Operational Amplifiers - Part 2

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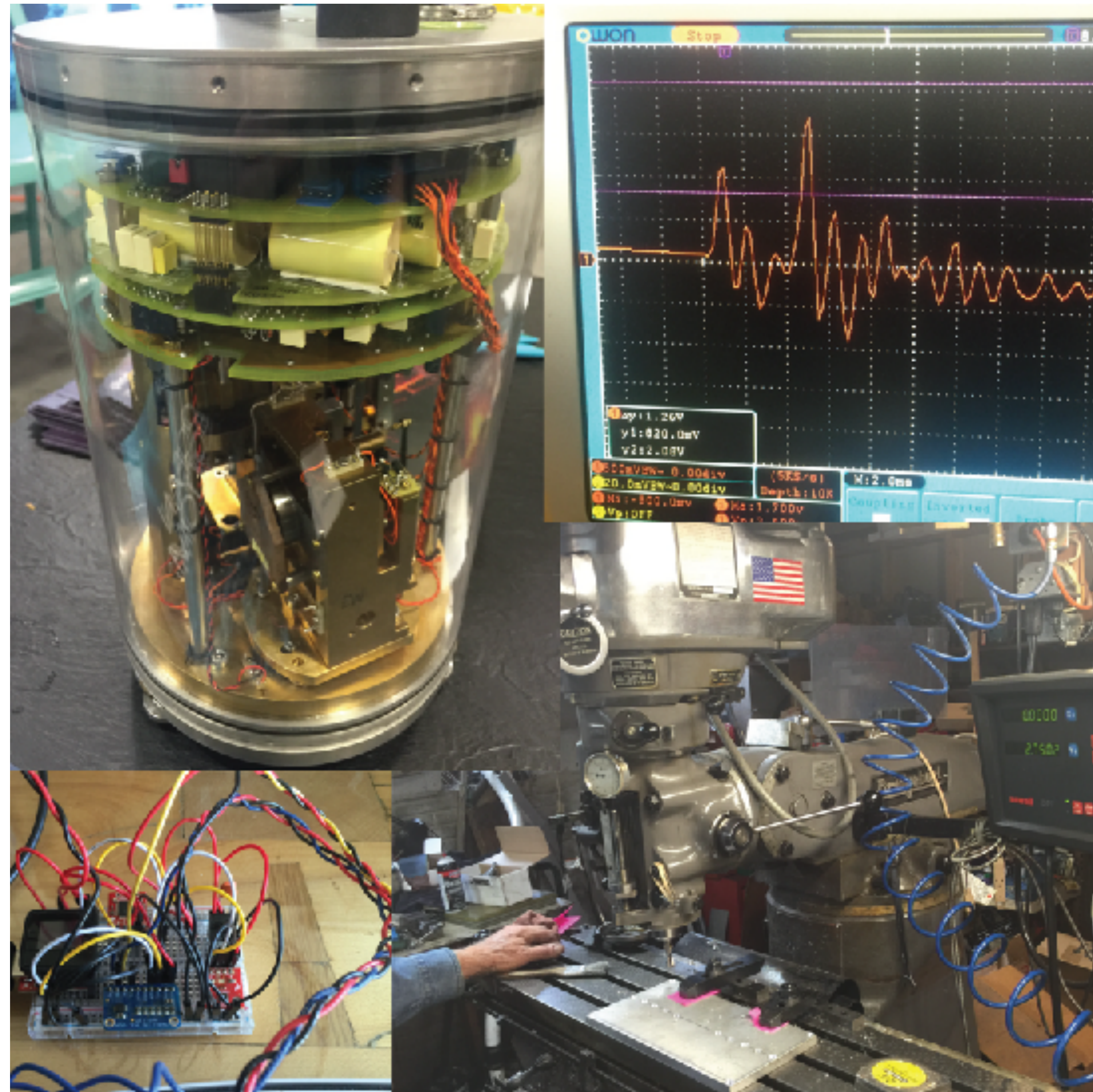
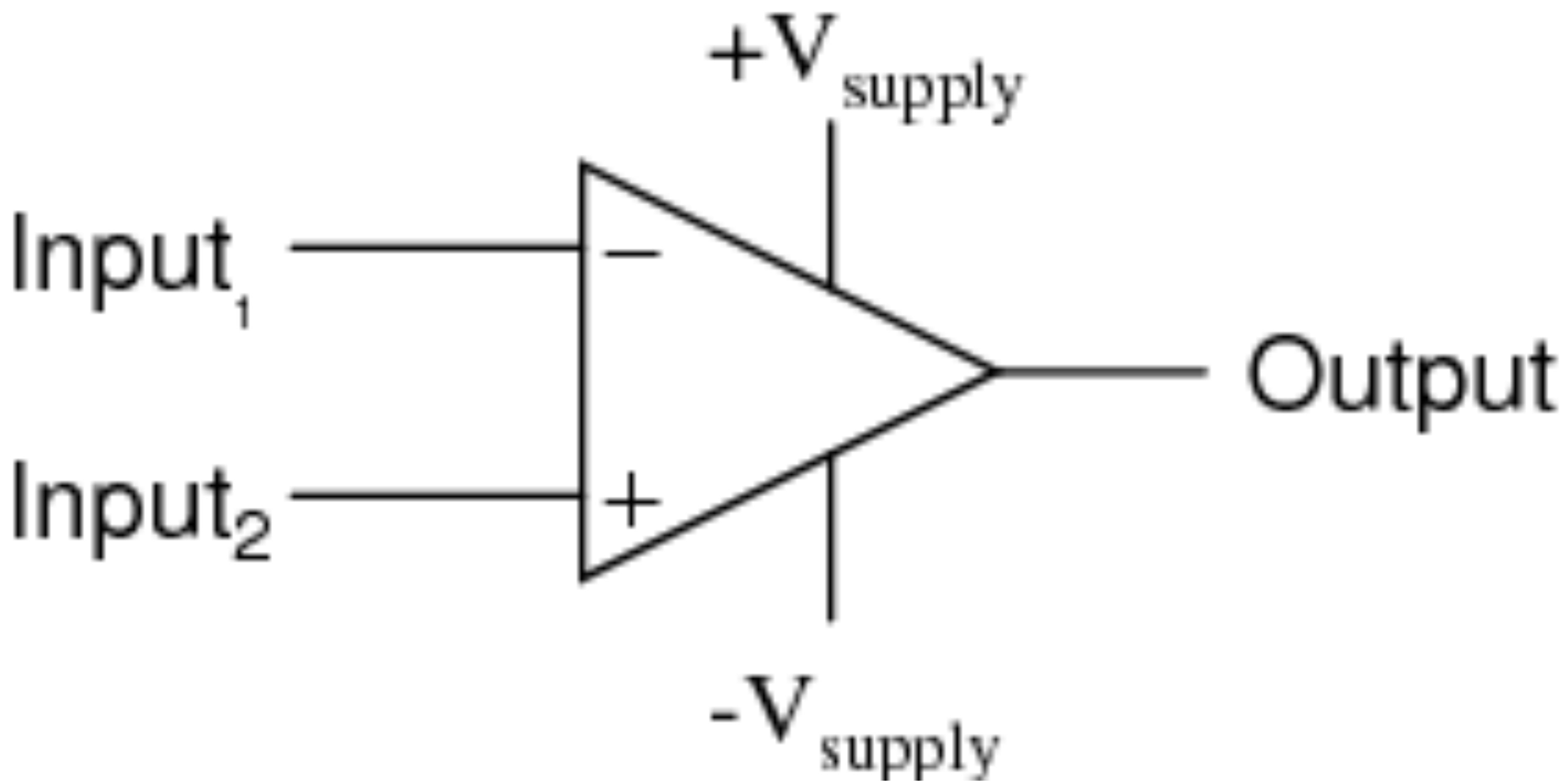
Techniques of Geoscientific Experimentation

November 1, 2016



- **Project Parts Status**
- **Review**
- **Finish operational amplifiers**
- **Instrumentation amplifiers**

Let's look at some terminals of the operational amplifier

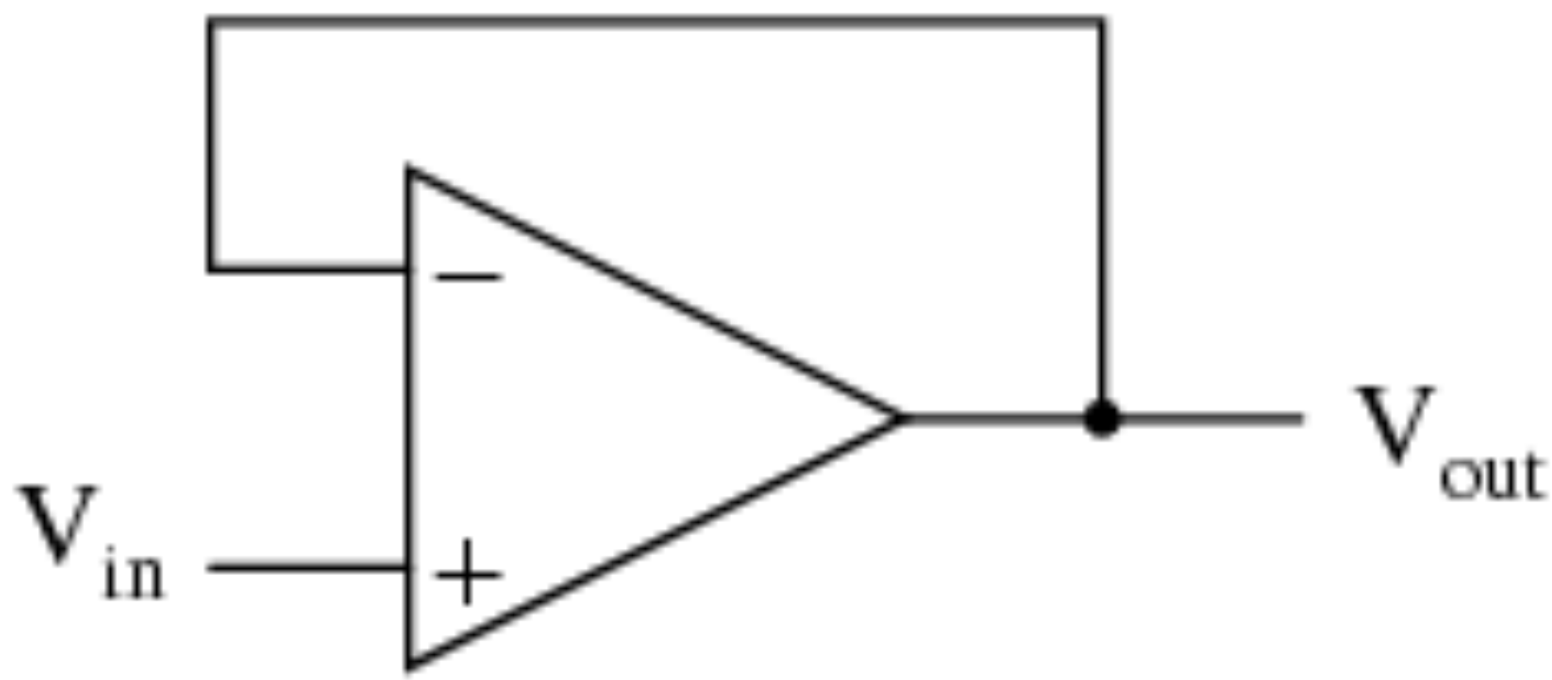


Images: allaboutcircuits.com

The op-amp always “wants” both inputs (inverting and non-inverting) to be the same value. If they are not, the same value, the op amp output will go positive or negative, depending on which input is higher than the other.

Chris Gammell

What happens if we hook up the amplifier with negative feedback?



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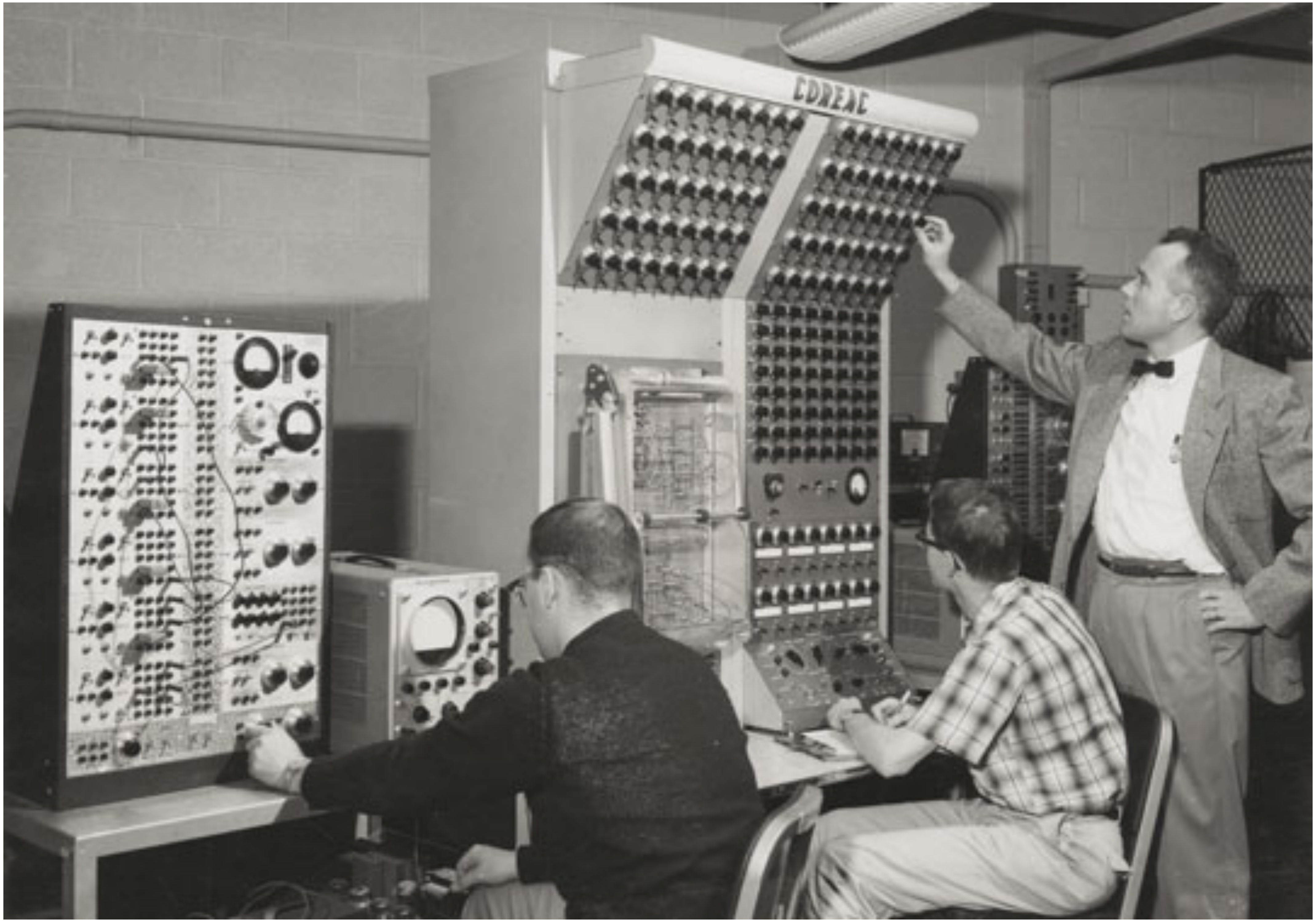
The name operational amplifiers implies more than a simple amplifier though



Images: Cornell

We can solve mathematical problems with analog computation, something still done in many devices

$$i_C = C \frac{dv}{dt}$$

Where,

i_C = Instantaneous current through capacitor

C = Capacitance in farads

$\frac{dv}{dt}$ = Rate of change of voltage over time

$$F = m \frac{dv}{dt}$$

Where,

F = Force applied to object

m = Mass of object

$\frac{dv}{dt}$ = Rate of change of velocity over time

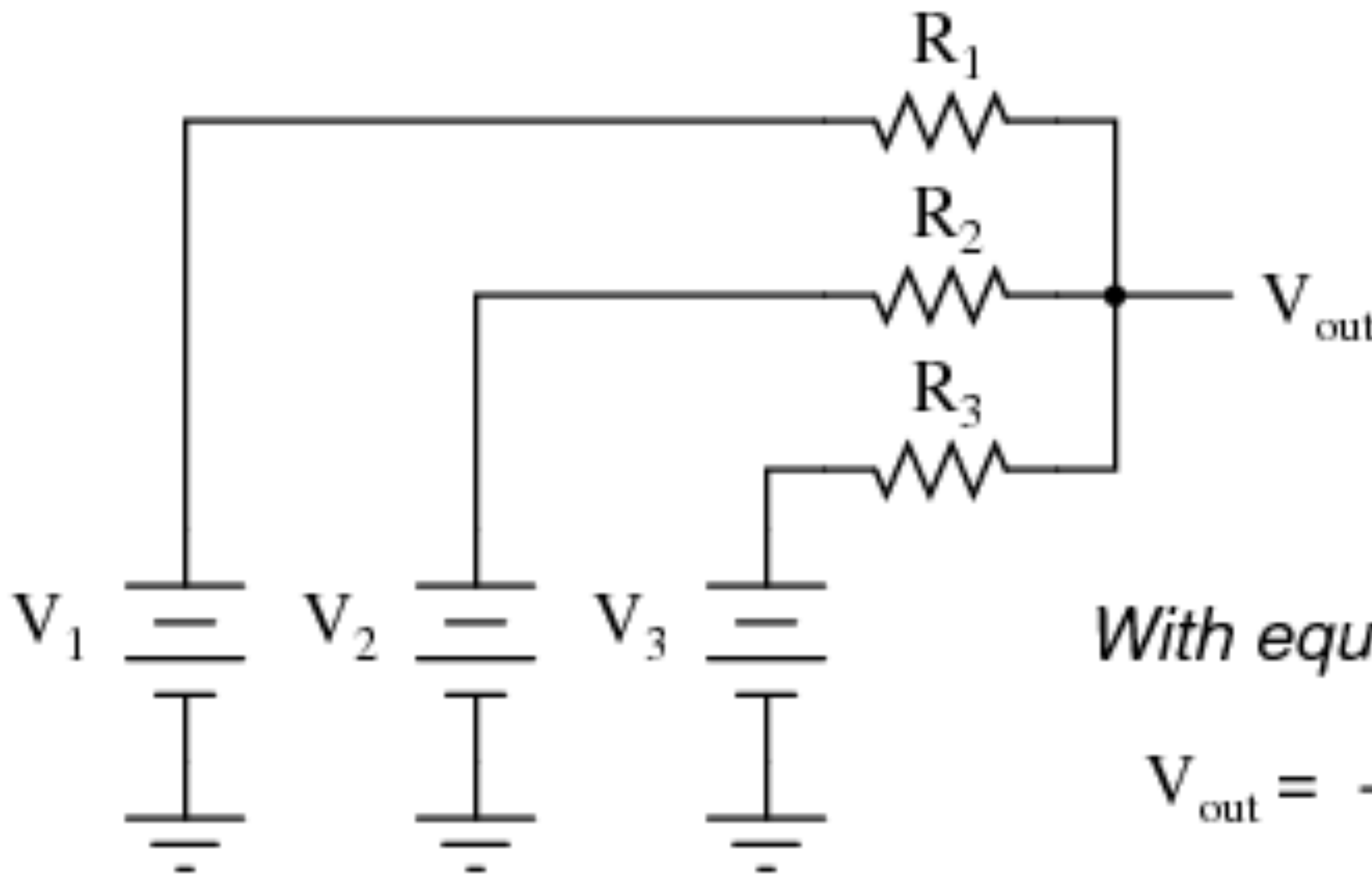
Images: allaboutcircuits.com

We'll cover the basic operations today:

- Summing
- Differentiating
- Integrating
- Differencing

Suppose we want to sum several voltages together

We’ll use the building block “passive averager” circuit



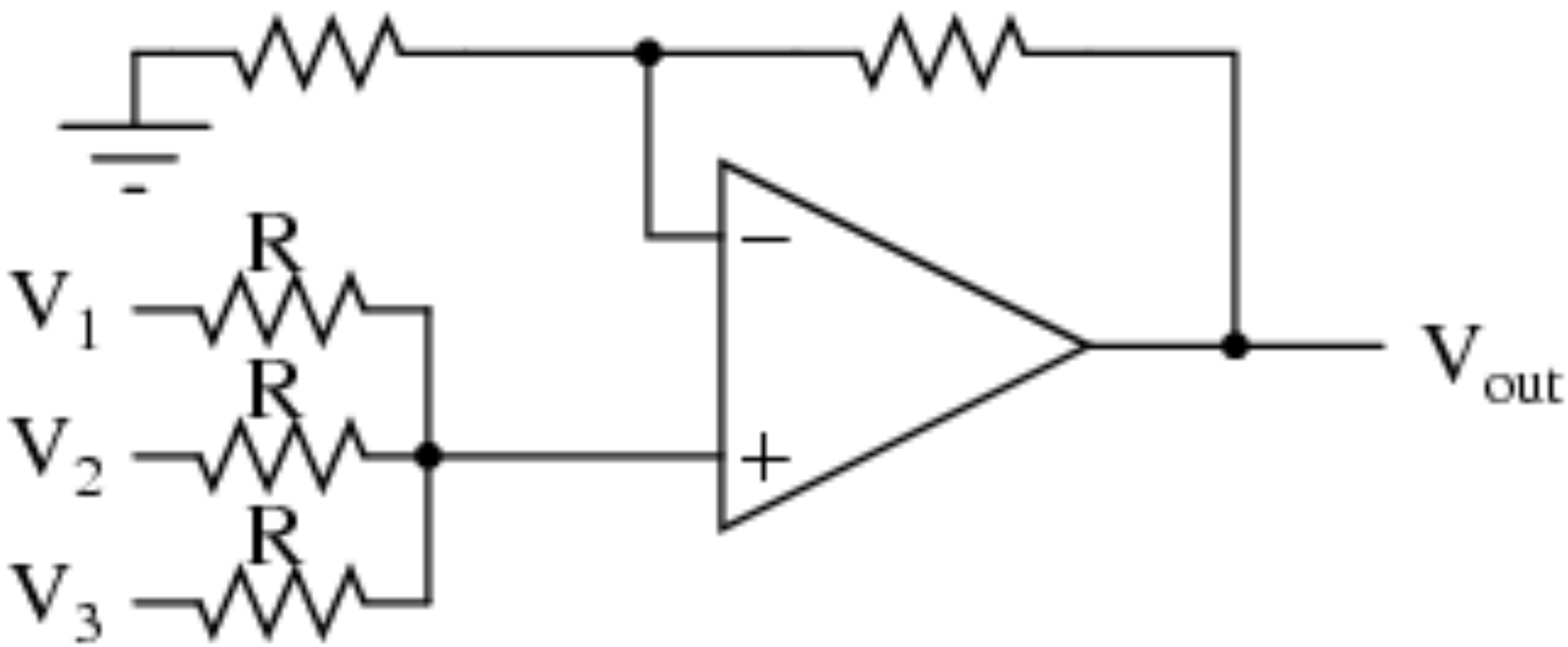
$$V_{out} = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

With equal value resistors:

$$V_{out} = \frac{V_1 + V_2 + V_3}{3}$$

Images: allaboutcircuits.com

We can use negative feedback to make a summing amplifier. What values should the resistors be?



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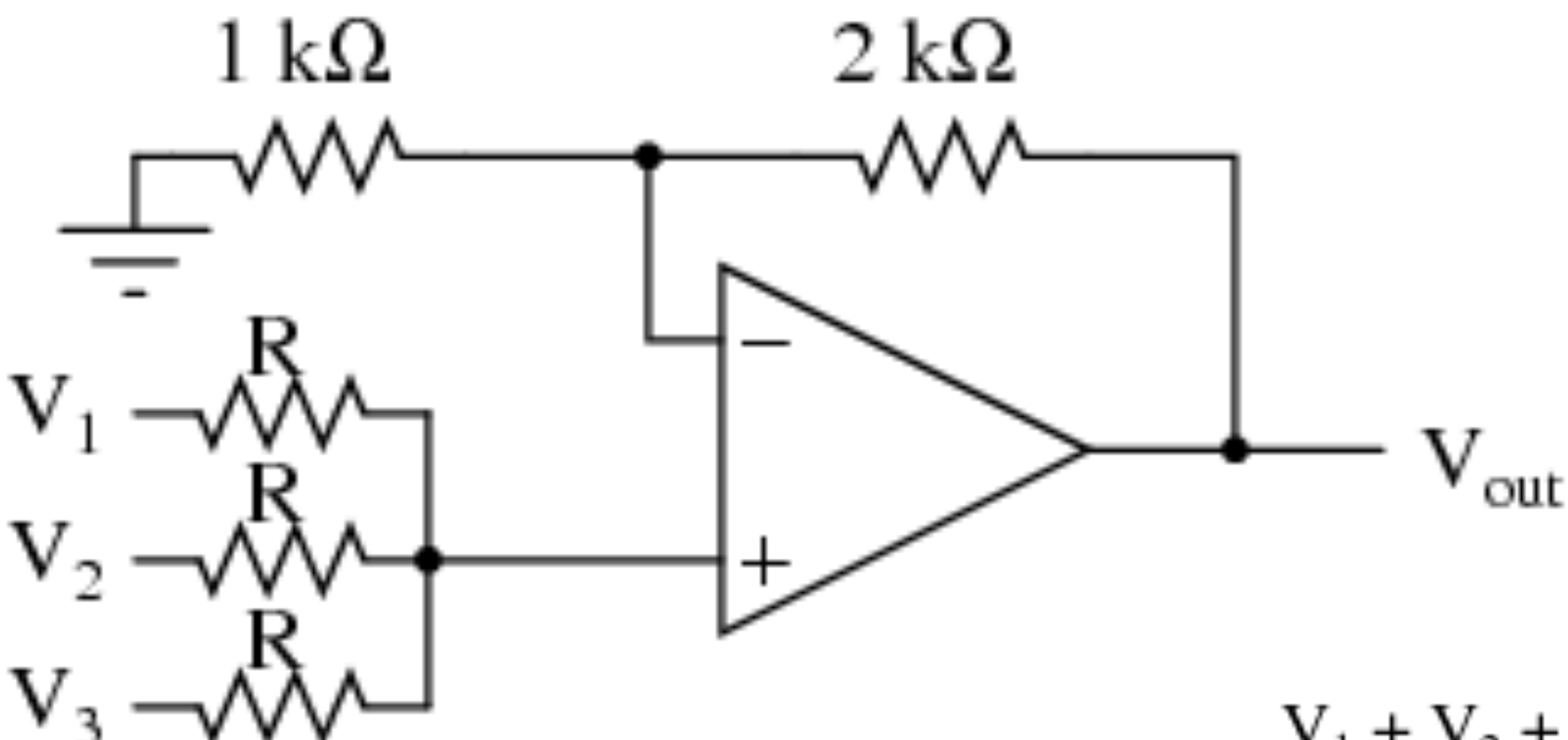
We can use negative feedback to make a summing amplifier. What values should the resistors be?



$$V_{out} = 3\ \frac{V_1 + V_2 + V_3}{3}$$

$$V_{out} = V_1 + V_2 + V_3$$

Images: allaboutcircuits.com

What component that we have talked about seems like it could be useful in measuring/coupling the change in voltage with time?

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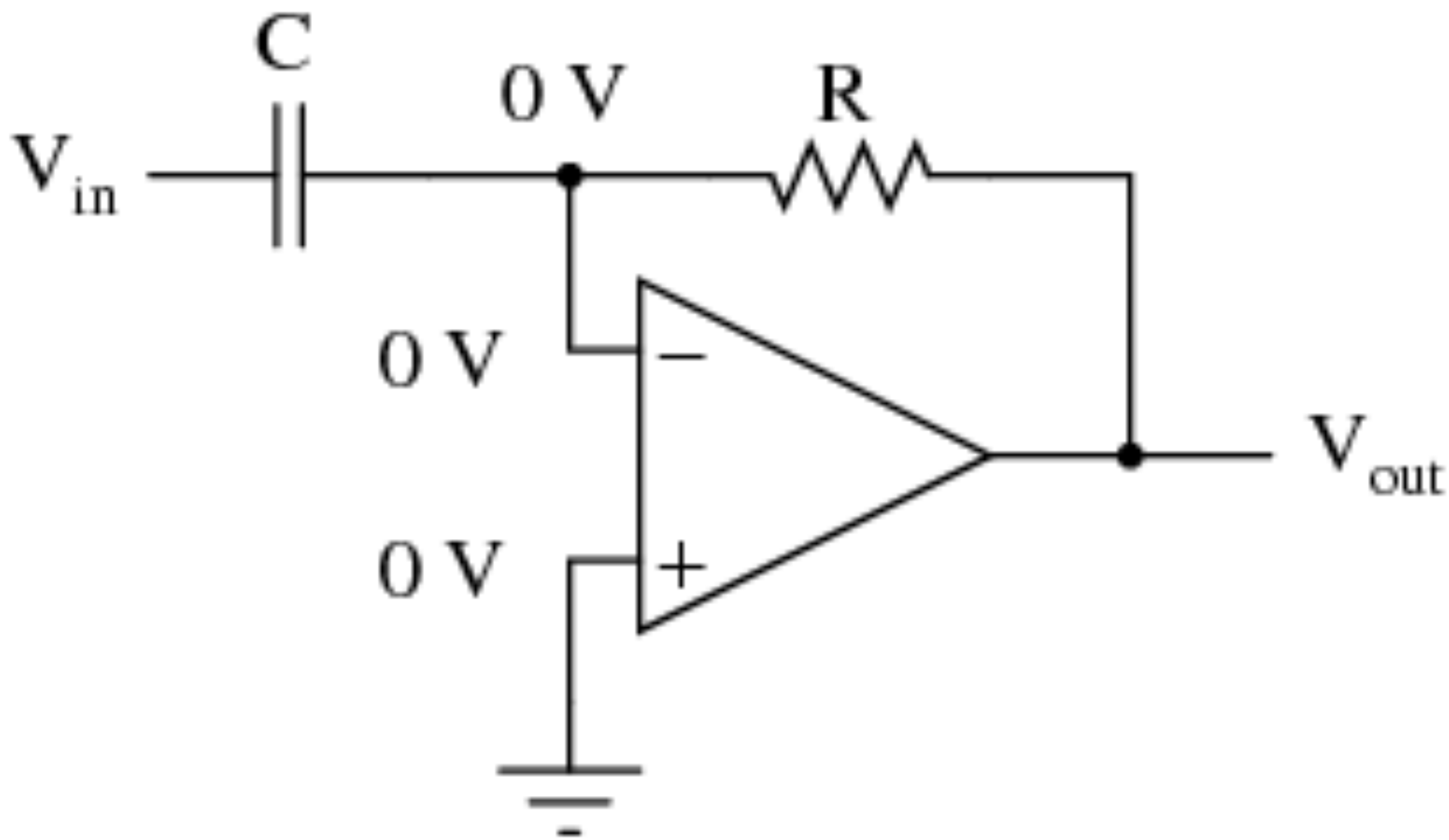
Images: capacitorguide.com

The differentiator yields the rate of change of voltage



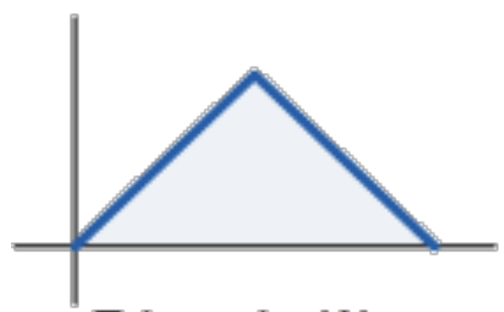
$$V_{OUT} = -R_F C \frac{dV_{IN}}{dt}$$

Images: allaboutcircuits.com

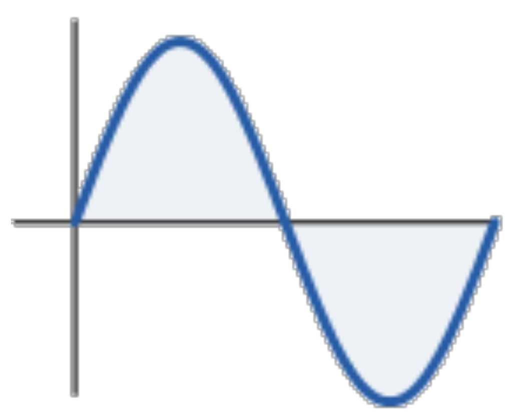
Draw the expected output signal from each input

Input Signal

Square Wave



Triangular Wave



Sine Wave

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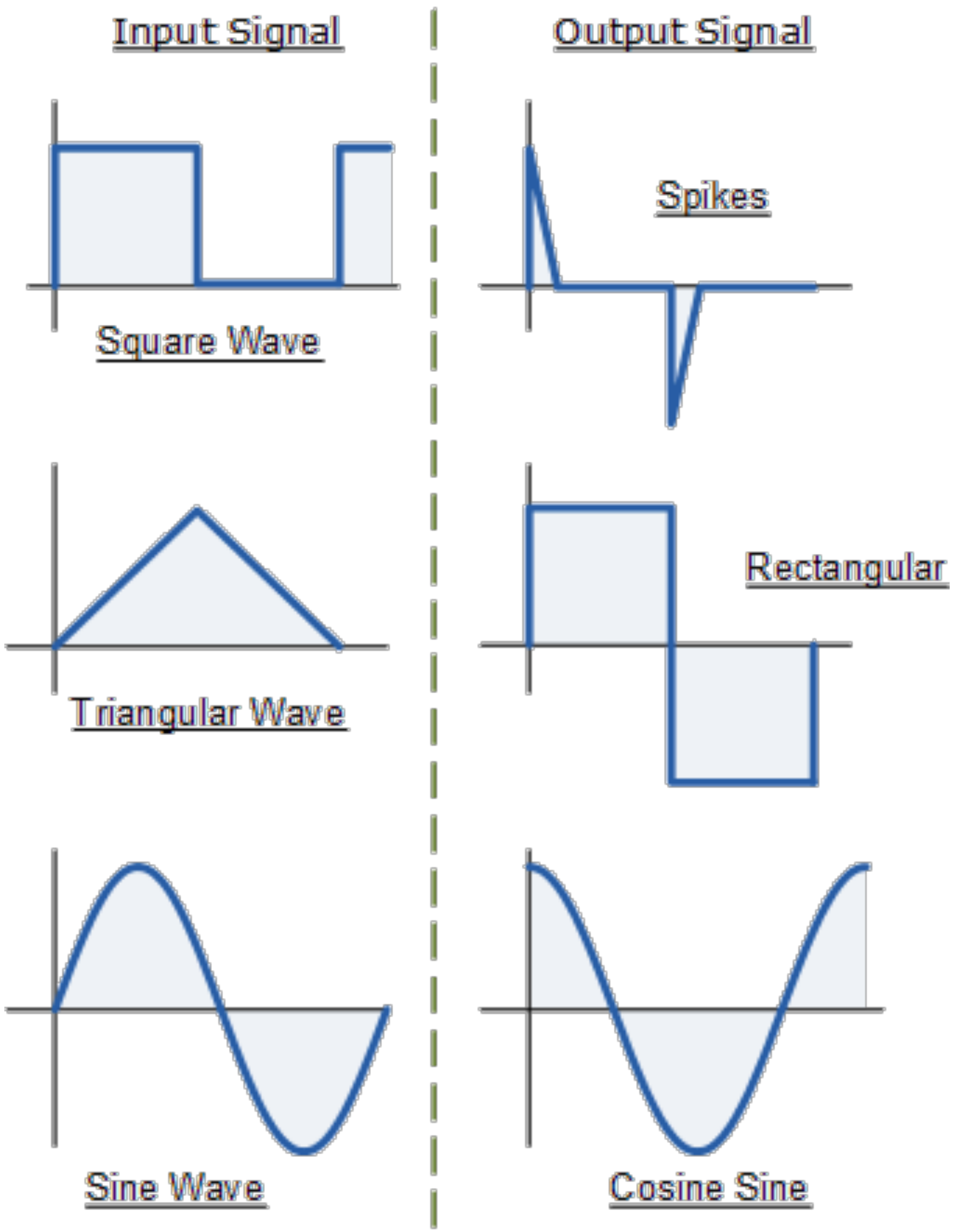
Draw the expected output signal from each input



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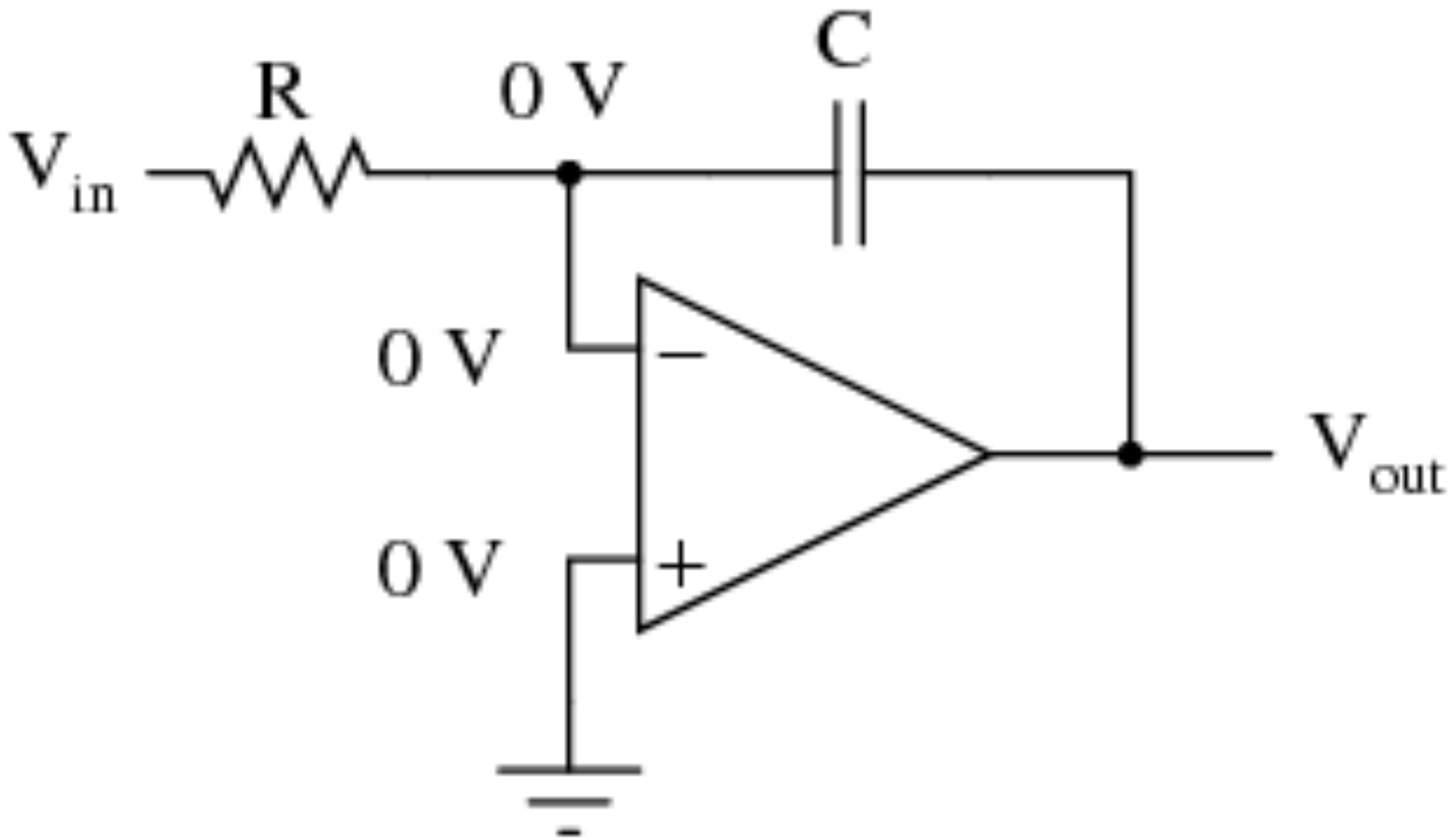
The integrator looks very similar, but sums voltage over time



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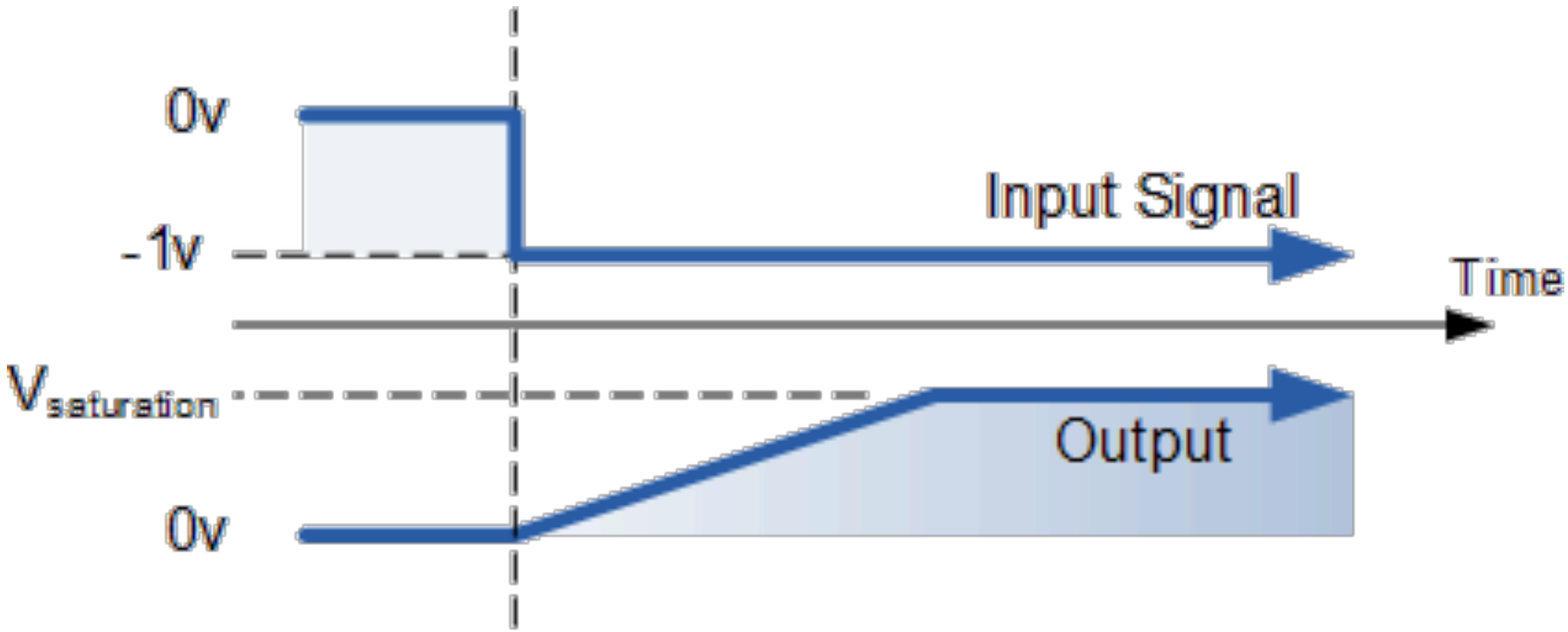
Let’s look at the response to a step in voltage



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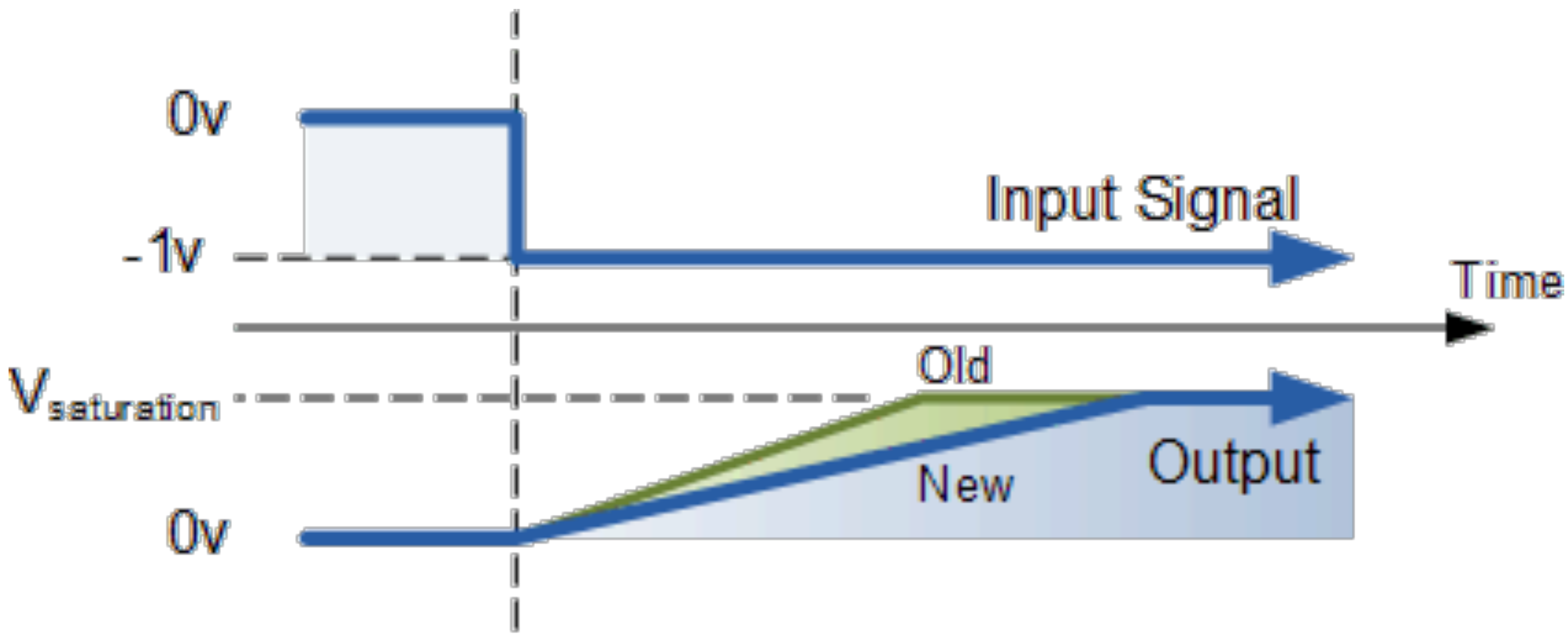
What if we changed the RC time constant?



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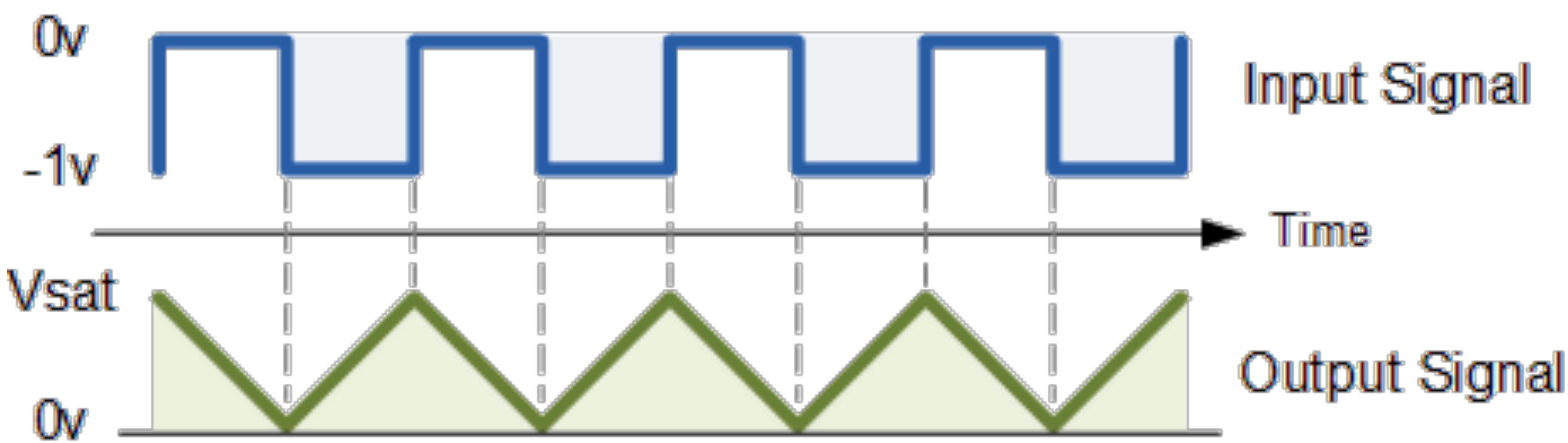
The integrator can be the basis for a simple ramp generator



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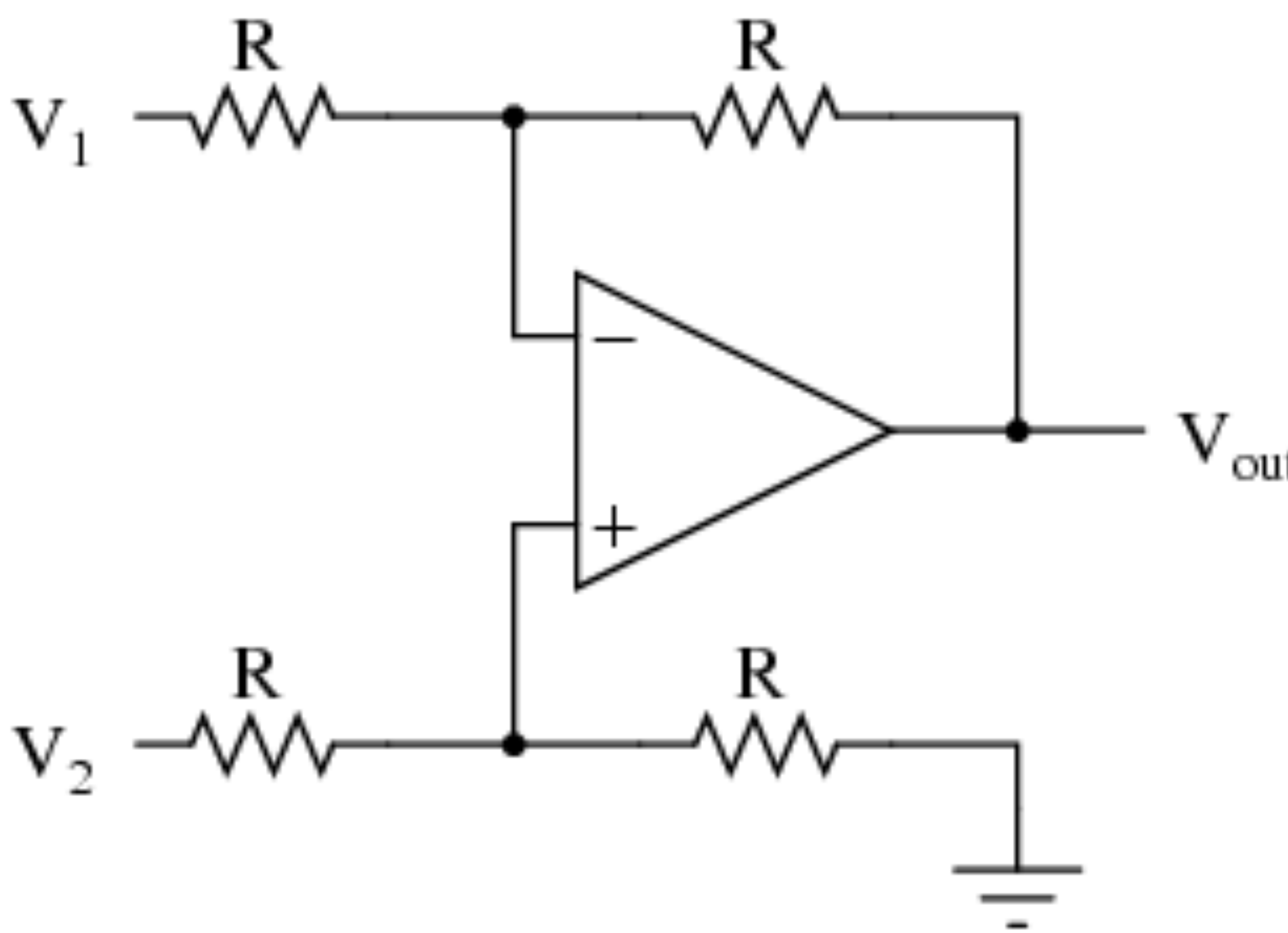
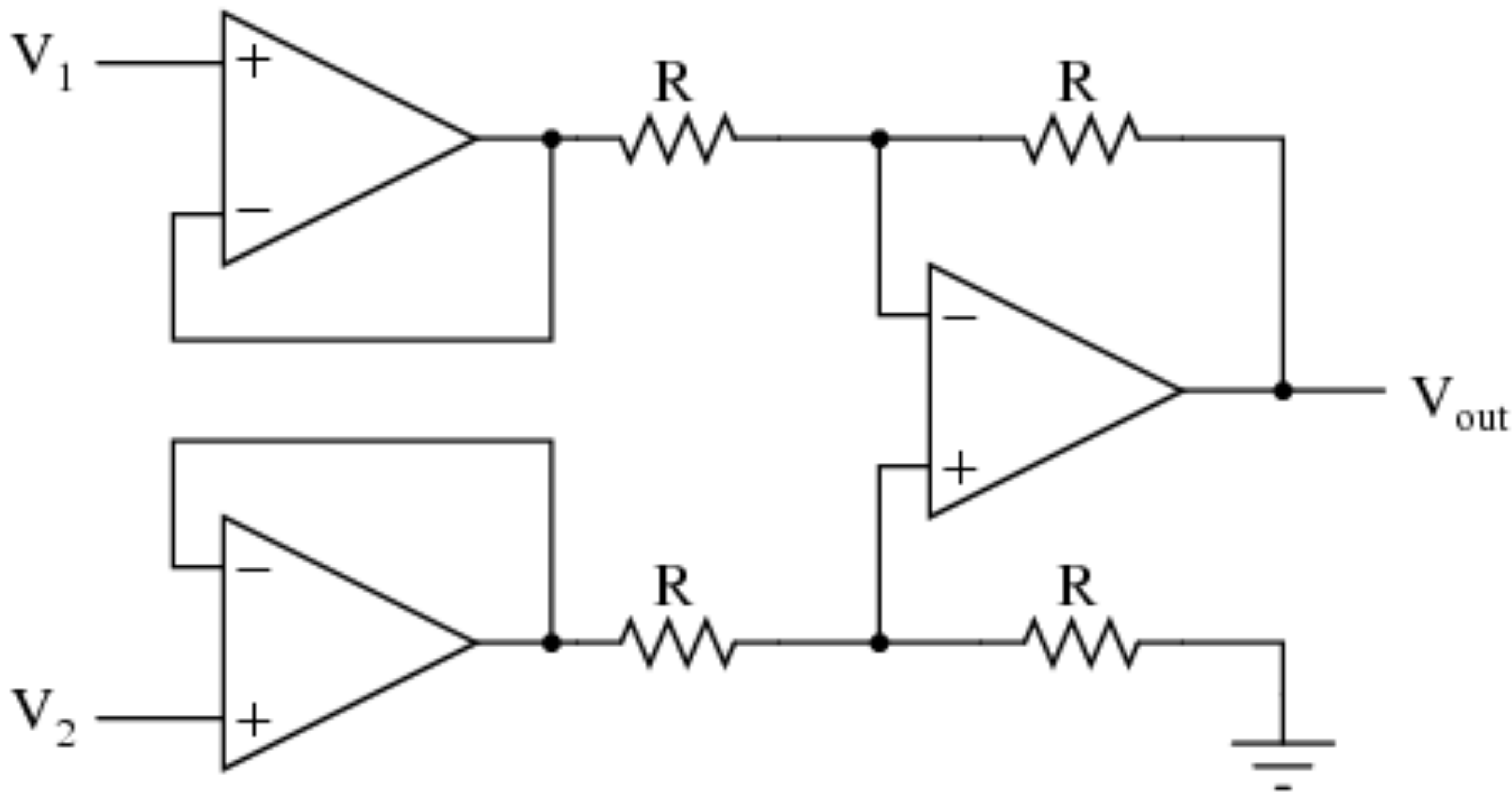
Amplifying a differential signal gets tricky very quickly



Images: allaboutcircuits.com

We can improve the differential amplifier with two voltage followers



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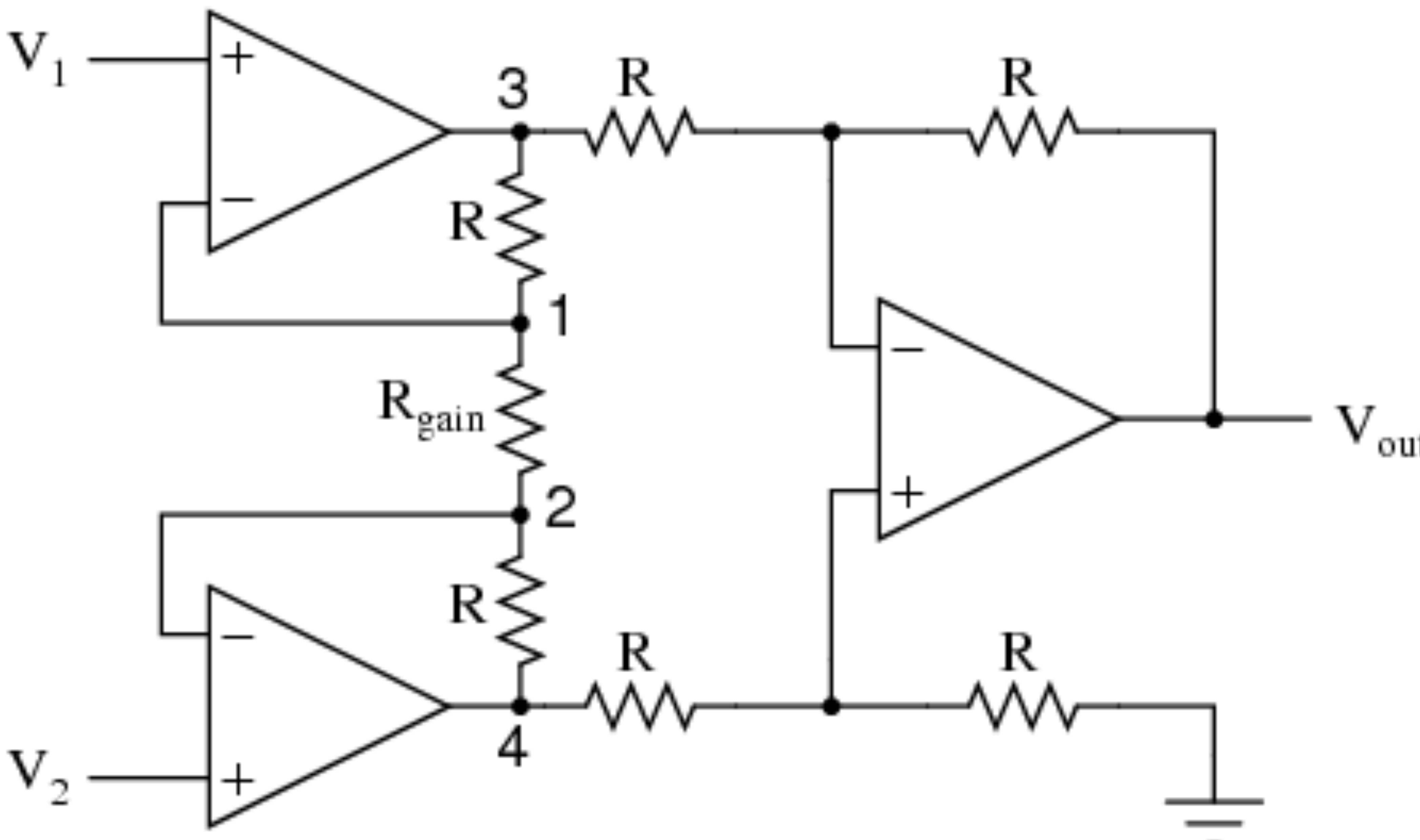
An instrumentation amplifier integrates all of this into one package and exposes a gain resistor to the user (sometimes)



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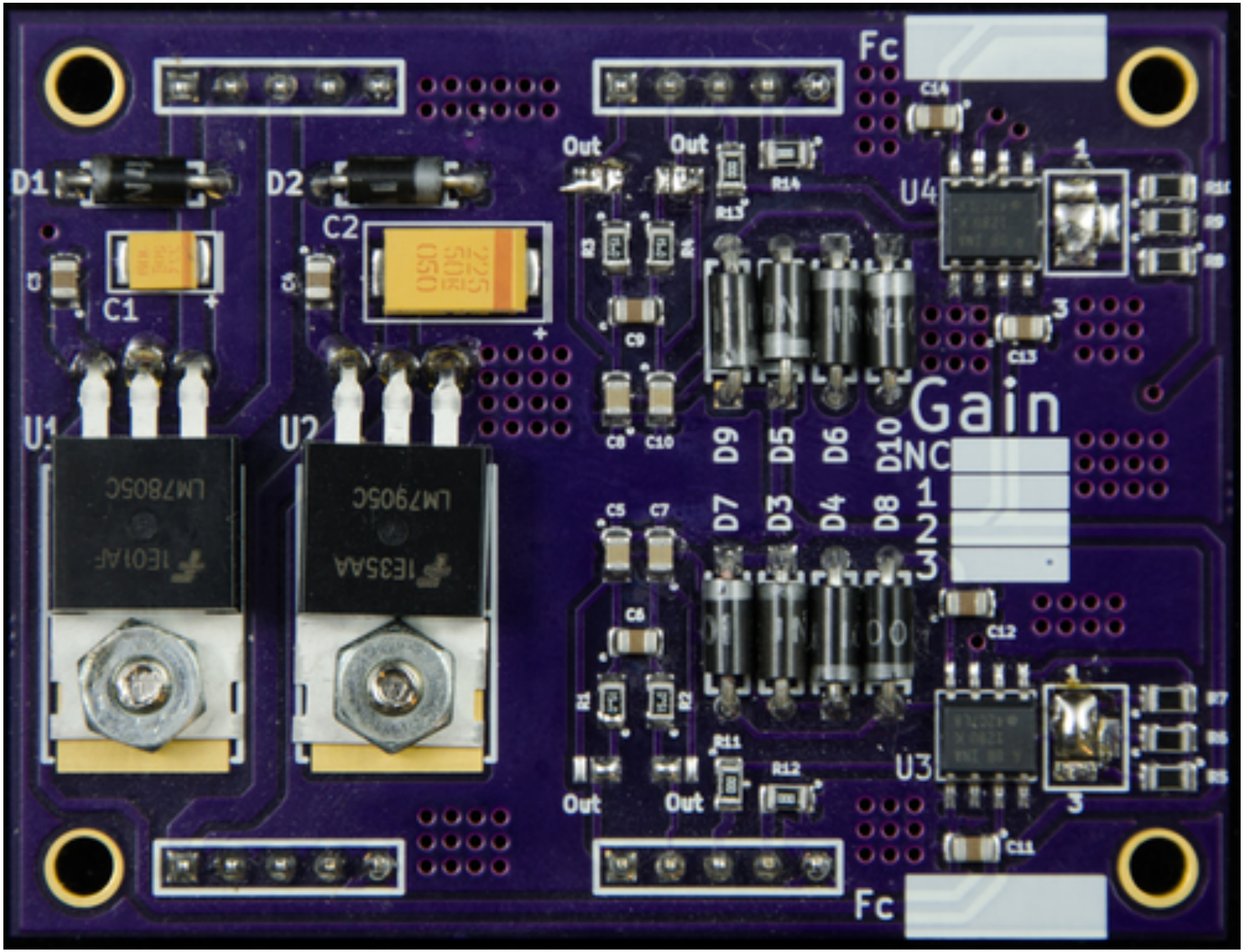
There are many families out there, but they are similar



Images: <u>leemangeophysical.com</u>

INA12x Precision, Low Power Instrumentation Amplifiers

1 Features

- Low Offset Voltage: 50 μV Maximum
- Low Drift: 0.5 μV/°C Maximum
- Low Input Bias Current: 5 nA Maximum
- High CMR: 120 dB minimum
- Inputs Protected to ±40 V
- Wide Supply Range: ±2.25 V to ±18 V
- Low Quiescent Current: 700 μA
- 8-PIN Plastic Dip, SO-8

2 Applications

- Bridge Amplifier
- Thermocouple Amplifier
- RTD Sensor Amplifier
- Medical Instrumentation
- Data Acquisition

3 Description

The INA128 and INA129 are low-power, general purpose instrumentation amplifiers offering excellent accuracy. The versatile 3-op amp design and small size make these amplifiers ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain (200 kHz at G = 100).

A single external resistor sets any gain from 1 to 10,000. The INA128 provides an industry-standard gain equation; the INA129 gain equation is compatible with the AD620.

The INA12x is laser-trimmed for very low offset voltage (50 μV), drift (0.5 μV/°C) and high common-mode rejection (120 dB at G ≥ 100). The INA12x operates with power supplies as low as ±2.25 V, and quiescent current is only 700 μA, ideal for battery-operated systems. Internal input protection can withstand up to ±40 V without damage.

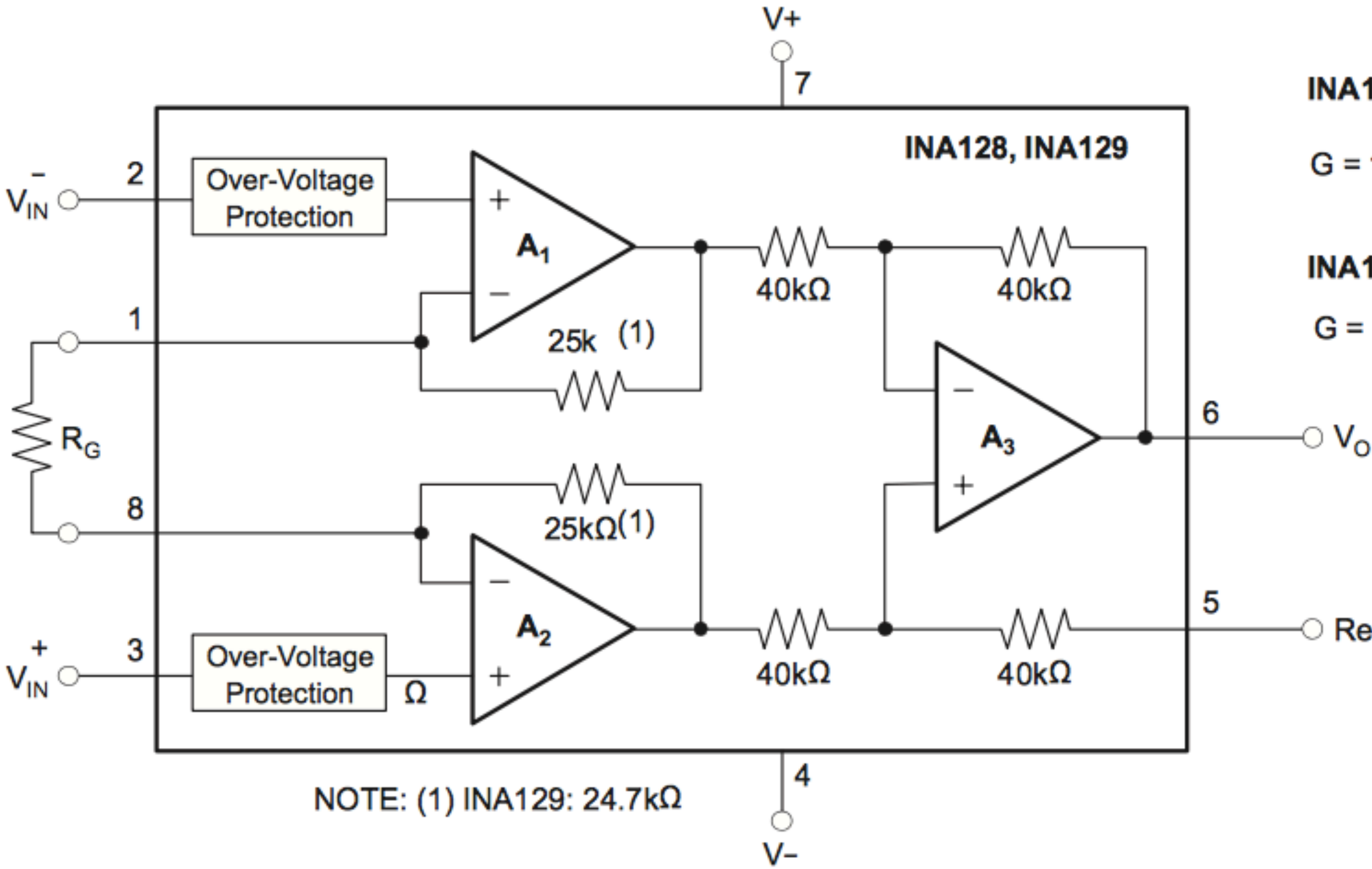
The INA12x is available in 8-pin plastic DIP and SO-8 surface-mount packages, specified for the –40°C to 85°C temperature range. The INA128 is also available in a dual configuration, the INA2128.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
INA128 INA129	SOIC (8)	3.91 mm × 4.9 mm
	PDIP (8)	6.35 mm × 9.81 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Simplified Schematic



NOTE: (1) INA129: 24.7kΩ

INA128:

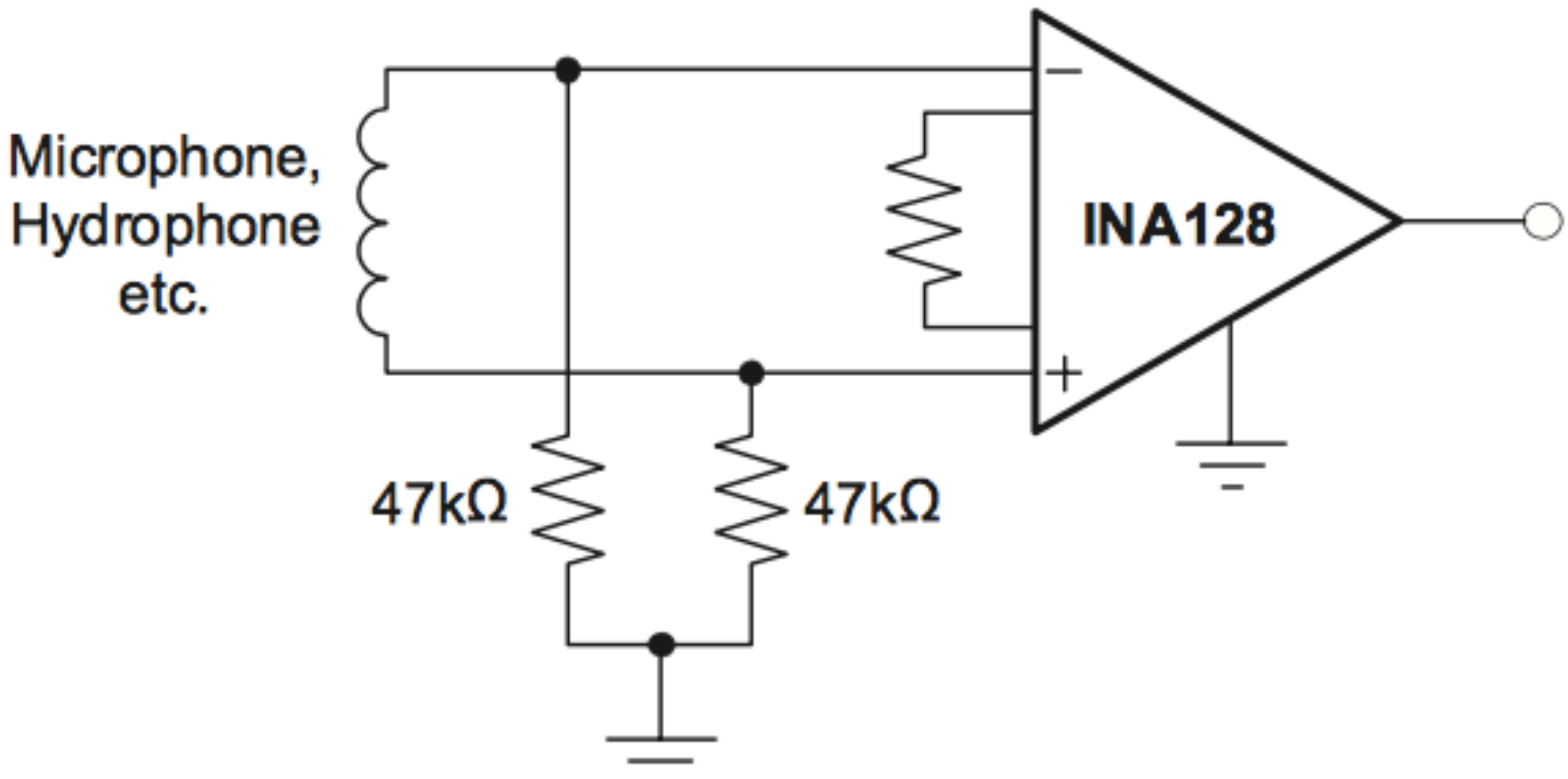
$$G = 1 + \frac{50k\Omega}{R_G}$$

INA129:

$$G = 1 + \frac{49.4k\Omega}{R_G}$$

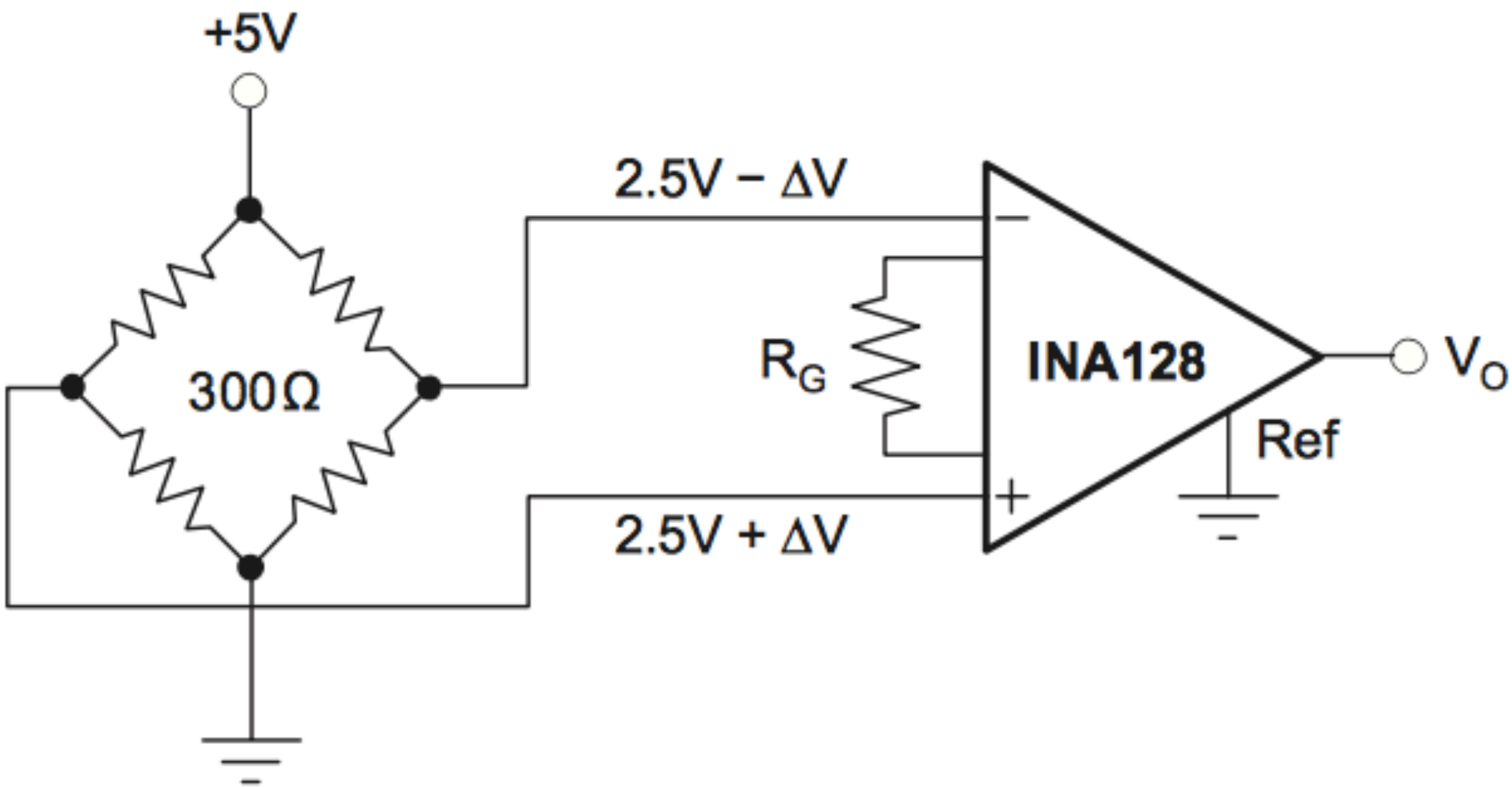
Images: TI

Don’t forget about bias currents!



Images: TI

How can we apply this circuit?



Images: TI