Experiment 1

Oscilloscope and Function Generator Operation

1   OBJECTIVE

To use the oscilloscope and function generator to calculate, obtain, and measure the amplitudes and durations (period) of various voltage signals.

EQUIPMENT REQUIRED

Instruments

Oscilloscope

Digital multimeter

Supplies

DC supply

Function generator

2   THEORY

Oscilloscope

The oscilloscope is the most important instrument available to the practicing technician or engineer. It permits the visual display of a voltage signal that can reveal a range of information regarding the operating characteristics of a circuit or system that is not available with a standard multimeter. At first glance the instrument may appear complex and difficult to master. Be assured, however, that once the function of each section of the oscilloscope is explained and understood the system is used throughout a set of experiments, your expertise with this important tool will develop quite rapidly.

In addition to the display of a signal, it can also be used to measure the average value, rms value, frequency and period of a sinusoidal or nonsinusoidal signal. The screen 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). If a particular signal occupies 6 vertical divisions and the vertical sensitivity is 5mV/div., the magnitude of the signal can be determined from the following equation:

Amplitude of signal voltage = voltage sensitivity (V/div.)×deflection (div.)
$$(1)$$
$$V_s = (5\text{mV/div.})(6 \text{ div.}) = 30\text{mV}$$

If one cycle of the same signal occupies 8 divisions on the horizontal scale with a horizontal sensitivity of 5μs/div., the period and the frequency of the signal can be determined using the following equations:

Period of signal voltage = horizontal sensitivity (V/div.)×deflection (div.)
$$(2)$$
$$T = (5\mu\text{s/div.})(8 \text{ div.}) = 40 \ \mu\text{s and}$$

$$f = \frac{1}{T} = \frac{1}{40\mu s} = 25kHz$$

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. 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.

Both the scope and the function generator are built to withstand some abuse, so do not be afraid to try various combinations of dial settings to fully develop your abilities with this laboratory experiment. In addition, if you are working in a group, do not let one person perform all the experimental work. You must spend the time in the laboratory, so you should learn how to use the equipment properly and develop the skills that you may need for a job that requires a firm understanding of how to use the oscilloscope and functions generator.

3 PROCEDURE

3.1 Part 1. The Oscilloscope

The instructor will provide a brief description of the various sections of the oscilloscope and function generator. In your own words, describe the function and use of each of the following controls or sections of the oscilloscope.

a. Focus of voltage trace:
   It focuses the beam on the screen.

b. Intensity of voltage trace:
   Adjust the brightness of the beam on the screen.

c. Vertical and horizontal position controls:
   Allows the moving of the trace in either screen direction.

d. Vertical sensitivity:
   Selects volt/divisions on y-axis.

e. Horizontal sensitivity:
   Unit of time/divisions on x-axis

f. Vertical mode selection:
   Selects between CH1, CH2, Dual and Add modes

g. AC-GND-DC switch:
   Allows for AC or DC coupling of signal to scope and at GND position,

establishes ground reference o screen

h. Beam finder:
   Locates the trace if it is off screen.

i. Calibrate switches:
   Provide for the adjustment of scope from external reference source.

j. Internal sync:
   In this position, a part of the input signal is applied from the vertical amplifier to the trigger circuit to cause the trigger signal synchronously with the input signal to drive the sweep circuit.

k. Trigger section:
   Determines mode of triggering of the sweep voltage.

l. External trigger input:
   In this position, the signal which is connected to EXT TRIG input becomes the triggering signal.

m. Input resistance and capacitance:
   The input impedance of many scopes consists of the parallel combination of a 1 Meg resistance and a 30 pF capacitor.

n. Probe:

Measuring devices which reduces loading of scope on a circuit and effectively increases input impedance of scope by a factor of 10.

3.2 Part 2. The Function Generator

Setup

a. Turn on the oscilloscope and adjust the necessary controls to establish a clear, bright, horizontal line across the center of the screen. Do not be afraid to adjust various controls to see their effects on the display.

b. Connect the function generator to one vertical channel of the oscilloscope and set the output of the generator to a 1000 Hz sinusoidal waveform.

c. Set the vertical sensitivity of the scope to 1 V/div. and adjust the amplitude control of the function generator to establish a 4 V peak-to-peak (p-p) sinusoidal waveform on the screen.

Horizontal Sensitivity

d. Determine the period of the 1000 Hz sinusoidal waveform in milliseconds using the equation $T = 1/f$. Show all work for each part of the experiment. Be neat!

$$(\text{calculated}) T = 1/f = 1/1000 Hz = 1\text{ms}$$

e. Set the horizontal sensitivity of the scope to 0.2 ms/div. Using the results of Part 2(d) predict and calculate the number of horizontal divisions required to properly display one full cycle of the 1000 Hz signal.

$$(\text{calculated}) \text{Number of divisions} = 1\text{ms}*(1\text{div}/0.2\text{ms}) = 5 \text{ division}$$

Use the oscilloscope measure the number of required divisions and insert below. How does the result compare to the calculated number of divisions?

(measured)Number of divisions=5 divisions

f. Change the horizontal sensitivity of the oscilloscope to 0.5 ms/div. without touching any of the controls of the function generator. Using the results of Part 2(d) how many horizontal divisions will now be required to display one full cycle of the 1000 Hz signal?

(calculated)Number of divisions=1ms*(1div/0.5ms)=2 divisions

Using the oscilloscope measure the number of required divisions and insert below. How does the result compare to the calculated number of divisions?

(measured)Number of divisions=2

g. Change the horizontal sensitivity of the oscilloscope to 1 ms/div. without touching any of the controls of the function generator. Using the results of Part 2(d), how many horizontal divisions will now be require to display one full cycle of the 1000 Hz signal?

(calculated)Number of divisions=1ms*(1div/1ms)=1 division

Using the oscilloscope measure the number of required divisions and insert below. How does the result compare to the calculated number of divisions?

(measured)Number of divisions=1

h. What was the effect on the appearance of the sinusoidal waveform as the horizontal sensitivity was changed from 0.2 ms/div. to 0.5 ms/div. and finally to 1 ms/div.
.2ms/div takes 5 boxes to display total wave
.5ms/div takes 2 boxes to display total wave
1ms/div takes 1 box to display total wave
Did the frequency of the signal on the screen change with each horizontal sensitivity? What conclusion can you draw from the results regarding the effect of the chosen horizontal sensitivity on the signal output of the function generator?
No, the frequency of the signal does not change. Increasing horizontal sensitivity - e.g. from .1ms to 20µ- enables more sensitive reading of the frequency.

i. Given a sinusoidal waveform on the screen review the procedure to determine its frequency. Develop e sequence of steps to calculate the frequency of a sinusoidal waveform appearing on the screen of an oscilloscope.

   (a) *Adjust timebase to obtain one cycle of the wave*

   (b) *Count the number of divs. occupied by the wave*

   (c) *Note the timebase setting*

   (d) *Multiply timebase setting by number of divs. occupied by the wave. This is equal to the period of the wave*

   (e) *Obtain its reciprocal; that's the frequency*

Vertical Sensitivity

j. Do not touch the controls of the function generator but set the sensitivity of the scope to 0.2 ms/div. and set the vertical sensitivity to 2 V/div. Using this latter sensitivity, calculate the peak-to-peak value of the sinusoidal waveform on the screen by first counting the number of

vertical divisions between peak values and multiplying by the vertical sensitivity.

$$(\text{calculated})\text{Peak-to-peak value}=2\text{div}*(2\text{V/div})=4V_{p-p}$$

k. Change the vertical sensitivity of the oscilloscope to 0.5 V/div. and repeat Part2(j).

$$(\text{calculated})\text{Peak-to-peak value}=8*(0.5\text{V/div})=4V_{p-p}$$

l. What was the effect on the appearance of the sinusoidal waveform as the vertical sensitivity was changed from 2 V/div. to 0.5 V/div.?
The signal occupied full screen.
Did the peak-to-peak voltage of the sinusoidal signal change with each vertical sensitivity? What conclusion can you draw from the results regarding the effect of changing the vertical sensitivity on the output signal of the function generator?
The peak amplitude did not change with a change in the setting of the vertical sensitivity.

m. Can the peak or peak-to-peak output voltage of a function generator be set without the aid of an auxiliary instrument such as an oscilloscope or digital multimeter? Explain.
No, there is no voltmeter built into function generator (Except some digital ones)

3.3 Part 3. Exercises

a. Make all the necessary adjustments to clearly display a 5000 Hz 6 V_{p-p} sinusoidal signal on the oscilloscope. Establish the zero volt line at the center of the screen.

Record the chosen sensitivities:

$$\text{Vertical sensitivity}=1\text{V/div}$$
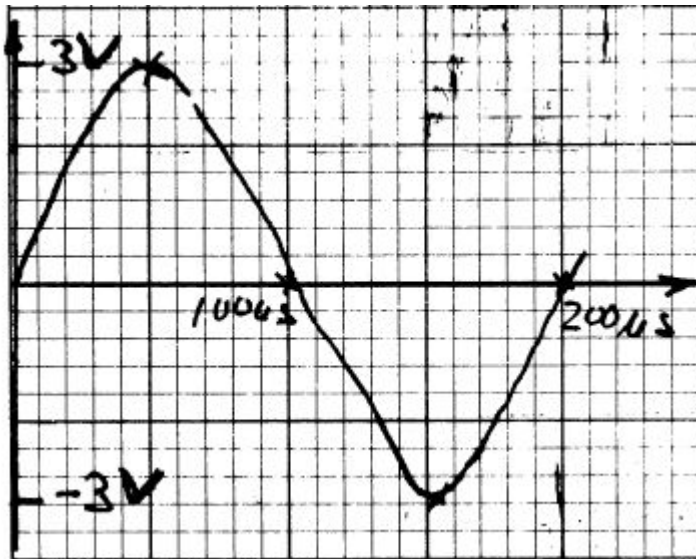$$\text{Horizontal sensitivity}=50\mu\text{s}$$

Figure 1:

Draw the waveform on Figure 1 carefully noting the required number of horizontal and vertical divisions. Add vertical and horizontal dimensions to the waveform using the chosen sensitivities listed above.

Calculate the period of the waveform on the screen using the number of horizontal divisions for a full cycles shown.

$$\text{T(calculated)}=4\text{div}*(50\mu\text{s/div})=200\mu\text{s}$$

b. Repeat Part 3(a) for a 200 Hz 0.8 V_{p-p} sinusoidal waveform on Figure 2

Vertical sensitivity=.1V/div
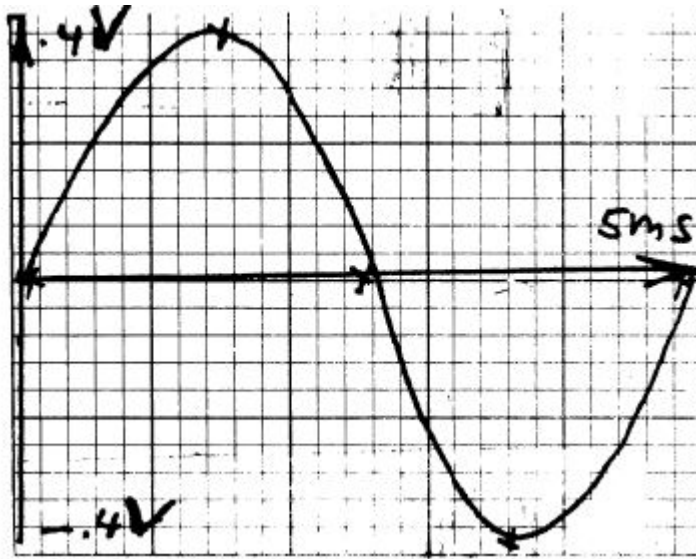Horizontal sensitivity=1ms/div
T (calculated)=5div*(1ms/div)=5ms

Figure 2:

c. Repeat Part 3(a) for a 100 kHz 4 V_{p-p} square wave on Figure 3. Note that a square wave is called for.

$$\text{Vertical sensitivity}=1\text{V/div}$$
$$\text{Horizontal sensitivity}=1\mu\text{s/div}$$
$$\text{T (calculated)}=10\text{div}*(1\mu\text{s/div})=10\mu\text{s}$$

3.4   Part 4. Effect of DC Levels

a. Reestablish the 1 kHz $4V_{p-p}$ sinusoidal waveform on the screen. Calculate the effective value of the sinusoidal waveform.

$$V_{rms} \text{ (calculated)}= V_{rms}=4\text{V}*1/2*.707=1.41\text{Volts}$$

b. Disconnect the function generator from the scope and measure the effective (rms) value of the output of the function generator using the digital meter.
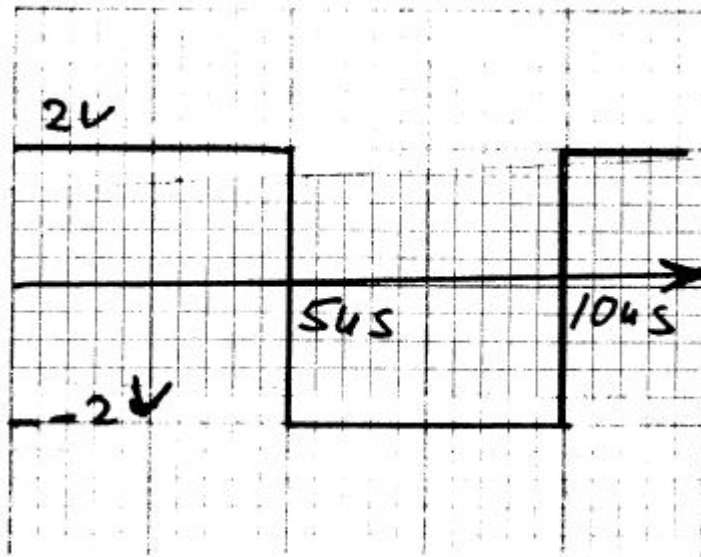
$$V_{rms} \text{ (measured)}=1.35\text{Volts}$$

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Figure 3:

c. Determine the magnitude of the percent difference between the calculated and measured levels using the following equation:

$$\%Difference = \frac{V_{calc} - V_{meas}}{V_{calc}} \times 100\%$$

%Difference=[(1.41-1.35)/1.41]*100=4.74

d. Reconnect the function generator to the scope with the 1kHz 4 V_{p-p} signal and switch the AC-GND-DC coupling switch of the vertical channel to GND. What is the effect?
No trace on the screen
Why? How can this scope function be used?
Adjust vertical position correctly.

e. Now move the AC-GND-DC coupling switch to the AC position. What is the effect on the screen display? Why? *Signal is restored. AC mode displays only AC component of the input signal.*

f. Finally, move the AC-GND-DC coupling switch to the DC position.

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What is the effect on the screen display? Why?
No difference. Applied signal has no DC component.

g. Construct the input of v_i of Figure 4 by placing a DC source in series with the output of the function generator. Be sure the ground of the oscilloscope is connected directly to the ground of the function generator. Measure and record the actual battery voltage using the DC mode of the digital multimeter.
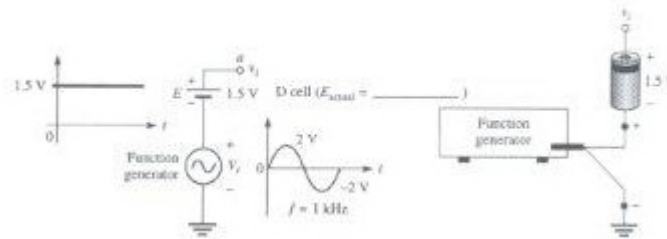
(measured) DC level=1.45Volts

Figure 4:

h. Apply the input voltage v_i of to one channel of the oscilloscope with the AC-GND-DC coupling switch in the GND position and set the resulting horizontal line (zero reference level) in the middle of the screen. Then move the AC-GND-DC coupling switch to the AC position and make rough sketch of the waveform on Figure 5 clearly showing the zero reference line and the number of vertical and horizontal divisions. Using the chosen sensitivities label the magnitudes of the various horizontal an vertical grid lines.

i. Switch the position of the AC-GND-DC coupling switch to the DC mode and make a rough sketch of the resulting waveform on Figure 6including the detail requested in Part 4(h).
The copy of the waveform above with a vertical shift which is equal to the DC offset. Did the vertical shift of the sinusoidal waveform equal
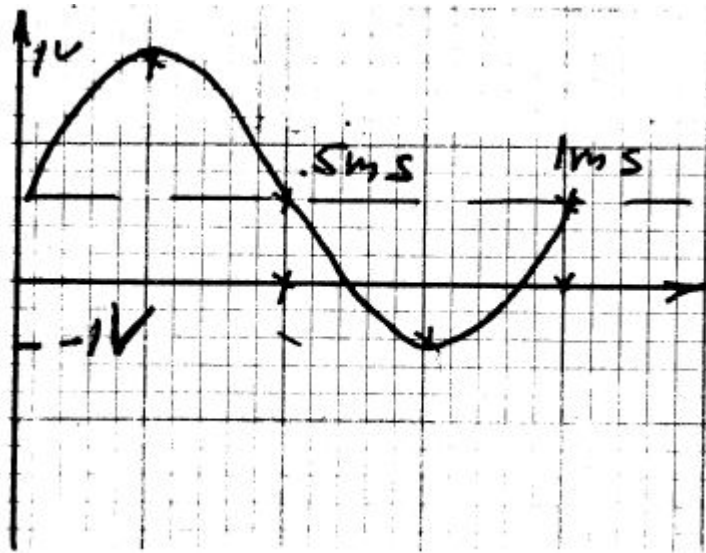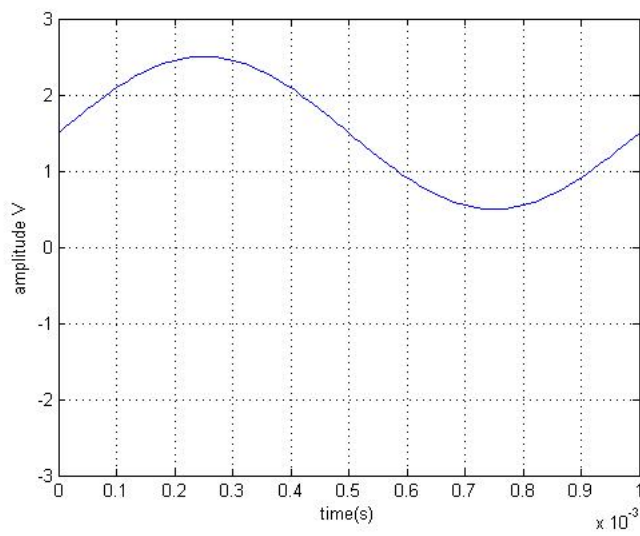
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Figure 5:

Figure 6:

the DC voltage of the battery.

Yes.

Is the shape of the sinusoidal waveform changed by moving the AC-GND-DC coupling switch through the various positions?

Yes, in AC position mean of the waveform is zero.

j. Reverse the polarity of the battery of Figure and repeat Parts 4(h) and (i). Observe the effect on the waveform in the AC and DC modes and comment below.

3.5 Problems

1. Given $v = 20sin2000t$, determine

   (a) ω
       ω=2000 rad/s

   (b) f
       $f = 2000/(2 * 3.14) = 318Hz$

   (c) T
       $T = 1/f = 1/318 = 3.14ms$

   (d) Peak value
       $V_{peak} = 20V$

   (e) Peak-to-peak value
       $V_{peak-peak} = 40V$

   (f) Effective value
       $V_{rms} = .707 * 20 = 14.1V$

   (g) DC level
       $V_{dc} = 0V$

2. Given $v = 8 \times 10^{-3} sin2\pi4000t$, determine

   (a) ω
       ω=2*3.14*4000=25.12rad/s

   (b) f
       $f = 4kHz$

   (c) T
       $T = 1/f$=1/4kHz=250μs

(d) Peak value

$V_{peak} = 8mV$

(e) Peak-to-peak value

$V_{peak-peak} = 16mV$

(f) Effective value

$V_{rms} = .707 * 8m = 5.66mV$

(g) DC level

$V_{dc} = 0V$

3. Given $V_{rms} = 1.2V$ and a frequency of 400 Hz, determine the mathematical expression for the sinusoidal voltage as a function of time.

$V(t)=1.7\sin(2.51\text{kt})$

4 Conclusions