CAN Newsletter Online

CAN NEWSLETTER MAGAZINE

Challenges for wiring harness development

We are living in an era of major disruption in the automotive industry. Driven by the rapid development of new technologies and the proliferation of automotive start-ups, both trends have implications on the development of vehicle wiring harnesses.

The complete article from Mentor Graphics and Siemens is published in the [March issue](#) of the CAN Newsletter magazine 2020. This is just an excerpt.

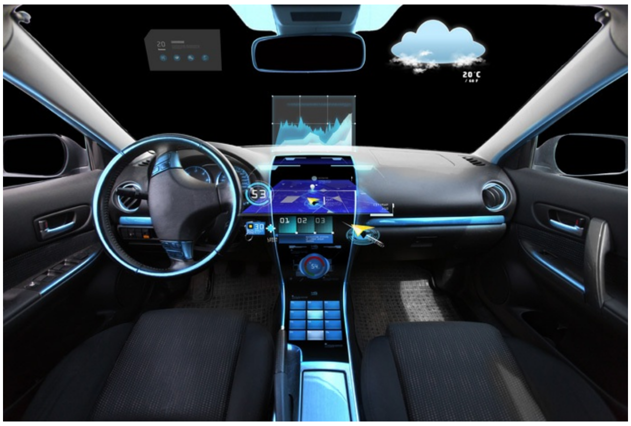

Figure 1: New automotive technologies such as artificial intelligence and connectivity are creating new challenges in wiring harness design (Source: Mentor)

The never-ending development of new technologies and their addition to modern vehicles leads to a phenomenon that can be labeled as the content dilemma. The content dilemma represents the conflict between the technology content that vehicle manufacturers try to integrate into their vehicles, and the weight, cost, and packaging space required for wiring harnesses.

Examples of recent technology trends that are driving the content dilemma include (Figure 1):

- Electrification
- Autonomous driving
- Artificial intelligence
- Connected vehicle

A key competitive factor for customers in an electric vehicle is range. The more miles a vehicle can drive with one charge, the better. Vehicle mass plays a key role in determining a vehicle's range, therefore, minimizing weight in an electric vehicle is crucial to bringing a competitive and successful vehicle to market. New vehicle technologies, however, require additional electrical wiring and other electronic components, increasing the weight of the vehicle. The introduction of the electric powertrain alone adds about 30 % more weight compared to an internal combustion engine powertrain.

Autonomous driving requires the addition of a multitude of hardware redundancies and fail safe mechanisms to prevent single points of failure that could disable the autonomous system unexpectedly. System redundancies are critical because unexpected failures may cause the vehicle to crash if the driver isn't paying attention or actively involved in the driving and steering process. How- ever, these safety redundancies can add significant weight and cost to the wiring harness by duplicating networks, powerlines, and some electronic control units (ECUs).

Artificial intelligence in vehicles enables facial recognition, computer vision, and other machine learning algorithms to help personalize the user experience and vehicle settings by processing and 'learning' from incoming data. This requires the inclusion of a myriad of cameras and other hardware all over the vehicle. These cameras are usually connected to an electric control unit via high bit rate net- works. Most automotive networks use unshielded twisted pairs of wires, such as CAN. In a CAN network, cables can sometimes even be twisted during harness assembly to avoid the use of costly specialty cables in the wiring harness. Higher bit rate networks, on the other hand, are more likely to need special grades of cable, shielding, and some- times more complex pre-assembled cable types like Coax. These specialty cables are significantly larger, heavier, and more expensive than conventional automotive wiring. Therefore, it is typically preferred to minimize the usage of these where practical.

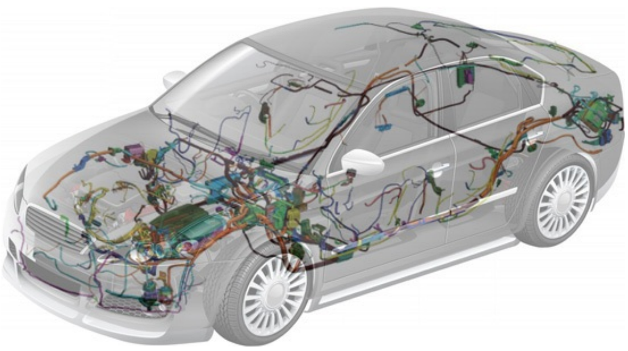

Figure 2: Growing electrical and electronic content in vehicles is increasing bandwidth demands in the vehicle. OEMs are responding by incorporating additional networks, both standard and specialized, leading to harnesses that are heavier, costlier, and more complex. (Source: Mentor)

Last, but not least, vehicles are becoming highly connected as part of the Internet of Things and Internet of Vehicles, transforming the vehicle into a seamless inter- face between our connected lives at home and at work. The integration of screens and displays into almost any imaginable interior surface demonstrates the vehicle's growing role as a hub for entertainment, communications, and productivity.

All this technology has to be connected together, driving OEMs (original equipment manufacturers) to incorporate more networks, such as CAN, and leading to wiring harnesses that are heavier, larger, costlier, and more complex (Figure 2). Some modern vehicles contain close to 40 different harnesses, comprised of roughly 700 connectors and over 3 000 wires. If taken apart and put into a continuous line, these wires would exceed a length of 2,5 miles (4 km) and weigh approximately 132 lbs (60 kg). In addition, OEMs will need to integrate high bit rate net- works with specialty cabling to support the increased features and functionality of new vehicles. Modern vehicles can contain more than 70 specialty cables, such as coax, high speed data, and USB cables. In older cars, this number was closer to ten.

How can today's automotive manufacturers solve the content dilemma? Via the introduction of methods that help development teams to reduce the impact of added content and technology on the weight, cost, complexity, and pack- aging space required for wiring harnesses.

One solution is to develop technologies that reduce harness weight. Ultra-small diameter wiring (0,13 mm^2) is one good example.

Unfortunately, the industry is still struggling to develop a sufficient number of terminal substitutions for all currently existing terminals that can crimp to such a small wiring diameter. Reducing the wire size on common circuit types, such as CAN networks, can achieve quick weight savings without necessitating a complex sub- set of connectors and pins, but the available products on the market currently do not support a large-scale migration to ultra-small diameter wiring.

The same applies to aluminum wiring. For small diameter wiring, pure aluminum is too brittle and thus not a feasible option. Terminal suppliers have begun developing optimal aluminum alloys for the specifications of their terminals. This has led to a multitude of different alloys on the market that, in most cases, are incompatible with other suppliers' terminals. This, in turn, means that a vehicle would have to be solely comprised of one supplier's connectors to be able to use aluminum across the full vehicle, which is not realistic.

Additionally, switching to aluminum wiring would require the compression of the aluminum core to reduce bundle sizes in addition to weight. Due to its material characteristics aluminum wire diameters have to be upsized by at least one size to keep the same conductivity as copper wiring. Switching to larger diameter aluminum wires across an entire vehicle, or even a portion of the vehicle, would result in a significant increase of bundle sizes and require more packaging space.

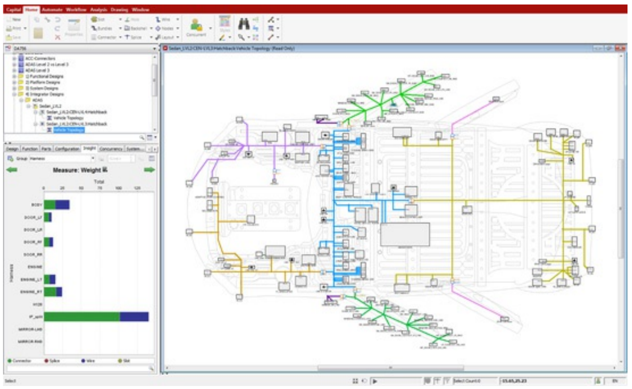

Figure 3: Capital enables tradeoff studies with cost, weight, and bundle size metrics top optimize a harness design. (Source: Mentor)

Finding alternatives to specialty cables will further reduce the weight, cost, and bundle diameters of harnesses. The number of cameras and displays will only increase in the future. OEMs must balance between using high bit rate networks that require specialty cabling or installing a greater quantity of lower bit rate networks, based on the resulting cost, weight, complexity, and risk of the harness. In the near term, widely used standards, such as CAN FD, that provide higher bit rates while operating on inexpensive twisted pair wiring may provide an easier and lower risk upgrade path. Alternatively, finding ways to multiplex these signals onto one shared specialty cable and having multiple devices tap into these cables, will have the same effect: reducing harness weight, cost, and bundle diameter.

Another approach is using advanced software solutions, such as Capital from Mentor Graphics, that support tradeoff studies to optimize module locations and identify any modules that can be combined to save weight, cost, and reduce bundle sizes (Figure 3). With the ability to compare and analyze layouts for their impact on harness weight, cost, and bundle diameter will enable engineers to choose the most optimal system architecture.

The advent of automotive start-ups

Over the last 10 years to 15 years, the automotive industry has been revolutionized by a second trend: the proliferation of automotive start-ups. Today, it is not just the established legacy OEMs like Ford, VW, or Toyota anymore. Since the founding of Tesla in 2003, more and more electric vehicle (EV) start-ups keep entering the market. This brings its own group of challenges with it.

EV start-ups face unique challenges such as:

- Reduced time-to-market
- Lack of infrastructure
- Bottom up design
- Constant change

Reduced time-to-market leads to something called the timing dilemma. New vehicle development cycles at an established OEM take about four years or five years. In comparison, most start-up EV companies commonly aim to launch a vehicle in a much shorter period of time, sometimes less than half of the time of an established OEM budgets. Further amplifying this dilemma is that start-up EV manufacturers are starting their development from scratch, without the legacy of previous vehicle programs. This short time to market leads to very short iterations or development phases.

Shortened iterative cycles and development phases are not problems in themselves, but become problems when paired with the long lead times needed for harness development. The usual lead-time for harnesses, from design release to product delivery, is approximately 23 weeks to 26 weeks. Variance in lead-time depends on the number of changes and the amount of progress that a project has made in the development cycle. To meet deadlines for the next development phase, harnesses have to be frozen (where the data/design is released and has to go through formal change management processes to be updated) leaving little-to-no time to examine or implement lessons learned in between development phases. Frequently, vehicle testing has not even started when the next freeze comes due. This can lead to massive rework efforts once the next build phase starts, or "machine gun" change requests to implement changes into the harness design as quickly as possible before the next freeze. Both alternatives can deteriorate the quality of the harnesses and can cause unnecessary delays during functional validation.

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