Lecture16: Amplifier

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Why amplifiers?

- Signal amplification
  - Usually, signals are "weak." (in the μV or mV range)
  - It is too small for reliable processing.
  - If the signal magnitude is made larger, processing is much easier.

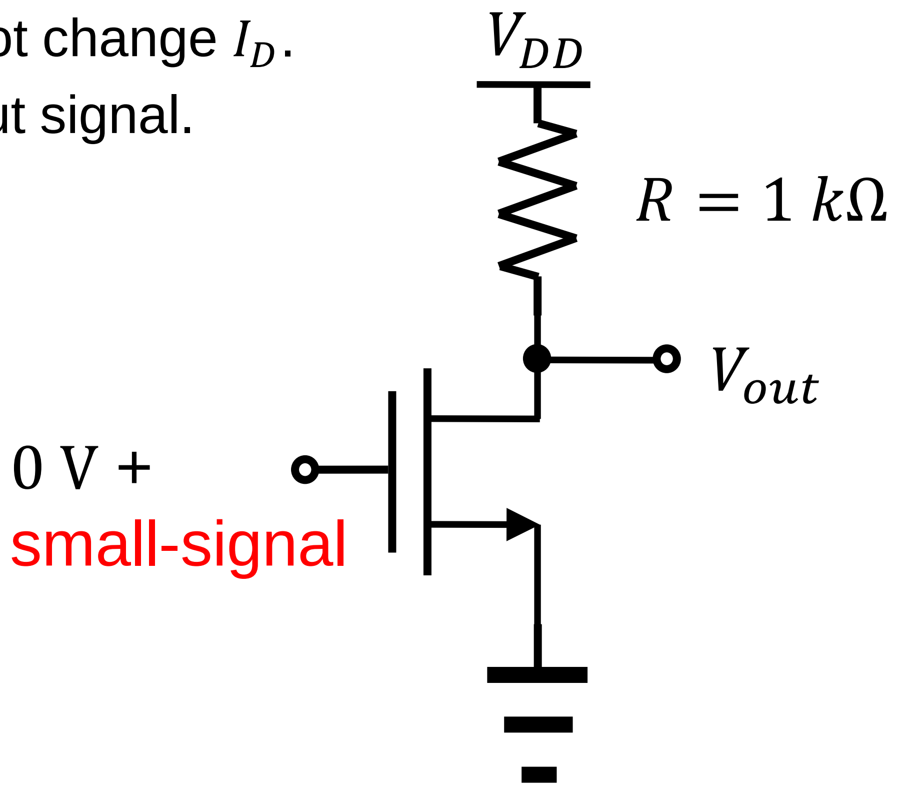
Voltage gain

- Voltage gain
  - For example, a voltage amplifier amplifies the input voltage signal. Its output is also a voltage.
  - When $V_{in}(t) = V_{DC,in} + v_{in}(t)$, ideally,we want to have $V_{out}(t) = V_{DC,out} + A_v v_{in}(t)$.
  - A_v is the voltage gain. (Of course, it is a unitless quantity.)

- How can we have a voltage-voltage relation?
  - Combining a transistor and a resistor!

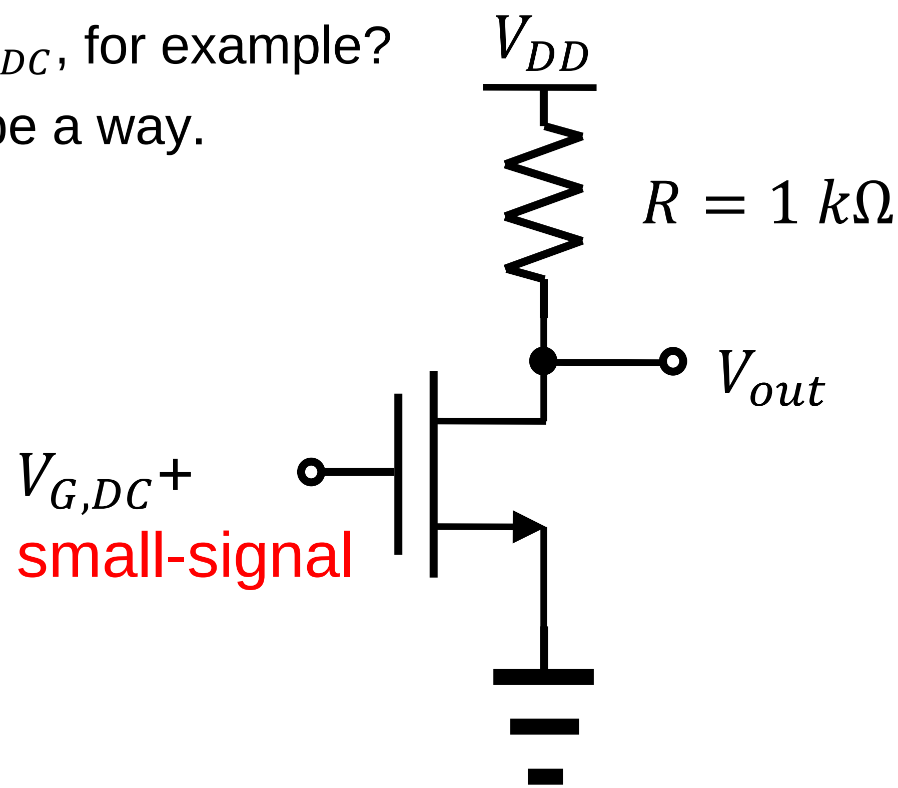
Transistor turned off

- Note that $V_{out} = V_{DD} - I_D R$.
  - But, the transistor is not turned on. ($I_D \approx 0$)
  - The transconductance(g_m) is zero.
  - A small increase in V_G does not change I_D.
  - The circuit generates no output signal.



This is a solution.

- The following circuit shows a revised circuit.
  - Assume that $V_{G,DC} > V_{TH}$.
  - It has a meaningful value of g_m.
  - Then, how can we generate $V_{G,DC}$, for example?
  - Use of a separate battery can be a way.



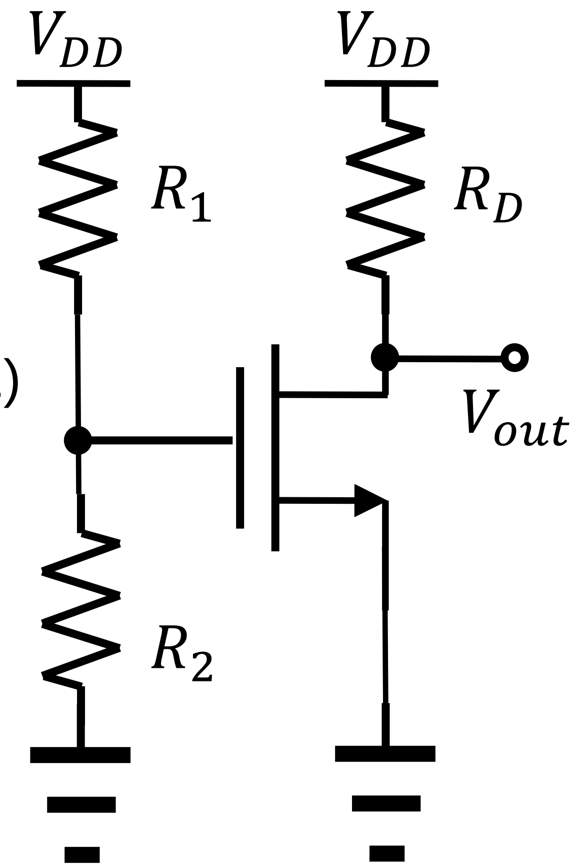
Simple biasing (1/3)

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

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

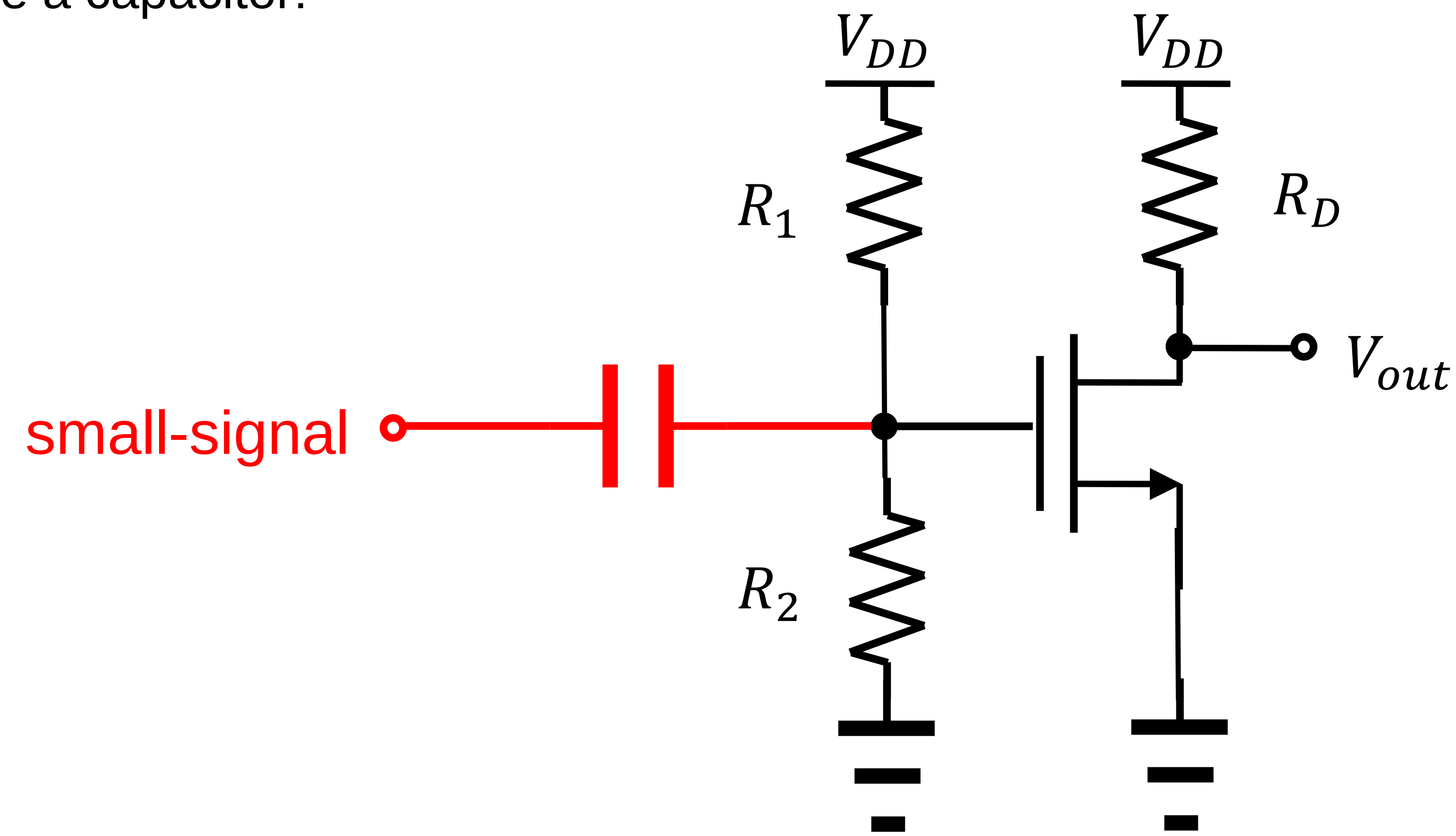
  - The drain current is

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



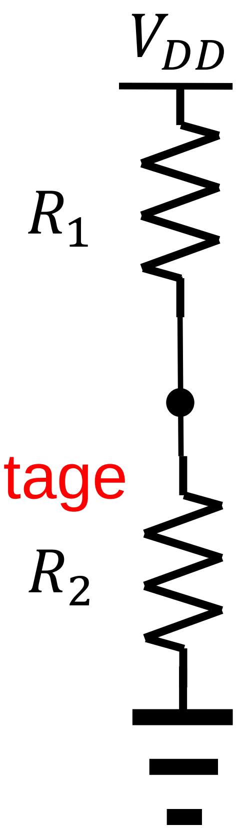
Simple biasing (2/3)

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

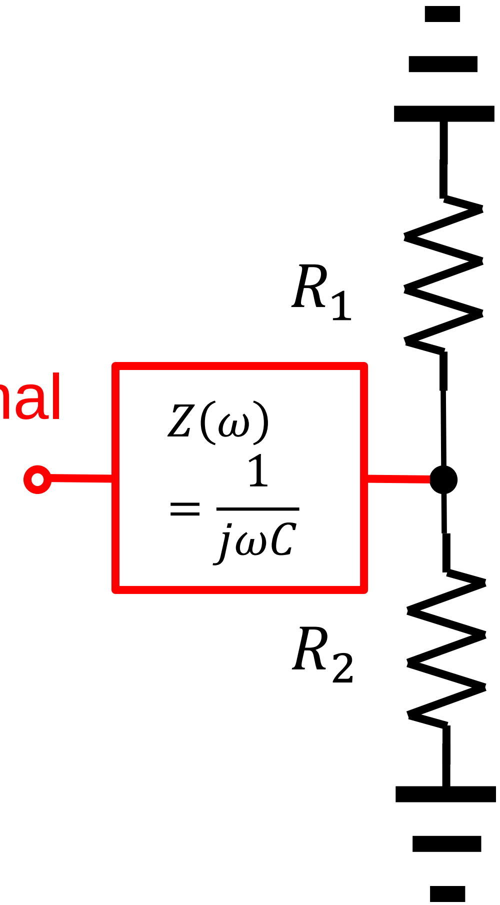


Simple biasing (3/3)

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



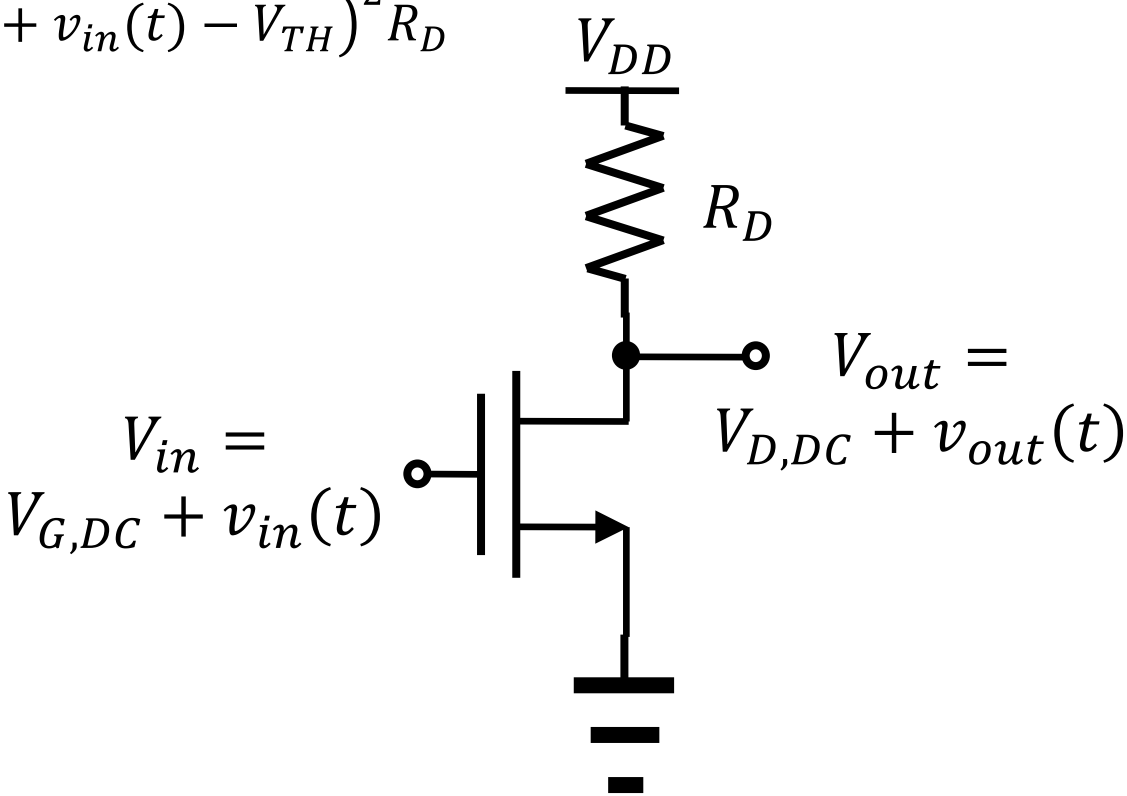
AC:
small-signal
voltage



Common-source amplifer

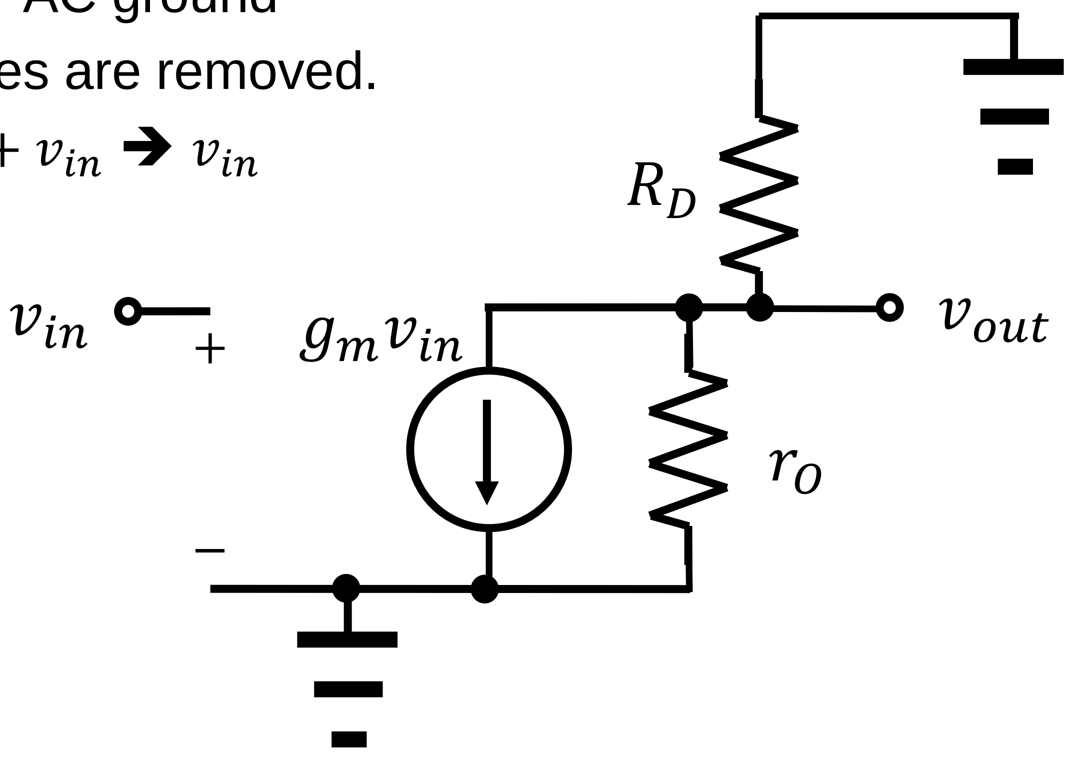
- The source terminal is the reference.
  - The output voltage is $V_{out} = V_{DD} - I_D R_D$.

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



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}



Homework#7

- Due: 09:00, **May 8 (Wed)**
- Solve following problems of the 2018 final exam.
  - P1
  - P2
  - P3
- Solve following problems of the 2017 final exam.
  - P22
  - P23
  - P24
  - P25

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

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