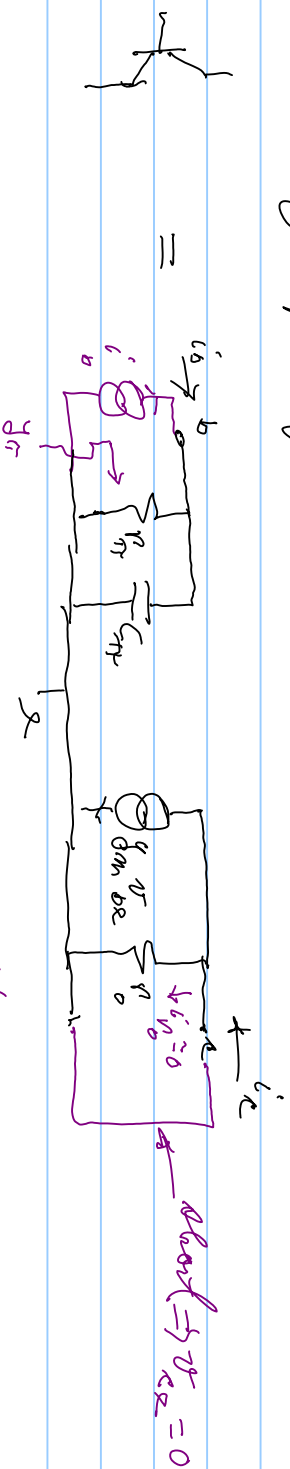


f_T = transition frequency



$$\left. \frac{i_c}{i_b} \right|_{v_{ce}=0} = \text{short circuit current gain}$$

$$g_m = \frac{I_c}{V_T}, \quad V_A = 1/g_o, \quad g_o = \frac{I_c}{V_A}, \quad 1/r_{\pi} = \frac{g_m}{\beta_0}$$

β_0 = low frequency beta

$$\begin{aligned} &= \frac{g_m v_{be}}{i_b} \quad i_b = i_{\pi} v_{be}, \quad g_{\pi} = g_{\pi} + sC_{\pi} \\ &= \frac{g_m}{g_{\pi}} = \frac{g_m}{g_{\pi} + sC_{\pi}} = \frac{\beta_0}{1 + s(\frac{C_{\pi}}{g_{\pi}})} = \beta(\alpha) \end{aligned}$$

for $s = j\omega$, $\beta(j\omega) = \frac{\beta_0}{1 + j\omega(C_{\pi}/g_m)} \Rightarrow f_T = \frac{\omega_T}{2\pi}$ for which $|\beta(j\omega)| = 1$

$$|\beta(j\omega)| = \frac{|\beta_0|}{|1 + j\omega \frac{C_{\pi}}{g_m}|} = \frac{\beta_0}{\sqrt{1 + \omega^2 \left(\frac{C_{\pi}}{g_m}\right)^2}} = 1 \text{ when } \beta_0^2 = 1 + \omega_T^2 C_{\pi}^2 / g_m^2 \Rightarrow \omega_T^2 = \frac{(\beta_0^2 - 1)}{(C_{\pi}/g_m)^2}$$

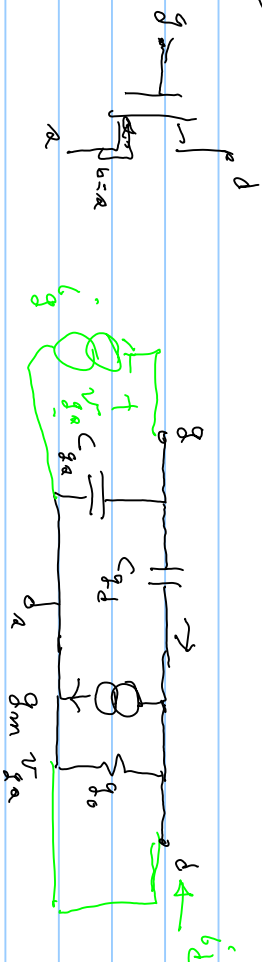
$$\omega_T \approx \sqrt{\frac{\beta_0^2}{(C_{\pi}/g_m)^2}} = \beta / C_{\pi}/g_m \text{ given by data sheet}$$

$$2\pi f_T = \omega_T$$

$$f_T = \frac{\beta}{2\pi(C_{\pi}/g_m)}$$

for 2N3904 $\Rightarrow f_T > 300 \text{ MHz}$

for MOS



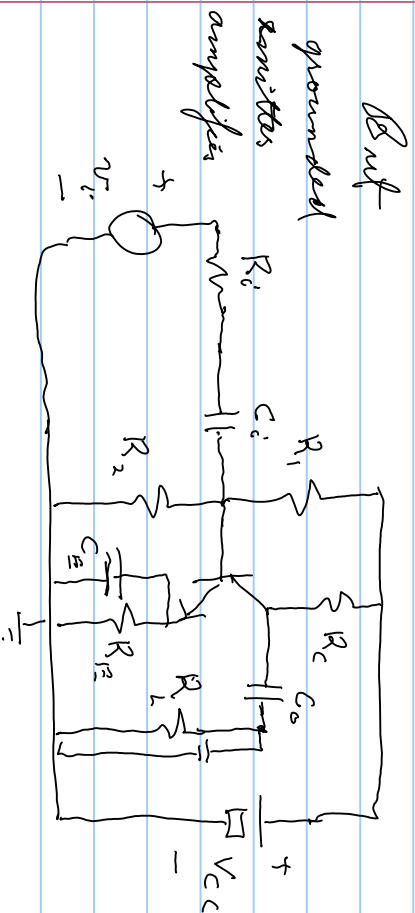
$$\left. \frac{i_d}{i_g} \right|_{v_d=0} \approx \frac{g_m v_{gs} - R_s C_{gd} v_{gs}}{(R_s C_{gs} + R_s C_{gd}) v_{gs}}$$

$$\frac{i_d}{i_g} = \frac{g_m - R C_{gd}}{R(C_{gs} + C_{gd})} \approx \frac{g_m}{R C_{gs}}$$

$$\left| \frac{i_d}{i_g} \right| \approx \frac{g_m}{j\omega C_{gs}} \Rightarrow 1 = \frac{g_m}{\omega C_{gs}}$$

$$f_T = \frac{g_m}{2\pi C_{gs}}$$

if include C_{gd}
 $| \text{numerator} | = \sqrt{g_m^2 + \omega^2 C_{gd}^2}$



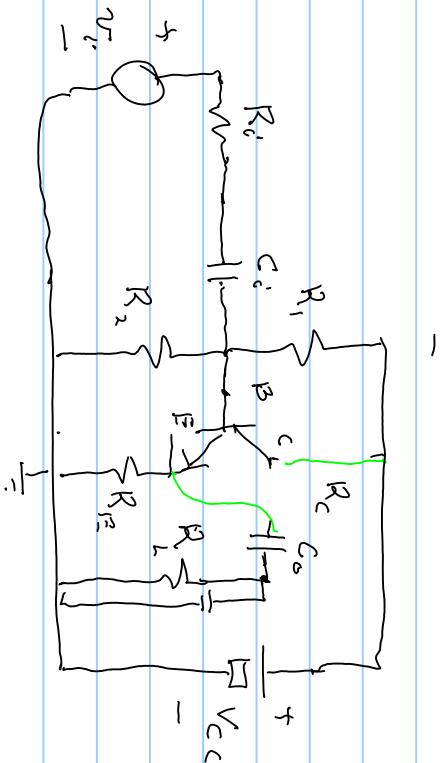
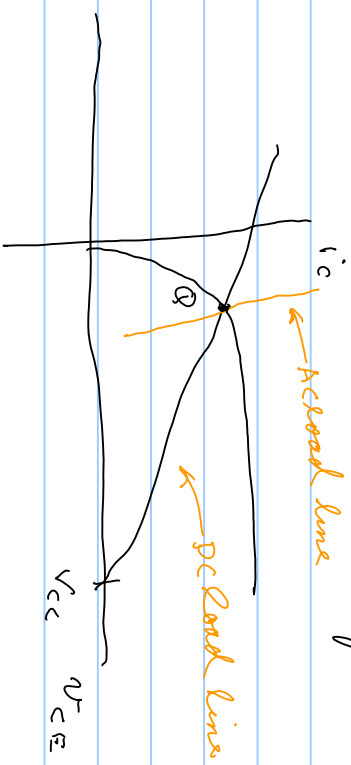
$$C \Rightarrow \text{open @ DC} \quad \frac{1}{C} = \frac{1}{\infty} \Rightarrow \infty$$

$R = 0 @ \text{DC}$

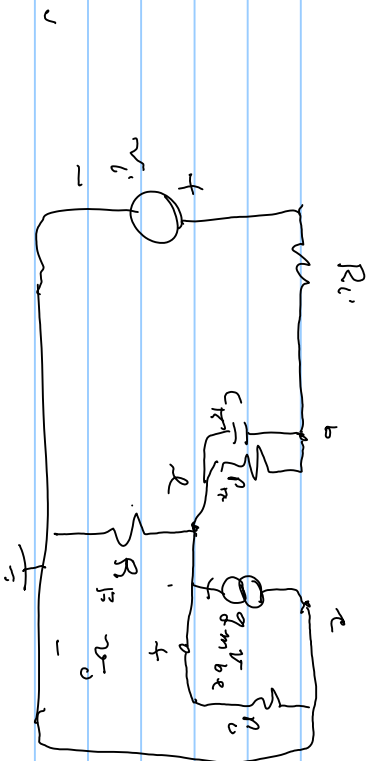
$$C \Rightarrow \text{short @ signal, } \frac{1}{\infty} = \frac{1}{0}$$

$$R = j\omega, \quad \left| \frac{1}{R} \right| = \frac{1}{C\omega} \Rightarrow \text{decreases, } 0 @ \text{nothing, } \omega \Rightarrow C \text{ large}$$

here R_i becomes in parallel with R_c & lowers the gain from $-g_m R_c$ to $-g_m \left(\frac{R_c R_i}{R_c + R_i} \right)$

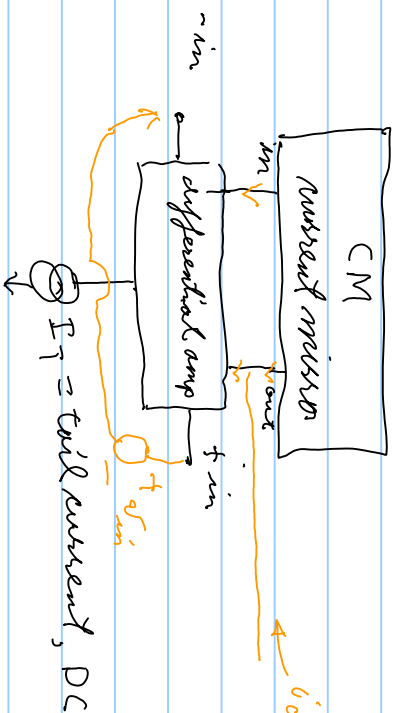


AC gain, < 1 in magnitude

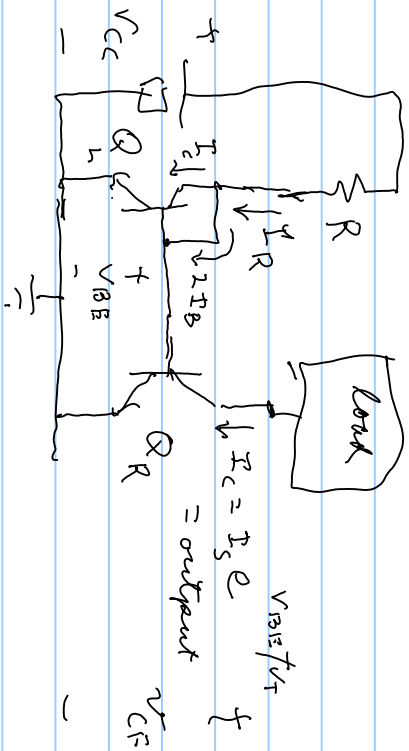


here $\left| \frac{v_o}{v_i} \right| < 1$
 $A = \beta \omega$

The OTA = operational transconductance amplifiers, the opice G

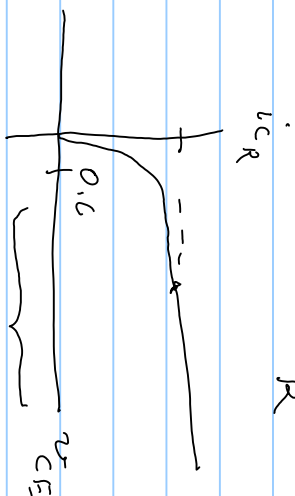


$i_{out} = G_m v_{in}$ for small signal
 $\approx I_T \tanh\left(\frac{v_{in}}{2V_T}\right)$ if BJT for large signal



$$R I_R = (V_{CC} - V_{BE}) = V_{CC} - 0.7$$

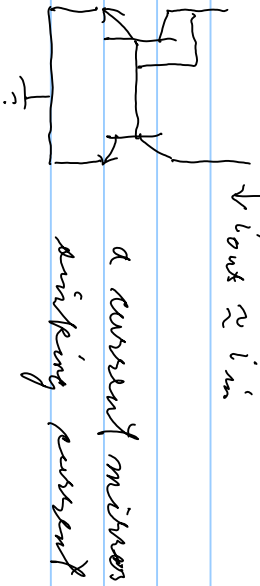
$$I_R = \frac{V_{CC} - 0.7}{R} \text{ on left circuit}$$



works well here for BJT

current source that is a sink
& is a current mirror

i_{in}
 $i_{out} \approx i_{in}$



a current mirrors
mirroring current

