Lecture12:
CMOS amplifier, biasing

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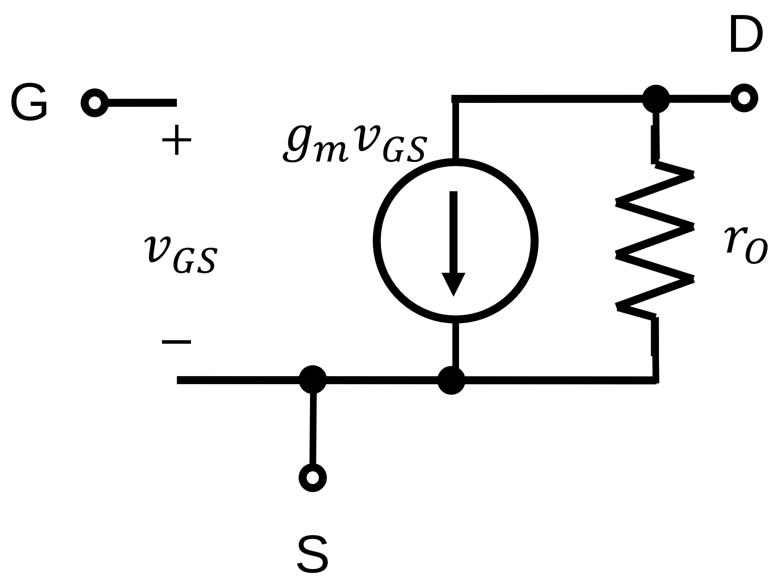
Summary

- Small-signal MOSFET model
  - Two branches are related with two partial derivatives.

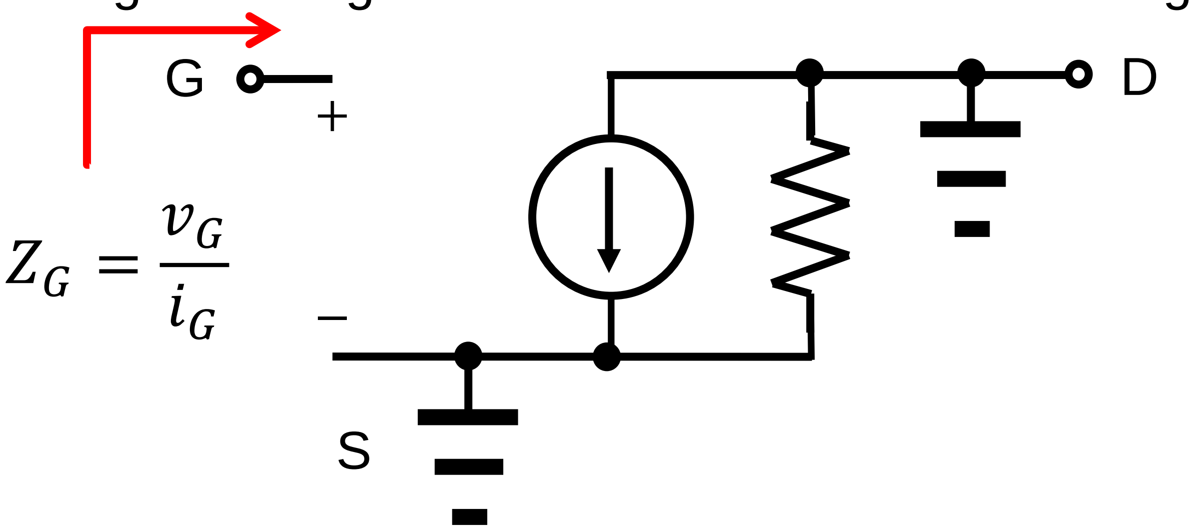


Impedances

- Resistance, $V(t) = R\,I(t)$
  - It is assumed that $V(t)$ and $I(t)$ are in the same phase.
  - Consider $V(t) = V_0 \sin \omega t$ and $I(t) = I_0 \cos \omega t$. Then, what is the resistance?
  - In this case, we can introduce a phasor voltage, $V(\omega)$, and a phasor current, $I(\omega)$.
  - The relation between $V(t)$ and $V(\omega)$ is
$$V(t) = Re[V(\omega) e^{j\omega t}]$$
  - When $V(t) = V_0 \sin \omega t$, the phasor voltage is $V(\omega) = -jV_0$.
  - When $I(t) = I_0 \cos \omega t$, the phasor voltage is $I(\omega) = I_0$.
- Impedance, $V(\omega) = Z(\omega) I(\omega)$
  - In the above example, $Z(\omega) = -j\frac{V_0}{I_0}$. A purely imaginary number.

Impedances of MOSFET

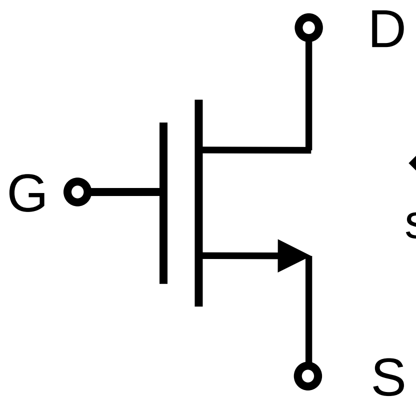
- "Looking into the *TERMINAL*," we see the impedance of the *TERMINAL*.
  - Consider the following cases:
  - 1) Looking into the gate. The source and drain are ac-grounded.



  - 2) Looking into the drain. The source and gate are ac-grounded.
  - 3) Looking into the source. The gate and drain are ac-grounded.

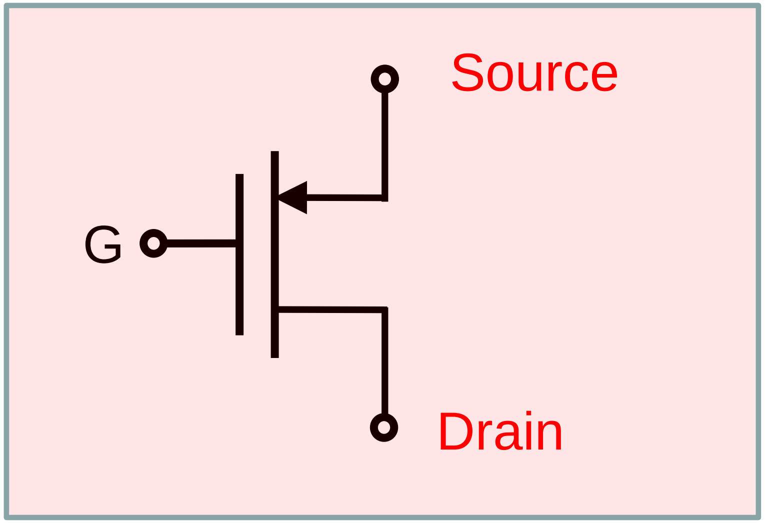
CMOS

- 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?

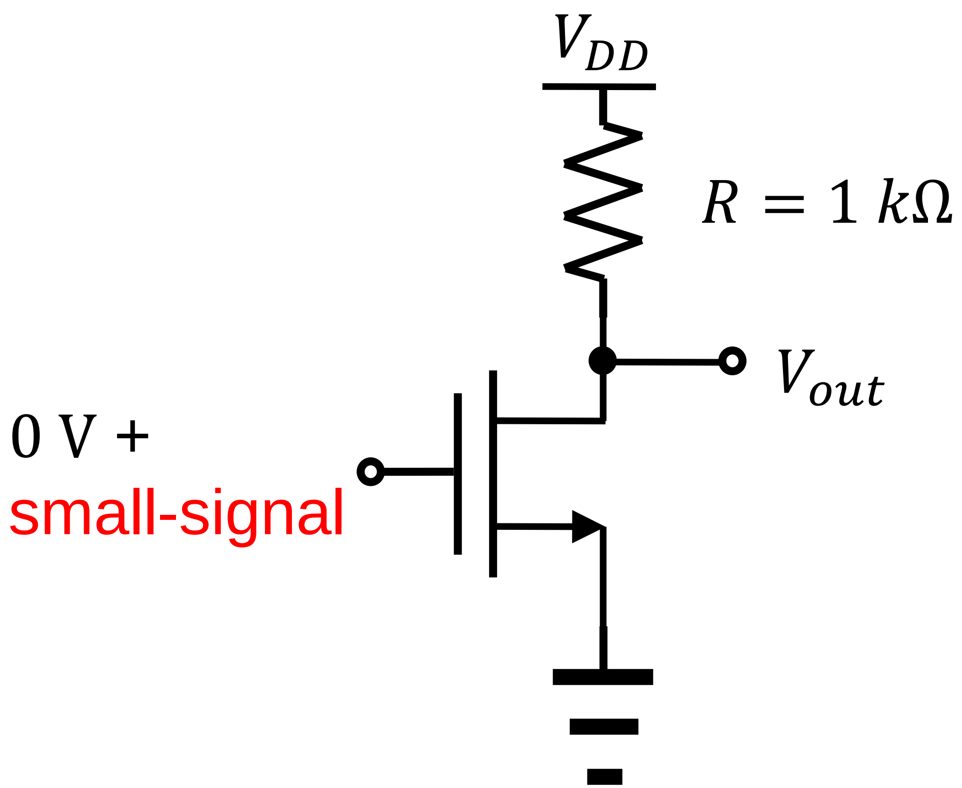
Why amplifiers?

- 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

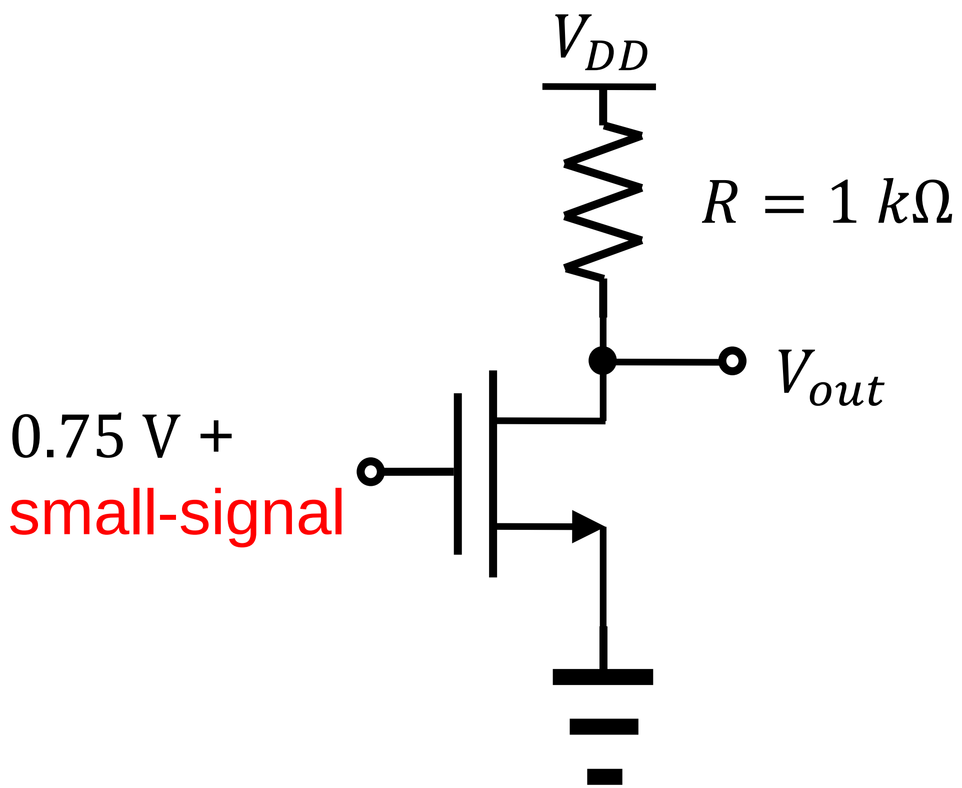
Transistor turned off

- 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.



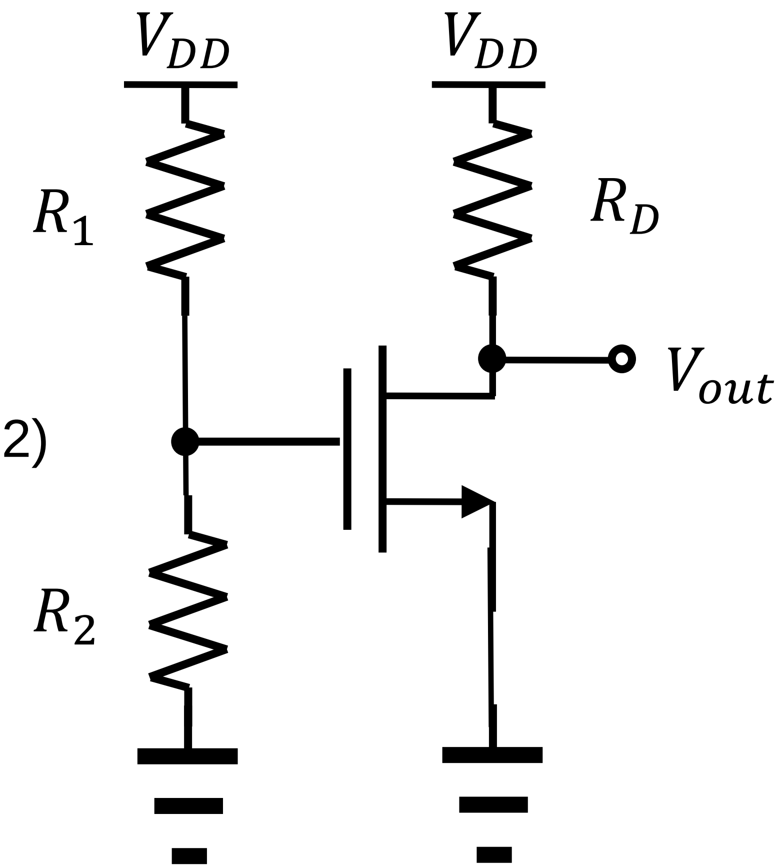
Simple biasing (1/2)

- 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!