Signal Generator Lesson Plan

Grade: 8th	Topic: Signal Generator	Lesson #2 of 3 lessons

Brief Lesson Description: In this lesson students are expanding their understanding of sound through another computer application, the signal generator. They get to explore a tool that plays the sounds and has a visual representation of them. They learn the concepts of **period**, **frequency**, and **pitch**. They explore the relationship between **amplitude** and **volume**. They get to explore the limits of human hearing. Students should be able to understand the connection between the physical characterics of a sound waveform and the perception of that sound

Performance Expectations:**MS-PS4-1.Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.** [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves.]

Lesson Concept: Analyze and interpret the data of wave patterns and their properties by playing with their scape, proportion, and quantity.

Investigative Phenomena: This part of the lesson sequence engages students in how properties of sound can be visualized in a waveform pattern.

Detailed Narrative: This is the second of three lessons where students get to visualize and tweak the different properties of sound: frequency, amplitude, and timbre. This lesson is intended to get students familiar with vocabulary related to sound and a chance to compare what they are seeing and hearing. Students will be playing with an online tool called The Signal Generator. Explore the site yourself first and ensure you know how to manipulate the display and produce sounds that are various frequencies, amplitudes, and timbres.

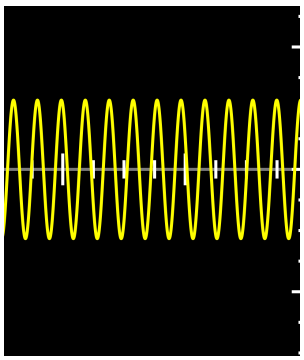
www.listeningtowaves.com >> sound exploration >> signal generator

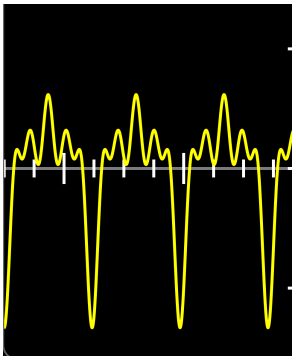
Background Information:
For this lesson it is very important that teachers understand the vocabulary and concepts related to different properties of sound waves. It is also very important that they understand how a speakerphone works to produce sound. The computer sends an electrical signal to the speaker, and the electrical signal makes the speaker vibrate back and forth, which in turns moves the air generating a pressure-wave (or sound).

Some sound waves are periodic, meaning that the same pattern repeats many times in a given amount of time, when this happens the sound has like a musical note (it is a tone). The faster the pattern repeats the higher the **"pitch"**. which is how high or low a musical note is. The term pitch refers to how we perceive sound. The time length of one pattern (or cycle) is called "**period"**, and is measured in units of time. For example, if a pattern repeats every 10 ms, it has a period of 10 ms. **Frequency** is how many cycles fit into an amount of time and is a numerical value recorded as Hertz. For example, if one pattern repeats 100 times in a second, then the sound has a frequency of 100 Hz.

It is common for people to confuse the terms **period** with wavelength. **Wavelength** is related to spatial length of a wave, and is measured in units of *space* (like cm). In this demo we can only see the period, which is measured in units of *time* (like seconds).

The **waveform** is the "shape" of the signal. It is common for people to think that all sound waveforms are "pure" (also called sine wave), which is the typical textbook picture of sounds, the squiggly line that goes up and down very smoothly (see figure below). In reality, sounds can have repeating patterns that are "complex". Adjusting the **"Pure waverform"** button and the **"Complex waveform"** buttons on the Signal generator will help illustrate this. When the waveform is a "sine wave", it is called pure, and the sound is called a **pure tone**. Some complex waveforms look like saws, triangles, or squares. Their sounds can be familiar to our ears because they were often used in video games and music synthesizers in the 70s and 80s.

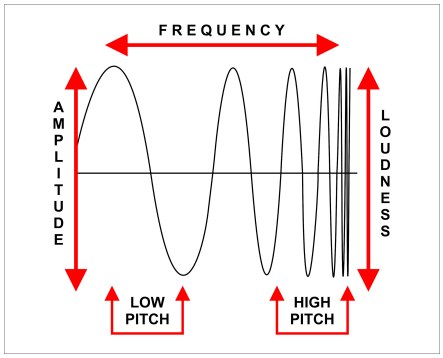

Pure Waveform


Complex Waveform

It's important to note that not all sounds are periodic. For example, the sound of a shutting door doesn't have anything periodic to it. When the sounds are periodic is when we can hear a "tone", like a musical note.

A musical note corresponds to one specific frequency. For example, A-440 is a note called "A" that has a frequency of 440 Hz. When an orchestra tunes their instruments, they make sure that their note A has 440 Hz. Two different instruments can play this same note but have a different "feel" because each instrument will produce different complex tones of this same frequency. Music is so popular in Austria, there was once a phone number people could call and it would play A440, so they could tune their instrument. This is no longer necessary because now there are many phone applications that can help with this.

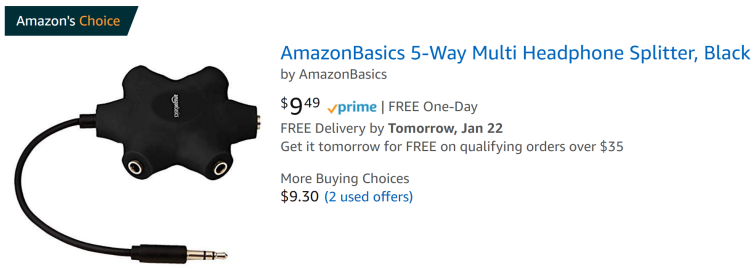
Because high frequency always goes together with high pitch and high amplitude with high volume, the terms get conflated and people speak of high amplitude or high frequency when referring to pitch and volume. Although the terms are conflated, is good to remember that pitch and volume refer to the perception, whereas amplitude and frequency to the physical description.



Each animal can hear sounds within a certain frequency range. For example, humans can hear sounds from about 50 Hz to 15000 Hz. Teenagers can actually hear higher frequencies than adults, and they love to learn that! Dogs can hear higher frequencies than humans, dog whistles generate high frequencies that dogs can hear, but humans cannot. Whales and elephants can hear lower frequencies than humans. Rats, bats, and dolphins can vocalize sounds that are too high for humans to hear.

Because of this, commercial microphones and speakers are made specifically for the frequency range that humans can hear. Subwoofers can vibrate pretty slowly and make low pitch sounds, tweeters can vibrate very fast and make high pitch sounds. In concerts we can see subwoofers vibrating, and feel the vibrations in our chest. If we want to record the sounds that bats or whales make, we need special recording equipment. Cell Phones typically have pretty bad speakers that don't vibrate very well at very low or high frequencies, that's why they sound dull.

*Note: Wearing headphones highly recommended. They can work in pairs or use signal splitters to work in larger groups:



Prior Student Knowledge:
Students know that some sounds come out of a musical instrument and some sounds come out of a speaker. Students have all heard electronic generated sounds/music. Some sounds come out of a speaker that were a recording of an instrument and some were generated digitally. Students have heard the word wavelength but most have a misconception about what wavelength is. Typically, they have the pure waveform model in mind. Some students may have heard the words Hertz, frequency, amplitude, and pitch. Many students know what a high vs a low pitch is in music. Many students also know about dog whistles and how humans cannot hear them. The students often speak of deep/squeaky sounds while describing low/high pitch.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts

● Developing and Using Models ● Analyzing and Interpreting Data ● Planning and Carrying out investigations	**PS4.A: Wave Properties** ▪ A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) ▪ A sound wave needs a medium through which it is transmitted. (MS-PS4-2) **PS4.C: Information Technologies and Instrumentation** ▪ Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)	● Patterns ● Scale, Proportion and Quantity ● Cause and Effect

Possible Preconceptions/Misconceptions:
Most people think that all sound waves are pure tones (sine waves) and they are not. Most are actually complex tones. Two sound waves can have the same exact frequency and amplitude but still sound different if their waveforms (the shapes of the signals) are different. A good way to clarify this is by playing the same note from different instrument or toggle the complex tone button repeatedly in the Signal Generator website.
Most people mistake wavelength with period. Wavelength corresponds to how long a cycle is in terms of space (for example 25 cm), period is how long a cycle is in terms of time (for example 15 milliseconds). The two concepts are very related (the higher the wavelength the higher the period). This online tool can show period (note that the x-axis represents time), not wavelength.

LESSON PLAN -Launch Explore Discuss (LED Model)

LAUNCH (5 min)
On the home screen display and image of various instruments: singing, guitar, drums, piano, flute, and electronic music. Review the previous lesson on how sound is a vibration that is transmitted through the air. Discuss and instruct students to draw a model of how the various instruments vibrate to make sounds (what part of the instrument is vibrating?). Students will respond with various explanations that should all have some element of vibration related to them. Discuss the electronic music answer last and with lots of detail. Hopefully students will respond by indicating the speaker is the object that is vibrating. Discuss that when you play sounds through a speaker you are sending an electrical signal that makes a membrane in the speaker move back and forth. It is just like a reverse version of a microphone. Discuss that the art of electronic music is designing the electrical signals to send to the speaker, and this can be done with electronic circuits or computers. In this lesson we will generate some electronic sounds. (You might want to play some electronic music as students enter the room and take their seats).

EXPLORE 1: Signal Generator Pitch & Frequency (5 min)
Instruct students to pull up the signal generator and have it displayed on the home screen

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Demonstrate to students to click anywhere on the gray area to make a sound. They will hear a sound and see the signal on the screen.

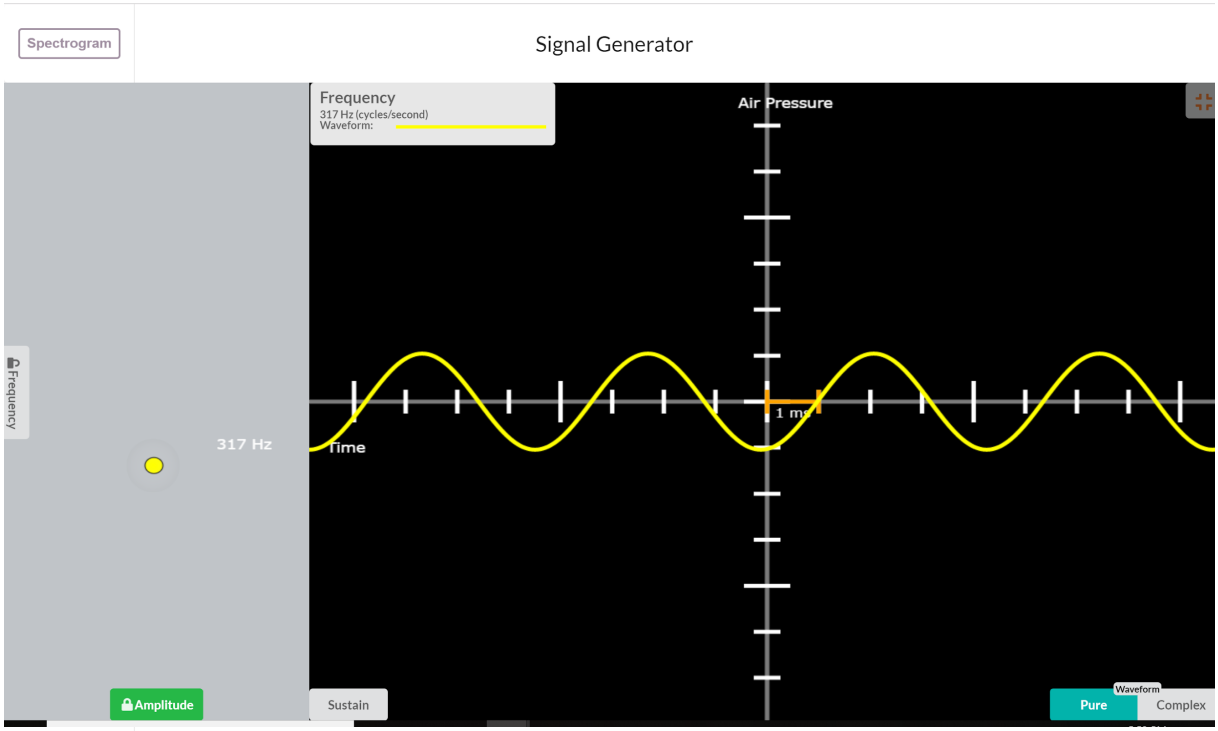
Instruct students to think pair share about what they are seeing. Students' responses may vary but should have something to do with the visual representing the signal that we are sending to the speaker. It represents how the speaker membrane is moving, and therefore how the air is moving. Like in the audacity lesson, instruct students that they will be going through a series of explorations over the course of the lesson. Instruct how to play with each explore section and give students about 5-10 min to play around during each exploration.

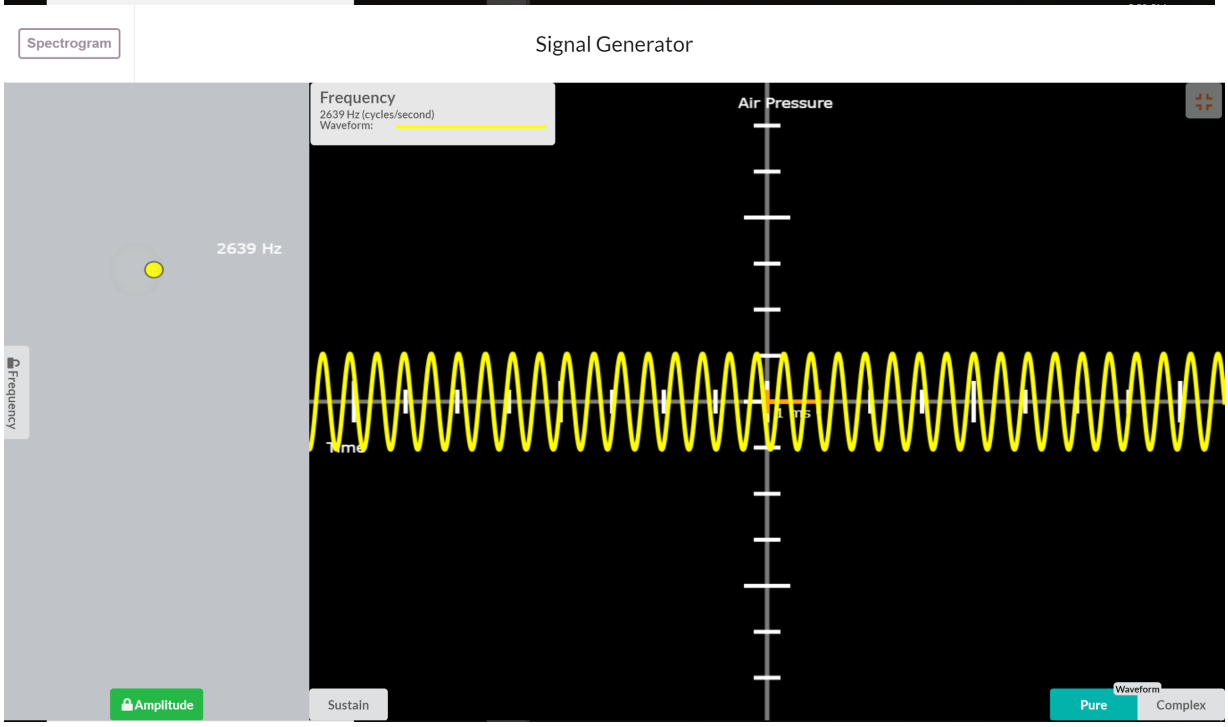
Signal Generator ***Pitch & Frequency***

Tell students to explore what happens when they move the mouse across different parts of the grey area. Instruct students to observe how they perceive the sound through their sense of hearing as well as how it looks in the screen, write the observations in their student guide. Let them do this for a few minutes (strangely they never get tired).

DISCUSS 1: Signal Generator Pitch & Frequency (5-10 min)

Bring the class back to the home screen and discuss some student answers to what happens visually and what they hear when they move their cursor up and down on the signal generator. Suggest they click on the lock next to the amplitude button, this way they will keep the amplitude fixed and change the frequency only. They should discuss how the waveform gets more spread out or packed together in the horizontal direction. They should discuss how what they hear is a pitch going high to low. Instruct students to collectively sing a low vs a high pitch. Ask students who has a voice with a higher pitch, an adult or a child, a dog or a bird, a bass or a flute. Instruct students to make a high pitch sound then together a low pitch sound alongside the signal generator. They should describe that low pitches look spread out and high pitches are close together. Illustrate this a few times. Return to the concept of how the speaker is vibrating to make sound. If the cycle (repeating pattern) repeats many times in an amount of time, then the cycles look closer together. If they repeat very few times they will spread out. Explain to students that when they see a repeating pattern in the signal generator this is the period of a wave form, the period is how long (in time) the repeating pattern lasts. The frequency is how many periods fit into one second. Draw student's attention to the number that appears next to the cursor. It shows the actual frequency in cycles per second. The number of cycles per second is called Hertz, and abbreviated Hz). Explicitly note that the vertical-axis in the grey area represents the frequency, but not the y-axis where the waveform is, which represents the pressure in the air increasing and decreasing as the speaker pushes and retracts really fast. Be sure to delineate the difference between frequency and pitch. Frequency is an actual measurement of cycle/time and pitch is more of a perceived perception as high or low.





For an additional visual you can instruct students to hold their hand up vertically. Have them vibrate their hands back and forth the same distance. Tell them to vibrate them faster but keep the same distance apart, this represents a high frequency. Have them vibrate their hands slower, but again at the same distance, this represents a low frequency. Play around with this and have them match their hand movements to various signals that you play on the signal generator. For example, a frequency of 1000Hz means that a pattern repeats 1000 times in one second.
Discuss with the students how low/high frequencies they can hear. You can have them testing each

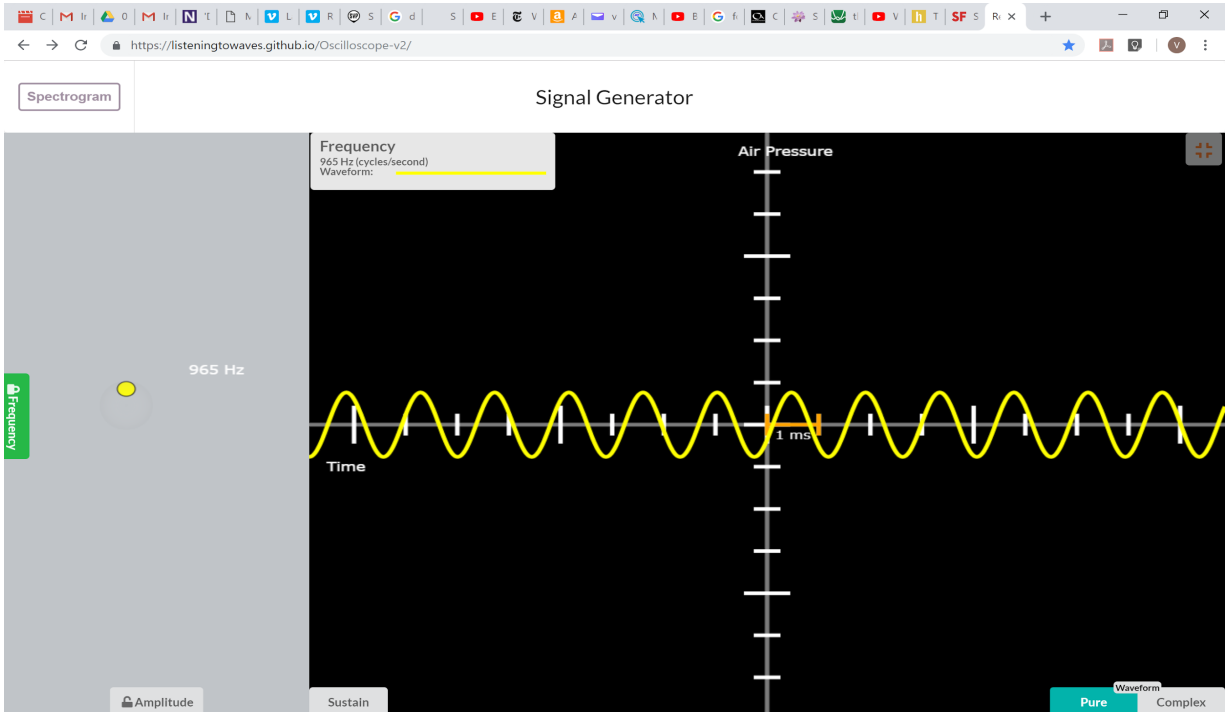
other in pairs. You can demonstrate that for very high frequencies, the students can hear them but the teacher cannot.

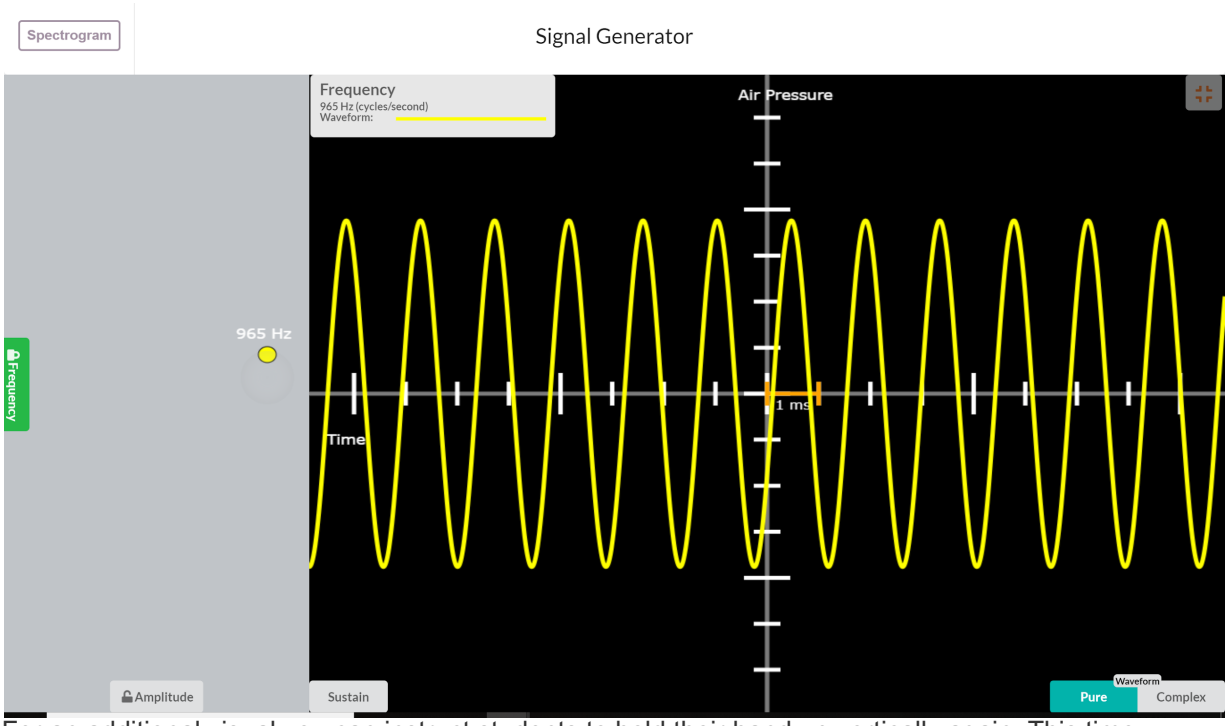
EXPLORE 2: Signal Generator Amplitude & Volume (5 min)

Instruct the students to play around with the signal generator again and this time to move the cursor from left to right. Instruct students to move their cursor left to right and write how they perceive the sound through their sense of hearing as well as how it looks in their student guide. Suggest they click on the lock next to the frequency button, this way they will keep the frequency fixed and only change the amplitude only.

DISCUSS 2: Signal Generator Amplitude & Volume (5-10 min)

Bring the class back to the home screen and discuss some student answers to what happens visually and what they hear when they move their cursor left and right on the signal generator. They should discuss how the waveform gets taller or shorter in the vertical direction. They should discuss how what they hear is volume going loud to soft. Instruct students to collectively make loud and soft noises. Instruct students to make a loud sound then together a soft sound alongside the signal generator. They should describe that loud sound looks tall and soft sounds look short. The visual of the waveform is called the amplitude. This is physically how large is the vibration of the speaker. Draw student's attention to the horizontal-axis of the waveform graph, note how moving right and left causes this amplitude to increase or decrease. To move in the horizontal direction only click the lock next to **frequency**, on the left of the screen, this locks the frequency so the only thing that moves is the amplitude.





For an additional visual you can instruct students to hold their hand up vertically again. This time instruct them to vibrate their hands close together or far apart. The distance their hands are moving represents amplitude. The larger the amplitude the further their hands should move, the smaller the amplitude the close their hands should move. Play around with this and have them match their hand movements to various signals that you play on the signal generator.

EXPLORE 3: Complex Tone & Timbre (5 min)

Finally, instruct students to play with the complex tone feature, making sounds for different waveforms, the control on the lower right allows to switch from a pure waveform to complex waveforms: such as random, square, triangle, or saw). Let them play for a few minutes. Suggest that to better compare across different waveforms they can use the sustain button, this way they can change the waveform but keep the frequency and amplitude constant. Then alternate between waveforms. Instruct students to write how they perceive the sound through their sense of hearing as well as how it looks in their student guide.

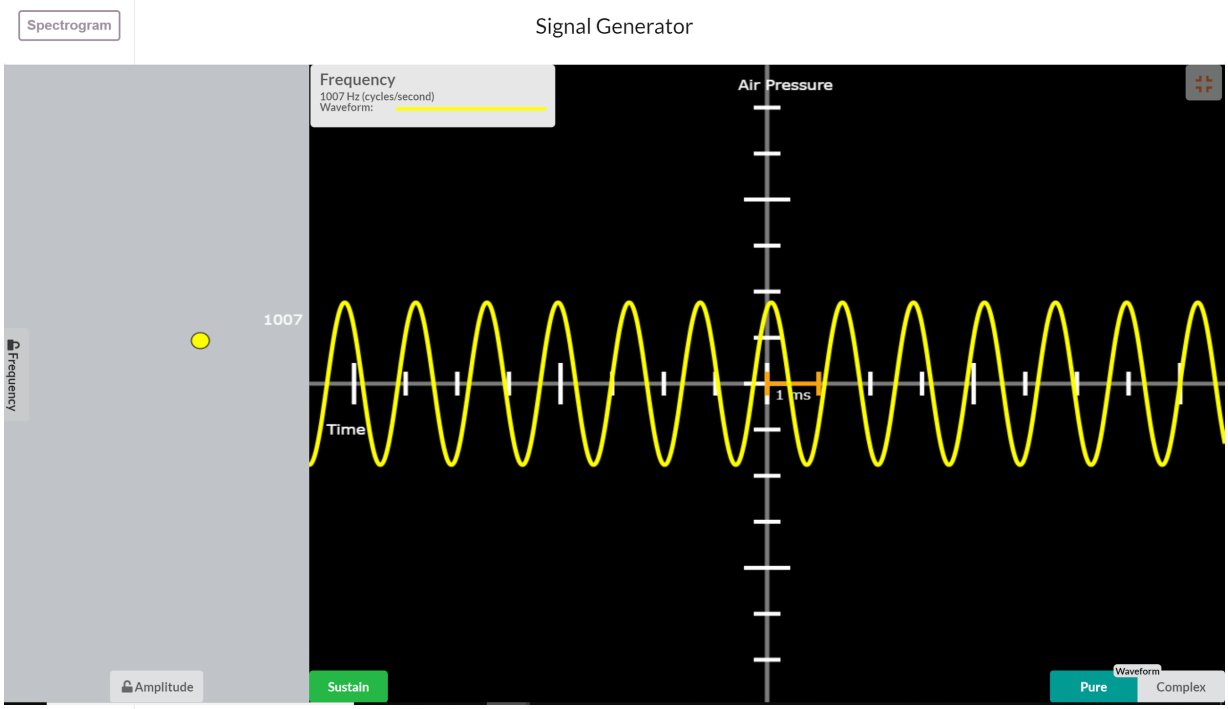
DISCUSS 3: Complex Tone & Timbre (5-10 min)

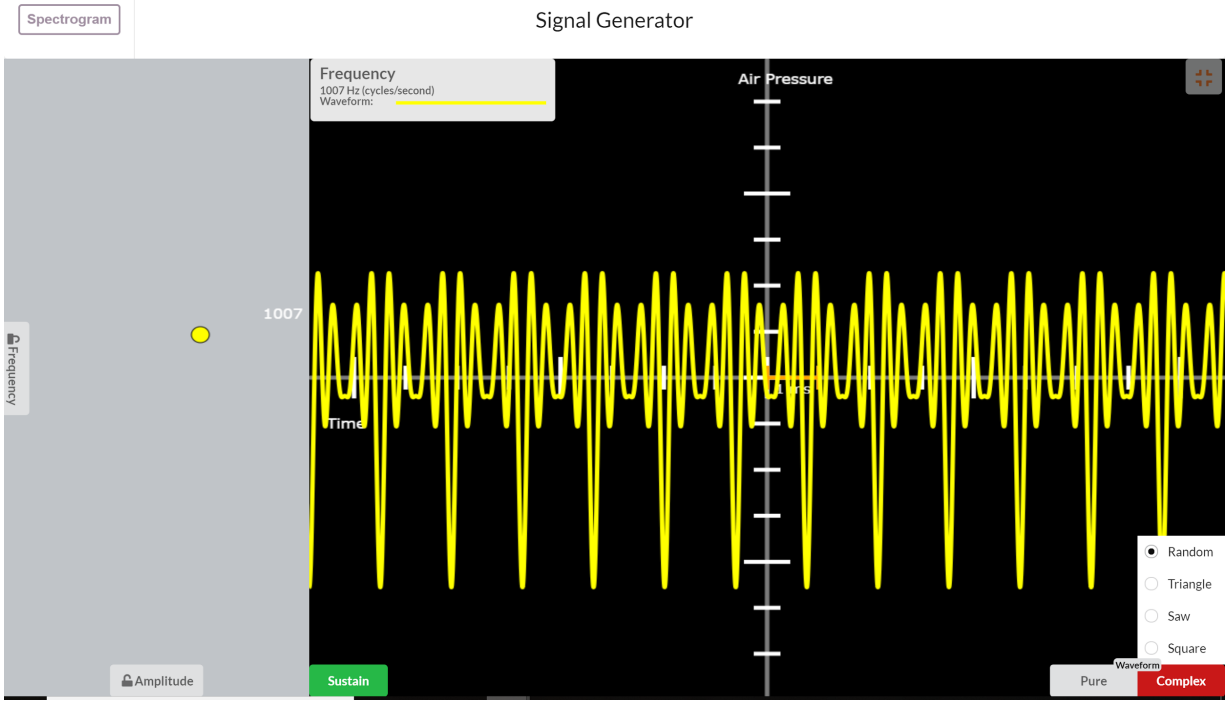
Bring the class back to the home screen and discuss some student answers to what happens visually and what they hear when they click the “Complex Waveform:” on the signal generator. They should discuss how the waveform changes its shape. They should discuss how what they hear has a different feeling (that different feeling is called timber). In a pure tone the repeating pattern goes up and down very smoothly and only once (this is the “text book” waveform and corresponds to a “sine wave”), in a complex tone the pattern is more complex, it can go up and down many times in a period and is not necessarily smooth. Draw student’s attention to the period of the waveform and how it does not change when you clock through the complex tones. Also draw their attention to the amplitude of the

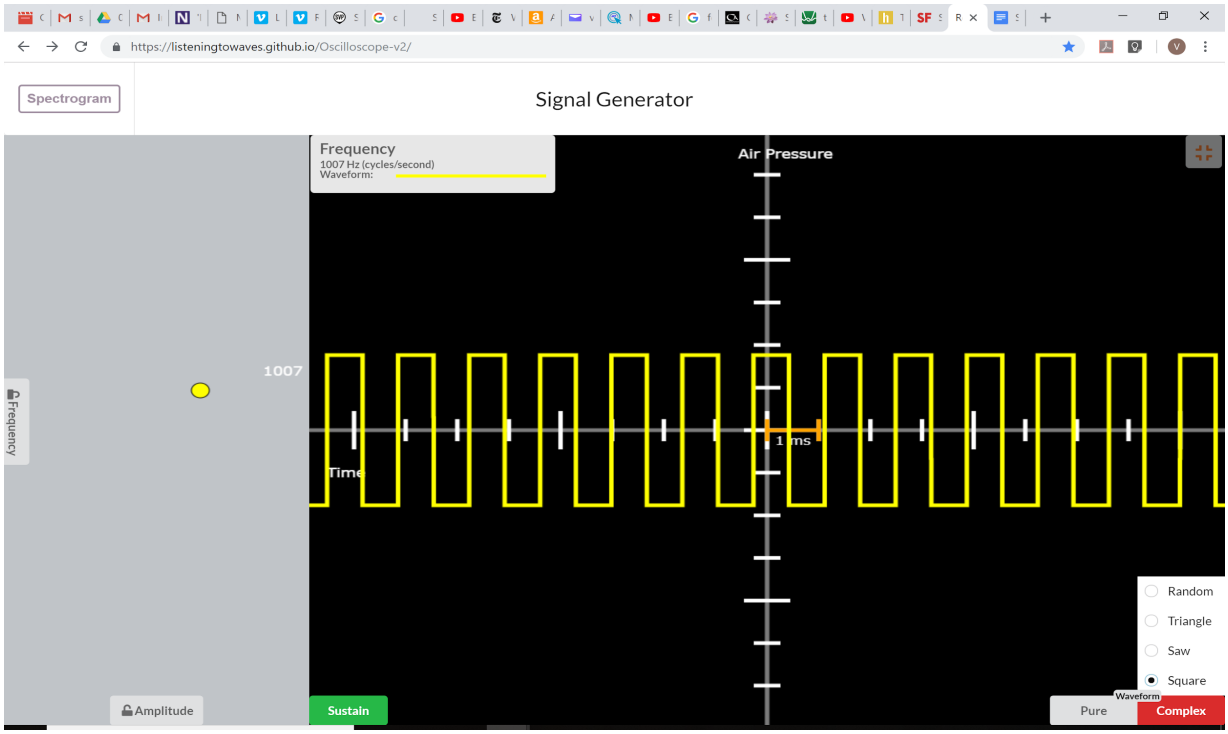
signal and how it also does not change when you click through the complex tone button. Two instruments can be playing the same note, in which case they will have the same frequency, but still they will sound different because they have different timbers (which are associated to the shape of the waveform).

Maybe they will say that the square and saw waveforms remind them of videogames. This is because these waveforms are very simple to create electronically and were used a lot in early videogames.

Highlight the difference between pure tones and complex tones on the home screen.







For an additional visual you can instruct students to hold their hand up vertically again. This time instruct them to vibrate their hands at the same distance and rate, only this time their hand movements should not be in a smooth movement. A complex tone vibration would be a more sporadic movement, although it would repeat over and over. Play around with this and have them match their hand movements to various signals that you play on the signal generator.