EE 420 / ECG 620

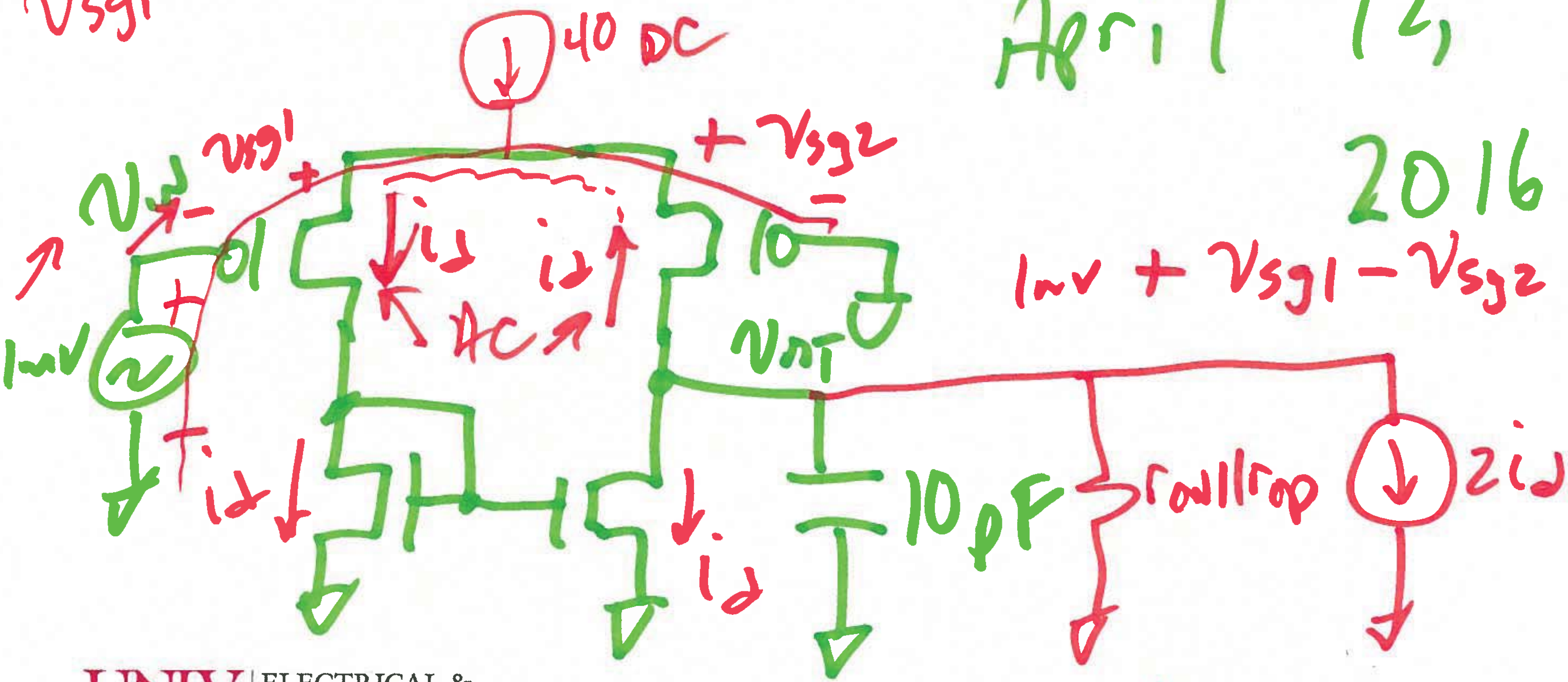
Analog IC Design

Lecture 22

April 12, 2016

$$f_{3dB} = \frac{1}{2\pi\, r_{on} \| r_{op} \cdot 10pF}$$

$v_{sg1} = -v_{sg2}$



$1mV + v_{sg1} - v_{sg2} = 0$

$1mV = -2v_{sg1}$

$v_{sg} = -\frac{1}{2} mV$

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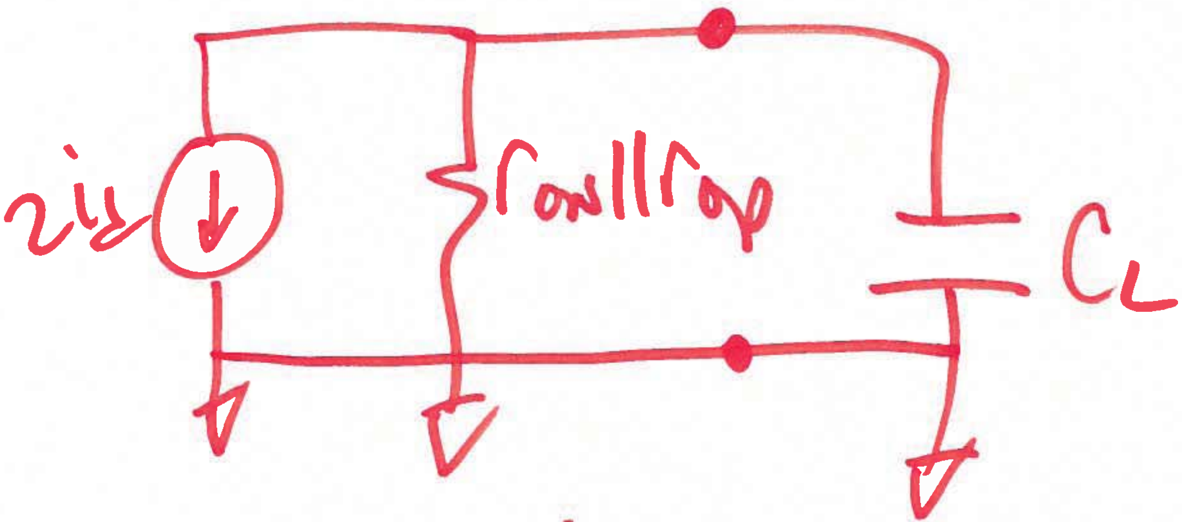
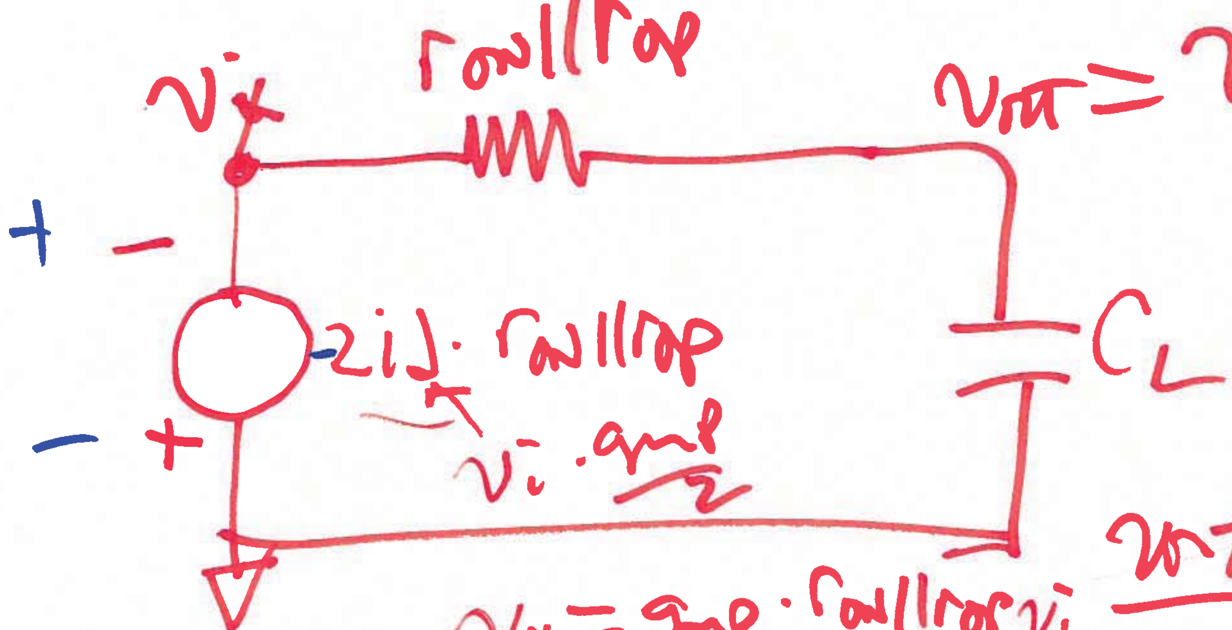
1)



$$1 = 2\pi f_{3dB} \cdot C_L r_{on}||r_{op}$$

$$f_{3dB} = \frac{1}{2\pi C_L \cdot r_{on}||r_{op}}$$

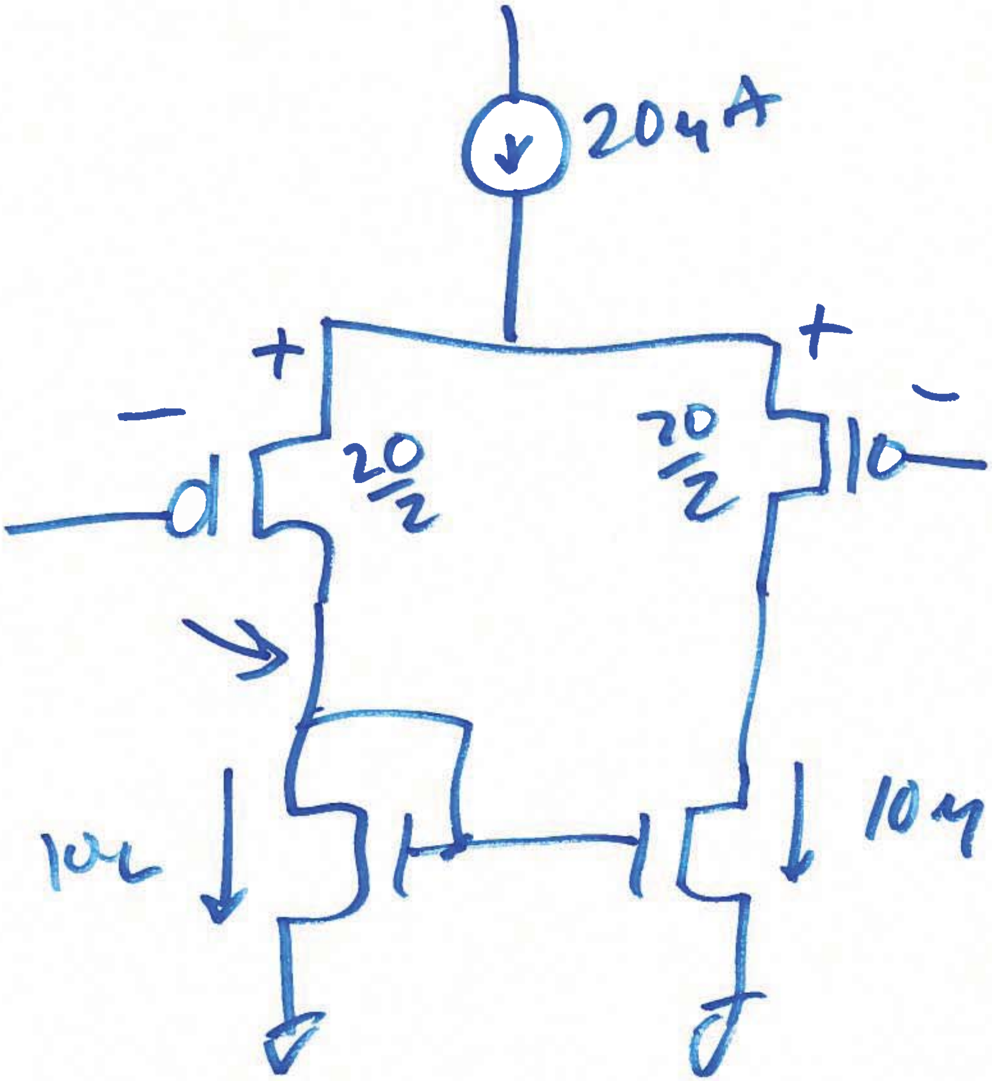


$$v_\pi = v_x \cdot \frac{1/j\omega C_L}{1/j\omega C_L + r_{on}||r_{op}}$$

$$v_x = g_{mp} \cdot r_{on}||r_{op} \, v_i$$

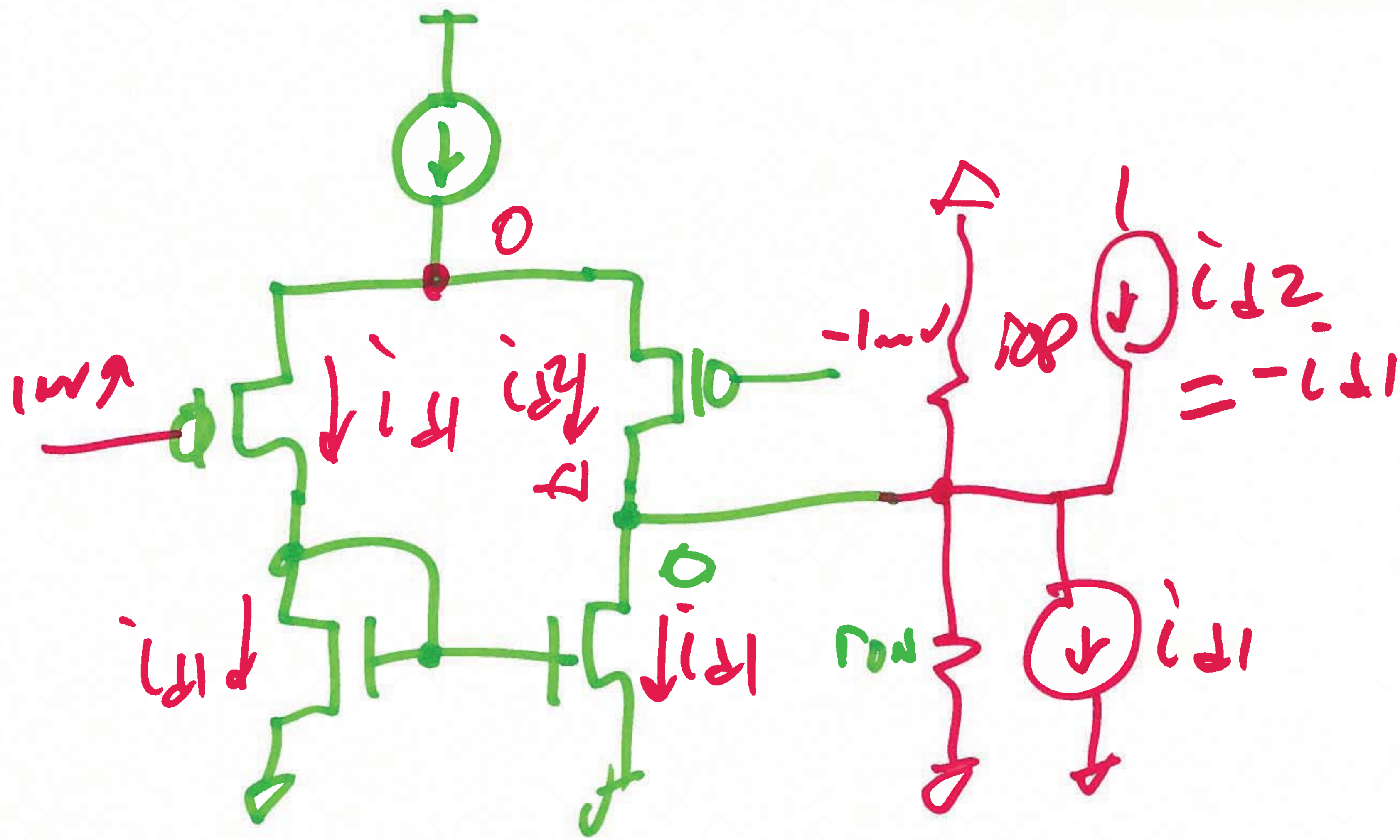
$$\frac{v_\pi}{v_x} = \frac{1}{1 + j\omega C_L r_{on}||r_{op}}$$

$$= \frac{1}{1 + j\frac{f}{f_{3dB}}}$$

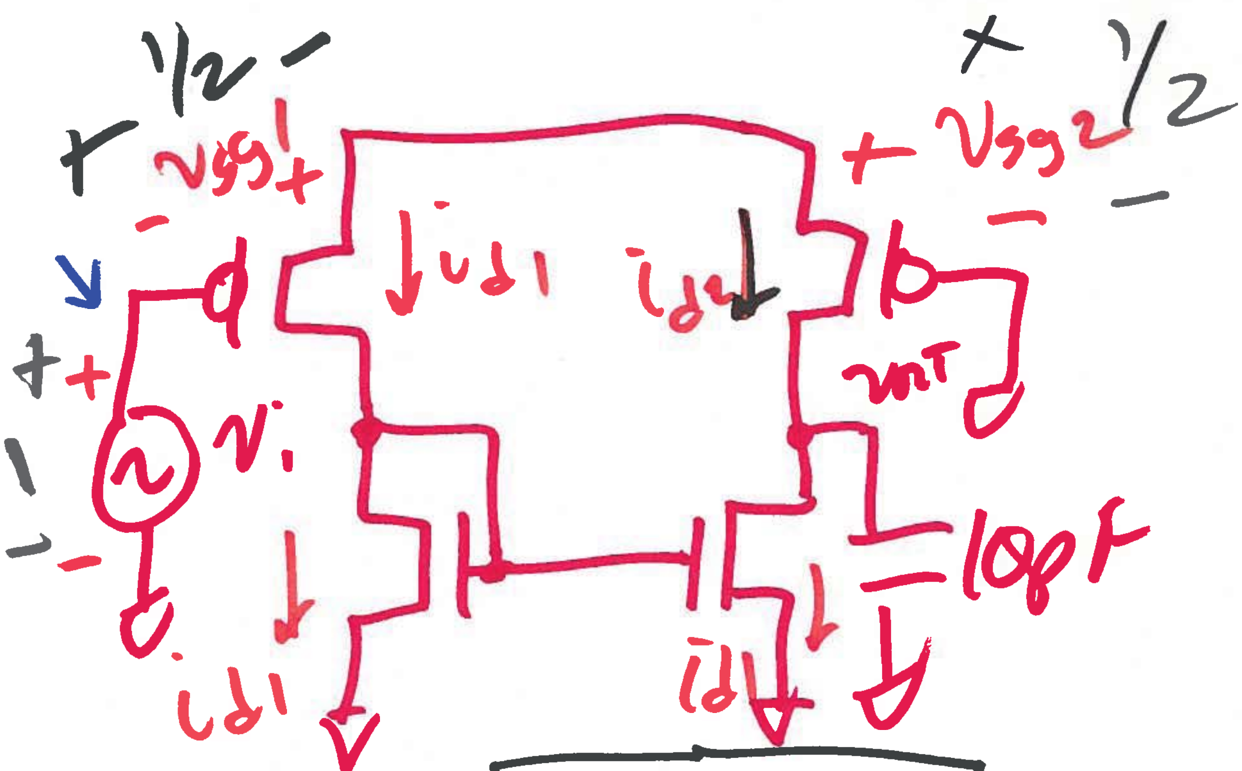


$$V_{SG} = \sqrt{\frac{2 \cdot 10uA}{40u \cdot \frac{20}{2}}} + .9$$

$$V_{GS} = \sqrt{\frac{2 \cdot 10uA}{120u \cdot \frac{10}{2}}} + .8$$



0
1mV
i_{d1}
i_{d2}
-1mV
r_{op}
i_{d2}
$= -i_{d1}$
0
i_{d1}
i_{d1}
r_{on}
i_{d1}



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

$$v_{sg1} = -v_{sg2}$$

$$v_i + v_{sg1} = v_{sg2}$$

$$v_i = 1\,mV$$

$$v_{sg1} = -\frac{1}{2}\,mV$$

$$v_{sg2} = +\frac{1}{2}\,mV$$

$$g_{mp} = \sqrt{2 \cdot 40\mu \cdot \frac{20}{2} \cdot 10\mu}$$

$$i_{d1} = g_{mp} \cdot \left(-\frac{1}{2}\,mV\right)$$

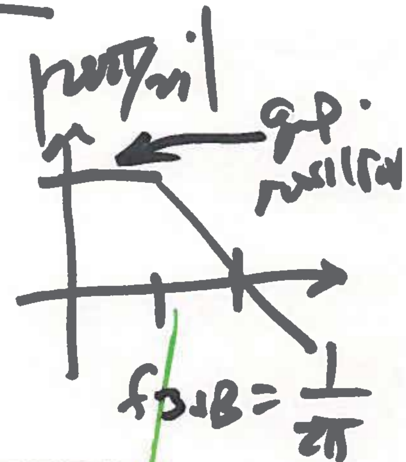
$$i_{d2} = g_{mp} \cdot \frac{1}{2}\,mV$$

$$\left(g_{mp} \cdot \frac{1}{2}\,mV\right) \cdot 2 = g_{mp} \cdot \overset{1mV}{v_i}$$

$$\boxed{v_{OUT} = g_{mp} \cdot v_i \cdot r_{on} \| r_{op}}$$

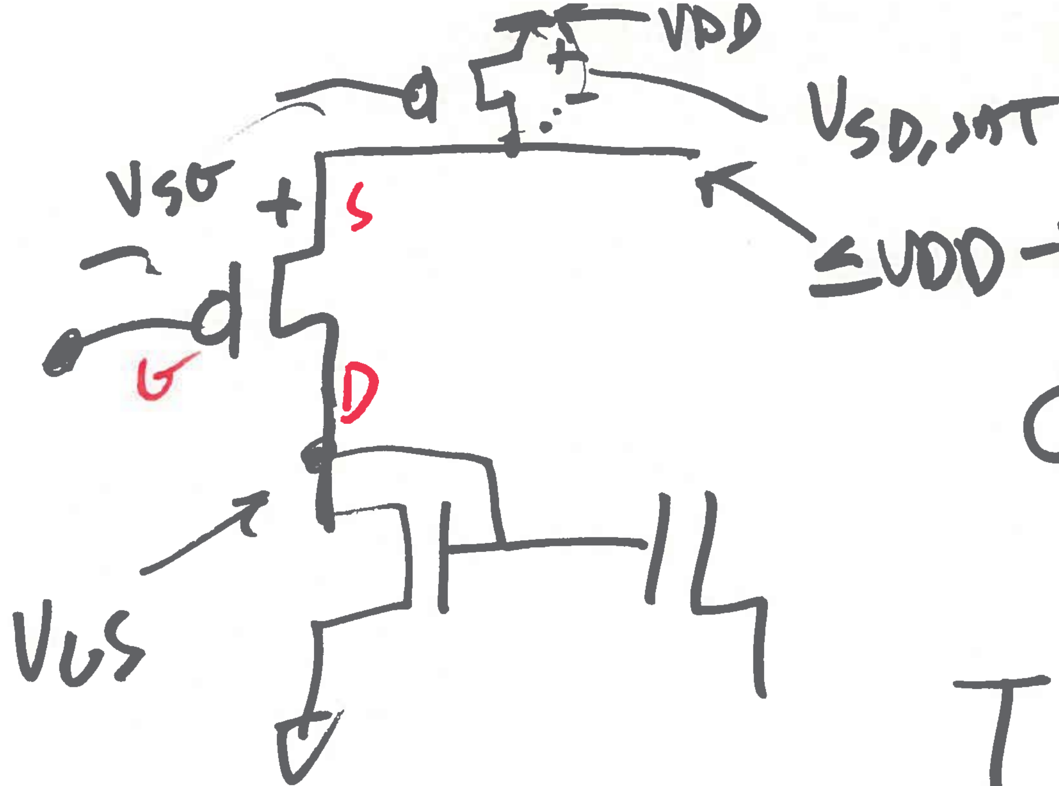
$$v_{out} = g_{mp} \cdot v_i \cdot r_{on} \| r_{op} \| \frac{1}{j\omega C_L}$$

$$\frac{v_{out}}{v_i} = g_{mp} \cdot \frac{(r_{on} \| r_{op}) \cdot \frac{1}{j\omega C_L}}{r_{on} \| r_{op} + \frac{1}{j\omega C_L}} = \left| \frac{g_{mp} \cdot r_{on} \| r_{op}}{1 + j\omega r_{on} \| r_{op} \cdot C_L} \right|$$



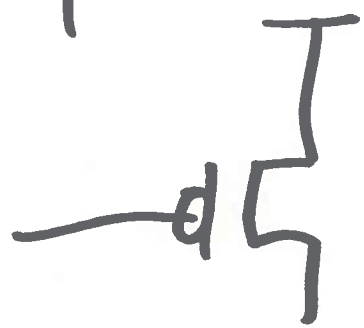
$$\left| \; \right| = 1 \approx \left| \frac{g_{mp} \cdot r_{on} \| r_{op}}{2\pi f_{un} \cdot r_{on} \| r_{op} \cdot C_L} \right|$$

$$f_{un} = \frac{g_{mp}}{2\pi C_L}$$



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

$$CMR\big|_{MAX} = V_{DD} - V_{SD,SAT} - V_{SG}$$

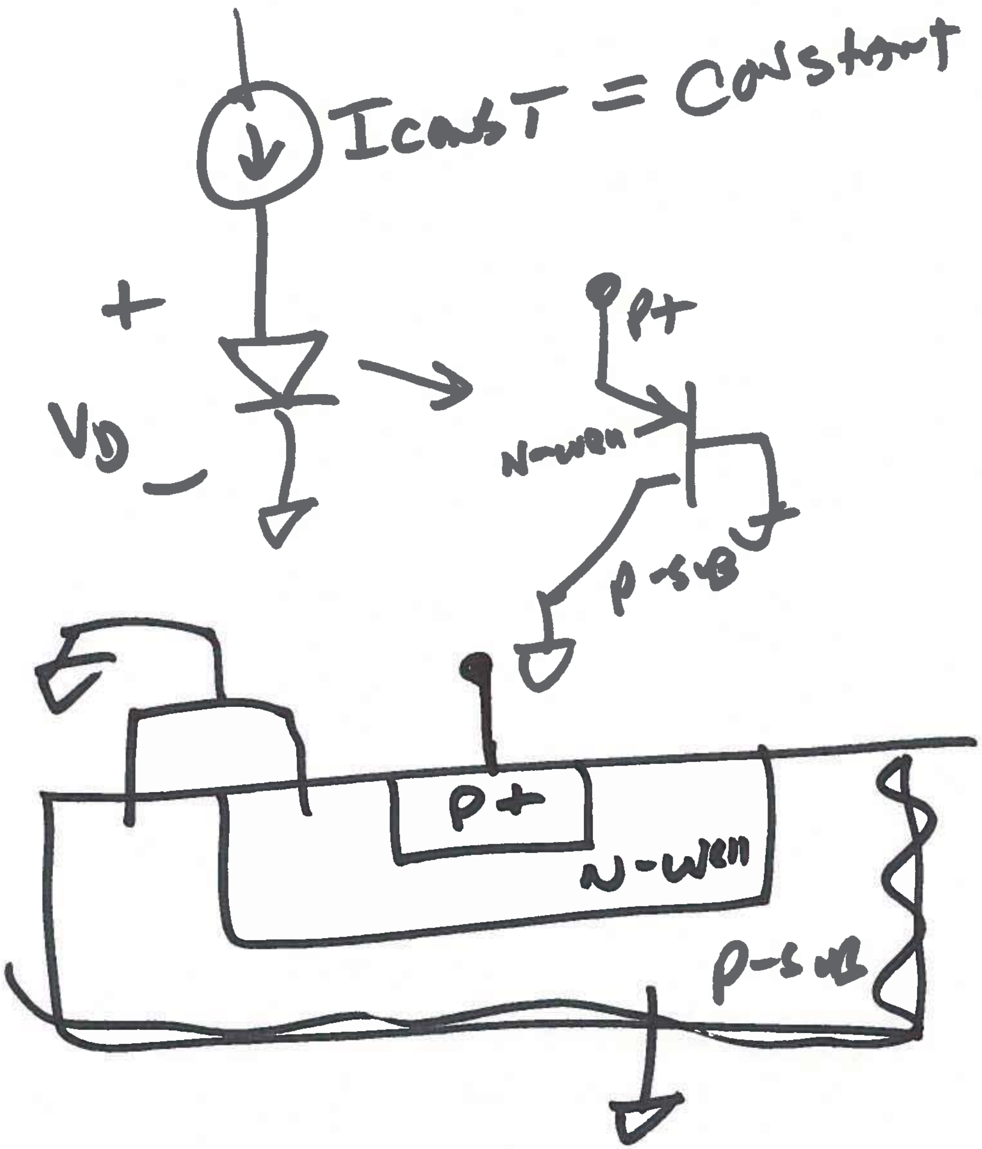


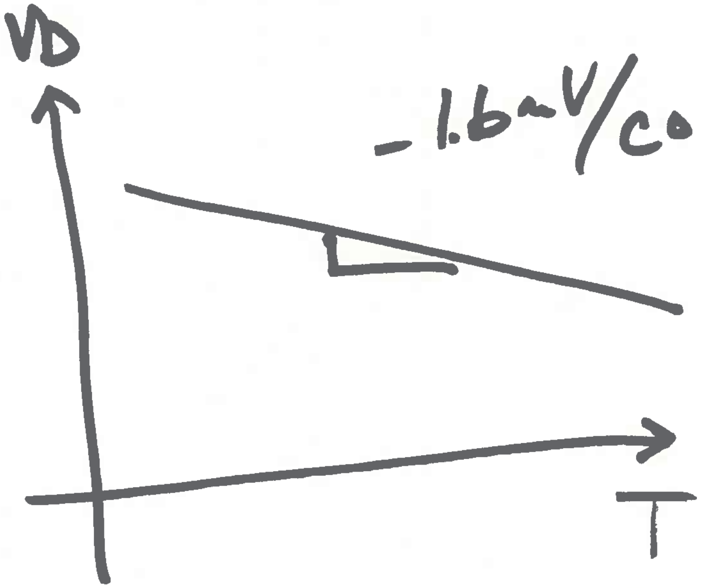
$$CMR_{MIN} = V_{GS} - V_{THP}$$

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

$$\overset{V_{GS}}{V_{O}} \leq V_{G} + V_{THP}$$

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

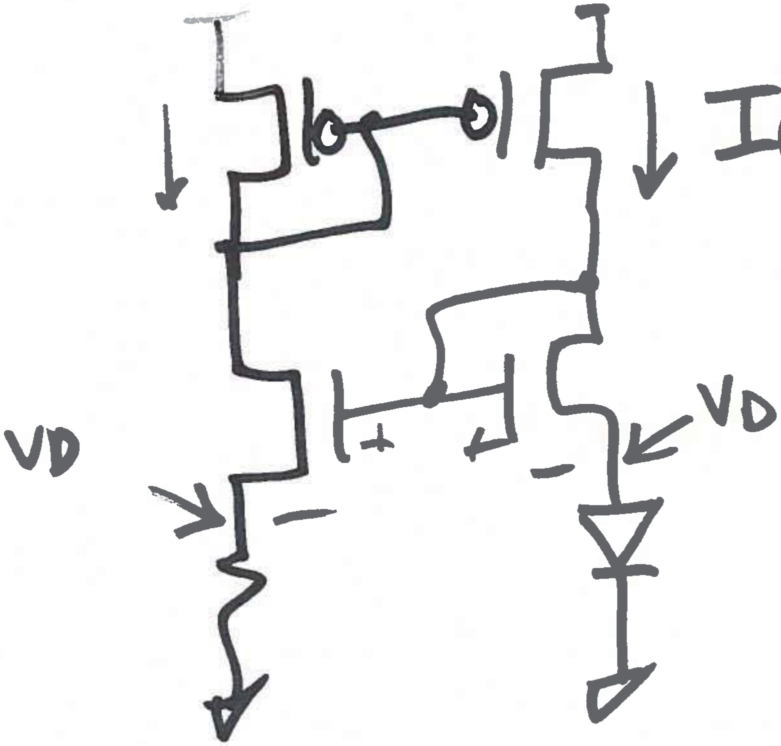




$$V_{fN} = \frac{KT}{q} \cdot \ln \frac{N_D}{N_i}$$

$$V_{fP} = \frac{KT}{q} \cdot \ln \frac{N_A}{N_i}$$

$$V_{Bi} = V_{fN} - V_{fP} = \frac{KT}{q} \ln \frac{N_A N_D}{N_i^2}$$



$$I_{REF} = \frac{V_D}{R} = V_D \cdot R^{-1}$$

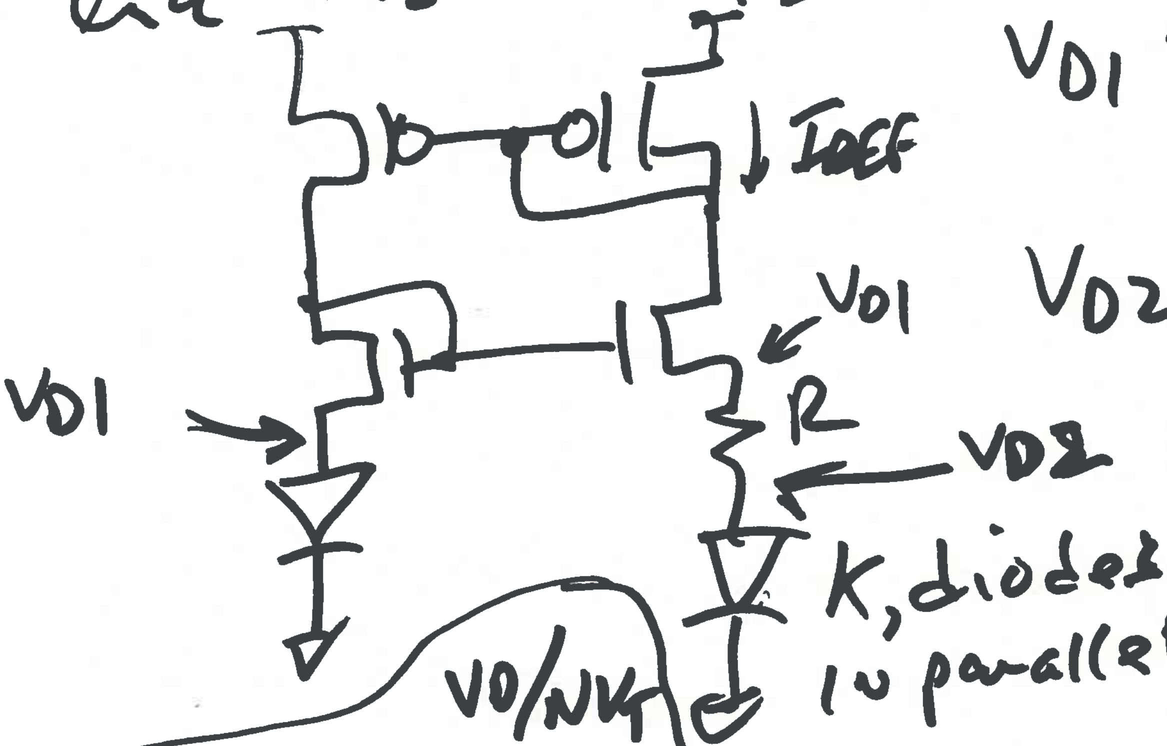
$$\frac{\delta I_{REF}}{\delta T} = \frac{\delta V_D}{\delta T} \cdot \frac{1}{R} + V_D \cdot (-1) \cdot \frac{1}{R^2} \frac{\delta R}{\delta T}$$

$$TC_{IREF} = \frac{1}{I_{REF}} \cdot \frac{\delta I_{REF}}{\delta T} = \frac{1}{V_D} \cdot \underbrace{\frac{\delta V_D}{\delta T}}_{-1.6\,mV/C^\circ} - \underbrace{\frac{1}{R} \frac{\delta R}{\delta T}}_{2{,}000\,ppm/C^\circ \,=\, 0.002}$$

$$\frac{1}{I_{RE}} = \frac{R}{V_D}$$

$$I_{RE}(T) = I_{REF}(T_0)\left(1 + TC_{IREF}(T - T_0)\right)$$

$\ln a - \ln b = \ln a/b$



$V_{D1} = NV_T \ln \frac{I_D}{I_S}$

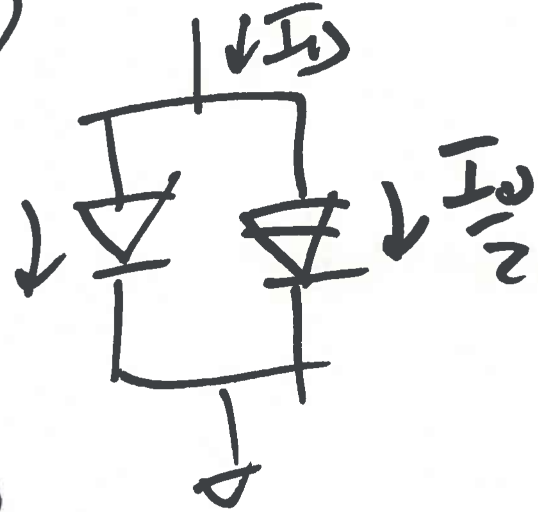
$V_{D2} = NV_T \ln \frac{I_D}{K \cdot I_S}$

$V_{D1} - V_{D2}$

$= NV_T \ln K$

$I_D = I_S e^{V_D/NV_T}$

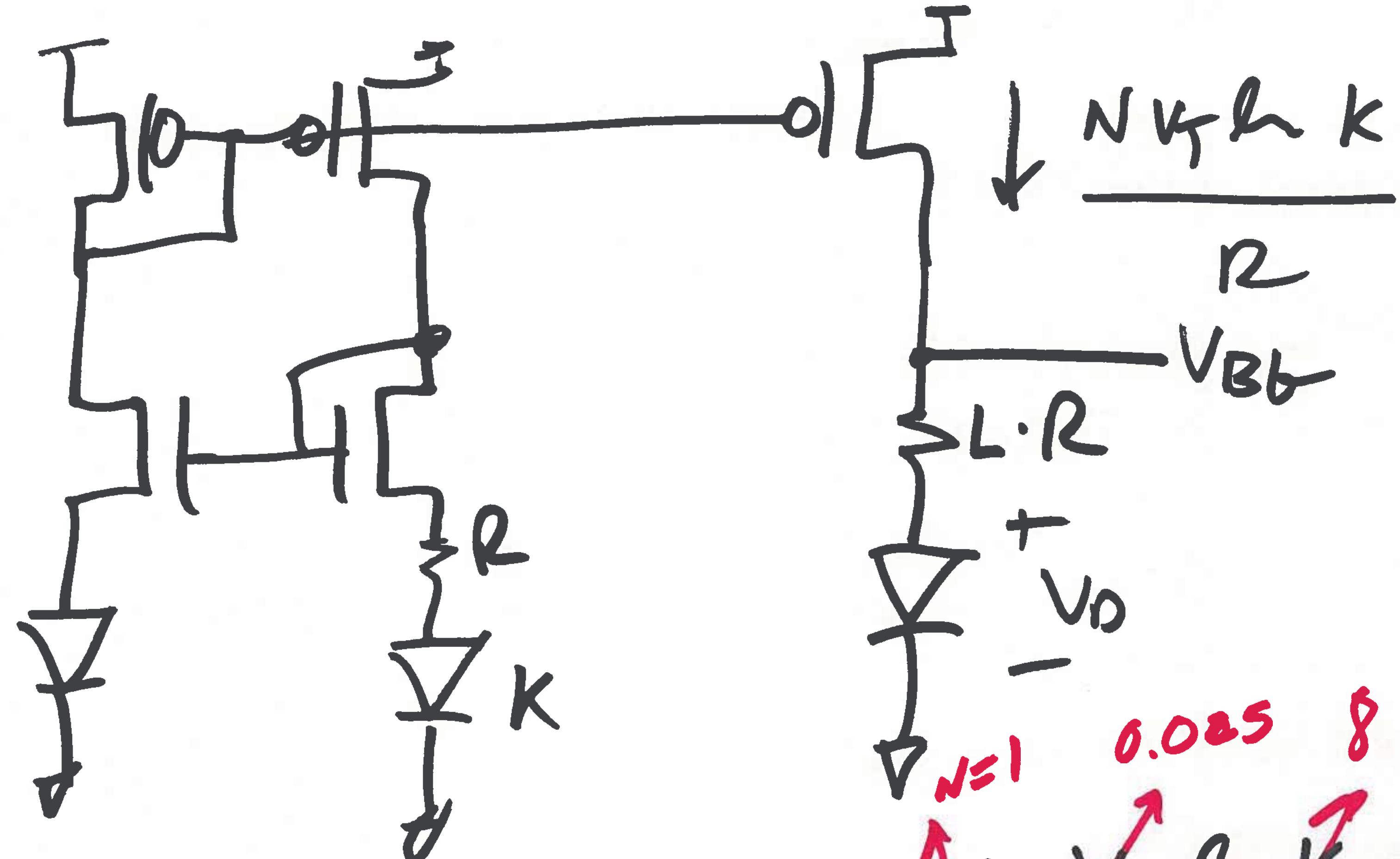
forward biased



$I_{REF} = \frac{V_{D1} - V_{D2}}{R}$

$\boxed{I_{REF} = \frac{NV_T \ln K}{R}}$

Thermal voltage reference



Thermal voltage reference

$$V_{BG} = \overset{N=1}{N} L \cdot \overset{0.025}{\cancel{V_T}} \underbrace{\ln \overset{8}{\cancel{K}}}_{2} + \overset{-1.6\text{mV}/C^{\circ}}{\cancel{V_D}}$$

$$\boxed{L = 9.41}$$