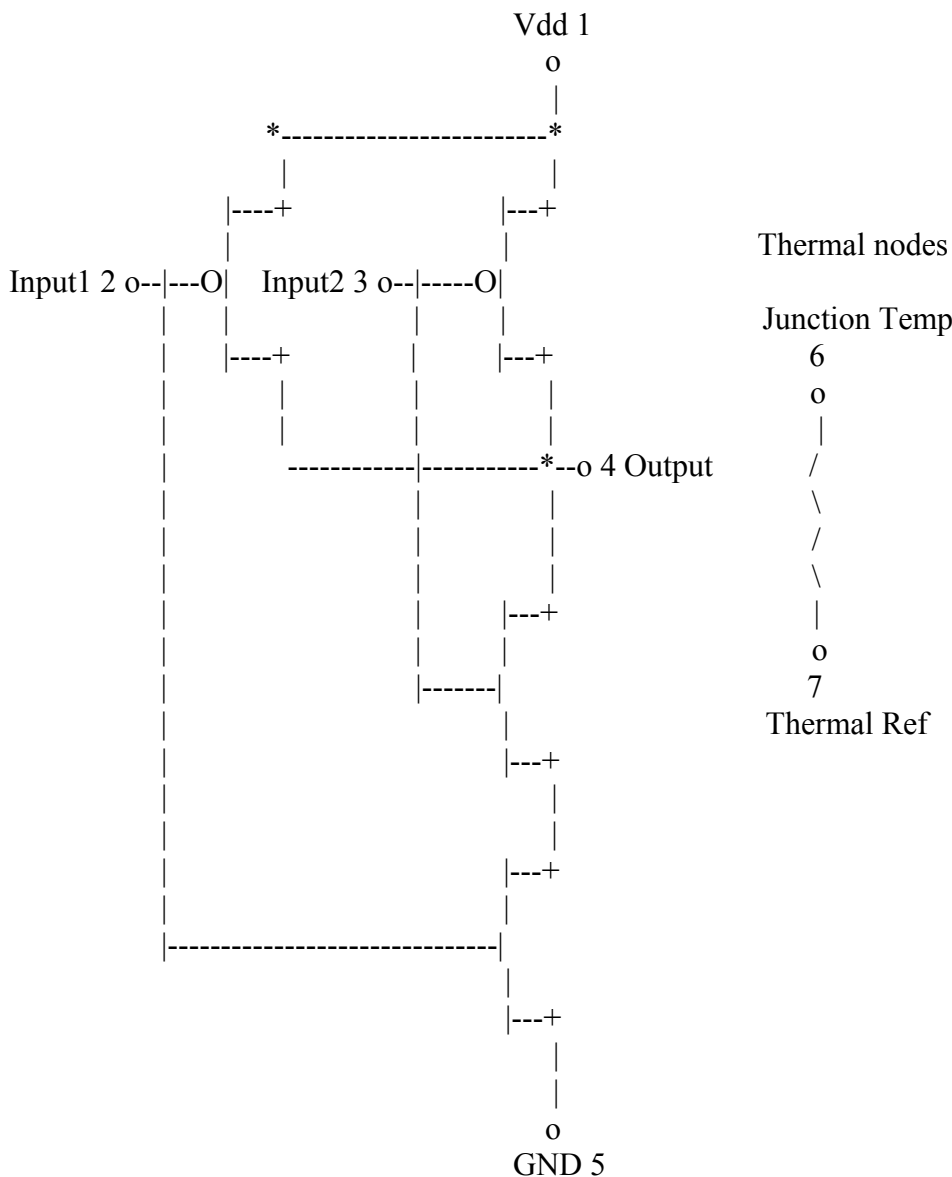


CMOS NAND Gate with Junction temperature



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Description:

This element implements a generic CMOS NAND gate and calculates junction temperature.

Form: moscnandt: <instance name> n_1 n_2 n_3 n_4 n_5 n_6 n_7 <parameter list>

instance name is the model name

n_1 is the NAND element Vdd node,

n_2 is the NAND element input 1 node,

n_3 is the NAND element input 2 node,

n_4 is the NAND element output node,

n_5 is the NAND element Ground node,

n_6 is the NAND element Junction temperature node,

n_7 is the NAND element Thermal Reference node.

Parameters:

Parameter	Type	Default value	Required?
vtn: NMOS threshold voltage (V)	DOUBLE	1	no
vtp: PMOS threshold voltage (V)	DOUBLE	-1	no
un: effective mobility of electrons in NMOS ($\text{cm}^2/\text{V-sec}$)	DOUBLE	500	no
up: effective mobility of holes in PMOS ($\text{cm}^2/\text{V-sec}$)	DOUBLE	200	no
en: permittivity of gate insulator in NMOS (F/cm)	DOUBLE	34.515e-14	no
ep: permittivity of gate insulator in PMOS (F/cm)	DOUBLE	34.515e-14	no
tox: thickness of gate insulator (cm)	DOUBLE	2e-6	no
wn: channel width of NMOS (cm)	DOUBLE	50e-6	no
ln: channel length of NMOS (cm)	DOUBLE	2e-6	no
wp: channel width of PMOS (cm)	DOUBLE	100e-6	no
lp: channel length of PMOS (cm)	DOUBLE	2e-6	no
td: response delay time (sec)	DOUBLE	0	no

thermal: thermal element flag	BOOLEAN	False	no
tnom: nominal temperature (K)	DOUBLE	300	no
zt: thermal impedance summation (K/W)	DOUBLE	310	no
c1: PMOS GS capacitance (F)	DOUBLE	1e-12	no
c2: NMOS GS capacitance (F)	DOUBLE	1e-12	no
c3: output GS (Miller) capacitance (F)	DOUBLE	1e-12	no
c4: parasitic diode capacitance from output to Vdd (F)	DOUBLE	1e-12	no
C5: parasitic diode capacitance from output to Ground (F)	DOUBLE	1e-12	no
freq: operating frequency (Hz)	DOUBLE	1e6	no
lk: leakage current (A)	DOUBLE	8e-6	no

Example:

moscnandt:nand 1 2 3 4 0 1000 "tref"

Model Documentation: (Start on a new page, Include English and make sure font sizes are consistent. Use figures if necessary. Please avoid using scanned image.)

MOSFET cutoff current I_{ds} , for $V_{gs} < V_t$:

$$I_{ds} = 0$$

MOSFET current factor β :

$$\beta = \mu * C_{ox} * (W / L)$$

MOSFET linear current I_{ds} , for $V_{gs} - V_t > V_{ds} > 0$:

$$I_{ds} = \beta * (V_{gs} - V_t - (V_{ds} / 2)) * V_{ds}$$

MOSFET saturation current I_{ds} , for $V_{ds} > V_{gs} - V_t > 0$:

$$I_{ds} = (\beta / 2) * (V_{gs} - V_t)^2$$

Power dissipation P_D :

$$P_D = (V_{sd,pmos} * I_{sd,pmos}) + (V_{ds,nmos} * I_{ds,nmos}) + (2 * freq * C * V_{dd}) + leakage$$

Junction temperature T_j :

$$T_j = T_{ambient} + (P_D * \theta_{jA})$$

References:

1. Mazen M Kharbutli. fREEDA element moscnand.
DEFAULT_ADDRESS"elements/Moscnand.h.html"
-

Sample Netlist:

* DC thermal CMOS NAND Test

* DC sweep input voltage from 0 to 5V

```
.dc sweep="vsource:Vin" start=0 stop=5 step=0.1
```

```
.options iniTmp=300
```

```
.ref "tref"
```

```
.ref 0
```

```
vsource:Vdd 1 0 vdc=5
```

```
vsource:Vin 2 0
```

```
vsource:Vdd2 3 0 vdc=5
```

```
moscnandt:nand 1 2 3 4 0 1000 "tref" thermal=1
```

```
res:R 4 0 r=1000000
```

```
***thermal circuit
```

```
res:R1 1000 1001 r=6e3
```

```
vsource:t1 1001 "tref" vdc=iniTmp  
cap:c1 1000 1001 c=1e-12
```

```
.out plot term 4 vt in "nand_voltage.out"  
.out plot element "moscnandt:nand" 4 ut in "nand_temperature.out"  
.out plot element "moscnandt:nand" 0 it in "nand_current.out"
```

```
.end
```

Validation:

This thermal CMOS NAND model adds thermal junction temperature calculation to the existing electrical CMOS NAND model (moscnand). Simulations were performed using the existing moscnand model in a netlist with a DC sweep from 0 to 5 Volts at the one input terminal. The second input terminal was connected to a DC voltage source of 5V. The resulting output voltage and current was recorded. The thermal CMOS NAND model (moscnandt) was validated by making a new netlist with the moscnandt model. The resulting moscnandt voltage output and current output was compared to those of the original moscnand model and identical electrical results were obtained. The resulting moscnandt junction temperature data was empirically verified by correlating junction temperature data points with manually calculated results.

The original moscnand model uses a default parameter of $w_p = 50e-6$ cm (channel width of PMOS). If this default parameter is used an erroneous element current output results. The moscnandt model uses a default parameter of $w_p = 100e-6$ cm, resulting in an expected element current output.

Known Bugs:

None.

Credits:

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