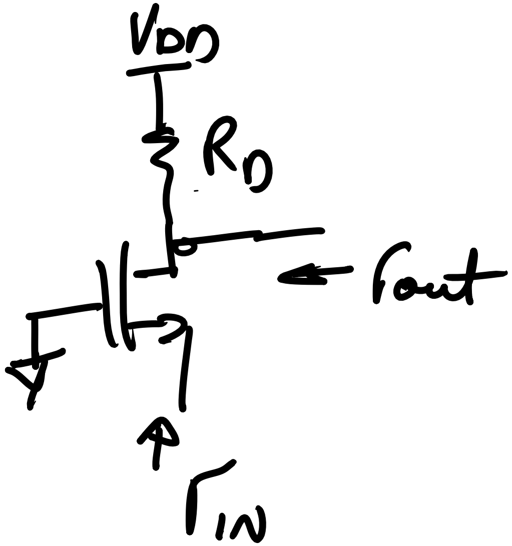
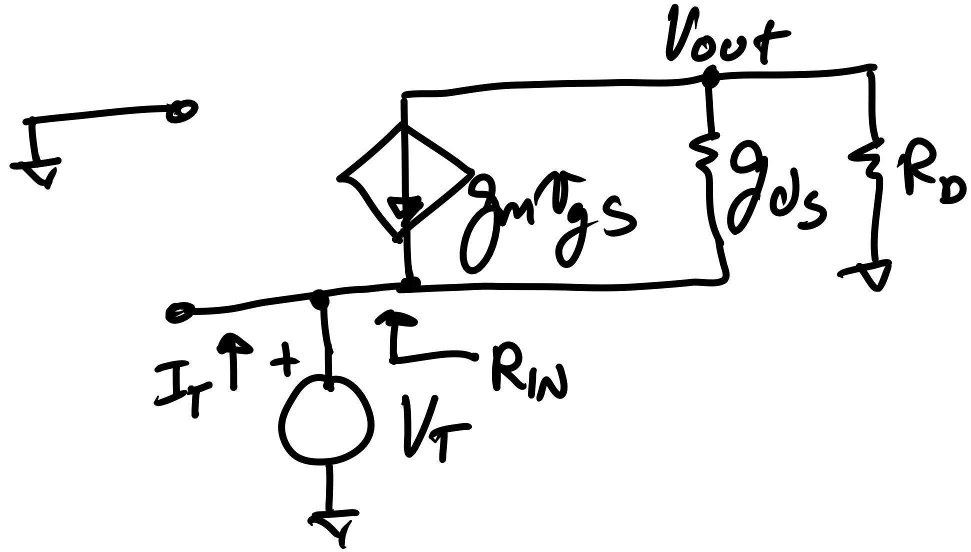
Lecture #7, Jan 21st, 2022

- Review Chapter 1 and 2 of Razavi book as needed. Course will start with Chapter 3.
- Moving to Chapter 12 next – Bandgap References.
- CAD 2 due next Tuesday, Jan 25th.
- Homework 1 out, due today.
- Homework 2 and Project 1 coming shortly.
- Class will be virtual next week.
- Discuss Single-Transistor Amplifier Configurations
  - Common-Gate Amplifier.
  - Common-Drain Amplifier.
  - Example problem.

Common-Gate Amplifier





$$r_{out} = (g_{ds} // g_D)^{-1}$$

$$= r_{ds} // R_D \cong R_D$$

$$\boxed{v_{gs} = -V_T}$$

R_{IN}: APPLY TEST SOURCE.

KCL @ V_{IN} ON NEXT PAGE.

Common-Gate Amplifier

KCL @ Vout

$$i_T + g_m V_{gs} + (V_{out} - V_T) g_{ds} = 0$$

$$i_T - g_m V_T + V_{out} g_{ds} - V_T g_{ds} = 0$$

CAN WRITE IN TERMS OF V_T

$$i_T - g_m V_T + \underbrace{V_T \frac{g_m + g_{ds}}{g_{ds} + g_D}}_{\text{~~VOLTAGE~~ GAIN ~~OF~~ CG}} \cdot g_{ds} = 0$$

$$i_T = V_T \left(g_m + g_{ds} + \frac{g_m + g_{ds}}{g_{ds} + g_D} \right) V_T$$

$$r_\pi = \frac{V_T}{i_T} = \frac{g_{ds} + g_D}{(g_m + g_{DS})(g_{DS} + g_D) + g_m + g_{DS}}$$

$$= \frac{g_{ds} + g_D}{g_D (g_m + g_{ds})}$$

Common-Gate Amplifier

$g_m \gg g_{ds}$

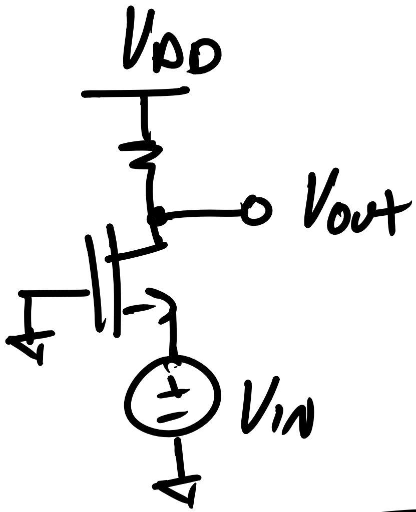
if $g_{ds} \ll g_D$ ($R_{DS} \gg R_D$, e.g. RESISTIVE LOAD)

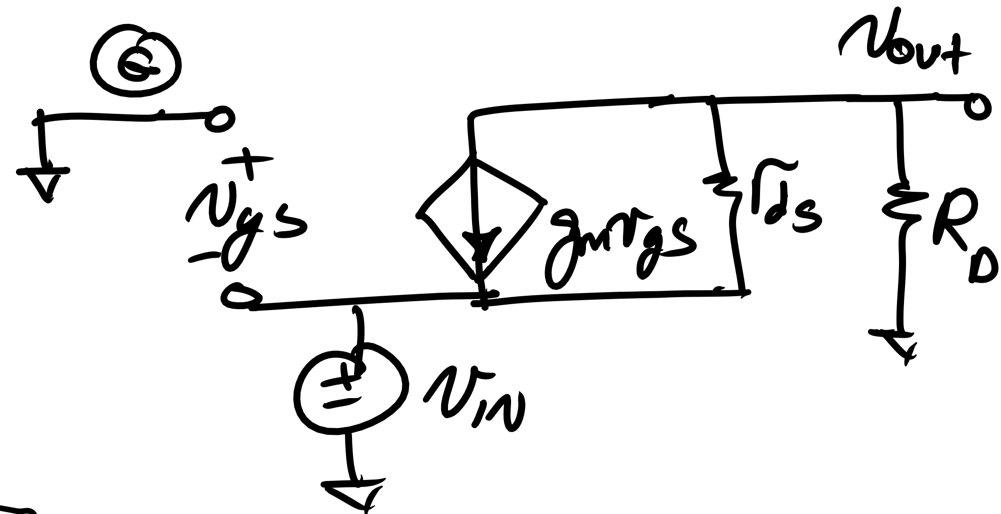
THEN $r_{IN} \cong \dfrac{g_D}{g_D g_m} = \dfrac{1}{g_m}$

SAME AS BJT, EXCEPT ~~THAT~~ FOR SAME CURRENT

$$\boxed{\begin{gathered} g_{m_{MOS}} < g_{m_{BJT}} \therefore \\ r_{IN_{MOS}} > r_{IN_{BJT}} \end{gathered}}$$

Common-Gate Amplifier





$$\boxed{\text{NOTICE} \quad v_{gs} = -v_{IN}}$$

KCL @ V_{out}

$$g_m v_{gs} + g_{ds}(v_{out} - V_{IN}) + g_D v_{out} = 0$$

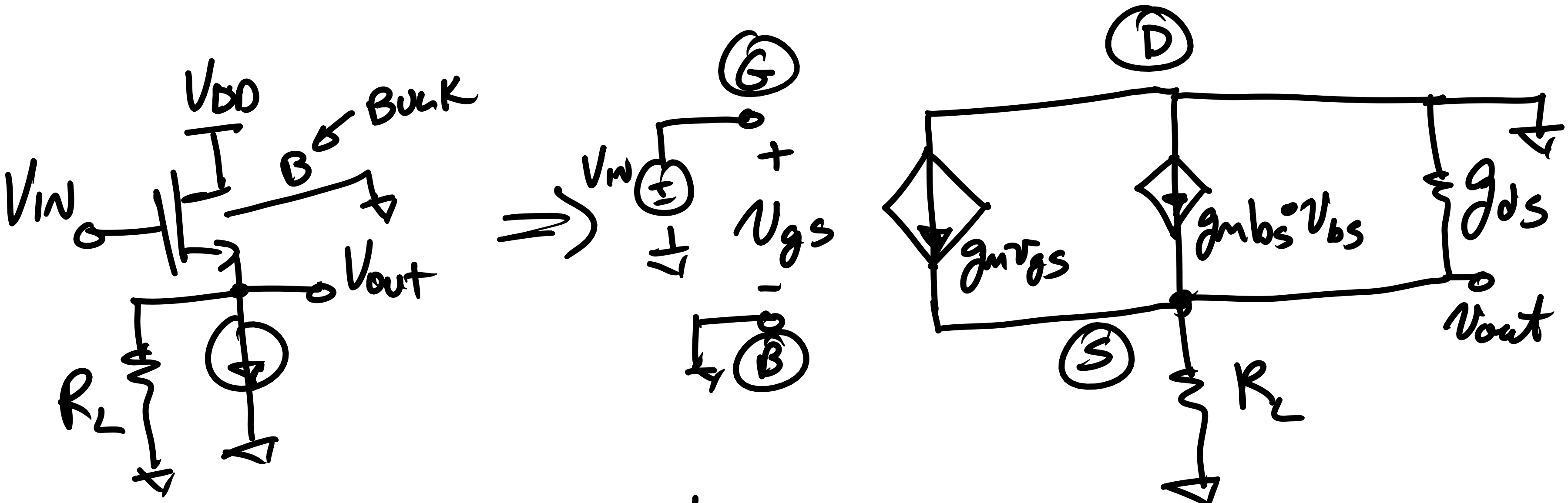
$$-g_m v_{IN} + g_{ds} v_{out} - g_{ds} v_{IN} + g_D \cdot v_{out} = 0$$

$$\boxed{a_v = +\frac{(g_m + g_{ds})}{g_{ds} + g_D}}$$

$g_m \,\&\, g_D \ll g_{DS}$ ∴

$$\boxed{a_v \cong g_m / g_D}$$

Common-Drain Amplifier



$$v_{gs} = v_{in} - v_{out} \; ; \quad v_{bs} = v_b - v_s = 0 - v_{out}$$

KCL @ Vout:

$$g_m v_{gs} + g_{mbs} v_{bs} = g_L \cdot v_{out} + g_{ds} v_{out}$$

$$g_m (v_{in} - v_{out}) + g_{mbs} (0 - v_{out}) = (g_L + g_{ds}) v_{out}$$

$$a_v = \frac{v_{out}}{v_{in}} = \frac{g_m}{g_m + g_{mbs} + g_{ds} + g_L} \leftarrow a_v.$$

Common-Drain Amplifier Output Resistance

$a_v \simeq 1$

$g_m \gg g_{mbs} \gg g_{ds}$ or $g_{ds} = 1/r_{ds}$

BY INSPECTION :

$$g_{out} = g_m + g_{mbs} + g_{ds} + g_L$$

$\Rightarrow$ LOW OUTPUT RESISTANCE.