ADAS-EV Evolving Systems and Signal Connectors

Introduction

Electronic and electrical trends in vehicle safety and control systems — including ADAS (Advanced Driver Assistance Systems) and vehicle electrification — are driving changes in vehicles ranging from passenger cars to on- and off-highway vehicles. This white paper offers insight and best practices on how both component and systems designers are turning to proven as well as emerging connector technologies. Their goal is to provide more robust, easier-to-assemble components capable of supporting higher density requirements in mission-critical vehicle electronic modules.

Growth of Vehicle Electronics

For the purposes of this paper, the term "automotive" includes passenger cars primarily, but also commercial vehicles. Anyone who is part of the automotive industry has seen the increased use of microprocessor-driven electronics in vehicles over the past few years. This rate of growth is increasing as time goes on — right now, we are approaching a 50% blended average (Figure 1). There are vehicles in which this percentage is much higher, especially in some higher end vehicles, but this encompasses autonomous functions, vehicle safety systems and infotainment, and power systems. Rapid advances and expansion of vehicle electrification is taking place on all vehicles, even internal combustion engine vehicles (e.g. belt-to-motor, 48V, start-stop).

The majority of the growth that has been taking place can be categorized into two camps: advanced driver-assistance systems (ADAS) and electrification, which includes everything involved in battery hybrid vehicles and internal combustion engines (as noted above). There are some common architectures but because there is also innovation taking place, so manufacturers are approaching this with different design perspectives completely.

ADAS. ADAS encompasses the safety systems that enable drivers to drive more safely and be more informed. It is, in its most fundamental hardware level, ultrafast, high-volume data collection and signal processing. High-speed signal processing is the foundation for the intelligence and safety systems that collect, process and present status for decisions to be made by either the driver or the system (higher level ADAS vehicle control).

Typical systems or subsystems within ADAS include vision systems, LiDAR, radar, and geo/telematics. It can reach into other aspects such as thermal or even acoustic sensing. There are a myriad of ADAS functions that are taking place on vehicles and every time a vehicle goes through a new model year or a new revision, the amount of growth continues.

Electrification. An internal combustion engine has inherent inefficiencies due to the loss of energy from heat. This is true even if the electric motor is not driving the vehicle, electric motors also drive fan belts, radiators, air conditioners, and other systems. With an electric motor, when it's off, it's not consuming electrical energy and is more efficient.

The electric vehicle (EV) is the complete move to electrification, compared to start-stop, hybrids, and plug-in hybrids, where the entire drivetrain is controlled or driven from electrical energy. The need to add more circuits and control them is leading to modifications of the architectures in many systems down to the printed circuit boards.

With a pure EV system, there are three main electrical 'drive train' components: the battery, the motor, and the controller. As architectures have evolved, designers are finding ways to combine (simplify) the controller architectures — for example, combining inverters and motor controllers directly into the motor, or combining battery chargers and DC converters directly into the battery packs. The effect of such evolution reduces mass, improves efficiencies, and reduces cost.

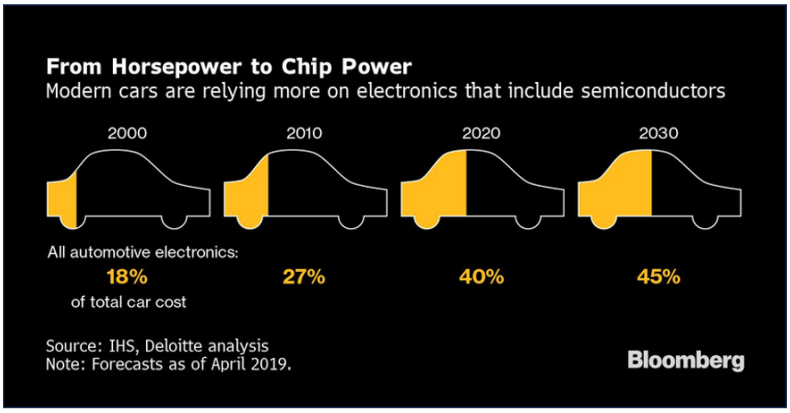

Figure 1. Modern cars are relying more on electronics that include semiconductors.

Automotive Electronics Requirements

In the automotive industry, there is a high bar of excellence from a quality and survivability standpoint. Fundamentally, automotive systems are designed typically to work for 10 years or more without incident. With the increased levels of new vehicle electronics, it is important that all the components both connecting modules to wiring as well as connectors and components inside also have the same level of performance. For instance, with an electric module inside the vehicle, like a control module, even though connectors joining printed circuit boards probably aren't going to have the same level of requirement as the connectors on the harness or the headers, such as waterproof ratings, they still need to be reliable under the tremendous and ongoing stresses of long-term shock, vibration and extreme temperature variations. To gain the trust of automotive engineers, the use of such connectors often requires that they are validated and tested to commonly recognized standards such as USCAR 2 in North America; some OEMs have their own variations, and in Europe, the standard is typically LV214. Typically, these components and systems need to be standardized to the Production Part Approval Process (PPAP). Another factor to consider is that often, assembly takes place in an assembly shop, where there is high-value features such as keying, reverse polarity detection, Poka-Yoke, and locking.

With the advent of intelligent systems and smart control modules, designers have been turning more to consumer-like connectors and architectures and many of these are not necessarily automotive-grade. The connectors in mobile phones and consumer electronics are not all designed with the same level of thermal and mechanical performance as is typically needed for connectors used in the automotive industry. Companies like Molex are selectively evaluating and upgrading connector systems used in consumer electronics for automotive use. Automotive systems are using larger displays and embedding more interfaces to sync to mobile devices, so there is an increased use of software and dynamically downloaded software.

High-speed computing also has become increasingly common in automotive systems and they also are requiring rugged and highly reliable connectors. From an architecture perspective, modules of the past often were single-board architectures and their only connector was a header connector on the back end or underneath. Now, there are a main and daughter or auxiliary printed circuit board inside the module for specialization and to keep the systems smaller.

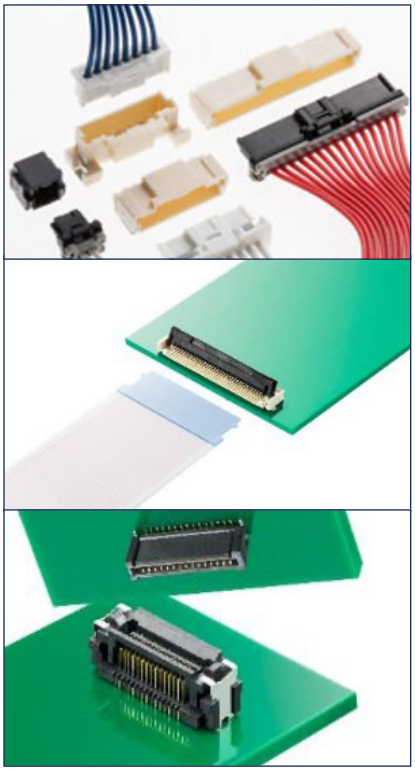

Figure 2. The three types of automotive interconnects are (top to bottom): Wire-to-board, FPC/FFC, and board-to-board.

Connector Systems

There are basically three types of connector systems used to connect either modules to printed circuit boards or printed circuit boards to things like display panels and human interfaces (Figure 2). The wire-to-board has been the traditional choice, but more recently manufacturers and designers have been turning to flexible printed circuit/flexible flat cable (FPC/FFC) connectors that are lightweight and simpler from an assembly perspective and also offer locking. Board-to-board connectors can use an FPC or FFC cable or can be two boards mounted together in a board-to-board configuration.

The FFC/FPC cables are ribbon-like cables that may have notches or flags that are typically there for increased retention for locking. There are various types of locks including dynamically activated where it locks when the cable is inserted; a button disengages it for servicing. Other locks are actuators that basically act as locking mechanisms. These connectors are categorized by their size or geometry and by the pitch — the spacing between the pins or the terminals. They can also be characterized by their overall form factor.

When we talk about the pitch, spacing, and form factor in the consumer world, smaller is almost always better. But in automotive, there is a point at which smaller isn't necessarily better. In some instances, due to the assembly process, it's not easy to assemble very fine-pitch connectors.

There is a similar way of categorizing board-to-board connectors in terms of their geometries — how high they are and their width. There is a bit more innovation taking place in these types of connectors for a couple of reasons. First, some of them have specialized terminals that are more optimized for power. Even though we call these signal connectors, sometimes they are used to route very low levels of power but within a small electric device. Board-

to-board connectors also can be rated by their pitch and width.

When selecting a connector, how do you know which type to choose? There are multiple questions to address including: What will the height be when the board are mated? If its floating, how much float is needed? Also, how much power is needed in terms of voltage or current or both? What is the frequency rating and how will they be assembled? What requirements are necessary in terms of standards?

Floating board-to-board connectors, which was mentioned earlier, is an innovation in which boards are mated together, typically in a mezzanine configuration (where two parallel boards are mated via the connector system). Even if/when the PCBs are securely fastened to the housing, there will at times be some relative movementbut there will be some relative movement between the top board and the bottom board. That is due to thermal variations where one board varies relative to the other board. If there is shock involved, there may be some transients from one board to the other: combined, these have the effect of putting stress on the soldered joints on the terminal. Floating features in the connector enable the boards to move relative to each other because the connectors are literally on a springform bed that allows them to move sometimes as much as a millimeter in the X, Y, or Z directions, or even at an angle.

There are a number of reasons that floating board-to-board connections are used (Figure 3). They provide more functionality and a bit more material, and although they cost more, they provide increased reliability. So, in automotive applications, when two printed circuit boards are mated together, designers turn to this type of connector.

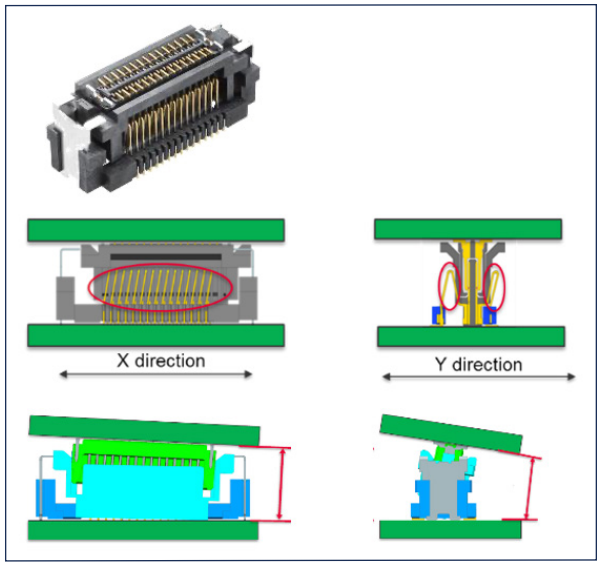

Figure 3. Floating board-to-board connections enable dimensional tolerance stacking, ease of assembly, and reduced stress on solder joints.

The battery assemblies have power ports/connection points. The entire assemblies are fully enclosed, meaning that it is acceptable for some level of exposure to occur with open connectors because the entire modules typically are sealed. Battery monitoring systems continuously check battery status down to individual battery cells for performance and safety in the event that one or more battery cells enter a runaway or over-stressed state — exhibiting irregular or non-conforming voltage or performance, the battery monitoring system should note this and take action (e.g., shut down the pack, declare an alarm).

Vehicles now have hundreds to thousands of lithium-ion battery cells and each of these cells has one or more wires or connectors going to a load monitoring unit or a battery monitoring unit (BMU). Sometimes there are multiple BMUs monitoring banks of batteries with connectors that monitor every battery. These interconnections are the focus for innovation. Until recently, these have been wire-to-boards but there is a an ongoing focus to lightweight and battery sensor circuits (and connectors). One direction is to turn to FPC/FFC cables/connectors, which are lightweight, to improve and simplify the assembly process. (Figure 4).

Another aspect of battery packs is some type of smart-level monitoring system or controller for the motors or systems, and each typically has built-in intelligence. These modules have evolved into an architecture in which there is a power control, various types of solid-state silicon carbide devices that can turn electrical energy on or off, and an intelligent layer that works through the network — this is typically where the microprocessors are. These are often isolated into a separate board and there are connections that mate or allow the microprocessor to connect to or control and drive the power for these modules.

EV Battery Packs and Power Control

Today, battery modules are typically meta-assemblies that include multiple battery packs in arrays of batteries. Typically, they are lithium-ion batteries – that may change and evolve as time goes on. Each array consists of a pack or a collection of multiple cells that are combined, provide higher voltage and higher current outputs.

ADAS Basics

ADAS involves ultrafast, ultra-high-volume data acquisition and signal processing in vision, LiDAR, radar, telematics, and other sensor points. In LiDAR and radar modules, what has been taking place from a system perspective is an expansion into lighter weight and lower cost as well as miniaturization.

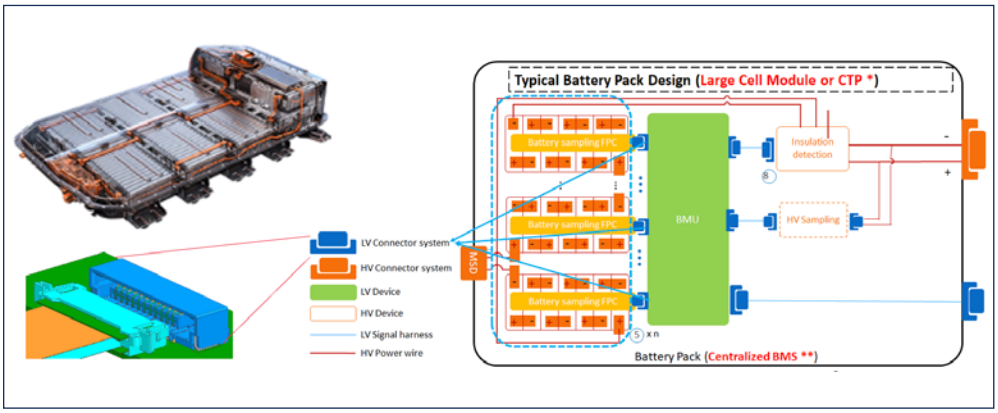

Figure 4. Today's battery packs consist of multiple cells; each with one or more wires or connectors going to a battery monitoring unit (BMU, shown in the green rectangle).

These are systems that are used to look forward, around, and behind the vehicle to detect obstacles and collect data to keep the vehicle safe; however, they do add cost. The resolution and the amount of data being collected continue to grow.

The need for higher speed, and higher performance in connectors is key to design decisions. Designers of LiDAR and radar systems are looking to the consumer industry which has been miniaturizing for decades (e.g. mobile phones) and turning to consumer-type connectors. Some of them are available for automotive applications, but they're all also driving companies like Molex to come up with finer-pitch miniaturized connector systems. In these systems, smaller is becoming better.

The first cameras on most vehicles were backup cameras. Now, they're appearing on all sides, in the mirrors, and at some point, in the not-too-distant future, they will combine with displays to reduce or replace the mirror, provide surround view, and then be used inside the vehicle for driver/occupant monitoring.

Vehicles from commercial to passenger cars are adding multiple cameras with each new system revision. These cameras are either integrated into modules or else are designed to be standalone systems that are mounted separately from the modules. Typically, they consist of a single wire with a connector, like a FAKRA connector — the back of which supplies both power and signal. Another layer goes through the connector from the exterior to the interior to an SMT connector to the printed circuit board or boards.

From the outside, the back half of the connector must be robust because these systems are subject to shock and vibration. Many designers use backshells with an integrated FAKRA connector and a micro-coax-type connector that extrapolates the moisture, shock, vibration, and torque so they do not create stress on the solder joints.

Consumer Interfaces

The capability to integrate consumer devices such as mobile phones is very important to automotive manufacturers, which are increasingly adopting integration and support for mobile devices. As a result, wireless and USB interfaces are important. Charging speeds, current handling, and speed rating continue to improve as manufacturers move away from USB connectors to USBC. When choosing these types of connectors, be sure to select an automotive-grade connector that has been PPAP qualified and meets all automotive requirements.

As far as antennas, most consumers are familiar with the exterior antenna, which often resembles a shark fin. However, inside the vehicle, there are various antennas that allow mobile devices to sync with the vehicle. With commercial vehicles, there is a rapid advance of telematics, which is becoming a common feature rather than just an upgrade or special feature. Designers are turning to new antenna systems, as well as telematics modules, allowing the vehicle to be constantly connected.

Summary

The amount of investment in electrification that has been announced on a global basis is astounding in North America as well as globally. Major automakers will be investing more than $100 billion in the next few years specifically in electric vehicles. You can expect to see increased demand as well as innovation taking place in signal connectors within the vehicle.

Author

Matt McWhinney is Business Development Manager for Antennas, Molded Interconnect Devices, and Microconnectors at Molex, working with customers and electronics manufacturers throughout North America. He supports products such as antennas and fine-pitch, high-speed internal and I/O connectors.

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