MATLAB/Simulink for Automotive Systems Design

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1. Automotive industry design challenges

Automotive systems are becoming increasingly difficult and expensive to design successfully as the market demands increasing complexity. Body electronics are particularly affected by this trend, a good example being power windows design. This seemingly mundane area involves meeting market and legislative requirements, which means creating a control system that combines the input from several sensors and follows complex behavioral rules [1].

Traditional design methodologies involve writing a text specification and implementing algorithms in C. However, algorithms cannot be verified without hardware. This approach leaves the engineer in the unenviable position of waiting for the last piece of hardware to arrive to enable them to test their system.

To avoid these problems, engineers need to decouple algorithm development and verification from the availability of hardware. To address this need, OEMs and suppliers around the world are switching to Model-Based Design.

2. Model-Based Design with MATLAB & Simulink

Model-Based Design is a design process based on a system model [2]. There are four concepts that make up the process: (1) Executable Specification with Models (2) Design with Simulation (3) Implementation with Code Generation (4) Continuous Test & Verification. At the initial stage, the design specifications are developed by and communicated from the customer to the supplier via a simulatable or executable model (which includes a high level model, inputs or test cases and expected outputs or acceptance criteria). Using an executable specification provides an unambiguous means to establish the customer requirements and allows for more precise communication between engineers with different engineering backgrounds and different nationalities.

Next, the executable specification serves as the basis for the design phase. Development engineers will design via simulation and elaborate the model until the algorithm and system are ready for implementation. During the design phase, engineers can use the simulation model to explore alternatives, looking for a design that meets the customer requirements for performance, cost, and quality. Engineers can verify that the design meets the requirements, since the modeling environment can be used to capture both the algorithm as well as plant behavior – this process is often referred to as "test as you go." This verification can be applied to hundreds of buildable vehicle combinations without the aid of a single prototype, something that is impossible in a non-executable design environment.

The implementation stage uses the design model to generate code. The design model itself is used as a 'golden reference' to verify the code implementation. Firstly the code is substituted for the model in the simulation (software in the loop, or SIL). The results can then be compared and if no errors are found, the code can be considered verified. Next the code is targeted to either a surrogate processor or the end processor to verify the hardware implementation of the design – this is referred to as either Rapid Prototyping or On Target Rapid Prototyping.

The value of the new process to the automotive industry comes at two points in the design process. Firstly, in the traditional process, design errors are not uncovered until the hardware is available, which means late and costly design changes have to be implemented. Secondly, once the design has been verified, the code can be quickly and efficiently generated via automatic code generation. Note the ease of code generation, leads to more upfront testing (via SIL and Rapid Prototyping), which in turn leads to better initial quality and lower costs as late changes are avoided.

3. Example of Model-Based Design

A number of automotive companies have successfully used this design approach, including Caterpillar, General Motors, Toyota, Continental Teves, Jaguar and others. At Caterpillar [3], as in most automotive companies, the level of system complexity was out pacing the ability of mechanical control systems, resulting in increased demand for control software. Caterpillar recognized that it needed to provide a mechanism to allow its controls groups that traditionally focused on mechanical systems design a means to develop innovative algorithms in software. Traditionally, when Caterpillar developed software, they incurred high non-recurring engineering

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(NRE) costs and slow turnaround time for software iterations. Caterpillar was also concerned about the potential for increased warranty costs with their increasing use of electronics. To meet their needs, Caterpillar implemented a Model-Based Design process in their Electronic & Electrical Systems (E&ES) team that focused on:

- System specifications and algorithm development using Simulink models.
- Rapid Prototyping for quick turnaround in machine and engine development organizations
- Code generation from the Simulink models

As a result of their adoption of Model-Based Design, Caterpillar was able to reduce the man hours to develop and implement a standard project by a factor of 2-4. Caterpillar also found that the total project time was reduced by a factor of 2. Simply put, with half the staff, Caterpillar was able to complete their projects twice as quickly.

References

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