Common-Gate Stage

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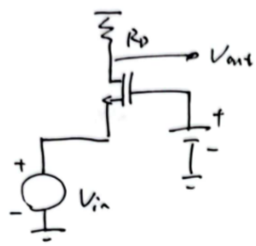
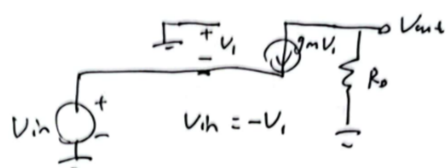
Small-Signal Properties

We assume that $\lambda = 0$.



Convert circuit model to small signal model.



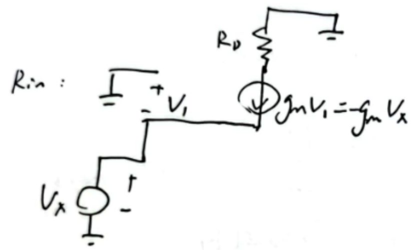
We get:

$$\frac{v_{out}}{R_D} = -g_m v_1 = g_m v_{in} \Longrightarrow A_v = g_m R_D$$

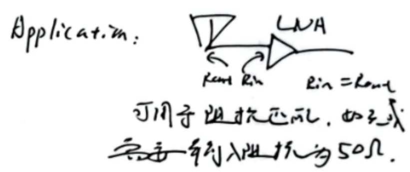
Input Impedance

Next we calculate the input and output impedance.

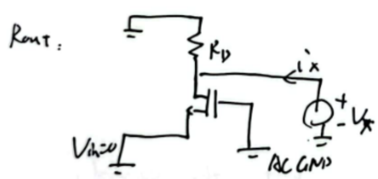
$$i_x = g_m v_x \Longrightarrow R_{in} = \frac{1}{g_m}$$



g_m is usually around tens to hundreds, which means that the input impedance of the common gate amplifier is very low. Such low impedance can be used for impedance matching of antennas and other devices.



Output Impedance



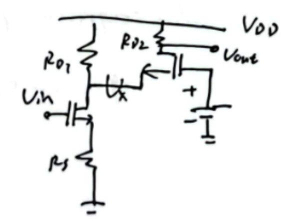
We get:

$$R_{out} = R_D$$

Example

$$\frac{V_{out}}{V_{in}} = \frac{V_x}{V_{in}} \frac{V_{out}}{V_x}$$

Because:



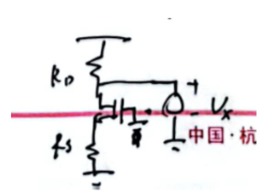
$$\frac{V_x}{V_{in}} = -\frac{R \text{ tied between AC Ground and Drain}}{\frac{1}{g_m} + R \text{ tied between Source and AC Ground}}$$

We can derive:

$$\frac{V_{out}}{V_{in}} = -\frac{R_{D1}||\frac{1}{g_{m1}}}{\frac{1}{g_{m1}} + R_S} g_{m2} R_{D2}$$

Output Resistance of CG Stage in a Special Case

Now we assume $\lambda \neq 0$



Use the conclusions you reached last time, we get:

$$R_{out} = R_D||[(1 + g_m r_o)R_s + r_o]$$

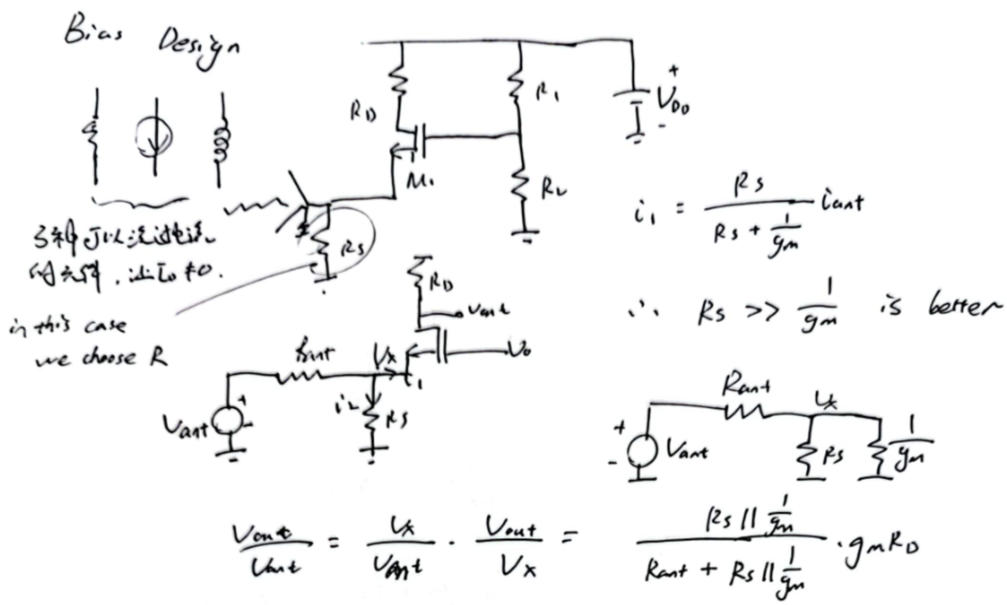
Bias Design

Use a resistor to ensure $I_D \neq 0$.

$$i_1 = \frac{R_s}{R_s + \frac{1}{g_m}} i_{out}$$

So if we want more signal to go into the common gate amplifier instead of being consumed by the resistor, we should ensure that:

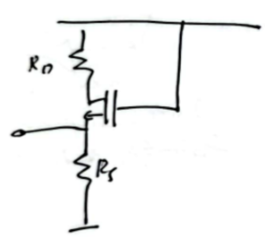
$$R_s >> \frac{1}{g_m}$$



We can also calculate the V_out using the input impedance.

$$\frac{V_{out}}{V_{ant}} = \frac{V_x}{V_{ant}} \frac{V_{out}}{V_x} = \frac{R_s || \frac{1}{g_m}}{R_{out} + R_s || \frac{1}{g_m}} * g_m R_D$$

Example



In actual situations, due to the need to ensure that the MOSFET works in the saturation region, we may not necessarily be able to satisfy that R_s is much greater than $\frac{1}{g_m}$.

In this case, $R_{smax} = \frac{V_{DD} - V_{GS}}{I_D} = 370\Omega$

Ensure that $I_D R_D \leq V_{TH}$, we choose $R_D = 500\Omega$.

Then we can calculate $A_v = 1.6$.

If double $\frac{W}{L}$, $A_v = 2.3$, but the capacitance will also become larger, leading to the drop of the speed.

Link

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