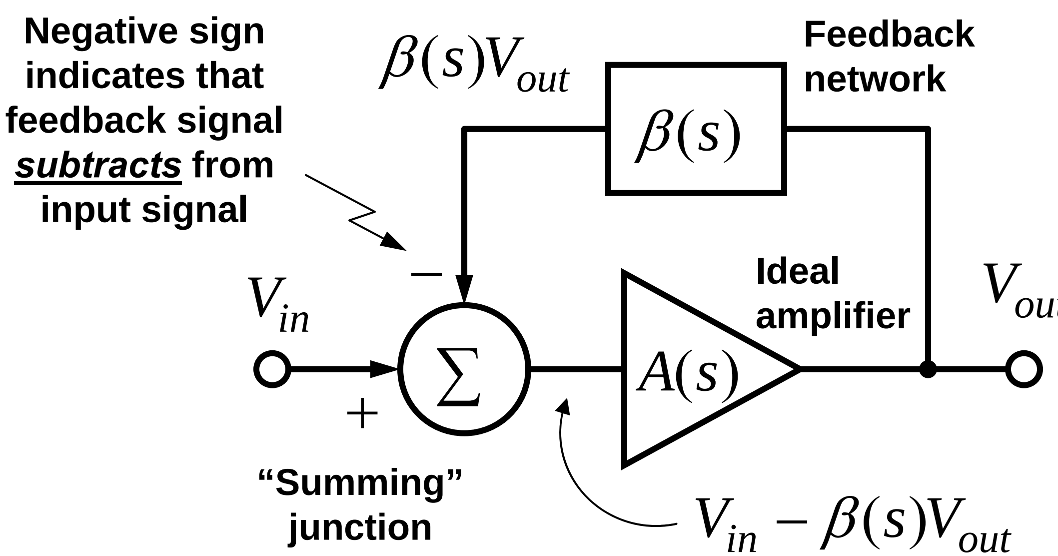
Basic Feedback Concepts

Consider an ideal gain stage with <u>negative</u> feedback



Here we are representing the signals as voltages, so *A*(*s*) and *β*(*s*) are <u>*voltage*</u> transfer functions, but other combinations (e.g. current feedback and transimpedance amplifiers)

$$V_{out} = A(s)\left[V_{in} - \beta(s)V_{out}\right]$$

***A*(*s*) Is the "open-loop gain". It is the gain of the amplifier by itself, with no external feedback path**

The gain of the system with feedback is given by: $$\frac{V_{in}}{V_{out}} = \frac{A(s)}{1+\beta(s)A(s)}$$

Basics of Feedback, continued

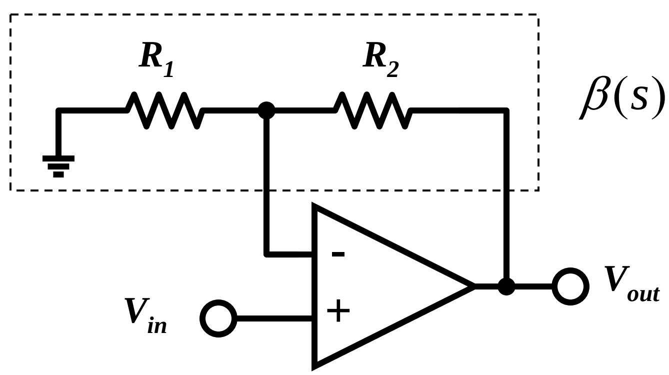
When the amplifier gain is very large,

$$\frac{V_{in}}{V_{out}} = \frac{A(s)}{1+\beta(s)A(s)} \Rightarrow \frac{1}{\beta(s)}$$

Thus the gain of the system is determined by the feedback components.

In transistor amplifiers, feedback allows us to stabilize the gain with respect to parameter variations

In op-amp circuits, most gain stages do not depend on the actual op-amp gain as long as the op-amp has a large gain and high input impedance)

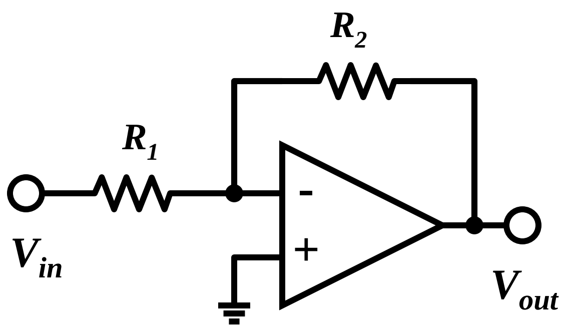


$$\beta(s) = \frac{R_1}{R_1 + R_2}$$

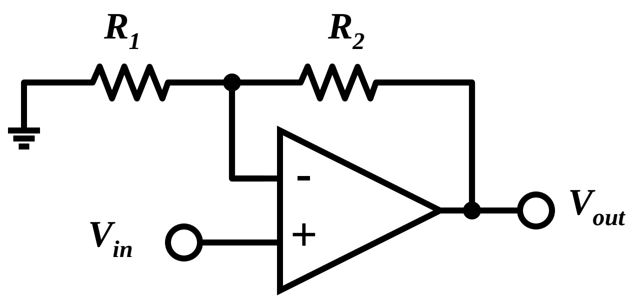
$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$

Basic Op-Amp Gain Stages

Inverting Amplifier



Non-Inverting Amplifier



Replacing the op-amps by the simple equivalent circuit (dependent source) gives:

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

$$\frac{V_{out}}{V_{in}} = \frac{A_v}{1 + \dfrac{A_v}{1 + \dfrac{R_2}{R_1}}}$$

For large gain $A_V \to \infty$

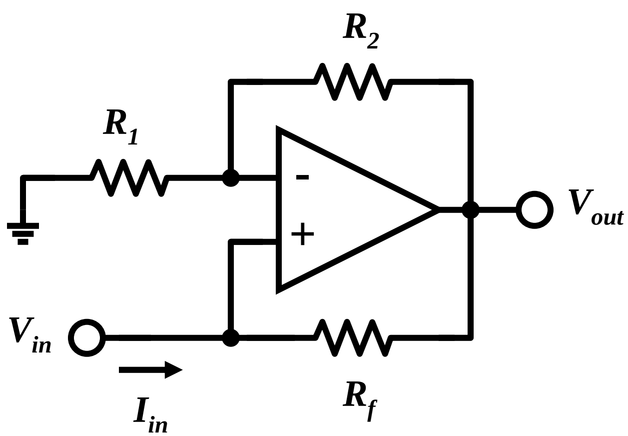
$$\frac{V_{out}}{V_{in}} \Rightarrow -\frac{R_2}{R_1}$$

$$\frac{V_{out}}{V_{in}} \Rightarrow 1 + \frac{R_2}{R_1}$$

Negative Resistance Circuit

Positive feedback is often associated with potential instabilities and usually avoided for that reason. But it can be exploited. This is an interestign example:

Use positive feedback to create a "negative resistor":



$$\frac{V_{in}}{I_{in}} = \frac{A_v R_f}{1 - \dfrac{A_v}{1 + R_1/R_2}} \Rightarrow -R_f\left(1 + \frac{R_1}{R_2}\right)$$

A negative resistance means that the input current flows out of the terminal, thus the circuit can supply energy to an external circuit.

Negative resistance circuits are often used in oscillators