Modular Synthesizer

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Introduction

A modular synthesizer is an electronic device that consists of individual modules that can be connected by a user to create a music instrument. Modules specialize in a task such as creating a specific signal or affecting a signal in some way. For example, a sawtooth oscillator may be one module and a device to mix multiple signals together (a mixer) may be another. By connecting these devices together in various ways many sounds, and musical uses may be produced.

Objectives

The end goal is to create enough modules and a variety of them to provide a versatile instrument. Specifically, we wish to create a power supply for the modules, an oscillator as a sound source, an ADSR envelope as a modulation signal, and a filter. All the modules should be voltage controlled, meaning they can be controlled by an input voltage from another module. A voltage to current exponential converter will be used to convert a controlled voltage (CV) to a controlled current. Doing this allows Operational Transconductance Amplifiers (OTA's) to be used in circuit design as a way of adjusting each module. By having each module be voltage controlled, the modules will be able to interact and control each other.

Constraints of the Design

•The Power Supply will have outputs for +/- 12 Volts and +5 Volts. It will be able to take any U.S. standard outlet for supplying the power supply through a wall wart

•Patches to modules on the user side will be done with standard 3.5mm ⅛ inch mono jacks. Stereo jacks will be used where appropriate if needed.

•One Volt per octave is the standard for the voltage to current converters. This means for each volt, the current doubles meaning, the frequency of the oscillator will double. This is a common tuning standard so that voltages correspond with musical pitches.

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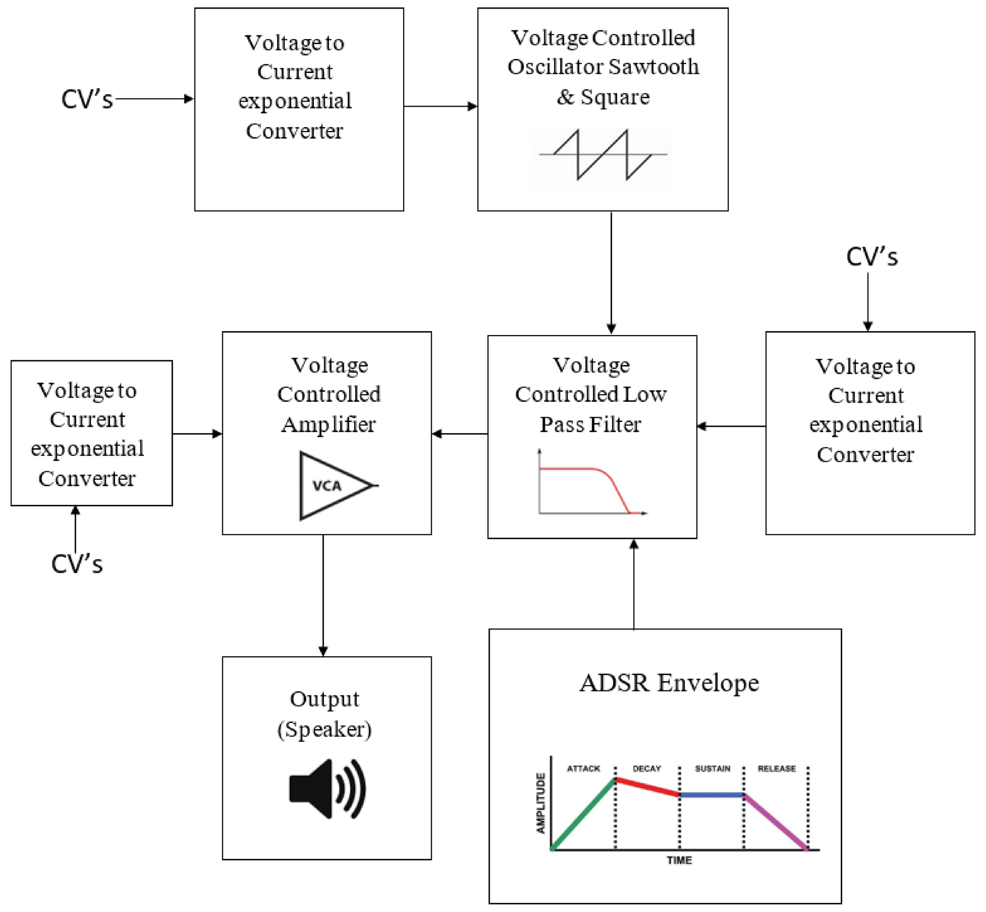
Steps of Design for Circuits

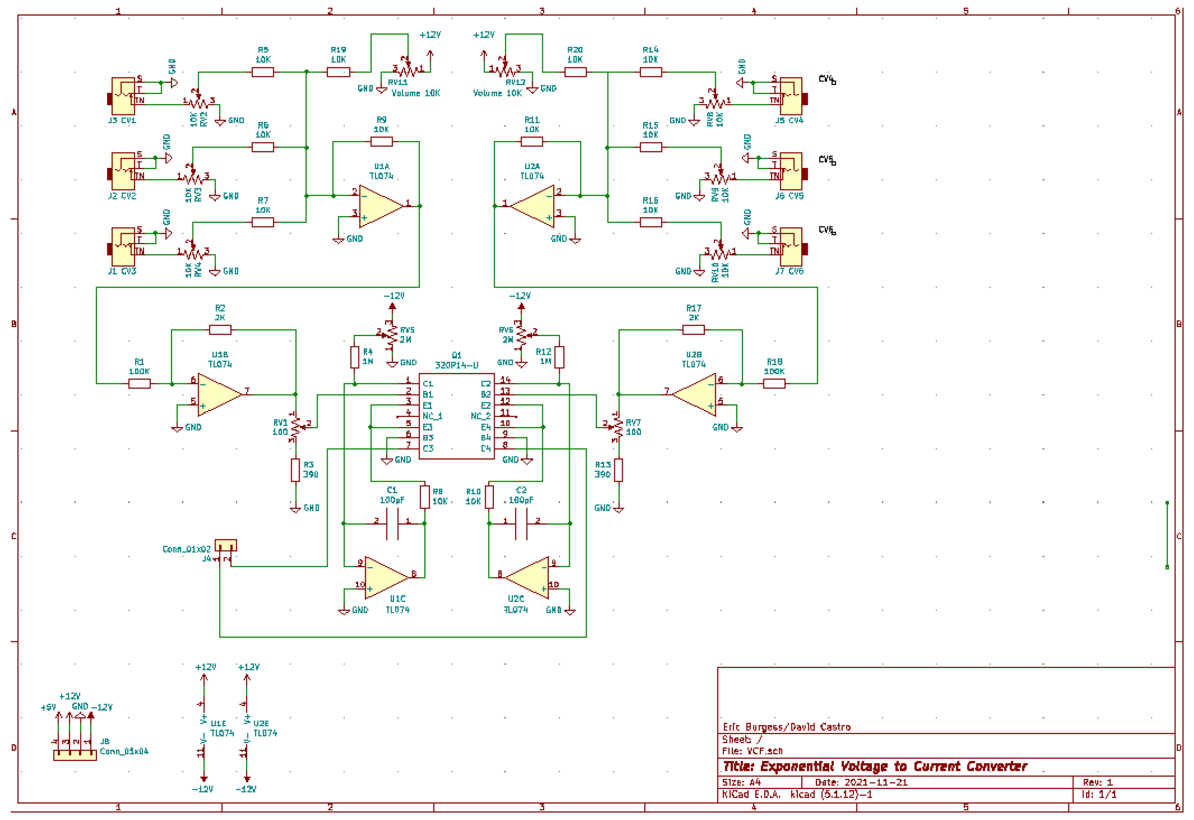
1. Circuits were designed and simulated in Multisim
2. The circuits were tested/built on a Bread board
3. Design EuroRack Standard Case
4. Were initially going to solder by hand, but decided upon using KiCad for PCB design and ordering the PCB's from an online website
5. Panels/Covers were initially going to be done by hand but decided to use the KiCad and PCB material to act as the panels/covers
6. Solder the components onto the PCB and then screw everything together
7. Test and Debug the circuits to see if they properly work

Block Diagram



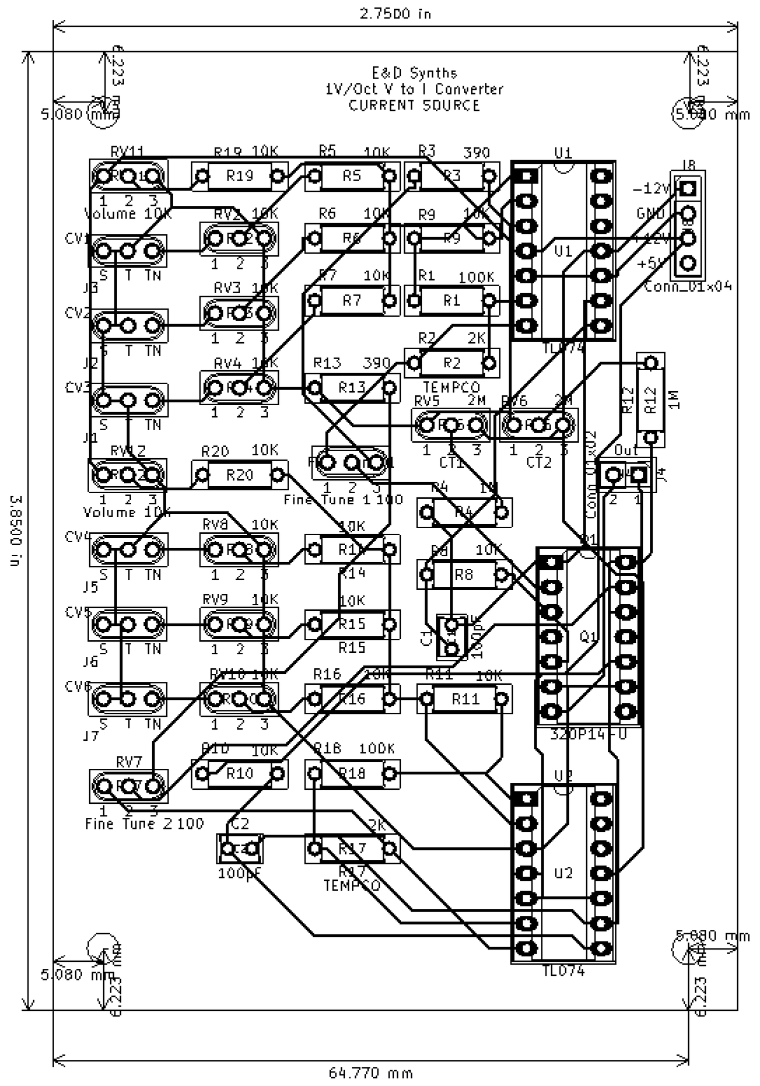
Description: This block diagram is an example of how the modules can be connected. The only thing standard is the CV's and the voltage to current converters before each voltage-controlled module. A different way of connecting the modules could be having the ADSR envelope connected to the oscillator or amplifier instead

Voltage to Current Converter Circuit (source)



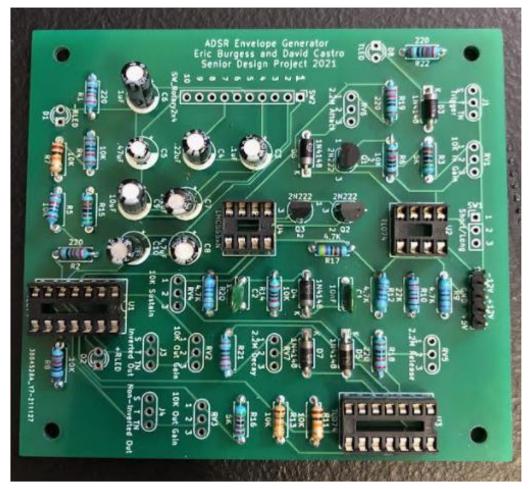
Description: The circuit shows 2 voltage to current converter circuits. Each have 3 control voltage inputs that are mixed through an active mixing circuit. From there it flows through an op amp gain stage that is used to tune down the voltage that will flow into the base of a BJT differential pair. The IC chip (320P14) is just two matched differential pairs (PNP). Nearly the same circuit applies for the circuit above the sink version. The main difference is that NPN BJTS are used in the differential pair chip.

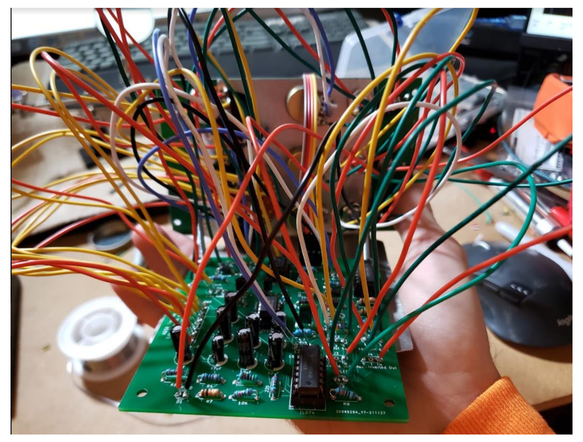
Layout of Voltage to Current Converter (KiCad)



Description: Due to time constraint an auto router was used for the layout. KiCad does not have a built in autorouter, but there as exterior tool that can do autorouting of a KiCad design and then be imported. Besides the routing, each of the PCB's were designed so that the screw holes would align up correctly with each other.

Printed Board of Voltage to Current Converted:

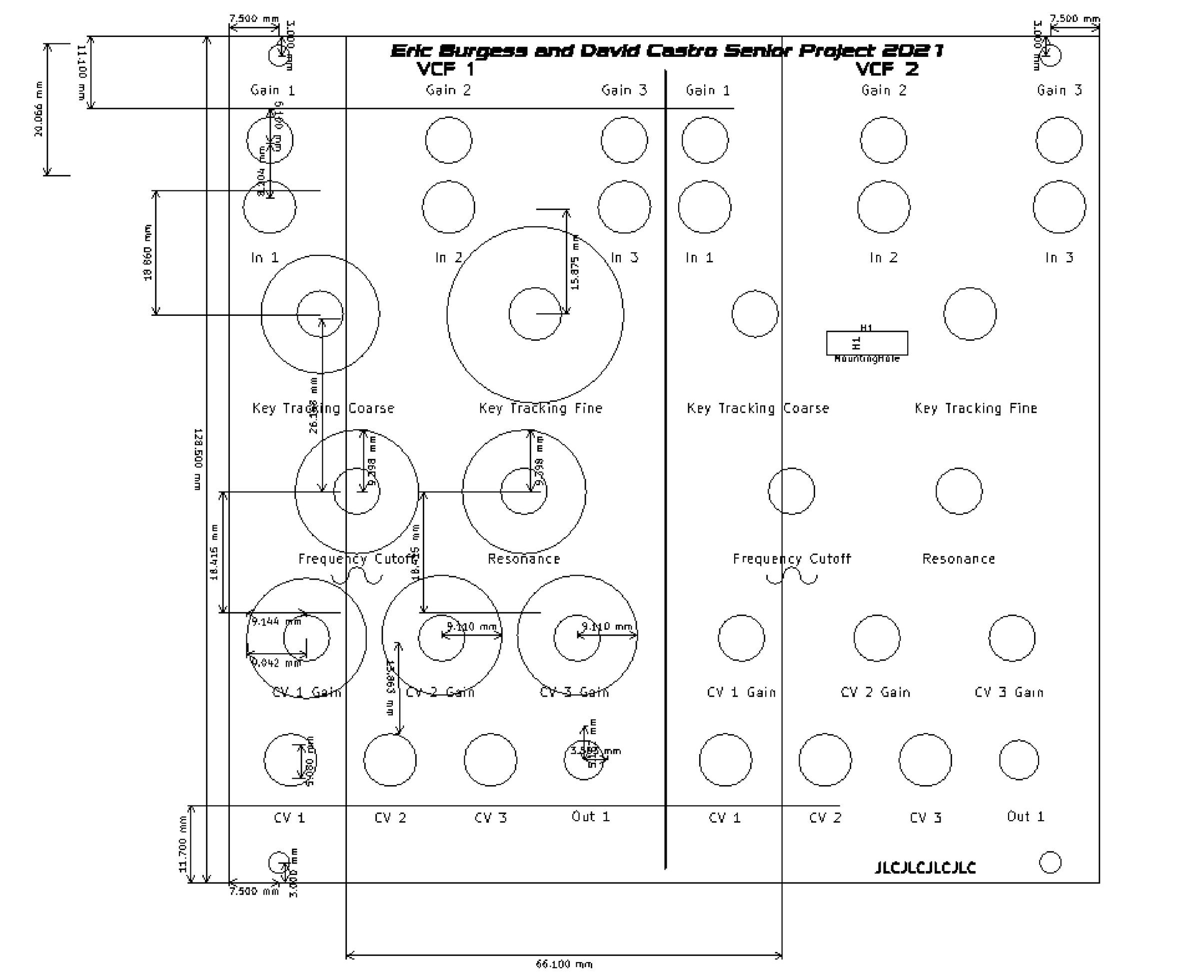


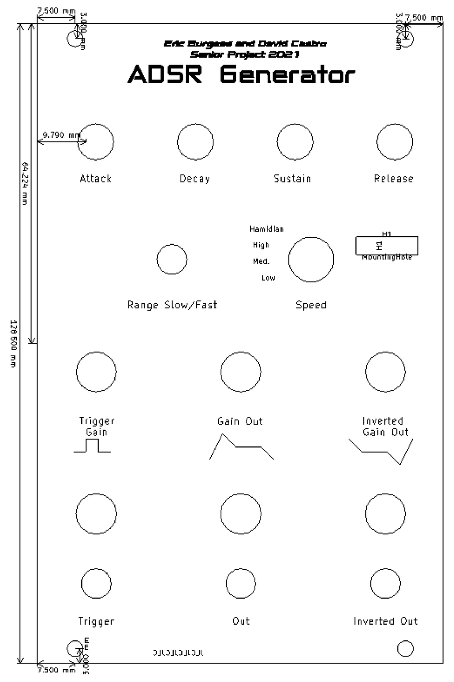


Description: The PCB board was designed as Though Hole (THT) with each of the chips, resistors, capacitors, etc inserted into the device. This process of PCB design is done for the VCO, VCA, and ADSR Envelope aswell.

Note: See Github link for the rest of the designs in KiCad

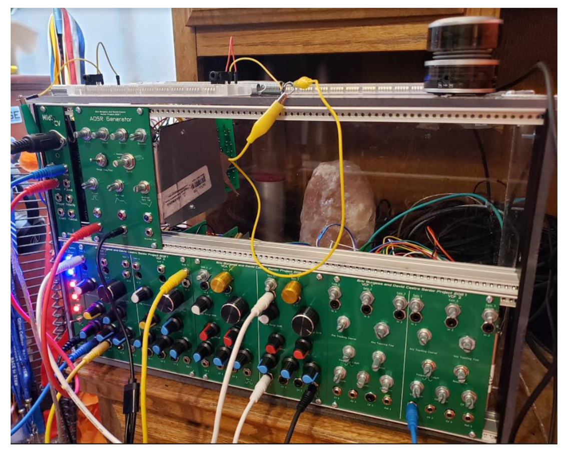
Example of Cover Panel Design (VCF)

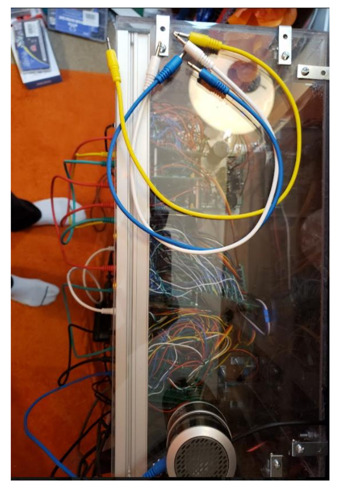




Description: The design were done in KiCad using the layout tool. It would be ideal for these to be done on aluminum sheets, but due the costs we decided on using PCB material, the same used for the circuits. This was done for each of the panels: VCA, VCF, ADSR Envelope, power supply, and MIDI device.

Final Product Pictures:





Inside Wiring within the case

Conclusion:

There were many problems that came along the way in order to achieve the goal of this project. Some of the modules did not initially work and currently there are some things in the final product that need adjustment. The layout and schematic designs had some errors that caused the need for there to be some external wiring or modding of the PCB board. One example is that the +Vcc and -Vcc were mixed up on one IC which caused the need to do some wiring off board. This problem also occurred for the ADSR where the BJTS did not have the same pinout on the layout. Also, a few of the devices when put in the case ended up having some functionality problems. This occurs because there are many wires and no cable management which means the wires are most likely touching and creating connections when there should be none. One of the sawtooth oscillators for example is affected by the PWM adjustment of the square wave. This problem was not seen until the module was put in the case and is believed to be caused by some wires touching each other. Another problem seen when putting the module in the case is the VCF where for some reason things will stop working at certain moments or sometimes a potentiometer would affect the other VCF. These problems could be fixed with proper cable management, but overall, the modules can be seen as a success as things behave correctly for the most part. In conclusion, a modular synthesizer was achieved, but some things need to be ironed out for it to always work properly.

References

Power Supply

http://musicfromouterspace.com/analogsynth_new/WALLWARTSUPPLY/WALLWARTSUPPLY.php
https://www.youtube.com/watch?v=pQKN30Mzi2g

Synthesizer Modules

Textbook resources:
Musical Applications of Microprocessors (Hal Chamberlin) - chapter 6

Websites of Synthesizer Designs and Explanations:

https://www.schmitzbits.de/expo_tutorial/index.html
•ADSR design https://www.schmitzbits.de/adsr.html
http://ijfritz.byethost4.com/sy_over.htm

Georgia Tech Professor: - Aaron Lanterman Lectures:

VCA - https://www.youtube.com/watch?v=96j2tNKFCPI&t=202s
VCO - https://www.youtube.com/watch?v=qF4G4QfC9dM&t=699s
Exponential Voltage to Current - https://www.youtube.com/watch?v=ZWJhApUmfEU
Playlist of Lectures:
https://www.youtube.com/playlist?list=PLOunECWxELQS5bMdWo9VhmZtsCjhjYNcV

Musical Instrument Digital Interface (MIDI)

Youtuber - Benny Bones: https://github.com/BennyBones/midi2cv

Github Link

GitHub Link of Final Report and all circuits and their designs in KiCad: https://github.com/EEdavidcastro/EE485-SeniorDesign-Modular_Synth