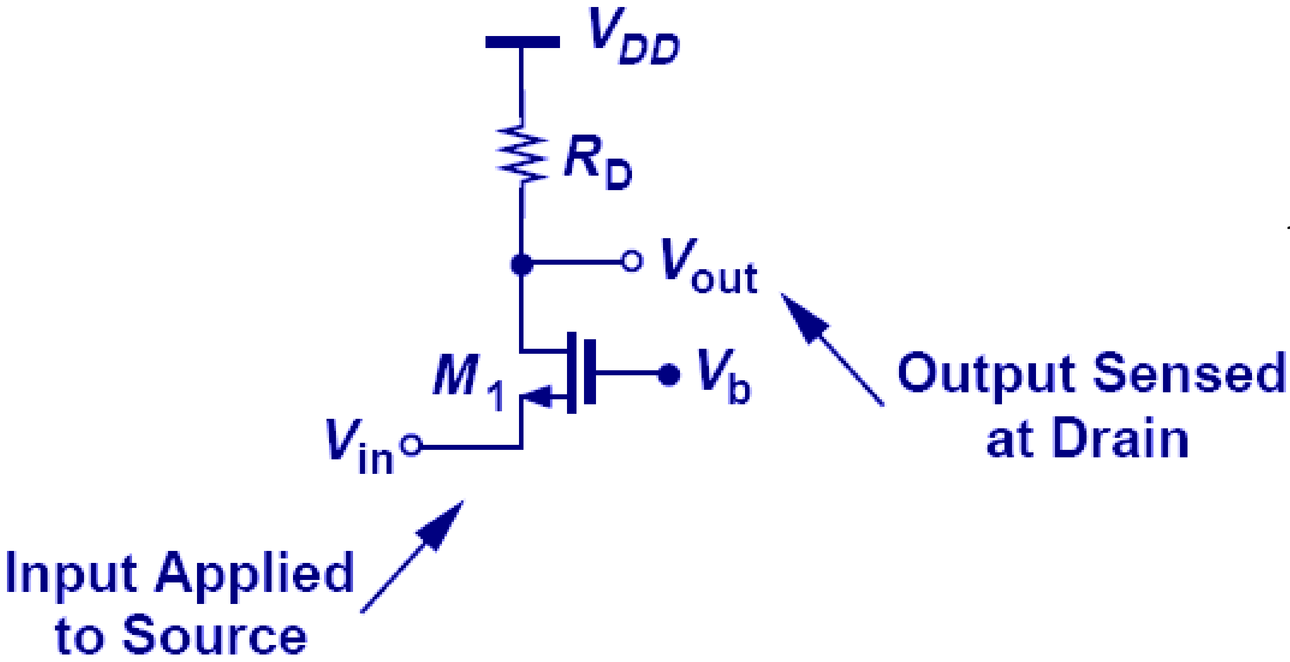
Lecture 19

OUTLINE

- Common-gate stage
- Source follower

- Reading: Chap. 7.3-7.4

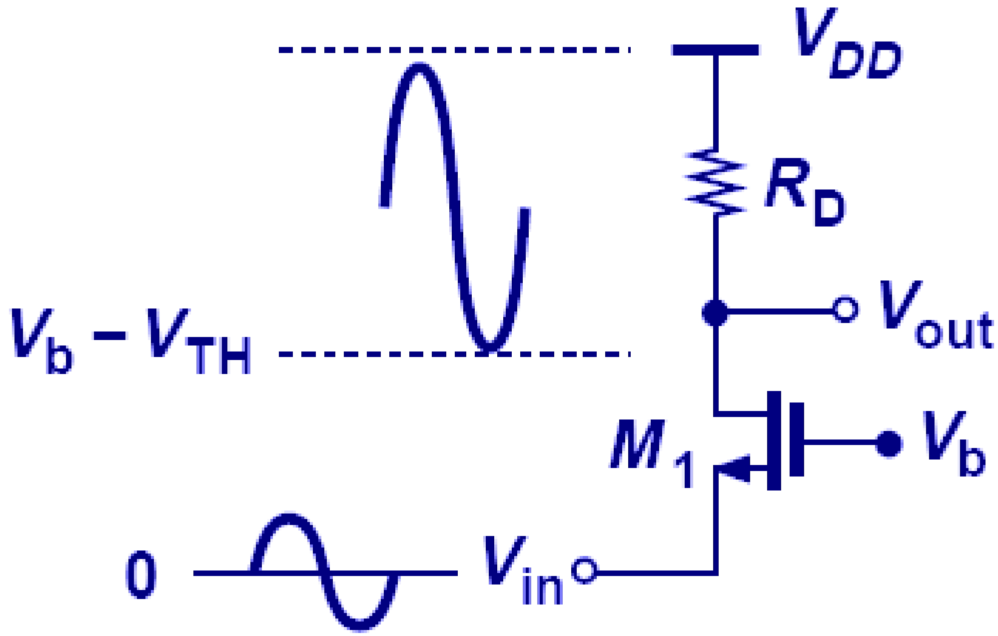
Common-Gate Stage



$$A_v = g_m R_D$$

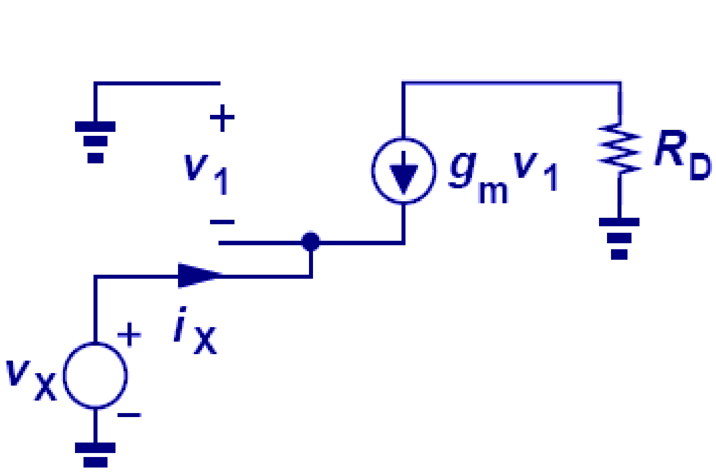
- Common-gate stage is similar to common-base stage: a rise in input causes a rise in output. So the gain is positive.

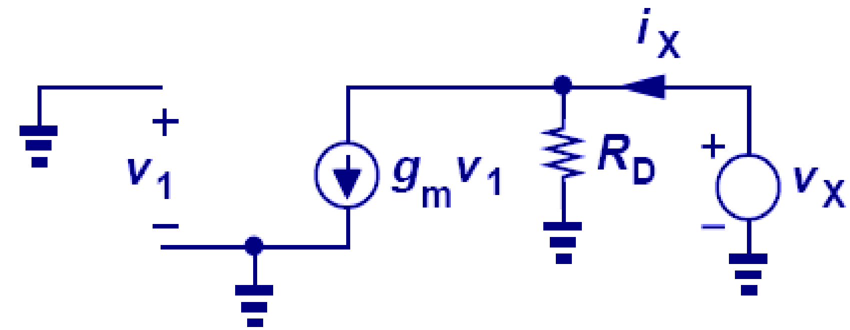
Signal Levels in CG Stage



- In order to maintain M1 in saturation, the signal swing at V_{out} cannot fall below V_b-V_{TH}

I/O Impedances of CG Stage

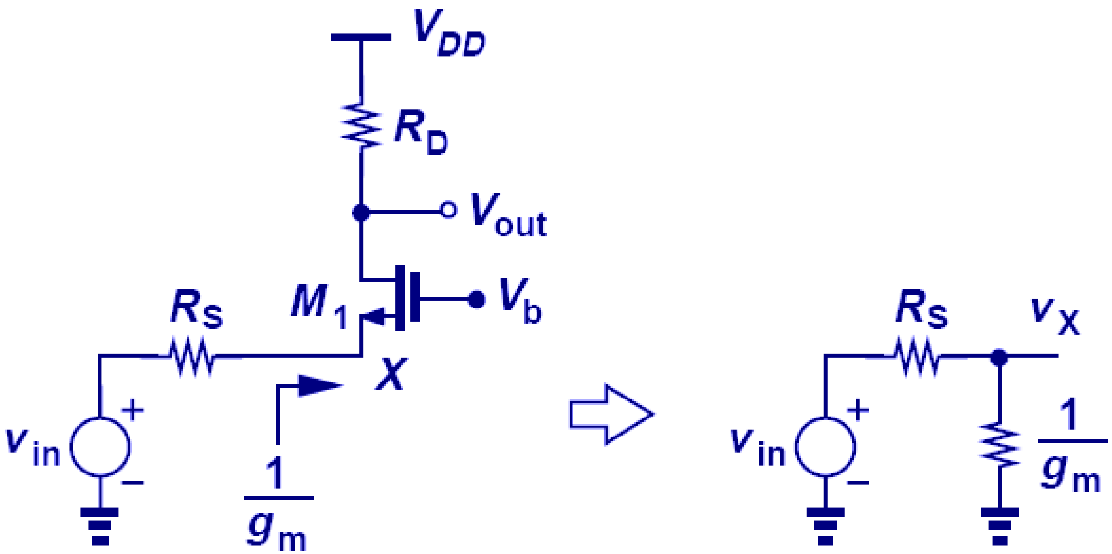




$$R_{in} = \frac{1}{g_m} \qquad \lambda = 0 \qquad R_{out} = R_D$$

- The input and output impedances of CG stage are similar to those of CB stage.

CG Stage with Source Resistance



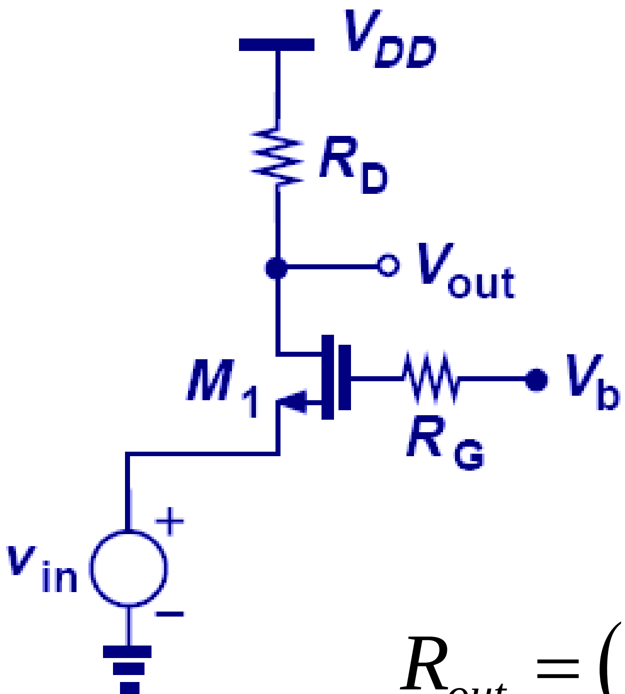
$$v_X = \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_S} v_{in}$$

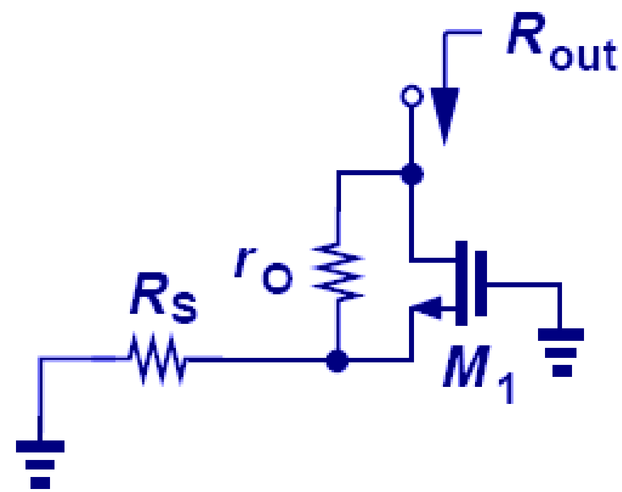
$$A_v = \frac{v_{out}}{v_x}\frac{v_x}{v_{in}} = g_m R_D \frac{\frac{1}{g_m}}{\frac{1}{g_m} + R_S}$$

$$= \frac{R_D}{\frac{1}{g_m} + R_S} = \frac{g_m R_D}{1 + g_m R_S}$$

- When a source resistance is present, the voltage gain is equal to that of a CS stage with degeneration, only positive.

Generalized CG Behavior

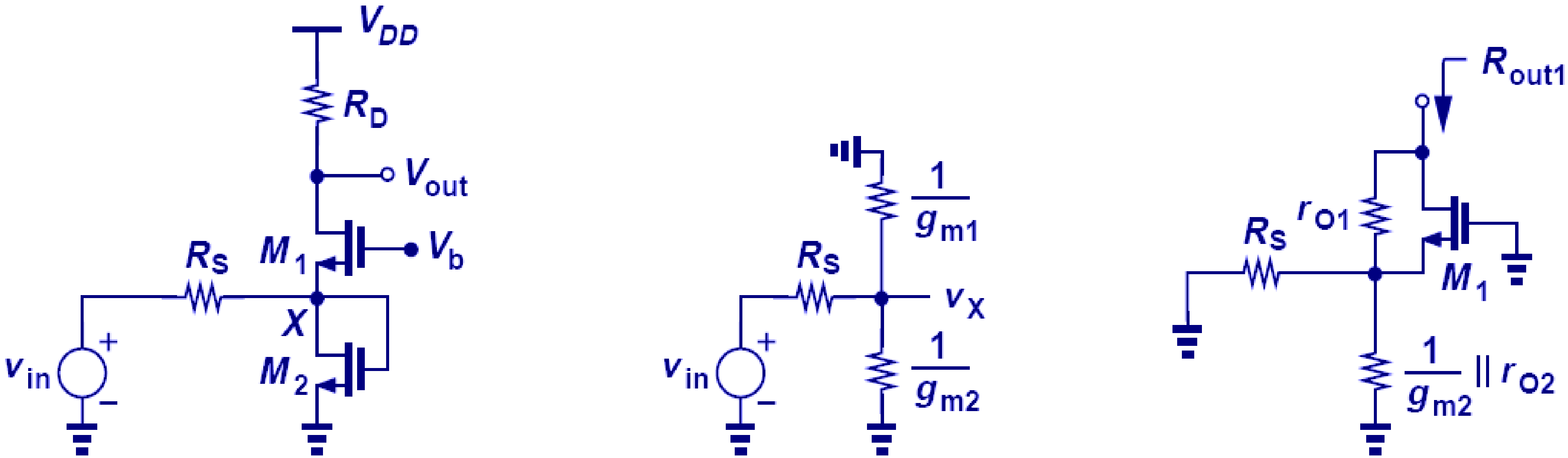




$$R_{out} = \left(1 + g_m r_O\right) R_S + r_O$$

- When a gate resistance is present it does not affect the gain and I/O impedances since there is no potential drop across it (at low frequencies).
- The output impedance of a CG stage with source resistance is identical to that of CS stage with degeneration.

Example of CG Stage

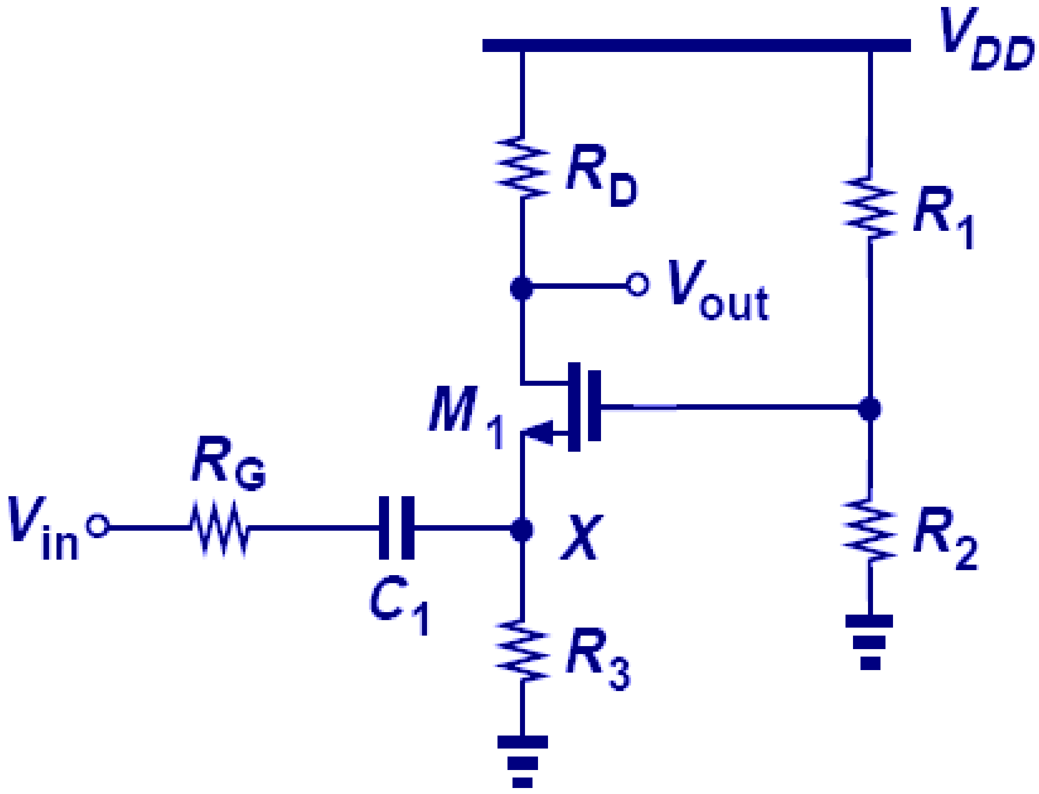


$$\frac{v_{out}}{v_{in}} = \frac{g_{m1} R_D}{1 + (g_{m1} + g_{m2}) R_S}$$

$$R_{out} \approx \left[g_{m1} r_{O1} \left(\frac{1}{g_{m2}} \| R_S \right) + r_{O1} \right] \| R_D$$

- Diode-connected M2 acts as a resistor to provide the bias current.

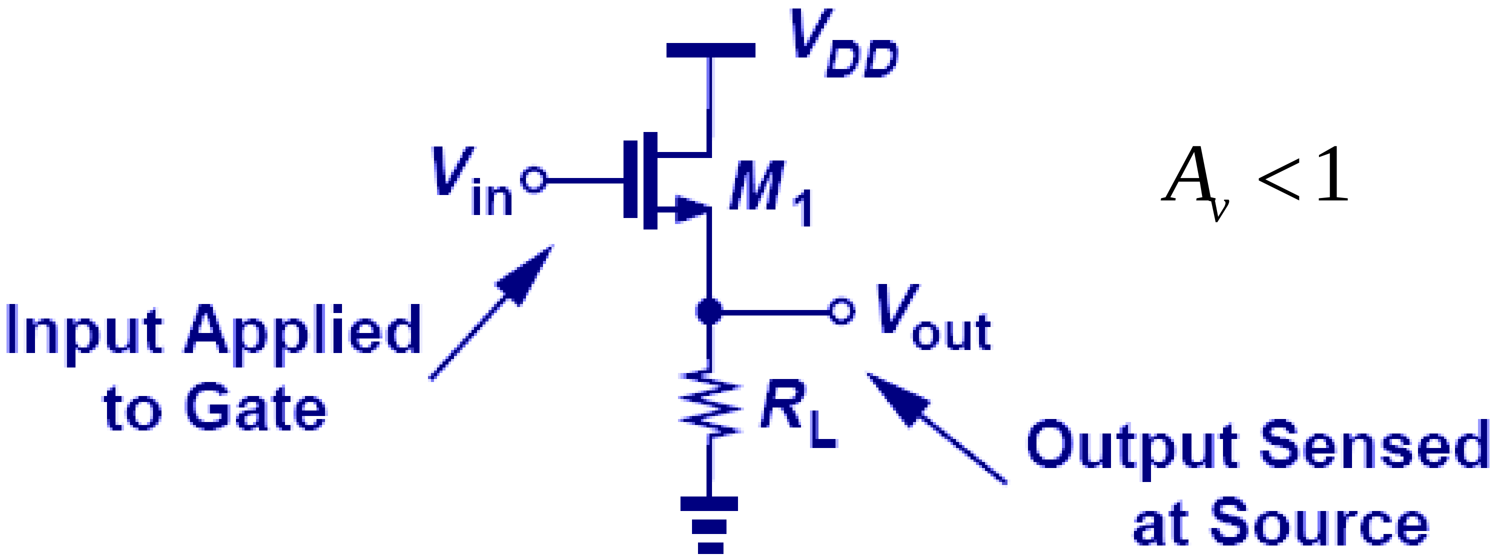
CG Stage with Biasing



$$\frac{v_{out}}{v_{in}} = \frac{R_3 \| (1/g_m)}{R_3 \| (1/g_m) + R_G} \cdot g_m R_D$$

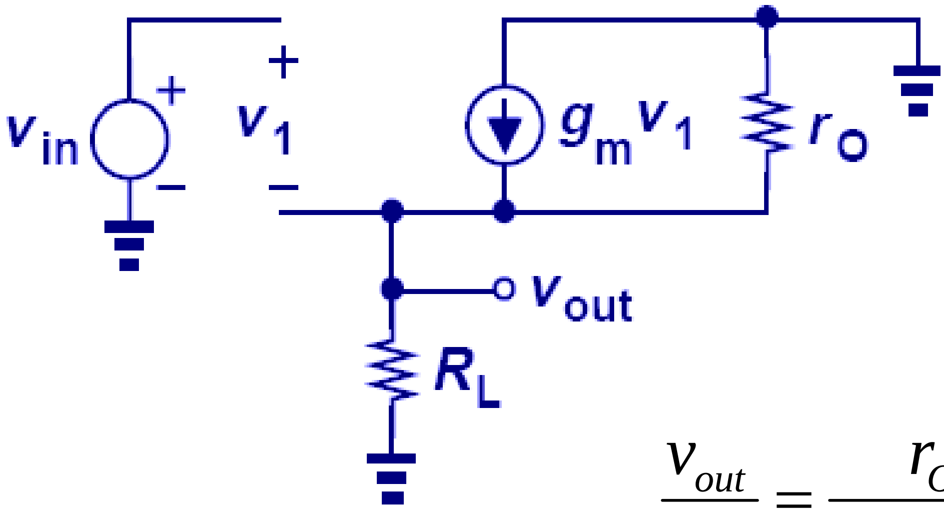
- R_1 and R_2 provide gate bias voltage, and R_3 provides a path for DC bias current of M_1 to flow to ground.

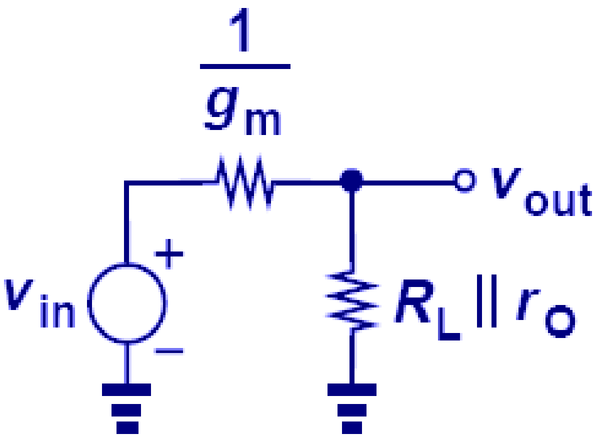
Source Follower Stage



$$A_v < 1$$

Source Follower Core

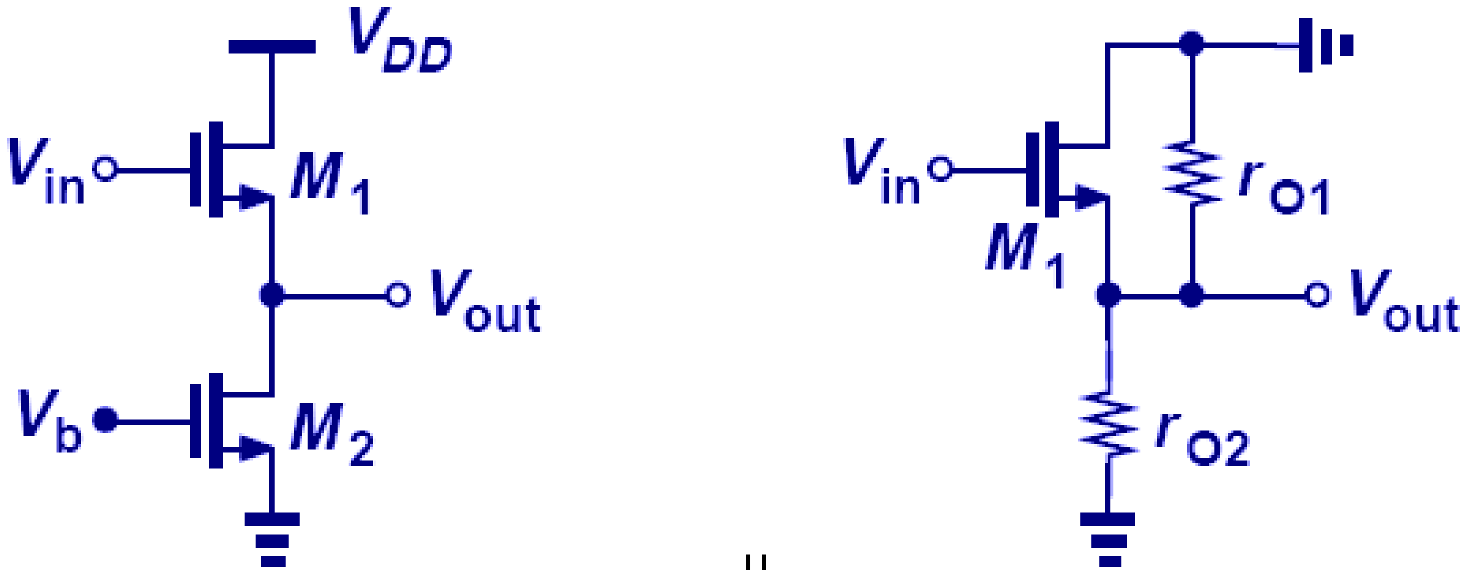




$$\frac{v_{out}}{v_{in}} = \frac{r_O \| R_L}{\frac{1}{g_m} + r_O \| R_L}$$

- Similar to the emitter follower, the source follower can be analyzed as a resistor divider.

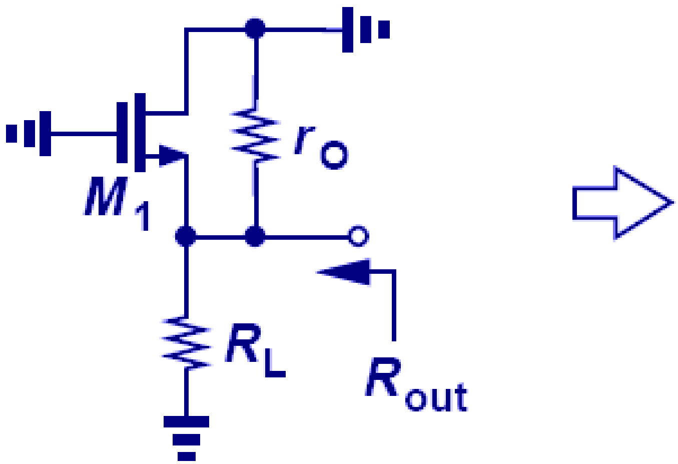
Source Follower Example

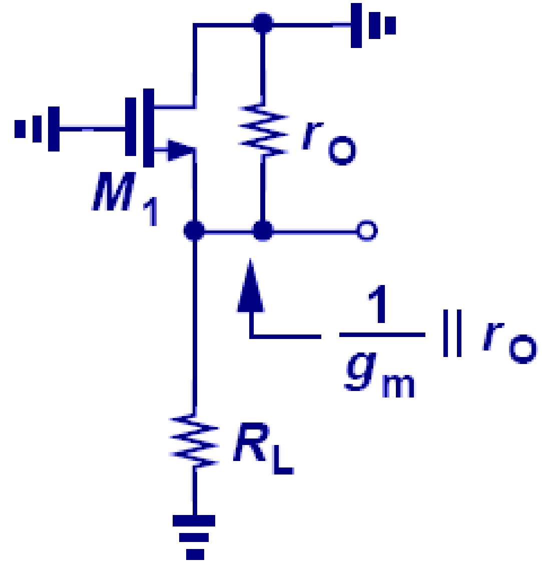


$$A_v = \frac{r_{O1} \| r_{O2}}{\dfrac{1}{g_{m1}} + r_{O1} \| r_{O2}}$$

- In this example, M_2 acts as a current source.

Output Resistance of Source Follower

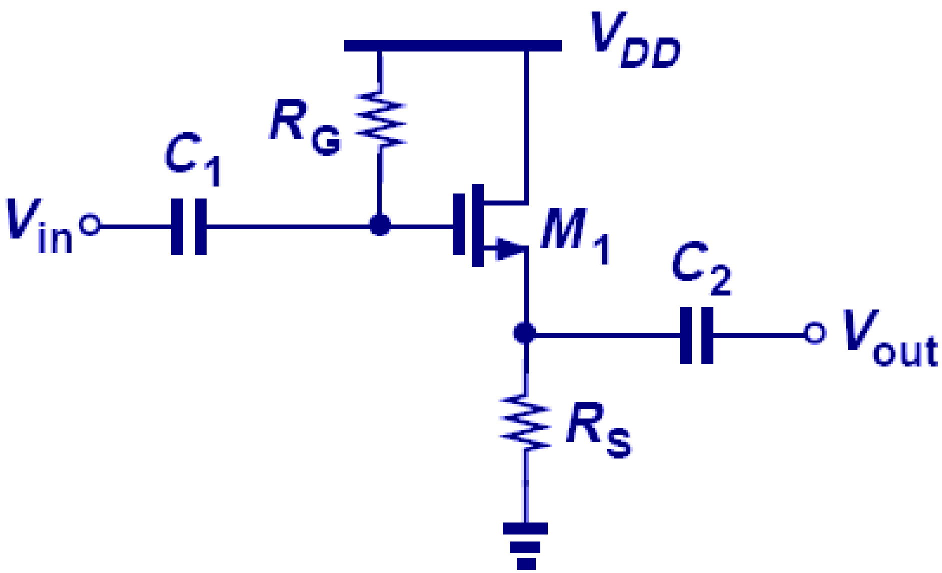




$$R_{out} = \frac{1}{g_m} \parallel r_O \parallel R_L \approx \frac{1}{g_m} \parallel R_L$$

- The output impedance of a source follower is relatively low, whereas the input impedance is infinite (at low frequencies); thus, a good candidate as a buffer.

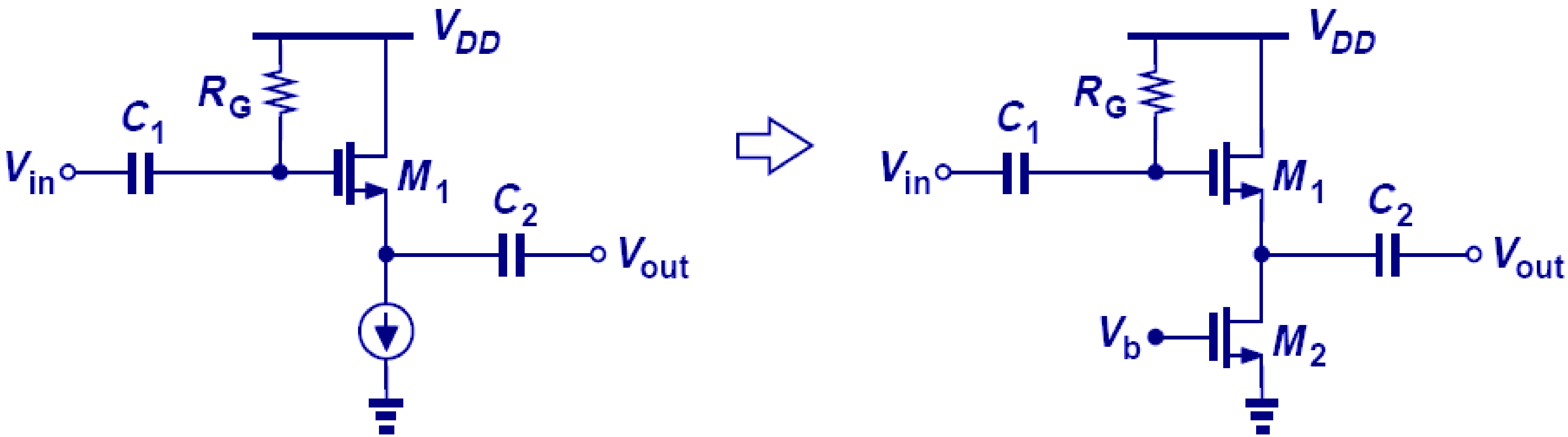
Source Follower with Biasing



$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left(V_{DD} - I_D R_S - V_{TH}\right)^2$$

- R_G sets the gate voltage to V_{DD}, whereas R_S sets the drain current
- The quadratic equation above can be solved for I_D

Supply-Independent Biasing



- If R_s is replaced by a current source, drain current I_D becomes independent of supply voltage.