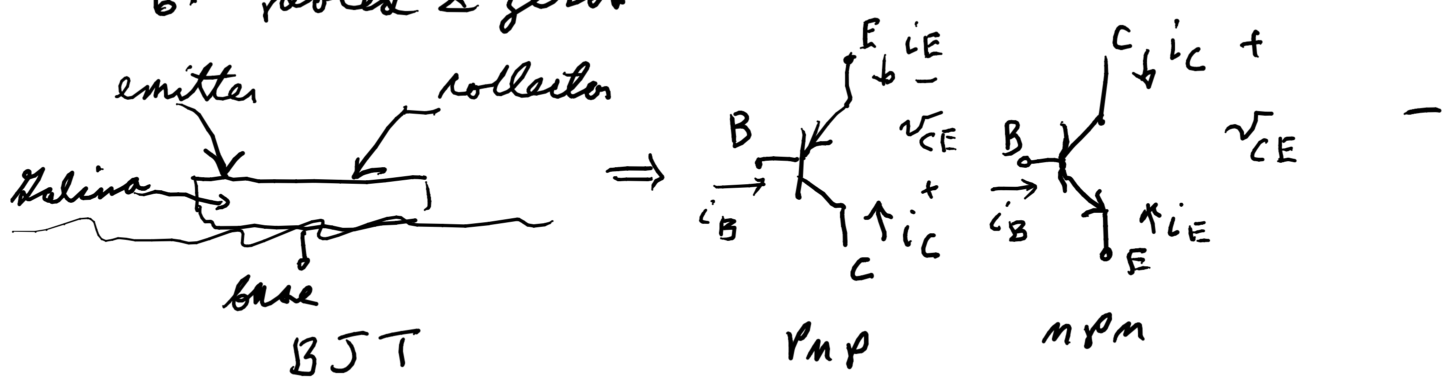
EE303H
10/27/11

Note Title 10/22/2011

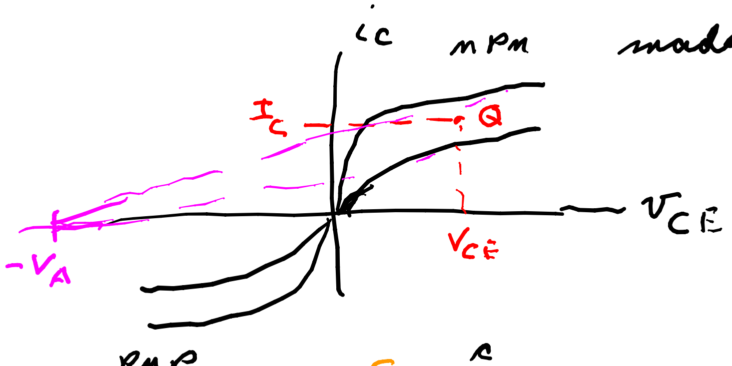
Exam: open book, notes

question topics

1. npn vs pnp (BJT)
2. small signal π equivalents BJT & MOS
3. emitter followers
4. current mirror, CMOS & input vs. output
5. op-amps with frequency response
6. poles & zeros



made solid state



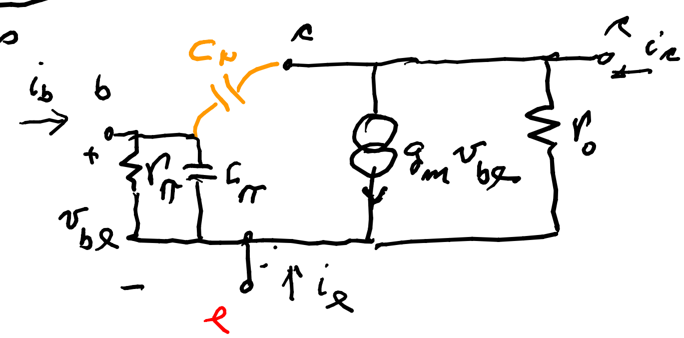
KCL: $0 = i_B + i_C + i_E$

$i_C = \alpha(-i_E) = \beta i_B$; $\alpha > 0$, $\beta > 0$

$\beta = \frac{\alpha}{1-\alpha}$, $\alpha = \frac{\beta}{1+\beta} < 1$

> 1

Small signal equivalent

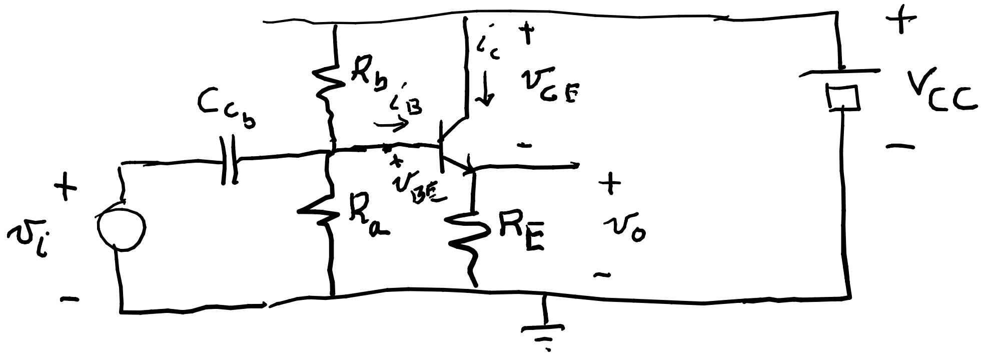


bias, $V_{BE} \sim 0.7$

$g_m = \frac{|I_C|}{V_T}$; $V_T = \frac{kT}{|Q|} \approx 26\text{mV}$ @ room T

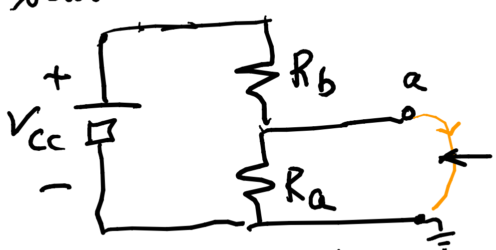
$g_\pi = \frac{g_m}{\beta}$, $g_o = \frac{|I_C|}{V_A}$

an emitter follower



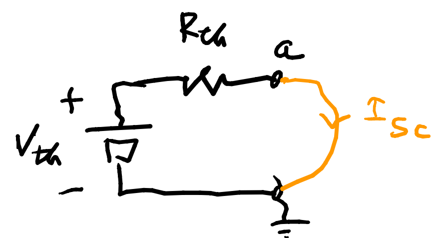
$v_{BE} = 0.7$

for bias



seen by base

Use Thevenin's equivalent

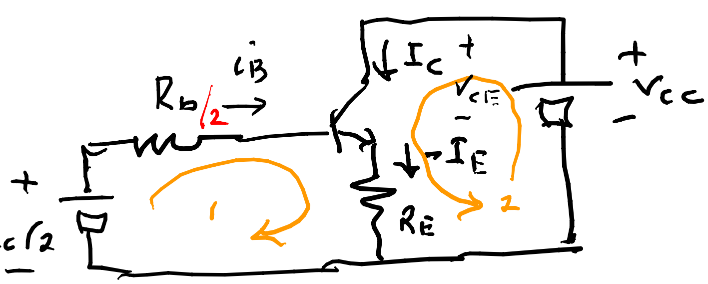


$$V_{oc} = V_{th} = \frac{R_a}{R_a+R_b} \cdot V_{cc}$$

$$I_{sc} = \frac{V_{th}}{R_{th}} = \frac{V_{cc}}{R_b}$$

$$\Rightarrow \quad R_{th} = \frac{R_b}{V_{cc}} \times V_{th} = \frac{R_b}{V_{cc}} \cdot \frac{R_a}{R_a+R_b} \times V_{cc} = \frac{R_a R_b}{R_a+R_b} = R_a \parallel R_b$$

if $R_a = R_b \Rightarrow R_{th} = \frac{1}{2} R_a$ so let $R_a = R_b$



$5 = v_{cc}/2$

$I_c = \alpha(-I_E)$

$v_{cc} = 10$, $v_{CE} = 6$, $R_a = R_b = 10^{+6}\Omega = 1\,\text{MEG}$, $\beta = 99$

find R_E

DC

KVL = 0 $\quad -\frac{V_{cc}}{2} + \frac{R_b}{2} I_b + V_{BE} + R_E(-I_E) = 0$, $\quad I_c = \beta I_B$

loop 1 $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad = -\alpha I_E$

1) $\Rightarrow -5 + 0.7 + \left(\frac{10^{+6}}{200} + R_E\right)(-I_E) = 0$ $\qquad I_B = \frac{\alpha}{\beta} \cdot (-I_E)$

$= \frac{1}{\beta+1} \cdot (-I_E)$

loop 2

2) KVL = 0 $\quad -V_{cc} + V_{CE} + R_E(-I_E) = 0$

$-10 + 6 + R_E(-I_E) = 0$

$$(-I_E) \overset{1)}{=} \frac{4.3}{5\times10^3 + R_E} = \frac{4}{R_E} \Rightarrow 4.3 R_E = 2\times10^4 + 4R_E$$

$$0.3\, R_E = 2\times10^4 \Rightarrow R_E = \frac{2}{3}\times10^5$$

$$= 6.66\times10^4$$

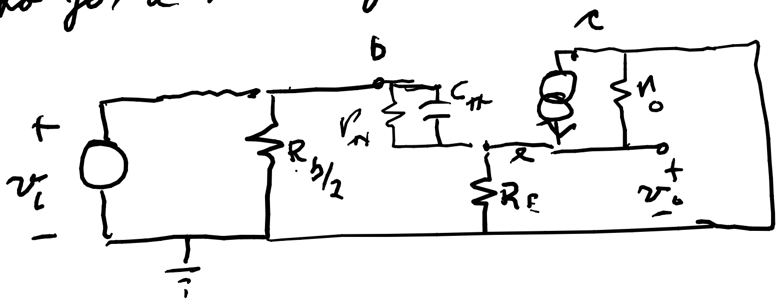
$$\approx 67\,K\Omega$$

$$-I_E = \frac{4}{2/3 \times 10^5} = 6\times10^{-5} = 60\times10^{-6} = 60\mu A$$

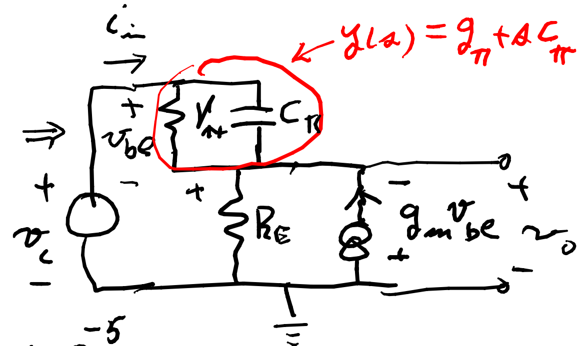
$$I_C = \alpha(-I_E) = \frac{\beta}{\beta+1}(-I_E) = \frac{99}{100} \cdot 60\mu A \;;\; I_B = \frac{I_C}{\beta} = \frac{60}{100}\mu A$$

small signal gain: assume $V_A = 100$

(also for a source follower)



$\Rightarrow$



$$g_m = \frac{I_C}{V_T} = \frac{60}{100}\times10^{-6}\times\frac{1}{26\times10^{-3}} = (3/1.3)\times10^{-5}\,\mho$$

$$g_\pi = \frac{g_m}{\beta} = \frac{3}{1.3}\times\frac{10^{-5}}{99} \approx 2\times10^{-7}\,\mho, \quad g_o = \frac{I_C}{V_A} = \frac{60}{(100)^2}\times10^{-6}$$

desire $\frac{v_o}{v_i} \Rightarrow$

$$v_i = v_{be} + v_o \;; \qquad 1)$$

$$y\, v_{be} = i_{in} = G_E v_o - g_m v_{be} \qquad 2)$$

$$2) \equiv \quad (y + g_m)v_{be} = G_E v_o \Rightarrow v_{be} = \frac{G_E}{y+g_m} v_o$$

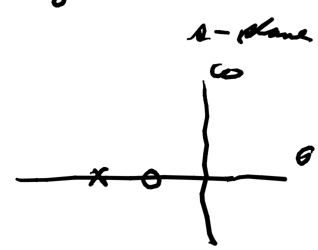
$$\Rightarrow 1) \quad v_i = \left(\frac{G_E}{y+g_m} + 1\right) v_o \Rightarrow \frac{v_o}{v_i} = \frac{y+g_m}{G_E+g_m+y}$$

$$= \frac{1}{1 + \frac{G_E+g_m}{y}}$$

$$\left|\frac{v_o}{v_i}\right| < 1 \;; \quad \frac{v_o}{v_i} = \frac{(g_\pi+g_m) + sC_\pi}{(G_E+g_m+g_\pi) + sC_\pi}$$

pole: $s = -(G_E + g_m + g_\pi)/C_\pi = -1/R_{eq}C_\pi$

zero: $s = -(g_m + g_\pi)/C_\pi$

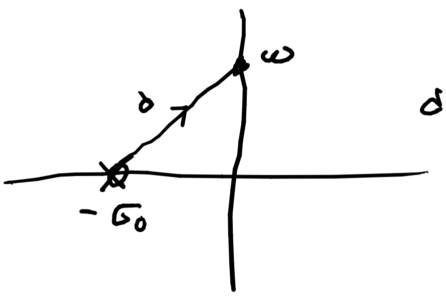


for sine waves, $s = j\omega$

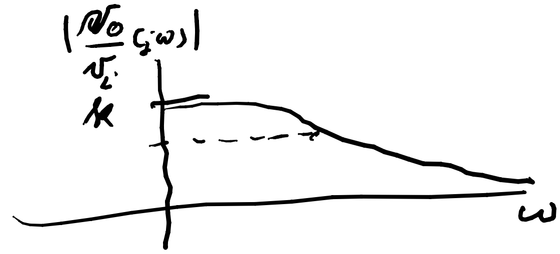
$$\frac{v_o}{v_i} = \frac{g_1 + j\omega C_\pi}{(G_E + g_1) + j\omega C_\pi} \; ; \quad \left|\frac{v_o}{v_i}\right| = \frac{\sqrt{g_1^2 + \omega^2 C_\pi^2}}{\sqrt{(g_1 + g_E)^2 + \omega^2 C_\pi^2}} < 1 \quad \text{for } \omega < \infty$$

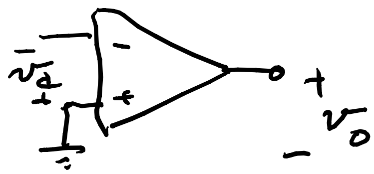
Look $\quad \frac{v_o}{v_i}(s) = \frac{k\sigma_0}{s + \sigma_0} \; ; \quad \left|\frac{v_o}{v_i}(j\omega)\right| = \frac{|k\sigma_0|}{\sqrt{\sigma_0^2 + \omega^2}}$

$\sigma_0 > 0$



$d = \sqrt{\omega^2 + (-\sigma_0)^2}$





$$\frac{v_o}{v_d} = \frac{k\sigma_0}{s + \sigma_0}$$

$\equiv$