ENEE 303
05/14/19

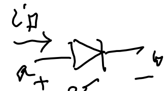
Th @ 08:00 final in class room open book open notes

Laws of connections: KCL Σ I's into closed surface to 0

KVL Σ v's around a closed loop = 0

Laws of devices: models = math-physics/chemistry (in Spice)

Basic "electronic" devices:

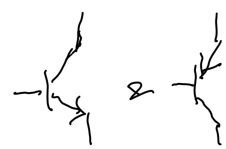


solid-state

$v_D = v_a - v_b$

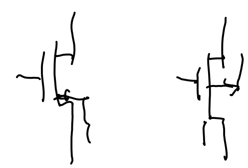
$i_D = I_S(e^{v_D/V_T} - 1)$

$V_T = \frac{kT}{|q|}$, $V_T| \approx 26\,mV$ (Room T = 300°K)



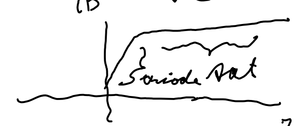
BJT

CCCS



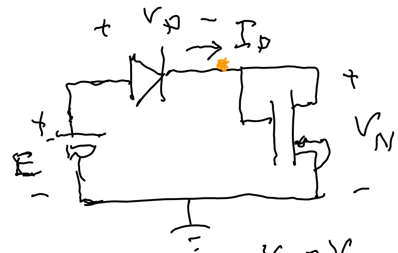
CMOS

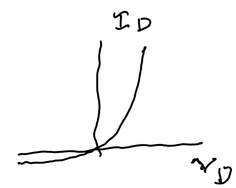
VCCS

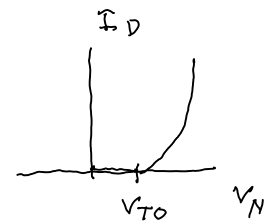


Ex: Load line

$i_D = I_S(e^{v_D/V_T} - 1)$



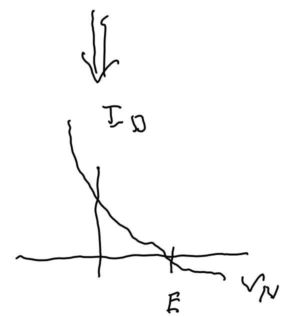




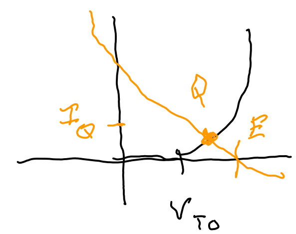
$V_{DS} = V_{GS}$

$\Rightarrow$ sat $\quad V_{DS} > V_{GS} - V_{TO}$ if $V_{TO} > 0$

$i_D = k(v_{GS} - V_{TO})^2(1 + \lambda v_{DS})$



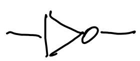
$\Rightarrow$

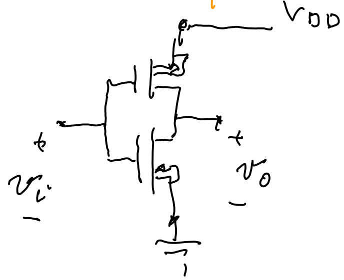


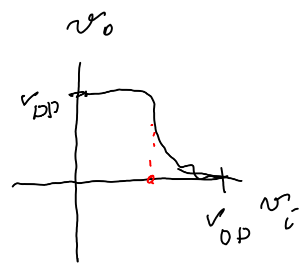
KVL: $0 = -E + V_D + V_N \Rightarrow V_D = -V_N + E$

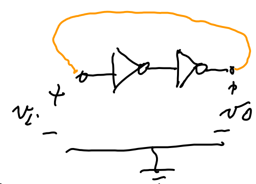
KCL: $I_D|_{diode} = I_D|$

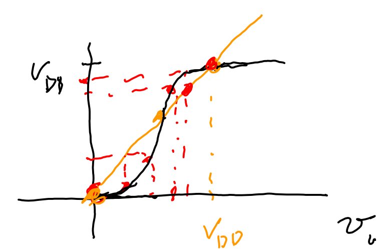
Ex: inverters

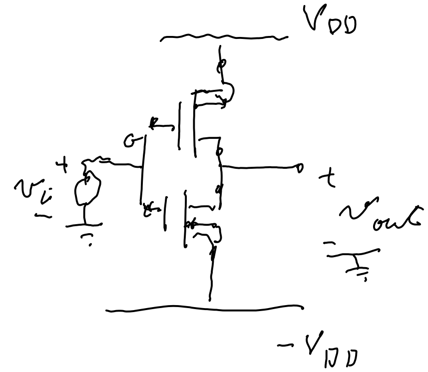


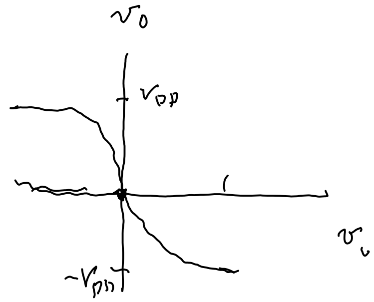




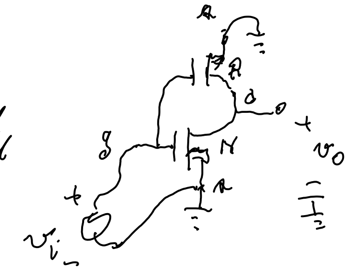


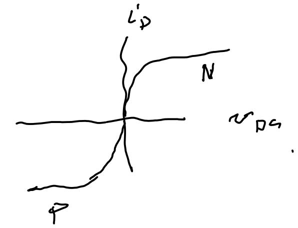




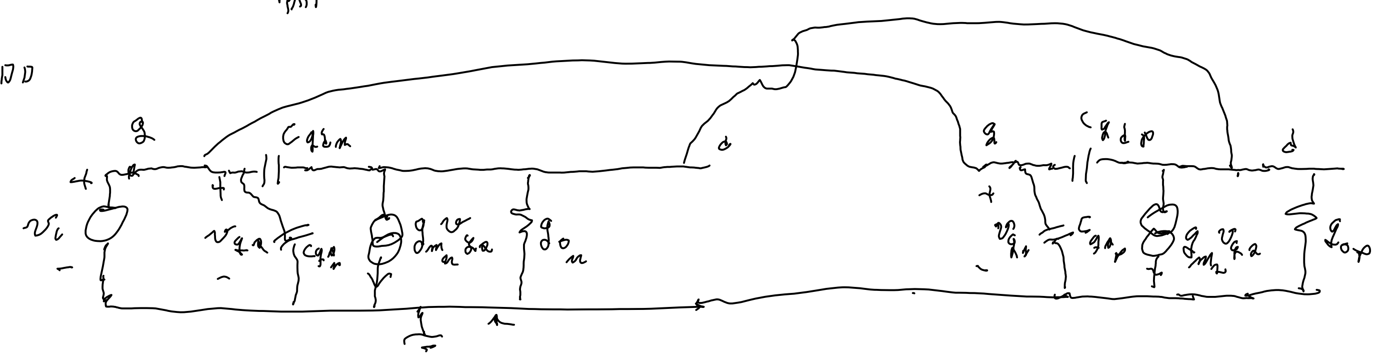


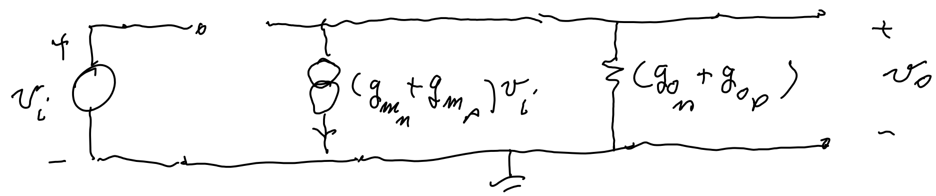
small signal ⇒





Eq. circuit.



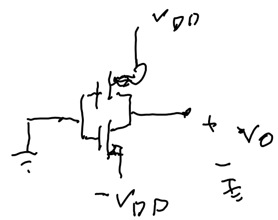


$$\frac{v_o}{v_i} = \frac{-(g_{o_n} + g_{op}) \cdot (g_{m_n} + g_{m_p}) v_i}{v_i}$$

$$= -(g_{total})(g_{m\,total})$$

c's also add

To get g_m & g_o need bias point



KCL @ drains gives $I_{D_n} = -I_{D_p} \approx I_{S_p}$

$$I_{D_N} = k_n (V_{GS_n} - V_{TO})^2 (1 + \lambda V_{DS_n}) = k_n (0 - (-V_{DD}) - V_{TO})^2 (1 + \lambda_n (V_o - (-V_{DD})))$$

$k_n = \frac{KP}{2} \cdot \left(\frac{W}{L}\right)_n$

$$= + I_{S_p} = k_p$$

$k_p = \frac{KP}{2} \cdot \frac{W}{L} \left(V_{SG} - |V_{TO_p}|\right)^2 \left(1 + \lambda_p (V_{DD} - V_O)\right)$

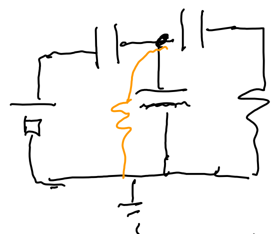
linear equations in V_O, can solve (should be near $V_O = 0$ if close to complementary transistors)

Spice: Need models (above often get KP, VTO, λ, γ, etc.; C_{ox} ⇒ to get gate C_g
$C_g = C_{ox} \times W \times L$)

Error types

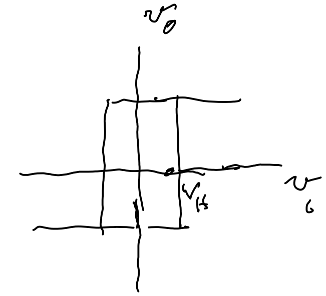
loop of L's
& V sources

to cure add
a small R
in the loop

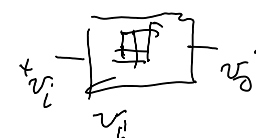


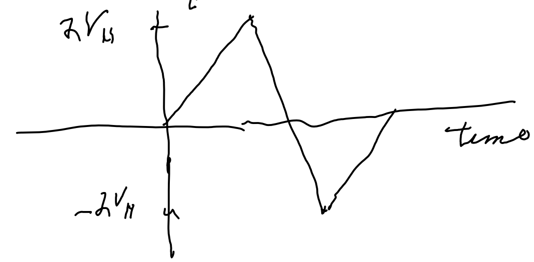
floating nodes
To cure add
a large R
from that node
to ground

non convergence
lower step size
but There are
many reasons

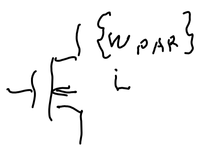


DC won't work
so transient analysis





then for PARAM
W_{PA} 6p



← error if no {·}