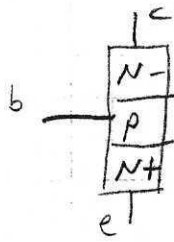


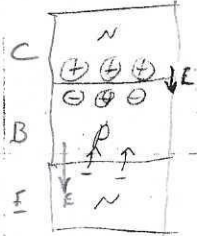
# Transistors at RF

Problem 1 Device parasitics & Input Loading  
 Consider transistor structure:



"Junction C"

"Diffusion C"



$$C = \frac{Q}{V}$$

(Similar issue in JFET & P-FET)

Example: MMBV5179 at  $I_c = 3\text{mA}$ ,  $V_{cb} = 4\text{V}$

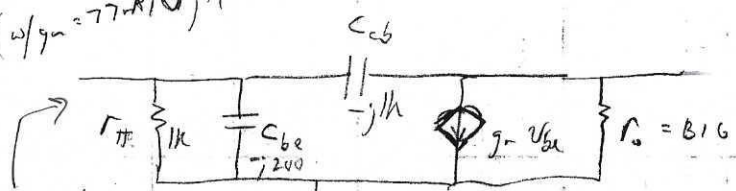
$C_{cb} = 1.5\text{pF}$   $X_{C_{cb}} = 1\text{K}\Omega$  @  $100\text{MHz}$

$C_{be} = 8\text{pF}$   $X_{C_{be}} = 200\Omega$  @  $100\text{MHz}$

Result  $f_T = \frac{1}{2\pi r_{\pi} C_{be}}$   
 ( $\omega/g_m = 77\text{A/V}$ )  $f_T = 1.56\text{GHz}$

(compare  $\omega / 1/r_{\pi} = h_{fe} \frac{1}{r_{\pi}} \approx 1\text{K}$ )

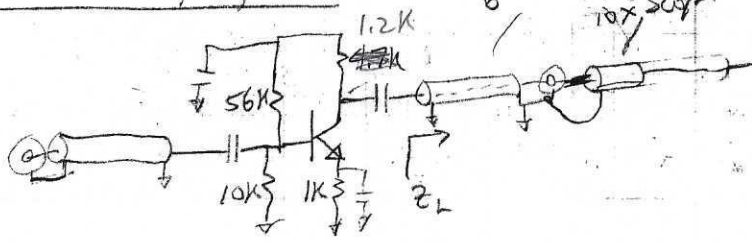
AC model @  $100\text{MHz}$



$Z_{in} \approx \frac{1}{2\pi f (C_{be} + C_{cb})}$

★ Show Data Sheet

Capacitive output  
Problem 2 ~~loading~~



6" coax @  $(3\text{pF/ft}) = 1.5\text{pF}$   
 10x Scope Probe ( $13\text{pF} || 10\text{M}\Omega$ )  
 muckless at high freq !!

★ Show COAX Data

$\Rightarrow Z_L = 10\text{M} || 15\text{pF} || (30\text{pF/ft} \times .5\text{ft})$   
 $\approx 10\text{M} || 30\text{pF}$   
 $\approx 510\text{M}\Omega$  @ DC

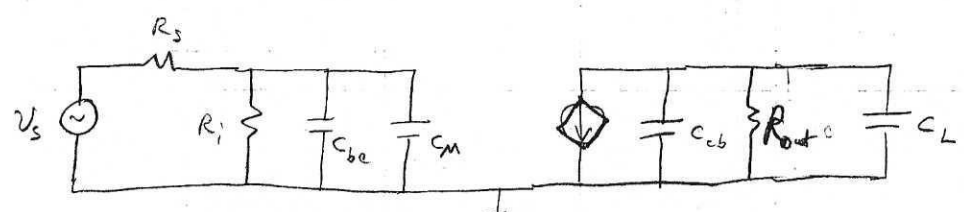
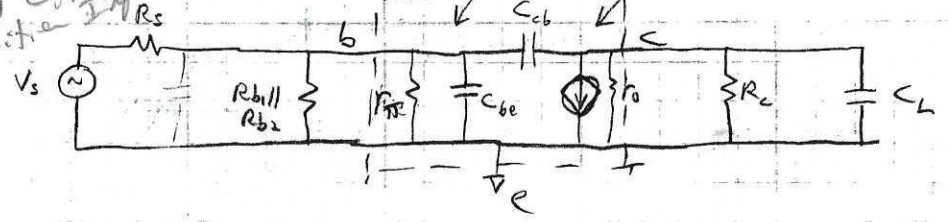
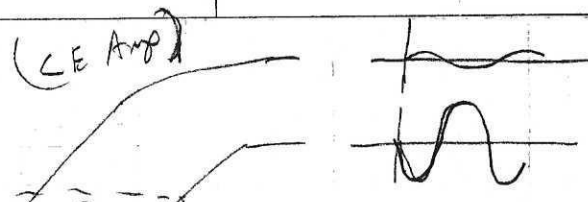
$\therefore 53\Omega$  @  $100\text{MHz}$  !

Compare with  $R_c = 1.2\text{K}$   
 and recall  $A_{v1}$  is now  $g_m / Z_c$   
 $\ll g_m R_c$

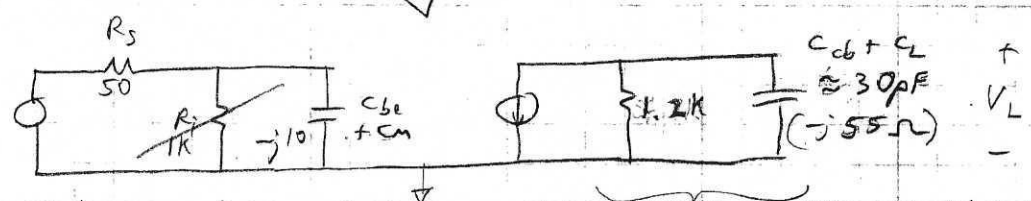
$f = \frac{1}{2\pi R C}$

High Frequency Response

~~Distortion~~  
 Feedback & Miller Effect  
 Magnitude Input Loadin

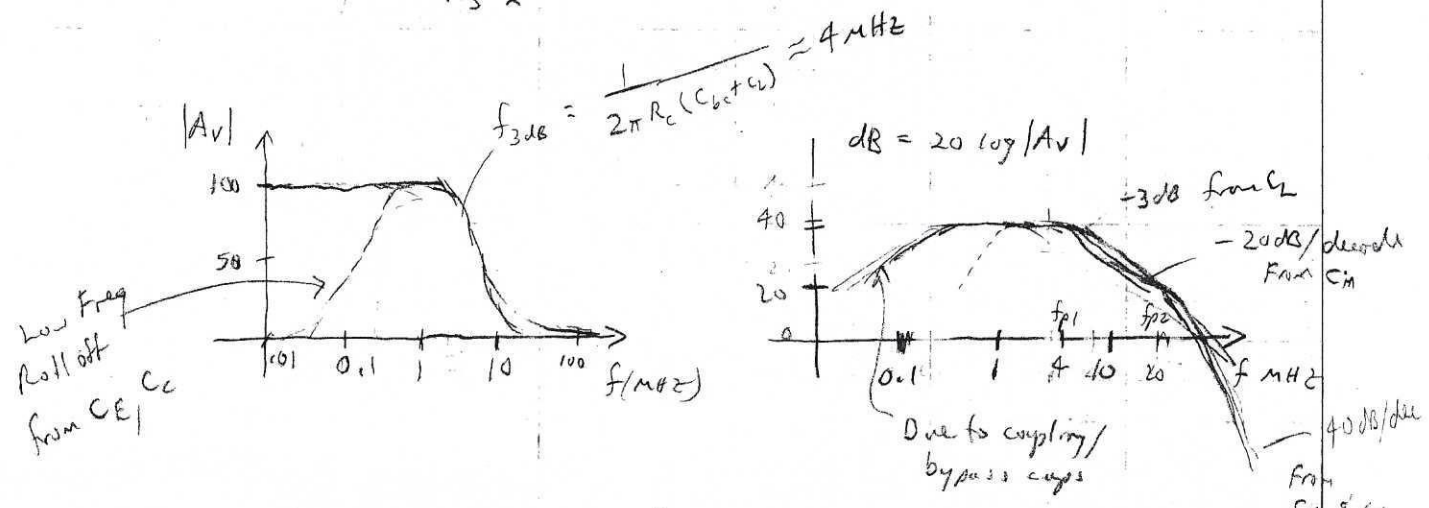


where  $C_m = (1 + |A_v|) C_{cb}$   
 $= \text{BIG!}$  (152 pF for  $A_v = 100$ ,  $C_{cb} = 1.5 \text{ pF}$ )  
 $= -j10 \Omega$  @ 100 MHz !!



$\approx 5:1$  Gain Reduction  
 $|X_{C_{be} + C_m}| \approx 10 \Omega$  at 100 MHz  $\ll R_s$

$\approx 22:1$  Gain Reduction!  
 $A_v = g_m (R_c || jX_c) \ll g_m R_c$  @ 100 MHz

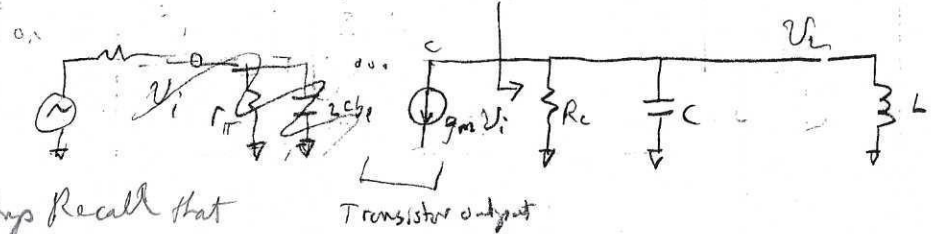


Might want to make lower corner = 100 kHz

60 SHEETS 50 SQUARE  
 100 SHEETS 50 SQUARE  
 200 SHEETS 50 SQUARE  
 42-392 100 RECYCLED WHITE 5 SQUARE  
 42-399 200 RECYCLED WHITE 5 SQUARE  
 Made in U.S.A.

Solution: 1 Resonance (at output)

Add inductor at output =  $Z$



For Basic Amp Recall that

$$\begin{aligned}
 |A_v| = \left| \frac{V_L}{V_i} \right| &= g_m Z \\
 &= g_m (R_c \parallel X_c \parallel jX_L) \\
 &= g_m \frac{1}{\frac{1}{R_c} + \frac{1}{-jX_c} + \frac{1}{jX_L}}
 \end{aligned}$$

Pick L so

gets to zero when  $X_c = X_L$

$$|X_L| = |X_c| \text{ at } f = f_0$$

Then

$$\left. \frac{V_L}{V_i} \right|_{f_0} = -g_m R_c !$$

Gain Fully Restored!

Plot  $A_v(f)$ :

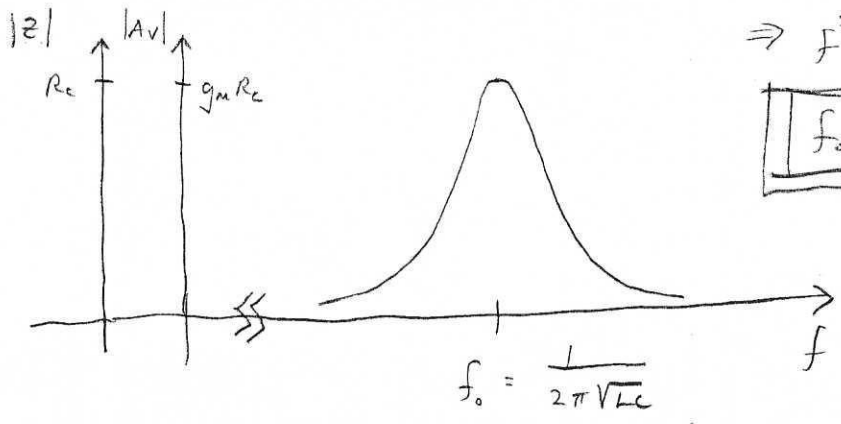
- At  $f \rightarrow 0$ ,  $X_c \rightarrow 0 \Rightarrow Z \rightarrow 0 \Rightarrow A_v \rightarrow 0$
- At  $f \rightarrow \infty$ ,  $X_c \rightarrow 0 \Rightarrow A_v \rightarrow 0$
- At  $f_0$   $X_c = X_L \Rightarrow Z = R_c \Rightarrow |A_v| = g_m R_c$

What is  $f_0$ ?

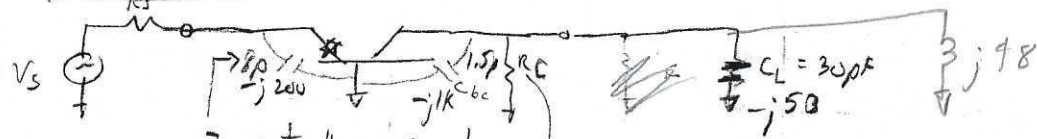
$$X_c = X_L \Rightarrow \frac{1}{2\pi f C} = 2\pi f L$$

$$\Rightarrow f^2 = \frac{1}{(2\pi)^2 LC}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



Solution 1 Use CB or Cascode configuration to address Miller effect.  
 CB AC SS ckt:  $A_v = +g_m(R_C \parallel \frac{1}{j\omega C_C})$  & Reduce  $C_{in}$



$$Z_{in} = \frac{1}{j\omega} \parallel -jX_{C_{be}} \approx \frac{1}{j\omega}$$

$$f_{3dB} = \frac{1}{2\pi(R_{in} \parallel R_s) C_{be}}$$

small

$$f_{3dB} = \frac{1}{2\pi R_C (C_{cb} + C_L)}$$

large

Explain "time constant" method

Not much problem

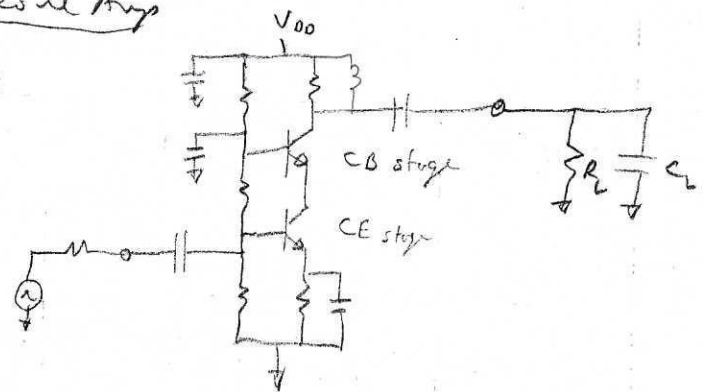
Still a problem

Since  $R_s \parallel R_{in}$  is small compared w/  $-jX_{C_{be}} = -j200$

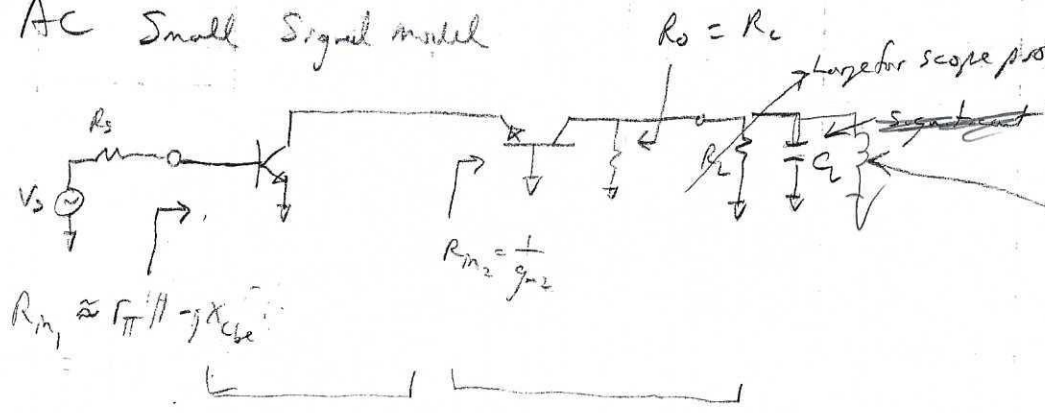
And ~~Miller effect~~ No Miller effect!

Cascode Amp

Full ckt:



AC Small Signal model



$$R_{in1} \approx R_s \parallel -jX_{C_{be}}$$

$$A_{v1} \approx -g_{m1} R_{in2}$$

$$= -g_{m1} \frac{1}{g_{m2}}$$

$$= -1$$

$$A_{v2} = +g_{m2} (R_C \parallel R_L)$$

Total

$$A_v = A_{v1} A_{v2} \approx g_{m2} R_C$$

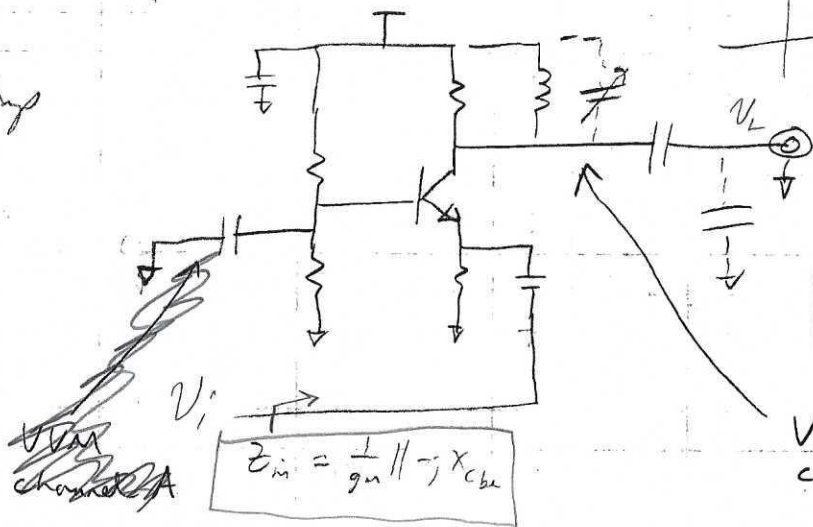
(Very small Miller effect)  
 $\Rightarrow$  input roll off fixed, mostly

Output gain from  $V_o$  to  $V_i$  since in CE amp  
~~still have Miller effect~~  
~~problem at output~~

13-762  
 500 SHEETS, FILLER, 5 SQUARE  
 42-381  
 50 SHEETS EYE-EASER, 5 SQUARE  
 42-382  
 200 SHEETS EYE-EASER, 5 SQUARE  
 42-392  
 100 RECYCLED WHITE, 5 SQUARE  
 42-399  
 200 RECYCLED WHITE, 5 SQUARE  
 Made in U.S.A.  
 National Brand

Complete ckt = (Project 1b)

CB RF Amp

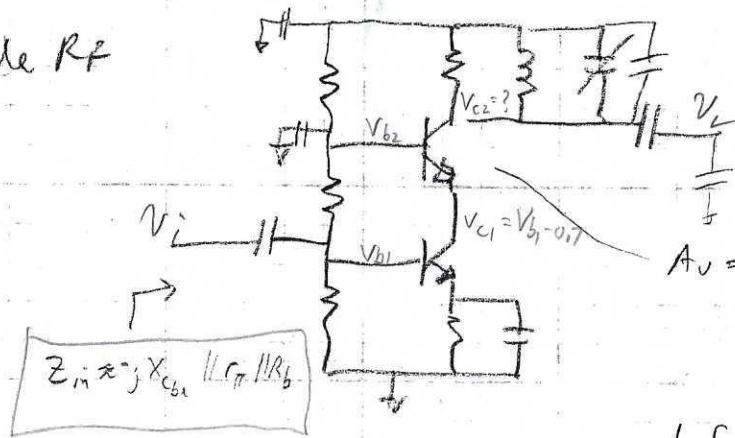


$$\frac{V_c}{V_i} = +g_m Z(f)$$

VVM channel B

$$Z_{in} = \frac{1}{g_m} \parallel -jX_{cbe}$$

Cascode RF Amp



$$\frac{V_c}{V_i} = -g_m Z(f)$$

$$A_v = g_m Z$$

$$Z = R_c \parallel X_L \parallel X_{ce} \parallel R_L$$

$$= R_c \parallel R_L$$

at f where  $X_{ce} = X_L$

$$Z_{in} \approx -jX_{cbe} \parallel R_{\pi} \parallel R_b$$

Find f where  $X_{ce} = X_L$

$$\frac{1}{2\pi f C} = 2\pi f L$$

$$\Rightarrow f^2 = \frac{1}{(2\pi)^2 LC}$$

$$\Rightarrow f = \frac{1}{2\pi \sqrt{LC}}$$

nTrans LNA +

★ Show inductor construction sheets

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