Lecture17:
Common-source amplifier (1)

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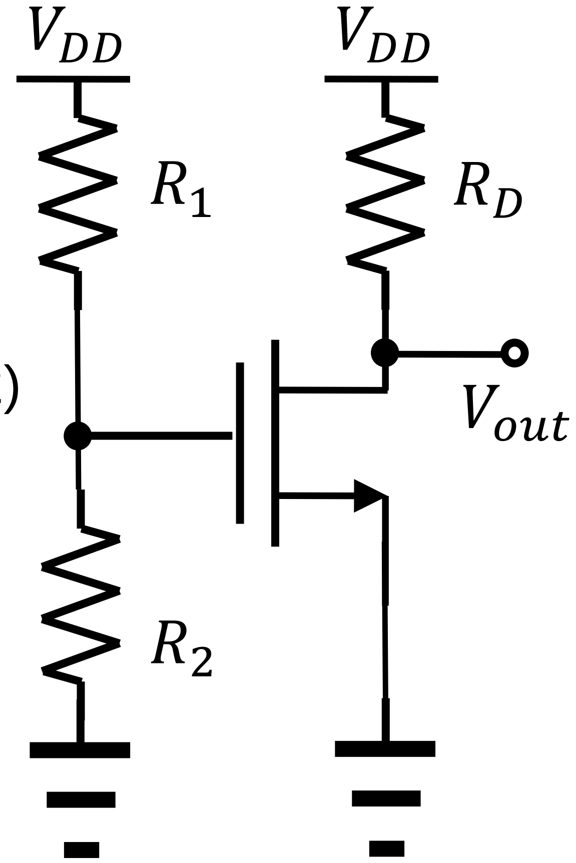
Simple biasing (1/3)

- A better way to provide the gate voltage
  - The gate bias voltage is

$$V_{GS} = \frac{R_2}{R_1+R_2} V_{DD} \qquad \text{(Razavi 17.10)}$$

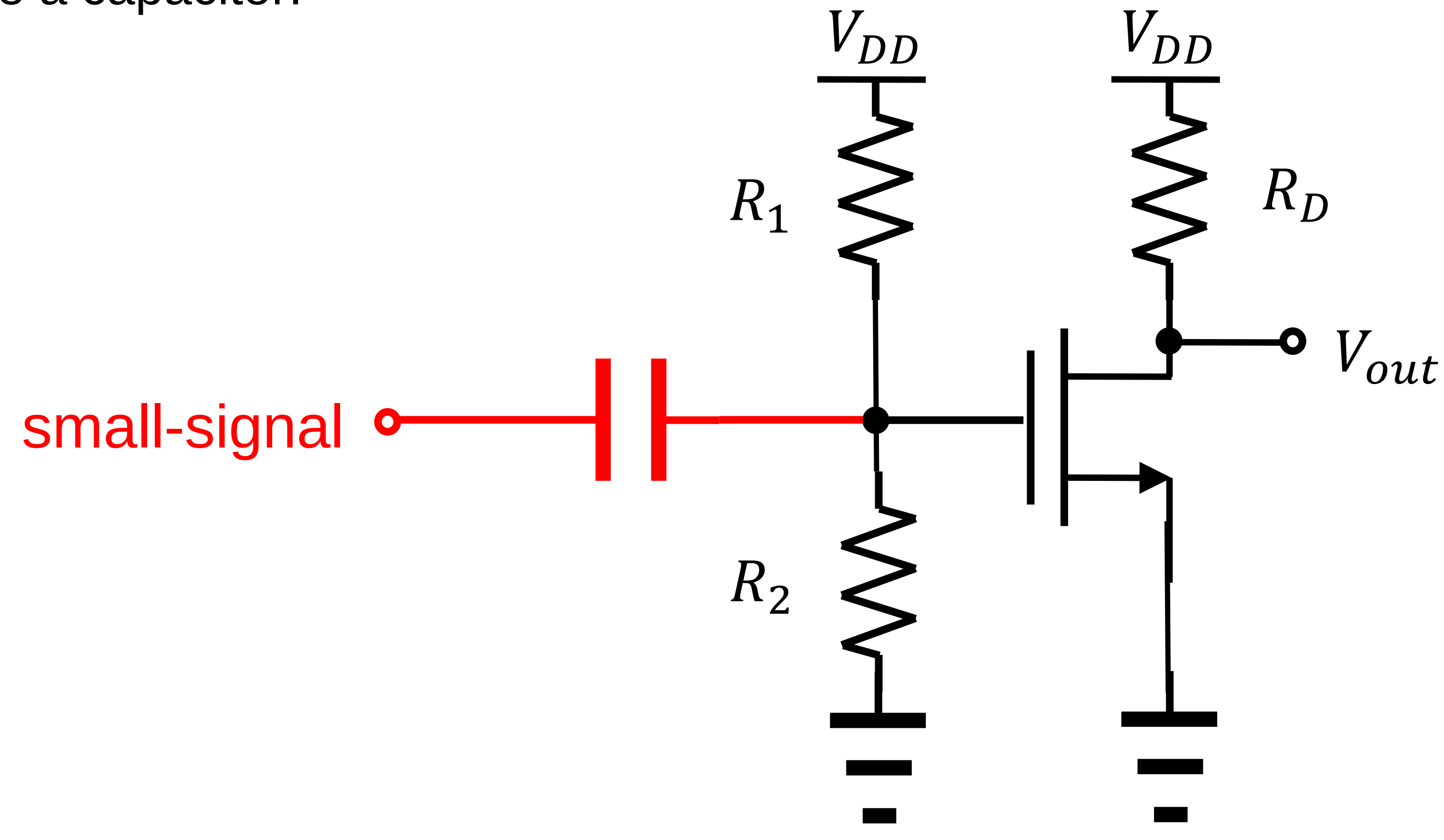
  - The drain current is

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left(\frac{R_2}{R_1+R_2}V_{DD} - V_{TH}\right)^2 \quad \text{(Razavi 17.12)}$$



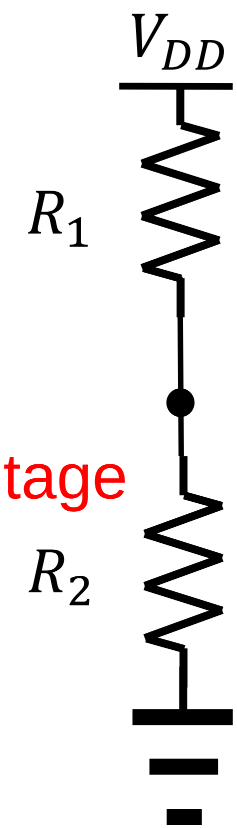
Simple biasing (2/3)

- How to apply the small-signal input
  - Use a capacitor!

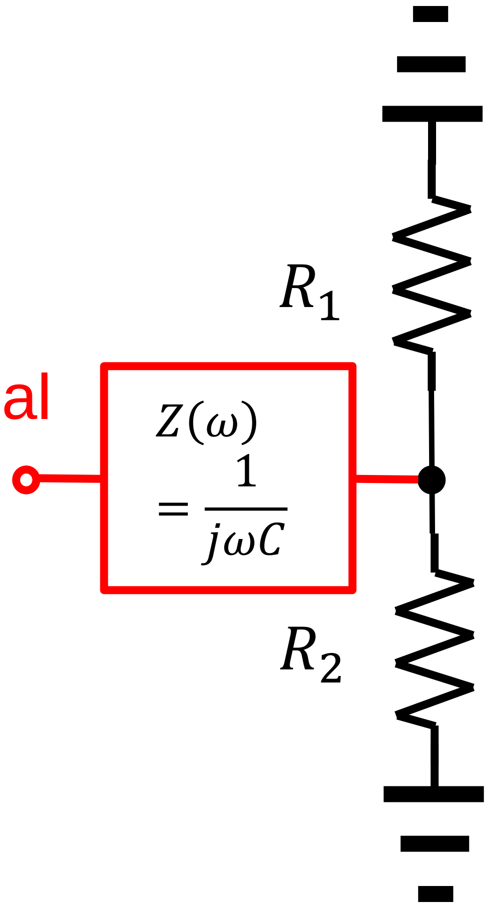


Simple biasing (3/3)

DC:
The capacitor
& small-signal voltage
do not contribute.



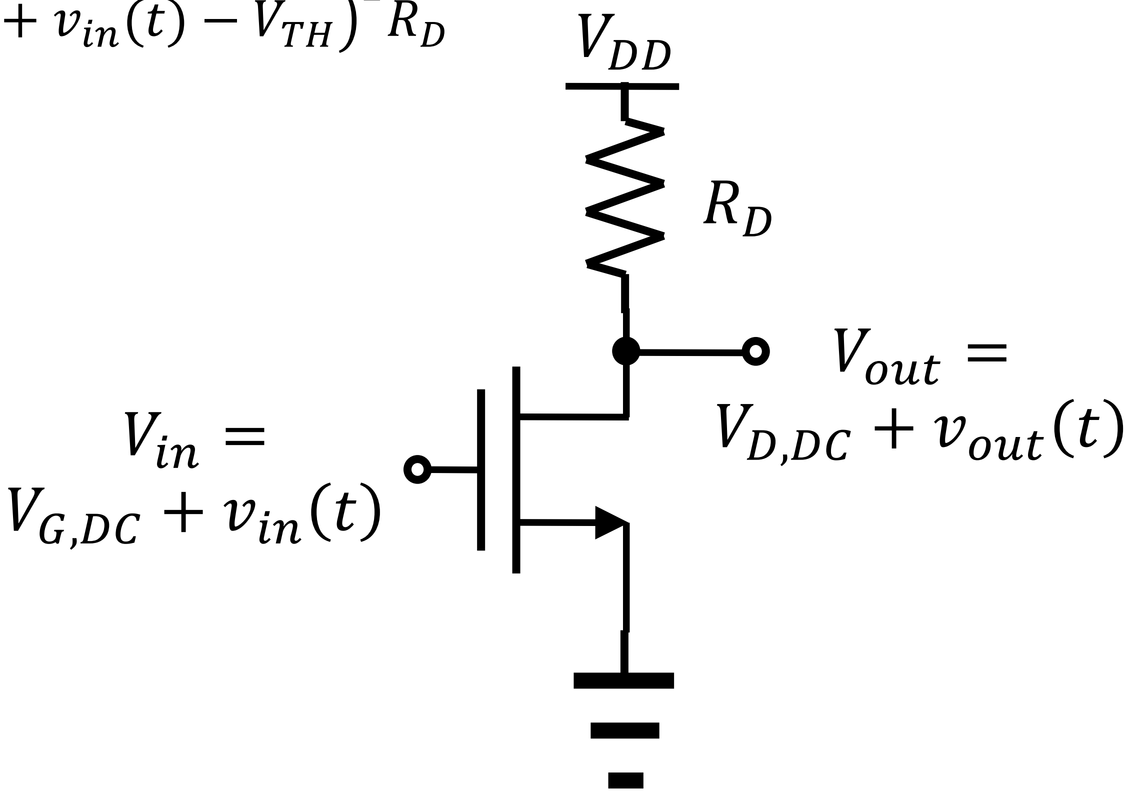
AC:
small-signal
voltage



Common-source amplifer

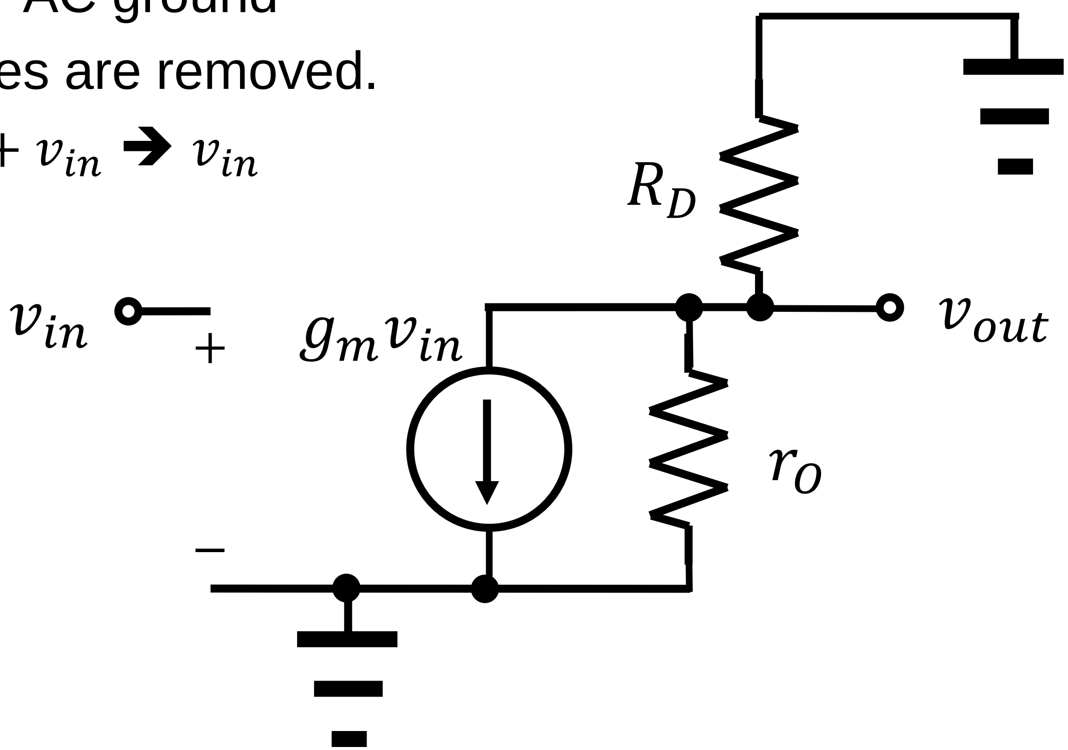
- The source terminal is the reference.
  - The output voltage is $V_{out} = V_{DD} - I_D R_D$.

$V_{out}(t) =$
$V_{DD} - \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left(V_{G,DC} + v_{in}(t) - V_{TH}\right)^2 R_D$



Small-signal model

- Let's draw its small-signal model together!
  - A transistor small-signal model is introduced.
  - Resistors ➔ resistors
  - Ground ➔ AC ground
  - DC voltages are removed.
  - Ex) $V_{G,DC} + v_{in}$ ➔ v_{in}



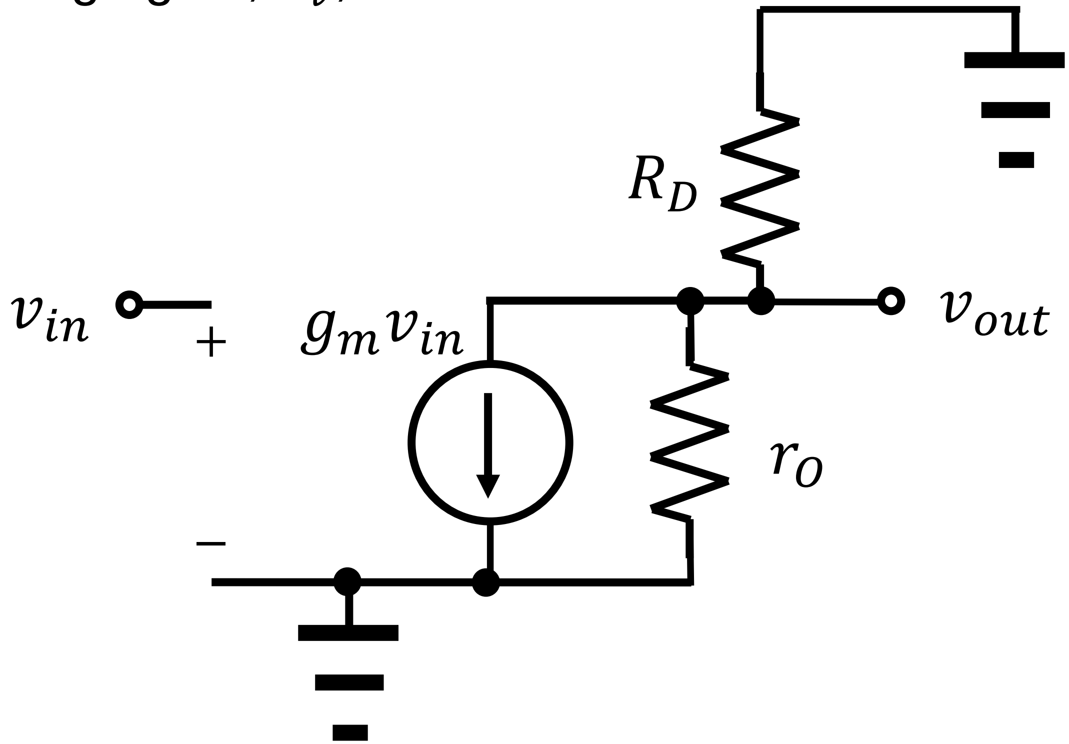
Gain

- Now, calculate the v_{out}.
  - KCL for the v_{out} node gives

$v_{out} = -g_m(R_D||r_O)v_{in}$

  - Therefore, the voltage gain, A_v, is

$A_v = -g_m(R_D||r_O)$



Increasing the gain

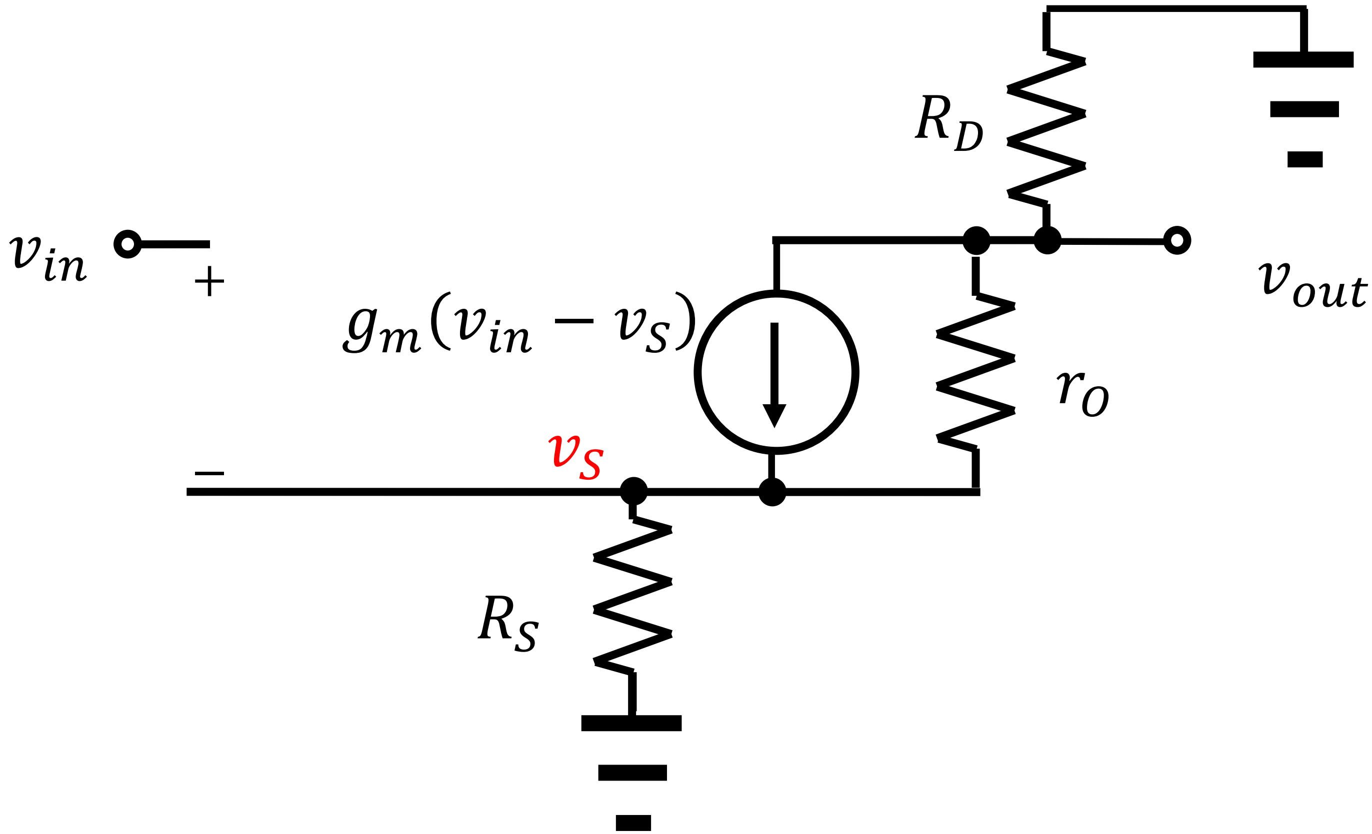
- The voltage gain has two factors.
  - Transconductance(g_m): Selecting W, L, and V_{GS} to maximize the transconductance
  - Resistance($R_D||r_O$): A large R_D value is desirable. However, there is a restrction.

$$V_{D,DC} = V_{DD} - R_D I_{D,DC}$$

  - A too large value of R_D reduces $V_{D,DC}$ too much. The triode mode is not suitable for the amplification due to its smaller transconductance.
  - A drain load other than a simple resistor can be tried.

Impact of R_S

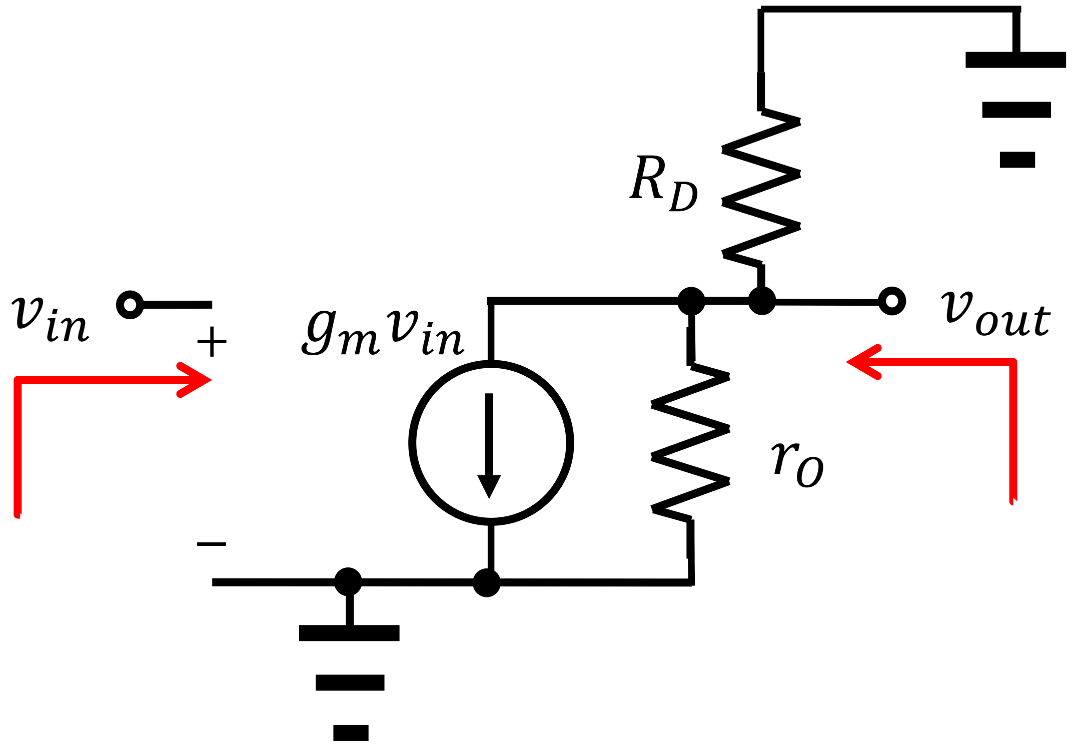
- Consider a source resistance, R_S.
  - Repeat the previous slide.



Input/output impedances

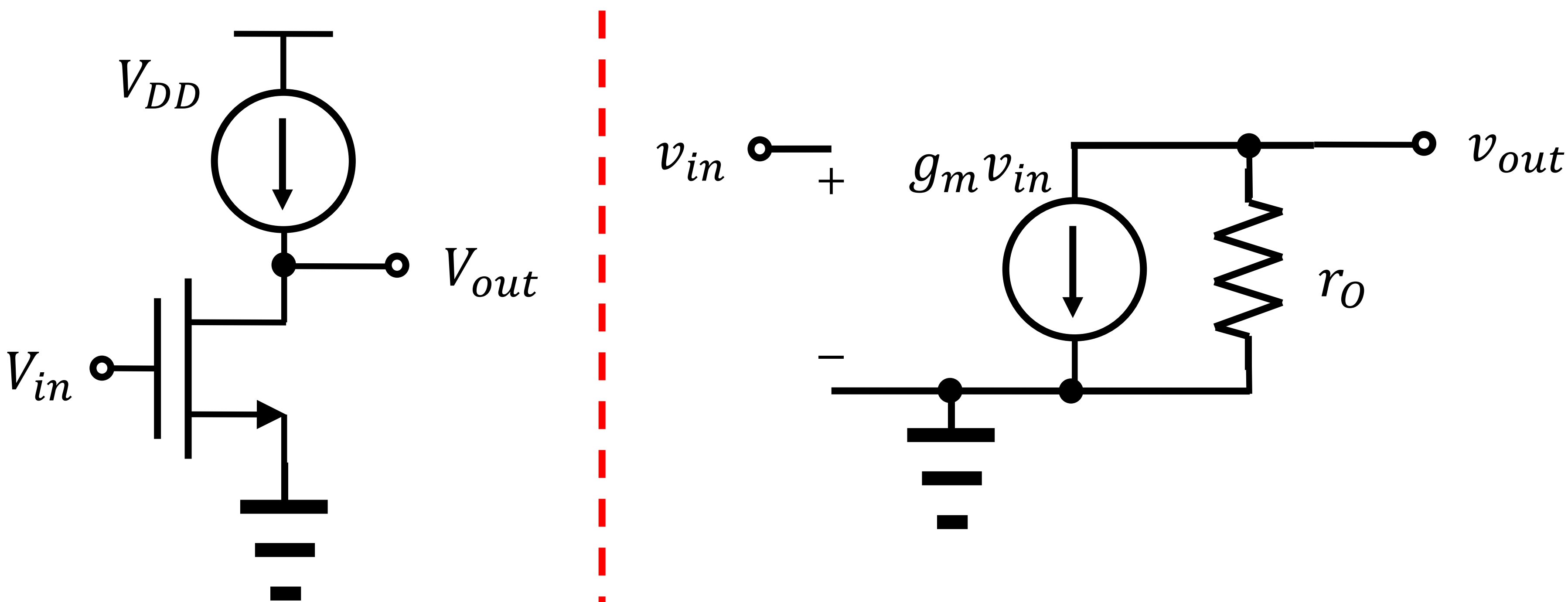
- When calculating the impedance, the voltage sources at other terminals are neglected.
- Input and output impedances

$$R_{in} = \infty$$
$$R_{out} = R_D || r_O$$



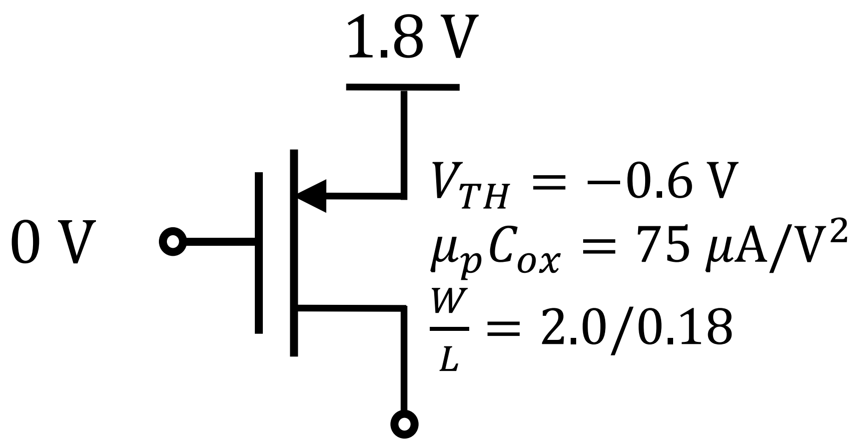
Current-source load

- When $R_D \rightarrow \infty$,
  - The gain can be maximized in its absolute value. ($A_v \rightarrow -g_m r_O$)



Biasing of PMOS devices

- Use a PMOS as a current source
  - The absolute value of the “gate overdrive” is $1.2\ \mathrm{V}$.
  - Of course, when the drain voltage is higher than 0.6 V, it is operated in the triode mode.

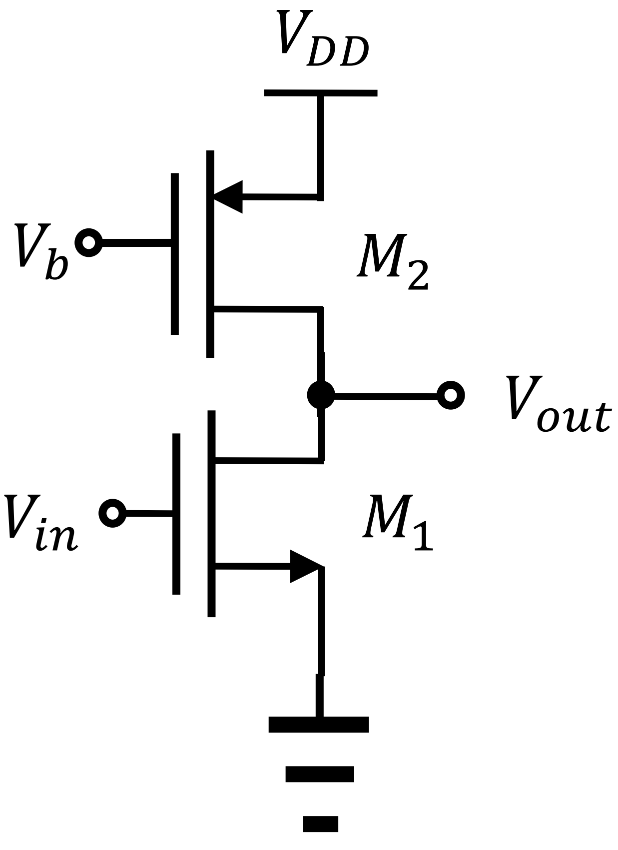


Real current-source load

- Use a PMOS as a current source.
  - It is not an ideal current source.

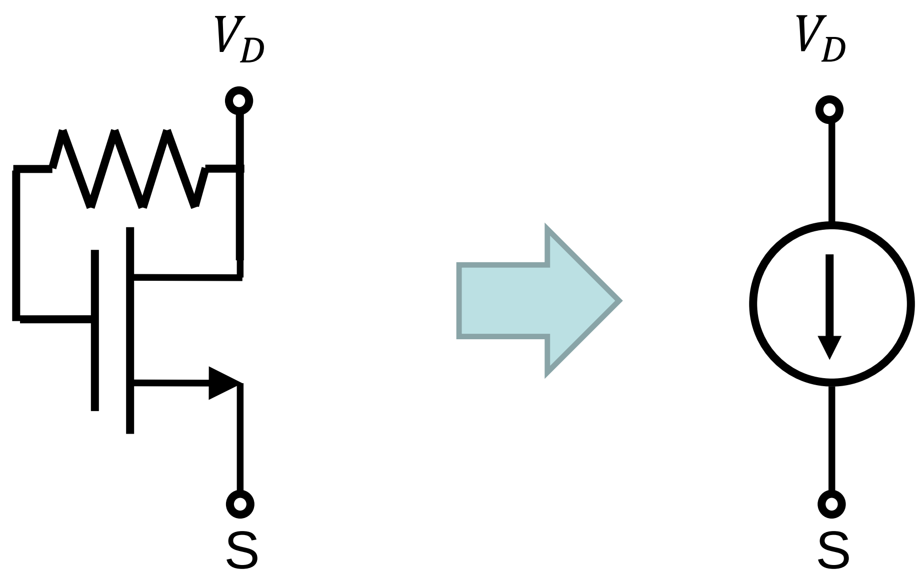
$$v_{out} = -g_{m1}(r_{O1}||r_{O2})v_{in}$$

$$A_v = -g_{m1}(r_{O1}||r_{O2})$$



Self-biasing

- Already covered in Razavi Example 6.13.
  - Always in the saturation region.



$$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_D - V_S - V_{TH})^2$$

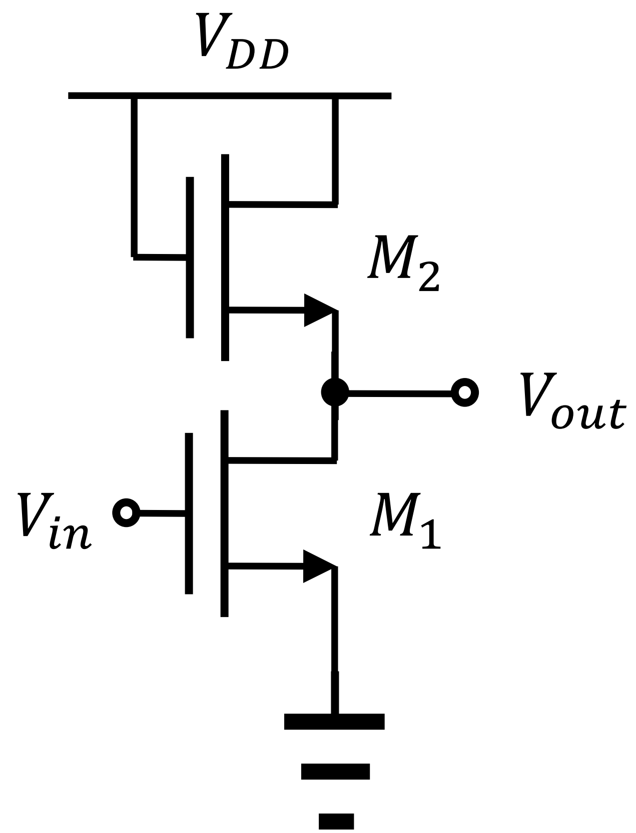
Gate and drain are tied.

Diode-connected load

- Use a diode-connected load.
  - It is not an ideal current source.

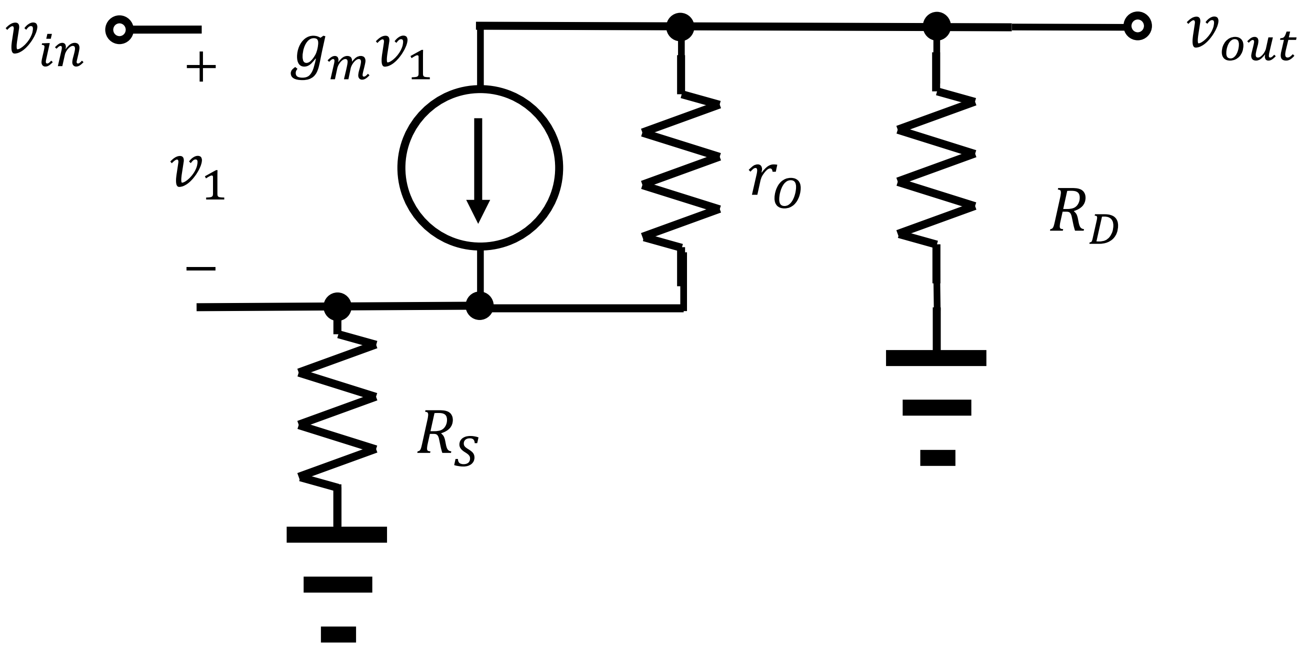
$$v_{out} = -g_{m1}\left(r_{O1}||\frac{1}{g_{m2}}||r_{O2}\right)v_{in}$$

$$A_v = -g_{m1}\left(r_{O1}||\frac{1}{g_{m2}}||r_{O2}\right)$$



Source degeneration

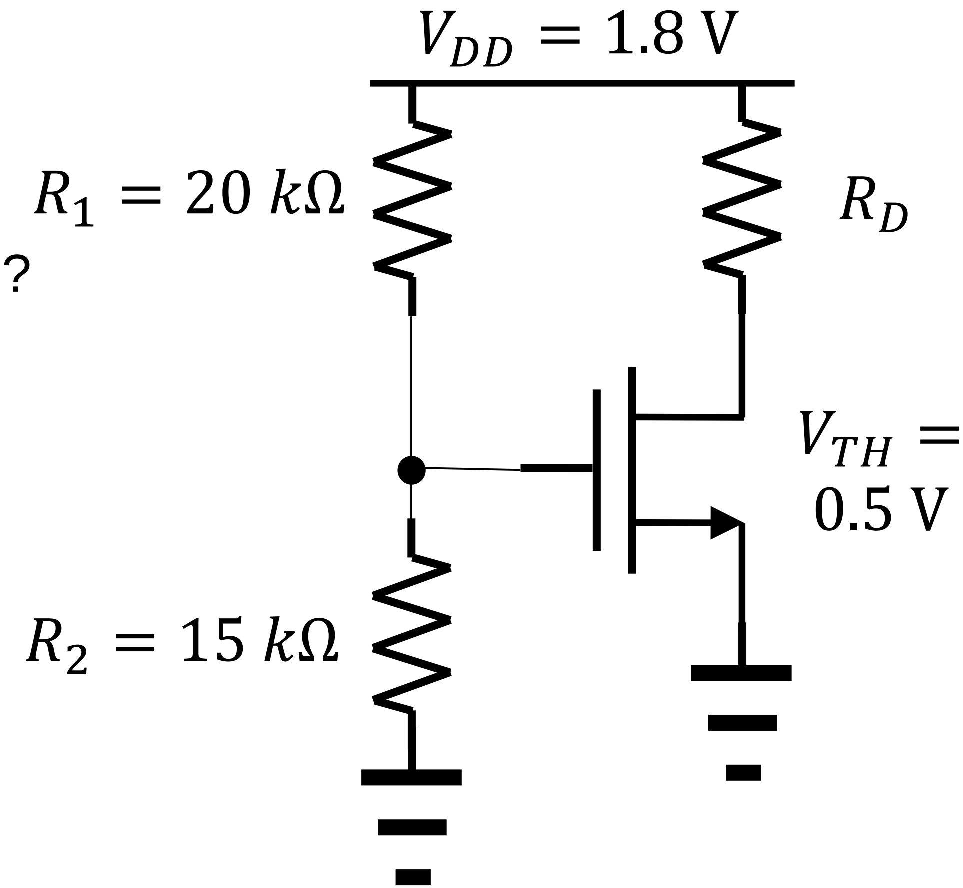
- Consider a case with a source resistor, R_S.
  - Caculate the gain and the output impedance.



Razavi, example 17.8

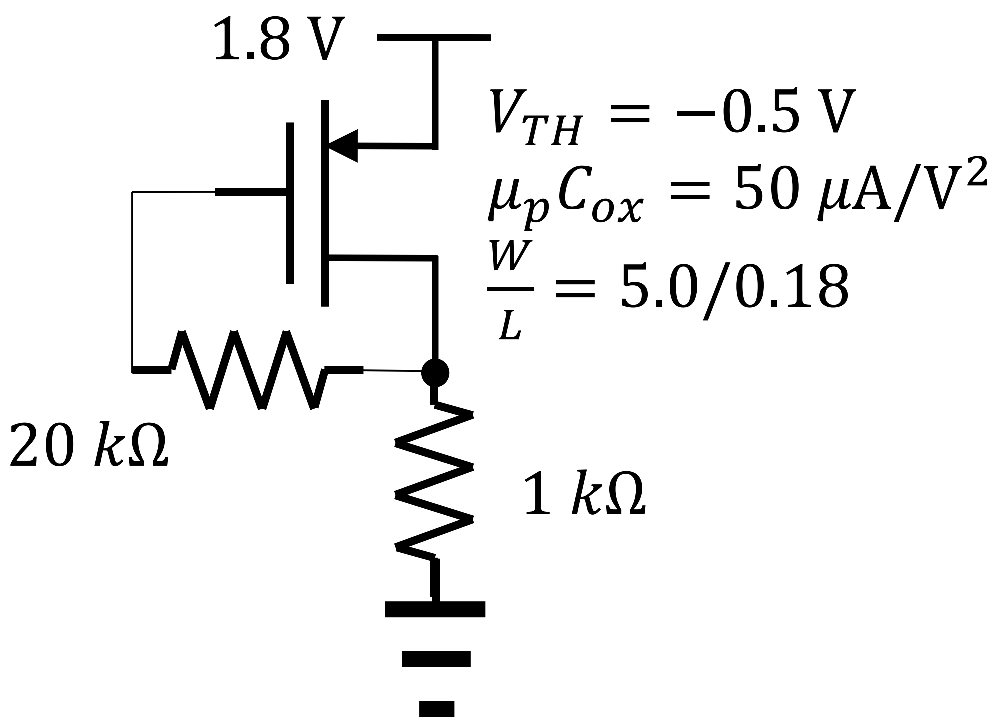
- Biasing
  - What is the gate voltage?
  - Condition for saturation mode?

$\mu_n C_{ox} = 100\ \mu\text{A/V}^2$
$W/L = 5/0.18$



Razavi, example 17.13

- Calculate the drain current. (BTW, where is the drain?)



Razavi, example 17.14

- Calculate the gain.
  - The gain is given by $A_v = -g_m R_D$.
  - How can we get the transconductance?

$\mu_n C_{ox} = 100\ \mu\text{A/V}^2$

$V_{TH} = 0.5\ \text{V}$

$W/L = 10/0.18$