Analog and Digital Controlled Modular Synthesizer for Audio Synthesis and Signal Processing

Team 33
Joshua Turnipseed, Michael Nelson, Tobi Adeyemi, Peter Dufka
College of Engineering and Engineering Technology
Northern Illinois University, Dekalb, IL, USA
josh.turnipseed@proton.me, z1808464@students.niu.edu, z1869980@students.niu.edu, z1913659@students.niu.edu
Faculty Sponsor: Dr. Fonseca (Electrical Engineering)
bfonseca@niu.edu

***Abstract*— A synthesizer is an electronic musical instrument that generates and manipulates waveforms via electronic circuits, software algorithms, or other techniques to create various sounds, from traditional instruments to experimental sound effects. A modular, analog synthesizer comprises of several modules connected with patch cables. Eurorack is a popular modular synthesizer format due to its versatility, flexibility, and scalability. The goal of this project was to create Eurorack-compliant modules for an analog synthesizer. To reach this goal, the team had to apply knowledge related to electronic circuitry, signal processing, and user interface design, as well as consider technical specifications and compatibility requirements. The result was a musical instrument for live performances, studio recordings, or experimental sound art projects.**

Keywords: Synthesizer, Modular, Analog, Eurorack.

I. Introduction

The goal of this project was to design and construct a modular Eurorack synthesizer. A modular Eurorack synthesizer is a customizable device that generates and manipulates sound using individual modules connected together. Eurorack is a popular synthesizer format due to its standardized size and power supply system, allowing modules from different manufacturers to be combined. Modules can be classified as audio sources, audio modifiers, Control Voltage (CV) sources, or CV modifiers, each with inputs and outputs to connect to other modules. The signal path consists of two different signals: audio and control. The audio signals are the sounds that can be heard while the control signals are not heard directly but affect the audio signals in some noticeable way. These signals are routed between each module's inputs and outputs by patch cables. External control can be achieved by CVs from other devices or from a Musical Instrument Digital Interface (MIDI) keyboard or controller. MIDI is a protocol for sending musical information digitally. For this information to be used in our device, MIDI messages must be converted to an analog CV. In short, the synthesizer accepts MIDI messages which are converted to CVs. It generates a waveform based on these CVs which is then processed by subsequent modules. Its output can be used for real-time sound generation or recordings for later playback. A high-level flowchart of this is demonstrated in Figure 1. This method of synthesis is known as subtractive synthesis. Under this method, a harmonically rich waveform is generated and then filtered to produce the desired sound.

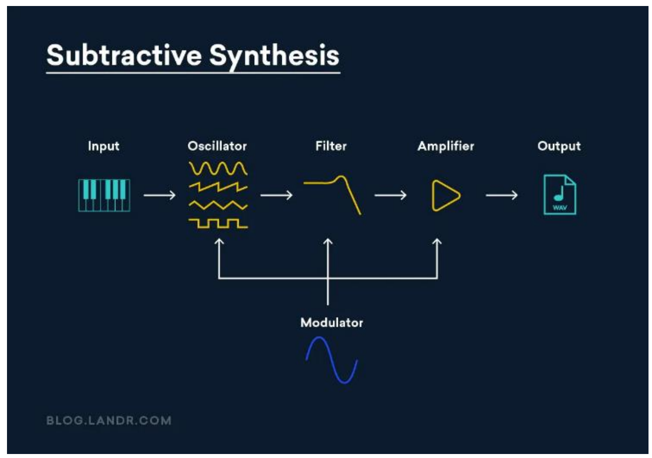

Figure 1. Subtractive Synthesis Basics [1]

II. Project Description and Scope

There are many considerations that come with synthesizer design. Because of this, the team decided to adopt the Eurorack synthesizer format. In this way, some design decisions would be constrained to adhere to the specifications of the Eurorack format. Eurorack was selected due to its flexibility, expandability, and popularity. Modules can be designed in parallel; mounted and powered by Eurorack cases; and interface with other 3rd party modules.

The Eurorack format lays out two distinct specifications: mechanical and electrical. The mechanical specification defines the physical dimensions of the modules and how they mount in a case. The electrical specification defines the voltage levels for power and signals. Eurorack power supplies provide ±12V. +5V is also provided for any digital components. Audio signals range from ±5V, while control signals range from ±2.5V for bipolar CV sources and 0V to +8V for unipolar CV sources. These are typically values for CVs; modules must withstand input voltages within the ±12V range. 3.5mm patch cables connect audio and CV signals between modules. Module parameters can be adjusted on the module's front panel or by CVs. Figure 2 shows how CVs are used to adjust module parameters.

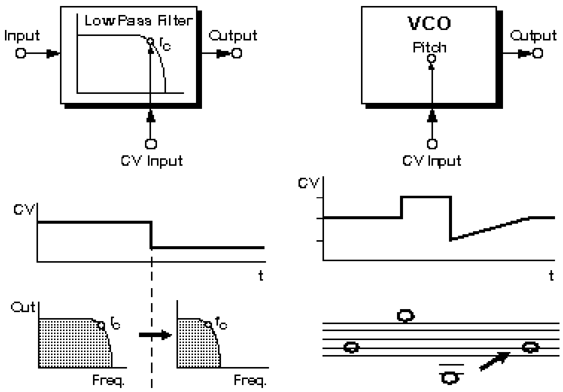

Figure 2. The Principles of Voltage Control [2]

III. Modules

The team has designed ten modules that perform the functions of a synthesizer. Those modules are as follows:

1. MIDI to CV

A MIDI to CV module translates MIDI signals from a digital message into analog CVs.

2. Voltage Controlled Oscillator (VCO)

A VCO module produces a waveform with a variable-frequency based on a CV.

3. Voltage Controlled Amplifier (VCA)

A VCA module controls the amplitude or volume of an audio signal based on a CV.

4. Voltage Controlled Filter (VCF)

A VCF module filters the frequency content of an audio signal with the cutoff frequency of the passband being controlled by a voltage.

5. Envelope Generator (EG)

An EG module produces a time-varying CV used to shape the amplitude, timbre, or other module parameters.

6. Low Frequency Oscillator (LFO)

An LFO module generates a periodic waveform used to modulate the pitch, amplitude, filter cutoff frequency, or other module parameters.

7. Mixer

A Mixer module is used to adjust the volume levels of multiple audio signals and sum them into one output signal.

8. Multiple

A Multiple module duplicates and distributes incoming signals to multiple output channels.

9. Attenuverter

An Attenuverter module can attenuate and/or invert incoming signals with adjustable levels of control.

10. Delay

A Delay module creates an echo or repeating effect by delaying and repeating an input signal with adjustable parameters such as delay time and feedback.

These modules can be connected in a variety of ways by a user to create different signal paths. These differing paths allow for unique and complex sounds to be generated and processed. Since these combinations of modules are created by patch cables, a user can easily change the signal path whenever they wish, even in mid performance. Figure 3 shows one example of how all ten designed modules can be connected together as a system.

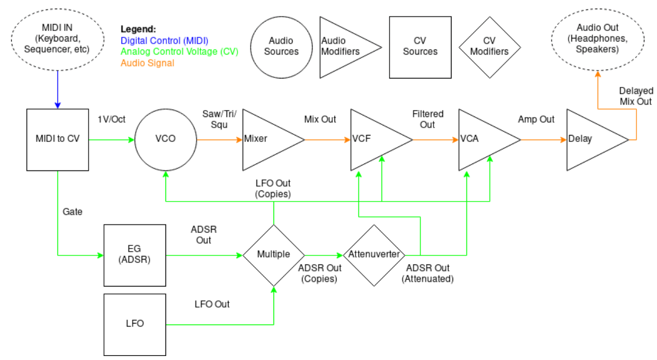

Figure 3. Example of System Block Diagram

IV. Results

Each module designed performs its functions as expected. The modules adhere to the Eurorack format and can interface together to form a larger synthesizer system. This synthesizer can be played and controlled by a user.

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