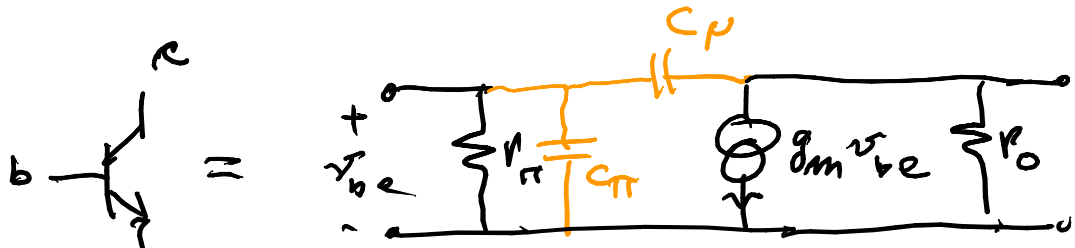
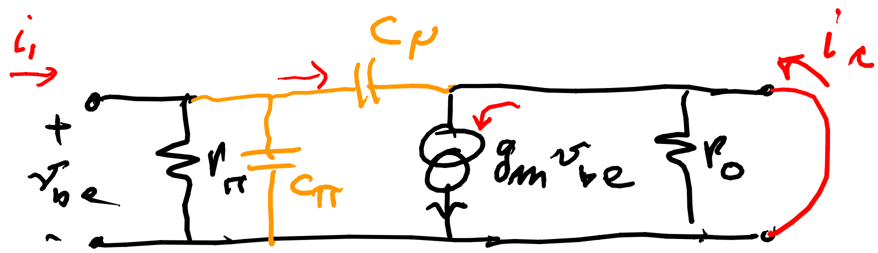


$$g_\pi = \frac{I_C}{\beta V_T} \qquad g_m = \frac{I_C}{V_T} \qquad g_o = \frac{1}{r_o} = \frac{I_C}{V_A}$$

short circuit current gain of the intrinsic transistor



$$i_{cap} = C\frac{dv_c}{dt} = sCv_c$$

$$y_{cap}(s) = sC$$

$$i_c = g_m v_{be} - sC_\mu v_{be} = (g_m - sC_\mu)v_{be}$$

$$i_1 = (g_\pi + sC_\pi + sC_\mu)v_{be}$$

$$\frac{i_c}{i_1} = \frac{g_m - sC_\mu}{g_\pi + s(C_\pi + C_\mu)} \approx \frac{g_m}{g_\pi\left(1 + s\frac{C_\pi}{g_\pi}\right)} = \frac{\beta}{\left(1 + s\frac{C_\pi}{g_\pi}\right)}$$

@ $s = 0 \equiv DC$ $\qquad \left.\frac{i_c}{i_b}\right|_{@DC} = \beta$; $s = j\omega \Rightarrow \frac{i_c}{i_b} = \frac{\beta_o}{1 + j\omega\frac{C_\pi}{g_\pi}}$

set $s = j\omega$

find at which $\omega = \omega_T$

$$\left|\frac{i_c}{i_b}(j\omega_T)\right| = 1 \Rightarrow \beta_o \approx \left|1 + j\omega_T\frac{C_\pi}{g_\pi}\right| = \sqrt{1 + \left(\omega_T\frac{C_\pi}{g_\pi}\right)^2}$$

$$\frac{\beta_0^2}{(C_\pi/g_\pi)^2} = \omega_T^2 \Rightarrow f_T = \frac{1}{2\pi}\cdot\frac{\beta_o}{C_\pi/g_\pi} = \text{transition frequency}$$

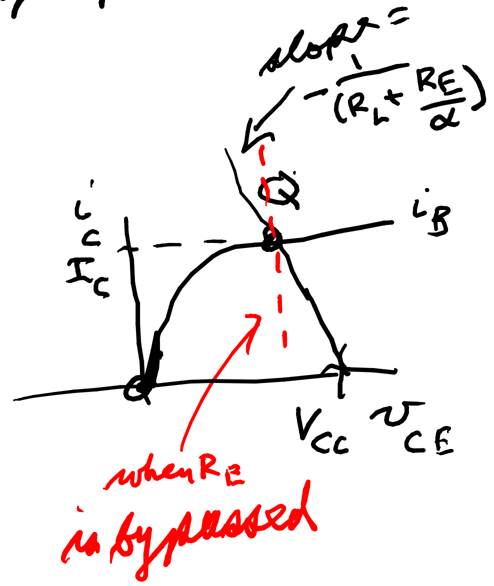
$\Rightarrow \beta \to 1$

Differential pairs

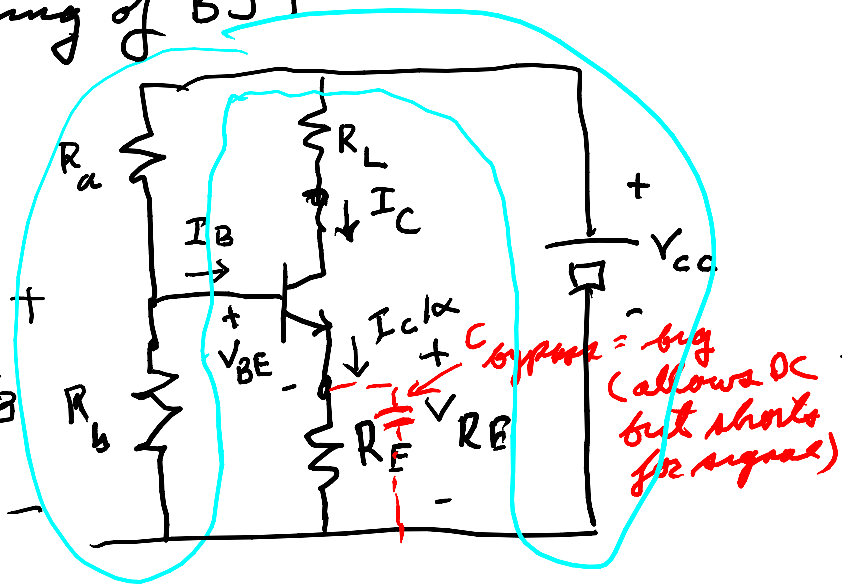
BJT p. 613, Fig. 8.15

MOS p. 595, Fig. 8.5

op-amp p. 1003
741



Biasing of BJT



assume $V_{BE} = 0.7v$

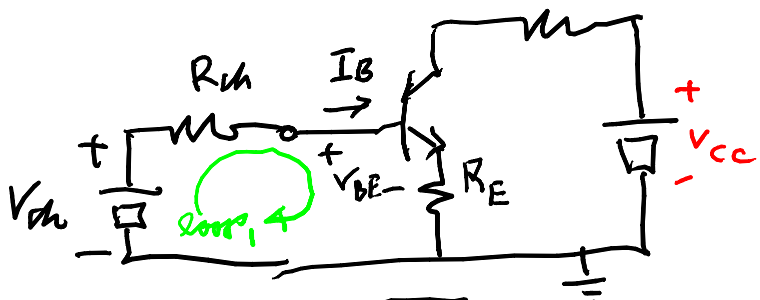
$= V_B - V_{RE}$

if $I_C \uparrow$ then due to R_E; $I_B \downarrow$ & then $I_C \downarrow$ due to feedback decreasing v_{BE}

(note $I_C = \beta I_B$)

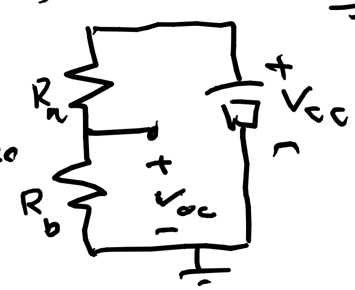
R_E prevents thermal runaway

by Thevenin's equivalent

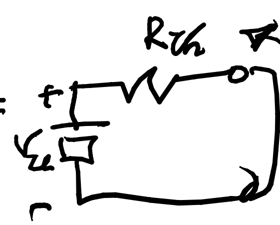


$V_{th} = V_{oc}$

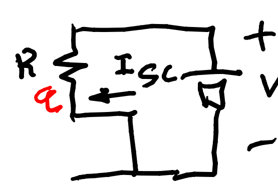
$= \frac{R_b}{R_a + R_b} \cdot V_{cc}$



$I_{sc} =$



$I_{sc} = -\frac{V_{oc}}{R_{th}}$



$I_{sc} = -\frac{V_{cc}}{R_a}$

$$R_{th} = -\frac{V_{oc}}{I_{sc}} = \frac{-\left(\frac{R_b}{R_a + R_b}\right) \times V_{cc}}{-V_{cc}/R_a}$$

$$= \frac{R_a R_b}{R_a + R_b}$$

by KVL: $0 = -V_{th} + R_{th} I_B + V_{BE} + R_E \frac{I_C}{\alpha}$, $\quad I_C = \beta I_B$

loop 1

$$0 = -\frac{R_b}{R_a + R_b} V_{CC} + \frac{R_a R_b}{R_a + R_b} \frac{I_C}{\beta} + V_{BE} + \frac{R_E I_C}{\alpha}$$

$$0 = -\frac{V_{CC}}{1 + \frac{R_a}{R_b}} + \left(\frac{1/\beta}{\frac{1}{R_b} + \frac{1}{R_a}} + \frac{R_E}{\alpha} \right) I_C + V_{BE}$$

desire R_a & R_b given I_C, $\beta = \frac{\alpha}{1-\alpha}$, V_{BE} & V_{CC} & R_E

choose 1 of R_a or R_b & check the other is > 0