18 Sine-Wave Measurements

OBJECTIVES:

After performing this experiment, you will be able to:

1. Measure the period and frequency of a sine wave using an oscilloscope.
2. Measure across ungrounded components using the difference function of an oscilloscope.

READING:

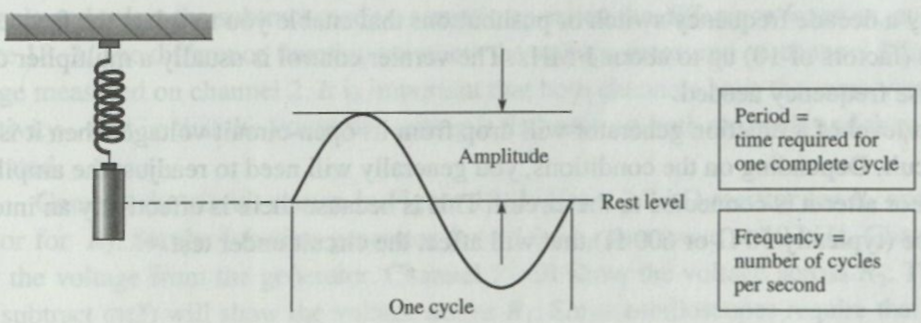
Floyd and Buchla, *Principles of Electric Circuits,* Sections 11–1 through 11–4, 11–10
Oscilloscope Guide pp. 7–14

MATERIALS NEEDED:

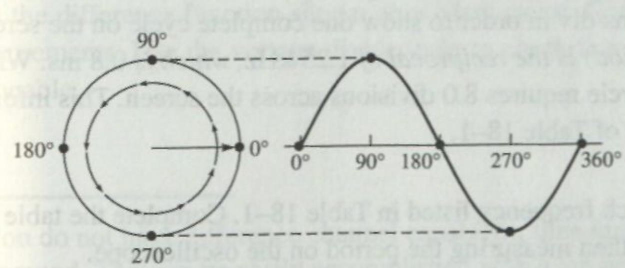
One 2.7 kΩ resistor, one 6.8 kΩ resistor

SUMMARY OF THEORY:

Imagine a weight suspended from a spring. If you stretch the spring and then release it, it will bob up and down with a regular motion. The distance from the rest point to the highest (or lowest) point is called the *amplitude* of the motion. As the weight moves up and down, the time for one complete cycle is called a *period* and the number of cycles it moves in a second is called the *frequency.* This cyclic motion is called *simple harmonic motion.* A graph of simple harmonic motion as a function of time produces a sine wave, the most fundamental waveform in nature. It is generated as the natural waveform from an ac generator. Figure 18–1(a) illustrates these definitions.



(a)



(b)

Figure 18–1

Sine waves can also be generated from uniform circular motion. Imagine a circle turning at a constant rate. The *projection* of the endpoint of the radius vector moves with simple harmonic motion. If the endpoint is plotted along the x -axis, the resulting curve is a sine wave, as illustrated in Figure 18–1(b). This method is frequently used to show the phase relationship between two sine waves of the same frequency.

The sine wave has another interesting property. Different sine waves can be added together to give new waveforms. In fact, any repeating waveform such as a ramp or square wave can be made up of a group of sine waves. This property is useful in the study of the response of circuits to various waveforms.

The Oscilloscope

As you have seen, there are two basic types of oscilloscopes—analog and digital. In this experiment, you will use an oscilloscope to characterize sine waves. You may want to review the function of the controls on your oscilloscope in the section at the front of this manual entitled Oscilloscope Guide—Analog and Digital Storage Oscilloscopes. Although the method of presenting a waveform is different, the controls such as SEC/DIV are similar in function and should be throughly understood. You will make periodic measurements on sine waves in this experiment. Assuming you are not using automated measurements, you need to count the number of divisions for a full cycle and multiply by the SEC/DIV setting to determine the period of the wave. Other measurement techniques will be explained in the Procedure section.

The Function Generator

The basic function generator is used to produce sine, square, and triangle waveforms and may also have a pulse output for testing digital logic circuits. Function generators normally have controls that allow you to select the type of waveform and other controls to adjust the amplitude and dc level. The peak-to-peak voltage is adjusted by the AMPLITUDE control. The dc level is adjusted by a control labeled DC OFFSET; this enables you to add or subtract a dc component to the waveform. These controls may not be calibrated, so amplitude and dc level settings should be verified with an oscilloscope or multimeter.

The frequency may be selected with a combination of a range switch and vernier control. The range is selected by a decade frequency switch or pushbuttons that enable you to select the frequency in decade increments (factors of 10) up to about 1 MHz. The vernier control is usually a multiplier dial for adjusting the precise frequency needed.

The output level of a function generator will drop from its open-circuit voltage when it is connected to a circuit. Depending on the conditions, you generally will need to readjust the amplitude level of the generator after it is connected to the circuit. This is because there is effectively an internal generator resistance (typically 50 Ω or 600 Ω) that will affect the circuit under test.

PROCEDURE:

1. Set the function generator for a 1.0 V_{pp} sine wave at a frequency of 1.25 kHz. Then set the oscilloscope SEC/DIV control to 0.1 ms/div in order to show one complete cycle on the screen. *The expected time for one cycle (the period) is the reciprocal of* 1.25 kHz, *which is* 0.8 ms. With the SEC/DIV control at 0.1 ms/div, one cycle requires 8.0 divisions across the screen. This information is presented as an example on line 1 of Table 18–1.

2. Change the function generator to each frequency listed in Table 18–1. Complete the table by computing the expected period and then measuring the period on the oscilloscope.

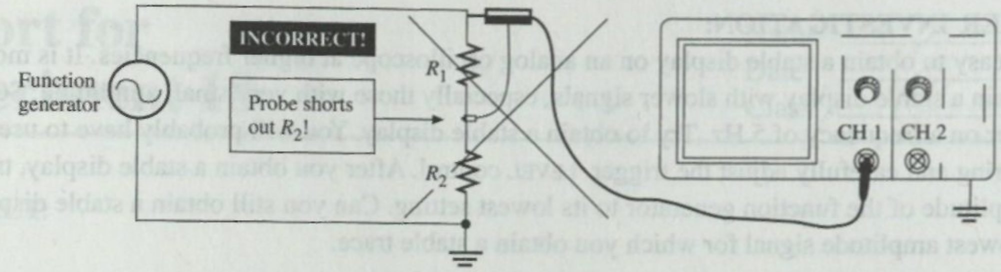


Figure 18–2

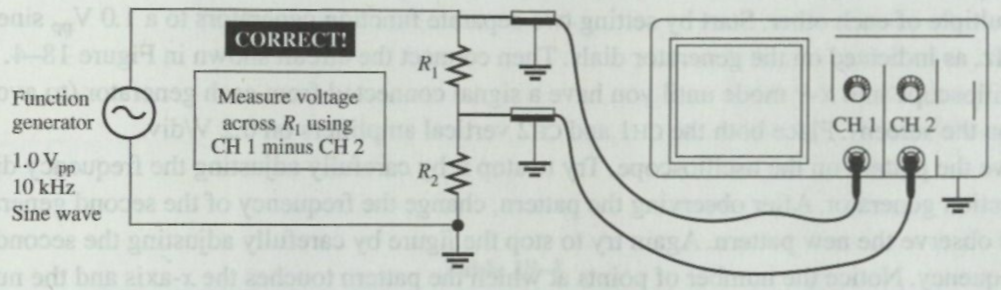


Figure 18–3

3. In this step you will need to use a two-channel oscilloscope with two probes, one connected to each channel. Frequently, a voltage measurement is needed across an ungrounded component. If the oscilloscope ground is at the same potential as the circuit ground, then the process of connecting the probe will put an undesired ground path in the circuit. Figure 18–2 illustrates this.

The correct way to measure the voltage across the ungrounded component is to use two channels and select the subtract mode—sometimes called the *difference function,* as illustrated in Figure 18–3. The difference function subtracts the voltage measured on channel 1 from the voltage measured on channel 2. It is important that both channels have the same vertical sensitivity—that is, that the VOLTS/DIV setting is the same on both channels and they are both calibrated.

Connect the circuit shown in Figure 18–3. Use a 2.7 kΩ resistor for R_1 and a 6.8 kΩ resistor for R_2. Set the function generator for a 1.0 V_{pp} sine wave at 10 kHz. Channel 1 will show the voltage from the generator. Channel 2 will show the voltage across R_2. The difference (CH1 subtract CH2) will show the voltage across R_1. Some oscilloscopes require that you ADD the channels and INVERT channel 2 in order to measure the difference in the signals.* Others may have the difference function shown on a Math menu. Complete Table 18–2 for the voltage measurements. Use the voltage divider rule to check that your measured voltages are reasonable.

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*If you do not have difference channel capability, then temporarily reverse the components to put R_1 at circuit ground. This can be easily accomplished with a lab breadboard but is usually not practical in a manufactured circuit. Although it is possible to isolate the oscilloscope ground and then use one channel to make the measurement, the procedure is not recommended.

FOR FURTHER INVESTIGATION:

It is relatively easy to obtain a stable display on an analog oscilloscope at higher frequencies. It is more difficult to obtain a stable display with slower signals, especially those with very small amplitude. Set the signal generator on a frequency of 5 Hz. Try to obtain a stable display. You will probably have to use NORMAL triggering and carefully adjust the trigger LEVEL control. After you obtain a stable display, try turning the amplitude of the function generator to its lowest setting. Can you still obtain a stable display? Measure the lowest amplitude signal for which you obtain a stable trace.

APPLICATION PROBLEM:

Some interesting and useful patterns called Lissajous figures can be used to compare two frequencies that are an exact multiple of each other. Start by setting two separate function generators to a 1.0 V_{pp} sine wave at 1.0 kHz, as indicated on the generator dials. Then connect the circuit shown in Figure 18–4. Do not put the oscilloscope into X-Y mode until you have a signal connected from each generator (to avoid leaving a dot on the screen). Place both the CH1 and CH2 vertical amplifiers on 0.2 V/div.

Observe the pattern on the oscilloscope. Try to stop it by carefully adjusting the frequency dial of the second function generator. After observing the pattern, change the frequency of the second generator to 2.0 kHz and observe the new pattern. Again try to stop the figure by carefully adjusting the second generator's frequency. Notice the number of points at which the pattern touches the x-axis and the number of points at which the pattern touches the y-axis. Move the second generator to 3 kHz and note the effect. Try adjusting the amplitudes of the generators. Describe your observations in your report. What effect does the frequency ratio have on the pattern? What effect does the amplitude control have? How could you use this method to calibrate the frequency of a signal generator against a standard?

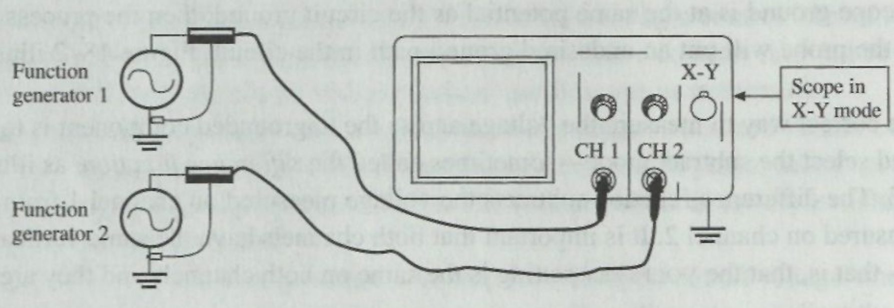

Figure 18–4

Report for Experiment 18

Name ______________
Date ______________
Class ______________

ABSTRACT:

DATA:

Table 18–1

Function Generator Dial Frequency	Computed Period	Oscilloscope SEC/DIV	Number of Divisions	Measured Period
1.25 kHz	0.8 ms	0.1 ms/div	8.0 div	0.8 ms
1.90 kHz				
24.5 kHz				
83.0 kHz				
600.0 kHz				

Table 18–2

	Function Gen. Voltage	Voltage across R_1	Voltage across R_2
measured			
computed	1.0 V_{pp}		

RESULTS AND CONCLUSION:

FURTHER INVESTIGATION RESULTS:

APPLICATION PROBLEM RESULTS:

EVALUATION AND REVIEW QUESTIONS:

1. (a) Compare the computed and measured periods for the sine waves in Table 18–1. Calculate the percent difference for each row of the table.

   (b) What measurement errors account for the percent differences?

2. Using the measured voltages in Table 18–2, show that Kirchhoff's voltage law is satisfied.

3. An oscilloscope display shows one complete cycle of a sine wave in 6.3 divisions. The SEC/DIV control is set to 20 ms/div.

   (a) What is the period? ______________

   (b) What is the frequency? ______________

4. You wish to display a 10 kHz sine wave on the oscilloscope. What setting of the SEC/DIV control will show one complete cycle in 10 divisions?

   SEC/DIV = ______________

5. Explain how to measure the voltage across an ungrounded component.

6. Explain when to select CHOP or ALTERNATE when viewing two signals on an analog oscilloscope.