Lecture 27

- Last time: Current-source supplies
- Today: Common-gate amplifier
- Finish common-gate
- Common-drain amplifier

\[ V_{gs} \]

\[ I_{ds} \]

\[ I_{gs} \]

\[ V_{gs} \]
CG Output Resistance

Kirchhoff's current law at the source resistor node: sum currents leaving node.

\[ \frac{v_s}{R_s} = \frac{1}{R_s + \left( g_m + \frac{1}{r_o} \right)} \]

\[ i = \frac{v}{r_o} \]

\[ v = (25 \times 10^3) \times 0.1 \]

\[ i = \frac{v}{r_o} = \frac{25 \times 10^3 \times 0.1}{25 \times 10^3} = 0.1 \]

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Common-Gate Output Resistance

Substituting $v_s = i_l R_S$

$$i_l R_S \left( \frac{1}{R_S} + g_m + g_{mb} + \frac{1}{r_o} \right) = \frac{v_t}{r_o}$$

"A PAIN"

The output resistance is $(v_t / i_l) || r_{oc}$

$$R_{out} = r_{oc} || \left( R_S \left( \frac{r_o}{R_S} + g_m r_o + g_{mb} r_o + 1 \right) \right)$$

Simplify

Huge!

BIG, $= \frac{v_o}{i_l}$ (HESS)

$$\frac{v_t}{i_l} \left( \frac{1}{2kT} \cdot 200kT \right) \approx 100$$
Common-Gate Two-Port Model

Function: a current buffer

\[ \text{Function: a current buffer} \]

\[ \frac{i_{\text{out}}}{i_{\text{in}}} \approx \frac{R_s}{(1 + g_m + g_{mb} + 1/R_s)} \]

\[ \text{Pout} \approx \frac{2R_s}{1 + g_m + g_{mb} + 1/R_s} \]
Common-Drain Amplifier

\[ I_D = \mu I_C \frac{(V_{GS} - V_T)}{2} \]

Backgate terminal

\[ V_{IN} = V_{GS} - V_T \]

\[ V_{OUT} = V_{IN} \]

\[ V_{GS} = V_{IN} \]

\[ V_{TH} = \frac{V_{GS}}{2} \]

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Approximating the CG $R_{out}$

$$R_{out} = r_{oc} \parallel [r_o + g_m r_o R_s + g_m r_o R_s + R_s]$$

The exact result is complicated, so let's try to make it simpler:

$$g_m \approx 500 \mu S$$

$$r_o \approx 200 k\Omega$$

$$R_{out} \approx r_{oc} \parallel [r_o + g_m r_o R_s]$$

Pretty good

Assuming the source resistance is less than $r_o$,$*$$R_{out} \approx r_{oc} \parallel [r_o + g_m r_o R_s] = r_{oc} \parallel \frac{r_o (1 + g_m R_s)}{r_o (1 + 2 R_s)}$
CD Voltage Gain

Note $v_{gs} = v_t - v_{out}$

$$A_v = \left. \frac{\text{Vout}}{\text{Vin}} \right|_{r_c=0}$$

$$r_{oc} = \infty$$

$$R_o = \infty$$

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CD Voltage Gain (Cont.)

KCL at source node:
\[ \frac{1}{r_{n1n2}} \left( g_m v_{in1} + g_m v_{in2} + g_m v_{ib} \right) = g_m v_{out} \]

Voltage gain (for \( v_{SB} \) not zero):
\[ A_v = \frac{g_m + g_m + g_m}{g_m + g_m + g_m} \]
\[ A_v \approx \frac{3}{3} = 1 \]
CD Output Resistance

\[ R_{in} = \infty \]

\[ R_s \]

\[ v_{gs} \]

\[ g_m v_{gs} \]

\[ -g_m v_t \]

\[ v_t \]

\[ I_t \]

\[ I_{oc} \]

Sum currents at output (source) node:

\[ R_{out} = (R_{oll} / I_{oc}) \parallel \left\{ \sum \frac{v_t}{i_t} \right\} \]

\[ -v_t \]

\[ I_t + g_m v_{gs} + -g_m v_t = 0 \]

\[ I_t = (g_m + g_m) v_t \]

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CD Output Resistance (Cont.)

\[ r_o \parallel r_{oc} \text{ is much larger than the inverses of the transconductances} \rightarrow \text{ignore} \]

\[ R_{\text{out}} = \frac{1}{g_m (g_{m+b} + g_{m+})} \]