piazza, bcourses, website

section

lab - LTSPICE

"normal" mode: $V_{BA} > V_x$

$V_{CA} > V_y > 0$

BJT "forward active"

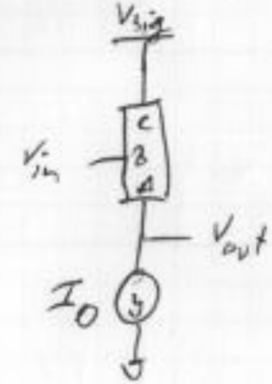
$V_{BE} \geq$ roughly 0.5V

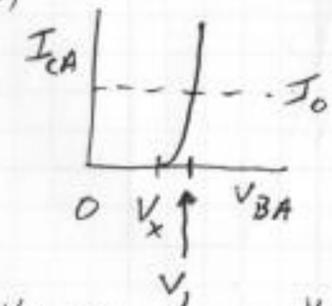
$V_{CE} > V_{CESAT} \approx 0.3V$

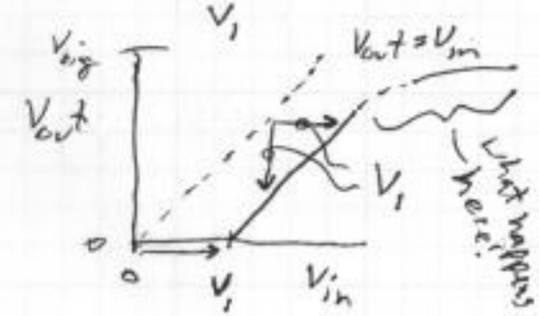
cathode follower (1934)

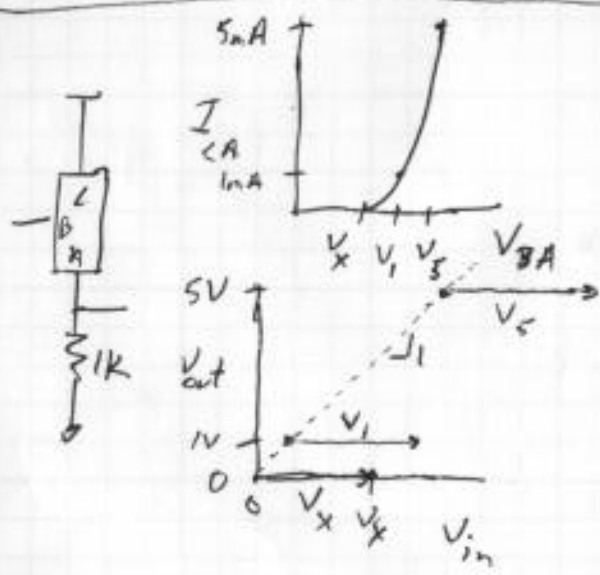
emitter follower

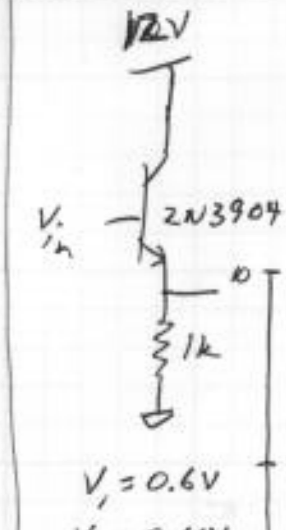
source follower

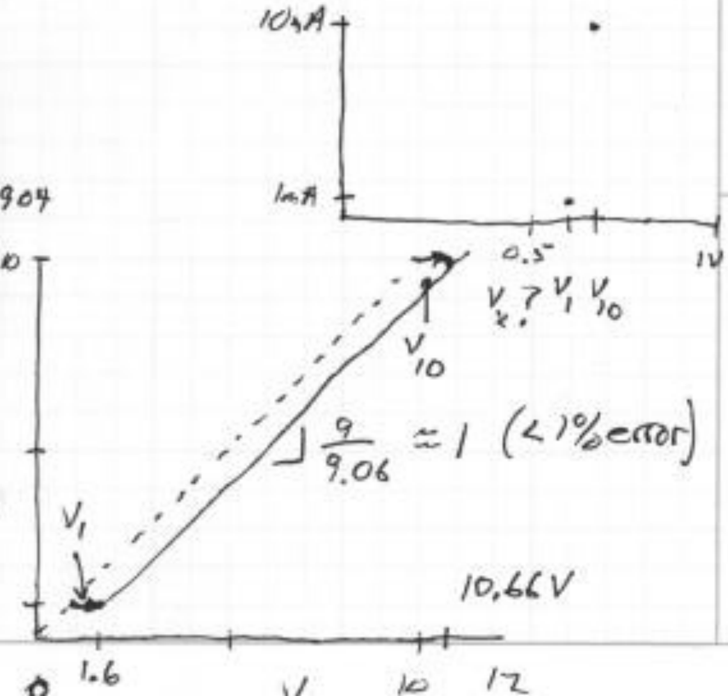










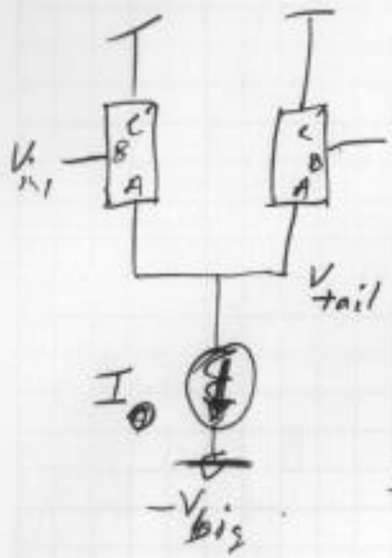


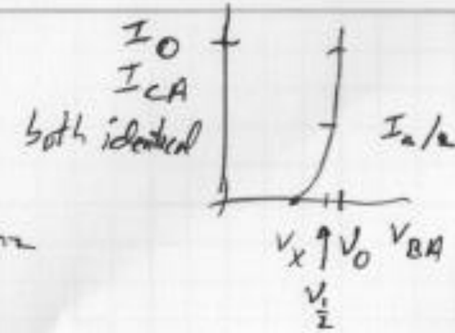
$\frac{9}{9.06} \approx 1$ (<1% error)

$V_1 = 0.6V$

$V_{10} = 0.66V$

Diff pair (1936)



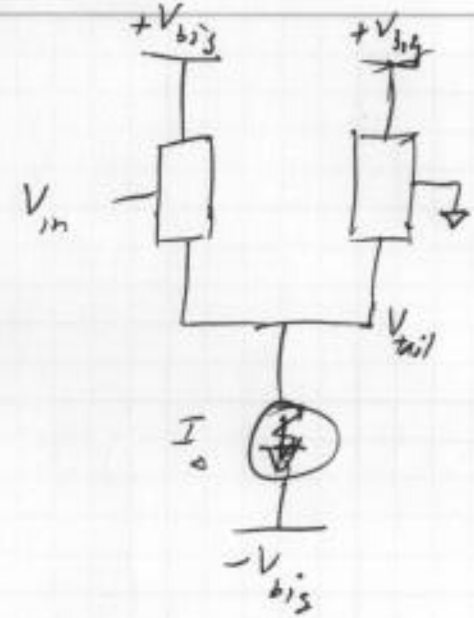


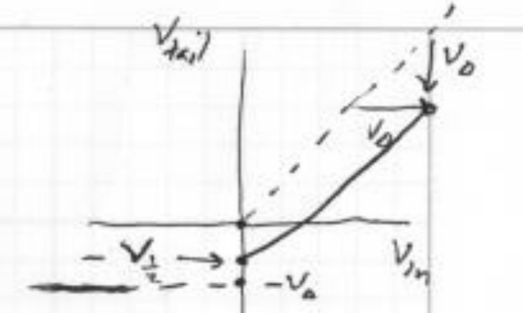
if $V_{in1} = V_{in2}$

$I_{CA1} = I_{CA2} = I_0/2$

If $V_{in1} >> V_{in2}$ $\Leftarrow$ how much?

$I_{C1} = I_0$ $\quad I_{CA2} = 0$

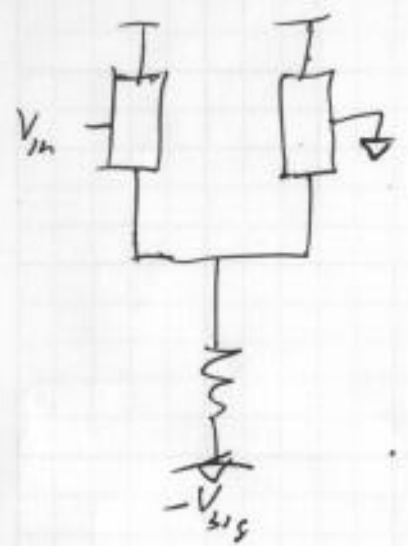




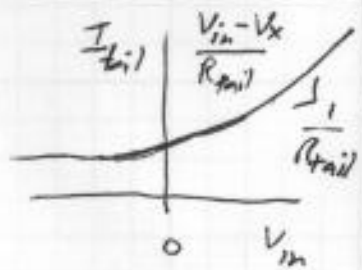
$V_{in} < 0$ $\quad I_{CA1} = 0$

$V_{tail} = V_{B2} - V_0$

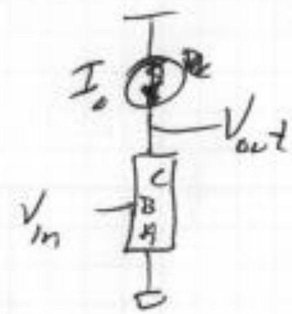
$= -V_0$

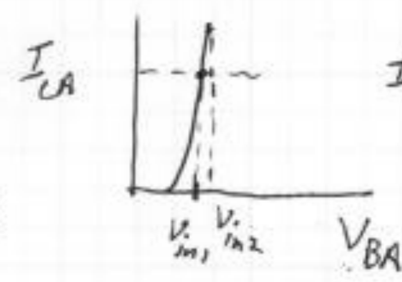


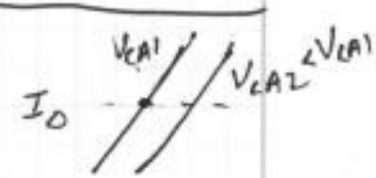
$\frac{0 - V_x}{R_{tail}}$

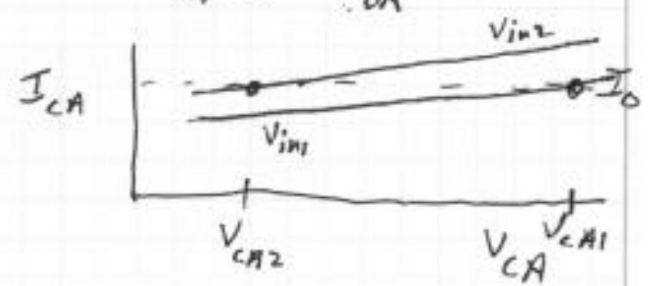


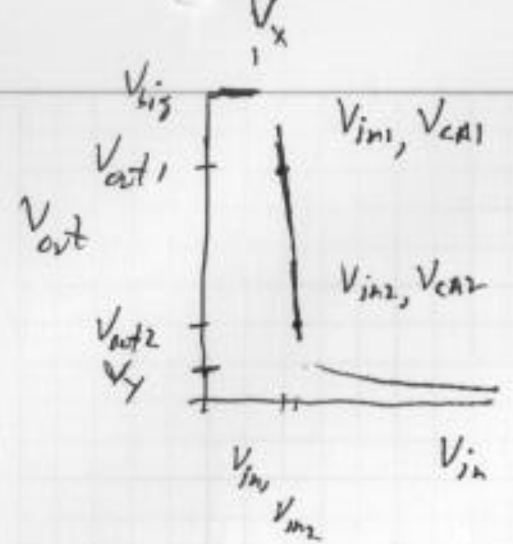
gain







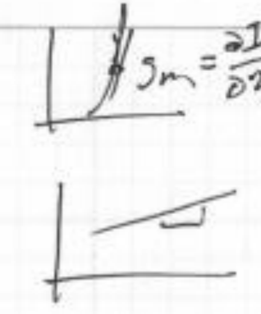




3 regions : too little, normal, too much

gain ⇒ input range is smaller than output range.

what's the gain?



input: $\delta i_i = g_m \delta v_i$

output: $\delta i_o = g_o \delta v_o$

but I_o is const, so $\delta i_i + \delta i_o = 0$

$$\frac{\delta v_o}{\partial v_i} = -\frac{g_m}{g_o}$$

Why not just calculate directly?

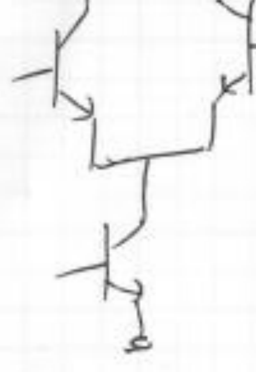
$V_o = V_{CC} - I_c R$

V_o

$$I_c = I_s\left(e^{\frac{V_{BE}}{V_{TH}}} - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$V_o = V_{CC} - RI_s\left(e^{\frac{V_{BE}}{V_{TH}}}\right)\left(1 + \frac{V_o}{V_{TH}}\right)$$

this you can solve by hand



essentially impossible to solve closed form by hand.

Easy for numerical soln.

linearization gives reasonable accuracy as long as you get the region of operation right

meaning depends on specs, but usually

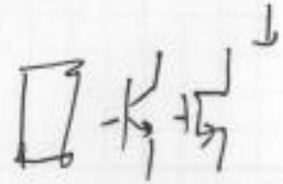
Taylor

$f(x,y)$ cont.

$f(X_0, Y_0) = f_0$

best approx near X_0, Y_0?

$$f(X_0+\delta x, Y_0+\delta y) = F(X_0, Y_0) + \left.\frac{\partial f}{\partial x}\right|_{X_0,Y_0} \delta x + \left.\frac{\partial f}{\partial y}\right|_{X_0,Y_0} \delta y + \text{h.o.t.}$$



$$I_D = \begin{cases} \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS}-V_t)^2 (1+\lambda V_{DS}) \\ \text{etc.} \end{cases}$$

Find some DC bias point $I_d(V_{GS0}, V_{DS0}) \equiv I_{D0}$

$$I_d(V_{GS}+v_{gs}, V_{DS}+v_{ds}) = I_{D0} + \underbrace{\frac{\partial I}{\partial V_{gs}}}_{g_m} v_{gs} + \underbrace{\frac{\partial I}{\partial V_{ds}}}_{g_o} v_{ds} + \underbrace{\text{h.o.t.}}_{\text{error}}$$

$I_d = I_D + i_d =$

$i_d = g_m v_{gs} + g_o v_{ds}$

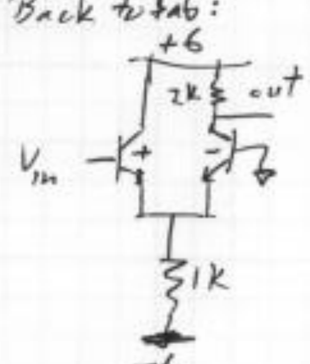
$$\begin{pmatrix}\text{full non-linear} \\ \text{statics}\end{pmatrix} = \begin{pmatrix}\text{one D.C.} \\ \text{operating} \\ \text{point}\end{pmatrix} + \begin{pmatrix}\text{small} \\ \text{signal} \\ \text{model}\end{pmatrix} + \text{h.o.t}$$

hard to solve — solve 1 nonlinear problem — Taylor local derivatives — error

gain exact at that 1 pt

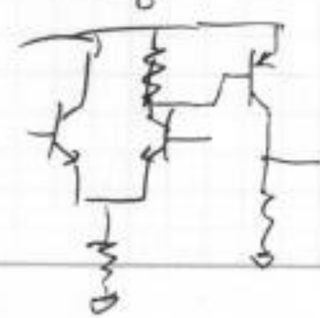
BJT/ESA model

Back to lab:



$V_{in} = 0$ DC bias point

What is V_{out}?



looks great in feedback!

DC sweep awesome

when I build it... gah!