How to improve ICCAP's ability to generate scalable bipolar compact models

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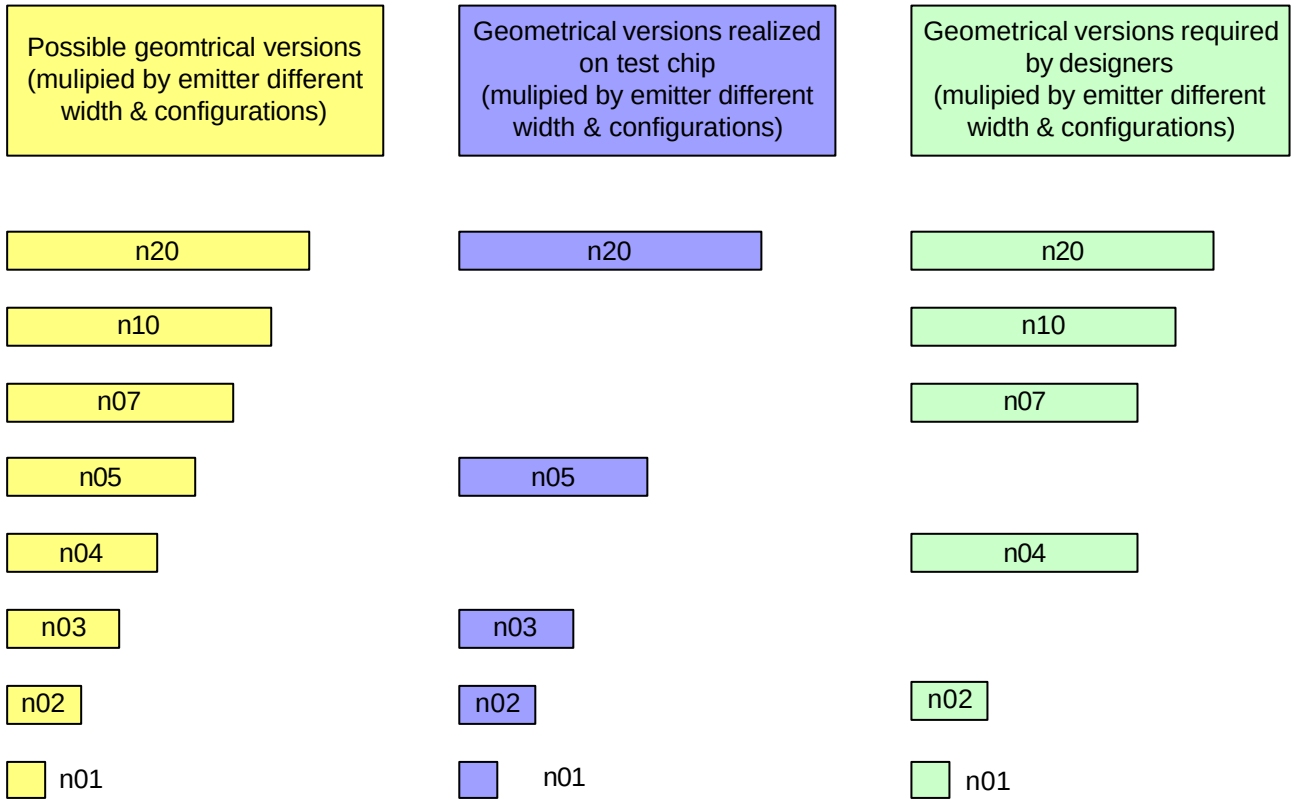
Bipolar Modeling Approach at Infineon
Why bipolar scaling ?

- There'll be ever a difference between possible, realized and required devices (by designers)
- Example: need for scaling to create models for n04, 07,10



Bipolar Modeling Approach at Infineon
What is a scalable model ?

- To avoid confusion, we should start with some definitions:
- MOS compact model: one model for all geometry's
- MOS compact model is scalable via W and L, which are design parameters

- Bipolar compact model: one device = one model par. set
- Library of model parameter sets is created, each with fixed We and Le, which are NOT design parameters
- Bipolar compact model is scalable, if it employs equations, that allow to find out scaling rules for the model parameters
- Scalability of a bipolar compact model is first of all important for the model engineer, not for the designer

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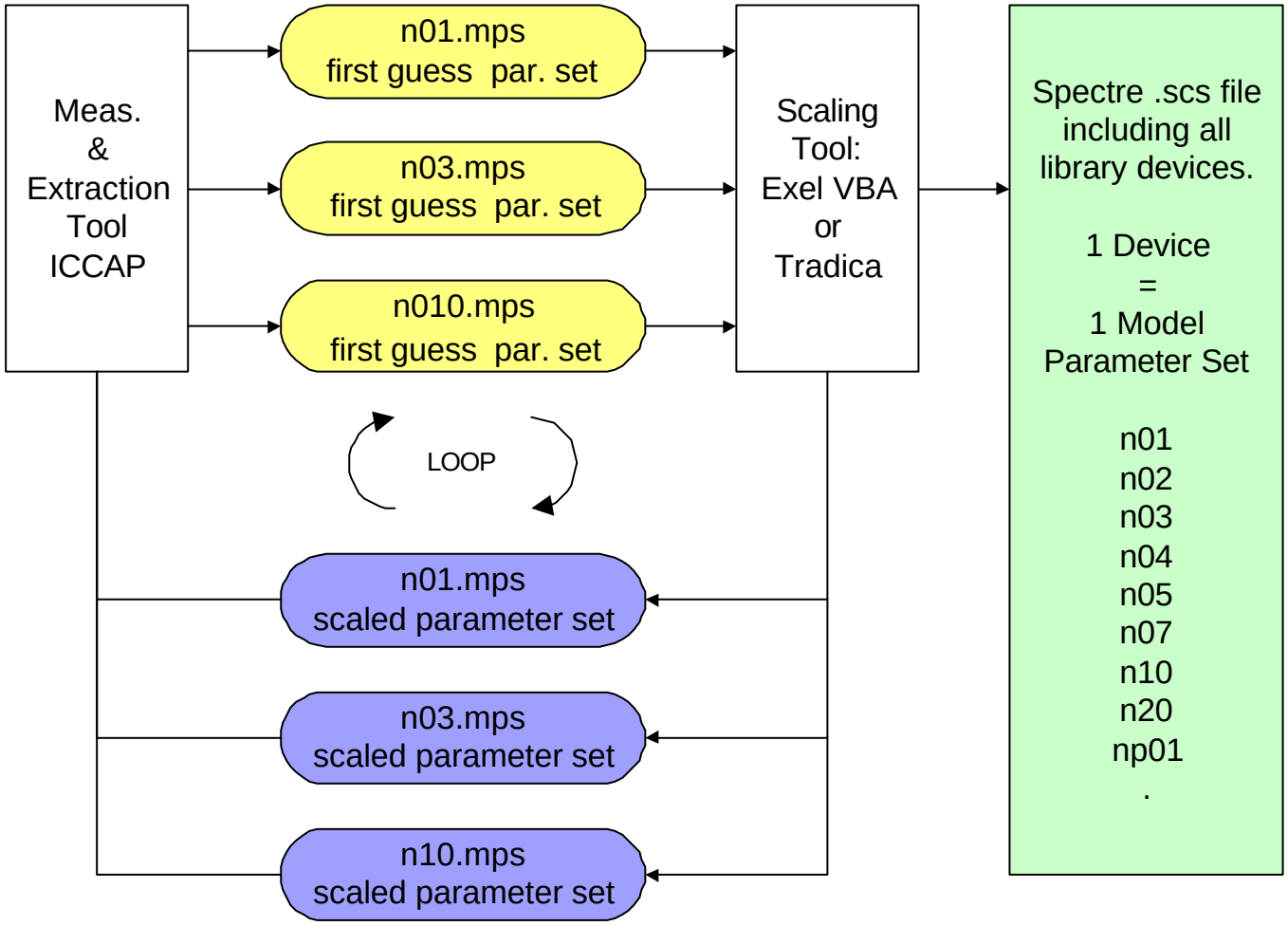
Overview



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Bipolar Modeling Approach at Infineon
Detailed Steps: first guess parameters

- Measure transistors and special test structures using ICCAP
- Definition of geometrical dimensions using Excel
- Extract certain absolute model parameters from transistor characteristics for each device using ICCAP, e.g. IS, BF
- Extract specific model parameters from measurements on special test structures using ICCAP and / or Excel, e.g. cje_area, cje_peri
- Extract specific model parameters based on theoretical equations and technological values using Excel, e.g. specific BE overlap capacitance cbeox_p
- write .mps files with first guess parameters for each measured transistor using ICCAP
- read in extracted first guess parameters into Excel

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Detailed Steps: optimization loop

- Loop start
- Analysis of extracted model param's vs. geometry, creating scaling equations for (hopefully) each model parameter (Excel)
- Insert specific param's extracted using other Excel sheets
- Calculation of scaled model parameters using Excel
- Write scaled .mps - files from Excel
- Read in .mps to ICCAP, run simulations. This step has to be repeated for each measured device.
- Compare simulated and measured curves for all measured devices in ICCAP
- Draw conclusions for changing specific param's
- Back to "Write scaled .mps from Exel"

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Bipolar Modeling Approach at Infineon
Detailed steps: Writing the design system parameter file

- At the very end of the parameter extraction process, the modeling engineer has to create a model parameter file for the design system
- This file has to include the model parameters for all devices, that are intended to be part of the library
- This file must agree with syntax requirements, that are different for different design systems and simulators
- The file consists usually of
- a file-header
- a model parameter section
- a subcircuit section
- a file-end

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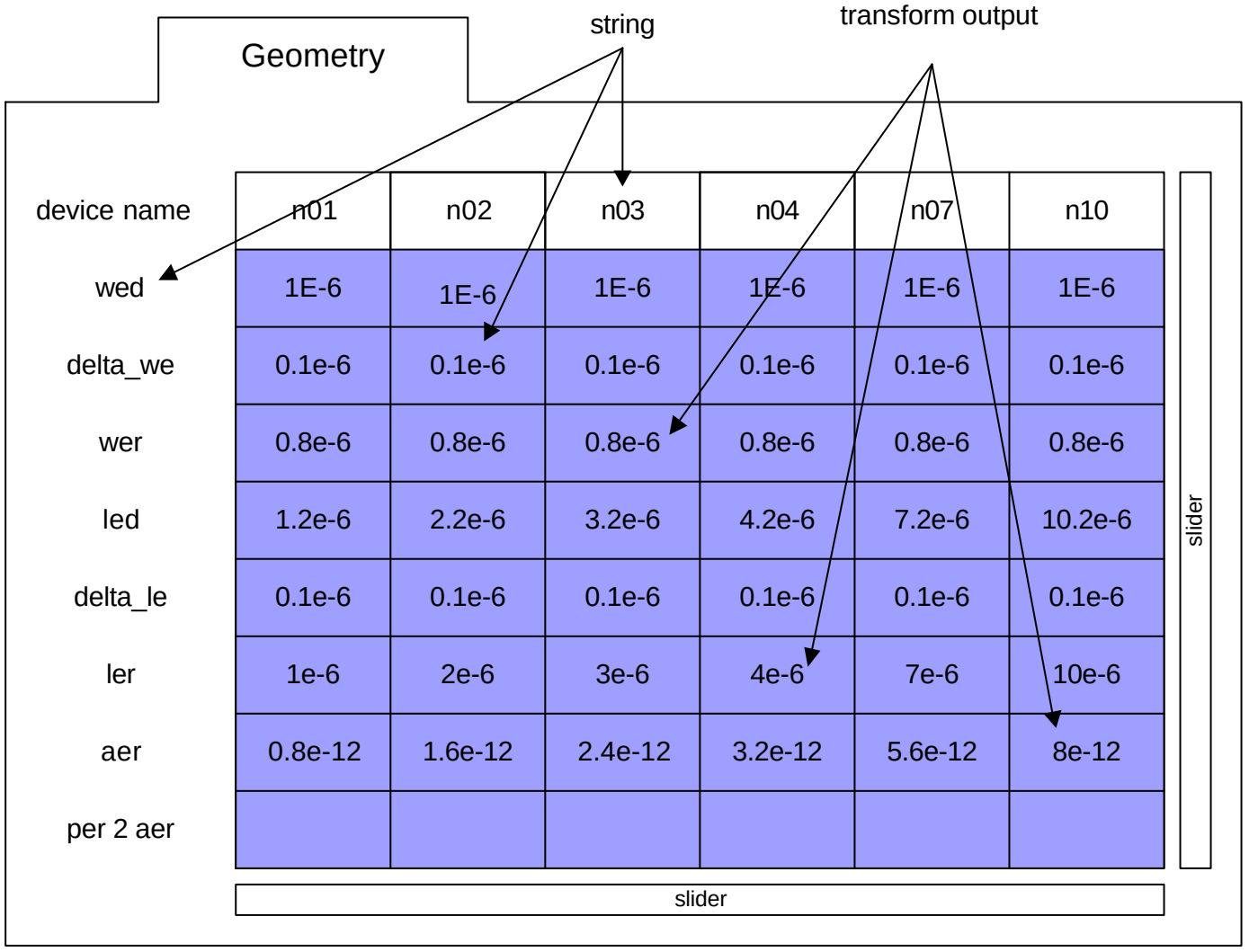
How this scaling approach may be realized in ICCAP ? New model tables

- The scalable Modeling approach may be realized in ICCAP using the following proposals:

- Introduction of a new geometry table
- Introduction a of new specific parameter table
- Introduction of a modified model parameter table

- This modified model parameter table includes more than one column, resulting the possibility to hold more than on model parameter set at the same time in ICCAP
- Introduction of additional model variables for selection of the appropriate parameter set

How this scaling approach may be realized in ICCAP ?
New geometry parameter table (1)



How this scaling approach may be realized in ICCAP ? New geometry parameter table (2)

- This table is used to define and / or calculate geometrical values, that are necessary for scaling of model parameters. It includes all devices, that is, both the test devices for measurements and the library devices.
- All fields of the geometry parameter table spread sheet may contain a string, number, an equation or a result of a transform, to be able to calculate arbitrary geometrical values.
- Important: the number of columns, used in the geometry table, defines the number fo columns for specific model parameter and the model parameter table too, that is, the spreadsheet of all three tables are of the same dimension
- The calculated geometrical values must be available for calculations in the model parameter table by an column / row index or (better) by the name of the geometrical value, e.g. wer for emitter width real

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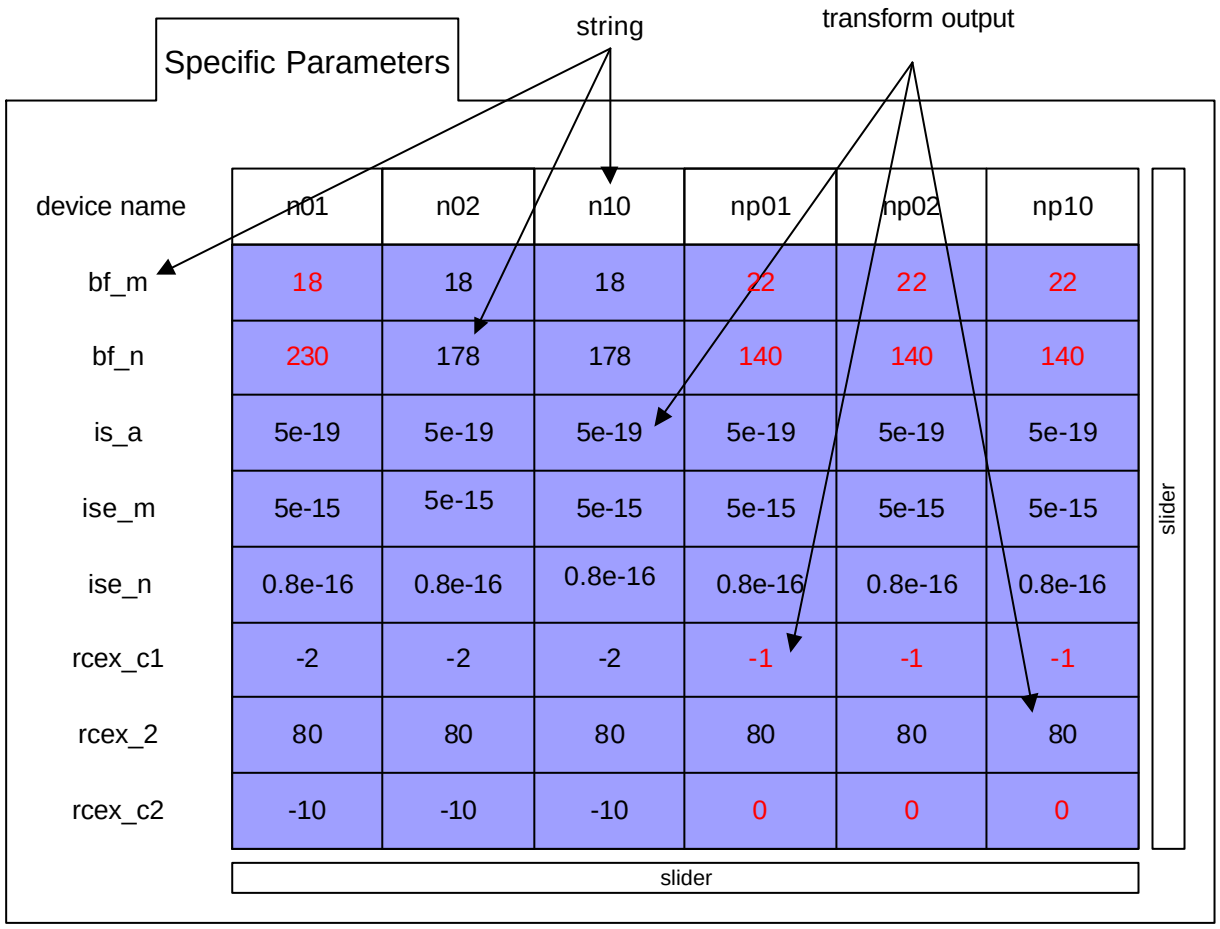
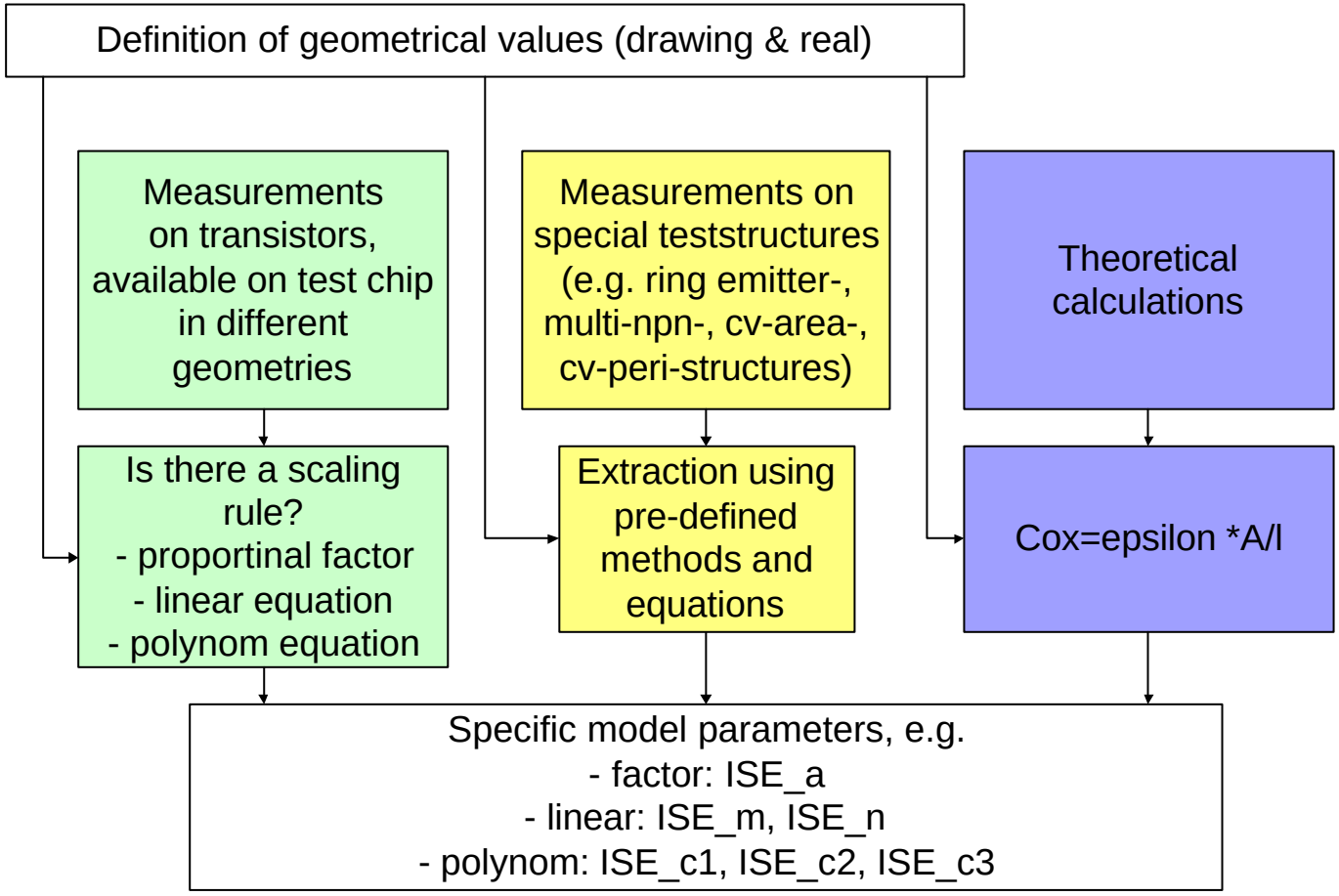
How this scaling approach may be realized in ICCAP ?
New specific parameter table (1)



How this scaling approach may be realized in ICCAP ? New specific parameter table (2)

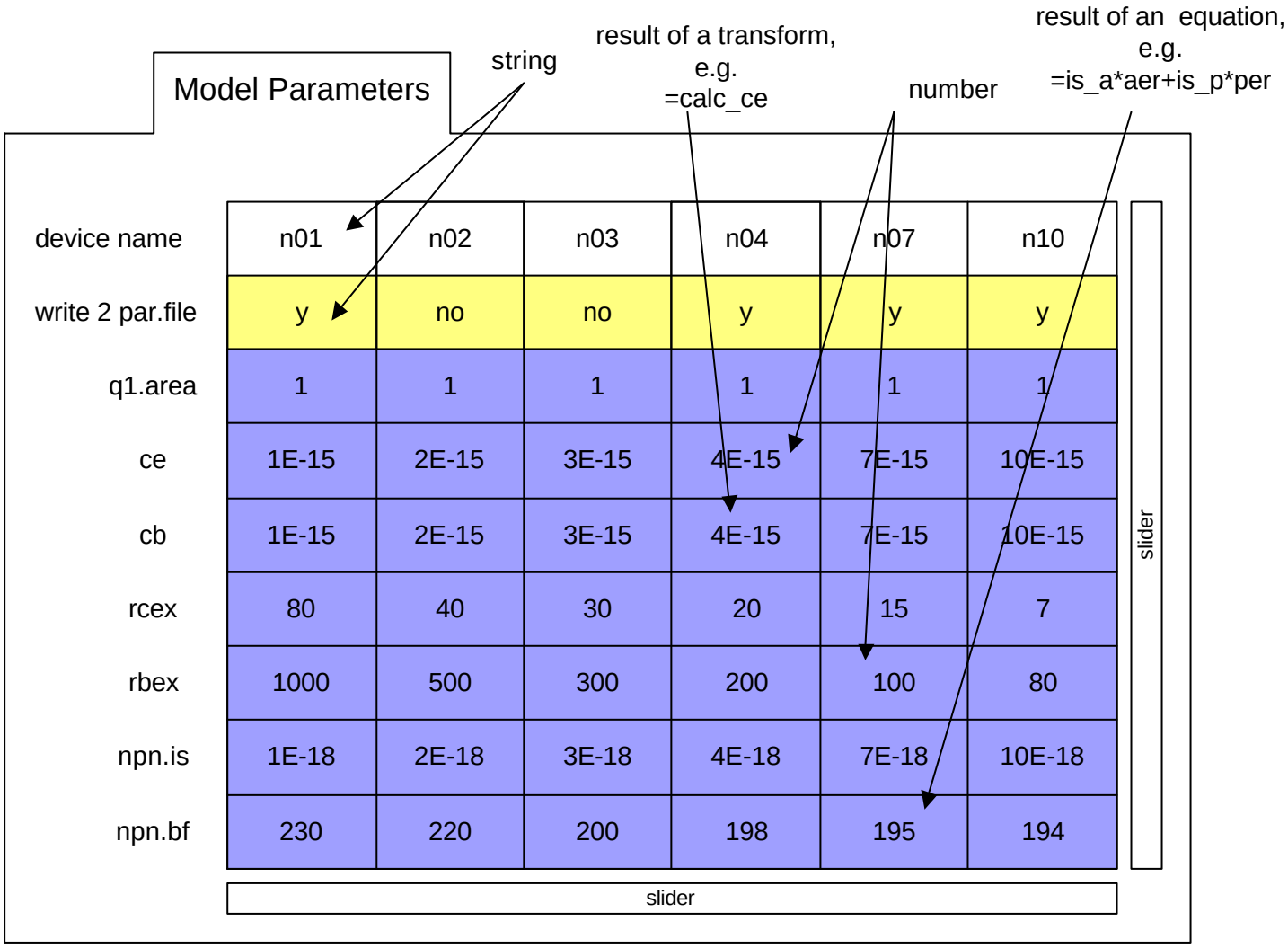
- There are different way's to get specific parameters



How this scaling approach may be realized in ICCAP ? New specific parameter table (3)

- The specific model parameter table contains the specific model parameters
- Number of columns same as for the geometry table
- Specific parameter table must be a spread sheet too, because for different device groups or for single devices different specific parameters may be necessary
- The cell's must be simple available for calculations in the model parameter table by an column / row index or (better) by the name of the specific parameter, e.g. is_a for the specific area component of the saturation current
- All fields of the specific parameter table spread sheet may contain a string, number, an equation or a result of a transform

How this scaling approach may be realized in ICCAP ?
New model parameter table (1)



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How this scaling approach may be realized in ICCAP ? New model parameter table (2)

- The new model parameter table contains a table instead of one column only. In this way ICCAP is is able to hold more than one model parameter set at the same time
- All fields of the model parameter table spread sheet may contain a string, number, equation or a result of a transform
- Need for selection, using new variables (default =1), e.g.: “Simulate_with_parameter_set=1,2,3…”, “Write_parameter_set=1,2,3…”, “Read_parameter_set=1,2,3…” etc.
- New variables may be used at setup-, dut- or model-level
- It is necessary to differ the scaled model parameters from the extracted parameters, using two types, e.g. (is.e for extracted and is.s for scaled)

How this scaling approach may be realized in ICCAP ? Writing the design system parameter file

- Model parameter file may be created using a transform, in which header, parameter section and subcircuit are defined, using a loop to read all parameter values for devices, that are selected for write
- For writing the model parameter file it must be possible:
- to select a subset of transistors for writing, using the row “write to parameter file” on model parameter table spread sheet
- to change the first parameter name (main.is -> npn.is)
- to change the case (main.is -> MAIN.IS)
- to format the numbers (2.3122e-13 -> 2.3e-13)
- to change the notation. A new model variable “Use_exponential_notation” is necessary to avoid problems reading the prefixes m, M, µ etc. in the scs-file by spectre

Summary

- ICCAP's ability for scaling of bipolar devices may improved by introduction of three new tables: a geometry, a specific parameter and a modified model parameter table.
- The goal is to realize inside ICCAP the following process :
- Defining geometrical dimensions using technological information and appropriate equations
- Analyzing measurement data oft transistors and special test devices for finding scaling equations
- Extraction of specific model parameter (normalized values) from measurements and / or calculations
- Calculation of scaled model parameters (absolute values) using the scaling equations
- Optimization of both specific and scaled model parameters
- Writing the model parameter file for the design system