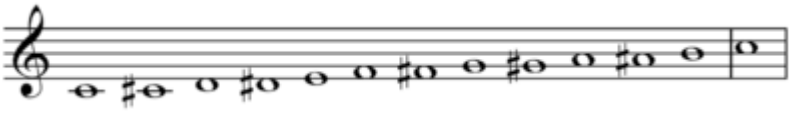
Unit 2: For Loops | **Skill Builder 3: Loop through the musical notes**

In this third lesson for Unit 2, you will learn about the relationship between the frequencies of the musical scale and write a program to play those notes that musicians have used for many centuries.

Objectives:

- Explain the 'twelfth root of two' relationship of the musical scale
- Write a program that plays successive notes in a scale



A Little Music Theory

Musical notes are determined by the frequency of a vibrating object such as a speaker, drum head, or string (like on a guitar or piano). The notes of the musical scale have a special mathematical relationship. There are 12 steps in an octave to get from a note in one octave to the same note in the next octave. If a note has frequency **F** then the very next note has frequency $\times \sqrt[12]{2}$.

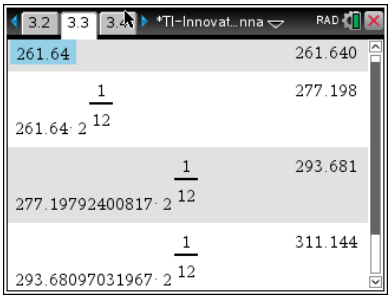
Multiplying a note's frequency by $\sqrt[12]{2}$ or $2^{1/12}$ (the twelfth root of 2) twelve times results in a doubling of the original frequency, so the last note in the octave (or the first note in the next octave) has frequency of $F \times (2^{\frac{1}{12}})^{12} = 2 \times F$. For example, if a note has a frequency of 440 Hz, the note an octave above it is 880 Hz, and the note an octave below is 220 Hz.

The human ear tends to hear both notes an octave apart as being essentially "the same", due to closely related harmonics. For this reason, notes an octave apart are given the same name in the Western system of music notation—the name of a note an octave above C is also C. The intervals between these notes are called 'semitones'.

In this project we'll take advantage of the $2^{1/12}$ principal to generate the 12 notes in an octave.

Middle C has a frequency of 261.64Hz. An octave above Middle C, also known as Treble C, has a frequency 2×261.64Hz or 523.28Hz. There are 12 steps (semitones) between these two notes, and each step is $2^{1/12}$ times the note before it.

In the image to the right, we entered 261.64 into the Calculator app, and then, in the next statement, multiplied it by $2^{1/12}$.



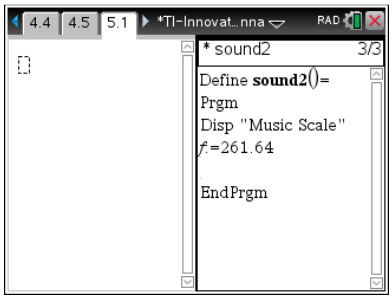
The calculator supplied **Ans** at the beginning (not shown) because the multiplication symbol requires something in front of it. Just pressing enter repeatedly creates the sequence of answers shown.

We will incorporate this repetitive principle into our program. If you continue the progression, the twelfth answer will be 523.28, exactly two times the starting value, because $F \times (2^{\frac{1}{12}})^{12} = 2 \times F$.

Teacher Tip: This can get complicated if students are not familiar with powers and roots. Having a piano or keyboard handy to demonstrate the principle on the instrument helps to illustrate the sounds of notes an octave apart and the 12 semitones in an octave (if you include the black keys!).

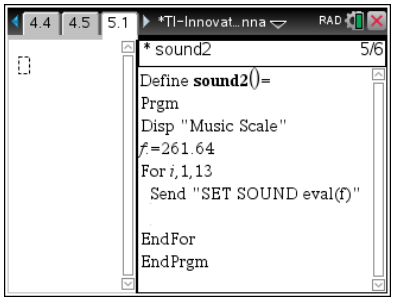
Setting up the Program:

1. Start a new program, and call it SOUND2.
2. Add **Disp**, add opening and closing quotation marks, and type the text Music Scale.
3. Assign the starting frequency, 261.64 to the variable *f*.
4. This variable will represent each of the 12 notes in the scale.



Setting up the For Loop:

5. Add a **For** loop that goes from 1 to 12 (for the twelve notes).
6. Add **Send "SET SOUND** statement from the ***HUB*** menu
7. Add **eval( )** for the variable ***f*** as shown.

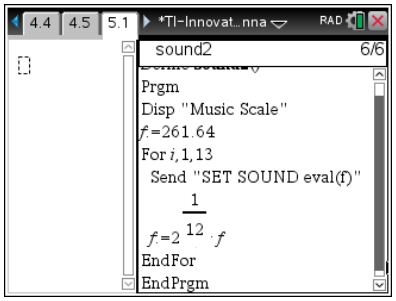


Evaluating the frequency:

8. Multiply ***f*** by $2^{1/12}$ and store the result back into ***f***:

   ***f* := *f* * 2^(1/12)**

   This statement takes the current value of ***f*** and changes it to the next higher note's frequency on the scale.
9. Store (**ctrl-B**) and run the program in the Calculator app.



Modifying the Program:

Try adding the **TIME** parameter to the **Send "SET SOUND** command and be sure to add an equivalent **Wait** statement to the program to let each note finish playing.

If a new command is received by the TI-Innovator Hub before it finishes its last task, then the device will process the new command instead of finishing the current one.