The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

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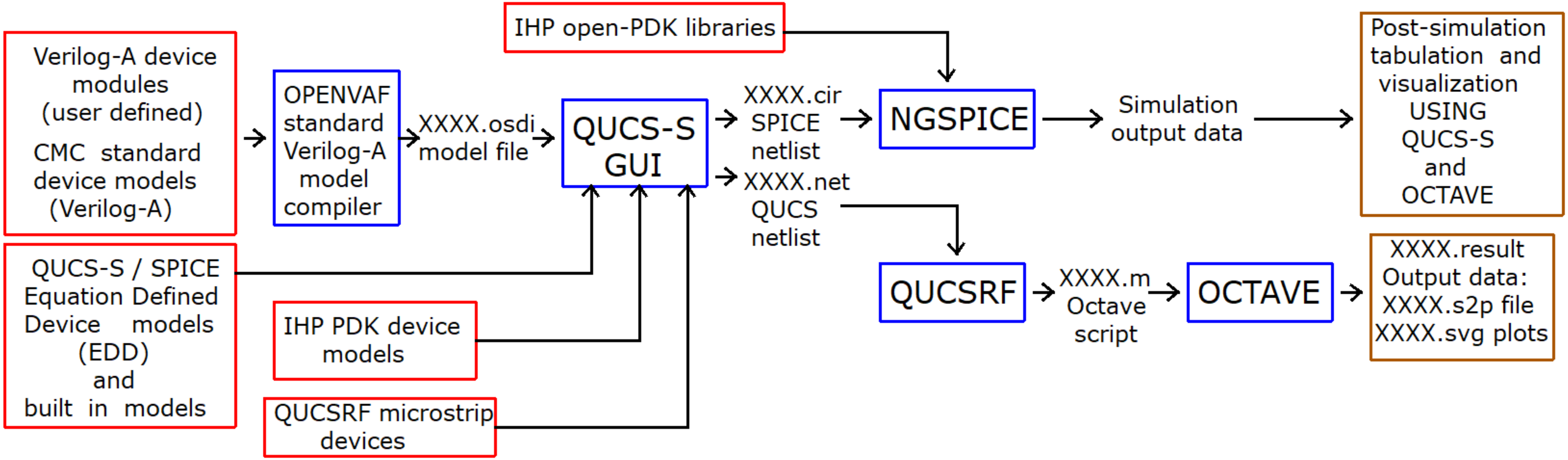
Abstract: On going improvements in semiconductor device technologies have highlighted the importance and the need for Free and Open Source Software (FOSS) that supports both compact modelling and IC circuit design based on "manufacturers open-source Process Design Kits" (PDK). This presentation outlines the evolution of the Quite Universal Circuit simulator (Qucs-S) as an integrated IC design tool with compact modelling capabilities and simulation features that support analogue, RF and mixed analogue/digital signal IC Design using the IHP 130nm BiCMOS Open Source PDK. A series of example models and simulation test benches are included. These demonstrate new Qucs-S features and their application. All the software introduced is freely available from the internet under GPL or equivalent license.

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK
Presentation topics

- Qucs-S block diagram and information flow
- IC design using the IHP 130nm BiCMOS Open Source PDK
- Qucs-S/IHP work directory structure and user initialization file .spiceinit
- Qucs-S/IHP Open Source PDK schematic symbols
- Passive component example AC simulation
- Open source PDK diode characteristics
- MOS dc output characteristic and inverter transfer function
- Current mirror corner simulation output data: IHP sg13_lv_nmos devices
- Qucs-S/IHP Monte Carlo simulation structure block diagram
- Monte Carlo analysis of worst case rxxx cap_cmim network: AC voltage gain:
  1. Qucs-S/Ngspice netlist; 2. Qucs-S/Ngspice histogram at 10 GHz
- Monte Carlo analysis of a two transistor current mirror:
  1. DC current transfer ratio; 2. Qucs-S/Ngspice histogram at 50μA and 1V dc bias
- IHP digital stdcell ring oscillator
- XSPICE digital IHP stdcell ring oscillator
- Qucs-S RF design:
  1. Qucs-S microstrip simulation; 2. KiCad, Octave/openEMS simulation
- Summary
- Acknowledgments
- Reference material and software links

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Qucs-S block diagram and information flow



Verilog-A device modules (user defined)
CMC standard device models (Verilog-A)
OPENVAF standard Verilog-A model compiler
XXXX.osdi model file
IHP open-PDK libraries
QUCS-S GUI
XXXX.cir SPICE netlist
XXXX.net QUCS netlist
NGSPICE
Simulation output data
Post-simulation tabulation and visualization USING QUCS-S and OCTAVE
QUCS-S / SPICE Equation Defined Device models (EDD) and built in models
IHP PDK device models
QUCSRF microstrip devices
QUCSRF
XXXX.m Octave script
OCTAVE
XXXX.result Output data: XXXX.s2p file XXXX.svg plots

□ → **Device and PDK models**

□ → **FOSS tools**

Qucs-S development started in 2014 and continues today. The current release is Qucs-S 24.2.1 with version Qucs-S 24.3.0 expected in September 2024.

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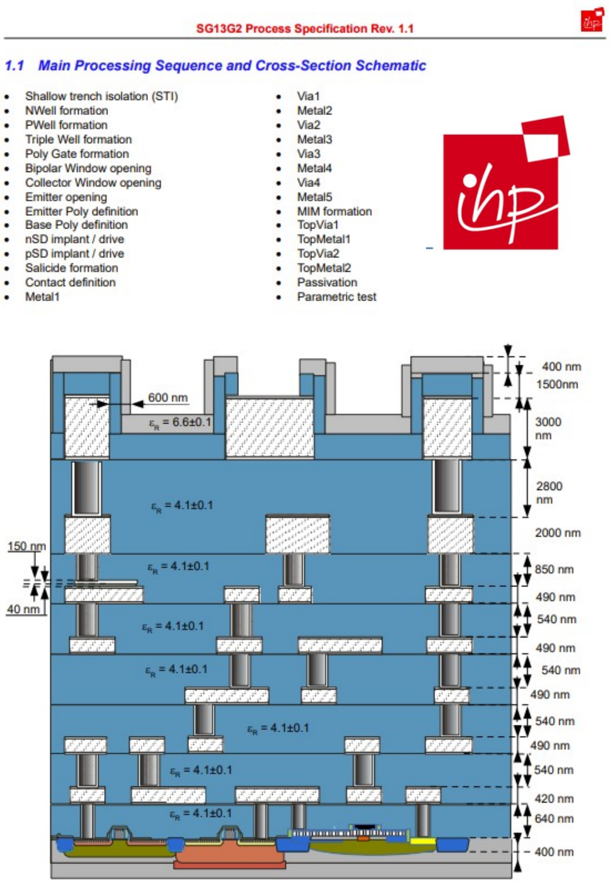


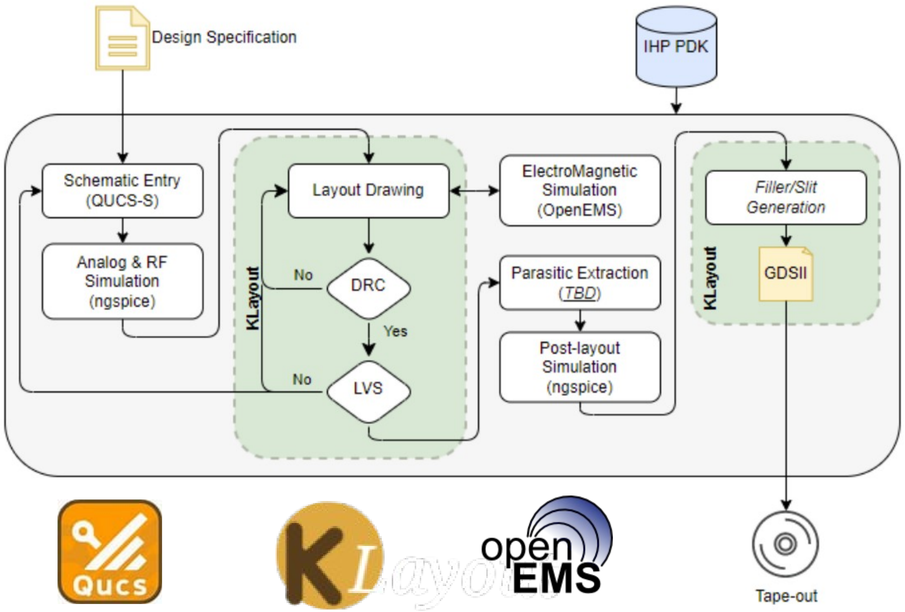
SG13G2 Process Specification Rev. 1.1

1.1 Main Processing Sequence and Cross-Section Schematic

- Shallow trench isolation (STI)
- NWell formation
- PWell formation
- Triple Well formation
- Poly Gate formation
- Bipolar Window opening
- Collector Window opening
- Emitter opening
- Emitter Poly definition
- Base Poly definition
- nSD implant / drive
- pSD implant / drive
- Salicide formation
- Contact definition
- Metal1
- Via1
- Metal2
- Via2
- Metal3
- Via3
- Metal4
- Via4
- Metal5
- MIM formation
- TopVia1
- TopMetal1
- TopVia2
- TopMetal2
- Passivation
- Parametric test

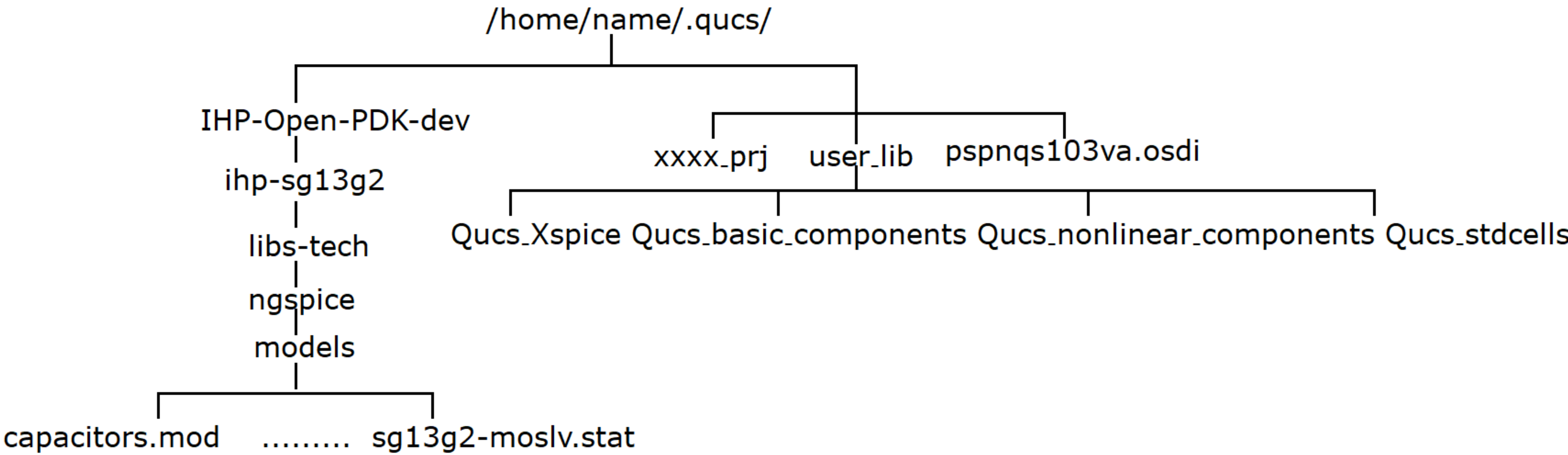
400 nm
1500nm
600 nm
ε_R = 6.6±0.1
3000 nm
2800 nm
ε_R = 4.1±0.1
2000 nm
150 nm
40 nm
ε_R = 4.1±0.1
850 nm
490 nm
540 nm
ε_R = 4.1±0.1
490 nm
540 nm
ε_R = 4.1±0.1
490 nm
540 nm
ε_R = 4.1±0.1
490 nm
540 nm
ε_R = 4.1±0.1
420 nm
640 nm
ε_R = 4.1±0.1
400 nm

Analog/RF OpenPDK/EDA Flow



- KLayout-oriented flow
  - Layout design
  - Parameterizable cells
  - Physical Verification
- QUCS-S
- ngspice
- OpenEMS
- … ?

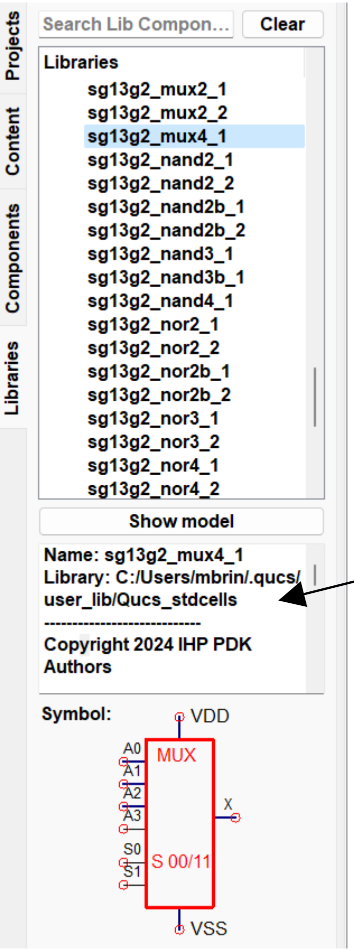
The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PD
Qucs-S/IHP work directory structure and user initialization file .spiceinit



File .spiceinit

```
* Qucs-S/Ngspice global initialization file. Copy this file to home directory.
* It is read after Ngspice spinit file and prior to passing Ngspice netlist.
setcs sourcepath = (  $sourcepath /home/name/.qucs/IHP-Open-PDK-dev/ihp-sg13g2/libs.tech/ngspice/models )
setcs sourcepath = (  $sourcepath /home/name/.qucs/IHP-Open-PDK-dev/ihp-sg13g2/libs.ref/sg13g2_stdcell/spice )
*load pspnqs103va.osdi as a global item so that it becomes available to Ngspice netlists.
osdi /home/name/.qucs/pspnqs103va.osdi
```

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK
Qucs-S/IHP Open Source PDK schematic symbols



Libraries

- sg13g2_mux2_1
- sg13g2_mux2_2
- sg13g2_mux4_1
- sg13g2_nand2_1
- sg13g2_nand2_2
- sg13g2_nand2b_1
- sg13g2_nand2b_2
- sg13g2_nand3_1
- sg13g2_nand3b_1
- sg13g2_nand4_1
- sg13g2_nor2_1
- sg13g2_nor2_2
- sg13g2_nor2b_1
- sg13g2_nor2b_2
- sg13g2_nor3_1
- sg13g2_nor3_2
- sg13g2_nor4_1
- sg13g2_nor4_2

Show model

Name: sg13g2_mux4_1
Library: C:/Users/mbrin/.qucs/user_lib/Qucs_stdcells

Copyright 2024 IHP PDK Authors

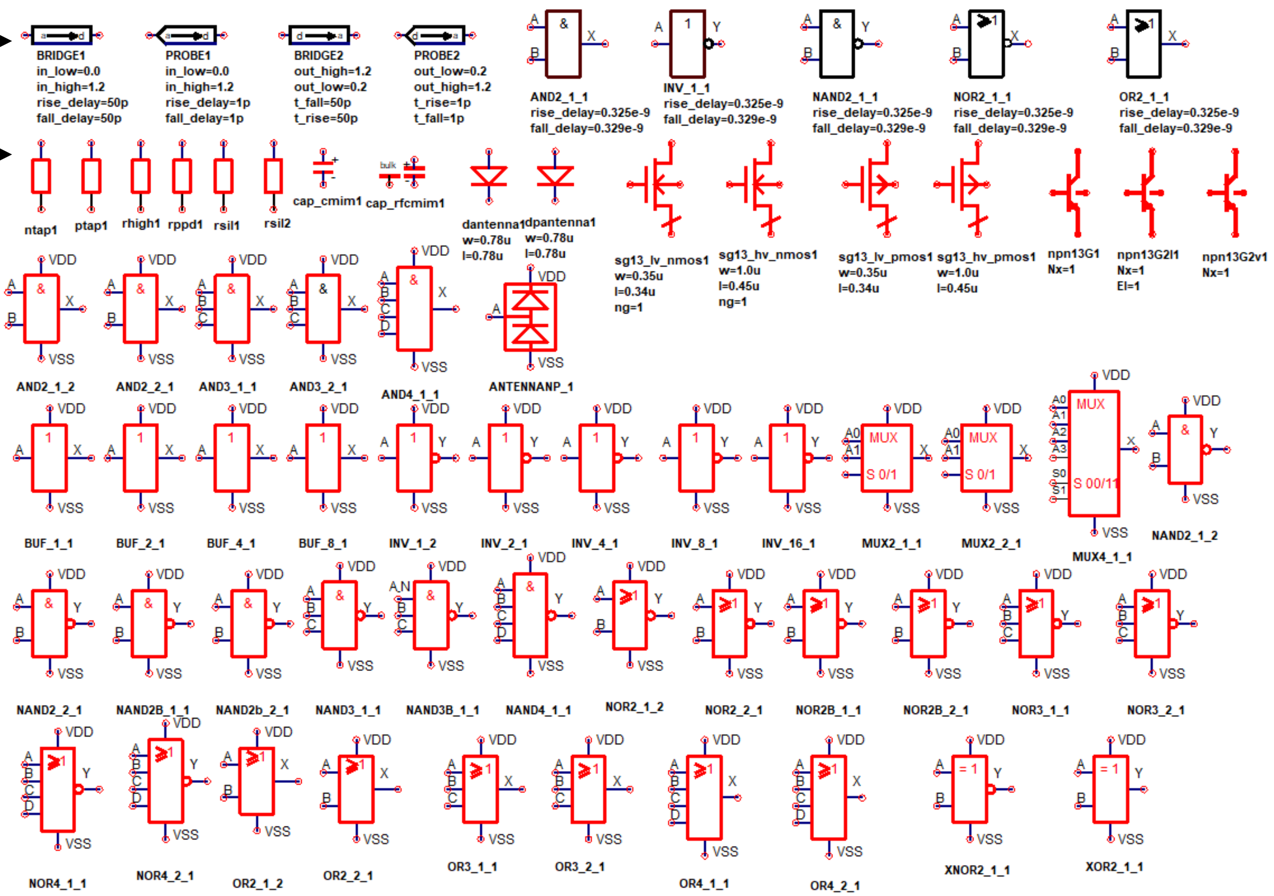
Symbol:

Qucs_Xspice

Qucs_basic_components
Qucs_nonlinear_components

Qucs_stdcells

User libraries

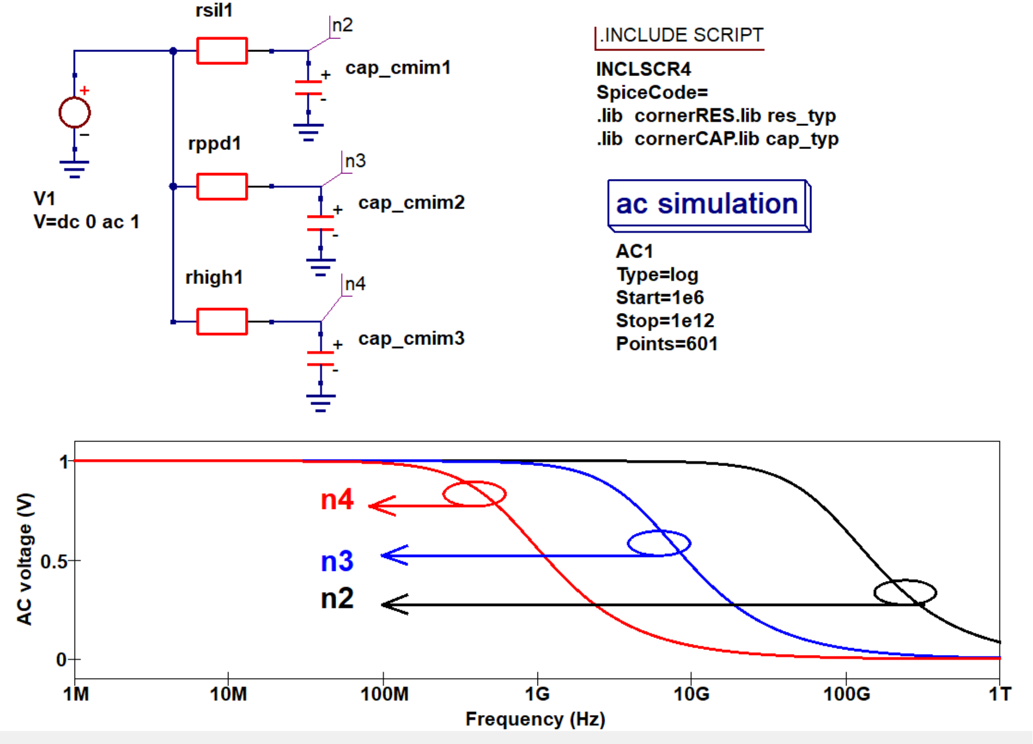


KEY

BLACK symbols: XSPICE digital models

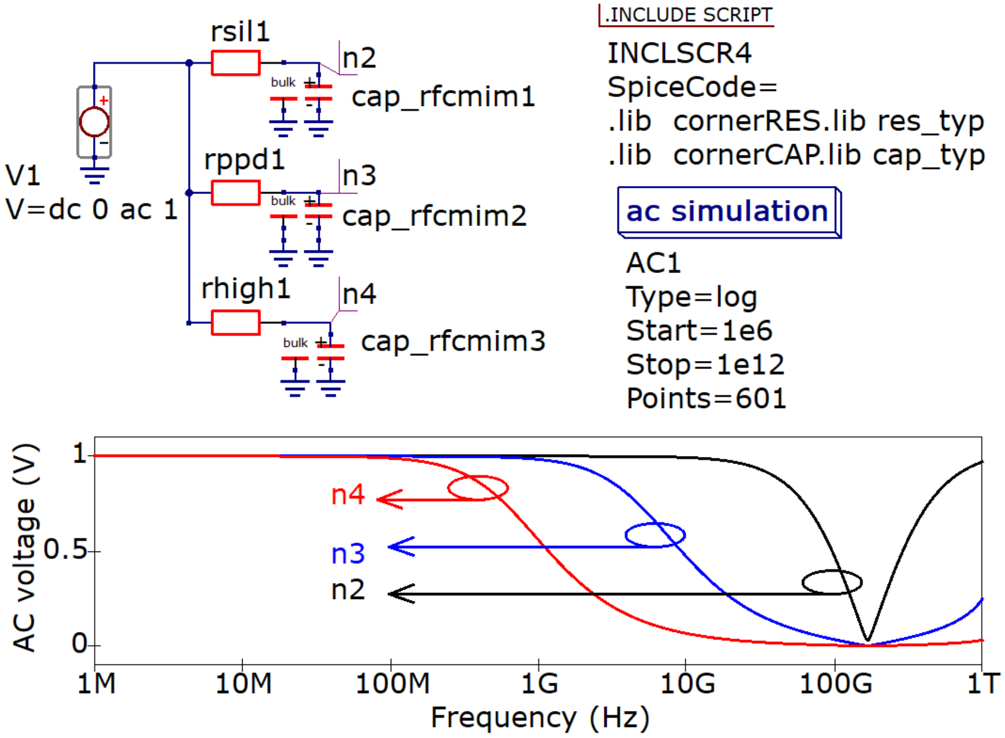
RED symbols: IHP PDK transistor level models

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK
Passive component example AC simulation



.INCLUDE SCRIPT
INCLSCR4
SpiceCode=
.lib cornerRES.lib res_typ
.lib cornerCAP.lib cap_typ

ac simulation
AC1
Type=log
Start=1e6
Stop=1e12
Points=601

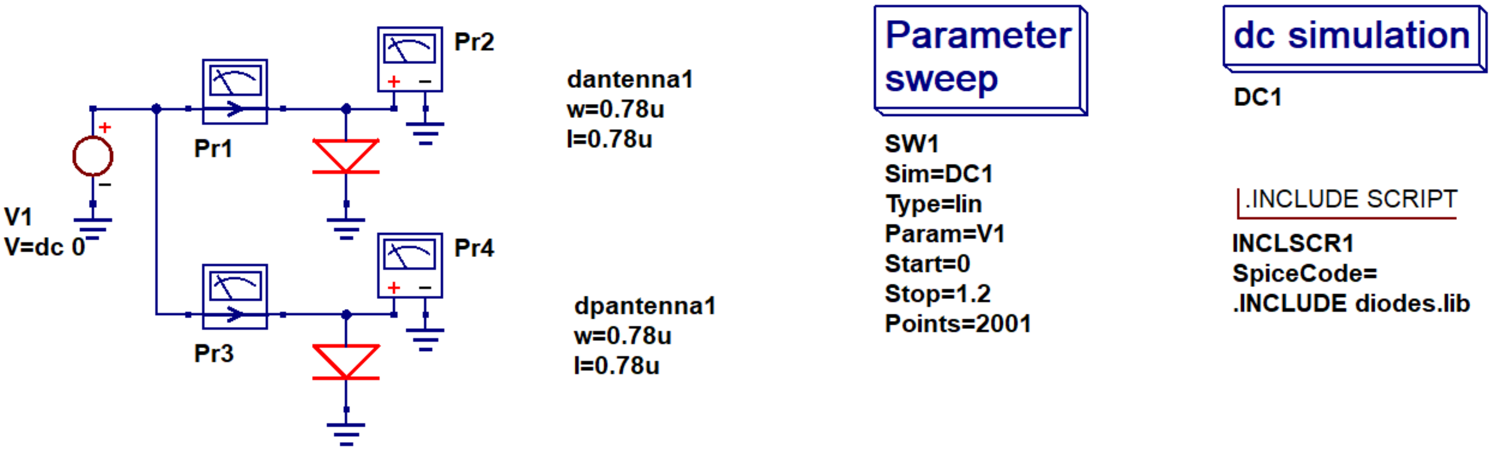


.INCLUDE SCRIPT
INCLSCR4
SpiceCode=
.lib cornerRES.lib res_typ
.lib cornerCAP.lib cap_typ

ac simulation
AC1
Type=log
Start=1e6
Stop=1e12
Points=601

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Open source PDK diode characteristics



V1
V=dc 0

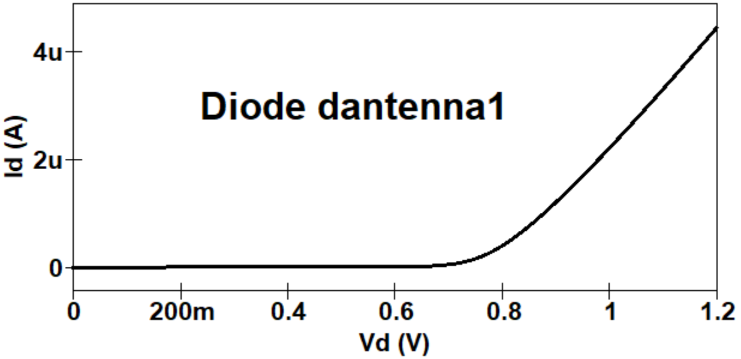
dantenna1
w=0.78u
l=0.78u

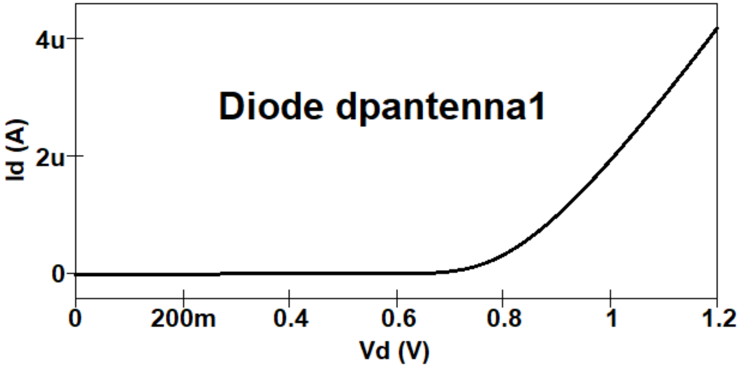
dpantenna1
w=0.78u
l=0.78u

SW1
Sim=DC1
Type=lin
Param=V1
Start=0
Stop=1.2
Points=2001

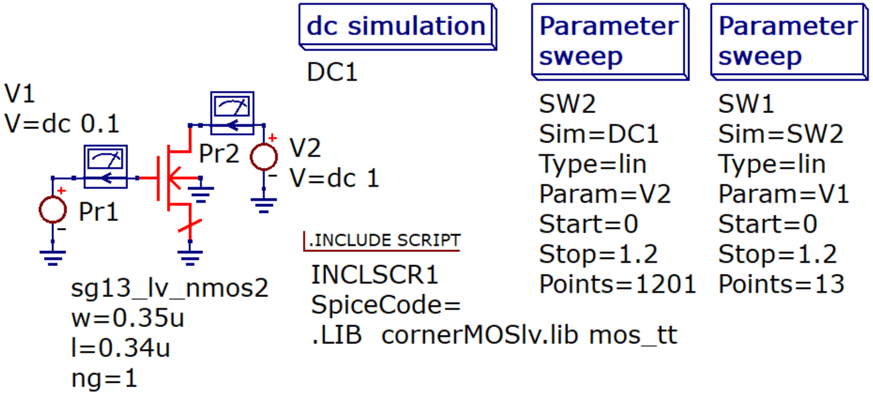
DC1

INCLSCR1
SpiceCode=
.INCLUDE diodes.lib





The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK
MOS dc output characteristic and inverter transfer function



dc simulation
DC1

Parameter sweep
SW2
Sim=DC1
Type=lin
Param=V2
Start=0
Stop=1.2
Points=1201

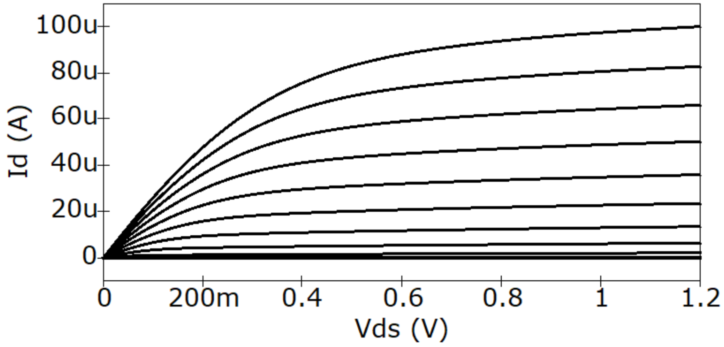
Parameter sweep
SW1
Sim=SW2
Type=lin
Param=V1
Start=0
Stop=1.2
Points=13

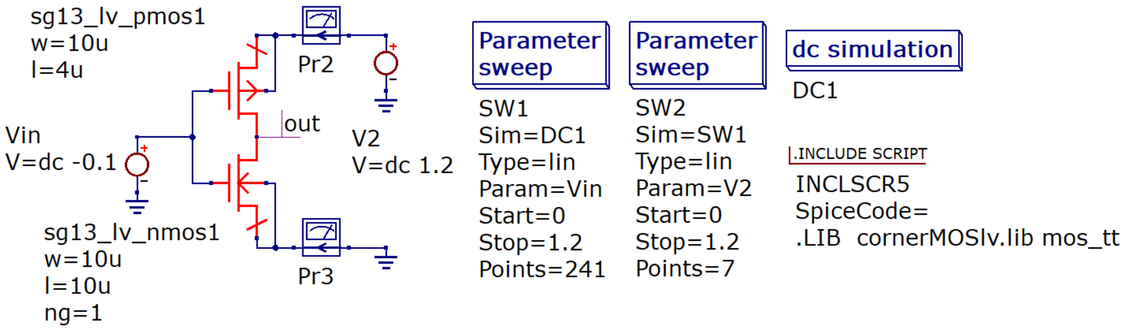
V1
V=dc 0.1

V2
V=dc 1

.INCLUDE SCRIPT
INCLSCR1
SpiceCode=
.LIB cornerMOSlv.lib mos_tt

sg13_lv_nmos2
w=0.35u
l=0.34u
ng=1





sg13_lv_pmos1
w=10u
l=4u

Vin
V=dc -0.1

V2
V=dc 1.2

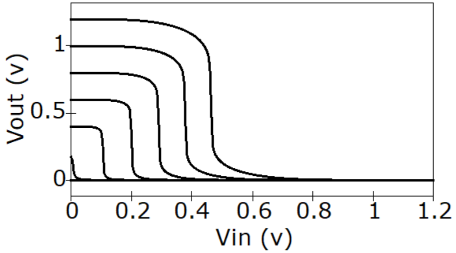
sg13_lv_nmos1
w=10u
l=10u
ng=1

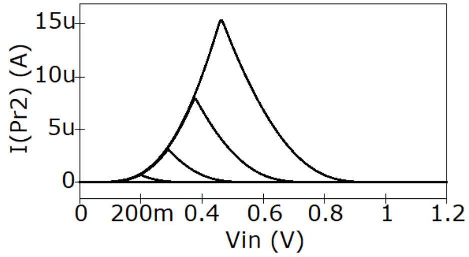
Parameter sweep
SW1
Sim=DC1
Type=lin
Param=Vin
Start=0
Stop=1.2
Points=241

Parameter sweep
SW2
Sim=SW1
Type=lin
Param=V2
Start=0
Stop=1.2
Points=7

dc simulation
DC1

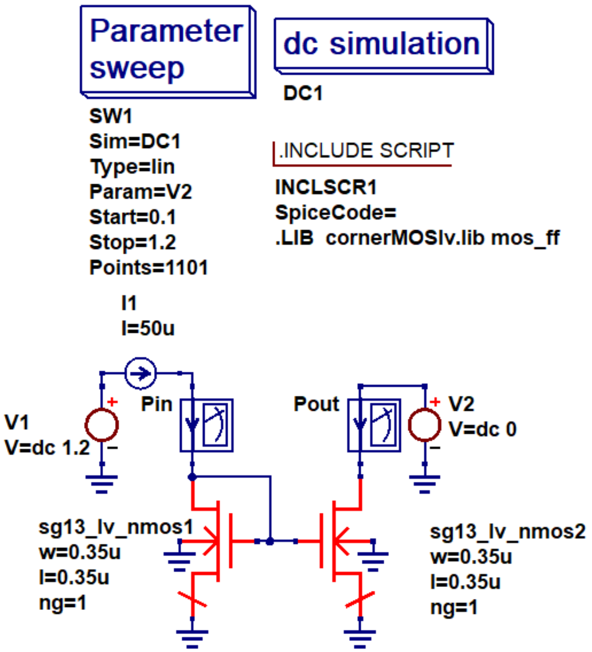
.INCLUDE SCRIPT
INCLSCR5
SpiceCode=
.LIB cornerMOSlv.lib mos_tt





The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Current mirror corner simulation output data: IHP sg13_lv_nmos devices



Parameter sweep

SW1
Sim=DC1
Type=lin
Param=V2
Start=0.1
Stop=1.2
Points=1101

dc simulation

DC1

.INCLUDE SCRIPT

INCLSCR1
SpiceCode=
.LIB cornerMOSlv.lib mos_ff

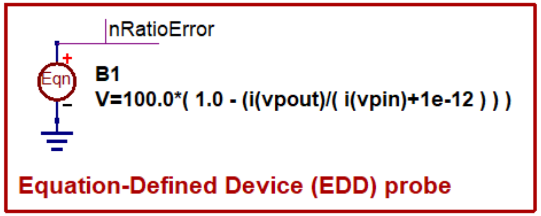
I1
I=50u

V1
V=dc 1.2

V2
V=dc 0

sg13_lv_nmos1
w=0.35u
l=0.35u
ng=1

sg13_lv_nmos2
w=0.35u
l=0.35u
ng=1

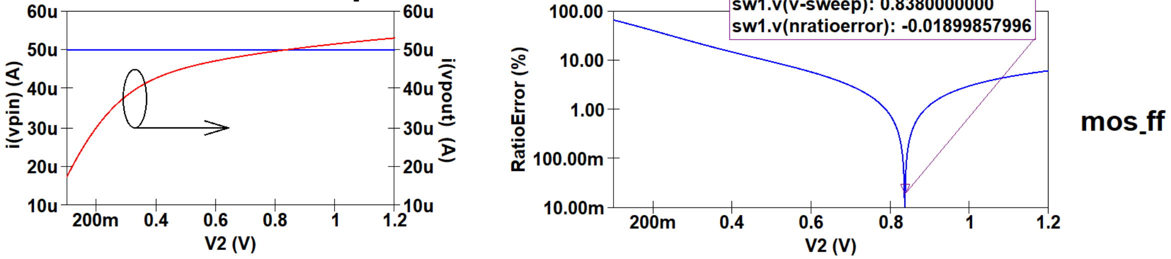


nRatioError

B1
V=100.0*(1.0 - (i(vpout)/(i(vpin)+1e-12)))

Equation-Defined Device (EDD) probe

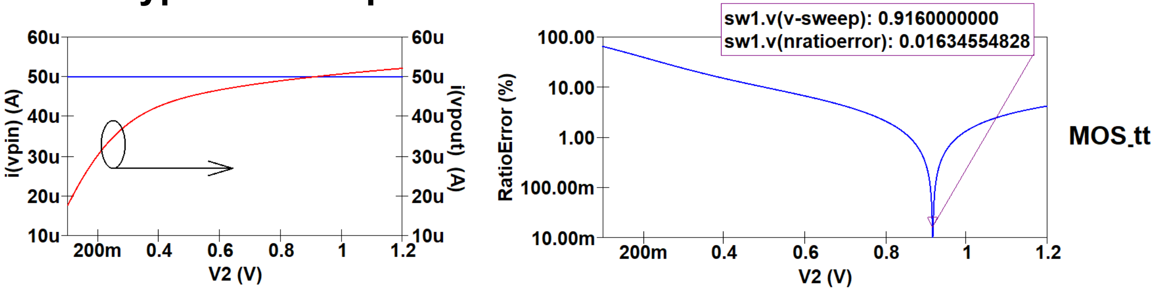
Fast n, fast p



sw1.v(v-sweep): 0.8380000000
sw1.v(nratioerror): -0.01899857996

mos_ff

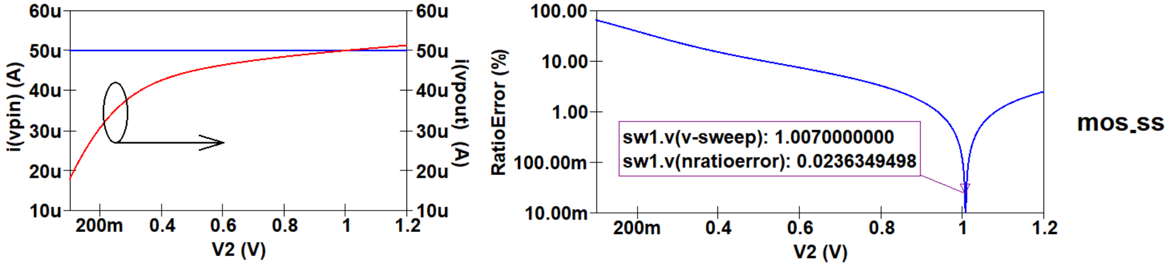
Typical n and p



sw1.v(v-sweep): 0.9160000000
sw1.v(nratioerror): 0.01634554828

MOS_tt

Slow n, slow p



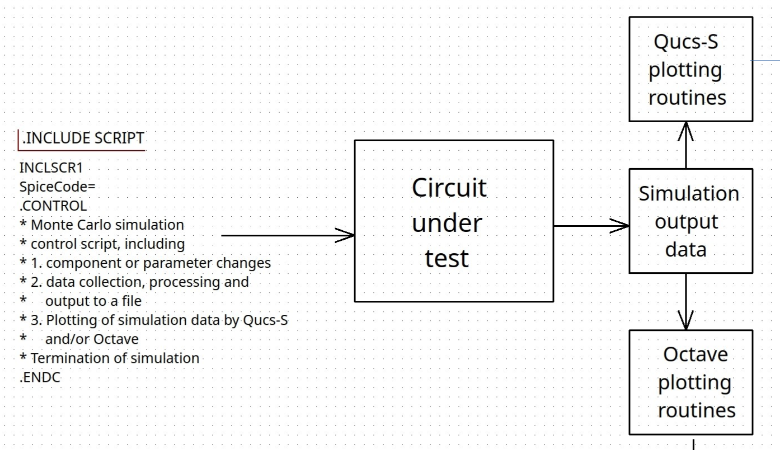
sw1.v(v-sweep): 1.0070000000
sw1.v(nratioerror): 0.0236349498

mos_ss

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

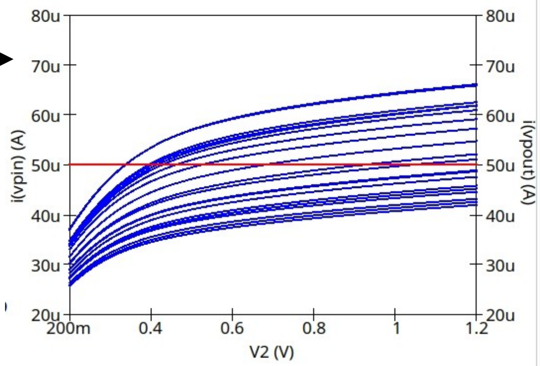
Qucs-S/IHP Monte Carlo simulation structure block diagram

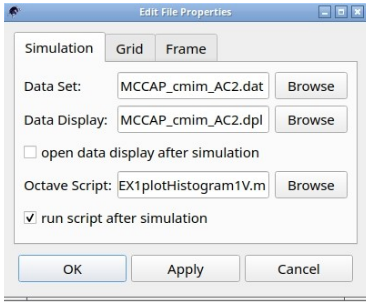
- Monte Carlo analysis is not implemented by SPICE 3,
- Ngspice uses SPICE .control … .ENDC scripts to implement and run Monte Carlo analysis,
- Qucs-S introduces a new combined circuit schematic/script technique for Monte Carlo analysis



```
.INCLUDE SCRIPT
INCLSCR1
SpiceCode=
.CONTROL
* Monte Carlo simulation
* control script, including
* 1. component or parameter changes
* 2. data collection, processing and
*    output to a file
* 3. Plotting of simulation data by Qucs-S
*    and/or Octave
* Termination of simulation
.ENDC
```

Typical Qucs-S plot





Data Set: MCCAP_cmim_AC2.dat

Data Display: MCCAP_cmim_AC2.dpl

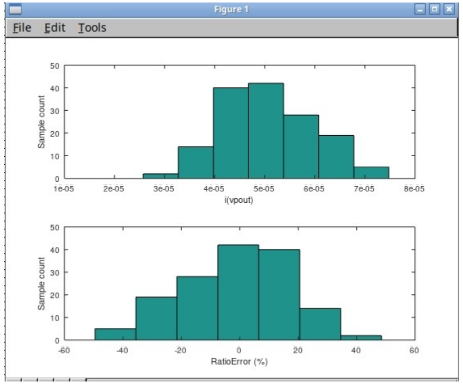
☐ open data display after simulation

Octave Script: EX1plotHistogram1V.m

☑ run script after simulation

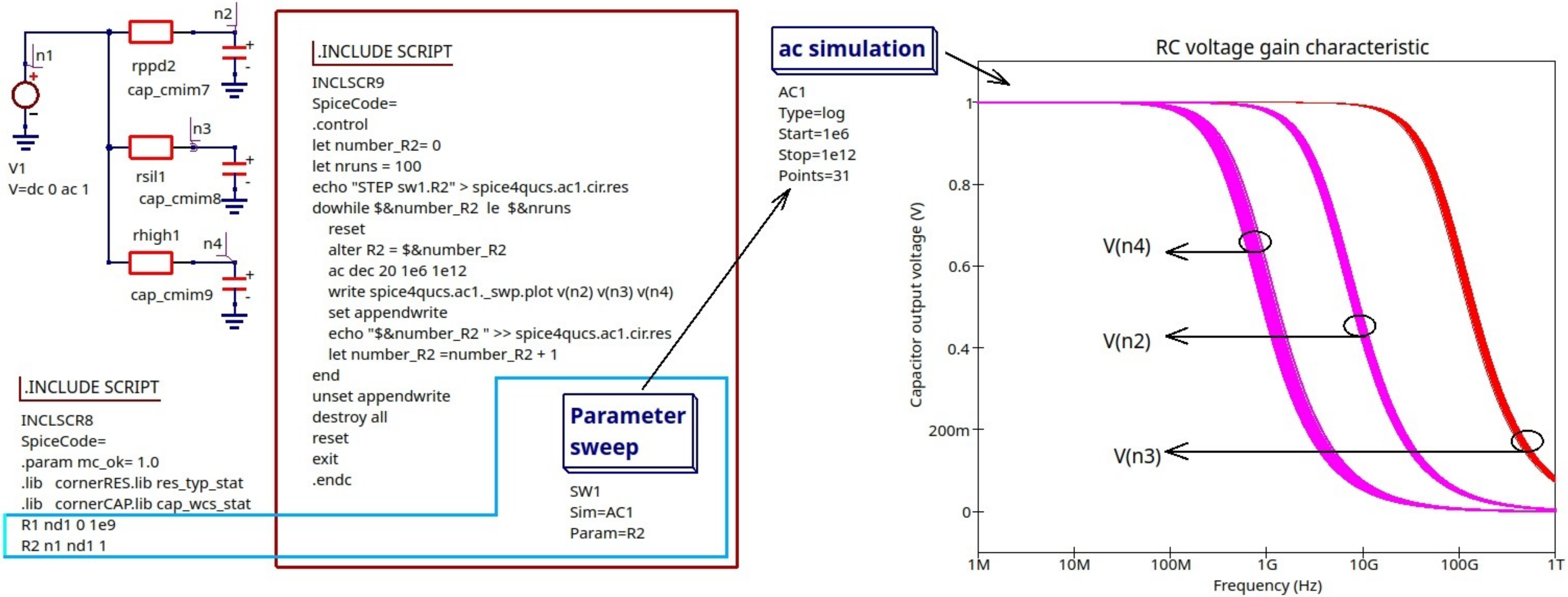
```
%
% Example 1 variable Histogram plot.
%
DataSetFile = "MCCAP_cmim_AC2.dat.ngspice"
Y1name = "ac.vpn2"
Y1label = "Sample count"
X1label = "iabs( v(pn2) - 0.4)"
nbins = 7
plotHistogram1V(DataSetFile, Y1name, Y1label, X1label, nbins)
```

Typical Octave histogram



The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Monte Carlo analysis of worst case rxxx cap_cmim network: AC voltage gain



```
.INCLUDE SCRIPT
INCLSCR8
SpiceCode=
.param mc_ok= 1.0
.lib   cornerRES.lib res_typ_stat
.lib   cornerCAP.lib cap_wcs_stat
R1 nd1 0 1e9
R2 n1 nd1 1
```

```
.INCLUDE SCRIPT
INCLSCR9
SpiceCode=
.control
let number_R2= 0
let nruns = 100
echo "STEP sw1.R2" > spice4qucs.ac1.cir.res
dowhile $&number_R2  le  $&nruns
   reset
   alter R2 = $&number_R2
   ac dec 20 1e6 1e12
   write spice4qucs.ac1._swp.plot v(n2) v(n3) v(n4)
   set appendwrite
   echo "$&number_R2 " >> spice4qucs.ac1.cir.res
   let number_R2 =number_R2 + 1
end
unset appendwrite
destroy all
reset
exit
.endc
```

Parameter sweep

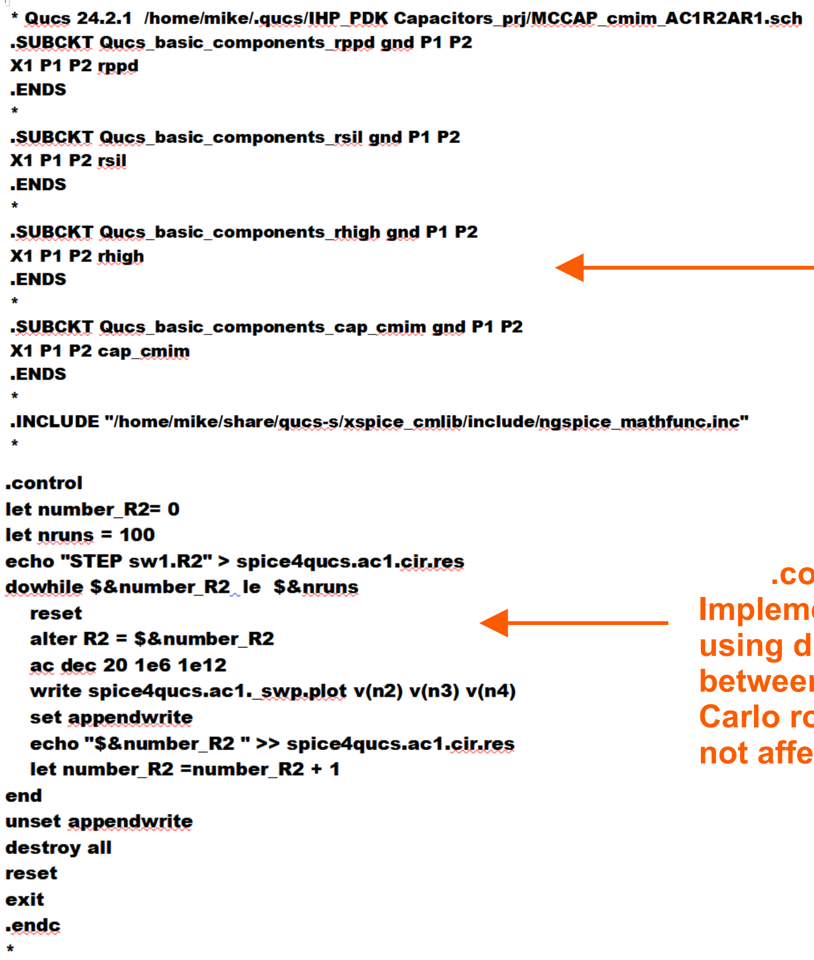
SW1
Sim=AC1
Param=R2

ac simulation

AC1
Type=log
Start=1e6
Stop=1e12
Points=31

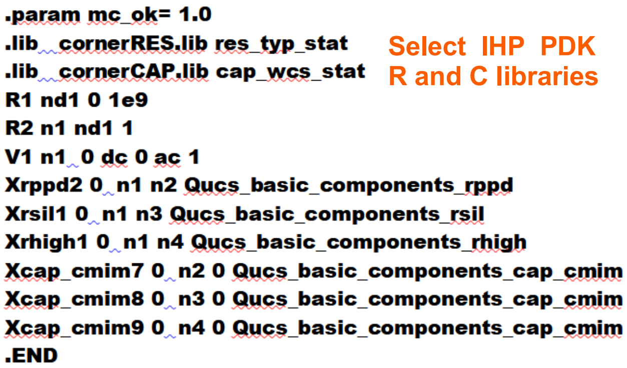
The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Monte Carlo analysis of worst case rxxx cmim LP filter: Qucs-S/Ngspice netlist



```
 * Qucs 24.2.1  /home/mike/.qucs/IHP_PDK Capacitors_prj/MCCAP_cmim_AC1R2AR1.sch
.SUBCKT Qucs_basic_components_rppd gnd P1 P2
X1 P1 P2 rppd
.ENDS
*
.SUBCKT Qucs_basic_components_rsil gnd P1 P2
X1 P1 P2 rsil
.ENDS
*
.SUBCKT Qucs_basic_components_rhigh gnd P1 P2
X1 P1 P2 rhigh
.ENDS
*
.SUBCKT Qucs_basic_components_cap_cmim gnd P1 P2
X1 P1 P2 cap_cmim
.ENDS
*
.INCLUDE "/home/mike/share/qucs-s/xspice_cmlib/include/ngspice_mathfunc.inc"
*

.control
let number_R2= 0
let nruns = 100
echo "STEP sw1.R2" > spice4qucs.ac1.cir.res
dowhile $&number_R2 le  $&nruns
   reset
   alter R2 = $&number_R2
   ac dec 20 1e6 1e12
   write spice4qucs.ac1._swp.plot v(n2) v(n3) v(n4)
   set appendwrite
   echo "$&number_R2 " >> spice4qucs.ac1.cir.res
   let number_R2 =number_R2 + 1
end
unset appendwrite
destroy all
reset
exit
.endc
*
```



```
.param mc_ok= 1.0
.lib  cornerRES.lib res_typ_stat
.lib  cornerCAP.lib cap_wcs_stat
R1 nd1 0 1e9
R2 n1 nd1 1
V1 n1  0 dc 0 ac 1
Xrppd2 0  n1 n2 Qucs_basic_components_rppd
Xrsil1 0  n1 n3 Qucs_basic_components_rsil
Xrhigh1 0  n1 n4 Qucs_basic_components_rhigh
Xcap_cmim7 0  n2 0 Qucs_basic_components_cap_cmim
Xcap_cmim8 0  n3 0 Qucs_basic_components_cap_cmim
Xcap_cmim9 0  n4 0 Qucs_basic_components_cap_cmim
.END
```

Select IHP PDK R and C libraries

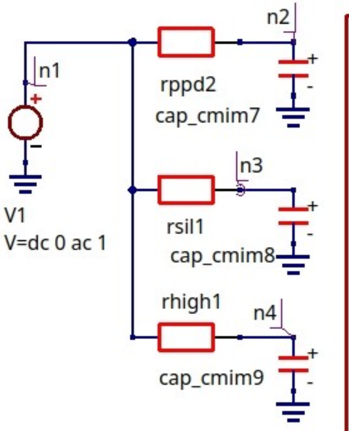
Call IHP PDK Ngspice subcircuits passing connection node names

.control ….. .endc Ngspice block

Implement and run Monte Carlo simulation, using dummy components R1 and R2 as a link between Qucs-S schematic graphics, the Monte Carlo routine and Ngspice netlist. R1 and R2 do not affect simulation results

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Monte Carlo analysis of Rxxx, Cmim network: Qucs-S/Ngspice histogram at 10 GHz



```
.INCLUDE SCRIPT
INCLSCR8
SpiceCode=
.param mc_ok= 1.0
.lib   cornerRES.lib res_typ_stat
.lib   cornerCAP.lib cap_wcs_stat
```

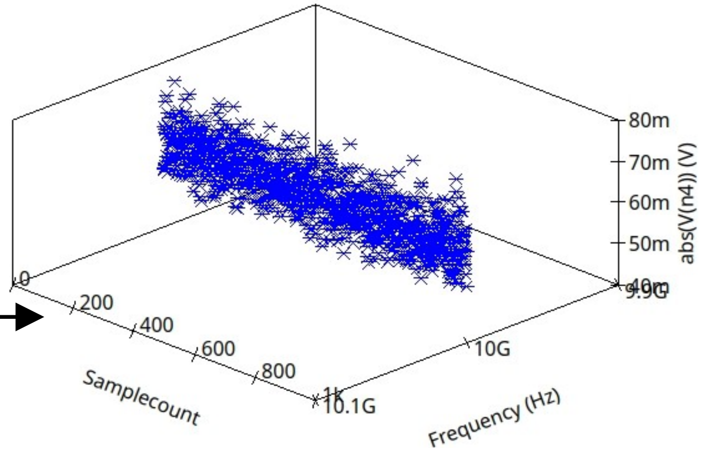
```
.INCLUDE SCRIPT
INCLSCR6
SpiceCode=
*
R1 nd1 0 1e9
R2 n1 nd1 1
.control
let number_r2 = 0
let nruns = 1000
echo "STEP sw1.r2" > spice4qucs.ac1.cir.res
dowhile $&number_r2 le $&nruns
  reset
  alter R2 = $&number_r2
   ac lin 1 1e10 10.1e10
   write spice4qucs.ac1._swp.plot v(n1) v(n2) v(n3) abs(v(n4))
   set appendwrite
   echo "$&number_r2 " >> spice4qucs.ac1.cir.res
   let number_r2 = number_r2 + 1
end
unset appendwrite
destroy all
reset
exit
.endc
.END
```

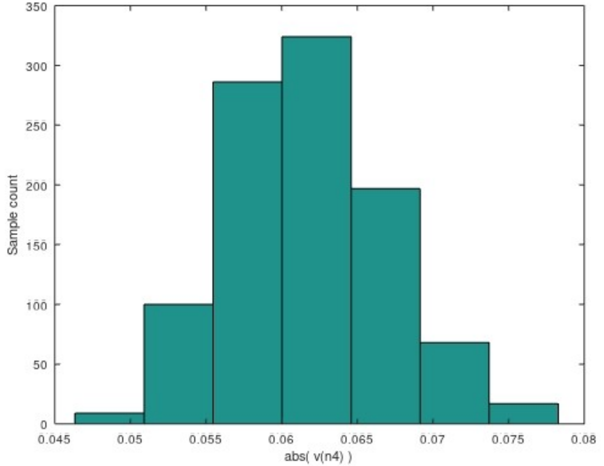
Parameter sweep

SW1
Sim=AC1
Param=R2

ac simulation

AC1
Type=const
Values=[10g]

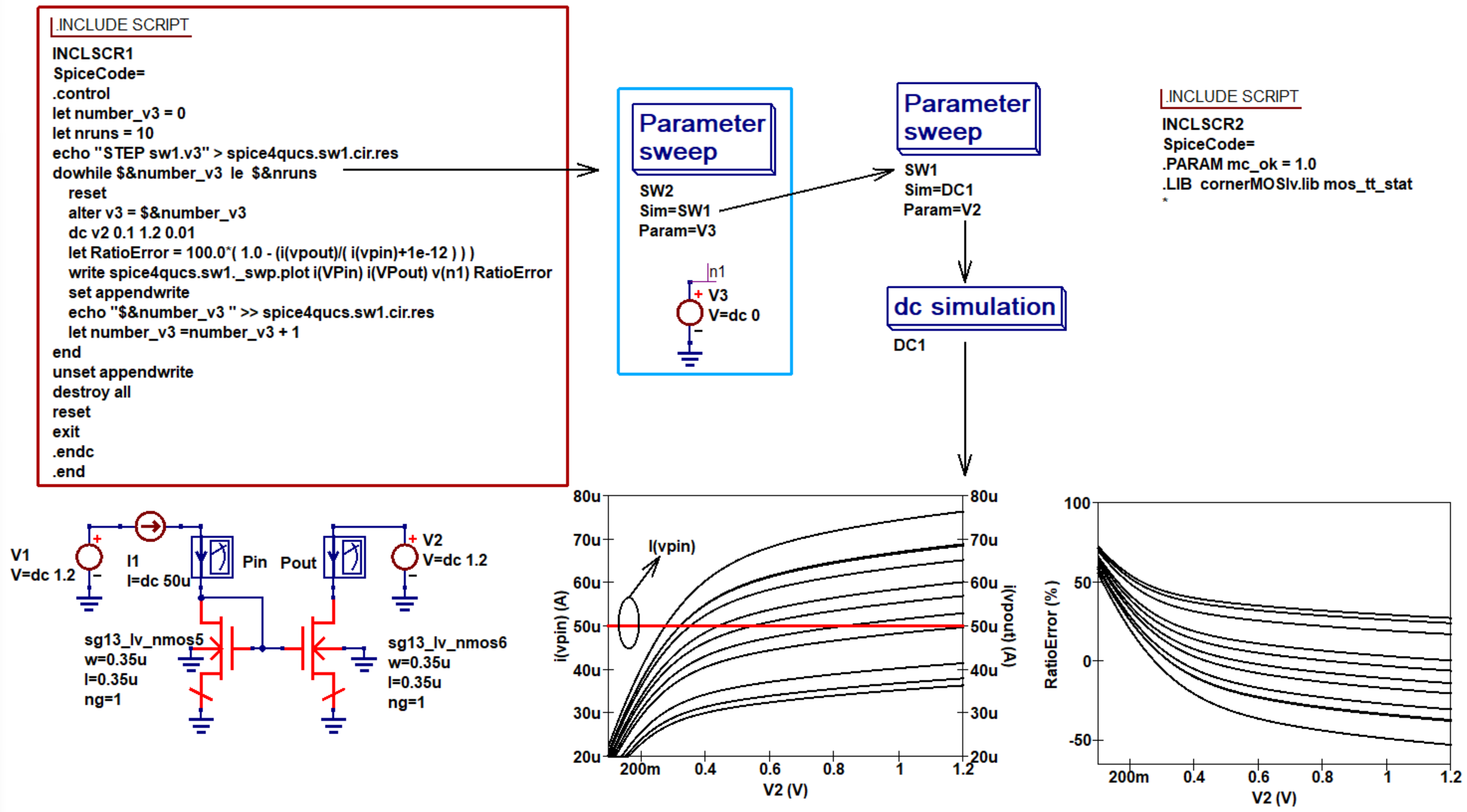




Note selection of res_typ_stat, and worst case cap_wcs_stat

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Monte Carlo analysis of a two transistor current mirror: DC current transfer ratio: 1



```
.INCLUDE SCRIPT
INCLSCR1
SpiceCode=
.control
let number_v3 = 0
let nruns = 10
echo "STEP sw1.v3" > spice4qucs.sw1.cir.res
dowhile $&number_v3  le  $&nruns
   reset
   alter v3 = $&number_v3
   dc v2 0.1 1.2 0.01
   let RatioError = 100.0*( 1.0 - (i(vpout)/( i(vpin)+1e-12 ) ) )
   write spice4qucs.sw1._swp.plot i(VPin) i(VPout) v(n1) RatioError
   set appendwrite
   echo "$&number_v3 " >> spice4qucs.sw1.cir.res
   let number_v3 =number_v3 + 1
end
unset appendwrite
destroy all
reset
exit
.endc
.end
```

Parameter sweep
SW2
Sim=SW1
Param=V3

Parameter sweep
SW1
Sim=DC1
Param=V2

dc simulation
DC1

```
.INCLUDE SCRIPT
INCLSCR2
SpiceCode=
.PARAM mc_ok = 1.0
.LIB  cornerMOSlv.lib mos_tt_stat
*
```

V3
V=dc 0

V1
V=dc 1.2

I1
I=dc 50u

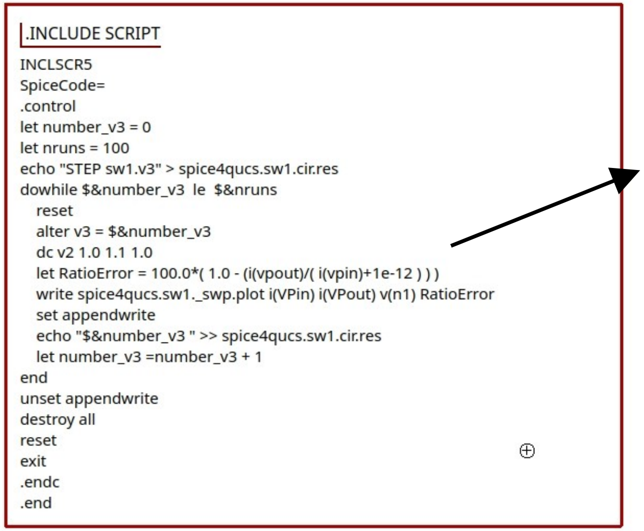
V2
V=dc 1.2

sg13_lv_nmos5
w=0.35u
l=0.35u
ng=1

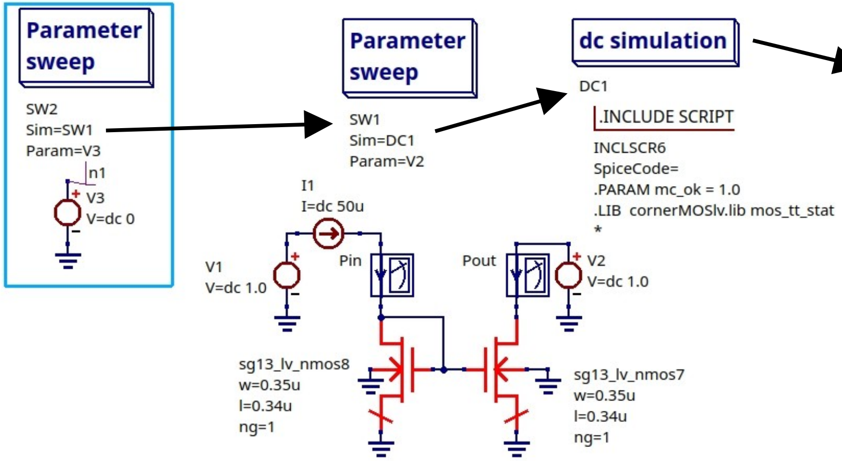
sg13_lv_nmos6
w=0.35u
l=0.35u
ng=1

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

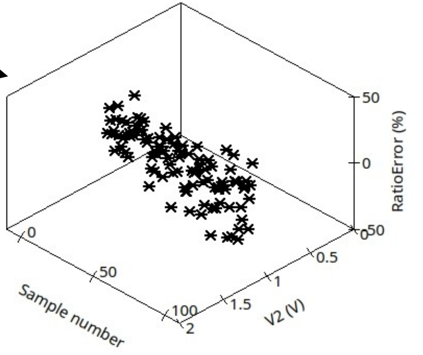
Monte Carlo analysis of a two transistor current mirror: DC current transfer ratio: 2

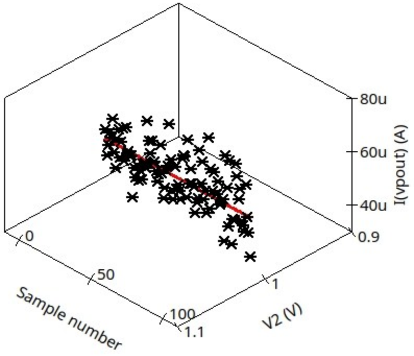


```
.INCLUDE SCRIPT
INCLSCR5
SpiceCode=
.control
let number_v3 = 0
let nruns = 100
echo "STEP sw1.v3" > spice4qucs.sw1.cir.res
dowhile $&number_v3  le  $&nruns
   reset
   alter v3 = $&number_v3
   dc v2 1.0 1.1 1.0
   let RatioError = 100.0*( 1.0 - (i(vpout)/( i(vpin)+1e-12 ) ) )
   write spice4qucs.sw1._swp.plot i(VPin) i(VPout) v(n1) RatioError
   set appendwrite
   echo "$&number_v3 " >> spice4qucs.sw1.cir.res
   let number_v3 =number_v3 + 1
end
unset appendwrite
destroy all
reset
exit
.endc
.end
```

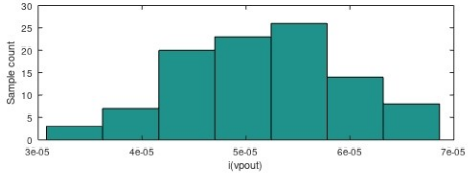


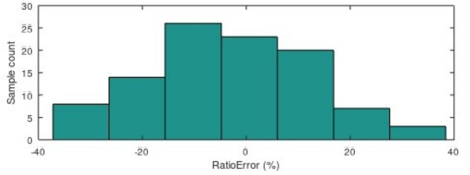
```
.INCLUDE SCRIPT
INCLSCR6
SpiceCode=
.PARAM mc_ok = 1.0
.LIB  cornerMOSlv.lib mos_tt_stat
*
```





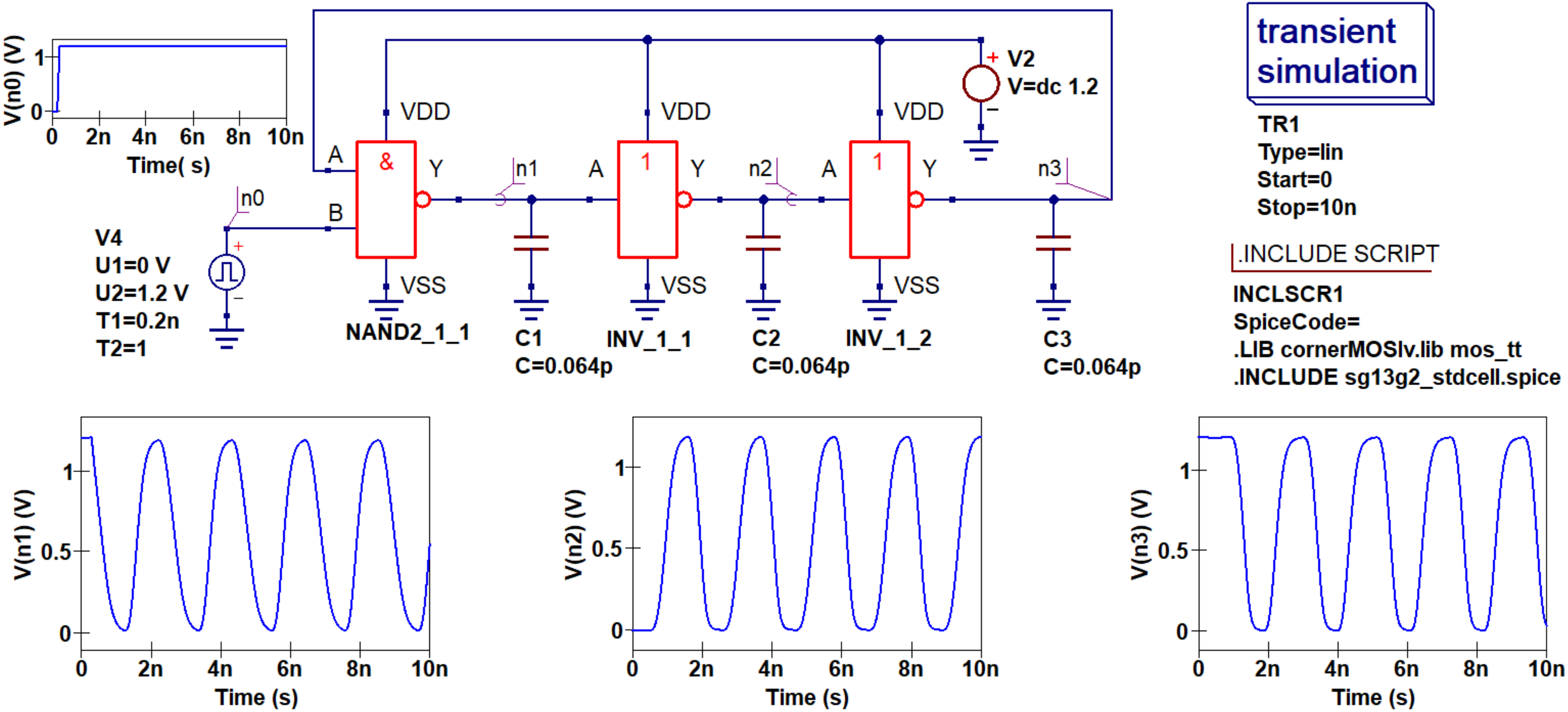
```
% Octave histogram plot.
DataSetFile = "CM_MC_S2_2A.dat.ngspice"
Y1name = "sw1.i(vpout)"
Y1label = "Sample count"
X1label = "i(vpout)"
Y2name = "sw1.ratioerror"
Y2label = "Sample count"
X2label =  "RatioError (%)"
nbins = 7
plotHistogram2V(DataSetFile, Y1name, Y1label, X1label, Y2name, Y2label, X2label, nbins)
```





The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Stdcell digital ring oscillator:



V4
U1=0 V
U2=1.2 V
T1=0.2n
T2=1

NAND2_1_1

C1
C=0.064p

INV_1_1

C2
C=0.064p

INV_1_2

C3
C=0.064p

V2
V=dc 1.2

transient simulation

TR1
Type=lin
Start=0
Stop=10n

.INCLUDE SCRIPT

INCLSCR1
SpiceCode=
.LIB cornerMOSlv.lib mos_tt
.INCLUDE sg13g2_stdcell.spice

Capacitors C2, C2 and C3 set to IHP measured values for "mid" size devices

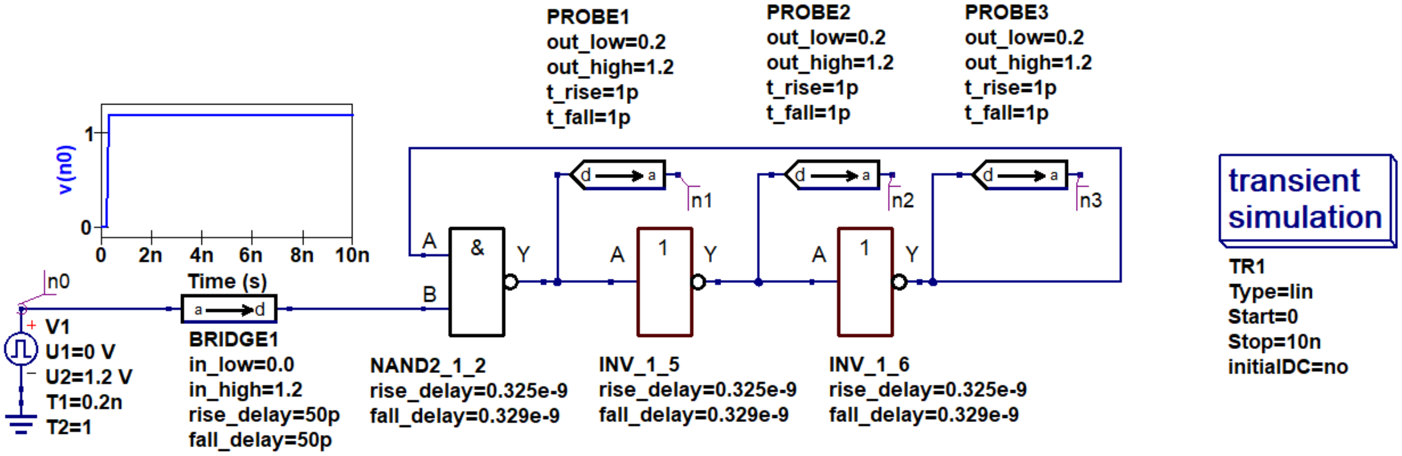
The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

XSPICE stdcell digital ring oscillator:

Xspice behvioural model for a IPH PDK ring oscillator

logic

1	=	1.2v
0	=	0.0V
U	=	0.6V



PROBE1
out_low=0.2
out_high=1.2
t_rise=1p
t_fall=1p

PROBE2
out_low=0.2
out_high=1.2
t_rise=1p
t_fall=1p

PROBE3
out_low=0.2
out_high=1.2
t_rise=1p
t_fall=1p

V1
U1=0 V
U2=1.2 V
T1=0.2n
T2=1

BRIDGE1
in_low=0.0
in_high=1.2
rise_delay=50p
fall_delay=50p

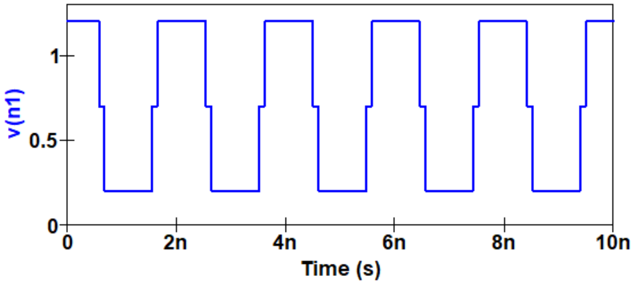
NAND2_1_2
rise_delay=0.325e-9
fall_delay=0.329e-9

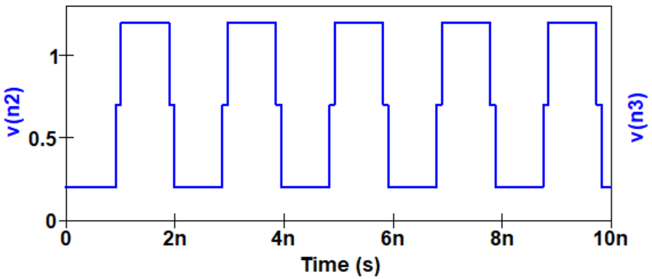
INV_1_5
rise_delay=0.325e-9
fall_delay=0.329e-9

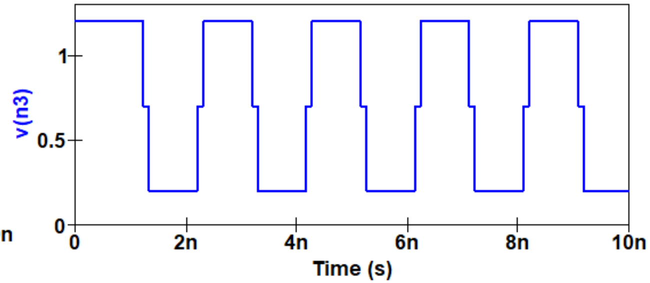
INV_1_6
rise_delay=0.325e-9
fall_delay=0.329e-9

transient simulation

TR1
Type=lin
Start=0
Stop=10n
initialDC=no

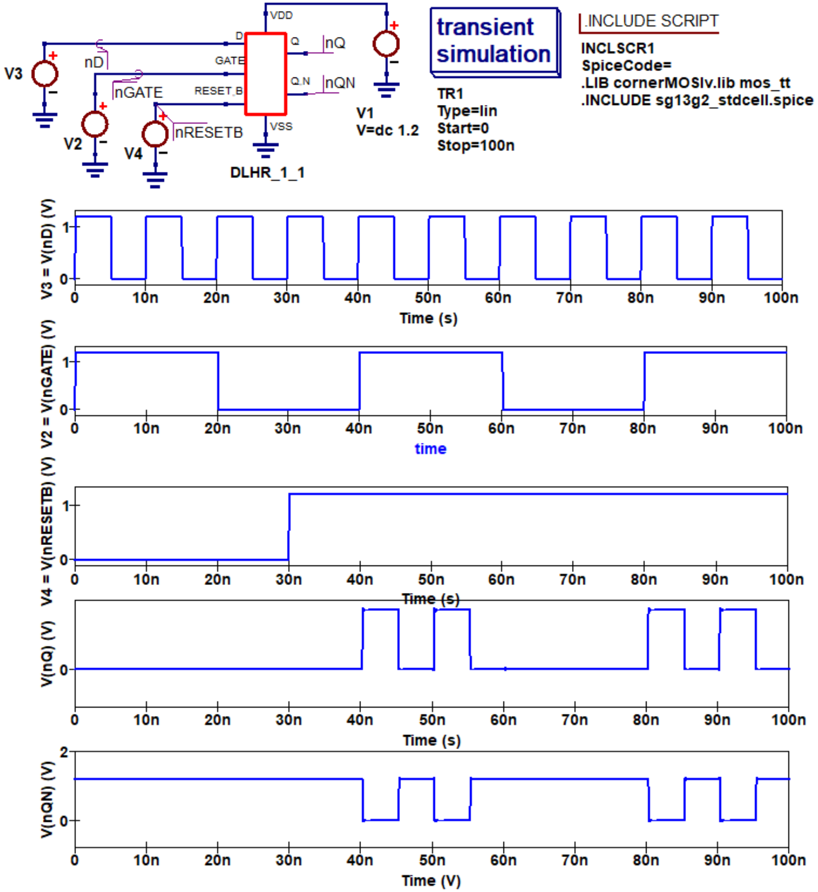






The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

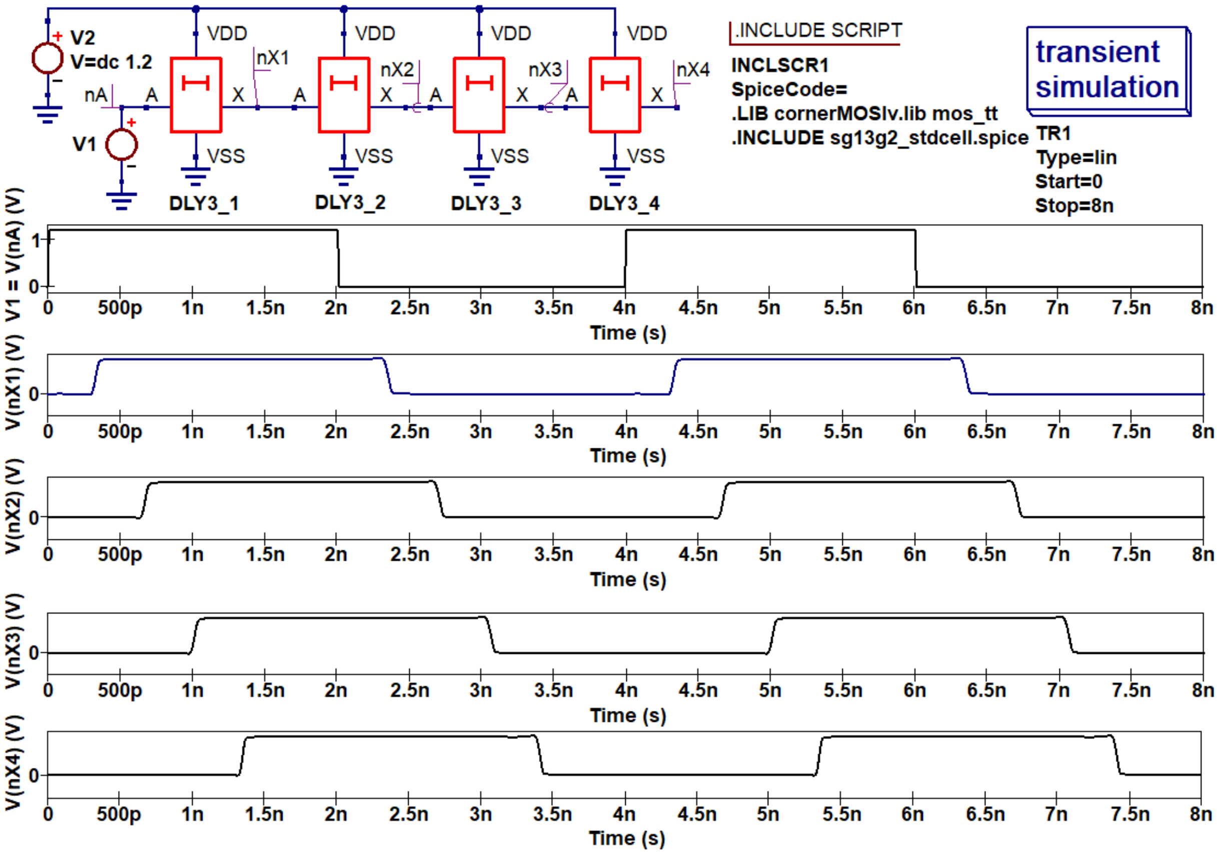
Example IHP stdcell digital components: sequential models and delay elements



.INCLUDE SCRIPT
INCLSCR1
SpiceCode=
.LIB cornerMOSlv.lib mos_tt
.INCLUDE sg13g2_stdcell.spice

transient simulation
TR1
Type=lin
Start=0
Stop=100n

V1
V=dc 1.2



.INCLUDE SCRIPT
INCLSCR1
SpiceCode=
.LIB cornerMOSlv.lib mos_tt
.INCLUDE sg13g2_stdcell.spice

transient simulation
TR1
Type=lin
Start=0
Stop=8n

V2
V=dc 1.2

Test simulations

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Qucs-S RF design: microstrip and openEMS simulation: 1

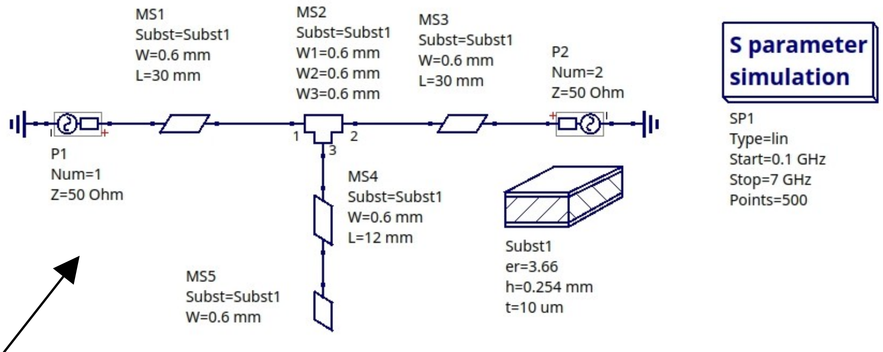
1. Qucs-Rflayout installation:

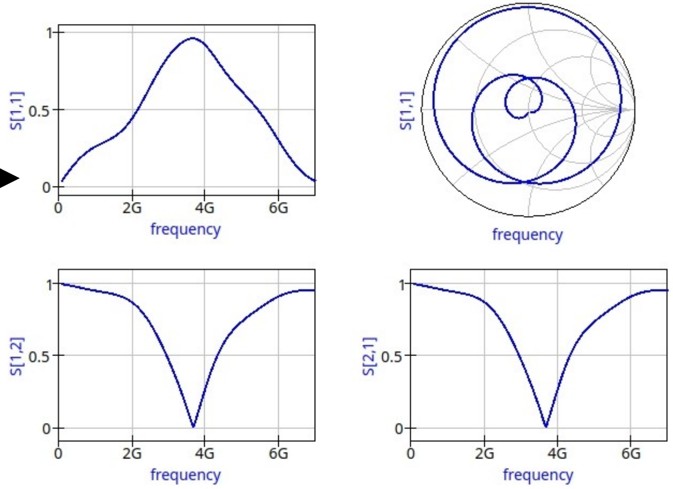
- Qucs-RFLayout installs and runs under Linux;
- Packages Qucs-RFLayout and openEMS should be downloaded from the internet. These install in /usr/bin:
  see https://github.com/thomaslepoix/Qucs-Rflayout for background and details.
- The Qucs-Rflayout tool is launched from the Qucs-S Tools menu: for example from */usr/*bin/qucsrflayout;

2. Introduction to features and operation:

- Enter a Qucs-S schematic for a microstrip design;
- Simulate the design to ensure correct function;
- Set the QucsRFlayout path to */usr/bin/*qucsrflayout;
- Launch the Qucs-Rflayout tool from the Qucs-S Tool menu;
- Fill in the Qucs-Rflayout Tool information boxes ;
- Write the generated layout data to file xxxx.m;
- Simulate xxxx.m with Octave.

see the next two slides

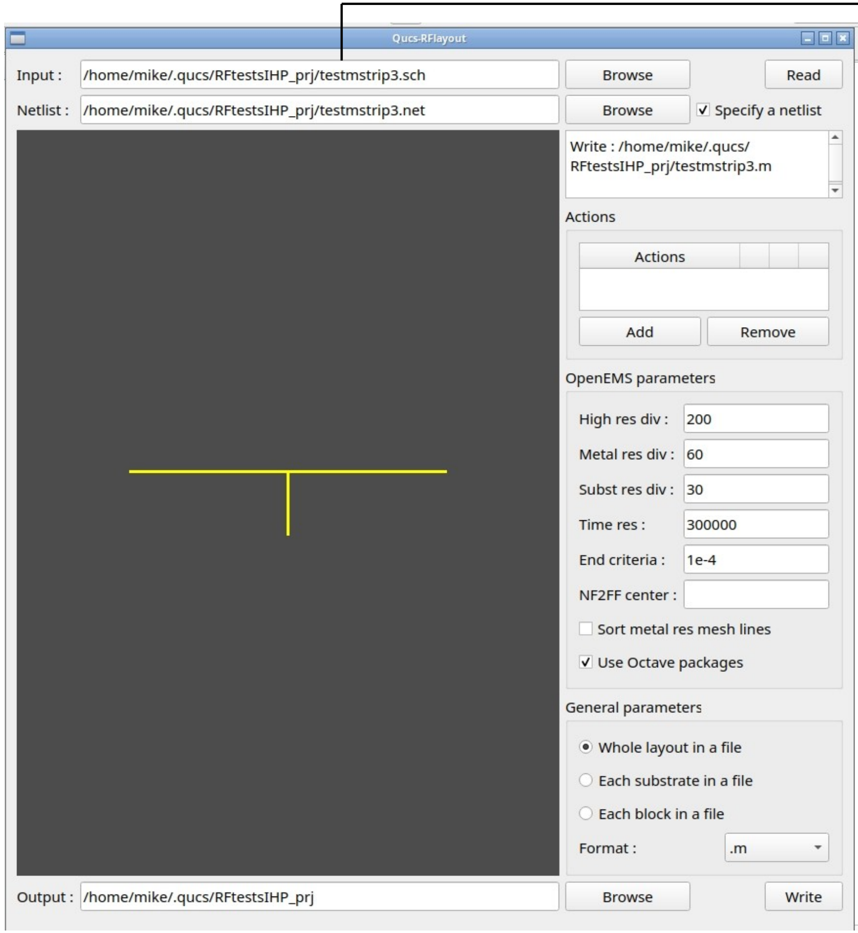




The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Qucs-S RF design: microstrip and openEMS simulation: 2

KiCad or Octave/openEMS



Qucs-RFlayout

Input : /home/mike/.qucs/RFtestsIHP_prj/testmstrip3.sch Browse Read

Netlist : /home/mike/.qucs/RFtestsIHP_prj/testmstrip3.net Browse ☑ Specify a netlist

Write : /home/mike/.qucs/RFtestsIHP_prj/testmstrip3.m

Actions

Actions

Add Remove

OpenEMS parameters

High res div : 200

Metal res div : 60

Subst res div : 30

Time res : 300000

End criteria : 1e-4

NF2FF center :

☐ Sort metal res mesh lines

☑ Use Octave packages

General parameters

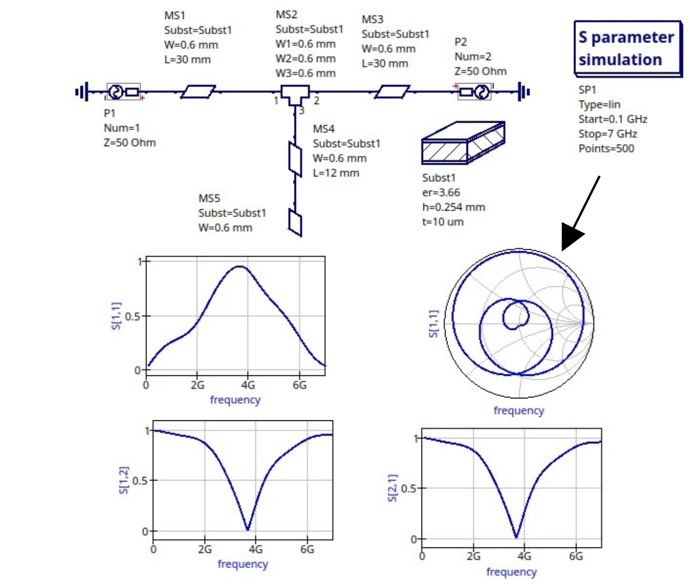
● Whole layout in a file

○ Each substrate in a file

○ Each block in a file

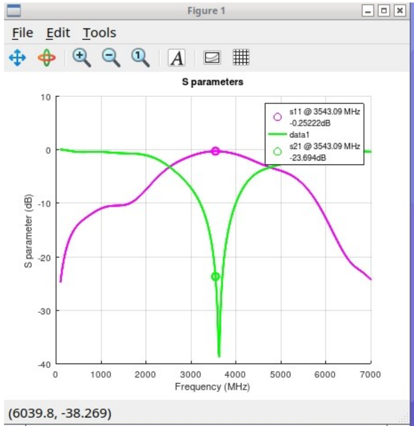
Format : .m

Output : /home/mike/.qucs/RFtestsIHP_prj Browse Write

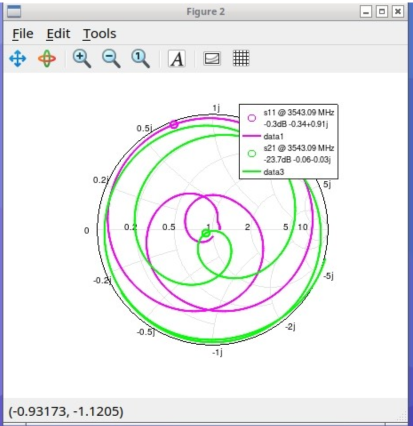


The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

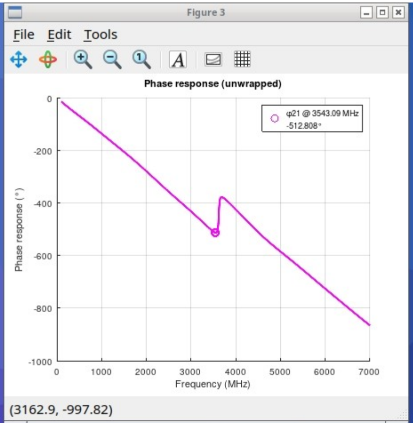
Qucs-S RF design: microstrip and openEMS simulation: 3



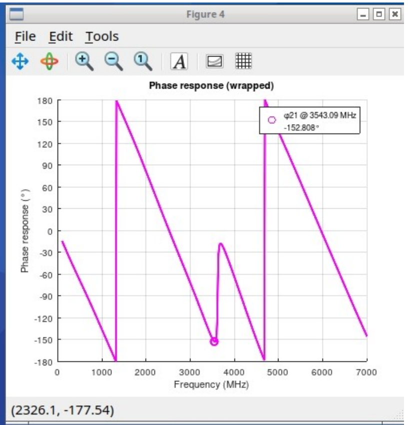
(6039.8, -38.269)



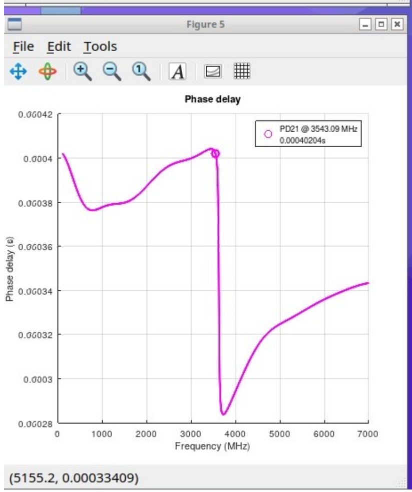
(-0.93173, -1.1205)



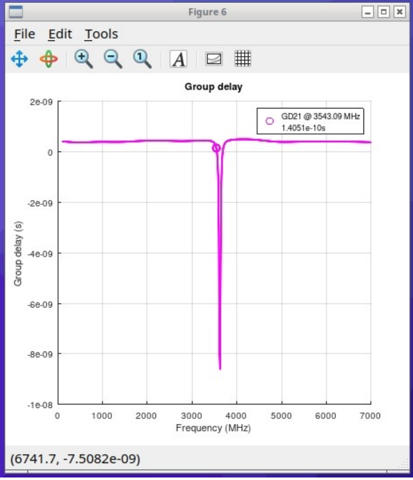
(3162.9, -997.82)



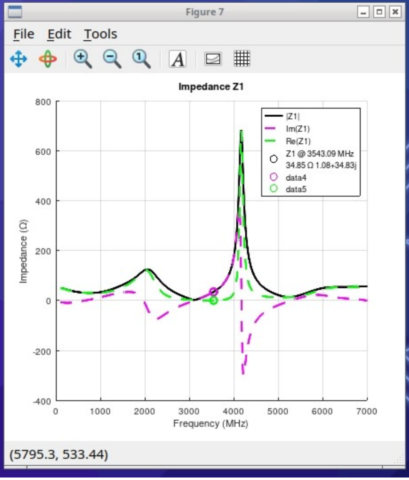
(2326.1, -177.54)



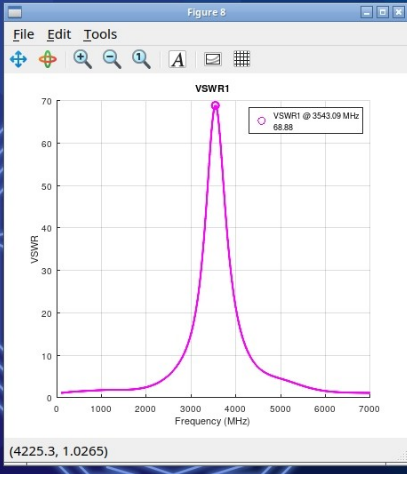
(5155.2, 0.00033409)



(6741.7, -7.5082e-09)



(5795.3, 533.44)



(4225.3, 1.0265)

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK

Summary

- The fast pace of semiconductor and device technology change has placed open source software tools under pressure to keep in step with user needs, particularly in areas driven by the recent release of Open Source PDKs.

- This presentation reports on recent developments in open source tools for analogue, RF and mixed analogue/digital IC design using the IHP 130 nm BiCMOS Open Source PDK (sg13g2).

- A series of Qucs-S/Ngspice/IHP Open Source PDK simulation test benches outline the application of Free Open Source (FOSS) tools, or equivalent licence software, for IC design.

- All the software tools outlined in this presentation are freely available from the web sites listed on slide 24.

- Future work in this area will concentrate on developing a series of analogue/RF test structures for production by IHP and subsequent performance measurement. This will allow the accuracy of the Qucs-S/Ngspice simulation output data to checked.

The evolution of Qucs-S as a software tool for RF and mixed signal IC design using the IHP 130nm BiCMOS Open Source PDK
Acknowledgments and software links

The IHP (Leibniz-Institut für innovative Mikroelektronik) Open PDK Development Team (project leader Rene Scholtz) : https://github.com/IHP-GmbH/IHP-Open-PDK

The Qucs-S Development Team: Qucs-S with SPICE https://ra3xdh.github.io/

The Ngspice Development Team: the next generation open source SPICE simulator https://ngspice.sourceforge.io/

The openEMS Development Team: open electromagnetic field solver https://github.com/thliebig/openEMS-Project

The openVAF Development Team: Next-Generation Verilog-A compiler https://openvaf.semimod.de/