16 Step Analog Sequencer with Digital Tempo Input

Team 1 - Justin Sconza and Kyle Vondrak

ECE 445 Project Proposal - Spring 2017

TA: Eric Clark

1 Introduction

1.1 Objective

Analog electronic musical instruments are generally very expensive. There are two main reasons for this. The first is simply because the market is small. The second reason is that certain analog, discrete-form electrical components, like matched BJT's for example, which are necessary for building analog electronic musical instruments, are expensive as well as not consistently manufactured.

Our objective is to build a modern take on a 70's style analog music synthesizer, which will be controlled by a digital step-sequencer. In the simplest possible terms, we aim to make a looping melody machine. The synthesizer will be driven by a voltage controlled oscillator implementing a linear voltage to exponential current circuit. A digitally controlled step-sequencer will continuously loop the oscillator through sixteen steps, defining sixteen notes in a user created melody.

Our implementation will be physically different in the sense that the schematic as well as the layout and design will be entirely our own. Additionally, these types of instruments are generally very over-priced and ours will cost much less than anything out there on the market currently. As an example of this last point, a good step-sequencer, like the Doepfer Dark Time, goes for around $725 [1]. A good analog VCO based synthesizer, like the Moog Voyager, goes for upwards of $3,000 [2]. And these two pieces must be bought separately in order to achieve what we aim to accomplish in one instrument.

1.2 Background

Musical electronic synthesizers with built-in with step-sequencers, as they are known today, first became available in the 1960's and 70's with the advent of commercially available transistors. During this golden age of the analog audio synthesizer, these devices were extremely expensive and were consequently for professional use only. Two famous examples of musical step-sequencers from this era include the Moog 960 and the Buchla 100 [3]. Beginning in the early 1980's, as home computers and other consumer-level digital products became more widely available, step-sequencers became digitally controllable as well as affordable by the average enthusiast. Examples from this period include the Linn LM-1 and LM-2 machines [4].

Beginning in the early 1990's however, hardware step-sequencers were mostly replaced by software, GUI based instruments [5]. Today, there are no widely available analog synthesizers with built-in step sequencers. In fact, there are only a handful of boutique companies that make analog synthesizers and unfortunately, they do not function exclusively as step-sequencers. Likewise, there are only a few companies that make hardware step-sequencers and sadly, they do not sequence sounds synthesized internally.

Our instrument will be both self-contained (a step-sequencer combined with a synthesizer) as well as less expensive than anything on the market currently.

1.3 High-Level Requirements List

- Tempo of sequenced melody must be digitally user-controllable and re-settable to any integer value ranging from 1 to 9,999 beats per minute.
- Sequencer must be programmable, via physical buttons on the device, to rest for any step as well as start over at any step during its loop.
- The linear-to-exponential voltage controlled oscillator must be capable of saw tooth, square and triangle wave output.

2 Design

From a high-level perspective, our design is composed of four stages. The first is the MCU stage, where the user may input a desired tempo for the looping melody. The TTL stage is for the actual step-sequencing of the melody. The user will set sixteen voltages via potentiometers and these sixteen voltages will be looped through by a TTL counter in combination with an analog MUX. The synthesizer stage consists of the analog, voltage-controlled oscillator (VCO). The type of waveform output by the oscillator will be selectable by the user as saw tooth, square or triangle. The last stage is the power supply, which will supply and regulate the correct power requirements for each of the three previous stages.

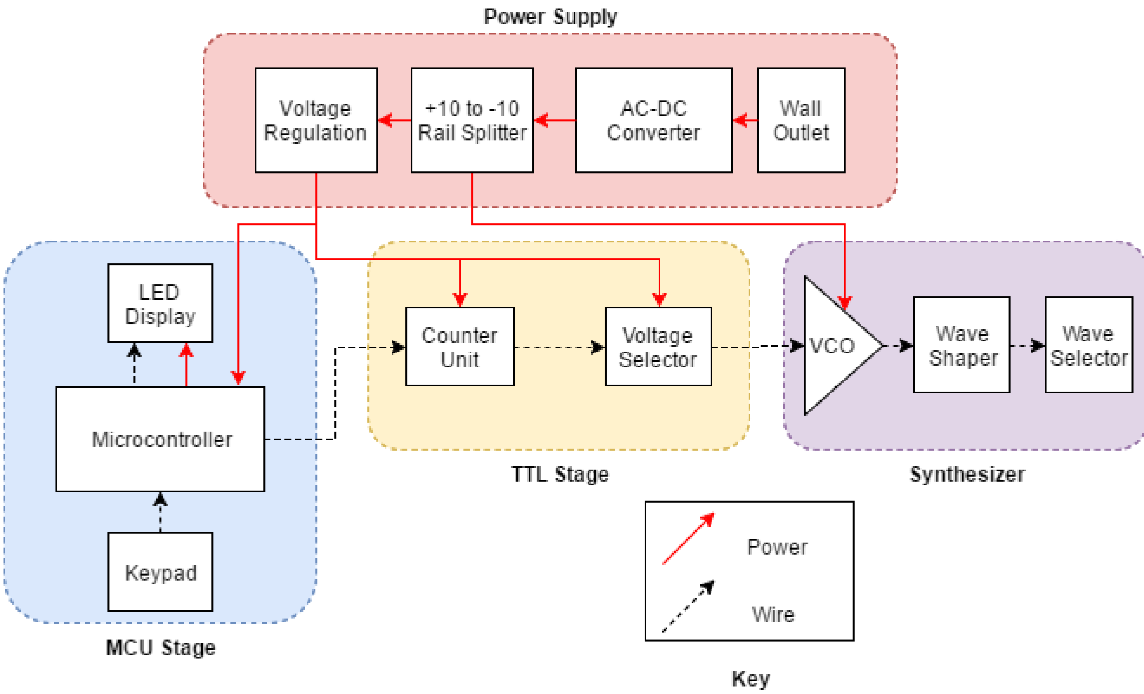

Figure 1: Block Diagram for Overall System

In Figure 2 below, we present a rough artist's rendition of what the physical device might look like upon completion. Because we have not selected which sliders or buttons will be used, it does not make sense to design a physical layout with precise dimensions just yet. This figure may prove useful however in terms of getting a feel for what the instrument might look like.

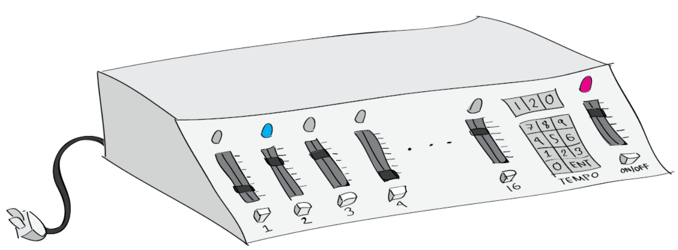

Figure 2: Artist Rendition

2.1 MCU Stage

The MCU stage manages the tempo that will be output by the unit, and allows an interface for the user to input and see the beats-per-minute value that they are typing in.

2.1.1 Microcontroller

The microcontroller we have chosen is an ARM MCU. It will handle converting the analog input from the keypad to a digital PWM wave that will then drive the clock for the TTL stage. It will also send analog output to the 7-segment display so the user is able to see the current beats-per-minute.

Requirement 1: *The supply must be 3.3V. +/- 5%.*

Requirement 2: *Must be able to convert input ranging from 1 beat-per-minute to 9999 to Hz, and then output a PWM at that frequency.*

2.1.2 Keypad

The keypad will allow the user to type in their desired beats-per-minute to control the ARM MCU. The $*$ and # keys correspond to clearing the tempo display and starting a new tempo

Requirement 1: $*$ *must clear the display but not stop the sequencer.*

Requirement 2: # *must restart the sequencer at a newly defined tempo.*

2.1.3 LED Display

The LED display will allow the user to know what the current beats-per-minute value of the overall system is. It should be updated every time the user changes the beats-per-minute value via the keypad.

Requirement 1: *Must display the current beats-per-minute of the microcontroller.*

2.2 The TTL Stage

The TTL stage is fed with a clock signal from the MCU stage, and combines that with user defined voltage values and consolidates it down to one signal that can then be sent to the synthesizer to create different tones.

2.2.1 Counter Unit

The counter unit consist of pressible buttons that can control a 4-bit counter via TTL logic. The counter will be supplied a clock from the MCU stage, and the buttons will control the starting, stopping and resetting of the counter.

Requirement 1: *Must count from 0 to the number of steps the user specifies.*

Requirement 2: *Button press must perform its task in a timely manner.*

2.2.2 Voltage Selector

The voltage selector unit will consist of a a 16:1 analog MUX. It will take inputs from potentiometers that the user will set, and select one at a time to be sent to the synthesizer. It will also contain LEDs that will show the user what step number the sequencer is currently on.

Requirement 1: *Must accurately select one of 16 voltages within +/- 1%.*

Requirement 2: *Potentiometers are able to create a voltage range from 0 to 5V.*

Requirement 3: *LEDs light up on the correct step, and are visible from at least 10 feet away from the unit.*

2.3 Synthesizer

The synthesizer stage consists of the linear-to-exponential voltage controlled oscillator followed by a waveshaper section. The user will be able to select a sawtooth, square or triangle waveform for the output.

2.3.1 VCO

The VCO is a linear-to-exponential oscillator that allows us to map frequencies from 20Hz to 20kHz from a voltage that does not have to sweep through the same values. The VCO also will allow the user to feed additional smaller signal and lower frequencies oscillations on top of the voltage controlled note in order to provide frequency modulation, sometimes called vibrato in the musical world [6].

Requirement 1: *Frequency output must be within 0.1%.*

Requirement 2: *Output voltage range must cover 5 octaves ranging from 3 below 440 Hz to 2 above.*

2.3.2 Waveshaper

The waveshaper takes the output from the VCO and converts it into three different wave shapes, those being sawtooth, square and triangle. This will allow for different effects that the user will hear.

Requirement 1: *Each waveshape voltage is affected by less than 1%.*

2.3.3 Wave Selector

The wave selector will provide a means for the user to select which wave shape they would like the system to output.

Requirement 1: *Correctly selects the desired wave shape.*

2.4 Power Supply

The power supply is required to keep the system running. Each of the previous three sections has different voltage requirements, so a power supply is needed to regulate the power to each stage.

2.4.1 AC-DC Converter

This converter will take 120 VAC from a standard wall outlet and convert it to 24 VDC. This will allow our system to be plug and play, so it is usable in any space where standard wall outlets are available.

Requirement 1: *Regulates wall outlet voltage to 24VDC +/- 1%.*

2.4.2 -10V to +10V Rail Splitter

The rail splitter chip will allow us to take the 24V DC signal and create a -10V and +10V with a common ground. The VCO stage requires a negative and positive voltages to operate.

Requirement 1: *Splits the input voltage to to one half +/- 2%.*

2.4.3 Voltage Regulator

For the voltage regulation we will utilize a 3.3V IC and a 5V IC to supply the correct voltages to the MCU stage and the TTL stage, respectively. The two chips must be able to handle the peak voltage from the AC-DC converter.

Requirement 1: *3.3V IC must supply 3.3V +/- 5% at 1A*

Requirement 2: *5V IC must supply 5V +/- 5% at 1.5A.*

2.5 Risk Analysis

The block which poses the greatest risk to successful completion of the project is the VCO. Getting frequency output within the audible range will not be challenging. The difficulty will lie in achieving linear-to-exponential conversion within a tolerance of 0.1% error. This is the degree of accuracy required to meet the exponential sensitivity of human hearing to frequency. If this level of precision is not met, the device will not function as a typical musical instrument capable of playing notes in melodies as other instruments do.

3 Ethics and Safety

There are a few safety concerns with out project. The concern would be making sure proper precaution is used when dealing with wall outlet voltage at 120V AC and converting it to 24V DC, which is for all intents and purposes, an absolutely manageable safety concern. We will utilize the one hand method and make sure our wall outlet contains a ground. Also, we will need to ensure that the AC-DC conversion is closed off from the user so they will never come into contact with high voltages.

Additionally, when dealing with high voltages, it can create large currents and dissipate heat [7]. We will need to ensure that precaution is taken on our part to ensure that this excess heat is handled correctly to avoid hazards in testing, but also in the final product so the user is never exposed to this.

We are responsible for all decisions made in the design of this product and it is our responsibility to disclose any issues that issues that might endanger the user per Section 1 of the IEEE Code of Ethics [8]. We believe that if properly designed, we will be able to mitigate these hazards to create a pleasant and enjoyable experience for the user.

Our system will be designed to be plug and play, being compatible with common wall outlets. Given the high voltage, and our lack of experience in designed high voltage converters and regulators, we have chosen to simply their design by utilizing ICs and off the shelf converters. This is in accordance with Section 7 of the IEEE Code of Ethics [8].

References

[1] (2017) Doepfer dark time - step sequencer with blue leds. Sweetwater. [Online]. Available: https://www.sweetwater.com/store/detail/DarkTimeBL?adpos=1t1&creative=175866237996&device=c&matchtype=b&network=g&gclid=COKLt92u-9ECFQMMaQod_ZIC_A

[2] Aluminium minimoog voyager. [Online]. Available: https://www.moogmusic.com/products/minimoog-voyagers/aluminium-minimoog-voyager

[3] (2017) Music sequencer. [Online]. Available: https://en.wikipedia.org/wiki/Music_sequencer

[4] (2017) Linn lm-1. [Online]. Available: https://en.wikipedia.org/wiki/Linn_LM-1

[5] L. Sasso. (2012, 04) Issue navigator. [Online]. Available: http://www.soundonsound.com/techniques/step-sequencing

[6] H. Chamberlin, *Musical Applications of Microprocessors.* United Kingdom: Hayden Bk.Co.,U.S., 07 1981.

[7] S. Electronics. (2010) Power and thermal dissipation. [Online]. Available: https://www.sparkfun.com/tutorials/217

[8] (2017) Ieee code of ethics. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html