Lecture17: CMOS amplifiers (4)

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GIST Lecture on May 4, 2015 (Internal use only)

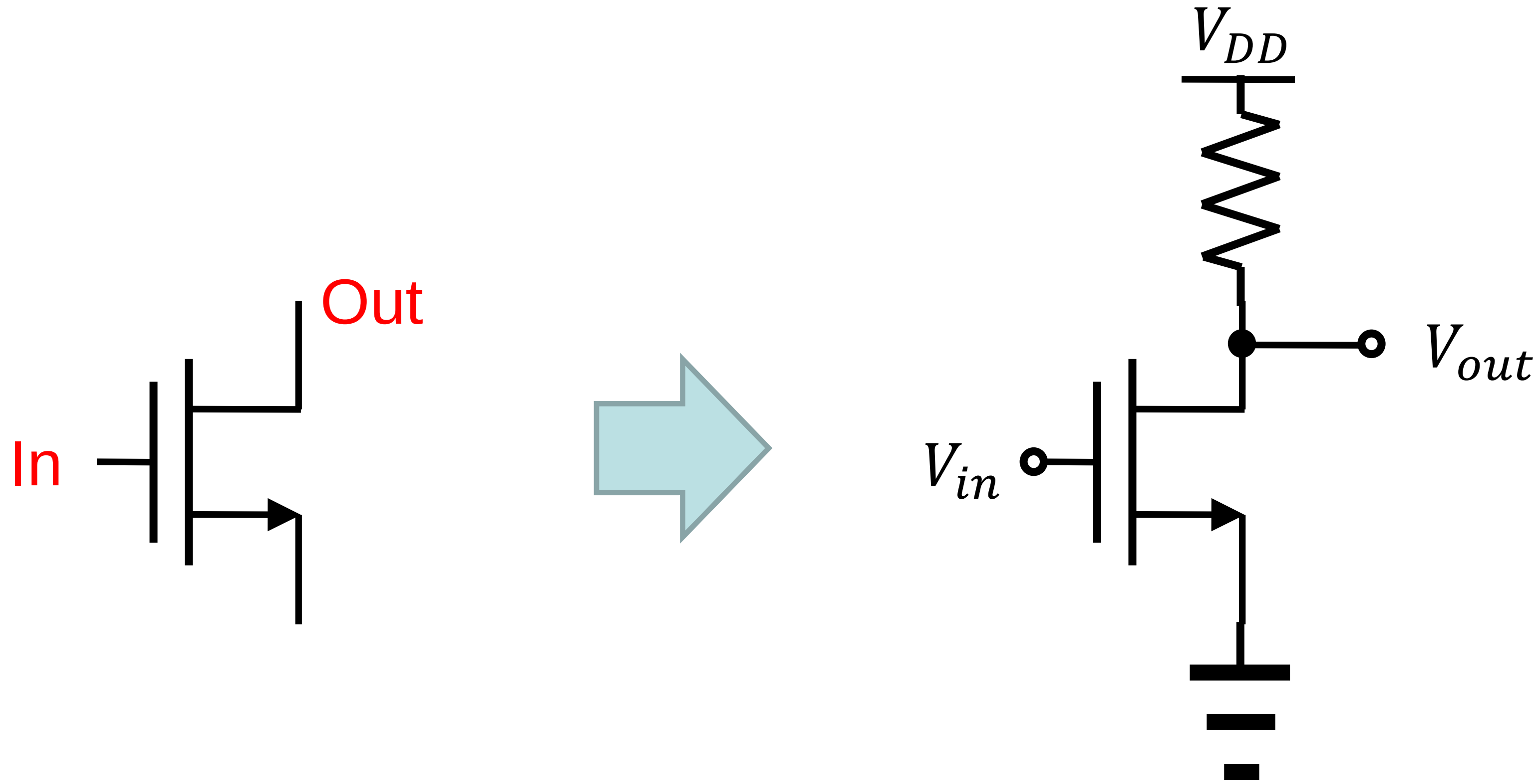
Read your textbook.

- Reading your textbook is important.

- Today, we will try to cover up to p. 773.
  - Common-source
  - Just before “CS Stage with Biasing”
  - 17. 4. 4 (Common-gate) and 17. 4. 5 (Source-follower) will be covered on Wednesday.

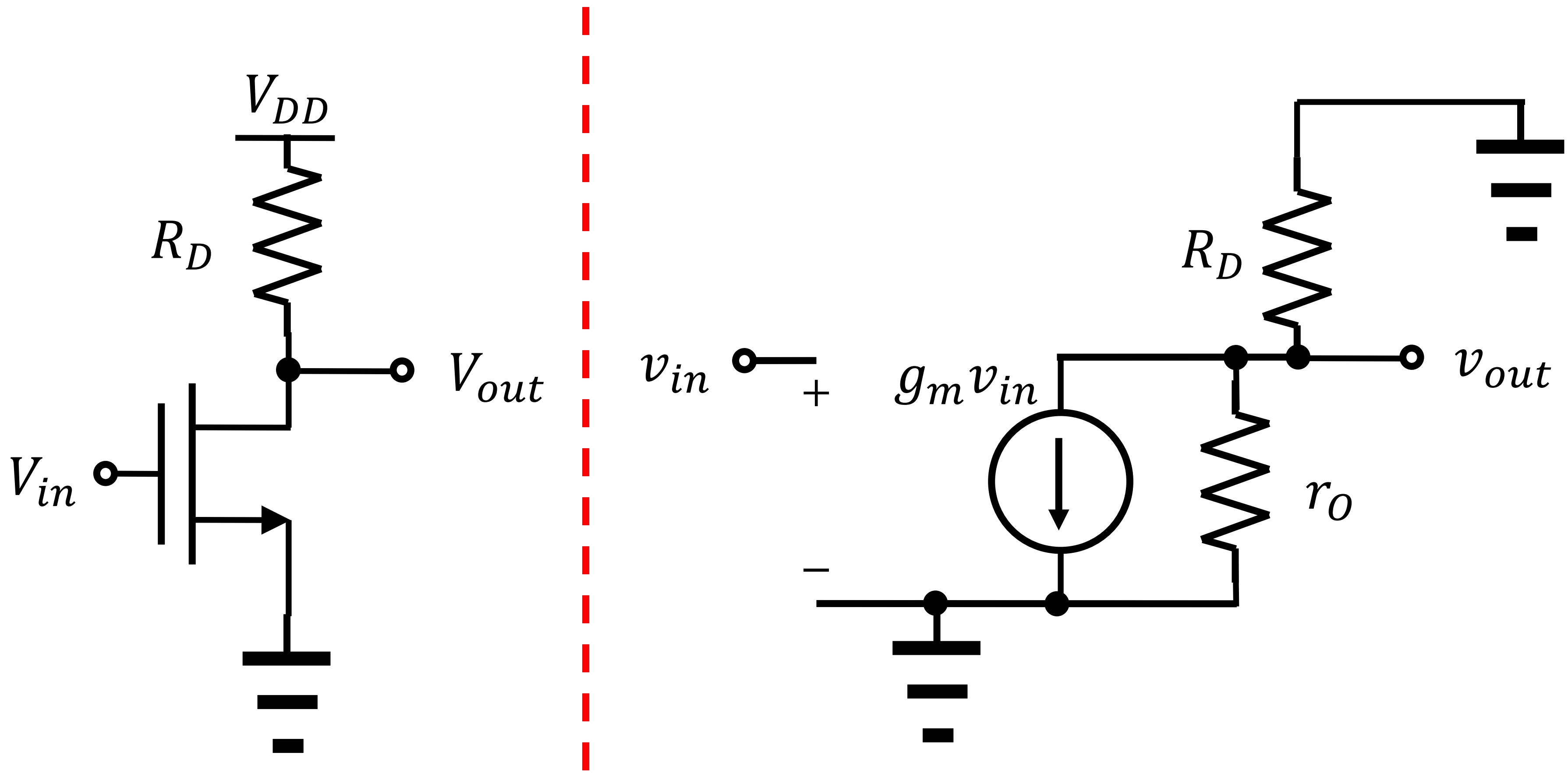
Common-source

- Source terminal is grounded.



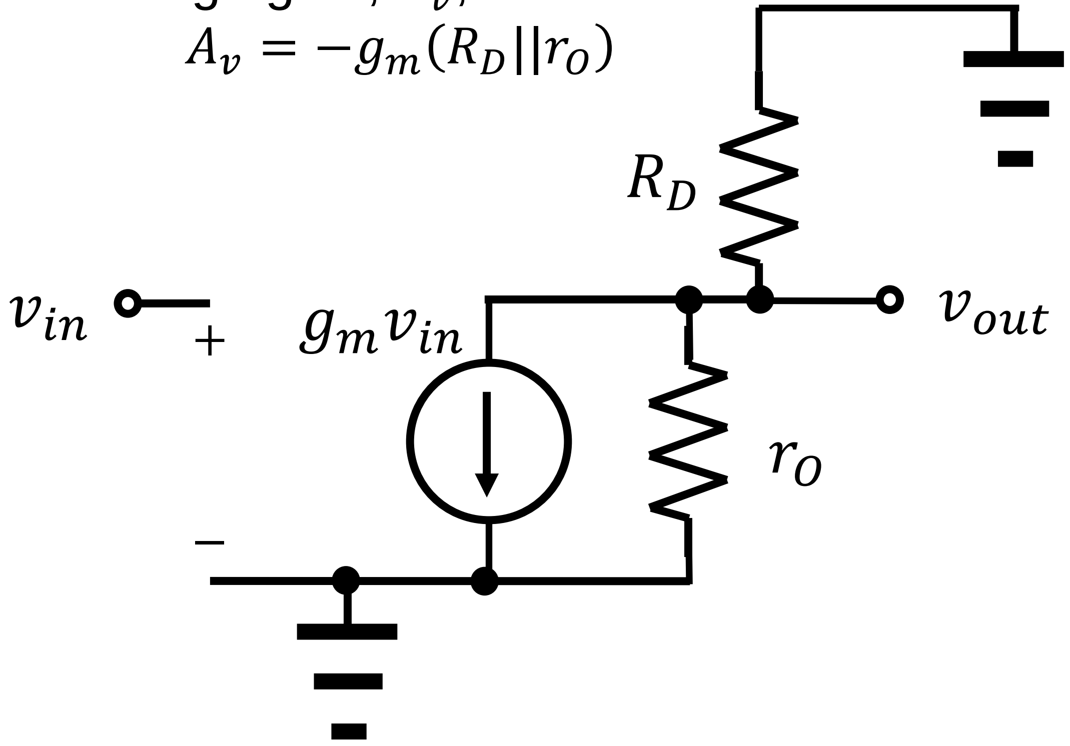
Small-signal model

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



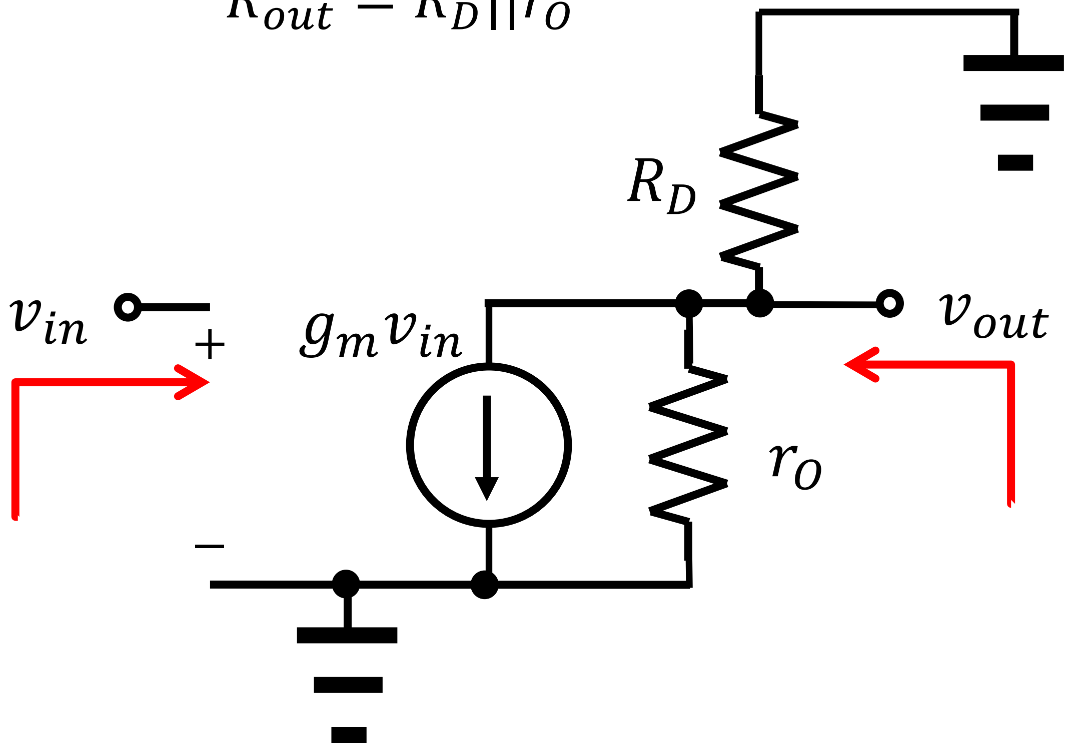
Input/output impedances

- Input impedance

$$R_{in} = \infty$$

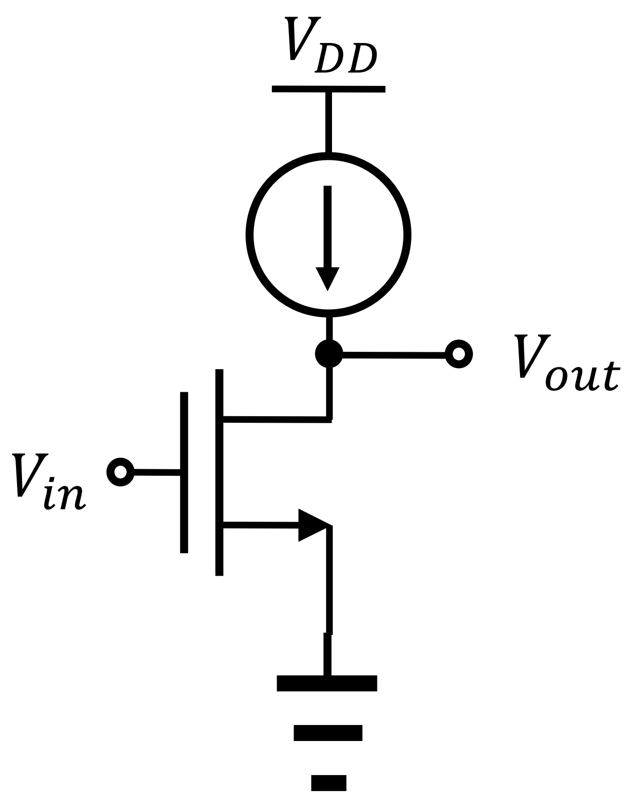
- Output impedance

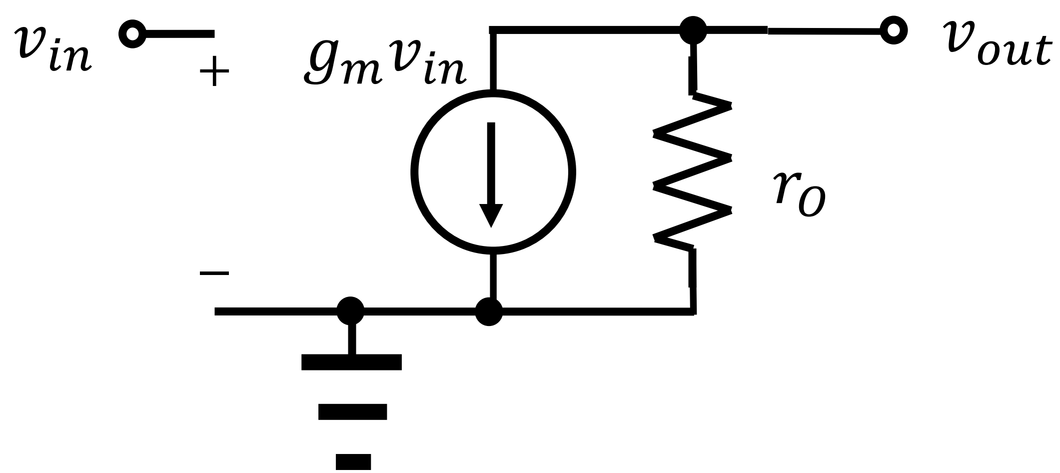
$$R_{out} = R_D || r_O$$



Current-source load

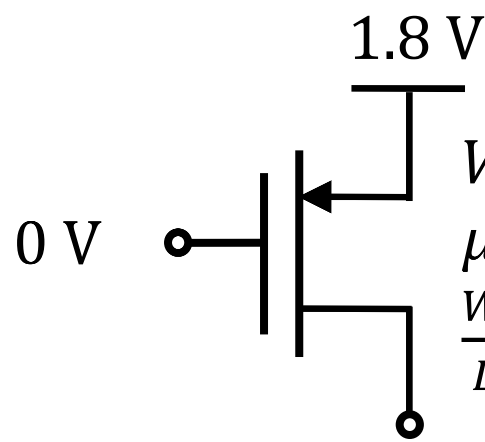
- When $R_D \rightarrow \infty$,
  - The gain can be maximized.





Biasing of PMOS devices

- Let's recall the problem18 of our mid-term exam.
  - The amount of "gate overdrive" is 1.2 V.
  - It is not 0.6 V.



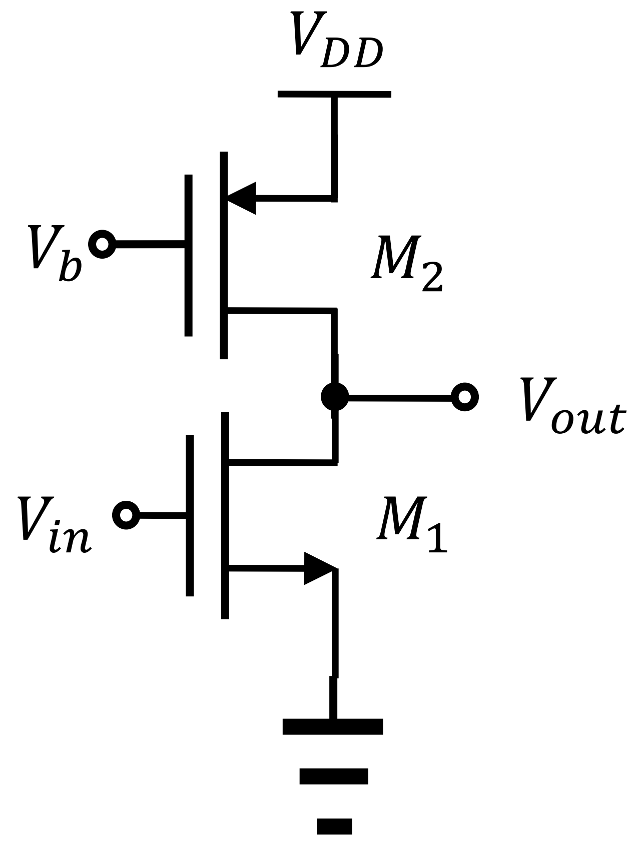
$$V_{TH} = -0.6\ \mathrm{V}$$
$$\mu_p C_{ox} = 75\ \mu\mathrm{A/V}^2$$
$$\frac{W}{L} = 2.0/0.18$$

Real current-source load

- Use a PMOS as a current source.
  - It is not an ideal current source.

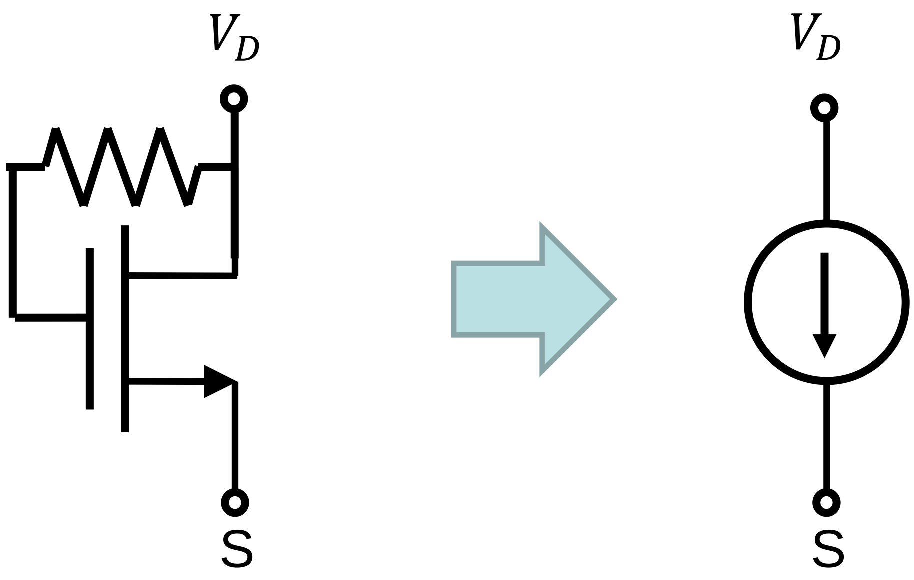
$$v_{out} = -g_{m1}(r_{O1}||r_{O2})v_{in}$$

$$A_v = -g_{m1}(r_{O1}||r_{O2})$$



Self-biasing

- Already covered in Example 6.13.
  - Always in the saturation region.



$$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_D - V_S - V_{TH})^2$$

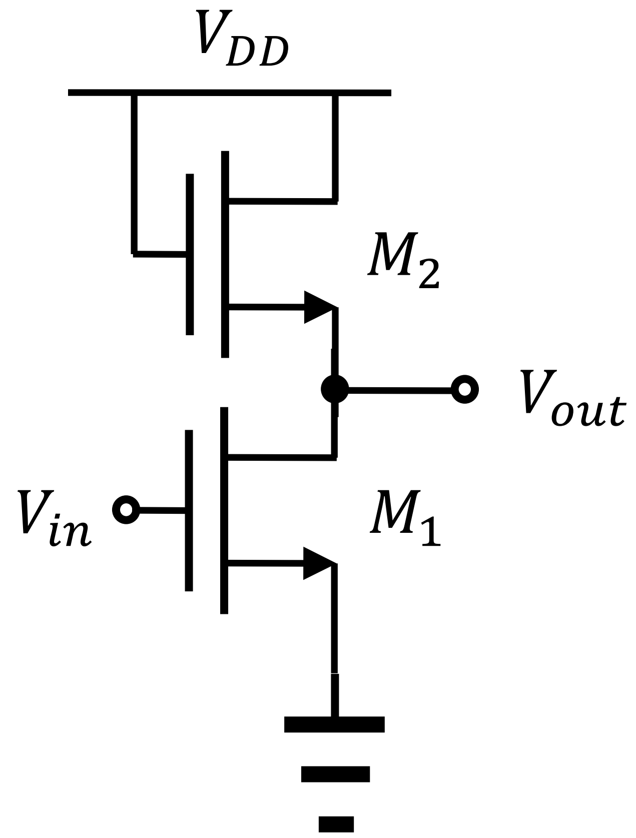
Gate and drain are tied.

In this case,

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

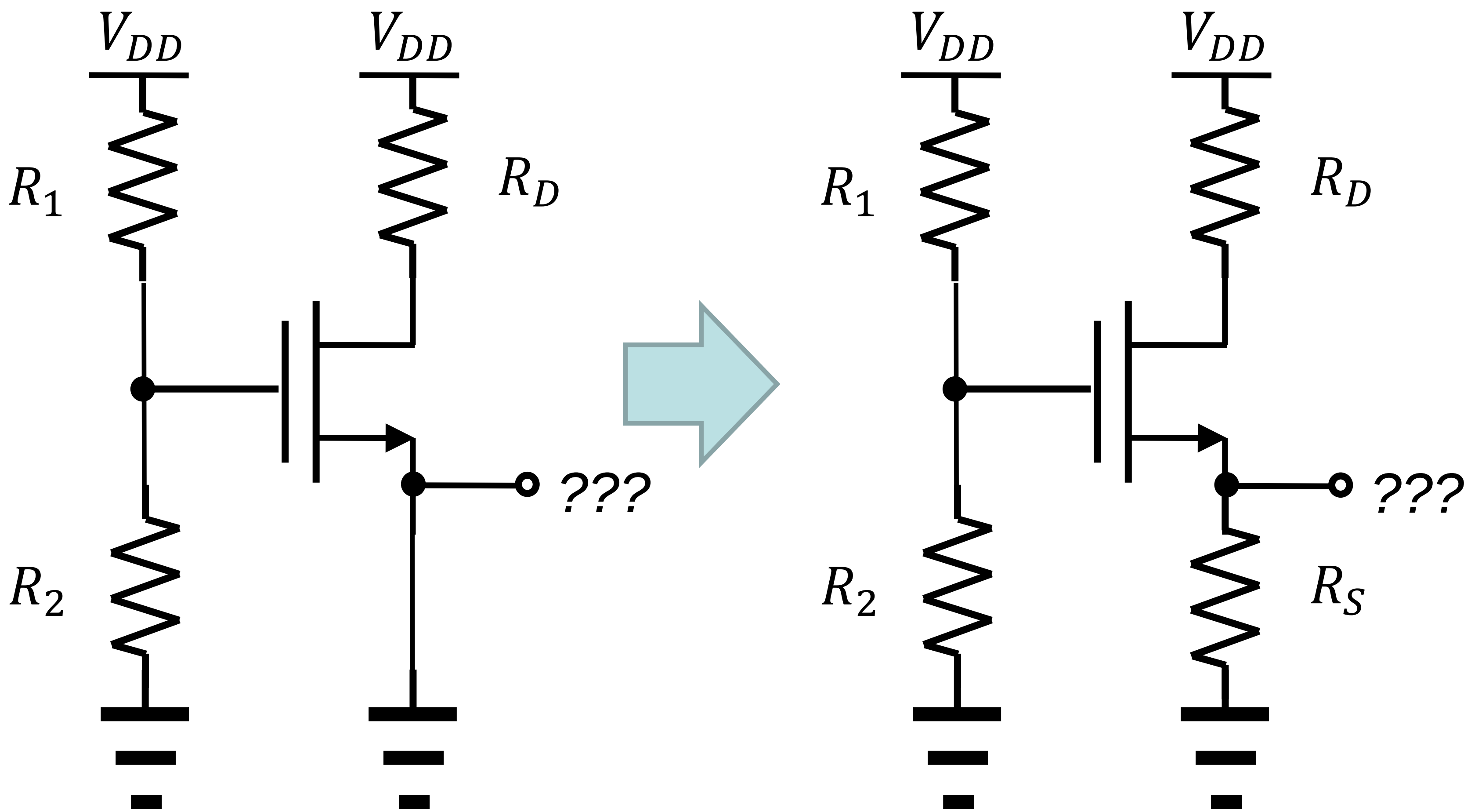
$$v_{out} = -g_{m1}\left(r_{O1}||\frac{1}{g_{m2}}||r_{O2}\right)v_{in}$$

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



Source degeneration (1/2)

- A resistor placed in series with the source terminal



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Source degeneration (2/2)

- Now we have to find the source voltage.
  - (Saturation current of the MOSFET) = (Current flowing through R_S)
  - After a simple manipulation, we can find

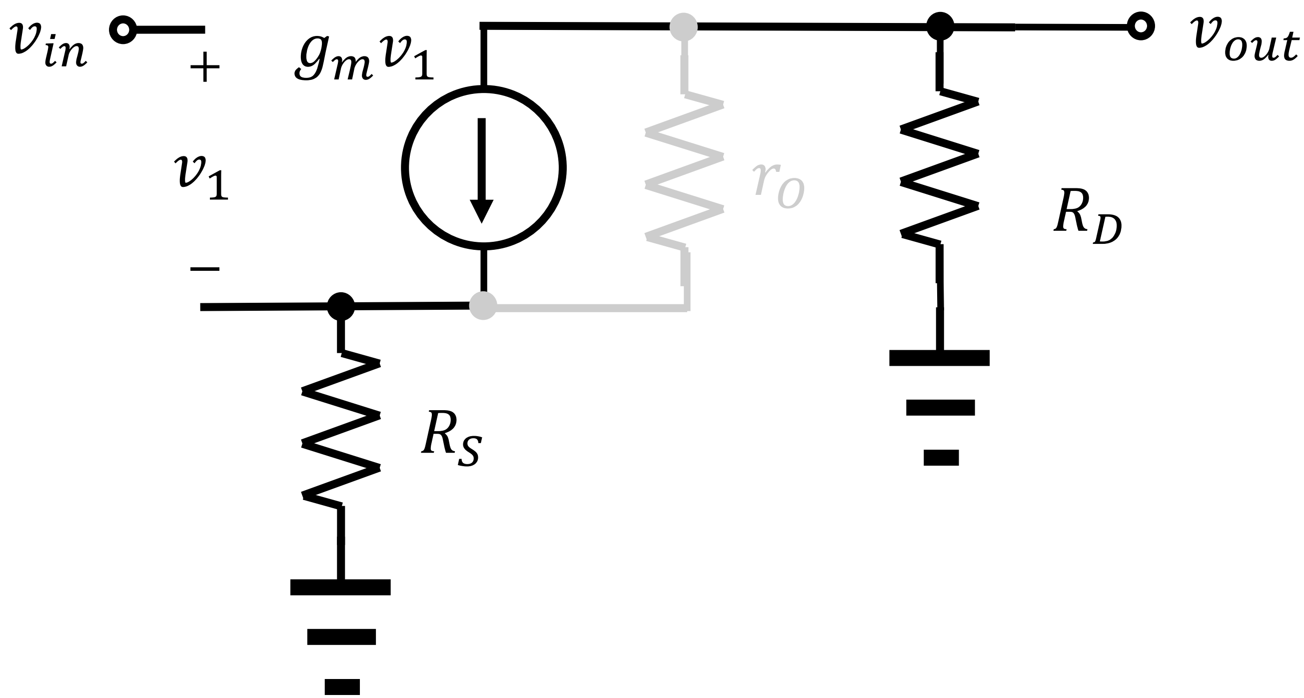
$$V_S = V_G + V_1 - V_{TH} - \sqrt{V_1^2 + 2(V_G - V_{TH})V_1}$$

  - Here,

$$V_1 = \frac{1}{\mu_n C_{ox} \frac{W}{L} R_s}$$

Effect of R_S (1/2)

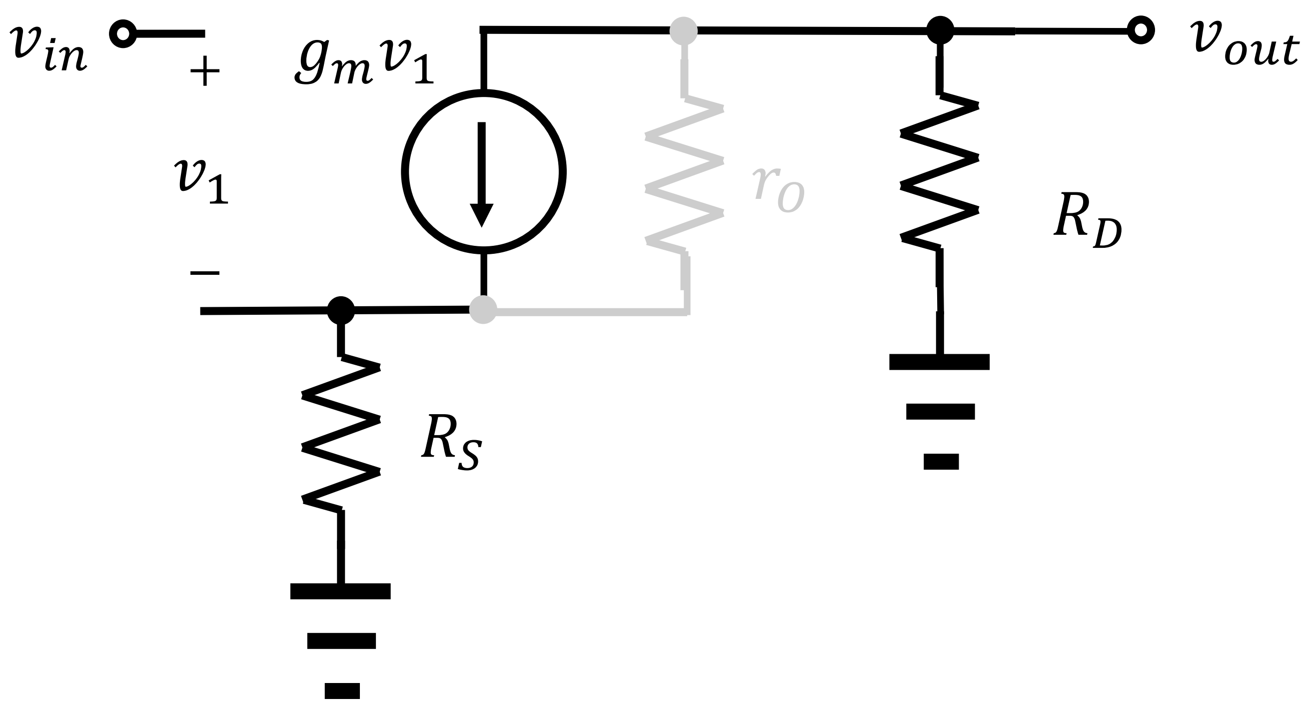
- Reduction of the gate-source voltage
  - Therefore, also reduction of the gain.
- For a while, neglect the channel-length modulation.



Effect of R_S (2/2)

- After a simple manipulation,

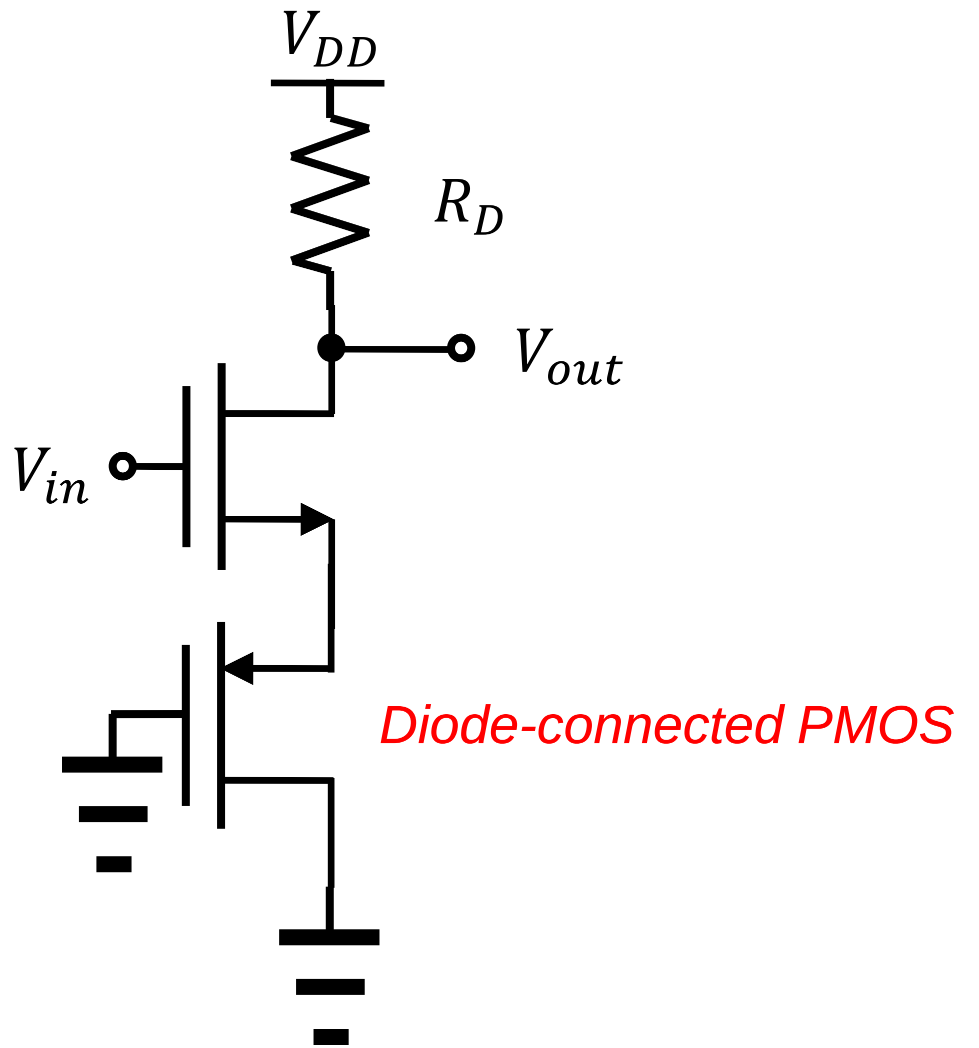
$$A_v = -\frac{g_m R_D}{1 + g_m R_S}$$



Example 17.20

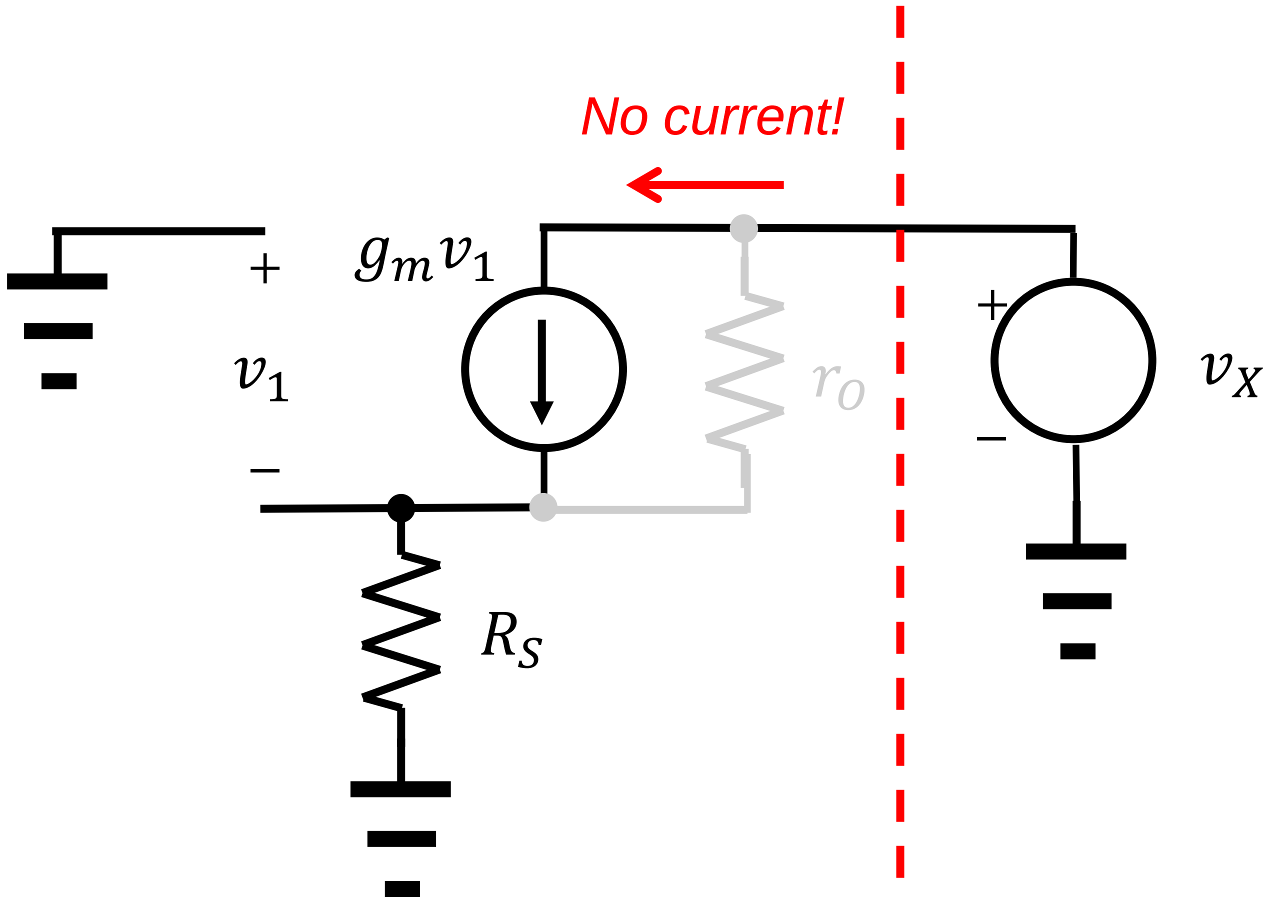
- CS with degeneration

$$A_v = -\frac{R_D}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$$



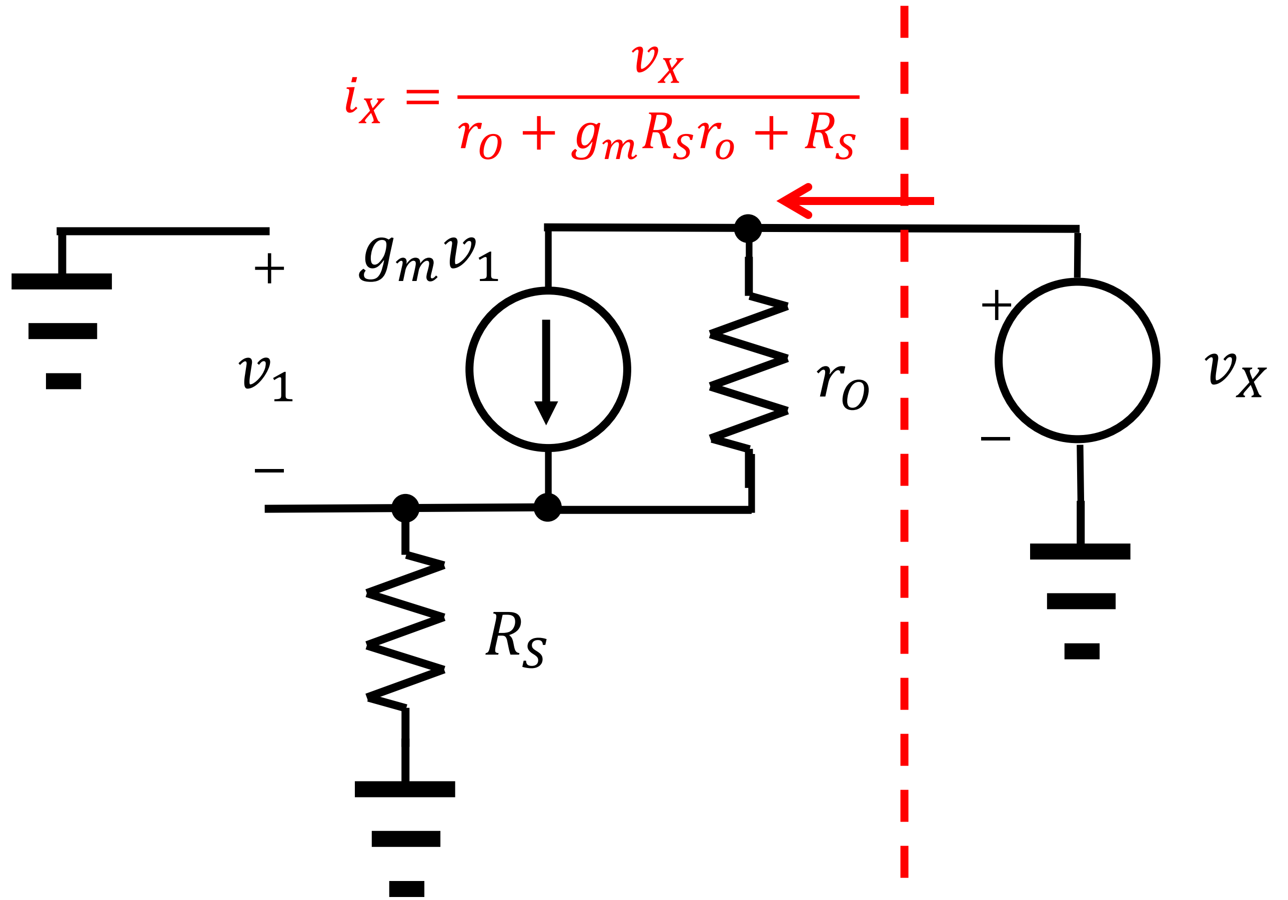
Output impedance of CS (1/2)

- Still neglecting the channel-length modulation
  - No current!



Output impedance of CS (2/2)

- Now considering the channel-length modulation
  - Output resistance is $r_O + (g_m r_O + 1)R_S$.



Examples 17.23 and 17.24

- Compute the output resistance.
  - What is the difference?