

Re: 2n7000 spice models

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From: Winfield Hill (hill_a_at_t_rowland-dotties-harvard-dot.s-edu)

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Winfield Hill wrote...

> *Jim Thompson wrote...*

>>

>> *Win, WHAT is important to you in power-FET modeling, subthreshold?*

>> *Maybe we can mutually determine the "fix" for the models?*

>

> *OK, here's what I wrote early in the discussion, last December 31st,*

Winfield Hill wrote...

>> *Well, then surely you'll want viable Spice MOSFET models, because*

>> *you'll be using the FETs throughout their useful linear range, and*

>> *the output-stage crossover region is critical.*

>>

>> *Sadly most standard Spice library VMOS models simply don't do the*

>> *subthreshold linear region. For example, see the 10-decade plots*

>> *on page 123 of our book. A jellybean 2n7000 is rather similar to*

>> *the VN01 that we show in figure 3.14, and certainly a proper Spice*

>> *model should be able to make that plot. But I'd be surprised if*

>> *your standard Spice libraries work properly below say 5 to 20mA,*

>> *which is not that far below the FET's maximum current. Keep in*

>> *mind that linear power FET circuitry always operates well below*

>> *the maximum rated FET switching current, to keep power dissipation*

>> *junction heating under control.*

>

> *With respect to the Id-vs-Vgs curves on page 123 of our book, and*

> *the gm plots on page 132, the spice models should be able to show*

> *this performance. At subthreshold currents a FET acts very much*

> *like a transistor with respect to transconductance, etc., and when*

> *a power FET is used in linear audio amplifiers, e.g. in class AB,*

> *it may go through this region during each cycle. So in using Spice*

> *to determine distortion and evaluate various design configurations,*

> *surely it's necessary for the FET model to smoothly simulate the*

> *subthreshold region, and properly progress to the current-saturated*

> *regions that are normally accurately modeled. I'm going to go in*

> *to the lab and take some detailed 2n7000 measurements later today.*

I've completed a set of measurements over the current range of 1pA to 10mA, and posted the results on a.b.s.e. (Above 10mA I'll have to take pulsed measurements, which requires a different setup.) As anticipated, the data looks similar to the VN01 data, AoE page 123.

As expected, the 2n7000 has an exponential gate-voltage-programmed drain current in the under-1mA subthreshold region, similar to a BJT. It follows the formula $I_d = I_s \exp(V_{gs}/V_t)$ and for my tested 2n7000 $I_s = 0.1\text{pA}$ and $V_t = 78\text{mV}$. The transconductance is $g_m = I_d / 0.078$ (by comparison BJT transconductance, $g_m = I_d / 0.025$, is 3x higher).

My measurements show conduction starting at 200mV, 1nA at $V_{gs} = 0.7\text{V}$, and 1.0mA at $V_{gs} = 1.8\text{V}$, with a $2.303 V_t = 178\text{mV/decade}$ slope (see plot on a.b.s.e.). This compares to 58mV/decade for BJT transistors.

Above 0.1mA the 2n7000 drain current (and transconductance) begins to fall below that predicted by the exponential formula. I tried improving the model by reducing V_{gs} by a term $I_d \cdot R_s$. This worked over 0.1 to 5mA with $R_s = 15$ ohms, but above 5mA the term overcorrects and the formula predicted too little current.

Note, the spice model I tried earlier showed 0pA up to 2.4V, where it suddenly and dramatically soared to about 100nA, and it continued with excessive transconductance up to over 100uA. It required $V_{gs} = 2.51\text{V}$ for 1mA, so it was *very badly* off the mark on all counts, and nearly useless for linear modeling.

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Thanks,
- Win