EE 420 / ECG 620

Analog IC Design

April 6, 2015

Lecture 20

$x + y = z$

$x = 10$

$y = 11$

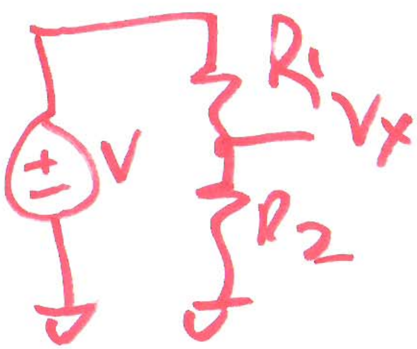
$z = ?$ 21

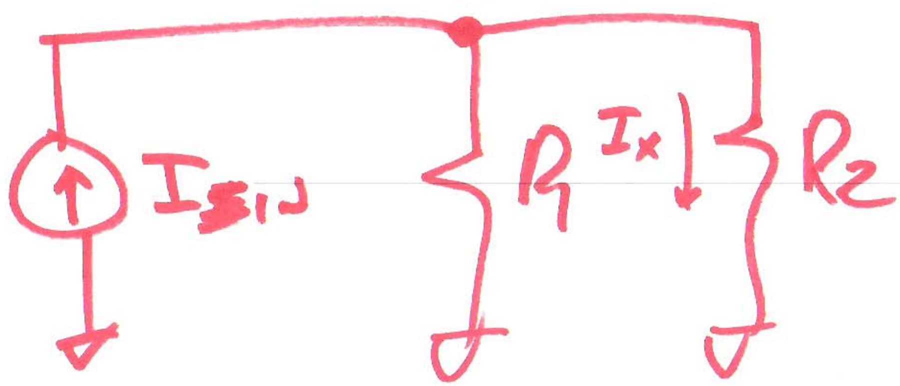
$x = 9$

$y = 12$

$\frac{R_1 R_2}{R_1 + R_2}$ ✓

$R_1 \| R_2 = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$





$I_{in} = \frac{V_x}{R_1} + \frac{V_x}{R_2} = V_x \cdot \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

$V_x = I_{in} \cdot R_1 \| R_2$

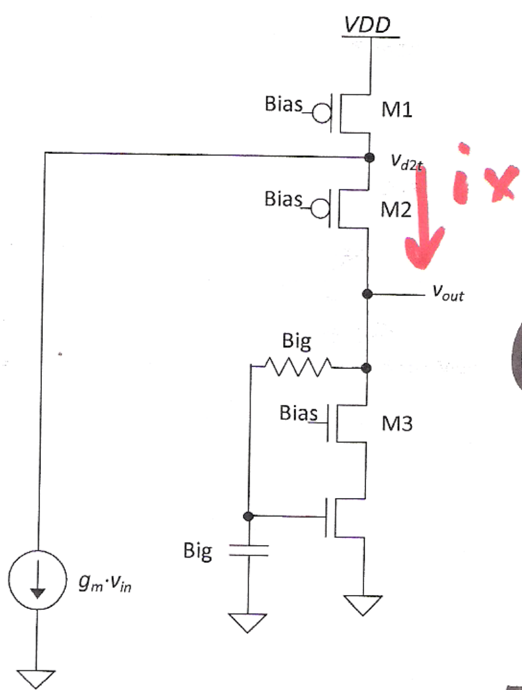
$V_x \quad I_x = \frac{V_x}{R_2}$

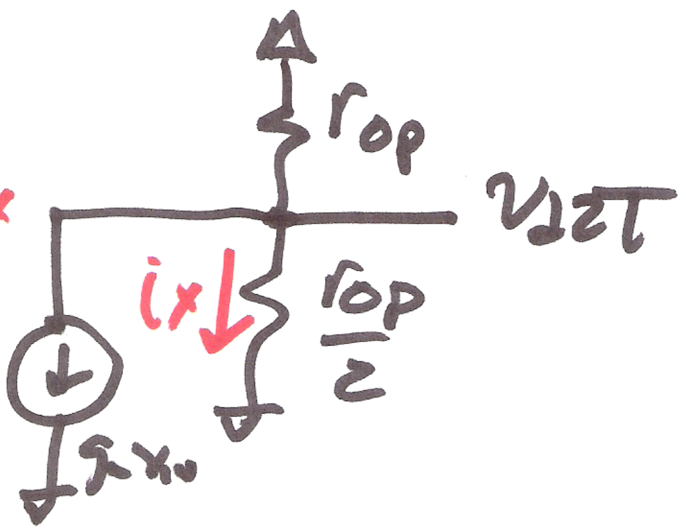
$V_x = R_2 I_x$

$\cancel{V_x} \quad I_{in} = R_2 I_x \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

$\boxed{I_x = I_{in} \cdot \frac{R_1}{R_1 + R_2}}$

4. Estimate the gains, v_{out}/v_{in}, ~~v_{d2t}/v_{in}~~, and v_{out}/v_{d2t} in the following circuit using R_{ocasn}, r_{op}, g_{mp}, and g_m. You can assume the small-signal resistance looking into: the drain of M1 is r_{op}, the source of M2 is $r_{op}/2$, and the drain of M3 is R_{ocasn}. (20 points)





$$v_{d2T} = -g_m v_{in} \cdot r_{op} \| \frac{r_{op}}{2}$$

$$\boxed{\frac{v_{d2T}}{v_{in}} = -g_m r_{op} \| \frac{r_{op}}{2}}$$

$$v_{outT} = i_x \cdot R_{OCASN}$$

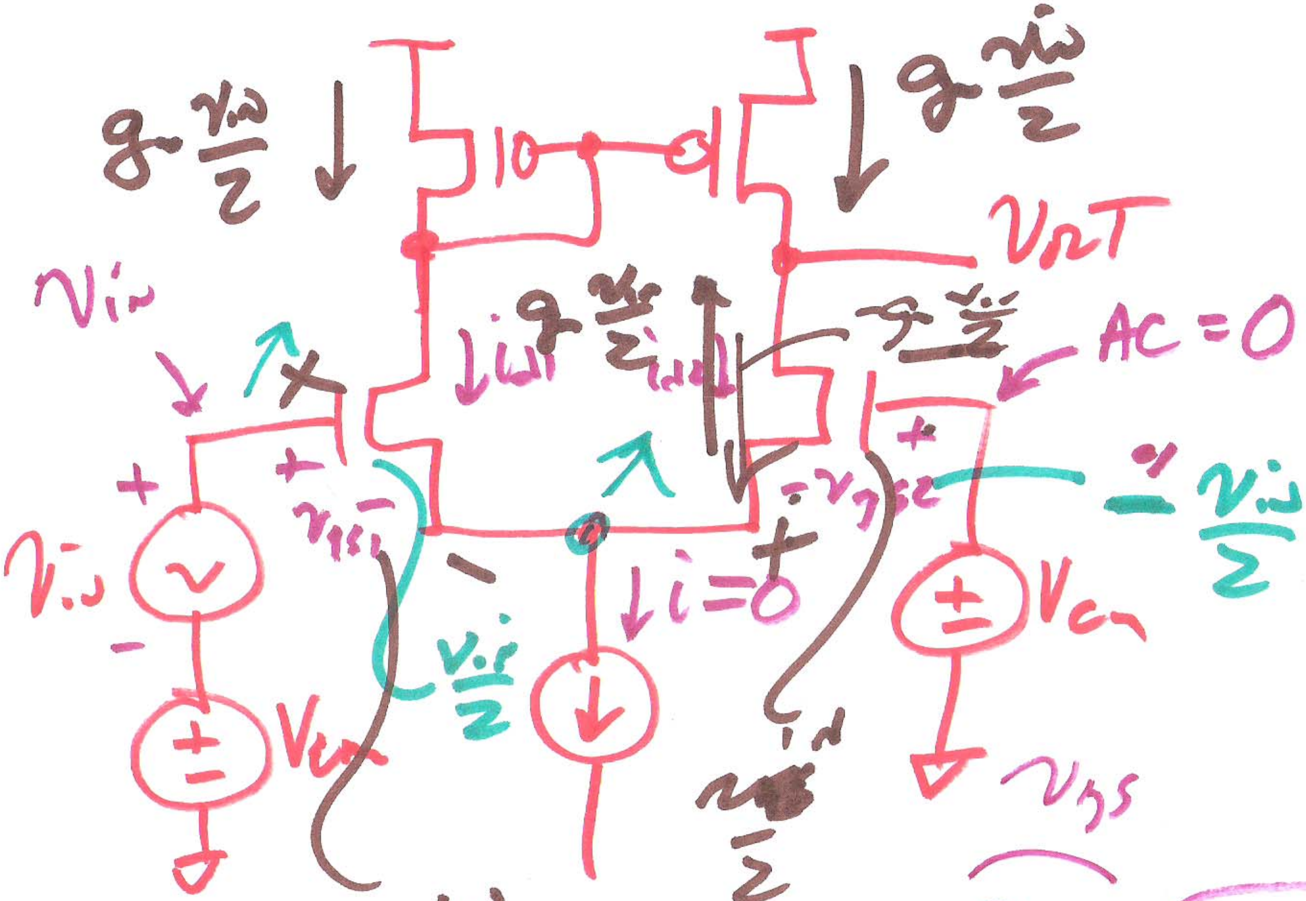
$$i_x = -g_m V_{in} \frac{r_{op}}{r_{op} + \frac{r_{op}}{2}}$$

$$\frac{v_{outT}}{v_{in}} = -g_m \frac{\cancel{r_{op}}}{\cancel{r_{op}} + \frac{r_{op}}{2}}$$

$$\frac{\frac{v_{outT}}{v_{in}}}{\frac{v_{in}}{v_{d2T}}} = \frac{-g_m \frac{2}{3} R_{ocas}}{-\frac{1}{g_m r_{op} \| \frac{r_{op}}{2}}}$$

2) $$\boxed{\frac{v_{outT}}{v_{in}} = -g_m \cdot \frac{2}{3}}$$

$$\boxed{\frac{v_{outT}}{v_{d2}} = g^2 \left(\frac{2}{3}\right) \frac{2}{3} R_{ocasn}}$$



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

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

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

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

$$v_{gs} = \frac{i_d}{g}$$

$$\boxed{v_{in} = \frac{i_{d1}}{g_{m1}} - \frac{i_{d2}}{g_{m2}}}$$

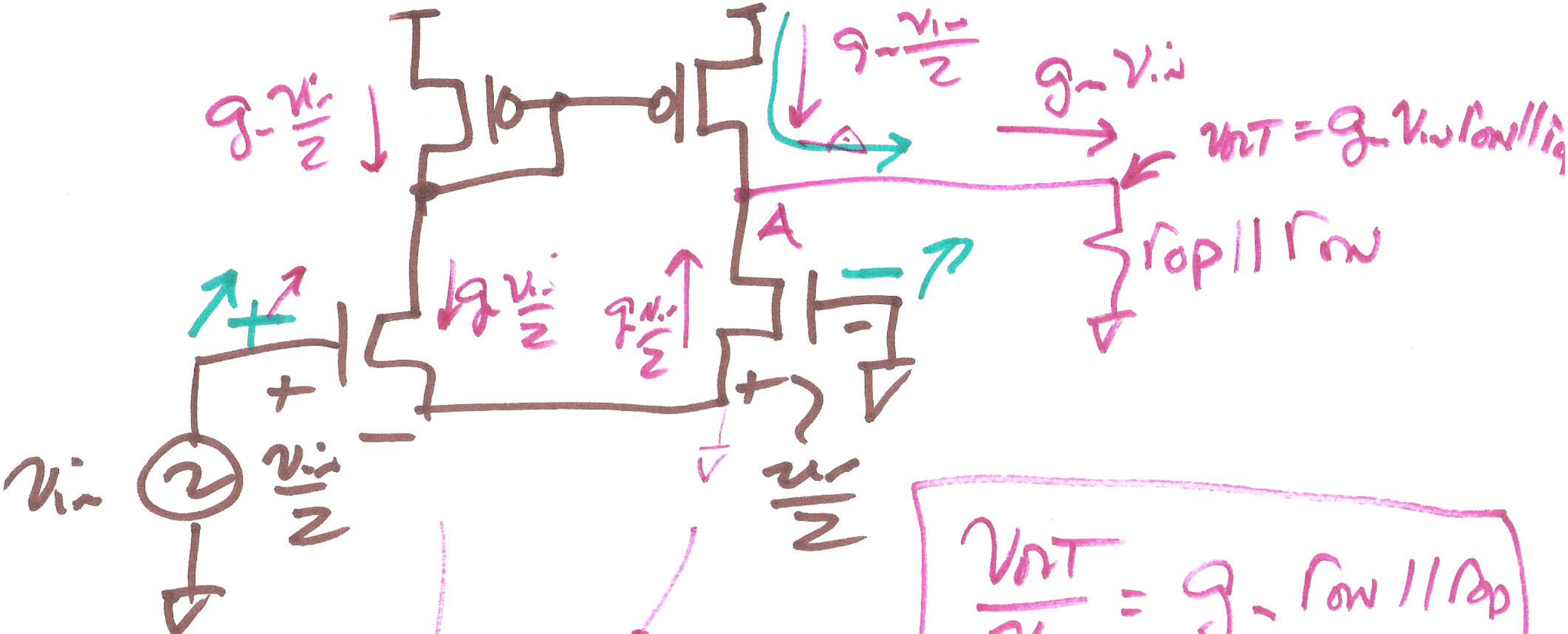
$$\frac{v_{in}}{2}$$

$$i_{d1} = g_{m1} \cdot \frac{v_{in}}{2}$$

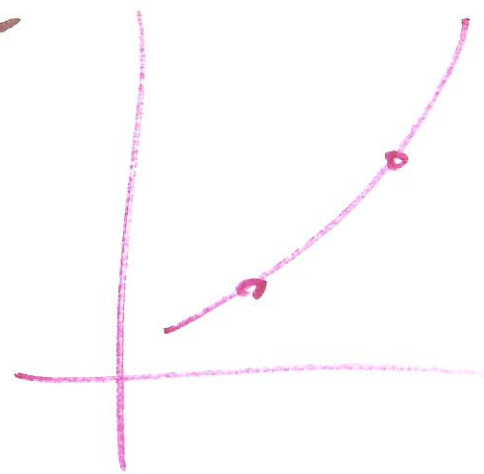
$$i_{d1} = \frac{g_{m1}}{2} \cdot v_{in}$$

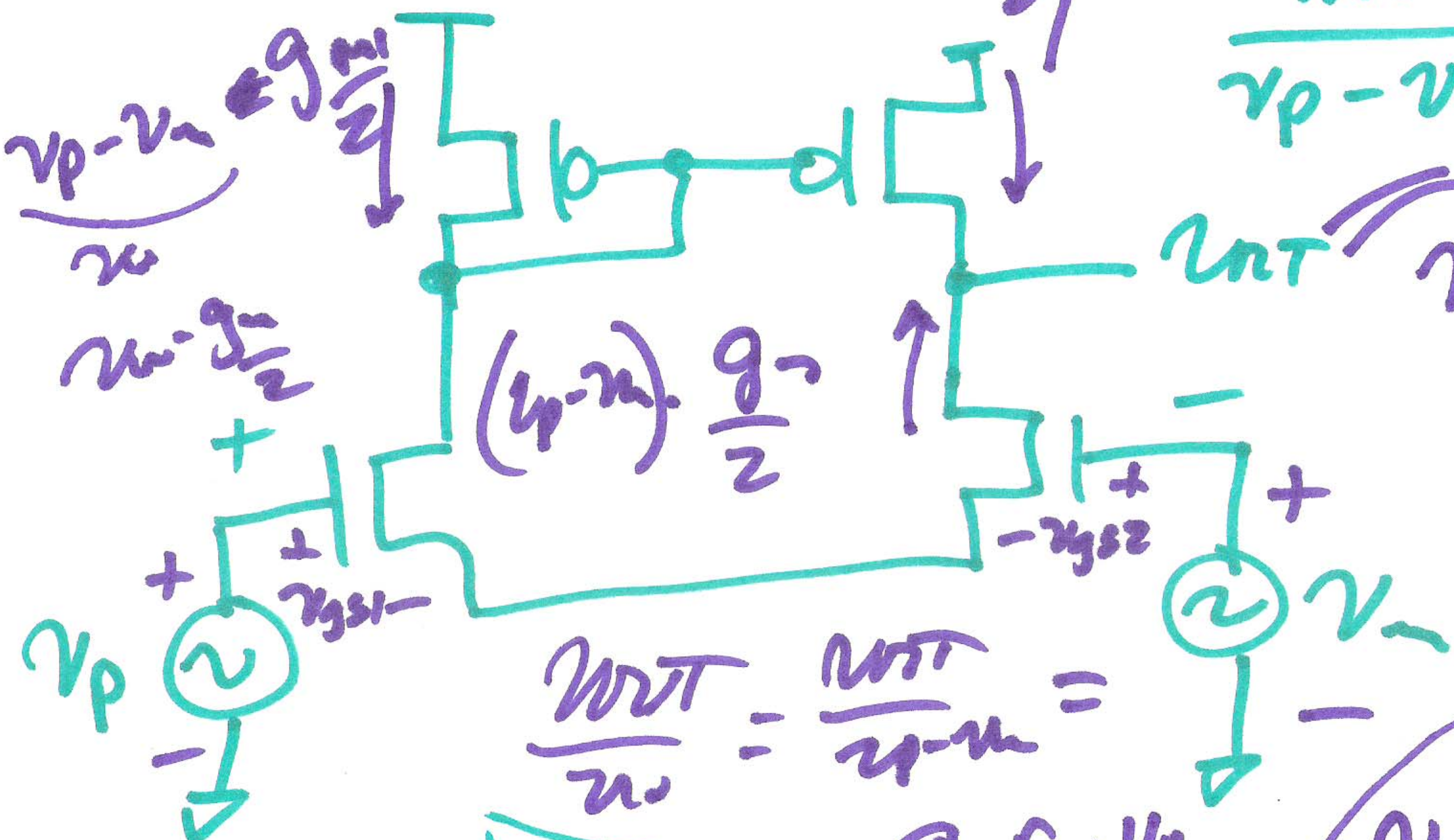
$$v_{in} = i_{d1}\left(\frac{1}{g_{m1}} + \frac{1}{g_{m2}}\right)$$

$$v_{in} = i_{d1} \cdot \frac{2}{g_{m1}}$$



$$\boxed{\frac{v_{out}}{v_{in}} = g_m r_{on}||r_{op}}$$





$$\frac{v_{out}}{v_p - v_m}$$

$\propto$

$$(v_p - v_m)\frac{g_m}{2} \cdot r_{on} \| r_{op}$$

$$v_p - v_{gs1} + v_{gs2} - v_m = 0$$

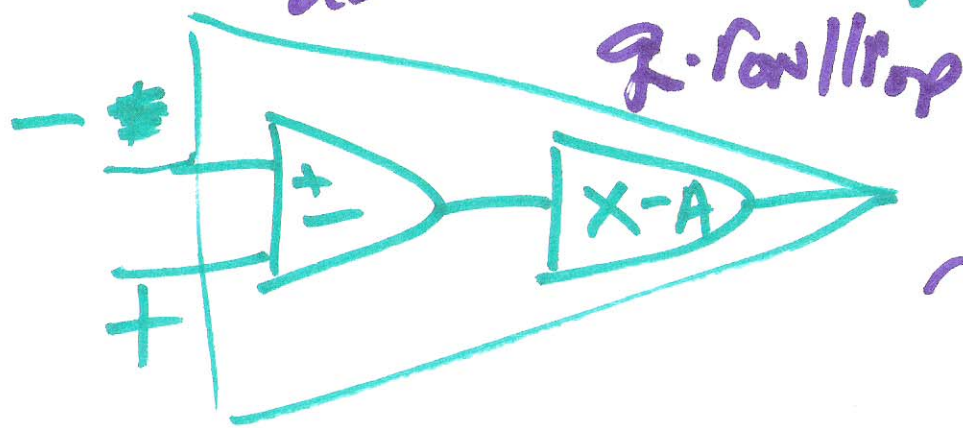
$$i_d = g_m v_{gs}$$

$$v_p - v_m = v_{gs1} - v_{gs2}$$

$$v_p - v_m = i_1 \cdot \left(\frac{g_m}{2}\right)^{-1}$$

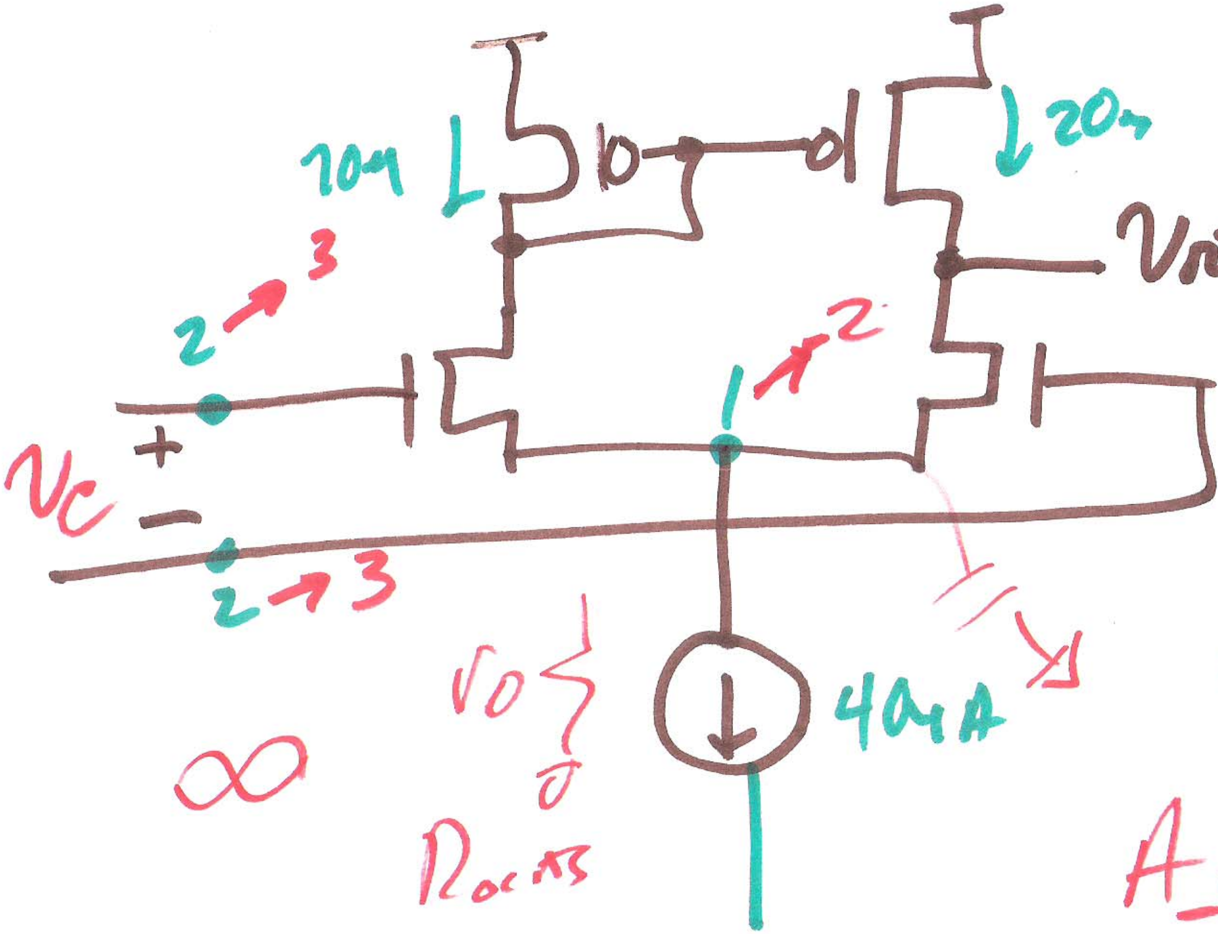
$$\frac{v_{out}}{v_m} = \frac{v_{out}}{v_p - v_m} =$$

$$g_m \cdot r_{on} \| r_{op}$$



$$v_p - v_m = \frac{i_{d1}}{g_{m1}} - \frac{i_{d2}}{g_{m2}}$$

$$= i_{d1}\left(\frac{2}{g_{m1}}\right)$$



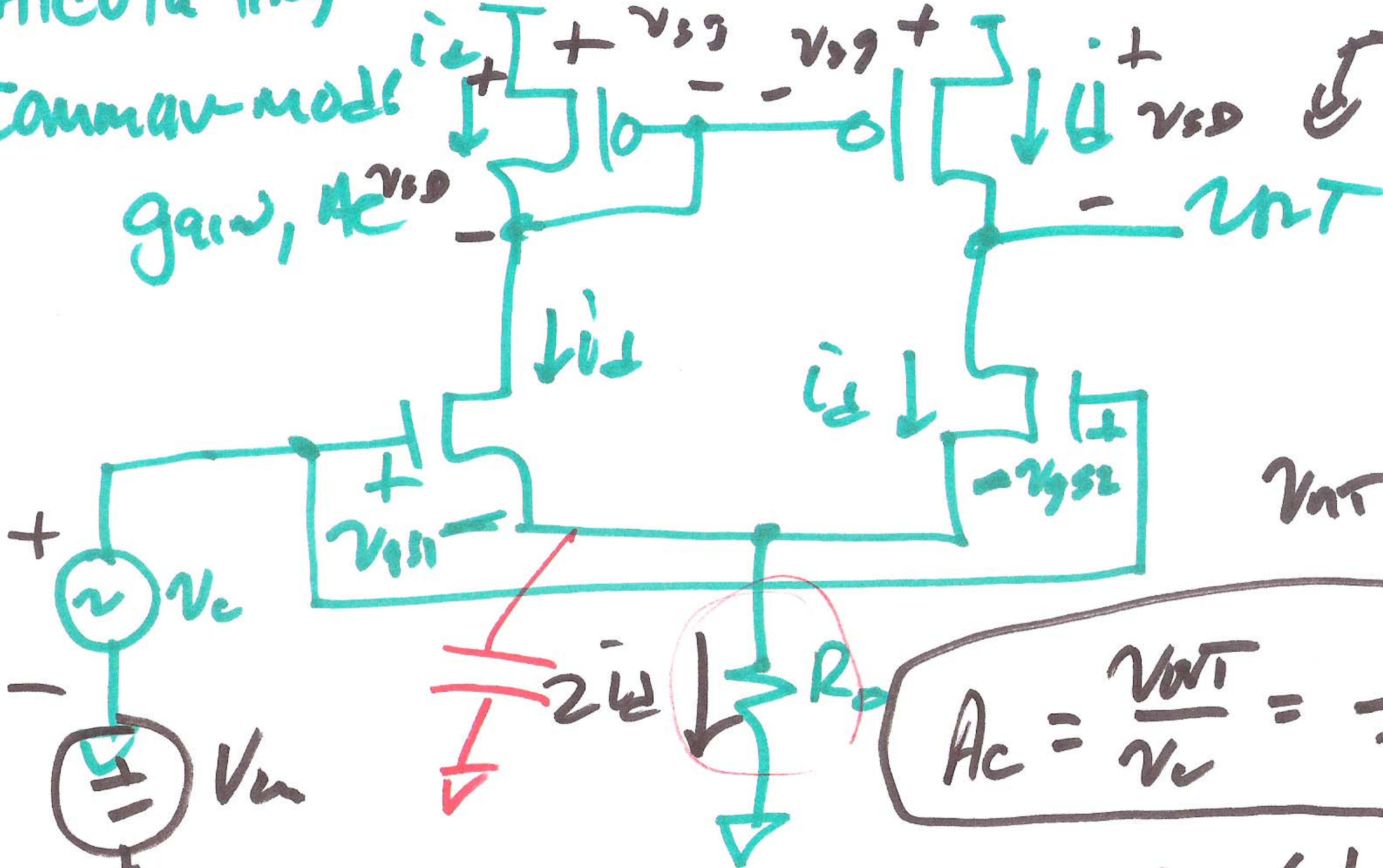
$A_c = \frac{v_{out}}{v_c}$ = common mode gain

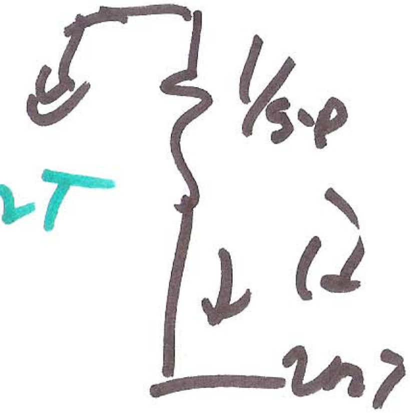
$CMRR = 20 \log \frac{A_d}{A_c}$

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

difference

Calculating common-mode gain, A_c

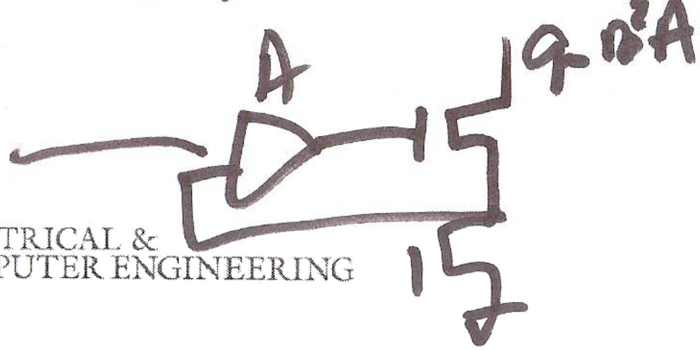




$$v_{out} = -i_d \cdot \frac{1}{g_{m,p}}$$

$$\boxed{A_c = \frac{v_{out}}{v_c} = \frac{-1}{2R_o \cdot g_{m,p}}}$$

$$v_c = v_{gs1,2} + 2i_d \cdot R_o = i_d\left(\frac{1}{g_m} + 2R_o\right)$$



$$\boxed{v_c \approx i_d \cdot 2R_o}$$