

Lab 15

Digital Oscilloscope

A. Purpose

To learn the basic operations of the digital oscilloscope and the function generator, and to observe beats and Lissajous curves on an oscilloscope.

B Introduction

An oscilloscope (scope) is an indispensable basic instrument in the laboratory. Whether in physics, chemistry, engineering, biology, or medicine experiments, a scope can observe any physical quantity that can be converted into an electronic signal. The most basic purpose of a scope is to read the change of the voltage signal over time. Oscilloscopes can be categorized into analog oscilloscopes and digital oscilloscopes.

The analog oscilloscope uses a cathode ray tube (CRT) to produce the display. The electron beam is ejected from the hot cathode at high speed and hits the screen directly in front of it after a distance, causing a bright spot on the screen. By controlling electric and magnetic fields, the analog oscilloscope can instantly reconstruct the signal. The digital oscilloscope uses the computer to sample the signal at regular time intervals, digitize it, and then display it over time. Therefore, the higher the sampling frequency, the more samples are taken, and the signal will be closer to the original one. *In other words, a digital oscilloscope is an instrument that rearranges and displays the signal* (See Fig. 1). However, because of the bandwidth limitation caused by the cathode ray tube in the analog oscilloscope and the rapid development of digital signal processing components and technologies, most current oscilloscopes are digital scopes instead of analog ones. The digital oscilloscope has many operational advantages. It can quickly analyze the signal and measure the frequency, amplitude, and period information. It can also add, subtract, multiply, and divide the signal and even perform operations such as Fourier transform. Most importantly, it digitalizes the signal, which allows us to save or print the data, providing convenience for data analysis. Therefore, the digital oscilloscope has now become mainstream.

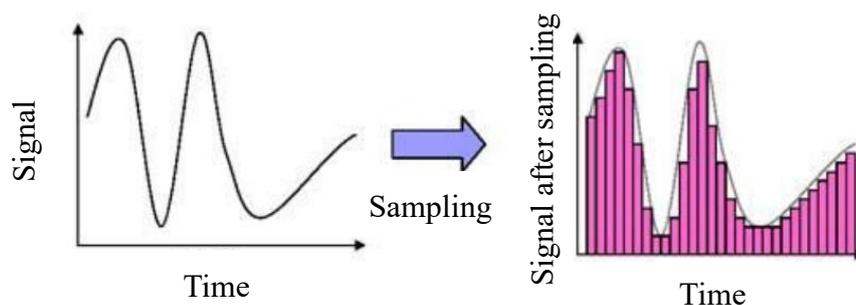


Fig.1. Sampling of the signal

C. Apparatus

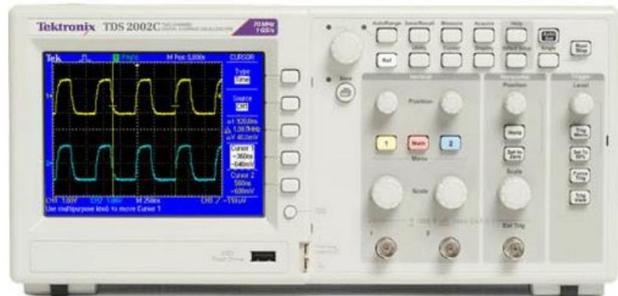


Fig.2. Digital Scope (TDS 2002C)
 User Manual: <https://reurl.cc/2DyzOn>



Fig.3. Signal Generator (DG1022)
 User's Guide: <https://reurl.cc/zM4lGa>



Fig.4. BNC to Alligator Clip Cable



Fig.5. BNC to BNC Cable

D. Procedures

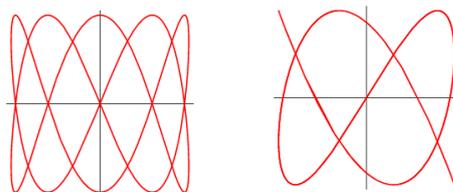
1. Pre-lab assignments (hand in before the experiment)
 - (0) Basic Tutorial on the oscilloscope by Prof. Shy: (in Mandarin)
<https://youtube.com/playlist?list=PLrfrBVVLZqhUnGIBDfJAKDY-4KKPj5ddF>
 - (1) Make a flowchart of this experiment and answer the questions.
 - (2) A Lissajous curve is a graph of a system of parametric equations

$$\begin{cases} x = A \sin(2\pi at) \\ y = A \sin(2\pi bt + \delta) \end{cases}$$

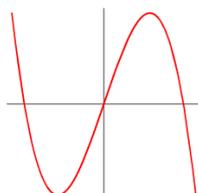
which describes complex harmonic motion. For example, a circle is a simple Lissajous curve with $a = b$ and $\delta = \pm\pi/2$. Please use Matlab to draw Lissajous curves under the condition of each combination formed by the following parameters.

$$\frac{a}{b} = 1, 2, \frac{3}{2} \text{ with } \delta = 0, \pi/4, \pi/2, 3\pi/4$$

- (3) Given two Lissajous curves of $\delta = 0$ below, determine their frequency ratio a/b .



- (4) Given a Lissajous curve of $\delta = 0$ below, if the phase difference between two input signals (x and y) is now $\delta = \pi/2$, what will the figure become? **Explain.**



- (5) Explain what the beat note is, and draw a graph of the beat note formed by two signals of the same amplitude via Matlab. *Can the beat note be formed if the amplitudes of two signals are **different**?*
2. In-lab activities (**Don't forget to take photos for each part as proofs of your work.**)
- (1) Measurement of Periodic Signals
- (a) Make sure the attenuation of Probe is X1 for both CH1 and CH2 in the scope.
 - (b) Use BNC to BNC cable to connect the CH1s of the scope and the signal generator
 - (c) Set the output of signal with Freq = 100 kHz, Ampl = 1 V_{pp}, Offset = 0 V, and then set the function of output signal to be Sine, Square, Ramp, and Pulse. At the same time, try to change Trigger source and Trigger level so as to understand the function of Trigger.
 - (d) Following (c), set the function of output signal to be sine. Use “Cursor” and “Measure” to obtain the frequency and amplitude, and compare the results with your setting.
 - (e) Set the function of output signal to be Square with Freq = 50 Hz, Ampl = 1 V_{pp}, Offset = 0 V. For the scope, change the input coupling to be DC coupling and AC coupling individually. Observe and describe the difference in your report.
 - (f) Set the function of output signal to be Sine with Freq = 100 kHz, Ampl = 20 mV_{pp}, Offset = 9.8 V. For the scope, change the input coupling to be DC coupling and AC coupling individually. Observe and describe the difference

in your report. For the AC coupling part, since the signal may be small, you can use the average function in Acquire Menu to reduce the noise..

- (g) Use BNC to Alligator cable to do this part with BNC end connected to the scope and Alligator end placed on the table . Now the screen should display a noisy signal with $\text{Freq} \approx 60 \text{ Hz}$. Why? Now, set the trigger source of the scope to be AC line. Observe and describe the difference in your report.
- (2) 2D Lissajous curve (for 3D Lissajous curve, see Ref 1)
- (a) Connect the CH1s and the CH2s of the scope and the signal generator by BNC to BNC cables. Set the output of CH1 to be sine wave with $\text{Freq} = 1 \text{ kHz}$, $\text{Ampl} = 5 \text{ V}_{\text{pp}}$, $\text{Offset} = 0 \text{ V}$, $\text{Phase} = 0^\circ$ and the output of CH2 to be sine wave with $\text{Freq} = 1 \text{ kHz}$, $\text{Ampl} = 5 \text{ V}_{\text{pp}}$, $\text{Offset} = 0 \text{ V}$, $\text{Phase} = 90^\circ$.
- (b) Press AligPha to align the phase, and adjust the Trigger level of the scope to get the stable signals. The result should be as shown in Fig. 6(a). Use the function Display X-Y to obtain Fig. 6(b).

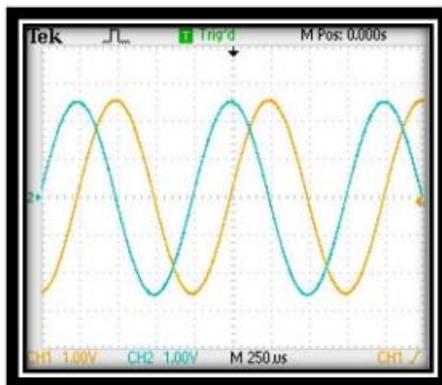


Fig. 6(a). Signals with Phase difference being 90° .

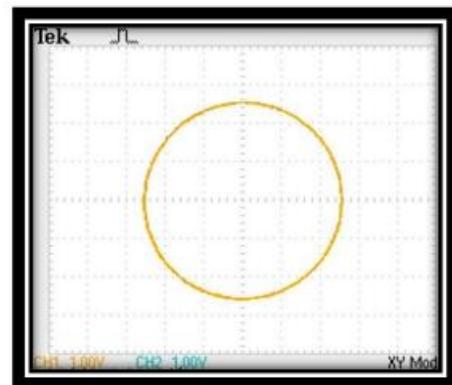


Fig. 6(b). Lissajous curve.

- (c) Change the frequency ratio a/b and the phase difference between the two signals to each combination given in pre-lab Q2. Compare the results with your Matlab results.
- (3) Beat note
- (a) Connect the CH1s and the CH2s of the scope and the signal generator by BNC to BNC cables. Set the output of CH1 to be sine wave with

Freq = 10.5 kHz, Ampl = 5 V_{pp}, Offset = 0 V, Phase = 0° and the output of CH2 to be sine wave with Freq = 9.5 kHz, Ampl = 5 V_{pp}, Offset = 0 V, Phase = 90°.

- (b) Press “Math” and choose the function “Add.” You will see the result as shown in Fig. 7. Compare the result with your Matlab result.

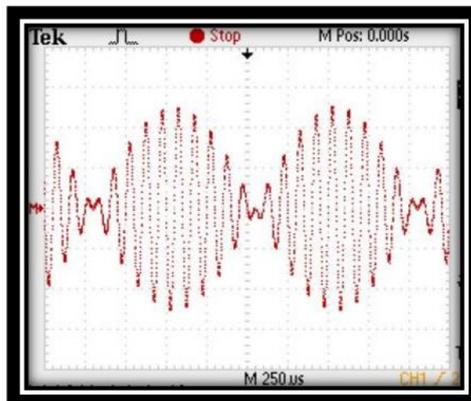


Fig. 7. Beat note formed by two sine waves

3. Post-lab report
 1. Recopy and organize your data from the in-lab tables in a neat and more readable form.
 2. Describe the findings in this lab with the photos.

D. Simulation Project (Optional)

Read and follow Ref. 1 to simulate and discuss the 3D Lissajous Figures.

F. References

- Li, Tiandong, et al. "Further Understanding for Lissajous Figures." *The Physics Teacher* 59.1 (2021): 62-65.
- Criado, C., and N. Alamo. "A Simple Construction to Illustrate Lissajous Figures." *The Physics Teacher* 42.4 (2004): 248-249.
- Lincoln, James. "Using an online virtual oscilloscope." *The Physics Teacher* 58.7 (2020): 526-527.