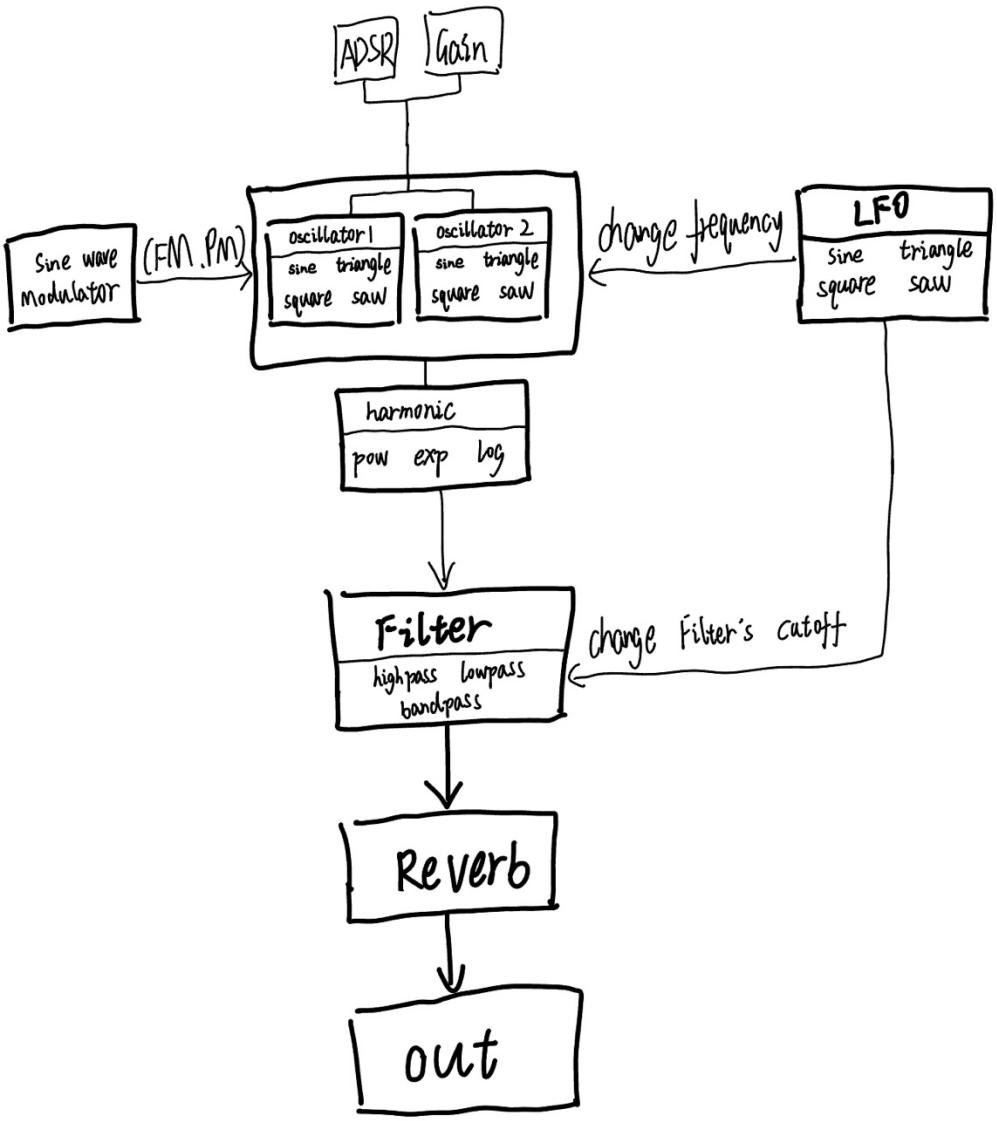
Hybrid Synthesizer Design and Implementation



Project Aims

The aim of this project is to develop a synthesizer capable of complex sound shaping and texturing to meet the needs of music producers and sound designers.

This synthesizer will incorporate advanced features such as a wide range of waveform options from basic sine waves to more complex custom shapes, allowing users to lay a versatile sonic foundation. To enhance the capability of sound shaping, it will include a variety of modulation tools, such as Low Frequency Oscillators (LFOs) that can be finely tuned and directed to influence specific elements of the sound. Furthermore, the synthesizer will be equipped with highly sophisticated modulation options, including phase and frequency modulation capabilities, enabling the creation of sounds with rich harmonic content and intricate dynamic behaviors.

Ultimately, this synthesizer aims to bridge the gap between technical possibilities and the creative vision of its users, providing them with a powerful tool that enhances their ability to express their musical ideas and design sounds that push the boundaries of conventional audio production.

Project Overview

The main objectives of this project include:

a) providing a variety of waveform generation capabilities, including sine waves, sawtooth waves, triangle waves, and square waves.
b) Implementing a highly flexible modulation system that includes frequency and phase modulation to create dynamic and complex sound textures, such as ringtones and metallic sounds.
c) Introducing selectable types of filters, including high pass filter, low pass filter and band pass filter, to support in-depth sound editing and tone shaping.
d) Contains low-frequency oscillator of various shapes to modulate the frequency of the output waveform and the cutoff frequency of the filter.
e) Includes harmonic type selection to enrich timbre effects.
f) Contains a reverb effect applied to the final output.

Detailed Introduction

Oscillators

The synthesizer features two independent oscillators, each capable of generating four basic waveforms. These waveforms can be utilized independently or mixed together, providing a robust foundation for sound design. Each oscillator can be individually configured with its own envelope and volume settings, allowing for precise dynamic control over the sound produced.

Additionally, an innovative 'harmonic' switch is available for each oscillator. When

activated, this switch enhances the output by generating corresponding harmonic effects, enriching the texture and complexity of the audio. The synthesizer offers three types of harmonic decay options, designed to cater to different sound characters and musical styles. This flexibility enables users to tailor the harmonic response according to the specific requirements of the piece or sound design they are working on, providing a versatile tool for creative expression.

Filters

Three types of filters were designed: low-pass, band-pass, and high-pass, which users can select as needed to finely adjust the spectral characteristics of the output waveforms.

Modulation Units

Low Frequency Oscillators (LFOs): Two LFOs are available to modulate the frequency of the oscillators and the cutoff frequency of the filters, adding rhythmic variation and dynamic effects to the sound. Users have the ability to select the shape of the LFO, and can control the modulation impact by adjusting the LFO's frequency and amplitude. In the design process, I have implemented a coefficient of 1000 for the LFO output applied to the filter cutoff frequency. This scaling factor ensures that the parameters displayed on the UI interface are consistent and intuitive for users to manipulate. This approach enhances the usability of the modulation features, making it easier for users to achieve precise control over the sound dynamics.

More Powerful Modulators: The synthesizer is equipped with two more powerful modulators that provide both frequency and phase modulation. These modulators can independently target each of the two oscillators, producing effects that are more pronounced than those achievable with LFOs. This capability is particularly suited for creating complex and richly textured sounds.

Users can fine-tune the modulatory effects by adjusting the frequency and depth of each modulator. In the design of the phase modulation functionality, I have applied a divisor of 20 to the modulator's frequency. This adjustment lowers the frequency range of the modulator, allowing it to generate deeper and more profound modulation effects that are distinctly different from those produced by frequency modulation. This feature greatly enhances the sonic palette, enabling users to craft unique and captivating soundscapes.

Usage Intentions for the Synthesizer

I envision this synthesizer being primarily used in three key areas: simulating instrumental tones, creating ambient textures, and producing interesting sound effects. Each area leverages different functionalities of the synthesizer:

Simulating Instrumental Tones:

a) Utilize the two oscillators to generate various waveforms.
b) Apply filtering to these waveforms.
c) Use LFOs to modulate both the filter's cutoff frequency and the oscillators.
d) In this case, the amplitude of the LFO is typically set very low, and there is no need to layer many waveforms to create complex textures.

Creating Ambient Textures:

Similar to simulating instrumental tones, the LFO's amplitude is adjusted very subtly. Enhance the sound by adding reverb effects to enrich the audio depth and space.

Producing Interesting Sound Effects:

a) Layer different waveforms and activate harmonic effects to enrich the sound texture.
b) Use the two LFOs to independently modulate the oscillators and filters.
c) Add FM (Frequency Modulation) and PM (Phase Modulation) to the oscillators, enabling the creation of sound effects such as alarm bells and engine sounds.

Programming and Code Features

In the design of this synthesizer, I have developed several classes to encapsulate specific functionalities:

Class Structure:

ChooseOscillator: Manages the selection and generation of different waveforms.

Filter: Handles audio filtering operations.
LFO (Low Frequency Oscillator): Responsible for modulation effects using low-frequency oscillations. It includes functions that can be invoked within the synth to select which component the LFO should apply to.

Modulation:

Features algorithms designed for phase modulation and frequency modulation to output the modulated frequency.

Synthesis Output:

The Synth class integrates all other classes to produce the final audio output. It synthesizes the contributions from each individual component class.

Function Implementation:

The Filter, LFO, and Modulation classes each include a startNote function. This design facilitates easy invocation of these functions within the startNote function of the Synth class, allowing for seamless parameter passing and operation initiation.

LFO Waveform Selection:

In the LFO class, an instance of the ChooseOscillator class is created. This allows the LFO to easily access and set the waveform type through the setType function of ChooseOscillator, enhancing the flexibility and functionality of the LFO settings.
This structured approach ensures that each component of the synthesizer can be independently managed while still contributing effectively to the whole system, allowing for complex and dynamic sound synthesis.