CoventorMP®
MEMS Platform

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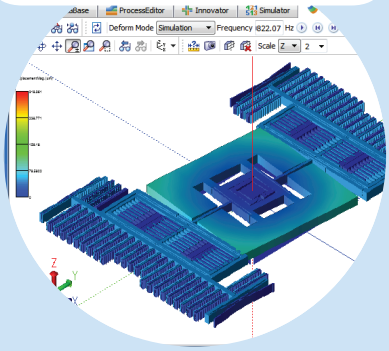
A Complete Platform for MEMS Design Automation

Addressing the Challenges of MEMS Design and MEMS/IoT Intergration

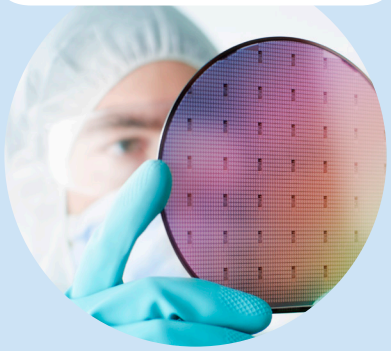
MEMS design presents specialized engineering challenges, including coupling between fabrication technology and design, complex structures with non-linear, coupled multi-physics, integration with CMOS circuits, and custom packaging requirements. Increasing demands for miniaturization and integration of MEMS in IoT devices have further increased the complexity of MEMS design. General-purpose design tools do not adequately address these challenges, contributing to missed project milestones and missed market opportunities. Coventor*MP* is a MEMS-specific design platform that enables MEMS development organizations to design, optimize and integrate MEMS more efficiently. Coventor*MP* combines the complementary strengths of Coventor's industry-leading software tools for MEMS design, CoventorWare® and *MEMS+*®, into a single, integrated MEMS design automation environment. Designs can be entered once and used to create compact finite element models (*MEMS+*) as well as conventional finite element models (CoventorWare). MEMS sensors and actuators can be seamlessly integrated into packaged systems targeted at the automotive, consumer, industrial or defense markets.

Complete Software Platform



Expert MEMS Support

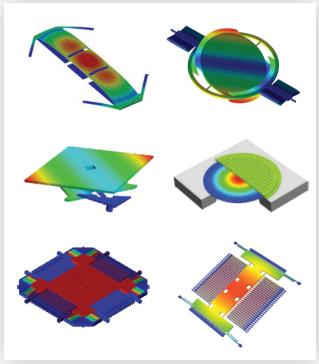
MEMS PDK Development



Applications

Coventor software is used by leading MEMS companies, foundries and R&D centers worldwide to design a wide range of MEMS, including:

- Accelerometers
- Gyroscopes
- Microphones
- Actuators
- Micro Mirrors
- Microbolometers
- Pressure Sensors
- Switches
- Resonators
- And more...



Benefits

- Accurately predict MEMS device behavior prior to fabrication, reducing costly and time consuming build-and-test cycles.
- Rapidly explore design concepts and optimize designs using compact models that simulate 100X faster than conventional finite element models.
- Run transient simulations that are infeasible with conventional, general-purpose tools due to excessive computing requirements.
- Avoid human errors introduced by manual transfer of designs between different tools.
- Automatically generate MEMS device models for Simulink® system diagrams and Cadence Virtuoso® circuit schematics, avoiding use of less accurate, hand-crafted device models.
- Design for manufacturing, using fully parametric models to investigate and reduce sensitivity to manufacturing variations.

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MEMS+®

MEMS+ provides an integrated environment for engineers who design MEMS devices and integrate MEMS with systems and circuits. It is ideal for designing and optimizing MEMS devices that depend on electrostatics for sensing and actuation. It also supports piezo-electric sensors and actuators.

CoventorWare®

CoventorWare is a suite of field solvers integrated with pre- and post-processing tools. The suite has many MEMS-specific features that make it the preferred choice over general-purpose finite element tools for simulating MEMS and other micro-fabricated devices.

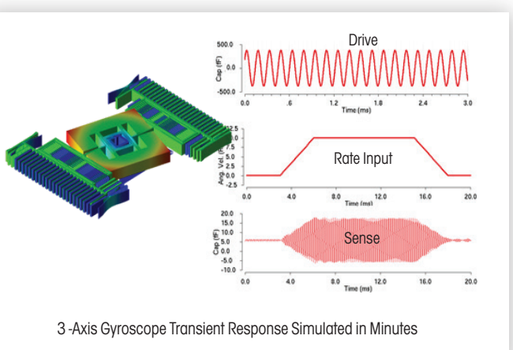
Fully Parametric Design Entry

Design entry in *MEMS+* starts with a parametric definition of the fabrication technology, including the process stack and material properties. The tool includes a library of parametric MEMS components, or building blocks, such as rigid shapes, flexible mechanical shapes, electrodes, and electorstatic combs. Custom rigid shapes can be imported from GDS2 layout. Designers assemble selected components into MEMS device models in an intuitive, 3D user interface. Everything is scriptable in MATLAB® or Python. The resulting parametric MEMS device models enable rapid, automated design studies.

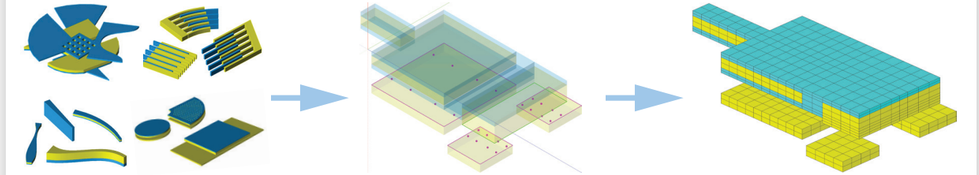
Fast Concept Exploration and Design Optimization

MEMS device models assembled from *MEMS+* components are, in fact, compact finite element models. Supported, fully coupled physics include mechanics, electrostatics, piezo layers, squeezed-film gas damping, and thermo-mechanical effects. Designers can simulate the multi-physics behavior of *MEMS+* models in the built-in Simulator, or in the MathWorks® or Cadence™ environments. *MEMS+* can automatically generate reduced-order models (ROMS) for export to Simulink and Verilog-A. Also, package thermo-mechanical effects can be imposed on MEMS devices to simulate temperature stability.

MEMS+ models are very compact in comparison to conventional finite element models. Most simulations run in a few minutes or less, as compared with hours for conventional finite element models. This simulation speed advantage together with the parametric nature of the models opens new possibilities for exploring design concepts, optimizing designs and evaluating sensitivity to manufacturing variations.



3 -Axis Gyroscope Transient Response Simulated in Minutes



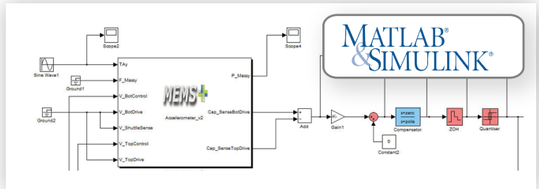
MEMS+ Parametric Component Library

MEMS+ Multi-Physics Device Model

Automatically Meshed Device Model

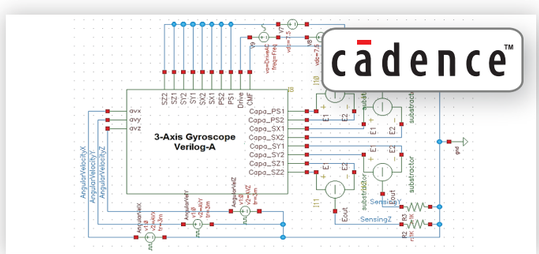
System-Level Modeling

Integration with the MathWorks environment makes it easy to automate simulations using MATLAB scripts and include *MEMS+* blocks in Simulink system models. Designers can perform DC, AC and transient simulations of the multi-physics MEMS device alone or connected with drive and read-out signals. Additional capabilities include electrostatic pull-in and lift-off analysis, and non-linear frequency response.



Circuit Modeling

Integration with Cadence Virtuoso makes it easy to import accurate *MEMS+* models and connect them with drive and read-out circuits. Designers can run DC, AC, transient and noise analyses to evaluate nominal behavior and corner cases. Also, *MEMS+* designs can be exported as Cadence parametric layout cells (PCells) for use in full-die layout and physical verification.



New Integration with CoventorMP

Export *MEMS+* device models, including material properties, to CoventorWare with one click

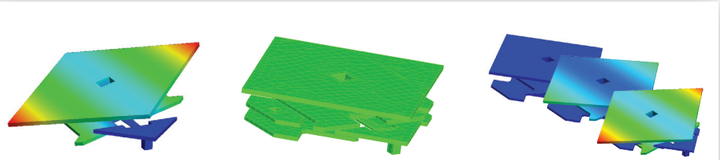
- Use *MEMS+* as a parametric front end for CoventorWare
- Investigate detailed behavior such as stress concentrations
- Create more accurate, custom models of sub-structures for *MEMS+*

Preprocessing and Meshing Optimized for MEMS

CoventorWare has many MEMS-specific features that make it easy to prepare efficient simulation models. 3D models can be built directly from layout or imported from other tools including *MEMS+*. Models can be easily partitioned based on layout to allow finer meshing in high-stress regions. To efficiently mesh the high-aspect-ratio structures typical of MEMS, it is imperative to use hexagonal (hex) elements rather than tetrahedral elements. CoventorWare includes a selection of meshing algorithms for generating hex-dominant meshes that are optimal for MEMS structures.

World-Class Coupled Electro-Mechanics

CoventorWare is widely appreciated for simulating electrostatic capacitance and force, and non-linear, coupled electro-mechanics effects such as pull-in, lift-off and electrostatic spring softening with unparalleled accuracy and efficiency. Other finite element tools require meshing the "air" gaps around moving parts, with associated mesh re-generation and robustness issues when surfaces make contact, or meshing air gaps with parallel-plate electrostatic elements that neglect electrostatic fringing fields. CoventorWare uses a hybrid finite-element/boundary-element (FEM/BEM) approach that avoids these compromises to accuracy and efficiency.



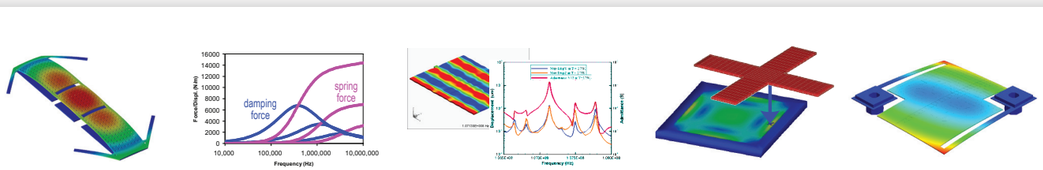
Finite Element (FEM) Non-Linear Mechanics

Boundary Element (BEM) Electrostatics – No need to mesh air

Hybrid FEM/BEM Pull-In/Lift-Off/Harmonics

Special MEMS Physics Simulation

CoventorWare has additional capabilities for fast and accurate simulations of MEMS-specific physics such as fabrication-induced pre-stress, gas damping, piezo-electric (PZE) coupling in bulk acoustic resonators, piezo-resistive (PZR) sensing, and electro-thermal effects in actuators and microbolometers.



Pre-Stress Effects on MEMS Structures

Reynolds and Stokes Solvers for Gas Damping

Fast Frequency Sweep for Piezo (PZE) Resonators

Piezo-Resistance (PZR) for PZR Sensors

Electro-Thermo Effects for Microbolometers

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Product Features

CoventorMP is a complete environment for MEMS Design Automation and MEMS/IoT integration. Product features and capabilities are available in standard *MEMS+* and CoventorWare feature bundles with various add-on feature bundles.

MEMS+ Parametric Design Entry

- Parametric Material Properties
- Parametric Process Definition
- Parametric, Customizable Component Library
- Parametric 3D Design Assembly
- MATLAB and Python Scripting Interfaces
- Layout Editor with GDS2 and DXF Import/Export
- Layout-to-3D Model Building
- 3D Model Export to CoventorWare

MEMS+

Base Features

- Parametric Design Entry (See Above)
- Device Simulation:
  - DC (Equilibrium) Analysis
  - Modal Analysis
  - Small-Signal AC (Harmonic) Analysis
- 3D Visualization and Animation
- Fully-Coupled Multi-Physics Modeling: Mechanics, Electrostatics, Gas Damping, Pressure Loads, Piezoelectric Layers, etc.

Required Options (at least one)

- MathWorks Integration
  - MEMS + System Transient Simulations
  - Complete MATLAB Scripting Interface
- Cadence Integration
  - MEMS + IC Transient Simulations
  - Noise Analysis
  - Export of Cadence Layout PCells

Add-Ons

- Advanced Sensor Modeling
  - Automatic reduced-order model (ROM) generation to Simulink and Verilog-A
  - Package thermo-mechanical effects
  - Built-in Noise Analysis
  - Pull-in/Lift-off Analysis
  - Non-linear Frequency Response
- Cadence APS support

CoventorWare

Standard Features

- Material Properties and Process Entry
- Layout Editor with GDS2, DXF Import/Export
- Layout-to-3D Solid Modeler
- Preprocessor for Model Preparation
  - Automatic Meshing
- Finite Element Solver
  - Mechanics, Thermal, Thermo-Mechanics
  - Equilibrium, Modal, Harmonic, and Transient Analysis
  - Detailed Stress Field Analysis
- Boundary Element Solver
  - Electrostatic Force, Capacitance
- CoSolve quasi-static coupled electro-mechanics
  - Pull-In, Lift-Off, Electrostatic Spring Softening
- Result Visualization (2D, 3D, and Data Queries)

Add-Ons

- Ansys Mesh Export (.CDB)
- MEMS Extended Analysis
  - Piezoelectric (PZE) effects, including fast frequency sweep for BAW resonators
  - Piezoresistance (PZR) effects for PZR sensors
  - Gas Damping – Reynolds and Stokes Solvers

MEMS Process Design Kits (PDK)

A MEMS PDK can help MEMS foundry customers create "first time right" designs for a proven MEMS technology, saving development costs and reducing time to market for the foundry and its customers. Coventor is partnering with leading MEMS foundries to develop MPDKs. Coventor provides MPDK development services as well as applications support to help foundries leverage their proven MEMS technologies.

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