Lecture # 15

Example of parameter extraction from I-V curves:

Actual curves from Intel's 14nm Technology Transistors:

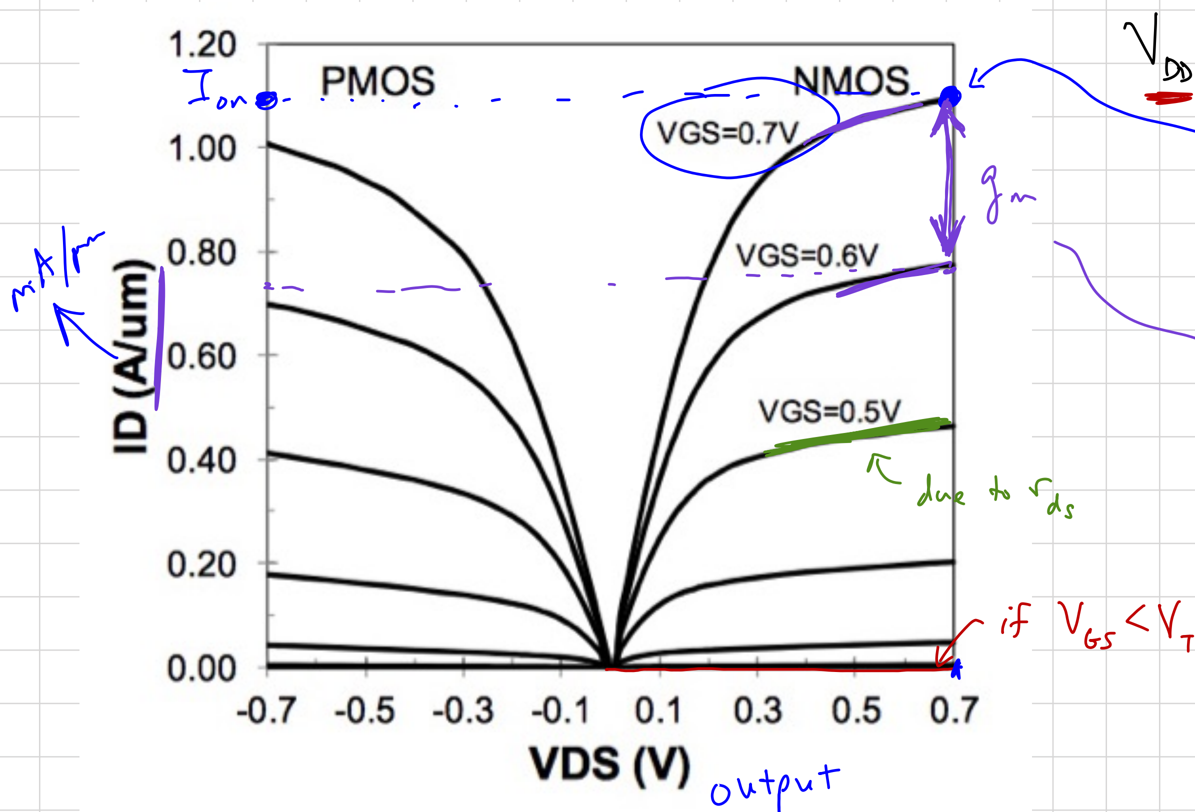


Figure 5: Transistor I-V Curves

$V_{DD} = 0.7V = V_{GS} = V_{DS}$

on-current

$I_{on} \approx 1.1 mA/\mu m$

$$g_m \approx \frac{\Delta I_D}{\Delta V_{GS}} \Bigg|_{@V_{DD} = V_{DS} = V_{GS}}$$

$$= \frac{1.1 mA/\mu m - 0.75 mA/\mu m}{0.7V - 0.6V} = \approx mS/\mu m$$

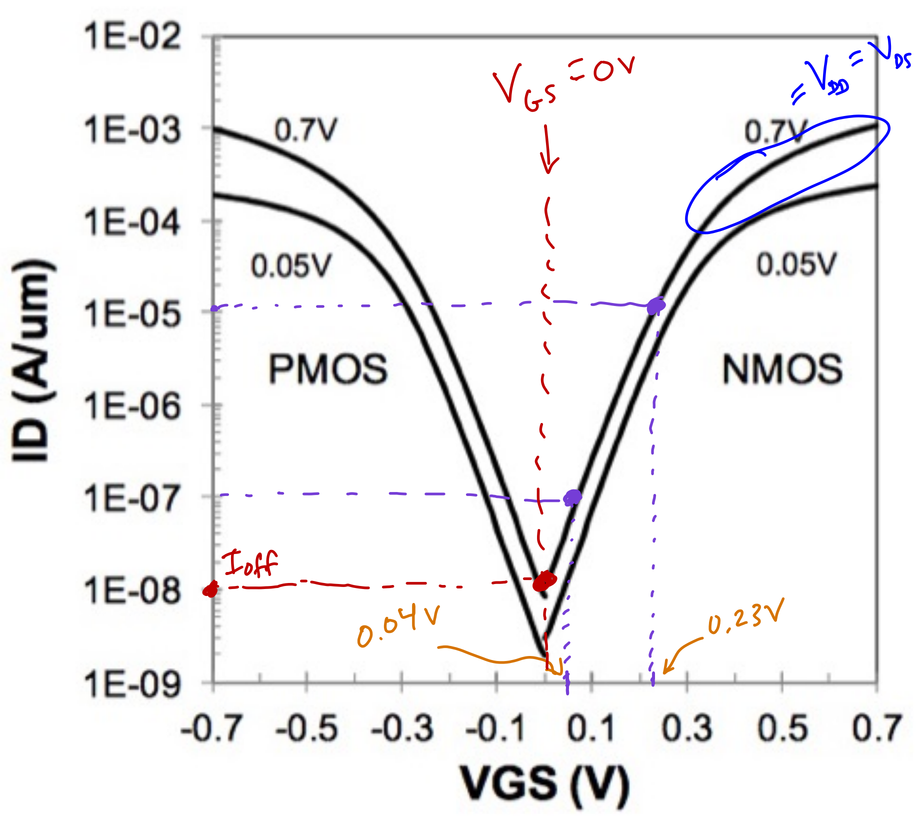


Figure 6: Subthreshold Curves

* it is never negative!!!

$$SS^{-1} = \frac{0.23V - 0.04V}{2 \text{ decades}}$$

units mV/decade

MOSFETs – Equivalent Circuit

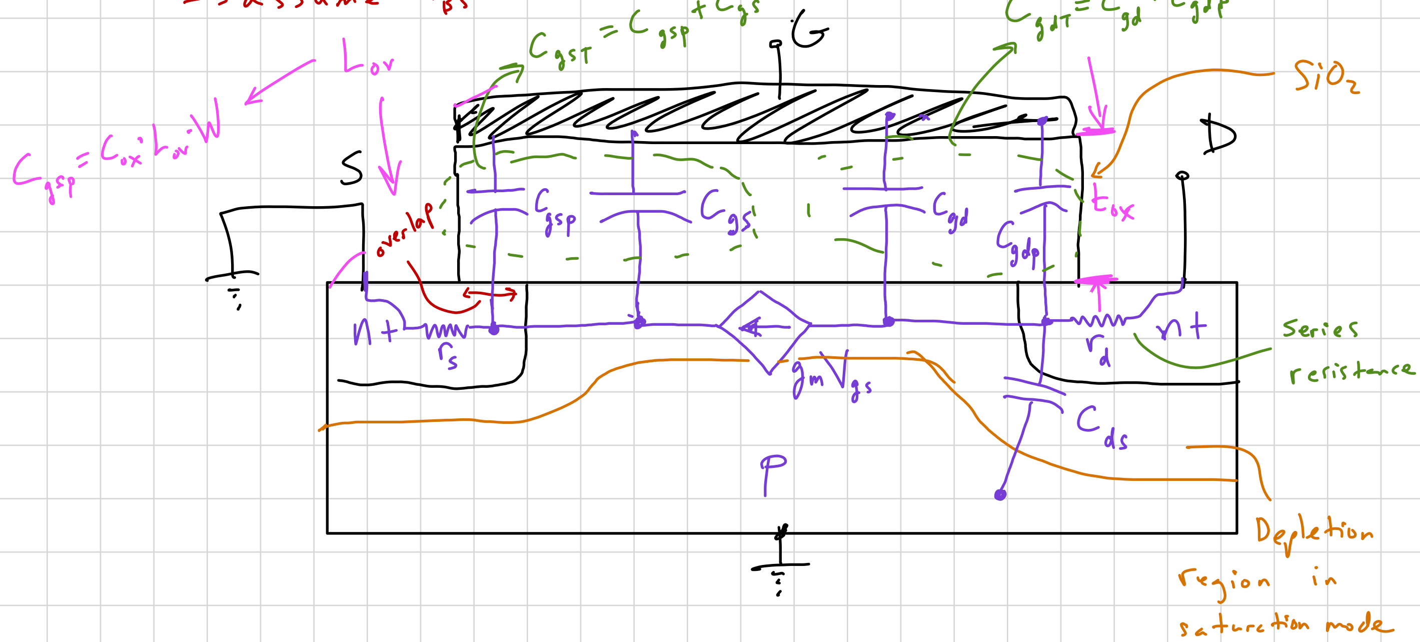
Small-signal Equivalent Circuit

↳ now referring to signal amplitude, but can be high or low frequency

→ Just as for diode, a small ac signal is added on top of some dc bias operating the transistor (operating point)

→ must consider all of the impedance effects (capacitances & resistances)

→ assume $V_{BS} = 0$

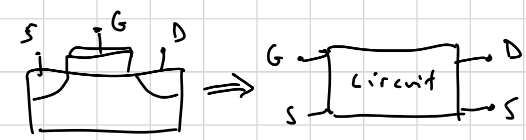


$$C_{ox} = \frac{\epsilon_0 \epsilon_{ox}}{t_{ox}} \Rightarrow F/cm^2$$

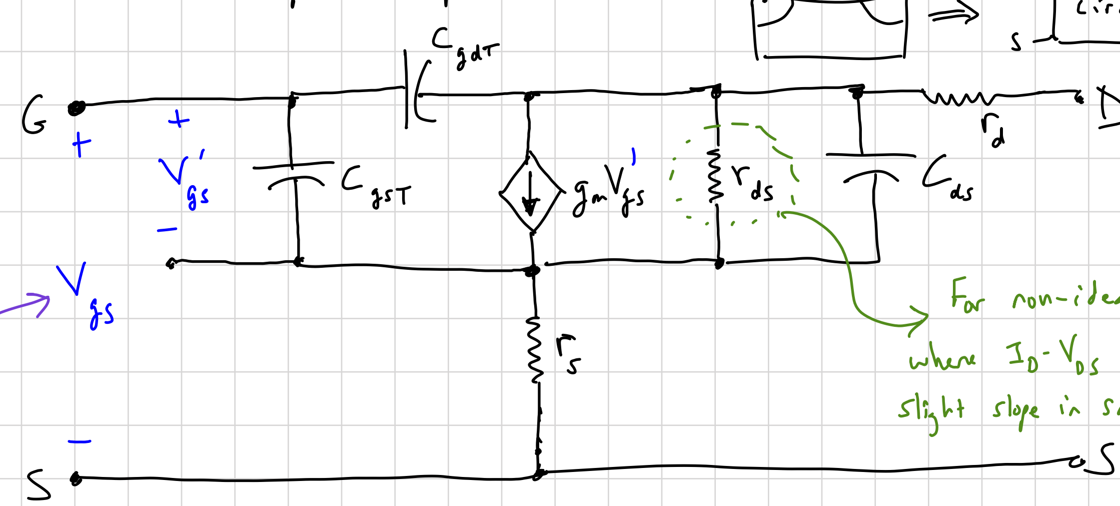
Sidenotes: • C_{gsT} is dominated by C_{gs}, while C_{gdT} is mostly C_{gdp}

• Now lower-case subscripts indicate ac parameters for V, C, I, etc.

→ view the MOSFET as a simple two-port network:



"common source" because S is ground



applied small-signal voltage

For non-ideal devices where I_D-V_{DS} has a slight slope in saturation region

→ Low frequencies

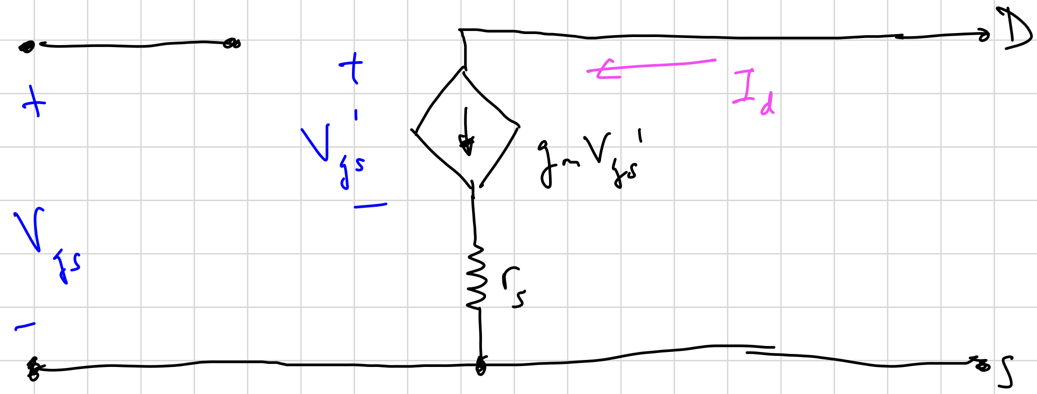
→ capacitors will behave (to 1st order) like open circuits ≡ infinite gate impedance

→ neglect all resistances except r_s, which has dominant impact

$$I_d = g_m V_{gs}'$$

$$V_{gs} = V_{gs}' + (g_m V_{gs}') r_s$$

$$\Rightarrow I_d = \left(\frac{g_m}{1 + g_m r_s}\right) V_{gs}$$

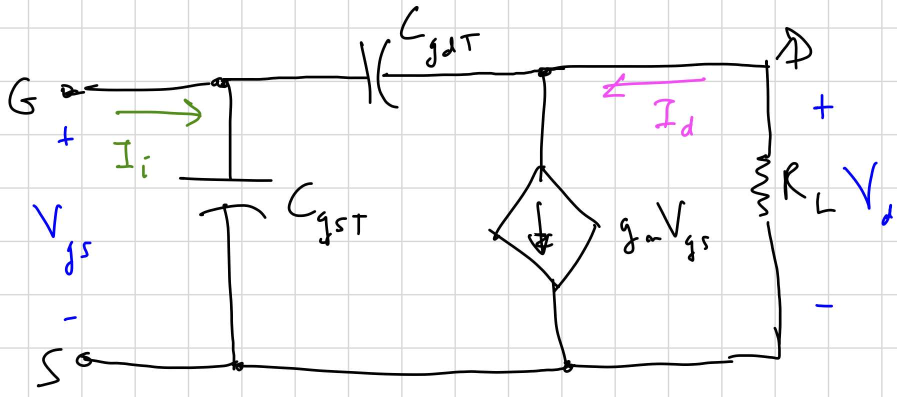


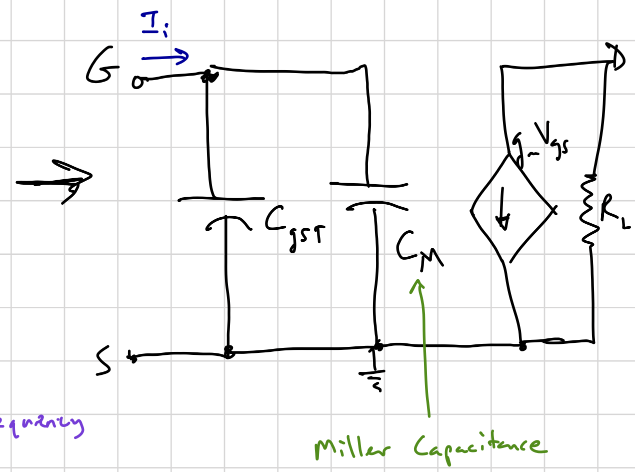
→ High frequencies

→ capacitors charging time now a limiting factor

→ Focus on dominant impedances, so neglect r_s, r_d, r_{ds}, C_{ds} for high freq.

→ add the load resistance, R_L





→ recalling that the impedance from a capacitor is $j\overset{\text{frequency}}{\omega} C$

→ nodal (KCL) analysis gives: $I_i = j\omega\left[C_{gsT} + \underbrace{C_{gdT}(1 + g_m R_L)}_{= C_M \text{, Miller capacitance}}\right]V_{gs}$

(neglect $j\omega R_L C_{gdT}$)