EXPERIMENT 3

DIGITAL STORAGE OSCILLOSCOPE

3.1 Objective:

In this experiment, you will learn the basic usage of digital storage oscilloscope (DSO) of *GW Instek Technologies*. More specifically you will learn,

1. How to determine the amplitude and frequency of a signal using DSO,
2. How to make some mathematical operations on signals using DSO,
3. Identifying the phase difference between the output and input signals in capacitor circuits using DSO,
4. X-Y mode of operation in digital oscilloscopes.

3.2 Equipment List:

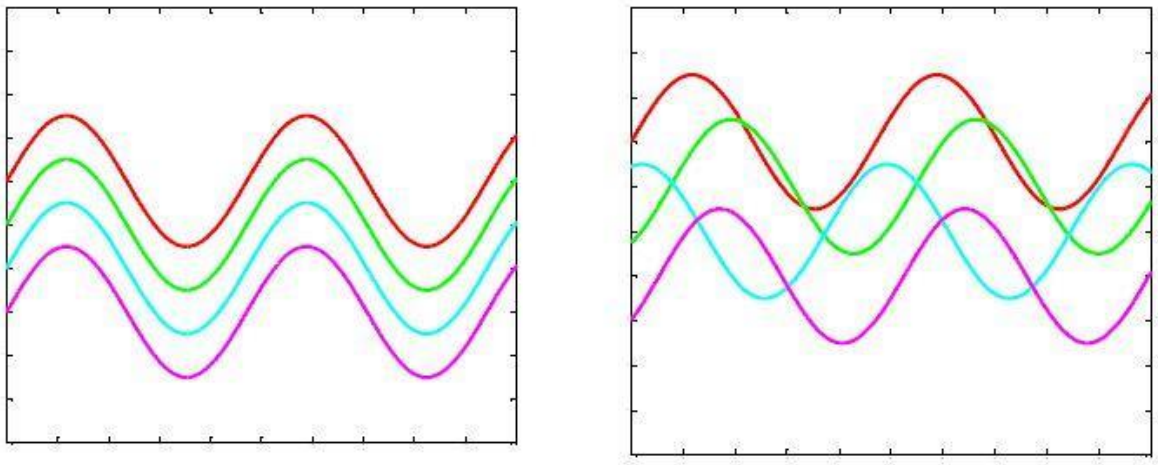
1. Digital Storage Oscilloscope (GW Instek GDS-1072A-U)
2. Function/Arbitrary Waveform Generator (AATech AWG 1020A)
3. Breadboard
4. Carbon Resistors (3.3 kΩ , 10 kΩ, 18 kΩ),
5. Capacitor (47 nF),

3.3 Preliminary Work:

1. Read the "*Notes on Oscilloscopes*" document.
2. What is DSO? What are the differences between CRO and DSO?
3. What is phase difference?
4. What does the terms "leading" and "lagging" mean?
5. Explain the measurement techniques of phase difference.

Useful Information for the Experiment

In some applications, one may need to monitor or compare two or more signals simultaneously. A typical example can be the comparison of the input voltage with the output voltage of a two-port (input and output ports) circuit. If the signals that are being monitored have the same frequency, a time delay may occur between the signals (i.e. one signal may lead the other or vice versa). Two waves that have the same frequency, have a phase difference that is constant (independent of t). When the phase difference (modulo 2π) is zero, the waves are said to be in phase with each other. Otherwise, they are out of phase with each other. If the phase difference is 180 degrees (π radians), then the two signals are said to be in anti-phase. If the peak amplitudes of two anti-phase waves are equal, their sum is zero at all values of time, t.



(a) **(b)**

Figure 3.1. (a) In-phase waves, **(b)** Out of phase waves

The phase difference is expressed in terms of radians or degrees. In Dual Mode of the oscilloscope the phase difference can be calculated easily as follows. Given the two signals having the same frequency, as shown in Figure 3.2,

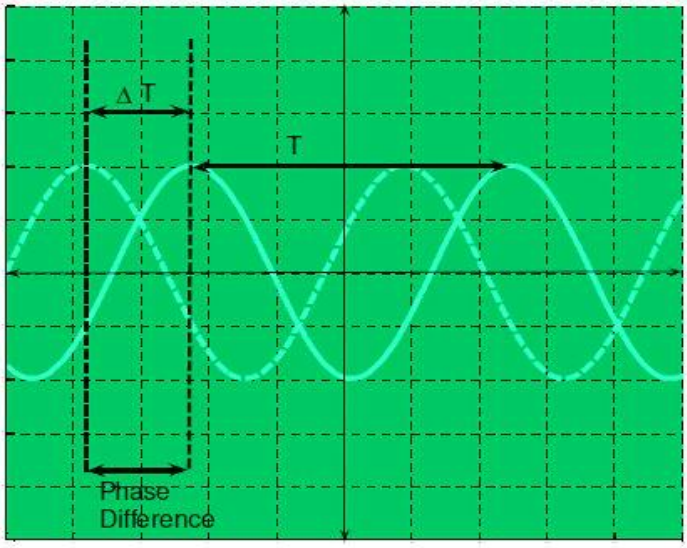


Figure 3.2. Two Signals Displayed in DUAL Mode

define,

Δ T = horizontal spacing of the peak values (or the zero crossings) of the two signals.

T = horizontal spacing for one period.

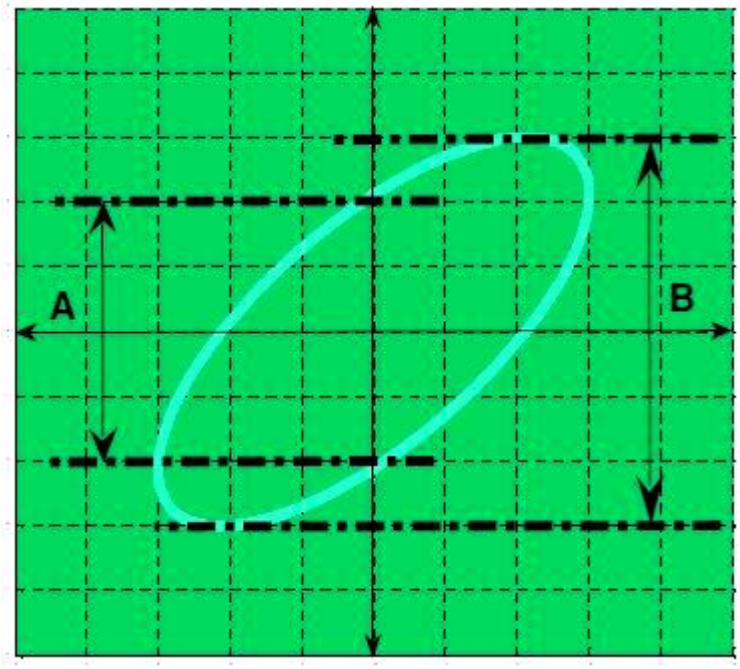
Then the phase difference, θ is;

$\theta = \frac{\Delta T}{T} \times 360°$ (in degrees)

$\theta = \frac{\Delta T}{T} \times 2\pi$ (in radians)

Note that, one has to specify the leading or the lagging signal in order to fully describe the time difference between the two signals. In the figure above, the signal represented with dashed curve leads the other. Suppose that the signal represented by the dashed curve is connected to Channel I of the oscilloscope, and the other one is connected to Channel II. In such a case Channel I is leading the Channel II with phase difference equal to θ, and Channel II is lagging the Channel I with phase difference equal to θ. Determining the leading or the lagging signal may be frustrating at first, but note that the dashed curve reaches its maximum value before the other does.

The phase difference between the signals can also be determined in XY mode of the oscilloscope by using Lissajous figures. In the XY mode, the x-axis data is taken from one channel, y-axis data is taken from the other. In that way, Channel I vs Channel II graph can be obtained, so that the variation of a signal with respect to another can be observed. Figure 3.3 shows a typical graph (Lissajous figure) in XY mode, of two signals having a constant phase difference.



Phase difference is equal to,

$$\theta = \sin^{-1}\left\{\frac{A}{B}\right\}$$

Figure 3.3. Phase Difference Calculation in XY Mode

It should be noted that, the center of the ellipsoidal shape (sometimes circular or linear shapes) on the screen should be at the origin of DSO unless any DC component is added to one of the signals.

In XY mode, the leading or the lagging signal can not be determined. One has to switch to DUAL mode in order to specify the leading signal.

3.4 Experimental Work:

The front panel of *GW Instek* GDS-1072A-U oscilloscope is shown in Figure 3.4 and Figure 3.5. You may refer to these figures during the experiment.

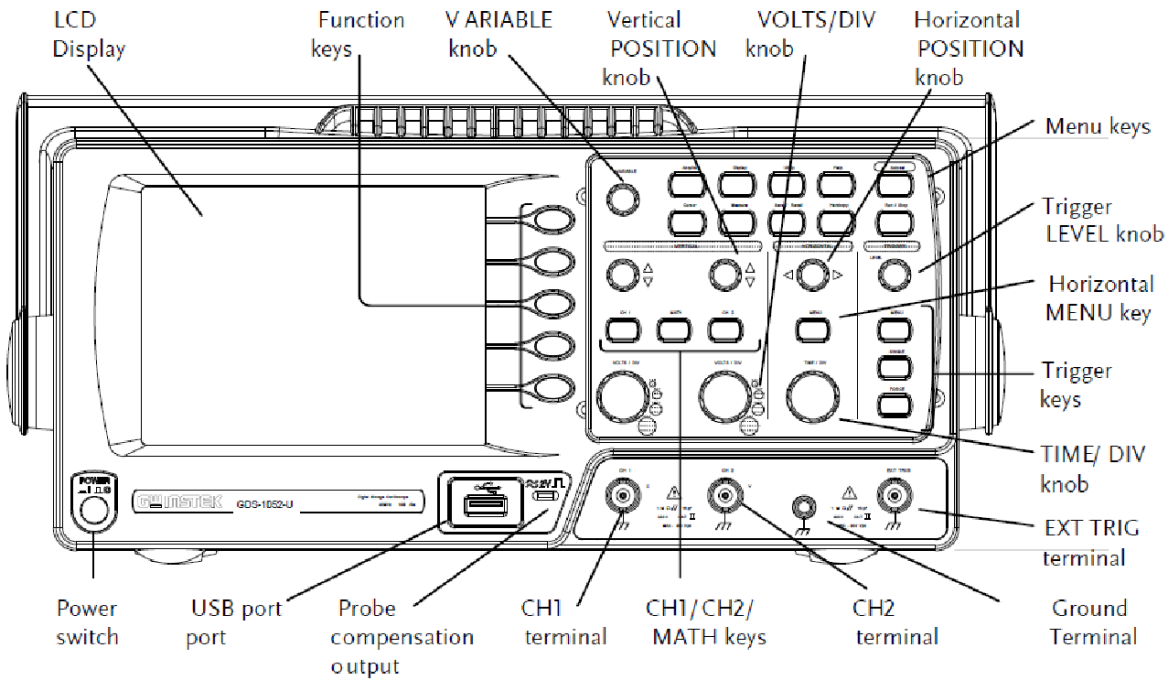
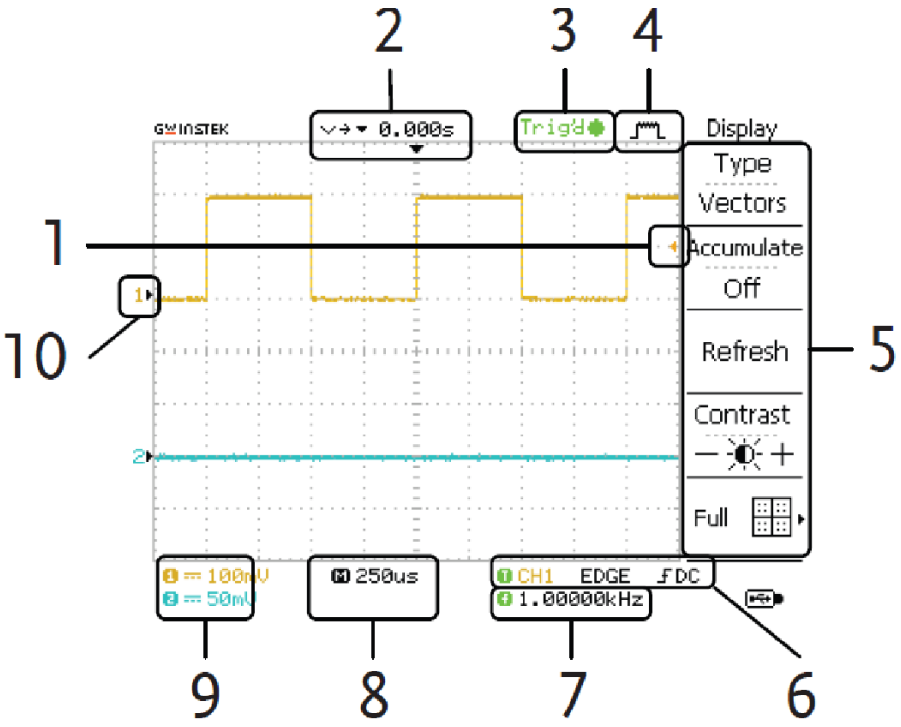


Figure 3.4. *GW Instek* GDS-1072A-U DSO Front Panel Overview



1-Trigger Position,

2- Waveform Position,

3- Trigger Status,

4- Acquisition,

5- Menu,

6- Trigger Condtion,

7- Frequency,

8- Horizontal Status,

9- Vertical Status,

10- Waveform Marker

Figure 3.5. *GW Instek* GDS-1072A-U DSO Display

1. Turn the oscilloscope on by pressing the "POWER switch". Connect the signal lead of the probe corresponding to Channel 1 to the "Probe Compensation Output" of the oscilloscope. Press the "Autoset" key. (Wait a few seconds until the oscilloscope completes the operation.) At this instant you observe a square wave signal generated by the oscilloscope. Observe the reference point shown by (1→) sign in the left side of the display which corresponds to the ground level of the waveform (Figure 3.5 (**10**)). Measure the peak-to-peak amplitude and the period of the signal by counting the squares in the display. Record these values.

a. Play with the "VOLTS/DIV knob" of the Channel 1 and observe the changes in the waveform. What is happening? Explain briefly.

b. Play with the "TIME/DIV knob" of the oscilloscope and observe the variations in the display. What is happening? Explain briefly.

c. Play with the "Vertical Position knob" of the Channel 1 and observes the changes in the display. Explain briefly.

d. Play with the "Horizontal Position knob" and observe the changes in the display. Explain briefly.

2. Press Channel 1 selection button (CH1). Be sure that Channel 1 is active. If not, press Channel 1 selection button again. At this instant you should be observing a menu in the right side of the display as shown in Figure 3.6.

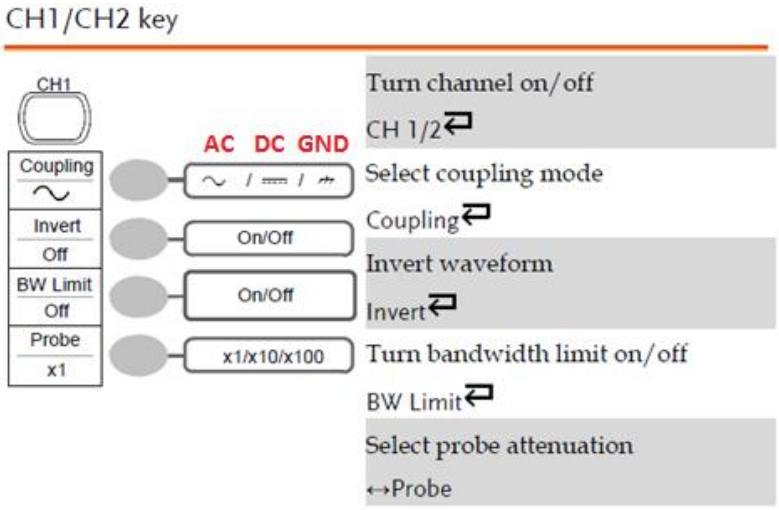


Figure 3.6. CH1/CH2 Key Menu

a. From that menu, press to the soft key (by using Function keys) corresponding to "Coupling" to change the coupling mode from "DC" mode (⎓) to "Ground" mode. Observe the changes in the waveform. Press again to the same softkey to make the coupling mode to "AC" mode (~). Observe the changes and plot the resulting waveforms to the graph paper.

b. Return to the "DC" coupling mode by selecting the "DC" mode from the "Coupling" submenu. Plot the waveform. Now press the "Invert" soft key from Function keys to activate "Invert" property (ON). Plot the resulting waveform and observe and explain the change in the waveform.

3. Cancel the "Invert" mode operation of Channel 1 and observe the regular waveform on the display. (CH1 "Invert" OFF)

a. Press the "Cursor" button which is in the Menu keys. "Cursor" menu will appear in the right side of the display. Press the TOP soft key to make the source "CH1". Press the bottom soft key "X↔Y" to obtain horizontal cursors "Y1" and "Y2" (to measure voltage). Then, select the cursor "Y1" by pressing to the "Y1" soft key. Change the position of the cursor "Y1" by playing with the "VARIBALE Knob". Similarly, press the soft key corresponding to cursor "Y2" and change the position of the cursor Y2 by playing with the "VARIBALE Knob".

b. Now using the cursors measure the peak to peak amplitude of the waveform and record this value. (The measured voltage value can be seen on the screen under the "Y1Y2" submenu.)

c. Change the cursor type from "Voltage - Y" to "Time - X" by pressing the "X↔Y" soft key. Now cursors "Y1" and "Y2" are replaced with "X1" and "X2". Repeat the same operations for the vertical cursors to measure the period and frequency of the waveform and record these values.

4. Press "Cursor" button to close the cursors, then press "Measure" button. A menu will appear in the right side of the display.

a. Now, the measured values which are peak to peak voltage (V_{pp}), average Voltage (V_{avg}), Frequency, Duty Cycle and Rise Time for both channels (1: CH1 and 2: CH2) are appeared on the screen inside the menu. Record these values.

b. You can change the measured quantities by pressing the corresponding button. Press "Rise Time" soft key, press "Time" soft key in new submenu and by varying "VARIBALE Knob" choose "Period", and press "Previous Menu" soft key. Now you can measure the "Period" of both channels instead of measuring "Rise Time". Record the period values.

5. Set up the circuit of Figure 3.7. To generate the desired sinusoidal signal, press "Sine" soft key. By using the soft keys, set the frequency of the sinusoidal signal to 2 kHz and peak-to-peak voltage to 4 V to obtain $V_{in}(t)=2\sin(4000\pi t)$. Enable the CH1 output of the *AATech AWG 1020*A function generator by pressing the "Output" button of CH1 on the front panel of *AWG-1020A*

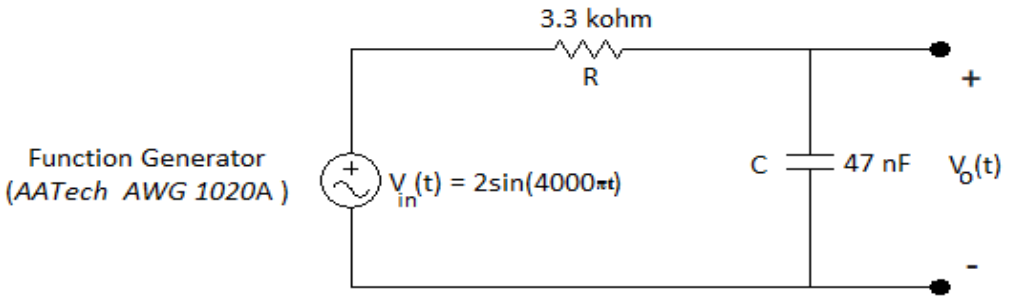


Figure 3.7 The circuit used in Part 5.

a. Observe and plot $V_{in}(t)$ and $V_o(t)$ simultaneously. Determine the phase difference using the cursors properly.

b. Set the oscilloscope to "XY" operation. For this purpose press "Menu" button on the front panel of DSO. From the menu appeared on the screen, press "XY" soft key for "XY" mode (If "XY" is not appeared on the screen press "Menu" button again). Observe and plot the figure on the screen. Determine the phase difference.

6. Set up the circuit in Figure 3.8. Connect Channel 1 and Channel 2 of the oscilloscope as shown in the figure and press "AUTOSET" button to see the signals of both channels. Then, press "MATH" button. A menu will appear in the right side of the oscilloscope screen. You will also observe a third signal (the red one) on the oscilloscope screen.

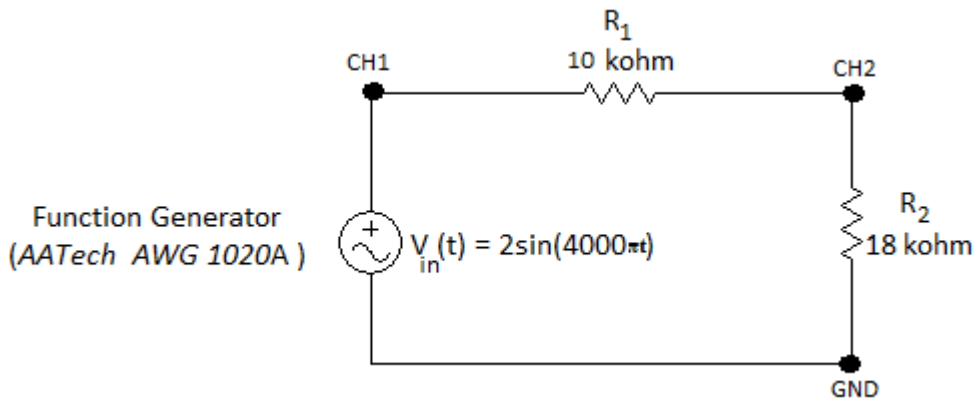


Figure 3.8 The circuit used in Part 6

a. Press the soft key corresponding to "Operation" to make the operation "CH1-CH2". This operation subtracts the signal in Channel 2 from the signal in Channel 1 and the third signal you observed corresponds to the difference signal. Plot the all three signals.

b. Press the soft key corresponding to "Operate" repeatedly to select the operation "CH1+CH2". Observe the sum of the two signals in Channel 1 and 2 on the display. Plot the resulting waveform.

c. How can you measure the voltage of R_1 by using oscilloscopes? Measure and plot the voltage signal of R_1.