because energy is dependent on how many 1 and 0 transitions a given task requires inside logic. Dynamic energy can be reduced by scaling down V_{DD} for a yield of V_{DD}^2 in energy savings; while static energy can be reduced by an order V_{DD}.

Dynamic Voltage Scaling (DVS) vs. Adaptive Voltage Scaling (AVS)

Two popular approaches to voltage scaling are dynamic and adaptive voltage scaling. Dynamic Voltage Scaling (DVS) is an open-loop approach that adjusts the voltage and frequency in pre-characterized parings or with a voltage vs. frequency look-up table. Adaptive Voltage Scaling (AVS) is a closed loop approach that constantly adjusts the supply voltage to maintain a minimum margin.

The DVS system utilizes a pre-characterized voltage/frequency table that the processor uses to optimize dynamic power. When the processor wants to scale frequency, it looks up the corresponding voltage and commands the power supply to transition to that voltage. These voltages need to be high enough to maintain functionality over all parts and temperatures, and power supply variation. While this open-loop approach yields a reasonable amount of energy savings, it cannot realize all the energy savings possible.

AVS utilizes real time process and temperature feedback from the processor to provide the lowest voltage for any given condition. The voltage is updated continuously through a closed loop that is formed between the processor and power supply. When the processor wants to scale frequency, the loop optimizes the supply voltage autonomously, and provides a flag to the processor when it is safe to scale frequency. Since the AVS loop uses feedback from a performance sensor on the processor, it can adjust for process, temperature, and power supply variation, reducing voltage margin over the DVS system.

Adaptive Voltage Scaling (AVS) Implementation

AVS is a system level power management approach. The key blocks in the system are illustrated in figure1. The Advanced Power Controller (APC), licensed by National Semiconductor, provides the AVS loop control and all voltage/frequency scaling handshaking. The PowerWise® Interface (PWI) is an open standard interface developed by National Semiconductor. This two-wire serial interface provides the necessary bandwidth and protocols for AVS. Finally, the Energy Management Unit (EMU) provides the voltage scaling and regulation.

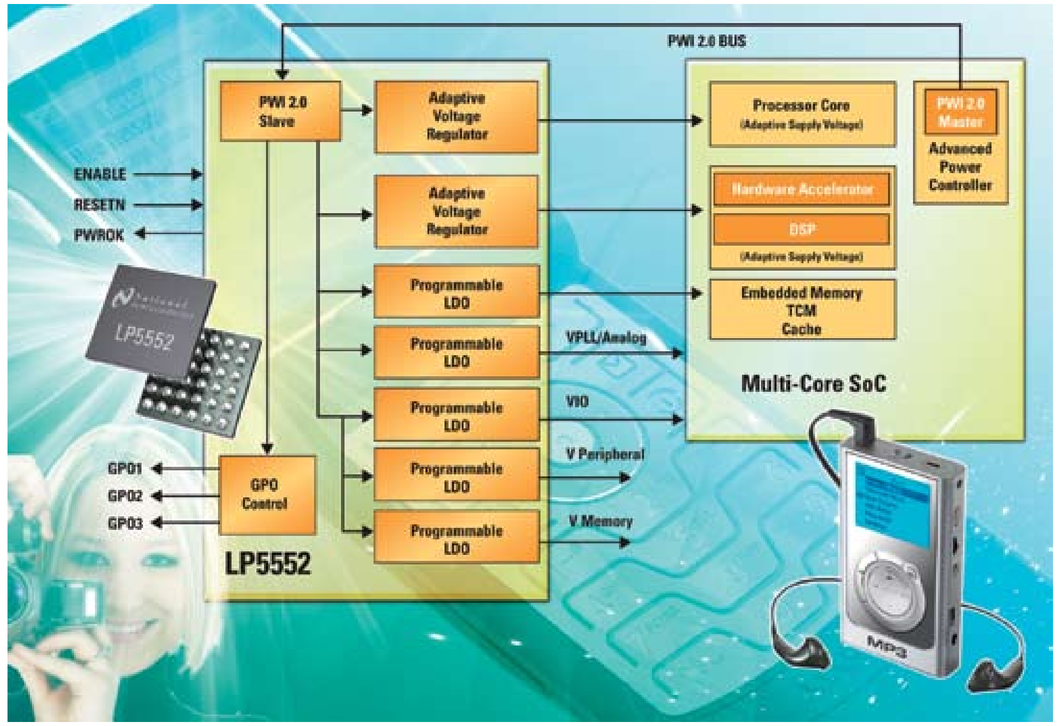


Figure 2: AVS Implementation with PWI 2.0.

The Adaptive Power Controller (APC) handles all aspects of voltage control, and has the ability to actively minimize the power consumption of the host processor. It is realized in synthesizable RTL and has the following functional components: (i) Hardware Performance Monitor (HPM), (ii) digital loop filter and (iii) PowerWise® Interface (PWI) master module. These elements work together to allow accurate voltage control from the external power supply.

The hardware performance monitor (HPM) and digital loop filter are used in AVS to measure the performance of the digital circuit for a given operating performance requirement. The measurement data from the HPM is processed in the digital loop filter and sent to the PWI master to output a voltage request to the power supply. The APC can also be used for DVS through a programmable voltage-vs.-frequency lookup table.

PWI is a simple and fast (up to 15MHz), two-pin serial interface specifically designed to meet the needs of AVS and DVS while offering extensive programming options for versatile applications. Two version of the PWI are available: PWI 1.0 and 2.0. PWI 1.0 supports a single master and a single scaling domain. This is ideal for simple processor designs with only one scaling voltage domain. PWI 2.0 supports up to two masters and 4 scaling domains for more complex systems. The advantage of multiple scaling domains is that the application can further optimize dynamic power loss by independently scaling different parts of the processor. For example the processor could have a core and a hardware accelerator that scale frequency and voltage independently. Both version of the PWI provide general power management control such as shutdown, sleep, wakeup, etc. In addition to the scaling domains, both the PWI also provide commands to set voltages for auxiliary supplies such as PLL, I/O, and memory.

Conclusion

Processor design for today's media centric mobile devices is challenging in many ways. More and more data intensive applications are being introduced as portable devices and the networks they connect to become faster and more capable. Achieving higher performance and integration requires lower process geometries and higher clock frequencies. In the wake of these trends, aggressive power management techniques have become increasingly necessary. Both leakage and dynamic power loss must be accounted for in order to successfully design an efficient system. Fortunately, an array of techniques can alleviate excessive power loss in both leakage and dynamic switching. Every application is different, but with the right use of techniques discussed here, both a high performance and low power processor design can be achieved.

For more information about PowerWise® Adaptive Voltage Scaling Technology, please visit www.national.com/analog/powerwise/avs_overview

www.national.com

Power Systems Design NORTH AMERICA

PSDNA Green Power ENERGY EFFICIENCY

White Goods

Energy Efficient White Goods Need Accurate Control

Surface-mount current transducers open up new applications

With the demand for better efficiency moving into the domestic market, manufacturers are now required to re-evaluate their products. No longer are these appliances simple in electrical design. Motor drives especially are required to run more efficiently and more effectively, avoiding wastage and vibration noise.

By Stéphane Rollier, Bernard Richard and David Jobling, LEM, Geneva, Switzerland

Traditional current transducers are unsuitable for the fast developing and changing markets such as domestic electrical products and air conditioning systems because they are too big and expensive. Smaller and lower-cost transducers are now making current measurement a reality in these vital everyday systems.

LEM, a market leader in providing innovative and high quality solutions for the measurement of, electrical parameters used in a broad range of applications in industrial, traction, energy and automotive markets, has developed the Minisens integrated current transducer. This industry-leading device combines all the necessary electronics with a Hall-effect sensor and magnetic concentrators in a single eight-pin, surface-mount package (Fig 1). Characteristics such as sensitivity and isolation can be varied by changing the design of the PCB layout.

The most common way to use Minisens is to locate it over a PCB track that is carrying the current to be measured. To optimise the function of the transducer, some simple rules must be applied to the track dimensions. By varying the PCB and track configuration, it is possible to measure currents ranging from 2 to 100 Amps.

One possible configuration places the IC directly over a single PCB track (Fig 2).

In this configuration, isolation is provided by the PCB and currents in the range from 2 to 20A can be measured.

Isolation can be improved by placing the transducer on the opposite side of the board, but still directly over the line of the track. The thickness of the board and the track itself will both affect the sensitivity. Sensitivity is also affected by the width of the track (Fig 3). It is important to note that sensitivity is greater for thinner tracks. However, the thinner the track, the quicker the temperature rises.

Figure1: LEM's Minisens in a tiny SM package.

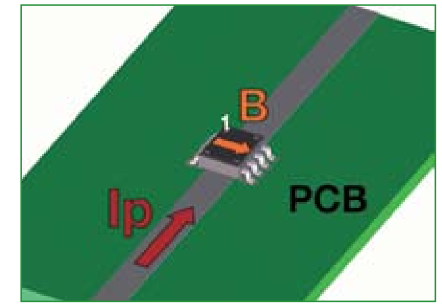


Figure 2: Typical PCB design with the track routed underneath the Minisens.

The maximum current that can be safely applied continuously is determined by the temperature rise of the track. The use of a track with varying width gives the best combination of sensitivity and track temperature rise. To maintain temperature levels, the width, thickness and shape of the track are very important.

For low currents (under 10A), it is advisable to make several turns with the primary track to increase the magnetic field generated by the primary current. As with a single track, it is better to have wider tracks around the Minisens than under it to reduce temperature rise (Figs 4 and 5).

For example, a four-turn design (Fig 5) underneath the Minisens on the opposite side of the PCB provides a high insulation configuration. Another way to increase the sensitivity is to use a narrower track.

The sensitivity can be increased further by other techniques, such as using a 'jumper' (wire) over the Minisens to create a loop with the PCB track, or multiple turns can be implemented in different PCB layers. Larger currents can be measured by positioning the transducer farther from the primary conductor.

Many Minisens parameters can be configured by the on-chip non-volatile memory. This can be used to adjust the transducer's gain, offset, polarity, temperature drift and gain algorithm.

Two outputs are available: one filtered, to limit the noise bandwidth, and one unfiltered which has a response time of less than 3μs, for current short-circuit or threshold detection.

Minisens operates from a +5V power supply. To reduce power consumption in sensitive applications, it can be switched to a standby mode by means of an external signal. It is manufactured in a standard CMOS process and assembled in a SO8-IC package.

The accuracy reached at +25°C by Minisens itself is determined by the following parameters:

- Sensitivity (V/T) error (+/-3%)
- Tolerance on the initial offset at no field (+/-10 mV)
- Non-linearity error (+/-1.5%).
- However, this does not represent the accuracy in the final application, where several other parameters that

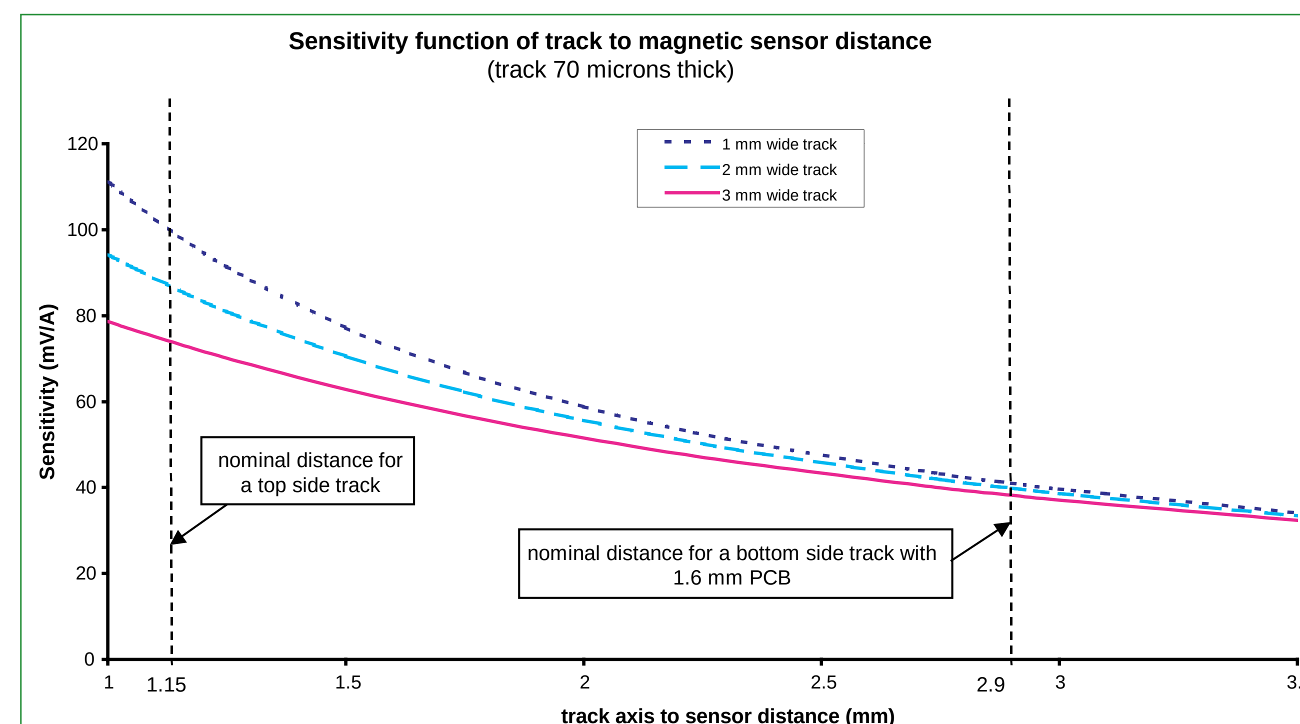
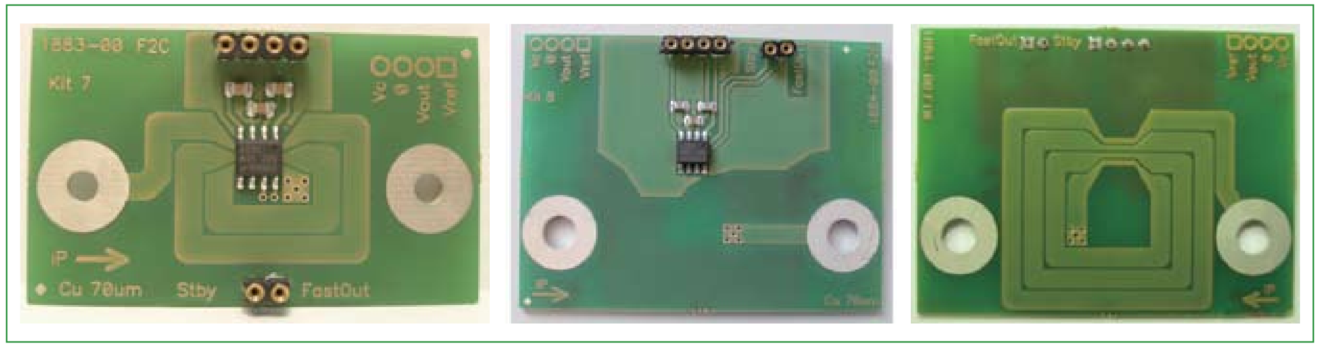


Figure 3: Sensitivity (mV/A) versus track width and distance between PCB track and the sensing elements.



Figures 4 and 5: Possible 'multi-turn' designs.

influence the accuracy must be taken into account, including:

- The distance and shape variations of the primary conductor vs. the IC as well as the IC placement error on the PCB (the mechanical design parameters),
- The adjacent perturbing (stray) fields.

The final sensitivity depends on mechanical design parameters. Each inaccuracy or change will lead to a change in the final sensitivity.

The parameters that are subject to change due to variations in industrial production include:

- solder joint thickness
- copper track thickness
- PCB thickness
- primary track width
- positioning of the IC along the Y axis
- rotation of the IC around the X and Z axes

These parameters must be closely controlled in the production process. Alternatively, in-circuit calibration of the Minisens can be used to avoid most of these errors. Two other parameters must be also be taken into account: sensitivity temperature drift at +/-300ppm/K and offset drift at +/-0.15mV/K.

By integrating all the necessary electronics and magnetics into such a small, easily mounted package, Minisens brings current sensing technology to many new applications, just at a time when it is needed most. The precise data provided by it enables power electronics to drive the motor more efficiently and with lower losses providing energy savings.

www.lem.com

Smart Energy Meters in Home Appliances

Help cut energy use

There are several strategies that can be put in place to reduce energy consumption in our homes. The most obvious is to develop more efficient appliances increasing the overall efficiency of the converters, motor drivers and control electronics. Most of the expertise developed for battery operated electronic devices can be transferred into power grid connected appliances.

By Cosimo Carriero, Senior Field Application Engineer, Analog Devices Inc

The next generation of appliances are being designed environmentally friendly to drastically reduce power consumption. In order to balance the higher costs associated with increased efficiency in some countries, governments are granting incentives to encourage people to buy these appliances.

But savings come also from smart energy use. Numerous studies show that simple awareness can produce savings of 20% or more. Given the opportunity to save money by curbing energy use and given the technology to take action to reduce it, consumers will take the action, with savings up to 50%. Monitoring is the critical first step in dealing with energy use in homes.

Smart Grid and Home Area Network

Monitoring of power consumption in homes brings to the concepts of Smart Grid and Home Area Network.

A Smart Grid is an electricity network that delivers electricity from suppliers to consumers using digital technology to save energy and cost. Use of robust two-way communications, advanced sensors, and distributed computing technology will improve the efficiency, reliability and safety of power delivery and use.

Smart grid features could expand energy efficiency beyond the grid into the home by coordinating low priority home devices such as water heaters so that their use of power takes advantage of the most desirable energy sources. Some of the benefits of such a modernized electricity network include the ability to reduce power consumption at the consumer side during peak hours.

Smart grid connected devices make

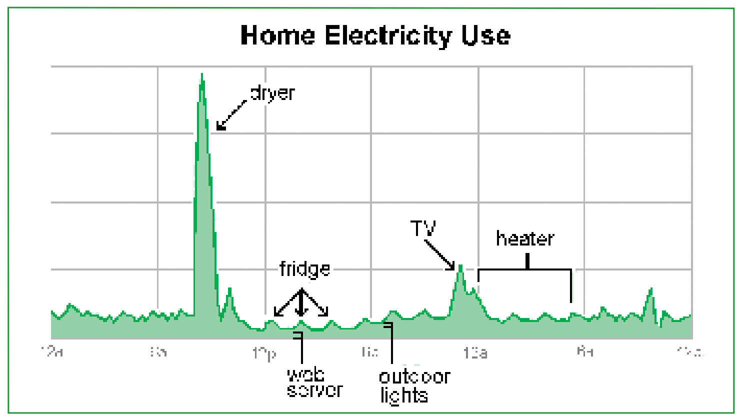


Figure 1. Home electricity use.

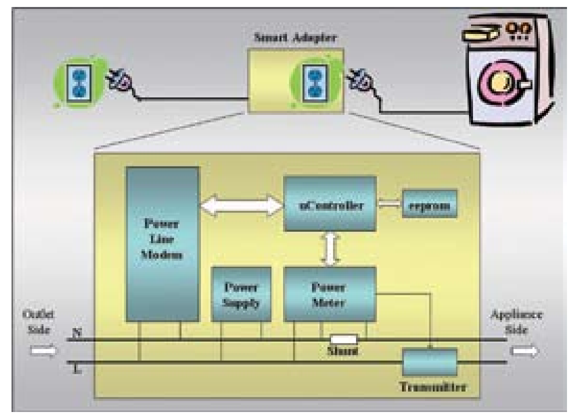


Figure 2. The smart adapter concept.

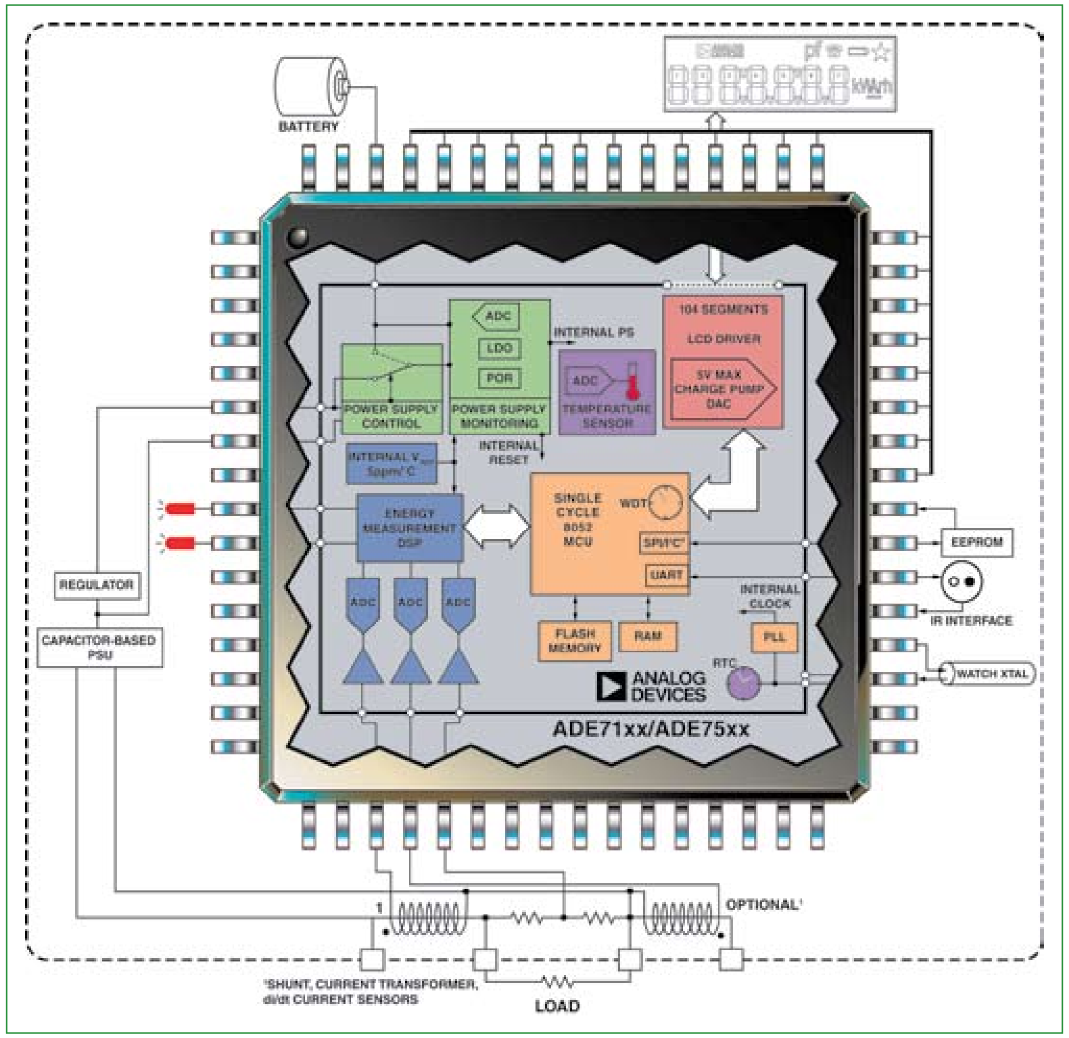


Figure 3. Energy meter system diagram.

up the Home Area Network (HAN). These devices empower consumers with real time control of their energy use communicating with the smart grid. Interoperability between products from different manufactures is one of the main challenges for an effective household appliances network.

Utilities, vendors and research institutes are working on the development of global standards. One remarkable initiative is the Smart Energy Profile developed by the ZigBee Alliance, Homeplug Powerline Alliance, EPRI and leading utilities.

The significance of the Smart Energy Profile is that consumers will be able to purchase thermostats, in-home displays and smart appliances from any retail channel and register these with their energy delivery company in order to participate in advanced demand response and energy conservation programs. The future smart energy home will consist of heterogeneous devices capable of communicating with the energy grid.

Another remarkable initiative is Google Power Meter, a product which will allow consumers to see their own energy usage information and help them improve their efficiency in a variety of ways. To get access to energy information homes need to be equipped with advanced energy meters, called smart meters. Smart meters need to be coupled with a strategy to provide customers with easy access to near real-time data on their energy usage.

Google PowerMeter, now in prototype, will receive information from utility, smart meters and energy management devices and provide anyone who signs up access to his home electricity consumption right on his iGoogle homepage. The graph in Figure 1 shows how someone could use this information to figure out how much energy is used by different household activities.

The Smart Appliance

GE has launched in the US a program to introduce a suite of smart energy enabled appliances. The appliances will be enabled to receive a signal from their local utility and will react based on the internal programming. Some operation may be delayed from occurring during peak energy usage hours enabling the utility to easily manage peak load conditions. On the other hand consumers will benefit from the dynamic pricing being notified of critical peak pricing on a display on their appliances letting them know when higher rates are in effect. Appliances will be programmed to avoid energy usage during that time but consumers may choose to override the program, giving them ultimate control.

In Europe white goods manufacturers like Indesit Company have been working for a long time on the smart appliance concept. Indesit introduced in 1995 Margherita Datalogic, the first electronic washing machine and in the following years invested a lot on networking on line services and smart products able to generate, transmit and share information.

Indesit, in cooperation with University of Parma (Italy), has developed a low cost power line communication for electrical appliances networking. The idea is shown in figure 2.

It is based on the concept of Smart Adapter, a device for connecting to a network any electrical appliance. The smart adapter embeds a communication node (based on any protocol) and a power meter and is located between an electrical appliance and its outlet. The communication node ensures HAN connection; the power meter analyses the absorbed electric current and generates useful information (functional, statistical, diagnostic and energy consumption) related to the appliance itself. The connection to the HAN is by Power Line Modem, but it could be any standard protocol, including ISM band RF wireless communication standard like the IEE 802.15.4 (ZigBee).

A point-to-point technique called Power Modulation is used by the appliance to communicate with the smart adapter and is based on the modulation of an internal load; this modulation is detected and decoded by the power meter [1]. The smart adapter has the big advantage of moving away from the white goods the costs of the communication node that is still too high for this market.

Overview of Energy Measurement ICs ADE71xx/ADE75xx family

With more than 225 million energy meters using ADI's technology deployed worldwide, Analog Devices has delivered more energy measurement solutions than any other semiconductor company. The ADI Energy Measurement ICs combine industry-leading data conversion technology with a fixed function DSP to perform the calculations essential to electronic energy metering. Grid current and voltage are measured by means of dedicated analog to digital converters and analog front end electronics. Special care is devoted to the current channel, due to the very high dynamic range; a high resolution sigma-delta converter is combined with a programmable gain amplifier (PGA) in order to achieve high accuracy over a dynamic range of 1000:1. Moreover the devices are able to interface several current sensors; simple low cost shunts, current transformers and di/dt sensors like the Rogowski Coils.

The ICs can achieve four quadrant active, reactive and apparent power and energy measurement exceeding the main standards requirements like IEC 62053-21, IEC 62053-22, IEC 62053-23, EN50470-3 Class A, Class B and Class C, ANSI C12-16.

The wide bandwidth (14kHz) allows fundamental and harmonic measurement.

Also instantaneous and rms values of current and voltage are available and the meter can perform power line quality verification, detecting voltage sag, peak and zero crossing and measuring period/frequency.

Part Number	Antitamper	W+VA+rms	VAR	di/dt	5V LCD	RTC	Flash (kB)	Package
ADE7166	Yes	Yes	No	No	Yes	Yes	8/16	64-lead LQFP
ADE7169	Yes	Yes	Yes	Yes	Yes	Yes	16	64-lead LQFP
ADE7566	No	Yes	No	No	Yes	Yes	8/16	64-lead LQFP
ADE7569	No	Yes	Yes	Yes	Yes	Yes	16	64-lead LQFP

Table 1. Selection guide

Figure 3 shows the Energy Meter System Diagram featuring the ADE71xx, and ADE75xx product family that builds on Analog Devices' 10 years of experience in energy measurement to provide the best analog to digital converters combined with the advanced digital signal processing required to build an accurate, robust and fully featured energy meter with LCD Display.

Two analog inputs allow line and neutral current measurement for tampering protection. Another analog differential input is for voltage. The three analog inputs have dedicated 24 bits Σ-Δ ADCs. Each Analog input channel has one PGA with possible gain selection of 1, 2, 4, 8 and 16.

Other features are the embedded Battery Management which enables low power consumption in battery mode and optimal power supply management when line voltage is lost, and the low power Real Time Clock with nominal and temperature dependent crystal frequency compensation.

Table 1 is the single chip solution selection guide.

Conclusion

Smart Grids, Advanced Metering Infrastructures, Smart household appliances are seen as key potential technologies to improve energy efficiency, ultimately helping in the goal to reduce carbon emissions. Analog Devices is committed to providing innovative and energy efficient devices to enable this market and to doing its part in improving energy efficiency and promoting energy conservation.

www.analog.com

Cooling White Goods

Maximizing performance and efficiency with AC and DC fans

When it comes to household appliances, designing products with cooling fans is becoming more than just an issue of cooling. From refrigeration units to convection ovens to venting ducts over stove ranges, the functions served by fans and fan trays not only include cooling and circulating air, but can include increased functionality, maximizing energy efficiency, simplifying BOMs and decreasing production costs.

By Bob Knight, President, Knight Electronics, Orion Fans

In white goods applications, AC and DC fans must be capable of operating within extreme temperature ranges, from very cold freezers and refrigerators to extremely hot convection ovens. Different materials and designs are available to achieve the necessary performance and reliability across a variety of applications. For example, low-noise fans in refrigeration units, coolers and range hoods are being used to perform different functions while reducing the amount of noise normally present in older product designs. AC fans constructed to Class B and Class F UL insulation standards are being specified for higher temperature applications ranging from 130ºC - 155°C.

Low-noise fans are often selected for refrigeration and wine cooler applications to prevent condensation yet not contribute significantly to audible noise levels. Condensation can build up on the inside of these units, forming not only on the glass, but within the enclosure itself. The use of an internal fan creates just enough air movement to prevent condensation. The same situation exists in store refrigeration units. The appearance of condensation in the enclosed case or on the glass can imply food is not properly frozen. Low-noise fans are employed in these applications not only to prevent condensation build-up, but to minimize the noise level and reduce power consumption. These types of fans are available in both AC and DC configurations.

Another way fans can be used to maximize performance is through the use of high-temperature construction. A high temperature fan with higher insulation Class B or F construction often eliminates or reduces premature failures caused by inadequate airflow in hot areas. AC fans are often utilized in high temperature applications such as oven control assemblies and forced air convection units. The temperature of Class B insulation is specified at 130°C, while the temperature of Class F insulation is specified to 155°C. These maximum temperatures at which the plastic and insulation materials are rated includes the normal temperature rise of the fan, so care must be taken to ensure these ratings are not exceeded when designs are contemplated.

Orion's fans are capable of employing high insulation Class F materials for use in high temperature oven applications.

Components exposed to high heat are susceptible to failure over time, with fans being no exception. The classification of the insulation system is based on the lowest rated component in the system, or in this, case the fan. The materials and parts specified in the construction that affect the insulation class include the motor winding, the wire and the insulation on the wires, the enamel coating on the magnet wire, as well as the visible parts of the fan or fan tray such as the frame and impeller.

Special Report – White Goods

Increasing Functionality and Maximizing Energy Efficiency

The functionality of fans has also increased dramatically, to the point where product manufacturers are now utilizing fans with "smart" controls. Such controls include tachometer output, locked rotor alarm, pulse width modulation (PWM) input, and thermal and constant speed controls. These special functions provide end users with intelligent control options and feedback that increase functionality and optimize fan performance, while also minimizing energy consumption. With controls like these, manufacturers are able to better monitor airflow and operating temperature, ensuring the fans are operating properly and at optimal conditions.

AC and DC smart control fans ensure optimal operating conditions while maximizing energy efficiency in microwave and oven applications.

Tachometer output, for example, provides design engineers with an accurate means of monitoring and reporting a fan's rotational speed, as well as indicating if the fan's speed falls below a certain RPM. This can be used as a lower cost alarm or indicator by monitoring the fan speed to determine relative temperature. Typically, the tachometer output option is available as either a 5V TTL signal, or as an "open collector" signal.

Fans and fan trays equipped with locked-rotor alarms indicate whether a fan is running or has stopped by transmitting a high or low output signal, minimizing fan downtime and averting an overheating situation. A PWM option also allows users to digitally control the speed of the fan through an existing bus system or PLC.

Fans or fan trays with thermal speed control employ a thermistor-controlled circuit that increases fan speed only when the temperature rises above a determined set-point. This reduces overall energy consumption by lowering fan speed when temperatures within the enclosure are below the set-point. Thermistor control circuits can be mounted directly in the fan hub or remotely mounted via a lead wire, and can be positioned anywhere within the enclosure, giving design engineers the flexibility to regulate fan speed based on ambient temperature in a specific area. The constant speed function senses variable input voltage, which causes variations in power output, and maintains the fan's constant speed regardless of input voltage fluctuations.

Fully assembled and tested fan trays provide appliance manufacturers with additional benefits by lowering supply chain costs, reducing lead times on materials, reducing the number of SKUs, reducing parts inventory, improving quality and lowering overall production costs. Not only does the tray provide a complete solution, it reduces part numbers and stocked inventory of cooling parts from tens to one. Tray manufacturers like Orion Fans also assemble, test and ship when needed, reducing lengthy lead times.

Conclusion

Today, AC and DC fans have more demands placed on them than simply cooling and controlling airflow in white good applications. With an extensive number of capabilities now available, including higher temperature ranges, speed controls and tachometer output signals, to name a few, manufacturers of white goods are using fans as a means of providing increased functionality, maximizing energy efficiency and decreasing end unit cost.

www.orionfans.com

Taking Control in White Goods

More efficient electric motor control solutions

The international market for electric motors is vast and although the automotive and industrial sectors receive a large part of the attention, consumer devices and in particular white goods are rapidly becoming key application areas.

By Vincent Mignard, Segment Marketing Engineer, Renesas Technology Europe

This sector represents a significantly different market from industrial control or automotive, with its own unique demands. It is characterised partly by the amount of power the motors need to deliver, which subsequently determines the type of motors used and the way they are controlled. Because of their low cost and simple control requirements, DC motors have for a long time dominated in this cost sensitive market. However, with renewed emphasis on power efficiency, as well as overall safety, more sophisticated motors are penetrating the consumer/white goods market. In fact, their use can create significant differentiation for suppliers, as they are typically smaller, quieter and more efficient than DC variants.

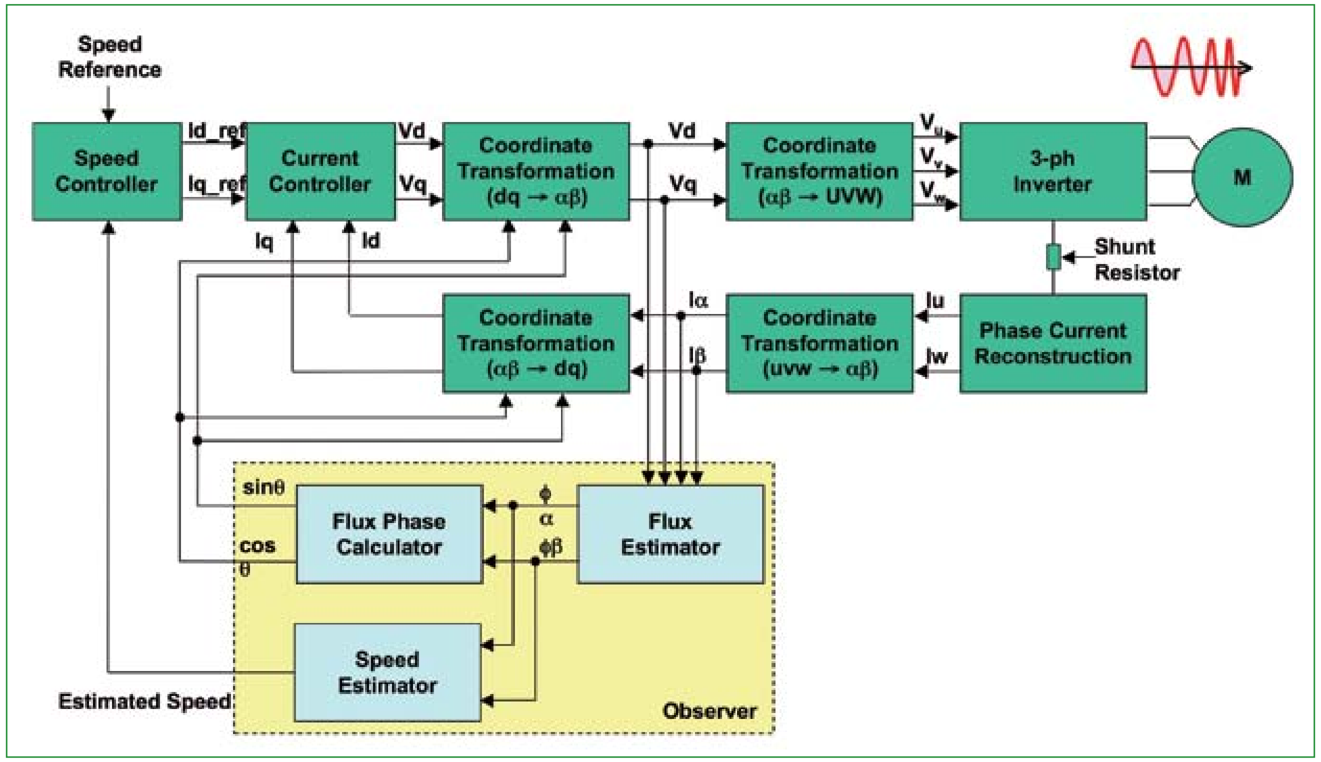


Figure1: Block diagram of sensorless field-oriented motor control.

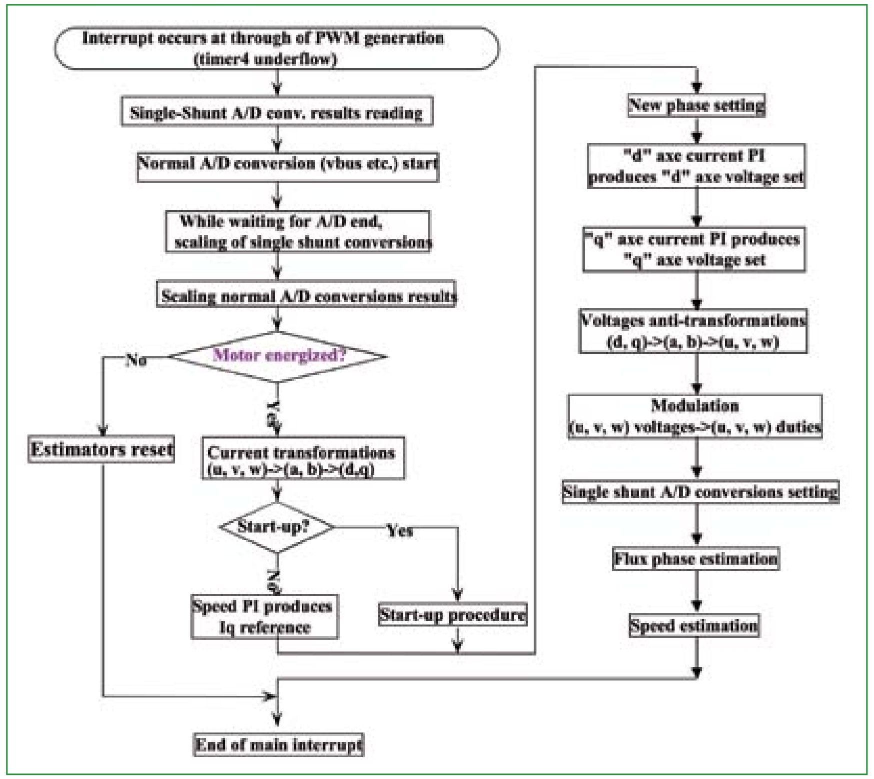


Figure2: Software sequences for a field-oriented motor control.

As a result, the motor of choice in this application area is now more likely to be a 3-phase brushless DC motor (BLDC) or induction motor. A BLDC can be as much as four times smaller than a DC motor, which in an appliance such as a washing machine or dishwasher can represent a massive space saving and enable much smaller appliances to be developed. In addition, the motor itself is much lighter so the torque to weight ratio is higher. Another advantage to using a brushless motor is that it does not generate any electrical noise.

Smaller, faster, cheaper

These applications can be classed as 'low power' applications; that is, the motors must deliver 1kW or less of power, and they could all benefit from the introduction of BLDC or induction motors. Their power requirement alone sets them apart from the industrial automation market where, by contrast, often multiple motors are needed, delivering far in excess of 1kW each. In industrial applications, the control systems will often need to communicate to each other in order to maintain safe and efficient operation, leading to complex and highly optimised control solutions.

Common to all electric motors, including those targeting the consumer sector or white goods applications, is a requirement for an external control system. While that control system may not be as complex as one found in an industrial automation application, the new class of low power motor, nevertheless, does require more sophisticated control solutions compared to those used for DC motors. In turn, this has created demand for a range of low power, low cost motor control solutions that meet the technical and commercial demands of the consumer and white goods markets.

Just as with most functions within embedded system design, choices exist; for a single, low power motor control system, the choice is largely between using a microcontroller (MCU) or a digital signal processor (DSP).

In recent years, both MCU and DSP manufacturers have identified the need for control solutions that meet the needs of low power motor control for consumer products and white goods. This has given rise to variants that either offer greater integration of ancillary functions, such as amplifiers or other mixed signal devices, or solutions that offer less integration of peripherals but with concentrated efforts on 'tuning' their core architecture for control functions. The latter is particularly relevant for DSP variants, now targeting motor control applications through the commonly termed Digital Signal Controller (DSC).

For the most part, either an MCU or a DSP/DSC can be used to control the relatively more complex BLDC or induction motors, particularly in low power applications where, typically, only one motor is present. The choice of which to use can be dependent on many parameters.

For some applications, OEMs standardise on partitioning the control function from other system activities, in which case the DSP/DSC is ideal. Fundamentally, the their architecture was originally designed to perform complex algorithms which are largely loop based; they perform the same tightly constructed calculations repeatedly, very efficiently (in terms of processor cycles). For control functions, DSPs are less applicable and it is for this reason that manufacturers have developed the DSC variants.

This type of control system also needs to be able to respond, in real-time, to external events that may impact the motor's operation. Typically this could be a change in the motor's load, which must be compensated for as quickly as possible in order for the device to continue operating at maximum efficiency and within safety tolerances.

For this reason, the integration of control functions and the ability to

Special Report – White Goods

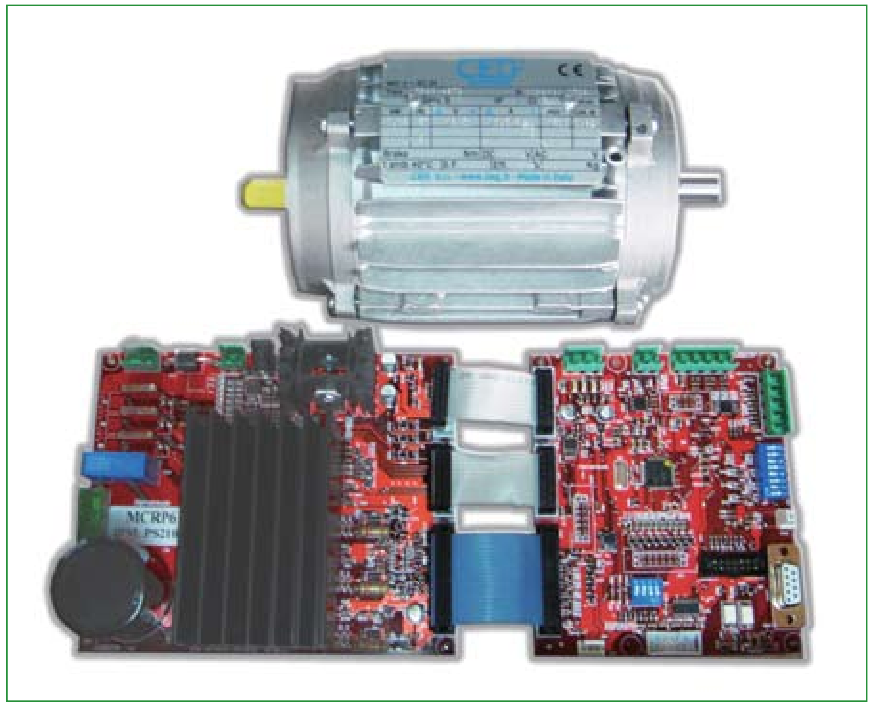


Figure3: Example of a MCU-based motor control reference platform.

adapt the motor drive, in real-time and in response to external events, becomes more important. This is particularly relevant where commercial pressures demand that a single processing element provides both motor control and general housekeeping, typical of low power applications in the consumer space or white goods sector.

No soft option

In this regard, the continued development of microcontroller architectures and, more importantly, the drive towards faster silicon platforms on which to build them, has largely delivered the performance needed to obtain real-time control. However, fundamental to these platforms, and common between both MCUs and DSP/DSC architectures, is the role software plays in providing that control.

Developing the motor control algorithm, in software, is a crucial stage in creating an efficient motor control solution. The ease with which that software can be developed however is not necessarily common across platforms. For the vast majority of applications, the software will be developed in C/C++, the 'de facto' programming language for embedded systems. When targeting an MCU, it is far easier to develop, validate and port a control algorithm written in C between platforms; for DSPs it is more common for the tight loops to be coded at a lower level and much more dependent on the underlying hardware architecture, which not only makes porting them more difficult, but actually presents a greater challenge when tuning the software.

Moving to BLDC/induction motors provides the OEM with an extended roadmap for their product and a chance to differentiate by simply replacing the motor with the latest version, which may offer a greater power/weight ratio or better efficiency. However, taking advantage of that opportunity requires a certain amount of engineering work, predominantly in retuning the control algorithm for a different mechanical arrangement. The speed and efficiency with which an OEM can make that upgrade may well be governed by how easily they can adjust the software algorithm driving the motor. With an MCU approach, where the software is written in C/C++, these adjustments can be achieved easily, the same isn't necessarily true for a DSP/DSC based control system.

Manufacturers are also looking to take full advantage of the benefits a BLDC offers in terms of exactly how it is controlled. Increasingly, this means moving away from simple control algorithms based on the voltage and frequency applied to the motor, towards using a sensorless vector control approach. This makes the software more complex and, arguably, means it is even more important to retain accessibility to the MCU software by standardising on C/C++, as opposed to being forced to develop the algorithm at a lower level of abstraction.

Renesas provides a series of MCU-based motor control reference platforms (MCRP04/5/6).

It is very ease to tune the motor control by using a connected PC and GUI application. A simple header file allows you to adapt the operating parameters, such as start-up procedure, torque & speed range, and acceleration/deceleration ramps, to suit the application requirements. Tools also allow the fine-tuning of the motor control algorithm; considered an important aspect of any such MCU-based application.

The use of more complex but more efficient and cost effective electric motors in the consumer sector and, in particular, white goods is a trend that is set to continue. This will present OEMs with the opportunity to extend their products' life cycle, deliver greater differentiation and provide 'greener' solutions to the customers. However, it will also present them with some important decisions, which will require careful consideration before standardising on the solution that best meets their requirements.

www.renesas.eu

Economic and Ecological Energy Prevails

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

Will the momentum of 'going green' be maintained in the financial downturn? This surely will be the 'litmus test' for commitment. During my recent visit to APEC in Washington DC, I saw that although the financial crisis is certainly real and painful, the commitment to the development of higher efficiency products and systems, many utilizing digital power techniques, in our industry remained reassuringly strong.

Reuters recently reported that the credit crunch is making an impact on smaller European green energy projects, but cash-rich utilities and the larger lending institutions will continue to get deals done, green power experts say. The European Wind Energy Association (EWEA) attributes the main problem for the smaller developers to the short-term freeze on lending, adding that the credit crunch could lead to consolidation in the sector.

A ring of giant wind turbines connected by underwater cables is a central part of the European Commission's plan for bolstering energy security and curbing unreliable imports of fossil fuels. The European Council recently endorsed the European Commission's Strategic Energy Review (SER), which contained its commitment for a blueprint for a North Sea grid. The Council described work on this offshore grid as a priority action. EWEA considers the

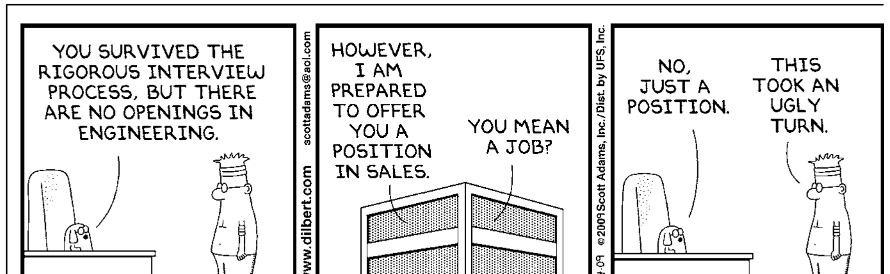
development of offshore wind and its integration into the electricity network key to achieving the EU's 20% renewables targets by 2020.

There is currently 1,471 MW of installed offshore wind capacity, all of it in European waters. There is enough wind blowing over the seas to supply all of our power, yet without an offshore grid and increased interconnector capacity to transport power to consumers, this vast potential will remain untapped.

EWEA Chief Executive Christian Kjaer said. "In its conclusions, Council confirms the EU's need to turn to an indigenous energy supply and to 'promote renewables and tackle barriers to energy from renewable sources'. These actions are essential for increasing our use of renewables and so boosting the EU's energy security, reducing our fuel imports, avoiding CO_2 emissions and carbon costs, creating jobs and putting money to work at home rather than spending it on importing fuel from unstable regions abroad."

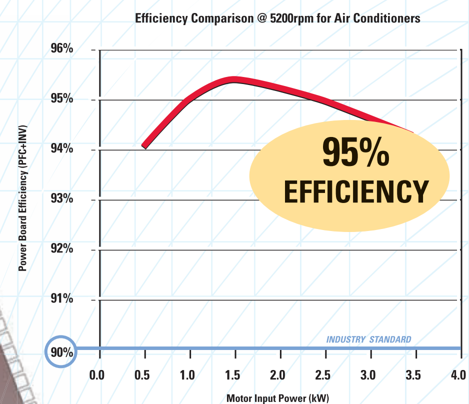
In its conclusions, the Council also proposed that the Commission prepare a Sustainable Energy Financing Initiative with the European Investment Bank to mobilise large-scale funding from capital markets for investments in renewable energies.

www.powersystemsdesign.com/greenpage.htm



Simple, Sensor-Free Motor Control For Air Conditioning

Gain Efficiency, Remove Design Risk, Accelerate Time-To-Market



DIGITAL

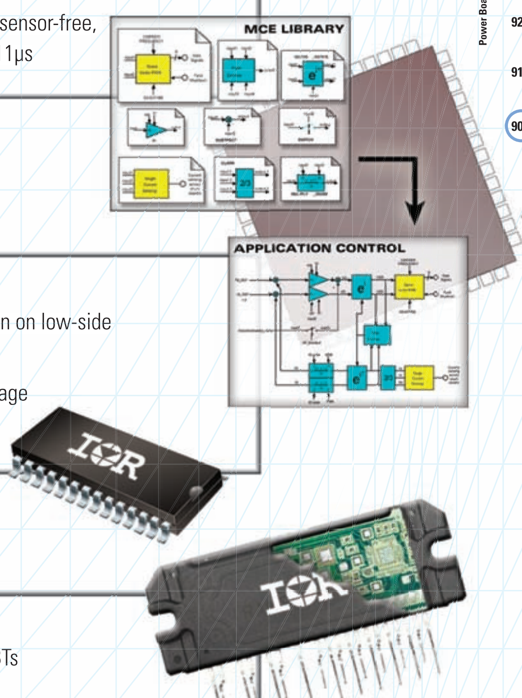
- Monolithic mixed mode controller with integrated 8051 core
- Enables simultaneous control of compressor, fan and PFC
- No coding, simple graphic block editing
- Motion Control Engine™ executes sensor-free, field oriented control algorithm in 11µs

ANALOG

- Enables single DC line configuration on low-side IGBTs for current sensing
- Integrated over-current, under-voltage and cross-conduction protection

POWER

- Efficient, depletion-stop trench IGBTs
- Discrete and IPM packages



From the front panel and power entry to the motor terminals, *iMOTION* brings powerful digital, analog and power silicon together with algorithms, development software and design tools.

With *iMOTION*, you can design a system that:

- Turns a motor for evaluation in days instead of weeks
- Performs more efficiently without added cost
- Easily accepts your proprietary code
- Helps you meet, if not beat, aggressive design schedules

Select *iMOTION* for industry-leading motor control.

LEAD FREE

for more information call 1.800.981.8699 or visit us at www.irf.com/motion

Motion Control Engine and IR's iMotion (ai mo shan), representing the intelligent motion control Motion Control Engine and Analog Signal Engine, are trademarks of International Rectifier

International IOR Rectifier

THE POWER MANAGEMENT LEADER