

Understanding the Automotive Shift: The Rise of 48V Systems and Architectural Evolution

By **Ian Moulding**, European Marketing Manager - Diodes Incorporated,
and **Roger Smith**, Automotive Segment Marketing Lead - Diodes Incorporated

1. Introduction

The automotive industry is undergoing a structural transformation driven by rising efficiency requirements, tightening emissions regulations, and growing electronic content in vehicles. While battery electric vehicles (BEVs) receive much of the attention, the evolution of vehicle electrical architectures is equally important. A central element of this shift is the increasing adoption of 48V systems.

Although 48V technology has long been used in industrial and telecommunications applications, its deployment in passenger vehicles is relatively recent.

Automotive adoption of 48V began with mild hybrid electric vehicles (MHEVs), in which manufacturers sought additional efficiency and performance gains beyond those achievable with a conventional 12V system alone.

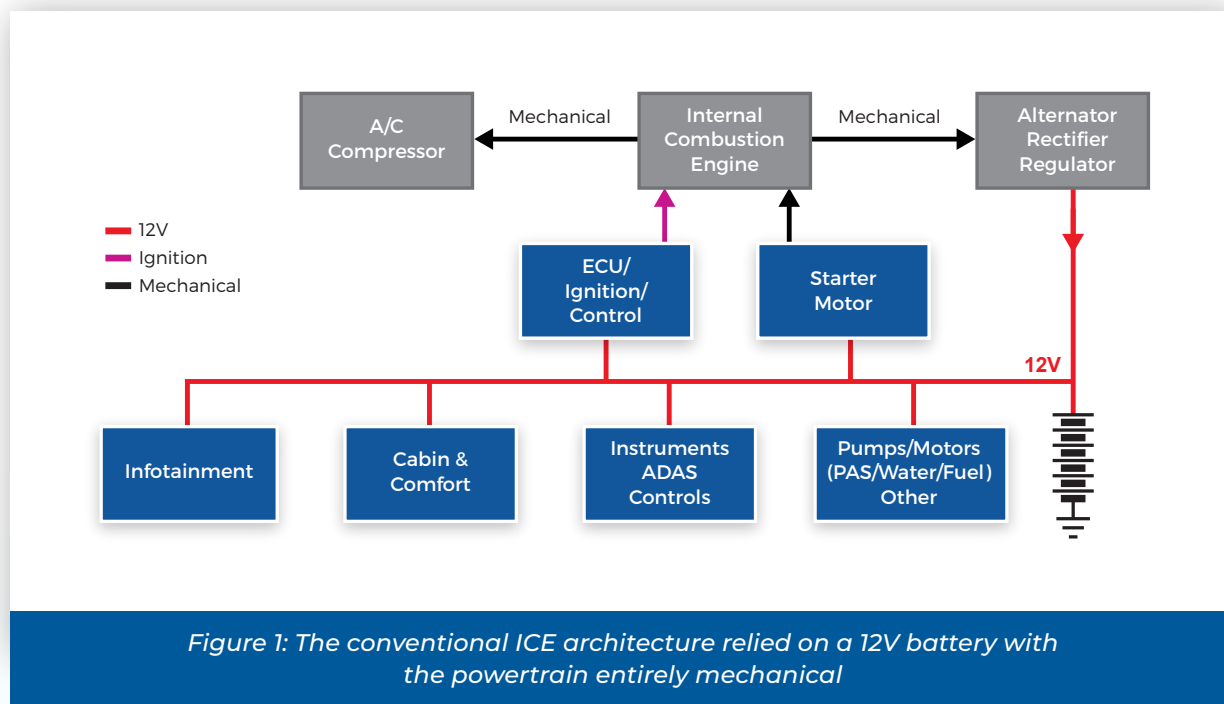
This white paper examines why the industry is moving toward 48V, how vehicle architectures are evolving as a result, and which applications are driving its adoption. It also discusses the challenges of this transition and how component suppliers, such as Diodes Incorporated (Diodes), support engineers designing next-generation 48V systems.



2. The Evolution from 12V to 48V

For decades, internal combustion engine (ICE) vehicles relied on a single 12V battery to power all electrical loads, while propulsion remained entirely mechanical (Figure 1).

This architecture was sufficient when electrical demand was limited to lighting, infotainment, and basic control electronics.



As vehicles became more complex, the limitations of 12V systems became increasingly apparent. New electrical loads, such as electric pumps, compressors, advanced driver assistance systems (ADAS), and emissions-reduction technologies, require significantly more power.

Delivering this power at 12V demands very high current, leading to excessive resistive losses, larger wiring harnesses, increased weight, and higher cost.



The first major architectural change came with the introduction of 48V systems in MHEVs (Figure 2). In this configuration, vehicles retain a 12V battery for legacy, functional redundancy and low-power systems while adding a 48V battery to support higher-power loads.

A bidirectional DC-DC converter links the two voltage domains, and an integrated starter generator (ISG) operating at 48V enables stop-start functionality, regenerative braking, and torque assist.

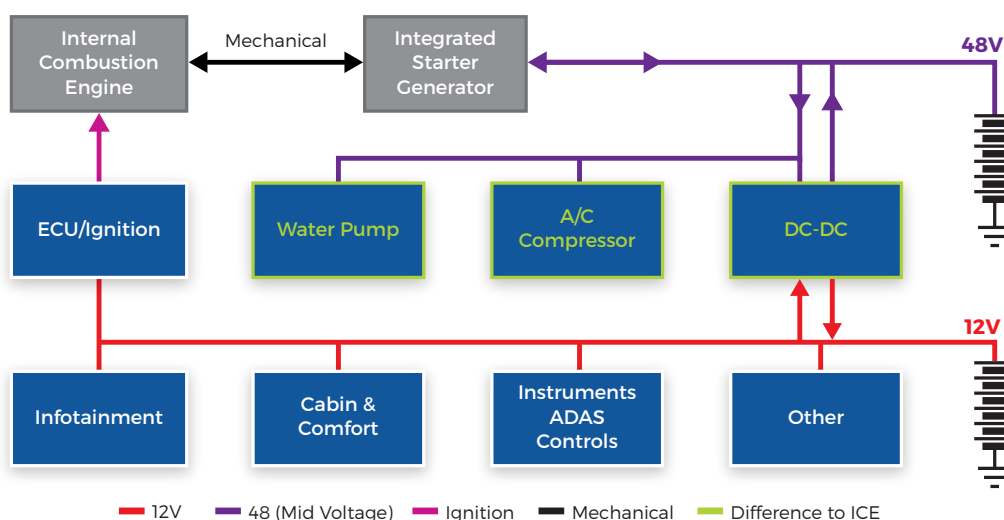


Figure 2: The 48V mild-hybrid architecture uses a 48V battery but retains the 12V battery for low-voltage systems

Beyond the ISG, the 48V rail powers high-current auxiliaries, such as eTurbo, electric water pumps, electric air-conditioning compressors, and other motor-driven systems that would be inefficient or impractical on a 12V bus.

Looking ahead, 48V is expected to play a larger role in BEVs and plug-in hybrid electric vehicles (PHEVs). Current BEVs typically combine a high-voltage traction battery (300V–900V) with a 12V auxiliary battery (Figure 3).



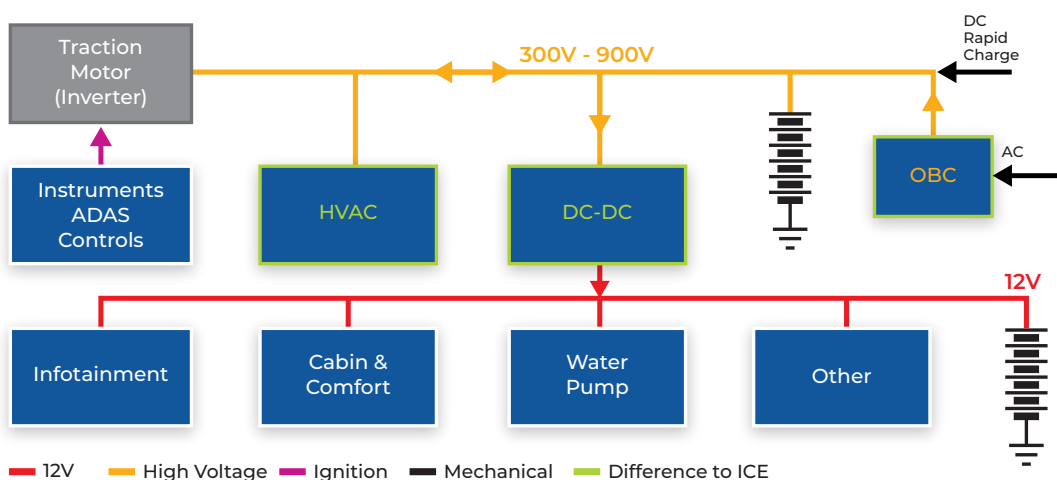


Figure 3: Current BEVs have a high-voltage battery and 12V battery for low-voltage auxiliary systems

Future architectures are trending toward eliminating the standalone 12V battery keeping a two-battery approach: a high-voltage traction battery and a 48V system

that distributes power throughout the vehicle (Figure 4). Lower voltages, such as 12V and 5V, are generated locally using point-of-load (POL) DC-DC converters.

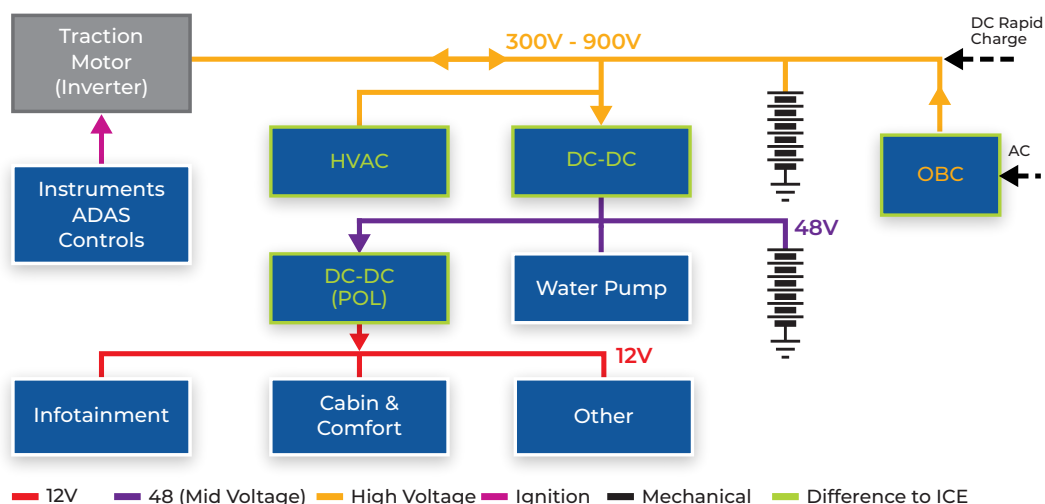


Figure 4: The latest BEV designs feature a high-voltage battery and a 48V battery with the 12V/5V derived using DC-DC buck converters

This transition represents a fundamental change in vehicle power distribution and

lays the groundwork for more efficient, scalable electrical architectures.

3. Why 48V is Needed

The technical rationale for 48V is rooted in basic electrical principles. Power is the product of voltage and current ($P = V \times I$), while resistive losses scale with the square of current ($P_{\text{loss}} = I^2R$). Increasing voltage allows the same power to be delivered with proportionally less current.

For example, delivering 1kW at 12V requires more than 80A, whereas the same power at 48V requires just over 20A. Reducing the current by a factor of four reduces resistive losses by a factor of sixteen. This dramatic reduction directly improves efficiency and thermal performance.

At 12V, higher current levels necessitate thicker copper conductors, adding weight, cost, and packaging complexity. Moving to 48V enables thinner, lighter wiring

while maintaining or increasing power capability, an increasingly important consideration as vehicle mass directly affects efficiency and emissions.

Beyond efficiency, 48V enables applications that are impractical at 12V. Electrically heated catalytic converters (e-cats), electric turbochargers (e-turbos), and high-power motor-driven auxiliaries often require 1kW or more. At 12V, the resulting current is prohibitive. At 48V, these systems become feasible and efficient.

48V is also essential for energy recovery. In MHEVs, the 48V ISG captures kinetic energy during deceleration and stores it in the battery. This energy can then be reused to assist the engine or power electrical loads, reducing fuel consumption and emissions.

4. The Advantages of 48V

The transition to 48V offers several interrelated benefits:

Improved Efficiency: Lower current significantly reduces I^2R losses, improving overall electrical efficiency and reducing heat generation.

Reduced Wiring Weight and Cost: Thinner conductors lower harness mass and copper usage, improving vehicle efficiency and reducing material costs.

Support for High-Power Loads: 48V enables efficient operation of motor-driven auxiliaries, emissions-control systems, and performance-enhancing features.

Enhanced Performance: In MHEVs, 48V torque assist improves acceleration and responsiveness, while e-turbos expand the usable torque band.

Architectural Flexibility: 48V supports distributed power architectures in which energy is delivered efficiently across the vehicle and converted locally to lower voltages.

Scalability: The same 48V concepts apply across ICE vehicles, xHEVs, and fully electric platforms, enabling gradual and cost-effective electrification.

Collectively, these advantages make 48V a practical compromise between legacy low-voltage systems and high-voltage traction architectures.

5. Architectural Changes for 48V Integration

In current MHEV designs, 48V is added alongside the existing 12V system. A dedicated 48V battery powers the ISG and other high-power loads, while a DC-DC converter maintains compatibility with the 12V domain. This approach minimizes disruption to existing vehicle platforms while delivering measurable efficiency gains.

Future BEV and PHEV designs are moving toward zonal electrical architectures enabled by 48V. Instead of numerous function-specific electronic control units (ECUs) distributed throughout the vehicle, electronics are organized by physical zones (e.g., front, rear, left, right).

A 48V power bus distributes energy efficiently to zone control units, which locally regulate voltage down to 12V, 5V, or lower as required. This approach reduces wiring length, simplifies harness design, and lowers system complexity.

Unlike earlier domain-based architectures, zonal architectures are inherently tied to higher-voltage power distribution. They also align well with software-defined vehicle concepts, where centralized processing and over-the-air updates are increasingly important.

6. Market and Implementation Considerations

Despite its advantages, the transition to 48V presents challenges. Electrification has progressed more slowly than earlier forecasts suggested, and xHEVs are expected to remain relevant for many years. OEMs must therefore support multiple powertrain strategies simultaneously.

Platform development is costly, and adapting legacy ICE platforms for electrification is often less efficient than designing clean-sheet EV architectures. While 48V can reduce long-term system cost through material savings, it requires upfront investment in new components, validation, and manufacturing processes.

Standardization is another challenge. Industry-wide standards for 48V connectors, protection strategies, and architectures are still evolving, increasing development complexity.

Consumer factors also influence adoption. High EV purchase prices, limited charging infrastructure, and range concerns limit EV adoption, making MHEVs a more attractive alternative for many buyers. Regulatory pressure to reduce emissions across entire fleets further reinforces the role of 48V systems as a near- and mid-term solution.

7. How Diodes Incorporated Supports the 48V Transition

Diodes has extensive experience of supplying automotive-compliant analog and power solutions and is expanding its power, sensing, connectivity, and timing portfolio.

Transitioning from 12V to 48V systems requires higher voltage rated power products, typically 80V to 100V. Diodes' high-voltage (80~150V) MOSFETs are optimized for low $R_{DS(ON)}$ to minimize conduction losses and are housed in thermally efficient packages such as 8×8 and TOLL. These devices fulfil the requirements for high-current motor control applications, including ISGs, pumps, and e-turbos.

Zonal architectures rely on efficient local voltage regulation. Diodes offers DC-DC buck converters with input voltage ratings up to 100V, allowing direct operation from a 48V bus. These devices generate regulated outputs for microcontrollers, sensors, and communication devices within zone control units. Product families such as the AP68xxx series are designed specifically for these applications.

Diodes also provides evaluation boards, reference designs, and documentation to support automotive EMC, thermal, and reliability requirements.

8. Conclusion

The shift to 48V electrical systems marks a critical stage in the evolution of automotive power architectures.

As electrical loads increase, and efficiency and emissions requirements tighten, traditional 12V systems can no longer deliver the necessary power without excessive losses, weight, and complexity. By operating at a higher voltage, 48V enables more efficient power distribution, lighter wiring, and the practical implementation of high-demand electrical applications.

Initially adopted in MHEVs, 48V has proven its value through features such as regenerative braking, torque assist, and the electrification of auxiliary systems. Its role is now expanding beyond hybrids, forming the foundation for future BEV architectures.

In these platforms, 48V supports distributed power delivery and zonal electrical architectures, where local DC-DC conversion reduces wiring complexity and improves scalability.

While market dynamics, cost considerations, and standardization challenges remain, 48V offers a balanced and flexible path that supports both near-term emissions compliance and long-term vehicle electrification. It bridges the gap between legacy 12V systems and high-voltage traction batteries, enabling performance improvements and architectural simplification without the full cost and complexity of high-voltage electrification.

By supporting both 48V and legacy 12V domains, Diodes delivers scalable, high-efficiency analog and power solutions that simplify system design and accelerate time-to-market. With strong quality standards and long-term supply assurance, Diodes is a trusted partner for next-generation automotive platforms.