# POWERING THE FUTURE

## THE RISE OF 48V AND THE TRANSFORMATION OF AUTOMOTIVE E/E ARCHITECTURE

# INTRODUCTION

The automotive low voltage electrical system has been operating at 12V since the 1960's.

However, today's vehicles have evolved into an interdisciplinary engineering marvel with complex electronic systems, enhanced safety features, and much higher levels of comfort and convenience. This results in the continuous increase in electrical power demand, which has pushed the established 12V system almost to its operational limit. In response, the automotive industry began the journey to a higher voltage level – 48V. This transition is gaining momentum globally, as it offers more efficient power delivery and lays the groundwork for innovations essential to future mobility.

This white paper aims to explore the strategic and technical imperatives driving the automotive industry's transition to advanced 48V electrical architectures. It outlines the limitations of the 12V system in meeting the growing demands of future vehicles and demonstrates how 48V – particularly when paired with zonal architecture – offers a scalable and efficient foundation for next-generation vehicle design.

# THE IMMEDIATE BENEFITS FROM 48V E/E SYSTEM

The most direct benefit from 48V architecture is the optimization of the wiring harness. Governing by Ohm's law, electric power is the product of current and voltage. The increasing power demand in modern cars means the current increases at the same rate as the power increase, for which the wire size must be larger enough to carry. The automotive industry has been experiencing such increase in wire size, causing significant additional weight and costs to OEMs.

The other immediate improvement that 48V will deliver is on the energy efficiency. All electrical components consume some electric energy due to their intrinsic resistance. Such wasted energy is in proportion to the square of current level ($W=I^2R$). So, with the increasing current level, the power loss increases exponentially in the form of heat dissipation.

In some cases, it has caused major thermal management challenges, which require larger fans or even liquid cooling to address.

Once the voltage level increases 4 times to 48V, the current level can be reduced to a quarter for the same power demand. Therefore, a much smaller wire can do the job carrying the current from the power source to the application. Theoretically, this will save more than 85% copper in the wiring harness. From this, OEMs will have significant material cost saving, the whole wire harness will be lighter, thinner and smaller (for connector interfaces), and the vehicles can achieve better fuel economy or longer range due to the weight reduction.

Meanwhile, the energy dissipation, or heat generated in the system, will be reduced to only 1/16. This drastically reduces the need for complex thermal solutions, improving both reliability and system efficiency.

HARNESS WEIGHT REDUCTION

COST EFFECTIVE SOLUTION

INCREASED SAFETY AND PERFORMANCE

ROBUST AND FLEXIBLE

FUEL SAVINGS / EMISSIONS REDUCTIONS

# THE LIMITS AND IMPEDIMENTS OF 12V SYSTEM

Above, the direct benefits from 48V systems have been widely discussed and relatively well understood. However, when automakers design the next generation of vehicles, they face more challenges that stem from the limits and impediments of an antiquated 12V system.

### Antiquated Technologies

The current 12V power supply architecture is based on building blocks such as the 12V lead-acid battery, belt-driven alternator, and irreversible pyro fuse box. While cost-effective, these technologies are no longer suitable for needs of the next generation of vehicles. For example, the bulky 12V lead-acid battery has a very low energy density and requires regular maintenance. The tolerance of blade fuses is too high for many sophisticated electronics in today's vehicles. Additionally, the fuse box requires mandatory accessibility because the pyro fuse is irreversible.

### Voltage Stability Issue

Transient high-power loads will cause extremely high in-rush currents – reaching up to 100 amps for pumps and exceeding 220 amps for steering systems – which severely impact voltage stability in the system. These sudden voltage drops can compromise the performance and reliability of mission-critical applications throughout the vehicle. To make things worse, these events often occur with high slew rates, causing significant electromagnetic compatibility (EMC) issues that further jeopardize system integrity.

### Power Supply and Delivery Bottleneck

Power demand in modern vehicles has reached – and is surpassing the limits of what traditional 12V system can support. Simply increasing current capability is not viable due to the compounding effects on wire sizes, heat and costs. As a result, power delivery within 12V systems is often constrained, which may require temporary shutdowns or performance degradation in other systems to accommodate peak load demands.

# THE NEEDS OF FUTURE VEHICLES

Regardless of the powertrain – whether internal combustion, hybrid, or fully electric – the next generation of vehicles demand a far more capable low-voltage electrical system. The electrical/electronic (E/E) architecture functions as the vehicle's neural network, coordinating the complex interactions between software, sensors, actuators, and safety systems. Just as muscles (powertrain) rely on the nervous system to function effectively, the powertrain can only operate at peak efficiency when the underlying E/E infrastructure is intelligently orchestrating.

### Software-Defined Vehicles and X-by-Wire

Software-defined vehicles (SDVs) depend on X-by-wire systems to replace traditional mechanical linkages with electronic control. This shift not only enables greater design flexibility (e.g. skateboard chassis concepts) but also allows for scalable component standardization across multiple platforms. X-by-wire technology forms the foundation for advanced levels of autonomy, where accurate and dependable actuation is critical. Supporting these functions are high-performance sensors, cameras, radars, and lidars – all of which increase the vehicle's electrical power demands.

### Intelligent, Electrified Cabins

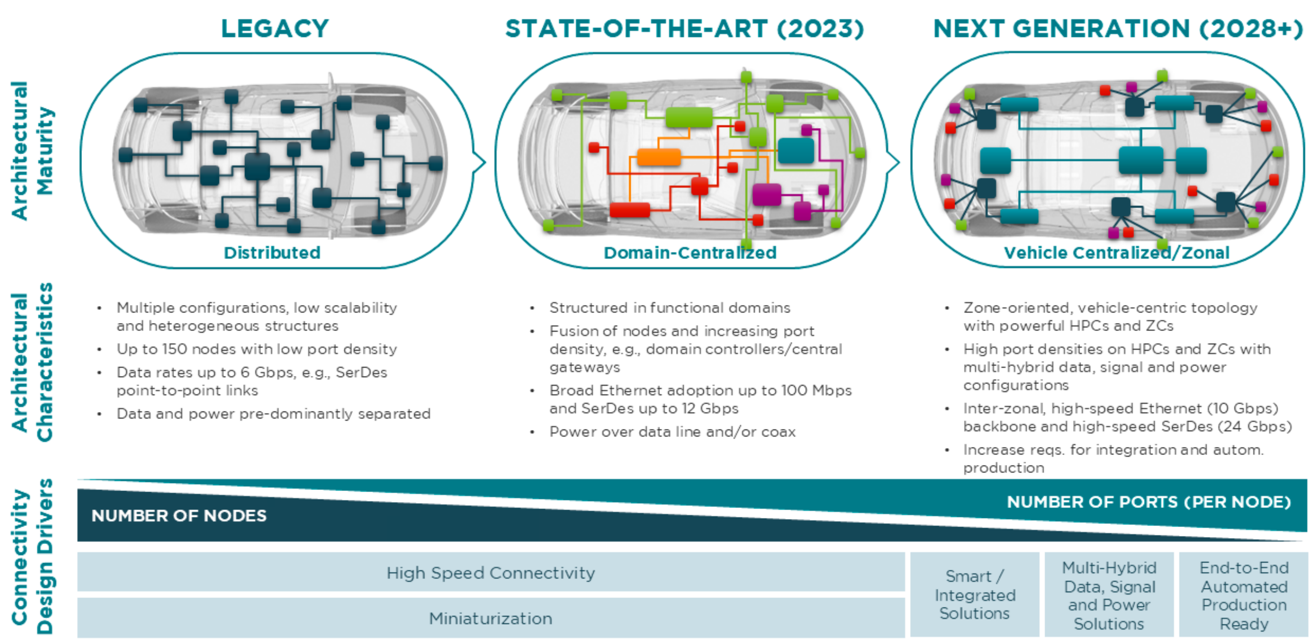
The cockpit is rapidly becoming a key area of vehicle differentiation, loaded with advanced infotainment systems, ambient sensing, and user-centric experience technologies. These features require higher and more stable power delivery – requirements that the aging 12V system struggles to support.

While incremental improvements may temporarily extend the life of 12V systems, the transition to 48V is both necessary and inevitable. Automakers that adopt 48V early will be strategically positioned to lead in innovation, system integration, and overall vehicle performance.

# 48V AND ZONAL ARCHITECTURE: A PERFECT MATCH

Another major evolution in automotive E/E systems is the shift to zonal architecture. Traditional vehicle architectures rely on centralized power distribution, where individual applications are routed to a main Power Distribution Unit (PDU). This approach results in complex, heavy, and costly wiring harnesses. In contrast, the zonal architecture divides the vehicle into regions – each managed by a zone controller, which also functions as a localized PDU. This decentralized model significantly reduces wiring complexity, improves scalability, and provides a more efficient framework for supporting software-defined features and the growing number of intelligent devices within the vehicle.

Zonal architecture improves modularity, reduces the number of discrete ECUs, and significantly streamlines wiring harnesses. When combined with a 48V backbone, the result is a highly efficient and scalable power distribution model.



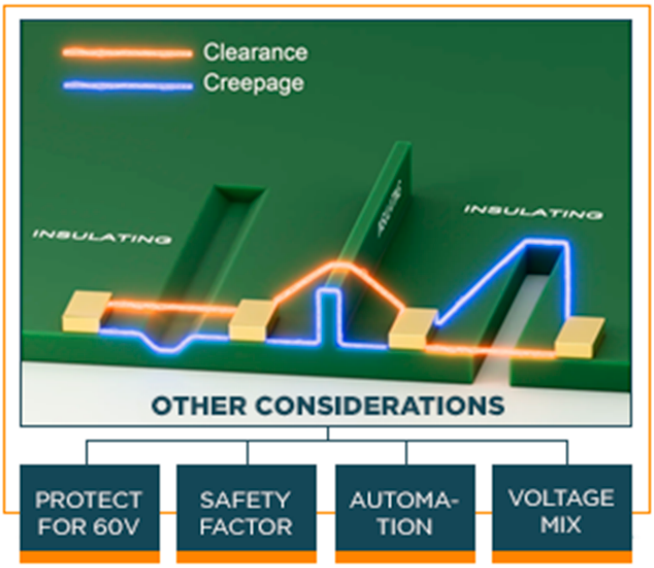

Source: TE Connectivity

In this architecture, 48V power is distributed from the central PDU to zone controllers, which serve as secondary PDUs for applications within their respective zones. In the zonal controller, a localized DC-DC converter steps down the voltage for any legacy 12V applications, utilizing short, localized 12V lines – significantly reducing their overall footprint.

This architecture will dramatically reduce harness weight and complexity, improve system modularity, and enable more scalable and flexible vehicle designs. It supports the development of scalable, software-defined platforms that can be rapidly adapted across multiple vehicle models and configurations.

# TE'S 48V SOLUTIONS: ENGINEERED FOR SAFETY, EFFICIENCY AND SCALABILITY

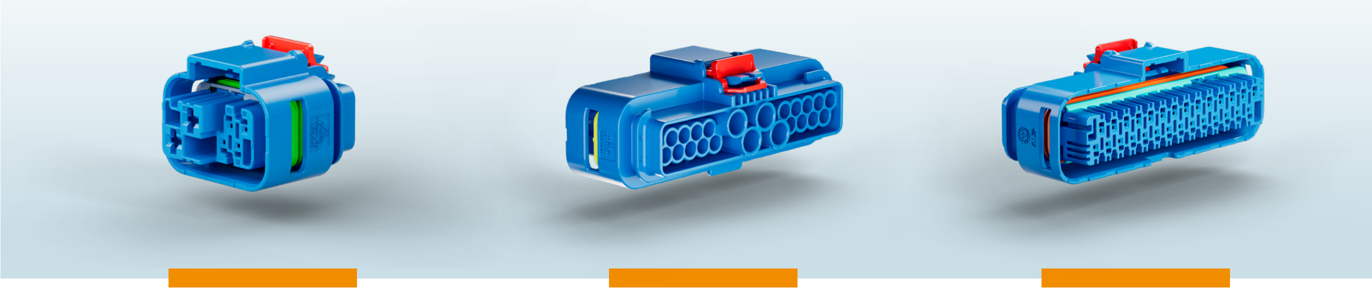
As the automotive industry transitions to 48V systems to meet rising power demands, ensuring electrical safety and design efficiency becomes increasingly critical. One of the key challenges in 48V systems is to maintain appropriate creepage and clearance (C&C) distances – the shortest paths between conducting elements across insulating surfaces and through air. These parameters directly affect the reliability of high-power electrical connectors, especially under elevated voltage conditions.




To address this, TE Connectivity has embedded creepage and clearance considerations into every stage of our 48V connector development, ensuring that contact spacing, terminal separation, and housing design align with industry standard DIN EN60664-1 guidelines for required distances to ensure safe electrical separation between different circuits as well as evolving OEM specifications.

As the industry leader in connectivity solutions, TE has designed a new 48V Low-Voltage Connector System portfolio (48V LVCS Series) to the LVCS standard – engineered from the ground up to combine high performance with compact design. Collaborating closely with the lead OEM's adopting 48V systems, TE has developed a suite of thirteen standardized interfaces combining 0.64mm, 2.8mm, discrete, and hybrid connectors that address a wide range of application needs. This standardized 48V LVCS product family are designed to maximize packaging efficiency and scalability, while meeting stringent creepage and clearance requirements.

## TE'S 48V LOW-VOLTAGE STANDARDIZED CONNECTORS



In parallel, TE continues to assess and expand our current portfolio of 48V-compatible products. Many existing connectors, such as those in the MCON family, already meet 48V requirements and are available in distinct blue variants that signal 48V readiness. These offerings enable customers to upgrade their architectures with minimal design disruption while maintaining compliance.

Beyond creepage and clearance, TE also prioritizes arcing prevention, particularly during hot plugging and unplugging events. Our future designs integrate mitigation strategies to prevent thermal damage and ensure long-term connector integrity in demanding environments.

Through industry collaboration, technical leadership, and a forward-compatible product strategy, TE Connectivity is enabling OEMs to transition to 48V architectures safely, efficiently, and at scale – helping power the future of intelligent, electrified mobility.

# CONCLUSION

The automotive industry stands at the threshold of transformation. As electrification, connectivity, and autonomy redefine what vehicles can do, the limitations of 12V systems have become an undeniable bottleneck. The transition to 48V is not a mere technological enhancement — it is a strategic leap that addresses the core power, efficiency, and scalability challenges of next-generation vehicle design.

48V systems, especially when paired with zonal architectures, offer a blueprint for a smarter, lighter, and more modular electrical future. They simplify complexity, reduce weight, improve energy distribution, and enable new features critical to software-defined vehicles. While hurdles remain—from standardization to component development—the direction is clear and irreversible. Forward-thinking OEMs and suppliers who embrace this shift now will be best positioned to lead the automotive landscape of tomorrow.

**To learn more, please visit te.com/48v**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