Experiment BT-7: Time Varying Signals

Equipment Required

PC or Mac Computer

IX-TA-ROAM recorder, USB cable, power supply

A-BMET-B BMET Trainer Board

C-DIN-BB DIN to Breadboard Cable

C-BNC-BB BNC to Breadboard Cable

A-BMET-EC Electronic Components Set

Jumper Wires

Setup

1. This setup will only utilize the TA-ROAM recorder.

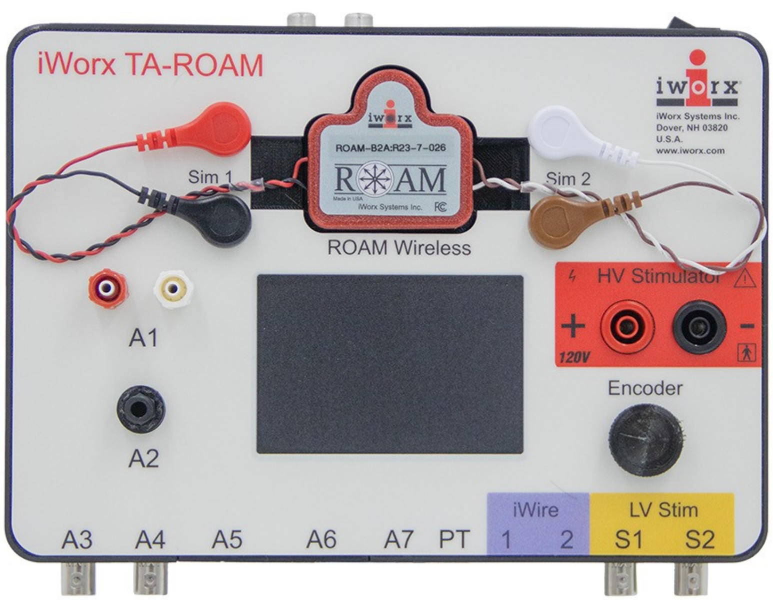


Figure BT-7-S1: IX-TA-ROAM.

Note: Using the S1 channel, a sine wave will be output and visualized in LabScribe.

Experiment BT-7: Time-Varying Signals

Background

Many biomedical signals, including ECGs, EMGs, and EEGs, change continuously over time. In previous labs, you worked primarily with direct current (DC) signals, which remain constant over time. In contrast, alternating current (AC) signals vary with time and are often represented by repeating waveforms such as sine waves.

In this lab, you will extend the circuit concepts learned in previous labs to AC signals. Using the iWorx TA-ROAM and LabScribe, you will generate and measure time-varying waveforms and investigate properties such as amplitude, frequency, and phase. Understanding these characteristics is important because many biomedical instruments process and analyze time-varying physiological signals.

Theory

1. Overview

The general formula for an AC signal is

$$A(t) = A \cdot \sin(2\pi f + \theta) + \beta$$

where *A(t)* is the time-dependent signal value, *A* is the amplitude, *f* is the frequency, *t* is the time, θ is the phase, and β is the DC offset. These components and others are explained below:

2. Sinusoidal

Sinusoidal simply means “shaped like a sine wave”. Even the cosine function is considered sinusoidal.

3. Amplitude

Amplitude describes how powerful a signal is. For a sinusoidal waveform, it is the height measured from the center of the wave to the peak, represented by V_p in Figure 1.

V_{pp}: Amplitude can also be represented by the **peak-to-peak** value (e.g. V_{pp}), which is double the normal amplitude since it is measured from the lowest point to the highest point of the wave.

V_{RMS}: A third way to represent amplitude is the **RMS** value (e.g. V_{RMS}), which is the “effective” value of an AC wave. It tells us what DC value would return the same amount of power, and it is given by the formula below. The reason it involves the square root of 2 is because the derivation is centered around power, which is proportional to the square of voltage and current (P = $\frac{V^2}{R} = I^2 R$).

$$V_p = \text{Peak voltage} - \text{Center voltage}$$

$$V_{pp} = 2V_p = \text{Peak voltage} - \text{Trough voltage}$$

$$V_{RMS} = \frac{V_p}{\sqrt{2}}$$

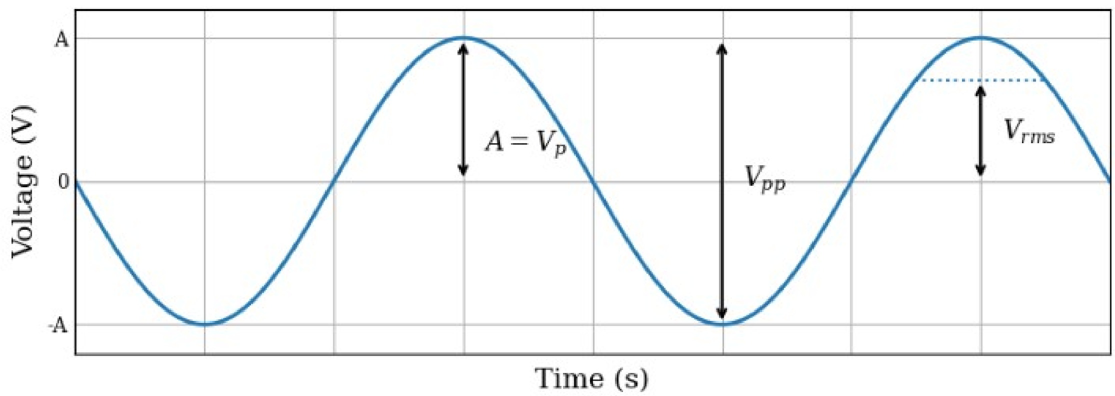


Figure 1. Amplitude of sinusoidal AC signal

4. Period & Frequency

The period is the time required for one complete cycle.

Frequency describes how often a signal repeats itself. It is measured in hertz (Hz), which are equal to reciprocal seconds ($\frac{1}{s}$ or s^{-1}).

$$T = \frac{1}{f}$$

where T is the period (s) and f is the frequency (Hz).

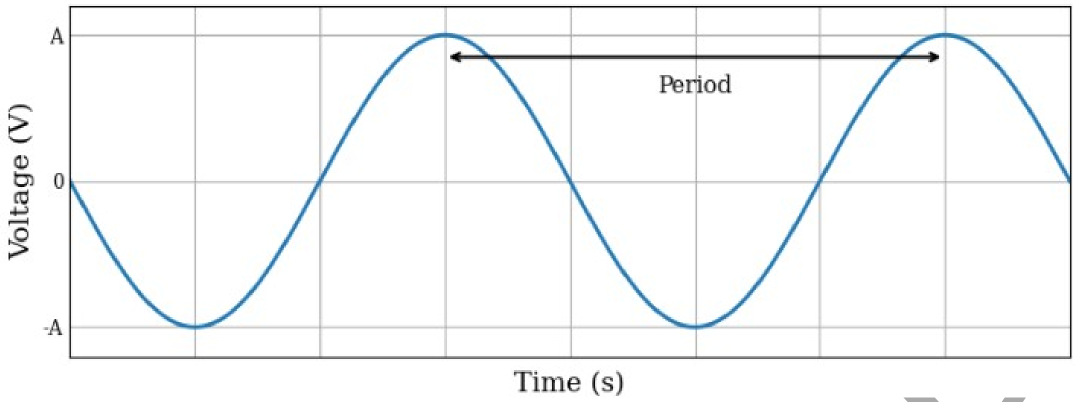


Figure 2. Period of sinusoidal AC signal

5. DC Offset

AC signals have a DC component to them (Remember that AC signals are time-varying and DC signals are constant). This means that we can shift our AC signal up or down the y-axis by adding a fixed (DC) value. This is what is referred to as the "DC offset", represented by β (beta) in the formula above.

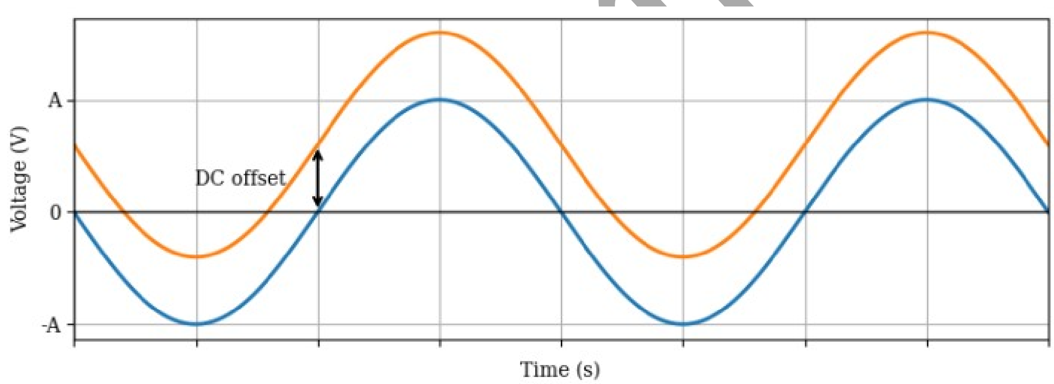


Figure 3. DC Offset of sinusoidal AC signal

6. Phase

Similarly to how the DC offset shifted our AC curve up and down, the **phase** shifts it left and right. This means that the shift is on the x-axis (time), so it depends on how delayed the wave is. We can find the phase shift from this time delay with the following equation:

$$\text{Phase Shift} = \text{Time Delay} \times f \times 360^{\circ}$$

where f is the frequency.

Phase shift is an **angle**, so it is measured in degrees or radians. (Remember that a circle is 360°, or 2π radians around. Multiply an angle by $\frac{180^\circ}{\pi}$ to convert to degrees, or by $\frac{\pi}{180^\circ}$ to convert to radians.)

Phase is usually represented by the symbol θ (theta) or ϕ (phi).

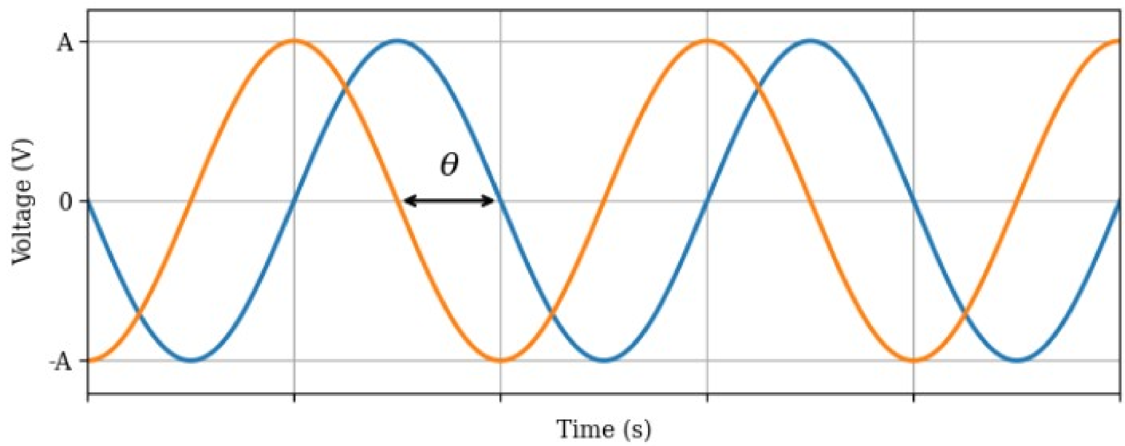


Figure 4. Phase shift of sinusoidal AC signal

7. Types of Waveforms

We have discussed sinusoidal waves, but there are also triangular and square waves:

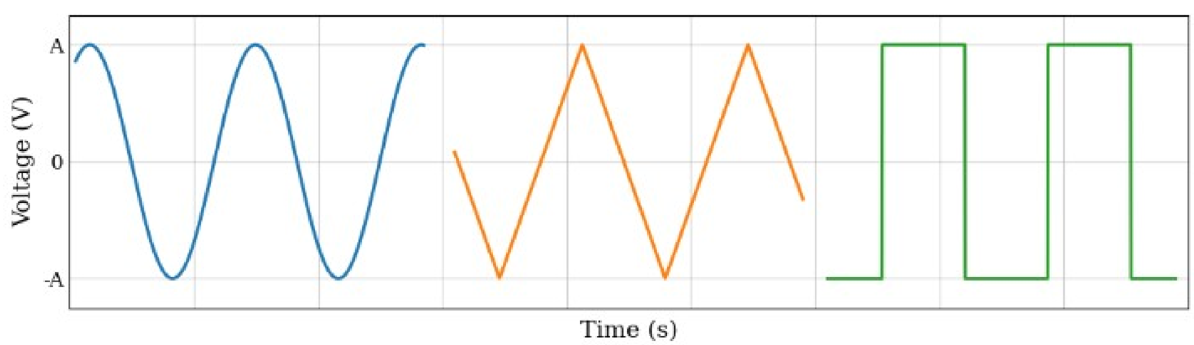


Figure 5. sinusoidal, triangle, and square wave

Each of these waveforms is used for different applications. For example, square waves are often used for computing and clock timing since the high and low voltage values can represent 1s and 0s.

In this lab, we will stick to sinusoidal waves.

8. AC Voltage

AC voltage sources are represented by the symbol in Figure 6.

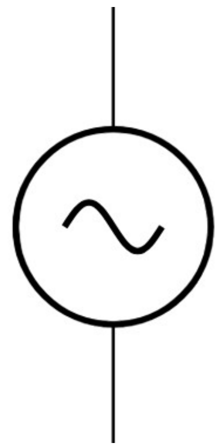


Figure 6. AC voltage signal

Pre-Lab Questions

1. What is the difference between a DC signal and an AC signal?
2. What does the amplitude of a waveform represent?
3. What is the relationship between frequency and period?
4. A waveform has a frequency of 10 Hz. How long does one cycle take?
5. What happens to a waveform when the DC offset is increased?

Experiment BT-7: Time-Varying Signals

Exercise 1: Sinusoidal Signals

Aim: Generate a sinusoidal waveform using LabScribe's built-in function generator and measure the signals amplitude, period, and frequency.

Approximate Time: 20 minutes

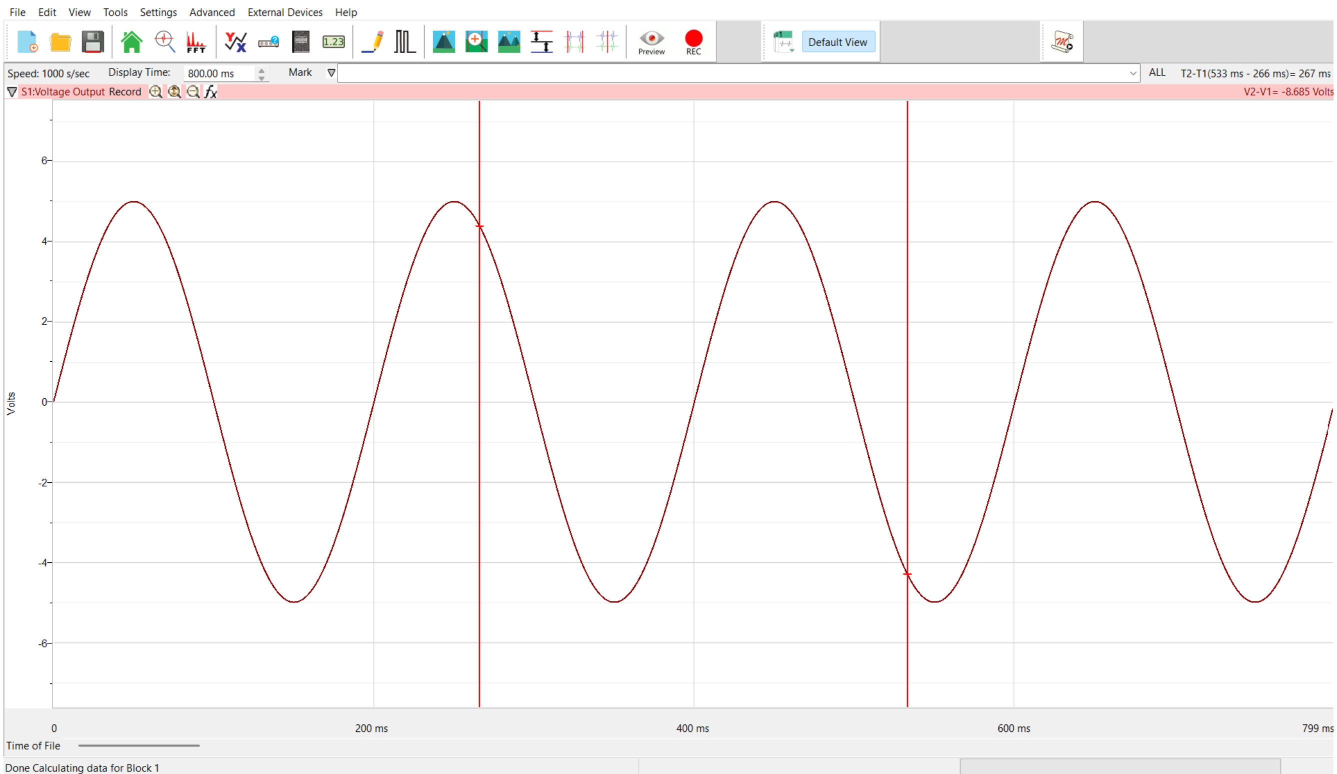
Procedure

Note: This lab will not use the BMET Trainer board. Waveforms will be generated using LabScribe.

1. Press the red REC button in LabScribe to generate a sinusoidal waveform on the S1 stimulator channel.
2. Record for 5 seconds.
3. Press the black STOP button to stop the signal output.

Data Analysis

1. Use the Half Display Time icon (single mountain peak) to view only 3-4 peaks in the display window, as shown in the image below.
2. Scroll to the beginning of the data file.



3. Enter into the Analysis window by clicking on the magnifying glass icon in the top toolbar.

4. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Value1, Value2, V2-V1, Time1, Time2, and T2-T1 should appear in this table. Values for these parameters on the channel are seen in the table across the top margin of the channel.

5. Place the cursors in the correct locations for measuring the maximum and minimum voltage.

6. Record these values in Data Table BT-7-L1.

7. Repeat steps 4-6 for determining the peak-to-peak voltage and the period of the waveform.

8. Calculate the amplitude and frequency from the measured values, and record these values in Data Table BT-7-L1.

Table BT-7-L1: Data Table for Exercise 1 – Sinusoidal Signals

Data from Sinusoidal Signal

Value Type	Units	Measured Value
Maximum Voltage		
Minimum Voltage		
Peak-to-Peak Voltage		
Amplitude		
Period		
Frequency		

Questions

1. Calculate the frequency of the sinusoidal waveform using the measured period. How does the calculated frequency compare to the frequency setting in LabScribe?
2. What is the relationship between peak-to-peak voltage and amplitude for a sinusoidal waveform?

Exercise 2: Changing Frequency

Aim: Investigate how changing the frequency of a sinusoidal waveform affects the timing of the signal.

Approximate Time: 20 minutes

Procedure

1. Access the S1 stimulator output in LabScribe's Preferences menu by navigating to:
   a) **Edit – Preferences** (PC) *or* **LabScribe – Preferences** (Mac)
   b) Click on the **Stimulator** tab.
   c) Ensure the S1 stimulator is selected from the drop down menu.

d) Locate the **Frequency (Hz)** parameter, and set it to 10 by entering “10” into the box, or by using the up/down arrows to the right of the dialog box.

e) Important: Make sure to click the **OK** button at the bottom right of the dialog window to save the changes.

2. Press the red REC button to generate the waveform.

3. Type “10 Hz” into the mark box and press ENTER on the computer keyboard to mark the recording.

4. Press the black STOP button to stop the signal output.

5. Go back into the **Stimulator** Tab.

   a) Ensure the S1 stimulator is selected from the drop down menu.

   b) Locate the Frequency (Hz) parameter, and set it to 20 by entering “20” into the box, or by using the up/down arrows to the right of the dialog box.

   c) Important: Make sure to click the **OK** button at the bottom right of the dialog window to save the changes.

Data Analysis

1. Use the Half Display Time icon (single mountain peak) to view only 3-4 peaks in the display window.

2. Enter into the Analysis window by clicking on the magnifying glass icon in the top toolbar.

3. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Value1, Value2, V2-V1, Time1, Time2, and T2-T1 should appear in this table. Values for these parameters on the channel are seen in the table across the top margin of the channel.

4. Place the cursors in the correct locations for measuring the period of the signal.

5. Record the values in Data Table BT-7-L2.

Table BT-7-L2: Data Table for Exercise 2 – Changing Frequency

Data from Sinusoidal Signal

Frequency (___)	Period (___)
5 (from Exercise 1)	
10	
20	

Questions

1. As the frequency increased from 5 Hz to 20 Hz, what happened to the period of the waveform?
2. Describe the relationship between frequency and period. Are they directly or inversely related?

Exercise 3: Changing Amplitude

Aim: Investigate how changing the amplitude of a sinusoidal waveform affects the timing of the signal.

Approximate Time: 20 minutes

Procedure

1. Access the S1 stimulator output in LabScribe's Preferences menu by navigating to:
   a) **Edit – Preferences** (PC) *or* **LabScribe – Preferences** (Mac)
   b) Click on the **Stimulator** tab.
   c) Ensure the S1 stimulator is selected from the drop down menu.
   d) Locate the **Frequency (Hz)** parameter, and set it back to 5 by entering "5" into the box, or by using the up/down arrows to the right of the dialog box. The frequency will remain at 5 for the remainder of Exercise 2.
   e) Locate the **Amplitude** parameter, and set it to 5.
2. Important: Make sure to click the **OK** button at the bottom right of the dialog window to save the changes.

3. Press the red REC button to generate the waveform.
4. Type “5” into the mark box and press ENTER on the computer keyboard to mark the recording.
5. Press the black STOP button to stop the signal output.
6. Repeat the procedure for Amplitude values of **8** and **10**.

Note: Use the “Autoscale All Channels” button (double-headed arrow icon), to adjust the y-axis so that the complete waveform is visible on the screen.

Data Analysis

1. Use the Half Display Time icon (single mountain peak) to view only 3-4 peaks in the display window.
2. Enter into the Analysis window by clicking on the magnifying glass icon in the top toolbar.
3. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Value1, Value2, V2-V1, Time1, Time2, and T2-T1 should appear in this table. Values for these parameters on the channel are seen in the table across the top margin of the channel.
4. Place the cursors in the correct locations for measuring the period of the signal.
5. Record the values in Data Table BT-7-L1.

Table BT-7-L3: Data Table for Exercise 3 – Changing Amplitude

Data from Sinusoidal Signal	
Amplitude (___)	Peak-to-Peak (___)
5	
8	
10	

Questions

1. Did changing the amplitude of the waveform affect the period or frequency of the signal? Explain your answer using your measurements.

2. How did the peak-to-peak voltage change as the amplitude setting was increased?

Exercise 4: Changing DC Offset

Aim: Investigate how adding a DC offset changes the position of a sinusoidal waveform.

Approximate Time: 20 minutes

Procedure

7. Access the S1 stimulator output in LabScribe's Preferences menu by navigating to:

    a) **Edit – Preferences** (PC) *or* **LabScribe – Preferences** (Mac)

    b) Click on the **Stimulator** tab.

    c) Ensure the S1 stimulator is selected from the drop down menu.

    d) Locate the **Frequency (Hz)** parameter, and set it back to 5 by entering "5" into the box, or by using the up/down arrows to the right of the dialog box. The frequency will remain at 5 for the remainder of Exercise 2.

    e) Locate the **Amplitude** parameter, and set it to 5.

8. Important: Make sure to click the **OK** button at the bottom right of the dialog window to save the changes.

9. Press the red REC button to generate the waveform.

10. Type "5" into the mark box and press ENTER on the computer keyboard to mark the recording.

11. Press the black STOP button to stop the signal output.

12. Repeat the procedure for Amplitude values of **8** and **10**.

Note: Use the "Autoscale All Channels" button (double-headed arrow icon), to adjust the y-axis so that the complete waveform is visible on the screen.

Data Analysis

1. Use the Half Display Time icon (single mountain peak) to view only 3-4 peaks in the display window.

2. Enter into the Analysis window by clicking on the magnifying glass icon in the top toolbar.

3. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Value1, Value2, V2-V1, Time1, Time2, and T2-T1 should appear in this table. Values for these parameters on the channel are seen in the table across the top margin of the channel.

4. Place the cursors in the correct locations for measuring the period of the signal.

5. Record the values in Data Table BT-7-L4.

Table BT-7-L4: Data Table for Exercise 4 – Changing DC Offset

Data from Sinusoidal Signal		
Offset (___)	Maximum Voltage (___)	Minimum Voltage (___)
0		
1		
5		

Questions

1. How did increasing the DC offset change the maximum and minimum voltage values of the waveform?

2. Did changing the DC offset affect the amplitude or frequency of the waveform? Explain.

Post-Lab Questions

1. How did increasing the frequency of the sinusoidal waveform affect the appearance of the signal in LabScribe?
2. When the amplitude of the waveform was increased, what measurement changed and what measurements remained the same?
3. How did changing the DC offset affect the position of the waveform on the display?
4. A biomedical signal has the same frequency but a larger amplitude than another signal. What does this tell you about the signal strength?
5. ECG, EMG, and EEG signals are all time-varying signals. Why is it important for biomedical equipment to accurately measure changes in both signal amplitude and timing?