Lecture 28: Generally Loaded Transistor

- Announcements:
- HW#9 online and due Friday via Gradescope
- Lab#5 due Tuesday, Nov. 12, 5 p.m.
- Midterm 2 coming up in about 2 weeks
  - Friday next week, Nov. 15, @ 7 p.m., in 160 Kroeber Hall
  - More info this coming Friday
  - Review Session will likely be Tuesday, 6-8 p.m., next week
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- Lecture Topics:
  - Other Amplifier Configurations
  - Generally-Loaded Transistor
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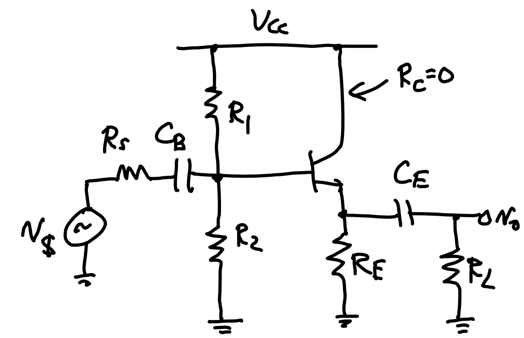
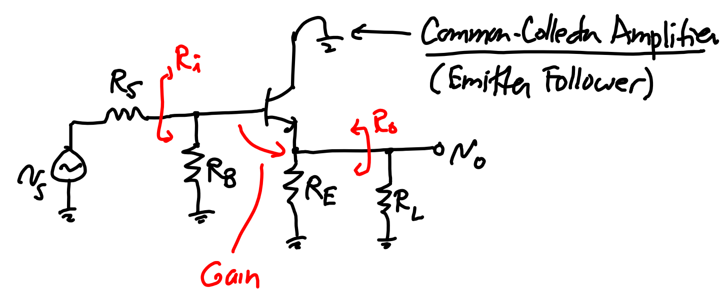
- Last Time:
- Introduced inspection analysis and Miller effect
- Now provide the knowledge needed to properly inspect analyze general circuits

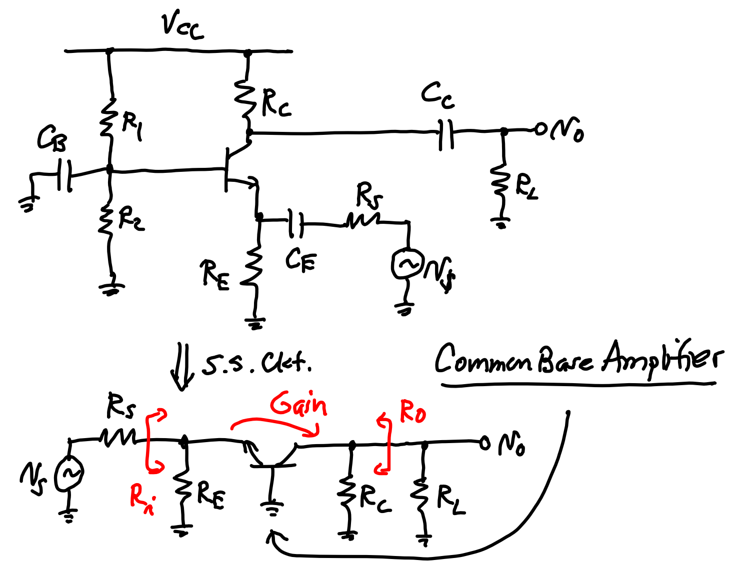
Other Popular Amplifier Configurations

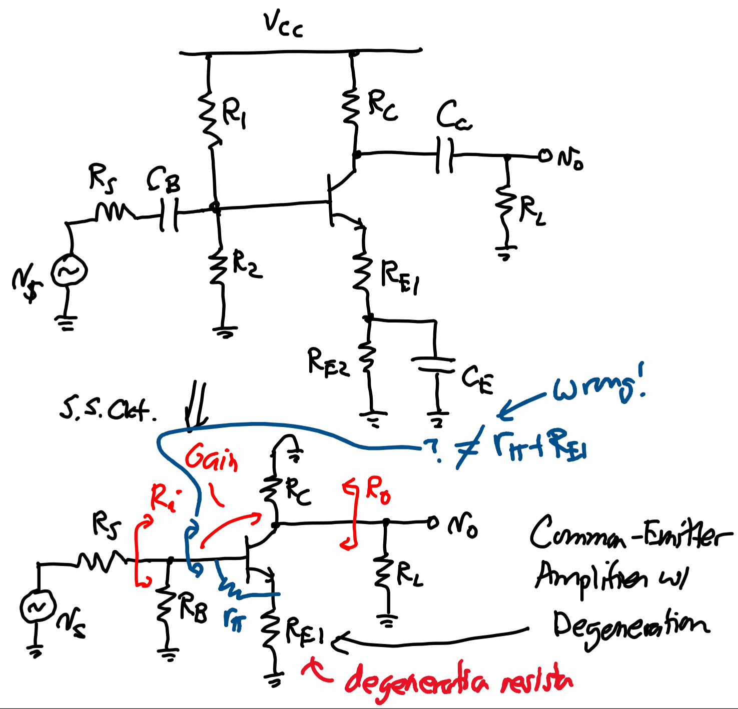
- By merely altering the placements of input/output signals and bypass/coupling capacitors, one can realize other amplifier configurations
- Some examples:



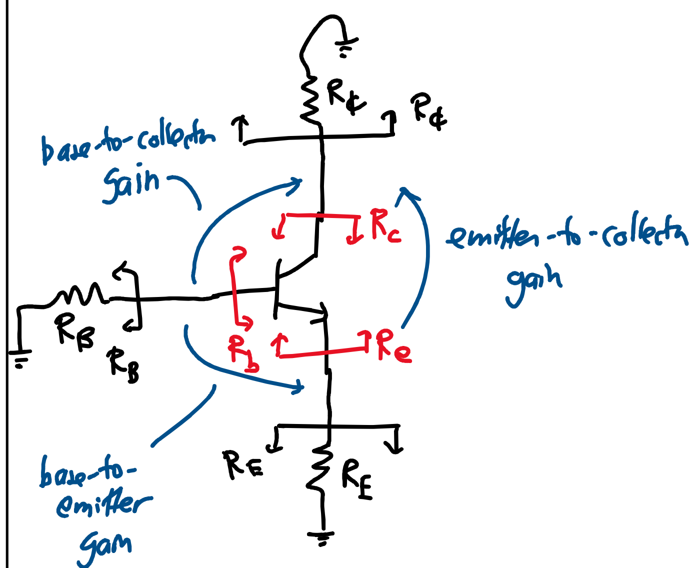
⇓ s.s. ckt.







Generally Loaded Transistor



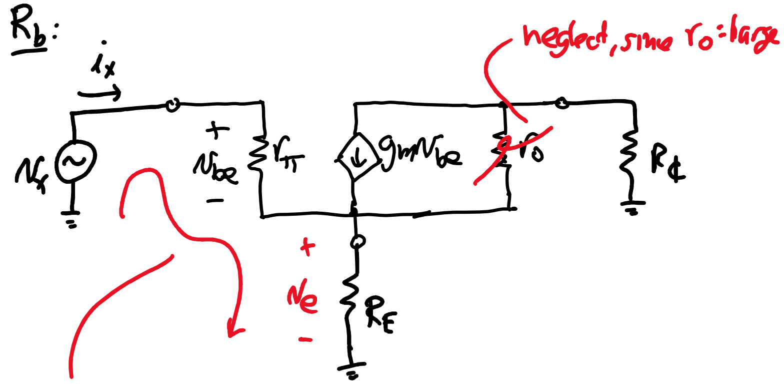
Find the terminal resistances: (i.e., the resistances seen looking into each terminal)

R_e: we've already derived this in association w/ finding R_{ES} for ω_L using SCTC analysis!

$$\boxed{R_e = \frac{r_\pi + R_B}{\beta+1}} \approx \underbrace{\frac{1}{g_m}}_{= r_e} + \frac{R_B}{\beta+1} \qquad [r_o \gg R_t]$$

R_b:

neglect, since r_o = large



KVL: $v_x = v_{be} + v_e$

$v_{be} = i_x r_\pi$

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

$v_x = i_x r_\pi + i_x (1 + \underbrace{g_m r_\pi}_{\beta}) R_E$

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

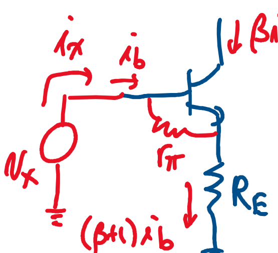
typ. 2.5kΩ

$(\beta+1) \times$ → 400kΩ

~4kΩ

$$\boxed{R_b = \frac{v_x}{i_x} = r_\pi + (\beta+1) R_E \approx r_\pi (1 + g_m R_E)}$$

✓ $[\beta = g_m r_\pi \gg 1]$



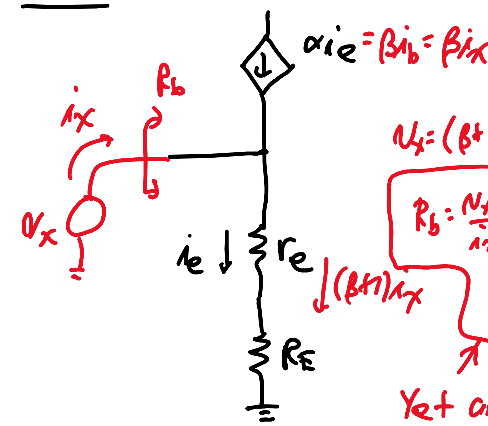
following the currents

$v_x = i_x r_\pi + (\beta+1) i_x R_E$

$R_b = \frac{v_x}{i_x} = r_\pi + \underbrace{(\beta+1)}_{} R_E$

This comes from amplification of $i_b \to i_c$

T-Model:



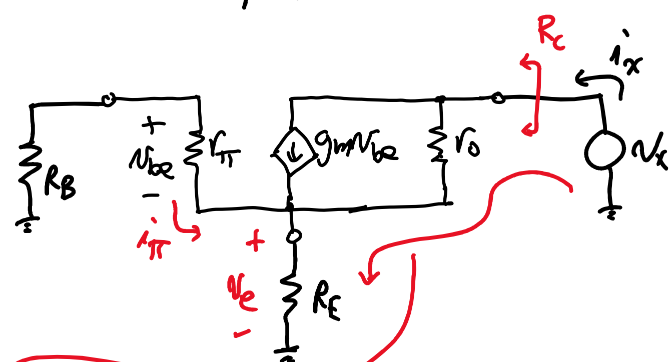
$v_x = (\beta+1) i_x (r_e + R_E)$

$R_b = \frac{v_x}{i_x} = (\beta+1)(r_e + R_E)$

$= (\beta+1)\left(\frac{1}{g_m} + R_E\right)$

Yet another form of the same R_b equation

Find R_c: (note that R_B can influence, so include in analysis)



KVL: $v_x = r_o (i_x - g_m v_{be}) + v_e$ * —

[Usually, for cases that matter, $R_E \ll R_B + r_\pi$]

for this class

$\therefore$ most of i_x flows thru R_E

$\therefore$ $v_e \cong i_x R_E$

$$i_\pi = -\frac{v_e}{r_\pi + R_B} = -\frac{i_x R_E}{r_\pi + R_B}$$

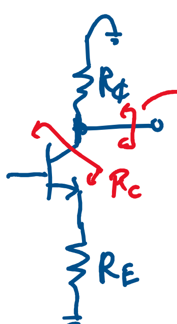
$$\therefore v_{be} = -\frac{i_x r_\pi R_E}{r_\pi + R_B}$$

$$* \quad v_x = i_x\left(1 + \frac{g_m r_\pi R_E}{r_\pi + R_B}\right) r_o + i_x R_E$$

$$\therefore R_c = \frac{v_x}{i_x} = r_o\left(1 + \frac{g_m R_E}{1 + (R_B/r_\pi)}\right) + R_E$$

$$\therefore \boxed{R_c \cong r_o\left(1 + \frac{g_m R_E}{1 + (R_B/r_\pi)}\right) \approx r_o(1 + g_m R_E)}$$

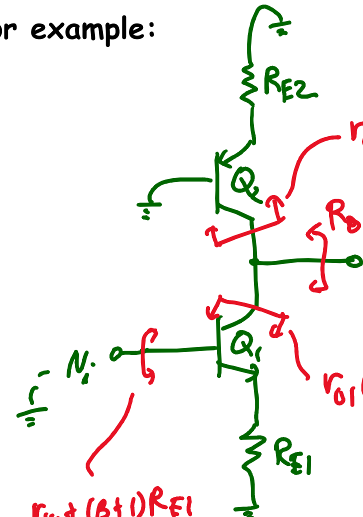
$(r_\pi \gg R_B)$ even bigger than r_o!



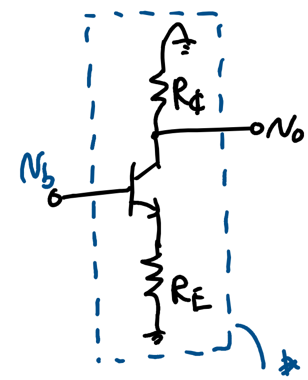
$R_o = R_C \| R_c \approx R_C$

huge

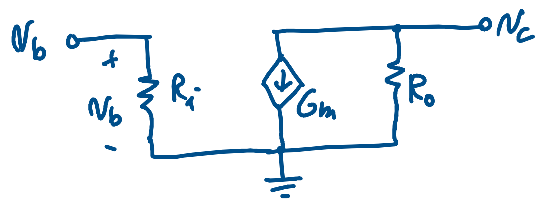
- **Remarks**:
- R_c ~ (1+(0.04)(1k))(100kΩ) ~ 4.1MΩ (this is huge)
- Rarely use R_c in discrete circuits, since it is generally much larger than R_C
- In integrated circuits, however, the loading can be very large, especially if it comes from another transistor
- For example:



Base-to-Collector Gain



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



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

?

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

$$G_m = \left.\frac{i_c}{v_b}\right|_{v_c=0}$$