Threshold Voltage Estimation technique for jFET Devices

JC Maillet (c) 2008 - 2015

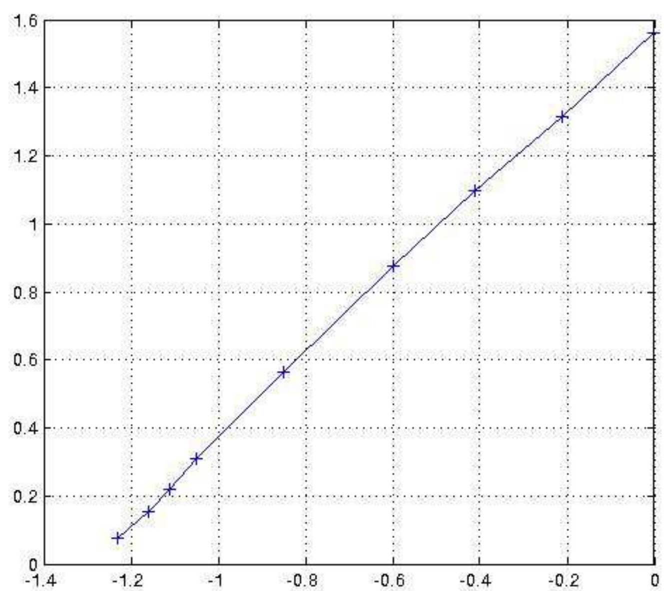
When the channel of an N-jFET transistor is maintained at a fixed voltage (Vds) its Drain current dependence on Vgs is closely *approximated* by the following single variable quadratic expression :

$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2$$

IDSS represents the Drain current value when Vg = Vs (Vgs = 0), and suggests a canonical **maximum operating current**. While **V**P (sometimes written as Vth) is the Threshold voltage defined by the **point (onset) where Drain current first achieves a zero value**. Together these numbers suggest device operating limits, but they can also be used for basic device characterization and matching.

Idss is dependent on Vds and is easily measured directly, whereas Vp is a fixed constant voltage (independent of Vds) that cannot be measured directly. Data sheets show strong potential variation in both values, and do so independently from one another; creating a two-dimensional variance.

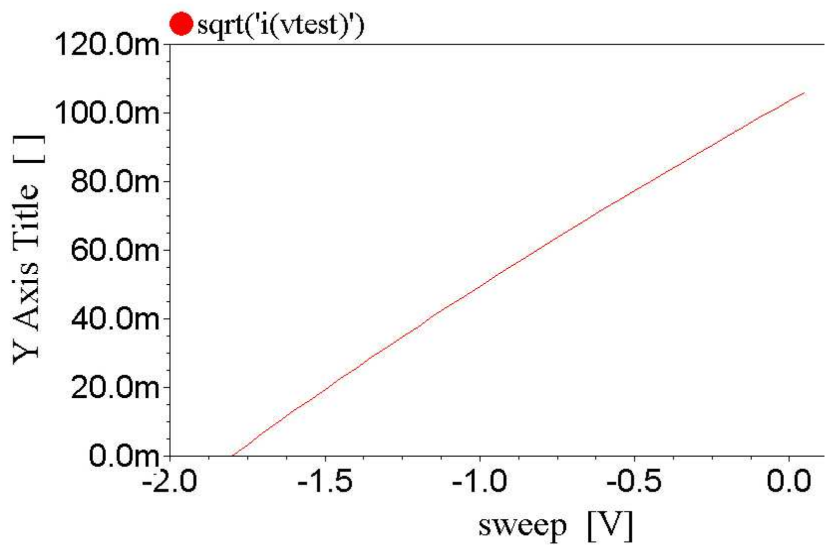
If we derive $I_{D(Vgs)}$ transfer function data from actual bench measurement, or SPICE simulation, and plot the Square-Root of this data we find a resulting **composite curvature that is not linear, strictly speaking**. **This therefore indicates that the Id(Vgs) function curve itself is not "exactly" quadratic**. This also means that the single variable equation listed above for Id is not perfectly sufficient or exact in itself. As an example, below is shown the Square-Root transformation of measured Drain current for a **Fairchild 2n5457 n-channel jFET device held fixed at Vds = 7.50 volts**; (note: the fixed Vds test voltage is chosen to lie well above the Pinch-Off voltage for that device.)



Square-Root transformation of actual 2n5457 Drain Current measurements.

Next is shown the Square-Root transformation of the **Drain current for a 2n5484 model held at Vds = 10.00 volts simulated with AIM-Spice.**

.MODEL J2N5484 NJF(VTO=-1.8 BETA=0.004 LAMBDA=0.01 RD=24.5 RS=22
+ CGS=2.5E-12 CGD=4E-12 IS=9.48E-15)



In both cases the Square-Root of the Id transfer curve does not form an exact straight line and therefore the original transfer function cannot be considered exactly quadratic by nature either. We see however that **this SQRT transformation isn't that far from being linear itself, and so can be itself interpolated with good accuracy using a quadratic function. From this quadratic function we can then infer a good "estimate" for Vp by finding the left quadrant x- intercept.**

2nd order interpolation requires three data pairs; and the following are suggested:

Vgs = 0	**Id = D1 (Idss)**
Vgs = D2	**Id = D3 (around D1/3 to D1/2)**
Vgs = D4	**Id = 10uA**

In MATLAB, two vectors are defined and ROOTS and POLYFIT functions are employed to generate a pair of roots; … one serving as approximation for Vp, the other physically irrelevant.

```
x=[D4 D2 0];
y=[SQRT(10e-6) SQRT(D3) SQRT(D1)];
ROOTS(POLYFIT(x,y,2))
```