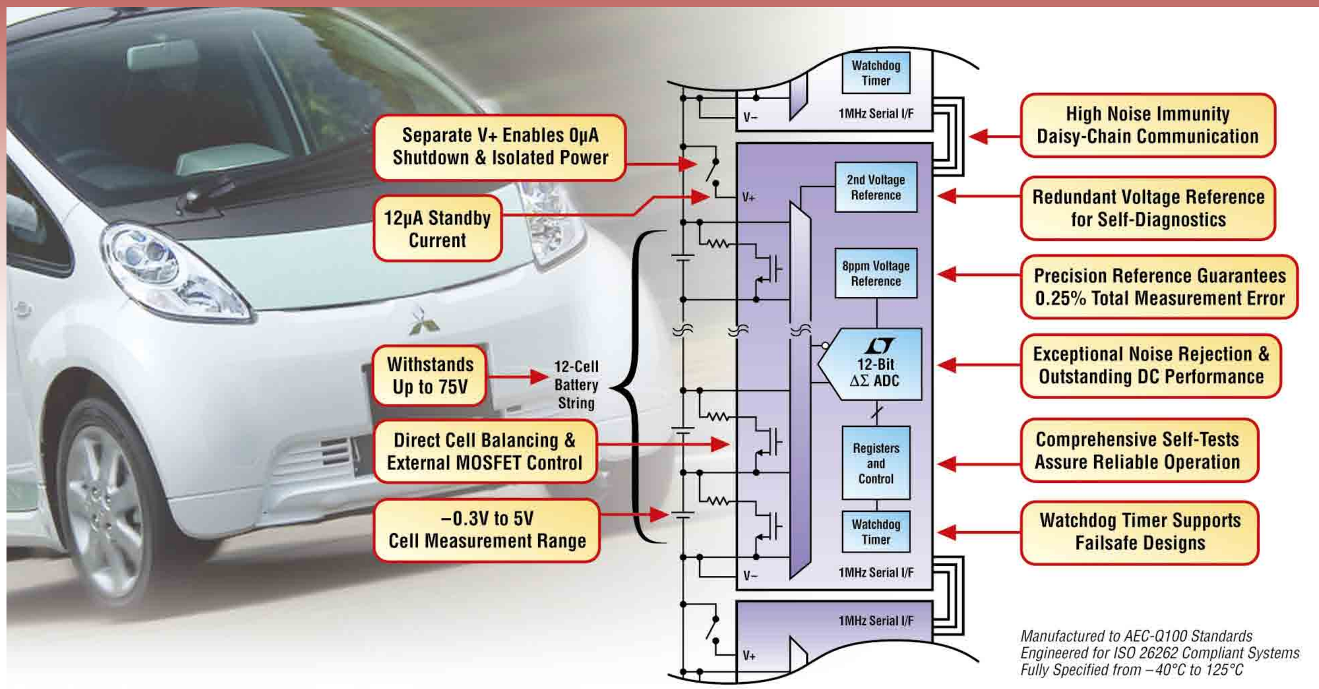
July/August 2011

PSD NORTH AMERICA

Power Systems Design: Empowering Global Innovation

SPECIAL REPORT: AUTOMOTIVE ELECTRONICS (PG25)

Road Proven Battery Stack Monitor



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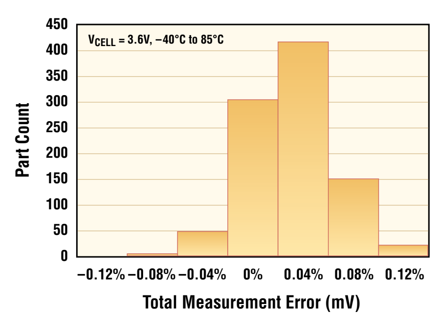

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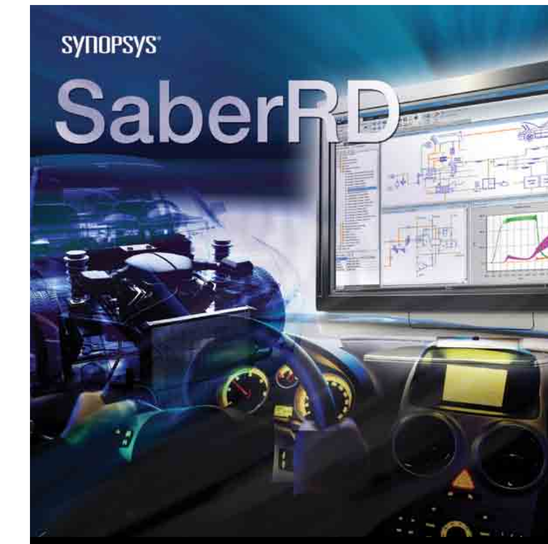

COVER STORY
Multi-Domain Simulation (pg 15)

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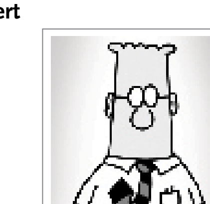

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AUTOMOTIVE POWERS-UP

Welcome to this issue of PSD for N. America, where we are featuring automotive electronics. With the rise in gas prices and the heightened ecological sensitivity in the public domain driven by the mass media, HEVs and EVs are fast becoming a commercial viability. This is great news for the power industry and great for our children. Also, with the political uncertainty and volatility of oil production outside of the US, many are concluding that electric power is the way forward for our autos. Further rises in gas prices could help accelerate the adoption of EVs and HEVs.

It's reported that New York City has bought 50 Chevrolet Volts that will go to the NYPD, as well as to the fire and sanitation departments. The 50 Volts were among 70 EVs in NYC's latest round of buying under green Mayor Michael Bloomberg, a big fan of electrics. Also bought were 10 electric Ford Transit Connect vans and 10 electric Navistar eStar utility trucks.

There are of course, challenges. Many of them you can read in this issue of PSD, aimed at giving you solutions. The visionaries are talking about infrastructure for widespread charging while power engineers are working out how to design the new vehicles with all its drive, control and power issues presented by the battery management, lighting and electronic control for all the electronics. Quite a challenge, but it will get there in the end, power engineers will fix it.

But what a wonderful project for any power engineer; working on an auto that is clean, in terms of emissions, with the new LED lighting systems and a new control system. This is a project with a wonderful legacy for mankind. I just hope they can build them cheap enough and importantly, with improved range.

Quad-core PC microprocessors now are set to conquer the notebook segment with about half of the mobile computers shipped in 2015 expected to employ these advanced chips according to IHS. The recently introduced graphics-enabled microprocessor places the graphics processor on the processor die. These microprocessors will be found in excess of 90% of notebooks sold in 2015 delivering improved power management of the on-chip graphics unit, although in terms of graphics performance, are not able to outperform discrete graphics cards. Again, power is the key.

GM and wireless charging product maker Powermat this year announced a $5 million investment from the new GM Ventures subsidiary, which could put Powermat inductive charging for devices such as smartphones in many Chevrolet, Buick, GMC and Cadillac cars as soon as mid-2012.

I do hope you enjoy the magazine, please keep the feedback coming, and do check out Dilbert at the back of the magazine.

All the best

Cliff
Editorial Director & Editor-in-Chief
Power Systems Design
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DESIGN TOOLS FOR EV/HEV

Simulation and test expert firm, dSPACE, is in the business of developing tools for the design of electronic control units (ECUs) and mechatronic systems.

Testing Virtual ECUs
The virtual ECU, or V-ECU, comprises components from the application and the basic software, and provides functionalities comparable to those of a real ECU. Unlike a soft ECU, which uses only a simplified Simulink®/Stateflow® model, a V-ECU usually has the same software components that will run on the finished ECU. There is no strict dividing line between a soft ECU and a V-ECU, but a V-ECU generally represents the real ECU more realistically.

Customers can use virtual ECU models for testing and validation throughout the ECU development process. The term 'virtual ECU testing' covers all simulation scenarios in which virtual ECUs are used.

Today's ECU software comprises numerous software components (SWCs) with intensive interactions. In the large ECU networks frequently installed in current vehicles, the number of SWCs can easily reach the thousands, and because the task of developing ECU components is usually shared by several departments or even different companies, not only the SWCs themselves have to be tested and validated, but also the interactions between them.

Early Testing Without Hardware
Previously, the testing and validation of ECU software could not even begin until the prototype ECUs were available. With virtual ECU testing (VET), the SWCs, which are already available, are combined to create a virtual ECU model. This is then tested and validated in offline simulation on a standard PC. This lets developers investigate real-world issues such as task scheduling, the behavior of the basic software, and communication behavior on a virtual CAN bus

Simulating EV/ HEV Drives
The dSPACE ASM Electric Components simulation package is now supported by JMAG, a Finite Element Analysis (FEA) tool for electromechanical design developed by the JSOL Corporation. Automotive Simulation Models (ASM) electric components are designed for the real-time simulation of vehicle electrical systems or hybrid drivetrains.

With JMAG, users can now define the key characteristics of electric motors and export them to parameterize the generic ASM electric motor models. After virtual electric motors are defined, they can be executed on a hardware-in-the-loop (HIL) simulator in real time. The tool coupling gives users convenient graphical designs of complex systems and real-time performance. The easy workflow and high precision speed up developments and ensure the highest quality.

www.dspace.com

GOOD NEWS TIME

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

I had the pleasure to meet with Thomas Neyer, Vice President of High Voltage Semiconductor Technology at Fairchild Semiconductor, to discuss the setup of the company's new High Voltage R&D Centre in Munich.

Prior to working at Fairchild, Thomas served at Grace Semiconductor in Shanghai as EVP and Head of R&D and Fab Operation with the Vision to build the first Foundry for differentiated Technologies in Asia. Thomas holds a PhD in Physics from the Vienna University of Technology.

This was an enjoyable meeting for me personally with the announcement of Fairchild's new High Voltage R&D Centre, which will develop innovative products for the automotive and industrial markets. Thomas is now evaluating the availability of suitable premises to house the company's exciting new venture.

Thomas explained to me, that with the focus on Electric and Hybrid Electric Vehicles to use clean energy with low emissions, Fairchild is well placed to exploit this lucrative market. At the moment Japanese suppliers have over 50% of the HEV market share, but by 2016 strategy analysts predict that the EV market will be more uniformly spread. The opportunity for Fairchild is immense. Hence the applaudable investment in this R&D centre.

The scope of the new centre will include:

- Device and process simulation
- Design and layout
- Characterization and testing lab
- Process integration, device architecture,
- New materials and module development.

For the initial phase, Fairchild is currently building the team for the start-up of this inspirational and expanding centre in Munich including fundamental and scientific research which has a high strategic impact and priority within this successful global company.

The mission of this team will be to advance Fairchild's power technology and product portfolio for High Voltage applications for Industrial, Automotive and Consumer markets to take over the leading-edge position in the industry.

The newly formed R&D centre will liaise closely with existing global Fairchild Technologists in US, Sweden and Korea, as well as to work in partnership with Research institutes and hand selected partnership programs with competitors.
The start-up team of the new centre will address next generation IGBT and SuperJunction device concepts utilizing state-of-the-art process and device simulation techniques, establishing new processing modules in Fairchild's advanced 6/8" manufacturing plants and focusing on improved device ruggedness and key figures of merit. Hence, wafer level device characterization, modelling expertise and advanced high power packaging expertise will be established accordingly.

For the mid-term horizon, more efforts are being assigned to pursue development of wide bandgap switches and rectifiers, which are predicted to take over significant market share for high power and high efficiency types of application in the second half of this decade. Fairchild is certainly in this for the long-haul. Notably, in order to seize a head start in this, Fairchild has recently acquired TranSiC in Stockholm, which owns significant IP and expertise in SiC technology. Moreover, Fairchild is assessing several options to make a bold move into GaN technology where the R&D centre in Munich will be instrumental to mature and commercialize new product lines.

Certainly this is good news for Fairchild, and great news for our industry.

www.fairchildsemi.com

AUTOMOTIVE INDUSTRY WILD WEST: SILICON SLINGERS AND ELECTRIC SALOONS

By Alastair Hayfield, Research Director, Automotive and Transport, IMS Research

It is rare to get a glimpse into the past, but researching the electric vehicle industry at the moment gives a fascinating insight into the twilight years of the 19th century when Diesel, Benz, and others were leaving their indelible mark on a coming century of automotive transport.

Electric vehicles are nothing new; but like those early years, now is a 'wild' time of innovation, exploration and just a little uncertainty. There are different opinions on implementation – should we go full battery or hybrid? What type of hybrid? There are different views on charging – AC? DC? Fast or slow? And everybody knows that their design will be the next Model T.

So what can the past tell us about the future? Opportunity breeds innovation and vice-versa. There is clear and growing demand for electric vehicles regardless of type (a forecast 15% of light vehicles produced in 2021 will be 'electric', versus 1.5% in 2010 according to IMS Research), prompting vehicle OEMs, tier1s, and other suppliers in the supply chain to join the electric bandwagon.

Compared with 'regular' internal combustion engine vehicles, hybrid and electric vehicles require far higher semiconductor content, most notably for the battery management system and the inverter used to drive the main electric motor(s). IMS Research estimates that the semiconductor content per electric vehicle drivetrain will be over $600 in 2021.

By 2021, IMS Research forecasts that the semiconductor opportunity in electric vehicle drivetrains will approach US$10bn. Much of this growth is being fuelled by power discretes, the core components at the heart of the electric vehicle inverter and AC/DC power supply unit. In fact, total sales of power discretes and modules is forecast to top US$8bn in 2021.

The battery management system is another area where semiconductor vendors are 'eyeing' their prospects. Li-ion battery technology looks set to be the de facto 'standard' for storing power on board electric vehicles. Less stable than NiMH, Li-ion batteries require significantly more battery management (temperature monitoring, cell balancing, etc.) which increases the semiconductor content. IMS Research estimates that the semiconductor content of a LI-ion battery is currently five times that of an equivalent NiMH battery, with the majority of the difference coming from the number of ASSPs needed for cell pack voltage monitoring.

Automotive OEMs have considerable intellectual property tied up in the design of their internal combustion engines. The same is true for hybrid and electric vehicles on the market at the moment, with the theory being that electric motor control is one way of keeping expertise in-house. But is this really the ideal way of getting the most out of an electric vehicle?

Much of the expertise needed to control high speed electric motors can be found in the industrial automation or motor industry. Players in these markets are setting their sights on the electric vehicle market, particularly with 'off-the-shelf' inverter modules. Not only do these 'modules' play to their strengths, but they give vehicle OEMs the opportunity to reduce R&D costs by outsourcing motor control design.

The automotive OEMs have a big decision to make: do they go it alone on motor control design to retain the "engine IP", or do they work with existing experts to take advantage of their experience?

www.imsresearch.com

POWER SUPPLY DEVELOPMENT DIARY PART XIV

By Dr. Ray Ridley

This article continues the series in which Dr. Ridley documents the processes involved in taking a power supply from the initial design to the full-power prototype. The second layout of the PC board incorporates significant changes in the power stage, changing the number of outputs from three to five. Some of the issues involved in the coupled-inductor magnetics design are discussed.

Three Output Coupled-Inductor Design

The original specification for the power supply design was as follows:

1. Output 1 – 35 VDC @ 10A isolated
2. Output 2 – 35 VDC @ 10 A isolated
3. Output 3 – 15 VDC Bias power and regulated output, primary referenced
4. Maximum power 350 W (only one output fully loaded at a time, application is for audio.)
5. Input – 180 – 265 AC
6. Power Topology: Two-switch forward

Figure 1 shows the schematic of the three-output forward converter. A single core inductor is used with three windings, one for each of the outputs. This coupled-inductor approach provides the best cross-regulation between each of the outputs. There are two major advantages of coupled inductors – firstly, all of the outputs are tied together through the transformer action of the inductor, preventing them from having individual resonant frequencies. Secondly, regardless of individual loading on each of the outputs, the coupled inductor forces all of the outputs

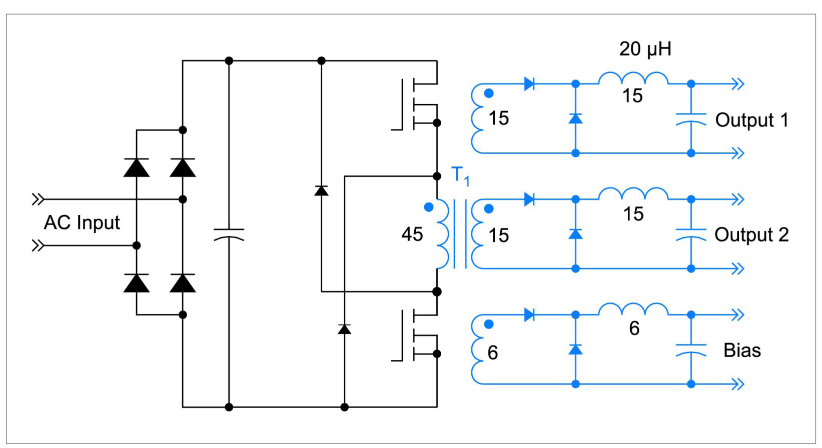

Figure 1: Forward Converter with Three Coupled-Inductor Outputs

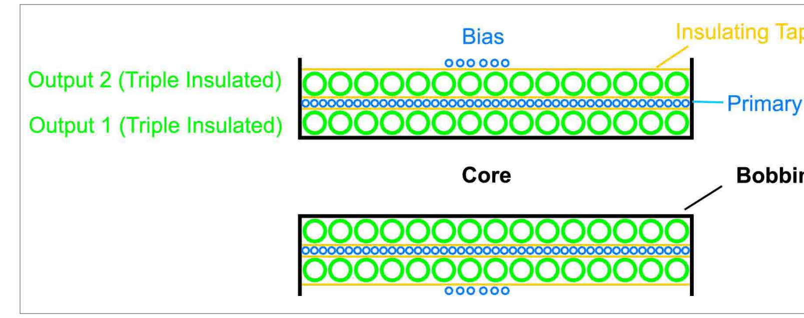

Figure 2: Three-Output Transformer Winding Layout

to be in either continuous or discontinuous mode concurrently, greatly improving the regulation.

As shown in an earlier part of this series, excellent regulation was achieved with a wide variation of output loading.

Figure 2 shows the winding layout for the three-output transformer. The first layer of winding was the first secondary output, consisting of 15 turns wound with triple-insulated kapton wire. This winding used a single strand of wire, with a gauge selected to exactly fill one layer of the bobbin. One layer of magnetics tape was added on top of this secondary to provide a smooth winding surface for the subsequent windings.

The next layer of winding is a single layer primary with 45 turns of magnet wire, followed by a layer of tape. The third layer is the other high-power secondary, followed by 6 turns on the final layer for the bias supply and regulation winding. For coupled designs, the lowest power winding is placed on the outside

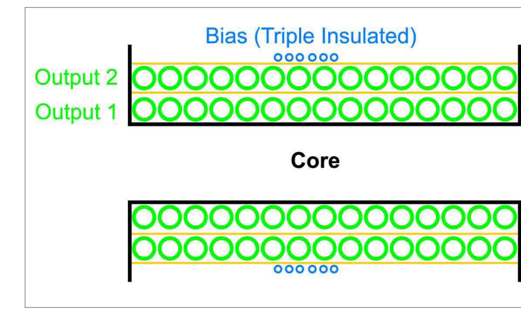

Figure 3: Three-Output Coupled-Inductor Winding Layout

of the winding sequence for best cross-regulation.

Figure 3 shows the winding layout of the coupled inductor. Notice from the schematic of Figure 1 that the turns ratios of the inductor and transformer are critical, and the ratio between the different secondaries must match exactly. Hence the transformer has a ratio of 15:15:6 for the secondaries, and this exactly matches the turns count for the inductor. Apart from this caution, the design of a coupled inductor is not particularly difficult. The simplest approach is to design the inductor as though it were a single-output design rated at the power of the sum of the three outputs. This sets the required number of turns for the inductor value required with the selected core area.

The layout of the inductor in this case is the same as the transformer, starting with each of the high power secondaries, and finishing with the bias winding. Notice that the bias winding, which is primary referenced, is the one with the triple-insulated kapton wire. This reduces cost of materials and processing time during the inductor construction.

Five-Output Coupled-Inductor Design

The original plan for this project was to provide two main power outputs, and one regulation winding. A second power supply was to be used to provide the exact same outputs to a second load amplifier of a stereo pair.

However, during system testing, it became clear that the final load was less than expected, and that all four outputs could possibly be provided with a single power stage. A decision was made during the second board layout to incorporate this change into the design, providing five outputs from a single forward converter. The schematic of the five-output converter is shown in Figure 4.

This is a significant change

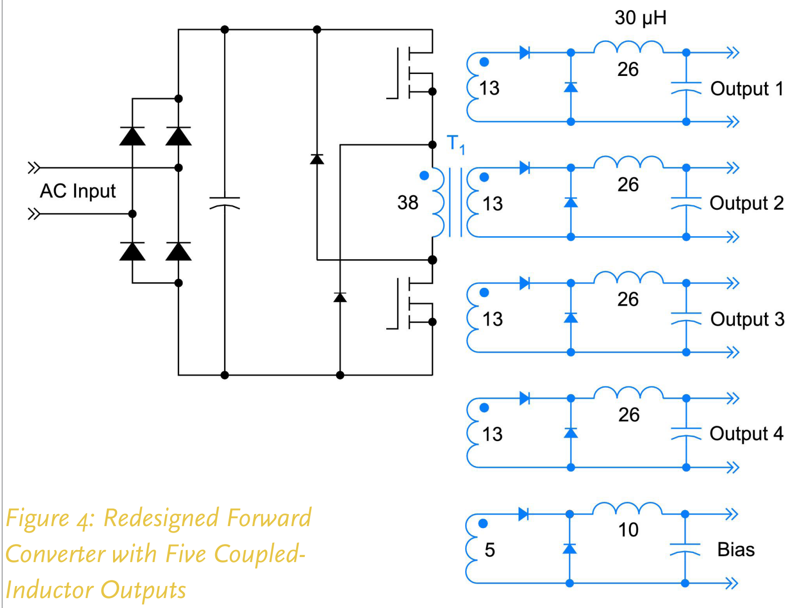

Figure 4: Redesigned Forward Converter with Five Coupled-Inductor Outputs

to the project, but one which provides substantial savings in parts, board area, and cost. The risk is in whether the tight cross-regulation is lost with more outputs. The new design also presents something of a technical challenge during the board layout. One of the significant complications of coupled-inductor designs is managing the multiple connections of the transformer, the inductor, and the rectifier diodes on the printed circuit board.

The extra outputs also present significant changes to the transformer and inductor designs. There are now a total of six windings in the transformer, and changes must be made to accommodate the extra complexity. Figure 5 shows the winding layout of the transformer. The first two secondaries are wound bifilar with each other to exactly fill the layer with 13 turns on each secondary of magnet wire.

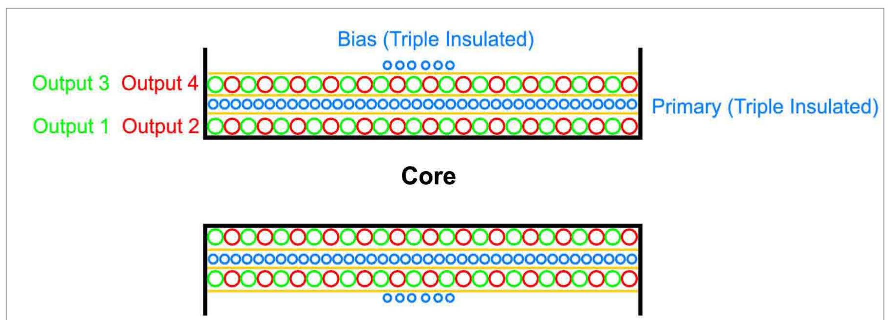

Figure 5: Five-Output Transformer Winding Layout

The turns count was reduced because the primary layer could no longer accommodate the same 45 turns as before in the bobbin. With more secondaries, it made better manufacturing sense to use triple-insulated wire for the primary rather than the secondaries. Only 38 turns could fit in the layer neatly. This reduced turns count raises the core excitation, and the switching frequency must also be raised slightly to 250 kHz from 200 kHz in order to avoid saturation of the transformer.

After the primary is wound, the remaining two secondaries are placed on top of this, wound bifilar with each other. Five turns of the bias winding complete the transformer design.

The secondary turns ratio of the transformer is now 13:13:5, and this ratio must be maintained exactly in the inductor. For the previous inductor design, 15 turns were used in the inductor main outputs, but this pushed the design hard in terms of flux level, and only 20 µH inductance could be used, resulting in significant output ripple.

With the reduced power requirements observed in the system testing, a decision was made to raise the turns count on the main output to 26. This allowed a larger inductance of 30 µH with a reduced core flux

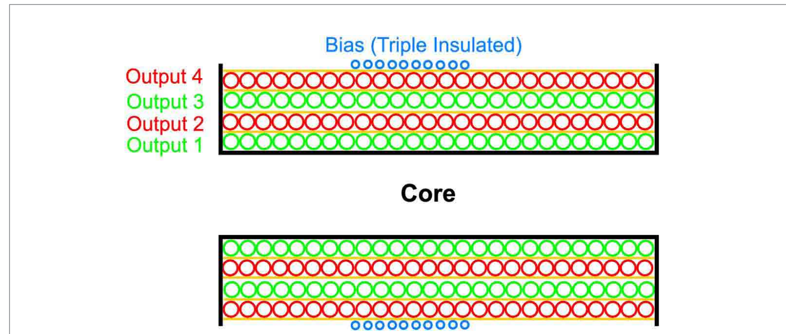

Figure 6: Five-Output Coupled-Inductor Winding Layout

level. The value of 26 was chosen since it allows us to exactly the match the transformer turns ratio when 10 turns are placed on the bias winding of the inductor. Normally for a forward converter inductor, the value of inductance and the number of turns are determined by the current level and core area. In the case of the coupled inductor design, however, maintaining the proper turns ratio is paramount, and the number of turns is set by this requirement. This allows the value of inductance to be increased as a consequence.

It must be remembered that in magnetics design, we have many degrees of freedom, and there are no hard rules determining the value of an output inductor. It is important not to overconstrain thinking, a common error of many design books on magnetics. For example, many texts will fix the value of inductance to give a specified ripple current, but this removes freedom for the designer to choose a value that, in reality, can be varied over a significant range without detriment to the overall performance.

The layout of the new inductor is shown in Figure 6. Each winding occupies a single layer of the inductor, with the wire gauge choses to exactly fill the layer neatly. The final layer is the 10 turns of bias winding, using triple insulated wire.

Summary

The turn of a PC board is usually a major project milestone. It presents the opportunity to clean up previous errors in a board, improve manufacturability, and move a step further towards a final product.

However, in many projects, the PC board iteration is often seen as an opportunity to revisit project goals, and make major changes to a design project and its specifications. In this particular project, a large number of changes have been made, and the risk of incorporating these changes has to be balanced against the potential gains in the final product. The risk here is not too great since there is always the option of reverting back to the previous design of just three outputs if the regulation achieved during testing is insufficient.

It must be stated, however, that substantial changes to components, especially the magnetics, will result in the need to reiterate much of the testing of the power supply, and the time to do this must not be underestimated. The changed turns of the transformer and inductor will affect the cross-regulation, EMI, ringing, snubbers, current protection, and semiconductor stresses.

If the second iteration had been undertaken with none of these changes, and the design remained unchanged with three outputs, there is a reasonable expectation that this would be the final PC layout before production. However, the substantial changes make it likely that a third layout pass will be needed before finishing the design.

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MULTI-DOMAIN SIMULATION

Automotive power electronics components and systems

By Thorsten Gerke & Kurt Mueller

Electrification is driving the need for comprehensive multi-domain system simulation in hybrid-electric and electric vehicles.

A vehicle's power electronic components, coupled with the overall power management and control system, introduces a new set of challenges for electrical system design. These power electronic components include: energy storage devices (such as batteries, ultracapacitors), DC/DC converters, inverters, and drives.

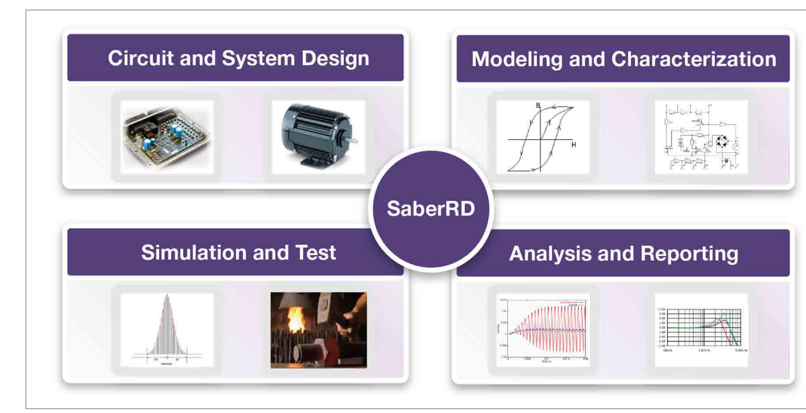

Figure 1: Structure of the SaberRD environment

SaberRD, the latest addition to the Synopsys® automotive product portfolio, is designed for modeling and simulating power electronics with a focus on addressing the challenges of integrated power system design and validation.

The combination of electrical drive systems to traditional low voltage power networks takes the design challenge of vehicle level efficiency to new dimensions. Weight, aerodynamics and engine efficiency have always been a significant consumer of vehicle power. In today's complex vehicle designs, the electrothermal and electromagnetic behavior of DC/DC converters, electric motors, and drives are a significant piece of overall vehicle power. Consumer demands for greater fuel efficiency, reduced carbon footprint along with traditional vehicle performance require new and creative trade-offs between important system characteristics that can only be done at an integrated, multi-domain level.

During a panel discussion at Convergence 2010 in Detroit, Michigan, Senior Chief Engineer from Honda, Yoshio Suzuki, emphasized that carmakers need more support from software providers to help them model and simulate complete systems in an electronics context. SaberRD was developed specifically to target this need: an intuitive tool for power electronics design, validation and system integration built upon 25 years of experience and success in the power electronics industry.

The complexity of modeling and simulating physical systems can be daunting, especially for someone coming from a less power-electronics focused point of view. As a result, tool developers are faced with a delicate balancing act – making the product simple and intuitive to use so that even novices can quickly and effectively simulate, but capable enough to deliver accurate simulation results. To guide users through a simulation-based development project, SaberRD uses a modern integrated development environment (IDE) to step users from initial design creation through to the final analysis and interpretation of simulation results.

The environment includes four primary modules (see Figure 1):

- Circuit and system design for defining the system topology as schematics of interconnected multi-domain blocks
- Modeling and characterization for fast, accurate development of simulation models including power semiconductor devices (IGBTs, MOSFETs, diodes), electrical machines, control blocks, and a variety of additional effects to account for thermal, magnetic, and other behaviors of interest
- Simulation and test procedures for intuitively creating test benches, defining test scenarios and analyzing worst-case scenarios
- Analysis and reporting with logging of measurements and the automated evaluation of system robustness and quality including thermal, electrical and magnetic losses, efficiency metrics, and statistical distributions

Intuitive and Flexible Modeling

The key to capturing integrated physical behavior of a system is to have accurate and appropriate simulation models available. In order to accurately quantify the efficiency of an electric drive system, it is best to model the system in a single simulation environment. This environment needs to incorporate important loss mechanisms such as magnetic effects (saturation, thermal dependencies), electrical effects (electro-thermal coupled transistor behavior), mechanical loading, along with control algorithms. In automotive power electronics, self-heating behavior and statistical production variation can give rise to unpredictable complex system interactions. Inclusion of these physical domains allows for optimization at the component, sub-system, system and control software levels to meet overall vehicle design criteria.

Modeling these behaviors is difficult - how does one go from physical devices to models with enough detail to accurately describe system behavior? Primary challenges include access to proprietary data about particular components or subsystems, inclusion of enough detail for system relevant quantities (e.g. thermal effects on electrical signals) without overly complicated formulas (e.g. co-dependent equations based on physics first principles), and methods for validating that the model is accurate. SaberRD addresses these modeling needs with an extensive library of over 30,000 physical models in all domains mentioned as well as providing graphical tools for creating or characterizing models beyond those available in the library. These tools include the ability to bring in datasheet characteristics or measurement data and use optimization algorithms to match model performance to the desired component behavior, all without requiring a user to have knowledge of modeling methods or programming languages. For those who need additional flexibility and capability, SaberRD supports open standard Hardware Description Languages (HDLs), including VHDL-AMS and OpenMAST.

Another important source of system models is finite element solvers, computational fluid dynamics solvers and electromagnetic field solvers. Generation of behavioral models for power semiconductor devices (IGBTs, MOSFETs, and diodes) from device simulators (such as Synopsys TCAD tools) allows for early and accurate loss calculations for Hybrid and Electric Vehicle DC/DC converters and motor drive inverters.

Extraction of S-element data for signal integrity analyses from electromagnetic field solvers such as those from CST AG permits physical layer validation of signal integrity for internal control communication busses such as CAN, LIN and FlexRay. Moreover, SaberRD helps companies to protect their investment in their existing model libraries by providing a high de-

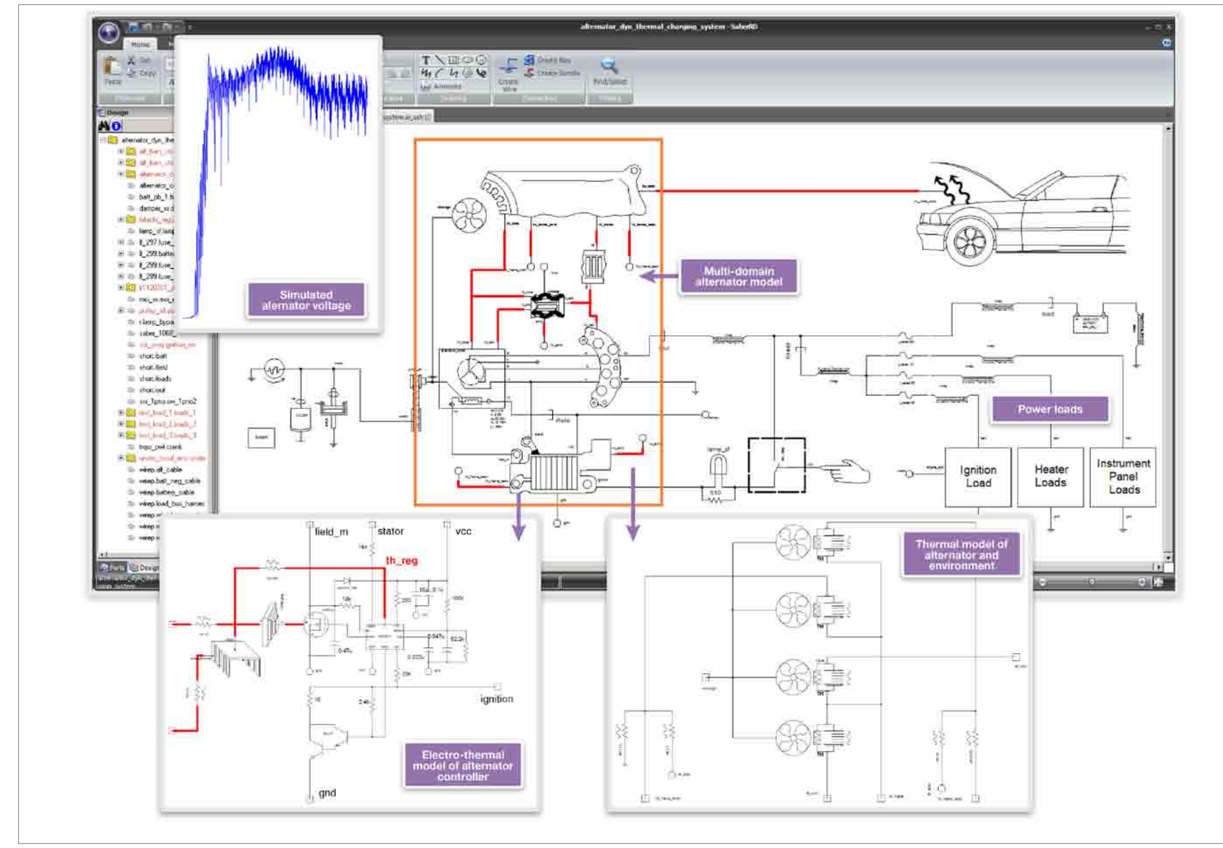

Figure 2: Multi-domain modeling of a generator

gree of flexibility to reuse models originally created in other software (e.g. SPICE).

Figure 2 shows an example of an alternator charging system that models mechanical dynamics of the crankshaft to rotor, electro-thermally coupled active electronics (diodes), a thermo-magnetically coupled machine model, as well as system heat sinks, electrical protection and electrical network loads. This level of detail in simulation allows for a deep understanding of the electrical system characteristics of the alternator and AC rectification scheme including ripple voltage and harmonics.

The simulation models used to build up the alternator charging system testbench, including the multi-domain model of the alternator, are taken directly from SaberRD's existing model library or have been created using one of several device characterization tools. For example, the alternator regulator contains a power MOSFET that controls the current that is supplied to the rotor windings. This model can be created based on semiconductor datasheet information using the Power MOSFET characterization tool in SaberRD.

The tool supports both modeling of pure electrical or coupled electrothermal behavior. In addition, the environment around the transistor has been modeled to represent the dynamic thermal behavior of the circuit by using a thermal impedance network. The alternator model includes several effects critical to the design, including the electric, magnetic and mechanical dynamics to represent the translation of the rotational power into electrical power made available to the vehicle power network after rectification.

The core of the alternator is also modeled to take into account the dynamic thermal effects that reflect the impact on the alternator's capability to supply electrical current. In order to do so, the core has been equipped with a thermal network model, including the air windage (e.g. cooling) effects. In order to construct the testbench with a realistic electrical consumer and supply environment that would be found in a vehicle, additional parts have been added from the standard SaberRD model library: Lithium Ion battery, cabling, and configurable power loads to model various mission profiles of the vehicle.

Consumer loads are incorporated to model load dump scenarios and can be either be used directly from the model library or modeled with a load modeling tool. This feature allows users to graphically define loads and configure models with different operating characteristics (e.g. cyclic switching). From here many important system simulations can be performed to validate and optimize resonant load behavior, load dump and transient suppression protection or detailed field current regulator implementations.

Important accurate fault behavior can be analyzed for conditions such as shorted or open diode connections, or field winding shorts in the alternator. The system model also accounts for dynamic charging and discharging behavior of the battery depending on the system loadings and the alternator's ability to supply sufficient electrical power.

The alternator's supply ability is impacted by the rotational speed of the armature shaft as well as losses due to mechanical friction, damping and thermal behavior associated with the alternator components. All of these effects can be taken into account using the SaberRD simulation and modeling solution. Vehicle platform optimization can no longer afford to overly simplify or ignore the impact of electrical systems on size, mass, placement, performance and cost of the components and subsystems that define the final production vehicle.

SaberRD's links to TCAD device simulation tools provide another important opportunity for hybrid-electric and full electric vehicle applications: co-optimization of the devices (IGBTs, MOSFETs, and diodes) and the application (inverters, DC/DC converters, etc.). Rather than having to rely on repackaging of existing classes of power devices and then utilizing circuit techniques to compensate for less than ideal performance of devices, it is now possible to perform virtual device iterations and generate accurate circuit-level models in a short enough timeframe to link the efforts of the circuit designers and device designers in real time. For different applications, different device characteristics can affect overall efficiency of the circuit.

Understanding the application needs and being able to create accurate circuit simulation models from detailed device physics allows power semiconductor companies to more quickly develop differentiated solutions specifically designed for vehicle power electronics challenges. Add to this the capability to extract thermal impedance models from detailed 2-D and 3-D geometric and material data in the TCAD environment and then quickly generate an equivalent thermal impedance network for system simulation and now there is a comprehensive tool flow addressing two of the most critical aspects of hybrid-electric and electric vehicle design long before physical prototypes are even available.

Support for a Model Supply Chain

Today's complex electrical systems are composed of components and sub-systems designed, developed and manufactured by numerous different companies. In order to understand system behavior, it is important to have a common language between different tiers of the supply chain through which to communicate requirements, performance and anomalous operation characteristics of the physical content of the system.

As domain experts with respect to the components and subsystems they deliver, suppliers are typically the best equipped to create simulation models that accurately reflect performance of real hardware. Further, they have the most direct access to performance measurements and test data required for model validation.

The needs of a sub-system or system integrator have to be balanced against each contributing supplier's ability to protect their intellectual property, yet still provide portable models that allow sub-system and system-level integration and test in a single simulation environment. The hybrid and electrical vehicle community has been looking to adopt methods and technology gained in other domains with similar power electronics content such as the aerospace industry.

Saber® tools have been used successfully for power electronic system design, validation and Federal Aviation Administration (FAA) certification at major aircraft OEMs for over a decade. Typical aircraft power systems involve different voltages busses (115AC, 230AC, 28VDC, 5VDC) driven by either fixed or variable frequency generators (400Hz fixed, 380Hz – 800Hz variable) and a wide variety of loads, many of which include active power factor correction (PFC) circuitry and internal DC/DC converters. System stability is critical especially due to negative incremental resistance of DC/DC converters loads.
These systems, while larger and more complex than typical automotive systems, have much in common with hybrid-electric and electric drivetrain power architectures. SaberRD models and simulation technology built up over years of usage in aerospace applications can readily be leveraged for hybrid-electric and pure electrical vehicle power systems.

Saber's multi-domain modeling capabilities and robust simulation algorithms typical of switch-mode power systems coupled with the ability to protect intellectual property have put Saber technology at the center of these efforts. SaberRD supports standard encryption mechanisms for industry standard HDLs (e.g. IEEE standard for VHDL-AMS encryption) that allow for portability and protection from one level of the supply chain to the next. SaberRD's analysis, post processing and report generation capabilities enable clear specification and validation definition as well as easy mechanisms to transfer pertinent data from the simulation environment to other useful forms for report generation and documentation.

Another complexity arises when the different companies within a supply chain use different tools and/or languages (HDLs, programming languages, or other data standards such as IBIS or Touchstone) to model physical behavior of components. Figure 3 illustrates the range of modeling languages and formats supported by SaberRD to support modeling of physical behavior from a variety of available sources.

Multi-domain simulation of physical systems is only a part of the overall tool chain necessary for system design, validation and production of power electronic systems for hybrid-electric and electric vehicles.

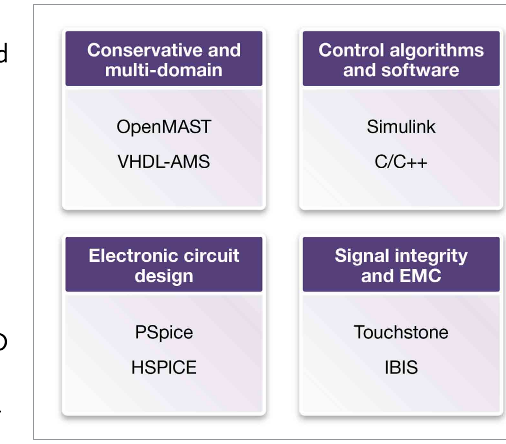

Figure 3: Model formats in SaberRD

SaberRD supports various important classes of integrations that enable extensive digital modeling and simulation of such systems, including:

- Digital verification through co-simulation with popular digital logic simulators
- Design and verification of embedded algorithms/software through co-simulation and model import with/from MathWorks® Simulink® and other tools
- Validation of embedded control systems running on virtual ECUs through Synopsys Virtual Prototyping solutions
- Verification of board-level analog electronics through integration with popular PCB design environments
- Verification of electrical wiring and cabling through integrations into Saber Harness and

other third-party design environments
- Generation of power semiconductor models in connection with Synopsys TCAD device simulation products

Complex power electronics, in conjunction with stringent space, weight, performance and cost considerations, require integrated optimization of vehicle electrical systems. Electrical system impact on thermal, mechanical and magnetic behavior (and vice-versa) needs to be accurately accounted for to inform pragmatic and feasible system-level tradeoffs for viable vehicle development. Software controls of power systems also require physically representative models to validate system stability and control algorithms over the full range of normal and anomalous operation.

Hybrid-electric and electric vehicle systems are driving traditionally mechanical-based engineering organizations to incorporate more and more complex electronics into their platform designs. Optimization at the software, hardware, and system level is necessary - linking component, sub-system and system integrators earlier in the design cycle. SaberRD provides a unified environment, an extensive set of model libraries and modeling tools, as well as intellectual property protection allowing for early virtual integration in a multi-domain simulation environment suitable for novices and experts.

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EMC COMPLIANCE

Best practice design recommendations

By Paul Lee

International regulations regarding electromagnetic compatibility (EMC) affect many aspects of circuit and system design. However, there are numerous techniques that can be applied to reduce both the emissions from and susceptibility to, electromagnetic interference (EMI).

Starting at the power supply end of the system, make sure that any supply line loops are minimized and the lines are decoupled at local boundaries using filters with low Q (see Figure 1). High-speed sections of the system should be placed closest to the power line input, and the slowest sections further away, to help reduce power plane transients.

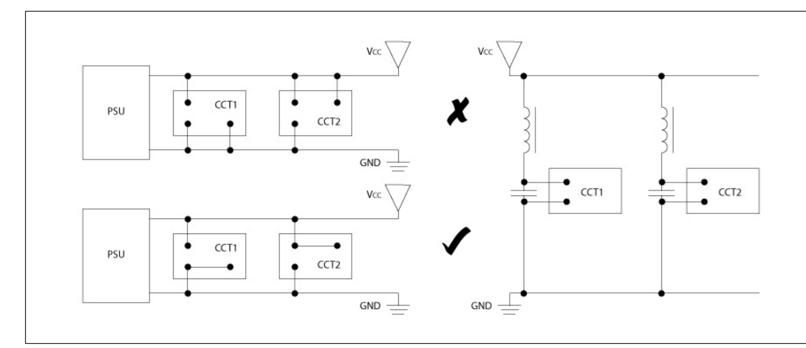

Figure 1: Supply lines – eliminate loops and decouple at local boundaries

Make use of low pass filters on signal lines to reduce the bandwidth to the minimum necessary. On wide bandwidth lines, keep feed and return loops close. The terminations of lines carrying HF or RF signals need to be implemented correctly to minimize reflection, ringing and overshoot. Lines carrying signals external to a board are best terminated at the board edge; avoid lead terminations within the board and loose leads crossing the board. It's important that all signals on the board are tracked with no 'flying leads'.

To avoid resonance within a signal conductor, steer clear of cabling or tracking which is close to a quarter wavelength of the signal frequency. Slew rate limiting, that is, minimizing rise and fall times on signal and clock edges, reduces crosstalk since sharp edges produce wide HF spectra.

PCB Considerations

There are quite a few things to consider when optimizing a PCB layout for EMC performance. The following aspects of board design should be avoided. The use of slit apertures, particularly in ground planes or near current paths. Also, do not use narrow tracks for power lines. This creates areas of high impedance and gives rise to high EMI. Do not overlap power planes. Keep them separate over common ground in an attempt to reduce system noise and power coupling.

Track stubs should not be used.

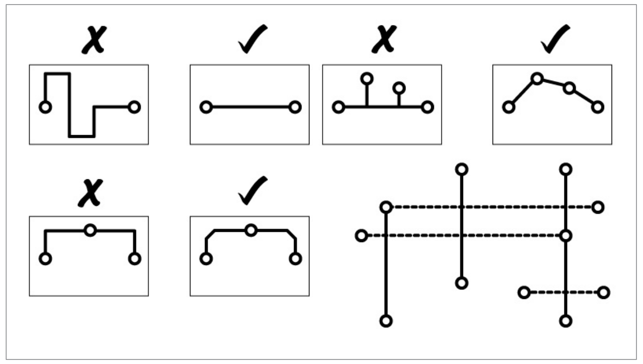

Figure 2: Keep HF tracks short, avoid track stubs, make mitre corners and orthogonal tracking on separate layers

These cause reflection and harmonics (see Figure 2). Likewise, do not make localised concentrations of via and through-hole pads. Do not loop tracks, even between layers since this forms very effective receiving or radiating antenna. In the same way, do not leave any floating conductor areas - these act as EMI radiators. If possible connect to the ground plane. Often these sections are placed for thermal dissipation, hence polarity should be unimportant but check the component data sheet.

Ensure that all signal tracks are stripline and include a ground plane and power plane whenever you can. Remember that the return current from a signal line is 'mirrored' in a ground plane above or below it and these mirror paths should not be interrupted or combined. Keep HF and RF tracks as short as possible and lay out the HF tracks first. Track mitring (bevelling the edges at corners) helps to reduce field concentration, which is helpful when considering EMC performance. A final tip for signal lines is to where possible, make tracking run orthogonally between adjacent layers. These tips are illustrated in Figure 2.

On sensitive components and terminations, a surrounding guard ring and ground fill can be used (see Figure 3). A guard ring around trace layers reduces emission out of the board. Only connect to ground at a single point and make no other use of the guard ring (i.e. do not use it to carry ground return from a circuit).

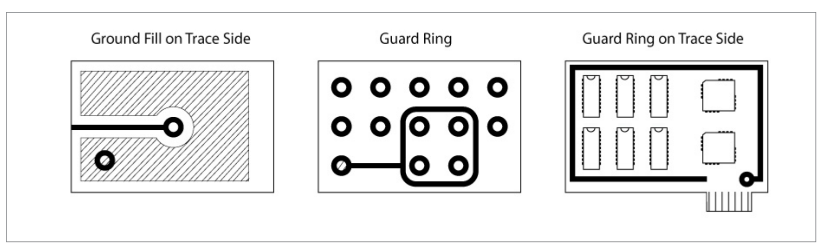

Figure 3: Use guard ring and ground fill

Component considerations

Now, let's look at EMC considerations surrounding specific components. The first step is to locate biasing and pull up/down components close to driver or bias points. The output drive from clock circuits should be minimized. An excellent way to increase coupling between a signal line and its return and cancel stray fields between current carrying and signal lines is to use common mode chokes.

Reduce component noise and power line transients by decoupling close to chip supply lines. For decoupling and bypassing, ceramic multilayer capacitors are preferred due to their low impedance, high resonant frequency and stability.

Where possible, use discrete components for optimum filtering effect. Surface mount is preferable due to lower parasitics and antenna effects of terminations on through-hole parts. Include filtering of cables and over voltage protection at their terminations. This is especially important for cabling which is external to the system. If possible, all external cabling should be isolated at the equipment boundary.

You can minimize capacitive loading on digital outputs by minimizing fan-out, especially on CMOS ICs since this reduces the current loading and surge per IC.

Shielding, whilst effective at improving EMC performance, can be expensive and should therefore be kept as a 'last resort'. Where shielding is available, use it on fast switching circuits, mains power supply components and low power circuitry. Consider specifying magnetic shields or 'belly bands' around transformers or inductors and electrostatic shields between transformer windings. In general, keeping the bandwidth of all parts of the system to a minimum and isolating circuits where possible reduces susceptibility and emissions.

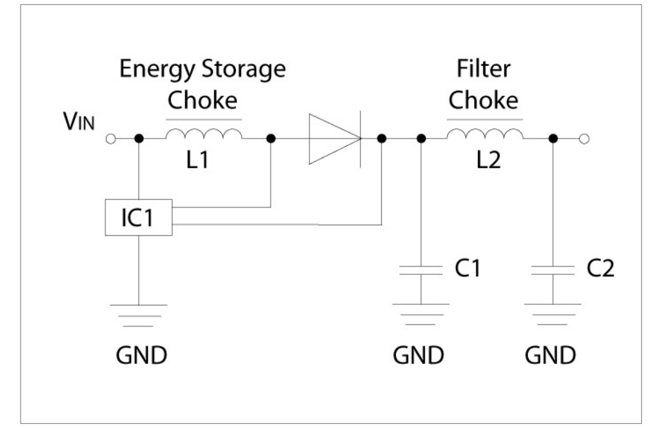

Figure 4: Basic SMPS and filter configuration

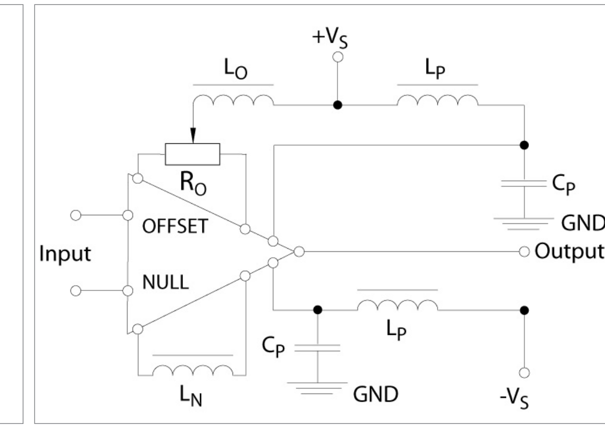

Figure 5: Amplifier filtering with inductors

EMC-specific components

Parts like transformer isolators, standard inductors and common mode chokes can offer simple solutions to specific EMC problems within an existing circuit.

Inductors

Inductors are ideal for reducing EMI on power lines and for filtering high current signals. In switched mode power supply (SMPS) circuits, inductors are used for both energy storage and line filtering (see Figure 4). We recommend that a toroidal or shielded inductor be used if EMC problems are suspected. Toroidal inductors better maintain the magnetic field within the core shape and hence have virtually zero radiated field. By the same token, the susceptibility of a toroid to EMI is also very low.

In power sections of circuits, an inductor between the local supply and the main feed provides good filtering of the supply and reduces noise from localised circuits in the system, preventing noise from polluting the main power line. To select an inductor, consider the current handling and relative switching speed of the circuit section. Generally, use the lowest value of inductance that gives the desired filtering effect as higher values have lower self-resonant frequencies which can produce troublesome ringing with circuit disturbances. A resistor across the inductor is often useful to lower the Q of the filter circuit to dampen ringing waveforms. Low inductances will also generally have lower DC losses and will produce lower transient voltages with load steps.

In signal lines with a reactive load or driver, a matched termination may be required using a passive reactive circuit. The frequency response of the load/driver needs to be known, but can be matched by a relatively simple and easily characterised RCL network. Another area where inductors can be used with great benefit to the EMI of a circuit is in an amplifier bias network (see Figure 5). By using an inductive element in the bias or compensation arms, a filter can be added to the circuit without loading the signal with additional inductance. Careful choice of inductance value is required and placement close to the amplifier is essential. This method is suitable for filtering HF noise, particularly on video and TV type signals.

Common Mode Chokes

Common mode chokes can be employed in signal lines to eliminate common mode noise or EMI on cables or induced in signal tracks. The choke should be located as near to the driver/receiver circuit as possible, or at the entry point of a signal to a board. The

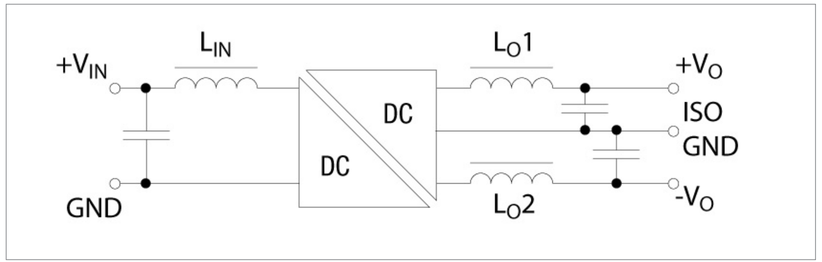

Figure 6: Filtering a DC-DC converter

choke works by cancelling interference appearing on both signal and return lines (i.e. induced EMI) while allowing wanted differential mode signals and DC to pass.

Choosing the right inductance will also help in maintaining a match to the characteristic line impedance and act as a filter to bandwidth-limit the termination.

On power lines, common mode chokes are employed to reduce common mode EMI. Differential mode noise can also be filtered in the same component by judicious selection of a common mode choke that is deliberately designed to have less than perfect coupling between windings. This results in 'leakage' inductance which acts as a series mode choke in each line.

Transformers

The main EMC benefit of using a signal transformer is to provide an isolation barrier between a signal line and associated circuits. This is particularly the case where the signal line exits the board or system. This is true of signals being driven or received, since isolating the line reduces common mode noise and eliminates ground (or signal return) potential differences between systems.

Isolated DC-DC converters

An isolated DC-DC converter can really help reduce susceptibility and conducted emissions by isolating both power rail and ground from the system supply. Isolated DC-DC converters are switching devices and as such, have a characteristic switching frequency themselves which may need some additional filtering, such as the setup shown in Figure 6.

These general design recommendations should prove a useful guide to minimizing EMI and help systems achieve EMC certification first time.

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Special Report: Automotive Electronics

PSD NORTH AMERICA

Power Systems Design: Empowering Global Innovation

Inside:

AUTO EFFICIENCY

Fuel saving automotive start/stop electronic systems

By Bruce Haug

Many automotive manufactures have devised a clever way of saving fuel in automobiles by using a new concept called a "Start/Stop" system. This system automatically switches off the engine when the car is at a standstill and in neutral, then restarts it as soon as the driver presses the clutch pedal again.

The principle of this is simple, if the engine is not running, it does not consume fuel. In a traffic jam or even in stop-and-go traffic, simply putting the car into neutral and taking the foot from the clutch will activate the function. A Start/Stop message on the info display will signal that the engine has been turned off. To start up the engine again, depress the clutch, put the car back into gear and the engine immediately springs back to life ready to drive on without delay.

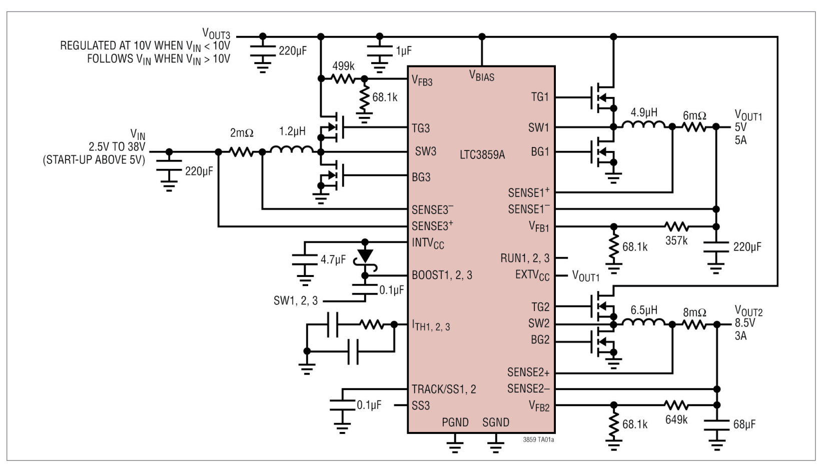

Figure 1: Typical LTC3859A Start/Stop Application Schematic

Driving comfort and safety are not affected by the Auto Start/Stop function. The function is not activated, for example, until the engine has reached an ideal running temperature. The same applies if the air conditioner has not yet brought the cabin to the desired temperature, if the battery is not adequately charged or if the driver moves the steering wheel.

The Auto Start/Stop function is coordinated by a central control unit that monitors data from all relevant sensors, including the starter motor and the alternator. If necessary for comfort or safety, the control unit will automatically restart the engine. For example, if the vehicle begins to roll, the battery charge falls too low or condensation forms on the windscreen. Furthermore, most systems recognize the difference between a temporary stop and the end of the trip. It will not restart the engine if driver's seatbelt is undone, or if the door or trunk is open. If desired, the Auto Start /Stop function can be completely deactivated with the press of a button.

However, when the engine restarts and there is an infotainment system on or any other electronic device requiring greater than 5V, there is a possibility that the 12-volt battery can dip to below 5 volts causing these systems to reset. Some infotainment systems operate from a 5V and 8.5V input voltage fed from a step-down converter operating from the car battery. When the input voltage dips to below 5V during an engine re-start (cold crank), these systems will reset when the DC/DC converter only has the capability to stepping-down the input voltage. Obviously, it is not acceptable to be watching a video or listening to a CD and have them automatically reset every time the car restarts.

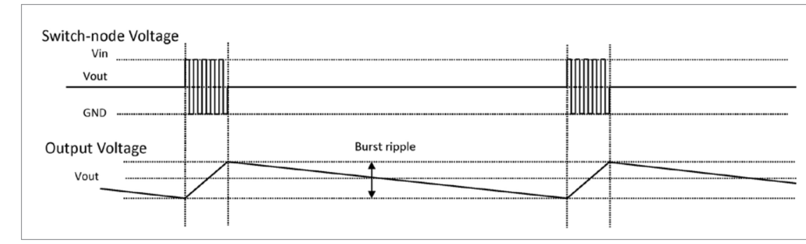

Figure 2: Burst Mode Operation Voltage Diagram for the LTC3859A

A New Solution

Linear Technology has a triple output DC/DC controller, the LTC3859A that combines a synchronous boost controller and two synchronous step-down controllers in a single package. The synchronous boost converter output feeds the step-down converters to maintain a high enough voltage to prevent electronic systems requiring greater than 4V to reset during an engine restart. In addition, when the input voltage from the car battery to the boost converter is higher than its programmed output voltage, it runs at 100% duty cycle and simply passes the input voltage directly to the step-down converters minimizing power loss. Figure 1 shows a LTC3859A schematic with the synchronous boost converter supplying 10 volts to the synchronous step-down converters when the battery voltage drops below 10 volts. In addition to powering the two step-down converters, which produce 5V/5A and 8.5V/3A in this example, the boost converter can be used as a third output that can provide an additional 2A output.

The LTC3859A is low quiescent current, current mode control, triple output synchronous DC/DC controller that operates with all N-channel MOSFETs from input voltages ranging from 4.5V to 38V during start-up and can operate down to 2.5V after start-up. The two buck controllers, channels 1 and 2, operate 180 degrees out of phase and can produce output voltages from 0.8V to 24V that are ideal for navigation, Infotainment systems, processors and memory. The boost controller, channel 3 operates in phase with channel 1 and can produce output voltages up to 60V. The powerful 1.1Ω onboard gate drivers for each channel minimize MOSFET switching losses. The operating frequency can be programmed from 50kHz to 900kHz or can be synchronized to an external clock with internal phase-locked-loop (PLL) over a 75kHz to 850kHz range. The LTC3859A differs from the LTC3859 by having an internal clamp on the INTVCC pin. This clamp is a failsafe approach that prevents excessive voltage on the INTVCC pin if the user inadvertently uses a leaky schottky bootstrap diode.

Additional features include an onboard LDO for IC power and gate drive, programmable soft start, a power good signal and external VCC control. The VREF accuracy is ±1% over an operating temperature range of -40°C to 85°C and the LTC3859A is available in the 38-lead SSOP or a 38-lead 5mm x 7mm QFN packages.

Extending Battery Run Times

Any battery powered system that requires an "Always-On" power bus while the rest of the system is turned off must conserve battery energy. The need for low quiescent current to conserve battery energy is especially important in automotive applications that can have several electrical circuits such telematics, CD/DVD players, remote keyless entry and multiple always-on bus lines.

The LTC3859A draws a mere 75µA when in sleep mode with the boost converter and one of the buck converters on. With all three channels on and in sleep mode the LTC3859A draws only 100µA which significantly extends battery run times when in idle mode. This is done by configuring the part to enter high efficiency Burst Mode® operation, were the LTC3859A delivers short bursts of current to the output capacitor followed by a sleep period where the output power is delivered to the load by

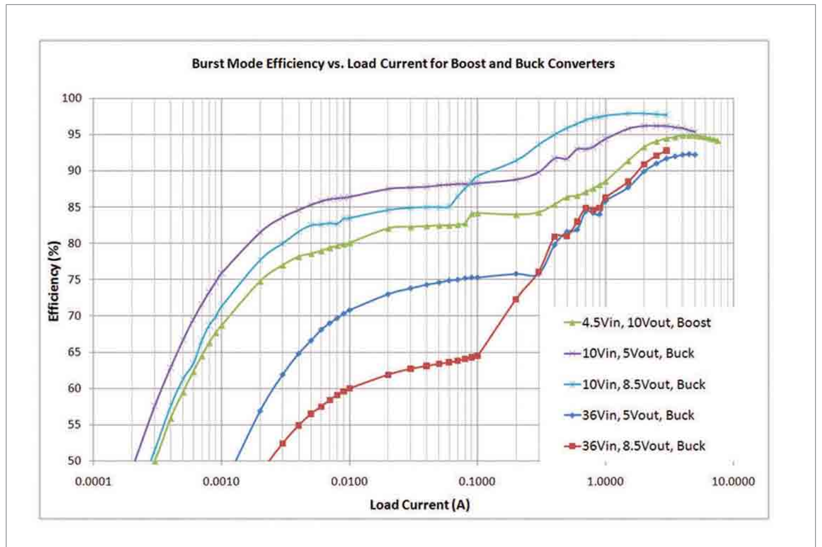

Figure 3: LTC3859A Efficiency vs. Load Current for Different Converter Sections

the output capacitor only. Figure 2 shows the conceptual timing diagram of how this works.

The Burst Mode output ripple is load independent, only the length of the sleep intervals will change. In sleep mode, much of the internal circuitry is turned off except for the critical circuitry needed to respond quickly, further reducing its quiescent current. When the output voltage drops enough, the sleep signal goes low and the controller resumes normal Burst Mode operation by turning on the top external MOSFET. Alternatively, there are instances when the user will want to operate in forced continuous or constant frequency pulse skipping mode at light load currents. Both of these modes are easily configurable, will have a higher quiescent current and a lower peak to peak output ripple.

Load-Dump/Efficiency/Solution Size

Load dump is a term that refers to the inductive kick that happens after the starter motor is turned

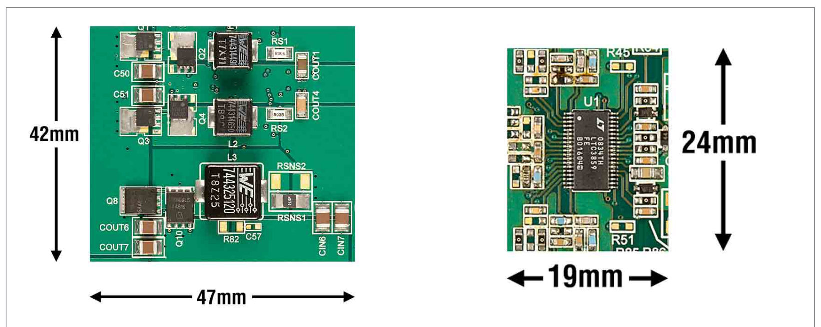

Figure 4: Size & Layout of LTC3859A Demo Board (a) Top and (b) Bottom sides

off. This surge voltage is normally clamped to 36 volts maximum for a 12 volt lead acid automotive type battery system. This surge requires the controller, MOSFETs and associated components being capable of operating at the clamped voltage. These higher voltage devices (such as 40V MOSFETs) can degrade efficiency and care must be taken to minimize this effect. Based on the circuit in Figure 1, the efficiency is above 92% for each rail as shown in Figure 3. For clarity the efficiency of each buck and boost section is show separately. In addition, the layout and circuit size for this circuit is shown in Figure 4 with the tallest part being 4.8mm high.

Soft Start or Tracking

The TRACK/SS1 and TRACK/SS2 pins of the two buck controllers can be used for adjusting the soft start turn-on time or to track two (or more) supplies with Coincident or Ratiometric tracking during start up. These associated curves are shown in Figure 5 and is accomplished by putting a resistor divider from the master supply, to the TRACK/SS pin of the slave supply.

At higher temperatures, or in cases where the internal power dissipation causes excessive self heating on chip, the over temperature shutdown circuitry will shut down the LTC3859A. When the junction temperature exceeds approximately 170°C, the over temperature circuitry disables the on-board bias LDO, causing the bias supply to drop to zero volts and effective shutting down the entire LTC3859A in an

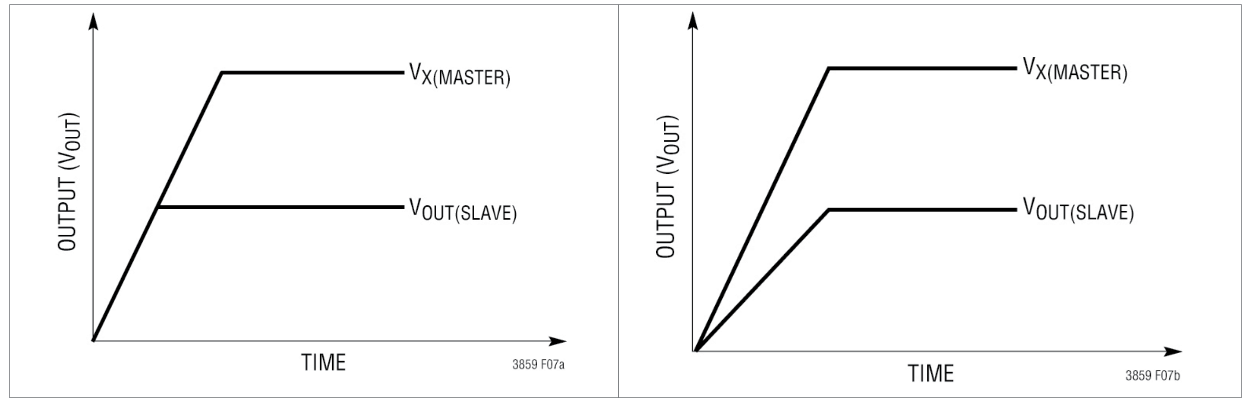

Figure 5: LTC3859A Output Voltage Tracking: (a) Coincident Tracking and (b) Ratiometric Tracking

orderly manner. Once the junction temperature drops back to approximately 155°C, the LDO turns back on.

Conclusion

The LTC3859A provides a solution by boosting the battery voltage to a safe operating level with is on-board synchronous boost controller. Combined with two synchronous step-down controllers, ideal for powering many automotive electronic devices, the LTC3859A maintains regulation for all output voltages during an engine restart.

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AUTOMOTIVE LIGHTING

HID applications: ballast and igniter

By Evangelista Boni, Davide Montanari, Luca Caliari, John Bultitude, Reggie Phillips, Mark Laps, Bill Sloka, William Buchanan

High Intensity Discharge (HID) headlamps are superior replacements for conventional heated-filament headlamps that require about 25kV applied to the lamp electrodes to ionize the Xenon gas and 'strike' an arc.

HID technology simply uses the light emitted when ionized Xenon gas in a sealed bulb changes energy states. Once the gas is initially ionized, the light-emitting arc is sustained by an AC potential of about 90V applied across the electrodes in the bulb.

The resulting arc emits light with a high luminous intensity, hence the name High-Intensity Discharge or HID. The HID lamps consist of the following units: Ballast, Igniter, and Bulb. A simplified equivalent circuit is given in Figure.1. The ballast is comprised of the DC/DC converter, which can boost the battery voltage up to the HID lamp voltage and the DC/AC inverter.

For the starting of the HID lamp, the DC/DC converter increases the input voltage of the igniter to reach the Breakdown Voltage of the arc gap.

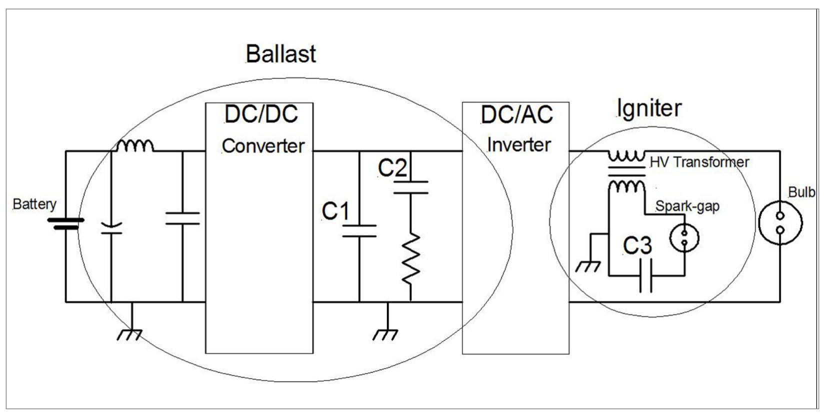

Figure 1: Ballast-Igniter Circuit

KEMET film technology department has developed two special series for the HID Xenon headlamps (see Figure 2):

Igniter: HNS – film naked capacitors using stacked technology (high peak currents withstanding) available in SMD and in leaded version made with PEN dielectric able to work up to 170°C.

Ballast: SWN – SMD film naked capacitors using wound technology made with PEN dielectric able to work up to 150°C and focused on withstanding high voltage peaks during the ignition phase.

Igniter unit

The igniter capacitor must be able to support high voltage, high currents and critical humidity environment. Due to the fact the ignition circuit is usually integrated with the Xenon lamp, the max ambient temperatures surrounding the capacitor could reach 170°C and the dimension of the capacitors should be as low as possible.

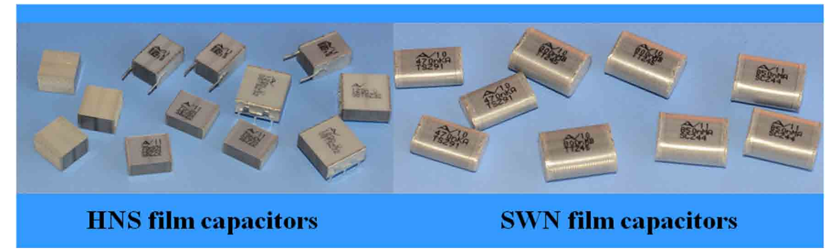

Figure 2

The SMD technology requires the LF reflow process. In order not to decrease the efficiency of the igniter circuit, high capacitance stability is required. Considering the harsh automotive environment, several tests in severe humidity conditions (loaded, up to 85°C – 85% RH) are carried out without any significant capacitance drop up to 1000h.

A critical parameter for the igniter capacitor is the voltage withstanding, especially after the LF reflow process. In order to monitor the igniter capacitor performance from this point of view, a voltage value is recorded to indicate the first occurrence of partial discharges when a constant voltage ramp-up is applied on the capacitor (First Breakdown Voltage - FBDV). What is measured in this way is not the real 'breakdown' of the dielectric, but only a partial discharge that, in some cases, can create only very small and brief current flow. The FBDV results recorded after the solder-reflow process with different peak temperatures (233°C and 245°C) have shown that the first partial discharges appear for voltages higher than 1300Vdc.

Ballast unit

In the equivalent circuit of the ballast of Figure 1, the capacitor C1 filters the current pulse from the flyback inverter running at hundreds of kHz. This capacitor provides the initial current to the lamp during ignition. The energy stored in the C2 boost capacitor assures good heating of the lamp electrodes and completes the glow to arc transition of the HID lamp. The max ambient temperature for the ballast is usually 125-135°C due to the non-proximity of the ballast to the lamp.

The main requirements are small dimensions, withstanding voltage peaks (300 to 600V), critical humidity environmental conditions, and LF reflow process. Wound technology was chosen for its intrinsically good performances in withstanding voltage peaks.

Since the withstanding of voltage peaks and the dimensions were the main application requirements, efforts have been focused on these characteristics, with the result of reducing the film thickness by about 33% from the general-purpose SMD naked stacked PEN capacitor. This dramatically reduces the volume of the capacitor, leads to increasing capacitance range, and significantly improves the FBDV results.

The boost capacitor's working temperature is currently up to 125°C, but with the upcoming new 25W version, the integration between the igniter and the ballast circuits might be an option. For this reason, the boost capacitor's working temperature can rise up to 150°C, validating even more the choice to use the PEN dielectric.

KEMET has also developed a special SMD leaded multilayer ceramic capacitor series (KPS AUTO). These ceramic capacitors can be operated reliably above 125oC but to achieve the high capacitances required by many designs, larger case sizes must be used and this presents another set of challenges. Unlike film capacitors, there is no self-healing mechanism in MLCCs so the parts must be designed to be robust and applied such that they are not over-stressed in the application.

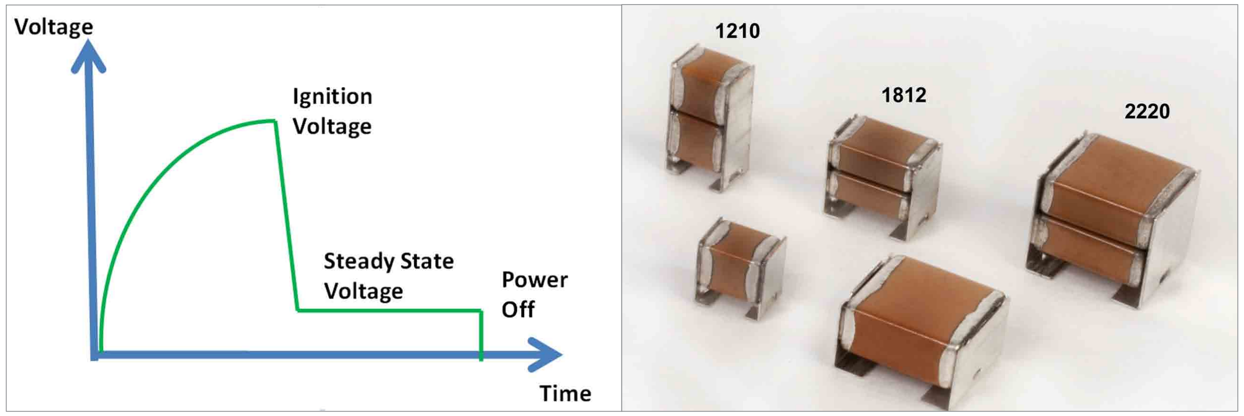

Figure 3: The KPS AUTO series has 1 or 2 Multi-Layer Ceramic Capacitors in a surface mountable J-lead stack in case sizes 1210, 1812 and 2220.

The J-lead allows two MLCCs to be placed in the same pad space on the circuit board doubling the capacitance compared to using one. The J-lead also adds significant compliancy that prohibits cracking of the ceramic during board flexure so the KPS AUTO can tolerate flexures 3X higher than the MLCC mounted directly to the circuit board. The leads also allow these parts to tolerate a significant mismatch in the coefficient of thermal expansion (CTE). The MLCC typically has a CTE ~ 10 PPM/oC or less compared to 15 PPM/oC for FR4 or above this for various insulated metal substrates. These differences are magnified for larger capacitors.

Rapid thermal cycling of the assemblies can cause the ceramic to crack in the MLCC whereas the J-leads additional compliancy absorbs this mismatch in KPS AUTO.

The break strength is also an important consideration and this depends on the type of ceramic dielectric used. KPS AUTO has two alternative dielectrics, X7R and CoG. The CoG has twice the break strength of X7R in the larger 2220 case size.

Although the X7R has lower break strength, it also has higher capacitance. The capacitance of X7R declines significantly with applied voltage and at temperatures of 150oC. This combined effect can reduce the available capacitance by up to 70% compared to the nominal value for X7R. These make X7R appropriate for ballasts that are not exposed to large mechanical stresses or thermal shock.

The CoG has much higher break strength and does not experience any significant loss of capacitance with temperature or voltage. The insulation resistance of CoG remains high at 150oC, making this preferred for high temperature applications that require robust mechanical performance.

The development of KPS AUTO supports the demand for higher temperature designs. When combined with films KEMET can now support a broader capacitor design space for automotive HID headlamps.

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AUTOMOTIVE PROTECTION

EMC pulse immunity system-level tests

By Stephan Gerlach

System-level tests for EMC pulse immunity have been established in order to test the immunity of an electronic device or module against strong electromagnetic fields such as a close AM or FM transmitter station or the short, intense shock from a flash that can damage or at least disable vehicle electronics.

Many car manufacturers and Tier1 suppliers have tried to simplify test procedures and to standardize both the test set-up as well as workbenches. By using mature but still valid test cases they aim to reduce the use of wiring harness, interacting modules and the car's body to only the basic functional minimum. Unfortunately, this led to a large number of experimental set-ups that were similar but incompatible for comparing technical parameters. Two examples developed by car OEMs are explained in this article.

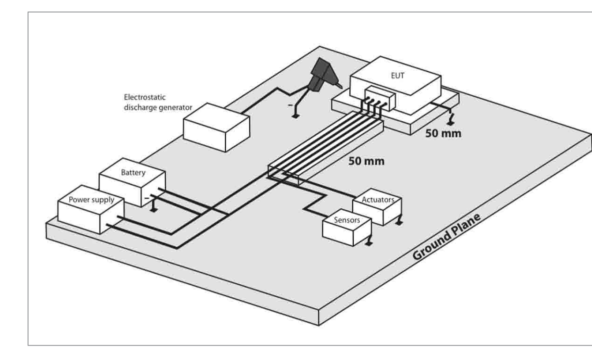

Figure 2: Workbench of a major European Car Manufacturer

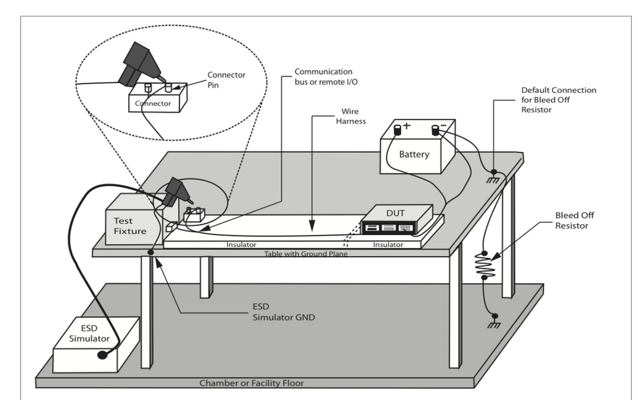

Figure 1: Principle of Car Wiring Harness Pulse Immunity Test Using an ESD Simulator ("ESD Pulse Gun")

Figure 2 shows an example that is comparable to the set-up of figure 1 regarding functionality, but leads to differing results. To overcome this obstacle, a major European car manufacturer started an initiative that was accepted by all major car OEMs. The proposed test set-up simulates a wiring harness that is exposed to ESD events. Since 2007 this set-up has been part of the international standard ISO 10605 as Annex F.

Functionality of EMC Pulse Immunity System-level Testing

By using an ESD gun different pulses with positive and negative polarity in the range of 1 to 30kV are applied to three test pads. The so-called conducted discharge is utilized to guarantee the highest possible repeatability which is a

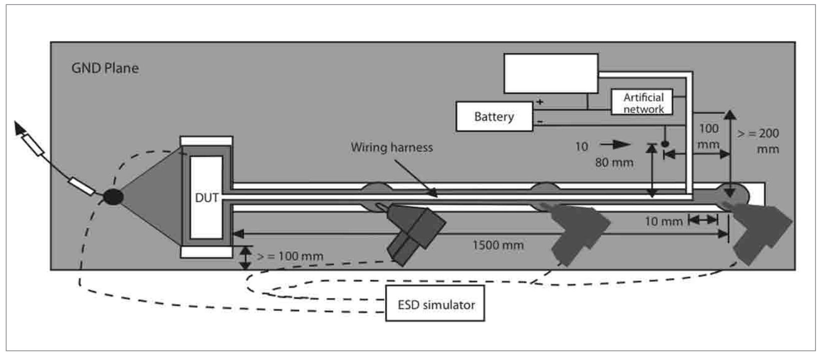

Figure 3: EMC Pulse Immunity System-level Test According to ISO 10605 Annex F (1 = metal ground plane, 2 = ESD resistors, 3 = reference ground, 4 = optional ground line, 5 = DUT1 (master), 6 = wiring harness, 7 = car battery, 8 = DUT2 (slave), 9 = artificial mains network, 10 = battery ground, 11 = ESD pulse generator with gun and ground cable)

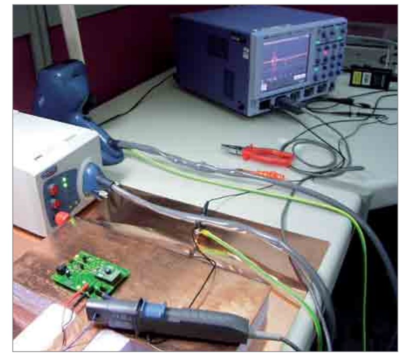

Figure 6: Workbench System-level EMC Pulse Immunity Test – Pulse Measurement

vitally important characteristic of any test procedure. Nevertheless, it cannot be ruled out that a single pulse delivers the same reaction on the device under test. The standard procedure therefore prescribes a repetition rate of 10 ESD pulses for each polarity. To guarantee 100% test reliability, this procedure has to be repeated on the test fixture for all three pads.

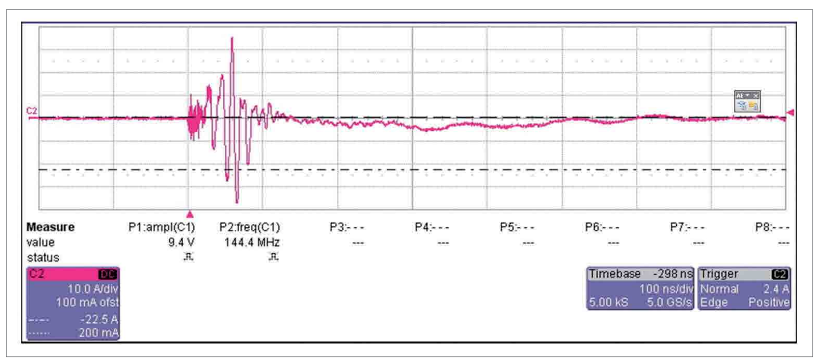

Figure 4: Stimulated Transient Signal Measured with Current Probe (Clamp-on Ammeter)

The reason for this is quite simple: To a certain extent, the shape and amplitude of the stimulated waveform within the wiring harness is arbitrary. Moreover, because the ESD pulses are applied to a "living system" (i.e., ongoing LIN communication between master and slave) they have a different impact on the DUT's failure behavior until final destruction.

Figure 4 shows that current spikes of up to 37A are created with a burst frequency of several hundred MHz. As explained above, neither the pulse shapes nor the effects are identical. A DUT can withstand 5 or 7 pulses, but the 8th pulse will cause final destruction.

Figure 5: Workbench System-level EMC Pulse Immunity Test in Application Lab

The rigorous ESD tests applied to automotive systems greatly reduce the possibility of a potentially catastrophic failure in modern electronics intensive systems. We take these systems very much for granted in our daily routines, until something goes wrong. These vital tests ensure a higher level of system reliability and driver confidence and safety.

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SYSTEM-ON-CHIP GNSS SOLUTION

Integrating MEMS Gyros Enables Urban Canyon Applications

By Jeff Wilson

Global Navigation Satellite System (GNSS) is the general term for satellite tracking systems and covers GPS, Galileo, GLONASS, QZSS and Compass constellations.

Systems for urban canyon applications need to incorporate a range of functions including GNSS tracking, inertial measurement, telemetry, and telematics processing. Given the volumes emerging telematics solutions are manufactured in, these functions often have to be spread across a number of discreet chipsets. With the advent of new low power, single-die, System-on-Chip GNSS solutions and MEMS inertial sensors, these functions can now be consolidated into one chipset, reducing the power-consumption, complexity, and cost of the overall system.

By Jeff Wilson is a 20+ year Senior Staff Engineer with STMicroelectronics in Schaumburg, Illinois. He has been designing GPS Reference Designs, GPS Dead-Reckoning Systems, and Automotive Car-Multimedia systems for the last 10 years

The Urban Canyon Problem

GNSS signals are primarily "Line of Sight" and work by "Time of Arrival" (ToA) ranging methods that measure and calculate the position and velocity of a receiver based on the signal path delay from the GNSS satellites. As a result, the accuracy and stability of the solution can be severely affected in urban canyon environments where the signals are degraded by multipath or obscured by tall structures. Even with the use of highly sensitive receivers and alternative startup measures (such as providing ephemeris assistance data), the positional accuracy can be still be degraded to the point of not being useful for certain functions like navigation, emergency-call, road-tolling, congestion-surcharge monitors, or pay-as-you go insurance modules. False positions in these scenarios will result in lost-drivers, incorrect charges and possible loss of life in emergency call situations.

Dead Reckoning Solutions

In many of these applications, the only current solution is a Dead-Reckoning (DR) system that uses the GNSS data coupled with the vehicle's speed sensors to provide additional accuracy when needed. This approach, while expensive to develop, works well for large volume telematics providers (such as OnStar), but is inadequate when the unit needs to be installed as an after-market device due to problematic access to the vehicle data bus.

Some units get around the vehicle bus problem by using a CAN1-based On-Board-Diagnostic interface (OBD-II or EOBD in the case or Europe) for speed information and then an on-board gyro to provide for heading data. This solution, while easier to develop and integrate, results in high production costs due to the

need to integrate a GNSS module, inertial sensors (gyros and accelerometers), a general purpose microprocessor, a vehicle interface, and a network communications module (usually a cellular modem module).
To be cost-effective in the emerging telematics markets, a method to provide more accuracy and lower-cost is required.

A Multi-Constellation GNSS Receiver
In urban-canyon environments, accuracy and availability2 are directly related to the number of satellites the receiver can find and track, and since there are a fixed number of satellites in a given GNSS constellation, there is a fixed limit to the accuracy and availability that can be achieved in any particular environment. To achieve better accuracy and availability beyond this point requires the use of dead-reckoning (using the vehicle sensors to augment the GNSS solution) or adding more satellites to the tracking solution.

ST's new Teseo-II line of multi-constellation, System-on-Chip (SoC), single-die with integrated RF, GNSS receivers support additional accuracy and availability by tracking GPS, GLONASS, and Galileo satellites at the same time, with the net result of nearly doubling the number of available satellites in most signal environments. In the future, there will be the prospect of tripling the number of available satellites when the Galileo and QZSS GNSS systems become active in the 2016 to 2018 time-frame. Additionally, dead-reckoning algorithms can be integrated alongside the GNSS receiver functions to provide for additional accuracy where needed.

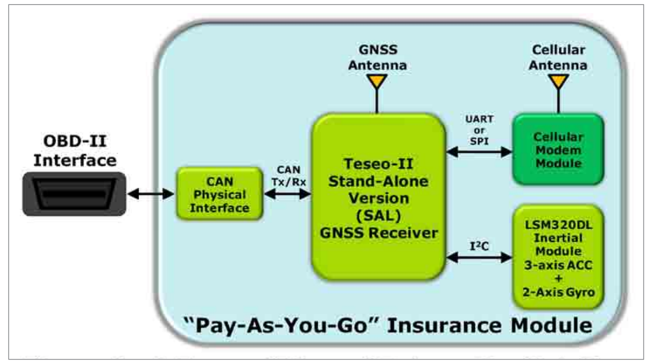

Figure 1 - A Teseo-II Telematics based Solution

In urban-canyon testing over a 24-hour period, the Teseo-II's GPS + GLONASS tracking engine achieved 2.5 times better accuracy and 3.8 times more availability than a GPS-only solution. In this 24-hour test run there were 380-minutes of outage (no position fix) when using a GPS-only solution, while Teseo-II's GPS + GLONASS solution had no loss of position (see Table 1 below).

24-Hour Urban Canyon	GPS-Only Solution	GPS+GLONASS Solution
No. Visible Satellites	4.4	7.8
Period of "No Fix"	380 minutes	Never
HDOP	5.3	2.1
Accuracy	x-meter	(x * 0.40)-meter

Table 1: Teseo-II Urban Canyon Performance

In some application areas, the additional accuracy and availability of the Teseo-II's GPS + GLONASS solution may also make it possible to completely replace a current GPS + Dead-Reckoning solution resulting in reduced complexity and system costs.

A System-on-Chip Approach to Low-Cost Telematics
While there are volume, certification, and regulatory road-blocks to "super-integrating" the cellular modem module into mid to low-volume telematics architectures, ST's Teseo-II telematics processors and MEMS sensor solutions allow for integration of the GNSS receiver, the dead-reckoning sub-system, the inertial measurement sub-system and the network communications protocol stacks into a 2-chip solution that significantly reduces production costs (see Figure 1 – A Teseo-II based Telematics Solution).

Figure 1 details a simplified, low-cost "Pay As You Go" Insurance module that incorporates the Teseo-II STA8088SAL GNSS System-on-Chip, a LSM320DL inertial sensor module, a cellular modem module, and a CAN interface (the Teseo-II architecture includes up to two 2.0B Active CAN controllers built in).
The "Stand-Alone" version of the Teseo-II includes a 4M-Byte System Flash for program use, 256K of Static RAM, two UART ports, an I2C and SPI port, a USB 2.0 Full-Speed interface, and a 3-channel 10-bit analog to digital converter. While not all of the System Flash or SRAM is available for user applications, there is plenty of space to host simplified communications stacks to communicate (via cellular modem) road usage data. In this application, the Teseo-II architecture achieves the best overall low-cost solution.

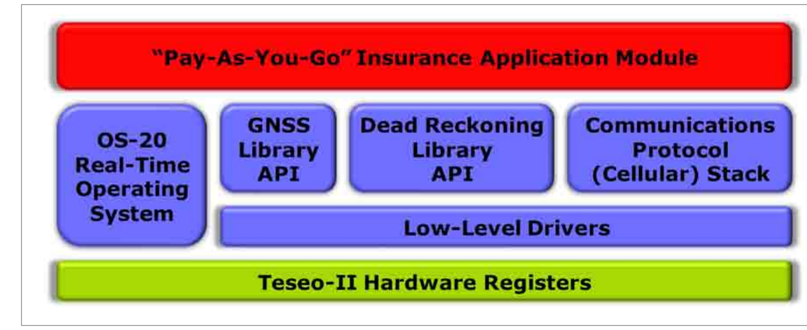

Figure 2 - Application Software API Diagram

For more complex telematics solutions, there is also a "System-on-Chip" variant (the STA8088EX) that includes, in addition to the above, an external memory interface, two SD/MMC memory card interfaces, an extended function timer, and an audio codec interface.

Software Architectures and APIs
The standard GNSS tracking software library implemented within the Teseo-II SoC is the GNSS-API-Library. It allows for integration of custom application code and driver sets to fully implement a telematics system.
In addition to the GNSS-Library, there are also libraries available for dead-reckoning, SD-MMC Card file I/O, graphics-libraries and various low-level device-driver libraries for audio, UART and CAN interfaces (see Figure 2 –Application Software API Diagram).

The communication libraries used will depend on the modem module in use and the server component/system it communicates with. Some possible implementations include TCP/IP and HTTP protocol stacks to communication with corporate databases and web-engines for transferring of customer data, or Short-Message-Service (SMS) data transfers of user data to database servers.

The file-storage library also comes in handy when embedding map content which may be required for certain applications such as road-tolling, congestion-tax usage, or Advanced Driver Assistance Data (ADAS) applications for in-vehicle road-content information such as NAVTEQ's "Map and Positioning Engine".

Conclusion
Urban canyon telematics applications can greatly benefit from the reduced cost and complexity, and improved performance of the new multi-constellation GNSS SoC solutions now available.

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EV/HEV MEASUREMENTS

High-Voltage onboard EHV testing

By Dipl.-Ing.(FH) Harry Störzer

Recent industry trends toward high-performance electric and hybrid vehicle (EHV) drives has created a whole new set of testing requirements.

New Drive Technologies, New Safety Requirements

New systems call for onboard electrical energy stores and drive units with battery power requirements of up to 1000 Volts depending upon vehicle size and type. While such high-voltage systems are commonly known for their stationary use within power generation and energy distribution applications, they are still fairly unfamiliar to onboard EHV applications, though nonetheless are steadily increasing in popularity.

It is important to understand that, if EHV drive construction was the same as traditional 12-, 24- or 42-Volt (nominal) on-board systems, units would create unreasonably high power requirements and end user costs, directly affecting a manufacturer's ability to produce cost-competitive new vehicles. Since power is a byproduct of both current and voltage, EHV on-board system voltage must

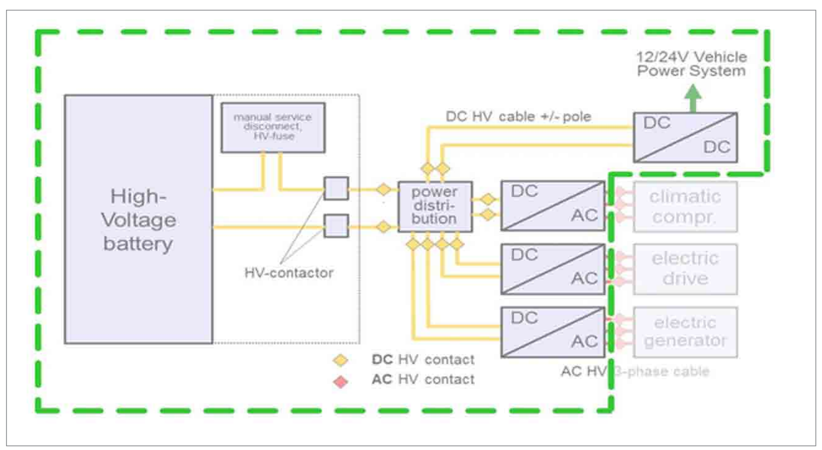

Figure 1: Typical positioning of high-voltage vehicle components

increase to keep currents within "reasonable" limits.

Such increased capabilities can diminish cable cross-sectioning requirements while fully optimizing drive system efficiency. To ensure optimal EHV performance, numerous tests must be conducted during the new vehicle development process. Suitable mobile vehicle data acquisition systems are vital for ensuring system competency, functionality and efficiency. In addition, proper incorporation of this technology as a viable onboard power source within an operating EHV requires a commitment to stringent safety testing and risk-mitigating hardware and accessories.

Understanding a Typical High-Voltage Onboard System

A typical high-voltage onboard system consists of two key components: the direct current grid (DC voltage) of the energy storage device; and the three-phase alternative current grid of the RPM-regulated drive (rotary current, 3~AC). An example of typical EHV high-voltage component positioning is shown below, as well as a typical block diagram of direct and alternating circuits found within these systems. Please note that universal safety precautions for AC and DC voltages must be followed at all times.

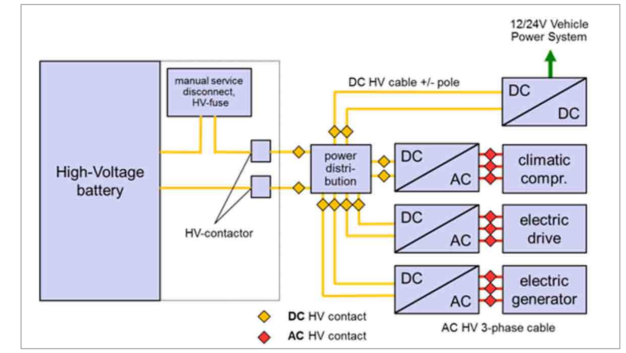

Figure 2: Principal block diagram of onboard direct and alternating circuits

Common Measurement Parameters

Electrical drive energy balance is a key EHV drive system measurement parameter, and particularly, studies of charge and discharge behavior and onboard energy storage device efficiencies, as well as high-voltage batteries and battery cooling systems, both single cell and total systems. Motor, generator and converter load behavior and drive component efficiencies may also be tested. Generally speaking, drive unit testing is typically conducted right on the test bench. A critical requirement is thus voltage and current detection within the direct current grid and if necessary, rotary current. Voltage data acquisition within this environment is conducted directly at the contact measurement point. System current data acquisition can be facilitated either via a shunt resistor to divide the conductor or via a current clamp.

On-road EHV testing calls for considerably greater data acquisition and wiring challenges than stationary applications. Onboard or road test data collection within a typical test track environment subjects instrumentation to higher-than-usual shock and vibration inputs, placing greater mechanical demands upon components and systems. Onboard vehicle testing environments also tend to be more space constrained.

Space limitations and associated added vibration friction risks can chafe improperly installed conductors. Wiring can also be damaged or severed, should it come into contact with sharp-edged vehicle parts. Cables can also be inadvertently crushed or sheared in test, affecting measurement integrity and compromising safety. Finally, risk of damage to components assembled after testing is considerably higher within onboard applications because they were simply not designed with high cross-sections or additional mechanical protection (e.g., protective tubing, wire mesh). If damage to an onboard high-voltage system goes undetected, undesirable consequences, ranging from loss of system functionality to serious personal injury, can result. Thus, use of a highly rugged data acquisition system that can be easily installed and wired within hard-to-reach areas of the vehicle is critical.

Added Safety Considerations

Direct current within EHV drive systems is outputted at much higher levels than typical alternating current. Prolonged exposure can cause thermal damage to the human body, including burns and cell tissue modifications. In addition, the practice of arcing when dividing direct current circuits with high inductivity requires special attention.

IEC 61010-1 also sets forth instrumentation requirements for EHV testing. In addition, stringent safety guidelines are recommended by the European VDE Association for Electrical, Electronic & Information Technologies.

Understanding Risks

A typical high-voltage on-board system design is similar to an IT network. In other words, the onboard system does not have a low ohmic connection to conductive parts, such as a vehicle body or chassis. To avoid risks of electrostatic discharge, both pins are high-ohmically connected to the vehicle mass via a RC-element. Connection security and safety should always be checked prior to working on the vehicle.

As the schematic in figure 3 illus-

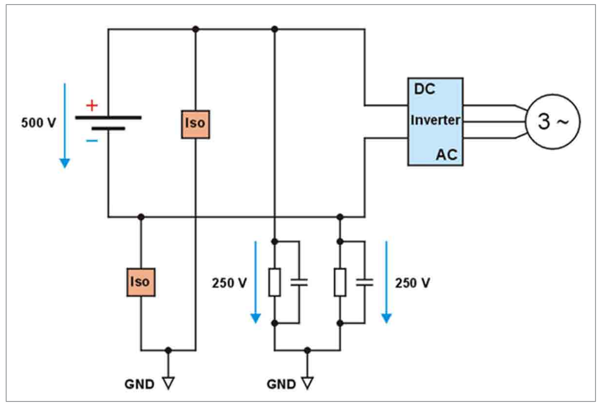

Figure 3

trates, a simple system insulation error (single connection to vehicle mass) poses no potential dangers, provided that no other simultaneous insulation errors occur. To ensure safety, any first insulation errors must be immediately detected and fixed. Within an EHV drive system, vehicle mass is at half-system voltage, or 500V and 250V, meaning that all onboard measurement devices, including data acquisition, absolutely require galvanically isolated insulation to avoid errors and risk of injury.

In addition, suitable measuring cables must also be safely assembled and maintained. Common in-laboratory slotted lines are insufficient for this type of testing. All IPETRONIK high-voltage conductor wires are double insulated with true white core insulation beneath the black or red thin external insulation, allowing for easy detection of minor damages and cable replacement before a potential safety risk can occur. Another protective measure is use of a pre-scaler with the high-voltage cable.

Hardware Requirements

Stringent safety regulations dictate that only IEC category I thru IV measuring devices can be specified to support high-voltage EHV drive testing. The IPETRONIK TÜV-certified high-voltage Iso divider and four-channel high-voltage Iso data acquisition system are authorized for category I applications up to 1000 VDC and category II applications up to 600 VAC, allowing them to meet all high DC-voltage requirements to 1000V. When measuring with current clamps, the current clamp and subsequent measuring system (e.g. multimeter) must also correspond to the appropriate IEC category. The high-voltage Iso divider, compatible with any IPETRONIK measurement system or category I and II application can also be used to safely apply a high-voltage system current clamp. Another alternative is to use the high-voltage Iso data acquisition system, a compact four-channel system with direct CAN output, for safe and effective power balancing at the direct current area.

Converter Circuit Data Acquisitions

EHV AC circuit data acquisitions between frequency converter and drive (motor/generator) are less frequently required, as key data is generally collected on the test bench. AC testing requires use of measuring devices which correspond at a minimum to IEC category III, as they must be able to safely handle surges up to 6000V at a nominal voltage of 600 VAC.

IPETRONIK IPEmotion™ software includes a special hardware plug-in for power analyzers that configures and acquires data real-time, with online calculations of energy and

Figure 4 HV battery view

power balance and user-defined signal scaling and acquisition rate settings. Acquired data can be evaluated with IPEmotion™ or directly converted into data formats and saved for further analyses.

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AUTOMOTIVE LIGHTING

Challenges and solutions for driving and diagnosing LEDs

By Herbert Hopfgartner and Stefan Stoegner

One of the latest automotive design trends is LED lighting. LEDs (Light Emitting Diodes) are used for tail lights, interior lights such as ambient lighting, and LED front lights.

Front light LEDs enable brand recognition beyond the typical car attributes. In addition to the new design possibilities, reliability and reduction of fuel consumption are key arguments for LED instead of bulbs. However, this new light source challenges the car electronics architecture as well as the fault diagnostics, which is required for maintenance, security and legal perspectives. Those challenges and solutions are explained in this article.

The typical body electronics architecture for exterior and interior lighting consists of a body control module (BCM), wires and the light sources as shown in figure 1. The BCM includes communication interfaces (i.e. CAN, LIN), micro controllers, intelligent semiconductor switches, and driver ICs. Control and diagnosis of the loads is realized by integrated semiconductor switches such as Infineon's latest PROFET+ family within the BCM. Usually, the BCM is mounted in the passenger or engine compartment in plastic or partial aluminum housings.

Body electronic architectures supporting LED lamps are very similar, but there is more intelligence required directly at the light source, i.e. the LED. LEDs need to be driven with a constant current. Infineon offers for each application a suitable LED driver:

- *Basic LED Driver: Linear current sources for low to medium brightness LEDs*
- *Power LED Driver: DC/DC converters and controllers for high brightness LEDs*
- *LIN LED Driver: LIN controlled LED driver for RGB or multicolor ambient lighting (under development)*

Today the BCM's tasks are becoming greater, because more electrical functions are established (e.g. ambient lighting) and included within it. Consequently, the physical dimensions of the BCM should not be increased. This conflicts with the required space for additional semiconductor devices but also with the maximum power dissipation. Today there are many car platforms where LEDs are not used for all car variants. Therefore, the BCM should support driving bulbs as well as LEDs, so that only the light source is differing. This requires smart concepts for the diagnostic, which is discussed later in this article.

New light features like AFS (Adaptive Frontlighting Systems) require extensive functionalities and intelligence. They are usually implemented directly in the LED lamp, which is shown in figure 2.

Therefore, in either case, the required PCB (Printed Circuit Board) contains a micro controller and a system basis chip. Thus, the step to an innovative body electronic architecture is not so significant. In other words: All functions like dimming, diagnostics or fail safe actions could be done directly inside

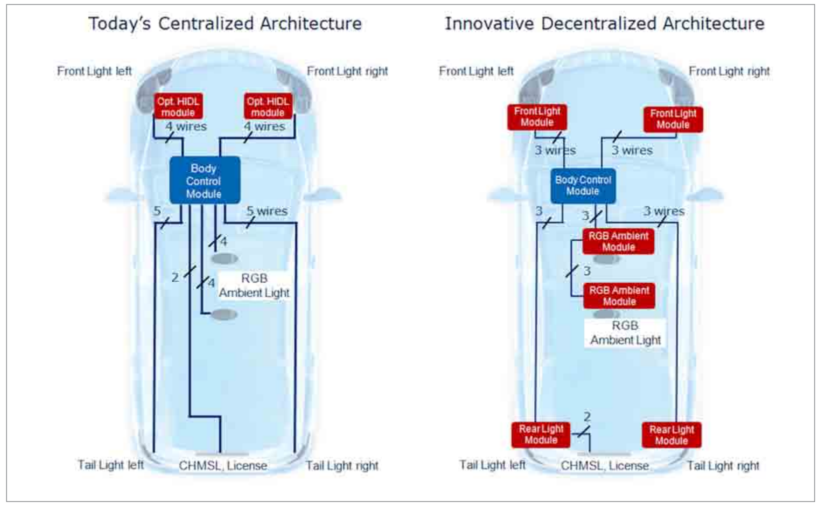

Figure 1: The new innovative body architecture allows a significant wire harness reduction in comparison to today's architecture

the smart decentral lamp module. The intelligence and power of the LED module are increased on one hand, on the other hand the above mentioned BCM limitations are relaxed. E.g. A failing LED would be reported via a bus interface like CAN or LIN to the BCM. Furthermore, another LED could be activated in dimmed mode to replace the failing LED function.

Figure 1 compares today's body architectures to potential innovative decentral architectures mainly supported by LED lamps, because some of the required hardware such as PCB is already present. Smart decentral light modules inside the LED lamp require only a protected supply line and the bus lines as a connection to the BCM. This reduces the cars wire harness. For example: for the left tail light with five light functions, five power wires would be replaced by only one power wire and one or two bus wires (ground connection locally). The new concept reduces wire harness cost but also car weight. Another benefit is that additional diagnostic features can be realized easier, e.g. diagnostics for each LED or LED-chain.

What are the Challenges for the Diagnosis?

Especially in the automotive area it is often required to know the exact load status. This is guaranteed by a quick diagnosis in case of a malfunction and serves the user's convenience and protection. In the following the diagnosis of a LED light-module is described in detail on a decentralized architecture.

Figure 3 shows a possible simplified BCM in connection to a LED module. The protection and diagnosis for the load's status is realized with a micro controller that interprets the sense signal of a PROFET+.

The BCM is usually designed to drive different types of loads with varying current profiles and therefore has to offer flexibility to make the connected load interchangeable. There are several critical cases, which endanger the electronic components or the user's safety.

These are the most common failures of the load-side:

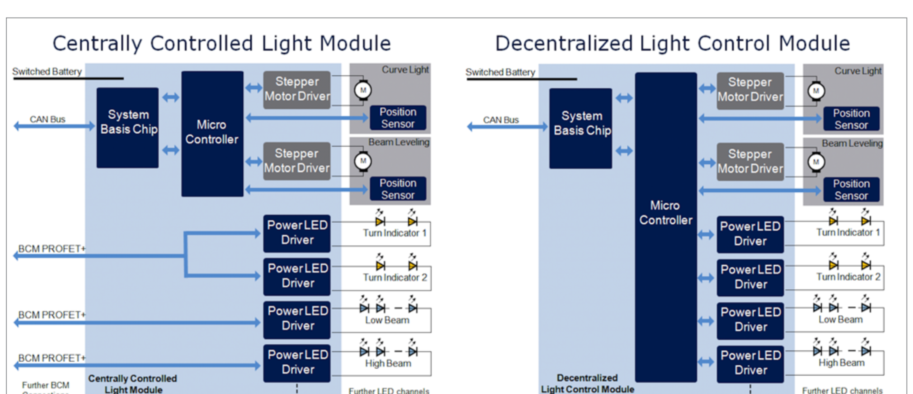

Figure 2: Decentralized light modules allow in comparison to centrally controlled modules a significant reduction of wires

- *Short Circuit: Connection to battery or to ground*
- *Open Load: Failure of the whole LED-module / partial module fail*

A short circuit to battery or ground is a well known issue that is highly safety relevant, if no protection is available. We will not go into more detail for this case as the high short circuit robustness of the latest generation of high-side switch offers good protection, and the diagnosis is now a standard procedure.

The open load scenarios are more challenging for the diagnosis circuits and the micro controllers' interpretation of the signal. Especially if a pure bulb solution is replaced by a LED module after some car facelift or upgrade, the current range changes significantly. While a front light architecture with bulbs uses typically an H1 55W bulb for the low beam (LB) and an indicator (IND) with a P21/27W bulb. Equivalent LED solutions offer a comparable brightness with only 30W or 4W respectively.

Solution	Watts	DC Current
Bulb LB	55W	5A
LED LB	30W	1A
Bulb IND	21W	2.7A
LED IND	4W	0.2A

While the bulb failure causes a difference of several amps and is easy to detect, the LEDs require more accurate diagnosis circuits.

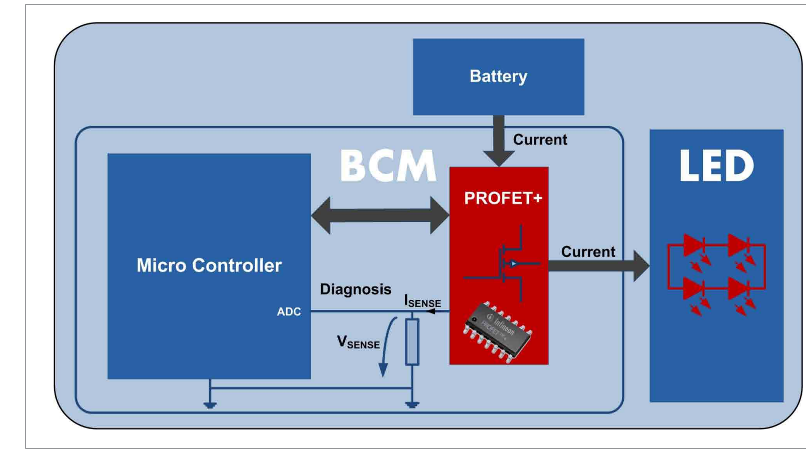

Figure 3: High-side switches like Infineon's PROFET+ family allow in combination with LED drivers an accurate diagnosis modules a significant reduction of wires

How can we realize the diagnosis for LEDs?

As mentioned before, the diagnosis is performed by the micro controller, which receives an analog sense signal (VSENSE) from the PROFET+ and converts it to a digital value for the interpretation through the software. The ISENSE current is proportional to the load current, which is converted to a voltage VSENSE via a sense resistor. Therefore one of the main drivers for the secure load state detection is the accuracy of the sense current from the high-side switch. Infineon's new PROFET+ switches can reach a sense accuracy of up to +/- 5.5% in higher current ranges, which makes them the most accurate devices on the market.

Assuming the complete loss of a LED light function such as the low beam would require a high-side switch sense accuracy of approximately +/- 30%, depending on the sense resistor and ADC accuracy.

However, some light functions are built up of several LED chains (see figure 2, turn indicator), which means a fail of one LED leads to a loss of one chain, while the other chain is still working. This is not detectable by the BCM, because the physical limit of the system accuracy is surpassed. It requires a complete deactivation of the entire light function at the centrally controlled light module or a diagnosis at the decentralized light control module as shown in Figure 2 to make it detectable.

For more information on Infineon Automotive Lighting Products please visit: www.infineon.com/lighting

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EV CHARGING SOLUTIONS: A NEW OUTLET FOR POWER DESIGNERS

By David G. Morrison, Editor, How2Power.com

Over the next few years, the adoption of electric vehicles is expected to accelerate as more consumers across the globe adopt plug-in hybrid electric vehicles (PHEVs) and battery-only electric vehicles (EVs). With their extensive requirements for power management, the development of these plug-in vehicles has already begun to create many opportunities for power electronics engineers in the automotive industry.

However, the arrival of PHEVs and EVs also signals the beginnings of a new industry that is building the energy management infrastructure needed to support these vehicles. This article looks at one component of this infrastructure—the electric vehicle charging station—and how the technical challenges associated with its development will likely create many new opportunities for power electronics engineers and other EEs in the years ahead.

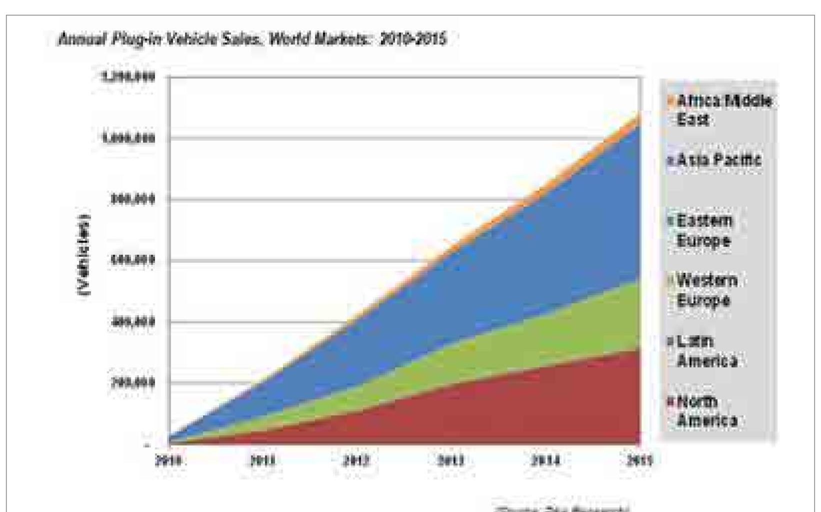

Fig. 1. Unit sales of plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs) is forecast to surpass 1 million vehicles by 2015 with strong growth in North America, Western Europe, and the Asia Pacific region. (Source: Pike Research)

The much anticipated arrival of PHEVs and EVs in the global automotive marketplace has begun and market analysts are predicting a rapid rise in the sales of these "plug-in" vehicles over the next few years. According to Pike Research, annual sales of plug-ins will grow from several thousand last year to over a million vehicles by 2015 (Fig. 1). Although these figures represent a small fraction of the overall number of cars on the road, the trend points toward a more substantial market share and a potentially dominant future for plug-in vehicles.

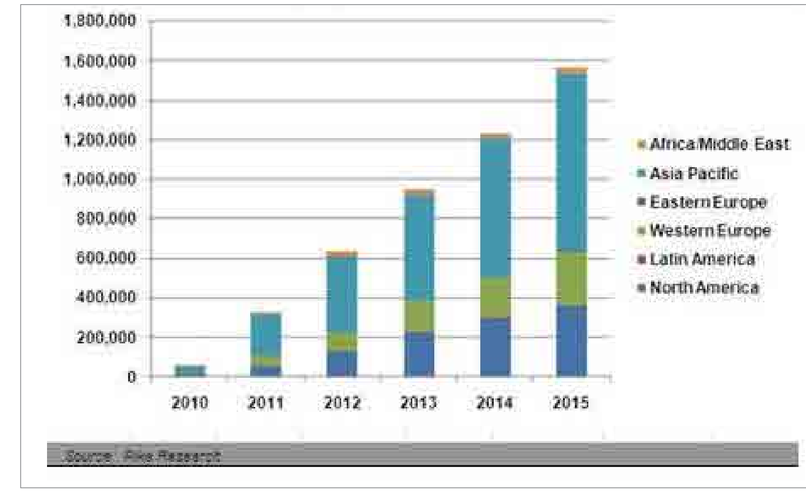

Fig. 2. In the global marketplace, annual unit sales of electric vehicle charging stations, also known as electric vehicle supply equipment or EVSEs, are forecast to rise at a pace similar to that of plug-in vehicles. (Source: Pike Research)

To support the rollout of plug-in vehicles, particularly the EVs, a refueling infrastructure consisting of EV charging stations (EVCSs) is developing (Fig. 2.) These charging stations, which are more formally referred to as electric vehicle supply equipment (or EVSEs), are being created to meet the needs of different residential and commercial environments, with their different requirements for functionality, performance, durability, and price. In terms of performance, a key differentiator for EVSEs is the speed with which they can recharge an EV's batteries.

This charging time is largely determined by the applicable EVSE standards. For example, in North America, the Society of Automotive Engineers (SAE) has established the J-1772 standard, which defines Level 1 charging from a conventional 120-Vac outlet and Level 2 charging from a 208- to 240-Vac source such as would be commonly used to power certain household appliances. In Europe, IEC 61851 defines comparable forms of charging under its Mode 1 and Mode 2 specifications.

Electric vehicles are typically provided with Level 1 capability on board, but the Level 2 chargers afford a much faster charge. As Dan Ciarcia, who is the product manager for GE's EVSE product line in North America, explains, a Level 2 EVSE may recharge an EV's batteries in less than one third the time required with a Level 1 EVSE. "A full charge of a 24-kWh battery can be reduced from 18 hours on a Level 1 charger to 4 to 8 hours on a Level 2 charger," says Ciarcia.

Then, there are the so-called Level 3 chargers, which charge EV batteries in still less time. John Gartner, a market analyst at Pike Research, notes that the level 3 terminology is used loosely in industry to refer to any equipment that charges batteries faster than Levels 1 or 2. This encompasses dc fast charging such as that defined by the CHAdeMO standard, which has been adopted by Japanese automakers. Just as an example, a CHAdeMO-compliant dc fast charger can bring the Nissan Leaf's 24-kWh battery up to 80% charge in approximately 30 minutes.

Although supported by some EVSE manufacturers, ChAdeMO has not been adopted by U.S. car makers. In the U.S., the SAE is said to be developing a standard for dc fast charging that is not expected to be compatible with ChAdeMO. So, there will likely be two fast-charge standards supported in America to accommodate the early lead from Japanese suppliers, plus the proposed SAE standard.
The situation is even murkier in Europe. Although not all European auto makers support ChAdeMO, it has been adopted by Citroen and

Peugeot, which are highly visible brands with serious sales numbers.

Currently, CHAdeMO and multiple other proposed fast charge standards are vying for acceptance in Europe, where it's typical for individual automakers (dominated by France, Germany and Italy) to drive their own country specifications. Navigating the various standards and satisfying their diverse requirements will no doubt add to the burdens of EVSE product development.

However the standards competition plays out, dc fast charging technology is considered crucial to the success of EVs in the marketplace as it offers convenience on par with filling the gas tank of a conventional internal-combustion-engine vehicle. And among EVSEs, dc fast chargers represent the product category that poses the greatest design challenges and opportunities for power electronics engineers.

But before looking at some of the specific issues faced in fast charger design, let's consider some of the issues facing developers of Level 1 and 2 EVSEs as many of these issues will be common to the development of all charging stations.

EVSE Design Challenges

Although the terms electric vehicle supply equipment and electric vehicle charging station are often used interchangeably, the latter term may be somewhat misleading since the actual battery charger is typically inside the vehicle.

"As the EVSE provider, we're responsible for delivering electricity to the vehicle. The vehicle is really a master that dictates how much energy it wants, and makes that request through communications to our charging station," says Ciarcia.

Or as Mike Calise, the director of Electric Vehicle Business for the Power Business at Schneider Electric North America, explains about EVSEs, "The products needed to deliver safe and reliable power to an electric vehicle are really power distribution products."

This underlying power distribution technology is mature, consisting of well-known components such as contactors, connectors, fuses, and ground fault interrupters (GFIs). Nevertheless, given the voltage levels present in Level 2 chargers and especially dc fast chargers, requirements for UL compliance and user safety still pose power design challenges.

Calise illustrates this point with an extreme scenario. "Although the industry doesn't promote this, a child should safely be able to pick up the charger plug in a rain storm, plug it into a vehicle, and be 100% safe," says Calise. As a result, implementation of ground fault interruption, surge suppression, and thermal management become the main power design challenges, according to Calise.

But power distribution circuitry is only part of the EVSE design. There are numerous energy management issues which call for control and monitoring features within the EVSE, and in certain applications, communications capabilities between the charger and the vehicle and between the charger and host systems belonging to the charging station owner or the utility. These issues will not only affect hardware and software design in the EVSE, but also impact the requirements for electrical distribution equipment upstream of the charging station. Plus, there are user interface and environmental issues that affect EVSE display design, and mechanical design of the enclosure.

The energy management issues add power electronics complexity to even Level 2 chargers as Calise describes.

"Ultimately, people are interested in wired or wireless control of on/off switching at the circuit level. For example, let's say you're allowed to charge your car at night and in the morning, but we don't want you charging during peak hours because that's when we have the highest loads and the highest rates. So you have timing elements and remote controlled switching elements which allow the power to be switched on or off during certain given time sequences... or where you govern the power down and allow it to charge at a lower rate. Some higher-end EV auto manufactures may have this feature built into their vehicles, but not all EVs do, so it's always worth having this capability in your EVSE and it's a very small cost adder."

As more and more EVSEs are deployed, energy management issues will abound as both utilities and charging station owners address load balancing issues. This will include not only managing the energy delivered to the EVs to keep down charging costs, but eventually vehicle-to-grid power delivery. Plus, there will be energy management issues associated with using renewable energy systems to charge EVSEs, and tying both in with the grid. All of these advanced energy management capabilities will involve implementation of Smart Grid functionality, which should create further opportunities for power electronics engineers.

To read more about the technical issues power electronics engineers must address in the development of electric vehicle charging stations, read "Fast DC Chargers Pose Industrial Strength-Design Challenges" in the online version of this article, where you'll also find a list of EV charging station manufacturers.

www.how2power.com

About the Author

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

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GREEN AUTOS?

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

The automotive market is not normally an area that one would associate with green issues; big cars burning gas and puffing out toxic fumes. But the imminent hopeful proliferation of EVs and HEVs in design, development and production by auto makers plus the popularity of the Toyota Prius here in the U.S. hopefully marked the start of a new way of thinking as to what we want to drive.

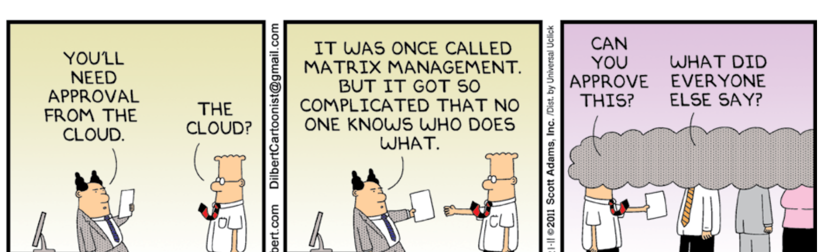
The LED lighting market will be helped along by the adoption of these energy saving devices by the automotive manufacturers. The LED driver ICs market grew 26% in 2010 to reach $1 billion, according to IMS Research. Macroblock Inc (3527:TT) was the only top 5 supplier who exceeded this growth, increasing its revenue share to 6%. Ranked 9th in 2006, they have made significant strides within the signage segment and are the 3rd ranked supplier in 2010. Texas Instruments Inc remained the dominant supplier, with 17% of the market, in 2010. With the acquisition of National Semiconductor Corp not expected to close until late 2011, they remain separate entities until then.

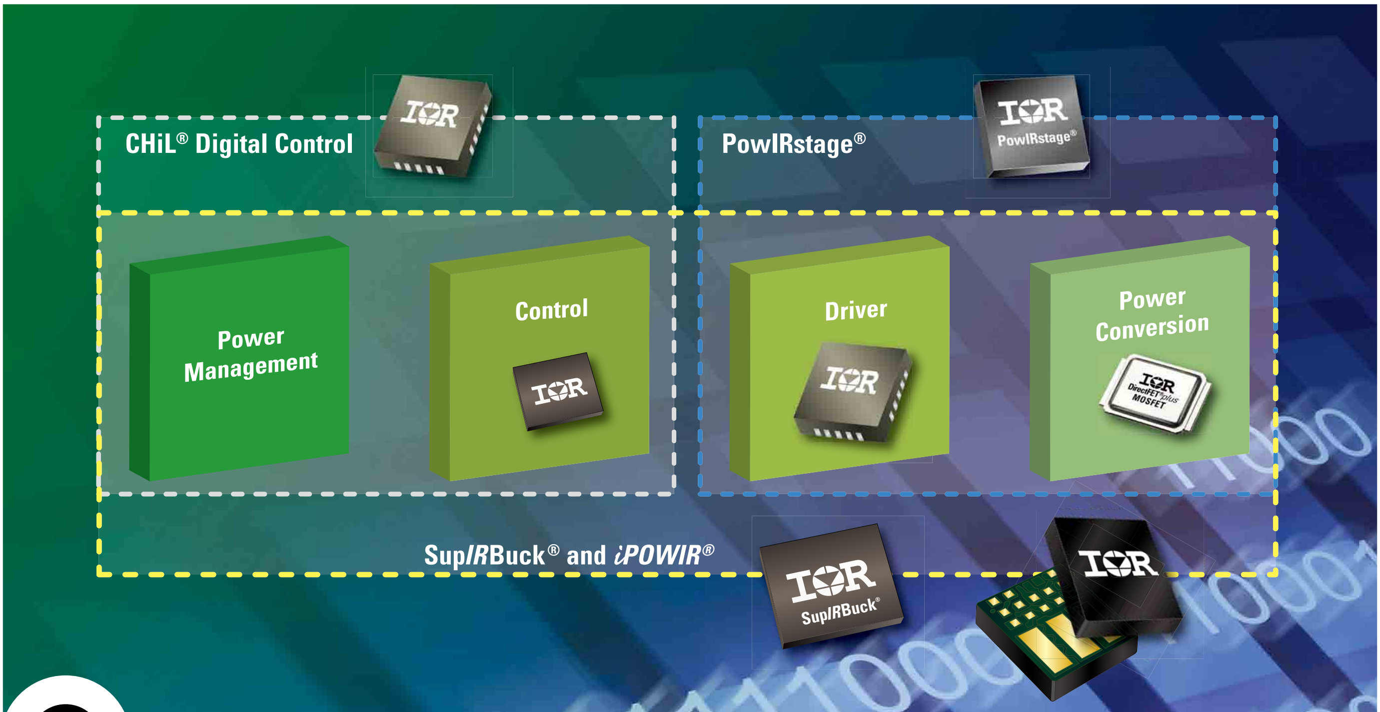
Two UTC Power fuel cells installed at a Coca-Cola Refreshments plant in East Hartford, Conn., and unveiled during a dedication ceremony are the latest additions to the company's commitment to green innovation. The fuel cells represent one of the cleanest energy-generation sources available in the world today, and it is claimed will enable the company to reduce its energy use by 30%. They are expected to provide 100% of the electricity and 50% of the heat required to operate the East Hartford facility.

Following 2010's massive increase, the global PV inverter market is predicted to decline below $6bn in 2011, a fall of more than 10% according to a new report from IMS Research which revealed a very mixed outlook for the PV inverter industry this year. Installations are predicted to grow by 16% in 2011, driven by demand in the Americas and Asia, however shipments of PV inverters will in fact fall by around 5% due to oversupply into the market towards the end of 2010.

The potential energy and pollution savings by the adoption of these new power electronics systems, especially with the advent of production EVs and HEVs, will give us all a greener environment, of which we should be hopeful, grateful and proud. Power engineering will always be at the heart of this bright new future.

www.powersystemsdesign.com





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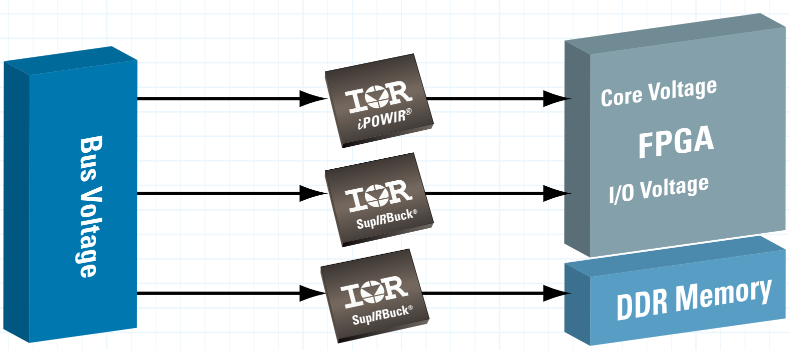

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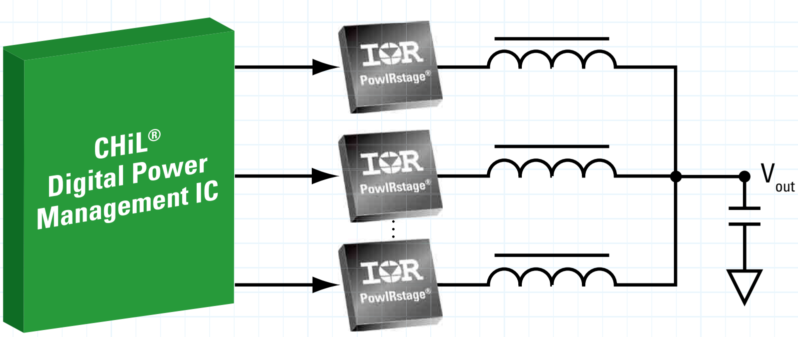

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