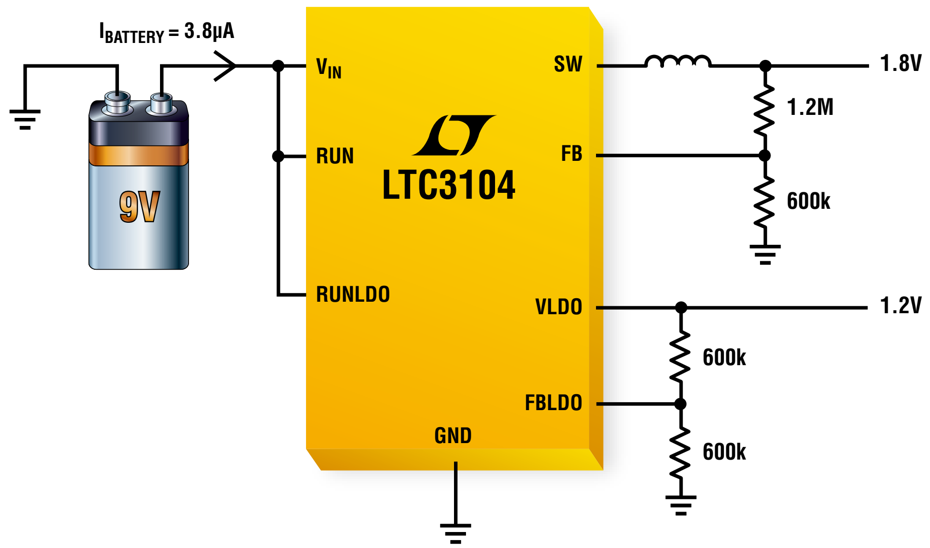
PSD EUROPE

Power Systems Design: Empowering Global Innovation

December 2011

SPECIAL REPORT: RENEWABLE ENERGY (PG25)

Change Batteries in 2018



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Enabling long battery life in an "always-on" system means drawing very little active standby current. Fortunately, our LTC®3104 does just that: its buck regulator can deliver 300mA with up to 95% efficiency with a no load quiescent current of just 1.8µA when in Burst Mode® operation. Its 10mA low noise LDO adds just 1.0µA of quiescent current and can be powered from the buck output. The LTC3104's wide 2.5V to 15V input voltage range accommodates a variety of input sources, making it ideal for remote sensor networks, portable instruments and a wide range of battery-powered devices.

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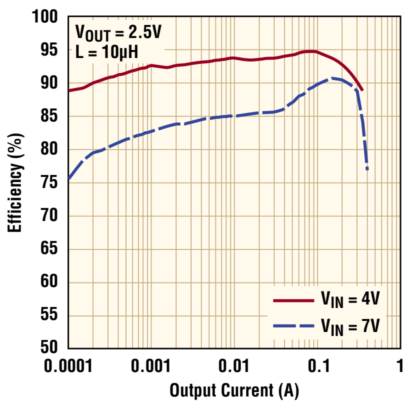
- V_{OUT} Range: 0.6V to 13.8V
- 300mA Buck I_Q = 1.8µA
- 1.2MHz Constant Frequency, Current Mode Architecture
- 10mA LDO I_Q = 1.0µA
- LDO Dropout = 150mV
- 3mm x 4mm DFN14, MSE16 Packages
- LTC3103 for 300mA Buck Only in 3mm x 3mm DFN, MSE10

LTC3104 Efficiency Curve
(Automatic Burst Mode Operation)



Info & Free Samples

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LTC3104 Video Product Brief

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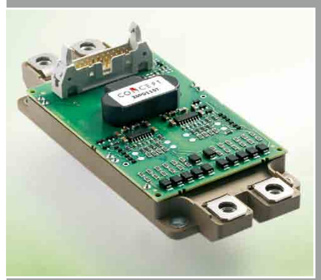

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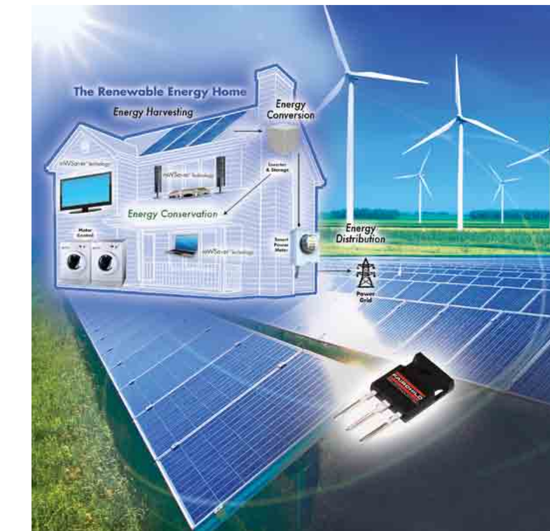

COVER STORY
Spoilt For Choice (pg 12)

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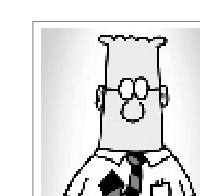

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THE GOOD, THE BAD AND THE UGLY

Welcome to this issue of PSD where we are carrying a special feature section on Renewable Energy. This area of our business has given birth to a huge wave of innovation. In this business, whether in solar, wind, wave power or indeed, any other method is crying out for our engineers to deliver products and systems to deliver ever higher levels of efficiency.

New materials such as Silicon Carbide (SiC) and Gallium Nitride (GaN) are now becoming 'real products', but it all comes at a cost. Not only this, the level of reliability of these devices and systems must be at the very highest level: Repairing or maintaining a remote solar farm or offshore wind farm is a highly expensive and time-consuming operation. Something the operators want to avoid at (almost!) all cost. This is a huge challenge for our industry and from what I have seen at tradeshows such as APEC, PCIM and Intersolar, one that has been embraced enthusiastically and with much vigour by the power industry. Again, it's engineering to the rescue.

In this issue, we have a wealth of feature articles on this intriguing topic, which re-affirms to me, the tremendous amount of work and investment that is going into this exciting sector of our industry. Also, on our website there is a feast of information in the form of product and industry news features as well as the interviews I have done with industry leaders under the department of 'TechTalks'. Please check it out.

The power management semiconductors market in 2011 will grow more slowly than expected, due to a general slowdown in consumer spending and the disruption caused by the March Japanese earthquake, according to an IHS iSuppli Power Management Market Tracker report from the information and analysis provider.
Revenue in 2011 from power management semiconductors is expected to reach $33.1 billion, up 6.7% from $31.0 billion in 2010—much slower growth compared to the market's astounding 37.8% rebound last year. The market is predicted to rise a meagre 3.9% next year to a projected $34.4 billion.

It looks like a powerful time in the long term for the renewable energy sector, certainly the companies here are very busy, but the consumer market unsurprisingly, given the ugly times we are all experiencing, will slow the growth in the PMIC area. But who knows what the future brings for sure?

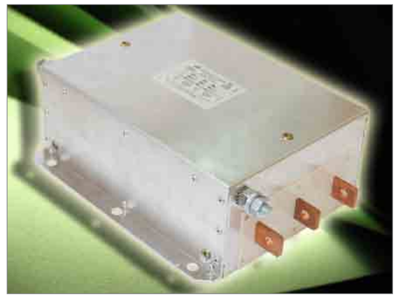
I hope you enjoy this issue of our magazine, keep your comments and opinions coming in, and do check out Dilbert at the back of the magazine.

All the best

Cliff

RENEWABLE ENERGY FILTERS

These new three phase filters from Premo require no neutral line and are especially suitable for renewable energy applications such as those experienced in wind generation



Renewable energy sources are now becoming an ever-growing alternative to generating electricity by conventional methods which give out potentially harmful environmental pollution. This is certainly not the case with the increasing use of power generation through wind turbines. However, the power injection into the grid network must be executed cleanly; this means that the power generated must be radio frequency (RF) noise free.

The radio frequency noise that typically ranges from 10kHz to 30MHz can be unintentionally injected into the grid network and therefore requires the use of an appropriate filter element wich includes the desired frequency range attenuation and also the ability to handle safely the current capacity required.

Premo has developed its HCWMGF-series of filters for applications in renewable energy equipment, UPS, inverters and power inverters, with a maximum operating voltage of up to 720Vac.

Main characteristics:

- Three phase filter incorporating three stages (high performance)
- Insertion loss better than 40dB over the whole range (reaching 80dB between 200kHz & 1MHz)
- Dielectric Strength above 3000Vdc
- Flammability specified to standard UL94 V2

The HCWMGF series is available in a three phase version L1, L2, L3 (without the need for a neutral line) with ratings from 150A to 2500A, delivering extremely low power losses of less than 0.02%.

Premo EMC has a long experience in the development of filters in both DC and AC single and three phase, and all PREMO filters have been developed taking into account the specific needs of the application they are intended, in terms of attenuation levels, volume, weight, connections, mechanical shape, etc.

In collaboration with development centres, universities, suppliers and customers, Premo has incorporated into its design many industry-leading innovations and new magnetic materials to provide results that fully meet customer needs and requirements in this new and demanding area of renewable energy generation.

Premo EMC has a fixed and a mobile laboratory for EMC testing machines / facilities for its customers and ensures EMC solutions for compliance with specific regulations to be applied.

www.grupopremo.com

POWER SEMICONDUCTORS MADE IN GERMANY

By Martin Hierholzer, Vice President and General Manager Industrial Power, Infineon Technologies

Today's challenge to support the world with clean green energy in the near future has brought wind- and solar power generation stronger into focus.

Now, windmills have grown to output powers of several megawatts and solar arrays in an equally demanding power range have been set up throughout the world, relying on power semiconductors "made in Germany".

Due to outstanding characteristics in efficiency, robustness and reliability accompanied by excellent support by skilled application engineers, Infineon Stack-Assemblies became the number one solution for power electronics in the renewable energy market. More than 500MW of power are installed in solar power systems; 2GW of installed power are exceeded in wind power generation – every year. In essence, 75% of the windmills in the world run on Infineon power semiconductors and an equally high share of solar systems features "power by Infineon".

Besides the main task – harvesting energy from wind – a windmill is a complex system with several auxiliary drives like the blade's pitch controller. Here too, highly reliable power electronic systems need to be build to ensure the extraordinary life-time expectations. Despite the rough conditions the devices are subjected to – humidity, temperature swing, vibration and centrifugal forces along with maybe salty atmosphere – these safety relevant systems are mandatory parts to keep the windmill operational.

For most efficient energy transport from off-shore wind farms to the continent, high-voltage DC-lines (HVDC) are state of the art. This technology, also used for energy transfer from continental Europe to the United Kingdom, allows the transport of electricity with optimized use of resources as only a single line is used. At the same time, the DC-transfer is far more efficient than the AC approach.

Converting a wind farm's cumulated power from AC to DC, transfer it to the continent and bring it back to AC is a classical task for power electronics. Though this is served with bipolar elements today, especially Infineon's Light Triggered Thyristors (LTT), first IGBT-based converters have been commissioned lately.

It is safe to assume, that the integration of renewable energies of any kind, electric vehicles with their needed infrastructure and energy storage devices into the upcoming Smart Grids will mainly be driven by the developments in power electronic. As in the past, Infineon will stay the leading company in energy efficient technologies, enabling highest power densities and system miniaturization.

www.infineon.com

A YEAR IS A LONG TIME IN THE SOLAR INDUSTRY

By Ash Sharma

Twelve months ago in this MarketWatch I wrote about the incredible growth the market had seen and how optimistic and upbeat suppliers were about the future.

Now, the market has grown again – we estimate by 27% to 24GW - but the industry is now in turmoil. At the start of 2011, a shutdown in two of the largest markets, Italy and Germany, led to massive oversupply and collapsing prices. This was true both for panels, but also, for the first time, for inverters too. As a result we've seen many large panel companies shut down plants and some file for bankruptcy.

The end of 2011 will see some significant cuts to PV incentives in many of the major markets, including Germany and the UK. Germany will be a making a scheduled 15% cut to its feed-in tariff, whilst the UK has brought forward a review of its incentives amidst fears of overheating and looks set to make a 50% cut to tariffs in December. Italy, which has been a key driver of growth this year, is rumoured to be set for further reductions due to a rapidly diminishing budget because of its oversubscribed feed-in tariff and its sovereign debt problem. Similarly the USA, which installed at least 2GW this year, has a very uncertain future. Its Federal "1603 cash grant" and investment tax credit scheme has helped drive installations but is due to change at the end of 2011.

But despite all the doom and gloom, the PV industry still has an incredibly positive future. Its share of total electricity supply is still tiny and its potential to scale and expand to fill the growing energy deficit is massive. Costs have fallen rapidly in recent years and it is on the brink of grid parity - in several countries, becoming accepted as a viable and credible energy source rather than just filling a niche. A year certainly is a long-time in this industry and I am sure it will be another interesting year ahead!

Author: Ash Sharma
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IMS Research

www.imsresearch.com

DESIGNING A TWO-STAGE OUTPUT FILTER FOR LOW OUTPUT IMPEDANCE

By Dr. Ray Ridley

Dr. Ridley demonstrates how the proper configuration of a second-stage output filter can significantly lower the output impedance of your power supply. The correct arrangement of components is essential for optimal performance, and is often overlooked.

Output Filter Configurations

A powerful design technique for reducing the noise on the output of a switching power supply is to utilize a two-stage output filter. Dramatic reductions in noise can be obtained with small filter components. If the design is done properly, the filter can be incorporated into the main feedback loop for optimal regulation.

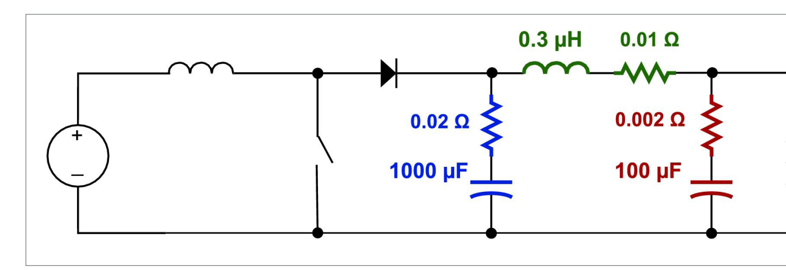

Figure 2: Two-Stage Output Filter with First Capacitor Larger than Second Capacitor.

Figure 1 shows the schematic of a 1 kW boost converter, operating at 75 kHz. Notice that there are two different types of output capacitor, one used for bulk energy storage, and one to provide low impedance for the high pulses of current that flow in the output capacitor.

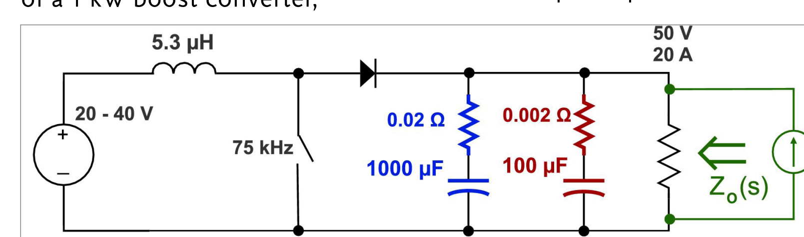

Figure 1: Boost Converter with Two Different Output Capacitors.

While the two-capacitor approach to an output filter works reasonably well, it is far more effective to incorporate a second-stage inductor between the two capacitors to attenuate the noise further. Figures 2 and 3 show two different ways to configure the output filter using a 300 nH inductor.

In Figure 2, the large capacitor is on the left, and the small capacitor is on the right. In Figure 3, the position of the

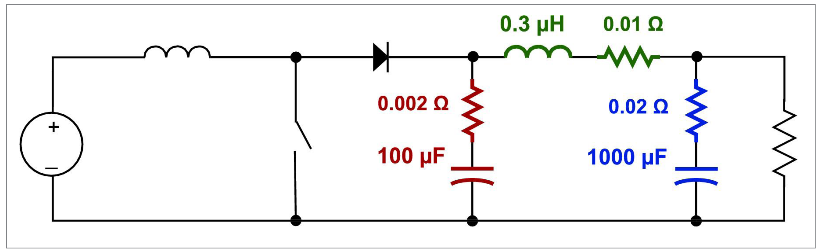

Figure 3: Two-Stage Output Filter with First Capacitor Larger than Second Capacitor.

capacitors is reversed. Both of these arrangements produce similar power-stage control and attenuation characteristics, as analyzed in [1] and [2], and at first glance appear to be equivalent.

Some designers consider the second capacitor and filter to be a noise filter, and therefore simply use small values for the second inductor and final capacitor. However, as we will see later, this is not the best configuration for the second filter.

Power Supply Output Ripple

Figure 4 shows the simulated output ripple with the second-stage LC filter in place. The gold waveform shows the ripple without the second inductor, and the red waveform shows the ripple after the inductor is added. Even though the second inductor is only 300 nH (about 5% of the value of the main inductor), the second filter provides a 20 dB reduction in output noise. Clearly, the use of a two-stage filter is very beneficial.

The effect on very high frequency noise spikes, not shown in this simulation, can be even more dramatic.

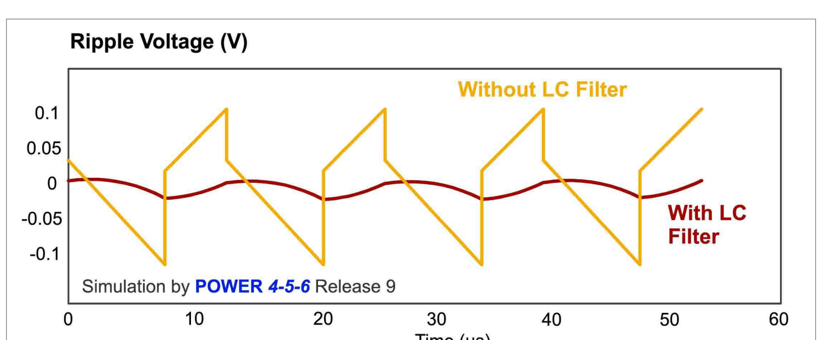

Figure 4: Simulated Output Ripple Voltage with Second-Stage Filter.

Loop Gain with Second-Stage Filter

Many designers worry that the additional poles and phase delay of a second-stage filter will compromise the loop stability. Figure 5 shows the loop gain of the system with and without the second stage filters. The gold curve shows the loop gain without the second inductor, and the red and blue curves show the loop gains with the two different configurations of output filter.

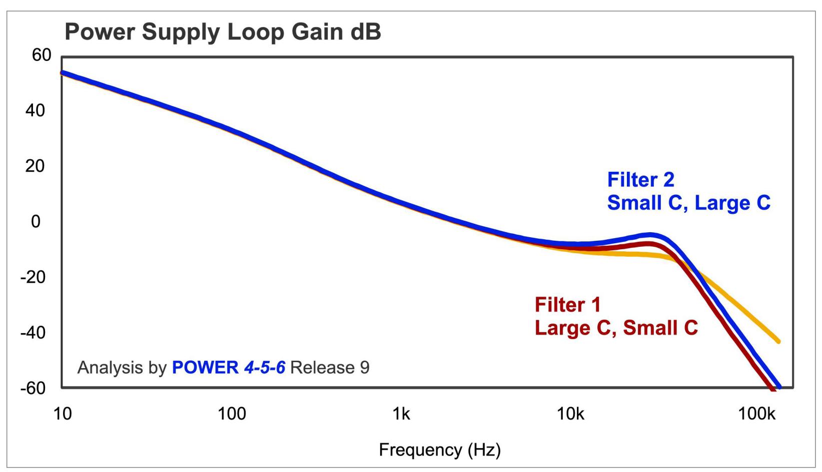

Figure 5: Effect of Second Stage Filter on Current-Mode Loop Gain.

The two filter configurations have almost identical loop gains, and there is not significant stability difference between them. It can also be seen that there is plenty of phase margin in the system when the filters are added.

Output Impedance with Second-Stage Filter

It has been shown so far that the two different configurations of filter have almost identical attenuation characteristics and stability. However, they are dramatically different when we look at the output impedance of the power supply. Output impedance is measured by injecting a current source into the output of the power supply, as shown by the components in green in Figure 1.

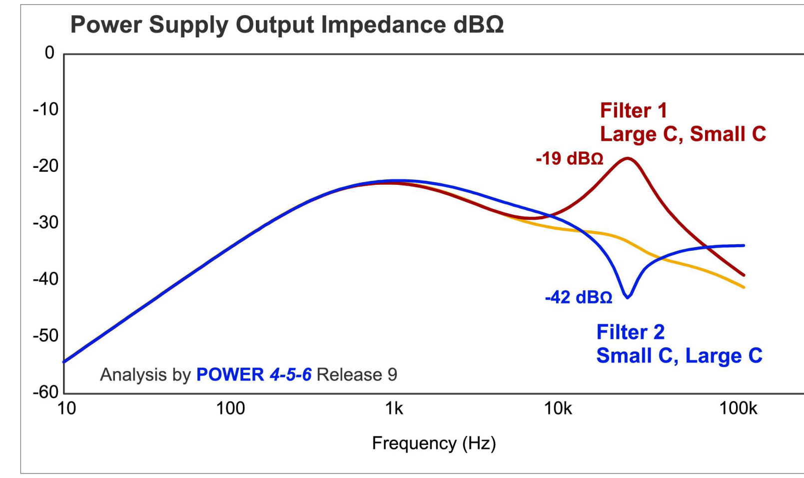

Figure 6: Closed-Loop Output Impedance with Different Filter Designs

The output impedance for each of the three filter configurations is shown in Figure 5. The gold curve shows the filter of Figure 1 with two capacitors, and the red and blue curves show the output impedance with the two different arrangements of the capacitors on either side of the second inductor.

The curve in red shows the impedance obtained when the first capacitor is large, and the second capacitor, closest to the load, is small. The peak of the output impedance at the second resonant frequency (about 30 kHz) is more than ten times higher than the output impedance of the other filter configuration, shown in blue.

The optimal configuration of the filter, with the small capacitor followed by the large capacitor, has a dip in the output impedance at the second resonant frequency. This is clearly a much better arrangement for the filter components.

The use of two different types of capacitor is quite common for high-power systems where performance is paramount, and higher quality components are possible within the budget. Electrolytic capacitors are usually used for the large bulk capacitors, and film capacitors for lower value, low ESR capacitor.

For lower cost power supplies, the usual technique is to use the same type of low-cost capacitor throughout, splitting them approximately equally between the first capacitor and the second.

Summary

Two-stage filters are a powerful design tool used by advanced power supply designers. They provide dramatic reduction of noise, and can be incorporated into the feedback control loop if properly designed.

The design verification process should always include output impedance measurement of a power supply. This is the parameter that will have a strong dependence on the arrangement of the second filter components. When using different types of capacitors for an advanced filter, it is best to put the smaller value of capacitor first, and the large value of capacitor next to the load.

Additional Reading

"Secondary LC Filter Design Techniques for Current-Mode Controlled Converters", Raymond B. Ridley, IEEE Transactions on Power Electronics, October 1988.
"Second-Stage LC Filter Design", Ray Ridley, Ridley Engineering Design Center at www.ridleyengineering.com

All waveforms and transfer functions in this article were generated by POWER 4-5-6 Release 9, available from www.ridleyengineering.com . Techniques for measuring output impedance can be found under the analyzer section of www.ridleyengineering.com

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SPOILT FOR CHOICE - POWER SWITCH TECHNOLOGIES FOR RENEWABLE APPLICATIONS

Selecting the right power transistor depends on many factors

By Alfred Hesener

With 7 billion human beings living on this planet, and at the same time, the energy consumed by human beings is shifting more and more from oil to electricity

Improving power density and efficiency in power electronics subsystems

It comes as no surprise that power electronics subsystems play a significant role in many applications, and determine their main features to a large extent. They are at the heart of energy production, distribution, and conversion. At every conversion step, some of that precious energy is lost in the process, hence the first main requirement for power electronics is the reduction of losses, or the improvement of efficiency.

With the widespread use of electronic power control in more and more applications, the number of power subsystems is also dramatically increasing. For example, new regulations for industrial drives prescribe the use of efficient BLDC motors, requiring electronic control. The second main requirement is therefore increased power density, or reduced size for the power electronics subsystem.

With many more electronic power subsystems connected to the grid, most of them operating at high switching frequencies, the noise coupled back into the grid is ever-increasing, despite severe EMI regulations the applications have to comply with. It is therefore advantageous to develop power subsystems that produce less EMI to begin with, e.g. through fast switching with little voltage or current peaks, which is the third requirement.

And the fourth requirement is the need for these applications to have high reliability and robustness, especially in the case of applications like renewable energy conversion, where e.g. in the case of an offshore windmill, the power electronics subsystem may not easily be accessed for maintenance and repairs.

Renewable energy consumption offers interesting questions for all the four requirements mentioned above. For solar inverters, much of the race for better efficiency has been completed, with most companies offering inverters with 98% or better peak efficiency. Light load efficiency is still lower, and further reductions can substantially reduce heatsink size and weight, so it is not over. However, the development is now also focused on reducing size and cost, while adapting to the newly developing markets like the BRIC countries, while maintaining the robustness and reliability capabilities achieved so far. But where the PV inverters exist in a wide variety of output power, from 2kVA to 1000kVA e.g. for string inverters, the power range for wind power generators is much more limited, and really focusing on the higher power range, currently up to 6MVA per turbine, and increasing. At the same time, significant technical evolution is driving this application: With more and more offshore installations, the average power is increasing, as the rotors can be made larger and the average wind speed is higher. And in order to reduce the weight and cost of the turbine housing, efforts are underway to remove the mechanical gearbox that is needed to maintain constant rotational speed of the turbine, and replacing it with a boost converter / inverter system that will produce constant output voltage and frequency, and can more easily comply with reactive power guidelines. And with larger wind power installations being connected to the mainland grid via a HVDC link, generators with regulated output voltage can simplify the installation and configuration of this offshore subsystem.

Figure 1: Offshore wind park "Lillgrund" in Sweden is connected to the main land via a 138kV high-voltage DC link

Technology	Main Characteristics	Typical Component	Applications
Si Bipolar Transistor	Low cost, high breakdown voltages possible; low switching speed, SOA may be limited	Many	LFL ballasts
Emitter-Switched Bipolar Transistor	Medium cost, high breakdown voltages possible; medium switching speed and good robustness	FJAF510	Flyback converters for very wide input voltage range
Planar MOSFET	Low cost, robust; medium power density	FCP7N50NZ	Lighting applications, lower-density power supplies
Superjunction SuperFET® MOSFET	High performance, fast switching enables reduction of passive components	FCA47N60F	High density power supplies, solar inverters, lower power motion control
Superjunction SupreMOS® MOSFET	Highest performance for very high power densities and size reduction	FCA76N60F	High density power supplies, solar inverters, industrial electronics with highest power density
IGBTs with Low VCESAT	Low saturation voltage for lowest conduction losses in high current applications, low switching frequency	FGA30N60	Robust higher power motion control, frequency inverters at lower switching frequencies
IGBTs with Low Switching Losses	Low switching losses, but higher saturation voltages; suitable for medium switching frequencies at higher currents than MOSFETs	FGL40N120	Higher power motion control, boost converters e.g. in solar inverters
SiC Bipolar Transistor	Very fast switching speed, lowest losses and high temperature stability, promising to have good reliability and robustness	BT1220	Solar inverters and other highest-efficiency applications, high temperature applications
SiC JFET	Very fast switching speed, lowest losses and high temperature stability, promising to have good reliability and robustness		Solar inverters and other highest-efficiency applications, high temperature applications
SiC MOSFET	Very fast switching speed, low losses		Solar inverters and other highest-efficiency applications, high temperature applications

Table 1: Overview of different power switch technologies

Many power switch technologies co-exist

Power electronics subsystems like inverters, boost converters or power conversion stages today almost exclusively come in the shape of a switched-mode power conversion topology. Designers of power electronics applications never had such a wide choice of different and competing technologies for power switches in their applications, ranging from older silicon bipolar transistors, junction and planar (MOS) FET devices to more modern superjunction MOSFETs, IGBTs that exist in many different versions, up to the recent developments using wide bandgap semiconductors such as silicon-carbide ("SiC") or gallium-nitride ("GaN"). But which device is suitable for which applications, what are the advantages and drawbacks? Below table gives a first overview of the different device types, considering commercially available technologies for power conversion applications at higher breakdown voltages above 600V.

The silicon bipolar transistor has been around for a long time, used e.g. as deflection transistor in CRT television sets, with breakdown voltages up to 1500V. It is a well-known device that exhibits good robustness but rather slow switching speeds. The fact that it requires a base current to stay on has some impact on the gate driver design. It has recently become more interesting in cascade circuits, using a low voltage MOSFET as the lower transistor to improve switching speed and benefit from the high breakdown voltage at the same time.

One of the most widely used power switch technologies are power MOSFETs. They combine fast switching speeds with high robustness and a built-in body diode with relatively easy gate drive control. Over time, the older planar designs have been succeeded by superjunction devices such as SuperFET® MOSFETs or SupreMOS® MOSFETs from Fairchild Semiconductor, resulting in significant reductions in on-state resistance and switching losses. MOSFETs are the preferred device for all applications operating at higher switching frequencies above 20kHz, and for voltages up to 1000V.

The other widely used power switch is the IGBT, the combination of a bipolar transistor with a MOSFET to control its base. This device offers much easier control, similar to MOSFETs, with the robustness and high voltage capability of bipolar transistors. Different optimization points for low saturation voltage or low switching losses lead to proliferation of IGBT technologies for different applications. IGBTs are the device of choice for applications at high voltages above 1000V, and for lower switching frequencies and high currents, since the conduction losses do not increase linearly with current as in a MOSFET.

Silicon carbide as new base material for semiconductors has been around for a while, in the form of Schottky diodes for high voltages as well as for blue LEDs. The explosive growth of the usage of white LEDs for general lighting applications (which are blue LEDs with a phosphor layer on top) has helped to significantly improve the substrate quality of SiC wafers and the unit process steps necessary for handling this material in a factory. Today's material is much better, and with the resulting increase in wafer diameter, the device cost of these new switches is approaching the necessary cost point for widespread use in industrial applications, taking into consideration the reduction in system cost they allow elsewhere.

But, different SiC device concepts are emerging, like bipolar transistors, JFETs or MOSFETs, and they all have their distinct advantages and disadvantages.

The first power switches in SiC were JFETs that use pn-junctions to control the width of the conducting channel inside the device. They are commercially available today from various vendors, and two main categories exist: Normally-on and normally-off devices. With the first, the threshold voltage of the FET has a negative value, so that at VGS=0V the device actually is conducting current. This requires a strong negative voltage to turn the device off, in some cases up to -30V. These devices will exhibit very fast switching and low losses,

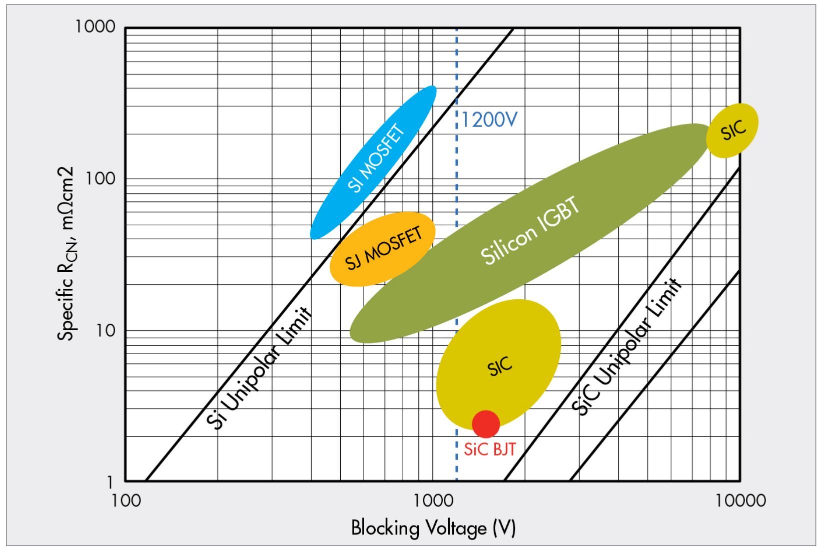

Figure 2: Comparison of different switch technologies against theoretical limits

but the gate drive circuit can be quite complex. A typical use of these devices is in a cascade circuit, in combination with a low-voltage MOSFET. This increases complexity but allows very fast switching combined with easy gate control.

Normally-off JFETS are modified so that their threshold voltage is positive. This keeps most of the advantages of SiC JFETs but makes the gate drive circuit a little easier. Still, a negative voltage is required to turn the device quickly and securely off, and to fully turn it on the gate-channel junction may have to be driven positively, in which case a DC gate current needs to be provided by the driver.

Both devices have a similar increase in R(DS)ON with temperature compared to Silicon MOSFETs, with the normally-on device showing lower R(DS) ON values in comparison, and the normally-off device degrading more quickly at higher temperatures.

For a long time, it was difficult to create stable gate oxides on SiC base material, but these problems appear to be solved now and SiC MOSFETs are commercially available. These devices have a positive threshold voltage in the range of 2V, comparable to silicon MOSFETs, but the manufacturer recommends to drive them with a voltage swing of +20V to -2...5V, whereas silicon MOSFETs generally operate with a gate voltage swing of 0V...12V. The SiC MOSFET only shows a weak increase in RDSON with temperature. Still, high temperature operation is difficult with a SiC MOSFET as it can degrade quickly.

A very promising device in SiC is the bipolar transistor. It shows very fast switching, on a par with the other devices, easy high temperature operation, and a good robustness and ease of manufacturing. At the same time, it is very efficient in the usage of substrate surface and has the lowest conduction losses of all these devices, allowing very good performance at moderate chip sizes as compared to the other three devices. But, it will require a DC current to turn on and remain turned-on, so the gate driver needs to be designed accordingly. When the gate driver fails and can no longer provide base current, the bipolar transistor will turn off, providing added fail-safe security. The required base current is a function of the current gain of the device, and the collector current. Using proportional drive, the base current can be reduced at light load, improving the losses and achieving a more uniform efficiency across the entire load range. Also, since for the same reason the SiC bipolar transistor will turn into a current source at roughly twice the load current, it will limit the current in the system in case of a short circuit, potentially avoiding catastrophic failure.

All four devices share an interesting characteristic, they exhibit no or very little tail current at turn-off. This is the main reason that enables high switching frequency operation, and is a strong helper to reduce EMI. On the other hand, the tail

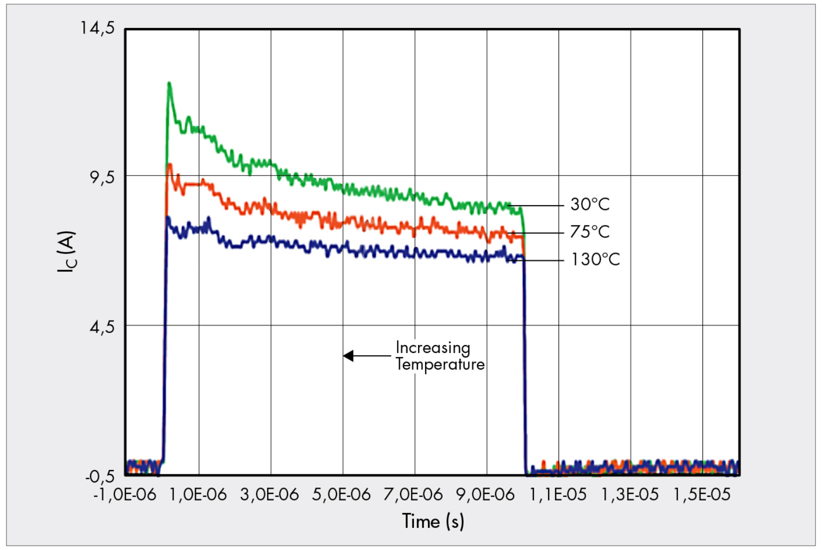

Figure 3: Measured short-circuit waveforms for three different temperatures. Note that the current limit decreases with temperature, providing added safety. The devices safely survived the test.

current in a silicon IGBT can help to damp parasitic oscillations in the system that may exist due to parasitic passive components or layout, so in order to exploit the big advantage of SiC switches, careful layout with minimal stray inductances is required, to avoid voltage peaks.

Just appearing on the horizon are new HV switches in Gallium-Nitride (GaN). First prototypes are available, and these devices already offer interesting performance levels. But their manufacturing process can be expensive, both because some GaN devices are produced on a SiC or Sapphire base wafer, and because the process of growing GaN on various substrates is complex and slow. Also, the device processing requires metal and gate systems similar to other 3-5 devices that are not as low cost as conventional silicon processes. Technological research is ongoing to produce these devices on cheaper substrates like silicon, and some companies have announced product availability. And, as they are lateral devices (meaning the current flows horizontally, parallel to the surface of the die, with both drain and source connections on the top of the device), there can be area wasted for bonding pads and current density limitations due to metal stripe current density. Increasing die size for a given R(DS)ON. Lastly, there are still a few unsolved topics regarding ruggedness and reliability of these new devices that will require more research.

Robustness and reliability are not the same

All the applications targeted for these power switches, and in particular renewable energies, require high robustness and reliability. These two terms certainly do not mean the same, but are often misused. Robustness really is the capability of the device to survive abnormal system states, like high peak voltages, currents or temperatures that are not part of the "usual" system operation, without failure. Reliability means that the device, when operated within datasheet limitations, does not drift or otherwise degrade in performance.

Robustness is important, since the power grid is more and more becoming a challenging place to operate in. With large load variations causing strong voltage variation and spikes, more and more decentralized power generation, short circuits, and the new guidelines to provide reactive power in case of too high voltage or frequency, the capabilities of the power devices to absorb energy in case of faults is more and more demanded. And in industrial applications, reliability has always been an important factor for the power subsystem, especially e.g. in the case of offshore wind power generation, where it is difficult and even sometimes impossible to replace a faulty power subsystem in bad weather.

Large wind turbines do adjust power output through rotation of the blades, meaning there are three servo drives with inverter inside the rotor to perform this function. They are subjected to large mechanical stresses, vibration and challenging environmental conditions, yet their faultless operation is absolutely critical for the rotor to not being destroyed in very strong wind conditions, at which points the blades have to be adjusted for minimum wind resistance. Similar requirements exist for the servo drive used to position the rotor into the wind, again with potentially catastrophic consequences should this drive fail.

Conclusion

At this point, design engineers are at a crossroads, one road leading away from well-known silicon switches with very good and well-characterised robustness and reliability, and one heading toward new power switch technologies – such as the Bipolar SiC transistors from Fairchild Semiconductor – that offer superior performance but are not yet field-tested to a large extent. Some insight into the device physics, beyond the manufacturers' claims, is required to make a well-founded decision for industrial applications that are more and more approaching mission-critical requirements.

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POWER MODULE MOUNTING

flow90 – The power module of choice for 90-degree mounting

By Patrick Baginski

The mounting option for power modules has always been somewhat limited, meaning that the designer is constrained to a standard configuration. These new modules overcome this problem.

Most power modules come with a copper layer or base plate at the bottom to transfer heat to the cooler. Spring contacts, screw terminals, solder pins, or Press-fit pins on the opposite side provide an electrical connection to the printed circuit board. The pins of the flow90 module, however, are arrayed at a 90-degree angle to the module's DBC substrate. This brings considerable benefits to book-sized inverters and 19-inch rack-mounted applications. Standard topologies such as CIB / PIM and PACK configurations are available with 600 V and 1200 V components. Vincotech also offers rectifier modules, including half-controlled versions and with an optional brake transistor. The internal layout is symmetrical so a six-pack module's power rating may be increased by connecting the three legs together to form a half-bridge.

In most conventional modules, the electrical connection sits on the opposite side; that is, where the cooling area is located. The module is soldered to a PCB and mounted to a heat-sink or vice versa. This can be done on the PCB side with through-hole and other components sited on the solder side.

Both options have their advantages and drawbacks. The module is usually mounted on a flat heat-sink for higher power applications, which simplifies production. Of course, this option is also viable for lower power ratings. However, the drawbacks of switching mode power supplies designed for use in a 19-inch rack or book-size inverters in flat modules often outweigh any potential advantages. In such cases, heat-sinks frequently sit on the back of the inverter or on the left or right of a 19-inch device.

Vincotech offers a wide range of power modules, one line of which

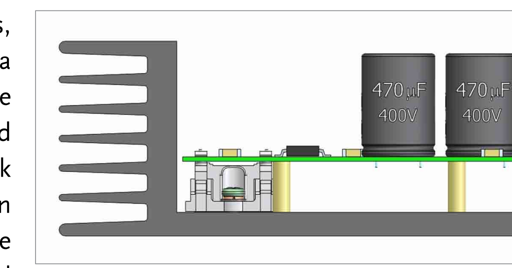

Figure 1: State-of-the-art configurations

is the perfect match for book-sized inverters and 19-inch rack-mounted power supplies with a 90-degree angle between the heat-sink and PCB. Called flow90 and featuring pins arrayed at a 90-degree angle, these modules are available as standard products with CON, PIM, and PACK configurations. Topologies for SMPS are also commonly used in this package.

The concept behind flow90

This module affords engineers the opportunity to make a mechanical connection between the heat sink and PCB at a 90-degree angle within the device. It requires no additional mechanical components or special heat-sinks. The power module is installed vertically, on the same side as all other components, rather than horizontally as is the case with conventional designs. What's more, there is no longer a need for specially designed heat-sinks. This simplifies manufacturing and reduces operating costs. Beyond that, flow90 allows end devices such as frequency inverters to be built in a more compact format. This method of mounting modules is perfect for power components housed in narrow control cabinets where cooling is performed at the back of the cabinet, as well as for all other applications requiring the heat-sink and PCB to be arrayed at a 90-degree angle.

The electrical connection to the PCB is easily made. The module's internal structure, particularly the DBC layout, is mapped to optimize the power flow from the input rectifiers to the output inverter IGBTs. This streamlines printed circuit board routing and leaves a much smaller footprint. The housing may be handled like any standard THT component. And with the 90-degree mount, there is no need for a flexible PCB, which makes the system even more reliable.

Two plastic clips that engage in the PCB attach the module to the board. The heat-sink may be affixed conventionally using screws or with the aid of two clips. The clips screw onto the heat-sink or wedge into a groove. Clip fastening can prove very useful in instances where it is difficult or impossible to screw the module on because of obstructions posed by larger components such as capacitors.

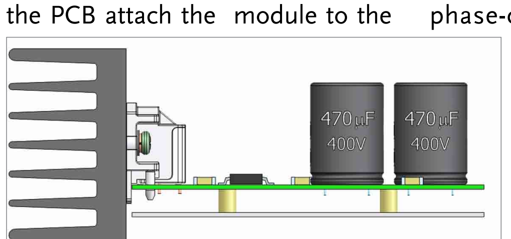

Figure 2: Mounting with a flow90 module

The flow90 housing is designed to preclude the need for additional mounting brackets near the module between the PCB and heat-sink. This also cuts the costs of assembly material and mounting. In addition, it prevents potential tolerance differences when additional spacers or brackets are employed. The plastic housing consists of a small pin in the center, which bends the DBC to a convex shape. This ensures low thermal resistance and improved operating performance.

Figure 3 shows how the module is fixed in place in the PCB and heat-sink.

In contrast to discrete components, the flow90 module ships with electrical isolation on board, so additional pads or foils are unnecessary. Vincotech can furnish these modules with a pre-applied phase-change material. This material has high thermal conductivity, melts at temperatures above 45 degrees centigrade, and has beneficial EMI properties. Components are arrayed closely together with shorter connecting paths

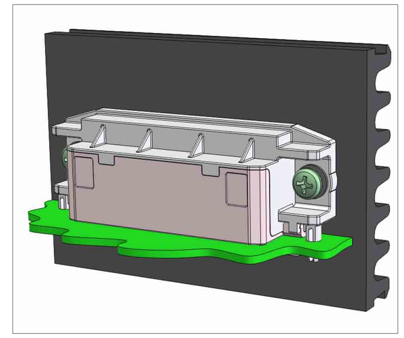

Figure 3: Detailed view of the flow90 module

to create a low-inductance design with better dynamic response.

Conclusion:

Featuring an integrated input rectifier, brake, and motor inverter, flow90PIM combines the benefits of a power module - isolation, good thermal coupling with the heat-sink, and enhanced reliability - with the advantages of the 90-degree mounting option customarily used for discrete components. flow90CON and flow90PACK modules are available to extend the power rating. Topologies are easily customized. The flow90 module is the perfect fit for book-sized inverters and 19-inch rack applications such as switching mode power supplies. When mounted vertically on the board, the module can be installed on the same side as other through-hole components, and wave-soldered along with these other components in one pass. Modules with a pre-applied phase-change material are available on demand.

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MINIATURIZED MODULES

The shrinking world of ceramics

By Mark Porter

Ceramic technologies are complementing semiconductor advances in enabling ever-more sophisticated and smaller wireless electronic systems

Improvements in ceramic materials technology have led to dramatic size reductions in components and sub-assemblies in recent years. This trend is so marked that the limiting factor for some designs is not the size at which particular components are available but the ability of automatic assembly equipment to handle the smallest types. Nowhere is the demand for miniaturization more prevalent than in the design of wireless devices, both for cellular and non-cellular applications.

Cellular and non-cellular wireless

While many people think of wireless in terms of cellular networks, the world is rapidly becoming much more complex, both within cellular phones and due to the growing number of stand-alone wireless devices now available across a range of different applications and standards. Figure 1 shows Murata's view of the likely wireless connectivity that will appear in cellular phones over the next few years. GPS satellite, mobile television (DVB-H), FM transmitters that provide a link to car radio receivers, 802.11x WiFi transceivers, Bluetooth transceivers, wireless security keys and e-money transceivers (Near Field Communications), ultra-wideband (UWB) wireless links, Wibree, FM radio receivers, and WiMax transceivers are some of the options. That's a lot of wireless technologies, plus of course the cellular network radios themselves – which may be tri- or quad-band GSM plus UMTS. In the not too distant future, we could be looking at handsets with wireless capabilities stretching from 13MHz to 6GHz. The challenge for handset makers is get the right combination of technologies into each of their phones for the intended markets they wish to serve, without making the size, power consumption of cost of the product unacceptable. Smaller components, higher levels of functional integration and the use of hybrid modules or other building blocks all have a part to play.

Figure 1: A wireless handset may need to cover 13MHz to 6GHz in future – figures show the Murata estimate for the take-up of various technologies

Developments in components

When surface mount multilayer ceramic capacitors first became available 20 years ago the 'standard' size was 1206, in other words a 3.2 x 1.6mm footprint. Today, the most common values of decoupling capacitors in RF circuits - 1000pF, 0.01µF and 0.1µF - are all available in an 0201 package measuring just 0.6 x 0.3mm – a size reduction of 96%. And at the lower end of the capacitance range, a 47pF capacitor – a popular standard value used in oscillators and filters - can be just 0.4 x 0.2mmm, the 01005 size. That's 98% smaller than its 1206 counterpart. At the other end of the scale, there are 100μF multilayer ceramic capacitors manufactured at 1206 size and components up to 47μF in the smaller 0805 size (2.00 x 1.25mm.) Of course, lower operating voltages of semiconductors have contributed to the trend for smaller passive components because dielectric layers can be thinner while still providing sufficient dielectric strength. On the other hand, the more stable dielectrics often needed in wireless applications tend to have lower dielectric constants than 'general purpose' types, limiting the capacitance that can be packed into a given size.

In practice, it is the challenges of component handling, inspection and re-work that limits the adoption of some of the smaller packages. At the time of writing, the cellular phone industry is in the process of moving from 0402 to 0201 for components where suitable capacitance values are available.

Similar size reductions have been achieved in other passive components. Chip inductors for power supply filtering through to coils for use at microwave frequencies have been shrinking year on year. For wireless devices the 01005 package is the smallest in general use. Coils up to 120nH are available in this size, rated at 150mA, or with a self-resonant frequency of at least 600MHz. Coils up to 5.1nH have a typical self-resonant frequency of over 6GHz.

As a result of these improvements, EMI filters comprising combinations of ferrites, wound inductors and capacitors, have all shrunk too.

Developments in devices

With respect to wireless applications, ceramic devices, as distinct from the simplest components, include dielectric antennas, connectors, piezo speakers, surface-acoustic wave (SAW) filters, isolators, ceramic resonators, ceramic duplexers and gyro sensors. In devices for combining, filtering and separating signals great advances have been made in recent years and rapid progress continues, as shown in Figure 2. Only recently, single frequency SAW filters were in an industry-standard 2.5 x 2.5 mm package – now you get the same device in a 1.4 x 1.1mm package. SAW duplexers and diplexers have followed a similar size reduction trends. Murata's Switchplexers™ are RF diode antenna switches on ceramic substrates, with integral low-pass filtering on the transmit side and a diplexer to split the GSM channels. Today, a 6-band device that will handle 3 x GSM and 3 x UMTS bands comes in a 4.5 x 3.2mm package but this is expected to become a 7 band part with its size reduced to 2.5 x 2.5mm within 2 years - no mean feat when you consider the challenges of isolating individual filters to prevent signal leakage and crosstalk between channels. These advances in ceramic-based devices are being achieved through improvements in materials technology, design and processing techniques.

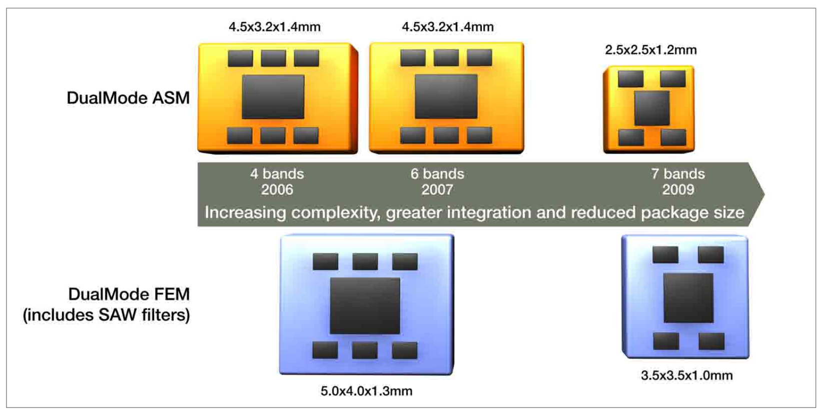

Figure 2: Within 2 years a 7-band antenna switch will measure just 2.5 x 2.5mm, including filters

Migration to modules

The growing complexity of both baseband and RF technologies within wireless systems, together with the imperative of reducing costs, is driving handset OEMs, and others, towards a platform approach to system design. Semiconductor manufacturers produce ASICs that handle various circuit functions within industry-defined standards. ASIC development within the wireless OEM companies themselves has become too expensive for most to consider, mainly due to rising costs resulting from shrinking geometries in semiconductor fabrication.

Much of the differentiation of final products is created in software or through the design of system packaging. In fact, for mobile phone makers, some 80% of their design effort is now software development. This trend is further evidenced by the growth in the use of pre-assembled modules. In other words, the system designers are specifying more pre-fabricated circuit blocks in order to focus their efforts on achieving rapid time-to-market and product differentiation.

In order to produce competitive modules, companies such as Murata now work as closely with semiconductor manufacturers as they do with OEMs. The design of modules and the implementation of successful reference designs based around them, means ensuring that passive components work well with their associated semiconductor devices.

This has been a relatively easy task in the past but as wireless operating frequencies rise into the GHz region, even apparently simple capacitors take on greater complexity. For example, every conductor, including the component terminations, contributes inductance to a circuit and when considering capacitors, how impedance and equivalent series resistance (ESR) varies with frequency needs to be considered. At 2.5GHz 10pF capacitor from one company can be a different component to a 10pF capacitor from another – even where similar dielectric characteristics are claimed. For example, specifying a COG (or NPO) dielectric based on its stated temperature characteristics may not fully describe how the component will function in a given application.

Wireless modules are assembled on ceramic substrates, so it is no surprise companies with their origins in ceramic electronic component now dominate the ceramic modules business. A well-design module based on standard low temperature co-fired ceramics (LTCC) will require only half the XY area of a conventional printed circuit board (PCB). Today, the Bluetooth transceiver module shown in Figure 3 is available in a 6.15 x 6.15mm package - complete with crystal and EPROM. 802.11B transceivers come in modules measuring 8.4 x 8.2mm. A new non-shrink LTCC technology has been developed by Murata to produce a further 20% space saving. The non-shrink substrate enables more aggressive design rules to be used, with circuit interconnect and components laid out closer together. As a result, 2008 will see a combined Bluetooth and 802.11x module appear in a tiny 10 x 10mm package.

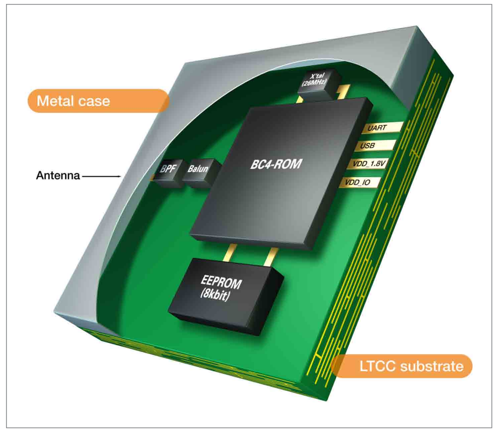

Figure 3: The world's smallest complete Bluetooth module is just 6.15 x 6.15mm

Conclusion

The growth in transistor density within ICs and the capabilities of the resulting chips are well documented. Equally important, but perhaps less well appreciated, are the advances that have been made in materials and processes related to ceramic technologies. These are the technologies enabling electronic systems designers to take even greater advantage of progress in the semiconductor industry.

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ANALOG ISOLATION

AMC1200 provides galvanic isolation from the controller

By Frank Ohnhaeuser

Applications like motor control, solar inverter, power supplies or e-meter sense the current or the voltage of a phase.

The current is typically measured by the voltage drop caused by current across a shunt resistor. A resistive divider is used between the phase and a second potential to measure the phase voltage. A microcontroller digitizes and processes the information. The controller mostly operates on a different potential, which might be the neutral line. Analog galvanic isolation is required. The isolated amplifier AMC1200 from Texas Instruments performs this task.

For the current measurement, the voltage drop across the shunt should be small to minimize the power loss. On the other side, it is difficult to remain a high signal performance with small the voltages. Also, analog signals cannot be isolated with reasonable performance. The shunt voltage therefore is digitized first, the digital signal is transferred through the isolation barrier and then converted back to analog.

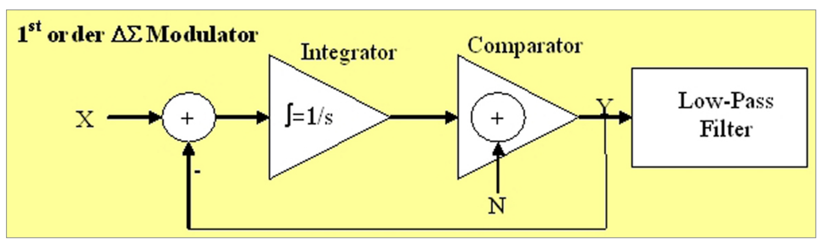

Figure 1: Block-diagram of a delta-sigma modulator

The preferable analog-to-digital converter in this application is the delta-sigma modulator. Its architecture achieves high accuracy even at small signal levels due to oversampling and filtering. It also provides a so called bit stream output with only one data-line and optionally a clock-line. The isolation circuitry can therefore be reduced to a minimum allowing a low cost system solution.

The delta-sigma architecture is preferably described in the frequency domain (see Figure 1). It basically is a control loop, where the digital output Y is subtracted from the analog input X. The error signal is integrated in the loop and then digitized by a comparator. The digitization adds the so called quantization noise N.

This block diagram results in the following transfer functions:

$$(X-Y)\cdot\frac{1}{s}+N=Y \qquad (1)$$

$$Y = X\cdot\frac{1}{1+s}+N\cdot\frac{s}{1+s} \qquad (2)$$

The delta-sigma modulator forms a low-pass filter for the analog input signal X. The quantization noise N is suppressed at low frequencies. Only high frequency portions can passes. This effect is called noise shaping. If the digital output Y is low-pass filtered, the remaining quantization noise is suppressed and the analog input signal passes with high quality. This noise shaping increases, if more than one integrator is used. In this application, two integrators are standard, causing the noise to increase with 40dB per decade. The digital output should therefore

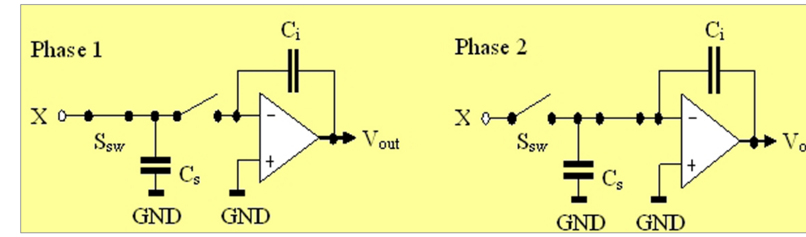

Figure 2: Switched capacitor architecture

be filtered with a low-pass filter of 3rd order to cut the noise off most effectively.

Additionally, circuit noise contributes to the system performance. For a delta-sigma modulator, which is typically implemented in a switched capacitor approach (see Figure 2), the biggest noise source is the input stage including a sample capacitor CS and the first integrator. During the positive clock phase, CS is charged to the input voltage, the charge is then transferred to the integrator during the negative clock phase.

Any input resistance, which might also be the on-resistance Ron of the sample switch Ssw, is causing thermal noise with

$$n^2 = 4kTR_{on}f_{eff} \qquad (3)$$

In equation 3, k is the Boltzmann constant and T the absolute temperature. The effective bandwidth feff is the -3dB frequency multiplied by p/2.

$$n=\sqrt{4kTR_{on}\cdot\frac{\pi}{2}\cdot\frac{1}{2\pi R_{on}C_s}}=\sqrt{\frac{kT}{C_s}} \qquad (4)$$

Equation 4 shows that the noise only scales with the size of the sample capacitor. The larger the capacitor, the smaller is the noise. The smaller the noise, the smaller can the input voltage range, the shunt value and its power loss be. The AMC1200 is therefore using a sample capacitor Cs of 3.6pF.

During sampling, Cs has to be charged to the input voltage via the shunt or the resistive divider. The charging is based on an exponential settling. The capacitor is fully discharged at the beginning of the sampling period, as the charge is transferred to the integrator during the negative clock cycle. The limited sampling time Ts, which is 50ns for the AMC1200, causes a small difference e between the sampled voltage and the input voltage Vin, which is expressed in Equation 5.

$$\varepsilon = V_{in}\cdot e^{-\frac{T_s}{R_{in}\cdot C_s}} = g\cdot V_{in} \qquad (5)$$

Fortunately, this error e is proportional to the input voltage and therefore only generates a gain error g and not offset or linearity errors. This gain error is insignificant, when used with an input resistance of less than 500W. In case of the resistive divider, the switched capacitor approach however has an additional effect.

This switched capacitor circuitry constantly consumes charge from the resistive divider, as the sample capacitor is charged with every clock cycle. The average current is calculated in equation 6 and 7.

$$C_s=\frac{\Delta Q}{\Delta V}=\frac{I\cdot t_{clk}}{V_{in}}=\frac{I}{V_{in}\cdot f_{clk}} \qquad (6)$$

$$I=C_s\cdot V_{in}\cdot f_{clk}=\frac{V_{in}}{R_{mod}} \qquad (7)$$

The AMC1200, which is clocked with 10MHz, forms an equivalent input resistance Rmod of

$$R_{mod}=\frac{1}{C_s\cdot f_{clk}}=28k\Omega \qquad (8)$$

If the AMC1200 is used together with a voltage divider to measure a phase voltage VHV, then its input resistance of 28kW is connected in parallel to R1 as shown in Figure 3 and affects the divider ratio as calculated in equation 9, where VR1 is the voltage across R1.

$$\frac{V_{R1}}{V_{HV}}=\frac{\frac{R1\cdot R\mathrm{mod}}{R1+R\mathrm{mod}}}{\frac{R1\cdot R\mathrm{mod}}{R1+R\mathrm{mod}}+R2}=\frac{1}{1+R2\cdot\frac{R1+R\mathrm{mod}}{R1\cdot R\mathrm{mod}}} \qquad (9)$$

If the phase voltage for example is 240Vrms, then a divider ratio of 1:1356 is anticipated considering the AMC1200 input range of 177mVrms (±250mV). R1 and R2 might be 300W and 406.5kW. The AMC1200 input resistance Rmod now changes the ratio to 1:1370 and causes a systematic gain error of -1%. Fortunately, this error is very constant over temperature, supply or life time. And the gain is normally calibrated in the application anyhow, because of the limited accuracy (1%) of R1 and R2.

Summarized, the modulator's input is simple to drive and can

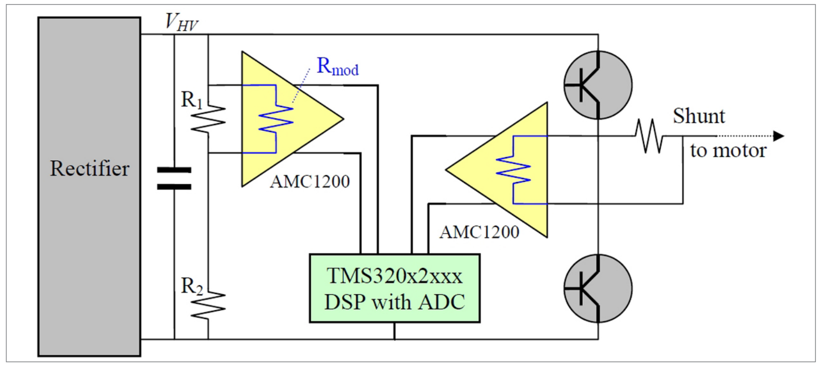

Figure 3: AMC1200 used in motor control to measure DC link voltage and phase current

directly connect to the shunt or the resistive divider.

Figure 1 shows that a modulator output is the digital output of the comparator, which is generating a series of zeros and ones dependent on the analog input voltage. This bit-stream needs to be low-pass filtered to eliminate the quantization noise. A digital filter can perform this task, which has the advantage that digital processing will not add noise or non-linearities. Furthermore, the digital filter can be adjusted for either high update rates or high performance. Two filters can run in parallel, one with a high update rate and lower accuracy used for failure protection, the other for low update rate and high resolution for the control loop. Products with digital output are the AMC1203 and AMC1204 from Texas Instruments.

The AMC1200 filters the bit-stream with an analog filter to receive an analog output voltage again. The analog solution is easier to connect in the application. However, the filter bandwidth needs to be fixed to the highest required bandwidth (e.g. failure protection). Consequently, more noise will remain in the output signal. It is therefore preferable to add another low-pass filter between the AMC1200 and the analog input of the microcontroller. The AMC1200 provides a gain of 8 for better noise immunity.

The third order filter inside the AMC1200 has its -3dB-frequency at 100kHz. Integrated resistors and capacitors only provide an accuracy of 15%. Some variance of the bandwidth and the filter delay has to be expected. The minimum bandwidth for the AMC1200 is at 60kHz. The third order filter optimizes the noise suppression and the signal delay. Higher order filters as used in competitive products improve the noise only insignificantly, but increase the signal delay.

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Special Report: Renewable Energy

PSD EUROPE

Power Systems Design: Empowering Global Innovation

Inside:

SMART ENERGY METERING APPLICATIONS

The importance of digital Isolation

By Petre Minciunescu and Brian Kennedy

DC tolerant current transformers have long been used to sense ac currents in smart energy meters, but they have drawbacks and can be expensive.

For some applications, resistive shunts make better current sensors as they are inexpensive, highly linear, and immune to magnetic influences. Unfortunately, resistive shunts do not have the inherent electrical isolation of current transformers. In applications such as smart energy meters that require isolation, digital isolators with isolated power technology combined with shunt resistors offer a good solution to this problem.

Single-Phase Anti-Tamper Smart Meter

Consider the single-phase anti-tamper smart meter in Figure 1. The analog front-end (AFE) IC calculates energy and monitors the quality of the load by measuring the phase current using a resistive shunt and the phase voltage using a simple voltage divider. In this application, the power line phase voltage serves as the ground reference for the AFE. The neutral line current measurement must be isolated so as to protect the AFE from high voltages. The AFE transmits the computed electrical quantities to a microcontroller (MCU) using standard SPI or I2C communications. The MCU then sends the data to a communication module, usually using a UART interface where safety isolation must be ensured and ground loops avoided. Thus, the MCU must either be isolated from the AFE, sharing ground with the communication module (Isolation 1), or from the communication module, sharing ground with the AFE (Isolation 2).

The meter power supply is derived from the power lines, but two power domains are created by the safety isolation barrier. PS1 in Figure 1 is in the same domain as the phase and can be used without isolating the AFE. However, either safety isolation barrier 1 or 2 requires the use of an isolated power supply, PS2, to provide power to the MCU and communications module (Isolation 1) or only to the communications module (Isolation 2).

To summarize, multiple points in a single phase anti tamper meter require isolation:

- The neutral line current sensing
- Between AFE and MCU (Isolation 1) or between MCU and communication module (Isolation 2).

The signals that must pass isolation barriers 1 and 2 are digital. Many technologies have been developed to isolate digital signals. The traditional approach uses optocouplers with LEDs and photodiodes. However, newer technology exists in the form of digital isolators that use chip-scale transformers. iCoupler® digital isolators,

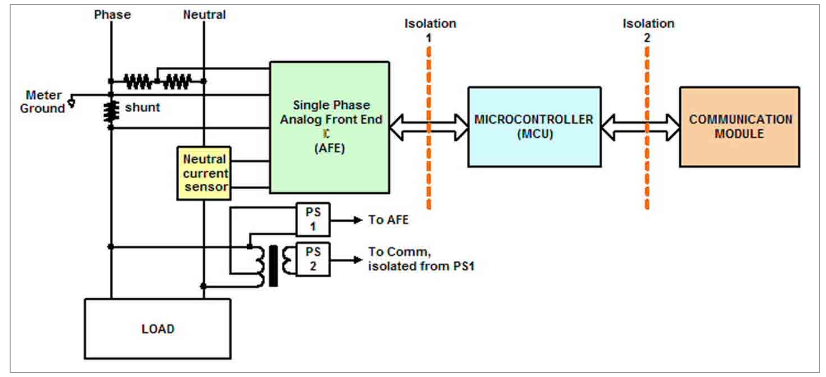

Figure 1: Single-phase anti-tamper smart meter

for example, offer advantages over optocouplers, including improved reliability, smaller size, lower power consumption, higher communication speed, better timing accuracy and ease-of-use. Chip-scale isolation technology can also be combined with other semiconductor circuits to achieve highly integrated solutions in a small footprint. These advantages are strongest in applications with higher data rates. Smart energy metering is one such application as newer meters now require a much higher flow of real-time information.

with isoPower® isolated dc-to-dc converters integrated into the same surface-mount, low-profile package as the isolated data channels. Consider neutral line current sensing in the example above. A current transformer is traditionally used because it provides inherent isolation, but current transformers must be dc tolerant to avoid being saturated, and this increases their cost. They also introduce phase delay that differs by frequency components and is thus difficult to compensate across an entire frequency spectrum. Shunts offer appreciable advantages. They are less expensive, cannot be influenced by external ac or dc magnetic fields, and would have identical characteristics with the shunt used to sense the phase current. However, they are not inherently isolated. This can be overcome using digital isolators that incorporate an integrated dc-to-dc converter with isolated data channels. This allows for a new structure of the single-phase anti-tamper smart meter (Figure 2).

This new structure uses AFE1 to measure electrical quantities derived from the line current and AFE2 to measure the electrical quantities derived from the neutral currents. Both currents are measured with shunts that are immune to external magnetic fields, thus eliminating tamper concerns. AFE2 receives power using an IC containing an isolated power supply based on digital isolators. It communicates with the MCU using isolated data channels that are embedded within the same IC and use

Chip-scale transformers may also be used in an isolated dc-to-dc converter, allowing both data and power isolation to be integrated into a single package. iCoupler products offer this capability

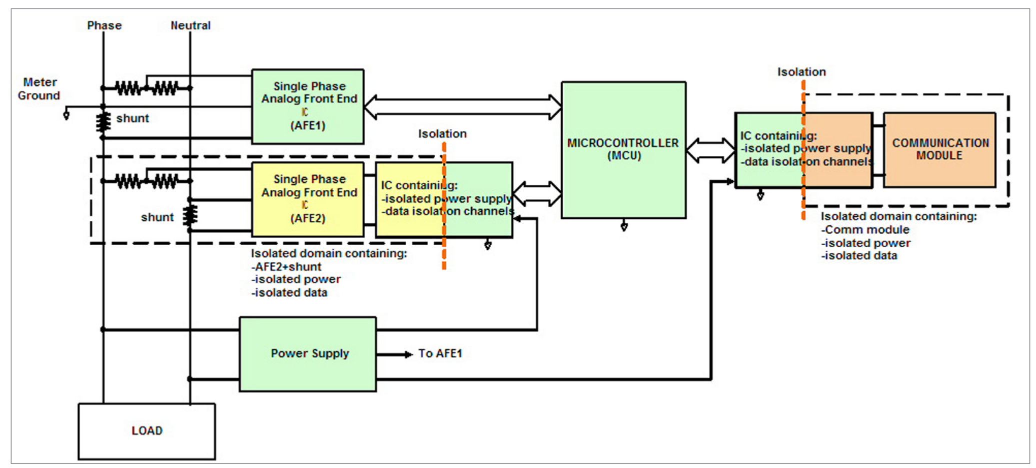

Figure 2: Single-phase anti-tamper smart meter with ICs containing chip scale transformers

the same technology.

The same approach, having an IC containing an isolated power supply together with isolated data channels, can be applied to the communication module, as it also needs an isolated power supply and data communication through the isolation barrier.

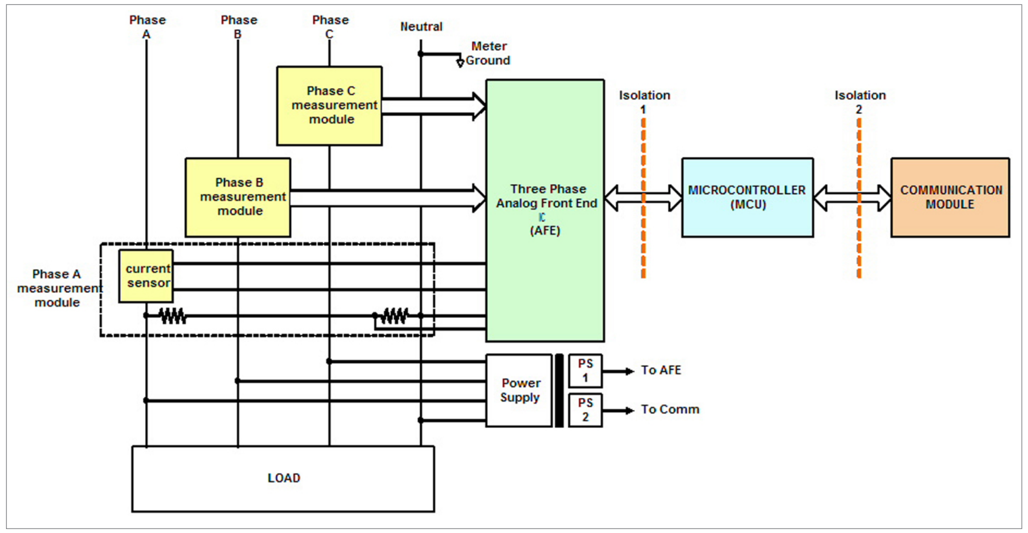

Figure 3: Three-phase smart meter

The advantages of this approach are clear when compared to large, expensive isolated power supplies that are difficult to certify. Digital isolation technology creates the industry's smallest UL certified dc-to-dc converter. The ICs have high thermal and mechanical stability, excellent chemical resistance, and good ESD performance. Designers can now focus on improving the system design, not worrying about isolation.

Three-Phase Smart Meter
The same approach can be taken when dealing with three-phase smart meters (Figure 3). In classic four-wire systems, the neutral line is selected as the ground reference for the meter AFE. The phase currents are measured using current transformers. The power supply uses all three phases to create two domains: one that supplies the AFE and one that supplies the communication module, which must be isolated for safety reasons. The MCU can be placed in either domain, so one isolation barrier exists between AFE and MCU (Isolation 1) or between MCU and the communication module (Isolation 2).

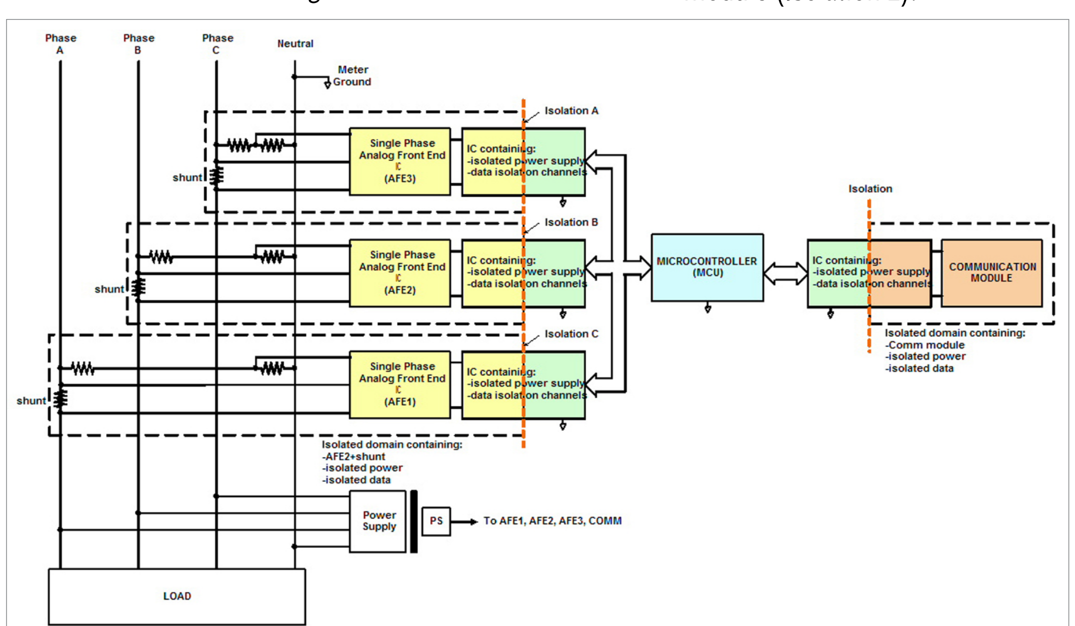

Figure 3: Three-phase smart meter

Similar to the approach in the single-phase anti-tamper meter, using digital isolation technology, the current sensors can be replaced with isolated modules that use shunts, and the communication module can be supplied and communicate with the MCU using an IC containing the isolated power and data channels that communicate through the isolation barrier (Figure 4).

DC tolerant current transformers can be successfully replaced with shunts and digital isolators that use chip-scale technology to integrate both data and power isolation. These digital isolators provide benefits over traditional optocouplers, and various serial communications can be supported: SPI, I2C, or UART. They are indeed an alternative to optocouplers because they offer more performance, are easier to use, and are more reliable.

This changes the system perspective of architecting smart meters:
-Phase and neutral currents can be sensed with resistive shunts, eliminating the threat of magnetic tampering and the difficulties in dealing with current transformer phase delay.

-Both single- and three-phase meters can use a single main power supply, using UL-certified ICs. Particularly in three-phase meters, this can dramatically reduce the power-supply footprint, allowing for smaller meter case dimensions.

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COST-OPTIMIZED SOLAR

Considerations for Energy Storage, Illumination & Communications

By Willie Chan

The influence of clouds, trees, dirt, on the solar cell panel and the rotation of the sun causes problematic fluctuations in the amount power generation.

The typical output current and output voltage characteristics for solar cell panels are shown in Figure 1. An interesting trend emerges in that regardless of the lighting conditions for a given panel, the maximum output power will be delivered when the output voltage is at a relatively constant voltage, VMPP. The I-V curves shown in Figure 1 demonstrate this property by using successively increasing loads under constant illumination

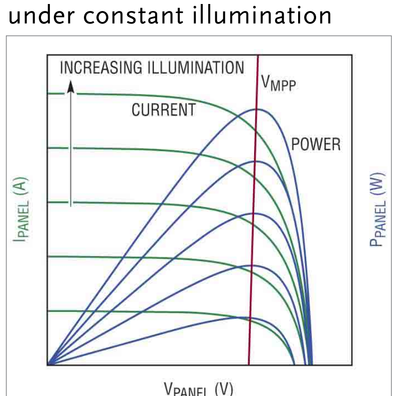

Figure 1: Typical Solar Panel Output Current & Power vs. Output Voltage Curve

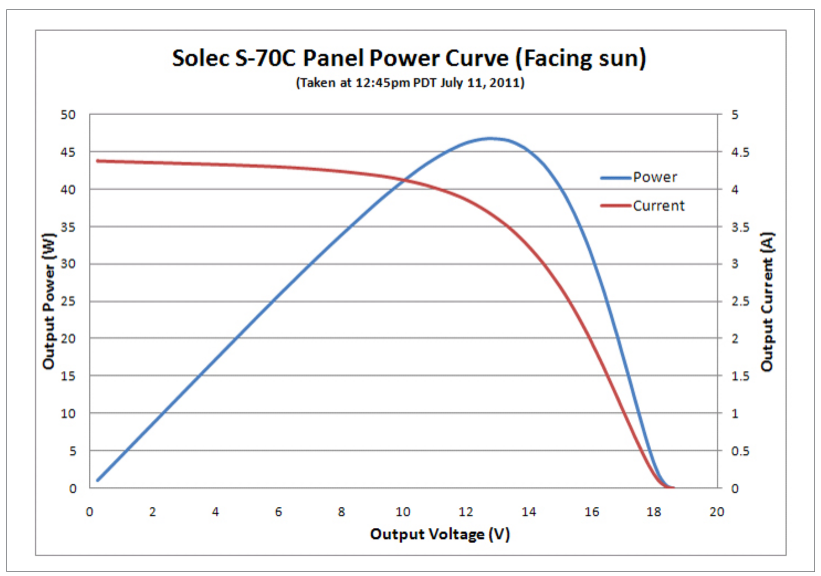

Figure 2: Solec S-70C Panel: Output Current vs. Output Voltage Curve

conditions that were quickly simulated by facing the panel at various angles to the sun.

The data in Figure 2 was gathered within a minute period with the panel aimed directly at the sun under clear skies. As indicated by the graph, an uncontrolled load could cause the net output power to vary anywhere from under 2 Watts to 47 Watts in direct sunlight.

If it were possible to maintain the output voltage of the panel constant at approximately 13V, we could be assured that the maximum amount of power is available to the load.

Optimizing Solar Cell Power

A convenient approach to reduce impedance mismatch is achieved by employing a Maximum Peak Power Tracking (MPPT) circuit between the output of the solar cell panel and the load. The circuit may be built with a device such as the LTM®8062 switching µModule® battery charger. The MPPT offered by the LTM8062 is a simple solution adjustable by a single resistor to ensure maximum power is delivered to the load under widely varying illumination conditions. The effectiveness of the MPPT circuit may be best demonstrated by comparing the output power of two identical set-ups using a Solec S-70C panel with MPPT enabled and MPPT disabled, the latter implemented by pulling the VINREG pin of the LTM8062 to VIN. The test circuit schematic is presented in Figure 3.

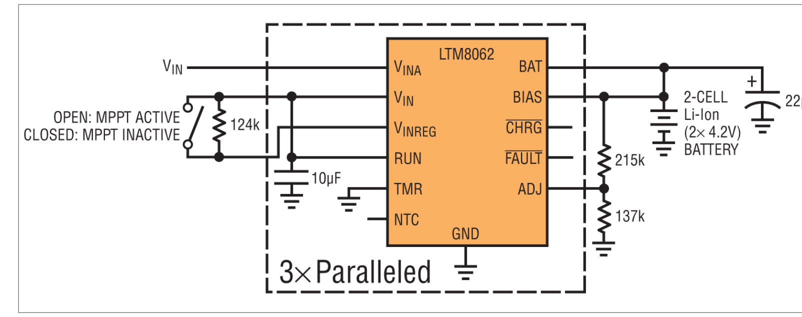

Figure 3: MPPT Effectiveness Test Circuit Schematic for 6A Maximum Charge Current

The LTM8062 is a highly efficient integrated constant current, constant voltage (CC/CV) step-down switching battery charger solution accepting a 4.95V to 32V operating input voltage range. The user-programmable battery float voltage up to 18.8V allows it to support a battery stack consisting of up to 8 cells of sealed lead acid, 4 cells of Li-Ion or Li-poly, or 5 cells of $LiFePO_4$. The integrated MPPT circuit saves a great deal of design complexity compared to a discrete implementation suggested by other industry members consisting of more than ten components. As mentioned previously, the circuit drives the LTM8062 to automatically reduce or increase the battery charge current up to 2A to source the maximum output power from the solar cell(s). In the most basic application, the LTM8062 requires just 3 external components for operation in comparison to anywhere from 15 to 30 components for a traditional discrete implementation.

The charging process terminates after a user-adjustable time period expires or charge current falls to a minimum threshold (200mA) with a battery voltage accuracy of 1.5% over temperature. Two open-collector status indicators CHRG and FAULT are compatible for use with LEDs for visual cues. The CHRG indicator signals when the device is charging the battery. The FAULT indicator signals if the battery has not responded to charge within a fixed time period or if an overtemperature condition has occurred using the optional NTC thermistor input pin.

The LTM8062 will automatically recharge the battery should the voltage drop below 2.5% of the programmed float voltage or a new battery has been inserted. An internal blocking diode is available to prevent reverse current from the battery back to the source when the solar cell voltage collapses at night. For increased charge current, the outputs of multiple LTM8062s can be paralleled together. In this arrangement the modules can share a single pair of feedback resistors as shown in Figure 3. Three LTM8062 modules were connected in parallel for a maximum charge current of 6A ±7.5% in the constant current charging state.

Since the initial charge state of the battery in a real world application is highly variable depending on the system usage, size of the battery, and sky conditions on prior days among other factors, an electronic load was used to simulate a maximum power draw from the solar panel approximately at the transition between constant current and constant voltage charge regions of the battery. By challenging both circuits at this operating point, we can be

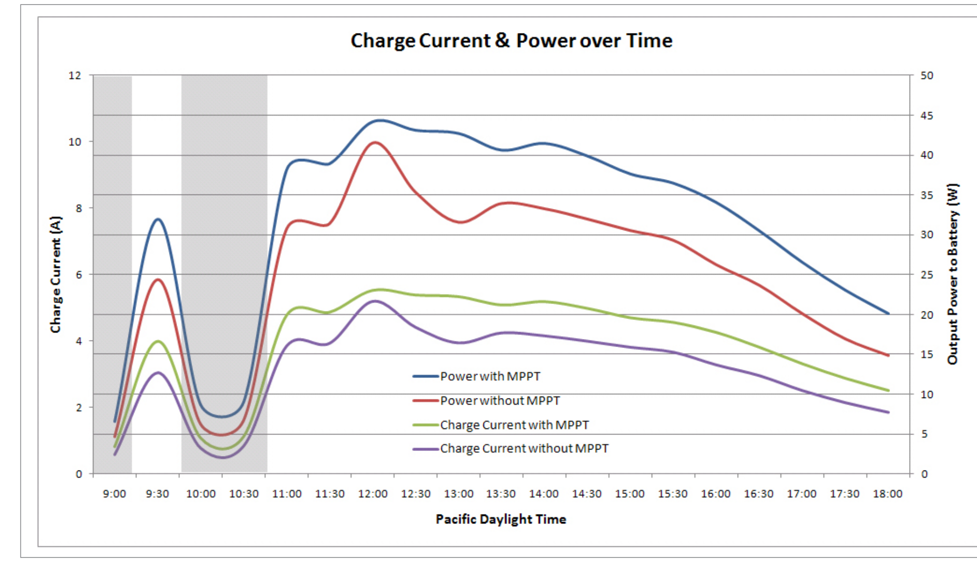

Figure 4: Charge Current & Power with & without MPPT

certain the circuit will support all other events in the charge cycle. With an 8.4V charge termination voltage corresponding to a two-cell Li-Ion stack, the electronic load was asked to pull up to 6A from the three LTM8062 charger modules in parallel while maintaining a voltage of approximately 8V.

The current and power delivered to the simulated battery cell is dramatically higher with the MPPT circuit active compared to the circuit inactive. The current to the load showed a 20% - 40% improvement with the exception of the noon period where the LTM8062's internal maximum charge current limit was reached when MPPT was enabled.

Reliable Energy Efficient Illumination

With the maximum output power now efficiently stored in the battery, the most reliable and efficient way to provide nighttime illumination today is with LEDs. Cost of ownership is also reduced as LEDs last ten times longer than their fluorescent counterparts. Furthermore, LEDs require DC power to ensure operation fits perfectly with the DC power available from the solar cells and batteries. Mirroring the LTM8062 in efficiency, reliability, and convenience, the LTM8042 constant current LED driver presents a worthwhile solution for illumination needs.

Whether a boost, buck or even buck-boost operation is required, the LTM8042 and LTM8042-1 are easily configured to deliver a constant current up to 1A and 350mA, respectively. In this experiment, the simulated 8.4V Li-Ion battery pack would deliver most of its energy at approximately 7V, allowing the LTM8042 to support a 700mA LED string up to 16V for a luminous flux of 1300 lumens using neutral white XLAMP XM-L LEDs by Cree. With the same battery pack, the LTM8042-1 could drive a 24V LED string at up to 350mA, delivering a luminous flux of 1040 lumens using neutral white Luxeon Rebel ES LEDs by Lumileds. If two solar panels are stacked in series to raise the VMPP to 26V and the battery stack is increased to 16.8V, a luminous flux up to 2880 lumens can be achieved with the XLamp XM-L LEDs or 1430 lumens with Luxeon Rebel ES at 350mA. Both the LTM8042 and LTM8042-1 form a complete LED driver solution operating from an input voltage of 3V to 30V, requiring as few as 3 external components.

To save power during dusk and dawn hours, the LTM8042 supports two dimming methods. A dimming ratio up to 3000:1 can be achieved using a PWM input. Analog dimming can be applied using a resistor or voltage. The switching frequency is adjustable from 250kHz to 2MHz and can be synchronized to an external clock up to 2.5MHz for noise-sensitive applications.

Clear Communication is Key
Low noise radiated solutions are important in wireless communications for improved signal reception and transmission. Linear Technology offers eight simple and easy to use DC/DC step-down µModule regulator products which are certified to meet the EN55022 Class B radiated EMI (electromagnetic interference) specification with the highest output power ratings in the industry. Tests were performed using the standard demonstration board whose Gerber files are available to all design engineers. Their EMI performance is proven by third-party independent tests reports which may be reviewed online. Linear Technology's line of EN55022 Class B certified step-down µModule regulators accept operating input voltages up to 36V and deliver output currents up to 8A with support for accurate output current sharing among multiple modules increasing output current capability to over 32A. Engineers designing wireless communications networks with high uptime requirements have already found them to be a valuable tool.

Conclusion
The Maximum Peak Power Tracking feature of the LTM8062 µModule battery charger delivers up to a 40% increase in the amount of power extracted from a solar cell panel in a compact, convenient reliable and efficient solution.

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SOLAR BATTERY CHARGER

For off-grid and mobility applications

By Michele Sclocchi and Martin Williams

Photovoltaic cell technology over the last few years has reached levels of cost and efficiency that enable its use in new markets.

Due to the varying sunlight conditions, energy storage in batteries is essential. Also, the need to extract the maximum amount of energy possible from a PV system has led to the development of increasingly efficient maximum power point tracking devices.

The increasing interest in environmental issues due to the production of electric energy from fossil fuels and their growing cost are drawing remarkable amounts of capital and interest of the scientific community to energy production techniques from renewable sources.

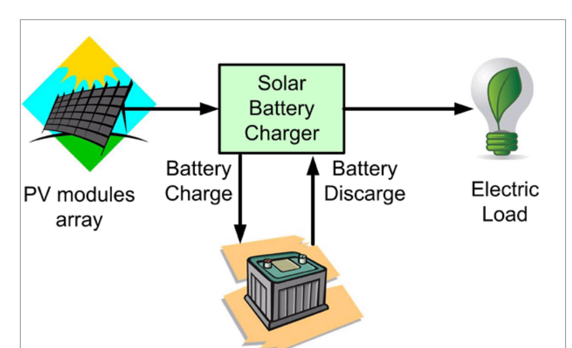

Figure 1: Typical off-grid PV system

Distributed energy production allows rural areas to be supplied where grid connections are impossible, or too expensive.

The cost of PV modules is dropping significantly thanks to the development of emerging silicon technology and the increasing competition between module manufactures. For these reasons the PV market is expected to grow even faster in the coming years. Off-grid installations are a niche market today due to the fact that in developed countries electric grid is sufficiently widespread and reliable for small producers. Nevertheless off-grid PV is going to become a large market with the diffusion of PV installations in rural areas of developing countries.

An off-grid PV system, also called a stand-alone system is designed to provide electricity to homes or remote loads, without drawing supplemental power from the electrical utility. This system consists of a PV panel or array of panels, battery charger and a battery bank.

In order to understand the main requirements of an off-grid PV system optimised for mobility applications, it is necessary to review the simplified electric model of a PV cell, and the techniques used to extract the maximum available power from a photovoltaic source.

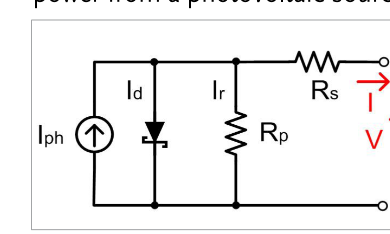

Figure 2: electric model of a photovoltaic cell

PV cell model and PV module
A PV cell can be modeled by a current generator in parallel with a diode (Figure 2). The photo current (Iph) is a function of the solar irradiation. A series resistor Rs and a parallel resistor represent respectively the voltage loss and the leakage current of the cell. The diode D characterises the non

linear behavior of the cell and the dependency of its performance on ambient temperature.

The typical voltage to current (V-I) and voltage to power (V-P) characteristic of a PV cell is shown in figure 3. The open circuit voltage (Voc) is about 0.6V for a crystalline solar cell and it is relatively independent of the solar irradiation. The current produced by the cell depends on the irradiation, ambient temperature, surface area of the cell, and the voltage at which it is operating. The maximum power point (MPP) is the point at which the solar cell current (Imp) and voltage (Vmp), produces the maximum power. At MPP of the curve, the voltage is about 80% of the Voc.

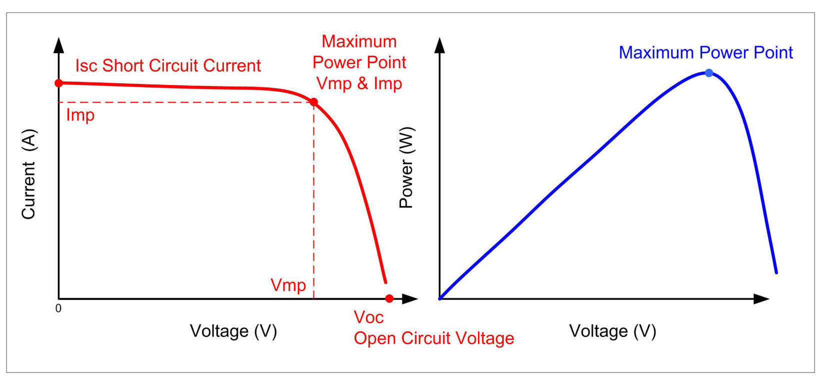

Figure 3: V-I and V-P characteristics under normal operating conditions

A PV module is realised by a series of cells called strings. Each string is protected by a bypass diode that prevents damage through overheating if one or more cells are shaded or defective. These strings are connected in series or parallel to get respectively higher voltage or higher current out of the panel. In ideal conditions, with uniform irradiation and temperature among the panels, the V-I and V-P characteristics of a module are similar to that of a cell, except for their different scale factor.

Several factors influence the output performance of a photovoltaic module: cell material, sunlight intensity, cell temperature, load resistance and irradiation mismatch.

Because all cells of a module are connected in series, they all share the same current. The cell that has lower irradiation will impose the current on all the other cells. For this reason even partial shading of a photovoltaic module will result in a dramatic reduction in output.

The actual impact of energy yields due to partial shading mismatch is difficult to predict with a simple calculation because it depends upon many factors such us internal module cell interconnections, module orientation, PV module array series-parallel connections and the specification of the solar battery charger.

PV Controller Types

PV off-grid systems require specific solar battery chargers connected between the PV panels and the battery (figure 1).

The primary function of a charge controller in an off-grid PV system is to maintain the battery at high state of charge (SOC) while protecting it from overcharging, which can lead to the electrolyte boiling. Various types of charge controller are available. These include simple switch on/off controllers, pulse-width modulated (PWM) charge controllers which charge the battery with constant voltage or constant current (the most commonly used controllers in PV systems), and maximum power point tracking (MPPT) controllers. The MPPT types are more costly and better suited to large systems where the investment in an expensive MPPT regulator gives quick returns. The actual benefits of MPPT depend on the operating temperature of the PV module, the battery state of charge, and possible mismatch shading present on the PV array.

MPPT solar charger controller

An MPPT controller is a high efficiency DC-DC converter which performs as optimal electrical load for the photovoltaic panel or array, and converts to a voltage and current level that is more suitable to charge the battery.

The controller allows tracking the maximum power point of the array throughout the day in order to deliver the maximum available solar energy to the battery.

Step-down MPPT controllers allow a higher voltage array to be connected to a battery bank, with some saving on wiring sizing. However it presents the same limitation of a standard PWM controller when PV operating voltage falls below the battery voltage (due to temperature or partial shading). This limitation can be problematic in small off-grid systems like PV streetlights and mobility applications.

Off-grid systems for mobility applications like RV, boats and vehicles share the same basic components of a standard remote energy system for home-rural installations. The primary difference is that the solar panel array is smaller than that of a typical off-grid home installation, and the PV modules needs to be adapted to relative small areas with different characteristics.

In a typical off grid renewable energy system, much care can be taken to avoid shade from the surrounding obstacles. In RV or any mobility system, shade can not be avoided or planned by definition. Different tilts, orientation, partially shaded areas, salty environments, dirt are all synonymous of mismatch between modules or group of cells.

Amorphous or thin film solar electric panels work much better under these partial shading conditions. The downside with these panels is that they are larger in overall area for the same given wattage of a traditional poly-crystalline or mono-crystalline solar panel.

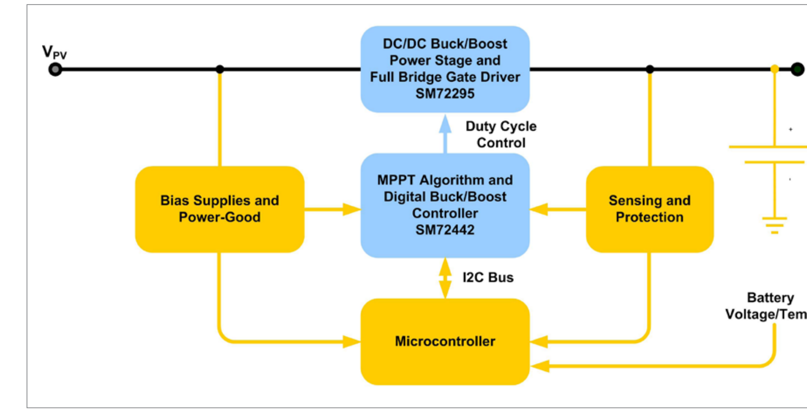

Figure 4: Block diagram of a DC-DC buck-boost battery charger controller with SolarMagic™ chipset by Texas Instruments

Figure 4 shows the block diagram of a DC-DC MPPT battery charger designed with SolarMagic™ chipset from Texas Instruments. The SM72442 mix signal device implements a proprietary MPPT algorithm that reacts to irradiation changes in a few msec. It's high integration level and low power consumption allows the design of high efficiency MPPT controllers.

- Use MPPT DC-DC controllers with a wide input voltage range, in order to adapt to different PV array configurations and shading conditions.
- Avoid configuration with long strings of cells to minimise the partial shading effect, and ensure a DC bus voltage adequate to charge the battery in partial shading conditions.
- Distribute MPPT controllers when possible: distributing more DC-DC controllers with MPPT among modules or arrays addresses the problem of partial shading and mismatch conditions.

A standard battery charger controller or MPPT with only step down function would not be able to reach the MPPT point and deliver to the battery only one third of the available power. An MPPT charger with buck-boost configuration and wide input voltage range will recoup the maximum energy available.

Conclusions

Through careful design of the PV installation and the use of distributed MPPT battery chargers, it is possible to achieve highly efficient off-grid energy systems, contributing significantly to a reduction in the dependence on fossil fuels and consequently reducing emissions.

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CIRCUIT PROTECTION DESIGN

Considerations for small solar power systems

By Neal Schultz

Increasing demand for clean electrical power has led to a focus on renewable energy sources such as solar power.

Solar power systems are independent power generation systems meant to power an individual structure or an entire community. The solar power block diagram in Figure 1 describes a typical system of solar panels, a controller, energy storage and an inverter for conversion of DC to AC, and shows how the solar power generator can be connected to the power grid if desired.

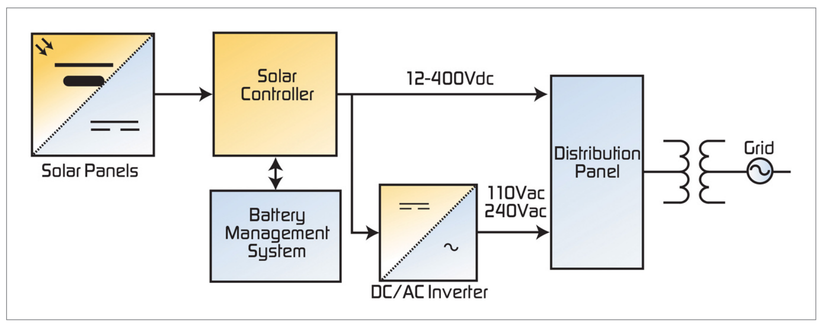

Figure 1: Typical solar power system diagram

Lightning Protection

To maximize light exposure over the solar panels they are usually installed in open fields or in elevated locations (e.g., rooftops of buildings). These installations can make solar power generation systems vulnerable to transients, such as ring-wave and lightning, as well as coupled transients from adjacent cables like power/control lines in the same conduit. In compliance with the electrical environment category of IEC61000-4-5, the power connect cabling out of the solar panel is a Class 4 subset of the IEC61000-4-5.

Protection levels of Class 4 electrical systems are 2kV line-to-line and 4kV line-to-ground, although adopting 6kV protection levels is recommended. The surge-handling capacity of overvoltage protection devices is particularly important in these applications. An effective, coordinated protection solution helps minimize downtime, an important consideration since solar power systems usually consist of unattended operations with long maintenance and service life requirements.

The cable of each solar panel in the solar power system is first connected to the header box of the solar system controller. Figure 2 illustrates an overvoltage protection design with MOV (metal oxide varistor) overvoltage protection devices applied to the input terminals of the header box and controller. For solar applications with higher voltage and reliability requirements, gas discharge tubes (GDTs) connected in series with MOVs help provide a greater level of protection – especially for cabling running outside of premises.

For lower power systems with voltages less than 48VDC, GDTs can be used alone for overvoltage protection. Consideration must also be made for failure modes of overvoltage devices from follow-on current. A coordinated overcurrent/overvoltage protection scheme can help improve system reliability in the case of overvoltage device failure. The resettable polymeric positive temperature coefficient (PPTC) devices shown in the coordinated solution can be used for AC or DC powered loads in the system.

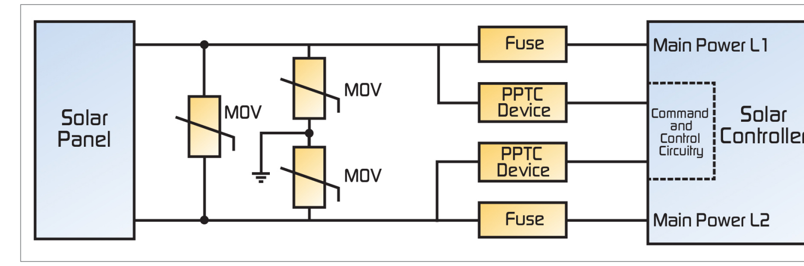

Figure 2: Coordinated solution for solar controller input protection

For the DC load of solar power systems, the circuit design in Figure 2 may also be applied for lightning protection. For lightning protection of AC loads (i.e., output of inverter) the protection circuit design shown in Figure 3 can be utilized.

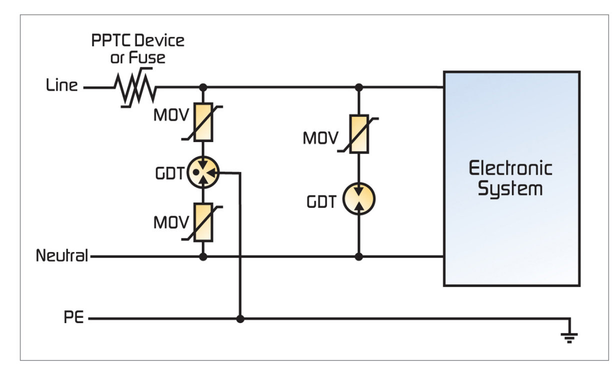

Figure 3: Lightning protection circuit for the AC load of solar power system

Controller and inverter protection

The power output generated by the solar panels can vary depending on light levels received due to clouds or other types of shading effects. One example is when the sun traverses the horizon and shade from trees or structures prevent light from striking the entire array, causing droops in power levels received by the controllers and inverters.

Controllers and inverters are susceptible to many types of transients. Electrostatic discharge (ESD) sources include human, open air or a phenomenon of transients that are generated from the glass of the solar panels and discharged into the controller and inverters. Coupled transients like EFT (electrical fast transient) and ringwave, and lightning, whether by direct or indirect (close proximity) hits, can also generate transients. Communications ports on controllers and inverters are susceptible to these transients.

Protecting the controller and inverter and their communications ports from overvoltage transients can be accomplished with the 2Pro device, which combines a PPTC overcurrent component with an MOV into one thermally protected device. This device helps to provide resettable current limiting for overcurrent conditions and voltage clamping during overvoltage events.

Under normal operating conditions the AC line voltage applied to an MOV is not expected to exceed the device's maximum AC root mean voltage (VACRMS) rating and, provided that the transient energy does not exceed the MOV's maximum rating, short-duration transient events are clamped to a suitable voltage level. However, a sustained abnormal overvoltage/limited current condition may cause the MOV to go into thermal runaway.

Standard unprotected MOVs are typically rated to 275VACRMS for a universal input voltage range. In a loss of neutral condition they may overheat with negative consequences, even if a fuse or power resistor is used upstream. In a worst case scenario, as shown in Figure 1, a voltage of 400VAC instead of 230VAC, derived from a loss of neutral, is applied.

In such an unlimited current condition, the unprotected MOV will first fall to low impedance of a few ohms, but due to the high amount of energy present it may rupture. If there are devices

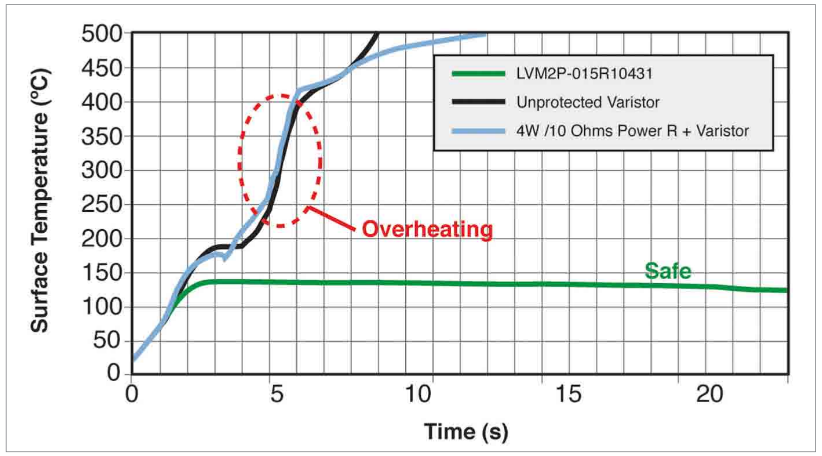

Figure 4: Effect of loss of neutral condition on various devices

placed on the AC line return path to limit current flow these may also overheat due to the failure of the MOV.

Figure 4 illustrates the effects of these abnormal overvoltage conditions on three devices or a combination of devices:
2Pro device (TE's LVM2P-015R10431 device)
Single MOV (10mm, 275 VRMS – TE's ROV10-431K device)
MOV/4W with power resistor (10 ohms)

As shown in Figure 4, the 2Pro device's PPTC element helps prevent thermal runaway, maintaining varistor surface temperature at less than 150°C, and prevents the device from reaching unsafe temperatures caused by overvoltage transients. This approach helps manufacturers comply with IEC 60950 and IEC 60335 and helps equipment remain operational after specified lightning tests according to IEC 61000-4-5.

Battery Pack Protection

In solar power systems the safety of the battery pack is a very important design consideration. Both lead acid and lithium batteries that are integrated into the system or installed with an external wire connection can be affected by potential failures such as cable short circuit, misconnection of the battery's positive and negative poles, or overtemperature issues. Such failures can cause minor damage to the equipment's circuit or result in serious property damage or safety issues.

Battery packs are also subject to external short circuit events during transportation and installation, and overcurrent protection is required to improve safety and system performance. The Metal Hybrid PPTC (MHP) device was developed for these types of battery pack applications and provides over 30A of working current when the specified voltage is over 30VDC.

Activation steps of the MHP device

The MHP device connects a bimetal protector in parallel with a PPTC device. The device helps provide resettable overcurrent protection in high-rate-discharge battery packs while also utilizing the low resistance of the PPTC device to help prevent arcing in the bimetal protector at higher currents, and to heat the bimetal to keep it open and in a latched position.

Summary

Rising energy costs and increasing support for clean, renewable energy sources have made solar power generation a growth industry. Protecting the photovoltaic system against damage resulting from overvoltage and overcurrent transients is critical to improving reliability, safety and longevity. TE Circuit Protection offers a wide variety of innovative devices for these applications and works closely with OEM customers to develop convenient, cost-effective solutions for emerging technologies.

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PV SYSTEMS AND INVERTER ENGINEERING TEAMS ARE SCALING UP

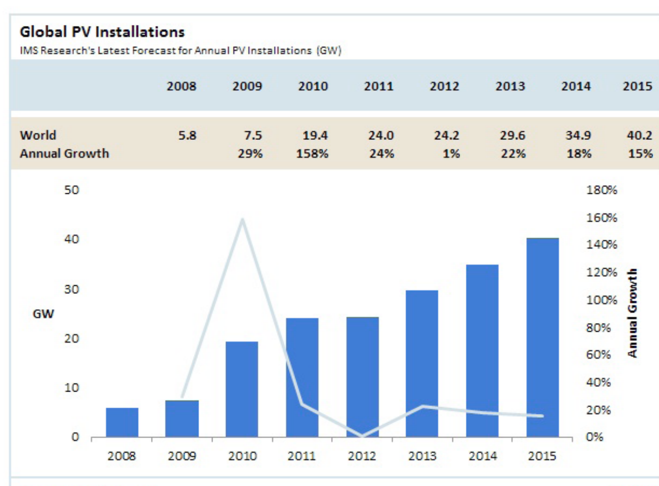
By David G. Morrison, Editor, How2Power.com

Forecasting the growth of solar (photovoltaic or PV) power is a tricky business. The PV marketplace is highly dynamic with respect to time and place. The growth of PV power today is very much dependent on government policy, which varies from country to country and in the U.S. from state to state...

Policy even changes from one year to the next in some cases as incentives are added or removed. In recent years, the adoption of solar power has also been impacted by supply chain issues such as the under or oversupply of PV modules. Then there are the ongoing fundamental issues such as the ability of module suppliers to lower their manufacturing costs, and the impact of technological advancements on the cost of the PV modules and complete systems.

These are some of the issues that underlie the volatility in the recent growth of the PV market, and serve as a note of caution when viewing current projections of (mostly) double-digit annual growth in this market (see the figure.)

According to IMS Research, the amount of new photovoltaic (PV) power generating capacity installed annually worldwide is expected to continue to rise. But note the wide variation in annual growth rates (both recorded and projected) over the selected time period.[1]



Figure

However, for engineers who are interested in the potential impact that a growing PV industry could have on their career opportunities, the pool of current job openings in this field provides another barometer of how much PV equipment manufacturers expect the industry to grow. In this column, we once again focus on the opportunities for power electronics (PE) engineers within solar inverter companies.[2] A recent sampling of manufacturer websites reveals that there are still many openings for PE engineers in this industry.

In a previous column, we discussed the technical requirements and experience sought by manufacturers for these types of positions. Here, we'll discuss some of the market trends that will influence the types of solar inverter design challenges PE engineers will be called on to address in the years ahead. We'll also look at salary and hiring trends in the solar inverter industry as reflected in the results of my recent survey of inverter manufacturers. These survey results will appear in the online version of this article.

Utility-Scale PV Is Growing

As noted above, the market for solar PV power can be divided along regional lines. It also breaks down into three categories by end application—residential, commercial, and utility. Going forward, the different growth rates and needs of these different markets will impact engineering requirements and opportunities in the solar inverter industry.

Phil Vyhanek is president of Solectria Renewables, a Lawrence, Massachusetts-based manufacturer of grid-tied inverters for residential, commercial, and utility PV markets. Over the next few years, Vyhanek expects growth in all three segments. However, he believes the fastest growth will be seen in the utility-scale PV applications. Between now and 2015, Vyhanek expects the utility-scale PV market in the U.S. to grow by a factor of four to five in terms of installed power-generation capacity. Meanwhile, he also expects good growth in the residential and commercial PV sectors with those markets tripling and doubling, respectively, between now and 2015.

As a result of its anticipated growth, the utility-scale applications are expected to dominate the market. "In terms of megawatts deployed in the U.S., by 2015, utility scale is going to be the largest segment of the market, probably by a factor of three to four," says Vyhanek who adds that the utility-scale PV market will also become the largest segment worldwide, particularly in China and India, in the same timeframe.

According to Vyhanek, there is more interest now among installers, system integrators, and investors in utility-scale PV applications because the larger scale of these projects means the potential payoff is bigger. For many companies, he says, the thinking with respect to utility-scale PV power, is "if I'm going to spend engineering resources, I'm going to spend them on a 500-kilowatt or a megawatt system as opposed to engineering and installing a 20-kilowatt system."

At the same time, the utility-scale PV market is newer than the residential and commercial markets, so it's starting from a smaller base and can naturally grow at a faster rate, says Vyhanek. He also notes another factor that will contribute to the utility-scale segment dominating the PV market: The installation of a single utility-scale PV deployment could account for 50 or 100 MW of new capacity, which is the equivalent of many residential systems.

On the other hand, there are system integrators and installers who focus on the mass residential markets for solar power using standard products. However, Vyhanek believes there are fewer companies focusing on small deployments of solar power requiring custom engineering as those engineering costs are hard to justify. New entrants into solar will try to go after the residential market but will probably be dominated by national companies such as SolarCity, says Vyhanek.

Policy Still Drives Growth

Among the forces driving adoption of solar power, government policy is the most influential according to Vyhanek.

"The biggest growth of solar is still dependent upon policy. If you look at growth numbers throughout the U.S., it's really state and local-level policies that drive where solar's getting deployed," says Vyhanek, who notes the same considerations apply globally "Why was solar so popular in Europe, particularly Germany? It's because they had a regulatory environment that was supportive of it."

However, government policies on solar power change over time. Just within the U.S., there are many examples of this variability. "New Jersey had a very attractive renewable energy credit market, now it's not so attractive. New York, Ohio, and Massachusetts all have varying levels of incentives. All these variations create a dynamic market, region by region and state by state, in terms of how much solar is installed and how good the payback and return on investment look," says Vyhanek.

This variability makes it difficult to forecast the development of the solar power market and accounts for the wide variation in projections from one firm's market analysis to another's. "If you believe that policy will continue to be favorable, or become more favorable, then you're going to have an optimistic view of where solar deployments [are headed] and how many megawatts will get deployed," says Vyhanek.

Naturally, another big factor that's driving the growth of solar power is cost reduction.

"Everybody talks about grid parity" says Vyhanek. "Clearly, the rapid decline in PV module prices [due to increased supply] have made it a much-more feasible system. So that helps gain adoptions," says Vyhanek. In the long term, getting solar costs competitive with traditional energy sources is important for the health of the industry. Nevertheless, lower module prices have cut into the suppliers' profit margins, which creates business challenges for the industry as a whole, and he believes, will lead to industry consolidation, particularly among module manufacturers.

But, speaking as a supplier of central inverters, he says the inverter is not subject to the same price pressures as the module. The inverter piece, says Vyhanek,is "not the primary cost driver of the systems." There is also less room for cost reduction in the inverter because "the power electronics associated with the inverters is a little bit more established" than the modules. What's more, the inverter is a mission-critical function.

"There's a desire, of course, that we need to be cost competitive, but more important is that we're highly efficient and highly reliable. And I think that has a much greater value on the inverter piece because if you've got a massive system, you might have thousands of modules and if you lose a module that's bad and you may lose one one-thousandth of your energy production. But if you lose an inverter you could potentially lose your entire array," says Vyhanek.

The inverter also plays a control and supervisory role in the PV system. "It's the piece that monitors the performance of your system, especially on utility-scale systems. There's a lot of additional value add and functionality that the inverter offers both in terms of system monitoring and control, particularly managing reactive power. So, there's a lot from an engineering perspective that we can do on utility-scale systems that add value to the utilities and add value to the grid beyond renewable power," says Vyhanek.

For more on how utility- scale PV systems are driving expansion of engineering teams in solar inverter companies, see "Utility-Scale Deployments Are Highly Custom" in the online version of this article, where you'll also find a listing of current job openings for power electronics engineers in the solar inverter industry, as well as the hiring and salary survey of companies in this industry.

About the Author

David G. Morrison is the editor of How2Power.com, a free portal providing information on all aspects of power conversion. Morrison is also the editor of How2Power Today, a free monthly newsletter presenting design techniques for power conversion, new power components, and career opportunities in power electronics. Subscribe to the newsletter by visiting www.how2power.com/newsletters

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RENEWABLE REVOLUTION

By Cliff Keys, Editorial Director & Editor-in-Chief, Power Systems Design

Isn't 'green' a wonderful thing? If we focus on those who are making a real, viable contribution, we see that it is technology that is the main engine and engineers are the true drivers.

Who else in our community could work out how to effectively turn sunlight and wind into electricity in a manner that can support a now vast industry?

With the financial disruptions we are seeing at the moment, even with sporadic job losses in the renewables sector, I am convinced that over the long haul it is the only way to go and will pick up eventually and thrive, simply because it must. The alternative of oil or coal dependence with all the political and environmental issues that are connected to their use is, to say the least, scary.

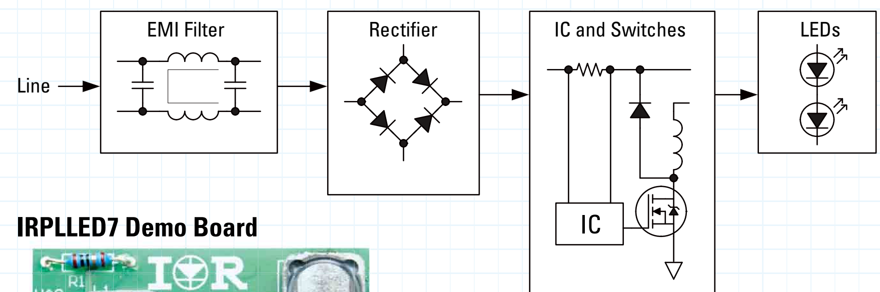
Renewable energy is now big business, even with the 'doom and gloom' prophecies that abound in the news and media. It will continue so and be further refined by good engineering and more advanced technologies and materials giving better financial returns for the operators of solar or wind farms and users alike.

Global solar PV installations will reach 24GW in 2011 according to a new report from IMS Research. The report found that despite the relatively weak start to the year, installations will rise by 24% in 2011 to reach 24GW, up from 19GW in 2010. The research also revealed that European installations will rise by just 3% this year and that Italy will displace Germany as the world's largest market. However, although installations have grown considerably, this has not necessarily translated into a surge in demand for PV components because of high inventory levels in the channel, with customers installing previously purchased modules and inverters.

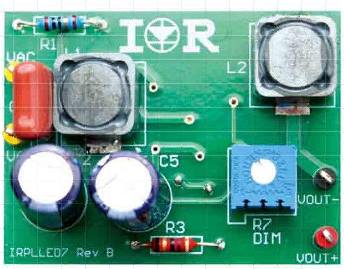
One thing is for sure, we need renewable energy deployment – and we should not delay. The renewable revolution is well underway. Long may it flourish.

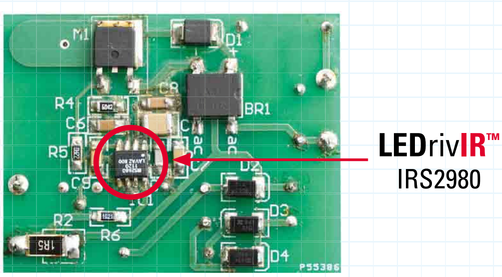
www.powersystemsdesign.com

High-Voltage Buck Control ICs for Constant LED Current Regulation

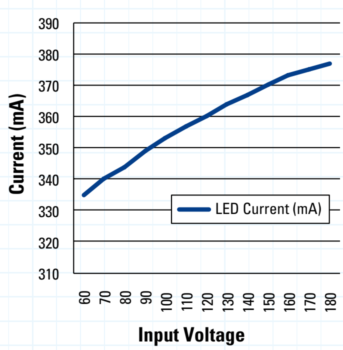


IRPLLED7 Demo Board





LED Current vs Input Voltage



Features

- Internal high voltage regulator
- Hysteretic current control
- High side current sensing
- PWM dimming with analog or PWM control input
- Free running frequency with maximum limiting (150kHz)

Benefits

- Low component count
- Off-line operation
- Very simple design
- Inherent stability
- Inherent short circuit protection

Specifications

- Input Voltage 70V to 250V (AC)
- Output Voltage 0V to 50V (DC)
- Regulated Output Current: 350mA
- Power Factor > 0.9
- Low component count
- Dimmable 0 to 100%
- Non-isolated Buck regulator

Part Number	Package	Voltage	Load Current Regulation	Startup Current	Frequency
IRS2980S	SO-8	600V	+/-5%	<250 µA	<150 kHz
IRS25401S	SO-8	200V	+/-5%	<500 µA	<500 kHz
IRS25411S	SO-8	600V	+/-5%	<500 µA	<500 kHz

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