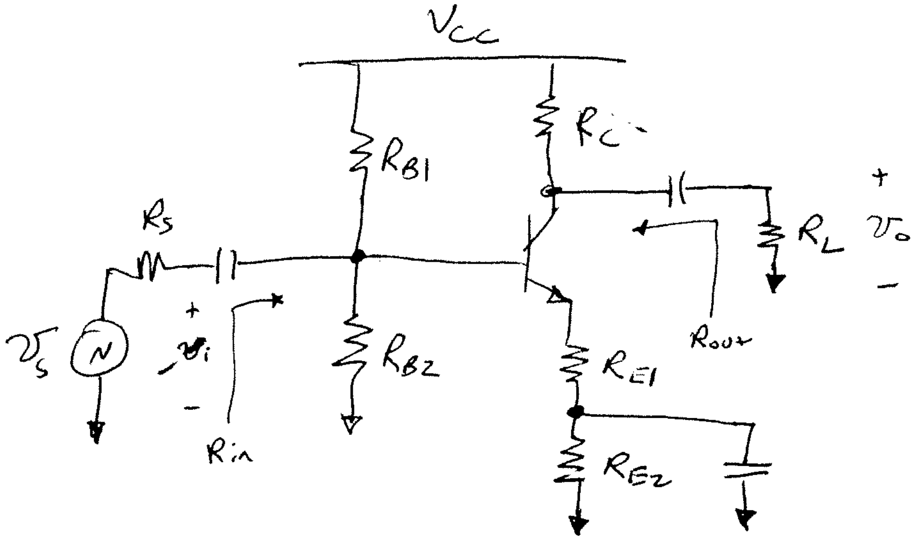
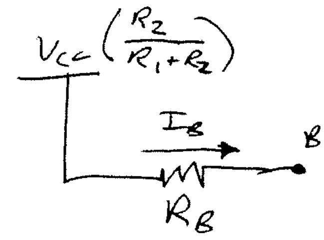
Common Emitter w/ Emitter Resistance

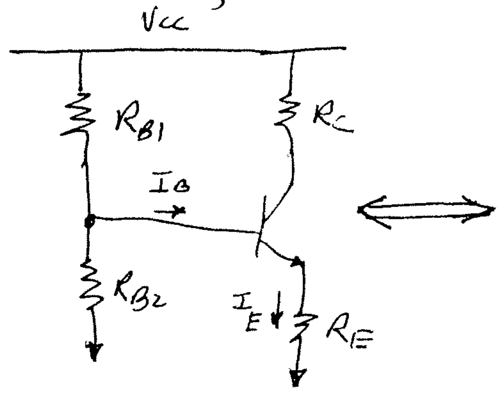




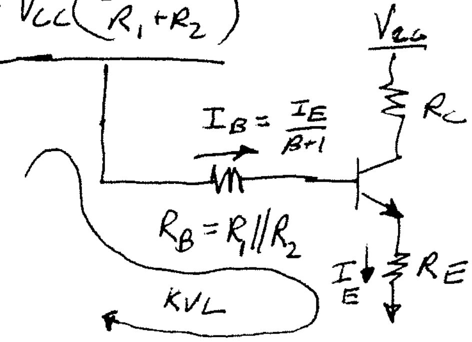
Why $R_E = R_{E1} + R_{E2}$?

The emitter resistor provides a DC bias point more robust to variations in β and temperature. This comes at the cost of reduced gain.

* DC Biasing



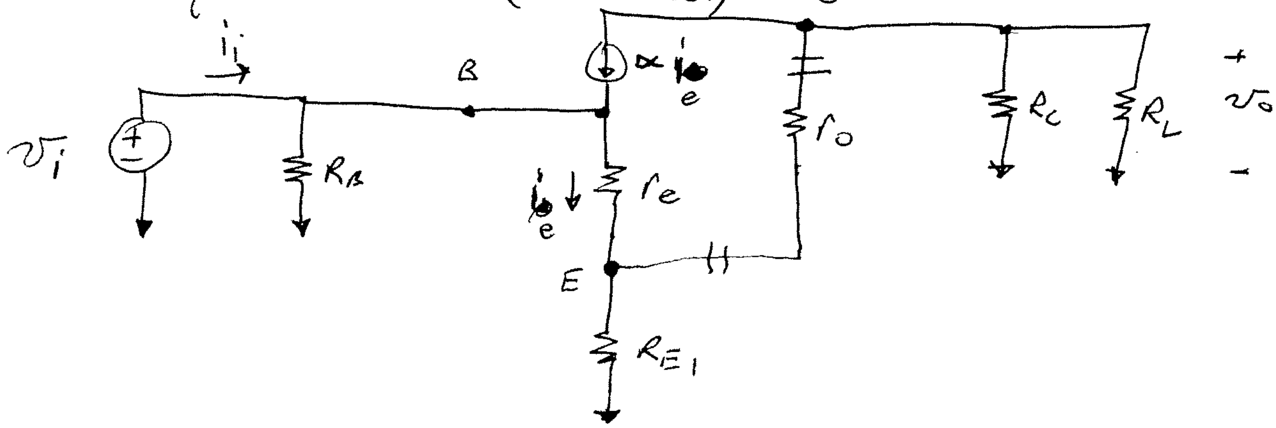
$$V_{BB} = V_{CC}\left(\frac{R_2}{R_1+R_2}\right)$$



$$\text{KVL}: \quad \underbrace{-V_{CC}\left(\frac{R_2}{R_1+R_2}\right)}_{-V_{BB}} + \frac{I_E R_B}{\beta+1} + V_{BE} + I_E R_E = 0$$

$$\Longrightarrow \quad I_E = \frac{V_{BB} - V_{BE}}{R_E + \frac{R_B}{\beta+1}}$$

AC Equivalent Circuit (w/ T model)



Neglecting r_o to simplify analysis

$$v_o = -\alpha i_e (R_C \| R_L)$$

$$i_e = \frac{v_i}{r_e + R_{E1}}$$

$$\boxed{\Rightarrow A_V = \boxed{\frac{v_o}{v_i} = -\frac{\alpha (R_C \| R_L)}{r_e + R_{E1}}}}$$

using $r_e = \frac{\alpha}{g_m}$

$$A_V = -\frac{\alpha (R_C \| R_L)}{\frac{\alpha}{g_m} + R_{E1}} = \boxed{-\frac{g_m (R_C \| R_L)}{1 + \frac{g_m R_{E1}}{\alpha}}}$$

A_V reduced by roughly $1 + g_m R_{E1}$

so, if $g_m R_{E1} \gg 1 \Rightarrow$ gain approaches $-\frac{R_C}{R_{E1}}$ (and R_L big)

$\Rightarrow$ with Emmitter cap can get both stable DC bias and high AC gain

~~For Rin:~~ $\cancel{i_i = \frac{v_i}{R_B \| (r_e + R_{E1})}}$

* For R_{in}: KCL @ Base

$$-i_i + \frac{v_i}{R_B} + \frac{v_i}{r_e + R_{E1}} - \frac{\alpha v_i}{r_e + R_{E1}} = 0$$

$$v_i \left[\frac{1}{R_B} + \frac{1-\alpha}{r_e + R_{E1}} \right] = i_i$$

$$v_i \left[\frac{1}{R_B \,||\, \left(\frac{r_e + R_{E1}}{1-\alpha}\right)} \right] = i_i$$

$$\boxed{R_{in} = \frac{v_i}{i_i} = R_B \,||\, \left[\frac{r_e + R_{E1}}{1-\alpha}\right] = R_B \,||\, (\beta+1)(r_e + R_{E1})}$$

using $\beta + 1 = \frac{1}{1-\alpha}$

$$\boxed{= R_B \,||\, \left(r_\pi + (\beta+1) R_{E1}\right)}$$

~~if R_B is large $\Rightarrow$ R_{in} increases by roughly $(\beta+1)R_{E1}$~~

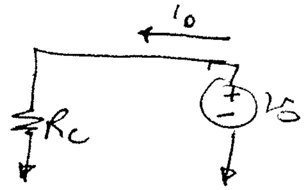
Using $\beta = g_m r_\pi$

$$R_{in} = R_B \,||\, \left(r_\pi + (g_m r_\pi + 1) R_{E1}\right)$$

$$\simeq R_B \,||\, r_\pi (1 + g_m R_{E1})$$

$\Longrightarrow$ R_{in} has increased by roughly $1 + g_m R_{E1}$

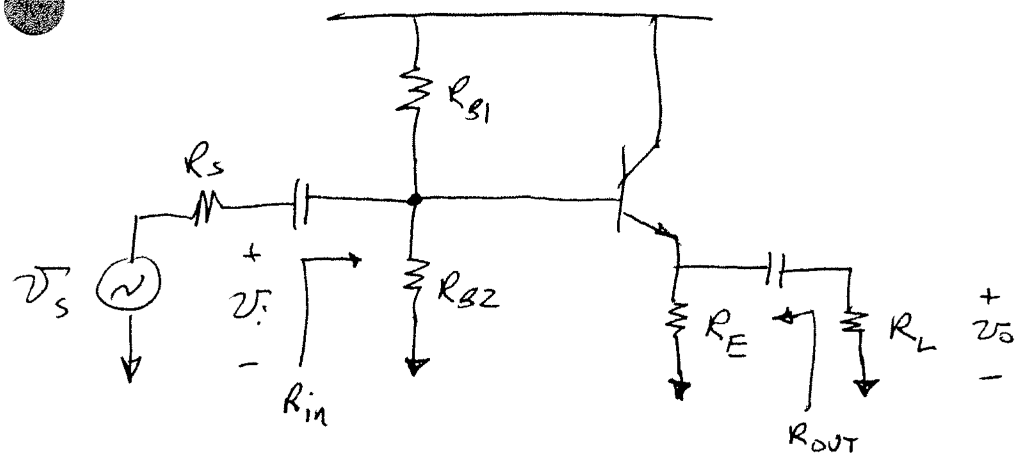
* For R_o: W/ $v_i = 0$, $i_e = 0$



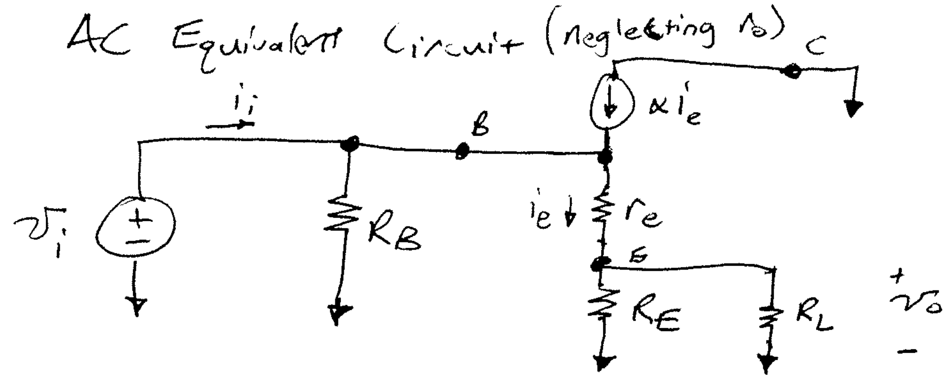
(Not affected much)

$$\boxed{R_{OUT} = R_C}$$

Common Collector



AC Equivalent Circuit (neglecting r_o)



$$v_o = i_e (R_E \| R_L)$$

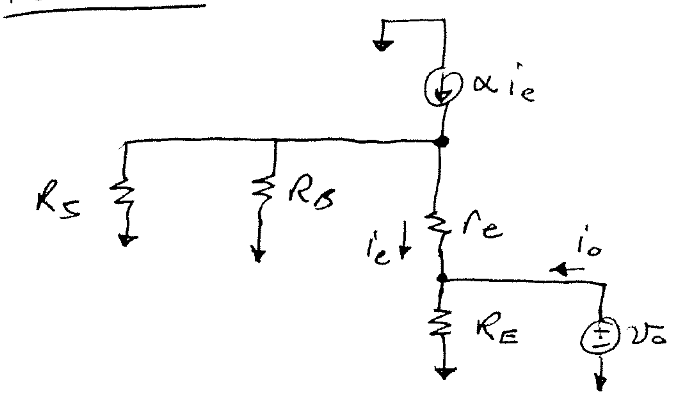
$$= \frac{v_i (R_E \| R_L)}{r_e + R_E \| R_L}$$

$$\boxed{A_v = \frac{v_o}{v_i} = \frac{R_E \| R_L}{r_e + R_E \| R_L}} \quad (<1)$$

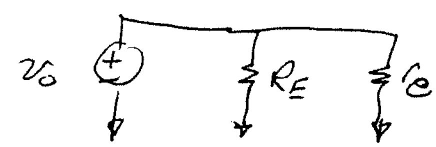
For R_{in}: Same as CE, but w/ $R_E \| R_L$

$$\boxed{R_{in} = R_B \,\|\, \left[r_\pi + (\beta+1)(R_E \| R_L) \right]} \quad \left(\text{High } R_{in}\right)$$

For R_{OUT}

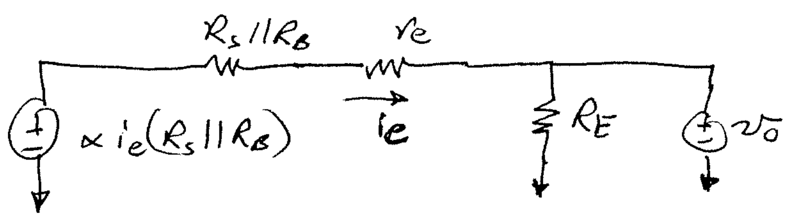


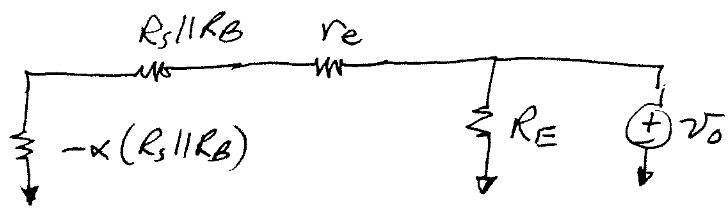
If $R_S = 0 \Rightarrow$



$R_{OUT} = R_E \| r_e$

W/R_S





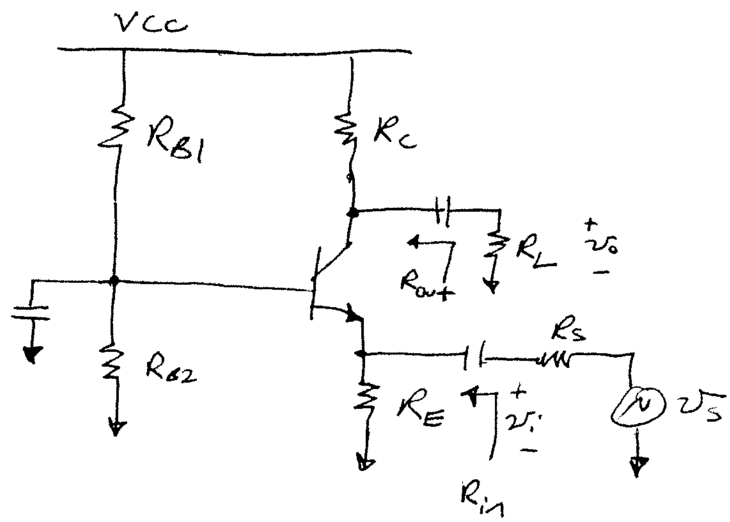
$$R_{OUT} = R_E \,\Big\|\, \left[r_e + (R_S \| R_B)(1-\alpha) \right]$$

$$\boxed{R_{OUT} = R_E \,\Big\|\, \left[r_e + \frac{R_S \| R_B}{\beta + 1} \right]}$$

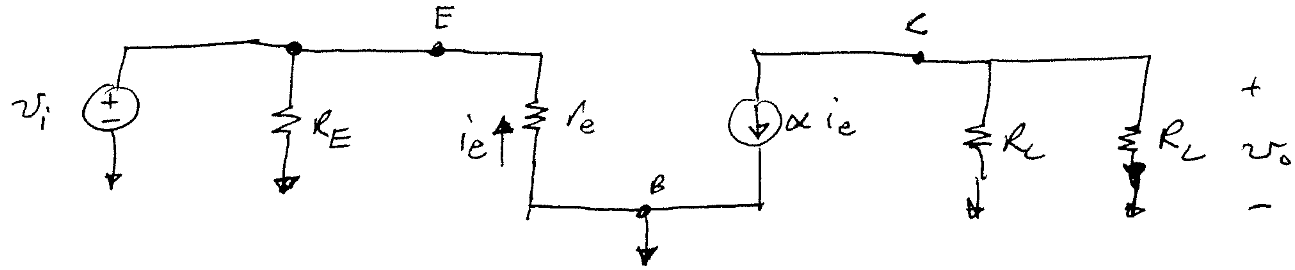
(Low)
$\approx r_e$

* While this circuit has $A_v < 1$, it has high R_{in} and low R_{OUT} $\Rightarrow$ Useful as a buffer or output stage

Common Base



AC Equivalent Circuit (Neglecting r_o)



$$v_o = -\alpha i_e (R_c \| R_L)$$

$$i_e = -\frac{v_i}{r_e}$$

$$\boxed{A_v = \frac{v_o}{v_i} = \frac{\alpha (R_c \| R_L)}{r_e} = g_m (R_c \| R_L)}$$

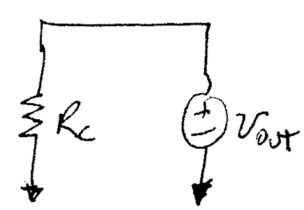
(Medium gain)

(Non-Inv)

$$\boxed{R_{in} = R_E \| r_e}$$

(low)

For R_{OUT}



$$\boxed{R_{OUT} = R_C}$$

(High)