Operational Amplifier & aplikasinya

Elektronika
(TKE 4012)

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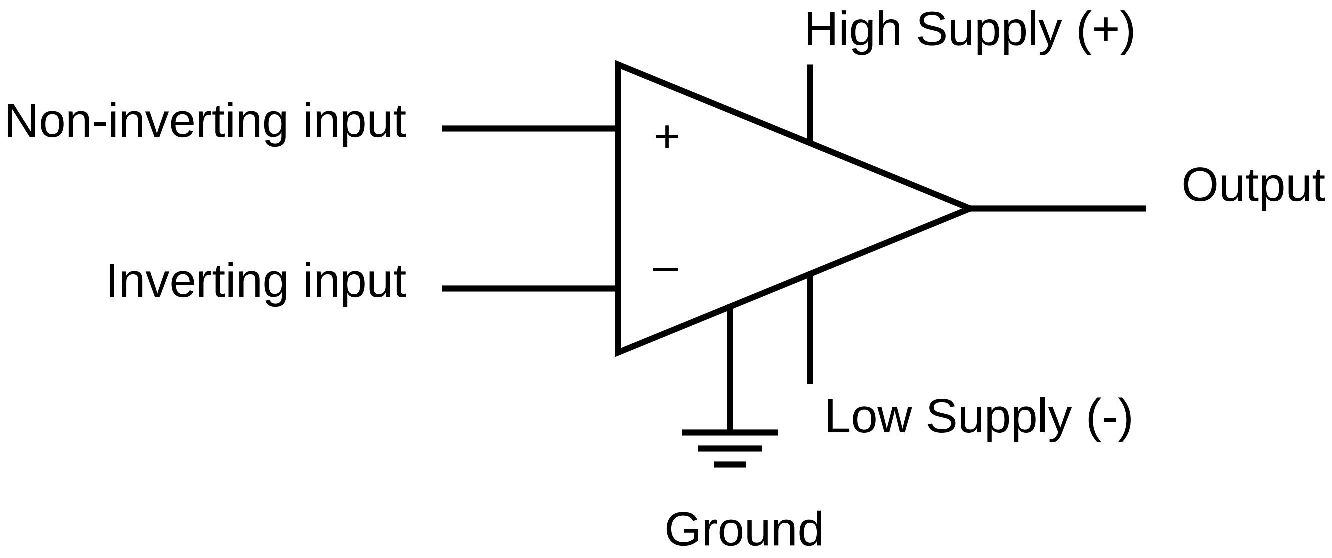
Op Amp

- Op Amp is short for operational amplifier
- Amplifiers provide gains in voltage or current
- Op amps can convert current to voltage

Simbol Op Amp



Applications of Op Amps

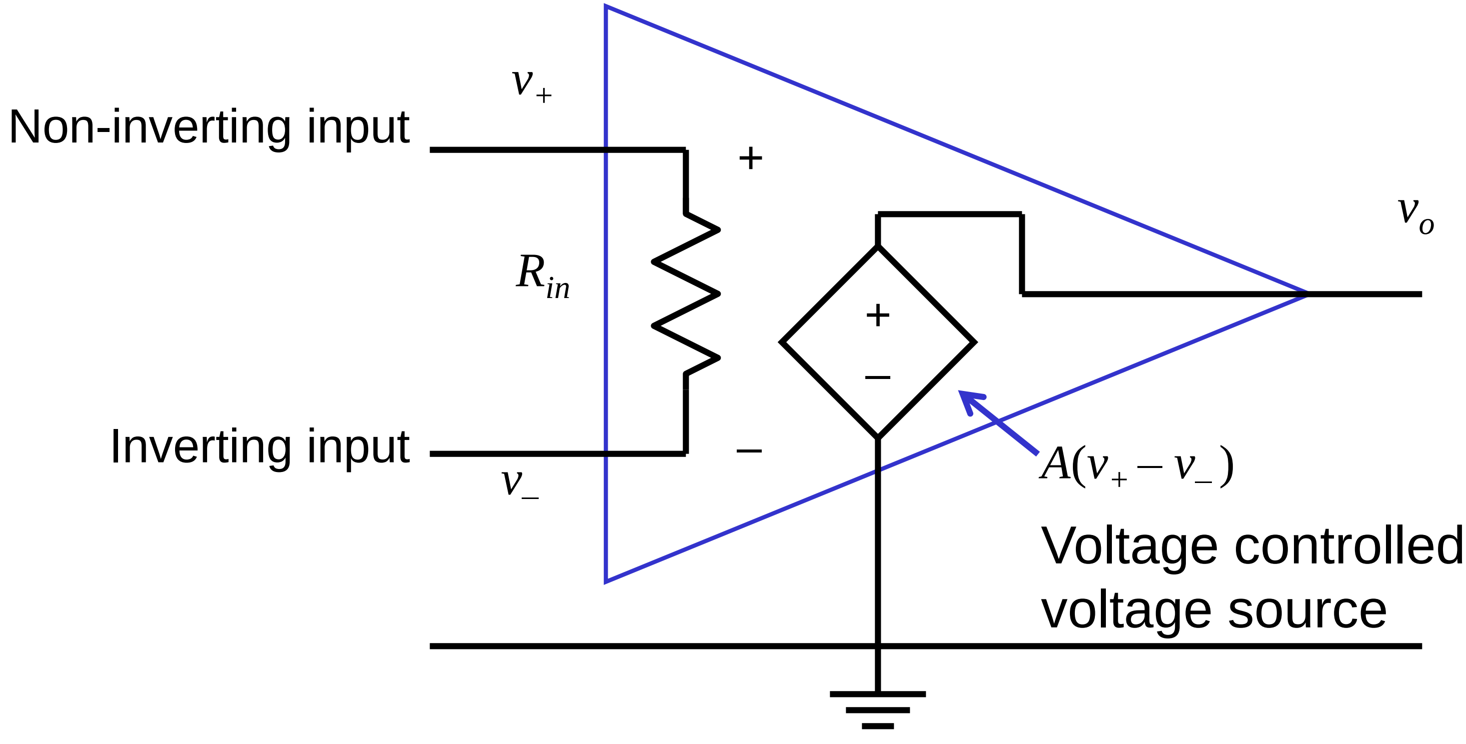
- Op amps can be configured in many different ways using resistors and other components
- Most configurations use feedback
- Op amps can provide a buffer between two circuits
- Op amps can be used to implement integrators and differentiators
- Lowpass and bandpass filters

Aplikasi Op-amp

- Komparator
- Penguat Non-inverting
- Penguat Inverting
- Penguat penjumlah
- Voltage follower
- Converter Tegangan ke Arus
- Integrator & Diferensiator
- Penguat diferensial
- Penguat instrumentasi
- Penguat histerisis

The Op Amp Model

- An operational amplifier is modeled as a voltage-controlled voltage source.



Typical vs. Ideal Op Amps

Typical Op Amp:

- The input resistance (impedance) R_{in} is very large (practically infinite).
- The voltage gain A is very large (practically infinite).

Ideal Op Amp:

- The input resistance is infinite.
- The gain is infinite.
- The op amp is in a negative feedback configuration.

Consequences of the Ideal

- Infinite input resistance means the current into the inverting (–) input is zero:

$$i_{-} = 0$$

- Infinite gain means the difference between v_{+} and v_{-} is zero:

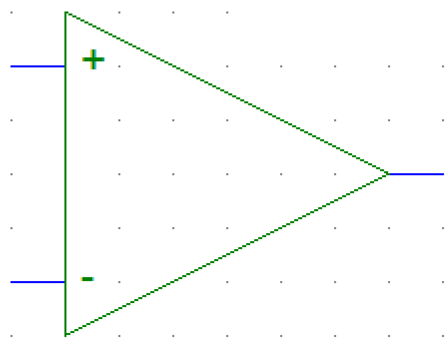
$$v_{+} - v_{-} = 0$$

Typical Op Amp Parameters

Parameter	Variable	Typical Ranges	Ideal Values
Open-Loop Voltage Gain	A	10^5 to 10^8	∞
Input Resistance	Ri	10^5 to 10^{13} W	∞ W
Output Resistance	Ro	10 to 100 W	0 W
Supply Voltage	Vcc/V^+ -Vcc/V^-	5 to 30 V -30V to 0V	N/A N/A

Symbols for Ideal and Real Op Amps

OpAmp



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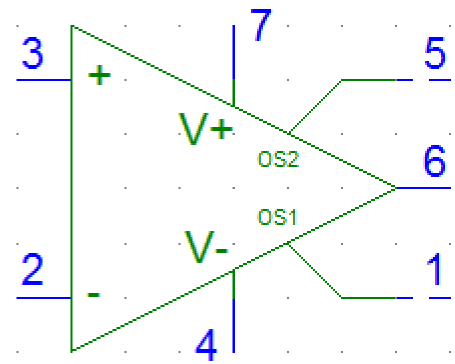

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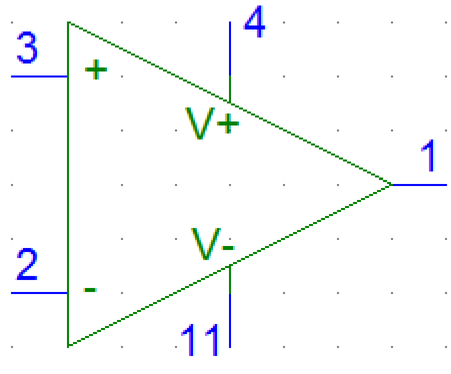

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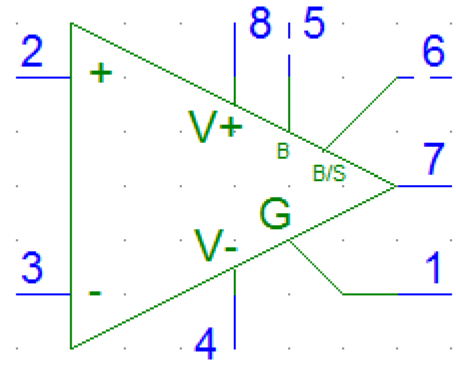
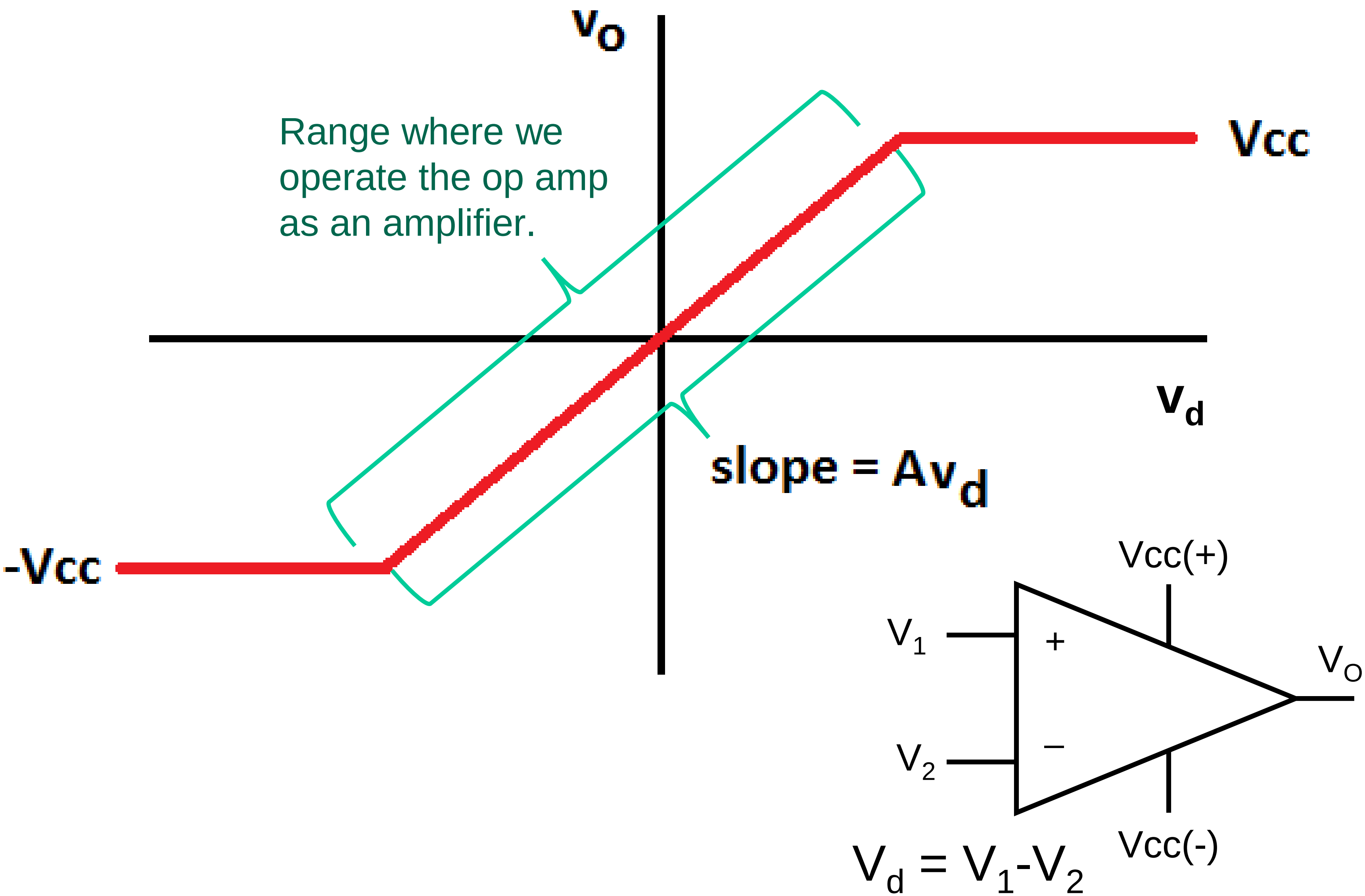
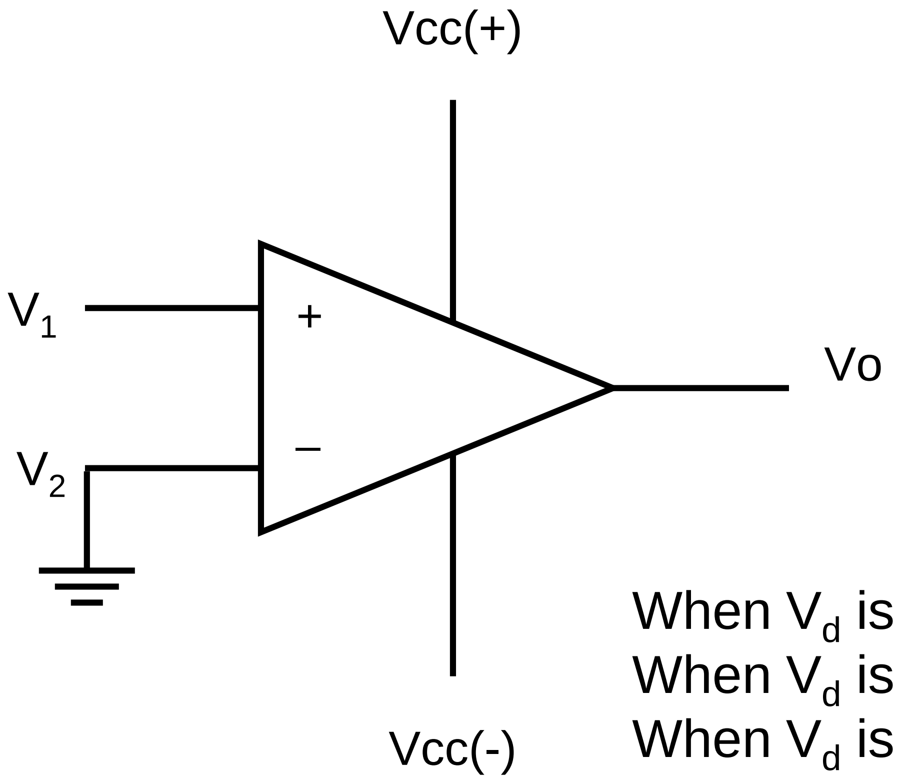


Voltage Transfer Characteristic



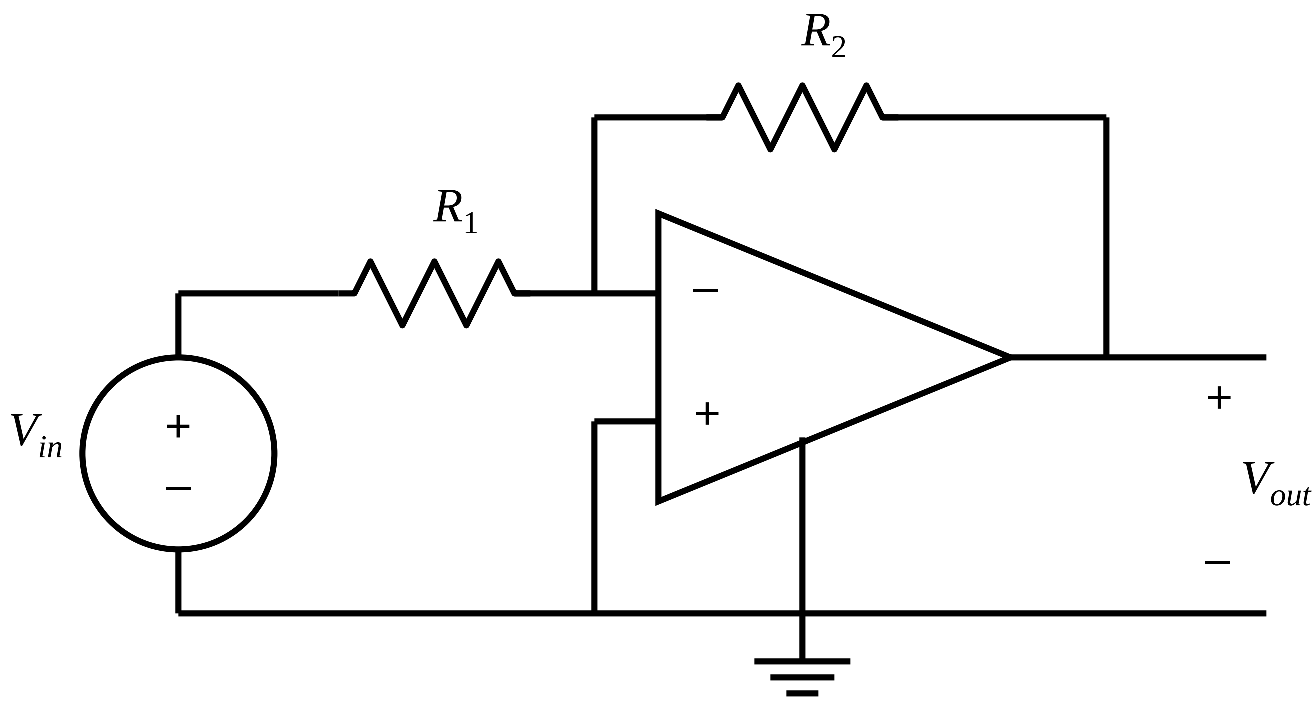
Example #1: Voltage Comparator



$$V_d = V_1 - V_2$$

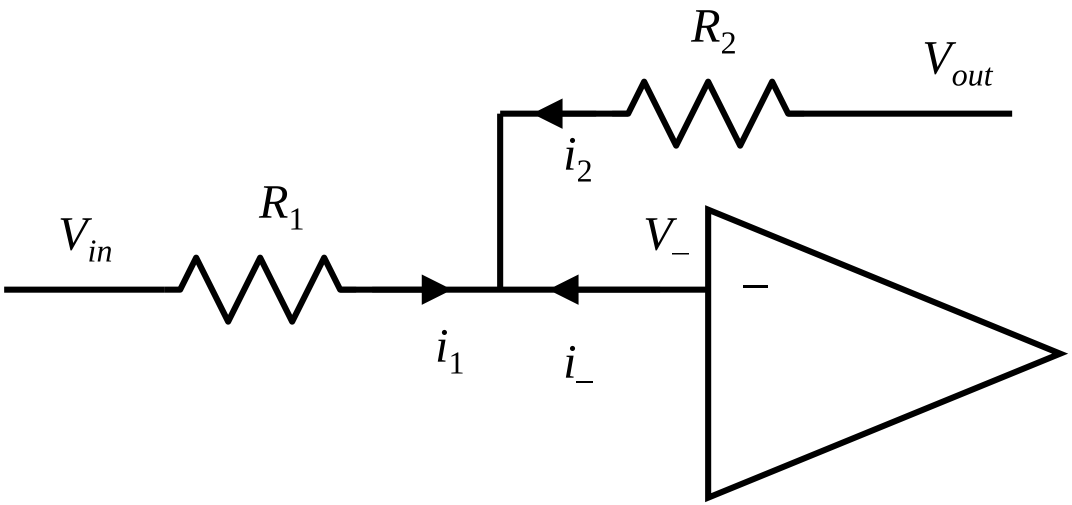
When V_d is larger than 0V, Vo = $Vcc_{(+)}$.
When V_d is smaller than 0V, Vo = $Vcc_{(-)}$.
When V_d is equal to 0V, Vo = 0V.

Penguat Inverting Basic



Solving the Amplifier Circuit

Apply KCL at the inverting (–) input:



$$i_- = 0$$

$$i_1 = \frac{V_{in} - V_-}{R_1} = \frac{V_{in}}{R_1}$$

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

$$i_1 + i_2 + i_- = 0$$

Solve for V_{out}

- From KCL

$$i_1 + i_2 + i_- = 0$$

$$\frac{V_{in}}{R_1} + \frac{V_{out}}{R_2} + 0 = 0$$

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

- Thus, the amplifier gain is

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

Recap

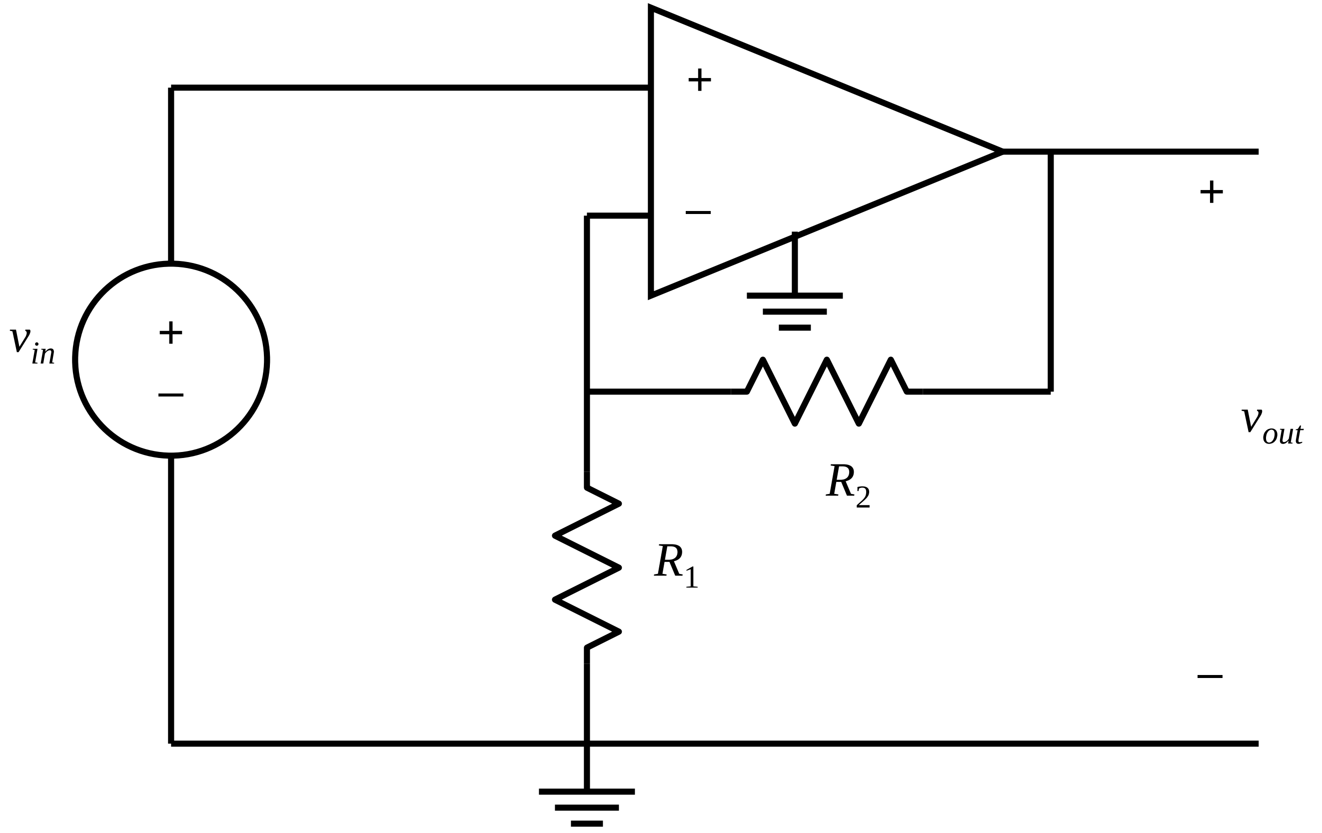
- The ideal op-amp model leads to the following conditions:

$$i_{-} = 0 = i_{+}$$

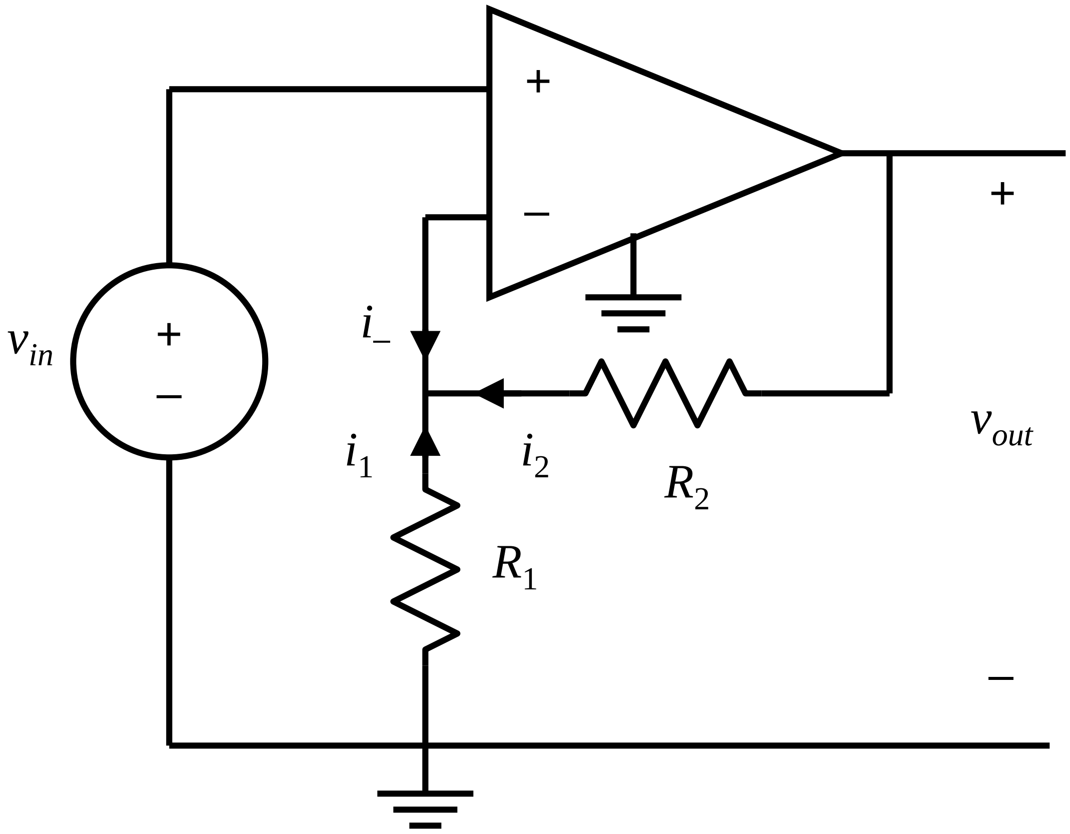
$$v_{+} = v_{-}$$

- These conditions are used, along with KCL and other analysis techniques (e.g., nodal), to solve for the output voltage in terms of the input(s)

Penguat Non-inverting



KCL at the Inverting Input



$$i_- = 0$$

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

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

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

Solve for v_{out}

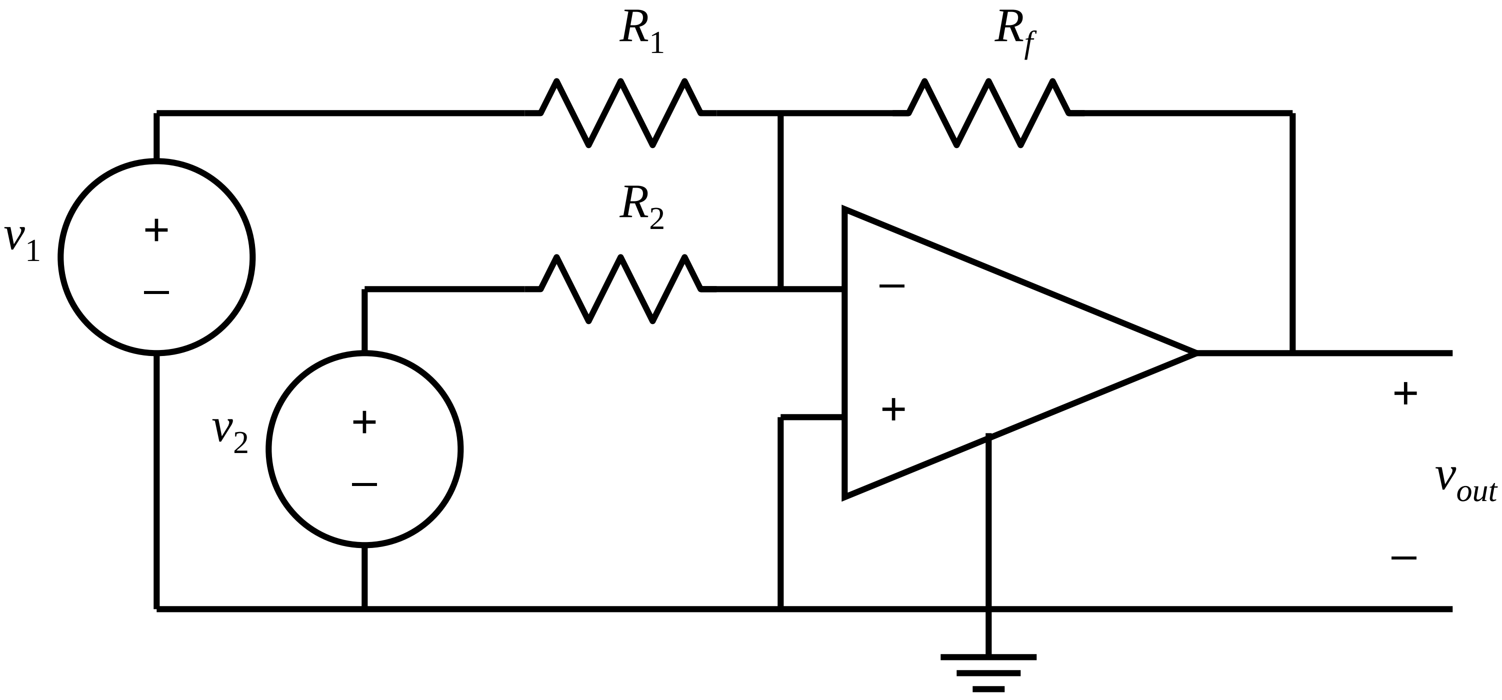
$$i_1 + i_2 + i_- = 0$$

$$\frac{-v_{in}}{R_1} + \frac{v_{out} - v_{in}}{R_2} = 0$$

$$v_{out} = v_{in}\left(1 + \frac{R_2}{R_1}\right)$$

- Hence, the non-inverting amplifier has a gained output (> unity) relative to the resistance ratio

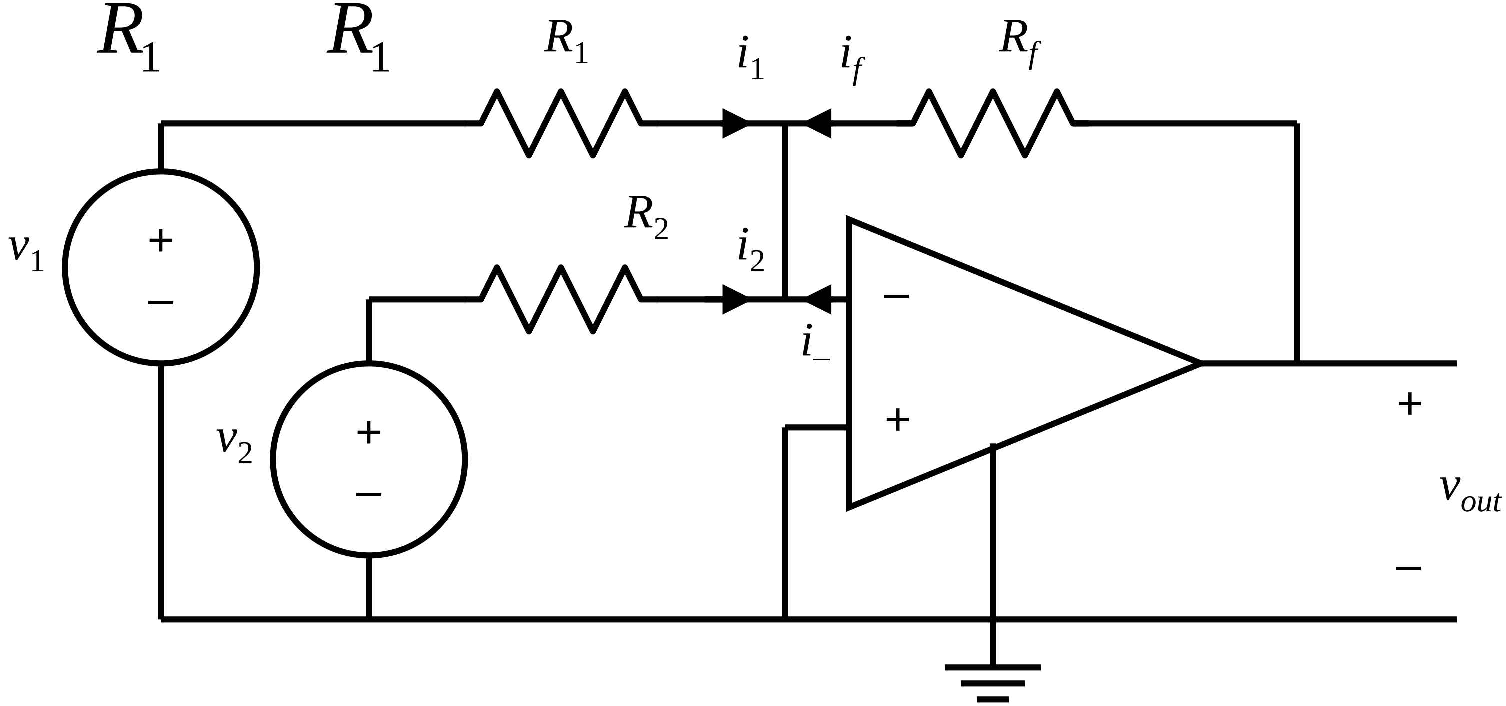
Rangkaian Penjumlah



KCL at the Inverting Input

$$i_1 = \frac{v_1 - v_-}{R_1} = \frac{v_1}{R_1}$$

$$i_- = 0$$



$$i_f = \frac{v_{out} - v_-}{R_f} = \frac{v_{out}}{R_f}$$

$$i_2 = \frac{v_2 - v_-}{R_2} = \frac{v_2}{R_2}$$

Solve for v_{out}

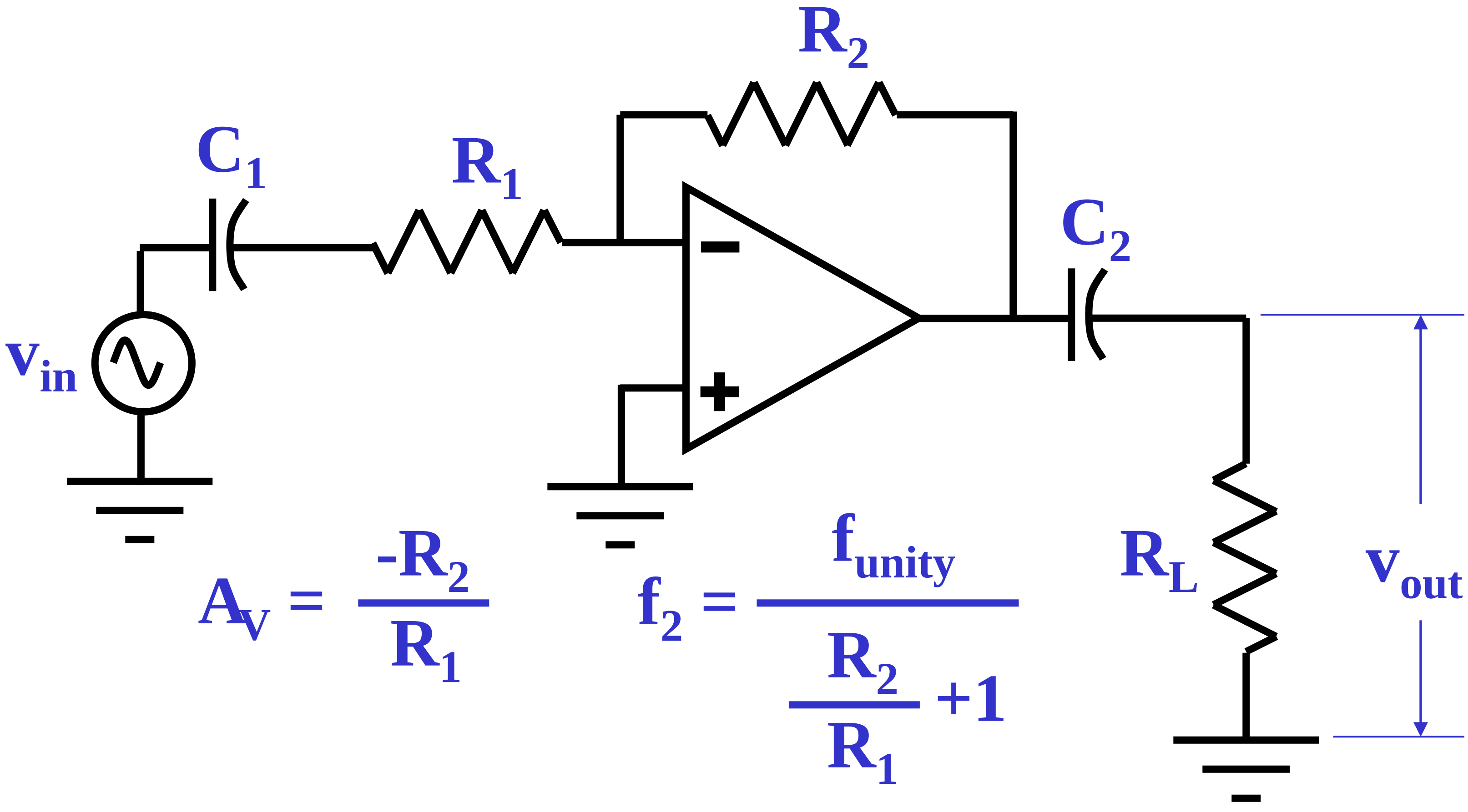
$$i_1 + i_2 + i_f + i_- = 0$$

$$\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_{out}}{R_f} = 0$$

$$v_{out} = -\frac{R_f}{R_1} v_1 - \frac{R_f}{R_2} v_2$$

- So, the mixer circuit output is a (negative) combination of the input voltages

ac coupled inverting amplifier

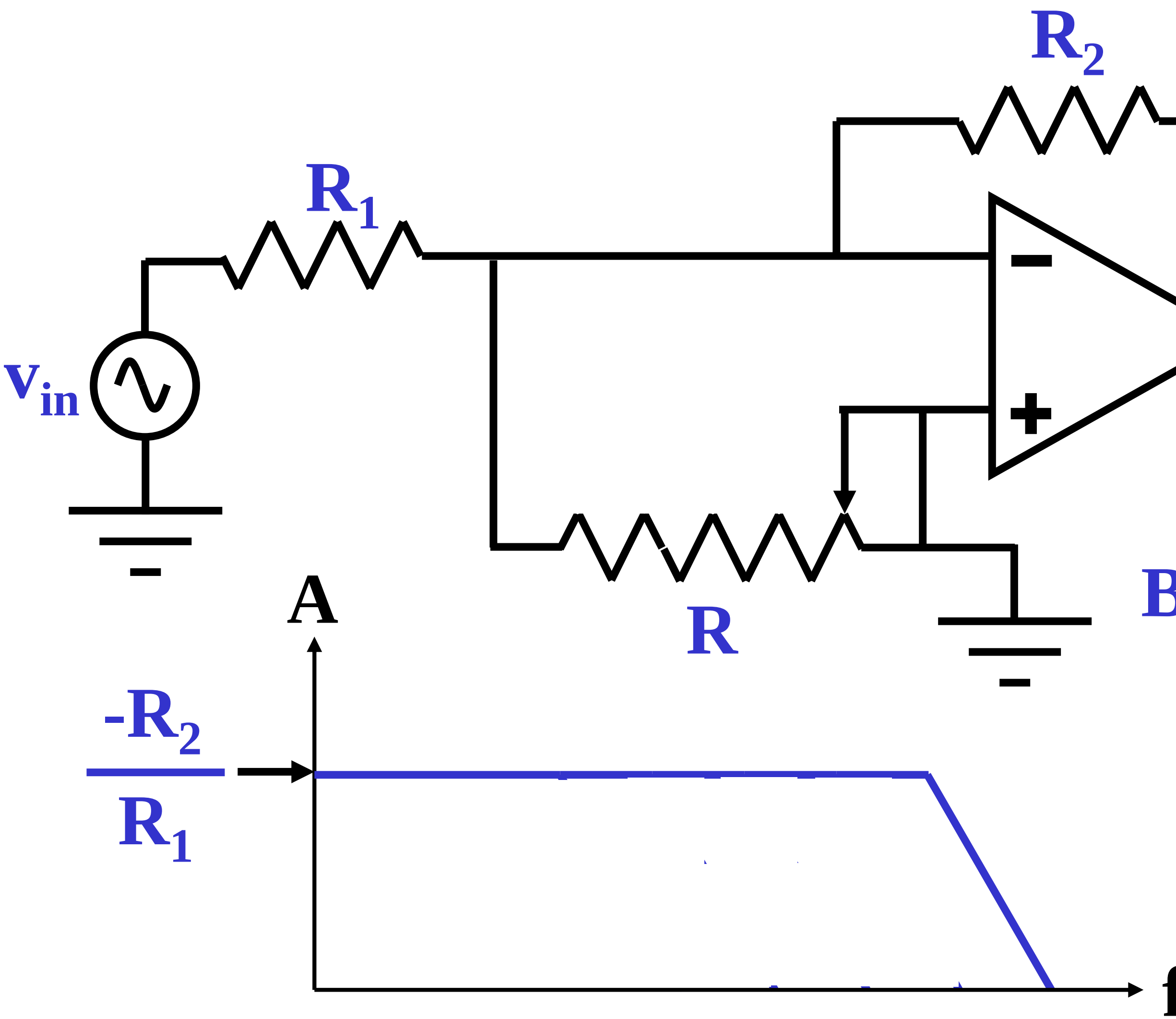


$$A_V = \frac{-R_2}{R_1}$$

$$f_2 = \frac{f_{unity}}{\frac{R_2}{R_1} + 1}$$

$$f_{c1} = \frac{1}{2\pi R_1 C_1} \qquad f_{c2} = \frac{1}{2\pi R_L C_2}$$

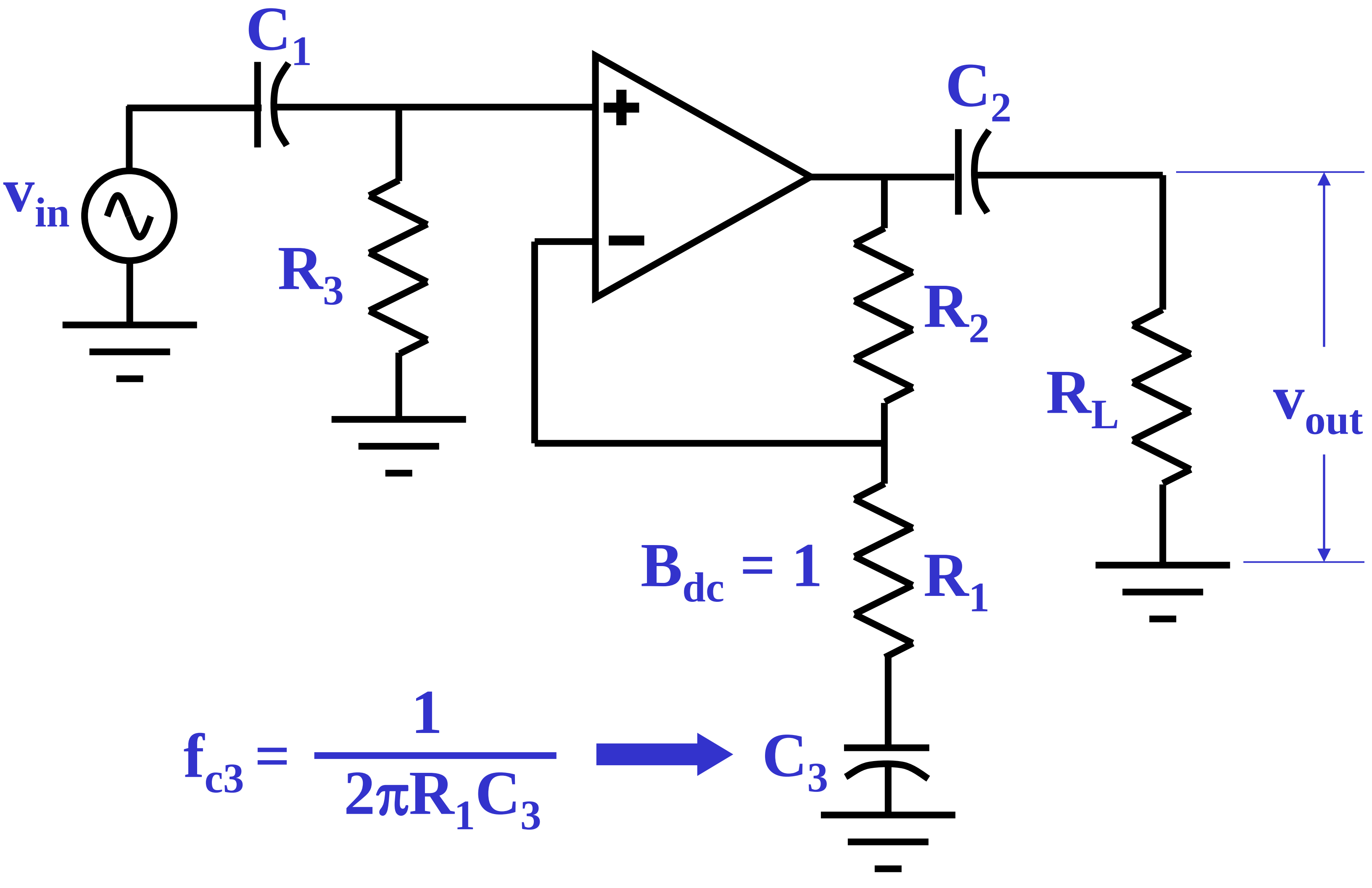
Adjustable bandwidth



$$B = \frac{R_1 \| R}{R_1 \| R + R_2}$$

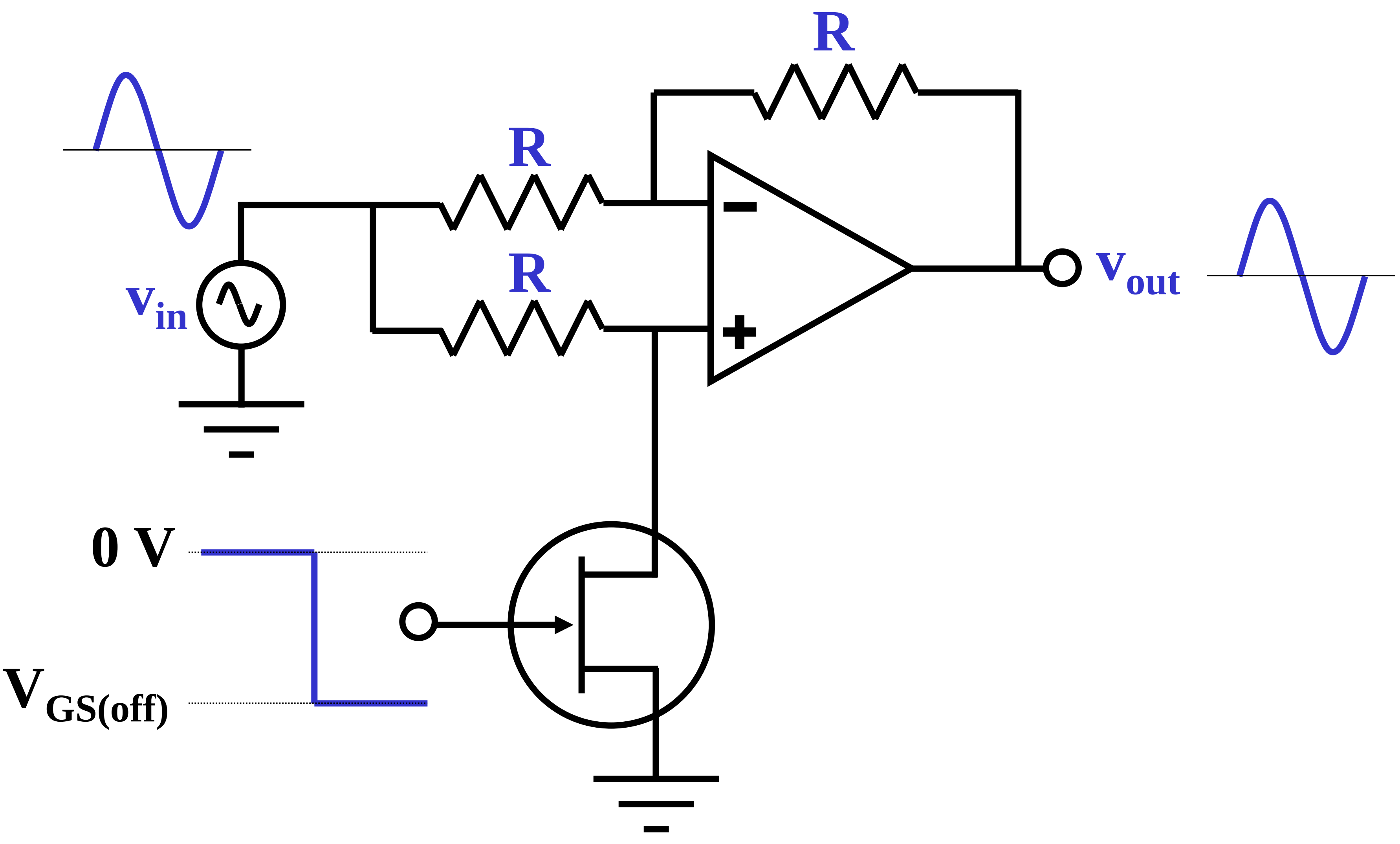
$$f_2 = Bf_{unity}$$

ac coupled noninverting amplifier

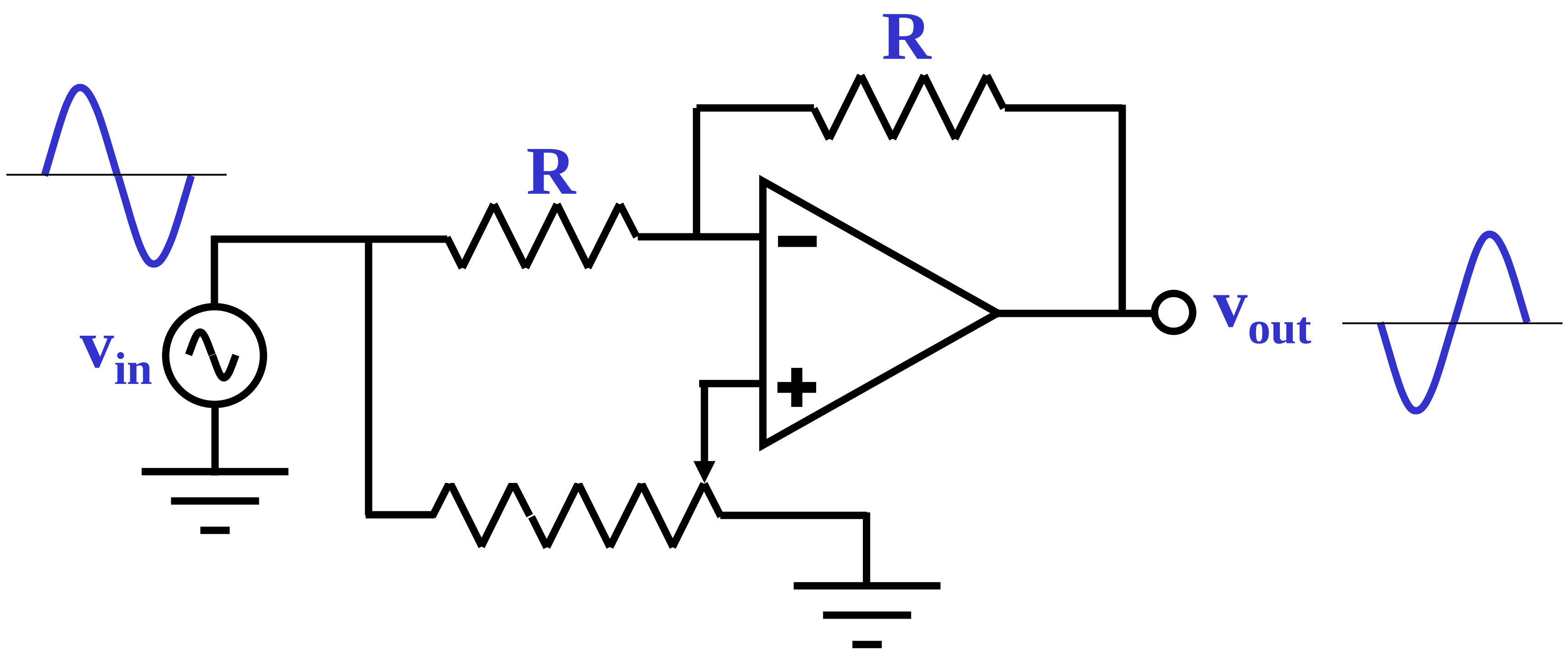


$$f_{c3} = \frac{1}{2\pi R_1 C_3}$$

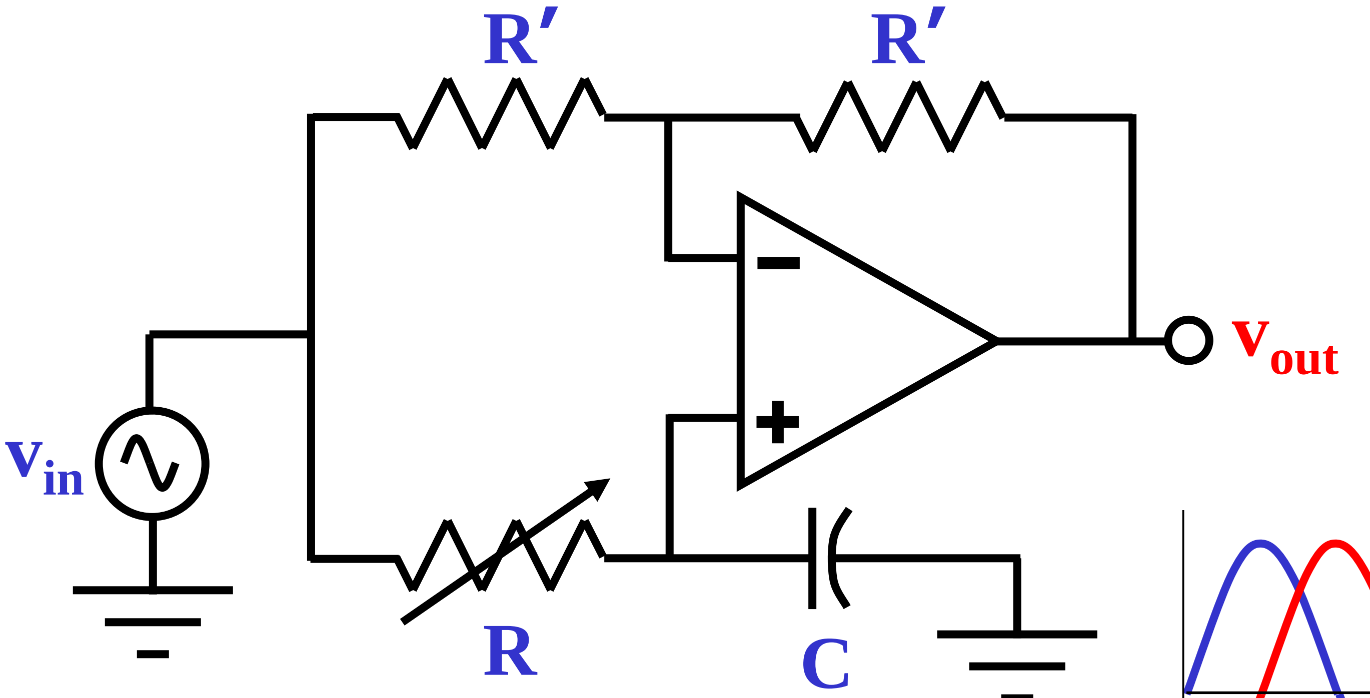
JFET controlled inverter/noninverter

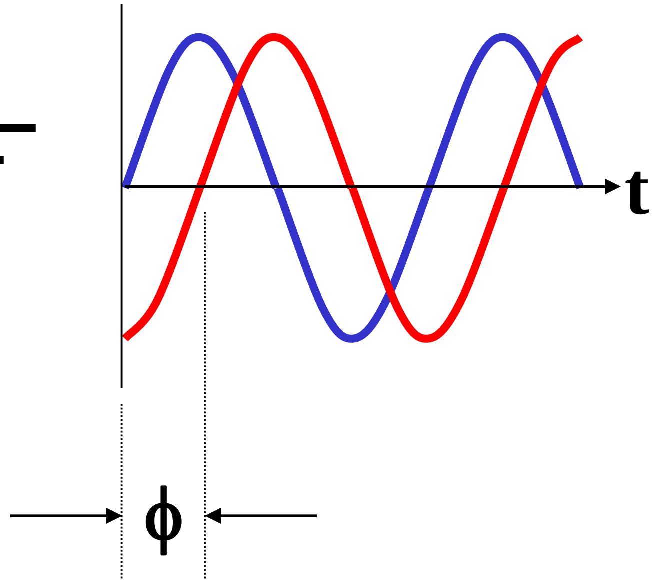


Adjustable gain of ± 1



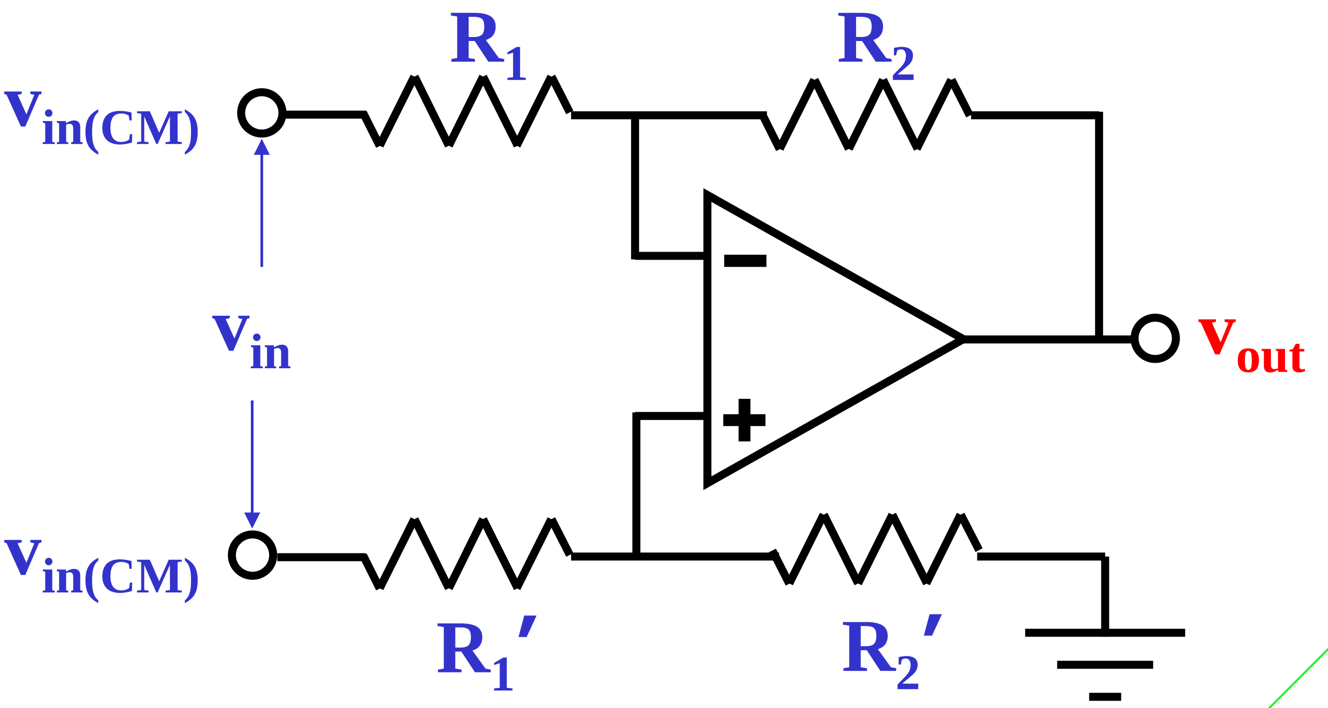
Phase shifter





$\phi = -2 \arctan 2\pi RCf$

Differential amplifier



$$A_V = \frac{-R_2}{R_1}$$

CMRR limiting factors are the op amp itself and the tolerance of the resistors.

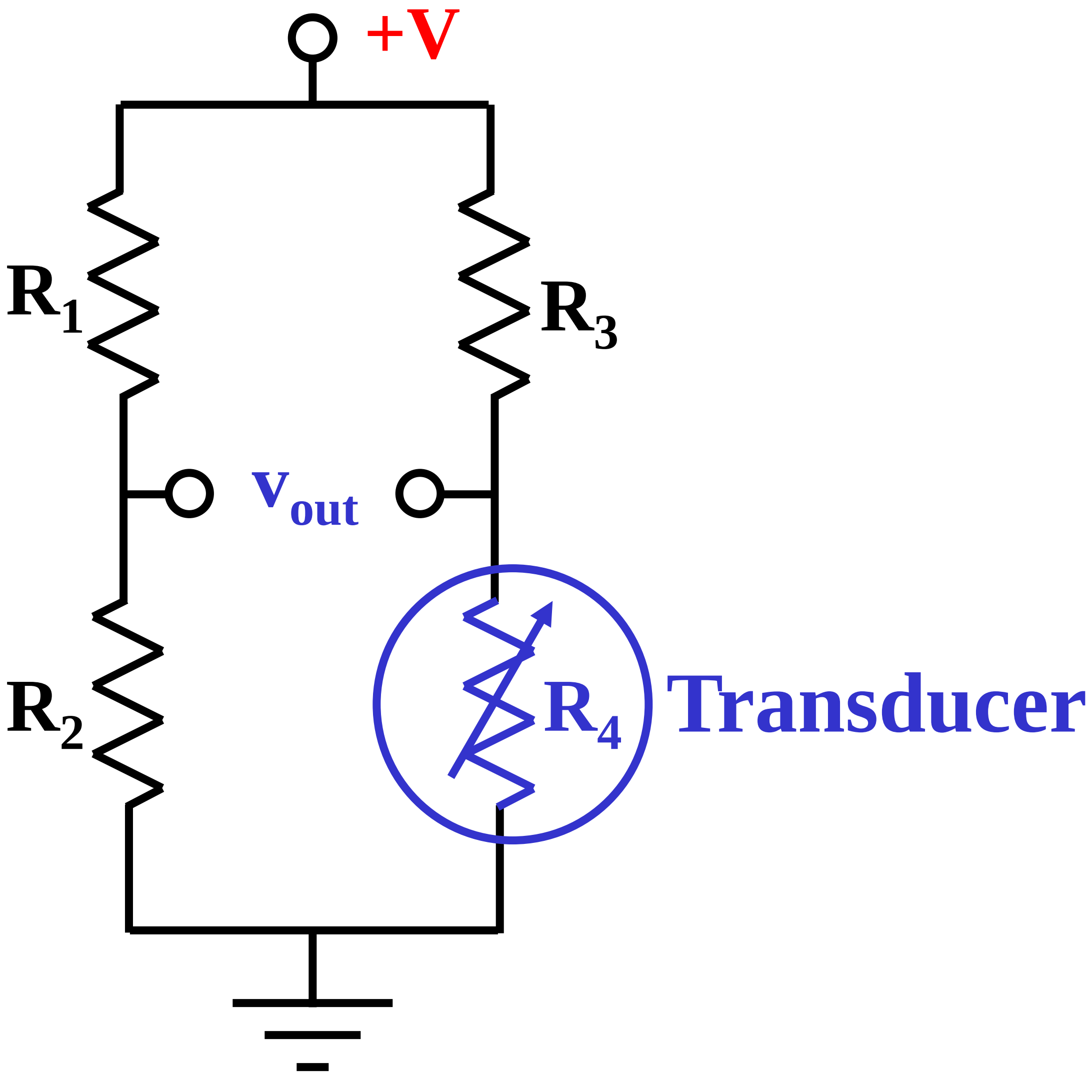
Ideally:

$R_1 = R_1'$

$R_2 = R_2'$

$$\pm 2 \frac{\Delta R}{R} < A_{CM} < \pm 4 \frac{\Delta R}{R}$$

Wheatstone bridge



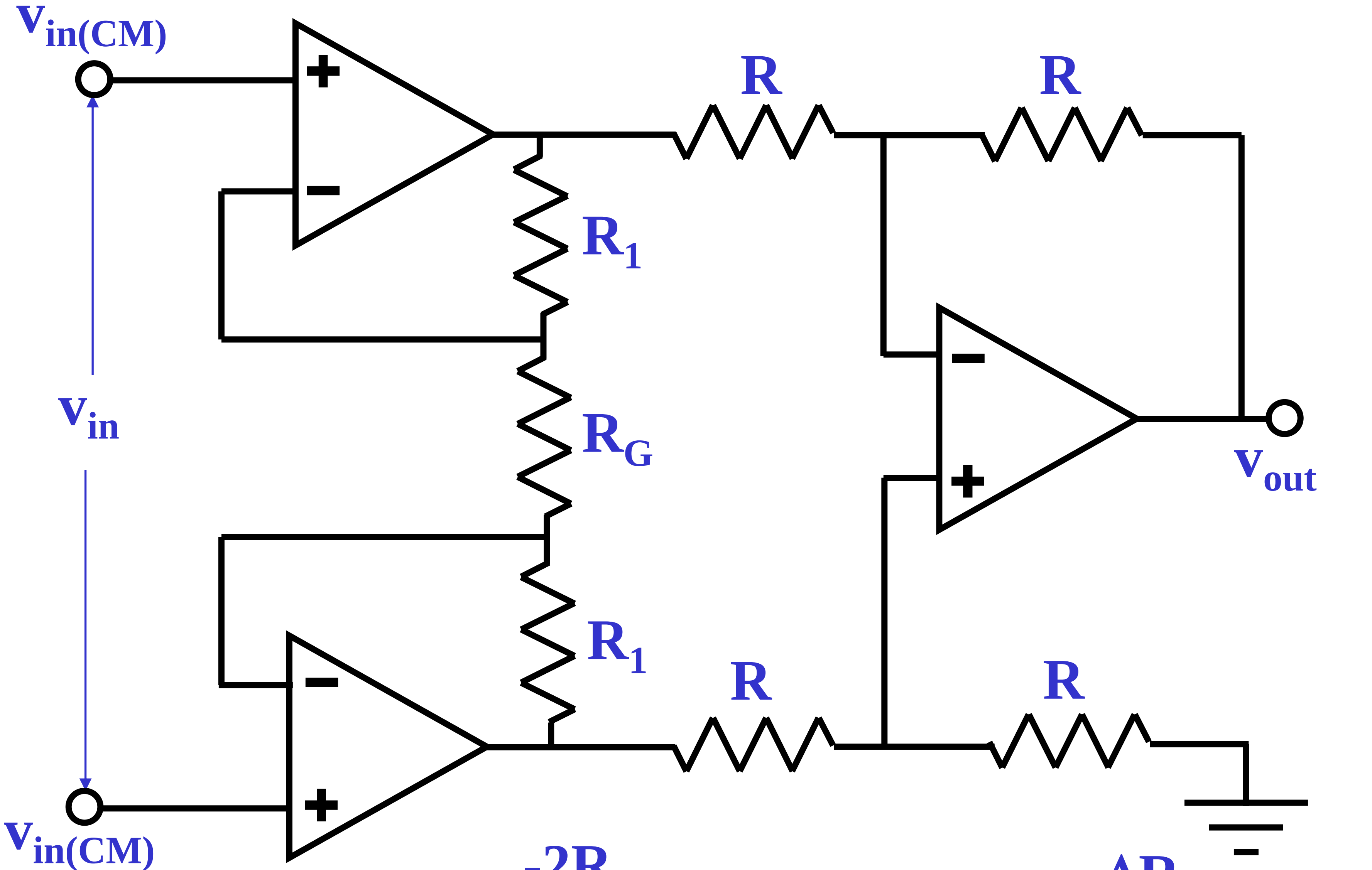
Wheatstone bridge

- The differential output signal is small.
- The common-mode output signal is large.
- Differential amplifiers are a good match.
- Transducers convert nonelectrical quantities into an electrical quantity such as resistance:
  - examples: photoresistor, thermistor, strain gage

Instrumentation amplifiers

- Differential amplifiers optimized for dc performance
- Large differential voltage gain
- High CMRR
- Low input offsets
- Low temperature drift
- High input impedance

Instrumentation amplifier

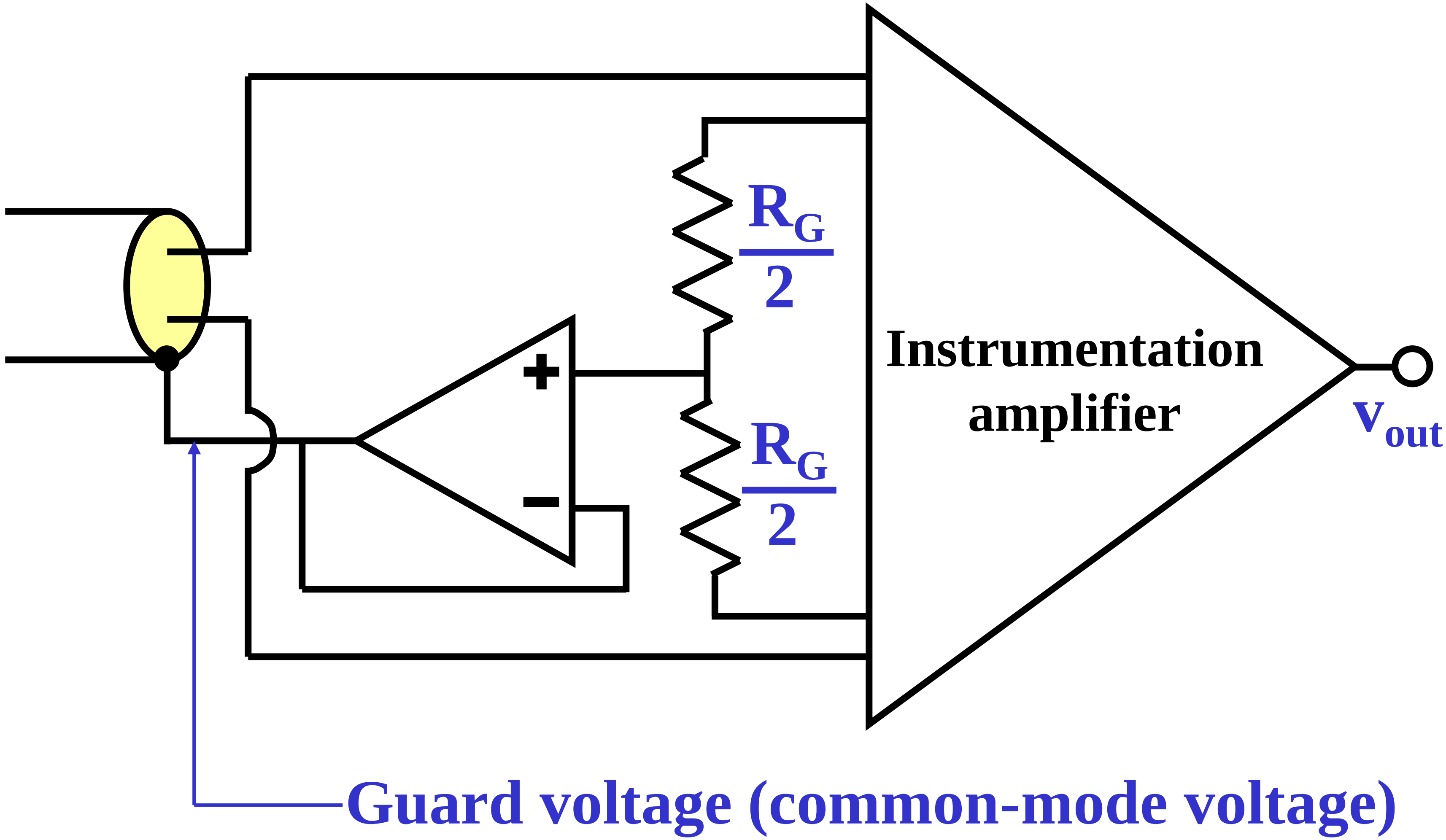


$$A_V = \frac{-2R_1}{R_G} + 1 \qquad A_{CM} = \pm 2\frac{\Delta R}{R}$$

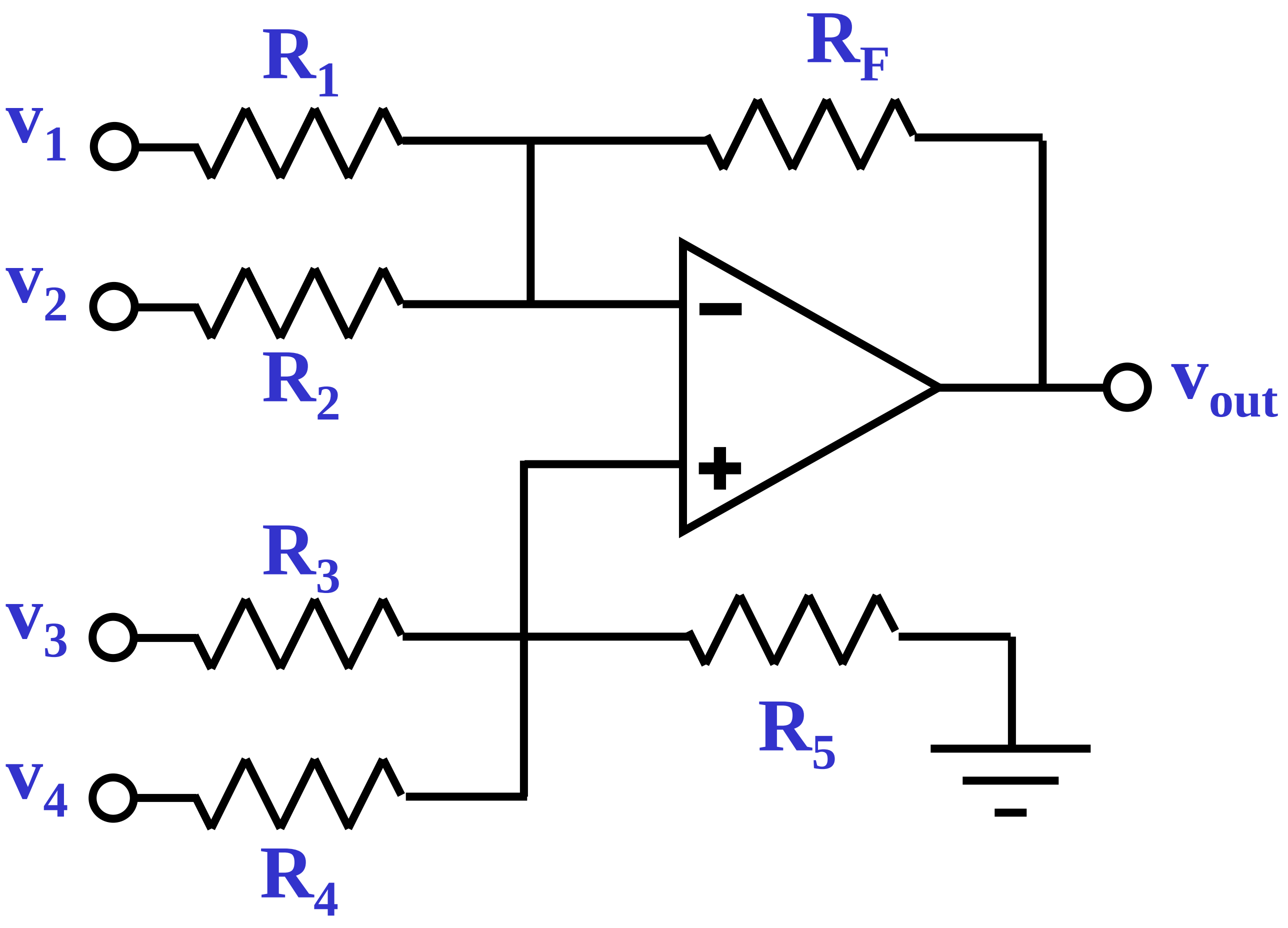
Monolithic instrumentation amplifiers

- **Use laser-trimmed resistors for high performance.**
- **Resistor R_G is external and is selected to set the differential gain.**
- **Resistor R_G can be split into two devices for *guard driving* (bootstrapping the cable shield to the common-mode potential).**

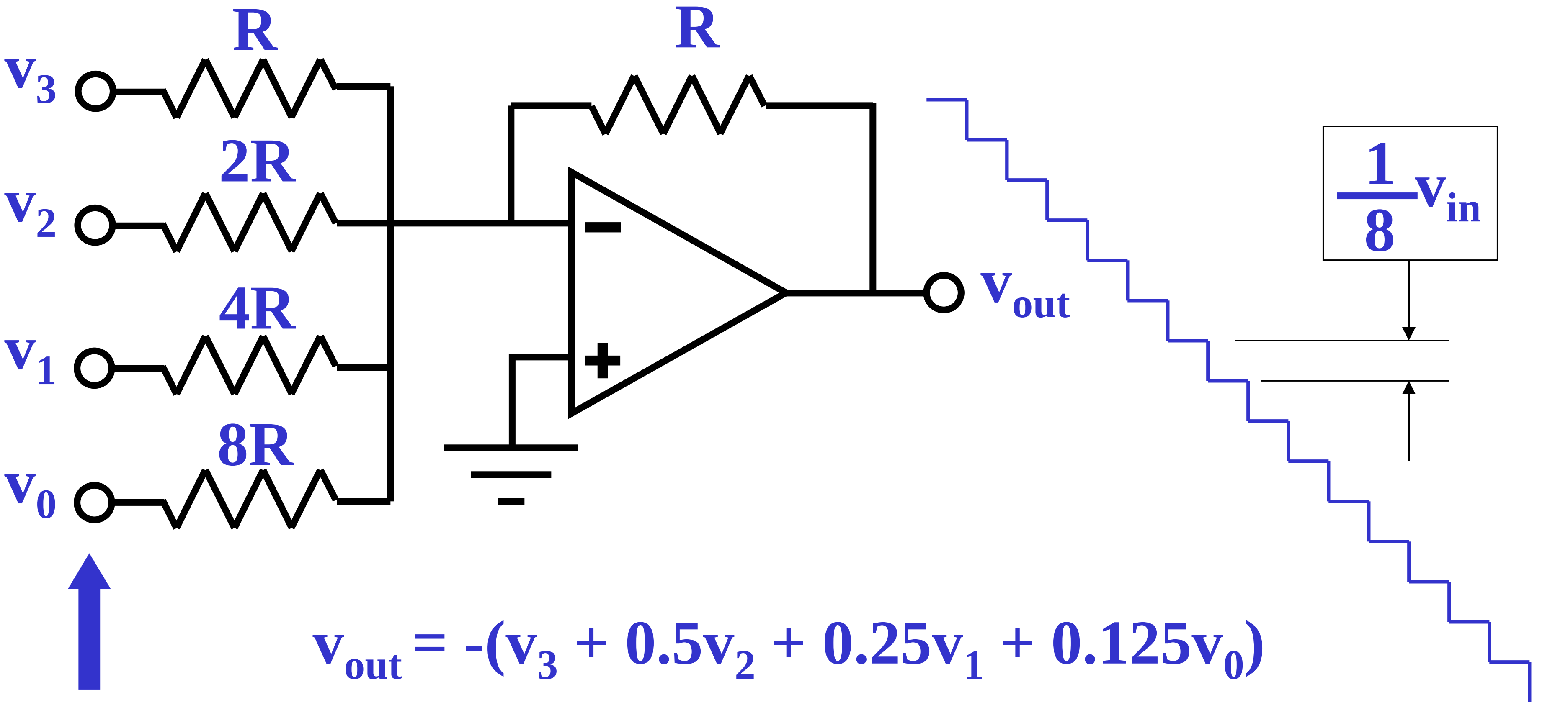
Guard driving



Summing amp with inverting and noninverting inputs



D/A converter

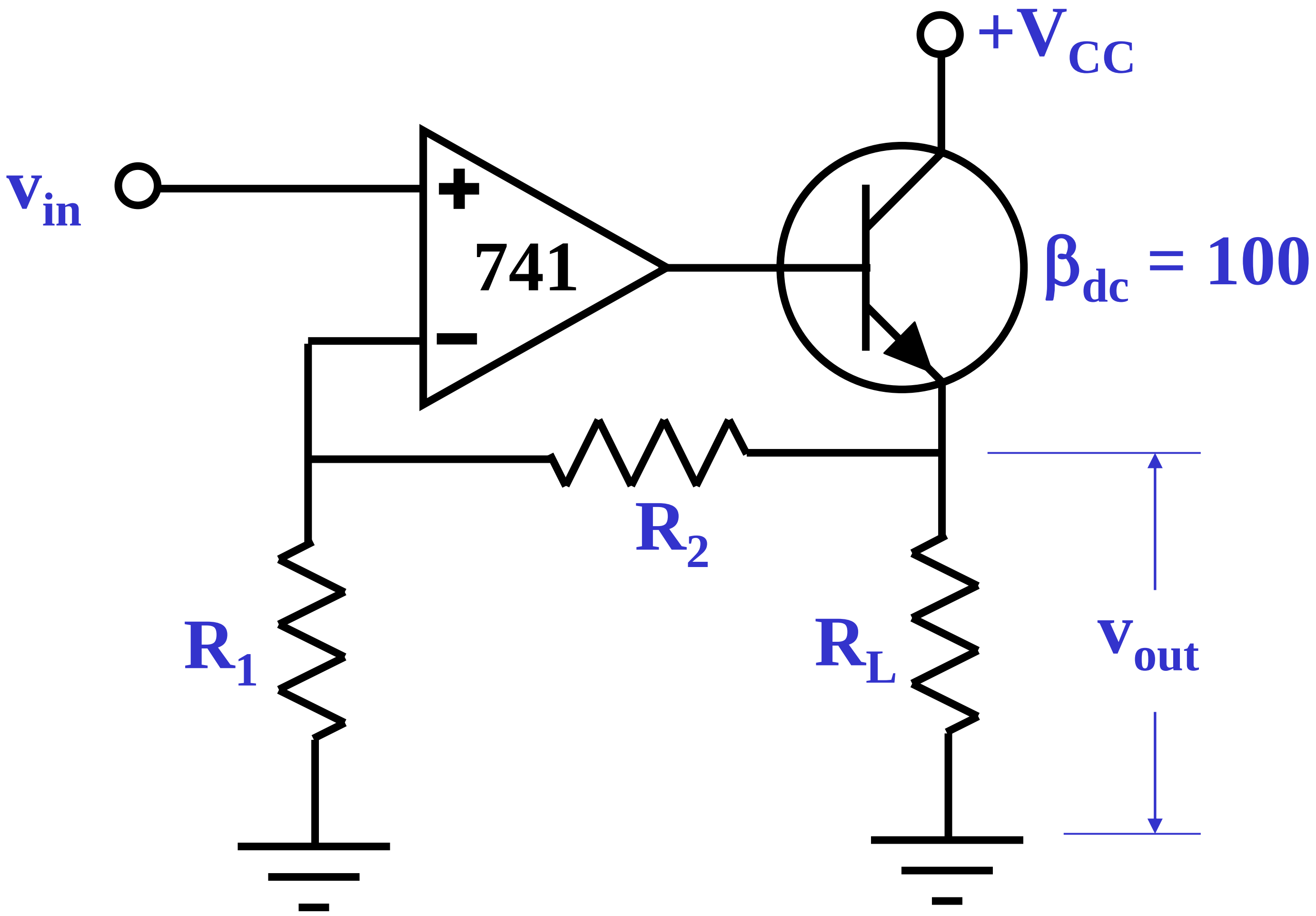


$$v_{out} = -(v_3 + 0.5v_2 + 0.25v_1 + 0.125v_0)$$

N = 4

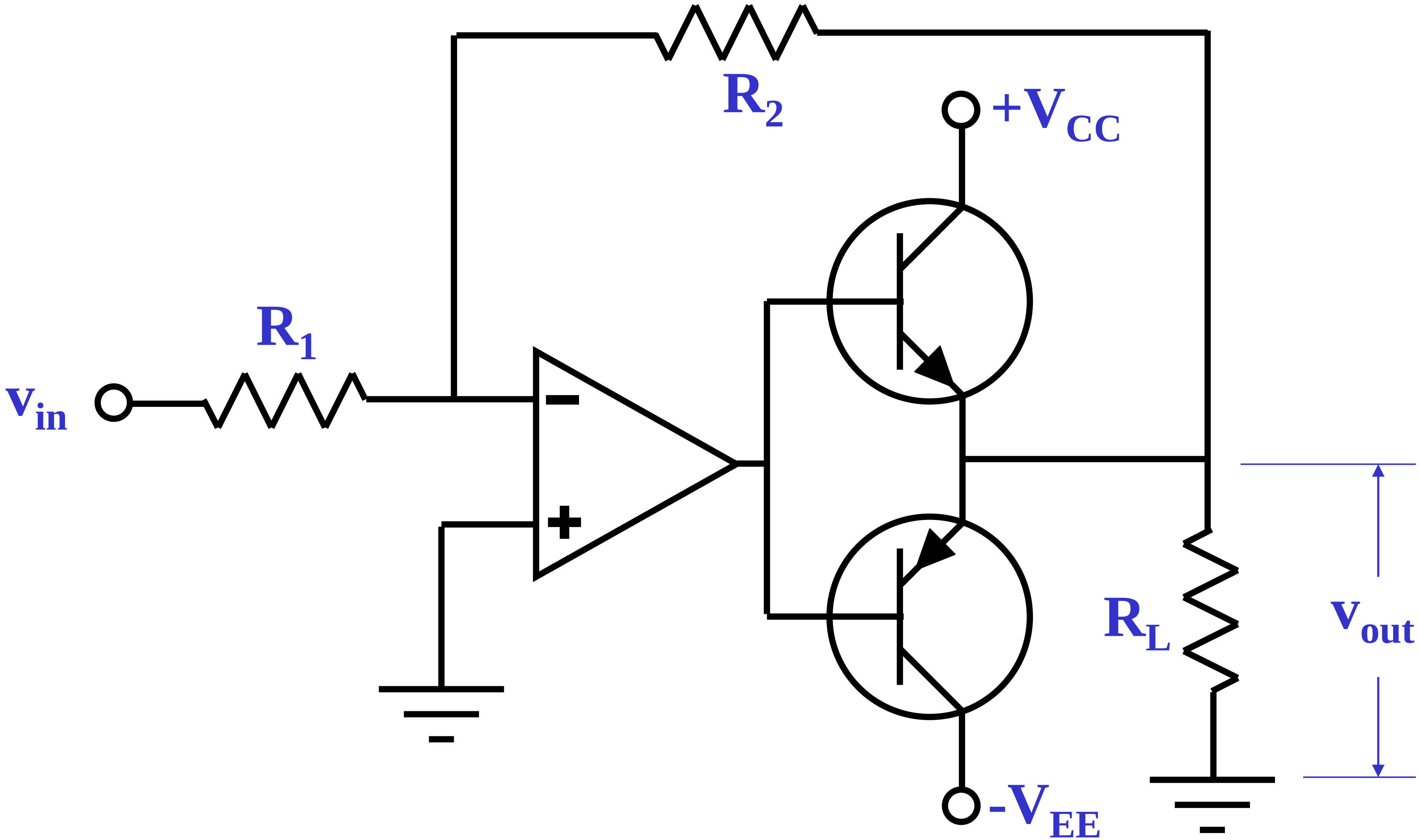
Possible combinations = $2^N = 2^4 = 16$

Unidirectional current booster

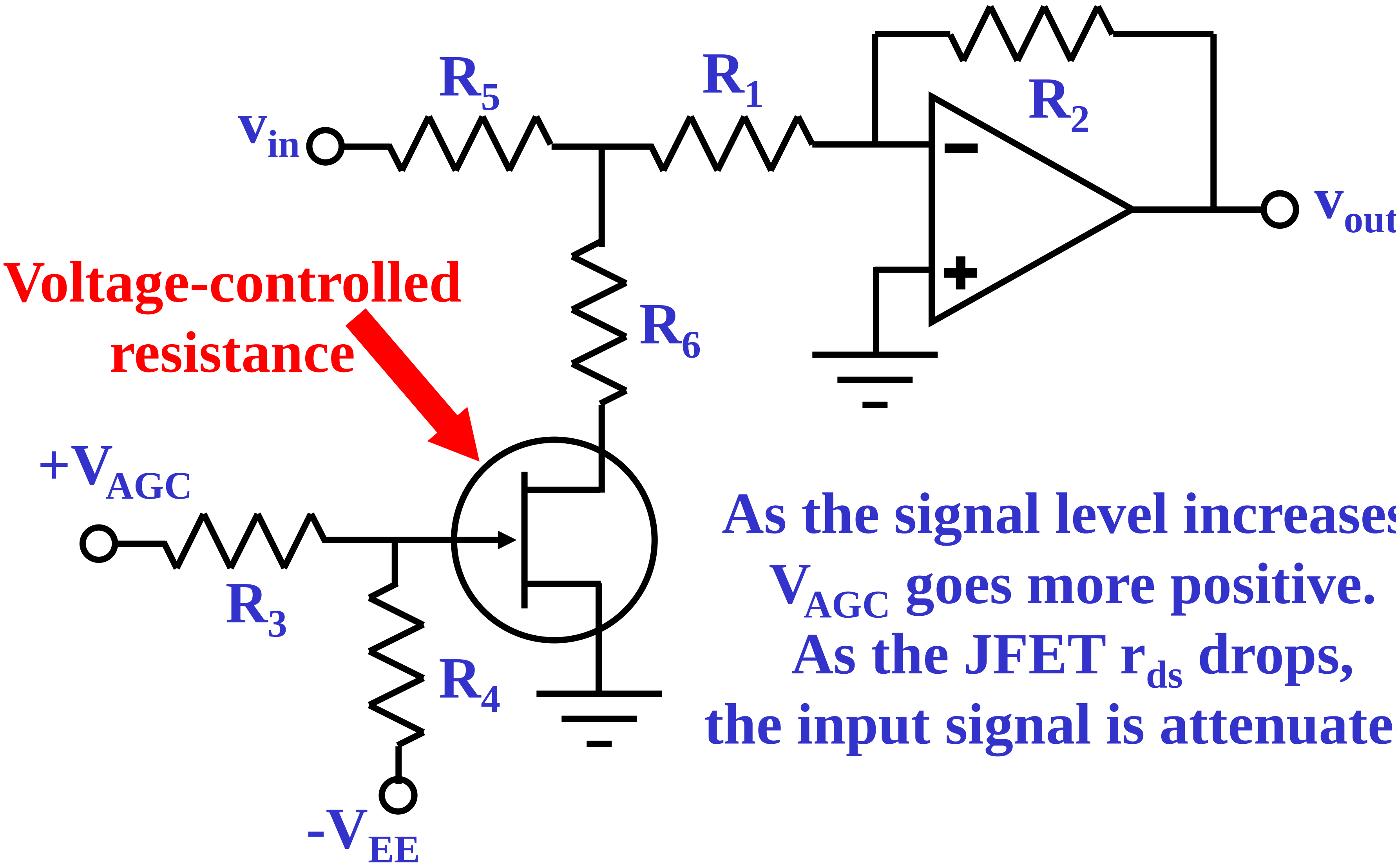


$$I_{max} = \beta_{dc} I_{SC} = 100(25\text{ mA}) = 2.5\text{ A}$$

Bidirectional current booster



AGC circuit



As the signal level increases, V_{AGC} goes more positive. As the JFET r_{ds} drops, the input signal is attenuated.

Single-supply inverting amplifier