

4.7. МОДЕЛИРОВАНИЕ НА ЭЛЕКТРОННОМ УРОВНЕ И SPICE

Один из основных форматов для обмена электрическими схемами это SPICE (SPICE - Simulation Program with Integrated Circuit Emphasis) (SPICE - это программа моделирования радиоэлектронных компонентов).

Большинство программ моделирования поддерживают экспорт и импорт в текстовой формат SPICE2.

К сожалению модели микроэлектронных приборов "вшиты" в SPICE и хотя можно тюнить параметры - все равно HDL-AMS языки дают больше контроля над происходящими процессами.

Очень краткое описание SPICE языка:

* КОММЕНТАРИЙ
[ТИП_ИМЯ_КОМПОНЕНТА] [УЗЕЛ1] .. [УЗЕЛ_N] [ПАРАМЕТР_1] ... [ПАРАМЕТР_N]
.END ставится в конце файла

Типы компонентов

Rxx	resistor	резистор
Lxx	inductor	катушка индуктивности
Cxx	capacitor	конденсатор
Vxx	voltage source	источник напряжения
Ixx	current source	источник тока
Exx	voltage controlled voltage source	
Hxx	current controlled voltage source	
Fxx	current controlled current source	
Gxx	voltage controlled current source	
Dxx	diode	диод
Jxx	junction FET	JFET транзистор
Mxx	MOSFET	MOS транзистор
Bxx	GaAsFET	транзистор на арсениде галлия GaAs
Qxx	BJT	биполярный транзистор

Резистор

Rxx	NODE1	NODE2	RESISTIVITY
R1	1	0	1.0ohm
R3	7	8	4M

Источник напряжения

```
Vxx      V_NODE  GND_NODE  VOLTAGE
V1       1        0          3.0volt
V2       2        3          4K
```

Источник тока

```
Ixx      NODE    NODE    CURRENT
I4       2        4        15m                                // 0.015 A
```

Конденсатор

```
Cxx      NODE    NODE    CAPACITY
C1       1        0        1.5u                                (microfarad)
C2       2        3        4pF
```

Индуктивность

```
Lxx      NODE      NODE      INDUCTIVITY
L3        1          0         10m
```

Voltage controlled voltage source

```
Exx      ONODE      ONODE      INODE      INODE      GAIN
E3        1          2          3          4          5
E4        1          2          (3,        4)        10
-----
```

E3: $V(1-2) = V(3-4) * 5$
E4: $V(1-2) = V(3-4) * 10$

Для диодов, транзисторов итд используются модели

```
.MODEL NAME      TYPENAME (PARAMETER=VALUE,...)
```

TYPENAME is:

CAP	capacitor
IND	inductor
RES	resistor
D	diode
NPN	BJT n-p-n
PNP	BJT p-n-p
NJF	n-JFET
PJF	p-JFET
NMOS	n-channel MOSFET
PMOS	p-channel MOSFET
GASFET	GaAs n-JFET
CORE	non-linear magnetics
VSWITCH	voltage-controlled switch
ISWITCH	current-controlled switch

Параметры модели диода

```
Dxx      +NODE      -NODE      MODEL
D5        5          7         MyDiode
```

IS	Saturation current	A
N	Emission coefficient	1
RS	Parasitic resistance	Ohm
CJO	zero-bias p-n capacitance	Farad
VJ	p-n potencial	V
M	p-n grading coefficient	1
FC	forward-bias depletion capacitance coefficient	1
TT	transmit time	sec
BV	reverse breakdown voltage	V
IBV	reverse breakdown current	A
EG	bandgap voltage	eV
XTI	IS temperature exponent	1
KF	flicker noise coefficient	1
AF	flicker noise exponent	1

Параметры модели MOSFET

Mxx	DRAIN	GATE	SOURCE	BULK	MODEL
	NODE	NODE	NODE	NODE	NAME
M1	2	3	5	0	NMDideal

L	channel length	meter
W	channel width	meter
LD	lateral diffusion (length)	meter
LW	lateral diffusion (width)	meter
VTO	zero-bias threshold voltage	meter
KP	transconductance	amp/volt^2
GAMMA	bulk threshold parameter	volt^(1/2)
PHI	surface potencial	volt
LAMBDA	channel-length modulation	1/volt
RD	drain ohmic resistance	ohm
RS	source ohmic resistance	ohm
RG	gate ohmic resistance	ohm
RB	bulk ohmic resistance	ohm
RDS	drain-source shunt resistance	ohm
RSH	drain-source diffusion sheet resistance	ohm
IS	bulk p-n saturation current	A
JS	bulk p-n saturation current area	A/meter^2
PB	bulk p-n potencial	volt
CBD	bulk-drain zero-bias p-n capacitance	farad
CBS	bulk-source zero-bias p-n capacitance	farad
CJ	bulk p-n zero-bias bottom capacitance/area	farad/meter^2
CJSW	bulk p-n zero-bias perimeter capacitance/area	farad/meter
MJ	bulk p-n bottom grading coefficient	1
MJSW	bulk p-n sidewall grading coefficient	1
FC	bulk forward-bias capacitance coefficient	1
CGSO	gate-source overlap capacitance/channel width	farad/meter
CGDO	gate-drain overlap capacitance/channel width	farad/meter
CGBO	gate-bulk overlap capacitance/channel width	farad/meter
NSUB	substrate doping density	1/cm^3
NSS	surface state density	1/cm^2
NFS	fast surface state density	1^cm^2
TOX	oxide thickness	meter

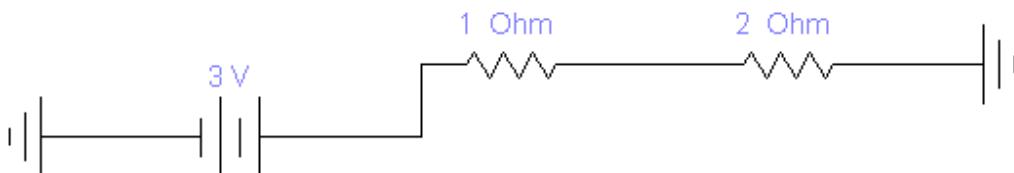
```
TPG      gate material type (-1=as bulk,+1 opposite, 0 = aluminium)
XJ       metallurgical junction depth                         meter
UO       surface mobility                                     cm^2/(V*sec)
VMAX    maximal drift velocity                                meter/sec
XOC     fraction of channel charge attributed to drain   1
DELTA   width effect on threshold                           1
KF      flicker noise coefficient                          1
AF      flicker noise exponent                            1
..... etc
```

BJT

```
Qxx      COLLECT BASE      EMMIT      BULK      MODEL
        NODE     NODE      NODE     NODE      NAME
Q1       2         3         5         0      NMDideal
```

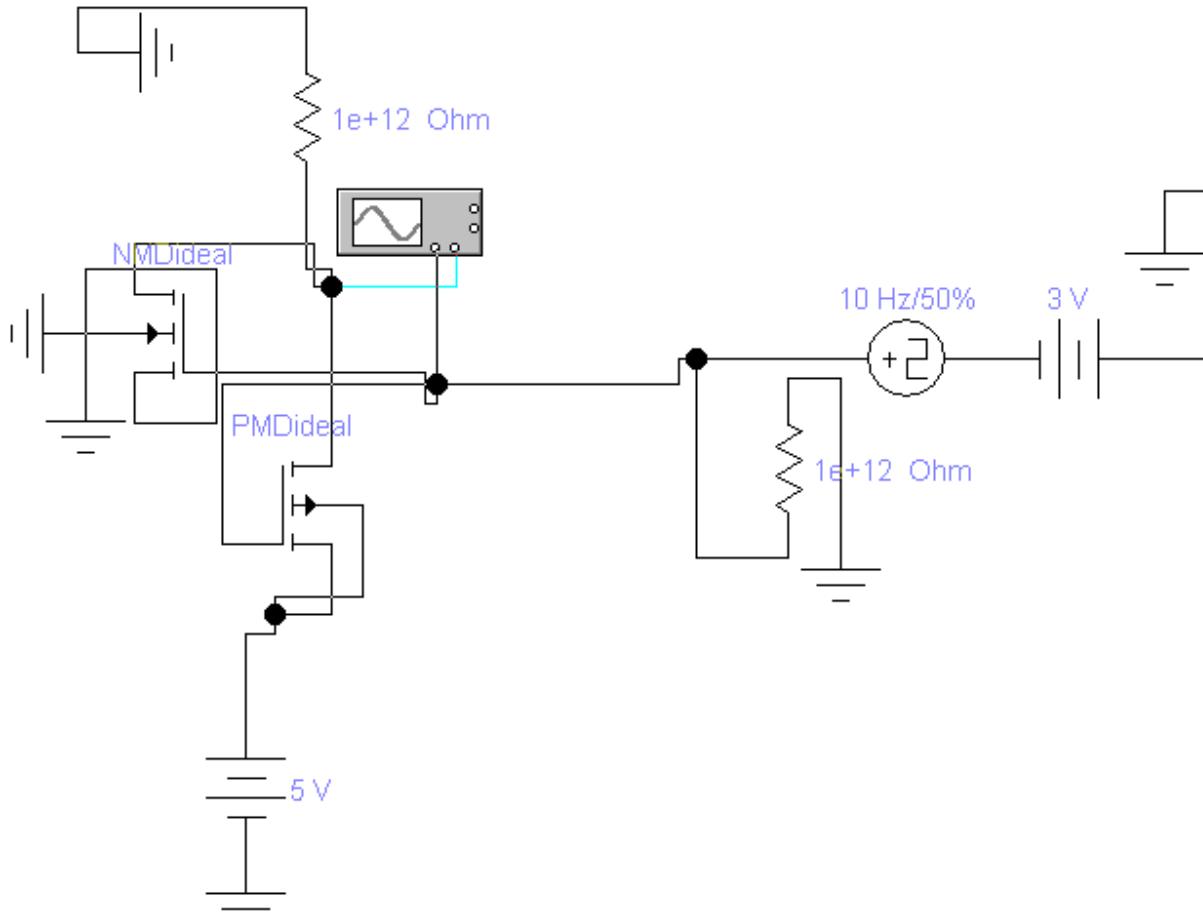
Параметры модели BJT приводить не будем

Примеры



```
* Simple Circuit
Vin 1 0 3.0volt
R1 1 2 1.0ohm
R2 2 0 2.0ohm
.END
```

C1 1 0 1pF



Пример схемы CMOS инвертора:

```
* Oscilloscope(s)
.PROBE V(14, 0)
R_o_scope_0_0 14 0 1Tohm
.PROBE V(15, 0)
R_o_scope_0_1 15 0 1Tohm

* Function Generator(s)
V_fg_plus 14 0 DC 0V AC 3V
+PULSE(-3V 3V 0 100ns 100ns 50ms 100ms)

* Battery(s)
V1 12 0 DC 5

* 3-Terminal Depletion N-MOSFET(s)
M_N_DM_Q1 15 14 0 0 NMDideal

* 3-Terminal Depletion P-MOSFET(s)
M_P_DM_Q2 15 14 12 12 PMDideal

* Connector(s)
* node = 0, label =
* node = 1, label =
* node = 1, label =
* node = 2, label =
```

```
* node = 0, label =
* Misc
.TRAN 1.4ms 700ms 0s 1.4ms

.MODEL NMDideal NMOS(VTO=0 KP=20u LAMBDA=0 PHI=600m GAMMA=0 Rd=0 Rs=0
+IS=10f Cgbo=0 Cgdo=0 Cgso=0 Cbd=0 Cbs=0 PB=800m RSH=0 CJ=0 MJ=500m CJSW=0
+MJSW=500m JS=0 TOX=100n NSUB=0 NSS=0 TPG=1 LD=0 U0=600 KF=0 AF=1 FC=500m
+TNOM=27)

.MODEL PMDideal PMOS(VTO=0 KP=20u LAMBDA=0 PHI=600m GAMMA=0 Rd=0 Rs=0
+IS=10f Cgbo=0 Cgdo=0 Cgso=0 Cbd=0 Cbs=0 PB=800m RSH=0 CJ=0 MJ=500m CJSW=0
+MJSW=500m JS=0 TOX=100n NSUB=0 NSS=0 TPG=1 LD=0 U0=600 KF=0 AF=1 FC=500m
+TNOM=27)

.OPTIONS ITL4=25
.END
```

[Index](#) [Prev](#) [Next](#)