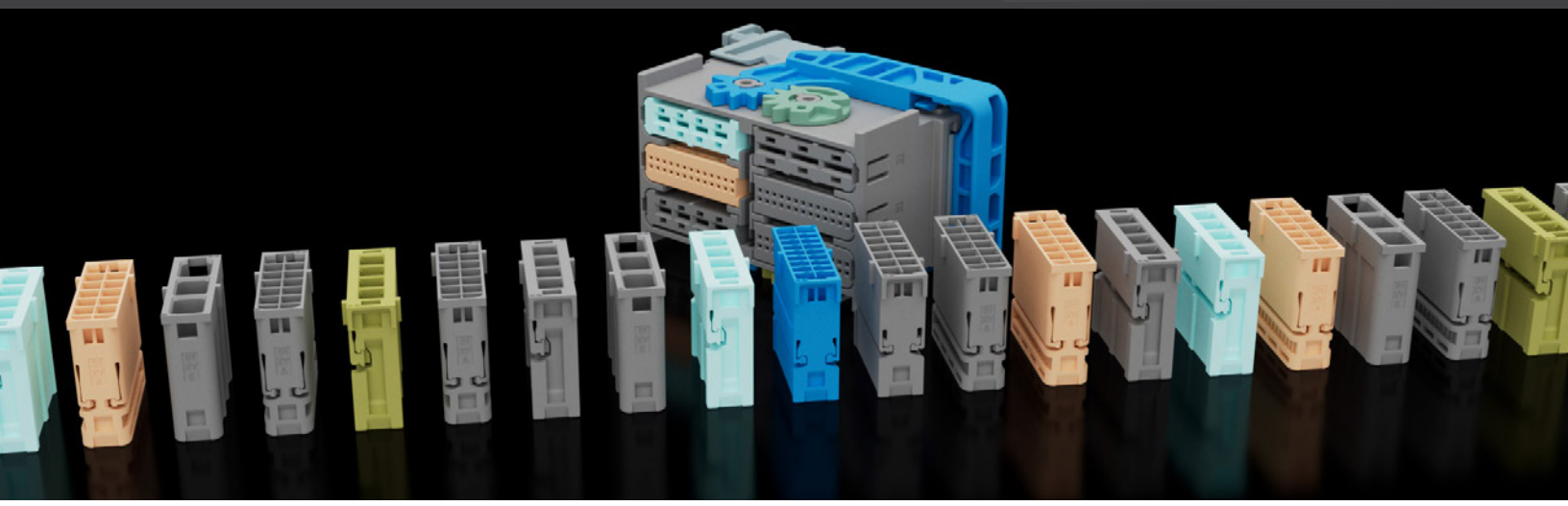


Modular Connectors Clear the Way for Automation Innovation

The complexity of automotive electrical/electronic architectures is staggering, and it continues to increase as more devices and more data communications and power circuits are added to deliver ever more advanced features to consumers.

Body wiring harnesses in today's vehicles can include more than 2,000 wires and 600 connectors. Because of those harnesses' size and flexibility, the assembly process is extremely difficult to automate, and it can take 40 to 80 hours for workers to assemble a single harness manually.

Moving to modular connectors will be critical to incorporating more automation into the harness assembly process. Modular connectors enable the creation of simplified harness kits, the use of auto-plugging and better quality control. An ideal modular connection system will offer maximum flexibility in the quantity and types of connections while maintaining standardized dimensions for use with automated systems. Done right, this one innovation can unlock a wealth of possibilities in assembly automation.

MULTIPLE CHALLENGES

To keep up with consumer demand, automakers are continually adding advanced capabilities to their vehicles. While the capabilities are often enabled by software, the software requires sensors to take in data from the outside world and actuators to perform software-defined actions. All of the devices and peripherals throughout the vehicle require data communications connections and electrical power lines.

Of course, the software also requires compute hardware. Traditionally, OEMs have added an electronic control unit (ECU) every time a new capability has been introduced, but that approach has become unsustainable with the sheer volume of capabilities being added and the resulting complex network of ECUs and devices.

The industry has responded with two key shifts to simplify the vehicle architecture: zonal architectures and centralized compute, both of which are key tenets of Aptiv's Smart Vehicle Architecture™ approach. A vehicle's device connections are terminated at several zone controllers, which consolidate data communications onto backbones that lead to centralized compute modules. The centralized compute uses sophisticated software to up-integrate the functions that had been handled by individual ECUs. These changes simplify the electrical/electronic architecture and segment the wiring harnesses into smaller, more manageable zones.

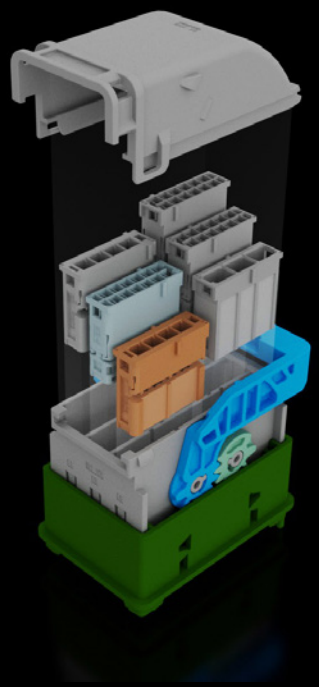
However, to fulfill the promise of zonal architectures and centralized compute, zone controllers need to be designed to accommodate a lot of connections in a limited space.

Furthermore, the smaller wiring harnesses associated with vehicle zones present an opportunity for increased automation, but connectors traditionally have not been designed with automation in mind. In the coming years, labor costs are expected to continue to rise, and labor availability is expected to continue to shrink, so automation will become an important factor in production. In addition, the automotive industry is looking for ways to leverage automation to better manage supply chain risks by moving harness production closer to vehicle assembly.

The missing piece of the puzzle is a new style of connector that can enable automation, achieve the connector density required and meet all of the requirements of today's architectures while giving OEMs the flexibility they need for their individual architecture designs. That is where modular connectors come in.

THE RIGHT FIT

Modularizing connectors allows different types of connections to be assembled into the same housing.



THE MODULAR REVOLUTION

Modular connectors represent a simple yet powerful concept. Instead of terminating cables with a mix of interfaces that have different sizes and shapes, modular connectors use a standard size and shape (typically rectangular), regardless of the type of interface being supported. One module might be constructed to accommodate, say, three connections at 4.8mm^2, and another might accommodate 26 miniaturized connections at 0.5mm^2. But under a modular approach, the outside dimensions of the rectangular connector modules would be exactly the same.

The next step is to create standard housings for the modules to fit into. A typical housing might fit four modules, but housings could be created to accommodate as many as eight modules, or even just a single module.

Ideally, the housing would be designed to stabilize and balance the connection, keeping four contact points in place as the housing is mated to the header and ensuring that the connection is made cleanly across all of the modules within it.

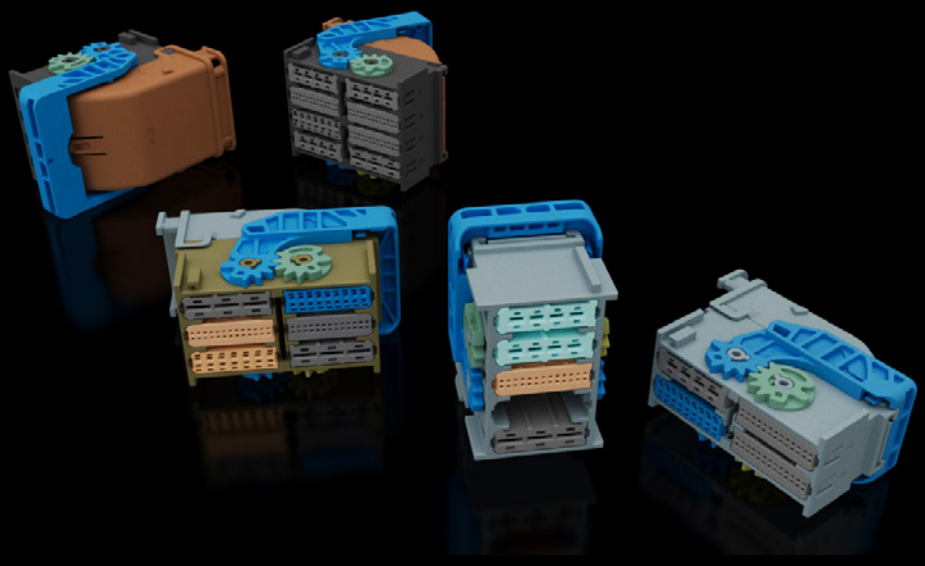
MODULAR VS. MIXED VS. HYBRID

Several major types of automotive connection systems have emerged to solve different challenges:

- Modular connection systems consist of building blocks of various terminal types and sizes, packaged in high-volume, standardized modules that can be aggregated into a collector housing
- Mixed connection systems combine multiple terminal sizes (e.g., 1.2, 0.50, 2.8, etc.)
- Hybrid connection systems combine data terminals with standard signal and power terminals (e.g., H-MTD®, MCA)

MIX AND MATCH

Standard housings can be designed to accommodate different numbers of modules, in different orientations, depending on the design requirements.



BENEFITS OF MODULAR CONNECTORS

This approach to connectors has several key benefits over other types:

Auto-plugging. Because they are designed for auto-plugging during harness assembly, modular connectors can reduce the risk of wire damage during plugging, which in turn enables wire gauge reductions. Lower wire gauges result in less mass and cost.

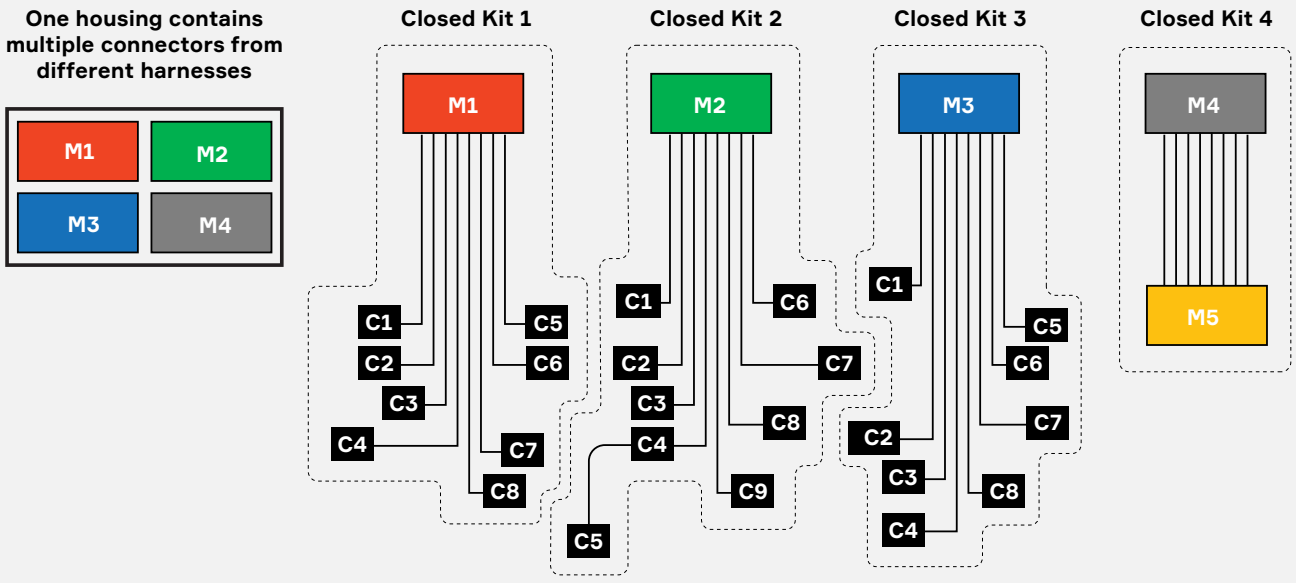
Terminal mix and grouping options. By accommodating a mix of terminals, modular connectors enable optimal closed kits during harness manufacturing, improving quality. The mix also allows for the optimal I/O for the device requirements.

Flexibility. With various housing options available, manufacturers can choose the one that best matches their devices' footprint and I/O needs. Because the housings can work with any module, manufacturers can easily swap modules out in the future for modules that have a different terminal mix. This is especially important as data needs grow over time and data standards evolve.

Smaller harness kits. Zonal architectures segment a vehicle's electrical/electronic architecture, and manufacturers can take that concept a step further by segmenting zones into smaller wiring harnesses that join at the point of the zone controller. Each harness kit could terminate at a module, and those modules could be grouped within a housing where they would meet the zone controller.

HARNESS SEGMENTATION

Modular connectors allow manufacturers to use smaller wiring harnesses that connect at the same location. Smaller harnesses are easier to handle and enable assembly automation.



THE RISE OF AUTOMATION

Modular connectors fit well with an automation strategy. The standard shapes and sizes of the connectors and housings are easy for robots to grasp and assemble. With components becoming more miniaturized, they are becoming too small for humans to handle; modular connectors enable automated assembly.

The smaller wiring harnesses are less unwieldy for a machine to handle than a full wiring harness is. Kitting design is an integral part of the wiring harness and architecture design, and modular connectors enable the creation of simplified harness kits — quality-controlled, with no swapped pins and no back-outs.

QR codes printed on modules can enable a robot to read the code and verify the module's placement. In addition, by printing QR codes on modules, everything can be easily traced. Traceability is key for ensuring the quality of these critical vehicle components.

BRINGING IT ALL TOGETHER

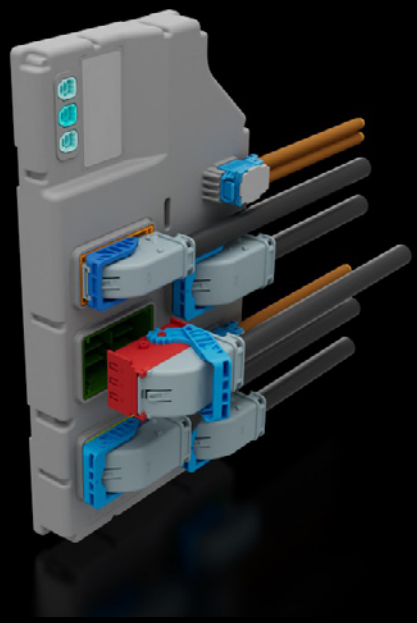
To maximize the benefits of automation, connection systems must be designed to work hand in hand with the electrical distribution systems that they terminate. With long-standing expertise in both areas, Aptiv is working to increase assembly automation of low-voltage harnesses from 15 percent in 2023 to more than 60 percent by 2030.

Modular connectors are fundamental to the implementation of that strategy. Not only do they enable auto-kitting and auto-plugging, but the resulting smaller harness kits are easier for robots to handle — meaning that they can handle more taping, apply more body clips, and generally take on more assembly tasks that previously had to be done manually. Aptiv's tests have shown that robots will be able to work two to three times faster as well.

As the only provider of both the brain and the nervous system of the vehicle, Aptiv is uniquely positioned to lead the industry in the evolution of this area, where the brain and nervous system meet, and many more innovations are still to come.

PLUG AND PLAY

Housings containing dozens of modularized connectors can be mated to headers integrated into major architectural components – such as zone controllers – in one swing of the lever.



ABOUT THE AUTHOR

Andreas Urbaniak
Senior Product Engineer

Andreas Urbaniak oversees designs for modular connectors, working with teams across Aptiv and with customers to develop products and process technologies to meet customer needs. He has been with Aptiv for more than 20 years, developing new and innovative products, including 48V support, miniaturized housing systems, and connector sealing elements.

Marek Manterys
Senior Manager – EDS Core Engineering, Manufacturing Engineering Strategy and Automation

Marek Manterys defines, controls and implements the Automated EDS Manufacturing roadmap at Aptiv, ensuring that it is aligned with customer needs and rolling it out to manufacturing operations. He has been with Aptiv more than 16 years, holding positions as a technical process innovation manager and EMEA Manufacturing Excellence Center manager.

Tony Knakal
Product Line Director, Traditional Interconnects – Americas

Tony Knakal is responsible for Aptiv's global housing business, ensuring that Aptiv has the right products available to meet customer needs for low-voltage interconnects now and in the future. Tony has been with Aptiv since 2020, supporting both high- and low-voltage interconnect solutions. Prior to joining Aptiv, Tony held roles in product and program management for automotive lithium-ion batteries and in the defense industry.

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