

Modular Analog Synthesizer

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1 Introduction

1.1 Objective

Music is a passion for people across all demographics. From young to old, across the globe, music plays a major role in the lives of many. Music education in particular is a favorite of many schoolchildren at young ages because it is usually enjoyable and they love learning about music. One thing that most music education at young ages lacks is access for students into something called timbre. Timbre is a term that refers to the sound quality of a note. It deals with the “smoothness” or “pleasantness” of a tone. One instrument that can produce a wide variety of timbres is the analog synthesizer, which some may consider a wonder of the 20th century.

Our goal is to bring this great technology to the people who may truly appreciate its use in modern times. Aside from being a fresh take on a classic instrument, our project will serve the additional role of bringing electronic musical theory to the classroom in one easy, portable machine. We will include not only the classic musical keys and pitches, but also a way for students to experience the concept of timbre with different waveforms of sound.

1.2 Background

Musical synthesizers first became popular in the 1960's with the popularization of modular synthesizers. This type of synthesizer employed the use of separate electronic modules like voltage-controlled oscillators (VCOs), voltage-controlled filters (VCFs), and voltage controlled amplifiers (VCAs). They were connected using patch cables to pass the signal between modules. These synthesizers were almost like a sandbox of sound, where one could synthesize

any sort of tone if given the proper amount of time to configure its numerous dials, switches and modules[3]. This was usually very time consuming and tedious, which is what led to the advent of presets programmed into keyboards in the 1980s.

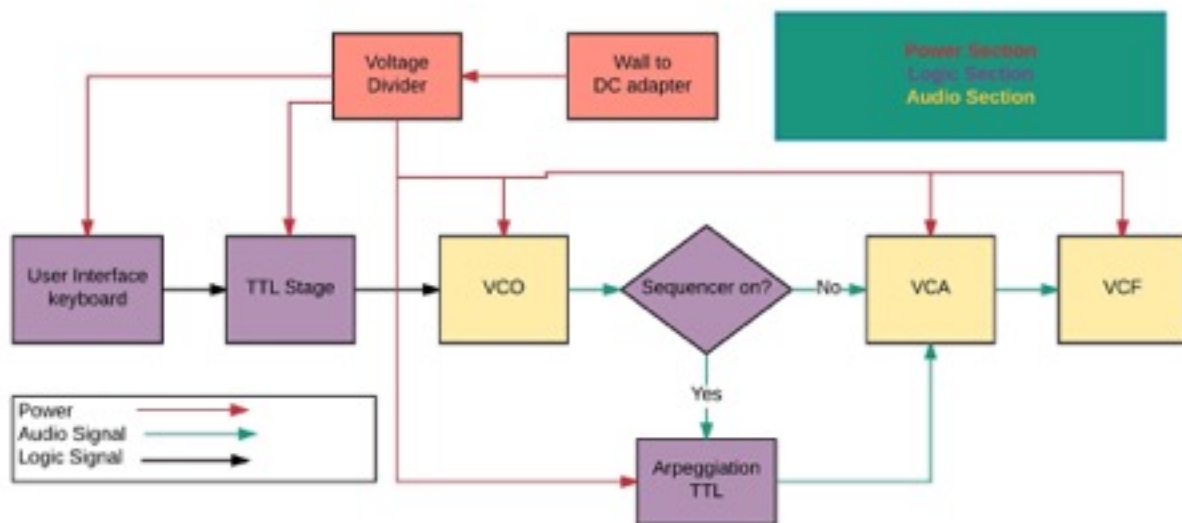
Something that has been scarcely available on the market is an easy way to explore timbre in relation to pitch with a keyboard setting. There is one product available (Haken Continuum) that accomplishes this, but it goes for over \$5000 and takes up a considerable amount of space[1]. This is because this system in particular is very advanced in that it provides a very precise measurement on a continuous spectrum of both pitch and timbre by tracking the two-dimensional position of one's finger as it presses down on a pad. The intricacy and precision of this device is unnecessary for our synthesizer. We will make a space-efficient, cheap, and accessible instrument intuitive enough for a child to understand, sophisticated enough to make complex tones and be fun for a musical aficionado to enjoy. This will be achieved by having three sets of keys, each with a noticeably different timbre as opposed to a system to track position of where the key is pressed. We will cut down on cost as well by eliminating most of the processing and computing that takes place in the Continuum, as they are unneeded for our application. We have selected the waveforms of sine, square, and triangle because these are three of the most popular in the industry with notable differences between them.

1.3 High-level requirements list

1. The voltage-controlled oscillator must produce frequencies ranging from 32.7 Hz to 261.63 Hz within 3%[2].
2. The voltage-controlled oscillators must produce 3 unique waveforms/timbres.

3. The arpeggiator must produce 4 separate and unique rhythms as specified in the arpeggiation TTL section below.

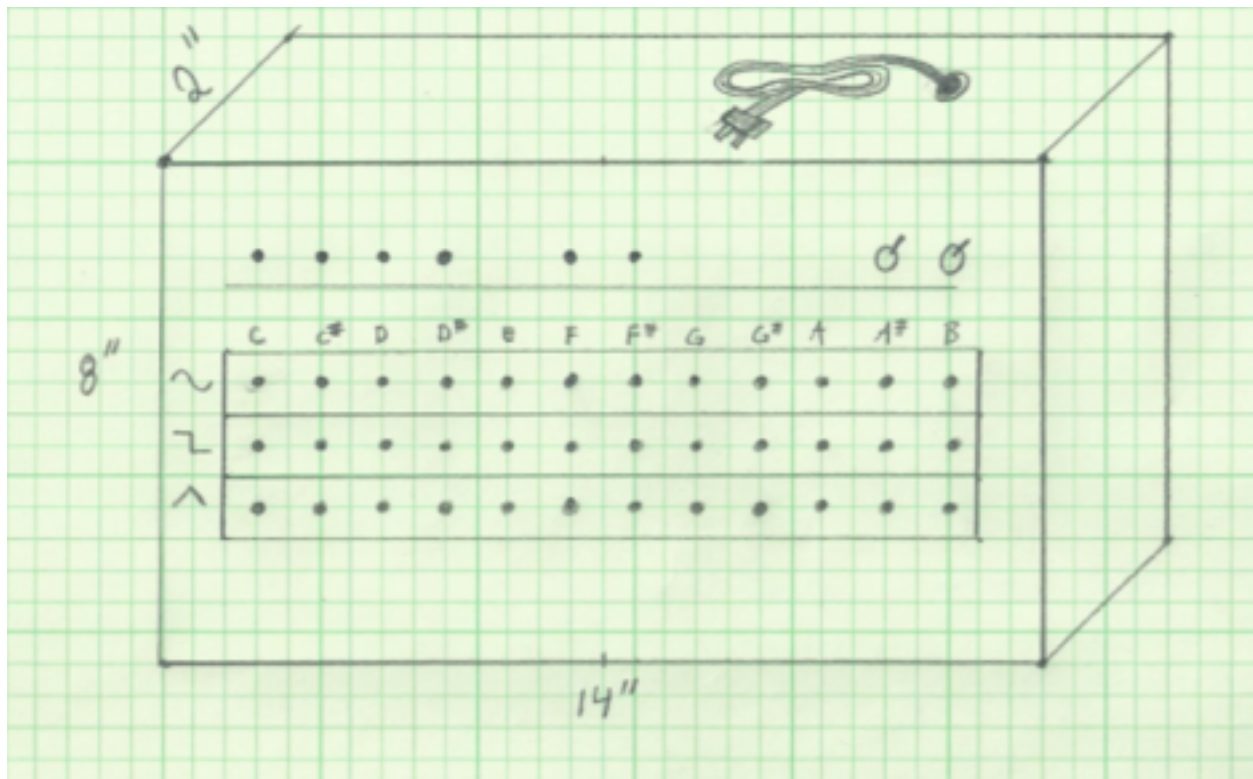
2 Design



2.1 Physical Design

This synthesizer will have a box shape with proposed dimensions of 14" long, 8" wide and 2" deep. The length and width of the box are basically decided but the depth of the box may be subject to change given that we will try to slim the box down as much as possible for a sleek appearance. The face of the box was designed around the keyboard and all 36 keys are placed into a grid consisting of one inch square boxes. Extending this grid over the rest of the face is how we arrived at the design. The face gets a one inch margin around the edges plus an extra inch at the bottom to create space for resting your hands. Above the row of keys, there is a one

inch margin for visual separation between the control knob section and the note keys. The sketch provided below is drawn to scale and each green box from the graph paper represents one half inch. The outer appearance of the box will naturally evolve throughout our design process with things like beveled/rounded edges or higher quality buttons. The main part is the grid of 36 buttons that make up the keyboard. There are 12 keys, representing one octave, for each waveform. There is a space below these keys to place a wrist pad is desired. The top row of buttons/knobs from left to right are for the four arpeggiator selection keys, arpeggiator on/off, the synthesizer on/off, octave switching knob and the volume knob. A power cord connects to the back of the box.



2.2 Power delivery

2.2.1 Wall to DC adapter

The wall to DC adapter is responsible for converting the 120 VAC from the wall into 24 VDC for the synthesizer.

Requirement: The wall to DC adapter must deliver 24 VDC to the synthesizer.

2.2.2 Voltage Divider

The voltage divider will be responsible for distributing power to each of the other components. It will take 24 VDC from an AC/DC wall adapter and distribute appropriate voltages to each section accordingly.

Requirement: Must provide the correct voltage to each component within +/-1%

2.3 Logic Stages

2.3.1 Keyboard Input

The keyboard input will consist of 3 rows of 12 momentary switches, the 12 notes in an octave with 3 waveforms each. Each switch will correspond to one logic coordinate for the TTL stage to select which voltage to send through.

Requirement: Each switch must correspond to a separate and unique binary number for use in selection.

2.3.2 TTL Logic

The TTL will be responsible for relaying the correct voltage to the VCO. It will take 36 inputs and distribute them accordingly to the proper VCO. The TTL stage will also be responsible for delivering the correct waveforms to the arpeggiation function.

Requirement: The TTL logic must relay the correct voltage when a switch is pressed.

Requirement: The logic must deliver the correct voltage to the arpeggiator.

2.3.3 Arpeggiation TTL

The arpeggiation TTL is responsible for deciding which notes to play at which times. There are 4 preset rhythms set to play each wave by itself at a separate time.

Requirement: The Arpeggiation TTL must play the sequence (sine, sine, square, square, triangle, triangle, sine, square).

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2.4 Signal Processing

2.4.1 VCOs

The VCOs are the central component, operation-wise. This is the stage that produces the signal that will later become audible sound. It is imperative that these provide consistent outputs for their corresponding voltages and waveforms. There will be one VCO for each waveform.

Requirement: Each VCO must produce its correct waveshape (sine, square, and triangle).

Requirement: Each VCO must produce its correct frequency from each voltage within +/-1%.

2.4.2 VCF/ Waveshapers

The waveshapers and VCF are responsible for regulating the waves' integrity and sound quality. The VCF will be an active filter that helps to eliminate noise and static from the sound before it gets amplified. The waveshapers will help to make sure the sound waves are in the proper shape.

Requirement: The VCF will act to eliminate noise and static caused by high-frequency fluctuations.

Requirement: The waveshapers will regulate the shapes of the waves coming out of the VCO.

2.4.3 VCA

The VCA will actively amplify the signal so that it will be able to be heard when sent through a speaker.

Requirement: The VCA will amplify the signal to have a 20 VPP amplitude.

2.5 Risk Analysis

The most significant point of failure is definitely in the TTL stage. This is where the instructions for the signals are sent. The VCO has a possibility of going wrong, but is not nearly as fragile as the TTL stage. If we cannot pass the different voltages through our MUXes almost exactly, the wrong frequency will be produced and we will fail to achieve our intended result.

3 Ethics and Safety

The only relevant safety concern for our project is the danger presented by the use of electricity. It is supplied by 120 VAC from the wall and then converted to 24 VDC inside the closed box.

Our team has years of experience working with these voltages and in fabricating electrical circuits. We will follow all the normal safety guidelines such as the one-hand method. However, the only danger presented to the end user will be plugging in the power cord to the wall outlet.

In accordance with IEEE Code of Ethics Section 7, this synthesizer box will be designed so the

end user will not be exposed to any hot wires[4]. The danger exists inside the synthesizer box and it is designed to remain closed for the end user. Certain ethical concerns have been raised about preloaded melodies and so we have eliminated this by designing a unique method for arpeggiation where the user chooses the sequence of notes from the keyboard.

References

[1]<http://www.hakenaudio.com/Continuum/hakenaudiopricia.html>

[2]Olson, Harry F. (1967). Music, Physics and Engineering. Dover Publications. pp. 248–251.
ISBN 0-486-21769-8.

[3]http://www.vintagesynth.com/sites/default/files/2017-05/moog_voyager_xl_lg.jpg

[4]<http://www.ieee.org/about/corporate/governance/p7-8.html>