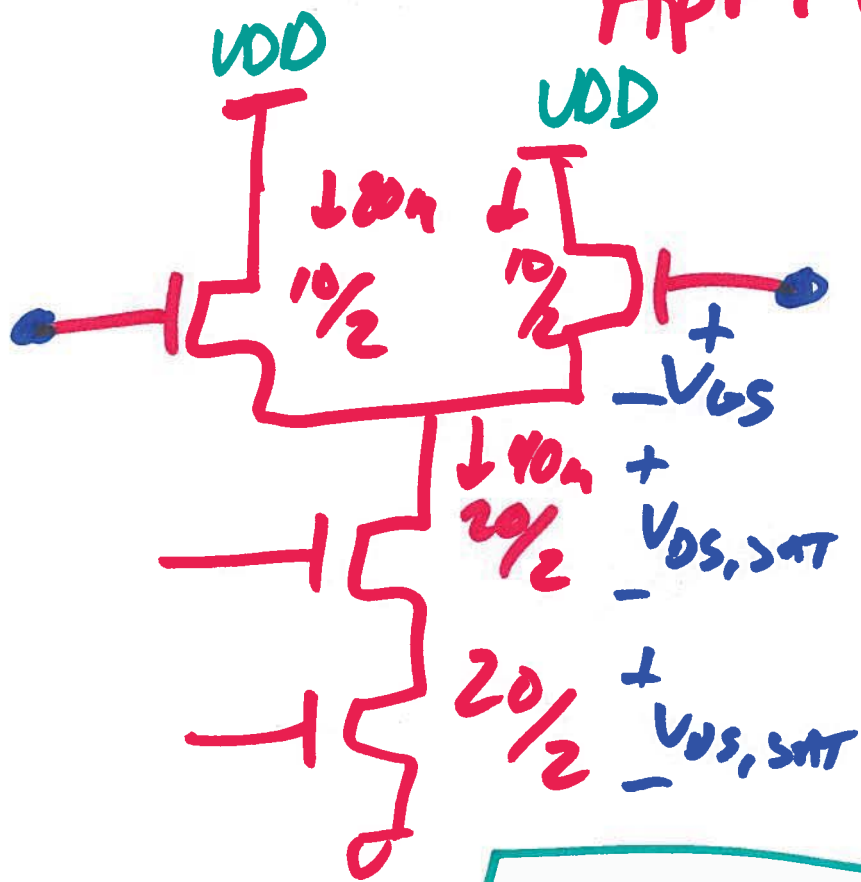


EE 420/ELG 620

Analog IC Design

Lecture 20

April 17, 2019



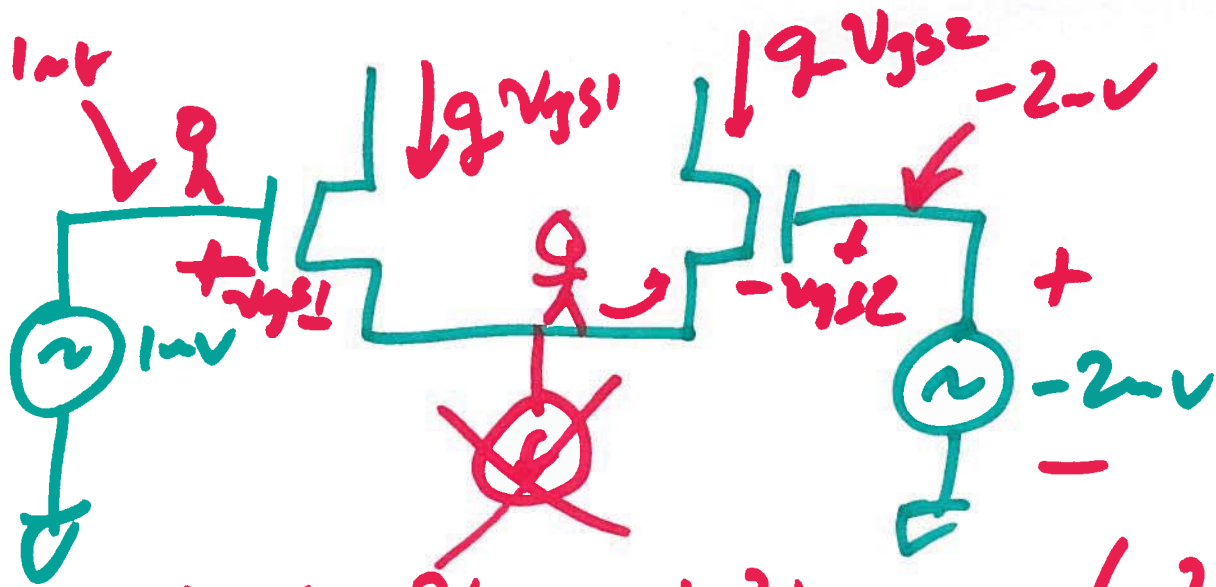
$$\begin{aligned}C_{in,max} &= V_{GS} + 2V_{DS,sat} \\ &= 1.05 + 500mV \\ &= 1.55V\end{aligned}$$

$$V_{DS} \geq V_{GS} - V_{THN}$$

$$V_G - V_S \geq V_G - V_S - V_{THN}$$

$$V_{DD} \geq V_G - V_{THN}$$

$$C_{in,max} = V_{DD} + V_{THN} = 1.58V$$



$$1\text{mV} - V_{gs1} + V_{gs2} - (-2\text{mV}) = 0$$

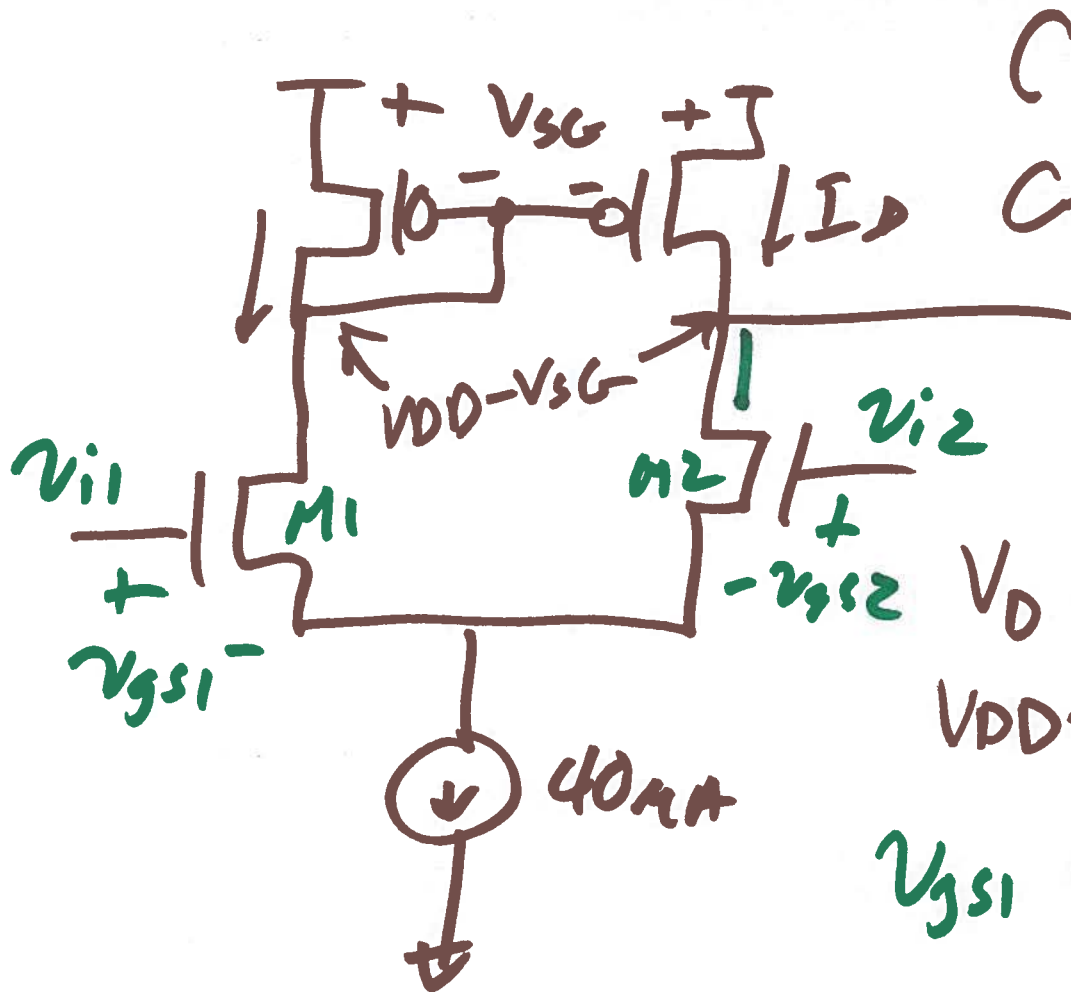
$$3\text{mV} = V_{gs1} - V_{gs2}$$

$$1.5\text{mV} - (-1.5\text{mV})$$

$$g_m = 150\mu\text{A/V} \quad 225$$

$$i_{d1} = g_m \cdot 1.5\text{mV} = 225\mu\text{A}$$

$$i_{d2} = g_m(-1.5\text{mV}) = -225\mu\text{A}$$



$CMR_{min} = 1.55$
 $CMR_{max} = V_{DD} - V_{SG} + V_{THN}$

$V_D \geq V_G - V_{THN}$
 $V_{DD} - V_{SG} \geq V_G - V_{THN}$

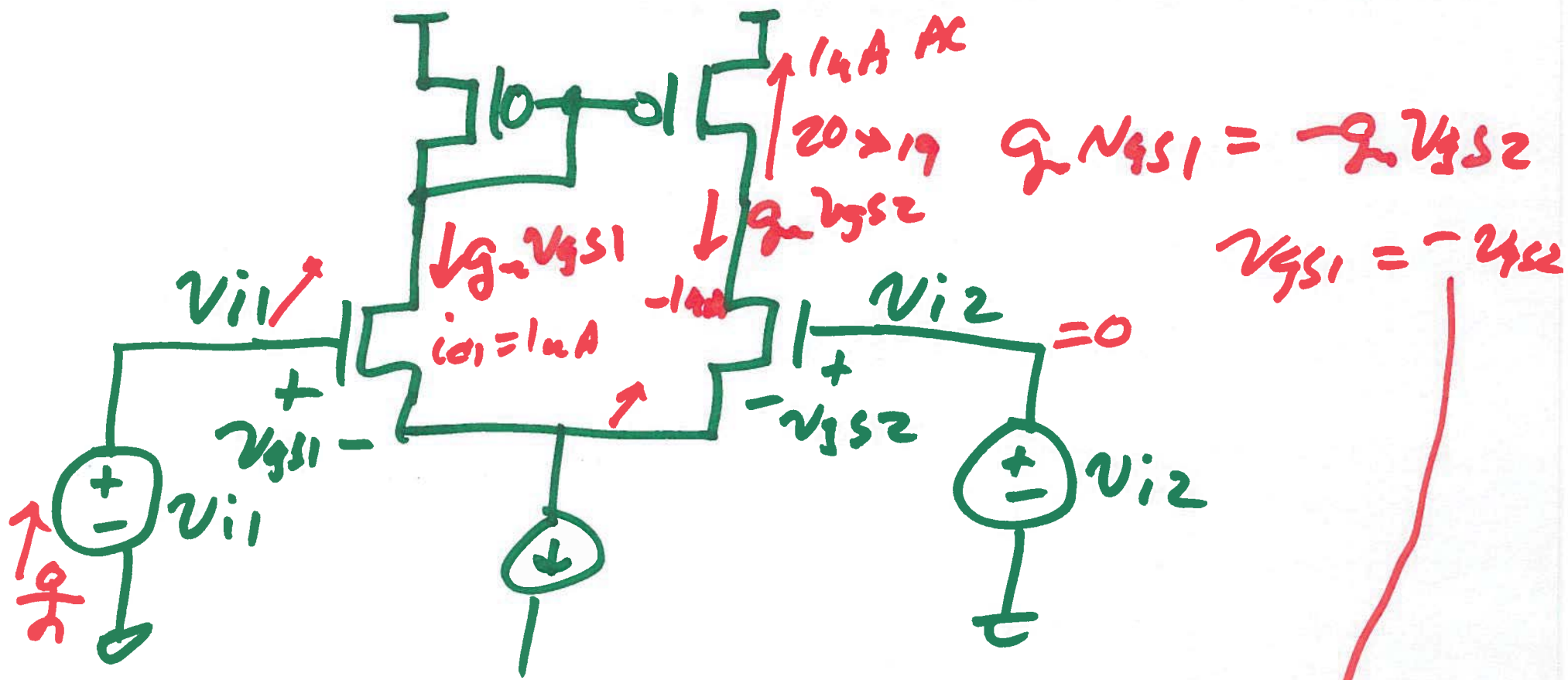
$v_{gs1} = \frac{v_{i1} - v_{i2}}{2}$

$v_{i1} - v_{gs1} + v_{gs2} - v_{i2} = 0 \Rightarrow v_{gs2} = -v_{gs1}$

$v_{i1} - v_{i2} = v_{gs1} - v_{gs2}$

3)

~~Handwritten scribbles and crossed-out text.~~

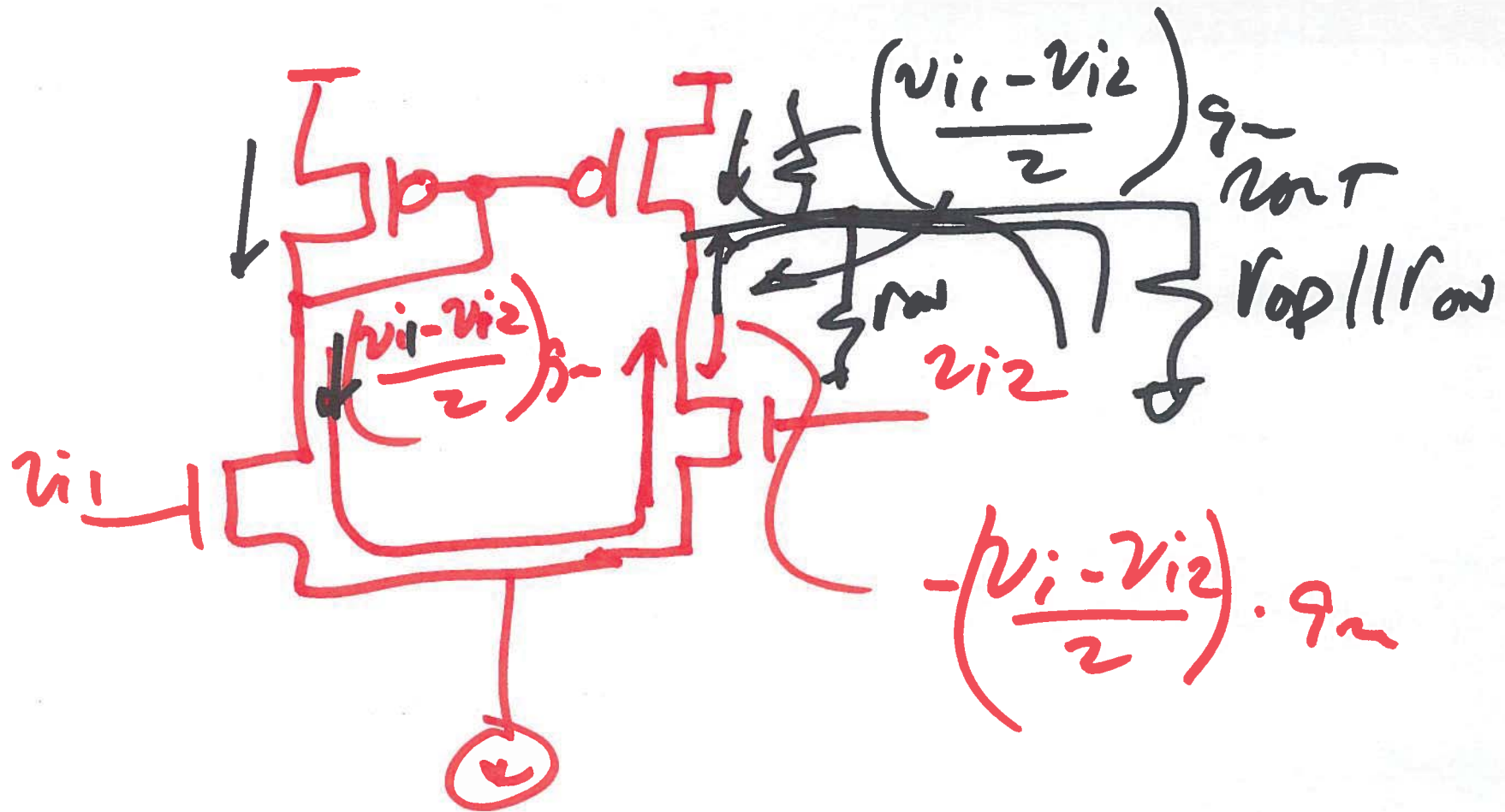


$$V_{i1} - V_{GS1} + V_{GS2} - V_{i2} = 0$$

$$V_{i1} - V_{i2} = V_{GS1} - V_{GS2} = 2V_{GS1}$$

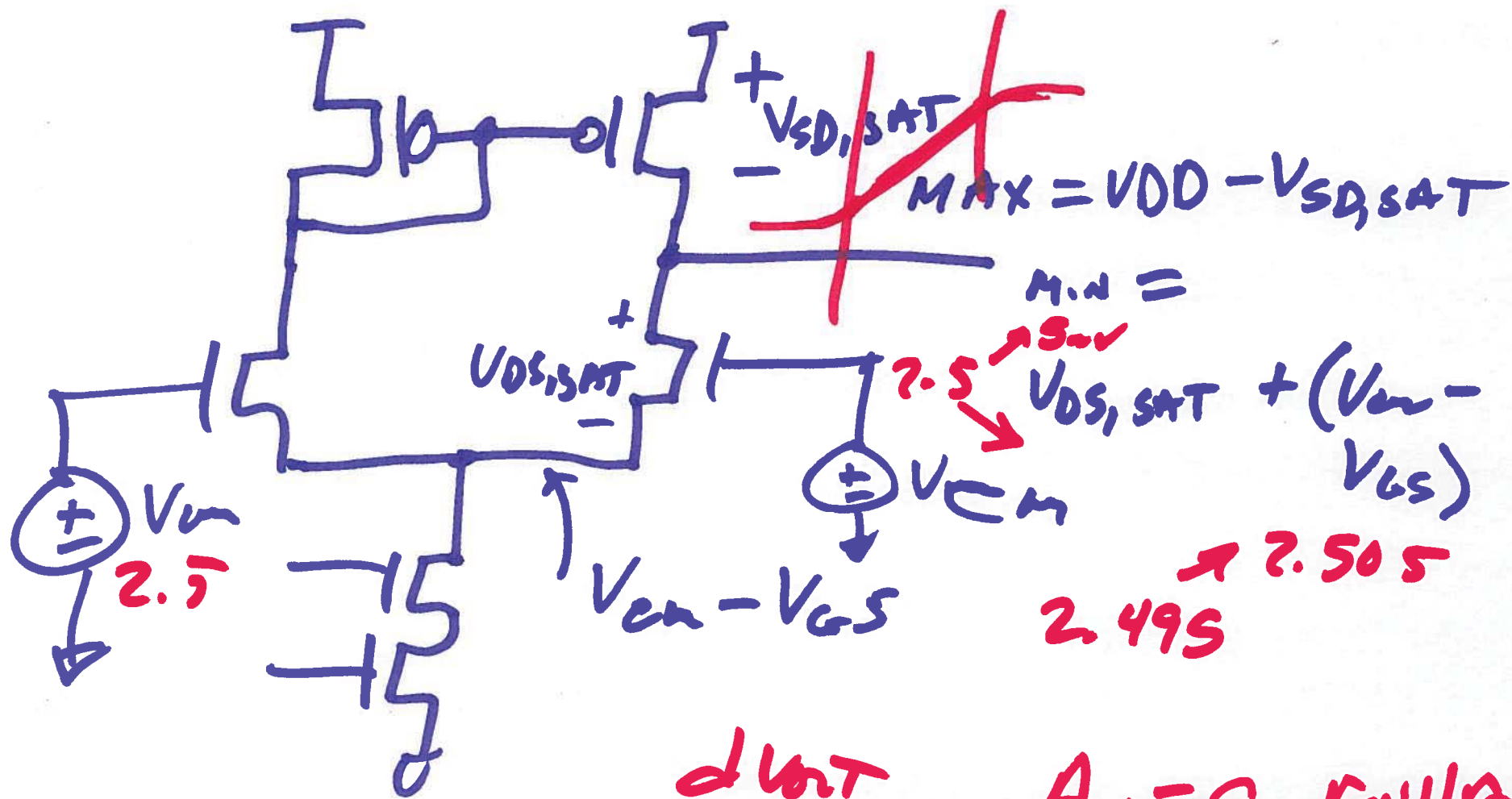
$$V_{GS1} = \frac{V_{i1} - V_{i2}}{2}$$

4)



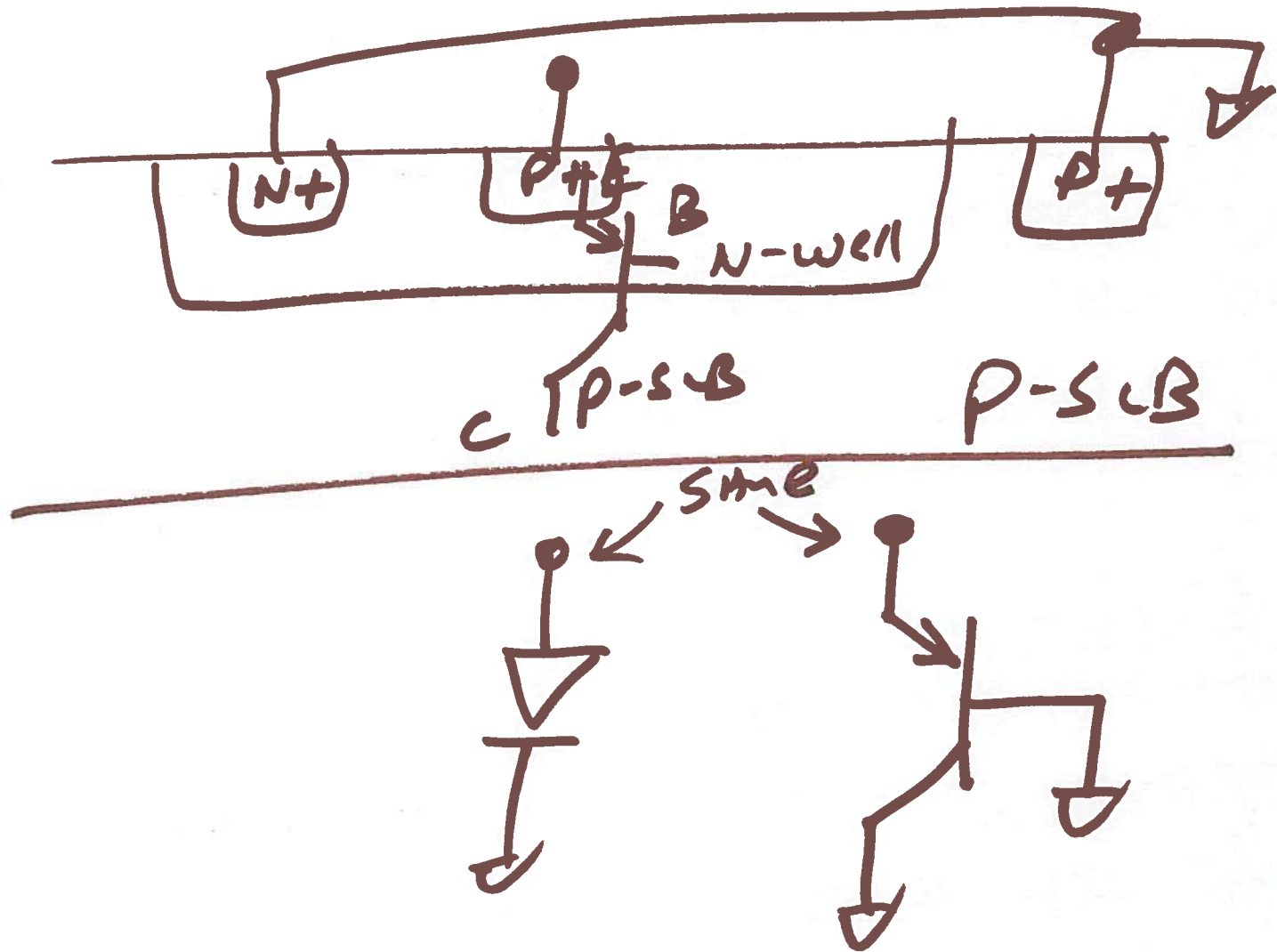
$$v_{oT} = 2i_d \cdot r_{oP} || r_{oN}$$

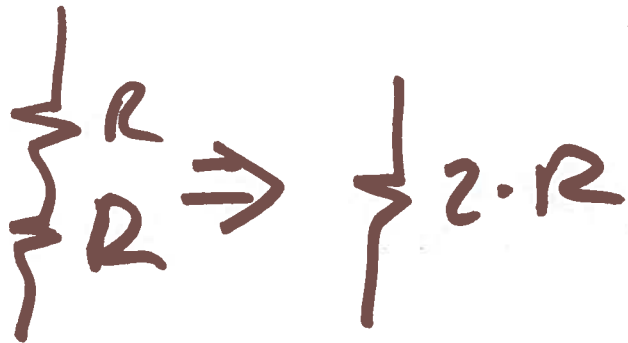
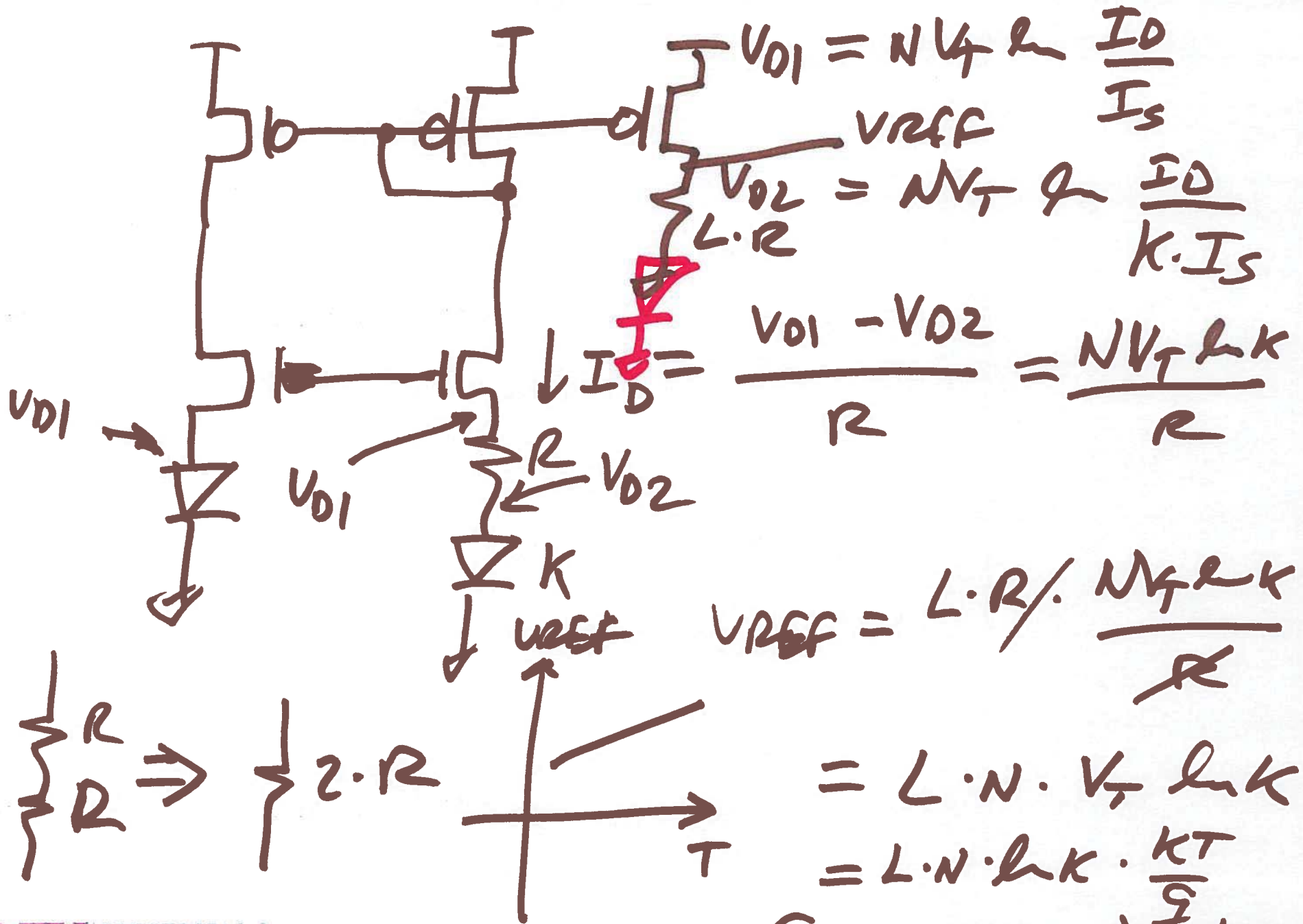
$$v_{oT} = g_m (v_{i1} - v_{i2}) \cdot r_{oP} || r_{oN}$$



$$\frac{dV_{out}}{dV_{in}} = A_v = g_m r_{out} || r_{op}$$

Parasitic PNP





$\frac{dV_T}{dT} = 0.085 \text{ mV}/^\circ\text{C}$

BAND GA P

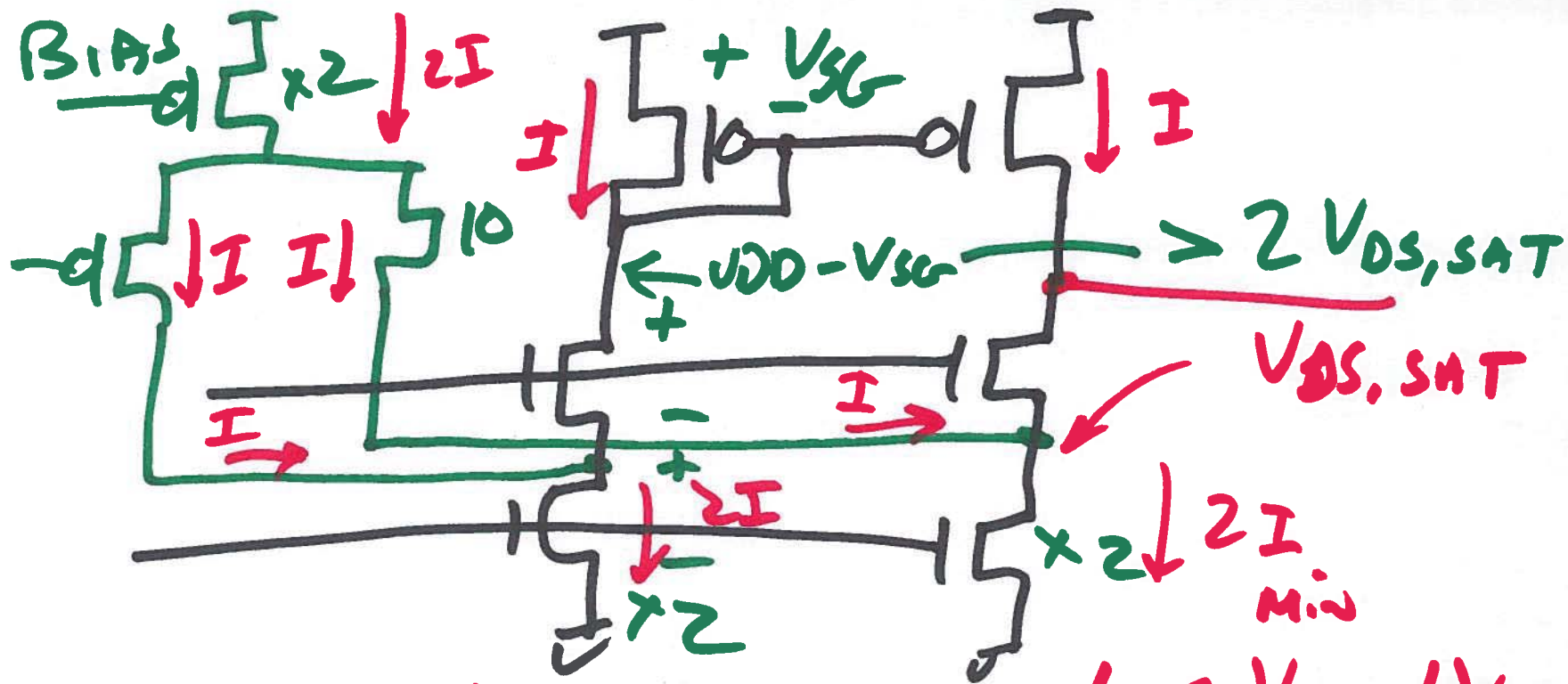


$$V_{BG} = L \cdot R \cdot \frac{N \cdot V_T \cdot Q \cdot K}{R} + V_D$$

$$\frac{\delta V_{BG}}{\delta T} =$$

$$L \cdot N \cdot Q \cdot K \cdot \frac{K}{q} + \frac{\delta V_D}{\delta T} = 0$$

$$\frac{\delta V_{BG}}{\delta T} = \underbrace{L \cdot N \cdot V_T \cdot Q \cdot K}_{PTAT} + \underbrace{V_D}_{CTAT} \quad -1.6 \frac{mV}{C}$$

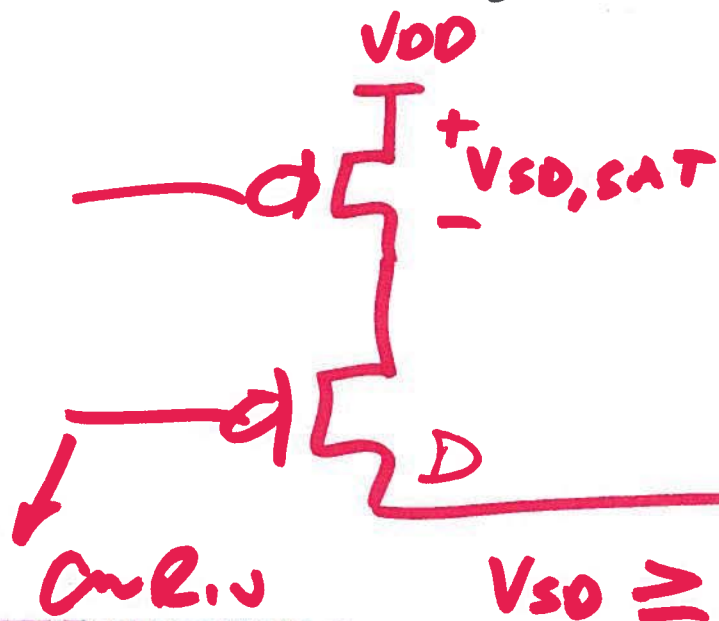


$> 2V_{DS,SAT}$
 $V_{DS,SAT}$

$$V_D \leq V_G + V_{THP}$$

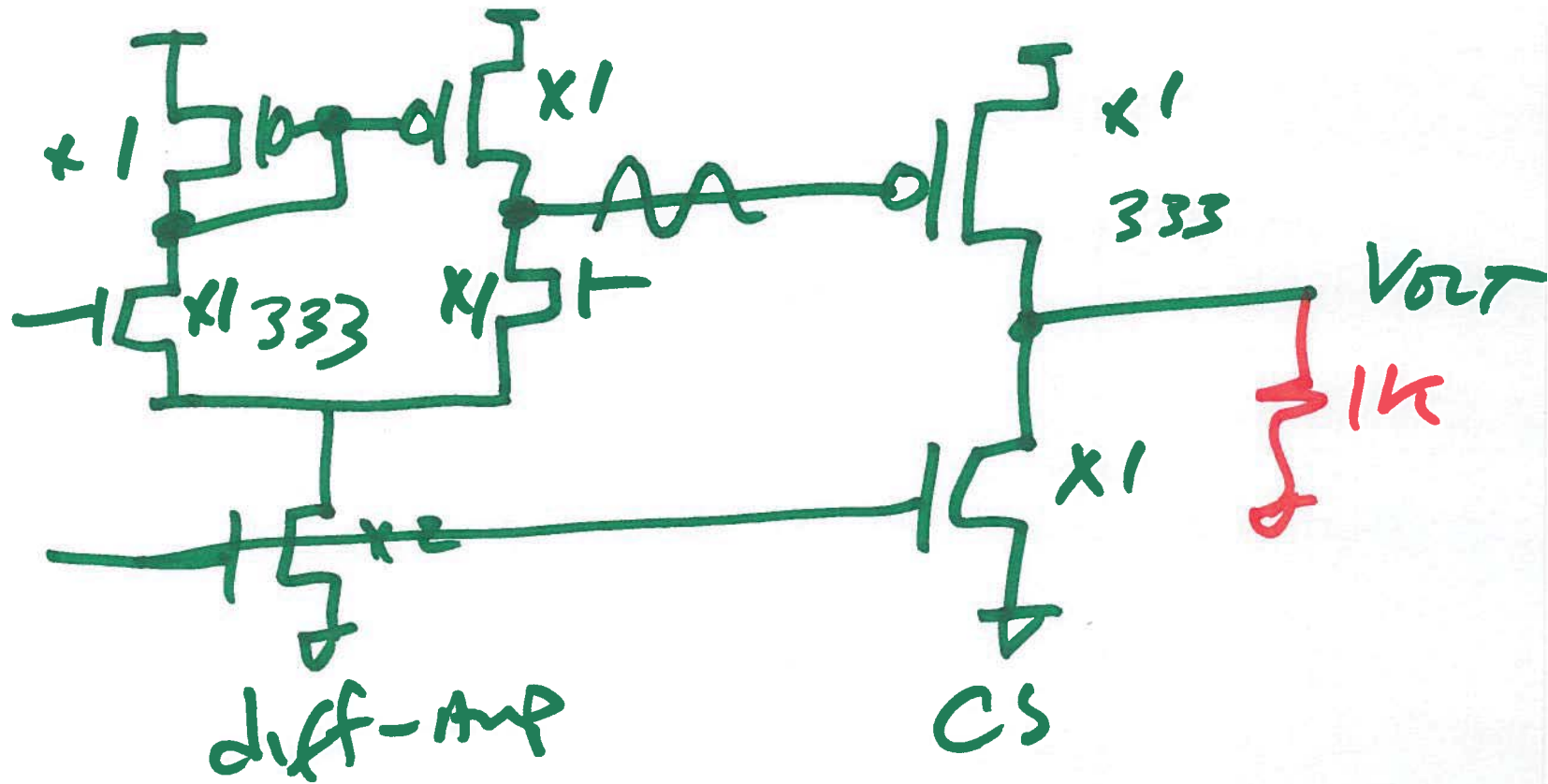
$$V_{DS,SAT} - V_{THP} \leq V_G |_{min}$$

$$V_G \geq V_{DS,SAT} - V_{THP}$$



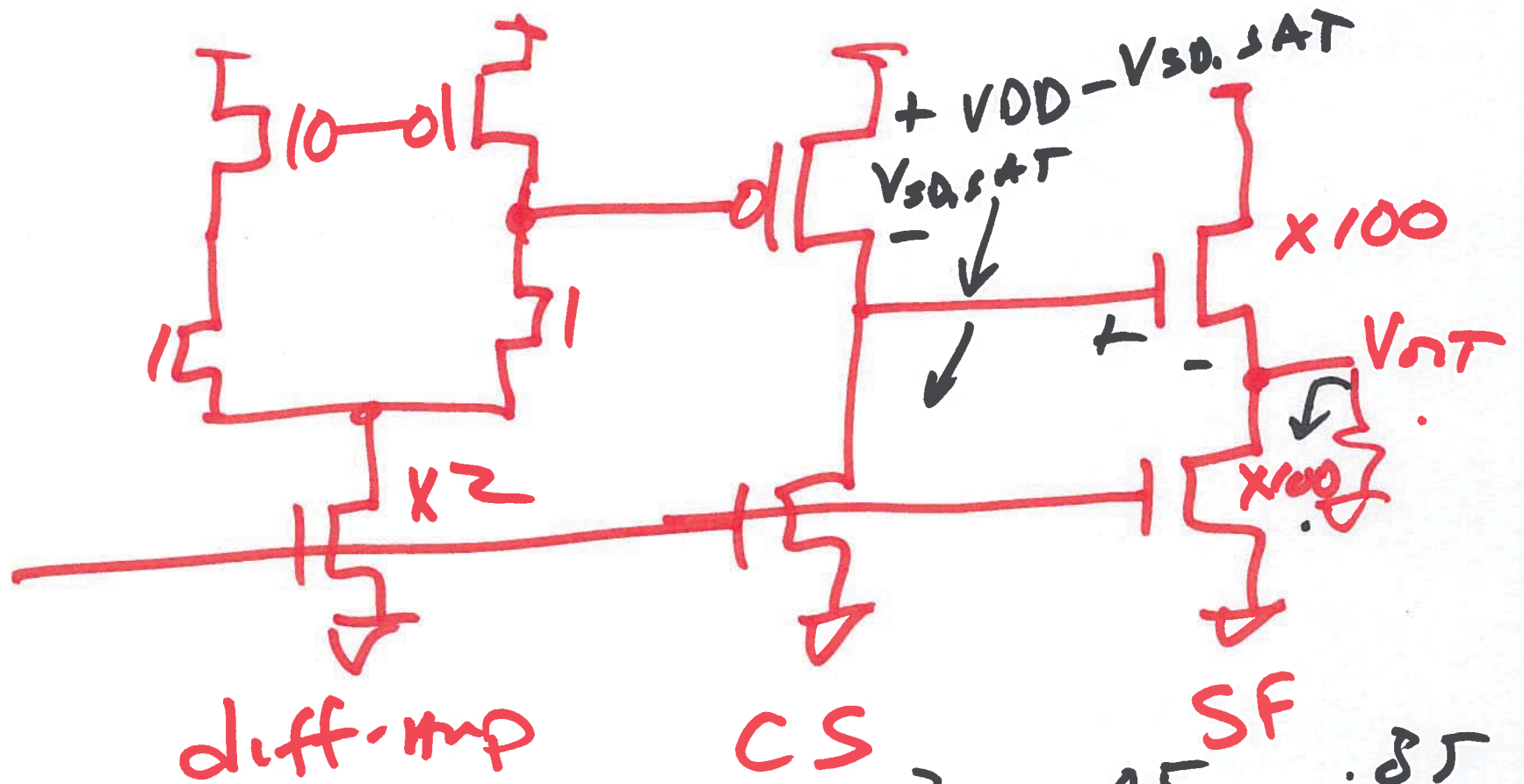
$$V_{SD} \geq V_{SG} - V_{THP}$$

$$V_S - V_D \geq V_S - V_G - V_{THP}$$



BASIC op-amp

11)



$$\begin{aligned} \text{MAX } V_{out} &= V_{DD} - V_{SD,SAT} - V_{GS} && 2 \quad .05 \quad .85 \\ \text{MIN } V_{out} &= V_{DS,SAT} && \begin{matrix} 1.1 \\ \downarrow \\ .05 \end{matrix} \end{aligned}$$

push-pull output

