Lecture22: Bipolar amplifiers (1)

Sung-Min Hong (smhong@gist.ac.kr)

Semiconductor Device Simulation Lab.
School of Information and Communications
Gwangju Institute of Science and Technology

Final exam

- June 10 (Wed)
  - PM 01:00 ~ 02:14 (Class time)

- Lecture schedule
  - L22 (Today): BJT amplifiers
  - For remaining 4 lectures, op amp and digital circuits will be covered.

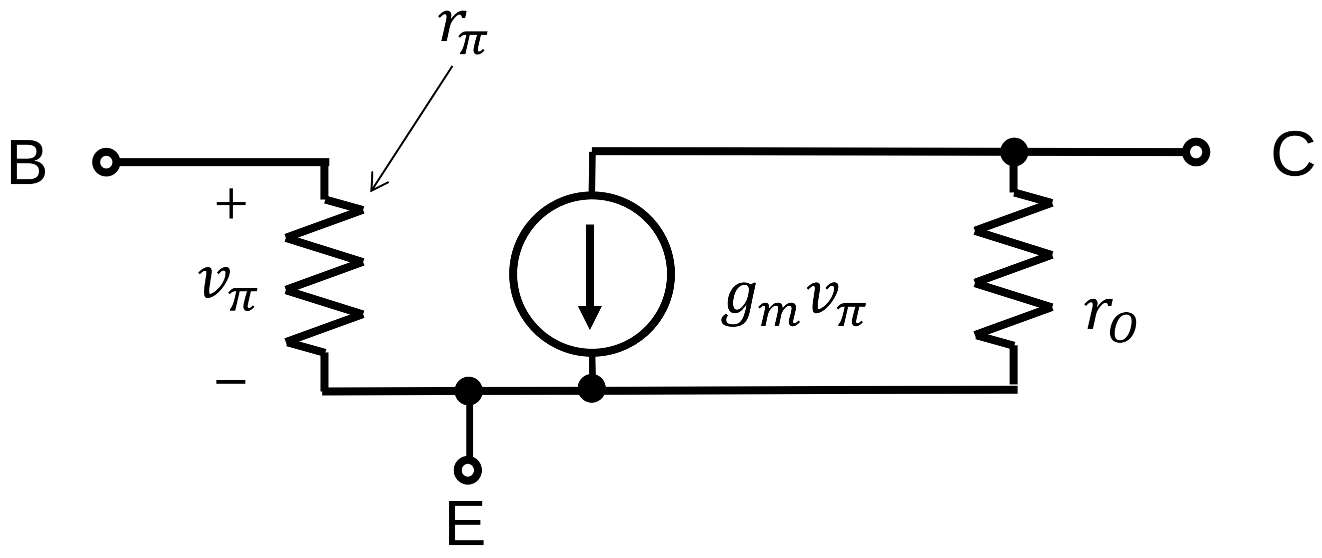
Small-signal model

- Useful expressions

$$g_m = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\beta}{g_m}$$

$$r_O \approx \frac{V_A}{I_C}$$

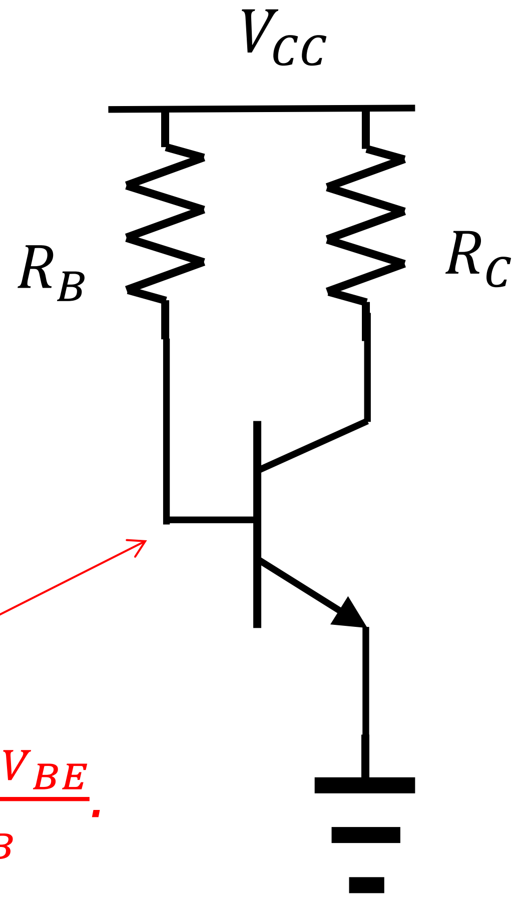


Biasing

- Example 5.7
  - DC analysis?
  - (Recall its MOS counterpart.)

  - Specific values

$V_{CC} = 2.5\text{ V}$
$R_B = 100\ k\Omega$
$R_C = 1\ k\Omega$



Voltage?
It would be $\frac{V_{CC}-V_{BE}}{R_B}$.

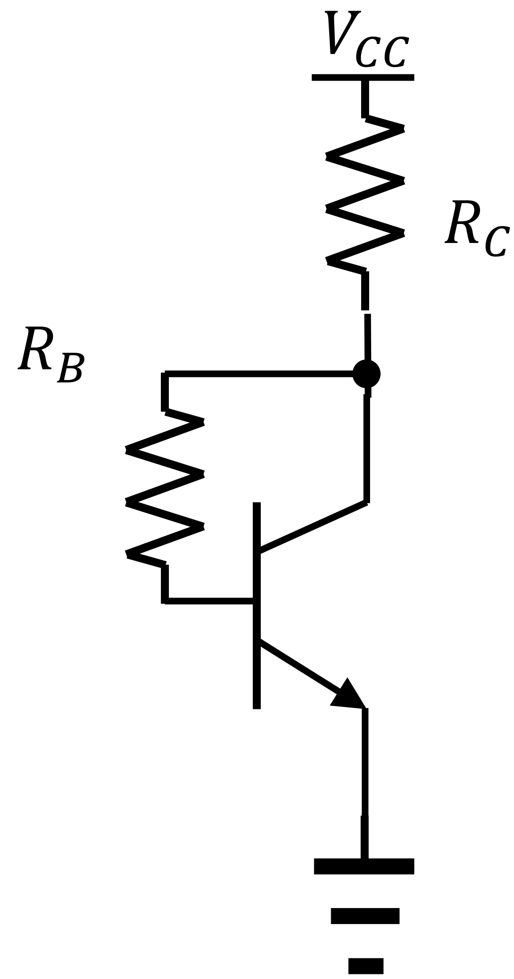
Self-biased stage

- Which one is higher?
  - Collector voltage or base voltage?
  - In the forward active region!

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + \frac{R_B}{\beta}} \longleftarrow \text{Why?}$$

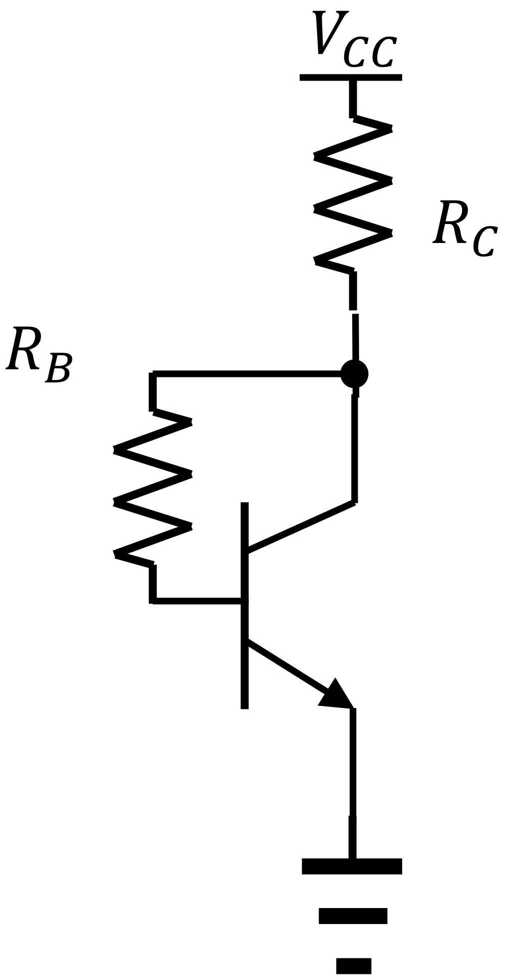
  - Uncertain V_{BE} and β
  - What can we do?

$$R_C \gg \frac{R_B}{\beta}$$



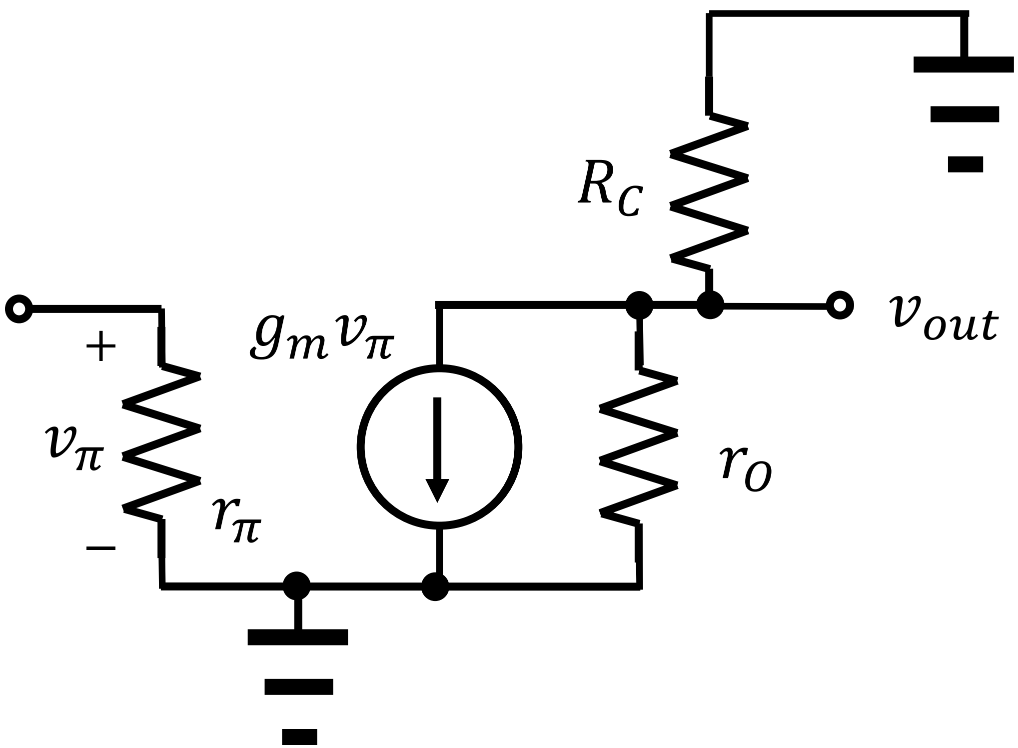
Example 5.14

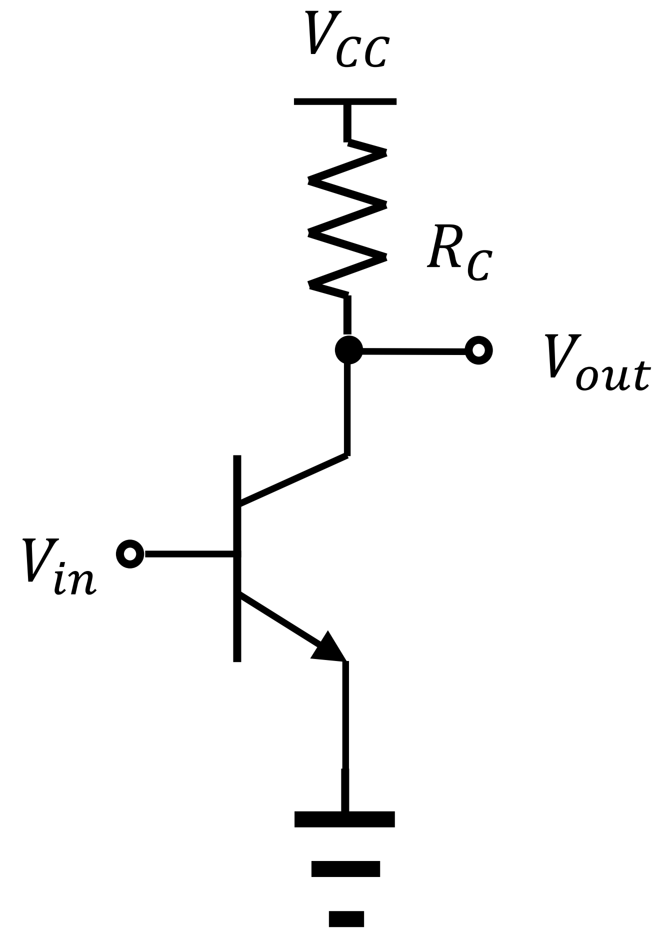
- Design the self-biased stage.
  - In this example, we assume
$$R_C \approx 10\frac{R_B}{\beta}$$
  - It means $I_C = \frac{V_{CC}-V_{BE}}{1.1R_C}$.
  - We want to have g_m of $\frac{1}{13\ \Omega}$ in this example.
  - For BJTs, $g_m = \frac{I_C}{V_T}$. Therefore, $I_C = 2\ \text{mA}$.
  - Then,
$$R_C \approx \frac{V_{CC}-V_{BE}}{1.1\ I_C} = 475\ \Omega$$



Common-emitter (1/2)

- You can easily imagine that
  - There is a common-emitter configuration.





Common-emitter (2/2)

- Voltage gain?
  - Same with the CS stage:

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

- Impedances?
  - Input impedance

$$R_{in} = r_\pi = \frac{\beta}{g_m}$$

  - Output impedance

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

Common-emitter (2/2)

- Voltage gain?
  - Same with the CS stage:

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

  - When we have a very large R_C, $A_v \rightarrow -g_m r_O$.
  - For BJTs, $g_m = \frac{I_C}{V_T}$ and $r_O = \frac{V_A}{I_C}$.

- Impedances?
  - Input impedance

$$R_{in} = r_\pi = \frac{\beta}{g_m}$$

  - Output impedance

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

Example 5.21

- Collector current of 1 mA and $R_C = 1\ k\Omega$.
  - Then, g_m is readily available.
$$g_m = \frac{1}{26\ \Omega}$$
  - When, the Early voltage is 10 V, $r_O = \frac{10\ \mathrm{V}}{1\ \mathrm{mA}} = 10 k\Omega$.
  - Overall, $R_C||r_O = \frac{1}{1.1} k\Omega \approx 0.91\ k\Omega$.