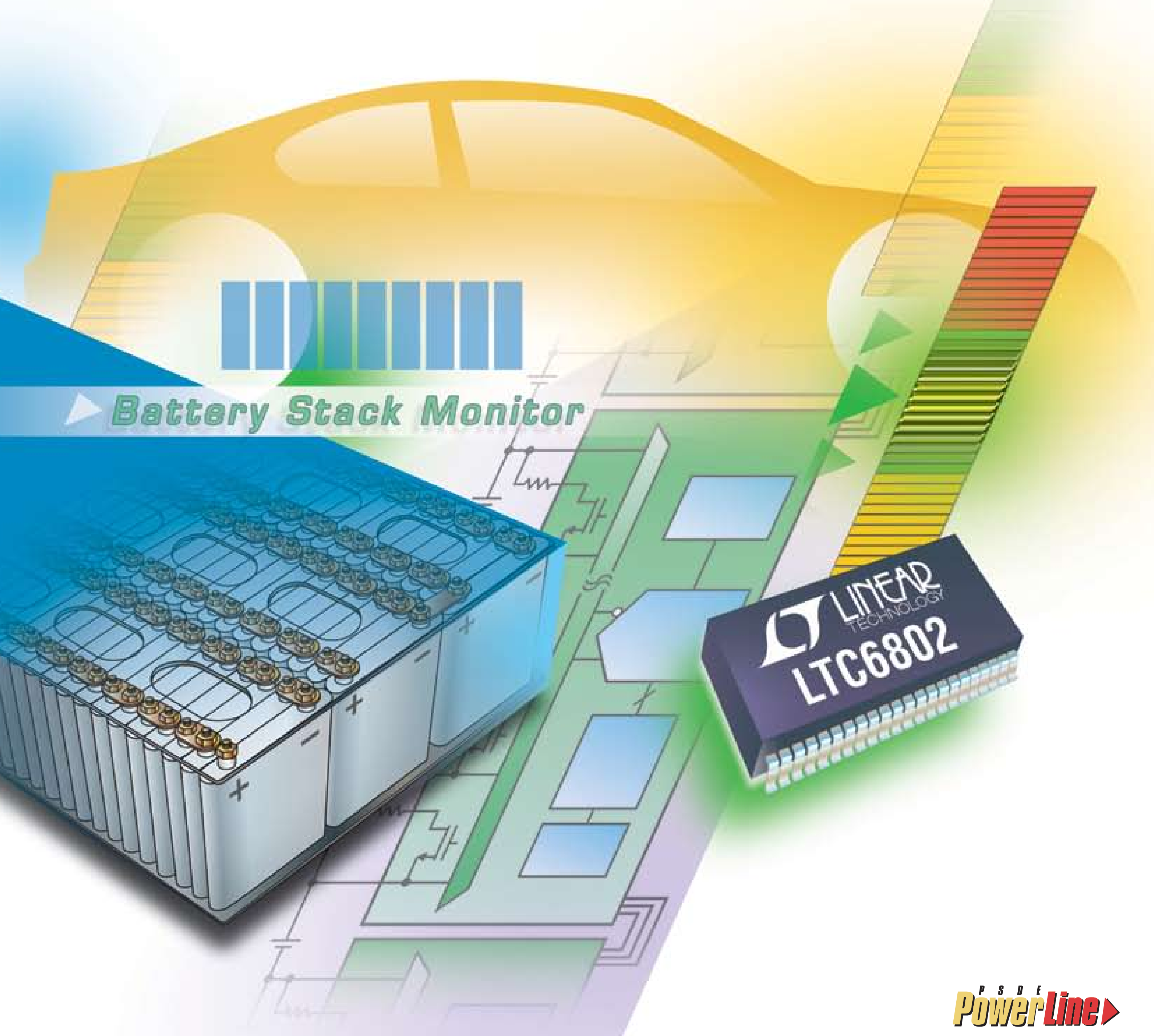
Power Systems Design
EUROPE

Empowering Global Innovation

September 2008



PSDE PowerLine

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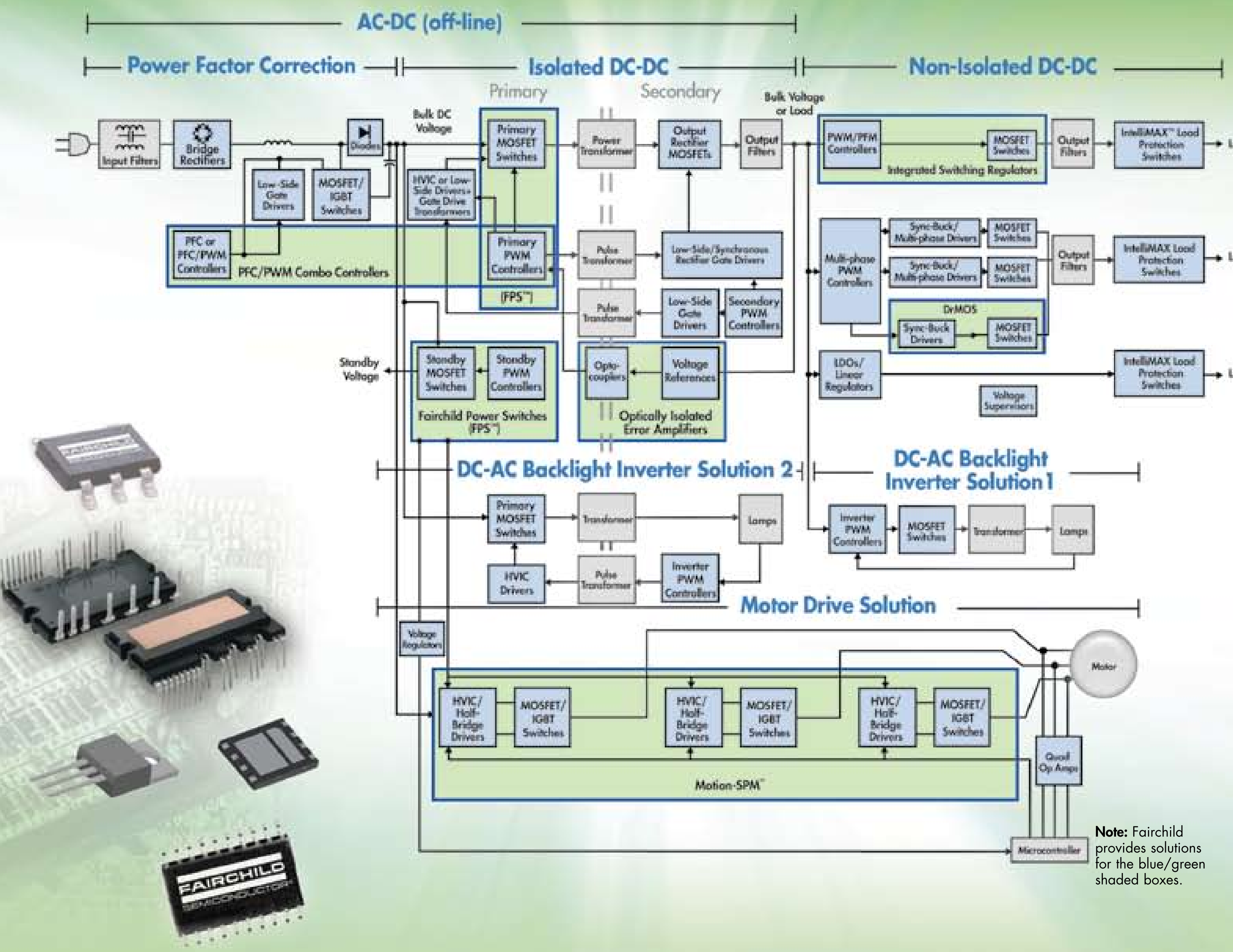
PSDE Green Power
ENERGY EFFICIENCY

Special Report Automotive Electronics – Part II

ISSN: 1613-6365


AC-DC (off-line)
Power Factor Correction
Isolated DC-DC
Non-Isolated DC-DC
Primary
Secondary
Input Filters
Bridge Rectifiers
Diodes
Bulk DC Voltage
Low-Side Gate Drivers
MOSFET/ IGBT Switches
HVIC or Low-Side Drivers+ Gate Drive Transformers
Primary MOSFET Switches
Power Transformer
Output Rectifier MOSFETs
Output Filters
Bulk Voltage or Load
PFC or PFC/PWM Controllers
PFC/PWM Combo Controllers
Primary PWM Controllers
(FPS™)
Pulse Transformer
Low-Side/Synchronous Rectifier Gate Drivers
Pulse Transformer
Low-Side Gate Drivers
Secondary PWM Controllers
Standby Voltage
Standby MOSFET Switches
Standby PWM Controllers
Fairchild Power Switches (FPS™)
Opto-couplers
Voltage References
Optically Isolated Error Amplifiers
PWM/PFM Controllers
MOSFET Switches
Integrated Switching Regulators
Output Filters
IntelliMAX™ Load Protection Switches
Load
Multi-phase PWM Controllers
Sync-Buck/ Multi-phase Drivers
MOSFET Switches
Sync-Buck/ Multi-phase Drivers
MOSFET Switches
Output Filters
IntelliMAX Load Protection Switches
Load
DrMOS
Sync-Buck Drivers
MOSFET Switches
LDOs/ Linear Regulators
IntelliMAX Load Protection Switches
Load
Voltage Supervisors
DC-AC Backlight Inverter Solution 2
Primary MOSFET Switches
Transformer
Lamps
HVIC Drivers
Pulse Transformer
Inverter PWM Controllers
DC-AC Backlight Inverter Solution 1
Inverter PWM Controllers
MOSFET Switches
Transformer
Lamps
Motor Drive Solution
Voltage Regulators
Motor
HVIC/ Half-Bridge Drivers
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FAIRCHILD SEMICONDUCTOR


POWER

Organic LED Drivers

Enhanced Image Quality, Energy-Efficient Displays

High-Performance Analog>>Your Way™

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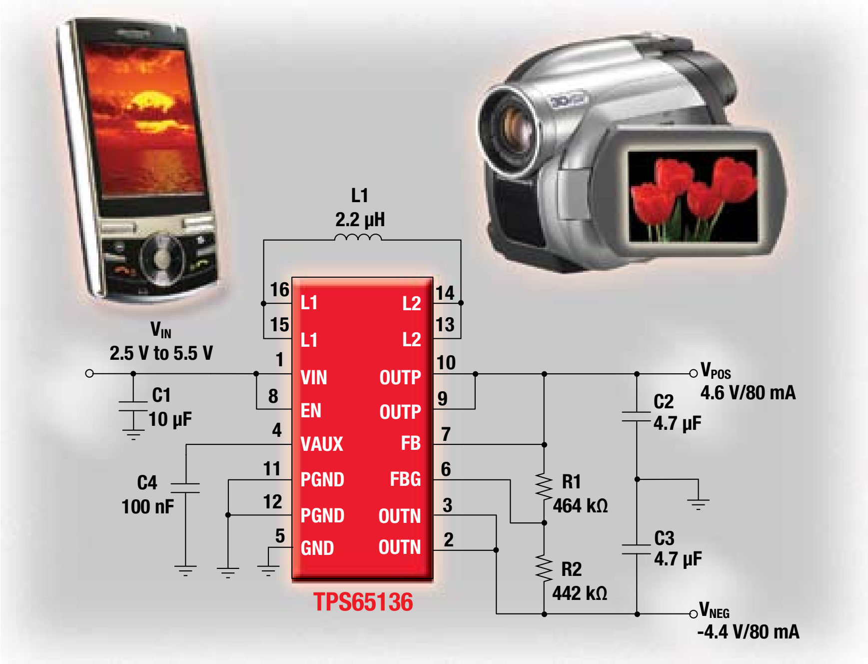
- OLED displays up to 2.5"
- CCD sensor bias
- Positive and negative analog supplies
- Active Matrix OLED (AMOLED) power supplies and displays used in mobile phones
- Mobile internet devices
- Portable media players and digital cameras

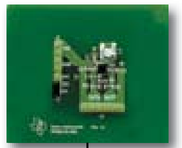
Features

- 2.3-V to 5.5-V input voltage range
- Fixed positive output voltage of 4.6 V
- Negative output voltage down to -7 V
- Short circuit protection
- Superior line regulation
- Buck-boost mode for both outputs
- Supports new batteries with input voltages up to 4.8 V



The **TPS65136**, part of TI's OLED driver portfolio, enhances the image quality for Active Matrix OLED displays used in portable applications. Based on TI's single-inductor output regulator technology, the OLED driver supports positive and negative voltages, and achieves the smallest solution size using a single inductor.

Device	V_{IN} (V)	V_{OUT} (V)	I_{OUT} (A) (typ)	Output Efficiency (%)	Package
TPS65130	2.7 to 5.5	–15 to 15	0.8	89	24-pin QFN
TPS65131	2.7 to 5.5	–15 to 15	1.95	89	24-pin QFN
TPS65136	2.3 to 5.5	–6 to 4.6	0.7	70	16-pin QFN



www.ti.com/tps65136-e or call toll free:
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Get Datasheets, Evaluation Modules, Samples and the Power Management Selection Guide

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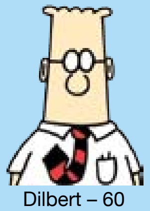

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Volume 6, Issue 7

Where did all the oil go?

Welcome to the September automotive part-two issue of PSDE. This topic has proven extremely popular with our readers and manufacturers alike. Not surprisingly perhaps that with the much publicized ‘energy crisis’ with its incumbent haggle of followers, this topic has been escalated to the general public through the media. Hardly any news report goes on-air without featuring some aspect of the situation. Engineering, of course, has seen this for decades; that is, before it became fashionable as a popular speaking platform.

Historically, the energy crisis has been met with a knee-jerk desire to drill more, find ‘oil substitutes’; nuclear, fossils and even corn and other bios. Now the picture seems to be getting a lot more thoughtful: How can we cut our consumption? How can we find clean sources that will not pollute the environment further or steal vital foodstuff from hungry mouths?

We have all seen these news reports regarding world oil supply. It is a particularly unstable environment, apart from the basic fact that it is dirty and poisonous to the environment.

It is also a finite energy resource, so we need to move on…and fast. Plain common sense has persuaded many of us of this.

In the automotive arena, the power electronics industry has already seen the need and is making huge strides forward in terms of power conservation. It will be a struggle though as the last bastions of oil based political power let go of a losing battle and change sides to become the newly-converted, or at least put a foot in each camp.

But for us, it’s an exciting time for the best of reasons. The floodgates of engineering ingenuity are set to open wide as we transition into an energy savers’ paradise to generate and use new, clean and sensible sources of energy for cars and trucks in the cleanest and most efficient way. Just think of the millions of tonnes of CO and CO_2 that will be saved from our future generations’ lungs, the new appreciation of the earth’s natural resources and the new jobs and wealth generated by the creative engineering of this ‘new’ power and control technology.

Only engineering, science and technology have the key to the solution. The rest is just execution and funding. This is where politicians can actually help the world.

Later this month I will be traveling again extensively throughout the US. There, I’ll be visiting the headquarters of all the major players that are vital to our European power business. As usual, I will bring back home my observations and comments on the key meetings we at PSDE have lined up for the trip.

In this issue we have for you another compendium of great features, articles, reports and industry comment from those who really know.

We are also busy using your valuable feedback to give you all the features within the magazine and online to ensure that you get the right information in the right way for your work. I appreciate all your comments and suggestions for the magazine and can assure you that it will be used. After all, engineers can’t be expected to save the planet and make a healthy profit for their companies without the right tools and information!

All the best!

Cliff Keys

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

International Rectifier Rejects Vishay's Unsolicited Proposal

Oleg Khaykin, IR's Chief Executive Officer - committed to creating long term shareholder value

International Rectifier has announced today that its Board of Directors has unanimously determined that the unsolicited, non-binding proposal by Vishay Intertechnology, Inc. to acquire all of the outstanding shares of International Rectifier for $21.22 per share in cash is not in the best interests of IR and its shareholders.

The Board reviewed the proposal with the assistance of its financial and legal advisers Goldman, Sachs & Co. and Fried, Frank, Harris, Shriver & Jacobson LLP, respectively.

Richard J. Dahl, Chairman of the Board of International Rectifier said: "Vishay's proposal significantly undervalues the Company and its future prospects when compared to the shareholder value realizable under our recently adopted strategic plan. On August 1, we announced that the Company had successfully completed the restatement process of prior financial periods. The Company has also added considerable strength and depth to its senior management team during the past year and is poised to enhance its competitive position in the marketplace.

"The Board believes that the proposal by Vishay does not value the Company and its future prospects appropriately. In our judgment, IR shareholders will be better served by allowing management to move forward with its strategic plan. We believe that IR's valuation is still under the cloud of legacy issues. The Board and our management team look forward to executing the exciting opportunities available to our Company and to delivering this value to our shareholders," concluded Mr. Dahl.

Oleg Khaykin, Chief Executive Officer of the Company added: "We look forward to fulfilling our potential as we continue to follow our strategic plan and focus on long term value creation for our shareholders."

The Board of Directors communicated its decision in a letter sent from Richard J. Dahl, Chairman of the Board of International Rectifier to Vishay Intertechnology's Executive Chairman of the Board of Directors, Dr. Felix Zandman and President and Chief Executive Officer, Dr. Gerald Paul.

www.irf.com

Indium Expands Solar Engineering Team

Indium Corporation has announced the expansion of its solar engineering team with the appointment of Clark Scharett and Justin Weiler as Manufacturing Process Engineers.

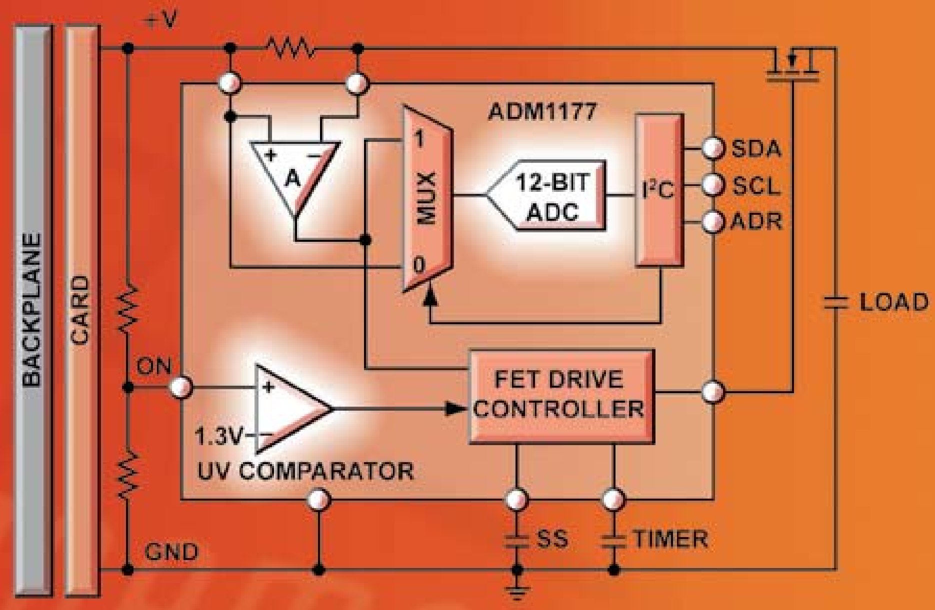
Clark Scharett joins Indium's Solar Copper Tabbing team, supporting process development, equipment selection and installation, and high-volume commercialization initiatives. He brings to Indium more than 16 years experience as a senior project engineer and plant engineer.

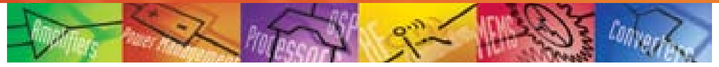
Clark has expertise in both design and installation of a wide range of manufacturing and facility equipment, as well as in manufacturing process optimization. He has associates' degrees in English and Science and a bachelor's degree in Mechanical Technology. He is currently pursuing a master's degree in Advanced Technology at the State University of New York Institute of Technology.

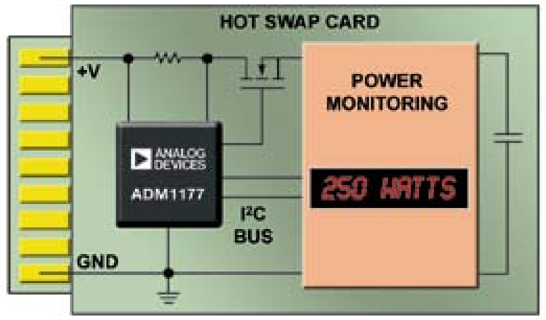
Justin Weiler is responsible for solar rotatable and planar target manufacturing, including process development and optimization and new technology research. Prior to joining Indium he was an Engineering Analyst with Critical Imaging, LLC, and also has been involved in research focused on alternative energy modeling and simulation.

Justin holds a bachelor's degree in Mechanical Engineering from the Rochester Institute of Technology and a master's degree in Aerospace Engineering from Georgia Tech.

www.indium.com







Industry's most accurate Hot Swap and power monitor ICs provide accurate data on power consumption, enabling better control and conservation of energy.

Part Number	Hot Swap Range (V)	Integrated Power Monitoring	Features	Package	Price @ 1k ($U.S.)*
ADM1175	3.15 to 16.5	Yes	Manual convert pin	10-lead MSOP	2.50
ADM1176	3.15 to 16.5	Yes	16 I²C addresses	10-lead MSOP	2.50
ADM1177	3.15 to 16.5	Yes	Dedicated SOFT START pin	10-lead MSOP	2.50
ADM1178	3.15 to 16.5	Yes	Overcurrent ALERT pin	10-lead MSOP	2.70
ADM1170	1.6 to 16.5	No	Separate VCC pin	8-lead TSOT	2.10
ADM1171	2.7 to 16.5	No	Current sense output	8-lead TSOT	2.20
ADM1172	2.7 to 16.5	No	Power fail comparator	8-lead TSOT	2.00

Japanese Firms Plan Solar-Powered Cargo Ship

The world's first cargo ship partly propelled by solar power is set to take to the seas later this year in a joint project between two Japanese companies.

A huge freighter capable of carrying 6,400 automobiles will be equipped with 328 solar panels at a cost of over one million Euros, said a spokesperson at shipping line Nippon Yusen.

The ship, which is expected to be completed in December, will be used to transport vehicles for Toyota Motor Corp. as part of trials by Nippon Yusen and energy distributor Nippon Oil Corp.

It will be the world's first attempt to use solar energy to help power a large ship's propulsion system, the official said. So far its use has been limited to lighting and by crew in living quarters.

"Conditions are very different from land transport due to the risk of (the system) getting wet with sea water or being subjected to constant shaking" by the wind and the waves, the spokesperson said.

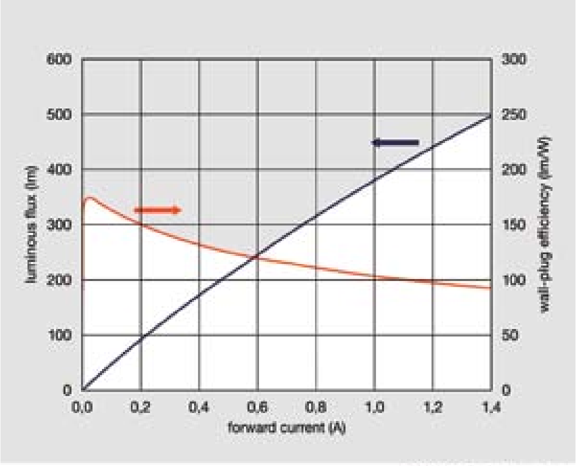
The companies aimed to build a 40-kilowatt solar power system, which would initially cover 0.2 percent of the ship's energy consumption for propulsion and hope to raise the ratio to one percent by 2010, when they are considering ordering a ship with a new solar system.

The experiment is part of Nippon Yusen's plan to halve fuel consumption and carbon-dioxide emissions for marine transport by 2010.

www.nykline.co.jp/

www.eneos.co.jp/english/

White LED Record in the OSRAM Laboratory



© OSRAM Opto Semiconductors

By improving all the technologies involved in the manufacture of LEDs, OSRAM development engineers have achieved new records for the brightness and efficiency of white LEDs in the laboratory. Under standard conditions with an operating current of 350 mA, brightness peaked at a value of 155 lm, and efficacy at 136 lm/W. White prototype LEDs with 1mm^2 chips were used.

The light produced had a color temperature of 5000K, with color coordinates at 0.349/0.393 (cx/cy). Potential applications include general illumination, the automotive sector and any applications that call for large high-power LEDs.

The key to success was the efficient interplay between all the advances made in materials and technologies. A perfectly matched system of optimized chip technology, a highly advanced and extremely efficient light converter and a special high-performance package combined to produce the world records -155lm for brightness and 136lm/W for efficacy. The semiconductor light sources are also suitable for high operating currents. At 1,4A they can produce up to 500 lm of white light.

www.osram-os.com

Ultracapacitors Provide Energy Storage for Hybrid and Electric Vehicles

Maxwell TECHNOLOGIES

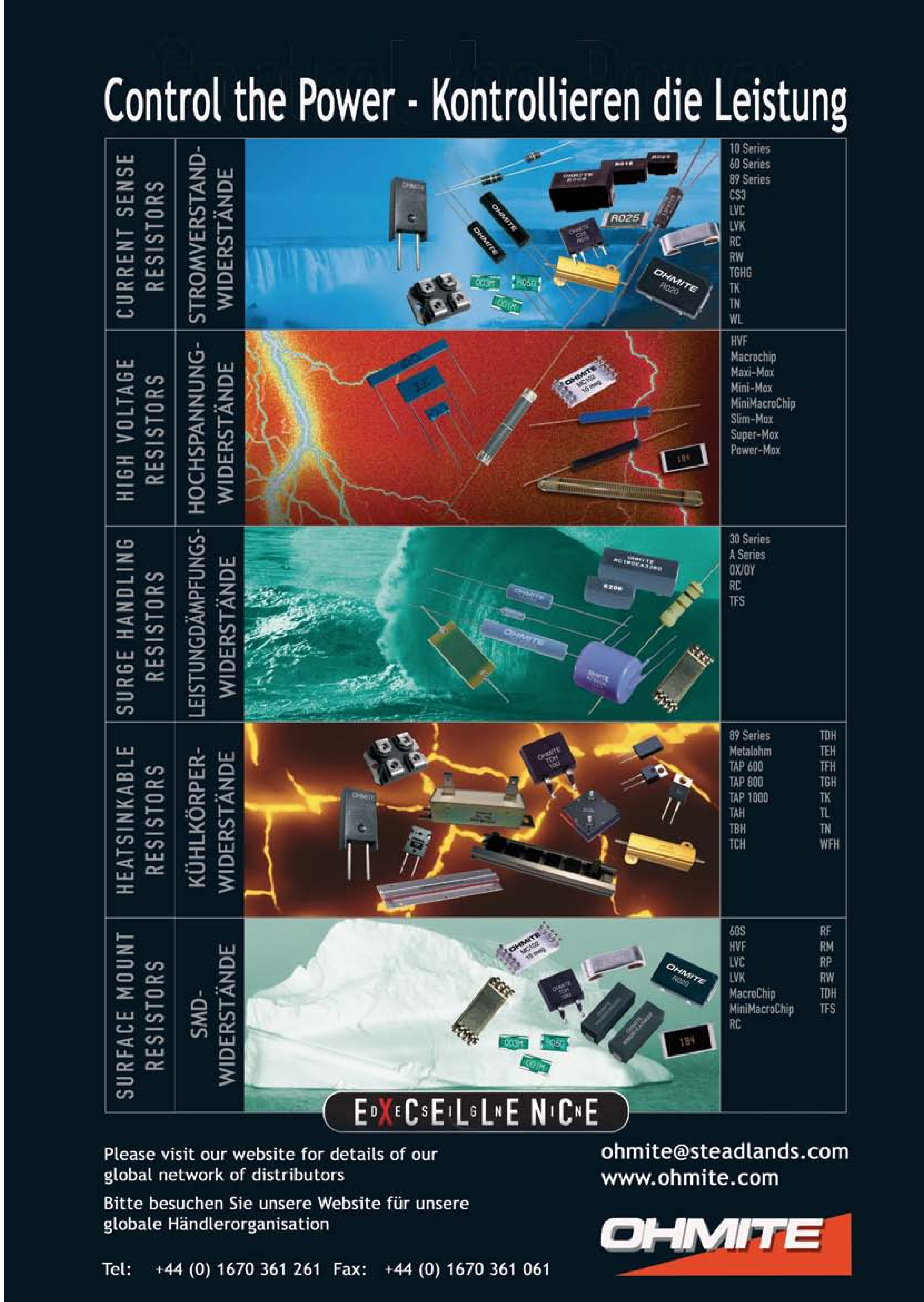
Maxwell has announced today that Golden Dragon Bus Co. Ltd., one of the world's leading producers of medium and heavy duty buses, has selected Maxwell's BOOSTCAP® ultracapacitors for braking energy recuperation and torque assist in fuel-efficient, low-emission, diesel-electric hybrid buses Golden Dragon is producing for the Hangzhou, China, Public Transport Group Co., Ltd. Maxwell has completed delivery of 720 48-volt BMOD0165 P048 multi-cell ultracapacitor modules to Golden Dragon for installation into 45 hybrid buses ordered by Hangzhou.

BMOD0165 P048 modules are encased in a rugged, splash-proof, aluminum chassis. They weigh 14.2kg and are 12.6 liters in volume (416.2mm x 190.1mm x 156.7mm). These durable "smart boxes" include temperature and voltage monitoring and internal cell voltage management that give designers "plug and play" solutions and makes them versatile building blocks for systems with higher voltage requirements. A complete data sheet may be accessed via the following link: www.maxwell.com/ultracapacitors/products/modules/bmod0165-48-6v.asp.

www.maxwell.com

Power Events

- ***electronicAsia 2008,***
  October 13-16, Hong Kong, China,
  www.electronicasia.net
- ***electronica 2008,***
  November 11-14, Munich, Germany,
  www.electronica.de
- ***SPS/IPC/Drives 2008,***
  November 25-27, Nürnberg, Germany,
  www.mesago.de/en/SPS/main.htm



MTS Sensors Monitor Petroleum Shipments

MTS Systems Sensors Division is providing its MG Level Plus liquid-level transmitters to Truman Arnold Companies (TAC) of Texas, US to measure and monitor its daily shipments of more than 5 million Liters of petroleum. When TAC management decided to implement a wireless solution that would allow them to monitor the shipments remotely while maintaining accuracy, they chose a method that combined MTS' MG transmitters with Siemens Energy & Automation's wireless control capabilities.

For every ten-day cycle, the terminal receives an average of 200,000 barrels of petroleum that is stored in nine closed-roof storage tanks ranging in size from 20,000 to 110,000 barrels, with a total storage capacity of 650,000 barrels.

The challenge when moving such a large amount of petroleum products is maintaining accurate control of the process. TAC cannot afford to run out of any of the petroleum products they carry or have inaccuracies during custody transfer. Inaccuracy can result in the company either paying for product that was not received or by not charging for product that was delivered. For every 0.5% in custody transfer error that TAC endures, the company loses 1,000 barrels of product per cycle at the terminal. If this was spread out over the year, and included other terminals that TAC also operates, the cost of inaccuracy quickly reaches into tens of millions of dollars.

A wireless interface was the key to TAC's implementation. MTS Sensors worked with Siemens Energy & Automation to provide TAC with the ability to go wireless. The MTS / Siemens solution provided TAC with a highly accurate MTS digital transmitter and wireless connectivity to a central control panel in their office.

The Siemens transceivers and I/O modules work together with a selection of accessory equipment from Siemens to create a wireless network for any application. WiPS-Link configuration software is used to configure the transceiver and network parameters to utilize the Modbus output of the MG transmitter. TAC used the output from the transceiver to control a graphical display to allow the employees at the terminal to easily view the tank levels from their office.

TAC engineers experienced an easy installation process by using the MG transmitter and its stainless steel flexible hose, which allows a single person to carry the transmitter to the top of the tank and install it through any 1" process opening with an adjustable NPT fitting. A larger opening is needed to install the floats on the transmitter before insertion.

TAC ordered its MG transmitter with Modbus output, which is available for vessels from 508mm to 18,288mm and is ideal for process control, bulk storage, precision inventory control and product level, interface level and temperature monitoring.

Another key feature was field replacement of the transmitters without downtime. The MG achieves this through its modular construction, which allows the transmitter to be serviced or replaced without having to shut down the tank or process.

Customers choose the model MG transmitter due to its ability to provide measurement of product level, interface level and temperature. Every transmitter is custom built for the application and is available in lengths from 508mm to 18,288mm. The model MG can operate on either 12 or 24Vdc power via its 4-wire Modbus connection.

www.mtssensors.com

Energy Efficiency and Safety Drive Auto Electronics

By Jochen Hanebeck, Senior Vice President and General Manager, Automotive, Infineon Technologies

For innovation in automotive electronics in the area of safety, fuel consumption and CO_2 reduction will increase the semiconductor content in cars. Market predictions indicate a compound annual growth rate of about 8% during the next five years. With increased awareness on climate change, stringent emission controls and the certainty of higher energy costs, it is vitally important that vehicles become more energy efficient while further increasing functionality. Automotive semiconductors are key to achieve this goal.

On average, today's vehicles contain up to 80 electronic control units, each comprising around 300 electronic components. As data communication increases, so does network complexity and thus the probability of errors. Central domain controllers will play a greater role in vehicle electric/electronics architectures. At the same time, functionality can be spread out over several sub-units by means of software (e.g. AUTOSAR). New functions, such as the integration of braking and chassis, can therefore be introduced more flexibly.

In order to cope with this complexity, the challenge for the automotive industry is to ensure a seamless and efficient communication between components, control units and systems and to easily connect components and systems from different suppliers.

Reduction in complexity requires innovation, but the automotive industry has to adhere to the highest-quality innovative technologies at attractive mass volume prices. Cost optimization of existing systems or achieving savings through economies of scale need to be supported by new innovative concepts and products. Only by very close cooperation of all stakeholders in the automotive value chain and early involvement of the semiconductor manufacturer will the automotive industry be able to deliver solutions that fit within a competitive cost framework and offer brand differentiation potentials in the marketplace.

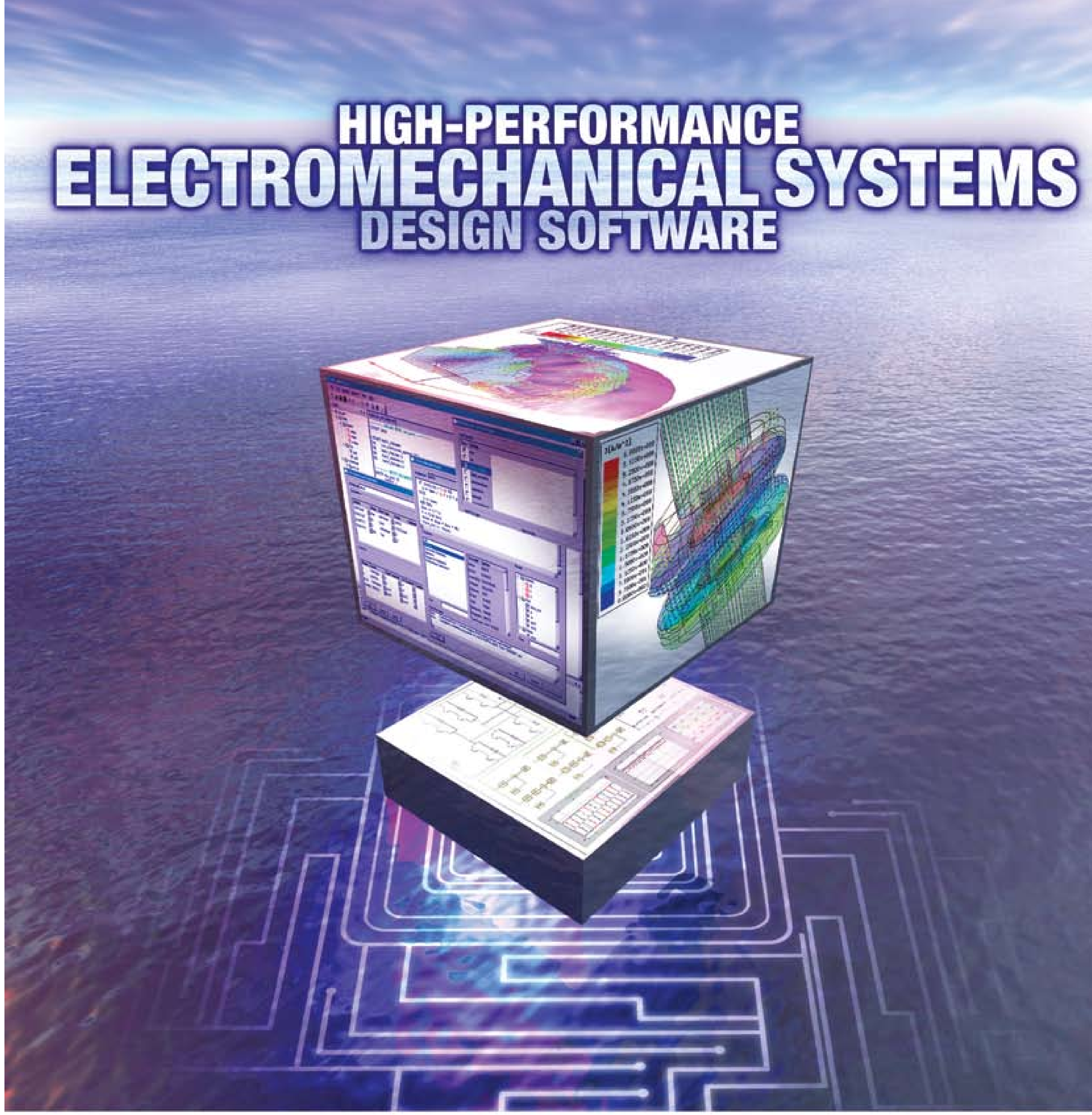
Hybrid drives are only part of the equation to reduce fuel consumption and emission of vehicles. Sensors, microcontrollers and power electronics are improving conventional powertrain solutions with ideal fuel/air mixture in the engine, independent of the air pressure and optimum power transfer from cam and crank. There are also significant improvements possible in areas such as tire pressure monitoring, reduced idle current in control units, EPS, fuel/water pumps and energy-efficient alternators where a further 10% fuel efficiency improvement can be gained. Infineon offers semiconductors for all these applications.

In addition to fuel efficiency and emission reduction, safety electronics is the fastest growing segment in automotive electronics where a growth of about 10% yearly for the next five years is expected.

Safety features sell cars. In middle and economy-class vehicles, these features include ABS/vehicle stability control, airbag systems and electric power steering. Legislation further increases demand for automotive safety. The European Union will continue its 'Safety Action Program' to reduce road fatalities 50% by year 2010 and also plans to have every new car equipped with an emergency call (eCall) application as of 2010/2011. Many EU countries have already signed a Memorandum of Understanding. ABS, airbags and electronic stability control have significantly reduced road accidents and in the future, electronically assisted systems will actively help avoid car accidents by means of adaptive cruise control, lane departure warning and intelligent lighting.

Infineon has pioneered automotive electronics for over 40 years. The company's objective is to develop more intelligent automotive semiconductors to help make cars more energy-efficient, safer and more convenient.

www.infineon.com/automotive



Future Cloudy for Power Management Semiconductors

But short-term growth expected to be healthy

By Marijana Vukicevic, iSuppli Corp.

Power management semiconductor vendors may have to live by the creedo of innovate or die, in order to stay alive in an increasingly competitive landscape, according to iSuppli Corp.

While the short-term growth for power management semiconductors remains healthy, growing at 5 percent in 2008 to yield revenues of approximately $27.7 billion, their longer-term outlook remains cloudy.

For several quarters now, iSuppli has pointed to turmoil roiling the power management market, showing some companies to be succeeding better than others. iSuppli believes that the power management space has evolved into a more predatory space, with some players growing significantly—partly due to market growth—but largely due to the commoditization of products and from benefits gained by working productively with OEMs and Original Design Manufacturers (ODMs).

At the same time, some suppliers that introduce innovative products early on will be able to capture market share at the expense of others, iSuppli predicts.

Although many established suppliers have been investing in the development of new designs for power management semiconductors, scores are also being challenged by new design houses that possess excellent strategies to attack the markets and grab existing business relationships from competitors.

For instance, suppliers of switching regulators will find difficulty in maintaining strong revenue growth over the next five years and the only way for established "old-timers" to survive will be to add functionality and quality to their products in ways that cannot be easily repeated by smaller Taiwanese and Chinese suppliers.

2007				2008				2009			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
6.22	6.42	6.83	6.88	6.65	6.82	7.07	7.10	6.99	7.23	7.64	7.65

Spource: iSuppli Corp. July 2008

Figure1: Worldwide Quarterly Power Management Semiconductor Revenue Forecast (Billions of U.S. Dollars).

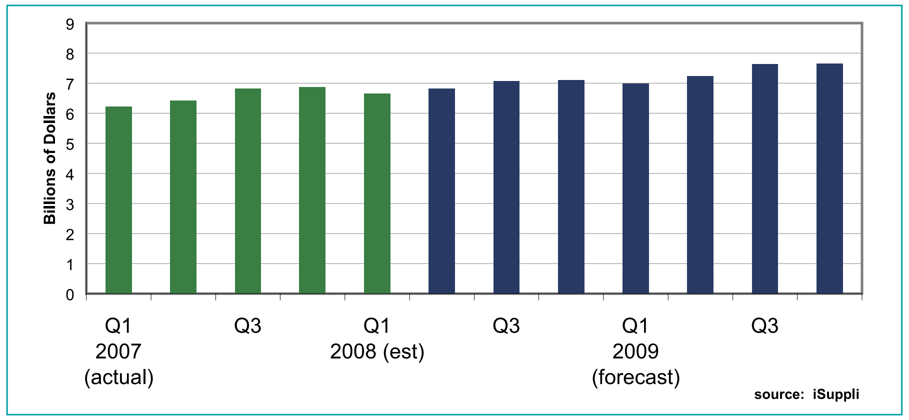
Outlook remains bright for rest of the year

Given this shakey future, the current market for power management semiconductors remains optimistic, posting only a slight 1.6 percent decline during the first quarter of 2008 and less than the 3.5 percent decline that iSuppli expected initially, owing to a good fiscal-year closing for Japanese suppliers. Demand is forecast to pick up during the second quarter of 2008, with revenue growing 2.5 percent over the first quarter. Inventory levels at suppliers are approaching a seven-year low, but quantities remain quite high and continue to have a negative impact on Average Selling Price (ASP) rates.

For the second half of the year, iSuppli projects a 3.6 percent growth in the third quarter for power management semiconductors, with growth slowing down in the fourth quarter to a moderate 0.4 percent.

Data processing will be the strongest application market in 2008, with power management semiconductors alone predicted to grow 9.5 percent. Notebook computers will bring 26.4 percent growth to power management this year, iSuppli predicts, propelled by the launch of the new Intel Montevina platform. Conversely, the wired communication platform will be the weakest application market for power management semiconductors in 2008, posting a decline of 1 percent this year.

Figure 1 shows iSuppli's quarterly revenue forecast for the entire power management semiconductor market for 2008 and into 2009.



source: iSuppli

Figure 2: Worldwide Quarterly Power Management Semiconductor Revenue Forecast (Billions of U.S. Dollars).

One influential factor affecting the entire market is the U.S. consumer confidence index, which plunged in June along with the confidence index of the European Union, causing many to wonder about the industry's prospects. With the current negative economic outlook and ever-rising oil prices, a radical turnaround in consumer confidence indices is not likely to happen this year nor in 2009.

The year 2009 holds brighter promise, with power management expected to grow 6 percent over 2008. Switching regulators and low-voltage power MOSFETs will grow rapidly in the next five years, but iSuppli expects the strongest growth of 10 percent Compound Annual Growth Rate (CAGR) to occur in the data processing segment. Markets that will drive power management growth for the next five years will include notebook computers at 18.7 percent growth, Liquid Crystal Display (LCD)/Plasma Display Panel (PDP) TVs at 19.8 percent, automotive safety and control at 10.3 percent, and mobile infrastructures and appliances at 9.5 percent CAGR.

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Power Supply Control Design Tools – Part 5

Buck-Boost Converter with Voltage-Mode Control

In this article, Dr. Ridley presents a summary of the buck-boost converter with voltage-mode control. Free analysis software—the fifth in a series of six—is provided to readers of this column to aid with the analysis of their voltage-mode buck-boost converters.

By Dr. Ray Ridley, Ridley Engineering

Voltage-Mode Buck-Boost Converter

In the early days of power electronics, there were three basic topologies: the buck, the boost, and the buck-boost. Variations of these three topologies solved most power conversion problems, and continue to do so today.

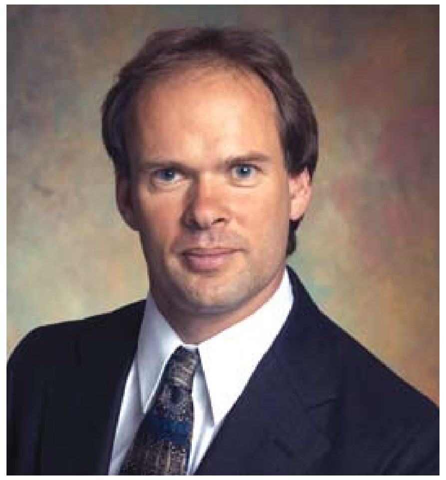
In the last 4 articles, the buck and boost converter control characteristics have been presented, using voltage-mode or current-mode control. The final two articles of this series present the buck-boost converter (or, in its isolated version, the flyback converter.) Like the boost converter, the buck-boost can be a challenging converter to stabilize.

Figure 1 shows the standard buck-boost converter operating with voltage-mode control.

For the buck-boost converter of Figure 1, the equation for the control-to-output transfer function is:

$$\frac{\hat{v}_o}{\hat{d}} = \frac{V_g}{D'^2}\frac{\left(1+sCR_c\right)\left(1-s\frac{DL_e}{R_L}\right)}{1+\frac{s}{\omega_o Q}+\frac{s^2}{\omega_o^2}} \quad \text{Eq. 1}$$

Where the resonant frequency is given by



$$\omega_o = \frac{1}{\sqrt{L_e C}} \quad \text{Eq. 2}$$

And the equivalent inductance is determined by the duty cycle:

$$L_e = \frac{L}{D'^2} \quad \text{Eq. 3}$$

The Q of the filter is a complex combination of the parasitic resistances shown in the circuit and the load resistance. For this equation, you can refer to either [3] or [5].

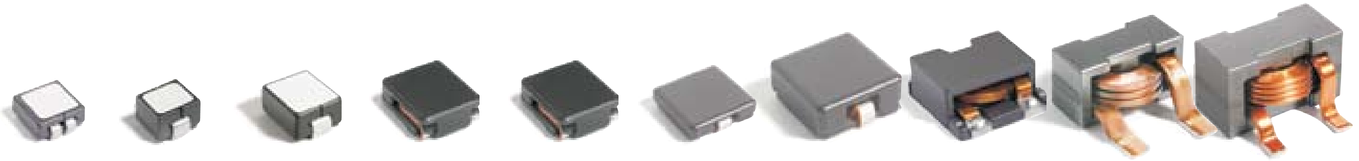
Buck-Boost Converter Right-Half-Plane Zero

Like the boost converter, the buck-boost converter has a right-half-plane (RHP) zero, as seen in the transfer function above. As with the boost, when the buck-boost converter switch is turned on for a longer period of time, the inductor is disconnected from the load for a longer period of time. That means that the output initially drops, even though the control command is trying to make it increase. This is the classic characteristic of a RHP zero.

Figure 2 shows the effect on the gain and phase of the RHP zero. At heavy loads, the RHP zero frequency is the lowest, and the phase delay is the greatest. At light loads, the RHP zero frequency is higher, and the converter is easier to control.

The operation of the buck-boost converter also causes a shift in the resonant frequency with input voltage, as can be seen from the control equations. Figure 3 shows how the characteristics of the buck-boost converter varies significantly with a wide input voltage.

For converters with RHP zeros, design is usually done at the lowest input line and the maximum load. This condition has the lowest value of RHP zero, and the lowest value of resonant frequency. The moving resonant frequency can create problems at different operating points, and the whole range of operation should be carefully checked with both



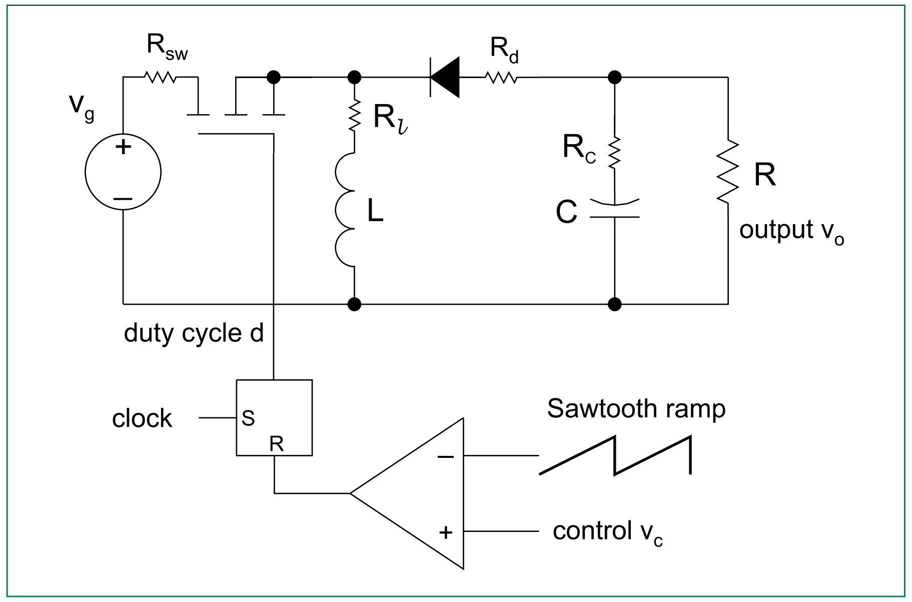


Figure 1: Buck-Boost converter with voltage-mode control.

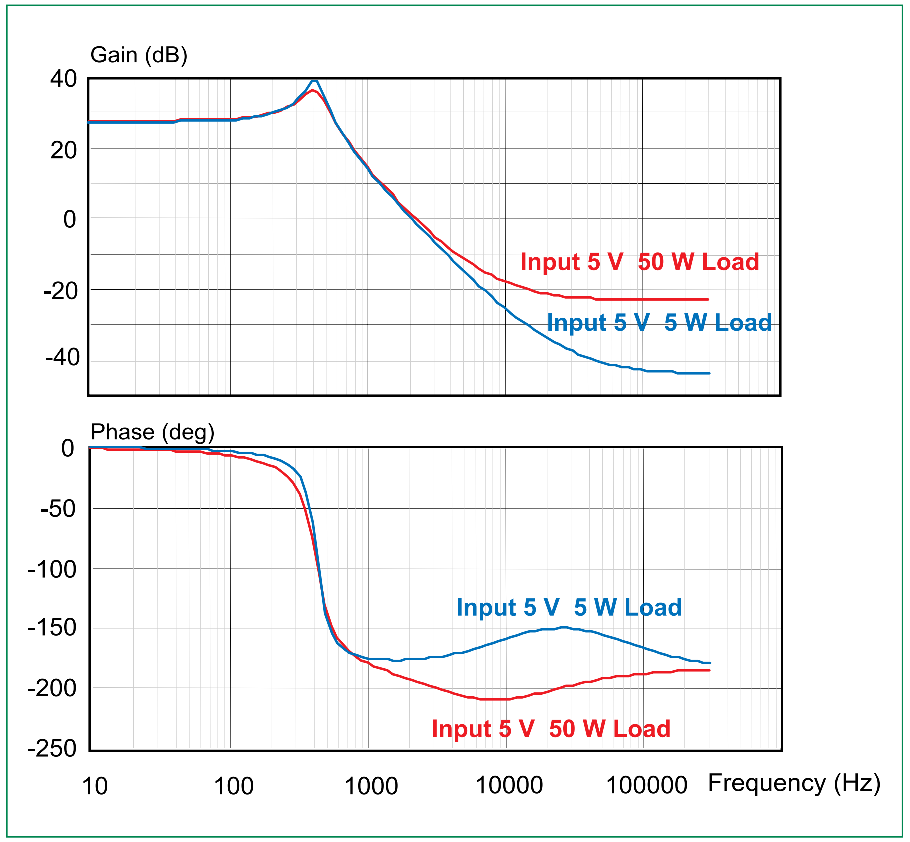


Figure 2: Effect of changing loads on the control characteristic of the buck-boost converter.

prediction and measurements.

More equations are created when the buck-boost converter operates in discontinuous-conduction mode (DCM). The free software provided for the boost converter will automatically assess which mode of operation your converter is in, and provide the proper transfer function.

Important Characteristics

There are several important points to remember about the buck-boost converter operating in continuous-conduction mode:

1. There is a double pole at the resonant frequency of the LC filter. The frequency of this double pole will move with the operating point of the converter since it is determined by the equivalent inductance of the circuit, and this is a function of duty cycle. At low line, the resonant frequency has its lowest value.

2. There is a zero in the control-to-output transfer function corresponding to the ESR of the output filter capacitor.

3. The buck-boost converter has a right-half-plane zero which can make control very difficult. This RHP zero is a function of the inductor (smaller is better) and the load resistance (light load is better than heavy load). The bandwidth of the control feedback loop is restricted to about 1/5th the RHP zero frequency.

In discontinuous conduction mode, the resonant frequency of the filter is eliminated from the control characteristic, as predicted by the switch model in [5]. This simplifies the control loop design, but higher power boost converters are usually designed to operate in CCM for efficiency reasons.

Most buck-boost (or flyback) converters are low power – 10 W or less. And most of them are designed to operate only in discontinuous conduction mode. This makes the control much simpler, but it is often very difficult to avoid going into CCM under all conditions. As power levels rise, trying to keep the converter in only DCM puts excessive stress on the power switch. As we will see with the next article, current-mode control makes the RHP zero issue much more manageable.

Buck-Boost Converter Voltage-Mode Software

Software is available for download that allows you to predict the small-signal response of your buck-boost converter with voltage-mode control. After entering your power stage values and switching frequency, the transfer function gain and phase of the power stage is plotted for you, and the resulting poles and zeros given.

The software is designed to run under either Excel 2007 or Excel 2003. Make sure when you open the software that the macro features are enabled in order to use the program properly. Please go to http://www.ridleyengineering.com/freesoftware.htm to download the software.

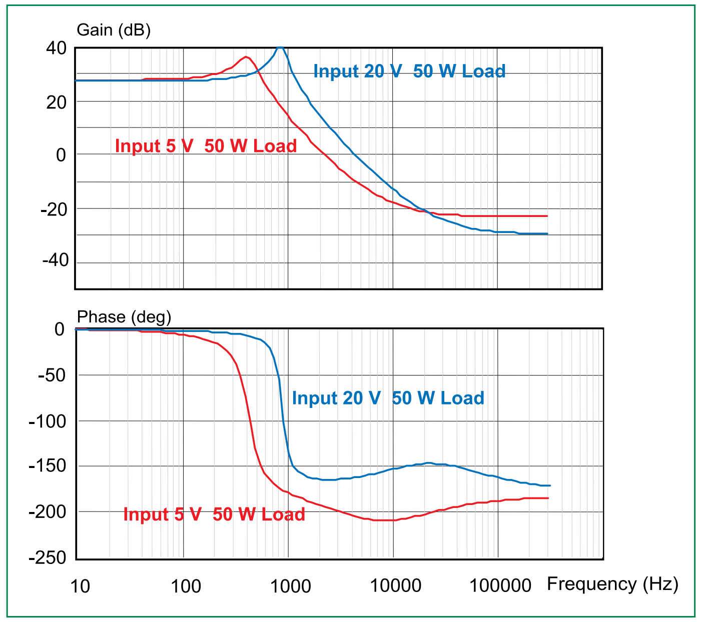


Figure 3: Effect of input line variation on the control characteristic of the buck-boost converter.

Summary

The buck-boost converter is very widely used in industry, in the format of the isolated flyback. It is a very useful topology, but care and time must be taken to properly design the control loop, especially when operating in CCM. The inductor should be chosen carefully for a controllable power stage RHP zero characteristic. It is not necessary to run the converter always in DCM, but this may be the preferred mode of operation for low-power converters. As with all converters, measurement[2] is essential to ensure a stable and rugged product.

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On the Road

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

EPCOS

I was privileged to attend the Epcos press conference at the company's impressive facility in Austria where the management team took us through the latest developments and have compiled a brief summary here for your information.

Thermistors - Sensors for accurate medical thermometers

The new disposable thermometers from EPCOS are characterized by a high accuracy of up to ±0.1K and a short response time of 7s. This allows fast and simple measurement of a patient's body temperature. The concept of these disposable sensors relies on the proven ceramic technology for NTC thermistors on a chip basis, the use of materials such as polypropylene qualified by the US Food and Drug Administration (FDA), and new process technologies. By contacting the NTC chip and copper interconnections with silver paste in a low-temperature process, process-related resistance drifts of the NTC thermistor are greatly minimized. This cannot be achieved by other connecting technologies such as soldering or welding. The great advantage of disposable thermometers is their very short response time. To reduce the measuring time, conventional solutions must extrapolate a patient's expected body temperature in a complex predictive mode. This is not required in the EPCOS solution. The costs of the additional electronics are thus unnecessary.

New medical disposable thermometers from EPCOS.

EPCOS has developed reusable thermometers for long-term measurements – such as for monitoring the body temperature of patients during operations or of infants in incubators. They are characterized by their great accuracy, rugged design and high resistance to sterilization cycles. They feature an operating life of more than 100 sterilization cycles at 121°C for 20min or at 134°C for 4min. The plastic injection molding technology used by EPCOS assures good humidity resistance. In contrast, sensor systems produced by conventional potted solutions have a lower impermeability. Another advantage is the double insulated and highly flexibly cable with an insulation resistance of more than 100MΩ for reliable body temperature measurement on the surface of the skin.

Varistors - World's smallest package for varistors and CeraDiodes

EPCOS is the first manufacturer of ESD protection components to offer low-capacitance CeraDiodes® and multilayer varistors (MLV) in a 0201 package. The variants with capacitances of 22pF are distinguished by a low clamping voltage and are suited for the protection of LED background lighting, for example. Types with capacitances of up to 10pF have also been developed for USB and Ethernet systems. Because of the need to minimize parasitic capacitances, especially in RF technology, EPCOS is developing a special antenna varistor with a capacitance of less than 1pF.

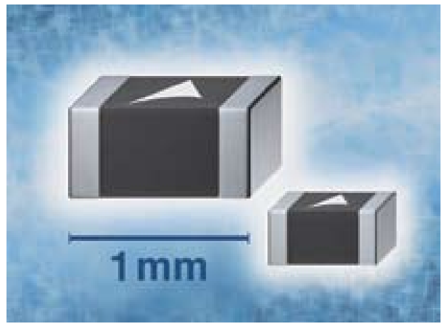
Epcos first to offer low-capacitance CeraDiodes® and multilayer varistors (MLV) in a 0201 package.

Integrated ESD/EMI filters comply fully with the trend toward miniaturization and integration of components designed specifically for mobile phones. EPCOS has developed two types of ESD/EMI filter arrays. The 0405 audio filter protects microphone and loudspeaker leads from ESD damage and interference, and RC filters in 0508 and 0306 packages were developed to protect display lines. While the audio filter replaces ten discrete components, the RC filter takes the place of twenty components packed in a single package. This level of integration allows the number of individual components on the circuit board to be reduced, thus increasing the reliability of the equipment, as fewer solder points are needed. In addition, development costs are also reduced.

Multilayer piezo components

Piezo-resonator enables smallest linear motor worldwide

EPCOS, world market leader in piezo actuators for fuel injection systems, has developed a series of innovative miniaturized multilayer piezo components. In addition to the ultra-flat piezo transformers already on the market, EPCOS now also offers piezo benders and resonators. The latter has allowed US Company New Scale Technologies to develop the world's smallest linear motor that is powered directly by a battery voltage of 2.8V. With a length of 6mm, its height and width are just 1.55mm^2.



Advanced piezo actuators from Epcos.

The motor consists of a threaded pin running inside a threaded nut. Activating the ultrasonic resonator causes the nut to oscillate torsionally and drive the threaded pin forward and back. This simple and rugged construction allows forward speeds of up to 10mm/s with a resolution as fine as 0.5µm to be attained. The operating frequency of the piezo resonators is in the ultrasound range of 150kHz.

Previous piezo-based linear motors require an operating voltage of about 30V. By contrast, the new piezo resonators from EPCOS require just 2.8V. In combination with its compact dimensions, it is suitable for use in battery-powered devices. One possible application is an optical zoom plus autofocus for camera systems in mobile phones.

For further information on the latest advanced devices from EPCOS, visit:

www.epcos.com

Diodes Drives Forward in Europe with Zetex Acquisition

I had the opportunity to talk with Colin Greene about the new company formed when Diodes Inc. acquired Zetex semiconductor. The formal acquisition was completed in early June making the timing of my call just about right to see what had happened. Colin was extremely open and positive about the new operation.

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

Diodes Incorporated has recently announced key appointments and promotions approved by the Board of Directors.

Hans Rohrer, who has over 30 years experience in the semiconductor industry, has been appointed as Diodes' Senior Vice President of Business Development, and Collin Greene appointed as the Europe President and Vice President, Europe Sales and Marketing.

Hans was the former CEO of Zetex plc, the former and Colin was COO, and both joined Diodes as a result of the Company's recent acquisition of Zetex.

The Zetex brand has been well established and earned for itself a respected position in the high-end European semiconductor market. With operations in Germany France and UK, the company is well known for its portfolio of integrated, discrete and combination analog products.

Diodes Incorporated is a global manufacturer and supplier of application specific standard products within the broad discrete and analog semiconductor markets. It is well known and respected in the US and Asia and now with the Zetex organization is sure to make a big impact in the European market. Diodes is already serving consumer, computing, communications, industrial and automotive markets. Product lines include diodes, rectifiers, transistors, MOSFETs, protection devices, functional specific arrays, amplifiers and comparators, Hall-effect sensors and temperature sensors, power management devices including LED drivers, DC-DC switching, regulators, linear voltage regulators and voltage reference along with special function devices including USB power switch, load switch, voltage supervisor and motor controllers. It's a formidable list and I suspect will be a formidable force in the marketplace worldwide.

When I asked about the quality of customer support under the new company, Colin told me that the new organization would now be able and well equipped to bring much more to his European customers with the broad portfolio now available as a direct result of the Diodes acquisition. With a stronger force on the ground both in sales and engineering and a wider product portfolio, the one-stop-shop looks to become a feature of the new company. With many customers needing to cut their costs and reduce their vendor base, this should indeed be good news.

In many ways the companies are so 'in-tune' it seems a natural development to join forces. It certainly looks in reality to be the win-win scenario all players seek in these partnerships. The Zetex product brand will remain under the Diodes overall company structure and customers will certainly be relieved that part numbers of existing Zetex lines will not change.

In the automotive environment, Zetex has the expertise to transfer across Diodes product lines. The company has the recognized certifications and experience necessary in this demanding field. This specialized knowledge base will certainly be of great value going forward.

www.diodes.com

www.zetex.com

Announcing the GreenPower Leadership Awards 2009

AGS Media Group, publishers of Power Systems Design Europe and China magazines, announce the second annual GreenPower Leadership Awards program.

The GreenPower Leadership Awards recognize the editorial contribution of individuals, companies and organizations that significantly advance the development of energy efficiency and/or renewable energy sources. Winning articles are chosen from those published by Power Systems Design Europe bearing the *"GreenPower"* logo. • Voting is tabulated automatically as subscribers to Power System Design Europe read PSDE's eNewsletter. • The *GreenPower Leadership Awards* winners will be announced at PSDE's podium discussion May 2009 at the PCIM Europe Conference and Exhibition in Nürenberg, Germany and will also be published in the June 2009 issue of Power Systems Design Europe.

For details about sponsorship opportunities contact: Julia Stocks, Publisher, Power Systems Design Europe, at **Julia.Stocks@powersystemsdesign.com**. Power Systems Design Europe will donate a portion of the proceeds from the sponsor companies to an engineering college or university chosen by the author of the winning article.

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Battery Management Architectures for Electric Vehicles

Flexible & accurate battery monitoring

Next generation electric (EV) and hybrid electric vehicles (HEV) are pushing the development of new battery technologies. To minimize cost and maximize efficiency, vehicle system designers need to exploit the full usable battery storage capacity. A battery monitoring architecture must be comprehensive, accurate, and robust, without compromising cost and reliability. The new LTC6802 Battery Stack Monitor from Linear Technology gives system designers the flexibility to optimize their systems to achieve their required performance.

By Jim Douglass, Design Manager, Linear Technology Corp

Remarkable progress has been achieved on battery technologies for EVs and HEVs. Battery energy densities have steadily increased, and batteries today can be reliably charged and discharged thousands of times. If designers can effectively exploit these advancements in energy capacity, EVs and HEVs have the potential to be competitive with traditional vehicles in terms of cost, reliability, and longevity.

A battery's specified capacity refers to the amount of charge the battery can supply from 100% state of charge (SOC) to 0% SOC. Charging to 100% SOC or discharging to 0% SOC will quickly degrade a battery's life. Instead, batteries are carefully managed to avoid complete charge or discharge conditions. Operating between 10% SOC and 90% SOC, using 80% of the specified capacity, can reduce the total number of charging cycles by a factor of 3 or more, when compared to operating between 30% and 70% SOC (40% of capacity).

The tradeoff between effective battery capacity and battery lifetime creates challenges for battery system designers. Consider the above case of 40% cycling versus 80% cycling. If a system limits batteries to only 40% cycling in order to increase battery longevity by a factor of 3, the battery size must be doubled to achieve the same usable capacity as the 80% cycling case. This would double the weight and volume of the battery system, increasing costs and reducing efficiency.

Vehicle manufacturers typically demand battery lifetimes exceeding 10 years, and they specify the required usable battery capacity. The challenge to the battery system designer is to squeeze the maximum capacity out of the smallest battery pack. To accomplish this, the battery system must carefully control and monitor the batteries using precision electronics.

Electric Vehicle Battery Pack Systems

An electric vehicle battery pack consists of dozens of batteries stacked in series. A typical pack might have a stack of 96 or so batteries, developing a total voltage in excess of 400V for Li Ion batteries charged to 4.2V. While the vehicle power system sees the battery pack as a single, high-voltage battery—charging and discharging the entire battery pack at once—the battery control system must consider each battery's condition independently. If one battery in a stack has slightly less capacity than the other batteries, then its state of charge will gradually deviate from the rest of the batteries over multiple charge/discharge cycles. If that cell's state of charge is not periodically balanced with the rest of the batteries, then it will eventually be driven into deep discharge, leading to damage, and eventually complete battery stack failure. To prevent that from happening, each cell's voltage must be monitored to determine state of charge. In addition, there must be a provision for cells to be individually charged or discharged to balance their SOCs.

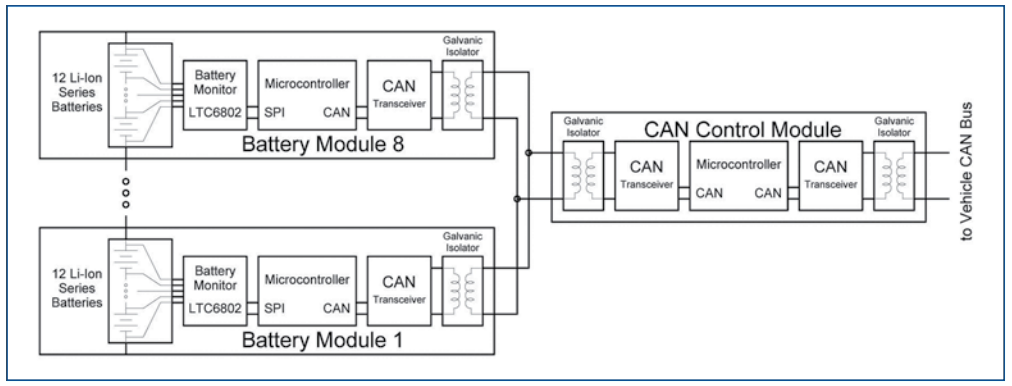


Figure 1: Parallel independent CAN mondules.

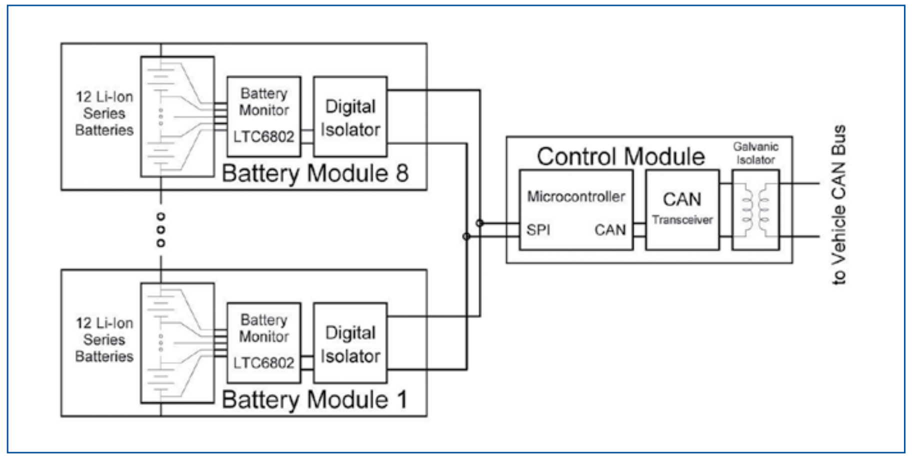


Figure 2: Parallel modules with CAN gateway.

An important consideration for the battery pack monitoring system is the communications interface. For communication within a PC board, common options include the Serial Peripheral Interface (SPI) bus and Inter-Integrated Circuit (I^2C) bus. Each has low communications overhead, suitable for low-interference environments. Another option is the Controller Area Network (CAN) bus, which has widespread use in vehicle applications. The CAN bus is very robust, with error detection and fault tolerance, but it carries significant communications overhead and high materials cost. While an interface from the battery system to the main vehicle CAN bus may be desirable, SPI or I^2C communications can be advantageous within the battery pack.

Linear Technology has introduced a device that enables battery system designers to meet these difficult requirements. The LTC6802 is a battery stack monitor integrated circuit that can measure the cell voltages of up to 12 stacked cells. The LTC6802 also has internal switches that provide for the discharge of individual cells to bring them into balance with the rest of the stack.

To illustrate the battery stack architecture, consider a system with 96 Li-Ion cells. Eight LTC6802s would be required to monitor the entire stack, with each device operating at different voltage levels. Using 4.2V Li Ion batteries, the bottom monitoring device would straddle 12 batteries with potentials scaling from 0V to 50.4V. The next group of batteries would have voltages ranging from 50.4V to 100.8V, and so forth, up the stack. Communicating between these devices, at different potentials, presents a difficult challenge. A variety of approaches have been considered, and each has advantages and disadvantages in light of the priorities of the vehicle manufacturers.

Battery Monitoring Requirements

There are at least five major requirements that need to be balanced when deciding between battery monitoring system architectures. Their relative importance depends on the needs and expectations of the end customer.

Accuracy

To take advantage of the maximum possible battery capacity, the battery monitor needs to be accurate. A vehicle, however, is a noisy system, with electromagnetic interference over a wide range of frequencies. Any loss of accuracy will adversely affect battery pack longevity and performance.

Reliability

Automobile manufacturers must meet extremely high reliability standards, irrespective of the power source. Furthermore, the high energy capacity and potentially volatile nature of some battery technologies is a major safety concern. A fail safe system that shuts down under conservative conditions is preferable to catastrophic battery failure, although it has the unfortunate potential of stranding passengers. As result, battery systems must be carefully monitored and controlled to ensure complete control

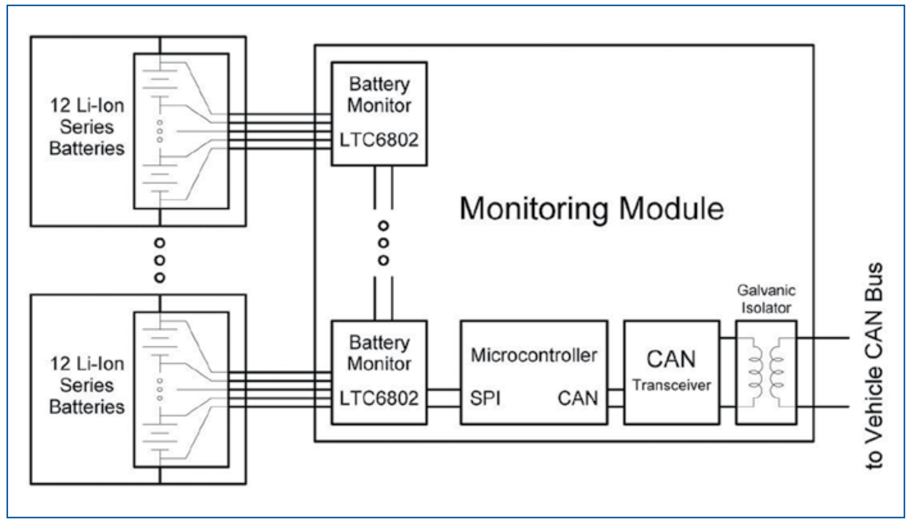


Figure 3: Single monitoring module with CAN gateway.

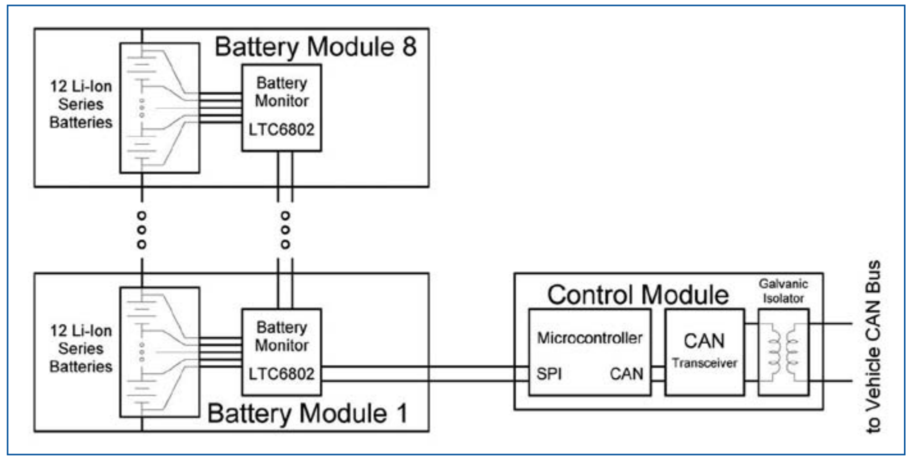


Figure 4: Series modules with CAN gateway.

over their entire life in the system. To minimize both false and real failures, a well-designed battery pack system must have robust communications, minimized failure modes, and fault detection.

Manufacturability

Modern vehicles already contain a vast array of electronics with complicated wiring harnesses. Adding sophisticated electronics and wiring to support an EV / HEV battery system is an additional complication for automobile manufacturing. The total number of components and connections must be minimized to meet stringent size and weight constraints and ensure that high volume production is practical.

Cost

Complicated electronic control systems can be expensive. Minimizing the number of relatively costly components, like microcontrollers, interface controllers, galvanic isolators, and crystals, can significantly reduce total system cost.

Power

The battery monitor itself is a load on the batteries. Lower active current improves system efficiency and lower standby current prevents excessive battery discharge when the vehicle is off.

Battery Monitoring Architectures

Four architectures for battery monitoring systems are depicted in Figures 1-4 and described below. Table 1 summarizes the pros and cons of each architecture, assuming a 96-battery system organized into 8 groups of 12 batteries. In every case, one LTC6802 monitors each group of 12 batteries.

Each architecture is designed to be an autonomous battery monitoring system. Each provides a controller-area network (CAN) bus interface to the vehicle's main CAN bus and is galvanically isolated from the rest of the vehicle.

Parallel Independent CAN Modules (Figure 1)

Each 12-battery module contains a PC board with an LTC6802, a microcontroller, a CAN interface, and a galvanic isolation transformer. The large amount of battery monitoring data required for the system would overwhelm the vehicle's main CAN bus, so the CAN modules need to be on local CAN sub-nets. The CAN sub-nets are coordinated by a master controller that also provides the gateway to the vehicle's main CAN bus.

Parallel Modules with CAN Gateway (Figure 2)

Each 12-battery module contains a PC board with an LTC6802 and a digital isolator. The modules have independent interface connections to a controller board containing a microcontroller, a CAN interface, and a galvanic isolation transformer. The microcontroller coordinates the modules and provides the gateway to the vehicle's main CAN bus.

Single Monitoring Module with CAN Gateway (Figure 3)

In this configuration, there is no monitoring and control circuitry within the 12-battery modules. Instead, a single PC board has 8 LTC6802 monitor ICs, each of which is connected to its battery module. The LTC6802 devices communicate through non-isolated SPI-compatible serial interfaces. A single microcontroller controls the entire stack of battery monitors via the SPI-compatible serial interface, and it also is the gateway to the vehicle's main CAN bus. A CAN transceiver and a galvanic isolation transformer complete the battery monitoring system.

	Parallel Independent CAN Modules	Parallel Modules with CAN Gateway	Single Monitoring Module with CAN Gateway	Series Modules with CAN Gateway
Accuracy	+ LTC6802s local to battery module	+ LTC6802s local to battery module	– Sensitive analog wires routed to single board	+ LTC6802s local to battery module
Reliability	+ CAN provides robust communications over cables, but extra circuitry gives increased failure modes	+ SPI interface not as robust as CAN over cables, but parallel communications minimizes negative impact	++ Communications local to a single board, minimizing cable connections and sensitivity to communications interference	– SPI interface not as robust as CAN over cables
Manufacturability	– Significant parallel communications wiring required	– Significant parallel communications wiring required	– Single precision board, but analog sensitivity can create wiring challenges	+ Communications wiring in series between modules
Cost	– – Microcontrollers, CAN interfaces, and isolation in every module, plus a main controller board	– Single microcontroller and CAN transceiver, but separate precision PC boards with digital isolators	+ + Single microcontroller, CAN transceiver, and isolator, on one precision PC board	+ Single microcontroller, CAN transceiver, and isolator, but separate precision PC boards
Power	– – Multiple microcontrollers and CAN interfaces require excessive power consumption	– High-speed digital isolators have significant current draw	+ + Minimal circuitry with low - power SPI interface	+ Minimal circuitry, but SPI interface requires more power to communicate between boards

Table 1: Battery Monitoring Architecture Comparison.

Series Modules with CAN Gateway (Figure 4)

This architecture is similar to the single monitoring module, except each LTC6802 is on a PC board within its 12-battery module. The 8 modules communicate through the LTC6802 non-isolated SPI-compatible serial interface, which requires a 3- or 4-conductor cable to be connected between pairs of battery modules. A single microcontroller controls the entire stack of battery monitors via the bottom monitor IC, and also acts as the gateway to the vehicle's main CAN bus. Once again, a CAN transceiver and a galvanic isolation transformer complete the battery monitoring system.

Battery Monitoring Architecture Selection

The first and second architectures are generally problematic due to the significant number of connections and the external isolation required for the parallel interface. For this added complexity, the designer has independent communication to each monitor device. The third (single monitoring module with CAN gateway) and fourth (series modules with CAN gateway) architectures are simplified approaches with minimal limitations. The LTC6802 can address all four configurations, leaving the choice to the system designer two variants of the LTC6802 have been created, one for series configurations and one for parallel configurations.

The LTC6802-1 is designed for use in a stacked SPI interface configuration. Multiple LTC6802-1 devices can be connected in series through an interface that sends data up and down the battery stack without external level shifters or isolators. The LTC6802-2 allows for individual device addressing in parallel architectures. Both variants have the same battery monitoring specifications and capabilities.

Electric vehicles place huge demands on battery packs. Vehicle manufacturers expect cost-effective battery systems that meet their stringent reliability requirements. The latest battery monitoring integrated circuits from Linear Technology give system designers the flexibility to choose the best battery pack architecture without compromising performance.

www.linear.com

Incremental Efficiency Improvements Result in Large Energy Savings

Energy goals most effectively achieved using digital control

Energy costs have soared in recent years, putting a financial strain on the global marketplace and economy. One of the areas affected most is the IT equipment industry. Because of the extreme rise in energy prices, the cost of operating equipment used in server farms is quickly exceeding the original purchase price of the hardware. Utility costs, over the life of the server, are expected to be three to five times the server cost.

By Deepak Savadatti, Vice President of Marketing, Primarion

Aggravating this situation is the increasing power usage within these installations due to the proliferation of users and resulting processing requirements. Server power grows at approximately 20 percent per year, with typical, four-year electricity bills starting to surpass the initial equipment cost of €1.950.

Within a typical data center, however, it is possible to gain an energy saving up to nearly €16.000 each year.

Last year, Google engineer Luis Andre Barroso predicted that energy costs would dwarf equipment costs “possibly by a large margin.” If you are Google, or any other company building massive data centers, utilizing cheap hardware might be just a short-term tactical advantage. However, the long-term strategic advantage would be to build not only inexpensive hardware, but to also ensure that it is highly efficient.

Computers use a tremendous amount of power on a daily basis. As the power capabilities of processors and components advance, the amount of energy they need also increases. Many of the current systems now in use often consume nearly as much power as a standard, household microwave oven. Even though the power supplies are rated for the power output they provide, the amount of power that they actually pull from the wall is much higher; and that poses a problem.

The definition of a power supply’s efficiency is the ratio of the DC output power (Watts) to the AC input power (Watts). The efficiency rating of a power supply, in essence, determines how much energy is wasted or lost when it converts the wall outlet power to the components it powers. For example, a 75 percent efficient power supply that generates 300 Watts of output power would draw roughly 400 Watts of power from the wall; and you will have to pay for that power usage on your electric bill. Some people do not think about the dissipated heat and additional costs required to cool a home’s power supply.

It is important to note that the power supply efficiency varies with input voltage and output load requirements due to the various circuit operational stages. Therefore, it is important to match the capacity of a power supply to the power needs of the computer. The energy efficiency of power supplies drops significantly at light loads, and efficiency generally peaks at a load percentage from about 50 to 75 – the curve varies from model to model. Typically, a power supply that is more than twice the required size, is significantly less efficient and will waste a considerable amount of electricity.

Many power supply manufacturers label units as high efficiency (HE).

This marketing term can vary between manufacturers, and even models. A high efficiency model might reach an 80 percent efficiency level, while another might reach up to 85 percent. Yet, the 85 percent efficiency unit may only reach that percentage when it is operating at a 50 percent power load. When the unit is at 25 or 75 percent power loads, it may only have a 70 percent or lower level of efficiency. To clarify to customers, there is a growing trend to list the power supply efficiency ratings as a function of power supply load levels.

Modern processors in computer systems have dramatic swings in current demand. Increases and decreases in current demand occur when a processor transitions between states of inactivity, such as a sleep, or when the processor is waiting for data during normal or intense computations. System loads can have an extreme variance of more than 100 percent. Consider a latest server CPU, where a typical load can vary from a full load of 120A to less than 20A during an idle mode operation.

Such a shift from steady loads to variable power loads is adding additional requirements to the power supply industry. The requirements do not just regulate the voltage and current outputs, but require the adjustment of the power supply efficiency to the variations of the load requirements. The efficiency of typical analog power supplies varies as the load changes, with peak efficiencies at 50 percent of the load, and lower efficiencies at light and higher loads (See Figure 1).

Typically, analog power supplies are designed to provide peak efficiency at stated loads. It becomes increasingly difficult and complex to design an analog power supply that will provide peak efficiencies across the load variation. In other words, the efficiency of the power supply efficiency needs to be flattened to a high level irrespective of the load changes.

Most analog power supplies provide power at fixed efficiencies and phasing while running at only 30 to 40 percent of full load. Most often, these power supplies are not utilized at lower and higher loads. Analog power supply technology has reached its inherent efficiency limits of passive and active component capabilities, and in order to reach the next level in the quest for the "holy grail" of 100 percent efficiency, intelligence needs to be added to the equation.

Intelligent management of power can provide extremely flexible solutions and improve efficiency over the whole range of power loads. Such power management needs to be locally situated to provide fast responses to the changing loads. It needs to control not only currents and voltages, but also the number of operating phases by turning on or shutting off sets of switching converter FETs in order to optimize power management. Loop gain needs to be dynamically compensated in order to keep the system stable during such phase changes. These intelligent management goals can be most effectively achieved by using digital control of the power.

A solution to meet and exceed these requirements can be implemented using digital multiphase controllers with dynamic phasing, which can drive up to six synchronous-rectified buck-converter channels in parallel. Interleaved timing of the channels results in a higher ripple frequency, thus reducing the input and output ripple, and facilitating the filtering of the higher resultant frequency. Four to six phases in parallel would provide a typical load of 120 Amps with excellent efficiency over the whole load range. Higher output power can be achieved by interconnecting and synchronizing multiple devices.

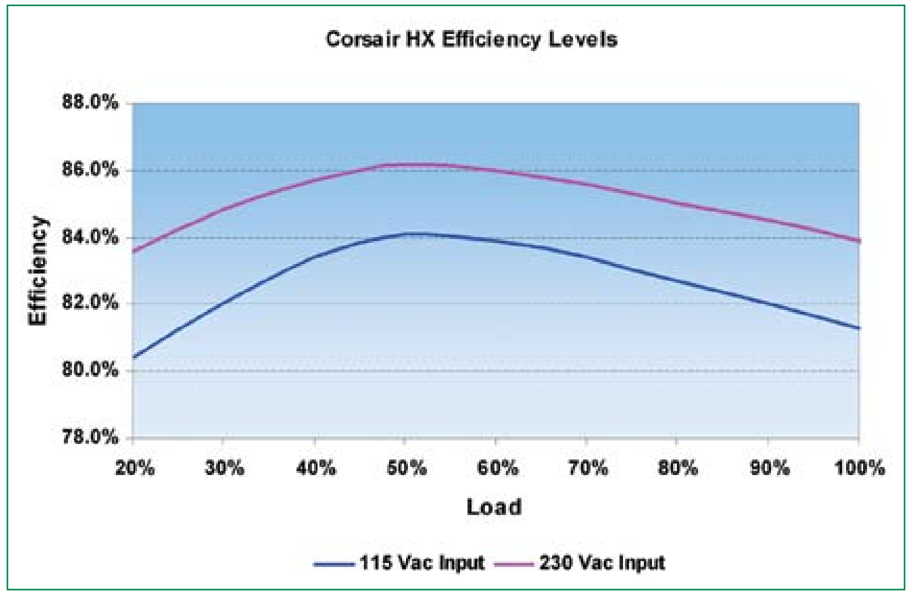


Figure1: Efficiency variation vs. load.

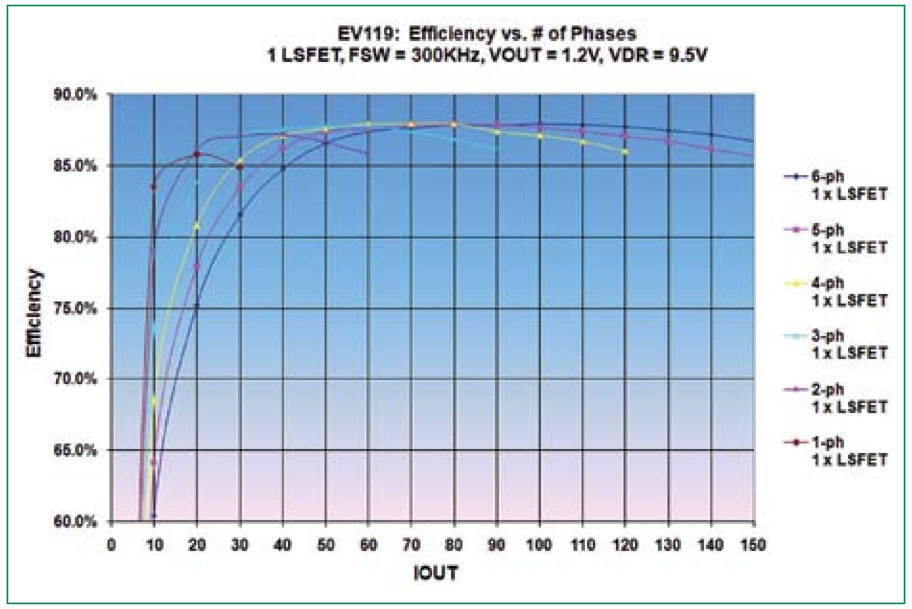
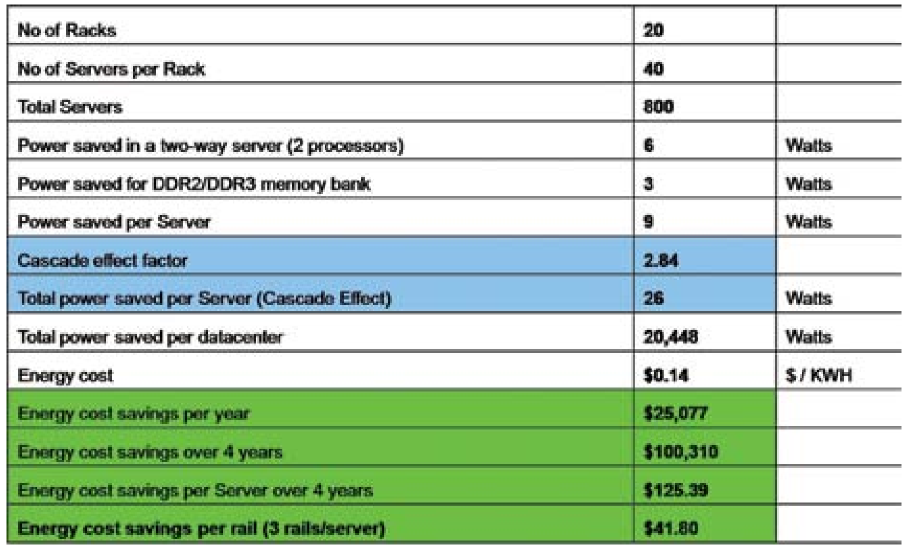


Figure 2: Efficiency vs. output current.



No of Racks	20	
No of Servers per Rack	40	
Total Servers	800	
Power saved in a two-way server (2 processors)	6	Watts
Power saved for DDR2/DDR3 memory bank	3	Watts
Power saved per Server	9	Watts
Cascade effect factor	2.84	
Total power saved per Server (Cascade Effect)	26	Watts
Total power saved per datacenter	20,448	Watts
Energy cost	$0.14	$ / KWH
Energy cost savings per year	$25,077	
Energy cost savings over 4 years	$100,310	
Energy cost savings per Server over 4 years	$125.39	
Energy cost savings per rail (3 rails/server)	$41.80	

Figure 3: Impact of real time efficiency improvement.

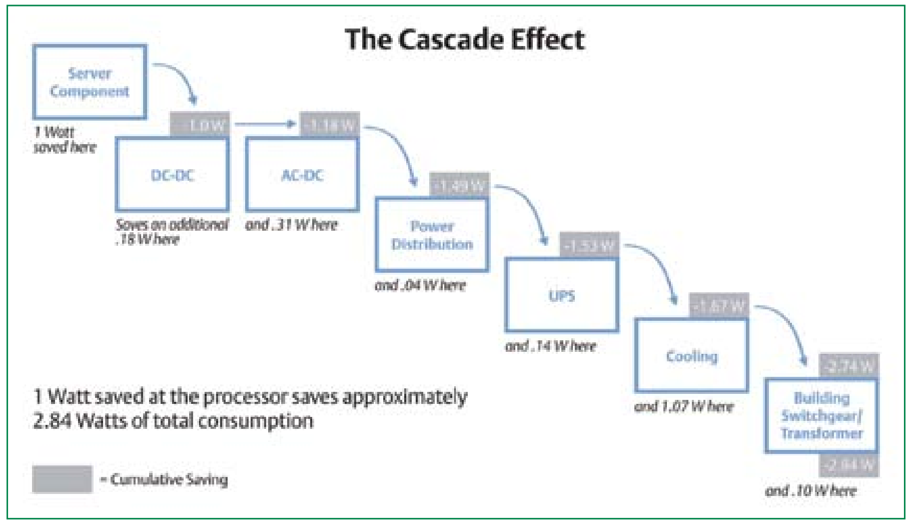


Figure 4: Cascade effect shows that a 1 Watt saving at the server component level creates a reduction in facility energy of approximately 2.84 Watts.

These controllers can also communicate with the overall system through two-pin I^{2}C logic. This will dynamically change the number of operating phases based on the monitored load requirements, and/or would lower the operating frequency in order to maintain a high efficiency under any load. The loop compensation is optimized for the number of active phases to ensure the most stable and reliable operation, while providing a quick transient response.

The enclosed Figure 2 chart shows how the efficiency, by dropping phases, is not only flattened over the operating range, but also increased, when matched to the load current requirements. For example, by dropping the phases from six to one at a 20A load, the efficiency increases from 75 to 86.5 percent.

As shown in Fig. 3, the amount of energy savings, for a typical 800-server data center based on energy cost of $0.14 per KWH, translates to approximately $25,077 in energy cost-savings per year.

The impact of real time efficiency improvement not only translates to savings in energy cost, but also results in savings for cooling equipment requirements. It also improves reliability due to lower temperature operation; lowers equipment acoustical noise because of the requirements for smaller and quieter cooling fans; and additionally, small requirements for heat sinking allows for space reduction.

A recent Emerson white paper titled, "Energy Logic: Reducing Data Center Energy Consumption by Creating Savings that Cascade Across Systems," states:

"…..a 1 Watt reduction at the server component level (processor, memory, hard disk, etc.) results in an additional 1.84 Watt savings in the power supply, power distribution system, UPS system, cooling system and building entrance switchgear and medium voltage transformer. And consequently, every Watt of savings that can be achieved on the processor level creates approximately 2.84 Watts of savings for the facility…."

In conclusion, therefore, by adding digital control to the power conversion toolbox, one can achieve a multitude of incremental efficiency improvements, which provide lower energy usage and large financial savings. Saving just 3 Watts of power per channel, results in system savings of more than €16.000 per year. In these times where energy is now recognized as a precious resource and of finite availability, utilizing proven digital techniques makes real sense in the design and planning of these vital but power-hungry installations.

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Motion Control and Automation Go Forward

An industry sector on the move

The emergence of Digital Signal Controllers, AC induction motors and improved network communications are fuelling the spread of motion control and automation applications.

By Jamie Furness, Global Technology & Development Manager, Farnell

Motion control and automation is a sector of the electronics market that is evolving and advancing rapidly. With the number and diversity of applications growing, and a trend for designers to demand higher levels of control and efficiency, there is a lot of innovation and change. The number of different approaches that can be adopted to solve applications has also increased, giving design engineers important choices to make if they are to optimise their product designs.

The key elements of motion control and automation where there have been significant developments are motors, motor control, and networking / communications. The emergence of AC Induction motors, Digital Signal Controllers (DSCs) and communications approaches such as Ethernet and Zigbee respectively are the recent highlights in each area that are helping to drive the market forwards. They will ultimately make life easier for designers and help to spread the use of motion control and automation across both existing and new market sectors.

AC Inductor motors join the party

Until recently, designers engaged in the development of motion control and automation applications could choose from stepper motors, DC brush motors or brushless DC motors. These three have now been joined by AC induction motors, which have been existence for a long time, but were only previously used for straightforward 'on / off' applications. Now modern digital control techniques have allowed them to be considered for motion control and automation tasks with stringent requirements for control and efficiency.

The three established approaches are all linked by the fact that they utilise an electromagnetic field to create torque in either a rotating or linear axis. Aside from the number of phases of control each requires, the key operational differentiator is that stepper motors, unlike DC brush and brushless motors, do not require an encoder due to their integrated self-positioning capability. Encoders provide feedback to the motor controller that enable it to generate the appropriate algorithms to change the motor from its actual position to the one desired.

DC brush and brushless and stepper motors all have advantages and disadvantages that designers must carefully consider when developing their applications. Brushed DC motors can operate at high speeds of over 10,000rpm, but due to the inclusion of brushes in their construction, are prone to problems such as arcing and degradation over time. Stepper motor designs overcome this but tend to be noisy, can cause vibration and typically only operate at speeds up to a maximum of around 5,000rpm. Brushless DC motors also avoid arcing and degradation, but suffer from external commutation and a high level of complexity which tends to necessitate a higher external component count.

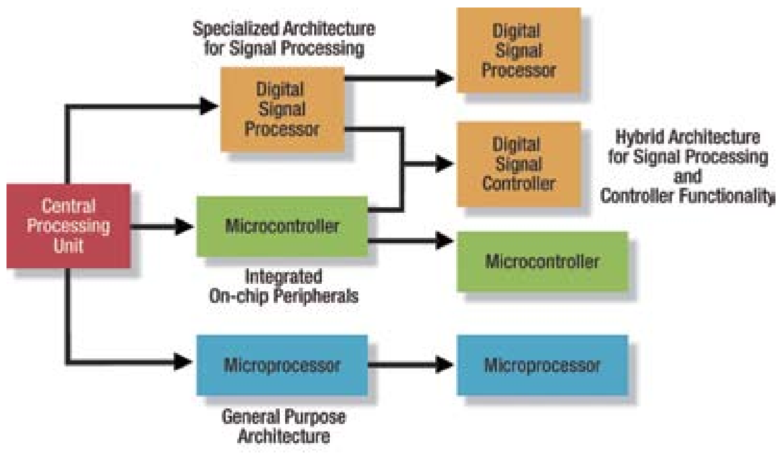

Figure 1: The DSC is a hybrid of the microcontroller and the DSP that harnesses the benefits of both in a single chip solution.

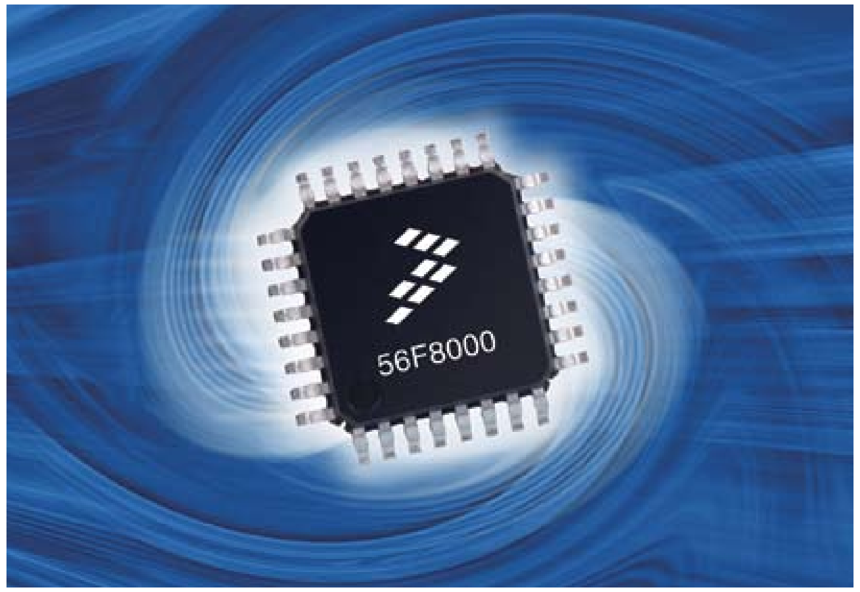

Figure 2: Freescale Semiconductors 16-Bit DSCs.

AC Induction motors have a completely different construction and method of operation compared to the three established approaches described. Their simple and rugged construction leads to high levels of reliability and eases manufacture. Achievable efficiency levels of up to 80% will please OEMs who, in the current global climate, are always eager to reduce energy consumption and minimise the 'waste Watts' of their end products. AC induction motors also offer a greater degree of flexibility with single and polyphase, plus high and low power options making them suitable for a large number of different applications.

There are two basic types of AC induction motor; these are known as squirrel-cage and wound-rotor; of these squirrel-cage is the most commonly used. The disadvantages of induction motors, which have now been largely overcome by the replacement of analog control with modern digital approaches, are their complex mathematical models, non-linear behaviour at saturation and electrical parameter oscillation - These could be collectively described as 'difficult controllability.'

Digital Signal Controllers – combining the attributes of DSPs and micros?

Digital rather than analog control of motion control and automation applications is well established with Digital Signal Processors (DSPs) and Microcontrollers now being joined by a hybrid of the two – the Digital Signal Controller (DSC).

Analog components for motion control and automation tend to suffer from variations and drift in their values and performance over time. This inconveniently necessitates regular calibration in order to maintain accurate operation of the application. In addition to overcoming this problem, digital approaches also allow any updates to be easily implemented in software.

DSCs have emerged as a single chip approach capable of combining the benefits of both DSPs and microcontrollers in an easy-to-implement solution. They fit well in a market where performance, fast time-to-market and low cost are all on the wish list of designers. Because of this, DSCs have taken away and continue to erode the microcontroller and DSP market share of the motion control and automation sector.

Microcontrollers were developed to provide a high degree of flexibility to designers by virtue of their programmability. However, this was typically at the expense of overall performance. The on-chip peripherals of the MCU such as ADCs and PWMs and various memory types give flexibility and mean that few external components are required. Despite a relatively slow speed in performing signal processing operations, microcontrollers are very good at carrying out many other types of operations on data. Because of this, they are most often used in applications that have a control loop which is likely to require a number of diverse tasks to be performed rather than intensive and repetitive numerical operations.

Conversely, DSPs are ideal for execut-

Figure 3: Digital Signal Controllers (DSCs), such as the dsPIC® DSC family from Microchip Technology, enable embedded sensor processing, digital motor control and power factor correction to be implemented on a single chip.

ing a small quantity of specific number crunching tasks at such high speed that they achieve real-time performance. On the down side, they do not have the control capabilities of microcontrollers.

Before DSCs were an option, the natural progression for engineers tasked with designing embedded systems for motion control and automation was to get the benefits of a DSP and a microntroller by using both; the DSP implementing the control algorithm and the microcontroller performing all other tasks. Although from a functional standpoint this worked well, there were numerous issues, these included: wasted machine cycles due to the handshaking requirements of two processors, and the need to provide a high-speed path to move data back and forth. But perhaps the most serious drawbacks were the increased design cycle time due to the work and learning curve in achieving successful integration between the two processors and the prohibitive overall cost.

The convergence of the DSP and the microcontroller has given rise to the DSC. These low-cost, easy-to-design devices are proving ideal for accurate and efficient motion control due to their ability to execute both efficient digital signal processing and numerous controller operations on a single chip. Easy programmability, low power consumption, peripheral capabilities and the cost and design benefits of a reduced component count add further to the DSCs impressive portfolio. Good examples of these devices are Microchip's dsPic, TI's TMS320C2000 and Freescale's 56F80xx families.

Networking and communication for motion control

Industrial Ethernet and wireless technologies such as Zigbee are revolutionising how digital controllers in motion control and automation applications communicate with themselves and the outside world. This is enabling more advanced applications and a greater degree of control and oversight than was ever possible before.

Industrial Ethernet has captured a growing share of the global automation networking market, but research indicates that many other types of industrial networks have also been expanding during the past two to three years.

It is thought to be likely that as machine automation system designs evolve to use more Ethernet-based devices, then industrial device networks and motion control networks will naturally migrate to industrial Ethernet in favour of other control networks.

As networks move from centralised to distributed control with intelligent I/O, more bandwidth will be needed to facilitate communications around the network. Also, as the number of devices on a network increases, so larger address space is needed – these requirements match well with the capabilities of industrial Ethernet.

Furthering the adoption of industrial Ethernet still more, is the fact that implementing multiple infrastructures is problematic. This scenario requires multiple interfaces to be developed to allow different protocols to work together. Therefore it is natural for applications to propagate towards one 'best fit' approach.

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Watching Me - Watching You

IP convergence in security monitoring market accelerated by PoE technology

Monitoring our every move using cameras is a market that has seen rapid growth in recent years. Where once only private premises were monitored, now, most public places are covered by networks of cameras aiming to make life safer and more secure for the general public. For those designing and developing hardware and software, the challenge is how to support this growing infrastructure with affordable yet reliable and flexible solutions.

By Koen Geirnaert, Senior Marketing Engineer, Communications High Voltage Products,
ON Semiconductor

Power over Ethernet (PoE) has emerged as a technology that can drastically reduce overall costs, simplify installation and allow a security network to be easily re-configured. Maintenance costs are also kept low compared to older, conventional analogue closed circuit TV (CCTV).

Security Market Trends

In the video surveillance market the days of CCTV cameras are numbered with the Ethernet poised to dominate. The IP camera is stealing a market previously held by analogue cameras, at the same time as security awareness is boosting the quantity of cameras installed worldwide. In addition to cameras, the market for access systems, RFID tracking, biometric identification equipment, fire detectors, and a host of other security equipment, continues to balloon. Due to the widespread availability of IP networks, Ethernet is in a prime position to become the dominant network for security systems. With more and more devices connected over Ethernet, the scenario looks set to be one where virtually everything can be interconnected.

Convergence

In the security industry, like many others, convergence is a key driver. The convergence of all security equipment on the same network brings many advantages such as allowing access from anywhere via the Internet.

Total cost of ownership and flexibility of a security network infrastructure is lower thanks to the ready availability of off-the-shelf interfaces and switches with plug-and-play capability. This makes networks scalable and easy to enhance without complex rewiring and disruption to the environment in which they are installed. The progressive convergence of building security networks and enterprise data networks is a clear illustration of the way things are going in this sector. The parallel evolution of network security tools like firewalls make sure that the converged network can protect the transferred data.

Integration

With numerous features and capabilities being added to systems, integration has become an important trend in the security market. Security cameras in particular have profited from numer-

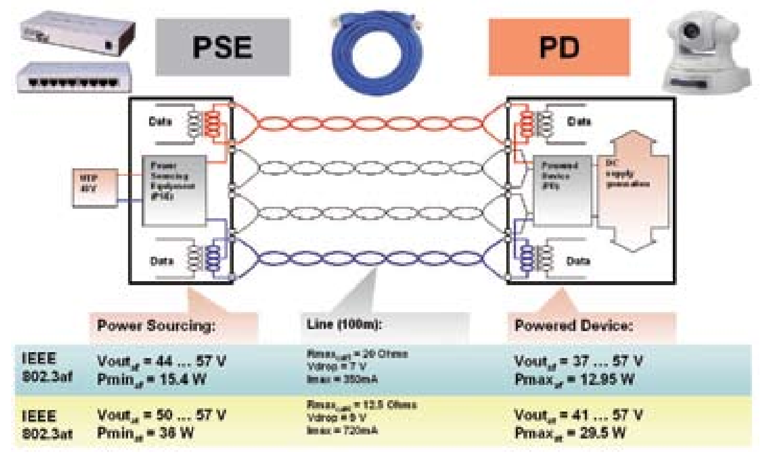
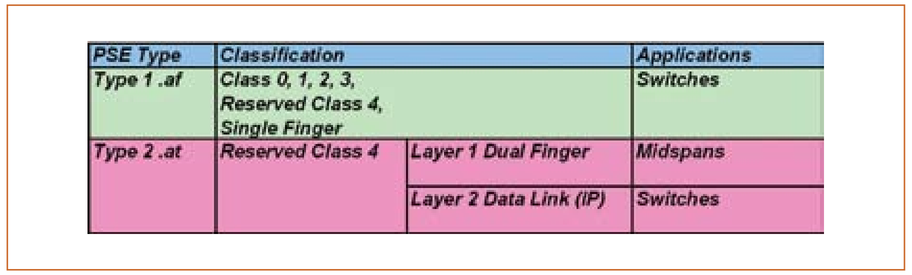


Figure 1: 802.3af & at Standard Comparison.



PSE Type	Classification		Applications
Type 1 .af	Class 0, 1, 2, 3, Reserved Class 4, Single Finger		Switches
Type 2 .at	Reserved Class 4	Layer 1 Dual Finger	Midspans
		Layer 2 Data Link (IP)	Switches

Figure 2: Power Loss Contributors.

ous technology advances. For example, CMOS image sensors have lead to improved image quality and higher frame rates, while network and media processors are enabling the handling of captured image data and its organization into IP packets. Additionally, tracking capabilities have been successfully implemented via on-board stepper motors. For outdoor camera applications, heaters and fans are being added. Now, the camera market is ready to add even more features such as speakers, microphones and sensors.

Standards

Initially the IEEE802.3af PoE standard adequately supported the modest power needs of devices such as VoIP phones, wireless LAN access points and even box cameras. But the standard is evolving to the higher-powered IEEE802.3at, also known as PoE+. This emerging standard supports the delivery of even higher power levels which in turn serve the convergence principle. With PoE+, most types of cameras can be connected at virtually any point on the network. No power plugs need to be provided, additional wiring can be avoided and repositioning is easily achieved through plug-and-play. Power supply backup via an uninterruptible power supply (UPS) on the Ethernet switch is easy to implement with PoE enabled systems. In the market today, PoE convergence has encompassed box cameras so long as their power consumption is within the 13W power budget of the IEEE802.3af standard. With the development of the IEEE802.3at PoE+ standard and its associated 30W capability, the security market will be able to include functionality such as pan-tilt-zoom (PTZ) and dome cameras in the power budget.

Power and functionality growing

Integration of functionality is also driving camera power requirements. As the advantages of UPS backup become more obvious and the ability to integrate multiple functions on silicon becomes more feasible, more external features will be attracted to the camera platform. Crucially, integrating functions on silicon means that the original camera enclosure can be retained despite the extra functionality.

Higher integrated power will be a requirement for most new pieces of equipment in the security market so a key question is what are the latest decisions in the IEEE802.3at standard committee and how can PD circuits support these higher power requirements? The .at standard is targeted to deliver up to 30W to the load. This is accomplished by raising the minimum voltage on the cable from 44V for the .af standard to 50V for the .at standard. A cat5e/6 cable is proposed for higher power because of lower resistance. The configurations are depicted in figure 1.

The power level in IEEE802.3at is raised from 13W to 30W by increasing the maximum cable current from 350mA to 720mA. However, it is important to note that the 30W power budget is not fully available for the PD as a fraction of the sourced power is dissipated between the Ethernet input jack and the voltage regulator output.

The three primary areas of power loss are shown in figure 2. The losses are spread over the path between the input diodes, the PD pass switch and the DC-DC converter. The overall efficiency between input and output will be in the range of 85%, resulting in a maximum power budget for the application of 25W for IEEE802.3at and 11W for a .af setup.

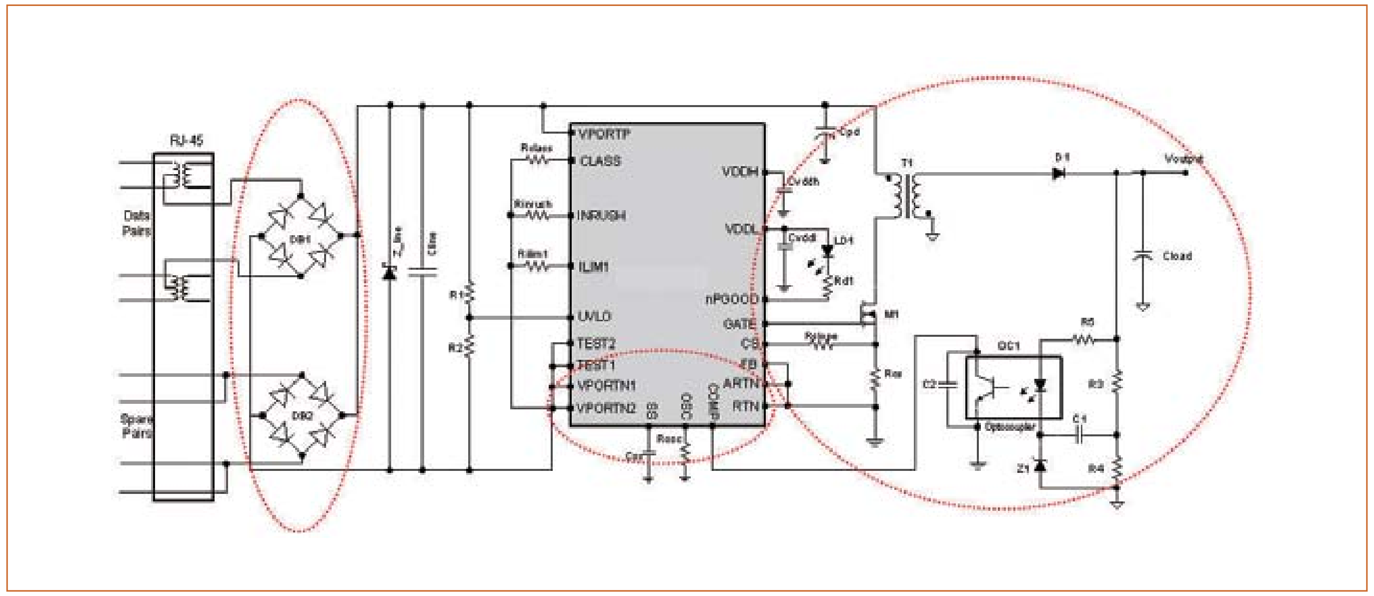


Figure 3: Classification Handshake Protocols.

Classification Techniques for Enabling Higher Power

Classification describes the power request protocol used between PoE enabled powered devices (PD) and power sourcing equipment (PSE). Two classifications are being considered by the IEEE standard that will enable higher power equipment deployments. These are explained in Figure 3. In the first method the reserved Class 4 handshake is applied twice. This is so-called Layer 1 handshaking and is implemented in the hardware of PSE and PD devices. Interest in the Layer 1 approach is mainly driven by the need for basic Midspan equipment where it is desirable to avoid having to access the data channel stream.

A second method is to apply the reserved Class 4 handshake on the PD, start up under low power conditions and communicate via the data channel between the switch and the application that requires more power. This method is known as Layer 2 handshaking.

Figure 2 illustrates a highly integrated PD with high power capabilities and currents above 1A. In a single unit this device combines a high power PoE-PD hot-swap pass-switch and a highly efficient DC-DC converter. The PoE-PD device is fully compliant with the IEEE 802.3af standard and supports Layer 2 handshaking of the 802.3at specifications. Highly integrated solutions such as this lead to a reduced bill of materials and contribute to a size reduction in the complete system.

In this application, the output voltage serves several parts of the camera. For example, on a PTZ camera platform there is not only an image sensor and a media processor, but also the stepper motor drivers for controlling the axis movement. The stepper motor drivers consume a significant amount of the power budget and therefore the IEEE802.3at standard enables PoE for these platforms. There are additional power hungry elements to consider such as heating systems and on-board fans designed to help remove moisture. Other devices such as MIMO wireless LAN access points and RFID access points can require more power than 13W to operate.

Summary

Power over Ethernet is well positioned to serve IP convergence and integration trends in the security and security camera market. PoE+ is emerging as a way to meet the power requirements of a broader range of security applications. Several PoE PD devices already provide solutions that are fully compliant with the latest developments of the IEEE standardization activities. This is a trend that we can expect to accelerate with the widespread deployment of a new class of products in the security market.

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Solar Power Shines!
Part I

Implications of solar panel technologies and system power ranges

The photovoltaic energy market appears to be very sunny now, with impressive growth rates and much innovation. But the market drivers vary significantly from country to country. One thing they all have in common is the need to deliver the highest efficiency, making solar cells and photovoltaic inverters a fine example of high technology. This article explores the implications of different solar panel technologies and system power ranges, and breaks down the inverter into a front-end boost converter and a back-end frequency inverter, to explain the tremendous differences in requirements and how to solve them.

By Alfred Hesener, Director for Applications and Marketing, Fairchild Semiconductor, Europe

Solar power is a fast-growing market, with around 35% CAGR over the past two years. This is not surprising since it is driven by strong improvements in panel efficiency, guaranteed feed-in tariffs in more and more countries and last but not least, by the fact that it represents “clean” energy, with no noise or pollution during usage. Compared to other renewable energies, it has significant advantages. Solar energy is available almost everywhere; the installations are scalable from small systems for individual houses to large-scale plants; no supplies are required to keep it operating, and there are no moving parts that significantly impact reliability. Other alternatives used today, like oil, coal, or nuclear energy have disadvantages such as availability and sustainability, even with the environmental side effects aside.

So it is not unexpected that growth rates are forecast to remain strong for many years to come. Solar electricity clearly represents a market in full upswing.

All the large solar cell manufacturers are building large factories to participate in the strong momentum that this market shows. But as much as external factors are driving the market, this market is at the same time, characterized by immense technological developments and improvements in cell efficiency. In fact, market development has been so strong that there is now a shortage in one of the basic materials, in raw silicon, the same base material the semiconductor industry also needs. Silicon is one of the most common elements on the earth, but the process to clean this element is extremely time-consuming and expensive. As shown in Figure 2, thin-film cells that use much less silicon (or other materials) have gained in momentum, despite the fact that their efficiencies are lower than the mono-crystalline cells.

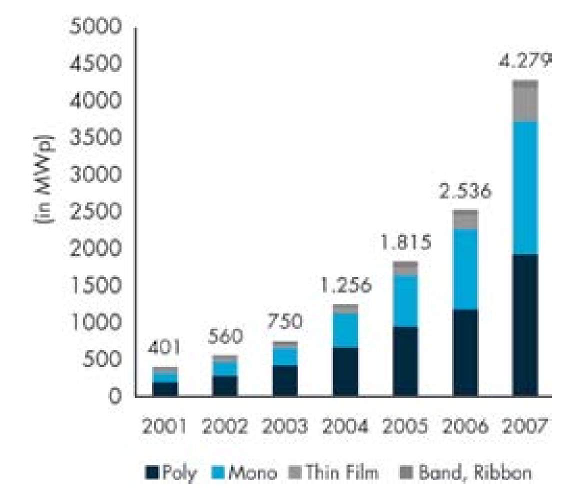

Figure 1: Panel production capacity in the past years by cell type. (Source: Photon)

Today, four different panel types dominate the market:	
Type	Efficiency
a-Si, or polycrystalline silicon	10%
CdTe (Cadmium Telluride)	12%
CIGS (Copper-Indium-Gallium-Sulphur-Selenide)	14%
c-Si, or monocrystalline silicon	16%
CPV (concentrator PV using triple-junction cells)	25% (prototypes)

The biggest market in Europe for solar cells today is Germany. However, solar electricity in Germany only represented roughly 4% of all renewable energy sources in 2007, which equals about 0.6% of total electricity consumption in this country. The German government, like many other European governments, has clearly defined goals to increase their share of renewable energy, and the space and potential for wind, biomass and water energy is limited. With this consideration in mind, it is increasingly clear that solar electricity has great growth potential. Comparing the German market with the Spanish market (the second biggest in Europe), there are important differences:

- The solar radiation density is much higher in Spain
- Predominantly direct radiation (versus indirect radiation in Germany)
- Population density is lower

Consequently, the type of systems installed is very different, whereas in Germany many individual home-owners are operating smaller-scale systems on their roofs (in a power range of 5kW to 20kW) and conversely, the predominant type of installation in Spain consists of large power plants in the megawatt range, with tracking systems to follow the sun’s movement and optimize the yield, combined with large inverters. For these power plants, large pieces of land are required that are easier to find in Spain. The differences also imply a difference in cell types, with large concentrator cell plants being an interesting new concept for Spain, since these cells can easily handle higher illumination densities.

The efficiency values are industry-average estimates for mass production and as such can only give a relative indication. Today, around 85% of all panels are built with c-Si. As mentioned before, raw silicon as a base material has become rare, but a recent breakthrough may change that. Various companies have developed a process to provide umg-Si (short for “ upgraded metallurgical silicon”), which is not as pure as the silicon used for semiconductors, but may be good enough for solar cells, and is more cost-effective and easier to produce. This fact could mean that solar panels might become less expensive, putting significant cost pressure on the other components of the solar systems, namely, the inverters, to follow a similar cost-reduction path.

The output of PV systems can suffer from various issues. Most of them have to do with the way the light reaches the cells, like cast shadows, diffuse shading, or dirt or other particles on the modules. Figure 3 shows how even small plants can cause a significant loss in output power:

Why is this a challenge? The typical panel output voltage of 50V can only be reached by series-connection of many cells, all acting as current sources. If one of the cells is shaded, its source impedance rises significantly, and only little current can flow through the whole chain – one cell is effectively shutting down a whole string of cells. At panel level, by-pass diodes can prevent this from becoming a larger issue, but the panel itself has significantly reduced power output.

Figure 2: Monocrystalline solar cells.

Figure 3: Shading caused by trees.

The second large category of challenges has to do with the cells, either broken or mismatched within the panel. And the matching of the cells to the inverter is critical to ensure that the system operates at maximum efficiency most of the time.

Thirdly, corrosion can be a significant issue, since the lifetime of the systems can usually exceed 20 years. Water or dust entering the panels, connectors or the inverter can cause early failure.

The block diagram in Figure 4 shows a PV system, with the panels on the left side providing a DC input, and the connection to the grid on the right hand side. Most systems today are connected to the grid, and feeding the generated power into the mains. Some systems in more remote locations are not connected to the grid but usually provide the same output as normally found on-grid.

Inverters come in different topologies,

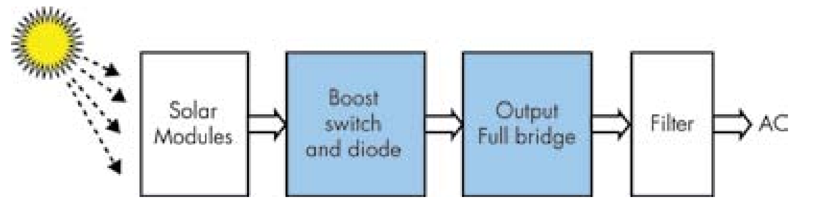

Figure 4: Transformer-less topology instrumental in optimizing efficiency.

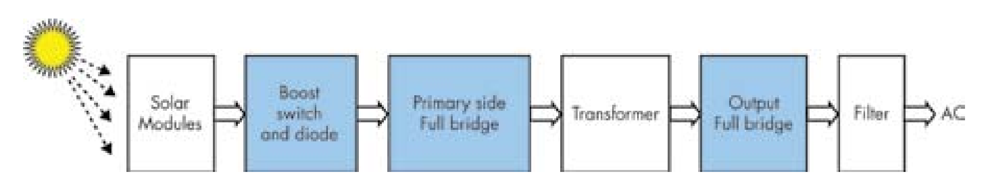

Figure 5: When isolation is required, a transformer needs to be introduced.

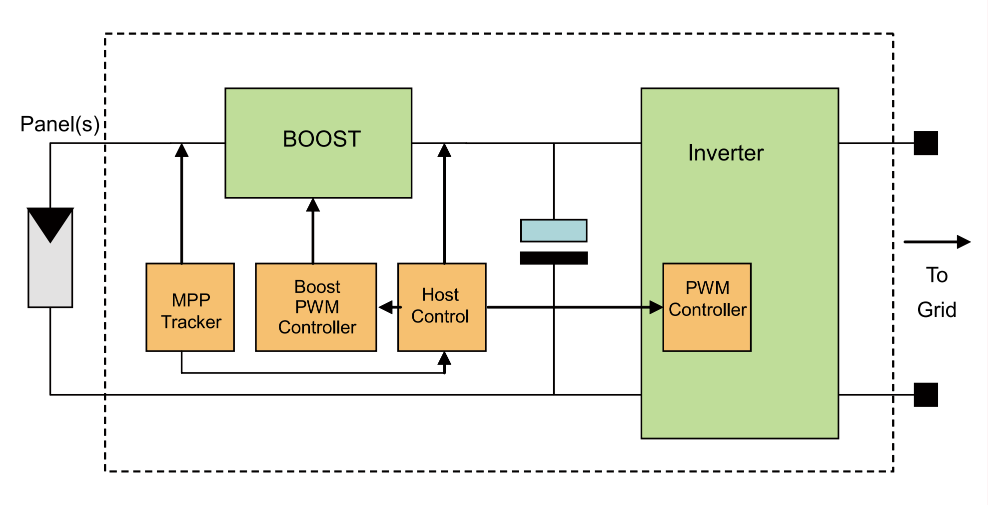

Figure 6: The inverter is the main element between the panels and the grid.

depending on whether isolation is needed or not.

In order to keep the transformer small, another full bridge is used to drive it at high frequency, reducing the overall efficiency somewhat.

The inverter provides proper loading to the cells, to draw the maximum power and converts this energy into an AC output current. To do this, a MPP tracker is used ("Maximum Power Point"). The cells can be thought of as a voltage source with a non-linear source impedance, and the MPP tracker varies the loading until the product of voltage and current is maximized, by changing the input impedance of the boost converter. In a second stage, this DC current is then converted into the required AC output current. For this, the inverter will monitor the grid voltage and frequency and its own output current, to control the inverter stage appropriately. The inverter really works as an AC current source, driving the grid impedance. The intermediate voltage has to be higher than the desired peak output voltage, plus some margin – at 220VRMS, the peak voltage is 308V, so the intermediate voltage is usually chosen to be 350V-390V. This means the second inverter can act as a pure step-down circuit, simplifying the topology. It is not uncommon to find several boost converters connected in parallel, to be able to connect multiple strings of panels. They all "feed" into one inverter.

Figure 7: Small inverter for 3kWp output power

Figure 7 shows an inverter, with the main PCB dedicated to the power conversion. In the center, power IGBTs can be seen under clips that press them to a heat sink. On the right, electrolytic caps are used as intermediate caps between the boost converter and the inverter, to store the energy needed to bridge individual 50Hz cycles. Here, many caps in parallel are chosen over one large cap in order to minimize the equivalent series resistance. The flat cable in the middle connects to the microcontroller placed at the front of the case, where the display is also located. This is a transformerless inverter, and the two big inductors on the top are the output inductors.

In a typical smaller-scale installation with an output power of 5kW to 10kWp, a separate electricity meter may be used to count the Kilowatt-Hours the system is producing. In larger solar power plants, the inverter can be used for this purpose, since it is measuring voltages and current anyway. Here, a remote host is communicating with the inverters and tracking the yield of each part of the system. Web-based interfaces allow easy checking even from a distance.

Alfred Hesener continues this topical theme next month with the second part of Solar Power Shines!

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Power Systems Design
EUROPE

Automotive Electronics
Part II

Image Courtsey of Tesla Motors

Integrated Half Bridges for Automotive Applications

Protected solutions for electric motor drives

Integrated half bridges offer a compact space-saving solution for electrical motor drive applications in the automotive environment. Compared to a relay solution and discrete semiconductor solutions the integrated half bridges offer PWM capability and current sense together with additional protection features.

By Rainald Sander, Jonas Grönvall, Mario Noziczka, Infineon Technologies

The need for efficient electrical motor control in modern cars is steadily increasing. This is driven by additional comfort and safety functions as well as by the need to reduce fuel consumption. Talking about electrical motor drives, there is a wide range of motor solutions possible. Dependent on the application, different motor concepts are used. Common electrical motors used in automotive applications are e.g. DC brush (BDC) motors, Brushless DC (BLDC) motors, stepper motors and permanent magnet synchronous motors.

The most common motor is the DC brush motor due to its relatively low cost and ease of use. There are different ways to drive a DC brush motor. The simplest one is of course a mechanical switch but in modern cars the motors need to be electronically controlled. An easy solution is to control the motor via a relay, see Figure 1. The biggest benefit of the relay solution is their price. But in functionality they have weaknesses which can be a blocking point dependent on the application requirements. The main points are a missing PWM capability and the absence of protection functions. Also with regards to reliability and lifetime the semiconductor is still a step ahead.

If the application requires controlling the speed of the motor, normally the voltage on the motor inputs needs to be controlled. Due to energy efficiency reasons PWM comes more and more in use. The use of PWM requires a semiconductor solution, e.g. discrete MOSFET plus a MOSFET gate driver. Here often N-channel MOSFETs are used for both the high and low side switch, see Figure 2.

The next logical step is to integrate the power (MOSFET) and control functions together in one package, see Figure 3. This saves PCB area and offers a PWM capable solution. The integrated solution can also be configured with logic level inputs for ease of use.

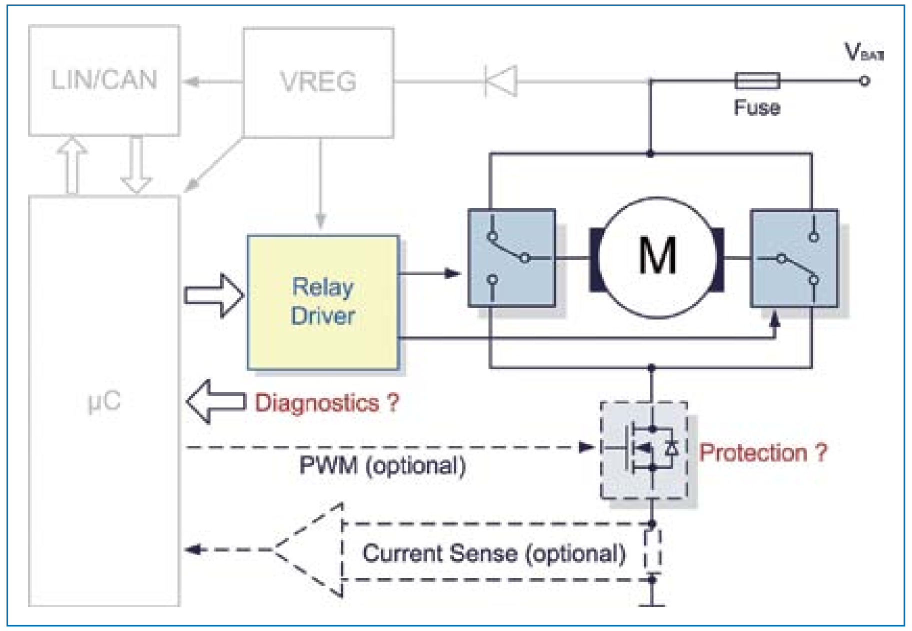

Figure 1: Relay solution for bidirectional motor control (H-Bridge configuration) does not offer PWM capability.

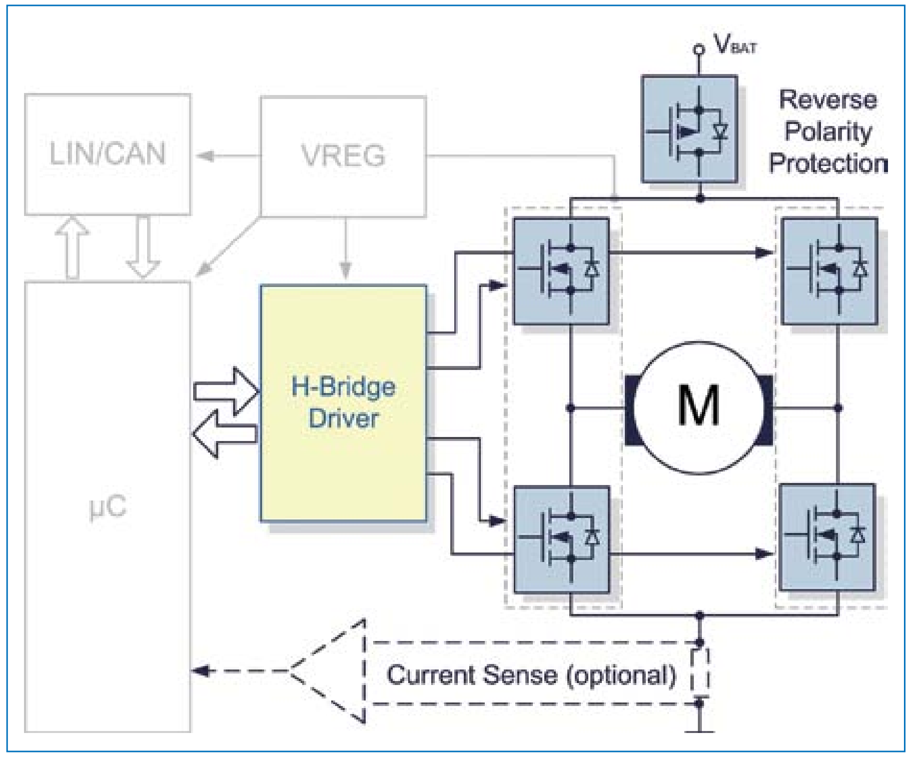

Figure 2: The discrete semiconductor solution for bidirectional motor control (H-Bridge configuration) offers PWM capability but occupies significant PCB area.

The advantages of integrated half bridges

Compared to relay solutions an integrated solution offers various protective functions, diagnostic features and gives new load current control opportunities due to the PWM capability. The presented integrated concept is basically built up on a half bridge solution. By using a complementary P/N MOSFET chip arrangement a standard common non-split lead frame can be used. In addition, this concept needs no integrated charge pump or bootstrap technique as needed for N-channel high-side solutions, saving the charge pump and lead frame pins for an external bootstrap capacitor. This complementary P/N channel concept also improves EMC performance compared to the use of charge pump.

The integrated concept gives also the opportunity to monitor the load current in the high- and low-side switch. This current control is used as a protection feature for overload control and offers the feature that the load current can be monitored without additional external components. The functionality of a shunt plus operational amplifier is incorporated. In the integrated solution a current sense output signal is offered, which can be easily transformed by an external resistor to a scalable voltage signal as input for the microcontroller.

The advantages in the application are that certain defined load conditions can be directly recognized.

Due to the integrated concept a direct temperature control of the power switches are embedded. At a certain temperature threshold the power switches are shut off and a failure signal will be generated. Both features, the integrated current limitation in combination with the over temperature shutdown, supports short circuit protection.

All in one, the P/N concept and the protection features, gives full pulse width modulation capability with any duty cycles. To optimize switching power dissipation in balance to switching induced emission filtering efforts the slew rate can also be adjusted. One important challenge with high PWM frequencies is to minimize additional power losses due to cross currents through the high and low side switch. This ability is implemented by an integrated deadtime generation adaptive to the switching slew rate.

Self-evident to mention that a logic input is offered to simplify the interface to a microcontroller. To reduce the quiescent current of the integrated circuit in power-off mode to microampere level a sleep modus is provided.

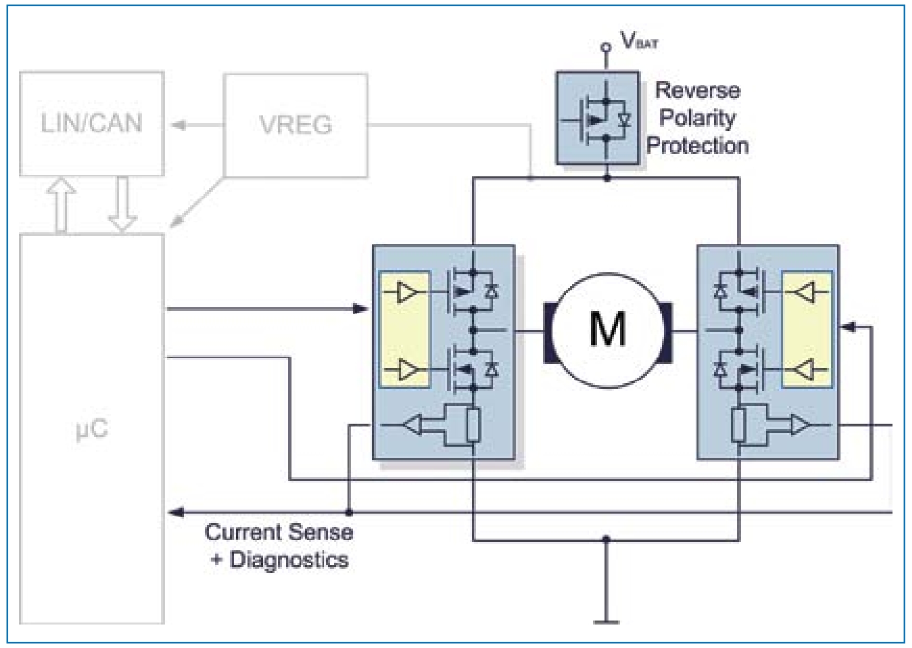

Figure 3: The integrated half-bridge semiconductor solution for bidirectional motor control (H-Bridge configuration) offers PWM capability and significant PCB area savings.

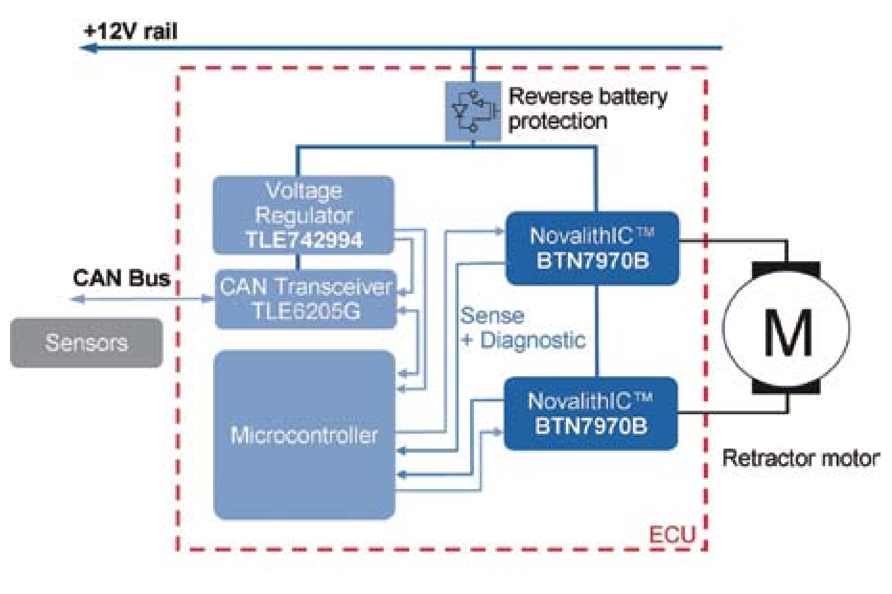

Figure 4: Compact realization of a seat belt pretension system with integrated half-bridges.

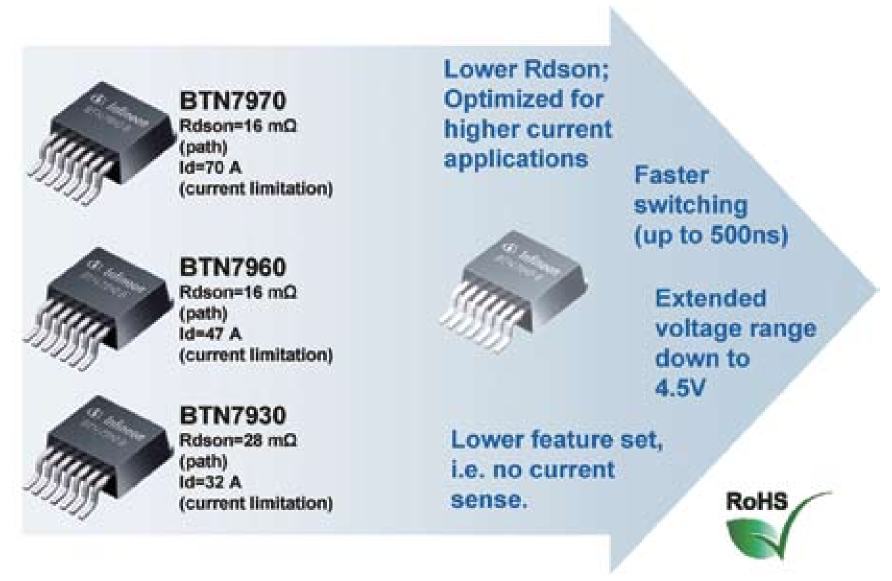

Figure 5: Trends for future half-bridge products goes in the direction of lower Rdson, higher current capability and PWM capability with faster switching.

Application example

The trend to further improve the safety in modern cars is very strong. Seat belt retraction system tightens the seat belt and minimizes the loads on the human body in case of a crash. So far, pyrotechnical retraction systems are dominating this market. For additional safety electrical retractor systems are coming more and more in use. Working together with a pyrotechnical device these offer the functionality of eliminating slack and tensioning the seat belt in a pre-crash situation to further minimize the load on the human body.

These kinds of systems can also offer comfort functionality by slightly tightening the seat belt when driving through curves minimizing the influence of G-forces. The challenge for this application is to control an electrical motor with a relatively high current for a very short period of time. The advantages the integrated half bridges offers for this application are high current peak capability, low board space consumption and current sense. The high current half-bridge IC, the NovalithIC BTN7970B, is rated with a 70 A current limitation level at Vs=13.5 V enabling the high peak currents required for this application.

Compared to using discrete MOSFETs and a gate driver, the PCB area saving can be up to 50 percent. Several protection functions offered, such as over- and under-voltage, over-temperature, current limitation and short-circuit protection also helps out in optimizing the system and simplifies the system control concept. The whole system can be realized with two integrated half-bridges, microcontroller, voltage regulator and communication, see Figure 4.

Modern cars contain in the range of 50 electrical motors and the use of electrical motors in automotive applications is steadily increasing. In addition to the example above, electrical motors come also in use for applications like gearbox, window lifts, seat positioning, HVAC fans, fuel pumps, oil pumps and water pumps. The technical requirements from these applications go in the direction of lower Rdson, higher current capability and PWM capability with faster switching, see Figure 5. The future will see more integrated products focusing on these trends paving the road to even more efficient motor drive solutions in the automotive segment.

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Powering Automotive Design

Model-based design to test and verify automotive embedded software

Embedded software, power and control electronics represent an increasing percentage of the engineering content of an automobile. By 2010, electronics are expected to comprise 40 percent of automotive material costs, up from 10 percent in 1970. Embedded software and electronics are used across the car's functional areas, replacing or simplifying mechanical and hydraulic systems in core functions, such as steering and braking, and implementing advanced features, such as active safety systems and driver information systems that add significant customer value in terms of convenience, comfort, and safety.

By Jim Tung, Mathworks Fellow, The MathWorks, Massachusetts, US and Cambridge, UK

This rapid growth in complexity of embedded software and electronics coupled with the difficulty of testing and verifying these systems however, has been associated with a rise in quality issues and recalls.

Model-Based Design has become the preferred approach for developing automotive embedded software because it improves the specification, design, and implementation phases. Now, new tools and capabilities are available for Model-Based Design that help address test and verification challenges, improving embedded software quality and shortening the test and verification cycle.

Model-based design for test and verification

Automotive engineers typically use models when developing functions that will run on an electronic control unit (ECU). The models in this Model-Based Design are used in multiple ways: to provide executable specifications, to analyze the system's dynamic behavior, to simulate system components and environmental conditions that reduce or eliminate the need for costly physical prototypes, and to design the algorithms. Furthermore, automatic code generation from these models has become an accepted way to implement production ECU software. In the coming years, it is expected to become the primary approach for implementing embedded control software in many automotive companies.

From a quality perspective, automatic code generation already helps by optimizing the design through analysis and simulation, as well as by the repeatable quality of automatically generated code. In addition, code can be generated from system-component and environmental models to generate hardware-in-the-loop tests.

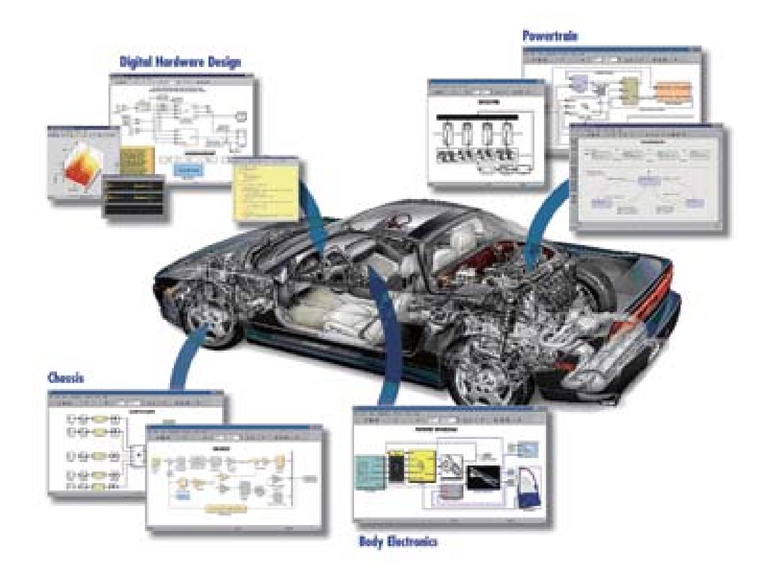


Figure 1: With the continued growth of electronics and embedded software in automobiles, Model-Based Design assists in reducing development time and improving quality through all domains of automotive electronics.

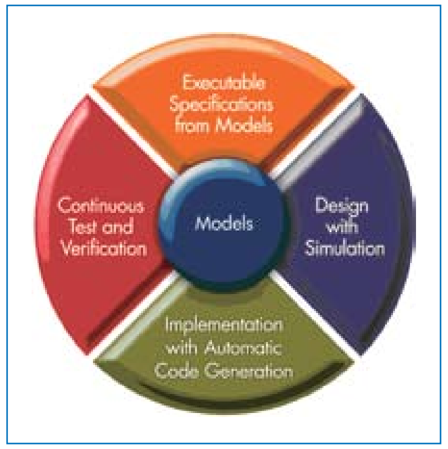
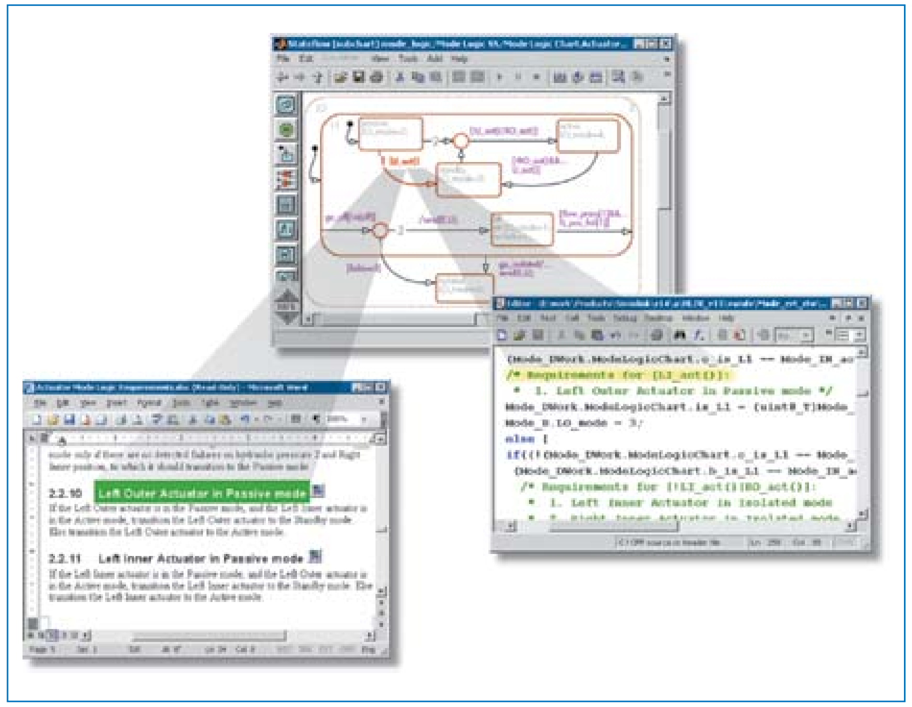


Figure 2: Model-Based Design leverages system models throughout the development process, from requirements capture and design to implementation and verification.

Now, new and enhanced approaches can leverage these same models in more diverse and powerful ways—including requirements-based testing, coverage analysis, and test generation—to accelerate and improve the test and verification activities for today's complex embedded systems, including both embedded software and electronic components.

Tracing and checking requirements

Most software or process standards, such as CMM-I, require bidirectional traceability of the design to the requirements throughout development. The implementation code must also be traceable to the design, so that it may be reviewed and verified. Tools for Model-Based Design can link the textual requirements, captured in Excel, Word, or a requirement-management tool, to the model (the design). Any requirement that isn't satisfied in the design can be flagged, as can any design element that doesn't match to a requirement. If a requirement (or design) is changed, the tools indicate which corresponding design elements (or requirements) might be affected. In addition, the automatic code generator can insert HTML links into the generated C code so that the implementation can be traced back to the model, which is especially important for safety-critical systems. Together, these capabilities provide a complete traceability path from the code to the requirements (Figure 3).



2.2.10 Left Outer Actuator in Passive mode

If the Left Outer actuator is in the Passive mode, and the Left Inner actuator is in the Active mode, transition the Left Outer actuator to the Standby mode. Else transition the Left Outer actuator to the Active mode.

2.2.11 Left Inner Actuator in Passive mode

```
(Mode_DWork.ModeLogicChart.c_is_L1 == Mode_IN_ac
/* Requirements for [L1_act()]:
 * 1. Left Outer Actuator in Passive mode */
Mode_DWork.ModeLogicChart.is_L1 = (uint8_T)Mode_
Mode_B.LO_mode = 3;
else {
if((!(Mode_DWork.ModeLogicChart.c_is_L1 == Mode_
 (Mode_DWork.ModeLogicChart.b_is_L1 == Mode_IN_a
 /* Requirements for [!L1_act()|RO_act()]:
  * 1. Left Inner Actuator in Isolated mode
```

Figure 3: Requirements tracing using Model-Based Design.

In addition to linking requirements to the design, tools for Model-Based Design offer capabilities for confirming that the design satisfies certain requirements. These requirements are inserted in the design model as properties (or assertions), and formal-method algorithms determine mathematically whether the properties are satisfied for all valid situations. If a scenario exists that would violate the property, the formal-method tool generates a counterexample, which the engineer can use in simulations and add to the test plan.

Model style checking

During the design phase, an initial high-level model is transformed into a model suitable for implementation purposes, including characteristics that are needed for implementation, such as fixed-point details, and removing portions that will not be implemented. In the same way that software engineers establish source-code style guidelines to make the code easier to read, test, and implement, engineers working with Model-Based Design establish model style guidelines to ensure that the model can be implemented and to facilitate understanding and testing of the model.

Depending on the desired workflow and whether a design represents a new feature or a modification to an existing feature, there are two approaches: limit the options available from the beginning to the designer, or apply checks later to the design as it is being transformed.

In the first approach, frequently used in safety-critical systems or designs that are small modifications of an existing implementation, the constraints are applied at the outset. Typically, this strategy is based on defining a constrained subset of model components (blocks or state machines), modeling constructs (how blocks are connected), and other settings (e.g., fixed-point aspects) that do not need to be checked manually in each design, because they can be checked systematically by the tools.

In the second approach, the model is checked against guidelines sometime later in the development process. This deferred checking enables the designer to start with an unfettered design, then gradually constrain and transform the design into a robust and testable implementation. Ideally, this model-checking is done in the modeling environment so that the developer can quickly flag issues and edit the design in an efficient and iterative manner.

Recently tools have been introduced that enable an engineering team to define and customize a set of model-checking rules, apply it to models, and address the exceptions immediately (Figure 4).

Analyzing and ensuring model coverage

The model provides an opportunity early in the design process, prior to implementation, to perform the types of tests that might be done later with source-code-based testing. Engineers fully stress the controller to verify its design integrity and to detect problems, such as dead sections of the design that would later appear as dead code).

Often, to confirm that a design works properly and is robust, engineers run exhaustive model simulations. However, those simulations are only as useful as the scenarios they are running.

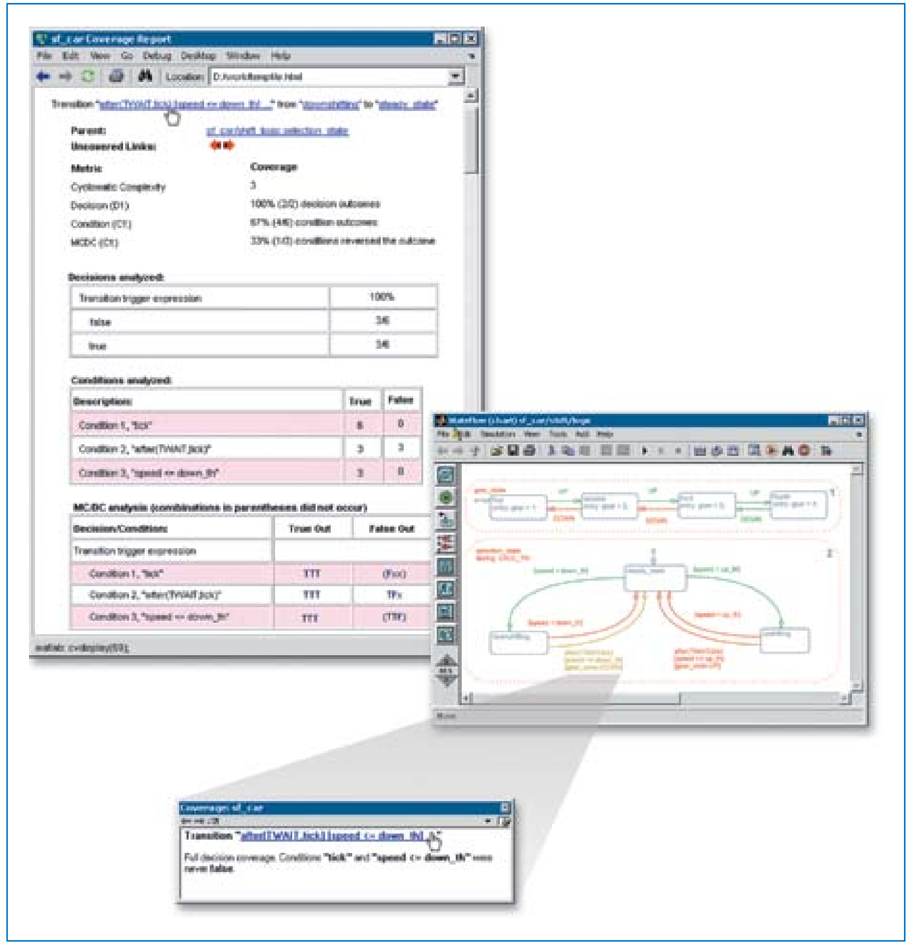
Stress testing the model by running simulations using minimum and maximum numerical values helps ensure that overflow conditions will not occur. It is also important to ensure that the simulations exercise all parts of the design, and all modes and logic branches of the design behavior.

☐ Simulink Verification and Validation
- ☑ Requirements Consistency
- ☑ Modeling Standards
  - ☑ Check for blocks not using one-based indexing
  - ☑ Check for invalid filenames
  - ☑ Check for invalid model directory names
  - ☑ Check for non-discrete blocks
  - ☑ Check for prohibited sink and data store blocks
  - ☑ Check for non-white background on all Simulink diagrams

Check for non-discrete blocks

The following blocks are not permitted for discrete controllers:

Figure 4: Checking the model for compliance with standard and customer-defined guidelines.



Parent:

Uncovered Links:

Metric	Coverage
Cyclomatic Complexity	3
Decision (D1)	100% (2/2) decision outcomes
Condition (C1)	67% (4/6) condition outcomes
MCDC (C1)	33% (1/3) conditions reversed the outcome

Decisions analyzed:

Transition trigger expression	100%
false	3/6
true	3/6

Conditions analyzed:

Description:	True	False
Condition 1, "tick"	6	0
Condition 2, "after(TWAIT,tick)"	3	3
Condition 3, "speed <= down_th"	3	0

MC/DC analysis (combinations in parentheses did not occur)

Decision/Condition:	True Out	False Out
Transition trigger expression		
Condition 1, "tick"	TTT	(Fxx)
Condition 2, "after(TWAIT,tick)"	TTT	TFx
Condition 3, "speed <= down_th"	TTT	(TTF)

Figure 5: Requirements-based test coverage analysis.

Model coverage analysis assesses the cumulative results of a test suite to determine which blocks or states were executed during a simulation, and which were not. Certain coverage analyses are well established in source code languages, such as C, C++, and Ada, but these types of analyses have not been available at the model level until recently.

Modified Condition/Decision Coverage (MC/DC) is considered by the FAA to be the most stringent coverage level necessary to satisfy safety-critical systems. This coverage analysis, among others, is now available within Model-Based Design, and is conducted based on simulation runs. When performed within the simulation tools, MC/DC enables the automatic logging and reporting of coverage metrics for the model (Figure 5). As a result, the test engineer can assess the completeness of the test scenarios in terms of the design structure. The challenge then becomes defining sets of tests that will efficiently result in complete coverage.

Automatic test generation

A new set of tools for Model-Based Design can automatically generate test patterns that will satisfy specified coverage objectives, such as MC/DC, by mathematically analyzing the structure of the model and using formal methods to generate the patterns. This structural analysis also identifies any portion of the model that will never execute, which might be an indication that something was missed during specification, implementation, or test creation.

These test patterns can then be combined with other test scenarios derived from requirements, test bench data, Monte Carlo scenarios, and plant/environment models to exhaustively test the model through simulations, as well as the actual implementation later on (Figure 6).

Code compliance checking

The Motor Industry Software Reliability Association (MISRA) has published "Guidelines for the Use of the C Language in Vehicle Based Software." This set of guidelines, informally known

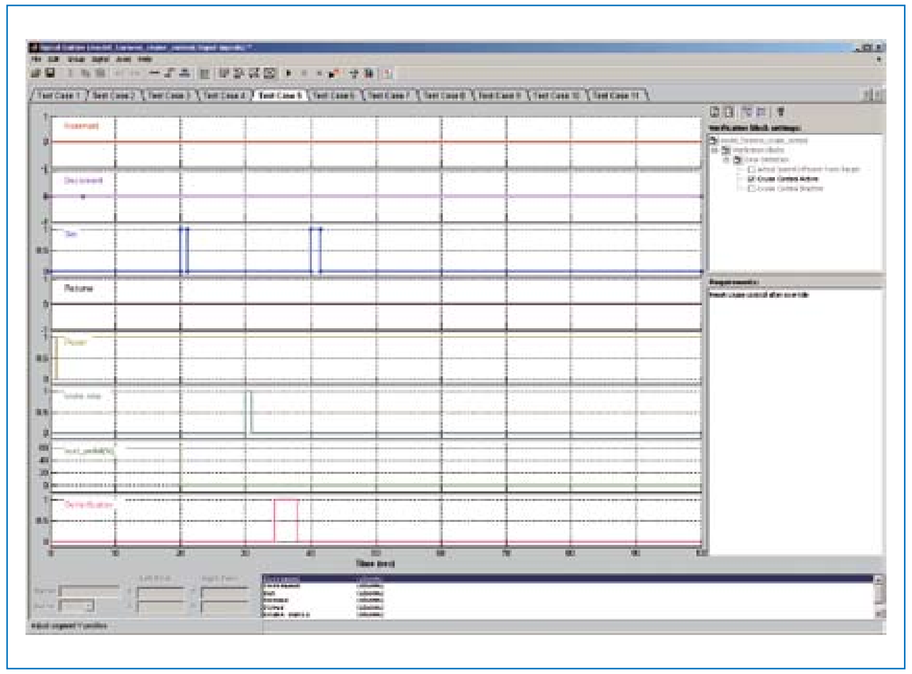


Figure 6: Test patterns for use in simulation and test harnesses.

as MISRA-C, has been adopted by a growing number of automotive manufacturers and suppliers. A significant amount of model checking for MISRA-C compliance can be done by looking at what the automatic code generation tool systematically generates, rather than checking all of the generated code as one must if it is manually created.

But checking the code generation tool doesn't address scenarios, such as imported handwritten legacy code. Open model interfaces can be used to automatically check for these scenarios. Using this approach, the checks are performed after model creation and then prior to code generation to ensure that the imported or generated code passes the checks. Another option is to include a MISRA-C code checker or static analysis tool into the code generation and build process.

Detecting runtime errors

Run-time errors can be particularly difficult to detect at the model level or during simulation, and can cause significant problems during software development and testing. Run-time errors are latent faults that often surface under specific combinations of data values, which make them expensive to find by dynamic testing. In fact, they are generally revealed by their consequences on functional behaviors, including unexpected commands sent to actuators, mathematic co-processor halt, and unexplained and hard-to-reproduce software failures. In these cases, lengthy debugging is then necessary to trace the problem to its source.

Static analysis is one approach to addressing run-time errors. In recent years, static verification tools have been introduced that apply advanced static analysis techniques and reduce the number of "false positive" results that require manual inspection or testing. Such tools perform static and some dynamic analysis of C code, regardless of whether the code is handwritten or automatically generated.

The integration of these verification tools with tools for Model-Based Design provides significant improvements to the workflow. By connecting the analyzed code and the model from which it was automatically generated, the static verification tool can present its results in both the source code and the model. Being able to navigate from the code to the model, make the change, then automatically regenerate and recheck the code, provides a powerful way to analyze, debug, and modify algorithms using both high-level and detailed perspectives. It encourages a development process in which changes are made to the model rather than directly in the code, which contributes to the longevity and reusability of the models from project to project.

Final observations

The key philosophies described in this article represent three best practices for leveraging Model-Based Design for test and verification.

First, you should reuse models as a test bench for the implementation. From running the model simulations, to running the implementation software linked against models, to running on a host computer or on the target processor, to running the full embedded system on a test bench, you can accumulate knowledge, test data, and other information in a way that can be reused later in the development and testing process.

Second, you should test as early as possible. Test in simulation before real time, test in real time on the bench before applying to real world, and test the model before the code. Testing early is often easier, with the higher abstraction level, and the cost benefits of catching errors early are well-documented.

Third, you should take advantage of all available techniques. Simulation and formal methods should leverage each other; model-based and code-based techniques for test and verification complement each other; and all of them are available to use with Model-Based Design from a range of tool vendors.

Many automotive original equipment manufacturers and suppliers are using Model-Based Design to generate executable specifications, simulate their performance and automatically generate code. Many of these companies are beginning to take the next step by leveraging their existing models for test and verification purposes. This article surveys a wide range of current methods to illustrate practical approaches that can be used to improve the quality and reduce the cost of automotive embedded software.

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Driving Lights in Automotive

Switching regulators for LEDs

LEDs are fast becoming the standard lighting choice in modern vehicles. Gone are the days when only the luxury end of the auto market sported these devices. The fall in price and increase in light output has brought this technology into the general automotive marketplace.

By Walter Trovo and Luigi Pistoni, Application Engineers, STMicroelectronics, Italy

LEDs are used more and more in the automotive field as a replacement for incandescent lamps. The main applications for interior purposes are backlighting of LCD or dash panels (satellite navigation units, car radio, air conditioning systems, odometers, etc.) and reading lights.

For exterior purposes the major applications are in brake lights and Centre High Mount Stop Lamps (CHMSLs), reversing lights, Day Time Running Lights (DTRLs), rear and front turn signals and side marker lamps. Recently, LED devices have extended their application into luxury cars (Audi, Cadillac and Lexus), where they have been used successfully for low and high beam headlamps.

LED advantages

LEDs are becoming a very attractive proposition in this market segment for many reasons:

- Light output has achieved critical milestones (>100 lumen/Watt). This implies energy saving and lower CO_2 emissions. It is estimated that moving from incandescent bulbs to LEDs for headlights can generate reduction in fuel consumption of approximately 0.2 per cent.

- No hazardous materials (mercury or toxic gases). This makes LEDs the cleanest lights in ecological terms.

- High color rendering and stability, making the illuminated objects appear more natural (e.g. reading lights).

- Wide availability of colors. As consequence, unlike the conventional lights, the use of color filters can be avoided.

- Long lifetime, resulting in a very high reliability.

- Maintenance free, which contributes to simplify non conventional design solutions (LEDs can be placed in locations difficult or impossible to access).

- Easiness of placement. This makes some functionalities feasible (illuminated buttons on the steering wheel, flash indicators for anti-theft alarms, etc.).

- Infinitely variable dimming capability. Therefore the LED lighting can be adjusted from virtually 0 up to 100%, without any change in the emitted color.

- Wide operating ambient temperature, which is essential in automotive due to extreme operating conditions.

- Extremely fast turn-on and turn-off response. This helps meet safety requirements. Just think to the brake lights: the faster they respond, the sooner they are perceived.

- Wide current range availability, covering several applications, from low power LEDs (few milliamps) up to medium and high power LEDs (more than one amp).

Finally, the cost of LEDs has come down very quickly, making them even more attractive, not only in luxury cars.

LED driving solutions

The driving of LEDs implies the control of the current that, in turn, determines the brightness of the emitted light.

The simplest way to regulate the LED current from a DC voltage source (e.g. car battery) is to use a linear regulator, accepting its inherent poor efficiency.

However, the increasing content of electronic components in automobiles makes the power conversion efficiency more and more critical. For this reason, dc-dc converters are becoming the natural choice to drive LEDs.

The selection of the most suitable device must take into account the specific requirements dictated by the automotive applications, in particular:

- Wide operating temperature range. For most of applications an operating temperature range from -40 to 125°C is required.

- Wide operating input voltage range. A typical requirement is from 6V (battery voltage at extreme low temperatures) up to 36V to manage the load dump

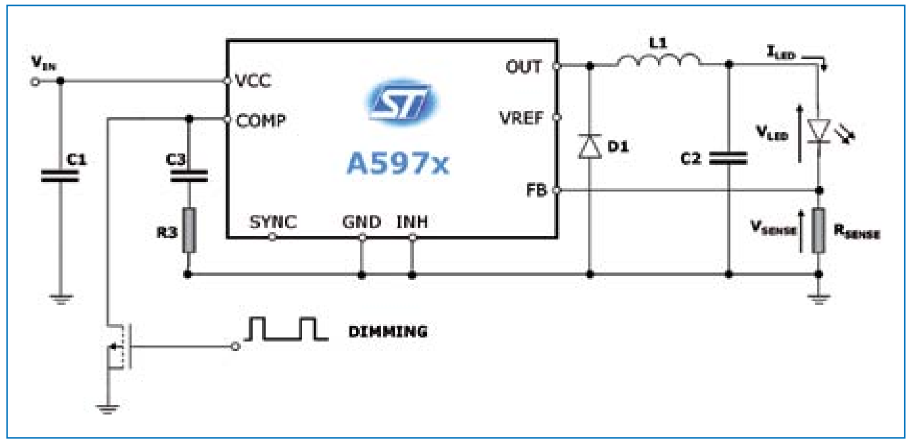

Figure1: A597x in buck topology to drive LEDs.

conditions (abrupt load disconnection from the battery while the car is running, which causes the voltage to temporarily increase)

In addition, extremely high quality and reliability levels are relevant for automotive applications to such an extent specific standards for ICs are available (AEC-Q100).

Another consideration concerns the topology to implement for driving LEDs.

During normal operation, the battery voltage ranges from around 8V to 14V and the voltage across most of the LEDs is approximately 3.5V.

Depending on the number of LEDs and how many are connected in series, a buck (1 or 2 LEDs), buck-boost (3-4 LEDs) or boost (more than 4 LEDs) conversion may be needed.

Considering the various applications, low, medium or high current LEDs can be required, covering a range from 20mA up to 1A and even more. Evidently, the demand of specific devices for different applications arises to manage different current requests.

Finally, the modulation of the LED brightness for safety reasons (e.g. brake light brightness proportional to the braking intensity) or simply to dim the light (e.g. the fading effect of the courtesy lights), preserving at the same time the color, brings to the need for specific dimming techniques (PWM dimming).

In this area, STMicroelectronics offers a variety of dc-dc converters for efficiently driving LEDs.

A first example is provided by the A597x family, composed of standard Automotive Grade (qualified following the AEC-Q100 standard) step down dc-dc converters.

The wide input voltage range (4.4V up to 36V), together with a high current capability (up to 2A), makes this family suitable for matching the above requirements for the automotive world.

Some application tricks can utilize these dc-dc converters, which accurately regulate the output voltage, as LED drivers capable of setting accurately the current flowing through a string of LEDs (see figure1).

An additional external switch allows PWM dimming, the performance of which depends on the input voltage and the number of LEDs (dimming ratios lower than 5% can be achieved).

With few changes in the schematic and without any significant component addition, the A597x family is easily convertible to a buck-boost topology whenever the input and output voltage ranges demand it (see figure 2).

In addition to the above characteristics of A597x family, the A6902 (also an Automotive Grade step-down dc-dc converter) offers the advantage of a built-in current loop (see figure.3)

The very low voltage across the sense resistor used to set the LED current (100mV), significantly contributes to increased efficiency.

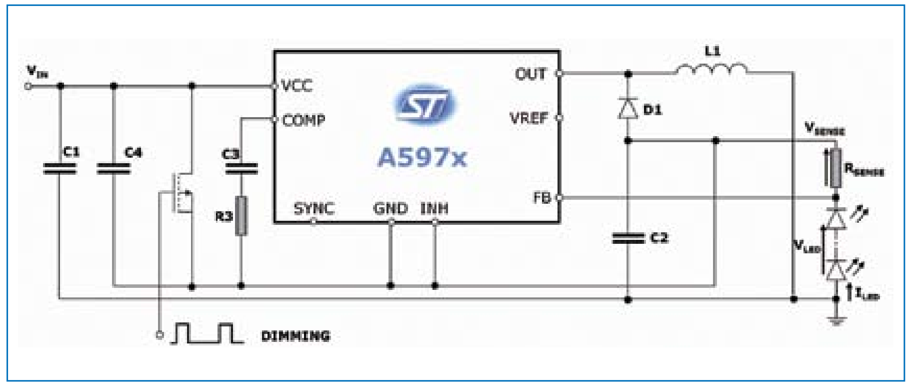

Figure2: A597x in buck-boost topology to drive LEDs.

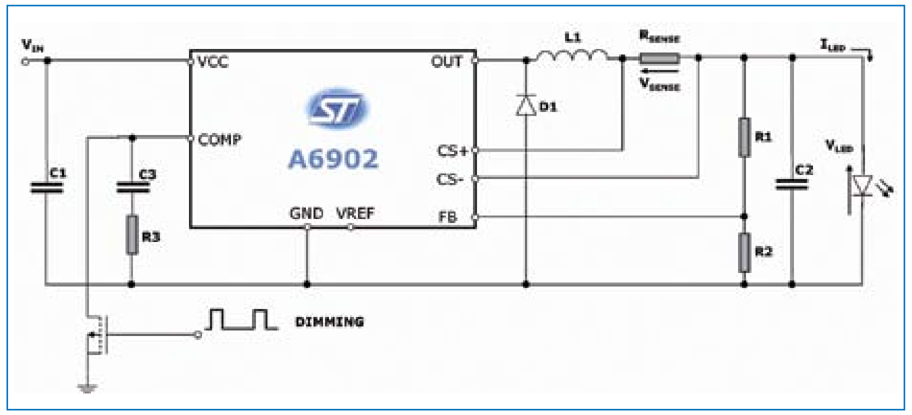

Figure3: A6902 in buck topology to drive LEDs.

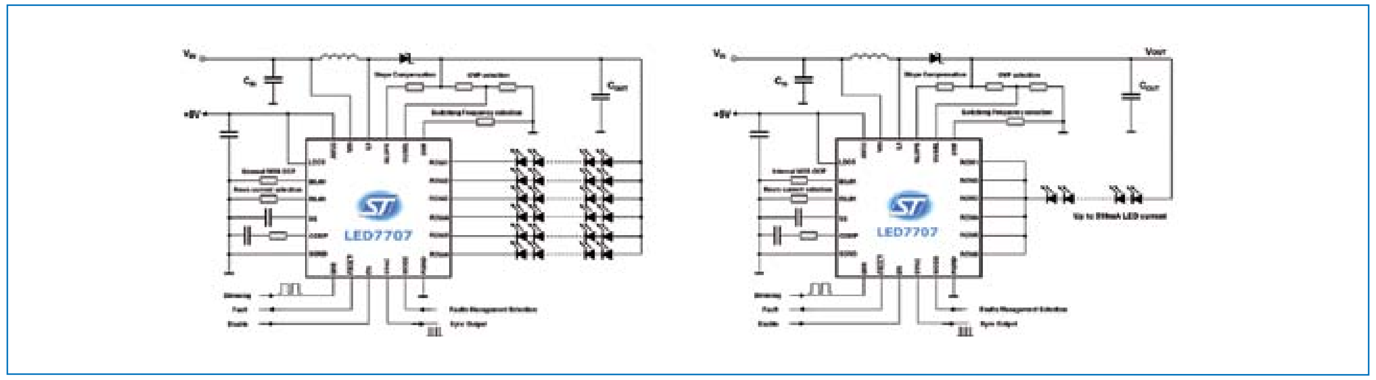

Figure4: LED7707: six channels up to 85mA (left) or one string of LEDs up to 0.51A (right).

When the application requires a boost conversion, a solution is provided by the LED7707, a dc-dc converter dedicated to LED driving applications (see figure 4). It integrates the boost converter and six current generators. The input voltage ranges from 4.5V up to 36V and each current generator provides from 20mA up to 85mA (with a current matching of ±2% which is essential for brightness uniformity).

Since the current generators can be connected in parallel, a maximum current of 0.51A (six channel in parallel) can be provided. This can be used to drive, for example, a string of high brightness LEDs (350mA, achievable with approximately 60mA per row).

Two internal loops accurately regulate the row current generators and adapt the voltage across the current generators in order to maximize the efficiency (which exceeds 90%).

A flexible fault management allows the detection of open-channel conditions and shorted-LED events and to leave the unused rows floating.

Moreover, the excellent time response of the current generators is a key factor to achieve high PWM dimming performance (1:1000 dimming ratio).

Conclusions

LED technology has become prevalent in many automotive applications, due to key advantages in terms of performance, reliability and power consumption.

A broad portfolio of dc-dc converters is now available from STMicroelectronics to efficiently drive LEDs in automotive applications over a wide range of current requirements in many configurations.

www.st.com

Automotive EMC Design Considerations

Switching regulator LED lighting applications

The use of switching regulators is necessary to maximize the efficiency gains offered by LED lighting solutions in automotive applications. The automotive environment is a tough one and switching regulators have unique properties which, if harnessed correctly, can significantly enhance circuit design. This article discusses automotive EMC considerations for LED illumination using switching regulator drivers and recommends circuit techniques to help minimize emissions and susceptibility.

By Adrian Wong, Systems Engineer, Diodes Incorporated

Until now, wiring harnesses have been used to distribute power and signals throughout automotive systems. However, as can be seen in Figure 1, they are usually routed to accommodate long paths and remote LED lighting switching regulator locations are far away from the car battery. Moreover, they have parasitic inductances or capacitances which incur the adverse resonant effects associated with noise currents. As a result, there are two typical EMC problems arising with respective solutions as described in Table 1.

Major problem	Solution(s)
Conducted emissions and immunity	1. A line filter is installed on the harness close to the emission source and away from the senstive circuits by inserting a high impedance path to the noise current flow.
	2. It also minimizes the "cross talk" capacitive coupling from the device to the power supply wiring.
Radiated emissions and immunity	1. Cables are shielded with the termination of a low impedance path for noise currents.
	2. Cables are twisted to minimize the loop area for the conductive noise coupling.

Table 1: Automotive EMC problems.

Instead of implementing all of the above common but costly measures, it is recommended to focus on suppressing the noise source as much as possible. In the application circuit shown in Figure 2, the necessary damping circuits are therefore incorporated around the LED lighting switching regulator. Also, the use of the fast hysteretic converter can dither the switching frequency, and benefit from a lower frequency operation, which attenuates the overall emissions.

Automotive EMC standards

Particularly for automotive lighting applications, EMC standards become vehicle manufacturer dependent with various test limits and even different test frequency ranges. Table 2 summarises the automotive test standards for a generic tier 1 car manufacturer which is derived from a consideration of most of the larger vehicle manufacturers' EMC standards. The tests cover the supply of electrical products to a vehicle manufacturer only and do not extend to whole vehicle testing, which remains exclusively the domain of the vehicle manufacturer.

Switching topology

From an EMC perspective the type of switching topology can yield quite different EMI performance. The choice of operating frequency is important too. It is often desirable from space and cost considerations to choose a high frequency switching regulator with small inductors. However the fast edges associated with high frequency switches can cause harmonics that are difficult to damp down - a prerequisite if conducted and radiated tests are not to be failed. PWM with a fixed frequency looks attractive, as the strong dominant fundamental can be relatively easy to filter out. Simpler hysteretic converters offer a variable frequency output, which if handled with care can produce an inherent spread spectrum response that reduces average radiated and conducted emissions. If noise filters are needed then the lowest operating frequency needs to be known to design a suitable filter.

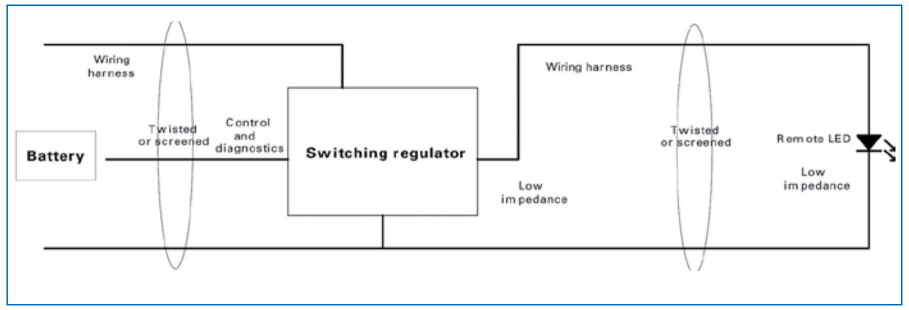

Figure 1: A simple diagram showing remote LED from switcher.

ESD and RF immunity considerations

Switching regulators are no different from any other analogue circuit with respect to ESD. Normal system considerations should be taken into account to ensure the circuit is shielded or protected by suitable ESD diodes. The same is true for RF, although the RF levels in automotive tests are much more severe than in commercial and industrial environments. Low impedances are more immune than high impedances. This is particularly important on control and status pins.

A Typical interior lighting application

Figure 2 shows a 350mA LED driver circuit for car interior lighting. The circuit is intended to be implemented with the LED remote from the switching circuit which is also connected to the battery via long wires.

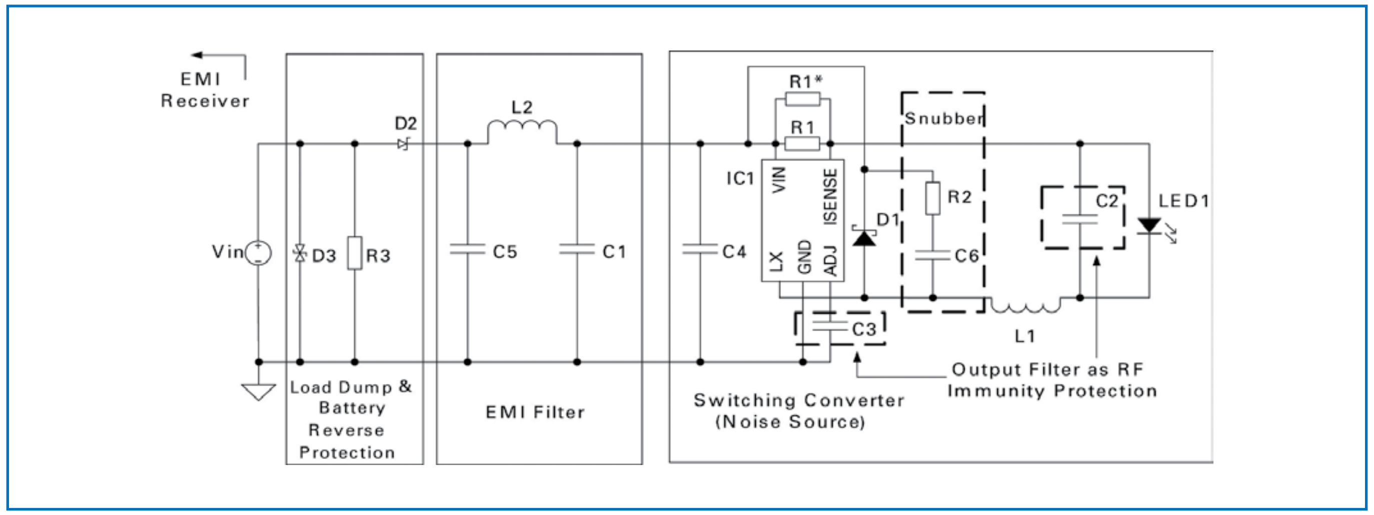

Figure 2: Circuit diagram of a 350mA LED driver for car interior lghting.

EMC measures for a basic hysteretic converter

In order to properly dissipate the heat generated by a power LED, it is often required to expose an adequate copper area on both sides of the PCB together with a number of interconnecting thermal vias for soldering and heat transfer. As a result, the routing of a long path to the LED is unavoidable. So a capacitor C2 is added not only to reduce the LED ripple current but also to filter its noise current. In some worst cases, an extra common mode choke may need to be inserted.

For this lighting solution a 60V ZXLD1362 based buck converter employing hysteretic current control was used. With reference to Figure 2 the full EMC solution consists of the following measures: For load dump protection a bi-directional transient suppressor diode D3 is added. Its fast instantaneous clamping response to high transient over-voltages with high peak pulse power makes it ideally suited to this particular function. The EMI filter consists of an inductor L2 and two capacitors C1 and C5 that form a simple π filter which attenuates the

Automotive standard	Test(s) covered
CISPR-25	Conducted and radiated emissions
ISO 11452-2 & -4	Radiated immunity
ISO 7637-2	Conducted transient immunity
ISO 10605	Electrostatic discharge

Table 2: Automotive test standards.

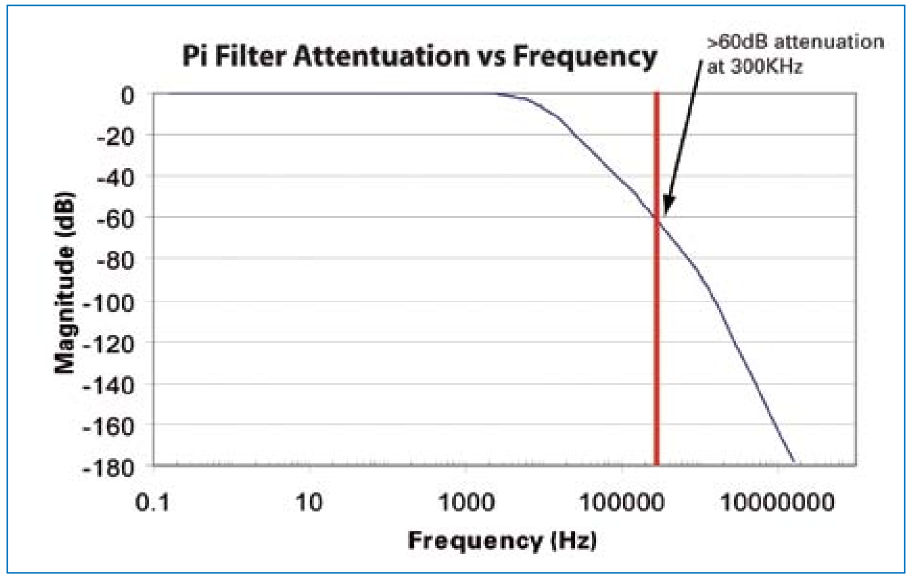

Figure 3: π filter attenuation vs frequency.

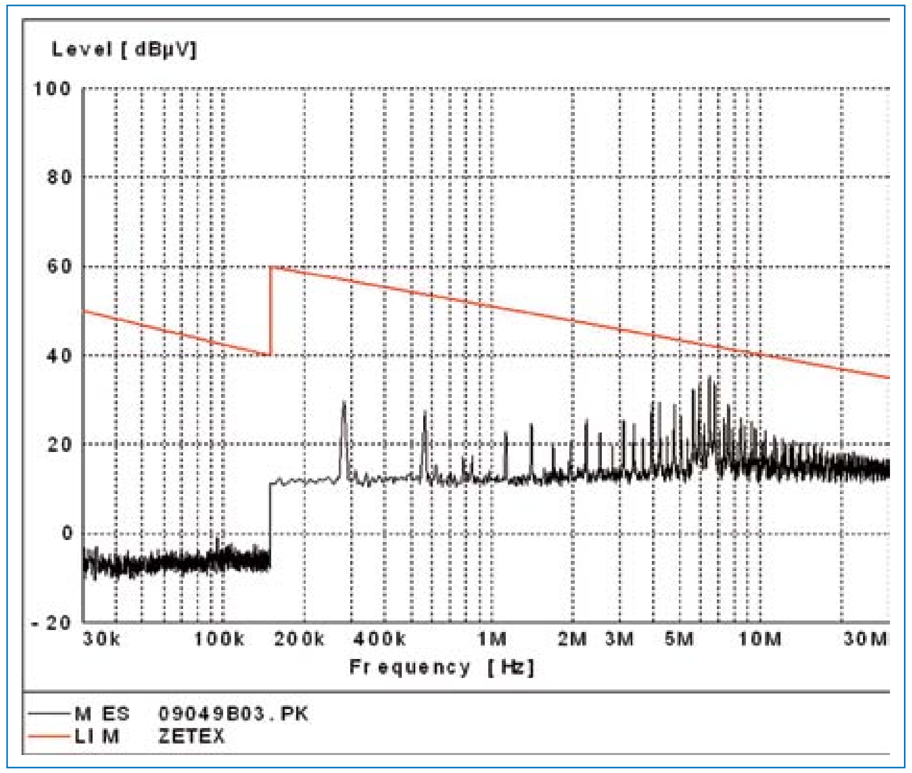

Figure 4: Conducted EMI scan.

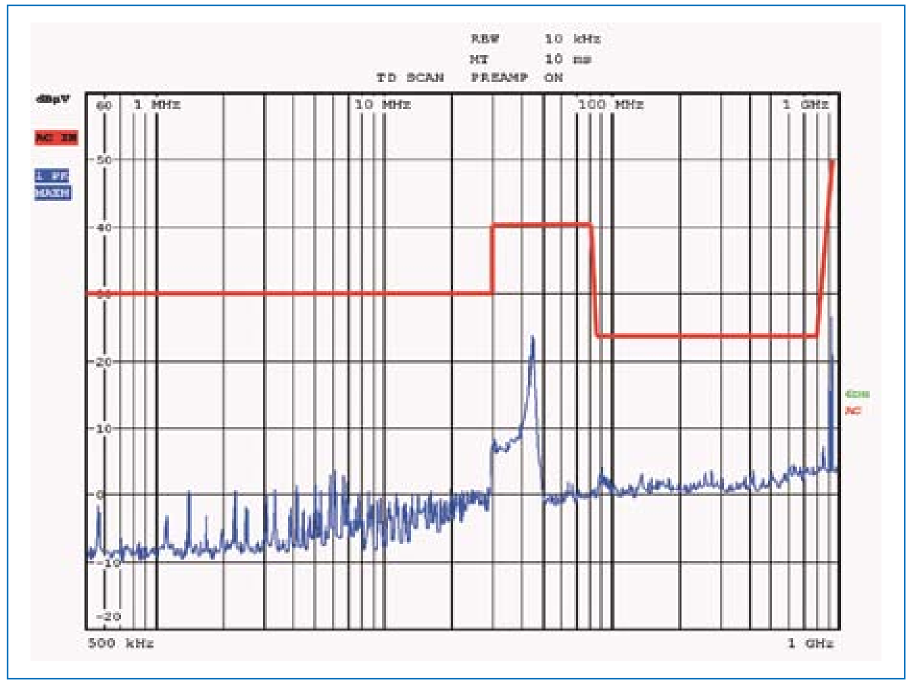

Figure 5: Operating emission using GTEM.

conducted EMI. A capacitor C3 of 10nF is connected from ADJ pin to ground to filter noise pickup which may create flickering during the immunity test. An optional basic RC snubber (R2-C6) could be connected across the diode D1 to control both the spike's transition rate and shape. The capacitor controls the rise time and the resistor the peak voltage. In fact this was not required to meet the EMC test conditions but EMC measures are better to be designed in and removed rather than retrofitted. Cores of both the switching inductor L1 and the filter inductor L2 are shielded, ferrite-based and closed magnetic field type, in order to provide suppression of radiated emissions as well as immunity to external fields.

EMI filter design analysis

The hysteretic converter is a variable frequency topology. EMI filters need to be designed to take into account lowest operating frequency. In order to successfully attenuate the switcher noise a 4th-order low-pass π filter, is formed by C5, L2 and C1. The filter offers more than 60dB attenuation at 300 kHz according to the transfer function analysis. In the circuit, the switching frequency at VIN=12V is about 300 kHz. As such, the filter has been optimized to provide enough attenuation at the fundamental frequency as well as its harmonics in order to meet the conducted EMI requirement only with the simplest π structure.

PCB layout considerations

In designing for EMC, PCB layout plays a critical role in producing an effective solution. For this design the following measures were taken.

- The capacitor C3 connected from ADJ pin to ground is as short as possible.
- The high di/dt loop (LX-D1-VIN-C4) with a fast switching current is made as small as possible. This minimises the differential mode noise related the loop inductance multiplied by the fast transient switching (L•di/dt).
- A simple π filter (C5-L2-C1) is placed as close as possible to the input terminals performing the optimal conducted EMI attenuation.
- The perpendicular configuration of the EMI filter components lowers the capacitive coupling between the inductor and capacitors.
- A V-connection of the filter capacitors C1 and C5 helps prevent self resonance and so avoids degrading the EMI performance.
- Careful component placement avoids the mutual coupling of noise generating nodes to noise sensitive nodes.

Results/graphs for EMI and susceptibility

The EMC test results are shown in Figures 4, 5 and 6 in accordance with the following automotive standards with limit lines identified by the customer.

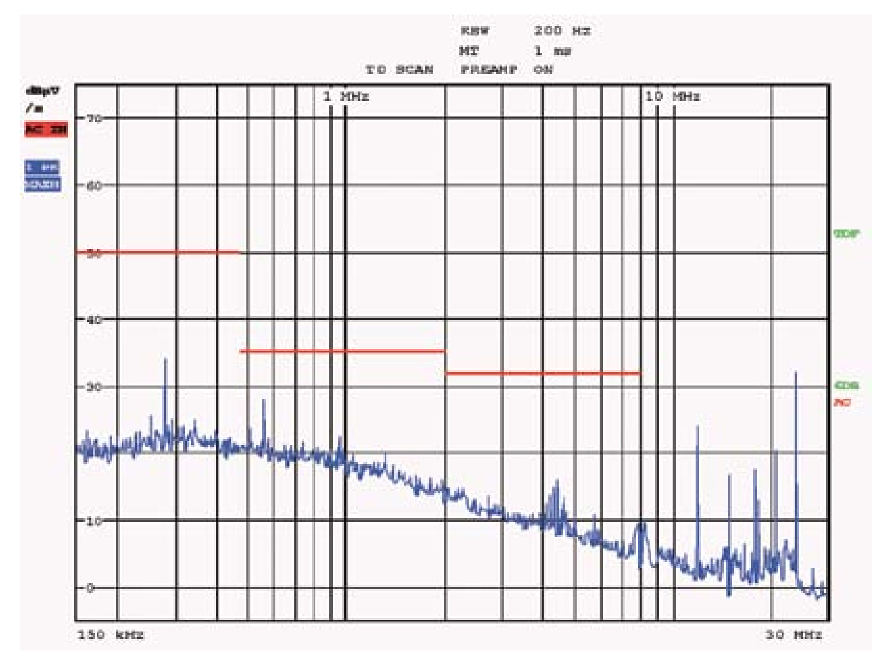

Figure 6: Operating emission with loop antenna in 1m range.

- CISPR-25: Conducted and Radiated Emissions (European and Worldwide Standards)
- ISO11452: Radiated Immunity (North American and Worldwide Standards)
- 95/54/EC: Radiated Emission (European Standards)

It should be noted that the radiated immunity test is correlated by the strip-line measurement inside a GTEM cell while the radiated emission test is correlated by the absorber chamber verification using an active loop antenna at 1m range.

Conclusion

Successful implementation of a switching regulator to drive LEDs can be achieved in the tough automotive environment. There are many EMC specifications that are manufacturer-dependent so circuits must be designed to meet a customer-specific requirement. Defensive measures must be designed to cope with conductive and radiated emissions as well as creating a robust RF immune system. Choice of topology, good circuit design and PCB layout are essential to ensure the lighting solution operates correctly in an automotive application.

www.diodes.com

www.zetex.com

Automotive-Grade 3-Phase MOSFET Pre-Driver IC

The new A4935 from Allegro MicroSystems Europe is an automotive-grade 3-phase MOSFET pre-driver IC targeted at automotive and industrial applications.

This third-generation device includes enhanced performance and operational features, and is ideal for systems that use sinusoidal control of the motor phase currents. This commutation method provides smooth operation, reducing audible noise and minimizing torque ripple at the load.

The A4935 is targeted at the rapid growth in 3-phase brushless DC motor applications in the automotive and industrial sectors. The new device integrates a regulating charge pump which provides full gate drive capability for battery voltages down to 7 V and reduced gate drive for battery voltages as low as 5.5 V.

Also included are performance enhancements of the current sense amplifier, as well as better fault diagnostics and reporting to decode and identify faults. Features such as top-off charge pump and bootstrap charge management make the A4935 much easier to manage in terms of ensuring an adequate bootstrap capacitor charge under varying PWM conditions.

Other features include cross-conduction protection with adjustable dead time and a low-current 'sleep' mode. The A4935KJP-T is supplied in a small-footprint 48L eLQFP small profile thermally efficient exposed-pad package which is lead (Pb) free with 100% matte tin leadframe plating.

www.allegromicro.com

Power Management ICs Qualified for Automotive

DIODES INCORPORATED

Diodes Incorporated has announced the qualification of a series of its popular Zetex power management ICs to the AEC-Q100 automotive quality specification. The newly qualified products include monitors, regulators and references, which meet the requirements of AEC-Q100 Grade 1 for operation in automotive environments at temperatures up to 125ºC. As previously announced, Diodes closed the acquisition of United Kingdom-based Zetex plc on June 9, 2008.

The ZXCT1008 and ZXCT1080 current and voltage output current monitors, the ZTL431 and TLV431 shunt regulators, and the LM4040 precision micropower voltage reference devices support measurement and protection duties in a wide range of reliability-critical subsystems, including window motor control, air conditioning and courtesy lighting.

"Qualifying these very popular devices at such a stringent automotive quality specification provides automobile manufacturers the benefit of more precise power management coupled with significantly increased reliability," said Mark King, Diodes' Senior Vice President of Sales and Marketing. "From a business perspective, this step is a natural progression for our Company. The Zetex range of high efficiency bipolars and MOSFETs has long been qualified to the AEC-Q101 specification for discrete parts. Our AEC-Q100 compliant monitors, regulators and references are a perfect complement, which substantially increases the value proposition we offer to the automotive sector."

www.zetex.com

www.diodes.com

25V DirectFET® Chipset Optimized for High Efficiency

International Rectifier has introduced a 25V synchronous buck converter DirectFET® MOSFET chipset for point-of-load (POL) converter designs. The new 25V chipset combines IR's latest generation HEXFET® MOSFET silicon and benchmark DirectFET packaging technology to deliver a high density, single control and single synchronous MOSFET solution in the footprint of an SO-8, and with slim 0.7 mm profile. The new IRF6710S2, IRF6795M and IRF6797M devices are characterized with very low on-resistance ($R_{DS(on)}$), gate charge (Qg) and gate-to-drain charge (Qgd) to achieve increased efficiency and thermal performance, and enable operation in excess of 25A per phase.

The IRF6710S2 is ideally suited as a control MOSFET due to the device's very low gate resistance of 0.3 Ohms and very low Miller charge (Qgd) of 3.0 nC which significantly reduces switching losses.

The IRF6795M and IRF6797M feature extremely low $R_{DS(on)}$ to significantly reduce conduction losses while the integrated Schottky reduces diode conduction losses and reverse recovery losses making these devices well suited for high current synchronous MOSFET circuits. The IRF6795M and IRF6797M have a common MX footprint to allow easy migration from existing SyncFET devices.

www.irf.com

Maxwell to Supply Ultracapacitors for Emission-Free Electric Buses in Milan

Maxwell Technologies announced that Vossloh Kiepe GmbH, a leading producer of heavy vehicle drive systems, has selected Maxwell's 125-volt BOOSTCAP(R) ultracapacitor modules for braking energy recuperation and torque assist in emission-free electric buses it is producing in collaboration with Van Hool NV for the Milan, Italy, municipal transit system.

The Vossloh-Van Hool buses for Milan are low-floor articulated vehicles equipped with ultracapacitor-based energy storage systems that absorb and store energy from recuperative braking for reuse in powering zero-emission electric motors. The basic drive system can be augmented with energy supplied via overhead lines or a 100-kilowat diesel generator set that is certified in compliance with the Euro-5 emission standard. The city of Milan recently announced that it is taking delivery of the first 15 of a total of 70 vehicles it has ordered from Vossloh Kiepe and Van Hool.

The HTM125 is encased in a rugged, splash-proof, IP 65-compliant, aluminum chassis, weighs less than 60kg and measures 315x425x744mm. Integrated monitoring capabilities and a highly efficient cooling configuration enable it to sustain continuous current of up to 150 amps with minimal temperature increase in high-temperature environments. Up to 12 125-volt modules may be linked in series to deliver a total of as much as 1,500 volts. Maxwell also offers a complete line of standard 15- to 75-volt multi-cell modules.

The HTM125 data sheet is available at Maxwell's website:

http://www.maxwell.com/ultra-capacitors/products/modules/bmod0063-125v.asp

Software Tool for Power Analysis

MELCOSIM 4.0 is the name of the latest software from Mitsubishi Electric, which helps design engineers selecting the best-fitting MITSUBISHI power semiconductor modules for their individual application. The software tool takes into account important issues such as power loss occurring in power modules under specific user application conditions as well as junction temperature rises as a consequence of power loss.

In addition to version 3.0 the new MELCOSIM version 4.0 offers the possibility to calculate the maximum junction temperature – an essential feature for determining the junction temperature at relatively low output inverter frequencies of less then 30 Hz as the temperature swing caused by power losses and thermally equivalent RC elements of the power module is a significant issue in this low-frequency range.

Like the previous versions the new MELCOSIM 4.0 operates with fast algorithms, structured input/output windows and the possibility to generate graphical outputs for further analyses and successive changes of individual application condition parameters within the specification limits. Furthermore, all calculation results can be exported into a text format file.

The algorithms used in MELCOSIM 4.0 are based on typical specified data and numerical approaches for determining steady state as well as dynamical losses. The specified dynamic thermal resistance data of the power modules is used for the calculation of the temperature rise in junction.

MELCOSIM's graphical user interface ensures that the software tool is easy to use. For example, the input-output view is divided into four sections: module type number, specified property of the module, input field for the application conditions and output field for calculation results. MELCOSIM always expects the following nine inputs dubbed "application conditions" in order to be able to calculate power loss and junction temperature: modulation strategy, output current, DC-link voltage, switching frequency, output frequency, on and off gate resistances, power factor, modulation factor or duty and the heat sink temperature measured directly under the chip.

Having entered these data MELCOSIM instantaneously provides information about the average power loss of the IGBT and the free wheeling diode (divided into static and dynamic parts), the total power loss for the power module, case temperature as well as the average and maximum junction temperatures in the transistor and in the free wheeling diode.

The latest version of MELCOSIM is available at www.mitsubishichips.com/Global.

www.mitsubishichips.com

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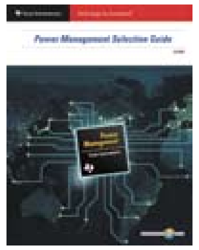
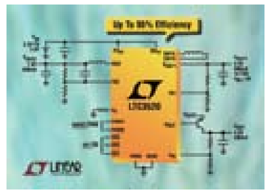
PowerPack Power Systems Design

Texas Instruments



Texas Instruments offers a full line of high-performance products ranging from standard linear ICs to plug-in and integrated power solutions. And, TI makes designing easier with leading-edge support tools such as training, a broad selection of evaluation modules, application notes, data sheets and more. Visit **www.ti.com/analogelab** for complete information on all TI's analog training opportunities. Free samples and small orders (shipped within 24 hours via TI authorized distributors) are available to help accelerate your time-to-market. Download your copy of TI's Power Management Selection Guide for a comprehensive review of TI's complete line of high-performance power products...

Linear Technology



Linear Technology Corporation announces the LT3080, a 1.1A 3-terminal LDO that may be easily paralleled for heat spreading and is adjustable with a single resistor. This new architecture regulator uses a current reference to allow sharing between multiple regulators with a small length of PC trace as ballast, enabling multi-amp linear regulation in all surface-mount systems without heat sinks.

The LT3080 achieves high performance without any compromises. Featuring wide input voltage capability from 1.2V to 40V, it has a low dropout voltage of only 300mV at full load. The output voltage is adjustable, spanning a wide range from 0V to 40V, and the on-chip trimmed reference achieves high accuracy of +-1%. The wide V_{IN} & V_{OUT} capability, tight line and load regulation, high ripple rejection, low external parts count and parallel capability make it ideal for modern multi-rail systems.

www.linear.com

Fairchild Semiconductor

Increase Efficiency in DC-DC Converters with Fairchild's Power33 and Power56 MOSFETs

Fairchild's power MOSFETs in 3.3 x 3.3mm and 5 x 6mm MLP packaging increase efficiency and output power in Point of Load and DC-DC converters. Offering industry-leading Figure of Merit (FOM) and low $R_{DS(ON)}$, these <250V power MOSFETs are instrumental in reducing switching losses.

http://www.fairchildsemi.com/products/mosfets/index.html

Magnetics

Magnetics is pleased to announce the addition of **XF**LUX^{TM}, a distributed air gap 6.5% SiFe material, to our existing powder core line. A true high temperature material, with no thermal aging, **XF**LUX offers lower losses than powder iron cores and superior DC Bias performance.

XFLUX cores are ideal for low and medium frequency chokes where inductance at peak is critical. One of the many challenges facing designers of high power circuits is maintaining inductance in the power choke at maximum load. **XF**LUX is the cost-effective solution to getting enough inductance in a reasonable size package.

Seven toroid sizes (60 permeability) are currently available. Outside diameters range in size from 21mm to 47mm. New sizes and permeabilities will be added in the future.

www.mag-inc.com

Microchip Technology

Microchip Offers Free Field Oriented Control Algorithm for New Low-Cost Motor Control Digital Signal Controllers

Microchip announces 10 new 28- and 44-pin 16-bit Digital Signal Controllers (DSCs) for motor control designs requiring increased memory, performance, or enhanced peripherals, while obtaining cost and size savings by using lower pin-count devices. Additionally, Microchip announced five motor control software solutions for: Power Factor Correction (PFC), sensorless Field Oriented Control (FOC) of a PMSM motor, sensorless FOC of an ACIM motor, sensorless control of a BLDC motor using Back EMF filtering and sensorless BLDC control with Back-EMF Filtering Using a Majority Function.

www.microchip.com/DSCMOTOR

250A Power MOSFET for Higher Motor Drive Efficiency in Traction Applications

STMicroelectronics has introduced a 250A surface-mount power MOSFET with the lowest on-resistance in the market, to minimize energy conversion losses and enable higher performance.

The new device, the STV250N55F3, is the first power MOSFET to combine ST's PowerSO-10™ package with ribbon bonding to achieve ultra-low die-free package resistance. Implemented in ST's high-density STripFET III™ fabrication process, the device offers a typical on-resistance of 1.5 milliohms. Further benefits of STripFET III include low switching losses and rugged avalanche characteristics. The nine-lead source connection also reduces on-resistance, in addition to aiding heat dissipation.

Overall, the package is rated for 300W dissipation at 25°C.

The high current rating allows engineers to design-out multiple parallel MOSFETs to save board space and BOM costs. Standard driving thresholds also simplify driver-circuit design. The STV250N55F3 is rated for applications up to 55V.

The ability to operate at temperatures up to 175°C makes the STV250N55F3 suitable for use in high-current electric-traction applications such as forklift trucks, golf carts and pallet trucks, as well as lawnmowers, wheelchairs, and electric bikes. Reliability and robustness are assured through 100% avalanche testing both at wafer level as well as on finished products. In the future, the device will be eligible for automotive-grade applications.

Within the same family, ST also has the 55V STV200N55F3, which implements a four-lead source connection and is rated for 200A continuous drain current.

www.st.com

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Power Systems Design Europe
Green Page

PSDE Green Power
ENERGY EFFICIENCY

Let there be Light…and Wind

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

Automotive manufacturer, General Motors, will install solar panels on the roof of its factory in Zaragoza, Spain to create the world's largest rooftop solar power source. The electricity produced by this 10 megawatt installation will be used by the plant with surplus sold to the local power grid. The company may install similar projects at GM Europe's eleven other assembly and eight component plants, depending on the results here. Powered by approx. 85,000 solar panels covering about 183,000 m^2 of the roof, the plant will assemble over 480,000 vehicles a year for the European market.

Ericsson predicts that more than 90% of new cellular subscriber growth will now be in emerging markets. One of the most challenging issues operators face is how to get power to the site. A typical site in rural areas consumes as much as 20,000 liters of diesel fuel per year and as prices soar, energy represents a major part of operational cost. Instead of using the normal configuration of two diesel generators working alternately, Ericsson now replaces one of these generators with a battery bank using batteries that can handle the heavy charge and discharge rates. The company continues to exploit solar power with more than 200 solar-sites in operation in northern Africa, Mexico and Indonesia.

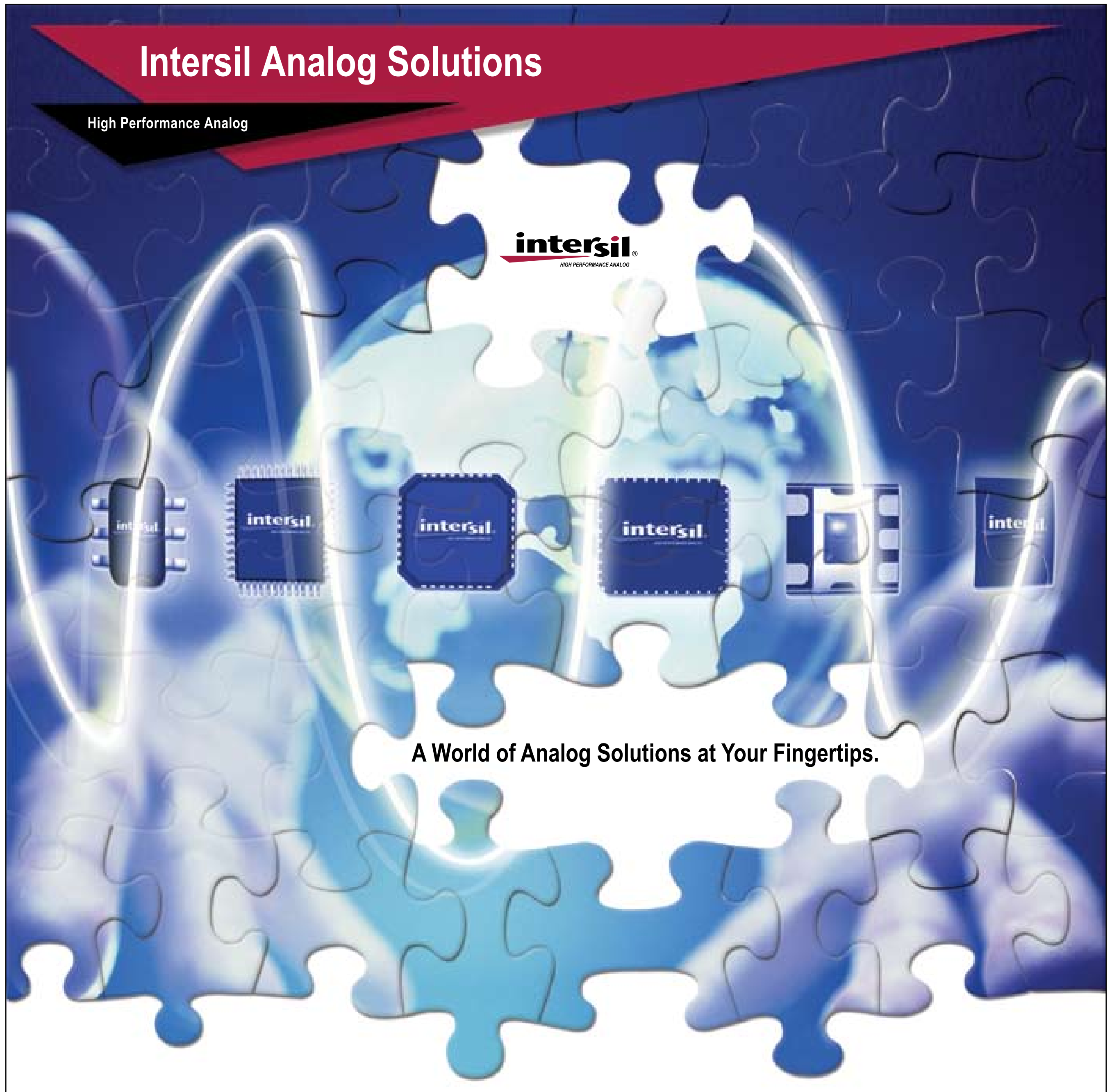
Inventux Technologies AG, Berlin-based thin-film solar module manufacturer, has contracted Linde Nippon Sanso (LNS) to provide the full range of high purity gases for the manufacturing process of their new Berlin plant. The long term contract comprises turn-key gas systems engineering plus exclusive supply of all gases to drive the solar cell production line. Gas was turned on at the end of June, with the first thin-film modules shipping from the 33 MWp factory soon after. Inventux is one of the earliest users of the micromorph tandem technology, a process that has potentially high efficiency and low production costs. Instead of a single light trapping layer, tandem uses two different layers in the cell; one working with the blue part of the light spectrum and one with red, to boost efficiency by more than 40%.

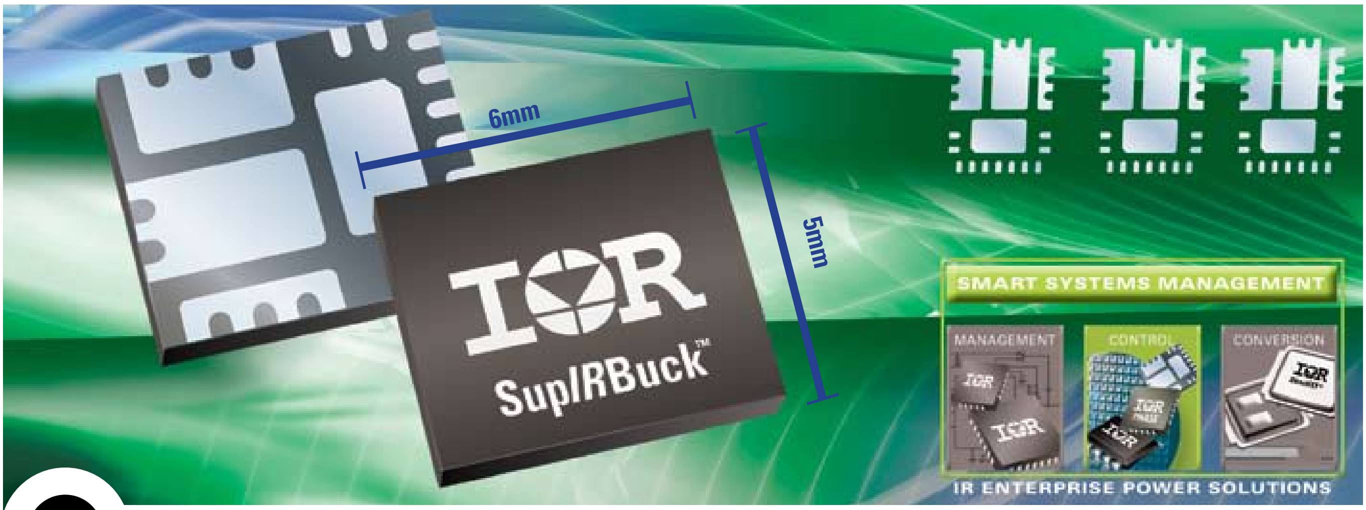
Even though wind is free, the cost of harnessing its power certainly is not. Each wind turbine can cost around a million Euros and utilities will need to invest heavily to build transmission lines to transport this 'free' power from the often remote sites. Wind is not going to solve all our generation problems and it will be interesting to watch how the regions within Europe deal with this resource.

Denmark generates 20% of its electricity from wind, and on a really stormy day, the power produced can exceed the country's needs. Today, over 80% of Danish windmills are owned by co-operatives or farmers. Substantial tax credits got this industry moving, but this government's support has paid off handsomely.

I wonder if other 'committed' regions will follow this successful model?

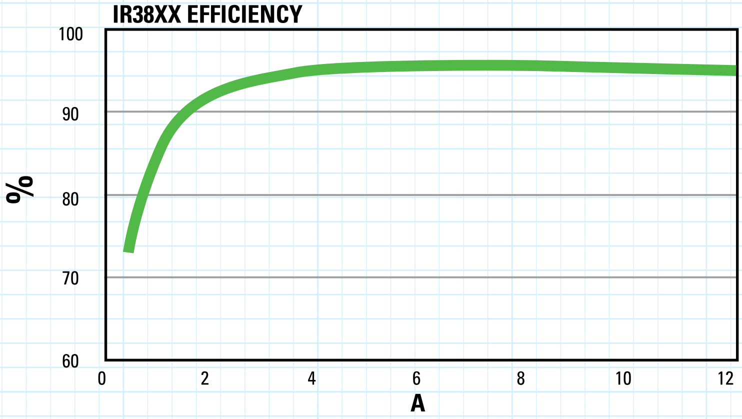
www.powersystemsdesign.com/greenpage.htm





Sup*IR*Buck™ Integrated Regulators: Simply Smaller, Cooler

Save Energy, Accelerate POL Design, Shrink Footprint 70%



The SupIRBuck™ family of versatile point-of-load (POL) voltage regulators shrink silicon footprint 70% compared to discrete solutions and offer up to 10% higher full-load efficiency than monolithic power ICs.

Features

- 600kHz switching frequency
- 4A/7A/12A output options
- Programmable soft start with enable
- Programmable over-current protection
- 0.6V reference voltage with 1.5% accuracy
- 2.5V to 21V conversion Input
- Pre-Bias protection
- Integrates rugged control and sync FETs with control IC in one simple 5mm x 6mm power QFN package
- Optional 300kHz, DDR memory tracking, programmable PGOOD

Benefits

- Ease of implementation
- Enables single input voltage rail
- Wide input voltage range
- Common footprint for 4A, 7A and 12A power regulators
- Fewer discrete components

Part Number	V_{IN} Max/Min	V_{OUT} Max/Min	Max Current	F_{SW}	Package	Features
IR3812MPBF	21 / 2.5	12 / 0.6	4A	600KHz	5mm x 6mm QFN	OCP; OTP; Tracking
IR3822MPBF	21 / 2.5	12 / 0.6	4A	600KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3822AMPBF	21 / 2.5	12 / 0.6	6A	300KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3811MPBF	21 / 2.5	12 / 0.6	7A	600KHz	5mm x 6mm QFN	OCP; OTP; Tracking
IR3821MPBF	21 / 2.5	12 / 0.6	7A	600KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3821AMPBF	21 / 2.5	12 / 0.6	9A	300KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3810MPBF	21 / 2.5	12 / 0.6	12A	600KHz	5mm x 6mm QFN	OCP; OTP; Tracking
IR3820MPBF	21 / 2.5	12 / 0.6	12A	600KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3820AMPBF	21 / 2.5	12 / 0.6	14A	300KHz	5mm x 6mm QFN	OCP; OTP; PGood

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or visit us at www.irf.com/dcdc

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THE POWER MANAGEMENT LEADER

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