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What is generative design and why do you need it?

Executive summary

The automotive industry is undergoing an electronic revolution. As design complexity increases, the legacy methods and tools used by OEMs are struggling to meet the demands of this new automotive landscape. Engineers are being asked to produce more sophisticated designs under a perfect storm of complexity, cost, and change management pressures. Generative design empowers automotive design teams to navigate this storm by employing automation, data re-use and synchronization, and framing design in the context of a full vehicle platform.

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Introduction

Automotive executives see innovation as critical to the success of their companies. Today, that innovation is largely the result of electrical, electronic, and embedded software advancements. The increasing implementation of advanced driver assistance systems (ADAS), vehicle connectivity, and active noise cancellation is enabled by advancements in sensor, processor, networking, and other technologies.

In sum, the automotive industry is undergoing an electronic revolution. Embedded computers and sensors now operate a majority of the critical systems in modern road cars, such as the throttle, braking, and steering systems. Electronics also enable an array of cabin amenities like infotainment systems, air conditioning, and heated seats. High-end luxury cars have even more options, some of which require more sophisticated on-board computing.

The result is a massively complex system of electronic control units (ECUs), sensors, actuators, and more that all must interconnect through a wiring harness that runs throughout the car. In some cases, a modern vehicle may contain greater than 100 million lines of software, 90 computers and control modules, and a wiring harness that can weigh 110 pounds (Car and Driver, 2016). Even mid-range vehicles contain hundreds of systems and electronic control units that each support multiple features in the vehicle.

As design complexity increases, the legacy methods and tools used by OEMs are struggling to meet the demands of this new automotive landscape. Engineers are being asked to produce more sophisticated designs under tight budgets, time constraints, and safety and reliability standards.

The perfect storm

In the new automotive design landscape, engineers face pressure from three external sources: increasing design complexity, managing cost, and managing design change between domains that must interact more frequently (Figure 1). The pressures of cost, complexity and change management create a demanding environment in which engineering teams are pushed to design increasingly complicated systems under increasingly demanding time constraints. Any increase in the efficiency of the design process can result in a significant advantage over the competition.

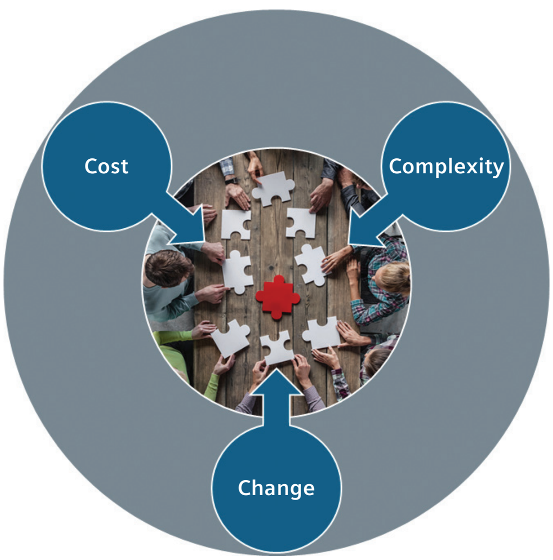

Figure 1: Increasing complexity, cost, and change management create a perfect storm for today's automotive engineers.

Variation complexity

The sophistication of vehicle platforms is growing due to increasing electrical content, but two factors compound this complexity and further elevate the challenge of modern vehicle design. First, any given vehicle model can be equipped with an array of electronic systems and features, meaning millions of different versions of a wiring harness will exist (Figure 2). In fact, just 20 optional features results in more than 1,000,000 unique buildable vehicles. For companies that operate in global markets, this number is even larger as regional differences can affect the features that will be in demand.

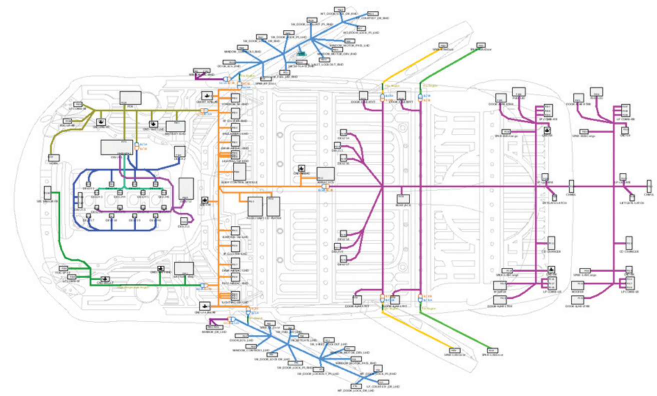

Figure 2: A vehicle platform will have many different harness variants to support the myriad potential combinations of optional features.

Next, automakers must also meet strict safety, efficiency, and reliability guidelines. Functional safety standards, like ISO 26262, require automakers to demonstrate that automotive systems "fail safely", meaning that a failing or malfunctioning E/E system does not create unreasonable risk. They must also demonstrate that safety critical signals are reaching their intended destination, and that the receiving ECUs are generating the correct response.

New vehicle designs begin by defining hundreds of requirements based on the optional features list, safety regulations, efficiency and performance goals, vehicle type, and more. Over the course of the design cycle, it is critical that the engineers are able to track these requirements to ensure the accuracy of final designs and adherence to various safety standards. Some of these requirements will be standard across each harness variant, while others will be unique to certain features. Engineers must be able to demonstrate that they are meeting these design requirements, and managers must be able to track these requirements across a vast web of harness variants.

Cost

Cost is a paramount concern in the intensely competitive automotive industry. Increasing demand for electric and electronic features means that companies must keep larger inventories on hand, parts become obsolete driving re-design efforts, and miss-builds become more likely as automakers handle massive numbers of design variants. Design, marketing, manufacturing, logistics and engineering groups must work in concert to meet market demands for features and performance while managing production cost. Leveraging data from all of these domains is critical to constraining these costs.

One solution is to minimize the amount of new design work required during new vehicle development by re-using systems and implementations from other vehicles. Many automotive OEMs target 80% or more of a new vehicle design to be re-used from previous vehicles. By doing so, automotive manufacturers can greatly reduce the time and cost needed for engineering and verifying new vehicle designs.

Material and labor prices are other substantial contributors to the cost of a complete wiring harness. Choosing different metals and shielding for the wires can generate significant cost savings. Similarly, new low-cost labor centers may be identified to manufacture the harness. These decisions, however, may also increase the logistical challenge of assembling the harness if the new materials and manufacturing locations are less accessible.

Finally, among recalled vehicles, electrical system faults account for the third highest number of affected vehicles (Figure 3). A problem discovered after the car is on the market is up to fifty-times more expensive to fix than one that is identified in development. Large-scale recalls are even more expensive because they cause damage to the manufacturer's brand in addition to the financial cost of recalling cars.

Impact of design change

Engineers must consider the impact of multiple domains on the wiring systems. Changes in the requirements for the vehicle platform and systems are the most obvious as they can require all new connectivity schemes. Component selection will have implications on the wiring due to variable power or bandwidth requirements. Mechanical considerations can also have a substantial impact on the overall harness architecture. Thermal analysis of one of the boards in the vehicle may force a redesign of the board with a new pin out. This may alter the interface of the board with the rest of the system. Or, a new fascia design may require the relocation of an ECU out of the harness.

Each change affects the rest of the system, and the unforeseen effects can be very difficult to predict. Migrating an ECU to a new location or network in the architecture may affect performance elsewhere in the system. This change in behavior may cascade, causing any number of sub-systems or functions to fail. Such a change can even completely invalidate the technical implementation of the architecture, driving the redesign of multiple systems.

Recalls – Total number of potentially affected vehicles (model years 1990+)

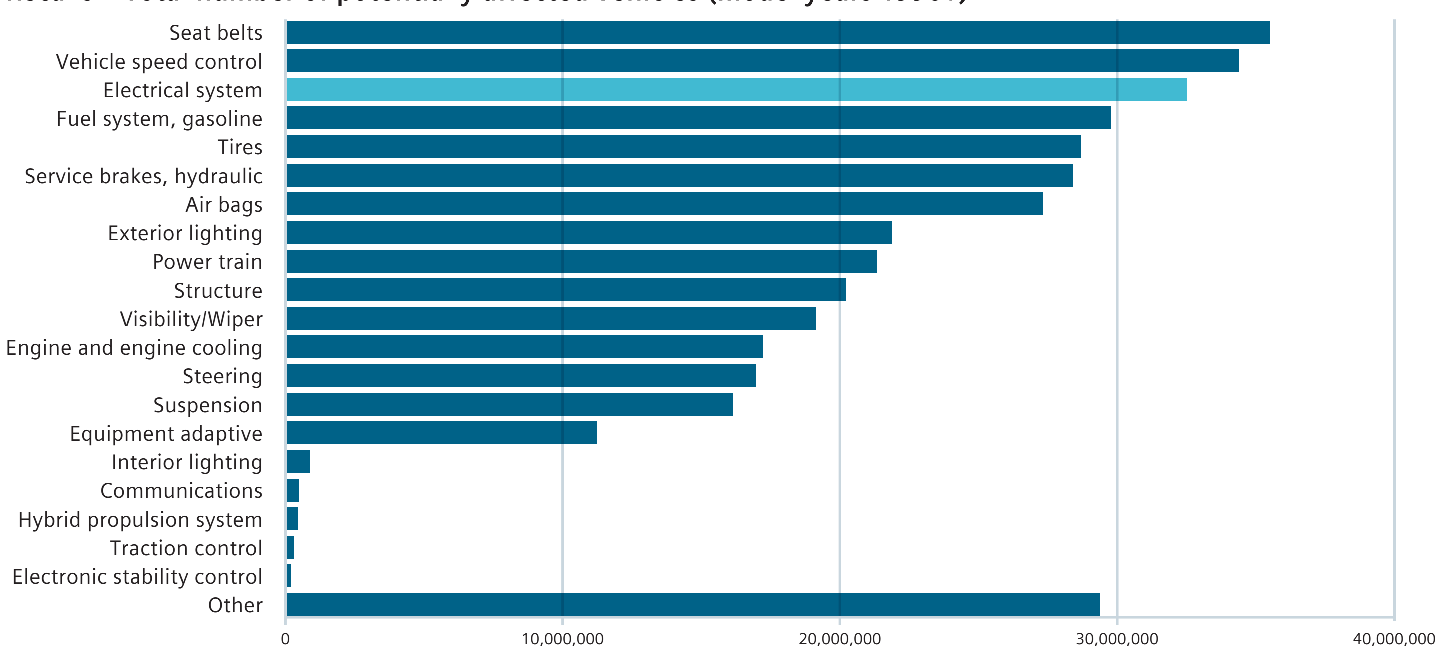

Figure 3: Electrical systems faults account for the third highest number of recalled vehicles (NHTSA & Edmonds Inc., 2013).

Navigating the storm

If a design process could address all three of these issues, what kind of capabilities would it need? This design flow would need to help engineers manage increasingly complicated electrical and electronic systems, costs that result from this complexity, and more numerous design changes that have wide-ranging effects. Generative design fulfills each of these requirements.

Generative design uses automation to generate architectural proposals for the logic, software, hardware, and networks of the electrical and electronic systems (Figure 4). This enables engineers to iterate on these proposals, optimizing for performance, reliability, and weight. Through generative design, teams can address the rising challenges of complexity, cost, and change management.

Firstly, employing automation throughout the process will help design teams manage complexity without increasing time-to-market. Automation empowers engineers to focus on the most critical aspects of the design and verification of the E/E system by reducing the reliance on manual design work. Automation also reduces the need for design changes by quickly generating proposals that engineers can evaluate and iterate on to reach optimal designs.

Next, generative design enables teams to create the electrical and electronic systems in the context of the full vehicle platform. Designing in the full platform context aids in understanding the way signals are implemented across the entire vehicle platform, thereby reducing errors at interfaces or due to the intricacy of the harness. As a result, engineers are better able to handle the increasing complexity of today's cars. Additionally, the effects of design changes can be understood across the entire vehicle platform.

Generative design – Workflow

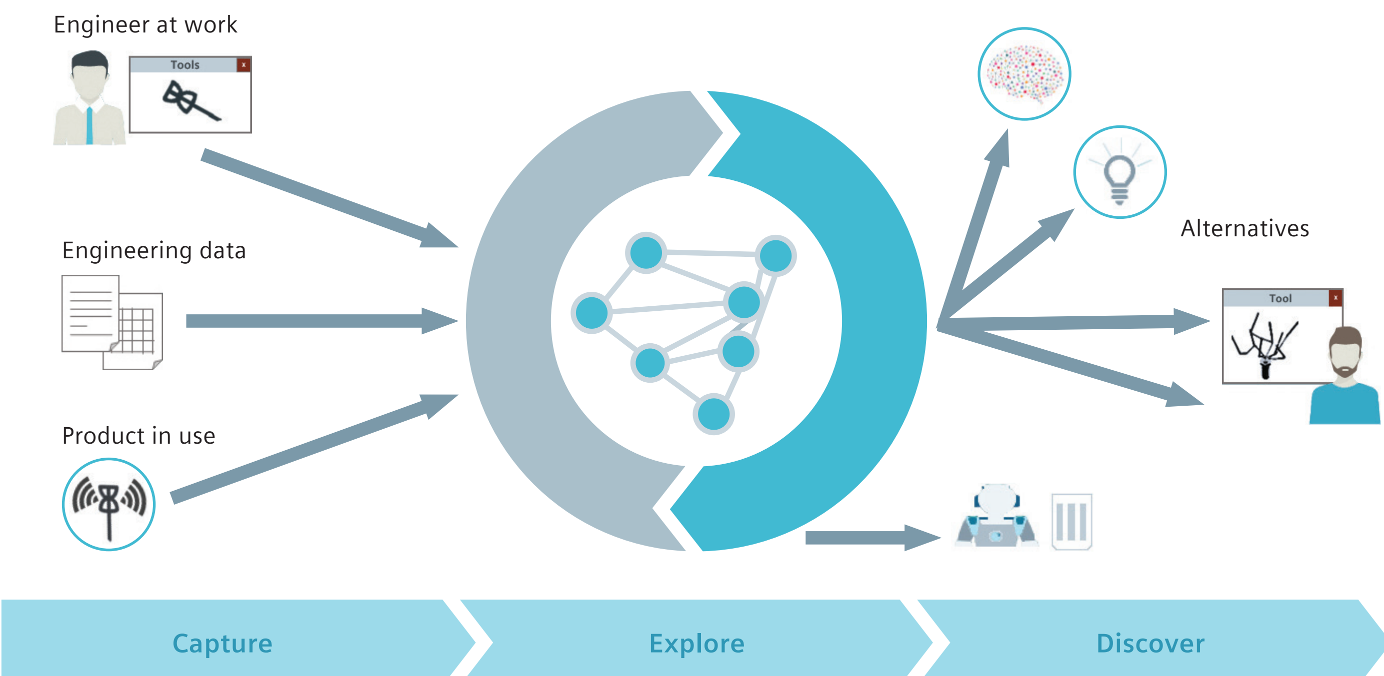

Figure 4: Generative design uses rules-based automation to generate proposals for the logic, software, hardware, and networks of the E/E system.

Teams must also be able to re-use validated data across vehicle platforms to improve quality and reduce development costs. Design re-use accelerates development cycles by leveraging known-good design data in a new vehicle platform. This prevents the design teams from spending time and resources manually re-designing vehicle systems that may already exist. Generative design enables engineers to apply existing data to new platforms effortlessly to maximize the benefits of re-use.

Finally, a generative flow enables the electrical engineers to share data with engineers and tools in other domains, such as mechanical or ECU design. The interactions between the electrical, mechanical, and software components of a vehicle are increasing. Seamless synchronization of data between these domains improves the integration of them into a single system, reduces errors associated with design changes, and reduces cost.

Generative design can enable automotive design teams to overcome the pressures of complexity, cost, and change management. Implementing such a flow, however, requires a tool set that supports advanced design automation, a holistic view of the project in a platform context, and seamless integration between design domains and upstream and downstream tools. Part two will explore how generative design can be achieved in electrical and electronic design, delivering engineers tooling to deal with complexity, cost and change management.

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