Piazza, web page, bcourses

Lab 1 LTSPICE

HW 1

Reading

notation convention

$$\underset{\text{actual, total, instantaneous}}{V_a} = \underset{\text{bias}}{V_A} + v_a$$

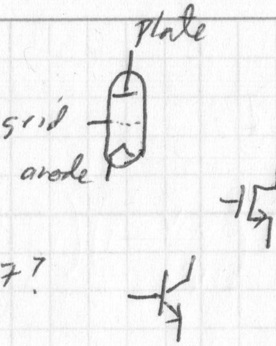
$$I_b = I_B + \underset{\text{small signal}}{i_b}$$

Devices

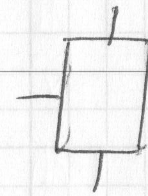
de forest 1911?

Lillienfield 1927?

Bardeen, Brattain, Schockley 1947?



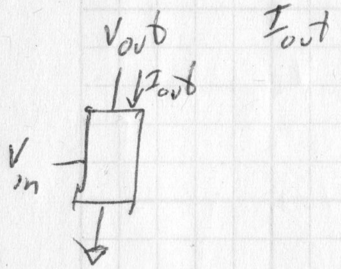
All have the same basic property:



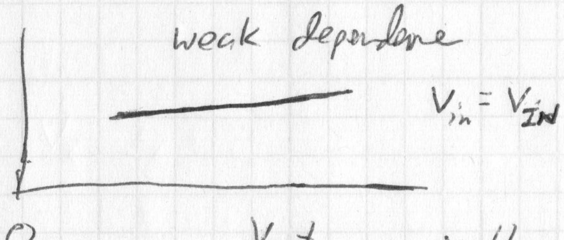
1 input has a strong influence on current in the other

1 has a weak influence.

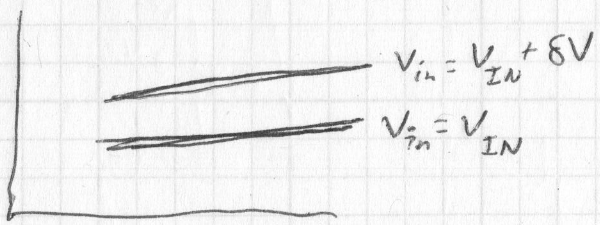
tube, BJT, MOS



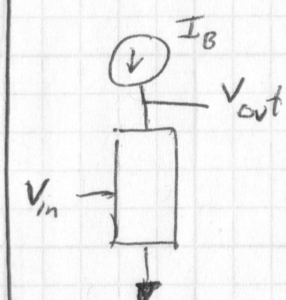
weak dependence

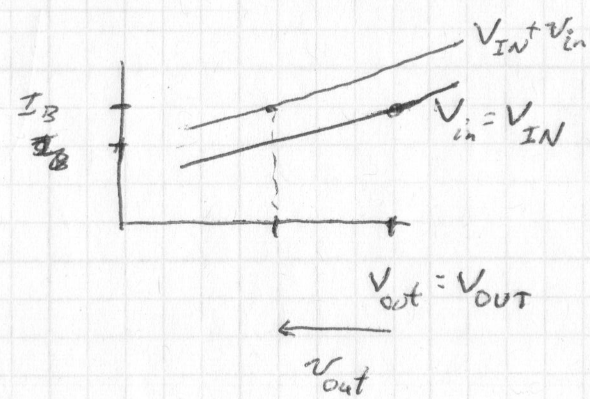


(to hundreds of volts for some.)



strong control - δV in millivolts



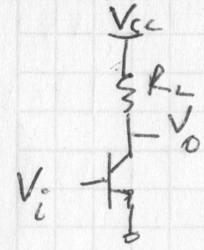


Small v_{in}

big (negative) v_{out}

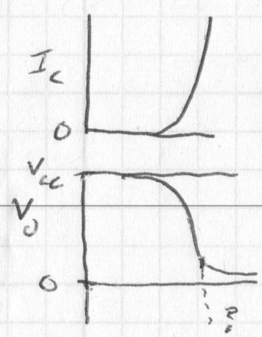
steep and shallow hillsides, and contours

Bairearization

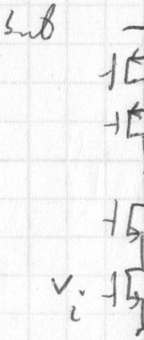


$$V_o = V_{cc} - I_c R_L$$
$$= V_{cc} - I_s\left(e^{V_i/V_T} - 1\right)\left(1 + \frac{V_o}{V_A}\right) R$$
$$\approx V_{cc} - I_s e^{V_i/V_T} R$$

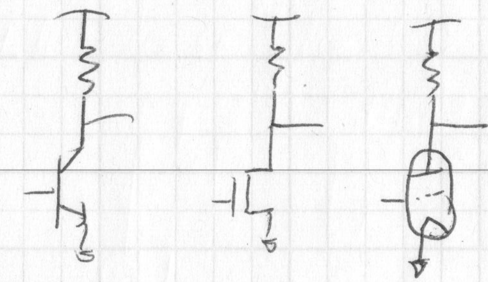
~ Accurate nonlinear o/p valid in some region of operation.

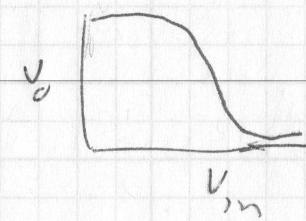


that one can be solved closed-form, but even very simple circuits can't.

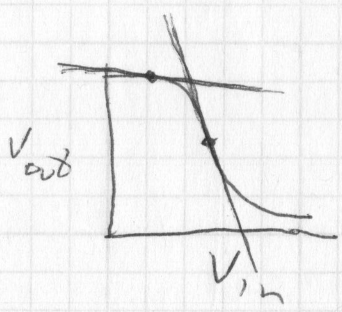


So we linearize.





- pick a point on the curve (operating point / bias point)
- take derivatives around that point
- Valid linear model in some nbrhood.



$A_v = -G_m R_{out}$ why?

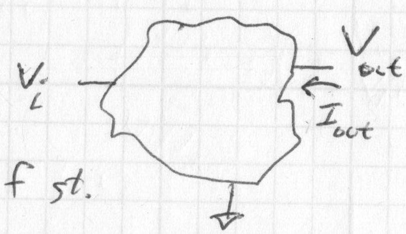
$$\begin{pmatrix}\text{full nonlinear}\\ \text{"correct"}\\ \text{solution}\end{pmatrix} = \begin{pmatrix}\text{single}\\ \text{point}\\ \text{solution}\end{pmatrix} + \begin{pmatrix}\text{small}\\ \text{signal}\\ \text{model}\end{pmatrix} + \text{h.o.t.}$$

accuracy of model
region of validity
depend on

and models are not reality
but for modern CMOS they're pretty close.

Where did $-G_m R_{out}$ come from?

Given any circuit



there is some function f s.t.

$I_{out} = f(V_i, V_{out})$ in some nbrhood.

pick some point (V_I, V_{OUT}) where $I_{out} = 0$

near that point

$$I_{out} = f(V_I, V_{OUT}) + \left.\frac{\partial f}{\partial V_i}\right|_{(V_I, V_{OUT})} \delta V_i + \left.\frac{\partial f}{\partial V_{out}}\right|_{(V_I, V_{OUT})} \delta V_{out} + \text{h.o.t.}$$

g_m : effect of input voltage chge on output current

g_{out} : " " output " " " " "

$R_{out} = \dfrac{1}{g_{out}}$

$I_{out} = I_{OUT} + i_{out}$

$V_i = V_I + v_i \qquad \delta V_i = v_i$

$V_{out} = V_{OUT} + v_{out} \qquad \delta V_{out} = v_{out}$

$$\underbrace{I_{OUT}}_{0} + i_{out} = 0 + g_m v_i + g_{out} v_{out}$$

$$\frac{v_{out}}{v_i} = -\frac{g_m}{g_{out}} = -g_m R_{out}$$