Block 21 — Op-Amp Basics

Student Group

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Learning objectives

After this 90-minute block, you can

- …

Preparation at Home

Well, again

- read through the present chapter and write down anything you did not understand.
- Also here, there are some clips for more clarification under 'Embedded resources' (check the text above/below, sometimes only part of the clip is interesting).

For checking your understanding please do the following exercises:

- …

90-minute plan

1. Warm-up (x min):
    1. ….
2. Core concepts & derivations (x min):
    1. …
3. Practice (x min): …
4. Wrap-up (x min): Summary box; common pitfalls checklist.

Conceptual overview

1. …

Core content

Fig. 1: undistorted signal

hallo.mp3

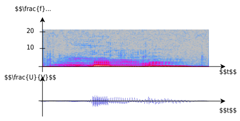
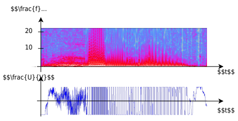


Fig. 2: overdriven signal

hallo_verzerrt.mp3



Introductory example

Acoustic amplifiers, such as those found in mobile phones, laptops, or hi-fi systems, often exhibit an unpleasant characteristic when heavily amplified: the previously undistorted signal is no longer passed on as usual, but clatters. It is distorted in such a way that it no longer sounds pleasant.

For this purpose, you will find an acoustic example with pictures in figure 1 and figure 2 respectively. The bottom of each image shows the time course of the voltage output to a loudspeaker (x-axis: time, y-axis: frequency). The upper picture has three dimensions: It shows in color intensity which frequencies are used at which time. The frequencies in grey areas are not used. If a frequency is shown in red at one point in time, it has a relatively large amplitude.

It can be seen that the distorted signal has large amplitudes in the time course of the voltage as well as a wide distribution of frequencies (= a broad spectrum). The high frequencies in particular can promote wear of the diaphragm in loudspeakers.

The signal distortion is due to the design of the amplifier, which can only output the maximum possible voltage and otherwise clipping. The structure of an acoustic amplifier is similar to that of a feedback operational amplifier, as seen in the simulation.

Acoustic amplifiers are usually constructed like operational amplifiers, which will be considered in the following chapters.

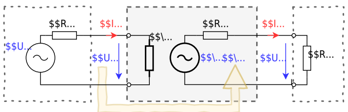
Circuit symbols and basic circuitry

This chapter deals with operational amplifiers or in general with measuring amplifiers. One application for this is the measurement of voltages, currents, and resistances. These must be determined very precisely in some applications, for example for accurate temperature measurement. In this case, amplification of the measurement signals is useful and necessary.

This amplification is done by measuring amplifiers. Measuring amplifiers have to fulfill some characteristics:

- Measurement amplifiers should not have any feedback effect on the measured variable. An operational amplifier should have the highest possible input resistance. This prevents the voltage to be amplified from collapsing.
- Measuring amplifiers should have a high sensitivity. An operational amplifier should have a large differential gain $A_\rm D$.
- Measuring amplifiers should show a defined transmission behavior, i.e. the output signal should be clearly related to the input signal. An operational amplifier concretely should show a linear relationship.
- Measuring amplifiers should show good dynamic behavior. The output signal of an operational amplifier should follow the input signal without any time delay.
- Measurement amplifiers should produce an “impressed output signal”. This means that the components at the amplifier output cannot change the output signal. An operational amplifier, specifically, should be able to maintain the desired output signal with the necessary current to do so. Since the current $I_\rm O$ can become very large (by electronic standards), this means that an operational amplifier must have a low output resistance $R_{\rm O} =\frac{U_{\rm O}}{I_{\rm O}}$.

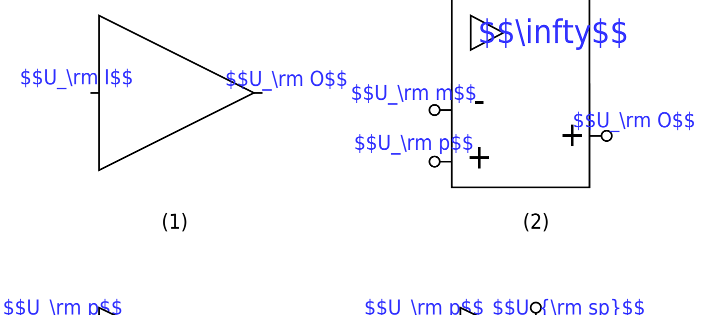
Fig. 3: Equivalent circuit diagram of an amplifier



In general, a measurement amplifier is constructed as in figure 3. This has already been described in chapter Amplifier Basics. In the following, only operational amplifiers will be considered. An operational amplifier is a measurement amplifier, which is often used in electrical engineering.

The circuit symbol of the amplifier is an isosceles triangle, at the apex of which the output signal originates and at the base of which the input signal enters. In figure 4 you can see different circuit symbols:

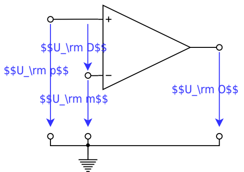
Fig. 4: Circuit Symbols of Amplifiers



- Circuit symbol (1): In block diagrams (not to be confused with circuit diagrams, see chapter 1) this circuit symbol is used for general amplifiers. The input signal enters an input and exits through an input. This symbol will not be found again until Chapter 5.
- Circuit symbol (2): According to DIN EN 60617, this circuit diagram is to be used for operational amplifiers. It indicates with the infinity sign the ideally infinitely high amplification. in the following this symbol is not used, because it is not used in all international circuits and tools.
- Circuit symbol (3): The circuit symbol (3) is the most commonly used symbol for an operational amplifier. On the left is the **inverting input** with voltage $U_{\rm m}$ (minus) and the **non-inverting input** with $U_{\rm p}$ (plus). The output with voltage $U_{\rm O}$ is shown on the right.
- Circuit symbol (4): The circuit symbol (4) is additionally drawn with the supply voltages $U_{\rm sp}$ (supply plus) and $U_{\rm sm}$ (supply minus). Power is provided from the supply for the output voltage of the operational amplifier.
- Circuit symbols (5) and (6): these symbols show **no** operational amplifier. These symbols show the NOT gate and the tri-state gate. Both of these components have already been discussed in fundamentals of digital engineering. Unfortunately, the representation of these digital components in various circuits is not unlike the operational amplifier. An example of this is the transceivers[1)] SP3481 or SP3485. If digital input values are considered, assuming that the circuit symbol does not represent an operational amplifier.

Notice: opamp input

Fig. 5: Voltages at the operational amplifier



The inputs of the operational amplifier are designated as **inverting input** $U_\rm m$ and **non-inverting input** $U_\rm p$.

The voltage $U_{\rm D} = U_{\rm p} - U_{\rm m}$ is called the differential voltage (see figure 5).

Common pitfalls

- ...

Exercises

Worked examples

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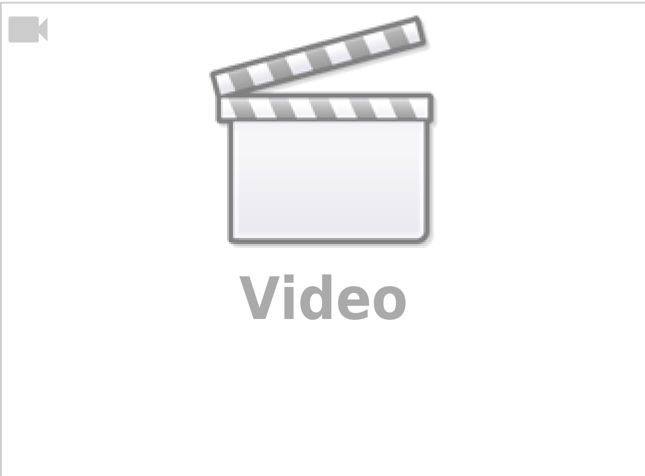
Embedded resources

What is an operational amplifier?



[1] _ckgedit_QUOT_transmitter and receiver“, meaning transmitter-receiver, or interface adapter