Experiment No. 1

Oscilloscope and Function Generator

1. OBJECTIVES

** To understand basic operation and controls of an oscilloscope.

** To make measurements using an oscilloscope (to learn how to determine the Amplitude, Time period and Frequency of a given waveform using CRO).

2. THEORY

Oscilloscope

An oscilloscope is an electrical measuring device that displays a graph of a voltage as a function of time. This allows a user to make both voltage and time measurements that is not available with a standard multimeter. Many oscilloscopes can display more than one voltage signal on their screen, which gives us the powerful ability to compare the behavior of these signals. The screen of oscilloscope is divided into centimeter divisions in the vertical and horizontal directions. The vertical sensitivity is provided (or set) in volts/div, while the horizontal scale is provided (or set) in t time (s/div)

Some of the uses of an oscilloscope are:

•Measure voltages, voltage differences, and time intervals.

•Measure the frequency of a repetitive signal.

•Compare two or more signals varying in time and see their relationships (for example, whether a particular feature on one waveform occurs before or after a feature on the other waveform).

•See the effect of adding or removing a component on a circuit.

•Measure the DC and AC parts of a waveform.

•Measure various characteristics of a waveform, such as peak-to-peak voltage, RMS voltage, period, rise time, fall time, etc.

•Plot one voltage versus another voltage. This is called XY mode and is an exception to the statement that the scope displays a voltage as a function of time.

Digital Oscilloscope

Modern Oscilloscopes are typically digital; the digital oscilloscope performs two basic functions: acquisition and analysis. During acquisition the sampled signals are saved to memory and during analysis the acquired waveforms are analyzed and output to the display. There are a variety of digital oscilloscopes and those presented are the most common used in this lab.

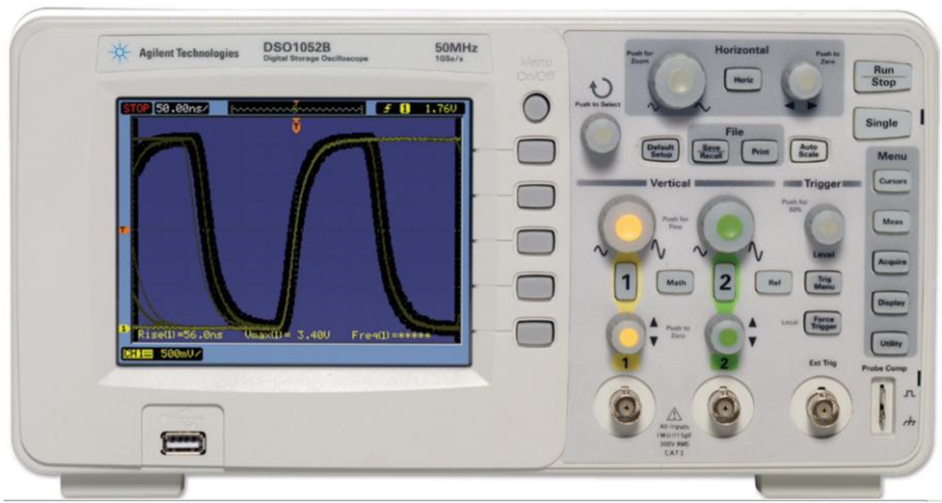


Fig. 1: DSO1052B Digital Oscilloscope.

Figure 2 shows the front panel of the DSO1052B oscilloscope. The controls are keyed to the numbers in the following table:

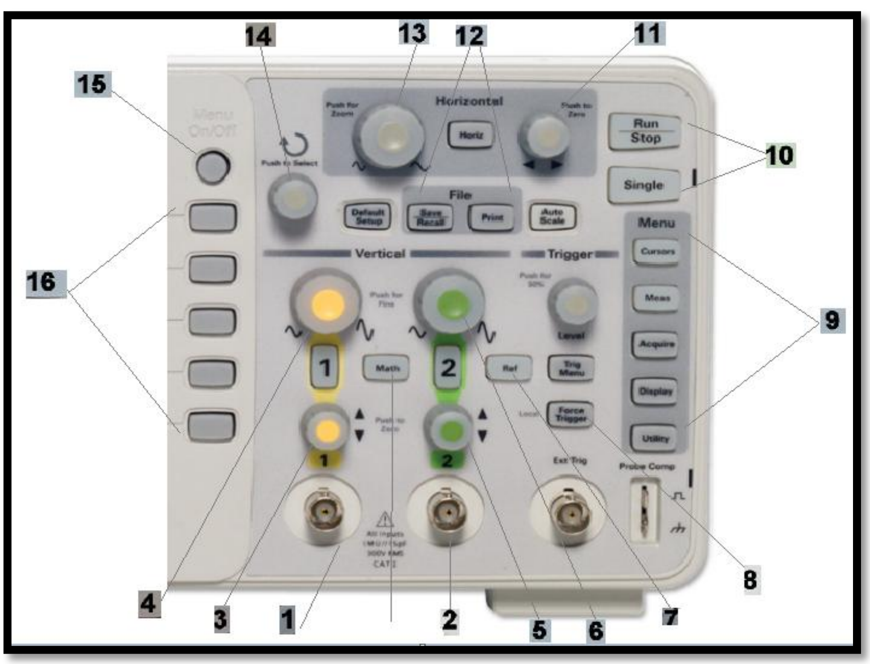


Fig. 2: Front view of the control units of the digital oscilloscope (DSO1052B).

Number	Button label	Function
1	None	Input male BNC terminal for channel 1's vertical amplifier.
2	None	Input male BNC terminal for channel 2's vertical amplifier.
3	Push to zero	Position knob (change Channel 1's vertical position of the waveform on the screen.
4	Push for fine	Scale knob (change the voltage per division setting for a waveform on the screen of channel 1).
5	Push to zero	Position knob (change Channel 2's vertical position of the waveform on the screen.
6	Push for fine	Scale knob (change the voltage per division setting for a waveform on the screen of channel 2).
7	Ref	Turns the reference waveform menu on and off.
8	Force trigger	Immediately forces the oscilloscope to trigger. This is useful when the trigger mode is set to NORMAL in the absence of a trigger signal, as you can see where the trace is on the screen.
9	Menu controls	The function menu controls various options that influence the operation of the oscilloscope. Pressing one of these buttons causes the right hand options list and soft keys on the display to reflect the currently selected function.
10	Run/stop Single	This key will toggle capturing the scope between run mode (capturing data) and stop mode (display last captured data). The scope is running when the button is green (yellow) and stopped when it is red.
11	Push to zero	Position knob (change horizontal position of the waveform on the screen.
12	File (save/record and print)	When pressed, the displayed waveforms are saved into a file in external memory (e.g., a USB thumb drive). You can choose to either save the waveforms as either a CSV (comma-separated values) or four types of bitmap images (8 bit BMP, 24 bit BMP, GIF, or PNG).
13	Push for zoom	Scale knob (change the time per division setting for a waveform on the screen).
14	Push to select	This knob is the general-purpose adjustment knobs for numerical settings and menu choices in menus.
15	MENU ON/OFF	For any displayed menu, turns the menu on and off.
16	None	Soft keys. Their function is shown at the right side of the screen. The button 15 (MENU ON/OFF) can be used to turn the menu on and off.

Function Generator

The function generator is a voltage supply that typically provides a sinusoidal, square-wave, and triangular voltage waveform for a range of frequencies and amplitudes. Typical frequency ranges are from 0.01 Hz to 10 MHz. Although the frequency of the function generator can be set by the dial position and appropriate multiplier, the oscilloscope can be used to precisely set the output frequency. The scope can also be used to set the amplitude of the function generator since most function generators simply have an amplitude control with no level indicators.

Fig. 3: GFG-8250A Function Generator.

AC, DC and Electrical Signals

AC means Alternating Current and DC means Direct Current. AC and DC are used when referring to voltages and electrical signals.

An electrical signal is a voltage or current which conveys information, usually it means a voltage. One distinction is whether the signal is periodic or not. Periodic means that the signal repeatedly takes on the same set of values over various intervals.

Examples:

**Sinusoidal waveforms

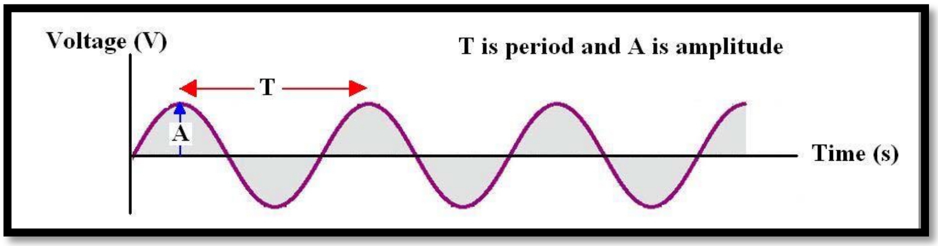
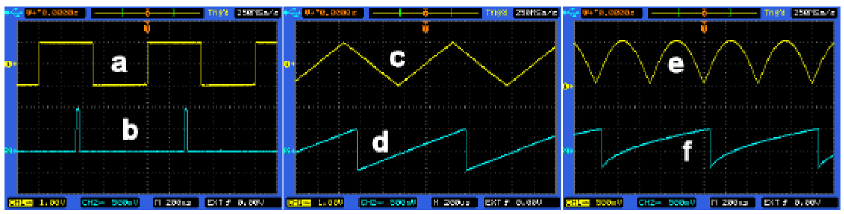


Fig. 4: Sine wave

**Non-sinusoidal waveforms

There are other often-encountered waveforms that have special names. The following figure shows some examples:



a	Square wave
b	Pulse waveform (note the pulse's minimum values here are 0 volts and the peak voltage is 1 volt)
c	Triangle wave
d	Ramp wave (also called a sawtooth wave)
e	Rectified sine wave ($\|\sin(\omega t)\|$)
f	Square root wave (amplitude is proportional to the square root of the time from the start of the wave's period)

Fig. 5: Some examples of Non-sinusoidal wave.

Measurements using an oscilloscope

Here's an example of an oscilloscope diagram of a sinusoidal signal:

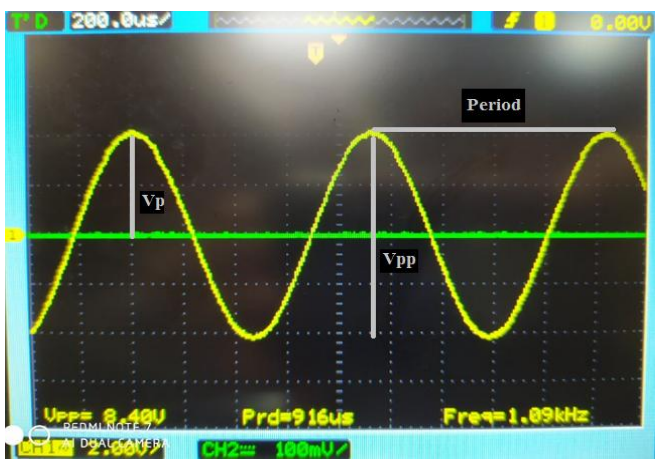


Fig. 6: Oscilloscope diagram of a sinusoidal signal.

Amplitude Measurements

The amplitude of the wave (V_P) is the difference between the height of the peaks of a wave and the wave's equilibrium (the value which the wave is oscillating around). In this case I've centered the wave to oscillate around the center horizontal grid line. The distance between this equilibrium line and either the high or low peak of the wave is 2 vertical grid divisions. Since volts/div is set to 2V, 2 grid divisions equal 4V, so the amplitude of the wave is 4V.

A common measurement of a waveform on an oscilloscope's graph is the peak-to-peak voltage (V_{PP}). This is the vertical distance from the minimum point to the maximum point on the waveform. Here you can see that the minimum point is at -2 divisions, measured from the V = 0 axis. The maximum point is at +2 divisions. Hence, the peak-to-peak amplitude is 2 - (-2) or 4 divisions. The scope's vertical channel gain is set to 2 V per division, so we get a measured peak-to-peak voltage of (4 div) x (2 V/div) = 8volts. Note this measurement is shown by the scope in the lower left corner of the picture and demonstrates that some scopes can be set up to display various waveform measurements of interest.

Frequency Measurements

The period of the wave is defined as the amount of time (expressed in seconds) required to complete one full cycle. From this figure the distance between two peaks is 4.6 divisions. The scope's horizontal axis is set to 200 µs/div. Thus, the period is 4.6 x (200 µs/div) = 920 µs. The frequency of a signal is the reciprocal of the period:

Frequency = $\frac{1}{\text{period}}$

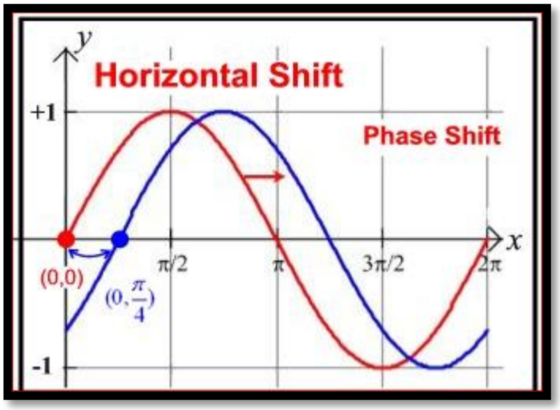
Frequency is measured in Hz (hertz) and is dimensionally equal to reciprocal seconds. So $f = \frac{10^6}{920} = 1.086\ KH_z$. The scope has also provided this measurement at 1.09 KH_z.

Measurement of Phase Difference

Here's an example of an oscilloscope diagram of XY time mode.

Fig. 7: Oscilloscope diagram of XY time mode.

The XY time mode converts the oscilloscope from a volts-versus-time display to a volts-versus-volts display using two input channels. Channel 1 is the X-axis input, channel 2 is the Y-axis input. This figure shows a common use of the XY display mode by measuring the phase difference between two signals of the same frequency with the Lissajous method.



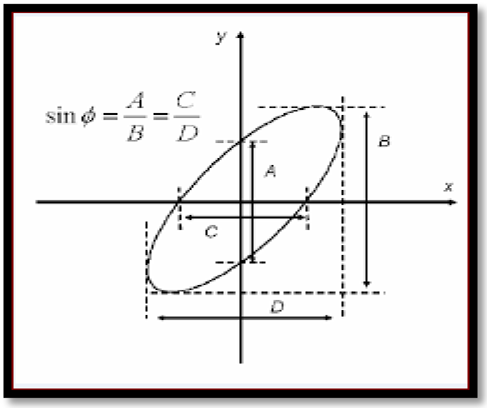


Fig. 8: The phase difference between two signals of the same frequency with the Lissajous method.

3. PROCEDURE

Part 1

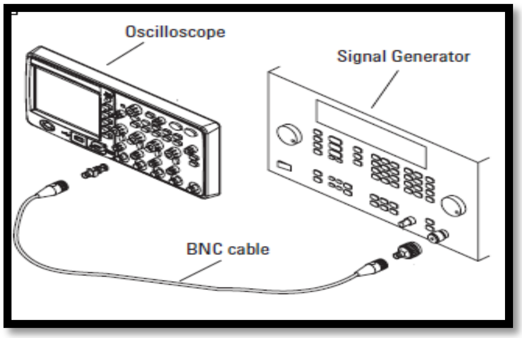


Fig. 9: Oscilloscope connected with signal generator with BNC cable.

1. Make the connections as the diagram shown above.
2. Turn on the power of the CRO and function generator.
3. From the Function Generator select the desired frequency and amplitude of the wave.
4. Measure Peak-to-peak voltage of the waveform by obtained the number of divisions along the Y-axis in between peak to peak of the waveform (i.e. sine waveform / Triangular waveform /Square waveform) and multiplying with the divisional factor of the amplitude note in volts.
5. Measure Time period which is calculated from X-axis.
6. Calculate Frequency by formula F=1/T.

7. This frequency is compared with the frequency applied using function generator and also with the value provided on the oscilloscope screen.
8. By repeating the above steps we can find frequency and voltages of square wave & triangular waveforms.

Observations:

TABLE 1

S. No.	**No. of Vertical Divisions(n)**	**Voltage/ Division (V/Div)**	$\boldsymbol{Vpp = n * V/Div}$	$\boldsymbol{Vp = Vpp/2}$

TABLE 2

S. No.	**No. of Horizontal Divisions(n)**	**Time/Division (time/Div)**	$\boldsymbol{T = n * time/Div}$	$\boldsymbol{f = 1/T}$
1 KH_z				
1.5 KH_z				
2 KH_z				

Part 2

Measurement of Phase Difference:

1. Connect the RC phase shift network as shown above in the circuit diagram.

2. Obtain a sinusoidal signal of 5V (Pk- Pk) at 1 KHz from the function generator.

3. Connect the signal from the function generator to the input of the RC phase shift network and the same signal to the CH-1 of the CRO.

4. Connect the output of the Phase shift network to the CH-2 of the CRO.

5. Press X- Y mode button.

6. The pattern obtained on the screen will be an ellipse.

7. The phase difference between the two signals (θ) is given by θ = sin-1(B/A).

8. By varying the different values of the resistances from DRB, frequencies, note the values of B and A and hence find θ.

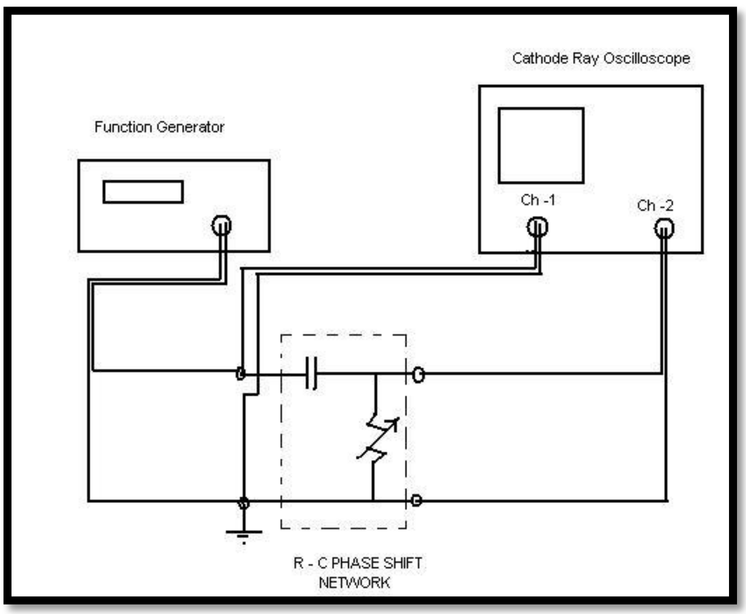


Fig. 10: R .C Phase shift network

Observations:

TABLE 3

S. No.	f	R	C	$\theta = \tan^{-1}(\frac{1}{\omega RC})$	B	A	$\theta = \sin^{-1}(\frac{A}{B})$