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Connectivity is the 'Final Mile' in Automotive Systems

No matter how it is powered, a modern car is an amalgam of multiple powered subsystems. No matter how sophisticated the core technologies are, however, the resulting vehicle is only as good as the connectivity solutions used to integrate the parts.

The motor vehicle has been a part of society almost since it was invented, with cars, trucks, and buses, among other modes of transportation, reflecting the society they serve. Our vehicles are often extensions of ourselves, a traveling part of our household, hobby, or business and an integral part of it. One important aspect of this connection is that many people want to do everything in their vehicles that they do in their homes, from eating to entertainment and communication.

This causes pressure to integrate every aspect of modern society into our modes of transportation. The modern car is being impacted by every developing technology being commercialized, from Cloud-enabled AI-empowered autonomy to next-generation power transistors. This means the number of electronic subsystems in an automobile are growing in number and complexity, regardless of the kind of motivation under the hood.

All of these technical advancements must be properly integrated, as the demands placed on vehicle electronics are severe. Cars are exposed to harsh environmental situations, shocks and vibration, and every subsystem must be able to handle everything the road can throw at it. However, no matter how advanced in operation and functionality the devices involved are, the sum of the whole is only as good as the connectivity solutions between them.

An Expanding Need for Connectivity

Technology advancements are always raising the bar when it comes to the automotive electronic infrastructure. Logic and software advancements require more complex computing systems to run them, creating increasing power and signal connection demands. Other new solutions placing pressure on vehicle developers include wide-bandgap semiconductors, materials superior to Silicon in efficiency and performance.

Power circuits based on these materials, SIlicon Carbide (SiC) and Gallium Nitride (GaN), place pressure for higher levels of performance on all related systems, from the motors and devices being driven to the passives and magnetics in the circuit itself. SiC is finding itself in high-power systems like EV drivetrains, whicle GaN is a piezoelectric semiconductor that can switch very rapidly, and thus can empower fast-cycle applications like LIDAR and RF systems.

This migration to advanced automotive solutions brings changes and challenges in how to design, develop, and create key system infrastructures like power management, motor control, and sensor integration. These advanced solutions require sophisticated core subsystems. Improper system integration will result in reduced capa-

bilities, safety, reliability, and functionality. Not only must the various subsystems work in an optimal fashion to support one another's functionality, they must be connected to one another in the most effective manner.

A vehicle motor-control circuit with a power management solution able to drive it well, accurately, and efficiently reduces thermal control issues, among other things. This includes aspects like electronic noise, which can impact the optimal performance of the vehicle's sensor suite or infotainment system. Any subsystem that fails to deliver optimally can create a cascade of failure that could result in a potentially catastrophic loss of vehicle functionality.

Adding to the connectivity issues are potentially redundant subsystems like electromechanical braking (EMB), that present further complexity in that there are different approaches that can achieve the desired results. An EMB system can be deployed as a replacement for a legacy hydromechanical system, for a dry braking architecture, or as a secondary system for safety redundancy. This is further complicated depending on how vehicle dynamics control, ABS, wheel slip control, regenerative braking, and traction control are managed.

Connection Considerations

When it comes to connectivity, the cables and interconnects present a myriad of solutions. Choices range from popular protocols like USB to custom solutions in special configurations. Application demands must be the primary consideration, especially in the areas of continuity, reliability, and fastness. The risk of dust or moisture in a vehicle is guaranteed. Everything in or near any of the devices in a car vibrate or are at least being shaken or struck. What about dust or microparticles? What if someone or something accidently puts any strain in any vector on the connector?

There is a lot of talk about wireless connections, as it enables you to place sensors and cameras in places difficult to serve with cabled solutions. However, in a vehicle they should have wired redundant systems for optimum reliability and safety, and we're back to needing good, wired connections again. A hybrid solution should be implemented wherever possible. A wireless subsystem is great, but wired connection ensures continuous operation.

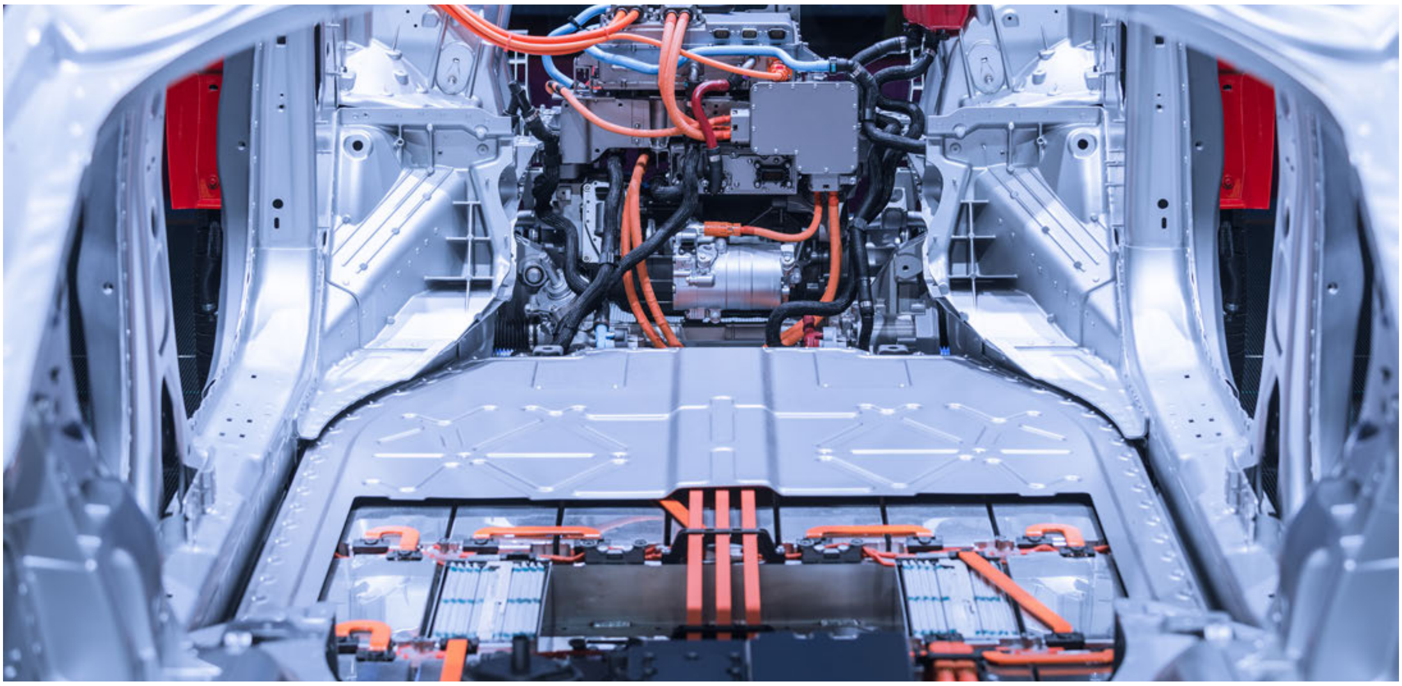
An example of a hybrid connection solution could be a device powered by wire but reporting in a wireless fashion. Another could be a system where there is a primary wired connection for power and communications, but the system is kept in housekeeping mode, maintaining connection wirelessly. Every vehicle application has novel aspects which can be best served in a specific manner with the right connector solution mix.

Motors in a vehicle come in all types, shapes, and sizes, each with its own drive, power, and interface requirements. Pick the type of motor best able to perform the kind of motion needed in that part of the vehicle, then use the most effective drive methodology for that motor type. For example, in a switched reluctance motor, power is delivered to windings in the stator rather than the rotor and can be driven by a high-power electronic switching system that enables tight control and power shaping. This means a high level of performance, but only if the driver electronics and power management system is properly integrated in an optimal fashion.

Sensors are a critical aspect of any vehicle, and there is no precision without feedback. Sensors capture information ranging from light and sound to temperature and attitude. Active sensors include devices such as laser- (LIDAR) and microwave-based (RADAR) systems and can also use noncoherent light and even sound. Each of these sensors has different power and signal conditioning considerations, and each must be properly connected for optimal operation. A bad connection will make clean data or power difficult, and even cause failure of the sensor involved.

The big thing today is sensor fusion, where all data from all sources is integrated by the logic involved to create complete situational awareness. That way if any given sensor stops working, the system can interpolate data from the other sensors. This demands cables and connections that must always perform optimally, as they represent the critical links in the system, both for electronic performance as well as environmental resistance.

When it comes to environmental resistance, any place connectors get plugged in can be an ingress to the enclosure, possibly letting in things not conducive to proper function. Water let in through a leaky connection point, for example, could create a situation of catastrophic failure with thermal runaway and significant potential for damage. This also applies to dust and microparticles from the weather, user actions and processes, caustic or explosive gasses, and vermin.



The upside is the need for proper environmental protection isn't just a cost, it can add to performance. The better the connection, the cleaner the signal or current going through it, and EMI shielding works best when continuous. Vibration-resistant rugged cables and screw-down connectors ensure vehicle systems can move and flex where needed. This also goes for connectors intended for high-temperature places, as if the cables and/or connectors fail, everything else does as well.

A good vehicle cable and connector solution must be able to handle water, dust, extreme temperatures (generated internally or externally), mists and gasses, rough handling, extremes in pressure differences, as well as any user-brought materials that may be present. Power handling and signal performance is also important, as the most rugged cable is useless if it cannot move the electrons properly.

The importance of the performance and environmental durability of the cables and connectors in vehicle systems cannot be overemphasized. Any failure in the cables or where they attach to device packages can create a cascade of failure that could result in the loss of the subsystem involved, risking cascading problems. Proper cable and connector selection will ensure these critical connections are up to the task.

Features like start/stop, electric power steering, and electronic braking systems have increased the car's battery's power load. Therefore, prioritizing these loads on a scale from comfort to safety level has been a significant issue in a vehicle's electrical system. Beyond requirements like meeting vibration and temperature extremes, there are others like space-saving and weight which are also important.

Vehicle designers must also think about automotive standards and the required approvals, like LV214 and USCAR, especially with systems that communicate with critical automotive systems like ADAS. For interconnects this means meeting automotive standards and be transparent with their performance and qualification results to ensure all the requirements are being met, like Terminal Positioning Assurance for correct positioning & retention, Connector Positioning Assurance so two mating halves locked in their proper position, and polarization to avoid incorrect mating.

LVDS stands for Low-Voltage Differential Signaling, an interface standard for high-speed data transmission, LV214 was developed by German carmakers, and USCAR stands for the US Council for Auto Research. These standards address things such as the quality of a given crimped terminal, which must maintain a specific crimping force for use in automotive wire harnesses.

Driving Forward

Automotive technologies such as battery chemistries, logic and power solutions, and system topologies will continue to evolve, and the electronics that manage and monitor those battery cells and vehicle systems will become more and more sophisticated. This means that the cable and connector solutions provided must also continue to migrate upwards in capability, performance, and reliability to properly address the needs of those advanced vehicle systems. That way the connectivity, security, and safety of the entire vehicle can be maintained.

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