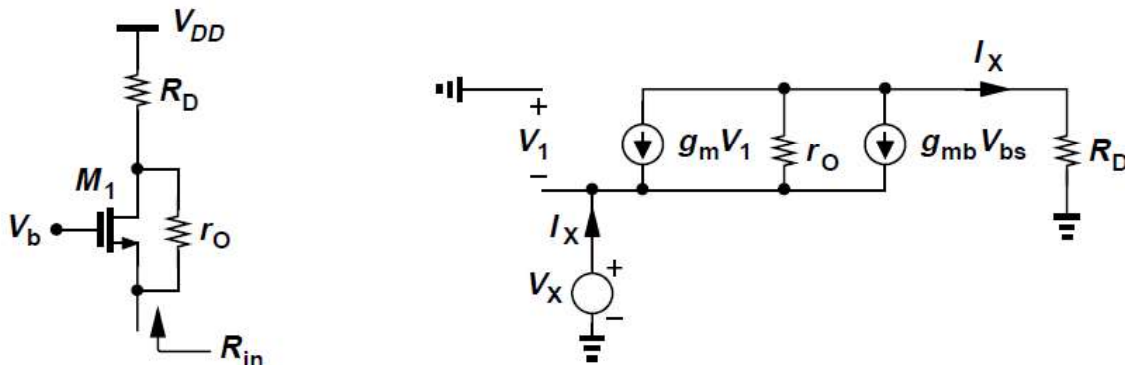


Common-Gate Stage: Input Impedance



- From the small-signal equivalent circuit for finding input impedance, we have

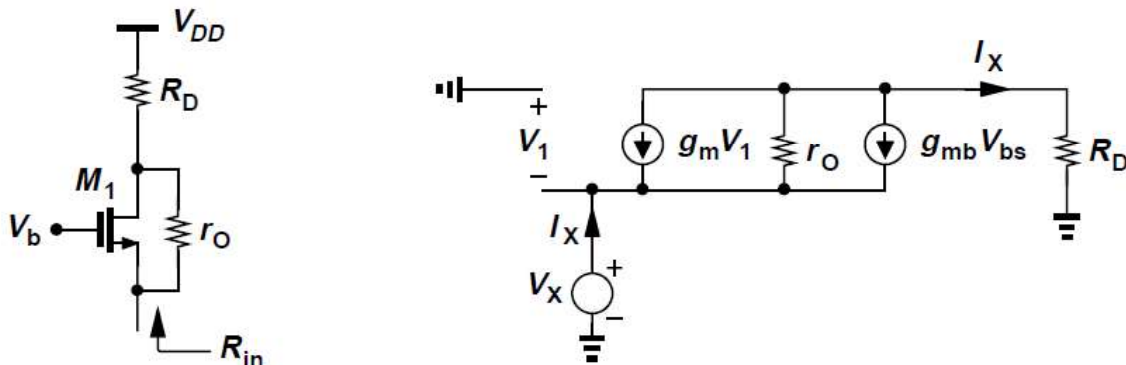
$$V_1 = -V_X$$

- The current through r_o is equal to $I_X + g_m V_1 + g_{mb} V_1 = I_X - (g_m + g_{mb}) V_X$

- Voltages across r_o and R_D can be added and equated to

$$R_D I_X + r_o [I_X - (g_m + g_{mb}) V_X] = V_X$$

Common-Gate Stage: Input Impedance



- Thus,

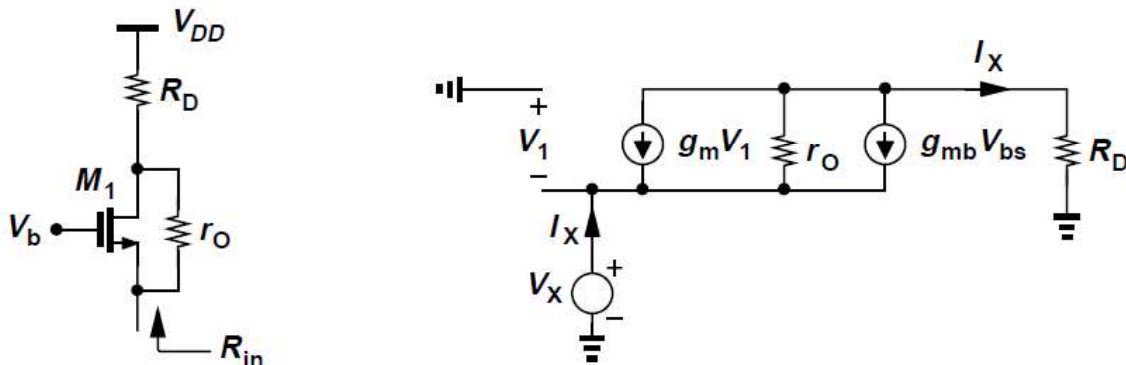
$$\frac{V_X}{I_X} = \frac{R_D + r_O}{1 + (g_m + g_{mb})r_O}$$

$$\approx \frac{R_D}{(g_m + g_{mb})r_O} + \frac{1}{g_m + g_{mb}}$$

If $(g_m + g_{mb})r_O \gg 1$

- The drain impedance is divided by $(g_m + g_{mb})r_O$ when seen at the source
 - Important in short-channel devices because of their low intrinsic gain

Common-Gate Stage: Input Impedance

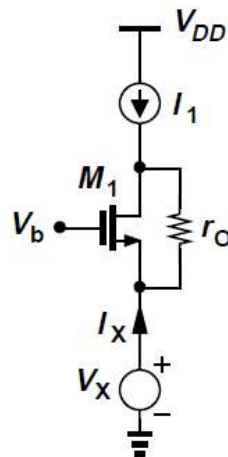


- Suppose $R_D = 0$, then

$$\begin{aligned} \frac{V_X}{I_X} &= \frac{r_O}{1 + (g_m + g_{mb})r_O} \\ &= \frac{1}{\frac{1}{r_O} + g_m + g_{mb}}, \end{aligned}$$

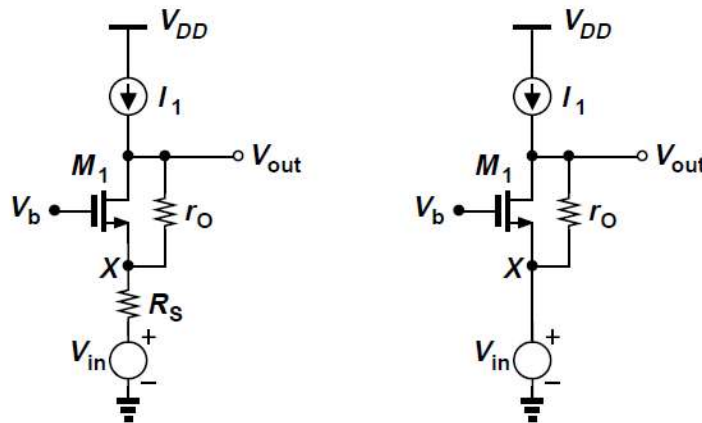
- This is the impedance seen at the source of a source follower, a predictable result since with $R_D = 0$ the circuit configuration is the same as a source follower

Common-Gate Stage: Input Impedance



- If R_D is replaced with an ideal current source, earlier result predicts that input impedance approaches infinity
- Total current through the transistor is fixed and is equal to I_1
- Therefore, a change in the source potential cannot change the device current, and hence $I_x = 0$
- The input impedance of a CG stage is relatively low *only* if the load impedance connected to the drain is small

Common-Gate Stage

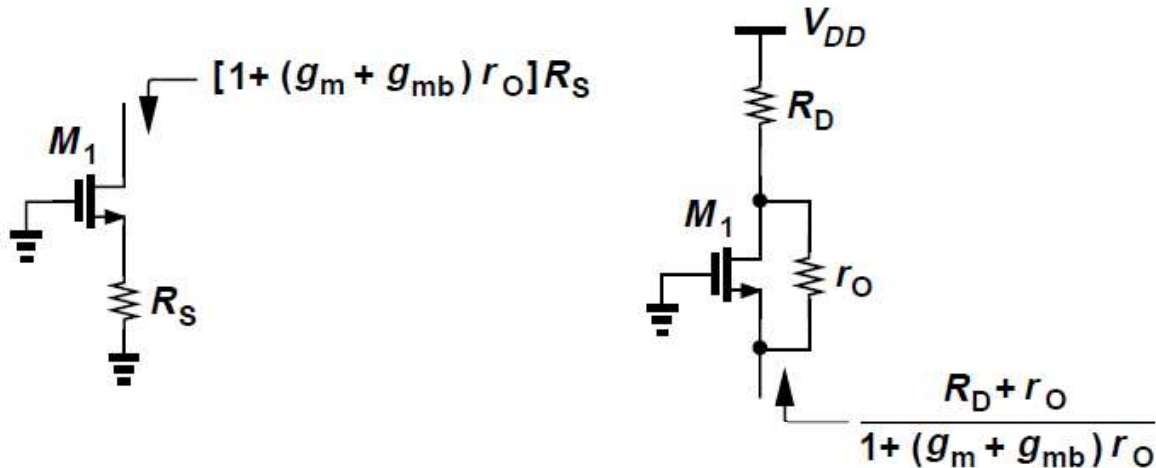


- In a CG stage with a current source load, substituting $R_D = \infty$ in the voltage gain equation, we get

$$A_v = (g_m + g_{mb})r_O + 1$$

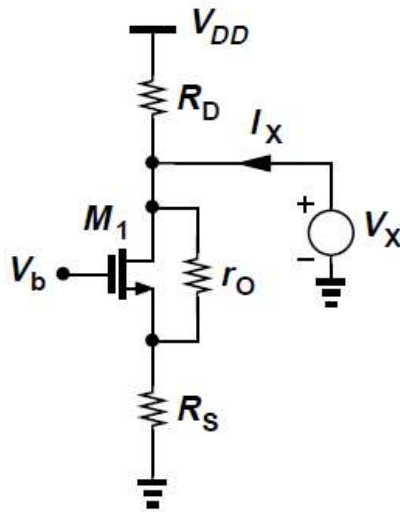
- Gain does not depend on R_S
- From the foregoing discussion, if $R_D \rightarrow \infty$, so does the impedance seen at the source of M_1 , and the small-signal voltage at node X becomes equal to V_{in}

Common-Gate Stage



- In a degenerated CS stage, we loosely say that a transistor transforms its source resistance *up*
- In a CG stage, the transistor transforms its drain resistance *down*
- The MOS transistor can thus be viewed as an resistance transformer

Common-Gate Stage: Output Impedance



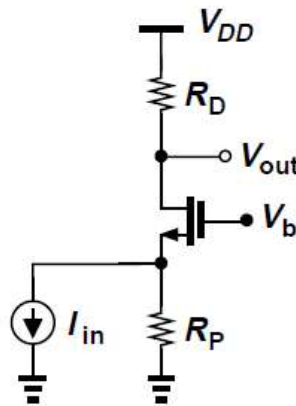
- From the above small-signal equivalent circuit, we can find output impedance as

$$R_{out} = \{[1 + (g_m + g_{mb})r_O]R_S + r_O\} \parallel R_D$$

- Result is similar to that obtained for a degenerated CS stage

Common-Gate Stage

- Input signal of a common-gate stage may be a current rather than a voltage as shown below



- Input current source exhibits output impedance of R_P
- To find the “gain” V_{out}/I_{in} , replace I_{in} and R_P with a Thevenin equivalent and use derived result to write

$$\frac{V_{out}}{I_{in}} = \frac{(g_m + g_{mb})r_O + 1}{r_O + (g_m + g_{mb})r_O R_P + R_P + R_D} R_D R_P$$

$$R_{out} = \{[1 + (g_m + g_{mb})r_O]R_P + r_O\} || R_D$$

- Output impedance is simply given by