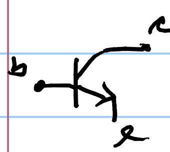
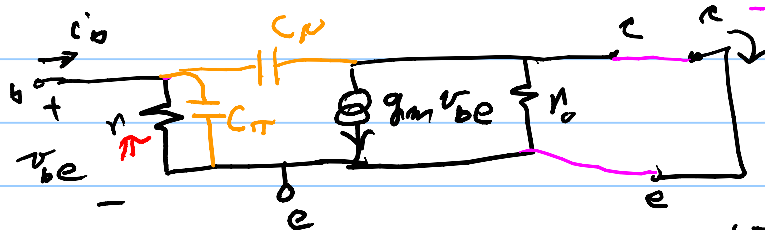
EE 303H
02/17/09

pp. $f_T \Rightarrow$ p. 489 & BJT small signal
MOS small signal p. 591
current mirrors p. 563 & 649
differential pairs p. 704, 710 (BJT)
p. 721 (MOS)

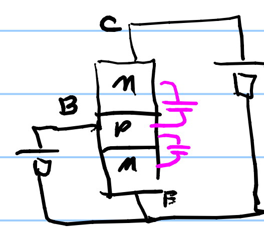
f_T = transition frequency for BJT
frequency at which $|i_c/i_b| = 1$; i.e. β drops to 1
for small signals





$$-i_c = -g_m v_{be} = -g_m r_\pi i_b$$

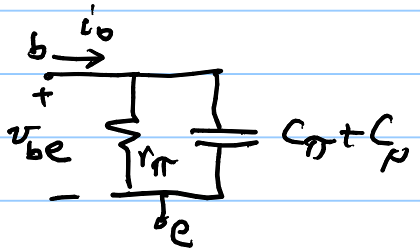
$$\frac{i_c}{i_b} = \beta = g_m r_\pi \qquad g_m = \frac{|I_c|}{V_T}$$



C's on p. 486

$$C_\pi = C_{de} + C_{je}$$

$$C_{je} = \frac{C_{je0}}{\left(1 - \frac{V_{BE}}{V_{0e}}\right)^m} \qquad V_{0e} \approx 0.75\,V$$



$$i_b = y_{be}(s) \cdot v_{be}$$

$$y_{be} = g_\pi + s(C_\pi + C_\mu)$$

$$-i_c = -g_m v_{be} = -g_m\left(\frac{i_b}{y_{be}(s)}\right) \Rightarrow \frac{i_c}{i_b} = \frac{g_m}{g_\pi + s(C_\pi + C_\mu)}$$

$$\beta(s) = \frac{g_m r_\pi}{1 + s(C_\pi + C_\mu)/g_\pi} = \frac{\beta(0)}{1 + s(C_\pi + C_\mu) r_\pi}$$

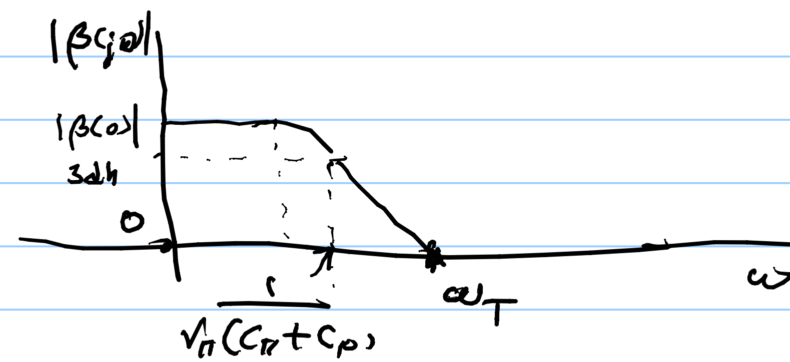
$$f_T \Rightarrow \left| \frac{i_c}{i_b}(j\omega) \right| = 1 \quad \text{i.e. when } |\beta(j\omega)| = 1$$

$$|\beta(j\omega)| = \left| \frac{\beta_0}{1 + j\omega(C_\pi + C_\mu) r_\pi} \right| = \frac{\beta_0}{\left(\sqrt{1 + \omega^2 (C_\pi + C_\pi) r_\pi}\right.}$$

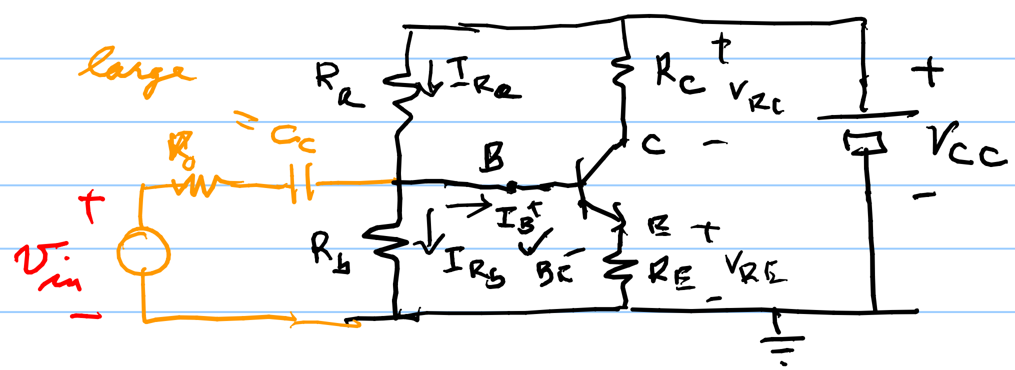
$$\approx \frac{\beta_0}{\omega (C_\pi + C_\mu) r_\pi} \quad \text{when } \omega \text{ large}$$

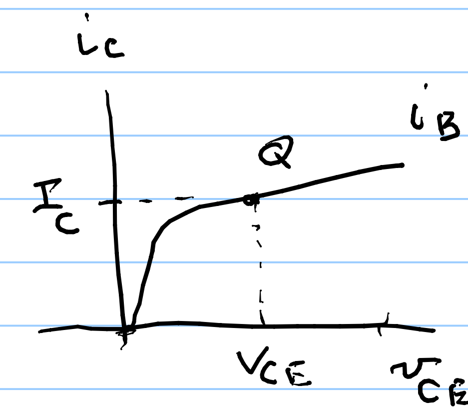
$$= 1 \Rightarrow \quad \omega_T = \frac{\beta_0}{(C_\pi + C_\mu) r_\pi} = 2\pi f_T$$

$$f_T = \frac{\beta_0}{(C_\pi + C_\mu) r_\pi}$$



Biasing of BJT's for small signal use





let $I_C = 2mA$, $\beta(0) = 100$; $I_B = \frac{I_C}{\beta} = \frac{2\times10^{-3}}{10^2} = 2\times10^{-5}$
$= 20\times10^{-6}$
$= 20\mu A$

use $V_{BE} = 0.7V$ also

$I_E = \frac{I_C}{\alpha}$; $\alpha = \frac{\beta}{1+\beta} = \frac{100}{101}$

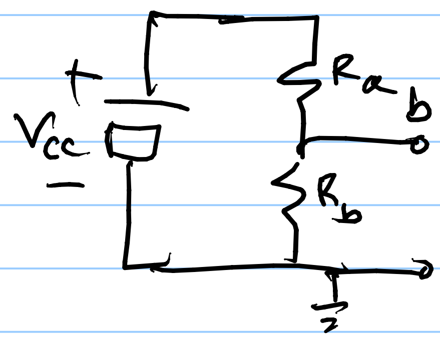
$V_{RE} = R_E \times \frac{I_C}{\alpha}$

choose R_C & R_E as 1 KΩ

$V_{R_C} = R_C I_C = 10^3 \times 2\times10^{-3} = 2V$

$V_{RE} \simeq 2V$

Make a Thevenin's equivalent for base to ground looking left



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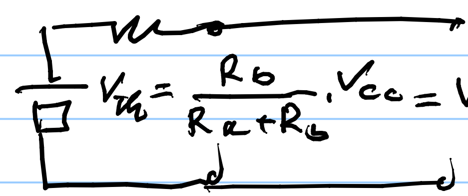
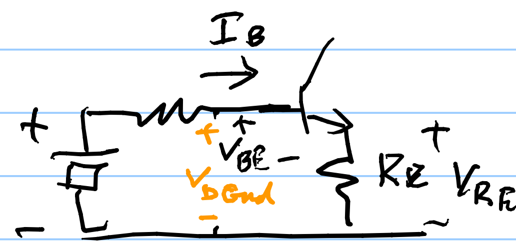
$R_a \| R_b = \frac{V_{oc}}{I_{sc}}$



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



$V_{BG} = V_{BE} + V_{RE}$

$\approx 2.7V$

$I_B = 20\mu A$

$$\frac{R_b}{R_a+R_b} V_{CC} = \frac{R_a R_b}{R_a+R_b} \cdot I_B + V_{BGnd}$$

$$\frac{1}{1+\left(\frac{R_a}{R_b}\right)} V_{CC} = \frac{1}{\frac{1}{R_b}+\frac{1}{R_a}} \cdot 20\times10^{-6} + 2.7$$

Have 3 unknowns & 1 eq.
Vcc is usually a battery say 9V.
still have 2 others: Ra & Rb can choose one
choose one large Ra say of 10 MEG ohms
& then solve for Rb (can solve as linear eq. but would get a negative value).
can have the computer solve subject to constraints.

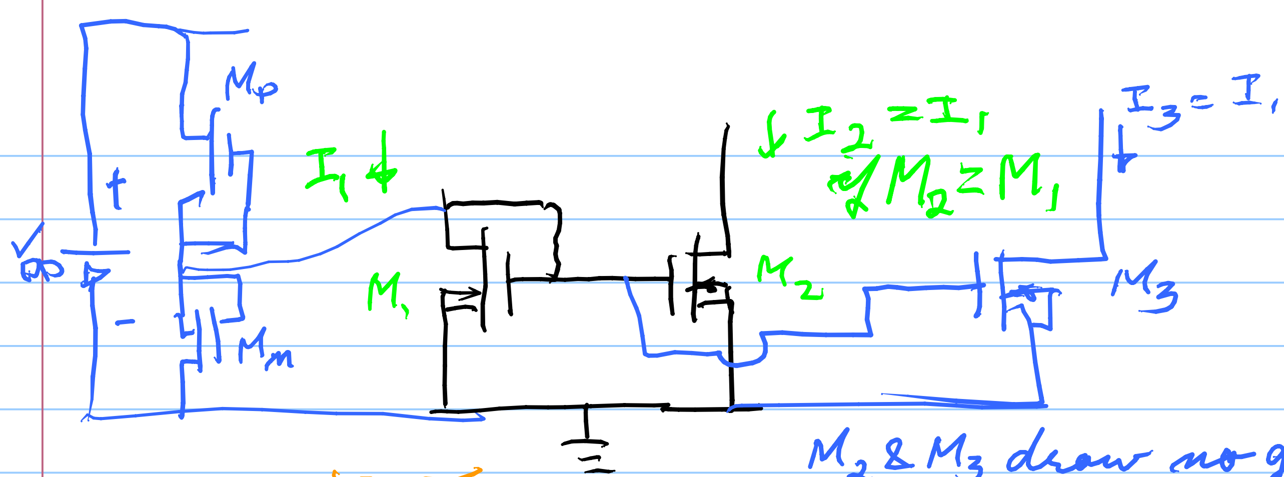
Note for a diode $i_D = I_S(e^{v_D/kT/|q|} - 1)$

as temperature, T, increases i_D decrease and becomes useless

R_E is present to stabilize the circuit w r t increases in I_C or I_B

If take signal off of R_E the circuit is an emitter follower as v_{RE} follows v_{in} (also $|v_{RE}/v_{in}| < 1$) but isolates v_{in} from loads.

Current mirrors:



in saturation
as $V_{DS} = V_{GS} > V_{GS} - VTO$ if $VTO > 0$

M_2 & M_3 draw no gate current (for bias)