ME133 Lecture 15 3/7/23

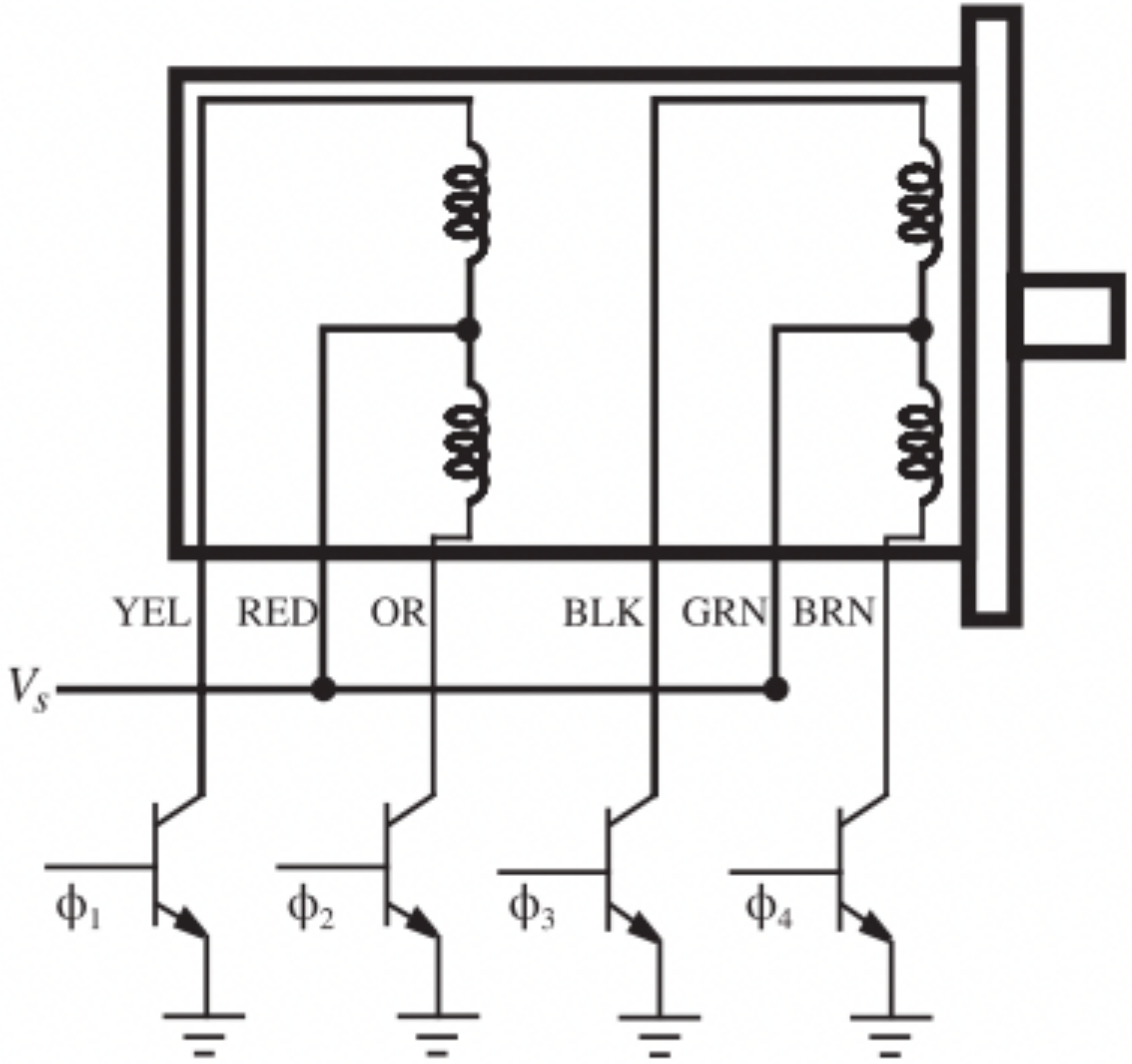
Last time:

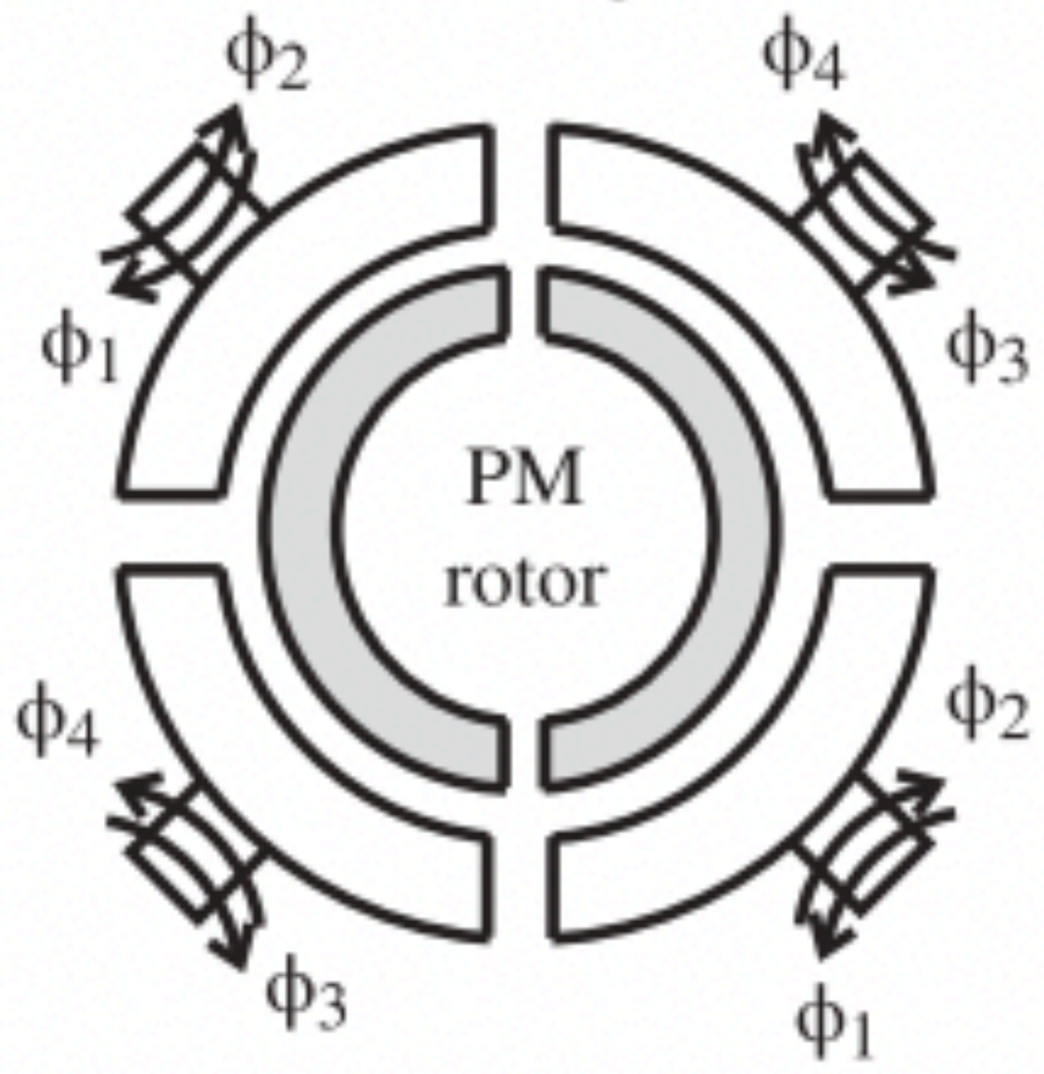
> Motors

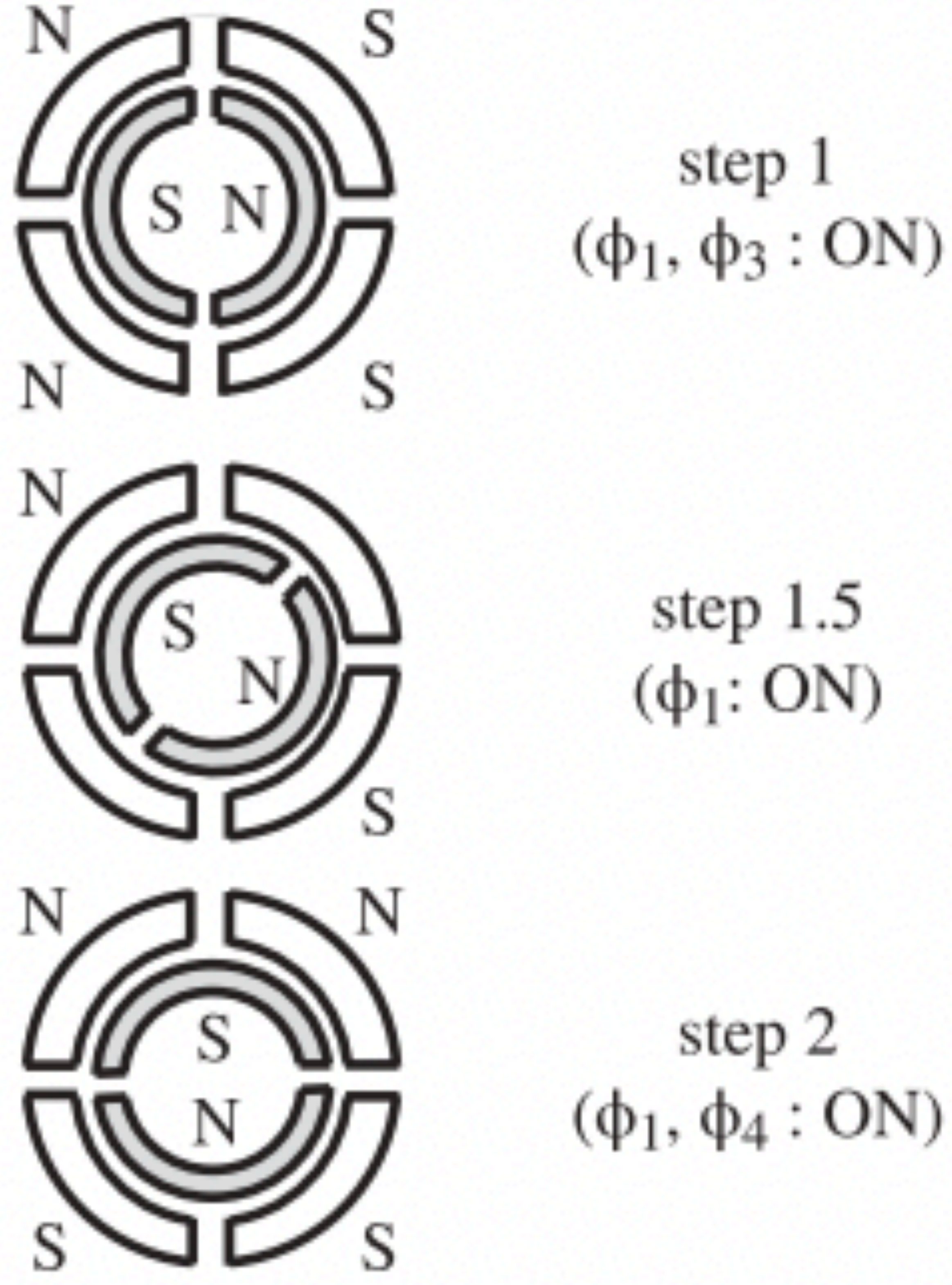
Today:

> Op Amps and Analog Signal Processing

Power Transistors Design and Control
Unipolar (one power supply)







Step	ϕ_1	ϕ_2	ϕ_3	ϕ_4
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF

Power Transistors Design and Control
Bipolar (switchable power supply)

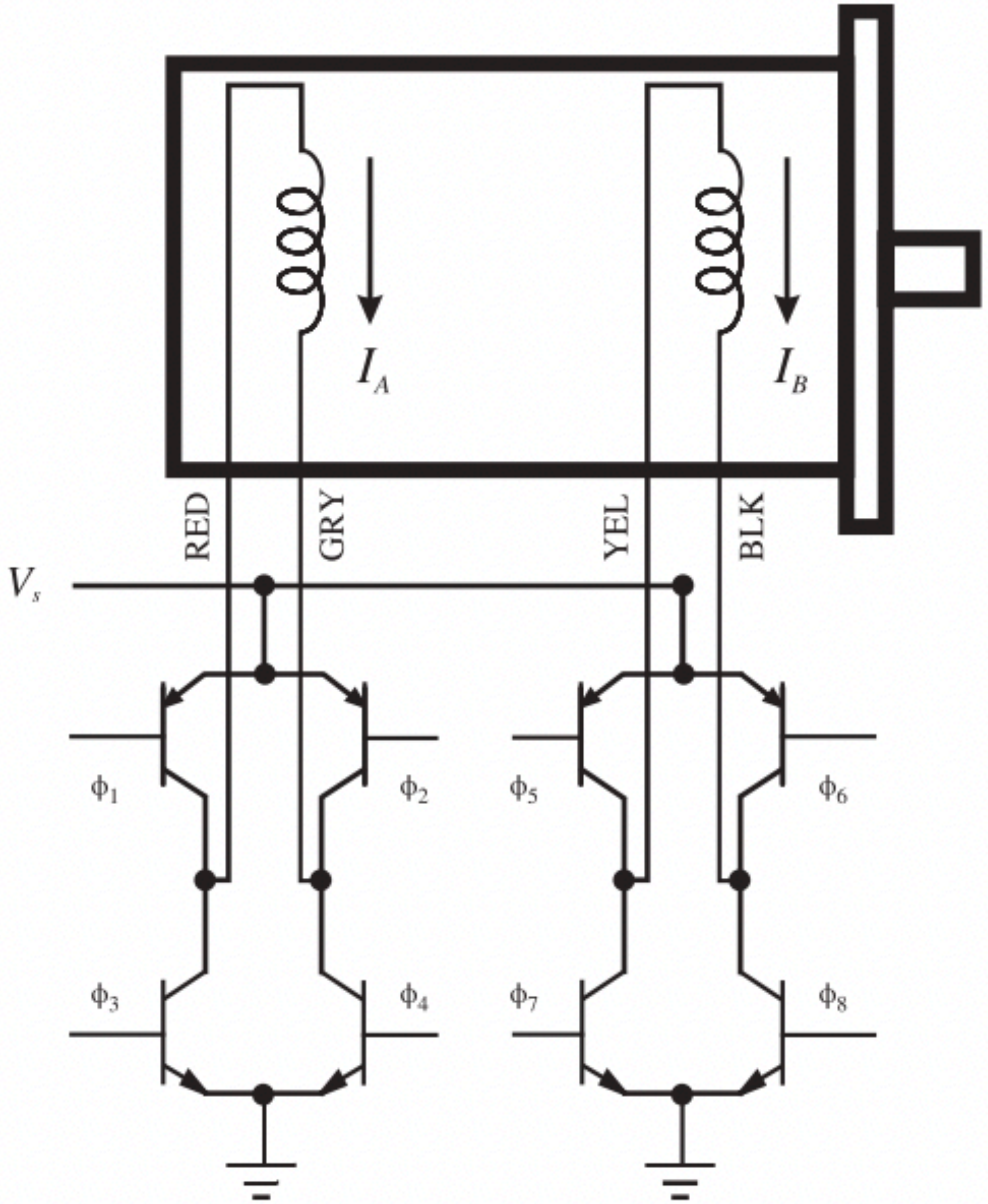
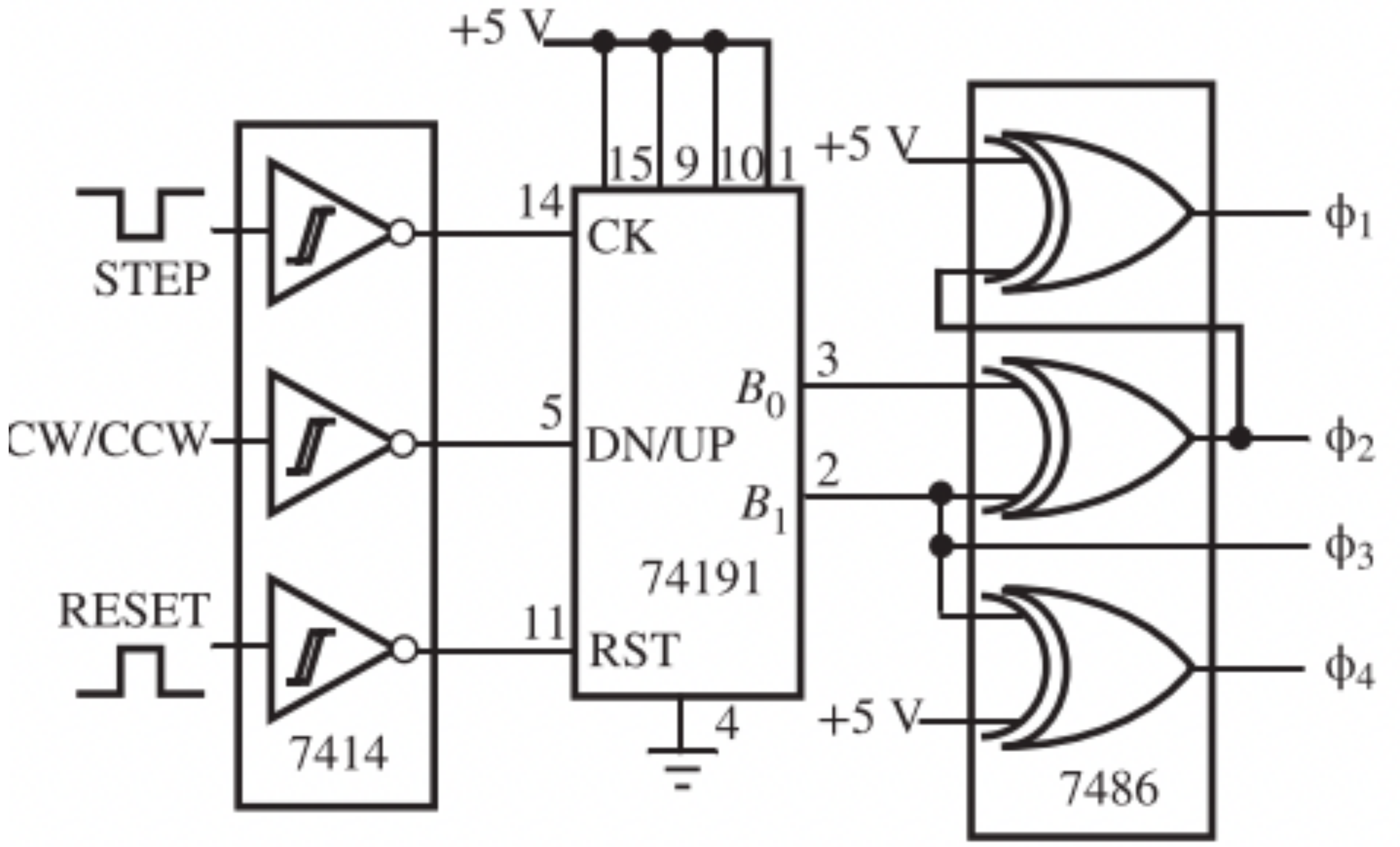


Table 10.3 Bipolar full-step phase sequence

	Step	ϕ_1 and ϕ_4	ϕ_2 and ϕ_3	ϕ_5 and ϕ_8	ϕ_6 and ϕ_7
CW	1	ON	OFF	ON	OFF
↓	2	ON	OFF	OFF	ON
CCW	3	OFF	ON	OFF	ON
↑	4	OFF	ON	ON	OFF

For both bipolar and unipolar, there are drive circuits to take care of phasing



7414 Schmitt trigger buffers, a 74191 up-down counter, and 7486 Exclusive OR gates

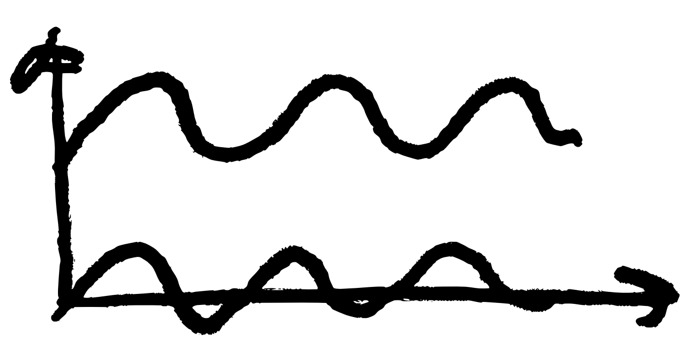
Analog Signal Processing Overview

Problem: often sensor outputs & actuator inputs are analog signals that need some form of conditioning (modification).

→ signal processing.

Conditioning?

- too small
- noisy
- DC offset

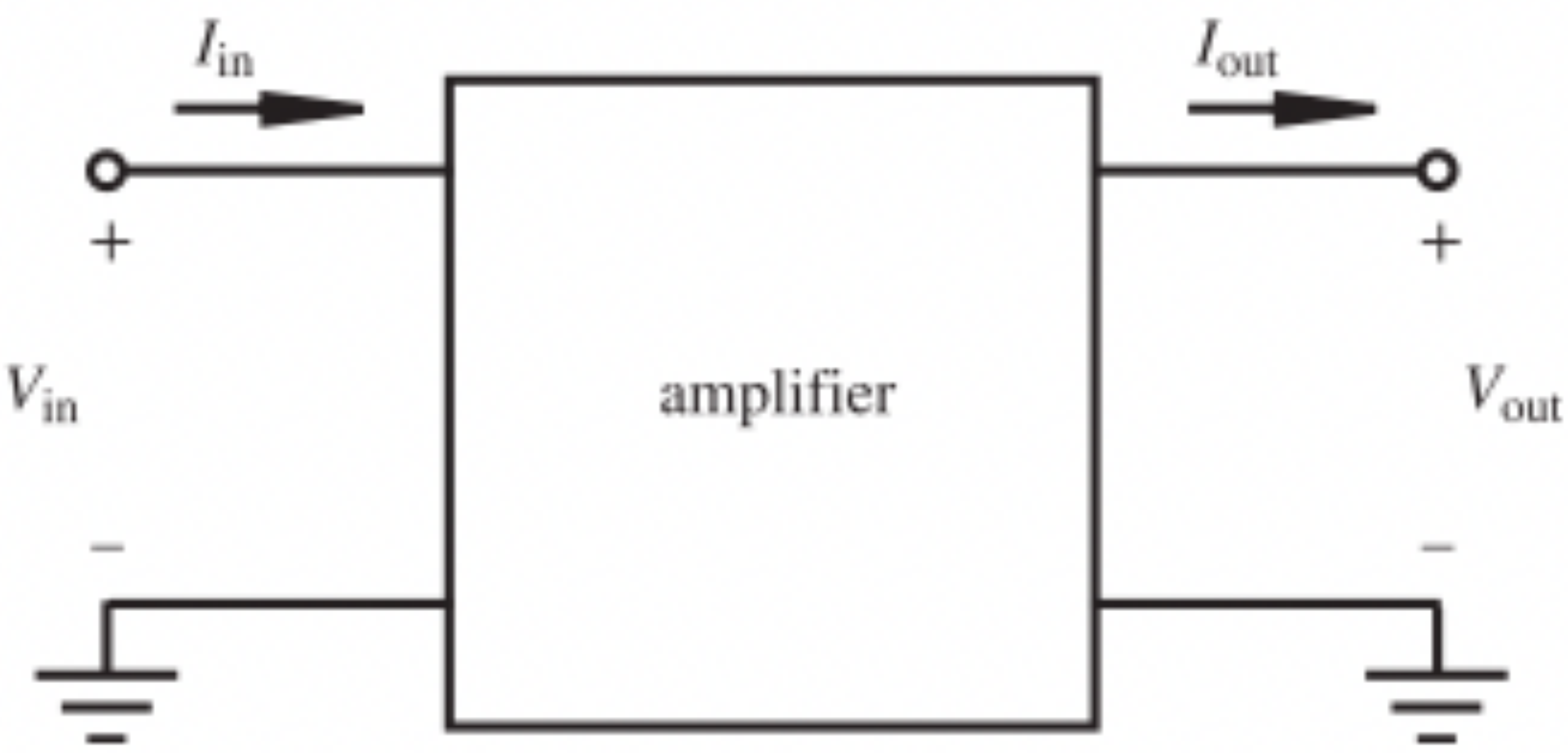


Forms of signal processing

- amplification
- filter (lowpass noisy)
- differentiation
- intergration
- addition
- substraction

(differentiation, intergration: analog computer)

Amplifier Model



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

Ideal amplifier

- linearity
- large bandwidth
- input/output impedance characteristic are important!

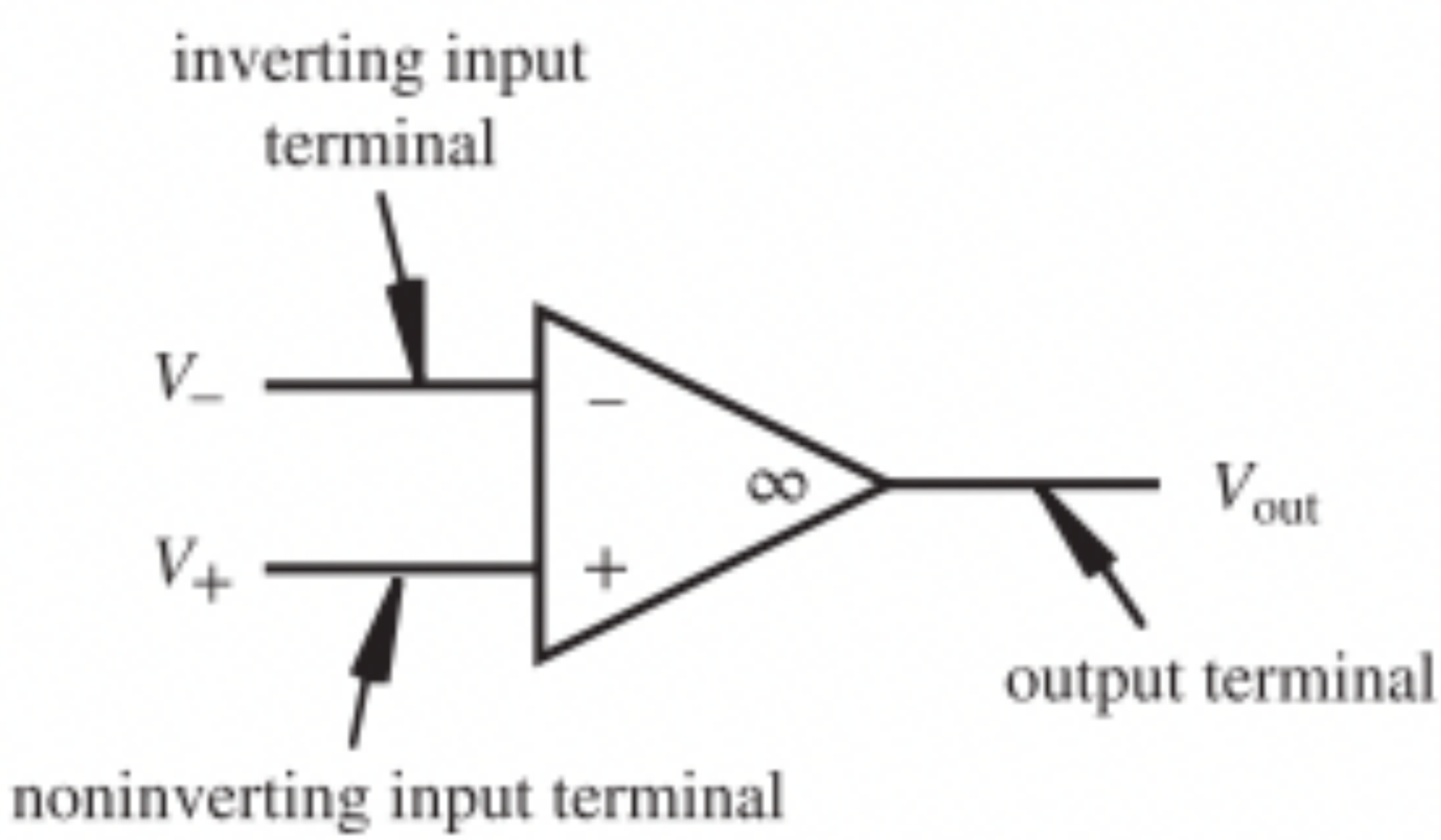
Z → generalization of Ohms Law. $V = IR \rightarrow R = \frac{V}{I}$

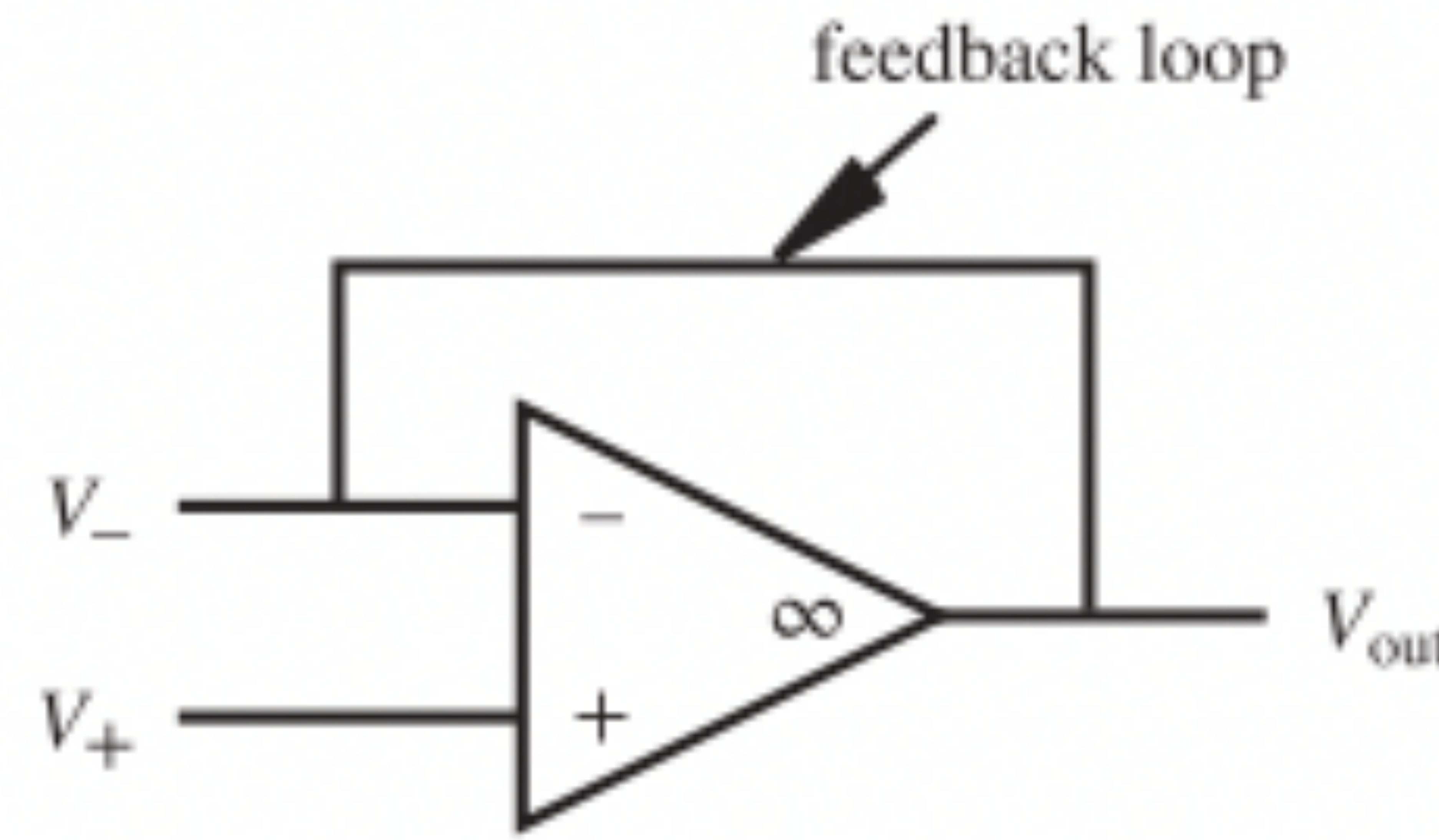
$$Z_{in} = \frac{V_{in}}{I_{in}} :$$

$$Z_{out} = \frac{V_{out}}{I_{out}}$$

Operational Amplifier

: most important hardware component for analog signal processing





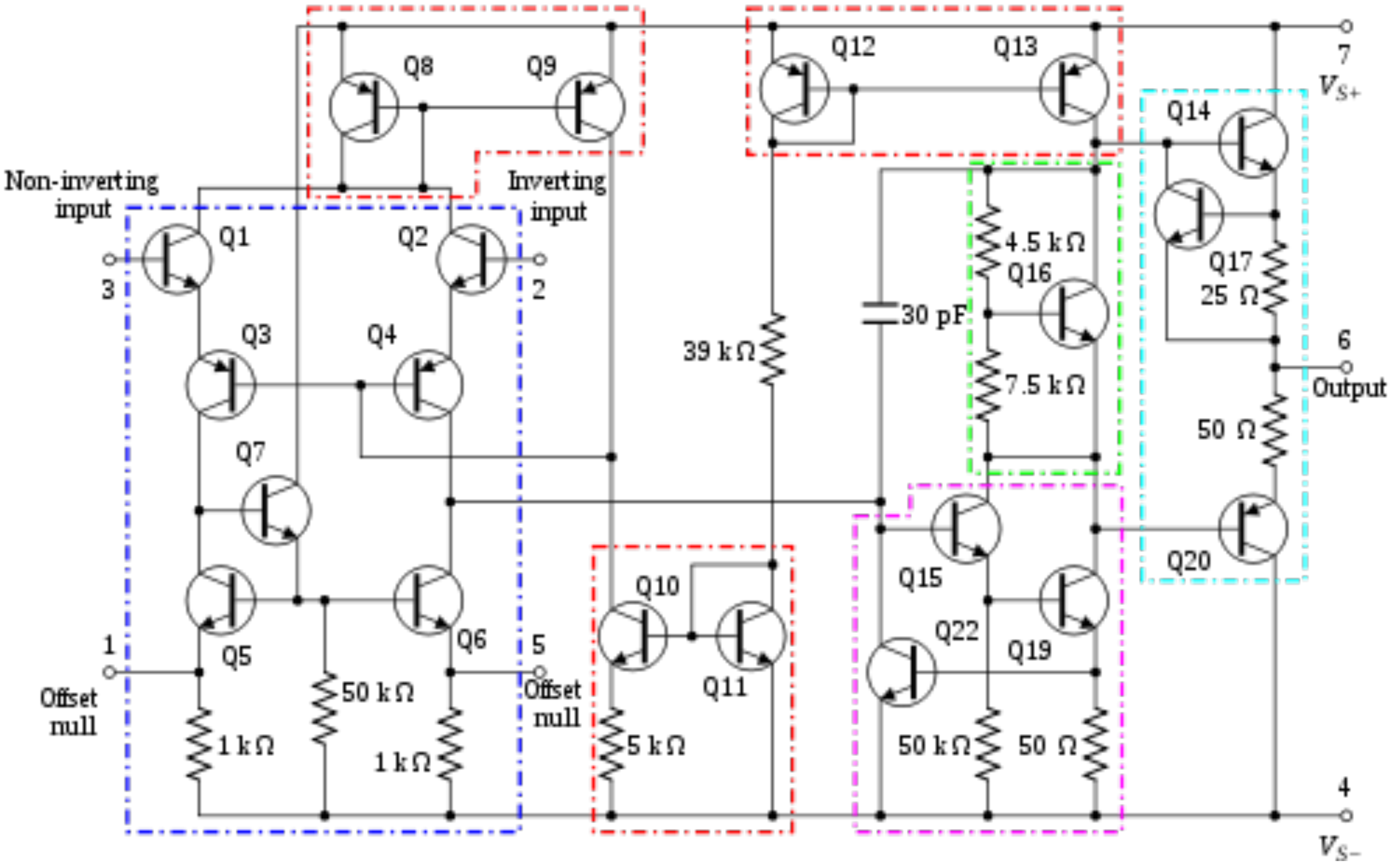
Open-loop configuration

Closed form almost always

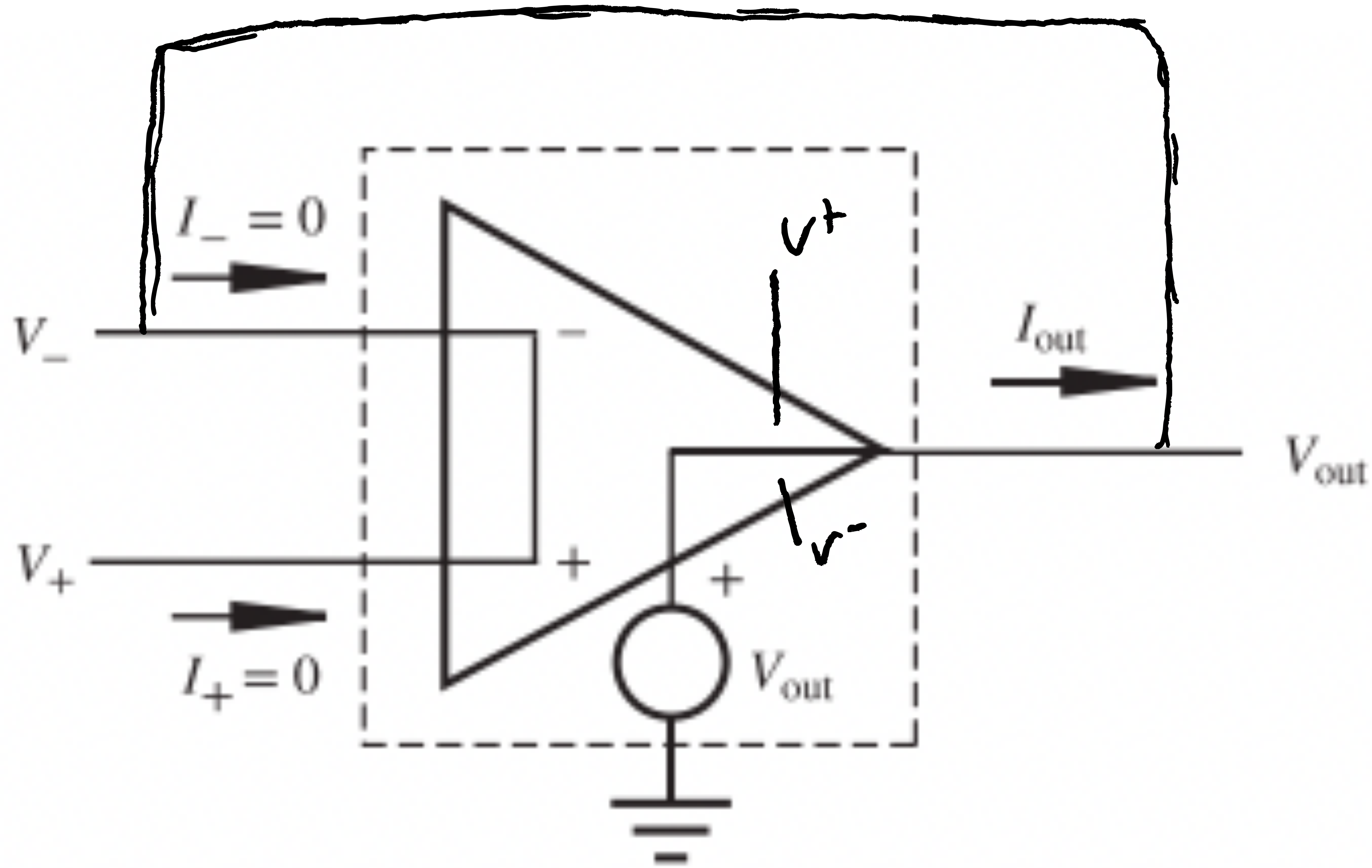
How are they made? ⟶

OpAmps made with transistors!

741 op amp



Ideal OpAmp Assumptions



$$V_{out} = A_{OL}(V_+ - V_-)$$

A_{OL} → ∞: open loop gain

1. Infinite impedance @ both inputs

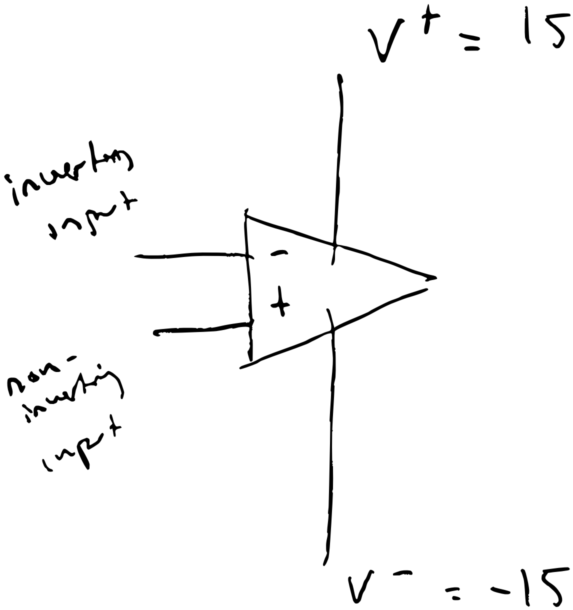
$$I_- = I_+ = 0$$

2. Infinite gain

$$V_+ = V_-$$

3. output impedance is zero:

Vout doesn't depend on Iout



V+ = 15
inverting input
-
+
non-inverting input
V- = -15

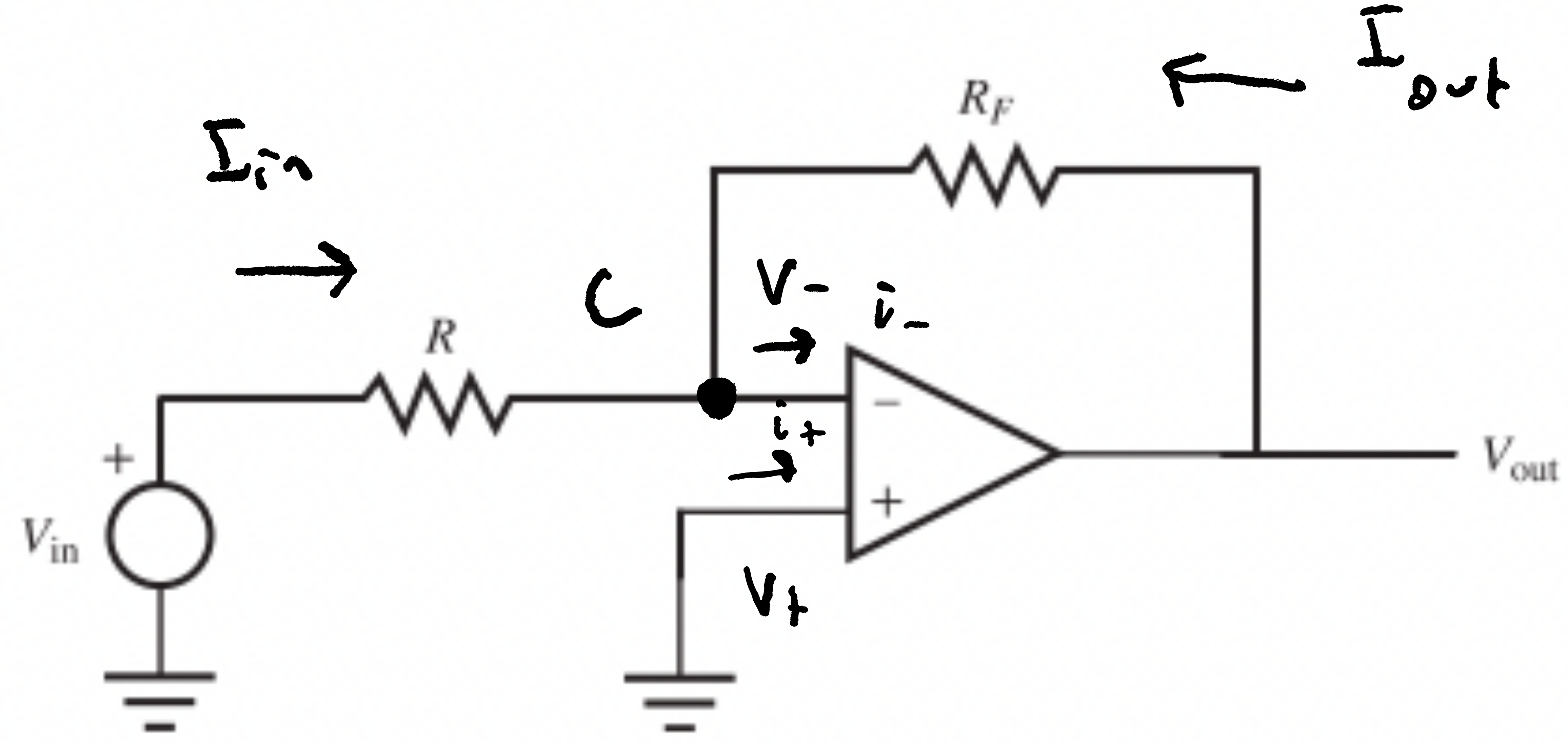
Example: Inverting Amplifier

$V_- = V_+ = 0$

$i_- = i_+ = 0$

$V = IR$

$I = \frac{V}{R}$



KCL @ Node C

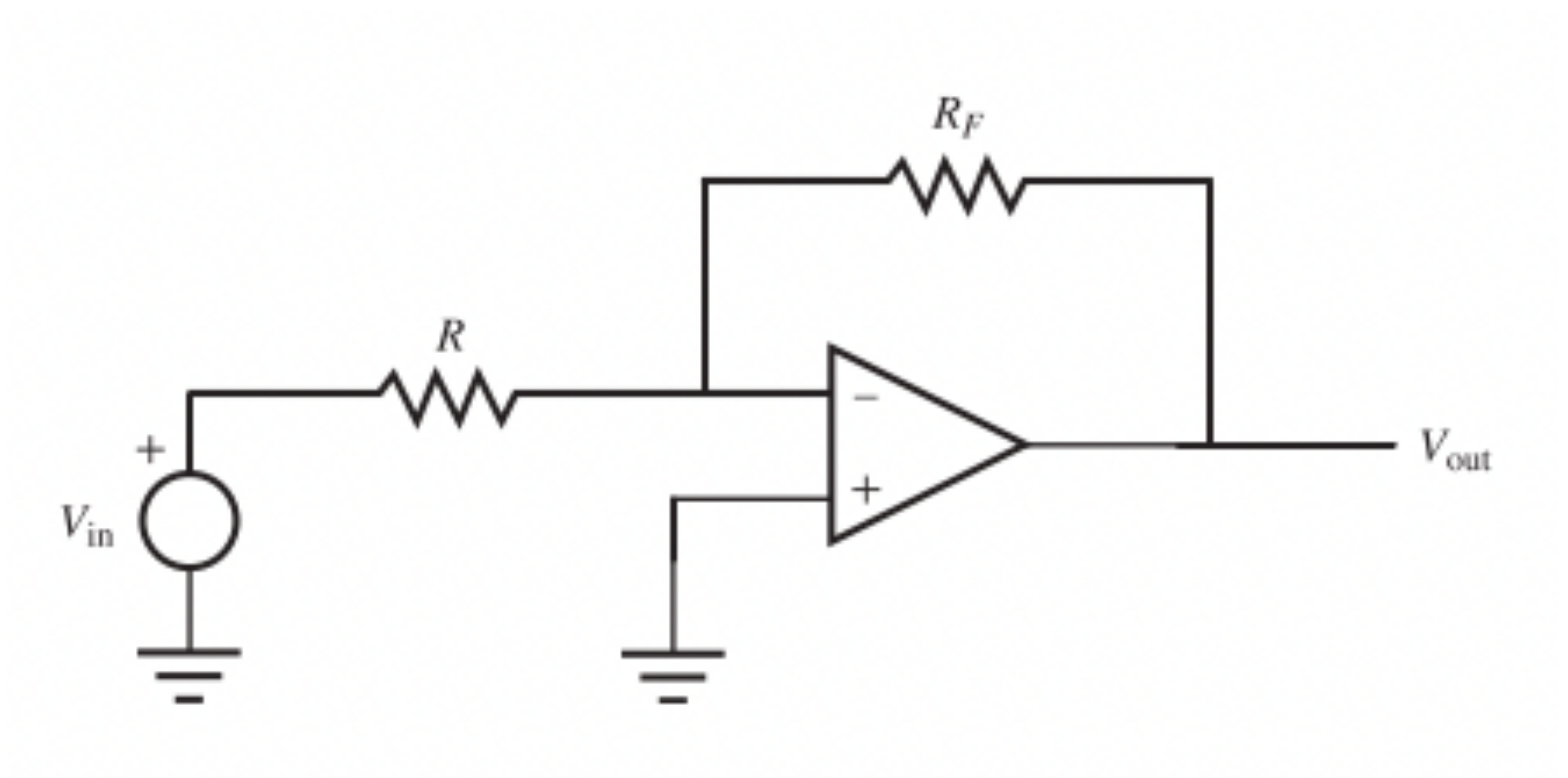
$I_{in} = -I_{out}$

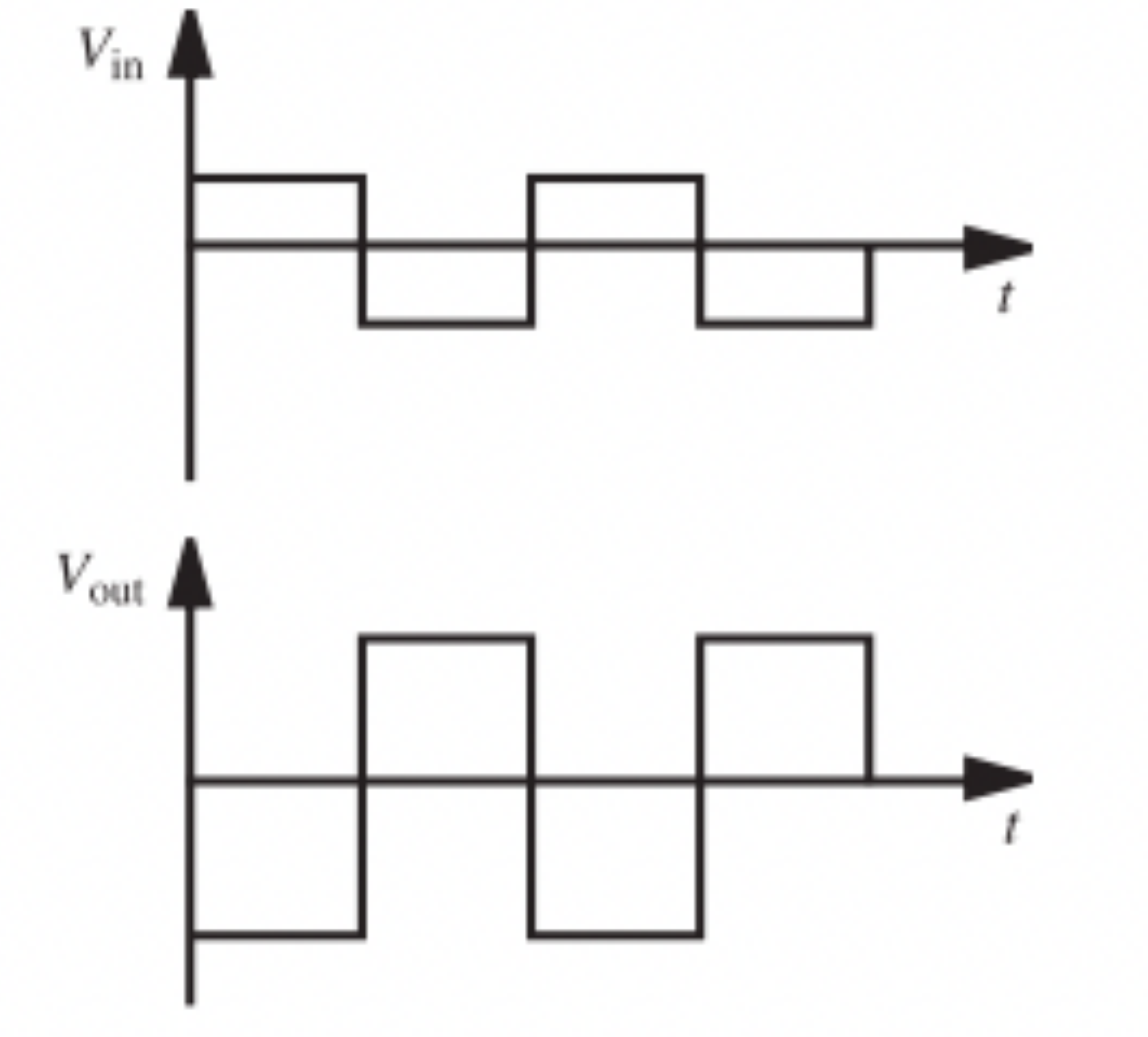
$V_C = V_- = 0$

$$\frac{V_{in}}{R} = -\frac{V_{out}}{R_f}$$

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R}$$

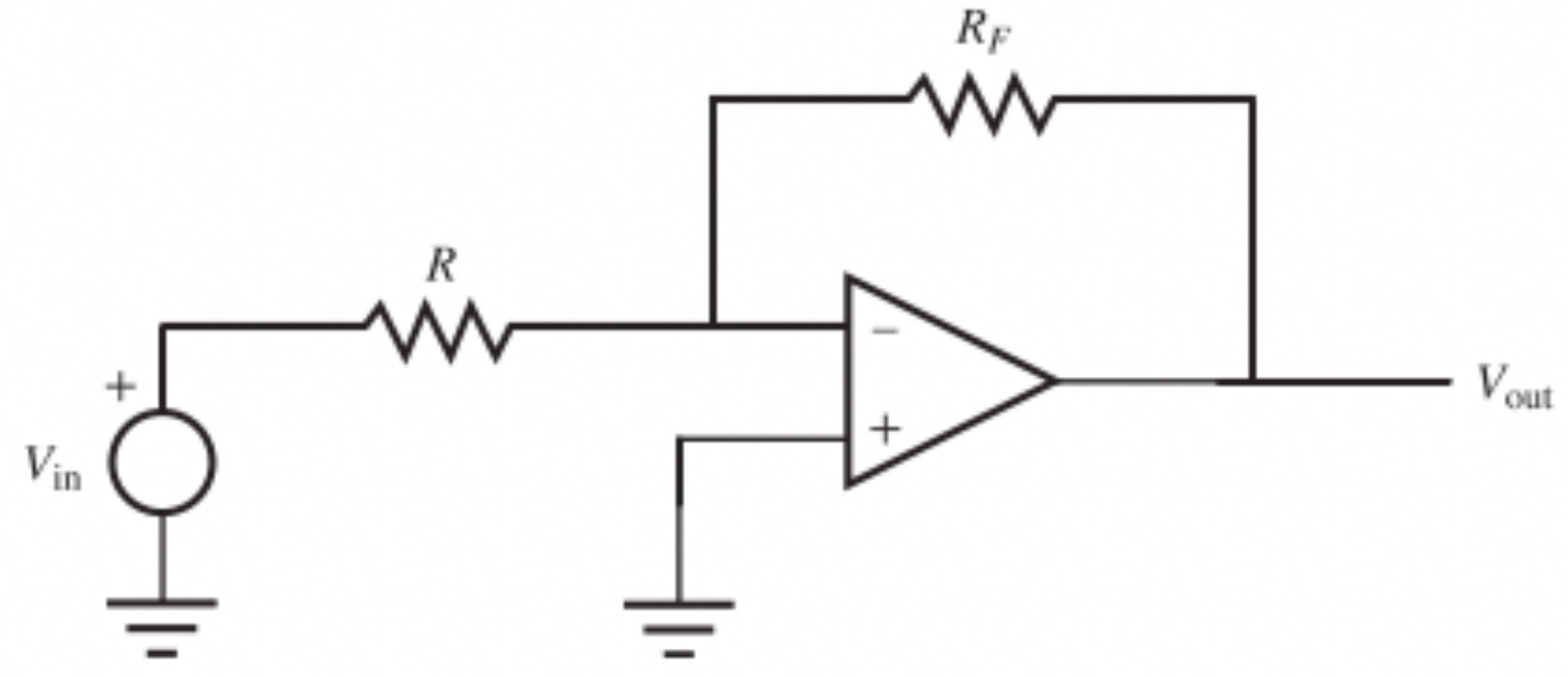
Example: Inverting Amplifier





Inverts and scales

Example: Inverting Amplifier



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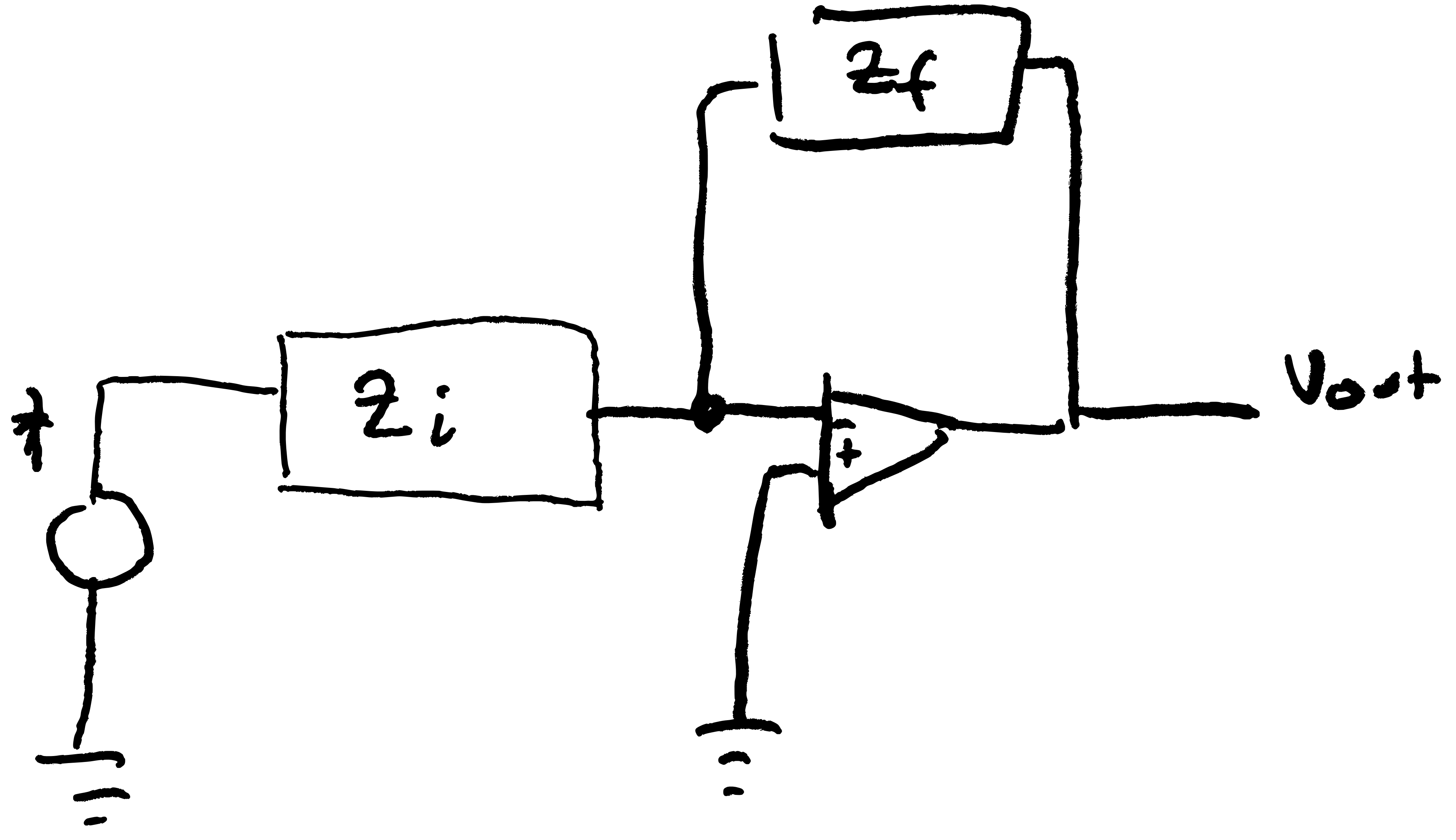
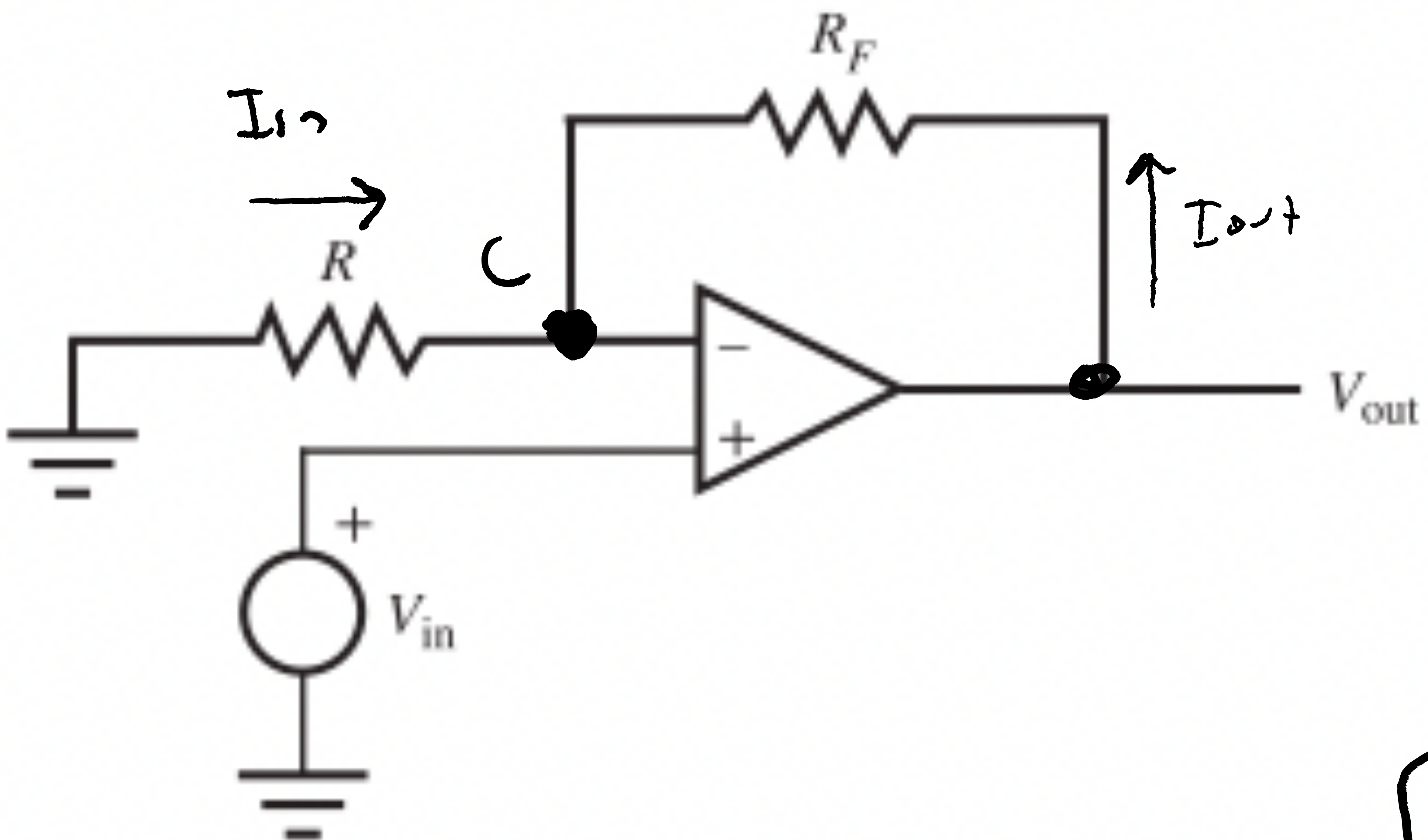


$$\frac{V_{out}}{V_{in}} = -\frac{Z_f}{Z_i}$$

Example: Non Inverting Amplifier



$$\begin{cases} I_- = I_+ = 0 \\ V_- = V_+ = V_{in} \end{cases}$$

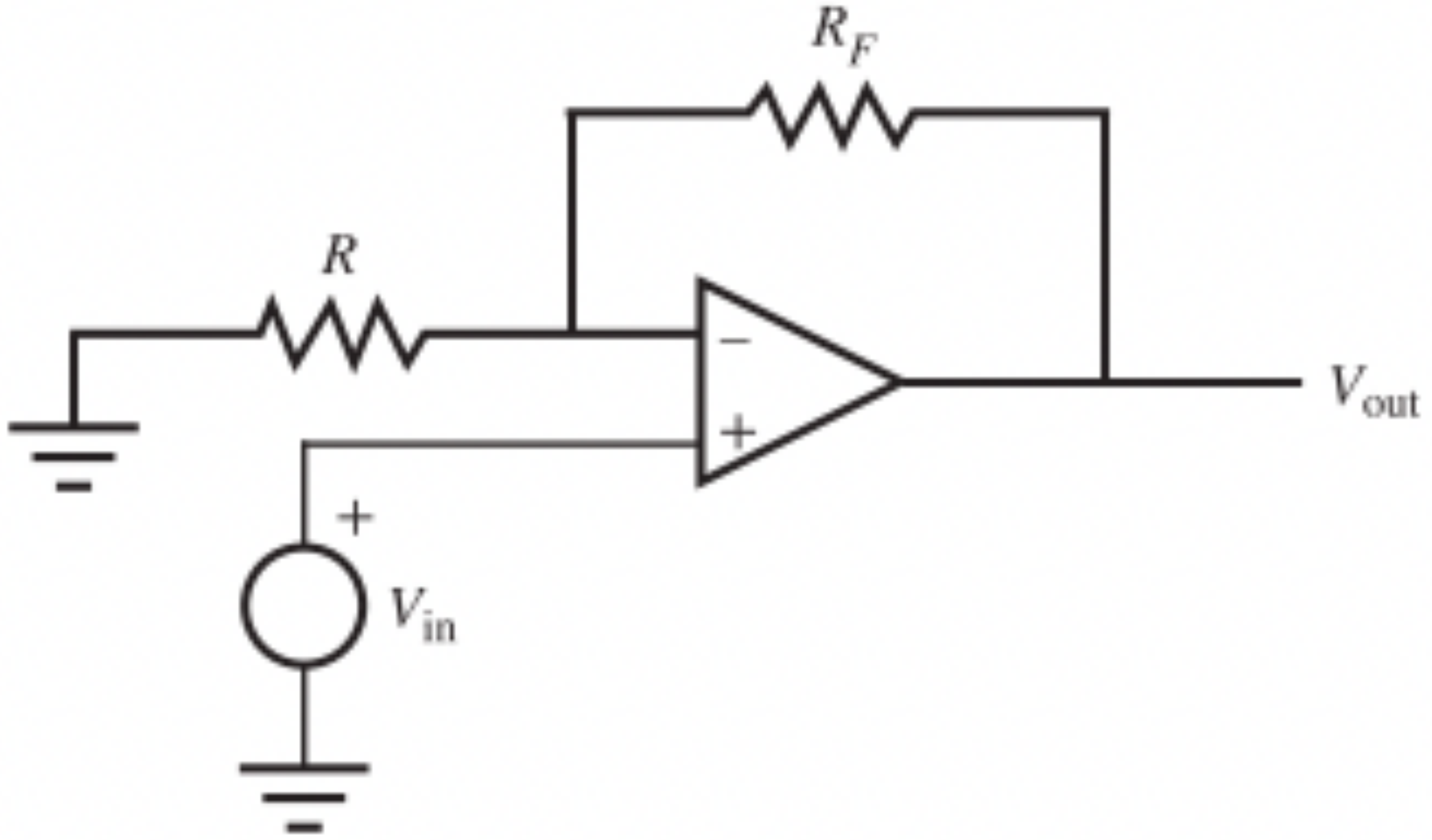
KCL @ Node C:

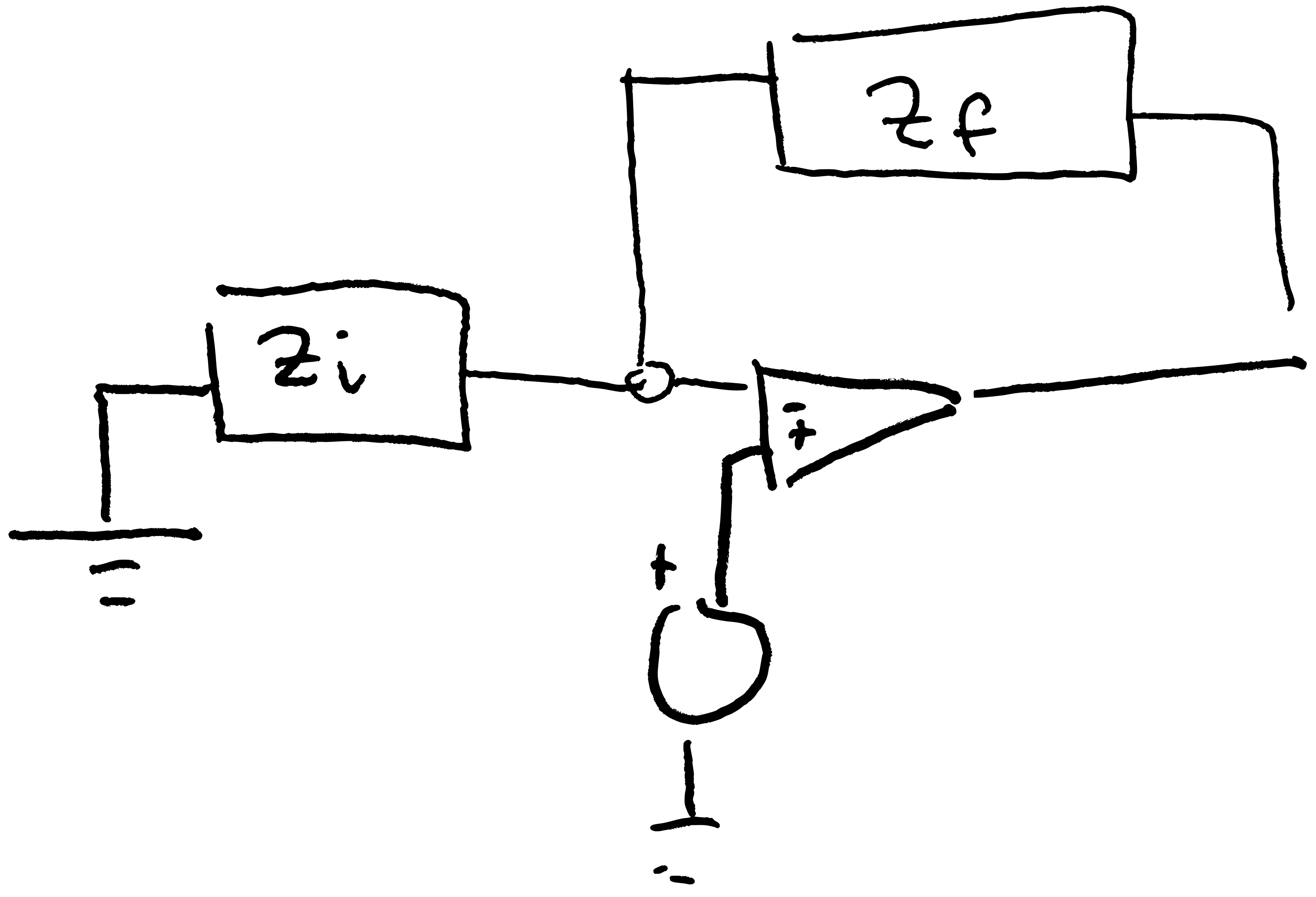
$$\rightarrow I_{in} = -I_{out}$$

$$\begin{cases} I_{in} = \dfrac{-V_{in}}{R} \\ I_{out} = \dfrac{V_{out} - V_{in}}{R_f} \end{cases}$$

$$\frac{-V_{in}}{R} = \frac{-(V_{out} - V_{in})}{R_f} \Longrightarrow \boxed{\frac{V_{out}}{V_{in}} = \left(1 + \frac{R_f}{R}\right)}$$

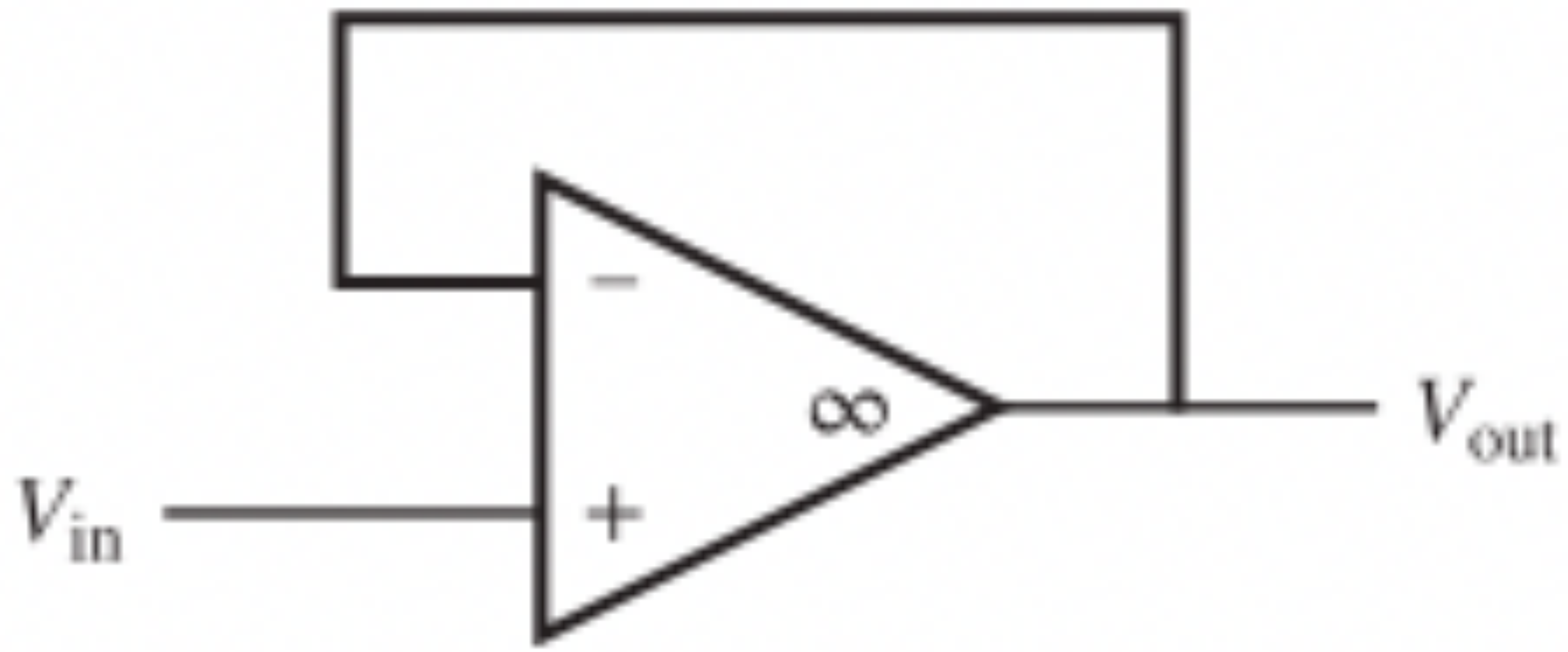
Example: Non Inverting Amplifier





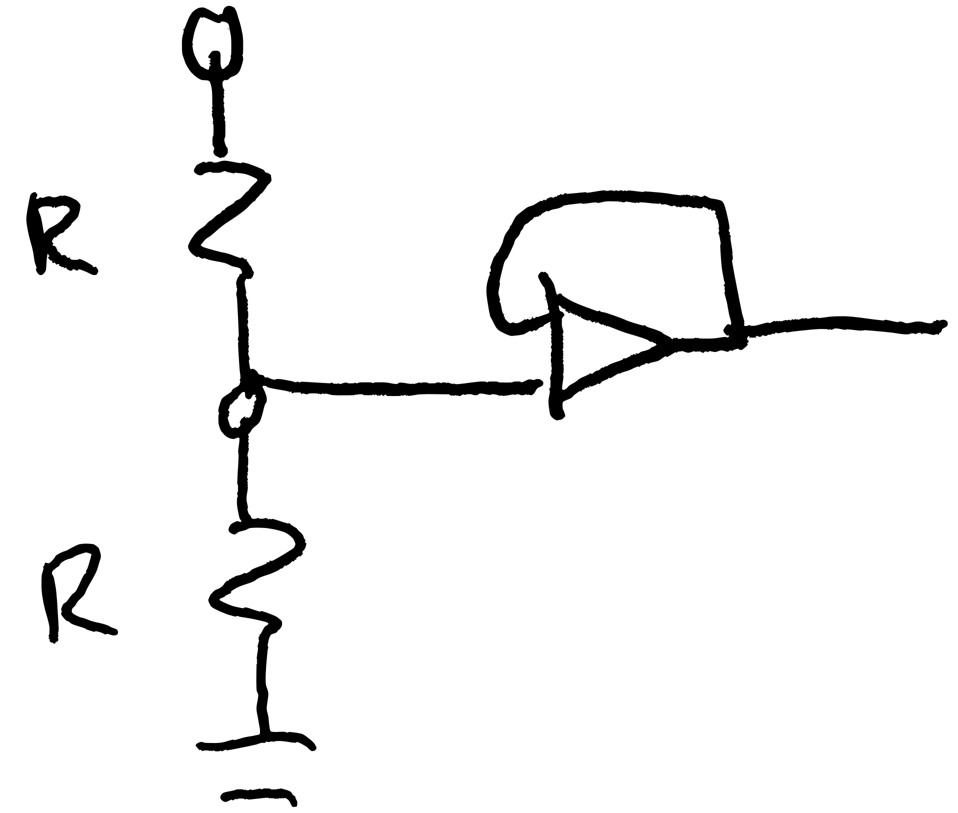
$$\frac{V_{out}}{V_{in}} = \left(1 + \frac{Z_f}{Z_i}\right)$$

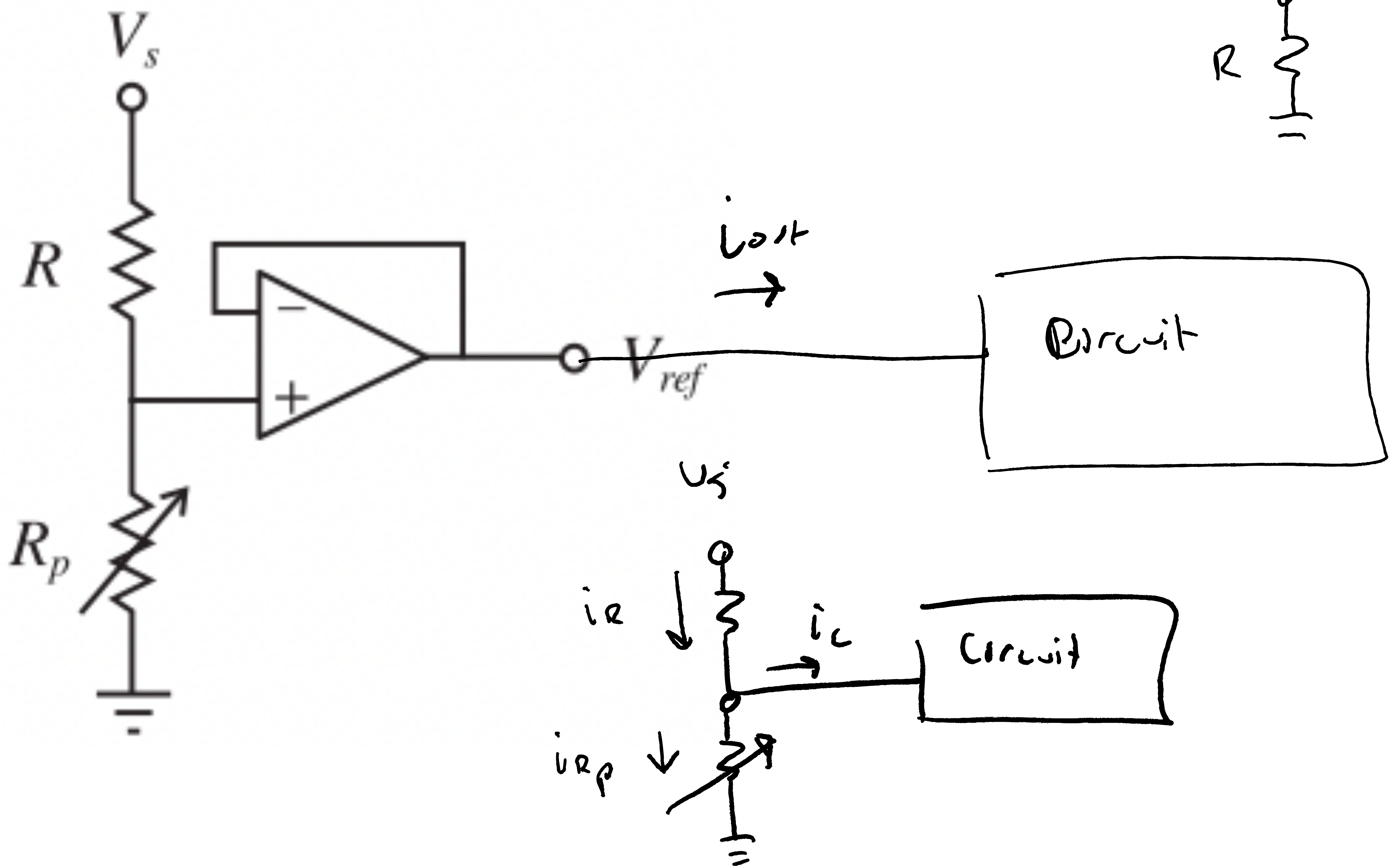
Example: Buffer or Voltage Follower



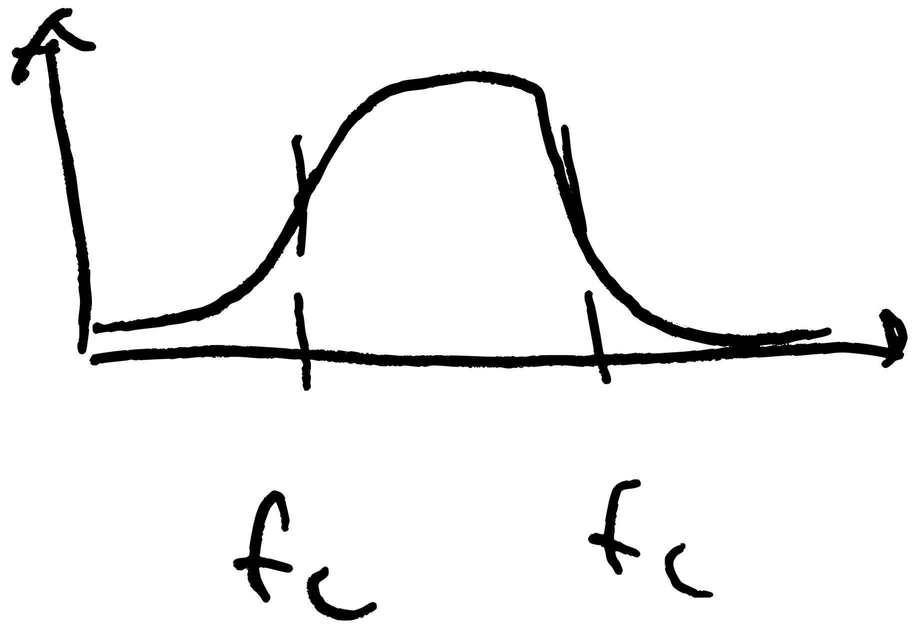
$$\frac{V_{out}}{V_{in}} = \left(1 + \frac{R_f}{R}\right) = 1$$

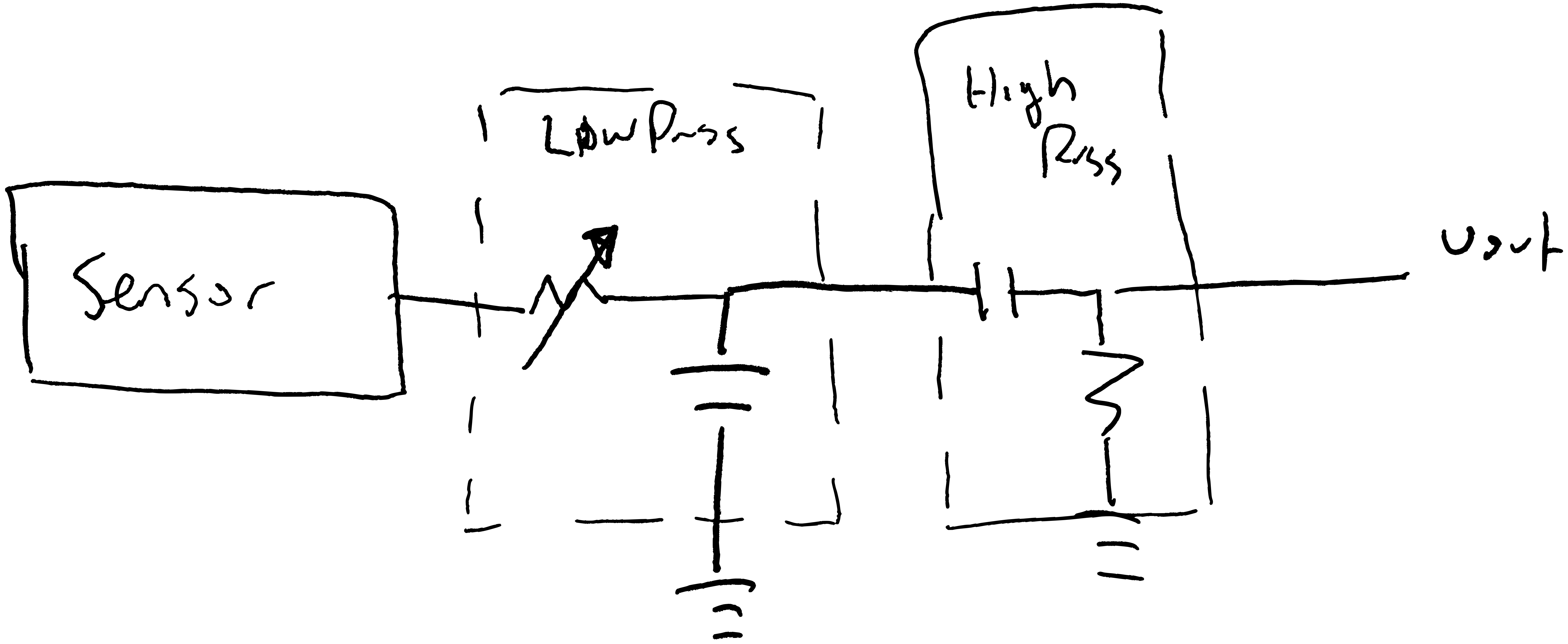
Example: Buffer or Voltage Follower

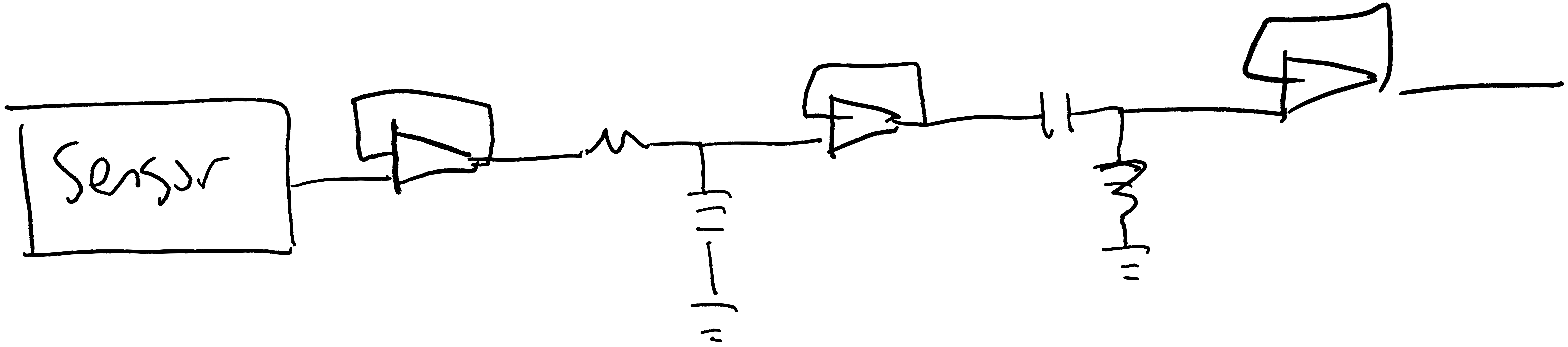




Example: Buffer or Voltage Follower







■ CLASS DISCUSSION ITEM 5.3

Example of Positive Feedback

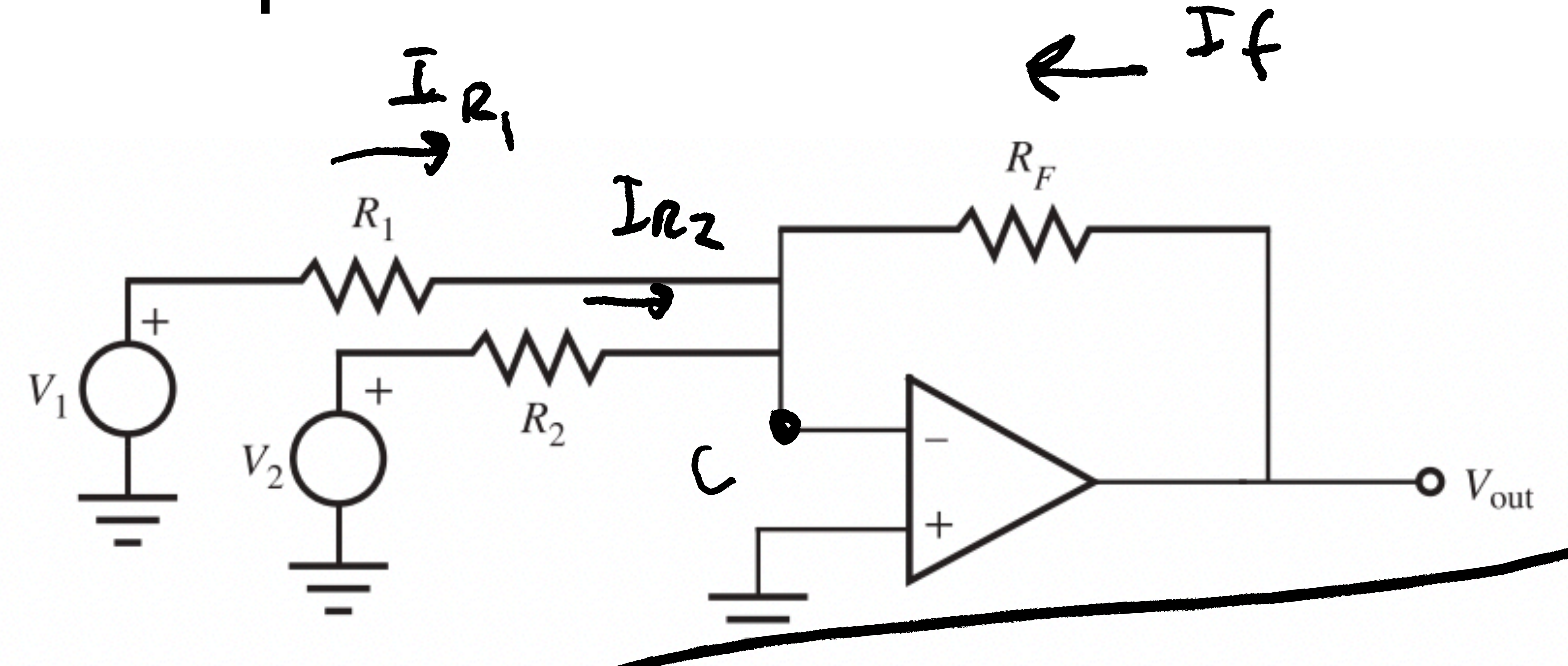
A good example of positive feedback is the effect Jimi Hendrix used to achieve when he would move his guitar close to the front of his amplifier speaker. Describe the effect of this technique and describe what is going on physically. Video Demo 5.5 demonstrates how positive feedback can be used to accentuate string harmonics (modes of vibration), and Video Demo 5.6 shows an example of Jimi's performance style, which was quite unique and impressive.

■ CLASS DISCUSSION ITEM 5.4

Voltage Divider with No Follower

With the voltage-divider follower circuit in Figure 5.13, what effect does the choice of resistance values have? Also, explain in detail what would happen if the follower circuit were not included and the reference voltage were used to source current to another circuit or device.

Example: Summer



KCL @ Node C:

$$I_{R_1} + I_{R_2} = -I_f$$

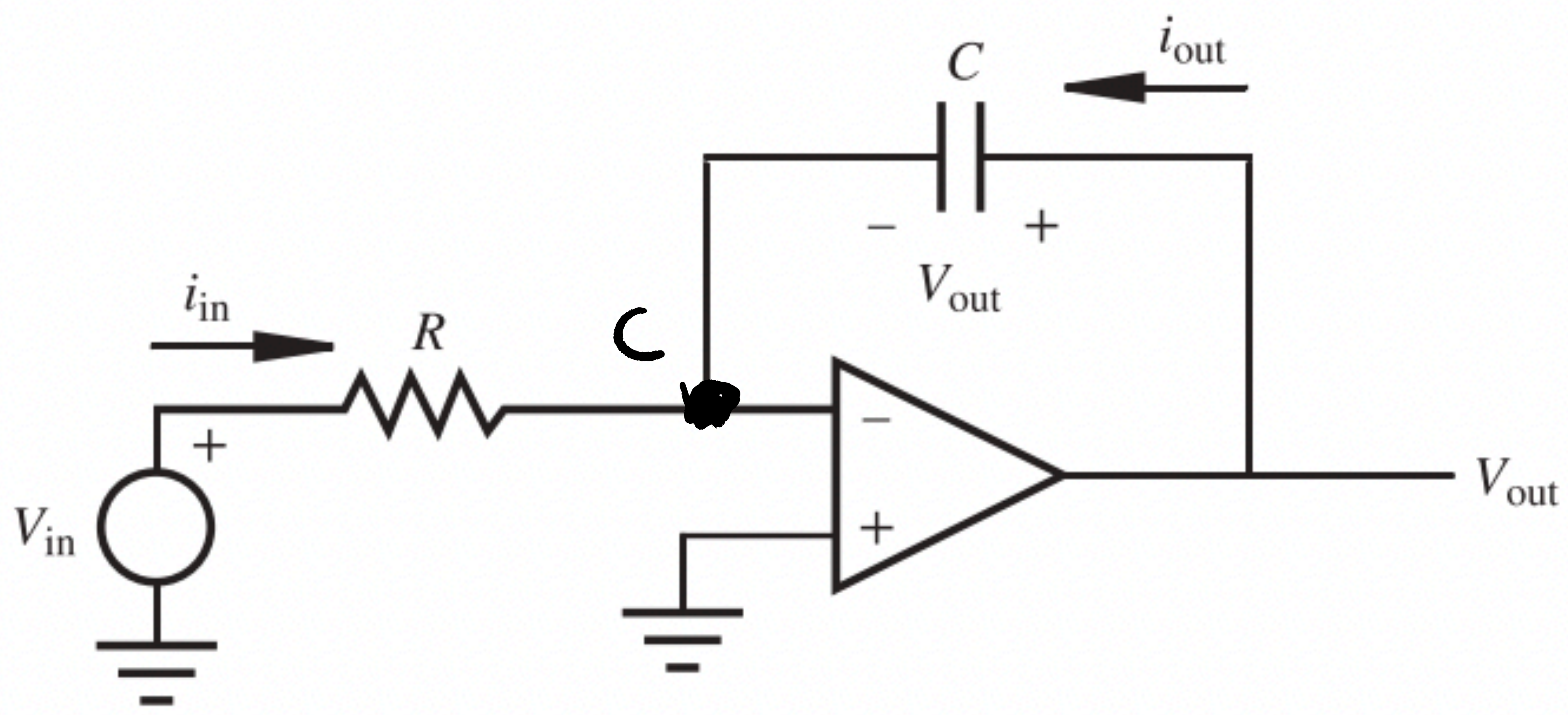
$$V_- = V_+ = 0$$

$$I_- = I_+ = 0$$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = -\frac{V_{out}}{R_f}$$

$$V_{out} = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2\right)$$

Example: Integrator



C_s V_{out}

KCL:

$$I_R = -I_{out}$$

$$\frac{V_{in}}{R} = -C\frac{dV_{out}}{dt}$$

$$\dot{V}_{out} = -\frac{1}{RC}\cdot V_{in}$$

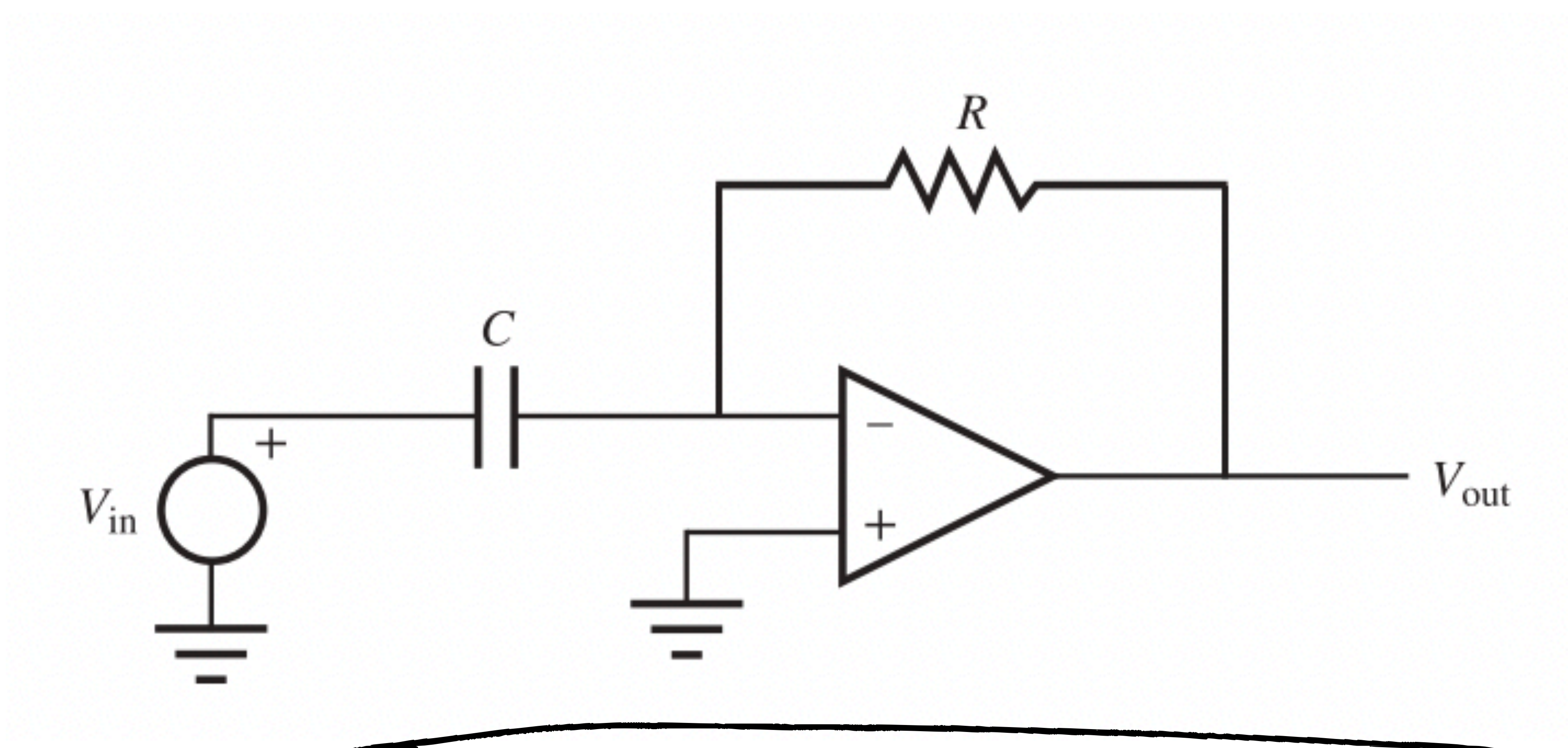
$$V_{out} = \frac{-1}{RC}\int_0^t V_{in}(t)\,dt$$

→ retrieve input from serial monitor.

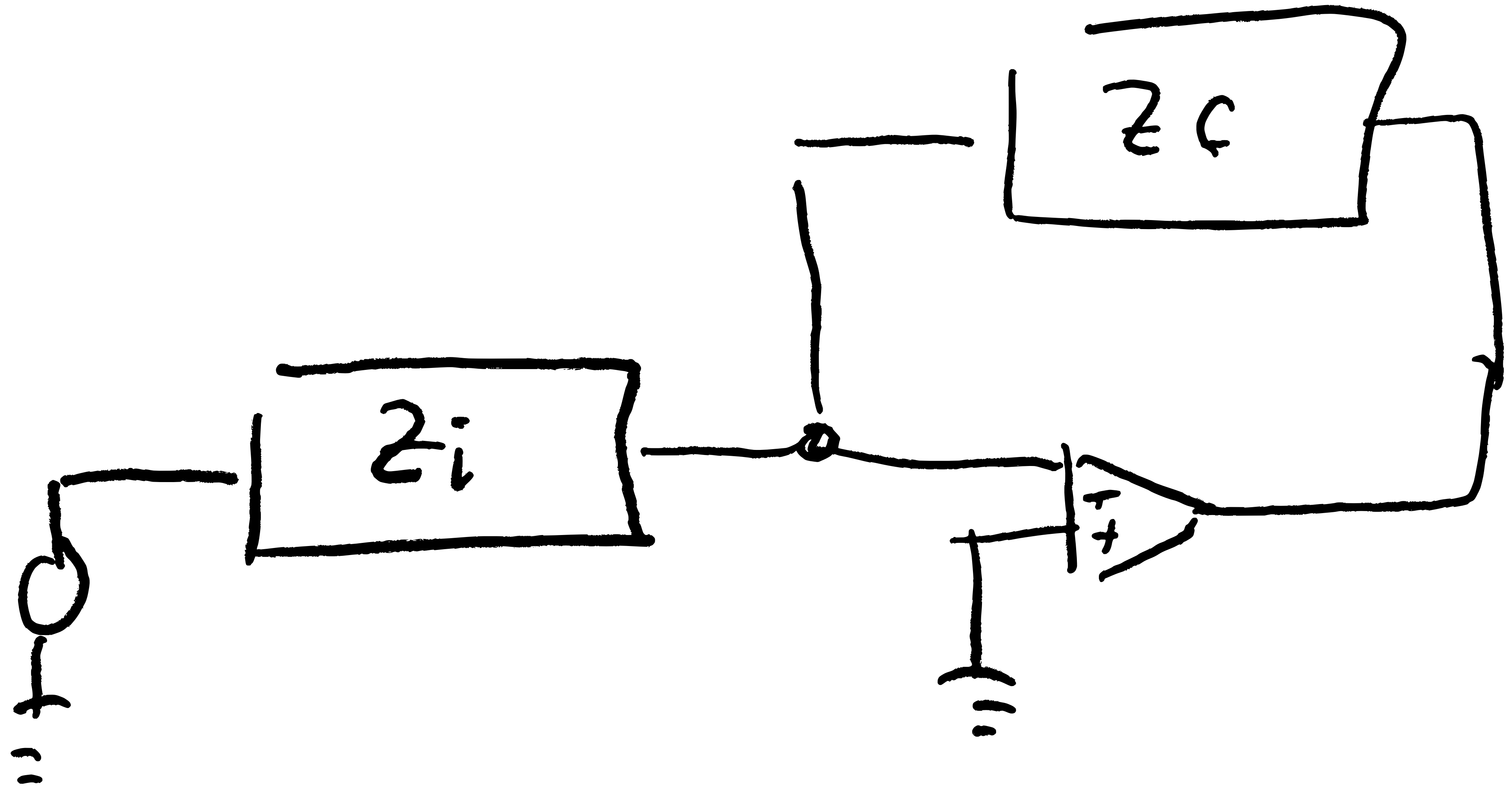
What key do wanna play?

0, -1

Example: Differentiator

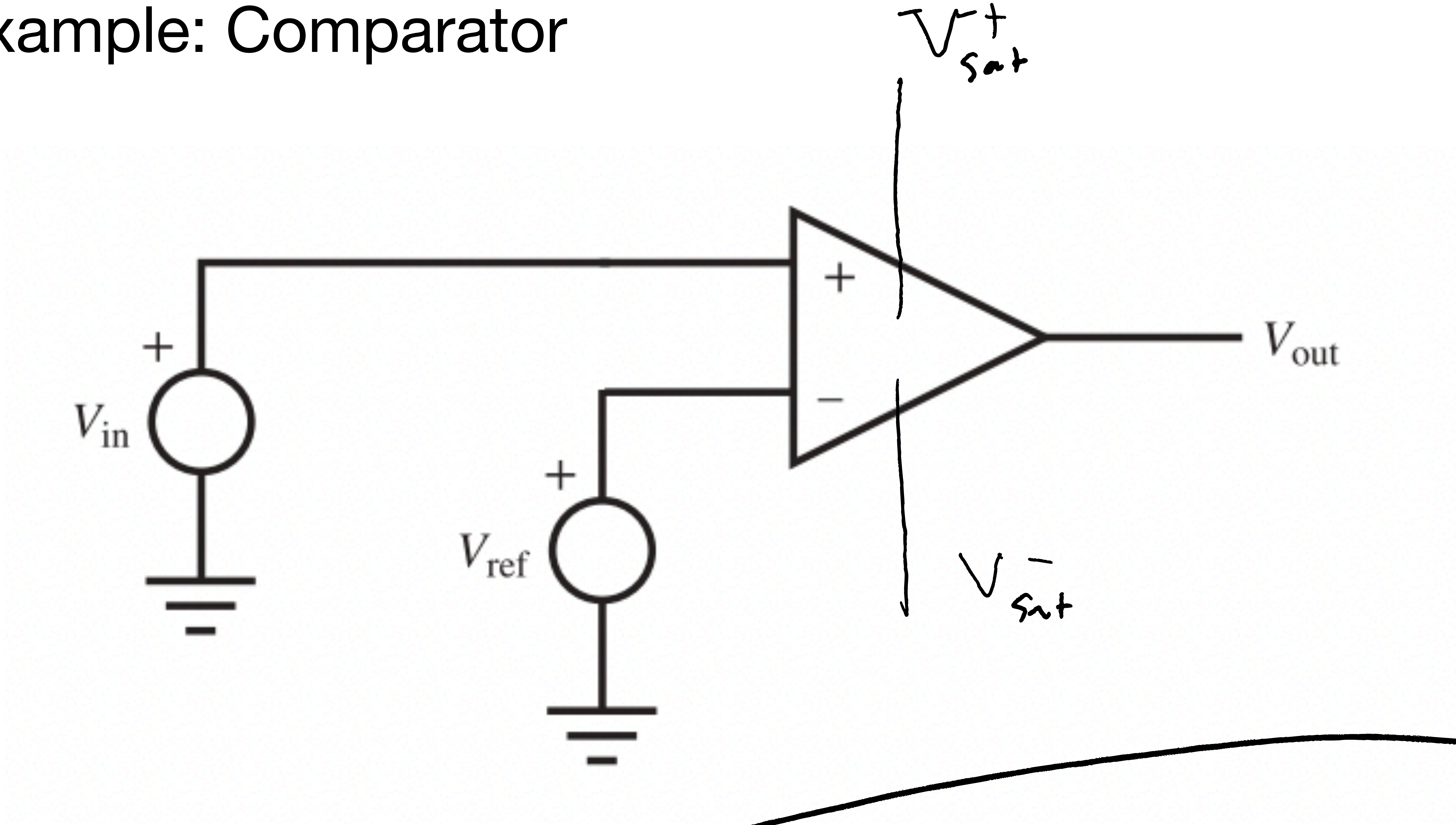


$$V_{out} = -RC\,\dot{V}_{in}$$



$$\frac{V_{out}}{V_{in}} = -\frac{Z_f}{Z_i}$$

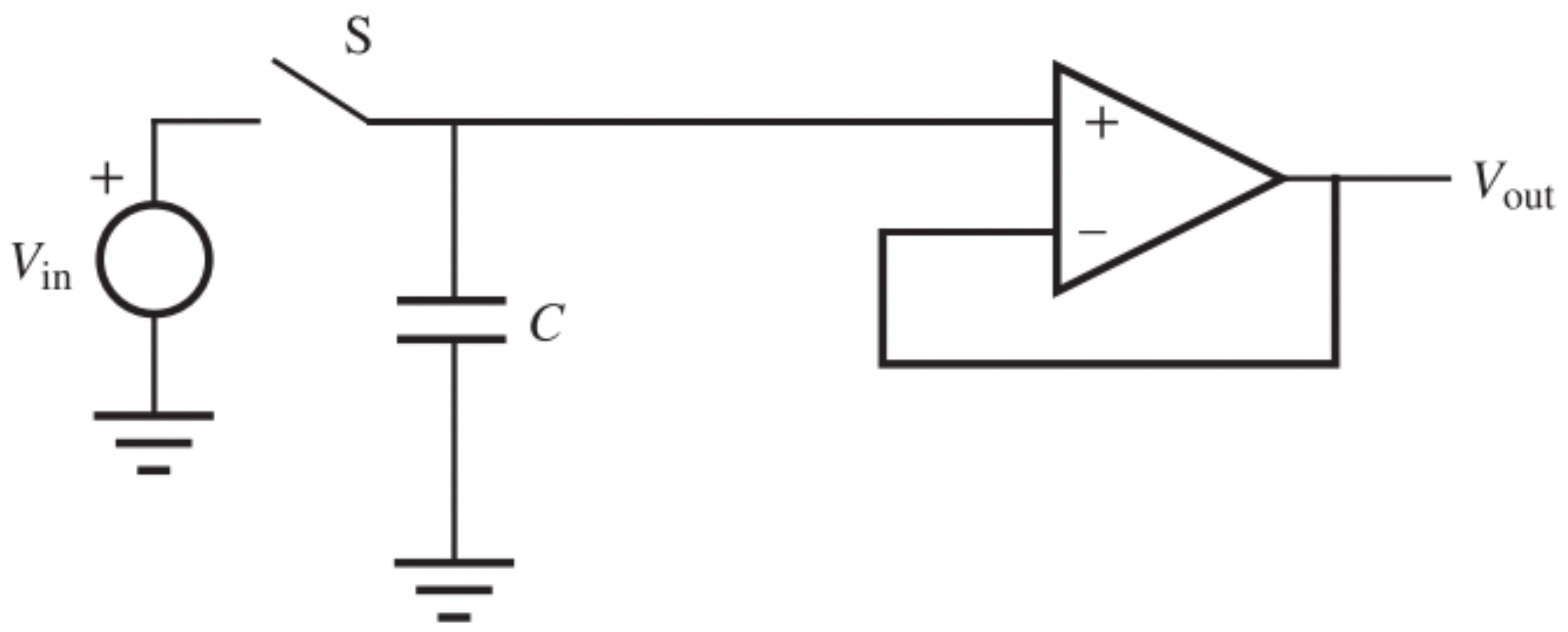
Example: Comparator



$$V_{out} = \begin{cases} +V_{sat} & V_{in} > V_{ref} \\ -V_{sat} & V_{in} < V_{ref} \end{cases}$$

Example: Active Filters

Example: Sample and Hold



$$V_{out}(t - t_{sampled}) = V_{in}(t_{sampled})$$

where tsampled is the time when the switch was last opened.

Example: Instrumentation Amplifier