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Special Report: Internet of Things (IoT) (pg 32)

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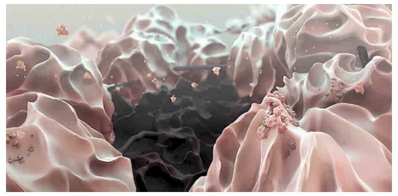

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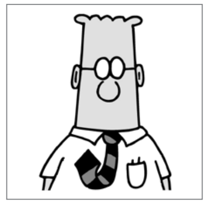

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The internet of everything

It is a fascinating time to be in the electronic engineering industry, especially in the power sector, as society moves forward into the Fourth Industrial Revolution. This promises to be the last, barring the takeover of industry by intelligent robots, as all of the parts are in place and the core technologies have been developed for connected intelligent devices, cars, homes, factories, villages, and cities.

The creation of the Cloud and the Internet of Things (IoT) involves far more than just getting everyone's smart phone to control their house lighting and having remote devices connect to one another. It will eventually bring together every powered device into an intelligent network where device functionality and performance will be monitored and managed by remote interconnected infrastructures.

What this means for the electronic engineering industry is that every designer must take into consideration not only the current needs and requirements involved in their product development, but potential future expansion and wider integration into Cloud-based systems. Board-level management must not only extend down to the point of load; it must also extend upwards into the Cloud itself.

One way to look at it is to adopt the term C3I from the military with one small change: command, control, Cloud (for communications), and intelligence. By putting the situation in this perspective, we can make it easier to understand in context. Future systems must be able to accept commands with the ability to control every aspect of their functionality anywhere in the Cloud, while providing monitoring telemetry for system oversight and intelligence.

One day it will be considered ludicrous and primitive for any powered device to exist without some kind of connection to the greater Cloud to enable monitoring and control for purposes ranging from enhanced functionality and efficiency to improved safety and disaster management. Even the largest most basic industrial processes will be as easy to remotely monitor and control as a toy robot from your smart phone.

This is challenging to the power electronics industry, which is still in the throes of integrating basic digital control protocols into power delivery systems at every level. Ensuring that the analog systems involved are optimally designed while the related digital communication and control protocols are properly integrated is just a start. Software is now just as important to the proper operation of a system as the hardware components in it.

It is this integration of hardware and software systems in a way that ensures they have a high level of functionality in an intelligent interconnected environment that will help determine the real winners and losers. This is a challenge that has to be meet by everyone on a product development team, from how the package designers lay out the buttons (real and virtual) to the webmaster responsible for the product's online user interface. Only a gestalt approach that takes in every facet of a device's attributes will be able to properly function in a Cloud-based economy.

Best Regards,

Alix Paultre
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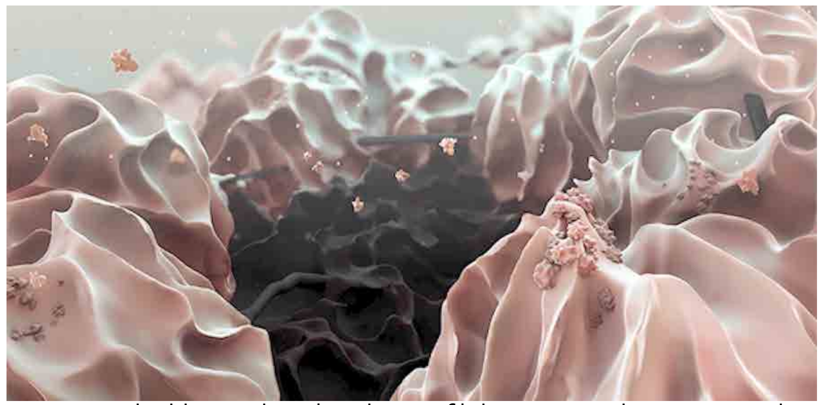
New design points a path to the 'ultimate' battery

Scientists have developed a working laboratory demonstrator of a lithium-oxygen battery which has very high energy density, is more than 90% efficient, and, to date, can be recharged more than 2000 times, showing how several of the problems holding back the development of these devices could be solved. Lithium-oxygen, or lithium-air, batteries have been touted as the 'ultimate' battery due to their theoretical energy density, which is ten times that of a lithium-ion battery.

Such a high energy density would be comparable to that of gasoline. However, as is the case with other next-generation batteries, there are several practical challenges that need to be addressed before lithium-air batteries become a viable alternative to gasoline.

Researchers from the University of Cambridge have demonstrated how some of these obstacles may be overcome, and developed a lab-based demonstrator of a lithium-oxygen battery which has higher capacity, increased energy efficiency and improved stability over previous attempts. Their demonstrator relies on a highly porous, 'fluffy' carbon electrode made from graphene (comprising one-atom-thick sheets of carbon



atoms), and additives that alter the chemical reactions at work in the battery, making it more stable and more efficient.

While the results, reported in the journal Science, are promising, the researchers caution that a practical lithium-air battery still remains at least a decade away. "What we've achieved is a significant advance for this technology and suggests whole new areas for research – we haven't solved all the problems inherent to this chemistry, but our results do show routes forward towards a practical device," said Professor Clare Grey of Cambridge's Department of Chemistry, the paper's senior author.

What Liu, Grey and their colleagues have developed uses a very different chemistry than earlier attempts at a non-aqueous lithium-air battery, relying on lithium hydroxide (LiOH) instead of lithium peroxide (Li_2O_2). With the addition of water and the use of lithium iodide as a 'mediator', their battery showed far less of the chemical reactions which can cause cells to die, making it far more stable after multiple charge and discharge cycles.

By precisely engineering the structure of the electrode, changing it to a highly porous form of graphene, adding lithium iodide, and changing the chemical makeup of the electrolyte, the researchers were able to reduce the 'voltage gap' between charge and discharge to 0.2 volts. A small voltage gap equals a more efficient battery – previous versions of a lithium-air battery have only managed to get the gap down to 0.5 – 1.0 volts, whereas 0.2 volts is closer to that of a Li-ion battery, and equates to an energy efficiency of 93%.

www.cam.ac.uk

Enabling the AR-VR revolution

By: Dr Harry Zervos, IDTechEx

Microdisplays, initially developed for large screen projectors, found a perfectly matching application in head-mounted displays. When Google Glass launched in 2013, it integrated a reflective, near-eye Liquid Crystal on Silicon (LCoS) display based on an LCoS chip from Himax Display. There are several suppliers of liquid crystal microdisplays that are currently available and have been integrated in different headsets.

Kopin's transmissive LCD on single crystal silicon transistors has been utilized in smartglasses from Vuzix and Recon, as well as in the company's own brand headset, the Solos. Devices based on ferroelectric liquid crystals (FLCoS for short), having made a wide impact on applications as diverse as optical correlation and holographic projection, are also of interest here, as they are inherently faster switching than other liquid crystals.

Microdisplay technology options: OLED microdisplays

Non-emissive systems, like the LCoS described above, have light always incident on every pixel, irrespective of whether said pixel is on or off, an undesirable trait for any portable application where battery life is paramount. Emissive types of displays rectify that problem and can be more energy efficient, one of the main reasons there is a significant interest in micro-OLED displays. Along with higher contrast, faster response time and a wider operating temperature range, μ-OLEDs have been used in prototypes such as the smartglasses from Atheer Labs, with several companies developing products worldwide (e.g. eMagin, Yunnan OLiGHTECK, MICROOLED).

Unfortunately, current generations of μ-OLEDs are limited in brightness and experience short device life-times when run in high brightness conditions. As a result, there is significant research and development effort in making brighter, longer-lifetime OLEDs, with prototypes that use direct color emission rather than RGB color filter arrays showing significant promise in that respect.

Microdisplay technology options

Micro-LEDs, also an emissive display technology that benefits from reduced power consumption, have been demonstrated to operate efficiently at higher brightness than that of an OLED display, and in that respect can deliver an emissive, high brightness solution. The drawback of LEDs is that they are inherently monochrome - the phosphors typically used in converting color in LEDs do not scale well to small size - which leads to a requirement for more complicated device architectures and it is not yet clear how scalable these can be.

Which will be the winning technology?

In the short to mid-term, the two major competing technologies are the two more mature ones; OLED and LCoS microdisplays. Other than the liquid crystal displays already in products, eMagin has just signed a non-exclusive agreement to supply its OLED microdisplay technology to an undisclosed client, with an $1m licensing fee as a down-payment, while other headset developers are testing OLED displays and their performance in their devices.

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IoT wearables and power electronics

By: Kevin Parmenter, Power Systems Design Contributor

If you attended CES 2016, you were told that everything there was the most important thing available in the universe. Every product introduced collects data about your car, your house, your appliances, your life, your pets, and all the things and people around you and, most importantly, you. A subset of this new existence of the IoT is wearable tech. Reports say that wearable technology will be worth as much as $31.3 Billion US Dollars by 2020. That's a lot of "wear". The overall market is supposed do grow at a CAGR of 17.8% between 2016 and 2020.

The driving factors include consumer preference for sophisticated gadgets, smart watches and the like, for fitness, medical devices, wearable scanners, and computing devices in warehouse, logistics and other operations where operational efficiency is desirable. Consumer wearable devices are used in fitness, sports, entertainment and fashion, to name a few.

These devices won't be just utilitarian computing and communications devices, they will be fashion and style statements, so expect to see the "celebrities" wearing them soon. It's no surprise that the usual sports apparel and fitness brands are jumping on this trend fast. The Americas market is forecasted to grow at the highest CAGR for many reasons these include technical innovations, which have lad to the introduction of new products and demands from consumers in medical applications.

It's no secret that the US market has the higher incidences of chronic diseases, diabetes and cardiac issues and such so the market is ripe for tele-health & wearable medical sensors. So what does this mean for power electronics in these applications?

Power management at the chip level and packaging concerns will be paramount. SOC designers will need to consider energy harvesting and sophisticated techniques to achieve high efficiency low power consumption operation. EDA tools to design these sophisticated applications will be more important than ever. The ability for artificial intelligence and software to sort out useful information from the noise will be huge and this will need efficient power. Moreover, the communications systems to stay connected with all of these things and store and process the information will need power i.e. "Big data" if you will.

Power will be top of mind from the point of use in the wearable all the way to the point where the data is stored and used. Consumers will want to take these systems everywhere and expect the power to just work and last for months or even years before having to consider the power source. This is going to be a big challenge for all aspects of power electronics from energy harvesting, components, packaging and magnetics, wireless charging, super capacitors & batteries for storage, efficient processors, SOC's, and communications chips. Not to mention the software to insure data security, running the billing systems to pay for all the fun and protect it all from malfeasant hackers and actuaries will be very important. The future will be interesting indeed.

Current-mode control Part II

By: Dr. Ray Ridley, President, Ridley Engineering

In this second part of this series of articles, we show how Dr. David Middlebrook approached the analysis of current-mode control, and the consequences of the modeling approach on loop gain predictions.

Current-mode control circuit

Figure 1 shows a buck converter with peak current-mode control. The instantaneous value of the inductor current is added to a compensating ramp, and compared to a control reference, v_C. The inductor current can be sensed in numerous ways, but the important thing is to make sure the sensing is an accurate representation of the real current in the inductor, without any filtering.

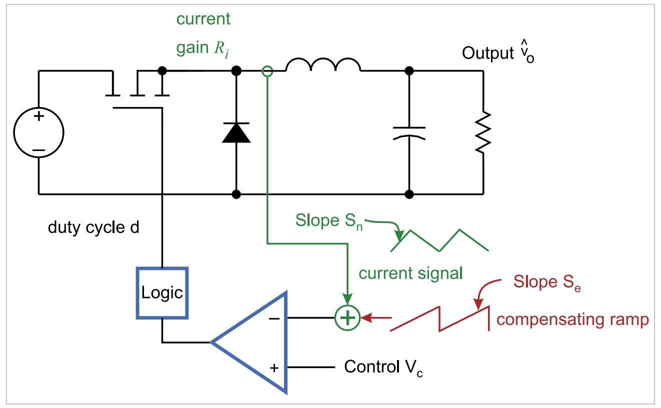

Figure 1: Buck Converter with Current-Mode Control

Figure 2 shows the average model for the buck converter with current-mode control. A feedback loop around the inductor current represents the system. R_i is the gain from inductor current to the voltage signal which is one input to the comparator. All quantities are known in this diagram except for the gain of the modulator, F_m.

Early discrepancies arose in determining the gain of this modulator. Different researchers found different solutions to the same problem. **Figure 3** summarizes the most common approaches being used in the industry in 1986. The infinite-gain solutions found by Barney Holland and Unitrode are highlighted in **Figure 3**.

The infinite gain is what is needed if we assume the inductor has been changed into a current source. In reality, it is not a perfect current source since the peak of the current and the average value of the current are not the same. In this second part of this series, we will examine how Middlebrook looked at the current modulator.

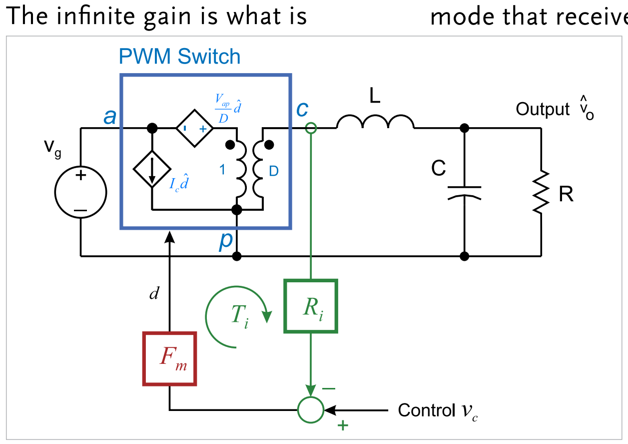

Figure 2: Average Model of the Current-Mode Buck Converter

Middlebrook's modulator gain model

In 1986, Middlebrook published his famous paper on current-mode that received a lot of industry and university attention [1]. Current-mode had been popularized several years before this, but Middlebrook brought attention to how the system should be modeled in his own unique and special style (see **Figure 4**).

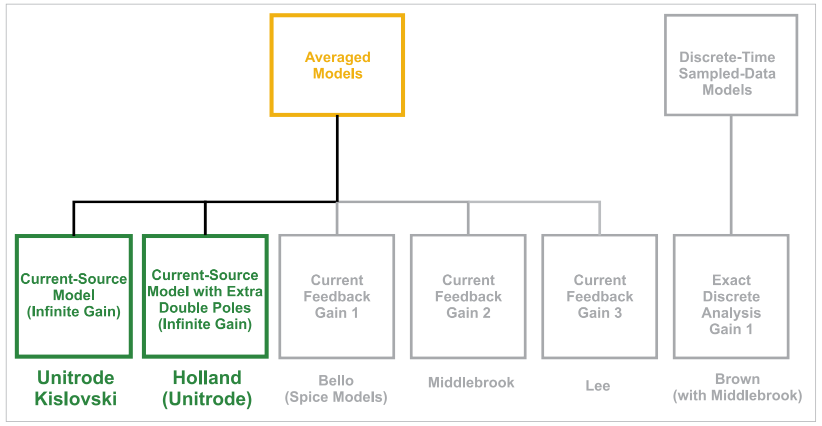

Figure 3: Current-Mode Control Models In 1986: Infinite Gain Models

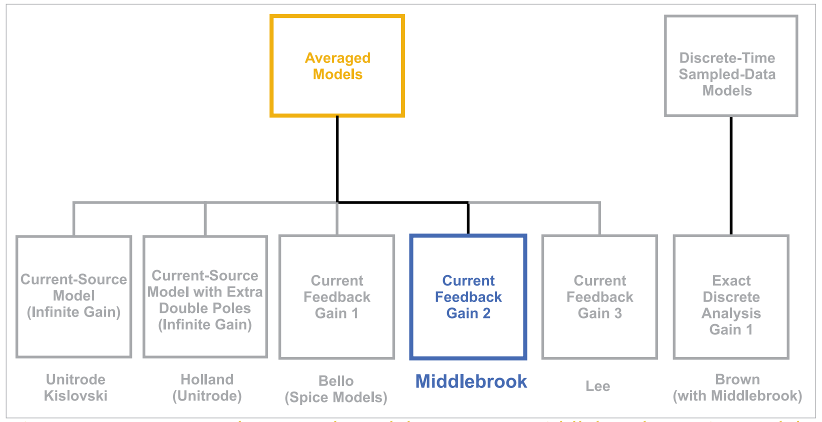

Figure 4: Current-Mode Control Models In 1986: Middlebrook's Gain Model

The first thing he did was to define what is meant by the term "average" current. Middlebrook's explanation for this was very simple and intuitive: the average current was the value of the inductor current without the ripple. In **Figure 5**, this is defined as being halfway up the slope of the inductor current which makes good practical sense.

Figure 6 shows the control waveforms with perturbation applied to the system. In order to find the modulator gain, we need to assess how much the duty cycle will change for a given change in the inductor current. The green waveform shows the inductor current in steady-state. At the end of the cycle, the inductor current has returned to exactly the same current level as it was at the beginning of the cycle.

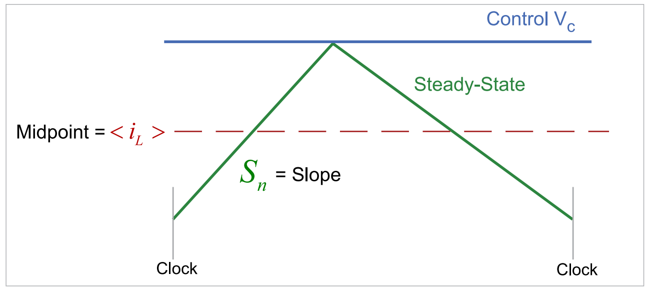

Figure 5: Middlebrook's Definition of Average Inductor Current

Now consider a small perturbation $\hat{i}_L$ introduced at the beginning of the clock cycle. When the current hits the control voltage, the perturbation is given by $\hat{d}$. The equations of Figure 6 show that the perturbation in duty cycle is just the reciprocal of the slope, multiplied by the initial change in current. However, the perturbation in the average current, $\hat{i}_L$, is only half the perturbation in the initial current since the average current defined by Middlebrook is the midpoint of the slope. From this, it follows that the modulator gain for the system is twice as high, given by:

$$F_m = \frac{2}{S_n}$$

If a compensating ramp is added to the system, the modulator gain term is modified to be:

$$F_m = \frac{2}{S_n + 2S_e}$$

Middlebrook's current-loop gain and phase

Given this value of modulator gain, we can now plot the transfer function of the current loop gain that has been created for this system. (For the poles and zeros of this transfer function, please read reference [2]). **Figure 7** shows the result for a circuit operating at a duty cycle close to 50%, and without any external

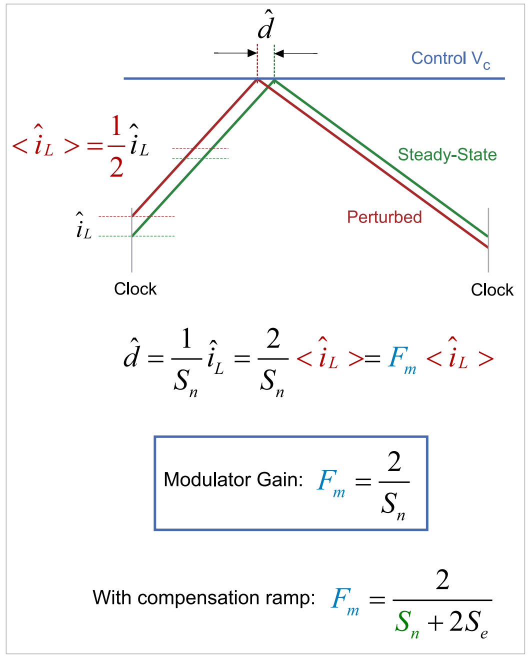

Figure 6: Modulator Gain Derivation Using Middlebrook's Average Current Definition

compensating ramp added to the system.

The gain has a low-frequency zero before the resonant frequency, then a double pole given by the resonance of the LC filter of the buck power stage. After the resonance, there is a fixed -20 dB/decade slope. The final crossover frequency for this 50% duty cycle is given by:

$$f_x = \frac{2}{\pi F_s}$$

In his original paper, Middlebrook described how this current loop crossover translated into a second pole of the control-to-output transfer function at about 2/3 the switching frequency.

In the introduction to his paper [1] he makes the following statement:

> ..... Therefore, although current programming tends to make the power stage output behave as a current source, the control-to-output voltage transfer function exhibits, in addition to the familiar dominant pole, a second pole at the current loop gain crossover frequency, which may lie anywhere from one-sixth to two-thirds of the switching frequency.

Interestingly, the crossover asymptote of the current-mode loop (without a compensation ramp) is completely independent of the current-sensing gain, or any other circuit values, which seems like an unusual result. The explanation for this is as follows: if we increase the gain of the current sensor we have a higher gain from duty cycle to sensed signal in **Figure 2**. However, we now have a larger slope on the current, and the modulator gain reduces by the exact same amount. So when we have current mode control, we really don't have design freedom over the current loop. All we can do is reduce the gain by adding a ramp, but we cannot increase the gain beyond that shown in **Figure 7**. There is a second interesting point to be made. The crossover frequency of the current loop predicted by Middlebrook is in excess of half the switching frequency. This would seem to be a violation of the Nyquist criteria which states that you cannot exceed half the switching frequency in a feedback loop. Although the system is nonlinear and time varying, control theorists should immediately be concerned about this predicted outcome.

We will discuss this more later in this series after deriving other possible solutions for the modulator gain for the current-mode system.

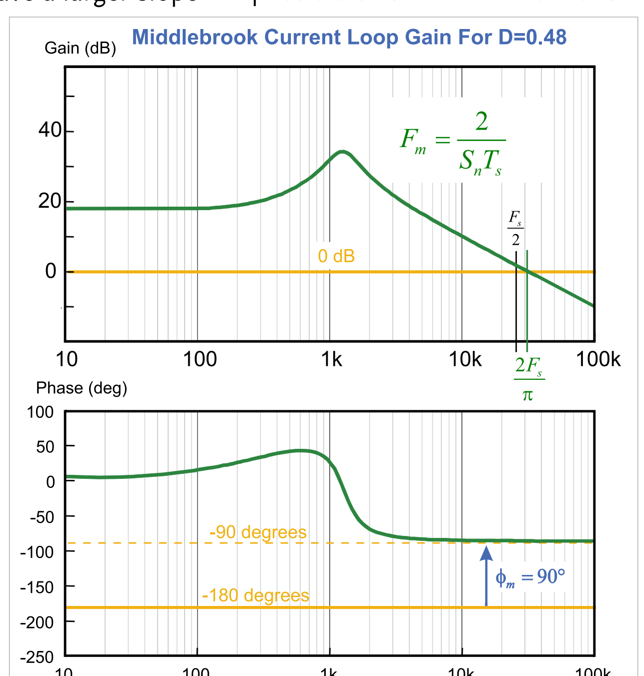

Figure 7: Middlebrook's Predicted Current Loop Gain and Crossover with 50% Duty Cycle

Middlebrook's method

In this article, we have shown how Middlebrook derived the current-loop modulator gain for his assumed definition of average inductor current. The unusual result of predicting a crossover frequency in excess of the Nyquist frequency is caused by the modulator gain that Middlebrook found in his analysis. It should be stressed at this point that there are not any mathematical errors in Middlebrook's paper, and we will have to look for another explanation for this anomaly.

www.ridleyengineering.com

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Inductors for everything

Selecting magnetics for emerging applications

By: Len Crane, Coilcraft

Electronic devices have been ubiquitous in modern life for some time. So it is perhaps easy to assume that everything necessary has already been accomplished in the world of passive components. As consumers, we are all well aware of faster computers, smaller and smarter phones, brighter and flatter TV screens, and an increasingly connected world.

As engineers, we are constantly thinking about changes on the inside. Are there still important component choices to be made? Are the inductor decisions now trivial? Can this be done by "cookbook? If this were true, then power inductor choice should be quite easy, but today's power electronics engineer knows the situation to be exactly the opposite.

Higher frequencies

The most common trend in dc-dc converters is to try to increase the switching frequency to allow the use of smaller passive components. The math for determining a new lower inductance value for a new higher frequency is very straightforward. $L= V/(di/dt)$ so L is proportional to dt and therefore inversely

proportional to frequency. For "all other things are equal", this could imply inductor size is simply proportional to switching frequency. But all things are not equal for at least two reasons.

First, reducing inductance value does not directly correlate to the same proportional reduction of inductor size. The type of inductor construction impacts the inductor size / inductance value relationship, and one must be clever to insure that mechanical details like terminal size and spacing don't limit the amount of size reduction.

With a large increase in switching frequency, the inductor type for optimal size reduction and performance may require a different structure or shape altogether than was best for a lower frequency. Second, high frequency switching also means that new parameters have to be considered. The main one, of course, is the introduction of ac loss mechanisms that weren't significant at lower frequency.

Along with changing frequency, new applications drive the need for inductors to be used in new ways, causing a re-prioritization of all inductor parameters like saturation current, ac losses, and dc losses, which must be re-balanced against each other to optimize the solution. New types of use environments, like display screens for home appliances and Ethernet for cars mean the power electronics designer is making new choices. These new applications likely involve converter operation at new operating voltages, new duty cycles, and with new control techniques, placing emphasis on different inductor parameters.

Inductor choices

Consider a fairly traditional buck converter operating at 500 kHz to step down 12 Volts to 5 Volts with a 2 Amp load. For example, the 10 µH Coilcraft MSS1260-103 is a nice inductor choice. Operating

500 kHz	1 MHz
	
MSS1260-103	MSS7341-502
PCB area = 144 mm2	PCB area = 53 mm2
Volume = 864 mm3	Volume = 217 mm3

Figure 1: Buck Converter with Current-Mode Control

in these conditions, the inductor ripple current is 30% of the load current, or about 0.7 A pk-pk. At full load, the inductor temperatur` rise will be about 15° C due to self-heating, mostly as a result of DCR. The inductor body is about 12 x 12 mm with a 6 mm height.

What happens if we double the frequency to 1 MHz and assume the same operation with about 30% ripple current? We can select a Coilcraft MSS7341-501 which, at 5 µH, has half the inductance. The loss and temperature rise are about the same, with a little more of the loss coming from ac loss mechanisms.

The bottom line is that by doubling the frequency from 500 kHz to 1 MHz it was possible to keep the same ripple current and efficiency while reducing inductor size from a footprint of 12 x 12 mm (144 mm²) down to 7.3 x 7.3 mm (53 mm²). That's a PCB area reduction of more than 60% and a total inductor volume reduction of more than 70% (see **Figure 1**). This example illustrates a fairly straightforward case in which increasing switching frequency had a substantial size reduction benefit, without sacrificing efficiency.

The previous example shows how to reduce inductor size when using fairly traditional ferrite core with air gap inductors. A major trend over the past few years has been the increased popularity of so-called soft saturation inductors which utilize powder cores. The distributed air gap of these core materials gives the highly-desirable benefit of making inductors insensitive to incremental current increases.

An inductor of this type designed into a 3 A application, for example, won't have significant inductance drop if the current should spike or occasionally rise to, say, 6 or 7 A. This gives the designer the opportunity to design with the smallest inductor size while knowing that for a temporary period or for an unexpected spike in current, the inductance value will stay in a fairly narrow range, allowing continued stable control loop operation. **Figure 2** shows the difference between inductors with a traditional ferrite core and a soft saturation type core. In this case both inductors are clearly suitable up to 3 A peak current, but the advantage of the soft saturation inductor is dramatic at higher currents.

Comparing differences

Soft saturation style power inductors clearly have the favorable property of the inductance being insensitive to current peaks, and have been enthusiastically adopted

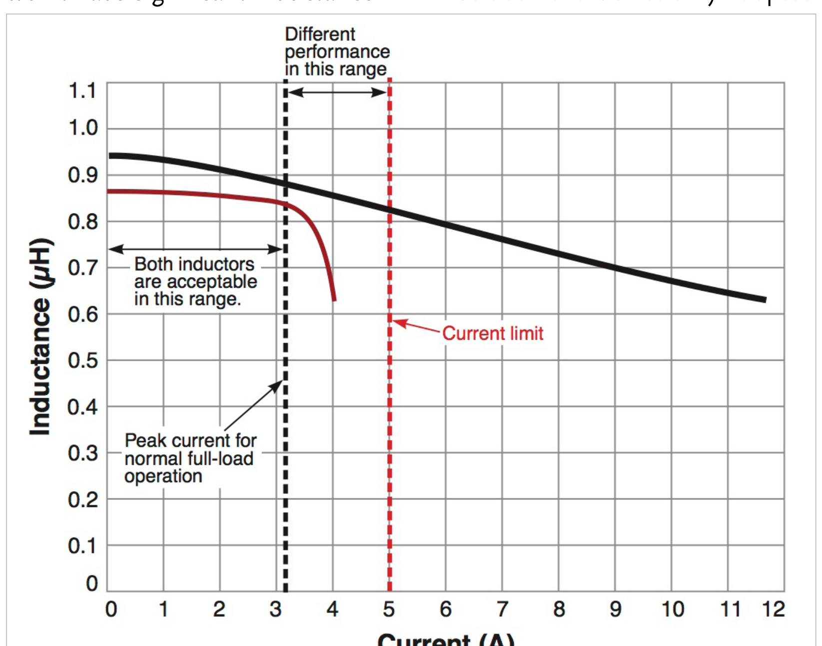

Figure 2: Difference between traditional and soft saturation inductors

	From Data Sheet			From online calculator tool	
	Size	L	Isat	Total Loss	AC/DC Loss
LPS3010-102	3 x3 x1	1.0	1.6	79 mW	2/77
XPL2010-102-	2 x2 x1	1.0	1.8	87 mW	7/87

Table 1: Traditional vs Soft Saturation at 1 MHz

by the industry for miniature devices, including wearables, in which minimum component size is crucial. With such an outstanding performance, it requires a closer look to understand some of the limits and other tradeoffs between inductor types.

One of the best and easiest ways to consider the bigger picture of all inductor parameters is with a device like Coilcraft's Power Inductor Analysis & Comparison tool. It simplifies side-by-side comparisons of up to six inductors under the same operating conditions; not just their datasheet specifications but also L vs I graphs, loss calculations, and other frequency- and temperature-dependent changes.

Consider two 1 µH inductors that might be used in a typical 1 MHz converter, with 1 A load current and 0.4 A pk-pk ripple as might be found in a small continuous or critical conduction mode converter. For wearable applications, we select components that are 1mm height or less. We are able to select a soft saturation inductor in 2 mm x 2 mm footprint to perform with comparable efficiency to a traditional inductor style of 3 mm x 3 mm with about a 50% PCB area reduction (see **Table 1**).

But under another set of conditions, the choice could be different. What happens if the frequency were increased to 4 MHz? At the same time let's also reduce the load current by half to 0.5 A, and double the ripple current to 0.8 A pk-pk, such as in low duty cycle or discontinuous conduction mode.

In this case the performance is still comparable between the traditional inductor and the smaller size soft saturation choice. It is notable

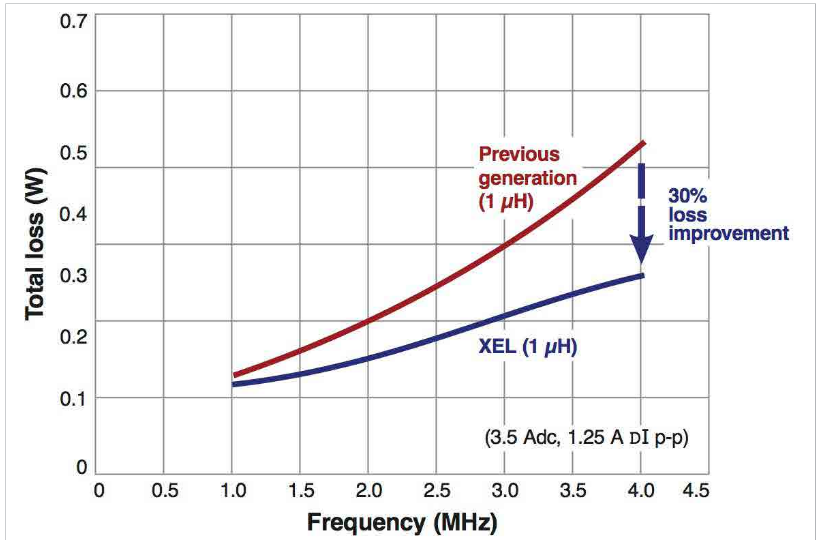

Figure 3: Improved inductor loss in new generation of inductors

that the inductor losses are predominantly ac losses now, whereas in the previous example DCR loss was dominant. Nevertheless, the designer has a choice between the soft saturation inductor and the larger, slightly more efficient traditional one.

This is very typical of the choices faced by designers every day, with the "right" inductor selection depending very much on the specifics of the application. In this case it is likely the soft saturation style would be the inductor of choice, offering substantially smaller footprint for only a 10% penalty in efficiency (see **Table 2**).

From these examples, we can see that the balance of inductor losses between ac and dc loss mechanisms changes significantly with application conditions. It is easy to predict that there will be some combination of frequency, ripple current, and load current at which different style inductors will be preferred.

This also demonstrates that a complete set of detailed inductor performance information must be available from the manufacturer. The traditional parameters of inductance, DCR, and saturation current are not adequate to sufficiently compare inductors over a range of possible application conditions. The good news for the designer is that there are many inductor sizes, styles, and materials to address the wide range of applications.

For the continuing trend to higher frequency, the power converter designer can utilize better information now available from inductor suppliers in the form of enhanced datasheets as well as online tools. In addition, the designer can expect inductor manufacturers to improve inductor performance to meet this trend. For example, Coilcraft is has introduced an enhanced soft saturation family of inductors specifically optimized for high frequency. The XEL inductor families maintain the low DCR and high saturation capacity that is expected, with the addition of lower losses at high frequency. **Figure 3** shows the reduction in overall inductor losses that can be achieved with this new generation of inductors.

	From Data Sheet			From online calculator tool	
	Size	L	Isat	Total Loss	AC/DC Loss
LPS3010-102	3 x 3 x 1	1.0	1.6	163 mW	144/19 mW
XPL2010-102	2 x 2 x 1	1.0	1.8	180 mW	160/20 mW

Table 2: Traditional vs Soft Saturation at 4 MHz with High Ripple

What's next?

Beyond today's improved inductors, the converter designer may soon be able to consider completely new inductor styles in order to take advantage of big frequency leaps in future switching converters that are expected to be enabled by new devices and topologies. For frequencies over 10 MHz or 20 MHz, inductors without cores may be considered.... or versions with just enough magnetic material to provide shielding.

This brings into play the type of inductors previously considered for RF applications. Just as the Internet of Things opens up the possibility to connect everything, thinking outside the present inductor "box" will create the exciting possibility of a power solution for everything.

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A fresh look at efficiency

When analyzing power in order to improve efficiency in electric devices and appliances, it can be beneficial to take a step back and look at the measurement instrument

By: Bernd Neuner, ZES ZIMMER Electronic Systems

Although efficiency has been replaced by effectiveness as favorite criterion in the business world, it still dominates the world of engineers and technicians. The hunt for improved utilization of electricity permeates every level in the electronics industry, from individual semiconductor components over circuits and modules to entire devices and even complex systems. While the exact definition of efficiency inevitably depends on the context, all variations have in common the consideration of results vs. effort, or in more technical terms, output vs. input.

Consequently, when aiming to improve efficiency, two possible approaches suggest themselves:

(I) Achieving the same output with less input ("doing the same with less")

(II) Achieving more output with the same input ("doing more with the same")

Of course, there are hybrid cases, e.g. when you have to increase the input by 10% to grow the output by 20%, but for simplicity's sake we will subsume those scenarios under "doing more with the same", since the bigger change occurs on the output side. In power electronics, the key variable is electrical efficiency, which defines the ratio of useful power output to total power input. Depending on the complexity of the device under test, there might be multiple stages of power conversion, which can all be evaluated separately. The principle remains the same, overall efficiency is a result of the concatenation of those partial efficiencies.

Extending the scope

Precisely measuring those efficiencies under all kinds of circumstances and operational conditions is a key purpose and raison d'être of dedicated power analyzers. Typically, when comparing analyzers, the accuracy of efficiency measurements – especially for taxing applications like variable frequency drives and the like – is the key metric for judging the instrument. This is necessary, but not sufficient. Why not extend efficiency considerations to the measurement process and the instrument itself?

The question "What do we get out of it for our investment?" is a reasonable one to ask, also regarding the power analyzer itself. In that scenario, the output consists of the results obtained by measuring, while the input is defined by the necessary investment to arrive at those results. The term 'investment' is used in its broadest possible sense here, including time and effort as well as capital and operational expenses.

Power analyzers vastly differ in their number of channels, accuracy, bandwidth etc. For the purpose at hand, let us assume those models not capable of producing the target output with sufficient accuracy have already been weeded out. Thus, we can focus on the input side of measurement efficiency: the total investment required to generate the output.

Since power analyzers with similar specifications are generally in a similar price range, let us also exclude hardware costs from our considerations from here on. The bulk of the remaining investment is made up by the engineers' time to carry out the required

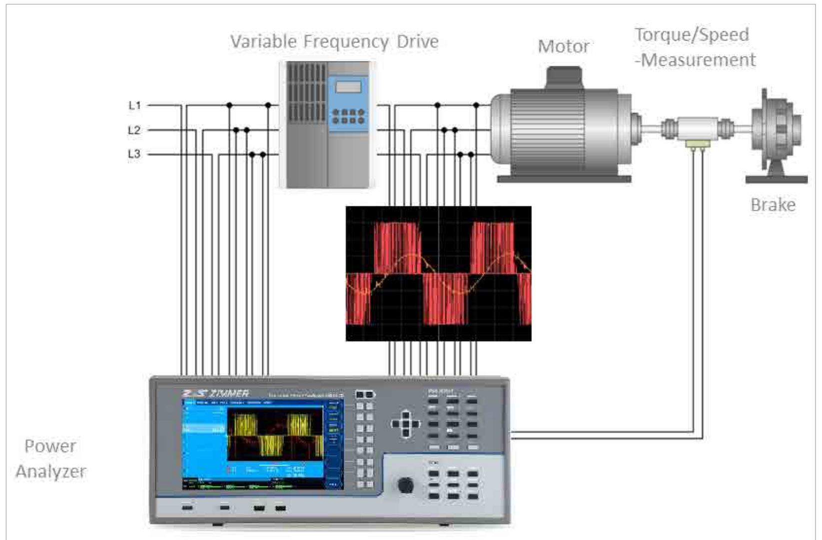

Figure 1: VFD power measurement setup

measurements. Generally, once the setup is completed, the largest influence on total measuring time is the number of measurements. Twice the number of unique operating points to characterize, twice the time.

There are certain scenarios, however, that demand at least twice the effort per point than others. Sometimes, it is required to repeat the measurement with exactly the same settings of the DUT. When does this occur, and is there a way to avoid it?

Analyzing variable frequency drives

A prime example is the analysis of electric drive systems, as depicted in the exemplary setup of **Figure 1**. In order to measure the total power output e.g. of a variable frequency drive (VFD), the measurement bandwidth should be as broad as possible in order to capture high-frequency byproducts of the switching frequency.

Figure 2 shows an example power spectrum of a frequency converter with harmonics of the switching frequency and other side effects on the right hand side. For those type of measurements, all available filters should be deactivated to avoid unnecessary truncation of the spectrum. Even the anti-aliasing filters (AAF)? Yes, since there is no danger of aliasing when determining power – this is an issue frequently misunderstood.

People often cite the Nyquist–Shannon sampling theorem, arguing that e.g. an analog bandwidth of 5 MHz is pointless with a sampling rate of 1MS/s, since all frequencies above 500 kHz are no longer accurately represented by the sample values. This is only half true: according to the theorem, you can no longer accurately reconstruct the original wave shape, if the sampling rate falls below half the signal frequency. The good news is: for power measurements you do not have to.

Power measurement with a digital power analyzer is a statistical process which can roughly be described as averaging over a large enough number of samples. You need to make sure you actually hit the wave at a sufficient number of points when sampling, and you also need to be careful not to always hit it at the same phase angle. The latter can be avoided by intelligent choice of the sampling rate in relation to the frequency of the signal. This is sufficient for correct power measurement, there is no need to reconstruct the exact shape of the signal. After all, there is an infinite number of different signals that all end up having the same power value.

Same DUT, different setup

Power is not the only relevant result when characterizing VFDs. For deeper analysis of the DUT's behavior, e.g. with respect to causes of power leakage and electromagnetic compatibility, harmonic analysis is inevitable. And all of a sudden the Nyquist–Shannon theorem becomes relevant. Statistical averaging is no longer good enough when it comes to judging the frequency distribution of the signal.

We can turn the above argument upside down and state that many signals with exactly the same

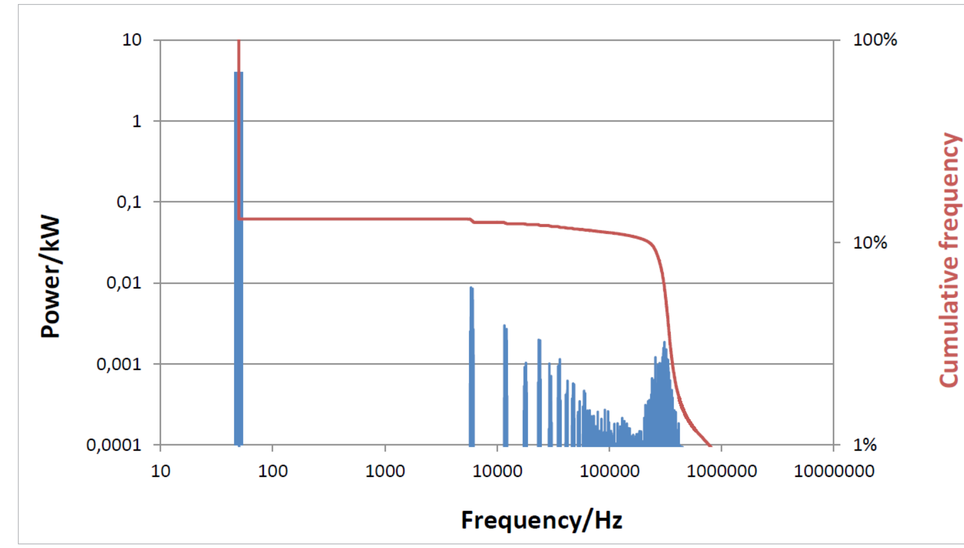

Figure 2: VFD power spectrum

power can have wildly differing spectra. In order to precisely measure the harmonic content of a given signal, we have to be very careful to eliminate any content with a frequency above half the sampling rate. Otherwise, that portion of the signal would be undersampled and erroneously reconstructed as lower-frequency content, thus distorting the true power spectrum.

Let us consider a VFD with a switching frequency of 40 kHz as an example, using a power analyzer with a 1 MS/s sample rate. By proper use of an AAF, any signal content above 500 kHz will be removed, and the remainder will be analyzed properly in accordance with the sampling theorem. Harmonic analysis is possible up to the 12th harmonic at 480 kHz. The results of the analysis will be free from aliasing.

Deactivating the AAF will create an entirely different picture: all frequencies above 500 kHz will be misrepresented. The 13th harmonic will appear at 480 kHz after sampling and thus erroneously added to the 12th. The 14th harmonic at 560 kHz will be interpreted as 440 kHz and thus added to the 11th harmonic, the 14th will be added to the 10th etc. In short: the results will be completely invalid. After sampling, there is no way to distinguish the true harmonics from the mirror images created by aliasing. Filtering at this point is useless, at least for the purpose of the prevention of aliasing.

Testing time vs. hardware cost

The above illustrates that if we want to obtain both power and harmonics results, we have to employ two mutually excluding instrument setups, one with and one without AAF. The most common approach is to start without filters for power measurement, and then to repeat the procedure with filters for harmonic analysis. "Repetition" has to be taken with a grain of salt, though, since it is as good as impossible to reproduce the exact same point of operation twice . An alternative is to measure the same signal on two power analyzers with different filter settings in parallel, but the cost for doubled measurement hardware renders this solution rather unattractive. Therefore, serial repetition is the most widespread approach.

While investing twice the time seems less painful than spending twice the money, it is still fairly inefficient, since there is a huge overlap between the two series of measurements – the only difference being initial activation or deactivation of the AAF. As the main purpose of using power analyzers is to reach new pinnacles of efficiency for the device under test, it is quite unsatisfactory to use a measurement procedure that is rather inefficient in itself. Therefore, we have often been challenged by our customers, most of whom share a predilection for efficiency, to find a way out of this dilemma.

It should be noted that it is not completely unheard of that the

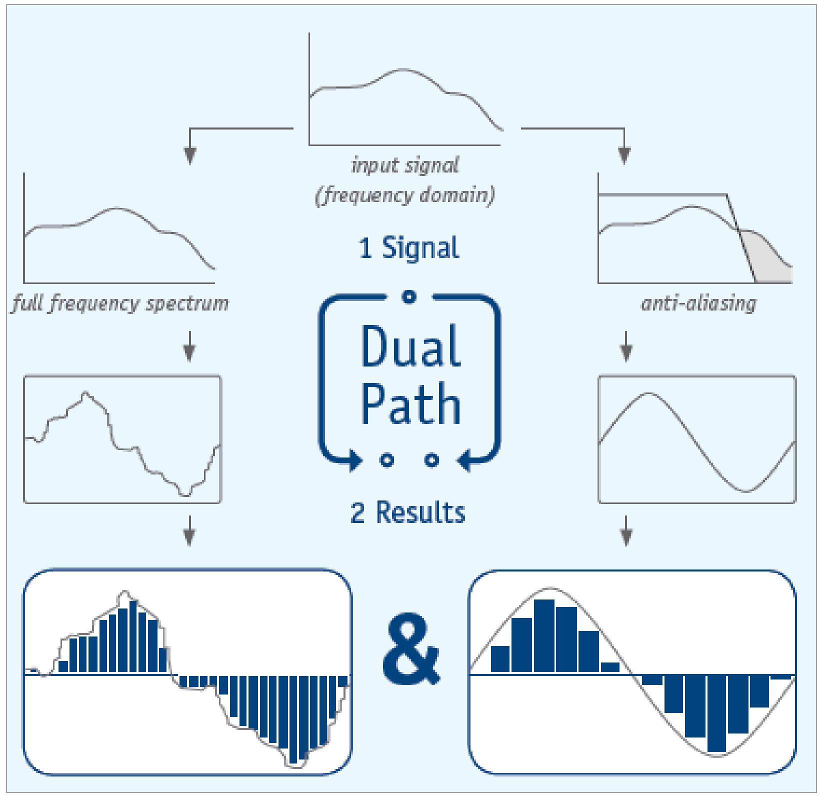

Figure 3: DualPath implementation of two completely independent signal paths

danger of aliasing gets consciously ignored, although such approach completely voids the purpose of precision power measurement in the first place. There is no point in choosing a sophisticated instrument while arbitrarily introducing an error of unknown magnitude to the measurements.

Engineering the solution

When designing our latest generation of power, it was clear to us that doubling all hardware components was out of the question, and it was also clear that the Nyquist–Shannon theorem presented a barrier not easily overcome. A closer look at the situation revealed, however, that the only functional part of the instrument required twice for taking both desired measurements at the same time was the sampling stage. All subsequent processing could be left mostly unaltered.

Instead of measuring with two instruments, it is sufficient to split the incoming signal, feed it into two independent analog-to-digital converters, and process the output accordingly. One of the signals thus obtained needs to be bandwidth limited before sampling in order to avoid aliasing, as described above in the section explaining the requirements of harmonic analysis.

We have named this novel architecture DualPath to highlight the hardware implementation of two completely independent signal paths already prior to sampling (see **Figure 3**). The placement of the AAF before the analog-to-digital converter cannot be emphasized enough, as the order cannot be reversed: it is not allowed to sample first and filter later, thus splitting the signal stream only after sampling. While this approach obviously would turn out cheaper in terms of hardware costs, it violates the Nyquist–Shannon theorem and produces the kind of measurement errors described in the paragraph about harmonic analysis.

A considerable impact

Returning to the initial reflections on efficiency in test and measurement, it is clear that a 50% reduction in measuring time has a considerable impact on the overall effort to obtain efficiency values for the DUT. While the time required for setup and configuration cannot be neglected entirely, it typically exerts a lesser influence.

Since efficiency measurements form part of a feedback loop implemented to optimize the design of the DUT, any reduction in test time directly results in more time to be spent on the actual design. Thus, improving the measurement efficiency of the power analyzer, as defined above, through better parallelization of measurements contributes to improved efficiency of the DUT itself.

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Power & EMC in the Medical space

Recent developments increase concerns in terms of interferences and equipment disturbance

By: Patrick Le Fèvre, Powerbox

Gadgets and vital connected devices in the Internet of Things (IoT) are everywhere, and we see them gradually changing our lives. The exponential development of products with embedding radio transmitters is creating some concerns in terms of interference and equipment disturbance, especially in the case of medical applications where it could have severe consequences!

Figure 1: Hospital operating theatre with Connected Devices

With the multiplication of products transmitting radio signals, it becomes very complex for medical equipment manufacturers to ensure their equipment is secure, using either published IEEE standards or proprietary protocols, which many are operating at unlicensed frequencies in the ISM (Industrial, Scientific and Medical) or in the MICS (Medical Implant Communication Service) bands to properly operate, without interfering in been interfered by other equipment.

Consequently, to ensure wireless coexistence in medicals applications, all over the world, regulatory bodies have focused efforts to standardize protocols and processes, which will require from power supplies manufacturers to include "Wireless Coexistence" testing and verification when designing power sources for medical equipment.

When unpredictable things happen

As the world would stop without reliable power, the power industry has a long history in building robust power systems. Industry permanently innovates new technology, improving energy efficiency, reliability, and safety throughout. Connected devices in medical applications, some powered by harvesting energy, are very sensitive to radio interference (whilst others might even get their power from radio-waves). The way we deal with power supplies and radio signals and need to be considered differently from our previous experiences; especially with medical equipment installed outside professional healthcare controlled environment, such as at home.

As the number of connected devices and radio transmission within medical environments increased, starting in 2010, the number of cases of medical equipment reporting false alarms, having random failures, or malfunctioning, has grown significantly, warning the medical community about the coexistence of multiple radio transmitting equipment that patients' lives might depend upon.

In many cases of reported faults, it was very difficult to pinpoint the exact cause, until in-depth investigations revealed radio interferences were the root cause of the problem. In the US, the Food and Drug Administration (FDA) records malfunctions in a central database "MAUDE", which includes a growing number of EMC problems.

When welding turns on an alarm

For example, a patient affected by respiration and heart problems was connected to a very advanced ventilator at home, coupled to a wireless cardio-monitoring. The patient's health was monitored from a remote healthcare center, which received a series of alarms. After calling the patient, who fortunately was doing very well, all alarms were classified as false, motivating the replacement of the monitoring units.

Despite replacing the system, it was still randomly signaling warnings! The equipment manufacturers conducted a thorough analysis, without finding either hardware or software issues. By coincidence, a Nurse visiting the patient noticed a strange noise coming from the radio and, at the same time the monitoring alarm came on.

Further investigation identified that a nearby industrial company was using a high energy welding equipment, which had a default shielding; radiating radio waves were interacting with the control loop of sensors, trigging alarms. This example is probably anecdotal, but is one of many motivating the medical industry to rethink electromagnetic interferences within the medical space, ensuring everything works smoothly and safely.

Hospital operating theatre

Considering the amazing evolution of tele-medicine, including remote surgery operated by robots, radio interference in medicals applications has become a high priority. **Figure 1** shows a hospital operating theater in which a number of strategic and vital equipment, including more and more connected devices.

Electricity signal cables, infusion pumps, echo cardiogram and anesthetic machines, physiological monitoring systems, pressure infusers, pacemakers, transit-time flowmeters, and even mobile phones and pagers are all generating radio signals, not to mention high-energy equipment such as plasma knifes and such that could generate electromagnetic interferences. In such environments, adding the IoT dimension makes it obvious that thorough procedures guaranteeing the electromagnetic compatibility and immunity to RF interference is a must, which the is what the IEC 60601-1-2 4th Edition (2014) is addressing to make the unpredictable more predictable.

IEC 60601-1-2 (2014)

With the need for intensive work and cooperation between the different players, including Power Supplies manufacturers, the International Electro Technical Commission (IEC) published a revision of the electromagnetic compatibility (EMC) requirements for medical devices under a 4th edition of IEC 60601-1-2 in 2014. These revisions contained a number of changes, including new immunity and more robust risk-analysis requirements.

Taking in consideration the growing number of connected devices, new radio frequency bands, and the risk of interference between different pieces of medical equipment, the revised standards include increased immunity test levels, with the range for radiated immunity, magnetic-immunity, conducted-immunity, as well as significant increases in electrostatic discharge (ESD) levels and voltage dips and interruption phase angles.

In addition, immunity testing has been added, which follows the rationale of 60601-1-11 (Collateral standard for Home Healthcare) in the form of immunity to proximity fields from RF wireless communications equipment at

	IEC 60601-1-2 3rd Edition	IEC 60601-1-2 4th Edition	
		Prof. Healthcare	Home Healthcare
ESD IEC 61000-4-2	8 KV Air Discharge (Max.) 6 KV Contact Discharge	15 KV Air Discharge (Max.) 8 KV Contact Discharge	
Radiated Immunity IEC 61000-4-3	3 V/m – Non Life Support 10 V/m – Life Support 80 MHz – 2.5 GHz 80% @ 2Hz (or 1 KHz) AM Modulation	3 V/m 80 MHz – 2.7 GHz 80% @ 1 KHz AM Modulation	10 V/m 80 MHz – 2.7 GHz 80% @ 1 KHz AM Modulation
EFT/Burst IEC 61000-4-4	±2 KV, 5KHz – AC Mains ±1 KV, 5KHz – I/O Ports 5 KHz or 100 KHz PRR	±2 KV – AC Mains ±1 KV – I/O Ports 100 KHz PRR	
Surges IEC 61000-4-5			
AC Mains, Line to Ground	±0.5, 1, 2 kV	±0.5, 1, 2 kV	
AC Main, Line to Line	±0.5, 1 kV	±0.5, 1 kV	
DC Input (>3m) Line to GND	No test	±0.5, 1, 2 kV	
DC Input (>3m) Line to Line	No test	±0.5, 1 kV	
I/O Line to GND	No test	±2 kV (outdoor lines only)	
Conducted Immunity IEC 61000-4-6	3 V (0.15 – 80 MHz) 10 V ISM Bands (Life Support)	3 V (0.15 – 80 MHz) 6 V ISM Bands	3 V (0.15 – 80 MHz) 6 V ISM Bands + Amateurs
Magnetic Immunity IEC 61000-4-8	3 A/m – 50 and 60 Hz	30 A/m – 50 and 60 Hz	
Voltages Dips And Interrupts IEC 61000-4-11	>95% dip, 0.5 periods, 0° and 180° 60% dip, 5 periods 30% dip, 25 periods Interrupt >95% drop, 5 seconds	100% drop, 0.5 periods, 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315° 100% dip, 1 period 30% dip, 25/30 periods Interrupt 100% drop, 5 seconds	
Proximity Field from Wireless Transmitters (NEW TEST)	No test	9 V/m to 28 V/m 15 specific frequencies	

Orange text highlights the changes from the Third Edition.

Figure 2: IEC 60601-1-2 4th Editions changes

significantly higher levels than have been used for radiated RF immunity testing in the past. The main goal of the 4th edition is to ensure that the medical practices aimed at saving lives are not disturbed by common EMC phenomena. By testing, verifying and certifying units according to the new standards, including collateral, products will become safer and secured to operate in harmony with others equipment.

What's new in the 4th edition?

Figure 2 summarizes the differences between IEC 60601-1-2 (2007) 3rd Edition and the (2014) 4th Edition, though major changes can be summarized in few points:

Used environments - Taking in consideration that medical equipment is operated in environments controlled and exposed to different risks, three categories have been identified. In the previous 3rd edition of the standard, the requirements were based on the purpose of the equipment. In the current 4th edition, the requirements are based on the intended use/ environment of the equipment:

- Professional healthcare facility environment (Hospital, Physician offices…)
- Home healthcare environment (Homes, Nursing Home, Public places…)
- Special Environment (Military areas, Heavy Industrial areas, High Power Medical Equipment)

In addition, the 4th edition introduces new definitions:

- Intended use (medical purpose only)
- Normal use (including medical use and transport, maintenance, standby)

EMC compliance

The EMC compliance tests and limits will be defined according to risk and intended use instead of a device type. Tests are based upon where the equipment will be operated in the three defined categories; Healthcare facility, at Home or in a Special Environment such as military, heavy industrial, or medical treatment area with high-powered medical equipment. All tests will be performed with "Intended Use." (Note: Manufacturers will

Figure 3: Low EMI external medical power supply Powerbox EXM30 to power IoT

need to prepare a test plan/risk analysis prior to testing. Clause 6.2 requires that an EMC test plan be provided to the EMC test lab).

Special environments

Considering the immunity test levels, higher or lower, than those specified for the professional healthcare and home environments might be appropriate, which has to be defined, during the design phase, in close cooperation with final user.

EMC risk management

Risk management analysis will be required from the medical equipment, including external power supplies manufacturers to state the risk from EMC disturbances. This test includes new frequencies and different levels depending on the category.

ESD level goes up

Products will be subjected to increased immunity test levels to minimize the risk of electromagnetic interference: for example, the ESD test levels are increased to 15KV air and 8KV contact and the levels of conducted immunity testing are now increased to 6v in the ISM frequency bands.

Wireless proximity

As a result of increased wireless equipment and strength of radiated signals, the radiated immunity test level is now up to 28V/m at certain frequencies. These levels have been raised to evaluate the products susceptibility to interference from common wireless devices. (Note: all products must comply with the new test).

Immunity levels

Very low flexibility to use lower immunity levels for compliance; the Annex "E" describes the process for determining the immunity test levels for products used in special environments where different immunity levels could be justified. To assist manufacturers to prepare their test plans, a guideline has been added in Annex "G" of the standard.

Implementation

IoT and Smart Connected devices continue to take the world by storm, even in the medical device industry, so it is essential that the industry adopts as quickly as possible the new standard. The fourth edition of the IEC 60601-1-2:2014 standard is out and the revision mandates compliance of new products by April 2017 in the USA though, in late 2014, the FDA issued a letter recommending that devices undergo EMC testing to the 4th standard as soon as possible. Taking in consideration the number of new Connected Devices addressing the medical space, as well the growing risk of interferences, it has been reported that the FDA is asking for compliance with the 4th Edition now; on new 510(k) applications.

In Europe, the withdrawal date of the 3rd Edition is expected in a 2017-2018 timeframe. The estimated compliance date of EN 60601-1-2:2014 was December 31st 2018. However, this date will be finalized upon the information being published in the European Official Journal though, considering FDA in US pushing for quick implementation, it could happen much earlier. After the published date, all medical devices sold to the EU must comply with the new standard.

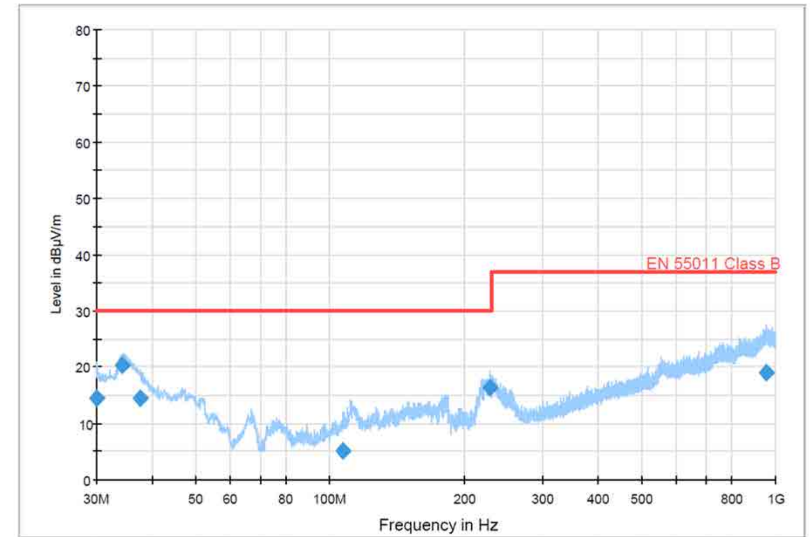

Figure 4: EXM30 Radiated EMI curves pushing down the limits

Powering IoT in medical space

Taking in consideration that EMC is very important when powering equipment, but even more important when supplying power to medical applications and medical IoT, power supplies manufacturers developed new technologies to reduce EMI, without having to package final product in heavy metal cases. Power switching units designed for self-contained EMI (see **Figure 3**) are now reaching the market; performing across all bands (30 MHz to 1 GHz) an average of 15 dB below the EN 55011 Class B (see **Figure 4**). Low EMI is very important when the power supply coexists with low power sensors, such the ones deployed in medical applications and reducing the level of EMI to almost no radiation at all, will require new technologies.

IoT devices in the medical world are being rapidly deployed, requiring the power industry to rethink the basic fundamentals of radio interferences and radio coexistence, which is exciting for power designers and opening up amazing fields of technological innovations.

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Active power management using fewer components

How integrated PMBus DC/DC regulators can simplify PoL configuration and control

By: Ramesh Balasubramaniam, Product Marketing Director, Infineon AG

Requirements to optimize efficiency and to address the complex power requirements of CPUs, ASICs and other sophisticated ICs are making active power management a critical design requirement in applications such as datacenter servers, embedded telecoms systems and networking equipment. At the same time, engineers tasked with designing power schemes are expected to keep board space to a minimum while reducing the time between initial concept and final product.

To address the challenges of active management, engineers are increasingly considering digital power schemes built around the PMBus specification, which offers a standardized platform for monitoring and controlling power management devices. And to address the real estate issue they are looking to implement these schemes with the lowest possible number of components. Highly integrated digital power converters with built-in PMBus support provide a way for designers to meet both sets of challenges.

DC/DC conversion design challenges

The typical distributed power architecture employed in servers and network infrastructure equipment comprises the AC/DC front end responsible for generating a DC voltage of typically 48 V in a datacom system (see **Figure 1**) and in some computer servers. This is fed into a DC-DC converter that supplies the 12 V or 5 V intermediate bus architecture (IBA) and the intermediate voltage is then distributed to multiple point-of-load (POL) converters on the board to provide the power rails for the ICs. Historically, the choice of 12V for the intermediate bus has been considered high enough to allow the power supply to satisfy the demands of the ICs on board, while incurring the lowest possible conversion and distribution losses.

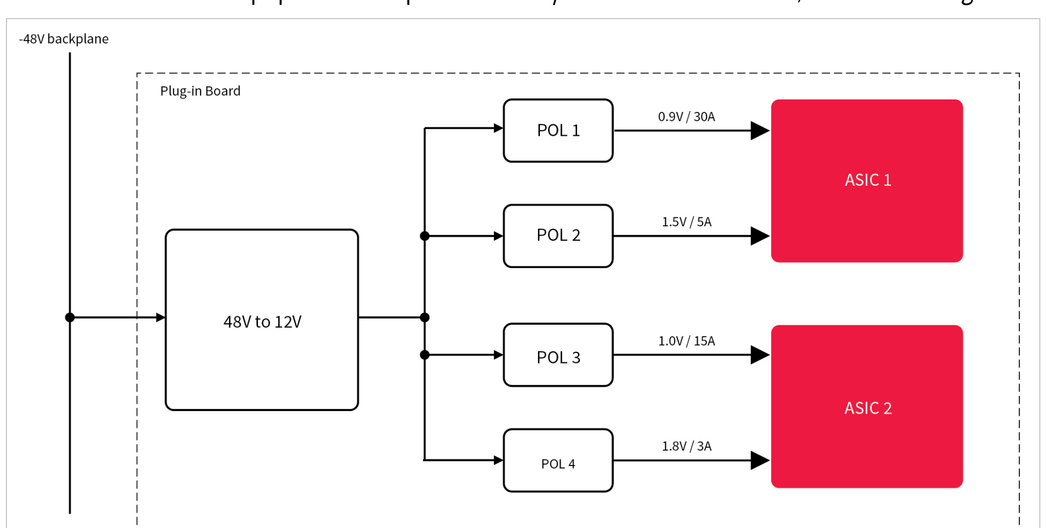

Figure 1: The intermediate bus architecture minimizes conversion losses, and is evolving to allow dynamic optimization of bus voltages

Now, however, a need for more flexible power distribution is emerging. The traditional IBA with fixed bus voltages is known to lose efficiency when the load on the converters is reduced at time of low compute demand or data traffic. At the other end of the scale the peak power consumption of server boards is increasing, driven by insatiable end-user demand for better and faster services.

Moore's Law scaling now allows designers to pack multiple high-performance processors within the confines of a standard-size server board. Experts are suggesting that peak power could exceed 5 kW per blade in the near future. Bearing in mind that today's network and datacenter operators are already concerned about power consumption as a major component of their overall operating costs, power supplies need to be able to adapt dynamically to ensure optimum efficiency at all load levels.

The power requirements of the major functional ICs of a typical board are also becoming more complex, partly driven by the push for greater computing performance. Today's multi-core processors, fabricated at advanced process nodes such as 20 nm or beyond, are capable of drawing significantly more than 100 A at core voltages of 1.0 V or lower, while also requiring I/O voltages such as 3.3 V or 2.5 V.

Moreover, board designers are also incorporating other devices such as complex ASICs or FPGAs to further accelerate performance within the constraints on board real estate imposed by fixed rack dimensions. These devices add further complexity to the demands placed on the power architecture.

Digital power

Digital power technology, which is capable of supporting techniques such as dynamic adjustment of intermediate bus and IC supply voltages, phase spreading, control over fault-protection settings, and telemetry, is now being deployed to meet the demands placed on next-generation power distribution. Moreover, the digital power design flow addresses engineers' demands for an approach that is more flexible and faster than traditional analog power supply design.

The ability to adjust parameters in firmware in order to optimize performance is a major strength of digital power technology. This optimization can be done throughout the design stages, as well as in real-time while the power supply is active, without needing to interrupt operation.

The Power Management Bus (PMBus) provides a unified and standardized means of monitoring the status of digital power converters and adjusting parameters in real-time. The PMBus specification defines a set of instructions that are conceived to allow communication with power management devices and designed to run on top of the SMBus (System Management Bus) data packet protocol. SMBus itself is based around the established I^2C physical layer protocol.

PMBus defines a total of 200 instructions for controlling various aspects of the power supply, and enables interoperability between devices from different manufacturers. The instructions are concerned with issues such as converter configuration, turn-on/turn-off and margin testing, fault management, sequencing, status interrogation, telemetry and commanding output voltages.

The instruction set is diverse and covers a wide variety of power conversion requirements, such as offline conversion or point-of-load conversion. Hence a given controller may support only a subset of the total number of instructions.

As demand grows for intelligent power management, PMBus is becoming increasingly adopted. The instructions allow much greater flexibility in the power supply, for example by allowing dynamic bus voltage adjustment (DBV) to optimize the intermediate bus voltage to ensure minimum losses at maximum or minimum load.

The latest PMBus specification

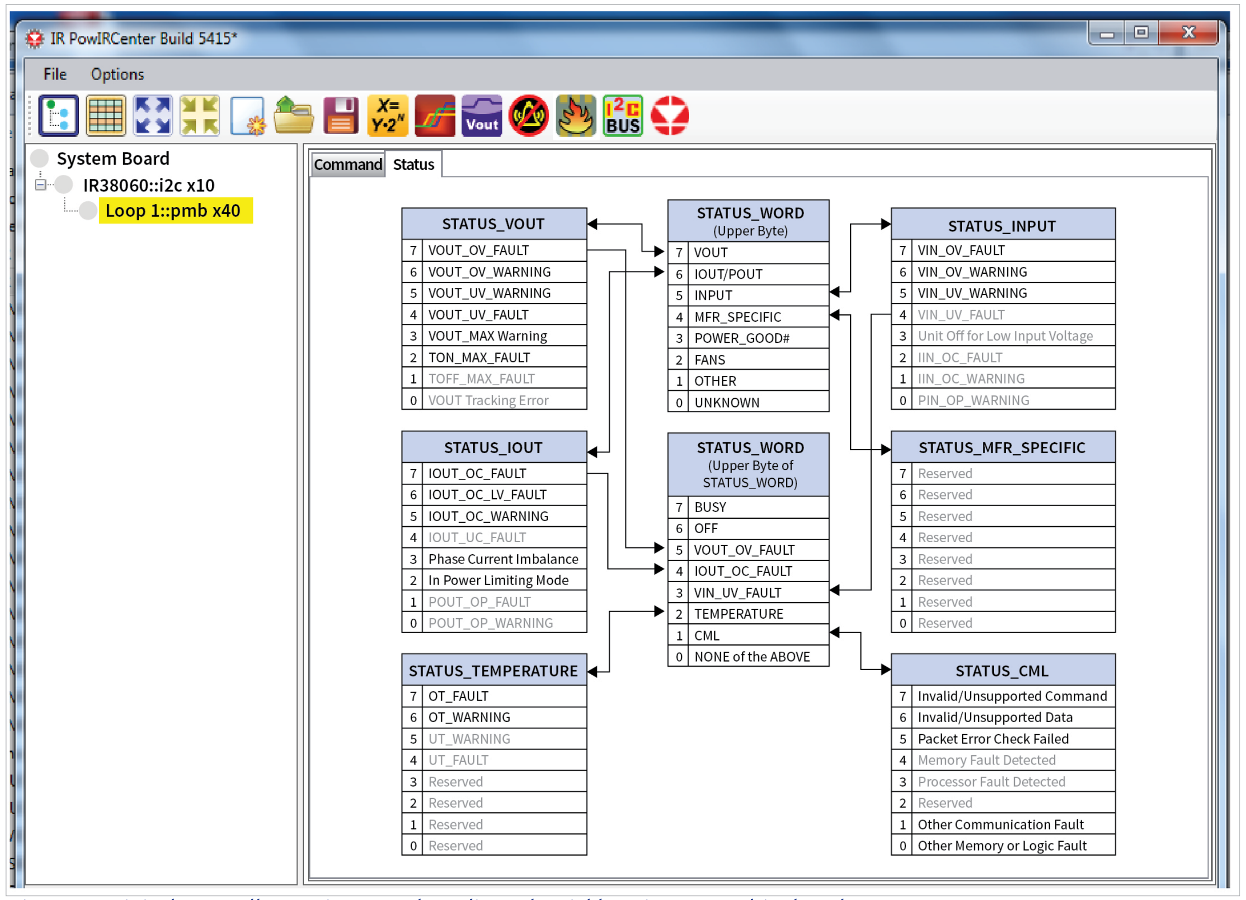

Figure 2: Digital controller settings can be adjusted quickly using a graphical tool

(version 1.3) introduces Adaptive Voltage Scaling (AVS), which supports the processor's ability to slow down its clock frequency and reduce the supply voltage autonomously and thereby minimize its own power consumption at times when the workload is light. This can deliver significant power savings, taking advantage of the quadratic relationship between voltage and power consumption in CMOS circuitry. At higher loads, AVS increases the operating voltage to permit faster switching of CMOS transistors. AVS also allows compensation for process and temperature variations in the processor.

In addition to the introduction of the 50 MHz AVSBus supporting adaptive voltage scaling, PMBus version 1.3 offers a number of further improvements such as a faster PMBus speed that allows increased data throughput, enhanced tracking of output voltages to inform warning thresholds, Fast Zone read/write for high-speed communication with high-priority devices, and a revised data format that allows higher precision over a wider range.

Faster digital power design

As well as the energy efficiency advantages that can be realized by taking advantage of the adaptability of digital power, developing and validating a digital power supply design is also faster compared to the traditional analog approach. The basic design can be accomplished quickly with the aid of software debuggers embedded in a development tool such as PowIRCenter to address and configure the controller internal registers via the PMBus connections.

Whereas debugging an analog design can be a time-consuming process that obliges the engineer first to ascertain the reason the power supply may be shutting down, the GUI-based digital approach allows fault status to be easily read and changes made on the fly to adjust the design, optimize fault-protection settings and make any necessary revisions to system fault behavior (see **Figure 2**).

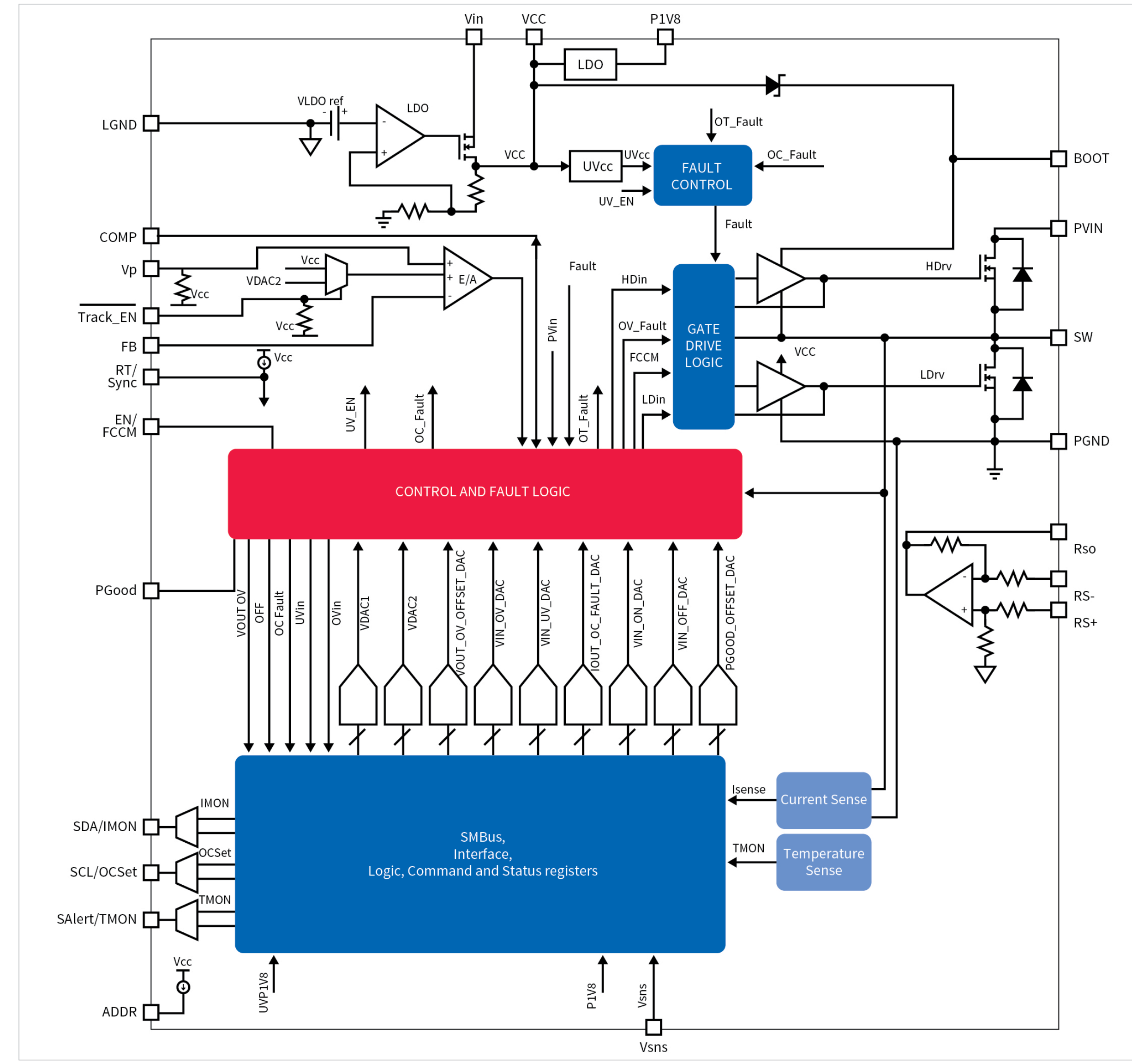

Figure 3: Block diagram of Infineon IR38060/IR38063 synchronous buck regulator with PMBus interface

Optimization and characterization are similarly fast and efficient, making it possible to finalize the validated power system design within about one week compared with the typical timeline of about six weeks for a conventional analog design.

The faster project cycles and simplified design approach enabled by digital power delivers greater advantages as system complexity increases. For example, powering a large FPGA that requires many supply rails at different voltages and power ratings, and even with different tolerances, presents complex challenges for which few tools are available to help accelerate a conventional analog design flow. With digital controllers and configuration tools, the task can be approached confidently and completed within a significantly shorter timeframe.

The flexibility of the digital controller also makes it possible to

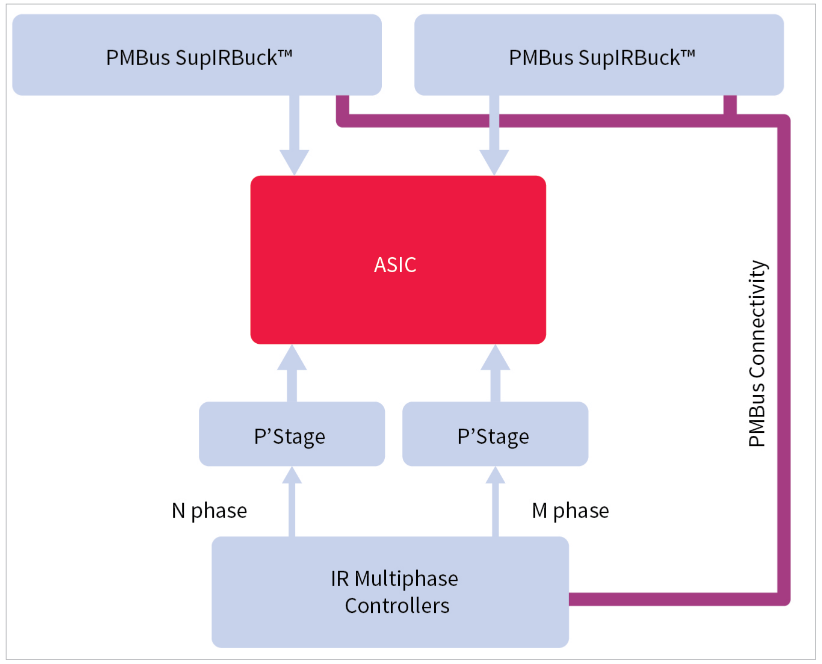

Figure 4. Integrated PMBus-compatible POL converters minimize the board space needed to supply multiple power rails

apply system updates in the field, whereas a conventional power system would require substantial hardware modification involving equipment recall and down time.

Integrated PMBus-compatible converters

For example, Infineon has now gone one step further with its fully integrated SupIRBuck family of synchronous buck regulators for digital POL applications. As shown in **Figure 3**, these regulators combine the PMBus controller with built-in high-performance control and sync FETs in the same package, saving around 70% of board real-estate over a comparable discrete circuit comprising a separate controller IC and output stage.

Infineon's IR38060, IR38062, IR38063 and IR38064 integrated buck regulators with PMBus interface are able to supply up to 6 A, 15A, 25A or 35 A respectively, taking advantage of synchronous rectification for optimum efficiency and are housed in thermally-enhanced 5 mm x 6 mm (IR38060) or 5 mm x 7 mm (IR38062/3/4) PQFN packages. A family of PMBus-compatible multiphase controllers is also available, allowing designers to quickly implement space-efficient, scalable and digital power management schemes for complex ICs requiring even higher currents as illustrated in **Figure 4**.

All parameters of the controller are set via firmware that is stored in non-volatile memory, giving the engineer control over areas such as number of phases, switching frequency, frequency response, dynamic voltage change, and fault and protection features including over-current and over-voltage protection.

Telemetry data is made available via the PMBus, including output voltage, high-accuracy output current data for individual phases, and total current, power stage temperature, controller temperature, input voltage, and input current. This data is useful both during debug and during normal operation. Because the PMBus supports two-way system communication, these control parameters can be modified in the deployed system.

Looking forward

Digital power holds the key to achieving the level of in-system adaptability essential for meeting the energy efficiency demands of tomorrow's data communication and networking industries. It is also the way power supply designers will be able to deliver new designs within tight turnaround times and cost constraints.

The PMBus specification provides a versatile instruction set for exercising the features and taking advantage of the adaptability of new digital controllers. The latest generation of integrated PMBus-compatible converters that combine the control IC and high-performance power stage in the same package deliver ease of use and flexibility in an extremely space-efficient solution.

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Special Report: Internet of Things (IoT)

NORTH AMERICA
Power Systems Design: Empowering Global Innovation

INSIDE:

Low Power is Key for IoT

The Internet of Things (IoT) has increased the demand for small, compact and efficient power converters

By: Tony Armstrong, Linear Technology

The proliferation of wireless sensors supporting the Internet of Things (IoT) has increased the demand for small, compact and efficient power converters tailored to un-tethered lower power devices. One of the more recent emerging market segments covered under the IoT that is particularly interesting from an energy harvesting perspective is the wearable electronics category.

In addition, wearable technology is not just for humans, there are many applications for animals, too. Recent examples include ultrasound-delivering treatment patches and electronic saddle optimization for horses to collars on other animals that variously track, identify, diagnose and so on. Nevertheless, regardless of the end application, most of these devices require a battery as the main power source even if it will be augmented with an ambient energy source provided one is available.

Power dressing

However, for human-based applications, it looks like there will soon be wearable fabrics that can generate electricity from different forms of ambient energy that might only require a small primary battery as a back-up source. These free energy sources include body temperature generation, photovoltaic sources such as indoor lighting or even just plain old daylight, as well as kinetic energy sourced from regular body movements.

A fitting term might be to call them "power suits!" One company at the forefront of such research is the European Union funded project Dephotex, which has developed methods to make photovoltaic material light (as in weight) and flexible enough to be worn. Naturally, the material will convert photons into electrical energy, which in-turn can be used to power various electronic devices worn by the user, or to charge their primary batteries, or even a combination of both.

Similarly, at the low end of the power spectrum there are nanopower conversion requirements for energy harvesting systems such as those commonly found in IoT equipment (think Google Glass) which necessitate the use of power conversion ICs that deal in very low levels of power and current. These can be 10s of microwatts and nanoamps of current, respectively.

State-of-the-art and off-the-shelf Energy Harvesting (EH) technologies, for example in vibration energy harvesting and indoor or wearable photovoltaic cells, yield power levels in the order of milliwatts under typical operating conditions. While such power levels may appear restrictive, the operation of harvesting elements over a number of years can mean that the technologies are broadly comparable to long-life primary batteries, both in terms of energy provision and the cost per energy unit provided.

Moreover, systems incorporating EH will typically be capable of recharging after depletion, something that systems powered only by primary battery cannot do. Nevertheless, most implementations will use an ambient energy source as the primary power source, but will supplement it with a primary battery that can be switched in if the ambient energy source goes away or is disrupted.

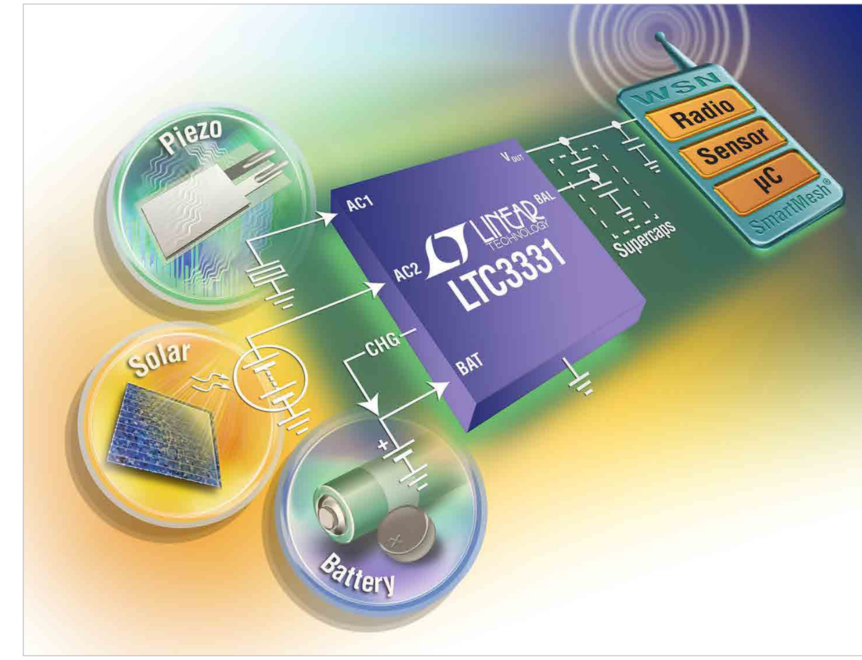

Figure 1: The LTC3331 converts multiple energy sources and can use a primary rechargeable battery

Solutions

Of course, the energy provided by the energy harvesting source depends on how long the source is in operation. Therefore, the primary metric for comparison of scavenged sources is power density, not energy density. EH is generally subject to low, variable and unpredictable levels of available power so a hybrid structure that interfaces to the harvester and a secondary power source is often used. The secondary source could be a re-chargeable battery or a storage capacitor (maybe even supercapacitors).

The harvester, because of its unlimited energy supply and deficiency in power, is the energy source of the system. The secondary power reservoir, either a battery or a capacitor, yields higher output power but stores less energy, supplying power when required but otherwise regularly receiving charge from the harvester. Thus, in situations when there is no ambient energy from which to harvest power, the secondary power reservoir must be used to power the down-stream electronic systems. For example, Linear has introduced a number of power conversion ICs which have the necessary features and performance characteristics to enable such low levels of harvested power to be used in IoT.

The LTC3331 is a complete regulating EH solution that delivers up to 50mA of continuous output current to extend battery life when harvestable energy is available (see **Figure 1**). It requires no supply current from the battery when providing regulated power to the load from harvested energy and only 950nA operating when powered from the battery under no-load conditions. The LTC3331 integrates a high voltage EH power supply, plus a synchronous buck-boost DC/DC converter powered from a rechargeable primary cell battery to create a single non-interruptible output for energy harvesting applications such as IoT devices, wearables and wireless sensor nodes (WSNs).

The LTC3331's EH power supply, consisting of a full-wave bridge rectifier accommodating AC or DC inputs and a high efficiency synchronous buck converter, harvests energy from piezoelectric (AC), solar (DC) or magnetic (AC) sources. A 10mA shunt enables simple charging of the battery with harvested energy while a low battery disconnect function protects the battery from deep discharge. The rechargeable battery powers a synchronous buck-boost converter that operates from 1.8V to 5.5V at its input and is used when harvested energy is not available to regulate the output whether the input is

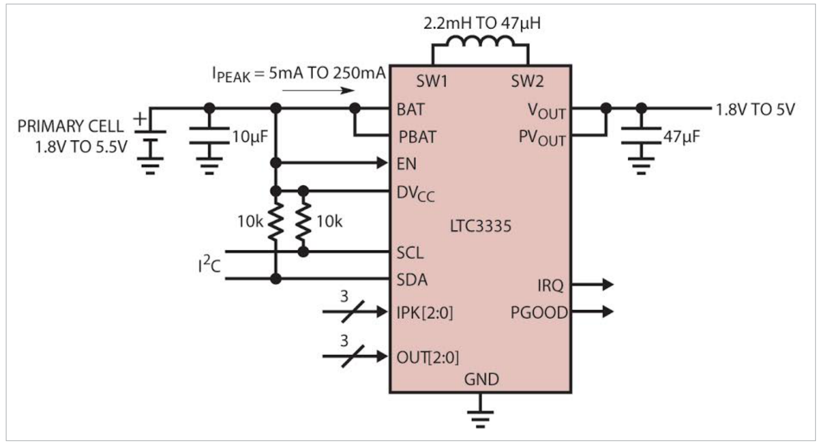

Figure 2: Typical application schematic for the LTC3335 nanopower buck-boost converter

above, below or equal to the output.

The LTC3331 battery charger has a very important power management feature that cannot be overlooked when dealing with micropower sources. The LTC3331 incorporates logical control of the battery charger such that it will only charge the battery when the energy harvested supply has excess energy. Without this logical function the energy harvested source would get stuck at startup at some non-optimal operating point and not be able to power the intended application through its startup. The LTC3331 automatically transitions to the battery when the harvesting source is no longer available. This has the added benefit of allowing the battery operated WSN to extend its operating life from 10 years to over 20 years if a suitable EH power source is available at least half of the time, and even longer if the EH source is more prevalent. A supercapacitor balancer is also integrated allowing for increased output storage.

Since harvested energy from wearables is very low, meaning nanoamps to milliamps, it is imperative that any DC/DC conversion uses as little power as possible in order to ensure optimum energy transfer. Thus, to attain such a strict objective, the DC/DC converter itself must consume current in the order of nanoamps. It was because of this that Linear Technology introduced the LTC3335 – a nanopower buck-boost DC/DC converter with an integrated coulomb counter aimed at WSN's IoT products, wearables and general purpose energy harvesting application (see **Figure 2**).

The LTC3335 is a high efficiency, low quiescent current (680nA) converter. Its integrated coulomb counter monitors accumulated battery discharge in long life battery-powered applications. This counter stores the accumulated battery discharge in an internal register accessible via an I^2C interface. The buck-boost converter can operate down to 1.8V on its input and provides eight pin-selectable output voltages with up to 50mA of output current. To accommodate a wide range of battery types and sizes, the peak input current can be selected from as low as 5mA to as high as 250mA and the full-scale coulomb counter has a programmable range of 32,768:1.

Its integrated precision coulomb counter monitors the accumulated charge that is transferred from a battery whenever the buck-boost converter is delivering current to the load. The buck-boost converter operates as an H-Bridge for all battery and output voltage conditions when not in sleep mode (see **Figure 3**).

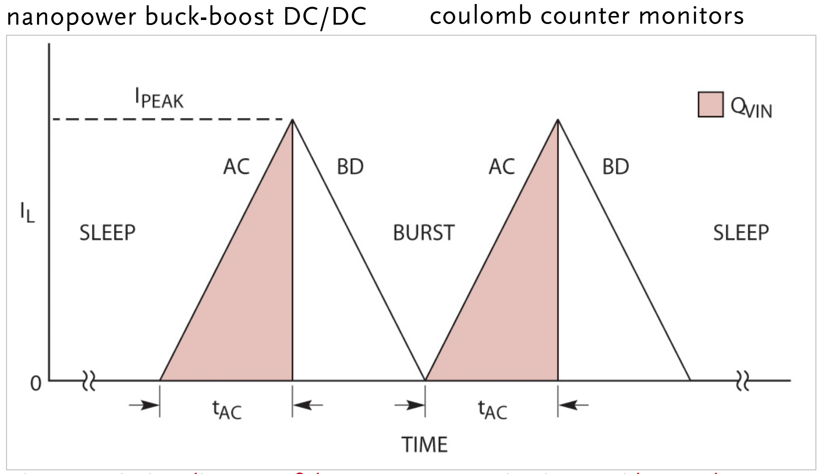

Figure 3: Timing diagram of the LTC3335 operating in H-Bridge mode

Switch A and C turn on a the beginning of each burst cycle. The inductor current ramps to Ipeak and then switches A and C turn off. Switches B and D then turn on unitl the inductor current ramps to zero. The cycle repeats until V_{out} reaches the sleep threshold. If I_{peak} and the switch AC(ON) time (t_{AC}) are both known, then the BAT discharge coulombs (shaded area in Figure 3) can be calculated by counting the number of AC(ON) cycles and multiplying by the charge per AC(ON) given in the formula below:

q AC(ON) = (Ipeak * tAC)/2

When the buck-boost is operating, the LTC3335 measures the actual AC(ON) time relative to the full scale ON time (t_{FS}, approximately 11.74µs) which is internally adjusted to compensate for errors in the actual selected I_{peak} value due to supply, temperature and process variations. This results in a very accurate "measurement" of the charge transferred ofrm the battery during each AC(ON) cycle.

Looking forward

It is clear that there will be numerous WSNs, wearable and IoT products which will need nanopower DC/DC conversion and coulomb counting to assure their optium performance and longevity. However, it is only recently that such products have become avaible on the market. Thanks to suppliers such as Linear Technology, there will be lots of options open to the designers of nanopower devices to choose from.

www.linear.com

Energy harvesting will fuel the 4th industrial revolution

The ability to operate without wires or batteries is significant

By: Matthieu Chevrier, Texas Instruments

Today's zeitgeist – or spirit of the age – within factory automation and process control professionals is to move towards "smart factories," often referred to as the upcoming fourth industrial revolution. If we look at previous industrial revolutions in order to help prepare for the next one, a pattern emerges.
In each revolution there was a combination of a new organization of information with a new source of energy. Examples through history include mechanical weaving looms with steam engines, the production line with oil, and robots with electricity.

The challenge that the new energy source needs to address is that of scalability. Manufacturers have a sea of devices spread over multiple factory sites and plants, and all need power at each location. Incumbent solutions using wires and batteries fail to answer this new challenge. Fortunately, the new energy source that will fuel the fourth wave of industrial revolution is already known – energy harvesting.

What is energy-harvesting?

Energy harvesting is an umbrella concept for self-powered systems which produce their energy from ambient sources. Amongst the possible ways to power a system are sunlight, indoor light, pipes with hot fluids flowing, pumps and motor vibrations, the list is almost endless. Energy harvesting generates power for the system where it is needed, it eliminates the need for more cables and increases reliability in applications where cables can lead to system issues caused by heavy vibrations (pumps), or systems with hinges (robots).

Energy harvesting also improves upon battery-powered radio systems. Process control equipment vendors have online simulators for their wireless highway addressable remote transducer protocol (WHART) products showing that battery lives can be as low as a few months. With energy-harvesting-powered devices, there is no need to send a technician anymore. Additionally, because energy harvesting technologies have wider temperature ranges than batteries, the system can be deployed in places with extremely low temperatures where batteries simply cannot function.

Maturity of energy harvesting

Despite all of its benefits energy harvesting has not yet crossed the chasm to reach its full potential. The two main reasons are economics and technical. On the economic side one has to look at a simple CR2032 battery, which can provide 200 mAh (2600J) for a few cents in high volumes. Amorphous photovoltaic (PV), or today's most mature energy harvesting technology, can provide 5 µW for 20 years and more (3000J) under reading light conditions (200 lux). This is a fraction of the battery's cost, and dye-sensitized solar cell (DSSC) / organic PV (OPV) offer the potential for even further reductions. Batteries are still the main technology today because, for shorter periods of time (say five years and power consumptions above 20 µW), batteries are still more cost-competitive.

As the system's average power goes down and expected life time goes up, energy harvesting is making its way into more markets. However, beyond economics, another challenge is on the technical forefront. It is the need for the full system design to achieve an economically viable solution.

While extremely talented designers are coming out of our universities, finding designers capable of assessing how much light energy is available on an average factory floor, or the amount of heat generated by a pipe in an oil factory, is a much higher challenge.

Designing for energy harvesting

Designing for energy harvesting is an incremental process. It involves engineers working hand in hand on the harvester and system electronics. On the harvester, two key aspects are critical to the success of the full system. Firstly, you have to select an energy harvester that provides the maximum amount of energy in a given environment, which is a function of the actual energy source.

For instance, a factory floor lit by LED or fluorescent lights has a spectrum that allows a DSSC/OPV panel to give more than twice as much as a c-Si panel [1] with the same active area. Alternatively, to monitor the outdoors of a chemistry plant will require a crystalline silicon (c-Si) panel to match the sunlight spectrum.

On the harvester's electrical output side, understanding its electrical parameters is key to ensure that the power management impedance matches that of the harvester. For a PV, dynamic impedance adjustment is key [1, 2].

Secondly, another key parameter is to understand the dynamic changes in the power source and how to adjust according to the power source's sampling rate. Indeed, being able to enable or disable harvesting power management based on input power availability is a further critical step to achieve total system efficiency.

An example of such a design is available in reference [3].

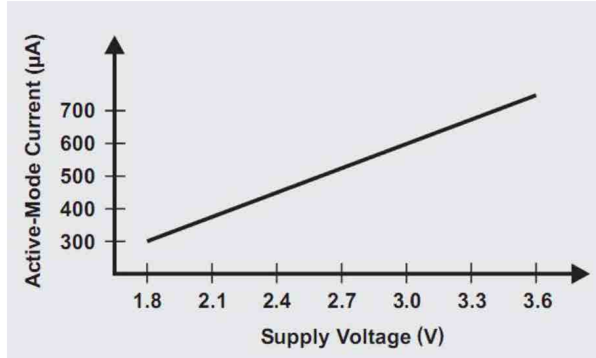

Figure 1: Two key parameters for optimizing current consumption for energy harvesting systems

Driving a low-power microcontroller

On the application side, let us look at a couple of practical examples. **Figure 1** shows two key parameters for optimizing current consumption for energy harvesting systems. The active-mode current measurements depend on the voltage supply measurements, which are taken using a microcontroller.

The easiest way to power a microcontroller (MCU) is to power it directly from a 3.6V battery using **Figure 1** leads to this equation:

$$P_A=3.6*700\mu A=2.5mW$$

If, however, we adapt the equations from reference [4] to an MCU powered by a nanopower buck convertor (like in the bq25570 or TPS62736), we get **equation 2**. Comparing **equation 2 and equation 1**, we observe a reduction by a factor of more than double the total power dissipation.

$$P_A=V_{Batt}*I_{QDCDC}+V_{SOC}*I_{SOC}=3.6V*0.3\mu A+2.2V*\frac{400\mu A}{\eta*V_{Batt}}=900\mu W$$

As a result, powering a low power MCU from this type of nanopower buck convertor brings significant gains.

Electronics optimization – reduce sleep current with a nanotimer

Another important aspect for low duty cycle systems is to optimize power consumption in "sleep" mode, in other words, when no processing is needed. For years the best practice was to run the MCU in real-time clock (RTC) mode as it was the lowest power mode possible which periodic wake-up was enabled.

A new family of devices, nanotimers, were released to further improve the total power consumption. The benefits are best highlighted when comparing a typical low-power sensor (see **Table 1**). In our example standby power is reduced by a factor of nearly three, a wake-up cycle of every second still leads to a gain of more than 25 percent!

SYSTEM 1	Normalized (1 sec)	SYSTEM 2 WITH TPL5000	Normalized (1 sec)
MSP430 active (1MHz at 3V)	1.58E-08	MSP430 active (1MHz at 3V)	1.58E-08
MSP430 in LPM3	6.00E-07	MSP430 in LPM4.5	1.00E-07
Op amp	1.55E-08	Op amp	1.55E-08
ADC ref	5.96E-09	ADC ref	5.96E-09
ADC core	1.56E-09	ADC core	1.56E-09
IRLED	1.26E-06	IRLED	1.26E-06
TPS61040	1.00E-07	TPS61040 in shut down	1.00E-07
--		**TPL5000**	5.00E-08
Total	2.00E-06	Total	1.55E-06
Standby current	7.00E-07	Standby current	2.50E-07
Lifetime	**8 years**	**Lifetime**	**10 years**

Table 1: Current consumption curves.

A practical implementation of such a low-power system based on nanotimers and achieving 60 nA average power consumption while still reacting to input changes is available in reference [3].

Looking forward

While the data management changes coming are getting increasingly clear for factory owners and plant managers (cloud computing, big data, machine learning, and many others) the energy source required to make this sea of sensors and actuators is still reserved to a few niches.

It is my experience that the perceived technical challenges are now more related to the difficulties to get access to the relevant expertise, rather than inherent technical or commercial challenges. As this expertise becomes more available, the rate of adoption will continue to accelerate. The fourth industrial revolution is just around the corner!

www.ti.com

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IoT remote energy monitoring

A procedure using LEM Split-Core CT (TOP) following the IEC 61869-2 Smart Grid standard

By: Patrick Schuler, LEM

IoT is perfectly suited for smart grid roll-out, thanks to the long range requirements and the small data size needed for transmission. Using narrow-band RF, the standard for long-range communication, an innovative remote energy monitoring solution is now possible.

The solution consists of wireless energy meters for the remote monitoring of electrical equipment with hardware, M2M connectivity (LORA, SIGFOX, 3G/GPRS...) and web services to manage the collected data (history, alerts, graphs, statistics, etc.). This IoT solution simplifies the implementation of the network and installation by the end-user, reduces infrastructure costs (no repeaters) and is typically compatible with existing solutions.

This approach is ideal for IoT due to the small power payload, the long range requirements and the small data size needed for transmission. The IoT star network configuration is typical for smart grid deployment.

Energy monitored apps

The typical application for energy monitoring is to identify energy consumption balance and overconsumption analysis to pin point the areas to repair. In **Figure 1**, each wireless energy meter (1), using in this example a LEM TOP (A) or LEM RT(B), is connected to the RF long range internet (2) and transmits (3) maintenance data to a secure web server (4). End-users can follow equipment usage remotely (cycles, working time, consumption, etc.) or receive alerts when an anomaly is detected, such as loss of power or power peaks (5).

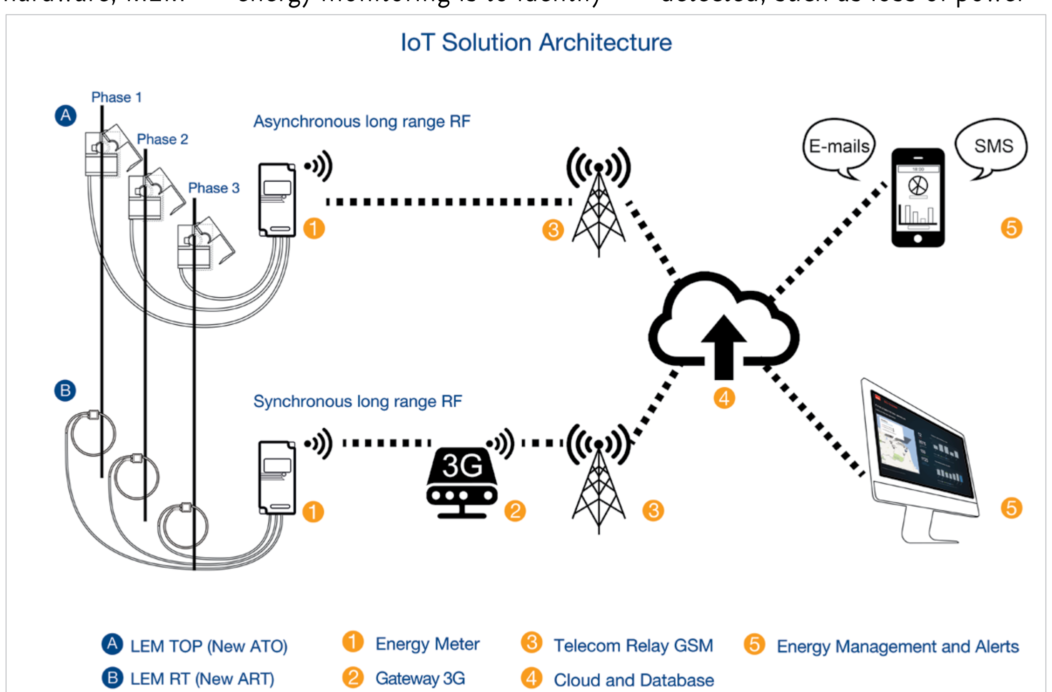

Figure 1: Energy monitoring identifies energy consumption balance with overconsumption analysis to pin point the areas to repair

The typical devices that have their energy measured are items with electrical motors, ventilators, pumps and compressors. The advantages of this solution are the simplicity of installation of a device such as the the LEM TOP or LEM RT, the connection over the internet, the real time measurements and the autonomy of the energy meter. The operating mode is RMS current acquisition of 1s every 10s and sends current consumption statistics every 10 minutes or 15.

The advantages of IoT based Remote Energy Monitoring are:

- No need for deploying a local network infrastructure
- Outdoor and indoor equipment monitoring
- Wide area coverage
- Very low energy consumption resulting in long lasting autonomous energy meters
- Affordable and deployable with LEM TOP or LEM RT sensors

Following IEC 61869-2

Split-core current transformers are not new, but conventional technologies used in these transformers have presented numerous shortcomings - among these were solutions using either expensive materials or providing poor performance. In this case, inaccuracy refers not to the readings themselves, but to the linearity, the sustainability of a reading over time and the accuracy of the current compared to the voltage (phase shift). The new Smart Grid IEC 61869-2 standard requires both accuracy AND phase shift to be within Class 1.

For example, the LEM split-core current transformer "TOP" with Ferrite can dramatically improve the magnetic permeability, enabling such transformers to have high accuracy and excellent linearity even at very low current levels following IEC 61869-2. The hardness of the solid material (consider Ferrite as a ceramic) allows very fine machining, providing air gaps down to a few microns that are stable over many years.

Laminated materials such as FeSi or FeNi do not allow air gaps smaller than 20 or 30 microns, and these are more sensitive to ageing and temperature changes. Add the small air gaps to the better linearity of the Ferrite at low magnetic excitation (i.e. for low current), and the Ferrite offers a better performance than FeNi-80%, and at a lower cost (see **Figure 2**).

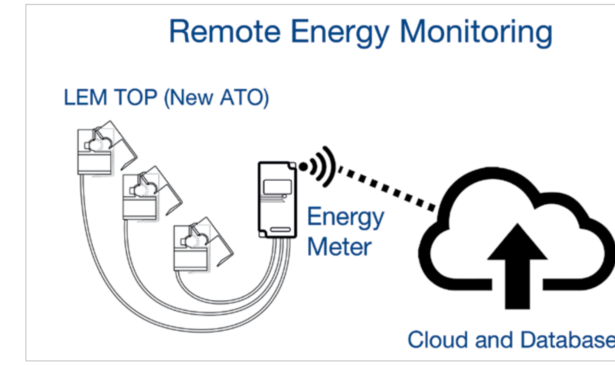

Figure 2: Ferrite offers a better performance than FeNi-80% at a lower cost

Final thoughts

IoT-based remote energy monitoring has an average amortization period of less than one year. Maintenance operators spend 30% of their work time on the road and any repair needs usually two to three trips, so this kind of solution saves time. Some sites or plant equipment are difficult to access (waste of time and risk to the operator) and there is no way to add solid core transformers without a costly shut-down of the system.

A device like the LEM contactless split-core self-powered current transformer TOP can simply be snapped over a cable, without the need to screw or weld on complex brackets, making installation and maintenance straightforward.

The IoT set-up combined with the IEC Smart Grid LEM TOP allows for immediate retrofitting of high-performance and cost-effective remote monitoring, energy metering and facility supervision systems.

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Overcoming IoT risks for businesses

Dealing with concerns over exposure to harm

By: Sue Moore, Laird

In the race towards the Internet of Things, some businesses are being left behind. In particular, companies that focus on critical supply chains have too much to risk by opening up their systems to the Internet. For them, one compromised machine could mean that the food, pharmaceuticals, energy, water or critical supply that millions depend on might be tampered with and subsequently destroyed. Or worse, the products actually evade detection and are introduced into the public supply.

All of the gains that could be provided by the Enterprise IoT (EIoT) are not enough for many to overcome the severity of these risks of exposure to harm. This means the productivity gains that can be realized by a connection to the resources (people and machines) in a plant can be achieved only if properly implemented in a manner that addresses their needs (see **Figure 1**). As a result, the processes needed to drive performance (like Six Sigma) are only as good as the systems that can be put into place to monitor processes and supply chains and the data that can be collected.

Disruptions create instability

Plant responses are delayed, and operations end up being easily shaken, by disruptions in supply and demand. To overcome the stability problems, companies resort to larger plants and batches that rely on fixed resources which lead to generic products, warehousing and distribution issues.

Large plants with fixed installations turn into more expensive fixed machinery, and integration costs that are becoming a larger part of the plant cost. ROI is measured in years, if it even happens.

If the data available through the EIoT were made securely available to these supply chains, it is easy to see how improvements could quickly be made with regard to efficiency, reliability, and employee safety.

How then can the risks related to deploying EIoT be eliminated? There are steps that can be taken to address these issues.

Security

Get your network away from the well-known standards that are targeted, and into strategies that make security possible.

- Use wireless as part of the network media... not WiFi, but layered protocols over wireless that are too complex to hack (S99 appendix).
- Install data packages tailored by Laird so that the security of that data remains uncompromised (S95).
- Use specific hardware interfaces to secure network from common devices (like Smart Phones, etc).

Reliability

Once a business has decided to deploy the EIoT in a plant, what kind of performance can they expect from the system? Are there guarantees that they can rely on?

- Systems with a dedicated wireless backbone using multiple transmission frequencies to make sure networks are never lost.
- Site surveys to verify that coverage is complete and interference is minimal.
- FCC licensed frequencies to insure that bandwidth is of the system has been validated, interaction with machines can begin to improve data collection and empower productivity and safety.
- Minimizing the motion interactions between humans and infrastructure so that each can do what they are best at.
- Be able to Stop/Start/Monitor lines at a safe distance with remote controls
  - o A fork truck driver can start a moveable pallet wrapper via 13849 remote.
  - o A line operator can stop a jammed machine within a safe zone remotely saving time, product and money.

Figure 1: Any IoT solution must address business needs

Safety

- Powering machines with radio based Safety MCUs to solve the integration issues that come from discrete estop installations.
- Provide machine and SCADA level mobile estops (better coverage for lines with long conveyors).
- Multiple e-stops to provide redundancy in multi user applications (like threading a redeployment of assets in a factory with data being instantly available via wireless.
  - o Monitor and adjust the production time available by all assets
  - o Find weaknesses in your process, allowing improvements and immediate feedback.

(Not to mention doing all of this with a reasonable Return on Investment so that adoption is rapid.)

Notes:

- ANSI/ISA-95, or ISA-95 as it is more commonly referred, is an international standard from the International Society of Automation for developing an automated interface between enterprise and control systems.
- Formerly designated ANSI/ISA-99.02.01-2009, this standard is part of a multipart series that addresses the issue of security for industrial automation and control systems. It has been developed by Working Group

This standard has been developed in large part from a previous Technical Report produced by the ISA99 committee, ANSI/ISA–TR99.00.02–2004, Integrating Electronic Security into the Manufacturing and Control Systems Environment. The majority of the contents of this Technical Report have been included in this standard and as such this standard supersedes the Technical Report.

The ISA99 series addresses electronic security within the industrial automation and control systems environment. The series will serve as the foundation for the IEC 62443 series of the same titles, as being developed by IEC TC65 WG10, "Security for industrial process measurement and control - Network and system security." - See more at: https://www.isa.org/store/ansi/isa–62443-2-1-990201–2009-security-for-industrial-automation-and-control-systems-establishing-an-industrial-automation-and-control-systems-security-program-/116731#sthash.JChkgeUY.dpuf

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You can't get here from there

By: Alix Paultre, Editorial Director, PSD

As we enter the Fourth Industrial Revolution, (or Industry 4.0 as it is often called), it is worth taking a moment to reflect upon where we are and how we got here. The integration of intelligent systems via the cloud infrastructure to support both design and manufacturing supply chains of both intellectual and physical property is already changing the way industry creates, makes, and distributes things.

The benefits of the cloud of course extend into the public sphere as well. People living in a developed country (and encouragingly more often in developing countries) in today's world are swimming in technology, from the smart phones in their hands to the medical implants in their bodies. The Internet of Things (IoT) is still in its infancy, with no real end to development in sight. Application spaces new and old are being revolutionized by the injection of intelligent connected technology, bringing the Cloud and its benefits into every facet of modern life.

It is very easy to forget how complex the system we are creating is, and that of its supporting hardware and software infrastructures. Everything from programming to plastic has had to adapt itself to serving the Cloud and the devices that make up the IoT within. To get here, each core technology has migrated through several generations of development, to the point where anyone from the long-ago dawn of integrated electronics over six decades ago would be hard pressed to recognize, much less work with, advanced SoCs and other highly-integrated chipscale packages. The same can be said for every other discipline, from radios to resistors.

Electronics are so advanced now that even the machines that make the machines have advanced to a point where the processes involved in the latest advanced technologies are almost unrecognizable to those who used to deal with legacy materials and processes. Silicon Carbide ingots must be grown in a high-temperature gaseous plasma, for example, and 3D printing is already changing how companies design and develop prototypes as well as finished products.

Alternative energy is also very well-suited to serving the Cloud and IoT. Harvested thermal, vibrational, and solar energy can power smaller devices completely, and extend the battery lives of larger portable products. A Smart Grid that can balance and manage a variety of energy sources also takes advantage of the same Cloud infrastructure that benefits consumers, reducing costs for all while increasing performance, safety, and reliability.

One day, people will look at a time where we pumped volatiles out of the ground and burned them to create energy with the same feeling of quant humor we feel when we look at pictures from the time of horses and gaslights.

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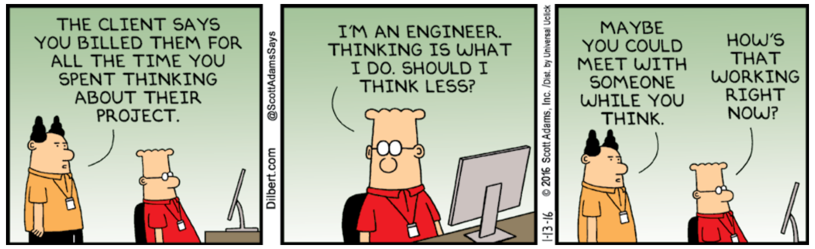
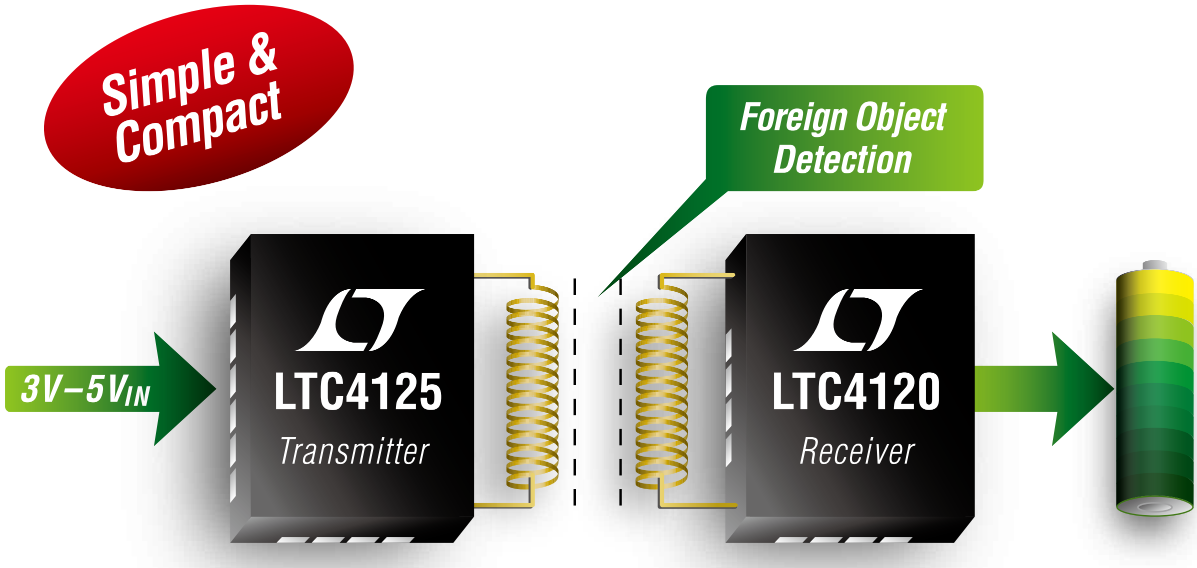


Complete Wireless Charging



Reliable Charging Tolerant of Coil Coupling Misalignment

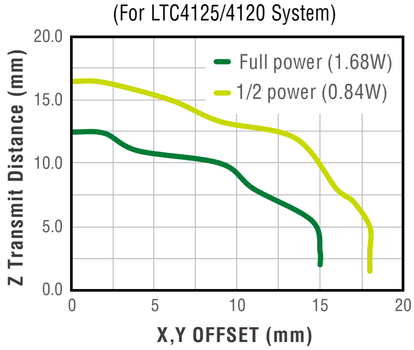
The LTC®4125 wireless power transmitter brings a new level of performance and simplicity to the transfer of up to 5W of power wirelessly to an electrically isolated receiver capable of that power level. It is a monolithic driver that controls the current flow in a series-connected transmit coil LC network. The LTC4125 features auto-resonant switching, allowing it to automatically adjust its driving frequency to match the LC network resonant frequency. It also implements foreign object detection, and auto-resonant switching improves performance with mismatched resonant components and poorly coupled coils. The LTC4125 completes a simple wireless power solution when combined with one of Linear's wireless power receiver ICs.

Features

- Uses Standard Coils
- Auto-Resonant Switching Frequency Adjusts to Resonant Capacitor & Transmit Coil Inductance
- Transmit Power Automatically Adjusts to Receiver Load
- Integrated 100mΩ Full Bridge Switches
- Foreign Object Detection
- 4mm x 5mm QFN-20 Package

Power Transfer vs. Alignment

(For LTC4125/4120 System)



Info & Free Samples

www.linear.com/product/LTC4125

1-800-4-LINEAR