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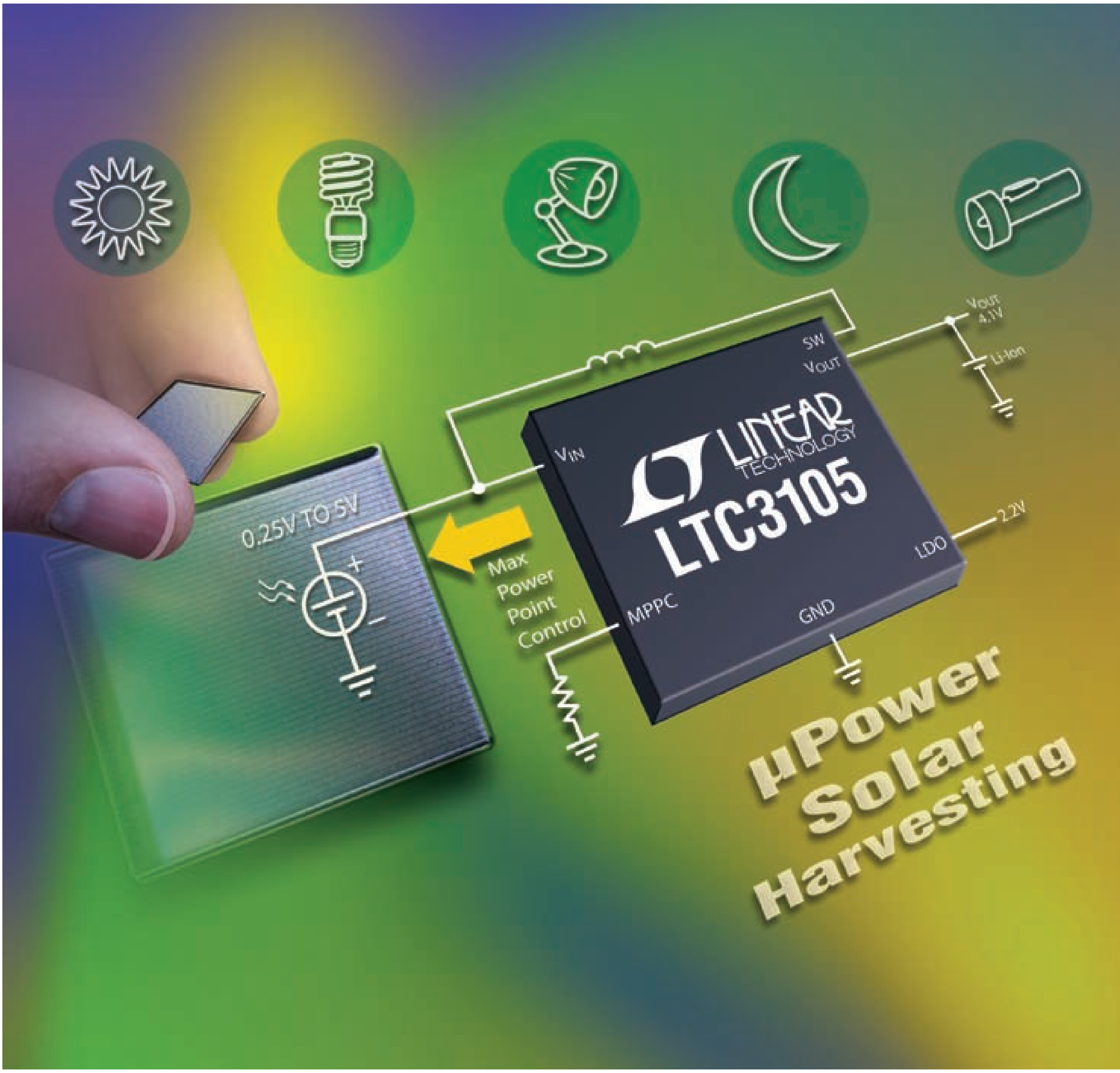
Power Systems Design: Empowering Global Innovation



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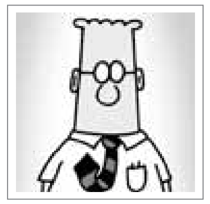

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AGS Media Group
146 Charles Street
Annapolis, MD 21401 USATel:
+410.295.0177
Fax: +510.217.3608
www.powersystemsdesign.com

Editor-in-Chief
Cliff Keys
cliff.keys@powersystemsdesign.com

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

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

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

David Morrison, How2Power
david@how2power.com

Publishing Director
Jim Graham
jim.graham@powersystemsdesign.com

Publisher
Julia Stocks
Julia.stocks@powersystemsdesign.com

Circulation Management
Kathryn Phillips
Kathryn.phillips@powersystemsdesign.com

Research Director
Meghan Corneal
Meghan.corneal@powersystemsdesign.com

Magazine Design
Louis C. Geiger
louis@agencyofrecord.com

Production Manager
Leo Jiang
leow@action-new.net

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Volume 7, Issue 8

HEALTHY BUSINESS

Welcome to this new and freshly designed special issue of PSDE in which we carry a feature on health, medical and mobility. We have taken your valuable feedback and completely redesigned the layout of our print magazines as well as a total redesign and rebuild of our website to give our power communities exactly what they have been asking us for. The feedback really works, and we would like to say a big 'thank you' to everyone supporting us by taking an active part in the development of this living power forum.

Power considerations in medical applications are a key factor in the success of many medical-related designs. With an ageing population and the need to reduce medical expenditure, many administrations and authorities are looking at distributed portable equipments to save on hospital admissions for routine tests and monitoring. Power, of course, is a vital consideration with the vast majority of products developed for these applications being dependent on battery power. Again, creative power engineers come to the rescue.

Although widely regarded in Europe as a growth area, it is reported that some US venture capitalists are holding back on the healthcare field as the level of venture capital decreases and regulatory hurdles increase due to an increasingly conservative and slow-moving US Food and Drug Administration. In Europe, the German government is providing matching funds for healthcare projects, Ireland recently launched a €3.75 billion investment program and China had more health care companies go public than the US last year.

The power discrete & module market is now set to regain much of its previous years' losses and will be worth $13.7 billion in 2010, increasing by 24.3% from 2009 according to IMS Research's latest report on the market. IMS forecasts discrete power semiconductors will account for almost 80% of the total market in 2010.

Discrete IGBTs, power MOSFETs and power rectifiers are predicted to register the highest growth rates. These levels could have been even higher, but limited available production capacity has resulted in the majority of power semiconductor suppliers supplying 'on allocation' only and shipping less than real demand would suggest.

The power module market is predicted to grow almost 30% in 2010 with standard IGBT modules and IPMs accounting for the major share of the expansion, especially in industrial motor drives, renewable energy inverters and hybrid and electric vehicles.

I hope you enjoy this new special issue. Please keep sending in the vital feedback: As you can see, it gives us the opportunity to continuously fine-tune and deliver what you need. And don't forget to check out our regular fun-site, Dilbert, at the back of the magazine. Smiling at adversities normally puts them into true perspective.

All the best,

Cliff Keys
Editor-in-Chief, Power Systems Design
Cliff.Keys@powersystemsdesign.com

LOW-NOISE CHOKES FOR CT SCANNERS

LSMP Sintermetalle Prometheus (SMP) has developed chokes for use in computed tomography. These inductive components are exceptionally quiet in operation as well as being low-loss and energy-efficient. This has been achieved with non-magnetostrictive materials that have been developed specially for use in medical equipment.

Computed tomography or CT is a medical imaging method that is used to generate a three-dimensional image of a part of the body from a series of two-dimensional X-ray images. The CT scanner generates a narrow X-ray beam that passes through the patient's body, where the rays are absorbed to varying degrees by the different areas of the body. A series of sensors arranged opposite the X-ray tube capture the X-rays, which are then transmitted to a computer where they are digitally processed. On the resulting CT images, doctors can clearly distinguish various tissue types, such as bones, muscle and organs. To minimize patients' exposure to the X-rays, modern CT scanners must operate at a very high speed, and be very accurate. The components used in the machine must therefore operate with these characteristics.

SMP has developed chokes for a well-known German manufacturer of CT scanners. The inductive components are installed in so-called gradient amplifiers, which supply output voltages and currents that are used to control the gradient coils. These encode the resonance signals for subsequent image reconstruction. The filter and mains chokes have the task of insuring a clean sinusoidal waveform within the gradient amplifiers and must insure a low-loss feedback of the unused energy.

A unique feature of these chokes is the non-magnetostrictive powder composites from which they are made. Developed by SMP specifically for this application, these materials allow the design of exceptionally low-noise chokes to minimize the humming noise that CT scanners generate during operation - noise which can be unsettling for the patient and make it difficult for medical personnel and patient to communicate over the intercom. During the scan the patient lays on a stretcher inside the scanner and the medical personnel leaves the room so as not to be frequently exposed to X-rays. To also minimize the burden the X-rays place on the patient's body, and the length of time for which the patient has to lie still in an enclosed and unfamiliar space, CT scanners must work quickly and efficiently. SMP's energy-efficient low-loss chokes provide the performance needed to meet these requirements, and their compact design saves space in the control cabinet, which is located immediately next to the scanner itself.

SMP choke developed for CT scanners

In addition to medical applications, SMP's chokes are used in photovoltaics, wind turbines and in railway engineering. For these and other applications in power electronics, power generation, and instrumentation and control, SMP supplies inductive components for frequencies up to 200kHz and current ratings up to 1000A. Depending on their application, they are constructed either as single-conductor chokes for high-current applications, single-phase individual chokes, three-phase choke modules, or LC filters. These components offer a high energy storage capacity in a compact and cost-conscious design as well as reduced losses and good EMC characteristics. SMP manufactures all components to customer specifications using in-house developed powder composites. All products are RoHS-and REACH-compliant and the materials used are UL-listed. To allow for a wide range of requirements, components can be made to all common international standards.

www.smp.de
www.westendorfassoc.com

POWERING HEALTHCARE

By Edmund Suckow

Portable medical electronic trends make it possible to reduce health care costs. Non-invasive battery-powered sensors are mobile and, when coupled with on-board memory, can capture a complete data pattern for a given symptom. Due to the continuous advances in ICs, these units are getting smaller, lasting longer, and therefore are more easily deployed in the field.

Compact battery technology has remained relatively unchanged over the last five years. Extending the life of these sensors has been a direct result of power supply design discipline and IC advances. Leveraging cell phone standards, these advances include: charging over USB, high efficiency DC/DC regulators, adoption of I/O standards (I2C, SPI, SDIO, etc), and display improvements.

Project design cycles have been historically long, often several years. A key electronic trend is improving time to market while mitigating risk. All applications require some form of power, typically a primary battery or a rechargeable battery for portable designs. The power from this battery must be regulated due the complex sensors used downstream. This practice extends the life of the battery and allows feature sets to be isolated from it.

DC/DC module integration

One such IC is Fairchild Semiconductor's FAN4603 uModule. The basic controller with integrated FETs is co-packaged into a single module with input and output capacitors as well as the switching inductor required in DC/DC buck topologies. The upfront advantages are obvious such as reduced size, only one part to inventory, and reduced design time. However, there are technical advantages as well.

With such close proximity of all active parts in a single module, high current and high frequency paths are physically smaller, resulting in a power supply with lower EMI, crucial to the medical industry with complex sensors and human body interfaces. Increasing the switching frequency of the buck topology to 6 MHz for this module allows the integration of a chip-scale inductor. As the switching frequency increases, inductor size decreases and since these passive components - inductor and capacitors - were selected by the actual PWM and FET designers, everything is tuned to perfect interoperability and efficiency for the recommended load range.

Downstream smart FET technology

To better distribute and control the power module's energy into downstream sensors, processors, and LCDs, a point of load power switch is gaining in popularity. This FET is surrounded by diodes and transistors for added features such as load discharge, in-rush current limit, and reverse current blocking (RCB). Intuitively obvious is the migration to an actual smart FET, which integrates these features into one IC. The IntellimaxTM line from Fairchild is one of many smart FET families available to designers, integrating over voltage protection (OVP), over current protection (OCP), RCB, slew rate control, and an error flag to notify the processor in the event of a fault trip.

Signal path technology advances
There have been advances in general small signal technology that bring value to medical applications. Products now include improved on-resistance and flatness, power-off protection, higher data rates, and much lower consumption.

Newer Ron flatness specifications guarantee a range of Ron for a given condition set. This allows uses in calibration and sensor multiplexing routines within medical devices requiring sub 400mohm Ron levels, much improved over previous 8 ohm levels. Complementing sensors is the recent power-off protection feature, allowing input signals to be present while Vcc = 0V. Actual operating current is now very low, measured in uA even if the control voltage line is lower than the Vcc with input to output leakage measured in nA (nano amps), further adding to battery life.

Impact on healthcare
As ICs advance, feature sets are more easily integrated into medical designs. With the dramatic size reductions in ICs, the integration possibilities are unlimited. Similar systems will monitor heart rate, blood oxygen, glucose, and temperature all in one sensor module. It could be wireless or plugged into a USB port once a day to show a complete data trend and offers a much more accurate prognosis than the single data point collected upon hospital admittance.

Author: Edmund Suckow
Field Applications Engineer
Fairchild Semiconductor

www.fairchildsemi.com

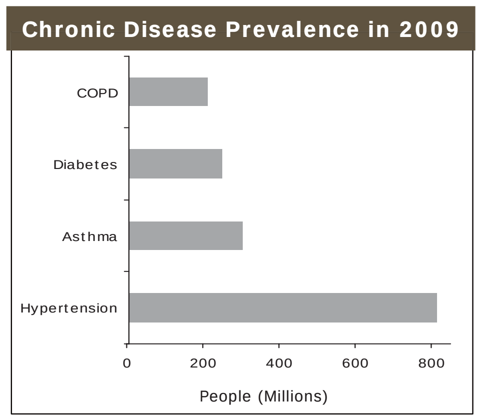
HEALTHY MARKET FOR COMPONENTS IN PORTABLE MEDICAL DEVICES

By Simon Harris

Spiralling healthcare costs, the rapidly ageing world population, and the increasing prevalence of chronic diseases, are contributing to a greater need for portable, home-use medical devices, such as blood pressure monitors, glucose monitors and insulin pumps.

Moreover, as consumers take a more active role in managing their health and fitness, there is a growing demand for affordable, reliable and easy to use devices that measure basic physiological parameters. With annual production volumes in the tens of millions, this market is a sizeable opportunity for component suppliers. IMS Research estimates that the global market for semiconductors and components used in consumer medical devices was worth more than $1bn in 2009.

It is an unfortunate fact that as we age our health often deteriorates. According to the Merck Institute of Ageing and Health, the average 75 year old American suffers from 3 chronic conditions and takes 5 prescription medications. The United Nations estimates that by 2050 the proportion of the world' s population over sixty will double, which will put an enormous strain on national healthcare systems. Home health technologies, particularly those with remote diagnostics capability, empower elderly people to live independently for longer. Moreover, home monitoring helps to reduce the need for costly physician and hospital visits, thus reducing the



Source: InMedica; The International Diabetes Federation (IDF); The World Health Organisation (WHO)

- 6% of the world's population suffers from diabetes.
- More than 800 million people with hypertension worldwide.
- Deaths from asthma to increase by nearly 20% over the next 10 years.

burden on healthcare providers.

In Europe on average, 37% of people have at least one chronic condition affecting their health, and chronic conditions account for 77% of the total disease burden and up to 86% of all deaths. For people that have been diagnosed with a chronic disease, such as diabetes and hypertension, home-use medical devices are a useful tool to help manage their condition and monitor responses to prescribed medication. Home monitoring is also encouraged by physicians as a great way to help sufferers understand their condition and lifestyle changes that may influence or relieve it.

The key design considerations for portable medical devices are low power consumption to prolong battery life, simple user interface, low cost and small form factor. Wireless connectivity is becoming more important as this enables consumers to upload their readings to computers and mobile phones. To fulfil these requirements, design engineers are increasingly using dedicated System-on-Chip (SoC) solutions, where the analogue components are embedded into the MCU, so as to minimise the product size and the cost. When it comes to the power management, there is a trade-off between low power consumption to extend battery life and the need for faster response times and higher functionality. The use of ultra low power microcontrollers and highly integrated power management units are key enablers.

Portable medical devices are playing an increasingly important role in improving the effectiveness of healthcare. With shipments set to grow at a double digit rate in the coming years, this market represents a healthy opportunity for component suppliers.

Author: Simon Harris
Senior Research Director - Medical Electronics
IMS Research

www.imsresearch.com

POWER SUPPLY DEVELOPMENT DIARY

PART VII

By Dr. Ray Ridley

This article continues the series in which Dr. Ridley documents the processes involved in taking a power supply from the initial design to the full-power prototype. In Part VII, the converter will operate at full power, and cross-regulation of the outputs will be tested.

Full Power Testing

As a reminder from Part I of this series of articles, the power supply specifications are as follows:

1. Output 1 – 35 VDC@10A isolated
2. Output 2 – 35 VDC@10 A isolated
3. Output 3 – Bias Supply, 12 W fixed load, ground referenced.
4. Maximum power 350 W (only one output fully loaded at a time, application is for audio.)
5. Input – 180 – 265 AC

Regulation on the outputs is not tightly specified. This design was for an audio application to replace an unregulated power supply with a 50/60 Hz transformer. As you can see in Figure 1, the three outputs of the converter are all on one common inductor core. This coupled-inductor approach provides the best regulation of the outputs, and is a very useful technique. With both outputs isolated, the intent was to regulate the converter from the grounded bias output.

Notice that the turns ratios on the inductor must be exactly equal to the secondary turns ratios on the transformer in order for this scheme to work properly.

Prediction of cross-regulation cannot be done theoretically, and the first major task after getting all of the semiconductors protected and prototype flaws fixed is to test the output regulation under all conditions.

Unprotected Diode Failure

The last three parts of this series [1] described how the semiconductors were protected with clamps, snubbers, and proper current limiting to make the converter rugged. This was implemented with low voltage applied to the converter. After this protection was properly designed, the converter was ready for full power testing. Unfortunately, when the input voltage was raised to 200 VAC with 300 W load applied to the output, there was a failure. The primary switch current climbed rapidly each time the switch was turned on, there were indications of magnetics saturation (limited by the current-limit circuit), and the output diode on the bias winding became extremely hot.

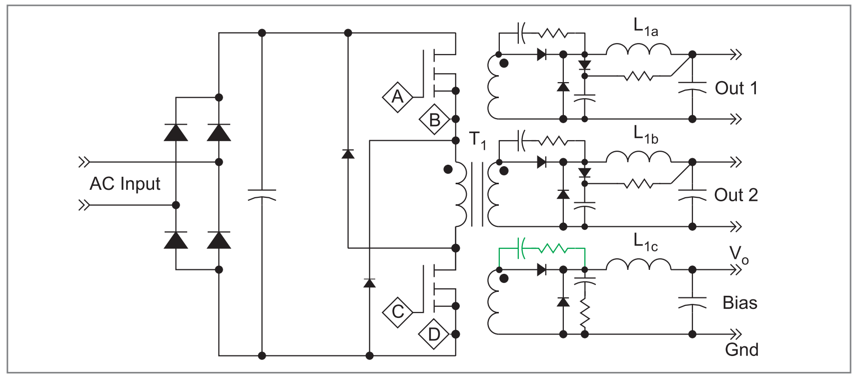


Figure 1: Three-output forward converter with secondary snubbers and clamps.

There are a total of six output diodes in this converter, two for each output. On the main outputs, an RCD clamp protected the catch diode, and an RC snubber sufficed to protect the forward diode, as shown in Figure 1.

The catch diode on the bias output (15 V and 12 W only) had an RC snubber, but the snubber across the forward diode, shown in green in Figure 1, was omitted. It was realized that the RC snubber had not been placed on the board. The low power of the output led to a common trap—not fully testing that particular diode, and assuming that the overrating of the diode was sufficient to protect it.

Figure 2 shows the ringing across the forward diode on the bias winding output with approximately 100 VAC applied to the primary of the converter (maximum voltage rating is 280 VAC). A peak voltage of 160 V is seen on the waveform, more than five times higher than the anticipated square wave voltage of 35 V.

This is a common mistake made in many production designs. The bias windings are often very low power, and high voltage diodes are commonly used, without any snubbers. However, the peak ringing voltages can be extremely high (as seen here), and must be properly suppressed.

Figure 3 shows the diode voltage after an RC snubber was added. Dissipation in the snubber was very low, less than ¼ W, but the snubber was very effective at suppressing the ringing. Once this diode was protected properly, there were no more failures during this phase of testing.

Figure 2: Secondary forward diode voltage waveform, VD, with 100 VAC applied and no snubber

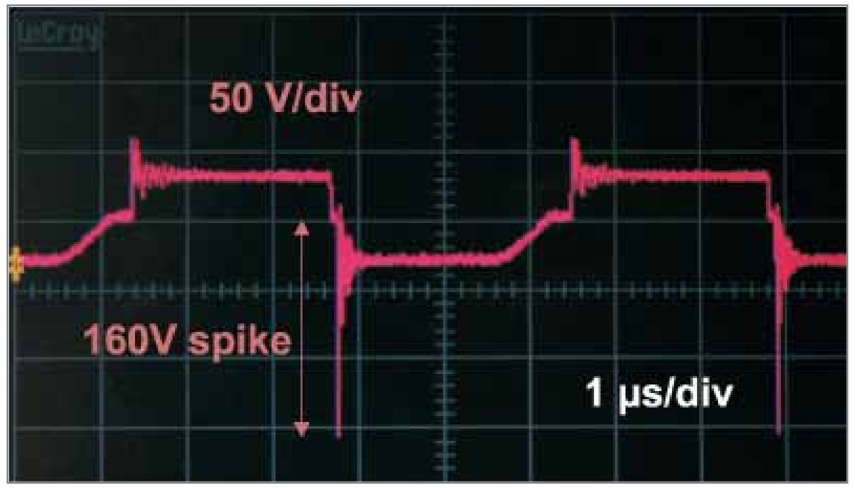


Figure 3: Secondary forward diode voltage waveform, VD, with 100 VAC applied, RC snubber

It is interes ting to note that the schottky diode fails in short-circuit mode. The current limiting in the primary prevents enough power being delivered to fuse the component. You should always remember that schottkys are not at all tolerant of overvoltage, and there should always be a good margin for a rugged design. Just to reiterate – make sure you test every semiconductor for peak voltage and current stress, regardless of how far within the ratings they may seem to be.

Power Supply Cross-Regulation Testing

The power supply was run with a fixed 12 W load on the bias winding. One of the main outputs was kept constant at about 25 W, and the load on the other output was varied from 1 W to 300 W. The converter was regulated from the bias winding, which was kept constant at 16.1 V. This process was then repeated with the other output loaded.

Figure 4 shows the cross-regulation curve for the two main outputs. The data is good – from 26W output to 300 W output, the variation in the output voltage is kept below 3%. For this particular application, this is more than sufficient, and certainly better than the previous unregulated power supply. Getting good cross-regulation is crucial to designing an effective switching power supply. This allows you to have multiple isolated output voltages without the complication and expense of isolated feedback

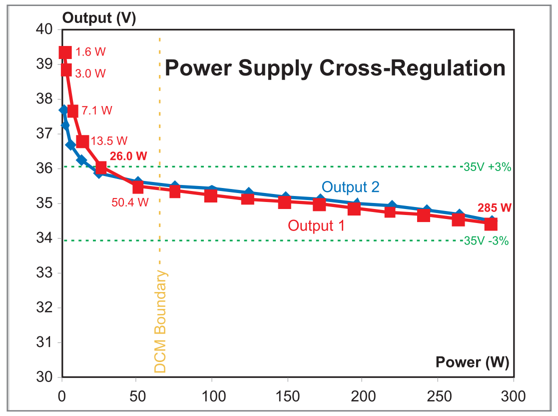


Figure 4: Power supply cross-regulation data. Bias output = 12W, main output = 1-300 W, second output = 26W.

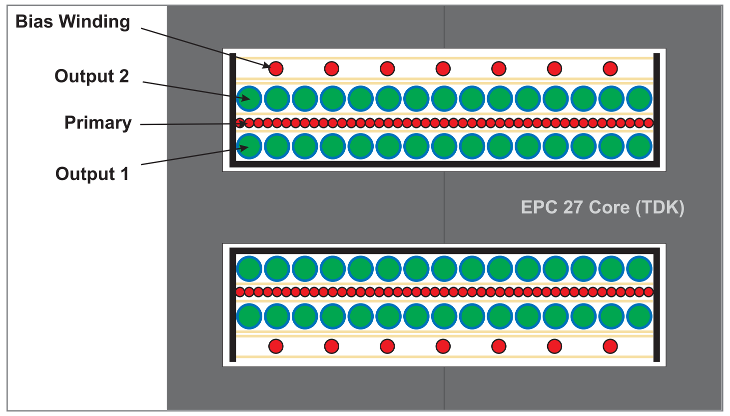


Figure 5: Transformer winding layout for good cross-regulation on EPC 27 core. The coupled-inductor winding has the same layout without the primary winding.

networks, and post-regulators.

The regulation curves of Figure 4 are typical for coupled-inductor designs, either flyback or forward derived. With well-designed magnetics, the output regulation will be very good from about 10% load to full load. At much lighter load, you can see that the curves turn upwards, and light-load regulation is not as good.

Notice, however, that good regulation is achieved even across the boundary of DCM operation, shown by the gold line in Figure 4. If you do not implement coupled inductors on the outputs, the cross-regulation if one of the outputs enters DCM is very poor.

Magnetics Winding Arrangement

For this converter, good cross-regulation was achieved due to the choice of winding arrangements in the magnetics elements. Figure 5 shows how the windings were arranged in the transformer. The main power outputs were either side of the primary, and the bias output was placed on the outside of the windings. The same arrangement was used in the inductor, with the omission of the primary winding.

The two high-power secondaries are not symmetric with each other in this arrangement, and the effect of this can be seen in the cross-regulation data. The red curve of Figure 4 loses regulation at a heavier load than the blue curve. The explanation for this is not well understood. In fact, it is hard to find many papers on coupled-inductor output regulation for the simple reason that you cannot write equations for how the outputs behave at light loads. There are so many parasitic elements involved in the switching process, and so many nonlinearities that come into play at light load, that proper analysis is impossible.

The only way to know how your converter will perform is to make extensive measurements on multiple prototypes under a wide array of different loads, input line, and temperature, to get statistical data on the regulation performance. Sometimes it is necessary to add a small fixed load to keep the outputs regulated at lighter loads. We will encounter analytical difficulties in predicting performance again later when looking at the small-signal characteristics of the coupled-inductor power supply.

Summary

When testing the circuit at full power, there was a diode failure. This occurred on the low-power output schottky diode, which appeared to have plenty of derating for a 16 V output (diode rating was 200 V, 20 A). You should remember that every single output rectifier must be tested for peak stress, and then protected accordingly. These steps are often overlooked.

With proper protection in place on the final diode, the converter was run at full power. The power outputs were regulated +/-3% from full load down to about 8% load. This enables the topology to be used without any isolated feedback networks from the main power output, and without any post-regulator circuits. This is the strength of the coupled-inductor topology with good magnetics design.

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1. "Power Supply Development Diary Part IV", Ray Ridley, Power Systems Design Magazine, June 2010.
2. "Flyback converter snubber design", Ray Ridley, Switching Power Magazine, 2005.

Author: Dr. Ray Ridley
President
Ridley Engineering
www.ridleyengineering.com

DIALOG POWERS INTEL® ATOM™ PROCESSOR E6XX

SINGLE-CHIP SYSTEM COMPANION IC FOR NEW INTEL® ATOM™ PROCESSOR E6XX SERIES

Reported by Cliff Keys

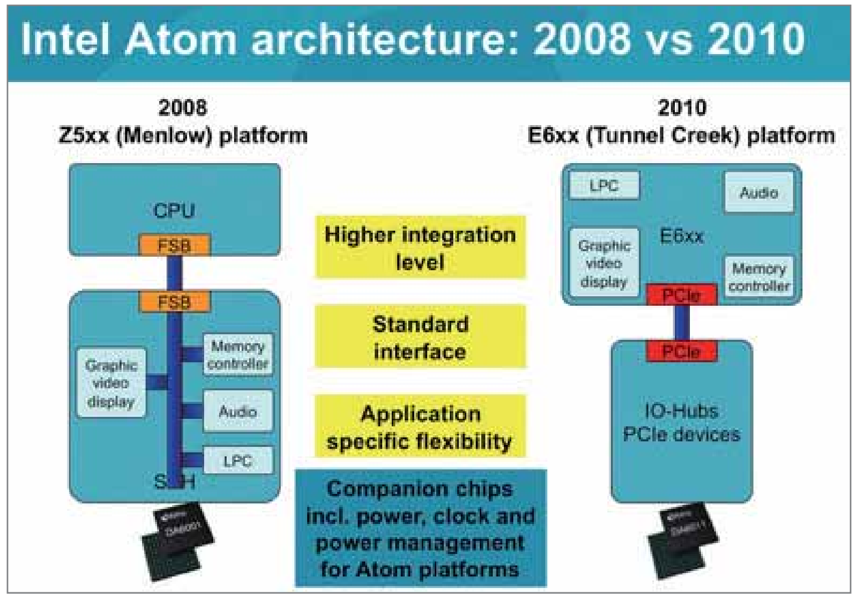
For developers in a broad range of applications using the Intel Atom processor, particularly in portable designs such as found in the new wave of medical equipment, Dialog's companion chip is the ultimate companion to control all power up, power management and power down functions to optimise the end-equipment system power.

Dialog Semiconductor plc, widely known as a leading provider of highly integrated innovative power management semiconductor solutions, has launched a single-chip system companion IC to optimise the power efficiency of embedded applications using the latest Intel® Atom™ processor E6xx series (formerly codenamed Tunnel Creek).

The DA6011 system companion chip integrates power management and clock driver functions and was designed in conjunction with Dialog's Processor Partner Programme. It was demonstrated at the Intel Developer Forum (IDF), San Francisco. The Intel Atom processor E6xx series was also officially unveiled at IDF.

At IDF Dialog also jointly demonstrated its DA6011, which is already sampling, running on Congatec's business card sized embedded PC, the conga-QA6, which is based on the Intel Atom E6xx series processor.

The Dialog IC manages the complete start-up, state-transitioning and power-down procedures on Intel Atom processor E6xx series-based platforms. It operates autonomously and reduces the overall system power consumption when going into stand-by or power down

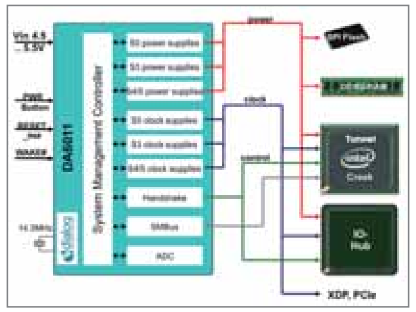


mode. The flexible state-machine implementation is designed to control the Intel Atom processor E6xx series platforms and I/O hubs from Intel (Intel® Platform Controller Hub EG20T), OKI Semiconductor (ML7223 / ML7213) and ST Microelectronics (ConneXt STA2X11).

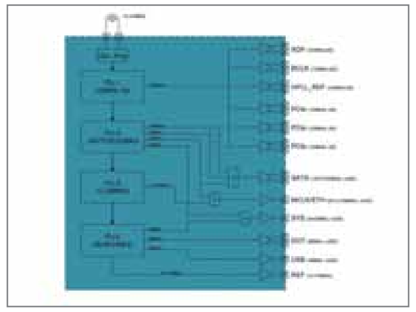
With its high level of integration the DA6011 significantly cuts development time for Intel Atom processor E6xx series-based designs. Furthermore, it improves battery life, simplifies design, improves system reliability, requires less than half the board space and cuts the bill-of-materials (BOM) compared with using a discrete power management system.

Improving on previous generations of the Intel Atom processor, the Intel Atom processor E6xx series integrates a memory controller and graphical video display with the CPU. The device is also the first in the Intel Atom family to adopt the open PCI Express interface, enabling third party companies to more easily create compliant devices that directly connect to the chip and delivering an unprecedented level of I/O flexibility for embedded computing devices.

Juergen Friedel, vice president and general manager at Dialog said: "The new Intel Atom processor will stimulate a new wave of innovation through its performance, I/O



DA6011: SoC PMIC for E6xx platforms



The DA6011 clock synthesizer is developed to source E6xx platforms and IO-hubs from multiple vendors

flexibility and function integration. Our second generation DA6011 companion IC together with the Intel® Atom™ processor E6xx series is ideally suited to the demands of embedded applications, like automotive infotainment systems, industrial automation, embedded PCs and IP media phones, and also portable devices."

"Our customers, particularly those in the automotive and portable markets, need to create high performance devices that run cooler for longer," said Jonathan Luse, marketing director of the Low Power Embedded Products Division at Intel. "Pairing the Intel® Atom™ processor E6xx series and the DA6011 means designers have more options when creating extremely power-efficient solutions to a variety of embedded market segments."

Technical specifications

The device integrates six DC-DC buck converters. This includes two IMVP-6 compatible buck converters dedicated to the Intel Atom processor E6xx series and three pass devices for a fully featured system with the lowest possible BOM.

Further platform power demands are supplied by 11 high-performance, low dropout (LDO) voltage regulators, which use Dialog's patented Smart Mirror™ technology, removing the need for a low power mode and simplifying power control in the system. A dedicated push-pull source/sink terminates the address lines of the external RAM, further minimising external components.

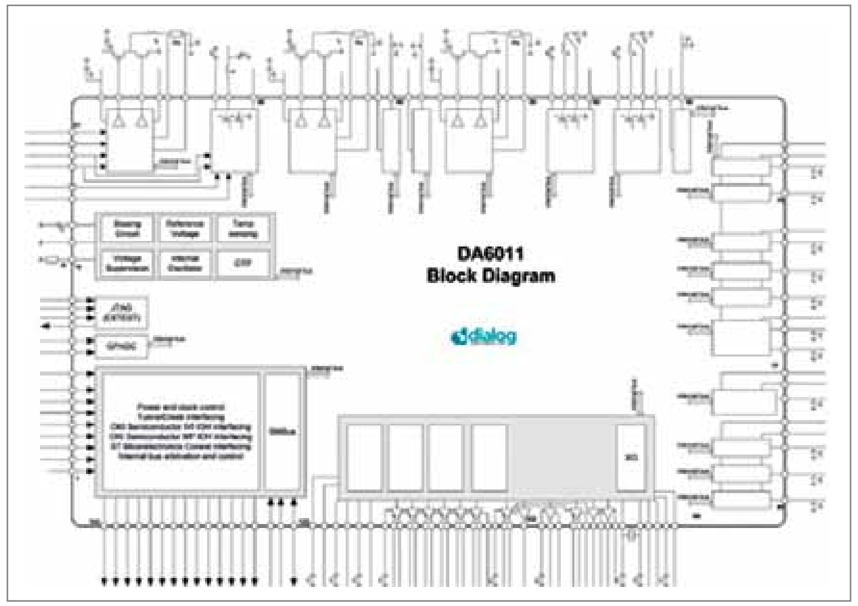
To manage the clock supplies four fractional division featured PLLs, two with spread spectrum capability, are included on the DA6011. The PLLs provide the clocks to the Intel Atom processor E6xx series as well as to the selected I/O hub, further shrinking the component count. The reference clock for the PLLs is generated via a 14.31818MHz crystal oscillator.

Two analog inputs can be multiplexed to a 10-bit ADC converter for signal measurements. An autonomous state machine manages the complete system start-up and shutdown procedures as well as the state transitions of the Intel Atom processor during all operational modes.
Designed with AEC-Q100 specifications in mind, the device operates at -40-+85oC to meet industrial and automotive temperature ranges. Engineering samples of the 11x11mm 169 VFBGA are already available with volume production parts for automotive applications available in Q1 2011.

DA6011 Intel Atom E6xx series companion IC adopted by congatec for business card sized Qseven embedded PC conga-QA6

Dialog Semiconductor's Intel® Atom ™ processor E6xx series companion IC, the DA6011, is being used in congatec's Qseven embedded PC conga-QA6 for clocking and power management.

Dialog's DA6011 is a single chip companion IC for the Intel Atom processor E6xx series, formerly codenamed Tunnel Creek, and integrates power management and clock driver functionality.
The DA6011 was designed in conjunction with Dialog's Processor Partner Programme to maximise the efficiency of by precisely regulating power and providing the clock



Block diagram

source to the core components of the system based on the Intel Atom E6xx series– the CPU, flash memory, RAM and I/O hubs.

At just 7x7cm the Qseven is amongst the world's smallest embedded PCs and has a footprint smaller than a typical business card. It is a low cost, low power board that only requires a user interface and battery, enabling new classes of embedded computing products that have small form factor and long battery life.

Jürgen Friedel, vice president and general manager of Dialog's automotive and industrial division said, "The Qseven enables incredibly small PCs to be created, but small PCs don't have large batteries so current cannot be wasted. We've partnered closely with both congatec and Intel to ensure the DA6011 precisely regulates power for those components at the heart of the Qseven and all Intel Atom processor E6xx series designs."

Gerhard Edi, CEO of congatec said, "Every square millimetre of savings on the Qseven counts. A single chip power management solution was essential, allowing us to further shrink BOM, cost and power consumption to the lowest possible levels without compromise."

With its focus and expertise in system power management, Dialog brings decades of experience to the rapid development of ICs for power and motor control, and audio and display processing. The company' s processor companion chips are essential for enhancing both the performance of hand-held products and consumers' multimedia experience. Automotive applications include intelligent motor control for comfort and safety. Dialog operates a fabless business model and is headquartered near Stuttgart, Germany with operations in Austria, China, Germany, Japan, Korea, Taiwan, UK, and the USA.

Author: Cliff keys
Editor-in-Chief
Power Systems Design Magazine

www.dialog-semiconductor.com

SOLAR ENERGY HARVESTING

Low Power in a Compact Footprint

By Jeff Gruetter

Energy harvesting is by no means a new idea. The first hydroelectric plant which combined water and gravity to drive electricity generating turbines was built in 1882 and offered a relatively "green" and sustainable source of electric power on a very large scale. However, as this type of power source is greatly dependent on the natural terrain, large and expensive transmission networks are required. Since transmission losses rise with distance, this dramatically reduces the amount of available power. Nevertheless, in many instances only a few milliwatts of power are needed to power a wireless sensor node, so a much smaller scale solution is needed.

A much more cost-effective and electrically efficient solution is to keep the power source very close to the load creating a point-of-load design that eliminates transmission losses. However, in order to create these designs, there needs to be a readily available power source that can operate in remote areas, is cost effective and is self-sustaining, thereby requiring no servicing over many years.

The solution for these applications has re-introduced the concept of energy harvesting from a very different perspective, creating an emerging market for compact, predominantly wireless applications at the very low end of the power spectrum. These applications require output power that ranges from a few nanowatts to tens of milliwatts. Although non-traditional power sources such as solar cells (photovoltaic cells), thermoelectric generators (TEGs), thermopiles and piezoelectric transducers are known sources of electrical power, harnessing power from these sources has been challenging. Each of these require some type of power conversion circuit that can efficiently collect, manage and convert these alternative power sources into a more usable form of electrical energy to power sensors, microcontrollers and wireless transceivers. Whether the source voltage is very low and must be up-converted to be useful, or even rectified and then down-converted in some cases, specific energy harvesting circuits are necessary. Historically, these circuits have needed very complex discrete circuits with upwards of 30 components and yet still struggle to provide high enough efficiency to be of practical use. It is only recently that specialized energy harvesting power ICs have been introduced that can offer compact, simple and very efficient power conversion and management solutions.

These ultralow power solutions can be used in a wide array of wireless systems, including transportation infrastructure, medical devices, tire pressure sensing, industrial sensing, building automation and asset tracking. These systems generally spend the majority of their operational lives in standby mode asleep requiring only a handful of µW. When awakened, a sensor measures parameters such as pressure, temperature or mechanical deflection and then transmits this data to a remote control system wirelessly. The entire measurement, processing and transmission time is usually only tens of milliseconds, but may require hundreds of mW of power for this brief period. Since the duty cycles of these applications are low, the average power that must be harvested can also be relatively low. The power source could simply be a battery. However, the battery will have to be recharged by some means or eventually be replaced. In many of these applications, the cost of physically replacing the battery makes it unfeasible. This makes an

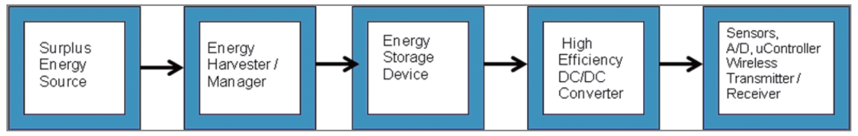


Figure 1: The five main blocks of a typical energy-scavenging system

ambient energy source a more attractive alternative.

Emerging Nanopower Wireless Sensor Applications

In the case of building automation, systems such as occupancy sensors, thermostats and light switches can eliminate the power or control wiring normally required and use a mechanical or energy harvesting system instead. This alternative approach can also mitigate the costs of routine maintenance normally associated with wired systems in addition to eliminating the need for wiring to be installed in the first place, or for regular battery replacement in wireless applications.

Similarly, a wireless network utilizing an energy harvesting technique can link any number of sensors together in a building to reduce heating, ventilation & air conditioning (HVAC) and lighting costs by turning off power to non-essential areas when the building has no occupants.

A typical solar energy scavenging system represented by the five main circuit system blocks shown in Figure 1 consists of a free energy source such as a small photovoltaic cell exposed to either direct sunlight or even indoor lighting. These photovoltaic cells are capable of generating over 50mW of electrical power per square cm of area, in peak sunlight and up to 100μW of electrical power in indoor lighting. However, the electrical energy they generate must be collected in a very specific manner using an energy harvesting circuit (see the second block in Figure 1) that can efficiently collect this low voltage energy and convert it into a more usable form, which can be used to continually charge a storage device. As the power generated by the solar cell will vary dramatically with the ambient lighting conditions, a rechargeable storage device such as a battery or supercap (block three in Figure 1) is required to provide continuous power when the ambient light is no longer available. In turn, the storage device, whether a battery or a supercap, combined with a simple step-down DC/DC converter (fourth block in Figure 1, which is usually not needed) can power downstream electronics while it is continually recharged. The downstream electronics will usually consist of some kind of sensor(s), analog-to-digital converter, ultralow power microcontroller and wireless transceiver (fifth block in Figure 1). These components take the harvested energy, now in the form of a regulated power supply, and wake up a sensor to take a readings or a measurements, making this data available for transmission via an ultralow power wireless transceiver. The most recent generation of ultralow power wireless microcontrollers include multiple ADCs and an integrated wireless transceiver. They generally require current levels of 20mA to 35mA for periods as short as 1mS while measuring and transmitting, after which they go into a sleep mode requiring only 3.5μA of supply current minimizing the average power requirements.

Each circuit block in this chain has had a unique set of constraints that have impaired its commercial viability until recently. Although low cost and low power sensors and microcontrollers have been available for sometime, only recently have ultralow power transceivers been integrated with microcontrollers to offer very low power wireless connectivity. Nevertheless, the laggard in this chain has been the energy harvesting IC.

Existing implementations of the energy harvester block are a relatively low performance discrete configuration, usually consisting of 30 or more components. These designs have low conversion efficiency and high quiescent currents. Both of these deficiencies result in the requirement for larger, more expensive batteries and solar cells compromising the performance of the end system. Without these larger storage elements, the low conversion efficiency will increase the amount of time required to power up a system, which in turn increases the time interval between taking a sensor reading and transmitting this data. High quiescent currents in the power conversion circuitry can severely limit the amount of “useable” energy that can be harvested and made available to the application load. Achieving both low quiescent current operation and high power conversion efficiency also requires a high degree of analog switchmode power supply expertise – which is rarely readily available.

The “missing link,” if you will, has been a highly integrated DC/DC converter that can harvest and manage surplus energy from extremely low power sources. However, that has all changed.

Energy Harvesting Case Study

As an example, consider an energy harvesting-based industrial monitoring system, such as a pipeline in the remote wilderness that needs to constantly monitor the flow rate, temperature and pressure of a pipeline for every 50-meter section of pipe. Each node has temperature, pressure and flow sensors built into the wall of the pipeline. Measurements must be taken and reported every five seconds. As the pipeline is hundreds of miles long, running power and information lines would be very expensive and subject to constant maintenance, potentially requiring expensive repairs. Replacing batteries periodically would also be very expensive due to their vast number and the ruggedness of the remote terrain. What is needed is a power source that can continually generate sufficient power, which is readily available and sustainable. One of the most popular and readily available energy sources would be a small solar cell combined with a storage device such as a battery or supercap to deliver continual power thru night time and poor weather conditions.

With the introduction of very low power sensors and microcontrollers with integrated wireless transceivers, average power requirements have been dramatically reduced. This makes them ideal for energy harvesting powered applications. Their power requirements range from 10μW in sleep mode, to about 50mw to 75mW during processing and transmission (in 1ms to 2ms bursts). The microcontroller requires a consistent source of power typically at 2.2V whereas the wireless transceiver generally uses 3.3V. Although a single photovoltaic cell only 1cm2 in size can easily provide the required power, its output voltage ranges from 0.25V to only 0.6V, which is too low to power the rest of the system. This is where an energy harvesting IC

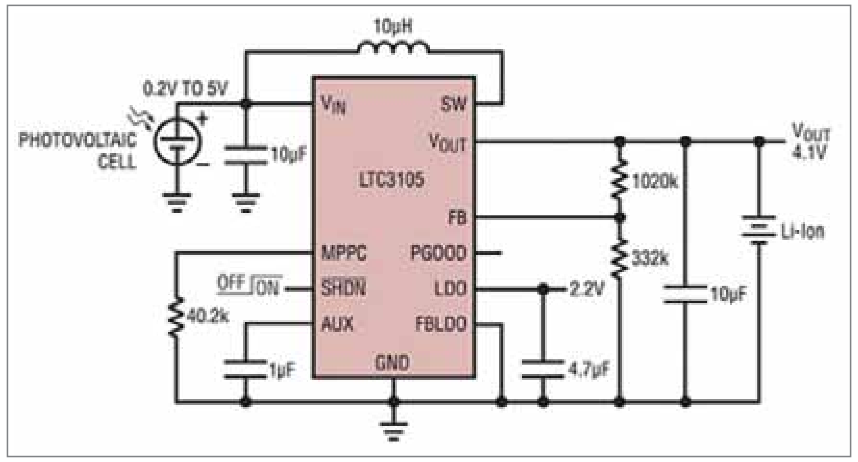


Figure 2: Single photovoltaic cell Li-Ion trickle charger

comes into play. It must boost the very low voltage source to a level capable of charging a single cell Li-Ion battery, generally around 4.1V. Additionally, it must not pull too much current from the solar cell as it will collapse its internal voltage. As allowable current draw varies with illumination, the harvester IC must continually monitor the solar cell's voltage and limit current accordingly. Finally, the harvesting IC must be as efficient as possible over a very wide range of charging currents and require the minimum level of quiescent current while the charging circuit is asleep in order to minimize the size of the battery.

The Energy Harvesting IC

Linear Technology recently introduced the LTC3105 - an ultralow voltage step-up converter specifically designed to dramatically simplify the task of harvesting and managing energy from low voltage, high impedance alternative power sources such as photovoltaic cells, TEGs (thermoelectric generators) and fuel cells. Its synchronous step-up design starts up from input voltages as low as 250mV, making it ideal for harvesting energy from even the smallest photovoltaic cells in less than ideal lighting conditions. Its wide input voltage range of 0.2V to 5V makes it well suited for a wide array of applications. An integrated maximum power point controller (MPPC) enables operation directly from high impedance sources, like photovoltaic cells, preventing the input power source voltage from collapsing below the user-programmable MPPC. Peak current limits are automatically adjusted to maximize power extraction from the source, while Burst Mode® operation reduces quiescent current to only 18µA, optimizing converter efficiency.

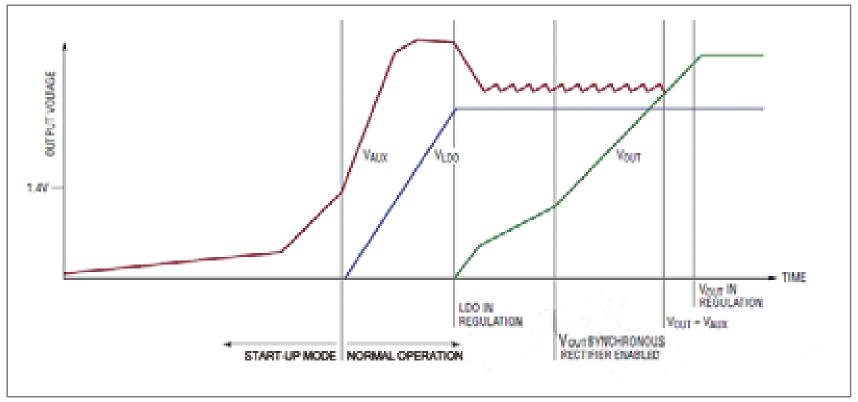


Figure 3: Typical LTC3105 start-up sequence

The circuit shown in Figure 2 uses the LTC3105 to charge a single-cell Li-Ion battery from a single photovoltaic cell. This circuit enables the battery to continually charge when the solar source is available, and in turn, the battery can power an application such as a wireless sensor node from the stored energy when the solar power is no longer available.

The LTC3105 has the capability to start with voltages as low as 250mV. During start-up the AUX output initially is charged with the synchronous rectifiers disabled. Once VAUX has reached approximately 1.4V, the converter leaves start-up mode and enters normal operation. Maximum power point control is not enabled during start-up; however, the currents are internally limited to sufficiently low levels to allow start-up from weak input sources. While the converter is in start-up mode, the internal switch between AUX and VOUT remains disabled and the LDO is disabled. Refer to Figure 3 for an example of a typical start-up sequence.

When either VIN or VAUX is greater than 1.4V, the converter will enter normal operation. The converter continues charging the AUX output until the LDO output enters regulation. Once the LDO output is in regulation, the converter begins charging the VOUT pin. VAUX is maintained at a level sufficient to ensure the LDO remains in regulation. If VAUX becomes higher than required to maintain LDO regulation, charge is transferred from the AUX output to the VOUT output. If VAUX falls too low, current is redirected to the AUX output instead of being used to charge the VOUT output. Once VOUT rises above VAUX, an internal switch is enabled to connect the two outputs together.

If VIN is greater than the voltage on the driven output (VOUT or VAUX) or the driven output is less than 1.2V, the synchronous rectifiers are disabled and operate in critical conduction mode, enabling regulation even when VIN>VOUT.

When the output voltage is greater than the input voltage and greater than 1.2V, the synchronous rectifier is enabled. In this mode, the N-channel MOSFET between SW and GND is enabled until the inductor current reaches the peak current limit. Once current limit is reached, the N-channel MOSFET turns off and the P-channel MOSFET between SW and the driven output is enabled. This switch remains on until the inductor current drops below the valley current limit and the cycle is repeated. When VOUT reaches the regulation point, the N- and P-channel MOSFETs connected to the SW pin are disabled and the converter enters sleep.

In order to power microcontrollers and external sensors an integrated LDO provides a regulated 6mA rail. The LDO is powered from the AUX output allowing the LDO to attain regulation while the main output is still charging. The LDO output voltage can be either a fixed 2.2V or adjusted via resistor divider.

The integrated maximum power point control circuit allows the user to set the optimal input voltage operating point for a given power source - see Figure 4. The MPPC circuit dynamically regulates the average inductor current to prevent the input voltage from dropping below the MPPC threshold. When VIN is greater than the MPPC voltage, the inductor current is increased until VIN is pulled down to the MPPC set point. If VIN is less than the MPPC voltage, the inductor current is reduced until VIN rises to the MPPC set point.

The LTC3105 incorporates a feature that maximizes efficiency at light load while providing increased power capability at heavy load, adjusting the peak and valley of the inductor current as a function of load. Lowering the peak inductor current to 100mA at light load optimizes efficiency by reducing conduction losses. As the load increases, the peak inductor current is automatically increased to a maximum of 400mA. At intermediate loads, the peak inductor current can vary between 100mA to 400mA. This function is overridden by the MPPC function and will only be observed when the power source can deliver more power than the load requires.

Input Undervoltage Lockout

In applications such as photovoltaic conversion, the input power source may be absent for long periods of time. To prevent discharge of the outputs in such cases, the LTC3105 incorporates an undervoltage lockout (UVLO) that forces the converter into shutdown mode if the input voltage falls below 90mV (typical). In shutdown, the switch connecting AUX and VOUT is enabled and the LDO is placed into reverse-blocking mode and the current into VOUT is reduced to 4µA typical. Reverse current through the LDO is limited to 1µA in shutdown to minimize discharging of the output.

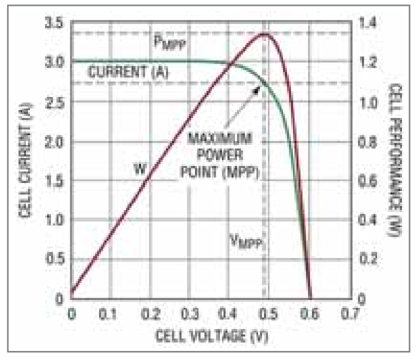


Figure 4: Typical maximum power point control point for a single photovoltaic cell

Conclusion

The LTC3105 energy harvesting DC/DC converter is specifically designed to dramatically simplify the task of harvesting and managing energy from low voltage, high impedance alternative power sources such as photovoltaic cells, TEGs (thermoelectric generators) and fuel cells. Its unique design enables it to start up from input voltages as low as 0.25V, and provides very high efficiency over a wide range of input voltages and current levels. Onboard maximum power point control optimizes the energy extracted from a wide range of sources under a wide range of conditions. Its very simple and compact solution footprint makes it a straight forward power solution for a growing number of energy harvesting applications.

Author: Jeff Gruetter,
Sr. Product Marketing Engineer,
Power Products,
Linear Technology
www.linear.com

UPS PROTECTION

Not only for emergency power backup

By Rob Morris

Companies often install uninterruptible power supplies (UPS) to provide backup power if the main supply is lost. But power outage is relatively rare. Are we missing a trick by not looking at other issues around power quality and the potential impact on businesses?

The reason for having a UPS is to provide a secondary source of power if the primary source is lost. Yet power outage is infrequent and focusing on this diverts attention from other important basic issues.

A key decision for a company is the choice between on-line or standby UPS. The selection is not a matter of how much protection is offered by a particular design, but rather, what type of technology the UPS is protecting. Many use a combination of both linear and switch mode power supplies. Linear supplies remain popular because they contribute less noise to the electrical environment. Switch mode is common because of lower cost, efficiency, size and low heat contribution.

Most linear power supplies do not have the internal storage characteristics to allow them to ride through the 4-6msec time period required for a standby UPS to switch from AC line to battery-powered inverter. Linear supplies are also voltage-sensitive, making well-regulated voltage a necessity. Switch mode supplies, however, enjoy substantial ride-through ability. They are relatively immune to even large swings in line voltage and will function satisfactorily on standby designs. The initial choice of UPS design should be made on these criteria: standby UPS for switch mode power supplies; on-line UPS for linear power supplies.

Installation of POWERVAR UPM at convenience stores, provides energy savings of 25% and protects against system crashes

It is a popular misconception that on-line UPSs always deliver a higher level of power quality by virtue of their double conversion (AC-DC-AC) design. In fact, a well-designed standby UPS (single conversion) that incorporates power conditioning technology can provide better protection than expensive poorly designed on-line systems.

Another decision is whether to install one large UPS or multiple smaller ones. You get economies of scale using a single large UPS - e.g., a 15kVA system is often cheaper than 30 individual 500VA units. Small individual UPSs offer flexible installation, less distribution wiring, easier maintenance and knowing that a UPS in one part of the system may fail without affecting others.

When a UPS is installed, power quality issues must be carefully considered. A system that cannot fail because of a power outage cannot fail for other reasons. Power quality is more than having a clean, noise-free electrical supply. It means controlling harmonics, power factor and power factor penalties. It depends on the requirements of the equipment being protected. Some of the issues are:

- Impulses – These short duration, high-energy events have significant destructive potential and can cause catastrophic failure of semiconductor devices. Even when not immediately destructive, impulses contain sufficient energy levels to erode or weaken semiconductor junctions leading to failure. The effects are mitigated with a surge diverter.
- Common mode voltage – This is any voltage measured with reference to safety earth. Since most computer systems use safety earth as their logic and communications reference, clean and quiet safety earths are mandatory. Computer problems associated with common mode voltage include processor lockup, lost/fragmented data, communication errors, or 'no trouble found' failures. Common mode voltage may occur in systems with daisy-chained or undersized neutrals, or when branch circuits become lengthy. Using an isolation transformer to create a separately derived power source eliminates common mode voltage.
- Noise – Resulting from distribution and use of electrical power. RFI and EMI are generated by every device that uses electricity. Ironically many of the disturbances that cause computer malfunction are induced by the computer's electrical system. Noise filters built from capacitive and inductive elements are used to divert disturbances to electrical system earth.
- Voltage regulation – More critical for linear power supplies than for systems powered by switch mode supplies - there are several methods of providing well-regulated voltage. These include tap-switching or

The POWERVAR UPM range

ferro-resonant voltage regulators and buck/boost autoformers. An on-line UPS provides natural voltage regulation because of its double conversion process.

- Outage – Mitigated with a UPS device that provides reserve power from batteries. Battery-powered UPS systems function as an effective bridge until either the utility is restored or another source is brought online.
- Frequency changes - Caused by variations from the fundamental operating frequency of the electrical system. Double-conversion UPS systems have an ability to function as a frequency regulator and a high-quality on-line UPS can tightly regulate output frequency over a wide range of input frequencies, unlike single conversion designs.

Single-conversion UPSs may not incorporate all the elements above. Surge diverters, tap-switching voltage regulators and battery-powered inverters are common in single conversion designs. However, most do not include either a powerline noise filter or an isolation transformer. Double-conversion systems typically provide superior protection against normal mode noise and impulses. They also produce an output free from voltage and frequency regulation problems. Like the standby UPS, however, many fail to incorporate an output isolation transformer, leaving the load exposed to disruptive common mode disturbances.

Providing clean, continuous power for most applications begins with an examination of the application and technology being protected. If linear power supplies are part of the application, the on-line UPS is a natural choice. If the application involves switch mode power supplies, either on-line or standby UPSs will provide backup power.

The choice may also involve personal preference, budget, etc. If harmonics and power factor are concerns, some on-line designs are available with unity power factor input and low front-end harmonic contribution. These can be compelling reasons for selecting one technology over another. Regardless of design, it is important to make sure the UPS provides a high level of protection from noise, impulses and common mode disturbances. This means noise filters, surge diverters and isolation transformers should be seen as core to UPS design.

Powerline noise and common mode disturbances are partly a function of branch circuit length. This means while these disturbances may be non-existent on the output of an isolated UPS, they will reappear gradually as the output circuit length increases.

This is one disadvantage of installing a centralised UPS. Even the most well-designed centralised UPS may prove incapable of providing clean power for a load located some distance away. So while the UPS portion of the overall power solution may be installed in a location selected for convenience and availability, the elements that ensure clean power must be installed as close as possible to the load they are protecting.

Systems that cannot fail due to a power outage must be protected from failures caused by other power anomalies. But not all UPS systems provide clean power. Select a UPS that provides complete protection, and combine it with other devices to achieve clean, continuous power.

Author: Rob Morris
UK Country Manager
Powervar

www.powervar.com

SUPERCAPS FOR UPS

Fast, Compact, Long Life, Green Storage Alternative to Batteries

By Michael Adams

The need to protect IT equipment from the effects of power transients, as well as to provide assured operation during power outages is evidenced by the steady growth in sales of uninterruptible power supplies (UPS) up to the global downturn of 2008/9. As markets start to bounce back post-downturn, the sales of UPS equipment has started to recover and are predicted to return to real growth during the coming 2-3 years.

With IT central to the successful operations of most modern organisations, the UPS has a central position in the critical physical infrastructure which supports servers, storage and communications equipment, and which ensures continuity of services during all local mains conditions.

Recently, escalating energy costs and increasing concern about the carbon footprint of organisational power requirements, has driven the need to consider alternative back-up technologies and evaluate their effectiveness to ensure 'business as usual' has become pressing.

Pressure on IT and facility managers to utilise green technologies, especially in Western Europe, continues to grow. In addition to the environmental benefits associated with lower carbon footprint, green technologies bring with them lower operating expenses by virtue of their more efficient operation and ability to deliver 'more with less', i.e., more compute cycles from less energy.

As a discipline, energy storage technology has acquired new levels of prominence as methods are sought to overcome intermittency issues associated with solar and wind power generation. Smart grid concepts are being tested which are likely to promote an increasing trend towards distributed power generation combining traditional power sources with renewable or green power sources.

The eco-friendly storage industry is currently small, but solutions are either on the verge of commercialisation, or are starting to experience mainstream uptake. But another wrinkle is posed by the fact that the choice of energy storage solutions is highly application-specific, as it varies as per application and requirement of the end-user.

Supercapacitors, or SuperCaps, are not a new concept and their effects were first noted in the late 1950's. Consequently, the technology is well established; has experienced significant advances over the last 10 to 15 years and has also seen recent reductions in cost. At the moment, supercapacitors have been successfully adopted in three different sectors; transportation, industrial and consumer electronics.

SuperCap core technology is environmentally friendly and offers high power density

Why should we consider SuperCaps in UPS applications?
SuperCaps core technology is environmentally friendly and offers a high power density (4000W/kg). They have low internal resistance (ESR) and can operate in a wide temperature range which is very useful for data centres. They also offer a low total cost of ownership (TCO) and are capable of over 1 million cycles and offer instant recharging.

There is no doubt that there have been significant developments with battery technology over the years, but despite all these advances, they all suffer from the same basic problem in that they utilise a chemical reaction. This means they suffer from a limited life, and can only operate in a limited temperature range.

In addition, traditional batteries that experience constant high demands for current, have a shortened operational lifespan. Therefore in order to ensure reliability and long lasting cover, facility managers are forced to deal with higher maintenance costs.

It is well known that batteries die after a period of time, and need replacing on average, every two, five or seven years. Any technology that can offer a longer lifetime, so that users do not have to spend their precious budget repeatedly on replacement batteries, will prove to be a big incentive.

The SuperCap UPS provides a useful alternative solution in this context as it is ideally suited to provide a short-term "bridge" power until standby power generation equipment kicks in. As the SuperCap industry continues to experience a lot of R&D and maturation, SuperCap UPS are now becoming highly competitive with, and in many cases superior to, older bridge technologies.

TCO Considerations
Offering a wide temperature range, long life, and flexible voltage range, SuperCaps provide an extremely reliable solution for bridge power.

The very high cycle life of a SuperCaps UPS means that unlike lead acid batteries, there will likely be little or no need for constant replacement. The facility to repeatedly charge and discharge for up to a million cycles without disintegrating, means that the lifetime cost of the SuperCap is expected to break even with lead acid batteries.

Longevity is helped by the fact that their high power density results in reduced strain on the battery in times of need. Another major consideration is the fact that the SuperCap also has the ability to recharge instantaneously, in a few seconds. This is really useful in data centres, to help cut power costs associated with keeping batteries charged.

Another important factor is the ability of SuperCaps to offer versatile functioning in a wide temperature range, dramatically reducing cooling costs. This is because the function of a SuperCap does not require a chemical reaction, and therefore, does not involve an optimal temperature range for best performance or longevity.

It has been estimated that the SuperCap can be used from -40°C to +70°C, without degradation in its performance characteristics. This is in stark contrast to the lead-acid battery, which when used in industrial applications, almost always requires a mechanically cooled environment.

Pros and Cons
The SuperCap is green in two ways. Firstly, it reduces waste because it has a very high cycle life, and therefore decreases disposal issues. Secondly, the materials and substances used in the SuperCap UPS are toxin free and biodegradable, e.g., nano carbon particles are commonly used. They can operate in a wide temperature range without any degradation of performance characteristics, and it also has the ability to recharge instantaneously in a few seconds.

SuperCaps are ideal energy storage devices for fast and short-term peak power delivery, which is why they are so suited for UPS systems. They are also more efficient than conventional batteries as they do not release any thermal heat during discharge, and various figures have shown that they operate at around 80% - 95% efficiency in most applications.

SuperCaps also take up much less room compared to lead-acid batteries, and indeed weigh less as well, which can be an important factor in certain situations or locations. The following table contrasts the pros and cons of SuperCaps with traditional UPS technology.

Conclusion
There is no doubt that the industrial market needs an energy storage solution that is both reliable, and can offer a quality service. SuperCaps offer high power density,

Table 2: Pros and Cons of the SuperCap UPS (Maxwell Technologies)

Pros	Cons
A SuperCaps UPS is green and does not contain toxic materials	Despite their indefinite life cycle, SuperCaps have the ability to provide only very short-term power
Can operate in a wide temperature range, without a degradation in its performance characteristics	High initial cost of ownership. SuperCaps are more expensive than flywheel, as it is still in its nascent stage of commercialisation
Do not release any thermal heat during discharge	End users are unable to perceive or experience the true advantages of this technology due to early stages of take-up and lack of awareness
A SuperCaps UPS is much more efficient than a conventional battery	Lack of industry standards to regulate and stimulate full commercialisation of the technology. Design time is longer, which results in a longer lead time to get a product ready for the end user
Ideal energy storage device for fast and short-term peak power delivery, for indefinite cycles.	The SuperCaps UPS is unable currently to store as much energy as a battery because there are no chemical reactions taking place that can sustain the slow discharge of current to power equipment
Up to 20 years lifespan	-
Reduced footprint compared to lead-acid batteries, and also weighs less	-
Scalable-modular nature that make it well suited for many applications	-
A SuperCaps UPS, used strictly as a bridge, has high power density that is well suited to supply high power for short periods of say around 30-100 seconds	-
Flexible voltage range	-
A SuperCaps UPS is inherently reliable because of its composition and construction. There are no mechanical moving parts, eliminating maintenance	-
Capable of sitting on a charge voltage for extended periods without any loss of capacity, unlike a battery	-
Development of the technology is being pushed by massive industry heavyweights in the transportation sector. Honda for example has developed its own SuperCaps for its vehicles	-

cycle life, and thermal susceptibility, and the increasing adoption of renewable energy expands the possibilities of using SuperCap-based technology.

Frost and Sullivan reported the total world ultracapacitor (SuperCap) market had generated revenues of $113.1 million in 2008 and is likely to reach $381.9 million by 2015. It feels that this market has witnessed growth (despite the economic situation) due to the great interest in propelling alternative energy storage mechanisms by governments. Indeed, Europe has given the highest priority to any environmentally friendly technology and has a proud tradition of being one of the first global markets to accept new technology and consider its applicability in various solutions. The high price of oil, coupled with high electricity costs, the need for devices that can reduce the power burden of a data centre represents a significant opportunity. The increasing use of SuperCap technology within the transportation industry will also serve to spur new developments and help drive down the initial cost of ownership.

Author: Michael Adams
Global Vice President, Data & IT
AEG Power Solutions

www.aegps.com

SEPIC CONVERTER DESIGN

Provides a Compact and Efficient AC/DC Supply

By Brian King

Some low-power (less than 5W) electrical systems that derive their power from an AC source do not require isolation. Because of safety concerns, these are systems that are not end user accessible. Examples include power meters and telecom equipment.

Most isolated low-power AC/DC power supplies tend to use the flyback topology due to its simplicity and decent efficiency. Removing the isolation requirement allows other topologies to be used, such as the buck or SEPIC. However, the buck topology requires driving a high-side switch, which often leads to excess circuitry and wasted power. The flyback is still an option, but with no isolation requirement, the coupled-inductor SEPIC topology can reduce the size and improve efficiency compared to a flyback.

Figure 1 shows how the power stages of a flyback and couple-inductor SEPIC are very similar. In fact, the only difference between the two schematics is the addition of the coupling capacitor (Ccoupling). In both topologies, while the MOSFET (Q1) is on, the core of the transformer/coupled-inductor is energized. While the MOSFET is off, the energy in the magnetic device is directed to the output through D1. At the instant when Q1 is turned off, any residual energy remaining in leakage inductances must go somewhere. In the flyback, a clamping circuit is usually added to the MOSFET to prevent this leakage energy from causing an over-voltage stress on the device. In the coupled-inductor SEPIC, the leakage energy is redirected to the output through the coupling capacitor, clamping the voltage on the MOSFET. Redirecting the leakage energy reduces power loss and can improve the supply's efficiency by approximately two percent. The coupling capacitor also clamps the reverse voltage on the diode and significantly reduces ringing that can cause electromagnetic interference (EMI) problems in flyback converters.

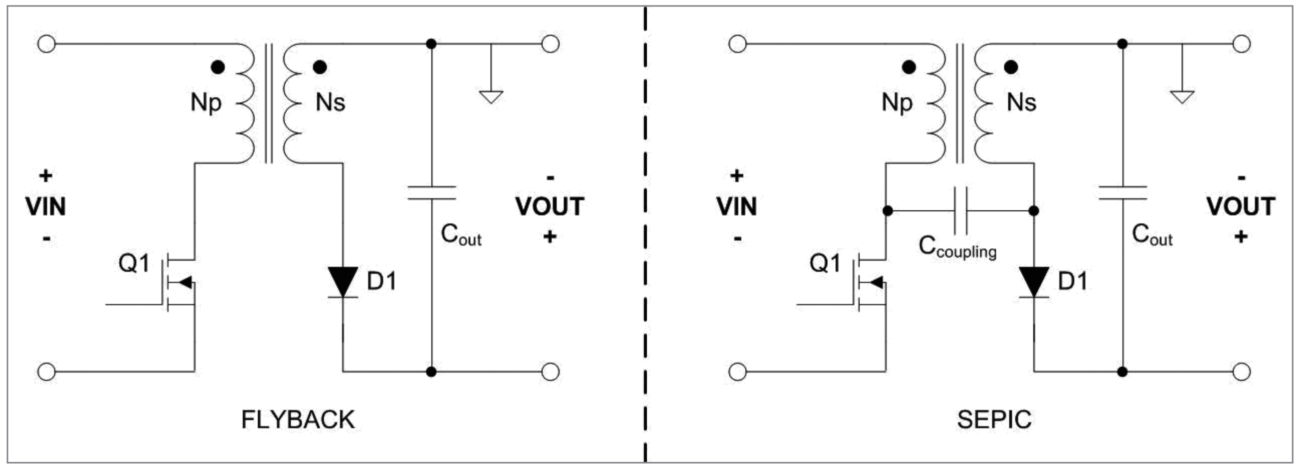


Figure 1: The power stages of flyback and SEPIC converters are very similar

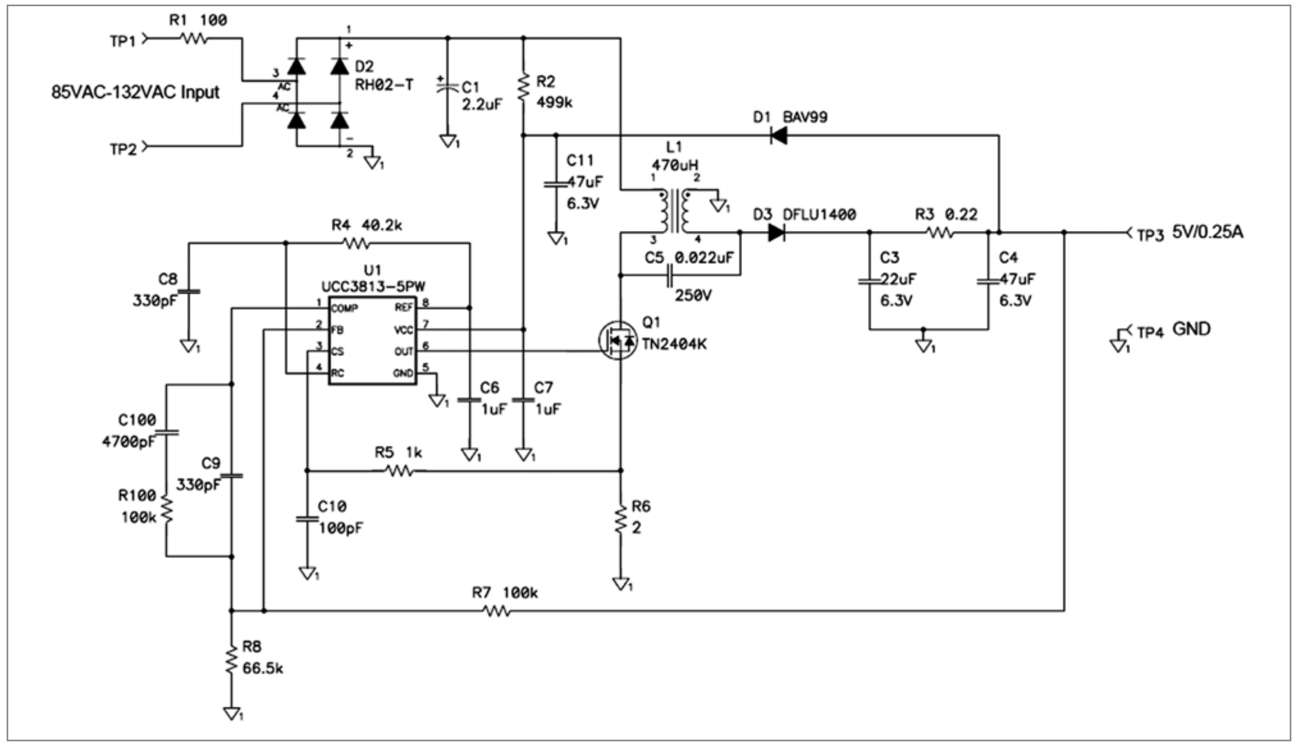


Figure 2: This schematic presents a SEPIC converter that generates a 5V output capable of providing 1.25W from an 115VAC input

The DC conversion ratio is the same for the flyback and coupled-inductor SEPIC. The resulting equations defining the duty cycle as a function of input and output voltage are given by Equation 1 for continuous operation and by Equation 2 for discontinuous operation. In a flyback, the number of primary and secondary turns can be adjusted and optimized for any given input range and output voltage. By contrast, the ratio of primary turns to secondary turns in a SEPIC must be 1:1. In applications with large input voltage to output voltage ratios, this creates design challenges and limits the flexibility of the SEPIC.

$$D_{CCM} = \frac{N_P \times V_{out}}{N_S \times V_{in} + N_P \times V_{out}}$$

Equation 1

$$D_{DCM} = \sqrt{\frac{2 \times V_{out} \times I_{out} \times L \times f_{sw}}{V_{in}^{2}}}$$

Equation 2

Figure 2 shows the schematic of a 5V/1.25W SEPIC converter that is powered from an 115VAC input. The rectified AC line voltage produces an input voltage of approximately 160VDC. For continuous operation, the SEPIC converter operates with a duty cycle of around three percent. For discontinuous operation, the duty cycle is even less. At these very small duty cycles the converter becomes sensitive to perturbations in on-time. By lowering the switching frequency, the on-time is increased and this noise sensitivity is reduced. Also, by using a large inductance, continuous operation and a wider duty cycle is guaranteed over a broader load range. In this example, a 40kHz switching frequency was selected, which is above the audible range, but low enough to keep the on-time at nearly 1μs during normal operation.

By carefully selecting the switching frequency and inductance, a physically small circuit can be designed. The coupled-inductor is one of the largest components. For this example, a dual-winding, surface mount, drum core inductor is chosen. These types of coupled-inductors are compact, cost-effective, and readily available from multiple vendors. When choosing a coupled inductor, be careful not exceed the maximum saturation current rating of the device. Also, pay particular attention to the core loss, which can become excessive at lower frequencies. Most vendors do a good job of providing core loss information in their datasheets. Selecting the proper controller is another key to reducing the amount of circuitry and size of the design. Most off-line pulse width modulation (PWM) controllers are intended to be used with an optocoupler and secondary-side regulation. Hence, they do not contain a reference or error-amplifier. Finding a controller with both of these features may require some hunting through IC vendor websites. In this design, the low output voltage places an additional constraint on the controller that it must operate with less than 5V on VCC. In our test we used the UCC3813-5 because it meets all of these requirements.

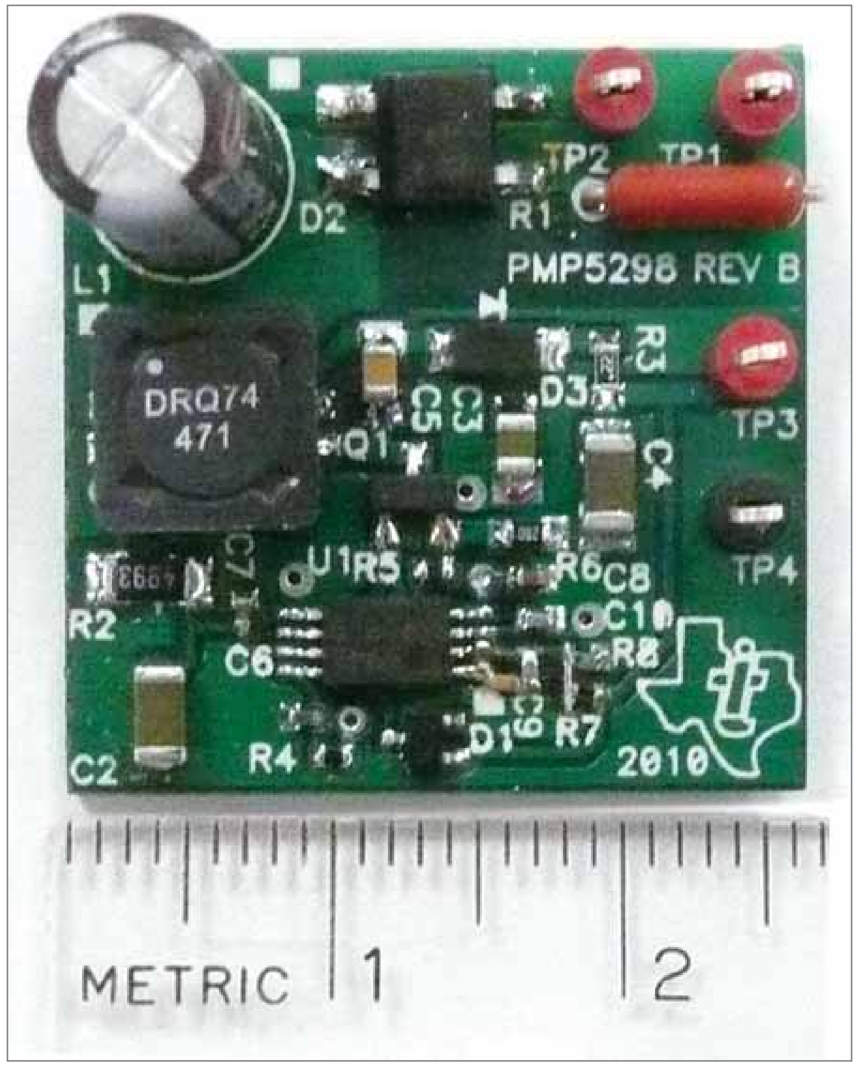


Figure 3: The entire circuit, including the diode bridge and input capacitor, consumes only one square inch of board space

With a high input voltage and low output power, the current stress on the MOSFET (Q1) is fairly benign. In this case it is around 25mArms. We used a 4-Ohm, 240V device in a SOT23 package because of its small size. Likewise, ceramic capacitors are used in the output filter to keep the design as compact as possible. The resulting design is able to fit into a small one-inch by one-inch single-sided PCB, as shown in the photograph of Figure 3.

In addition to being physically small, this circuit is also fairly efficient for such a large input-to-output conversion ratio. With a 150VDC input and 200mA being supplied to the output, this supply has an efficiency of 60 percent. Also, because the SEPIC tolerates wide input ranges well, this supply can operate down to 20VDC on the input. This allows this circuit to ride through brown-out conditions with very little input capacitance.

It might be tempting to extend this design to the universal AC input range of 85VAC to 265VAC. However, at 265VAC input, the rectified input to the converter is approximately 375VDC. At this input voltage, the duty cycle will be less than 1.5 percent, making it more noise sensitive and difficult to control. Moreover, the higher input voltage increases the overall size of the circuit. The coupled inductor is larger and may need to be custom designed. Additionally, the MOSFET would need to be rated for more than 400V, which means it will also be in a larger package. For this wider input range, a flyback normally makes more sense.

In conclusion, the SEPIC converter can provide a very compact solution for low-power bias supplies when isolation is not required. Using standard off-the-shelf drum core inductors is key to reducing the size. The design example given can be easily modified for other output voltages ranging from 3.3V to 15V with good efficiency.

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Author: Brian King
Applications Engineer, Power Group
Texas Instruments

www.ti.com

Raising the Wireless Bar

Single-chip complete 3G/4G power management solution

By Brian Huang

The term "3G" will become the substandard mobile broadband connection as "4G" debuts across major US cellular network carriers. At a nominal data transfer rate of 100Mb/s, 4G will supersede the current 14Mb/s 3G standard and grant mobile devices online freedom at speeds comparable to broadband speeds at home or at work.

Micrel's MIC2829 is a highly integrated Power Management Integrated Circuit (PMIC) designed to revolutionize the powering of 3G/4G platforms in the mobile broadband market. The device incorporates four HyperLight Load™ (HLL) DC/DC buck regulators, two 100 percent duty cycle PWM buck regulators, five general purpose LDOs, six high performance Low Noise Regulators (LNR) and digital level shifters for SIM Card support. The MIC2829 also features synchronized startup, fixed and adjustable output voltages, voltage scaling, external soft start delay and power on reset (POR). This high level of integration combines seventeen regulators and their features into an 85-bump 5.5mm x 5.5mm FBGA package or a 76-pin 5.5mm x 5.5mm LGA package with a junction temperature range from -40°C to +125°C. The MIC2829 represents the future of high performance design in mobile platforms because it integrates both the benefits of switching regulators and LDOs by providing high efficiency, improving performance and reducing solution size. The single-chip complete solution reduces valuable board space lost in the packaging when using multiple chip solutions and shrinks the total solution size below $250mm^2$. This enables the IC to easily fit onto portable USB dongles in 3G/4G wireless modems. The space saving leads to cost saving and is just the beginning. The technologies incorporated into the MIC2829 make it an elegant, high performance PMIC that delivers the best power management solution in mobile platforms.

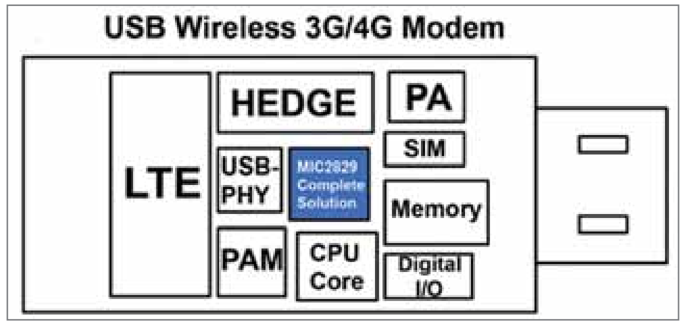


Figure1. Single-Chip Complete Solution for 3G/4G USB Modem

HyperLight LoadTM buck regulators

Micrel's HyperLight LoadTM buck regulators are some of the most advanced switching regulators on the market today. The "Hyper" refers to the ultra-fast load transient response of the HLL regulator. The "Light Load" refers to the high efficiency at light loads. Unlike traditional PWM buck regulators, the HLL buck regulator will automatically adjust its switching scheme from light load to heavy load in order to maintain high efficiency across the entire load range. At light loads, the HLL regulator will switch at a lower frequency to reduce switching losses. As the load increases, the switching frequency increases until the device goes into continuous conduction mode (CCM). Once in CCM, the HLL regulator will switch at a constant frequency to maintain high efficiency. The four HLL buck regulators on the MIC2829 (DC1 to DC4) are designed with all the benefits of HLL regulators including the low quiescent current and the easiness of input and output decoupling using tiny ceramic capacitors. The low quiescent current consumption reduces current draw during the sleep-mode (light load) operation. When full operation (heavy load) is required, the HLL buck regulators will continue to provide high efficiency to maximize battery life. The HLL regulators (DC1, DC2 and DC4) on the MIC2829 all have a 4MHz switching frequency in CCM. The high switching frequency allows for use with lower inductance, which generally translates to smaller sized inductors. The HLL regulator (DC3) is set at a higher output voltage and is specifically designed to switch at 2.5MHz in CCM to accommodate for the higher duty cycle. The output current capability of the HLL buck regulators on the MIC2829 is designed to meet the power requirements inside 3G/4G modems (DC1-1A, DC2-300mA, DC3-600mA and DC4-600mA). DC1, DC2 and DC4 can be used to provide power to the CPU Core, the digital input/output interfaces and the memory inside 3G/4G modem designs. The DC3 HLL regulator can be used to provide input power to the LDOs on the MIC2829 to improve the LDO efficiency. For example, since the efficiency of an LDO is approximately the output voltage divided by the input voltage, by setting DC3's output voltage slightly higher than the dropout voltage of the LDOs, the efficiency of the LDOs will be higher due to the low voltage drop. Driving the LDOs with the HLL buck regulator is a key advantage of the MIC2829 that helps maintain high efficiency throughout the entire system without sacrificing performance or solution size.

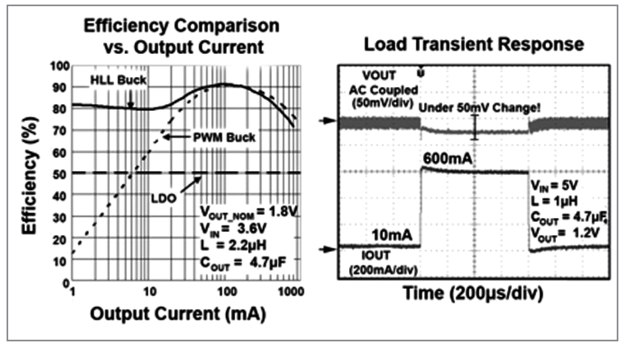


Figure2. HyperLight Load Efficiency and Load Transient Response

High efficiency PWM buck regulators

When integrating different types of voltage regulators into a single PMIC, it is advantageous to select the right type of regulator for the right application. There are two high efficiency, 100 percent duty cycle, 2MHz PWM buck regulators on the MIC2829 (DC5 and DC6). The advantage of using standard PWM regulators on the MIC2829 lies in their high efficiency in CCM, excellent output voltage accuracy and high duty cycle capability. Since the PWM regulator can maintain over 96 percent efficiency in CCM, it is ideal for powering RF transceivers and power amplifiers for the mobile RF antenna. If required, DC5 and DC6 can also be set at a slightly higher voltage to drive LDOs to improve LDO efficiency. The two PWM buck regulators on the MIC2829 are adjustable, using external resistors to support various voltage levels, and each has an 800mA output current capability for various application requirements. Since DC5 and DC6 are best used in CCM to benefit from the high efficiency, they are best paired with higher current power blocks which use higher currents for majority of the time. Using the PWM regulator under the best conditions will help benefit the overall system design by providing the highest possible efficiency given the space allowed.

General purpose LDOs

There are five general purpose 200mA LDOs; (LDO1-LDO4, LDO11) on the MIC2829. They are ideal for powering various baseband circuitries such as digital

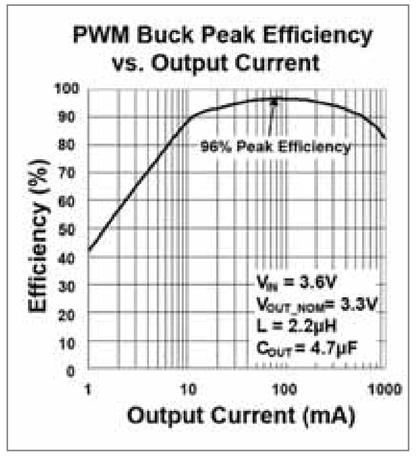


Figure3. High Efficiency PWM Buck Regulator

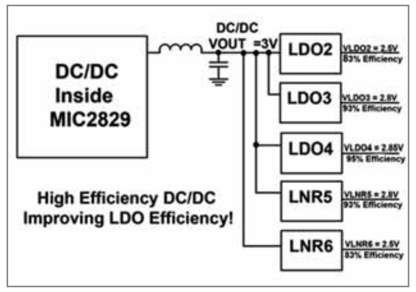


Figure4. Improving LDO-LNR Efficiency with DC-DC Switching Regulator

signal processors (DSP), various input/output (I/O) interfaces, phase lock loops (PLL), analog-to-digital (ADC) converters and pulse amplitude modulation (PAM) control power. The general purpose LDOs on Micrel's MIC2829 have all the advantages of LDOs such as low dropout, good input noise rejection and low ground current. One disadvantage of using LDOs is their low efficiency when the difference between the input voltage and the output voltage is large. On the MIC2829, the general purpose LDOs do not have to worry about this disadvantage since the high voltage drop from the main system power rail is managed by a switching regulator. The LDOs on the MIC2829 can be driven by a switching regulator with output voltage set slightly above the dropout voltage of the LDOs that it is driving. This guarantees that the LDOs will be operating with maximum efficiency. Since the switching regulator has high efficiency, driving the LDOs with it reduces the total system power loss. This translates into longer battery life without sacrificing performance or solution size; one of the advantages of using such a highly integrated PMIC.

High performance low noise regulators (LNRs)

The remaining six high-performance 200mA LNRs (LNR5-LNR10) on the MIC2829 are designed specifically to meet the requirements of noise sensitive RF circuitry inside 3G/4G applications. Each LNR has low dropout and ultra-low noise (20µVrms), maintains high PSRR (70dB at 1kHz) and requires just 20µA of quiescent current to operate. To improve efficiency, the LNRs can also be driven by a high efficiency switching regulator on the MIC2829. This helps keep the LTE/HEDGE RF circuitry inside 3G/4G applications running at maximum efficiency without sacrificing performance. The integration of LNRs in the MIC2829 covers the need for higher performance LDOs in RF circuitry without having to drive the RF section separately with other devices and waste space.

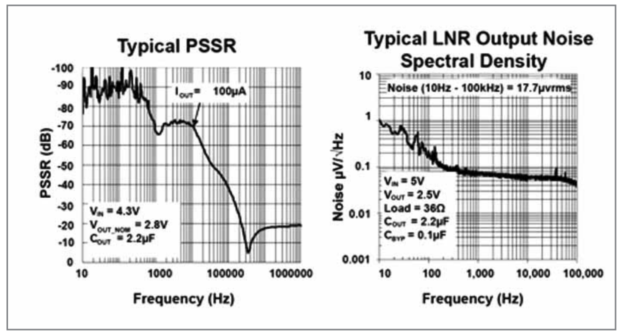


Figure5. LNR PSRR and LNR Output Noise Spectral Density

Digital level shifters for SIM card

The MIC2829 has built in SIM Card Level Translation. There is a tiny LDO capable of 50mA in the SIM Card interface designated for powering the level shifters. There are three digital level shifters that facilitate the communications between the RF, the baseband and the SIM card. The digital level shifters can shift the voltage from the baseband (1.8V) to the SIM Card (1.8V or 3.0V). The shifted voltage can be set to high or low using the Voltage Select Level Shifter (VSLS) pin. The integrated SIM Card level translation eliminates the need for another device to do the interfacing and simplifies the final design.

The MIC2829 PMIC advantage

During the wireless 3G/4G development stage, there are many solutions to choose from. Simply cutting and pasting multiple power management circuits together could work, but might not be the best solution possible and does not present an ingenious engineering design that creates change. A revolutionary technology such as 4G, is an engineering marvel that will transform how people experience the Internet and as such, deserves a meticulously engineered power management solution to support it. The MIC2829 integrates Micrel' s latest technology into a single-chip PMIC to deliver a complete solution for the next generation 3G/4G LTE/HEDGE applications. The fast, powerful and highly efficient HyperLight LoadTM regulators, the high efficiency, 100 percent duty cycle PWM regulators, the low dropout general purpose LDOs and the high performance LNRs have been available for system designers to use in their portable applications for years. These are all proven technologies that are currently being used globally. Inside the MIC2829 are carefully designed, enhanced and combined technologies ready to provide system designers who are working on 3G/4G applications a complete, single-chip solution that will reduce cost, provide high efficiency, improve performance and save valuable board space. This is the beginning of a highly integrated power management revolution that is going to create products that leap forward and raise the wireless bar.

Author: Brian Huang
Applications Engineer
Micrel Inc.

www.micrel.com

DESIGNING HIGH PERFORMANCE 4-CHANNEL AUDIO

Integrated driver facilitates Class D amplifier design

By Yasushi Nishinura, Liz Zheng and Jun Honda

Whether it is automotive entertainment or home theater systems, consumers have been asking for more channels and speakers with the ability to handle higher audio power levels per channel. In addition to higher Wattage, the audiophiles have been demanding improved sound quality with lower distortion and noise, and excellent isolation between channels.

In multi-channel design, driving each channel individually translates into higher power consumption, more components, and bigger board space resulting in a complex design with thermal issues, lower sound quality and reliability at higher cost.

Thus, to minimize power dissipation and simplify thermal management of multi-channel high performance audio systems, designers have been tapping the benefits of high efficiency class D audio amplifiers capable of achieving efficiencies over 90% across a wide range of output power levels. By comparison, the efficiency of traditional class AB amplifiers serving this market is around 50%. And it falls rapidly as the output power level drops. Likewise, to cut component count and minimize board space, engineers have been exploiting the benefits of integrated ICs.

Four channel driver

Accordingly, blending advances in DirectFET power MOSFETs with an innovative integrated audio driver, International Rectifier has developed a four channel class D audio amplifier design that is comparable in performance to a single channel solution. To achieve that, this circuit utilizes an integrated audio driver, labeled IRS2093M, that packs four channels of high-voltage power MOSFET drivers on the same chip. In addition, the 200V device includes on-chip error amplifier, analog PWM modulator, programmable preset dead-time and robust protection functions specifically designed for class D audio amplifier applications in half-bridge topology (Figure 1). Aside from preventing shoot-through and rush of current through the power MOSFETs, the programmable preset dead-time also enables scalable power design both in terms

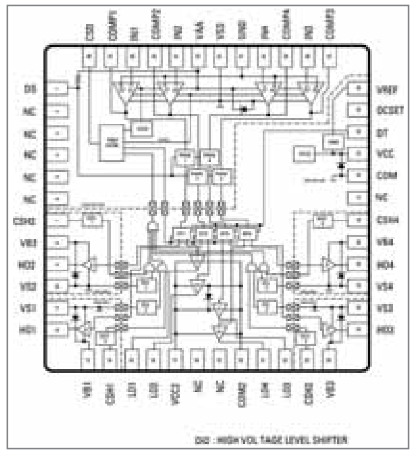


Figure 1: Besides integrating four channels of high-voltage power MOSFET drivers on the same die, this 200V device also includes on-chip error amplifier, analog PWM modulator, programmable preset dead-time and robust protection functions

of power and number of channels. The protection features include over current protection (OCP) with self-reset control and under voltage lock-out (UVLO) protection.

For excellent isolation between the channels, the audio driver implements proven high-voltage junction isolation techniques and floating gate drivers using Gen 5 HVIC process. As a result, there is excellent internal signal isolation on the die, enabling the circuit to process signals on more channels simultaneously. Thus, keeping the noise floor in each channel significantly low. And concurrently minimizing cross-talk between the channels.

Subsequently, incorporating the integrated class D audio controller and gate driver IRS2093M along with eight DirectFET power MOSFETs IRF6665 and a few passive components, a four channel half-bridge class D audio amplifier circuit has been built as shown in Figure 2. Each channel in this multi-channel audio amplifier is designed to offer 120W output power. For ease of use, this circuit contains all the required house keeping power supplies.

To achieve best overall performance, the power MOSFETs IRF6665 have been specifically optimized for class D amplifier design. Besides offering low on-resistance, these power MOSFETs are also tailored for achieving minimal gate charge, body reverse recovery and internal gate resistance. In addition, the DirectFET packaging offers lower parasitic inductance and resistance as compared to conventional wire bonded packages. In short, IRF6665 MOSFETs are optimized

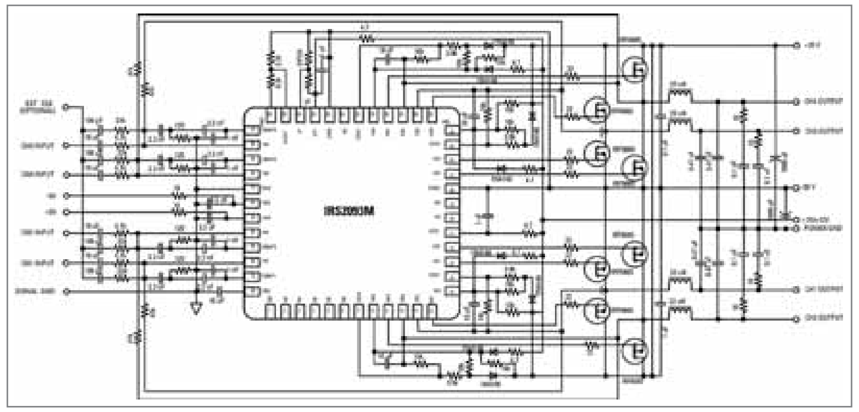


Figure 2: A four-channel half bridge class D audio amplifier design employs integrated class D audio controller and gate driver IRS2093M and eight DirectFET MOSFETs IRF6665 along with a few passive components

for delivering high efficiency and low total harmonic distortion (THD) and electromagnetic interference (EMI).

Features & Functions

For achieving smaller space with highest performance and robust design, this four- channel class D audio amplifier solution employs self-oscillating PWM modulation. Since this topology corresponds to an analog version of a second order sigma-delta modulation with class D switching stage inside the loop, all the errors in the audible frequency range are shifted to the inaudible upper frequency range by the nature of its operation. The result is lower noise. Also, sigma-delta modulation permits a designer to apply a sufficient amount of error correction to further lower noise and distortion.

As seen in figure 2, the self-oscillating topology comprises front-end integrator, PWM comparator, level shifters, gate drivers and output low-pass filter (LPF). Although, it can switch at much higher frequencies, this design uses 400kHz as optimum switching frequency for several reasons. First, at lower frequencies, the efficiency of the MOSFET stage improves but inductor ripple current increases, as well as output PWM switching carrier leakage rises. Secondly, at higher frequencies, switching losses degrade efficiency, but wider bandwidth is possible. While inductor ripple decreases, iron losses go up.

Since in a class D audio amplifier the direction of load current alternates with the audio input signal, an over current condition can occur either during a positive current cycle or a negative current cycle. Hence, to protect both high-side and low-side MOSFETs against over current in either direction, the programmable OCP offers bidirectional protection. For that, it uses RDS(on) of the output MOSFETs as current sensing resistors. In this design, when the measured current exceeds the preset threshold, the OCP logic outputs a signal to the protection block, forcing HO and LO pins low, and thereby protecting the MOSFETs from damage.

Due to the structural constraints of the high voltage ICs, current sensing is implemented differently for the high-side and low-side

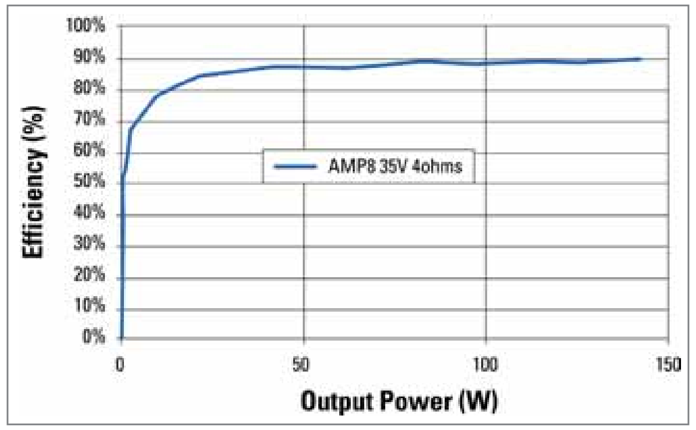


Figure 3: From less than 50W output to 120W into a 4Ω load, the measured efficiency curve shows that the efficiency per channel is about 90%

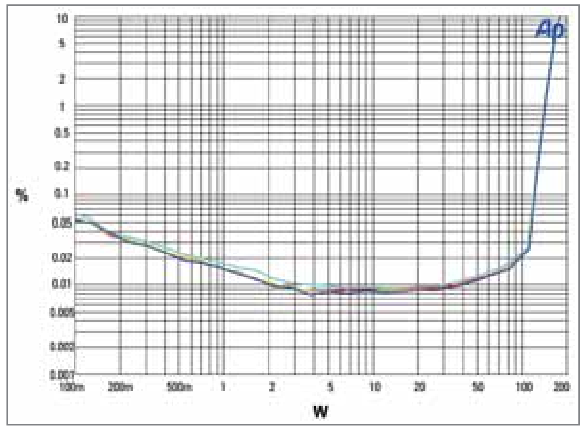


Figure 4: The total harmonic distortion plus noise (THD+N) is less than 0.01% below 50W per channel and begins to increase as the output power increases

MOSFETs. For instance, low-side current sensing is based on the measurement of VDS across the low-side MOSFET during on-state of the device. To avoid triggering OCP from overshoot, a blanking interval inserted after LO turn-on disables over current detection for 450ns.

The threshold voltage for low-side over current sensing is set by the OCSET pin, which is in the range 0.5 to 5.0V. Consequently, when the measured VDS of the low-side MOSFET exceeds the voltage at OCSET pin with respect to COM, the driver circuit begins the OCP protection sequence. To program the trip level for over current, the voltage at OCSET pin is calculated using the following equation.

VOCSET = VDS(low-side) = ITRIP+ x RDS(on)

In order to minimize the effect of the input bias current at OCSET pin, the resistor values R4 and R5 are selected such that the current through the voltage divider is 0.5mA or more. Also, using VREF to generate an input to OCSET through a resistive divider provides improved immunity from fluctuations in the supply voltage Vcc.

Likewise, for positive load currents, high-side over current sensing also monitors the load condition, which is based on the measurement of VDS across the high-side MOSFET during high-side turn on via pins CSH and Vs. Subsequently, when the load current exceeds the preset trip level, the OCP protection shuts down the switching operation. To prevent triggering OCP from overshoot, a blanking interval inserted after HO turn-on disables over current detection for 450ns.

Unlike low-side current sensing, the threshold for CSH pin is internally fixed at 1.2V. However, an external resistive divider R2 and R3 can be employed to program a higher threshold value. In either case, an external blocking diode D1 is used to block high voltages from feeding into the CSH pin while the high-side is off. Due to a forward voltage drop of 0.6V across D1, the minimum threshold for high-side over current protection is 0.6V.

In short, the threshold value of the CSH pin, V_{CSH}, can be calculated as:

$$V_{CSH} = \frac{R3}{R2+R3} \cdot \left(R_{DS(ON)} \cdot I_D + VF_{(D1)}\right)$$

Where ID is the drain current and VF(D1) is the forward voltage drop of D1. Also, reverse blocking diode D1 is forward biased by a 10kΩ resistor R1.

To prevent shoot-through or rush of current through both MOSFETs, a blanking period known as dead-time is inserted between either high-side turn-off and low-side turn-on or low-side turn-off and high-side turn-on. For optimized performance, the integrated driver permits the designer to select dead-time from a range of preset values, depending on the size of the MOSFETs selected. In fact, only two external resistors are required to set the dead-time via the DT pin of IRS2093. The end result is that there is no gate-timing adjustment required externally. Plus, it prevents outside noise from modulating switching timing, which is critical to audio performance.

While determining optimal dead-time, the user must take into account the fall time of the MOSFET. This is because the effective dead-time in an actual application differs from the dead-time in the datasheet due to the switching fall time tf. That means, to determine effective dead-time,

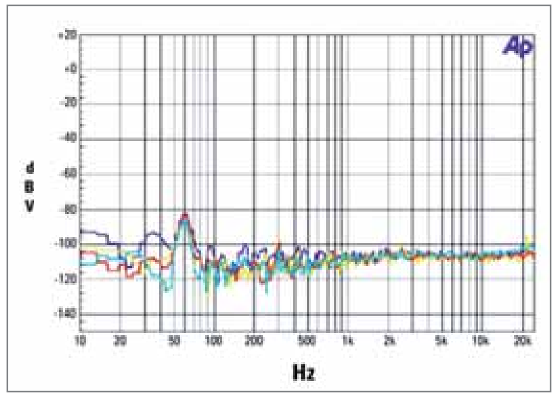


Figure 5: With no signal input, the noise floor in each channel remains below -80dBv over the entire audio range

the fall-time of the MOSFET gate voltage must be subtracted from the dead-time value of the datasheet.

Similarly, for UVLO protection, the driver monitors the status of voltage supplies V_{AA} and V_{CC} to ensure that both the voltages are above their respective thresholds before starting normal operation. If either VAA or V_{CC} falls below the UVLO threshold, the protection logic of IRS2093 turns off LO and HO. As a result, the power MOSFETs are disabled until both VAA and VCC rise above their voltage threshold values.

Furthermore, for optimum audio performance, the four channel audio board is designed to minimize trace impedances and curb coupling between analog and switching sections. Plus, it ensures that the analog signal ground is separated from the switching stage, as well as the power ground.

Measured performance

Using sinusoidal signal frequency of 1kHz at 1Vrms and 4Ω load impedance, efficiency, THD plus noise (THD+N) and EMI performance is measured on each of the channels. In addition, measurements were conducted to demonstrate the excellent isolation and cross-talk performance of the four channel class D audio amplifier design in figure 2. The supply voltages for the circuit board are ±35V, while the self oscillating frequency is 400kHz.

As illustrated in Figure 3, the efficiency per channel is about 90% from less than 50W power output to 120W output into a 4Ω load. Major factors contributing to high channel efficiency are low conduction and switching losses generated DirectFET MOSFETs IRF6665. And no cross conduction because of secure dead-time provided by the integrated driver.

It is observed that with such high power efficiency, this four-channel design is able to handle one-eighth of the continuous rated power, which is generally considered to be a normal operating condition for safety, without any additional heat sinks or forced air cooling.

Similarly, tests conducted for distortion indicate that the THD+N performance for each of the channels is identical over a wide output power range. As depicted in Figure 4, the THD+N is less than 0.01% below 50W per channel and begins to increase as the output power increases. For instance, around 100W output per channel, the distortion rises to 0.02%. This performance remains consistent over the entire audio frequency range of 20Hz to 20kHz, even as the output power is enhanced from 10W per channel to 50W per channel with a 4Ω load. Likewise, as exhibited in Figure 5, the noise floor in each channel remains below -80dBv over the entire audio range. The noise is measured with no signal input and self oscillator at 400kHz.

Similar tests conducted for channel separation suggests that the cross-talk between channels 1 and 3 and 1 and 4 is better than -70 dB over the entire audio range at 60 W output power per channel.

Also, this design offers good power supply rejection ratio (PSRR) of -68dB at 1 kHz signal. The high PSRR is the result of the self oscillating frequency of the driver. Thus, enabling the four-channel class D amplifier to deliver high performance even with the unregulated power supplies.

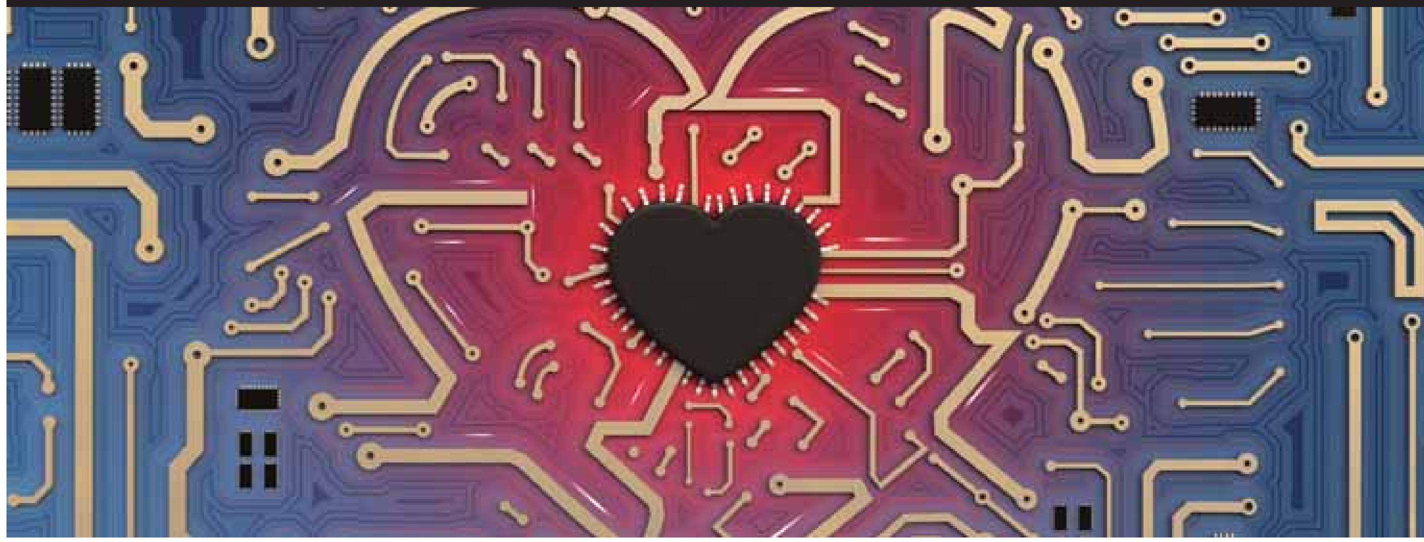
Conclusions

The efficiency, THD+N and EMI performance of this four-channel class D audio amplifier solution using integrated driver IRS2093M is comparable to single channel design. Additionally, the noise floor remains below -80 dBv over the entire audio range. And there is excellent isolation between the channels to keep intermodulation distortion (IMD) to a bare minimum for a satisfactory audio performance. While high efficiency eliminates heatsinks, the integrated audio driver realizes four-channel class D audio amplifier solution in a 50% smaller footprint.

Author: Yasushi Nishinura, Liz Zheng and Jun Honda
International Rectifier www.irf.com

SPECIAL REPORT: HEALTH & MEDICAL

EUROPE
Power Systems Design: Empowering Global Innovation



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SMART BATTERY MANAGEMENT IN MEDICAL DEVICES

Provides accuracy, ease-of-use and reliability

By Shadi Hawawini and George Paparrizos

Technology advancements over the past few years have generated many new developments that have specifically benefitted the portable medical device market. The focus of such efforts has centered on simplifying data collection/logging and reporting; developing products that allow patients to be monitored remotely; and centralizing patient databases for better and faster healthcare delivery.

New portable medical equipment take advantage of the wide adoption of electronic and passive components, materials and software utilized in consumer gadgets, by including features that demonstrate improved reliability, lower cost and faster market entry. As with many other aspects of the medical field, such system designs have their own idiosyncrasies that need to be addressed. Medical devices need to meet certain, stricter criteria for successful market introduction. These include measurement accuracy, product safety, fast charging, longer usable life, and user- and environmental-friendliness.

Measurement accuracy is a requirement for ensuring higher accuracy in the sensing portion of the medical device. In most cases, this translates to a need for keeping the medical equipment case temperature within certain tolerances. Higher temperature levels have a negative impact on the sensing precision and may require expensive methods for compensating for potential measurement errors. This is the main driver behind the need for high-efficiency battery charging in such system designs. The graph below demonstrates the power dissipation and temperature levels between a switch-mode and a traditional battery charging solution, while charging a 1700mAh battery.

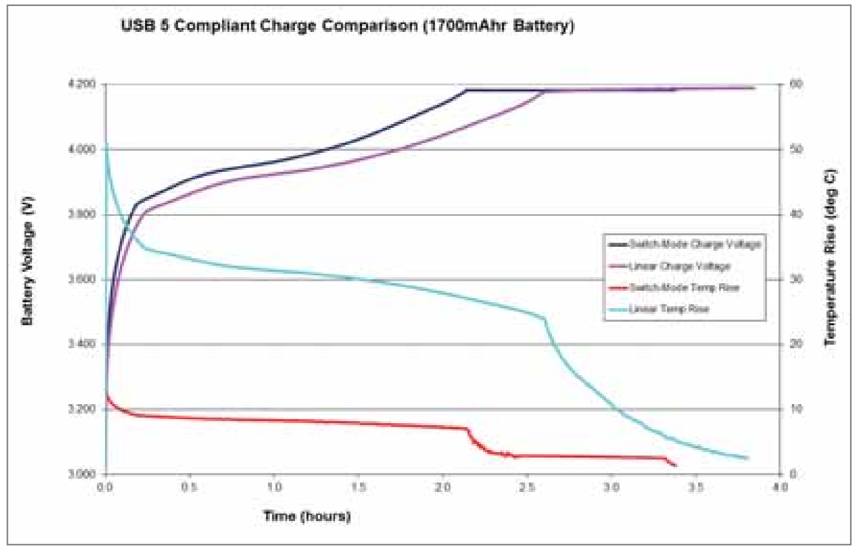


Figure 1: Power dissipation and temperature rise comparison between a linear and a switch-mode battery charging solution

The power dissipation in a linear mode battery charger can be significantly higher, than in a switch-mode battery charge, particularly in cases where the battery voltage is low and the charge current levels are high. The power dissipated for each battery charger type can also be calculated from the below equations. For a switch mode charger, the efficiency will be between 85% and 90%.

$$P_{Diss,Linear} = I_{BQ}\left(V_{in} - V_{batt}\right)$$

Equation 1: Power dissipation in a linear battery charger (Ibq = Battery Charge Current)

$$P_{Diss,Buck} = V_{batt} I_{BQ}\left(\frac{1}{\eta} - 1\right)$$

Equation 2: Power dissipation in a buck switch-mode regulator

High-efficiency charging can also significantly increase system reliability, since it reduces average ambient temperature levels, which in turn extend the life of other key components and of the portable device itself. Extending usable battery can also be accomplished by reducing frequent and unnecessary charge cycles when the battery voltage is above certain operational levels. Such functionality already exists in some of the modern battery charging solutions on the market and is utilized in other markets where battery charging initiation may be a frequent activity.

Product safety is also a very important factor given that many of the portable medical equipment are used by consumers in a variety of environmental conditions.

Figure 2: Graphic user interface demonstrates real-time monitoring of charging state and key failure sources.

Dynamic adjustment of critical charging and power delivery parameters allows for optimal and safe system operation. Medical equipment can also benefit by real-time monitoring and reporting of charging status and potential charging errors. Such functionality can proactively addresses system failures in a timely manner, which is very critical for patients. The figure below demonstrates an example of a battery charging IC that provides a variety of real-time status and fault information to the system.

The input voltage to a device and its subsequent protection is also one of the top safety concerns with medical devices in the field. Although a USB port or a wall adapter should be very well regulated in terms of voltage, a faulty port or wall/car adapter could potentially output 12V or more. Charging ICs are required to tolerate such over-voltage conditions, thereby protecting the downstream circuitry and eliminating damage to the portable equipment. Another important safety feature is battery temperature monitoring. If the temperature in a battery pack gets too hot, whether it is due to overcharging or high ambient temperatures, it can become a very serious safety hazard. In such cases, modern battery charging ICs can adjust charging voltage or current levels, and in extreme conditions even suspend charging to ensure battery and system health.

Faster charging is another key requirement for modern medical devices, since it allows quick deployment for critical and timely patient monitoring. This is another benefit of the switch-mode battery charging architecture, particularly when powered by a current limited supply like a USB port. For a switch-mode battery charger, charging from an input current limited source, the following equation gives the current that is "multiplied" to charge the battery, due to efficient input-to-output power transfer in stepping down the voltage. Assuming an efficiency of 90%, an input voltage of 5V, an input limited source capable of 500mA, and a battery voltage of 3V, the current that will go to charging the battery will be 750mA.

$$I_{BQ} = \frac{\eta V_{in} I_{in,limited}}{V_{batt}}$$

Equation 3: Calculation of battery charge current using an input limited source

Another major driving factor behind the development of new portable medical devices is the need for user-friendliness. Given that the devices are targeting a highly diverse population in terms of age, education, ethnicity etc., handling and controlling the device needs to be straight-forward. The easiest interface, and the most universally known and recognized is the USB one. The great benefit of USB for a consumer is its familiarity; it can plug into most PCs or wall adapters, and charge their device, while synchronizing or downloading data. The problem then arises for the device manufacturer, who must ensure that the product is robust and interoperable with a high number of USB hosts, hubs, and wall adapters that may vary in quality. While the USB Battery Charging 1.1 specification has tried to standardize charging from a physical USB cable or connector, there are bound to be non-compliant devices that need to be accounted for. Examples may include adapters that are not properly rated in terms of output current drive capability. Clearly if an adapter that can supply 700mA is expected, but the actual adapter can only supply 300mA, then there will be problems with the battery charging resulting in the inability of a patient to charge the device for use. An ideal battery charger should then be able to charge a battery in accordance with the USB Battery Charging 1.1 specification, but should also have the versatility and flexibility to deal with non-compliant peripherals.

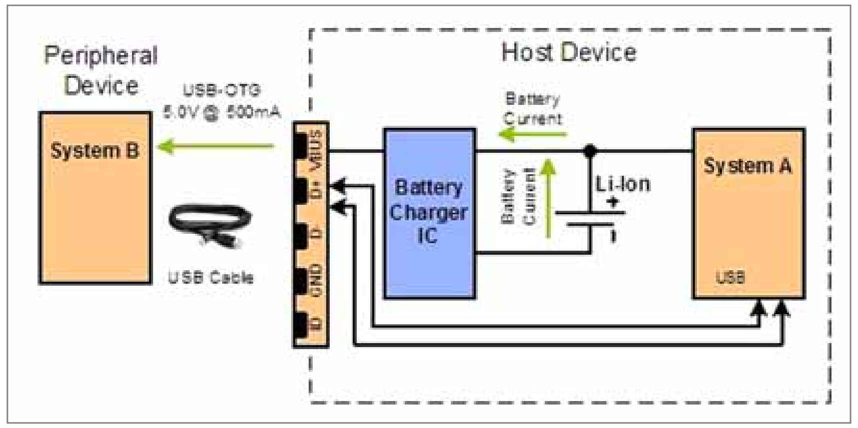


Figure 3: Block diagram demonstrating an innovative battery charging solution that can use the battery as its power source and provide the required power at VBUS for USB on-the-go support.

Two additional benefits of the adoption of USB as the de-facto interface are: a) the wide industry adoption of micro USB connectors and cables, which guarantees a low-cost solution, and b) the enabling of USB On-the-Go. The later allows peripheral and master medical devices to connect, communicate with each other and share data without the need of a personal computer. Such an implementation is shown in the below figure.

Environmental trends also have a large impact on new medical electronic designs. The ownership of the equipment requires manufacturers to be responsible for battery replacement and recycling. The transition to rechargeable battery technologies, such as Li-Ion and Li-Polymer, addresses this issue and eliminates prohibitive cost measures (collecting and recycling old batteries) that may also be shared by patients and the healthcare industry as a whole. These batteries are also manufactured with materials that are environmentally friendlier than their older counterparts.

Summary

With an aging patient population and tremendous pressure for cost reductions in the healthcare market, enabling remote medical diagnosis and treatment as well as real-time retrieval of patient data is inevitable. While taking advantage of the popularity, features and environmental friendliness of Lithium-ion battery cells, medical device and equipment makers today must also rely on innovative technology to deliver the most effective charging and power management solutions to meet the market's stringent requirements.

Author: Shadi Hawawini and George Paparrizos,
Summit Microelectronics

www.summitmicro.com

POWERING MEDICAL APPLICATIONS

Third edition medical safety standard impacts power supply selection

By Peter Blyth

Safety is paramount wherever power supplies are used, but nowhere more so than in medical applications where even small parasitic leakage currents may compromise safety. First published in 1977, the internationally accepted IEC 60601-1 standard has been continuously developed to help alleviate safety issues relating to all manner of medical equipment.

The latest version is the third edition that was published in December 2005 and that has been adopted on different timescales around the globe. In the European Union, the standard appeared as EN 60601-1:2006 and its three-year transition date expired last September. Similarly, most major countries have adopted IEC 60601-1 as their national standard, in some cases with national variations such as ANSI/AAMI ES60601-1 in the US and Canada's CAN/CSA C22.2 No. 601.1.

Clearly, minimizing risk is a crucial part of any medical equipment design process, and it is in strengthening this aspect that the updates within the third edition focus upon. The standard's range extends to equipment that has a single connection to the ac line supply and that is intended to diagnose, treat, or monitor patients under medical supervision. Qualifying equipment includes devices that make physical or electrical contact with the patient, and/or transfer energy to or from the patient, and/or detect energy transfer to or from the patient. The most significant change that the third edition introduces is that equipment manufacturers must now follow a formal risk management procedure that follows the ISO 14971 model, which effectively means that you now have to comply with a process standard as well as the fundamental product standard.

While the second edition simply addressed basic safety issues to ensure freedom from any electrical, mechanical, radiation, and thermal hazards, it did not require devices to remain functional—fail-safe was adequate, and compliance with test criteria relied upon a pass/fail result that did not take into account the essential performance of the device-under-test. Recognizing these limitations, the third edition introduces specifications for "essential performance" that requires equipment to continue functioning as its designers intended throughout the test process.

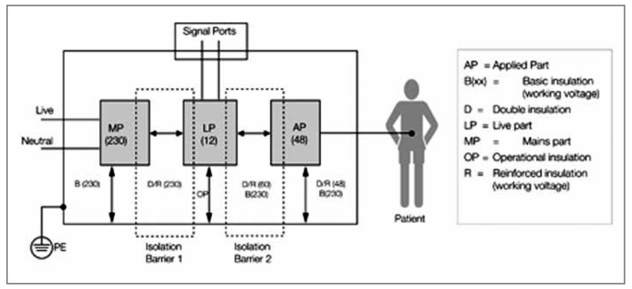
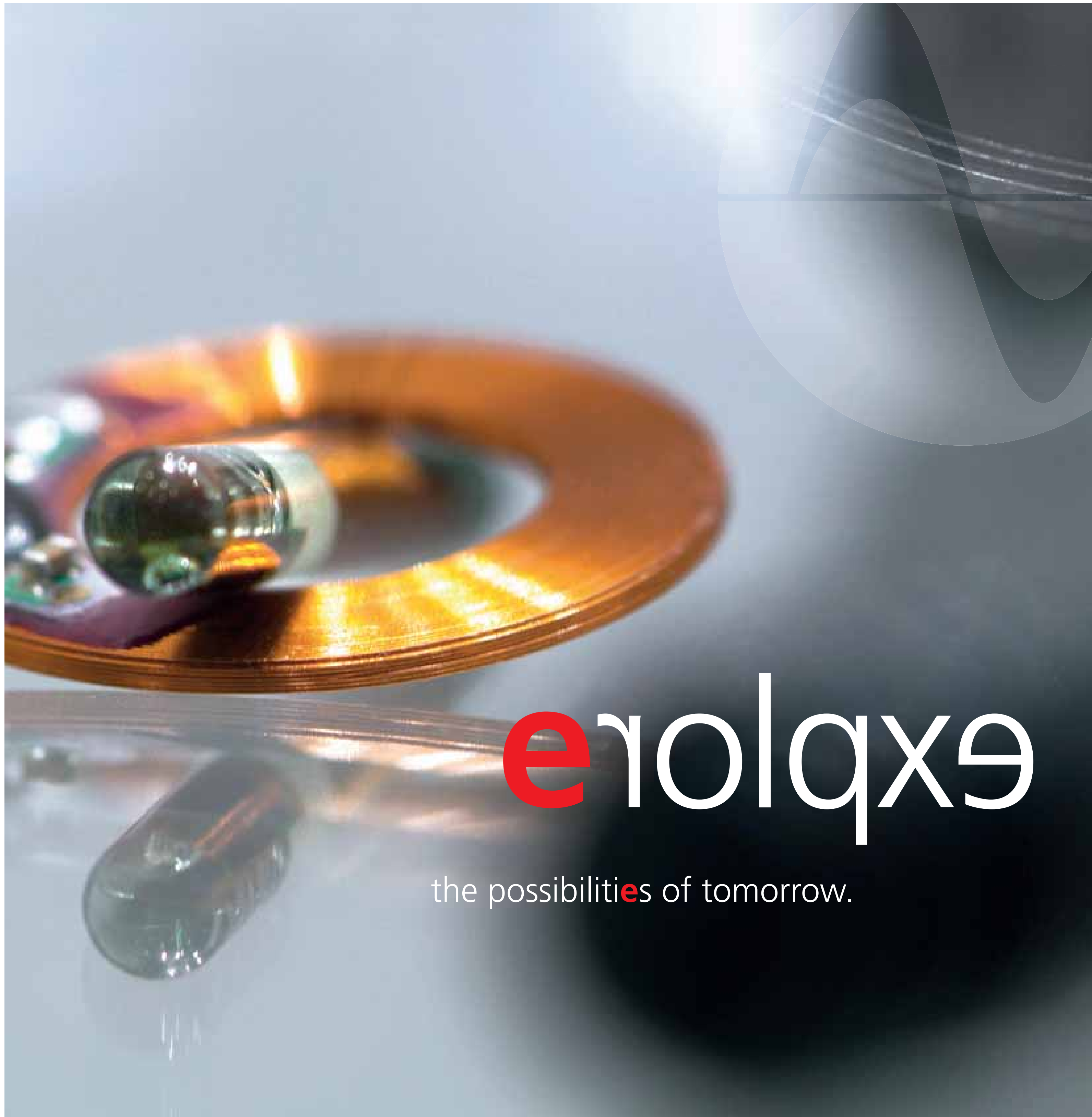


Figure 1: IEC60601-1 third edition demands that two means of protection (MOPs), or isolation barriers exist where patients may come into contact with equipment.



Within the electrical safety arena, the standard continues to require that equipment implements two Means of Protection (MOP) such that if a failure occurs within one area, a second mechanism safeguards the operator and/or the patient against any electric shock hazard. Figure 1 models the insulation diagram that applies to the main circuit blocks in a notional medical device, and shows the two isolation barriers that provide the two Means of Protection that must be present within a device that may come into contact with a patient.

The standard allows for three defensive approaches that may be used in various combinations—safety insulation, protective earth, and protection impedance. So far as insulation is concerned, a change in terminology sees basic insulation allocated a 1 MOP rating while double or reinforced insulation rates as 2 MOPs. It's therefore essential to determine several key factors from the outset of the equipment design process, including its insulation class and whether it will rely upon a protective earth connection. These considerations extend to the "applied part", if present, that is deliberately attached to the patient. Such applied parts are separately classified as to the level of electric shock protection that they provide.

Significantly for power supplies, the third edition distinguishes between protecting the equipment's operator and the patient within its Means of Operator Protection (MOOP) and Means of Patient Protection (MOPP) categories. This distinction can result in quite different safety insulation and isolation requirements for circuits that operators and patients may come into contact with. Specifically, anything that falls within the remit of operator protection only has to meet the clearance and creepage requirements that IEC/EN 60950 specifies for general-purpose information and technology equipment. By contrast, circuitry that falls within the realm of patient protection must meet the far more exacting requirements that the second edition of IEC 60601-1 introduced. Furthermore, some equipment may include parts that fall under both categories, with risk analysis techniques often being used to determine the respective boundaries.

In this respect, it's arguable that the third edition of IEC 60601-1 defines patient vicinity less well than its predecessor. While the second edition drew a boundary of 1.5 m around the patient, the latest version employs risk assessment to determine where the patient is and the likelihood of him or her making contact with any part of the medical equipment. If the risk assessment shows that there is negligible likelihood of contact being made, it's theoretically possible to relax the insulation requirements to those of IEC/EN 60950. This also applies to conscious patients, as the standard now differentiates between conscious and unconscious states and makes the implicit assumption that those who are unconscious require a greater degree of protection. That is, in theory at least, the safety requirements for equipment that only comes into contact with conscious patients may be the same as the requirements for operators.

Selecting suitable power supplies
The main attraction of being able to specify a supply that meets normal IEC/EN 60950 standards is the potential for cost reduction. For instance, a supply that's built to meet IEC/EN 60601-1's far stricter demands to satisfy its Means of Patient Protection category requires significantly larger creepage distances and air clearances that normal commercial-off-the-shelf supplies employ, together with greater levels of dielectric breakdown test voltages. However, any supply that is used within a patient's vicinity still has to meet IEC/EN 60601-1's earth leakage current requirements, which would almost certainly require significant modifications to a normal commercial unit. Such modifications typically include reducing the values of the Y-capacitors that help reduce the earth leakage current but this has a negative effect on the emissions produced by the power supply. As a result, the modified unit is less likely to meet EMC regulations and may require additional internal and/or external filtering. Re-qualifying a modified supply for safety or EMC concerns can then be a costly and time-consuming exercise.

Marketing considerations can play an important part here too. Despite the cost savings that using standard commercial supplies might present, many medical equipment manufacturers still choose to specify IEC/EN 60601-1-approved parts for any product that is likely to come into contact with a patient, as to do otherwise may compromise salability. From a commercial perspective, the manufacturer faces two main choices here—to possibly save money by purchasing IEC/EN 60950-compliant supplies when the risk assessment determines that

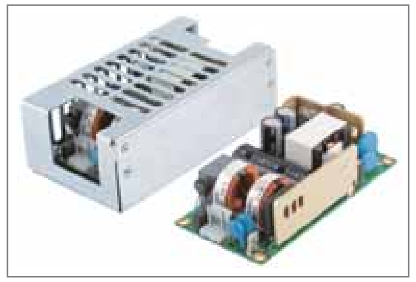


Figure 2: These 100W AC/DC switchers that meet industrial, ITE and medical specifications cost little more than ITE-only approved units

this is an option, or to go for a cost-effective IEC/EN 60601-1 approved unit. In a parallel development, component technology and design technique improvements now enable power-supply manufacturers to offer units that simultaneously meet industrial, information technology, and medical standards, with volume manufacturing lowering costs to make medical-quality supplies cost-competitive with commercial units.

For instance, a typical 60W medically-qualified power supply costs around $35 in quantities of a few hundred pieces. Substituting a normal IEC/EN 60950-compliant part is unlikely to save more than $5, while at the same time limiting application flexibility. Worse, if you then have to modify the commercial-quality supply to meet say leakage current requirements, this choice is no longer lower cost. It may also limit your market, compromise your brand, or introduce additional and avoidable risks. As a result, specifying IEC/EN 60601-1 approved units that comply with Means Of Patient Protection (MOPP) is becoming a preferred approach for device manufacturers.

Whilst the 3rd edition appears to offer the device manufacturer more options on the choice of power supply, the fundamental question of risk vs. cost must be considered; does one opt for a cheaper power supply with lower performance to save a few dollars or go for a higher specification power supply that might cost more but reduces the risk to as low as possible. After all, if you get it wrong in medical device design it could severely delay gaining regulatory approval or worse.

45W power supply with medical and industrial safety approvals
XP Power has announced what is believed to be the world's smallest open frame 45W AC-DC power supply. Setting a new benchmark at this power level, measuring just 50.7 x 76.2 x 26.7mm (2 x 3 x 1.05 inches), the ECS45 single output power supply is 25% smaller than the current industry standard of 2 x 4 inches.

All models have a no load power of less than 0.3W, helping the end equipment comply with internationally recognized energy efficiency standards. In addition, these convection cooled units are highly efficient, typically 87%, resulting in less waste heat to dissipate. The lower profile ECS25 model provides 25W output within the same footprint. They can provide full power output up to + 50 degrees C without the need for any external fans or forced airflow and operate up to + 70 degrees C with derating.

Both models provide the nominal outputs of +12, +15, + 24 or +48VDC. The ECS45 is also available with a single +5VDC 6A output. They have a wide input voltage range of 80-264VAC and are approved for Class I and Class II applications. The

units meet UL60601-1 / EN60601-1 medical equipment safety standards and UL60950-1 / EN60950-1 standards for IT and industrial equipment. They also comply with the EN55011 / EN55022 level B standard for conducted emissions without the need for additional filtering components. Overvoltage, overload and short-circuit protection features are included as standard across the whole range.

These power supplies suit designers of medical, IT or industrial equipment.
Applications can cover a wide variety, such as broadcast equipment, computing and data storage. The medical safety approval makes it suitable for products such as portable medical devices, home healthcare devices and personal drug delivery equipment. Covered versions of each model are also available for Class I installations.

Peter Blyth,
Medical Industry Director,
XP Power

www.xppower.com

LOWEST COST MEDICAL AND BEYOND

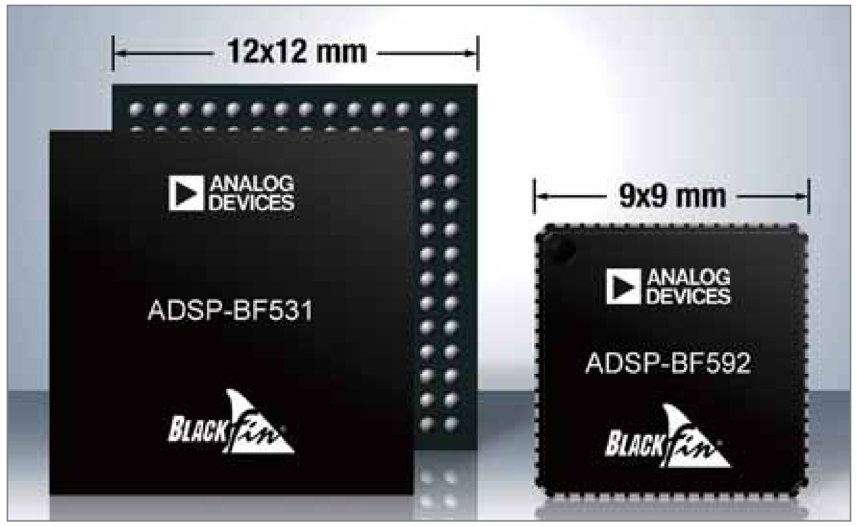
Analog's New Blackfin® DSP - Ultra Low Cost, 800 MMACs

Rick Murphy, as reported by Cliff Keys

Analog Devices products and technologies have made a significant contribution in healthcare designs – helping shape the future of diagnostics and monitoring equipment, as well as health and wellness devices. At ADI's Munich launch, Rich Murphy, Business Development Manager for Analog Devices' Processors-DSPs Core Products and Technologies Group, presented the company's new, lowest cost DSP including the vital evaluation kit and emulator which fits a broad range of cost-sensitive applications where performance cannot be compromised.

For over 40 years, Analog Devices has defined innovation and excellence in signal processing technologies. The company' s comprehensive portfolio of linear, mixed signal, MEMS and digital processing technologies set industry standards and are backed by comprehensive design tools, applications support, and systems expertise. A true systems approach to functional integration and collaboration with customers has created real differentiation in the marketplace.

Analog Devices, Inc. introduced the Blackfin ADSP-BF592 DSP with 800 MMACs/400MHz of performance for just $3 (10K quantities). Featuring active power draw as low as 88mW and a tiny 9mm x 9mm 64 lead LFCSP package, the Blackfin BF592 now makes integrating high-performance DSP (digital signal



Blackfin ADSP-BF592 DSP with 800 MMACs/400MHz performance processing) practical for many power-constrained and small form-factor applications in the industrial, medical, video, audio and general-purpose markets. To download the datasheet, visit the company's website.

Rich explained, "The low-cost, high-performance BF592 opens up many product possibilities for current and new Blackfin customers. Customers can now add very high-performance DSP to products that, due to cost and/or power constrictions, they were unable to before. Having an affordable 800MMACs of DSP allows designers to incorporate sophisticated signal processing previously only feasible for higher-priced end products."

The ADSP-BF592 processor is a member of the Blackfin® family of products, incorporating the Analog Devices/Intel Micro Signal Architecture (MSA). Blackfin processors combine a dual MAC state-of-the-art signal processing engine, the advantages of a clean, orthogonal RISC-like microprocessor instruction set, and single-instruction, multiple-data (SIMD) multimedia capabilities into a single instruction-set architecture.

This processor is completely code compatible with other Blackfin processors and offers performance up to 400MHz and reduced static power consumption.

By integrating a rich set of industry-leading system peripherals and memory, Blackfin processors are the platform of choice for next-generation applications that require RISC-like programmability, multimedia support, and leading-edge signal processing in one

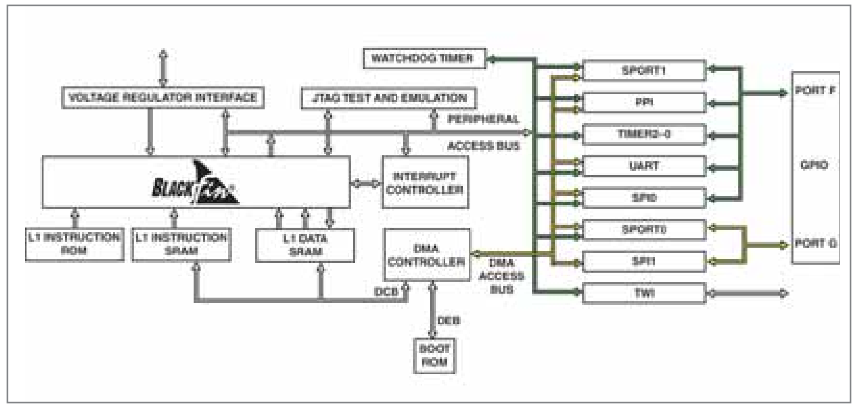


Figure 1: Processor block diagram

integrated package.

Portable Low-Power Architecture
Blackfin processors are produced with a low-power and low-voltage design methodology and feature on-chip dynamic power management, which provides the ability to vary both the voltage and frequency of operation to significantly lower overall power consumption. This capability can result in a substantial reduction in power consumption, compared with just varying the frequency of operation. This allows longer battery life for portable appliances.

System Integration
The ADSP-BF592 processor is a highly integrated system-on-a-chip solution for the next generation of portable medical, digital communication and consumer multimedia applications. By combining industry- standard interfaces with a high-performance signal processing core, cost-effective applications can be developed quickly, without the need for costly external components. The system peripherals include a watchdog timer; three 32-bit timers/ counters with PWM support; two dual-channel, full-duplex synchronous serial ports (SPORTs); two serial peripheral interface (SPI) compatible ports; one UART® with IrDA support; a parallel peripheral interface (PPI); and a two-wire interface (TWI) controller.

Processor Peripherals
The ADSP-BF592 processor contains a rich set of peripherals connected to the core via several high-bandwidth buses, providing flexibility in system configuration as well as excellent overall system performance (see Figure 1). The processor also contain dedicated communication modules and high-speed serial and parallel ports, an interrupt controller for flexible management of interrupts from the on-chip peripherals or external sources, and power management control functions to tailor the performance and power characteristics of the processor and system to many application scenarios.

The SPORTs, SPIs, UART, and PPI peripherals are supported by a flexible DMA structure. There are also separate memory DMA channels dedicated to data transfers between the processor's various memory spaces, including boot ROM. Multiple on-chip buses running at up to 100MHz provide enough bandwidth to keep the processor core running along with activity on all of the on-chip and external peripherals. The ADSP-BF592 processor includes an interface to an off-chip voltage regulator in support of the processor's dynamic power management capability.

Target applications for the BF592 include portable medical products; audio devices; imaging products, such as CMOS-sensor-based 2D barcode scanners and smart metering products in smart grid applications.

"Analog Devices is pushing the DSP cost/performance envelope to make it easier for designers to differentiate their price- and power-constrained products," said Tony Massimini, chief of technology, Semico Research Corp. "The Blackfin BF592 offers performance and lower power consumption at competitive pricing. These are important factors for designs in high-growth consumer markets, especially portable applications."

Blackfin BF592 Highlights

- The highest pure DSP performance for its price point - At 800 MMACs or 400MHz clock speed, the Blackfin BF592 provides developers the ability to run more sophisticated algorithms for more system-level advantages.
- The lowest power in ADI's Blackfin portfolio - The BF592 consumes 80 percent less power than comparable solutions. A low active power draw of just 88mW at 300MHz and low standby power of less than 1mW extends battery life.
- Smaller footprint – With a 9mm x 9mm footprint, the industry's smallest 800MMAC device allows designers to pack a tremendous amount of performance into space-constrained designs.
- Optimized for multiple applications - With a peripheral set including two SPORTs, a PPI, two SPI's, four general purpose counters and a factory-programmed instruction ROM block containing the VDK RTOS and C-runtime libraries, the BF592 is feature- and cost-optimized for compute-intensive applications that operate without the need for external memory or executable flash.
- The BF592 is offered in commercial and industrial temperature grades and is automotive qualified.

Low-cost development platform
An EZ-KIT Lite® evaluation kit for the Blackfin BF592 DSP is available for only $199, and includes an evaluation suite of ADI's VisualDSP++ development environment with the C/C++ compiler, assembler and linker. ADI also offers a $150 Blackfin emulator (ADZS-ICE-100B), which provides designers with a comprehensive development platform that lowers the cost of entry to the Blackfin BF592 DSP. In addition, a complementary selection of ADI's power ICs, data converters, sensors, signal conditioning ICs are available for optimizing processor and overall signal chain performance.

Innovative Design Demands Blackfin-Class Processing
Analog Devices' Blackfin 16/32-bit processors enable engineers to advance the intelligence, functionality and connectivity of

EZ-KIT Lite® evaluation kit for the Blackfin BF592 DSP

any application that benefits from a convergence of digital signal processing and control processing in a unified architecture. Delivering exceptional price/performance and energy efficiency, and complemented by a rich ecosystem of development tools, applications and third-party support, Blackfin is the processor of choice for a wide range of innovative applications including industrial, medical, automotive, security, digital home entertainment and portable devices.

Pricing and Availability
The Blackfin ADSP-BF592 is priced at $3.00 per unit based on 10,000-unit quantities. The processor is sampling today. EZ-KIT Lite evaluation kits (ADSZ-BF592-EZLITE) for the Blackfin BF592 processor are available now from ADI's authorized distributors and are priced at $199.

Cliff Keys, Editor-in-Chief, Power Systems Design

Author: Rick Murphy
Business Development
Processors-DSPs Core Products
Analog Devices
www.analog.com

PORTABLE ULTRASOUND SYSTEM DESIGN

Industry's first eight-channel transmit/receive chipset

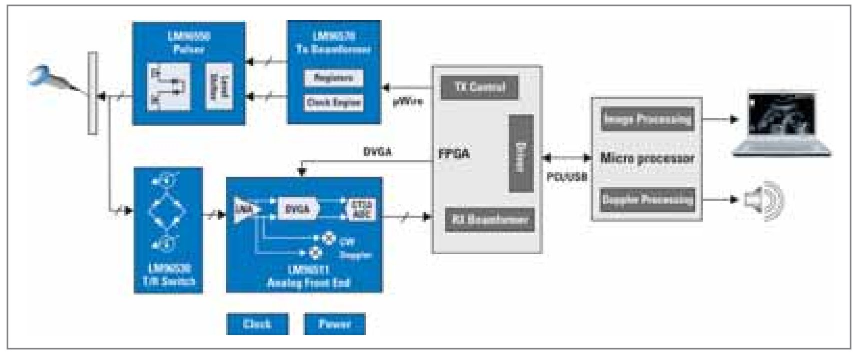
Suresh Ram as reported by Cliff Key

I had the great pleasure to talk with Suresh Ram, Director, Medical Key Market Segment at National Semiconductor Corporation. Suresh is responsible for driving the strategy and development of innovative system-level solutions targeted at the medical imaging market. He walked me through the company' s new medical chipset which enables highest image quality at lowest power, fresh from National's industry-renowned PowerWise portfolio.

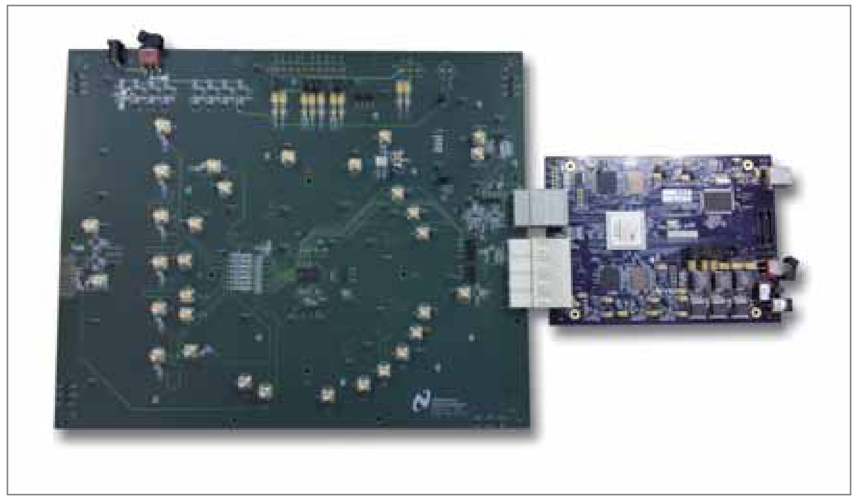
National, a leader in power management technology, widely known for its easy-to-use analog ICs and supply chain products, is addressing the needs of the medical design community with products that enable designers in this specialized area to reduce component count and system size and, importantly, to decrease development time and costs. The company's analog portfolio also provides high power efficiency and accuracy, low power and low EMI, enabling medical device designers to achieve significantly better signal path performance and system reliability.

National's launch of the industry' s first eight-channel ultrasound transmit/receive chipset specifically designed for portable ultrasound systems used in hospitals, clinics, ambulances and remote point-of-care facilities is a milestone in the company's path along the medical route.

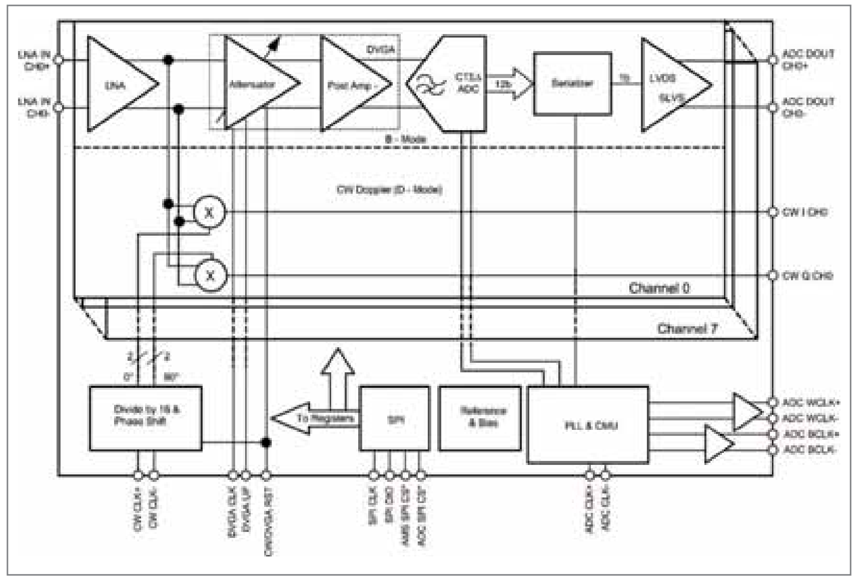
Suresh explained that with the increasing demand for accessible and affordable medical care, the need for portable diagnostic imaging equipment is growing. Much of the existing equipment is bulky, extremely expensive, and consumes excessive power. Ultrasound is the least invasive, most mobile imaging technology and with a much lower per scan cost than other options, it is positioned for the fastest growth. National's analog subsystem solutions enable smaller, more efficient portable ultrasound systems for hospitals, clinics, ambulances, and remote point-of-care facilities.



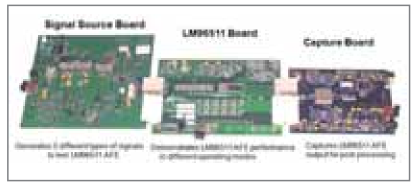
National's comprehensive ultrasound solution



LM96511 AFE Evaluation kit enables detailed chip performance in an easy-to-use format



Simplified LM96511 Block Diagram



With the industry's first eight-channel transmit/receive chipset designed exclusively for portable ultrasound systems, the company now gives designers the ability to deliver very high diagnostic image quality with low power consumption. The complete chipset includes receive analog front end (AFE), transmit/receive switch, transmit pulser, and configurable transmit beamformer to deliver imaging quality in portable systems that to-date has only been available with significantly larger, cart-based consoles.

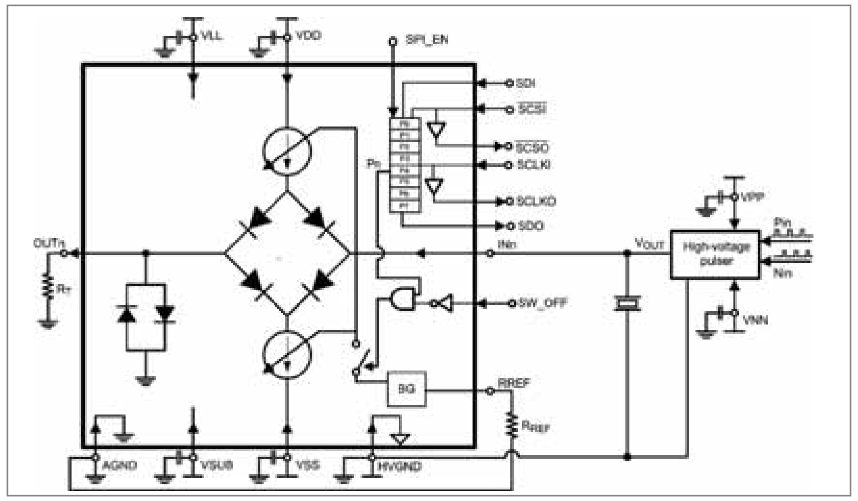
The PowerWise® chipset's innovative circuit architecture enables the design of both hand-carried and handheld units that deliver longer battery life and imaging performance which are comparable to much larger console-based systems.

This high-level of integration allows system designers to build lightweight 128-channel portable ultrasound systems with enhanced image quality and diagnostics in a very small footprint.

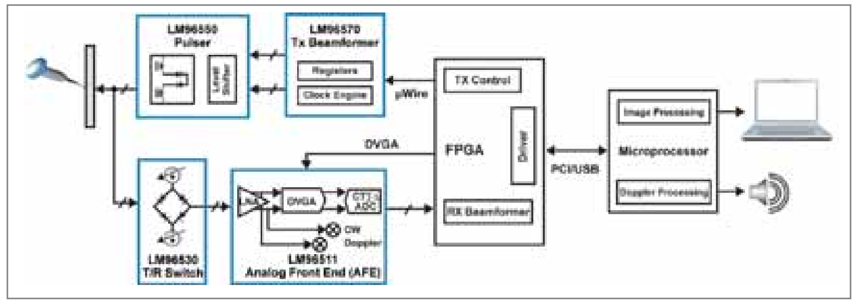
Dr. Norbert Gaus, chief executive officer of the Clinical Products Division of Siemens Healthcare commented "Previously, this level of ultrasound imaging quality was only attainable with large cart-based consoles. National Semiconductor has significantly raised the bar in terms of imaging performance and low-power consumption for portable ultrasound systems."

National's eight-channel chipset includes four integrated circuits (ICs) that work together to deliver unmatched performance and power efficiency. For example, the transmit beamformer can be configured to calibrate the board trace delay mismatch and pulser delay mismatch. This significantly improves the distortion performance and enables second harmonic imaging. The transmit/receive switch gives system designers the flexibility to trade-off power versus performance by selecting different bias current settings.

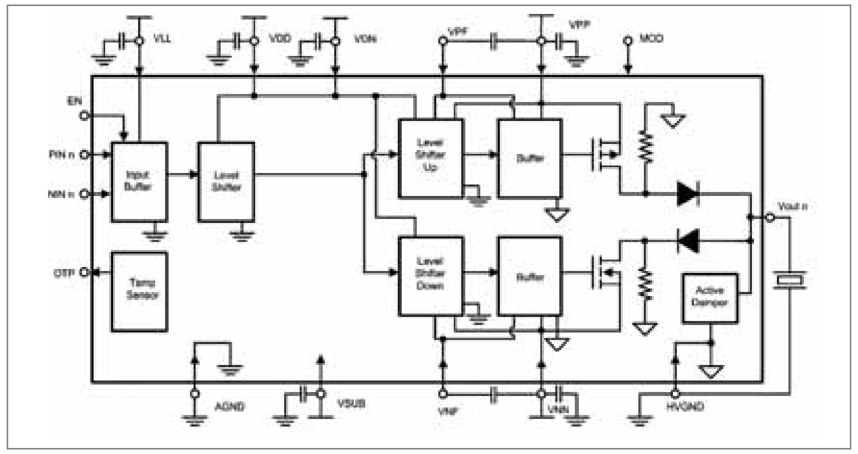
National's unique AFE architecture provides superior imaging quality and B-mode power consumption that is 10 percent lower than the closest comparable AFE. It includes the industry's highest resolution digital variable gain amplifier (DVGA) and a low-power continuous-time sigma-delta (CTSD) analog-to-digital converter (ADC). The DVGA offers several advantages over traditional analog VGAs such as better channel-to-channel matching and higher spectral performance. The CTSD ADC provides inherent brickwall anti-aliasing filtering in comparison to higher power consuming, low-order anti-aliasing filters found in other AFEs that use conventional pipeline ADCs.



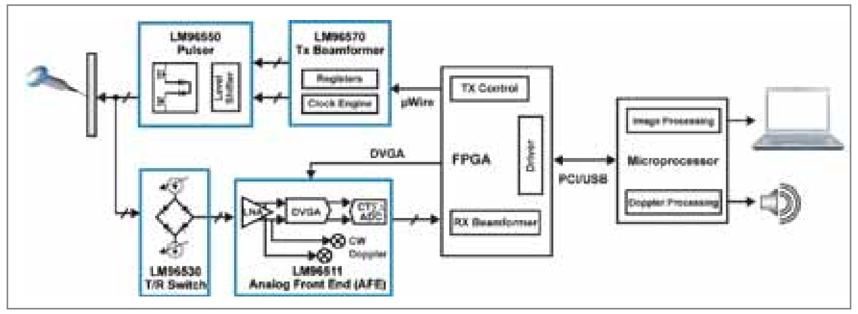
LM96530 Block diagram



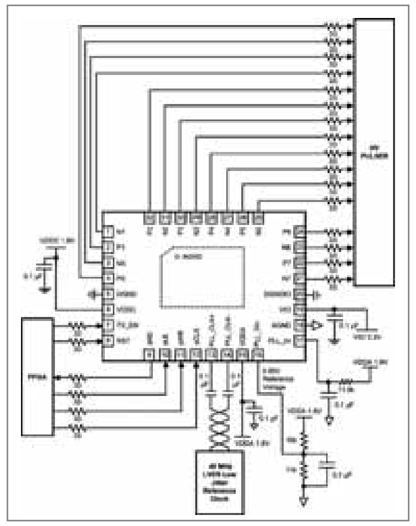
LM96530 Typical application



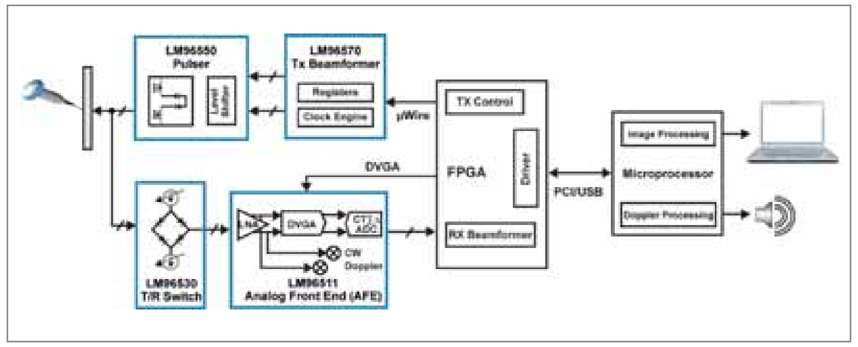
LM96550 Block diagram



LM96550 Typical application



LM96570 Block diagram



LM96570 Typical application

National offers a full signal path solution for portable ultrasound systems, including clocking devices and power management ICs. For more information on National's ultrasound transmit/receive chipset and evaluation system (visit www.national.com/ultrasound). To see a video demonstration of the LM96511 AFE operating in B-mode and CW Doppler-mode, with input signals that emulate a real ultrasound environment visit http://bit.ly/LM965xxDemoVideo.

Development Tools, Support Speed Time-to-Market

Throughout the whole design process, National's easy-to-use evaluation kits, reference schematics and tools allow fast and accurate evaluation to help designers to accelerate their time-to-market. National offers a full development package that includes the WaveVision 5 acquisition analysis hardware and software with user-friendly GUI for device programming and control.

LM96511 PowerWise Ultrasound Receive Analog Front End

The LM96511 AFE integrates eight channels of LNA, DVGA, 12-bit, 40-50 MHz ADC with LVDS data outputs and eight demodulators for CW Doppler beamforming. The AFE provides the lowest B-mode power consumption at 110mW per channel. It enhances image quality with channel-to-channel gain matching of +/- 0.06dB (typical) – and that is four times better than the closest comparable AFE. The integrated CW Doppler delivers 161dB per Hz of dynamic range, enabling measurement of low velocity blood flow in organs such as the liver. The AFE delivers this performance in a 187mm2 package that's 27 percent smaller than any other comparable AFE.

LM96530 PowerWise Ultrasound Transmit/Receive Switch

The LM96530 contains eight transmit/receive switches with integrated clamping diodes and offers an individual channel shut-off capability. Compared to other T/R switches, the LM96530 provides 55 percent better input referred noise (0.5nV/sqrt.Hz) and 53 percent lower on-resistance (16 Ohms), thereby increasing receiver sensitivity and image resolution. The LM96530 reduces board space by 4x compared to discrete solutions, and its daisy-chained SPI control reduces the number of FPGA I/O pins required for programming.

LM96550 PowerWise Ultrasound Transmit Pulser

The LM96550 contains eight pulsers with damper circuit that generates +/- 50V bipolar pulses with peak currents up to 2A and pulse rates up to 20MHz. The LM96550 features over-temperature protection by continuously monitoring on-chip temperature and providing power-down logic output.

LM96570 PowerWise Ultrasound Configurable Transmit Beamformer

The LM96570 provides an order of magnitude jitter performance improvement (25ps pk-pk) over beamforming traditionally done in FPGAs. This enables much higher resolution imaging in B-mode and low blood velocity measurements in CW Doppler mode. The LM96570 simplifies board layout since system designers can place it directly next to the pulser, thereby avoiding the typical routing challenges of connecting an FPGA's I/O pins to the pulser.

Author: Suresh Ram
Director, Medical Key Market Segment
National Semiconductor Corporation

www.national.com

MEDICAL EQUIPMENT DESIGN

Operation and design considerations for a digital stethoscope

By John Di Cristina

A stethoscope, whether acoustic or digital, is used mainly to listen to heart and lung sounds in the body as an aid to diagnosis. Listening, or auscultation, has been done with acoustic stethoscopes for almost two hundred years, but recently electronic digital stethoscopes have been developed and adopted.

The goal of a basic digital stethoscope is to have it retain the look and feel of an acoustic stethoscope but to improve listening performance. In addition, high-end digital stethoscopes offer sophisticated capabilities such as audio recording and playback. They also provide data to visually chart results by connecting to an off-instrument display such as a computer monitor. This advanced functionality increases the physician's diagnostic capability. Maintaining the existing acoustic stethoscope form (i.e., that "look and feel") while improving the performance digitally requires the use of small, low-power solutions.

Power management: Key to long use
Most digital stethoscopes use either one or two AAA 1.5V primary batteries. This design requires a step-up, or boost, switching regulator to increase the voltage to 3.0V or 5.0V, depending on the circuitry utilized.

If a single 1.5V battery is installed, the switching regulator will probably be on all the time, making low quiescent current a critical factor for long battery life. The longer the battery life, the more convenient the digital stethoscope is to use and the closer the experience will be to an acoustic stethoscope.

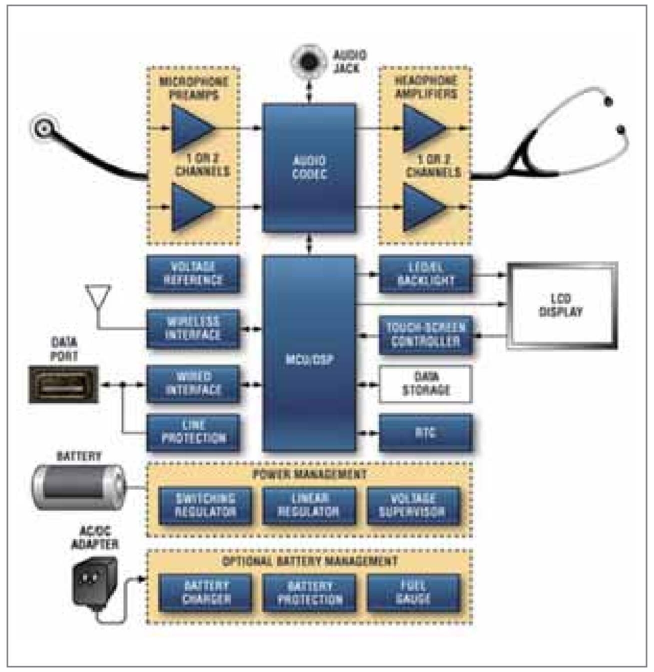


Figure 1: In a digital stethoscope, low-power operation is key. High-efficiency switching regulators with low standby power, as well as smart battery/power management are needed to ensure long battery life.

When using two 1.5V batteries in series, the switching regulator can be left on all the time or shut down when not in use. If the circuit operates from 3.6V down to 1.8V, then a switching regulator may not be needed. Cost will be reduced and space saved. A low-battery warning is required so that a patient's examination need not be interrupted to replace the battery.

In the stethoscope, rechargeable batteries can be used; the best choice is a single-cell Li+ battery. If a rechargeable battery is used, a battery charger is required either in the digital stethoscope or in a charging cradle. The charger can be built around a chip such as the MAX8900A or B, or if the battery charger can charge from the USB interface, a device such as the MAX1811 can be used. A fuel gauge such as the MAX17043 or '044 is a good solution to accurately determine the remaining battery life.

If the battery is removable, then battery authentication is also required for safety and aftermarket management. For example, the DS2784 includes a SHA-1 encryption capability for cell authentication. The authentication is used by the stethoscope vendor to prevent counterfeit batteries from damaging the stethoscope.

Audio signal path
The essential elements of a digital stethoscope are the sound transducer, the audio codec electronics, and the speakers (Figure 1). The sound transducer, which converts sound into an analog voltage, is the most critical piece in the chain. It determines the diagnostic quality of the digital stethoscope and ensures a familiar user experience to those accustomed to acoustic stethoscopes.

The analog voltage needs to be conditioned and then converted into a digital signal using an audio analog-to-digital converter (ADC) or audio codec. Some digital stethoscopes have noise cancellation that requires a secondary sound transducer or microphone to record the ambient noise so that it can be removed digitally. In this approach, two audio ADCs are required.

Once in the digital domain, a low-power microcontroller such as the MAXQ2000 or MAXQ2010, and/or a digital-signal processor (DSP) performs signal processing, including ambient noise reduction and filtering, to limit the bandwidth to the range for cardiac or pulmonary listening. The processed digital signal is then converted back to analog by a low-power audio digital-to-analog converter (DAC) or audio codec such as the MAX9856 or similar device.

A headphone or speaker amplifier conditions the audio signal before outputting to a speaker. A single speaker can be used below where the stethoscope tube bifurcates, with the amplified sound traveling through the binaural tubes to the ears. Alternatively, two speakers can be used, with one speaker at the end of each earpiece. The frequency response of the speaker is similar to that of a bass speaker because of the low-frequency sound production needed. Depending on the implementation, one or two speaker amplifiers are used.

A stethoscope must be most sensitive to cardiac sound in the 20Hz to 400Hz range and to pulmonary sound in the 100Hz to 1200Hz range. Note that the frequency ranges vary by manufacturer, and the DSP algorithms filter out sound beyond these optimal ranges.

Data storage and transfer
Once the captured sound is converted to an analog voltage, it can be sent out through an audio jack and played back on either a computer or through the digital stethoscope. The captured sound can also be manipulated digitally. It can be stored in the stethoscope using internal or removable nonvolatile (NV) memory like EEPROM or flash, and then played back through the stethoscope's speakers; or it can be transferred to a computer for further analysis. Adding a real-time clock (RTC) facilitates tagging the recording with time and date. The captured sound can also be transferred to a host system with a wired interface, such as USB, or with a wireless interface like Bluetooth® or another proprietary wireless interface.

Display and backlighting
Some digital stethoscopes have a small, simple LCD display due to the limited space available; others have only buttons and LED indicators. Backlighting for the LCD is required because the ambient lighting during medical procedure is often at a low level. The small display requires just one or two white light-emitting diodes (WLEDs) controlled by an LED driver. Alternately, an electroluminescent (EL) panel controlled by an EL driver or other display technology can be used. With the growing popularity of touch-screen technology and the lower associated costs, many of the user-interface buttons can be eliminated by using a touch-screen display and controller.

Author: By John Di Cristina
Director of Strategic Marketing
Maxim Integrated Products Inc.

www.maxim-ic.com

MEDICAL POWER SUPPLY VENDORS RELY ON GENERAL PRACTITIONERS TO CRAFT THEIR PRODUCTS

By David G. Morrison

As medical applications for electronics expand, the requirements for medical - grade power supplies also grow. According to market analysts, ac-dc power supplies for medical applications account for approximately S455 million to $640 million in worldwide revenue with somewhere around 4% growth in this revenue expected over the next few years (see the table). Although this growth rate is not spectacular, it is considered steady and said to be higher than other segments of the industrial power supply market.

Power supply manufacturers with significant business in medical applications include companies such as SL Power, XP Power, Emerson, Astrodyne, TDK-Lambda, and others. These manufacturers, while benefitting from the steady growth in sales, also must confront the challenges of shrinking profit margins for medical power supplies. "With companies now bringing out power supplies that meet both IEC60950 and IEC60601, the unit price has degraded," says David Norton, VP marketing at TDK-Lambda. "No more is there a large premium for medical power supplies."

Peter Resca, VP of sales and marketing at Astrodyne, also notes how the growth of the medical power supply market is tempered by growing competition. Medical power supplies are "important as a growing and sustainable market but this market is also becoming saturated with vendors," says Resca who notes that volumes tend to be lower than in other markets. And while the competition among medical power supply vendors has grown, "standards are rapidly changing which is a relatively significant barrier to entry for new vendors," says Resca.

In light of these trends, one might wonder whether there are unique opportunities, for engineers to design medical-grade power supplies within the merchant power supply industry. The answer is both yes and no. While power supply companies need engineers who can design medical-grade supplies, they also expect these engineers to work on other categories of power supplies. They may hire engineers who have experience with the medical power requirements. However these companies would just as soon instruct qualified designers in specific requirements such as those for leakage current, isolation, and spacing for creapage and clearance that are dictated by standards such as IEC 60601.

Table. Current Revenue and Projections for Medical Power Supply Market.

Power Supply Type	2010 Worldwide Revenue (U.S. dollars)	Forecast	Source
Ac-dc power supplies	635 to 640 million	3% to 3.5 % CAGR from 2011 to 2015	Vishal Sapru, industry manager for Energy & Power Systems, Frost & Sullivan, www.frost.com
	455 (see note 1)	4.7% CAGR from 2009 to 2014	Mohan Mankikar, president, Micro-Tech Consultants www.Micro-TechCo.com
Dc-dc converters (see note 2)	360 to 365 million	6% to 6.5% CAGR from 2011 to 2015	Vishal Sapru, Frost & Sullivan

Notes: 1. Includes some high-voltage supplies. 2. Sapru and Mankikar differ on the market for dc-dc converters. Mankikar comments "Dc-dc remains insignificant," as he has not seen any dc-dc converters that meet medical regulations.

Consequently, these companies are not looking specifically for medical power supply designers, but rather good designers well versed in the latest techniques for power supply design. And in contrast to some other application areas, experience as a power supply designer working in the medical equipment industry may not help you gain a position as a designer at a company that makes medical-grade supplies.

Medical Power Is Too Narrow
A recent sampling of the career sections of power supply vendor websites revealed very few openings for power supply designers in general, and no listings that specifically related to the development of medical power supplies. This would tend to support the notion that power supply companies are not looking to recruit medical power supply specialists.

TDK-Lambda's David Norton observes that there have only been "a handful of hires because of medical growth" at his company over the course of a few years. This growth resulted from a rise in orders for medical supplies from several customers in the Americas. Nevertheless, the company doesn't specifically hire medical specialists as power supply designers or FAEs.

"I don't know of any power supply engineers specializing in medical. I would not recommend it, mainly because of the way power supply companies are launching products that have both ITE & medical certifications" says Norton, who stresses understanding of the power supply technology is the key requirement for new hires. Peter Resca of Astrodyne, strikes a similar note with regard to hiring of designers, "We prefer medical power supply experience but do not preclude any qualified candidates on this point as we believe we can teach the unique design requirements [for medical applications]," says Resca who notes that the medical products account for about one fourth of his company's business. Consequently, designers hired by Astrodyne who are not yet up-to-speed on medical specifications can work on supplies targeting other markets, comments Resca.

When power supply companies look to enter new markets, they sometimes look for designers who have worked at original equipment manufacturers (OEMs) in those markets. This helps provides the power supply manufacturer with knowledge about the application requirements. However, because the medical power supply market is relatively mature, the suppliers already have that knowledge. In fact, Norton comments that it may be difficult for a power supply designer who gained his or her experience in the medical OEM industry to get hired by power supply vendors.

"Power supply design has gotten so specialized now, especially with digital control, that an engineer from a medical device company who hasn't been working with cutting-edge technologies would be hard pressed to get a comparable job with a power supply company," explains Norton.

Opportunities in Medical Equipment Industry

While the power supply industry might not be seeking medical specialists to design its supplies, the same isn't necessarily true in the medical equipment industry. A recent survey of OEMs serving the healthcare industry turns up a number of openings for power electronics engineers needed to perform research and product development for medical applications. You can view some of these openings in the table that accompanies the online version of this article. As the job descriptions attest, knowledge of medical applications is a plus in some cases, though it's also clear that the OEMs are looking for candidates who are highly skilled and knowledgeable in power supply and motor drive technologies.

About the Author

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

Author: David G. Morrison
Editor
How2Power.com
www.how2power.com/newsletters

MEDICAL GETS GREENER

By Cliff Keys

Energy efficiency has certainly become the mantra of many of today's industry segments.

The special feature within this issue of PSD is focused on health, medical and mobility and much of the equipment designed for this growing market are designed to be run on batteries in a portable application, sometimes with the same performance attained only by larger, hospital based and more power hungry installations. Engineering has already progressed significantly in powering the medical sector and I would expect the trend to continue with the imminent need to reduce health costs in an ageing society remaining high on any government or administration's priority list.

Recently, Siemens Healthcare, one of the world's largest suppliers to the healthcare industry and a leader in medical imaging, announced a wide-ranging strategic alliance with National Semiconductor to advance ultrasound technology; creating ultrasound imaging systems that produce enhanced image quality and advanced 3D/4D imaging capabilities, while consuming less power. The alliance brings together Siemens' leadership in ultrasound technology with National's energy-efficient analog semiconductor capabilities. National will provide leading-edge power management, signal path and transducer solutions, working closely with Siemens. Based on the collaboration, Siemens' ultrasound systems will provide energy-efficient, next-generation imaging quality and ground-breaking new applications. Working together, the end goal is to provide medical ultrasound systems that change the game in workflow efficiency, diagnostic reliability and ease of scanning.

Auto battery re-use

While on the topic of battery power, ABB and General Motors have signed a non-exclusive memorandum of understanding to cooperate on a research and development project that will investigate uses for electric vehicle batteries once their useful life in the vehicle is over. The project will examine the potential of reusing spent lithium-ion battery packs from GM's electric car, the Chevrolet Volt, as a means of providing cost-effective energy storage capacity, which will improve the efficiency of electrical systems as they evolve into smart grids.

ABB said that future smart grids will incorporate a larger proportion of renewable energy sources and will need to supply a vast e-mobility infrastructure – both of which require a wide range of energy storage solutions; an exciting prospect exploring the feasibility of employing electric car batteries in a second use that could help build needed storage capacity and provide far-reaching economic and environmental benefits.

According to GM, the Volt's battery will still have significant capacity to store electrical energy, even after its automotive life, hence the joining of forces with ABB to find ways to make these batteries provide environmental benefits that stretch beyond the highway. The relationship will facilitate solutions to optimize the full lifecycle of the Volt's battery.

Cliff Keys
Editor-in-Chief
Power Systems Design Magazine
www.powersystemsdesign.com