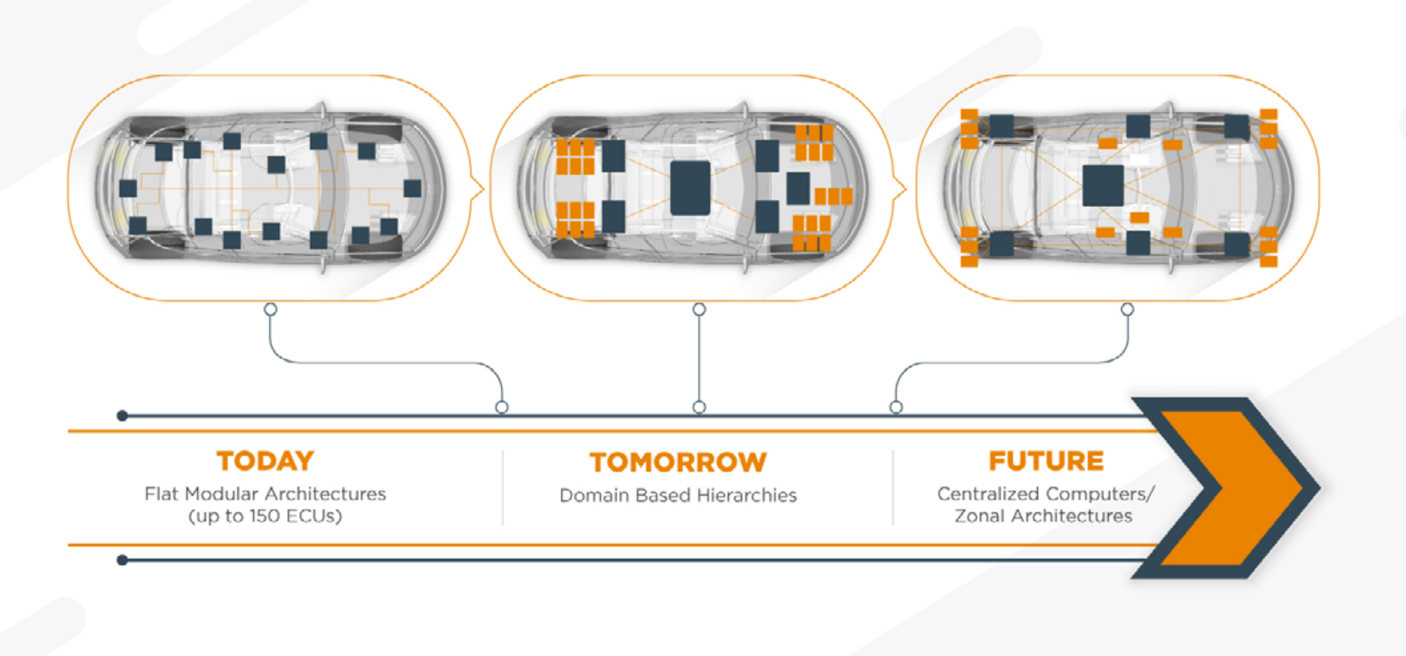
CONNECTIVITY IN NEXT GENERATION AUTOMOTIVE E/E ARCHITECTURES



Executive Summary

Current automotive E/E architectures have reached their scalability limit and the industry is now evolving towards a centralized service orientated approach. This paper will examine the role of physical connectivity to both enable the design as well as realizing the benefits of these new architectures. Specifically, it will focus on the significance of hybrid connector component design to support automated harness assembly to support ECU consolidation and will look at examples of TE Connectivity's (TE) solutions.

1. Transformation to "Smart" Architectures

New car buyers will be familiar with the process of selecting all the features, functionality and add-ons for their new vehicle. At a basic level, this could be selecting the paint color or upholstery material but increasingly it includes choosing from a vast array of electronic safety, convenience, entertainment and communications options.

This selection is often made using simple on-line "drag and drop" configurator tools without the buyer ever setting foot in the car showroom. Consumers, however, will be less familiar with the sheer level of complexity, "under the hood," that is required to realize their choice - with each vehicle containing a unique electrical/electronic system (E/E) customized to their specific choice.

The new generation of automotive consumers increasingly expect a fully customizable driving or passenger experience. The automotive industry has responded by adding more and more new features and functions - with an ever-increasing number of sensors, actuators and electronic control units (ECUs) - with millions of lines of software code. Indeed, modern cars can contain over 150 ECUs and 5 km of wiring – with the main wire harness, at up to 80 kilograms, often being the third heaviest component in the vehicle.

However, the automotive industry has realized that the complexity of the current vehicle E/E architecture has reached its scalability limits. The industry is now exploring a new approach that will transform the vehicle from flat and highly fragmented E/E architectures to more centralized "domain-" or "zonal-" architectures.

This E/E architectural transformation will be based on the following core principles:

Consolidation/Centralization
Consolidation of multiple functions, that are today served by separate dedicated ECUs – with up to 200 software suppliers,

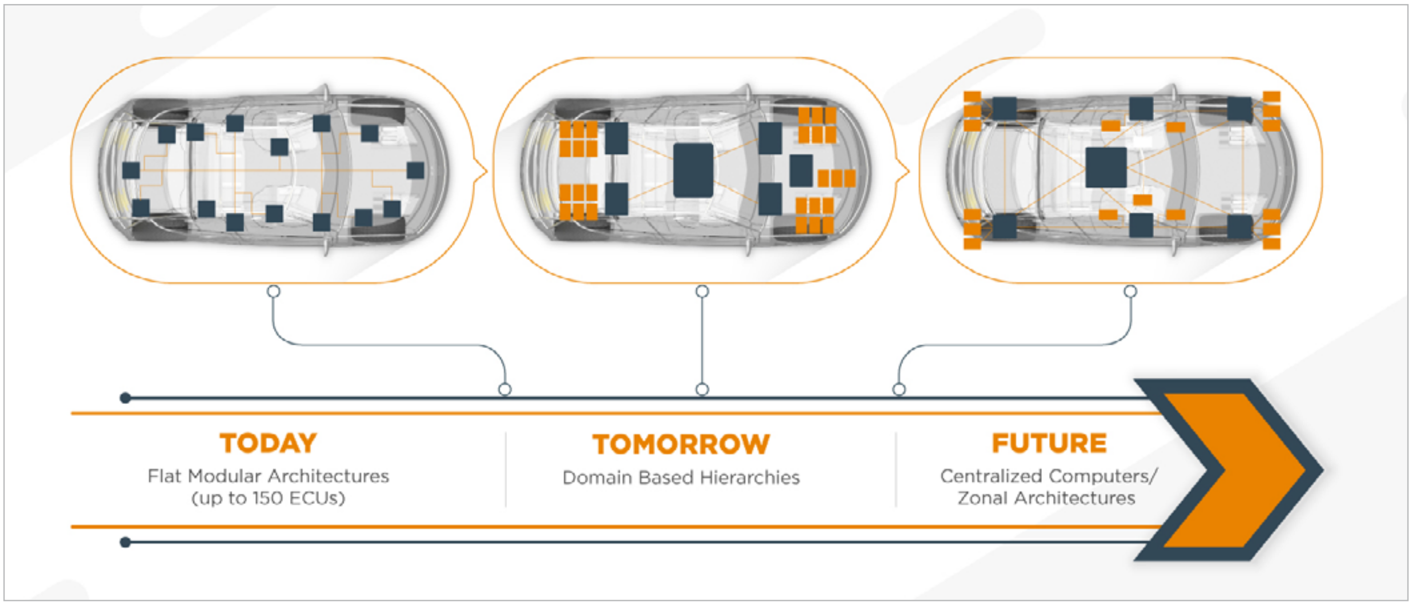


Figure 1: Automotive E/E Architecture Evolution

Figure 2: 254 Position hybrid header for an engine management ECU: 160 x NanoMQS (0.5 mm), 78 x MCON 1.2 mm, 16 x AMP MCP 2.8 mm (example).

into highly powerful centralized platforms. These will feature a reduced number of software instances with richer multi-functional functionality that can support an increasing number of interdependent automated driving functions.

Wiring Optimization
New networking topologies to reduce complexity, cable length, weight and cost. This E/E architectural transformation will be based on the following core principles:

Software-Driven Service-Oriented Architecture
Evolution towards a Service-Oriented Architecture whereby the historical role of the ECU is performed by service specific software on common operating systems that can be easily updated, over-the-air, in response to new safety or security requirements.

The above would require new a high-speed communication network moving away from legacy bus architectures to a modern Ethernet-based backbone. In addition to the reduction in physical complexity, there are a number of other significant technology and business drivers of this centralization.

Figure 3: Generation Y 68P Sealed Hybrid Inline Connector. Generation Y 0.64 mm and MATE-AX Mini Coax Connector for applications where separate low voltage power and signal connectors run alongside traditional data connectivity. Typical applications include high-resolution cameras and displays, antenna connections, transfer of video and sensor signals. Learn more.

The evolution towards autonomous driving, with an increasing number of automated driving functions, will require massive computing power, high-speed networking across multiple interdependent functions, high levels of functional redundancy as well as strong cyber security and on-going updates.

In addition, OEMs may be able to benefit from after-market extensions and upselling that would have previously have been highly impractical - with the requirement for integration of additional hardware and other wiring modifications. In theory, with these new architectures, it would be possible to just simply “turn-on” new features via over-the-air (OTA) updates. Other advantages include after-market purchase of new software-based functions, live vehicle diagnostics as well as new business models based on the sale of vehicle generated data.

2. The Role of Connectivity in Centralized E/E Automotive Architectures

Connectivity has always been a key enabler of automotive E/E architectural design. Connector systems have needed to support highly complex and reliable connections between sensors, ECUs and actuators - often in extreme high-vibration/high-temperature environments. More recently, connector technology has been required to keep pace with the geometric challenges of reduced wire sizes and the increasing space constraints of the modern vehicle, with their vast number of electronic devices and wiring. They have also needed to comply with regulations governing insertion forces during assembly in order to protect the health of assembly line workers.

Connectivity therefore plays a critical role in meeting some of the key design challenges and leveraging some of the benefits from the evolution of automotive E/E architectures as they evolve toward more centralized designs. In particular, with the increasing importance of functional safety measures, the reliability of manually manufactured harnesses may no longer be sufficient.

3. Hybrid Connectivity

As mentioned, the evolution towards more centralized networked E/E architectures will reduce the number of ECUs while the numbers of sensors and actuators will continue to increase. Wiring topologies will therefore evolve from multiple separate point-to-point connections to a fewer number of one-to-many connections. That means ECUs will increasingly need to accommodate connections with multiple sensors and actuators. This will necessitate hybrid connector interfaces, whereby signal and power connections are accommodated in a single connector housing.

Figure 4: Koshiri design and guidance ribs

In addition, with the increase in sensor-driven interdependent ADAS and automated driving functions, these hybrid connections will increasingly also need to support data connections. These could include coaxial and differential connections for cameras, sensors as well as ECU networking.

3.1. Hybrid Connector Design Requirements

ECUs can require high pin-count connections (over 250 positions) with around 75% of the circuits being dedicated to low power signal connectivity with the remaining positions dedicated to higher power connections that generate more heat. Such connectors have a number of key design requirements:

Within automotive devices, power density is increasing due to growing functional integration. More power inside means less heat transfer from the interface into the device with active cooling designed to manage heat dissipation. In addition, advanced thermal simulation is required to enable an intelligent design of the connector pockets, in terms of spacing and separation, to ensure the required heat management whilst minimizing wire cross-section, connector size and PCB footprint.

In addition, this increased power density will require EMI (electromagnetic interference) simulation in cases where a connector incorporates data communication in addition to power. This will support an optimal design in terms of spacing between power and data terminals as well as the overall connector configuration.

Within the header or male connector counterpart, the large number of pins are more exposed and therefore vulnerable to pre-bending if the connector collides with a foreign object. Therefore, pin protection plates may be needed to protect the pins from misalignment that may cause damage during mating. In addition, koshiri and other guided mating features are required to eliminate the risk of “stubbing” that can damage the pins during mating.

3.2. Block-loading Readiness

With the increasing number of ADAS features as well as the automation of high safety integrity level (SIL) functions, the physical on-board network will play an increasingly critical role. Today, a vehicle’s E/E architecture is comprised of a complex and heavy network of cables and devices that take many manual production steps to produce and assemble and are therefore prone to error.

It is therefore highly desirable to minimize the amount of manual work in the wire harness assembly processes in order to eliminate or minimize potential sources of error. One example is “block-loading” which involves the automated

Figure 5: TE Connectivity OCEAN 2 Applicator

Figure 6: TE Connectivity NanoMQS 18 position connector housing

Design Element	Parameter	Blocking-loading Suitability
No. of Contact Rows	Single/double row modules	🟢
	Multi-row (> 2) modules	🟡
Module Length	≤ 60 mm	🟢
	≤ 100 mm	🟡
	> 100 mm	🔴
Cable-cross Section Combinations	0.13 mm^2 to 2.5 mm^2	🟢
	Combination of 4 mm^2 and 6 mm^2	🟡
	> 6 mm^2	🔴
Cable-cross Section Size Ranges	0.13 mm^2 to 2.5 mm^2	🟢
	4 mm^2 and 6 mm^2	🟡
	> 6 mm^2	🔴
Number of Contact Types	≤ 3	🟢
	≤ 5	🟡
	> 5	🔴

Table 1: According to DIN 72036. DIN 720 specifies limitations up to 2.5 mm^2. Cross sections exceeding this limit should be in consultation with the OEM. Guidelines apply to Flexible and Flame Retardant (FLR) wires only.

insertion of multiple terminated wires into multi-cavity connector housings, with each insertion monitored and documented for accuracy.

In this regard, connector systems play a key role in enabling automated wire harness assembly processes for new E/E architectures. TE Connectivity has already developed a range of standardized connector components based on its NanoMQS, MCON and AMP MCP contact systems that were specifically designed to support machine processing along with the associated wire crimping tools (applicators).

3.3. Connector Design for Block-loading Readiness

The primary design principle for the connector housing design is the shape and size of the insertion chambers. The number of chambers is also a key factor, as automated housing assembly becomes more complex to implement with tighter chamber spacing, for example with multi-row housings that are often in use today. Therefore, the insertion chamber grid dimensions, including the number of contact rows, are also an important design consideration. In addition, other factors, such as sealing, are also taken into consideration.

3.4. Housing Assembly Simulation and Testing

TE Connectivity collaborates with machine tool manufacturers to simulate the housing assembly process to verify the viability of the basic insertion process as well as simulating the inserted contact's behavior, in the event of error scenarios such as angled insertions.

The housing simulation results are subsequently verified, by the machine tool manufacturers, in assembly trials using both existing tooling machines (crimping tools) and prototypes. These trials include the recording of force-displacement patterns, during the insertion process as well as pull tests to verify the required contact locking and retention strength.

All these design guidelines must be fulfilled before serial tools can be developed and commissioned for connector system components and their related crimping tools.

3.5. Hybrid Connector Block-loading Readiness

Modularity is also a key part of TE Connectivity's basic design guidelines for automated housing assembly, which is particularly important for hybrid connectors. These guidelines support the combination of various standardized connector modules within a frame. Cable sub-sets can then be automatically assembled as modules which, once fully assembled, can subsequently be inserted and checked automatically.

In addition, TE Connectivity has developed a set of connector design guidelines based "traffic light" that illustrates the parameters determine hybrid connector block-loading suitability (table 1).

LEARN MORE ABOUT TE'S HYBRID CONNECTIVITY SOLUTIONS

4. Outlook

The transformation to simpler more consolidated E/E architectures provides an opportunity, for the first time, to reduce the scale and complexity of the physical network while simultaneously standardizing the interfaces between each module. In addition, the increased digitization of the E/E architecture will enable a complete system simulation. This will enable engineers, who must consider thousands of functional system requirements, to avoid critical design rules potentially being overlooked. This includes the interdependencies of signal, data and power that, in the foreseeable future, can be analyzed at an early stage using artificial intelligence to design the optimal layout of an E/E architecture and its physical layer.

Hybrid connector design, supported by thermal and EMC simulation and optimized for harness automation – including block-loading – will be a key enabler of this transformation. Based on these design principles, TE Connectivity has already developed a range of standardized connector components supporting signal and power and is developing further connector components for different types of data connectivity. In addition, in collaboration with the machine tool industry, TE is helping automotive manufacturers fully leverage the advantages of harness simplification hybrid connector designs that are optimized for harness process automation, such as block-loading.

About TE Connectivity

TE Connectivity is a $12 billion global industrial technology leader creating a safer, sustainable, productive and connected future. Our broad range of connectivity and sensor solutions, proven in the harshest environments, enable advancements in transportation, industrial applications, medical technology, energy, data communications and the home. With approximately 80,000 employees, including more than 7,500 engineers, working alongside customers in approximately 140 countries, TE ensures that EVERY CONNECTION COUNTS. Learn more at **www.te.com** and on **LinkedIn**, **Facebook**, **WeChat** and **Twitter**.

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