EE 423: Communication Electronics
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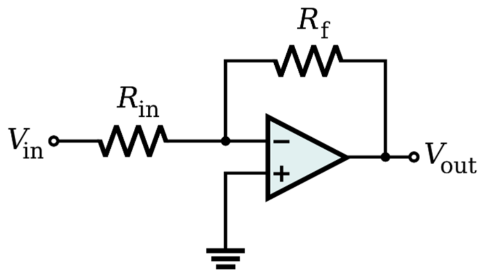
Fundamental Operational Amplifier (Op-Amp) Circuits

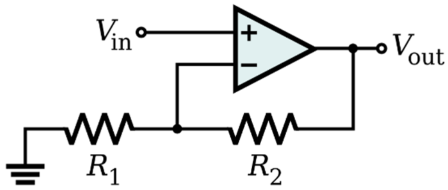
Inverting Amplifier
Notice that the input is fed to the inverting (negative) terminal of the Op-Amp. An inverted sinusoidal output signal has a 180° phase shift with the input signal.

$$V_{\text{out}} = \frac{-R_f}{R_{\text{in}}} V_{\text{in}}$$



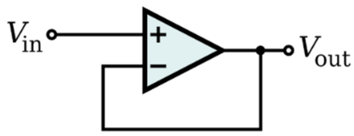
Non-inverting Amplifier
Notice that the input is fed to the non-inverting (positive) terminal of the Op-Amp.

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



Voltage Follower (unity buffer amplifier)
This circuit can be thought of as a non-inverting amplifier where $R_2 = 0\ \Omega$ and $R_1 = \infty\ \Omega$.

$$V_{\text{out}} = V_{\text{in}}$$



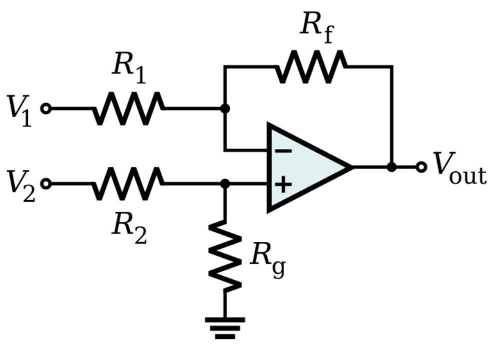
Differential Amplifier (difference amplifier) (subtraction)
Amplifies the voltage difference between the two inputs.

When

$$\frac{R_f}{R_1} = \frac{R_g}{R_2}$$

We have

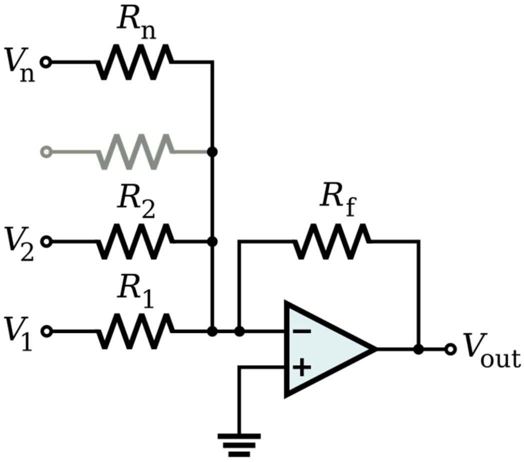
$$V_{\text{out}} = \frac{R_f}{R_1}(V_2 - V_1)$$



Summing Amplifier (Adder)

This circuit can have two, three or any number n of input signals. It can also be re-designed with non-inverting amplifier.

$$V_{\text{out}} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots + \frac{V_n}{R_n}\right)$$

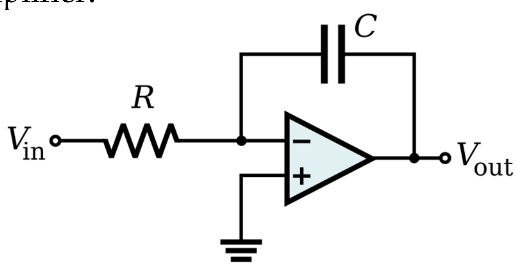


Inverting Integrator

Can also be designed with non-inverting amplifier.

$$V_{\text{out}}(t_1) = V_{\text{out}}(t_0) - \frac{1}{RC}\int_{t_0}^{t_1} V_{\text{in}}(t)\,dt$$

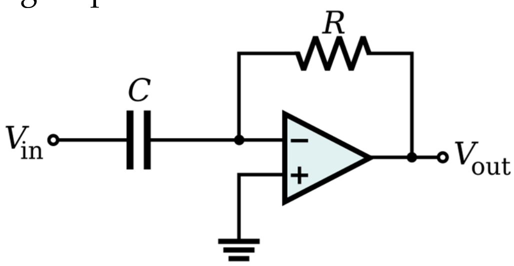
$$V_{\text{out}}(\omega) = \frac{-1}{j\omega RC} V_{\text{in}}(\omega)$$



Inverting Differentiator

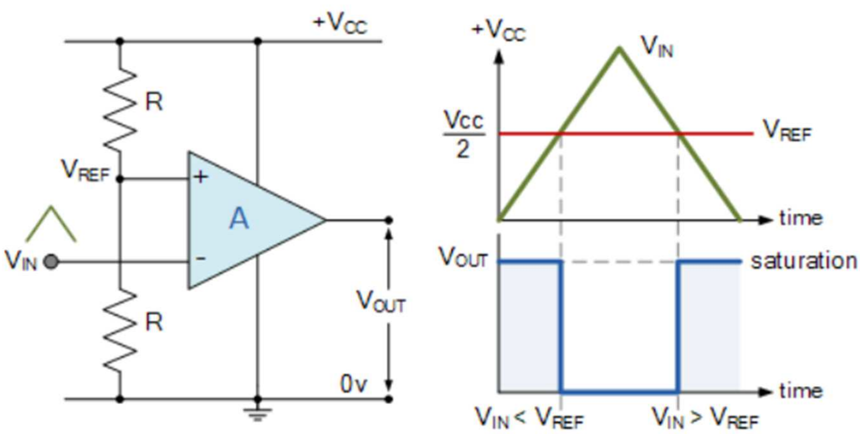
Can also be designed with non-inverting amplifier.

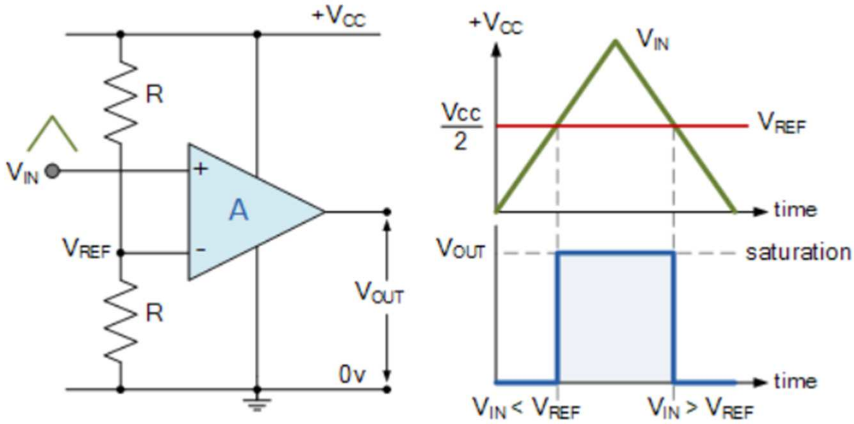
$$V_{\text{out}} = -RC\,\frac{dV_{\text{in}}(t)}{dt}$$



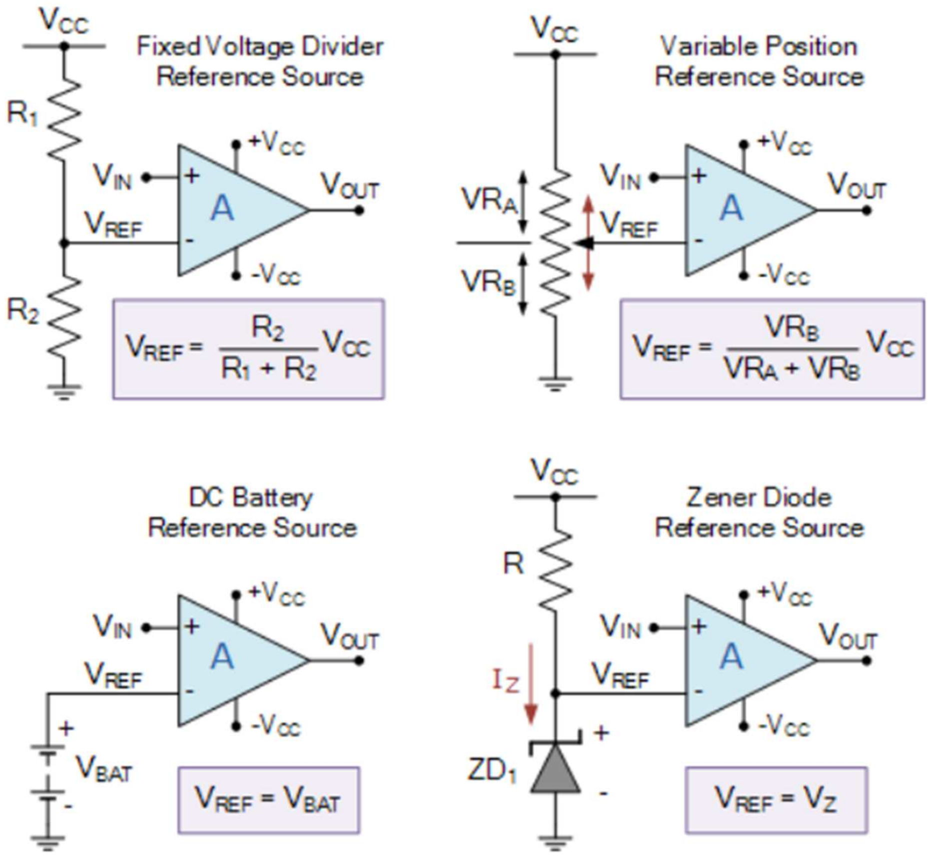
Comparator

Can be designed as inverting or non-inverting comparator as shown below:





The reference voltage for the comparator can also be generated using techniques other than a simple voltage divider as shown below:



There are also many other possibilities not shown here.