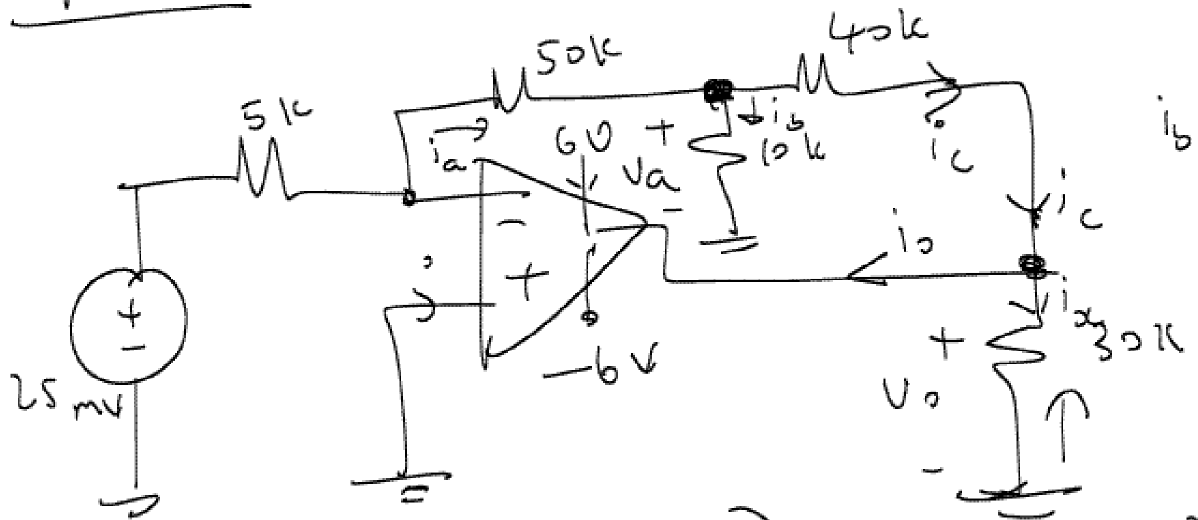
Chapter 5

(5.5)



$$i_b = \frac{v_a}{10k} \checkmark$$

$$i_a = \checkmark$$

$$i_c + i_b = i_a$$

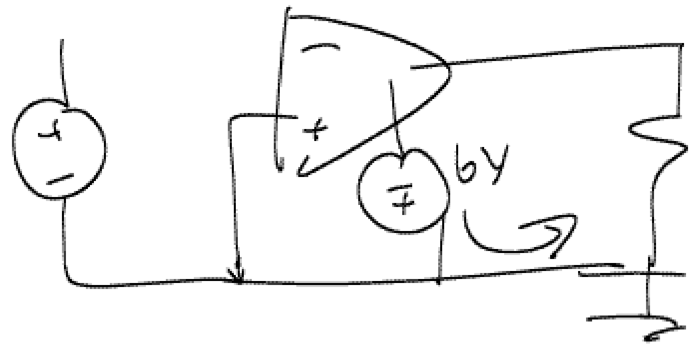
$$\Rightarrow i_c = \checkmark$$

$$v_o = \checkmark$$

$$i_x = \frac{v_o}{30k}$$

$$i_o + i_x = i_c$$

Inverting amplifier

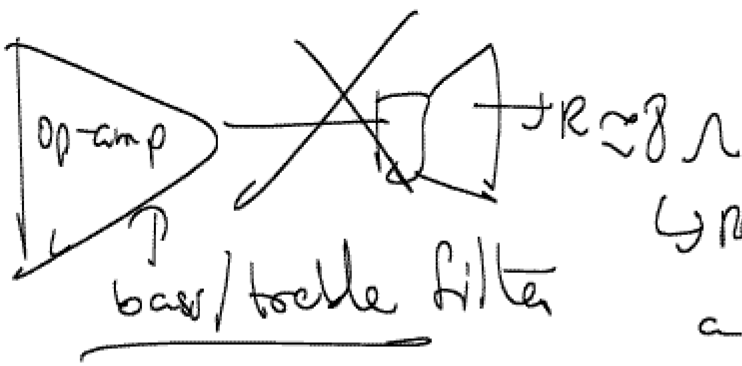


(Q:) Is output voltage unaffected by load (i.e. resistance) at the output?

(A:) Ideally: No, unaffected
[world of the tablet PC, blackboard etc

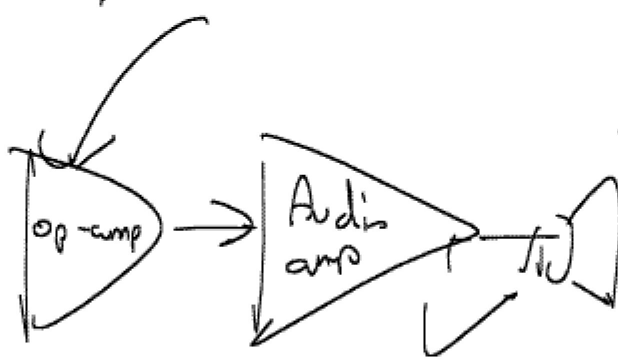
Non-ideality: IT MATTERS !!!!!!

Ex: Your audio project

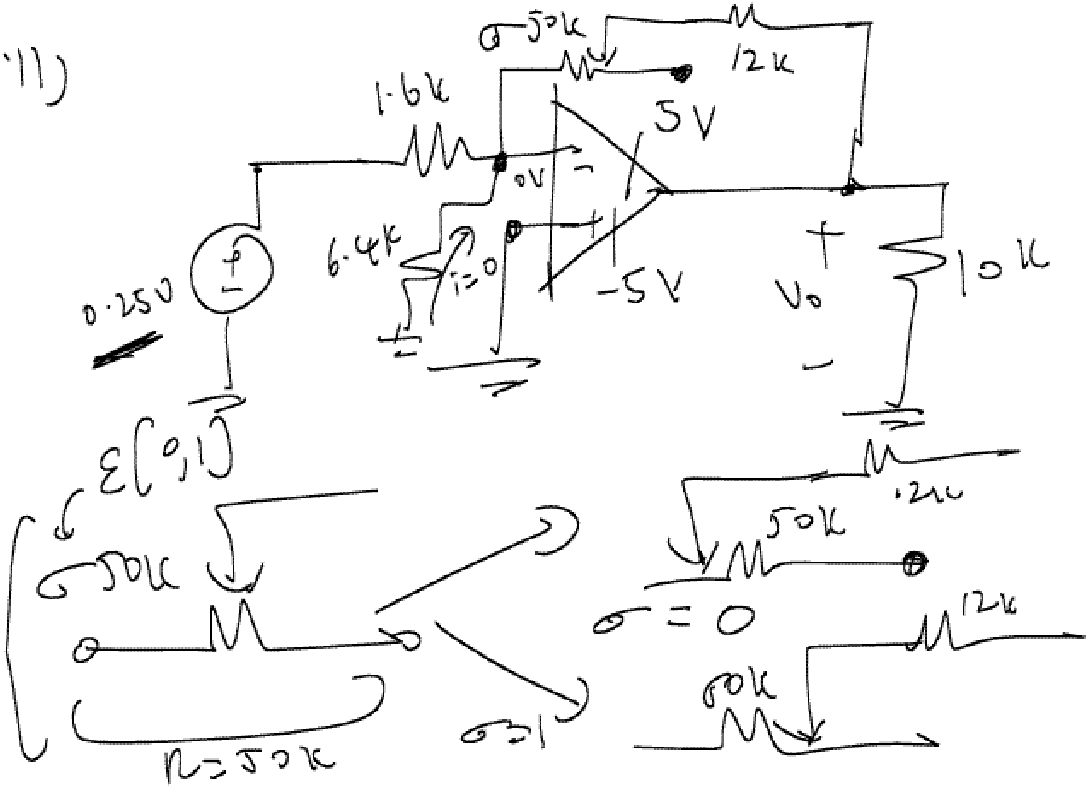


↳ resistance of a speaker is too low
⇒ too much current from op-amp output.

Solution:



(5.11)



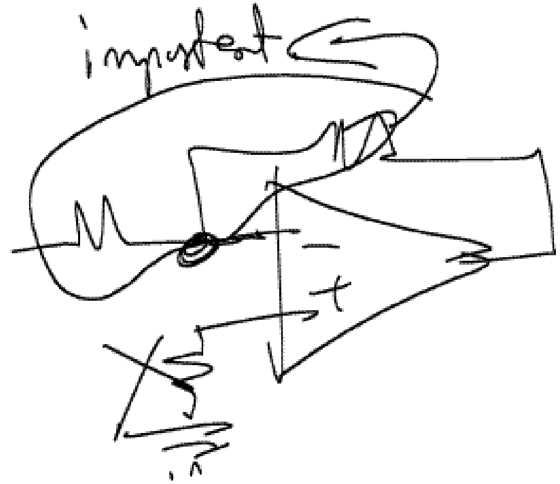
Note! Circuit symbol for potentiometer (variable resistor) → 

old school

(Q:) What resistors are important in amplifiers?

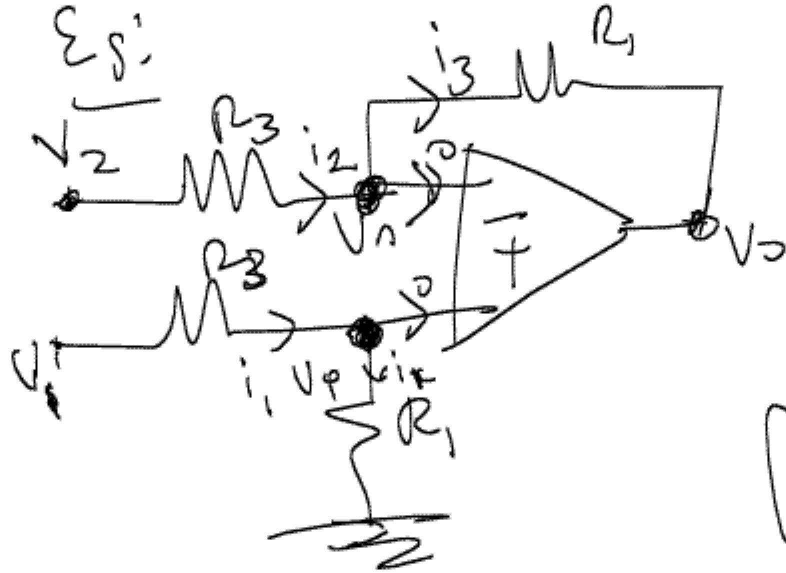
A: Hard to say, usually resistors connected ~ feedback path are important

eg:



Sometimes, you can't even tell if amplifier is inverting/noninverting.

Eg:



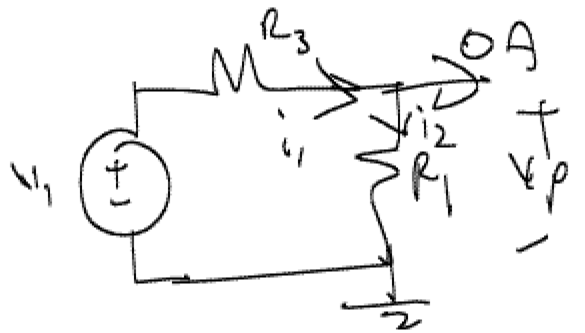
Find $V_o = f(V_1, V_2)$.

Don't worry about rails

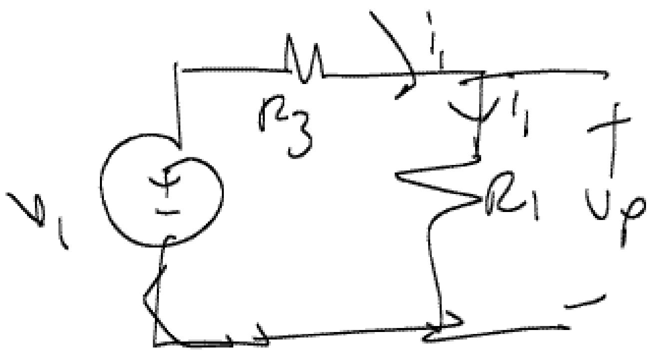
[i.e., assume op-amp never saturates]

Step (1)

Op-amp is linear: $V_n = V_p$



$\Longleftrightarrow$ $V_p = \left(\frac{R_1}{R_1 + R_3}\right) V_1$ [voltage divider]



$V_p = i_1 R_1$

$$V_p = \left(\frac{V_1}{R_3 + R_1}\right) R_1$$

$$V_n = \left(\frac{R_1}{R_1 + R_3}\right) V_1$$

Step 2: KCL @ V_n:

$$i_2 = i_3 \Rightarrow \frac{V_2 - V_n}{R_3} = \frac{V_n - V_o}{R_1}$$

$$\Rightarrow \quad V_2 - V_n = \frac{R_3}{R_1}(V_n - V_o)$$

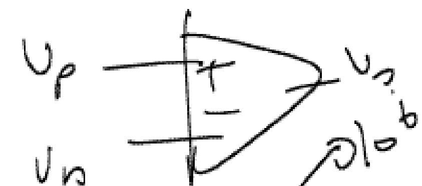
$$\Rightarrow \quad V_2 - \left(\frac{R_1}{R_1+R_3}\right)V_1 = \frac{R_3}{R_1}\left(\frac{R_1}{R_1+R_3}V_1 - V_o\right)$$

$$\Rightarrow \quad V_2 - \frac{V_1 R_1}{R_1+R_3} = \frac{R_3}{R_1+R_3}V_1 - \frac{R_3}{R_1}V_o$$

$$\Rightarrow \quad \frac{R_3}{R_1}V_o = \frac{R_3 V_1}{R_1+R_3} + \frac{R_1 V_1}{R_1+R_3} - V_2$$

$$\frac{R_3}{R_1} V_o = \frac{R_3 v_1 + R_1 v_1 - (R_1 + R_3) v_2}{R_1 + R_3}$$

Simplicity: $R_1 = R_3 = R$



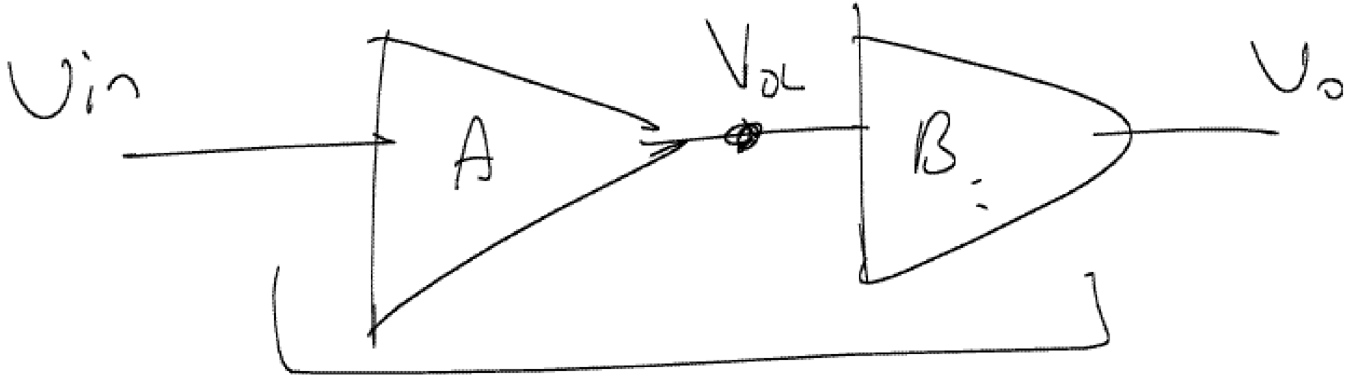
10^6

$V_o = A(v_p - v_n)$

$$\therefore V_o = \frac{RV_1 + RV_1 - 2RV_2}{2R}$$

$$\boxed{V_o = V_1 - V_2}$$

H.W #1 Add on:

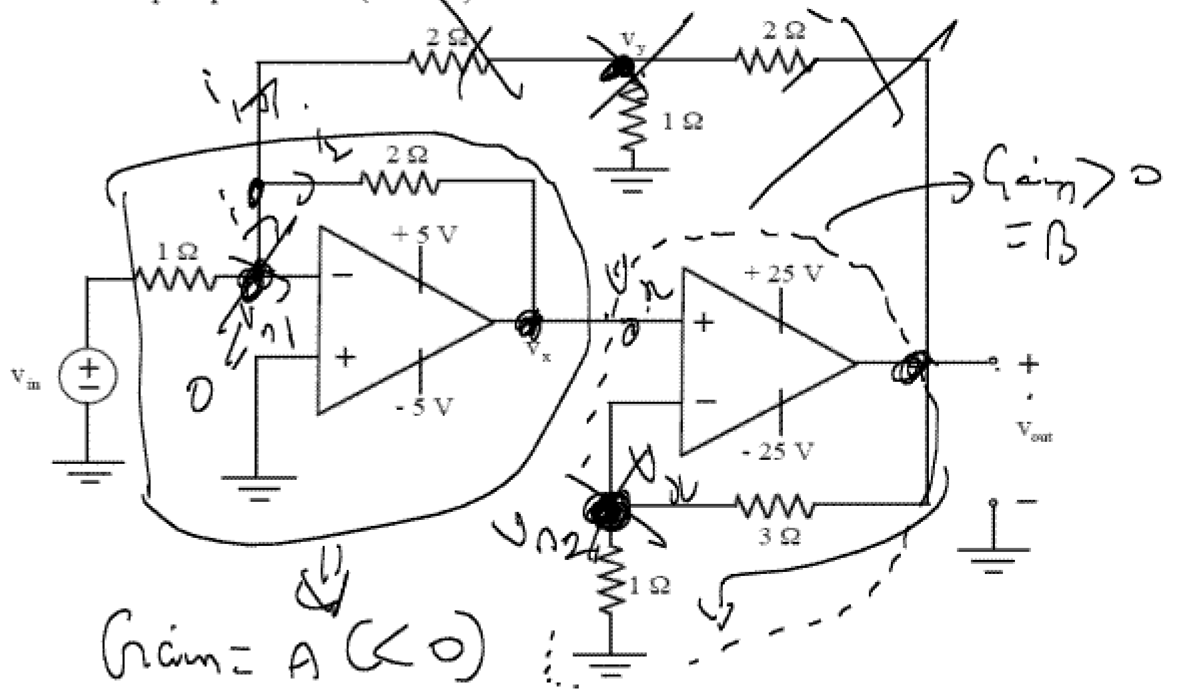


$$V_o = A \cdot B \, V_{in}$$

$V_x = A V_{in}$ | $V_o = B \cdot V_x$

$$v_o = B[A v_{in}] \Rightarrow \boxed{v_o / v_{in} = BA}$$

loop gain for both op-amps is infinite ($A = \infty$).



a.) Is the above circuit inverting or non-inverting? Answer this by inspection only. Explain your logic.

(b) Write KCL @ V_{n1}, V_y & V_{n2}

KCL @ V_{n1}: $\frac{V_{in} - 0}{1\Omega} = i_1 + i_2$

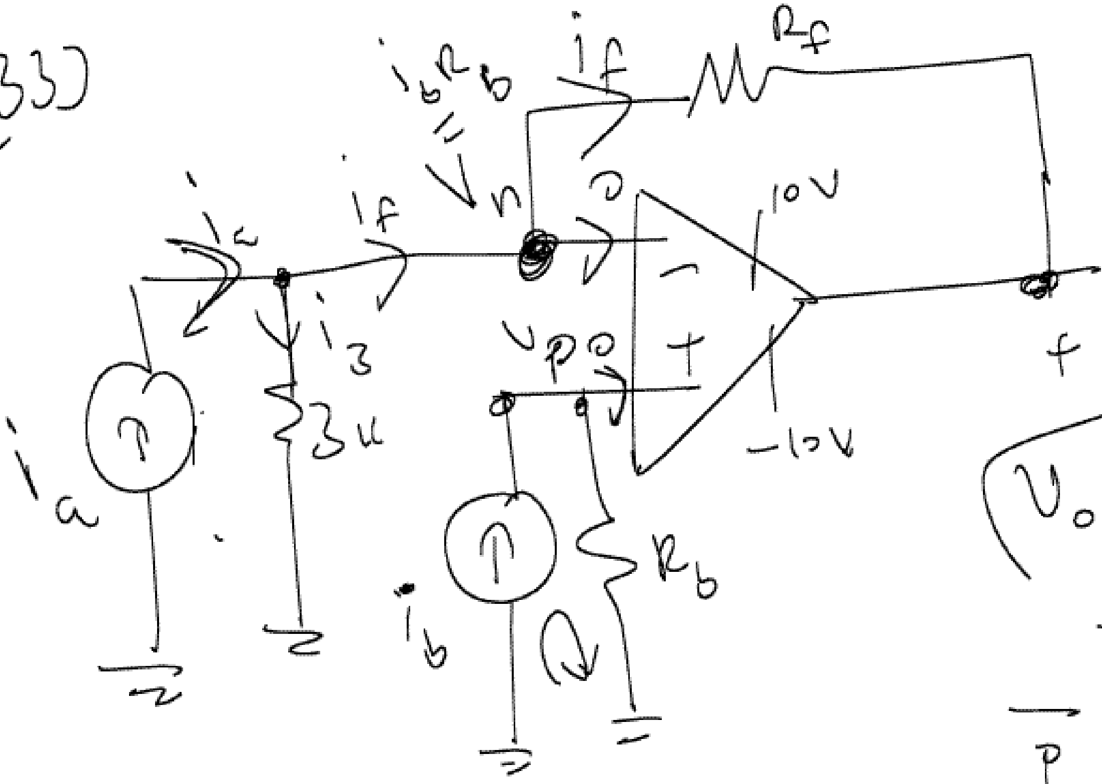
$= \left(\frac{0 - V_y}{2}\right) + \left(\frac{0 - V_x}{2}\right)$

KCL @ V_y: Relationship between V_y & V_{out}

KCL @ V_{n2}: Relationship between V_{out} & V_x

$V_{out} = f(V_{in})$

(33)



$V_o = 2000(i_b - i_a)$

$V_n = \cancel{i_a}(3k)$ ($i_a \neq i_3$) $V_p = i_b(R_b)$

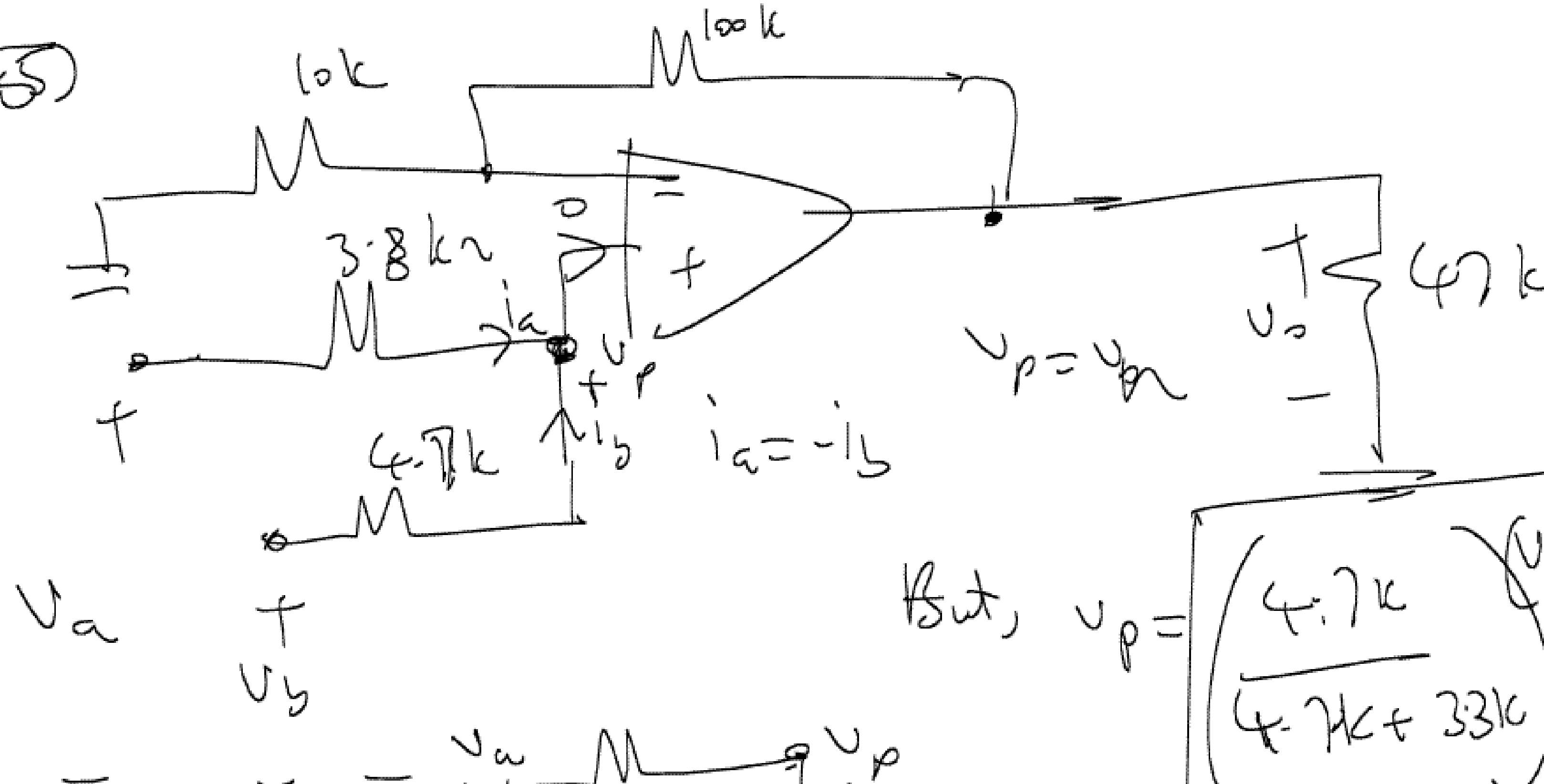
Assume op-amp is ideal $\Rightarrow V_n = V_p = i_b(R_b)$

$$i_3 = \frac{V_p}{3k} = \left(\frac{i_b R_b}{3k}\right) \quad ; \quad i_f + i_3 = i_a$$

$$i_f = \frac{V_n - V_o}{R_f}$$

$$i_f = i_a - \left(\frac{i_b R_b}{3k}\right) = \frac{i_b R_b - V_o}{R_f}$$

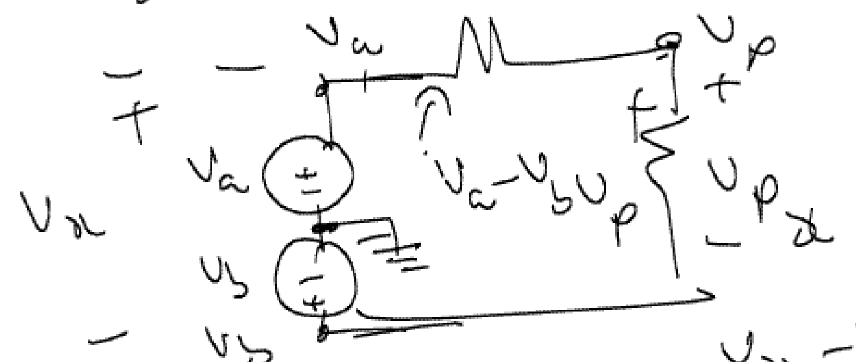
(255)



$v_p = v_n$

$i_a = -i_b$

But, $v_p = \left(\frac{4.7k}{4.7k + 3.3k}\right)(V_a - V_b) + V_b$



$v_x - V_a + V_b = 0$

$$\therefore V_n = \left(\frac{4.7k}{8.0k}\right)(V_a - V_b) + V_b$$

$$\Rightarrow V_n = 0.5875 V_a + 0.4125 V_b$$

KCL @ V_n:

$$V_n = f(V_a + V_b)$$

$$= \alpha V_a + \beta V_b$$

$$\frac{0 - V_n}{10k} = \frac{V_n - V_o}{100k}$$

$$\Rightarrow \quad v_n - v_o = 10 \cdot (-v_n)$$

$$\Rightarrow \quad 11 v_n = v_o$$

$$v_o = 11 \left[\frac{4.7k}{8.0k} \right] (v_a - v_b)$$

$$v_a + v_b$$