All you need to know about EE.

Music 250a

CCRMA - autumn 2002

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1 Basic quantities and units

Name	**Symbol**	**Unit**
Charge	per pound	Coulomb (C)
Voltage	V	Volts = Joule/Coulomb
Current	I	Ampere = Coulomb/sec
Power	P	Watts (W) = Joule/second
Resistance	R Ω (Ohm)	
Capacitance		Farads (F)
Inductance		Henry (H)

2 Ohm's laws

$$V = IR$$

3 Kirchoff's laws

Voltage law:

$$\sum V_{loop} = 0$$

This is the conservation of energy. The sum of the voltage drops around a closed circuit loop is zero.

Current Law:

$$\sum I_{node} = 0$$

This is the conservation of charge. The sum of the currents flowing into a point is zero.

3.1 Series and parallel combinations

Circuit elements are connected in series when a common current passes through each element.

The equivalent voltage drop of a combination of resistors connected in series is given by summing the voltage drops across each resistor.

$$V = \sum_i V_i = I \sum_i R_i$$

Example:

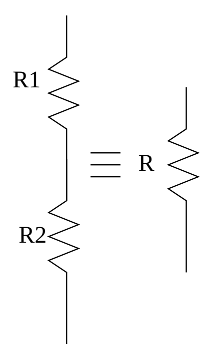

Figure 1: Resistors in series.

$$R = R_1 + R_2$$

Circuit elements are connected in parallel when a common voltage is applied across each element.

The equivalent resistance of a combination of resistors connected in parallel is given by summing the current through each resistor.

$$I = \sum_i I_i = \sum_i \frac{V}{R_i}$$

Therefore we can calculate the equivalent resistance of the circuit in figure 2 by:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

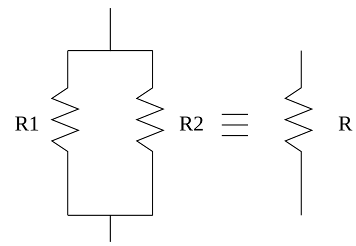

Figure 2: Resistors in parallel.

or

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

3.2 Voltage divider

$$v_{out} = \frac{R_1}{R_1 + R_2} v_{in}$$

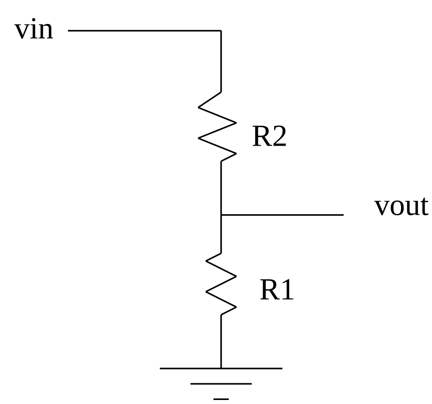

Figure 3: Voltage divider.

Voltage division gives rise to the **potentiometer**.

4 Operational-amplifiers (Op-amps)

An operational amplifier is an amplifier with two inputs (+ which is the non-inverting and - which is the inverting), as shown in figure 4.

Its role is to amplify $v_d = v_+ - v_-$.

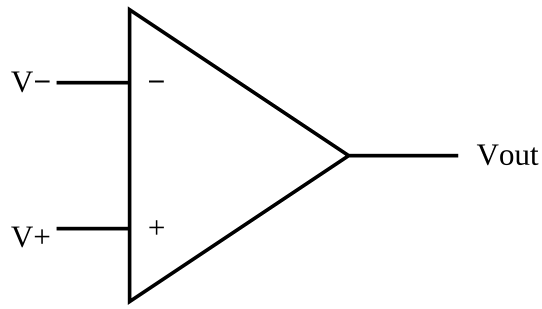

Figure 4: OP-Amp circuit symbol.

4.1 Inverting amplifier configuration

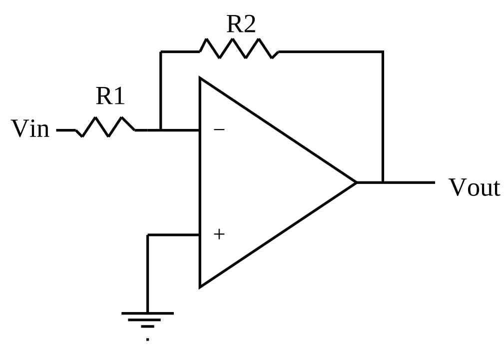

Figure 5: Inverting Op-Amp.

$$iR_1 = -iR_2$$

$$v_{out} = i_{R_2} R_2$$

$$v_{in} = i_{R_1} R1$$

$$v_{out}/R_2 = -v_{in}/R_1$$

$$v_{out} = -v_{in} \frac{R_2}{R_1}$$

where $\frac{R_2}{R_1}$ is the gain and R_1 is the input impedance. Its role is to amplify and invert the input voltage.

4.2 Non-inverting Op-Amp

$$v_+ = v_- = v_{in}$$

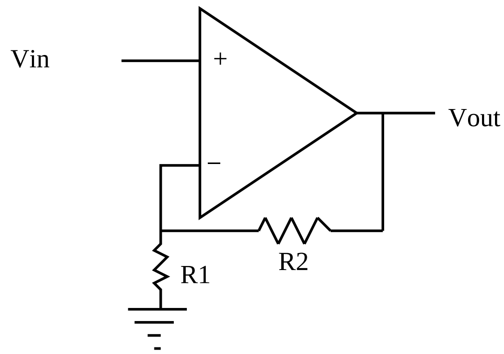

Figure 6: Non-inverting Amplifier.

$$i_{R_1} = i_{R_2} = \frac{v-}{R_1} = \frac{v+}{R_1} = \frac{v_{in}}{R_1}$$
$$v_{out} = v_{in} + \frac{v_{in}}{R_1} R_2$$
$$v_{out} = v_{in} \frac{R_1 + R_2}{R_1}$$
$$v_{out} = v_{in}(1 + \frac{R_2}{R_1})$$

The input impedance is ∞. The gain must be greater or equal to 1.0.

As a special case we have:

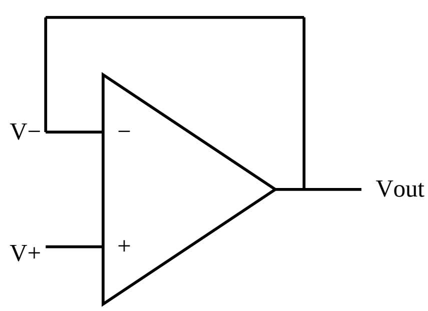

Figure 7: Unit-gain amplifier.

$$v_{out} = v_{in}$$

4.3 Mixer

$$v_{out} = -[(R_1/R_2)v_2 + (R_1/R_3)v_3 + (R_1/R_4)v_4]$$

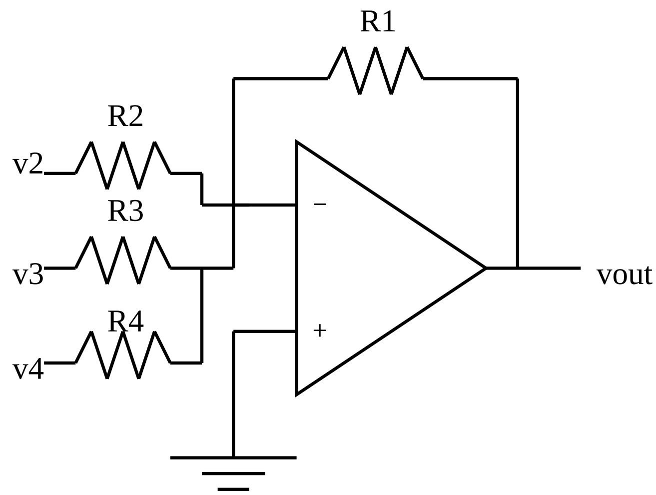

Figure 8: Mixer circuit.

5 Filters

5.1 Low-pass filter

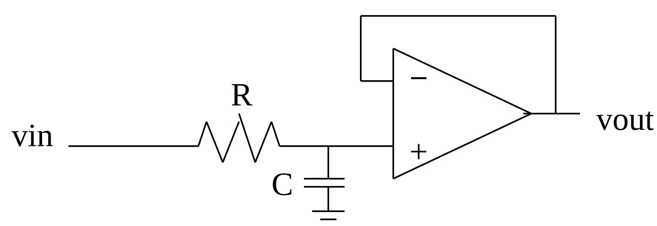

Figure 9: Low-pass filter.

$$T = RC$$

Cutoff frequency f_c

$$f_c = 1/(2\pi T)$$

Since this filter is pretty weak, it is also possible to have two of them in series as figure 10 shows.

It is also possible to build a two-pole filter using a single op-amp. The second stage of the filter is at ten times the impedance of the first stage so it does not overload the first stage (see figure 11.

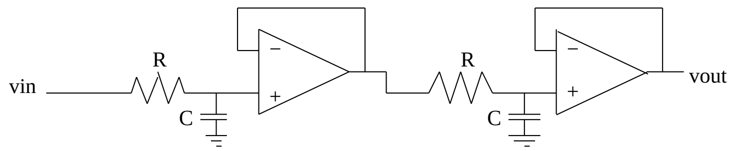

Figure 10: Two low-pass filters in series.

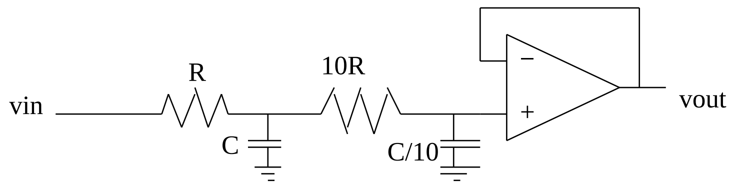

Figure 11: A two-pole filter with a single op-amp.

5.2 High-pass filter

Figure 12 shows the circuit for a simple high-pass filter.

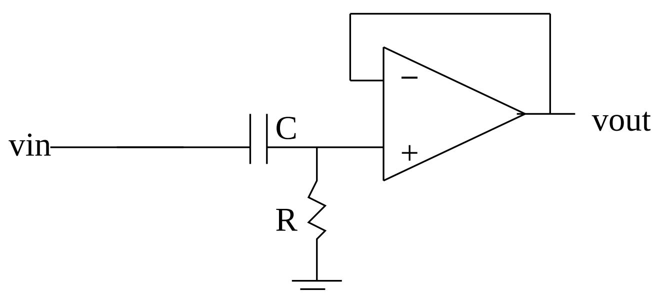

Figure 12: High-pass filter.

5.3 Bandpass filter

Figure 13 shows a two-pole bandpass filter.

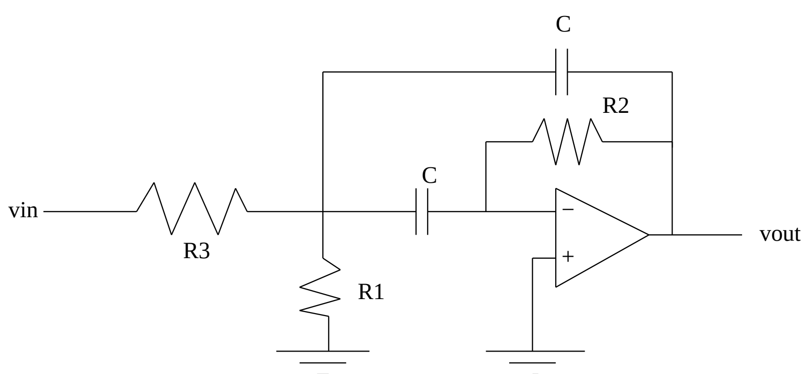

Figure 13: Bandpass filter.