Power, Noise and Reliability Analysis for Automotive Electronic Systems

2012 Automotive Simulation World Conference
“Megatrends” in Automotive Electronics

- Electro-mobility
- Powertrain Control

Environment

Energy Efficiency

Interference

Networking

Safety

Reliability

Scalability

Affordability

- Connectivity
- Compliance

- Reliability
- Smart Sensors

- Cost
- Robustness
Requirements for Electronic Systems: Power Reduction

Challenges
- Ultra-low power design complexity
- Impact on reliability
- Heat dissipation to system

Simulation Requirements
- Early power estimation/monitoring
- Perform design trade-offs
- Reduce power automatically

“Automotive OEMs are demanding lower power-consuming devices with smaller footprints and better performance to address broader concerns about the environment and fuel consumption.”
Renesas, EETimes Europe, July 2012
Requirements for Electronic Systems:

High Performance

Challenges

• Operation of airbag systems depend on MCU speed
• Operating speed of MCU depends on quality of power supply it receives
• Poor Power Delivery Network design can reduce MCU performance by 60MHz

Simulation Requirements

• Model full chip/package/board supply system
• Model excitation from chip through package and PCB

"... power consumption is the main driver for the move to dual-core MCUs ... to handle next-generation power train control."

Freescale, EETimes, 10/12/2011

Requirements for Electronic Systems: Thermal Management

Challenges

- System-wide issue for Automotive Electronics
- Close proximity of on-board electronics creates cooling challenge
- Modeling materials with high thermal conductivity

Simulation Requirements

- Chip Thermal Model
- Thermal Boundary Conditions
- Package/PCB Thermal Modeling
- Thermal Back-annotation to IC

“...the auto industry is migrating from purely mechanical and hydraulic systems to electromechanical or mechatronic systems. This requires locating sensors, signal conditioning, and control electronics closer to heat sources.”

Analog Devices, Analog Dialogue, April 2012

Max. temperature ranges in automotive systems


Package: Thermal profile
Requirements for Electronic Systems:

**EMI / EMC Compliance**

**Challenges**
- Semiconductor content of automobiles increases 15% per year
- EMI is a key safety concern
- Traditional EMI modeling neglects core noise

**Simulation Requirements**
- Chip emission modeling (core, I/O)
- Package/PCB/cable radiation analysis

*Increasing need to predict the true post-silicon EMC behavior vs. increasingly aggressive EMC targets dictated by marketing, customers, and international standards*

Dr. Davide Pandini, ST Microelectronics

ST Microelectronics, Doriol et al., DAC 2009
Components in Automotive Electronics

Printed circuit board (PCB) with multiple package chips

- **Chip**
  - On-chip decoupling
  - Die parasitics
  - Current signature
  - Bump map

- **Package**
  - Plane shapes
  - Discrete decoupling
  - I/O routing
  - Ball map

- **PCB**
  - Channel/SSO Analysis
  - Multi-domain
  - EMI Due to Current Signature

**MCU:**
Chip inside wire-bond package
Design Flow for Power/Thermal Management

- **Power-Performance-Area Trade-offs**
- **Identify and eliminate power bugs**

- **RTL Power**
  - Early Grid Prototyping
  - Power Integrity Verification

- **IC Power**
  - System PI, SI, EMI, thermal
  - Cost down and risk mitigation

- **System Power**

- **Chip Architecture**
  - Netlist

- **Chip Design**
  - RedHawk/Totem

- **System Design**
  - Sentinel/Icepak
PowerArtist: RTL Power Management

ESL Design

RTL Design

Logic Synthesis

Physical Design

GDSII
SoC Power Supply Noise Analysis Steps

- **Chip (IC)**: CAD flow independent (GDS/DEF/Netlist/Models)
  - Operate on industry standard formats
- **Package**: Only solution for on-die ‘L’ extraction and simulation
  - Silicon validated down to 22nm
- **PCB**: Pico-second resolution
  - Best-in-class performance
- **Simulation**: Enable automatic and user-guided debug
  - Interactive ‘what-if’ and incremental simulation
- **Root Cause Identification**: Single-step model creation out of IC analysis
  - Multi-domain, distributed and coupled

RedHawk
System-aware IC Power Integrity

Q3D

Sentinel-NPE

RedHawk Package Compiler

RedHawk Totem

Dynamic Voltage Drop

In-Rush Current

Electromigration

ESD

3D-IC
**Totem: Custom Analog and RF Designs**

‘Analog Mixed-Signal Support’

- Complex RF Designs
- Custom Analog Designs
- PMIC Designs
- I/O Designs: DDR, SERDES
Reliability: Noise Analysis for Automotive

• Today’s auto chips combine high-voltage switching and 1V CPUs
  – E.g. engine controller with actuator outputs

• How to prevent high-V noise from upsetting low-V circuits?
  – Use IC processes with special isolation features for DC isolation, AC shielding
  – Careful chip/package/system design to limit noise coupling

• Totem Substrate analysis enables chip designers to analyze noise impact
  – Substrate-conducted noise
  – Inject, simulation, measure noise
  – Visualize noise levels to suggest solutions
Electrical Co-Design of Chip-Package-System

• Chip Power Model (CPM)
  – Captures chip current and RLC parasitics
  – SPICE-ready
  – Direct CPM import enablement

• Co-Design Enablement:
  – AC, DC, Transient Analysis
  – Package, PCB de-cap planning and optimization
  – Thermal Analysis
  – System-level EMI, Far Field, Near Field
Chip Aware System Power Integrity

RedHawk Totem

CPM (Chip Power Model)

Sentinel-PSI

Slwave

Chip Power & Emission Model

DC IR-Drop

AC Analysis

Dynamic Voltage Drop Analysis

EMI/EMC
Why RTL2Gate Power?
- Consistency
- Coverage
- Flexibility

Early CPM Generation: RTL2GATE

RTL Analysis
~ Million Cycles

RPM

Physical Design
~ 20 cycles

RedHawk

PowerArtist

System Design

Sentinel

SIwave

CPM(Layout)+Pkg
CPM(RPM)+Pkg
Pkg only
EM Modeling Product Portfolio

3D Full-Wave

Full-wave Analysis
Large-scale and application specific

Accuracy

Speed

Sentinel-PSI

HFSS
Golden Standard Full wave analysis
Flexible full 3D
Strong extraction for critical net
Layout front end for HFS
System level sign off
Critical PCB signal extraction

Sentinel-PSI
High Speed FEM of Prism element
PI/Sl analysis for Package
Complement 3D effect for Slwave
The power supply for SSO and Signal of package and board with single substance EMI

Slwave
High speed Hybrid solver for PKG/BRD
Large scale analysis
Large-scale board power supply model extraction
Package-Board EMI analysis
Co-Design Enablement of Chip-Package-System
Chip-Package-System PDN Analysis

Capacitor in package
Capacitor in board
BGA Package
Bulk capacitor
Power
Ground

System AC Simulation

System AC Simulation

Capacitor placement
Time domain system analysis

w/o pkg decap (192mV)
w/1/2x pkg decap (68mV)
w/original pkg decap (58mV)
Chip and System-level Thermal Co-analysis

**Chip Thermal Model (CTM)**

- Accurate chip power distribution for system level thermal analysis
  - Chip Thermal Model (CTM) generated from RedHawk full-chip power analysis
  - CTM-converged power/thermal map generated by Sentinel-TI

- System-level thermal Boundary Condition for Package thermal analysis
  - Constant coefficients on package top/sides and board top/bottom generation in ANSYS Icepak
Thermal Management Flow for Automotive

RedHawk

CTM

Sentinel – TI + SIwave

Conv. Power Map
Board current

Heat transfer coefficient

Icepak

Chip Aware Package and System Thermal Analysis

System Aware Package and Chip Thermal And Reliability Analysis
Motivation for EMI Analysis

**IC level**
- EMC of active and passive components

**Module level**
- EMC behaviour of components and PCB

**System level**
- System EMC behaviour in standarized test setups

**Vehicle level**
- Complex antenna structures in ‘real emc world’

 Currently EMI checks done here only

*ST Microelectronics, Doriol et al., DAC 2009

EMI needs to be improved in all of above levels
ANSYS-Apache CPS EMI Flow

CPM

HFSS/Siwave/Sentinel-PSI

Near/Far Field Radiation
Chip-Package-System EMI Simulation

Chip-aware System EMI Analysis

- CPM from RedHawk
- Smartphone EMI Simulation in HFSS

IC-level EMI Hotspot Analysis

- 2nd harmonic
- 5th harmonic

RedHawk: EMI Source Maps

Sentinel-PSI Package EMI Map

Noise Spectrum
# Addressing Power Noise Challenges for Automotive Electronics

**Comprehensive Chip-Package-System simulation solutions**

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<td>Ensure MCU will operate at desired clock frequency</td>
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<td>Meet regulatory EMI/EMC requirements for system</td>
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<td>Thermal Simulation</td>
<td>Develop thermal management solution necessary to achieve performance and reliability target</td>
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<td>Reliability (ESD)</td>
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Enabling ‘Converged’ Electronic Designs for Automotive Applications

Enable design prototyping
Identify errors early in the process
Reduce overall system cost
Overcome design boundaries