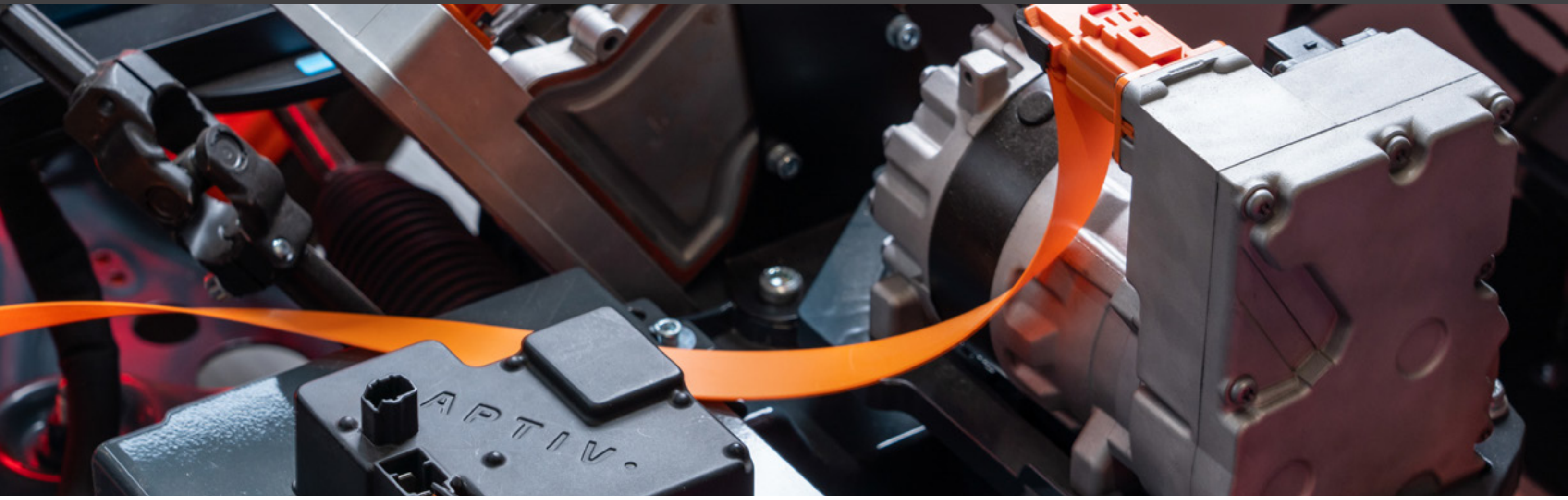


Flat Cables Bring New Dimension to Electrical Architecture

Vehicle architectures are at an inflection point. The advent of battery electric vehicles represents an architectural break — an opportunity to rethink how we design electrical/electronic architectures — and the high amount of content in hybrid and ICE vehicles is making innovative approaches necessary there as well. Meanwhile, the move from 12V to 48V across all vehicle types also provides an opportunity to rethink the wiring and connectors used throughout.

Flat cables have emerged as an important option for power and signal connections in certain circumstances. Each main variety — flexible flat cables and flexible printed circuits — brings unique strengths in terms of size, weight, heat dissipation and automation.

New manufacturing techniques, components and connection systems are needed to fully take advantage of these strengths — and developing them will open the door to new levels of design flexibility.

GETTING A SECOND LOOK

Take a look inside today's battery electric vehicles, and it is hard not to notice just how flat the architecture is, given that it is dominated by battery pack modules that lie like tiles just beneath the floor of the cabin. It is also hard not to notice how many power, signal and data lines there are interconnecting the various components.

Put those two factors together, and it is no wonder that automakers are looking more closely at using flat cables in their electrical/electronic architecture designs.

Flat cables are not new to the automotive industry. As early as the 1960s, flat cables emerged as a way to make connections within a vehicle while taking up less space. But as smaller-gauge wiring and terminals became available, OEMs found that they could meet many of their requirements with round wires instead.

Today, the density of wiring and connections needed to enable feature-rich, electrified vehicles is greater than anything the industry has ever seen, and flat cables offer some distinct advantages — including weight and volume savings, increased heat dissipation and support for higher levels of automation.

WHERE TO USE FLAT CABLES

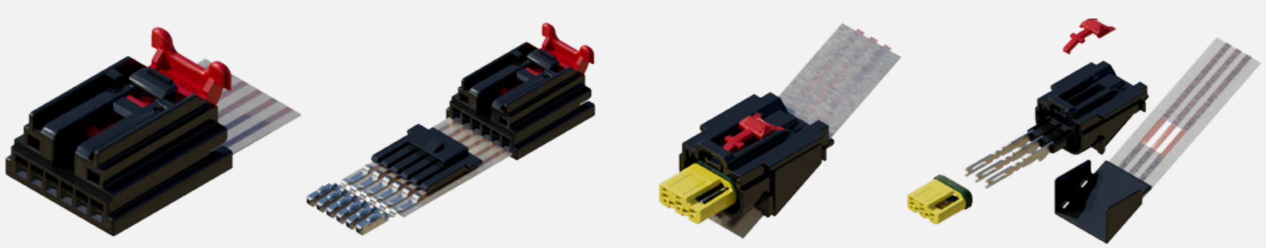
Flat cables make sense in modern zonal architectures in particular. Zone controllers consolidate connections to I/O, simplifying and streamlining wiring harnesses into a point-to-point architecture of parallel power and signal connections to central compute, distributed devices and even other zone controllers. These connections typically have shorter wires, and fewer of them, than traditional architectures do.

Flat cables also make sense in harnesses intended for cramped spaces, such as doors, seats, antennas, headliners, fascia and bumpers, windshield wiper heaters, power mirrors, headlamps and rear lighting.

Emerging applications for flat cables include power/data buses, direct-attach flex-to-sensors and flex-to-ECUs, camera deicing and defogging, EV battery current collectors, and EV battery interconnects with integrated voltage sense, temperature sense and fusing.

Flat Renaissance

The re-emergence of flat cables in automotive applications demands innovation in connection system technologies. Here are examples of Aptiv's latest solutions.



THE TYPES OF FLAT CABLES

There are two primary types of flat cables: flexible flat cables (FFCs) and flexible printed circuits (FPCs), each of which has unique advantages and disadvantages.

Flexible flat cables

FFCs consist of many straight, flat copper or aluminum conductors in parallel that are either extruded with a thermoplastic insulation such as polyurethane or laminated with a coverlay material such as polyethylene terephthalate. The laminate is then laser-cut to expose contact pads on the conductor. Because FFCs are straight, they are often folded to create the required shape.

The continuous-run manufacturing process means that FFCs can be any length. Conductor thickness can be higher than 1mm, but thicker conductors will result in a stiffer FFC. Individual conductors are typically limited to 16mm in width, with the maximum FFC width determined by the manufacturing process. Creating FFCs is the fastest and most cost-effective flat-cable process.

Flexible printed circuits

FPCs are created with flexible copper clad laminate. The material is masked and chemically etched to remove the copper according to the required pattern, and then a coverlay material is applied with holes cut out to expose contact areas of the conductor.

FPCs can replace not only traditional wires but also traditional rigid printed circuit boards. They can support multiple conductor layers, and they

FFCs vs. FPCs

The two primary types of flat cables have some of the same advantages in architecture design, but they are made differently and have very different properties.

	Flexible Flat Cable (FFC)	Flexible Printed Circuit (FPC)
Manufacturing Process	Forming and additive processes where flat conductors are extruded or laminated with insulation and then folded to create the needed shape	Flexible Copper Clad Laminate (FCCL) masking and chemical etching followed with laser cutting for openings of laminates
Materials used	Thermoplastic polyurethane (TPU) for extrusion process and polyethylene terephthalate (PET) for lamination process, flat copper/aluminum conductors	FCCL etching plus overlay laminate made of polyimide, polyethylene naphthalate or PET
Potential replacement for	• Individual traditional wires / cables	• Individual traditional wires / cables • Traditional rigid printed circuit boards (PCB)
Description/ Capabilities	• Length limited only by the take-up reel size • Conductor thickness can be higher than 1 mm • Fast and most cost-effective FC process • Extruded cables are more robust — no adhesives	• Single-, double- and multi-layer flex circuits • Conductors can have integrated electronics with surface-mount devices, fuses and crossovers • More reliable / ruggedized than FFCs
Limitations	• Straight parallel circuits only and no patterned shapes • Generally, less than 32 mm width	• Chemical etching resulting in high material waste • Generally limited to copper thickness up to 2 oz • Generally limited to length up to 1.2 m *(3 m is ideal for automotive harness applications)* and width of 600 mm

can integrate electronics with surface-mounted devices, fuses and crossovers. Plus they are more ruggedized than FFCs and can support a width of up to 600mm.

However, FPCs are generally limited to a copper thickness of 2 oz and a length of 1.2m. Plus the chemical etching results in high material waste.

Other flat-cable technologies beyond FFCs and FPCs are being developed for potential automotive applications, so innovation is likely to accelerate in this area.

BENEFITS OF FLAT CABLES

There are several key benefits to using flat cables rather than traditional wiring harnesses.

Size and weight

Flat cables enable the use of thinner conductors without compromising mechanical strength and durability. Typically, this advantage can result in a weight reduction of up to 40 percent and volume savings of up of to 35 percent, when taking into consideration the full wiring harness and all of the changes related to connectors, clips, taping and so forth.

The unique construction of flat cables is the primary enabler for these reductions. With round wires, any reduction in size is limited by the need for the individual cable and termination to take on any stress or strain imparted on the connectors and wiring harness. In comparison, the layers that make up flat cables provide strain relief and enable robust termination — allowing for the use of thinner and smaller conductors in many scenarios.

Heat dissipation

Compared with round wires, flat cables have superior thermal characteristics. Flat cables have a larger surface area per equivalent volume, which dissipates heat and allows for higher current to be carried by the same volume of conductor.

Design flexibility

Flat cables offer several advantages in terms of design flexibility. They are obviously well suited for planar surfaces, such as inside battery modules. Their flexibility makes them a good solution for locations with some movement or a tight bend radius, such as steering wheel airbags. They can be mounted using adhesive instead of mechanical clips and do not need the taping or other covering that may be required to protect traditional wiring harnesses.

Power and signal connections are needed for most devices in a vehicle, and this approach allows power and signal lines to be integrated onto a single flat cable, such as a backbone to connect the primary compute devices in a Smart Vehicle Architecture™ configuration.

Automation

Flat cables lend themselves well to automation. They have stable, fixed geometries and a robust structure that arranges the conductors for easy handling and termination. They are better suited for plugging terminals into connectors or welding for preinserted terminals. They work well in a modular connection system and can benefit from the automation advantages of those systems. And they can take advantage of pressure-sensitive adhesive to allow robots to stick the cables into place.

A FLAT FUTURE

Modern flat cables require modern terminal designs. Many crimp-style terminals used in the past do not meet USCAR-21 requirements and are not suitable for higher levels of current. Each terminal system for flat cables must be validated to the latest customer requirements.

Aptiv is developing terminal and connection systems for the next generation of flat cables, with a focus on welding technologies that provide robust, zero-resistance electrical terminations. Welding is also a scalable technology for automated harness assembly. Adaptation of traditional female terminals and development of "tuning fork"-style female interfaces can provide a variety of solutions for flat cables. Aptiv will leverage modern sealants/adhesives and proven silicone connector seals to provide sealed flat-cable solutions.

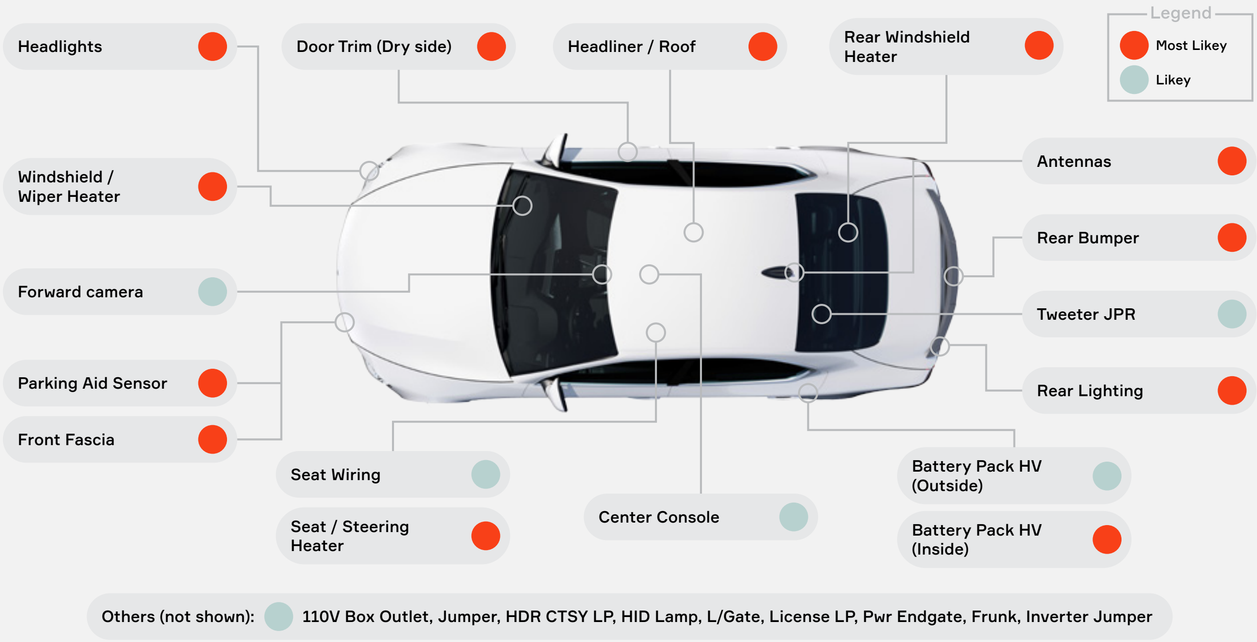
As 48V electrical architectures become more prevalent, flat cable applications are likely to proliferate due to the use of smaller conductors carrying less current. Plus, 48V power backbones can benefit from the improved heat dissipation of flat cables. As with the proliferation of electric vehicles, the transition to a 48V architecture provides an opportunity to rethink the vehicle wiring. As new devices are designed for 48V, it is an opportune time to define connector pinouts optimized for the parallel conductors of flat cables.

Similarly, there is an opportunity to use flat-cable designs to address requirements for high-speed data applications, such as connections to camera and radar sensors. Flat cables can evolve to eventually replace coaxial cables and differential data pair cabling.

Flat cables are not for every application. But as automakers start to design the next generation of vehicles — with new power distribution architectures, streamlined approaches to data communications and a simpler overall design — flat cables are sure to be a part of that equation.

Potential Applications

Flat cables can be used in places with specific packaging constraints, such as flat surfaces with limited vertical space, wiring with embedded electronics, tight bend radii, and moving parts.



ABOUT THE AUTHOR

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Kurt Seifert is responsible for advanced development of Aptiv's connection systems, with a concentration on flat cables, high-speed data, Smart Vehicle Architecture™ technologies, and automation. He has been with Aptiv for more than 37 years, holding positions in manufacturing development, quality systems, terminal crimp technology and product development. His team is focused on working with customers to develop and introduce new technologies for a sustainable future.

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