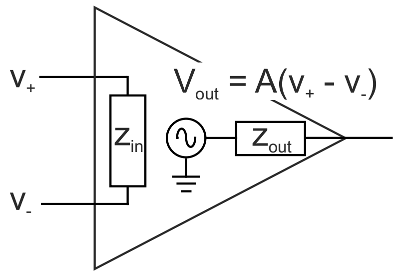
1st-year Circuits
Lectures 8 and 9

Robert Smith

Michaelmas 2019

14 Operational amplifiers



An operational amplifier (or op-amp) is an active (powered) device whose output is given by $V_{\text{out}} = A(V_+ - V_-)$ where A is the open-loop gain and V_+ and V_- are the voltages at he two input terminals. Note, this equation only applies until the outputs *saturate* at the power supply voltages (usually $\pm 15\,\text{V}$). Typically op-amps have a large input impedance Z_{in}, a small output impedance Z_{out} (see diagram) and a large open-loop gain.

14.1 The ideal op-amp and feedback

An *ideal* op-amp is one which has $Z_{\text{in}} = \infty$, $Z_{\text{out}} = 0$ and $A = \infty$. An infinite open-loop gain means that in order for the output not to saturate we require $V_+ = V_-$. To achieve this we apply negative feedback where some of the output is fed back into the (usually $-$) input to ensure $V_+ = V_-$ is a stable point. Whether the feedback is positive or negative can be checked by considering if a small fluctuation of V_{out} changes $V_+ - V_-$ in such a way as to increase or decrease V_{out} – for negative feedback the resulting change will *oppose* the initial fluctuation. For an ideal op-amp operating with negative feedback we can apply the op-amp **GOLDEN RULES**:

1. The inputs draw no current (because $Z_{\text{in}} = \infty$).
2. $V_+ = V_-$ (because $A = \infty$).

14.2 Example circuits

Using the golden rules we can easily solve some simple op-amp circuits. For example, below we have, from left to right:

- A non-inverting amplifier which has a gain of $\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{R_1+R_2}{R_2}$.
- A inverting amplifier for which $\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_2}{R_1}$.
- A integrator for which $\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{1}{RC}\int_0^t V_{\text{in}} dt$.