Basic Feedback Concepts

Consider an ideal gain stage with negative feedback

Here we are representing the signals as voltages, so \( A(s) \) and \( \beta(s) \) are voltage transfer functions, but other combinations (e.g. current feedback and transimpedance amplifiers)

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

\( A(s) \) is the “open-loop gain”. It is the gain of the amplifier by itself, with no external feedback path

\[
\frac{V_{in}}{V_{out}} = \frac{A(s)}{1 + \beta(s)A(s)}
\]
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**

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

**Non-Inverting Amplifier**

\[ \frac{V_{out}}{V_{in}} = \frac{A_v}{1 + \frac{A_v}{R_2} \frac{R_2}{R_1}} \]

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 interesting example:

Use positive feedback to create a “negative resistor”:

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

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.