Spice3 library for Modelica

- Overview-

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Spice3 library for Modelica

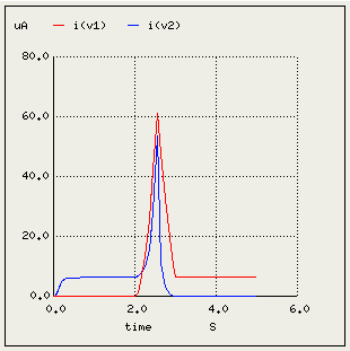
The simulator SPICE3

SPICE3
Simulation Program with integrated Circuit Emphasis

SPICE-netlist

```
inverter

Mp1 12 1 13 12 MPmos L=5U W=2U
Mp2 22 13 23 22 MPmos L=5U W=2U
Mn1 13 1 0 0 MNmos L=5U W=2U
Mn2 23 13 0 0 MNmos L=5U W=2U

Vgate 1 0 PULSE(0 5 2s 1s)
Vdrain 11 0 PULSE(0 5 0s 1s)
V1 11 12 0
V2 11 22 0

.model MPmos PMOS (ld=0.8u vt0=1 )
.model MNmos NMOS (lambda=0.02
kp=3.1e-5)

.tran 0.01 5

.control
run
set options no break
plot  i(v1) i(v2)

.endc
.end
```

simulator SPICE



types of analysis:
transient
DC
AC

SPICE3 – predefined model set

Basics

R, C, L, G
linear controlled sources

Lines

U-Line, O-Line, T-Line

Sources (Current, Voltage)

Constant
Pulse
Damped Sine
Exponential
Piecewise linear

Semiconductors
Resistor
Capacity
Diode
Junction field effect transistor (JFET)
Metal semiconductor field effect transistor (MESFET)
Metal oxid semiconductor field effect transistor (MOSFET)

			min. Length/ µm
Level 1	MOS1	(Shichman-Hodges)	5
Level 2	MOS2	(more realistic)	2
Level 3	MOS3	(semi-empirical)	1
Level 4	BSIM1	(Berkely Short Channel IGFET M.)	0.8
Level 5	BSIM2		0.35
Level 6	MOS6		
Level 7/8	BSIM3	(scalable)	0.25

Bipolar Junction Transistor (BJT)
Ebers-Moll, Gummel-Poon

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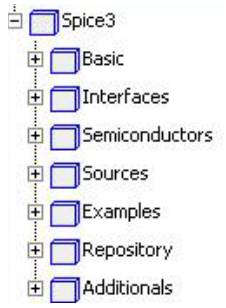
Bipolar Junction Transistor (BJT)
Ebers-Moll, Gummel-Poon

- will be translated to Modelica

Spice3 library for Modelica

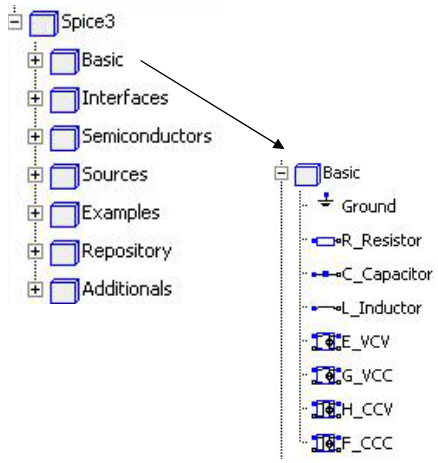
Structure of the library

Spice3 library for Modelica
- structure -



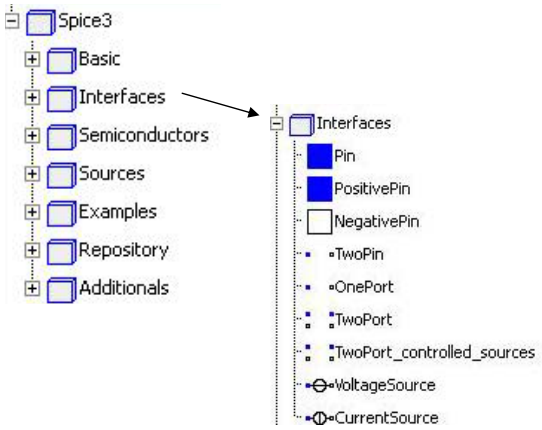
the library contains:
- basic elements
- interfaces
- semiconductors
- sources
- examples
- a repository (not for users)
- additionals

Spice3 library for Modelica
- structure -



the package basic contains:
- ground
- resistor
- capacitor
- inductor
- controlled sources
  - voltage controlled voltage
  - voltage controlled current
  - current controlled voltage
  - current controlled current

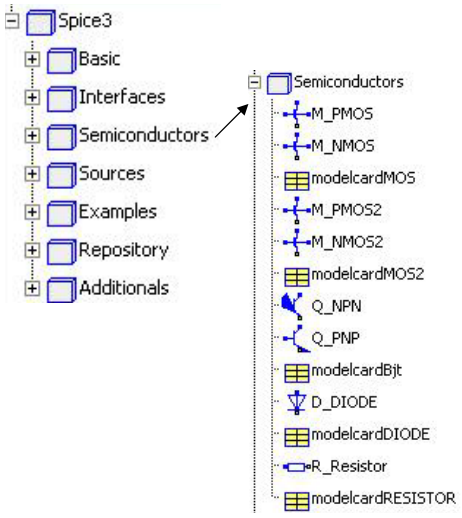
Spice3 library for Modelica
- structure -



the package interfaces contains:
- pins (positive, negative)
- TwoPin
- OnePort
- TwoPort
- TwoPort_controlled_sources
- voltage source
- current source

The Spice3 library is compatible to MSL.Electrical.Analog.

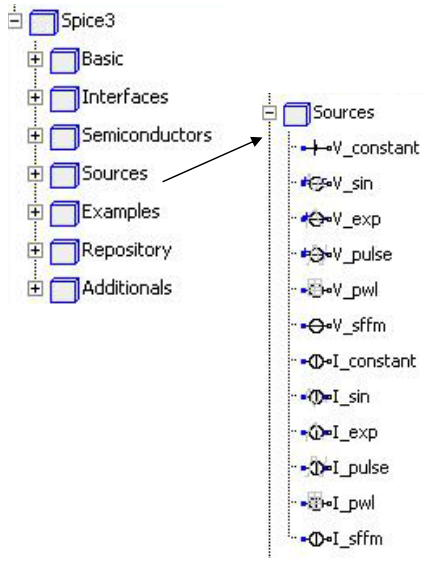
Spice3 library for Modelica
- structure -



the package semiconductors contains:
- mosfet transistor level 1 (PMOS, NMOS)
- mosfet transistor level 2 (PMOS, NMOS)
- modelcards for mosfet transistor level 1 and 2
- bipolar transistor (NPN, PNP)
- modelcard for bipolar transistor
- diode
- modelcard for diode
- semiconductor resistor
- modelcard for semiconductor resistor

Modelcards are typical for SPICE. They contain the so called technology parameters which are adjustable for more than one model at the same time.

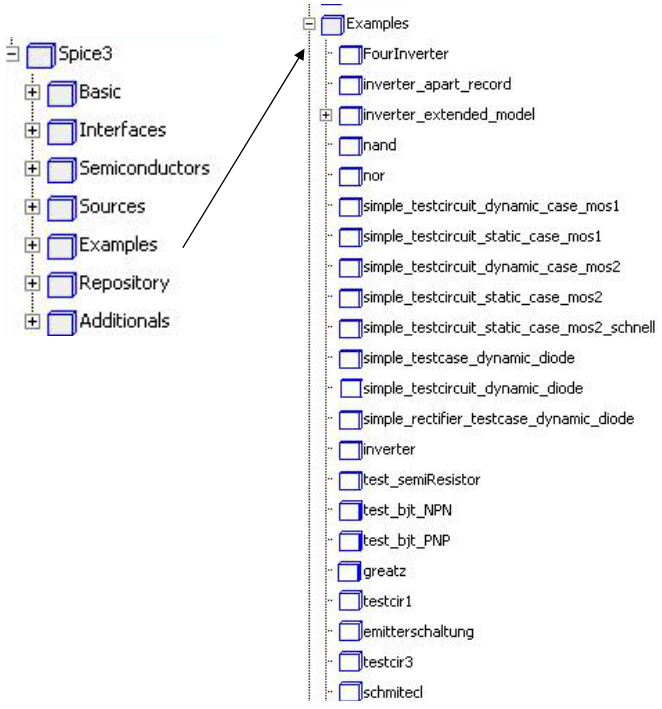
Spice3 library for Modelica
- structure -



the package sources contains:

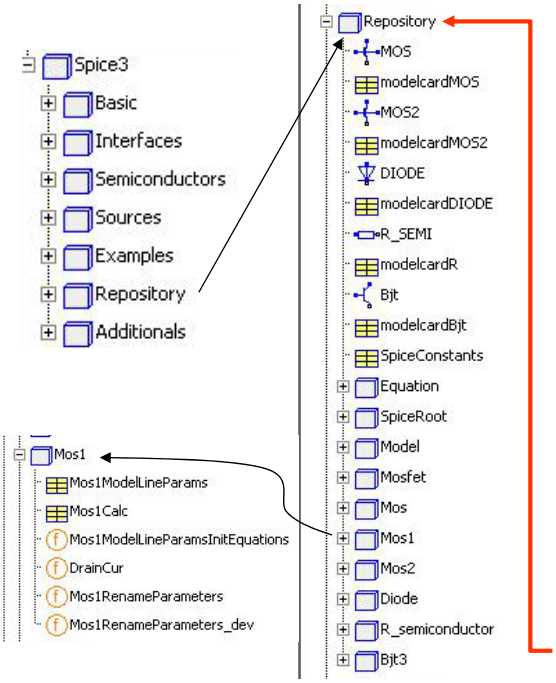
- voltage and current souces:
  - constant
  - sinusoidal
  - exponential
  - pulse
  - piece-wise-liniear
  - single-frequency

Spice3 library for Modelica
- structure -



- contains some useful example circuits.
- Some very simple to check parameter influence on behavior of the component

Spice3 library for Modelica
- structure -



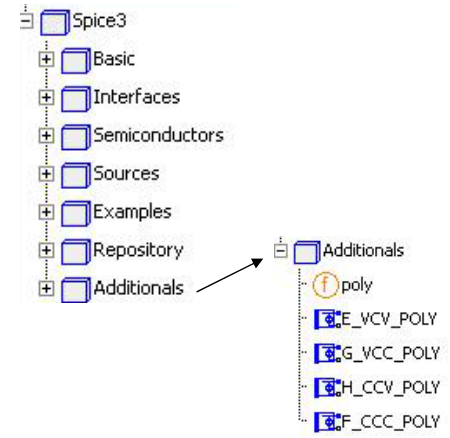
repository contains
- functions
- modelcards with parameters
- records with data

→ needed for semiconductor models

- package not for user access.
- e.g. package MOS1 contains
  - two records with parameters, data
  - four functions, e.g. “DrainCur” (calculates drain current of the MOS1 transistor.)

not for user access

Spice3 library for Modelica
- structure -



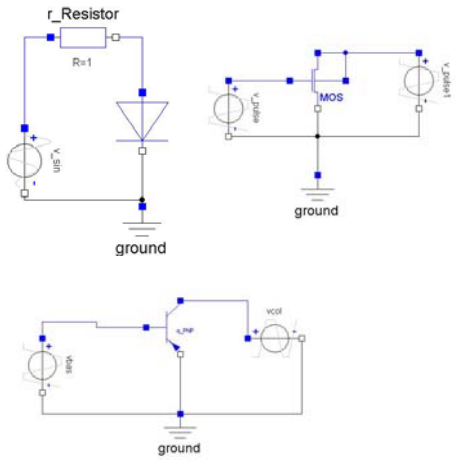
The package additionals contains useful components that are not originally from SPICE3:
- polynomial sources (from PSPICE)
  - voltage controlled voltage source
  - voltage controlled current source
  - current controlled voltage source
  - current controlled current source

Spice3 library for Modelica

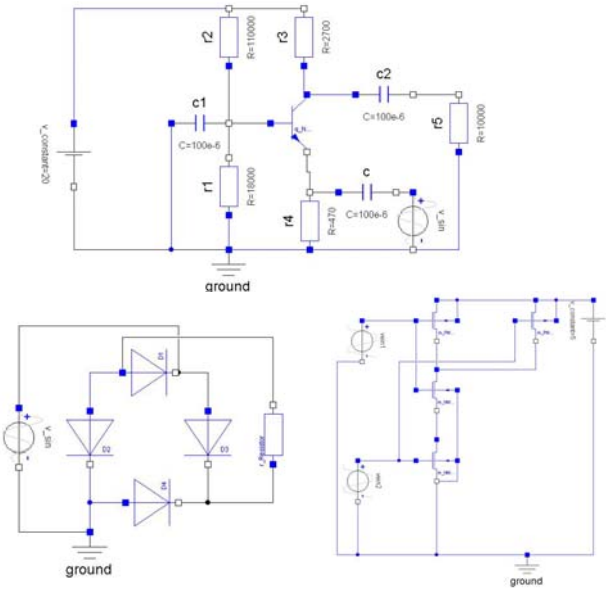
How the library was tested

Spice3 library for Modelica
- tests -

simple circuits to check the principal behavior



"complex" circuits

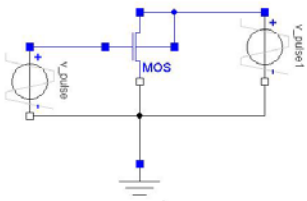


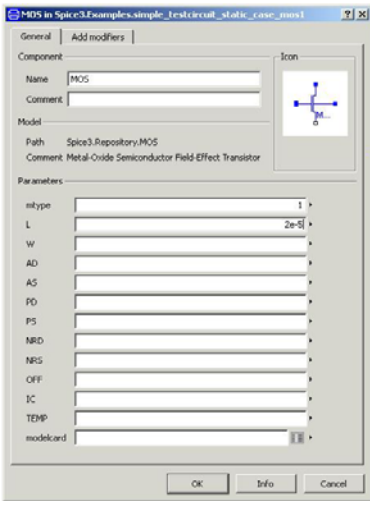
Dymola results are always compared with SPICE3 results

Spice3 library for Modelica
- tests -

Mosfet level 1 transistor

to check the parameter influence on characteristics the following circuit was used:





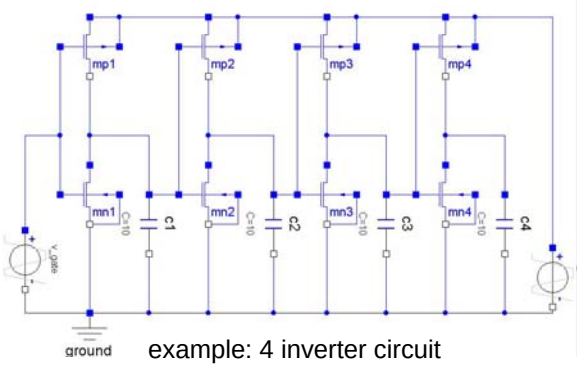
- step by step each parameter was tested alone
- combinations of parameters were tested

results:
- about 400 tests (single parameters and combinations)
- in most cases Dymola and SPICE3 are in accordance
- big errors are not expected
- since capacitances can be set to zero now, such tests are necessary

Spice3 library for Modelica
- larger circuit tests -

Mosfet transistors

the MOS1 transistor was tested in larger circuits:



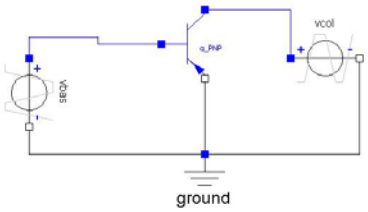
example: 4 inverter circuit

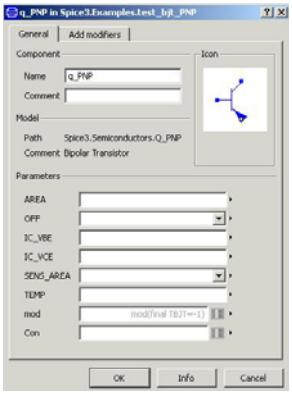
results:
- in most cases Dymola and SPICE3 are in accordance
- big errors are not expected
- since capacitances can be set to zero now, such tests are necessary
- since the MOS2 transistor has still an error in the simple test cases, test in larger circuits were not done yet

Spice3 library for Modelica
- tests -

Bipolar transistors

to check the parameter influence on characteristics the following circuit was used:





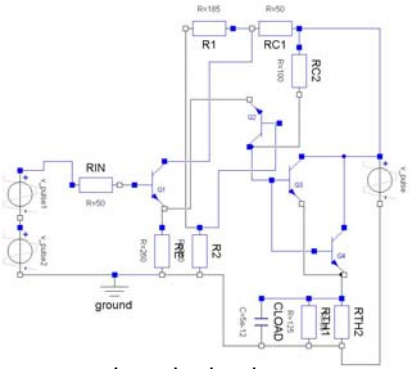
- step by step each parameter was tested alone
- combinations of parameters were tested

results:
- 40 tests of this kind (single parameters and combinations)
- in most cases Dymola and SPICE3 are in accordance
- big errors are not expected
- since capacitances can be set to zero now, such tests are necessary

Spice3 library for Modelica
- larger ciruit tests -

Bipolar transistors

beside the simple parameter tests the bipolartransistor was tested in larger circuits:



example: schmitt trigger

results:
- 14 circuits were simulated
- in many cases some capacitances need a value different from zero
- 6 circuits are in accordance with SPICE3
- → further test are necessary!
- in progress in Eurosyslib

Spice3 library for Modelica
- tests -

tests are not completed yet → further test are necessary

Basic elements	intensively tested, correct
Sources	intensively tested, correct
Semiconductor resistor	intensively tested, correct
Diode	intensively tested, correct
Mosfet level 1 transistor	further tests are necessary, principally correct
Bipolar transistors	further tests are necessary, principally correct
Mosfet level 2 transistor	errors still occur

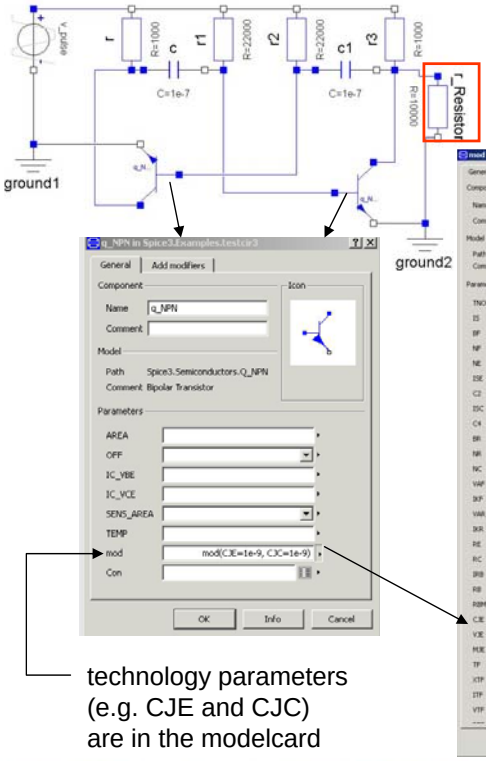
→ Spice3 library is delivered without mosfet level 2 transistor so far

Spice3 library for Modelica

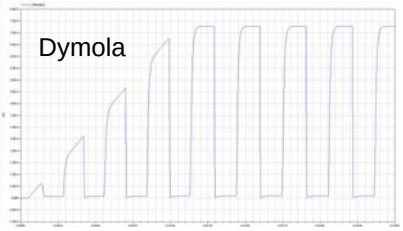
Illustration by examples

Spice3 library for Modelica
- examples -

test of bipolar transistors



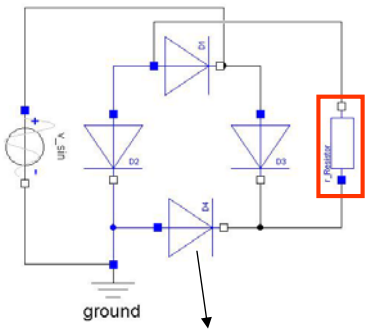
technology parameters
(e.g. CJE and CJC)
are in the modelcard



simulation results (current trough r_Resistor) are correct

Spice3 library for Modelica
- examples -

graetz circuit



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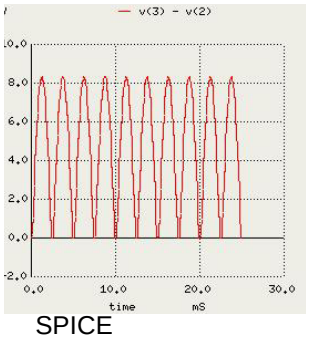
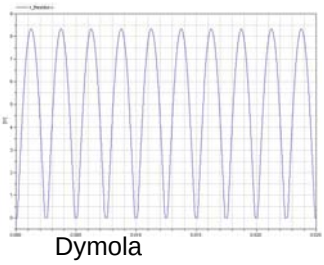


SPICE

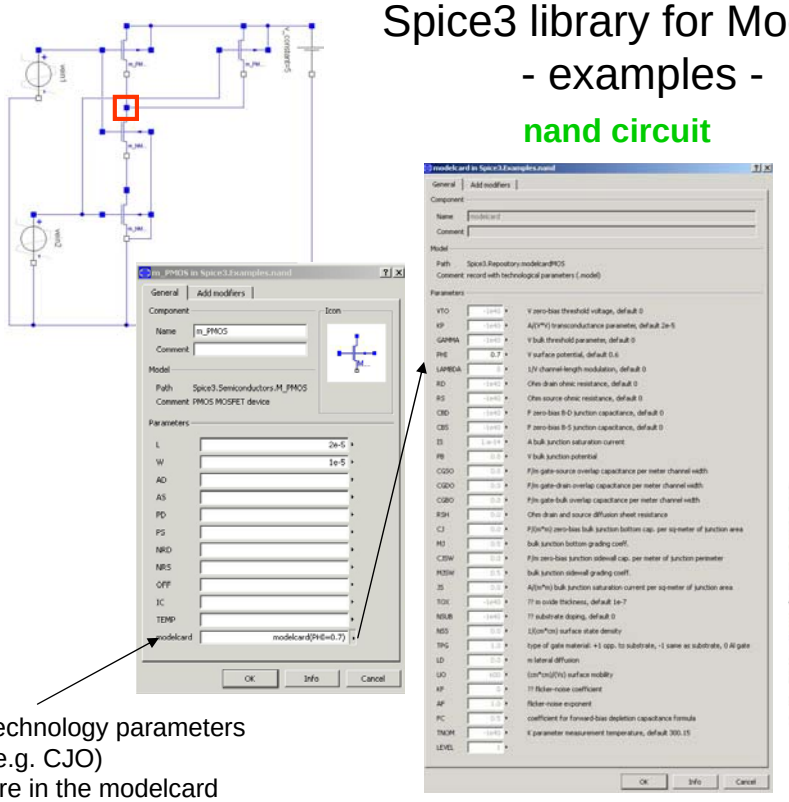


Dymola

simulation results (voltage over r_Resistor) are correct

Spice3 library for Modelica
- examples -

nand circuit



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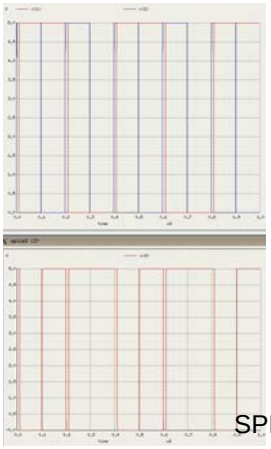
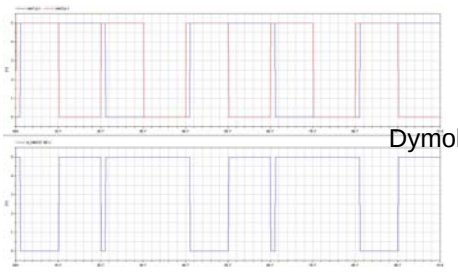


SPICE



Dymola

simulation results (voltage at nand output) are correct

Spice3 library for Modelica

Conclusion

Spice3 library for Modelica
- conclusion -

- aim: to have exactly the SPICE3 models
  → complicated way (extracting original SPICE3 models from source code)
- not all models from SPICE3 were planned to translate to Modelica (“matter of time”)
- it cannot be excluded that no errors occur because of the complexity
- open elements maybe will follow
- Adding Spice3 library to MSL would promote it by valuable feedback
- a netlist translator is necessary, started