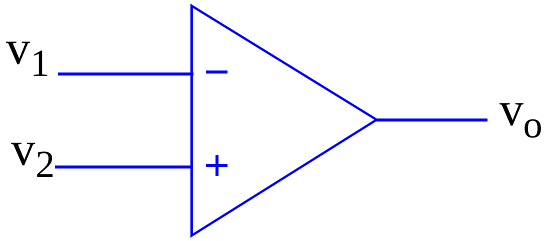
CMRR

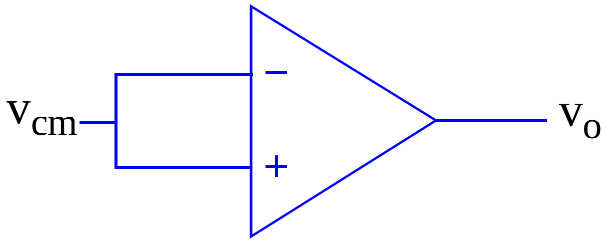
- One important measure of the goodness of an opamp or an opamp circuit is the common mode rejection ratio (CMRR)
- Ideally, opamps are expected to amplify the differences between v_1 and v_2 with nearly infinite gain
- Due to transistor nonidealities, some small amount of amplification occurs due to the common signal of both inputs

open loop gain



$$A = \frac{v_o}{v_2 - v_1}$$

common mode gain



$$A_{cm} = \frac{v_o}{v_{cm}}$$

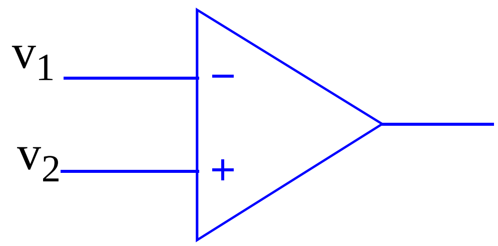
$$CMRR = \frac{A}{A_{cm}}$$

CMRR

- We would like to have an infinite CMRR

$$v_{id} = v_2 - v_1$$

$$v_{Icm} = \frac{v_2 + v_1}{2}$$

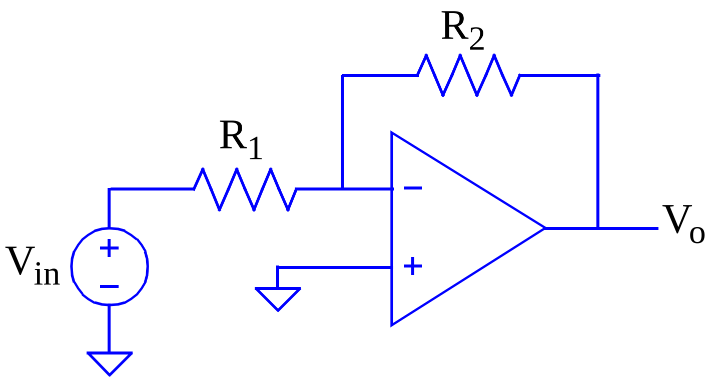


$$v_o = Av_{id} + A_{cm}v_{Icm}$$

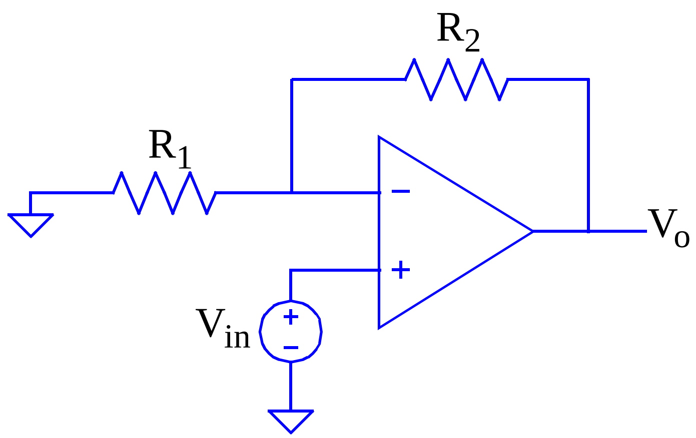
- A typical CMRR is 80-100dB at low frequency
- Would the CMRR improve, or get smaller with increasing frequency?

CMRR

- Not really a problem for inverting amplifier configurations --- why?

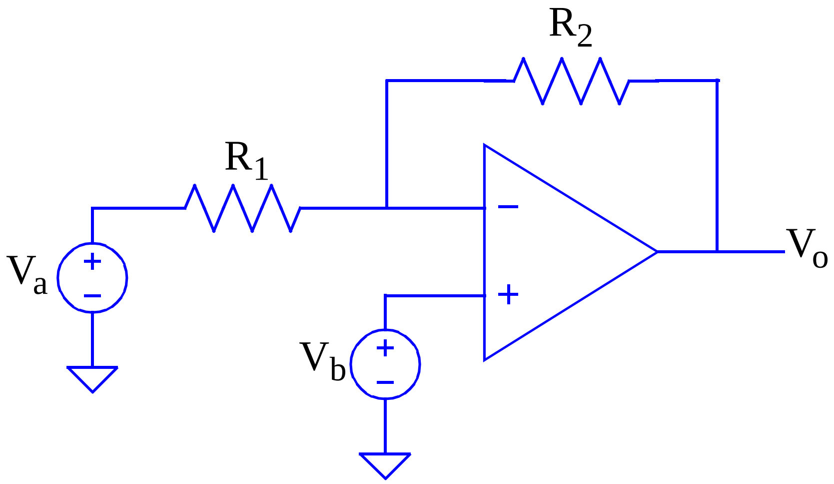


- But definitely a problem for noninverting amplifier configurations --- why?



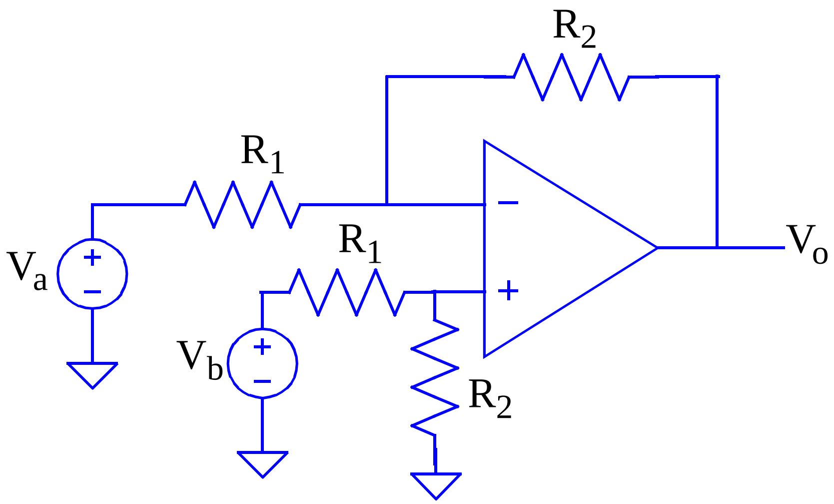
Difference Amplifier

- Also a problem for difference amplifiers



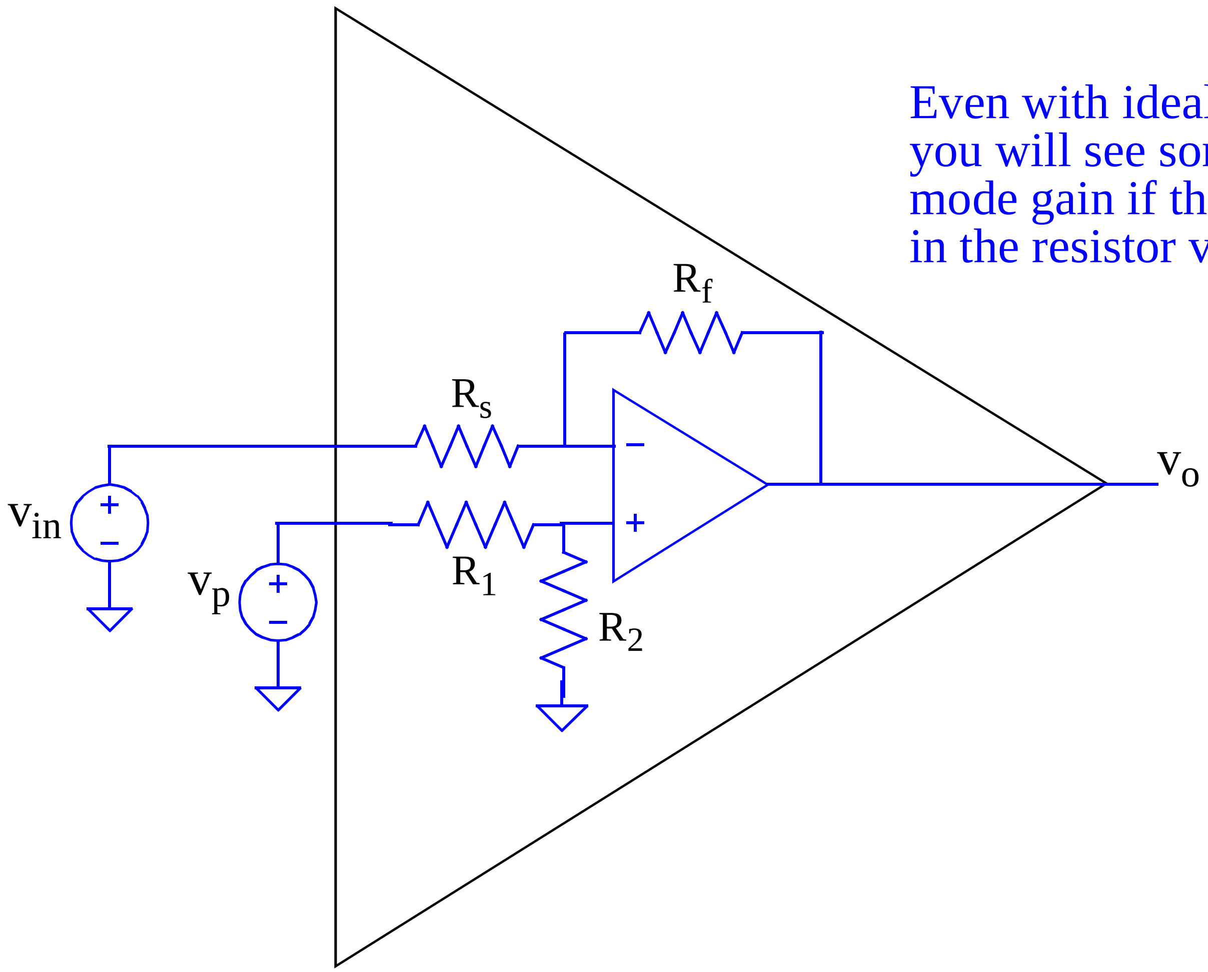
Difference Amplifier

- We have to scale the voltage v_b to achieve balanced amplification of v_b-v_a



CMRR

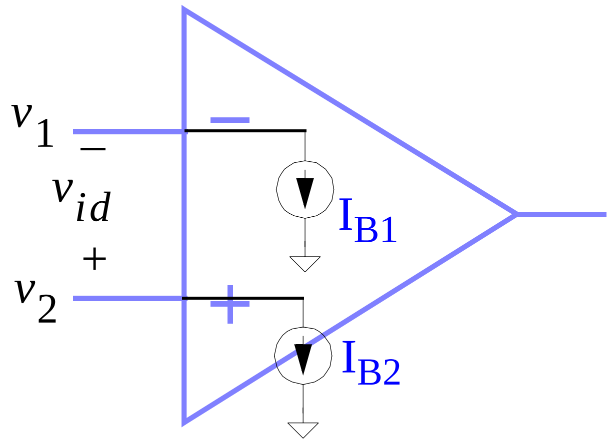
- Opamp data sheets specify the CMRR for the opamp itself, but the opamp differential amplifier circuit also has a CMRR



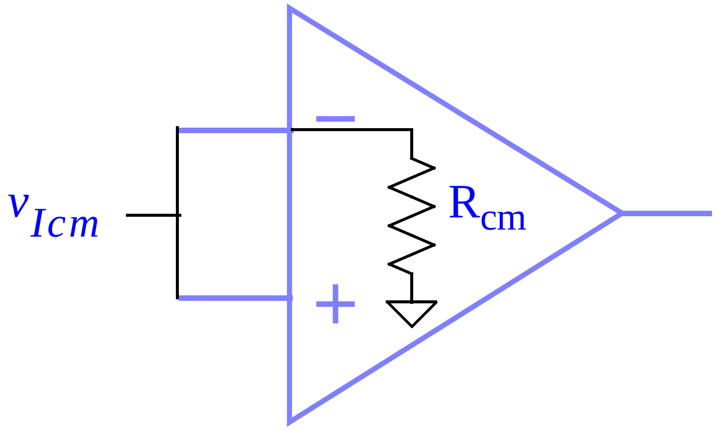
Even with ideal opamp model you will see some common mode gain if there is a mismatch in the resistor values

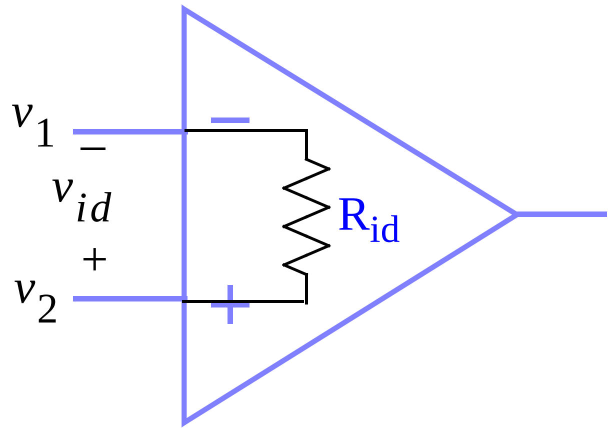
Input-Currents and -Resistances

- There is some small dc current flowing into/out of the inputs at all times -- input bias current



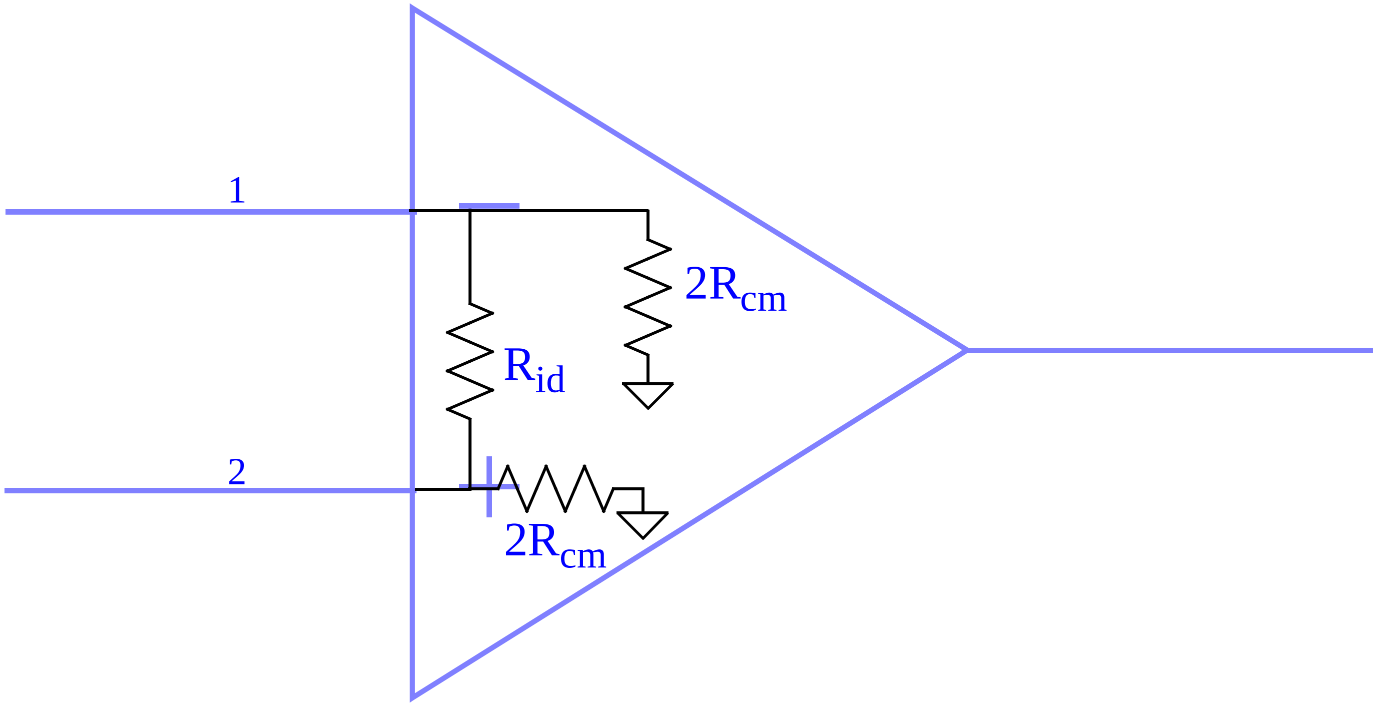
- There is also a component of input current that changes with input voltage (both common mode and differential) --- input resistances





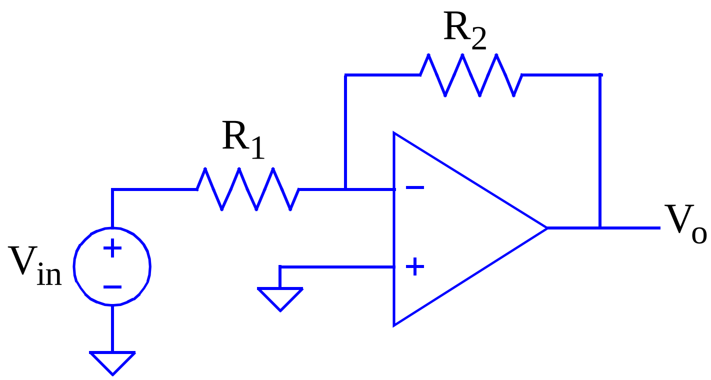
Input Resistance

- These resistances are generally quite large: R_{cm} ~ 100MΩ, and R_{id} ~ 1MΩ
- These resistances are even larger for MOS opamps

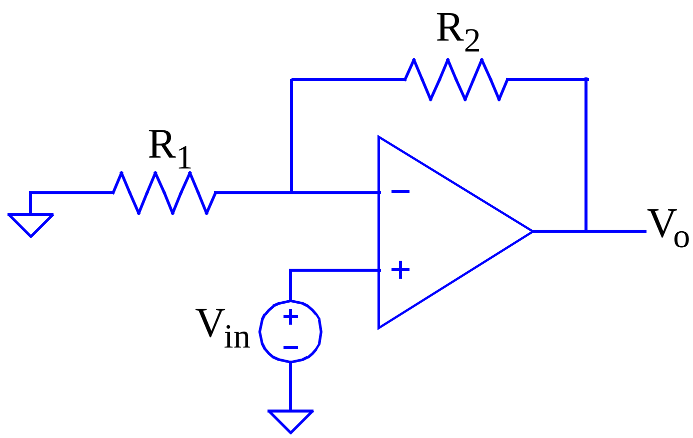


Input Resistance

- These opamp input resistances do not affect an inverting amplifier configuration as long as R_1 is much less than R_{id} and R_{cm}

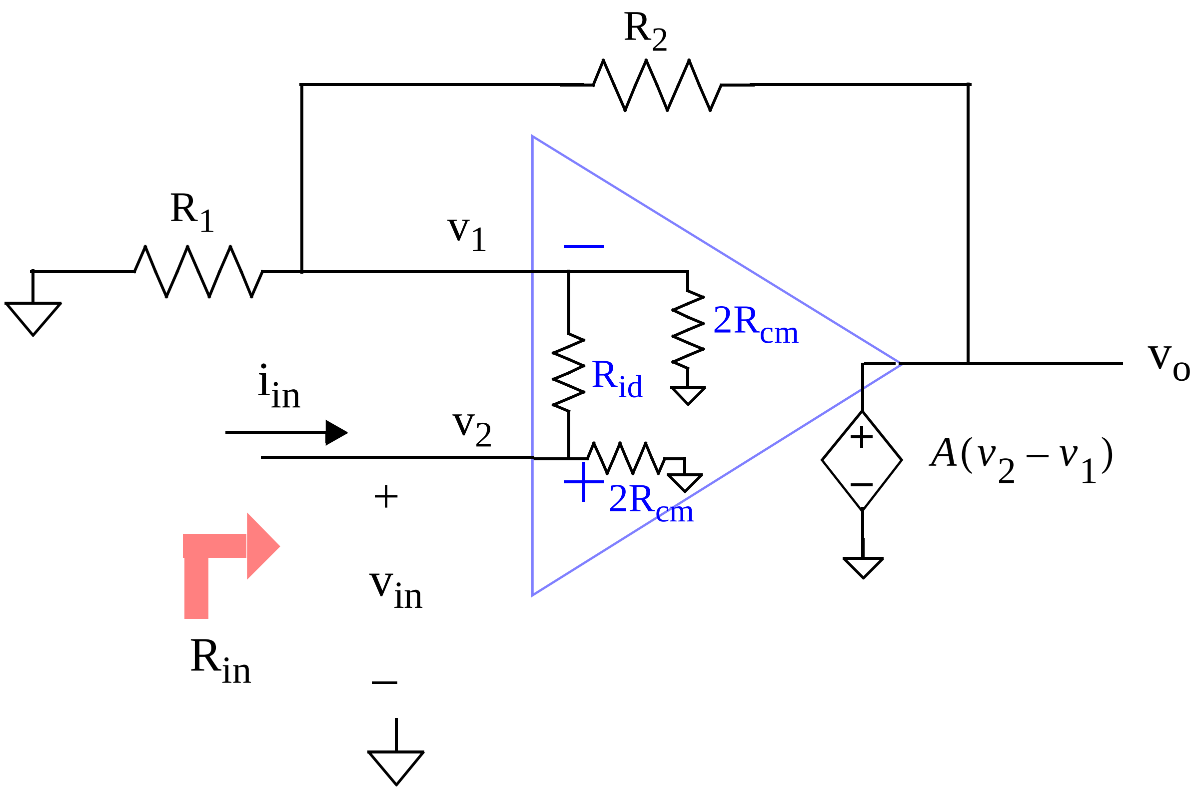


- But these resistances are what determines the input resistance of a non-inverting amplifier configuration

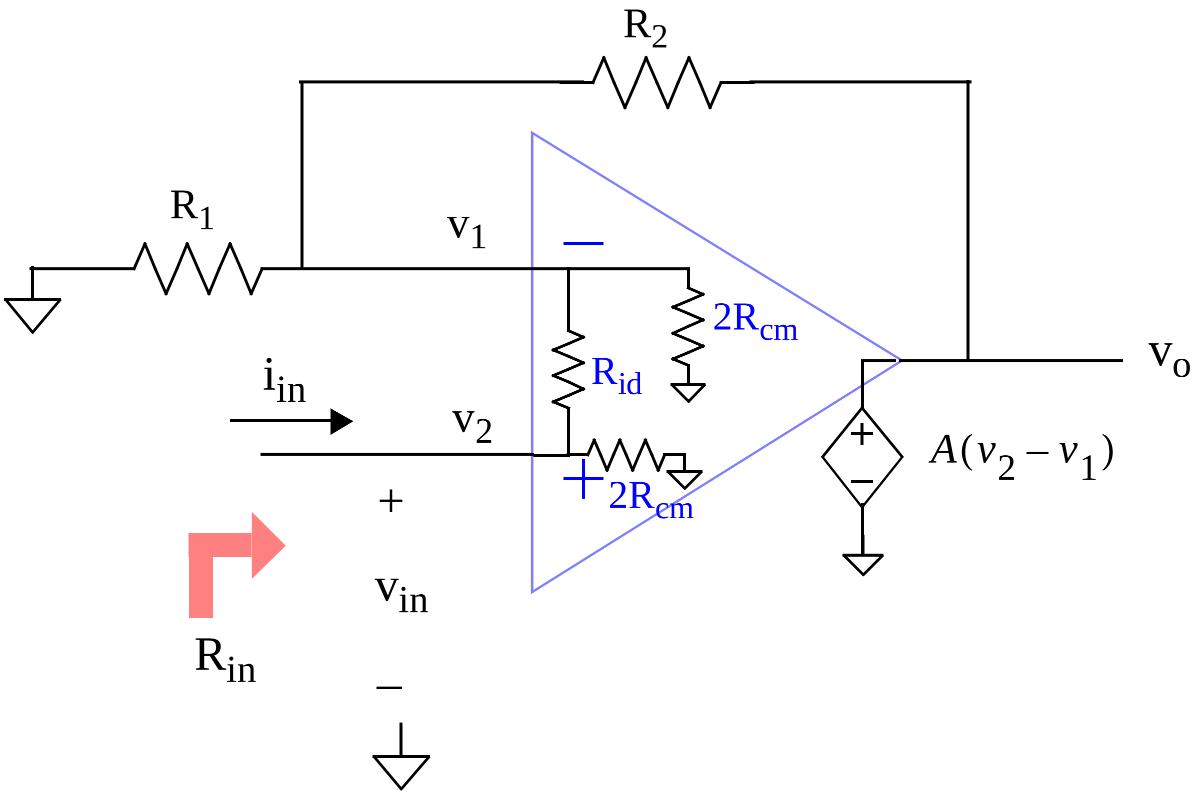


Input Resistances

- The resistors R_1 and R_2 should be kept significantly smaller than the input resistances for the gain to be close to ideal

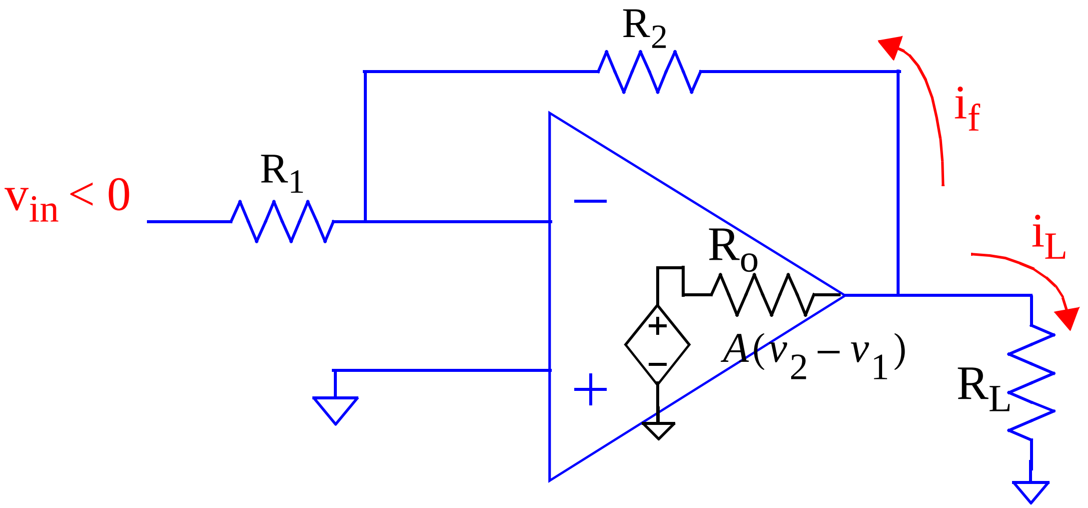


Input Resistances



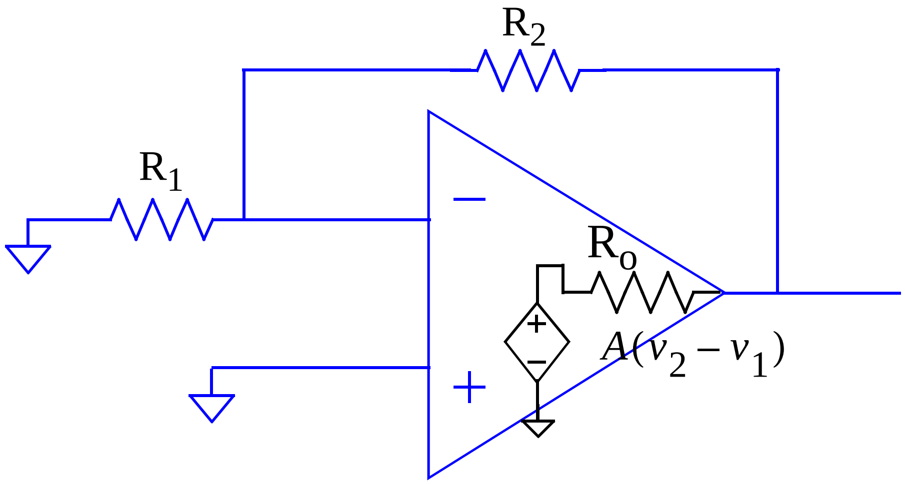
Nonzero Output Resistance

- We also have to keep in mind that the opamp output cannot source an infinite amount of current --- so we can't drive arbitrarily small resistance loads
- This is modeled by an output resistance, R_o



note that v_o definition is changed when output resistance is added to the model

Measuring Output Resistance

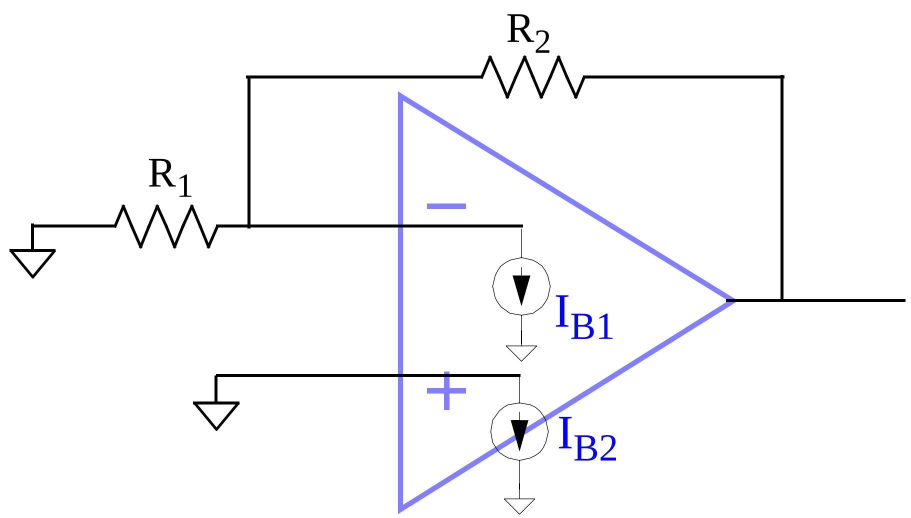


Modeling Output Resistance

- Since the open loop gain depends on frequency, so does the opamp circuit output impedance

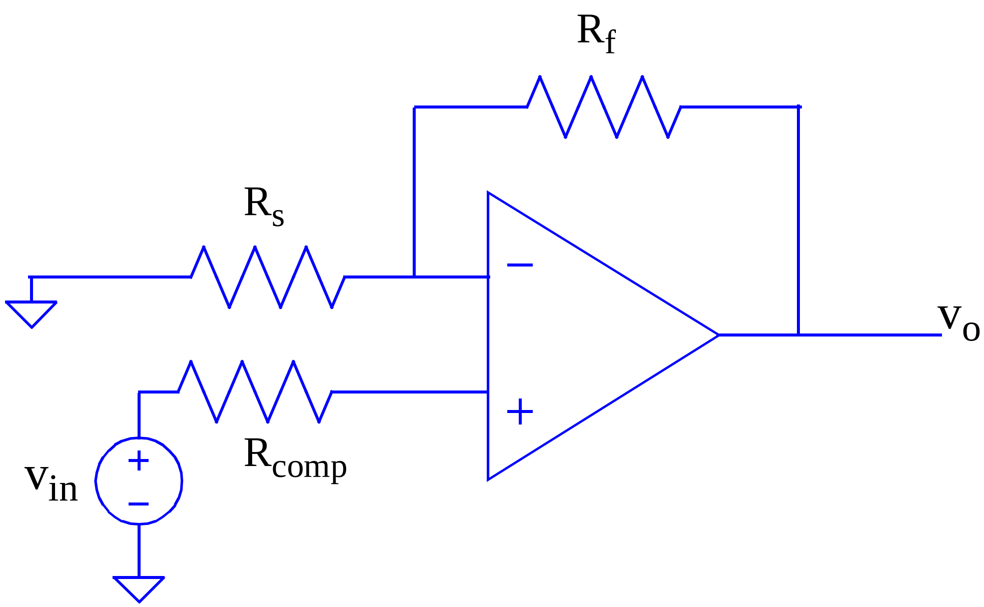
Input Bias Current

- The input bias current is not frequency dependent, but can cause an unwanted dc output response

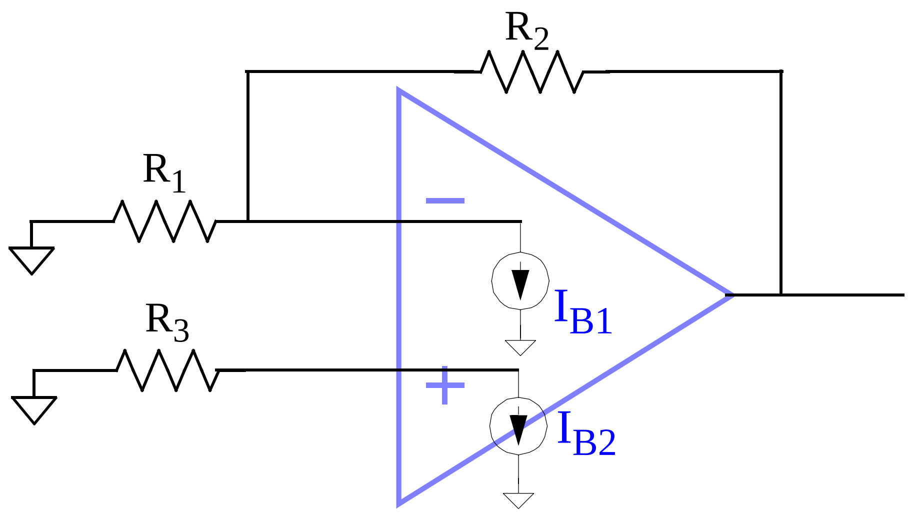


Compensating for I_B

- In practice, a resistor is added so that the bias current drops are compensated properly between the two ports

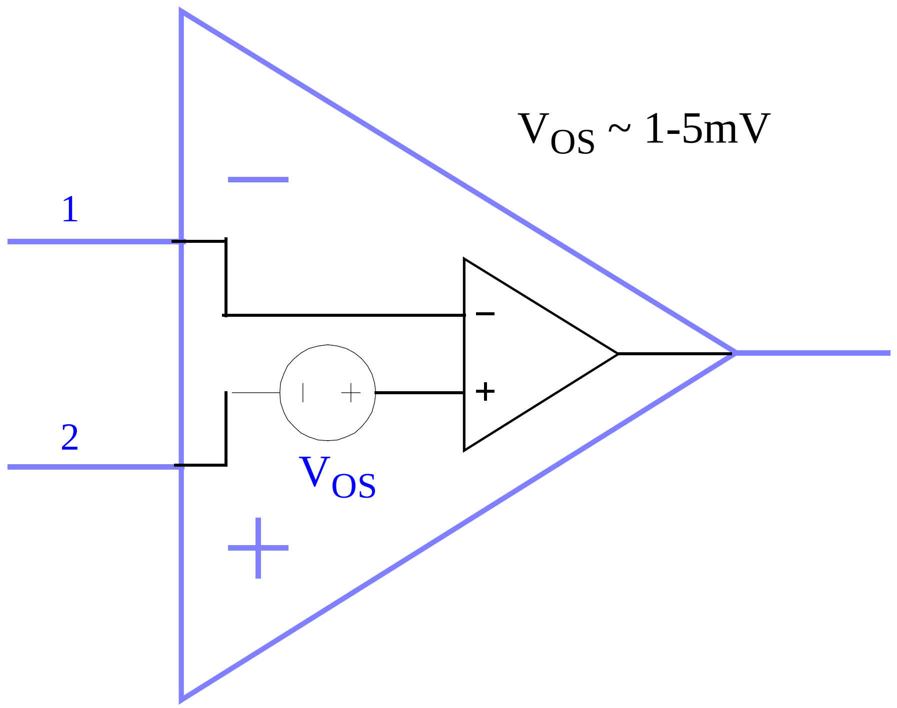


Compensating for I_B



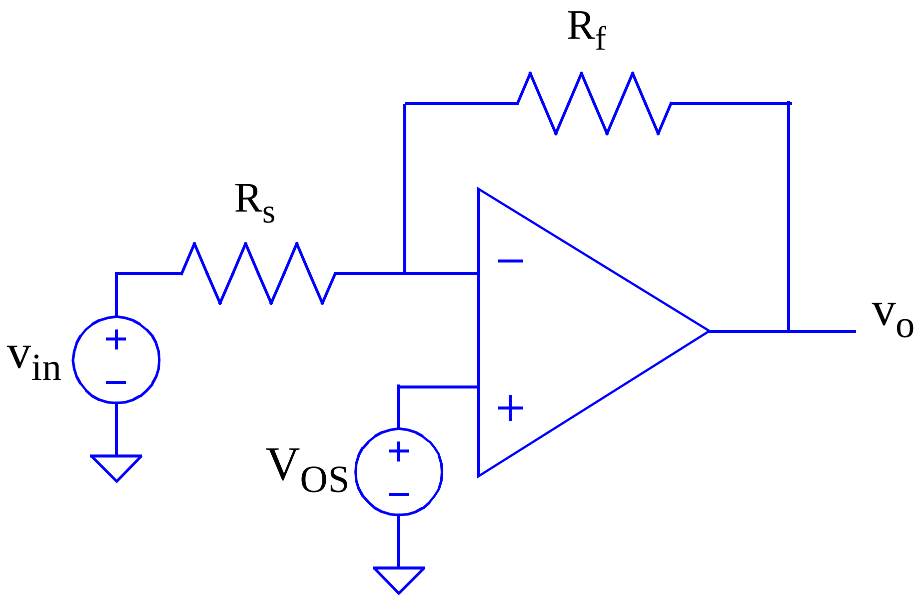
dc Offset Voltage

- Another unwanted dc output signal is due to the dc offset voltage
- A dc differential input is required for a real opamp to zero the output
- This offset is due to mismatch in transistor parameters, and is temperature dependent --- more on this later in the course



dc Input Offset Voltage

- Calculate output voltage due to dc input offset voltage



ac Coupling

- We can avoid this offset voltage at the output by using ac coupling