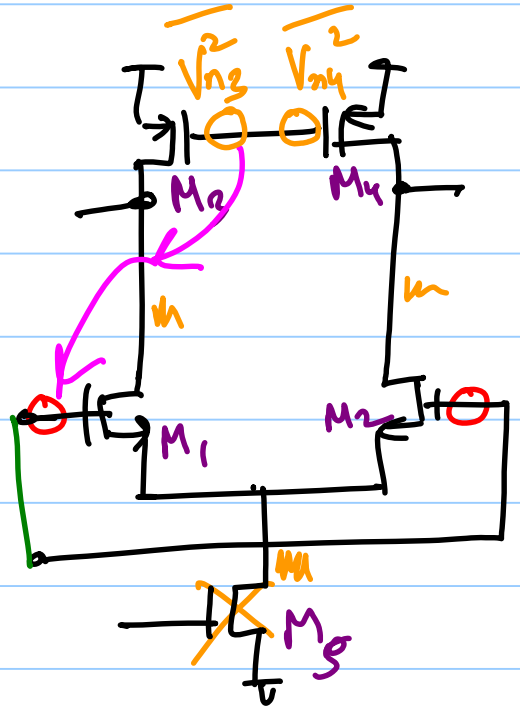
ECE 614 – Lecture 13

Note Title 10/7/2014



$$\overline{V_{n,in}^2} = \overline{V_{n1}^2} + \overline{V_{n2}^2} + \overline{V_{n3}^2}\,\frac{g_{m3}^2 (r_{o1} \| r_{o3})^2}{g_{m1}^2 (r_{o1} \| r_{o3})^2}$$

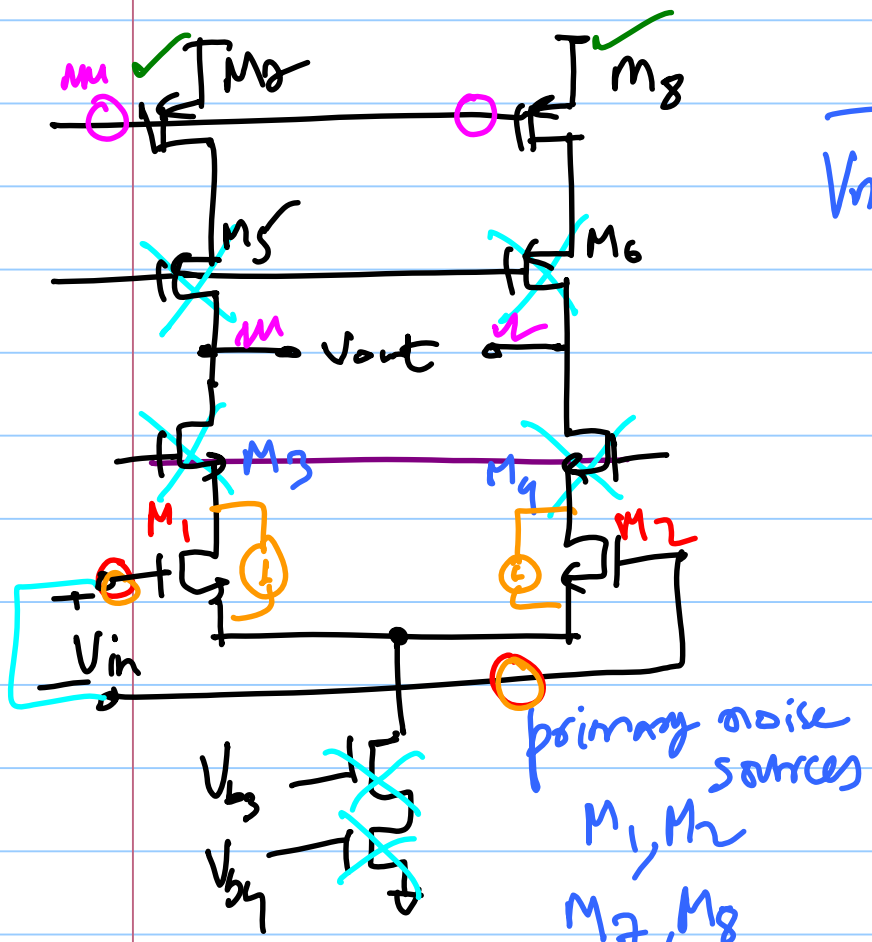
$$= \overline{V_{n1}^2} + \overline{V_{n2}^2} + \overline{V_{n3}^2}\,\frac{g_{m3}^2}{g_{m1}^2} + \overline{V_{n4}^2}\,\frac{g_{m4}^2}{g_{m2}^2}$$

$$= 4kT\left[2 \times \frac{1}{3 g_{m1}} + 2 \times \frac{g_{m3}}{g_{m1}^2}\right]$$

$g_{m1} = g_{m2}$

$$\overline{V_{n,in}^2}_{f} = \frac{2K_n}{C_{ox}(WL)_{f}} + \frac{2KP_n}{C_{ox}WL_{p}f} \cdot \frac{g_{m3}^2}{g_{m1}^2}$$

Telescopic Opamp

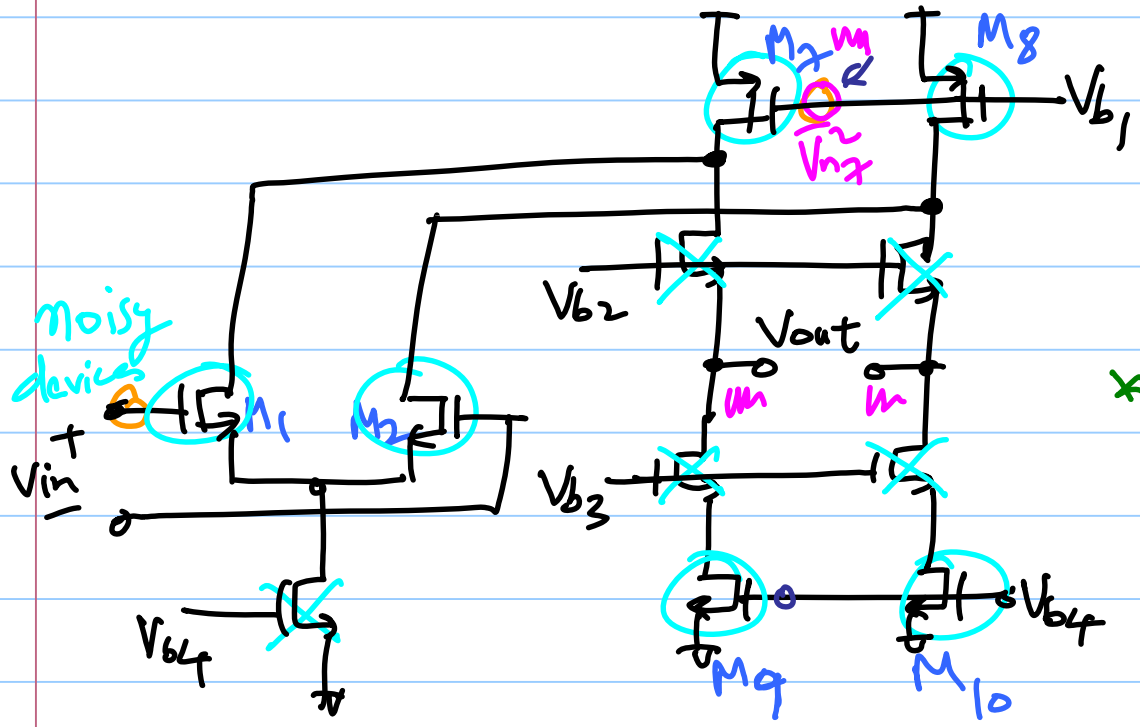


$$\overline{V_{n,in}^2} = \frac{8}{3}\frac{kT}{g_{m1,2}} \times 2 + \frac{8}{3} kT \frac{g_{m7,8}}{g_{m1,2}^2} \times 2$$

$$= 8kT\left[\frac{2}{3 g_{m1,2}} + \frac{2}{3}\frac{g_{m7,8}}{g_{m1,2}^2}\right]$$

$g_{m1,2}$ ↑ ⇒ $g_{m7,8}$ ↓

Folded Cascode:



+ Mentally change gate voltage of each transistor by a small amount
× Estimate $\overline{V_{n,out}^2}\big|_{M_7}$
× Divide by A_v^2 to refer back to the input port

$$\frac{\overline{V_{n,out}^2}\big|_{M_7}}{A_v^2}$$

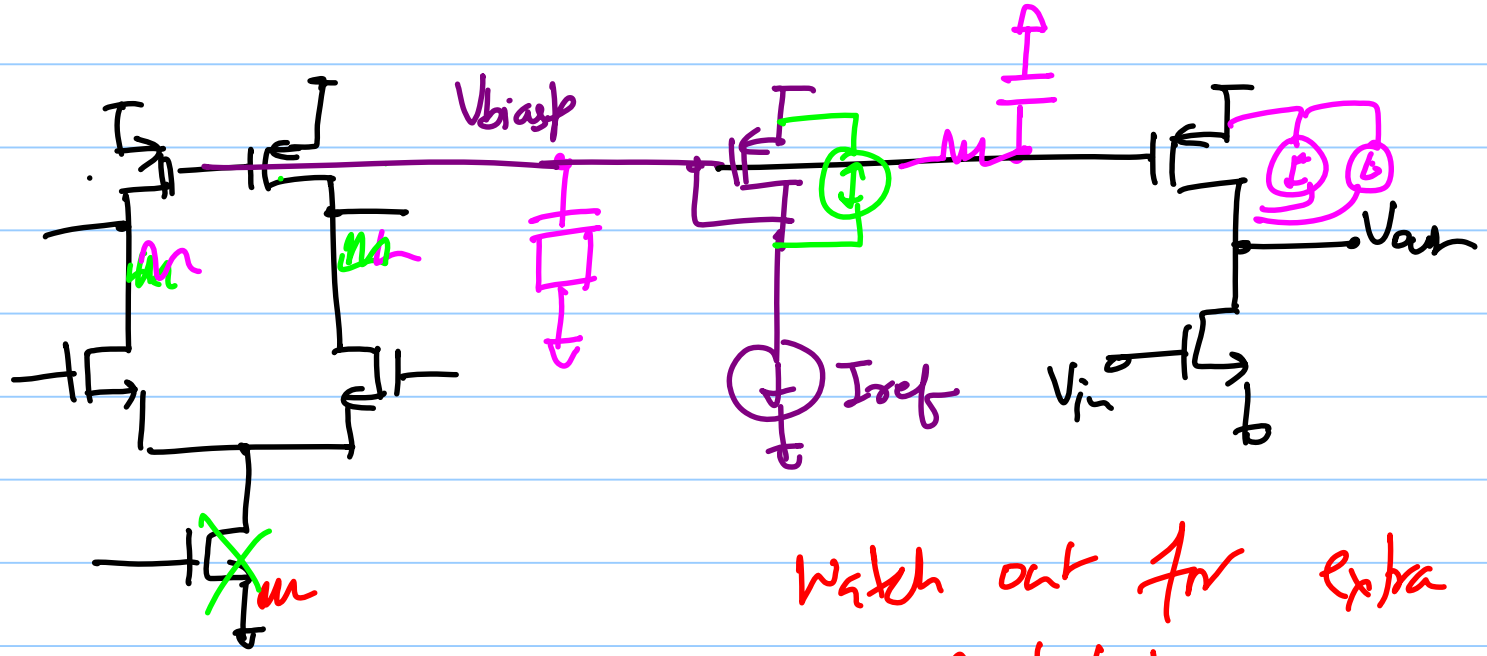
$$\overline{V_{n,out}^2}\Big|_{M_{7,8}} = 2\left[4kT\cdot\frac{2}{3g_{m7,8}}\times \underbrace{g_{m7,8}^2 R_{out}^2}_{\text{gain seen from } M_{7,8}\text{'s gate}}\right]$$

$$\overline{V_{n,out}^2}\Big|_{M_{9,10}} = 2\left[4kT\cdot\frac{2}{3g_{m9,10}}\times g_{m9,10}^2\cdot R_{out}^2\right]$$

$$A_v^2 = g_{m1,2}^2 R_{out}^2$$

$$\overline{V_{n,in}^2} = 8kT\left[\underbrace{\frac{2}{3g_{m1,2}}}_{\text{input pair}} + \frac{2}{3}\frac{g_{m7,8}}{g_{m1,2}^2} + \frac{2}{3}\frac{g_{m9,10}}{g_{m1,2}^2}\right]$$

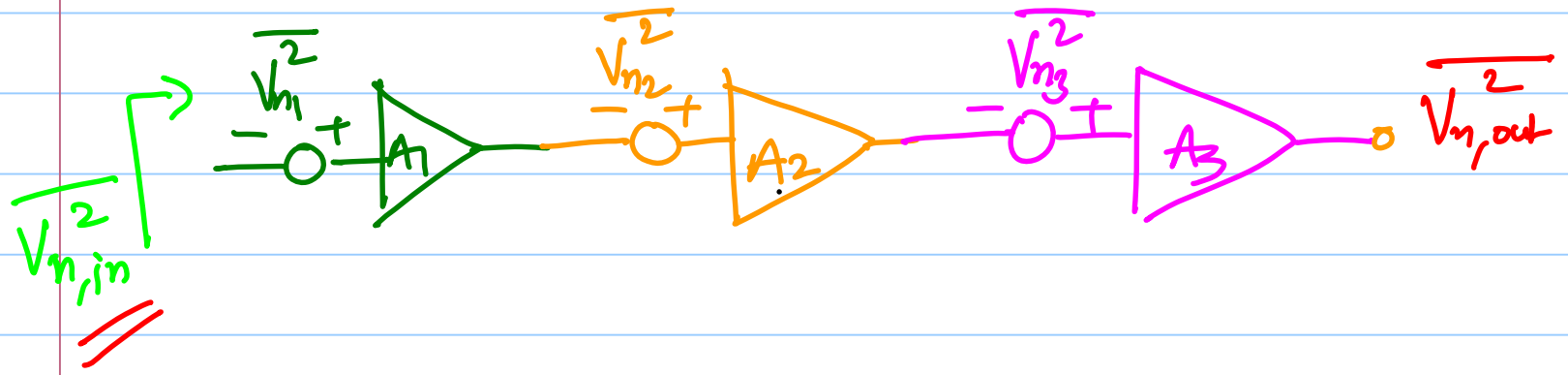
✗ more noisy than Telescopic



Watch out for extra devices contributing noise

Noise in Cascaded Amplifiers:

$A_v = A_1 A_2 A_3$



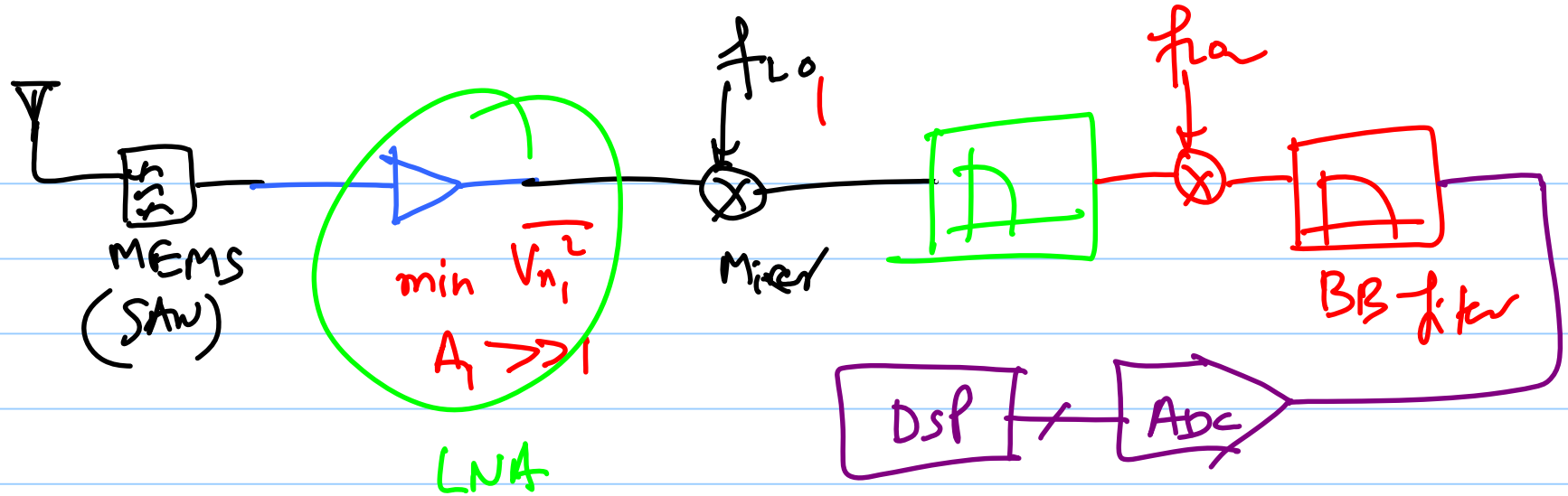
$$\overline{V_{n,out}^2} = \overline{V_{n1}^2} \cdot A_1^2 A_2^2 A_3^2 + \overline{V_{n2}^2} \cdot A_2^2 A_3^2 + \overline{V_{n3}^2} \cdot A_3^2$$

$$\overline{V_{n,in}^2} = \frac{\overline{V_{n,out}^2}}{(A_1 A_2 A_3)^2} = \overline{V_{n1}^2} + \frac{\overline{V_{n2}^2}}{A_1^2} + \frac{\overline{V_{n3}^2}}{A_1^2 A_2^2}$$

first stage dominates

first stage gain

RX. chain

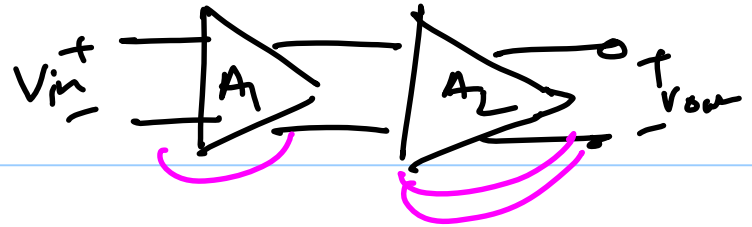


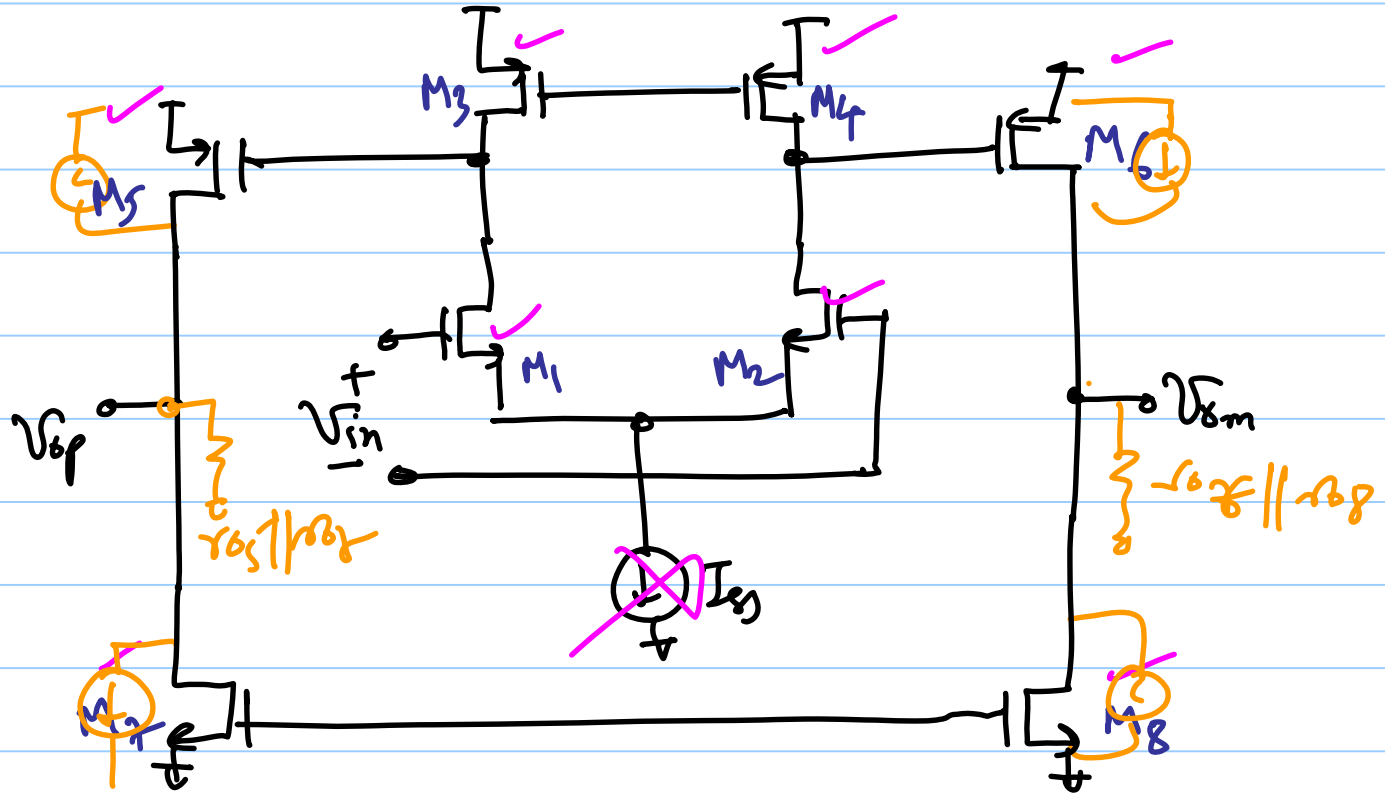
$NF > 1\,dB$

$$NF = 10\log_{10}\left(\frac{SNR_{in}}{SNR_{out}}\right)$$

$$NF = 1 + \frac{\overline{V_n + I_n R_S}^2}{4KTR_S}$$

Two-Stage opamp





* Noise current of M_5 & M_7 flows thru $r_{o5}||r_{o7}$

$$\overline{V_{n,out}^2}\Big|_{M_5-8} = \frac{2 \times 4kT \cdot \frac{2}{3}(g_{m5}+g_{m7})(r_{o5}\|r_{o7})^2}{g_{m1}^2(r_{o1}\|r_{o3})^2 \cdot g_{m5}^2(r_{o5}\|r_{o7})^2}$$

$A_1^2 A_2^2$

$$\overline{V_{n,in}^2}\Big|_{M_5-8} = \frac{16kT}{3}\frac{(g_{m5}+g_{m7})}{g_{m1}^2 g_{m5}^2 (r_{o1}\|r_{o3})^2}$$

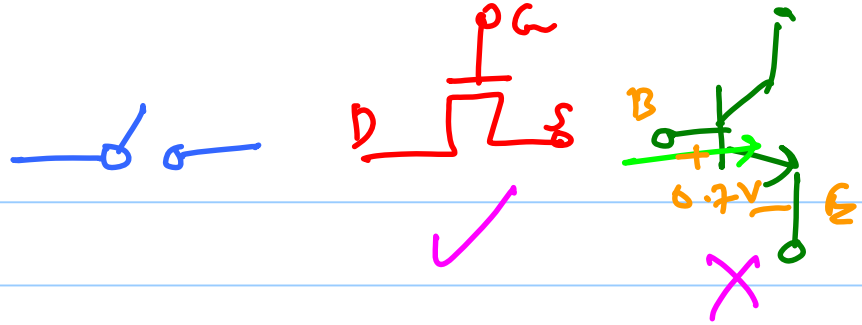
$$\overline{V_{n,in}^2} = \frac{16kT}{3}\cdot\frac{1}{g_{m1}^2}\left[(g_{m1}+g_{m2}) + \frac{g_{m5}+g_{m7}}{g_{m5}^2(r_{o1}\|r_{o3})^2}\right]$$

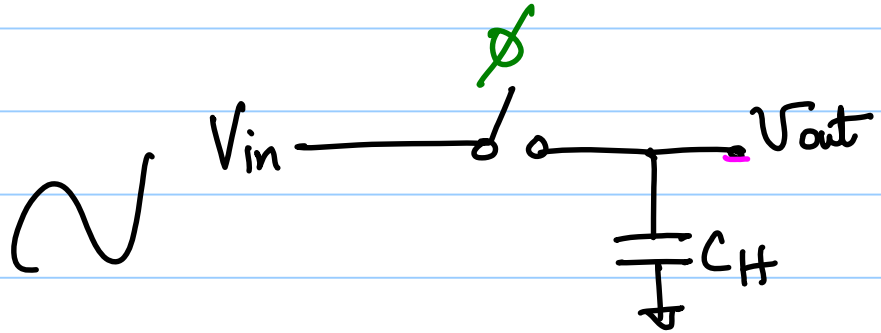
1^{st} stage

2^{nd} stage

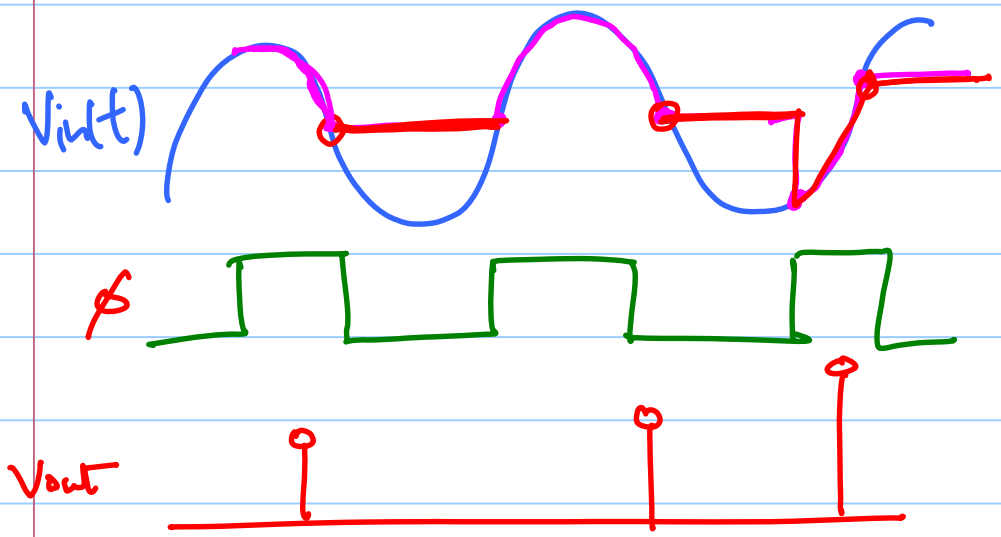
small is A is large

Sampling Switches:

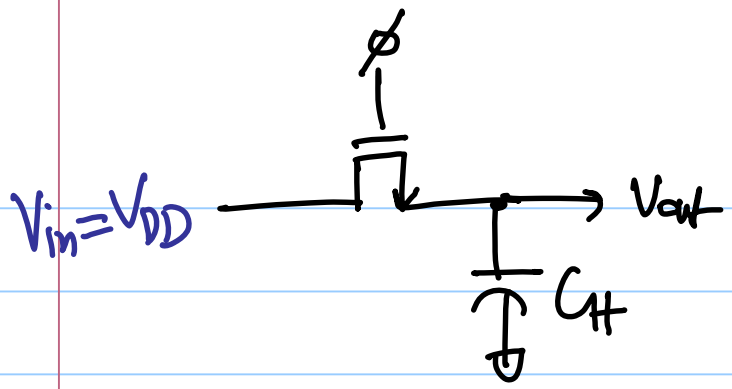


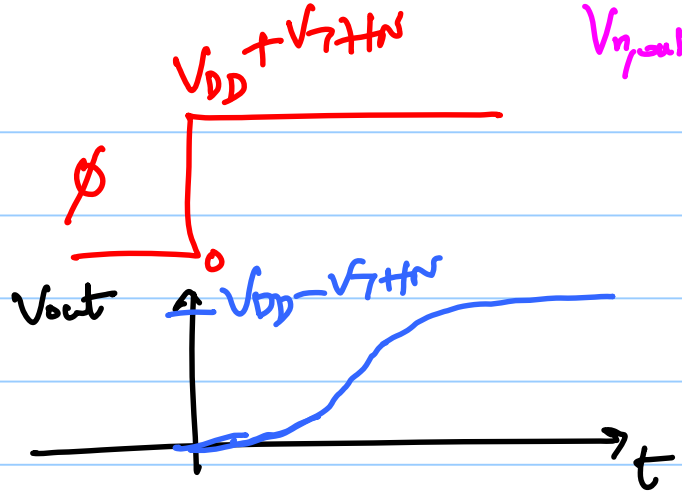


Track-and-Hold



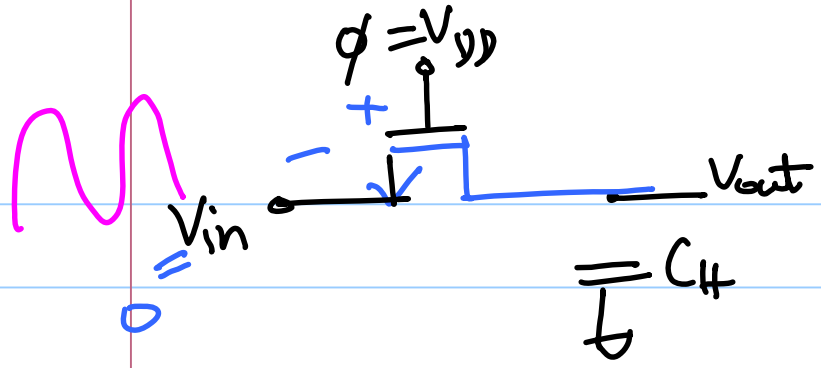
$V_{out}[nT_S]$

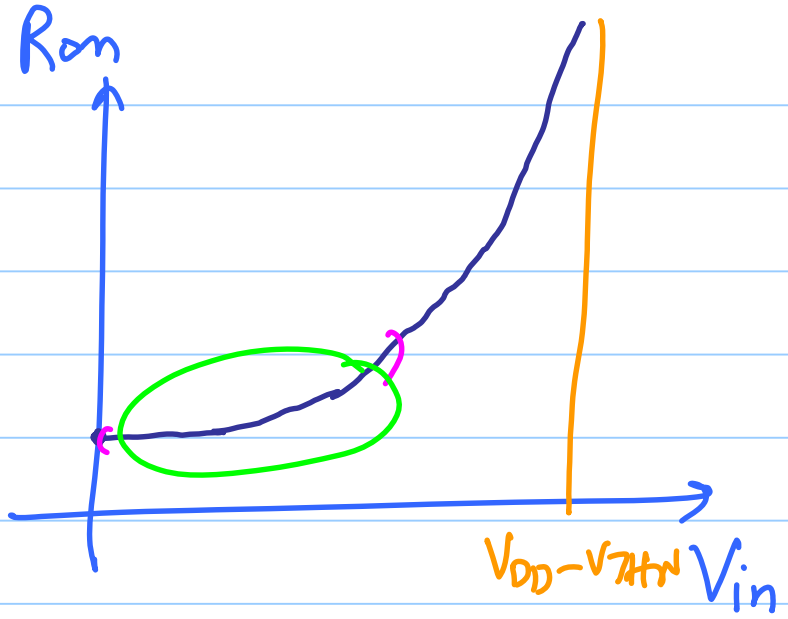




$$V_{n,out,rms} = \sqrt{\frac{kT}{C_H}}$$

Bootstrap

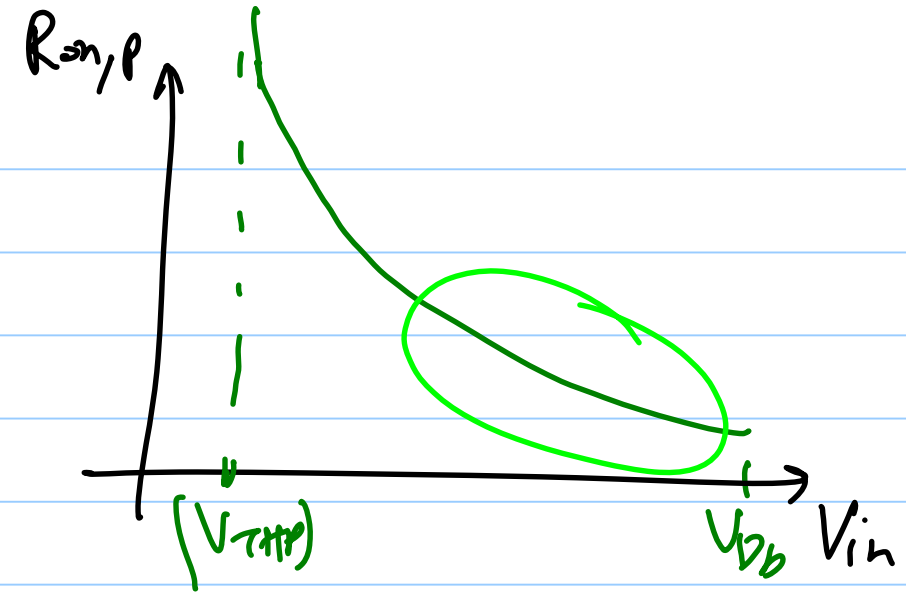




$$R_{on} = \frac{1}{K_n \frac{W}{L}\left(V_{GS} - V_{THN}\right)}$$

$$= \frac{1}{K_n \frac{W}{L}\left(V_{DD} - V_{in} - V_{THN}\right)}$$

$$R_{on,p} \simeq \frac{1}{K_p \frac{W}{L} (V_{in} - |V_{THp}|)}$$



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