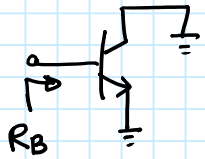
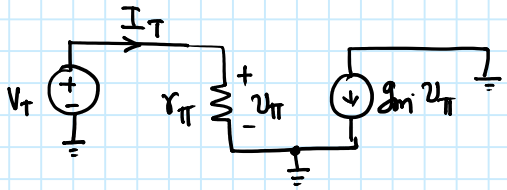
Lecture 23

BJT terminal impedances:

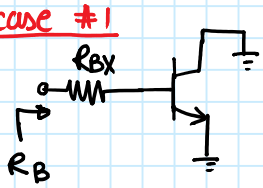
Impedance looking into base (when emitter & collector are incremental ground)

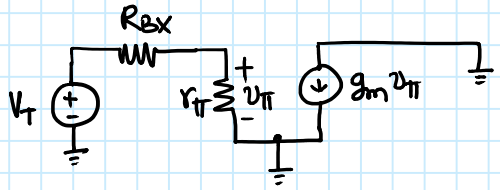




$$I_T = \frac{V_T}{r_\pi} \Rightarrow R_B = r_\pi$$

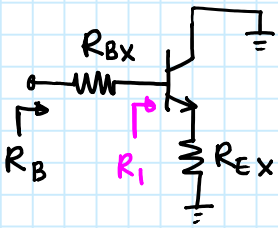
Special case #1

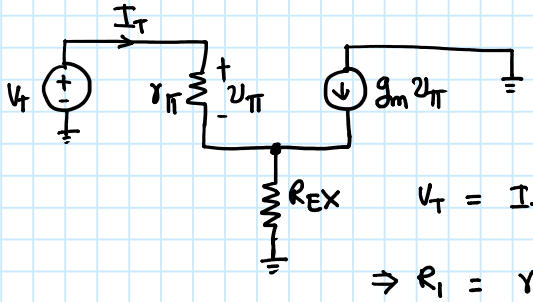




$$R_B = R_{BX} + r_\pi$$

Special case # 2





$$V_T = I_T r_\pi + (1+\beta) I_T \cdot R_{EX}$$

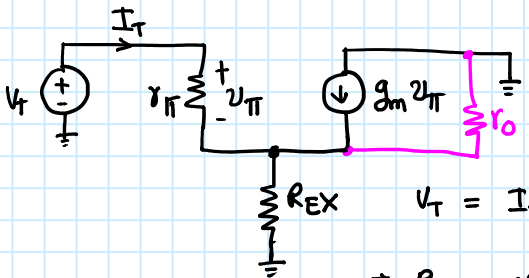
$$R_B = R_{BX} + R_1$$

$$\Rightarrow R_1 = r_\pi + (1+\beta) R_{EX}$$

$$R_B = R_{BX} + r_\pi + (1+\beta) R_{EX}$$

$\Rightarrow$ Emitter resistance (R_{EX}) looks $(\beta+1)$ times larger when looking from base

Special case 2 w/ r_o:

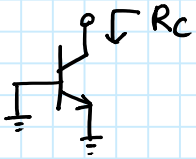


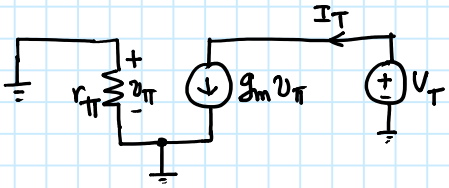
$$V_T = I_T r_\pi + (1+\beta) I_T \cdot (R_{EX} \parallel r_o)$$

$$\Rightarrow R_1 = r_\pi + (1+\beta)(R_{EX} \parallel r_o)$$

$$R_B = R_{BX} + r_\pi + (1+\beta)(R_{EX} \parallel r_o)$$

Impedance looking into collector: (when B & E are at incremental ground)

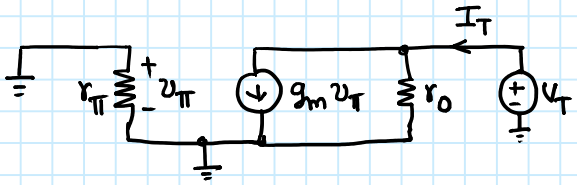




$v_\pi = 0 \Rightarrow I_T = 0$

$\Rightarrow R_C = \infty$

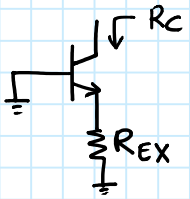
when $r_o \neq \infty$:

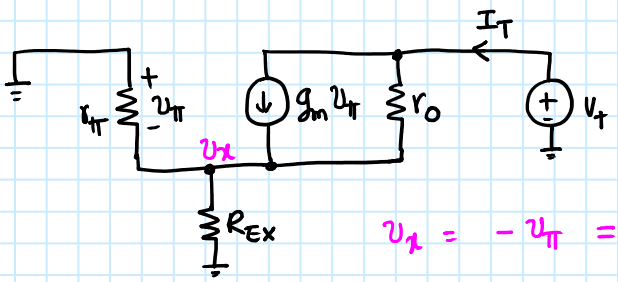


$$I_T = \frac{V_T}{r_o}$$

$$\Rightarrow R_C = r_o$$

Special case w/ emitter resistance:





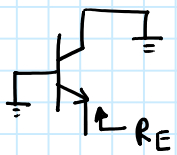
$$v_x = -v_\pi = I_T (r_\pi \parallel R_{EX})$$

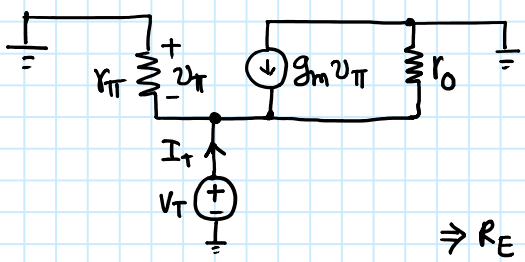
$$I_T = -g_m I_T (r_\pi \parallel R_{EX}) + \frac{V_T - I_T (r_\pi \parallel R_{EX})}{r_o}$$

$$I_T \left[1 + g_m (r_\pi \parallel R_{EX}) + \frac{r_\pi \parallel R_{EX}}{r_o} \right] = \frac{V_T}{r_o}$$

$$\Rightarrow R_C = \frac{V_T}{I_T} = r_o + (r_\pi \parallel R_{EX}) + g_m r_o (r_\pi \parallel R_{EX})$$

Impedance looking into emitter (when B & E are at incremental ground)



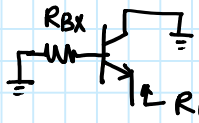


$$I_T = \frac{V_T}{r_\pi} + g_m V_T + \frac{V_T}{r_o}$$

$$= V_T \left(\frac{1 + g_m r_\pi}{r_\pi} \right) + \frac{V_T}{r_o}$$

$$\Rightarrow R_E = \frac{r_\pi}{1+\beta} \parallel r_o \approx 1/g_m \quad \begin{matrix} \beta \gg 1 \\ g_m r_o \gg 1 \end{matrix}$$

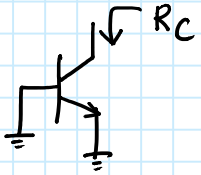
w/ base resistance R_{BX}:

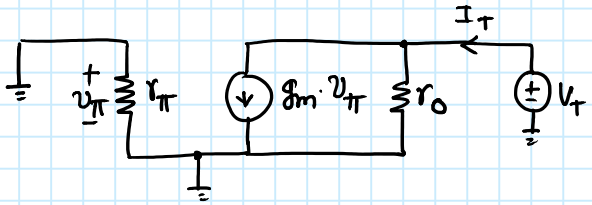


$$R_E = \frac{R_{BX} + r_\pi}{1+\beta} \parallel r_o$$

R_{BX} appears $(1+\beta)$ smaller when looking from emitter.

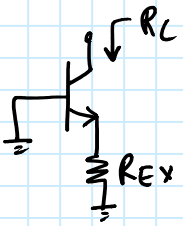
Impedance looking into collector: (with B & E at incremental ground)





$$v_\pi = 0 \Rightarrow R_C = \frac{V_T}{I_T} = r_o$$

R_C with emitter resistance R_{EX}:



Using analysis in the context of common-emitter stage output impedance calculation:

$$R_C = \left[1 + g_m (R_{EX} \| r_\pi)\right] r_o + (R_{EX} \| r_\pi)$$