PocketLab Voyager: Beat Phenomena with LEDs and #50 Lamps

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Introduction

It is quite well known that when two frequencies of sound are close together, beats are produced and heard. Demonstrations of this phenomenon are common in acoustical studies in physics classes. In this lesson we investigate three laboratory techniques for ***seeing** beats instead of hearing them*. These visual beats can be recorded and studied by the use of the PocketLab app and Voyager's light sensor. The first technique uses two #50 lamps that are driven at slightly different AC sine wave frequencies. The second technique uses two LEDs that fade in and out at two slightly different rates. The third and final technique makes use of two LEDs that are blinking on and off at different frequencies.

Technique #1: Two #50 Lamps Driven at Slightly Different AC Sine Wave Frequencies

Although any appropriate function generator and power amplifier could be used, the sine wave signals used by the author were produced using two pairs of Vernier Software & Technology's (vernier.com) LabQuest™ 2 (LABQ2) and Power Amplifier (PAMP). The AC sine waves were set to frequencies of 1.25 Hz and 1.375 Hz.

Figure 1(a) shows the two #50 lamps in their holders with the wires from the two function generators and power amplifiers attached. One of the holders is tilted toward the other so that the two bulbs are very close together. Figure 1(b) shows the lamps covered by a small translucent food storage container. This container is used to diffuse the light from the lamps and to hold Voyager. Figure 1(c) shows a snapshot of the complete setup after collecting data (50 points/sec) and a combined video with the PocketLab app. The snapshot shows two beats created by the varying combined intensities of the two lamps. A must see video of the data capture accompanies this lesson.

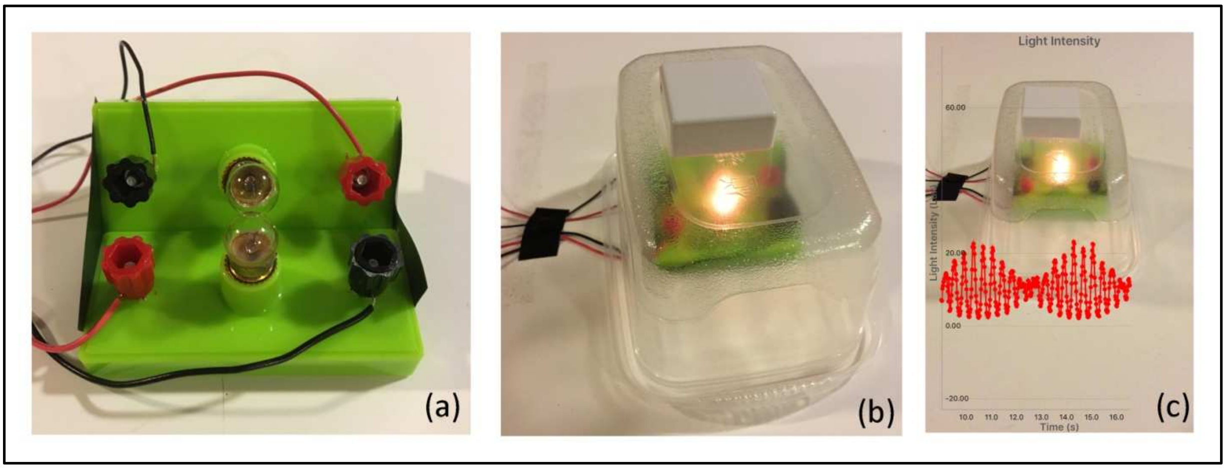

Figure 1

Figure 2 shows a complete graph designed in Excel with the data recorded from the PocketLab app. There are a total of 8 beats in a time period of 32.7 seconds, giving a beat frequency of about 0.25 Hz. The theory of beat phenomena tells us that the beat frequency is $|f_1 - f_2|$, where f_1 and f_2 are the frequencies of the two driving sources. |1.25 – 1.375| = 0.125 Hz. This is only half the beat frequency that we observed from the graph of Figure 2. Students should be asked to explain why.

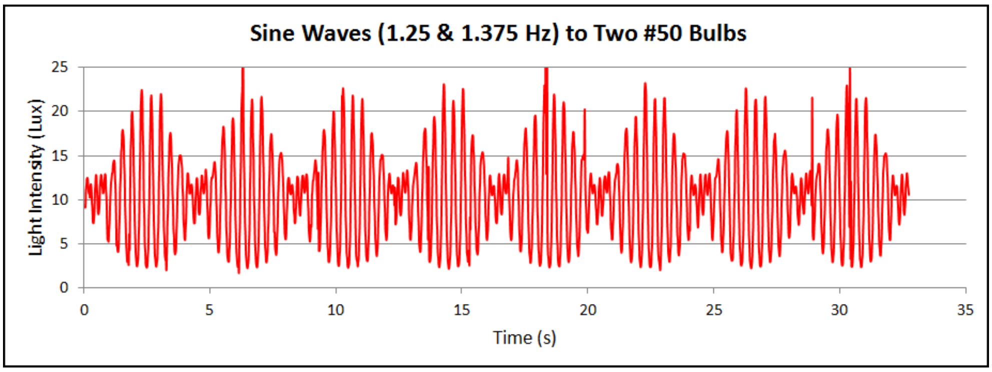

Figure 2

Technique #2: Two LEDs Fading In and Out at Slightly Different Rates

The technique just discussed made use of *analog* variation in light intensity of tiny incandescent lamps. Technique #2 uses a pair of LEDs that fade in and out using ***p****ulse* ***w****idth* ***m****odulation* (***PWM***). One could accomplish this by the use of a pair of Arduino boards, a couple of resistors and two LEDs. A simple sketch (Arduino lingo for "program") that causes the LED to fade in and out is loaded onto each of the two Arduino boards, each sketch having a slightly different fade rate. (See the description and downloadable code for the sketch here.)

The author, however, decided to make life a bit simpler by quickly assembling a pair of identical littleBits circuits—no need for any special wiring—just snapping magnetic modules together. littleBits has an Arduino module that is a scaled down version of the Arduino Leonardo module, including PWM pins. Figure 3 shows the circuit setup.

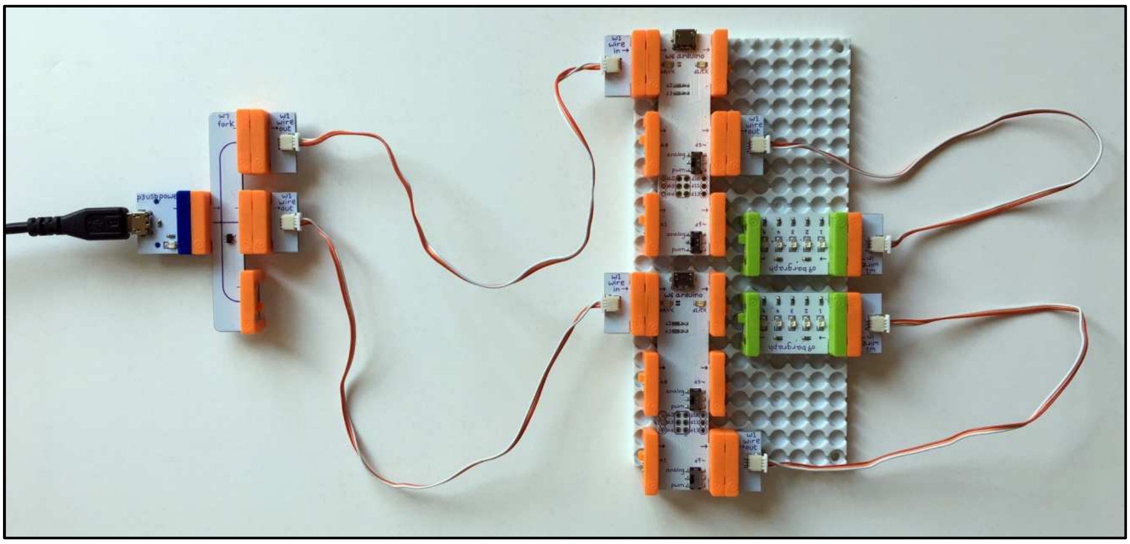

Figure 3

The far left of Figure 3 shows the USB connection that is used to power the two Arduino modules on the right. The top Arduino module connects pin d5~ to a bargraph module that lights up more LEDs as the signal gets stronger. Similarly the Arduino on the bottom connects pin d9~ to a bargraph. The bargraph modules are mounted close together to provide a more uniform field of light.

Figure 4 shows a snapshot of the complete setup after collecting data (50 points/sec) and a combined video with the PocketLab app. The snapshot shows one beat created by the varying combined intensities of the two LEDs. A video of the data capture also accompanies this lesson.

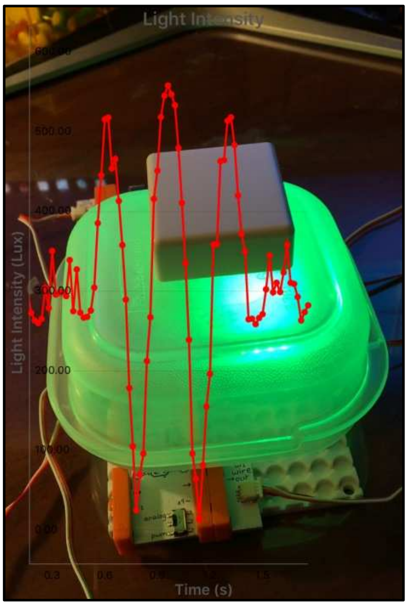

Figure 4

Figure 5 shows a complete graph designed in Excel with the data recorded from the PocketLab app. Students can be asked to determine the beat frequency from measurements on the graph. As an additional investigation, they should collect data for each of the two LEDs running by itself. From graphs they can then determine the frequencies for each of the two LEDs and compare the theoretical beat frequency $|f_1 - f_2|$ to the results from the graph showing the beats. The author found in his investigation that the beat frequency (0.81 Hz) for the graph of Figure 5 agreed to the nearest 0.01 Hz with the theoretical beat frequency $|f_1 - f_2|$.

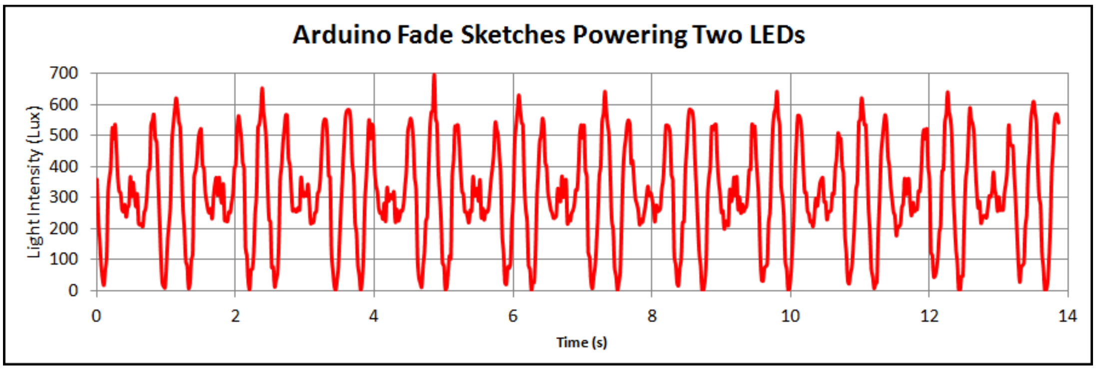

Figure 5

Technique #3: Two LEDs Blinking ON and OFF at Slightly Different Rates

If you have every looked at two LEDs blinking on and off at slightly different rates, you may have noticed that at times they are in sync with one another, both on or both off at the same time. At other times, they are out of sync, one on while the other is off. The result is a beat effect in which the light intensity is greatest when they are in sync and both on. The greatest light intensity when they are out of sync is only half that of when they are in sync.

Each of the two LEDs with this third technique blinks on and off at a regular rate as shown in the graph of Figure 6, obtained from data collected with the PocketLab app and Voyager's light sensor. The wave is much more of a square wave signal, whereas with techniques 1 and 2 the individual signals were much closer to a sine wave.

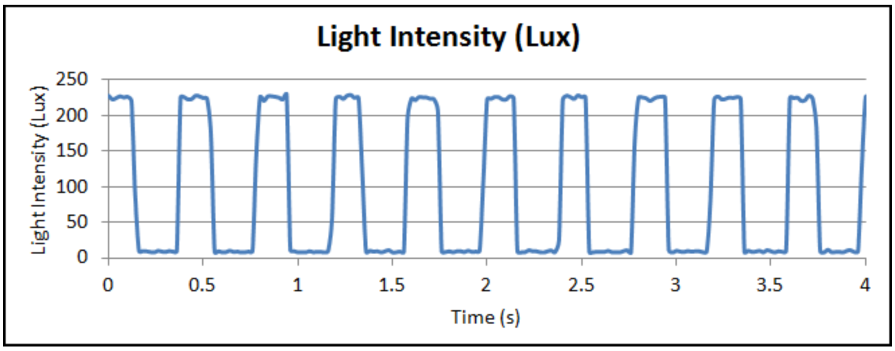

Figure 6

As with technique 2, the author decided to make use of a simple littleBits circuit shown in Figure 7. The USB module provides power to a pair of pulse modules to which bargraph modules have been connected. The pulse modules have adjustable speed controls, allowing controlled blinking rates for the LEDs, which are either on or off at any given time. Since this circuit doesn't use Arduino modules, no programming is required!

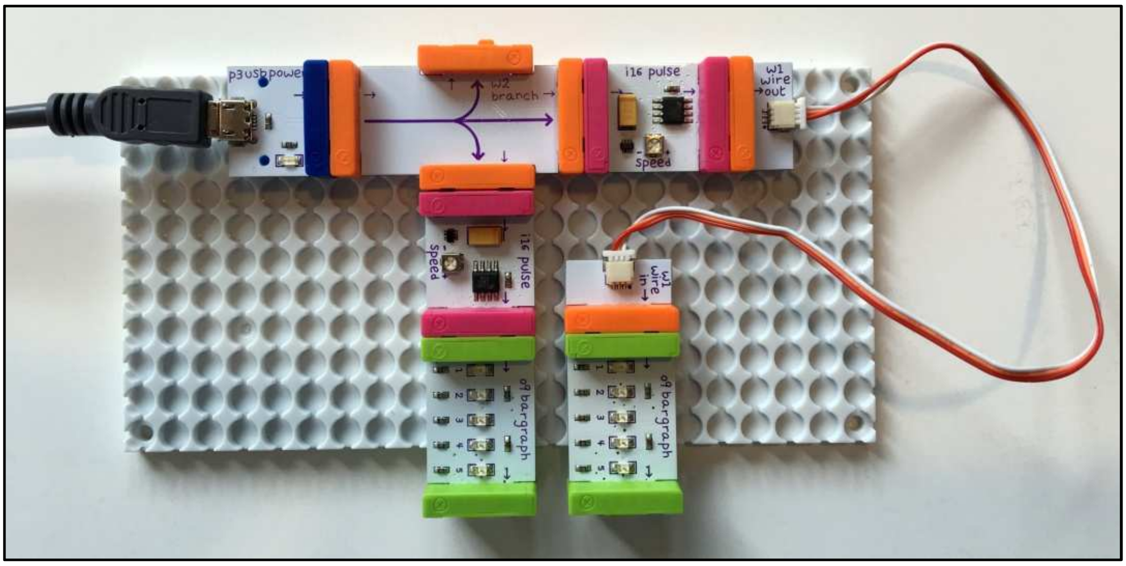

Figure 7

Figure 8 shows a snapshot of the complete setup after collecting data (50 points/sec) and a combined video with the PocketLab app. The snapshot shows a portion of one beat created by the varying combined intensities of the two LEDs. A video of the data capture also accompanies this lesson.

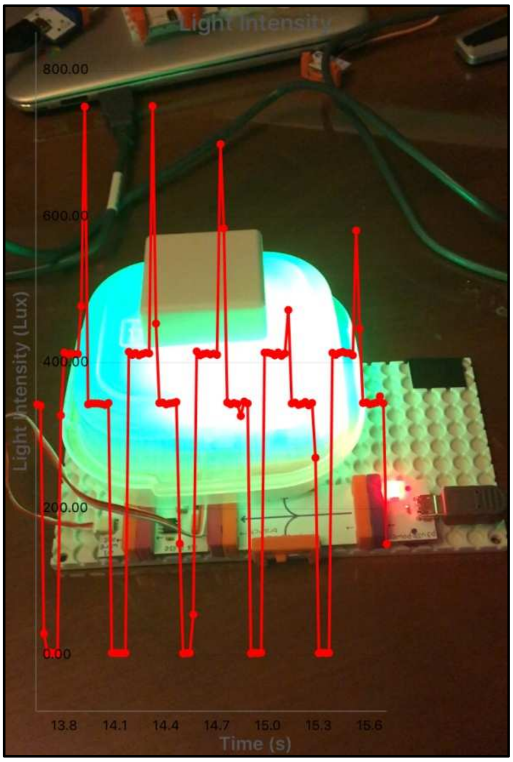

Figure 8

Figure 9 shows a complete graph designed in Excel with the data recorded from the PocketLab app. Students can be asked to determine the beat frequency from measurements on the graph. As an additional investigation, they should collect data for each of the two LEDs running by itself. From graphs they can then determine the frequencies for each of the two LEDs and compare the theoretical beat frequency $|f_1 - f_2|$ to the results from the graph showing the beats. The author found in his investigation that the beat frequency (~0.05 Hz) for the graph of Figure 9 agrees well with the theoretical beat frequency $|f_1 - f_2|$.

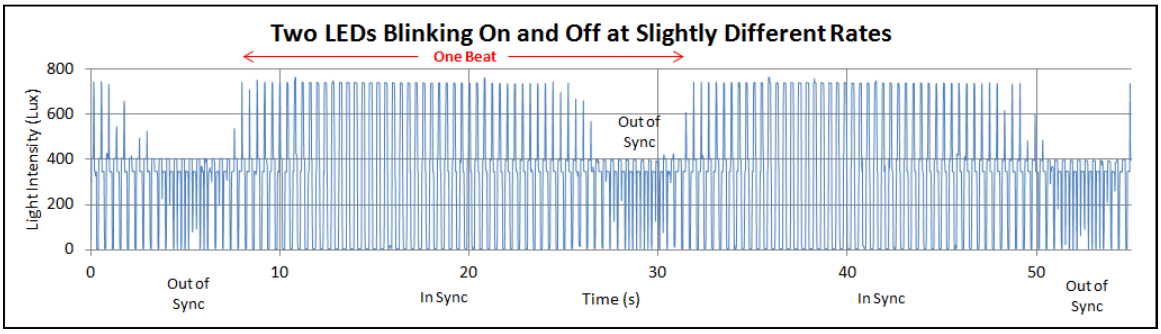

Figure 9