Lecture13: CMOS amplifier, biasing

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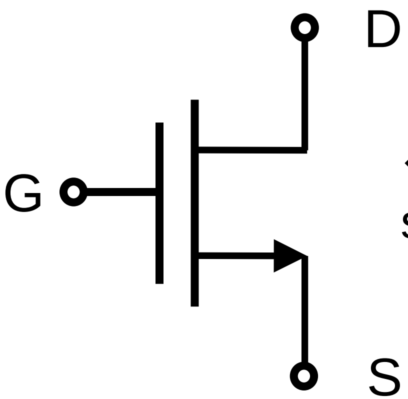
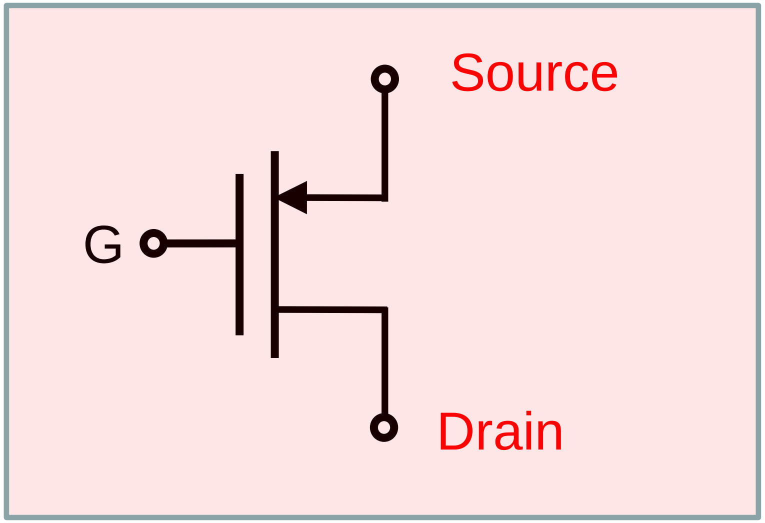
CMOS

- 9’s complementary of 123?
  - 876
- Complementary MOS
  - Here we have an NMOSFET.
  - A device where the transport is dominated by holes.



← NMOSFET symbol

PMOSFET symbol →



- Why is it important?

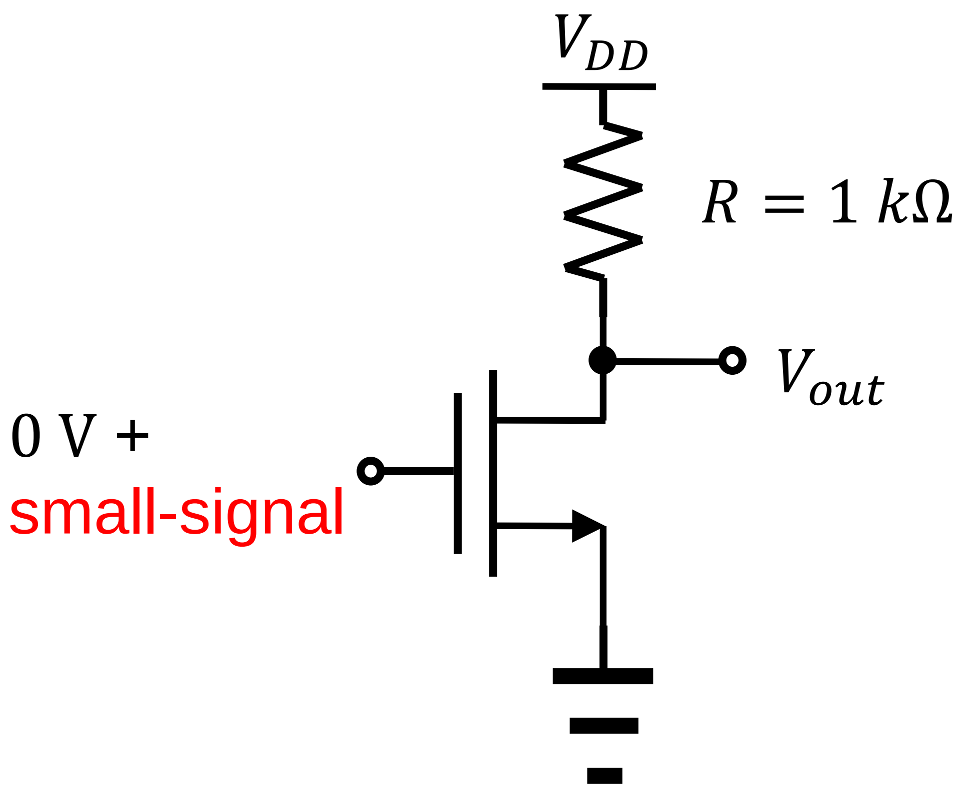
Why amplifiers?

- Signal amplification
  - Usually, signals are “weak.” (in the $\mu\mathrm{V}$ or mV range)
  - It is too small for reliable processing.
  - If the signal magnitude is made larger, processing is much easier.

- Desirable properties
  - Low power consumption
  - High speed operation
  - Low noise

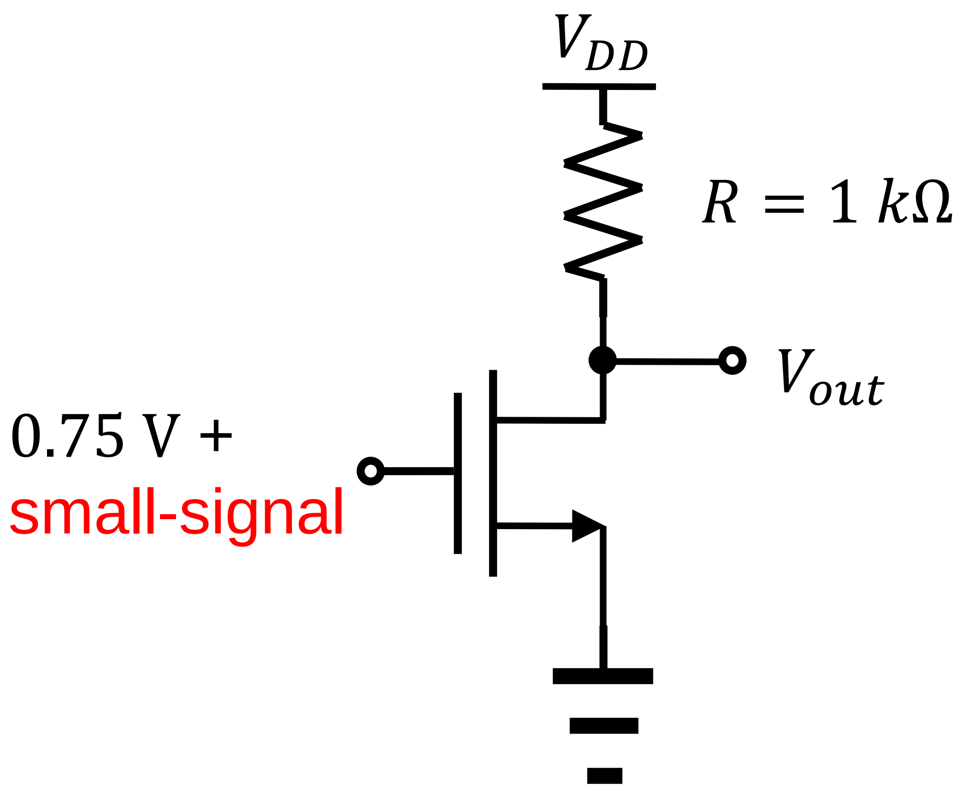
Transistor turned off

- The example 17.5 shows an amplifier circuit.
  - But, the transistor is not turned on.
  - The circuit generates no output signal.



This is a solution.

- The example 17.7 shows a revised circuit.
  - Then, how can we generate $0.75\ \mathrm{V}$, for example?
  - Use of a separate battery can be a way.



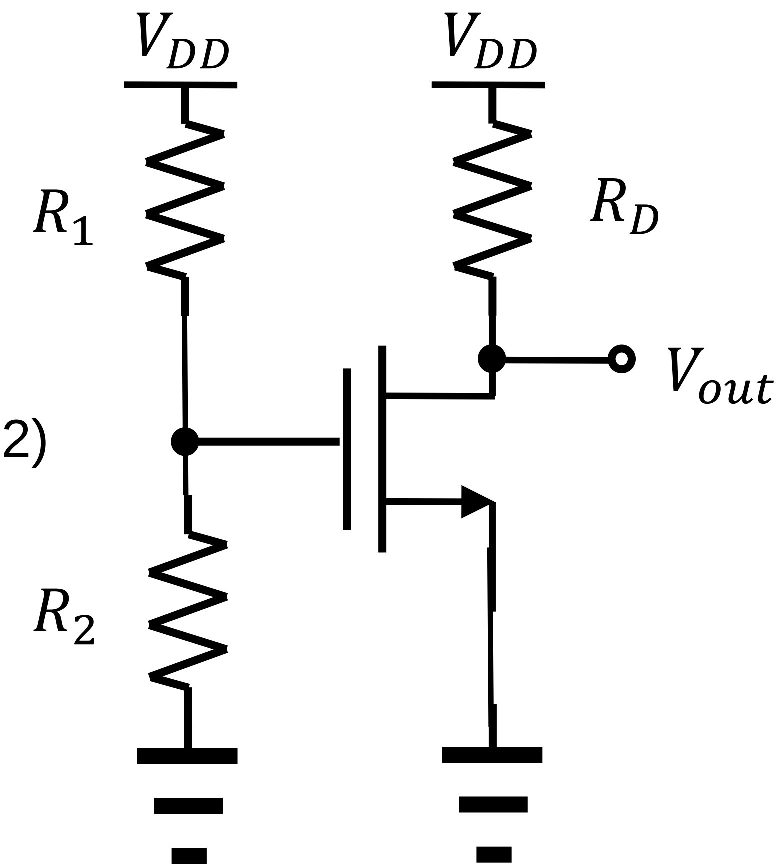
Simple biasing (1/2)

- A better way
  - The gate bias voltage is

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

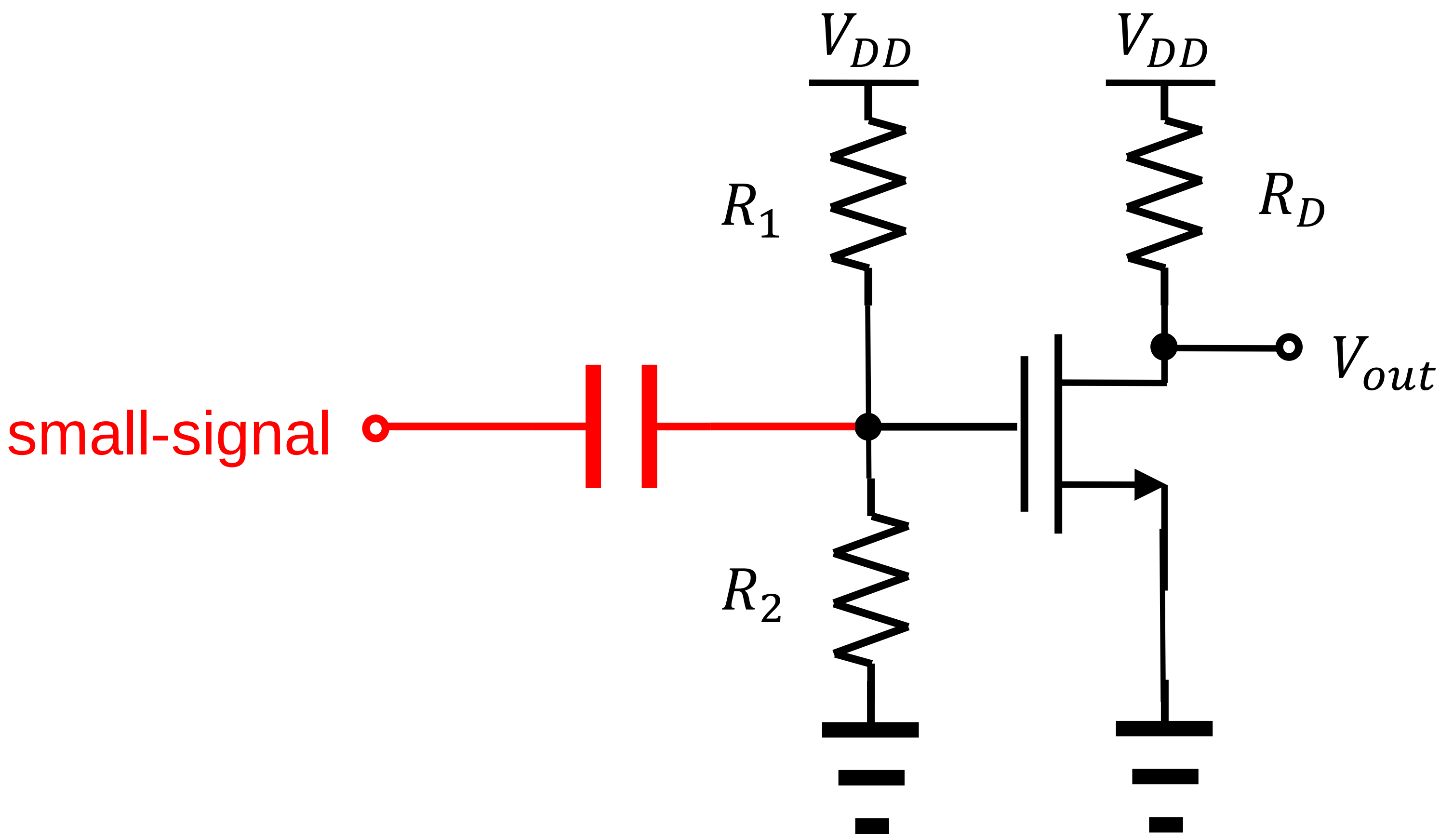
  - The drain current is

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



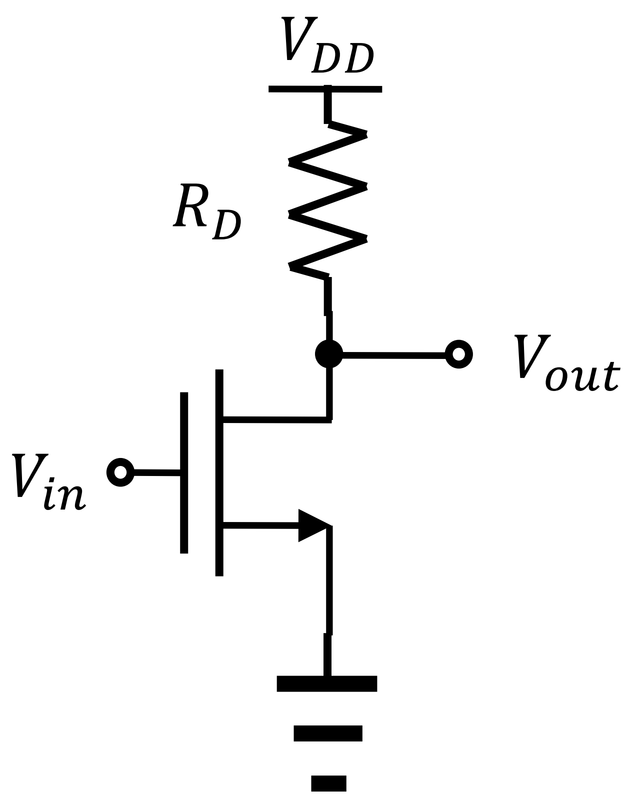
Simple biasing (2/2)

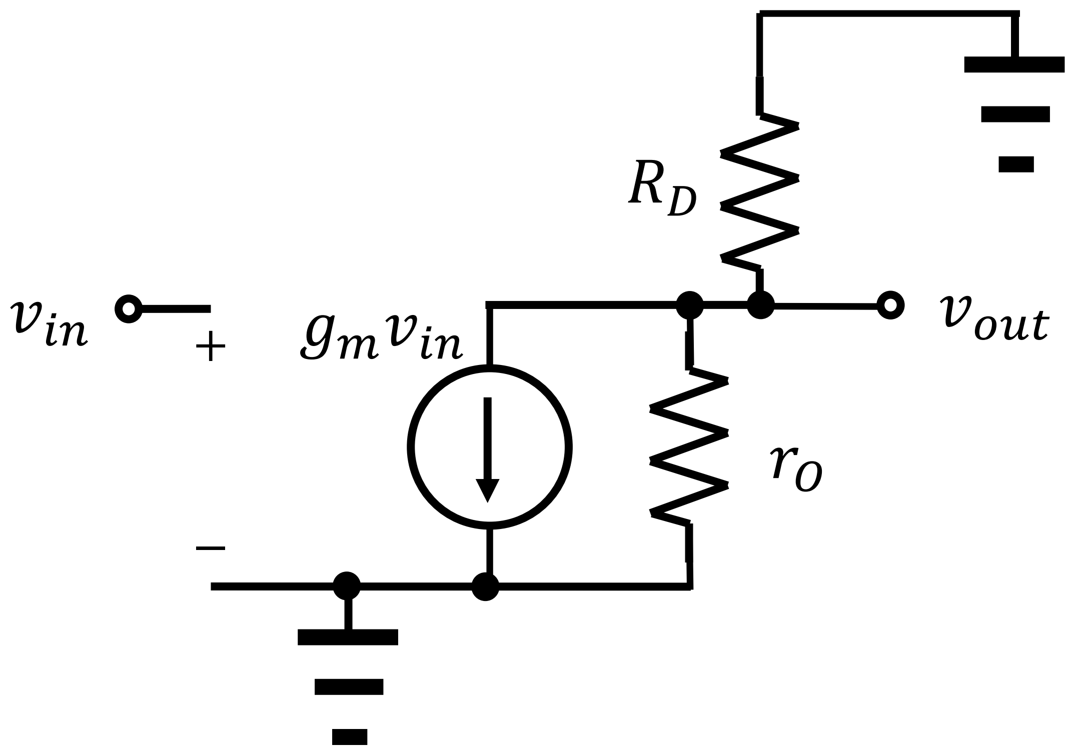
- How to apply the small-signal input
  - Use a capacitor!



Small-signal model

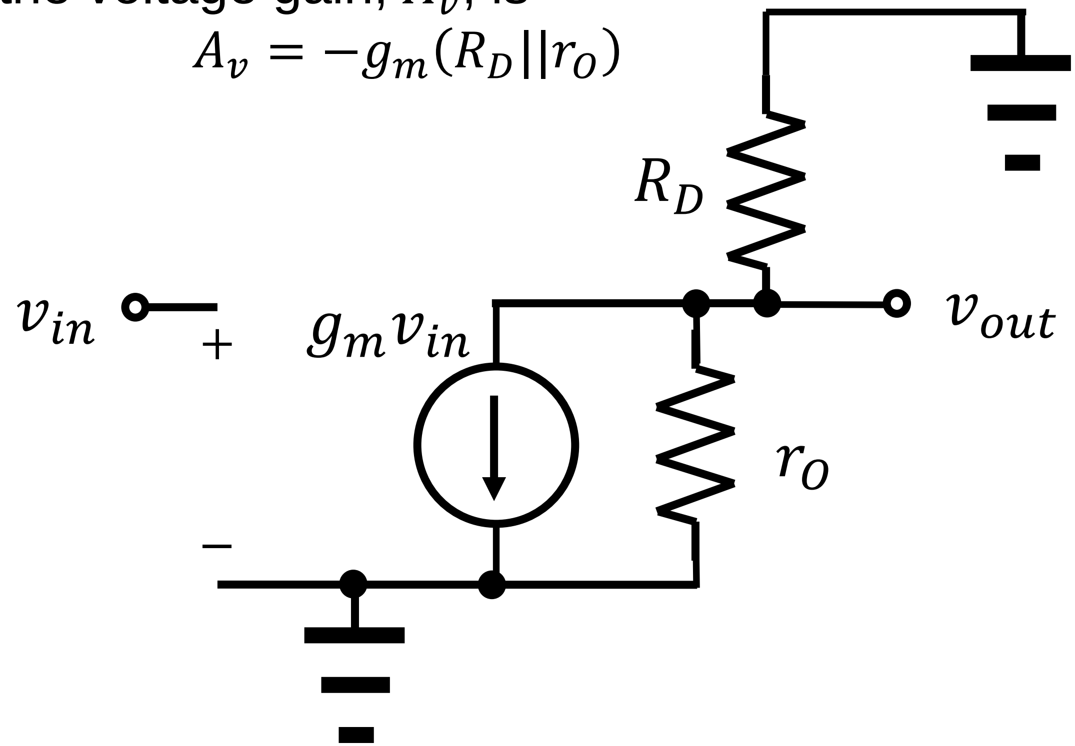
- Let's draw the small-signal model together!





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



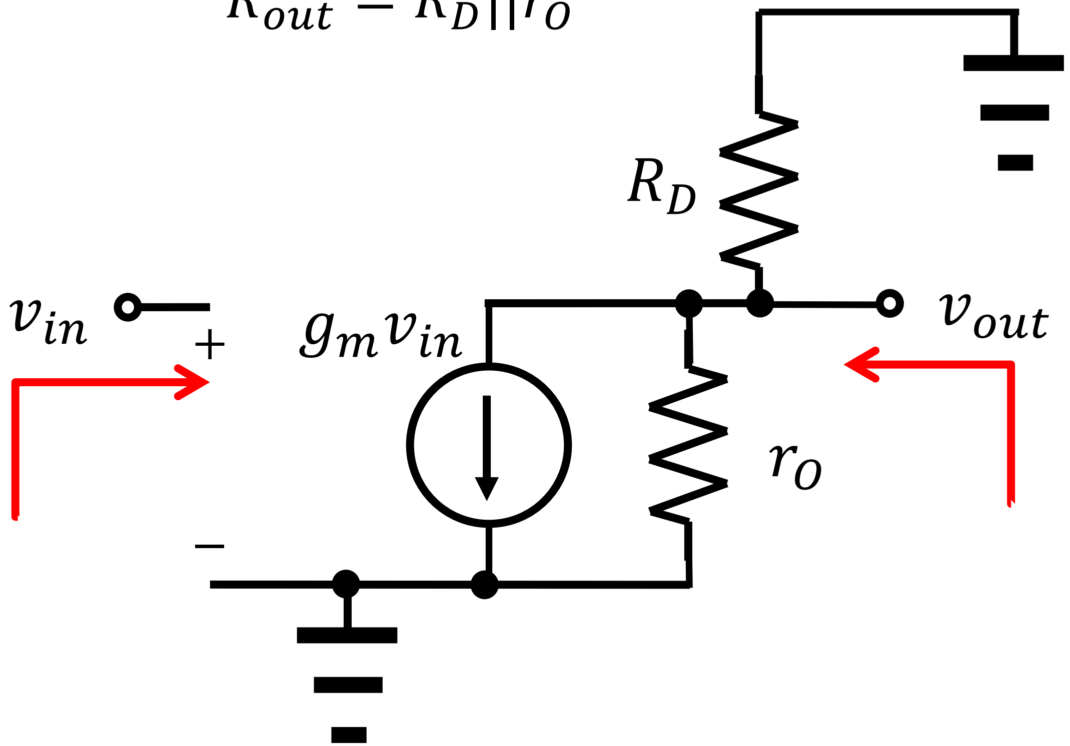
Input/output impedances

- Input impedance

$$R_{in} = \infty$$

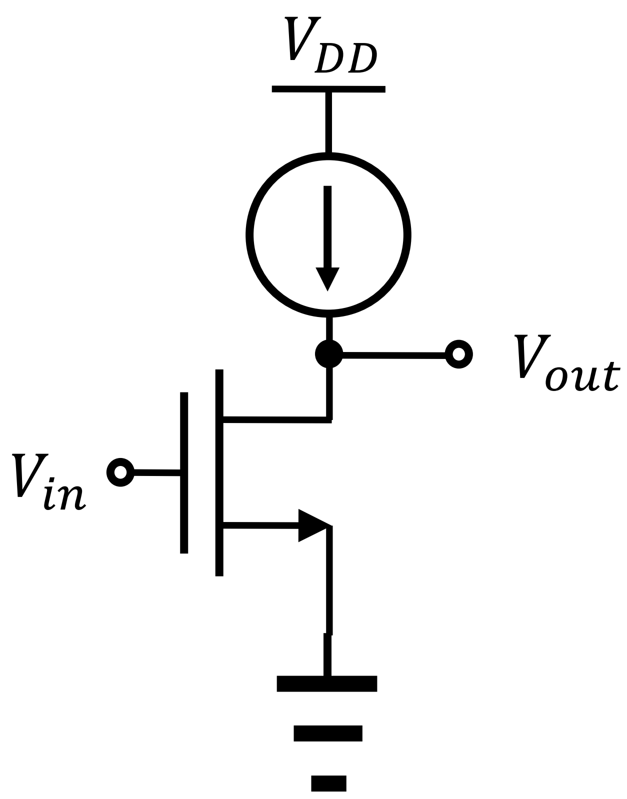
- Output impedance

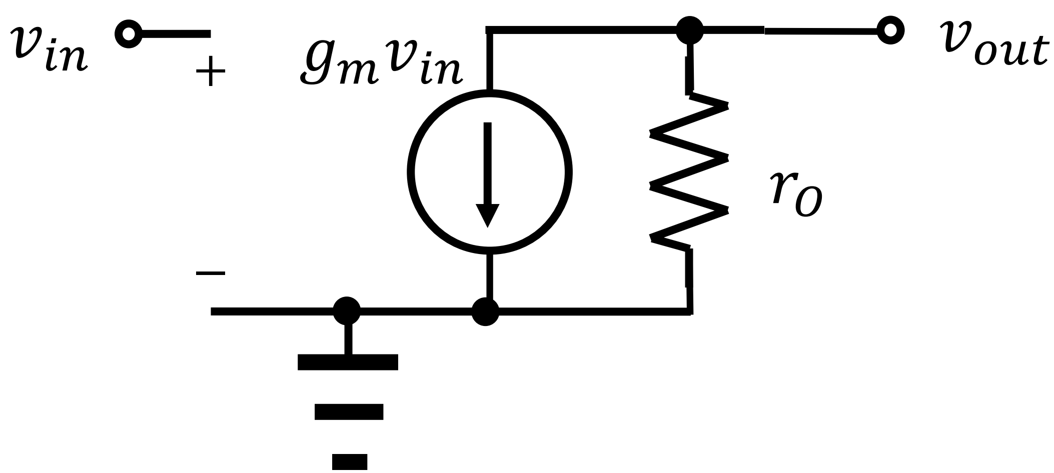
$$R_{out} = R_D || r_O$$



Current-source load

- When $R_D \rightarrow \infty$,
  - The gain can be maximized.



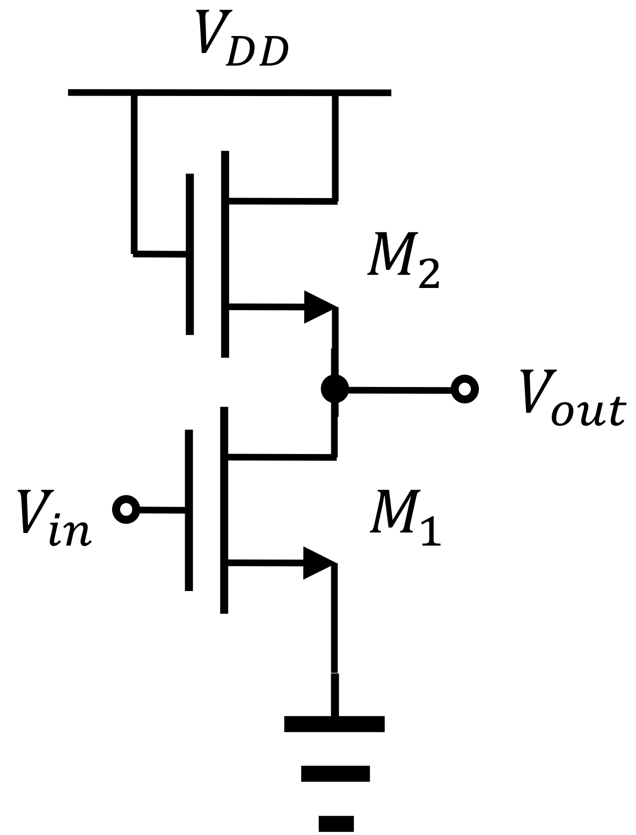


Diode-connected load

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

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

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



Homework#6 (1)

- Due: 09:00, April 30
- Write a program, which reads a netlist file.
  - In this program, the matrix describes a system:
  - For a voltage source:
    - The voltage difference between two terminals is fixed.
    - Sum of two terminal currents vanishes.
  - For a resistor:
    - The terminal current and the voltage difference satisfy Ohm’s law.
    - Sum of two terminal currents vanishes.
  - For every element terminal, the terminal voltage is equal to the circuit node voltage.
  - For the GND node, the node voltage is zero.
  - For all other circuut nodes, the KCL is applied.

Homework#6 (2)

- (Continued)
  - For example, consider the example in Homework#4. A voltage source and a resistor are found.
  - The matrix is explicitly shown below.

$$\begin{bmatrix} 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & -1/R & 1/R & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} I_1^V \\ I_2^V \\ V_1^V \\ V_2^V \\ I_1^R \\ I_2^R \\ V_1^R \\ V_2^R \\ V_0 \\ V_{in} \end{bmatrix} = \begin{bmatrix} V_{source} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Homework#6 (3)

- (Continued)
  - In Homework#6, just solve the set of equations shown in the previous slide.
  - The fully functional code will be needed in Homework#7.

Homework#6 (4)

- Solve the following problems of the mid-term exam in 2018. (Not 2017)
  - P4
  - P27
  - P28
  - P35
  - P36
  - P41
  - P42