# Rethinking Power Delivery for Evolving EV System Architectures

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Electric vehicles continue to improve in efficiency, driving increased electrical complexity. Most platforms still retain a legacy 12 V auxiliary battery, originally intended to support systems in internal combustion engine vehicles. As EV architectures adopt higher bus voltages for traction inverters, always connected functionality, zonal electrical distribution, and a growing number of ancillary systems, the suitability of the traditional 12 V auxiliary battery is increasingly being questioned.

This paper examines the architectural role of the 12 V auxiliary battery in modern EVs, outlining the technical, safety, and system-level reasons for its continued use, while also highlighting its inherent limitations. As ancillary loads shift from intermittent to continuous operation, standby efficiency, functional safety coverage, and system reliability become dominant design considerations—exposing the drawbacks of conventional auxiliary battery approaches.

The paper then explores what is required to eliminate the 12 V battery entirely, defining the electrical and safety demands placed on a replacement power architecture. In this context, highly integrated micro-DC-DC (µDC-DC) converters are introduced as a viable alternative, capable of supplying low-voltage domains directly from the high-voltage battery stack during normal operation, standby, and fault conditions.

By leveraging wide bandgap devices, planar magnetics, and scalable flyback based topologies, µDC DC architectures can support wide-input-voltage operation and cost effectively deliver high efficiency across load conditions. They also enable ultra low standby power consumption, compact size, and a path to parallel, redundant power stages. These characteristics align well with next generation EV architectures, including zonal distribution and battery less auxiliary power strategies.

Ultimately, eliminating the 12 V auxiliary battery represents a shift in responsibility rather than simply removing a component. This paper positions µDC DC centric power architectures as a practical and technically credible path forward, while highlighting the design considerations required to ensure safety, reliability, and overall vehicle efficiency.

## Eliminating the 12 V Auxiliary Battery in Electric Vehicles: Architecture, Challenges, and Design Considerations

The continuous advancement of lithium ion battery technology has given electric vehicles longer driving range, faster acceleration, and higher power output than ever before. These improvements are largely driven by higher energy density cells, increased traction battery voltages, and more efficient power electronics—enabling modern EV platforms to rival or exceed the performance of internal combustion engine (ICE) vehicles.

Yet, most EVs on the road today still rely on a 12 V lead acid battery to provide standby power. This auxiliary battery supplies low voltage subsystems when the traction battery is inactive or isolated—an architectural carryover from legacy vehicle designs that predates electric drivetrains.


**Figure 1 – 12 V lead acid battery**

## The Legacy of Lead-Acid Batteries

Inexpensive and dependable, lead acid batteries have been used for more than 100 years, including in early electric vehicles in the 1890s.

Their ability to deliver high peak currents, tolerate abuse, and operate over wide temperature ranges made them well suited for automotive applications long before the emergence of modern power electronics. They provide the high current—up to 500 APK in cold conditions for up to 5 seconds—needed to start an internal combustion engine. In addition to engine starting, the entire low voltage electrical architecture of ICE vehicles was designed to be powered by the 12 V battery when the engine is off. As a result, vehicle lighting, body electronics, control modules, and safety systems have long been optimized around a 12 V supply.

As the automotive industry transitioned from ICE vehicles to hybrid and plug in hybrid platforms, the need to start a combustion engine remained—driving the continued use of the lead acid auxiliary battery.

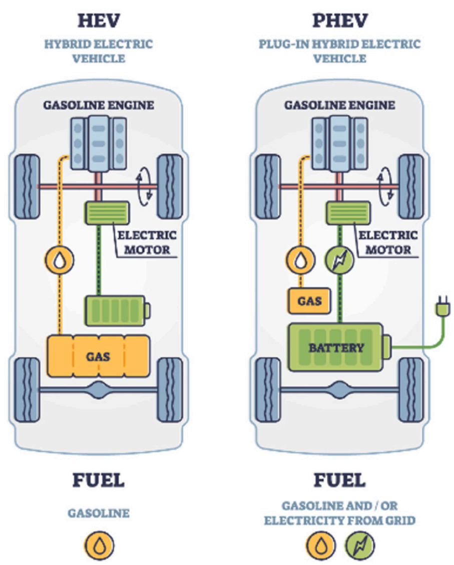


**Figure 2 – HEV and PHEV power architectures**

## What About Vehicles Without an ICE?

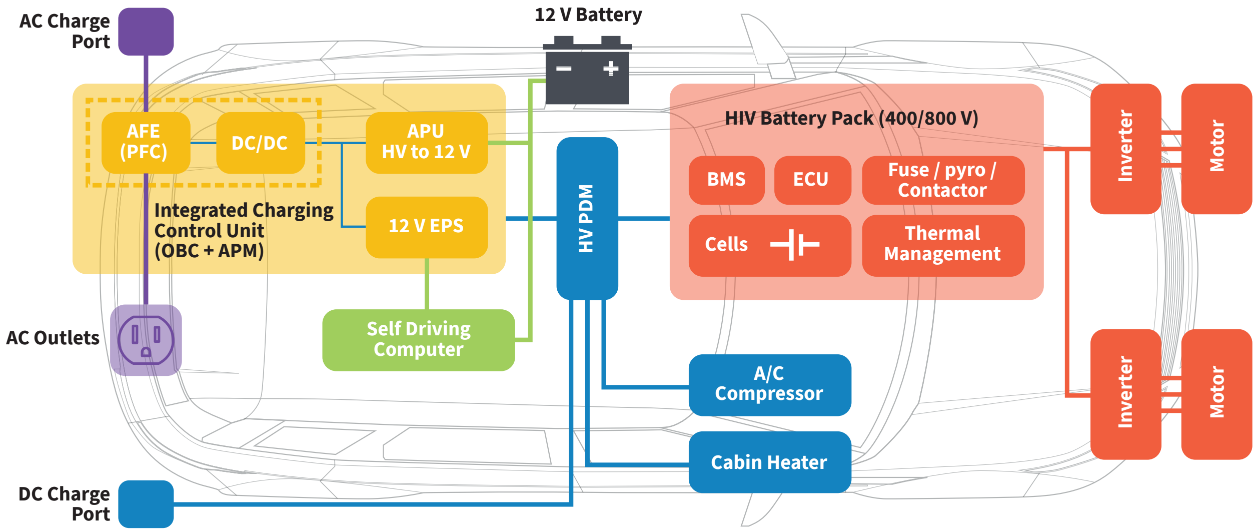


Figure 3 – EV power distribution architecture

## Role of the Main DCDC / Auxiliary Power Unit (APU)

In the first generations of EV architectures, the 12 V system no longer operates independently. Instead, it is tightly coupled to the high-voltage traction system through an auxiliary power unit (APU), typically implemented as a high-voltage-to-low-voltage DC-DC converter. The APU plays a central role in supplying regulated 12 V power to vehicle subsystems and operates in conjunction with the 12 V lead-acid battery.

During normal vehicle operation, the APU provides regulated 12 V power to all low-voltage subsystems while maintaining the charge of the 12 V battery. The battery acts as a buffer, absorbing load transients and ensuring uninterrupted power delivery during rapid changes in demand.

When the vehicle is off and the high-voltage (HV) system is inactive, the interaction between the APU and the 12 V battery becomes critical. A growing number of electrical subsystems require either continuous low-power operation or fast wake-up capability, including:

- Software driven modules with rapid startup requirements
- Cabin HVAC and preconditioning functions
- Battery management systems (BMS)
- Telematics, connectivity, and vehicle security systems
- Sentry mode and similar monitoring features

In these modes, most vehicle functions are powered by the 12 V battery, with the APU periodically reenabled to recharge the battery from the HV pack as needed. This coordinated strategy allows EVs to support modern “always-connected” or “always-on” features while minimizing HV system on-time and associated losses.

## Why a 12 V Battery Still Exists in EVs?

Fully electric vehicles eliminate the internal combustion engine and, with it, the need for high-current engine cranking. Propulsion is instead provided by an all-electric drivetrain powered by a HV traction battery, typically operating at 400 V to 800 V.

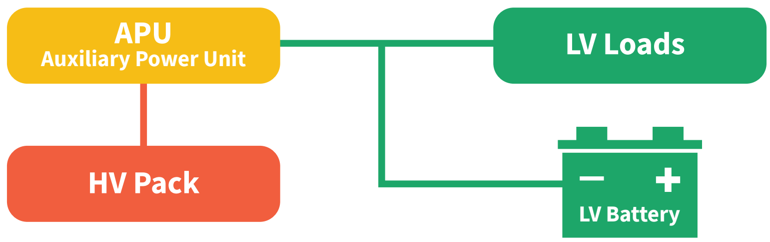


**Figure 4 – Centralized APU architecture with LV battery support for LV loads**

Despite this shift, the conventional 12 V auxiliary battery is still retained to power essential vehicle subsystems, particularly when the traction system is inactive. As a result, most EV platforms continue to include a 12 V auxiliary battery for several key reasons:

**Safety:**
Most low voltage systems are located close to vehicle occupants. Supplying these directly from a 400 V or 800 V source—particularly in scenarios where the vehicle structure may be compromised during a road traffic accident—introduces additional safety concerns. A 12 V battery allows the high voltage system to be isolated from critical subsystems, while high voltage within the passenger compartment requires multiple layers of protection.

**Functional Safety:**
The 12 V battery also provides an independent energy source that ensures critical systems remain powered when the high-voltage battery is disconnected due to faults, shutdowns, or maintenance. This supports functional safety and fault-recovery requirements defined by ISO 26262 and similar standards, enabling safety-related electronic control units to achieve and maintain a safe state while preserving system availability under fault conditions.

However, the disadvantages of a heavy 12 V lead-acid battery are beginning to outweigh its benefits. As a result, some recent EV designs have started replacing lead-acid batteries with smaller, lighter lithium-based low-voltage batteries, albeit with lower available peak output current.

## What Are the Limitations of 12 V Auxiliary Batteries in EVs?

While smaller auxiliary batteries can simplify system design, they also introduce drawbacks that become more pronounced as EV platforms evolve and electrical loads increase:

- **Weight and packaging:** Even a small auxiliary battery adds weight and consumes valuable space within increasingly constrained vehicle architectures.
- **Limited lifetime:** Lead acid batteries are not well suited to the partial state of charge operation typical in EVs, resulting in reduced service life—typically in the range of 3 to 5 years.
- **Maintenance and replacement:** Auxiliary battery failures remain a common cause of vehicle service events, impacting reliability and customer experience.
- **Parasitic power loss:** Continuous standby consumption accelerates battery degradation and can affect vehicle availability over extended idle periods.

These limitations are driving efforts to eliminate the auxiliary battery entirely.

## What Does It Take to Eliminate the 12 V Battery?

Eliminating the 12 V battery requires a rugged power supply that can efficiently and reliably draw energy from the high voltage traction battery pack. This power source must continuously support all low voltage vehicle subsystems under normal operation, fault conditions, and startup scenarios—without relying on any additional stored energy.

It must provide a wide input voltage range, ideally from 30 VDC to 1000 VDC, to cover both 400 V and 800 V nominal battery architectures. In addition, it must continue operating at reduced input voltages to support safety critical functions when the HV bus is interrupted due to a catastrophic system failure. The replacement power source must also be highly efficient to minimize thermal stress and reduce discharge of the traction battery during extended idle periods, such as vehicle transport or storage. A low component count is equally important to reduce size, improve reliability, and lower system cost.

## µDC DC as a Replacement for the 12 V Auxiliary Battery in Electric Vehicles

In this architecture, the converter assumes full responsibility for low voltage power delivery across all operating modes. Highly integrated µDC DC solutions are well suited to meet these requirements.

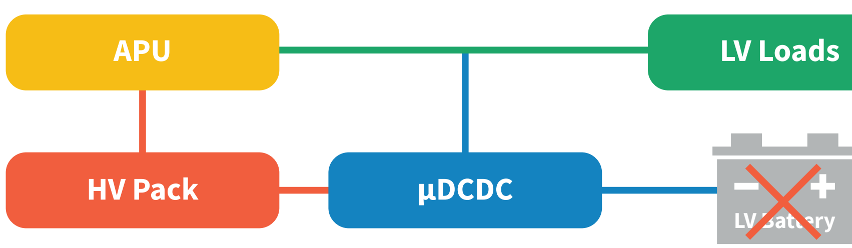


**Figure 5 – APU and µDC-DC LV power architecture without battery support**

µDC DC converters are typically implemented as highly integrated flyback power supplies, incorporating an integrated primary switch, secondary side synchronous rectification (SR), and quasi resonant (QR) operation. This approach enables high efficiency, high voltage operation, low electromagnetic emissions, and compact size with minimal external components. Functionally, the topology builds on proven flyback architectures—such as those used in Power Integrations' InnoSwitch™ family—while extending their capability to operate directly from EV traction battery voltages and meet automotive grade requirements.

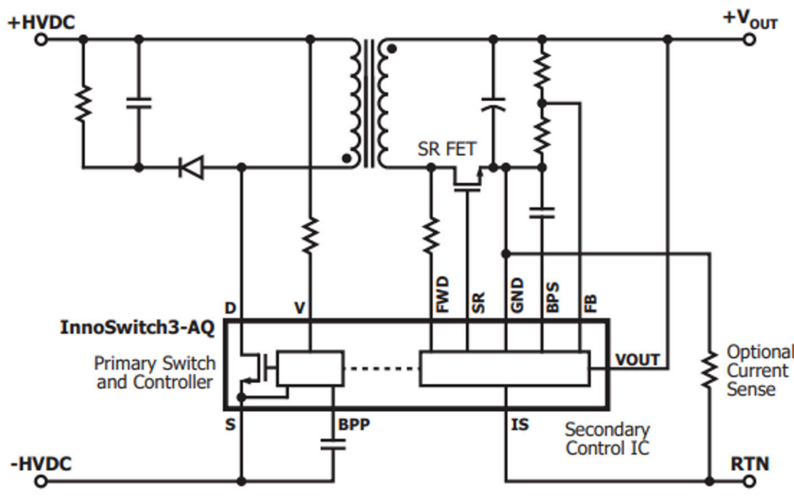


**Figure 6 – InnoSwitch3-AQ flyback converter**

## Wide Input Voltage Operation Using Wide Bandgap Devices

As noted previously, a fundamental requirement of auxiliary battery free architectures is the ability to operate from a wide input voltage range, spanning both present and emerging traction battery platforms. µDC DC implementations address this with wide bandgap (WBG) power switches integrated into the converter:

- 900 V GaN devices enable direct operation from 400 V nominal systems
- 1700 V SiC MOSFETs enable direct operation from 800 V nominal systems

By integrating the primary switch, µDC DC designs can safely support input voltages operating from 30 VDC up to nearly 1000 VDC. This capability enables continued power delivery during abnormal or degraded operating conditions, supporting functional safety requirements and fault recovery modes.

## Power Capability and Efficiency

µDC DC converters are well suited for auxiliary and control domain systems, typically delivering up to 100 W of output power while achieving efficiencies of up to 93% across the load range under nominal operating conditions.

In EV applications, efficiency at light load and standby is equally critical, driven by the increasing use of always on electronics. QR operation helps reduce switching losses by turning on the primary power switch at low voltage, while SR minimizes conduction losses on the secondary side. Together, these techniques enable high efficiency across a wide load range and significantly reduce standby power consumption.

If higher efficiency is required beyond what QR flyback converters can deliver, active clamp flyback architectures with zero voltage switching (ZVS) can be employed. ZVS further reduces switching losses while retaining the simplicity, isolation, and wide input voltage capability needed for auxiliary battery free EV power architectures.

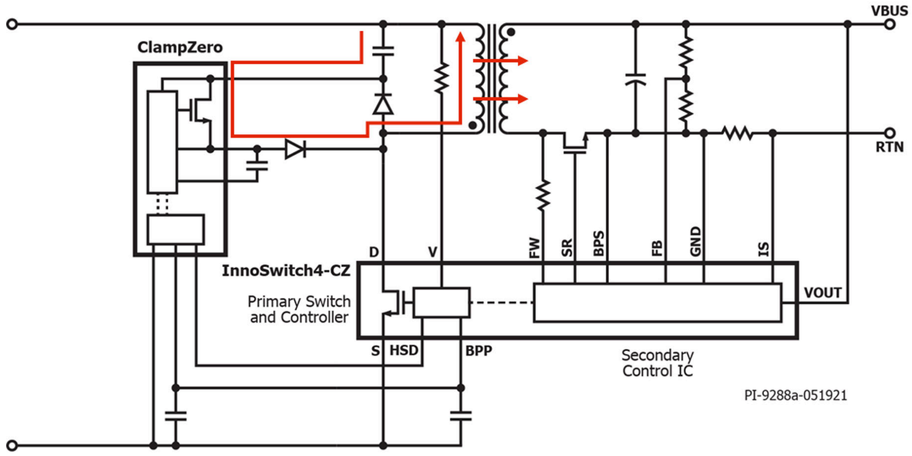


**Figure 7 – InnoSwitch4-CZ flyback converter with ClampZero**

## Transformer Technology: The Role of Planar Magnetics

To further improve power density, manufacturability, and thermal performance, µDC DC converters can leverage planar transformer technology. Compared to conventional wire wound transformers, planar transformers offer:

- **Lower profile and smaller volume,** supporting compact power modules
- **Improved thermal performance,** with better heat spreading through PCB copper layers
- **Tighter parameter control,** improving consistency and reducing variation across production
- **Compatibility with automated assembly,** aligning well with high volume automotive manufacturing

In battery less architectures, where the power supply becomes a core subsystem, the mechanical robustness and repeatability of planar magnetics provide additional system level reliability benefits.

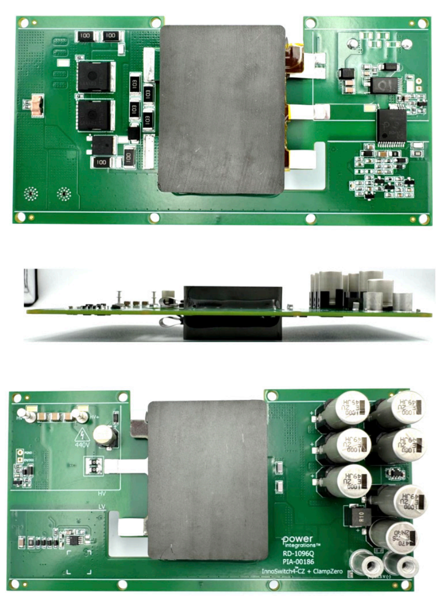

**Figure 8 – Planar transformer-based µDC-DC**

## System Level Benefits of a µDC DC Centric Architecture

By supporting the electrical and safety requirements associated with eliminating the auxiliary battery, µDC DC architectures enable several system level advantages:

- **Improved vehicle efficiency:** The growth of standby loads—such as multi-gigabyte over-the-air (OTA) updates, continuous video-based security, and real-time remote user interaction—places increasing demands on energy consumption during idle operation. µDC-DC converters, with ultra-low standby consumption and high light-load efficiency, significantly reduce energy loss in these modes.

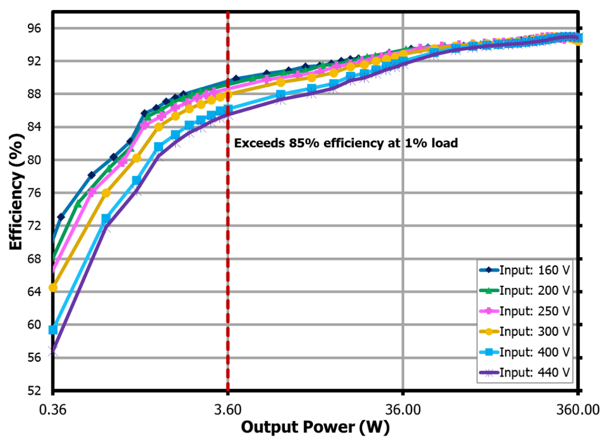


**Figure 9 – >85% efficiency at 1% load: 360 W flyback (InnoSwitch4-CZ + ClampZero)**

- **Direct low-voltage power delivery:** With wide input capability, fast startup, and high efficiency, µDC DC converters can fully supply low voltage domains—removing the dependency on a centralized auxiliary energy source.
- **Compatibility with zonal architectures:** As vehicles transition to zonal electrical architectures, compact µDC-DC modules can be distributed closer to loads throughout the vehicle. This reduces wiring complexity and weight, while minimizing power distribution losses.
- **Support for redundancy and functional safety:** µDC DC converters can be implemented in redundant or segmented configurations, supporting functional safety objectives while enabling controlled system behavior during faults or shutdown events.

## Evolution Beyond the Traditional APU – Higher Efficiency in Standby

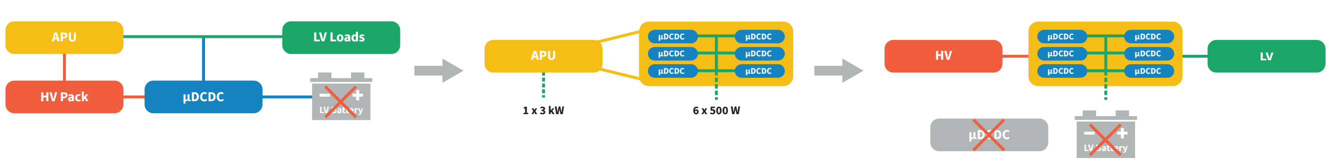


**Figure 10 - Transition from centralized APU to distributed µDC-DC architecture**

Conventional auxiliary power units (APUs) are most often LLC resonant converters, optimized for medium-to-high power levels, typically around 3 kW. As EV electrical loads continue to grow, APUs are increasingly expected to scale toward 5 - 6 kW. While well suited for centralized architectures and active driving modes, higher-power APUs tend t o become larger, less flexible, and exhibit significantly degraded efficiency at light load—particularly during key-off and standby operation, where EVs spend a substantial portion of their lifetime.

As vehicle electrical architectures evolve, it becomes increasingly practical to replace a single centralized APU with multiple µDC-DC converters operating in parallel. This distributed approach offers several advantages:

- **Compact, modular power units:** Smaller converters can be located closer to loads and integrated naturally into zonal architectures, reducing distribution distance and associated losses.
- **Improved efficiency across operating modes**: System efficiency is enhanced, particularly during standby and partial load operation. Only the required number of µDC DC stages operate at any given time, avoiding the inefficiencies of oversized converters running at light load.

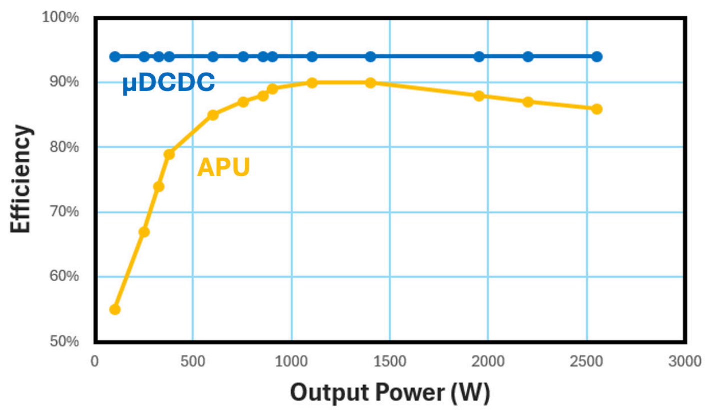


**Figure 11 – µDC-DC maintains higher efficiency across wide load range**

- **Scalability through load sharing:** Power capability can be increased incrementally by adding converters, eliminating the need to oversize a single centralized unit.
- **Inherent redundancy:** Parallel architectures improve system availability and fault tolerance.
- **Lower system cost:** Cost reductions are achieved by minimizing overdesign and reusing common building blocks.

By distributing auxiliary power delivery across parallel µDC-DC converters, EV architectures can maintain high efficiency during both active and key-off states while avoiding the penalties associated with increasingly large centralized APUs.

## Architectural Implication

In EV platforms that eliminate the 12 V auxiliary battery, the power supply transitions from a supporting element to a core architectural function. µDC-DC solutions based on highly integrated wide-bandgap (WBG) flyback architectures—combined with planar magnetics and scalable, parallel deployment—offer a practical path to higher efficiency, improved reliability, inherent redundancy, and seamless alignment with next-generation zonal vehicle architectures.

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