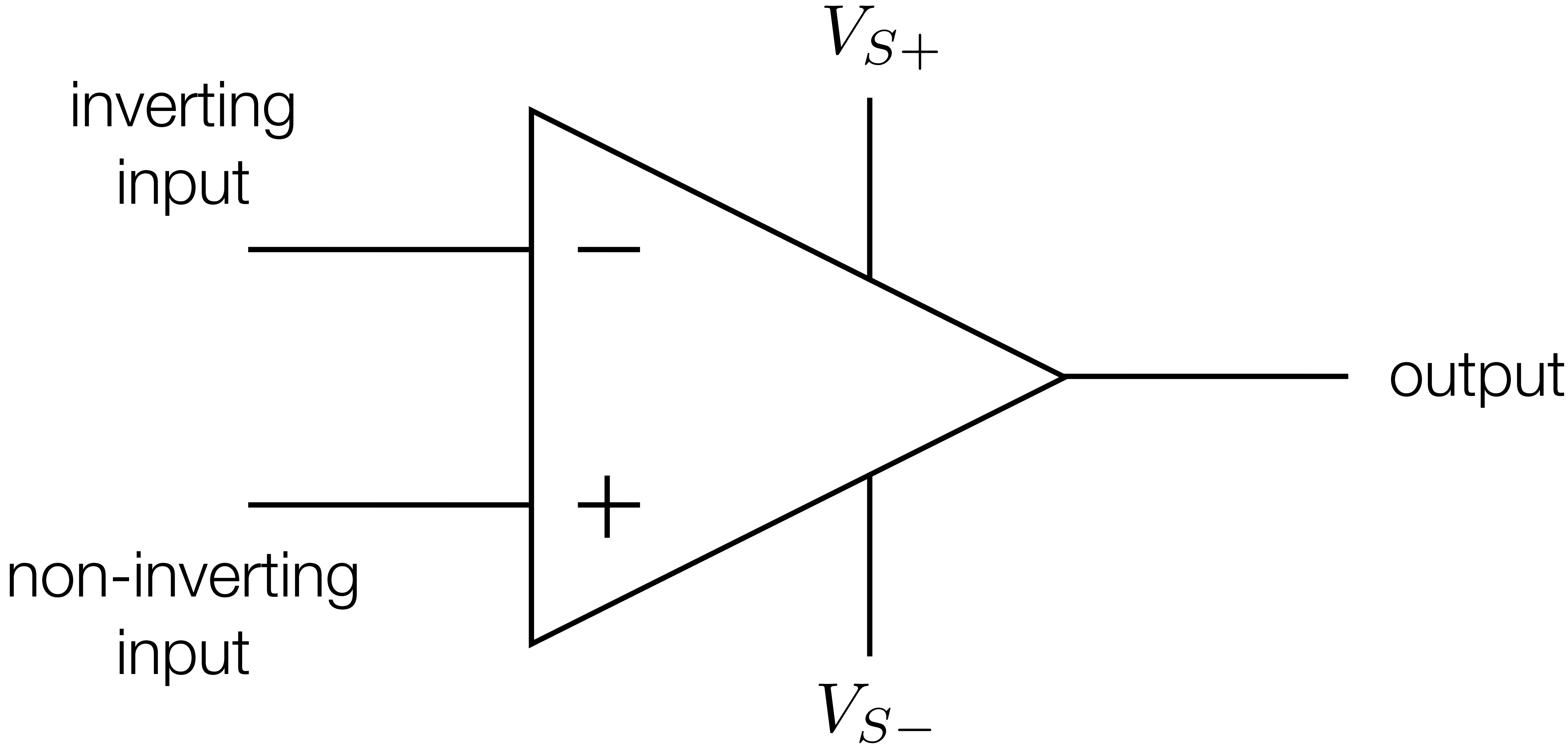
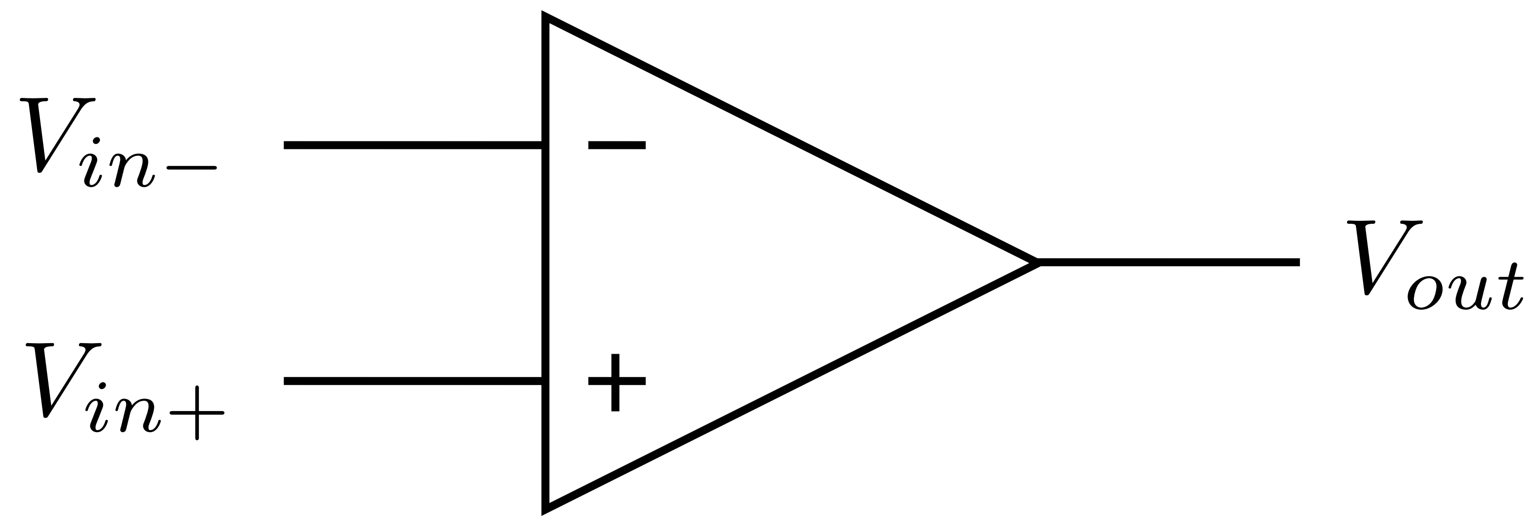
Operational Amplifiers



V_{S+}
inverting
input
−
+
output
non-inverting
input
V_{S-}

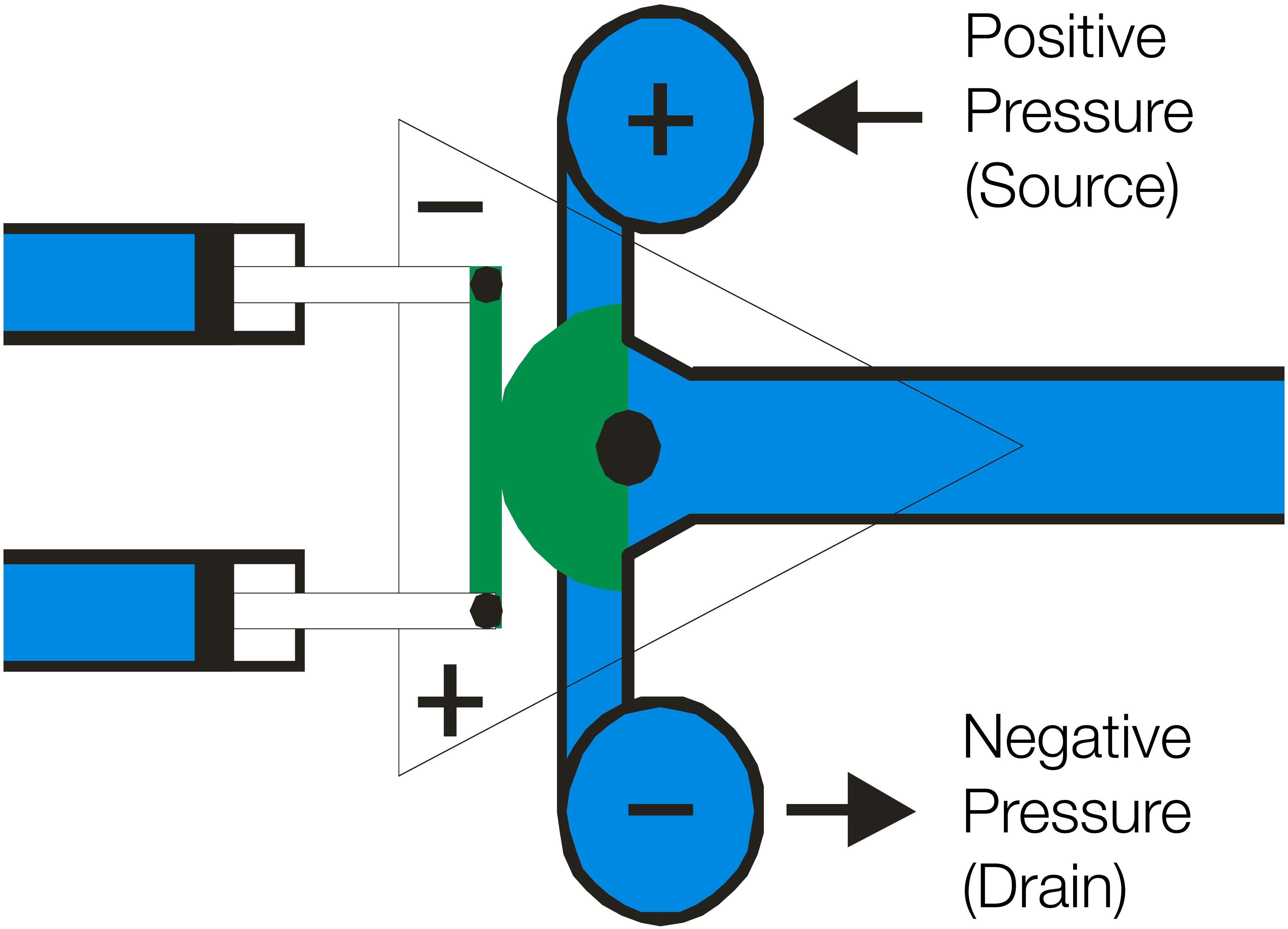
output = amplified difference between inputs



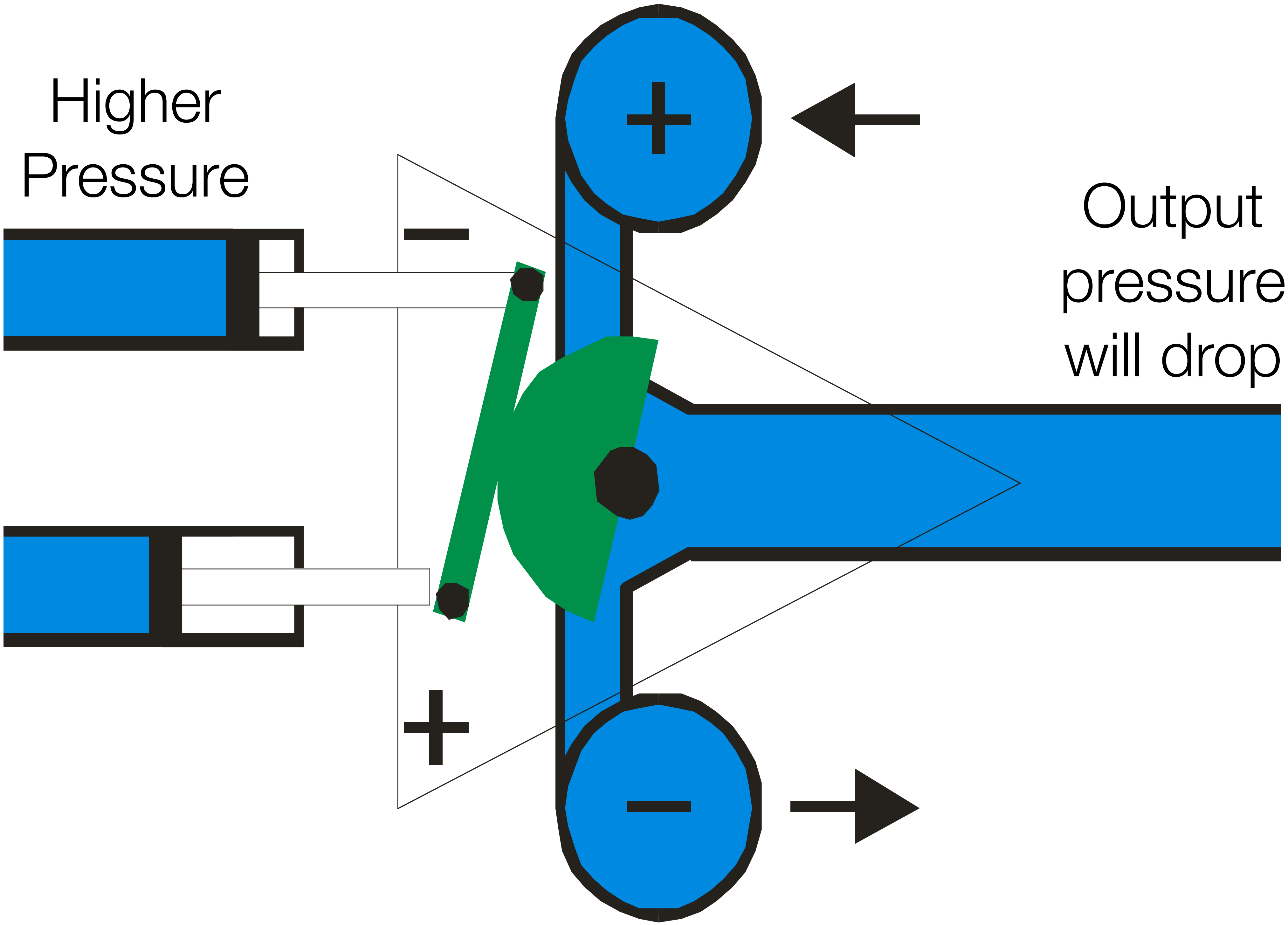
$$V_{out} = (V_+ - V_-)A$$

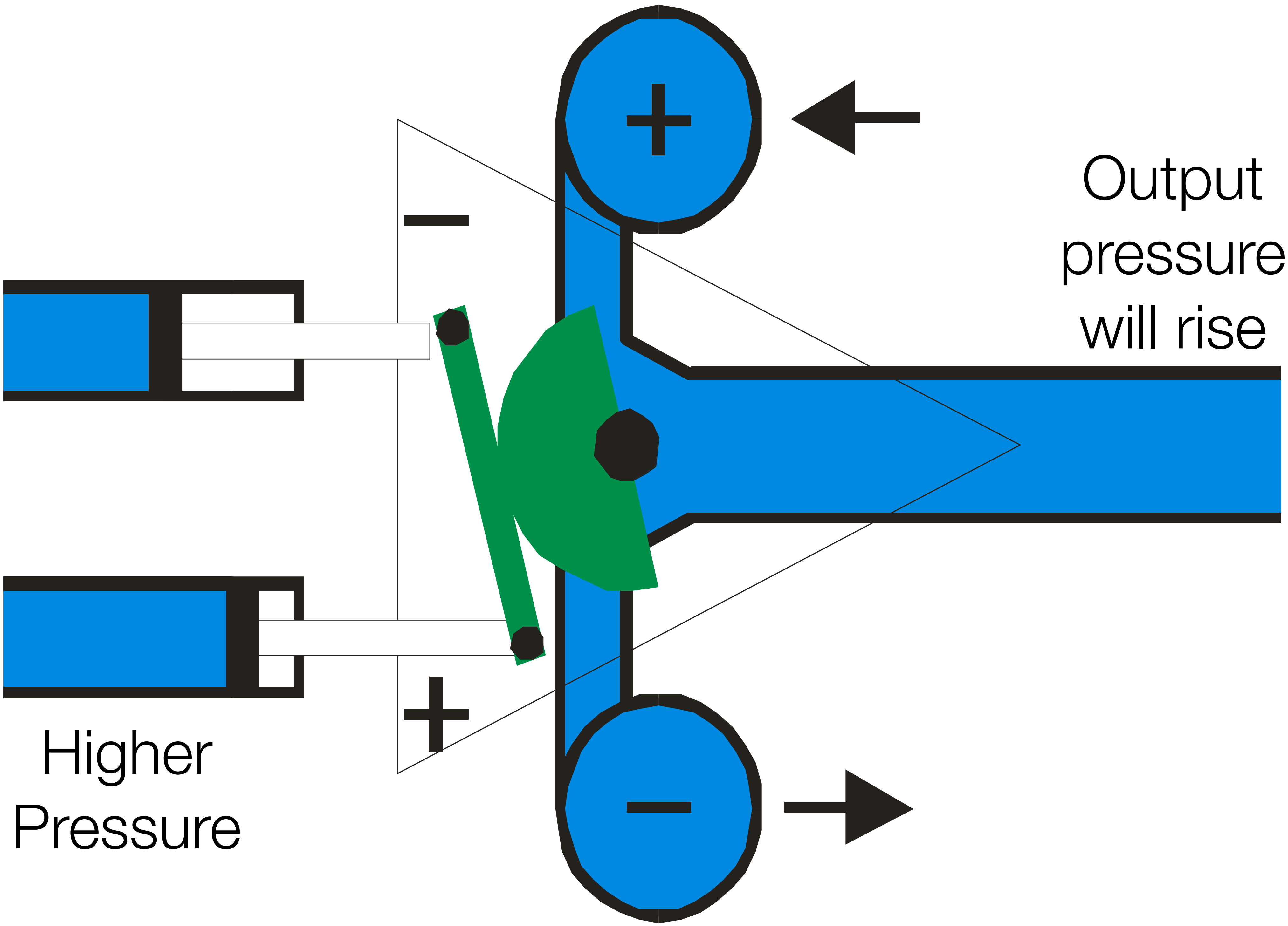
where the gain is typically extremely large

$$A \geq 10^5$$



Positive
Pressure
(Source)
Negative
Pressure
(Drain)

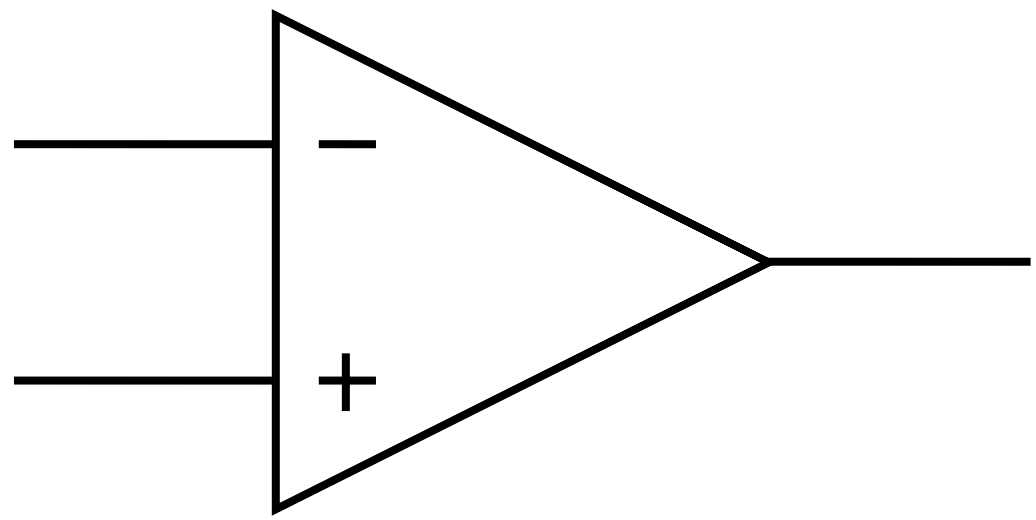

Higher
Pressure
Output
pressure
will drop
+
−
−
+



Output
pressure
will rise
Higher
Pressure

input impedance is very high $R_{in} \approx 4M\Omega$

output impedance is very low $R_{out} \approx 100\Omega$



very high bandwidth

For most op-amp circuits, we can safely assume:

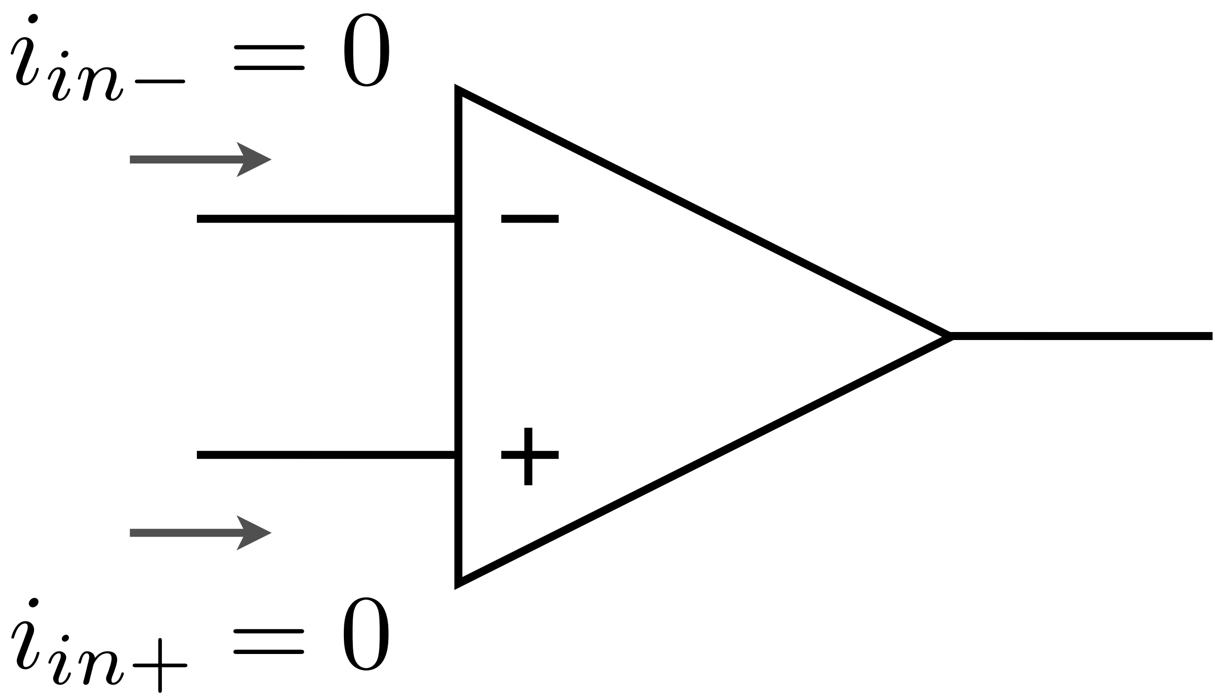
infinite gain

infinite input impedance

zero output impedance

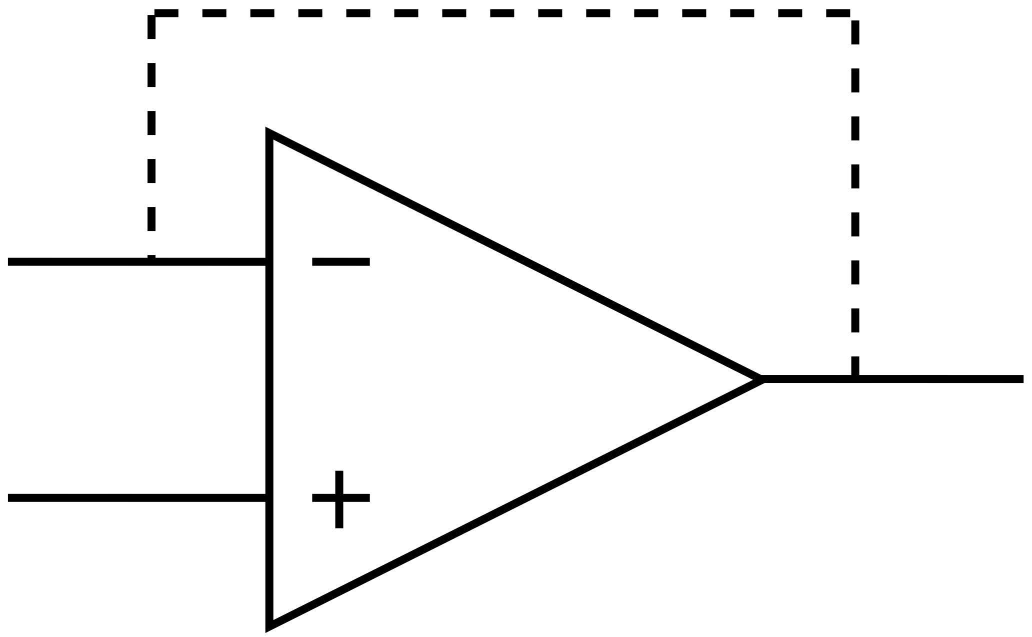
zero input offset voltage

The first golden rule of op amps



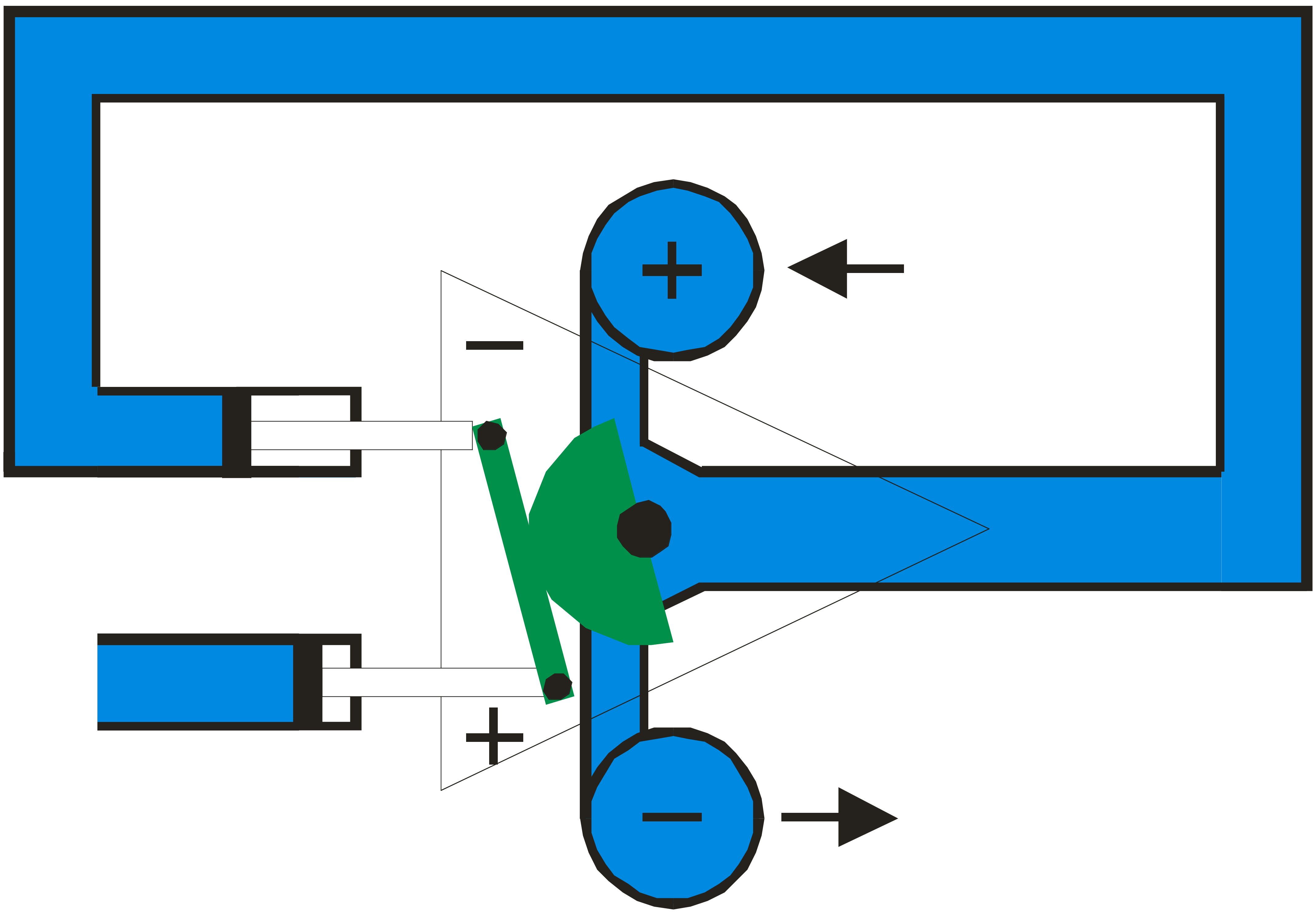
THE INPUTS DRAW “NO” CURRENT

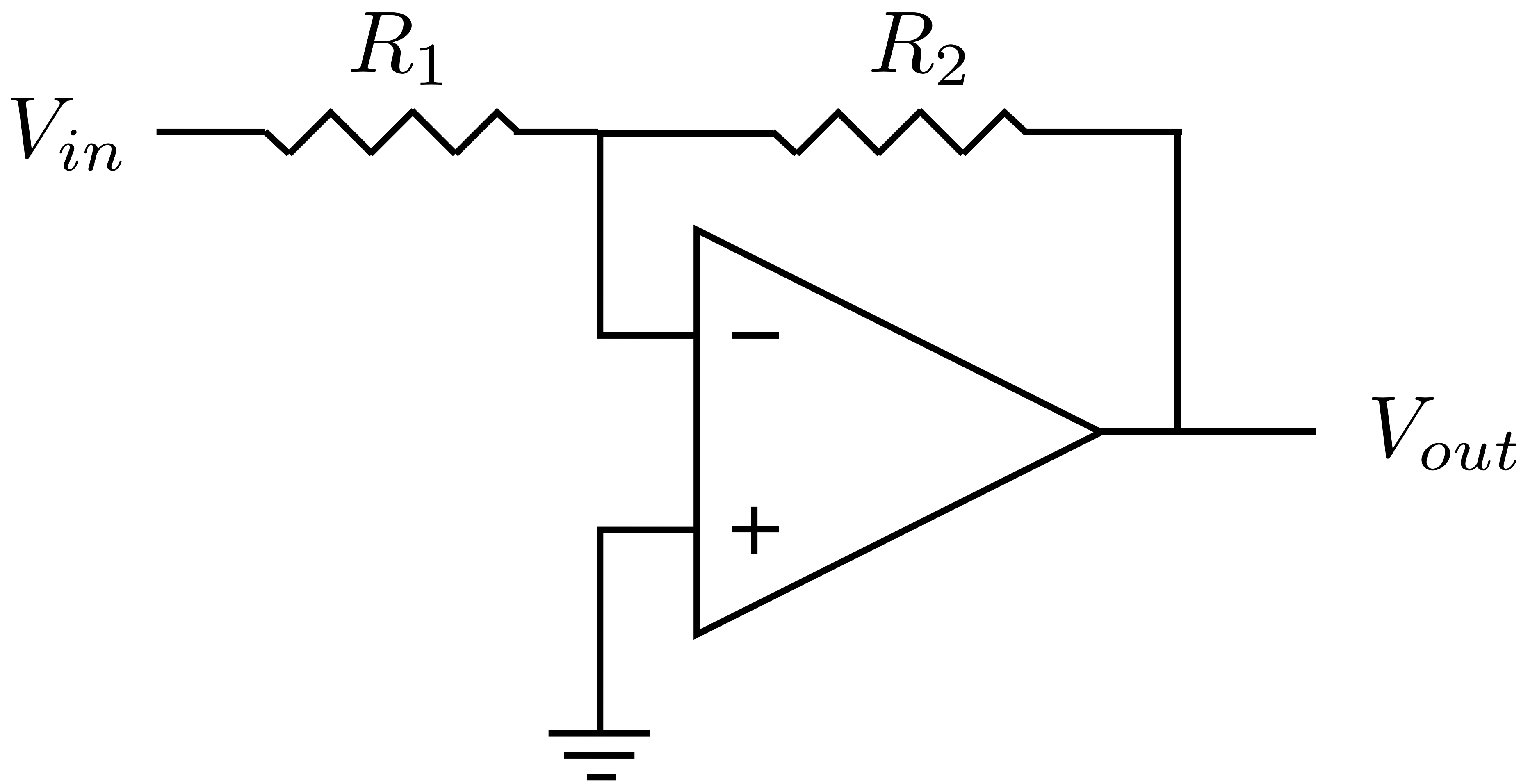
The second golden rule of op amps



IN NEGATIVE FEEDBACK,

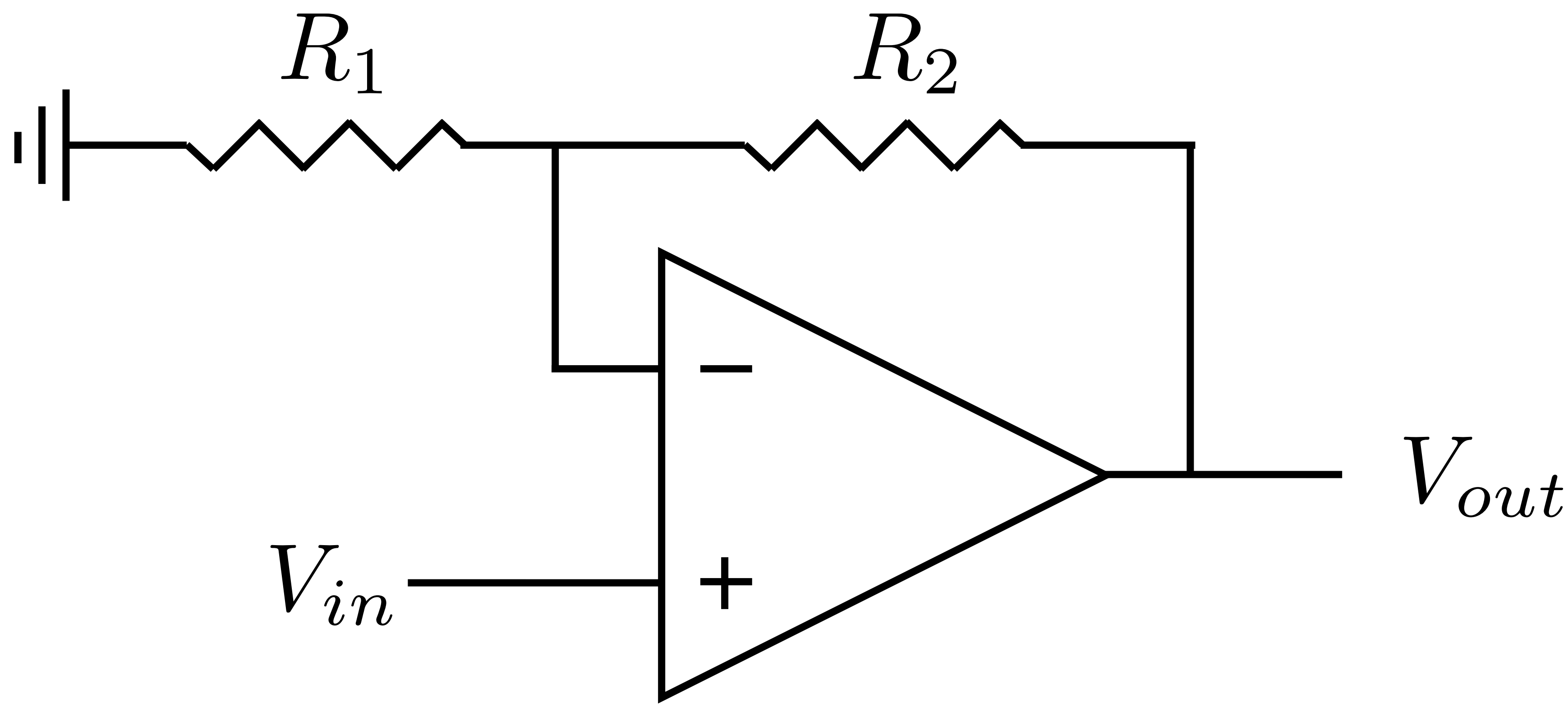
THE INPUT VOLTAGES WILL BE “THE SAME”





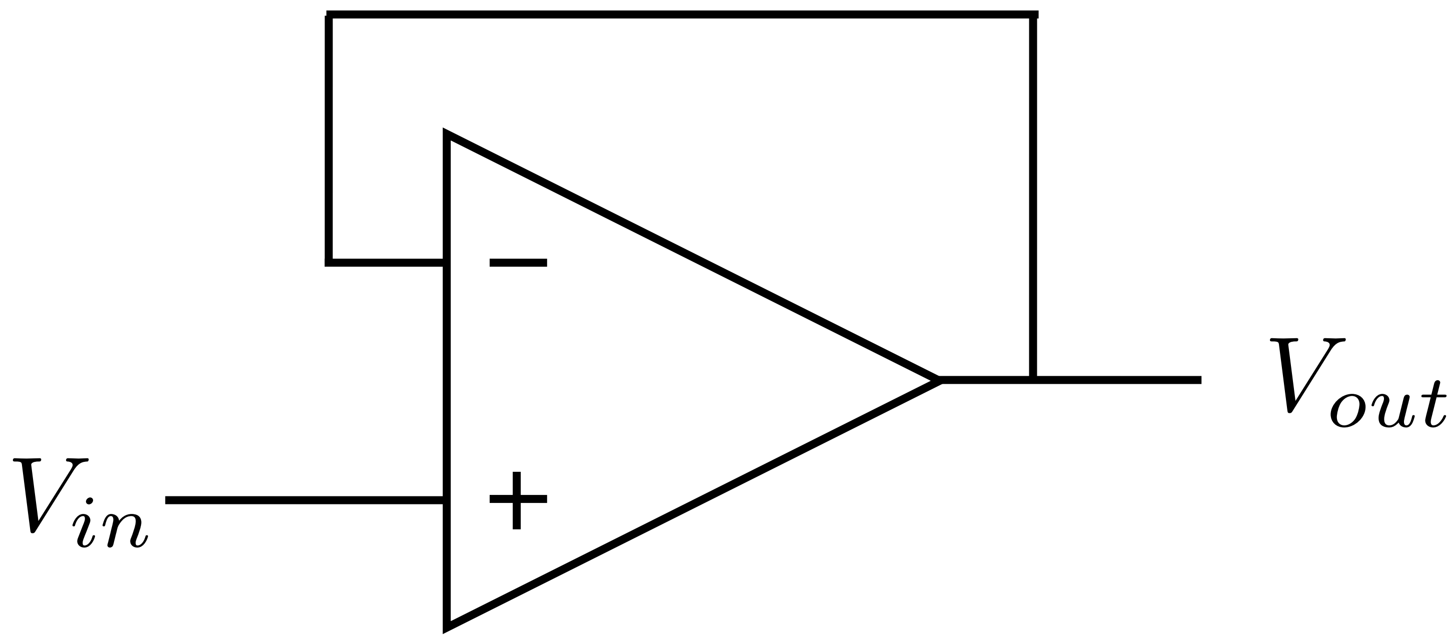
$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}$$

Standard “Inverting” Configuration



$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$

Standard “Non-Inverting” Configuration

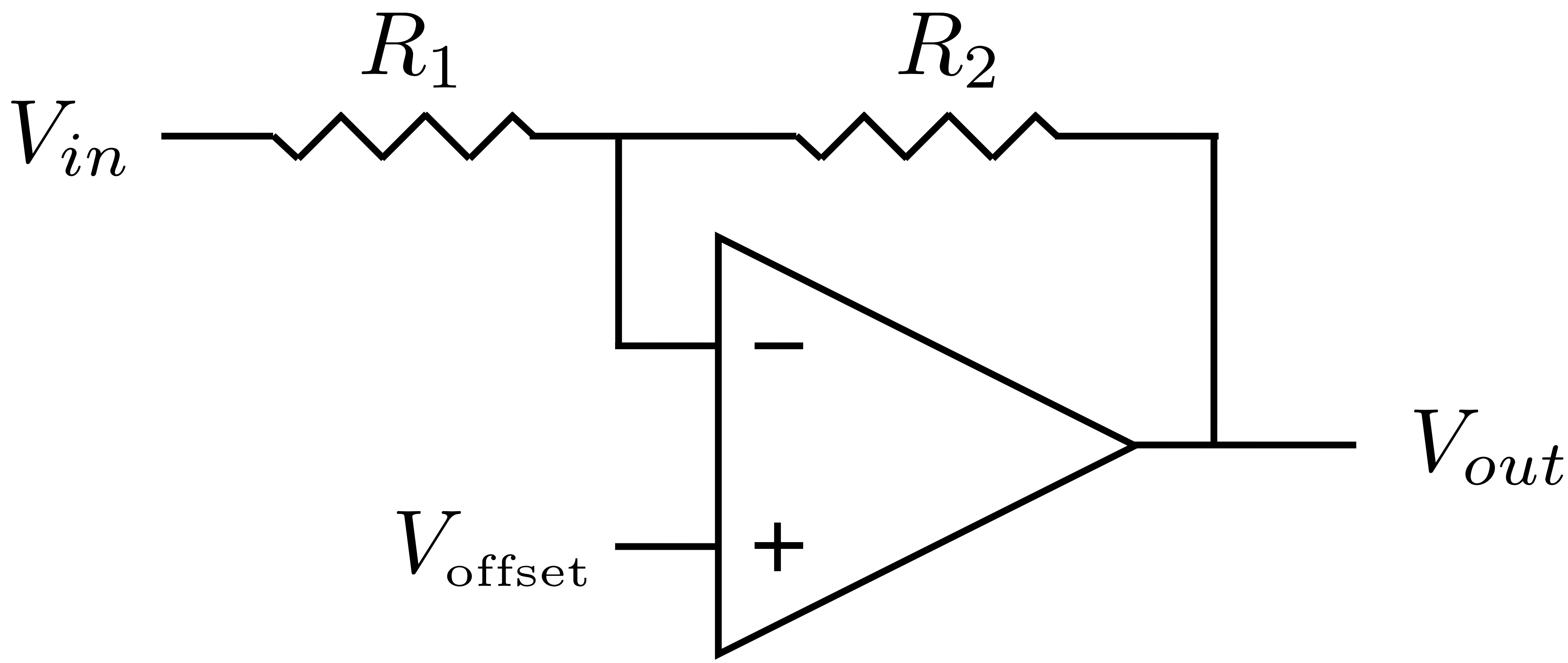


$$V_{out} = V_{in}$$

Standard “Buffer” Configuration

A challenge:

We have a 200 mV (peak-to-peak) sinusoidal signal that we want to amplify to 1 V (peak-to-peak) while maintaining phase.



$$V_{out} = V_{\text{offset}}\left(1 + \frac{R_2}{R_1}\right) - V_i\frac{R_2}{R_1}$$

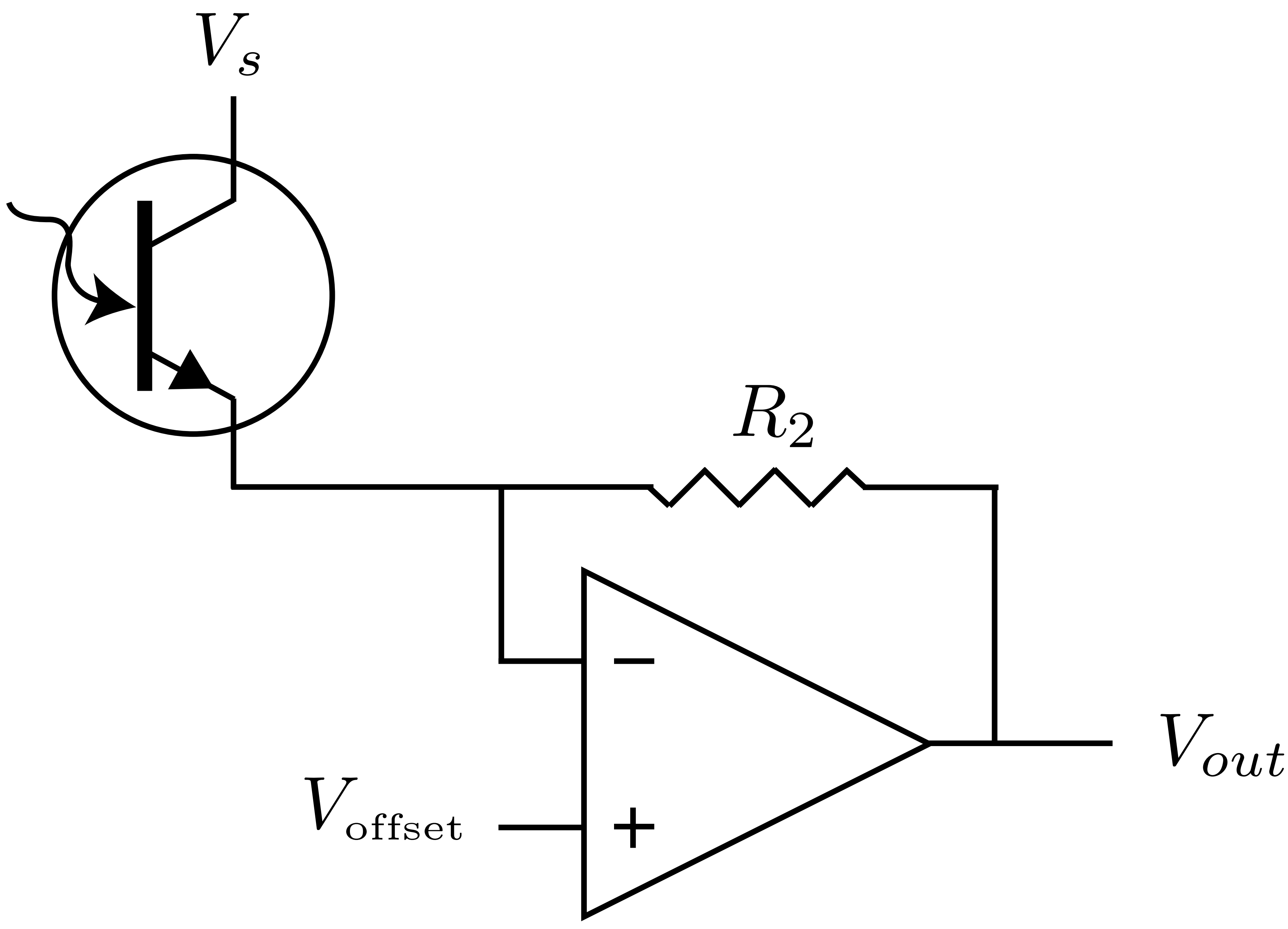
Inverting with Offset

Op Amp Design Methodology

determine whether you want inversion

choose the gain

determine offset



$$V_{out} = V_{\text{offset}} - R_2 \, i_{\text{photo}}$$

	qty	supply	CMMR	R-to-R	iO (mA)	cost
LM358	dual	3-32V ±1.5-16V	80 dB	N	8 / 20	$0.24
TLV272	dual	2.7-16V ±1.35-8V	85 dB	Y	7 / 8	$0.56
TLC2272	dual	±8V	75 dB	Y	50 / 50	$0.82
TCA0372	dual	0-40V ±20V	90 dB	~Y	1000	$0.83
LM324	quad	3-32V ±1.5-16V	85 dB	N	20 / 40	$0.27
LM6142 LM6144	dual quad	0-35V ±17.5V	107 dB	Y	25 / 25	$0.60 $1.07