Simple Synthesizer with ADSR, Filters, and Error Handling - Project Report

> **By Aryen Singhal**
> **PID: A17930399**

This application allows you to generate sounds with various waveforms (sine, square) and control their ADSR envelope (Attack, Decay, Sustain, Release). It also features low-pass and high-pass filters for further sound shaping.

1. Potential Applications

This synthesizer can be used for a variety of purposes, depending on the desired sound output. Here are some potential applications:

- **Music Creation:** Generate a wide range of musical tones and textures by experimenting with different waveforms, ADSR settings, and filters. It can be a valuable tool for musicians, sound designers, and composers to create unique sonic elements.
- **Educational Tool:** This synthesizer can be used as a learning tool to understand basic sound synthesis principles. By manipulating the various controls, users can explore how different parameters affect the sound characteristics.
- **Audio Effects:** The synthesizer can be used to create sound effects for games, films, or other multimedia projects. By adjusting the controls, various sound effects, from laser blasts to explosions, can be generated.
- **Ringtones and Alarms:** With careful selection of frequencies and ADSR settings, the synthesizer can create custom ringtones or notification sounds.

It's important to note that the appropriate frequency range will vary depending on the application. For instance:

- **Ambulance sirens** typically use a combination of high and low frequencies (around 500 Hz to 3 kHz) to create a piercing and attention-grabbing sound.
- **Fire alarm systems** often use a continuous high-pitched tone (around 3 kHz) to be easily audible and distinct from other sounds.

This synthesizer allows users to explore different frequency ranges to produce sounds suitable for various applications.

2. Synthesizer Controls

The synthesizer features several controls that influence the generated sound. Here's a detailed description of each control:

a) Frequency Entry (Hz):

- This allows users to specify the fundamental frequency of the sound in Hertz (Hz). The frequency range can be adjusted based on the desired sound characteristics.

b) Duration Entry (seconds):

- This control sets the total duration of the generated sound in seconds. Users can define the length of the sound they want to create.

c) Waveform Buttons:

- These buttons allow selection of the basic waveform shape used for sound generation. Options include:
  - Sine: Creates a smooth, continuous sound wave.
  - Square: Produces a buzzy sound with abrupt transitions between high and low values.

d) ADSR Sliders:

- These sliders control the envelope of the sound, which defines its amplitude (volume) over time. Each slider has a range of 0.0 to 1.0:
  - Attack: Determines how quickly the sound rises from its initial volume to its peak level (0.0 for instant rise, 1.0 for slower rise).
  - Decay: Controls how quickly the sound fades from its peak level to the sustain level (0.0 for instant decay, 1.0 for slower decay).
  - Sustain Level: Sets the constant volume level during the sustain phase of the sound (0.0 for silence, 1.0 for full volume).
  - Release: Controls how quickly the sound fades out from the sustain level to silence (0.0 for instant fade, 1.0 for slower fade).

e) Filter Selection:

- This section allows users to choose between applying no filter, a low-pass filter, or a high-pass filter to the generated sound:
  - No Filter: Leaves the sound unaltered.
  - Low Pass Filter: Gradually reduces the amplitude of high-frequency components above a certain cutoff frequency, resulting in a warmer sound.
  - High Pass Filter: Attenuates low-frequency components below the cutoff frequency, creating a brighter sound.

f) Cutoff Frequency Entry (Hz):

- When a filter is selected (low-pass or high-pass), this entry allows users to specify the cutoff frequency in Hz. This determines which frequencies are affected by the filter.

3. Concepts Applied from Class

This synthesizer applies the concept of **Digital Signal Processing (DSP)** techniques for sound generation. DSP involves manipulating digital representations of sound signals to achieve various effects. In this project, the following DSP techniques are used:

- **Waveform Generation:** Different waveforms (sine, sawtooth, square, triangle) are generated using mathematical functions.
- **Digital Filters:** Low-pass and high-pass filters are implemented using the `scipy.signal` library functions to modify the frequency content of the sound.
- **Envelope Shaping:** The ADSR envelope is created by applying time-varying gain adjustments to the sound signal.

4. Cited Code and Functions

The project utilizes the following external libraries and functions:

- **`sounddevice` library:** Used for audio playback