CHAPTER 8: Noise Model

8.1 Flicker Noise

8.1.1 Parameters

There exists two models for flicker noise. One is called as Spice2 flicker noise model, another one is called as BSIM3 flicker noise model [33,34]. The parameters in the models are listed in Table 8-1.

Symbols used in equation	Symbols used in SPICE	Description	Default	Unit
Noia	noia	Noise parameter A	(NMOS) 1e20 (PMOS) 9.9e18	none
Noib	noib	Noise parameter B	(NMOS) 5e4 (PMOS) 2.4e3	none
Noic	noic	Noise parameter C	(NMOS) -1.4e-12 (PMOS) 1.4e-12	none
Em	em	Saturation field	4.1e7	V/m
Af	af	Frequency exponent	1	none
Ef	ef	Flicker exponent	1	none
Kf	kf	Flicker noise parameter	0	none

Table 8-1. Flicker Noise Model Parameters.

8.1.2 Expressions

1. For Spice2 model

$$Flicker\ Noise = \frac{K_f I_{ds}^{af}}{C_{ox} L_{eff}^{2} f^{ef}} \tag{8.1a}$$

2. For BSIM3v3 model

1.1) If Vgs>Vth+0.1:

$$Flicker\ Noise = \frac{vtq^2 I_{ds}\mu_{eff}}{f^{Ef} L_{eff}^{2} C_{ox} 10^8}[N_{oia}\log(\frac{No + 2x10^{14}}{Nl + 2x10^{14}}) + N_{oib}(No - Nl) + 0.5N_{oic}(No^2 - Nl^2)] + \frac{vtI_{ds}^{2}\Delta L_{clm}}{f^{Ef} L_{eff}^{2} W_{eff} 10^8}\frac{N_{oia} + N_{oib}Nl + N_{oic}Nl^2}{(Nl + 2x10^{14})^2} \tag{8.1b}$$

where V_{tm} is the thermal voltage, μ_{eff} is the effective mobiity at the given bias condition, L_{eff} and W_{eff} are the effective channel length and width, respectively. The parameter N_0 is the charge density at the source given by:

$$N_0 = \frac{C_{ox}(V_{GS} - V_{TH})}{q} \tag{8.2}$$

The parameter N_l is the charge density at the drain given by:

$$N_l = \frac{C_{ox}(V_{GS} - V_{TH} - V_{DS}')}{q} \tag{8.3}$$

$$V_{DS}' = MIN(V_{DS}, V_{DSAT})$$

ΔLclm refers to channel length reduction due to CLM and is given by:

(8.4)

$$\Delta L_{clm} = \begin{cases} Litl \times \log\left(\dfrac{\dfrac{V_{DS}-V_{DSAT}}{Litl}+Em}{E_{SAT}}\right) & \text{if VDS > VDSAT} \\ 0 & \text{otherwise} \end{cases}$$

$$E_{SAT} = \frac{2 \times Vsat}{u_{eff}}$$

2. Otherwise,

(8.5)

$$FlickerNoise = \frac{S_{limit} \times S_{wi}}{S_{limit} + S_{wi}}$$

Where, S_{limit} is the flicker noise calculated at Vgs=Vth+0.1 and S_{wi} is given by:

(8.6)

$$Swi = \frac{N_{oia} VtI_{ds}{}^{2}}{W_{eff} L_{eff} \quad f^{Ef} \, 4x10^{36}}$$

8.2 Channel Thermal Noise

There also exists two models for channel thermal noise. One is called as Spice2 thermal noise model. Another one is called as BSIM3v3 thermal noise model. Each of these can be toggled by the **noimod** flag.

1. For Spice2 thermal noise model

$$\frac{8kT}{3}(gm + gds + gmb)$$

2. For BSIM3v3 thermal noise model

$$\frac{4KT\mu_{eff}}{L_{eff}{}^2}|Q_{inv}|$$

$$Q_{inv} = -W_{eff} L_{eff} C_{ox} V_{gsteff} (1 - \frac{A_{bulk}}{2(V_{gsteff} + 2vt)} V_{dseff})$$

The derivation for this last thermal noise expression is based on the noise model found in [35].

8.3 Noise Model Flag

The **noimod** flag is used to select different combination of flicker and thermal noise models discussed above, as given in Table 8.2.

noimod flag	Flicker noise model	Thermal noise model
1	Spice2	Spice2
2	BSIM3v3	BSIM3v3
3	BSIM3v3	Spice2
4	Spice2	BSIM3v3

Table 8-2. Noimod flag for differnet noise models

