

# Operation amplifier

An operational amplifier, or op-amp for short, is a circuit with a variety of uses in analog and digital electronics.

## Op-amp models

### Ideal

The ideal model of an op-amp assumes that the output voltage is proportional to the difference in voltage between the two input nodes, and that it responds instantly to changes in input voltages. Additionally, the input resistance is infinite (no current flows into or out of the input terminals) and the output resistance is zero (ideal voltage source, can source or sink as much current as needed to maintain the output voltage).

$$v_o = A(v_+ - v_-)$$

where  $v_+$  is the noninverting input,  $v_-$  is the inverting input, and  $v_o$  is the output voltage.  $A$  is the open-loop gain.

### Single-pole model

The single-pole model adds a pole to the ideal op-amp model, limiting its bandwidth.

$$\tau \frac{dv_o}{dt} + v_o = A(v_+ - v_-)$$

where  $\tau$  is the time constant of the pole of the transfer function. As  $\tau \rightarrow \infty$ , this equation becomes equivalent to the ideal model shown above.

## Op-amp approximations

## Op-amp circuits

## Implementation

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