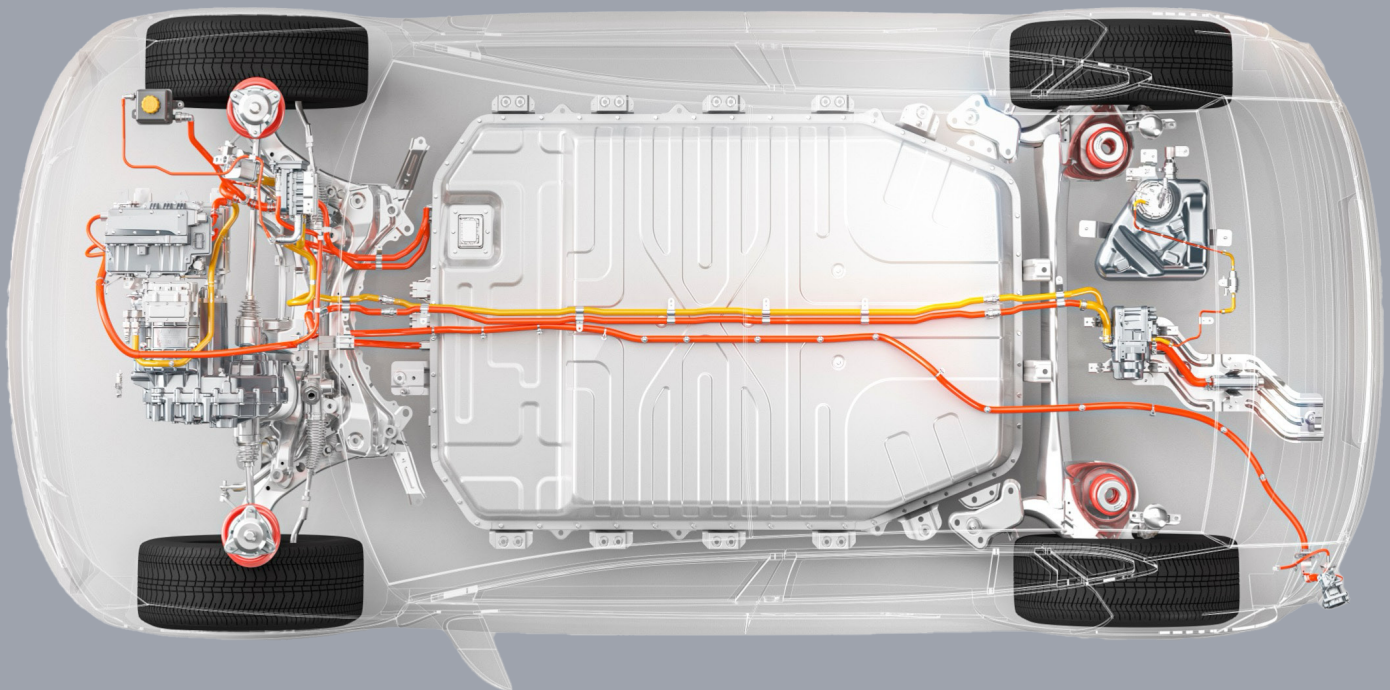


Challenges and Opportunities Presented by

# 48V Automotive Infrastructure



# Contents

<b>Executive Summary</b>	<b>3</b>
<b>Introduction</b>	<b>4</b>
<b>Challenges and Opportunities</b>	<b>6</b>
Outpacing Established Standards	7
R&D Expenses	7
Looking to the Future	7
Opportunities	7
<b>Strategies</b>	<b>8</b>
The Case for 48V	8
48V Use Across Industries	11
Zonal Architecture	11
Strategies Summary	13
<b>Allegro's Advantages</b>	<b>14</b>
Applications Expertise	14
Technologies	16
Future-Proofing Designs	18
Business Acumen	19
<b>Conclusion</b>	<b>20</b>
<b>Appendix</b>	<b>21</b>
Reduction in Wire Size	21
Reduction in Power Loss	21

# Executive Summary

**The shift from 12V to 48V automotive electrical systems is essential for meeting the power demands of modern vehicles.**

This paper highlights the opportunities and challenges of this transition. As 12V systems struggle with increased loads from components like ADAS and electric turbochargers, 48V offers advantages such as **reduced power loss, improved thermal management, and lighter, more compact wiring.**

These benefits lead to enhanced vehicle efficiency, lower emissions, and the integration of more advanced safety features. The transition to higher voltage electrical systems presents significant opportunities for companies that can design products optimized for this shift. Advanced batteries, power electronics, and smart control systems tailored to 48V operations will be in high demand, offering growth potential for designers. These innovations are critical not only for electric vehicles (EVs) but also for hybrid and internal combustion engine (ICE) vehicles, which increasingly rely on sophisticated electronic systems. By developing solutions that meet the evolving needs of these vehicles, companies will be well-positioned to capture new market share and drive industry-wide advancements in vehicle efficiency, safety, and performance.



# Introduction

Electronics in the early automotive industry began in the early 20th century with the introduction of basic electrical systems—primarily supporting ignition, lighting, and starting the engine.

The first major milestone was the introduction of the 6V electric starter by Cadillac in 1912, which replaced the hand-crank starter and marked the beginning of more widespread use of electrical systems in vehicles. The 6V infrastructure would remain the standard for decades to come.

By the 1950s, the industry began to shift from 6V to 12V systems to accommodate the increasing power requirements of new automotive technologies like radios, heaters, and windshield wipers. This low-voltage infrastructure has served ICE well, enabling decades of innovation and ensuring vehicles remain functional, safe, and efficient. However, as cars become increasingly electrified with more advanced features like electric power steering, turbochargers, and autonomous driving systems, the power demand has outgrown the capabilities of the 12V system.

Today is an exciting time for designers of automotive electrical systems—we're facing challenges and opportunities similar to those of the 1950s but at a vastly larger scale. Increasing electrical demands of modern vehicles, which the traditional 12V system struggles to support efficiently, are dictating a shift to higher and mixed-voltage systems. Some of the key reasons for that shift include:



## Increased Power Demands:

Modern vehicles are equipped with more power-hungry systems, including advanced driver-assistance systems (ADAS), infotainment, electric turbochargers, and more advanced safety features. The 12V system is no longer optimal to efficiently power these advanced technologies.



## Efficiency and Emissions Reduction:

Higher and mixed-voltage systems allow for the implementation of mild hybrid technology (MHEVs), which provide fuel-saving features such as steer-by-wire, regenerative braking, and electric boosting. These improve fuel efficiency and help reduce CO<sub>2</sub> emissions.



## Enhanced Safety:

Increasing the available electrical current enables the implementation of advanced safety features that were previously limited by the power constraints of 12V systems.



## Thermal Management:

The reduced current in higher voltage systems results in lower heat generation in electrical components through power loss. This means less need for cooling, improving the durability and lifespan of electrical systems and enabling the use of more compact components without overheating issues.



## Size and Weight Reduction:

Operating at a higher voltage reduces the size and weight of electrical infrastructure, as the current required to deliver the same power is lower. This results in thinner wires, smaller connectors, and lighter components.

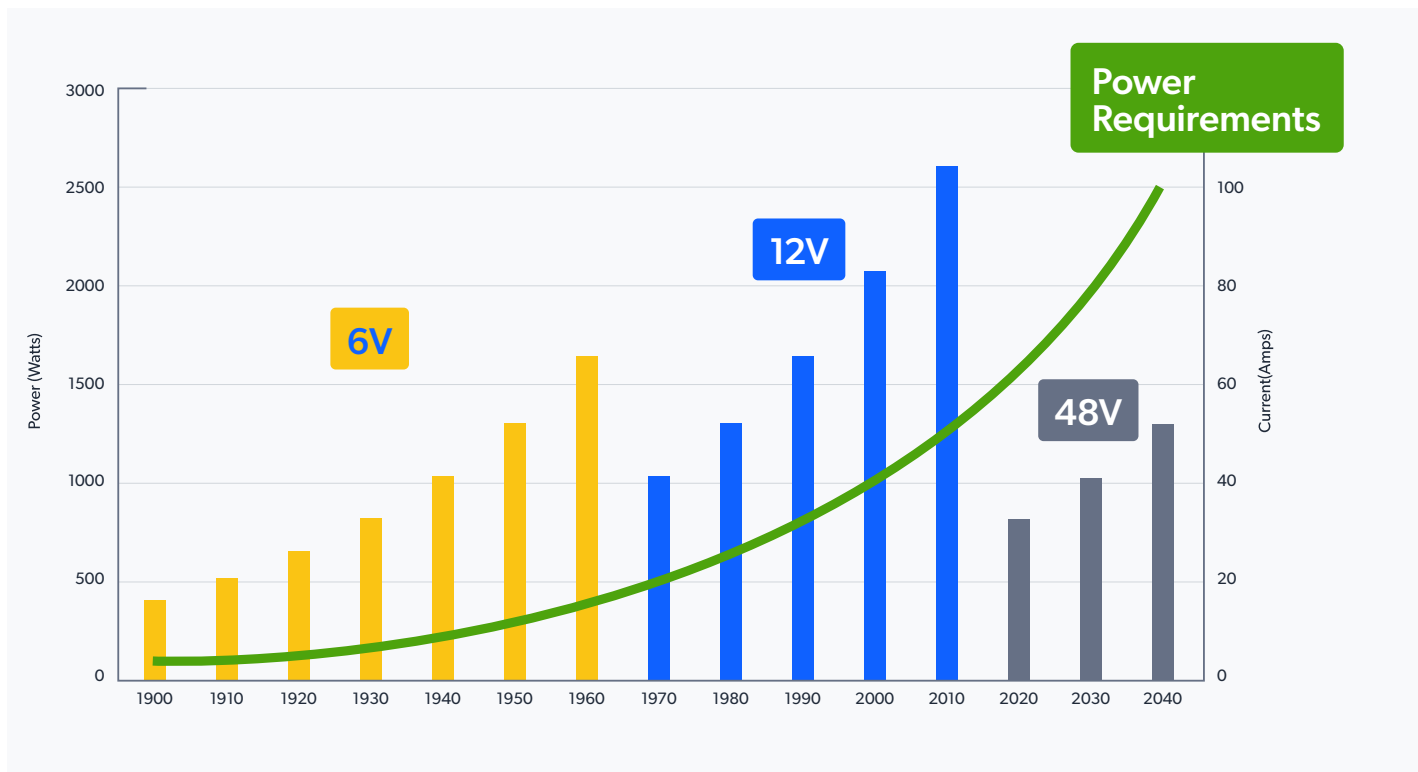


Figure 1. The shift to higher voltage systems accommodates increased power requirements in automobiles.

The transition to **next-generation automotive electrical systems** is a critical milestone in the evolution of vehicle architectures, enabling the industry to meet the increasing demands of modern vehicle technology.

This paper explores the opportunities and challenges these advancements present, their potential to drive innovation, and, most importantly, how Allegro MicroSystems is at the forefront of comprehending and shaping these developments. Allegro’s research and solutions are actively driving the integration of these new systems, positioning the company as a key player in the future of automotive electrical systems.



# Challenges and Opportunities

**Migrating from a 12V to higher voltage electrical systems in automotive electronics presents challenges similar to the 1950s shift from 6V to 12V systems.**

There are new product designs that don't sacrifice reliability or safety, lack of standards, adoption by customers, and many more.



**Higher voltage systems** force companies to reconsider how they approach vehicle design and engineering.

### **Outpacing Established Standards**

Electric technology is advancing quicker than best practices and standards, a problem also seen in the 1950s when transitioning from 6V to 12V systems. This creates a chicken-and-egg scenario: without standards, it's difficult for companies to design and test new systems, but without practical designs in the market, developing meaningful standards is challenging. A few seasoned and experienced companies can help break the logjam by developing best practices, proven architectures, and products that lay the groundwork for product and system definition.

### **R&D Expenses**

The development of new components for higher voltage systems also presents a significant hurdle. Manufacturers must design and test new electrical components that can operate effectively at higher voltages without sacrificing reliability or safety. This requires substantial research and development efforts, as well as collaboration with suppliers to ensure that new parts meet the necessary specifications. Today's automotive suppliers must balance potential gains in efficiency and performance outweigh the costs of retooling factories, retraining workers, and redesigning vehicles.

### **Looking to the Future**

Finally, companies must think strategically about how higher voltage systems will support future innovations, much like the 1950s shift to 12V laid the groundwork for advancements in automotive technology. As the automotive industry continues to evolve, the broader landscape of vehicle electrification needs to fit into higher voltage systems design. Additionally, consumer acceptance remains a challenge, as the advantages of higher voltage systems may not be immediately clear to all consumers, requiring companies to educate the market about the benefits of these new systems.

### **Opportunities**

On the upside, the transition to higher voltage electrical systems in automotive electronics opens significant opportunities for designers who can successfully create products that support this shift. Companies that can develop advanced batteries, power electronics, and smart control systems that are optimized for higher voltage operations will be well-positioned to capitalize on this market. These products are essential not only for electric vehicles but also for hybrid and ICE vehicles that are increasingly dependent on sophisticated electronic systems.

Automotive suppliers that can create adaptable systems that are both cost-effective and easy to integrate will have a competitive edge. These solutions might include zonal architectures, modular power distribution units, adaptable wiring harnesses, or versatile energy storage systems that can be tailored to different vehicle configurations. In addition to the technical benefits,

the shift to higher voltage infrastructure provides strategic advantages for automotive electronics companies. By leading in the adoption of this technology, companies can position themselves as innovators in the industry, attracting partnerships and investments and influencing emerging standards.

# Strategies

**As discussed, there are considerable challenges to migrating to higher voltage systems, including managing increased power requirements, ensuring compatibility with existing systems, simplifying the vehicle's electrical architecture, and navigating the lack of established industry standards for higher voltage systems.**

This section will explore various strategies to overcome these obstacles, highlighting both existing solutions and approaches still in development.

## The Case for 48V

The automotive industry appears to be settling on 48V as the emerging standard for higher voltage systems. 48V strikes a balance between efficiency, safety, and practicality. A 48V system can deliver significantly more power than the traditional 12V system, enabling the support of energy-intensive components like electric turbochargers, active suspension systems, and advanced driver assistance systems (ADAS).

Let's look specifically at 48V and quantify the improved efficiency over a 12V system, especially regarding cable weight, power loss, and material costs. First, as power demands increase, the currents within a 12V system increase linearly, and reduced current means a proportionally smaller wire size. In the example in Figure 2, holding the power requirements constant at 480W and measuring the current across one meter of wire, 48V allows a reduction in the wire size from 8 AWG (8.35mm<sup>2</sup>) to 15 AWG (1.65mm<sup>2</sup>)—for a 5x weight reduction (from 74.8g to 14.8g) for one meter of wire. (For a detailed description of these calculations, refer to "Appendix A. Comparing 12V vs. 48V Infrastructure".)

Power loss (and associated unwanted dissipated heat) is similarly improved by increasing the system voltage to 48V. Again, referring to Figure 2 we can see that power losses increase with the square of the current. In our example, a 12V system creates a power loss of 3W for one meter of wire; 48V produces approximately a 3:1 reduction in power loss and a corresponding reduction in dissipated heat.



### Why Not 64V or 96V?

While higher voltages, such as 64 or 96 volts, could theoretically provide even more power, they would introduce greater complexity in terms of insulation requirements, safety protocols, and overall vehicle design.

For example, ISO 21780:2020 includes guidelines on insulation, protection against electrical shocks, and system durability, all specific to 48V automotive subsystems.

Other organizations such as Underwriters Laboratories (UL), the National Fire Protection Association (NFPA), and the Occupational Safety and Health Administration (OSHA) consider voltages higher than 60 volts DC to be dangerous to human lives.

Therefore, any system operating at DC voltages higher than 60 volts must implement special safety measures to isolate the supply voltage from any user interaction. There are significant cost implications to designing a product with these safety measures and for many systems—the cost impact is not worth the benefit of further reducing the system current.

Load	Voltage	Weight	Power Loss	Material Cost (\$ .0089/g USD)
<b>LOAD</b>  <b>480W</b>	<b>48V</b> <b>15 AWG</b> ←———— 1m —————→ <b>Current = 10A</b> <b>Wire thickness = 1.45mm</b>	14.8g	1.36W	\$ .132 USD
	<b>48V Advantage:</b>	<b>~5X</b>	<b>~2X</b>	<b>~5X</b>
	<b>12V</b> <b>8 AWG</b> ←———— 1m —————→ <b>Current = 40A</b> <b>Wire thickness = 3.26mm</b>	74.8g	3.33W	\$ .667 USD

Figure 2. 48V presents substantial advantages over 12V in weight, power loss, and material costs.

## Other Automotive Subsystems Using 48V

In addition, many automotive subsystems today employ 48V, including:

### Components of Mild Hybrid Vehicles (MHEVs):

48V components are commonly used in mild hybrid electric vehicles, where they provide additional power for start-stop systems, regenerative braking, and electric turbochargers. This helps improve fuel efficiency and reduce emissions without the complexity of full hybrid or electric powertrains.



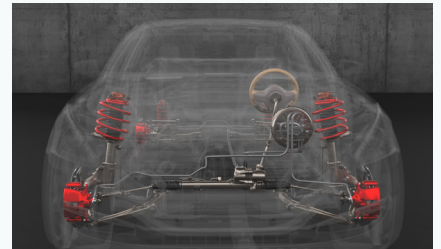
### Electric Power Steering (EPS):

48V systems power electric power steering systems, offering more precise control and reducing the load on the internal combustion engine.



### Active Braking & Suspension Systems:

Utilizing 48V power, these systems enhance real-time vehicle performance with improved suspension comfort and handling, while delivering faster, more precise braking for better safety and control.



### Electric Superchargers:

48V systems are used to drive electric superchargers for ICE vehicles, which can provide a boost to engine performance by reducing turbo lag.



### Auxiliary Systems:

48V power can also support other high-demand auxiliary systems like air conditioning, heating, and infotainment.



# Trends

At Allegro, we have identified the following trends which relate to 48V use in automotive:

## 48V Use Across Industries

Moreover, the adoption of 48V systems is not limited to the automotive industry. Other industries, such as industrial equipment and data centers, are also moving towards 48V power systems, creating an economy of scale that benefits all sectors. This cross-industry adoption further supports the case for 48V systems, as it leads to reduced costs, increased availability of components, and accelerated development of technologies that can be shared across different applications.

## Zonal Architecture

One of the primary strategies involves adopting zonal architecture—reorganizing the vehicle’s electrical and electronic systems into distinct zones. Each zone is responsible for a specific vehicle area, significantly reducing the complexity and length of wiring harnesses. This shift not only streamlines manufacturing and maintenance but also reduces the vehicle’s overall weight, leading to improved energy efficiency.

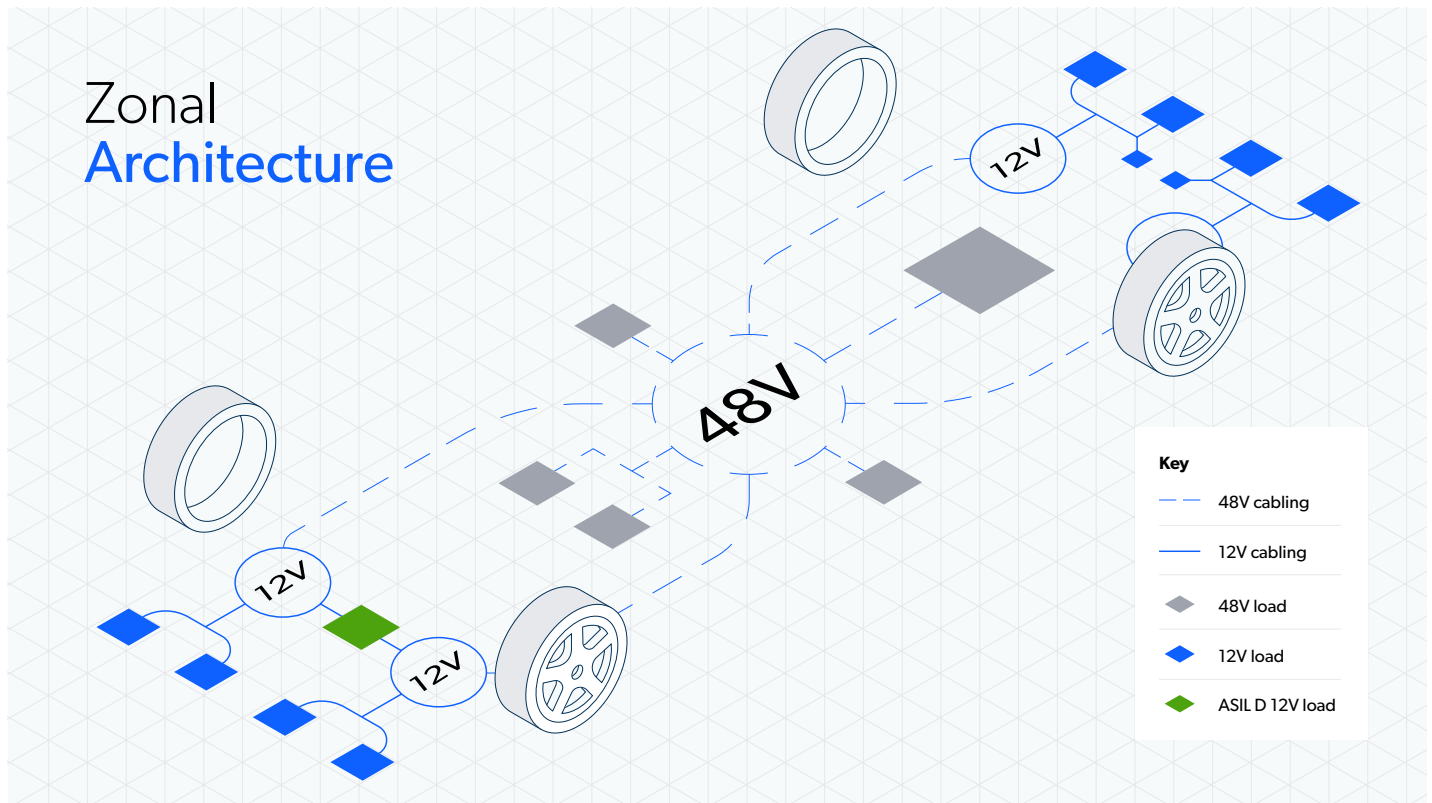


Figure 3. Zonal Architecture

# Zonal Architecture

## Simplification

A zonal automotive electrical architecture significantly simplifies vehicle design and manufacturing by organizing the vehicle's wiring and electronic control units (ECUs) into distinct zones. In traditional architectures, wiring harnesses often resemble a tangled web, with wires criss-crossing the entire vehicle, complicating assembly and maintenance. Zonal architecture reduces this complexity by localizing electrical components within specific zones—such as the front, rear, or passenger compartment—and connecting them through a standardized data and power backbone. This approach minimizes the length and number of wiring harnesses required, reducing the vehicle's overall weight and the likelihood of wiring-related issues. Additionally, it streamlines the design process, allowing engineers to develop and test modular components independently before integrating them into the vehicle, which can lead to faster development cycles and improved quality control.

## Cost Efficiency

A zonal architecture lowers material costs and reduces the vehicle's carbon footprint. For example, Rivian reported a 20% savings in material costs and a 15% reduction in carbon footprint by implementing their new zonal system.



## Power Distribution

Power distribution is a critical factor in modern vehicles, especially as they incorporate more electrified systems and higher power demands. Zonal architecture enhances power distribution by enabling more efficient and direct routing of electrical power within each zone. In a zonal system, power can be delivered closer to the point of use, reducing losses associated with long wiring runs and the need for multiple power conversion stages. This localized power management also allows for the integration of different voltage levels within the same vehicle, such as 48V systems for high-power components and power transmission, while still supporting traditional 12V (and below) systems for other functions. This flexibility ensures that power is used more efficiently, reducing overall energy consumption and improving the vehicle's fuel economy or range of electric vehicles.

## Modular and Scalable

Zonal architecture is inherently modular and scalable, making it ideal for accommodating the diverse needs of different vehicle models and configurations. Each zone operates as a self-contained module, which can be easily added, removed, or upgraded without necessitating a complete redesign of the vehicle's electrical system. This modularity simplifies the process of scaling the architecture to different vehicle sizes and types, from compact cars to large trucks, and even electric or hybrid vehicles. Manufacturers can create a common platform that serves multiple models, reducing development costs and time to market. Furthermore, as new technologies emerge—such as advanced driver-assistance systems (ADAS) or infotainment upgrades—they can be integrated into the existing zonal structure with minimal disruption, future-proofing the vehicle's electrical architecture.



## Safety

Safety is a paramount concern in automotive design, and a zonal electrical architecture enhances it in several ways. By localizing power distribution and reducing the complexity of wiring harnesses, the risk of electrical faults, such as short circuits or overheating, is minimized. Each zone can be equipped with its own dedicated safety mechanisms, such as circuit breakers or fuses, which can isolate faults and prevent them from affecting the entire vehicle.

Additionally, zonal architecture facilitates better monitoring and diagnostics, enabling the detection of issues at the zone level before they escalate into more serious problems. This not only improves the vehicle's safety but also simplifies maintenance and repairs. In the event of a collision, the zonal approach allows for quicker isolation of damaged areas, reducing the risk of electrical fires or other hazards, and enhancing the overall crash safety of the vehicle.

## Strategies Summary

Overall, the transition to higher voltage infrastructure presents both challenges and opportunities for automotive electronics companies.

By adopting strategies such as **zonal architecture**, **efficient power distribution**, and **modular design**, these companies can not only overcome the challenges but also reap significant benefits.

This section has outlined some of the key strategies that can be employed, showcasing how they can contribute to the success and competitiveness of companies in this space.



# Allegro's Advantages

## Applications Expertise

Allegro is an established leader in automotive electronics with extensive experience in sensing and power IC solutions. This broad experience has enabled us to move quickly into 48V solutions (Figure 4).

Allegro's application expertise is evident in its ability to innovate and create products that meet the demanding automotive standards for safety such as ISO 26262, the associated ASIL requirements, and robustness standards, including SAEJ1211/AECQ-100.

Allegro identified the 48V trend early on and strategically developed a robust portfolio of 48V solutions, many of which are already integrated into vehicles on the road today, including leading EV brands. This proactive approach has positioned Allegro as a leading partner for 48V innovation in the automotive industry. Our success is not just about releasing products; it's rooted in our proven track record and deep applications expertise. We have consistently delivered innovative solutions that meet the demanding requirements of modern automotive systems, making us a trusted partner for manufacturers looking to excel in the evolving landscape of automotive electronics.

Allegro's ability to anticipate market trends and prepare for the industry's shift to 48V systems underscores its application expertise. By developing a broad portfolio of products that enable a smooth transition from 12V to 48V systems, Allegro positions itself as a valuable partner for automotive manufacturers looking to future-proof their designs. Our focus on integrating safety features, such as diagnostics and redundancy, further solidifies our reputation as a company that understands the critical importance of reliability and safety in automotive electronics.

## Electric Vehicle Powertrain

▶ High Voltage Traction Inverter and Motor

▶ DC/DC Converters and Charging

▶ Battery Management Systems

▶ 48V Mild Hybrid Starter Generator

▶ On-Board Chargers

▶ Thermal Management

## Conventional Powertrain

▶ Pump Systems

▶ Engine Management

▶ Transmission

▶ Cooling Fans

## Safety and ADAS Applications

▶ Electric Power Steering

▶ Steer-by-Wire

▶ Braking Systems

▶ Heads-up Display

▶ Detection and Ranging

▶ Driver Monitoring

▶ Lighting

▶ Seat Position

▶ Seatbelt

## Comfort

▶ HVAC Systems

▶ In-Cabin Motors

▶ Infotainment

Figure 4. Allegro's automotive application areas.

## Technologies

As a leader in the sensor and power ICs arena, Allegro has developed multiple technologies that enable companies who use their products to develop **better designs and do it faster.**

These technologies are valuable for automotive but also useful in other industries like **industrial automation and clean energy.** Some of these technologies include:

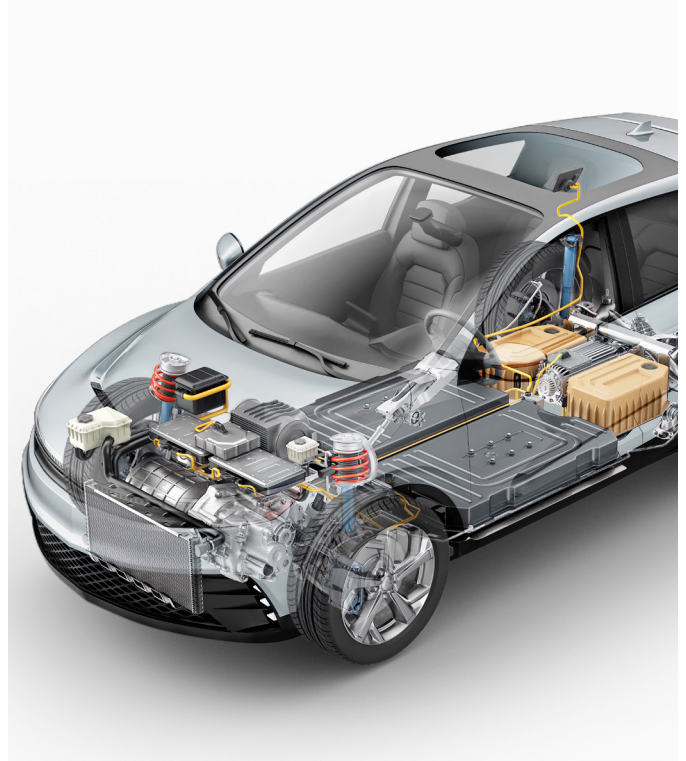
### **XtremeSense™ Tunneling Magnetoresistance (TMR) Technology**

Designed for advanced driver assistance systems (ADAS) applications, the innovative XtremeSense™ TMR technology offers industry-leading resolution and accuracy, providing up to eight times greater sensitivity than the GMR equivalents. Measured against traditional Hall-effect sensors, the improvement in resolution is even more pronounced.

Allegro's groundbreaking XtremeSense™ TMR-based solutions are developed in close collaboration with key market-leading customers and are redefining the future of sensing technologies for safety-critical systems and the autonomous vehicles of tomorrow.

### **Power-Thru Technology**

Allegro's Power-Thru technology simplifies high-power system designs by integrating the isolated gate driver and the isolated power supply into a single, efficient package. It includes—within the integrated circuit—a single magnetic coupling device that transfers the gate on/off logic signal with the power needed to drive the gate of the switch, eliminating the need for external auxiliary power.

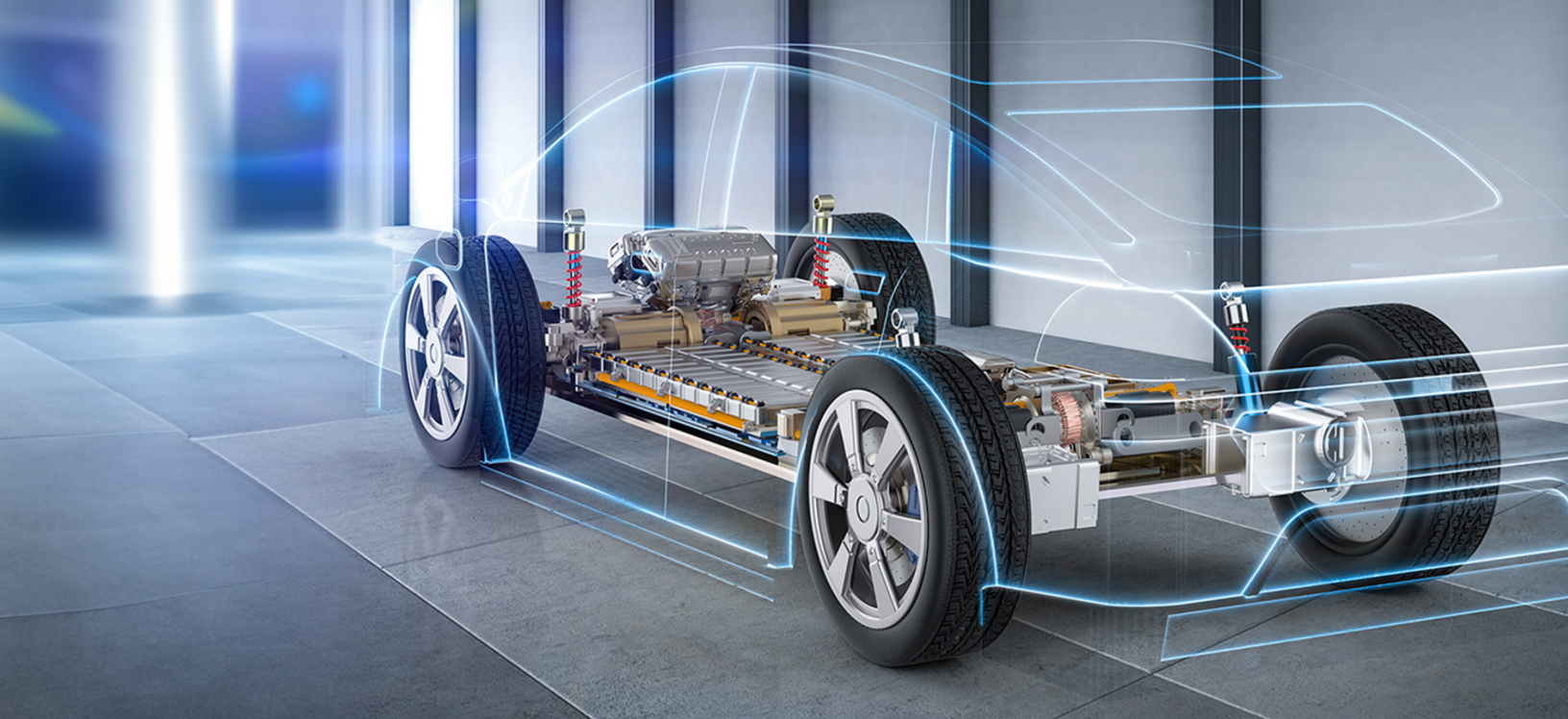


### **Giant Magnetoresistance (GMR) Sensor Technology**

GMR offers the ability to improve signal-to-noise, increase resolution, or reduce the required field level for a given solution (smaller magnets, larger air gaps, etc). Additionally, sensing in-plane to the wafer or IC surface gives the ability to create new, more robust, differential magnetic solutions not possible with planar Hall technology.

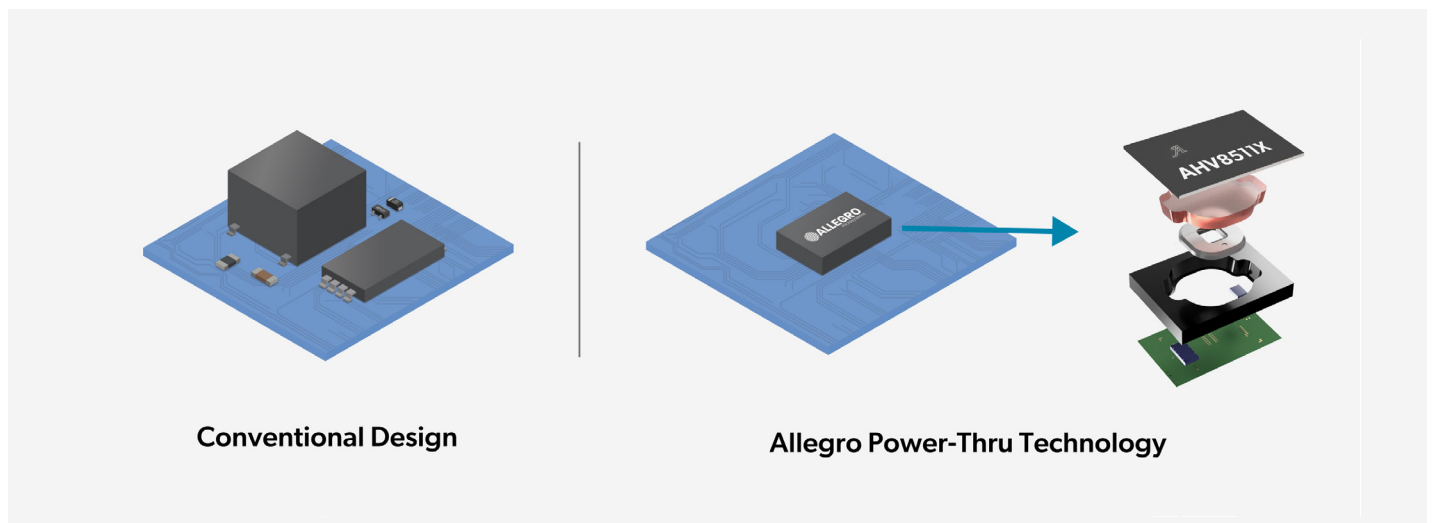
### **Hall-Effect Sensor Technology**

The effect of a magnetic field on the current through a conductor (the "Hall effect") was first discovered in 1879. Today, Allegro leverages this fundamental property of physics, along with modern semiconductor technology, to build speed, position, linear, angle, and current sensors. Our Hall-effect sensor integrated circuits incorporate one or multiple Hall elements with other circuitry, such as op-amps and comparators, to make digital angle/position sensors and speed sensors, as well as linear and angle sensors with analog outputs.



This patented approach reduces component count, minimizes electromagnetic interference (EMI), and boosts power density, enabling engineers to create more compact and reliable systems. Power-Thru technology eliminates the need for complex bootstrap components, bulky DC-DC isolated power modules, additional PCBs, and multiple connectors, which traditionally complicate designs.

By combining these essential components into one solution, Power-Thru technology offers significant benefits, including up to 50% fewer components, 2x the power density, and up to a 20dB reduction in EMI. This results in faster time to market, improved efficiency, and cost savings—making Power-Thru technology a game-changer for engineers looking to streamline their designs while enhancing performance.



**Figure 5.** Power-Thru technology uses magnetic coupling to deliver switching power with logic, eliminating the need for external auxiliary power supplies.

## Future-Proofing Designs

**Allegro MicroSystems develops semiconductor components that are not only supply-capable but also system-capable, a distinction that's becoming increasingly important as the automotive industry moves toward 48V systems.**

While “**supply-capable**” refers to components that can handle specific input voltage levels, such as 12 or 48 volts, Allegro’s system-capable components are designed with the future in mind.

These components are not only capable of operating within today’s 12V systems but are also designed to transition seamlessly to 48V architectures—reducing redesign times and requalification efforts. This approach means manufacturers can integrate Allegro’s components now and be confident that they will continue to perform as system demands evolve.

For instance, many of Allegro’s chipsets are engineered to work efficiently in existing 12V systems and can be upgraded to 48 volts without requiring costly requalification. This flexibility allows manufacturers to adopt Allegro components today and integrate those designs into next-generation electrical systems. By focusing on system-capable designs, Allegro ensures that their components not only meet current needs but will also simplify the transition to higher voltage systems, saving time and design costs.



## Business Acumen (Why Allegro?)

Automotive manufacturers partner with Allegro because **our semiconductors consistently meet or exceed design requirements.**

Electrical engineers trust Allegro not only for the performance and reliability of our products but also for the comprehensive support we provide throughout the design process. From offering detailed recommended application circuits to conducting in-depth design reviews, we ensure that our customers have the accurate information and the human support they need to achieve successful outcomes. Our approach goes beyond just selling chips—we are committed to delivering a complete, successful design project from conception through scaled production.

Procurement specialists rely on Allegro for **our robust and resilient supply chain,** which is designed to minimize risks and deliver reliable, budget-friendly products with a focus on zero defects.

We excel in supply chain management and collaborate closely with our customers from the design phase to production. This collaboration, combined with our focus on specific markets, gives us a competitive edge that procurement teams value. Allegro is not just a vendor; we are a committed partner dedicated to ensuring that your projects are successful from start to finish.

Design managers choose Allegro because **we understand the importance of trust and reliability** in the development process.

We work closely with design teams to deeply understand their challenges, which allows us to help reduce risks and speed up design times. By integrating multiple functions onto a single device, we simplify the design process, enabling faster design cycles and higher reliability, resulting in faster time-to-market. Moreover, we can offer custom packaging and even customization of the device itself to meet specific needs. With a resilient, ISO-certified supply chain, we ensure that our customers' delivery forecasts are consistently met, making us a partner who contributes to creating the best designs and ensuring on-time delivery.



# Conclusion

The transition from a 12V to 48V infrastructure in the automotive industry is not merely a response to growing power demands but a critical evolution necessary for supporting the advanced functionalities of modern vehicles.

From electric power steering to autonomous systems, the increasing complexity of vehicular electronics requires a more robust power supply to ensure efficiency, safety, and performance. By adopting a 48V architecture, automakers can overcome the limitations of the 12V system, providing more power where it is needed while simultaneously reducing the strain on electrical components, minimizing energy losses, and improving overall vehicle efficiency.

Allegro MicroSystems is an established leader in the development and implementation of 48V systems, recognizing the shift towards higher voltage architectures early on. This foresight allowed Allegro to build a comprehensive portfolio of 48V solutions that are already being utilized in today's advanced vehicles, including those from leading EV manufacturers.

Electrical engineers and design managers trust Allegro not just for our innovative semiconductor products but for the full support we provide throughout the design process. By integrating multiple functions onto a single device, Allegro enables simplified designs, shorter development times, and increased reliability.



**Discover more about 48V technology here!**

Our commitment goes beyond merely supplying chips; we engage deeply with design teams, from providing recommended application circuits to conducting in-depth design reviews to ensure every project succeeds from conception through scaled production. Moreover, procurement specialists value Allegro's resilient, ISO-certified supply chain, which minimizes risk and guarantees on-time, budget-friendly delivery, making us the preferred partner for automotive manufacturers looking to future-proof their designs with dependable, high-performance solutions.

## In short:

- ▶ Allegro prioritizes automotive-grade designs, ensuring parts are optimized specifically for the automotive industry.
- ▶ Automotive-grade components that are fully compliant with stringent thermal, safety, and quality standards.
- ▶ Provides 48V future-proof components that are supply-capable and system-capable, ready for today's and tomorrow's systems.
- ▶ Advanced technology enables more efficient designs, such as the patented Power-Thru technology
- ▶ Allegro is a trusted partner with strong support resources and tools, plus supply chain reliability for seamless business operations.

# Appendix A.

## Comparing 12V vs. 48V Infrastructure

### Reduction in Wire Size

First, as power demands increase, the currents within a 12V system increase linearly (Electrical Power Formula):

$$P=V \times I$$

$$I=P/V$$

where P = Power (Watts); V = Voltage; and I = Current. Assuming the power requirements of a component remain constant, as the voltage increases the current decreases linearly. Reduced current means a proportionally smaller wire size. In the example in Figure 2, holding the power requirements constant at 480W and measuring the current across one meter of wire, 48V allows a reduction in the wire size from 8 AWG (8.35mm<sup>2</sup>) to 15 AWG (1.65mm<sup>2</sup>)—for a ~5x weight reduction (from 74.8g to 14.8g).

### Material cost

The smaller wire size results in reduced material costs. Assuming the conductor is copper, ignoring changes in insulation and connectors, and a price of \$.0089USD/g (as of this writing), there is approximately a 5X reduction in the material cost of the wire.



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### Revision History

Number	Date	Description
-	October 24, 2024	Initial release

### Reduction in Power Loss

Power loss (and associated unwanted dissipated heat) is similarly improved by increasing the system voltage to 48V. Again, referring to Figure 2, and employing Joule's law (which describes the relationship between an electric current passing through a conductor and the amount of electrical energy converted into heat):

$$P=I^2 \times R$$

where P = the rate at which energy is dissipated as heat (Watts); I = Current; and R = resistance. First, we can see that power losses increase with the square of the current. In our example, and using American Wire Gauge (AWG) tables for resistance of copper wire, a 12V system creates a power loss of ~3W for one meter of 8 AWG wire:

$$P_{loss}=(40A)^2 \times 2.08m\Omega$$

$$P_{loss}=3.328W$$

Similarly, for a 48V system using 15 AWG:

$$P_{loss}=(10A)^2 \times 13.6m\Omega$$

$$P_{loss}=1.36W$$

48V produces approximately a 3:1 reduction in power loss, with a corresponding reduction in dissipated heat and increased vehicle efficiency.

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