SYNOPSYS®

Saber-MATLAB Integrations: Enabling Virtual HW/SW Co-Verification

Lee Johnson—Synopsys

June 2004

Introduction

The amount and complexity of embedded content in automotive systems is continually increasing. Driven by pressures to increase content and reduce costs, automotive OEMs and suppliers are relying more on embedded systems for control, configuration, and calibration of advanced technologies such as X-by-wire systems, in-vehicle networking, and electric hybrid systems. Accordingly, more effort is dedicated to development of embedded systems and verification with the controlled mechatronic hardware.

Several tools are available today that streamline the embedded software development process. In particular, model-based design techniques are becoming increasingly common, allowing designers to create and maintain an executable specification of embedded software that can be used for control algorithm development through automatic code generation targeted to a specific microcontroller.

Despite the advances in software design tools, embedded software verification is typically not emphasized until late in the design cycle. In many cases, designers must wait for a physical prototype of the mechatronic system to become available before concentrating their efforts on software validation. Hardware-in-the-loop (HIL) simulation eliminates the need for a physical prototype of the mechatronic system during software verification; however, HIL platforms are expensive and cannot be implemented until microcontroller hardware and target code is available. Because they are performed relatively late in the design process, prototyping and HIL testing techniques focus primarily on verifying execution performance of the software and little on the behavior and robustness of the underlying control strategies. This paper provides an overview of three links between Saber® and MATLAB®/Simulink® that enable early validation of embedded control algorithms with simulated mechatronic hardware—a virtual HW/SW co-verification platform.

HW/SW Co-Verification

The automotive industry is placing increased importance on full system verification throughout the entire embedded system design process. Accordingly, a complete solution for validating hardware and software performance in a simulated environment is required, i.e. a virtual HW/SW co-verification platform (see Figure 1). HW/SW co-verification is initiated early in the design process, where control strategies are verified and optimized in conjunction with simulated models of the mechatronic systems being controlled. Later on, as control algorithms are implemented as code, the focus shifts towards verifying the execution performance of the operating system, peripheral drivers, and control applications, where it is critical to take cycle-accurate behavior into account.

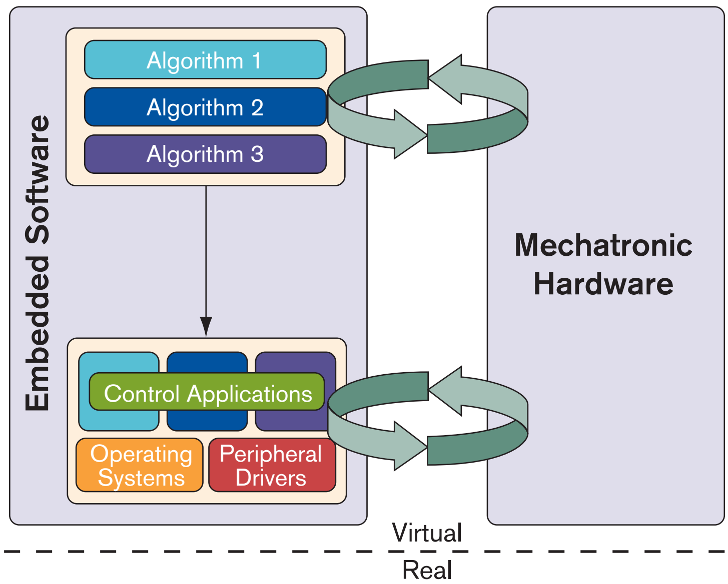

Figure 1. Virtual HW/SW Co-Verification Platform

The benefits of HW/SW co-verification can be realized by not only the embedded software designer, but the mechatronic systems integrator as well. With early access to the software implementation, the systems integrator can begin full system validation and avoid waiting until a prototype is available before problems are discovered.

Striving for a complete virtual environment for HW/SW co-verification of embedded systems, Synopsys has developed a set of integrations between Saber and MATLAB/Simulink from The MathWorks. Saber, a production-proven tool recognized throughout the automotive industry for multi-technology simulation analysis, provides the capability to accurately model virtual mechatronic systems, including electrical, mechanical, hydraulic, pneumatic, and magnetic behaviors. Likewise, MATLAB and Simulink are widely used throughout the automotive industry for model-based development of embedded software. By linking the complimentary solutions offered by Saber and MATLAB/Simulink, embedded systems designers and mechatronic systems integrators have the capability to perform earlier co-verification of complex embedded systems.

The Saber-MATLAB integrations include Saber-Simulink co-simulation, Simulink-to-Saber Model Import, and SaberLink Post-Simulation Data Exchange.

Saber-Simulink Co-simulation

The Saber-Simulink co-simulation interface allows the embedded software designer to concurrently simulate control algorithms modeled in Simulink with a mechatronic system modeled in Saber. In the context of HW/SW co-verification, this interactive co-simulation link provides the ability to verify algorithm robustness and calibrate controller parameters, all with an entirely virtual representation of the complete embedded system.

Saber-Simulink co-simulation is enabled through a synchronous interface that exchanges data between simulators at a fixed interval, effectively modeling the discrete-time communication between a real microcontroller and sensors in the physical mechatronic system (see Figure 2). In other terms, the co-simulation interface performs a behavioral analog-digital conversion between the controller and the mechatronic system.

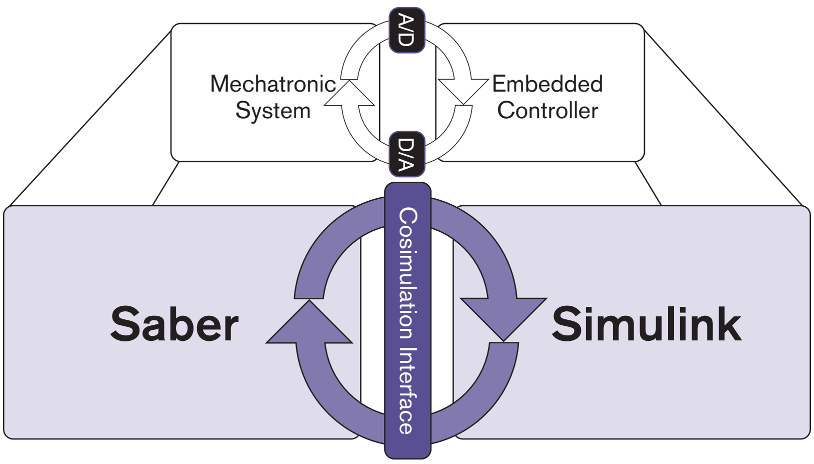

Figure 2. Saber-Simulink Co-simulation

Saber-Simulink co-simulation is initialized and controlled entirely through the Saber user interface. At the same time, the Simulink interface remains active and accessible to the user, allowing immediate alterations to model parameters or topology. Because Saber acts as the master, the designer can take advantage of Saber's advanced analysis capabilities, including iterated and statistical analyses (e.g. Vary and Monte Carlo).

Full HW/SW System Simulation with Simulink-to-Saber Model Import

While co-simulation offers interactive access to both Saber and Simulink for the purpose of verifying and debugging control algorithms, it is not the optimal arrangement for the system integrator constructing a virtual mechatronic system in Saber. Instead, it is convenient to provide a model of the embedded software algorithms that can run solely in the Saber environment and not depend on an active connection with Simulink. The Simulink-to-Saber Model Import Utility offers a "one-click" method for converting Simulink or Stateflow models into a form that can be simulated entirely in Saber.

Utilizing The MathWorks' Real-Time Workshop„ the Simulink-to-Saber Model Import Utility generates C-code for a Simulink/Stateflow model that is then compiled as a dynamically linked library and accessed through the Saber foreign routine interface. A Saber MAST template and Saber Sketch symbol are also automatically created, resulting in a stand-alone model of embedded software algorithms that is ready for use in the Saber environment (see Figure 3).

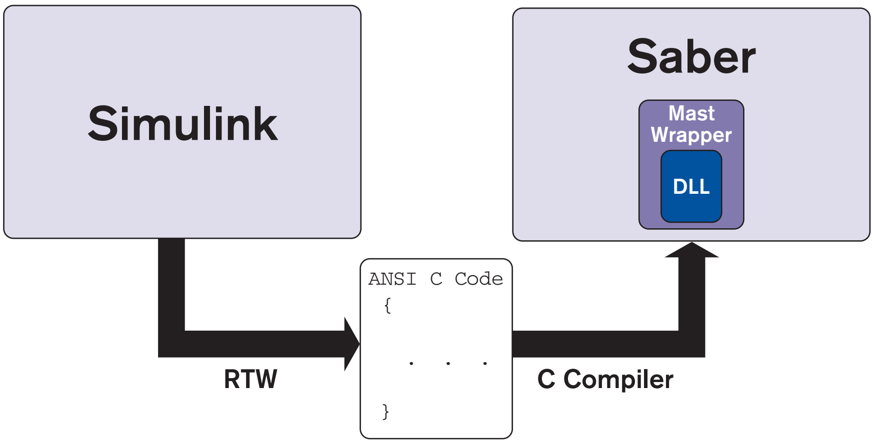

Figure 3. Simulink-to-Saber Model Import

Sharing Simulation Results with SaberLink

Using multiple simulation tools for co-verification of embedded software and mechatronic hardware often poses an obstacle after the analyses have been completed. Analysis results from a Saber-Simulink co-simulation are stored in formats specific to each simulator, making it difficult to compare data in each tool. Saber and MATLAB each have their strengths in analysis data post-processing, so it is undesirable to confine simulation results to a single environment.

The SaberLink data exchange interface provides a direct connection between CosmosScope' and MATLAB, allowing the user to quickly and easily transfer post-simulation data between each environment and eliminating any difficulty posed by collecting simulation data from each tool (see Figure 4).

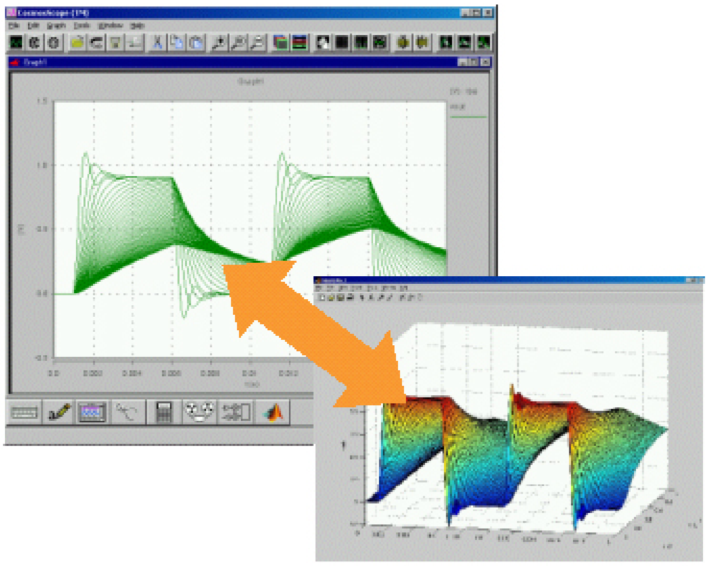

Figure 4. SaberLink Post-Simulation Data Exchange Between Saber and MATLAB

The SaberLink interface allows users of both Saber and MATLAB to take advantage of the wide array of post-processing capabilities in each tool. CosmosScope, Synopsys' standard simulation data and waveform analysis tool, features analog and digital waveform handling, a comprehensive set of measurement tools, and a waveform calculator for creating complex combinations of signals. Alternatively, MATLAB features a wide array of toolboxes for performing signal processing, system identification, and 3-D visualization.

Summary

The links between Saber and MATLAB/Simulink form the foundations of a virtual HW/SW co-verification platform, allowing the software designer and the mechatronic systems integrator to validate embedded system performance earlier in the design process. With Saber-Simulink co-simulation, embedded control algorithms in Simulink can be interactively tested with the physical system modeled in Saber. Encapsulating Simulink models in a Saber design with the Simulink-to-Saber Model Import Utility enables further mechatronic system refinement within a single environment, streamlining the design process. SaberLink post-simulation data exchange allows sharing of simulation results between Saber and Matlab. A summary of the Saber-MATLAB integrations for virtual HW/SW co-verification is shown in Figure 5.

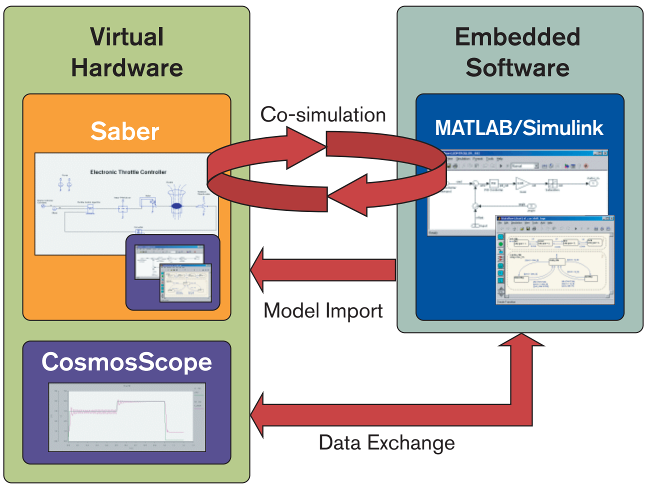

Figure 5. Saber-MATLAB Integrations for Virtual HW/SW Co-verification

700 East Middlefield Road, Mountain View, CA 94043 T 650 584 5000 www.synopsys.com