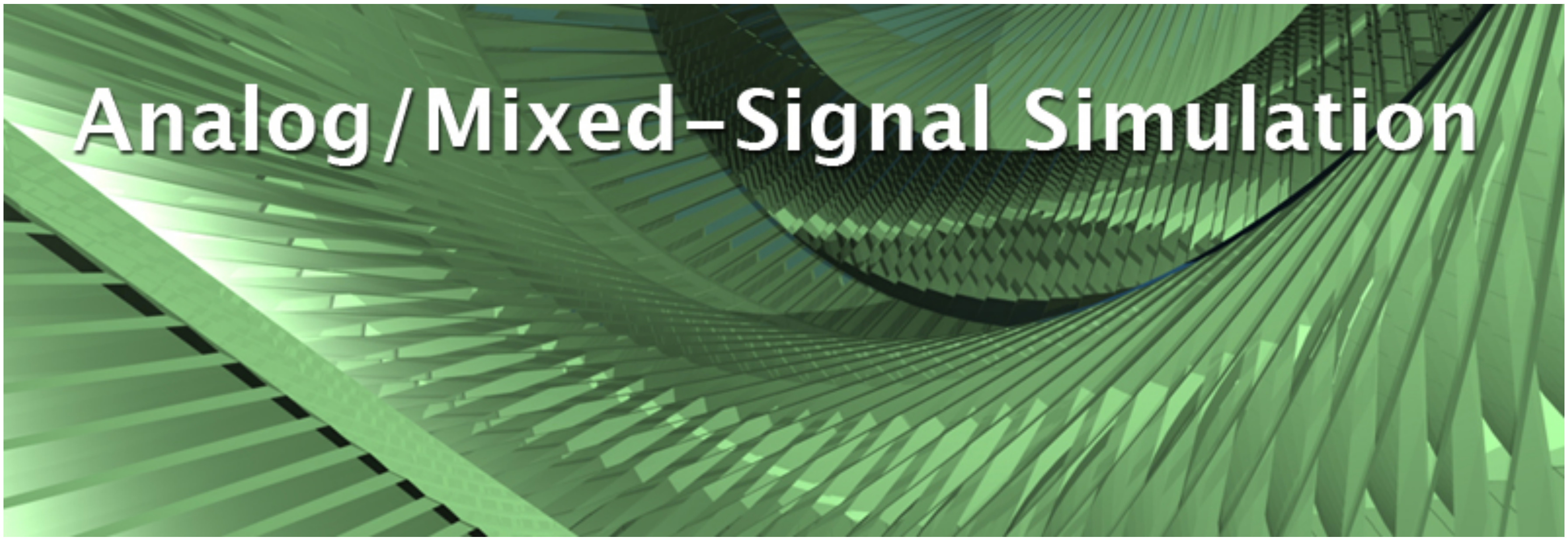
SmartSpice Training Program



Part 4: SmartSpice Optimizer

MULTI CORE PDK TOKEN WORLD LICENSE

SILVACO

What Is SmartSpice Optimizer?

- The SmartSpice Optimizer is a fully integrated feature of SmartSpice that performs parametric optimization of circuits
- At the core of the optimizer, is a general purpose optimizing engine that requires initial and target parameter values to be set
- The optimizer then iterates these parameters until the target values are reached
- The optimizer provides a comprehensive interface and an interactive display system for visualizing the optimization process as it is executed

What Is SmartSpice Optimizer? – Performance Measure Optimization

- In performance measure optimization, the values and parameters of circuit components are automatically altered so that individual electrical characteristics meet specifications
- The Optimizer can fine-tune delay, rise/fall times, trip point, maximum and minimum current, and any other circuit performance measurement that can be calculated by a SmartSpice .MEASURE statement
- Simultaneous multi-target optimization of several performance measures is also possible

What Is SmartSpice Optimizer? - Function Optimization

- Function optimization matches calculated curves with desired curves for DC, AC, and transient analyses. The desired curves can represent the results of theoretical research or physical measurement
- There are no restrictions on the type of circuit analysis that can be performed. Circuits can be optimized in steady state, frequency, and time domain

Optimizer Using `.MODIF`

- The `.MODIF` statement is a powerful design feature, which can be used to perform **parametric optimization** and **statistical analysis**
- Two stop conditions are available to investigate a circuit for sets of parameters that change over a specified range:
  - A limit on the number of repetitions of an analysis.
  - A logical condition on a circuit performance measurement
- A parameter set contains any number of the following parameter types:
  - parameter labels defined in a global `.PARAM` statement
  - model parameters
  - device parameters
  - temperature parameters
  - parameter GMIN/DCGMIN

SmartSpice Optimizer Syntax

- To perform optimization in SmartSpice, the .MODIF statement must be used. For a circuit with a known topology, the .MODIF statement allows you to:
  - Solve a separate optimization problem
  - Sequentially solve several optimization problems
  - Sequentially solve optimization problems and perform parametric analysis
- **Syntax**

```
.MODIF <PROFF> <PRTBL> <RESTORE> <constpar_spfc>+ OPTIMIZE
param_spfc + TARGETS targ_spfc + OPTIONS <opt_spfc>
<<modif2_spfc> ... >
```

- **`PROFF:`** This flag suppresses online printing of .MEASURE statement results
- **`PRTBL:`** This flag causes SMARTSPICE to print the final table of parameter and measure values obtained from all iterations
- **`RESTORE:`** This keyword causes SMARTSPICE to restore all modified parameters in the specified set to their original values
- **`constpar_spfc:`** Definitions for all parameters that will be held constant through the optimization process
- **`OPTIMIZE:`** This keyword is followed by the list of optimization parameters
- **`param_spf:`** Definitions for all parameters that will be changed during optimization. For each parameter a minimum, maximum, and initial value must be specified

SmartSpice Optimizer Syntax (cont)

- `TARGETS:` This keyword is followed by the list of targets for optimization
- `targ_spf`: Definition of all targets that will be optimized. For each target, the name of a measured and a desired value must be specified
- `OPTIONS:` This keyword is followed by the list of optimization control options
- `opt_spfc:` Optimizer control options. You can specify an option and value to replace a default option
- `modif2_spfc:` This definition follows the keyword MODIF. The procedure defined here is called immediately after the final iteration of the current optimization. The procedure could be another optimization or a parametric analysis. In either case, the circuit parameters correspond to those just calculated by the current optimization

SmartSpice Optimizer Input Deck

- A typical input deck created for optimization contains:
  - One or more analysis statements to simulate a circuit in either steady state, frequency, or time domain
  - One or more `.MEASURE` statements to calculate performance measurements or differences between simulated and desired curves
  - One or more `.DATA` statements to describe desired curves for function optimization
  - One or more `.PARAM` statements to define parameter labels if needed
  - A `.MODIF` statement to define the names of device and model parameters; their minimum, maximum and initial values; targets; and control options for optimization
  - A `.IPLOT` statement to plot output variables while the optimization is in progress

SmartSpice Optimizer Input Deck (con't)

- In order to match circuit specifications, the Optimizer performs a number of iterations, beginning with the user-defined initial values of parameters
- On each iteration, the Optimizer simulates the circuit, calculates target electrical specifications, updates parameters using defined mathematical strategies, and simulates the circuit again
- The Optimizer will stop the optimization process when one or more of the stop criteria specified in the Optimizer control statements is satisfied
- If SmartSpice is running in window mode, the intermediate results of the optimization process are immediately visible
- SmartSpice allows you to observe the history of parameter, and target values obtained from all iterations
- A Stop button can be used to stop the optimization process on any iteration; change parameter values, targets, or control options; and continue the optimization process from the last parameter values calculated

Timing Optimization Using Bisection

- Bisection is a method of optimization that uses a binary search to find the value of an input variable for specified value of an output variable (goal)
- Over some interval the function is known to pass through goal value because “function value - goal” changes sign
- Evaluate the “measured function value - goal” at interval’s midpoint and examine its sign
- Use the midpoint to replace whichever limit has the same sign
- After each iteration the bounds containing the root decrease by factor of two
- When the size of interval (distance between bounds) is within the error tolerance and latest “measured function value” > “goal”, bisection has succeeded, and stop
- **Note**: Bisection search is applied to only one parameter

SmartSpice Bisection Optimization Syntax

```
.MODIF <PROFF> <PRTBL>
+ OPTIMIZE parname = OPT(lower upper <initval>)
+ TARGETS measname = goalval
+ OPTIONS METHOD=val <MAXERR=val> <NUMITER=val>
```

- **PROFF**: This flag suppresses online printing of .MEASURE statement results.
- **PRTBL**: This flag causes SMARTSPICE to print the final table of parameter and measure values obtained from all iterations.
- **OPTIMIZE**: This keyword is followed by the bisection optimization parameter.
- **parname**: Name of the bisection optimization parameter.
- **OPT**: Mandatory keyword followed by lower, upper and initval in parentheses.
- **lower**: Left bound for bisection optimization parameter.

SmartSpice Bisection Optimization Syntax (con't)

- **upper:** Right bound for bisection optimization parameter.
- **initval:** Initial value for bisection optimization parameter. Default initval=(lower+upper)/2
- **TARGETS:** This keyword is followed by the target for optimization
- **measname:** Name of the measure calculated by a .MEASURE statement. It can be a circuit performance measure like delay, rise/fall time, maximum/minimum value, or difference between a desired and a simulated curve calculated by the ERR .MEASURE statement
- **goalval:** Goal value.
- **OPTIONS:** This keyword is followed by the list of optimization control options

SmartSpice Bisection Optimization Syntax (con't)

- METHOD=val: Keyword to indicate which bisection optimization method to use:
  - 1. Bisection method, the measure results for lower and upper bounds of optimization parameter must be on opposite sides of goal value
  - 2. PASSFAIL method, the measure must pass for one limit and fail for the other limit
- MAXERR=val: Relative optimization parameter error tolerance. When the difference between the two latest test input values is smaller, then:
  - parTol = max(interval x MAXERR, 10E–16)
- where:
  - Interval = max(initval - lower, upper - initval)
  - Bisection optimization process will be terminated. Default is 0.01
- NUMITER=val: Maximum number of iterations. The bisection optimization process will be terminated, when the number of iterations reaches:
  - ITERlimit = max (log(1 / MAXERR) / log(2) + 10, NUMITER)
  - Default is NUMITER=15.

SmartSpice Bisection Optimization Syntax (con't)

- **Example**:

```
.PARAM vddv=5
.PARAM DelayTime=0
.MODIF
+ OPTIMIZE DelayTime = OPT(0.0n, 5.0n, 0.0n)
+ TARGETS MaxVout = vddv
+ OPTIONS METHOD=1 MAXERR=1.e-3 NUMITER=20
.MEASURE TRAN MaxVout MAX ‘vddv-v(D_Output)’
```

HSPICE Compatibility Syntax

- **Example**:

```
.PARAM vddv=5
.PARAM DelayTime=0
.MODIF
+ OPTIMIZE DelayTime = OPT(0.0n, 5.0n, 0.0n)
+ TARGETS MaxVout = vddv
+ OPTIONS METHOD=1 MAXERR=1.e-3 NUMITER=20
.MEASURE TRAN MaxVout MAX 'vddv-v(D_Output)'
```

HSPICE Compatibility Syntax

- **parname**: Name of the Bisection optimization parameter
- **OPTxxx**: Optimization parameter reference name must agree with the OPTxxx name given in the .TRAN statement associated with the keyword OPTIMIZE
- **initval**: Initial value for bisection optimization parameter
  - Default is initval=(lower+upper)/2
- **lower**: Left bound for bisection optimization parameter
- **upper**: Right bound for bisection optimization parameter
- **OPTIMIZE**: This keyword is followed by the Bisection optimization parameter
- **RESULT**: This keyword is followed by the target for optimization
- **measname**: Name of the measure calculated by a .MEASURE statement. It can be a circuit performance measure like delay, rise/fall time, maximum/minimum value, or difference between a desired and a simulated curve calculated by the ERR .MEASURE statement
- **MODEL**: This keyword is followed by the optimization model.
- **modname**: The model name. It is used by Bisection optimization to reference a particular model

HSPICE Compatibility Syntax (con't)

- METHOD: Keyword to indicate which bisection optimization method to use. Default is BISECTION
- BISECTION: The measure results for lower and upper bounds of optimization parameter, must be on opposite sides of goal value
- PASSFAIL: The measure must pass for one limit and fail for the other limit
- RELIN=val: Relative optimization parameter error tolerance. When the difference between the two latest test input values is smaller, then:
- parTol = max(interval x RELIN, 10E-16)

where

  - Interval = max(upper – lower),
  - and for "=" relation case
  - |val – goal|<max(|goal| x RELIN, 10E-16) with val > goal,
  - Bisection optimization process will be terminated. Default is RELIN value is 0.001.
- **`ITROPT=val`**: Maximum number of iterations. The Bisection optimization process will be terminated, when the number of iterations reaches:
  - ITERlimit = max(log(1 / MAXERR) / log(2) + 10), ITROPT)
  - Default is NUMITER=20
- **`GOAL=val:`** Goal value. Default is 0

SILVACO

HSPICE Compatibility Syntax (con't)

- **Example**:

```
.PARAM vddv=5
.PARAM DelayTime=Opt1(0.0n, 0.0n, 5.0n)
.TRAN .1n 8n
+ SWEEP OPTIMIZE = Opt1 RESULT = MaxVout MODEL =
 OptMod
.MODEL OptMod OPT METHOD=BISECTION
.MEASURE TRAN MaxVout MAX 'vddv-v(D_Output)' Goal =
 'vddv'
```