Laboratory1

Signals generation and visualization

Purpose: Familiarization with the basic functions of an oscilloscope and of a signal generator. Adjusting and measuring specific parameters of signals.

Theoretical aspects

The oscilloscope (often abbreviated *scope*) is a device that allows vizualization of the instantaneous value of a voltage $u(t)$ as a function of time, and quantitative measurements of voltage and time on the waveform $u(t)$. In this lab we use the Tektronix TDS1001 digital scope. The description that follows corresponds to this model.

For signal visualization, the function generator will be connected to the oscilloscope using a cable with BNC connectors.

Figure 1 shows an example of a cable with a BNC connector on one end and „crocodiles" clips on the other end. This is a cable commonly used in the laboratory. Figure 2 presents also a BNC type connector. This connector has a metal shield (outer side) which is connected to the black „crocodile", as well as a central metal pin which is connected to the red „crocodile".

Figure 1. BNC- „crocodiles" cable

Figure 2. Detailed BNC cable

Observation 1: Devices that have an output or input with a BNC type plug and that generate or receive a voltage type signal, have the outer screen connected to the ground of the device (Ground), i.e. to the reference potential of 0 volts. The black „crocodile" will therefore have an electric potential of 0V and the red „crocodile" will have a non-zero volts potential.

Main parameters of a periodic signal

As previously mentioned, the signals that will be analyzed in the lab are generated using the function (signal) generator and they are periodic signals. The main parameters of a periodic signal are (Figure 3):

- period and repetition frequency: $f = 1/T$
- maximum value: U_{max}
- minimum value: U_{min}
- *peak-to-peak* value: $U_{VV} = U_{PP} = U_{max} - U_{min}$;
- mean value (continuous component or *offset*): U_{med} or U_{CC};
- peak value (signal amplitude): $U_0 = U_{max} - U_{CC} = U_{CC} - U_{min}$

Observation 2: if $U_{CC} = 0$, the amplitude, the maximum and minimum value are equal in modulus.

Observation 3: The measurement unit V_{VV} (*engl.* V_{PP}) does not define another „type of volt" but it means the limits between which the voltage is measured in volts, are from one peak to the other peak. Some devices specify the amplitude as a peak value, others as a peak-to-peak value, the distinction being made according to the measurement unit.

- other parameters for certain waveforms, for example, **square signal** are:

- *duty cycle*: $\eta = \tau/T$ (τ is the duration of the positive value and T is the period of the signal)
- rise time / fall time: t_{rise} , t_{fall}.

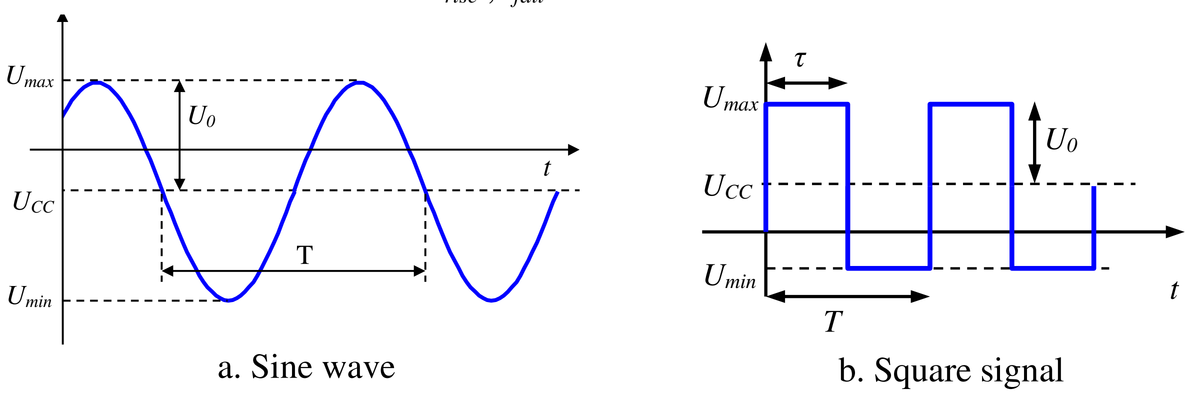


Figure 3. Periodic signals: sine, square (rectangular)

Oscilloscope Settings

The oscilloscope is a device that allows visualization of the waveform in the time domain of voltage signals, *u(t)*. To display the waveform, the oscilloscope has a screen graded into divisions (Figure 4). Typically, the oscilloscope screen is divided into 8 vertical divisions and 10 horizontal divisions. Each division is divided into 5 subdivisions, resulting in a subdivision value of 0.2 divisions.

Since the time variation of a voltage-type signal will be visualized on the oscilloscope screen, ***the vertical axis of the screen*** will measure ***signal values*** expressed ***in volts***, and **the horizontal axis** will measure ***time durations*** expressed ***in seconds***.

On horizontal axis, the duration corresponding to the length of a screen division is externally adjustable from the C_x knob (**horizontal deflection coefficient**). It is graded in units of time per division [s/div]. The following relationship between the number of N_x divisions occupied by a certain event and its duration t_x is valid:

$$t_x = N_x \cdot C_x$$

On vertical axis, the voltage U is applied on the external terminal Y. The value of U voltage that occupies N_y vertical divisions on the screen can be determined as:

$$U = Ny \cdot C_y$$

C_y is called **vertical deflection coefficient** and it is graded in volts per division [V/div].

Observation 4: The values of deflection coeficients, C_x and C_y, can be adjusted from the oscilloscope control panel (Figure 5).

Observation 5: Modifying the deflection coefficients will also modify the image visualized on the screen. For example, if a sine wave with an amplitude of 4V is visualized, the amplitude of the signal will be displayed on two divisions (N_{y1}=2 div) if the deflection coefficient C_{y1}=2V/div, but it will be displayed on four divisions (N_{y2}=4 div) if the deflection coefficient is changed to 1V/div (C_{y2}=1V/div).

Observation 6: In the previous example, changing the deflection coefficient changes the way the signal is displayed on the oscilloscope screen. **The amplitude of the signal can only be changed from the generator**.

Example: A period of the sine wave in Figure 4 occupies 7 horizontal divisions on the screen, and the time base is set at **Cx=5ms/div** (marked with **M** on the screen). Thus, the period of the signal is 35ms. On vertical axis, the peak value occupied 3 divisions and using **Cy= 2V/div** (notat **CH1** pe ecran), a peak amplitude of 6V is obtained.

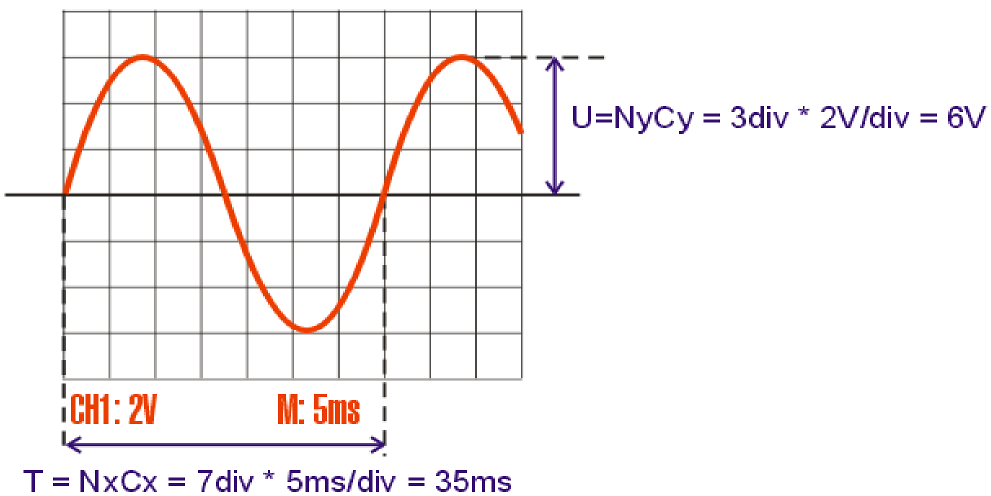


Figure 4. Values of deflextion coeficients C_X=5ms/div, C_Y=2V/div

The values C_x and C_y are called *calibrated* and have standard values of{1, 2, 5}*$10^{+/-K}$ for C_y and {1, 2.5, 5}*$10^{+/-K}$ for C_x. The calibrated coefficient values for usual oscilloscopes are:

$C_y \in$ {5; 10; 20; 50; 100; 200; 500 mV/div; 1; 2; 5 V/div}

$C_x \in$ {5; 10; 25; 50; 100; 250; 500 ns/div; 1; 2,5; 5; 10; 25; 50; 100; 250; 500 μs/div;

1; 2,5; 5; 10, 25; 50; 100; 250; 500 ms/div, 1; 2,5; 5; 10 s/div}

Oscilloscope front panel

Figure 5 shows an image of the front panel of the oscilloscope used in the laboratory. It can be seen that, in addition to the screen, the oscilloscope has the signal inputs and a series of control buttons.

The oscilloscope in TDS1000 group has two signal inputs, **CH1** and **CH2**, which allows two signals to be viewed simultaneously. There is also the **EXT TRG** input, which is used to input an external sync signal. This signal cannot be viewed on the screen.

The control buttons are grouped according to their role (Figure 5). The most important groups of buttons are those related to the controls for the vertical axis (**VERTICAL**), for the horizontal axis (**HORIZONTAL**), respectively for synchronization (**TRIGGER**). It is also noticeable that next to the screen, on the right side, there are ***side screen menu buttons***, also called ***Soft Keys***, which correspond to a menu that is displayed on the right side of the screen. Depending on the selected menu, **CH1/CH2 MENU**, **HORIZ MENU**, or **TRIG MENU**, the corresponding configuration fields will be displayed on the screen, whose values can be controlled from the ***side screen menu buttons***.

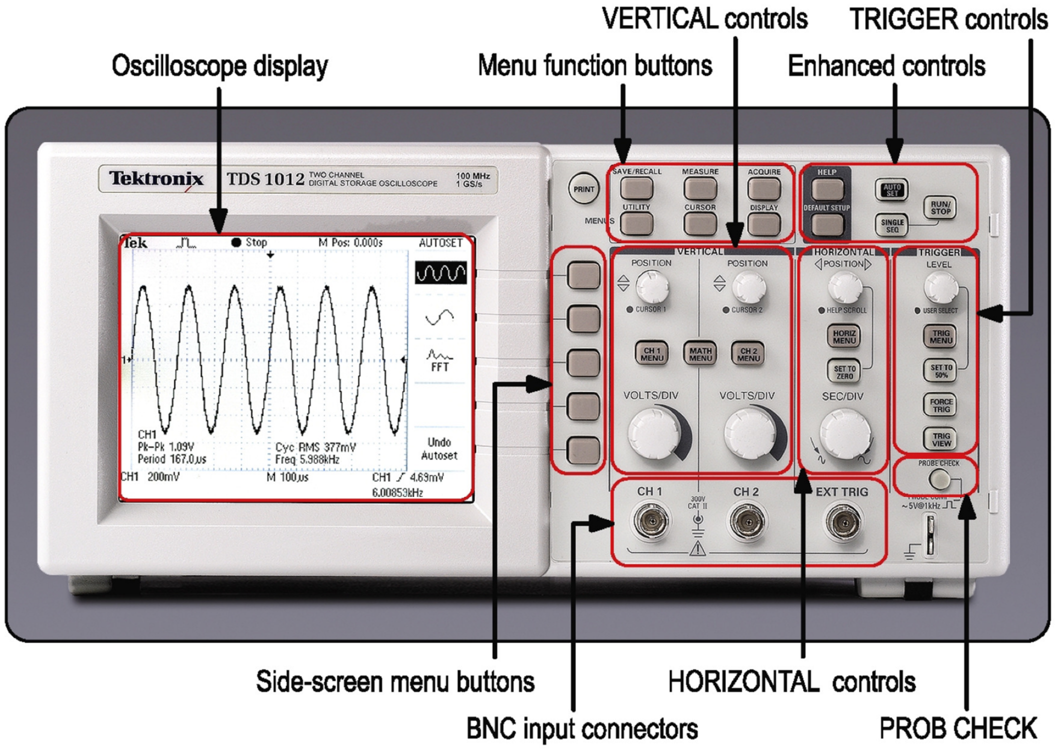


Figure 5. Oscilloscope front panel [3]

VERTICAL adjustments

The controls for the vertical axis are doubled, with one set of controls for each oscilloscope input, **CH1** and **CH2** respectively. The functions of the controls are:

- **VOLTS/div adjustment**: rotative knob that allows adjustment of the vertical deflection coefficient (**C_y** or **CH1** as shown on the oscilloscope screen).
- **POSITION:** rotative knob that allows image shift on vertical axis. When using this knob, the indicator **1>** from the left side of the image will shift also. It indicates where on **OY** axis the voltage **0V** is found.
- **CH1/CH2 MENU**: displays the menu for vertical adjustments (Figure 6). This button also has the function of turning on or off (**ON/OFF**) the image display on the corresponding channel by successive pressing.
  - **Coupling**: selection of coupling mode: **AC**, **DC**, **Ground**.
    - **AC** mode: only the alternative part of the signal is displayed, without the continuous component, U_{CC}.
    - **DC** mode: the continuous component is also displayed.
    - **Ground** mode: 0V voltage level is displayed.
  - **BW Limit**: the frequency band can be limited.

- **Volts/Div**: has two adjustments possibilities: **Coarse** and **Fine**. In **Coarse** mode, the vertical deflection coefficient C_y can be adjusted only in calibrated values. These values are very precisely adjusted, for this reason the **Coarse** mode is preferred for measurements. In **Fine** mode, the vertical deflection coefficient C_y can be adjusted to any value.
- **Probe**: possible values: **1X, 10X, 100X, 1000X**. The values of **10X, 100X, 1000X** are useful when using an attenuator probe to measure big signals. To compensate the attenuation introduced by the probe with 10, 100, 1000, the deflection coefficient C_y is artificially increased by 10, 100, 1000 times by selecting the values **10X, 100X** for **Probe**.
- **Invert**: allows visualization of the reversed signal.

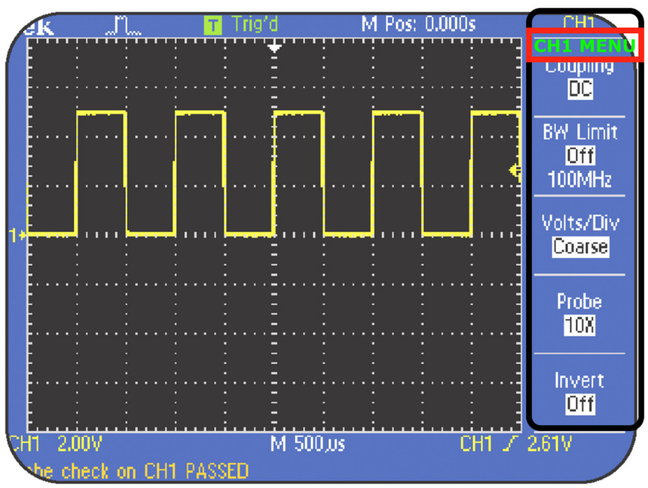


Figure 6. Menu for Channel 1 (CH1 MENU) [3]

HORIZONTAL adjustments

It refers to the controls for the horizontal axis. These controls are:

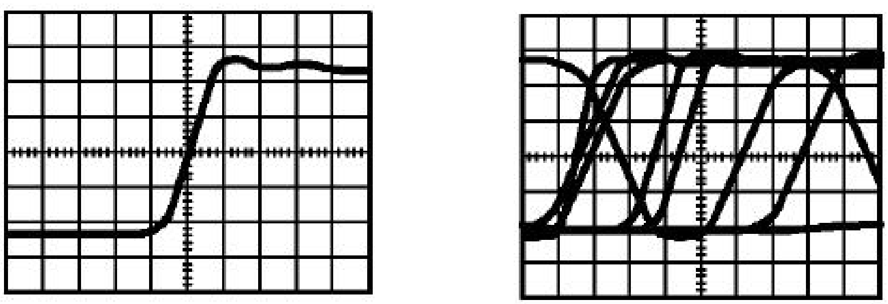
- **SEC/div adjustment**: rotative knob that allows adjustment of the horizontal deflection coefficient (**C_x** or **M** from **„Main Time Base”** as displayed on the oscilloscope screen). As previously presented, this coefficient is measured in seconds/division or submultiples of a second per division.
- **POSITION**: rotative knob that allows image shift on horizontal axis (left-right). When **POSITION** knob is modified, the indication on top of the screen **Trg'd (↓)** modifies too. It indicates where the trigger is set on the horizontal axis.
- **Set to Zero**: Brings the indication **Trg'd (↓)** in the middle of the horizontal axis.
- **HORIZ MENU** – displays the menu for the horizontal axis controls.

TRIGGER controls

This option refers to the controls for image synchronization (getting a stable image on the screen).

- **Level** - adjusts the level of the synchronization threshold (trigger) voltage, the voltage value that the synchronization signal must have in order to trigger a new display;
- **Set to 50%** - automatically adjusts the trigger voltage value to 50% of the signal variation range;
- **Trg View** -for trigger voltage visualization;
- **TRIG MENU** - the trigger settings menu.

Oscilloscope synchronization. An image that is stable on the display of the oscilloscope is called *triggered* (*synchronized*). The physical meaning is the following: when 2 successive images of a periodic signal start at the same moment in time (relative to the signal period), the two images will overlap perfectly, and so will happen for subsequent images. Thus, the eye perceives a single stable image, although, in fact, we constantly have a new image superimposed on the previous one. An example in case of displaying a rising slope is given in Figure 7 (a). But if every display starts with some other moment of time, the images will differ, and the eye will perceive many different superposed images – Figure 7 (b). In this case the image is called *untriggered* (*unsynchronized*) and is difficult or impossible to interpret.



a) synchronized image **b) unsynchronized image**

Figure 7: sincronizarea osciloscopului [1]

To achieve a synchronized image, the following *synchronization adjustments* are available: *the signal* used for synchronization (*Source*) – signal on CH1, CH2 or any other signal, its *level* and a *front (slope)* where you want to start displaying the image. These settings are usually grouped together in a *sync menu – Trigger Menu.*

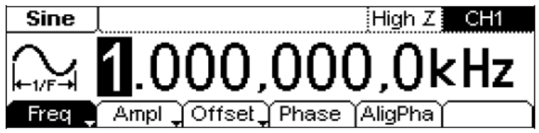
Usually, for an image to be synchronized, *Trigger Level* must be between the [minimum, maximum] level of the signal. A smaller or larger level means that the *Trigger Level* does not intersect the signal, therefore it cannot trigger a display.

During this lab, the following synchronization settings will be used: ***Source*** **= CH1**, ***slope*** **= Rise**, ***Mode*** **= AUTO.** To automatically adjust the *Trigger Level* to the middle value, press the **Set To 50%** button.

Generator settings

The Rigol DG1022 function generator allows the generation of several waveforms (sine, square, triangle, etc.) with various adjustable parameters. The waveform type is selected using the buttons marked accordingly:

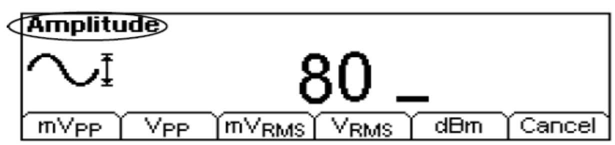
The parameters of a certain waveform are selected by pressing the function buttons (without marking), whose functions correspond to the indications on the display:



For example, if the function button 

is pressed, the respective function (frequency adjustment) is selected, and the value can be entered either from the numeric keypad or changed from the rotative adjustment. On function buttons that have a small arrow drawn (like **Freq** above), successive presses allow setting parameters in several ways. For example, except from the amplitude setting (**Ampl**), it can also be set the **HiLevel** value which corresponds to U_{max} from Figure 1a).

After entering the numerical value, choose the desired measurement unit by pressing the functional button below it.



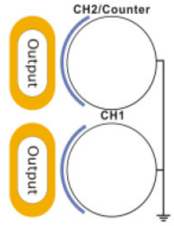
Attention! According to Figure 1a), the amplitude U_0 and the value U_{max} are equal only if U_{DC}= 0V (null mean value). To eliminate possible confusions, this generator allows setting the amplitude in values of V_{PP} (*peak-to-peak*) which means that, actually, by choosing this measurement unit, the function key **Ampl** sets the peak-to-peak value, which is double the amplitude for a signal with no DC level. A symmetric signal with 2V is actually a signal with $4V_{PP}$.

For asymmetrical signals (with U_{CC} nonzero), the peak-to-peak value remains the same while U_{max} and U_{min} change (see Figure 1a)).

Observation: the shortcut V_{RMS} refers to the effective value that will be later study in another laboratory entitled „voltages measurements".

The generator has 2 channels which can generate different waveforms. The above settings have effect on the channel that is selected using the 

and correspondingly, **CH1** or **CH2** will appear on the display. Moreover, the output of the respective channel is only active when the corresponding **Output** button is pressed and it lights up.



Measurement of a continuous component of a signal

Figure 8 shows two sine waves, the first without a continuous component, and the 2nd with a continuous component. It is observed that the signal without continuous component is symmetrical with respect to 0V. The following exemplification consideres a sine wave with peak value $\boldsymbol{U_V = 2V}$, with and without a constant value $\boldsymbol{U_{CC} = -1V}$ called ***the continuous component*** (the constant, time-invariant component of the signal) or ***Offset***:

$u(t) = U_V \sin \omega t$ [V] $\rightarrow$ $u(t) \in$ [-2V, +2V] [1]

$u(t) = U_{CC} + U_V \sin \omega t$ [V] $\rightarrow$ $u(t) \in$ [-2-1V, +2-1V] = [-3V, +1V] [2]

Both situations are illustrated in Figure 8. The arrow on the left marks the 0V level:

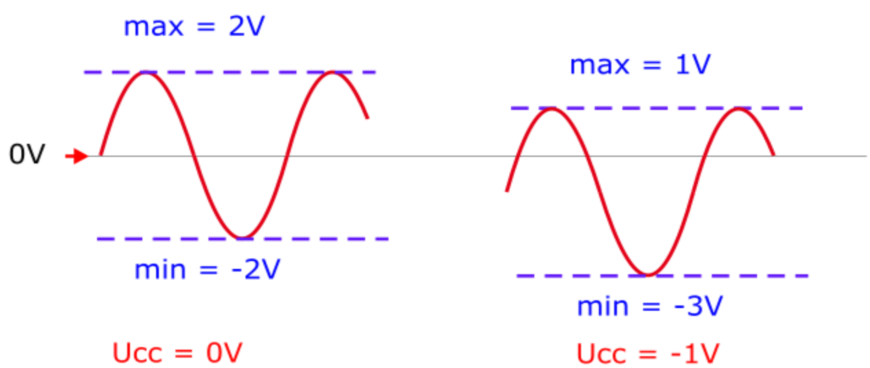


*Figure 8. Signal $u(t) = U_{CC} + U_V \sin \omega t$ with **Ucc= 0** (left) and with **Ucc= -1V** (right)*

It is observed that the two signals are shifted from each other vertically by a value equal to the value of the continuous component. The second signal is lower because the U_{CC} is negative.

If the sine wave with continuous component given by Equation [2] is displayed on an oscilloscope that has **DC** coupling mode selected, then the image will be viewed on the oscilloscope as in Figure 8 right. If the **AC** coupling mode is selected, where the signal is displayed on the screen without a continuous component, then the sine wave will be viewed on the oscilloscope screen as in Figure 8 left.

Based on these observations, the method of measuring the continuous component of a signal using the oscilloscope is obtained:

Oscilloscope measurement of the continuous component of the signal: Visualized the signal on the oscilloscope in **AC**-coupled mode and note the position of a part of the image (e.g., a peak). Next switch to **DC** coupling mode and measure how much the chosen part has moved vertically. The value of this displacement expressed in volts represents the continuous component or average value of the signal. The sign of the **DC** component is given by the direction of the shift when switching from **AC** mode to **DC** mode. If it moves up, the sign is positive, if it moves down, the sign is negative.

Observație: the continuous component is also called the *average value* of the signal, since it is equal to the average over a period of *u(t)*. Notice in equations [1] and [2] above that integration over one period (equivalent to averaging) give the values 0V and U_{CC} respectively.

Practical measurements

1. Sine wave visualization

Using the function generator, generate a sine wave with the following parameters:

- channel 1 from the 

 button (**CH1** is displayed in the upper right corner)
- 

 button – sine wave
- **Freq** – the value f_1 written on the blackboard
- **AMPL** – the value A_1 written on the blackboard (Pay attention: to the measurement unit! An amplitude of 2V is, like previously mentioned, equivalent to $4V_{PP}$! the measurement unit eliminates all doubt regarding the limits between which the voltage is specified).
- no continuous component (**OFFSET** = 0V).

Press the **Output** key next to the CH1 output so that it is illuminated; connect the CH1 output of the generator to channel 1 of the scope using a coaxial cable (or two crocodile clips connected together).

On the oscilloscope, press **CH1 MENU** to display channel 1 settings (with repeated presses, channel 1 is successively turned off and on). Since a simple cable is used, press the **Probe** *softkey* until the indication is **1x**.

a) Set to the oscilloscope the values C_{X1} , C_{Y1} (written on the blackboard).

Observation: review Figure 2; the oscilloscope displays the C_Y of channel 1 with the notation **CH1**, and the C_X value is labeled **M** (*main time base*).

Notice that *one period of the signal is displayed on the screen*. Measure the period of the signal by counting the divisions and subdivisions N_x corresponding to this period and use the formula $T_{măs1}=C_x \cdot N_x$. Calculate the frequency $f_{măs1}=1/T_{măs1}$ and verify that it corresponds with the value indicated by the generator.

b) Without other changes, set $C_{X2} = 2C_{X1}$. Notice that *two periods of the signal are displayed on the screen*. Measure N_{X2} for one period and compute $T_{măs2} = N_{X2}C_{X2}$.

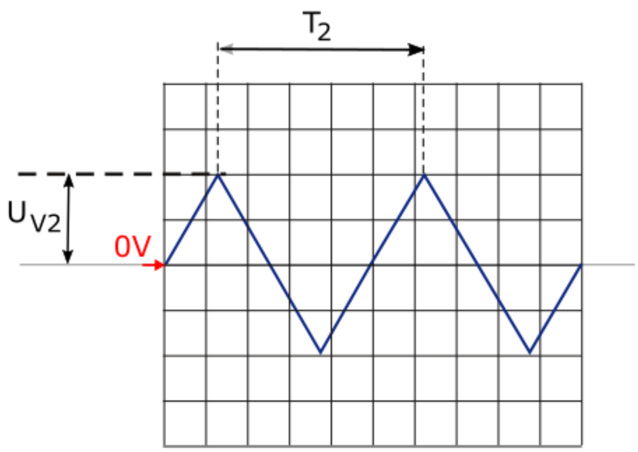
Since the generator frequency/period has not changed, do you expect any change between $T_{măs1}$ and $T_{măs2}$? Note: C_X stands for a horizontal zoom factor. Similar to the situation with a camera, changing the zoom changes the relative size of the image, but does not mean that the actual size of the photographed object changes!

c) On vertical axis, by counting the vertical divisions and subdivisions N_y for the ***peak of the signal*** and applying the formula $U=N_yC_y$, measure the amplitude of the signal (peak value U_V). In the same way, measure peak-to-peak value U_{vv}. Calculate the ratio between U_v and U_{vv} (measured values). What is the theoretical value of the ratio?

Observation: Appendix A can be used to identify the settings and indications of the oscilloscope.

2. ***Setting a triangular signal from the generator***

a) Generate a **triangular** wave, (**Ramp** button) with no DC component (**OFFSET** 0V), symmetry 50%, with frequency $\boldsymbol{f_2}$ and amplitude $\boldsymbol{U_{v3}}$ (written on the blackboard). the oscilloscope settings must be made so an image similar to the image in the following image is visualized (to have the start time like in the figure, press the **SET TO 50%** button below the *Trigger* level).



a1. What is the measured period of the signal (T_2)? Compute the necessary C_X Compute the necessary C_X to observe *exactly 2 periods* on the scope. Set this C_X value to the oscilloscope. How many divisions does a period occupy on the scope (N_X) ?

a2. Compute the necessary C_Y so the peak value U_{V2} to occupy exactly $N_Y = 2$ div. Set this C_Y value to the oscilloscope.

b)) The influence of C_Y on the displayed image
Modify C_Y to a new value $\mathbf{C_Y' = C_Y / 2}$. How many divisions $\mathbf{N_Y'}$ does the amplitude occupy now? Compute the amplitude based on the new image: $U_V' = N_Y'C_Y'$ and compare it with U_{V2}. Explain the relation between U_V' and U_{V2}..

c) The influence of C_X on the displayed image
Modify C_X to a new value $\mathbf{C_X' = 5C_X}$. How many divisions $\mathbf{N_X'}$ does one period occupy now? Compute the period based on the new image: $T' = N_X'C_X'$ and compare it with T_2. Explain the relation between T' and T_2.

3. ***Generation and measurement of a sine wave with DC component***

a) Generate a sine wave (

button from the generator), with the frequency $\boldsymbol{f_1}$**=20kHz**, amplitude $\boldsymbol{U_V}$ **=2V** and continuous component $\boldsymbol{U_{CC1}}$**= -1V**. To adjust the continuous component from the generator use **OFFSET** = -1V.

The deflection coefficients used on the oscilloscope are $\mathbf{C_{X1}}$**=25μs/div** and $\mathbf{C_{Y1}}$**=1V/div**. Using **Vertical Position** adjustment, set the 0V level (Ground – marked by an arrow with the channel number, on the left of the image) in the middle of the screen.

a1. Draw the image of the scope and *mark on the drawing* the ground level OV (the arrow on the left). Use **CH1 MENU->Coupling ->DC**. This coupling mode means the signal is applied directly, without altering the possible DC component of the signal. Mark on the image the position of arrow simbolizing the Ground level, C_x and C_y values.

a2. Draw the image when using AC coupling (**CH1 MENU->Coupling ->AC**). This coupling mode means that a capacitor is inserted in series between the signal and the oscilloscope signal path. The capacitors do not let continuous signals to pass through, but only alternative signals. v the position of the Ground level, C_x and C_y values.

b) How can the continuous component be measured using the oscilloscope ?

- set the oscilloscope to AC coupling: (**CH1 MENU->Coupling ->AC**); the DC component is *blocked*; therefore, the signal is symmetrical on the screen (as if OFFSET were not set from the generator).

- set **CH1 MENU->Coupling ->DC**. Now, the signal will rise or fall with a certain number of divisions N_Y. Taking as reference a point on the waveform (typically, the maximum or minimum value), count how many divisions the signal rises or falls when switching from AC to DC. If it rises, then the continuous component (offset) is positive if it falls, the continuous component (offset) is negative. Counting the number of divisions N_Y corresponding to U_{CC} value, taking also into consideration the sign, compute $U_{CC} = N_Y C_Y$. This value should be the same as the one set at the **OFFSET** to the generator.

Observation: If needed, adjust the trigger (**SET TO 50%)** so that the image is synchronised (it's possible that when we move the signal up or down, because of the offset, it does no longer cross the trigger level).

b1. Work in a team, as follows:

- Set at the oscilloscope **CH1 MENU->Coupling ->AC** to hide the DC level. Keep $\mathbf{C_Y}$ **= 1V/div.**
- *One of the team members* will set at the generator, from the function key **Offset**, a nonzero DC level marked with U_{DC1} in the interval (-2V, 2V), without telling the chosen value to the colleague. The value must be different than the one in point a). The amplitude remains 2V.

- *The other team member* will switch from **CH1 MENU->Coupling ->AC** to **DC**. Adjust the trigger (**SET TO 50%**) so the image will be synchronized. Count the number of divisions $\mathbf{N_{Y1}}$ corresponding to the signal's top rising or falling and compute U_{CC1} (value and sign): $U_{CC1} = N_{Y1}\, C_Y$. Compare this value with the value set by the colleague.
- Draw the image with the setting **CH1 MENU->Coupling ->DC** to see the continuous component as well (draw the level 0V arrow).

b2. Switch places and repeat b1. for a different offset value.

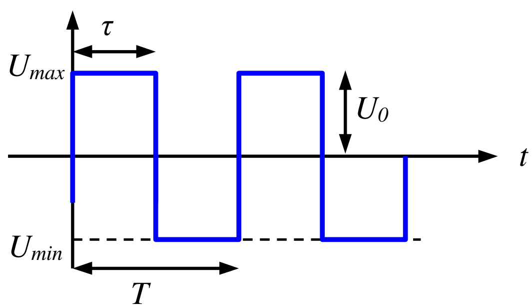
Explain why DC level measurement is performed by switching from AC to DC coupling, and not the other way around!

4. ***Setting a square (rectangular) signal; duty cycle***

Generate a square wave (**Square** button), no DC component (**OFFSET** 0V), with the amplitude of $\boldsymbol{U_{V4}}$, frequency $\boldsymbol{f_4}$ ((written on the blackboard). Compute the period $\mathbf{T_4}$.

Compute C_X, C_Y so that *exactly one period of the signal is displayed* on the screen and the amplitude occupies 2 divisions.

Visualize the signal with computed values of $\mathbf{C_Y}$ **,** $\mathbf{C_X}$ and coupling mode **CH1 MENU->Coupling ->DC**.



Adjust the ***duty cycle η*** for the square signal using the functional button *duty cycle* (**DtyCyc**), then the measurement unit which is implicitly % to the values $\boldsymbol{\eta_1}$**=20%** and $\boldsymbol{\eta_2}$**=50%**.

- Measure *(in divisions)* the values **T** and $\boldsymbol{\tau}$ on the image for both cases.
- Comute the ratio $\boldsymbol{\tau/T}$ (measured value of the duty cycle ***η;*** note that since the ratio is required, it is sufficient to measure the two quantities in divisions).
- Draw the signals for each corresponding duty cycle.

Important remark: the duty cycle is a parameter that has meaning **only** for a rectangular wave, according to the definition in Fig. 1b. it has no meaning for a sine or triangular wave! (you can set the symmetry of the triangle).

Solved exercises

1. A sine wave with a frequency of f=2kHz and amplitude of U_V=4V is displayed using an oscilloscope. The settings are: C_Y=1V/div, C_X=250 μs/div. Determine how many divisions the

amplitude and period of the signal occupy on the display of the oscilloscope.
Solution:

The amplitude of the signal displayed on the oscilloscope screen can be determined with the relation

$$U_V = N_Y \cdot C_Y \quad \Rightarrow \quad N_Y = U_V/C_Y = 4\,[V] / 1[V/div] = 4\ div$$

The period of the signal is $T = 1/f = 1/2000Hz = 500\ \mu s$

The period displayed on the oscilloscope's screen is

$$T = N_X \cdot C_X \quad \Rightarrow \quad N_X = T/C_X = 500\cdot 10^{-6}[s] / 250\cdot 10^{-6}\,[s/div] = 4\ div$$

2. A sine wave with a frequency of f=2MHz and amplitude of U_V=6V is displayed using an oscilloscope. Determine the values of C_X and C_Y such that the amplitude occupies 3 divisions (N_Y=3 div), and the period occupies two divisions (N_X=2div).
Solution:

The equations in previous exercise can be used:

The period of the signal is $T = 1/f = 1/2\cdot 10^6 s = 0,5\ \mu s$.

$C_Y = U_V/N_Y = 6V / 3\ div = 2\ V/div$

$C_X = T/N_X = 0,5\ \mu s / 2\ div = 0,25\ \mu s/div$

3. A sine wave is displayed using an oscilloscope. When the coupling is switched from AC to DC, the sine wave shifts down by N_Y = 2 div. The vertical deflection coefficient is C_Y=5V/div. Determine the continuous component of the signal.
Solution:

The continuous component value determines the shift down movement of the signal by a value that is equal to the value of the offset (for DC coupling). The direction of the movement determines the sign of the offset: shift up - positive; shift down - negative. Based on these observations, we can determine the continuous component:

$$U_{CC} = -N_Y \cdot C_Y = -10V$$

4. A sine wave is displayed using an oscilloscope. When the coupling is switched from DC to AC, the sine wave shifts down by N_Y = 4 div. The vertical deflection coefficient is C_Y=1V/div. Determine the continuous component of the signal.
Solution:

The difference from exercise 3 is that the switch is made from DC to AC mode. Because, after the elimination of the DC component (AC coupling), the signal shifts up, this means that it (the continuous component) was shifting the signal down (in DC coupling). This means that the value of the continuous component is negative.

$$U_{CC} = -N_Y \cdot C_Y = -4V$$

Optional exercises

1. Calculate on how many divisions, N_X and N_Y, the amplitude and period will be displayed on the oscilloscope screen for the following signals and settings:
   a) sine wave with the amplitude U_{V1}=4V and frequency f_1=20kHz. Scope adjustments: C_{X1}=10μs/div and C_{Y1}=1V/div.
   b) sine wave with the amplitude U_{V2}=6V and frequency f_2=8kHz. Scope adjustments: C_{X2}=25μs/div and C_{Y2}=2V/div.
2. Compute the deflection coefficients (C_{Xcalc}, C_{Ycalc}) that can be set to the oscilloscope to display a sine wave with the frequency f_3=1kHz and amplitude U_{V3} =2V, so that the amplitude is displayed on two divisions, and the period on four divisions.
3. An oscilloscope is set on C_y=0,5V/div. The amplitude of a signal measured on the oscilloscope screen is 3.8div. What is the amplitude of the signal in volts?

4. An oscilloscope is set on C_x=20ms/div. The period of a sine wave measured on the oscilloscope screen is 5 div. Determine the frequency of the sine wave.

5. Consider a sine wave with frequency 10kHz and amplitude 4V. Determine the values for the vertical and horizontal deflection coefficients so that the amplitude and period of the signal can be measured with maximum precision on the screen.

6. A sine wave is visualized with an oscilloscope. When the coupling button is set from AC to DC, the position the sine wave shifts down on the screen by 3 divisions. If Cy=1V/div, determine the continuous component of the signal.

Bibliografie

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