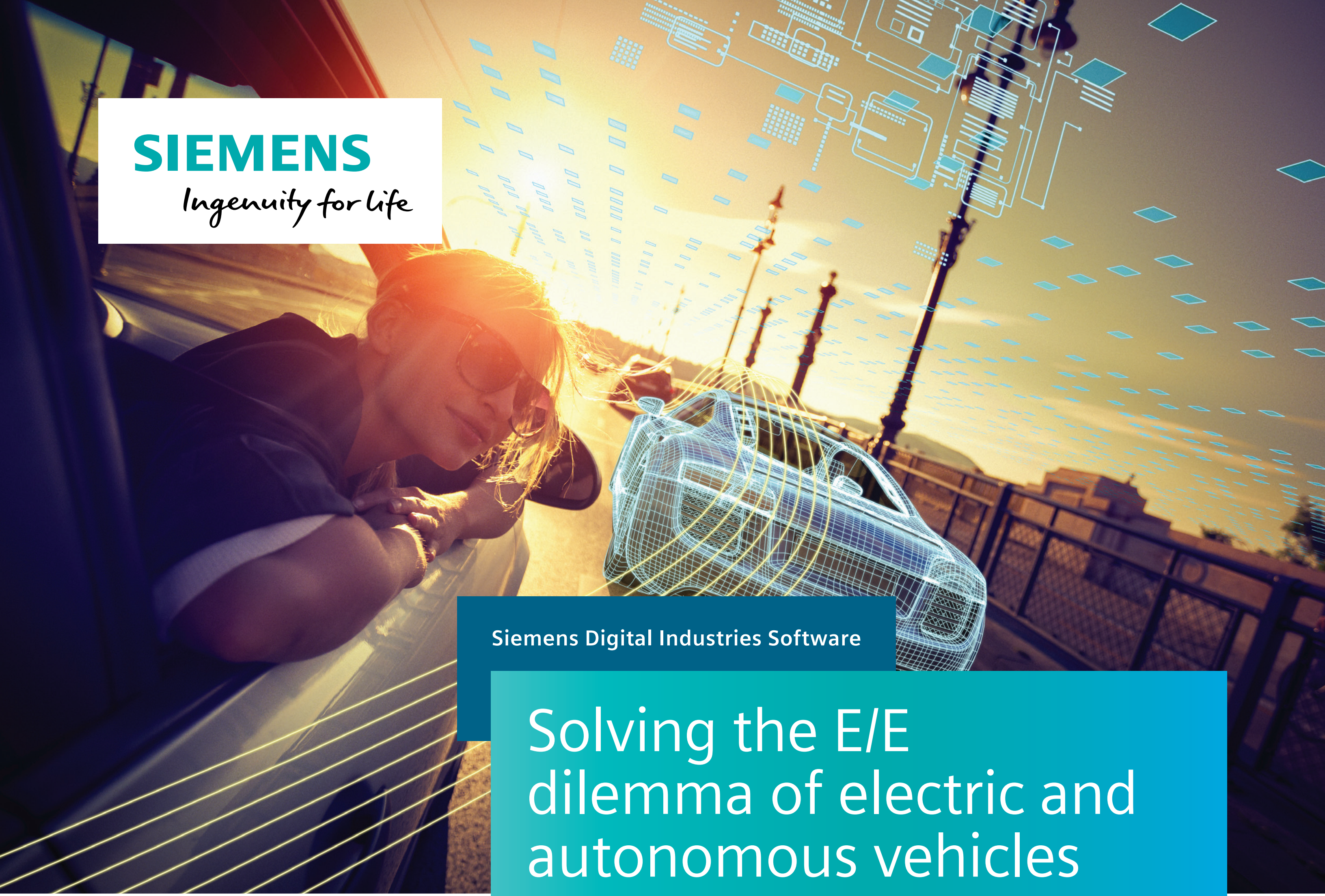

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Solving the E/E dilemma of electric and autonomous vehicles

Executive summary

Controlling change is one of the most important tasks when developing harnesses and having it all integrated into one SW tool would make life much easier for everyone involved.

Dan Scott, Siemens Digital Industries Software

Ulrike Hoff, Automotive wiring consultant

Abstract

Figure 1: The advancement of autonomous, connected, electric, and shared mobility technologies is causing conflicts in vehicle design.

In the automative industry, there are several dilemmas created by the introduction of advanced vehicle technologies to realize the trends of autonomy, connectivity, electrification, and shared mobility (ACES) (figure 1). These trends are not progressing in isolation; they are interconnected, but drive different challenges and aspects of product development.

Autonomy and connectivity are increasing demand for computing power to process incoming sensor data and stream it to cloud resources, other vehicles, and smart infrastructure. Autonomy drives a significant increase in vehicle hardware and the requisite need for electrical interconnections, driving up complexity of predominantly low voltage harnesses, often with new specialty cables.

Shared mobility services rely on many of these same capabilities to analyze demand and allocate vehicles to riders accordingly. All of these on-board systems consume power that an electric vehicle would otherwise use for fuel, motivating a need for advanced power management and batteries with higher capacity and efficiency. While each trend leans heavily on different key technologies, the vehicle electrical and electronic (E/E) system provides the foundation for them all.

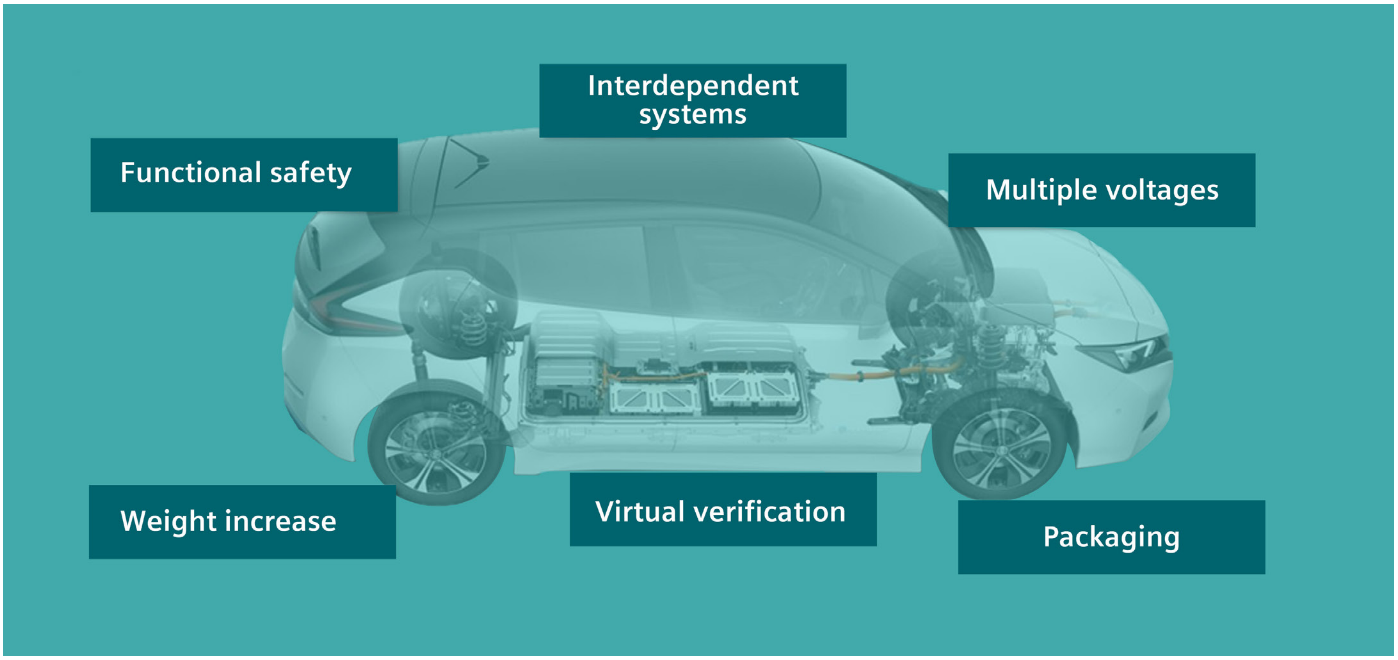


Figure 2: New technologies are creating new challenges.

In this paper, we will focus on the effects of vehicle electrification and automation on E/E systems development. Electrification is driving OEMs and EV startups to develop clean-sheet vehicles and E/E architectures to maximize the profitability of the EVs they sell (McKinsey & Co., 2019).

When we then look at the more detailed design and implementation requirements of the E/E system for an electric vehicle, three key areas need to be considered. First is the integration of the E/E system with the vehicle body and mechanical components. The mechanical and structural design of the vehicle has to be designed alongside the electrical system to take into account physical constraints such as wiring bundle diameters and minimum bend radii. As electrical and mechanical engineers negotiate E/E system packaging, design change control and release management is crucial to maintaining design integrity and data coherency.

Second are the designed-in safety assurances for the E/E system implementation. To enhance the E/E system safety, electrical engineers investigate signal routing and ensure proper separation between signals that may cause interference. Critical systems also require redundancies to prevent failures from becoming catastrophic.

This approach comes with challenges at the architecture and vehicle levels (figure 2)

1. Significant weight increase requires new architecture optimisation.
2. New safety considerations for high-voltage (HV) systems driven by regulations.
3. Multiple voltages for the vehicle powertrain and other on-vehicle devices demands verified separation of electrical wiring and automated checking of the electrical system design.
4. Previously unrelated systems are now highly interdependent, e.g. energy storage, braking, power electronics in EV braking systems.
5. A ‘rush-to-market’ for EVs requires increased design automation and virtual verification.
6. Manufacturers face extreme packaging challenges as they try to fit the largest HV battery in the vehicle as possible.

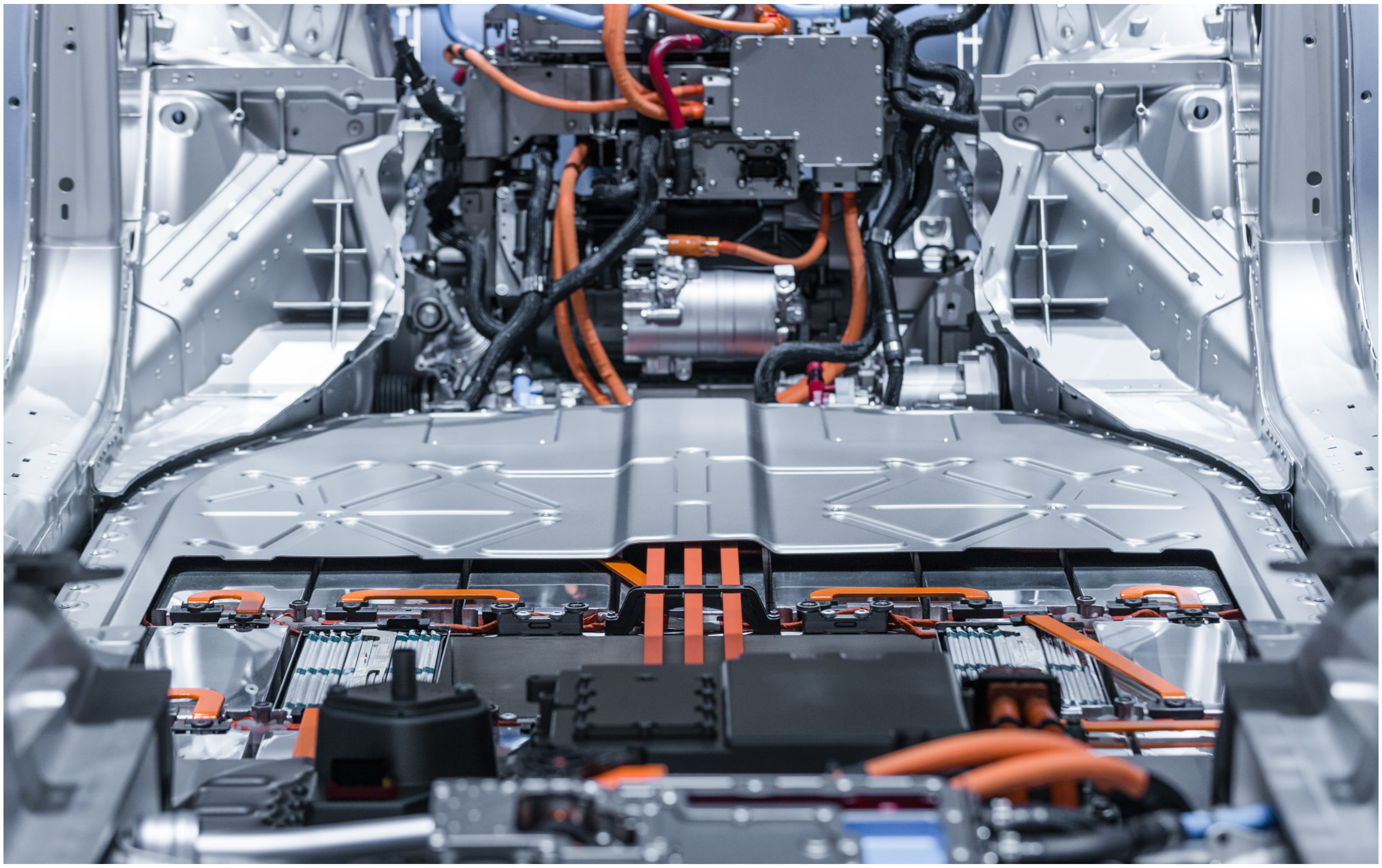


Figure 3: Electric vehicles bring new challenges for engineers developing E/E systems.

In the midst of this work, the electrical engineers must maintain complete traceability from the system implementation and testing back to the design requirements, and provide documented verification that the system meets those requirements. Then, they must create support documentation for diagnosing, maintaining, and repairing the E/E system. In the case of EVs, this means the vehicle will contain high voltages that can present significant safety risks if this documentation is incorrect.

The third key area is the use of simulation to verify the E/E system implementation early and often. Electrical load analysis solutions can help engineers to test the system under various simulated road conditions, such as rapidly alternating battery charging and discharging to simulate stop-and-go traffic.

Thermal and noise, vibration, and harshness (NVH) simulations are useful to verify that wiring bundles and electronic components are properly protected to withstand the rigors of automotive applications. Early simulations ensure correct-by-construction designs and eliminate costly iterations.

The content and complexity of E/E systems is experiencing another step change due to the arrival of autonomous technologies. The inclusion of thirty or more new sensors to enable the autonomous vehicle to 'see', and significant new processing power to interpret all of that new sensed data adds a significant amount of electrical and electronic content to a base vehicle. GM found that a self-driving version of the Cruise had forty percent more hardware than a human-driven counterpart. The added content creates weight, packaging, and complexity management challenges. Furthermore, a level 4 or greater autonomous vehicle will need to consume gigabits of data per second to operate safely. Intel's CEO has estimated that these vehicles will generate forty terabytes of data for every eight hours of driving (Network World, 2016).

How are companies responding to these transitions?

As we work with companies across the world grappling with these challenges from electrification, we see a number of trends in how the most forward-looking are adapting their approach, processes, and tools for vehicle development. Companies on the forefront of this transition share some key characteristics. They have integrated E/E engineering disciplines, accelerated their adoption of automation tools, began virtual verification at the concept stage, and established a cross-domain model-based systems engineering product development approach.

Integrating E/E engineering disciplines early in the design process minimizes late design changes that can delay development, simultaneously incurring cost. These changes commonly surface when integrating systems for the first time in development vehicles. Companies often find that different groups of engineers developing systems in parallel do not always make the same assumptions about system interfaces, data exchange formats, signal scaling, offsets in CAN messages, and more. This is especially common when engineering teams are under-resourced and under significant pressure to deliver hardware for vehicle milestones and to meet challenging start of production (SOP) timescales.

Next, successful companies are automating processes wherever and whenever they can. New entrants into the automotive industry, especially those whose background is in software development, are often the most progressive in this regard. Engineers at these companies possess a cultural expectation to automate everything possible, and thus have experience with implementing such automation in a variety of contexts. Companies used to operating in the safety-driven environment of automotive or aerospace have approached automation with more reservation, but established OEMs are responding to this trend.

Recent design tool advancements have enabled a 'shift-left', bringing verification earlier into the development cycle by accomplishing it virtually. Then, engineers can proceed through the design process knowing that accurate models undergird their actions. With accurate models, engineers can make better design decisions and optimize systems more quickly while still achieving the original design intent. Tight integrations between mechanical and electrical designs at this early stage are vital to ensuring systems perform as expected when they are realized in physical vehicles.

Finally, successful organisations are implementing model-based systems-engineering practices to manage the exploding complexity of the many interdependent systems in their vehicles. Already complex systems, such as braking systems, are experiencing a step change in integration complexity. Digitally tracing requirements and their realization in electrical system designs is the only way to develop systems of this complexity. Braking systems already rely upon electronic controllers, communication networks, mechanical components, and hydraulic systems to achieve their safety critical function. Now, with electric vehicles, designers have to consider several new aspects including battery cell chemistries, battery management system (BMS) current limits, the state and health of the high voltage battery, the characteristics and response times of power electronics, and vehicle-level energy management algorithms. This introduces new teams of engineers, often located in different physical locations, with different development methodologies. To manage this, designs have to be driven and managed from the system-level, not just at the start of programmes, but all the way through the programme. Moving forward, this management will need to continue after SOP, as service-oriented architectures enable over-the-air updates to vehicle functionality.

As companies attempt to install these new innovative processes, they will need a full, integrated flow from system-level design to E/E implementation (figure 4).

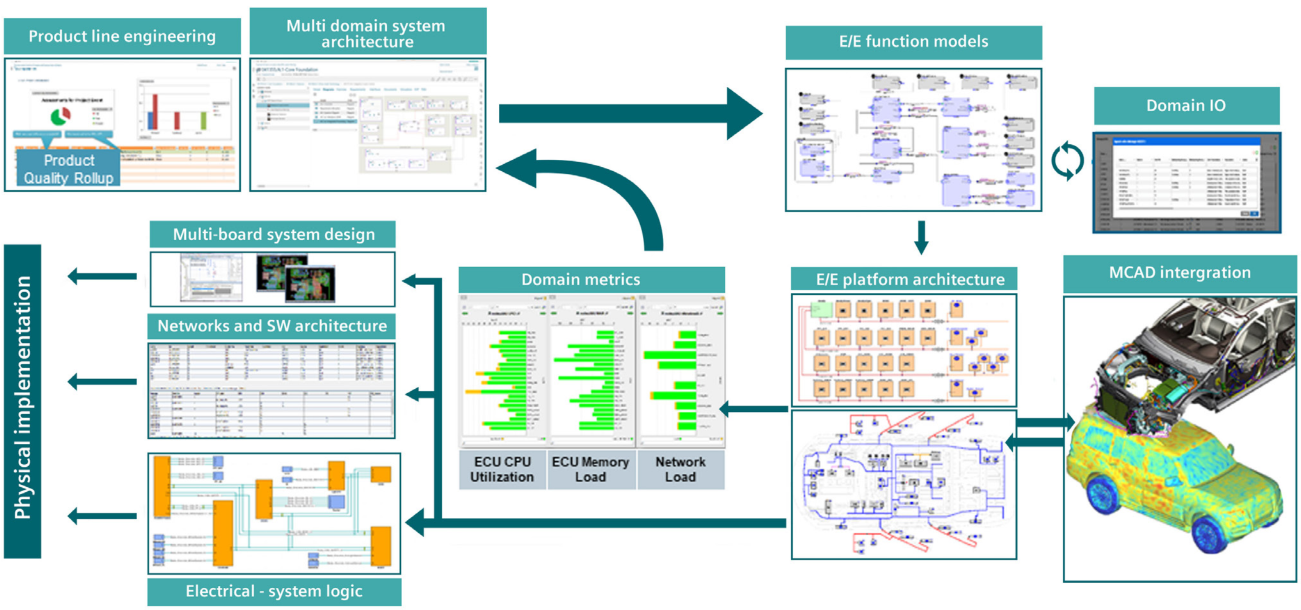


Figure 4: A full flow from system design to E/E implementation.

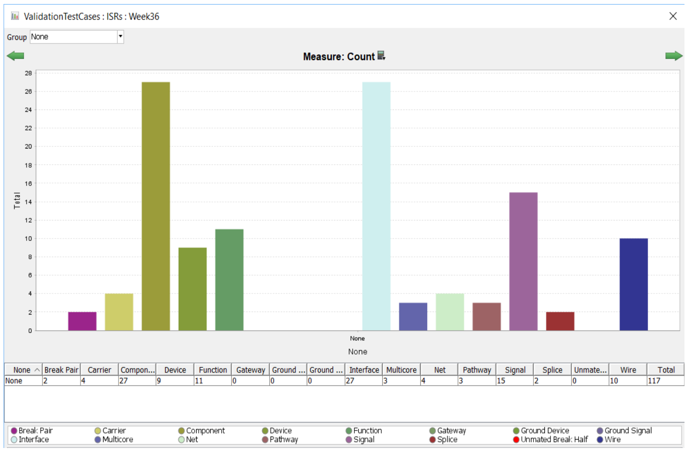
A new approach

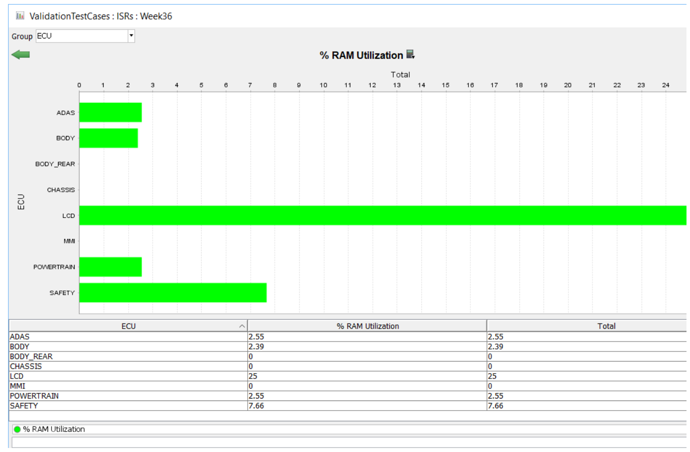
In this approach, E/E engineering is driven from a multi-domain systems architecture that accounts for mechanical, electrical, software, networks, fluids, and other domains. The electrical engineers can import domain specific functional models, which can exchange information on interfaces and I/O with E/E domains to inform the functional design (figure 5). These are then used to drive the E/E platform architectural design, which can be represented as a network view including ECUs and communication busses, or as a platform topology view. This stage is how we address the content dilemma, defined in our recent whitepaper [Automotive trends create new challenges for wiring harness development.](#) 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 electrical systems content, particularly wiring harnesses.

Analysis can then be carried out at the platform level to understand trade-offs and optimise key attributes such as space, cost, network utilisation, and CPU performance. These outcomes from the E/E architectural optimisation can also be fed back to the higher-level multi-domain system model (in a PLM solution) to ensure coherency across the design abstractions. Finally the E/E platform architecture is used to drive the design of multi-board PCB systems, the communication networks and software architecture, as well as the detailed implementation of the electrical system, all leading to a successful physical implementation in a vehicle.

In this flow, data is built upon at each step of the development process, enriching, enhancing and transforming design data from previous stages. This provides digital continuity through the whole vehicle lifecycle from E/E concept definition and trade studies, all the way through to in-service maintenance.

The intent is for organizations to capture as much of their engineering intellectual property as they can to ensure that it is consistently re-used when making minor decisions, freeing the engineer’s cognitive resources for more interesting challenges. Design automation can further free the engineer from manual tasks by leveraging company IP to generate components compliant with company design guidelines.





This also allows the engineer to evaluate many what-if scenarios to improve the design incrementally. Tasks ideal for automation include the allocation of functions to components, assignation of signals to network carriers, automated interface mapping, and the synthesis of logical systems, wiring designs, harnesses and more.

Design automation helps engineers to build correct designs rapidly, empowering teams to evaluate more what-if scenarios and arrive at superior designs. In other words, design automation is a critical enabling approach for achieving correct-by-construction design. Some of today's most advanced electrical systems engineering solutions feature automation features, such as:

1. A styling engine that allows users to modify styles or build custom styleset plugins. The styling engine only changes the appearance of designs but does not affect connectivity, making reviews and complying to customer specifications much easier.

2. Automated assignation of devices to a vehicle platform, with placement based on rules and constraints.

3. Wiring synthesis, which is the generation of wiring for the vehicle platform based on rules and the placement of devices. This greatly speeds up the development cycle because it eliminates manual routing of wires and splices.

4. Wiring diagram generation to automate the creation of wiring diagrams for manufacturing and service organizations.

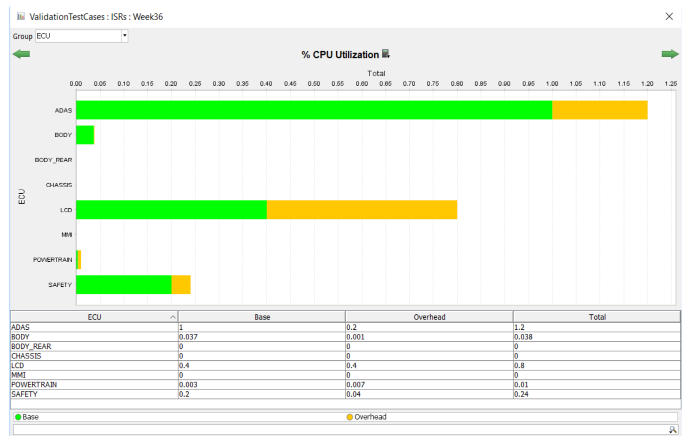


Figure 5: Functional design is informed by real-time metrics that update as engineers evaluate different options.

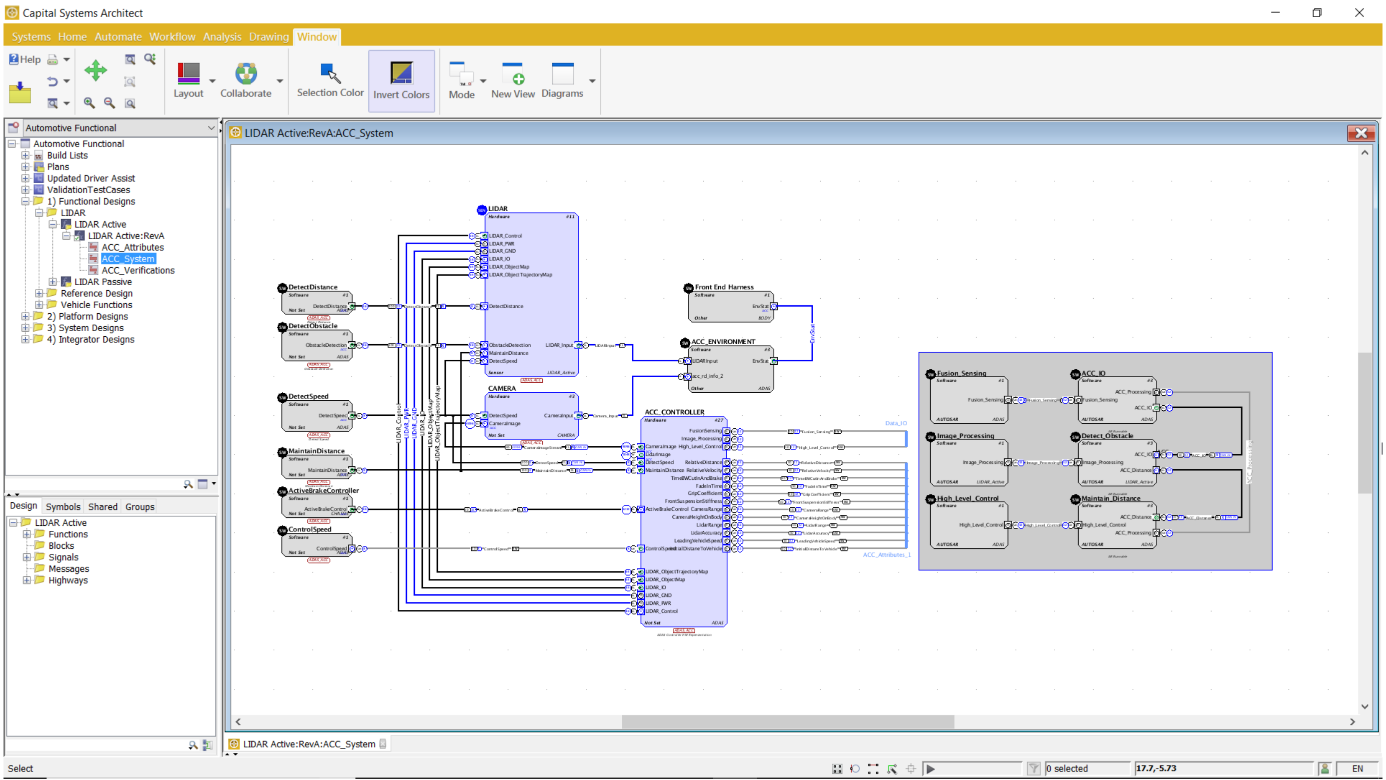


Figure 6: Let's examine a practical example of the additional safety planning required for an electric vehicle, and how an advanced E/E systems development solution, such as Capital, can help engineers manage this process.

The architecture for a vehicle line has to be defined, designed, and optimized at a platform-level in order to realize the many vehicle derivatives that volume OEMs need in order to be profitable. The key principles of reuse, configuration management, and complexity management are all driven from an appropriately designed and optimized E/E architecture. Advanced electrical systems design solutions are able to trade-off functional allocations at the platform-level, while providing system architects with the metrics and insights they need directly within the design tools. Immediate feedback works as a lever to increase the impact of good design decisions at this early stage. This gives confidence as the designs flow to the next stage of detailed design implementation.

Change is constant

Managing change effectively leads to successful programmes.

Product requirements are in near-constant flux, leading to hundreds of design changes at each project milestone. The impact of these changes has to be assessed for all buildable configurations of a product, and the changes applied only to the relevant configurations. Change impact assessment, propagation, and communication present the biggest challenges in product design for automotive companies.

Modern electrical systems engineering solutions can trace design data from the functional and logical abstractions all the way to wiring schematics and the harness design and build. This comprehensive traceability is crucial to maintaining data coherency throughout E/E architecture development. As design changes are identified and implemented, such functionality ensures that data inconsistencies between abstractions are detected, reported, and resolved, and that each of these activities is traceable to prevent duplicated effort. Change requests follow permission, design checks, and release management according to company procedures, and contain hyperlinks to make navigation through design data easy. Finally, a full audit trail of changes made is captured by the design solution to facilitate regulatory compliance and design accuracy.

But is it safe...

Autonomy and electrification are driving new levels of safety and security considerations in vehicles. Electric vehicles contain very high-voltage wiring to transmit power from the battery to the electric motors and other components. These high-voltage cables require special management in design to ensure they are safely integrated with other components. This includes appropriately isolating multiple voltages within the electric vehicle. Electric vehicle batteries also pose additional safety hazards, such as thermal runaway of battery cells, which requires additional safety mechanisms.

When control over vehicles is turned over to automated systems, even greater levels of safety are expected. Automated driving systems must be “fail operational” to prevent passenger or bystander harm in the event of a system failure. Maintaining basic operations during a failure in a self-driving car requires redundancy in the E/E systems and wiring harness, which further increases complexity. Furthermore, the intended functionality of automated driving and emergency systems may cause additional safety hazards. An automated emergency braking system may decelerate a vehicle faster than the capabilities of the human driving the trailing vehicle, increasing the risk of a rear-end accident. These eventualities must be considered during system design.

In this simple example, as we decompose the identified hazard down through the levels of functional safety analysis, we arrive at the hardware safety requirement to implement a high-voltage interlock loop (HVIL). A HVIL provides electrical safety when, for example, high-voltage connectors are removed as part of vehicle fault diagnosis or correction. Using Mentor’s Capital tools, a company can generate a set of design rules and checks that automatically generate the HVIL circuit while optimizing length and routing, and verifying circuit completeness. Additional details on this functionality can be found in this webinar, presented by Josh McBee.

Conclusion

Modern engineering solutions solve electric and autonomous vehicle design dilemma

Automotive technologies are advancing rapidly in the pursuit of fully autonomous, electrified, connected, and shared mobility. The technologies required for each are interrelated, but drive unique multi-domain challenges in vehicle design and engineering. In particular, these technologies demand higher sensor content, greater computing power, and more, acutely affecting the vehicle electrical and electronic systems. As engineers work to meet these demands, they will need to tackle new challenges that include significant weight increase from wiring and other electronic content, new safety considerations regarding high-voltage wiring, and an increase in system interdependence.

As companies strive to develop these advanced vehicle platforms and technologies, common trends have arisen in how forward-looking companies are adapting their design approach and processes. These companies have integrated E/E engineering disciplines, accelerated their adoption of automation tools, began virtual verification at the concept stage, and established a cross-domain model-based systems engineering product development approach.

The road to full autonomy is replete with incremental advances and technology innovations. The adoption of an integrated, automated, virtual, and model-based systems engineering approach will empower companies to launch innovative E/E technologies faster than competitors, while ensuring a high degree of quality and safety. As a result, companies that adopt such practices will be in a strong position to lead the industry into the future of mobility services.

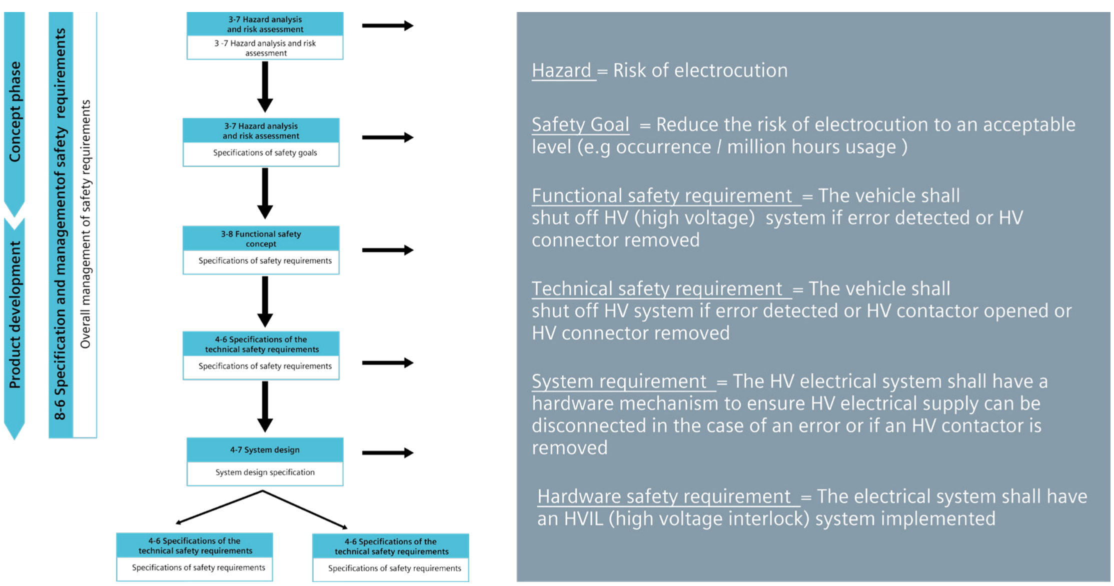


Figure 7: An example illustrating the additional safety planning needed for an EV. Image source: (International Standards Organization, 2018).

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International Standards Organization. (2018). Road Vehicles – Functional Safety (26262). Retrieved from https://www.iso.org/standard/68383.html

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