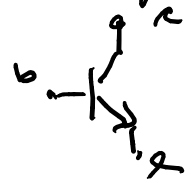
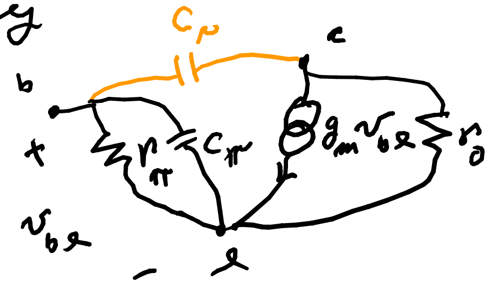
EE 303
02/15/12
correction 02/24/12

Note Title 2/15/2012

BJT high frequency



⇒



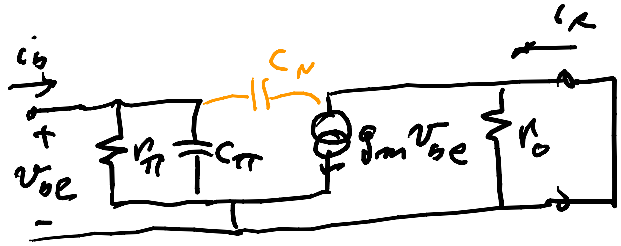
p. 711

$g_\pi = \frac{I_c}{\beta_o V_T}$, $g_m = \frac{I_c}{V_T}$

$= \frac{g_m}{\beta_o}$ $\quad g_o = \frac{I_c}{V_A}$

small signal
fwd bias BE
back bias BC

$\frac{i_c}{i_b}\Big|$ short ce



$$i_b = y_\pi \cdot v_{be} = (g_\pi + s C_\pi) \cdot v_{be} \quad + sC_\mu$$

$$i_c = g_m v_{be} - s C_\mu v_{be}$$

$$= g_m \cdot \frac{1}{g_\pi + s C_\pi} \cdot i_b$$

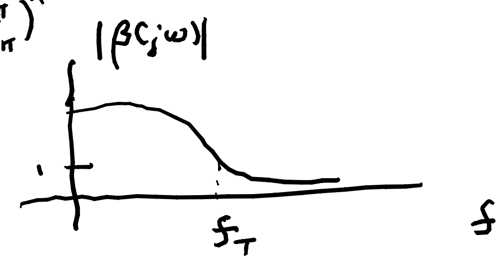
$$\Rightarrow \frac{i_c}{i_b} = \beta(s) = \frac{g_m}{g_\pi + s C_\pi} = \frac{g_m / g_\pi}{1 + s(C_\pi / g_\pi)} = \frac{\beta_o}{1 + s(C_\pi / g_\pi)}$$

$$\beta_o = \beta(0) = \beta\Big|_{@ DC} \; ; \; \beta(j\omega) = |\beta(j\omega)| e^{j \angle \beta(j\omega)} = \frac{\beta_o}{1 + j\omega(C_\pi / g_\pi)}$$

stops working $|\beta(j\omega)|$ drops to 1;

$$|\beta(j\omega)| = \frac{\beta_o}{\sqrt{1 + \omega^2 (C_\pi / g_\pi)^2}} \quad \Rightarrow 1 = \frac{\beta_o^2}{1 + \omega_T^2 \left(\frac{C_\pi}{g_\pi}\right)^2} \Rightarrow 1 + \omega_T^2 \left(\frac{C_\pi}{g_\pi}\right)^2 = \beta_o^2$$

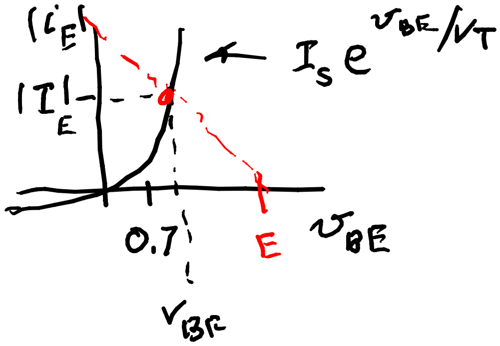
$$\Rightarrow \omega_T^2 = \frac{\beta_o^2}{(C_\pi / g_\pi)^2} \Rightarrow f_T = \frac{1}{2\pi} \frac{\beta_o}{(C_\pi / g_\pi)}$$

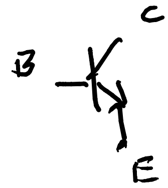


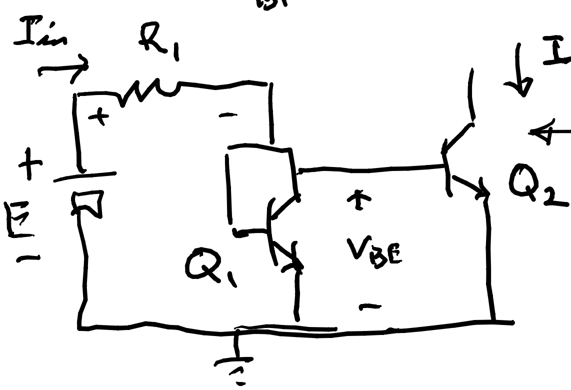
practical f_T is in MegHz.

"transition frequency"

Current mirror p.533







$I_o = I_{in}$ (α) if $Q_1 = Q_2$

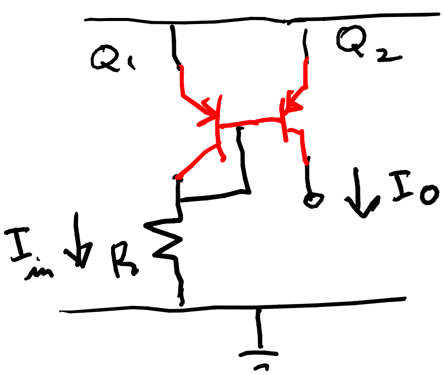
← back bias CB

(current sinks) uses npn

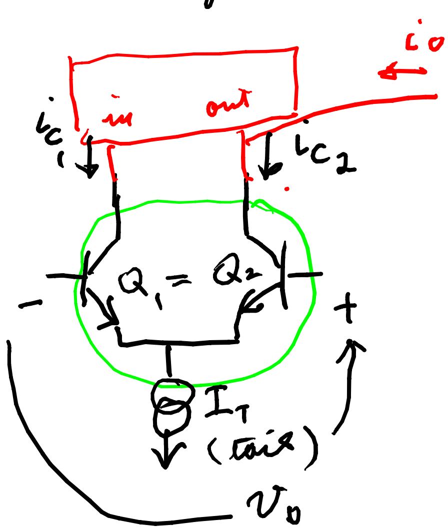
(current source) uses pnp

$V_{BE} \approx 0.7V$ $\quad I_{in} = G_1(E - V_{BE}) \Rightarrow G_1 = \frac{1}{R_1} = \frac{I_{in}}{E - 0.7}$

Current source that sources current



Differential pair, BJT p. 613, eqs. 616, active load p. 645



if i_{B_1} & i_{B_2} are small

KCL: $i_{C_1} + i_{C_2} = I_T$

$i_{C_1} = \alpha |i_{E_1}|, \quad i_{C_2} = \alpha |I_{E_2}|$

$v_o = v_{BE_2} - v_{BE_1}$

$|i_E| = I_s e^{v_{BE}/V_T}$ if forward bias BE

$i_{C_1} = \alpha I_S e^{v_{BE_1}/V_T}$ $\qquad$ $i_{C_2} = \alpha I_S e^{v_{BE_2}/V_T}$

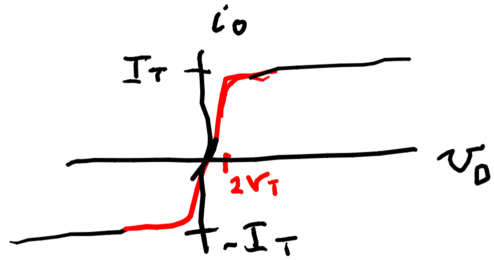
$$\frac{i_{C_2}}{i_{C_1}} = \frac{e^{v_{BE_2}/V_T}}{e^{v_{BE_1}/V_T}} = e^{(v_D/V_T)} \Rightarrow I_T = \left(1 + \frac{i_{C_2}}{i_{C_1}}\right) \cdot i_{C_1}$$

$$\Rightarrow i_{C_1} = \frac{I_T}{1 + e^{v_D/V_T}} \; ; \quad i_{C_2} = \frac{I_T \cdot e^{v_D/V_T}}{1 + e^{v_D/V_T}}$$

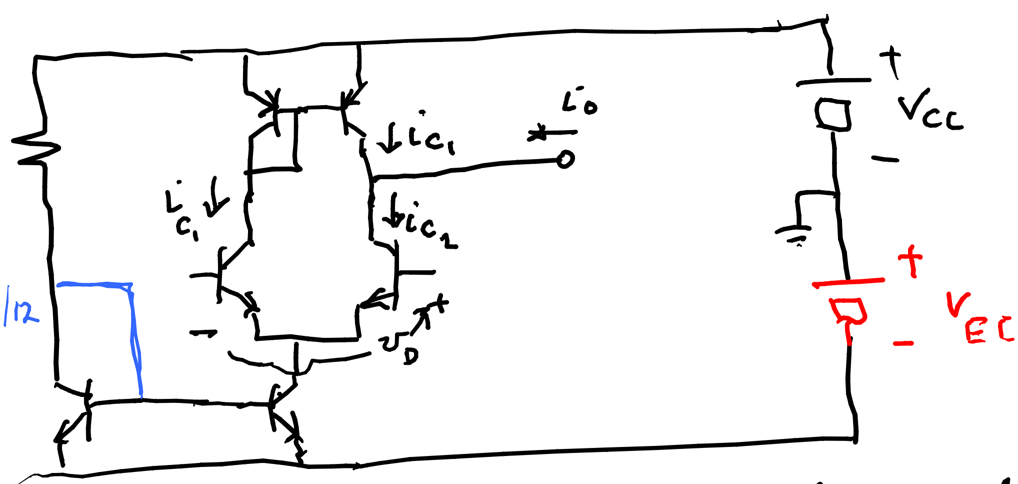
$$i_0 = i_{C_2} - i_{C_1} = \left(\frac{i_{C_2}}{i_{C_1}} - 1\right) i_{C_1} = \left(e^{v_D/V_T} - 1\right) \cdot i_{C_1} \; ; \quad \tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}} = \frac{e^{2x} - 1}{e^{2x} + 1}$$

$$\frac{i_0}{I_T} = \frac{e^{v_D/V_T} - 1}{1 + e^{v_D/V_T}} \cdot \frac{i_{C_1}}{i_{C_1}} = \tanh\left(\frac{v_D}{2V_T}\right)$$

$$i_0 = I_T \tanh\left(\frac{v_D}{2V_T}\right)$$



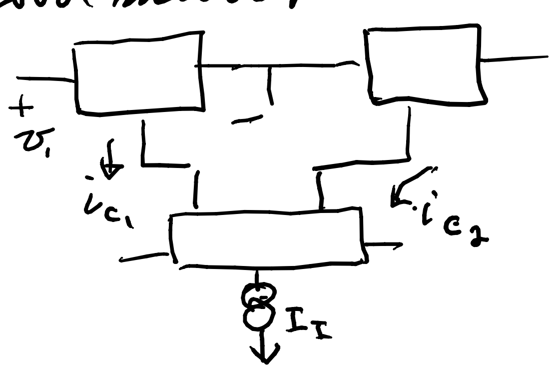
02/24/12



this is an OTA = operational transconductance amplifier

$$i_0 = I_T \tanh(v_D/2V_T)$$

To get a good multiplier



can get $i_0 = I_T \tanh\left(\frac{v_{D_1}}{2V_T}\right) \tanh\left(\frac{v_{D_2}}{2V_T}\right)$