What is design?

SS model

single pole amplifier

Done w/ devices models, on to circuits

Design: from specs to devices/circuits

Analysis: find operating point
(by solving nonlinear algebra.)

find linear model

 ⇒ $g_m, r_o, C_{gs}, C_{gd}, \ldots$

linear analysis
- gain, gain vs. freq (Bode)
- time domain response

nonlinear effects
output swing

Design

What specs?

"I need an amplifier"

what gain/freq response? current/voltage in/out?

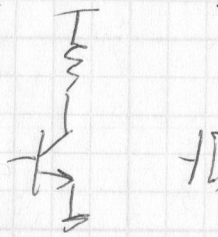
what output impedance? what is it driving?
resistive load, capacitive, ...

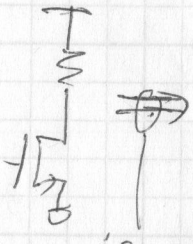
what does the source look like?
resistive, capacitive, ...

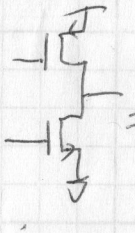
How accurate does the gain need to be?
⇒ feedback control
⇒ stability

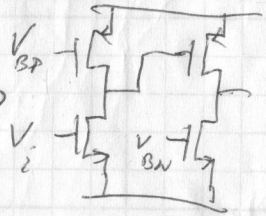
Power constraints

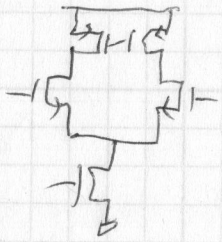
output swing











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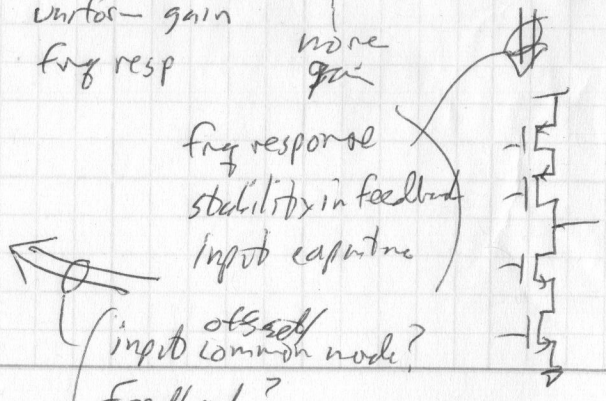
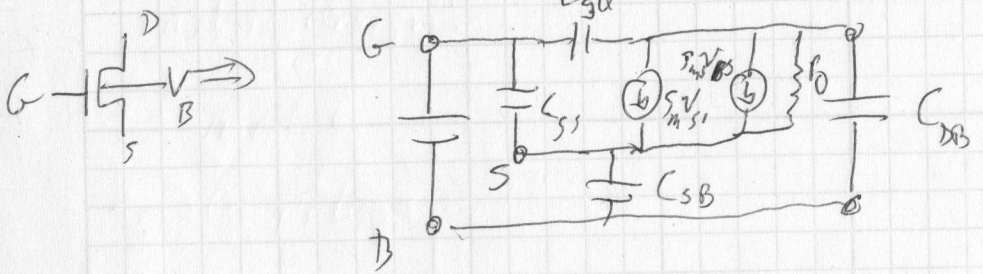


140/240A 1750 W3L-2

MOS linearized Fig 2.39



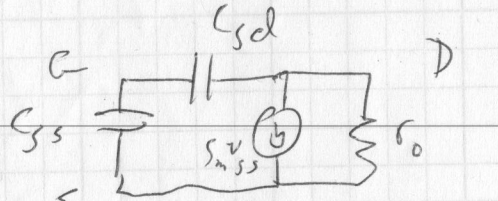
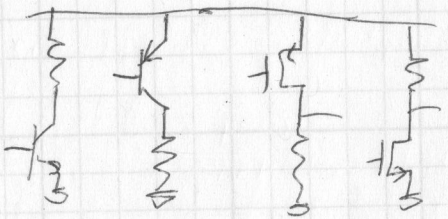


Fig 2.37

same model for NMOS & PMOS

almost the same for bipolar, JFET, tubes, ...

operating point



current depends on V_{out} & R_L

Varies a lot

g_m, r_o depends on current only for bipolar

current + geometry for MOS

$$I_D = \frac{\mu_n C_{ox}}{2} \frac{W}{L}\left(V_{GS} - V_{TH}\right)^2\left(1 + \lambda V_{DS}\right)$$

$\frac{\mu_n C_{ox}}{2}$ ↑ process (may have small # of discrete choices)

$\frac{W}{L}\left(V_{GS} - V_{TH}\right)^2$ ↑ design

$\lambda(L) \propto \frac{1}{L}$

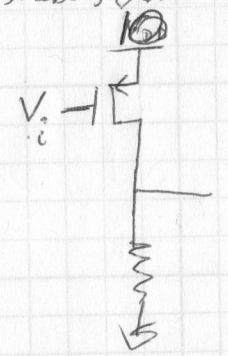
$$g_m = \frac{2I_D}{V_{OV}} = \mu_n C_{ox} \frac{W}{L} V_{OV}$$

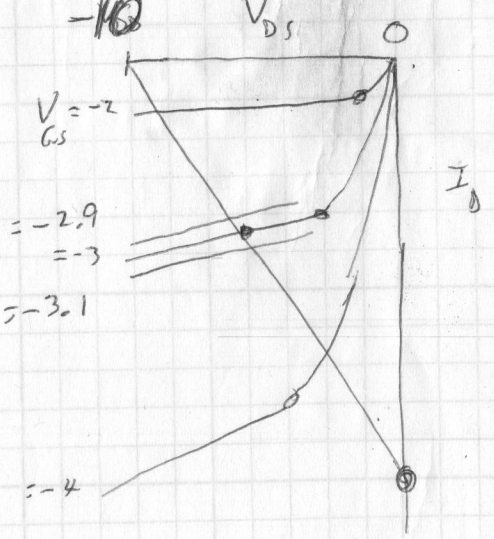
in general choose I_D, $\frac{W}{L}$, V_{OV} (maybe L)

to satisfy specs

pick any 2

small signal model





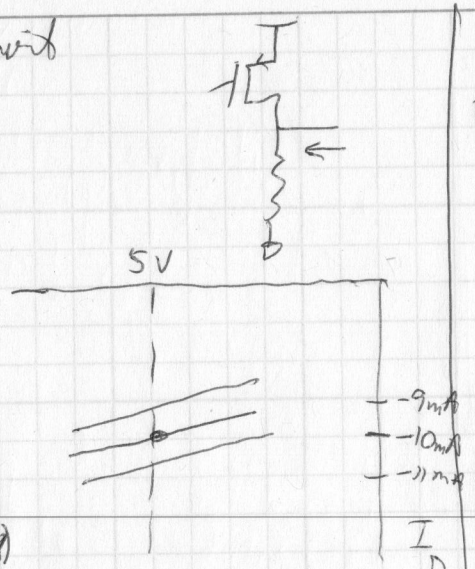
Pick $V_i = V_I = 3V$ operating point

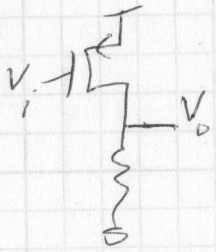
$\Rightarrow V_{OUT} = 5V$

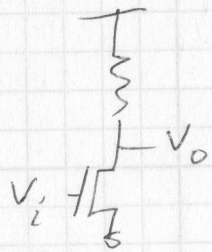
$$g_m = \left.\frac{\partial I_{out}}{\partial V_{in}}\right|_{\substack{V_{out}=V_{OUT} \\ V_{in}=V_{IN}}}$$

$$= \frac{\Delta I}{\Delta V} = \frac{-9mA-(-10mA)}{-2.5V-(-3V)}$$

$= 10mS$ positive!

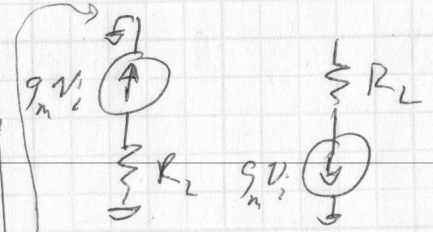




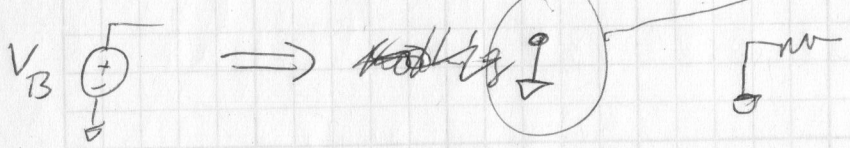


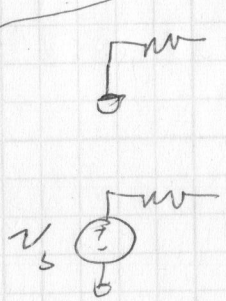
raise V_i w/ V_o const

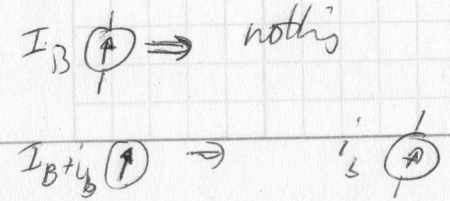
pulls more current out of the output decreases the voltage on the node if capacitive or resistive

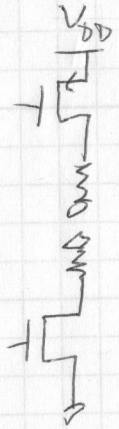


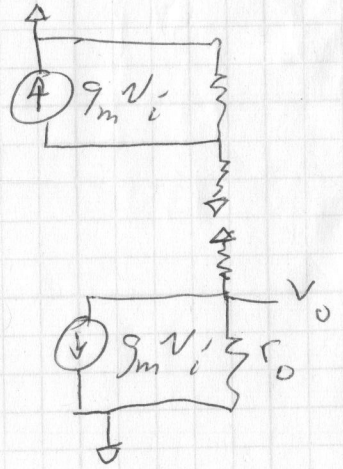
What's the SS model for a supply?











$$v_o = -g_m v_i (R_o \| R_L)$$