ENABLING SUPERIOR MOBILITY EXPERIENCES

Supercharging Data Connectivity to Meet Next-Generation Automotive Expectations

CONTENT

The new consumer perspective: PACES

The thrill of powerful engines is fading. In its stead are: **personalization** and the ability to integrate consumers' digital lives into the mobility experience; **autonomous** and **automated** features for greater safety and comfort; constant **connectivity** to everybody and everything; **electrification**; and sustainability. Furthermore, younger drivers are less fixated on owning cars as status symbols. In fact, tomorrow's consumers may only want to 'dip in' to the mobility market on an as-needed basis, with the concept of **shared** mobility and alternative transportation models taking hold. The ability of a carmaker at the forefront of development in these areas to provide solutions with the right mix of forward-looking immersive and interactive driving experiences, both physical and digital, will be predictive in terms of who dominates the market in the years to come – and who gets left behind[1].

This paper will look at how today's automotive market trends – using the shorthand PACES – is impacting the evolution of vehicle technologies, as well as the consequences for electrical/electronic (E/E) architectures. Specifically, it will focus on how data connectivity requirements are evolving to become key enablers of new architectural concepts.

Safer and more comfortable driving experience
AUTONOMOUS

CO_2 reduction and environmental responsibility
ELECTRIFIED & SUSTAINABLE

P A C E S

PERSONALIZED
Customized, digital-life integrated experience

CONNECTED
Smart interaction with the environment

SHARED
Convenient, on-demand and efficient mobility

[1] www.luxoft.com/blog/why-your-next-dream-sportscar-will-be-electric, accessed July 2023

Software-defined Vehicles: An innovative way to address new consumer demands

Software defined vehicles (SDVs) can be the answer to the increasing system complexity that is required to fulfill PACES expectations. They allow the carmaker to keep up with developments or to stay ahead of market needs. The setup of SDVs provides a platform for offering new types of products, services and business models that allow an extraordinary level of personalization and digital-life integration, making upgrades possible not only at the point of sale but also post-purchase. If properly pre-equipped, SDVs can continue to add value and features long after they leave the production line.

The seamless implementation, long known in smartphones, also plays a crucial part in SDVs, such as the integration of digital profiles, apps and online services that are already tailored to the consumer. But it has the potential to go much further than this, with the ability to sell new physical vehicle features as subscription services. A simple example, already available in more advanced cars today and alluding to future potential, is the activation of more performance or higher levels of autonomous driving to suit a driver's needs. Soon, even more sophisticated options will become available to (and affordable for) a broader consumer base.

SOFTWARE-DEFINED VEHICLE

OEM business model moves from traditional style and mechanical-based **differentiation** to customizable, on-demand **software defined** functionality:

Increased safety and comfort from shared environmental data	Continuous over-the-air updates to improve functionality and performance	Enable on-demand features with subscription-based models	Vehicle customization to driver's personal needs and preferences

"In order to participate from the software-enabled opportunities ... vehicles need to have (1) an electronics architecture supporting full over-the-air (OTA) upgrade capability; (2) high-speed network connectivity ...; (3) edge computing capacity to channel the enormous amount of data generated by the vehicle to the back-end (4) for autonomous driving readiness, a hardware stack (computing, sensors and actuators) that already meets all requirements for full autonomy.

UBS Q-Series: Rise of software – can the auto industry master it? Global Research and Evidence Lab, 30 November 2022, p. 30

But SDVs are much more than a mechanism for delivering on the PACES future: they're a new source of revenue for carmakers. While changing mobility models threaten to disrupt automotive markets and supply chains, it is estimated that software-enabled features – provided on demand – have the potential to offer "new business models worth up to $700bn by 2030."[2] The proceeds from such bookable services promise to compensate for the certain revenue gap caused by the effects of the transformation towards a PACES-ready future.

However, to make this a reality, SDVs will require a full hardware stack comprising the antennas, sensors, actuators, high-performance computers, etc. that support OTA updates. Before the owner of a SDV can subscribe to a higher level of autonomous driving, for example, the vehicle must already meet the technological requirements for full autonomy.

The essential link that makes it work

All the antennas, sensors, displays, actuators as well as the high-performance computing units responsible for split-second decisions are required to make PACES become a reality. But one essential element is missing, because without unhindered and fast flow on the vehicle's internal data highway, a SDV cannot come alive. Robust and reliable high-speed connectivity technologies link all essential entities of an SDV together – much like our nervous system. High-performance data communications and robust, purpose-engineered connectivity in the automotive industry are therefore key to meeting the high expectations the market has for PACES, both now and in the future.

At TE Connectivity, we are already at work to ensure that tomorrow's connectivity is faster, more secure, more reliable – and able to handle the exploding volumes of data. Our connectivity solutions are not only smarter and smaller but are also better able to handle multiple objectives at the same time, such as transmitting signals and power alongside high-speed data in a multi-hybrid setup and have been designed from the start with assembly automation in mind. Our connectivity solutions afford the flexibility to innovate in the following categories:

1. AUTONOMOUS DRIVING – providing a safer, more convenient and more economical driving experience, from L3[3] traffic-jam pilots to L4 autonomous trucks and robotaxis.

2. USER EXPERIENCE – relying on intuitive human-machine interfaces (HMIs) to provide drivers and passengers visual, acoustic, and tactile interactions, both with the vehicle itself and with the world outside the vehicle.

3. CONNECTED VEHICLE – smart high-speed interaction within the vehicle and with the environment required for automated or autonomous driving features, increased safety from V2X applications and new, highly personalized digital experiences via function-on-demand (FoD) and other OTA services.

AUTONOMOUS DRIVING

USER EXPERIENCE

CONNECTED VEHICLE

[2] UBS Q-Series: Rise of software – can the auto industry master it? Global Research and Evidence Lab, 30 November 2022, p. 4 (https://www.ubs.com/global/en/investment-bank/in-focus/2022/rise-of-software.html)
[3] SAE Levels of Driving Automation (https://www.sae.org/blog/sae-j3016-update)

PACES Accelerate Mobility Innovation

2023	2024	2025	2026	2027	2028

AUTONOMOUS DRIVING

Safer, more convenient and economical driving experience. developing from L3 traffic-jam pilots to L4 autonomous trucks and robotaxis

Trend/applications		L3 traffic jam pilots & L4 autonomous parking	L4 highway pilots	L4 auton. trucks (hub-to-hub) & L4 robotaxis (urban areas)
Camera ADs	ADAS/	CMOS (8 MP)	CMOS (12 MP)	
	Satellite	CMOS (3 MP)	CMOS (8 MP)	
	Interior	CMOS (1 MP)	Integrated CMOS (3 MP)	
Radars		3D Radars	Imaging radars	
LiDARs		Scan. LiDARs (1 MP/s)	Solid state LiDARs (5 MP/s+)	

USER EXPERIENCE

Simple and intuitive HMI for visual, acoustic and tactile interaction with the vehicle and the outside world

Trend/applications	Infotainment cluster	Multimodal user experience	
Displays	Up to 20'' high resolution displays/ instrument clusters	Pillar-to-pillar multimodal displays/HuDs/e-mirrors	
Consumer Interfaces	Device integration (USB 3.2 Gen 1)	Device integration (USB 3.2 Gen 2)	Device integration (USB 3.2 Gen 2x2/USB 4)

CONNECTED VEHICLE

Deliver increased safety from V2X applications and new digital experiences via FoD and other OTA services

Trend/applications	Function-oriented,domain-centralized architectures	Software-driven, function-integrated,vehicle-centralized and scalable zonal architectures
HPCs	Silver box HPCs	Central In-Vehicle Application HPCs (rack systems)
Antennas/Telematics	Broadcast (<1.6 GHz)	Fusion of antenna and telematics/ remote tuner units
	5G/GNSS (6 GHz)	

Next-generation application challenges

1. The road to autonomous driving

Many safety enhancements and advanced driver assistance systems (ADAS) are already in use today, and autonomous driving (AD) systems are predicted to soon become standard in new vehicles.[4] Even though a driver is still generally needed behind the wheel, some AD functionalities have been introduced that shift responsibility away from the driver or relieve the driver of tiresome driving tasks, like the L3 traffic-jam pilot that takes over so the human can do something else while inching forward or the robo-valet parker that drives the empty car off to the next available spot. Such features are authorized to be used on public roads and designated parking garages. In selected cities, the experiment has advanced to L4 robo-taxis that are permitted to operate within pre-defined areas, and driverless L4 trucks will soon be ferrying goods hub-to-hub. Besides safety and efficiency, the goal here is more than just convenience: it's not to waste a driver's valuable time and attention.

Enabling these features requires a host of sensors, such as cameras, radars, LiDARs, etc. They rapidly collect and combine a vast amount of environmental information and feed it to high-performance computers that analyze, prioritize and act upon that information in real time. Sensor technology development will have several impacts on connector design requirements over the next years.

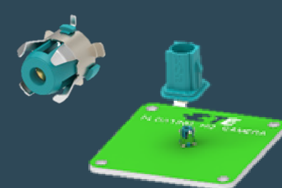
APPLICATION EXAMPLE
Camera Transformation

Today's vehicles typically contain just a few mono or stereo cameras placed all around the car. With a resolution of around 8 MP, they produce a corresponding data volume of around 8.5 Gbps each; they're generally connected with coaxial connectors.

To support ADAS and AD functionalities, the next generation of vehicles may need more than 10 cameras. They'll be smaller in size and have higher resolution (around 12 MP) to see further and with more detail than possible today. They'll produce a data volume corresponding to about 12 Gbps. For these compact but powerful cameras, the connector will not only have to support substantially higher bit rates but also offer a new level of physical integration into the device itself. In many cases the connector is already the largest component on the PCB, with the additional requirement to provide power – for e.g., active lighting or heat for defogging – even the smallest connector system can be a spatial challenge. Connector solutions will therefore need to be integrated right into the housing of such sensors.

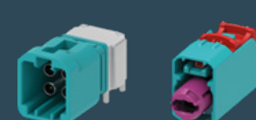
TE camera connection

Coaxial automotive camera connectors for all current and next-generation automotive coaxial SerDes protocols supporting up to 6 GHz bandwidth / 12 Gbps integrated into the camera housing.



MATE-AX – miniaturized coaxial connector systems

For coaxial data transmission, supporting up to 9GHz bandwidth with a 75% PCB footprint reduction.



[4] "... with full highway autonomy being a realistic target with a 5-year perspective." UBS Q-Series: Rise of software – can the auto industry master it? Global Research and Evidence Lab, 30 November 2022 (https://www.ubs.com/global/en/investment-bank/in-focus/2022/rise-of-software.html)

APPLICATION EXAMPLE

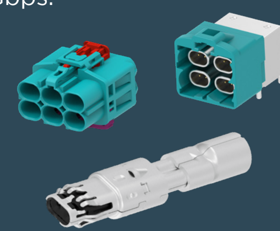
LiDAR transformation

LiDARs were already integrated into the vehicle Ethernet backbone when they were first introduced. Today, LiDAR technology used in vehicles is mainly scanning LiDAR. Typically, these sensors perform at 1 MP/s, which produces a data stream of 1 Gbps. But over the coming years, this technology is also expected to advance, with higher-resolution, solid-state LiDARs becoming the norm. These will perform at 5 MP/s and produce a 5Gbps ethernet-based data stream,

While today's scanning LiDARs can use unshielded differential connector systems, future solid-state LiDARs will instead require shielded systems. In addition, the space constraints (similar to those of cameras) are likely to drive adoption of hybrid data and power connectors that are physically integrated into the LiDAR device housing.

GEMnet – multi-gigabit automotive Ethernet connector system

Multi-gigabit differential connector system for multi-gigabit Ethernet and SerDes applications, enabling 15 GHz and up to 56 Gbps.



Transformation		**STATE-OF-THE-ART (2023)** **Data processed inside sensors grouped in functional domains**	**Next Generation (2028+)** **Multi-sensor data processing in centralized HPC**
Architecture	AD Cameras	2 Mono/stereo cams (8 MP/8.5 Gbps)	4-6 Mono/stereo (12 MP+/12 Gbps+)
	Satellite Cams	4 Surround cams (3 MP/3 Gbps)	4 Surround cams, 3 CMS (8 MP/8.5 Gbps)
	Interior Cams	1 DMS (1 MP/1 Gbps)	1 DMS, 1 OMS (3 MP/3 Gbps)
	Radars	2 LRR, 4 SRR (100 Mbps)	2 LLR, 4 SSR (1 Gbps)
	LiDARs	1 Scanning LiDAR (1 MP/s /1 Gbps)	1-2 Solid State LiDAR (5 MP/s+ /5 Gbps+)
Link Requirements	Coaxial	Up to 8.5 Gbps SerDes	Up to 12 Gbps SerDes
	Differential	Up to 1 Gbps Ethernet	2.5/5 Gbps Ethernet
	Type	Discrete connectors	Trend to hybrid and integrated solutions

Figure 1: Autonomous driving application technology evolution and connectivity requirements.

2. User Experience: A seamless continuation of digital life behind the wheel

Next-generation cars will have increasingly intuitive human-machine interfaces that enable easy visual, acoustic and tactile interaction with both the vehicle and the outside world. This will provide a personalized and interactive user experience: a seamless extension of mobile digital services inside the vehicle along with support for increasingly more powerful consumer devices.

APPLICATION EXAMPLE
HMI Transformation

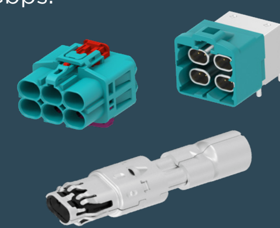
While today's digital cockpit may consist of up to five discrete high-resolution (up to 4K) displays and heads-up displays (HUDs), the next-generation vehicle is likely to be characterized by multi-modal, ultra-high resolution (up to 8K), 30-inch pillar-to-pillar dis-plays, as well as e-mirrors.

For consumer device integration, the adoption of USB 3.2 Gen 2x2 and USB 4 for multi-lane operation will require connectivity support in the range of 20 Gbps – compared to the 5 Gbps of today's USB 3.2 Gen 1.

These advancements will have a significant impact on the connectivity requirements for displays or consumer interfaces, which will probably need to support up to 20 Gbps (SerDes) / 10 Gbps (Ethernet) – as compared to 6 Gbps / 1 Gbps respectively in today's vehicles.

GEMnet – multi-gigabit automotive Ethernet connector system

Multi-gigabit differential connector system for multi-gigabit Ethernet and SerDes applications, en-abling 15 GHz and up to 56 Gbps.



Transformation		STATE-OF-THE-ART (2023) Discrete displays and heads-up-displays (HUDs) with point-to-point topology to domain controller	Next Generation (2028+) Seamless, multimodal, pillar-to-pillar displays, e-mirrors, HUDs with daisy chain topology to HPC
Architecture	Displays	1-5 high-resolution instrument clusters/center displays (Up to 20", 4K, 8 Gbps)	Up to 12 ultra-large screens (30"+, 8K, 3D and touch), e-Mirrors and heads-up displays (20 Gbps+)
	Consumer Interfaces	Device integration USB 3.2 Gen 1 (5 Gbps)	Device integration USB 3.2 Gen 2x2/USB 4 (20 Gbps)
Link Requirements	Coaxial	Up to 6 Gbps SerDes	20 Gbps+ SerDes
	Differential	Up to 1 Gbps Ethernet	Up to 10 Gbps Ethernet
	Type	Discrete connectors	Trend to hybrid and integrated solutions

Figure 2: Application technology evolution and connectivity requirements for infotainment and digital cockpit.

3. Connected vehicle: the evolution of automotive data communication

In the early days of developing ADAS, the interplay between camera and radar technologies could lead to a dilemma. Whereas radar systems sometimes mistook everyday objects like manhole covers or drink cans for another vehicle due to their wave reflections (a trait shared with actual cars), cameras could identify these as non-threats.

To better address such situations, sensor fusion was introduced whereby data was not processed in the sensors but rather in a central computing unit. Between sensor fusion and centralized data processing, the sensors themselves have become less 'intelligent', transmitting large quantities of raw, high-resolution data directly to central computing units of increasingly higher performance.

At the same time, one of the major promises of SDVs is the ability to offer new ways of customization with FoD upgrades using OTA technologies. However, trying to update dozens of ECUs individually over the air using relatively slow vehicle bus-systems for the last mile is clearly the wrong approach! To manage the complexity that permits OTA software/firmware updates and upgrades, centralized computation clusters and high-speed communication links are required.

Such vehicle developments impacting E/E architecture can be viewed as starting points for a more connected vehicle design, aimed at improving the management of large data streams both within and outside the vehicle.

Transformation		STATE-OF-THE-ART (2023)	Next Generation (2028+)
		Function-oriented set-up, distributed over multiple domains	**SW-driven, vehicle-centric/ zonal architecture with powerful high-performance computers and telematics for OTA and V2X connectivity**
Architecture	ECUs	Up to 150 distributed controllers	1-3 central HPCs with 3-4 zone controllers
	Antennas	Up to 25 passive/active	Smart antennas integrated with TCUs/RTMs
Link Requirements	Coaxial	Up to 6 Gbps SerDes (mainly cams)	12 Gbps+ SerDes (mainly cams)
	Differential	Up to 1 Gbps Ethernet (Backbone)	Up to 10 Gbps Ethernet (Backbone)
	Type	Discrete connectors	Trend to hybrid and integrated solutions

Figure 3: Technology evolution and connectivity requirements for the connected vehicle's E/E architecture

E/E architectures have, over time, become increasingly distributed and convoluted, because literally each new vehicle function introduced a new ECU. And, to connect up to 150 ECUs throughout the vehicle requires a complex wire harness with thousands of wires and connectors – which constitutes the third heaviest and third most expensive part of a passenger car.

Therefore, today's vehicles have smarter E/E architectures that reorganize the wire harnesses to support more efficient, higher-speed transmission of vastly more sensor and environmental data. The objective is fewer ECUs – often referred as nodes – with significantly more ports per node.

Domain-based architectures consolidate multiple nodes into specific functional domains like chassis, ADAS, infotainment, etc. Each domain has its own controller that communicates with each other through a central gateway[5]. The structural reorganization of domain-based E/E architectures facilitates data exchange among individual nodes within the same functional domain. A central gateway efficiently manages communication via Ethernet, currently at speeds of up to 100 Mbps but soon approaching 1 Gbps. Within each domain, sensors and displays communicate with the central nodes using SerDes protocols, soon with speeds of up to 12 Gbps.

[5] www.eetimes.eu/how-software-defined-vehicles-are-redesigning-mobility/, accessed 12 September 2023

APPLICATION EXAMPLE

E/E Architecture Transformation

Streamlined and consolidated architectures can simultaneously reduce vehicle complexity and the need for model-specific wiring systems. Vehicle-centralized zonal E/E architectures group functionalities based on their location within the vehicle. This radically different approach has the potential to further reduce both the complexity and the size/weight of the entire wiring system, as well as its manufacturing time and cost.[6] In principle, large quarters of the vehicle could be assembled as fully formed blocks that 'plug' together and tap into a high-speed, Ethernet-based data-processing backbone.

Over the next years, the emergence of zonal E/E architectures will further consolidate the number of port-dense nodes by connecting diverse but co-located vehicle functions to nearby zone controllers/computers (ZCs) that, in turn, link to high-performance computers (HPCs).

Working more like a computer network, with a high-speed Ethernet backbone that supports communication between HPCs and ZCs, inter-zonal communication will rely on high-speed Ethernet (10 Gbps), whereas high-speed point-to-point links to sensors and displays will tend to be SerDes-based, with data rates of 24 Gbps.

The main connectivity challenge, however, remains the increasing connector footprint on the HPCs and ZCs. Some future vehicle architectures can require dozens of differential and coaxial ports, in addition to multiple connections for signal and power. Here, multi-hybrid data connectivity solutions play a role, as they integrate coaxial and differential data ports with signal and power connections in a single, compact connector assembly.

NET-AX+ modular hybrid data connector

Supports coaxial and differential data connectivity for multigigabit Ethernet, SerDes and other application protocols and can integrate signal and power connections. Up to 40% PCB space reduction and 85% fewer mating assemblies

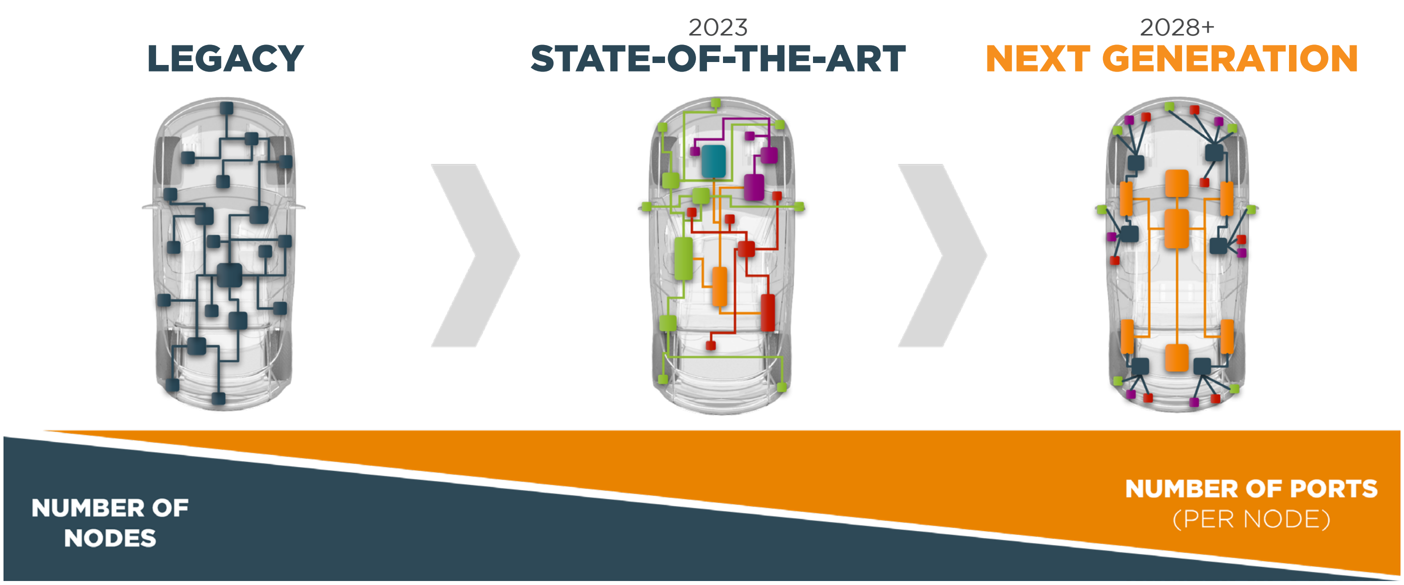


Figure 4: Automotive E/E architecture transformation and impact on connectivity design drivers. The ultimate goal is fewer nodes/ECUs but significantly more ports (connection opportunities) per node – linked together by Ethernet.

[6] www.electronicdesign.com/markets/automotive/article/21248116/molex-harnessing-the-potential-of-zonal-architectures-to-build-nextgen-vehicles, accessed 12 September 2023

Beyond the Need for Speed - The next connectivity challenge

A streamlined, modular E/E architecture may also allow OEMs to simplify vehicle assembly, thereby increasing production efficiency and speed. Standardized, modular parts enable component makers to use robotic assembly lines. Some carmakers are already targeting assembly time reduction by two thirds to about 10 hours[7].

In addition to production efficiency, automation reduces supply chain risks. Recent supply instabilities, along with growing public awareness of environmental impacts and greenhouse gas (GHG) emissions, are cogent reasons to co-locate supplies and production processes.

Furthermore, all the new safety-critical functions (ADAS and AD) require higher levels of production control than ever before. Automated manufacture and assembly of the wire harness would mitigate human-introduced errors. In addition, automation also enables the simplification of connector design, since the precision of robotic assembly eliminates the need for lever systems or secondary locks to ensure connectors are properly mated.

Relieving the connectors of such parts further trims down overall component size and material consumption, translating directly into GHG savings.

In addition to physical connector designs optimized for robot gripping and mating, the production processes and all the connector components themselves are digitized with coherent traceability ensured by virtual representations (digital twins),[8] representing a huge improvement over today's standalone reports for individual process steps.

[7] europe.autonews.com/automakers/how-vws-trinity-project-aims-catch-tesla, accessed 12 September 2023
[8] Platform Industrie 4.0 (www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/Details_of_the_Asset_Administration_Shell_Part1_V3.html)

In Conclusion: TE's data connectivity solutions enable superior mobility experiences

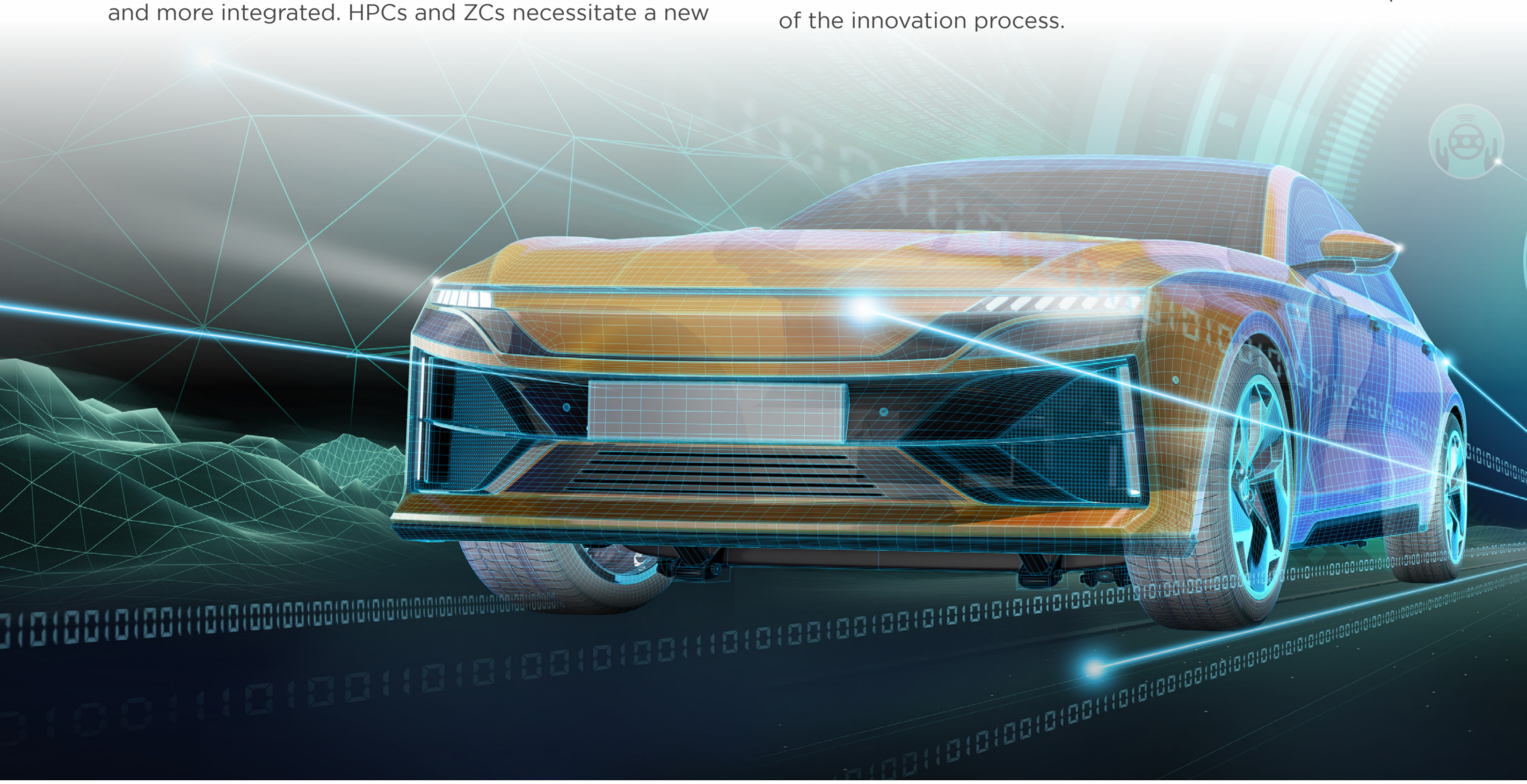
Autonomous driving features, personalized user experiences and connected vehicle capabilities are key to delivering the next generation of mobility experiences and meeting changing consumer expectations (PACES). However, these technology advancements and the associated complexity have pushed carmakers to transform traditional flat and distributed automotive E/E architectures, with their scores of individually cabled and heterogenous ECUs, into highly centralized and networked structures that rely on fewer nodes but much higher port densities.

At the same time, the design drivers for data connectors are also changing: today, speed and reliability are no longer USPs but are increasingly considered a given. Data connectivity solutions must therefore be smarter and more integrated. HPCs and ZCs necessitate a new breed of modular connector that can accommodate any permutation of high-speed coaxial and differential – as well as signal and power connections – in one compact, multi-functional, port-dense component.

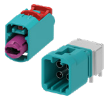
Moreover, the connectors need to support smart manufacturing processes and be robot-ready, meaning that they've been conceived and validated for use in automated wire harness production and assembly equipment. That means that every individual part of the connector must be designed from the start for automation.

Fulfilling PACES market expectations, while delivered by software, will rely on structural and hardware innovations, but the enhanced technology stack required to deliver the personalization and flexibility promised by SDVs can do nothing without smarter high-speed connectivity.

TE Connectivity's **data connectivity portfolio** combines best-in-class, market-compatible automotive products with breakthrough solutions designed specifically for the demands of next-generation automotive E/E architectures. In addition, our deep expertise and the tools we've developed for mechanical and electrical design and manufacture – across all current and next-generation E/E architectures – qualify us for highly effective collaborations with our customers at each step of the innovation process.



Coaxial Connector System

Products	Picture	Media	Bandwidth	Protocols	Speed	Example Applications	
MATE-AX		Coaxial	Up to 9 GHz	SerDes: GMSL2/3, FPD-Link IV APIX3, MIPI Analog (Antennas)	12 Gbps (NRZ) 24 Gbps (PAM4)	• 4K Cameras • Sensors • Hi Res. Displays	• WLAN Antennas • Mobile Internet (3G/ LTE)
FAKRA		Coaxial	6 GHz	SerDes: GMSL2/3, APIX3, MIPI Analog (Antennas)	Up to 6 Gbps	• Broadcast Antennas • GPS • Cellular (GSM)	• Cameras • Bluetooth • Keyless Entry
CAMERA CONNECTION		Coaxial	6 GHz	FPD-Link III/IV, GMSL 2/3, MIPI, ASA, GVIF	12 Gbps	• Rear view cameras, Surround view cameras, • Night vision cameras	• Lane departure warning, Park assist, Driver monitoring

Differential Connector System

Products	Picture	Media	Bandwidth	Protocols	Speed	Example Applications	
MATEnet		Twisted Pair	1 GHz	1000BASE-T1 100BASE-T1 HDBASET, PCIe A2B/C2B	Up to 1 Gbps	• In Vehicle Networking: Ethernet/ PCIe • Radar/LiDAR	• Rear View Cameras • Multimedia (HDBASET)
HSD		Star Quad Wire	2 GHz	SerDes: GMSL1, FPDIII, APIX2, USB 2.0	Up to 6 Gbps (dual channel)	• Legacy Infotainment • Dashboard /Touch Screens	• HD Screens • USB Connections
GEMnet		Twisted Pair	15 GHz	100/1000BASE-T1 2.5/5/10/25GBASE-T1	Up to 25 Gbps (NRZ) 56 Gbps (PAM-4)	• In Vehicle Networking: Ethernet/ PCIe • High performance computers, control units • Radar/LiDAR	• High-Res. (4K) Displays
BEAMnet		Twisted Pair Parallel Pair		GMSL3, APIX3, GVIF3, FPD-Link IV, ASA Motion Link, MIPI A-PHY and HDBaseT / USB and PCIe (BEAMnet only)			

Multi-Hybrid Connector System

Products	Picture	Media	Bandwidth	Protocols	Speed	Example Applications	
NET-AX+		Differential / Coaxial + Signal/ Power	15 GHz	Automotive Ethernet 100BASE-T1, 1000BASE-T1, 2.5/5/10/25GBASE-T1 SerDes: GMSL3, APIX3, GVIF3, FPD-Link IV, ASA Motion Link, MIPI A-PHY, HDBase-T Others: USB, PCIe	Up to 25 Gbps (NRZ) 56 Gbps (PAM-4)	Multi-port Electronic Control Units (Space & Weight savings + Modularity)	Next generation ADAS & Infotainment modules for new architectures

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TE automotive data connectivity solution page

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