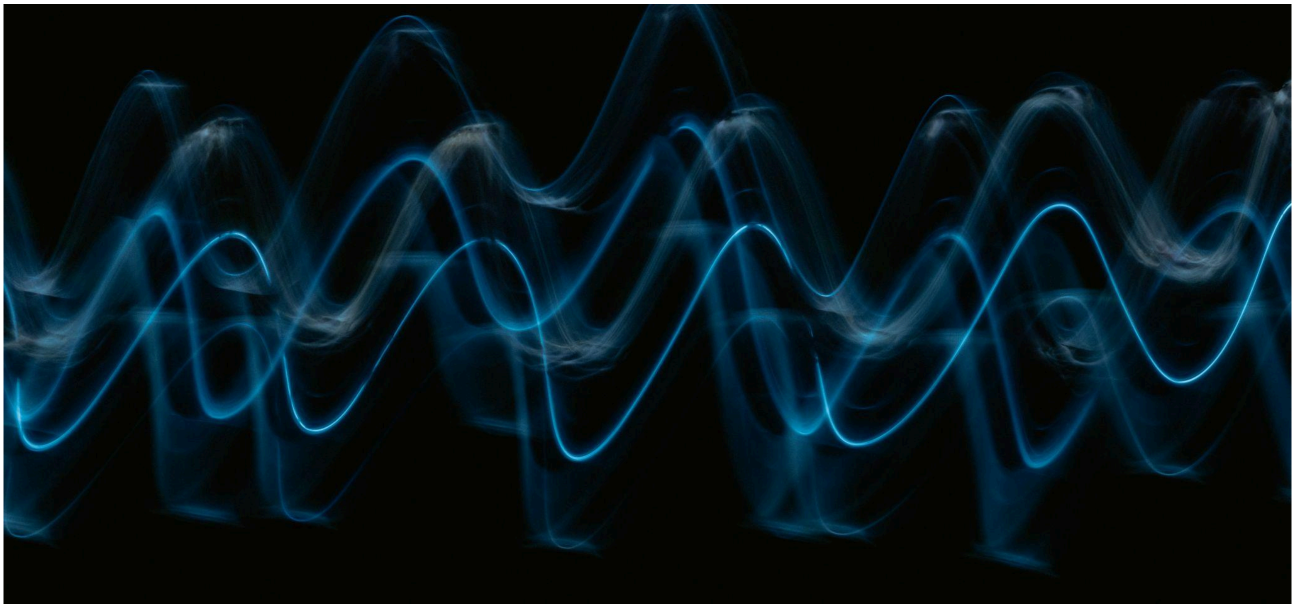
Sound Analysis – Mixing & Mastering



Purpose

Music is an important part of our lives for a variety of reasons. It can boost our moods, help us relax, provide a form of entertainment, and allow us to express ourselves. It can also bring people together, creating a sense of community and bonding. When creating music, we also utilize *mathematics*. In rhythm, harmony, balance, and more, we utilize math! In this lesson, we'll examine how mathematics and music connect, as well as how audio engineers balance and perfect music for listening.

Introduction

Music is connected to math in many ways. Two common concepts include:

Rhythm

Almost all songs are written with a *time signature*. This sets the number of *beats* within a *measure*.

For example, the 4/4 time signature states that there are 4 beats in every measure. Each beat is a quarter note (a 4th).

[Listen (the kick drum is the beat!).]

This is different from a 7/8 time signature, where there are 7 beats in every measure. Each beat is an eighth note (an 8th).

Listen (the kick drum is the beat!).

Different notes take up a different fraction of time during the song.

For example, a quarter note takes up 1 beat of a traditional 4/4 measure. 4 quarter notes fit in a 4/4 measure.

Listen.

Likewise, an eighth note takes up ½ beat of a traditional 4/4 measure. 8 eighth notes fit in a 4/4 measure.

[Listen.]

How many eighth notes do you think would fit in a ⅞ measure?

[Listen (the snare starts a new measure!).]

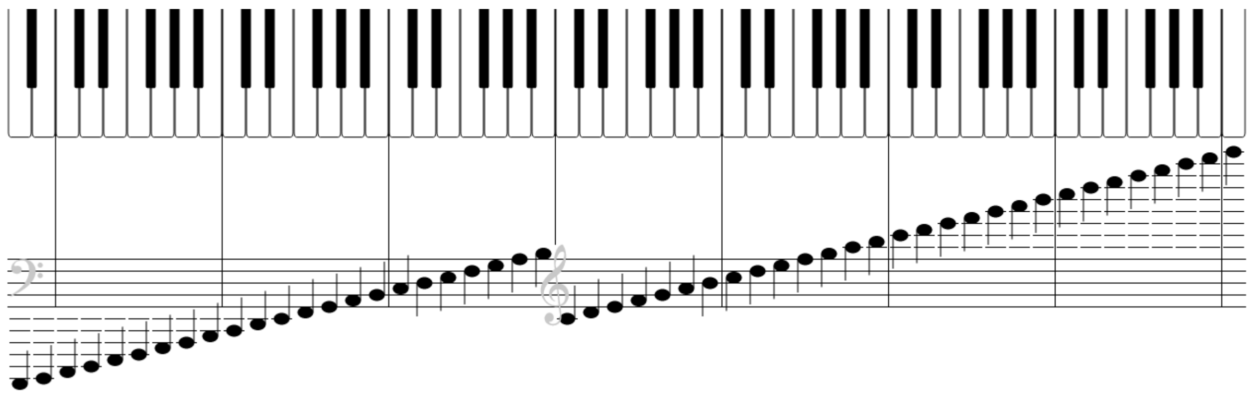
These different fractions allow us to compose various types of rhythms. In order, this showcases:

- A whole note (4 beats)
- A half note (2 beats)
- A quarter note (1 beat)
- An eighth note (1/2 beat)
- A sixteenth note (1/4th beat)

Keys/Pitches

We also determine **pitch** through mathematics. Pitch refers to the sound (high/low) that is produced. Pitches are represented by notes and produced through sound waves (more on this later!)

The notes of a keyboard (starting in the bass clef for lower notes, then rising to the treble clef). The bass clef (found on the far left) indicates notes in a lower range of pitches, and the treble clef (found in the middle) indicates nots in a higher range of pitches.:



In most Western music, each half-step (C, C#, D, D#, etc.) represents a note.

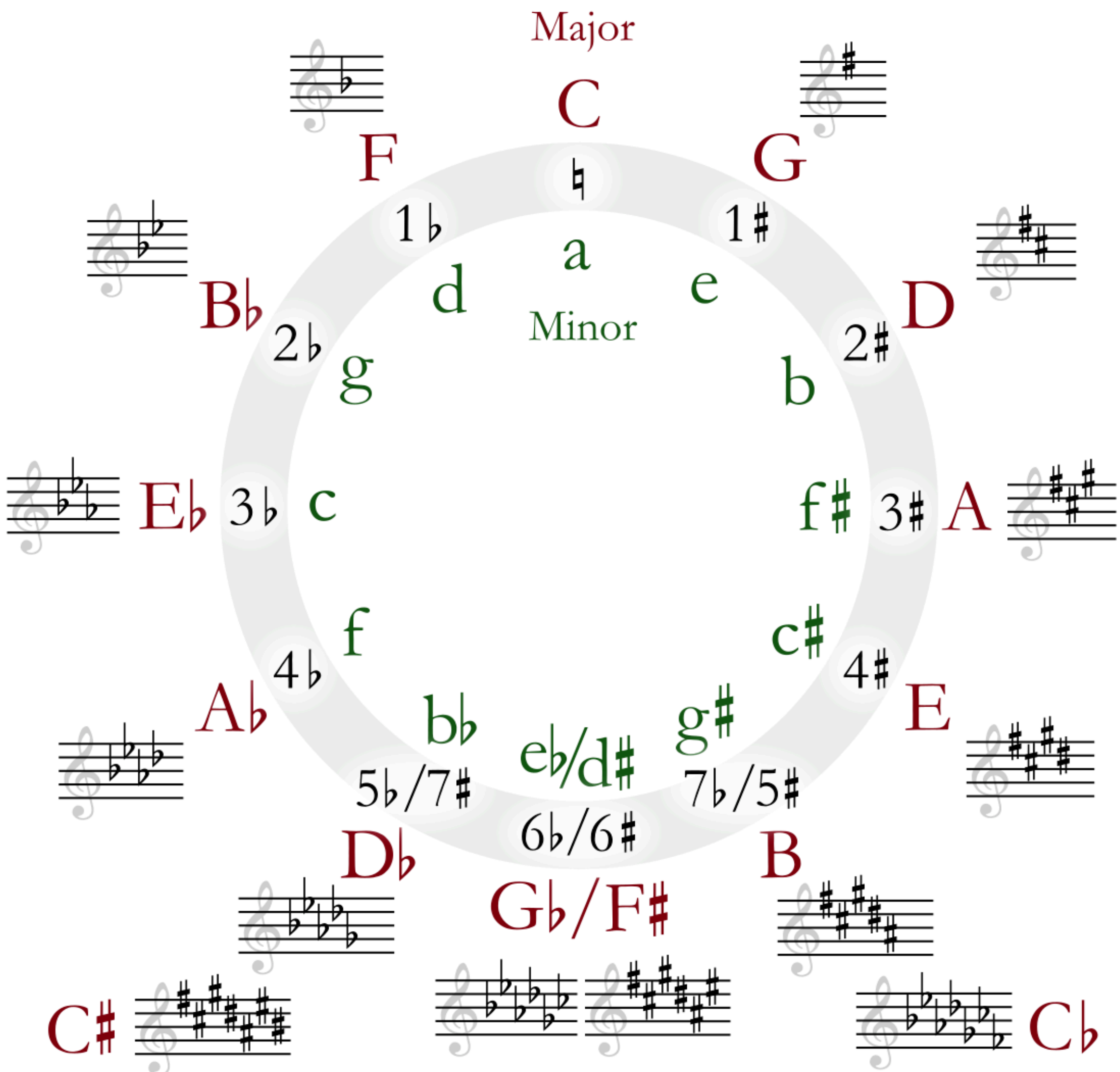
[Listen.]

In some music, such as what can be found in the Middle East, each *quarter*-step represents a note:

[Listen.]

These **equidistant** pitches frame all music, allowing us to enjoy what type of sound is produced!

It is beyond the scope of this lesson, but we arrange and compose Western music using the Circle of Fifths, a relatively complex mathematical formula for chords and writing music:



Consider This

In this lesson, we'll primarily focus on *editing* music as opposed to writing it. **Audio engineers** are people who focus on *mixing* and *mastering* music, radio, podcasts, and more so it sounds appealing to our ears.

Mixing refers to how we balance sounds as they're being recorded and played. For example, what instruments we use, what notes they're playing, how close they are to each other, the space they're recording in, and how loud and soft each instrument is.

Mastering refers to the final production stage where tools are used to modify sounds. Each modification uses math and science to function properly!

Hertz (Hz)

Hertz is a unit measuring frequency. To create sound, we're hearing waveforms that oscillate (moving at a constant rate) at different speeds. For example, a sound wave that completes an oscillation (cycle) at 20 times in a second would have 20 Hz. The faster a sound wave moves, the higher its pitch is.

For example, here's a note at 65.41Hz (a low C). Listen.

And a note at 440Hz (middle C). Listen.

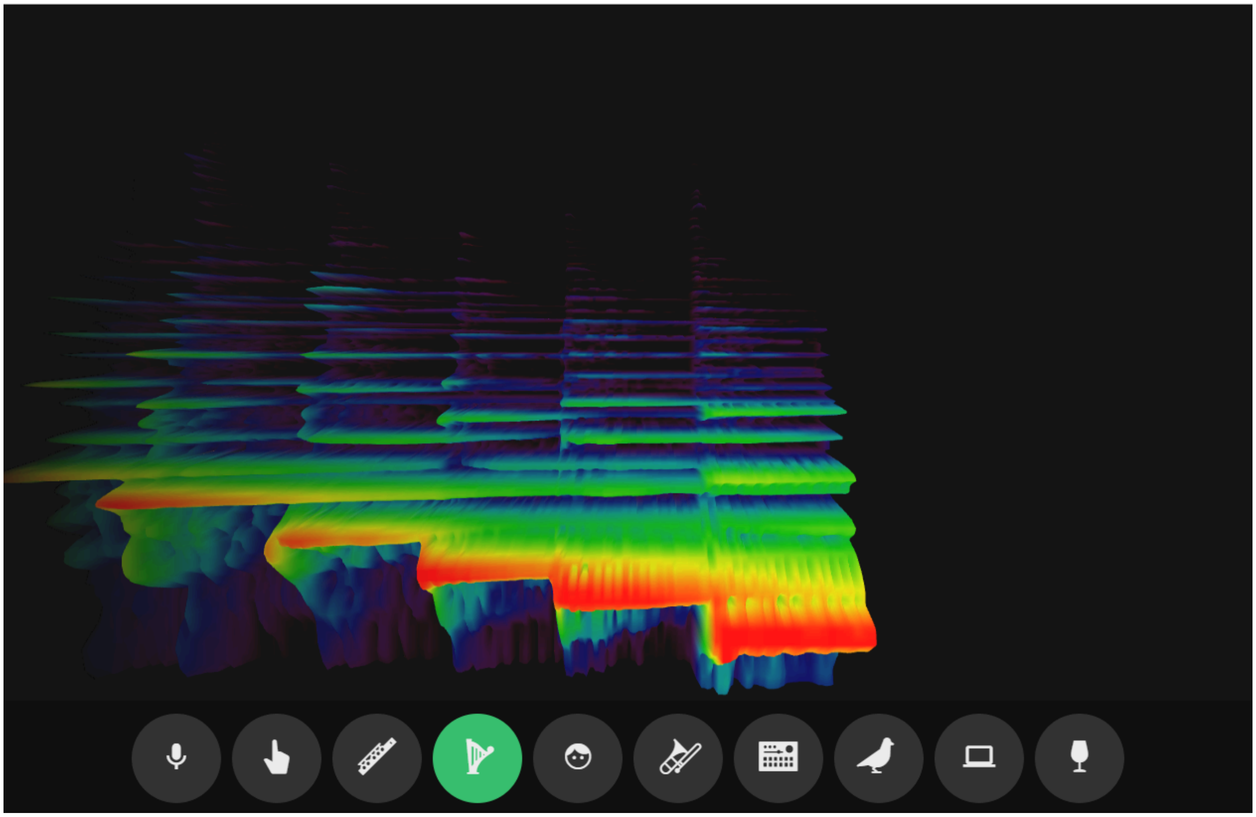
In the 1880s, the Music Commission of the Italian government decided that all music be tuned to "middle C" (the note in the center of a keyboard) at 440 Hz. Therefore, all music would sound the same when performed around the world. (Before this, middle C could be tuned anywhere around 440 Hz.)

Would a note at 300Hz be a lower or higher pitch than 440Hz?

Spectrogram

A spectrogram is a visualization of sound. (A free tool to visualize this can be accessed by Google Chrome).

SPECTROGRAM

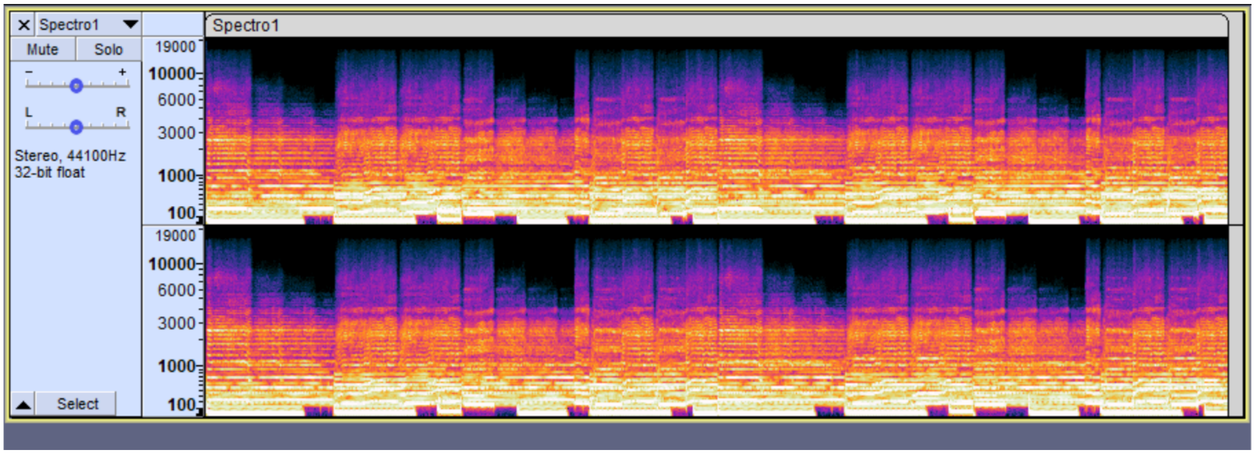


To read a spectrogram, you'll look at two properties:

1. Where the sound is on the diagram. The higher up the graph, the higher Hz it has.
2. The color of the diagram. More intense colors (white and red) indicate very loud sounds, whereas cooler colors (blue and magenta) are very soft.

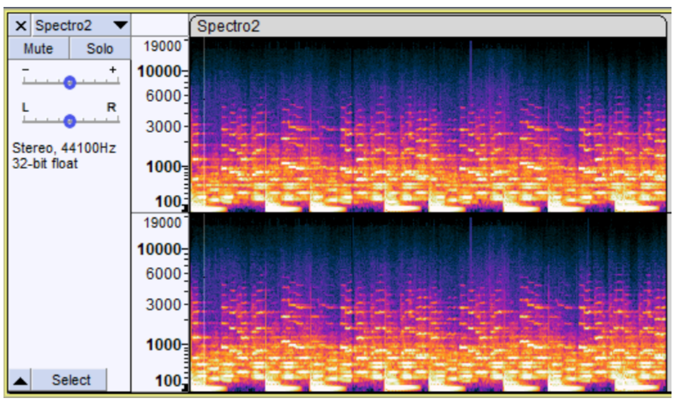
By looking at these two properties, we can see how loud different frequencies are produced.

For example, what do you think this would sound like? Is the pitch higher or lower? Is it louder or softer?



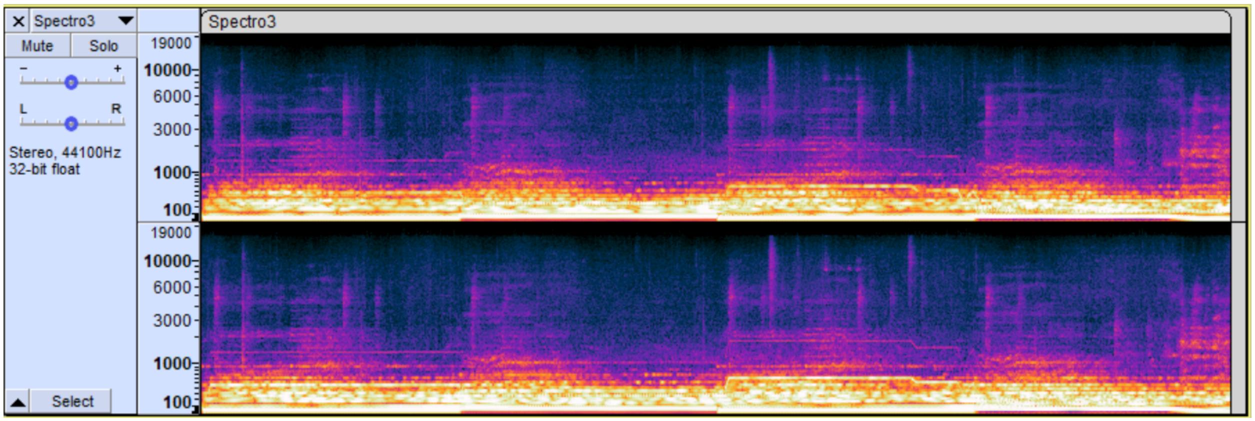
[After answering below, listen.]()

How about this one? What do you think this would sound like? Is the pitch higher or lower? Is it louder or softer?



[After answering below, listen.]()

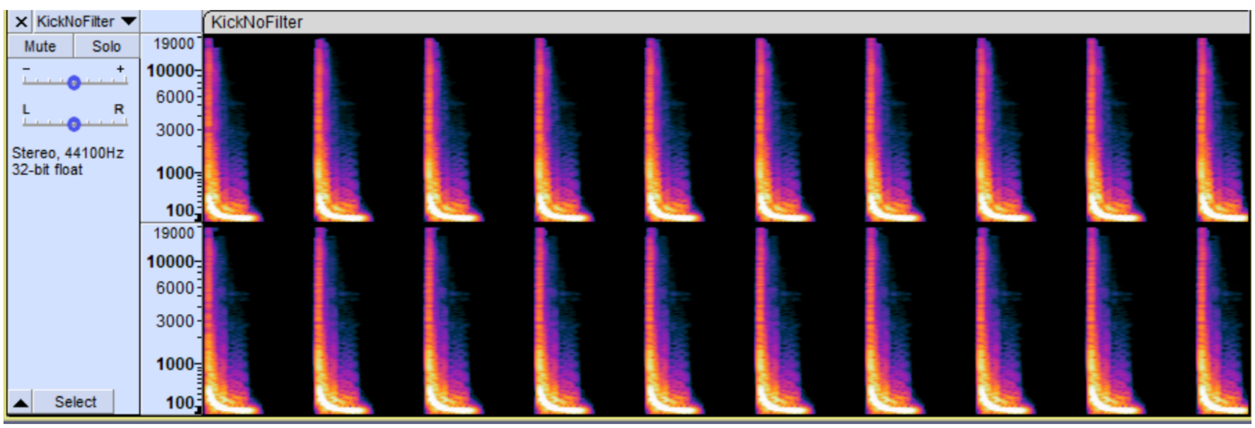
...And this one. What do you think this would sound like? Is the pitch higher or lower? Is it louder or softer?



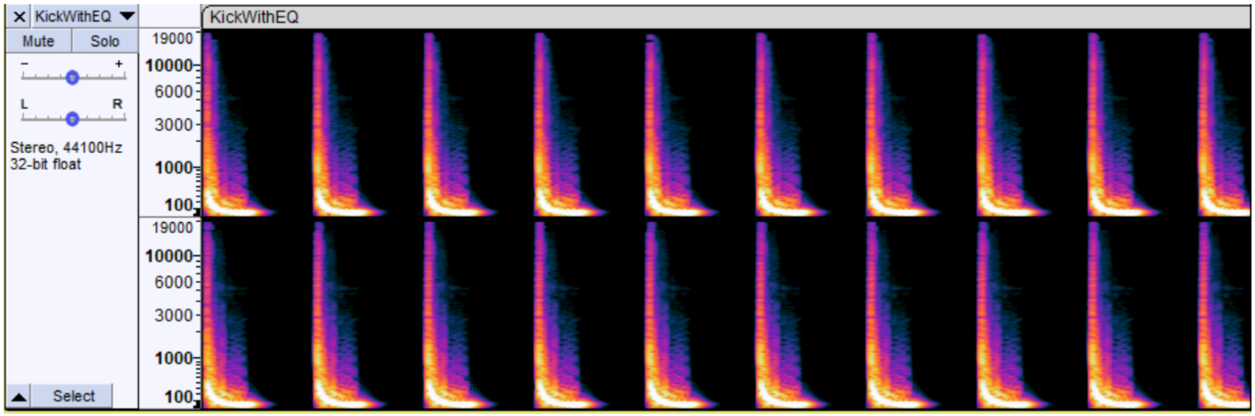
After answering below, listen.

This is incredibly important for *mastering* as audio engineers use *equalization* (EQ) to modify the spectrogram. This can cut out high or low frequencies that can distract, harm, or hurt a mix.

For example, here's a kick drum with this spectrogram. Listen.



And here's the same kick drum with EQ. Listen.



This is a subtle change that slightly lowers the amount of high spectrum frequencies in the mix.

When we utilized EQ, we cut out the high frequencies (Hz). This clears up space for a cleaner vocal sound, which has a higher frequency, to shine through. Listen.

Likewise, here's what this would sound like *without* EQ. Listen.

Can you tell the difference between the melody with kick EQ vs no EQ? It can be difficult to tell without certain types of speakers! If you noticed a difference, what was it?

Filters, Limiters, and Compression

Likewise, audio engineers use other tools to control sound. Basic ***filters*** are used to completely morph sounds by eliminating certain frequencies. This can be used to produce a "lo-fi" (low frequency) beat.

Here's the beat without a low frequency filter. Listen.

Here is it *with* a low frequency filter. This means *only* low frequencies are allowed to pass. Listen.

How does it sound different?

Limiters are used to prevent sounds from becoming too loud. If an audio engineer sees that a sound is "peaking" (entering the red or white area of the spectrogram), they will often choose to limit the frequency. This prevents static-y or over-the-top loudness in a mix.

Here's a beat without a limiter. Listen.

And after a limiter. Listen.

Compression is used to make an instrument or voice clearer by lessening the loudness and increasing the softness of a track. This prevents sound from becoming unclear. For example,

Here's a beat without compression. Listen.

Here's a beat with compression. Listen.

And sometimes we intentionally *over*compress, which causes audio distortion. Listen.

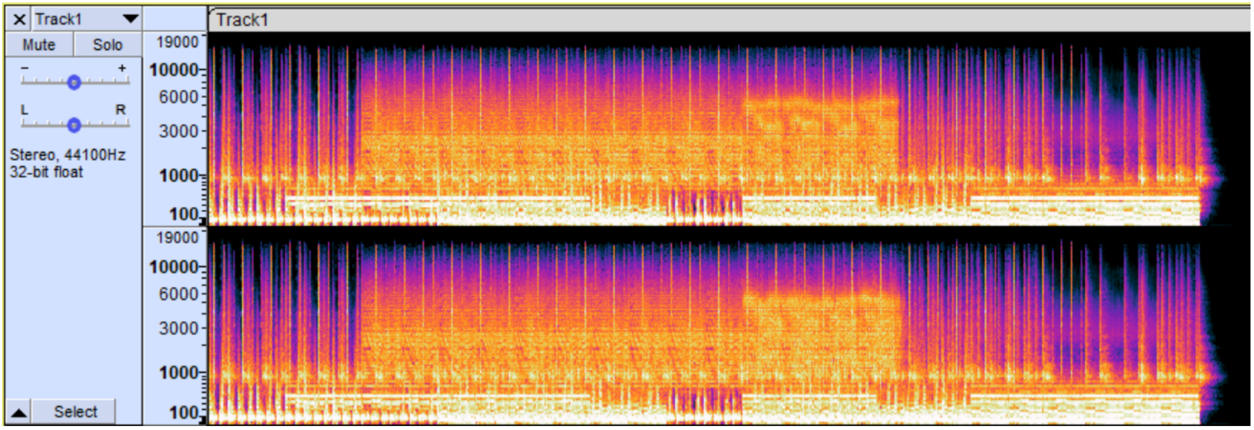
What do you notice as we increase compression?

Diving Deeper

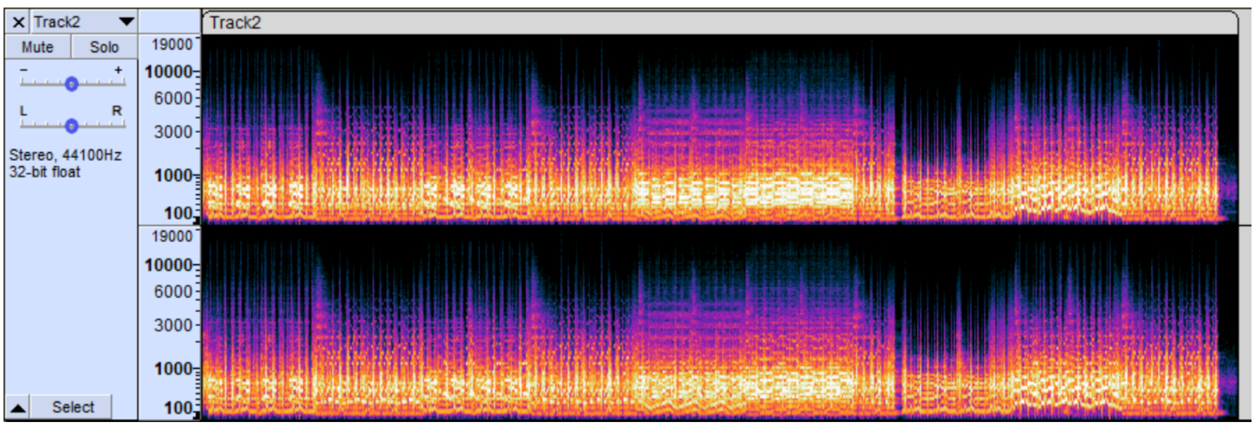
Now, we'll view a variety of spectrograms and listen to music to determine what audio mastering techniques each track needs.

Bonus points if you can analyze these without listening at all!

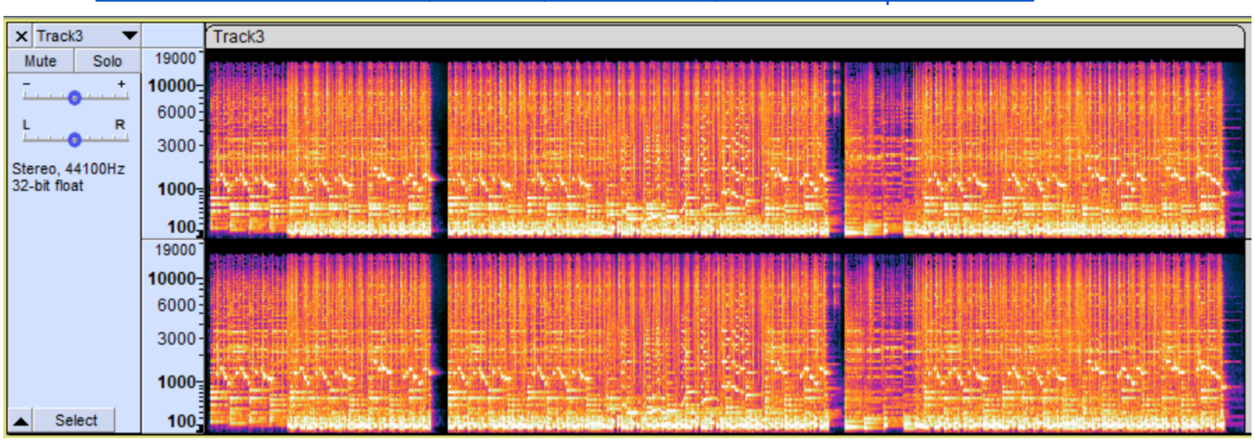
1. Listen to the following beat. How would you use the tools above to master the track? Consider what is too loud, too soft, sounds "off", or needs improvement.



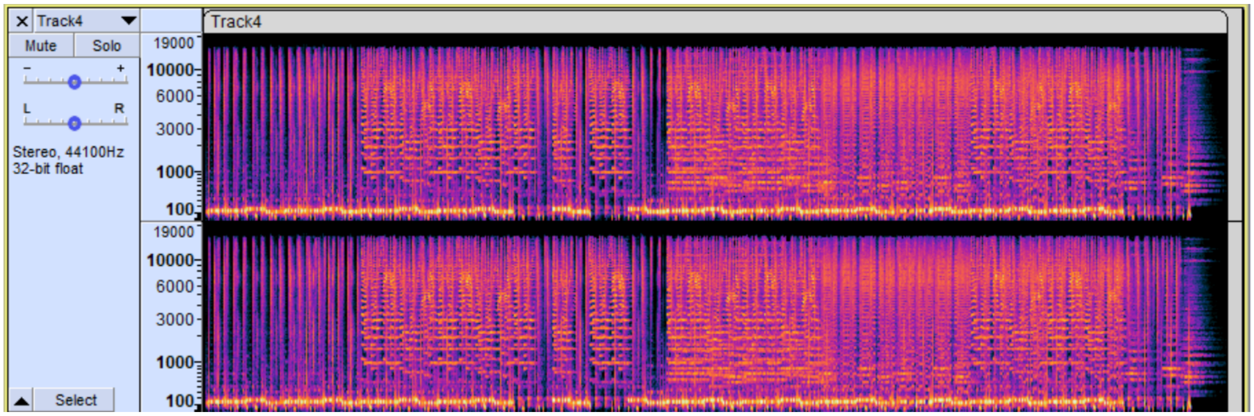
2. [Listen to the following beat. How would you use the tools above to master the track? Consider what is too loud, too soft, sounds "off", or needs improvement.]



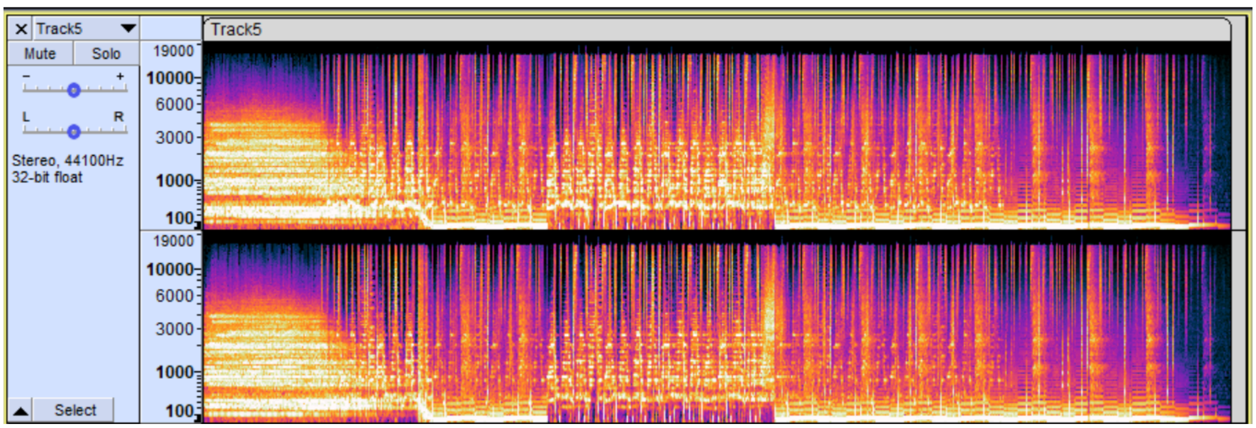
3. [Listen to the following beat. How would you use the tools above to master the track? Consider what is too loud, too soft, sounds "off", or needs improvement.]



4. Listen to the following beat. How would you use the tools above to master the track? Consider what is too loud, too soft, sounds “off”, or needs improvement.



5. Listen to the following beat. How would you use the tools above to master the track? Consider what is too loud, too soft, sounds “off”, or needs improvement.



Reflect

How would you rate your understanding of this concept? *Place an "X" in the corresponding box below.*				
				

How has your understanding of this concept changed as a result of this lesson?

Which individual or community actions could this activity inspire?

Why would it be important to understand the relationship between mathematics and music?