

- **Digital Sound Effects**

- Estimated time required: 75 minutes
- Target group size: 15-30 students
- Target grade level: High school, 9-12th

- **Summary of activity**

- This activity examines digital modeling of sound effects, primarily echo, harmonic distortion, and filtering. The bulk of the activity is concerned with echo, and includes active exploration of different types of physical echoic environments as well as an anechoic sound booth.

- **Pre-requisite knowledge requirements**

- Familiarity with Fourier's Theorem, i.e. that any periodic signal can be represented as a sum of individual frequencies (sine waves)
- Familiarity with the concept of harmonics
- Familiarity with Garageband for the iPad helps keep the activity within the time limit

- **Dependencies on other SMT activities**

- Waves and Sound introduces Fourier's Theorem and the concept of harmonics
- Instrument acoustics I and II solidify the concept that instrument timbre is partially related to relative amplitudes of harmonics (but isn't necessarily required for this activity)
- Music production introduces Garageband for the iPad

- **Learning objectives**

- After this lesson, students should understand:
 - how echo is modeled using time-shifted copies of a signal
 - how one would change the echoic response of a room by adding or removing objects with specific reflective/absorptive properties
 - that distortion (in a musical context) is the alteration of harmonic components of a signal via wave-shaping in the time domain
 - that filtering means selectively changing the amplitudes of different frequencies of a signal
- Students should be able to:
 - Listen to different echoic environments and conceptualize how one would model the response of the room

- **Relevant educational standards** (download Mathematics PDF and Science and Technology PDF from [here](#))

- Math
 - Mathematics I High School—Modeling
 - F-TF: Trigonometric Functions
- Science
 - 3.1.10.A: Systems
 - 3.1.10.B: Models
 - 3.7.10.A: Tools

- 3.7.10.D: Computer Software

- **List of materials**

- Per Student:
 - 1 iPad with:
 - SMT Echo & SoundFX app
 - Garageband
 - Dingsaller
- In addition to the individual materials, this activity is best implemented in a space with varying echoic environments. Optimally, students can explore:
 - an environment with a single slapback-type echo (these are the hardest to find)
 - a room with a flutter-type echo (multiple rapid, yet distinct echoes usually due to hard parallel surfaces)
 - a larger room where individual echoes are not distinct, but a long decaying tail can be heard
 - an anechoic chamber or sound recording booth

- **Detailed description of the activity**

- I. Echo**

1. Introduction/Motivation:
 - the instructor should begin a discussion of echo by asking for a definition
 - relate echo to common experiences (e.g. echoic response of empty rooms vs. rooms filled with furniture)
2. Background
 - echoes are time-shifted copies of a signal
 - reflections aren't perfect reproductions, but are attenuated in loudness depending on the material properties
3. New Vocabulary/Definitions
 - Echoic/anechoic
4. Procedure
 - Before the activity
 - find suitable echoic spaces and plan a tour
 - distribute a garageband project on all iPads with a single test track containing a clap or other percussive sound, a voice recording, and some music
 - With the students
 - lead introduction talk
 - lead students on the tour of several different echoic/anechoic environments and discuss the difference in sound of each environment and how one would model these environments digitally
 - after the tour, students will open the Garageband project and follow the Activity 1.1 section
 - encourage experimentation with long and short delay times, and note the point at which we begin to perceive distinct copies of the sound
 - ask students to try to approximate some of the different environments they heard on the tour

- open Dingsaller and follow the Activity 1.2 section
 - draw parallels between the echo feedback and more familiar types of feedback (e.g. guitar feedback, microphone feedback)
- After the session
 - ask students how far apart the two copies had to be to hear two distinct echoes
 - ask how they approximated the different environments
 - move on to the distortion section of the activity
- 5. Safety Issues?
 - safety may depend on the environment and extent of the tour (i.e. certain spaces may have particular safety concerns)
 - in Dingsaller, maxing out the amplitude of all three echoes and turning up the feedback slider all the way leads to runaway feedback that may damage hearing
- 6. Troubleshooting tips
 - See help sections in Garageband and Dingsaller

II. Distortion

1. Introduction/Motivation:
 - listen to examples of clean vs. distorted guitar; ask which sounds like it has more high frequency content
 - relate to common experience of accidentally overdriving the input of a hi-fi amplifier
2. Background
 - harmonic distortion generates or modifies harmonics of a signal via waveshaping (i.e. clipping or compressing peaks and valleys of a wave)
 - amplifiers generate distortion when we put too large a signal in the input
 - amplifier stages are designed to have a particular $\text{Gain} = V_{\text{out}}/V_{\text{in}}$
 - if, for a given V_{in} and Gain, V_{out} would roughly exceed the supply voltage of that amplifier stage, then the peaks and valleys of the waveform will be clipped or compressed (note: this is a simplification)
3. New Vocabulary/Definitions
 - Harmonic distortion
 - Waveshaping
4. Procedure
 - Before the activity
 - find audio examples of roughly the same guitar signal played clean and distorted (or set up a live demo using a distortion pedal)
 - With the students
 - lead a discussion into the differences between clean and distorted guitar (which one contains more high-frequency content?)
 - follow Activity 2 in the handout
 - keeping the clipping threshold constant, boost the signal until it is clipped; make sure to relate this to overdriving the input of a hi-fi (or even demonstrate it)
 - After the session
 - move on to the filtering section

III. Filtering

1. Introduction/Motivation:

- ask for a definition of a filter
- emphasize that any audio EQ is a filter
- discuss how a telephone makes our voices sound different by filtering low and high frequencies
- discuss how some physical materials block certain frequencies while allowing others to pass (e.g. we can easily hear the low frequencies of music playing in an adjacent room)

2. Background

- a filter is something that changes the frequency content of a signal
- many sound effects use filters as a primary effect (e.g. parametric and graphic EQs, wah-wah pedals, amplifier modelers, etc.), but nearly all audio effects employ some type of filtering

3. New Vocabulary/Definitions

- Filter

4. Procedure

- Before the activity
 - in the SoundFX app, make sure the clipping threshold is set high enough so that the signal isn't distorted while filtering
- With the students
 - follow Activity 3 in the handout
 - allow the students to experiment with different filter shapes
- After the session
 - ask what type of filter shape would make music sound like it was coming from the next room
 - ask how would we make our voices sound like we were talking over the phone

• Investigating question

- See the activity question sheet

• Assessments

- Pre-activity assessments are mainly discussion-based
- During the activity, the instructor should ask the students to set parameters in their models to achieve some constraint (see each activity's procedure above)
- Following the echo activity section, the instructor may wish to give the students the optional question sheet