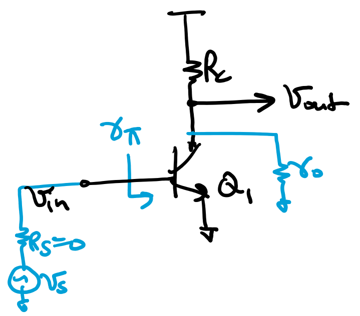
ECE 310 - Lecture 32

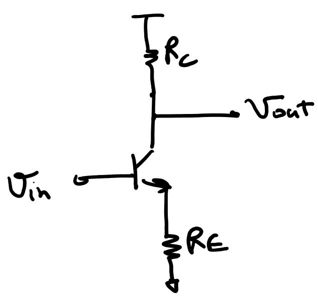
CE amplifier

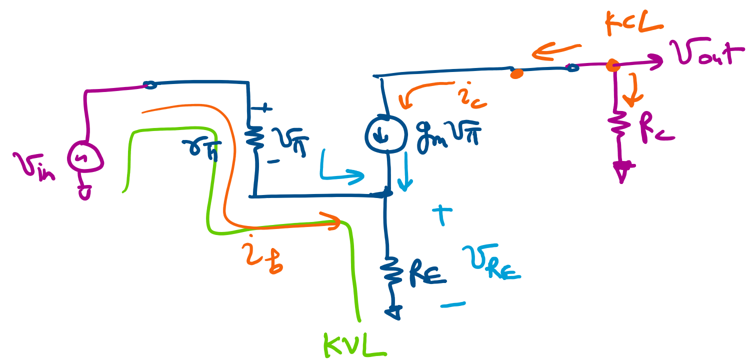


$$A_v = -g_{m_1}(r_o \| R_C)$$

CE with Emitter Degeneration :

$$V_A \to \infty \Rightarrow r_o \Rightarrow \infty$$





KCL @ the output $\Rightarrow$

$$\frac{v_{out}}{R_C} + g_m v_\pi = 0$$

or

$$v_\pi = -\frac{v_{out}}{g_m R_C} \longrightarrow (1)$$

$$v_{RE} = \left(\underbrace{\boxed{\frac{v_\pi}{r_\pi}}}_{i_b} + g_m v_\pi\right) R_E \longrightarrow (2)$$

KVL:

$$v_{in} = v_\pi + v_{RE}$$

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

$$(r_\pi \quad ,$$

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

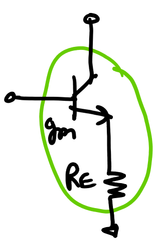
$$\Rightarrow \quad \frac{v_{out}}{v_{in}} = - \frac{g_m R_C}{1 + \left(\frac{1}{r_\pi} + g_m \right) R_E} \qquad \because r_\pi = \frac{\beta}{g_m}$$

for $\beta >> 1$, we have $g_m >> \frac{1}{r_\pi} = \frac{g_m}{\beta}$

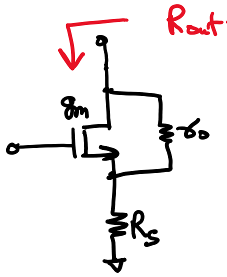
$$\Rightarrow \boxed{\frac{v_{out}}{v_{in}} = - \frac{g_m R_C}{1 + g_m R_E}}$$

gain falls off by a factor of $(1 + g_m R_E)$

↳ But this amplifier is more linear
⇒ Similar to CS+SD amplifier



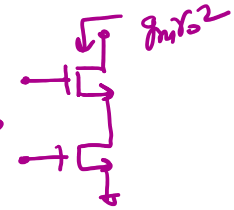
$$G_m = \frac{g_m}{1 + g_m R_E}$$

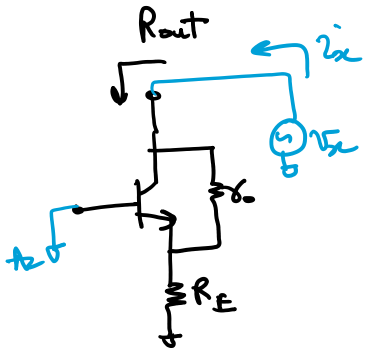


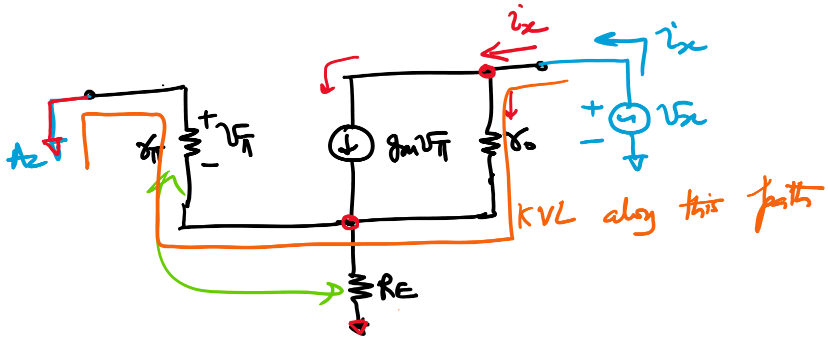
$R_{out} = g_m r_o R_S + r_o + R_S \Leftarrow$ Cascode output resistance

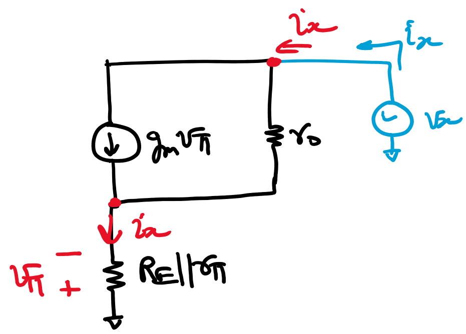
$\simeq g_m r_o R_S$ for $g_m r_o \gg 1$

$= g_m r_o^2$ if $R_S = r_o$









$$v_\pi = -i_x (R_E \| r_\pi) \longrightarrow ①$$

KVL: $$v_x = (i_x - g_m v_\pi) r_o - v_\pi$$

$$\Rightarrow v_x = [i_x + g_m i_x \cdot R_E \| r_\pi] r_o + i_x (R_E \| r_\pi)$$

$$\Rightarrow R_{out} = \frac{v_x}{i_x} = [1 + g_m R_E \| r_\pi] r_o + R_E \| r_\pi$$

new term

$$\boxed{R_{out} = r_o + (g_m r_o + 1)(R_E \| r_\pi)}$$

Compare with MOSFET Cascode $R_{out} = r_o + (g_m r_o + 1) R_E$

for $g_m r_o \gg 1$

$$\Rightarrow R_{out} \simeq r_o + g_m r_o (R_E \| r_\pi)$$

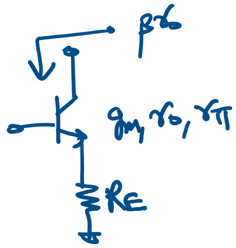
$$= r_o \left[1 + g_m (R_E \| r_\pi) \right] \simeq \boxed{g_m (R_E \| r_\pi) r_o}$$

r_o is "boosted" by a factor of $g_m (R_E \| r_\pi)$

Now for $\underline{R_E \gg r_\pi}$ $\Rightarrow$ $R_{out} \simeq r_o (1 + g_m r_\pi)$

$$\simeq g_m r_o r_\pi$$

$$= \beta r_o \qquad \because r_\pi = \frac{\beta}{g_m}$$

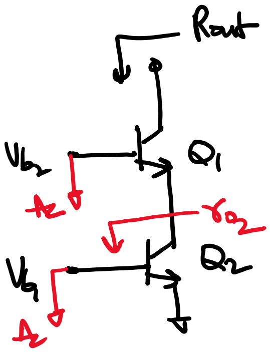


r_o is boosted by β

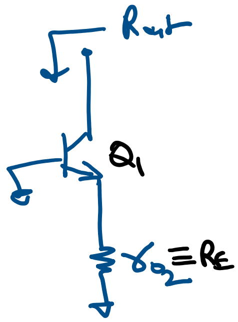
What if $\boxed{R_E \ll r_\pi}$ $\Rightarrow$ $R_{out} \simeq (1 + g_m R_E) r_o$

$$\simeq (g_m r_o) R_E$$

Similar to the MOSFET Cascode



$\Rightarrow$



$$R_{out} = [1 + g_{m_1}(R_E \,||\, r_{\pi_1})]\, r_{o_1}$$

$$= \boxed{[1 + g_{m_1}(r_{o_2} \,||\, r_{\pi_1})]\, r_{o_1}}$$

$$\cong g_{m_1} r_{o_1} \cdot (r_{o_2} \,||\, r_{\pi_1})$$

$$\cong g_{m_1} r_{o_1} r_{o_2} \text{ only if}$$

$$r_{o_2} << r_{\pi_1}$$

$$r_{o_2} << \frac{\beta_1}{g_{m_1}}$$

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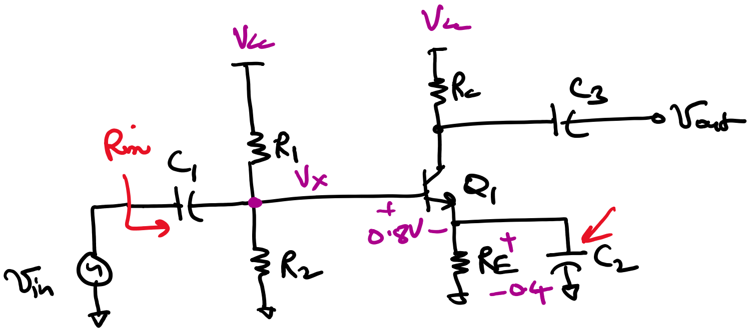
Ex 5.34

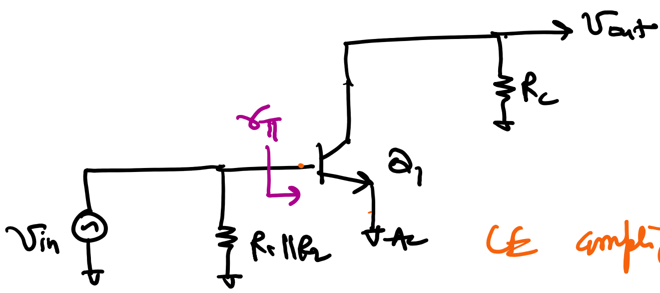


$I_C = 1\,mA$; $V_{BE,nom} = 0.8V$

Voltage Drop across $R_E \Rightarrow 400mV$

find $A_v = \frac{v_{out}}{v_{in}}$ & R_{in}

AC picture:



CE amplifier

$R_{in} = R_1 || R_2 || r_\pi$

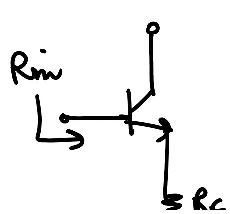
$A_v = -g_{m_1}(r_o || R_C)$

* If C_2 is removed

$$A_v = -\frac{R_C}{\frac{1}{g_m} + R_E}$$

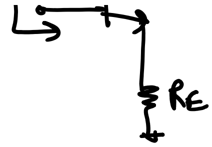
& $R_{in} = (r_\pi + (\beta+1)R_E) || R_1 || R_2$

Prove this as an exercise.



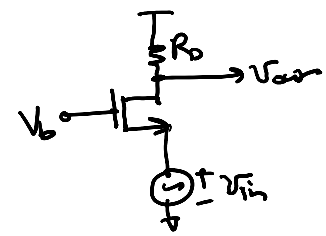
$R_{in} = r_\pi + (\beta+1)R_E$

Boosts input impedance of the

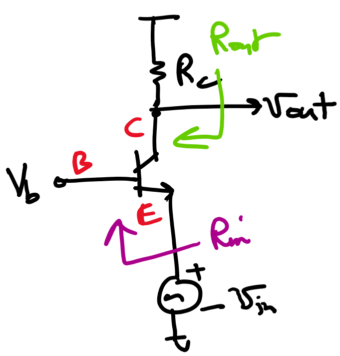


Boosts input impedance of the CE with emitter degeneration

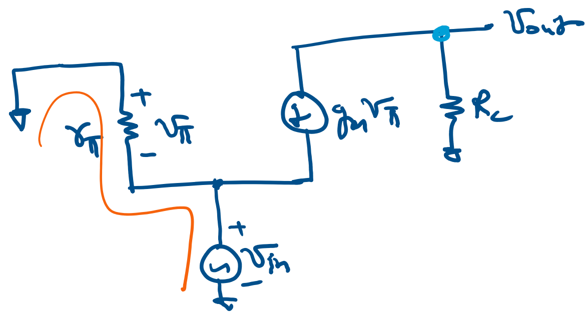
CG



Common-Base Amplifier



$V_A = \infty$



$$-\frac{v_{out}}{R_c} = g_m v_\pi$$

$$\Rightarrow \quad v_\pi = -\frac{v_{out}}{g_m R_C}$$

Also $\quad v_\pi = -v_{in}$

$$\frac{v_{out}}{v_{in}} = +g_m R_c$$

$$R_{in} = 1/g_m$$

$$R_{out} = r_o \| R_c \simeq R_c \quad \text{if} \quad V_A \to \infty$$

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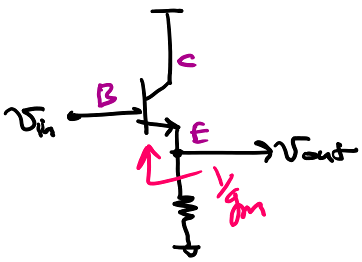
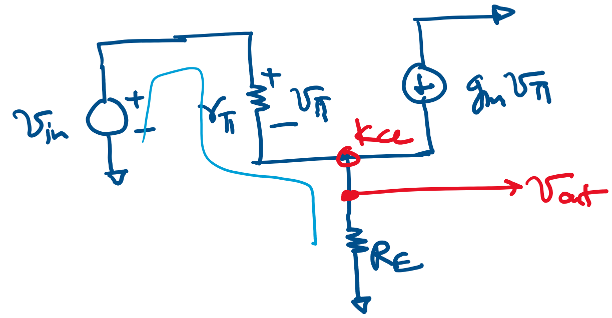
Emitter follower: (Common Collector) circuit





$V_A = \infty$
$\Rightarrow r_o \to \infty$

KCL: $$\frac{v_\pi}{r_\pi} + g_m v_\pi = \frac{v_{out}}{R_E}$$

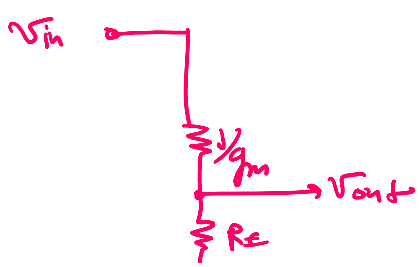
$$\Rightarrow v_\pi = \frac{r_\pi}{\beta+1} \cdot \frac{v_{out}}{R_E} \longrightarrow (1)$$

Also, $$v_{in} = v_\pi + v_{out} \longrightarrow (2)$$

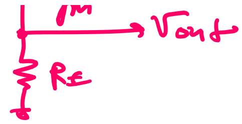
From (1) & (2) we get

$$\frac{v_{out}}{v_{in}} = \frac{1}{1 + \frac{r_\pi}{(\beta+1)} \cdot \frac{1}{R_E}}$$

$$\simeq \frac{R_E}{R_E + 1/g_m} \quad \text{for } \beta >> 1$$



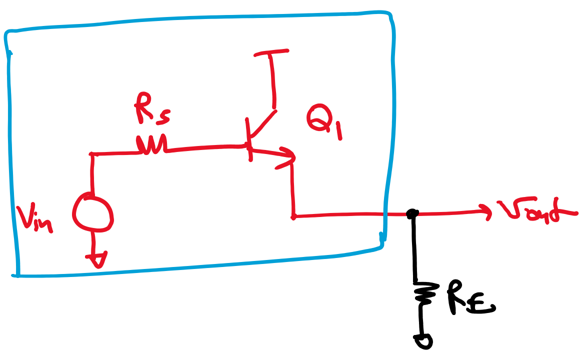
Voltage divider understanding.



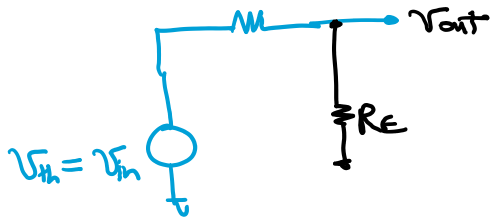
$$R_{out} \simeq \frac{1}{g_m} \parallel R_E \simeq \frac{1}{g_m} \quad \text{for } g_m R_E \gg 1$$

* Very good voltage buffer similar to the MOSFET source follower.

Emitter follower circuit



$$R_{th} = \frac{1}{g_m} + \frac{R_s}{(\beta+1)} \simeq \frac{1}{g_m}$$



$$\frac{v_{out}}{v_{in}} = \frac{R_E}{R_E + \frac{1}{g_m} + \frac{R_s}{(\beta+1)}}$$