Lecture20:
Other amplifiers

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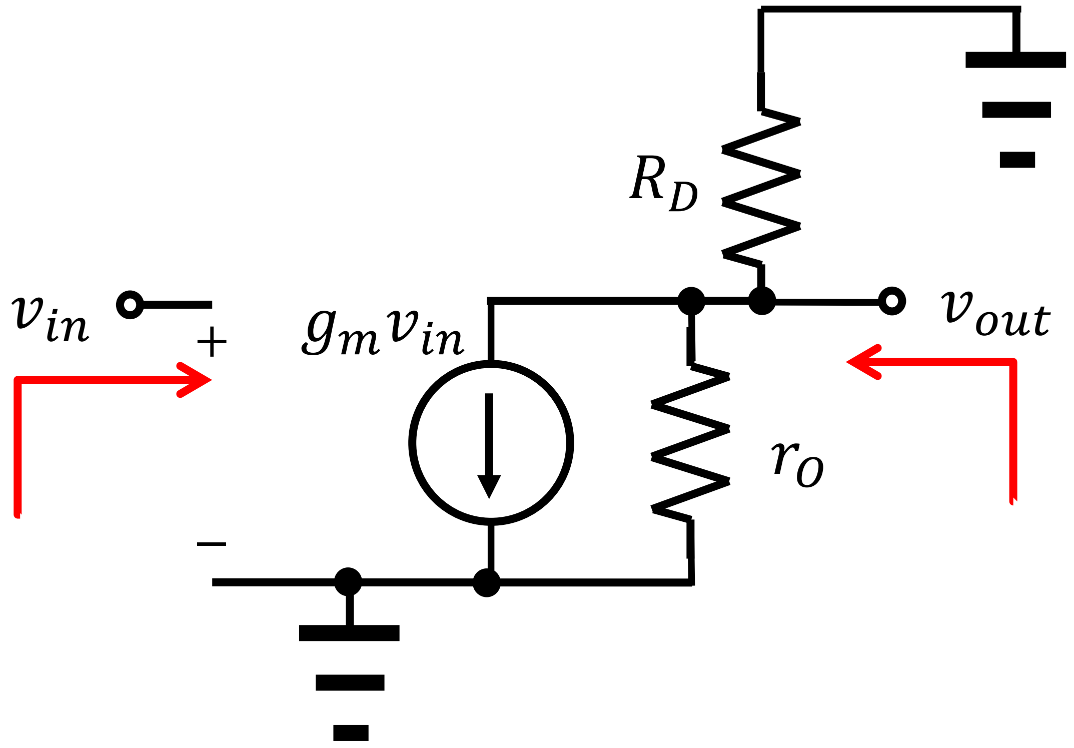
Review of the last lecture

- Active loads
  - Ideal current source
  - PMOS
  - NMOS
- Concept of input impedance
  - Why do we need it?

Input/output impedances

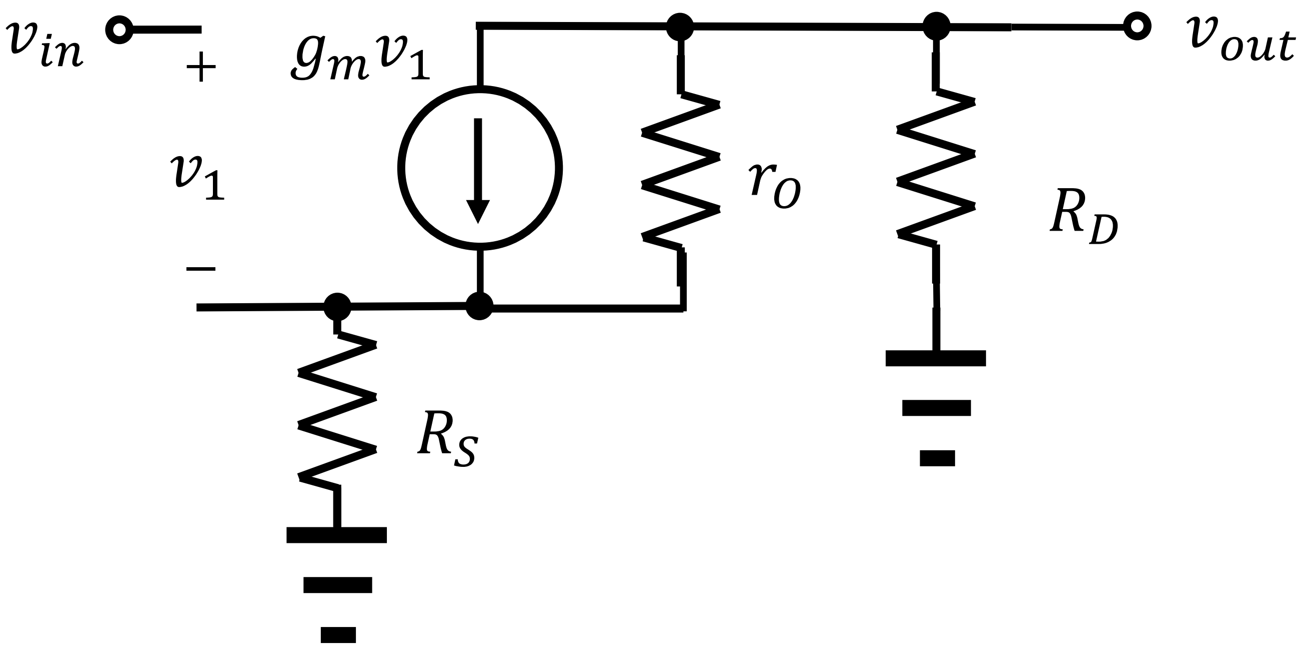
- When calculating the impedance, the voltage sources at other terminals are neglected.
- Input and output impedances

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



Source degeneration

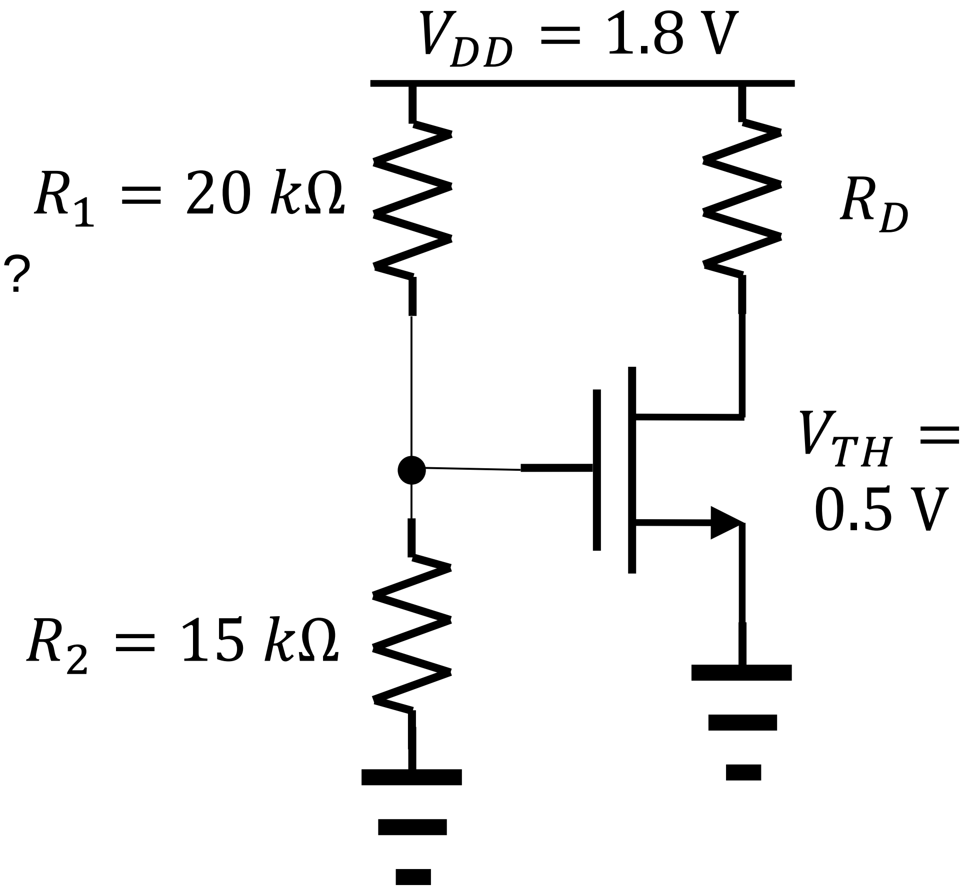
- Consider a case with a source resistor, R_S.
  - Caculate the gain and the output impedance.



Razavi, example 17.8

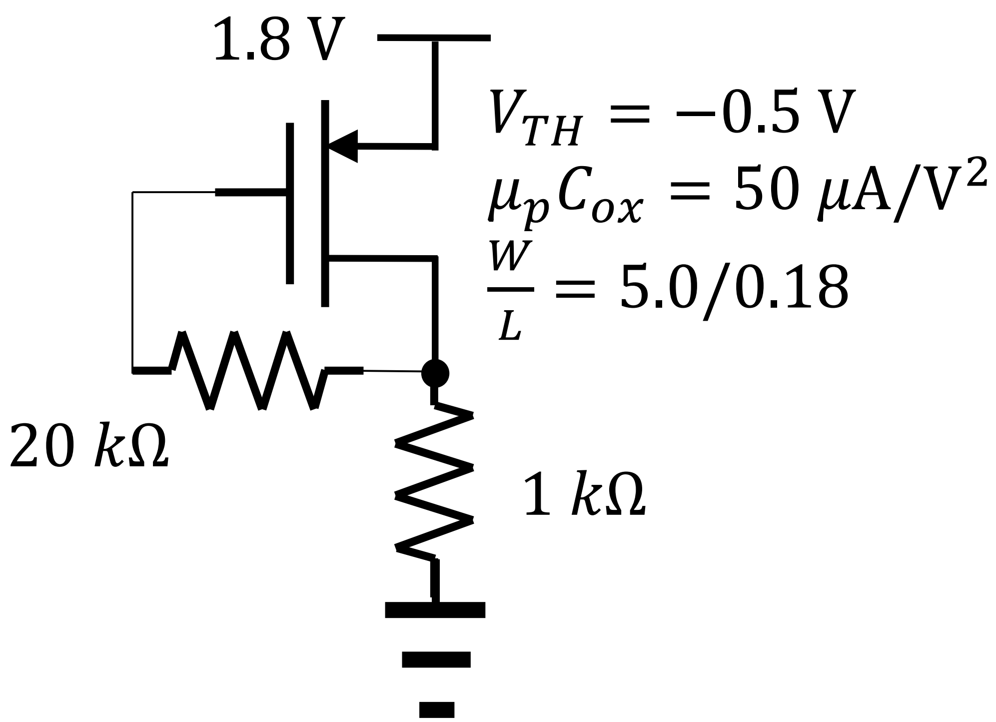
- Biasing
  - What is the gate voltage?
  - Condition for saturation mode?

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



Razavi, example 17.13

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



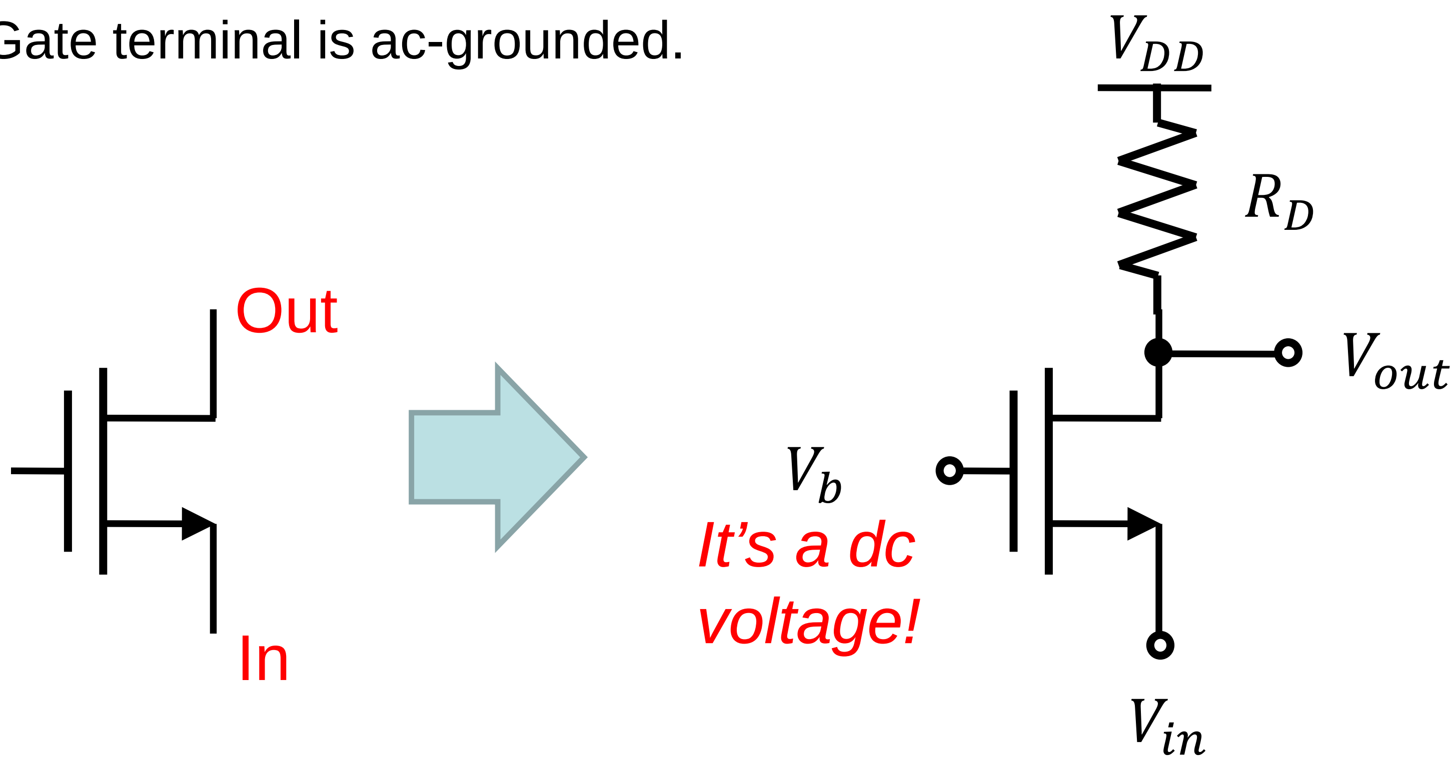
Configurations

- Three terminals of the MOSFET
  - The common terminal, the input terminal, and the output terminal

Source	**Gate**	**Drain**	**Remark**
Common	Input	Output	Common-source amp.
Common	Output	Input	X
Input	Common	Output	It will be covered.
Output	Common	Input	X
Input	Output	Common	X
Output	Input	Common	It will be covered.

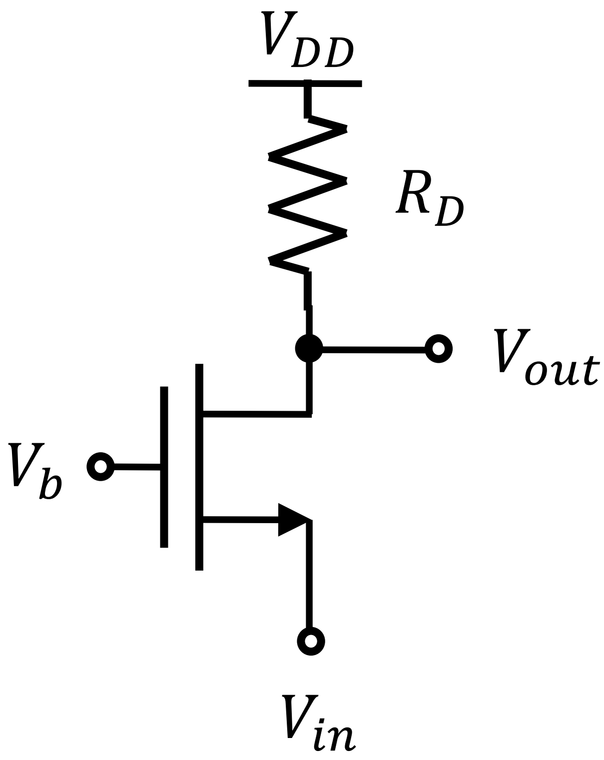
Common-gate amplifier

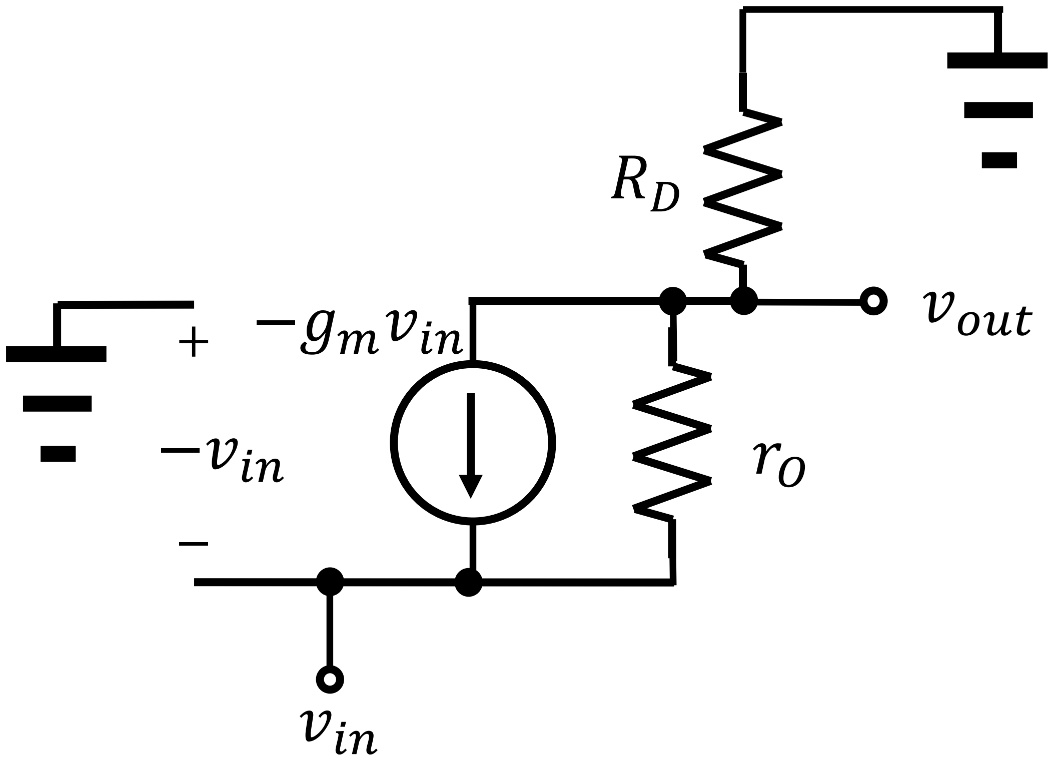
- Why do we study other amplification topologies?
  - Different circuit properties
- Common-gate amplifier
  - Gate terminal is ac-grounded.



Small-signal model

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





Gain & input impedance (1/2)

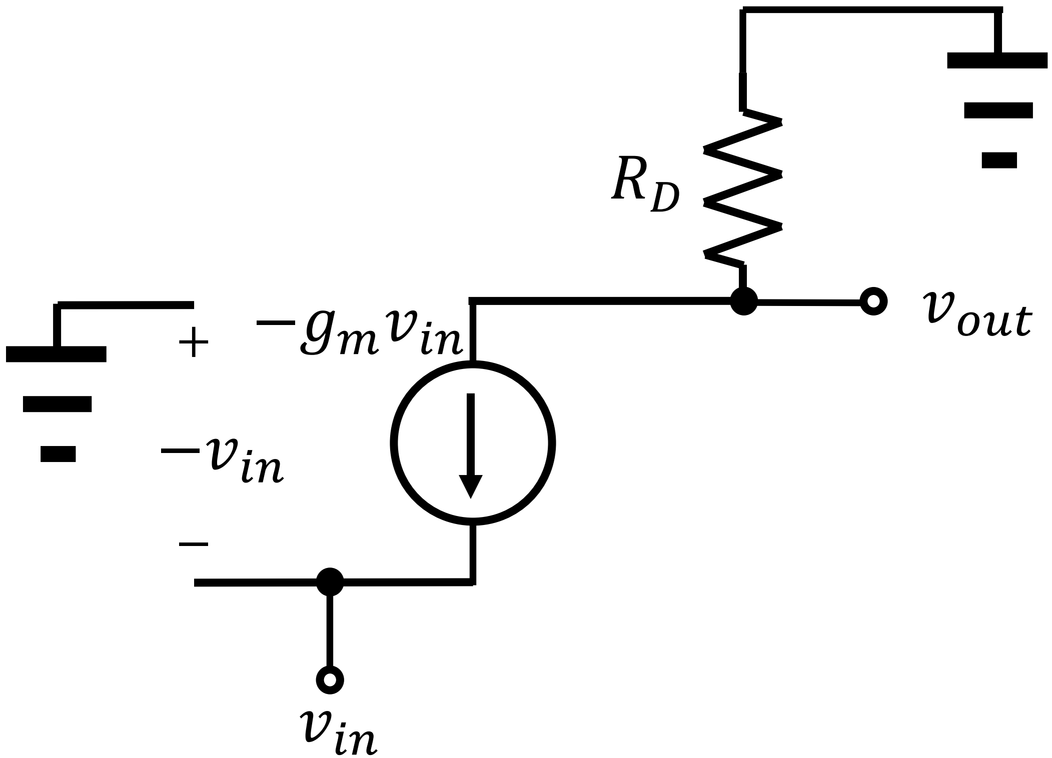
- Neglect the output resistance, r_O.
  - Voltage gain

$$A_v = +g_m R_D$$

  - Input impedance

$$R_{in} = \frac{1}{g_m}$$

It's small!



Gain & input impedance (2/2)

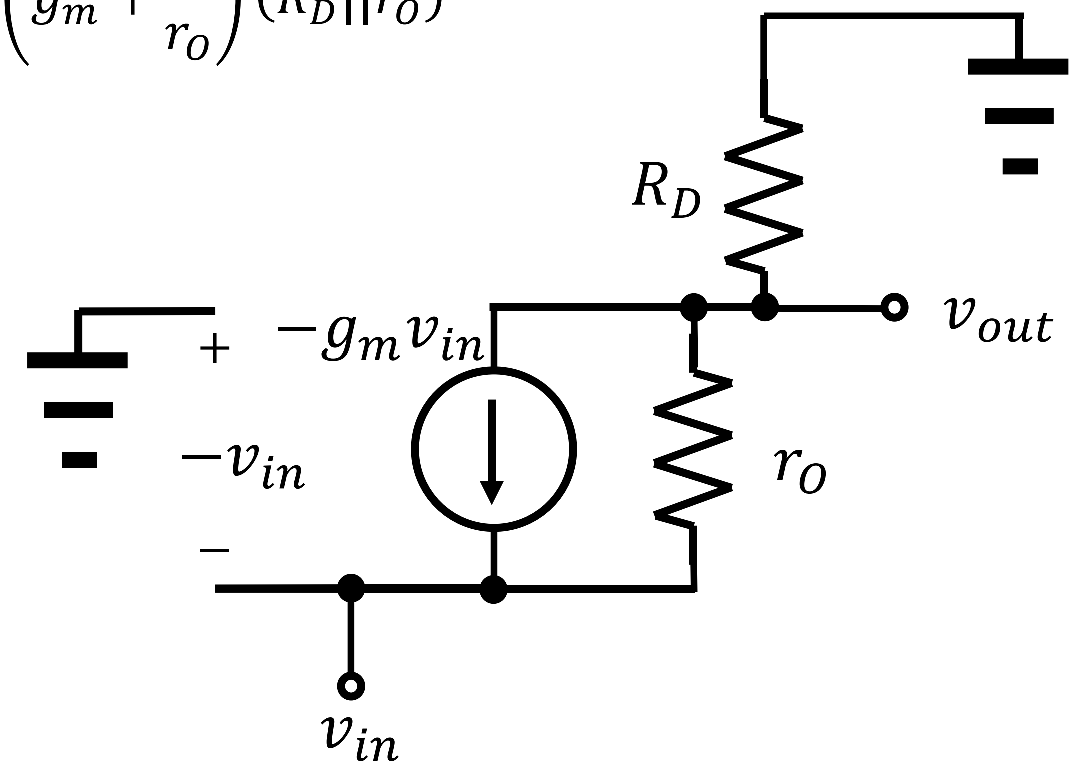
- Consider the output resistance, r_O.
  - Voltage gain

$$A_v = +\left(g_m + \frac{1}{r_O}\right)(R_D||r_O)$$

  - Input impedance

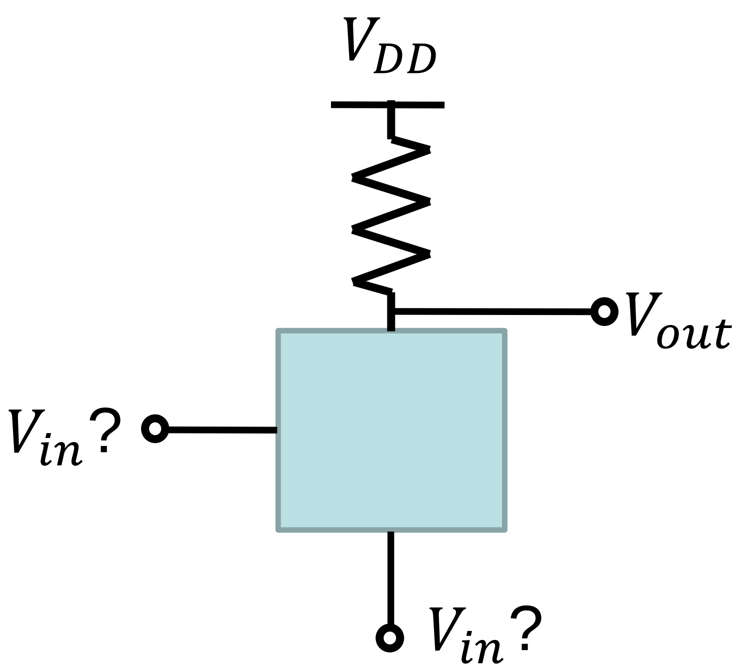
$$R_{in} = \frac{r_O + R_D}{g_m r_O + 1}$$

It's small!

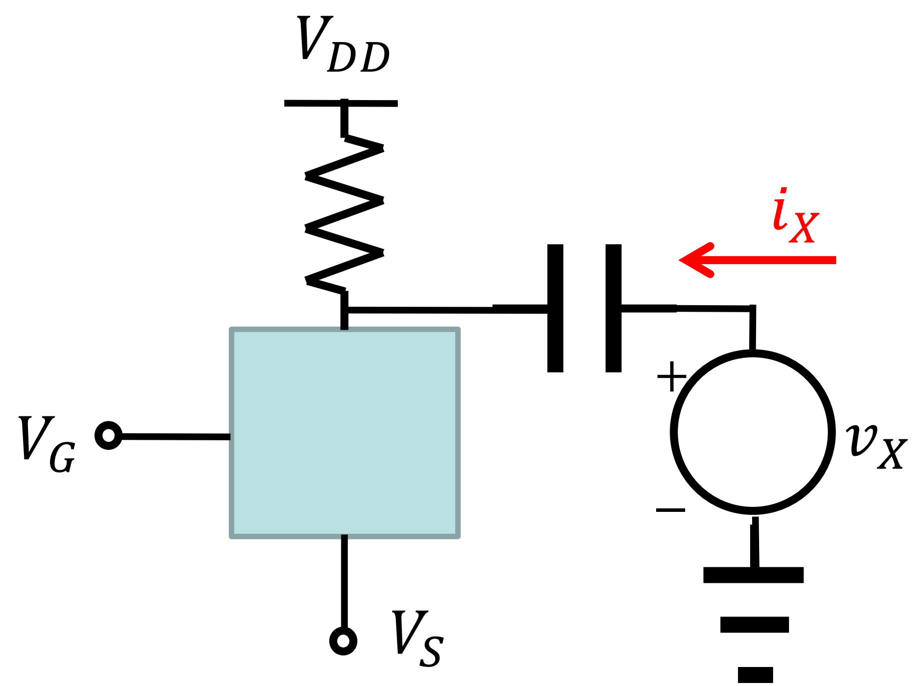


Output impedance

- Without a finite source resistance, $R_{out} = r_O \,||R_D$



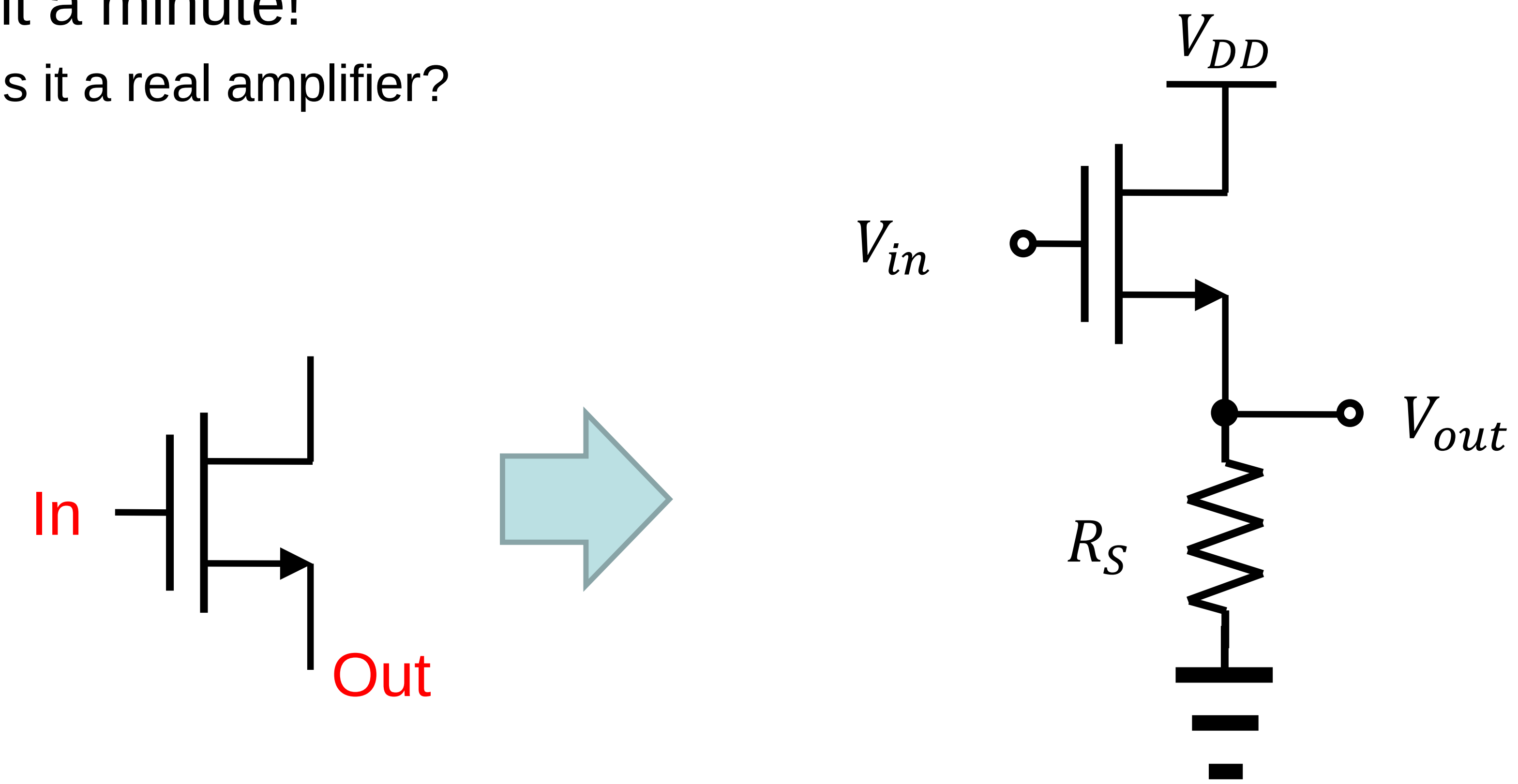
Generic form of CS and CG stages



Setting for calculating R_{out}

Source follower

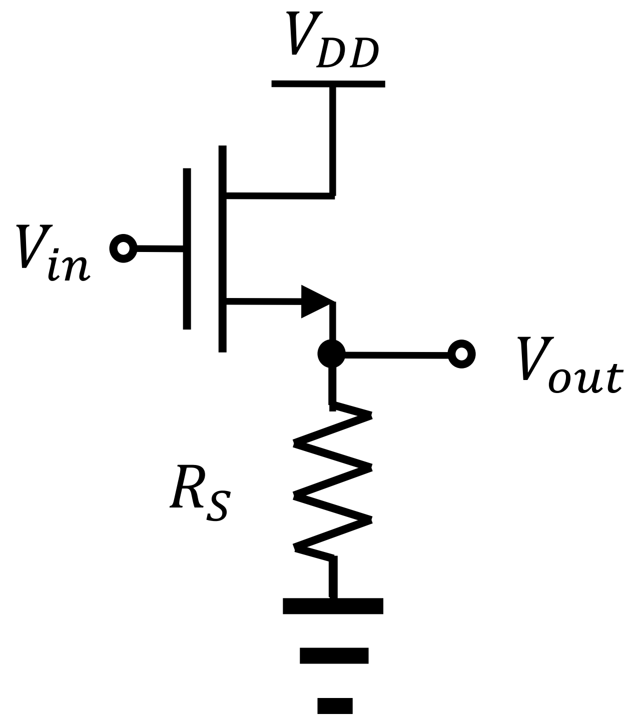
- Also called the “common-drain” stage
  - The drain is ac grounded.
- Wait a minute!
  - Is it a real amplifier?



Its core

- Gain is less than 1?? (Neglecting r_O)

$$A_v = +\frac{g_m R_S}{1 + g_m R_S}$$



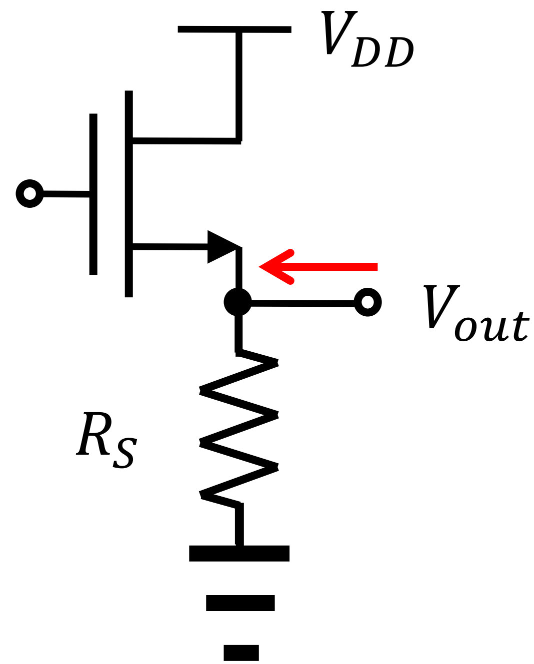
You should be able to draw the small-signal model.

Useless?

- Calculate the input and output impedances.
  - Since the gate is the input terminal, the input impedance is very high at low frequencies.
  - How about the output impedance?

$$R_{out} = \frac{1}{g_m} || r_O || R_S$$

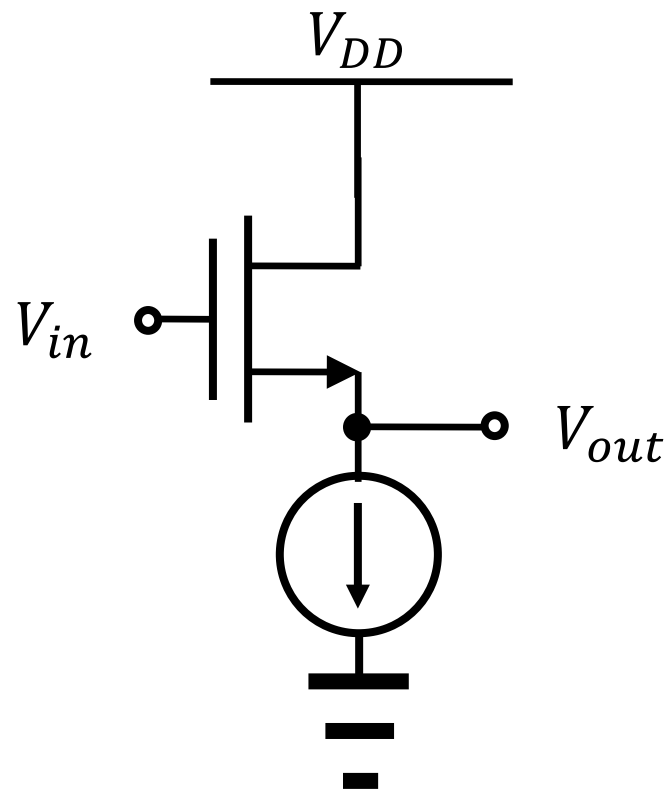
  - It is relatively low.



- High input imp., low output imp.
  - They can serve as good "buffers."

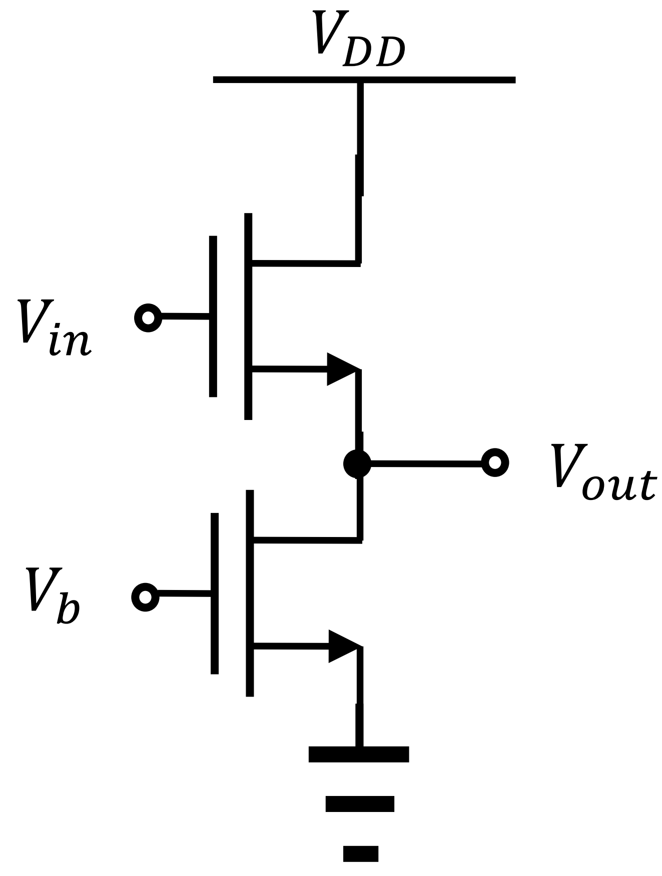
Razavi, example 17.36

- In integrated circuits, the follower is typically realized as shown below. Determine the voltage gain if the current source is ideal. Neglect the channel-length modulation.



Razavi, example 17.37

- A source follower is realized as shown below. Calculate the voltage gain of the circuit.



Razavi, example 17.39

- Design the source follower.
  - Determine W/L and R_S.
  - The DC drain current is 1 mA.
  - The voltage gain is 0.8.