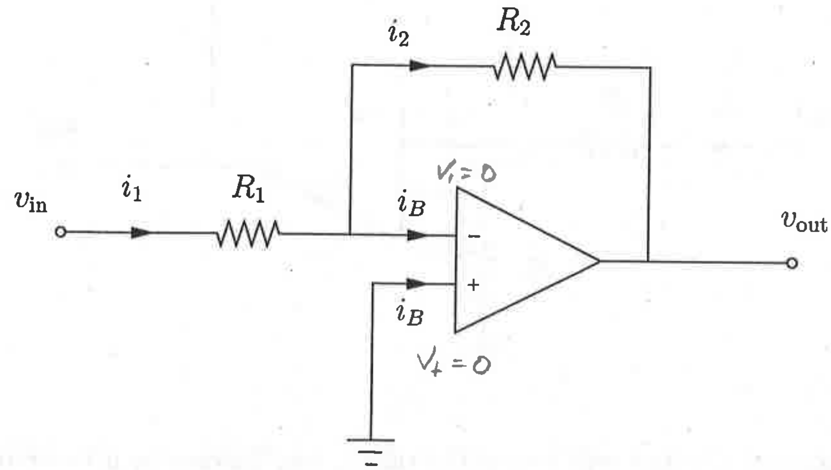
An Example of Non-Ideal Op-Amp Behavior (and a fix)

The inputs to real op-amps do draw some current. Let's consider an op-amp that is ideal in all respects *except* that a constant bias current i_B flows into both the inverting and the non-inverting inputs.



Determine an expression for v_{out}.

Op-amp voltage rule: $V_+ = V_-$

Non-inverting input grounded $\Rightarrow V_+ = V_- = 0$

$$i_1 = \frac{v_{in} - 0}{R_1}$$

Kirchoff Current Law: $i_1 = i_B + i_2 \Rightarrow i_2 = i_1 - i_B$

Ohm's Law:

$$v_{out} = -i_2 R_2$$

$$= -(i_1 - i_B) R_2$$

$$= -\left(\frac{v_{in}}{R_1} - i_B\right) R_2$$

$$= -\frac{R_2}{R_1} v_{in} + i_B R_2$$

↑ Gain of ideal inverting amplifier

↑ offset

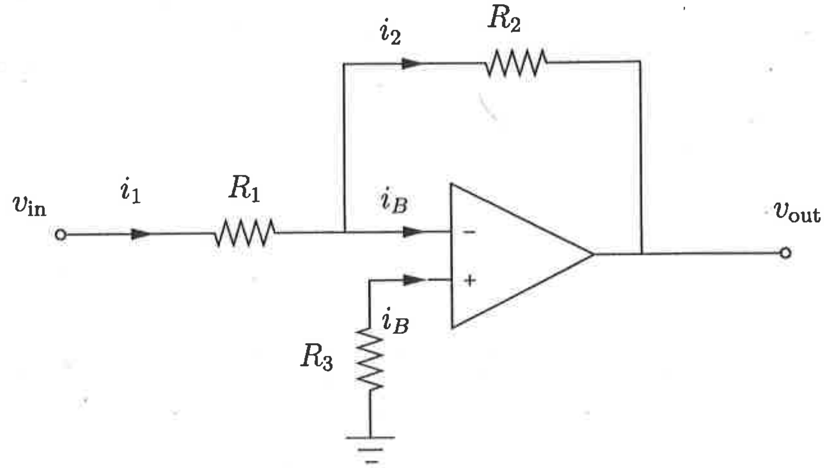
Consequences:

If $i_B = 100\,nA = 0.1\,\mu A$

$R_2 = 100\,k\Omega$

$I_B R_2 = 10^{-7} \times 10^5 = 0.01\,V = 10\,mV$

Consider the illustrated "fix." The bias current flowing through R_3 will result in a non-zero voltage v_2 at the inverting input. With a proper choice of R_3 we can cancel the offset in the output that results from the non-zero bias current.



Determine the value of R_3 that will cancel the offset, i.e., determine a value of R_3 that will make the output

$$v_{out} = -\frac{R_2}{R_1} v_{in}$$

as it was for an ideal op-amp.

$V_+ = -i_B R_3$

$\Rightarrow V_- = -i_B R_3$

$\Rightarrow i_1 = \dfrac{(V_1 + i_B R_3)}{R_1}$

KCL: $i_2 = i_1 - i_B$

$V_{out} = V_- - i_2 R_2$

$= -i_B R_3 - (i_1 - i_B) R_2$

$= -i_B R_3 - i_1 R_2 + i_B R_2$

$= -i_B R_3 - \dfrac{(V_1 + i_B R_3) R_2}{R_1} + i_B R_2$

$= -\dfrac{R_2}{R_1} V_1 + i_B \left(R_2 - R_3 - \dfrac{R_3 R_2}{R_1} \right)$

↑ gain of ideal non-inverting amp

Choose R_3 to make this → 0.

$R_2 - R_3 - R_3 \dfrac{R_2}{R_1} = 0$

$R_2 = R_3 \left(1 + \dfrac{R_2}{R_1} \right)$

$R_3 = \dfrac{R_2}{1 + \frac{R_2}{R_1}}$

$= \dfrac{R_1 R_2}{R_1 + R_2}$

↑ This is the R_3 of Fig. 10.4 in lab manual.