Key Challenges Facing Analog/RF/Mixed-Signal Devices in the Next 5-7 Years

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Outline

- The IC Landscape
- Analog & Software Drive IC Product Differentiation
- How Market Success Depends on Analog Success
- Analog Is Rapidly Evolving
- And Getting Analog Right in Getting More Difficult
- Summary
Today, Platforms Define The Winners
Platforms Are Rapidly Going Into Deep Nanometer
IC Market Growth for Rest of This Decade

IC Market Growth Rates by End-Use Application
(2014-2019F CAGR)

- Automotive: 6.7%
- Comm: 6.5%
- Ind/Med: 5.8%
- Gov/Mil: 4.3%
- Total ICs: 4.3%
- Computer: 1.8%
- Consumer: 1.2%

Source: IC Insights
## Major IC Segments

<table>
<thead>
<tr>
<th>Terminology</th>
<th>AMS IC</th>
<th>nm AMS IC</th>
<th>SoC</th>
<th>Memory IC</th>
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</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Analog-Rich</td>
<td>Analog Mixed-Signal ICs</td>
<td>Digital Mixed-Signal ICs</td>
<td>Standalone Memory ICs</td>
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<tr>
<td>Process Nodes</td>
<td>0.5u – 130nm, Specialty Nodes</td>
<td>130nm – 28nm</td>
<td>90nm – 10nm</td>
<td>Dedicated Nanometer</td>
</tr>
<tr>
<td>Applications</td>
<td>Automotive</td>
<td>Wireless Transceivers</td>
<td>CPUs</td>
<td>Non-volatile Memory (FLASH) and DRAM</td>
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<tr>
<td></td>
<td>Consumer</td>
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<td>Industrial</td>
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<td></td>
<td>Power</td>
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<td></td>
<td>Sensor</td>
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<td></td>
<td>Clocking ICs</td>
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<td></td>
<td>LED Lighting</td>
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<td></td>
<td>Optical ICs</td>
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<td></td>
<td>Standard analog</td>
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<tr>
<td>Example Companies</td>
<td>TI, On Semi, STMicro, Analog Devices, Maxim, Infineon, Skyworks</td>
<td>QCOM, NXP, On Semi, BRCM, Marvell, Mstar, IDT, Inphi, Motorola, Spreadtrum, ST Micro, SiLabs, Sony</td>
<td>Apple, Samsung, QCOM, Intel, AMD, Oracle, Fujitsu, MTK, NVIDIA, BRCM, Spreadtrum, Cavium, Altera, Xilinx</td>
<td>Samsung, Micron, SKHynix, Toshiba, Intel</td>
</tr>
<tr>
<td>Flows</td>
<td>Highly Fragmented ICs</td>
<td>Analog dominates flow</td>
<td>Digital dominates flow</td>
<td>Yield dominates flow</td>
</tr>
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</table>

**Analog Is Increasingly Becoming the Differentiator for Each Segment’s Unique Needs**
Analog Brings Increasing Dimensions of Verification - Making It Harder to Get First Silicon Right

- Complexity giving rise to more dimensions

- New First-order Effects That Impact Electrical Performance
- Low-Power AMS & What It Means for Verification
- Objective-driven Verification Strategies
- Statistics In Verification
- Reliability
What’s Changing In AMS?

- Analog going into nanometer nodes
- Merchant BCD and Specialized Platforms have now arrived
- MEMS technologies becoming prevalent
- More digital circuitry embedded with analog
- Ultra-low-power analog arrives
- Reliability for analog becomes critical
- “More-Than-Moore” Becomes As Important as “Moore”
Design Starts by Process Node Through 2020

Source: International Business Strategies, Inc. 2015
Going Nanometer: First Order Nanometer Physical Effects

Technology Perspective:
- Increasing device model complexity for FinFET
- Need to include huge number of parasitics (R, C, Cc)
- Need to include device noise effects
- Complex layout effects impacting design specs
- Low-voltage driving intensive noise analysis
- Increasing PVT corner count

Design Perspective:
- Low power applications for analog IP
- Reinventing designs for low-supply-voltages
- Fully SPICE accurate simulation with very low noise floor
- Need Monte Carlo and many corners to ensure operation

- Huge netlists
- New effects
- Longer Simulations
- Lots of Simulations
More Digital Embedded With Analog: Driving Up Mixed-Signal IC Complexity

Up to 70% of design starts
- D/a, A/d, and D/A
- Tightly-coupled architectures

Mixed-signal verification
- Inadequate tools
- Difficult setup
- Complex flows
- Compromise accuracy/speed

Over 50% first silicon failures

Lack of fast, nm-accurate mixed-signal verification limits design success
Increasing Integration

- Increasing integration is
  - driving innovation via new mixed-signal circuit architectures
  - enabling advanced mixed-signal devices that avoid performance compromises

Critical Functions

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<th>Speed</th>
<th>Precision</th>
<th>Power</th>
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<tr>
<td>Fast conversion (ADC/DAC) and processing</td>
<td>Processing small signals with high resolution</td>
<td>Maximize battery life</td>
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<tr>
<td>Receivers and transmitters for RF and data</td>
<td>Measure with high absolute accuracy</td>
<td>Minimize energy consumption</td>
</tr>
</tbody>
</table>

Source: Global Semiconductor Association, Silicon Series, 2013
IoT Driving A Revolution in Ultra Low-Power Analog, RF, and Mixed-Signal

Source: Silicon Labs, ARM, Freescale, Mouser

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Emergence of Merchant BCD Technology Platforms Is Changing The Game

- The BCD technology platform has a broad range applicability and cost-effectiveness - contrary to popular perception.
- The increasing availability of full-fledged BCD platforms will accelerate changes in profitability and valuation as incumbents are attacked.
- Fabless analog IC vendors are now achieving high performance previously reserved for established traditional vendors.
MEMS Becomes Pervasive

MEMS Market Forecast (2014-2020) By Device
Source: Yole Developpement
Using Moore vs More-than-Moore for Platform Control
Bringing It All Together

AMS IC
- Analog-Centric ICs

nm AMS IC
- Analog-on-top nanometer-scale ICs

SoC
- Digital-on-top nanometer-scale ICs

Memory IC

Packaging: 3-D innovation road map
3-D stacking will enable significant improvements in overall system performance

R. Subramanian- Semicon West 2016
These Changes Bring Tremendous Challenges

<table>
<thead>
<tr>
<th>The Change</th>
<th>The Challenge</th>
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<tbody>
<tr>
<td>Nanometer Analog</td>
<td>Need to simulate more physical effects that create problems in electrical performance of circuits</td>
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<tr>
<td>Merchant BCD Platforms</td>
<td>Need to be able to handle complex high-voltage devices, sensors, and MCUs on same design</td>
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<tr>
<td>More Digital Mixed In With Analog</td>
<td>Increasing amount of digital control, calibration, and processing forces verification complexity to explode</td>
</tr>
<tr>
<td>Ultra-low Power Analog</td>
<td>Ultra-low voltage and current require careful analysis of all effects and careful measurement methodologies</td>
</tr>
<tr>
<td>“More than Moore”</td>
<td>Increasing use of interposers, TSV, etc in 3-D-IC technologies requires packaging simulation and multi-technology multi-die simulation</td>
</tr>
</tbody>
</table>

These are all now the focus of intensive R&D efforts across the EDA industry