Lecture 29: Transistor Terminal Gains

- Announcements:
- HW#9 online and due Friday via Gradescope
- Lab#5 due Tuesday, Nov. 12, 5 p.m.
    - If you are using excel or matlab to compute equations for Lab#5 → you will regret doing this when taking midterm 2
    - You need to design by hand at least 3 times before going to a computer
    - This is the only way to get familiar with the process
    - You cannot see the trade-offs without analyzing by hand
    - You need to put the work in to be able to recognize things
- Midterm 2 coming up in about 2 weeks
    - Friday next week, Nov. 15, @ 7 p.m., in 160 Kroeber Hall
    - Review Session will be next Tuesday, 6-8 p.m., in 400 Cory
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- Lecture Topics:
    - Generally-Loaded Transistor
        - —Terminal Resistances
        - —Terminal-to-Terminal Gains
        - —Inspection Analysis Sheet
        - —Examples
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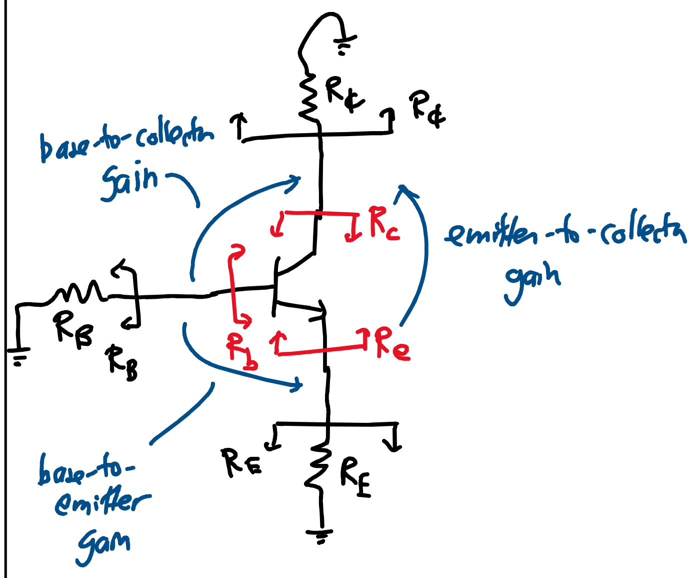
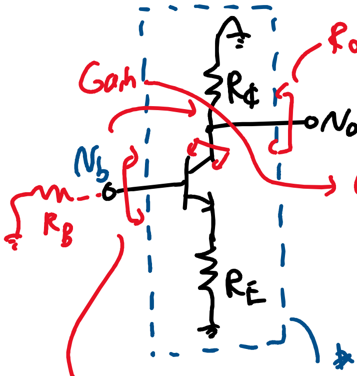
- Last Time:
- In the midst of getting terminal-to-terminal gains
- Now, continue with this …

Generally Loaded Transistor



Base-to-Collector Gain

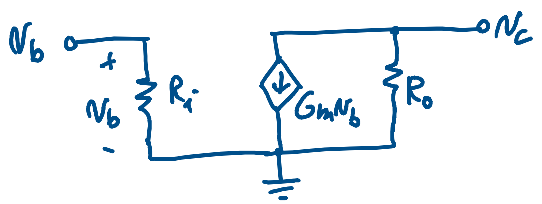


$$R_o = R_{C'} \,\|\, \underbrace{r_o\left(1+\frac{g_m R_E}{1+\frac{R_B}{r_\pi}}\right)}_{\text{huge}} \approx R_{C'}$$

$$\text{Gain}: \frac{v_c}{v_b} = -\left(\frac{g_m}{1+g_m R_E}\right) R_{C'}$$

$$R_i = r_\pi + (\beta+1) R_E$$

* Convert to an "equivalent Xsistor" y-parameter model:

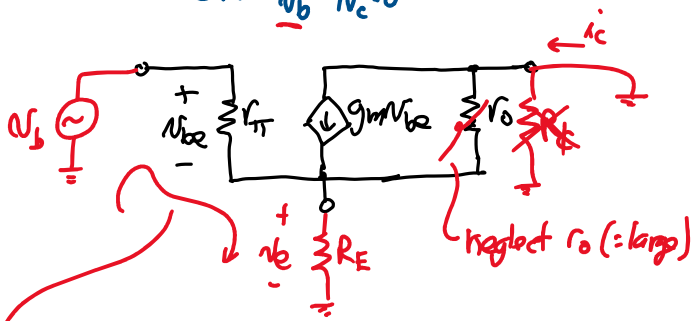


$$\frac{v_c}{v_b} = -G_m R_o$$

?

All we need is $G_m \triangleq$ short ckt. transconductance

$$G_m = \frac{i_c}{v_b}\Big|_{v_c=0}$$



$$v_e = \left(\frac{v_{be}}{r_\pi} + g_m v_{be}\right)R_E = v_{be}\left(\frac{1}{r_\pi} + g_m\right)R_E$$

KVL: $v_b = v_{be} + v_e = v_{be}\left(1 + \left(\frac{1}{r_\pi} + g_m\right)R_E\right)$ *

$i_c = g_m v_{be}$

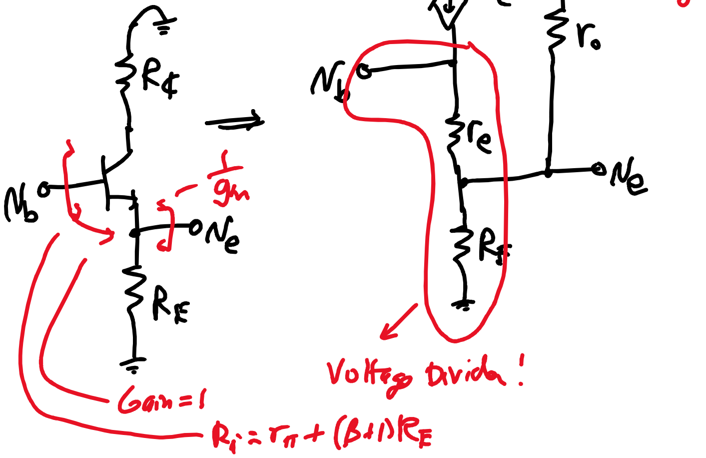
*

$$G_m = \frac{i_c}{v_b}\Big|_{v_c=0} = \frac{g_m \cancel{v_{be}}}{\cancel{v_{be}}\left(1 + \left(\underbrace{\cancel{\frac{1}{r_\pi}}}_{\frac{1}{r_\pi} \ll g_m} + g_m\right)R_E\right)}$$

$$\boxed{G_m = \frac{g_m}{1 + g_m R_E}}$$

$$\boxed{\begin{array}{l} \text{Gain} = \dfrac{v_c}{v_b} = -G_m R_o \\ \qquad\qquad\quad \uparrow \\ \qquad\quad G_m = \dfrac{g_m}{1 + g_m R_E} = \dfrac{g_m}{1 + \frac{R_E}{r_e}} \end{array}}$$

Base-to-Emitter Gain



Voltage Divider:

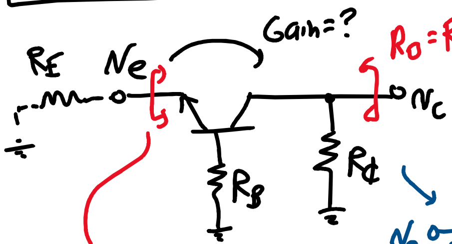
$[r_o \gg R_E]$ kΩ

$$\boxed{\frac{v_e}{v_b} \doteq \frac{R_E \| r_o}{r_e + R_E \| r_o} \approx \frac{R_E}{r_e + R_E} = \frac{g_m R_E}{1 + g_m R_E} \approx 1}$$

$\frac{\alpha}{g_m} \approx \frac{1}{g_m} = 25\Omega$ $[I_C = 1mA]$

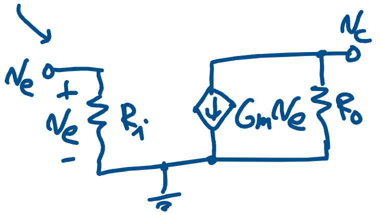
∴ call this a "voltage follower"

Emitter-to-Collector Gain



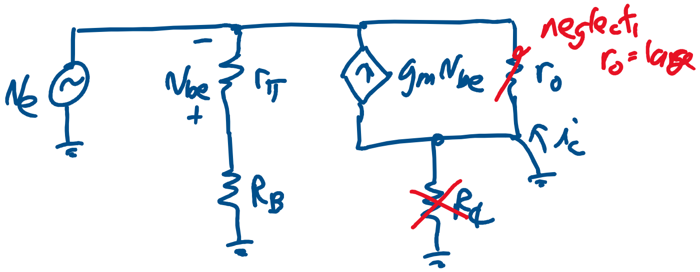
$R_o = R_C \| r_o\left(1 + \frac{g_m R_E}{1 + \frac{R_B}{r_\pi}}\right) \approx R_C$

$R_i = \frac{r_\pi + R_B}{\beta + 1} = \frac{1}{g_m} + \frac{R_B}{\beta + 1}$



Again, Gain: $\frac{v_c}{v_e} = -G_m R_o$

Again, all we need $G_m = \frac{i_c}{v_e}\Big|_{v_c=0}$ ≙ short-ckt transconductance



$v_{be} = -\frac{v_e r_\pi}{r_\pi + R_B}$

$∴ i_c = g_m v_{be} = -\frac{g_m r_\pi}{r_\pi + R_B} v_e$

$$\boxed{G_m = \frac{i_c}{v_e}\Big|_{v_c=0} = -g_m\left(\frac{r_\pi}{r_\pi + R_B}\right)}$$

$G_m = -g_m$
$R_B = 0$

Thus,

$$\boxed{\frac{v_c}{v_e} = -G_m R_o = +g_m\left(\frac{r_\pi}{r_\pi + R_B}\right) R_C \overset{\text{if } R_B = 0}{\approx} g_m R_C}$$

- Now go through the Inspection Analysis Handout