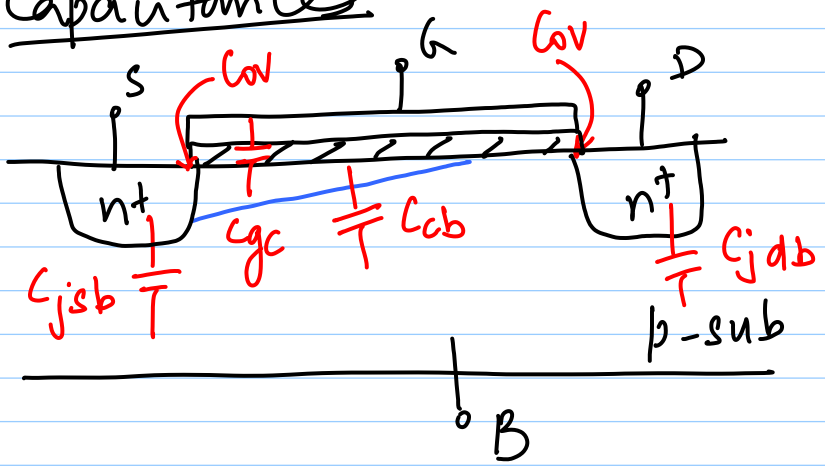
5/1/12 Lec 3 – MOS caps; S.C. effects
Simple amplifier ckts

Capacitances



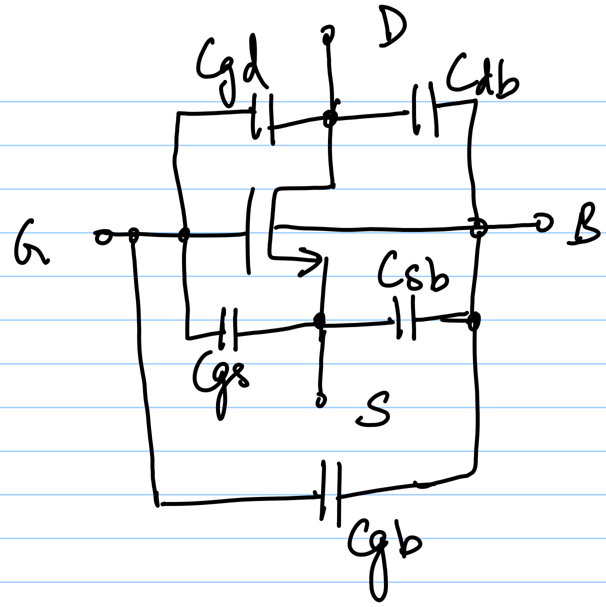
* L_D = overlap of G over D-S
* $L_{eff} = L - 2L_D$

$$C_{gc} = W L_{eff} C_{ox} \quad ; \quad C_{ox} = \epsilon_{ox}/t_{ox}$$

$$C_{cb} = (\epsilon_{si}/x_d) \cdot W L_{eff}$$

$$C_{ov} = W L_D C_{ox}$$

Cap	OFF	TRIODE	SAT
C_{gs}	C_{ov}	$C_{ov} + C_{gc}/2$	$C_{ov} + \frac{2}{3} C_{gc}$
C_{gd}	C_{ov}	$C_{ov} + C_{gc}/2$	C_{ov}
C_{gb}	$C_{gc} \parallel C_{sb} < C_{gb} < C_{gc}$	0	0
C_{sb}	C_{jsb}	$C_{jsb} + C_{cb}/2$	$C_{jsb} + \frac{2}{3} C_{cb}$
C_{db}	C_{jdb}	$C_{jdb} + C_{cb}/2$	C_{jdb}



Short-channel Effects

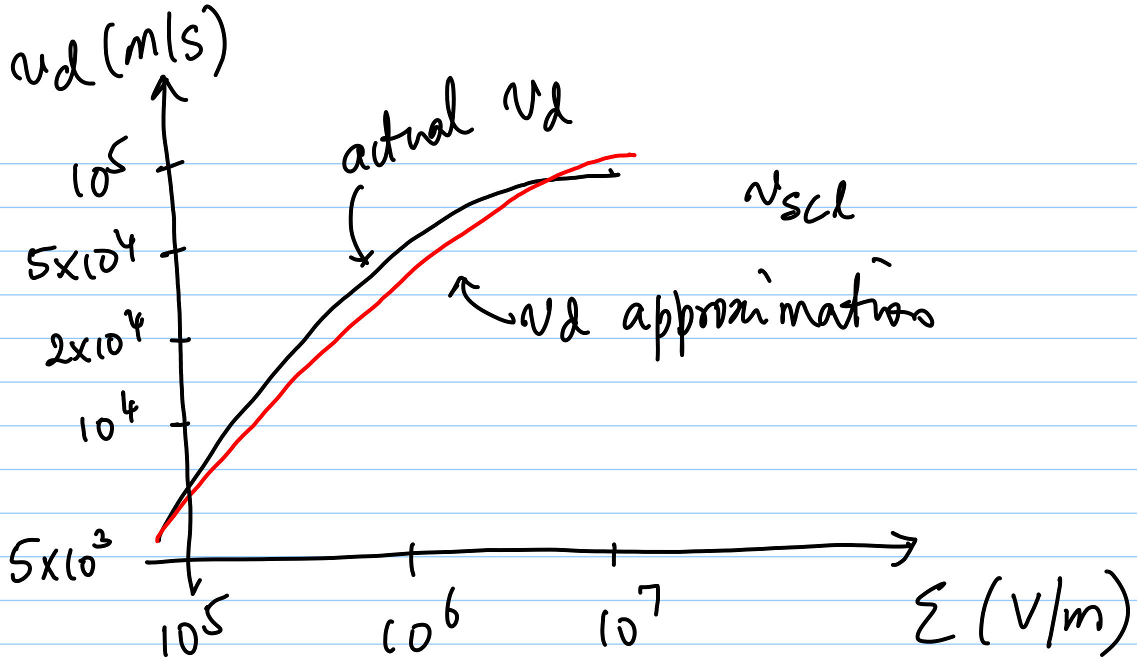
"Long" channel device equations

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$$

→ derived using drift velocity expression:

$$v_d(y) = \mu_n \mathcal{E}(y)$$

- v_d: drift velocity
- μ_n: mobility
- $\mathcal{E}$: horizontal $\mathcal{E}$-field
- y: length along channel



At high fields,

$$v_d = \frac{\mu_n \mathcal{E}}{1 + \mathcal{E}/\mathcal{E}_c}$$

scattering limited velocity

$$v_{scl} = \mu_n \mathcal{E}_c$$

typical values:

$$\mathcal{E}_c \sim 1.5 \times 10^6 \ V/m$$

$$\mu_n \sim 0.07 \ m^2/V.s.$$

$$v_{scl} \sim 1 \times 10^5 \ m/s$$

Long channel $V_{DSAT} = (V_{GS} - V_T)$

write

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T) V_{DSAT}$$

In general,

$$V_{DSAT} = (V_{GS}-V_T) \,||\, (L \cdot \mathcal{E}_c)$$

$$= \frac{(V_{GS}-V_T)\cdot(L\cdot\mathcal{E}_c)}{(V_{GS}-V_T)+(L\mathcal{E}_c)}$$

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_T)\cdot\left[(V_{GS}-V_T)\,||\,(L\mathcal{E}_c)\right]$$

How to determine s.c. operation?

* compare $\frac{V_{GS}-V_T}{L}$ and $\mathcal{E}_c$

ratio is small ⇒ Long channel ok

* actual length of gate is irrelevant!

Howevel,

→ as L ↓, smaller $(V_{GS}-V_T)$ is required to exhibit s.c. effects!

In deep vel. sat.,

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\cdot(V_{GS}-V_T)\cdot(L\mathcal{E}_c)$$

$$= \frac{1}{2}\mu_n C_{ox} W \mathcal{E}_c (V_{GS}-V_T)$$

→ I_D indep. of L !

→ $I_D - V_{GS}$ relationship is linear

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = \frac{1}{2}\mu_n C_{ox} \cdot W \cdot \mathcal{E}_c$$

$$C_{gs} = \frac{2}{3} WL\, C_{ox} \quad \text{(same as before)}$$

$$\omega_T = \frac{g_m}{C_{gs}} = \frac{3}{4}\frac{\mu_n \mathcal{E}_c}{L}$$

$\Rightarrow \omega_T \propto \frac{1}{L}$ {was $1/L^2$ for L.C. device}

$\Rightarrow$ ω_T independent of bias conditions

* PMOS devices – vel. sat. happens @ higher fields

Simple Amp ckts

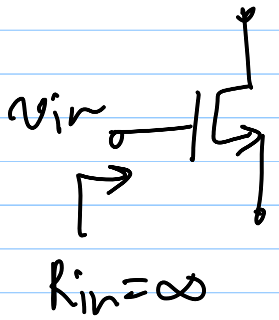
Objectives:

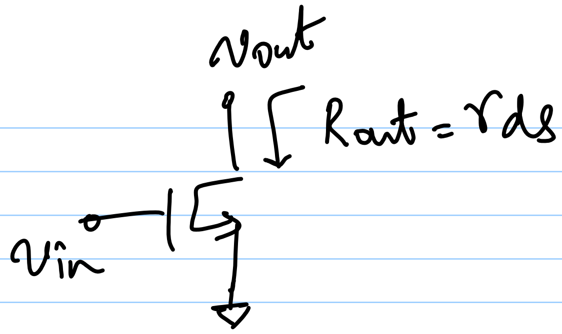
1) Visualise propagation of v & I signals through the ckt
2) Develop insight into ckt performance based on (1)

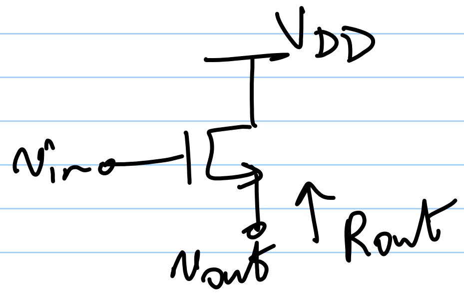
3) Identify relative impedance levels at all nodes in signal path

4) Freq. response: identify relative position of poles & zeroes based on impedances & caps @ each node in signal path

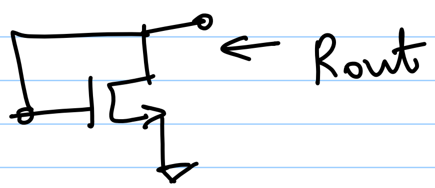
5) VTC of clct can give insights into output voltage range (i.e. output swing)





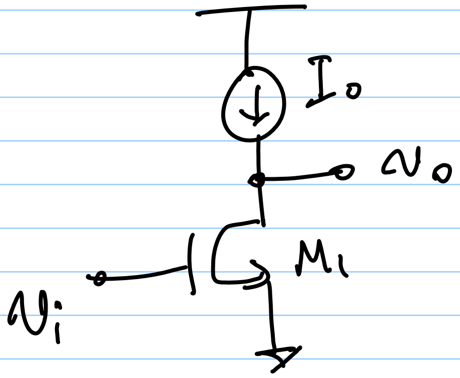


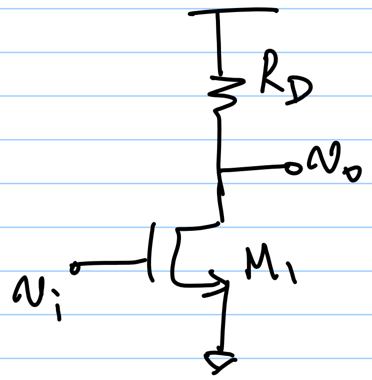
$$R_{out} = \frac{1}{g_m + g_{mbs} + g_{ds}} \approx \frac{1}{g_m}$$

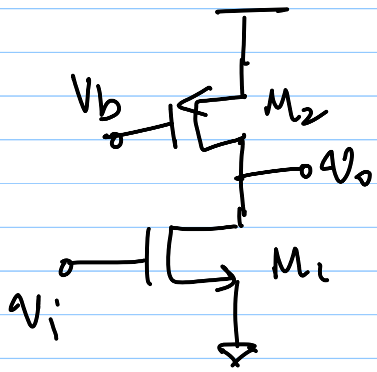


$$R_{out} = \frac{1}{g_m + g_{ds}} \approx \frac{1}{g_m}$$

C.S. Amp:



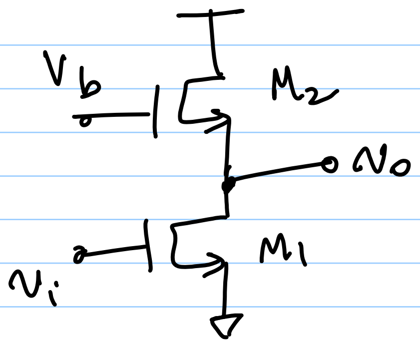


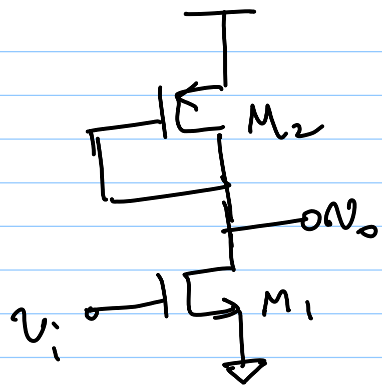


$a_v = g_{m1}/g_{ds1}$ $\qquad a_v = \dfrac{g_{m1}}{g_{ds1} + g_D}$ $\qquad a_v = \dfrac{g_{m1}}{g_{ds1} + g_{ds2}}$

note! $V_{BS} = 0 = v_{bs}$

$\Rightarrow g_{mbs} v_{bs} = 0$





$$a_v = \frac{g_{m1}}{g_{m2} + g_{mbs2} + g_{ds2} + g_{ds1}}$$

$$a_v = \frac{g_{m1}}{g_{m2} + g_{ds2} + g_{ds1}}$$

* All of the form

$$a_v = \frac{g_m}{g_{out}}$$