Design Enablement for the Next Generation of MEMS Products - SEMICON Europa 2018

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Predicting Actual from Virtual

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Motivation for MEMS Design Enablement

► Concerns about design enablement
  ▪ Design can be concurrent with technology development
  ▪ Technology data is not mature
  ▪ Lack of flexibility to account for process changes
  ▪ Effort (ROI) required to implement the design enablement
    (one process, one design)

► Possible benefits of design enablement
  ▪ Consistent way to convey technology specification and options to MEMS designers
  ▪ Enable MEMS designers to do rapid evaluation of technology options
  ▪ Rapid feasibility assessment of customer projects
  ▪ Common platform for collaborative design and technology development
  ▪ Vehicle for delivering reference designs
Overview

- Levels of Design Enablement and “MEMS PDK”
- Examples of design enablement, including CEA Leti M&NEMS platform
- Advanced enablement example based on XFAB XMB10 technology
- Conclusion and benefits
Library-Based Design: Enabling the Design Flow

Technology description
- Material properties
- Fabrication process

Library of MEMS-specific, parametric components

Assemble Device
- Export GDS2, Cadence PCells

Simulate
- MATLAB
- Simulink
- Virtuoso
- MEMS+ Simulator
- Exported Verilog-A or Simulink ROM

Visualize in 3D
Levels of MEMS Design Enablement

- **Top-Level Layout Assembly**
  - MEMS device(s)
  - Paths, PADs, frame

- **Device IP**
  - Sensor IP Blocks

- **MEMS PDK**
  - Suspension
  - Custom Models: Electrostatic element, PZ, PZE elements
  - Custom Layout Add-Ons: TSV, Path, PAD

- **MEMS+ Custom Component Library**

- **Material Database**
  - Material properties

- **Process Editor**
  - Process cross-section
Zoom-in on the MEMS PDK

**Container for all technology information**

**MEMS PDK**
- Custom Models
  - Suspension
  - Electrostatic element
  - PZR, PZE elements
- Custom Layout Add-Ons
  - TSV
  - Path
  - PAD

**MEMS+ Custom Component Library**
- Customized components, dedicated usage
- Layout export specifications

**Material Database**
- Material properties

**Process Editor**
- Process cross-section

- Reusable parameterized sub-structures
- Reusable parameterized layout cells
- Driven by Design Rules
- MPDK enforces the use of the intended material properties, based on expert definition
- Guarantees the correctness of these material properties implementation
Example of Customized MEMS Design Environment

Collaboration with CEA Leti on M&NEMS Platform
Example of Coventor and CEA Leti Collaboration

► CEA Leti M&NEMS advanced and versatile technology platform using an innovative concept, to produce small sized accelerometer, gyroscope, magnetometer and pressure sensors on the same platform.

**CEA Leti M&NEMS** technology cross-section

**Piezoresistive Nano-Gauges**

**MEMS+ accelerometer model**
Example of Coventor and CEA Leti Collaboration

► Accelerometer model assembled with customized Components

ANCHOR: Fixed Geometry
COMB fingers: Electrostatic Model
MASS: Rigid Plate
SPRING: Mechanical Beam

► NEMS Gauge: Piezo resistive, mechanical structure
- Sub-structure created by assembling Component primitives
- Validated against FEA and measurements
- Parameterized and re-usable across design

Top view of the MEMS+ Model of the M&NEMS Accelerometer
Gauge bindings are created with Shell elements, the beam is created with 5 Bernoulli beams which support the piezo resistive model, Shell Plates for the bindings and fillets.

- The gauge with bindings to the PADS in MEMS+
- The parameterized gauge element in MEMS+
Simulations of the Accelerometer Compact Model

Gauges Conductance and $y$ displacement as a function of actuation voltage

Tumble test: gauge $y$ displacement as a function of the gravity force
Simulation in Cadence Analog Design Environment

Output voltage versus actuation voltage

Tumble test: output voltage
Simulations of the Compact Model versus Measurements

Output voltage versus actuation voltage

Tumble test: output voltage versus angle

First resonance frequency quality factor versus pressure
Monte Carlo Study Outputs

Monte Carlo analysis of first resonant frequency and sensibility varying the following process variables:

- NEMS Gauge Thickness: 250nm ± 6nm
- NEMS Gauge Width: 250nm ± 25nm
- MEMS Silicon Thickness: 20µm ± 1µm
- MEMS Silicon Suspension Width: 1µm ± 0.1µm

The resonance frequency = 1954.5 Hz (±160 Hz)
Sensitivity output = -1.4115 mV/g (±0.3 mV/g)
Example of Advanced Level Design Enablement

XFAB XMB10 MEMS PDK
Levels of MEMS Design Enablement: Top-Level Layout Assembly

- Ease complex layout finishing using automation
- Enable physical verification to avoid manufacturability and connectivity issues
Example of XFAB XMB10 MEMS PDK

Coventor MEMS+ XMB10 Component Library

Single-Axis Accelerometer Core Assembled with MEMS+ XMB10 Library

ANCHOR: Fixed Geometry
MASS: Rigid Plate
COMB fingers: Electrostatic Model
SUSPENSION: Beams
SOLID FRAME: Fixed Geometry
Coventor MEMS+ Single-Axis Accelerometer Core Assembled with MEMS+ XMB10 Library

Cadence Virtuoso

MEMS core PCell imported from MEMS+

Using XMB10 PDK PCells: Add seal ring and pads

Using XMB10 PDK PCells: Add interconnect, wire crossings, fixed/moving transitions
Physical Verification with X-FAB’s XMB10 MEMS PDK

- 2D DRC of MEMS core device and final chip layout

- Avoid Connectivity issues via LVS verification
  - Comb structure recognition in the layout, matched with capacitors in the equivalent schematic
  - Verify proper connectivity to the PADS (no short, no opens, no missing vias openings ...)

Exported and finished layout in Cadence

Equivalent schematic created in Cadence using capacitors
Conclusion and Benefits

► Benefits of design enablement:
  ▪ Repository for the technology information and the design know-how
  ▪ Enables sharing between the foundry and their customers, between the process and design team of integrated manufacturers
  ▪ Enable rapid technology evaluation and exploration versus design requirements
  ▪ Parameterized environment for process description and design creation
  ▪ Customized components models, ready to be used
  ▪ Integration with EDA tools enables the sharing of the same model between the MEMS and IC designers

► Establish an interactive and flexible design enablement platform
  ▪ Easy to use development interface (no need of advanced scripting knowledge or PDK development expertise)
  ▪ Levels of Design Enablement can occur in stages, aligned with process and design maturity