Affordable Analog Synthesizer
1. Introduction

1.1 Objective

The main goal of the project is to create an analog synthesizer that is capable of reproducing many iconic synthesizer sounds. To this end, the synthesizer must be sufficiently complex so that it is capable of producing such a large variety of sounds. Another consideration is cost, as synthesizers tend to be very expensive. We are aiming to build a synthesizer that is both capable and relatively affordable. Typically the synthesizer will produce sounds corresponding to notes played on an external MIDI keyboard, but an additional objective is to be able to have the option of playing saved sounds via an SD card.

1.2 Background

To further understand the purpose that the project holds, our team did research on the interest in music synthesizers in the market. Music synthesizers are extremely expensive at market value and for most people, it is not reasonable to own a music synthesizer due to the high cost. As many people are interested in creating music, or using synths but may not have the budget to own one, the objective of the project is to create an affordable analog synthesizer. Also, According to Technavio, “the music synthesizers market is poised to grow by USD 62.90 million during 2021-2025, progressing at a CAGR of over 2% during the forecast period” [1]. Being able to create an affordable model holds values with the growth in market and demand for music synthesizers, as well as documentation for the homemade solution that we make.
1.3 Physical Design:

The physical design of the project will be a box that connects to an external MIDI keyboard and speaker. The top of the box is the front panel that will detail specific knobs in regard to the different components that contribute to the synthesizer module and the microcontroller. For the microcontroller, there will be a button to specify if the input is coming from the keyboard or from the SD card, and buttons to cycle through a list of files on the SD card. When the “play” switch is pressed then it will be taking input from a preloaded SD card, and when it is not pressed it will be taking input from the MIDI keyboard.

The controls for the synthesizer are broadly divided into controls for the oscillators, the filter, the envelope generator, and the low-frequency oscillator. The oscillators produce the basic tones of the synthesizer, either an adjustable square wave or triangle wave, which then get mixed and filtered. They then go through an envelope that modulates the amplitude and filter’s cutoff frequency. Additionally, knobs will control a low-frequency oscillator that is used to modulate other parameters of the synthesizer. The depth of the modulation for each parameter can also be set using the knobs. There will also be a built-in speaker on the front panel which can be disabled and an audio output for connecting higher quality external speakers.

Figure 1: Music Synthesizer Physical Design
1.4 High Level Requirements:

1. Recreate well known synth sounds used in popular songs. Some examples of sounds would be the synthesizer parts of Cinema Show, On the Run, and Lunar Sea.
2. The synthesizer will be able to produce the correct pitches for at least 24 consecutive keys, or two octaves, from the MIDI keyboard.
3. Have the ability to read key inputs from a file on an SD card and play them back through the synthesizer as if they were notes being played on the keyboard. Also, the SD card can have multiple files, and the file being played can be cycled through.
2. **Design**

2.1 Block Diagram:

![Block Diagram](image)

2.2 MIDI Module

The MIDI module is responsible for receiving key presses and generating a voltage corresponding to the note’s frequency that will then go to the synthesizer module. The key presses can come from either the MIDI keyboard or from a file saved onto an SD card. Multiple songs can be saved onto the SD card as separate files, and these can be cycled through using buttons on the front panel. The MIDI has two inputs, it will come from either the SD card via a button on the device, or the MIDI microcontroller will receive inputs from the MIDI keyboard. The MIDI microcontroller will use an ATMega Board [2] as this is a lower cost option and will act as a stand alone MIDI device that can then be connected to the MIDI keyboard. There is an option to use a USB
connector to be connected into the computer as well, so this can be explored further through testing.

2.3 Synthesizer Module

The synthesizer will work on the principle of subtractive synthesis. First, two voltage controlled oscillators (VCOs), one of which is a square wave and the other is a triangle wave, will be generated. These can be mixed together in a controlled amount. Additionally, the pulse-width of the square wave can be controlled, as well as the relative time between the rising and falling of the triangle wave, and these will both be categorized as the “shape” of the oscillators. The relative pitch of the oscillators can also be tuned.

Then the output of the mixed, complex wave is fed into the low pass filter. This has a controllable cutoff frequency and resonance.

This goes into the envelope generator, which shapes the amplitude to produce a sound which varies in loudness over time. The envelope generator can also modulate the cutoff for the filter, allowing for example the higher harmonics to only be present at the beginning of the sound.

Another function is the low-frequency oscillator (LFO). This frequency can be selected in the range of less than 1Hz to about 20Hz. It can be used to modulate the frequency of the oscillators, the shapes of the oscillators, the cutoff of the filter, and the sound’s amplitude. The level of modulation can be controlled individually for each parameter.

2.4 Power Supply

Power supply is used to power the microcontroller through a MIDI connector that has 5 pins. Pins 4-5 will pull in 5V [5]. The synthesizer module will require +10 V as it is an analog synthesizer. Taking into consideration the power needed for both the midi connector and what is required for the synthesizer, the holistic voltage needed will be +10 V estimate, and may be required to add +5 volts if needed through testing.

2.5 Audio Output

The synthesizer module will be connected to an audio output that will be in the form of a connected speaker that will play the sound that is passed from the envelope generator. There will be two speakers that will play the outputs. One will be a built-in speaker
included on the front panel, and the other will be an external speaker connected with an audio cable. The speaker to be used is selectable by a switch in on the front panel, and there is also a volume knob.

2.6 Risk Analysis/Tolerance Analysis

In order for the device to function as intended, it is imperative that the device is unit tested as it is built. Since the audio output (which is the main goal of the project), relies on a chain of inputs with both the microcontroller and the synthesizer module. Utilizing unit tests will mitigate risks for the overall project as the device will be built section by section and then tested thoroughly.

One of the challenges with the synthesizer module will be designing each component of the module to be voltage controlled. The voltage control aspect is important to have the device function accurately and this will be dependent on the gain, bias and waveshape.

3. Ethics and safety

After reviewing IEEE Code of Ethics document, section 7, we do not perceive there to be a privacy risk of data or information that is stated in the first statement of the IEEE Code of Ethics. There will not be any user specific data that will be stored in the current design, so that the safety of user data will be protected. In section 1.5 the ethics document specifies that it is a professional's opportunity to acknowledge and correct errors [3]. As a team we will uphold this by routinely evaluating roadblocks that occur within the project and remaining honest if there are flaws in implementation.

Also, the project will uphold the code detailed in the ACM Code of Ethics and Professional Conduct [3]. Specifically, ACM states in Section 1 that computing professionals must honor confidentiality. In order to uphold this, the project will not be containing any confidential or any patent application initially. In Section 2, Professional Responsibilities, professionals working should ensure that they are creating high quality work and communicating with either stakeholders or team for transparency. This is important because it will ensure that awareness of potential consequences is understood, and through this project the team's responsibilities will be to communicate effectively with TA and professors and the rest of the team to mitigate any discrepancies. Furthermore, in section 2.9 of ACM, it is the professionals responsibility to design and implement solutions that are robustly secure. The responsibility aligns with continuously patching and reporting when there could be a security breach. The
music synthesizer will not be connected to any public interface, for example public web facing applications which will keep the device secure from third party threats.

References


