Stuff

Exam 3 Monday 4/7/03

Primarily Ch.4 (BJTs), but may include any earlier material. Old exams are available on the HW web page.

MOSFET Lab today: Bring lab card with at least \$4.50.

Bring your textbook to lab

Tomorrow the seniors will be presenting their senior projects

HW #19, due: W, 4/2 Hw 19 handout

A. Stolp 4/1/03

Spice #S2, due: F, 4/4 2 handouts

HW #20, due: M, 4/7 Ex4.45, Ex4.46

Problems 4.120, 4.119, The transistor of HW 19, problem 1 has C_π = 11pF, C_μ = 2pF & 1pF of stray capacitance between the base & collector, find f_{CH} due to these.

ans 4.120 $r_o || \frac{r_\mu + r_\pi}{\beta + 1}$ last problem $1.82 \cdot \mathrm{MHz}$

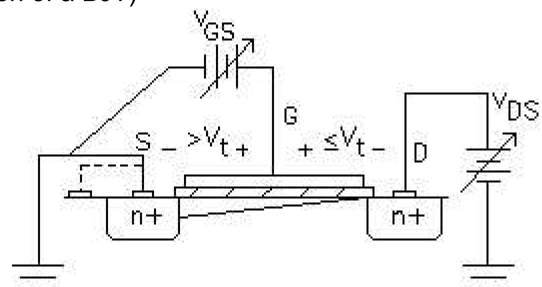
HW # 21, due: F 4/11 Ex5.1 - Ex5.8

ans: Ex5.7: V_{SB}=4V, i_D=0.182mA, r_o=578ohm

Start with MOSFET part of Monday's notes

Saturation Region (Beware, this is nothing like the saturation region of a BJT)

What happens if the Drain-end is just barely pinched off?



Where: $v_{GD} = V_t$ or... $v_{DS} = v_{GS} - V_t$

Drain current = $i_D = k'_n \cdot \frac{W}{L} \cdot \left[(v_{GS} - V_t) \cdot v_{DS} - \frac{1}{2} \cdot v_{DS}^2 \right]$

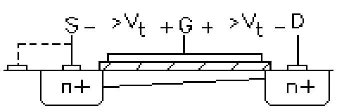
$= k'_n \cdot \frac{W}{L} \cdot \left[(v_{GS} - V_t) \cdot (v_{GS} - V_t) - \frac{1}{2} \cdot (v_{GS} - V_t)^2 \right]$

OR: $= k'_n \cdot \frac{W}{L} \cdot \left[\frac{1}{2} \cdot (v_{GS} - V_t)^2 \right]$ $= \frac{1}{2} \cdot k'_n \cdot \frac{W}{L} \cdot (v_{GS} - V_t)^2$ **<-- IMPORTANT EQUATION**

Once the channel is "pinched off" the current levels off and no longer increases much with increased v_{DS}.

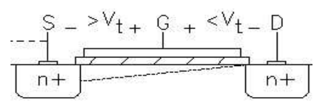
So the equation is actually pretty good whenever $v_{GD} \le V_t$ or... $v_{DS} \ge v_{GS} - V_t$

Characteristic Curves



triode region

(a.k.a., ohmic or linear)



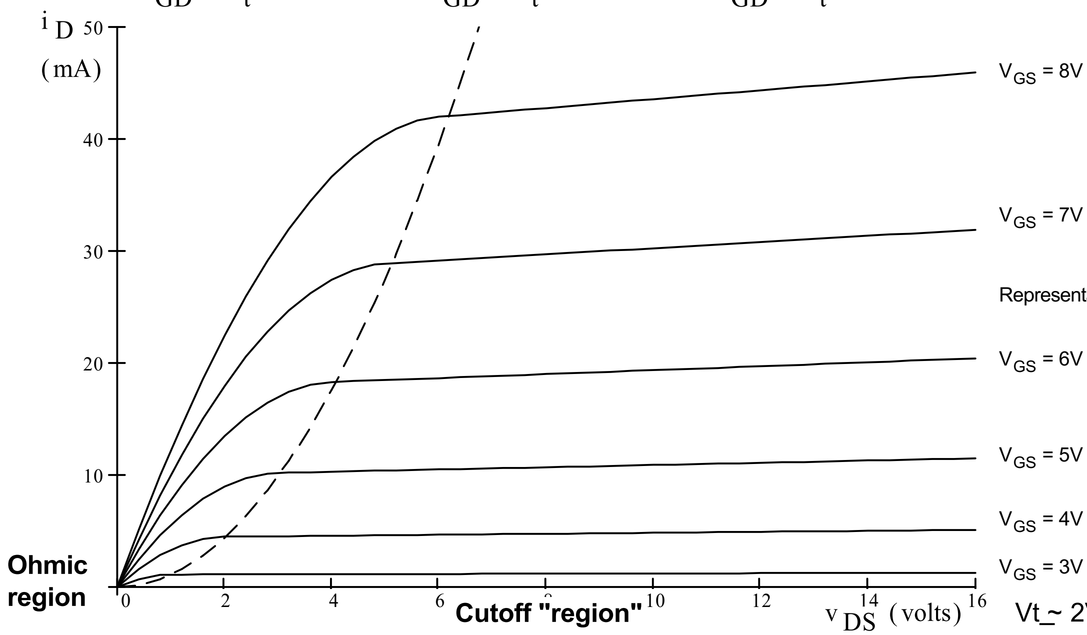
saturation region

(a.k.a., constant current or active)

$v_{DS} < v_{GS} - V_t$ $v_{DS} = v_{GS} - V_t$ $v_{DS} > v_{GS} - V_t$ $i_D \approx \frac{1}{2} \cdot k'_n \cdot \frac{W}{L} \cdot (v_{GS} - V_t)^2$

$v_{GD} > V_t$ $v_{GD} = V_t$ $v_{GD} < V_t$

neglecting Early effect (r_o), or near triode-saturation boundary



Vt ≈ 2V

Representative i_D vs v_{DS} curves

Saturation Region Beyond Pinch-off

(Again beware, this is nothing like the saturation region of a BJT)

Actually, the channel doesn't completely pinch closed at the Drain end. It just gets so small that it has a relatively high resistance compared to the rest of the channel. The pinching effect is proportional to $V_{DS} - V_t$, so the resistance is proportional to the same voltage that is trying to overcome the resistance.

$$i_D = \frac{V_{DS} - V_t}{R_{pinch}}$$

so i_D is quite constant once the channel is "pinched".

R_{pinch} \ proportional to: $V_{DS} - V_t$

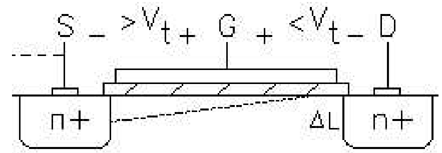
Note: This is a "warm & fuzzy" reason which works for us. The real reason is dependent on quantum physics and is more than you want to know. OR, in book-speak: "It is beyond the scope of this course" which translates into: "I don't know, someone told me it was so and I believed them."

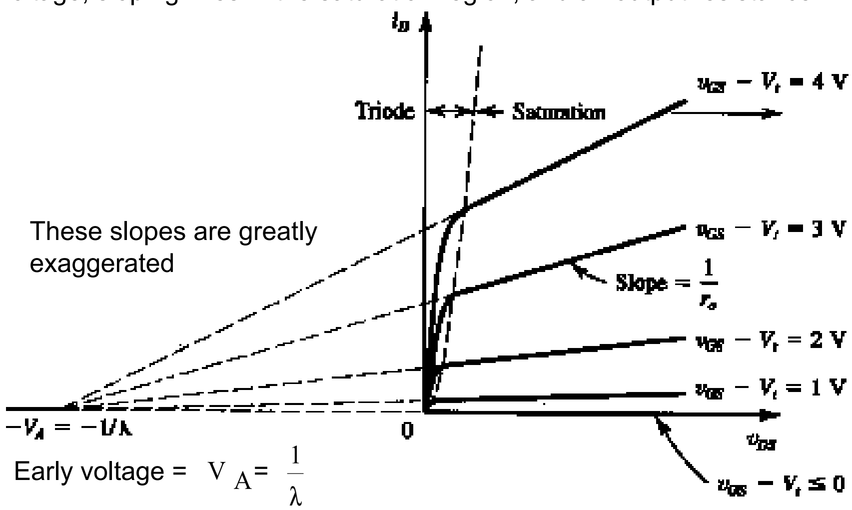
IE: Once "pinched-off", the current remains fairly constant with increasing V_{DS}

The remainder of the V_{DS} ($V_{DS}-(V_{GS}-V_t)$) is simply lost getting the electrons to cross the pinched-off spot.

Early effect, channel length modulation (r_o)

However, the pinched-off spot does get bigger as V_{DS} increases, leading to a shortening of the rest of the channel, and correspondingly more current. This leads to "channel length modulation" which is just like base width modulation in the BJT. It also leads to an Early voltage, sloping lines in the saturation region, and an output resistance.





Early voltage = $V_A = \frac{1}{\lambda}$

including Early effect (r_o), due to channel length modulation

$$\lambda = \frac{1}{V_A}$$

$$i_D = \frac{1}{2}\cdot k'_n \cdot \frac{W}{L}\cdot\left(v_{GS} - V_t\right)^2\cdot\left(1 + \lambda\cdot v_{DS}\right)$$

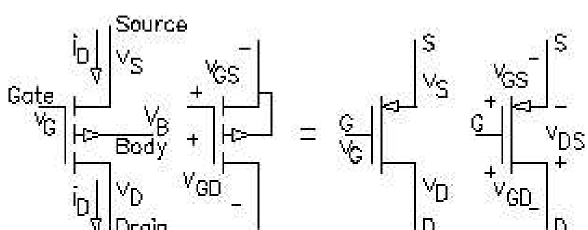
IMPORTANT EQUATION

$$r_o = \frac{\Delta v_{DS}}{\Delta i_D} = \frac{1}{\lambda\cdot\left[\frac{1}{2}\cdot k'_n\cdot\frac{W}{L}\cdot\left(v_{GS} - V_t\right)^2\right]}$$

$$\cong \frac{1}{\lambda\cdot I_D} = \frac{V_A}{I_D} = r_o$$

IMPORTANT EQUATION

p-Channel MOSFETs



Use the same equations as for the n-channel, but:

Swap < for > and > for < in all the voltage tests.

Swap k'_p for k'_n in all equations

V_t will be negative

i_D comes out positive because the v_{DS} used in the equations is negative

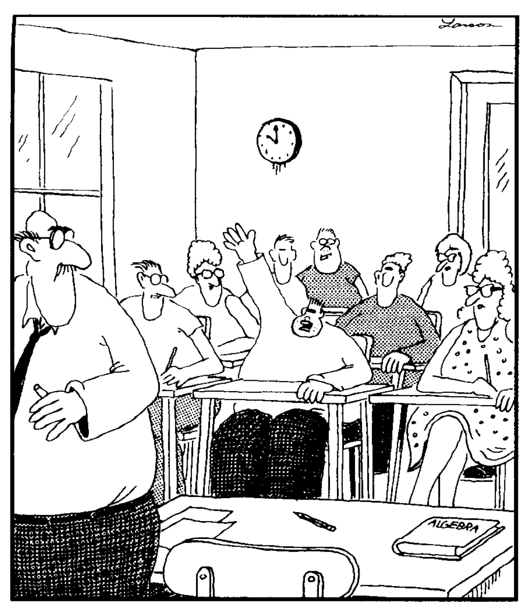
Always shown in your book with the source on top, but that is not a requirement of the part symbol.

OR, just mirror the circuit and use an n-channel for purposes of analysis and then interpret the results.

The mobility of holes is only about 40% of the mobility of electrons.

So: **$k'_p = \mu_p C_{ox} \cong 40\% k'_n$**

p-channel parts have to be $2^1/_2$ times as wide as an equal n-channel part. That means more $



"Mr. Stolp, may I be excused? My brain is full."