SPICE Model Formulas

Jim Hagerman
11/26/91

Diode:

```
.model _name d()
```

Pick two points on Vd - Id curve at low Id, one at highest Id.

$$N = \frac{38.5(Vd1 - Vd2)}{\ln(Id1 / Id2)}$$

$$IS = Id1 \exp[-38.5(Vd1) / N]$$

$$RS = \frac{Vd3 - [(N / 38.5) \ln(Id3 / IS)]}{Id3}$$

Use reverse recovery time info. Ir is negative.

$$TT = \frac{trr}{\ln[(If - Ir) / -Ir]}$$

Pick three points on Cd - Vd curve. One at V = 0, one at low V, one at high V. Start with VJ = 0.5, then iterate M and VJ. Vd is negative.

$$CJO = Cdo$$

$$M = \frac{\ln(C2 / C3)}{\ln[(VJ - Vd3) / (VJ - Vd2)]}$$

$$VJ = \frac{Vd2}{1 - [CJO / C2]^{(1 / M)}}$$

EG = 1.11 Si
0.69 Schottky
0.67 Ge

XTI = 3.0 p-n
2.0 Schottky

Use breakdown voltage and leakage currents. Vbr is negative.

BV = -Vbr

IBV = Ir leakage current at 80% or more of breakdown

Zener:

Subcircuit. Uses two diode, one voltage source.

```
.subckt _1n751 1 2

   Dx 1 3 z$dx
   Vx 3 2 dc 4.00
   Dy 2 1 z$dy

   .model z$dy d(
+                 n   = 1.17
+                 is  = 3.7e-14
+                 rs  = 1.1
+                 cjo = 160e-12
+                 m   = 0.66
+                 vj  = 0.78
+                 bv  = 8.2
+                 ibv = 80e-6
+               )

   .model z$dx d(rs = 17)

.ends _1n751
```

DY diode is made as a normal diode except for breakdown.

BV = 1.6 Vz

IBV = 2 Ir   leakage at 80% of breakdown

DX, VX, use zener current and impedance.

RS = Rz

$$VX = Vz - \frac{[\ln(Iz / 10e{-14}) + 1]}{38.5} - Rz(Iz - Ir)$$

BJT:

```
.model _name npn()
.model _name pnp()
```

$$BF = Hfemax$$

Pick two points on Vbe - Ic curve at low Ic.

$$NF = \frac{38.5(Vbe2 - Vbe1)}{\ln(Ic2/Ic1)}$$

$$IS = Ic1 \exp[-38.5(Vbe1/NF)]$$

Pick two points on Vbesat, Vcesat - Ic curves. One at low Ic, one at max Ic. Ic/Ib is usually 10.

$$RB = \frac{Vbesat - (NF/38.5) \ln(Ic/IS)}{Ib}$$

$$RC = \frac{Vcesatmax - Vcesatmin}{Ic}$$

$$NR = NF$$

$$BR = \frac{IS\{\exp[38.5(Vbesatmin - Vcesatmin)/NR]\}}{Ib - (IS/BF)\{\exp[38.5(Vbesatmin/NF)]\}}$$

Pick two point on Vce - Ic graph at higher Ic. Else use hoe.

$$VAF = \frac{Ic1(Vce2 - Vce1)}{Ic2 - Ic1} - Vce1$$

$$VAF = Ic/hoe - Vce$$

Find Ic at intersection of upper asymptote on Hfe - Ic curve. Pick two points on lower asymptote. Il is at intersection of lower asymptote.

$$IKF = Ic \text{ at intersection}$$

$$NE = \frac{NF}{1 - \dfrac{\ln(BF) - \ln(hfe2)}{\ln(Il) - \ln(Ic2)}}$$

$$ISE = (IS/BF)[Il/IS]^{(1 - 1/NE)}$$

Pick three points on C - V curves. One at Vr = 0, one at low Vr, and one at high Vr. Start with a guess of VJx = 0.5 and MJx = 0.3, then iterate. Note Vrx is negative. If capacitance at Vr = 0 is unknown, then use:

$$CJx = C[1 - Vr/VJx]^{MJx}$$

CJC = Cobo or Ccb at Vr = 0

$$MJC = \frac{\ln(C1/C2)}{\ln[(VJ - Vr1)/(VJ - Vr2)]}$$

$$VJC = \frac{Vr1}{1 - [CJC/C1]^{(1/MJC)}}$$

XCJC = 0.8

CJE = Cibo or Cbe at Vr = 0

MJE = similar to MJC

VJE = similar to VJC

CJS = Ccs collector to substrate

MJS = similar to MJC

VJS = similar to VJC

Pick two points on ft - Ic curve, one at max, and the intersection of the asymptote for high Ic rolloff. Leave VTF at infinity.

$$TF = \frac{1}{2(\pi)ftmax}$$

XTF = 4

ITF = Ic at upper asymptote.

Use storage time data. If forward and reverse currents are unknown,use second equation.

$$TR = \frac{ts}{BR \ln[(Ibf + Ibr)/(Ic/BF + Ibr)]}$$

$$TR = \frac{2\, ts}{BR}$$

JFET:

```
.model _name njf()
.model _name pjf()
```

Use Vgsoff or Vgs - Id curve. Vgs may be negative. Also Idss.

$$VTO = Vgsoff$$

$$BETA = \frac{Idss}{VTO^2}$$

$$BETA = \frac{yfs}{2[1 + LAMBDA(Vds)][Vgs - VTO]}$$

$$BETA = \frac{Id}{2(Vds)[Vgs - VTO] - Vds^2}$$

Use yos data.

$$LAMBDA = \frac{yos}{BETA(VTO^2)}$$

Pick two points on yfs - Id curve, one at high Id, one at low Id.

$$RS = \frac{yfs1[\ln(Id2)/\ln(Id1)]}{yfs2\{yfs1[\ln(Id2)/\ln(Id1)] + 1\}}$$

Use capacitance data at Vr = 0.

$$CGS = Cgso$$

$$CGD = Cgdo$$

$$PB = \frac{Vgs - Vds}{1 - [CGD/Cds]^2}$$

MOSFET:

```
.model _name nmos()
.model _name pmos()
```

Use Vgsoff - Id curve. Note Vgs may be negative. Vbs is negative.

VTO = Vgsoff at Vbs = 0

PHI = 0.6

Use Vgsoff - Vbs curve.

$$GAMMA = \frac{Vgsoff - VTO}{[PHI - Vbs]^{0.5} - [PHI]^{0.5}}$$

Use Vgs - Id curve. Pick a point at high Id.

$$KP = \frac{2\ Id}{[Vgs - VTO]^2}$$

Pick two points on Vds - Id curve at high Id.

$$LAMBDA = \frac{Id2 - Id1}{(Id1)(Vds2) - (Id2)(Vds1)}$$

$$LAMBDA = \frac{gos}{Id}$$

Pick two points on gfs - Id graph, one at high Id, one at low Id.

$$RS = \frac{(gfs1)\ln(Id2/Id1)}{2(Gfs2)[(gfs1)\ln(Id2/Id1) + 1]}$$

RD = RS