Operational Amplifiers

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Early operational amplifiers (op-amps) were used primarily to perform mathematical operations such as,

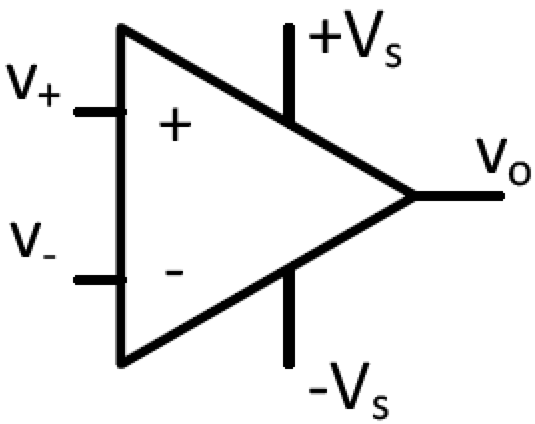
Addition
Subtraction
Integration
Differentiation

thus the term **operational.**

These early devices were constructed with vacuum tubes and worked with high voltages.

Today’s op-amps are linear integrated circuits (ICs) that use relatively low dc supply voltages and are reliable and inexpensive.

Specialized circuit made up of transistors, resistors, and capacitors fabricated on an integrated chip

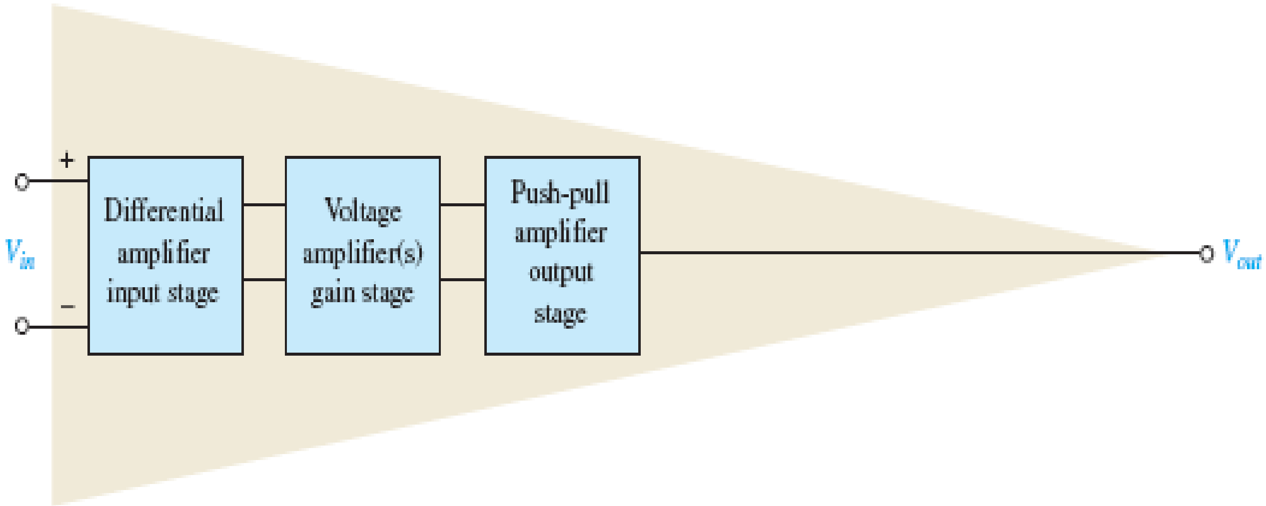


Uses:

- Amplifiers
- Active Filters
- Analog Computers

The Practical Op-Amp

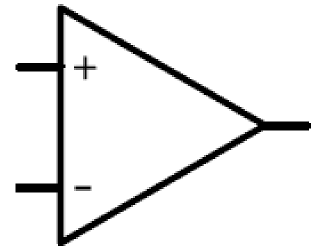
Characteristics of a practical op-amp are
very high voltage gain,
very high input impedance, and
very low output impedance.

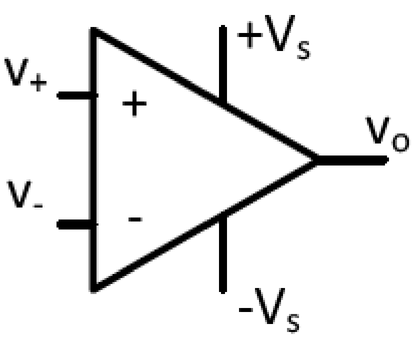


Op-Amps in Circuits

- Active Element: has its own power supply
- Symbol ignores the +/- V_s in the symbol since it does not affect circuit behavior

Symbol:

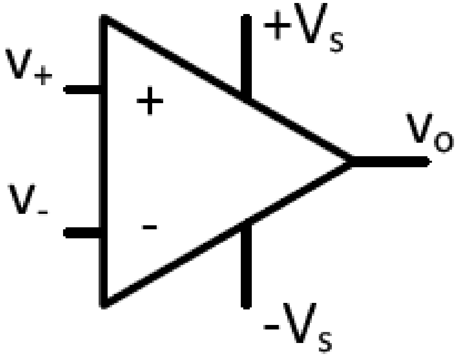




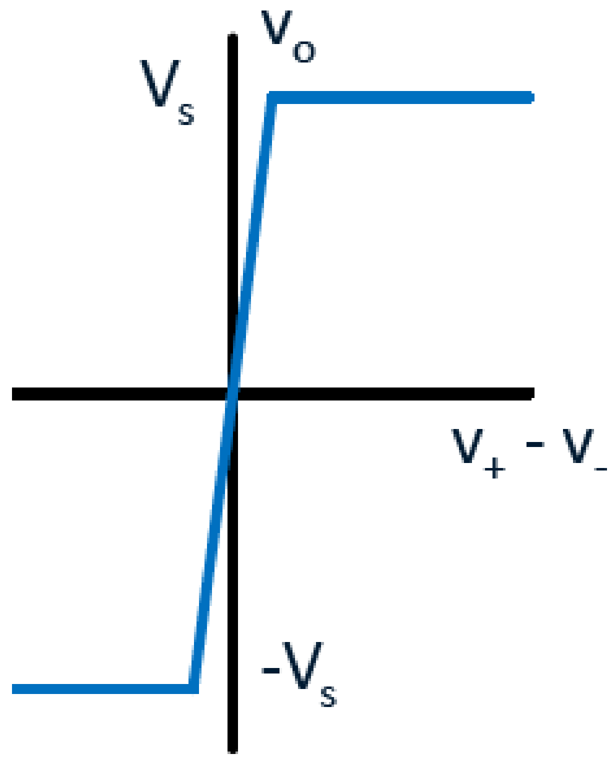
V_s = 10V, 15V

Signal	PIN
V_-	2
V_+	3
$-V_s$	4
V_o	6
$+V_s$	7

Open Loop Behavior



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



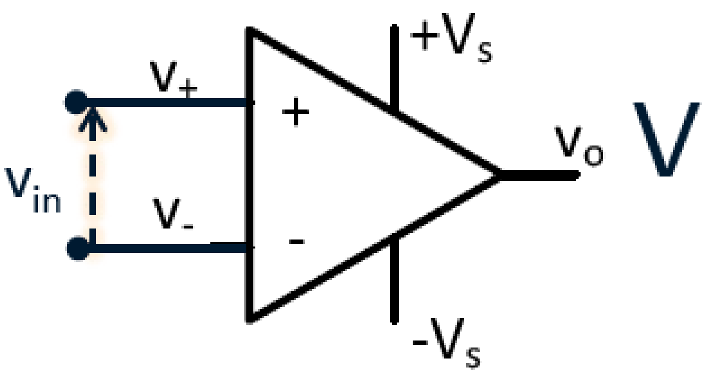
The inherent open-loop voltage gain of a typical op-amp is
very high (usually greater than 100,000).
Therefore, an extremely small input voltage drives the op-amp into its saturated output states.

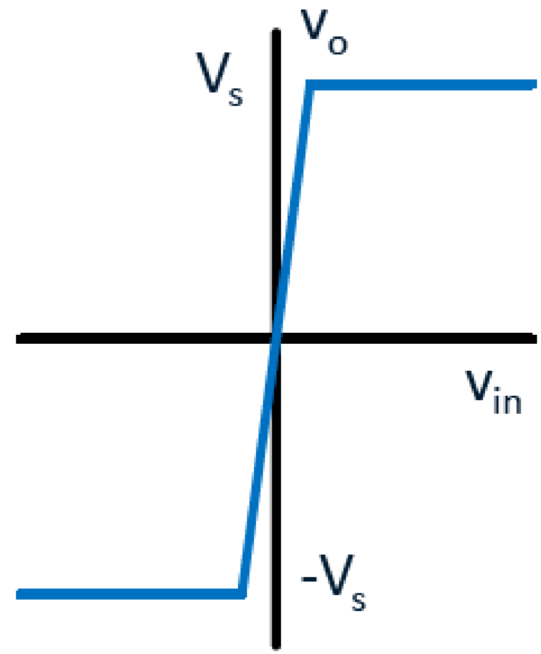
In fact, even the input offset voltage of the op-amp can drive it into saturation.
For example, assume V_{IN} 1 mV and A_{ol} 100,000.

Then,

$$V_{\mathrm{IN}}A_{ol} = (1\ \mathrm{mV})(100{,}000) = 100\ \mathrm{V}$$

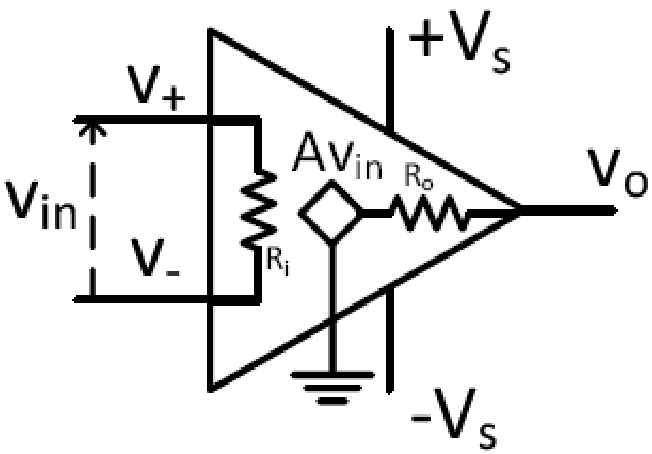
Comparator Circuit

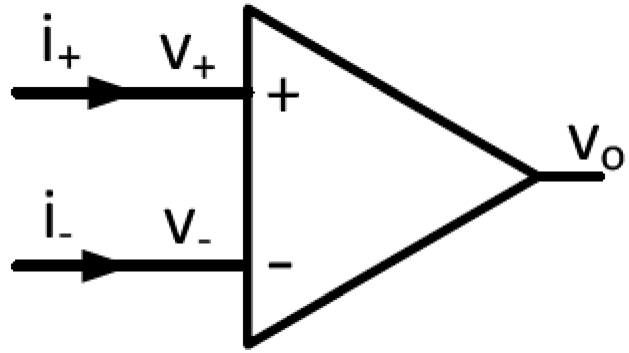




$$V_o = \begin{cases} V_s & \text{if } v_{in} > 0 \\ -V_s & \text{if } v_{in} < 0 \end{cases}$$

Ideal Op-Amp Behavior



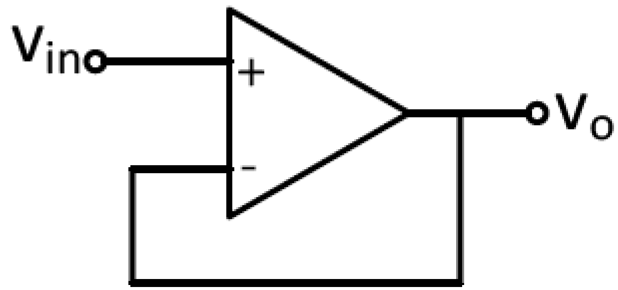


$$\boxed{\begin{array}{l} i_+ = i_- = 0 \\ v_+ - v_- = 0 \end{array}}$$

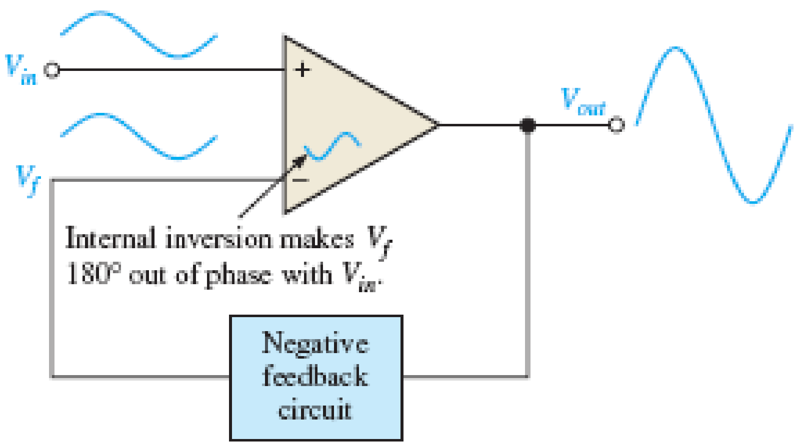
Negative Feedback

Buffer circuit

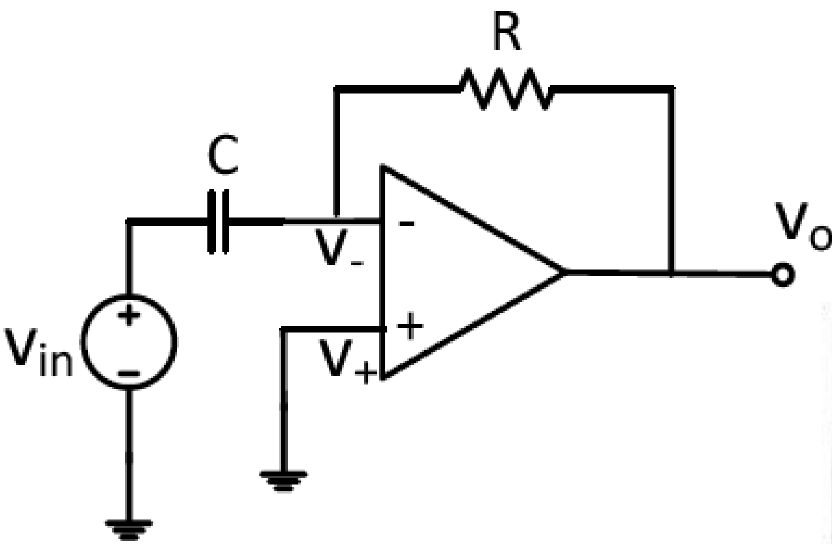
Use to boost the power without changing the voltage waveform.



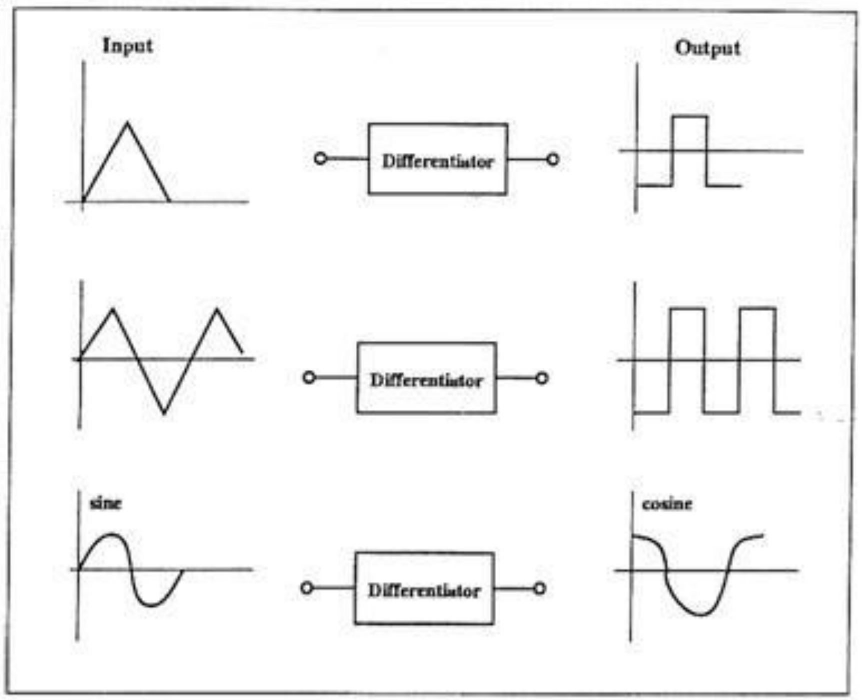
$$\boxed{V_{in} = V_o}$$



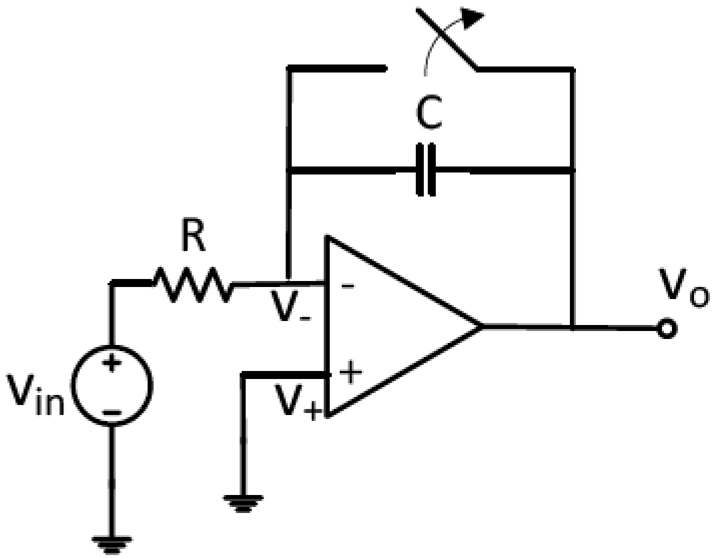
Differentiator Circuit



$$V_o = -RC\frac{dV_{in}}{dt}$$



Integrator Circuit



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