AMS Verification using COHO-REACH

Chao Yan
Synopsis
chaoyan@cs.ubc.ca

Jijie Wei
Google
weijijie@cs.ubc.ca

Mark Greenstreet
University of British Columbia
mrg@cs.ubc.ca

Many analog-mixed-signal (AMS) circuits and control systems are naturally modeled as hybrid systems: state machines with a continuous dynamics given by ordinary differential equations (ODEs) at each state, and transitions whose guard conditions depend on the values of the continuous variables. The continuous dynamics for these models are often weakly non-linear. In particular, the intended behaviour may be linear [1], and the non-linearities are primarily a concern for showing that the circuit or control system will converge to its intended operating point (e.g. [2]). These observations motivate using linear-systems theory and its extensions [3] to show that a system satisfies its specification when it is at its operating point, and using hybrid-systems techniques with linear differential inclusions to show global convergence. We address the challenges of showing global convergence for AMS circuits.

AMS circuits often take the form of a few, simple analog blocks embedded in multiple feedback loops, where the feedback loops are implemented primarily by digital circuits. These feedback loops are often designed to operate on widely separated time scales, allowing the engineer to consider the operation of the loops relatively independently. On the other hand, this time-scale separation complicates the verification process by producing moderately stiff ODEs. Furthermore, the mixed-signal approach often leads to convergence to a switching-surface: for example, a digital PLL converges to a limit-cycle where the phase and frequency errors are quite small, or a switching converter converges to a limit-cycle where the voltage is kept close to the target value.

We present describes effective methods for analysing weakly non-linear systems with the stiffness arising from multiple, simultaneously converging control loops. We implemented these methods using COHO-REACH, an enhancement of the COHO reachability tool. COHO [4], [5] was originally optimized for the highly non-linear dynamics of VLSI circuits modeled at the transistor level. COHO-REACH adds support for mode switching along with optimizations to improve the performance and reduce the over-approximation error for weakly non-linear models. COHO-REACH’s novel method for component-wise bounding solutions of linear differential inclusions allows COHO-REACH to compute much tighter bounds that can be achieved by prior approaches. By computing on-the-fly linearization of non-linear models, COHO-REACH avoids the over approximations and increased computation cost of hybridization-based approaches for creating linear inclusions from non-linear models. We show that COHO-REACH’s Matlab-based API provides a natural way to decompose the verification task into a small number of lemmas that are motivated by an intuitive understanding of the design. This decomposition provides an encapsulation of the convergence to a switching surface, enabling greater automation of the verification process, shorter run-times, and tighter bounds for the final result. We demonstrate COHO-REACH by verifying global convergence for a state of the art digital phase-locked loop (PLL) [6].

REFERENCES


This research was funded in part by generous support from NSERC Canada and Intel through their CRD and URO grants.