Oscilloscope

An oscilloscope is an electronic measuring device that displays the course of voltage over time.

We divide oscilloscopes according to their technical design into **analog , digital and software.**

Principle of analog oscilloscope

In principle, an oscilloscope consists of three parts:

- screen (picture tube)
- vertical amplifier
- time base generator

To these parts, of course, it is necessary to add sources of high voltage needed to sufficiently accelerate the electrons in the screen and sufficiently hard current sources for the glow.

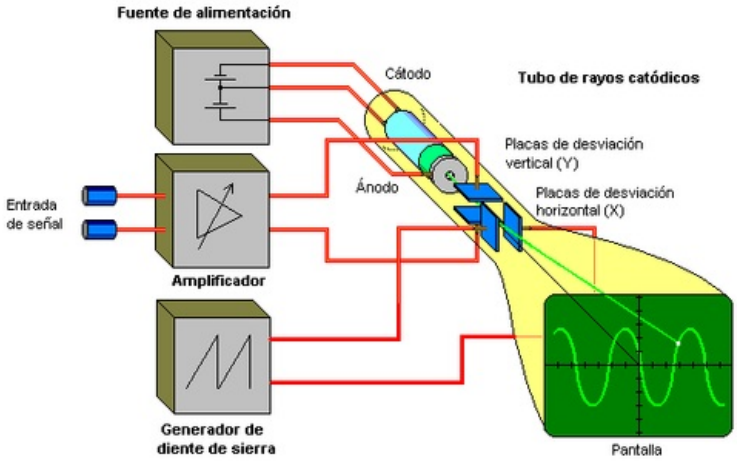

Diagram of an analog oscilloscope

Picture tube

Key to the principle of an analog oscilloscope is an electrostatic deflection screen , the principle of which is shown in the figure. Roughly, the principle can be summed up in the statement that the screen works in such a way that electrons are emitted in one of its parts, they are focused, deflected in a targeted manner and fall on a luminescent substance. It can be seen from this that a vacuum inside the screen is a condition for the functioning of the screen. Furthermore, it should be noted that this screen is quite substantially different from television screens, which use the magnetic field of coils to deflect electrons, precisely because of the electrostatic deflection.

The first part of the screen, which is the farthest from us in the picture even with the usual use of the screen, is the electron gun or cathode ray tube . Even the English name (cathode ray tube) gave the basis for the designation of CRT monitors. The electron gun begins directly with a heated cathode , i.e. in principle a wire made of a material resistant to high temperatures. When it is heated, electrons are released into the surroundings (thermoemission of electrons), their quantity depends on the temperature and therefore on the incandescent current. At the same time, the cathode is the bearer of a negative potential with respect to the further placed anode. Thus, an electric field is created between the anode and the cathode, which attracts electrons to the anode. Because a force acts on electrons in an electric field, they are of course accelerated. Additional electrodes with a negative potential are placed between the cathode and the anode, whose task is to focus the electron beam. The actual anode is adapted so that the electron beam at least partially passes through and can continue further.

Behind the electron gun is a system of deflection electrodes. In principle, there are two pairs of plates, one pair is placed horizontally and the other pair vertically. Depending on the polarity and magnitude of the applied voltage , the electron beam is deflected to the left or right in the case of horizontal deflection plates (whose surfaces are vertical!), or up or down in the case of vertical deflection plates. The angle that can be achieved is usually around 15°, so the screen needs to be quite long to make the screen large enough.

The last part of the screen is a screen covered with phosphor . This is a substance that, after the impact of electrons, goes into an excited state and returns to the ground state by emitting photons in the visible region. The shade is usually supplemented with filters, because X-ray radiation is also produced during the operation of the screen .

note 1: Although magnetic deflection reaches much higher angles, it has two disadvantages that make it impossible to use in an oscilloscope. The first disadvantage is that the deflection of the electron beam depends on the current passing through the deflection coil non-linearly, so it would be difficult to introduce this non-linearity into the oscilloscope. The second disadvantage is the increase in the impedance of the deflection coils with frequency . Already at relatively low frequencies, it reaches such values that a suitable amplifier ceases to be practically feasible.

note 2: The properties of the phosphor may vary depending on the application. For a TV or a regular oscilloscope, the phosphor is required to go out very quickly. In other applications, on the other hand, it is required that it shine as long as possible. Such applications were, for example, radars (requirement that the phosphor be lit long enough for the operator to register the target) or memory oscilloscopes recording one-time events (requirement that the trace on the screen be lit until it is evaluated or photographed).

note 3: White light was desirable for black and white televisions, green became the standard for oscilloscopes. Color screens do not differ in principle, only their system is "tripled" for red, green and blue. The perceived color is then created by the combination of different intensities of the individual components.

Vertical amplifier

The vertical amplifier is used to amplify the measured voltage enough to be able to sufficiently deflect the electron beam in the screen after being fed to the vertical deflection plates. The natural requirements are a high input resistance (to load the measured circuit as little as possible) and a wide frequency response (to distort fast events as little as possible). The adjustable gain switches the voltage range.

Most oscilloscopes have two input amplifiers, they are called channel A and B. By switching, it is then possible to display channel A, channel B or both waveforms simultaneously.

note 1: Two modes are used to display two waveforms. In ALT mode, which is more suitable for higher frequency signals, channels A and B are displayed alternately. In CHOP mode, which switches between channels A and B at high frequency, it is more suitable for lower frequency signals.

note 2: Another common mode is the XY mode, where the signal from one channel is fed to the horizontal and the other to the vertical deflection plates. This arrangement serves, for example, to measure the frequency by comparing it with a standard using Lissajous figures.

Time base

The time base is used to control the movement of the electron beam from left to right (from the operator's point of view) during normal operation. In fact, it is nothing more than a generator of saw-shaped voltage pulses. As the voltage increases more slowly, the electron beam moves and leaves a trail. With a faster decline, the so-called reverse run, it is technically ensured that the electron beam is interrupted. Adjusting the time base frequency changes the time resolution of the oscilloscope.

The start of the saw pulse can be determined in several ways. The simplest is a free-running time base in which sawtooth pulses are generated with a fixed frequency. However, in the general case, this can lead to the fact that the image on the screen moves. The solution is either a fine correction of the frequency of the time base (time magnifier), or the use of a triggered time base. In the second case, the sawtooth pulse is generated only under given conditions, usually that the voltage at the input reaches a certain value.

note: Most oscilloscopes have the option of so-called external triggering. This means that another signal is fed into the oscilloscope, which is used exclusively to control the time base.

Digital oscilloscopes

A digital oscilloscope basically consists of several parts:

- amplifier
- A/D converter
- built-in computer
- LCD display

The amplifier is mainly used to amplify too weak signals and to adjust the range. The requirements are usual, i.e. the largest possible input resistance and the best possible frequency characteristic.

The analog-to-digital converter is used to convert the voltage at the output of the input amplifier into digital form. It is required to convert as fast as possible, so that it is possible to observe fast enough events, that is, to have the highest possible sampling frequency (number of measurements per second). On the other hand, it is required that the discretization error is as small as possible, i.e. that the voltage is converted to as many digits as possible. Unfortunately, in the technical implementation, these requirements are somewhat contradictory.

The built-in computer analyzes the measured signal and displays it on the LCD display. Older and cheaper types of digital oscilloscopes allow only a simple analysis consisting at most of measuring voltage (sometimes also maximum, effective and average) and frequency. Modern types allow for relatively advanced signal analysis (Fourier analysis, power spectrum), the built-in computer then enables the smooth export of measured data to a personal computer for further analysis, or perhaps the connection of an oscilloscope to a bus (e.g. GPIB), which allows more complex measurements to be controlled from one computer.

Software oscilloscope

A software oscilloscope is based on the same principle as a digital oscilloscope. It differs primarily in that it uses the components of a regular computer on which it is run. As an input, it uses, for example, the input on the sound card (after slight modification), which contains both an amplifier and an A/D converter. The advantage is the low purchase price, there are also freeware or open source oscilloscopes. The main disadvantage is that sound cards have a fixed and, compared to oscilloscopes, very low sampling frequency. Another disadvantage is the limited voltage range of the sound card input. Another problem is that the inputs of sound cards contain a low-frequency filter , so very slow events will not be measured. Finally, susceptibility to destruction can also be a problem.

Measuring card

The measurement card is a compromise between a digital and a software oscilloscope. It is actually an amplifier and an A/D converter with the necessary electronics, which, depending on the type, can either be built into a computer or connected to USB. Even the measurement card does not reach the qualities of a digital oscilloscope, but especially when it comes to tasks with lower frequencies (e.g. most measurements of physiological events), then it is a relatively cheap and at the same time sufficiently high-quality solution.

Links

External links

- Osciloskop (czech wikipedia)
- Oscilloscope (english wikipedia)
- Princip osciloskopu na webu MFF UK (http://physics.mff.cuni.cz/kfpp/skripta/elektronika/kap4/4_2.html)
- Podrobný popis osciloskopu na stránkách Integrované střední školy (http://www.jsmilek.cz/skripta%20pdf/mereni%204%20osciloskopy%20skripta.pdf)
- KUBATOVA, Senta. *Biofot* [online]. [cit. 2011-01-31]. <http://uloz.to/1162346/biofot.doc>.