Module 3. Computer-Generated Sound and Music

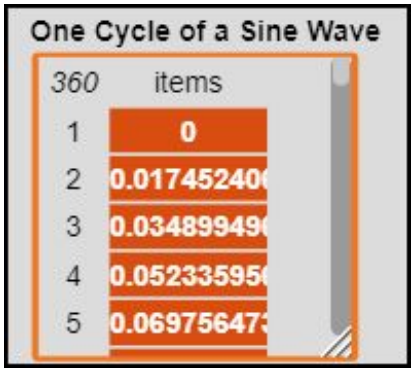
The concept of periodic motion in a vibrating object was introduced in the previous module. The way in which the digital representation of periodic motion in the form of a sine wave can be used to generate a tone will be explored in this module.

Topic 3.1 Generating a Tone

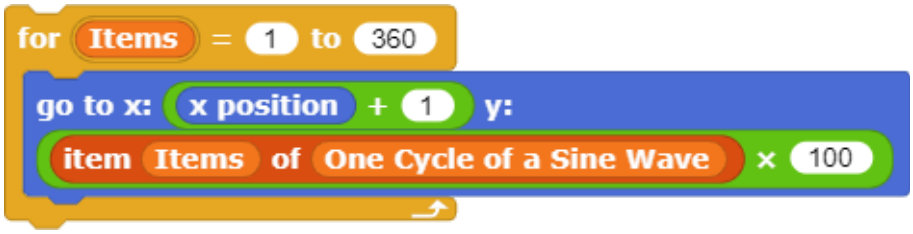
One method used to generate a tone with a digital computer is based on construction of a table of sine values. First a new variable, One Cycle of a Sine Wave, is created. Then the value of the variable is set to an empty list.

A loop is then used to construct a table of sine values from 0 to 359 degrees. In the example below, each value in the list constructed in this manner has been assigned to a variable named *One Cycle of a Sine Wave*.

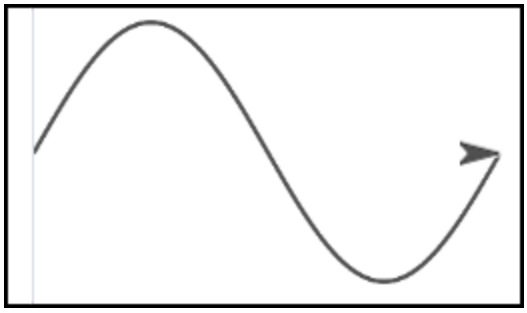
This procedure generates a table such as the one below that lists the sine value for every degree from 0 through 359, for a total of 360 items.



The values in the table can be graphed to verify that they are correct. The following loop causes the turtle to move through the vertical positions represented by the table of sine values. Since the sine values are less than one, each value is multiplied by 100 so that the resulting graph can be seen more clearly.



The graph that results is the classic shape of one cycle of a sine wave, indicating that the table of sine values has been correctly constructed.

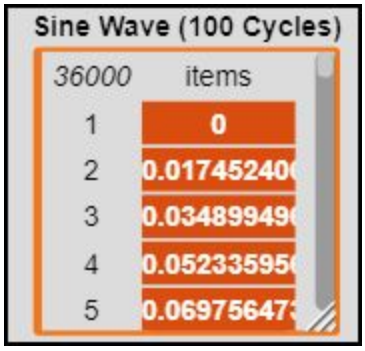


The values in the table will be sent to the computer's speaker produce a sound. The positive numbers cause the computer's speaker cone to move forward while the negative numbers in the table cause the speaker cone to move backwards.

For the sake of mathematical simplicity, 36,000 samples per second will be sent to the computer's speaker. A mathematical calculation tells us that if the 360 values in the table are sent to the computer at a rate of 36,000 samples per second, the sound will last for one one-hundredth of a second.

To create a tone that lasts a full second, one hundred of these cycles are needed. A second table, named *Sine Wave (100 Cycles)* can be constructed using a loop that appends one hundred of the cycles to the new table.

The table that results has 36,000 items. The single cycle of a sine wave constructed in the first table has been copied one hundred times to create the second table.



The values in the table of sine values can be sent to the computer's speaker using the **Play Sound** code block.

Because one hundred cycles are sent to the speaker in one second, a 100 Hz tone results. This tone is perceived as a low pitch lasting one second. If the playback rate is doubled, the same number of cycles will be sent to the computer's speaker in half the time, resulting in a 200 Hz tone.

Similarly, if the playback rate is increased by a factor of three, a 300 Hz tone will result.

When the playback rate is doubled, the samples are sent to the computer's speaker in half the time. This not only doubles the frequency of the tone, it also decreases the duration of the tone by half. However, if tones of equal duration are desired, additional cycles of the 200 Hz tone could be added to the table. In the loop below, the contents of the Sine Wave (100 Hz) have been copied twice to create a second table with twice as many values.

A tone can be generated by the computer by sending digital numbers in a table of sine values to the computer's speaker. The digital numbers control the direction and strength of electrical current in an

electromagnet. The electromagnet, in turn, moves the computer's speaker back and forth, creating a tone.

Exploration 3.1 Generating a Tone. Create a table of sine values. Use the **Play Sound** code block to send the values in the table to the computer's speaker. How does the playback rate affect the perceived pitch of the tone generated? Construct a 250 Hz tone. What playback rate would be needed to produce a tone of this frequency?

Topic 3.2 Generating Noise

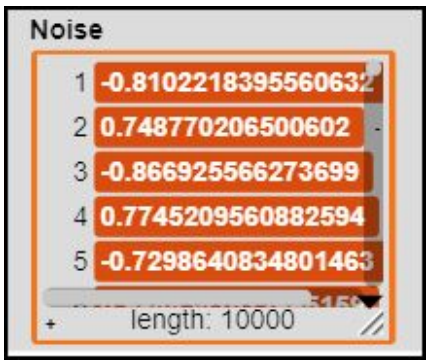
The tones generated in the preceding section represent periodic motion. The motion in the speaker cone is periodic because each cycle of the sine wave is the same as the one before.

A sound wave that has no discernable pattern is known as aperiodic sound. Noise is an example of aperiodic sound. Noise can be generated with a computer through use of random numbers.

In this example, a variable named *Noise* has been created. The value of this variable has been assigned to an empty list.

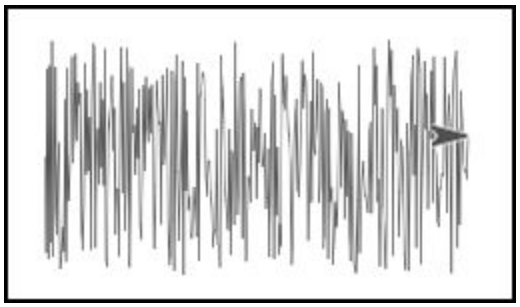
A table of 10,000 random numbers ranging from - 0.999 to + 0.999 is then created and assigned to the variable.

The table generated in this manner would be similar to the example below. Since the numbers are randomly generated, the exact numbers will vary each time the table is created.



The same procedure used to graph the table of sine values can also be used to graph the table of randomly-generated numbers.

In contrast to the clear pattern that appeared when the table of sine values was graphed, there is no discernable pattern that can be readily identified when the table of random numbers is graphed.



The **Play Sound** code block can be used to send the table of randomly-generated numbers to the computer's speaker.

The ear also does not detect a pattern in the sound that results. Therefore, the resulting sound that is produced is perceived as noise. The tone is said to be *periodic,* while the noise is said to be *aperiodic*. One has a recurring pattern; the other does not.

Exploration 3.2 Generating Noise. Create a table of random numbers ranging from – 0.999 to +0.999. Use the **Play Sound** code block to send the values in the table to the computer's speaker. How is the resulting sound perceived? Explore creation of a table with a different range of random numbers. For example, a table could be created with randomly-generated numbers ranging from -0.500 to +0.999. Does changing the range of randomly-generated numbers affect the perceived quality of the sound produced?