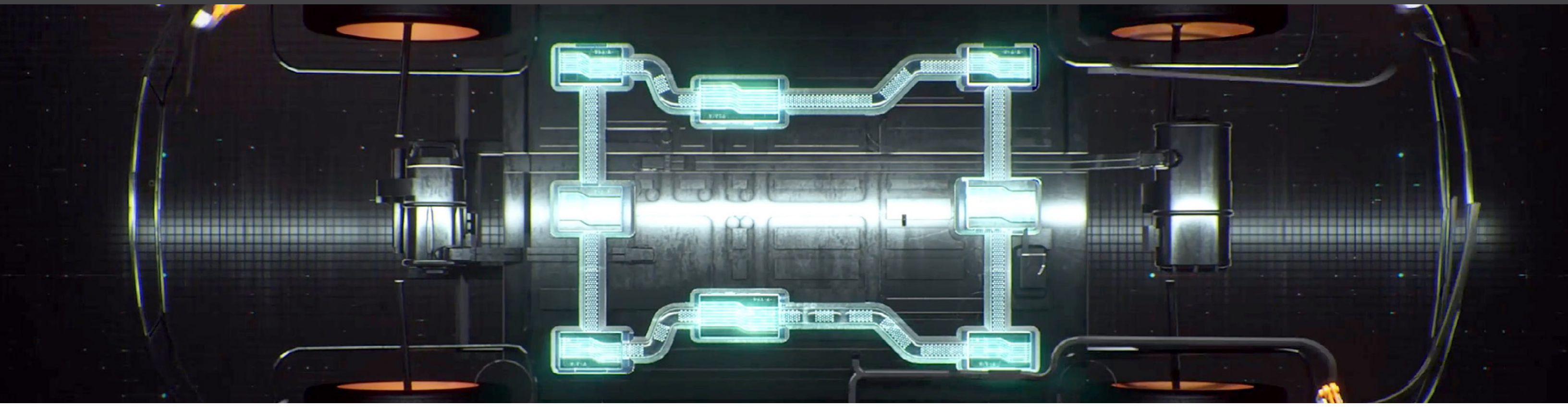
WHITE PAPER



Zone Controllers Build Bridge to Tomorrow’s Technology

Several key trends are coming together to force a change in the way vehicles are designed and built. The number of electronic control units (ECUs) in a vehicle is growing, creating complexity in the wiring needed for power and data distribution. An explosion in sensor technologies to support active safety features is driving complexity in I/O. Rising labor costs are prompting manufacturers to look for more automatable assembly of wiring harnesses. And electrical power requirements are evolving to enable greater electrification, toward hybrid and full battery electric vehicles.

A critical piece of the solution to all these dilemmas — across a wide range of vehicles — is the zone controller. With a few strategically placed zone controllers, OEMs can not only reduce complexity and costs, but also accelerate the important migration toward vehicle architectures of the future.

The automotive industry has entered what could be the most exciting time in its history, with technology advances promising unparalleled safety, productivity and environmental benefits. But fully electric vehicles with self-driving capabilities won’t become mainstream or affordable overnight. Automakers realize they need to build the right architectural foundation for the vehicles of today and tomorrow.

Zone controllers are integral to that foundation. Zone controllers are nodes in a vehicle that serve as hubs for all of the power distribution and data connection requirements for devices – the various sensors, peripherals and actuators – within a physical section of the vehicle. Their role may sound simple, but it is necessary to get the complexity of today’s vehicles under control and to take several steps forward.

SMART FUSING

As power distribution hubs, zone controllers become the natural location for smart fusing. With smart fusing, traditional melting fuses in relays are replaced with semiconductors, an approach that has several advantages.

First, smart fusing enables better energy management, as the fuses throughout a vehicle can be managed centrally. This is especially critical with electric vehicles; if the battery is running low, the system can use the smart fuses to switch off functions judiciously for brief periods of time throughout the vehicle. For example, less critical features that require significant power include seat heaters or window heaters. The system could decide to switch off these functions for short intervals that would be imperceptible to the driver in order to free up power when more vital functions are demanding peak loads, such as power steering during a sharp turn.

SMART FUSING ELIMINATES BOXES

Smart fusing allows a more compact design by removing bulky fuse boxes.

Smart fusing using semiconductors

Traditional melting fuses and relays

Second, a smart fuse can detect when the wire attached to it is close to failing and pass that information back to a central system. This kind of predictive maintenance helps drivers address potential problems before they affect vehicle operation. And it is especially important to fleet operators responsible for maintaining large numbers of vehicles.

Third, smart fusing allows for savings in cabling. In the past, wires had to be designed up to 30 percent larger in diameter than physically needed to allow enough tolerance for peak loads without having a melting fuse blow. By contrast, with smart fusing, wires can be specified to the physical limit of the load over a specified period of time. That often means a reduction of one wire gauge — for example, going from 4mm^2 to 2.5mm^2 — and therefore a reduction in weight.

UP-INTEGRATION

Zone controllers are also logical concentration points for multiple ECUs. As the number of sensors and other electronic components has grown throughout vehicles, adding individual ECUs becomes unwieldy. Each ECU requires its own power and data connections, making the cabling requirements very complex. To save space, simplify management and streamline the physical architecture, OEMs are moving from a distributed compute model to a more centralized approach. The zone controller plays a pivotal role in this migration, as it is the logical location to consolidate input/output (I/O) from the various sensors, peripherals and actuators, as well as to up-integrate functionality of certain electronic controls. Examples of ECUs that are ripe for up-integration include body and security control, HVAC control, audio management, and non-ADAS-related vehicle sensors and actuation.

In a study for one OEM, Aptiv found that the use of zone controllers allowed nine ECUs to be consolidated and hundreds of individual wires to be eliminated — resulting in a reduction of 8.5kg from the weight of a vehicle. Every bit of weight removed reduces CO_2 emissions and extends the range of electric vehicles.

In addition, because zone controllers divide the electrical infrastructure of a vehicle into more manageable segments, assembling wiring harnesses becomes easier to automate. Roughly half of harness cost is labor. Aptiv estimates labor costs could increase between 25 percent and 50 percent over the next five years, depending on the country where the assembly takes place. Manufacturers will turn to automation to offset the rising costs, but that automation is not possible with current wire harness designs. It requires a new architecture.

Up-integration into zone controllers reduces the physical complexity of today's cable harnesses and the large number of individual ECUs and puts the focus on software, as multiple functions are integrated into the zone controllers and other centralized devices. This is a natural next step in the progression toward software-defined vehicles. To simplify this process and ensure that OEMs are free to reuse existing software, Aptiv is working on sustainable software architectures designed to make integration easier and more efficient, while supporting freedom from interference among functions when needed.

SEPARATING I/O FROM COMPUTE

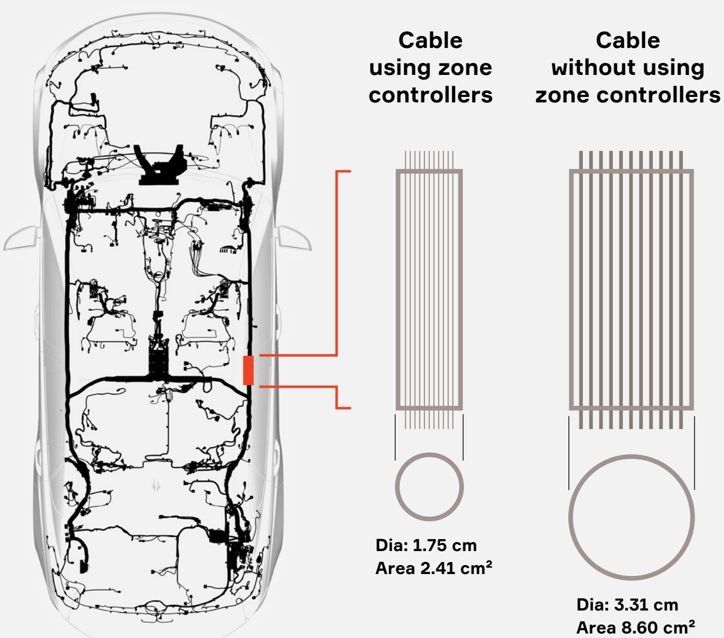
Today, all sensors, peripherals and actuators connect directly to a domain controller. Radars, cameras, lidars and ultrasonic sensors all run data lines from their various locations in the vehicle to an active safety domain controller. Similarly, seat position sensors, the motor control for adjusting seat position, and the temperature sensors for heated seats all connect to the seat ECU. The fan speed control for HVAC and the temperature sensors for zonal climate control connect to the HVAC ECU. And so on.

In an architecture that uses zone controllers, each sensor and actuator instead connects to a local zone controller based on its location. The zone controller then performs some local data transformation, aggregates the data and puts it onto a single high-speed cable that connects to the compute.

In this way, the I/O is abstracted from the compute, which actually does the processing of information. The zone controller handles the communication with end devices via a controller area network (CAN) or local interconnect network (LIN) bus to ECUs or body control-related sensors and actuators, Ethernet or low-voltage differential signaling (LVDS) interfaces to cameras or other advanced driver-assistance systems (ADAS) sensors, using each device's preferred format. It then aggregates those signals onto Ethernet or PCI Express for the high-bandwidth ADAS sensors or onto CAN-FD (CAN-flexible data-rate) for lower-bandwidth body control functions, and sends the data to the appropriate domain controller.

DOORSILL SAVINGS

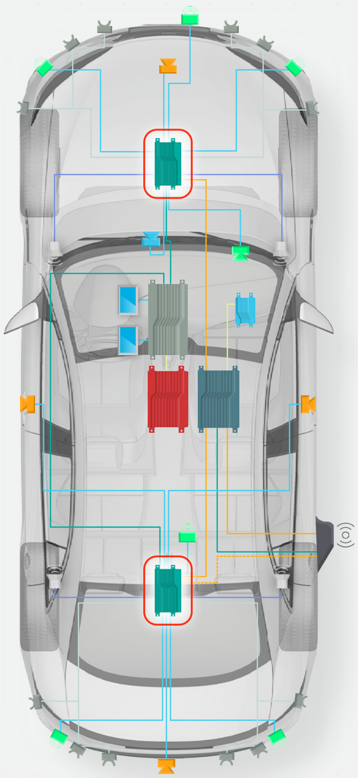
A zone-controller approach can reduce cabling needs through the critical area of doorsills. In one example, Aptiv was able to reduce the diameter of the cabling assembly, resulting in a space reduction by a factor of 4.



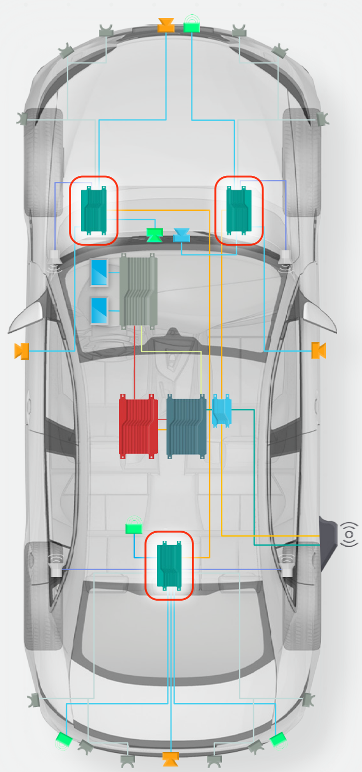
ZONE CONTROLLERS KEY TO NEXT-GEN ARCHITECTURES

Zone controllers represent a key component of an advanced vehicle architecture for power and data distribution. The number of zone controllers can vary depending on the requirements and complexity of the vehicle. Here are three sample configurations.

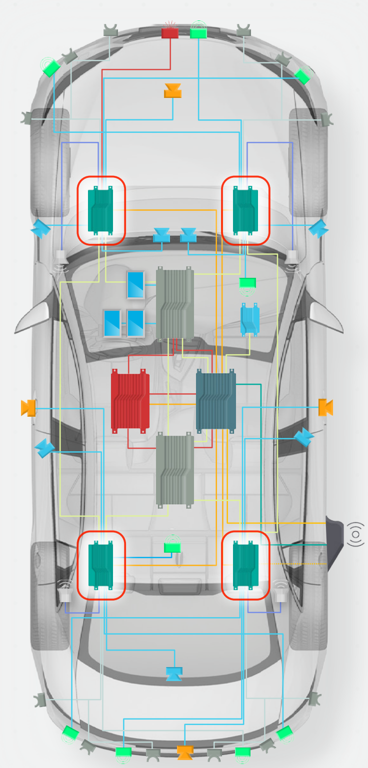
Two zone controllers



Three zone controllers



Four zone controllers



- Audio
- Displays
- External Radar
- Driver State Sensing Camera
- 360° Camera
- ADAS Camera
- Ultrasonic
- LiDAR
- Open Server Platform
- Propulsion and Chassis Controller
- Central Vehicle Controller
- Zone Controller (Power Data Center)
- Connected Vehicle Server

In Aptiv's Smart Vehicle Architecture™ approach, the zone controllers include customizable models corresponding to progressively higher levels of automation. The processing is distributed among several central compute devices. The Open Server Platform is responsible for compute-intensive applications such as ADAS and user experience. The Powertrain and Chassis Controller is responsible for vehicle dynamics, which includes motor/transmission, braking, steering and suspension. And the Central Vehicle Controller (CVC) is responsible for body control, as well as overall network management. While different OEMs may choose to take modestly different approaches to where and how to add these software-defined features, the fundamental principles and technology building blocks required to realize this approach are the same.

The CVC is also the body and power control master for all of the zone controllers, and it handles communications with the outside world. It receives over-the-air (OTA) updates and distributes them to systems in the vehicle as needed. It has its own direct connections to the zone controllers, so it can send them updates, and the zone controllers can in turn update other units connected to them.

Eventually, the communications will evolve. Body control can be handled via a CAN-FD network, with a star topology featuring the CVC at the center. A star topology is an efficient approach when the network is organized into manageable zones, and it can support selective wake-up. ADAS sensor communication will be handled via a separate network based upon either the Ethernet Time-Sensitive Networking standard or Automotive PCI Express, connected via a separate star topology network to the CVC. When redundancy is required — at Autonomous Level 3 and higher — the ADAS sensor network will form two rings, with major nodes on the rings including the central compute node, the CVC and the zone controllers. While a ring topology is modestly more expensive than the star topology it replaces, it reliably delivers fail-operational performance without the need for duplication. As a result, it is far more cost-efficient than alternative approaches for supporting Level 3 automation and above.

MOVE TO 48V

Another application of zone controllers is that they simplify migration toward 48V electrical architectures. These architectures support so-called "mild hybrid" vehicles that are able to attain 70 percent of the benefit of a full hybrid system at 30 percent of the cost and improve fuel economy by 15 percent to 20 percent. Because they still operate well below 60V, they do not require the more expensive components and wiring associated with high-voltage systems and all-electric vehicles.

These 48V systems are becoming popular because they provide vehicle designers numerous benefits. For example, a 48V system can improve the smoothness of a mild hybrid's auto-start/-stop function — where a vehicle shuts off the engine automatically as it comes to a stop, and restarts it as the driver lifts their foot off the brake. Similarly, it allows OEMs to provide a performance boost via integrated e-turbos.

A 48V system allows vehicles to power major electrical components more efficiently than a combustion engine could, such as the air conditioner compressor, engine fan and power steering. It cuts down on energy loss because it delivers the same electrical power but with much less current — and the lower the current, the less power is lost due to the resistance inherent in the conductors.

The move to 48V also solves the challenge of voltage drops during cold cranking. If a vehicle is started when the ambient temperature is too low, a 12V source can fluctuate as low as 3V or 4V. If an electronic component requires 5V, that fluctuation can cause the component to reset. In the past, vehicle architectures have had to employ a back-boost supply to keep the voltage up in those conditions. In contrast, a system using 48V won't fluctuate to levels low enough to reset those components, which means that the back-boost can be eliminated.

GETTING THERE IN STEPS

The challenge is that most electrical components available for vehicles are still designed for the traditional 12V standard. Some vehicle designers have resorted to having two separate systems in the vehicle with their own batteries — one operating at 12V for those legacy components and the other operating at 48V for the newer connections.

A zone controller simplifies and streamlines the architecture. With a zone controller architecture, a vehicle has just one battery source, providing 48V and distributing that power to the zone controllers. The zone controllers are configured to deliver 48V to the components that are ready for it and can simultaneously step down the power to 12V for those components that are not.

For example, it could be expensive to migrate all of the motors and other electrical components in a door controller at once from 12V to 48V. Instead, an OEM might choose to migrate just the window lifter to 48V since that requires the most power, but leave all other components at 12V or less. The zone controller handles the conversion as needed.

This incremental approach to migrating to tomorrow's vehicle technologies is what makes zone controllers so compelling. OEMs can realize cost savings and weight reduction immediately, while knowing they are laying the necessary groundwork for Smart Vehicle Architecture™, enabling a future of feature-rich, highly automated vehicles.

ABOUT THE AUTHOR

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Martin Bornemann is responsible for the hardware and system aspects of Aptiv's Smart Vehicle Architecture (SVA) in the CTO office. He has been with Aptiv for more than 20 years, holding positions in innovation management, project management and hardware development. Before joining Aptiv, he designed telecom equipment for Ericsson and conducted wireless LAN research for Bosch.

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