ECE 511 — Lecture 22

Note Title 4/16/2013

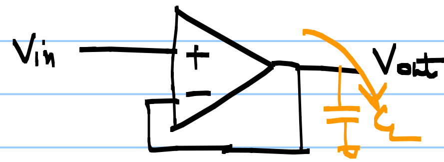
$$A_{cL} = \frac{A_v}{1+A_v} \longrightarrow 1$$

* Slewing

small signal TF

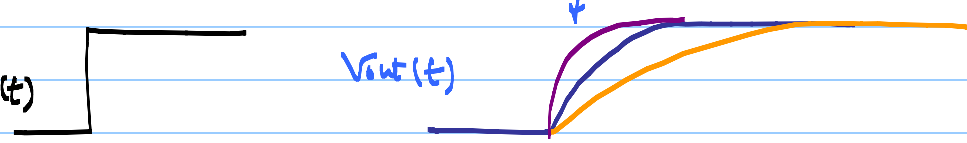
$$A_{cL}(s) = \frac{1}{1+\frac{s}{\omega_{3dB}}}$$

$$\omega_{3dB} = \frac{\omega_{un}}{A_{cL}}$$

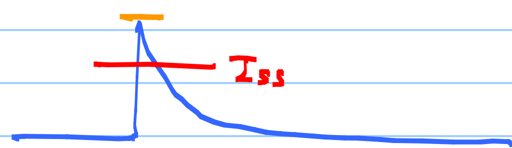


linear response

$(1-e^{-t/\tau})u(t)$

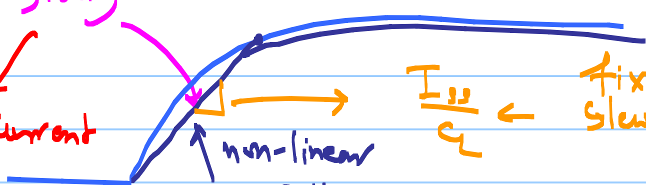


$$i_L = C_L \frac{dV_{out}}{dt}$$



slewing

fixed current

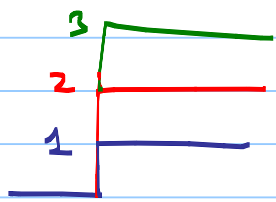


$\frac{I_{SS}}{C_L}$ ← fixed slewing rate

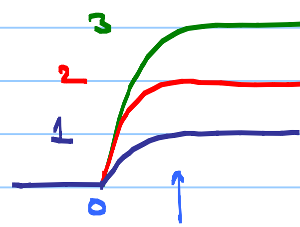
charging / discharging a large cap (C_L)

$$V_{out}(t) = V_o\left(1 - \underbrace{\overset{(1-\epsilon)}{e^{-T/\tau}}}_{\text{error}}\right)$$

$V_{out}(t)$



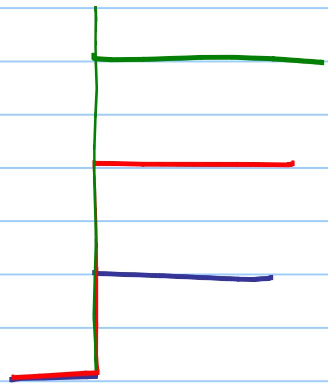
Linear settling

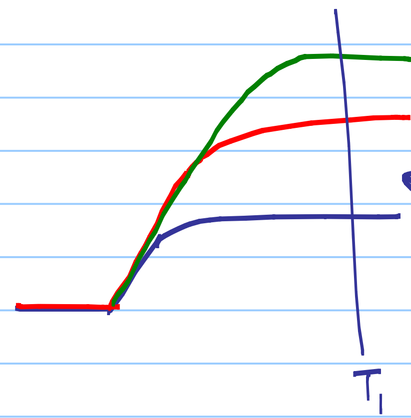


$V_{out,final} = V_o$

$V_{out,final} = \alpha V_o$

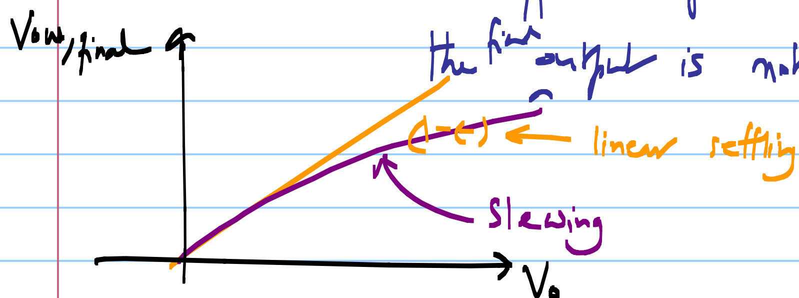
constant (α)





The settled values are not proportional

with different input step height the final output is not "linear"



"non-linearity"

④ Output swing

↳ trades off with device size, V_{ov}, current & speed

SNR trade off

→ Use FD circuit

S → 6dB
N → 3dB

SNR 3dB gain

⑤ Linearity

① FD circuits → eliminate even-order harmonics

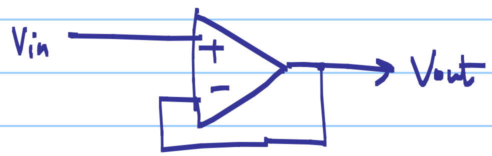
$$f_{odd}(x) = \frac{f(\overset{V_{in}/2}{x}) - f(\overset{-V_{in}/2}{-x})}{2}$$

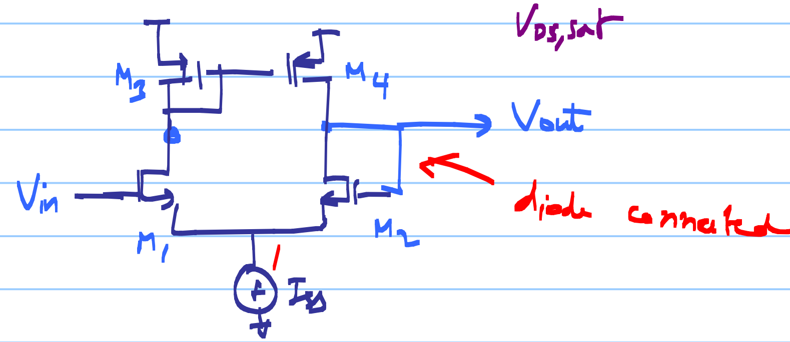
② Use large open-loop gain ⇒ reduces non-linearity

* Noise & offset ⟶ ECE 614

* Supply noise rejection ⟶ FD circuits

UGB



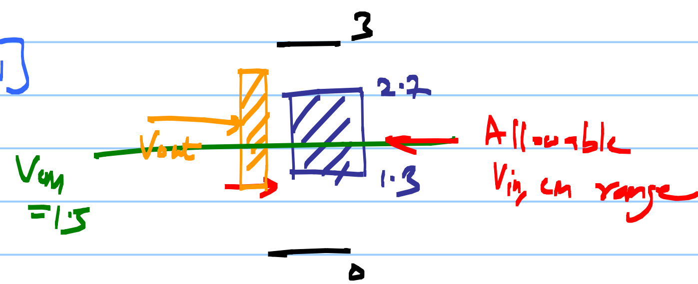


$V_{DD} = 3V$
$V_{THN,P} = 0.7V$
$V_{ov} = 0.3V$
$V_{DS,sat}$

* Input CMR

$V_{in,cm} \in [V_{GS_1} + V_{DS,sat},\ V_{DD} - V_{SG_3} + V_{THN}]$

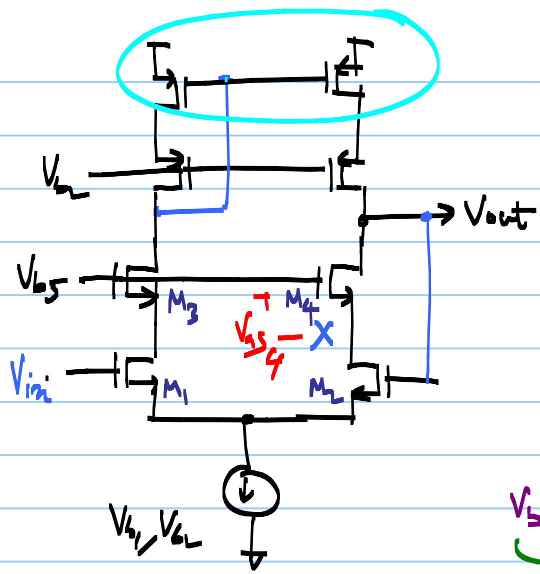
$= [1.3,\ 2.7V]$



$$R_{o,CL} = \frac{R_{o,OL}}{1 + \text{loop-gain}} = \frac{r_{op} \| \cancel{r_{on}}}{\cancel{1+}\; g_{mn}(r_{op} \| \cancel{r_{on}})} \simeq \frac{1}{g_{mn}}$$

$\Rightarrow$ low output impedance

$\because$ loop gain is also large



* M_2 & $M_4 \rightarrow$ SAT

$$\overset{V_G}{V_{out}} \le \overset{V_D}{V_x} + V_{THN} \rightarrow ① \quad : M_2 \text{ SAT}$$

$$V_{out} \ge V_{b5} - V_{THN} \rightarrow ② \quad : M_4 \text{ SAT}$$

$$V_x = V_{b5} - V_{GS_4} \rightarrow ③$$

$$\underbrace{V_{b5} - V_{THN}}_{V_{min}} \le V_{out} \le \underbrace{V_{b5} - V_{GS_4} + V_{THN}}_{V_{max}}$$

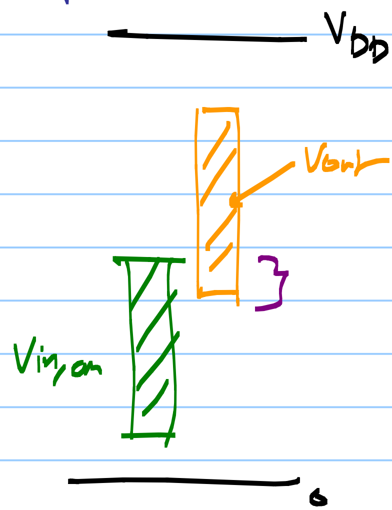
allowed output range: $V_{max} - V_{min} = 2V_{THN} - V_{GS_4}$

$$\simeq \underbrace{V_{THN} - V_{ov_4}}_{\text{very small range}}$$

* Can't make a UGB with a single-stage Telescopic opamp

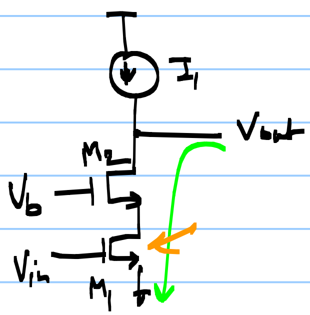
(−) limited output swing

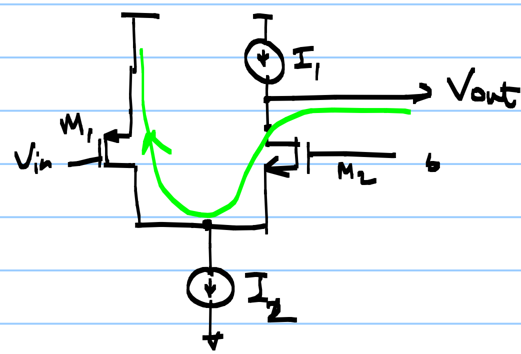
(−) difficulty in shorting input & output



Folded Cascode Amplifiers

NMOS Cascode



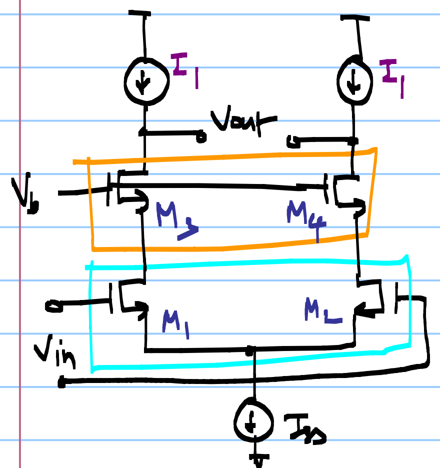


$I_2 > I_1$

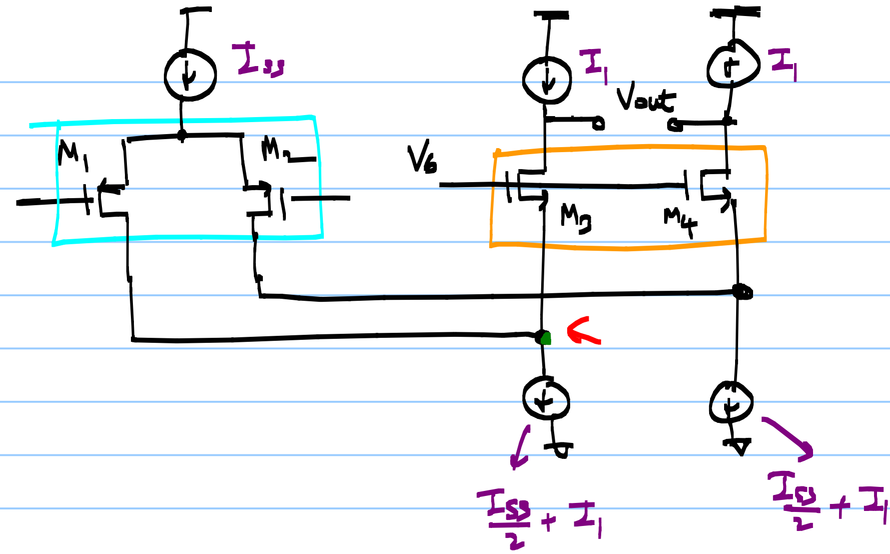
Gain: $\boxed{A = -g_{m_1} \cdot R_{out}}$

(+) FC doesn't "stack" the cascode transistor on top of the input device.

↳ helps with headroom issues

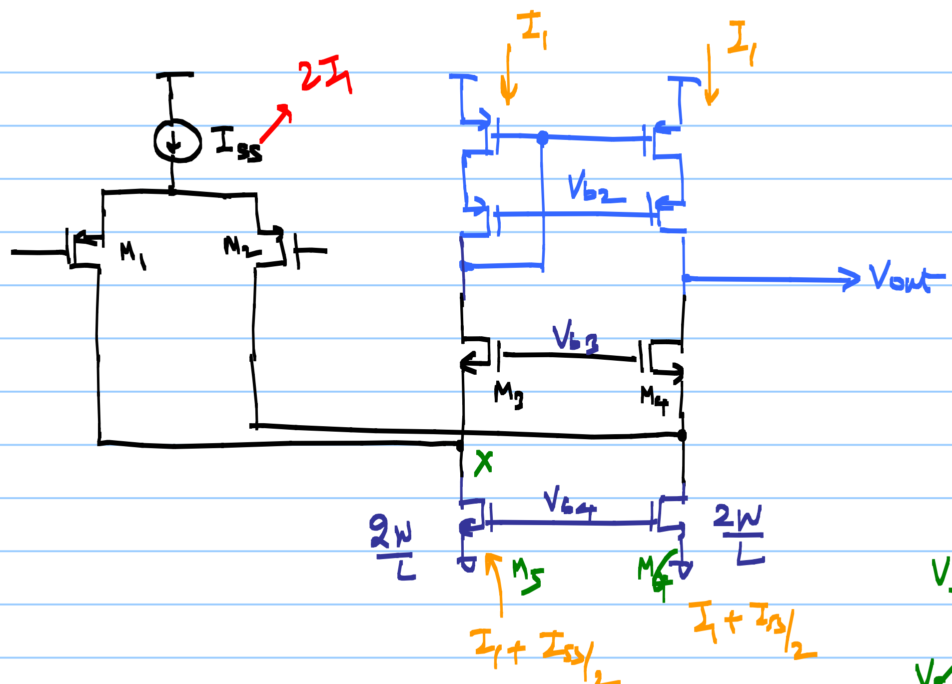


$V_{cm,in} \le V_b - V_{GS_1} + V_{THN}$



to keep M_1 & M_2 is SAT

$V_{cm,in} \ge \underbrace{V_b - V_{GS_3}} - V_{TH_1}$



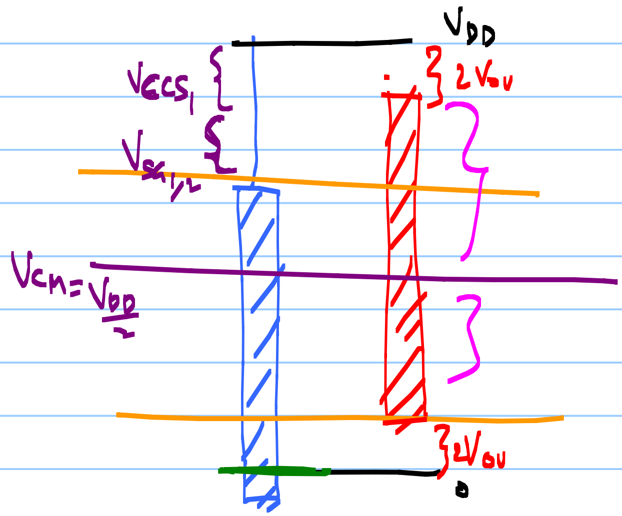
$V_{CM,in} \le \underbrace{V_{DD} - V_{CCS}} - V_{SG_{1,2}}$

$V_{SD_1} > V_{SG_1} - V_{THP}$

$\cancel{V_S} - V_{D_1} > \cancel{V_S} - V_{G_1} - V_{THP}$

$V_{G_1} > V_{D_1} - V_{THP}$

$V_{in,cm} \ge V_{DS,sat_5} - V_{THP} < 0$



* Easily short input & output
* Wide input CMR
* PMOS input CMR includes GND rail
* NMOS input CMR includes the V_{DD} rail

* Consumes 2X bias current → higher power consumption than telescopic