From chip to system design using a co-verification environment

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This article demonstartes how systems comprising electrical, electromechanical and purely mechanical elements can be modeled, using the example of a semi-active car wheel suspension, where damping, is controlled according to information from a sensor.

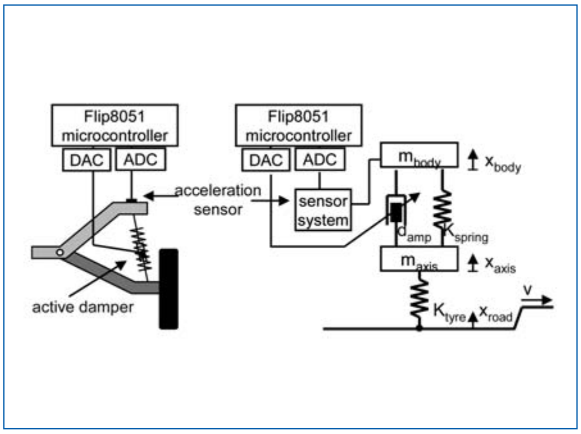

Figure 1. Active car suspension

The field of mechatronics encompasses all applications where electrical, electro-mechanical and pure mechanical elements are applied to build up a system with a required functionality. For rapid and reasonably priced development, it is an absolute necessity, along with the construction of prototypes, to simulate all involved components commonly in an efficient way. This is a sharp departure from PCB design practice. Dolphin Integration thus provides designers with models of elementary mechanical elements as an addition to the electronic devices of the library DIADEM. The included mechanical elements form the basis for modeling whole mechatronic applications. The library EMBLEM contains generic models of devices from various application fields of mechanics, electro-mechanics and power electronics.

A semi-active car wheel suspension system is presented in the following, to enable control of damping of the car as a function of the information provided by a sensor system. The whole suspension system contains a MEMS (micro electro mechanical system, here a capacitive acceleration sensor system), macro mechanics (car body) and a 8051-based controller circuit as an example for the modeling and simulation of mechatronic applications (figure 1).

The sensor consists of an electrically conductive seismic mass, which is fastened to its environment with four identical micro-mechanical meander beams acting as springs. Two comb structures with asymmetrical finger distance are connected to the mass. The movement of the mass results in a capacity change between the finger arrays that can be analyzed with a suitable analogue circuit. A possibility for detecting acceleration in x-direction is an analysis of the comb capacities. Another possibility for detection is the analysis of a driving voltage. For this, an electrical voltage is applied at one of the combs in order to hold the mass with almost any acceleration at a fixed position. The position of the mass is determined thereby over the capacity difference of the two comb structures. In this operation mode the value of the electrical voltage is a measure for the acceleration the sensor.

The sensor modeling will be eased through the use of models from the library EMBLEM-Mecha supplied by Dolphin Integration. This library offers models of the most important effects occurring in and between mechanical elements, i.e. bending of beams, inertia of masses and attraction and capacity effects between two conductive plates. All models can be parameterized at the user's choice. With the help of these "basic effect" models, it is possible to build up models of high complexity with every desirable level of accuracy. The models are implemented in the IEEE standardized hardware description language VHDL-AMS, which offers the possibility to simulate complete mechatronic systems in a circuit simulator. A symbol library for SoC HLE is bound to the model library and supports the modeling of the complete mechatronic system in a schematic editor. With the netlisting feature, one can create the netlist of the complete system (electronics + mechanics) for simulation with SMASH.

Thanks to the model of the micro-mechanical sensor device, the whole system can now be modeled. It consists of a microcontroller (Flip8051) running an embedded program which controls the suspension of the car. According to the real-time information provided by the sensors, the program actuates the active suspension to soften/harden the damper in order to make the drive more comfortable. The acceleration sensors are connected to the Flip8051 through analog-to-digital converters while the feedback on the active suspension is performed through a digital-to-analog converter (figure 2).

The verified and optimized micro-mechanical models are ready to be integrated into a complex system in a hierarchical way. This way of development prevents you from reinventing the wheel again and again. In this example of a semi-active car wheel suspension, the easy integration of modules becomes more obvious. The models of the acceleration sensor and the active damper

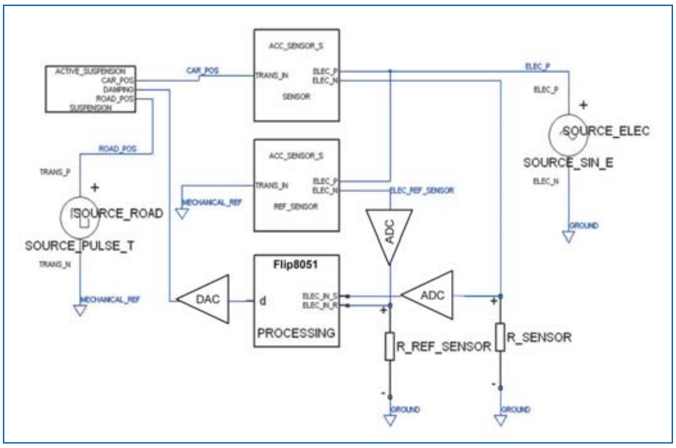

Figure 2. Modeling of a semi-active car wheel suspension

come from suitable libraries. The modeling of the further elements of the car wheel suspension will be eased by the use of the same basic effect models as the ones used in the acceleration sensor model. For this application, the parameters of the mechanical elements have only to be set up for matching with the values of the real suspension. High-level models of the electrical converters (behavioral model) can be used as a first step in modeling. As soon as more accurate simulation results become necessary, the high-level models could be replaced by the real models of the converters.

SUCCESS enables to benefit from the SMASH multi-level simulator together with the µVision2 integrated development environment from Keil. Application code and microcontroller (Flip8051) are simulated by the µVision2 while the peripherals are simulated in SMASH. Thanks to SUCCESS, it becomes obvious how to determine early in the project the processing power required by the system and then to find the best-adapted processor for this application, which is a complex task without such a tool. The Flip8051 family includes various options from 1x to 11x times accel-

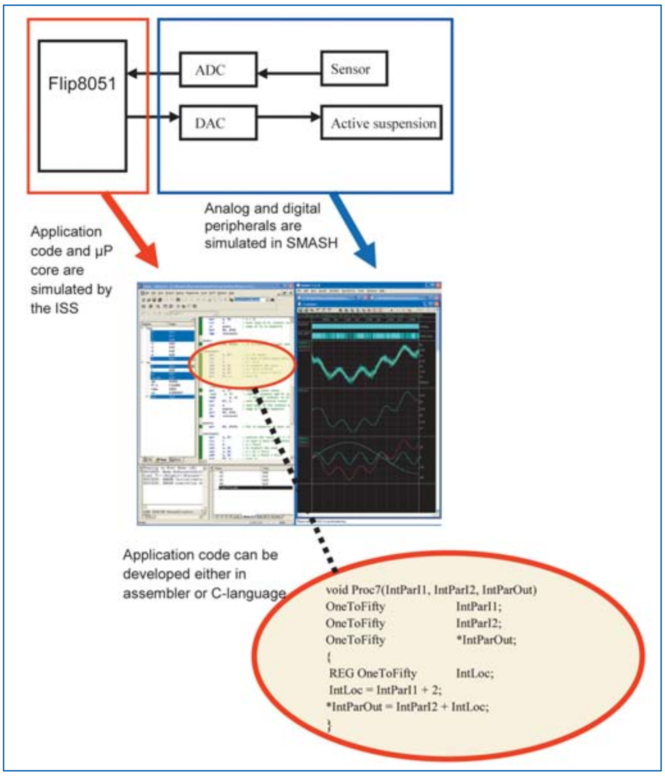

Figure 3. Debugging and simulation/validation possibilities of the embedded software in the system environment

erated. SUCCESS allows to select the right option for the targeted application. This tool enables also to determine if the selected processor is able to control the semi-active suspension of the four wheels.

Figure 3 shows debugging and simulation/validation possibilities of the embedded software in the system environment. Thanks to SUCCESS it becomes possible to write the specification of a system and to perform a virtual validation through hardware/software co-verification in an early project stage, without waiting for a hardware prototype. SUCCESS enables to benefit from µVision2 IDE; to develop the Flip8051 application program thanks to the debug capabilities of the µVision2 as well as to modify in real-time the feedback performed by the micro controller on the micro-mechanical system, and check directly the results thanks to the simulation windows.

The instruction-accurate model of the Flip8051 simulated by the instruction set simulator of µVision2 allows the programmer to develop the application code for any peripheral, be it logic, analog, mixed signal or mechanical, while still benefiting from a well-known development environment with advanced debug capabilities. For instance, the developer can check the reaction of the active damper to the switch between "comfortable" mode and "sport/hard" mode using the step-by-step function of µVision2.

SUCCESS combines the flexibility of the µVision2 IDE providing a user-friendly C or assembler source code development and debug environment with the display capability of the SMASH multi-level simulator. The simulation of the complete mixed domain systems consisting of electronics virtual components (analog + logic), mechanical elements and application program, allows to detect problems at the early project stage. Another cost-saving possibility is the use of pre-modeled and verified elements in new applications. Thanks to this co-verification environment the cost and time of development are reduced perceptibly. ■