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Developing Advanced High-Power Interconnects to Meet Latest Automotive Demands

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The automobile industry is currently in a period of transition that is unlike anything that it has experienced before. For over a century, vehicles have relied on the use of internal combustion engines (ICEs). Now, the need to have more sustainable and ecologically-acceptable forms of personal transportation is resulting in a move to vehicles with electrically-based propulsion. The compound annual growth rate (CAGR) for electric vehicle (EV) shipments is forecast to be close to 22% between now and the end of this decade (according to data compiled by analyst firm Research & Markets). By the end of that period, annual shipments will be around 39 million units.

Differentiation in ICE vehicles was mainly focused on areas like engine performance and vehicle handling. Automotive manufacturers could rely on their tier 1 suppliers to implement new advances here and drive the technological progression. Now that we are entering the EV era, the rules of the game are changing. It is within the powertrain and the battery that the vast majority of differentiation will be seen, and in some cases (though not always) the manufacturers are deciding to take care of this work themselves.

By way of an example, take the traction motor. If this is made smaller, then the weight reduction will mean that the range over which the vehicle can travel between recharges will expand. Such benefits can also be derived by increasing the battery's energy density and mitigating system power losses (in the DC-DC converter, the inverter, the on-board charger, etc.).

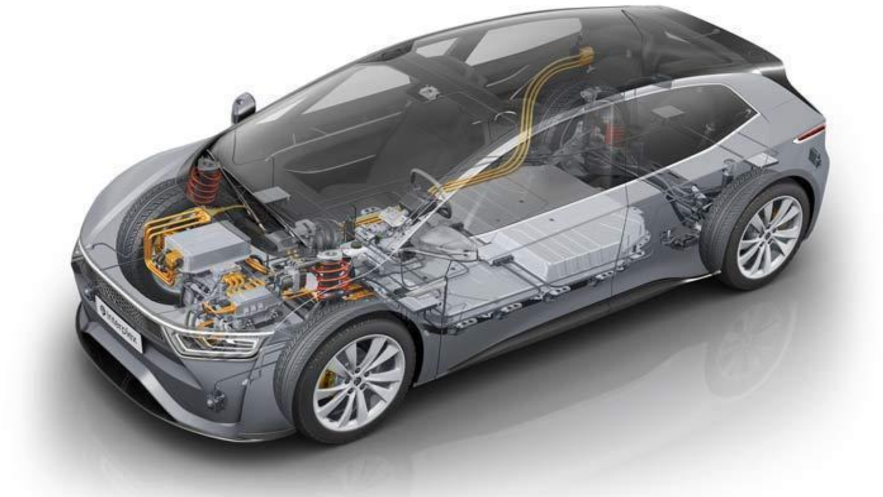


Figure 1. An overview of a typical EV architecture

New approach to vehicle development

The financial outlay on EV research and development is now outstripping that of ICEs, with almost all future investment dedicated to this part of the automotive market. This shows a dramatic shift in focus by vehicle manufacturers, reflecting the massive increase in EVs' sales that the market is now seeing. At the same time, the nature of the EV market is different to the conventional ICE market. It is not just the established OEMs that are making technological advances, but new start-ups are also bringing massive contributions.

If they are to prove fully effective, the interconnect products employed in EV powertrains need to exhibit the following attributes:

- Interconnects must offer long-term reliability despite the harsh conditions that they may be subjected to. Having to conduct component replacement or maintenance needs to be avoided, because there is a likelihood that this could harm a vehicle manufacturer's reputation. Even worse would be the costs and brand damage resulting from having to carry out costly recalls due to a vehicle model having fault interconnections.
- In order to make them more efficient and reduce power losses, the powertrains in the upcoming generation of EV models will be running at higher voltages (rising above the current 400V). The interconnects specified must therefore be able to support these elevated voltages.
- Specified interconnects also need to be compact enough to deal with the acute space constraints involved. This will only become more critical as the size of powertrain subsystems gets smaller.
- They should also have low manufacturing costs associated with them, as automotive OEMs are placing pressure on their suppliers to provide them with attractive price points, so that they can maximize their profit margins.
- To be effective within a vehicle context, interconnects should have a simple construction methodology - with only a minimal number of elements contributing to the overall assembly, and there being no difficulties in these being attached to their assigned subsystems.

On top of technical considerations, there are also logistical ones to be attended to. The most prominent of these is being able to avoid supply chain disruption by having access to local manufacturing and/or local component inventory.

Use cases

The following examples are intended to illustrate the different considerations when applying interconnects to EV sub-systems. Each of these will look at the engineering problems that automotive manufactures have to contend with, and outline what can be done to overcome them.

1. Motor stator interconnection

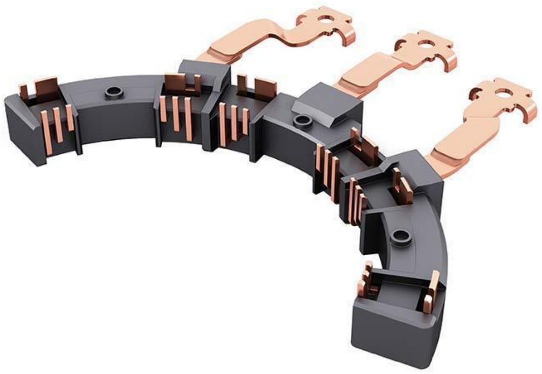
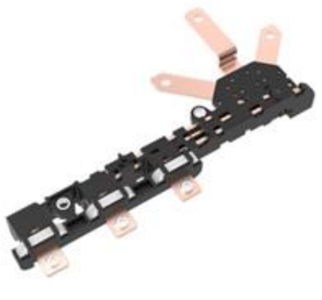


Figure 2. A robust motor stator busbar is needed for harsh automotive environments

Here molded bus bars will be utilized. These can have diameters as small as 100mm, with copper conductors and plastic packaging normally being specified. Their close proximity to the motor means that resilience to vibrations is paramount. They also need to be able to deal with high currents and voltages (normally 150A, 600V), as well as dissipating heat, while still being thin and having a lightweight construction. Because of the effect that rapidly changing high currents could have on neighboring systems, integration of EMI filtering will also be essential. Another important aspect will be that the constituent materials (the conductor, the resin, the plastic packaging) all have similar coefficients of thermal expansion (CTE). This will mean that less stress is placed on the assembly during heat cycling - as it will otherwise cause fatigue over time, meaning they will not last as long. Matching of the inductance values of the different material layers will also be advantageous, as this will prevent unwanted heat being generated.

Exposure to continued vibrations could make the selection of flexible busbars applicable. Flexible busbars are comprised of thin high-conductivity copper foils that are bonded together at the mounting areas. They are thus able to slide against one another - allowing an effective interconnect to be provided, even when the busbar is subject to vibrational or torsion forces.

2. AC molded busbar
Here is an example of using molded busbars to minimize the amount of plastic and shorten plastic lengths. Conventional arrangements leave space between busbar elements, but filling with a plastic material will prove difficult in relation to customization and integration requirements. New approaches look to minimize the amount of plastic, and thereby reduce CTE mismatches.



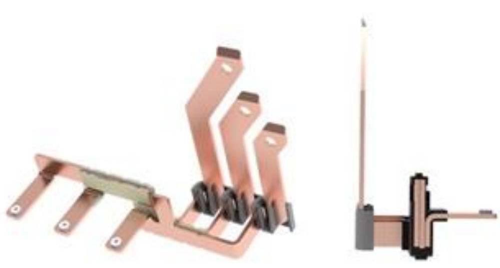


Figure 3. Comparison between a conventional busbar (left) and a molded one (right)

A conventional assembly is shown in Figure 3, with a 2.3mm spacing between the busbars (for plastic flow). Next to it is a molded assembly, which has an insulator film added. This has only minimal CTE mismatches, and is thus less impacted by mechanical stress.

Another consideration is to incorporate stress relief and flexibility into the busbar design. It is also becoming increasingly important to holistically design for optimal flexibility, so as to minimize stresses from both temperature and vibrational factors. Key mitigation methods include building in busbar edge relief to distribute stresses and using flexible connections within the assembly.

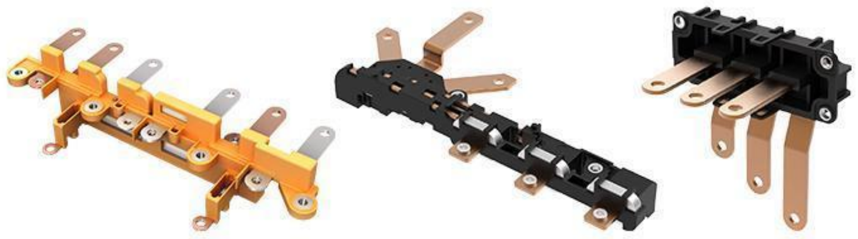


Figure 4. Busbars are a one-piece connection solution to streamline assemblies

By implementing processes that reduce the number of different pieces involved, suppliers can not only keep the cost of their interconnects down, but also benefit from increased reliability. By taking a modular approach, busbars can be manufactured cost-effectively while still being adaptable enough that there is plenty of scope for adding differentiation.

Conclusion

With automobile manufacturers realizing just how fundamentally important the powertrain will be to making their EV models standout from those of the competition, they need to seek as much advice as possible from their interconnect suppliers. This is why EV manufacturers need to engage with such suppliers earlier in the product life cycle - often at the initial concept phase.

About the Author

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