

How to Save \$20 per Car by Optimization of the E/E System?

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ABSTRACT

Today, the electrical and electronic system in vehicles is one of the core systems - with big influence on functionality and quality. And it is - besides the engine - the most expensive part of the vehicle. The ongoing pressure on saving cost (and weight) is also a major challenge to the developers of the E/E system. Every cent saved on a car creates substantial savings, since most systems are applied to platforms with several million cars per year.

A cost saving target of \$20 per car (without negative influence on the functionality and quality) sounds impossible for most insiders.

This presentation identifies some areas where the potential for savings is not (fully) exhausted. For each area there are examples out of the global automotive industry where substantial savings with \$10 or more have been achieved.

Furthermore, the presentation will propose approaches for “Value engineering” and “Redesign2Cost”. It will also look at the requirements for the tools to support such an approach together with aspects such as required data or engineering skills.

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INTRODUCTION

The dramatically increased complexity of E/E systems in the automotive industry is well known. One aspect is the sheer quantity physical E/E components involved, like the number of ECUs or the number of wires. And different from the virtual design artifacts such as signals on a bus or software complexity, these physical components have a direct influence on the cost and weight of a vehicle. With such substantial increases over the recent decades, the E/E system is now to the most expensive “system” in a vehicle. So now, “cost savings” is a must in the industry - both for OEMs and the suppliers.

AREAS FOR COST SAVINGS

The E/E system is separated often into two segments where physical implementations influence the cost structure:

- ECUs and fuse/relay boxes
- Wiring system

Often these two areas are investigated separately for cost savings potential because of organizational reasons. But in our considerations we want to stay on the system level, as experience shows that some optimization can only be achieved in the balance of both areas.

The next segment describes areas that typically show substantial savings potential:

E/E-Architecture and Functional Packaging

The approach of E/E-Architecture (EEA) starts with the functional design and the allocation of the functions to real ECUs. This allows the perfect use of ECU infrastructure such as microcontroller computing power, memory capabilities or available ports. And this also enables a topological packaging, for example, packaging a high-side driver into an ECU close to the actuator using the shortest wire length. But using this method of topology-optimized packaging has one prerequisite that is often not specified in today's automotive industry: supplier-provided package constraints are no longer accepted.

Today we most often encounter the situation where supplier “A” is responsible for a specific functional domain, for example, keyless entry, and supplier “B” is responsible for another domain such as normal comfort functions. What we commonly see is that these two suppliers end up producing two physical ECUs, one for each functional responsibility. This means that all the hardware and software building blocks needed for the one functional domain is concentrated in the ECU developed and produced by supplier “A” and in parallel the same happens for supplier “B”. As a result today's cars can have 50-80 ECU-boxes!

Of course there are solid reasons that support the need for such a high number of ECUs, including technical challenges related to integrating the functions with the related software of different suppliers in a

single ECU. Although AUTOSAR does provide a basic solution for that, there are still unresolved commercial and legal aspects like the question of who takes responsibility for a multi-vendor ECU.

Though there are some practical evaluations that identify a potential \$10 savings in the area described above, we'll not take this into consideration here, as this potential is not accessible in many current use cases.

Physical Architecture and Topological Optimization

Besides the dimension of packaging the functions into ECUs there is another dimension in the architecture work: the optimized allocation of components to locations within the vehicle. The components to be packaged include ECU's of course, but also fuse-and-relay-boxes as well as subcomponents in the wiring system like eyelets or splices.

Project experience has shown however that the achievable cost-saving effects are limited here, as the location influences the cost by only a few cents. Bigger savings result if there is an opportunity to move a component from a wet environment to a dry one - as this provides savings on the sealing costs. Another interesting area for optimization is the partitioning of the wiring system into different harnesses. Clever approaches that take into account influence on the logistics and harness production can create real savings in the range of \$1-3.00 in this area.

All things considered, the potential of topological optimization is often overestimated. There are many constraints that limit freedom of design - fixed positions of sensors and actuators for the ECUs it is already make it difficult to find space. This optimization phase can yield a total saving of \$3-5. And while the savings potential may seem relatively small, it is a valuable achievement for a platform with 1 million cars per year or more!

Optimization of Conducting Medium

Now we'll move on to discuss the wires and cables of the wiring system; they transport signals and realize the distribution of power. With the increasing electrification of vehicles, we have to take into consideration the requirement to transport an increased power load throughout the vehicle.

As a result the perfect dimensioning of wires is a key area for savings. For signal wires there is almost no current to be transported, so their wire gauge can be reduced to a minimum while still maintaining the mechanical constraints. Many wires with reduced CSA (up to AWG 24) are available to replace more commonly used, thicker wires. But this design process needs a cross-domain approach - the designer needs knowledge of the routing of the wires in the harness bundles and about other geometrical constraints in order to determine if a smaller gauge is an appropriate choice. If the designer doesn't consider this information and just optimizes the CSA based on the schematic, the result could be poor quality effects such as broken wires.

For the power wires there are several ways of optimization. One is the use of different conductor materials like aluminum cores. This can create substantial cost and weight savings especially for high-current wires like battery leads. But note that it is more than replacing a copper wire with an aluminum wire on the schematic diagram; the designer must apply a system approach to make sure an aluminum wire can be used by checking geometrical aspects like bend radius or permitted bundle diameters.

Besides swapping conductor materials there is also the field of CSA dimensioning that is not fully optimized today. Theoretically, there are many tool approaches on the market with simulation functionalities etc. But in the real practice most wires are dimensioned using a much less sophisticated approach. Most often there is a rough estimation and comparison with previous similar use cases- and if there is any doubt about wire gauge, then it's generally deemed a better choice to take the thicker wire to be on the safe side.

To be clear: real optimization of wires means selecting the thinnest possible wire without introducing quality or safety risks. And such optimization is a complex process in practice.

Contributing to the complexity, are the influences of varying current consumption of actuators in different use cases like a power window motor in summer or winter. We have the combination of several consumers, controlled by software functions, and of course we have the combination of fuse and wire size with new approaches like electronic fusing strategies instead of conventional melt fuses.

Without going too deeply into the details, we know real project experiences that intensive and comprehensive optimization of the conductor medium for all 1250 wires in a mid-class vehicle resulted in the reduction of more than 6 pounds of copper. This is already a savings of more than the "promised" \$20!

Later we will show more about the prerequisites to be applied to realize such considerable savings.

Variant Optimization

Variants are a major headache for every of E/E designer. Here we want to concentrate just on the wiring part of the E/E system, as variants have a tremendous influence in the industrialization of the wiring systems. The situation is extreme if the OEM offers 100+ end user selections like many of the European OEMs. But even without those extremes we have the challenge of handling variants. Most American OEMs apply the solution of composite harnesses, which means using a set of predefined harness variants to cover the end user configurations. So for an end user car with its specific options, one of several (50) predefined harnesses is used; typically one with the minimum give-away content (unused connectors and wires).

It is already complicated enough to ensure that the set of predefined harness variants can cover all possible end user configurations, and because of that, there is only limited attention given to optimizing the harness variants. OEMs have to decide how many harness variants (part numbers) make sense and then optimize them. In the end, for minimization the give-aways to give optimal cost and weight results