

MODULE 01

VOLTAGE MEASUREMENT USING AN OSCILLOSCOPE

1. GOALS

- 1.1. Able to use an oscilloscope to measure voltages' functions, frequencies, magnitudes, and phase differences.
- 1.2. Understand AC and DC voltages and current measurements using the right tools.
- 1.3. Able to analyse electrical signals using provided mathematical operational functions.
- 1.4. Understand wave characteristics and superposition principles.

2. TOOLS

- | | |
|------------------------------------|---------|
| 2.1 Digital oscilloscope | (1 pcs) |
| 2.2 Signal generator | (2 pcs) |
| 2.3 DC voltage source / battery | (1 pcs) |
| 2.4 Multimeter | (1 pcs) |
| 2.5 BNC – BNC connector | (2 pcs) |
| 2.6 Crocodile clip – BNC connector | (1 pcs) |

3. BASIC THEORY

An oscilloscope is a tool to examine voltage shapes that may be constant or dynamic. Oscilloscope applications can be found in laboratories, industries, to hospitals. In a hospital, an oscilloscope is used to examine a patient's heart beats. There are two types of oscilloscopes: analog and digital. An analog oscilloscope uses a cathode ray tube (CRT) that works under the analog electronics principle. Figure 1.1. shows a type of analog oscilloscopes and its schematic diagram. The core of the system is the electron gun. An electron gun consists of a heating element, a preheated cathode, lattices, and an anode. At a high temperature, electrons are excited from the cathode through a hole on the anode toward the

CRT screen. In short, the electron gun is used to generate electron scattering with a constant velocity towards the CRT screen. A pair of electrified parallel-plates work as a regulator of the electron scattering in its horizontal and vertical positions. By regulating the voltage on the plates, we can acquire a pattern on the CRT screen. Analog oscilloscopes are an early version of oscilloscopes. Nowadays, people commonly use digital oscilloscopes which have several plus points.

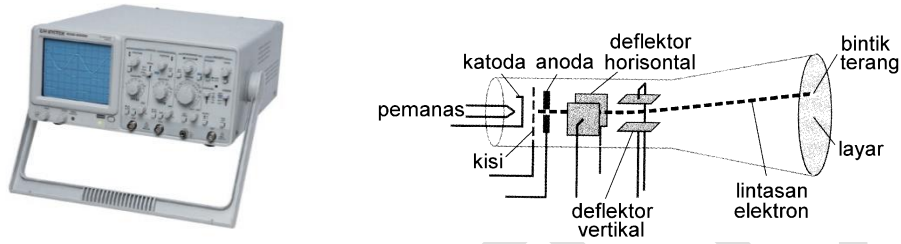


Figure 1.1. An analog oscilloscope schematic diagram.

A digital oscilloscope works using digital principles. In a digital oscilloscope, a CRT is no longer used as a display; an LCD monitor is used instead. Analog inputs are firstly amplified using a pre-amp before it is converted into digital signals through A/D Converter. Figure 1.2 shows a simple schematic diagram of a digital oscilloscope. The conversion process does not occur continuously, but discrete and periodically (sampling time), illustrated by Figure 1.3. The signal frequency that can be scanned is determined by sampling frequency f_s that is directly correlated with sampling time $T_s (= 1/f_s)$ in Figure 1.3. The higher the sampling frequency is, the closer the figure is with the original analog signal. In this experiment, an oscilloscope used has a maximum sampling frequency of 1 GSa/s. The conversion result is then transferred to memory and is displayed on an LCD. The sampling process, conversion, and else are controlled using a control logic unit in which the duration setting is adjusted accordingly to the trigger signal that may come internally or externally from the oscilloscope.

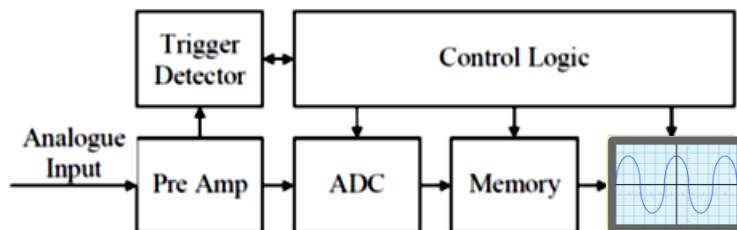


Figure 1.2. A simple block diagram of a digital oscilloscope.

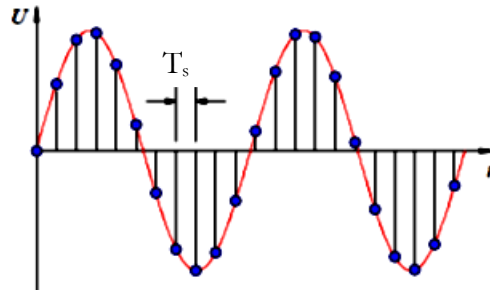


Figure 1.3. An analog to digital signal sampling illustration. A sampling happens (marked by the blue dots) periodically with a period of $T_s = 1/f_s$ where f_s is the sampling frequency.

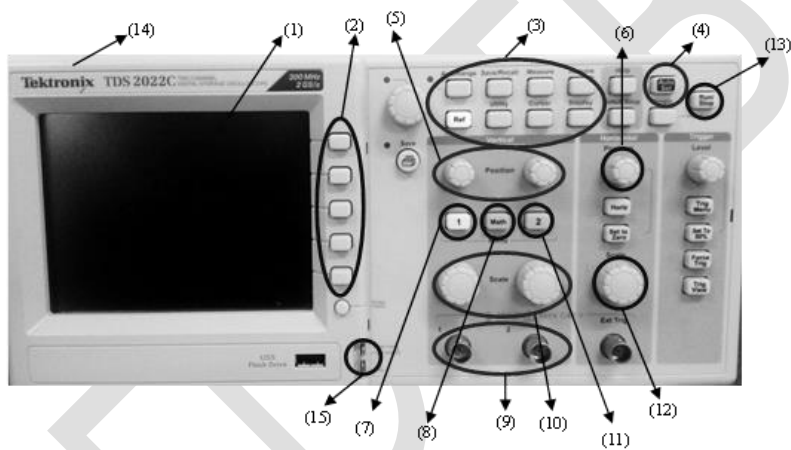


Figure 1.4. A front image of an oscilloscope that is used in this experiment.

There are some important parts of the oscilloscope that is used in this experiment. Figure 1.4. shows the important operational parts and buttons of the oscilloscope.

1. Oscilloscope Display
2. Multipurpose Switch
3. Menu Button Set
4. Auto Set Button
5. Vertical Position Knob
6. Horizontal Position Knob
7. Channel 1 Switch
8. Math Button
9. Probe Plug

10. Vertical Scale Knob
11. Channel 2 Switch
12. Horizontal Scale Knob
13. Run/Stop Button
14. Power Switch
15. Calibration Plug

A Lissajous pattern is a display on the oscilloscope screen that shows phase differences, frequency and magnitude comparisons of the two waves from the oscilloscope's probes.

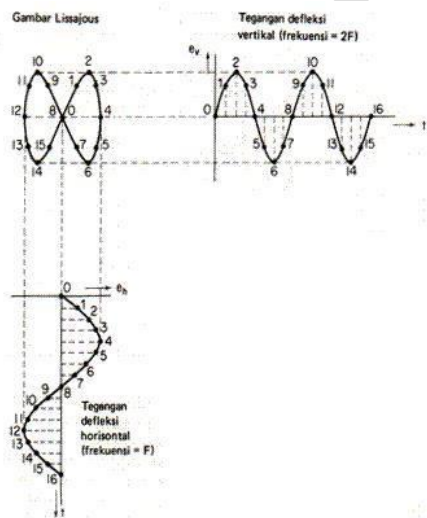


Figure 1.5. A Lissajous pattern that is formed from two waves with different frequencies

A phase difference of two signals from a Lissajous pattern can be determined using a method as follow

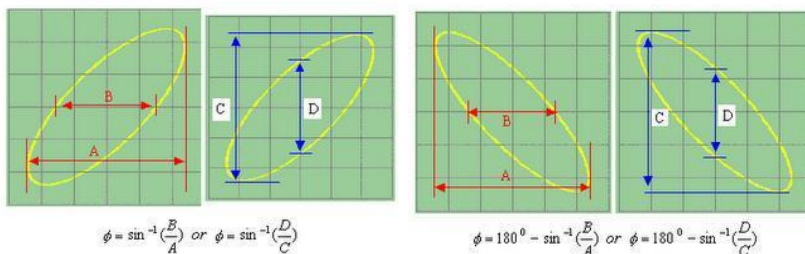


Figure 1.6. Determining the phase difference of two signals using a Lissajous pattern.

4. EXERCISE

- 4.1 Write down a time-dependent sinusoidal wave function and sketch it with time as axis. Explain the definition of each symbols used to represent the function in question.
- 4.2 On a piece of millimeter block sheet, sketch a random sinusoidal wave with a magnitude of 2 cm and a period of 0.02 s (put time on axis and make the scale to be 3 cm = 0.01 s).
- 4.3 Sketch the function's shape from number (2) with a phase difference of (a) -30° and (b) $+45^\circ$.
- 4.4 What is the meaning of V_{max} and V_{eff} ?
- 4.5 If two sinusoidal signals with the same frequency, no phase difference, but have different magnitudes with $V_1=3\text{ V}$ and $V_2=1.5\text{ V}$. How if both signals are operated mathematically? Sketch the results if we do (a) addition, (b) subtraction, and multiplication.

5. PROCEDURE

5.1 Setting-up oscilloscope

The aim of this stage is to ensure that the graphics acquired are clear and representative.

1. Turn the oscilloscope on. Wait until the grid is displayed.
2. Press Display button through Menu buttons set.
3. Adjust the display using multipurpose button.
4. Choose the format: YT, Type: Vector, Persist: Off.
5. Connect the probes to be used to the plugs.
6. Press Switch Channel 1.
7. Adjust the settings using multipurpose button.
8. Choose coupling: DC/AC (depending on the experiment that you are doing), BW limit: off, Volts/div: coarse, Probe: Voltage Attenuation 10x, Invert Off.
9. Connect the probes with the calibration plug.
10. Press auto set.
11. Press Measure and a rectangular signal with a maximum voltage of 5 V and a frequency of 1 KHz.
12. Release the probes from the calibration plug.
13. Check if the line on display is right on the axis. If not, adjust.

14. Oscilloscope is ready for use. The scale knob may be use to adjust the display scale.

5.2 Measuring DC voltage

In this experiment, we measure the voltages of several circuits with batteries. They are configured in series and parallel.

1. Prepare the oscilloscope to measure DC voltages.
2. Measure the batteries with a multimeter.
3. Note the measured voltages on the multimeter.
4. Connect the oscilloscope probes to the batteries.
5. Adjust Vertical Scale Knob so that the voltage function can be seen clearly.
6. Draw the wave forms and V_{rms} seen on the oscilloscope display.
7. Tabulate the data:

Table 5.2.1. DC voltage measurement using a multimeter and an oscilloscope.

Circuit	Multimeter	Oscilloscope
	V_{rms} (Volt)	V_{rms} (Volt)
Battery		

5.3 Measuring AC voltage

Prepare an oscilloscope for AC voltage measurement. Prepare a signal generator and connect it to an oscilloscope.

1. Draw the waves on the display.
2. Note V_{rms} , V_{pp} , V_{max} , V_{out} , and its period.
3. Repeat with variations in output voltage and frequency from the signal generator for 4 times.
4. Tabulate the data:

Table 5.3.1. AC voltage measurement using an oscilloscope and a multimeter.

AC source variation	Multimeter	Oscilloscope		
	V_{rms} (Volt)	V_{rms} (Volt)	V_{pp} (Volt)	V_{max} (Volt)
1				
2				
3				
4				

5.4 Making lissajous pattern

1. Use two signal generators as an input for each oscilloscope channel.
2. Adjust the signal generators so that a sinusoidal signal with a frequency of 10 KHz and a magnitude of 1 V is acquired.
3. Press Display button then choose format XY using the multipurpose knob.
4. You will get a lissajous pattern.
5. Draw the lissajous pattern generated.
6. Adjust the frequencies on channel 1 and 2 so that you acquire ratios of (1:1), (1:2), (3:1), and (3:2).
7. Draw the lissajous pattern generated from each frequency ratio.
8. Measure the phase difference of both signals from the 1:1 ratio.

5.5. Mathematical Operation in Oscilloscope and Wave Superposition Simulation

1. Use two signal generators as an input for each oscilloscope channel.
2. Adjust the signal generators so that a sinusoidal signal with a frequency of 10 KHz and a magnitude of 1 V is acquired.
3. Press Channel 2 button, then choose invert: on using multipurpose button.
4. Press Math button.
5. Note the results for + and – operations.
6. Repeat using two signal generators.
7. Examine the results of both signals with frequency differences of 0 Hz, 1 Hz, 10 Hz and 100 Hz.
8. Draw the patterns for + and – operations.

6. ANALYSIS

- 6.1 Compare V_{rms} results using multimeter and oscilloscope. Why are there differences? Explain!
- 6.2 Explain why there are differences on the values of V_{rms} in DC voltage measurement with lamp variations
- 6.3 Explain the signal characteristic differences from AC and DC signal sources.
- 6.4 Explain the physical aspects of the new signals acquired from + and – mathematical operations. Does it match the concept of wave superposition? Explain!

- 6.5 Explain the formation process of a lissajous pattern. What are the impacts of frequency differences to the lissajous pattern? Explain! Explain how to measure phase differences in analog and digital oscilloscopes.

7. REFERENCES

Cicero H Bernard, Chiold D.EPP, *Laboratory Experiments in College Physics*, 7th edition, John Wiley and Sons, Inc., 1995