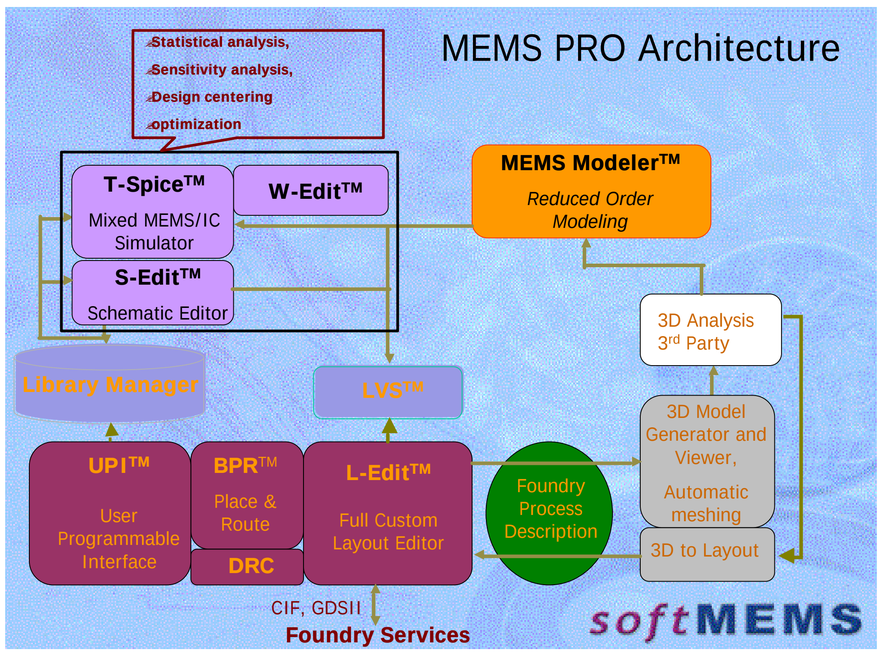
An illustrated approach to DfM for MEMS by softMEMS



Design for Manufacturing Tools through the design flow :

- Schematic level / parameterized behavioral modeling level :
  - –Monte Carlo analysis, sensitivity analysis,optimization (including IC design if necessary)
- Layout :
  - –Test structures libraries
  - –Design verification (DRC, LVS)
- 3d model generation
  - –Cross section view and 3D inspection
  - –Quick generation of geometry and meshing allows faster multi-simulations tasks
  - –Model reduction for system level simulations

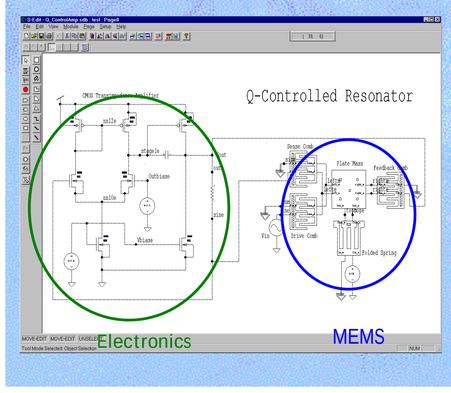
SENSITIVITY ANALYSIS :

- Sensitivity calculation: parameters contribution to performance
- Sensitivity analysis is performed to investigate influence of individual parameters on the device behavior
- Easy set up : parameter sweep simulations
- May help designers to indicate to foundry what process parameters must be closely watched

- MEMS and IC models to take into account all process variations on :
  - Material properties,
  - Thermal coefficients,
  - Etch rate ratios, over-etch variations.

Combined MEMS & IC Schematics

- Schematics can contain both IC and MEMS modules
  - IC modeled using standard IC models
  - MEMS modeled using behavioral macro models
- Component library
  - Behavioral models for standard MEMS components



- Simulation of MEMS Macromodels at ODE Level
- Model Representation
  - Equivalent Circuit Models
  - Functional Models
  - Table Based Models
- Transient/DC/AC Analysis
- Parametric Analysis

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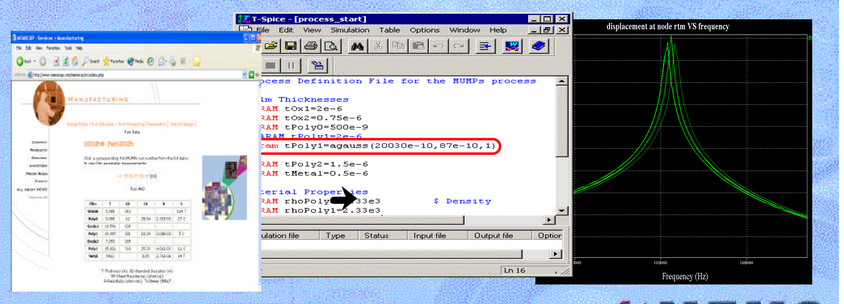
Statistical Analysis

- Statistical analysis based on process/mask variations
  - Incorporates statistical data from foundries into models
  - Develop process corners for simulation
  - Monte Carlo analysis



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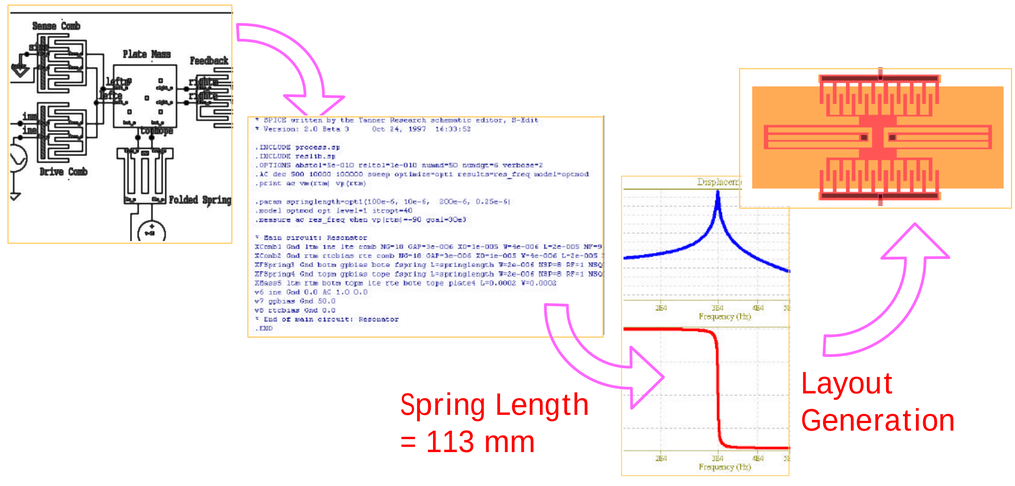
Optimization

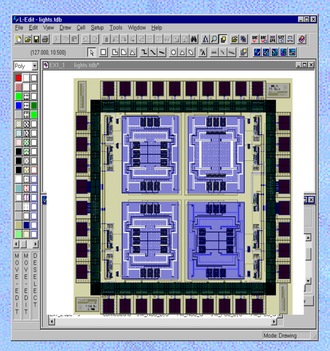
Example: Optimize springlength using mimimum area with resonant frequency = 30 KHz



Basic Bricks at the Layout Level

- Design Rules Checking
- Parameters and Parasitic Extractions
- Layout Versus Schematic
- 3D Modeling

Verification- Extraction



Extract →

```
* Project EXAMPLE3, FILE2
.INCLUDE 'MODELS.SPC'
M1    1  2  3  4 PSS L=2 W=5
M3    1  2  3  4 PSS L=2 W=5
M10   4  5  6  4 PSS L=2 W=5
M11   5  7  3  4 PSS L=2 W=5
M12   8  7  2  4 PSS L=2 W=5
C1    0  4     12pF
.END
```

- Extraction produces a multi-domain netlist of listing of MEMS devices and their connections
- Device is accompanied by listing of relevant parameters- geometry or higher level – C, N of. Comb fingers etc.
- Extraction also produces a set of lumped parasitic elements – capacitances and resistances on each signal or control line
- Values are computed from the geometry and process variables- layer thickness and dielectric constants

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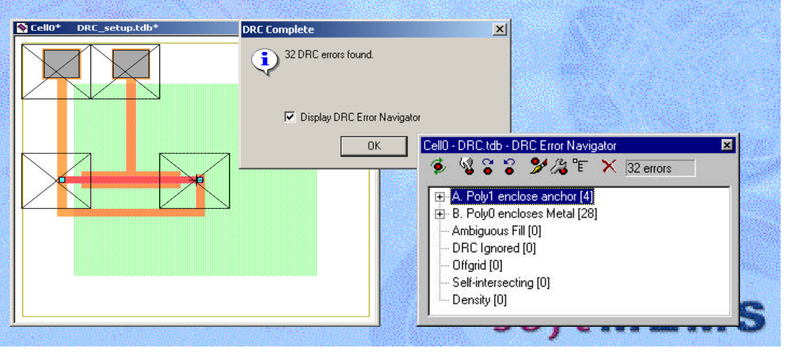
DRC- Design Rule Checking

- DRC set up to check manufacturing rules, spacing, surround, size, etc.
- Supports context sensitive rules- e.g. Number of etch holes per area on plates necessary to make sure plate is released.
- Supports device specific rules e.g. placement of stator over ground plane on motor



5TH ROUND TABLE ON MICRO/NANO TECHNOLOGIES FOR SPACE

October 3-5, 2005, Noordwijk, The Netherlands

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