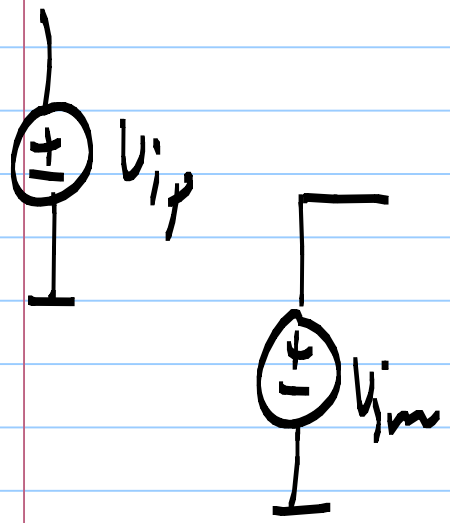
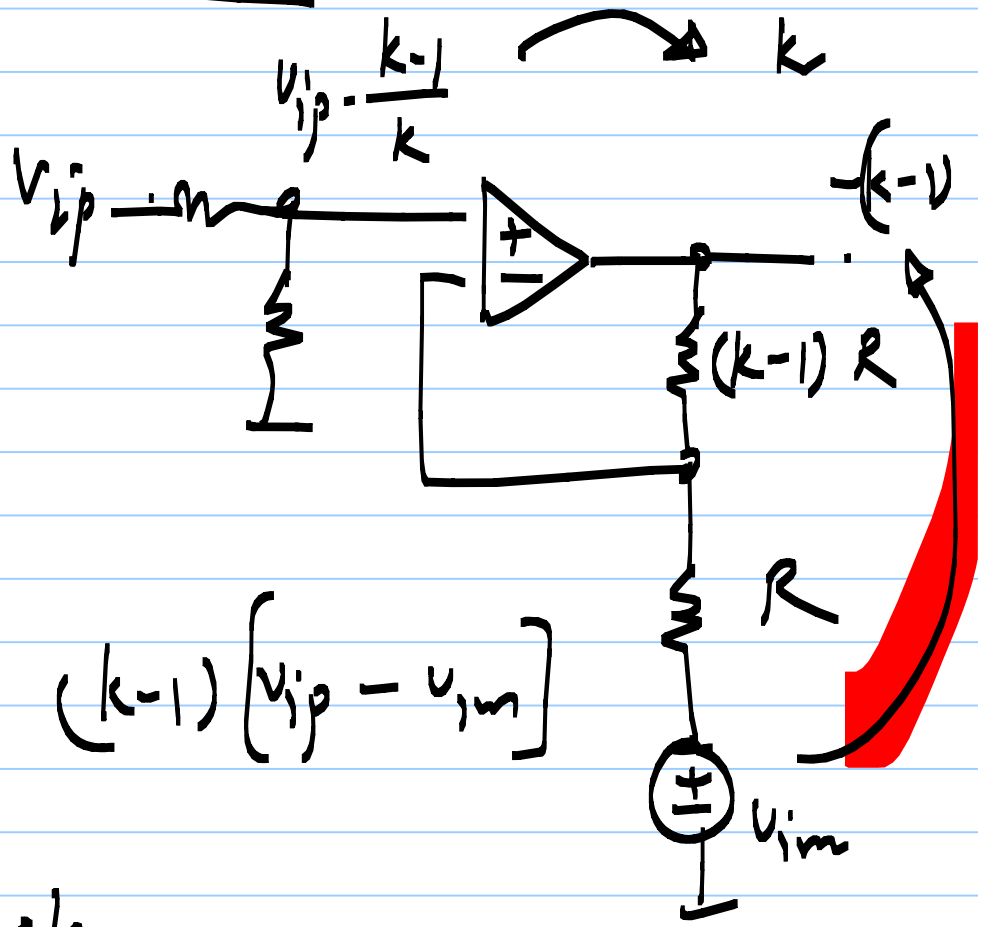
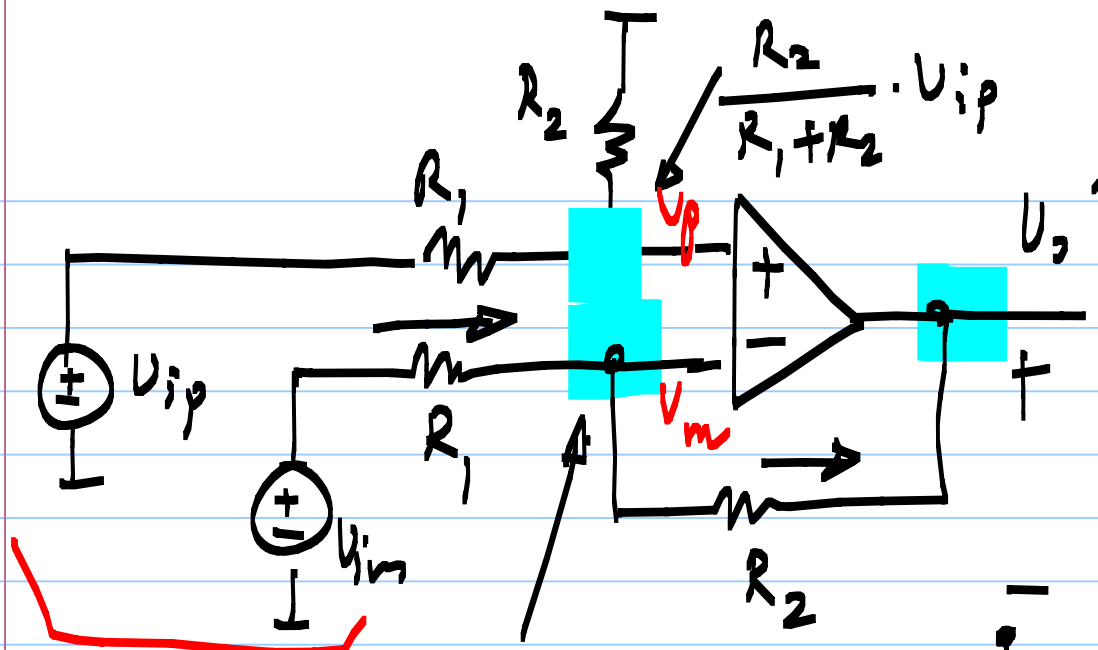
EE2019 Difference amplifier 21/3/2018

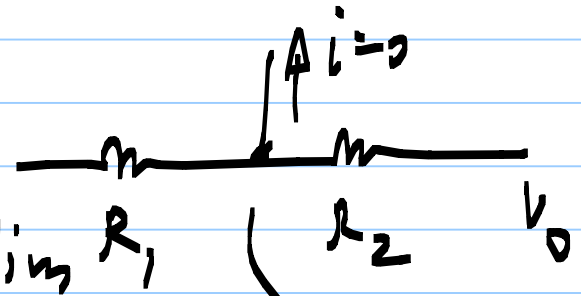




Amplify the difference between v_{ip} & v_{im}.
& provide a single ended o/p.



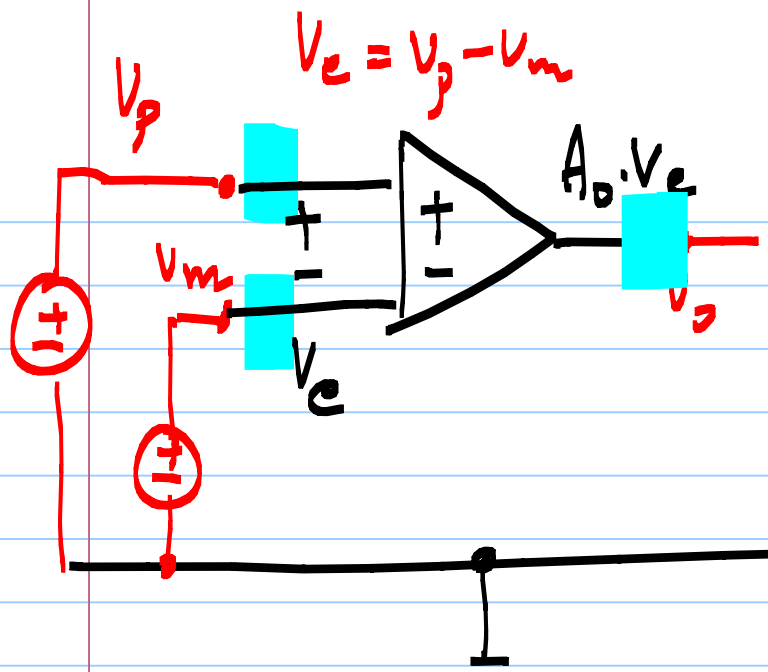
$$A_d \cdot U_d + A_{cm} \cdot U_{cm}$$

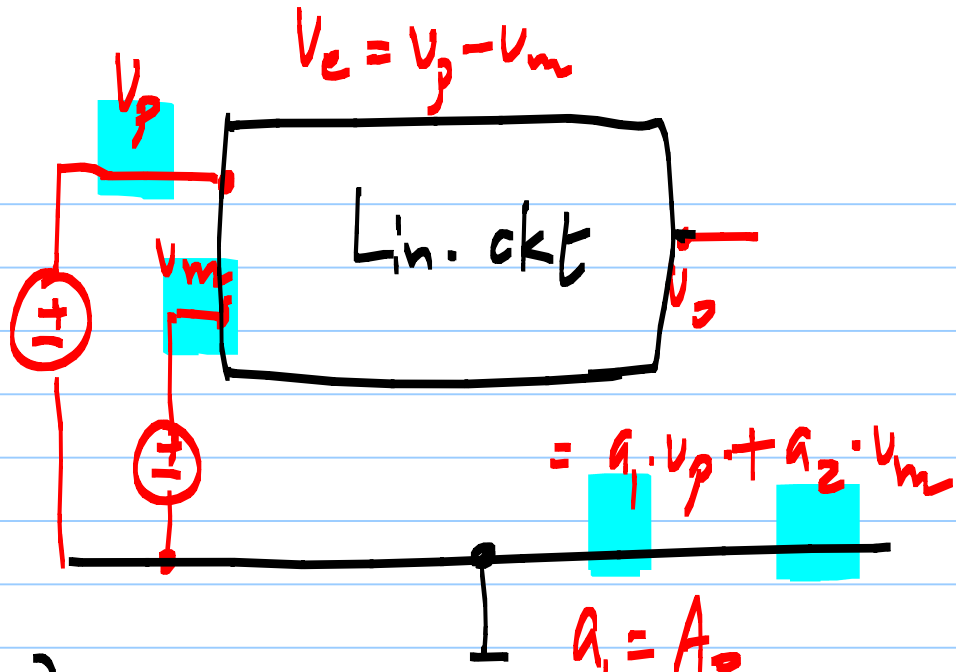


I

$$\frac{R_2}{R_1+R_2}\cdot U_{ip} = U_x = U_{im}\cdot\frac{R_2}{R_1+R_2} + U_o\cdot\frac{R_1}{R_1+R_2}$$

$$U_o = \frac{R_2}{R_1}\left(U_{ip} - U_{im}\right)$$





$a_1 = A_0$

$a_2 = -A_0$

$$V_{cm} = \frac{V_p + V_m}{2}$$ } Common-mode voltage

$$V_e = V_p - V_m$$ } difference voltage

$$V_p = \frac{V_p + V_m}{2} + \frac{V_p - V_m}{2}$$

$$V_m = \frac{V_p + V_m}{2} - \frac{V_p - V_m}{2}$$

$$v_o = a_1 \cdot v_p + a_2 \cdot v_m$$

$$= a_1 \left(\frac{v_p + v_m}{2} + \frac{v_p - v_m}{2} \right) + a_2 \left(\frac{v_p + v_m}{2} - \frac{v_p - v_m}{2} \right)$$

$$= \left(\frac{a_1 - a_2}{2} \right) \cdot (v_p - v_m) + (a_1 + a_2) \left(\frac{v_p + v_m}{2} \right)$$

$$= A_d \cdot v_d + A_{cm} \cdot v_{cm}$$

$\frac{A_d}{A_{cm}}$

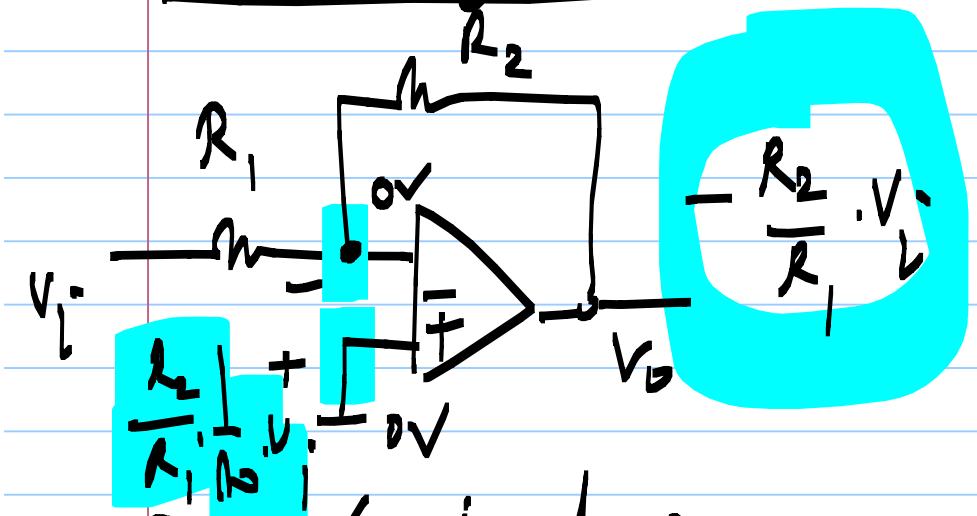
differential gain

difference voltage

common-mode voltage

Common-mode gain (Ideally = 0)

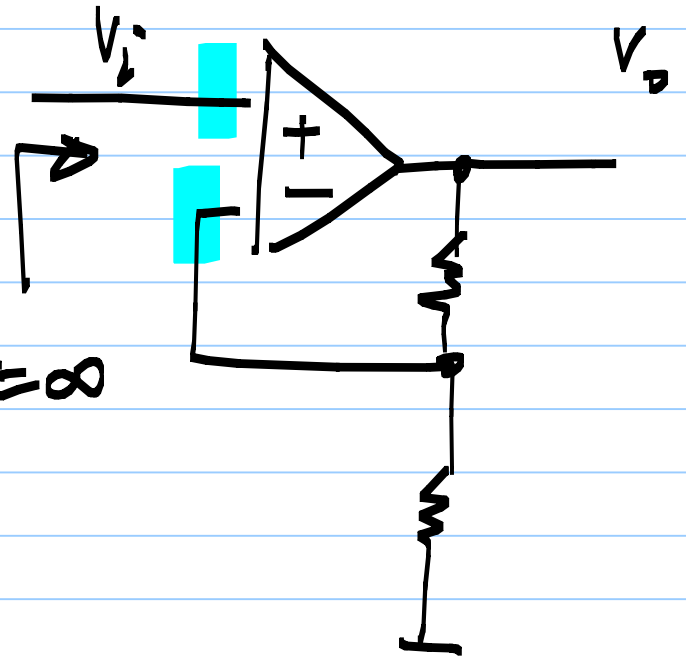
Inverting amplifier



Opamp's input common mode

Voltage = Zero

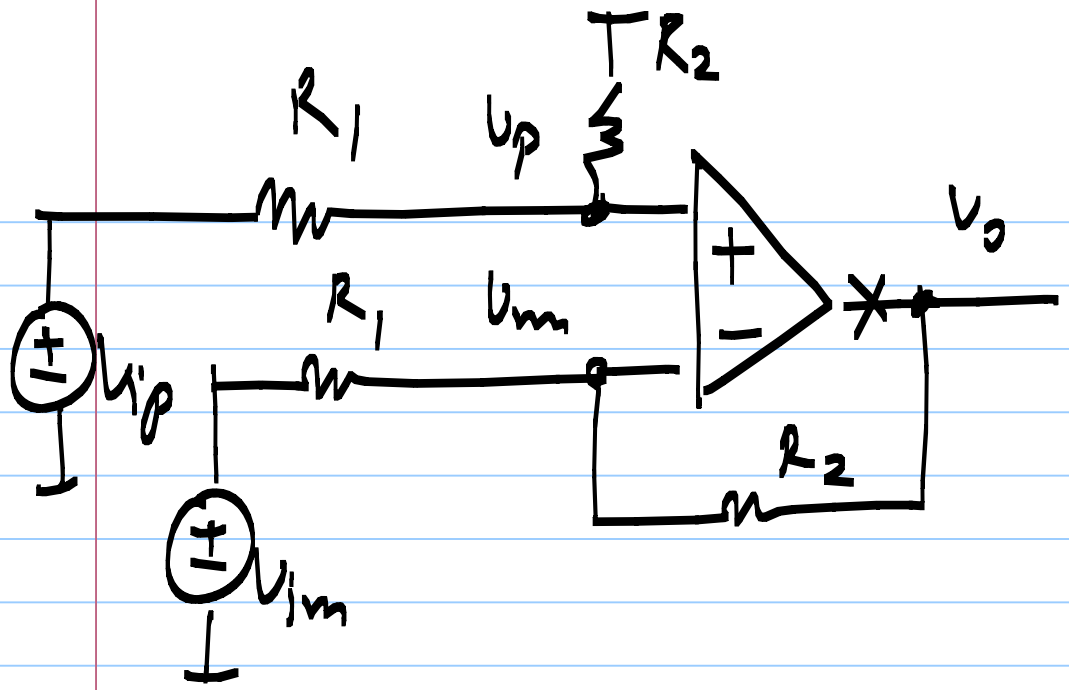
Non-inverting amplifier



$R_i = \infty$

Common-mode input

$= V_i$



$$U_p = U_{ip} \cdot \frac{R_2}{R_1 + R_2}$$

$$U_m = U_{im} \cdot \frac{R_2}{R_1 + R_2} + U_o \cdot \frac{R_1}{R_1 + R_2}$$

$$U_o = A_d \cdot (U_p - U_m) + A_{cm} \left(\frac{U_p + U_m}{2} \right)$$

$$A_d \cdot \frac{R_2}{R_1 + R_2} (U_{ip} - U_{im}) - A_d \cdot U_o \cdot \frac{R_1}{R_1 + R_2} +$$

$$A_{cm} \cdot \frac{R_2}{R_1 + R_2} \frac{U_{ip} + U_{im}}{2} + \frac{A_{cm}}{2} \cdot U_o \cdot \frac{R_1}{R_1 + R_2}$$

$$\frac{U_o}{A_d}\cdot\left(\frac{R_1+R_2}{R_1}\right) = \cdot\frac{R_2}{R_1}(U_{ip}-U_{im}) - \cdot U_o \cdot + \qquad \times\left(\frac{R_1+R_2}{R_1}\right)$$

$$\frac{}{A_d}\ R_1 \qquad\qquad \frac{}{2} + \frac{A_{cm}\cdot U_o\cdot}{2A_d}$$

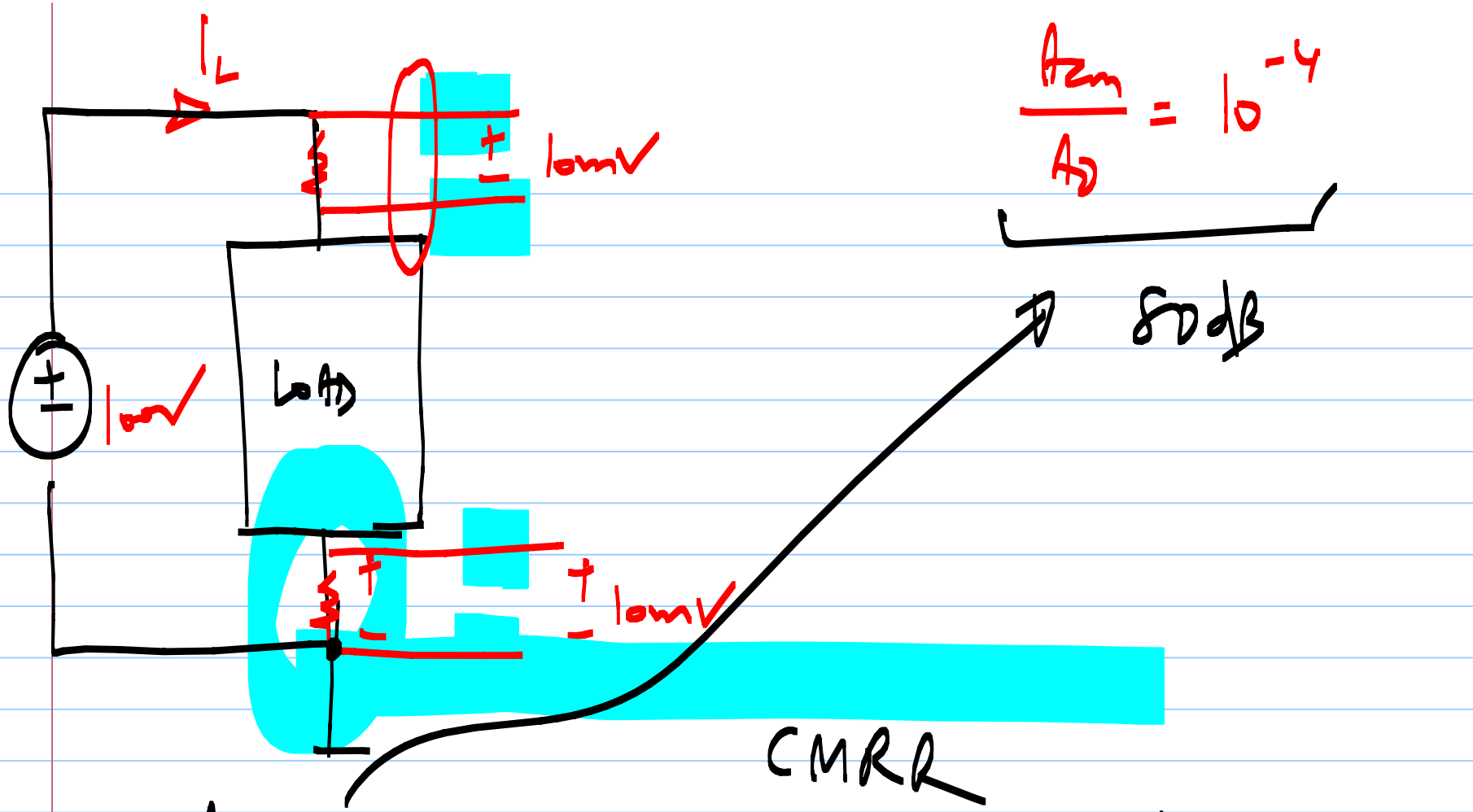
$$U_o = \frac{\frac{R_2}{R_1}(U_{ip}-U_{im}) + \frac{A_{cm}}{A_d}\cdot\frac{R_2}{R_1}\cdot\frac{U_{ip}+U_{im}}{2}}{\left[1+\left[\frac{1}{A_d}\cdot\frac{R_1+R_2}{R_1}\right] - \frac{A_{cm}}{2A_d}\cdot\right.}$$

$$v_o \simeq \underbrace{\frac{R_2}{R_1}\left(v_{ip} - v_{im}\right)}_{\text{difference input}} + \underbrace{\frac{A_{cm}}{A_d} \cdot \frac{R_2}{R_1}\left(\frac{v_{ip} + v_{im}}{2}\right)}_{\text{Common-mode input}}$$

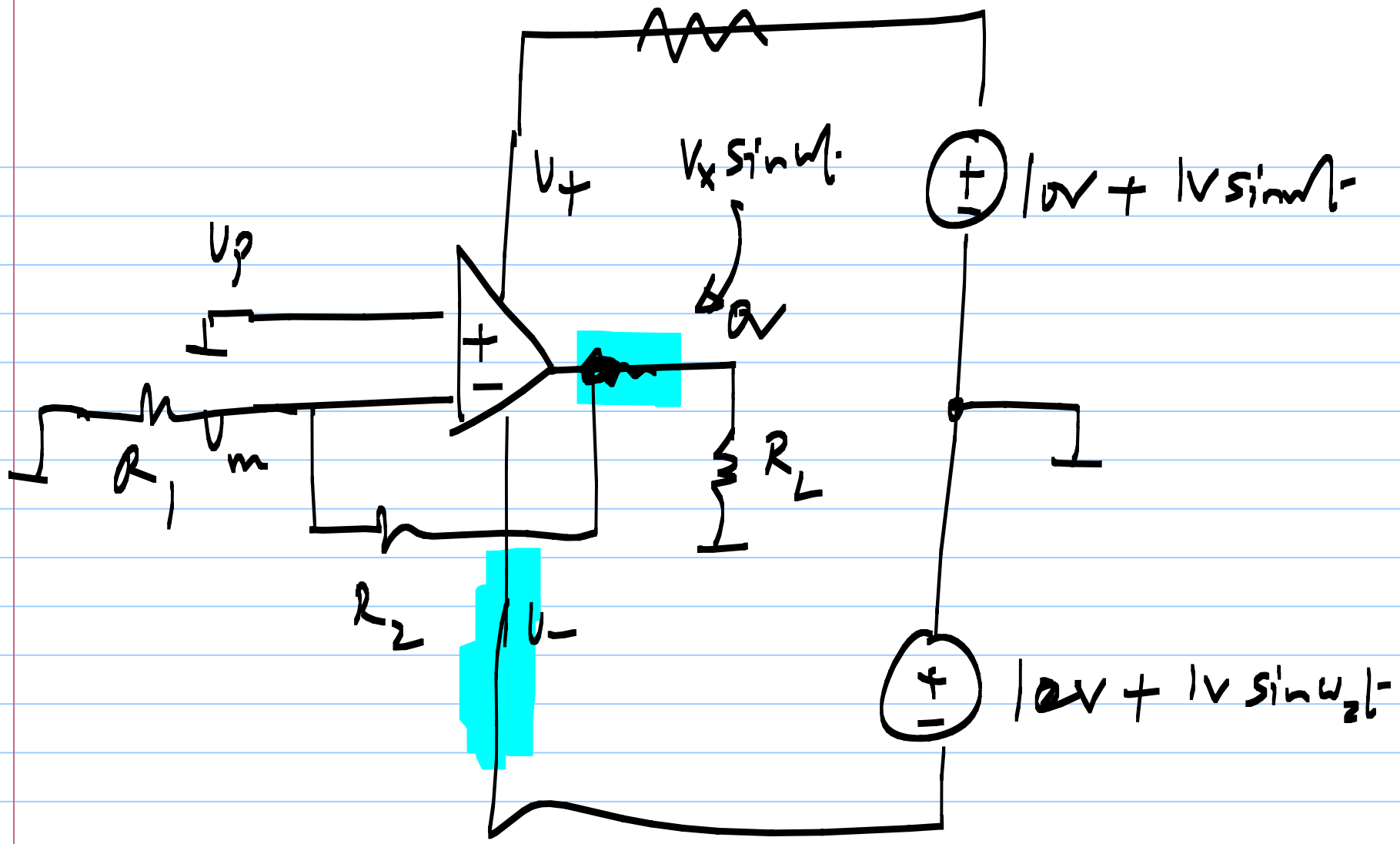
$v_{ip} = 1\,mV$ 10.001 V

$v_{im} = -1\,mV$ 9.999 V

$$\frac{R_2}{R_1}\left(10\,mV\right) + \frac{R_2}{R_1} \cdot \overbrace{10^{-4} \quad 100\,V}^{10\,mV}$$



$20\log_{10}\left(\frac{A_d}{A_{cm}}\right)$: Common-mode rejection ratio


V_+
$V_x \sin \omega_1 t$
$10V + 1V \sin \omega_1 t$
V_p
R_1
V_m
R_L
R_2
V_-
$10V + 1V \sin \omega_2 t$