STUDYAND DESIGN OF ANALOG,DIGITAL AND DESIGNOF ANALOG,DIGITAL AND MIXED-SIGNAL CIRCUITS,INCLUDING THEIR ANALYSIS AND OPTIMIZATSION

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Annotatsion: *This survey presents an overview of recent advances in the state of the art for computer-aided design (CAD) tools for analog and mixed-signal integrated circuits (ICs).*

Analog blocks typically constitute only a small fraction of the components on mixed-signal ICs and emerging systems-on-a-chip (SoC) designs. But due to the increasing levels of integration available in silicon technology and the growing requirement for digital systems to communicate with the continuous-valued external world, there is a growing need for CAD tools that increase the design productivity and improve the quality of analog integrated circuits. This paper describes the motivation and evolution of these tools and outlines progress on the various design problems involved: simulation and modeling, symbolic analysis, synthesis and optimization, layout generation, yield analysis and design centering, and test.

This paper summarizes the problems for which viable solutions are emerging and those which are still unsolved.

Keywords:*Analog and mixed-signal computer-aided design (CAD), analog and mixed-signal integrated circuits, analog circuit and layout synthesis, analog design automation, circuit simulation and modeling.*

Introduction

The microelectronics market and, in particular, the markets for application-specific ICs (ASICs), application-specific standard parts (ASSPs), and high-volume commodity ICs are characterized by an ever-increasing level of integration complexity, now featuring multimillion transistor ICs.

In recent years, complete systems that previously occupied one or more boards have been integrated on a few chips or even one single chip. Examples of such systems on a chip (SoC) are the single-chip TV or the single-chip camera[1].

Or new generations of integrated telecommunication systems that include analog, digital, and eventually radio-frequency (RF) sections on one chip. The technology of choice for hese systems is of course CMOS, because of the good digital scaling, but also BiCMOS is used when needed for the analog or RF circuits. Although most functions in such integrated systems are implemented with digital or digital signal processing (DSP) circuitry, the analog circuits needed at the interface between the electronic system and the "real" world are also being integrated on the same die for reasons of cost and performance. A typical future SoC might look

like Fig. 1, containing several embedded processors, several chunks of embedded memory, some reconfigurable logic, and a few analog interface circuits to communicate with the continuous-valued external world.

Despite the trend previously to replace analog circuit functions with digital computations (e.g., digital signal processing in place of analog filtering), there are some typical functions that will always remain analog.

• The first typically analog function is on the input side

of a system: signals from a sensor, microphone, antenna, wireline, and the like, must be sensed or received and then amplified and filtered up to a level that

allows digitization with sufficient signal-to-noise-anddistortion ratio. Typical analog circuits used here are low-noise amplifiers, variable-gain amplifiers, filters, oscillators, and mixers (in case of downconversion). Applications are, for instance, instrumentation (e.g., data and biomedical), sensor interfaces (e.g., airbag accelerometers), process control loops, telecommunication receivers (e.g., telephone or cable modems, wireless phones, set-top boxes, etc.), recording (e.g., speech recognition, cameras), and smart cards.

• The second typically analog function is on the output

side of a system: the signal is reconverted from digital to analog form and it has to be strengthened so that it can drive the outside load (e.g., actuator, antenna, loudspeaker, wireline) without too much distortion. Typical analog circuits used here are drivers and buffers, filters, oscillators and mixers (in case of upconversion). Applications are, for instance, process control loops (e.g., voltage regulators for engines), telecommunication transmitters, audio and video (e.g., CD, DVD, loudspeakers, TV, PC monitors, etc.), and biomedical actuation (e.g., hearing aids).

• The third type of blocks are the true mixed-signal circuits that interface the above analog circuits with the DSP part of the system. Typical circuits used here are the sample-and-hold circuits for signal sampling, analog-to-digital converters for amplitude discretization, digital-to-analog converters for signal reconstruction, and phase-locked loops and frequency synthesizers to generate a timing reference or perform timing synchronization.

• In addition, the above circuits need stable absolute references for their operation, which are generated by voltage and current reference circuits, crystal oscillators, etc.

• Finally, the largest analog circuits today are highperformance (high-speed, low-power) digital circuits.

Typical examples are state-of-the-art microprocessors,Which are largely custom sized like analog circuits, to push speed or power limits.

Clearly, analog circuits are indispensable in all electronic applications that interface with the outside world and will even be more prevalent in our lives if we move toward the intelligent homes, the mobile road/air offices, and the wireless workplaces of the future.

When both analog (possibly RF) and digital circuits are needed in a system, it becomes obvious to integrate them together to reduce cost and improve performance, provided the technology allows us to do so. The growing market share of integrated mixed-signal ICs observed today in modern electronic systems for telecommunications, consumer, computing, and automotive applications, among many others, is a direct result of the need for higher levels of integration

[2]. Since the early 1990s, the average growth rate of the mixed-signal IC market has been between 15% and 20% per year, and this market is predicted to surpass $22 billion by 2001. Recent developments in CMOS technology have offered the possibility to combine good and scalable digital performance with adequate analog performance on the same die. The shrinking of CMOS device sizes down to

the deep submicrometer regime (essentially in line with, or even ahead of, the predicted technology roadmap [3]) makes higher levels of system integration possible and also offers analog MOS transistor performance that approaches

the performance of a bipolar transistor. This explains why CMOS is the technology of choice today, and why other technologies like BiCMOS are only used when more aggressive bipolar device characteristics (e.g., power, noise, or distortion) are really needed. The technology shift from bipolar to CMOS (or BiCMOS) has been apparent in most applications. Even fields like RF, where traditionally GaAs

and bipolar were the dominant technologies, now show a trend toward BiCMOS (preferably with a SiGe option) and even plain CMOS for reasons of higher integration and cost reduction. These higher levels of mixed-signal integration,

however, also introduce a whole new set of problems and design effects that need to be accounted for in the design process.

CONCLUSION

The increasing levels of integration in the microelectronics industry, now approaching the era of systems on a chip, has also brought about the need for systematic design methodologies and supporting CAD tools that increase the productivity and improve the quality in the design of analog and mixedsignal integrated circuits and systems. This survey paper has presented an overview of the current context and state of the art in the field of analog and mixed-signal CAD tools.

After introducing the industrial context and the design flow, an overview has been given of the progress in analog and mixed-signal simulation and modeling, symbolic analysis, analog circuit synthesis and optimization, analog and mixedsignal layout generation, yield analysis and design centering, as well as analog and mixed-signal test.

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