WHITE PAPER

Meeting the Power Demands of Battery Supplied Automotive Electronics

Garden variety DC-DC Regulators aren't keeping pace with the evolution of automotive electronics and accessories

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Have you driven a new automobile recently? It can be an almost futuristic experience, with sophisticated gauges, touch screens, connected entertainment systems, and lighting - all of which need power. Behind all these electronics are battery regulators and battery chargers that manage the power both into and out of 12V, 24V and 48V batteries. Each year the 'must have' list of supported accessories and electronic systems grows with the expectation that the size, weight and number of supporting power components will keep pace with the increased power demands.

The emergence of 48V in automotive power

Automobile electronics consume a lot of power, and in an effort to keep up with these demands, many newer vehicles are equipped with dual battery systems comprised of traditional lead acid 12V batteries and 48V Lithium Ion batteries. Already popular in Europe, "micro" and "mild" hybrids are gaining momentum worldwide, including the U.S. market. Micro and mild hybrid vehicles use 12V batteries and 48V Li-ion batteries. These dual battery vehicles shutdown the engine when the vehicle comes to a stop, and restart it when the driver depresses the clutch or steps on the gas pedal. This automatic stop/start feature has been shown to improve fuel economy between 5-10%. In these systems, the 12V or 24V lead-acid battery supports cranking and all the typical electronics in traditional automobiles, like the dashboard, entertainment systems, and headlights, etc. The 48V Li-ion battery supplies power to the high-load systems like AC compressors and active chassis systems, which may include steering, regenerative braking and stability management. As seen in Figure 1, dual battery approaches rely on different battery technologies operating at different voltages to complement each other. This results in the need for line regulators that can accept wide input voltages and can switch between buck (step down) and boost (step up) modes while providing a stable regulated output.

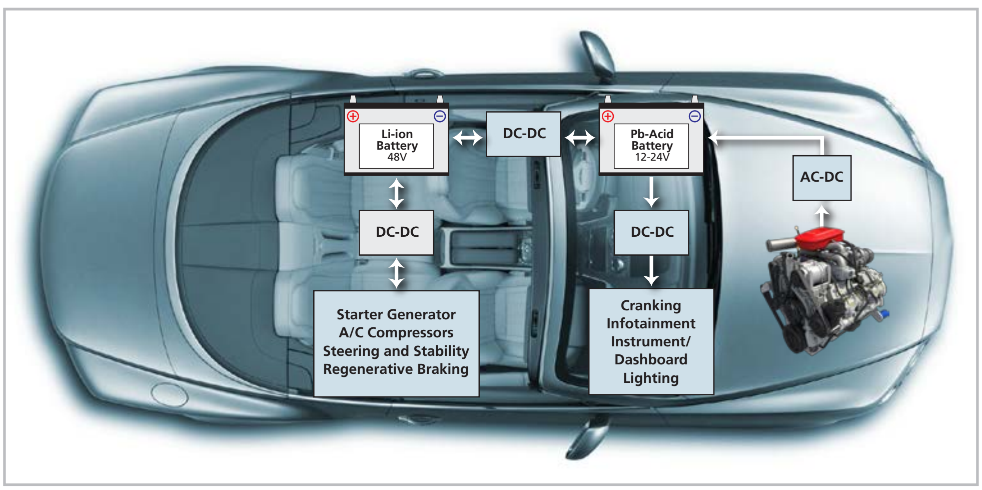


Figure 1
Generalized mild-hybrid dual battery architecture

Some would argue that the dual battery mixed voltage system is only a stepping stone to full 48V automotive systems. In the next 5-10 years, 48V electronics will begin displacing the traditional 12V rail for automotive electronics. During this transition, there will be an increased need for power components that can support legacy 12V systems and 48V systems of the future.

Versatility needed for DC-DC battery regulation and charging

DC-DC regulation and charging in battery supplied automotive applications and accessories have their own set of unique requirements and challenges. By their nature, battery supplied voltages vary widely over temperature, load, and state-of-charge (SOC). These wide voltage swings require a very flexible DC-DC regulator that can automatically and seamlessly transition between buck and boost modes.

For example, during regular use a typical 12V automotive battery output voltage can range from 8V-16.5V. See Voltage vs. SOC curves in Figures 2 and 3[a]. Voltage swings are further exacerbated by cold temperature or when measured on aged batteries. The line regulator must also contend with batteries which are charged from alternators and must be ready for load dump scenarios that produce large inductive voltage transients.

If unchecked, these voltage spikes can be as high as 120V and clamp circuits are required to keep these load dump voltages at or below 40V in 12V batteries and 60V in 24V systems. These wide input swings, which can be as high as 60V, are too much for many regulators and most will stop regulating when their input exceeds 36V. Very few solutions have the ability to manage voltage swings over the entire input range of 8V-60V while maintaining a stable regulated output during real world conditions.

Figure 2
Voltage vs. SOC charge

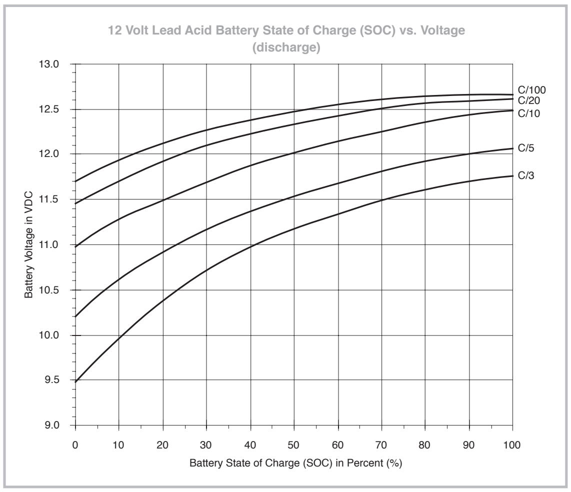
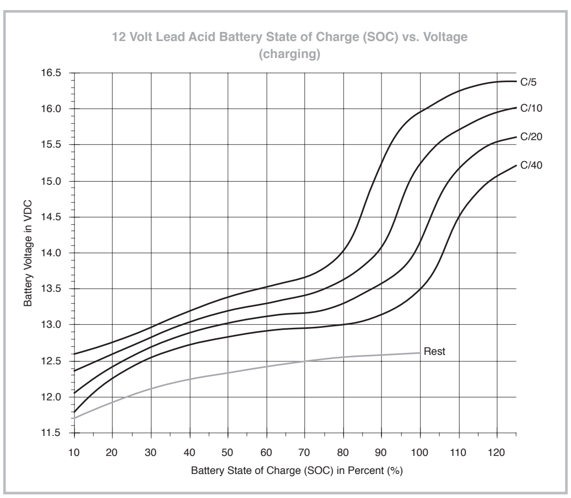


Figure 3
Voltage vs. SOC discharge



Battery regulators should support constant current and constant voltage

As a rule, load regulators are expected to provide stable load regulation with enough bandwidth to quickly adjust for load transients. When employed in a battery supplied system, there is the additional need to recharge the battery. To support both load regulation and battery charging, the regulator should also have the ability to switch between traditional voltage priority and current priority regulation modes. A regulator with the ability to switch back and forth between constant current/constant voltage (CC/CV) modes is needed to implement a typical CC/CV scheme used for charging batteries. Regulators with this capability eliminate the need for an additional dedicated regulator for battery charging.

The ability to support voltage priority and current priority with a single regulator allows one device to recharge a battery, pre-charge/recharge a large hold up capacitor, or regulate the load. As more electronics find their way into vehicles via the automotive accessory market, there's a growing need for versatile regulators which support battery charging schemes.

Uniform efficiency across line input range simplifies the system design

Next generation buck-boost regulators can also surpass traditional regulators by improving efficiency over a wide input range. At first glance, the importance of gaining just a few percentage points increase in regulator efficiency may not be obvious, but when put in context of the application it really matters. To be clear, efficiency has always mattered, even in relatively low power applications like battery operated mobile devices where efficiency equates to longer battery life. In higher power applications (greater than 50W) this is still true. An important characteristic to look at when judging a buck-boost regulator's performance is the flatness of the efficiency curve across the entire line input range. Many regulators tout high efficiency over a narrow range, which is ok for applications with a fairly stable input voltage. However, when regulating a battery's wide variations, the flatness of the regulator efficiency curve should be scrutinized more closely. The benefit of uniform line in efficiency is that it simplifies the thermal design, allowing the system designer to plan for a uniform heat load across the entire operating range.

The impact of efficiency on thermal design and costs

Conversion efficiency directly impacts thermal design and the reliability of the system, which in turn impacts the total system cost. The new generation of DC-DC regulators can easily enable a 2-3 point efficiency improvement compared to conventional DC-DC regulators. A 2-3 percent improvement in efficiency equates to 2-6W of power saved in a 100W-200W automotive application. At full load, this results in 2-6W less heat that must be removed from the system. These incremental improvements in efficiency also expand the thermal margin in the system. This margin enables full power delivery over a wider temperature range while lowering the associated cooling costs and providing a more robust design. Additionally, higher efficiency power conversion reduces demand on the source generator per unit of energy supplied to the load or supplied to recharge the battery.

Small size and light weight enable better solutions

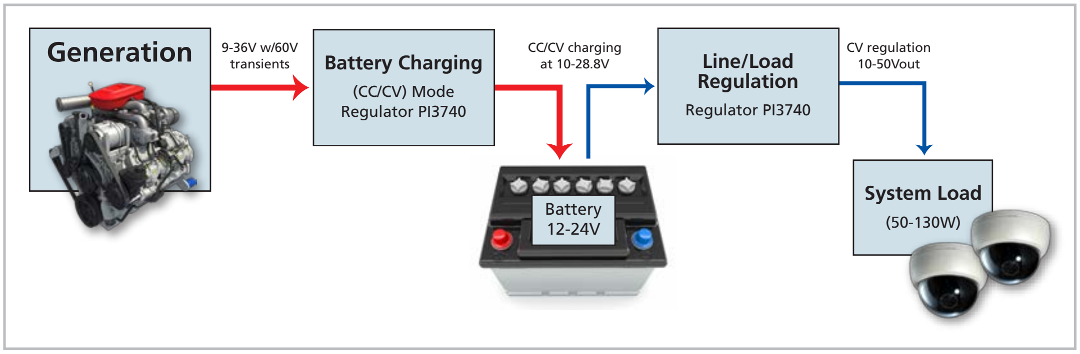
Size, power density and the need for higher efficiency solutions are still top priorities. In automotive battery powered applications, manufactures are being pressed for higher fuel economies, while consumers want more in-cabin electronics. But as the total number of in-cabin electronics steadily increases, the available cabin space remains fairly static. Finding space for regulators to support these additional electronics is difficult. Furthermore, the need for lightweight solutions is essential to meet vehicle weight targets and fuel economy standards.

As automotive accessories are upgraded, system designers are challenged to increase rated power capability without increasing the space allotted for the regulator, driving demand for light weight, power dense solutions that can support greater loads in the same or smaller footprint than legacy solutions. The new generation of buck-boost regulators addresses this need by increasing the switching frequencies at which they operate. Higher switching frequency allows for smaller energy storage and passive components, like the power inductor and associated filtering capacitors. Smaller power components and filtering elements help to reduce space and allow for higher power densities.

The Next Generation Buck-Boost Regulator

Dual battery automobile systems have become commonplace and are fueling the demand for new battery supplied DC-DC conversion solutions – a need that's compounded by the continued proliferation of aftermarket electronics including audio/video entertainment, navigation, and video surveillance systems, the latter of which are increasingly being added to public buses, delivery vehicles and taxis (Refer to Figure 4).

Figure 4
Power chain for automotive digital video recording system



Today's auto accessories require a new generation of buck boost regulators that are capable of wide input line regulation, and can provide both voltage and current priority regulation as part of a battery charging solution. With the ability to support both charging and regulation at high efficiency across the line input range, system designers can simplify their BOM and use a single DC-DC regulator to support multiple product designs.

Versatility is essential for a fast-changing automotive market

The number and variety of automobile electronics and accessories is growing, fueling the need for more advanced power components to support these electronics. These systems rely on multiple battery chemistries and can operate at different voltages, creating the need for a new generation of DC-DC regulators which can support both 12V and 48V systems. Flexibility, size, density and efficiency are some of the important characteristics that require careful consideration when choosing a power solution for today and tomorrow's evolving automobile.

Learn more

Vicor Corporation has an extensive family of buck and buck-boost regulators that can meet the wide demands of automotive and many other industrial applications.

[a] Figure 1 and 2 from Lead-Acid Battery State of Charge vs. Voltage
http://www.scubaengineer.com/documents/lead_acid_battery_charging_graphs.pdf