Experiment 2: Capacitors

Student Group

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Objectives of the experiment

Getting to know the following components

- Digital multimeter
- Function generator
- Oscilloscope
- Breadboard

electrical-engineering learning outcome in

- generating and displaying periodic signals
- determining capacitances
- measuring the characteristic curve of a diode and a Zener diode

Preparation for the lab

in the ILIAS course

Read the documents for Experiment 2 here.

Display of periodic signals on the oscilloscope

Build the following circuit in figure 1 with the function generator and the oscilloscope.

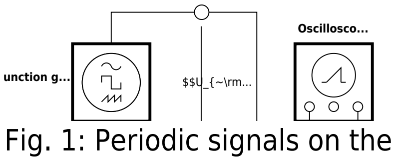


Fig. 1: Periodic signals on the oscilloscope

Set the signals listed in table 1 on the function generator and draw the corresponding oscilloscope screen images. The signal display on the oscilloscope should optimally fill the screen

Signal shape	**Frequency**	**Amplitude**
Sine	1.0 kHz	1.8 V
Triangle	4.0 kHz	3.0 V
Square (unipo...	2.0 kHz	5.0 V
Square (bipol...	5.0 kHz	2.0 V
Sine...	2.5 kHz	4.0 V...

Text is not SVG - cannot display

Tab. 1: Signals

Also document the settings of the used channels, the time base, and the GND line on the left side of the screen drawings.

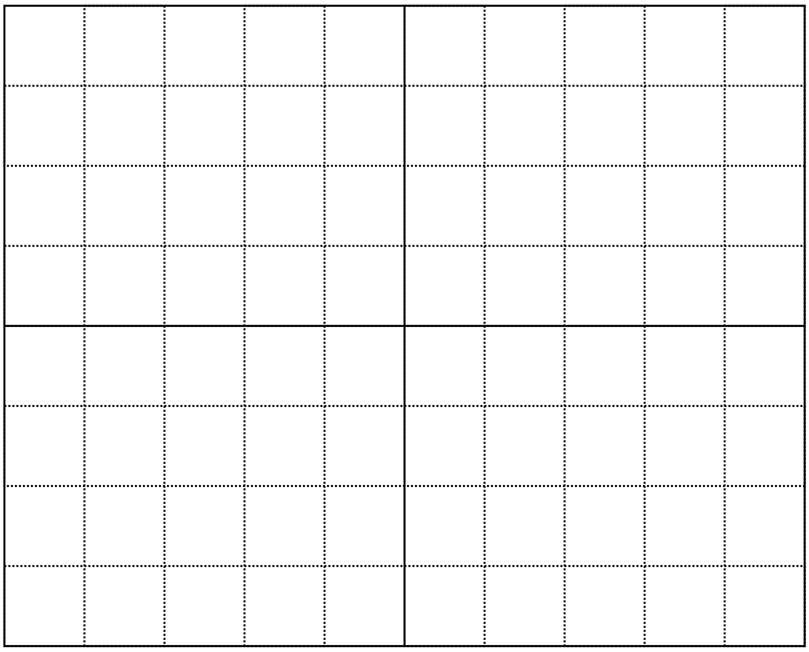


Fig. 2: Sine, f = 1 kHz, U = 1.8V

Channel 1: $\frac{V}{\rm DIV} =$

Time basis: $\frac{T}{\rm DIV} =$

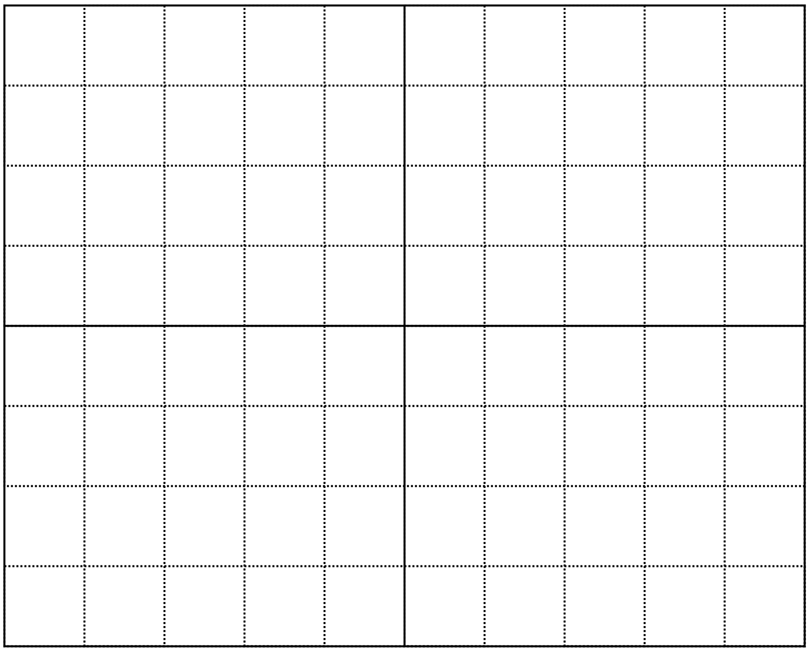


Fig. 3: Triangle, f = 4 kHz, U = 3 V

Channel 1: $\frac{V}{\rm DIV} =$

Time basis: $\frac{T}{\rm DIV} =$

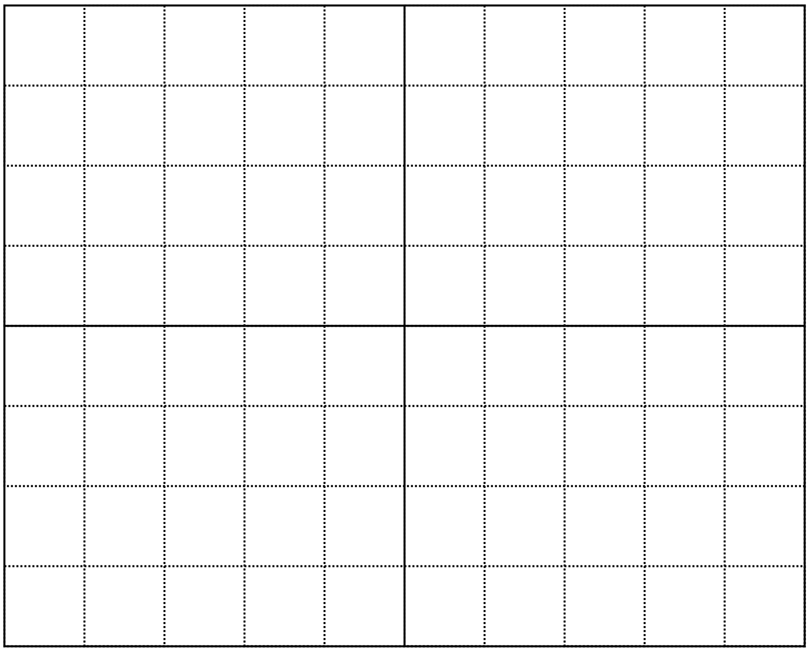


Fig. 4: Rectangle, unipolar, f = 2 kHz, U = 5 V Channel 1: $ \frac{V}{\rm DIV} = $

Time basis: $ \frac{T}{\rm DIV} = $

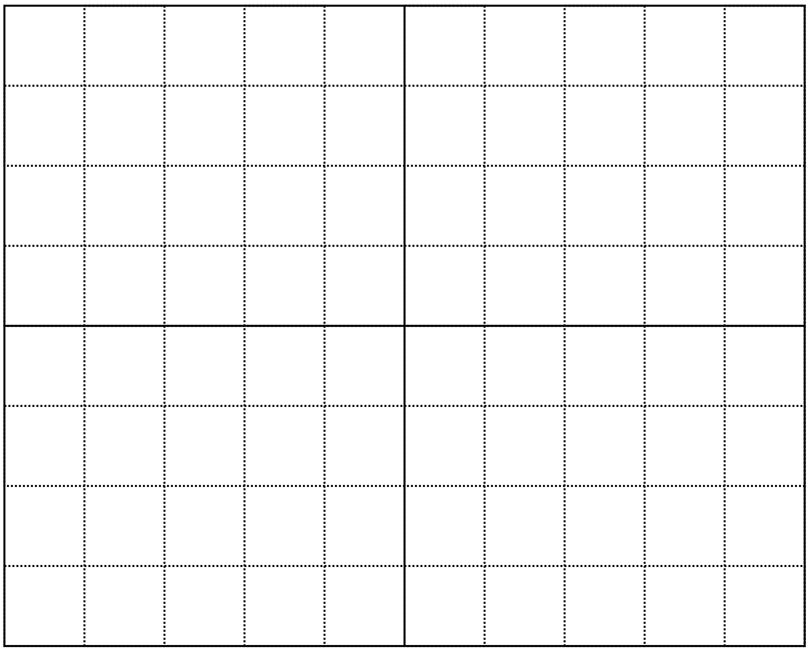


Fig. 5: Rectangle, bipolar, f = 5 kHz, U = 2 V

Channel 1: $ \frac{V}{\rm DIV} = $

Time basis: $ \frac{T}{\rm DIV} = $

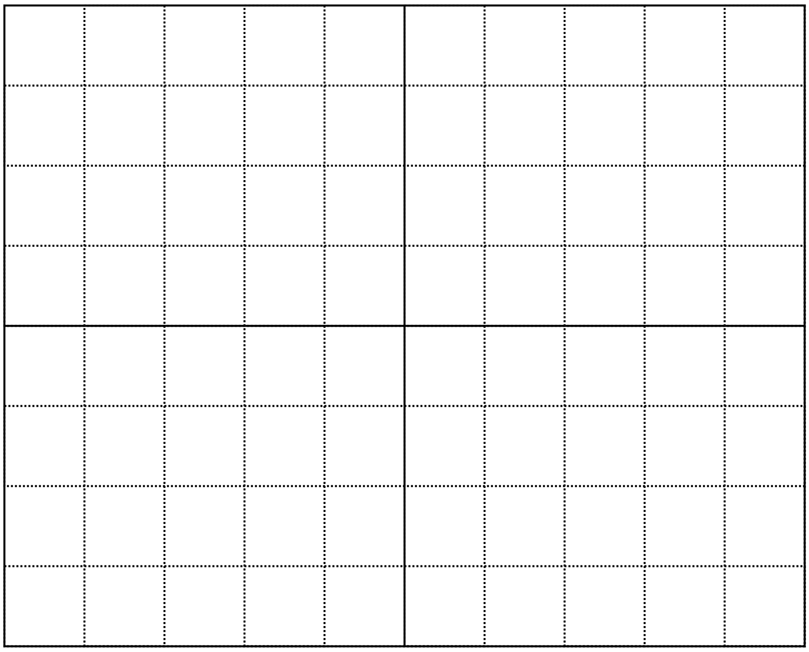


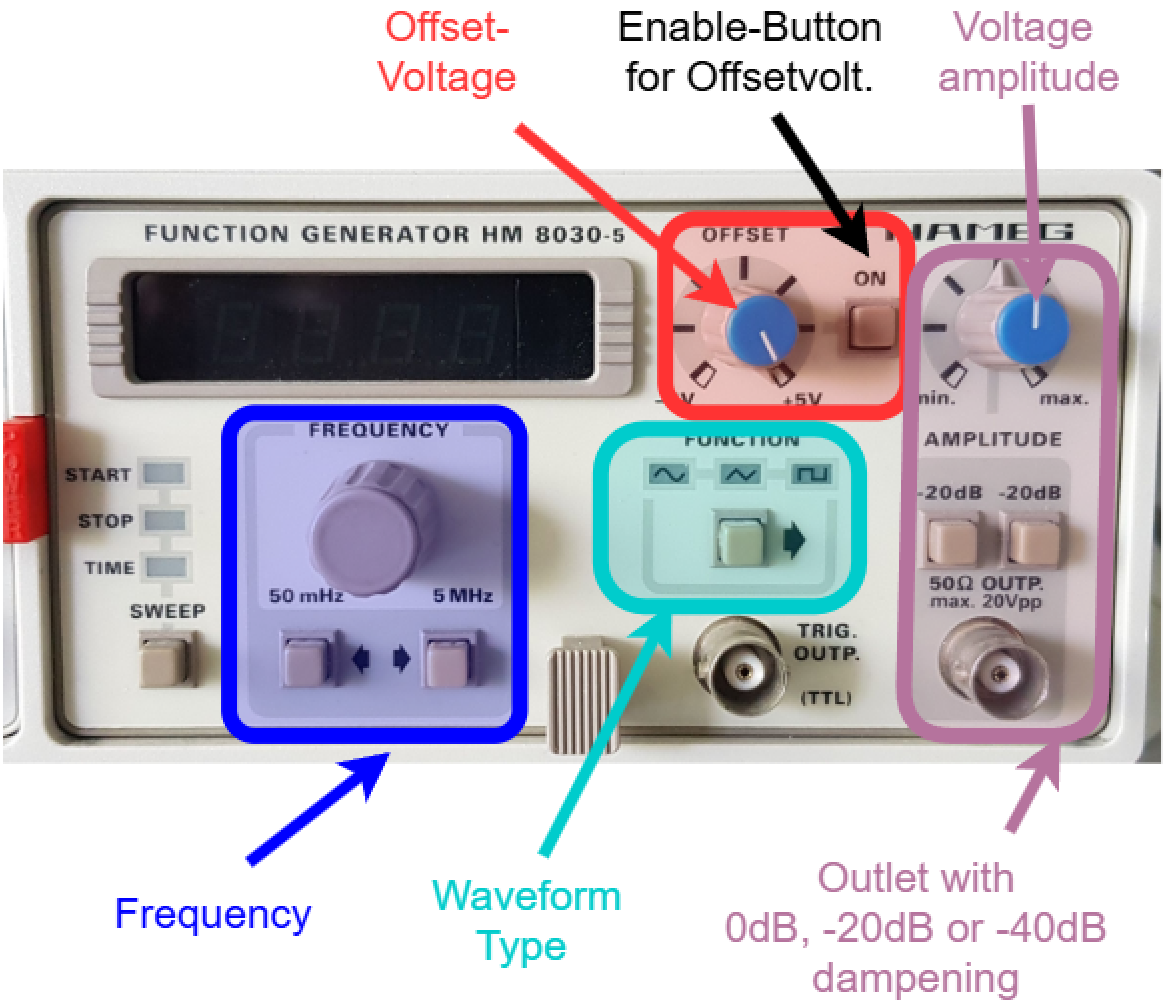
Fig. 6: Sine DC Offset, f = 2.5 kHz, U = 4 V, UDC = 2 V

Channel 1: $ \frac{V}{\rm DIV} = $

Time basis: $ \frac{T}{\rm DIV} = $

Function generator

Fig. 17: Function generator HM8030-5



A function generator provides a variable voltage source. In general, these signals can be generated with different waveform shapes, frequencies, and amplitudes. These values can be adjusted on real function generators. In contrast to an ideal function generator, the output current of a real system is limited. As with a real voltage source, an output impedance is specified here.

In figure 17 the function generator used in the lab is shown. It has an output impedance of $50~\rm \Omega$. In the following, the settings are briefly described:

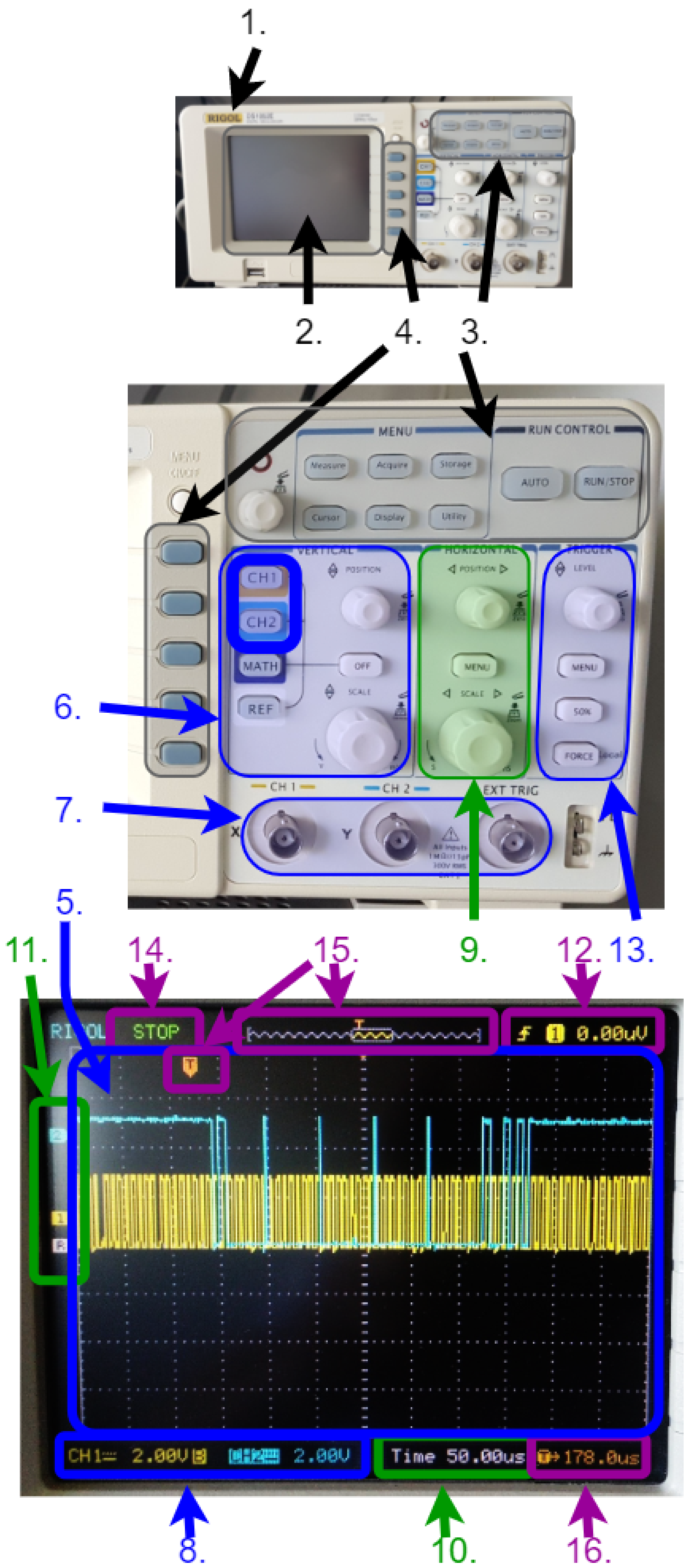
1. The waveform can be selected using the **FUNCTION** button. Pressing the button selects the next waveform. At start-up, the sine waveform (∿) is selected; the following waveforms are: triangle and square or pulse. The waveforms can be seen in the simulation below; a sawtooth signal is not possible with this function generator.
2. The frequency can be changed via two inputs
    1. The potentiometer under **FREQUENCY** allows precise adjustment. Turning clockwise increases the frequency.
    2. Using the buttons under the potentiometer, the frequency can be changed by one decade—i.e., by a power of ten—down (button with arrow to the left) or up (button with arrow to the right). The limits are $50~\rm mHz$ and $5~\rm MHz$.
3. There are also several controls for the voltage

1. The potentiometer **OFFSET** allows precise selection of the DC component. To enable a DC component, press the **ON** button.
2. At the output jack, two attenuations of $-20~\rm dB$ can be switched on. This reduces the peak-to-peak voltage range from [$0~\rm V$, $10~\rm V$] to [$0~\rm V$, $1~\rm V$] or [$0~\rm V$, $0,1~\rm V$].
3. The **AMPLITUDE**, i.e. the peak-to-peak voltage, can be finely adjusted using a potentiometer.

Oscilloscope used

Even before the digital multimeter, the oscilloscope is the most important measuring instrument in electrical engineering and electronics. It makes it possible to display a voltage waveform u(t) over time t, observe it in “real time,” and measure it. In many experiments and analyses, it is a central component because it can make electrical processes visible. In addition to quantitative statements (how high is the voltage and when?), it is also helpful for qualitative results (for example: Is there a fault in the circuit?).

Fig. 18: Display and control panel of the oscilloscope DS1052E


1.
2.
4.
3.
MENU
RUN CONTROL
Measure
Acquire
Storage
Cursor
Display
Utility
AUTO
RUN/STOP
CH1
CH2
MATH
OFF
REF
MENU
MENU
50%
FORCE
CH 1
CH 2
EXT TRIG
X
Y
6.
7.
5.
9.
11.
14.
15.
12.
13.
STOP
0.00uV
CH1 2.00V
CH2 2.00V
Time 50.00us
178.0us
8.
10.
16.

Good knowledge of the oscilloscope is necessary for this experiment. In figure 18 you can see the control panel of the DS1052E used, which is briefly described here.

Please use the buttons marked with “ ” to learn more about the individual functions

General operation

1. On/off switch (**1.**)
2. Display area (**2.**)
3. Selection of operating modes (**3.**)
4. Menu selection buttons (**4.**)

- The oscilloscope can be **turned on/off** using the button on the top (**1.**)
- In the **display area** (**2.**) information is shown in the user interface after switching on, which is explained below
- At the top right (**3.**) two **operating modes** can be selected: single acquisition after a trigger signal (RUN/STOP) and automatic selection of various settings (AUTO). In addition, there are various menu selection buttons there, e.g. for the cursor menu (**3.**).
- In the menus, displayed functions can be selected via five **selection buttons** (**4.**). The menus are not discussed further below.

Signal display and input

- Display window (**5.**)
- Channel selection / horizontal controls (**6.**)
- Input jacks (**7.**)
- Channel coupling / voltage scale (**8.**)

- The largest area is the **display window** (**5.**). The display window shows 10 horizontal and 8 vertical divisions (eng. divisions, abbreviation Div.). As a rule, the voltage-time waveform is shown here.
- In the figure, two waveforms are displayed simultaneously: channel 1 in yellow and channel 2 in mint. These can be switched on/off using the **channel selection** (**6.** top two buttons).
- The signals are fed in via the **input jacks** (**7.**) (CH 1 : channel 1, CH 2 : channel 2)
- For the signal, you can choose whether the DC component is suppressed (AC coupling) or not (DC coupling). The **channel coupling** is shown in the display (**8.**) as a line (= for DC coupling) or a tilde (~ for AC coupling)

Scaling

- vertical controls (**9.**)
- horizontal controls (**6.**)
- voltage scale (**8.**)
- time base (**10.**)
- signal mean values (**11.**)

- The voltage scale can be varied using the **vertical controls** (**9.**): **POSITION** shifts a waveform up/down. **SCALE** enlarges/reduces the vertical axis (= voltage axis).

- The same can be done for the time axis using the **horizontal controls** (6.): it can also be shifted with **POSITION** and enlarged/reduced with **SCALE**.
- The current scaling can be read from the display area: In the image, a **voltage scale** of `2.00 V/Div` for both signal waveforms (8.) and a **time base** of `50.00 us/Div` (**10.**) are shown.
- The **signal mean values** are drawn to the left of the waveform (**11.**) as a small yellow arrow (channel 1) and a mint-colored arrow (channel 2). If a signal is above or below the displayed area due to incorrect scaling, the corresponding arrow is also shown at the top or bottom edge.

Trigger

- Display of the trigger threshold at signal mean values (**11.**)
- Trigger threshold, trigger source (**12.**)
- Trigger level (**13.**)
- Acquisition status (**14.**)
- Position in memory (**15.**)
- Trigger delay (**16.**)

- As a rule, acquisition should be triggered when a certain threshold is exceeded or fallen below. This threshold is called the trigger threshold.
- The **trigger threshold**, **trigger source** (CH1 or CH2), and triggering on an exceedance (rising edge ↑) or falling below (falling edge ↓) can be seen in the display area (**12.**). The threshold is additionally marked to the left of the waveform (**11.**).
- The knob (**13.**) can be used to shift the threshold (**trigger level**). Pressing `50%` sets the trigger to the center.
- The **acquisition status** (**14.**) is located at the top left of the display area. `STOP` means a still image is shown. When running, `T'D` for triggered is shown here.
- The oscilloscope records a longer time period than the one displayed. The **displayed position in memory** (**15.**) is shown at the top of the display area. The trigger point is also drawn there. How many (nano-, micro-, or milli-)seconds the trigger point is currently shifted from the displayed center is shown at the bottom right (**16.**).

On the left you will find a nice introductory video. Note that the specific operation often depends on the manufacturer and model. However, the concepts are the same for all devices.

Virtual oscilloscopes

A virtual oscilloscope can be found on the pages of Aachen University. Try there to "oscilloscope" various function generator settings, e.g.:

- $200~\rm Hz$, sine, offset $1~\rm V$, amplitude $5~\rm V$
- $200~\rm Hz$, square, offset -$1~\rm V$, amplitude $3~\rm V$

What happens if the trigger level is set too high?

further virtual oscilloscopes

Hochschule Aalen also provides a virtual oscilloscope for practice.

Another virtual oscilloscope is offered by TU Berlin. However, due to the Java implementation it only works in a few browsers (e.g. Internet Explorer). In addition, the following must be done:

- Open the Windows app “Configure Java”: `<WIN>` » `Configure Java`
- Under `Security` » `Exception Site List` add the following servers:
  - `https://www.projektlabor.tu-berlin.de/menue/onlinekurs/scope/`
  - `http://www.projektlabor.tu-berlin.de/` (no http**s**)
- Confirm with OK

Preparation for the oral short test

For this experiment you should

1. be able to apply and explain the following concepts:
   1. periodic signal
   2. characteristic quantities in the signal-time waveform
      1. peak value (amplitude)
      2. peak-to-peak value
      3. arithmetic mean value
      4. RMS value (quadratic mean)
      5. rectified mean value
      6. period duration
      7. frequency
   3. creating the time waveform of a periodic signal
   4. graphical determination of the above quantities from the time waveform of a signal
   5. capacitance C
   6. behavior of current i and voltage u across R and C with a rectangular input voltage for $t=[0; \infty]$
   7. $i_{C,stat}$ and $u_{C,\rm stat}$ in steady state
   8. time constant τ
   9. determination of R, C, τ, $i_{C,\rm stat}$ and $u_{C,\rm stat}$ from the time waveform

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