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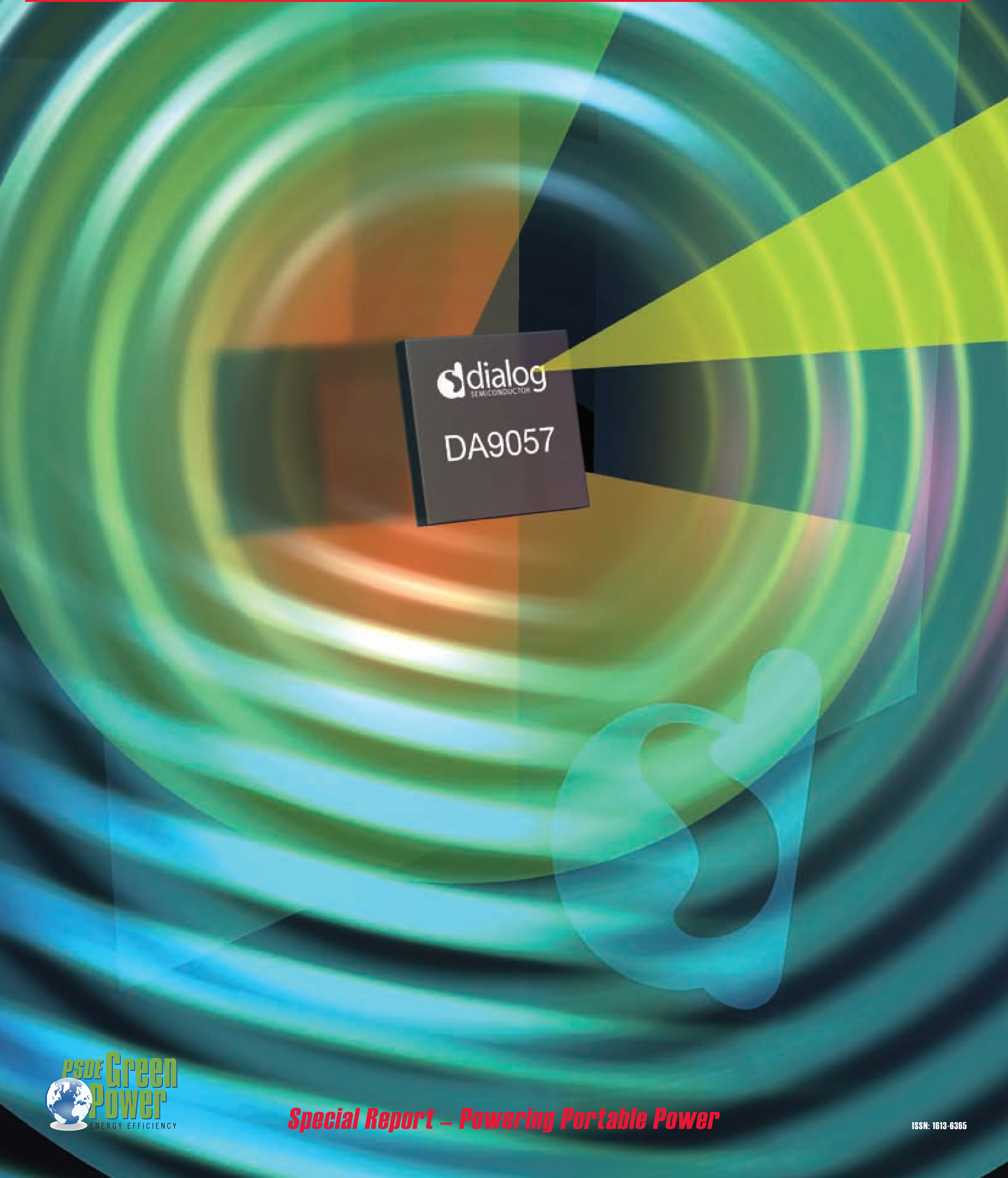

PSDE Green Power ENERGY EFFICIENCY

Special Report – Powering Portable Power

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ENERGY EFFICIENCY

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Volume 7, Issue 5

Pervasive Portable Power

Welcome to this issue of PSDE which carries the industry-inspiring theme of Portable Power. The powering of portable devices has never been as important as it is right now. We have seen a tidal wave of portable devices - from the first MP3 players to the rapid adoption of smart phones and now the tablet devices supporting a broad range of applications and connectivity. The one thing they all have in common is that they are powered by batteries. These batteries although slowly improving, need to have their stored energy carefully managed to maximize the run-time of the device and to enhance the user experience.

I am always impressed by the ingenuity that companies demonstrate in their quest for eking out every nanoamp of current in the portable products demanded by consumers. Power management has for years been at the forefront of successful products; the iPhone and iPad are great examples of what can be achieved by creative power engineering.

Recently I was in the centre of London to meet with Micrel, a company renowned for its creative power management solutions. Here, I heard about the company's new device; forming the power foundation for forthcoming 4G designs, representing a complete power management solution for processors, multi-standard RF transceivers and power amplifiers, memory, USB-PHY, associated I/O interfaces and many other system requirements. This product has huge potential in the imminent high volume 4G market. This is what I mean by creative power engineering.

Beginning with this issue of Power Systems Design Europe, I would like to highlight the first of a regular contribution from David Morrison, Editor of How2 Power. David will talk about design engineering opportunities and how jobs offered in our industry are developing, and will follow the magazine's editorial theme in each issue. This should be a valuable new career resource section. Please join me in welcoming David to our top team of regular contributors.

With the two major power conferences and exhibitions (APEC and PCIM) behind us there's a wealth of new products and real innovations from our industry. I attended both these shows and was amazed at the work that had obviously taken place during a very difficult recession. This tells me that our industry is alive and well, even during these difficult times. For those who could not attend, please visit our website where I have prepared a roundup report of what I saw at these two major events in our calendar. At PCIM I ran a forum themed on 'Designing for Power Conservation and Performance' the content of which can also be accessed from our website. Also, look out for our extended weekly web-blast, PowerSurge, which now contains an extra feature article or case study.

I hope you enjoy the issue. Please keep your valuable feedback and comments coming, and check out our fun-strip, Dilbert, at the back of the magazine.

All the best!

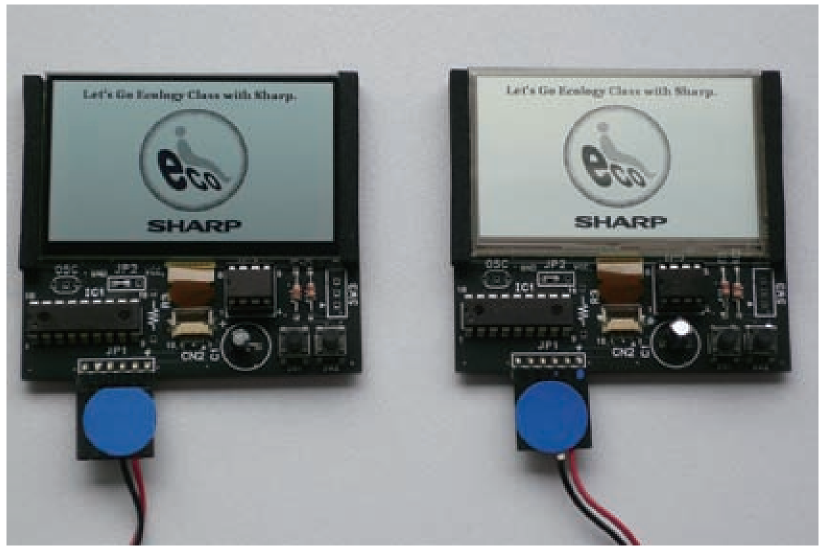
Cliff Keys.

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

Sharp's Line-up of Low Power LCDs

Sharp has introduced Memory LCDs in new sizes: two 2.7-inch (LS027B4DN01, LS027B4DH01) displays with a resolution of 400 x 240 and a 2.94-inch (LS029B4DN01) model with a resolution of 456 x 240 pixels.

Sharp is now planning the introduction of a 6.02-inch model in order to specifically address the e-books market and other portable reading devices. For this market segment, Sharp will supplement the range with transflective and touchscreen models in the second half of the year. Unlike the usual reflective memory LCDs, transflective memory LCDs offer the option of adding backlighting so that e-books or other applications can also be used in the dark. Memory LCDs with touchscreen ensure that these devices are user friendly. Thanks to the capacitive touchscreen, e-books can be designed in such a way that readers can turn the pages almost like a paper book.



Memory LCDs for low-power applications are available in two technology variants: High-reflective (HR) models (left) can be read very well from all sides; Polymer Network Liquid Crystal (PNLC) models (right) provide a silver-metallic appearance and are also suited for fashionable applications

These innovative System LCDs are based on Sharp's own Continuous Grain Silicon (CGS) technology. This enables it to equip each pixel with a 1-bit memory that stores the image information uploaded onto the screen. Image information therefore only needs to be rewritten in those pixels in which the content has changed compared to the previous picture frame. As reflective displays, Memory LCDs do not require any backlighting. The combined effect means that memory LCDs only have 0.8 percent of the power consumption of conventional displays of the same size.

Standard LCDs with backlight have a power consumption that is around 130 times greater than that of the newly developed memory LCDs. A 1.35-inch memory LCD uses 15μW in operation, whereas a standard LCD of comparable size requires around 2mW displaying an image.

Memory LCDs offer a unique image representation. Unlike other reflective displays, this new type of LCD does not require polarisers. Thanks to a special PNLC material, the image is generated by the status of the pixel changing from transparent to white with a reflectivity of 50%. This gives the display a silver-metallic appearance that is particularly suited to fashionable applications. With a slightly more conventional version of the memory LCDs, polarisers and high-reflective (HR) liquid crystals are used. They supply a purely black-and-white image with superb legibility and a very broad viewing angle.

Small solar cells can supply sufficient electricity to run the new Memory LCDs which are thus an ideal solution for small portable applications such as, for instance, e-books, wristwatches, heart rate monitors and other fitness devices, shelf labelling, etc. Using solar cells as a source of power, such systems can even be designed as self-sufficient applications.

In order to simplify the design-in for such energy self-sufficient solutions, Sharp also offers memory LCDs as 3-volt models so that when operated with conventional lithium ion rechargeable batteries, no charge pump is required in between. The new 6.02 inch display is already designed for this supply voltage and four other memory LCDs that are expected to be launched on the market in the second half of 2010 also only require the lower supply voltage.

The new memory LCDs are already available in 1.35-inch, 2.7-inch and 2.94-inch diagonals from the sales offices of Sharp in Europe and through distributors. Samples of the 6.0-inch models are anticipated to be available in Q2 2010.

www.sharpsme.com

Battery Fuel-Gauging

Needs, challenges and solutions

By Bakul Damle, Business Manager, Notebook, Battery, and Display Business Unit, Maxim Integrated Products Inc., Dallas, Texas

One of the most frustrating issues with portable electronic systems is turning the system on and finding that the battery is either dead or the system shuts down shortly after it is turned on. Although you could leave the system continually plugged in and charging when it is not in use, this can potentially reduce the life of the battery. What is needed is a form of fuel gauge, which is either built into the battery pack or into the system, to provide an accurate measure of how much charge is left in the battery.

Although many products already include low-battery indicators, such displays rarely give any indication of how much usage time is available once the system turns on. Portable computers, smartphones, and other high-end portable products do include better fuel-gauging options and often include some power-management options to help minimize power consumption when the devices are active.

However current-generation fuel-gauging techniques are not very accurate – typically delivering real-world results that are accurate to within only 10% to 30%. Such poor accuracy reduces the system's operating time since the gauge indicates that recharging is required a lot earlier than really needed. If, instead, the gauge was accurate to within a 5% or so, systems could run longer between charges, which would provide a better user experience. Additionally, the longer time between charges could reduce the cycling wear-out on the batteries, and thus let the batteries last a little longer as well.

There are two primary methods to calculate the battery remaining capacity: one is voltage-based, while the other is coulomb-counter based fuel-gauging. A simple voltage-only fuel-gauging approach measures the battery's voltage

based on the instantaneous voltage value. This is sometimes used in cell-phones and other applications which typically offer a "3 or 4 bar" battery indicator.

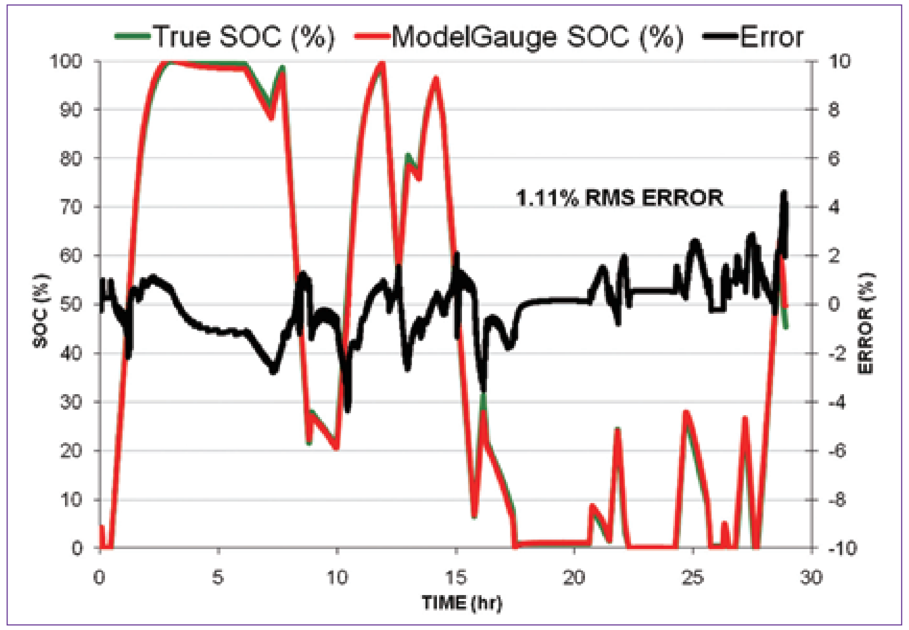
The only hardware needed for the voltage-only approach is an ADC to read the battery's instantaneous voltage to demine the battery capacity. Although inexpensive, it is inaccurate because the battery voltage is not only a function of the state-of-charge (SOC), but also a function of the load, temperature, and age of the battery. Also, the voltage-based fuel-gauge inaccuracy is due to the flat voltage vs. SOC characteristic that most Li+ batteries exhibit, requiring a larger, heavier and bigger battery to provide the same run-time.

The second approach to measure the battery's remaining capacity is to integrate the discharge-current measurements (i.e. coulomb counting) across a precision sense resistor. This method has the potential to predict the remaining capacity accurately, as long as appropriate compensation schemes are implemented to account for varying loads, temperature, and age of the battery. One concern about this method is the accumulation of the offset error while measuring current over time. This accumulated offset error causes the accuracy to worsen over time. Coulomb-counting algorithms must generally make their corrections during empty, full or system standby conditions leading to a more expensive bill-of-materials that requires a larger board area.

So today, most cost-sensitive battery capacity measurement systems are based on voltage-based approaches. Maxim also supports voltage-based schemes, but goes one step further with a new algorithm that greatly improves accuracy. The newly-released MAX17040/MAX17041 and MAX17043/MAX17044 family of 1- and 2-cell fuel-gauge ICs employ a patent-pending algorithm, ModelGauge™, to estimate the Li+ battery state-of-charge.

The new algorithm overcomes the limitations of other voltage-only fuel-gauging approaches by using a sophisticated battery-modeling scheme that delivers better accuracy than the other voltage-only solutions (see figure). The higher accuracy allows the system to run longer between recharge cycles, and that, in turn, could also extend the battery life since it would take longer to reach the maximum number of recharge cycles.

The fuel-gauge ICs also have the industry's lowest current consumption – just 50 µA, typical, which also helps extend the system run-time. The MAX17043/MAX17044 also include a programmable low-battery alert to warn the host system's microcontroller to take appropriate power management actions when the battery is nearly empty. Due to their simplicity and low active current, the ModelGauge-based ICs are a great match for wireless systems such as handsets, smartphones, e-books, portable games, portable navigation devices as well as digital cameras, blood glucose meters and many other portable products.



ModelGauge™ performance tracks the true State-of-Charge very closely, resulting in an RMS error of just 1.11%

These new ICs are the industry's only accurate fuel-gauge solutions that eliminate the current-sense resistor employed by the traditional coulomb-counting solutions. That reduces the number of components, saving both space and cost. ModelGauge ICs also eliminate the need for battery relearn cycles, as they do not require the system to reach empty, full or standby states required by typical coulomb-counting solutions. Additionally, the ICs can be mounted on the system-side instead of the battery pack. That lowers the battery-pack cost and allows designers to use batteries from more vendors. The ModelGauge ICs are shipped with factory calibration and that also helps simplify system manufacturing by eliminating calibration in the end-equipment manufacturing line.

For systems that require even higher accuracy, Maxim is developing a family of fuel-gauge devices that incorporate both voltage measurement and coulomb-counting schemes.

With this plethora of choices, it is easier and cheaper than ever for designers to make their products stand out by improving their system's usability by providing reliable battery indicators.

www.maxim-ic.com

Is Charging our Portable Electronics Costing the Earth?

By Ryan Sanderson, Market Analyst, IMS Research

Well over a billion mobile phones are shipped each year; each with their own proprietary charger. Handsets have a typical replacement time of once every 18 to 24 months. So, this means that every two years in most cases a charger becomes redundant. This amounts to tens of thousands of tonnes of redundant chargers generated each year, for which the energy consumed in manufacturing and transporting is huge.

However, it's not only wastage of redundant chargers that creates an environmental impact. The charging habits of many consumers are such that they will charge their device, such as a cell phone or a notebook, and leave the charger/adapter plugged in. This habit leads to a huge amount of wasted power (the so called "vampire effect").

One initiative which is predicted to have a large impact on the amount of energy wasted by chargers is the Universal Charging Solution (UCS), currently being driven by the GSM association. The initiative has been agreed by the majority of major mobile phone manufacturers and aims for all mobile phones shipped from 2012 onwards to have a standard micro-

USB charger which can be used in conjunction with an interoperable wired charger supporting a compatible connector. It's predicted that this will have a substantial impact on the market in the long term as consumers will be given the choice to opt out of receiving a charger with their new handset. IMS Research has studied the implications of this initiative closely and forecasts that it will be adopted initially in Europe and quickly transition globally. Whilst the growth of universal chargers is forecast to explode to reach almost 1 billion units shipped in 2015, the overall shipments of mobile phone chargers is projected to decline by around 25% in the same year.

Another rapidly emerging universal alternative to traditional charging in portable equipment is wireless charging (in particular inductive charging). Whilst offering convenience to the user, many wireless charging solutions have greater intelligence than traditional ones offering the ability to charge more than one device at once using the same charger and the ability to switch themselves off when they are not in use. As these solutions use a power adapter in the transmitter portion of the design, in the short term it is projected that they will complement the power adapter market and consumers will purchase solutions in addition to the supplied traditional charger. IMS Research's recent report, "The Growth Potential for Wireless Power and Charging", forecasts that over one billion portable devices will be enabled for wireless charging by 2019.

Despite these new initiatives aimed at reducing wasted adapters and new competing technologies such as inductive charging, the external power adapter market is still forecast to grow from $4.5 billion today to $6.5 billion in 2015 and so plenty of opportunities still exist!

www.imsresearch

Power Supply Development Diary

Part IV

This article continues the series in which Dr. Ridley documents the processes involved in getting a power supply from the initial design to the full-power prototype. In part IV, the transformer and inductor are plugged into the circuit and testing continues.

By Dr. Ray Ridley, Ridley Engineering

Initial Power Supply Testing with Magnetics

The schematic of the two-switch power stage is shown in Figure 1. Snubbers and other components are omitted for clarity.

In the last article of this series [1], the power stage was tested with a resistive load in place of the transformer. This allowed several issues to be resolved in the design, and verified the proper operation of the gate drives and FETs, and proper connection of instrumentation. The circuit was powered from the AC line as described in [2].

Figure 2 shows the resistive waveforms obtained for the voltage and current of the lower power FET, Q$_1$.

Once the resistive operation was verified, the power magnetics were ready to be plugged into the circuit. The full details of the magnetics design are beyond the scope of this article, but details of changes will be described in a future part of this series. All of the magnetics were designed with the assistance of the power supply design program **POWER 4-5-6** [3].

Figure 3 shows the waveforms obtained for the lower FET with the magnetics in place, and 40 VAC applied

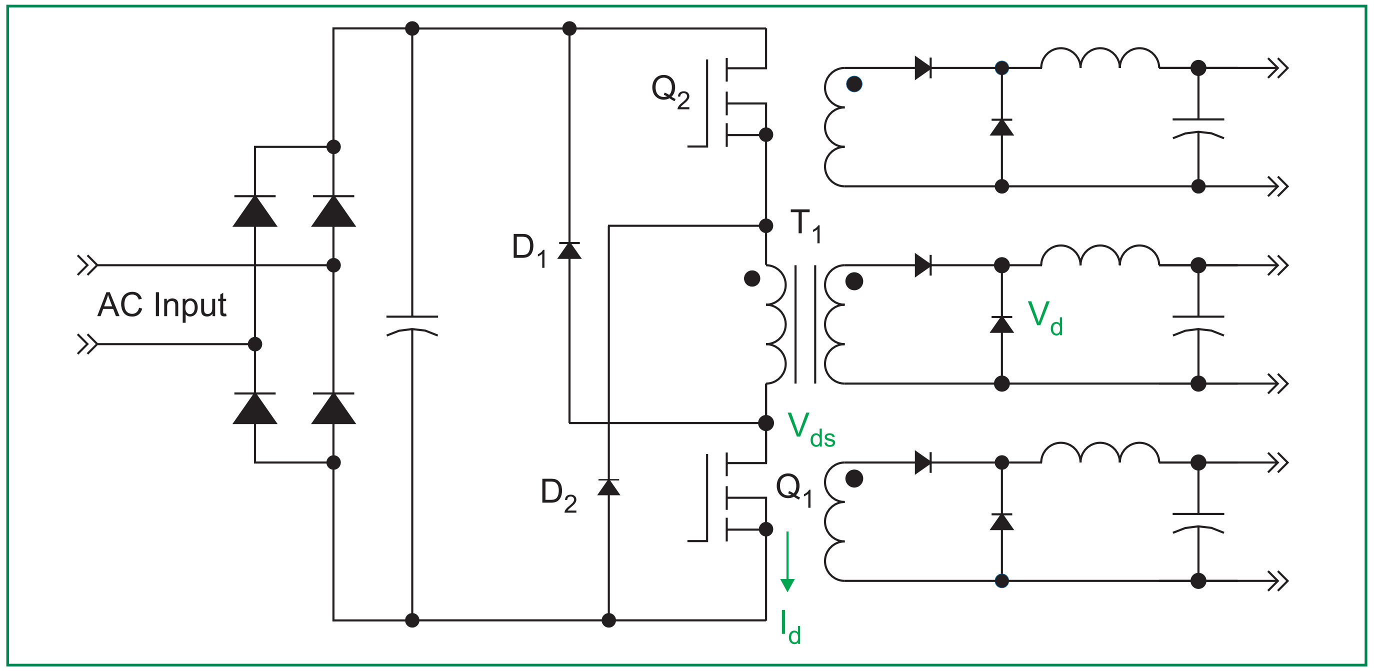


Figure 1: Power stage schematic. Some components are omitted for clarity.

to the circuit. The red waveform is the drain voltage, and the yellow waveform is the drain current. The FET turns on at time A, and the drain voltage falls rapidly to a low value. At the same time, there is a ringing observed in the drain current, denoted by A'. This ringing is caused by the leakage inductance resonating with the capacitances of the transformer and output rectifiers.

At time B, the FETs turn off, and there is a rapid rise in the drain voltage. This is caused by the energy stored in the leakage inductance, which rings with the output capacitance of the FET, and other stray capacitances of the circuit. This voltage should theoretically be clamped to the input voltage of the power supply through the diode D_1, but trace inductance causes an overshoot. This can be fixed with improved layout, as will be shown later in this article. The turn-off ringing can also be observed in the drain current at B'.

After a short period of time, the energy in the primary of the transformer is transferred to the secondary, with the exception of the energy stored in the magnetizing inductance. The magnetizing current leads to the slower rise time during the period denoted by D, after which the voltage is clamped to the input voltage through diode D_1 during the period E. Once all the energy is discharged from the magnetizing inductance, the voltage falls during the period F of the cycle.

For newcomers to the field of power supply design, the initial waveforms are a surprise. The severity of the ringing at the switching transitions often makes you wonder if such a circuit can ever be made to work reliably. The waveforms of Figure 3 are quite typical of power supplies, and a considerable amount of time must be spent in reducing the effects of the ringing waveforms in order to avoid excessive noise and stress on the semiconductors.

Ringing can also be seen on the secondary of the converter, as shown in Figure 4. Unlike the primary waveform on the FET, this voltage is not clamped. The peak voltage of 175 V at time A far exceeds the anticipated square wave voltage, 50 V during the main part of the switch on-time. If this is not controlled better, the secondary rectifiers will fail when full voltage is applied to the power supply. The method of controlling this spike will be the topic of the next article in this series.

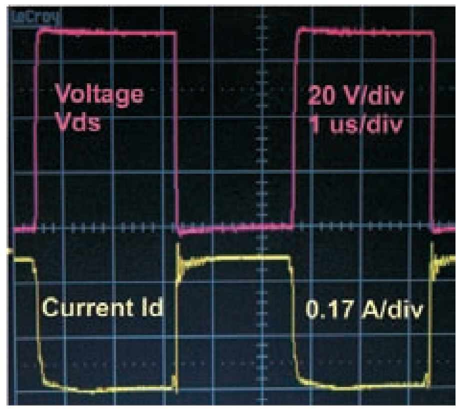


Figure 2: Lower FET voltage and current waveforms with resistive loading

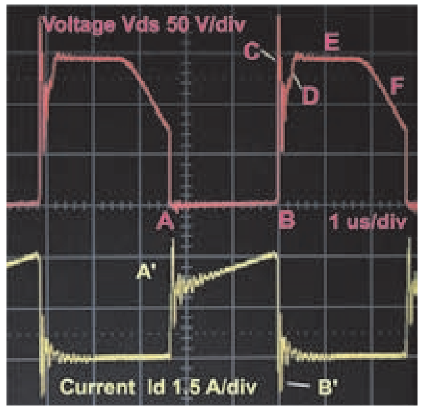


Figure 3: Lower FET Q_1 voltage and current waveforms with transformer loading at 40 VAC input

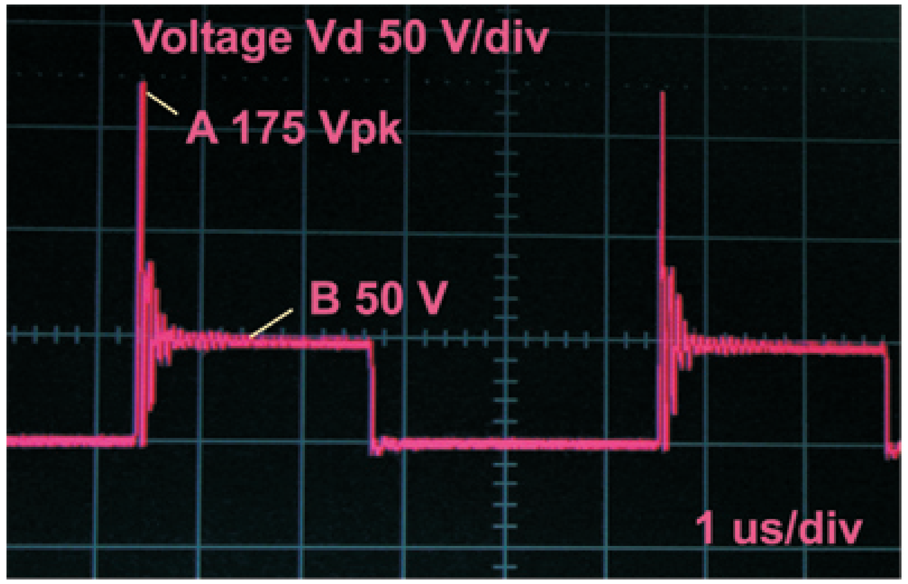


Figure 4: Secondary voltage waveform with 40 VAC applied

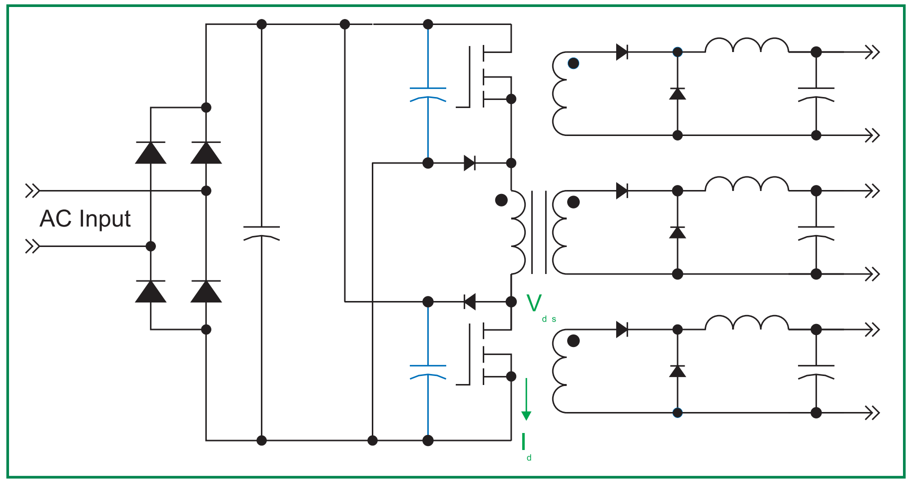


Figure 5: Local capacitors added for improved voltage clamping

Improved Primary Clamp Network

The first step in cleaning up the operation of the converter is to improve the primary clamp. The input bus capacitor was located a significant distance away from the FETs, and this introduced stray inductance in series with the clamp diodes. Mechanical board layout constraints make it difficult to place the capacitor closer. A practical solution is to add two new capacitors, as shown in Figure 5.

These two capacitors are located close to the FETs, and a very tight loop is provided from each FET through its clamp diode and capacitor. The traces from these capacitors back to the input bulk capacitor can be longer and are not critical high-frequency paths.

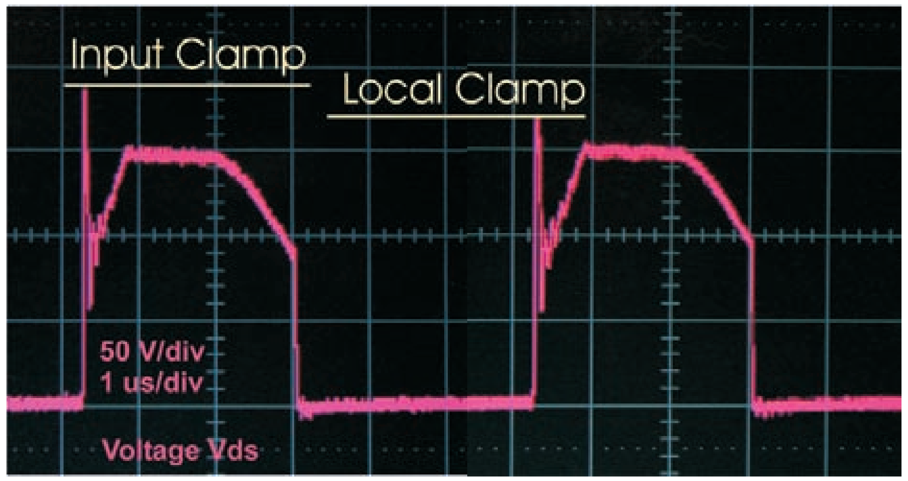


Figure 6: Voltage waveforms with and without local capacitors

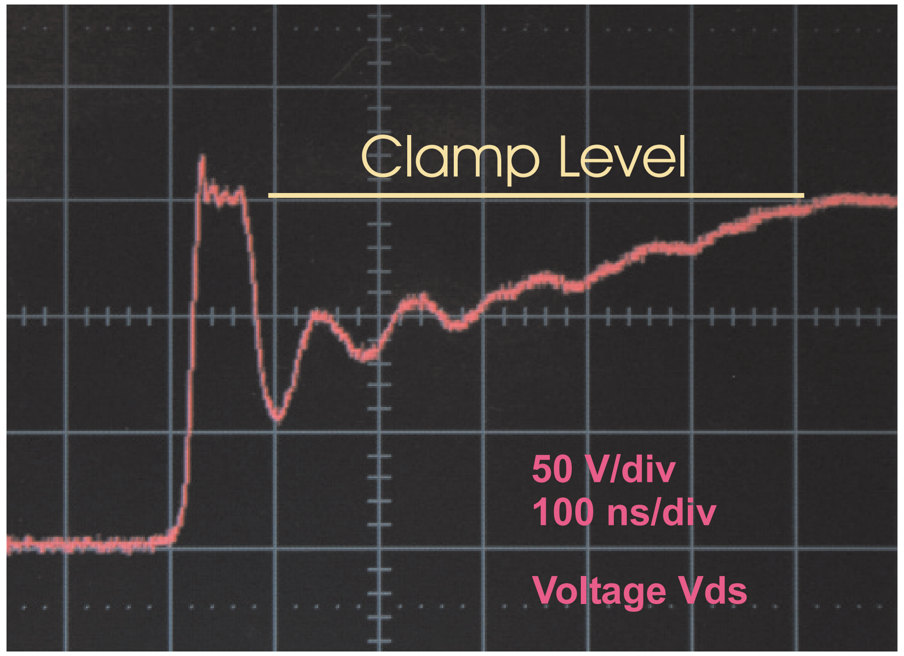


Figure 7: Detail of voltage waveforms with and without local capacitors

Figures 6 and 7 show the effects of the additional local clamp capacitors. The first waveform of Figure 6 is without the capacitors, and the second waveform includes the local capacitors. A significant reduction in the spike is achieved, and the details of this part of the waveform are shown in Figure 7.

Notice how narrow the highest part of the spike is, less than 10 ns. Controlling ringing frequencies like these is difficult, but they can be very destructive despite the short duration.

Failures and Build Errors Found

Event #9 Missing Current Sense Resistor

When the power stage was first turned on with the main transformer in place, the gate drive immediately shut down. This was due to the current sense resistor not being replaced when the current transformer polarity error was fixed as described in the last article. (The current-sense transformer was a socketed part since it was anticipated to be changed several times to fine-tune the circuit protection.)

Event #10 Solder Bridge on Secondary of Transformer

With the current sense resistor in place, excessively high currents were immediately seen on the primary of the converter. A small bridge of solder was discovered on the secondary side of the power transformer. This is a common occurrence when building prototype boards, even on a PCB. It also happens on production supplies – many times in reviewing designs as a consultant, I find that power parts have insufficient spacing for the high voltages that will be encountered, and the large parts that will be mounted on the board.

Summary

The introduction of magnetics into the power supply gives rise to significant high frequency ringing waveforms on all of the semiconductors. It is important to control the ringing spikes. One approach to this is to minimize trace inductance on the board. This is demonstrated in this article for the improved primary voltage spike with additional local capacitors.

In the next article of this series, the secondary ringing will be properly controlled with the addition of snubbers and clamp circuits.

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www.ridleyengineering.com

On the Road

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

Micrel Unveils New 4G Wireless PMIC

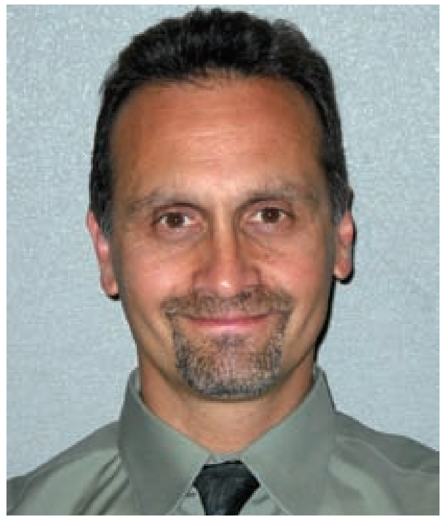
I had the enormous pleasure to meet with Micrel's Andy Khayat in the centre of the capital city of London, England. Andy has more than 28 years of high-tech and management experience and has been Director of Micrel's Portable Product Group since 2007. He has responsibility for the business unit's strategic marketing, roadmaps, business plans, product definition, pricing, product launch and promotion, as well as technical support for new design in activities. A very busy guy, he gave me an insight into Micrel's stunningly flexible new 4G PMIC.

Highly integrated and versatile power management solution

Micrel is acknowledged as an industry leader in analog, high bandwidth communications and Ethernet IC solutions and has just launched the MIC2829, a highly integrated Power Management Integrated Circuit (PMIC) for 4G wireless applications. The device represents a complete power management solution providing power to processors, multi-standard RF (such as HEDGE/ LTE or WiMAX) transceivers and power amplifiers, memory, USB-PHY, associated I/O interfaces and other system requirements. Forming the power foundation for forthcoming 4G designs, this product has huge potential in the imminent high volume 4G market.

Designed for 3G/4G (HEDGE/LTE and WiMAX) USB wireless applications, the MIC2829 is currently available in volume quantities with pricing starting at $2.95 for 10K quantities. Samples can now be ordered on line on Micrel's web site at: http://www.micrel.com/ProductList.do.

Andy explained, "The MIC2829 is a complete 4G wireless system PMIC. This release to the market represents the beginning of a new level of integration for USB and embedded based LTE



Andrew Khayat, Director, Portable Product Group, Micrel, Inc.

or WiMAX 4G standard based mobile communication devices. This product is the result of Micrel's focused efforts to revolutionize mainstream wireless PMICs.

The MIC2829 integrates all system power and analog functions supporting 4G wireless baseband, RF and digital/analog sub-systems into one IC. It features Micrel's HyperLight Load™ (HLL) DC converters that greatly extend battery life and Micrel's advanced LDO technologies for ultimate system performance."

The MIC2829 incorporates six DC/DC buck converters, eleven LDOs and digital level shifters for SIM Card support inside a single, compact package. Five general purpose LDOs provide low dropout, excellent output accuracy of ±3% and only require 40 microamps of ground current for each to operate. The remaining six are high performance Low Noise Regulators (LNRs) and provide high PSRR and low output noise for sensitive RF subsystems. Each LNR requires only 20 microamps of ground current to operate.

Four of the six integrated DC/DC buck converters incorporate HyperLight Load™ (HLL) technology. Each of these buck regulators operate at high switching speed in PWM mode (4MHz/2.5MHz) and maintain high efficiency in light load conditions. The high speed PWM operation allows the use of very small inductors and capacitors minimizing board area while the HLL mode enables 87 percent efficiency at 1mA.

HyperLight Load™ technology also has unmatched load transient response to support advance portable processor requirements. The remaining two DC/DC buck converters support 100 percent duty cycle operation and can deliver greater than 96 percent efficiency. The MIC2829 is available in both 76-pin 5.5mm x 5.5mm LGA and 85-bump 5.5mm x 5.5mm FBGA packages with an operating junction temperature range from –40 °C to +125 °C.

Micrel's flexible foundation for 4G power management solutions

This unique power management solution was made for today's fast developing 4G design and manufacturing industry arena. The company's involved in this business will no-doubt want their own refinements built in to differentiate their offerings to consumers. My knowledge of Micrel's speed and flexibility in refining its products tells me that this part will form the basis for many future 4G designs. I will feature a full article on the unique technical features of this device in a later issue of the magazine.

www.micrel.com

Long Play Portable Audio

Maximum runtime and fast charging are now key

The first generation Apple iPhone, launched in 2007, was a turning point in the way cellphones are used. It marked the transition from a communications-centric device to one that is driven primarily by the applications it hosts.

By Mark Jacob, Director of Marketing, Audio and Power Management division, Dialog Semiconductor

The cellular air interface, rather than being the primary function of the device, takes its place among a large – and still growing – set of subsystems and peripherals. The changing use model also impacts the power-consumption profile of the smartphone. Not only did the iPhone's user-friendly browser – and those of all the competing smartphones that have followed it into the market – mean people go online more frequently; the phone also gave users access to a plethora of applications – over 140,000 and still growing.

Google's smartphone operating system, Android, has quickly been adopted by multiple manufacturers such as HTC, LG, and Sony. This OS also comes with an applications store, and many of these gaming, business tool, mapping and multimedia software downloads require a permanent connection to the mobile and GPS networks. Users are now checking Facebook on the phone's browser, watching the BBC's iPlayer to catch up on the week's TV, downloading clips from YouTube and listening to streamed music via Spotify. More applications mean more time spent active rather than in standby, increasing energy consumption and bringing battery life back into the spotlight as a key product differentiator.

Faster-charging batteries

In fact, user expectations have proved to be fairly resilient. No manufacturer has taken his product to market with the explicit message, "If you want all these extra features, you will have to charge the battery every day rather than the every-few-days you were used to with your last-generation pure cellphone" – nevertheless, the market has accepted that reality. However, when frequent charging is accepted, rapid charging joins battery life as a key selling point.

Within a complex system such as the smartphone, the interfaces that drive signals out of the digital processing context, and into the real world of the user, tend to be points of significant power consumption; the cellular radio power amplifier, the display backlight, and the audio output

system. Users have high expectations of audio performance from today's portable products, whether they are portable media players, netbooks or smartphones. Not only high-quality, high-output headphone or earphone drives, but also loudspeaker outputs at usable loudness levels and of acceptable quality. Today's smartphones must use less power when playing audio content via speakers and headphones than their predecessors.

Achieving maximum battery life in such a complex device imply, among may other requirements, fine granularity of control of power feeds to all of the product's subsystems; put simply, if a given application does not need a certain function, then that system has to be in a very low-power standby-state or, preferably, switched off completely. Added to that is the fact that almost every system within the portable product requires different voltage levels, with different power demand profiles across the various application scenarios, and with differing tolerance of noise and other power-line parameters.

Power sequencing

This is of key importance for each of the product's radios, of which there will be several; cellular radios for multiple bands, Bluetooth, Wireless LAN, GPS and FM. As if that were not enough, in the process of configuring the device for its various applications, voltage rails must be ramped up and down in pre-defined sequences. The overall power-management function within such a smartphone or portable product has grown to be a very complex problem.

Nor is the reverse situation of battery charging necessarily simpler. As noted above, minimum charging times are a marketing necessity, so that the maximum power possible has to be delivered to the battery from any available source– both with, and without, concurrent operation of the smartphone's other systems. As is well known, high-energy-density lithium ion cells demand precision control of charging energy; even an efficient charging regulator will dissipate some heat, and there will be some dissipation in the battery itself, as it approaches its fully-charged state; add in the dissipation from the normal operation of the phone, and a thermal management challenge emerges. All of this activity is taking place within a tightly-packed plastic enclosure that is, as far as the manufacturer can ensure, sealed – N.B. in the iPhone itself, the battery is not removable, although other designers have not followed that paradigm.

Now, with the advent of the iPad, a similar set of power and thermal design constraints will have to be explored within a different form factor.

Single-chip PMIC and digital audio

It was for exactly this class of product, and to cater for a rapidly-evolving set of usage scenarios, that Dialog Semiconductor created the DA9057, a highly-integrated flexible energy management IC with on-board ultra-low power audio codec. This configuration draws a distinction with some earlier products that have sought to place all of the power-management and audio-signal-chain functionality on a single chip – including the audio power amplifier (APA). There is a case for that integration; both systems can exploit similar semiconductor device technology, and the combined IC takes one more part out of the bill-of-materials. It is also the case that the latest Class-D amplifiers have greatly improved performance in respect of EMI than some of their predecessors; nevertheless, the majority of portable-audio-product designers prefer to place the power amplifier IC close to the transducer (speaker) to minimise the distance covered by the circulating currents of switching-output amplifiers. Partitioning the function set into a combination of audio codec on the same silicon as all power-management functions; and a minimum-size, separate APA die, produces an optimum outcome.

The DA9057 therefore contains all the resources that a design team might need to control the flow of power to the functions of a smartphone, multimedia player or portable navigation device, with optimum efficiency, together with audio, and user-interface controllers. It has four DC-DC buck switching converters and ten low-dropout linear regulators (LDOs). A further DC-DC boost converter provides the higher voltage needed to drive series-connected "strings" of white LEDs for display and keypad backlighting. (Three strings, at 24V and 50 mA.) Each DC-DC converter and LDO is individually configurable on start-up to match its output to individual functional blocks.

Accelerated charging

The chip is intended for use with a single lithium-ion or lithium-polymer battery and supports multiple charging scenarios – use of a plug-in or docking-station charger, charging from USB, or even wireless (inductively-coupled) charging systems. An autonomous charging control block optimises power flow between AC-line charger, USB cable, battery and any functional blocks that are active, optimising available power to maximise charging rates in all states.

Both AC charger and USB sources can be safely connected simultaneously; the USB power-rail specifications are fully observed and, in addition to the protection that should be present at source in any USB connection, there is further internal 500 mA current limiting and voltage monitoring. Batteries that can sustain it, can be fast-charged at up to 1.3A; if the on-chip regulators approach their limits, thermal protection comes into play to ensure safe operation. The switching charger supports precise voltage and current profiles; when the battery is in a low state-of-charge the charging circuit will operate at an intermediate voltage level of 3.2 - 3.5V to minimise losses, reverting to full Li-ion cell voltage levels when the battery's charge has recovered. Compared to a linear charger, this strategy alone can save over 1W dissipation within the product's casing.

Many loads within a smartphone require low-noise, well-regulated power supplies, that the LDOs are well suited to providing. The losses inherent in the operation of an LDO can be minimised by cascading them with one of the switching regulators: the DC-DC block effectively reduces the battery line voltage to an intermediate level so that the LDO can complete the regulation chain with minimum losses. Linear regulators use Dialog's Smart Mirror adaptive biasing scheme, which ensures maximum efficiency over the complete range from light-load to

full-load, without requiring additional external components.

Today's sophisticated portable consumer products will contain one, or several, processor or DSP cores, appearing either as individual chips or integrated within system-on-chip (SoC) ICs. To conserve power, the processors will typically scale both operating frequency and supply voltages, according to their throughput at any moment. Signalling to control dynamic voltage scaling (DVS) is typically via a serial bus: the DA9057 supports DVS on three of the four DC-DC converters and the chip has twin serial interfaces (as well as a general-purpose 16-bit parallel interface). Each of those DC-DC converters can individually supply a maximum of 1A, within a 2.4A maximum for the four running in parallel: each is a four-mode device with alternate characteristics to suit RF, linear, or digital circuit loads. In total, the chip can supply up to 5A from its various outputs, from a package measuring just 7x7 mm.

Packaged together with the regulator functions is a collection of virtually every other functional block that the designer will need to assemble a system-management controller; for example, watchdog timer, general-purpose analogue/digital converter, real-time clock, and uncommitted register space; there is also a touch-screen interface block. As a processor-based device, the portable product may well have a memory-backup rechargeable coin cell, or other PCB-mounted battery, to retain essential data when the main battery is discharged; the DA9057 caters for that as well, with a secondary, low-current charging circuit that is totally independent of the main provision.

Optimising the audio path

Efficient control of power flow is an important part of maximising battery life, but by no means the only one. As noted earlier, the smartphone or media player is likely to spend a high proportion of its on-time processing and outputting audio, so optimising that signal path for power consumption offers good returns in overall power drain: and, the mixed-signal environment of the power management IC is a good environment in which to locate the function, thanks to the common requirement for precision linear transistors. However, as most of the audio codec is digital circuitry, integrating it on to the PMIC is readily achievable. The block is a high-quality, multi-rate-adaptive audio codec with an integrated Class-G, DC-coupled (capacitor-less) output, headphone amplifier. Class G amplifiers are linear,

but improve efficiency by running with low voltage supply rails while program content is at a low level, only stepping up the supply rail to faithfully reproduce high peak-level outputs. The result is over 70% more efficient than a Class AB amplifier.

The DA9057 has been designed to work directly-linked with the DA7201 Class D loudspeaker amplifier, to which it connects via differential line outputs (with 60 dB CMRR). The DA7201 is a stand-alone, single-channel filter-less chip that delivers 3W mono audio power into 4 ohm speaker loads. It has a $1.5mm^2$ outline and operates with a direct battery connection (rejecting power supply noise with a 90dB PSRR) simplifying placement in close proximity to the transducer; its peak efficiency is over 90%, saving battery power in extended playback, and contributing to reduced heat build-up in small enclosures. All this is achieved with no compromise on audio quality; signal/noise ratio is 98 dB and distortion is under 1%, and normal listening level playback of 24-bit audio, to headphones, takes a power budget of just 5mW from the battery (including regulator losses).

Returning to the DA9057, the design recognises that today's portable products are "authoring" as well as listening devices. There is a fully-featured audio mixer with up to eight sources, stereo/mono conversion, a general-purpose 5-band equaliser and per-channel equalisation, with automatic level control. Additionally, a general-purpose filter engine allows application specific or adaptive speaker equalisation to be introduced. To integrate these features with the host operating system of the smartphone or media device, Windows CE and Linux drivers are provided.

GUI development

It has long been the case that power systems tend to be attended to late in a product's development cycle. Elevating battery life to a top-priority specification point has altered that situation, forcing engineers to design for power demand from the outset. Against that, however, is the fact this class of product is very prone to specification changes and addition – or even deletion – of features late in the cycle. It is therefore desirable that configuring the PMIC should not involve low-level coding, or changes to peripheral passive components or – even worse – PCB layout changes.

In fact, complete set-up of the DA9057 is accomplished through a graphical user interface; on one side, it allows configuration of the power-management system through drag-and-drop interconnection of on-screen functional blocks, plus entry of parameters such as time-delays to set up sequences. In a separate window, are all of the parameters of the audio sub-system. The engineer can set up an audio path, configuring the codec and adding whatever filtering the application demands. The development environment includes a complete graphical filter design package with simple selection from a range of standard filter types; a graphical simulation immediately shows the effect of any particular set of filter coefficients.

Both PMIC and audio-subsystem configuration files are loaded to the chip over a serial interface and are retained in on-chip configuration registers.

Conclusion

Achieving the longest possible battery life has once again been thrust to the forefront of portable consumer multimedia product design, with the added customer expectation of fast recharge times from any available power source. Every functional block in the product must be designed with low power in mind, but a flexible global power management system is a necessity to handle the complex sequencing and voltage control that is now standard. The audio sub-system makes a natural pairing with the power-management system, implemented in the same energy-efficient mixed-signal silicon process, and careful attention to power dissipation throughout the audio chain – and especially in the output drivers – contributes significantly to meeting an application-centric media product' s specification.

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Power Station Revitalized

Breathing added life into failing heat exchangers

AEP Tanner's Creek power station found that using the latest technological advancements can add years to heat exchanger units. By more accurately and quickly replacing tubes, costs are slashed and service is life extended.

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

When heat exchanger tubes - sometimes numbering a thousand or more per unit - begin to crack or wear, the effects can lead to a cascade of subsequent failures in adjacent tubes. If too many tubes are plugged, heat exchanger effectiveness is compromised, and power generation may be curtailed by a substantial percentage. If conventional mechanical plugs are used, they can break loose, leak and fail. At that point the replacement of a very costly heat exchanger may be imminent.

However, if the latest sleeve installation technologies and techniques are used, the results can be lower materials and installation costs, improved heat exchanger performance, without the need to take generation units offline while the repair work is done. Perhaps most importantly, the sleeved heat exchanger can operate reliably for added years, saving the operator's capital until a planned rebuilding or replacement unit is installed.

AEP Tanner's Creek case

At AEP's Tanner's Creek 995MW station, located on the Ohio River near Lawrenceburg, Indiana, thermal stress cracking and wall loss indicated impending failures of 60 percent of the feedwater outlet tubes in the heat exchanger on the plant's 500MW super critical Unit 4. This was in the fall of 2009.

"We had done some testing and were hopeful that the heater could be repaired," explains Jay King, Process Supervisor. "It was not feasible to replace the heaters at this time. We had to have a certain amount of time to put together a replacement package to present to the board and show that is was justifiable to replace the heaters in the future."

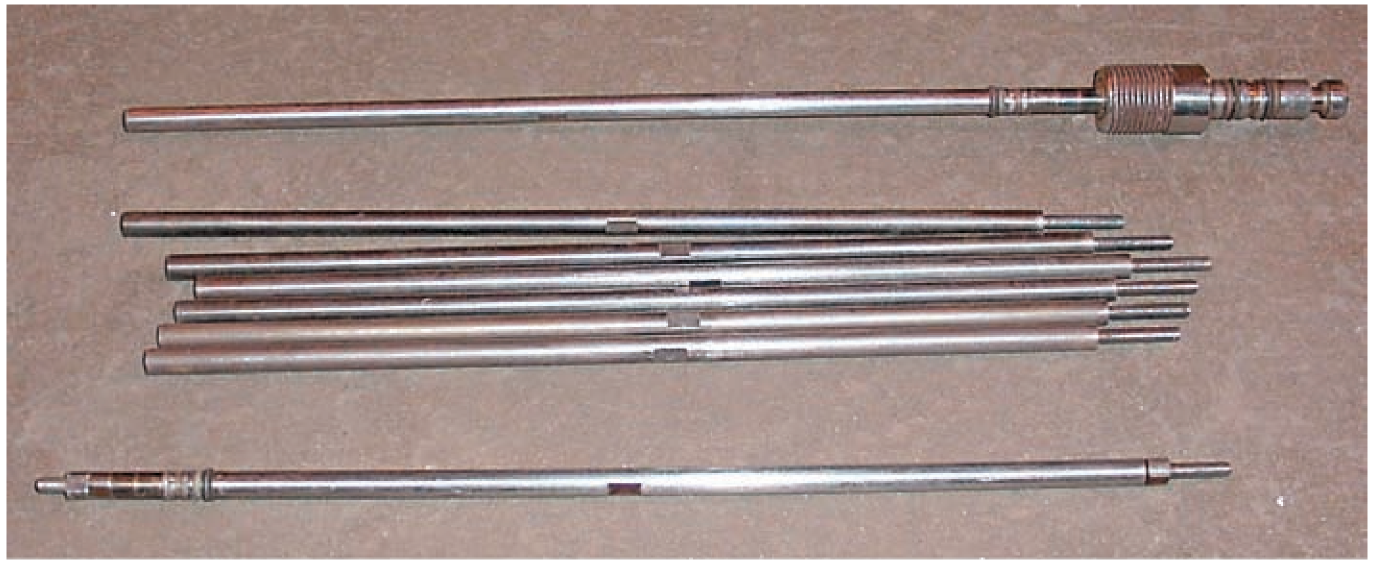
"We were at the point where we had to discuss abandoning the heaters until we could replace them. Unfortunately, this would possibly cut down our output because it would not be desirable to operate the heater in each string. This would greatly accelerate the end life of these heaters. To operate without any heaters in service would have meant as much as a 50MW curtailment," King added.

The two high pressure feed water heaters were eddy current tested and found

APS was able to extract a tube sample using their proprietary and patented advanced plasma arc tube cutter(P. A.T.C),APS's plasma arc tube cutter enables them to cut heavy wall tubes at any length up tothe tangent point of the U-bend in order to facilitate tube sample removal.

The pressure feed water heaters were tested and found to have severe stress cracks from the back face of the tube sheet in the de-superheating zone extending approximately six feet to the back of the zone

Instead of plugging the tubes we went in with sleeves that were roughly 7 ft.long and installed the sleeves in the ID of the tubes .The sleeves extended past the area where the stress cracking or excessive wall loss was located .



APS's innovative approach-they were able to sleeve the Tanner's Creek feedwater heaters despite the limited access within the feedwater heater and presence of heavy wall tubing,representing a very substantial savings to AEP over replacement heaters.

to have severe stress cracks from the back face of the tube sheet in the desuperheating zone extending approximately six feet to the back of the zone.

In order to verify the severity of the stress cracking, a tube sample was taken for laboratory analysis which proved the eddy current test was accurate. It would have been extremely difficult if not impossible to cut and pull a tube sample from these heaters via conventional methods due to the very heavy tube wall thicknesses. However, American Power Services (APS) was able to extract a tube sample using their proprietary and patented advanced plasma arc tube cutter (P.A.T.C.). APS' plasma arc tube cutter enables them to cut heavy wall tubes at any length up to the tangent point of the U-bend in order to facilitate tube sample removal. Since the thickness of the tube walls ranged between 0.083" and 0.115" thick, cutting and removal of a tube sample would be very tough to cut or even access otherwise.

"They came up with the idea of sleeving the outlet tubes to increase the longevity of the heaters and return the heaters to service," says King. "They sleeved all the feedwater outlet tubes that had 70% or greater wall loss and had signs of stress cracking."

More advanced sleeving

If the latest sleeve installation technologies and techniques are used, the results can lower material and installation costs, improve heat exchanger performance, without the need to take the generation units offline while the repair work is done. Once the repair work is done, the re-sleeved heat exchanger can operate reliably for added years, saving operator's capital until a planned replacement unit is installed.

"At Tanner's' Creek the tube defects were roughly up to 6 ft. back behind the tube sheet," says APS sales and services engineer David Grimes. "Instead of plugging the problem tubes we went in with sleeves that were roughly 7 ft. long and installed the sleeves in the ID of the tubes and the sleeves extended past the area where the stress cracking or excessive wall loss was located. So, if the tubes continued to weaken and fail, then we have those liners installed that should prevent the tubes with through wall cracks from leaking."

The use of a hydraulic expander provides a more uniform expansion and superior contact of the sleeve OD with the ID of the parent tube.Additionally, the sleeves were stregth welded to the parent tubes at the face of the outlet tubesheet

Grimes adds that APS chose to recommend installing the sleeves because plugging such a large percentage of tubes would have led to reduced thermal performance and increased feedwater velocity in the inlet of the unplugged tubes. Additionally, the plant may have had to cut a bypass orifice in the pass partition plate in order to prevent higher tube inlet velocities that, would have led to further heat transfer degradation.

As a result of APS' innovative approach, we were able to sleeve the Tanner's Creek feedwater heaters despite the limited access within the feedwater heater and presence of heavy wall tubing, representing a very substantial savings to AEP over replacement heaters.

"I would say that, using this technology, our customers can realize savings of over 80 percent of the cost of a new heat exchanger if they elect to install sleeves rather than replace their problem heat exchangers," says Grimes. After the sleeving project at Tanner's Creek unit was finished, Jay King was surprised to see that heater performance was substantially maintained.

"We would have expected to see slight performance decay, since you have the sleeves in place in the desuperheating zone, because it's now a heavier-walled tube, he said. But that didn't happen. We maintained the same performance levels. The TTD (terminal temperature difference) and the saturation temperature of the heater (based on the pressure) versus the feedwater outlet, have not decayed at all." Quite possibly that resulted from the selective, limited use of sleeving."

"The thing I liked best about going this route is that we didn't have to abandon the heaters," adds King. "That would have presented us with a very difficult situation on how we would start and shut down the unit without some serious pipe modifications and major changes in operating procedures. These heaters are used during start-up and are equipped with alternate drains that drain back to the condenser that must be utilized during start-up. The piping modifications would have meant a large added O&M expense and time lost for engineering to assess needed operational changes. The installation of the sleeves allowed us to maintain efficiency and return the unit to service maintaining a design basis."

In installing the sleeves, APS employed an advanced hydraulic expansion method that utilized a flexible hydraulic expansion mandrel. The use of a hydraulic expander provides a more uniform expansion and superior contact of the sleeve OD with the ID of the parent tube. Additionally, the sleeves were strength welded to the parent tubes at the face of the outlet tubesheet. Grimes added that with projects that utilize the advanced tube testing and sleeving technologies, there are benefits that are somewhat immeasurable. "In most cases, sleeving can be performed with the heater isolated while the unit remains online which allows the Utility to continue to generate electricity. The power generating capacity that these companies retain, as well as how much more heat transfer they are able to get out of that heat exchanger are additional cost savings that the utilities realize from this process. So, you would have to calculate that and how much less coal you would have to burn to maintain the same MW. Plus, the capital expenditures have to be considered regarding heat exchanger replacement."

For more information, contact American Power Services info@1aps.com or www.1aps.com

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Isolate to Communicate

System robustness through the rejection of system level noise

RS485 networks provide the backbone for communications in applications ranging from industrial control systems to roadside traffic message boards. In environments where high voltages are present, electrical isolation from the communication bus to logic controllers is regularly employed for human safety and equipment protection.

By Jeff Marvin, Design Center Manager and Brian Jadus, Senior Design Engineer, Mixed Signal Products Linear Technology Corporation

Often overlooked, are the benefits of isolation affecting system performance rather than simply protecting it from dangerous voltages. These benefits come in the form of uninterrupted, error-free communication in the presence of harsh ground perturbations and other system level noise that would otherwise render a non-isolated system inoperative.

Isolated RS485 transceivers are available from several manufacturers. Most of these solutions provide data isolation but do not provide the isolated power needed to drive the bus interface. The user is left to come up with the solution, requiring bulky, expensive discrete elements to make up the isolated DC/DC converter. The overall size, cost, power consumption, or complexity can deter the use of isolation in systems that could truly benefit from it.

New Isolator μModule® technology from Linear Technology provides a complete power and data isolation solution in small LGA and BGA surface mount packages. The LTM2881 incorporates a robust isolated RS485 transceiver and an isolated DC-DC converter capable of delivering up to 1W of power for the bus interface circuits and auxiliary circuits. The μModule transceiver requires no external components – even the decoupling capacitors and an electrically switchable network termination resistor are built in.

Ground and Common Mode Voltage Disturbances

RS485 was developed and standardized to allow communication between transceivers with ground potential differences of up to ±7V. The signals on the bus can assume voltages of -7V to +12V with respect to the local "ground" at any node. These ground potential differences arise from a variety of conditions including earth ground variations or voltage drops on ground returns that are shared by other circuits under load.

Under some circumstances extraneous transient events can produce ground shifts that far exceed ±7V. These conditions will likely introduce errors in the received data, or worse yet, damage transceivers and their associated system circuitry. Proper use of an isolated transceiver, like the LTM2881, extends the usable common mode voltage (mean voltage of the differential signal lines with respect to ground) to ±560V continuously or ± 3500V_{DC} for 60 seconds. This level of isolation offers protection and uninterrupted communication from severe voltage disturbances such as indirect lightning strikes to networks spanning multiple buildings.

Repetitive ground and signal disturbances can result from coupling to AC power lines routed adjacent to RS485 bus wires. Computers, printers, fluorescent lights, variable speed motor drives and other electronic non-linear loads can introduce significant frequency harmonics into power distribution neutral, ground lines, and communication network wires. These disturbances can cause real data errors in RS485 networks which isolation can alleviate.

Transmitted but Not Received

RS485 wiring configurations for non-isolated and isolated networks are shown in Figure 1. For simplicity, the illustration shows point-to-point unidirectional communication but the concept also applies to multi-node networks. Figure 1a shows a non-isolated, unshielded twisted pair connection implemented with Cat5e cabling. Figure 2 shows oscilloscope waveforms captured at points on this network while driving 100ft of cable and introducing a ground potential difference between driver and receiver. The trace colors correspond to the colors of the probe locations in Figure 1. All signals are measured with respect to earth ground at the output of the receiver.

Channel 3 (green) shows the data signal into the transmitting driver at DI, while Channel 4 (red) is the data output from the remote transceiver's RO pin, which should follow the data input by only propagation delay.

The yellow trace at the top of Figure 3 is the sine wave voltage signal introduced between grounds with 7V amplitude (14V_{PP}). Channel 2 (blue), shows the "B" signal at the negative receiver input after it has traversed the 100' cable. The digital data at "B" is nearly imperceivable compared to the large common mode voltage signal it is superimposed on.

Figure 2 shows obvious errors. There are two factors contributing to the loss of data, both relating to the finite common mode rejection capability of the RS485 receiver. First, the high frequency content of the common mode signal, here about 1.2MHz, exceeds the effective bandwidth of common mode rejection for most RS485 receivers.

Secondly, the amplitude of the common mode signals presented to the receiver far exceeds the allowed range of-7V to+12V. In this case, the signal amplitude at the end of the 100ft wire has peaked up to±20V even though the stimulus introduced at the near end had voltage peaks of only ±7V! This amplitude peaking is maximized at the resonant frequency of the network wiring. Note this does not refer to the differential characteristics of the bus, which behaves like a transmission line, but is a characteristic related to the common mode impedance. The resonant frequency is a function of the cable length, cable configuration (e.g., coiled or straight) and the complex impedance of the connected nodes. The interesting point is that a ±7V common mode signal was able to corrupt RS485 signal transmissions due to the frequency content and amplitude peaking.

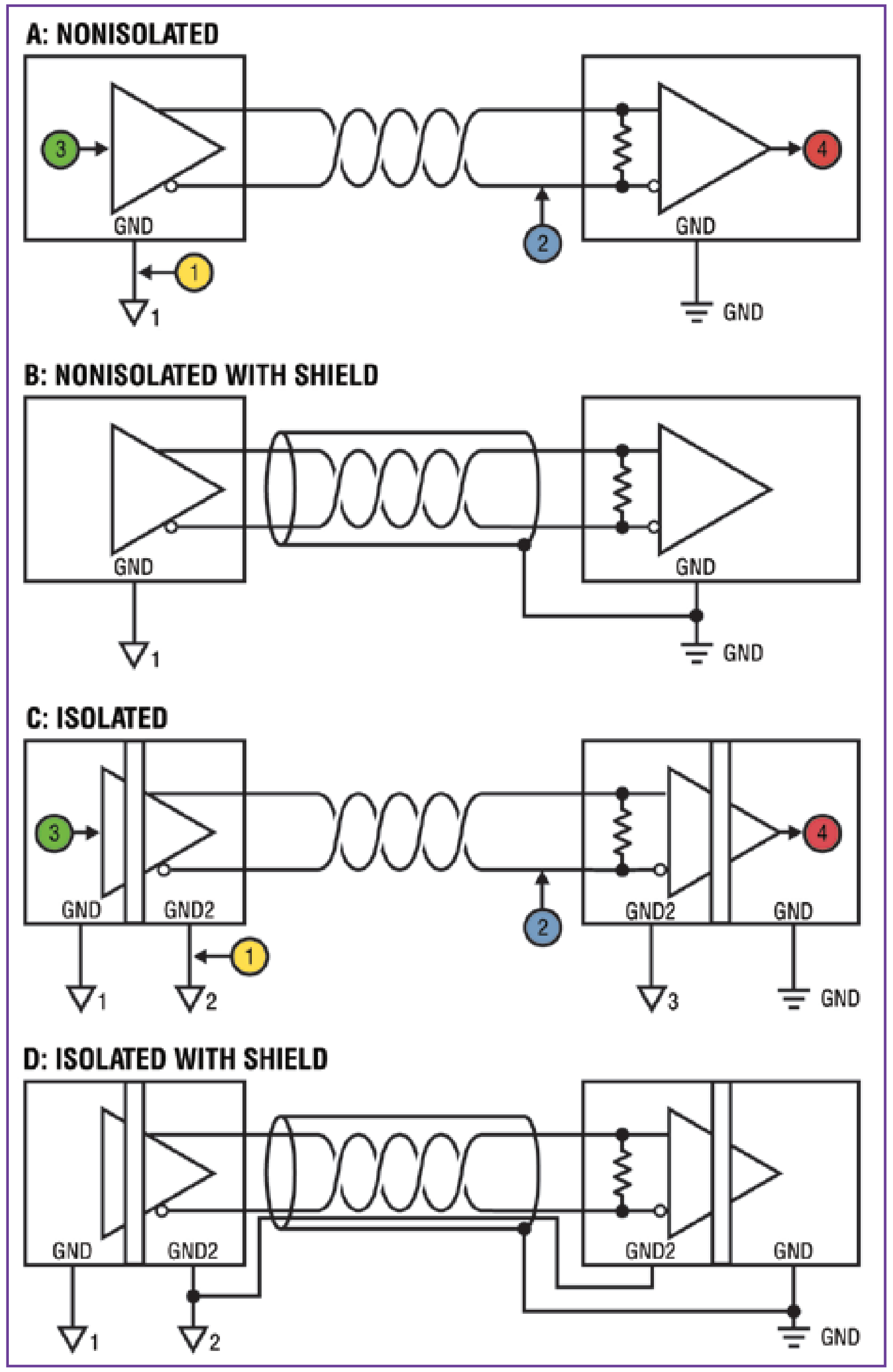

Figure 1: RS485 Wiring Configurations

Isolated Communication Works

Replacing the RS485 transceivers with LTM2881 Isolated RS485 transceivers (Figure 1c) solves the problem of data corruption as is evident in the corresponding waveforms of Figure 3. In this configuration, the common mode applied to the receiver inputs is mostly developed across the isolation barrier. The receiver isolated ground moves with the common mode voltage of the receiver inputs, simply riding on top of it. As a result, the receiver does not see this as a common mode variation and continues to reliably detect the differential data.

Notice that the common mode frequency has been increased to 2MHz, which causes the signal amplitude at the end of the cable into the receiver (blue trace) to increase significantly to 40V_{PP}. This common mode voltage amplitude is far beyond the specification called out in the RS485 standard and would challenge most non-isolated RS485 transceivers.

Wiring Improvements

Better choices for wiring include using shielded wire and a common wire that ties all isolated ground nodes together are discussed below.

Figure 1b shows the non-isolated network connected using a shielded twisted pair, such as Belden 9841 cable. The shield should only be tied at one point to avoid creating ground loops.

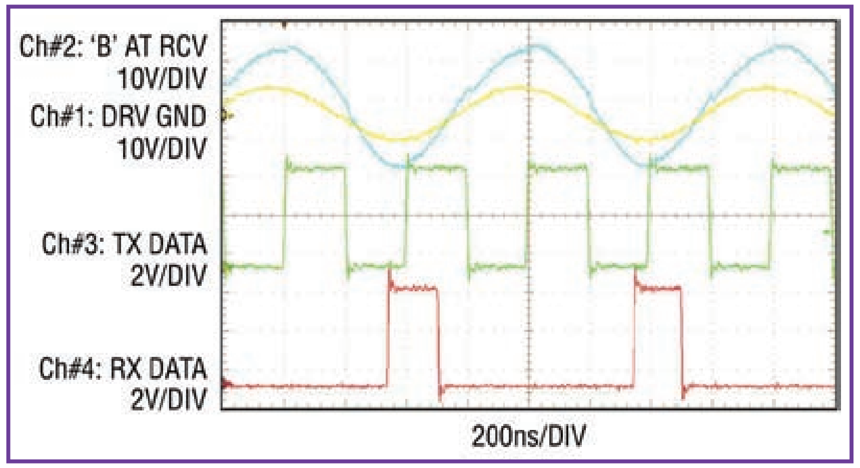

Figure 2: Non-Isolated Data Loss for network of Figure 1a

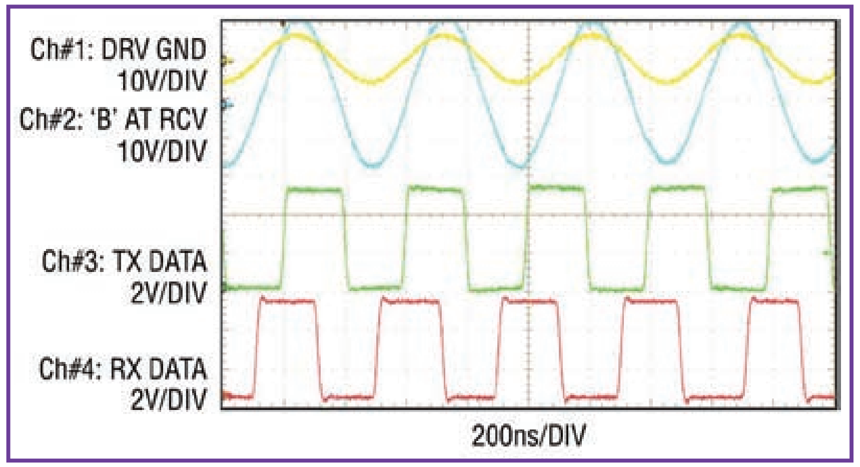

Figure 3: LTM2881 Isolated RS485 Transceiver communicating through severe common mode voltage

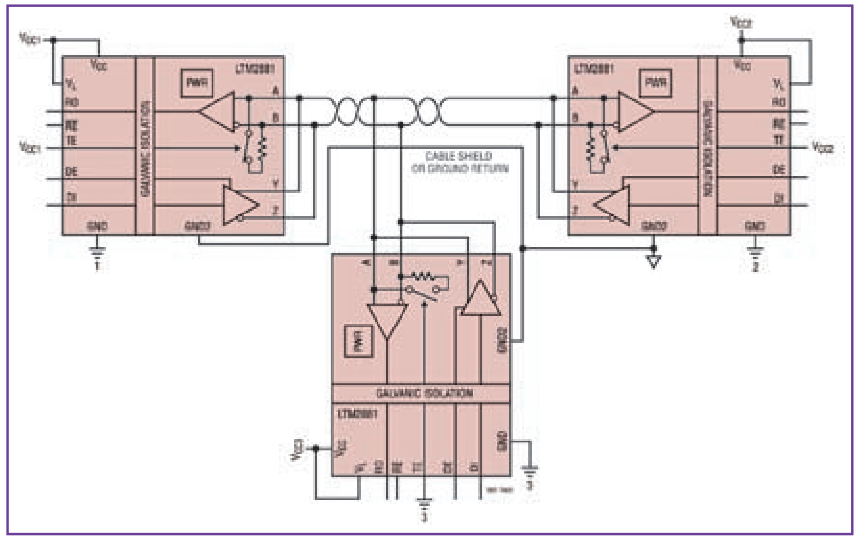

Figure 4: LTM2881 Typical Application

Connecting the shield to the receiver ground provides the best shunting for system performance. In multi-node, non-isolated networks the master node is typically the shield connection location. The shield serves to shunt coupled energy to ground rather than onto the signal wires and does not reduce the effects of ground differences between nodes.

The best wiring option for use with isolated transceivers is illustrated in Figure 1d. All isolated grounds at each node are tied together with a common wire. The common connection is tied to non-isolated ground at one point to establish the nominal voltage reference level of the otherwise floating network. This prevents the bus from floating to excessive voltages beyond the isolation rating.

This configuration elicits the best performance out of the RS485 receiver because the receiver's isolated ground potential follows the common mode of the input signals and is absorbed across the isolation barrier. Since the receiver ground moves with the signals, the receiver is not taxed with rejecting common mode voltage transients. Instead, the rejection happens at the isolation boundary where the LTM2881 encodes the data into differential digital pulses before inductively coupling it across the barrier. This communication method is tolerant of extremely high common mode transient events faster than 30kV/µs with no data loss or added jitter.

Figure 1d also shows a separate shield tied at one point to earth ground to shunt coupled noise. However, some systems will not have both a shield and separate reference wiring options. In this case, the best option is to tie the shield to the common terminal of each isolated transceiver and then to earth ground at one location. If RF immunity remains a concern, a high frequency, high voltage, capacitor from each receiver common to ground can help shunt the energy away from the transceiver.

Figure 4 shows a typical usage of the LTM2881 isolated RS485 transceivers arranged in a half-duplex network with their isolated common nodes (GND2) wired together for optimal performance as discussed.

Conclusion

Isolation improves system robustness through the rejection of system level noise. Products like Linear Technology's LTM2881 isolated RS485 µModule transceiver with integrated isolated power, make it easier than ever to get the best performance out of a communication system.

www.linear.com

Maximized Manufacturability

Self acting PressFIT module simplifies assembly - maintains reliability

Customers of power electronics increasingly require new, easy connection and mounting technologies. PressFIT technology creates the possibility of solderless mounting combined with an improved reliability.

By Marc Buschkühle and Thilo Stolze, Infineon Technologies AG, Warstein, Germany

To continue this approach, a new module platform based on PressFIT technology has been developed which furthermore offers an extremely fast and robust mounting concept to improve inverter manufacturing, reliability and design. Special emphasis has been put on mechanical robustness. Avoiding the risk of DCB cracks resulting from controllable forces originating from the module design, was one of the main approaches. To demonstrate the robustness, comprehensive mechanical tests were carried out.

Self acting PressFIT: the Smart principle

Regarding current module designs, there are three main improvement areas, which have to be combined into one solution: So the approach is, to get a module which is suitable for a single step mounting process with a high mechanical robustness, in combination with a robust contact system.

The Smart module is suitable for a single step mounting procedure by the use of PressFIT contacts, hence the name “self acting PressFIT”. This means that the fixation at the heatsink, the electrical contact and the PCB fixation is done in just one very fast process step, simply by tightening a screw.

A counterholder transfers the force from the screw to the PCB and pushes the contact pins into the dedicated holes. At the end, this pressure part rests onto the module and presses this to heatsink for a good thermal contact. Furthermore the PCB is fixed between the module frame and the counterholder after the mounting process, therefore no additional fixing points for the board are necessary around the module.

This Self acting PressFIT assembly is presented in the full Smart family. The family consists out of three packages, dedicated to the different power ranges. The following tests are carried out with the Smart1 module, but can be also roughly assigned for the Smart2 and Smart3, because of the similar mechanical concept.

The mechanical design is benchmark regarding robustness. This is realized by a duplex frame, which prevents the ceramic substrate from all screw forces and also from other external loads. It consists out of an inner module core with the ceramic substrate and an outer decoupled parts frame. The screw force is only applied on the outer frame. The inner part has a vertical degree of freedom. Those two parts are connected with elastic elements which pushes the inner part to the heatsink. Also the PressFIT pins, which are directly distributed on the substrate, push onto the substrate.

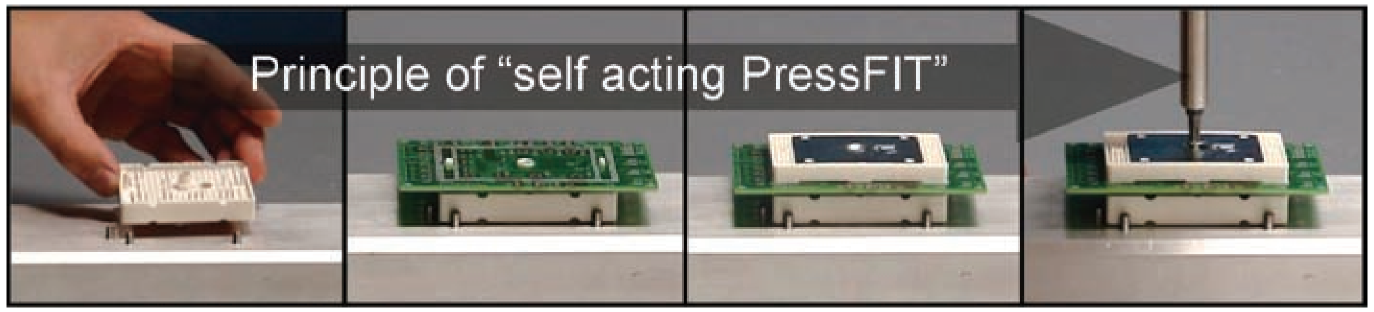

Figure 1: Module fixation and press-in process by tightening a single screw
Further information: www.infineon.com/smart

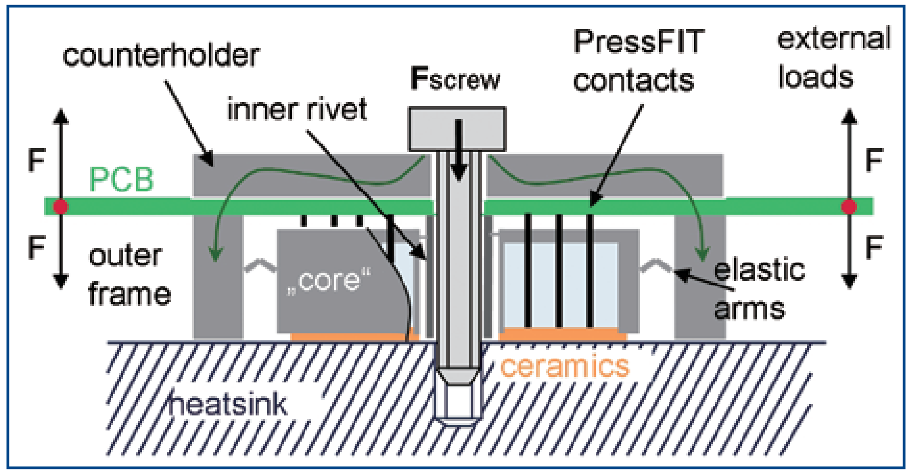

Figure 2: Schematic drawing of a Smart module: The forces of the screw are transferred to the outer part – the inner, decoupled part is protected

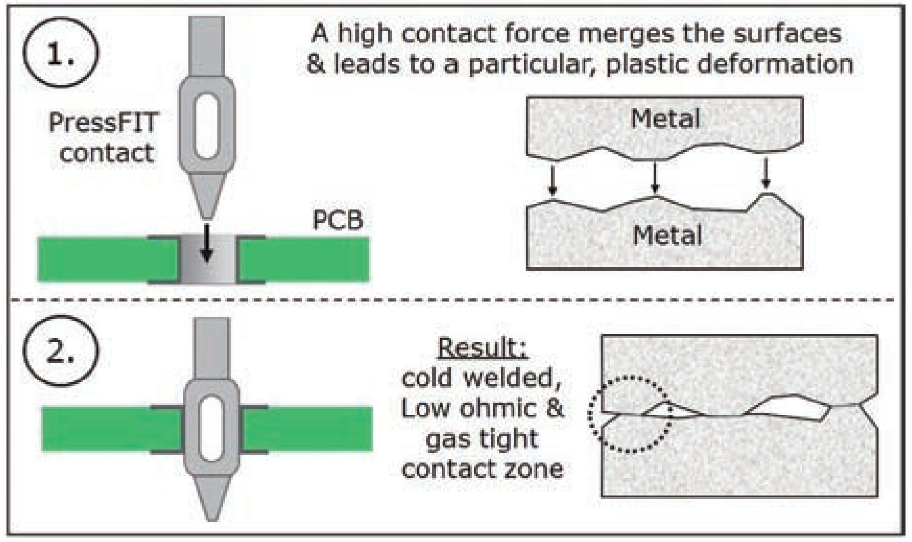

Figure 3: Schematic drawing of a PressFIT connection

High reliable connection to the PCB

To enable the single step mounting process, a solderless connection technology is required. Within the Smart modules, the well proven PressFIT contacts are used.

The reliability of a PressFIT contact is based on the gas tight contact zone, which is very robust against climatic influences and corrosive environments due to the particular plastic deformation in the local contact point which generates a cold welded connection. This results in very low FIT rates, which are approximately one decade below solder connections.

So PressFIT should be the connection method with the highest potential for the future.

No ceramic crack issue

A trend in the market of low power semiconductor modules is to build the modules without the classic baseplate. This means, the module base is designed as the ceramic substrate, where the high power dies are bonded.

In contrast to the smart concept, existing designs suffer the common risk of ceramic cracks due to high resulting pretensioning force of a screw. This results from the fact, that the force is applied directly onto the housing as can be seen. A ceramic crack leads to a safety relevant isolation failure, meaning the module has to be scrapped.

The thermal grease, which is state of the art necessary for a good thermal interface between power module and heatsink, increases the risk of cracks due to its viscosity and velocity proportional absorbability.

Unfortunately and especially if the thermal grease is applied by hand, there are some unavoidable fluctuations regarding the thickness of the grease. For the thermal behaviour of the module later on, these fluctuations are not objectionable, but due to the viscosity and velocity related damping of the grease material, they could be fatal for the ceramics and the isolation capability of the module. This comes from the inhomogeneous mechanical support and the resulting high, local bending stress which can lead to a crack. This risk becomes greater, the higher the mounting speed due to the speed of turning of the screw during assembly.

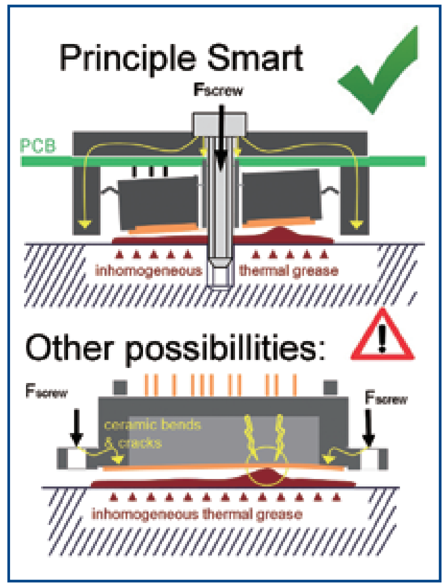

Figure 4: No ceramics cracks with the protecting Smart principle. Crack risk of ceramics in standard module due to direct loads on inhomogeneous thermal grease support

To ensure the functionality of the Smart principle, some simple tests have been carried out, where the application of the thermal grease has been purposely falsely applied.

Torque and speed of rotation

The request of modern manufacturing is to tighten screws as fast as possible. But as can be seen, a fastening machine is not able to stop exactly at a torque limit at that speed. It has an overshoot effect due to the inertia of the rotating masses. A common corrective action is to use a two step procedure, where the speed is reduced in the second one to values of 100U/min and below.

A Smart module is suitable for a real one-step-mounting procedure with a rotation speed of 500U/min, due to its robust and force-absorbing design.

Within the torque overload tests, thermal grease with a thickness of 100µm was applied. The Electrolube HTC material was chosen, because it has a very high viscosity, which is more critical for the crack sensitive ceramics.

The overload torque was adjusted to a maximum of 12Nm (Figure 6), which is corresponding to a torque of 9Nm at a friction value of 0.10. All modules have been inspected and measured due to their isolation capability before and after the test:

That means there is no DCB crack occurred and also the rest of the device was completely damage-free.

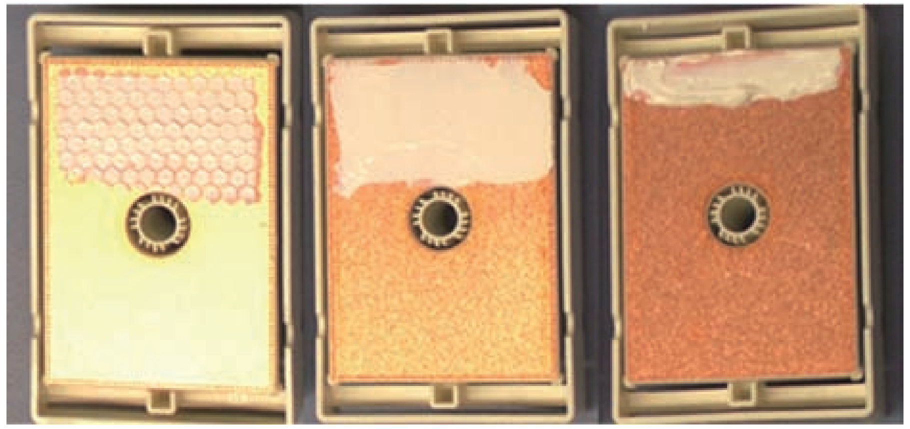

Figure 5: Although with inhomogeneous, wrong applied thermal grease: No damage of ceramics. The wrong application, exemplary shown in 0 could not crack or damage the DCB or the module in any way

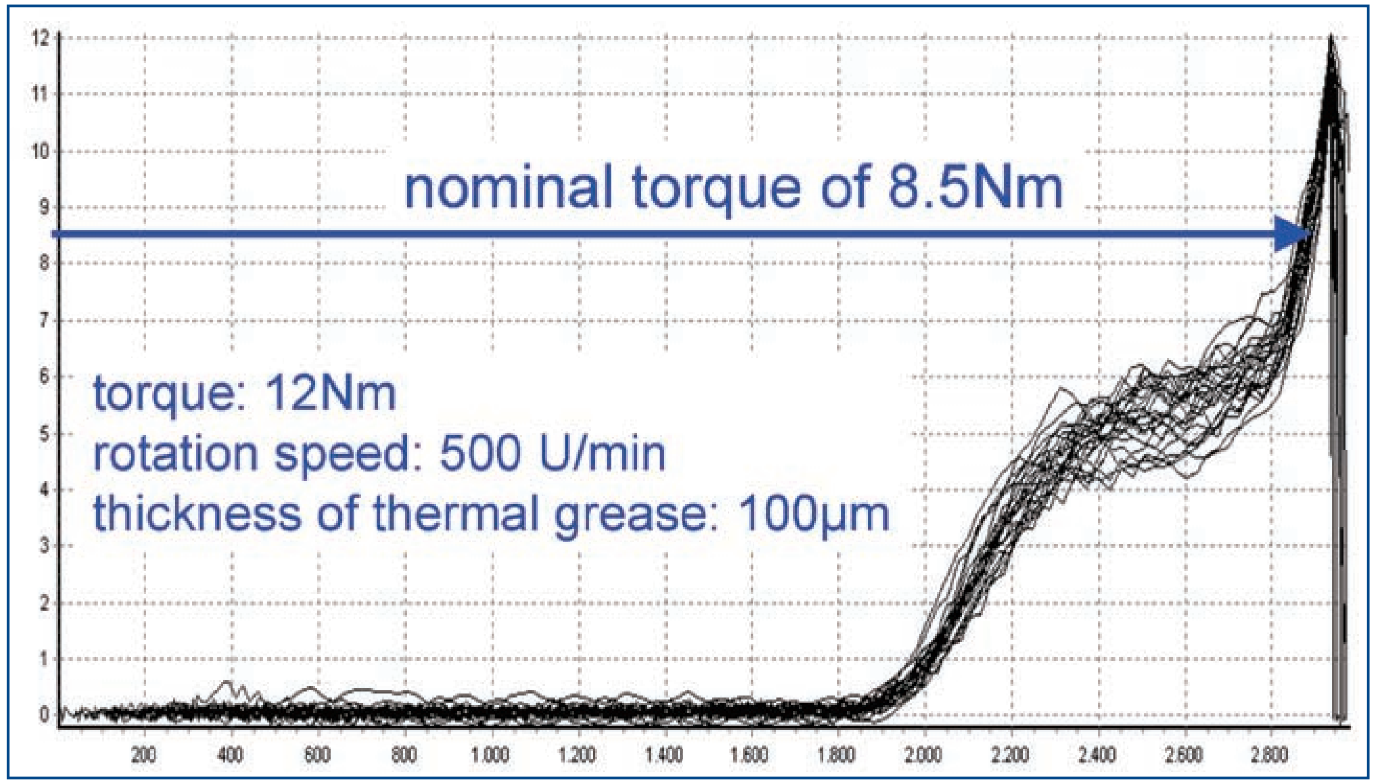

Figure 6: Torque rotation-angle diagram of a Smart1 module

Conclusion

Many tests on the mechanical robustness and behaviour of the Smart1 module have been performed. All show that the Smart principle is a realized approach to cover all of today's main improvement areas in one power module: A solderless, robust single step mounting concept, combined with a reliable and universal contact system. Certainly, the Smart family will be extended to higher power ranges, with the same features and the same robustness.

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Keeping Systems Running Cooler

Developing highly efficient power supplies

Taming the heat is one of the biggest design challenges facing system architects and power supply manufactures today. Free air flow through the power supply is critical for improving performance in both system and supply.

By Michael Bean, Global Product Manager, High Current Power, Molex Incorporated

Data centers are on the front line when it comes to targeting energy consumption. With the explosive growth in size and number of large data centers, server manufacturers are in hot pursuit of efficient system designs that include space-saving power supply strategies. Striving to achieve as much system efficiency as possible, the microprocessors, chassis fans and power supply losses combine to account for 50-80% of the total energy used in the average high-capacity server. On average, every 100 watts generated to power the system demands an additional 50 watts just to cool the system.

Power supplies must not only exhaust self generated heat but also be capable of exhausting some of the heat produced by the system which is why free airflow through the power supplies is vital. Better cooling strategies can reduce energy usage, lower carbon dioxide (CO_2) emissions, improve efficiencies and lower the chance you will suffocate your power supply.

Connector size, height profile, length, and design determine current densities and can have a significant impact on airflow within a power supply enclosure. Essentially, air flow must not be interrupted by the connector. The stronger the airflow, the more cooling that will take place. If air flow is inhibited or prevented from entering or exiting the enclosure, recirculation increases, static air mounts, draft is limited, and the temperature of internal components rises.

Choosing the right power connector is critical to the achieving the ideal thermal design equation. A new approach to low profile connectors enables greater airflow and lower temperatures through the power supply.

Traditional SSI connectors v. EXTreme LPH™ connectors

Consider, for example, a typical 1800 watt, 12.0V power supply with an 87% efficiency rating running two parallel 40mm fans. And let's say the enclosure size is 295.0mm long x 106.0mm wide x 40.0mm high.

Comparing two connectors, both with 10 power blades and 32 signal pins integrated into a single housing, one connector is a standard SSI type, the Molex EXTreme PowerPlus™, which is 100.3mm long x 14.5mm high. The other connector is a newer design, a low profile version by Molex called EXTreme LPHPower™ that is only 92.3mm long x 7.5mm high. The LPH connector is half the height profile of the standard connector. That height difference proves to be a measurable advantage in airflow.

If, at 1800 watts and 87% efficiency, there are 200 watts of heat to exhaust from the power supply enclosure. Assuming a target of 20°C temperature rise for safety rating purposes with 60% free air flow at the non EMC boundary grate, one can calculate the basic airflow required to meet the intended design specifications by calculating CFM using heat to be dissipated and desired temperature rise. In this example, $Q = 1.76\ W / Tc$ (Q=CFM airflow required; W = watts heat to be dissipated; Tc = temperature rise above ambient; and, slope=1.76). So, the required airflow should be 23.67 CFM to meet the desired design goal.

LPH connectors yield 14%-25% improved cooling

The EXTreme PowerPlus indicates 22.70 CFM at the measurement point, midway through the power supply, requiring fans running at full RPM to cool the supply, yielding excess energy usage. The taller connector tends to keep the movement of air to the upper half of the enclosure, producing stagnant and recirculated air flow to the bottom of the supply.

Recirculation may be desirable for large computer cabinets, but in small power supply enclosures most airflow is lost due to recirculation. A cross-sectional view demonstrates airflow blockage with the traditional SSI connector, based on velocity contours. Red indicates areas of high velocity, which is most desirable.

Conversely, the lower profile Molex EXTreme LPHPower™ connector in the same environment indicates airflow of 25.90 CFM – an increase of 14% over the taller connector. Although that may

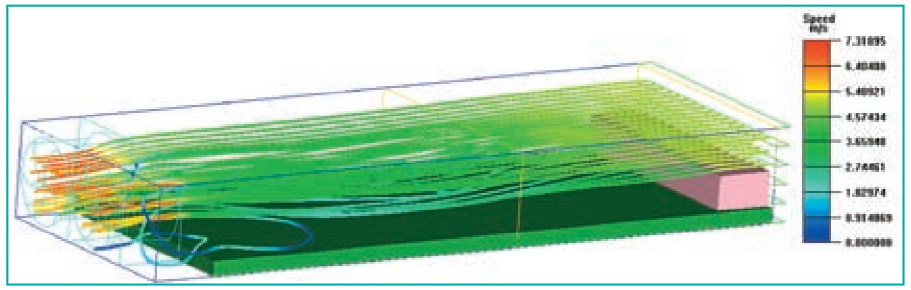

Figure 1: Airflow and draft through enclosure using standard SSI type connector (Molex EXTreme PowerPlus)

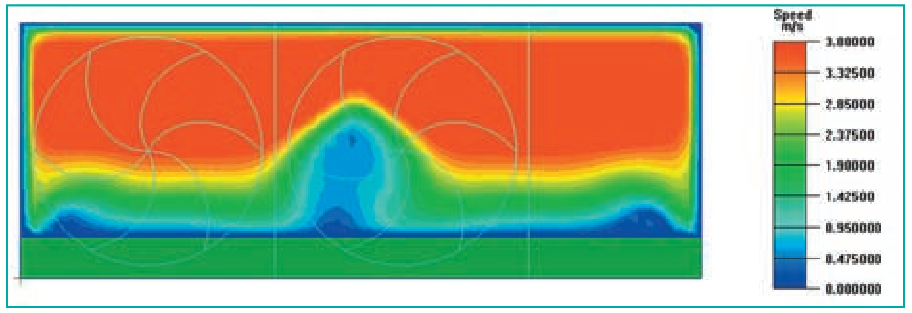

Figure 2: Airflow velocity using standard SSI type connector (Molex EXTreme PowerPlus)

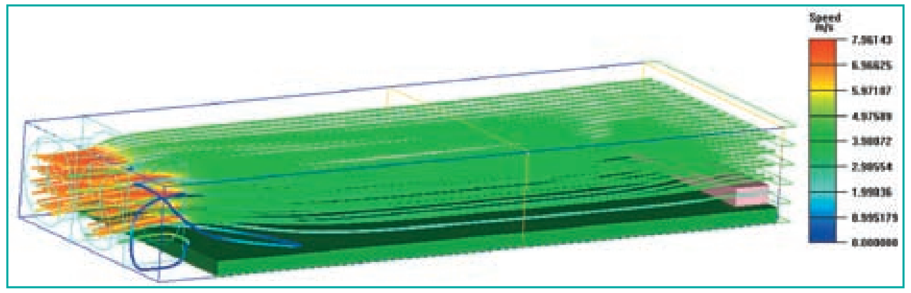

Figure 3: Improved airflow and draft through enclosure using lower profile Molex EXTreme LPHPower connector

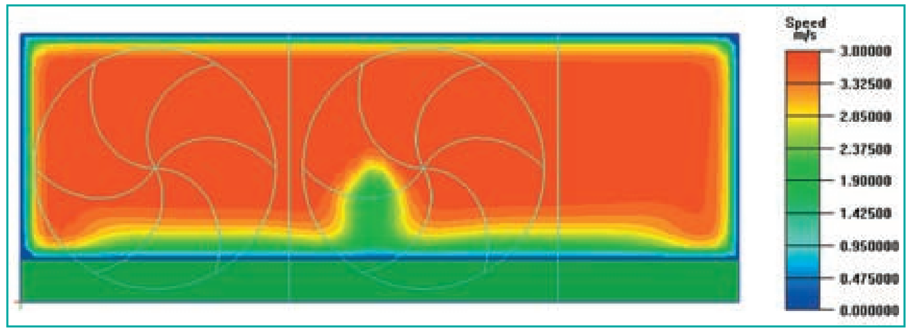

Figure 4: Improved airflow velocity using lower profile Molex EXTreme LPHPower connector

seem relatively insignificant, the difference equates to an increase power supply to 2000 watts, while maintaining safe 20°C temperature rise without altering thermal specifications. The extra airflow headroom also allows an extra boost of system cooling to accommodate ambient or other component conditions.

The contour plot of velocity for LPH-Power shows that draft is also vastly improved and promotes greater air flow to reach the lower extremes of the enclosure - meaning more internal components are cooled more efficiently.

On smaller sized 850 - 1200 watt power supplies that may have only a single 40.0mm fan squeezed next to the standard AC input IEC connector, the effects of the lower profile LPH style connector are even more pronounced. Compared with traditional SSI connectors, in identical test situations, the Molex EXTreme LPHPower™ connector can gain 25% more airflow with improved draft through the enclosure.

Conclusion

Industry demand for reduced energy and costs will continue to fuel demand for smaller enclosures, and better utilization of data center real estate— and will also accelerate the need for proven thermal reduction strategies. Smaller, higher speed fans can be a double-edged sword, boosting energy consumption and noise, while reducing MTBF (Mean Time Before Failure) of the fans and other internal components. Connector selection is a critical aspect of fan performance and overall power system design. Molex EXTreme LPH-Power connectors offer space-saving high-current configurations for improving power supply performance that help solve thermal design challenges associated highly efficient systems.

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Power Systems Design

Special Report- Powering Portable Devices

Battery Management

Importance of accurate measurements and temperature stability

Lithium Ion batteries are becoming the technology of choice for most portable applications requiring rechargeable batteries. The advantages include high energy density per volume and weight, high voltage, low self-discharge, and no memory effect.

By Odd Jostein Svendali, Field Application Engineer, Atmel, Norway

When selecting a lithium Ion battery, it is important to manage it correctly to get safe operation, the highest capacity per cycle and the longest lifetime - normally by using a battery management unit (BMU). For safe operation, it is important that the BMU ensures that the battery cells operate within the manufacturer's specification in terms of voltage, temperature and current.

When designing a battery management system, the worst-case conditions must be taken into account. One such example is the charge termination voltage – For standard notebook batteries for example, the battery cell voltage should never exceed 4.25V.

Usually, the recommendation is to look at the standard deviation of the voltage measurement in the BMU, and subtract 4 times the standard deviation from the charge termination voltage. Thus, if a BMU measures the voltage at 4.25V with a standard deviation of 12.5mV, charging should cease at 4.2V. This conflicts with the desire to get the highest capacity from a given cell, where charging to a higher voltage will give higher capacity. Also to extend the battery life, it is important to avoid excessively high charge voltage and a too low discharge voltage. The wear on the cells is most evident when the cells are outside the recommended End of Charge Voltage (EOCV) and End of Discharge Voltage (EODV). The voltage measurement accuracy determines the required safety margin to the EOCV and EODV.

The critical parameters to achieve voltage measurement accuracy over temperature are ADC gain drift, and voltage reference drift. The offset in the voltage measurement is typically less than 3μV compared to a measurement of 4200mV, and can thus be ignored in a practical design.

The most efficient way to implement a gas gauge for a lithium Ion battery is to accurately track the charge flowing in and out of the battery. An accurate voltage measurement can be used to compensate for errors in the charge flow due to the fairly constant relationship between Open Circuit Voltage (OCV) and State of Charge (SoC). Some of the latest Lithium Ion cells have a very flat voltage characteristic, making it much more challenging to correct an error in the current measurement with an OCV measurement. A small error in the voltage measurement can lead to a significant error in the SoC calculation. Optimum accuracy is achieved with accurate current and time base measurements. The offset in the current measurement ADC can be reduced by measuring the offset in a controlled environment, and then subtract this offset from every measurement. But this does not take into account the drift of the offset.

Figure 1 shows the remaining offset when using this technique for a number of parts. A better method has been implemented in Atmel's Battery management units. With the ATmega16HVA for instance, the offset can be cancelled out by periodically changing the polarity of the current measurement. With this method, a very small but fixed offset will remain. This can also be removed by measuring it before the protection FETs are opened, giving a known current flow through the battery pack.

As can be seen from Figure 2, a significant improvement is achieved by using this method. The remaining error caused by offset drift in the Atmel BMUs is below the quantization level. The advantage of eliminating the offset is that current measurement at low level can be performed accurately. For devices with a large offset, it is necessary at some point to stop measuring and start predicting the current value. Some BMUs have a snap-to zero band or dead-band of up to 100mA using a 5mΩ sense resistor. This is still a significant current considering that a notebook for instance, can stay in a mode with this current for a very long time.

Special Report – Powering Portable Devices

The current measurement ADC offset error limits the lowest current level that can be measured for a given sense resistor size. This leads to the important tradeoff between low sense resistor value and required dead band where the current level is too low to accumulate the charge flowing. Most equipment manufacturers are looking at ways to reduce current consumption, and stay in low power modes whenever possible, making it more important to ensure that small currents can be measured accurately.

Measuring a voltage in the μV range accurately is challenging in itself and when the chip is experiencing temperature variation, the challenge becomes greater. Atmel's offset calibration method is proven to be very efficient when temperature effects are taken into account. As can be seen in Figure 2 the temperature effects are eliminated, ensuring that the offset is not a problem for the accuracy of the measurement.

The bandgap voltage reference is a vital component to achieve high accuracy results. A deviation in the actual voltage reference value from the expected value in firmware will translate to a gain error in the measurement result. In most cases this is the most important error source for cell voltage measurements and measurements of high currents. A standard bandgap voltage reference combines a current that is proportional to absolute temperature (PTAT) with a current that is complementary to absolute temperature (CTAT) to give a current that is relatively stable over temperature. This current is run through a resistor to give a voltage that is relatively constant over temperature. However, since the CTAT shape is curved while the PTAT shape is linear, the resulting voltage curve over temperature is curved. The current levels in the bandgap reference have some production variation requiring factory calibration is to minimize the impact of this.

An example of variation in an uncalibrated reference is shown in the following plot. The maximum variation within the temperature range -20 - 85°C is -0.9 – 0.20%. As indicated in Figure 3, two outliers differ significantly from the other devices.

Standard bandgap references commonly used in BM devices are calibrated for nominal variation, providing very good accuracy at 25°C. To achieve improved performance over temperature variation, Atmel adds an additional calibration of the voltage reference where the temperature coefficient of the bandgap reference is adjusted. This calibration step will adjust the shape and position of the curvature and provide significantly improved stability over temperature, as shown in the following plot, Figure 4.

The maximum variation within the temperature range -20

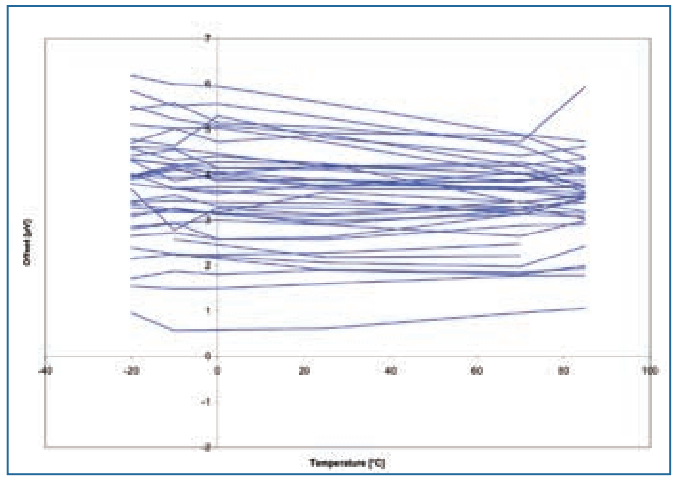

Figure 1: Typical offset after calibration using standard offset calibration method

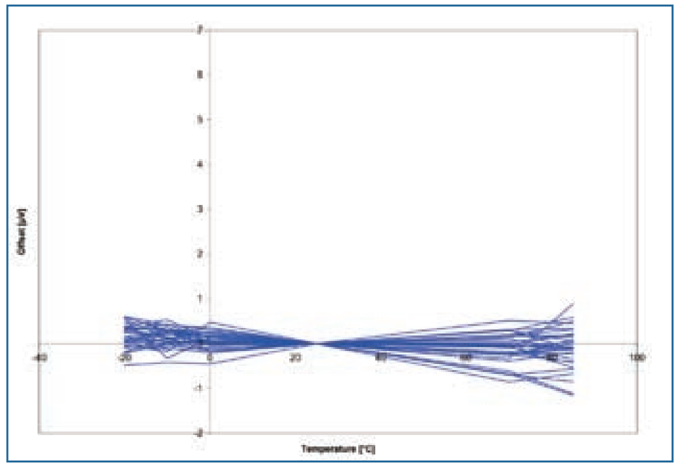

Figure 2: Remaining offset when using Atmel's offset cancellation technique

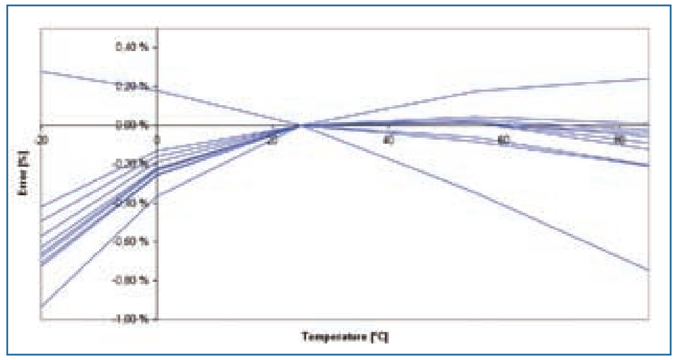

Figure 3: Bandgap results without curvature compensation

- 85°C is in this case as low as -0.5 – 0.0%. Note that the second calibration step not only provides significantly improved accuracy, it also enables detecting and screening outliers that have significantly different temperature characteristics than normal devices.

The second calibration step is normally not performed for

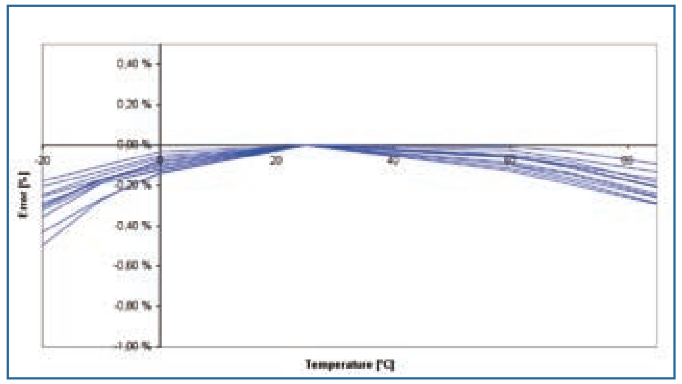

Figure 4: Bandgap with curvature compensation

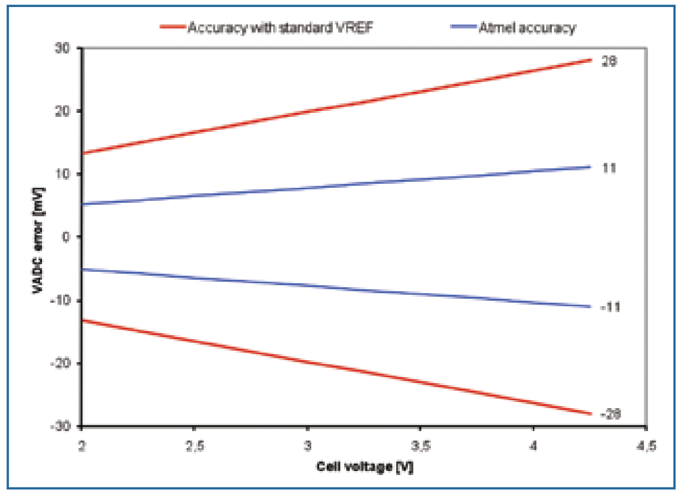

Figure 5: Voltage measurement accuracy over temperature

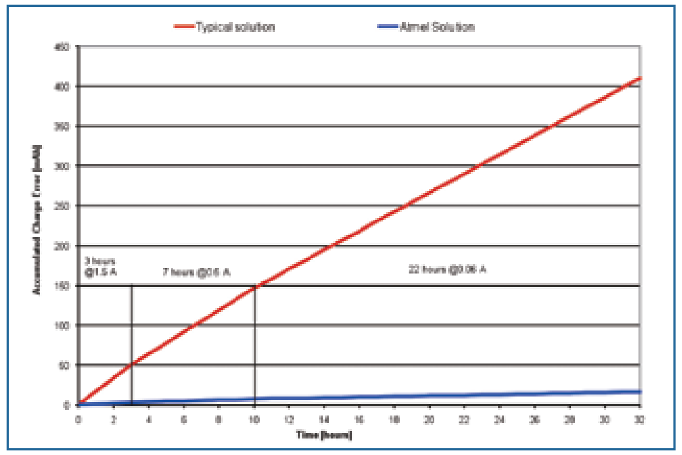

Figure 6: Gas gauge accuracy results based on current measurement accuracy

BM devices because of the added production test cost. The second calibration requires accurate analog test of packaged devices at two temperatures, while the industry norm is to test packaged devices at only one temperature. Adding a second test step with high analog accuracy requirements will normally give a significant cost increase.

Atmel has a novel method for performing the second test step that minimizes the additional cost. Atmel's patented method minimizes the test equipment requirements by utilizing features that are present in the BM unit itself. The on-board ADCs are used to perform the measurements using accurate, external voltage references, the CPU is used to perform the necessary calculations, and the Flash is used to store the measurement data from the first test step. As a result, very cheap test equipment can be used, while still achieving very high accuracy results. This method allows Atmel to provide industry leading performance with very little added test cost.

When the battery reaches a fully discharged or fully charged state, it is the voltage measurement that determines when to shut-down the application or stop charging the battery. The safety levels for maximum and minimum cell voltage cannot be compromised, so a guard band must be built in to ensure safe operation in all cases. The higher the guaranteed voltage measurement accuracy, the smaller guard band is required and more of the actual battery capacity can be utilized. For a given voltage and temperature, the voltage measurement can be calibrated, and the voltage measurement error in this condition will be very small. When taking the temperature drift into account, the main factor contributing to measurement error is the voltage reference drift.

Figure 5 shows the uncertainty when using a standard voltage reference compared to a curvature compensated voltage reference. As can be seen the curvature compensation gives significantly improved accuracy.

Conclusion

High measurement accuracy is vital for getting the most energy out of the battery per cycle, and the longest battery pack lifetime without sacrificing safety. To avoid extensive costs for calibration, the inherent accuracy in the BMU must be as high as possible. Also by utilizing clever calibration techniques using onboard resources of the MCU good calibration, cancelling out temperature effects, can be achieved at a minimal cost.

Figure 6 shows a discharge cycle of a 10Ah battery over 32 hours. 3 hours at 1.5A, 7 hours at 0.6A and 22 hours at 60mA. The variation in temperature is +/-10 deg C, and a sense resistor of 5mOhm is used. The error in the charge accumulation using a standard BMU with typical calibration methods is higher than 400mAh corresponding to more than 4% of the 10Ah battery in this example. Atmel's solution delivers a significantly better accuracy due to the clever analog design combined with patented calibration methods. Due to these improvements, the error is reduced to less than 20mAh, corresponding to 0.2%.

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Portable Efficiency

Powering SD flash memory in smartphones

The handset world is seeing a burgeoning need for memory storage. This article discusses memory trends and different methods of powering SD Flash memory.

By Peter A. Khairolomour, Technical Marketing Manager, Fairchild Semiconductor

The need for memory is being driven by rapid advancements in the ability to *capture*, *display*, and *share* both video and image content. *Capture* is making huge strides due to the emergence of miniaturized camera optics, highly integrated image processing, and flashes both in the form of increasingly bright LED solutions and shrinking xenon solutions. Thin and efficient touch screen LCD, AMOLED, and Super AMOLED solutions mated with intuitive user interfaces have made *displaying* photos and videos a simple and vibrant experience. Finally, *sharing* has been accelerated due to ubiquitous connectivity, social networks, and numerous sources of downloadable content.

These technologies are driving and enabling cell phone manufacturers to design phones with cameras capable of 8 or even 12MP image resolutions. Or in the case of video we are increasingly seeing cell phones with the capability to shoot 720p@30fps. These are all memory- intensive applications and typically this content is stored in the form of solid state memory.

While digital still cameras have historically demanded large memory capacities, this requirement for cell phones has only become prominent in the last few years. Fortunately though for the consumer, solid state memory density and production capacity have been increasing over time leading to significant reductions in both price ($/MB) and area (mm^2/MB). Figure 1 illustrates that in 2011 process geometries will likely breach 25nm for NAND-based flash memory.

The most common solid state memory format for consumer storage applications is SD Flash. Modern day SD Flash memory is based on NAND technology and comes in the three form factors SD card, mini SD card, and micro SD card shown in Figure 2. Though the three form factors differ in size they do not differ in electrical interface.

Independent of form factor, SD memory is also categorized based on capacity range. Standard SD cards provide a maximum of 2GB capacity, high-capacity (SDHC) cards have a capacity range of 2 - 32GB, and eXtended Capacity (SDXC) fall in the range of 32GB to 2TB.

There are also two clock rate categories. In default mode, the memory can operate with a clock rate range of 0 - 25MHz providing up to 12.5MB/sec interface speed (using 4 parallel data lines). In high-speed mode, the memory can operate with a clock rate range of 0 - 50MHz providing up to 25MB/sec interface speed (using 4 parallel data lines). It is up to the system designer to optimize this parameter based on the desired read and write speeds.

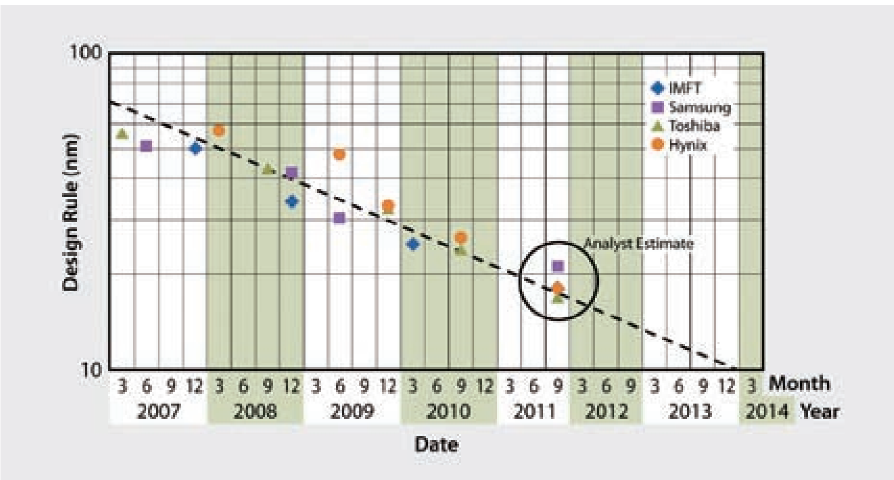

Figure 1: Process geometry trend for NAND flash memory technology

This matter becomes important when we get to the discussion of power supply considerations.

Power Supply Considerations

SD Specification Version 2.00 calls for an operating voltage supply range of 2.7 - 3.6V. 2.7V is defined as the minimum voltage required for guaranteed performance. Above that and up to 3.6V is acceptable but is also unnecessarily wasting power. Beyond 3.6V, performance is not guaranteed and in addition the memory is at risk of being damaged.

Another consideration for the power supply design is the current consumption of the memory. Current consumption varies depending on which of the four main states the memory is in: shutdown, standby, read and write. For a given memory card, read/write current consumptions can also vary depending on the rate at which data is being clocked into or out of the memory. Regular cards support clock frequencies of up to 25MHz and high speed cards can support up to 50MHz. As capacities become larger, it becomes apparent that fast clock rates are desired in order to ensure reasonable usage models for the consumer.

Small capacity SD cards operating at low speeds often consume less than 100mA. Given that Li-Ion batteries nominally operate at 3.7V and that memory supply rails are quite high, linear regulators have become the incumbent power supply of choice for SD memory. The selected linear regulator though has to be capable of operating with low drop out because the Li-Ions have an effective voltage range of 3.2 - 4.2V.

With the emergence of 8, 16, and 32GB high speed SD cards, it is not uncommon to see current consumptions in the range of 300 - 400mA. These

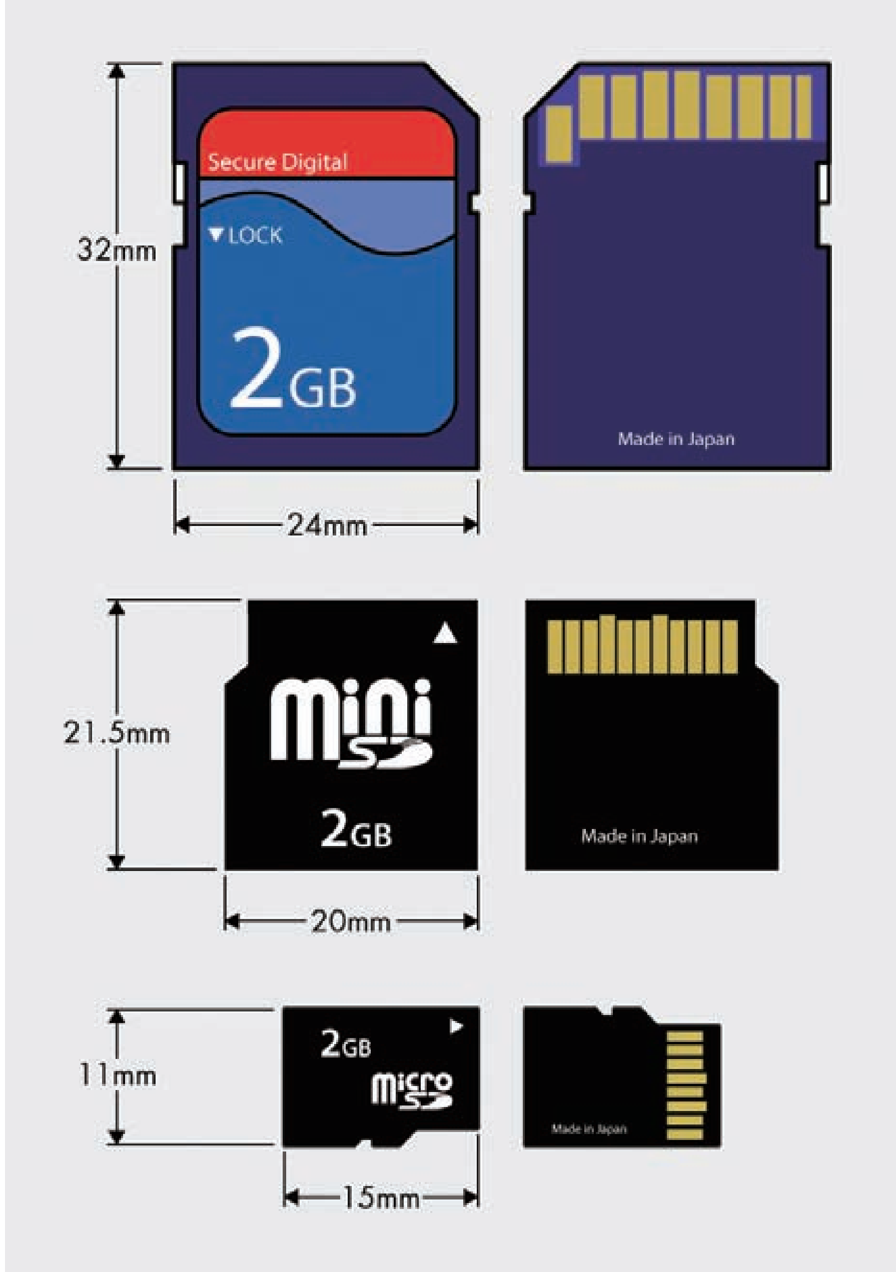

Figure 2: SD card, mini SD card and micro SD card size dimensions

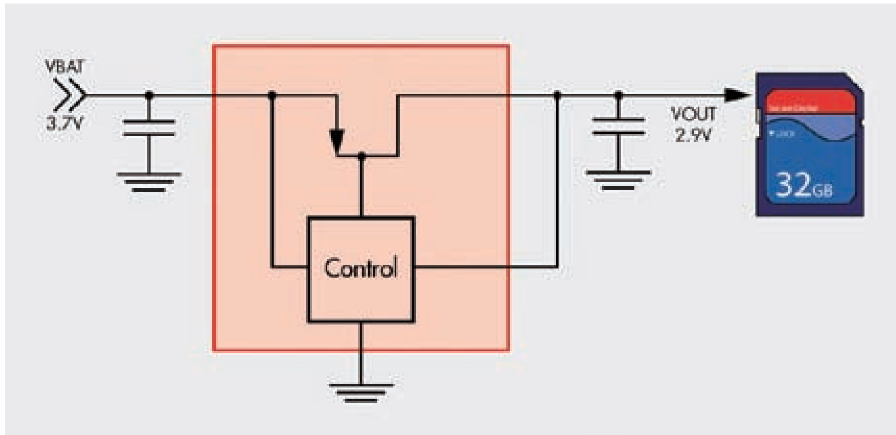

Figure 3: LDO powering SD Card at 2.9V

	VIN = 3.7V, VOUT = 2.9V, IOUT = 300mA		VIN = 3.7V, VOUT = 2.9V, IOUT = 400mA		Inductor
	Efficiency (%)	Dissipated Power (mW)	Efficiency (%)	Dissipated Power (mW)	
LDO	78	240	78	320	N/A
6MHz Buck	91	86	89	144	470nH - 0805
3MHz Buck	94	55	92	101	1μH - 0805

Table 1: Power supply comparison between LDO, 6MHz buck, and 3MHz buck

current levels are substantially higher than the 100mA of the lower capacity cards. At these new increased current levels, LDO power supply solutions begin dissipating substantial amounts of power. Figure 3 shows an LDO powering an SD card at a typical voltage of 2.9V. 2.9V is chosen with the assumption that the LDO can guarantee its output will never drop below 2.7V under any line, load, or temperature conditions.

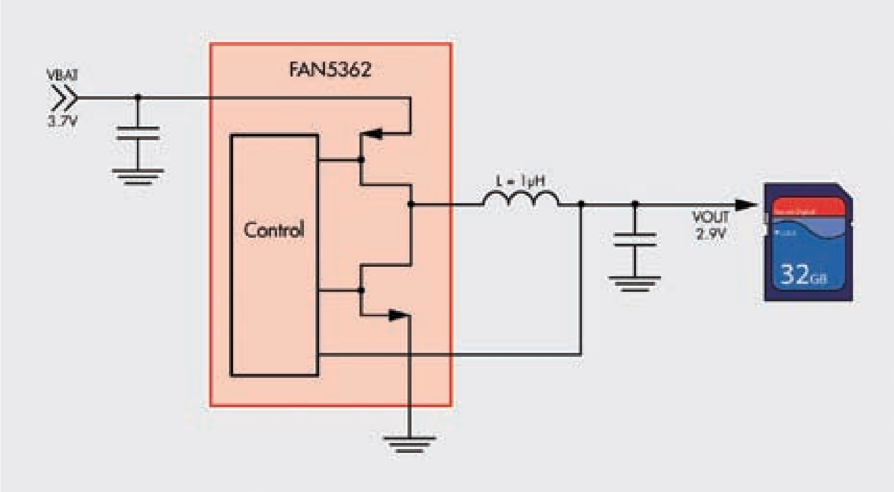

Figure 4: FAN5362 buck converter powering a SD card at 2.9V

Table 1 calculates conversion efficiency for the LDO scenario in Figure 3 at current levels of 300 and 400mA. The conversion efficiency of the LDO is 78% resulting in power dissipation of 240 and 320mW respectively.

Many system designers will understandably find 320 and even 240mW power loss to be unacceptable. Fortunately it is possible to use a switching converter as shown in Figure 4 to achieve higher power conversion efficiency.

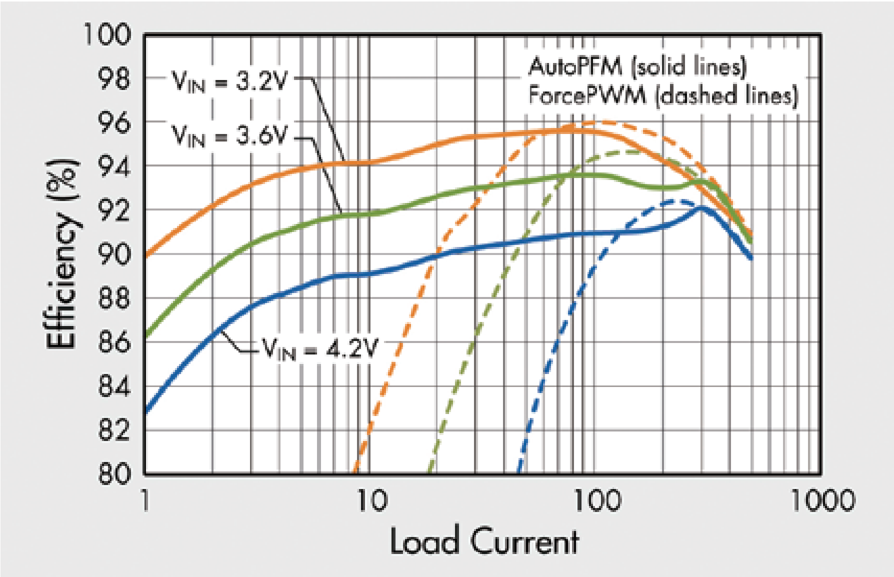

Figure 5: FAN5362 efficiency vs. load current, AutoPFM (solid line) ForcePWM (dashed line)

As calculated in Table 1, the FAN5362 can reduce dissipated power down to 55mW for the 300mA system and 101mW for the 400mA system. These efficiencies are based on measured efficiency curves taken on the FAN5362. Figure 5 below shows these curves for both AutoPFM (solid line) and ForcePWM (dashed line). While optimizing the FAN5362's efficiency, 3MHz was selected as the nominal switching frequency because it provided the best tradeoff between size and efficiency. As can be seen in Table 1, using a 6MHz switcher in this power conscious application dissipates considerably more power than a 3MHz switcher.

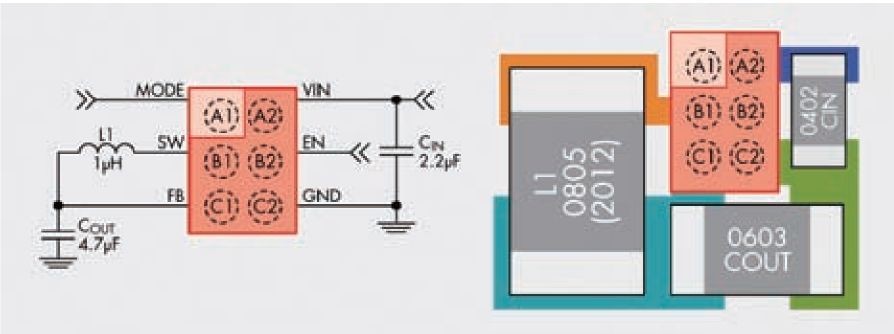

Figure 6: FAN5362 typical schematic and PCB layout

While the selection of a buck to replace an LDO may seem trivial, it is important to consider that the buck must be capable of operating at very high duty cycles. If the buck's output is set to 2.9V and the battery has come down to 3.3V, the buck is already operating at 88% duty cycle. At some conditions of load and input voltages the buck will even be forced to stop switching and operate at 100% duty cycle. The situation gets even worse during low VBAT situations if the phone starts transmitting GSM pulses. GSM pulses can be as high as 2A and during these pulses the output impedance of the Li-Ion battery will cause the battery to drop by as much as 400mV. For LDOs this sudden VBAT drop is palatable because LDOs are always operating in the linear region. It is a different situation though for buck converters because they must gracefully transition from switching to 100% on and then back to switching again once the battery returns to 3.3V. During the phase in which the high side device is fully on, the output voltage of the buck is simply VBAT – $R_{DS(ON)}$*I – DCR*I where $R_{DS(ON)}$ is the on resistance of the high side FET, DCR is the series resistance of the inductor, and I is the memory load current.

The FAN5362 was designed to handle the scenario described above with minimal over and undershoot. In addition, the control mechanism and $R_{DS(ON)}$ of the FETs were carefully designed such that the output voltage can be guaranteed to never drop below 2.7V, even including both line and load transients. This is critical for memory because SD Specification Version 2.00 calls for an operating voltage supply range of 2.7 - 3.6V.

Figure 6 shows a typical schematic and PCB of the complete FAN5362 power solution.

While process geometry advancements address the need for ultra compact and affordable SD memory, the resulting high capacity devices also present a power consumption problem. This problem can be overcome by replacing the incumbent LDOs with a buck converter such as the FAN5362, which was designed specifically for this application.

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Antenna Tuning Technology

Takes portable handsets to the next level

Thinner form factors, mobile TV and the requirement for power efficiency are placing extreme demands on the antenna, requiring a new approach to keep calls on track and antennas inside the handset.

By Tero Ranta and Rodd Novak, Peregrine Semiconductor

Footprints are shrinking inside wireless and mobile devices, making a significant impact on antenna performance. Portable system designers need to contend with very small antennas that must support voice calls from 824 to 2170 MHz (or more), different modulation schemes, high data rates, and mobile TV channels ranging from 470 to 862 MHz—all in a thinner form factor. Many of the latest portable wireless designs constrain the antenna to a historically small area, and, in many cases, the antennas are literally wrapped around peripheral functions in the handset. This approach often makes the antenna more susceptible to detuning by environmental effects and lowers the antenna's efficiency. As an added challenge for mobile TV, when an antenna is constrained to a very small form factor such as this, it cannot receive all of the required TV frequencies at high efficiency without some sort of reliable tuning technology.

To be viable in a portable device, antenna tuning technologies need to be low-loss, highly linear, able to handle very high RF signal levels of 30Vpk or +40dBm, and consume low power. Fortunately, electronically-tunable devices that are robust enough and use proven high-volume technologies are already available, and they will enable mobile handset designers to embed mobile TV antennas and take voice and data performance to the next level.

Antenna Tuning Challenges

As mobile handset antennas are wrapped and re-pathed, they lose efficiency. Fortunately, some of this lost performance can be recovered with antenna tuning, in which the system uses dynamic impedance tuning techniques to optimize the antenna performance for both the frequency of operation and environmental conditions. This same type of antenna tuning can be used to track mobile TV channels with an embedded antenna.

For mobile TV applications, the achievable bandwidth and input match is directly related to the physical size of the antenna and the mobile phone. A "tunable" internal antenna would cover a narrow section of the 470 to 862 MHz bandwidth that is quickly retuned as the desired receive channel changes, ensuring that most of the signal power captured by the antenna actually ends up in the receiver. The UHF band for DVB-H mobile TV is divided into 48 channels that are 8MHz apart. In order to provide high-quality mobile reception, the antenna will need 16 or 32 tuning states.

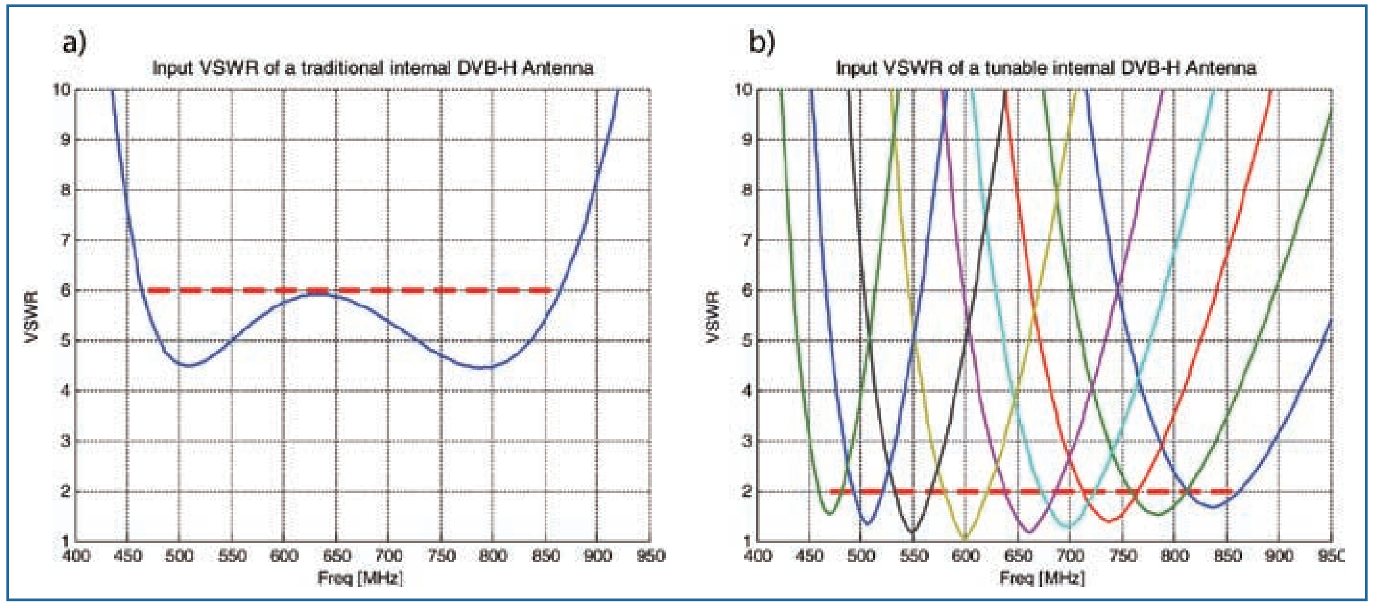

Figure 1: A traditional passive internal antenna covers the mobile TV bandwidth with very high VSWR (left) whereas a narrow tunable antenna can be moved in frequency to cover the same bandwidth with significantly better VSWR (right)

Figure 1 compares the input impedance of an embedded mobile TV antenna with fixed matching and one with a tunable matching circuit. Note the VSWR of the antenna without tuning is 6:1, but with tuning circuitry, matching is very good at better than 2:1 across the entire band. So, to achieve satisfactory performance, the only real options for handset designers incorporating mobile TV is to use an external whip antenna or a narrowband tunable antenna.

Mobile TV is a receive-only system, so an open-loop antenna tuning method (Figure 2) is required. Here, the center frequency of the antenna is tuned based on a look-up table for the tunable component as a function of the desired receive frequency.

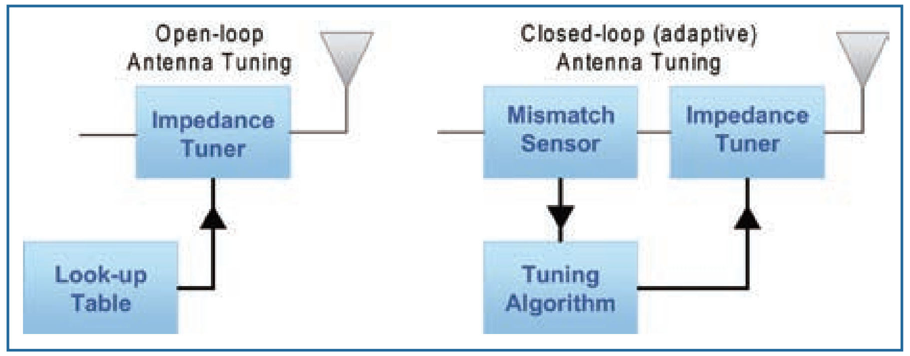

Figure 2: Open-loop (left) and closed-loop (right) antenna tuning

Because an open-loop system does not measure the operation of the antenna in real time, it cannot take into account environmental conditions. In a mobile device, the environment is constantly changing as a cellular subscriber walks, drives, or moves his or her fingers (the so-called 'head and hand' effect). To address the needs of cellular frequencies that are detuned due to low efficiency or environmental conditions, adaptive closed-loop antenna tuning can be used (Figure 2). Here, a mismatch sensor tracks the antenna's operation by measuring power that is reflected back to the antenna (VSWR) and makes necessary adjustments to the impedance tuning circuitry. In this way, a closed-loop antenna tuner tracks the optimal frequency and matches for the antenna in all use cases. The tuning algorithm forces the tunable elements to constantly track and adjust to the optimal setting as environmental conditions change.

It is clear why tuning technologies are necessary for embedded mobile TV antennas, but how necessary is antenna tuning for cellular frequencies? Absorption loss in the body, mismatch loss in the antenna, ripples in the RF filter passband, and reduction in output power due to low efficiency all combine to severely reduce the power radiated out of the handset. These effects are directly visible to the consumer as a decrease in battery life, degradation of call quality, and an increase in dropped calls. To guard against these problems, many network operators are adopting radiated power requirements for handset antennas. For example, Total Radiated Power (TRP) and Total Isotropic Sensitivity (TIS) specifications are now being tested by simulating actual use cases with head and hand configurations rather than testing the phone in free space or performing a conducted measurement in a controlled impedance environment.

In order to meet these new stringent power specifications, adaptive antenna tuning may be the only option for mobile handset designers. An antenna tuner forces the antenna to appear 50Ω despite environmental effects, so the rest of the system operates optimally, which significantly improves the TRP. Even though an antenna tuner causes additional insertion loss when the antenna is at 50Ω (VSWR 1:1), adaptive antenna tuning will significantly improve the overall insertion loss from the tuner input to antenna input compared to uncorrected situation (Figure 3), and provide performance improvements in the power amplifier (PA) and RF filters as well.

Tuning Solutions

While the case for antenna tuning technology has been strong for some time, the challenge has been the absence of a high-performance, electronically-tunable reactive component that is low loss and has a wide enough tuning ratio to handle both cellular and mobile TV frequencies.

Since it is connected to the antenna, any tuning circuit used needs to be

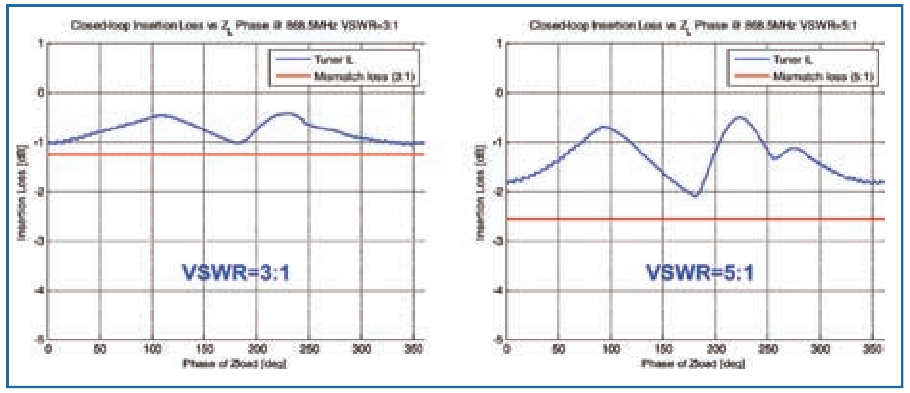

Figure 3: Simulation of an adaptive closed-loop antenna tuner showing insertion loss improvement with the antenna tuner (blue) compared to not having the antenna tuner (red)

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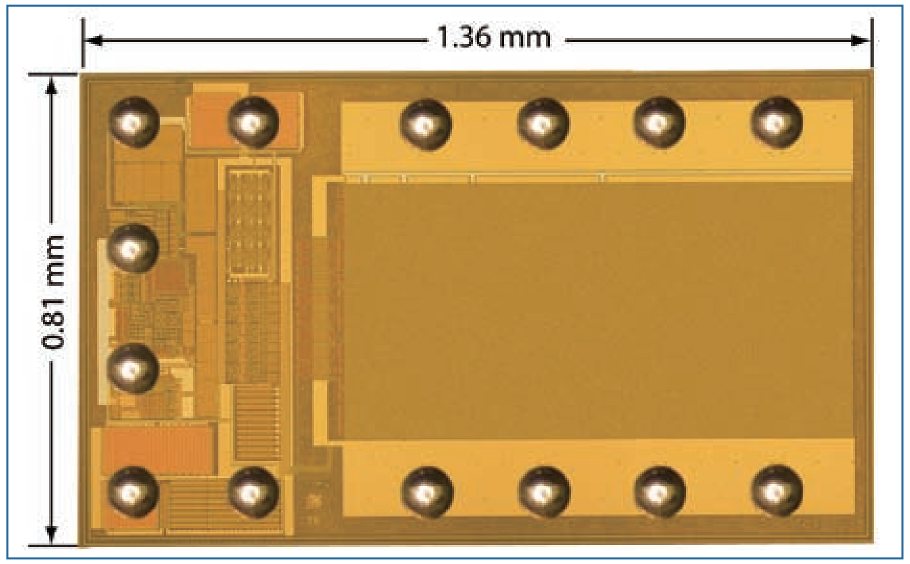

Figure 4: The DTC circuit for cellular applications is available in a flip-chip form for low parasitic inductance, and it measures 1.36x0.81mm

extremely linear so as not to generate harmonics or intermodulation distortion. The tunable element, such as variable capacitor, needs to have a tuning ratio of at least 3:1 or better. In addition, the whole circuit must have power consumption of less than 1mA. Finally, the tuning circuitry must be small, rugged, and reliable. It needs low insertion loss and a high quality factor (Q). The most challenging component requirements have been power handling and linearity, especially in the presence of GSM signals. Although GSM antennas transmit at power levels up to +33dBm, under mismatch conditions the tunable component must be able to handle RF signal levels up to 30Vpk or +40dBm.

Numerous materials and technologies have been proposed over the years to implement tunable antennas and filters, but these techniques have not been able to overcome technological and marketability hurdles, so they are not suited for high-volume production.

DuNE™ Technology

In response, designers at Peregrine Semiconductor have leveraged proven UltraCMOS™ process and HaRP™ design innovations to develop DuNE™ technology, a patent-pending design methodology that is being used to develop Digitally Tunable Capacitors (DTCs). This solid-state DTC can be designed to meet the challenges of both cellular handset and mobile TV antenna tuning. It is a fully integrated way to implement a variable capacitor with digital control whose basic design can be adapted for open-loop (mobile TV) and closed loop (cellular) antenna tuning applications.

Because they are manufactured on the UltraCMOS process, the DuNE DTC products can integrate the digital functions (CMOS control, digital processing, serial peripheral bus, tuning algorithm), analog functions (mismatch sensors, charge pumps, biasing circuitry), as well as RF passive (high Q capacitors), and RF active (switches, ESD protection) circuitry in addition to the DTC core. And, thanks to a fully insulating sapphire substrate, UltraCMOS field effect transistors (FETs) can be stacked to handle high RF power levels, unlike bulk CMOS and silicon on insulator (SOI) technologies. As a result, a DuNE DTC's power handling can be scaled from +20dBm to more than +40dBm, easily withstanding the high RF power levels encountered in GSM and WCDMA operation without degrading the Q or tuning ratio.

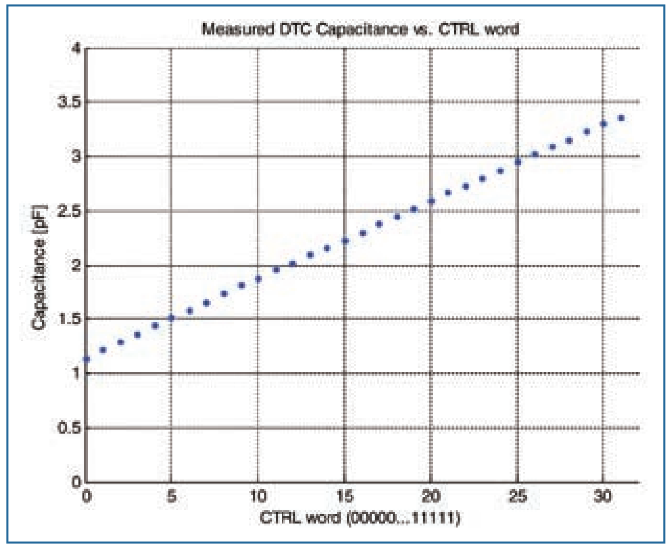

Figure 5: Measured 5-bit DuNE DTC showing very linear tuning characteristic and a capacitance range from 1.15 to 3.4pF (3:1)

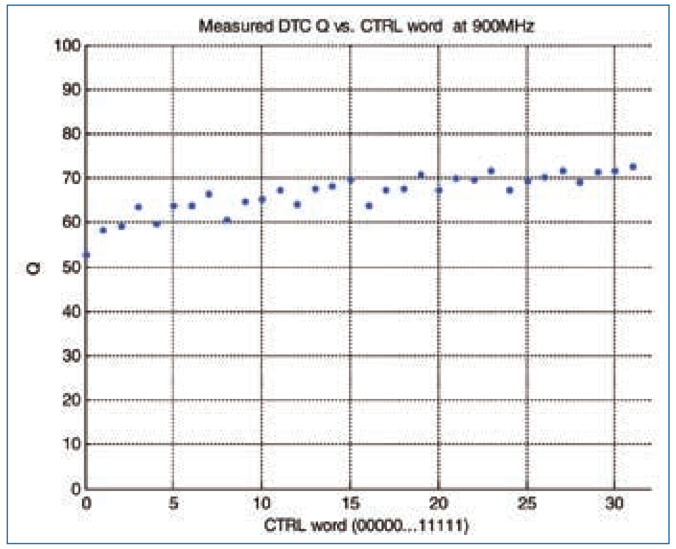

Figure 6: DuNE DTC with Q designed to be 60-70 at 900MHz

DuNE for Mobile Handsets

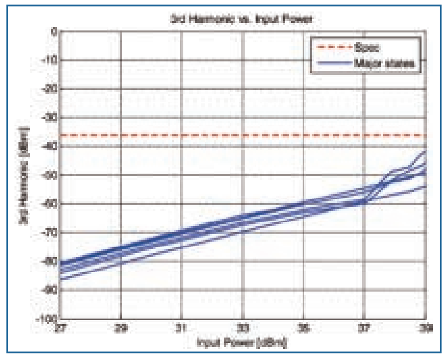

Figure 7: The level of the 3rd harmonic as a function of input power is largely independent of capacitance state and meets the -36dBm GSM specification up to +40dBm of input power

For cellular applications, DuNE DTCs (Figure 4) are being designed with capacitance values from 0.5pF to 10pF, with typical tuning ratios ranging from 2:1 to 10:1 with 5 bits or 32 states of resolution (Figure 5).

Typical Q values range from 40 to 80 at 1-2GHz (Figure 6). In addition to >+38dBm of power handling in 50Ω (Figure 7) and switching speed of better than 5μs, this new technology meets other necessary specifications for a cellular antenna tuning circuit. For instance, the power consumption is about 100μA.

The Future of Antenna Tuning

We expect the footprint for mobile handset circuitry will continue to shrink and performance demands will continue to grow. Fortunately, DuNE technology addresses all of the required performance points for embedding tunable antennas in mobile handsets. Depending on the application, these self-contained UltraCMOS RFICs communicate directly with the cellular transceiver and baseband or the mobile TV receiver chipset. They integrate a digital communication interface and all the other required functionality monolithically on the die, which minimizes lines and connections between devices.

This new technology is based on proven building blocks and process technologies that are already shipping millions of units per week to the handset industry. DuNE DTCs for cellular applications are sampling now, and they are expected to be in volume production in late 2010. Ultimately, DuNE technology allows for monolithic integration of the complete adaptive antenna tuner system, which promises to help handset designers meet and beat the challenging antenna performance and size requirements of the future.

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Keep on Running

Recharging a cell phone battery with … Batteries!

These days, people can't live without cell phones. This is not a monumental revelation to anyone who has been at an airport, a shopping mall, or a park watching their children play. We close business deals, talk to our friends and family, check email, and browse the web while waiting for a connecting flight. But how do we keep them running when on the go?

By Tom Karpus, Director of Handheld Systems and Applications Engineering, Semtech Corporation

The mobile phone has been transformed from what used to be called a "telephone" into a personal communication and data transfer device. All this communicating and data moving takes power, so phone designers and chip companies have poured a lot of effort into squeezing every last mAh (milliampere-hour) of battery life out of each mobile phone function. Talk times and standby times have declined as more complicated, feature-rich products have been adopted by the average user. Advances in phone power management have addressed this issue to some extent, but we still need to recharge our phone batteries when they run out of power.

Anyone who travels knows that it's not always convenient to pack a charger. Even if you have the charging adapter packed for the trip, there is no guarantee that you will have access to a power outlet when you really need it. So what else can you do? Accessories are now available that act as a portable charger for just such an occasion. This is a great idea – it's like carrying a portable electrical outlet and charging adapter all-in-one. Such an accessory can utilize different battery configurations to supply the charging power. One simple, low-cost choice is to use two disposable AA alkaline batteries to transfer energy to your phone's Li-ion battery. These batteries are inexpensive, available at any convenience store, and transferable between different devices (providing the option to raid the kids' games when you need to recharge your phone). Depending on the state of your phone battery, this power transfer system could top off the battery or provide just enough power to maintain an important call when your battery is nearly depleted.

A typical Li-ion battery charges to a final voltage of 4.2V, so a power supply level greater than 4.2V (typically 5V minimum) is needed to supply the charging circuit. Alkaline battery cells range between 0.8V and 1.6V, so a DC-DC boost converter is needed to boost the supply voltage and regulate the output voltage at the 5V needed to properly transfer charge to a Li-ion battery. The combination of a boost converter with a dual AA battery pack can serve as a 5V power supply for battery charging when a wall outlet or USB supply are not available.

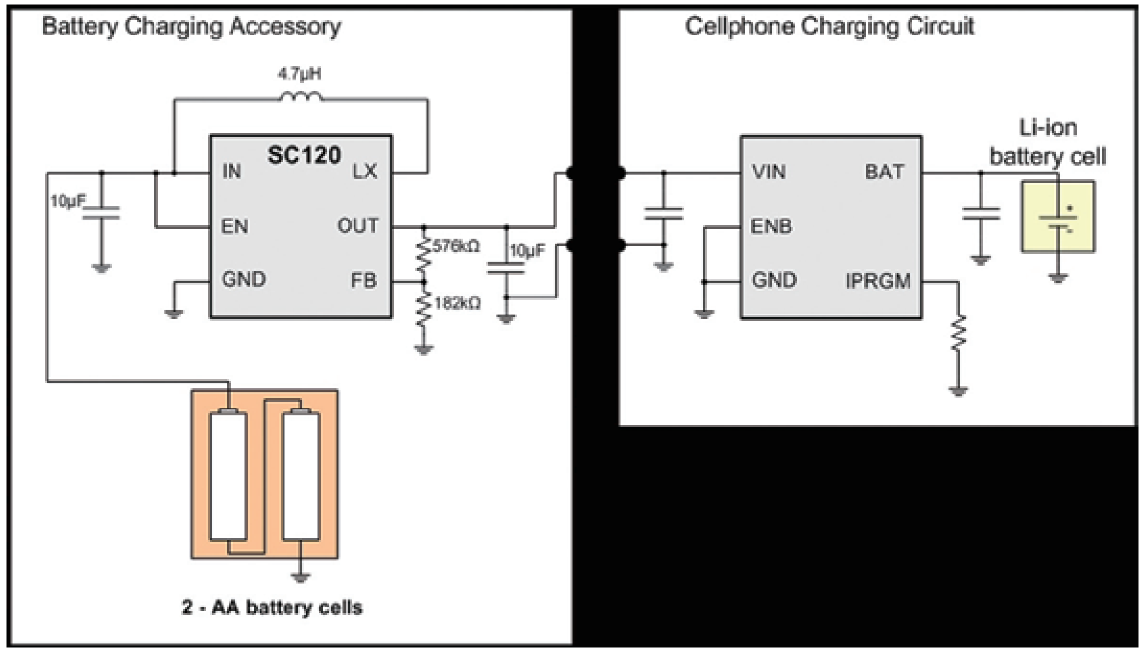

Figure 1: Application circuit for battery to battery charge transfer

A simple circuit can be constructed to provide the 5V needed by the battery charger using a standard DC-DC boost converter IC and some simple external components. Figure 1 demonstrates how this system works. In this example, the boost circuit is contained in an accessory capable of holding two AA battery cells. The 5V output is maintained throughout the duration of the charging operation as the AA batteries discharge. The boost converter used in this example – the SC120 from Semtech – is set to a 5V output by connecting a resistor divider network between the OUT and FB pins.

The charger IC typically resides inside the phone or in a charging cradle for removable batteries. Accessories with similar capability use standard USB connectors to attach to the phone charging system. The phone should limit the charge current internally to 100mA – the standard for low power USB charging. The fast charge current in this example is set to 100mA to illustrate charging performance under these conditions. Charging is terminated when the current into the battery drops to 10% of the fast charge current – in this case, 10mA. Figure 2 illustrates the Li-ion battery voltage and current during the charging process using a 750mAh battery, while Figure 3 shows the voltage and current profiles for the AA 2-cell pack throughout the same process.

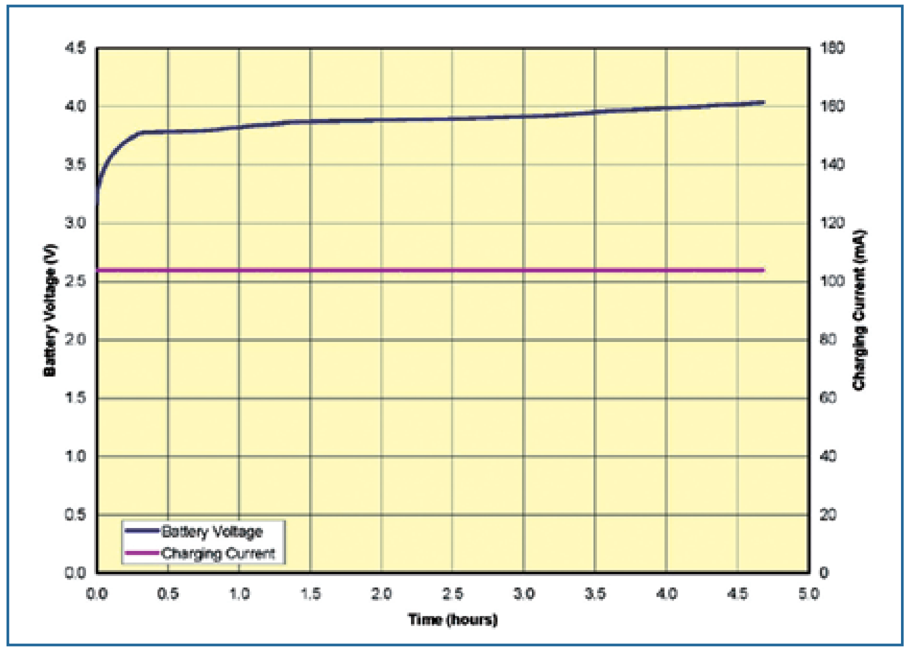

Figure 2: Li-ion battery charging voltage and current curves

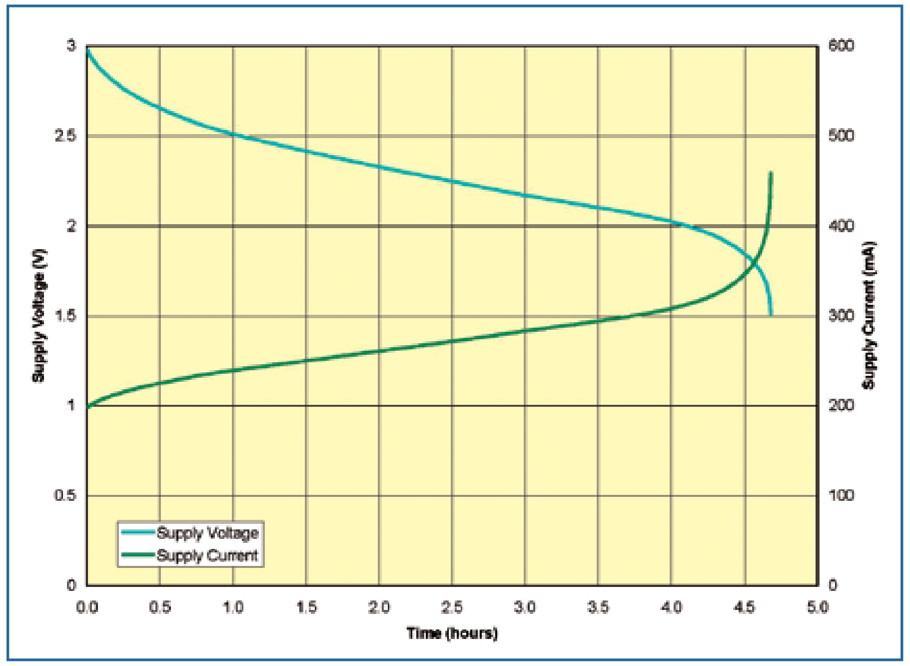

Figure 3: 2xAA alkaline battery cells discharge curves

Figure 2 demonstrates that normal battery charging occurs. The current is held constant at 100mA and the Li-ion battery voltage approaches 4.2V – the cell voltage at which it is fully charged. Figure 3 illustrates the state of the source batteries as charging occurs. The combined AA cell voltage decreases as charge is transferred to the Li-ion battery, and the battery current increases to maintain the boost output at 5V. In this example, the Li-ion battery was fully discharged at the start of charging, so two AA cells provided just enough power to charge the Li-ion battery to 4V (but not completely recharge it to 4.2V).

Variations to this system could be implemented using 3 AA cells or a single high-capacity Li-ion cell as the charging supply. Either supply configuration would be more efficient because they would operate the boost converter with less voltage drop. Their increased capacity and efficiency would also give the charger accessory more available charging capacity, which would allow a complete charging cycle or possibly multiple charges. Of course, more battery capacity translates into higher cost. Regardless of which configuration provides the best cost-benefit tradeoff, it is clear that this DC-DC boost converter design approach provides a simple mobile charging solution for the battery powered products that help make busy lives a little easier to manage.

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Challenging Charging

Choosing battery charging topologies for portables requires checklist analysis

This article discusses the selection process for deciding the battery charging topology in portable, consumer applications. The article analyzes system and battery conditions under which the benefits of specific solutions outweigh the benefits of others. The analysis focuses on technical issues, consumer usability and secondary effects, like cost, board size, complexity and flexibility. The large selection of battery packs and technologies combined with the wide variety of available battery charger ICs on the market and a wide range of system design approaches, makes the design very challenging -- especially if battery management is a new task for the engineer.

By George Paparrizos, Product Marketing Director, Summit Microelectronics

Battery Charging Types

There are three basic battery charging types: linear, switch-mode and pulse chargers. Each of these types provides advantages and disadvantages, which make them ideal for specific applications. This article will focus on the first two, since pulse-charging is nowadays an unpopular method due to reliability concerns associated with continuous pulsing of the battery cell and other design constraints. While some of the pros and cons of the two popular charging types may seem very obvious (like low efficiency for linear charging and high electrical noise for switch-mode charging), most of them depend on system architecture, battery type/technology and other design considerations. For example, unlike 5 years ago, modern smart-phone designs utilize a variety of switch-mode, high-frequency power converters with optimized layouts that isolate noise from sensitive (RF) circuit. This makes the adoption of switch-mode charging more likely in modern wireless gadgets. On the other hand, new battery technologies with a higher regulation voltage are on the horizon; such batteries reduce the efficiency losses of linear battery chargers, making such charging solutions more appealing.

Selecting the Ideal Battery Charger

The selection of the battery charging implementation has become a major challenge in modern portable designs. Like with any other power management related function, in many cases it is the little details that determine the use of a specific IC. Choosing the battery charging architecture is a constant balancing act, since on one hand the higher the charge current the shorter the charging time, but on the other hand high charge current levels also prevent the solution to fit in ever-shrinking portable designs. Understanding the different battery charging alternative methods and their trade-offs will assist in selecting the ideal charger for a specific design. The basic selection process depends on five main factors: battery pack specification, system power architecture, system cost, industrial design, and marketing requirements.

Battery Pack Specification

Each battery pack provides several specifications such as battery capacity, battery technology, pack size, and recommended charging and discharging profiles. Most of these specifications determine the required charging current levels and charge regulation voltage that ensure long and safe battery life. The larger the battery capacity, the higher current levels are required to meet marketing's targets for charging times and avoid consumer frustration. While the majority of the batteries utilized today are Li-Ion and Li-Polymer, newer technologies are becoming popular with lower (3.6V) as well as higher (4.35V) regulation (float) voltages. These new technologies will require or be able to accommodate different charging methodologies. For example, since the power dissipation of a linear charger increases proportionally with the input (adapter) to battery differential, a LiFePO4 battery with a 3.6V float voltage will more likely require a switch-mode charger. On the other hand, a battery with a regulation voltage of 4.35V can easily be charged at the recommended 1C rate via a linear charger, unless the industrial design is extremely slim or the battery capacity is too large.

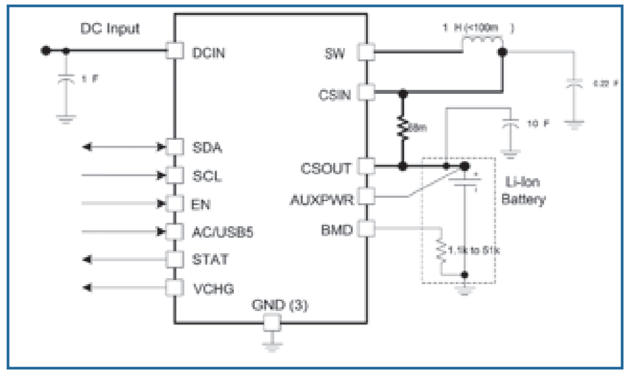

Figure 1: Typical switch-mode battery charging IC

Today most smart-phones are utilizing batteries with a capacity higher than 1100mAh and therefore have transitioned to switch-mode charging. The average battery capacities in the market keep getting higher to accommodate feature-rich portable devices, which consume ever-increasing power and thereby demand more frequent (and by definition also faster) battery charging. The figure below demonstrates charging time between linear and switch-mode charging from a current limited power source.

System Power Architecture

In addition to the battery selection, each new design utilizes a different power architecture. Many of the latest gadgets for example allow system operation without the presence of the battery, when the input power source is attached to the portable device. Such operation requires the system path to be separated from the battery path (CurrentPath™), thereby allowing instant-on system operation even with a deeply discharged or missing battery. Another component of the power architecture (ecosystem) is the wall adapter used for a specific application. Lower-cost, unregulated wall adapters may operate at higher voltages, thereby requiring a switch-mode charger for higher efficiency. On the other hand, even if the battery capacity is such that higher current is necessary for faster charging, if the adapter is limited to a lower current rating, a linear charger may be sufficient for meeting charging time targets.

The system architecture can also have an effect on the battery charging algorithm, since a higher number of sophisticated systems implement real-time system power and battery charging methods to ensure optimum (i.e. higher –performance) operation, while maintaining system safety. Such system approaches are calling for power conversion and battery charging solutions that incorporate digital bus communication, thereby allowing dynamic parametric and functional alterations based on system, environmental and other conditions.

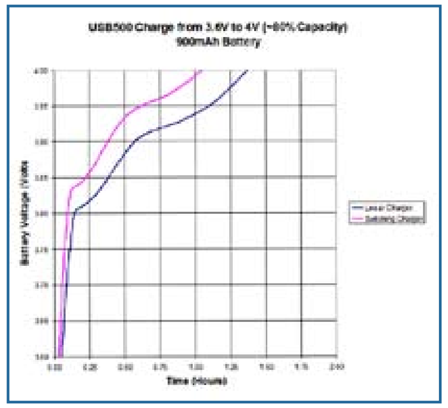

Figure 2: Charging time comparison between a linear and a switch-mode charger

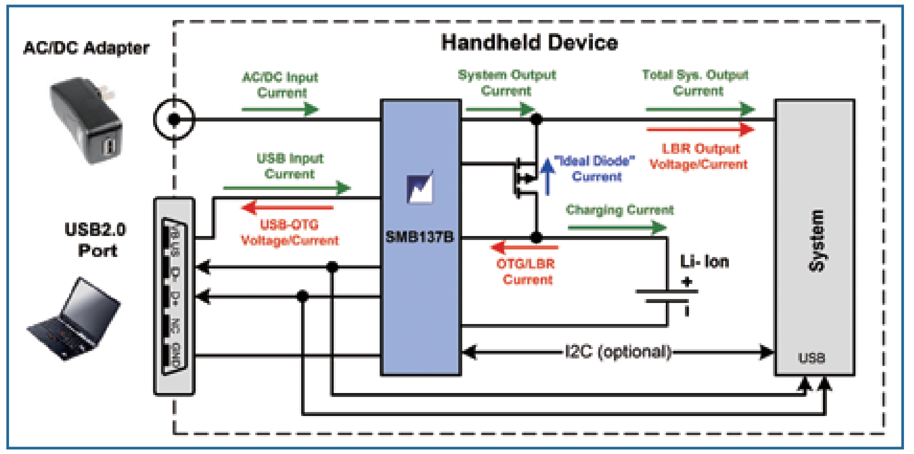

Figure 3: Example of system architecture utilizing CurrentPath™

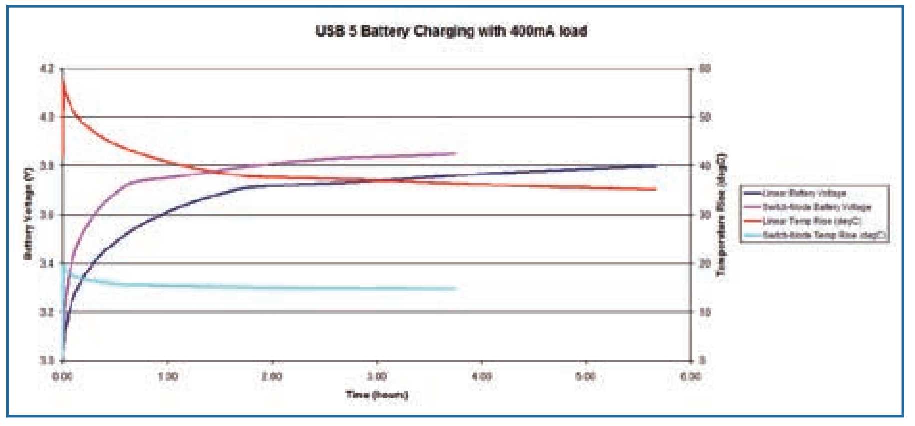

Figure 4: Power dissipation comparison between Linear and switch-mode charging

System Cost

An increasingly critical factor in the selection of any power management IC solution, including battery chargers, is the device budget. The focus point of a cost analysis is the total Bill-of-Material cost for a specific function vs. solely the IC cost. While linear chargers used to have a significant cost advantage due to large adoption rates and their relatively low external component count and cost, as system designs become more complex, switch-mode charging ICs are quickly closing the gap. When analyzing the cost impact of various charging topologies, a closer looks needs to be taken for additional functionality required by the system design. Functions like input over-voltage and over-current protection, power source identification (is the input power source a USB port or a wall adapter with a USB connector?), or USB On-the-Go power support may require additional chips and/or external components. Hence, the monolithic integration of such functions can result in significant cost benefits, both in terms of component cost and expenses associated with inventory and assembly.

Industrial Design

The "looks" and profile of cellular phones and other portable gadgets have been a major focus during the last two to three years, especially after the introduction of slick portable electronics such as the iPhone. In many cases the industrial design is the main driving force behind many of the other system- and battery-related decisions. Slim gadgets are pressured to keep temperature rise inside the case to a minimum, since there is not enough space for the heat to escape. The elimination of hot spots means a better consumer experience as well as higher system reliability. Keeping temperature levels low can be accomplished either by reducing the charging current level, which results in longer charging times and unhappy consumers, or by implementing a higher-efficiency charging method, such as switch-mode charging. The figure below demonstrates the difference in power dissipation associated with the linear and the switch-mode battery charging topologies when charging from a USB5 (500mA maximum) power source.

Marketing Focus Points

Portable electronic gadgets are marketed in appealing packages that contain specific technical characteristics and attributes. One popular (and obvious) marketing point is charging time. As mentioned in previous sections, high-efficiency battery charging topologies will always result in shorter charging time. Furthermore, the architecture of a switch-mode battery charging IC with TurboCharge™ technology is able to provide charge currents that are higher than the input currents, which again shortens the duration of the charge cycle. This current "multiplication" is extremely important with an increasing number of applications relying on charging from current limited USB ports and AC adapters, and with new-generation processors requiring a higher current level for system wake-up. Other technologies, such as the Low-battery Recovery Mode™, also exist on the marketplace, which enable a longer usable battery life. While in most designs once the battery reaches a typical cut-off threshold of around 3.4V the system is shut down, newer battery and power management implementations allow last-minute calls (911), even when the battery is more deeply discharged.

Conclusion

Defining and developing the battery charging subsystem of new portable designs is becoming an increasingly complex process. Budgetary, consumer, marketing and technology requirements are often at odds. Weighing the pros and cons of different charging topologies is key for optimizing the battery charging circuit of new product developments. It is important to look "under the hood" and understand the true benefits and costs of each topology and solution in relationship to the system's requirements. The goal is a sophisticated selection process that ensures that the end-products be reliable, provide a positive consumer experience, and keep total cost at acceptable levels.

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USB Modem Design

Overcoming space limitations

With USB being a standard interface in PC peripherals, the number of applications that can be powered from a USB port is increasing at an exponential rate. The need for flexibility and continuous connectivity in our lives is becoming more important than ever before. In a growing wireless world, many applications are taking portable form allowing users the ease and flexibility of connecting to the web anywhere, anytime. With all the benefits this brings, there are a number of extra requirements that need to be taken into account when designing a device that is powered from a USB port.

By John Constantopoulos, Systems Engineer, WW Low Power DC-DC, Texas Instruments

What is the problem?

A growing variety of wireless data cards for applications such as GSM, GPRS or WiMAX data communication use TDMA techniques which require peak current during the transmission of signals which can exceed the maximum current specified by the USB standard. Therefore the modem must be designed to limit the input power and draw on card-based storage for most of the energy requirement during a typical transmission cycle.

As shown in Figure 1, the GSM signal is transmitted over the carrier at a rate of 216 Hz (4.616ms pulse repetition interval). The transmission period is divided into eight time slots and depending on the power class being used (8, 10 or 12) , the duty cycle of this high current pulse can range anywhere between one-eighth of the cycle (577us) up to half of the transmission cycle (2.308ms).

Much of the work in GSM power supply design revolves around the transmission cycle due to the high current consumption in this mode. The main problem with the GSM or GPRS requirement is that in datacard applications, the average input current being drawn at the USB host is between 500mA – 700mA, while most transmitters will need 1.5A to 2A peak bursts to transmit at full power.

For example, when transmitting in GPRS Class 10, a maximum of two of the eight 577µs slots are used, while the remaining 6 slots are used to recharge the capacitor, during which the supply current is reduced to less than 100mA. Therefore the power supply must be able to supply at least the average current over one transmission period, as well as be capable of handling the 2A transmission bursts.

Clearly it is not possible for a power supply needed for a USB data card to operate correctly without any special design measures.

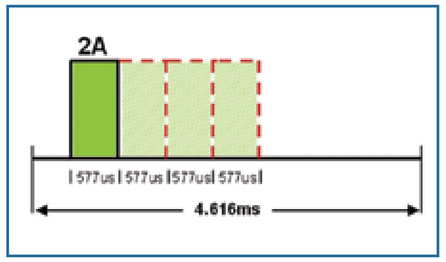

Figure 1: Transmission period of a typical GSM/GPRS pulse

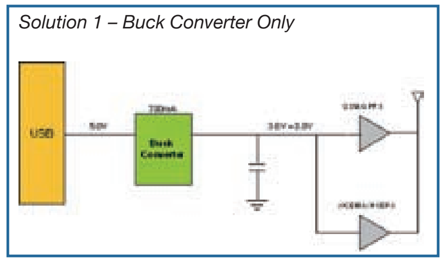

Figure 2: Overview of Buck Converter only solution

Different Design Approaches

There are numerous different topologies which can be used to power a wireless datacard. But for the purpose of this article we will compare a Buck Converter Only option versus that of using a Current Limit Switch and Buck Converter combination to demonstrate the significant savings a designer can achieve by using the latter.

Taking a look at figure 2, this provides us with the smallest converter size due to the use of only one buck converter. But due to the fact that 2A transmission pulses still need to be buffered, a large and expensive capacitor is required.

Assuming that the DCDC has an input current of around 700mA, with the supply voltage directly from the USB port (i.e. 5V) and an output supply for the RFPA of 3.8V, allows us to effectively supply around 920mA directly from the DCDC converter (no switching losses taken into account).

$$I_{OUT} = \frac{I_{IN} \bullet V_{IN}}{V_{OUT}} = \frac{0.7A \bullet 5.0V}{3.8V} =\sim 920mA$$

The rest of the energy for a GSM transmission slot needs to come from the capacitor.

$I_{CAP} = I_{GSM} - I_{DCDC}$

$I_{CAP} = 2.0A - 920mA = 1.08A$

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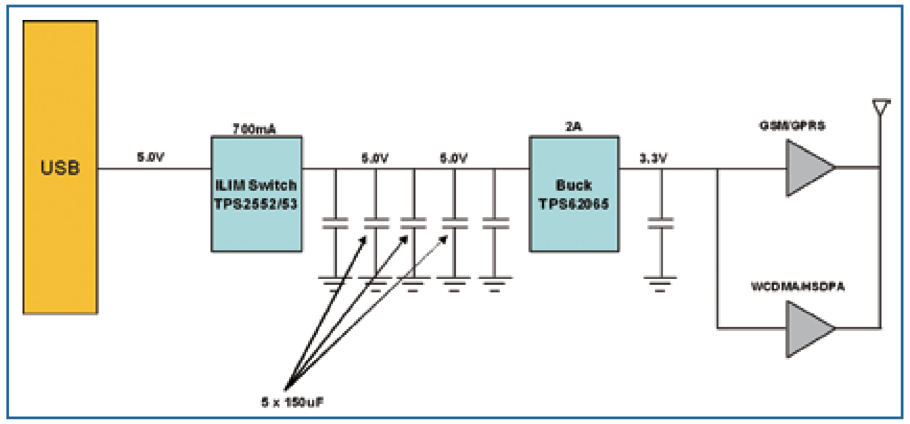

Figure 3: Overview of ILIM Switch + Buck Converter solution

Therefore the effective capacitance required to buffer each pulse assuming class 10 transmission (1.154ms slot) is equal to:

$$C = \frac{I \bullet \Delta t}{\Delta V}$$

$$C = \frac{1.08A \bullet 1.154ms}{500mV} =\sim 2.7mF$$

But as in many new applications, form factor and low price are firm requirements. And with the datacards this is no different. Newer models are being incorporated into small USB sticks which integrate small displays as well as the ability to add Micro SD flash memory.

This really constrains the amount of space available for electronic components, therefore using a large capacitor complicates layout of the design if space is restricted and is generally more expensive.

New Approach – Why store energy at higher voltages?

Taking both the requirements of size and price into account, there are alternative options to save on the bulk capacitor. By increasing the energy in the capacitor, the designer can drastically reduce the effective capacitance required, thereby reducing total solution size as well as costs!

The energy stored in capacitors is related to the charge at each interface, **q** (Coulombs), and potential difference, **V** (Volts), between the electrodes. The energy, **E** (Joules), stored in a capacitor with capacitance **C** (Farads) is given by the following formula:

$$\mathbf{E} = \frac{1}{2}qV^2 = \frac{1}{2}CV^2$$

Therefore the capacitance required is a function of the voltage squared. Hence the higher the bias voltage on the capacitor, the more energy stored which means you can reduce the total effective capacitance and still achieve the same amount of energy required to buffer a transmission load pulse.

To illustrate this topology, we used a current limit switch and buck converter from Texas Instruments. The figure below shows how this topology can be implemented by using DCDC converters from Texas Instruments'.

The TPS2552/53 USB power-distribution switches from Texas Instruments as intended for applications where precision current limiting is required or heavy capacitance loads and short circuits are encountered. These devices offer a programmable current-limit threshold up to 1.5A via an external resistor with accuracy as tight as ±6% at higher current limit settings.

The TPS62065 is a 3MHz high efficient step-down converter used as the post regulator to supply the 2A current pulses required by the RFPA during the transmission cycle. For low noise applications, the device can be forced into fixed frequency PWM mode by pulling the MODE pin high. The TPS62065 is available in a 2x2 QFN package.

Due to the total size restriction, low profile bulk buffer capacitors are required to supply the energy to the load and maintain the output voltage within the specified limits during the high current pulses. Here, three small 150µF, low profile, Sanyo POSCAP solid tantalum capacitors are used to provide power to the load during pulsed load events. Given the magnitude and the duration of the pulsed load current, the capacitors are chosen to meet the maximum input voltage droop of the step down converter (V_{IN_MIN} = 3.5V), while still maintaining a stable 3.3V supply to the RFPA.

The voltage drop in the circuit comprises two components, the IR drop associated with the capacitor's internal resistance (as approximated by ESR) and the drop in capacitor voltage at the end of the pulse. Neglecting the input current supplied by the source, the total output voltage droop is given by:

$$V_{DROOP} = I_{PULSE} \bullet \left(R_{ESR} + \frac{t_{PULSE}}{C_{OUT}} \right)$$

Where V_{DROOP} is the change in output voltage, I_{PULSE} and t_{PULSE} are the peak pulse current and duration respectively, R_{ESR} is the capacitor ESR and C_{OUT} is the output capacitance.

This energy storage benefit can be shown by comparing two different scenarios. As shown in the comparison below, two different bias voltages were applied to the buffer capacitor and the energy stored in the capacitor, as well as the total effective capacitance required has been calculated. For the purpose of the calculation we have used a Class 10 (1.154ms) transmission pulse.

To calculate the total capacitance (4) required to buffer a transmission pulse, requires that we understand how much energy the intermediate capacitors are charged up with and how much the buck converter needs to power the RFPA during transmission. (2) and (3) above are the direct energy requirements for the output voltage from (1). Taking these numbers into account, we can calculate how much energy is required from the capacitor and as a result the total capacitance required:

$$\mathbf{C} = \frac{2 \bullet E_{CAP}}{V^2} = \frac{2 \bullet 4.757mWs}{5.0^2 - 3.5^2} =\sim 750\mu F$$

As can be seen in Table 1 and the cal-

Design Parameter	Spec	Unit	
$V_{IN\_LOAD\_SWITCH}$	5.0	V	
$V_{OUT\_LOAD\_SWITCH}$	5.0	V	(1)
I_{IN_LIMIT}	0.7	A	
GSM Tx time	1.154	ms	
Energy Load	3.433	mWs	(2)
Buck ILIM	2.0	A	
V_{OUT_BUCK}	3.3	V	
Eff Buck	93%		
$V_{IN\_BUCK\_MIN}$	3.5	V	
Energy Buck	8.190	mWs	(3)
Energy from Cap	4.757	mWs	
Total Capacitance Required	***0.746***	**mF**	(4)

Table 1: Output Capacitance overview with current limit switch and buck

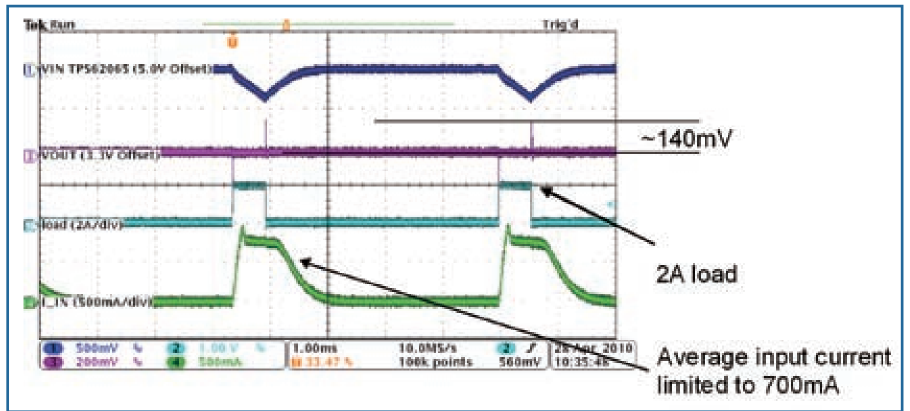

Figure 4: 2A load pulse at 577us Tx slot

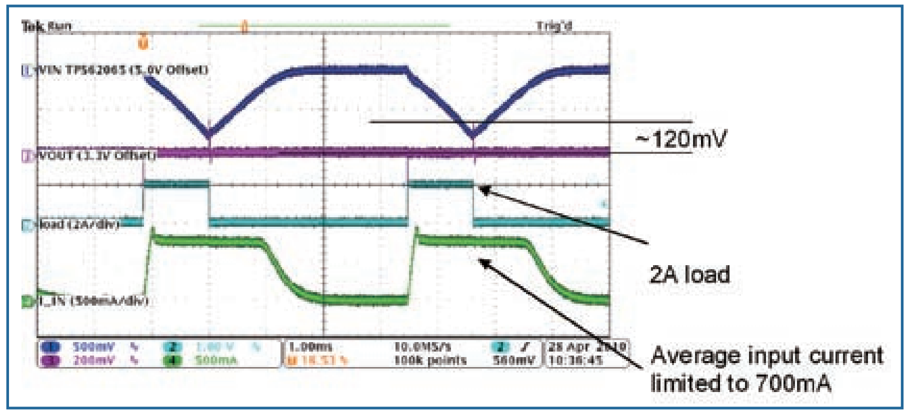

Figure 5: 2A load pulse at 1.154ms Tx slot

culations above, both comparisons have a significant advantage due to the total reduction in capacitance compared to that of the stand alone buck converter, while still maintaining the total required energy in the capacitor.

The energy that the TPS2552/53 supplies at a higher voltage effectively reduces the total capacitance. This in turn significantly reduces costs and solution size.

Figures 4 and 5 show screen plots of the TPS2553 + TPS62065 configuration, which uses 5 x 150uF (Sanyo POSCAP) as buffer stage, while being loaded with typical 2A pulses at power class 8 and 10 respectively (577us and 1.154ms). During the period where no transmission occurs, little or no current is being drawn from the device and the output voltage remains stable at 3.3V. As soon as a load pulse is applied during transmission, the output voltage of the current limit switch starts to droop while the required power level is supplied to the load, and the output of the buck remains stable during each transmission period.

Conclusion

Until recently, designers of portable systems have rarely used large capacitors for applications other than back-up or standby functions where currents are low and charge times are fairly long. But a growing range of new applications, led by a new generation of high performance data cards, demand high peak currents that are forcing designers to consider new solutions.

In these applications, designers are frequently looking for different approaches to reduce charge time, solution size and total cost, while still being able to deliver the high required peak currents. The compact solution using the TPS2553 USB power-switch and TPS62065 2A step-down converter from Texas Instruments is an optimal GSM/GPRS power supply solution for USB powered peripherals. Its small solution footprint, combined with today's low profile tantalum capacitors elegantly solves the pulsed load problem, providing a cost-effective, compact solution.

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Big Power Challenges in Little Products Create Opportunities for Power Specialists

By David G. Morrison, Editor, How2Power.com

In portable electronic devices, power levels may be small, but the challenges of power management can be monumental. Spurred by consumer demands, manufacturers of devices such as smart phones, portable media players, and laptops are continually driven to make these devices more sophisticated. The next generation of gadgets must always offer more functionality and better performance, while maintaining the same basic form factor and the same—or even longer—battery life.

Since increasing battery size is not usually an option, product designers must resort to advanced power management techniques to minimize power consumption. But that's not the only requirement for portable power management. Designers must manage the operation of multiple supply rails, maintain tight tolerances on supply voltages, deal with very fast load transients, keep noise problems at bay, and minimize design size and cost. Plus, with consumer products, product design cycles can be short, so time-to-market pressures impact the design.

To meet all of these design challenges requires engineers with experience in power system design. In the past, more of these engineers worked

for the original equipment manufacturers (OEMs) who designed, built, and marketed the portable electronic devices. But over time, many of these companies have come to rely on the semiconductor vendors to provide the power system design expertise needed to create the portable devices. So today, many of the opportunities for engineers in portable power design are at the semiconductor companies, which need IC designers and field application engineers (FAEs) to develop and support power management ICs for portable products.

Nevertheless, there are still opportunities for power specialists within portable device OEMs and within the original device manufacturers (ODMs) that work with them. However, roles within these companies are changing, and increasingly these employers are looking more for engineers who understand system-level power issues rather than the details of power converter design.

Understanding how power system design roles are changing within semiconductor and portable device companies may help you to take advantage of engineering opportunities in portable power design. (A sampling of current opportunities in this area can be found in the table that accompanies the online version of this article.)

Customers Expect Complete Power Solutions

As in other segments of the electronics industry, many portable device manufacturers have been letting go of their power supply designers, and relying more on semiconductor companies to help them with power design in their applications. It's no secret that many device manufacturers expect semiconductor suppliers to deliver power solutions as opposed to just supplying the chips. And it's now standard operating procedure for semiconductor companies to offer complete reference designs, evaluation boards, application notes and online design tools to support the use of their power management ICs in the customers' applications. But in many cases, this level of support is still not considered sufficient by device manufacturers.

Kevin Parmenter, the director of advanced technical marketing for Digital Power Products at Exar, explains that "among some device manufacturers the expectation is that the semiconductor company is going to do the design for them and hand them a working solution." Parmenter, who has years of experience in semiconductor applications engineering at Freescale, Fairchild, and ON, recalls a memorable visit to a major computer manufacturer, where an engineer summed up his company's needs. The engineer explained "what the semiconductor industry needs to understand is that they need to stop bringing us a cookbook and groceries, and bring us cooked food, ready to eat."

And it's not simply a matter of the semiconductor vendor delivering a complete, ready-to-build, power management solution after the customer has committed to purchasing their power management ICs. In some instances, the semiconductor vendor must deliver the complete solution before the customer decides to place an order.

Understanding Application Requirements

One lesson here is that the semiconductor vendor makes a heavy investment of its resources to win design-ins of its power chips. Another takeaway is that the chipmaker must have application engineers who understand the customer's application needs as well as (or maybe better than) the customer. As a result, says Parmenter, semiconductor companies like to hire engineers who have worked for their customers and understand the application requirements as well as power supply design.

And while the device manufacturers may be leaning heavily on the semiconductor suppliers for power design expertise, they still need engineers who understand how to address power requirements at the system-level. So, even if they're not expecting their engineers to design power converters from scratch, some device manufacturers still value the combination of power supply design experience and applications knowledge.

An engineer who works for a major laptop manufacturer explained, "What we try to do is understand what outfits like Intel say they need for a power supply and see if we really need the 'Cadillac' they want, or if we can find other ways to do the job. It's not uncommon for us to use good judgment in not taking their advice because that's what adds value." For example, in very high-volume applications, the laptop manufacturer can look for ways to make the power supply design cheaper than what' s recommended in the reference design.

Meanwhile, in the area of portable power IC design, semiconductor companies are more likely hiring engineers from their competitors rather than their customers, according to Parmenter. When the business climate is strong, semiconductor suppliers will be competing with one another for IC designers. In addition, they may face new competition from overseas semiconductor companies who want to get a foothold in portable power management by setting up design centers in the U.S. or Europe and hiring away experienced IC designers from other companies.

Technical Challenges Require Interdisciplinary Approach

As handsets and other portable devices evolve, the power management challenges in these devices grow. Within these devices, some processors require a power supply voltage accuracy of 1% over temperature, and they may have 5 or 6 modes of operation that allow for lowering of power consumption, says Parmenter.

"Those modes all require intelligent interaction of the processor with the power system. So the power engineer needs to know something about software, systems, digital, and analog." says Parmenter in describing how the semiconductor FAE's job encompasses many disciplines. Meanwhile, some of the power management ICs developed for portable applications have evolved into very large ASICs. "Some of these power parts are 396-pin BGAs with I/Os tightly packed at 0.4- or 0.5-mm pitches," says Parmenter. That creates layout and manufacturing issues, which naturally the FAEs will be called on to help their customers address.

Steve Schulte, senior staff systems engineer at Qualcomm, notes another technical challenge: Trying to supply clean power in the face of the very fast load transients generated by processors, which have long been a problem in desktop and laptop computers, and are now being generated by cellphone processors. This is forcing designers to resort to some of the tricky power supply topologies, says Schulte.

He also notes that the migration to finer CMOS process geometries in the digital realm creates power design challenges for those who are integrating power control in their microprocessors. This points to another area of opportunity in portable power design which resides within the world of embedded power design on chip.

Other Factors

Power Experience Migrates from OEMs to ODMs. Parmenter points out that the original equipment manufacturers (OEMs) that sell portable electronic devices are relying more on original design manufacturers (ODMs) to develop their products. That means, semiconductor companies are working more now with the ODMs to develop power management solutions for portable applications. This trend suggests that ODMs need to have engineers with system-level knowledge of power issues just as the OEMs do.

Commoditization means less hardware design. Highly commoditized products such as printers tend to be based on chipsets, both for the logic and the power management functions. These power management chips may be highly integrated like the example cited above of a 396-pin BGA. Plus, whichever IC Company is supplying the main chipset for the product, is probably specifying the power components as well. The companies making these products tend to differentiate through software rather than hardware design. As a result, says Parmenter, commoditized products offer fewer opportunities for power designers within the device companies that make them.

On the other hand, portable device manufacturers that sell more specialized, not-yet-commoditized products still view hardware design as a means to differentiate their products. So power supply designers still have a role to play within these companies.

Movement of Jobs Offshore. Since most manufacturing of portable electronic devices is done in the Far East, it's no surprise that some companies in the U.S. or Europe have moved their product design including power system design off shore. However, this trend may be less of a factor for products that are more specialized and less commoditized as discussed above.

Opportunities in the Semiconductor Industry

The larger the semiconductor company, the more likely it is to have their IC designers and FAEs specialize in portable power applications. In some cases, a particular IC design center will focus on portable power chips. With regard to FAEs, there's probably more variation as some companies may opt to have their engineers focus on portable power applications, while others may ask them to support a specific product category such as cell phones.

Some companies ask their FAEs to support power supply design across a wider range of applications. And at smaller IC companies, it's likely that the FAEs will be required to be generalists who support the design of power ICs and all the non-power chips the company sells. All of these variations will influence the particular knowledge and skill sets that semiconductor companies look for when hiring FAEs to support their portable power products. Beyond the requirements for technical expertise, there will also be differences in the sizes of the territories that FAEs will be asked to support. For example, at smaller companies, FAEs may be expected to support customers over a larger geographic area, which may mean more time spent traveling.

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/.

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Career Development

Solar PV or Solar Thermal?

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

More solar reports are coming in, but now solar-thermal energy is also increasingly finding its way into the news arena. In the Photovoltaic (PV) worldwide market, Germany continues to play a key role. But not only will it be the largest market for PV installations, its PV-friendly politics and FIT (Feed in Tariff) regulations serve as an example to other countries on how to promote solar energy.

PV installations in Europe will account for about 80% of the worldwide market, mostly coming from Germany, France, Italy and the Czech Republic. Italy and France, in particular, are becoming solar regions, with 1.0GW of solar installations in Italy and 500MW in France expected in 2010. But with both countries facing uncertainties about FIT cuts in 2011, these high numbers may be caused by a consumer race seeking to take advantage of government programs. Other countries such as Greece, Bulgaria, Spain and the UK appear to be prime investment opportunities, but administrative hurdles or installation limits are slowing the growth of PV in these areas according to iSuppli. For the foreseeable future, Germany will continue to lead Europe and many other parts of the world despite the FIT cuts that reduce the level of incentives to purchase solar systems.

Attractive investment conditions in the first half of 2010 indicate that Germany will experience an outstanding year for solar PV installations, with reports indicating that it will install 6.6GW worth of PV systems in 2010, up 71% from 3.9GW in 2009, and will see an even better year in 2011 as installations reach 9.5GW.

While most of the focus in the solar world is on PV power, the fastest-growing segment of the solar market is actually the solar thermal market, which will expand by a factor of 37 from 2009 to 2014, compared to just a six-fold rise for PV during the same period. Solar thermal, or Concentrated Solar Power (CSP), is undergoing a boom, as newly installed capacity grows explosively.

In contrast to PV systems which use arrays of cells to convert the sun's radiation into electricity, solar-thermal uses mirrors to reflect the sun's heat energy onto collectors filled with fluids or gases. This energy is then used to heat water and, in turn, drive a steam turbine to generate electricity. The most popular type is a parabolic trough version that heats a tube of synthetic oil, which is pumped through a heat exchanger to create water steam that drives a turbine electricity generator.

CSP plants can also store the sun's heat energy for release to steam generators at night. Forms of molten salt and graphite lead the list of storage alternatives for slowly releasing heat. This is something to watch for the future.

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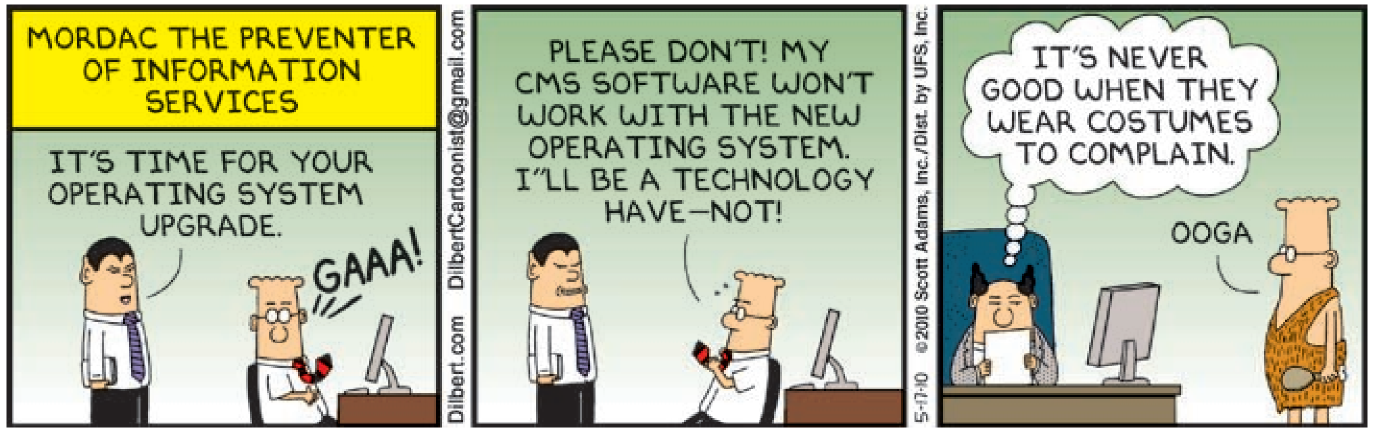

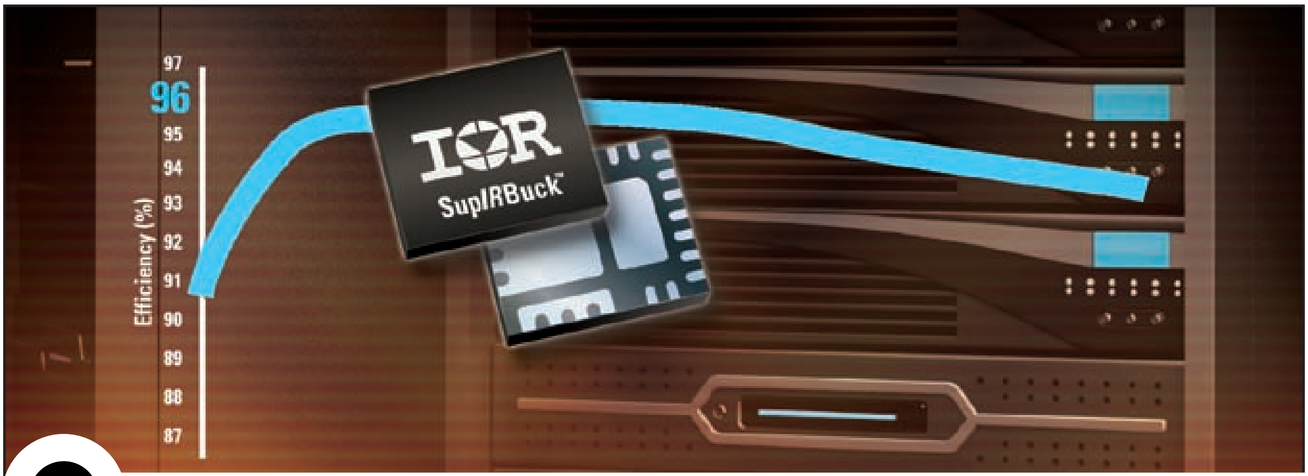

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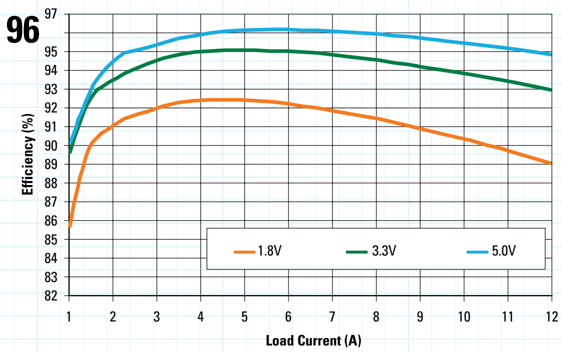

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