Unit-03   Basic Electricity II

Objective：

In this experiment, we would like to get you familiar with the theorem, structure and use of oscilloscope and learn how to interpret signals by use of oscilloscopes.

Apparatus：

Oscilloscope, function generator, digital multimeter, T-type splitter

Principle：

A. Oscilloscope

There are two types of Oscilloscope: analog and digital. The analog type mainly consists of cathode ray tube (CRT). In a CRT, an electronic beam is generated from the cathode. It then is focused and accelerated to hit the fluorescent monitor, creating a spot on it. If an electric field is added horizontally or vertically, the electric beam will deflect accordingly. Due to the fact that the deflection is proportional to the voltage, we can measure the voltage amplitude by the deflection.

The amplitude of the signal will be displayed on the monitor vertically. In order to observe the wave function, we have to add a set of deflection plate. Then this set of plate is added with a time dependence electric field, making the spot spread horizontally, with the horizontal axis functioning as the time axis.

In contrast to an analog oscilloscope, a digital oscilloscope uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. It acquires the waveform as a series of samples, and stores these samples until it accumulates enough samples to describe a waveform. The digital oscilloscope then re-assembles the waveform for display on the screen, as seen in Figure 1.

Digital oscilloscopes can be classified into digital storage oscilloscopes (DSOs), digital phosphor oscilloscopes (DPOs), mixed signal oscilloscopes (MSOs), and digital sampling oscilloscopes.

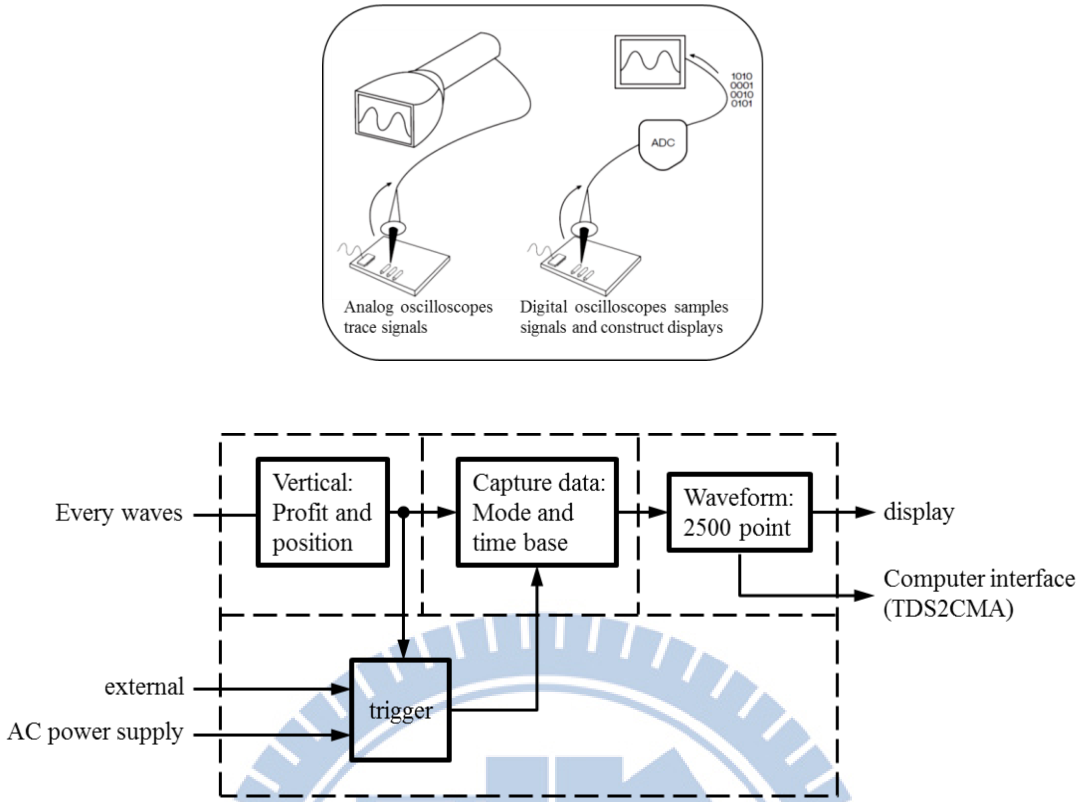


Figure 1. Oscilloscope principle schema

B. Function gemerator

Function generator signal generated by the oscillator, according to the frequency range can be divided into low frequency and high frequency two, low frequency signal generator, also known as audio signal generator, high frequency signal generator, also known as RF signal generator. Function generator can be used to test or troubleshoot circuit characteristics in various electronic instruments such as frequency response, gain, distortion, phase shift. So in the circuit repair, adjustment, testing is usually used with the oscilloscope.

C. Lissajous pattern

Input two sine waves individually into vertical and horizontal terminals, and a continuous wave called Lissajous pattern will be presented on the screen. When the frequency ratio is rational, the curve is closed and the pattern on the screen is stable (because the spot can “turn around” after a cycle). However, if the ratio is not rational, then the curve is open, and the pattern is unstable (Because the spot cannot turn back to the same place through the same phase, and the figure we see is varying). Figure 2 (a) shows a closed pattern with ratio=2, and the pattern can be drawn through 0 to 24 points on Figure 2 (b) and (c).

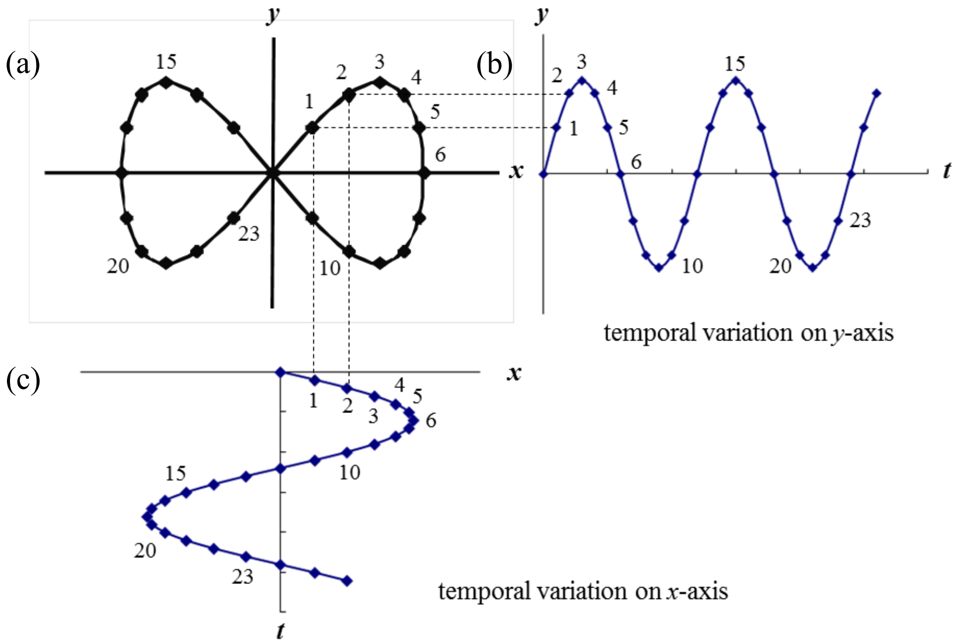
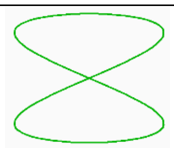
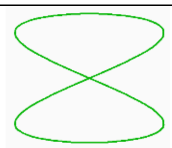
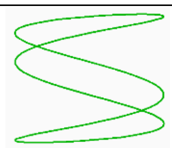
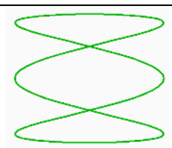
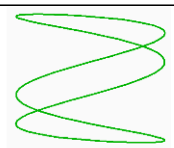
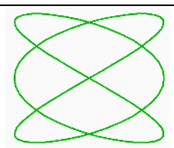
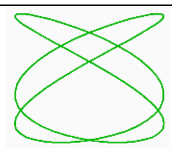
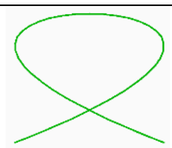
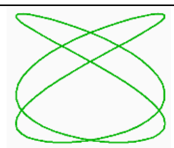


Figure 2 Lissajous pattern

As table 1, lists the pattern with different frequency ratio. Can you figure out the ratio by the relation above? The most famous pattern of Lissajous pattern is that we can combine two sine waves with the same frequency, amplitude, but different phase to draw different closed patterns depending on the phase difference input, and we can judge the patterns to figure out the phase difference θ between two sine waves

Table 1. Lissajous pattern with different frequency ratio and phase difference

Phase / $f_H : f_V$	0°	45°	90°	135°
1 : 1				
2 : 1				
3 : 1				
3 : 2				

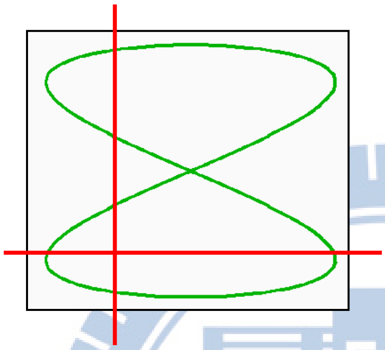
(a) Use the Lissajous pattern to figure out the frequency ratio of two sine wave

Set oscilloscope at XY mode, input the known frequency f_x and the unknown frequency f_y, and vary f_x until a closed pattern shows.

Draw a horizontal line and a vertical line in the Lissajous pattern and count the times the pattern intercept with x-axis and y-axis, and the ratio is equal to the inverse ratio of two frequencies:

$$f_H : f_V = n_V : n_H$$

[Example]



The times pattern intercept with x-axis $n_H = 2$

The times pattern intercept with y-axis $n_V = 4$

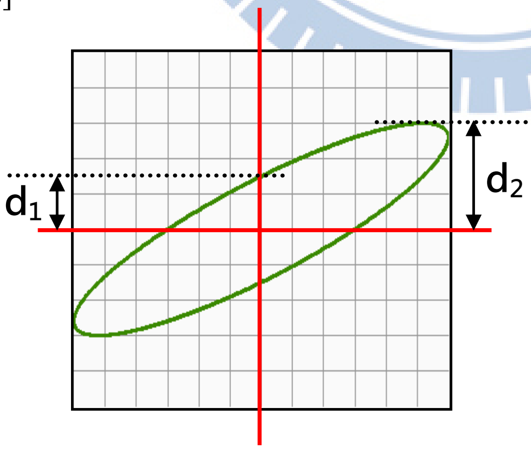
$$\frac{f_H}{f_V} = \frac{n_V}{n_H} = \frac{4}{2} = 2$$

(b) Use the Lissajous pattern to figure out the phase difference of two sine wave

Put the Lissajous pattern at the (0,0) point and record the intercept of y-axis d_1 and the maximum d_2 on y-axis to get the phase difference of two sine waves θ.

$$\theta = sin^{-1}\left(\frac{d_1}{d_2}\right)$$

[Example]



y-axis intercept $d_1 = 1.5$

y-axis maximum $d_2 = 3$

$$\theta = \sin^{-1}\left(\frac{d_1}{d_2}\right) = \sin^{-1}\left(\frac{1.5}{3}\right) = 30°$$

[Note] You can also calculate the phase difference by x-axis intercept and x-axis maximum by following the same procedure.

Remarks：

1. Before the experiment, read the user guide of the Oscilloscope and figure out the function of each of the buttons and switches.
2. When you don't know what kind of signal the Oscilloscope gives you, press the『AUTO SET』button, but you should not rely too much on this function.
3. Turn off the main power after you finish the experiment.

Procedure：(model TDS2022 and GDS1152A-U

➢ **Preparation**

1. Connect the CH1 to Function Generator with BNC-BNC cable.
2. Turn on Function Generator and choose output 1 kHz sine wave.
3. If the amplitude of the wave on the screen is too large or too small, rotate the「VOLTS/DIV」knob until the wave occupies 70% and there is 1~2 complete waves of the screen.

A. Voltage measurement

(a) Direct Observation

1. Count the number of vertical grids from wave crest to trough.
2. Record the 「VOLTS/DIV」 of the wave. (On the left side of screen)
3. Peak-to-peak voltage V_{P-P} = (the number of vertical grids that peak-to-trough voltage of the wave occupies) × (VOLTS/DIV).
4. Calculate the amplitude voltage $V_{\max}$ and root mean square of voltage V_{rms}.

(b) Cursor

Model TDS 2022

1. Press「CURSOR」 to enter CURSOR menu.
2. Press the Type to select 「**voltage**」, Source to select 「**CH1**」. The light of cursor1、cursor2 on the panel shall be on.
3. Rotate VERTICAL knob of CH1 and CH2 to make two cursors in line with wave crest and trough.
4. The delta on the right of screen is Peak-to-peak voltage V_{P-P}.
5. Calculate the amplitude voltage $V_{\max}$ and root mean square of voltage V_{rms}.

Model GDS 1152A-U

1. Press「CURSOR」 to enter CURSOR menu.
2. Press source to choose「**CH1**」, and X ↔ Y to choose horizontal cursor.
3. Press Y1 and rotate VARIABLE knob to make the cursor in line with the wave crest.
4. Press Y2 and rotate VARIABLE knob to make the cursor in line with the wave trough.
5. Record the Peak-to-peak voltage V_{P-P} on the right of screen.
6. Calculate the amplitude voltage $V_{\max}$ and root mean square of voltage V_{rms}.

(c) Measure

Model TDS 2022

1. Press「MEASURE」to enter Measure menu.
2. If there is no CH1 peak-to-peak value on the screen, follow the following steps.
3. Press any function button on the right to enter Measure Menu.
4. Press Source to select「**CH1**」 and press Auto to select 「**peak-to-peak**」. Record peak-to-peak voltage V_{P-P} on the right.
5. Calculate the amplitude voltage $V_{\max}$ and root mean square of voltage V_{rms}.

Model GDS 1152A-U

1. Press「MEASURE」to enter Measure menu.
2. If there is no CH1 peak-to-peak value on the screen, follow the following steps.
3. Press any function button on the right to enter Measure Menu. Press the third button on the right of screen to enter the menu. Rotate VARIABLE knob to choose V_{P-P}.
4. Press the BACK button on the right of screen to get back to MEASURE menu. Record peak-to-peak voltage V_{P-P} on the right.
5. Calculate the amplitude voltage $V_{\max}$ and root mean square of voltage V_{rms}.

(d) Digital Multimeter

1. Measure V_{rms} from the digital multimeter
2. Calculate the amplitude voltage V_{max} and peak-to-peak voltage V_{p-p}.

B. Frequency measurement

(a) Direct Observation

1. Count the number of horizontal grids of wave.
2. Calculate the TIME/DIV of the wave. (On the bottom side of screen)
3. Wave period T = (the number of horizontal grids of wave) × (VOLTS/DIV).
4. Calculate the wave frequency $\left(f = \frac{1}{T} \right)$.

(b) Cursor

Model TDS 2022

1. Press「CURSOR」to enter CURSOR menu.
2. Press Type to select **"time**」, Source to select 「**CH1**」. The light of cursor1、cursor2 on the panel shall be on.
3. Rotate the VERTICAL knobs of CH1、CH2 separately. Make the two cursors on the screen on the two consequent peaks.
4. The delta on the right of screen is period T.
5. Calculate the wave frequency f。

Model GDS 1152A-U

1. Press「CURSOR」 to enter CURSOR menu
2. Press source to choose CH1. Push X ↔ Y to choose the vertical cursor.
3. Press X1 and rotate VARIABLE knob to make the cursor in line with the wave crest.
4. Press X2 and rotate VARIABLE knob to make the cursor in line with the wave crest.
5. Record the wave period T on the right of screen.
6. Calculate the wave frequency f。

(c) Measure

Model TDS 2022

1. Press「MEASURE」 to enter MEASURE menu.
2. If there is no CH1 frequency value on the screen, follow the following steps.
3. Press any function button on the right to enter Measure Menu.
4. Press Source to select「CH1」and press Auto to select frequency f. Press Back to get back to MEASURE menu.
5. Record the period T and frequency f.

Model GDS 1152A-U

1. Press「MEASURE」 to enter Measure menu.
2. If there is no frequency value on the screen, follow the following steps.
3. Press any function button on the right to enter Measure Menu. Press the third button on the right side of screen to enter the menu. Rotate VARIABLE knob to select frequency *f*.
4. Press the Back button on the right to get back to MEASURE menu.
5. Record the period *T* and frequency *f*.

C. Measure the transmission speed of transmission line

1. Choose two transmission lines. One is 1 m in length and the other is 60 m.
2. Connect the T-type signal splitter to the output terminal of the function generator. Connect two transmission lines to the splitter and CH1, Ch2 separately. (CH1 for 1 m transmission line; CH2 for 60 m transmission line.)
3. Set the output signal to sine wave and the frequency to about 1.0 MHz.
4. Used cursor to attack two peaks, that the wave period difference is Δt .
5. From Δt , calculate transmitting frequency.

$$v = \frac{\Delta d}{\Delta t}$$

6. Repeat the steps above from 1.0~2.2 MHz, increasing 0.3 MHz in each step.

D. Lissajous pattern

1. Connect function generator to CH1 and CH2 terminal by BNC-BNC cables of same length.
2. Input two different frequency sine waves by two function generators into CH1 and CH2 separately.

Model TDS 2022

1. Switch Ch1 and CH2 to 5 VOLT/DIV. (displayed on the left side)
2. Press DISPLAY and choose XY, and then Lissajous pattern was showed.
3. Calculate phase difference by Lissajous pattern.
4. Observes by table 1, the signal by different frequency its phase difference to be whether more different than.

Model GDS 1152A-U

1. Switch Ch1 and CH2 to 5 VOLT/DIV. (displayed on the left side)
2. Press MENU on HORIZONTAL panel and then choose XY, and then Lissajous pattern was showed.
3. Calculate phase difference by Lissajous pattern.
4. Observes by table 1, the signal by different frequency its phase difference to be whether more different than.

Questions：

1. What is the influence of different frequencies to the speed of the transmission line? Why do we adopt such high frequency? Please explain.
2. George talks to his girlfriend Peppa on Net phone. He finds out he always hears echo of his voice 100 msec after his own voice. Assume that the frequency of carrier wave of the voice signal is 1.5 MHz. Please estimate which city is Peppa in whole George is in NCTU campus (Hsinchu)? Please explain.