SIEMENS

Ingenuity for life

Siemens Digital Industries Software

Automotive trends create new challenges for wiring harness development

Executive summary

The rapid introduction of new technologies and the influx of automotive start-ups into the market has led to a multitude of challenges for harness development. OEMs and startups alike must consider the number and sophistication of technology features they integrate into their vehicles as they have a direct effect on harness weight, bundle diameter, and cost. Electrification, autonomous drive and driver assistance, artificial intelligence, and connectivity features all place additional burden on the wiring harness.

Ulrike Hoff
Automotive wiring consultant

Dan Scott
Siemens Digital Industries Software

New technologies

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

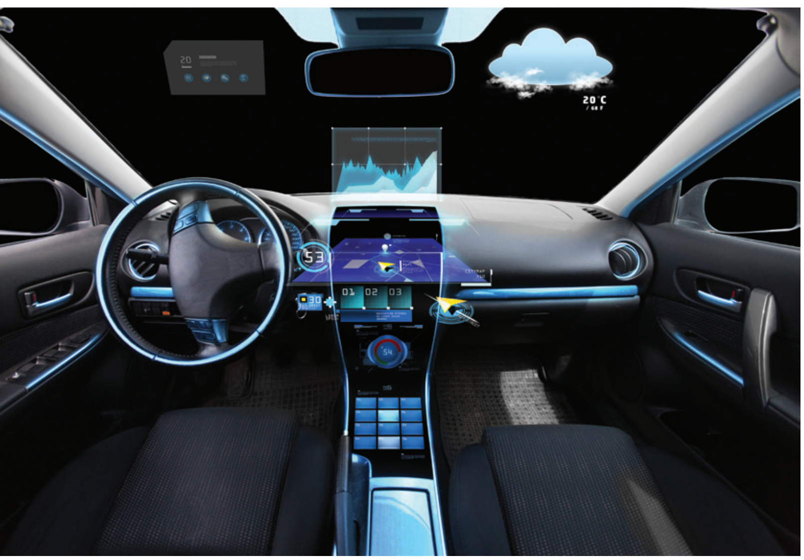

Figure 1: New automotive technologies such as artificial intelligence and connectivity are creating new challenges in wiring harness design.

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. However, these safety redundancies can add significant weight and cost to the wiring harness.

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 coax or high speed data cables, which are significantly larger, heavier and more expensive than conventional automotive wiring.

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 interface 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, which leads to the wire harnesses growing in weight, bundle diameter and cost (figure 2). Some modern vehicles contain close to 40 different harnesses, comprised of roughly 700 connectors and over 3000 wires. If taken apart and put into a continuous line, these wires would exceed a length of 2.5mi (4km) and weigh approximately 132lbs (60kg). In addition, there can be more than 70 specialty cables, such as coax, high speed data, and USB cables. In older cars, this number was closer to 10.

Figure 2: Modern automotive wiring harnesses continue to grow in size and complexity as new features are integrated.

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 and packaging space required for wiring harnesses.

One solution is to develop technologies that reduce harness weight. Ultra -small diameter wiring ($0.13mm^2$) 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. 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.

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, hence developing ways to transmit video and camera signals via standardized wiring will be crucial. 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, 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.

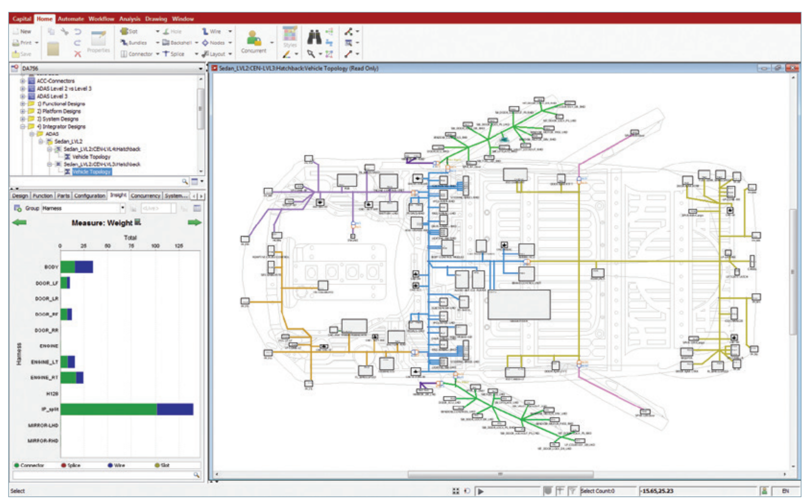

Figure 3: Capital enables tradeoff studies with cost, weight, and bundle size metrics top optimize a harness design.

The advent of automotive start-ups

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

EV startups 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 4 or 5 years. In comparison, most startup EV companies commonly aim to launch a vehicle in a much shorter period of time, sometimes less than half of the time an established OEM budgets. Further amplifying this dilemma is that startup 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 – 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 hasn't 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.

Capital digital thread

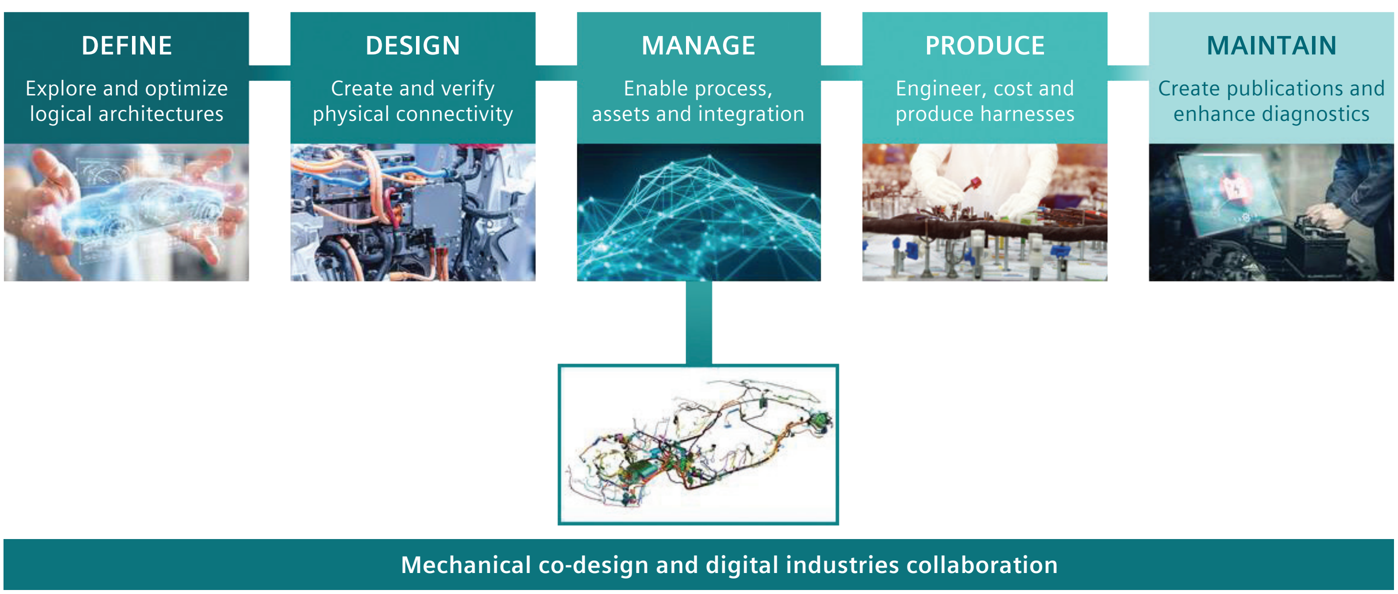

Figure 4: Automated data transfer reduces errors in the harness design by streamlining the interaction between domains.

Reducing lead times during the engineering and manufacturing phases will benefit all the engineering teams. More lead time provides teams with more time to find issues, determine appropriate wiring changes, and implement those changes in the design for the next validation phase. How can this lead-time reduction be achieved? By eliminating manual steps and automatically cascading information from one step to another (figure 4). This significantly reduces mistakes and the need to double check work results. The goal is to create a seamless integration between the vehicle manufacturer's and supplier's tool chains.

Lack of infrastructure

Startups endeavoring to develop new vehicles must also contend with a lack of business and engineering infrastructure. During the early stages of a startup there are no processes in place. Specifically related to wiring development, there is no device transmittal database to help with the gathering, organization, and verification of the electrical data needed for the harness design. Startup manufacturers also do not have a component library of certified connectors, terminals, seals and other accessories. At an OEM, this kind of infrastructure has been built up and tested over a long period. At a start-up, all of this has to be created from scratch, requiring a lot of time and effort when resources and time are limited.

With more and more startups entering the market, harness development tools with an integrated device transmittal database and component library will provide a profound advantage to wiring teams. They eliminate the need for tedious data gathering via Excel sheets and the manual data transfer into logical schematics, a process prone to human error. Harness development tools will streamline and automate the process to reduce mistakes and improve the overall harness quality from early design stages.

Such a database can also run automated reports for open-ended circuits, missing load information, and more. Having a component library in place will considerably reduce the need for part research to find terminals, seals or mating connector part numbers. Mispinned connectors, caused by operator error or incorrect information on the endview definition, are among the most common errors. A component library that provides endviews for each part number will eliminate the guesswork when assigning pin numbers to cavities and prevent these mistakes.

Design differences

Usually, established OEMs employ a top-down approach to system design. In a top-down approach, the system is broken down into subsystems that are further broken down into components. Each component is then custom-designed to support a particular vehicle feature and follow specific requirements, for example, using a connector from a limited set of connector families from approved suppliers.

The timing and budgetary restrictions present in a start-up do not usually allow a top-down approach. Instead, the engineering teams use a bottom-up design of the vehicle. The engineering teams are directed to use off-the-shelf parts that are closest to fitting the intended application. The systems engineering and wiring teams then are tasked with trying to fit all these puzzle pieces together to make up the vehicle functionality and create connectivity. Unfortunately, off-the-shelf parts cannot be altered or customized without significant investment. This regularly leads to compromises that result in the addition of wiring to the harness to integrate the part.

Additionally, instead of having a few selected and approved connector families, the wiring team is often forced to incorporate a wide variety of connector types that can lack USCAR certification, be difficult to procure, or be suboptimal for quality and manufacturing. The ideal harness development tool needs to be able to support bottom-up design flows and a multitude of connector types.

Change management

After the initial creation phase, most duties of the wiring engineer are related to implementing changes. The Greek philosopher Heraclitus' said "everything changes and nothing stands still". This is the daily routine for a wiring engineer. Change is a constant in wiring harness design and engineering. In start-ups, this is even more prevalent due to stricter time constraints, ad hoc processes, and "greener" engineers.

New experts join different departments almost on a weekly basis, bringing new insights to the team. These could be a better approach to solving a problem, or new technologies they were exposed to or developed in their previous roles. These new team members are excited to leave their mark and the start-ups are hungry for such input. As a result, these ideas likely will be implemented within a short period of time and with little regard to the overall system impact. This is paired with an environment where there are few processes in place, and where change discipline is still in its infancy. In such an environment, changes are not unified, making it difficult to track the most up-to-date design revision.

By comparison, legacy OEMs have established highly efficient and rigorous change management processes. These processes have been optimized over many years and projects, and have very high organizational buy-in. Not so at a startup. This results in constant change requests regardless of the freeze dates or current project stage.

Furthermore, not all suppliers are sourced from the beginning of the project, contributing to the recurring need for design changes. It can take a long time to source certain parts. To compensate, engineers resort to estimating data to meet the first few harness freeze dates. Once the supplier is sourced, the actual requirements usually do not match the engineer's assumptions, requiring change orders to have a functional part. In some cases, suppliers cannot meet program timing, or decide to terminate their participation. This means the parts have to be resourced. New parts rarely meet the exact electrical specifications of the original part. This leads to even more change requests modifying the harnesses.

It is extremely important to develop a structured and disciplined approach to change management early on in the project. Again, an advanced portfolio of harness development tools can provide an elegant solution. The integrated device transmittal database discussed earlier can be enhanced with certain change control mechanisms. With these enhancements, this database will provide the necessary structure and automatic change management immediately (figure 5).

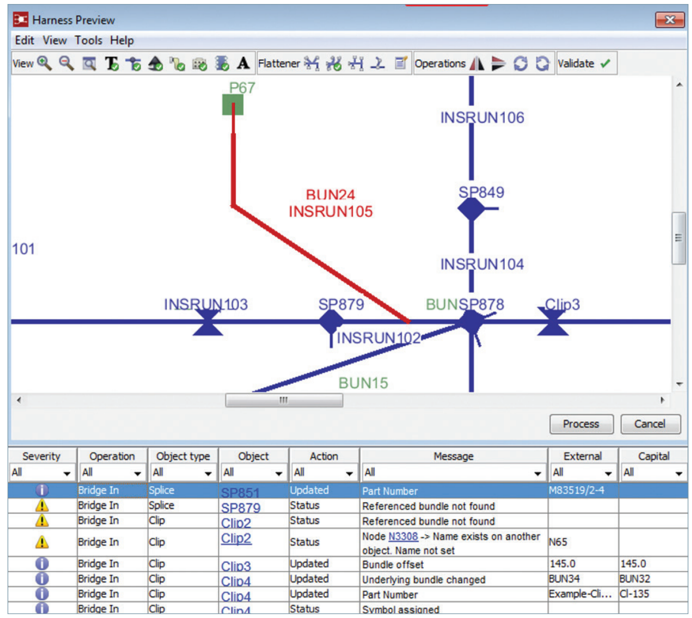

Figure 5: Modern harness design solutions have automated change management solutions.

The release engineer of a device can draft the device transmittal directly in the database and submit it for approval. Upon approval, the change will be updated automatically in the logical schematics. This eliminates the error-prone process of manually updating schematics from Excel files. It also prevents release engineers from making changes to outdated local copies found on their hard drives, and overwriting changes made to the device transmittal since the last update. Lastly, for each released set of logical schematics there will be an automatically generated list of change requests implemented in each release, thus linking each change back to a specific harness revision for future reference.

New challenges call for new solutions

The rapid introduction of new technologies and the influx of automotive start-ups into the market lead to a multitude of challenges for harness development. OEMs and startups alike must consider the number and sophistication of technology features they integrate into their vehicles as they have a direct effect on harness weight, bundle diameter, and cost. Electrification, autonomous drive and driver assistance, artificial intelligence, and connectivity features all place additional burden on the wiring harness. These features require the introduction of dozens of new sensors into a vehicle that all must connect to the wiring harness, sometimes with special wiring.

Startup automotive companies face additional pressures as they race to get products to market. Startups lack the foundation of legacy designs and the resources needed to custom design parts for optimal performance. Without these resources, engineers at these companies must turn to a bottom-up design approach in which off-the-shelf parts are adapted to meet functional requirements. Startups also lack established procedures for managing and tracking change. While established OEMs possess more tenured change management processes, they tend to rely on manual data entry and communication between teams. This leads to inefficient data exchange that is prone to errors.

Modern harness design and engineering tools provide an elegant solution to the problems being wrought by automotive innovation. Using tools such as Capital, with high levels of automation, advanced metrics and analytical capabilities, engineers can perform tradeoff studies to optimize materials, component placement, and routing for minimal harness weight, cost, and bundle diameter. Next, modern design tools can automate data transition between engineering teams and even between manufacturers and suppliers. Finally, innovative harness design software suites feature integrated change management tools that ensure all teams are working with up-to-date data. By adopting these solutions, established automotive OEMs and startups can better tackle the challenges of the new automotive landscape.

Siemens Digital Industries Software

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 314 264 8499

Europe
Stephenson House
Sir William Siemens Square
Frimley, Camberley
Surrey, GU16 8QD
+44 (0) 1276 413200

Asia-Pacific
Unit 901-902, 9/F
Tower B, Manulife Financial Centre
223-231 Wai Yip Street, Kwun Tong
Kowloon, Hong Kong
+852 2230 3333

About Siemens Digital Industries Software

Siemens Digital Industries Software, a business unit of Siemens Digital Industries, is a leading global provider of software solutions to drive the digital transformation of industry, creating new opportunities for manufacturers to realize innovation. With headquarters in Plano, Texas, and over 140,000 customers worldwide, we work with companies of all sizes to transform the way ideas come to life, the way products are realized, and the way products and assets in operation are used and understood. For more information on our products and services, visit siemens.com/plm.

siemens.com/plm

78115-C3 6/19 H