Lecture 15

- Last time:
  - Square-law MOSFET model
  - Linear MOSFET model
- Today :
  - MOSFET small-signal model: three (four) terminal device → complicated!

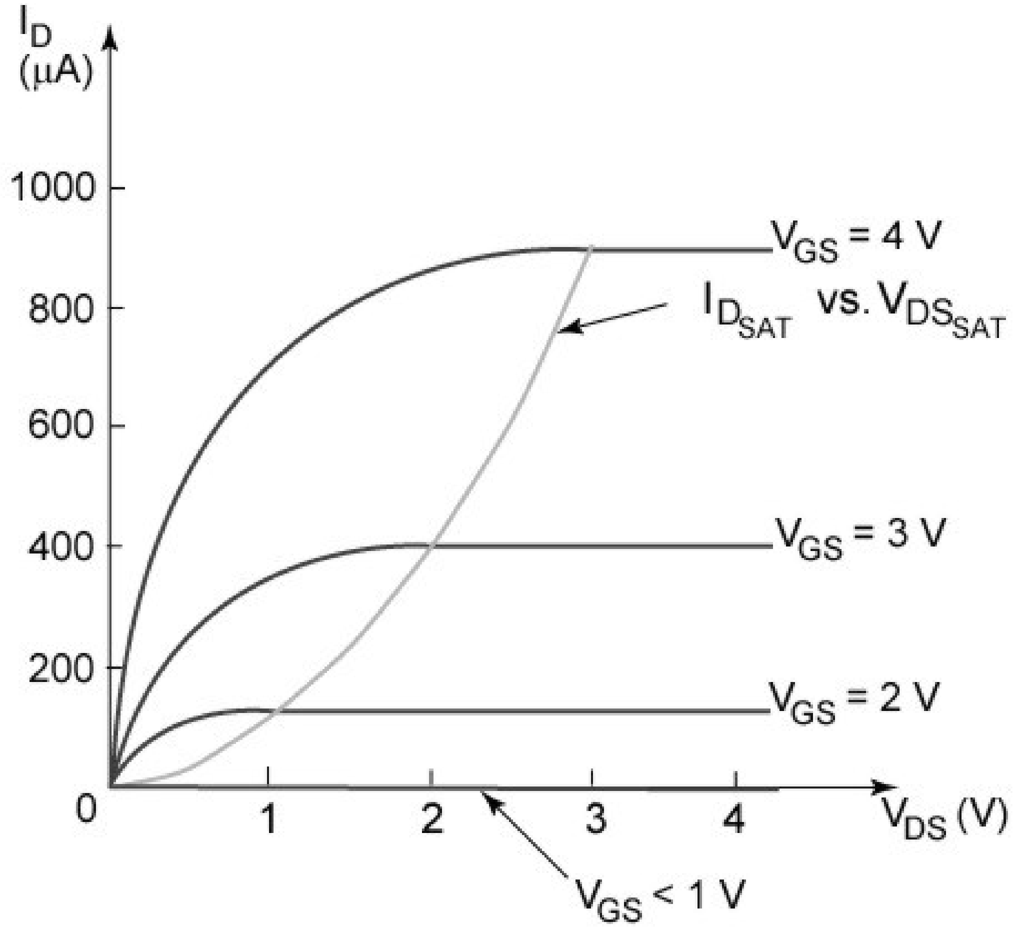
Why Find an Incremental Model?

- Signals of interest in analog ICs are often of the form:

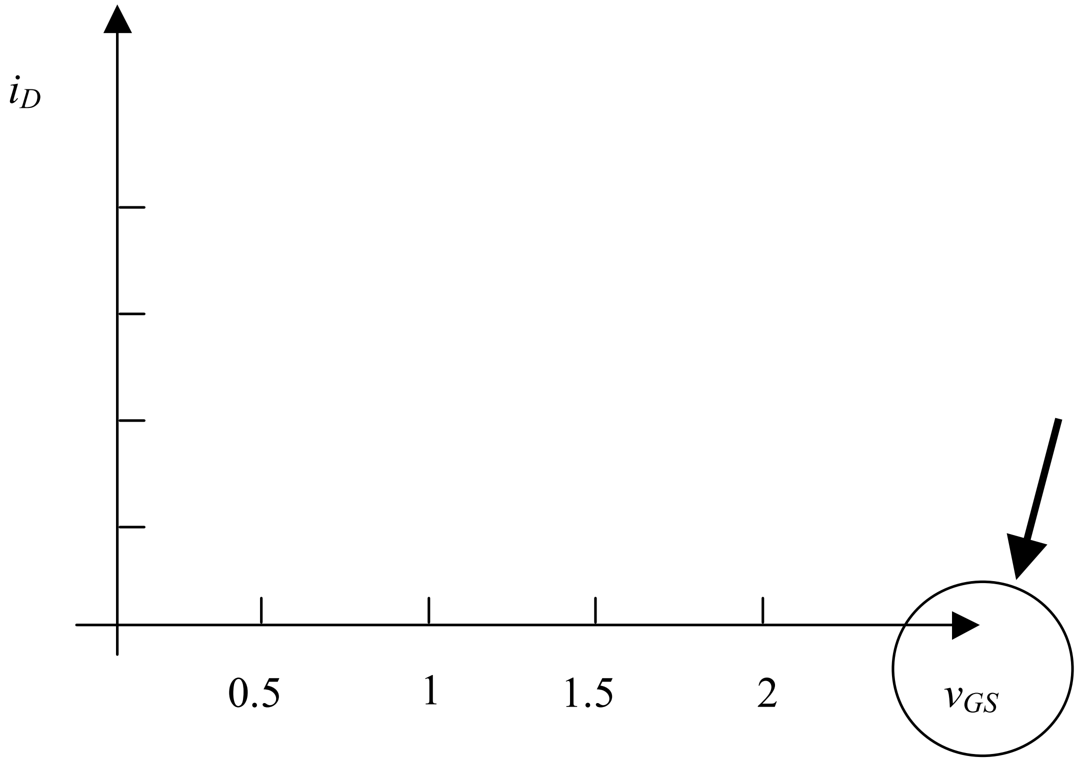
$$v_{GS}(t) = V_{GS} + v_{gs}(t)$$

Direct substitution into $i_D = f(v_{GS}, v_{DS})$ is tedious AND doesn't include charge-storage effects … pretty rough approximation

Which Operating Region?



Changing One Variable at a Time



Assumption: $V_{DS} > V_{DS,SAT} = V_{GS} - V_{Tn}$ (square law)

The *Transconductance* g_m

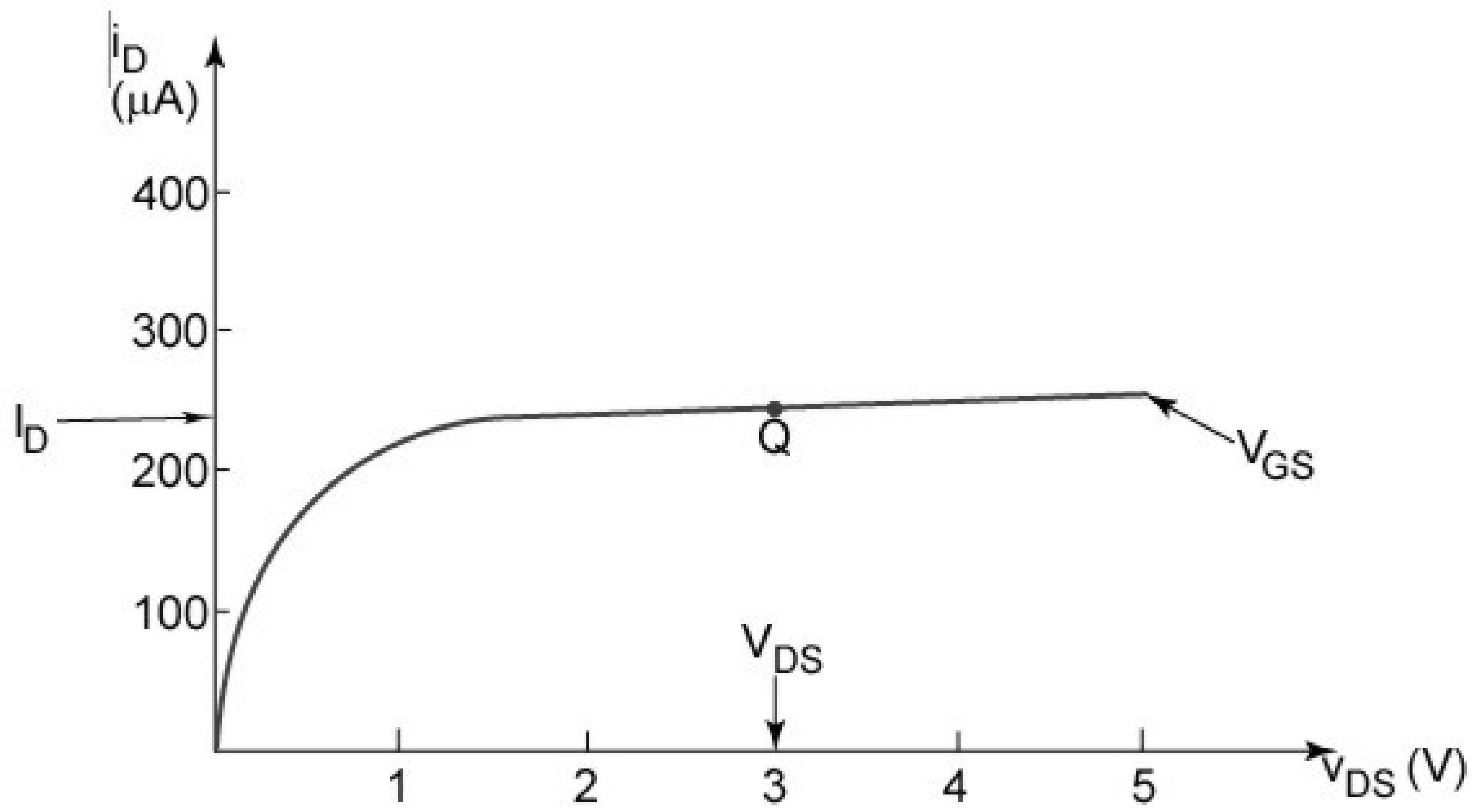
Defined as the change in drain current due to a change in the *gate-source* voltage, with *everything else constant*

$$g_m = \left.\frac{\Delta i_D}{\Delta v_{GS}}\right|_{V_{GS},V_{DS}} = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{V_{GS},V_{DS}}$$

Square-law: MOSFET saturation region

$$i_D = (W/2L)\mu_n C_{ox}(v_{GS} - V_{Tn})^2(1 + \lambda_n v_{DS})$$

Another Way to Find g_m



Evaluating g_m

Square-law characteristic: H&S 1st Edition

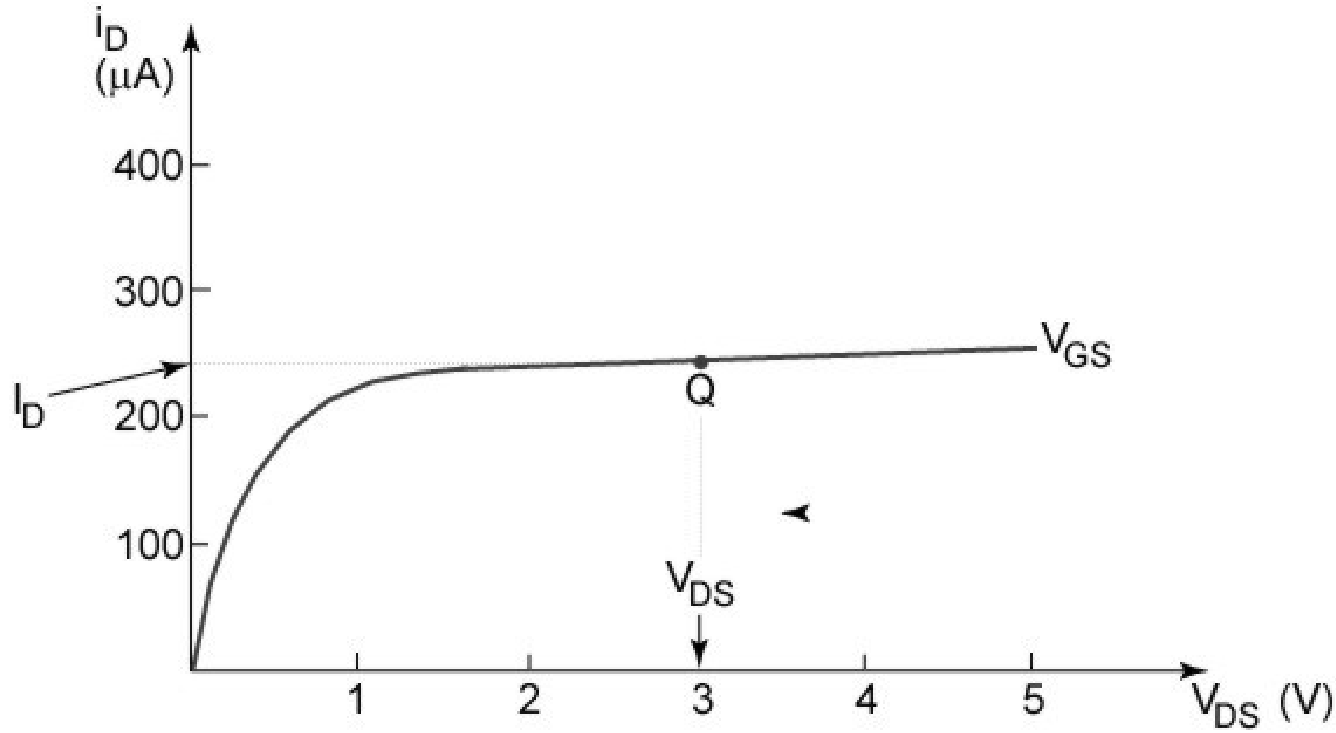
$$g_m =$$

Linear characteristic: better for submicron CMOS

$$i_{D,SAT} = v_{sat} W C_{ox} (v_{GS} - V_{Tn})(1 + \lambda_n v_{DS})$$

Output Resistance r_o

Defined as the inverse of the change in drain current due to a change in the *drain-source* voltage, with *everything else constant*

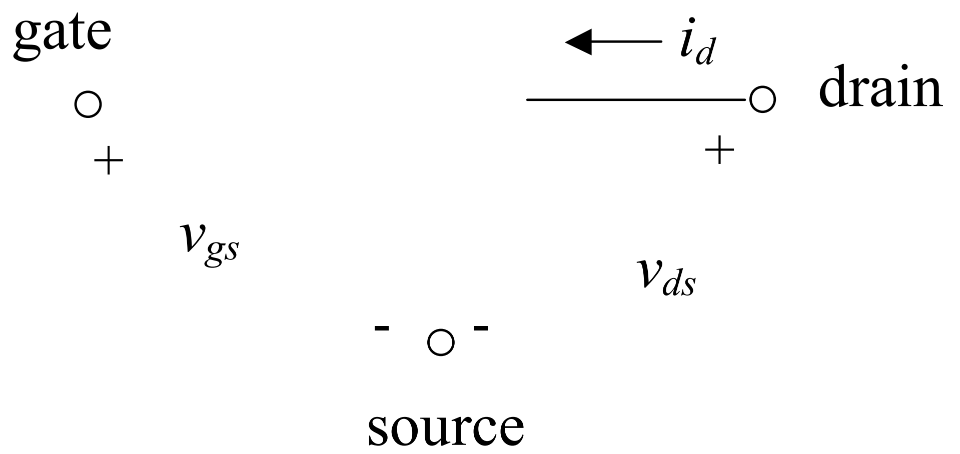


Evaluating r_o

$$r_o = \left(\left. \frac{\partial i_D}{\partial v_{DS}} \right|_{V_{GS}, V_{DS}} \right)^{-1}$$

Typical value:

Putting Together a Circuit Model



Role of the Substrate Potential

Need not be the source potential, but $V_B < V_S$

Effect: changes threshold voltage, which changes the drain current … substrate acts like a "backgate"

$$g_{mb} = \left.\frac{\Delta i_D}{\Delta v_{BS}}\right|_Q = \left.\frac{\partial i_D}{\partial v_{BS}}\right|_Q$$

Q = (V_{GS}, V_{DS}, V_{BS})