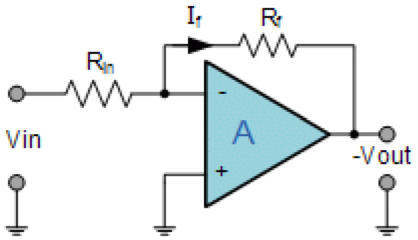


Operational Amplifiers Summary

Operational Amplifiers summary sheet defining the basic characteristics of the various operational amplifier configurations

We can conclude our section and look at **Operational Amplifiers** with the following summary of the different types of Op-amp circuits and their different configurations discussed throughout this op-amp tutorial section.

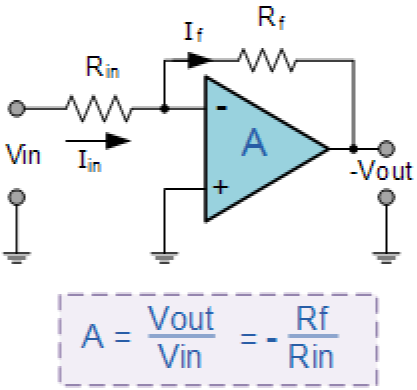
Operational Amplifier General Conditions

- The **Operational Amplifier**, or **Op-amp** as it is most commonly called, can be an ideal amplifier with infinite Gain and Bandwidth when used in the Open-loop mode with typical DC gains of well over 100,000 or 100dB.
- The basic Op-amp construction is of a 3-terminal device, with 2-inputs and 1-output, (excluding power connections).
- An Operational Amplifier operates from either a dual positive (+V) and an corresponding negative (-V) supply, or they can operate from a single DC supply voltage.
- The two main laws associated with the operational amplifier are that it has an infinite input impedance, ($Z = \infty$) resulting in "**No current flowing into either of its two inputs**" and zero input offset voltage $V1 = V2$.
- An operational amplifier also has zero output impedance, ($Z = 0$).
- Op-amps sense the difference between the voltage signals applied to their two input terminals and then multiply it by some pre-determined Gain, (A).
- This Gain, (A) is often referred to as the amplifiers "Open-loop Gain".
- Closing the open loop by connecting a resistive or reactive component between the output and one input terminal of the op-amp greatly reduces and controls this open-loop gain.

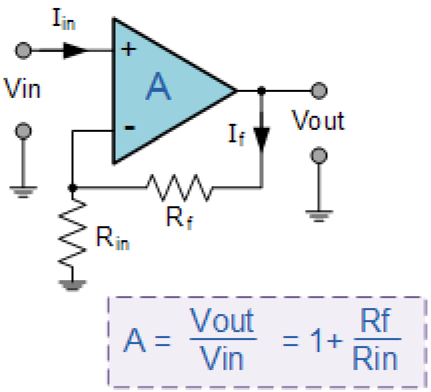
- Op-amps can be connected into two basic configurations, **Inverting** and **Non-inverting**.

The Two Basic Operational Amplifier Circuits

Inverting Op-amp



Non-inverting Op-amp



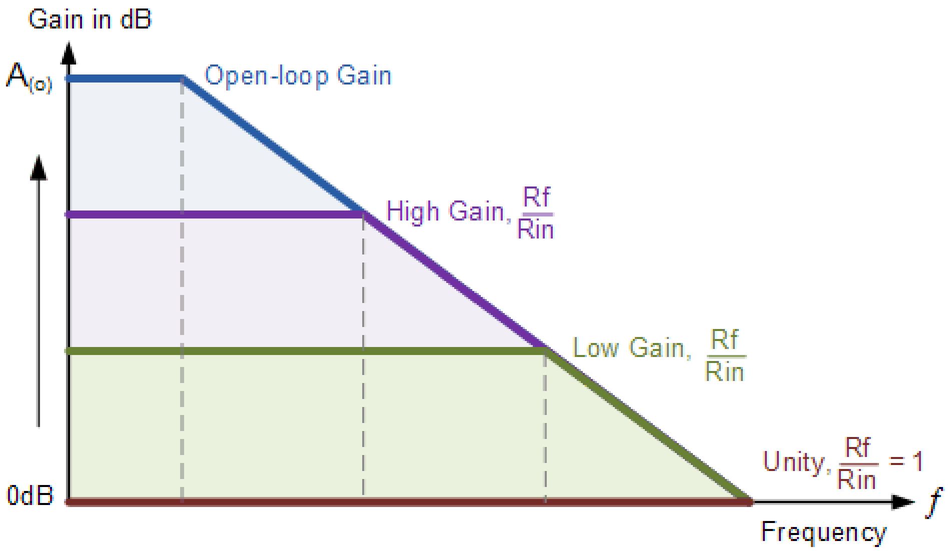
For **negative feedback**, were the fed-back voltage is in “anti-phase” to the input the overall gain of the amplifier is reduced.

For **positive feedback**, were the fed-back voltage is in “Phase” with the input the overall gain of the amplifier is increased.

By connecting the output directly back to the negative input terminal, 100% feedback is achieved resulting in a **Voltage Follower** (buffer) circuit with a constant gain of 1 (Unity).

Changing the fixed feedback resistor (Rf) for a Potentiometer, the circuit will have Adjustable Gain.

Operational Amplifier Gain



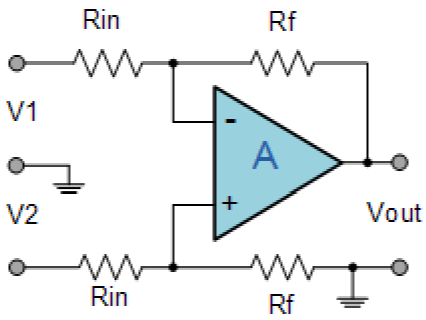
The Open-loop gain called the **Gain Bandwidth Product**, or (GBP) can be very high and is a measure of how good an amplifier is.

Very high GBP makes an operational amplifier circuit unstable as a micro volt input signal causes the output voltage to swing into saturation.

By the use of a suitable feedback resistor, (R*f*) the overall gain of the amplifier can be accurately controlled.

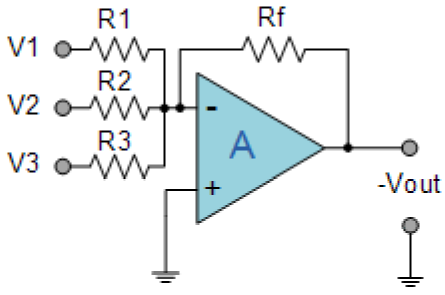
Differential and Summing Amplifiers

Differential Op-amp



$$V_{out} = \frac{R_f}{R_{in}}(V2 - V1)$$

Summing Op-amp



$$V_{out} = -\left(\frac{R_f}{R1}V1 + \frac{R_f}{R2}V2 + \frac{R_f}{R3}V3\right)$$

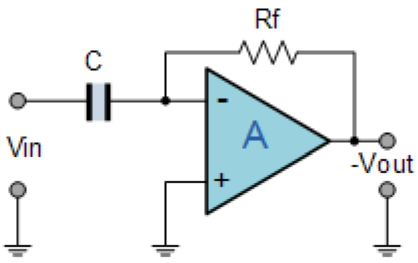
By adding more input resistors to either the inverting or non-inverting inputs **Voltage Adders** or **Summers** can be made.

Voltage follower op-amps can be added to the inputs of Differential amplifiers to produce high impedance Instrumentation amplifiers.

The **Differential Amplifier** produces an output that is proportional to the difference between the two input voltages.

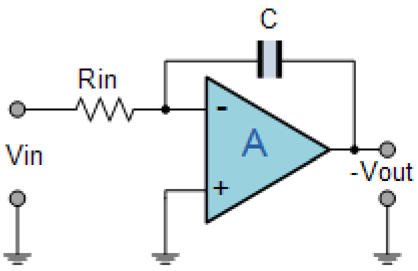
Differentiator and Integrator Operational Amplifier Circuits

Differentiator Op-amp



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

Integrator Op-amp



$$V_{out} = -\frac{1}{j\omega R_{in} C} V_{in}$$

The **Integrator Amplifier** produces an output that is the mathematical operation of integration.

The **Differentiator Amplifier** produces an output that is the mathematical operation of differentiation.

Both the Integrator and Differentiator Amplifiers have a resistor and capacitor connected across the op-amp and are affected by its RC time constant.

In their basic form, Differentiator Amplifiers suffer from instability and noise but additional components can be added to reduce the overall closed-loop gain.