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INVENTIVE

Verification Solutions for Digitally Calibrated Analog Design

November 09, 2010

By Art Schaldenbrand
Presented by Nebabie Kebebew

Agenda

- Silicon Realization
- Why use Digitally-Assisted Analog Design
- What is Digitally-Assisted Analog Design
- Verification of Digitally-Assisted Analog Designs
- Conclusion

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EDA360 for Silicon Realization

SYSTEM REALIZATION

SOC REALIZATION

SILICON REALIZATION

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Silicon Realization: Custom & Analog Flow

Industry's front-to-back custom & analog solution

Design

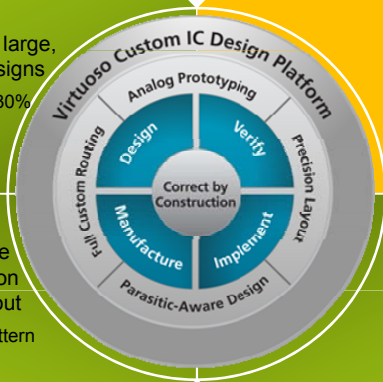
Fast/flexible design entry for large, complex custom/analog designs

- Speeds analog design by 30%

Verify

Comprehensive verification with industry leading simulation suite

- High performance multi-mode simulation throughout design cycle



Manufacture

Reliable, silicon-accurate manufacturing optimization and signoff prior to tape out

- Lithography, CMP, CAA, pattern matching, etc.

Implement

Accelerated physical layout of custom digital, analog and mixed-signal designs

- 25-50% productivity boost with selective automation

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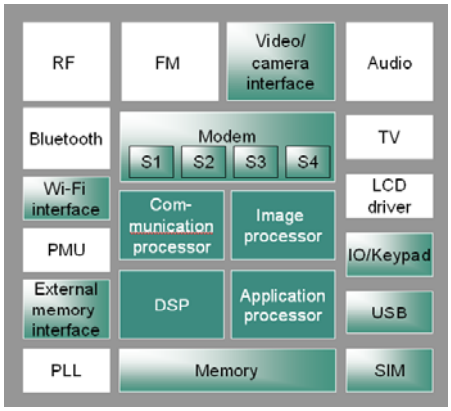
Effect of Analog IP on SoC Design

- Consumers interact with a products through a user interface
  - Differentiation is the user interface
- Real world interfaces are realized using analog functions
  - Integrating analog and digital is painful



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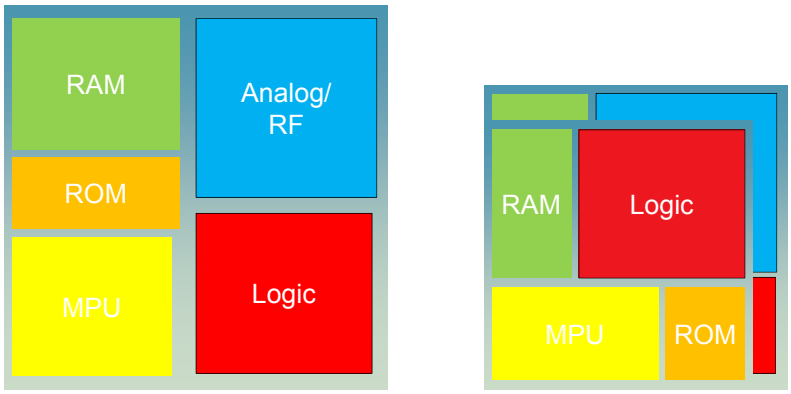
Challenge of Scaling Analog Circuits
Process Scaling Reduces Cost



65 nm 45 nm

Assuming digital scaling for digital and analog scaling for analog

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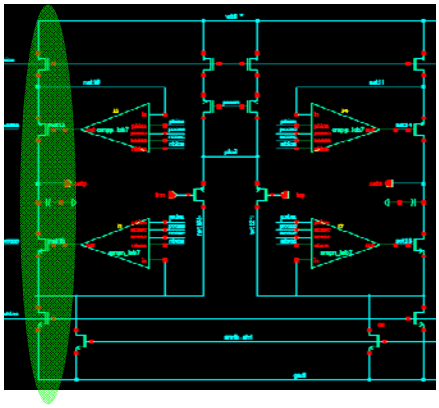
Challenge of Scaling Analog Circuits

- As the power supply voltage decreases
  - Maximum signal size is reduced degrading dynamic range
  - Can't stack transistors, hard to design high gain amplifiers
- As the power supply current decreases , op amp performance is degraded
  - Bandwidth is α I_T



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Analog IP Implementation Strategy
Digitally Assisted Analog Design

- As process technologies scale down: area and power become constraints to analog realization
- The primary method available to designers to overcome these constraints has been digital gates
- This style of design is called digitally-assisted analog design (DAA)

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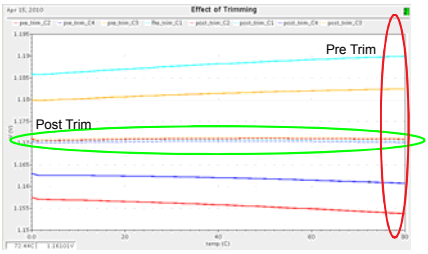
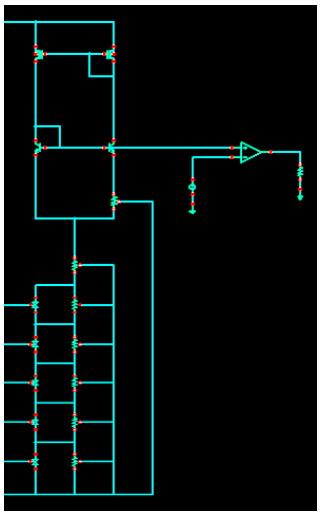
Digitally-Assisted Design
Quick Review of Trimming

- Analog designers have used trimming to minimize the effect of process variation on design
  - Laser trimmed resistors
  - Poly-Si fuses



Reference Voltage versus Temperature



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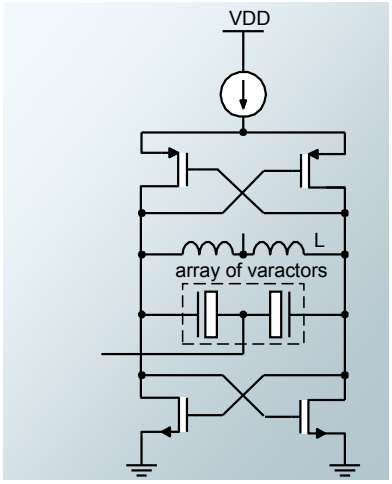
Digitally-Assisted Design
VCO Calibration Example

- **VCO have been tuned with an analog control voltage**
- **To overcome the limitations of the purely analog implementation, varactor control can be done digitally**
- **Digital calibration improves performance and enables additional functionality**



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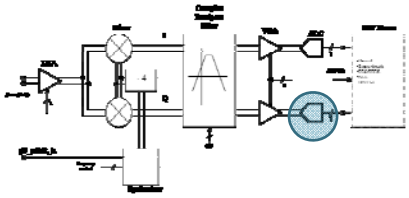
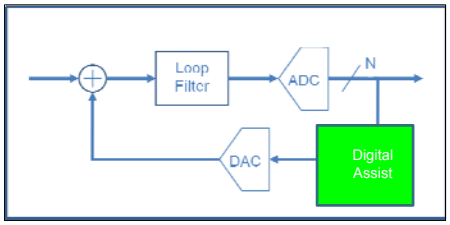
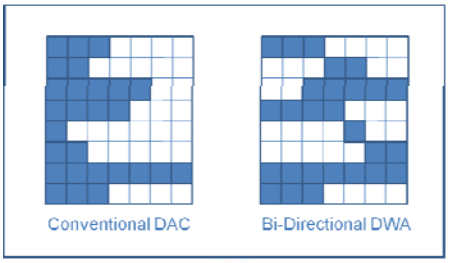
Digitally-Assisted Design Example
Using Correction/Compensation



- Multi-bit Delta-Sigma data converter architecture allows designers to reduce the clock frequency without reducing dynamic range
- Address the non-linearity with DAA





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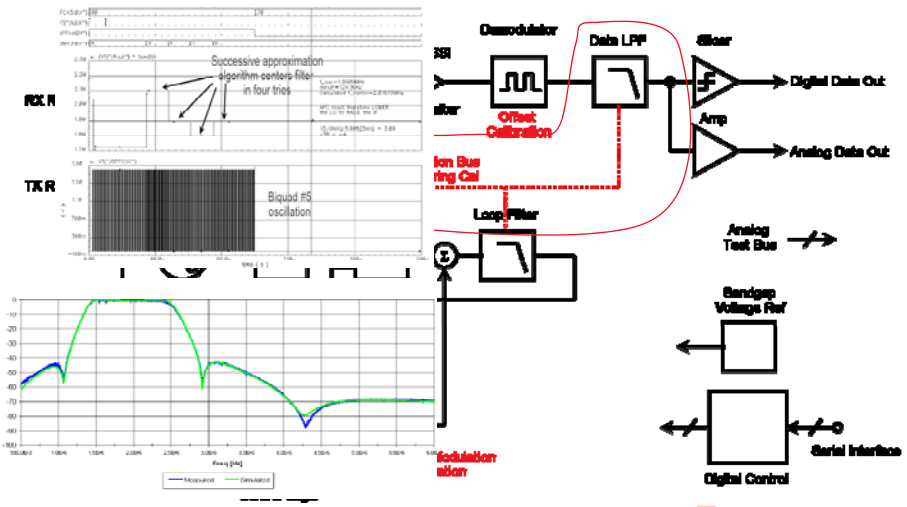
Digitally-Assisted Design Example
Using Calibration



A CMOS 2 MHz Self-Calibrating Bandpass Filter For Personal Area Networks,
C. Frost, G. Levy, B. Allison, International Symposium on Circuits and Systems 2003,

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Digitally-Assisted Design

- Correction/Compensation
  - One step process
    - Compensate non-ideality during operation

    → Dynamic
- Calibration
  - Two step process
    - Measure target parameter without calibration
    - Calculate calibration
    - Apply calibration during operation

    → Static

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Digitally-Assisted Analog Design

From the EDA Perspective

- Static and Dynamic Digitally-Assisted Analog
  - Need to include the effect of calibration, correction, and compensation in simulation
- Static Digitally-Assisted Analog
  - Design environment should manage the calibration process

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- Silicon Realization
- Why use Digitally-Assisted Analog Design
- What is Digitally-Assisted Analog Design
- Verification of Digitally-Assisted Analog Designs
  - **Mixed-Signal Simulation**
  - Verification with Calibration
- Conclusion

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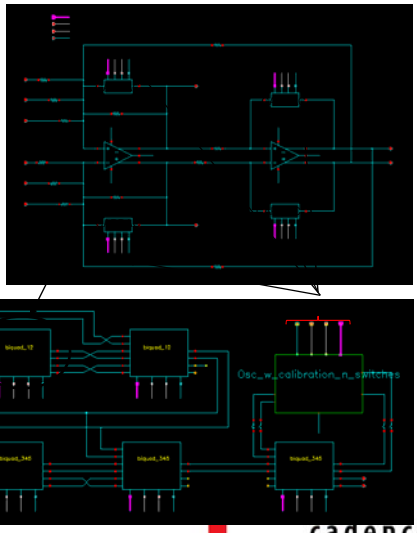
Digitally-Assisted Analog Design

Simulating Digitally-Assisted Analog Designs

- Different approaches for simulating digitally-assisted analog designs are available
  - SPICE
  - FastSPICE
  - Mixed-signal simulators
- Designers need to be able to verify the overall architecture before starting transistor level design



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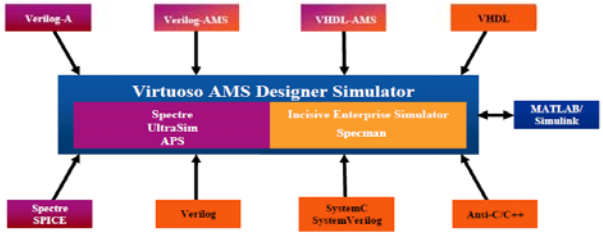
Digitally-Assisted Analog Design

Simulating Digitally-Assisted Analog Designs

- AMS Designer provides a total solution for mixed-signal design
  - User selectable analog solver
  - Extensive analog, digital, and mixed-signal behavioral modeling language support
- Advantages of using AMS Designer for mixed-signal includes:
  - Support for AC, small signal, analysis
  - Support for Monte Carlo analysis
  - Integration into ADE and



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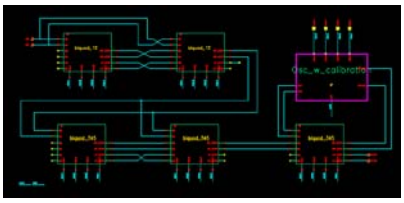
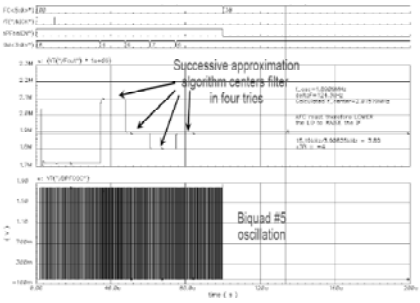
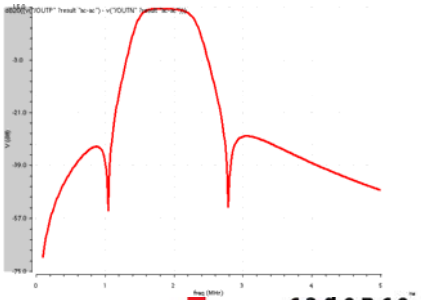
Digitally-Assisted Analog Design

Simulating Digitally-Assisted Analog Designs

- Transient analysis is useful for simulating calibration
- It is difficult to fully characterize post-calibration performance using just transient analysis







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- Silicon Realization
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- Verification of Digitally-Assisted Analog Designs
  - Mixed-Signal Simulation
  - **Verification with Calibration**
- Conclusion

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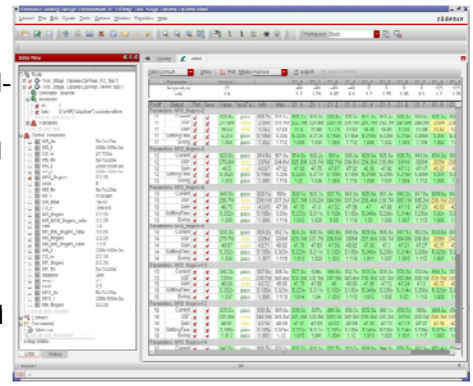
Digitally-Assisted Analog Design
Simulating Calibration

- Cadence has developed a new capability, ADE-XL for verification of analog and mixed-signal designs
  - ADE is the analog/mixed-signal design environment
- ADE-XL allows designers to verify specification compliance across operating conditions and process variation



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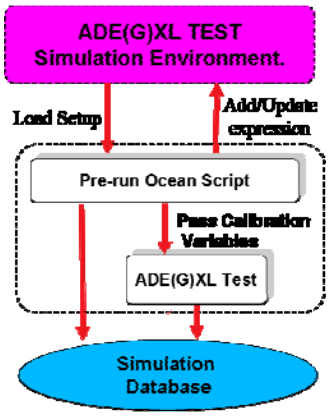
Digitally-Assisted Analog Design
Simulating With Calibration

- **ADE XL supports "pre-run" OCEAN script for each test**
- **The pre-run OCEAN script is used to perform the calibration**
  - Perform a pre-run to calibrate the design
  - Pass the calibration state to the testbench
  - Then simulate the design with calibration
- In development with partners, target release is IC615



"Cascaded Simulations", Oliver Weinfurtner, Hongzhou Liu, CDNLive!EMEA 2010

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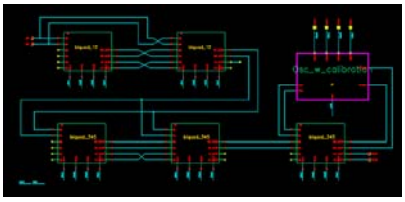
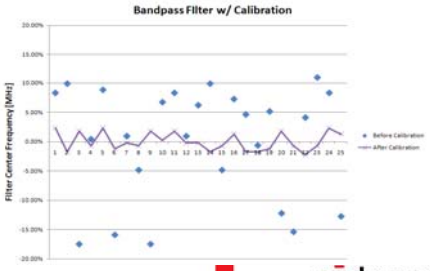
Digitally-Assisted Analog Design
Simulating With Calibration

- Calibration Example:
  - Goal:
    Tune a bandpass filter center to a target frequency :
    f_{center} = 2MHz +/- 5%
- Active RC filter
  - Tuned using capacitor DACs
  - Last stage used as an oscillator to tune value of capacitor DAC
    $f_{osc} = f_{filter\_center\_frequency}$



WPAN Transceiver – Channel Filter



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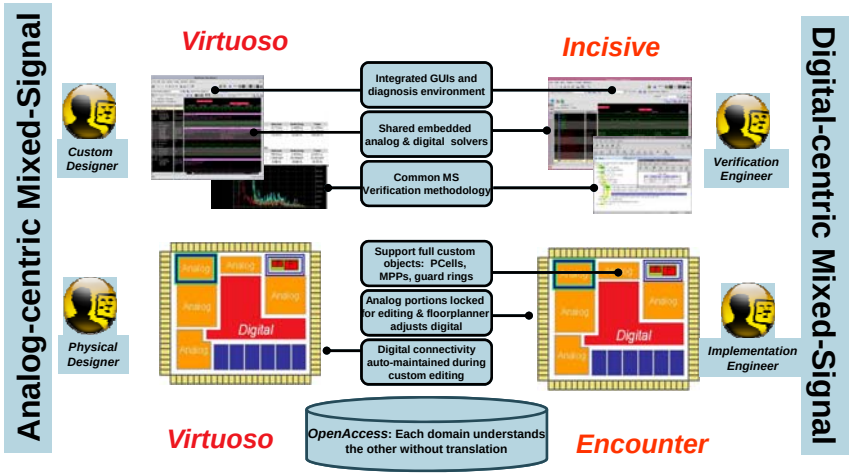
Mixed-Signal Design Platform
For Silicon Realization



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Conclusion

- Digitally-Assisted Analog Design
  - Is not “one-size fits all” solution
    - Depending on the target application, the implementation approach can vary significantly
- Cadence has added automation for Digitally-Assisted Analog Design in Virtuoso IC Design Platform
  - ADE-XL/GXL
  - Mixed-signal simulation with analog analyses

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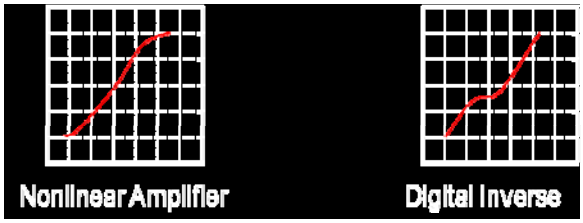
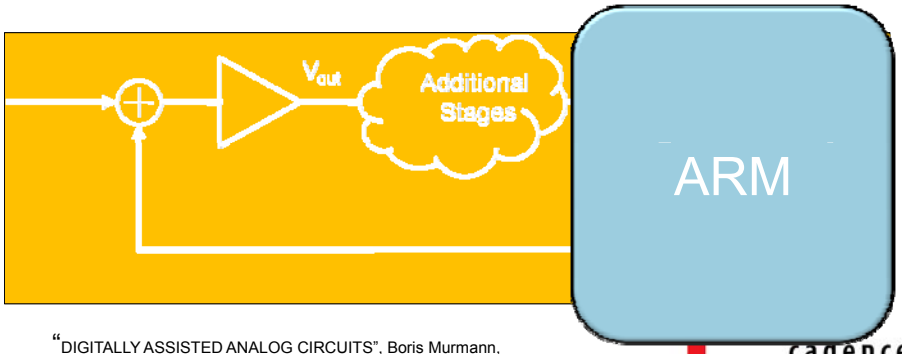
The Road Ahead





"DIGITALLY ASSISTED ANALOG CIRCUITS", Boris Murmann, HOT CHIPS, MARCH–APRIL 2006, pg. 38-47

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