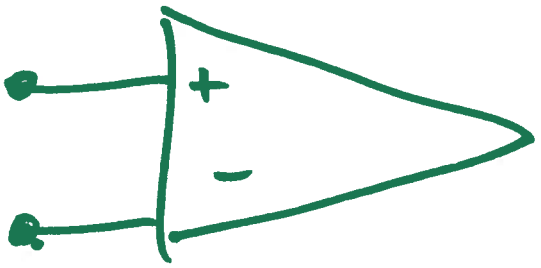
EE 420/ECE 620
Analog IC Design
Lecture 18
MARCH 27, 2017

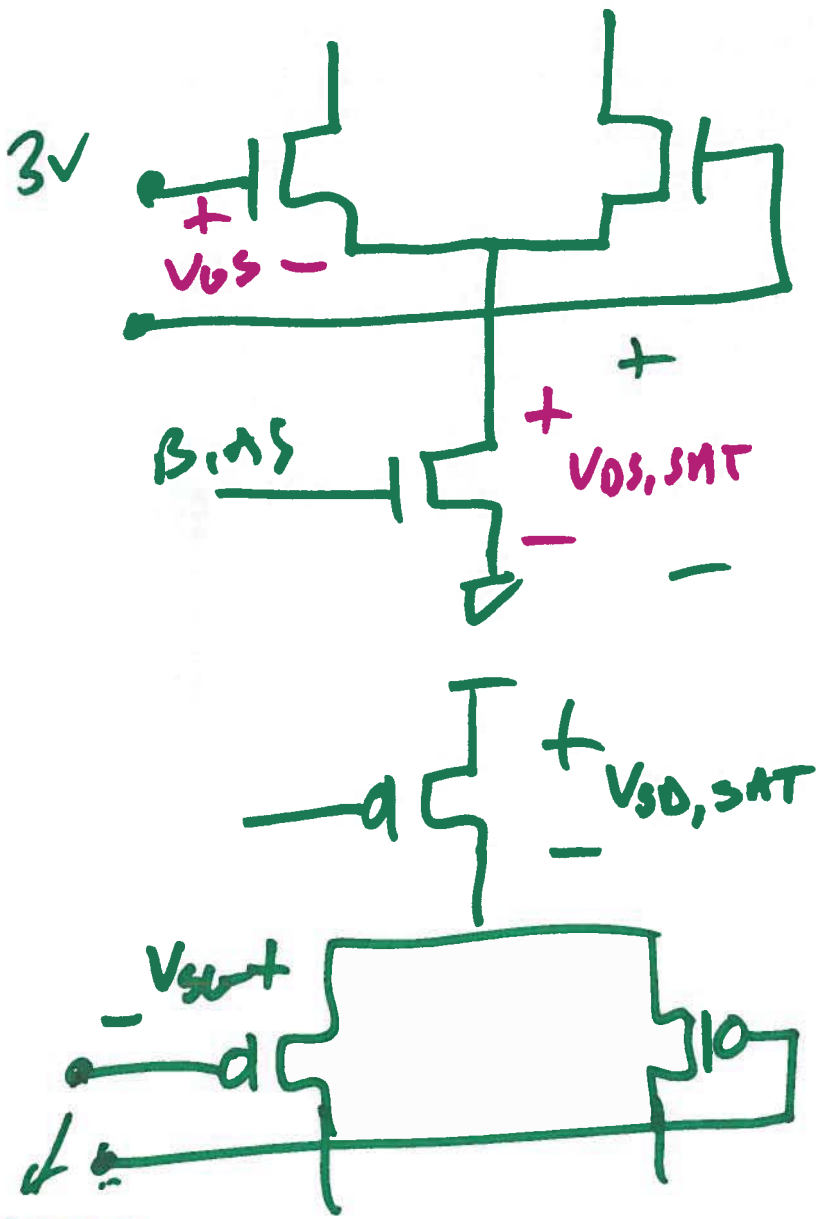
DC behavior of diff-Amps

INPUT COMMON-MODE Range (CMR)

CMR_{max}

CMR_{min}



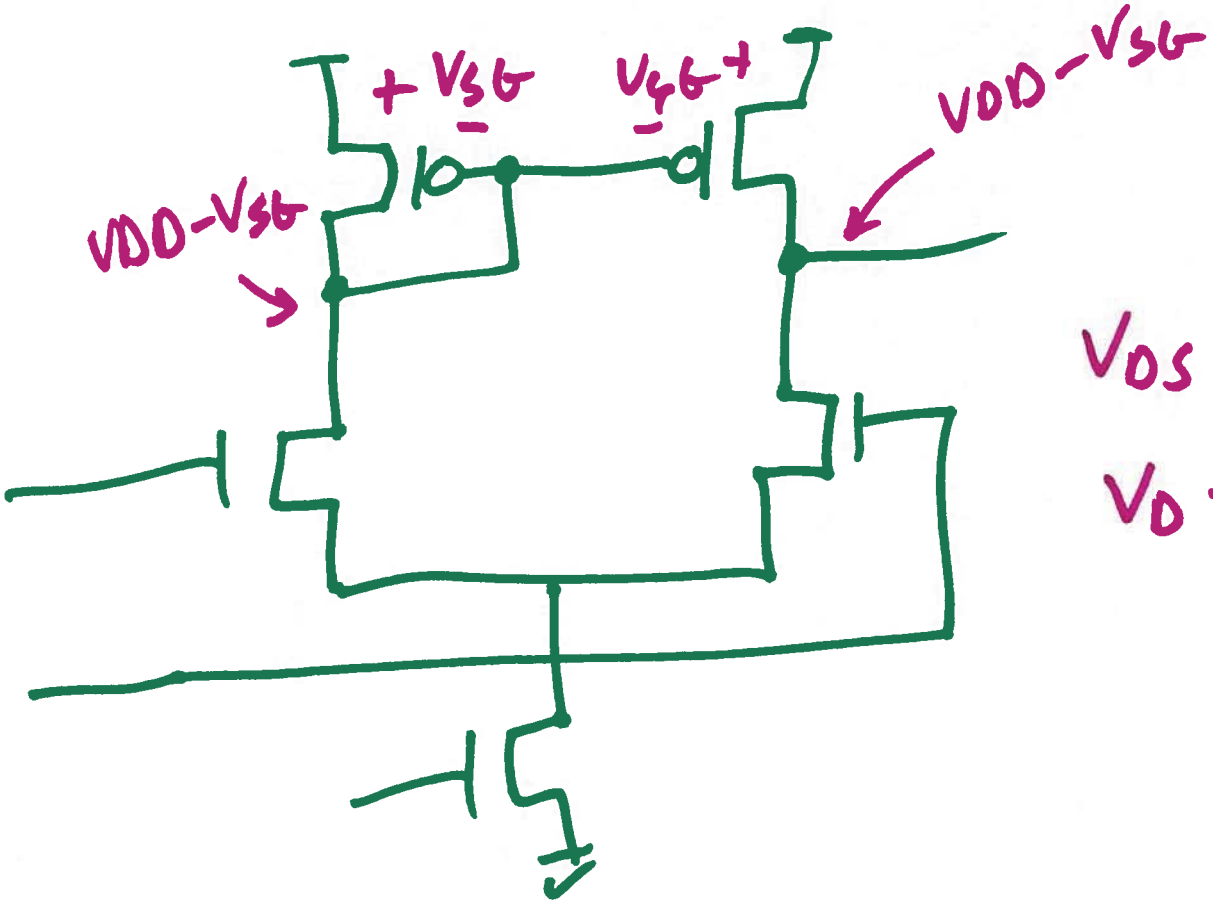


$$CMR_{MIN} = V_{GS} + V_{OS,SAT}$$

$$= 2V_{OS,SAT} + V_{THN}$$

$$= 1.3V$$

$$CMR_{MAX} = VDD - V_{SD,SAT} - V_{SG}$$



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

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

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

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

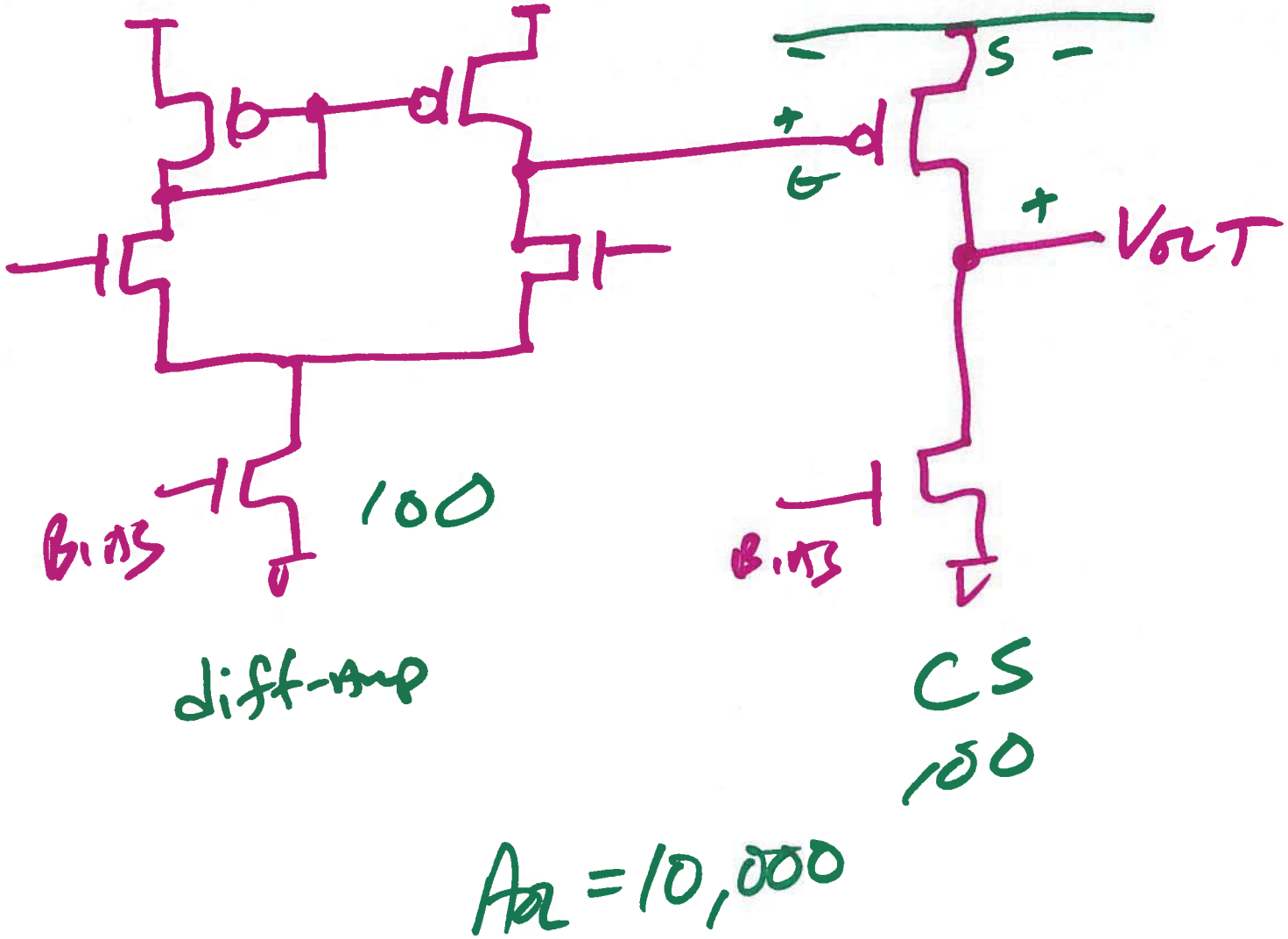
$$\leq V_{DD} - V_{SG} + V_{THN}$$

$$V_G < V_{DD} - V_{SD,SAT} - V_{THP} - V_{THN}$$

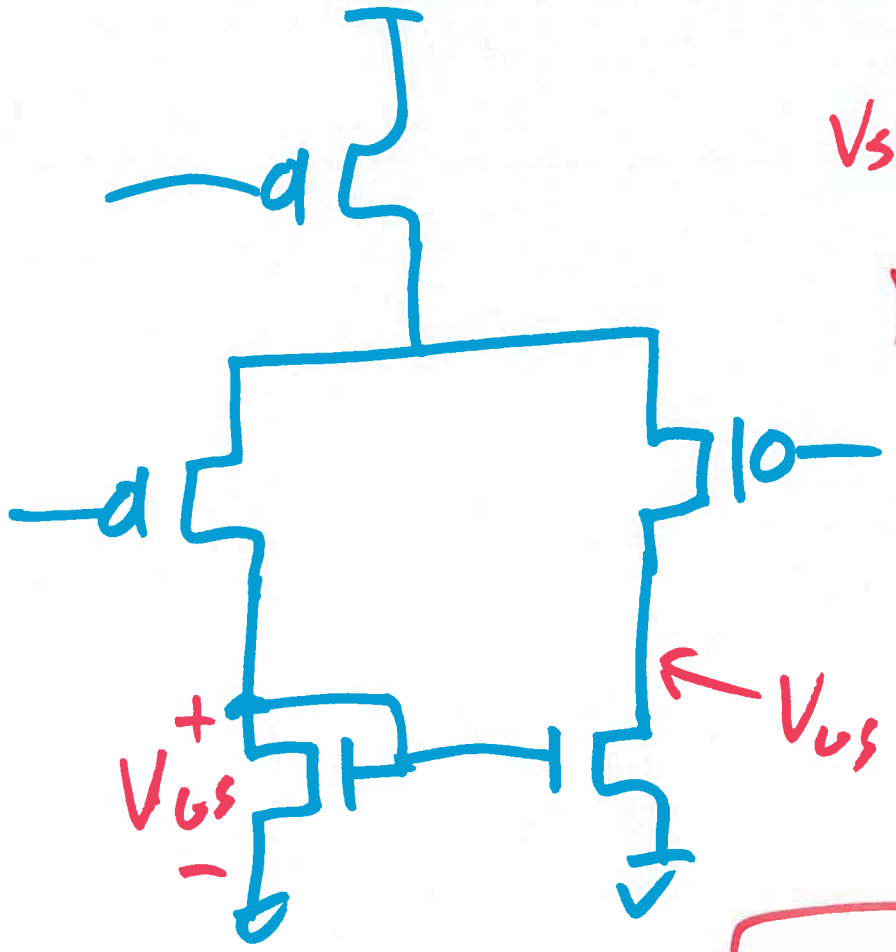
$$\approx V_{DD} - V_{SD,SAT}$$

$$CMR_{MAX} \approx V_{DD} - V_{SD,SAT}$$

two-stage op-amp



$A_{OL} = 10{,}000$



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

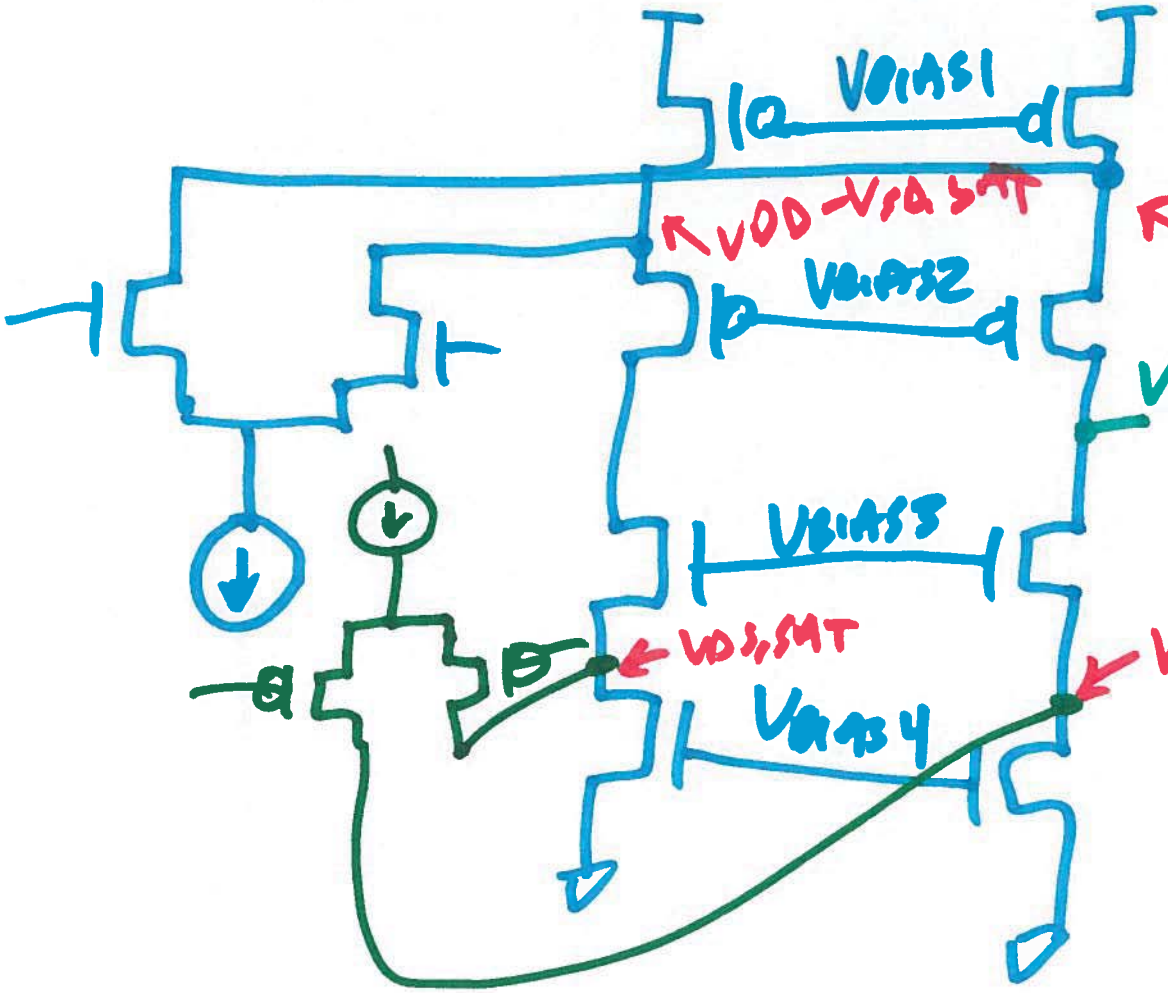
$V_S - V_D \geq V_S - V_G - V_{THP}$

$V_G \geq V_D - V_{THP}$

$\geq V_{GS} - V_{THP}$

$\geq V_{DS,SAT} + V_{THN} - V_{THP}$

$OVR_{MIN} \cong V_{DS,SAT}$



V_{OUT} CM Range

$V_O \geq V_G - V_{THN}$

$V_{DD} - V_{SD,SAT} \geq V_G - V_{THN}$

$V_G \leq V_{DD} - V_{SD,SAT} + V_{THN}$

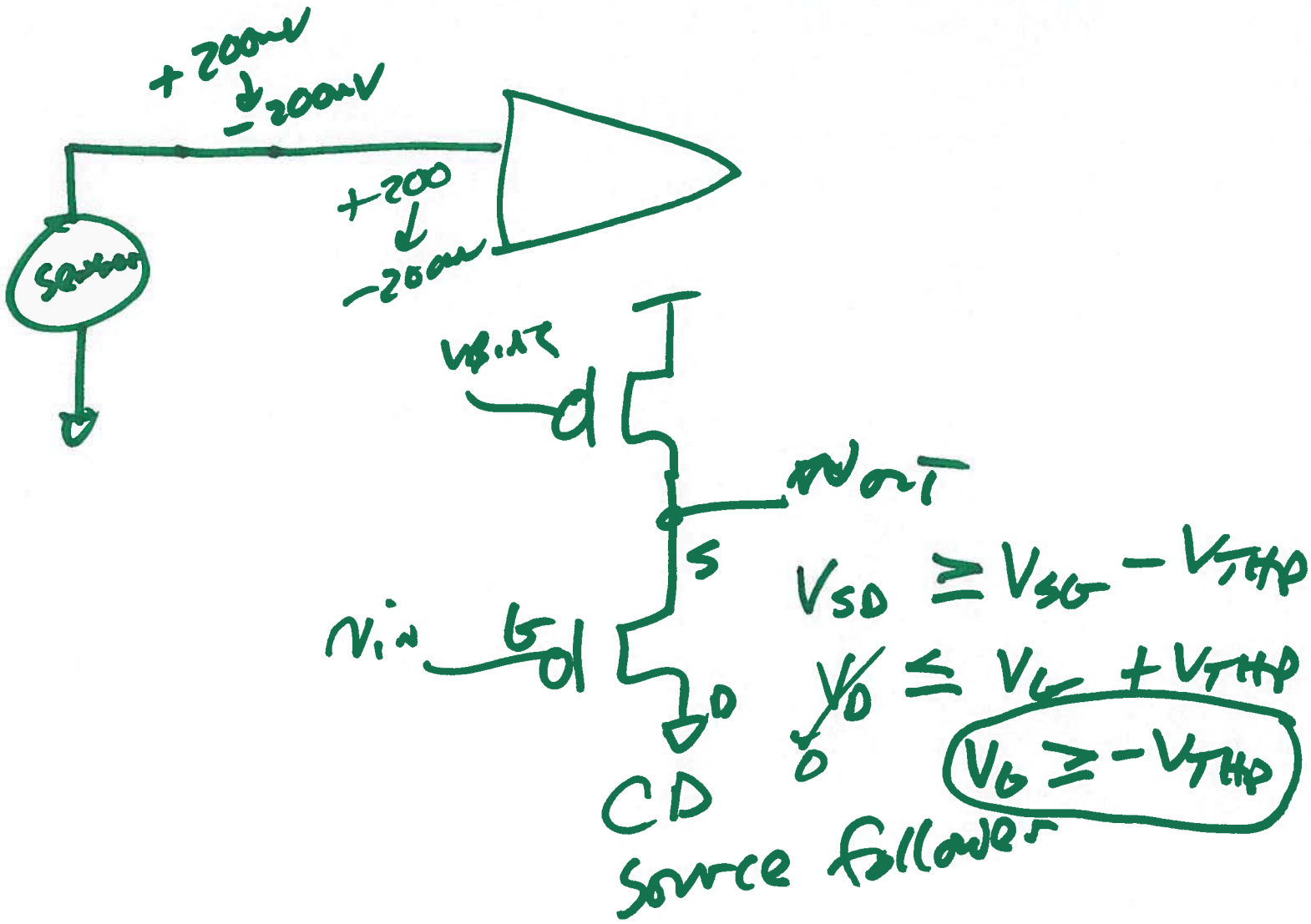
CM Range

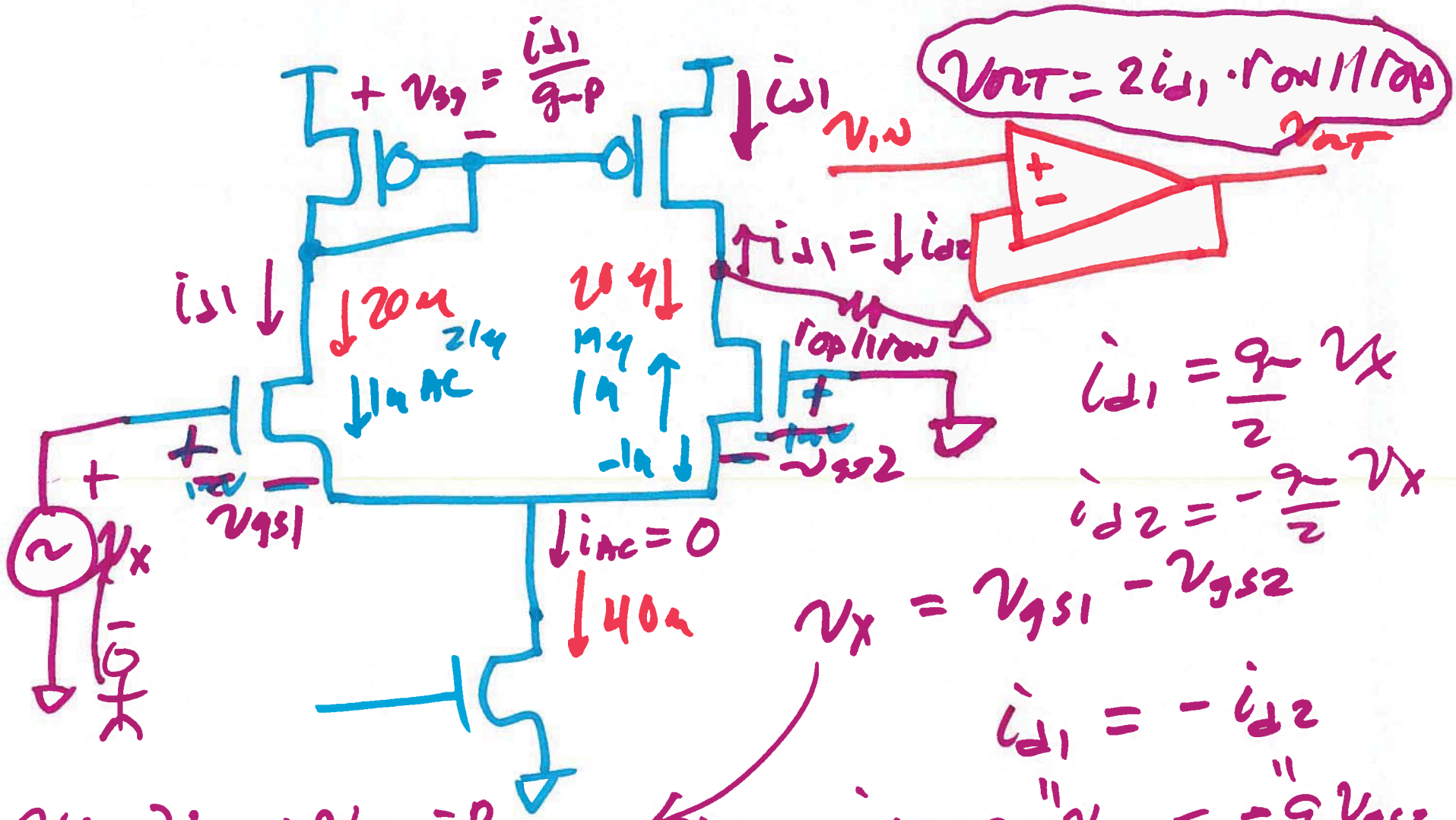
$V_{SD} \geq V_{SG} - V_{THP}$

$V_D \leq V_G + V_{THP}$

$V_{DS,SAT} \leq V_G + V_{THP}$

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


+200mV
-200mV
+200
-200mV
Sensor
VBIAS
VOUT
S
Vin
G
D
CD
Source follower
$V_{SD} \geq V_{SG} - V_{THP}$
$V_D \leq V_G + V_{THP}$
$V_D \geq -V_{THP}$



$$v_x - v_{gs1} + v_{gs2} = 0$$

$$v_x = v_{gs1} - v_{gs2}$$

$$i_{d1} = \frac{g_m}{2} v_x$$

$$i_{d2} = -\frac{g_m}{2} v_x$$

$$i_{d1} = -i_{d2}$$

$$g_m v_{gs1} = -g_m v_{gs2}$$

$$v_{gs1} = \frac{i_{d1}}{g_m}$$

$$v_x = \frac{i_{d1}}{g_m} - \frac{i_{d2}}{g_m}$$

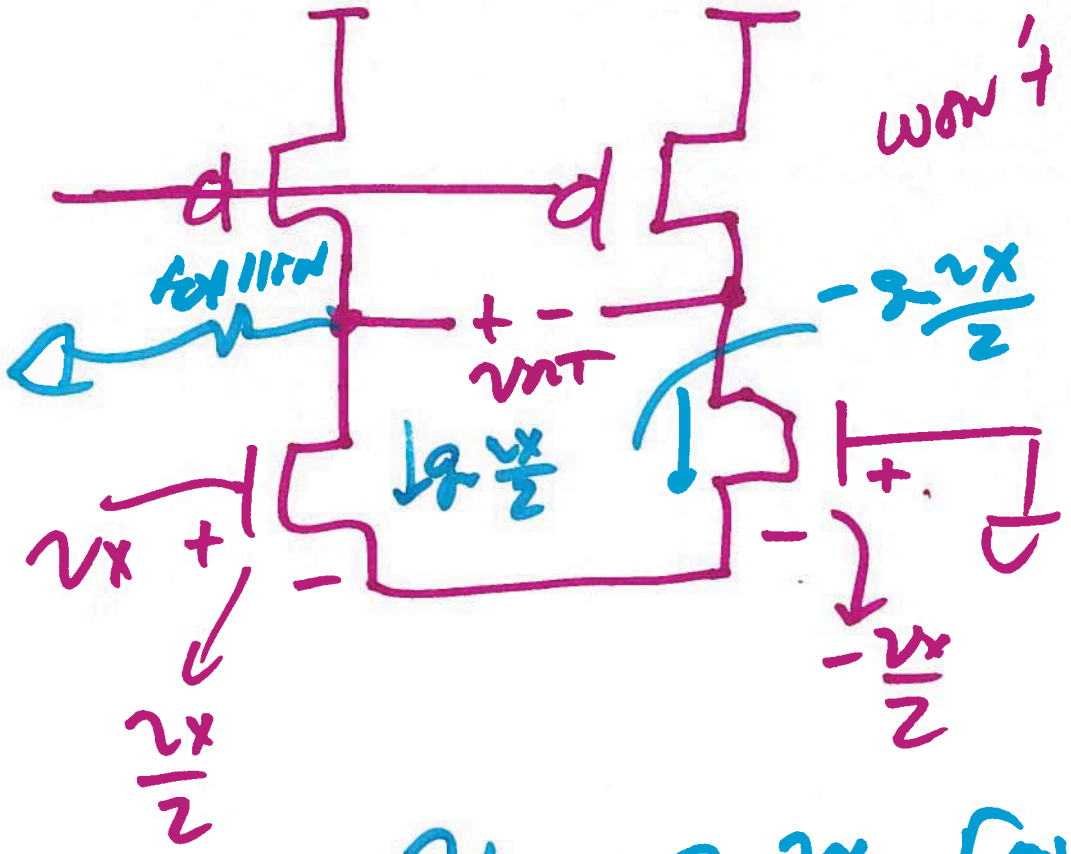
$$v_{gs2} = \frac{-i_{d2}}{-g_m} = \frac{i_{d2}}{g_m}$$

$$v_x = \frac{2}{g_m} \cdot i_{d1}$$

$$v_{OUT} = 2 i_{d1} \cdot r_{oN} \| r_{op}$$

$$v_x = \frac{2}{g_{mN}} \cdot i_{d1} \rightarrow i_{d1} = g_{mN}\frac{v_x}{2}$$

$$\boxed{\frac{v_{OUT}}{v_x} = g_{mN} \cdot r_{oN} \| r_{op}}$$



won't bias up without T

Common-mode feedback circuit

$$A_d = g_m (r_{on} \| r_{op})$$

differential mode gain

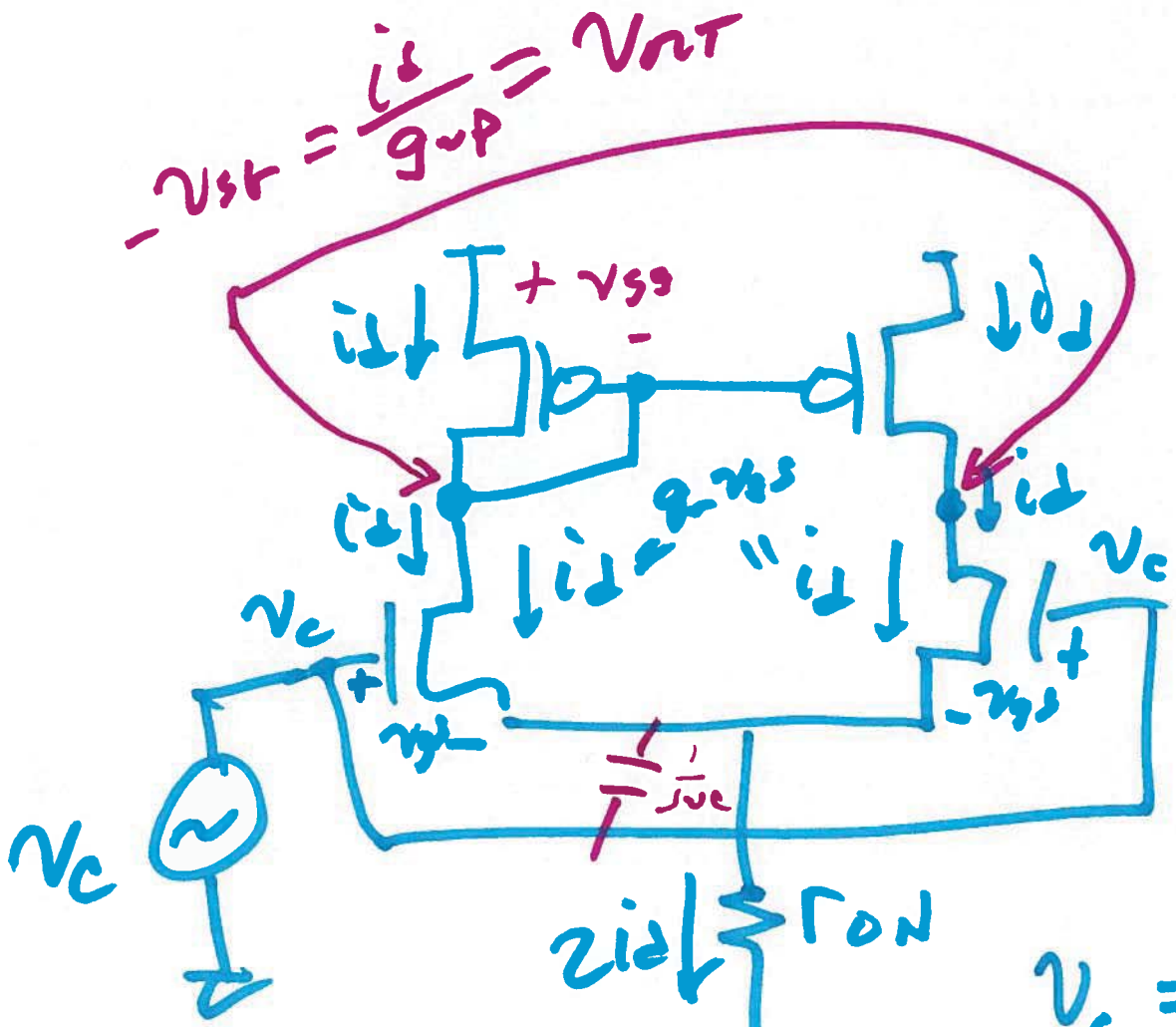
$$v_+ = g_m \frac{v_x}{2} \cdot (r_{on} \| r_{op})$$

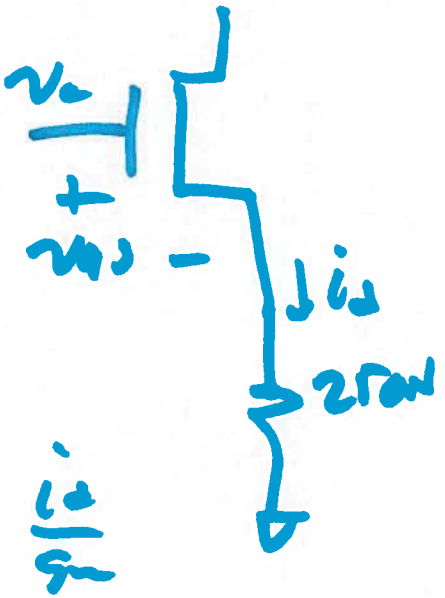
$$v_- = -g_m \frac{v_x}{2} (r_{on} \| r_{op})$$

$$v_{in} = v_+ - v_- = v_x \cdot g_m \cdot (r_{on} \| r_{op})$$

Common-mode reject

CMRR ← ratio
↑ reject





$$v_c = v_{gs} + 2 i_d \cdot r_{ON}$$

$$v_c = i_d \left(\frac{1}{g_{mN}} + 2 r_{ON} \right)$$

$$|A_C| = \left| \frac{v_{OUT}}{v_c} \right| = \left| \frac{\frac{1}{g_{mp}}}{\frac{1}{g_{mN}} + 2 r_{ON}} \right| \simeq \frac{1}{g_{mp} \cdot 2 r_{ON}}$$

common inputs

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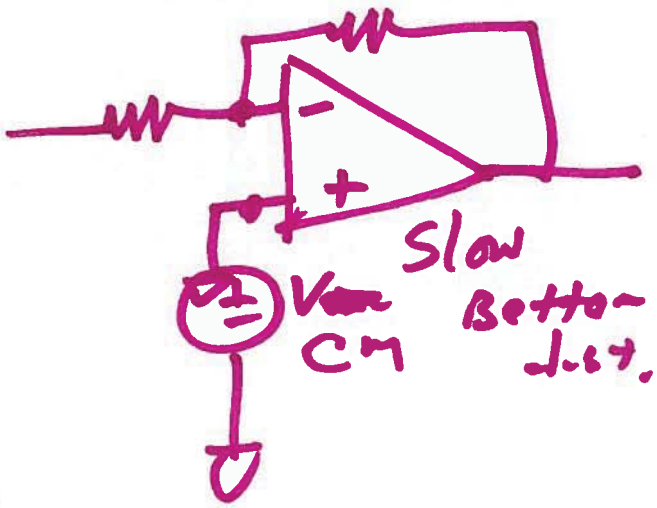
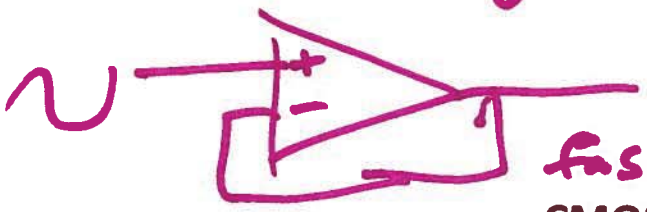
A_c = common-mode gain $= \frac{1}{g_p \cdot 2r_{ON}}$

A_d = difference-mode gain $= g_{mN} \cdot r_{ON} \| r_{OP}$

COMMON-MODE Rejection Ratio

$$CMRR = 20 \log \frac{A_d}{A_c}$$





CMRR = 60dB

200nV = ΔV_c

ΔV_{OUT} = 10mV

$\frac{10mV}{50} = .2mV$ ← V_{OS}

-26dB

$A_c = \frac{10mV}{200mV} = \frac{1}{20} = 0.05 = -26dB$

$CMRR = 20 \log \frac{A_d}{A_c} = 60dB$

$60dB = 20 \log A_d - 20 \log A_c$

$-26dB$

$+26dB$

$34dB = 20 \log A_d \rightarrow A_d = 34dB$

$= 50$

-6dB = $\frac{1}{2}$

-20dB = $\frac{1}{10}$

-14dB = $\frac{1}{5}$