Busbar Technology Is Anything but Flat

The rapidly accelerating shift from internal combustion engines to electric vehicles has contributed to a reimagining of vehicle architectures. OEMs have realized that the architectural break represents a tremendous opportunity to optimize components throughout a vehicle — right down to the fundamental building blocks of electrical architecture.

That spirit of innovation extends even to the cabling itself, as OEMs look at flat conductors called busbars as an alternative that carries more electrical power than traditional cables and maximizes the use of space within the vehicle — all while enabling greater automation in vehicle assembly to reduce costs and increase safety.

But despite busbars' clear advantages for certain applications, they also have some limitations. By addressing those limitations with innovative solutions, OEMs can build a better foundation for the next generation of electric vehicles.

A DIFFERENT APPROACH

For more than a century, round cables have provided the foundation for almost all electrical connections. Their flexibility is the key to their success: They can bend around corners and other obstacles to route through tight spaces, and having connectors at each end makes installation easy. Those advantages have often extended just as well to automotive electrical architectures, but there are several factors causing OEMs to increasingly choose conductors called busbars as an alternative to cables for certain applications.

Busbars are solid metal bars used to carry current. Typically made from copper or aluminum, busbars are rigid and flat — wider than cables but up to 70 percent shorter in height. They can also carry more current than cables with the same cross-sectional area. These attributes make busbars ideal for some high-voltage connections in electric vehicles (EVs) and a key component of the electrical architectures of tomorrow's vehicles.

BUSBAR DRIVERS

The first factor driving busbar adoption is the lack of space within today's vehicles. Every sensor, actuator and electric/electronic device in a vehicle requires power and data lines, along with all of the packaging space that goes with them. Because busbars do not sit as high as cables do, their lower-profile routing leaves room for other electrical content. They can also be formed at angles more tightly and more precisely than a cable can bend, fitting closely to vehicle profiles.

The second factor is the need for automated assembly. Even though much automotive assembly has become automated, installing wiring continues to be a largely manual task. The flexibility that has made cabling ubiquitous can make it very difficult for a robotic arm to hold a wiring harness and place it correctly in a vehicle. In contrast, it is much more straightforward for a robot to move a rigid busbar into place.

Automated assembly is less expensive from a labor standpoint, it enables higher quality, and it is also safer, given that EVs operate at high power and can expose assembly workers to powerful electric currents.

The third factor driving adoption is that busbars can carry more current because of their shape. OEMs are looking to increase power to their EVs' batteries to reduce charging times, and a busbar can support up to 15 percent more power than a cable with the same cross-sectional area.

In addition, the larger surface area of a busbar dissipates heat more efficiently than a cable over its entire length — another advantage as OEMs seek to increase power levels.

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CHALLENGES

Each of these factors makes busbars an attractive choice, but there are several hurdles that must be cleared before they will see wide use.

Connectors

Cables have a long and rich history of using connectors that allow the cables to be plugged, fastened and locked into place easily and securely. In contrast, most manufacturers to date have used bolts to fasten busbars.

While a bolt will work, there are several drawbacks. Bolts require more equipment and labor for installation than connectors do, and OEMs must measure the torque applied to the bolt to ensure that it is secure. Additionally, manufacturers try to avoid having loose metal items that could cause a short among the electric components during assembly, and a bolt is a separate piece that must be accounted for.

As with many high-voltage interconnects, standard interfaces have not yet been developed by the industry. However, we know that the ideal connector must be finger-safe to prevent accidental contact, minimize fretting and allow for position tolerance. Aptiv has developed pluggable female terminals as well as male-to-male busbar connectors that accomplish this, using a stainless steel spring that does not relax with heat, to hold the busbars in place.

Flexibility

There are several circumstances where introducing a level of flexibility into the busbar might be necessary. When a busbar is too rigid, it can be difficult to connect the ends due to manufacturing tolerances. Plus a rigid bar is unforgiving when it comes to thermal expansion or vibration.

For these reasons, OEMs are looking for ways to add flexing sections to busbars to retain their benefits while allowing for some degree of movement. These sections could be either at the terminal end or somewhere in the middle of the busbar.

One method is to substitute a section of the busbar with a braided strap, which maintains the flat configuration but could prove too flexible for automated assembly.

Another method substitutes the busbar section with thin strips of the conducting material and then stacks the strips. This approach provides limited flexibility in one direction.

Shielding

As with any electrical and electronic equipment, electricity flowing through a busbar creates electromagnetic radiation that can potentially interfere with electronics within the vehicle. As busbars continue to evolve, shielding options will have to evolve as well.

Similar to shielding on cables, busbar shielding uses a braided metal jacket that wraps around the busbar. This approach retains busbar benefits such as flatter routing and better heat dissipation than cables, while minimizing interference.

THE FULL PICTURE

Today, busbars are already proving to be valuable as battery interconnects, linking the short distances between battery cell modules in modern EVs. Even in this limited context, there is a need for some flexibility to absorb vibrations and provide tolerance.

As busbars expand beyond the battery, OEMs must weigh design decisions in the context of their full electrical/electronic architectures. The architecture will determine whether to use busbars, where to put them, how to connect them to other components, and where to add shielding or flexibility.

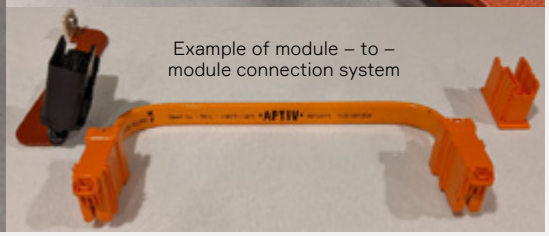
Aptiv has a long history of building cables and connectors that are innovative and reliable. With visibility into both the wiring and the connectors, we know how to design components that solve OEMs' toughest challenges.

Most important, we see those components as part of a complete vehicle architecture. Busbars are integral to Aptiv's Smart Vehicle Architecture™ vision for tomorrow's vehicles, which couples busbars with a modular zonal architecture and our Dock & Lock™ connection system to simplify the overall design and enable more automated assembly. Taken together, these are the technologies that will provide the foundation for the next generation of electric vehicles.

APTIV BUSBARS


Pluggable female terminal — finger-safe when unmated

Finger-safe module side terminals



Example of module – to – module connection system

ABOUT THE AUTHORS

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Randy Sumner leads Aptiv's business pursuits and innovation efforts in the rapidly growing global market for hybrid and battery electric vehicles. Randy began his career in 1980 with the organization that would become Aptiv, rising through process and product engineering supervisory and management roles to eventually lead a team focused on the high-voltage, high-power applications required by electric vehicles.

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