
Lecture15: Amplifier

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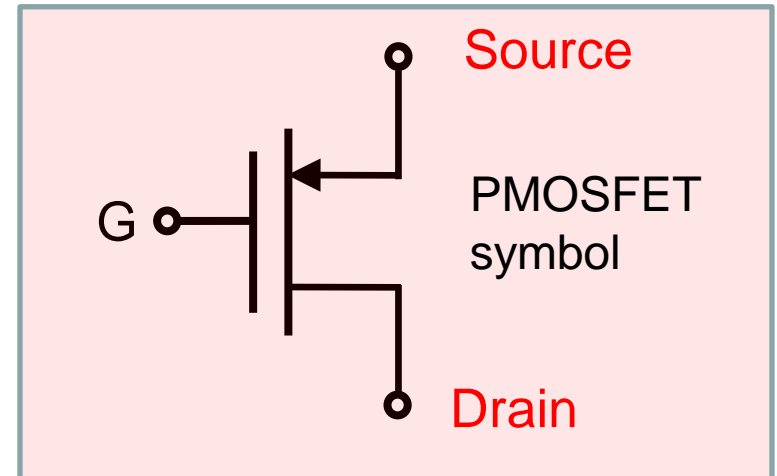
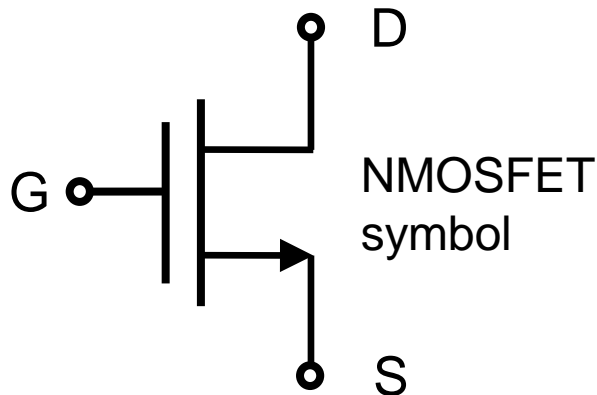
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NMOSFET

- In the NMOSFET, electrons are mobile carriers.
 - When V_{GS} is lower than V_{TH} , holes are depleted from the Si/SiO₂ interface.
 - When V_{GS} is larger than V_{TH} , electrons are collected at the Si/SiO₂ interface. (Electron inversion)
- Imagine its “dual” device with a negative V_{TH} .
 - When V_{GS} is larger than V_{TH} ($|V_{GS}| > |V_{TH}|$), electrons are depleted from the Si/SiO₂ interface.
 - When V_{GS} is smaller than V_{TH} ($|V_{GS}| < |V_{TH}|$), holes are collected at the Si/SiO₂ interface. (Hole inversion)
 - Is there such a device? Yes.

PMOSFET

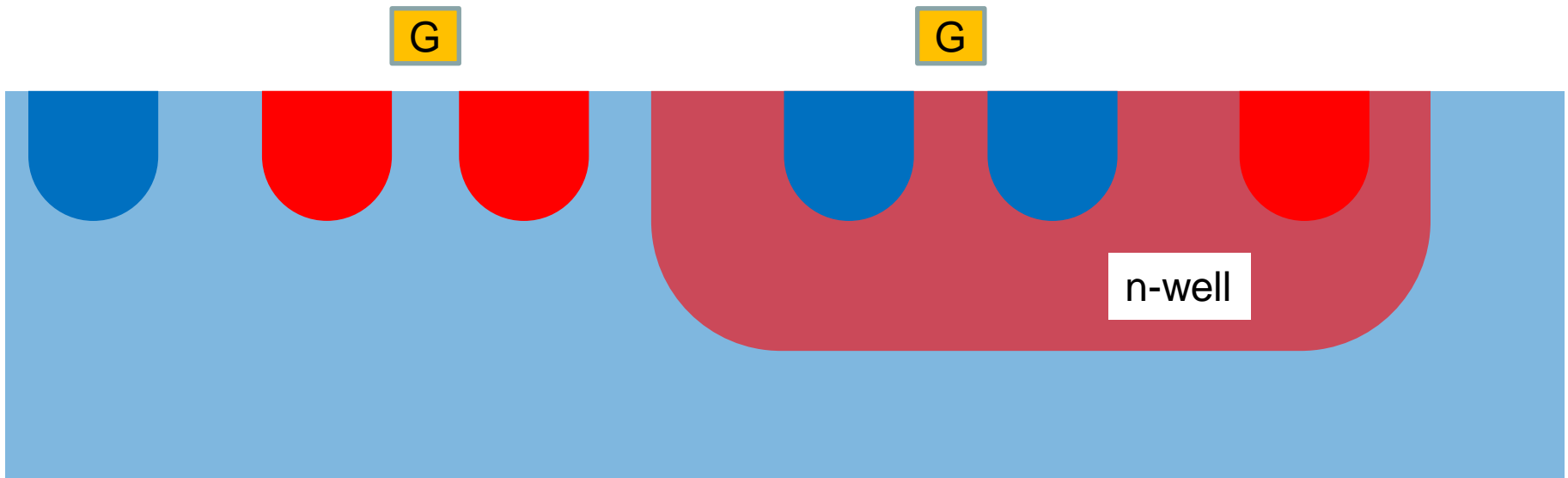
- The PMOSFET



- Example) $V_{TH,P} = -1.5$ V. Assume that V_S is 3 V. The gate voltage of 2 V does not turn on the transistor. 1 V turns on the transistor.
- The drain voltage is lower than the source voltage. In the usual operation condition, the drain current is negative.

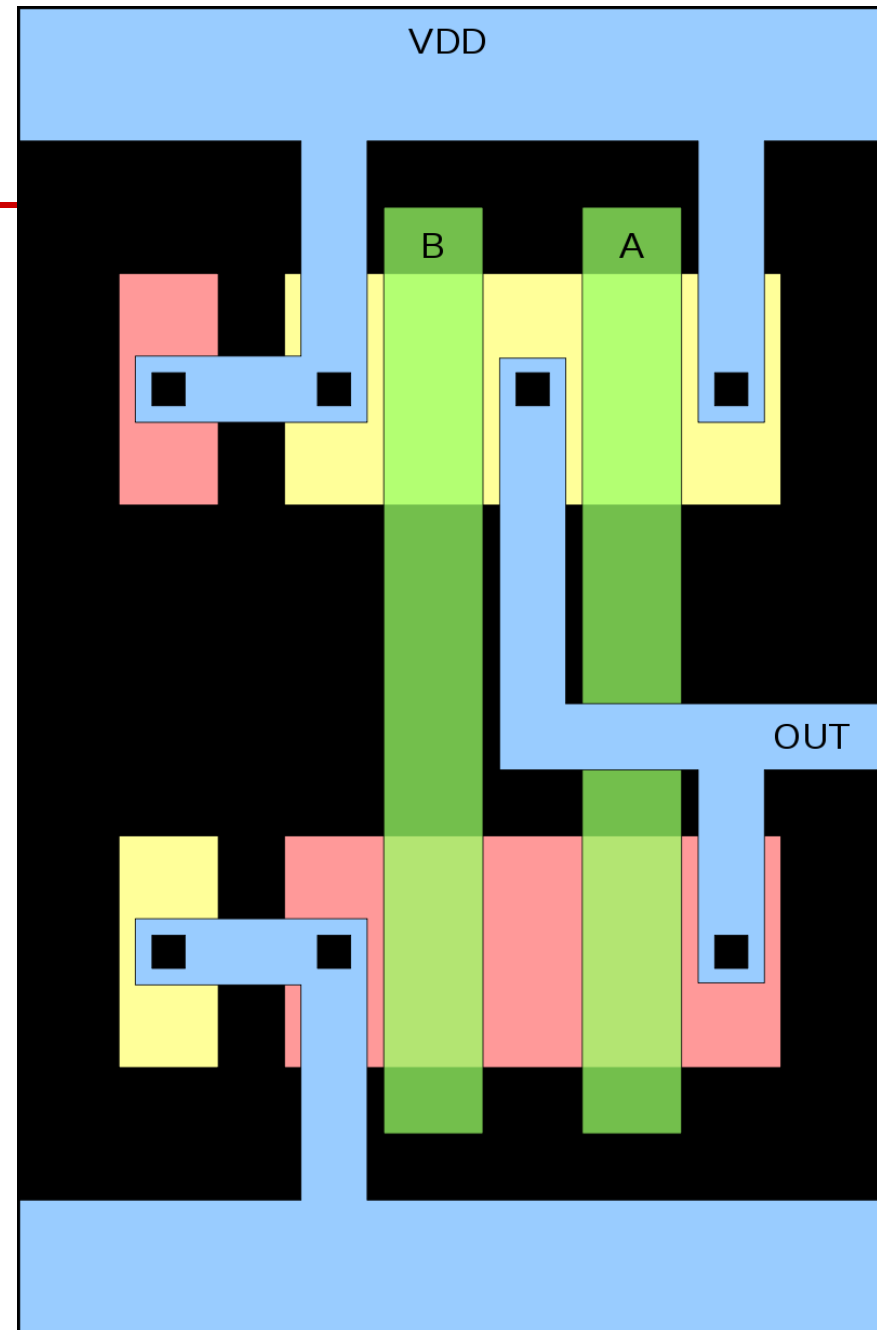
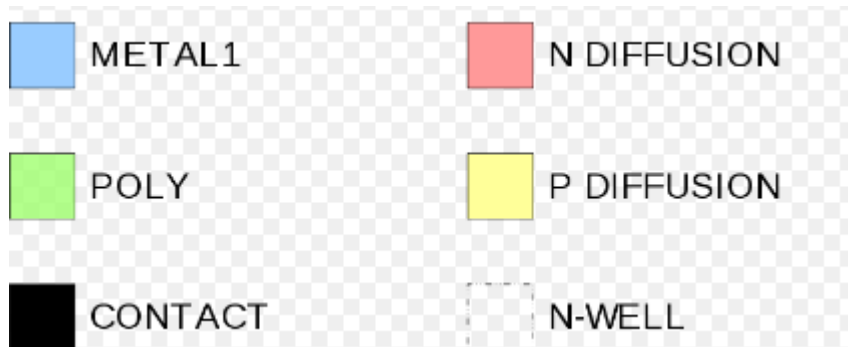
How to fabricate it

- We need an n-type substrate.
 - Also two highly doped p-type regions are required.



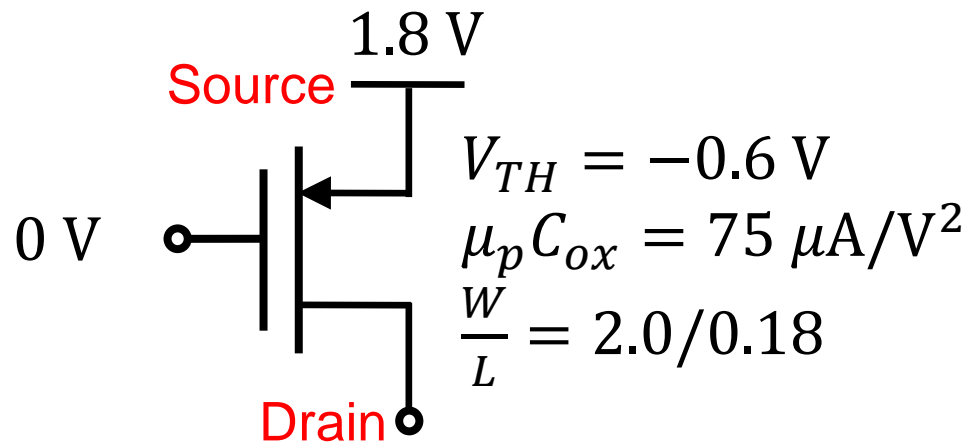
Layout example

- Taken from Wikipedia
 - Draw its circuit schematic.



Biasing of PMOS devices

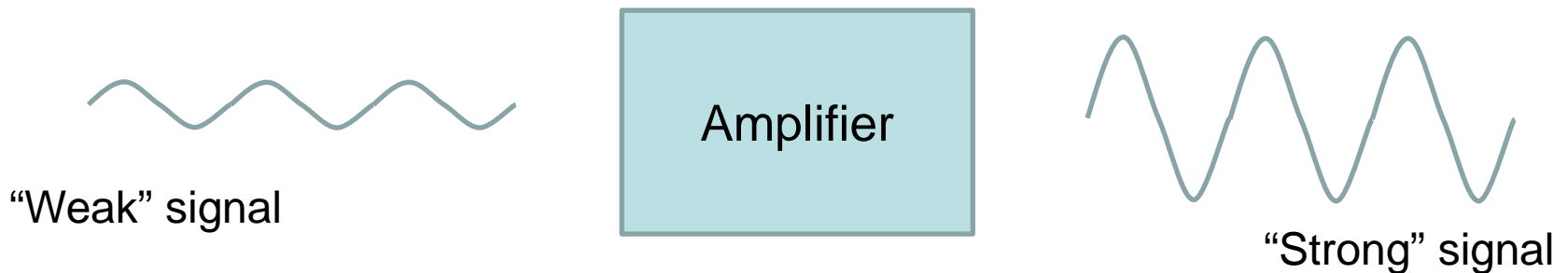
- Express the source current as a function of the drain voltage.
 - The absolute value of “gate overdrive” is 1.2 V.
 - It is not 0.6 V.



- Do the same job with the gate voltage of 1.8 V.

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.

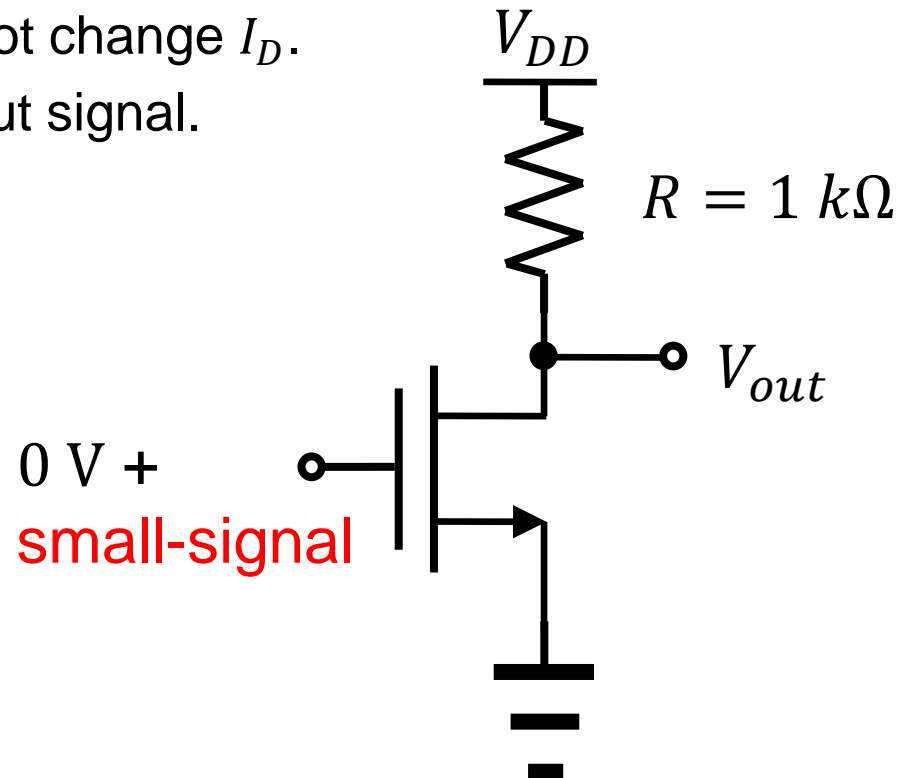


Voltage gain

- 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!

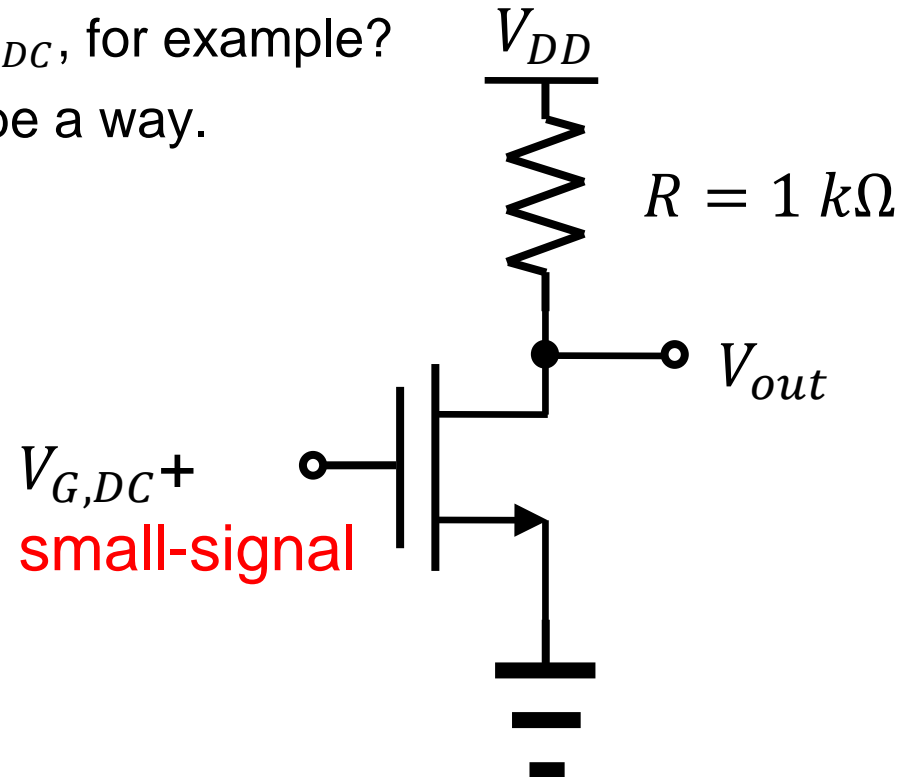
Transistor turned off

- 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)

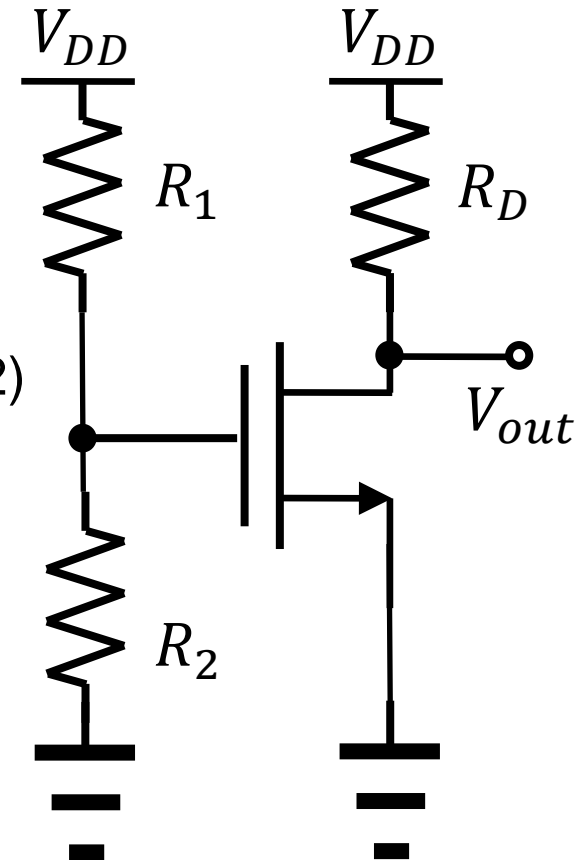
- A better way to provide the gate voltage

- The gate bias voltage is

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

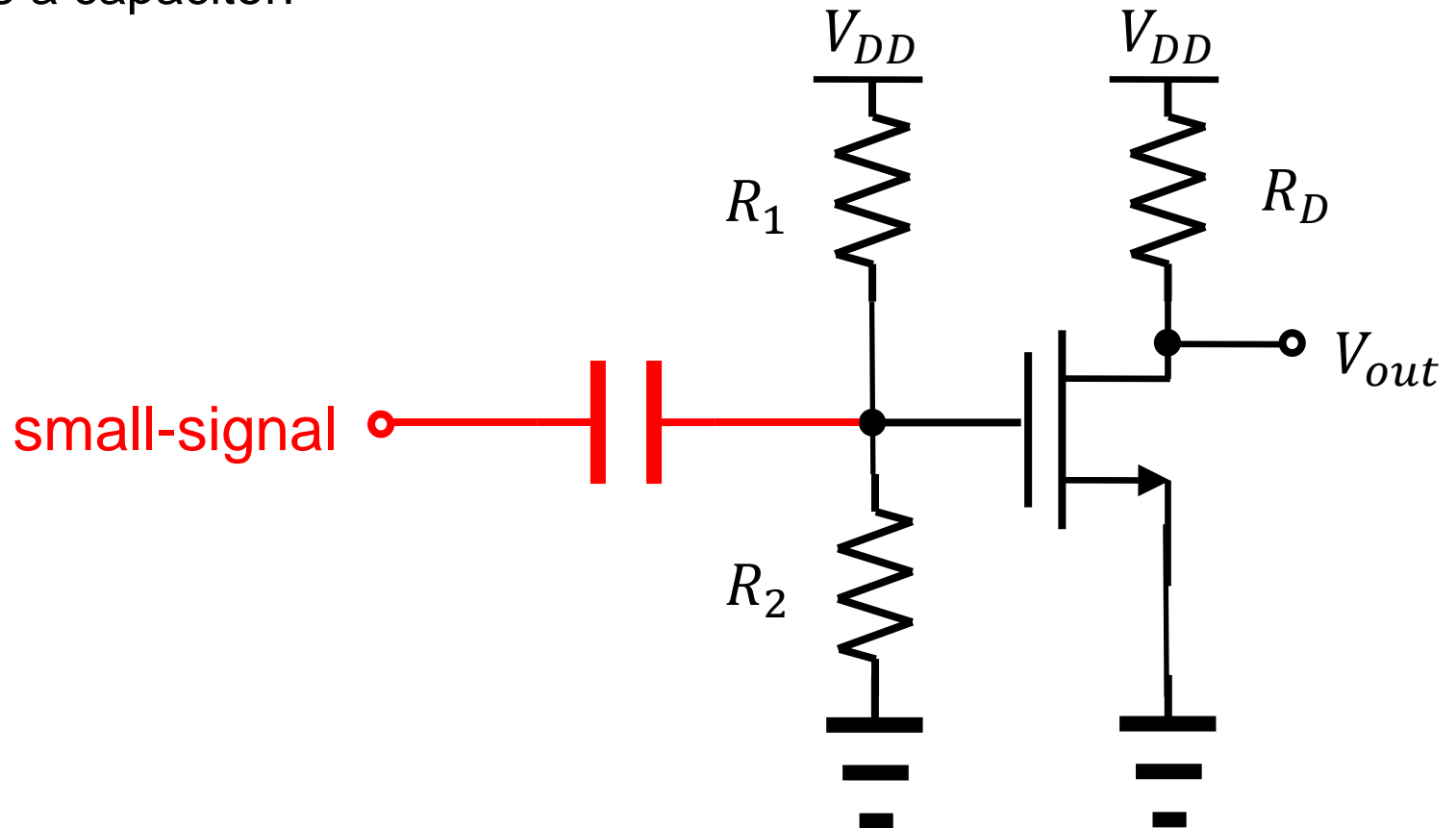
- The drain current is

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



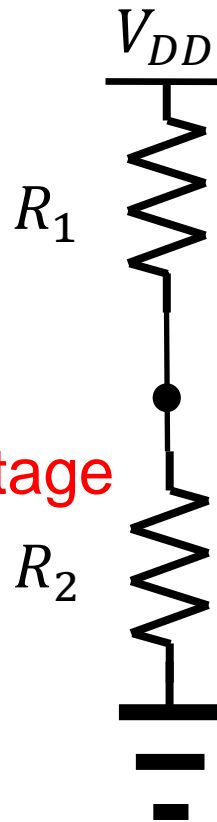
Simple biasing (2/3)

- 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

