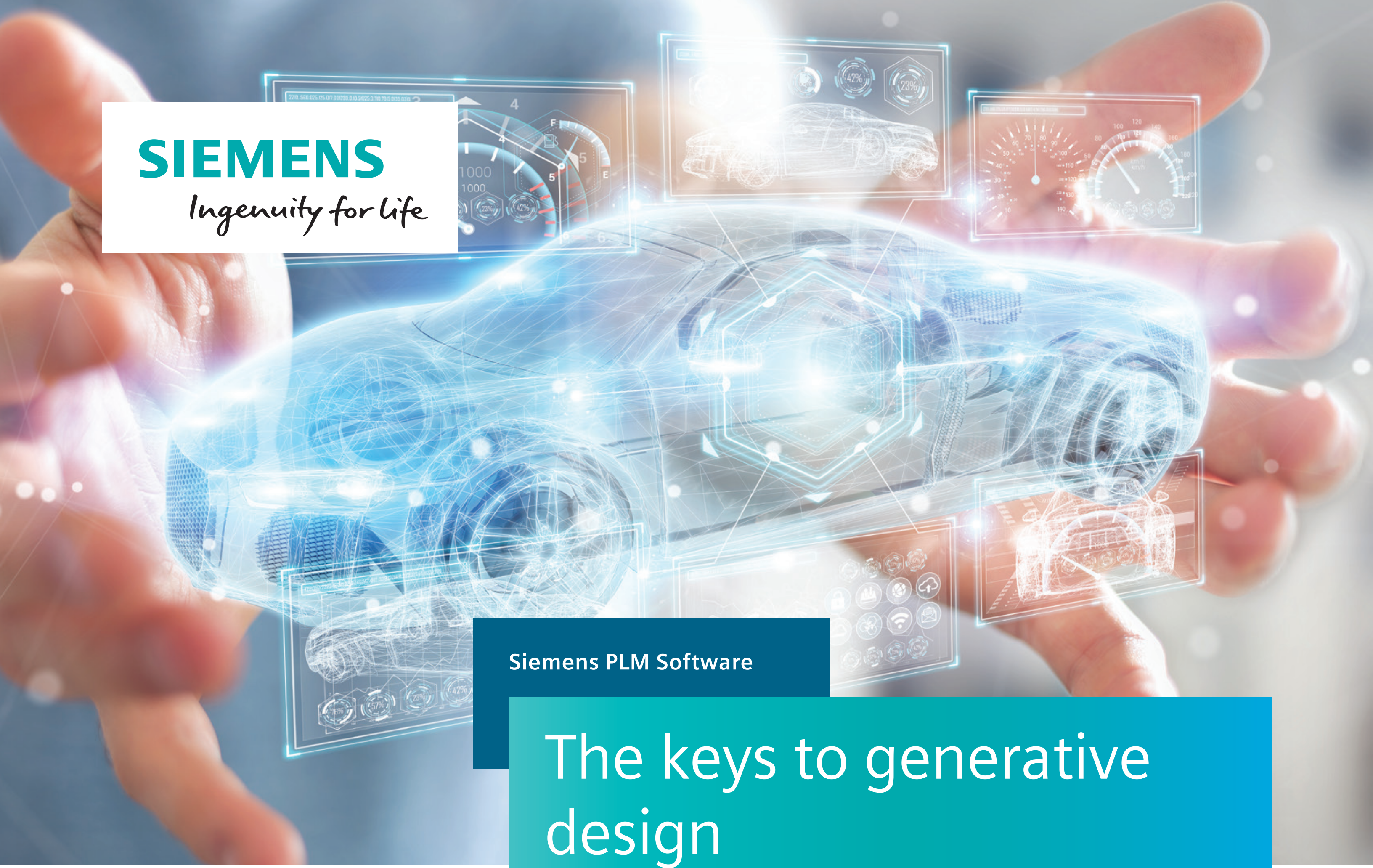

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The keys to generative design

Executive summary

Increasing automotive design complexity demands a shift away from legacy automotive design flows that heavily rely on manual design work, data exchange, and requirements tracking. The industry demands generative design. In part one we examined these challenges and briefly described how a generative design flow is instrumental to the solution. In part two, we will more closely examine the generative design flow to describe the keys to its successful implementation: automation, engineering within a platform context, and cross-domain integration.

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Introduction

Generative design will be a key enabler for new and established automotive companies as they develop nextgeneration internal combustion, electric and autonomous vehicle platforms. The ability to generate electrical system architectures automatically enables early design exploration and optimization while baking company IP into the design flow. Additionally, generative design creates a singular source of data that promotes consistency between domains, design re-use, and enhances the analysis of change impact. Finally, tight integrations between the electrical domains and with mechanical and PLM tools streamlines the entire design flow from conception through production.

Automakers are integrating more electrical and electronic content into their vehicle platforms to enable a wider array of electrically enabled features. Convenience and comfort amenities, such as heated seats and infotainment systems; enhanced safety features, like collision detection and automatic braking; and even safety critical functions such as throttle control and steering systems are implemented through the vehicle's electrical and electronic system. The result is a highly complex system of electronic control units, sensors, actuators and wiring.

This increasing complexity demands a shift away from legacy automotive design flows that heavily rely on manual design work, data exchange and requirements tracking. The industry demands generative design. In part one we examined these challenges and briefly described how a generative design flow is instrumental the solution. In part two we will more closely examine the generative design flow to describe the keys to its successful implementation: automation, engineering within a platform context and cross-domain integration.

Automation

The key aspect of automation in generative electrical system design is to combine simple system connectivity with the physical harness topology in such a way that it can synthesize the thousands of wires and splices that implement the electrical distribution system (figure 1). Such automation helps engineers to manage the immense volume of data created during design, and reduces errors by removing manual data entry and other error-prone tasks. By combining simple system designs consisting of devices and signals, within the physical context of the vehicle, synthesis can produce accurate and optimized wiring automatically.

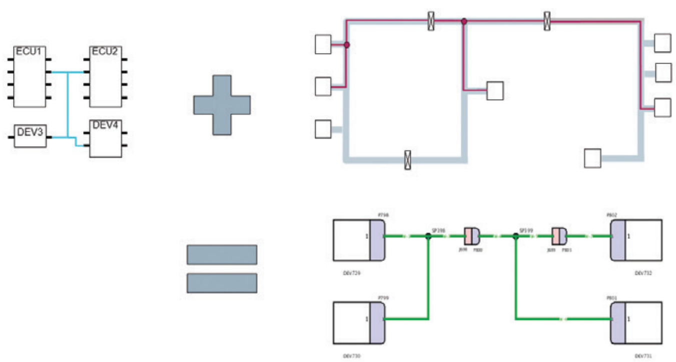

Figure 1: Generative design combines system connectivity definitions with physical harness layouts to synthesize wiring designs.

To support the increasing number of sensors, ECUs, and actuators needed in a modern vehicle, wiring harnesses are growing in size and density as they incorporate more wiring of various types. For example, ADAS and camera systems require sophisticated multicore cabling that imposes additional constraints on routing, electrical interference, and minimum bend radius. The wiring in a vehicle may also employ a variety of shielding materials to protect the wires from heat, chafing, moisture, vibration, and more. Additionally, synthesized network designs, such as CAN networks, must meet the relevant standards that govern their application, such as SAE J1939 and ISO 11898 and its derivatives.

Advanced wiring synthesis solutions support complex wiring types, multiple shielding materials, and various network protocols. With robust design rules, wiring synthesis can generate designs that implement multicore cabling where needed, and use appropriate shielding to protect the wiring in the vehicle. Wiring synthesis will optimize the use of wiring and shielding types to reduce cost while ensuring proper functionality.

Grounding is another area where wiring synthesis can optimize the implementation to reduce cost while adhering to grounding requirements such as signal and power ground separation. Advanced wiring synthesis solutions can distinguish between logical requirements, which result from the connectivity design, and the physical implementation. Furthermore, wiring synthesis can automatically determine the lowest-cost ground point for each device configuration, based on configurable constraints.

The wiring synthesis also ensures that the generated wiring correctly supports every buildable vehicle configuration. Each wiring harness must be able to support a variety of optional features that consumers may choose, and the millions of harness configurations that result from such feature choice. Automation must synthesize wiring for all these buildable vehicle configurations, ensuring as much common wiring between configurations as possible to minimize cost.

Platform context

Generative design enables engineers to assess the system design in the context of the entire vehicle platform. Vehicle system complexity affects all facets of the vehicle design. The vast interrelations between subsystems within the vehicle also means that design work in any system or sub-system does not exist in a vacuum. Designing in the context of the overall vehicle platform promotes accuracy in the design and supports comprehensive validation that can prevent costly recalls. A representation of this total vehicle enables design and validation of wiring data across the partitions between the various vehicle systems.

The platform context also has benefits for understanding the cost impact of architectural decisions across the vehicle. Platform changes can have effects that manifest across the entire vehicle. These effects, in turn, affect the cost of the design as wiring requirements, sensor type, or the number of ECUs required could all change. The cost implications must be captured and measured. With this data, engineering teams can compare and assess design alternatives to arrive at optimal solutions.

Common decisions and factors that affect the cost of the harness include:

- Combining fuse boxes to save space and weight
- Selecting locations where the harness will be manufactured. Cost of labor, regulations and other logistical factors can significantly alter the cost of the harness
- A design review determines the weight must be reduced by ten percent. The available solutions will have varying cost implications
- Changing the location and orientation of an electric vehicle’s battery cells
- Selecting a new material, such as aluminum, for the wiring

Bringing it all together

Automated wiring synthesis, cost analysis, and other capabilities within the platform context can't exist in isolation – they must form part of an overall flow (figure 2).

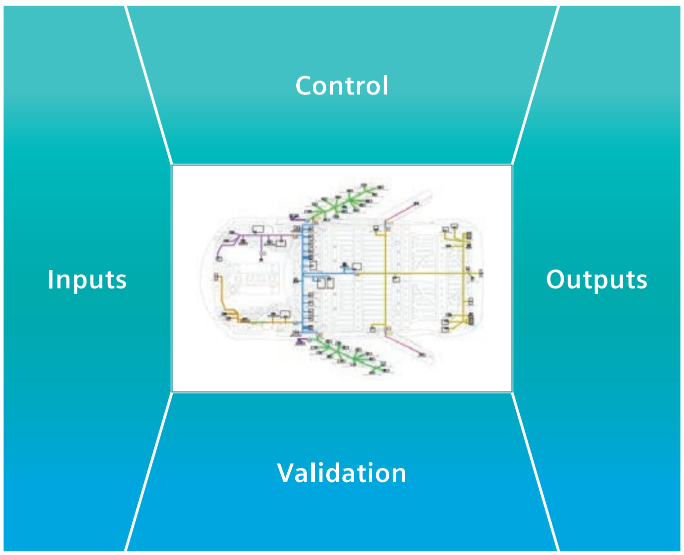

Figure 2: Generative design takes inputs from all areas of the platform and generates outputs under the governance of design and process controls, as well as validation against requirements.

Data inputs are needed to drive the automated synthesis process that generates outputs, such as wiring and architectural designs, to feed into downstream tools and processes. The data comes from design domains that are undergoing change. The automated synthesis must take this data and generate outputs that comply with the design requirements and any relevant standards. At this stage, the team can employ their existing knowledge and expertise to assess and validate the correctness of the design. Then, control can be exerted over the automated process to enhance its accuracy.

Changes come into this process from four primary inputs (figure 3):

- The bundle topology is essential to define the available routing paths through the vehicle. Since this is typically defined in a 3D model, tight integration with a variety of MCAD tools is necessary
- Logical system designs provide the requirements for how signals connect between devices. This connectivity would typically be defined in Capital Logic
- Marketing requirements for the vehicle program are captured as a product plan. This data is used to define the harness complexity required to support the features and functionality of the product
- Finally, device interfaces, the way that each function of a device is made available at a particular connector and cavity, must be captured. Keeping this data separate from the logical systems improves both the re-usability of the designs as well as change management

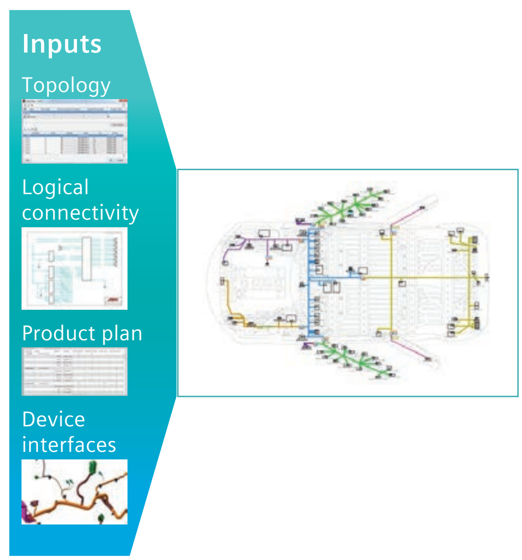

Figure 3: The four primary inputs to a generative design flow include harness topology, logical connectivity, product requirements, and device interfaces.

The process must then generate outputs (figure 4):

- Because wiring designs are not an input to this process, they become an output. The wiring designs are automatically generated from the synthesized wiring
- Tight integration with harness design tools, such as Capital Harness XC, provides an environment for creation of 2D harness drawings as well as onward integration to manufacturing tools
- Engineering teams can then use the synthesized data, including wiring diagrams, to generate accurate service documentation

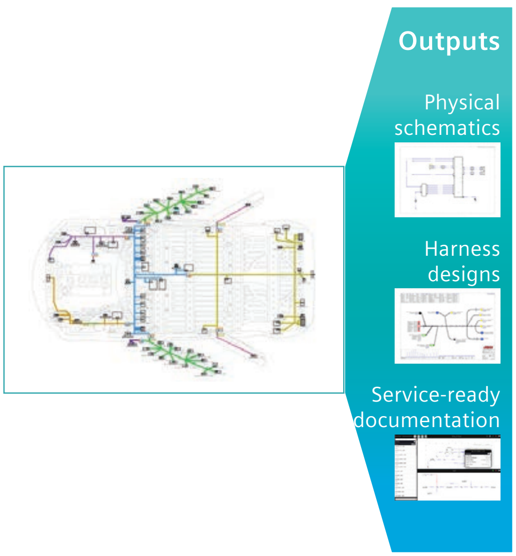

Figure 4: Generative design outputs physical schematics, wiring designs, and service documentation.

The whole process is driven by re-usable and configurable rules. These control every aspect of the automation and ensure compliance with marketing, manufacturing and certification requirements. The engineering teams can also use configurable metrics to measure and assess designs, providing insight into the impact of changes or alternative implementations (figure 5).

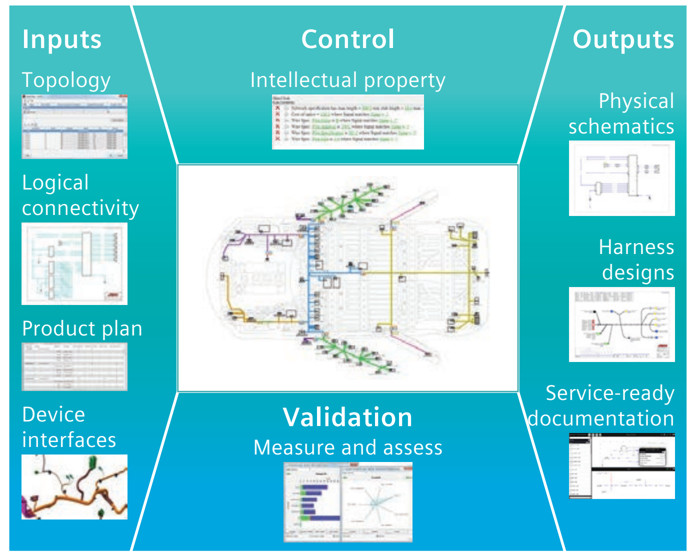

Figure 5: Generative design uses rules-based automation to generate outputs, and can create metrics to assess designs and change impacts.

Re-usable design data

Finally, generative design supports extensive design data re-use. To reduce cycle-time and development costs, engineering teams should re-use as much validated data as possible. Integrating existing designs into the platform context reduces the volume of work by eliminating the need to design new systems or subsystems to serve a given function. Re-use also removes the need to verify the functionality of a new design.

Therefore, once a system design is validated and released, the design must be captured and made re-usable across multiple platforms without the need for platform-driven changes. In addition to designs, it is important that settings, requirements, and other process controls are re-usable and transferrable across design domains and across designs. Highly automated processes need sophisticated controls to ensure repeatable results that meet business standards and needs. These controls can be created by capturing the expertise of engineers into instructions or constraints that force or restrict the behaviour of automated design systems. Sophisticated process controls make sure that the synthesized design data conforms to all relevant manufacturing and certification requirements.

Summary

Change in the automotive industry is only accelerating. Growing automotive complexity, tight budgets, and frequent design change combine to make automotive electrical and electronic systems design incredibly challenging. Engineering teams are tasked with building complete vehicle systems that incorporate a greater number of increasingly sophisticated electronic components, and must do so on budget and under dynamic design constraints. Existing design methodologies can no longer sufficiently cope with the pressures of complexity, cost, and change.

Engineering teams need a new design methodology to cope with the pressures inherent in modern automotive design. Design automation, a holistic platform context, and seamless integration between design tools are essential to empowering engineering teams to design accurate, optimized designs under budget and on schedule. In addition, this new design methodology equips engineers to manage the staggering complexity of modern electrical and electronic systems. With a generative design flow, teams can ensure that the design supports all possible vehicle configurations, integrate new systems without additional workers, manage dozens of multi-domain change orders, and optimize the entire system for functionality and profitability.

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