In-field Simulation Considering Analog Variability

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AMS (Analog/Mixed-Signal) simulation processes are well embedded into today's system development flows. Unfortunately, in many cases, the use of simulation processes ends when a design has been deployed to a target platform in the production field. The approach proposed in this work in progress paper is to extend simulation methods also for the use during the operation phase. Results of continuously executed simulation runs are analyzed and provide a basis for subsequent performance optimization and decision-making even under the presence of uncertainties.

First, for a new idea as illustrated in Figure 1 an abstract executable specification is formulated. Based on this formal specification a set of implementation models is derived which are further partitioned into software and hardware implementation blocks (model-driven design). In parallel, models for verification and system analysis are defined. They may have a specific purpose regarding the fulfillment of a verification and analysis objective (e.g., robustness, energy efficiency, safety). Of course, both types of models influence each other with the consequence that the modeling processes involve multiple refinement loops. However, all models defined so far are embedded in an appropriate simulation, analysis, and verification environment executed on a development computer.

As mentioned in the abstract section, we propose to embed simulations also in the operation phase. So-called in-field simulation processes have the goal of estimating the behavior of the system for a limited future time window. Such in-field simulations have even more impact when besides classical functional simulation also analog uncertainties are considered. For this approach, we focus on studying analog variability such as PVT, aging, degradation, jitter, etc., which significantly affect the performance of analog circuit parts. Simulation results and subsequent analysis processes provide qualitative statements which finally enables dynamic adaption and optimization of the system's operation (e.g., parameter tuning) even under considering limited analog variability.

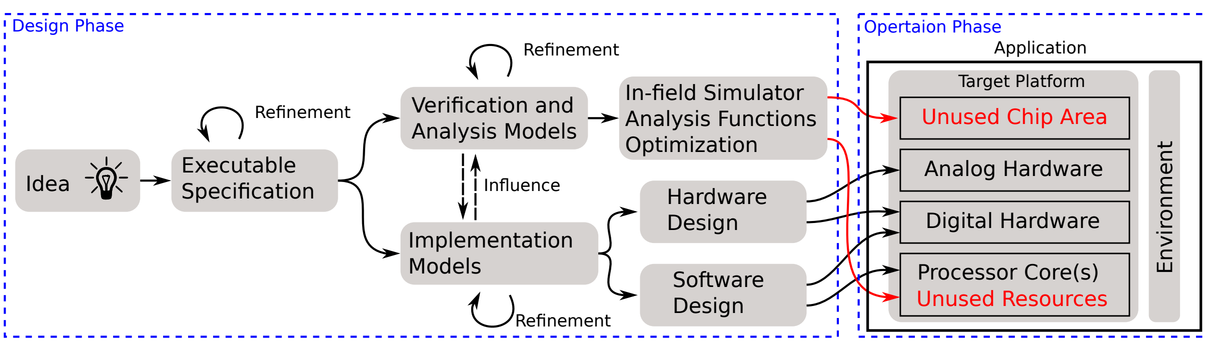

Figure 1: Abstracted system development flow. The parts in red indicate the allocation of in-fild simulation functions to unused target platform recources.

For the implementation of an in-field simulation framework as motivated above we identify the following requirements and challenges.

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Models: The models used for design time simulation have to be compatible with the in-field simulation framework. For our approach, we stick to C/C++ based model descriptions used for SystemC/AMS based simulators in the design phase. As indicated by the red arrows in Figure 1 previously defined verification and analysis models may be directly reused. However, the level of abstraction reflecting the complexity of the formulated model is significantly affecting the performance of the in-field simulation.

Modeling of analog uncertainty: Representing physical uncertainty, which consequences parameter deviations in models, is increasingly challenging. Classical multi-run methods, where simulations are executed multiply using different input valuations are no longer sufficient under the rising number of uncertain values and the complexity of uncertainty effects (e.g., correlations). Thus, analog semi-symbolic methods are due to their computational efficiency (algorithms calculate at least approximate worst-case estimates) and good expressiveness a promising approach for being used for in-field simulation [2].

Simulation core: The simulation software has to be modular and adaptable (compiler support) for execution on various modern target processor architectures (e.g., ARM, MIPS, RISC V). Execution resources are potentially very diverse and distributed. Thus, concepts of parallel discrete event simulation [1], AMS models of computation, transaction level modeling, and an open interface for expandability will be available in a toolbox style.

Analysis and decision-making: Analysis processes require computation time and resources as well and are thus similar to simulation functions implemented as modules each fulfilling a specific analysis and verification objective (e.g., sensitivity analysis, frequency domain analysis). Optimization and decision-making algorithms have to be explicitly defined for a given application including a behavioral model of the system's environment [3]. However, innovative approaches such as machine learning, blockchain technology, and collaborative decision-making algorithms are potentially applicable.

Deployment: As illustrated in Figure 1 permanently free, or even temporarily unused resources of the target platform are reserved for simulator execution (e.g., idle CPU processing power, processor cores, unallocated chip area). However, a coordinated integration of the in-field simulator functions into the hardware and software design is essential. Existing interactions and dependencies have to be resolved in software compile and hardware synthesis processes.

Controlability/observability: A requirement on the application is constant observability of the process state and adequate controllability of analog application parameters. Strictly speaking, for a simulation run the current state of the application has to be monitored, and for optimization, the parameters must be tunable in a way to maximize the performance even under the presence of uncertainty.

As a prototype implementation, we compiled the SystemC AMS simulation core in combination with a C++ library for semi-symbolic uncertainty modeling for the ARM processor architecture. The simulation is then executed sequentially on a Raspberry Pi platform, and an external analog op-amp application circuit is optimized considering voltage variability of an analog input signal.

References

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