WHITE PAPER

The Power Dilemma for the Next Generation of Automobiles

Robert Gendron
Vice President
Vicor Product Marketing

Electric, hybrid electric, driver assistance systems and infotainment are creating new power demands for automotive manufacturers. These demands are changing the way car makers are approaching power distribution within vehicles and how they deal with anticipated power needs.

Early cars had very few electronics compared to cars today. In the 50's, Chrysler introduced the first all-transistor radio. Audio systems and many other basic electrical devices had simple, relatively low power requirements, all of which could be served by the 12V battery. And 12V has served the automotive industry well for decades.

However, due to more advanced semiconductor processes, the internet-of-things (IoT), neural networks and smart technologies, this once mundane field is turning into a more dynamic area of interest. Electrical requirements have surged with autonomous vehicles, enhanced headlamps and scores of cabin features enabled by custom ASICs and GPUs. Automotive power requirements are now well beyond the capabilities of a traditional 12V power system.

The expanding family of battery and hybrid electric vehicles

Electric vehicles are making headway in the automotive market with promising benefits. They promote sustainable energy, cutting our dependence on fossil fuels through an electric motor interfaced by an inverter to a high-voltage battery. Instead of relying on fuels that are detrimental to the environment, energy can be harvested from various sources.

Electric vehicles

A pure electric vehicle is any car that derives its power and torque solely from a battery and electric motor. Popular examples are the Tesla Model S and Rimac Concept One. But if the internal combustion engine is retained, with the battery serving an adjunct purpose to the overall system, then the vehicle becomes a hybrid.

Hybrid vehicles

There are many kinds of hybrid vehicles, depending on the number of functions they support. Plug-in and full hybrids exhibit an idle stop / start feature, torque assistance, energy recuperation and an electric driving mode.

When in electric driving mode (i.e., the electric motor is doing all the work like a pure EV), a battery with large energy capacity is required. High energy density batteries and motors perform better on a vehicle when configured as a high-voltage system.

Mild & micro-hybrid vehicles

Mild hybrids do not have this mode. Their battery energy storage is smaller with lower power requirements, from 10 to 30kW peak bidirectional power. This enables battery voltages that are considerably lower, ranging from 48 to 300V. And a micro-hybrid cannot contribute torque at all, bringing down the battery voltage to the common 12V bus. To provide improvements in fuel efficiency and vehicle drivability, hybrids have many electrical components added that either replace or augment the functions of traditional automotive systems: the engine oil and vacuum pumps, transmission oil and coolant pumps, air conditioning compressors and cabin climate-control heaters. These additional electrical components are difficult to accommodate with a 12V standard bus voltage. The counterpart electric a/c compressor and electrically-heated catalytic converter themselves already draw a substantial 10kW load together, which is quite a hefty encumbrance to the overall power budget.

Advanced driver-assistance systems are coming of age

Driverless cars, or cars fitted with advanced driver assistance systems (ADAS) require a new level of power. These cars need to incorporate a myriad of features for safety and convenience, as well as a variety of sensors interfaced to a machine-learned (artificial intelligence) system that guide the vehicle to its destination.

Furthermore, the IoT has enabled diverse systems to communicate with other systems and transfer data to and from ADAS. Cars can transmit data on operating status and vehicular metrics, including those pooled by the machine-learned system, to an intelligent receiver via surrounding objects like traffic lights and other cars. The receiver processes the data and delivers useful information, such as optimum traffic routes for fuel efficiency or preferred driving routes based on tendencies.

Powering the plethora of devices and components that make up this system is an arduous endeavor. Multimedia interfaces, combined with a multitude of cameras and detectors, consume significant portions of delivered power collectively. The DSPs and CPUs, which consume much more power than the sensors and detectors, are distributed throughout the vehicle because they are embedded in their desired application. Thus, cabling and power delivery to these become a challenge to the automotive designer.

Electronic power demands continue to mount in the areas of safety and security. This is to be expected from any nascent technology that is still finding its feet in a real-world environment. Therefore, you can anticipate future shortfalls in power allocation if no action is taken towards system efficiency.

In-vehicle infotainment systems proliferate and innovate

The automotive industry is also finding innovative ways to pack more electronic devices into a vehicle that cater to on-demand user applications, mostly for in-car entertainment and convenience. Such devices are typically controlled by nexus CPUs in the head unit (HU) of an infotainment network system. A suitable automotive communications protocol connects the HU to several electric control units (ECUs). CAN, SAEJ1850, UBP (for UART support), ISO9141 (for domestic ports), J1939 (for real time closed loop control functions), TTP/C, LIN, Volcano (TTP on CAN), Byteflight and Flexray (both for safety critical applications) and TTCAN are examples of such protocols.

An automotive infotainment system may consist of interactive audio and video, bidirectional communication tools, satellite and Bluetooth® radio, rear displays, noise cancellation, navigation, and vehicle voice commands to name a few. With all of these services and features, power demands incrementally increase.

More demand, more power

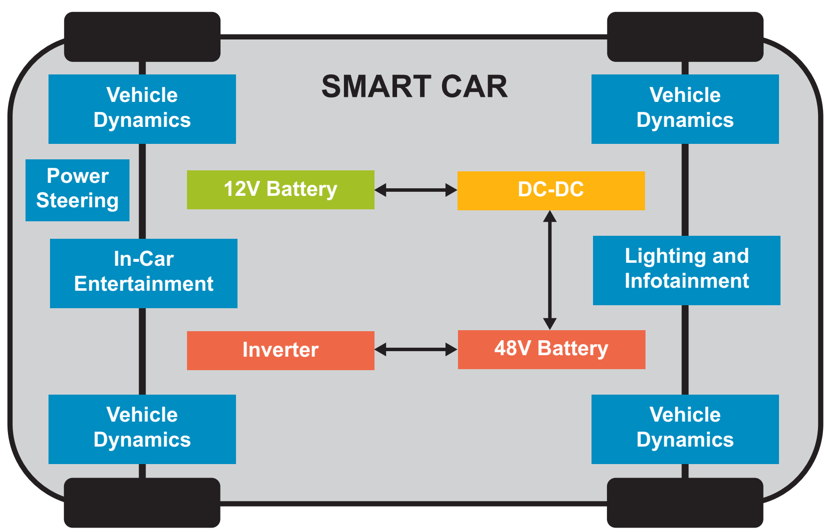
Emerging integrated electronic systems for vehicles draw substantial power. As the requirement for power accrues, it becomes apparent that the pre-existing standard 12V bus will no longer be a tenable option. Thus, designers are compelled to find a more effective solution to address this growing demand. One solution for the hybrid-electric vehicle is to explore 48V power, which in its infancy was used in early telephony applications. Today 48V is used in a variety of new applications and automotive is seeing the utility as well.

But how does the 48V bus equate to more power?

The answer hinges on "the cost of current". Transmitting high currents in an automobile is costly both because of the direct cost of copper and high current-connector materials, as well as the indirect cost of the added weight of conductors. By raising the nominal bus voltage for a given load power, the current required by that load power is directly decreased.

For example, a bus designed to carry 10A can provide 120W to 12V loads in a traditional vehicle. If the bus voltage were stepped up to 48V, the current demand of those same 120W loads would decrease in magnitude by an order equal to the ratio of the new and old bus voltages (i.e., 48V/12V = 4). Hence, the bus could be redesigned to use 1/16th of the copper and 1/16th of the weight, and power that same load with the same wiring distribution loss. This entails significant advantages to manufacturers with a miserly budget. Conversely, with the increasing load demands of today's vehicles, the same 10A bus could be used to effectively distribute 480W for a 48V system.

This solution does not completely replace the pre-existing standard 12V bus. It can coexist, serving as a complement to it. Why? Because of backward compatibility with electronics accustomed to a 12V architecture. In effect, the outputs of the DC-DC converters are still at 12V, and require an excess of intermediate power converters to satisfy the specific power rails of the connected electronics.



Take for example one of the head unit's CPUs that enhances in-cabin computer vision and deep learning for advanced self-piloted driving / digital cockpit systems. A central processing unit normally has a very low-input voltage range (~1V), so an additional step-down/buck converter is added from the 12V bus to the input of the CPU. This extra component is an additive to manufacturing cost and power consumption. Therefore, it would be a significant plus if the 48V bus line could be directly transformed to the required 1V input required by the CPU.

48V direct conversion boosts efficiency

The key to boosting efficiency is through a series of point-of-load (PoL) converters that remove the need for an additional buck converter, meeting the input voltage requirements of the CPU. A PoL converter is a DC-DC converter with an output voltage regulated particularly for the load (hence the term). It does the conversion with a single stage while maintaining a competitive set of electrical specifications comparable to its two-stage counterpart.

There are challenges to designing a PoL converter with a 48V input and 1V output, the most prominent being the wide voltage gap. Increasing the potential between input and output makes optimizing efficiency difficult. Ripple rejection and spike noise become harder to suppress as well.

Today 48V is used in a variety of new applications and automotive is seeing the utility as well.

Such challenges can be overcome with Vicor non-isolated regulator systems, offering world-class density and efficiency. For low power loads, zero voltage switching (ZVS) Buck and Buck-Boost converters are the way to go. But for higher currents and power loads similar to the previously mentioned CPU application, the Vicor factorized power architecture, which makes use of PRM buck-boost regulators and VTM current multipliers, is an efficient solution.

Aside from the header unit, savings can also be achieved in other parts of an infotainment system.

Power estimates for the electronics customarily found in infotainment system

Component	Power Cost
Header unit CPU and GPU for real-time communication (infotainment gateway) and user-interface applications (ex. 4x Qualcomm Krait 300 and Qualcomm Adreno 320)	~400 to 500W
Audio System (premium)	~250W
DSP (ex. Qualcomm Hexagon)	~100W
Flexible three-display concurrency (1080p60 center console + 720p60 navigation window for instrument cluster + 540p60 HUD)	~80 to 120W
Wi-fi (ex. Qualcomm VIVE 1-stream 802.11n/ac with MU-MIMO)	~20W

Note: Infotainment system components vary per car model /manufacturer. Electronics with inappreciable energy expenditures have been left out (ex., Bluetooth 4.1/Low Power, memory and storage, etc.).

Based on the table, power expenses total to approximately 1kW, with the audio system and header unit being major constituents. For a traditional 12V system only, this represents roughly 84A of load current. Using direct conversion for all components at 48V, the total current can plummet to 21A assuming constant design factors for the buck converter. This figure has the potential to decrease even further when the loads can be redesigned to accept higher input voltages.

If this infotainment system were to be installed in a mild-hybrid EV, the power allocation would have been around 10% given a 10kW power input. With the new 48V bus and single-stage conversion, the power allocation drops to 2.5%, providing much more room for additional components.

Traction power necessitates innovative power solutions

When dealing with higher voltages, like those in a full-hybrid or plug-in EV, voltage regulation and isolation become crucial elements in the power design. Consider the voltage of a lithium-ion battery, which can shift by as much as 30% during charge / discharge cycles, plus additional transients due to powertrain loading. The converter must be flexible enough to handle this voltage swing at its input, without sacrificing power density and efficiency. Furthermore, these higher voltages which are used to store energy for traction purposes require an efficient powertrain. The voltage must be stepped down whilst providing input / output isolation, which can come at the expense of both density and efficiency.

However, when distributing power to a high mix of sub-systems (infotainment, controls, in-cabin lighting) in mild-hybrid EVs, isolation is not necessary and thus a mix of 48 and 12V distribution can be used to lower the overall system weight compared to 12V only system. This hybrid power architecture requires a converter with a small package and high efficiency in order not to lose the advantages gained. The 2317 NBM is 23 x 17 x 7.4mm in a surface-mount package and is capable of bidirectional power conversion between 12 and 48V at over 98% peak efficiency. This non-isolated, fixed-ratio converter enables the optimal mix of 48 and 12V subsystems to help maximize fuel efficiency and power a broad range of subsystems running off of either 12 or 48V. High-efficiency power sharing between 12 and 48V energy storage technologies can also be realized using the bidirectional power conversion capability of the NBM.

Automotive trends point to a 48V solution

Statistics show a steady increase in market demand for electric vehicles, ADAS and in-car entertainment systems. This demand is driving power increases and 12V supply cannot sufficiently deliver what is needed. The number of sensors, CPUs and GPUs embedded in vehicles continues to escalate. This makes the migration to 48V a logical choice for power-hungry automotive applications.

Vicor offers new, highly efficient solutions for the rapidly changing automotive industry. EVs, mild hybrids and micro hybrids are changing the power landscape present in the latest vehicles. Vicor has flexible power components not only deliver more power, their innovative architectures deliver positive returns when total cost of ownership is calculated. As a leader in 48V solutions, Vicor not only makes innovation possible, it also makes it more energy efficient and cost effective.

Contact Us: http://www.vicorpower.com/contact-us

Vicor Corporation
25 Frontage Road
Andover, MA, USA 01810
Tel: 800-735-6200
Fax: 978-475-6715
www.vicorpower.com

email
Customer Service: custserv@vicorpower.com
Technical Support: apps@vicorpower.com