T4: Measurements with an oscilloscope

1. **Measurement properties of oscilloscope**

 The oscilloscope is a measuring device used to observe, measure and compare voltage signals and signals of other electrical and non-electrical quantities, after they have been converted into a voltage signal. Measurements and observations are most often made as a function of time, which is called the work of the X-t oscilloscope. You can also take measurements of functions that are functionally related to each other, which is called the X-Y work of the oscilloscope. In this case, time-independent characteristics are plotted on the oscilloscope screen, eg current-voltage characteristics of semiconductor devices or signals from any sensors with voltage output.

Compared to conventional measuring instruments oscilloscope characterized by two important features. These are: the possibility of observation of the time signal and measuring a very high versatility, manifested among others a large measuring range and a wide frequency band. A typical oscilloscope can be observed and measured waveforms of periodic voltages with frequencies from about 20 Hz to several dozen megahertz and values from individual millivolts to several dozen volts.

The disadvantage of oscilloscopes is their low accuracy (2 ... 5%). This is due to their high temperature and time instability, and the properties of the oscilloscope lamp. Significant measurement errors also result from inaccurate readings of the parameters of the analyzed waveform. In the measurement of voltage is determined lengths along the y axis, the time measurements - along the x axis. Commits at the error position to determine the initial and final points. In the condition of a still image with good brightness and sharpness, and with a line thickness not more than 0.5 mm, the absolute error of the reading is approx. ±1mm. So, for example, measuring a segment of 5cm in length will be affected by an error of about 2%. The mentioned errors are the reason for the small accuracy of the oscilloscope measurements, because in the most favorable conditions they will amount to several percent. Measuring accuracy is guaranteed by digital oscilloscopes (approx. 1%).

**2. The principle of operation of the oscilloscope**

The image on the screen of the oscilloscopic lamp arises as a result of the movement of the electron stream through two pairs of perpendicular plates: horizontal deflection X and vertical deviation Y. A voltage proportional to the instantaneous value of the input voltage is given to the plates Y, and the linearly increasing voltage is applied to the X plates. sawtooth voltage - moving the stream of electrons at a constant velocity in the direction of the X axis. As a result, the electron stream "sketches" the image of the instantaneous values of the input voltage. The source of the sawtooth signal is the so-called time base generator.

Observations and measurements with the oscilloscope can only be performed correctly if the waveform is still for a long time. Such a state is obtained by providing synchronous operation of the time base generator, which relies on such control thereof that each cycle of the sawtooth shape produced is dependent on the course of the measurement signal.

Often, in the measurement practice, there is also the need to observe two different shifts and evaluate the compounds that occur between them, eg in the measurement of amplitude ratio and phase shift. Hence, two-channel oscilloscopes are most often constructed, equipped with two measuring signal processing paths and an electronic switch. chopper - switching both signals on vertical deflection plates alternately. The switching of signals takes place so fast that the "flickering" of the waveforms is not visible on the screen.

**3. Digital Oscilloscope**

In the digital oscilloscope, the measuring signal from the analog form is converted into a digital version, which takes place in an analog-to-digital (A/D) converter. It is further accumulated in the memory, and then processed in a digital-to-analogue (D/A) converter and put on the screen.This seemingly circumferential way of signal processing has a deep justification, because it makes it possible to obtain results unattainable in analogue technology. For example, the signal image stored in memory can be transferred to the screen of the oscilloscope or to an external computer at any time. The signal from the memory can also be sent to a printer or flash memory.
  The sample collection can also be subjected to filtration and frequency analysis. Finally, the signal parameters are calculated from the selected sample set: average, effective, minimum, maximum and other values. These calculations are not burdened with errors that occur in measurements with an analog oscilloscope - errors caused by readings, oscilloscopes and amplifiers (bypassing the input amplifier).



Fig1. Simplified structure of digital oscilloscope

Switch and knob sets, due to the adjustable functions, can be divided into three groups:
a) knobs to determine the quality and location of the lines drawn,
b) adjustable elements in y-vertical y-channels (channels) for setting the so-called vertical extension,
c) adjustable elements defining horizontal X deflection conditions, mainly fixing the operating conditions of the time base generator.

The setpoints are aimed at obtaining the largest possible image of the waveforms. Therefore, the voltage delivered to the oscilloscope inputs, depending on their value, must be properly amplified or attenuated. The settings of the height of their images are obtained with the VOLTS / DIV knobs, which determine the so-called gain factor - given in mV / div or V / div, where the plot corresponds to the distance between the lines of the screen grid. The knobs of these knobs also have knobs for adjusting the image height continuously. Turning them to the right to the CAL position turns them off. This is always the way to proceed when taking measurements, because only then will the correct calculation results be obtained. On the other hand, a liquid setting is used when a specific height of the observer is requested. This is the case, for example, in the case of amplifier gain decreases due to frequency changes, i.e. in frequency characteristics measurements.

The correct image of the measurement signal waveform should represent at least one period. The number of observed signal periods depends on the set frequency of the time base generator. Its setting is carried out by means of two knobs - incremental and continuous setting. The step knob adjusts the so-called time factor (TIME / DIV), given in units of time (s, ms, us) per plot of the line grid. Similarly to the setting of the gain factor, if the time intervals are to be measured, check that the continuous control knob is turned off and in the CAL position.

The step adjustment knob also has the XY position, in which the time base generator is switched off, and the horizontal spread is realized by a signal connected to the X input. As mentioned in the introduction, this type of oscilloscope operation is used to observe the characteristics of various electrical and electronic components.

**5. Measurement program**

Understanding the principles of proper operation of the oscilloscope. For this purpose, connect the voltage generated by the signal generator to the oscilloscope input terminal and perform such manipulations with the buttons and switches on the front panel to obtain a clear and still image.
2. Understanding the principles of measuring with an oscilloscope. For sources located on the laboratory stand, take measurements of the generated voltages (table 1).

### 6. Example of calculations

The peak-to-peak voltage was measured with an oscilloscope. For setting the amplification factor cu = 0.5 V / div, the length of the section corresponding to the double amplitude of the signal was: lu = 2.5dz. Give the measuring result - Up-p±U(Up-p) if the oscilloscope accuracy is 3%, and length of a read error Δlu = ±0,2div.

Calculations

- measured voltage value: Up-p= cu lu = 0,5V/div 2,5div = 1,25V

- the standard (total) uncertainty results from the uncertainty propagation law:

.

Substituting values: δcu=3%, , it gives



- relative expanded uncertainty for the confidence level p=0,95 (expansion factor )

Ur(Up-p) =2 4,9% = 9,8%

- expanded uncertainty

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- measurement result: Up-p = (1,25±0,12)V, p=0,95.

 2. The period and frequency of the voltage were determined by an oscilloscope measuring the length of the segment corresponding to the period of the signal. For setting the time factor ct=0,2ms/cm - lt = 7,1 cm. Oscilloscope horizontal track was accuracy δct = 5% and readings made with an error Δlt = 0,1cm. Give the results of measurements.

Calculations

 - measured values: 

 

- the standard (total) uncertainty results from the uncertainty propagation law:

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 Substituting vslues: δct=5%, , it gives



- relative expanded uncertainty for the confidence level p=0,95 (expansion factor )

Ur(T) =2 3,0% = 6%

* expanded uncertainty of T and f measurements - if f=1/T, then Ur(f) = Ur(T):

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- Result od period: T = (1,42±0,09)ms, p=0,95.

- Result of frequency: f = (704±42)Hz, p=0,95.

### Protocol „Oscilloscope measurement”

Recorder ......................................................... Date. ...............................

Place of measurement: Laboratory of Electrical Metrology

The purpose of measurements.....................................................................................................

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Properties of oscilloscope

* name of oscilloscope ............................................................................
* type, company .......................................................................................
* screen dimensions ................................................................................
* range of gain factor settings..................................................................
* range of time factor settings..................................................................
* accuracy ...............................................................................................
* input resistance ....................................................................................
* bandwidth ............................................................................................

Tab. 1. Measurements of voltage, period and frequency with oscilloscope

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| --- | --- |
| Properties of measured signal | Up-p measurements |
| Readings | Measurement results |
| ludiv | cuV/div | Up-pV | Δludiv | Up-p±U(Up-p)p= ........ | Ur(Up-p)% |
| Source name ..................Kind of voltage ..............Frequency ............... |  |  |  |  |  |  |
| Source name ..................Kind of voltage ..............Frequency ............... |  |  |  |  |  |  |
| Source name ..................Kind of voltage ..............Frequency ............... |  |  |  |  |  |  |

c.d. tab. 1.

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| T and f measurements |
| Readings | Results of T | Results of f |
| ltdiv | ct | T | Δltdiv | T±U(T)p= ........ | Ur(T)% | f ±U(f)p= ........ | Ur(f)% |
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Notes: ..........................................................................................................................................

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