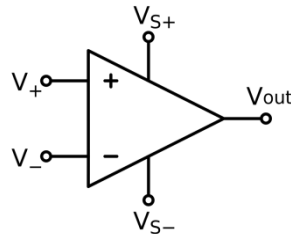


## Exercise C

The operational amplifier is used to amplify the electric signals (increase voltage or current), invert the signal and do a lot of other things in conjunction with an arrangement of a set of passive components. One of the most common applications – signal filtering. The operational amplifier is shown in the schemes by the following symbol:

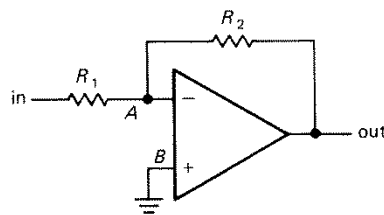


The behavior of operational amplifier is described by a pair of “golden rules”:

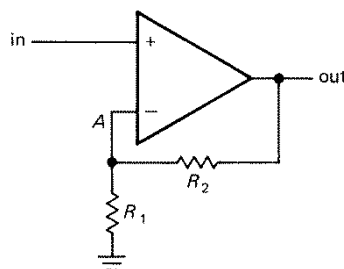
1. The output attempts to do whatever is necessary to make the voltage difference between the voltage input zero.
2. The inputs draw no current. (In fact, they draw very little input current. Operational amplifier OPA2350 that we shall use draws less than 10 pA and we round this off.)

Using these rules and Kirchoff's laws one can find the voltage gains for inverting and non-inverting amplifiers:

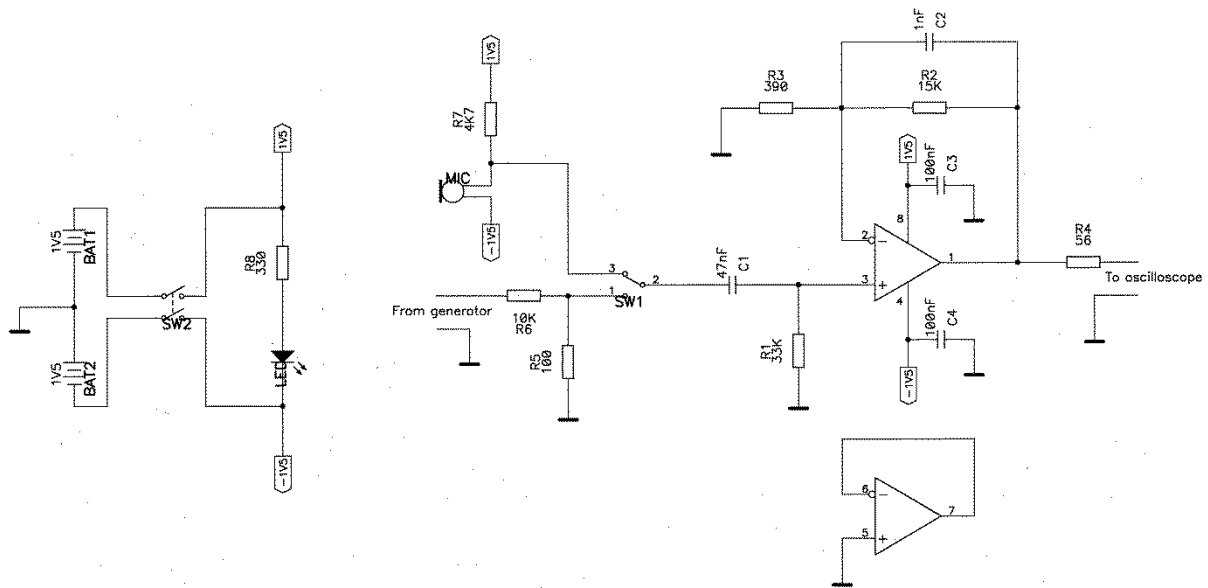
Inverting amplifier; Voltage gain =  $V_{out}/V_{in} = -R_2/R_1$



Non-inverting amplifier; Voltage gain =  $V_{out}/V_{in} = 1 + R_2/R_1$



- Build the following circuitry of OA-based microphone amplifier. The circuitry amplifies the signal approximately 30 times in frequency range 100 Hz – 10 kHz to fit the output of the electret microphone to +/-1 V input range of the sound card that will be used in the following lessons. Advice: measure the values of components (especially – capacitors) by multimeter before assembling the scheme. This will give a better match between measurement and theory.



Components:

Operational amplifier – OPA2350PA (Distrelec 648465)

Microphone – KPCM\_G60H50\_44DB\_1184 (Conrad 710778-62)

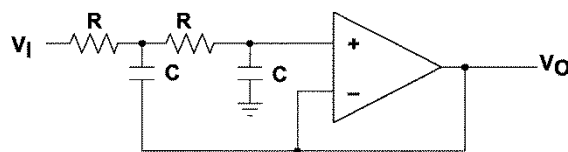
SW1 – SS-12 (Distrelec 200180)

SW2 – AS-22AP (Distrelec 200192)

Battery AAA socket (Distrelec 972521)

- Verify functionality of the circuitry using oscilloscope.
- Using the signal generator with 1/100 divider, apply sinusoidal signal to the input of amplification cascade. Find dependency of the voltage gain  $V_{out}/V_{in}$  and the phase shift between  $V_{in}$  and  $V_{out}$  on signal frequency. Plot the measured dependencies. Compare them with theoretical.

Considered previously RC-filters are very popular, but in some cases a sharper cutoff of unwanted oscillations at cutoff frequency is desired. In such cases more complicated filters of higher orders are used. One of the most popular is the Sallen-Key structure (1955) shown below.



- This is the second-order low-pass filter. Find dependence of its attenuation on frequency. Plot attenuation in dBs as a function of frequency in range 10 Hz – 100 kHz (log scale is preferable) for  $R = 10 \text{ k}\Omega$  and  $C = 16 \text{ nF}$ . Compare it with attenuation of a sequence of two identical RC filters (just when the lower end of the first resistor in the scheme above is connected to the ground instead of the amplifier output). What is the influence of feed-back in the Sallen-Key filter? Hint: use Kirchhoff's laws and Ohm's law in its generalized (complex) form (see H & H pp. 31-32).