Research Needs for
Analog and Mixed-Signal Devices (AMS)

Oct. 2008
Device Sciences, GRC
Semiconductor Research Corporation
P.O. Box 12053
Research Triangle Park, NC 27709-2053

Scope and Challenges

As emphasized in the ITRS *Executive Summary* [1], as scaling is being driven towards the limit, Functional Diversification is becoming an important aspect of scaling. This diversification mainly calls for integration of different functions and technologies on a single chip, and analog and mixed-signal devices and technologies are a big part of the enablers.

This document is prepared for the generation and reference of the next Call-for-White-Papers in the Device Science AMS thrust. Within the program structure of GRC-SRC, this thrust only deals with technology-related research. Other AMS-related works but focusing on circuit design or compact modeling are included in their respective thrusts, but tied together by the AMS cross-cut.

According to the Roadmap of the chapter *Radio Frequency and Analog/Mixed-Signal Technologies for Wireless Communications*, this discipline can be divided into 5 areas [2], with their respective challenges listed below:

- RF and AMS CMOS—Device scaling, in particular high-performance logic scaling, generally makes the analog characteristics worse. These issues include standby power (off current), parasitic resistance and capacitance, mismatch, channel strain causing mismatch and 1/f noise, SOI and FinFET lacking body contacts, etc.
- RF and AMS Bipolar Devices—To optimize speed (ft) while controlling punch-through and breakdown. To control high current/power, etc.
- On-Chip and Embedded Passives for RF and Analog—Passives such as resistors, capacitors, inductors, varactors, transformers, and transmission lines often determine the overall analog performance of the circuits, and often occupy more

area than the active devices. Optimization and miniaturization of these embedded components in a cost-effective manner is challenging.

- Power Amplifiers—These are further divided into handset and base-station applications. Handset PAs face decreasing battery voltage and thus higher current for the same power delivery. Base-station PAs require increasing frequency operation while maintaining or improving the amplifier efficiency.
- Millimeter Wave (beyond 10 GHz) —This arena is mostly limited to compound semiconductors, namely GaAs, InP, SiC, and GaN. The continuing challenges are substrate material quality and cost, incompatibility of tools and chemicals with the mainstream Si process, and the need for thin substrates for thermal dissipation for some power devices. There is growing utilization of Si CMOS and SiGe bipolar/BiCMOS, facing some challenge of a more lossy Si substrate.

To better identify more specificially the topics of needs for our member companies, we have listed the topics into finer details as shown in the attached table.

Research Needs: Categories and Topics

For active devices, we divide them into (a) mainstream MOSFETs, (b) other active circuit components, and (c) power amplifiers. The last 2 groups are passives and miscellaneous. In MOSFETs, the main scaling approach is similar to the ITRS low-standby power technology (LSTP) which is ~3 year behind that of the high-performance logic. Improving the analog specs on a digital technology is an area of interest. The second group contains all other active circuit components such as diodes, varactors, bipolar transistors, ESD protection devices, and I/O devices. The next group includes power amplifiers, power diodes, and other power devices. The fourth group contains the passive devices (capacitors, inductors, transformers, resistors, etc.) as well as materials for these. The last group contains all other technology aspects such as isolation schemes and integrated MEMS.

Research Needs: Priorities

Member company representatives were asked to vote on the topics of their preference, with high priority (H) or medium priority (M). Consensus is built on the average of inputs. This methodology yields a total of 5 topics of high priority, and 11 of medium priority. It is with these guidelines that we will call for and select proposals in this area of research.

Contributing AMS TAB members:

Jeff Smith (TAB Chair)	TI
Margaret Huang (TAB V-Chair)	Freescale
Leonard Rubin	Axcelis
David Greenberg	IBM
Brian Floyd	IBM
Mark Stidham	IBM
Rick Wise	TI
Robert Monteverde	TEL
Kwok Ng	SRC

Reference

[1] International Technology Roadmap for Semiconductors (ITRS) 2007 Edition. "Executive Summary".

[2] International Technology Roadmap for Semiconductors (ITRS) 2007 Edition. "Radio Frequency and Analog/Mixed-Signal Technologies for Wireless Communications".

Analog and Mixed-Signal Devices: Research Needs

1. Active: MOSFET

		Priority
1a	General analog performance [noise, linearity, intrinsic gain (Rout.gm)…especially on digital technology]	H
1b	High-speed performance (ft, fmax, parasitics, s-parameters, over temperature…)	M
1c	Analog transistor scaling	H
1d	Ultra-low power, ultra-low leakage MOSFETs	M
1e	Matching (variability)	
1f	Reliability (degradation, hot-carrier, NBTI, TDDB, electromigration…)	
1g	Advanced MOSFET structures for analog (surround/double gate, FinFET…)	H
1h	Advanced MOSFET using compound-semiconductor channel	
1i	Adaptive devices (e.g. back-gate to adjust between low-leakage or high-performance analog)	M

2. Active: Other circuit components

2a	Peripheral components: varactors, pin diode, Schottky diode, photodiodes…	
2b	High-performance bipolar (low-temp epi growth), BiCMOS…	H
2c	Integration and analog-performance of post-silicon-era devices: e.g. carbon or silicon nanotubes	M
2d	High-V ESD (SCR, bipolar…) and I/O devices	M

3. Actives: Power Devices

3a	MOSFET power amplifier (Ron, power density/efficiency, high-freq for RF…)	H
3b	High-efficiency power diodes	
3c	High-injection bipolar devices (IGBT…)	

4. Passives

4a	Capacitor (high-K, high density, linearity), resistor (high/med range, precision), inductor (high value), transformer… and their scaling	M
4b	High-performance material studies (dielectric absorption…)	M
4c	Emulating passives using actives	
4d	Trimmable devices	

5. Miscellaneous

5a	Isolation (cross-talk, deep trench…)	M
5b	Substrates [high-resistivity (SOI), high thermal conductivity…]	M
5c	Built-in self-test capabilities	M
5d	Integratable MEMS	M