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PSDE Green Power ENERGY EFFICIENCY

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PSDE Green Power ENERGY EFFICIENCY

Communication is Key

Welcome to this issue of PSDE.
It's been quite a refreshing month on the industry reporting side. I was invited to two announcement events from companies actually doing rather well: Linear Technology and Dialog Semiconductor. Neither complained bitterly about 'world-economies' and both were forthright in their assertion that it was their engineering and support staff that helped to carry them through. The financial crisis has been weathered by these two companies that actually are real 'investors in people' and by this I mean that it is not just a plaque on the HR department's wall, but a determined effort to create an environment where these people can give of their best. This is refreshing stuff indeed from companies that are actually good to work for.

After a projected decline of over 14% in 2009, the world market for power management & driver ICs is forecast to recover strongly in 2010 and then average around 10% growth each year over the next 5 years. This is according to the latest analysis from IMS Research (www.imsresearch.com). The fastest growing markets of the fifteen analyzed are predicted to be those for Power-over-Ethernet (PoE) ICs, integrated power stages (including both non-standard and Intel standard DrMOS), and Power Factor Correction (PFC) ICs.

In this issue we feature the theme of 'Powering Communications' an area of high growth prospects for the power industry. We have also launched a new online bulletin for news of special note called 'PowerSurge' to get the latest product and industry news to you in real-time. Send me your 'latest-and-greatest' and it could get exposure to over 60,000 of your design colleagues and management in PSD's global power audiences in Europe, China and North America.

More good news for communications: Growth in demand for digital power semiconductors will be driven by high-end servers as well as datacom and telecom equipment. By the year 2011, growth is expected to pick up in the lower-end computer markets such as notebook PCs and graphic cards.

Suppliers of digital power semiconductors have aligned behind Digital Controllers of Power (DCPs), setting the stage for a nearly sevenfold rise in revenue by 2013, according to iSuppli Corp. Global sales of digital power semiconductors are set to increase to $821 million in 2013, up from $127 million in 2008. The digital power semiconductor market consists of Digital Power Managers (DPMs) and DCPs. While DPMs currently dominate the market, DCPs will experience more rapid growth in the coming years. Global revenue from shipments of DCPs is set to rise to $236 million in 2013, up from just $16 million in 2008.

Hopefully we'll now start to turn the corner and can all make more positive plans for the future. Enjoy the issue, let me have your valuable feedback and check out our fun-site, Dilbert at the back of the magazine.

All the best!

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

High Reliability for Networking, Telecom, Servers and Data Storage

Maxim has launched the MAX16065/MAX16066; flash configurable sequencers/monitors that simplify power management and help conserve power consumption. The devices eliminate the need for external current-sense amplifiers to monitor current and thus save both space and cost. Each device can be programmed for monitoring and sequencing system voltages. The MAX16065 manages up to twelve supply voltages simultaneously, and the MAX16066 manages up to eight supply voltages.

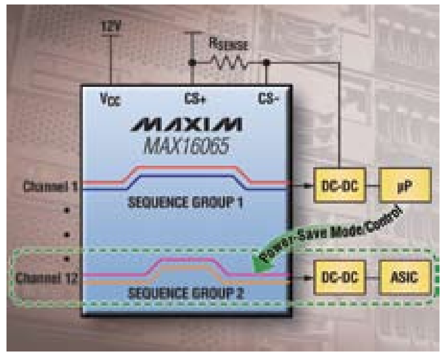
These sequencers/monitors integrate highly ±2.5% accurate current monitoring and group sequencing to monitor and conserve power. They also feature an analog-to-digital converter (ADC) and nonvolatile fault registers to store and read back fault data. An easy-to-use graphical configuration tool eliminates the need for tedious, time-consuming programming of complex devices like programmable logic devices (CPLDs) and microprocessors.

The MAX16065/MAX16066 provide ±1% accurate voltage monitoring and sequencing for complex systems where high reliability is critical. Networking, telecom, servers, and data storage are typical applications.

Reduced costs

Many systems require the current and voltage to be monitored continuously. Traditional sequencers/monitors used external current-sense amplifiers for the task. Those design configurations could become very complex and costly as the number of external amplifiers increased.

With an integrated, dedicated current monitor, the MAX16065/MAX16066 eliminate the need for any external current-sense amplifiers. As an additional benefit, when two inputs are configured as a differential pair, the devices can



monitor both the current in the power supply rail and the voltage of the power supply rail simultaneously.

By eliminating the need for external current-sense amplifiers, the MAX16065/MAX16066 add flexibility, simplify designs, save board space, and reduce costs.

Conserving power

There are many systems in the field today which require a set of functions to be enabled at all times. Lacking adequate flexibility for an application or offering limited programmability, those systems do little to manage power consumption efficiently.

To manage power consumption effectively, the MAX16065/MAX16066 offer a group-sequencing feature, which lets the designer customize and enable different application functions at different times. System functions can be programmed to operate while other functions are disabled. Activating selected functions at programmed intervals and turning off/ disabling a secondary set of functions allows the designer to manage power intelligently. The result will be a significant savings in power consumption and a lower carbon footprint for the board.

Increased reliability

When a system has a fault, a microcontroller may have a problem writing the status to external memory. However, the MAX16065/MAX16066 write to fault registers when a fault condition occurs and the system shuts down. The MAX16065/MAX16066 will perform a block write into nonvolatile flash memory. These fault registers provide a useful, higher level of long-term system reliability.

With these fault registers, customers can either save information about a monitored input that caused the problem, or write all of the measured values into flash. Users can then read back fault conditions to help debug design. If a system or board is returned to the factory, the manufacturer will now have useful fault data to analyze and determine what caused the failure.

Easy graphical configuration tool

Most of the power-management ICs for sequencing and monitoring systems require many hours to program. That is not the case with the MAX16065/MAX16066. These devices offer an easy-to-use graphical configuration tool which will save valuable engineering time. The tool will help to quickly generate data to analyze fault data or test different configurations with an I^2C or JTAG interface.

The MAX16065/MAX16066 have a wide 2.8V to 14V operating voltage range, which allows operation directly from an intermediate bus voltage. The devices are fully specified over the -40°C to +85°C extended temperature range. The MAX16065 is available in a 48-pin, 7mm x 7mm TQFN package; the MAX16066 is available in a 40-pin, 6mm x 6mm TQFN package. Samples are now available.

For more information visit: http://www.maxim-ic.com/Monitors.

www.maxim-ic.com

Telecom Power Drives Innovation

By Patrick Le Fèvre, Marketing Director, Ericsson Power Modules

From its early beginnings up to the present, the telecommunication industry has been innovative in terms of powering systems and applications, and an originator of several major technical evolutions - if not revolutions - such as distributed power architecture, high efficiency – high power density bricks, digital power control and management, and new ways to power sites while constantly reducing the level of CO_2 emissions.

For most of us telecommunications are part of daily life. However, this is not the case for a large percentage of the earth's population. Making it possible for them to access such technology will contribute to local development and reduce the digital divide, but simultaneously, it presents a real challenge to power engineers to secure sustainable sources of energy where, very often, they are simply not available.

Powering telecom for all - everywhere

How to power radio base stations in the middle of deserts, on top of mountains, in the middle of the rain forest or at any remote place where the power grid doesn't exist? How to charge mobile phones there and how to make it possible for a child living in those places to receive the same school programs as those living in towns? These are some of the challenges that the telecom industry has to address and generating sustainable sources of energy that will guarantee systems operate is a technical challenge indeed.

Alternative sources of energy such as solar, wind, bio-fuel, local hydroelectric generator and others have to be adjusted to their environment and optimized to deliver the highest available energy at any time of the operation whatever weather conditions and traffic demand.

For example a radio base station in the middle of Mongolia will benefit from combined sun and wind power when in India, bio-fuel generated from Jatropha oil can be used in diesel generators and in high sun ratio conditions, power generated from solar panels might be the most relevant technology.

Optimizing local sources of energy to power telecommunication in remote areas has driven innovations. The recent launch of a trial project by Ericsson and Telecom Italia of a radio base station with integrated solar panel (Eco Smart) is an interesting example of innovation to power remote telecom systems. The project perfectly illustrates the innovative aspect of powering telecom sites. In a novel approach, flexible solar panels are wrapped in a three-quarter circles around the tower, capturing the highest possible level of photons while located in a secure place preventing 'ground damage'. This type of development will immediately benefit other sites, reflecting the high level of research that the telecom industry invests in renewable energies.

Managing Energy for sustainability

Once power is generated and supplied from the local grid, the job for the power engineer is not finished, and how such energy is used within a telecom system is the next step on the 'Do List'. The telecommunications industry has always improved the usage of energy to give longer battery lifetime, lower power consumption - with the direct effect of reducing the level of CO_2 emissions per user, higher systems' reliability and many other benefits.

The range of possibilities ranges from the simple shutdown of a function on a single board to extended energy management including dynamic bus voltage (the bus voltage adjusted to reduce power losses to the lowest extend) and many other applications to other parts of the systems such as power amplifiers.

Powering telecommunications for all has been driven by power innovations and despite huge progress made over the last 50 years I would like to propose that we are at the early beginnings of a new power era, reducing CO_2 emissions while contributing to create a sustainable environment for future generations. To close, I refer to a sentence often used by Antoine de Saint-Exupery (1900 -1944), who said: "We have not inherited the earth from our ancestors; we borrow it from our children."

www.ericsson.com

www.ericsson.mobi

MarketWatch

The Communication Industry's Role in Reducing (or otherwise) Greenhouse Emissions

By Alex Green, Senior Research Director – Communications Segment, IMS Research

As world leaders prepare to meet in Copenhagen to decide on how to tackle global warming once Kyoto expires, the question of what part the communication industry will play arises. Inevitably a share of the targets will be passed on to the industry and IMS has attempted to examine the impact in a recent report looking at "The Green Last Mile".

One area examined was base stations. The number of base stations installed is forecast to approach ten million by 2014, each one on average having a similar carbon footprint per annum to that of a couple of mid-sized houses. So the emissions generated worldwide are similar to those from all residences in a medium sized country - a statistic that brings into focus just how influential the industry can be in addressing the wider green agenda.

Two approaches are being followed to try to reduce the base station carbon footprint. One is to reduce power consumption, the other is to adopt green power solutions. In terms of the ways that companies are looking to reduce the power consumption, a range base station components & functions are being examined. Initiatives include the use of PA envelope tracking, Doherty PAs, remote radio heads, fibre feeder cables, wider equipment temperature tolerances and dynamic TRX/PA activation/deactivation. Ironically, the

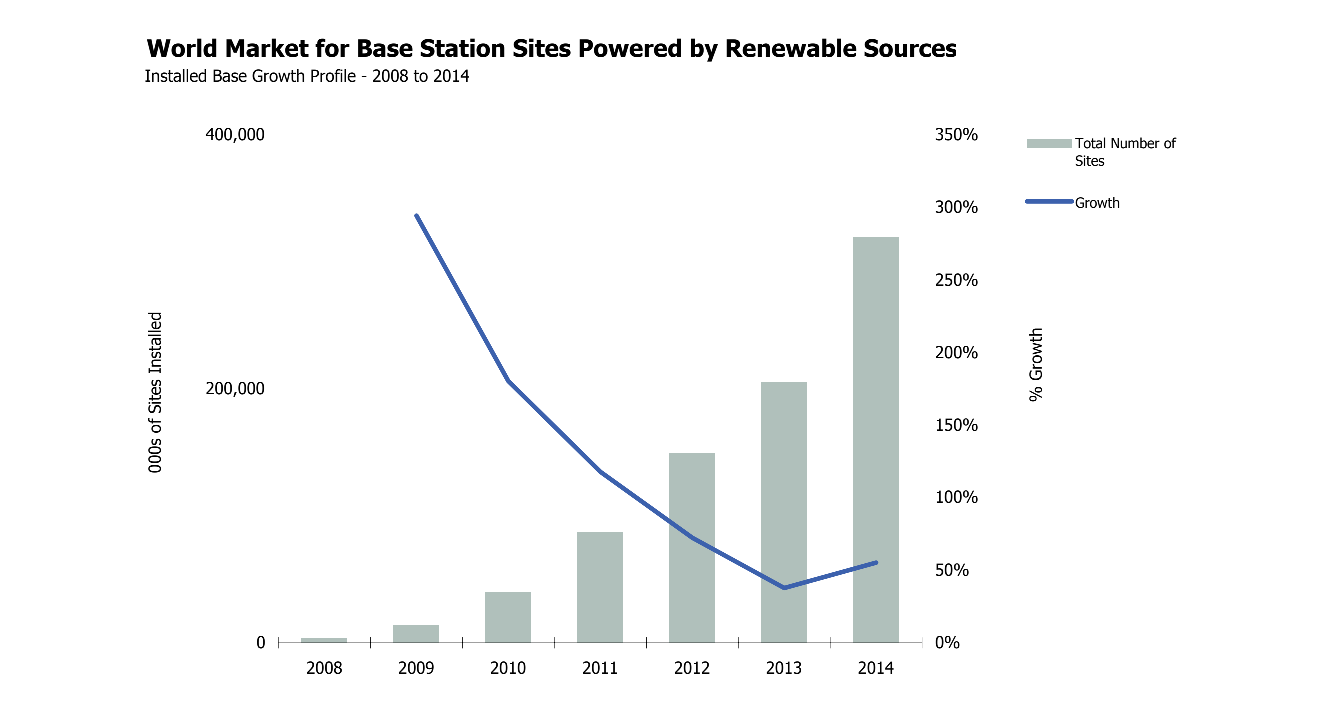
green agenda will not necessarily be the main driver for change here. Just as important are the potential operating expense savings that can be made when a network consumes less power. The result of all of these initiatives is that in five years time average site power consumption will be considerably lower than now.

The use of alternative green solutions to power sites is also not only being driven by the green agenda, but the need for base stations in remote areas where there is no access to the electricity grid. Demand for such sites is projected to drive the number of green base stations installed to over 300,000 by 2014, nearly all of which will be in developing countries where grid access is limited.

As well as base stations, the industry is also looking to reduce the energy consumption of the fixed comms sector with initiatives such as the EU Code of Conduct (CoC) on communication equipment. However, targets being set around guidelines such as the CoC may not always have the overall affect of reducing net power consumption. For example an increasing proportion of broadband CPE sold over the next five years is forecast to meet the EU CoC targets. However, at the same time the average power consumption of broadband CPE will increase!

The reason why relates to the way the targets are set. The target for an individual broadband device is based on the device functionality. So the target for a simple standalone modem is much lower than that for a residential gateway. IMS Research forecasts that like-for-like, an increasing proportion of devices will meet these targets. However, the market is forecast to change a lot in terms of the types of devices sold. A greater share will consist of devices with DECT, MIMO 802.11n, VoIP or femtocell functionality, for example. With each addition the CoC target can be increased - to the point that the added functionality will outweigh improvements in energy efficiency.

The result being that the carbon



footprint of the broadband CPE market will increase over time while the industry will "pat itself on the back" as more of the devices sold will comply with the CoC targets. OK, compared to doing nothing, emissions would be less, but in reality overall emissions will increase! Results such as this will certainly not help us achieve any targets that come out of the December's global summit.

www.imsresearch.com

Choosing the Inductor for a Buck Converter

In this article, Dr. Ridley examines how the value of a buck inductor should be selected. A supposedly simple process can turn out to be much more complicated than expected, and the range of allowable inductors is found to be quite large.

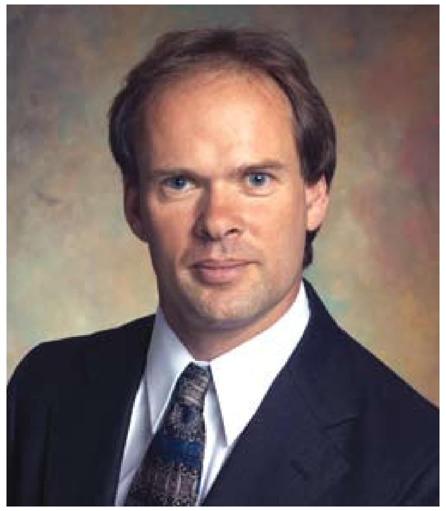
By Dr. Ray Ridley, Ridley Engineering

Design rules for choosing the inductor

Five or six times a year, I teach a class in power supply design to 24 working engineers. One of the design examples involves a buck converter, and the design starts with the choice of the inductor value. I always ask the students what value inductor should be used, or how much ripple current should be in the inductor. (Ripple current ratio is usually defined as the peak-to-peak value of the inductor current at high line, divided by the maximum load). Their answers typically vary, from a value of 10% up to perhaps 30%.

A traditional value of inductor current ripple is 10%, and you will find this in several books. Reference [1] uses this value as a starting point for design, but does suggest at the end of the article that the value can be changed depending on the desired output ripple. Further examination of literature shows a huge range of recommendations. References [1] to [13] suggest ranges from 2.5% to 50%.

References [14, 15] select the inductor according to the minimum load, with the intent of keeping the converter always in continuous-conduction mode (CCM). This can lead to a very large inductor if the light load is very small.



Which one of these is the correct value? As is often the case in designing power supplies, there is no one correct answer and it will always depend on the very specific converter that you are working on at the moment.

Where do the rules come from?

We usually find in power electronics that design "rules-of-thumb" arise from some practical basis in reality. There are several different factors that drive the choice of inductor value.

1. Output Ripple Voltage – older output capacitor types tend to drive inductor values to a higher number. Modern innovations in capacitor design have driven the ESR down to very low values, and rarely is the output ripple the driving factor in choosing the inductor.

2. Inductor Loss – Higher ripple current leads to higher RMS current in the inductor, plus greater AC currents and higher proximity losses. Core losses will also increase with larger ripple current. A higher value of inductor, with low ripple, has higher dc conduction loss.

3. Switch Conduction Loss – the RMS current in the switch climbs with inductor current ripple.

4. Rectifier Conduction Loss – the RMS current in the rectifier climbs with inductor current ripple. This is an impor-

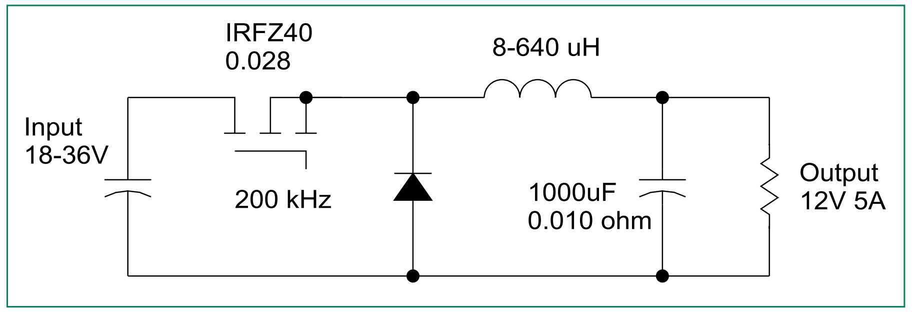


Figure 1: Buck Converter with Parameter Values.

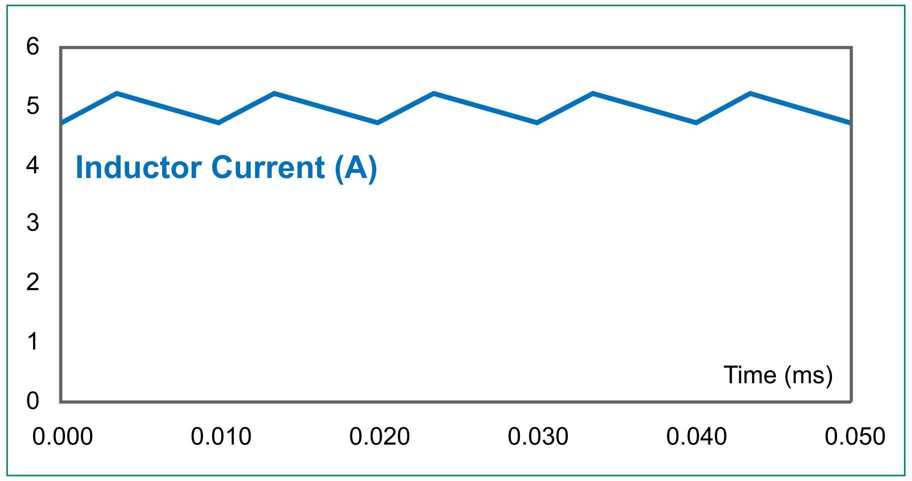


Figure 2: Inductor Current Waveforms 10% Ripple.

L (µH)	Ripple Ratio	Turns	DCR Ω	ACR Ω	Winding Loss (W)	Core Loss (W)	Inductor Loss (W)	FET Loss (W)	Total Loss (W)
640	2.5	221	1.7	53.8	43	0	43	0.41	43.41
160	10	58	0.112	5.5	2.94	0	2.94	0.26	3.20
80	20	31	0.30	1.5	0.88	0.003	0.883	0.25	1.113
40	40	17	0.10	0.4	0.41	0.015	0.425	0.25	0.645
20	**80**	**10**	**0.006**	**0.14**	**0.23**	**0.067**	**0.297**	**0.26**	**0.557**
10	160	7	0.003	0.03	0.24	0.179	0.419	0.31	0.729
8	200	6	0.002	0.02	0.25	0.264	0.514	0.34	0.844

Table 1: Inductor and Switch Loss with Different Ripple Values Using RM8 Core.

tant factor when using a synchronous rectifier, but less important when using a diode.

5. CCM operation – References [14, 15] choose the inductor to give a ripple which is twice the minimum load. This is to avoid DCM operation at light load. In the early days of power supply design, this was an important factor to keep good transient performance under all conditions. With a modern power supply, using current-mode control, there is no reason at all to keep the converter in CCM operation.

Buck Converter Design Example

Searching deeper into the literature than the short list included with this article will not lead you to any conclusions regarding the right value of inductance. For every converter design that you do, the proper answer will depend upon your very specific set of circumstances. And for each specific case, a detailed design must be completed and tested before coming to any conclusions about the right value.

For example, Figure 1 shows a specific design case. The switching frequency of the buck converter is 200 kHz, and the output specification is 5A at 12 V from a 18-36 V input. The output capacitor is preselected at 1000 µF with a 10 mΩ ESR. The choice of the output capacitor can be as wide ranging as the choice of the inductor value, and is not discussed in more detail in this article due to space constraints.

The ripple current in the converter is maximum at high line, and the value of the ripple is shown in figure 2 for an inductance of 160 µH which gives a current ripple ratio of 10%.

The peak-to-peak value of the current is 0.5 A, and this results in a 5 mV ripple on the output of the converter. In most practical design cases, the output ripple at the switching frequency is not the main driver for inductor choice, since it is much lower than is needed. It is almost always far lower than the high-frequency switching noise on the output.

There nothing special about choosing the 10% ripple value for Figure 1. It is just one value in the range that could be used. For each value, we must optimize the design of the inductor before we can really assess the performance properly. This can be a time consuming process, but for this study, it was automated using the design software POWER 4-5-6 [18].

The inductor designed for this case had the following practical design constraints applied when assessing each value of inductor:

1. Magnetics Inc. RM8 core with R material was used.

2. Turns were set to the nearest integer value.

3. Maximum flux level was designed for 0.3 Tesla, with 10% overcurrent limiting.

4. Maximum wire size was 20 awg (0.9mm diameter) to limit mechanical

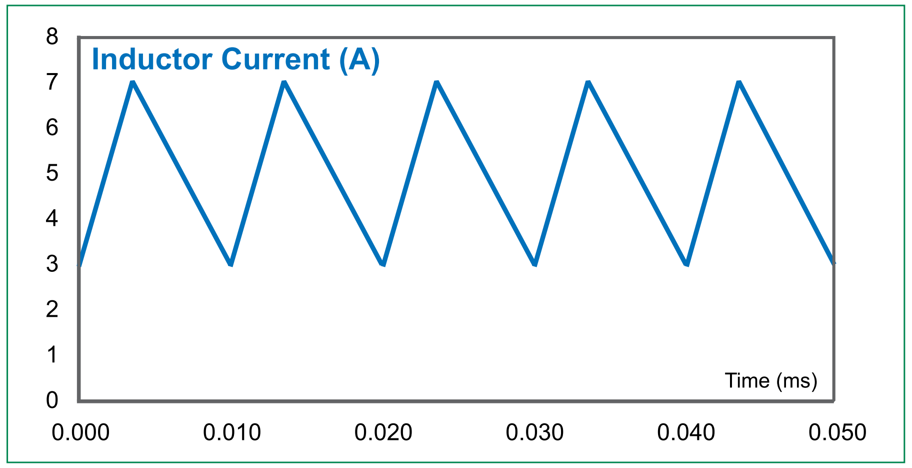


Figure 3: Inductor Current Waveforms 80% Ripple.

stress on bobbin.

5. Multiple strands of wire and multiple layers were used as appropriate.

6. Winding loss includes proximity loss as predicted by Dowell's equations [16].

7. Core losses include advanced modeling techniques [17].

There are hundreds of cores that could have been chosen, but the RM8 was convenient and available. It will not necessarily be the optimal choice since the definition of "optimal" varies for every user.

Table I shows the results for designs, with a range of inductance from 640 μH down to 8 μH. This corresponds to a ripple ratio ranging from 2.5 % (as in the example of [11]) up to 200%, the boundary of discontinuous conduction mode at full load.

It is clear from the table that for this design case, with the chosen core size, the largest inductor was a very poor choice, with a loss of 43 W in the inductor windings. The 10% ripple case also has a higher dissipation than is desirable. The designs from 40% ripple to 200% ripple were all excellent.

It is interesting to see that the big change in ripple from 10% to 200% (20 times) only incurred a relatively small increase in conduction loss of the power FET. The increase in the RMS current value does not change as dramatically as one might expect.

Core losses were low for all designs, as would be expected when using a ferrite material. This allows the inductor to operate at high ripple current without a big penalty. (This would not be true for many of the lower-cost core materials found in the standard component designs.) Overall, the overall lowest loss value of inductor gave an 80% ripple ratio. The current waveform for this case is shown in Figure 3.

Summary

Choosing the proper value of an inductance can have a tremendous impact on the final size, cost, and efficiency of a buck converter. There is, however, no single specific value that is correct for all converters. The value of the inductor can be freely selected over a practical range from 10% to 200%. In every power supply, the specific constraints impacting the design choice will be unique, and the optimal value for the inductor must be found by trying multiple values and, ultimately, testing the designs in the circuit.

The design example given in this article had an optimal ripple of 80%. If I had to choose one specific number to get people started, I would agree with Reference [2] and begin with a ripple factor of 40%, but with the clear understanding that it is not a problem to move significantly away from this number, and the number should not be blindly accepted.

Other Recommendations

1. Jerry Foutz, "Switching-Mode Power Supply Design Tutorial Simple Switching Topologies", http://www.smpstech.com/tutorial/t03top.htm start with 10% ripple.

2. Sanjay Maniktala, "Switching Power Supplies A to Z", 40% ripple.

Semiconductor Vendors

3. Micrel, "MIC4574 application note", http://www.micrel.com/_PDF/mic4574.pdf, 10% ripple (Figure 3), 34% ripple (Figure 1).

4. GMOS Technology Corporation, "GT1512 Datasheet", 15% ripple.

5. Microchip, "MCP1612 Datasheet", 16.5% ripple.

6. Texas Instruments, "TPS4000 controller reference design", 25% ripple.

7. Analogic, 30-40% ripple.

8. Sanjaya Maniktala, National Semiconductor, "Current Ripple Ratio Simplifies Selection of Off-the-Shelf Inductors for Buck Converters" http://powerelectronics.com/mag/power_current_ripple_ratio/, 25-50% ripple.

9. Maxim application note – 30% ripple.

10. National Semiconductor, "Selecting Inductors for Buck converters", http://www.national.com/an/AN/AN-1197.pdf, 30-40% ripple.

Magnetic Component Vendors

11. Douglas R. Kokesh, Tyco Electronics Power Components, CoEv Magnetics Group, "Sizing a Power Inductor - An aid to employment of switch mode power supplies", http://www.designfax.net/archives/0304/0304power_inductor.asp, 2.5% ripple.

12. Coiltronics, 10-30% ripple.

13. GB International Custom cores, "Using GBI's 4400 Series to Design Buck Regulators", http://www.gbint.com/Files/Apps/General Apps/GB-4400-001.htm, 2 x minimum load.

14. Wurth Electronics, "Power Inductors 8 Design Tips", 30% ripple.

15. Jim Holdahl and Terry VanConant, CoEv, "Demystifying Buck Inductors", http://powerelectronics.com/mag/power_demystifying_buck_inductors, 2 times minimum load.

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17. Ray Ridley and Art Nace "Modeling Ferrite Core Losses", www.switchingpowermagazine.com/downloads/7 Modeling Ferrite Core Losses.pdf

18. Ridley Engineering, "Power 4-5-6 Simulation and Design Software", http://www.ridleyengineering.com/software.htm

www.ridleyengineering.com

ON THE ROAD

On the Road

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

Linear Technology

It was a real pleasure to meet with Bob Swanson, founder of Linear Technology Corporation, serving as Executive Chairman and Lothar Maier, Chief Executive Officer of Linear Technology. Together they took us through the path Linear has taken through these rough and tough times and gave an encouraging look forward.

Linear Delivers

Investment in engineering pays off

Before I get into the meeting with the Linear Executive, I would like to quote from Bob and Lothar's final paragraph of the company's annual report. It gives an insight into why this company remains healthy while many others are frantically looking, or waiting for 'the next big thing'.

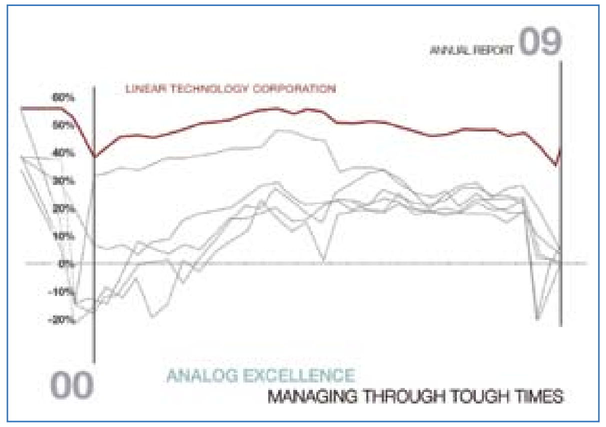
"We have managed through a difficult year and remained financially healthy. We have done this before during the dot-com bust and are doing it again during this global recession. We have had a consistent strategy of delivering unique, innovative, high performance analog solutions to our customers in traditional analog end-markets.

This year we are particularly grateful to our employees. They have had to deal with shutdowns, reductions in base pay and lower profit sharing. Their hard work and dedication delivered the results and have positioned us for growth in the future. Once again, to our customers, our goal is to be an excellent supplier. We are well positioned going forward".

Robert H. Swanson, Jr., Executive Chairman, Linear Technology Corporation.

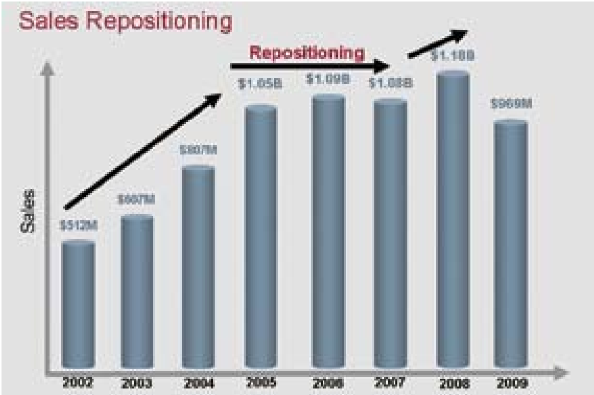
Lothar Maier, Chief Executive Officer, Linear Technology Corporation.

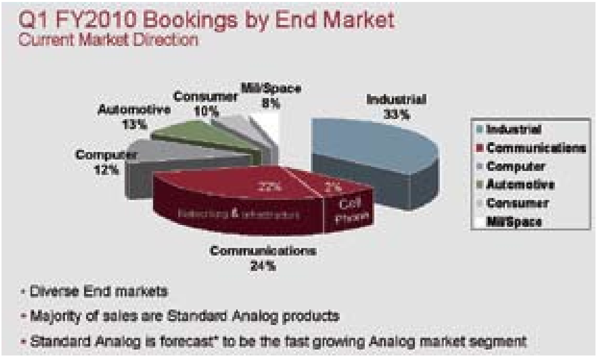
As can be seen from the graph taken from the company's annual report, Linear has a consistent and enviable margin performance; one that many have tried unsuccessfully to emulate.

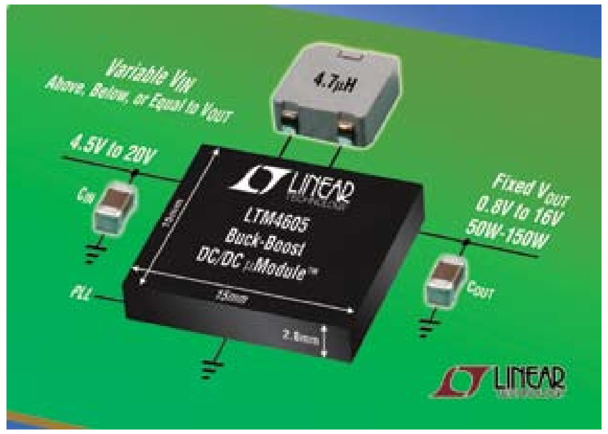


Linear is an undisputed leader in high performance Analog ICs with a unique, engineering-driven sales approach spanning a broad cross-section of end-markets; more than 7,500 product types in over 15,000 customers. The company prides itself with providing outstanding technology and support with a consistently strong engineering and R&D commitment. The quality and talent of its employees contribute hugely in the success of the company.

The company has over the last decade, however, repositioned its focus to wean itself off dependence on the volatile and margin-slashing consumer market, and today can congratulate itself in having achieved this by reducing the consumer part of its business from 28% to less than 9% while increasing penetration in Industrial, Auto, Mil/Space, Computer & Communications segments.







Lothar explained that sales in the September ending quarter grew 14% over the prior quarter and that the company continues to have the best financial performance of all its competitors.

In addition, the management team at Linear has maintained all its manufacturing capacity during the downturn and is now in the enviable position to be able to respond quickly to the business pickup. Lead times are holding steady at 2-4 weeks while its industry competitors are quoting much longer and growing lead-times due to their severe cut backs in capacity.

"The WW economic crisis has created opportunities as well as difficulties" said Lothar Maier. " It is driving new product innovation. Our customers want compelling Analog products that drive end-product differentiation and they tell us they want innovation as a first priority with cost coming in second place. Customers' new product development efforts are now in over-drive and they depend more than ever on our leading Analog expertise."

Linear's diverse field of activity spans a broad range of industry segments. Products launched onto the market normally get the margin and respect they deserve.

The μModule series, for example, which Linear introduced in 2006, provides a complete analog solution in IC format. Linear customers place great value in the flexibility and ease of use, so much so that since 2006, it has grown into a family of over 25 products. The new µModule products continue to gain market traction and are delivering steady and accelerating sales growth with more products introduced every quarter.

The Munich Design Center was opened in June 2006 making a total of 12 fully supported WW design center operations. The fruits of the investment are demonstrated by the design and release of 3 new power management products, with 7 more power management and mixed signal products expected by mid-2010.

Going back to the company's statement in its annual report and subsequently with my discussions with Bob and Lothar, it is apparent that the company's success has a high correlation with its investment in its valued employees and commitment to good engineering.

www.linear.com

Dialog Semiconductor

I had the pleasure to accept an invitation to participate with Dialog Semiconductor in the company's expansion into a new UK office in Swindon. This dynamic company led by Dr. Jalal Bagherli, made a very refreshing experience for me in these tough times. It was good to see a company expanding its operation and taking good care of its valuable and highly motivated staff. The event, attended by Dialog's senior management team and distinguished guests was a heartening experience showing just what can be achieved with good engineering, talented staff and real management.

Dialog Semiconductor Opens New Facility

Makes advances in portable audio market

Dialog Semiconductor has celebrated the opening of its prestigious new facility in Swindon UK. The company has been highly successful – even in these difficult times – and has now consolidated its UK activity into the new facility.

Right away I noticed the enthusiasm. From senior management to engineering, marketing and the support staff that helped make the day run so smoothly.

I was invited to report on the new technical announcements, but was delighted to also witness a company whose staff play a full and active part in the overall

Dialog Semiconductor's CEO, Jalal Bagherli (right), is presented with a 300mm wafer by TSMC's Franz Lux, account director highlighting Dialog's innovation leadership at the opening of Dialog's new Swindon facility.

Dialog Semiconductor's CEO, Jalal Bagherli (centre), is presented with a commemorative plaque by Phil Young (left), cabinet member for economic development, Swindon Borough Council and Tony Bray, area director, South West Regional Development Agency to officially open Dialog's new Swindon facility.

Dialog's impressive $1400m^2$ new facility in Swindon, UK is the new home for 85 employees with space for expected expansion to 125.

definition of what the company does and the way it operates.

I talked with Peter Hall, Dialog's Vice President of Supply Operations and Quality who answered some of my more oblique questions about the new facility. He told me that the planning, layout and implementation of all areas within the new facility were implemented with full participation of the company's employees. I believe it must have been a tough job indeed to please everyone – especially engineers - known for their precision and attention to detail, but one that obviously has a large effect on morale and loyalty.

I took the tour of the new facility and was positively impressed by the open, well planned environment. It was obvious to me that much attention to detail had been given with a campus-style working environment achieved.

Participating in the opening was a good mix of customers, representatives from the local borough council and the government. Dialog is good for Swindon and has its roots there; a fact that was underlined in the official presentations.

Dialog's further diversification

Dialog Semiconductor announced that it is further diversifying its product portfolio for portable devices and smartphones with the introduction of a new generation of ultra low power audio technology.

The company's recent success has been built upon integrated system power management devices, including standard audio codecs. By leveraging this expertise Dialog will now offer its customers a new generation of mixed signal audio technology, including codecs, speaker drivers and audio sub systems, at previously unattainable levels of low power consumption. With these new products Dialog substantially increases the addressable market for the company's mixed signal technology.

Designers of portable electronic devices are demanding higher quality audio performance with the freedom to be more innovative in order to support emerging user applications in portable devices. Dialog is now uniquely positioned to deliver this without compromising size, performance, power or flexibility. The technology is offered as stand alone devices, monolithically integrated with power management, and as stacked die solutions combined with other portable device SOCs.

"Offering our customers quality sound at ultra-low power for their portable devices is one of our new corporate strategic initiatives, which follows the establishment of an audio design centre in Edinburgh late in 2007. I am pleased that today we announced the first of a planned family of products which will drive a new phase of growth for Dialog, further endorsing our claim as Europe's fastest growing and leading mixed signal specialist company," said Dr Jalal Bagherli, CEO of Dialog Semiconductor.

www.dialog-semiconductor.com

New standalone Class-G audio codec has industry-beating 2.5mW consumption

Dialog Semiconductor announced the DA7210, a high performance Class G audio codec that incorporates the industry's first onboard general purpose filter (GPF). The filter is a configurable signal processing engine that enables fine-tuning and optimisation of the output signal for small speakers and enclosures. Its integration saves design time, board space and cost.

The DA7210 includes a true-ground, capacitor-less headphone driver which helps improve bass response. It features the industry's lowest quiescent headphone playback power consumption at

2.5mW and only 5mW operating power under listening conditions. This combination extends battery life significantly in low power digital portable audio products such as smart phones, personal media players, multimedia handsets and personal navigation devices.

DA7210 delivers 40mW output into 16 Ohm headphones. It uses output signal envelope tracking across multiple pre-defined levels for true ground operation and features an integrated PLL for sample rate flexibility. The device operates down to 1.8V simplifying digital processor interfacing.

The GPF enables onboard signal tailoring and performance tuning without degradation or loss of sound quality, and removes the need for a dedicated external DSP.

"With the introduction of the DA7210 Dialog has significantly eased the portable audio design process for portable applications without sacrificing sound quality. By incorporating a GPF on the codec we have not only offloaded these tasks from the processor, we have significantly lowered the cost and power consumption when compared with traditional solutions that require an external DSP," said Mark Jacob, Director of Marketing at Dialog Semiconductor. "The DA7210 delivers the ultimate mix of high performance audio, ultra low power consumption, and reduced system design complexity."

Traditional low power audio codecs rely on sophisticated external DSP devices running proprietary algorithms for audio enhancement or more complex noise suppression functions. Dialog's integral GPF comprises eight programmable bi-quad sections delivering flexible DSP processing functionality within the codec device itself. The audio signal sent to the speakers can be tailored for optimum response without modifying the host processor software. In addition to output tailoring, the GPF can be used for equalisation and notch filtering, for example, enabling the noise from camera zoom motors to be attenuated and other audio enhancements including 3D spatial effects.

The DA7210 features stereo playback/record, high signal-to-noise ratio (100dB DAC and 95dB ADC), a 24-bit sample rate up to 96kHz and an integral I2C/PCM interface. It includes differential stereo microphone amplifiers. It is packaged in a 0.4mm-pitch QFN or CSP package with a 0.5mm-pitch CSP option (named the DA7211).

Engineering samples are available with volume production delivery from Q1 of 2010.

www.dialog-semiconductor.com

Breakthrough in Audio Power

100W audio amplifiers are 20X more efficient than Class D chips

I talked with Huw Davies, CCO at Audium Semiconductor Ltd as he spearheaded the launch of the World's most efficient high power audio chip which enables battery-powered amplified speakers to run 3 hours per day for a stunning10 months on a set of 1.5V batteries. Traditionally the industry has accepted that Class D audio amplifiers were the way to achieve best-in-class efficiency. This has now changed.

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

Audium Semiconductor, based in Bristol, UK, is a young and energetic fabless semiconductor company with funding from Advent Venture Partners and Balderton Capital. The company has recently launched an audio power amplifier IC which, at normal listening levels (defined as 73dBC sound pressure level (SPL) at a distance of 1 metre, with a speaker sensitivity of 89dBC/W at 1 metre), is 20 times more efficient than competing devices such as Class D (see:http://tinyurl.com/cq6loh) amplifiers, without compromising audio quality.

The AS1001 operates from a nominal 1.5V power supply and delivers 100W peak power output. The amplifier is so efficient that battery-powered amplified loudspeakers can run for up to 10 months on a set of four 'C' batteries, playing for three hours per day, vastly reducing CO_2 from power generation and pollution from battery production.

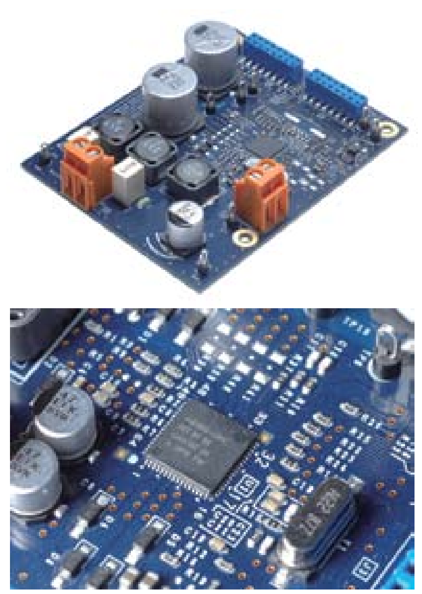
The amplifier also enables the development of smaller, cooler, mains-powered audio equipment, with fewer heat sinks. Applications include totally wireless speakers, home theatre surround sound speakers and battery-powered travel speakers. Future Audium ICs will support MP3 docking stations and USB powered speakers.

The AS1001 architecture uses patented techniques to minimise both fixed power losses and output-dependant variable power losses. The modulation scheme uses low switching rates to minimise switching losses, while power rail switching means that the amplifier operates efficiently from a low voltage rail most of the time, with a DC-DC boost converter driving higher voltage transistors on extreme audio peaks.

"Traditionally, audio amplifiers have only reached quoted efficiency figures at maximum output, which is like building a city-car that's only efficient at 200mph and anything but efficient at 30," explained Audium's Huw Davies. "The AS1001 marks a huge leap forward in efficiency and has come from examining how equipment is really used rather than striving for a marketable arbitrary figure."

"Over 700 million consumer audio devices are sold each year, so the real world efficiency of these has a huge impact on the amount of energy we consume," commented Malcolm Penn, CEO Future Horizon's analyst house. "Looking beyond the environmental implications, the technology behind the AS1001 will enable a whole new class of low power consumer products."

The market is wide open for Audium. With its revolutionary patented IP, the company is vigourously targeting battery powered applications in audio active speakers, wireless speakers, mp3 docking stations and USB powered devices. Following on will be the flat-panel TV 'sound bar' home cinema products and the automotive industry, where multi-channel audio is required to operate from behind the dashboard in a thermally-challenging operational environment.



The Audium AS1001 is the heart of a low-power audio system design.

The AS1001 is a single 64QFN package and operates directly from a 0.8V – 1.8V supply (compatible with, for example, alkaline primary cells and Ni-MH secondary cells). Samples are available now, priced from $8 each in 100+ quantities.

www.audiumsemi.com

Power Solution for Consumer Products

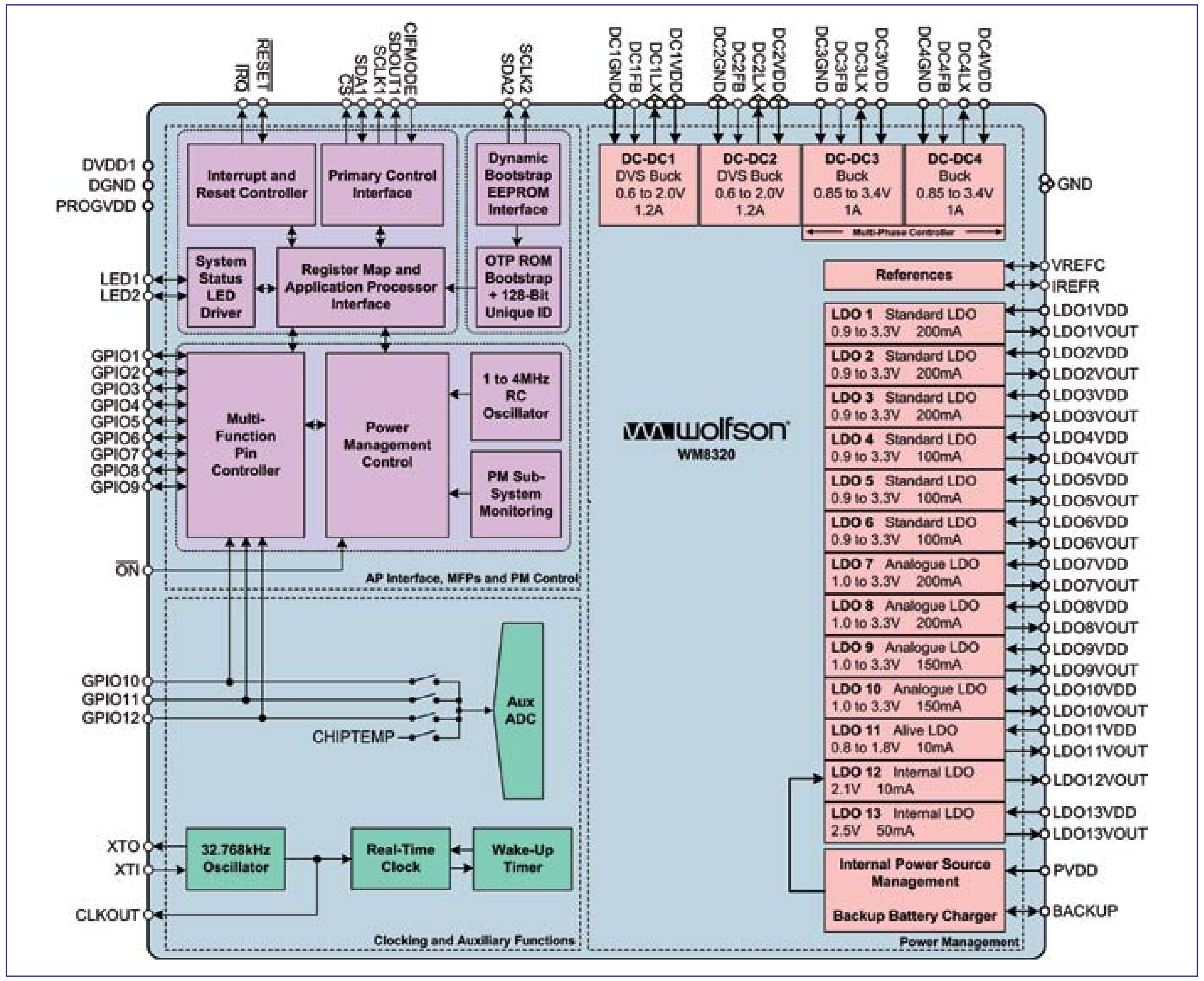
New addition to power management family

I talked with Jess Brown, Wolfson's Power Management Product Line Manager as the company, a world leading provider of high performance mixed-signal semiconductors to the consumer electronics market, announced the newest addition to its Power Management IC (PMIC) family.

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

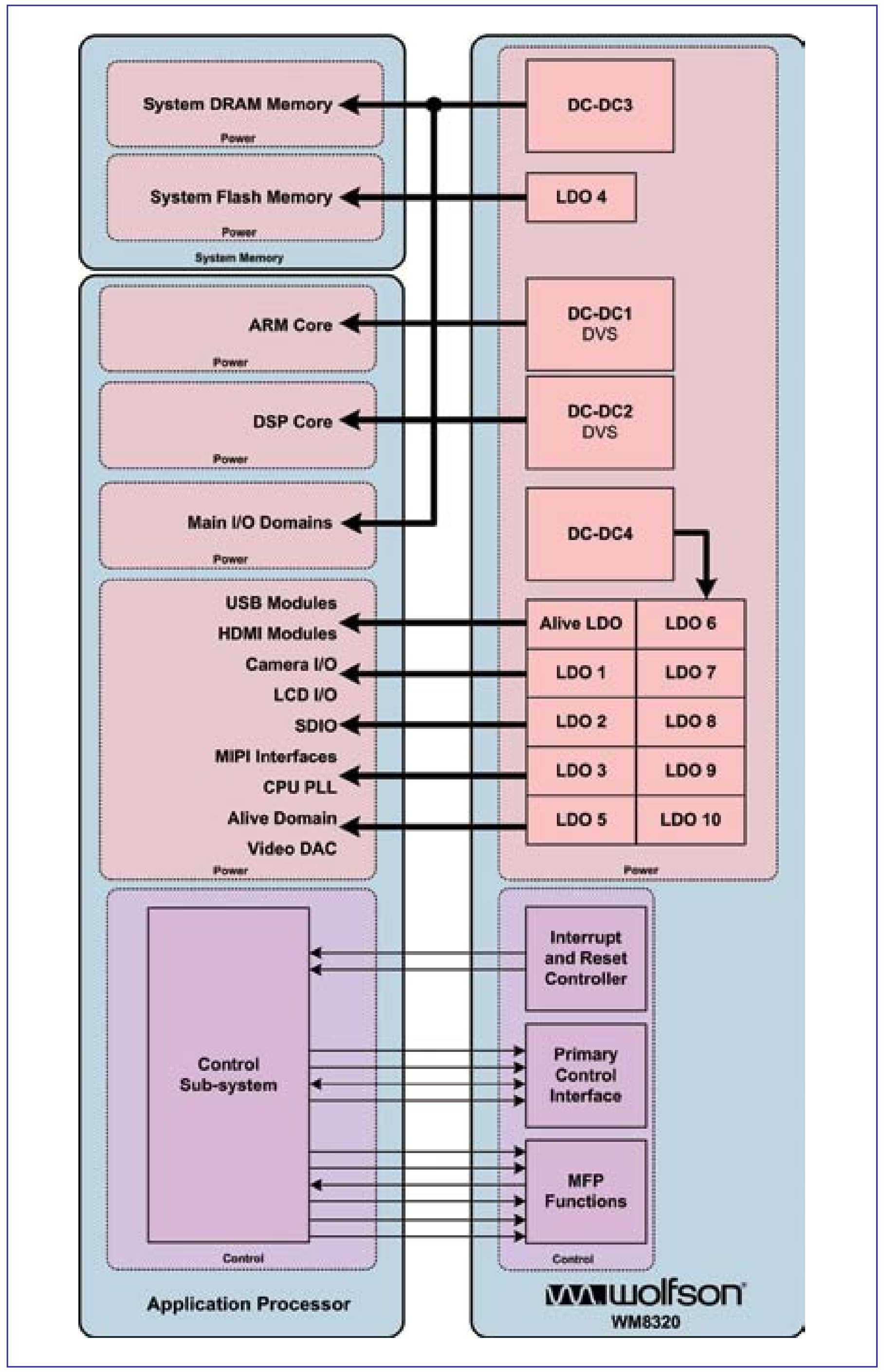
Wolfson Microelectronics launched the WM8320, a highly integrated power management solution to maximise processor performance and extend battery life to leading edge portable multimedia devices.

The WM8320 is the latest addition to Wolfson's WM83xx power management portfolio, and is targeted at providing smaller, more efficient, and lower cost solutions to applications that use ARM-based processors, particularly netbooks, mobile internet devices, smartphones, handsets and digital photo frames.

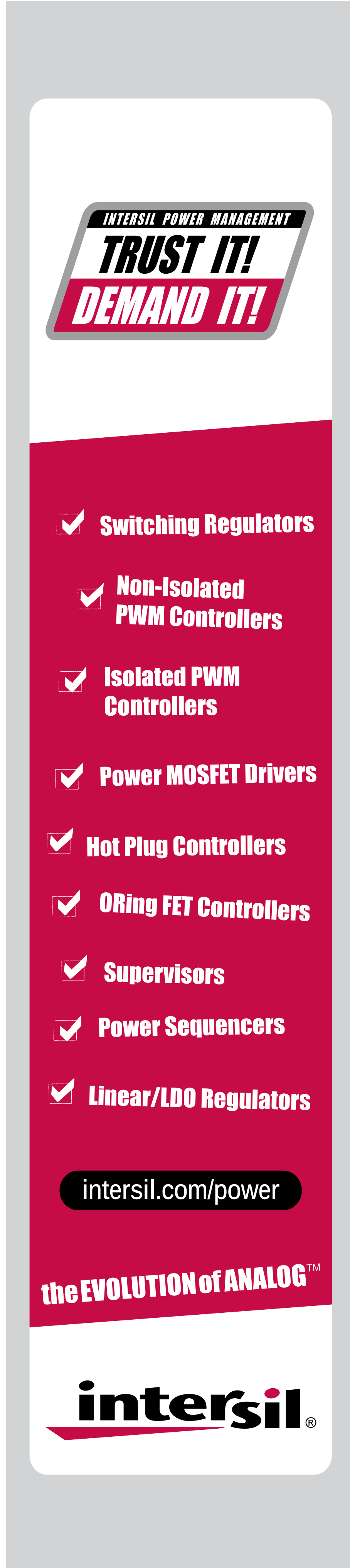


WM8320 Overview
Power Management

- DC-DC converters:
  - 2 x 1.2A synch BuckWise™ con verters
  - 2 x 1.0A synch buck converters
- Dual mode capability of DC-DC3 and DC-DC4
- 10 x LDOs + 1 'Alive' LDO
- Ultra low-power consumption:
  - <7uA in OFF mode
  - ~100nA in BACKUP mode
- OTP NVM programmable startup/ shutdown sequence and startup voltages



WM8320 PMU system block diagram.



Best-in-class transient performance.

• External EEPROM programming option
• Backup battery support

Auxiliary Functions
• Crystal oscillator
• Secure RTC for Digital Rights Management
• Auxiliary ADC
• Programmable WAKE/SLEEP sequence and sleep voltages
• Watchdog timer
• Twelve multi-functional GPIOs
• Control / sequencing of external regulators

The WM8320 incorporates Wolfson's unique BuckWise™ regulator technology, which enables the PMICs to cope with shifts in power requirements, as different product functions are switched on and off by the user.

Offering the best-in-class transient performance, the new BuckWise™ regulator technology eliminates any disturbances in the power supply outputs which can often be caused by rapid changes in power requirements, without the need to add large external components, or reduce the processor speed to lower the load current. The WM8320 can also be used in applications where there is no system battery, such as set-top boxes.

These features combine to enable the creation of new and exciting multimedia platforms, whilst significantly reducing power consumption, system cost, design & manufacturing complexity and time-to-market. With the WM8320, consumer electronics manufacturers can make significant cost savings by using smaller components such as SMT chip inductors rather than expensive large discrete wirewound inductors. In conjunction with this, board space area can be reduced by 25% over previous generation solutions.

Wolfson's power management product line includes a complete family of market leading Power Management Integrated Circuits (PMICs), delivering unprecedented programmability and unparalleled performance capabilities, offering product manufacturers an attractive combination of reduced time to market, improved end user experience, future proof design and lower total cost of ownership.

Sitting beside the application processor at the heart of consumer products, such as mobile phones, navigation devices and media players, PMIC devices intelligently manage and optimise the use of power within the system to maximise battery life. The unique design of the WM83xx family enables limitless configuration options making it compatible with all application and mobile graphics processors, including all ARM-based processors, and configurable to address other architectures.

Jess explained: "It is a challenge for systems engineers to deliver ever smaller and more efficient power management solutions, which still offer a high performance multimedia experience. From our close customer cooperation, we are building on Wolfson's strong power management portfolio to provide a lower-cost integrated solution which meets their needs, as well as helping our customers to deliver electronic consumer devices with new and improved end user experiences."

The WM8320 has four DC-DC synchronous regulators, two 1.2A, which incorporate BuckWise™ technology, and two 1.0A. The two 1A regulators can be grouped together to generate a combined 1.6A output to support large memory banks, or to increase efficiency by pre-regulating any of the ten LDOs integrated in the WM8320.

The enhanced transient performance also saves power, enabling the processor to run at lower voltages, improving power efficiency. System designers can choose to reduce processor power consumption by up to 25% over previous generations of regulators, or to increase processor speed by up to 25%. So that, for example, smart phone designers can enable users to multitask for longer while still maintaining high quality gaming, music playback and video resolution.

Patent pending EEPROM interface technology maximises design process flexibility, allowing product designers to override the "one time programmable" memory of the PMIC as many times as they want, while perfecting their design in terms of start-up sequences and voltage levels. Product development and migration needs are easily accommodated, making the WM8320 and the WM831x family future-proof choices.

Availability

The WM8320 is available for sampling now in a 7x7mm BGA package, and is priced at $3.72 in 10K volume.

WM8320 customer evaluation boards with the Wolfson Interactive Setup and Configuration Environment (WISCE) are available to aid device evaluation and development. WISCE connects to the evaluation board over USB and offers a unique interactive register map interface. This interface provides unprecedented control and overview of the device settings. www.wolfsonmicro.com or sign up for Wolfson eNews at:

www.wolfsonmicro.com/enews

Comprehensive Design-in and Sourcing

New power electronics eCommerce portal; telephone hotline, forum, TechChat, knowledge base

I talked recently with Dr. Walter Demmelhuber, CEO of SindoPower, a new and refreshingly 'customer focused' operation, dedicated to making the design-in, ordering and commissioning of power products a fast and simple operation. The portal serves engineers and purchasers of power products.

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

SindoPower GmbH (www.sindopower.com), a holding company of the SEMIKRON Group, went live with its B2B eCommerce Portal at the beginning of September after extensive and extremely positive customer trials.

SindoPower is the first portal in the field of power electronics to link eCommerce with technological consultation. This portal gives development engineers online access to an extensive pool of technical information and the opportunity to communicate with others in the technology forum, or to contact experts in the TechChat or on the telephone hotline.

The unique feature of the SindoPower portal is the breadth of comprehensive technical support service and the information pool brought to users through a wide variety of media tailored to suit every user: technology chat room, forum, e-mail and telephone service. This provides users with personal online and telephone support in all matters relating to power electronics.

The SindoPower portal features an online shop containing a wide range of SEMIKRON products that can be delivered straight from the warehouse. Power electronic modules can be ordered directly from the online store

Dr. Walter Demmelhuber, CEO, SindoPower.

at competitive prices and even in small quantities. Product information such as graduated price ranges, availability, replacement time and custom duty information can be accessed directly at www.sindopower.com.

Dr. Walter Demmelhuber, SindoPower's CEO, who spearheaded the operation, told me, "We were astounded by the huge take-up of the service. From day one it continues to flourish and grow. There is a huge need for this type of support in the power industry and we are finding that as our knowledge and experience grows, we can satisfy the vast majority of engineering and commercial queries in a matter of minutes. Many customers prefer the real-time chat portal to quickly resolve issues, while others prefer the telephone-help route. Either way, the issue gets resolved without the frustrating and costly delays which are prevalent in the industry".

In the "Knowledge Base" users can access a comprehensive information pool covering all areas related to power electronics. Besides help with registration and ordering, the portal also focuses on providing technological support. On the technology telephone hotline and in TechChat, power electronics experts are available to answer technological questions related to the different products. In the Community zone, users can communicate in the technology forum or access information in the power electronics info pool.

The SindoPower range offers comprehensive stock availability for IGBT modules, diode / thyristor modules, bridge rectifiers, CIB modules, as well as for discrete diodes and thyristors. Special types and modules of lower demand are available on request. Orders

The first B2B eCommerce portal in the field of power electronics to link eCommerce with technological consultation.

may also be split up online for delivery at different times to enable customers to benefit from scaled discounts.

"We are undertaking to meet the typical challenges that arise in relation to purchasing demands and inquiries," explained Dr. Walter Demmelhuber. "The slogan 'Power electronics in the web' is not intended to simply reflect the presence of power electronics on the internet, but is also designed to set new standards in B2B order processes, access to information and user networking. We analyse the content of customer inquiries in real-time and publish the solutions to frequently asked questions and issues online for the benefit of all users."

SindoPower also offers a number of additional services, such as express shipping, fax order placement, electronic invoicing, online consignment tracking and connection to an EDI interface. In future, presentations and web seminars containing audio recordings on a variety of topics relating to power electronics will also be available.

To register, users simply complete the online registration form. Products can be easily found, either using the full-text search option with name, number or product abbreviation, via the search by category feature or parameter search mask (search by current, voltage, topology and design) or by performing a thermal simulation. The SindoPower portal today serves users mainly in design/ development engineering, engineering management and purchasing roles, but is applicable to anyone involved in the area of power engineering and manufacturing.

www.sindopower.com

Powering the New Mobile Computing Era

Dedicated power management ICs boost performance

The netbook PC has evolved significantly since its relatively recent inception. What started off just two years ago as a small PC intended primarily for the 'One Laptop per Child' project with limited capabilities is now emerging as an important and popular business tool. Effective power management techniques can further improve efficiency and shrink the required board space in the new generation of ultra-portable lightweight computers.

By Michael Maurer, Technical Marketing Manager, Dialog Semiconductor

Crucially, the small size, low weight and, more recently, integrated 3G-connectivity of netbooks make these devices an ideal way to maintain contact with the office via the internet when travelling. As a result, netbooks and similar small format portable computing devices need to deliver the functionality of larger business PCs. In particular, they must keep users in touch, entertained, and productive while on the move.

However, delivering this means silicon architects are posed with substantial challenges. Designers must find ways of supplying sufficient computing power to run sophisticated operating systems and application software from battery power sources whilst delivering a rewarding user experience with acceptable run times even when devices are connected to 3G mobile broadband for several hours at a time.

And, as the netbook market becomes more and more crowded it is becoming increasingly difficult to deliver differentiated products. But, accurate power management and a shift from discrete solutions will allow designers to take the next step.

A quick history of the portable PC processor

Traditionally, the architecture of choice for devices that wished to exploit the massive base of Windows or Linux software was the IA-32 instruction set that Intel introduced for its first 32-bit processor in 1986. This is now changing and a growing number of chips are being created to meet the processing needs of the standard netbooks, the ultra-portable sub-netbooks and the plethora of devices in between. These demonstrate several new approaches to portable computing and provide designers with a hardware platform that's architecturally similar to previous PCs at instruction-set level, but with order-of-magnitude reductions in power consumption and circuit-board real estate. As a result, it's now possible to construct pocket-sized mobile internet devices (MIDs) that run familiar applications and embody additional functionality such as GPS mapping.

Qualcomm recently demonstrated an ASUS Eee PC that used its Snapdragon processor. This features integrated 3G broadband and GPS connectivity and Google's Android operating system was used for the demonstration. The Snapdragon is a relative newcomer to the market. However, the leading family of such chips in systems sold today is still Intel's Atom processor. It was used in the original Asus Eee and is now in similar devices from numerous manufacturers including Acer, Fujitsu, HP and

Samsung. For this reason, the following technical data discusses power management with respect to the Intel Atom Z5xx. The following principles can also be applied to similar processors.

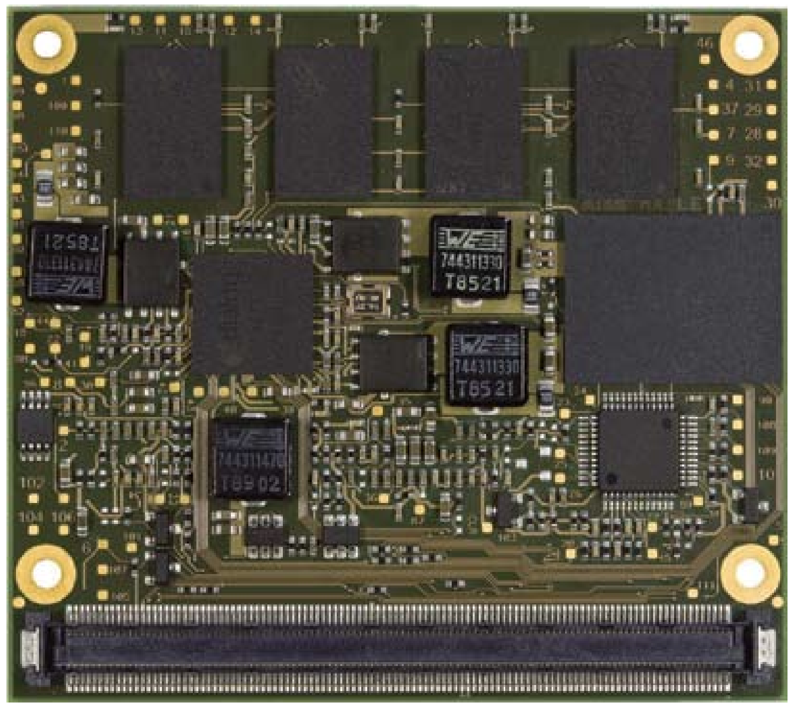
Power down by 90%, area by 80%

The Atom Z5xx series uses a 45nm CMOS process technology to fabricate around 47 million transistors on 25mm^2 of silicon. Designers are provided with seven options that span 800MHz to 2GHz operation with 400 or 533MHz front-bus interfaces. Two thermally-enhanced packages are also available to handle nominal power dissipation levels that range from 0.65W to 2.64W.

However, it's the IC's power efficiency that's arguably the greatest achievement of both the Atom and Snapdragon designs.

Power management hardware can take this further and, if precisely controlled, a top-speed netbook processor will consume just 2.5W. Compared with the 35W that the mobile Core 2 Duo processors typically consume, this is a power saving of more than 90 percent.

Another major achievement is the reduction in circuit-board area that this new generation of processors enable. Looking once more at the Atom; the processor is intended to work alongside a system controller hub (SCH) chip that integrates memory and I/O controllers together with Intel's Graphics Media Accelerator 500. It is estimated that using the Atom shrinks circuit-board area from 3,592mm^2 to just 666mm^2, a saving of more than 80 per cent. And, to build a complete system, you only need add your choice of peripherals, a flash memory to hold EFI (extensible firmware interface) BIOS code, some DDR2 RAM, a clock source that meets the clock synthesiser specifications and power management hardware to manage the platform's multiple power domains and control supply sequencing. However, these latter requirements are not trivial.



Precisely tailored PMICs simplify power management in portable devices.

A cutting-edge discrete power management solution will require at least 200 active and passive components.

A tailored solution

The first companion PMIC for the Intel Atom, the DA6001, was announced earlier this year. Here we look at the development of the DA6001 with respect to the Atom and determine the key steps required in the development of a tailored power management solution.

The Atom's low power states operate at two levels. At thread level, on-chip logic implements what loosely equates to ACPI (advanced configuration and power interface) protocols for processor power states. Because a change in the core's power configuration only occurs when both threads request it one thread can sleep while the other operates normally. Two software interfaces are available to control these features. The first mechanism exploits extensions to the processor's MWAIT instructions while the second consists of reads to the chip's ACPI registers in I/O space that the processor internally maps into a set of equivalent MWAIT codes. This second mechanism does not directly result in any I/O accesses on the front-side bus.

By contrast, a package level change requires external intervention. Again, the results generally map to processor states from C0 (active execution) through the C1 (one thread halted) and C2 states (one or both threads halted but still performing bus snoops to maintain cache coherency) to the C4, C5, and C6 sleep modes. These sleep modes have multiple layers that lower the processor core power supply to its minimum value. In the C6 mode an on-chip SRAM powered from the I/O supply holds the processor's state until a break event triggers a sequence that returns the processor to normal operation.

The system controller hub IC also has several sleep modes and therefore state transitions and handshake terminations to be controlled with supply domains that require switching off/on. The S3 'suspend to RAM' state writes the current state of the machine and the operating system to DDR2 RAM that is automatically refreshed by the memory controller. Most system components are powered down in this state, leaving a suspend power domain active to allow the GPIO, PCI Express, and USB interfaces to wake up the system. The S4 state is a hibernate or 'suspend to disk' state, which saves the machine and operating system states to disk, enabling the system to be essentially powered down. The very similar 'soft-off' S5 state does not save the operating system's context.

Software can configure the processor to run at different frequencies and voltages to yield the greatest efficiency in a given scenario. Changing frequency requires the reprogramming of the processor's PLL (phase-locked-loop), whereupon the processor automatically adjusts the core voltage to a suitable level and the PLL locks in. Furthermore, an enhancement to the thermal monitor mode can automatically cause the processor to move to a lower-voltage and lower-frequency mode if the die temperature becomes too high. This feature is configurable in software by setting appropriate values within the processor's MSR (model-specific register).

The processor changes core voltage by writing new values to its seven VID (voltage identification) pins to request VCC levels from 0.3V to 1.2V in 12.5mV increments. To ensure glitch-free transitions, the processor ramps the voltage that an IMVP (Intel mobile voltage positioning) compliant regulator supplies. Actual maximum and minimum VCC voltages for high and low frequency operation differ slightly between Atom variants, with most operating between 0.75V and 1.10V at maximum currents of 2 to 4A. The 0.3V core-voltage level applies during the C6 sleep state and must not fall below this value.

The VCCP plane that powers the processor's I/O tracks the main core voltage. Optionally, you can create a split VTT plane that makes it possible to disconnect power during C6 from all I/O pins except those that are necessary to wake the processor. This is accomplished by the system controller hub asserting a signal which gates an external MOSFET; this process reduces leakage currents by about 30 per cent. And during all power states the companion VCCP6 plane must be held at 1.05V.

The front-side bus employs a hybrid CMOS/GTL (Gunning transistor logic) interface to minimise power dissipation for most signals while maximising signal integrity for strobe lines, this requires the motherboard to supply reference voltages for the respective transceivers. In addition, the PLL requires a clean 1.50V supply that's permanently present.

More circuits, more power supplies

Other platform elements complicate the power supply and management requirements. For instance, the Intel system controller hub, SCH US15W, uses the same core and front side bus voltages for its host processor interface, but requires additional supplies for its DDR2 memory controller, graphics display system and numerous I/O interfaces. These additional levels include 1.5V, 1.8V, 3.3V, and 5V, several of which are dedicated to functions such as the display PLL, the LVDS (low-voltage differential signalling) interface, the PCI Express interface, and the USB system. And of course, the DDR2 and EFI memories require power sources and control that closely couples with the processor and its system controller hub.

Powering multiple power planes with quite different current requirements in consumer-volume devices demands a holistic approach that takes maximum advantage of the available silicon area at the lowest possible cost. For instance, existing power-management ICs (PMICs) that target the ARM-dominated world of baseband processors and RF-interface platforms that lie within virtually every mobile phone, boast a complement of fully-integrated switch-mode and linear regulators. And, in the case of a high-end smart phone, these can individually control as many as 30 circuit blocks.

However, the relatively high current levels that the core, system controller hub and memory systems require make it more cost-effective, and reasonable in terms of chip power dissipation, to partition supplies into those that can be fully integrated and those that better suit driving external MOSFETs. Using external MOSFETs also frees the designer to specify more efficient devices as they become available – changes in MOSFET design methods, which now focus on switching speed rather than resistance levels, reinforce the need to take this external component approach.

Dedicated PMICs improve efficiency and shrink board size

When precisely configuring the power management requirements of processors such as the Atom or Snapdragon, a long list of essential and desirable attributes should be considered. Essential requirements include a full complement of power supplies to efficiently down-convert input voltages to levels that suit the Atom platform's multiple power planes. Similarly, some form of supervision and control is essential to handle the system's start-up and shut-down sequences without any external intervention.

To provide a minimal footprint solution a dedicated PMIC is essential. This will include all the hardware and software 'hooks' necessary to seamlessly connect with the Atom, system controller hub and DDR2 / EFI memories.

Dedicated companion PMICs come with several benefits, most notably lowering the number of external components, thereby shrinking the required board space. By comparison, a discrete-component approach to satisfying all of the Atom platform's requirements can consume as many as 20 active and 180 passive components. The discrete approach also requires a microcontroller that runs all of the time to monitor and control transitions between the processor's operating modes. A state machine within the PMIC that replaces a conventional microcontroller can reduce this function's power consumption from several mA to around 100uA, and renders the need for programming obsolete.

Looking once more at the Atom, to provide a universal solution for all Atom Z5xx-series parts, the PMIC must integrate an IMVP-6 compliant switch-mode regulator that provides up to 4A of core power. A synchronous buck-converter that drives a pair of external MOSFETs suits downconverting input voltages of 3.6 – 5.25V to the levels that the Atom's VID pins dictate with minimal power loss. The voltage control loop should achieve around ±1.5 per cent accuracy, and including a pulse-skipping mode can greatly contribute towards conserving power under light load conditions. Using a switching frequency of 1MHz allows the use of inductors as small as 1.5uH.

5.2A is required by the system controller hub and its front bus interface while another 3.2A is necessary to power the memory system that supports up to 2GB of DDR2 RAM. Two similar integrated buck converters - that again drive external MOSFET pairs - optimally suit these power domains and require voltage accuracies of around ±3 per cent. Sensing the output voltage at the point-of-delivery maintains best tolerance, while using 1MHz-level switching frequencies constrains filter component footprint. Allowing for a maximum of 1100mA, the lower current needs of the platform's hardware engines make it possible to fully integrate a further buck converter that runs on a fourth phase of the internal frequency of 2MHz. It's desirable to drive all of these buck converters from a spread-spectrum clock source, with a spread of about ±45kHz being sufficient to minimise EMI concerns.

The six remaining power domains have current demands that are low enough to permit low-noise, low-drop-out-voltage linear regulators that are easy to integrate. Proprietary techniques can reduce their quiescent power consumption to a point where separate low-power modes are unnecessary. Ideally, an additional dedicated regulator should be included to sink and source current, driving the DDR2 RAM's termination resistors and maintaining their mid-point reference voltage.

The PMIC should also satisfy the Atom platform's clock-source needs, which must comply with Intel's CK610 specification. Three fractional-division PLLs with spread-spectrum capability that operate from a 14.31818MHz crystal reference provide a good solution to this. The inclusion of a charge pump will maintain the 5V domain, even if the input supply falls below this level. And, adding a two-channel, 10-bit analog-to-digital converter, which is capable of running autonomously, eases the monitoring of voltages and temperatures, to ensuring the system remains within its design parameters.

Conclusion

This new generation of processors significantly helps designers to meet the growing demand for truly portable PCs without compromising on functionality or battery life. Competition in the market has led to a plethora of devices that sit between the standard netbook and ultra-portable sub-netbook. This does, however, make it increasingly difficult for manufacturers to offer differentiated products. Through precisely tailored power management solutions designers will be able to make the next leaps forward in terms of battery life. This improved efficiency means lighter, smaller form factor devices can be created with fewer components, that run more complex operating systems, and can remain connected via Wi-Fi, Bluetooth, GPS and 3G mobile broadband for many hours without needing to recharge. Two years ago netbooks may have been intended as simplistic, inexpensive PCs but advances in processing technology, technology integration and power management have ensured they're now the ultimate portable business machines.

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Minimizing Power Supply Losses

New ferrite material N95 boosts efficiency

The new N95 ferrite material from EPCOS significantly reduces power transformer losses in switch-mode power supplies. Their efficiency can be greatly increased, especially when operating under no load or partial load.

By Probal Mukherjee, Product Development-Ferrites, EPCOS

At the beginning of April 2009, the European Commission issued its Directive (EC) No. 278/2009 for the power consumption of power supplies. It aims to remove the most power-hungry and inefficient power supplies from the European market by the year 2010. The EU hopes that this measure will lead to a reduction in power consumption of up to 9TWh by 2020.

Power supply losses occur in the ferrite cores and windings of transformers. The maximum efficiency condition at full load is defined as a particular ratio of winding to ferrite-core losses and depends on the choice of the ferrite material, operating temperature and frequency. Power converters are developed to operate optimally, i.e. with maximum efficiency, at a defined operating temperature. As the winding losses depend on the square of the current and thus on the load, they are significantly reduced at low loads. As the load decreases, the temperature drops, so does the specific resistance of the windings, which also contributes to reducing the winding losses. In contrast, the losses in power ferrites increase with decreasing temperature at a fixed voltage and frequency. That is why ferrite cores contribute primarily to the losses of the power converters at low loads or no-load.

Because the ferrite material is designed to minimize losses at the operating temperature under full load, the core losses must remain unchanged as the temperature drops in order to improve the efficiency under fractional load.

In contrast to conventional materials, the new N95 power ferrite material achieves this improved efficiency and the resulting energy savings at partial load. It is characterized by a flat loss minimum of 315kW/m3 at 100kHz, 200mT over a broad temperature range between 60°C and 100°C. Another advantage is its high flux density: 525mT at 25°C and 410mT at 100°C. It is available in both the commercial and customized cores used in power supplies.

Fig. 1 shows a comparison of the temperature profile of conventional power ferrite materials (N87, N97) with the N95 material producing an extremely flat temperature curve.

For the N87 and N97 materials, the loss minimum is close to 100°C, which

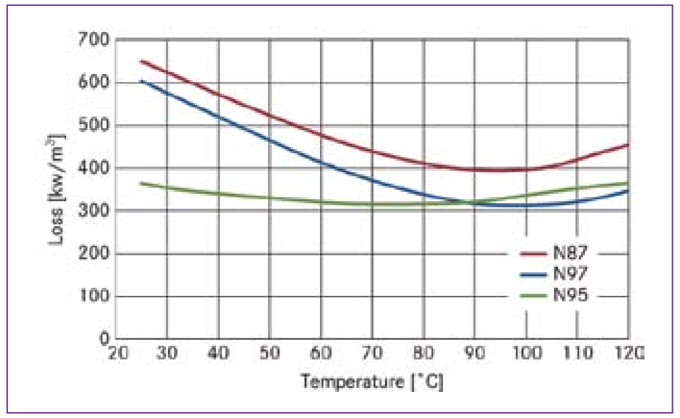

Figure 1: Comparison of power losses. N95 achieves a lower power loss than conventional materials up to a temperature of 90°C.

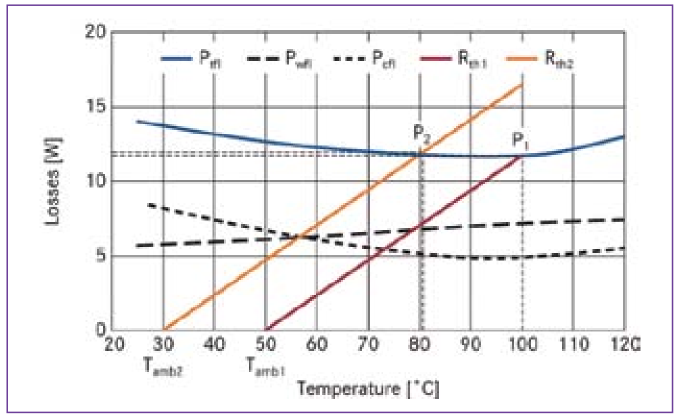

Figure 2: Typical power-loss curves of a ferrite core transformer at full load and under condition of maximum efficiency.

is typical for power ferrites. Of the two materials, N97 has lower losses and its curve characteristic is similar to that of N87. However, the loss curve of the N95 material is lower and shows a relatively flat characteristic over a broad temperature range between 25°C and 100°C.

Core loss, winding loss and thermal resistance

The curves shown in Fig. 1 refer to a specific core loss with sinusoidal flux measured on a toroidal ring core with a uniform magnetic cross-section. This data can be used for a power converter with a given core shape and a non-sinusoidal magnetic flux to determine the actual core losses using the concept of equivalent frequencies. The model is based on the following simplifications:

- The frequency and flux density amplitude remain constant.
- The output voltage remains unchanged with load variation; the output current drops linearly with a partial load.
- The power converter has a linear regulation over the entire load range from no load to full load.
- The duty cycle changes to compensate the effect due to regulation.
- The thermal resistance is linear and remains constant as the ambient temperature changes.

The core losses P_{cfl}, winding losses P_{wfl} and total loss Ptfl (sum of P_{cfl} und P_{wfl}) at full load are shown in Fig. 2 at maximum efficiency for a typical transformer with a power ferrite. Both the operating point P_1 and the thermal resistance R_{th1} are fixed for an ambient temperature of 50°C (T_{amb1}) and an operating temperature of 100°C at full load.

At a transition to a lower ambient temperature of 30°C, the slope of the thermal resistance curve is unchanged, but the operating point shifts to P_2. In this case, the changeover to cooler surroundings hardly affects the transformer losses at all.

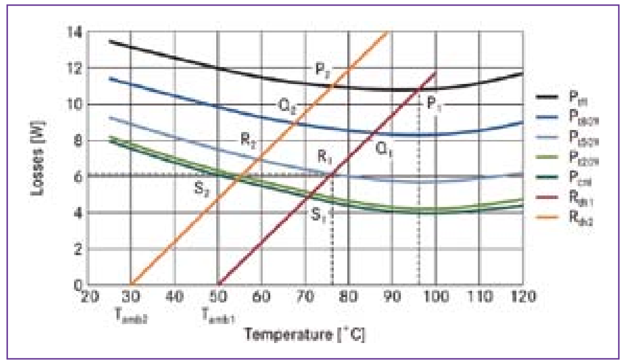

Figure 3: Curves of loss temperature for fractional loads for the N95 RM14lp push-pull converter, f = 100kHz, B = 200mT, shown with the thermal resistance curves at 50oC and 30oC ambient temperatures.

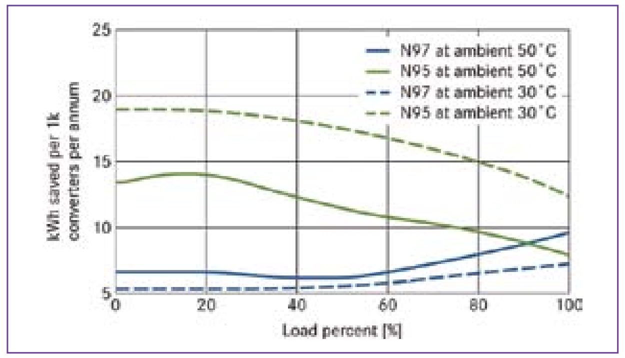

Figure 4: Potential energy saved by replacing a N87-RM14lp core by N97 and N95 in the push-pull converter at 100kHz and 200mT.

The curves of the transformer loss temperature (Fig. 3) at full load (P_{tfl}), 80% load ($P_{t80\%}$), 50% load ($P_{t50\%}$), 20% load ($P_{t20\%}$) and no load (P_{cnl}) can be shown using the simplified model. The selected ferrite core is a low-profile RM14 (RM14lp) and the power ferrite material is N95. The power converter operates in push-pull mode, the duty cycle is standardized to unity at full load, the frequency is 100kHz, the amplitude of the flux density is 200mT, the ambient temperature is 50°C and the temperature rise at full load is 50°C. The regulation of the transformer between no load and full load is 7.5%. The transformer operates with maximum efficiency under the specified conditions. The throughput of the power converter is 756W.

The operating points for full load, 80% load, 50% load and no-load are P_1, Q_1, R_1, S1 for an ambient temperature of 50°C, and P_2, Q_2, R_2, S_2 for an ambient temperature of 30°C. The change of loss and temperature rise at fractional load can be determined from these curves. The point R_1 on the curve yields an operating point at 50% load and an ambient temperature of 50°C. The transformer losses are 5.55W at an operating temperature of 73°C.

Fig. 4 shows the potential savings achieved by replacing a conventional N87-RM14lp core by the materials N97 and N95. The loss reduction results in a direct energy saving: assuming that the average load at the power converter is 50% at an ambient temperature of 50°C (point R_1 in Fig. 3), the annual energy saving in 1000 of these converters is 11 400kWh when N87 is replaced by N95 and 6100 kWh when it is replaced by N97. At an ambient temperature of 30°C (point R_2 in Fig. 3), savings of as much as 17 500kWh are achieved when N87 is replaced by N95 and 5500kWh when it is replaced by N97. Although the savings earned by N97 between 90 percent and full load are greater than those for N95 at an ambient temperature of 50°C, the N95 material unequivocally exhibits the better savings at all loads at an ambient of 30°C.

Less air-conditioning, more environmental protection

The energy saving at a low ambient temperature is greater with N95 than with N97. Temperature rise plays a significant role in the energy savings, as the power supplies for server applications are in most cases located in air-conditioned surroundings. A lower temperature rise thus brings additional indirect energy savings. The power requirement for a conventional air-conditioning unit is about 3.5kW per ton of treated air, and increases proportionally with the rise in temperature. With a power converter efficiency of 90%, the transformer alone can consume about 15% of the power required by the air-conditioning unit, corresponding to about 550W per ton of air.

The energy saved by changing over from N87 to N95 is 830kWh per ton of air/hour in the air-conditioning unit alone per annum – taking the pressure significantly off the environment.

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Step-Up Converters

Cost-effective solution to lower EMI

The TPS6108-5 and -7 are single channel step-up converters developed with a novel topology using adaptive off-time, which requires neither a slope compensation nor an oscillator. This article explains the benefits of the adaptive off-time and introduces the TPS61087 device as baseline.

By Nicolas Guibourg, DC-DC Converters Systems Engineer, Texas Instruments, Germany

With this novel topology, EMI emissions can be significantly improved and best-in-class load and line transient responses are achieved. The system offers also excellent stability over a wider range of applications compared to conventional step-up converters. As a result, smaller components can be used and the total BOM cost is therefore reduced.

Limits of the conventional PWM current mode controllers

Current mode controlled step-up converters running in a PWM scheme usually suffer from inherent instabilities, generally referred to as sub-harmonic oscillation. The system requires therefore the use of a slope compensation, an external ramp that helps disposing of this oscillation, happening when some perturbations occur. This is a key element for the stability of the system. But this is often an element complex to design since it needs to cover different application cases.

Another challenge in designing the slope compensation is that the regulation loop has to be fast enough to respond to sudden changes in output load or input voltages. And due to a certain inaccuracy, the circuit is often over-compensated and degrades the transient response of the system. In addition to that, the system requires an oscillator to set the switching frequency of the controller at a fixed level, which reduces the overall flexibility of the controller.

Adaptive Off-Time Topology and Quasi-Fixed Frequency

As shown in figure 1, the Adaptive(1) Off-time Current Mode Control does not have to deal with sub-harmonic oscillation present in conventional PWM controllers when perturbations occur, thus does not require any slope compensation.

(1) The so-called adaptive off-time changes its duration according to the Duty Cycle. In other words, the off-time "adapts" with V_{IN} and V_{OUT}.

As a current-mode-control converter, the inductor current is sensed via the switch node and triggers the start of the off-time, which is fixed for a certain V_{IN}/V_{OUT} couple. The same frequency is therefore maintained, also while varying these parameters. No oscillator is then required anymore.

The frequency on the TPS61087 is selectable between 1.2MHz and 650kHz via an external FREQ pin. Due to its architecture as well as external parasitic elements, the switching frequency of the system will slightly vary with the output load or the input voltage. However, in figure 2, the frequency is fairly constant for a certain V_{IN}/V_{OUT} combination over a wide output current range, and its variation tolerance does not exceed the one of PWM controllers using internal oscillators.

Taking advantage of the frequency change

The use of a slope compensation

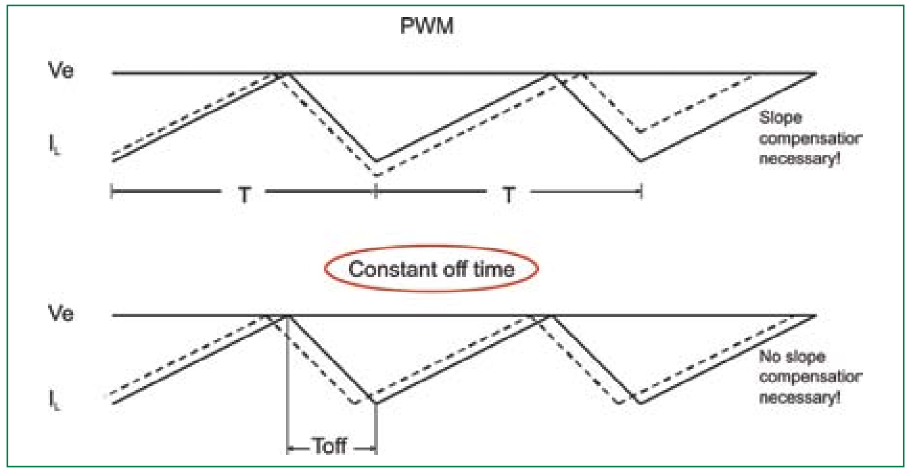

Figure 1: Inductor current waveform after perturbation.

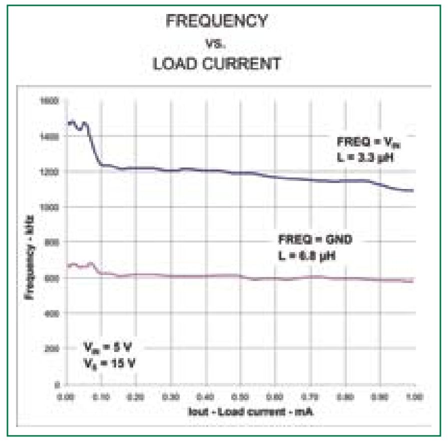

Figure 2: TPS61087's switching frequency.

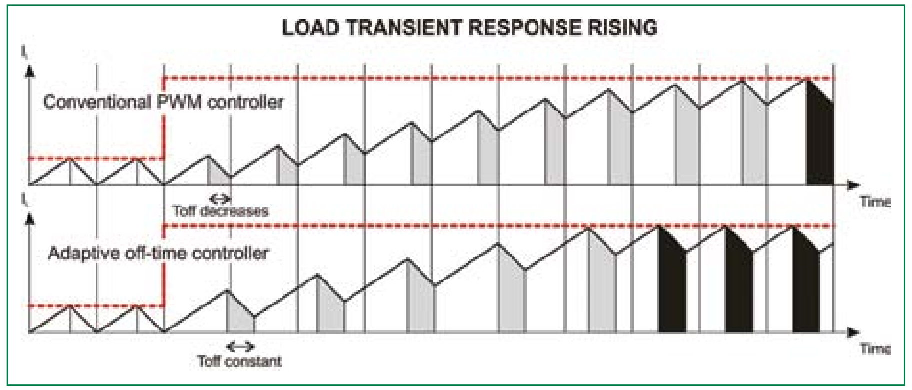

Figure 3: Theoretical load transient response comparison.

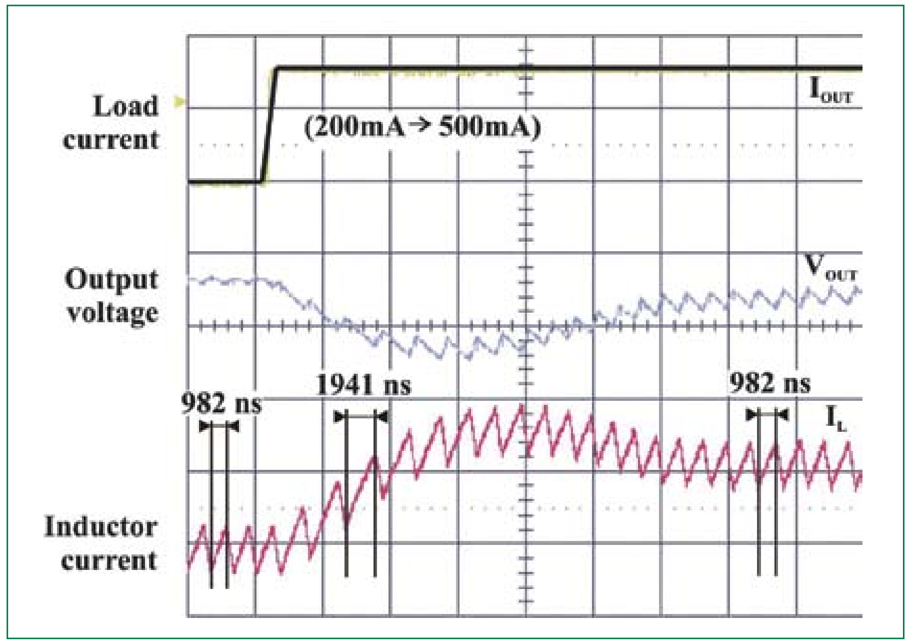

Figure 4: TPS61087's load transient response.

deteriorates the load and line transient responses because it has to be designed for the worst case application and therefore attenuates the modulator gain. This penalizes the system for most of the applications which are not the worst cases. With the adaptive off-time topology and the absence of such a ramp, the gain is increased at its best case and the current-mode-control loop can be designed with better response. The slight frequency variations have then some benefits since a longer/shorter on-time is permitted without changing the off-time duration.

Figure 3, compares the load transient response between a conventional Peak Current Mode Controller and a Adaptive Off-time Current Mode controller. The regulation level (red dashed line) is reached faster with the latter.

Figure 4 shows how the on-time duration increases while responding to a change in output load in order to regulate the output voltage as fast as possible. The frequency during steady state is fixed to approximately 630kHz, and it goes down to nearly 390 kHz during transient state. The off-time remains constant during the entire operation. To respond to a drop in output load, the on-time decreases so long that too much energy is provided to the output. Similar responses occur during line transient as well.

Where conventional converters' gain is internally limited for stability reasons, and the switching frequency is fixed, TPS61087 takes full advantage of its topology to offer a flexible system that respond at best to the external perturbations.

Comparison with a standard current-mode control step-up converter

Figure 5 shows the load transient response of Texas Instruments' TPS61087 compared to a pin-to-pin compatible device using conventional PWM scheme. Both parts are evaluated under the same conditions with a standard application. They are externally compensated accordingly to what stipulates the datasheet in such conditions.

As a result, TPS61087's response to a sudden output load change is much faster than the one of the conventional step-up converter. Closed loop measurements show that TPS61087 has in this application a bandwidth of 25kHz with a phase margin of 52° where the other part can only provide a 6.6kHz bandwidth for a 35° phase margin.

A cost-effective topology

Thanks to its fast response in transient behavior, the TPS61087 will also provide excellent performances shows the load transient response of the TPS61087 with C_{OUT} = 20µF only, half of the capacitance even while using smaller output capacitance.

The figure 6 used for the figure 5 measurements. The overshoot and settling time is still comparable to the one of a conventional step-up converter, even though the output capacitor is reduced by a factor of two. Therefore, regarding performances, using a 20µF output capacitor with the adaptive off-time equals the use of two 2µF output capacitors

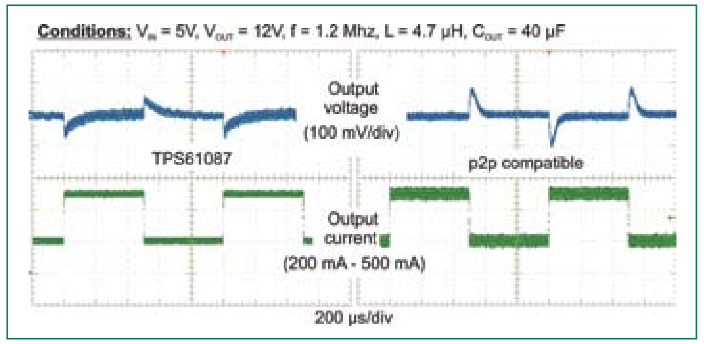

Figure 5: Load transient response comparison with C_{OUT} = 40µF.

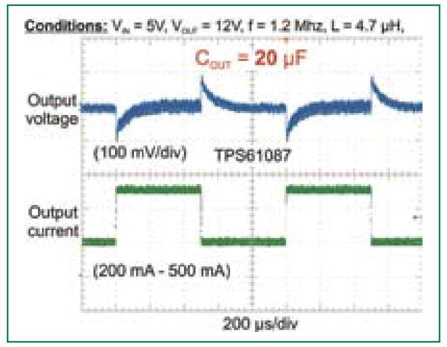

Figure 6: TPS61087's load transient response with C_{OUT} = 20µF.

with standard step-up converters running with current mode controller. The output voltage ripple remains lower than 30Vpp at full load and the BOM cost is reduced by at least $0.03.

Adaptive off-time helps reducing EMI emissions

Because of its inherent characteristics, making the adaptive off-time a very flexible controller, a slight jitter is added to the switching frequency of the converter, mainly due to the absence of oscillator. This jitter has the benefit of spreading over several frequencies the energy of the switching frequency. The level of EMI (Electromagnetic Interference) is thus not concentrated on one frequency anymore. It is distributed around the fundamental frequency and its harmonics, reducing the peak level while emitting the same overall energy. Together with an optimized turn-on time, the TPS61087's adaptive off-time provides over a wide frequency spectrum an important reduction of EMI as shown in Figure 7. The maximum EMI peak level is 11dB lower than the conventional step-up converter while the largest difference can go as high as 25dB.

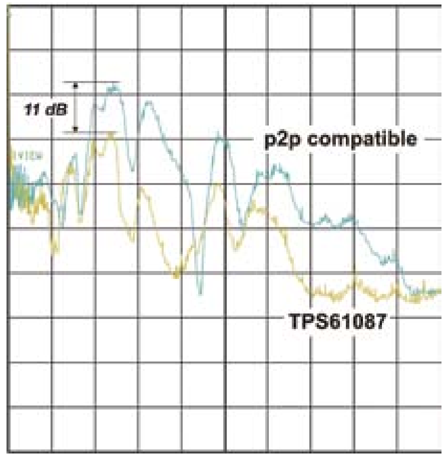

Figure 7: TPS61087's EMI vs. Standard step-up converter controller scheme.

Conclusion

Current-mode-control step-up converters like TPS6108-5 and -7 using adaptive, off-time topology provide superior stability and transient performances over a larger range of applications than conventional controllers. The EMI emissions are attenuated and beside these excellent performances this novel architecture allows also the user to reduce the component count, thus the total solution cost. The TPS61085/7 products are very competitive in performances as in price. Designing the IC in a specific application can easily be achieved using the Texas Instruments' online design tool 'SwitcherPro' available at www.ti.com/analogelab.

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Powering Communications

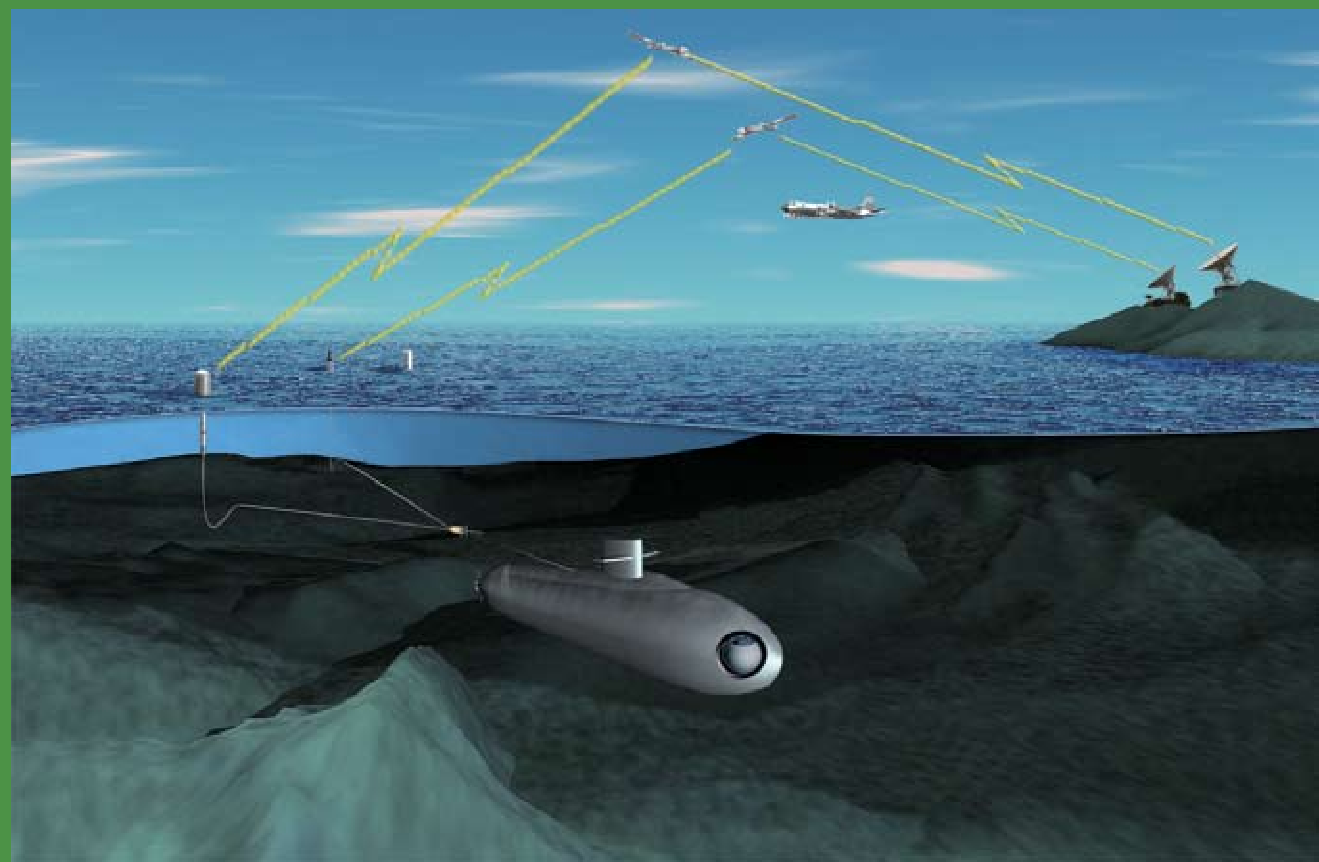


Image courtesy of Lockheed Martin

Powering Airport Comms

Chloride UPS keeps Heathrow connected

BAA recently completed an ambitious five-year programme to integrate Heathrow airport's voice and data infrastructure and applications into a single Internet Protocol (IP) network. At Heathrow, 471,000 aircraft movements are co-ordinated with the movement of 1.25 million tonnes of cargo and 67.3 million people annually, helped on their way by 70,000 staff. Critical to the safe operation of virtually every aspect of this vast logistical operation, from aircraft movements to retail and emergency response, is Heathrow's data and voice infrastructure.

Reported by Cliff Keys, Editor in Chief, Power Systems Design Europe

Andrew Clarke, BAA's Network Projects Project Manager, and Will Barrell, BAA's Infrastructure Project Manager, were in charge of the installation of the new data networks and voice solutions at Heathrow and, critically, to ensure that the new IP Telephony (IPT) networks were not vulnerable to power failures or any single point of failure. This necessitated the selection, design and integration of a robust Uninterruptible Power Supply (UPS) to support new IPT hardware in Heathrow's communications rooms, which is designed to permit the interface of 2,000 legacy handsets and devices with the new network.

"The new voice solution for Heathrow covers not just BAA locations but all the airlines, retailers, government agencies and anyone that uses any of about 600 airport phone handsets at Heathrow," explains Clarke. "The challenge for BAA was to design and integrate an IPT system that would be fail-safe in the event of power failures and could be rolled out without interrupting any services within the time and practical constraints of an airport environment."

Heathrow's existing voice infrastructure comprised of a telephone system

that ran on copper wires going back to switches, which was supported by its own battery backup system. In addition, data cabling went back to data communications rooms which provided the physical infrastructure for the LAN, all the PCs and applications on the network. Explains Clarke, "In order to dispense with a lot of the copper infrastructure we needed to turn all of the airport's telephony into another application that would sit on our network."

Powering communications: the design challenge

The equipment installed to run the new IPT system is Cisco's VG 224 voice solution, a 24-way switchport, which must be protected in the event of power failure. The system is vital to BAA as it allows existing endpoint telephone architecture such as handsets, fax and modem based devices, EPOS and emergency networks, to be integrated into the IP network. The complete system had to be free from any single point of failure, able to switch seamlessly between two redundant power supplies and be capable of running at full capacity on battery power for three hours.

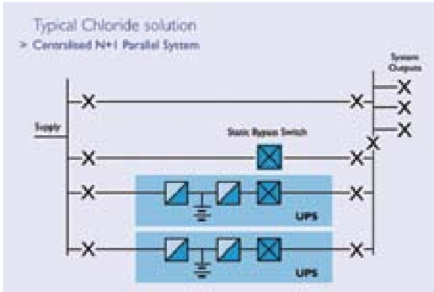
"BAA's in-house design team conducted a rigorous and objective technical evaluation of various products across the market," explains Barrell. "We found that Chloride's Active single-phase UPS was the best fit UPS solution. In addition to meeting our requirements in terms of power rating and reliability, it is rack mountable and supportable by dual power supplies - so if we lose one or both power distribution boards the IPT network will stay up regardless and can be remotely monitored so we know the power availability at all times."

It was an added bonus that the supply and service of the UPS could be integrated within existing contracts, with a supplier that was both familiar with and responsive to the particular demands of the airport environment. This factor proved to be critical to the eventual success of the project.

"Chloride is currently a member of the airport community, and is by far the largest UPS provider at Heathrow," comments Barrell. "We already had Chloride batteries, maintenance and warranty agreements. Despite this, we took an exhaustive look at the best-fit technical solutions available to us, and of these, Chloride's 3000VA Active single-phase UPS gave us both the best performance and the capabilities we needed."

The solution

Chloride's new single-phase Active 3000VA UPS system has been installed in phases as each stage of the IPT network has been rolled out. The UPS



systems now provide backup power and surge protection at ten critical points on site. These are located in communications rooms where 2000 analogue inputs, including Heathrow's emergency telephones, fax, modems and EPOS systems, interface with the IP network. In addition, Chloride's Automatic Transfer Switches have been installed at each point, so the UPS system will be able to switch seamlessly between two redundant 16 Amp electrical supplies, providing three hours of backup, should all external power be cut off. At each location, two Active 3000VA single-phase UPS systems are installed in a parallel 'N+1' configuration, a setup that was subject to rigorous testing and evaluation by BAA during the procurement and design phases.

Rigorous testing

It was essential that the correct equipment and designs were selected. Accordingly, a rigorous and objective process was adopted to ensure that the equipment was the best technical fit for the application and that it was in practice both up to the job and free from single points of failure.

Testing was undertaken at Heathrow's own facility and comprised the simulation of a variety of load scenarios, up to and including that of a full emergency, with the network at full capacity. At various stages power failures of different kinds were introduced, and the equipment was required to switch seamlessly between each of the redundant power supplies, in addition to the battery backup.

"We were particularly pleased both with the input from Chloride at this stage, and with the capabilities of the UPS system, which significantly outperformed its advertised capability," notes Clarke. "Chloride's batteries, for example, delivered the required level of backup power for a full half an hour longer than the three hours specified by BAA."

"This level of insight into the real world capabilities of our systems was crucial to the success of the project," he continues. "BAA and its deployment partner (2e2) confirmed that Chloride's design was the most efficient way to achieve high density analogue connectivity with resilient power backup. Chloride helped

Andrew Clarke and William Barrell, Infrastructure Project manager, pictured with Chloride's Active UPS. Deployed across ten communications rooms to support the IPT deployment, Chloride's Active 3000VA is installed in standard cabinets with MODBUS and SNMP cards, to ensure that voice communications are not lost in the event of power failures. Testing showed that the Chloride batteries will support the system at full load for 30% longer than the designed specification.

us to identify and eliminate single points of failure and, when we needed it, always provided a senior engineer to assist us."

A Chloride SNMP UPS controller card is also installed and currently on trial following testing and evaluation. Integrated alongside MODBUS systems, the controller card enables the full integration of the UPS equipment with the network, and allows the remote interrogation and management of the UPS system on all aspects of its function.

Project design: the right partner

Due to the complexity and unique demands of the project, it was important that Chloride could provide BAA with the necessary design, technical and project management input at each stage. At the testing stage, for example, limited laboratory time was a major challenge, and Chloride was able to provide answers to BAA's questions as soon as they arose.

Barrell explains, "We had a tight testing window of just a month to work with the solution in our laboratories. Fortunately, we were able to complete all testing with the aid of Paul Lyons, Chloride's Low-Power Technical Manager, who came on site at short notice whenever he was needed, at various times in the morning, afternoon and evening."

The IPT and UPS rollout was particularly demanding from a project management point of view. It had to be designed and implemented in such a way that it would go live in phases without any downtime across the communications network. Not only was laboratory time limited, but time windows for work on the data rooms were also constrained, and contractors had to work around time-consuming airside security procedures, often at short notice.

"Chloride brought additional value to this project through its responsiveness and ability to turn things round very quickly. It sent us engineers at short notice, all of whom had the right level of knowledge and resources," says Barrell.

Flying high

The final phase of the migration project has now been completed. Clarke and Barrell are pleased - both with the integration of the IPT project and with the level of its power protection. BAA has secured direct savings of over two million pounds per year and, as well as providing more handsets, will in future be able to benefit from a full range of third generation telephony services, such as the integration of email and voice mail and diversion to mobile devices. Critically these services now enjoy robust power protection.

"It was a seamless transition that went very well," concludes Clarke. "Chloride helped us to achieve this on time and on budget. We haven't turned off any services or disrupted our users. We were responsible for pulling the final design together, testing, authorisation and installation, and we have received excellent feedback from the operational teams who support and maintain it. Our operational engineers have been very appreciative of the professionalism of the Chloride UPS solution and the rigorous design. It has proved to be the ideal solution for meeting all our requirements within the technical constraints of the airport environment and has been a great success."

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Special Report – Powering Communications

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Special Report – Powering Communications

Hybrid Solar Solution Powers Wireless Network

South Pacific expansion augments diesel generators

An installed network installation of 35 microwave towers reduces costs and delivers high bandwidth for its customers, but many are in remote locations with no grid power. A hybrid solar system provides cost effective alternative to dependence on diesel generators.

By Morten Schoyen, CMO, Eltek Valere

In the telecommunication industry's move toward advanced power solutions, solar technology has been a late entry to the market, since it can be difficult to fully leverage and only makes economic sense in areas with very sunny weather and limited or difficult access to grid power. However, hybrid solar applications – where a solar panel array is augmented by diesel generators or grid power – are emerging as a way to leverage the power of the sun cost-effectively while still maintaining power reliability.

Roughly analogous to the gas-electric combination of hybrid vehicles, the solar-diesel hybrid power solution for telco is one of the most feasible alternative energy options to emerge. A prime example of this implementation comes from one major carrier in the South Pacific.

In the case of this carrier, the normal issues associated with network implementation were compounded by the remote locations of its network sites and the lack of grid access. To deliver more bandwidth and to better serve its customers, this carrier put in place a new wireless backhaul network across the rugged heart of the country where there are few roads and no grid power. A hybrid solar-generator power infrastructure helped the company make this network a cost-effective reality.

This carrier was faced with the challenge of migrating from a satellite transmission-based wireless backhaul network to a terrestrial backhaul network based on microwave towers at remote sites. These towers had to span across a spine of mountains running the length of the island that were covered with extensive dense rain forests. Across this landscape, the carrier needed to build a 35-tower high capacity microwave network to send signals across the country from North to South. Many of the tower sites are accessible only by helicopter.

Until the network build out, the company's backbone connections had mostly been through satellite transmission. The new network would expand bandwidth dramatically and lower costs. Initially, it had installed large battery plants in each location with diesel generators (gen-sets) to charge the batteries. Every month, a helicopter fuel run would refill the 2,000-liter tanks of these generators to ensure that network power was uninterrupted.

The economics of this solution led the carrier to consider how it could reduce the cost of charging these batteries. The 10-kilowatt hour (kWh) generators were running continuously, but only at 20% of load providing 0.5-kilowatt hours (kWh) per liter. This low utilization made the power conversion extremely inefficient and drove the cost per kWh to around US$6 per based on diesel costs at the time.

The mostly hot and sunny weather across the country made it possible to put in an all-solar solution. However, there was significant weather variability with a large number of cloudy and stormy days in the winter, meaning the number of solar panels installed would need to provide enough power for the worst-case light situations. The company calculated that this would require twice the number of solar panels to provide the necessary electricity in the winter compared with the summer. The maximum payback came when they calculated the cost of a solar plant sized for the summer light conditions augmented by a diesel gen-set for less than ideal conditions.

Additionally, the generators could not be removed entirely from the sites because of a need for a back up power source to prevent network outages if any of the solar panels were damaged by tropical storms.

Hybrid solution delivers

The best option for this implementation was a hybrid solar/generator solution provided by Eltek Valere, which has leveraged its high-efficiency (HE), power conversion technology into the Flatpack2 HE Solar Charger. The solar charger converts the AC from the solar panels into 48V DC for the telecom equipment.

With built-in maximum power point tracking (MPPT) technology, the charger can adjust its input to match the changing characteristics of the solar panels as the light levels increase and decrease during the day. This ability combined with HE technology ensures near 100% power utilization of available power. The charger solution also provides full galvanic isolation between solar panels and the telecom equip¬ment and batteries, protecting them from power surges.

This power system also used Flatpack2 rectifiers to convert the gen-set output into 48V DC power. These rectifiers sit in the same power shelf as the solar chargers, offering an integrated DC conversion solution for solar hybrid power systems. The Smartpack Controller, Eltek Valere's management and control system for the Flatpack product family manages the entire system. The Smartpack monitors battery power levels and input voltage levels from the solar system and knows when to charge from the solar system or from the diesel gen-set. When the power output from the solar panels starts to drop, for example, during a cloudy day or at dusk, the system switches over to the Flatpack2 rectifier and initiates the gen-set. Smartpack features also include advance battery monitoring routines, as well as gen-set optimization programs and considerable data log¬ging options.

Dramatic cost savings

The impact of this solution on this South Pacific carrier's network has been dramatic. The gen-sets have gone from continuous operation at low load and efficiency to being run only about four hours per day on average at 80%-90% efficiency. Other sources of cost decreases include reduced engine operating hours resulting in lower gen-set service and maintenance charges. All tolled, the solution has cut cost per kWh to US$1 in addition to reducing maintenance and fuel storage costs.

Whether they leverage grid power or diesel gen-sets, hybrid solar power solutions are ready to deliver a dramatic impact on network powering costs because they leverage the free power that comes from the sun to replace costly and environmentally unfavorable options. For this Oceanic regional carrier, that impact was a more cost-effective wireless backhaul network that can help the company better serve its customers living in remote locations off the grid.

www.eltekvalere.com

Efficient, Super-Wide Input DC-DC Converters

A two-stage approach

One of the parameters of an isolated DC-DC converter is the range of the input voltage over which the converter can operate. For the industry-standard "bricks" available for the nominal 48V input telecom marketplace, this range is usually 36V to 75V, or a ratio of about 2:1 from the highest to the lowest value. But there are many applications where a converter that can handle a much wider range of input voltage variation is desirable.

By Dr. Martin F. Schlecht – CEO, SynQor

In some systems the distributed input voltage has significant transients and surges that last too long to be removed by a filter. As an example, Table 1 shows the steady state and transient range of the distribution voltage that might be seen in various railway systems, as specified by the various agencies listed.

Military and vehicle specifications have a similarly wide range over which their distribution voltages may vary. Another reason for using a DC-DC converter that can operate over a wide input voltage range is to create a "universal" product that can be used in different DC systems. Instead of having to produce three different versions of a product to work off a nominal 36V, 48V, and 72V bus, a converter that could operate from 18V to 135V would permit a single solution, saving manufacturing costs and reducing inventory.

However desirable it might be to have a wide input converter, there is a major problem: in traditional products, the wider you make the operational input voltage range, the worse you make the converter's performance. Generally, both the converter's efficiency and the amount of power it can handle in a given size – such as a quarter-brick- is reduced. This is the natural consequence of having to design for the highest input voltage while at the same time needing to handle the very large input current that results when the input voltage is at its lowest. For a converter that handles a 2:1 input range, the product of this maximum voltage and maximum current is twice that of the power being processed - a penalty, but one that can be accepted as a reasonable compromise. But in the case of a converter designed to handle an 8:1 input voltage range, the product is now eight times the processed power, and the penalty is extreme. This is most severely felt by the power circuitry associated with the isolation transformer of the converter.

Due to the aforementioned limitations, there are not many DC-DC converters commercially available to handle very wide range input voltages. The few "ultra-wide" 4:1 input ratio converters that are available typically process less than one half the power in a given physical size compared to their counterparts that handle only a 2:1 input voltage range. In addition, their efficiencies are typically 10%-25% lower than 2:1 units.

One way to mitigate this loss in performance in wide input range converters is to separate the converter's "regulation" function from its "isolation" function, as shown in Fig.1. Here, the first stage of the converter is a non-isolated "down converter" that provides regulation by varying its duty cycle. The second stage then provides electrical isolation (and typically a further step-down according to the turns-ratio of the transformer) without any further regulation. This is how SynQor – a leading pioneer in highly efficient DC-DC converters – designs all its products.

	EN50155 Standard		NF F 01-510 Standard		RIA12 Standard	
Nom. Input	Continuous Range	Transient Range	Continuous Range	Transient Range	Continuous Range	Transient Range
12V	16.6V – 30V	14.4V – 33.6V	18V – 34V	12V – 40V	16.6V – 30V	14.4V – 84V
72V	50.4V – 90V	43.2V – 101V	50V – 90V	36V – 115V	50.4V – 90V	43.2V – 252V
110V	77V – 137.5V	66V – 154V	77V – 137V	55V – 176V	77V – 137.5V	66V – 385V

Table 1: Specifications of the input voltage range found in several Railway Standards.

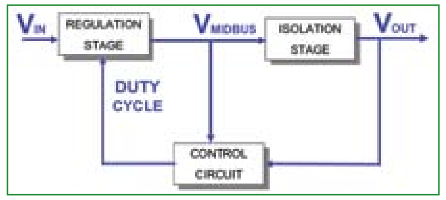

Figure 1: SynQor's two-stage DC-DC converter topology in which a non-isolated regulation stage precedes the non-regulating isolation stage.

SynQor's InQor™ Half-Brick *Peta* Family

$2:1V_{IN}$	$4:1V_{IN}$		$8:1V_{IN}$		
IQ12 Input Range: 9-25V Max. Power: 182W Eff. @ 3.3V: 87%	IQ18 Input Range: 9-40V Max. Power: 182W Eff. @ 3.3V: 86%	IQ36 Input Range 18-75V Max. Power 220W Eff. @ 3.3V: 89%	IQ32 Input Range: 9-75V Max. Power: 200W Eff. @ 3.3V: 83%	IQ64 Input Range: 18-135V Max. Power: 200W Eff. @ 3.3V: 86%	IQ90 Input Range: 34-160V Max. Power: 228W Eff. @ 3.3V: 89%
IQ24 Input Range: 18-50V Max. Power: 225W Eff. @ 3.3V: 89%	IQ70 Input Range: 34-135V Max. Power: 240W Eff. @ 3.3V: 88%				
IQ48 Input Range: 34-75V Max. Power: 255W Eff. @ 3.3V: 89%					
IQ72 Input Range: 42-110V Max. Power: 225W Eff. @ 3.3V: 89%					
IQ1B Input Range: 66-160V Max. Power: 225W Eff. @ 3.3V: 89%					
IQ4H Input Range: 180-425V Max. Power: 300W Eff. @ 3.3V: 87%					

Table 2: SynQor's new InQor product family showing power level and efficiency as a function of nominal input voltage and input voltage range.

Figure 2: SynQor's new IQ64 family of ruggedized half-bricks handles an 8:1 input voltage range.

The advantage of this two-stage design is that only the first stage sees the wide range of the input voltage. While a penalty for the wide range must be paid for by this first stage, it is not so severe because the first stage does not require an isolation transformer. The isolation stage, which does have the transformer, never experiences the wide input voltage range. In this two-stage design, the input voltage - the mid-bus voltage of the two-stage approach - is always constant. This permits the isolation stage to be optimized for a single operating condition, and it makes it much easier to implement a design based on synchronous rectifiers, which greatly reduces losses. The resulting increase of efficiency in the isolation stage goes a long way toward making up for any additional losses that occur in the regulation stage.

Figure 2 shows SynQor's new IQ64 half-brick DC-DC converter with the super-wide 8:1 input range. The matrix in Table 2 shows the InQor converters and the various input voltage ranges for which they are designed.

As can be seen, besides the normal 2:1 input ranges, there are products for 4:1 and even 8:1 ranges. The maximum power levels and typical efficiency for a 3.3V output version are also shown in the figure. Although there is some reduction in power and efficiency as the input voltage range widens, it is not very significant. This is the result of the two-stage approach to the power circuit design.

In addition to handling the various input voltage ranges required, the SynQor line of InQor DC-DC converters are fully encased and ruggedized to handle the harsh environments that often accompany systems that have such challenging technical requirements.

www.synqor.com

Flexible Sequencing

Multiple rail pre-biased load applications

Most large embedded systems are powered from a 48V input that is routed through the backplane to each PC card within the system and is commonly referred to as a distributed power system. The 48V is stepped down to a lower voltage via an isolated intermediate bus converter (IBC) usually in the range of 5V to 12V. This intermediate bus output voltage then needs to be stepped down again for sub-circuits and ICs on the boards which require voltages ranging from 0.8V and up at currents from tens of milliamps to tens of amps. These are referred to as point-of-load (POL) regulators.

By Bruce Haug, Product Marketing Engineer, Power Products and Johan Strydom, Ph.D., Senior Applications Engineer, Power Products, Linear Technology Corporation.

Distributed power systems typically incorporate microprocessors and digital signal processors (DSPs) that need a core power supply and an input/output (I/O) power supply which must be sequenced during start-up and shut-down. Designers have to consider the relative voltage and timing of core and I/O voltage supplies during power-up and -down to comply with manufacturers specifications. Without proper power supply sequencing, latch-up or excessive current draw may occur that could lead to damage to the microprocessor's I/O ports or the I/O ports of a supporting device such as memory, programmable logic devices (PLDs), field programmable gate arrays (FPGAs), or data converters. To ensure that the I/O loads are not driven until the core voltage is properly biased, tracking of the core supply voltage and the I/O supply voltage is necessary.

Certain processors demand that their I/O voltage rise before their core voltage, while certain DSPs require their core voltage to rise before their I/Os. Power down sequencing is also required. Application specific integrated circuits (ASICs) with up to 7 input voltage rails to sequence are common place. An ideal sequencer would allow arbitrary sequencing of any rail in the system and allow any rail to depend on any other rail. A dependency is established between these rails, such that if one of them does not come up to its full voltage during the power-up sequence, the sequence aborts. In addition, FPGAs, PLDs, DSPs and microprocessors typically have diodes placed between the core and I/O supplies as a component for electrostatic discharge (ESD) protection. These internal diodes can be destroyed when powering up or powering down if the input voltages are left uncontrolled or if the power source is unable to power a pre-biased load.

A pre-biased load is one in which a voltage has already been applied to it and can be in the form of a steady state voltage or a voltage in transition from powering-up or powering-down. An ASIC is a good example of an IC that could be pre-biased. Generally an ASIC will need multiple voltage rails to operate e.g. 1.0V, 1.1V, 1.2V, 1.8V, 2.5V and 3.3V; and have a diode between each of these rails within the ASIC for its own internal protection by not allowing certain voltages to be no more than a diode drop difference in potential. When powering up or down a condition can exist where the voltage between two of the rails can be much higher than the diode drop within the ASIC causing high currents to flow and result in diode failure. This high current can flow back into the DC/DC converter synchronous MOSFET and normally happens either during power-up or power-down. This problem can be prevented by using a DC/DC converter that will not allow a negative current to flow in the output inductor during turn-on or turn-off, which requires a DC/DC converter to operate in Burst Mode® operation or discontinuous conduction mode when powering up or down.

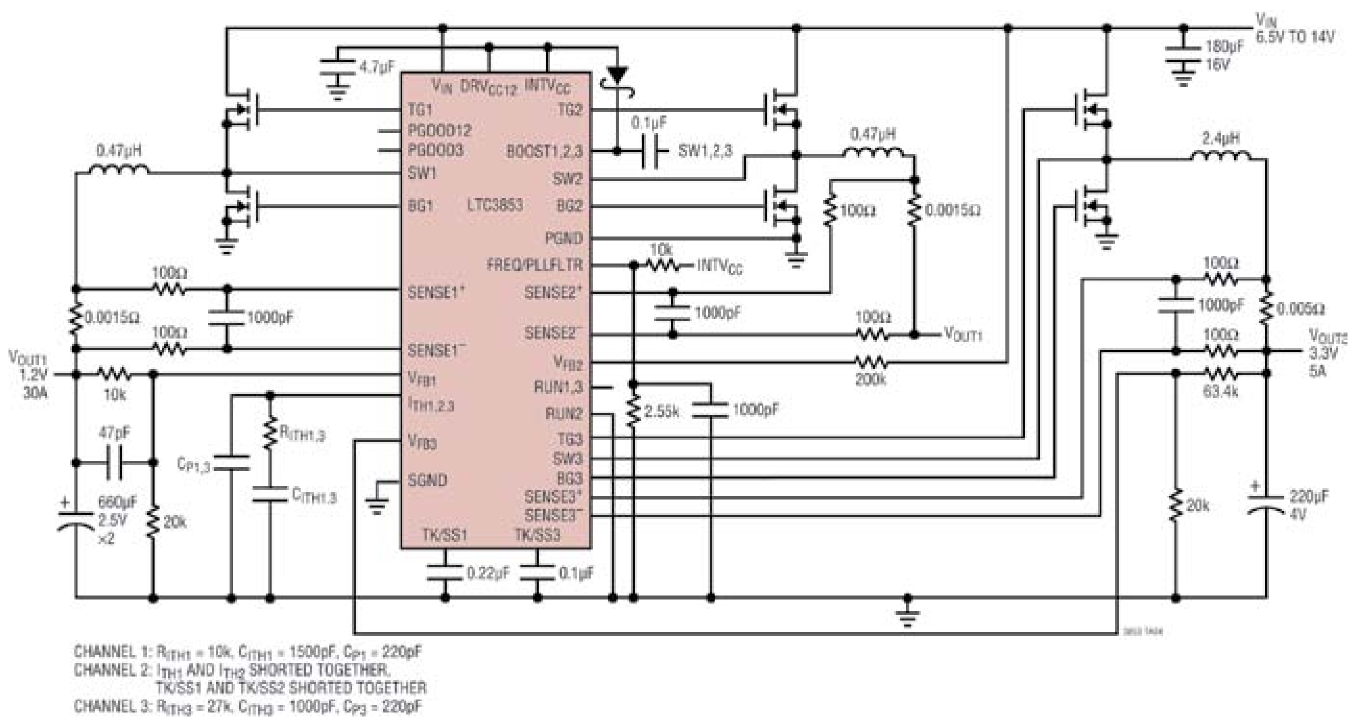

Figure 1: LTC3853 high efficiency dual output 1.2V/30A, 3.3V/5A schematic.

New solution to an old problem

Linear Technology's DC/DC converters can safely power pre-biased loads and the recently released LTC3853 triple output, multiphase synchronous DC/DC controller is one of the devices. The LTC3853 is a high efficiency, triple output synchronous step-down switching regulator controller with coincident or ratiometric tracking. Supply sequencing is easy to implement with accurate run thresholds and two power good outputs. It's 4.5V to 24V (28V Max.) input range encompasses a wide variety of applications including most intermediate bus voltages. The strong on-board gate drivers power all N-channel MOSFET stages and can produce output currents in excess of 20A per phase with output voltages ranging from 0.8V to 13.5V on one channel and from 0.8V to 5.5V on the other two channels. A constant frequency architecture allows a selectable fixed or synchronizable phase-lock-looped (PLL) frequency from 250kHz to 750kHz.

The LTC3853 can be configured for three individual outputs and can also be configured as a 2+1 controller, where 2 of the outputs can be paralleled with channels 1 and 2 tied together and channel 3 being an independent output. Power loss and supply noise are also minimized by operating the three stages 120° out-of-phase. When configured as a 2+1 controller, channels 1 and 2 are 180° out-of-phase to keep the input current optimally balanced when there is one high current output and one low current output.

Dual output converter with 2+1 operation

Figure 1 shows the schematic of a 2-output converter working from a 6.5V to 14V input. Channels 1 and 2 feed the

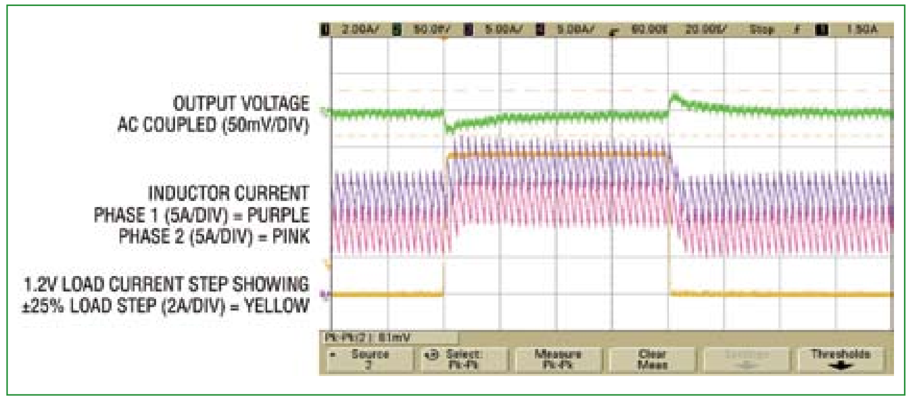

Figure 2: Post-Package trimming of the LTC3853's current sense comparators provides excellent current sharing between channels 1 and 2 when paralleled, even during a 75%-100% load step.

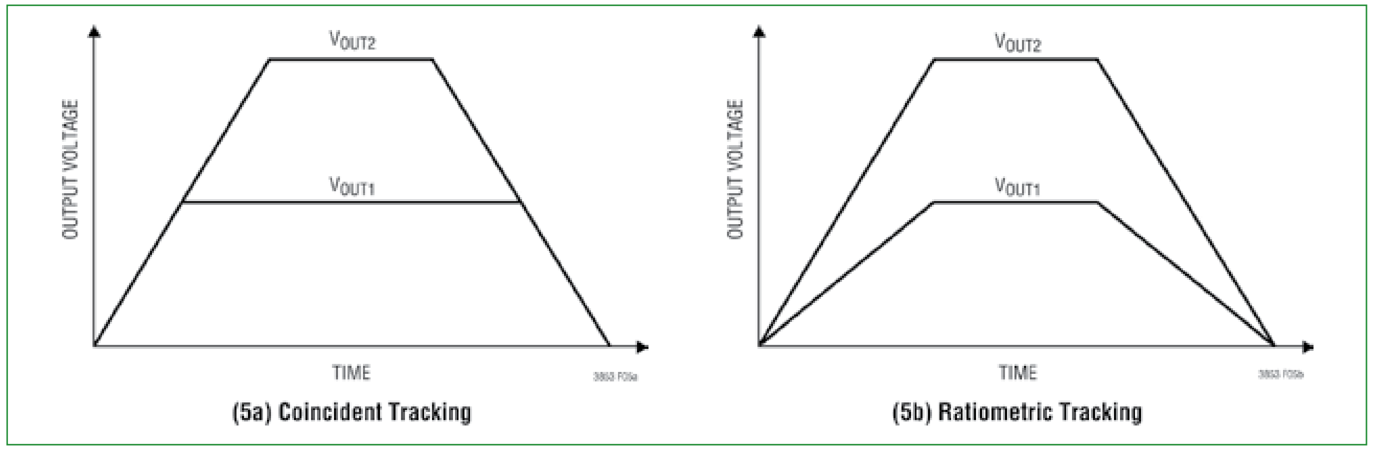

Figure 3: LTC3853 output voltage tracking curves.

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same 1.2V output, while channel 3 controls a second 3.3V output. This 2+1 configuration requires just one RUN pin (RUN1) to enable both channels 1 and 2. The feedback error amplifier of channel 2 is disabled and both share channel 1's feedback divider. Post package trimming of the current sense comparators provides excellent current sharing between channels 1 and 2. This is illustrated in figure 2, where the inductor current of each channel is shown for a +/-25% load step yielding an output voltage transient of about 63mVpp, less than +/-3%.

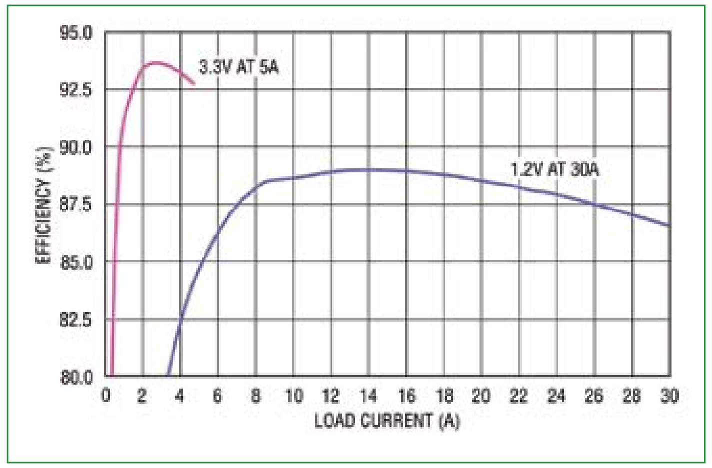

Figure 4: LTC3853 high efficiency dual output 1.2V/30A, 3.3V/5A efficiency results for 12Vin.

Soft start or tracking

The LTC3853 output voltages can be configured for programmable soft start or can be set up to track the output voltage of another channel or an external supply voltage with any of its 3 output voltages independently. When an output voltage is configured to soft-start, a capacitor needs to be connected to its TK/SS pin. This same TK/SS pin allows the user to program how its output ramps up and down with respect to another output voltage. Through these pins, the output can be set up for either coincident or ratiometrical tracking of its own voltages or another supply's output. These ramp curves are shown below in figure 3. When tracking another output voltage the soft start capacitor is removed. To implement ratiometric tracking, the same resistor divider network used for the output voltage feedback signal is tied to the appropriate TK/SS pin to track that output. To implement coincident tracking, connect an additional resistive divider to VOUT1 and then connecting its midpoint to the TK/SS pin of the slave channel accomplishes this. The ratio of this divider should be the same as that of the slave channel's feedback divider.

Nevertheless, the question arises as to which mode should be programmed? While either mode satisfies most practical applications, there are some tradeoffs. The ratiometric mode saves a pair of resistors, but the coincident mode offers better output regulation.

Operating modes

The LTC3853 can be set to operate in one of three modes under light load conditions, Burst Mode operation, pulse-skipping or continuous operation. Burst Mode operation offers the highest efficiency by switching in a burst of one to several pulses replenishing the charge stored in the output capacitors, followed by a long sleep period when the load current is supplied by the output capacitors. Forced continuous mode offers fixed frequency operation from no load to full load, providing lower output voltage ripple at the cost of lower light load efficiency. Pulse-skipping mode operates by preventing inductor current reversal by turning off the synchronous switch as needed. Pulse-skipping is a compromise between these other two modes, offering lowest ripple and better light load efficiency than forced continuous mode, but not constant frequency operation. Regardless of the mode, the LTC3853 operates in constant frequency at higher load currents. During start-up and shut-down the LTC3853 defaults to pulse-skipping mode and does not allow negative currents in the output inductor.

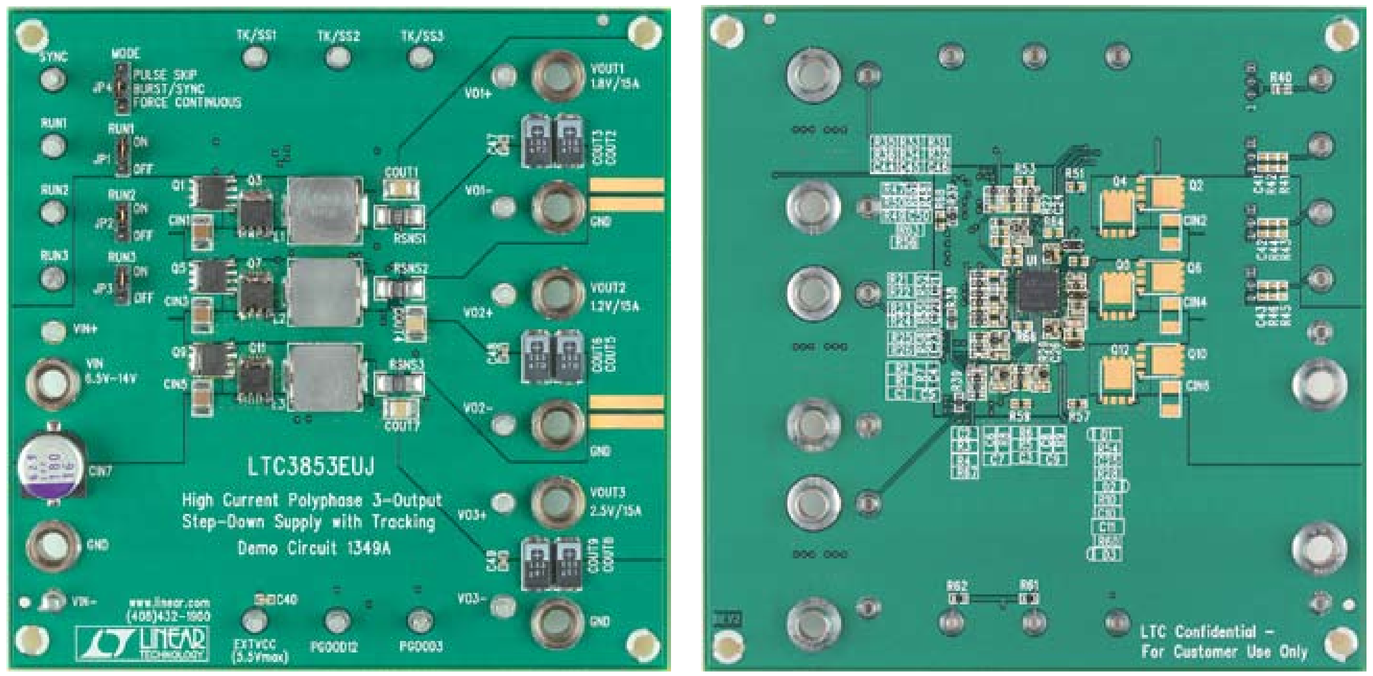

Figure 5: Front and rear views of LTC3853 demonstration board with 15A per channel outputs.

Multiphase operation

Multiphase is a general term for topologies where a single input is processed by two or more converters, where the converters are run synchronously with each other but in different locked phases. This approach reduces the input ripple current, the output ripple voltage and the overall Radio Frequency Interference (RFI) signature while allowing high current single outputs, or multiple lower current outputs with fully regulated output voltages. It also allows smaller external components to be used when multiple phases are paralleled for high power requirements and has the added benefit of improved thermal management.

Additional features

The LTC3853 has true current mode control that enables stable operation over a wide range of output capacitance and ESR values, including all ceramic input and output capacitors for the smallest solution size. Output current sensing is accomplished by measuring the voltage drop across the output inductor (DCR) or by using an optional sense resistor. Over current foldback limits MOSFET heat dissipation during short-circuit and overload conditions. The LTC3853 also features a precision 0.8V reference with an accuracy of ±1% over a -40°C to 125°C operating temperature range. With up to 98% duty cycle, the LTC3853 has a very low drop-out voltage, a useful feature for extending run times in battery-powered applications.

Since space and cooling are at a premium in distributed power systems, it is very important for any POL converters to be both compact and efficient. Figure 4 shows the efficiency of the circuit in figure 1, whereas figure 5 shows a picture of the 15A/channel LTC3853 demonstration board in an all ceramic capacitor configuration.

Conclusion

The number of voltage rails continues to grow in embedded distributed power systems which are needed to power a wide variety of ASICs, DSPs, PLDs, FPGAs and microprocessors. It is critical that the POL DC/DC converters powering these devices are compact, efficient and are able to start-up and shut-down in such a way such that none of these voltages are discharged through the power supply's synchronous rectifier and are able to power a pre-biased load. In addition, the voltage ramp-up and ramp-down needs to be controlled to ensure that the devices being powered do not latch-off or draw excessive current. Linear Technology's has a family of DC/DC controllers, monolithic switching regulators and µModule DC/DC converters which are easily programmed to track any number of voltage rails, most of which will not discharge a pre-biased load during power-up and power-down. The LTC3853 is triple output synchronous buck DC/DC controller that can be easily set-up to sequence or track any number of voltage rails and allows two of its output to be parallel in a 2+1 configuration for high current applications.

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2009 GreenPower Leadership Awards

Winners and Finalists Announced at PCIM Europe

For the past year the readers of Power Systems Design Europe have been voting for the best editorial contribution in the area of "energy efficiency". The 2009 GreenPower Leadership Awards program has been made possible by the financial contributions of our two Gold Sponsors: Intersil and Linear Technology.

The Winner is: Company: Fairchild Semiconductor, Article: "Solar Power Shines", Author: Alfred Hesener.

The four finalists (in alphabetical order by company) are: Company: Coilcraft, Article: "Designing for Efficiency at the Component Level", Author: Len Crane • Company: Linear Technology, Article: "Solving Current Source Design Challenges", Author: Robert Dobkin • Company: Microsemi, Article: "SiC Impacts 'Greening' of Power", Authors: Philip C. Zuk & Bruce Odekirk • Company: Philips Lumileds, Article: "Avoiding Current Spikes with LEDs", Author: Pat Goodman.

Educational Donation. A significant component of the *2009 GreenPower Leadership Awards* program is an educational donation, given to the European Engineering University of choice by the article author. This year's donation is awarded to: The Institute of Robotics at the University of Maribor, Maribor, Slovenia. The University conducts research on motion control solutions.

2010 GreenPower Leadership Awards. Voting has already begun for our expanded *2010 GreenPower Leadership Awards Program* and will continue through the April 2010 issue of Power Systems Design Europe. If you want to summit editorial content on "energy efficiency" to be judged for next years program, contact Cliff Keys, Editor-in-Chief, **cliff.keys@ powersystemsdesign.com** • For sponsorship opportunities, contact Julia Stocks, Publisher, **julia@powersystemsdesign.com.**

Engineering Lights the Way

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

The interest and use of lighting technology has accelerated over recent years with the steady move towards 'leaner and greener' light sources. There is still much to learn, and designers require solid data to commit a new product to mass production, particularly in sources such as those used for portable communications applications.

Philips Lumileds recently announced that it is to publicly publish LM-80 test report data for use by luminaire manufacturers evaluating the merits of using different LEDs in their solid-state lighting solutions. The LM-80 test reports adhere to and are published in accordance with the Illuminating Engineering Society (IES) LM-80-08 standard. The data clearly demonstrates that lumen maintenance performance exceeds ENERGY STAR® requirements by a wide margin as well as documenting lumen maintenance performance under various conditions. The test report is posted on the company's web site www.philipslumileds.com

OSRAM Opto Semiconductors has developed organic light emitting diode (OLED) prototypes as part of a research project. These are large transparent light sources only a few hundred micrometers thick. Due to new technology these OLEDs do not need separate encapsulation and can be made incredibly thin in any layout. The transparent test samples have a luminous area of $210cm^2$ and are already showing the enormous potential of OLED light sources. They offer a tantalizing glimpse of the extraordinary lighting applications that may one day become reality.

Even the 17 x $17cm^2$ OLED panels provide a clear indication of the direction that the OLED lighting market is taking. The demand is for large low-profile transparent light sources. With these samples OSRAM Opto Semiconductors has set an important milestone. The test samples were developed as part of the TOPAS research project funded by the Germany Ministry for Education and Research (BMBF). The aim of the project is to produce $1m^2$ large transparent OLED modules and will run until 2011.

Even though the modules will have to be made larger they already have many of the properties that distinguish OLEDs from other light sources. They are extremely slim and no longer need expensive encapsulation. Their thickness is now defined only by the substrate as the carrier material – at present this is between 300 and 700µm. Further development work will lead to an even thinner carrier material and therefore even thinner OLEDs. These low-profile OLED modules will be even easier to use in all kinds of applications. They can be made in any shape, take up very little space and can be integrated so discreetly that they are only noticed when they are switched on. The next stage is to integrate the processes into a stable manufacturing operation.

www.powersystemsdesign.com/greenpage.htm