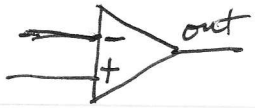
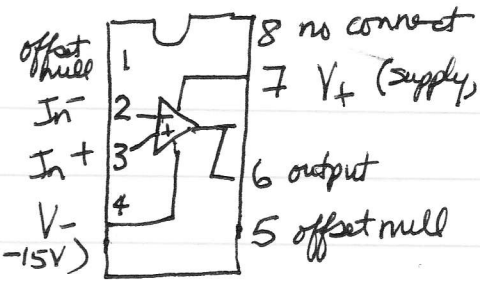
Op-amps

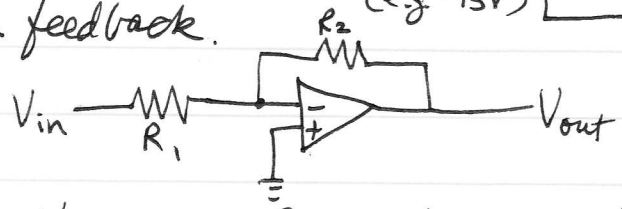


typical 8-pin DIP



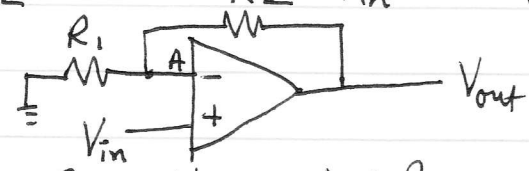
Rules
1. Op-amp makes the 2 input voltages the same.
2. Inputs draw no current.
3. Use with feedback.

Inverting amplifier



$$\frac{V_{in}}{R_1} = -\frac{V_{out}}{R_2}, \qquad \text{Gain} = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}$$

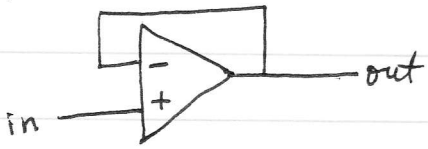
Non-inverting amplifier



$V_{in} = V_A$

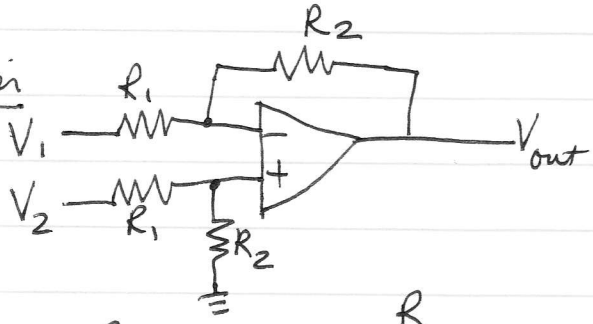
$$V_A = \frac{V_{out} R_1}{R_1 + R_2}, \qquad \text{Gain} = \frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$

Follower



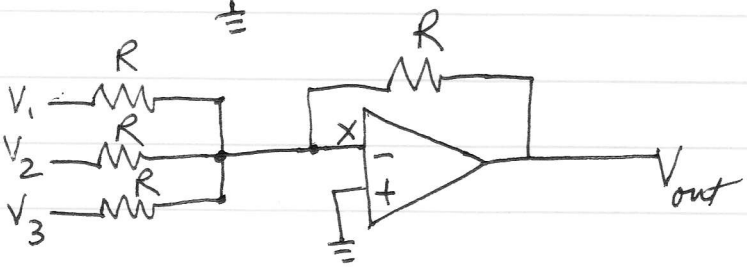
unity gain = buffer (isolating properties)
high input impedance, low output impedance

Differential amplifier



$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

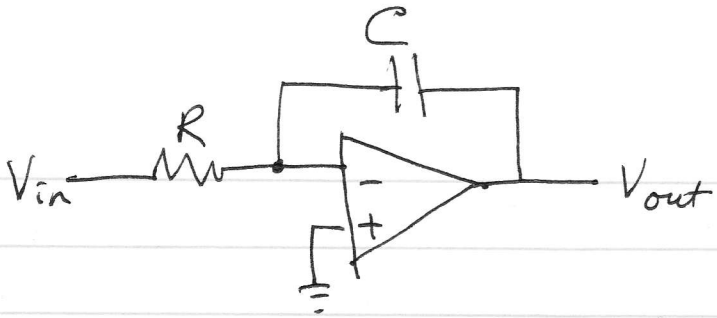
Summing amplifier



X is virtual ground.

$$\text{Input current} = \frac{V_1}{R} + \frac{V_2}{R} + \frac{V_3}{R} = \text{output current} = -\frac{V_{out}}{R}, \qquad V_{out} = -(V_1 + V_2 + V_3)$$

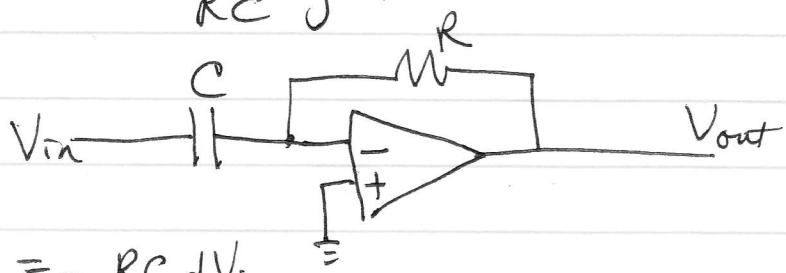
Integrator
active
(low-pass filter)



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

$$V_{out} = -\frac{1}{RC}\int V_{in}\,dt + \text{constant}$$

Differentiator
active
(high-pass filter)



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