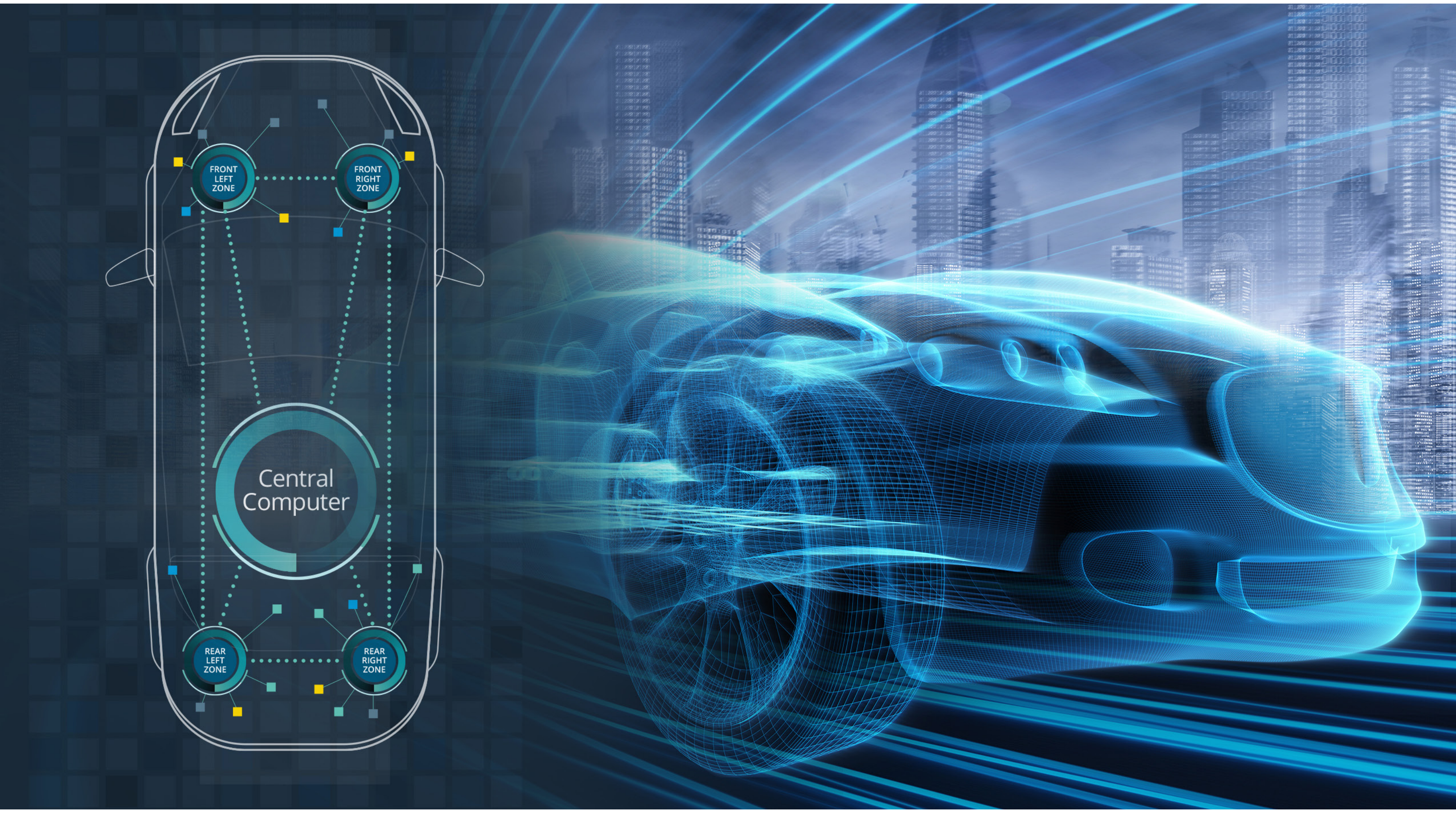
WHITE PAPER

ZONAL ARCHITECTURE: MAKING THE CAR OF THE FUTURE POSSIBLE



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molex

The automotive world is about to experience a revolution — one that will be far more profound than the move to electric propulsion, for that simply exchanges one power plant for another. Instead, this will be a fundamental change to how cars and other vehicles are made; it will be a change every bit as important as Mr. Ford's introduction of the moving assembly line in 1913.

Innovation has brought huge advances to the automotive industry. Manufacturers are constantly developing new technologies for their vehicles, whether they are improving safety, delivering greater performance or increasing passenger comfort. Some of these innovations have been the result of dedicated development within the automotive industry, while others have been adopted from the world of motorsports or even the aerospace industry. Going forward, advances in other disciplines also will play a major role. In a recent study co-sponsored by Molex and Mouser, Dimensional Research surveyed more than 500 automotive industry professionals. About 43% of respondents stated that one of the key drivers for change in vehicle design will be technological leaps in other areas that enable new capabilities. As a result, future vehicles will boast an enormous range of features that make them more sophisticated than ever before.

Despite the adoption of these new technologies, the way cars are built has not changed significantly in decades. The electronic systems within the modern vehicle often represent over half of its value, with new features constantly being added, but the techniques used to connect electronics have not advanced at the same rate as the hardware and software themselves. In fact, more than 57% of the professionals surveyed in the Molex and Mouser-sponsored study identified technology issues with manufacturing as one of the greatest barriers that must be overcome to achieve next-generation vehicle architecture.

The obstacles created by production technology issues are the result of how vehicle manufacturing has evolved. For example, currently new features and systems are developed and added to the existing vehicle wiring. Each feature is introduced as a new module, known as an electronic control unit (ECU), provided with its own dedicated wiring to connect it to the rest of the vehicle. As a result, the latest vehicles each require between 100 and 150 ECUs, along with the associated wiring harnesses. Not only are manufacturers running out of space in their vehicles for all these systems, but their wiring requirements are approaching the point of saturation.

The installation of large numbers of sophisticated components has happened gradually over many years, and the cable harness has grown in complexity as a result. Like a snowball rolling downhill getting larger and larger, cable harnesses are now among the most complex components used in vehicle manufacturing.

Modern cable harnesses are tasked with delivering power, data and control signals all over the vehicle, and their complex shape means that they are costly to make. Despite the adoption of highly automated production lines by the automotive industry, cable harnesses are one of the few systems of any vehicle that are largely made by hand. This has several important consequences for manufacturers.

Hand assembly of any component is expensive, and a component the size and complexity of a vehicle harness is more costly than most. There is also a significant impact on quality. One of the key benefits of robots building cars can be found in quality control, as robots are designed to repeat tasks with near flawless precision. Currently, robots cannot be used to create vehicle cable harnesses due to the complexity and pliability of the item. For example, wiring harnesses, because they lack rigidity, can flex, twist and otherwise move freely, making them difficult for a robot to handle.

With kilometers of wire and hundreds of connectors in every vehicle, the manual assembly of vehicle harness systems makes them a frequent cause of failures and warranty claims throughout the automotive industry. The impact of such claims on the manufacturers, both in material costs and the damage to their reputation, should not be underestimated.

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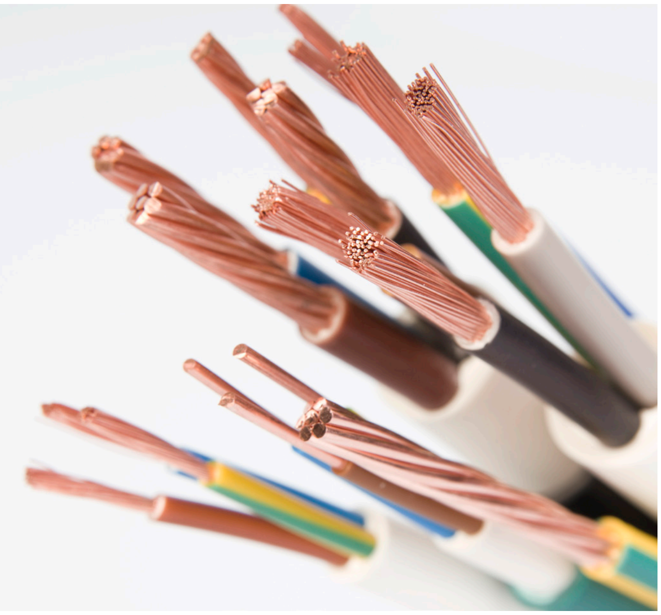
Copper cabling also plays a key role in vehicle performance, especially at a time when we are being encouraged to adopt smaller and more efficient modes of transport. The weight of such a large amount of copper cabling is a drain on the range and performance of cars and vehicles.

The next generation of vehicles will see even greater demand for electrical connections as new technologies are introduced into the automotive industry. Manufacturers are keen to take advantage of the latest 5G wireless communication to improve safety and user experience. For the first time, cars will form part of a dynamic network in which information is shared with other road users and even traffic control infrastructure, with the potential to make travel safer and more efficient. Known as vehicle-to-everything (V2X) communication, this technology will see cars equipped with more sensors, controls and computing power than ever before.



81%

believe Level IV autonomous driving will be standard in 10 years — putting more pressure on cabling and performance

This will be even more critical in the much-publicized move toward autonomous or “self-driving” vehicles. Of the professionals who participated in the Molex/Mouser survey, 81% believe that Level IV autonomous driving will be available as a standard feature in new vehicles within the next 10 years. Advanced driver assistance systems (ADAS) are already providing the user with sophisticated solutions for road safety. Interaction with other road users will depend upon systems that can collect, analyze and act upon information about their surroundings with the lowest possible delay or latency.

These innovations are taking place at the same time as the move toward alternative power sources. Hybrid vehicles are already common, and many manufacturers have made commitments to eventually end production of vehicles powered by internal combustion engines. Battery power and even hydrogen fuel cells are seen as sustainable solutions for the future. Electric power and high-speed communications will all place greater demands on the cable harness systems of the next generation of vehicles. Manufacturers are using this as an opportunity to address the fundamental question of how vehicles are designed and created.

FLAT AND DOMAIN ARCHITECTURES

The largest producers have decades of experience in building vehicles. As a result, the architecture of their vehicles has grown over many years in a cumulative process as new systems are added. Connections from device to ECU to vehicle have been added in a haphazard way, with much duplication of wiring and complex structures. The result is a “flat” wiring architecture, a highly complex structure comprising a considerable amount of cabling, making its assembly an inefficient and labor-intensive task.

This flat structure is unable to adapt to the new systems that the future of the automotive industry demands. Many manufacturers have moved to a more structured architecture, often referred to as a domain-oriented design. In this architecture, vehicle structures are grouped by function to provide control for the entire vehicle. Each domain features its own controller, whether for power train, safety systems or infotainment. And each domain controller communicates with others using a gateway to create a unified, whole-vehicle system.

However, the grouping of domains by function does not yet solve the problem caused by a profusion of cables. A single domain still comprises a range of devices deployed throughout the vehicle, requiring its own unique connection to the controller. While more adaptive than an old-fashioned flat architecture, the domain approach is still a long way from the ideal solution for the future. It does, however, serve as a stepping stone toward a completely new approach to vehicle electronics that will change not only how cars work, but also how they are made, updated and maintained.

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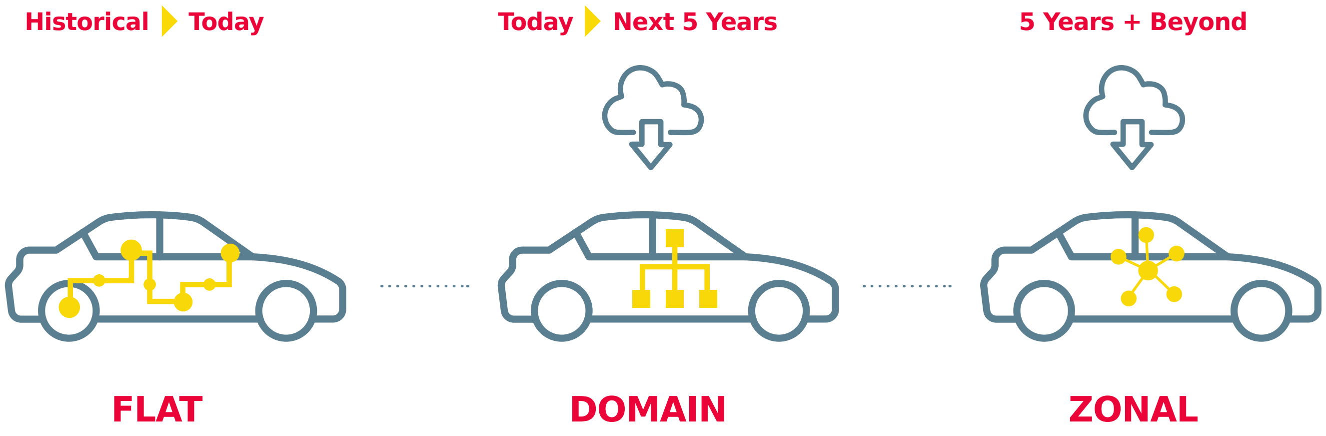
ARCHITECTURE EVOLUTION



INTRODUCING ZONAL ARCHITECTURE

Zonal architecture is the name given to this new approach to vehicle electronics. In contrast to a domain architecture in which vehicle systems are grouped by function, zonal architecture offers a more efficient solution. The functions within a vehicle are grouped by location into several zones. Each zone is responsible for the devices that are installed in a particular section of the vehicle and are connected to a locally installed zonal controller or gateway. Because a zonal gateway is close to the devices it controls, the cable lengths required to connect them are relatively short.

Each zonal gateway is connected to the central computing cluster at the heart of the vehicle. One of the critical changes is that the communication between zonal gateways and the central computer resembles that of a computer network rather than an automotive harness. As a result, this inter-zonal communication can take place over a small, high-speed networking cable that greatly reduces both the quantity and size of the cables that must be installed around the vehicle.

This new approach leverages the latest developments in computing power and high-speed communication, both of which will be essential due to the huge increase in data that this next generation of vehicle must process. The array of sensors that will form the eyes and ears of the latest ADAS and autonomous systems will create an unprecedented volume of information that must be processed at high speeds. The vehicle network of the future will see speeds of 10 Gigabits per second (Gbps) and greater. Cars equipped with zonal architecture will require computing power equivalent to several of the best desktop workstations — a “data center on wheels.”

Designers who are rethinking the concept of vehicle wiring are also looking at the distribution of power. Each of the devices, be they motors, sensors or ECUs, will require power. While conventional vehicle power is supplied at 12V, designers are investigating the potential to adopt higher voltages of up to 48V. Increased voltage would allow a corresponding reduction in current to deliver the same amount of energy to devices. As higher currents require wires of thicker gauges, a reduction in current would allow the power cables in this new architecture to be similarly reduced.

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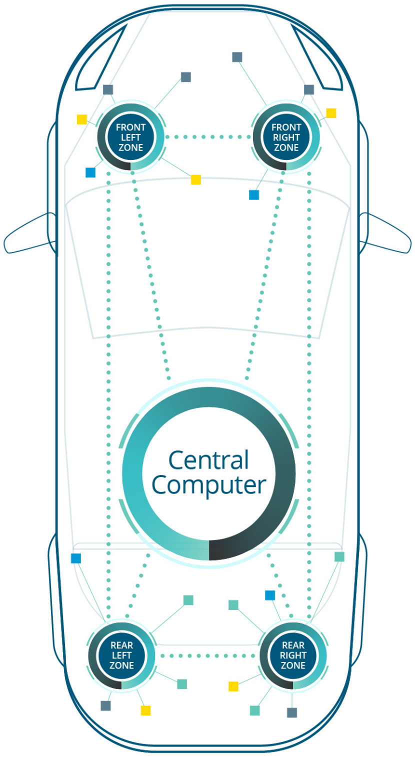

The advantages offered by zonal architecture will change automotive design completely.

At its heart, the zonal approach reduces the complexity required of the cable harnesses within the vehicle, in terms of both the number of wires and the distances they are required to travel. The connection of devices to a zonal gateway will be made locally, keeping cable lengths to a minimum. This will be true of data and power cables, as the zonal gateway can serve not only as a processing hub but also as a power distribution module.

The communication links between the zonal gateways and the central computing cluster can be achieved with few high-speed networking connections, perhaps constructed of a small number of twisted pairs. Even allowing for the redundancy that will be required in safety-critical systems, the quantity of copper cabling that will need to run through the body of the vehicle will be greatly reduced.

The effect on vehicle manufacturing will be enormous. Not only will the volume of copper wiring become far smaller, but its reduced size will also greatly simplify cable harness installation. Instead of handling harnesses that stretch over the entire length of the vehicle, each zone can be installed in a modular fashion. The reduced weight of these new cabling systems will also impact vehicle efficiency, allowing electric vehicles greater range and improved performance for a given motive power.

This modular functionality will also bring about a new era of standardization. In contrast to current techniques that require a bespoke harness for each model of vehicle, or even between different options within the same model, the hardware of zonal architecture can be universal. The connection between the central computing cluster and the zonal gateways can remain unchanged between different types of vehicles, and devices can be added in a modular fashion to each gateway to enable variations.

This flexibility will be driven from the central computing cluster, as much of the power of zonal architecture will be derived as a result of software-defined vehicles (SDVs). Unlike traditional ECUs, which are designed to perform one function, software-driven functionality will allow zonal gateways to be adapted and updated to accommodate new functions as required. In turn, zonal architecture will enable more efficient integration of these functions. Individual components such as sensors and motors can be swapped or added using plug-and-play functionality. This will allow repairs or updates to be applied easily within the dealer network rather than in complicated workshops. The connection of the vehicle to the 5G cellular network will enable software to be updated remotely, a feature that is already being employed by some manufacturers.

CHALLENGES OF IMPLEMENTING ZONAL ARCHITECTURE

The arguments for the adoption of zonal architecture in vehicle design are compelling, but its implementation does present challenges. The automotive environment itself is tough on components, especially the sophisticated electronics that zonal systems will employ. Even normal conditions will expose equipment to rain, wind and weather, along with the dirt and dust found on the road surface. At the same time, consumers demand a quite remarkable level of reliability from their vehicles. Drivers expect all of the features of their vehicle to perform flawlessly, whether they are driving a few hundred meters/yards or as many kilometers/miles.

The shock and vibration that cars experience in everyday use are a challenge to the functions, reliability and long-term quality of vehicle electronics, and especially to high-speed data connections. With data speeds in excess of 1 Gbps, even a momentary break in connection caused by vibration can lead to the loss of huge amounts of information. In safety-critical applications, this loss of connection has the potential for disaster, so connector design must overcome the risks caused by vibration. After all, the architecture of the central computing cluster will require a range of board-to-board connector solutions that are tolerant of vibration, even while providing connection speeds many times higher than those seen in the automotive world today

> Connectors must tolerate vibration while providing higher speeds

Connector design will play an important role in the implementation of zonal architecture. The environmental challenges that vehicles will face and the expectations of high performance mean that existing automotive connector solutions are not ready for zonal systems. The connectivity between a device and zonal gateway will require a new generation of hybrid or mixed connectors that can carry both power and high-speed signals, even in the tough conditions found on the road. With greater functionality packed into each single connector, harness installation will also be considerably easier, as fewer connection points will need to be made.

Connectors intended for use in the central computing cluster will need to provide far greater resilience than conventional board-to-board solutions, while also offering high pin counts and power connections. Designers will also need a standardized design to allow the use of swappable modules, both to simplify manufacturing processes and to enable easy upgrades.

ADAS and autonomous driving systems will be subjected to a huge amount of scrutiny to ensure the level of safety that consumers and regulatory bodies will demand. As a result, connector design will need to comply with a level of certification that is rarely seen in commercial or consumer applications. It is possible that government policy may yet be one of the greatest barriers to adoption of this new technology. Nearly a third of the industry professionals interviewed in the Molex/Mouser survey suggested that navigating the emerging government regulations on autonomous vehicles will be a significant challenge that must be overcome before cars can truly embrace their future as data centers on wheels.

Which global manufacturer will take the lead in zonal architecture?

There will also be differences in how individual manufacturers will adopt this new technology. While established manufacturers in Europe, the U.S. and Japan will be able to draw from their own huge resources to develop new solutions, their existing portfolio of products and established manufacturing processes means that they will be unable to adopt new techniques quickly. This is not true of the many startup companies that, while lacking the industrial might of established manufacturers, are approaching these challenges unlimited by existing customers or design philosophies.

Many such startups unencumbered by existing mental and physical frameworks are located in China, where they are leveraging the country’s expertise in the cellular and network communications markets to develop the automotive solutions of the future. Regional location will also have an impact on the standardization of hardware. In the U.S., USCAR regulations will need to be adapted for new automotive technology, while European manufacturers will likely revise LV214 standards. The approach that the Chinese manufacturers will take is, as yet, unknown.

Many larger companies are choosing to deploy zonal technology through their high-end, low-volume brands. Some are even creating new brands, enabling them to approach this technology with the fresh perspective of less-well established manufacturers, while still enjoying the industrial might that their parent company can deliver. Which automotive manufacturer becomes the leader in the implementation of zonal architecture will be partially influenced by government policy on infrastructure, such as EV charging stations and 5G. For example, according to Bloomberg, by the end of 2020, the Chinese had installed more than 800,000 public charging stations in anticipation of high demand for electric vehicles. Meanwhile, at the same time period, Europe had more than 350,000 and the U.S. nearly 90,000. More than a third of those surveyed in the Molex/Mouser study felt that a lack of investment in such infrastructure would hamper the advancement of new vehicle technology.

Consumer demand will also play an enormous part in the acceptance of this new technology in the automotive industry. Along with its world-leading EV charging network, China boasts a healthy demand for prestige car brands. Therefore, China and other similarly emerging markets will be key to the growth of new vehicle technologies. While individual customers are unlikely to choose a vehicle based upon its use of zonal architecture, the features it supports will influence buying decisions. This is a view shared by the industry professionals in the Molex/Mouser survey, who felt that computing power would have the greatest impact on consumer behaviour over the next 5 years. About 43% stated that cloud computing would be critical, and 32% viewed out-of-car connectivity as the next big market driver — all technologies enabled by zonal architecture.

Adoption will also be influenced by how the new generation of travelers will use vehicles. While more mature customers still want to buy their own vehicle, younger generations will be more interested in transportation-as-a-service (TaaS) models that reduce the emphasis on vehicle ownership and promote alternative solutions to mobility. The flexible approach of zonal architecture would allow easy optimization of vehicles for each customer type, from full ownership to a pay-as-you-travel model.

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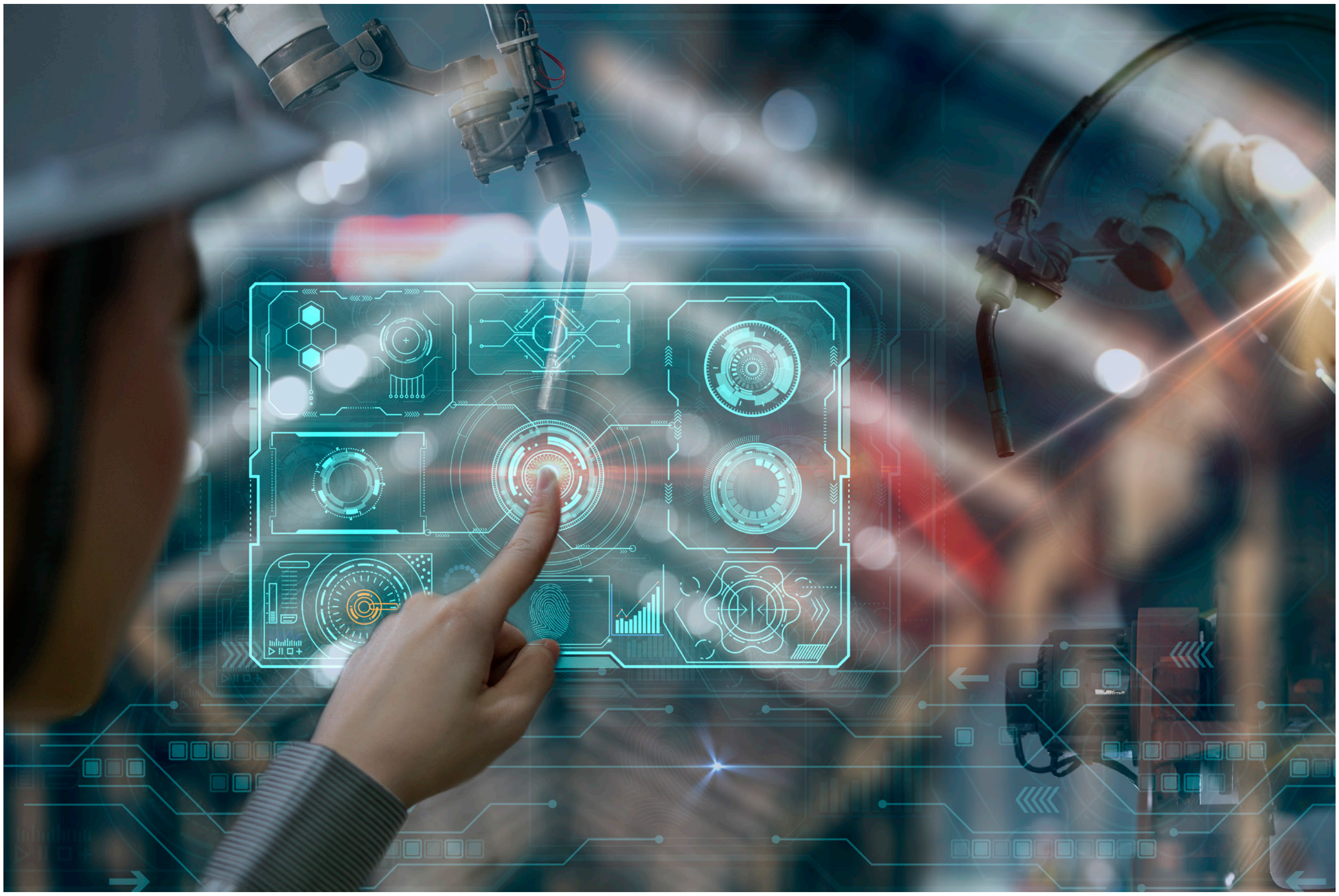

Although the move to zonal architecture will be led by software, the physical structure will play a huge part in making this concept a reality for manufacturers. Easier assembly, reduced weight and advanced modularity are just a few of the advantages that a zonal structure will bring to the task of building tomorrow's vehicles. Connectors will be critical to these designs, and Molex is already collaborating across markets and business units while leveraging its world-class signal integrity capabilities to deliver both high-power and high-speed solutions in this new automotive environment.

Of particular interest is the development of connectors that can be assembled by robots. Despite the advances of zonal equipment, the installation of cables and connectors will remain a manual process unless connections can be adapted for automation. Molex is taking its decades of experience in automotive connectors and applying it to the problem of robot handling. The result will be a range of connectors designed from the outset for automated assembly.

CONCLUSION

Zonal architecture will fundamentally change the face of vehicle manufacturing. It offers a huge range of benefits for manufacturers, dealers and customers, and will ready the automotive industry for the future of transportation, from ADAS and electrification to vehicle sharing and TaaS.

These benefits also present challenges for connector manufacturers. Solutions need to be developed that deliver power and high data speeds, while ensuring the reliability and safety required by the demanding automotive environment.

TECHNICAL EXPERTISE

AUTOMOTIVE EXPERIENCE

GLOBAL FOOTPRINT

Molex has the technical expertise, automotive experience and global footprint to develop connector solutions for zonal architecture. Whatever the requirements, Molex will be ready to meet and exceed these demands and help create the car of the future.

To learn more about our solutions that support the shift to vehicle zonal architecture, please contact Molex's experts, and to discover more about our upcoming hybrid connector solution, visit www.molex.com/link/mxdash.html.