Wrocław University of Science and Technology

ELECTRIONIC MEASUREMENTS
LABORATORY REPORT

Chair of Electronic and Photonic Metrology
ELECTRIONIC MEASUREMENTS LABORATORY

Theme of class: OSCILLOSCOPE

Group no: 1

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1 Introduction

The goal of the laboratory was to learn how to use an oscilloscope and a signal generator. We configured the signal, observed various signal shapes, and measured signal parameters such as frequency, magnitude, phase shift, period, and average value.

Theory

An oscilloscope, formerly known as an oscillograph, is an instrument that graphically displays electrical signals and shows how those signals change over time.

There are two types of oscilloscopes: analog and digital. An analog oscilloscope captures and displays the voltage waveform in its original form, while a digital oscilloscope uses an analog-to-digital converter to capture and store information digitally. Nowadays most engineers use digital oscilloscopes for designing and debugging digital circuits.

A brief history

The oscilloscope was invented by a French physicist André Blondel in 1893. His device was able to register the values of electrical quantities such as alternating current intensity. An ink pendulum attached to a coil recorded the information on a moving paper tape.

The first oscilloscopes had a very small bandwidth, between 10 and 19 kHz.

How does an oscilloscope work?

To fully understand experiments with an oscilloscope, we have to know how it works.

An oscilloscope is a combination of various components, among which we can pinpoint four that are the most important. These are:

- CRT
  - The cathode ray tube is used to display a graph of the voltage or current at a given point in time. The voltage is applied to the cathode, and the ammeter measures the current. The electrons are then accelerated towards the anode, and the voltage controls the beam's intensity. This creates a beam of electrons that scans the screen from left to right, and the beam's intensity is proportional to the current.
- Vertical control
  - Vertical control adjusts the voltage displayed on the screen. The height of the waveforms determines this voltage on the screen. The higher the waveforms, the higher the voltage. The vertical control allows you to adjust the voltage to match the waveforms on the screen.
- Horizontal control
  - Horizontal control allows the oscilloscope to display a single horizontal line on the screen. It can be used to adjust the timebase, which is the time it takes for the oscilloscope to draw a single horizontal line on the screen. This is measured in milliseconds (ms) and can be adjusted by turning the horizontal control knob.
- Triggering control

– Triggering controls the timing of the waveform display. The waveforms are displayed in the time domain, so triggering is used to control the start and stop times of the waveforms. Triggering is also used to control the acquisition of data.

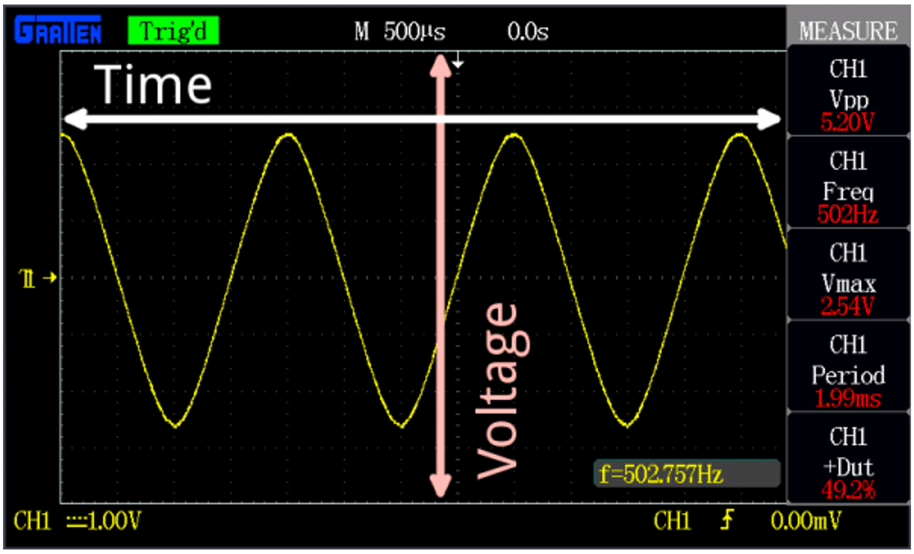


Figure 1: Scaled signal in time and amplitude

Digital Oscilloscope

A digital oscilloscope can be used to analyze the function of either analog or digital circuits and systems. A typical oscilloscope consists of a cathode ray tube (CRT) with an electron gun, a phosphor-coated screen, and a high voltage power supply. The CRT usually displays time on the x-axis and amplitude on the y-axis. Digital oscilloscopes are gaining popularity because they provide more accuracy than their counterparts, and many models offer features such as triggering, storage, multiple channels for simultaneous display, math functions such as integration and differentiation, persistence mode for viewing changes in signal over long periods without refreshing the screen every few seconds like most CR.

Digital oscilloscopes work by sampling voltage at a fixed rate and displaying the voltage waveforms on a digital screen. The voltage waveforms are displayed as a series of dots representing the voltage amplitude at a specific point in time. The oscilloscope samples the voltage waveforms at a fixed rate and calculates the average voltage between the samples. This process is repeated for every sample, and the resulting waveform is displayed on the oscilloscope's screen.

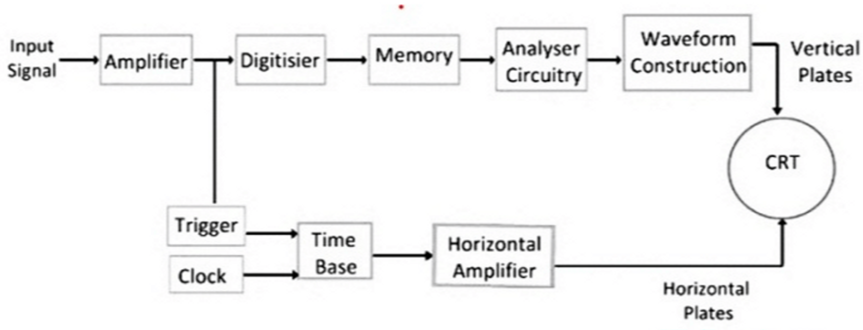


Figure 2: Analog oscilloscope schematic

2 Experiment

2.1 Setup

During the laboratory we used the SDG1025 signal generator and a "SDS1052DL+" oscilloscope.

Detailed explanation of how we used it

SDG1025 signal generator

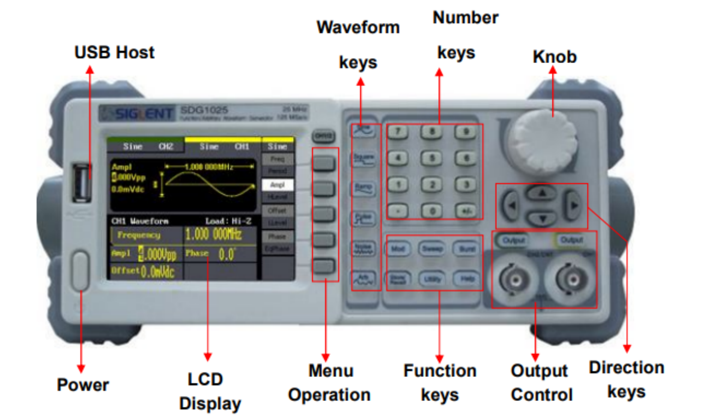


Figure 3: SDG1025

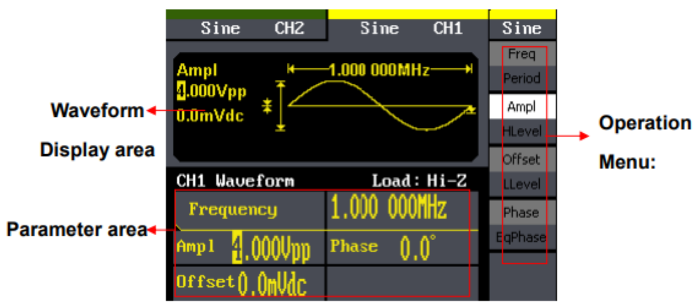


Figure 4: SDG1025 interface

- To set a waveform we used buttons with a waveform icon that are on **"waveform keys"** panel.
- With "Sine" button waveform window will display sine waveform.
- By setting frequency/period, amplitude/high level, offset/low level, sine signal with different parameters can be generated.
- To set freq and another parameters we used **Number keys**, all parameters displayed in "**Parameter Area**"

- We used two buttons on the right side of the operation panel, which are used to activate or deactivate the output signal.
- There are three sets of buttons on the operation panel, which are direction button, the knob and the keypad.
- The up and down keys were used to shift parameters and the left and right keys were used to shift digits.
- Keypad was used to directly set the parameters value.
- Knob was used to change a signal digit value whose range is 0 9

Function menu	Setting	Explanations
Freq/ Period		Set the signal frequency or period; The current parameter will be switched at a second press.
Ampl/ HLevel		Set the signal amplitude or high level; The current parameter will be switched at a second press.
Offset/ LLevel		Set the signal offset or low level; The current parameter will be switched at a second press.
Phase/ EqPhase		Set the phase of the signal; The current parameter will be switched at a second press.

Figure 5: Setting sign signals

- To Set the Output Frequency/Period we used "**Sine**" and "**Freq**" buttons. The frequency shown on the screen when the instrument is powered is the default value or the set value beforehand. When setting the function, if the current value is valid for the new waveform, it will be used sequentially. Also we used direction button to select the digit you want to edit and direction button to select the digit you want to edit. - We applied the same for the rest of the parameters using "**Ampl**", "**Offset**" and "**Phase**" buttons.

"SDS1052DL+" oscilloscope

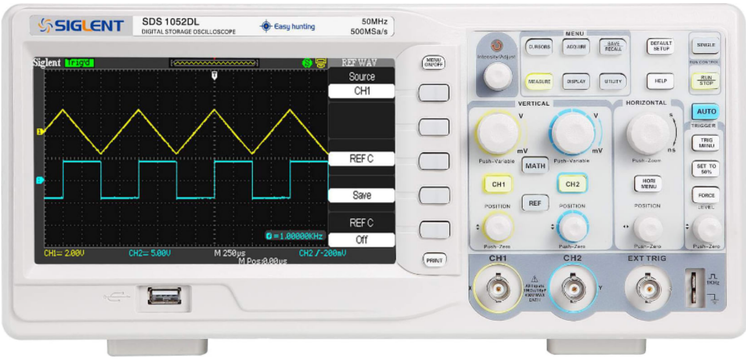


Figure 6: Schematic example

Menu and Control Button

- It would be better to start from channel buttons. We used them to turn that channel ON or OFF and open the channel menu for that channel. Also we can use the channel menu to set up a channel. When the channel is on, the channel button is lit.
- RUN/STOP: Continuously acquires waveforms or stops the acquisition.
- SET TO 50%: We used it to stabilize a waveform quickly. The oscilloscope can set the trigger level to be halfway between the minimum and maximum voltage level automatically.
- MATH: It used to display the Math menu. We can use the "**MATH**" menu to use the oscilloscopes Math functions.
- "HORI MENU": We used it to display the Horizontal menu. We can use the Horizontal menu to display the waveform and zoom in a segment of a waveform.
- MEASURE: Used to display a menu of measurement parameters.
- AUTO: Very useful button. Automatically sets the oscilloscope controls to produce a usable display of the input signals.
- SINGLE: Acquire a single waveform and then stops.
- Channel Connector (CH1, CH2): Input connectors for waveforms display.
- The horizontal position control establishes the time between the trigger position and the screen center. We can adjust the horizontal “POSITION” knob control to view waveform data before the trigger, after the trigger, or some of each. When we change the horizontal position of a waveform, we are changing the time between the trigger and the center of the display actually

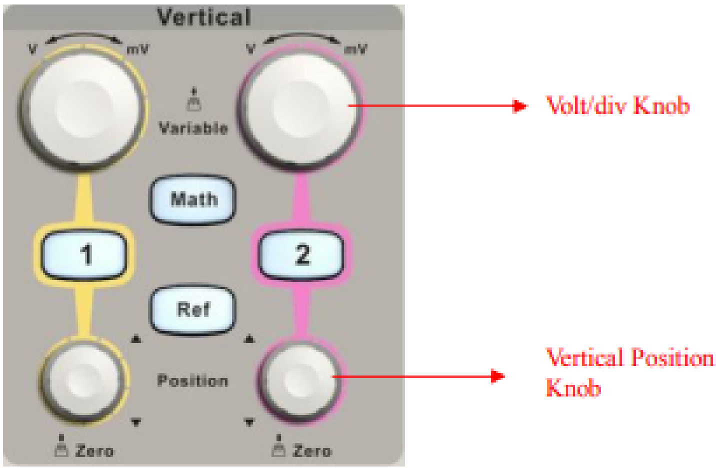
Universal Knob

Figure 7: Universal knob

This is a very useful knob. We used the Universal knob with many functions, such as adjusting the holdoff time, moving cursors, setting the pulse width, adjusting the upper and lower frequency limit, adjust X and Y masks when using the pass/fail function etc. We can also turn the “Universal” knob to adjust the storage position of setups, waveforms, pictures when saving/recalling and to select menu options.

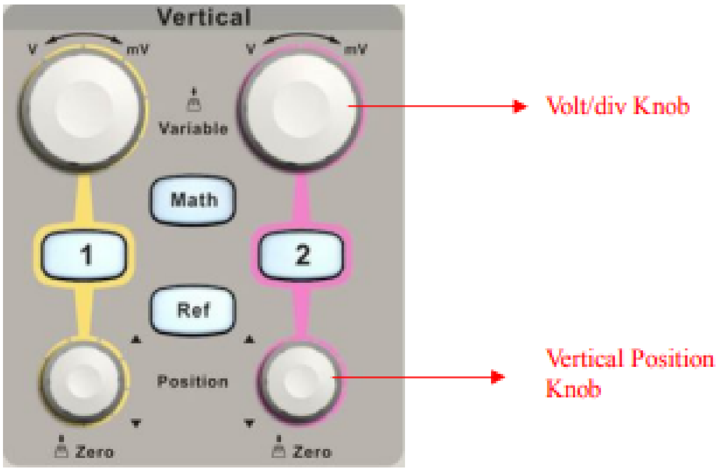
Vertical System

We used vertical control for displaying waveform, rectify scale and position.



Horizontal System

As shown on the picture below, there are one button and two knobs in the HORIZONTAL area. We used the horizontal controls to change the horizontal scale and position of waveforms. The horizontal position readout shows the time represented by the center of the screen, using the time of the trigger as zero. Changing the horizontal scale causes the waveform to expand or contract around the screen center.



2.2 Measurement methods

First, we explored different ways of obtaining the parameters' values. We configured the signal generator to $f = 864\,\mathrm{Hz}$, $V_{pp} = 2.6\,\mathrm{V}$ and connected it to the first oscilloscope channel.

Direct

To obtain parameters' values using the direct method, one must read the peak-to-peak distance from the oscilloscope's display and multiply it by the setting of the sensitivity knob. The picture may be shifted with knobs to facilitate reading.

The vertical sensitivity knob was set to 0.5 V. Table 1 shows the parameters' values.

$Y[div]$	C_y[V]	f[Hz]	V_{pp}[V]	V_m[V]	V_0[V]	T[µs]
5.1	0.5	864	2.55	1.275	0.3	1157

Table 1: Direct method (Y – peak-to-peak distance, C_y – sensitivity, f – frequency, V_{pp} – peak-to-peak voltage, V_m – magnitude, V_0 – average (DC) voltage, T – period)

V_{pp}, V_m and T calculations are shown in Equations 1, 2, 3.

$$V_{pp} = Y \cdot C_y = 5.1 \cdot 0.5\,\mathrm{V} = 2.55\,\mathrm{V} \tag{1}$$

$$V_m = \frac{V_{pp}}{2} = \frac{2.55\,\mathrm{V}}{2} = 1.275\,\mathrm{V} \tag{2}$$

$$T = \frac{1}{f} = \frac{1}{864\,\mathrm{Hz}} = 0.001\,157\,407\,407\,\mathrm{s} = 1157\,\mathrm{\mu s} \tag{3}$$

Cursors

In the cursors method, the measurement is performed indirectly via two pairs of horizontal and vertical cursors. The distance between a pair of cursors is displayed on the screen. Therefore, e.g. signal peak-to-peak voltage may be measured by aligning horizontal cursors with its opposite peaks.

The cursors were positioned at 1.64 V and −0.96 V. Table 2 shows the parameters' values.

V_a[V]	V_b[V]	f[Hz]	V_{pp}[V]	V_m[V]	V_0[V]	T[µs]
1.64	-0.96	864	2.6	1.3	0.3	1157

Table 2: Direct method (V_b – 1st cursor, V_b – 2nd cursor, f – frequency, V_{pp} – peak-to-peak voltage, V_m – magnitude, V_0 – average (DC) voltage, T – period)

V_m and T calculations are shown in Equations 4, 5.

$$V_m = \frac{V_{pp}}{2} = \frac{2.6\,\mathrm{V}}{2} = 1.3\,\mathrm{V} \tag{4}$$

$$T = \frac{1}{f} = \frac{1}{864\,\mathrm{Hz}} = 0.001\,157\,407\,407\,\mathrm{s} = 1157\,\mathrm{\mu s} \tag{5}$$

Measure

In the measure method, a "measure" button is pressed on the oscilloscope to obtain the results. The peak-to-peak value is then read directly from the display.

Table 3 shows the parameters' values.

f[Hz]	V_{pp}[V]	V_m[V]	V_0[V]	T[µs]
864	2.6	1.3	0.3	1157

Table 3: Direct method (f – frequency, V_{pp} – peak-to-peak voltage, V_m – magnitude, V_0 – average (DC) voltage, T – period)

V_m and T calculations are shown in Equations 6, 7.

$$V_m = \frac{V_{pp}}{2} = \frac{2.6\,\mathrm{V}}{2} = 1.3\,\mathrm{V} \tag{6}$$

$$T = \frac{1}{f} = \frac{1}{864\,\mathrm{Hz}} = 0.001\,157\,407\,407\,\mathrm{s} = 1157\,\mu\mathrm{s} \tag{7}$$

2.3 Triggering

In this part of the experiment we observed what happens to displayed signals when different trigger sources are used. We generated two signals and connected them to Channels 1 and 2.

- CH1
  - $V_0 = 0\,\mathrm{V}$
  - $V_{pp} = 2.3\,\mathrm{V}$
  - $f = 864\,\mathrm{Hz}$ or $f = 1\,\mathrm{kHz}$
- CH2
  - $V_0 = 0\,\mathrm{V}$
  - $V_{pp} = 2\,\mathrm{V}$
  - $f = 4\,\mathrm{kHz}$

Next, different frequency and trigger combinations were tried. Table 4 shows the collected data.

f_1[kHz]	f_2[kHz]	Trigger source	Graph
0.864	4	CH1	Unstable
1	4	CH1	Stable
1	4	CH2	Unstable
0.864	4	CH2	Unstable

Table 4: Frequency and trigger combinations

2.4 Oscilloscope functions

In the last part of the experiment we investigated two functions offered by the device: Math and Acquire.

The Math function facilitates performing operations such as signal addition, subtraction, multiplication, etc.

The Acquire function is used to control how the waveform is generated by varying the sample rate of the ADC (analog-to-digital) converter, and offers various acquisition modes. During the laboratory we used the Averaging Acquisition Mode - it averaged out the noise in the taken samples and displayed the underlying signal.

3 Conclusions

3.1 Measurement methods

All methods returned similar results. The direct method proved to be the least precise, which shouldn't come as a surprise as it involves the most amount of human work.

3.2 Triggering

Most combinations proved to be unstable, and the non-triggering wave appeared to be moving. This was a result of the trigger happening at the wrong time - we could only see a part of the wave that was getting re-drawn at certain intervals.

The combination $f_1 = 1\,\mathrm{kHz}$, $f_2 = 4\,\mathrm{kHz}$, Trigger source = CH1 was stable because:

- the first period was a multiplication of the second, so the drawing was always triggered at the beginning of each wave;
- the triggering wave had a bigger period, so by the time the trigger was released, the second wave was done getting drawn.

3.3 Oscilloscope functions

The Averaging Acquisition Mode is useful when we want to see the underlaying wave. It's worth noting, however, that this mode will remove any random noise, hence it should not be used when accurate reading is necessary.