Team 80

Modular Synthesis as an Educational Tool

Team Advisor: Dr. Jin-Woo Choi

Team Members:

Kyle Sellers

Project Manager

ECE

Taylor LeBlanc

Team Leader

EE

Rafael Alvarez

Team Treasurer

EE

Tarik Lopez

Team Secretary

EE

Keri Grevemberg

Meeting Leader

EE

LSU | School of Electrical Engineering & Computer Science

MODULAR SYNTHESIZER: WHAT IS IT?

A **synthesizer** is a musical instrument, typically operated using a keyboard, that can produce a wide variety of sounds by generating and combining signals of different frequencies.

A **modular synthesizer** is simply a synthesizer composed of separate modules of different functions that can be patched together.

Presented By: Taylor LeBlanc

PROJECT OBJECTIVE

To create a **modular synthesizer** that functions as both a **musical instrument** and a **tool for ECE Education.**

Presented By: Taylor LeBlanc

Functional Requirements

#	Function
F1	Assist Course Syllabi
F2	Generate Audio Signals
F3	Output Audio Signals
F4	Generate Control Voltages
F5	Manipulate Signal Frequency
F6	Manipulate Signal Amplitude
F7	Process Signals Digitally
F8	Operate Via Remote Control

QUANTITATIVE & QUALITATIVE CONSTRAINTS

Qualitative Constraint	How They Were Met
Customizable	Patch cables allow for customizable audio and CV routing
Engaging / Fun to use	The Audio and Visual elements
Good Sound Quality	Oscilloscope Readings
Easy to DIY	Schematics & Gerber Board files available to public
Easy to use	Labeling & Manual
Stable Waveform	Oscilliscope Tests

Quantitative Constraint	Specification	Actual
Cost	<$600	$880
Case Size	<4 ft^3	1 ft^3
Weight	<20 lbs	12.6 lbs
Power Consumption	<2.5 W	14 W
Bandwidth	>20 – 22kHz	<10 Hz - 33kHz
Operating Temperature	<60 C	27 C
Latency of Wireless Control	<100 ms	< 50 ms
Range of Wireless	>10 ft	> 50 ft *
Sample Rate	>44100 Hz	48000 Hz
Latency of Digital Module	<25 ms	2.6 ms
Instructional Material	>=7 labs	6 labs
Degree of Loudness	< 90 dB	93 dB

Prepared By: Kyle Sellers
Presented By: Tarik Lopez

Existing / Competing Technologies

LittleBits Synth Kit

- ☑ Compact
- ☑ Low Price
- ☒ Limited Customizability
- ☒ Purely Digital

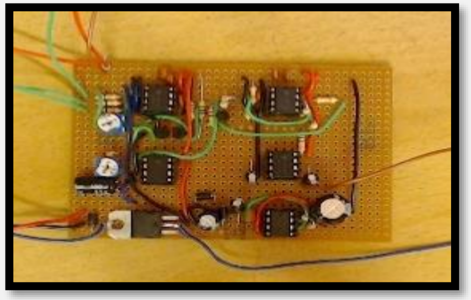
BASTL Instruments DIY

- ☑ DIY
- ☑ Lower Cost than comparable devices
- ☒ No circuit explanations

Moog Werkstatt

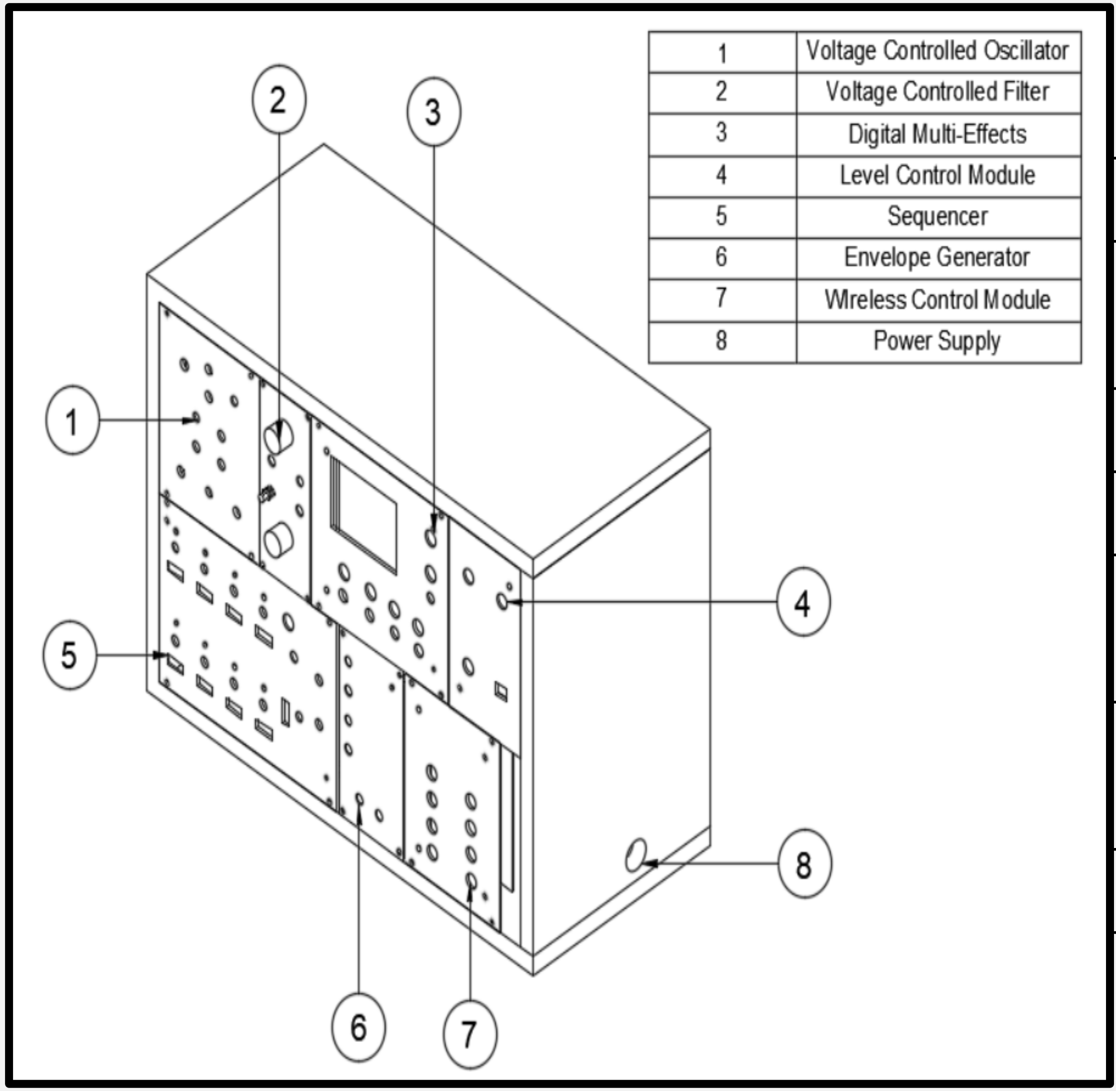
- ☑ Contains all modules we want
- ☑ Compact
- ☒ Static
- ☒ One big circuit, not explained

All About Circuits DIY Synth Series



- ☑ Vero Layouts + Perf Boards
- ☑ Circuits Thoroughly Explained
- ☒ Only 1 Module, VCO

WHAT TEAM 80'S UNIQUE SYSTEM INCLUDES: SEVEN MODULES



Module Name	**Simplified Module Function**
Voltage Controlled Oscillator	Signal production
Voltage Controlled Filter	Signal filtering – ex. High pass/ low pass
Envelope Generator – AD/AR	Signal parameter timing
Sequencer	Signal pattern production
Wireless Control	Wireless control of system using phone app
Level Control	System volume control and MyDaq compatibility
Digital Multi-Effects	Digital Signal Processing
Power Supply	Provide power to each module

FROM IDEATION TO REALITY

EDUCATIONAL VALUES

Tactile learning of important electrical engineering concepts.

Signals and Systems

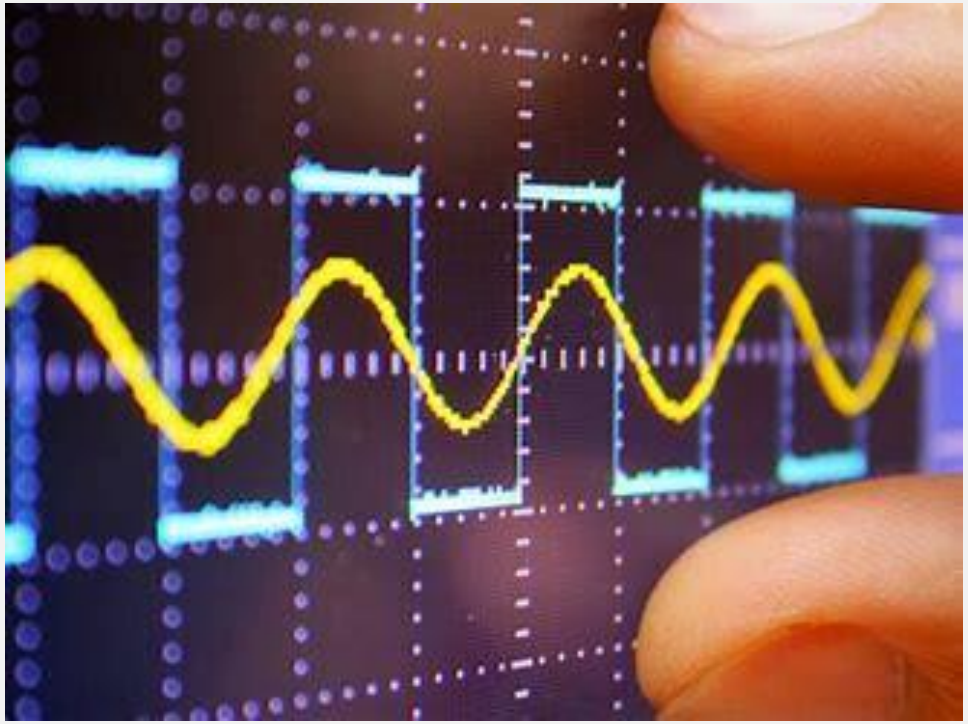
- Signal frequency and amplitude
- High-pass and low-pass filters

Electronics

- Op-Amp functions & configurations
- Diode & Transistor Applications

Digital Signal Processing

- Programming DSP
- Bit depth & sample rate
- FIR & IIR



LAB MANUAL

OBJECTIVE

- Understand the fundamental frequency of a note.
- Learn how to find the fundamental frequency of a complex periodic waveform using a Voltage Controlled Oscillator and Voltage Controlled Filter.

DISCUSSION

The synthesizer, in practice, is a device that musicians can use to produce and manipulate sound. In other words, the system we are working with today is an instrument. The “modular” part of the system refers to the many individual working subsystems that can be connected in a variety of ways depending on the preference of the user. Some synthesizers work by adding sin waves of the same fundamental frequency together to produce a sound enjoyable to the musician. The synthesizer used in this lab is a Subtractive Synthesizer which produces a complex periodic waveform and then essentially “subtracts” parts of the waveform to produce a sound.

The two subsystems we will be learning about today are the Voltage Controlled Oscillator, the VCO, and the Voltage Controlled Filter, the VCF. The Level Control module will be used to aid in connecting the system to an oscilliscope. This system uses all of the concepts taught in electrical engineering to achieve the versatility of musical production. In this lab, we will explore the basic concepts of an oscillator and a filter, and what these modules offer to the system as a whole. Along the way, students will learn about the relevance of the fundamental frequency of a periodic waveform.

EQUIPMENT LIST

- Oscilliscope
- Voltage Controlled Filter, Voltage Controlled Oscillator, and LCM
- Patch cables

Project Embodiment Module Breakdown

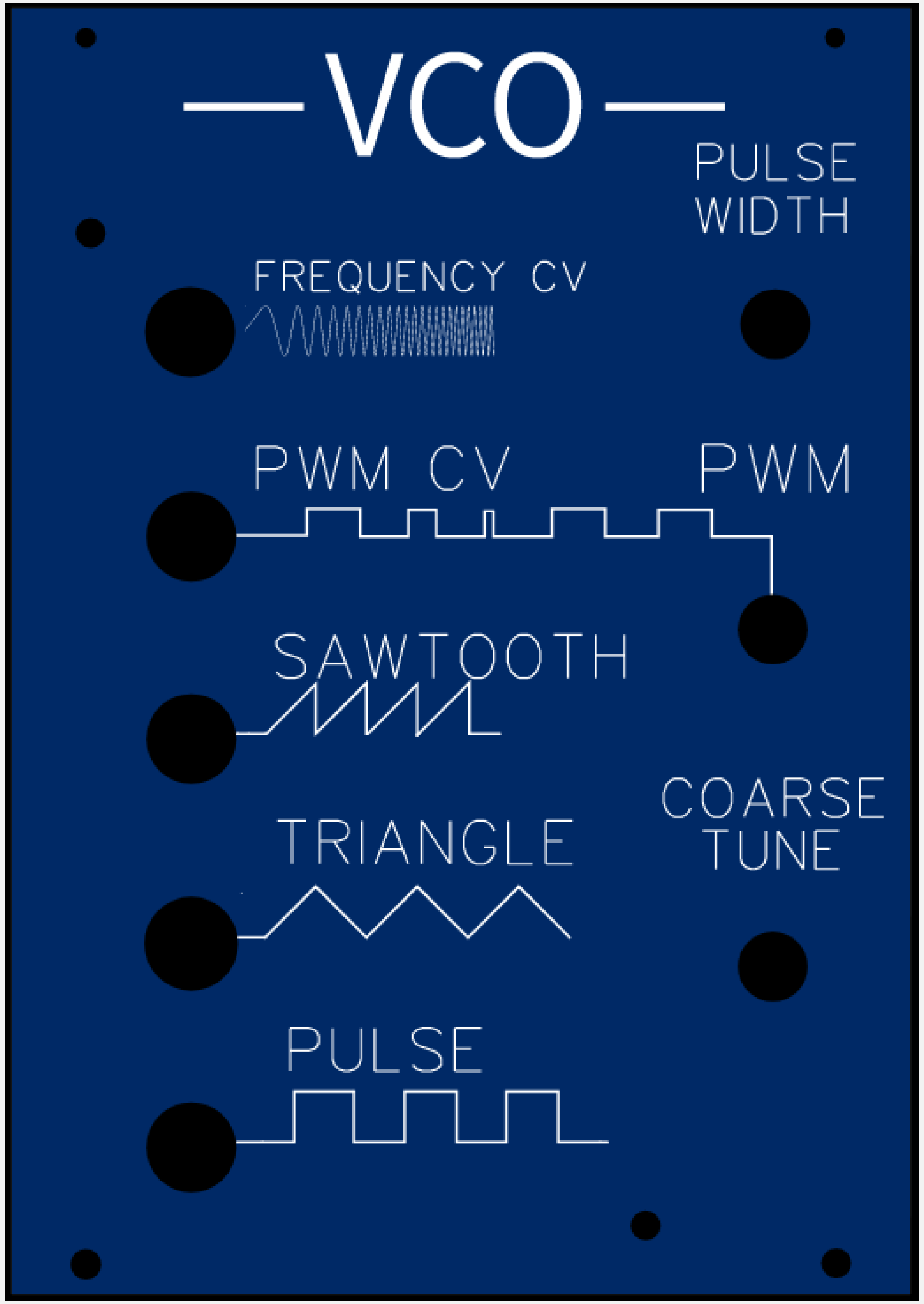
VOLTAGE CONTROLLED OSCILLATOR (VCO)

Purpose:

- Sound source of the synthesizer

Functions:

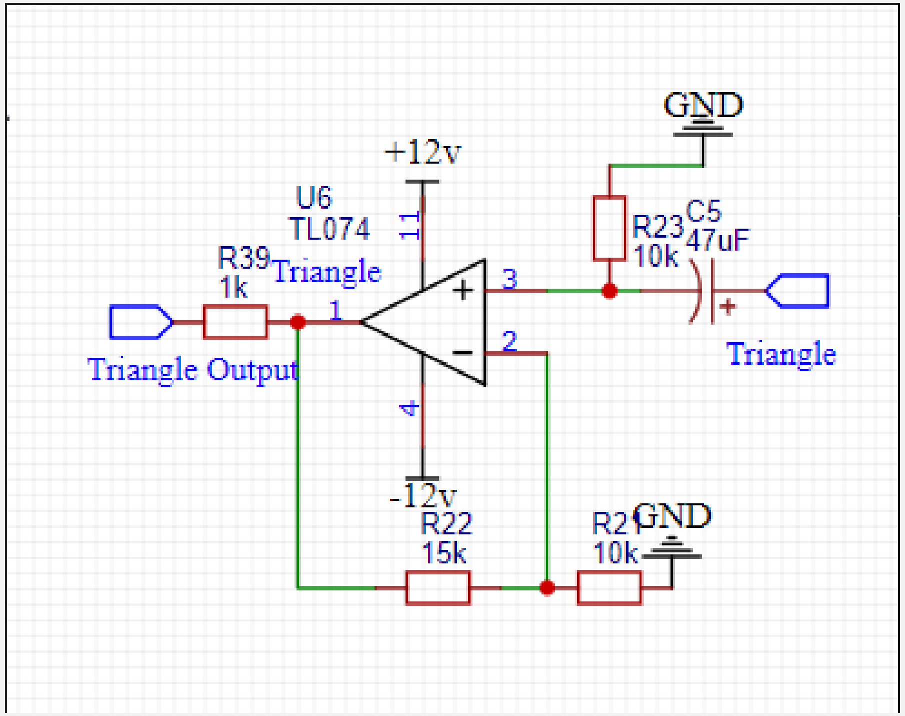
- Generates Audio Signals
- Manipulate Signal Frequency

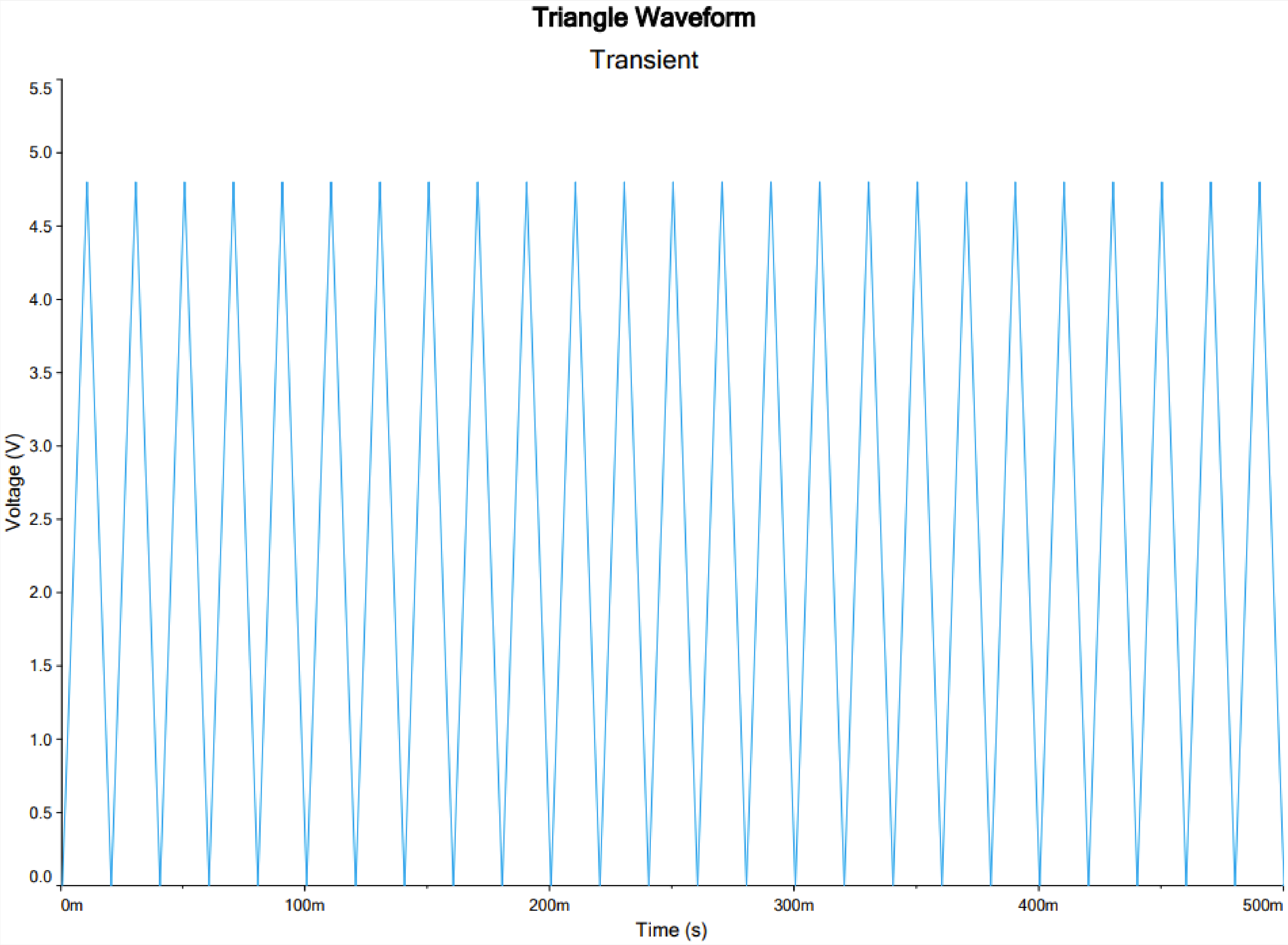


VCO ANALYSIS

Presented By: Rafael A Alvarez

Results	
Waveform	4.8v

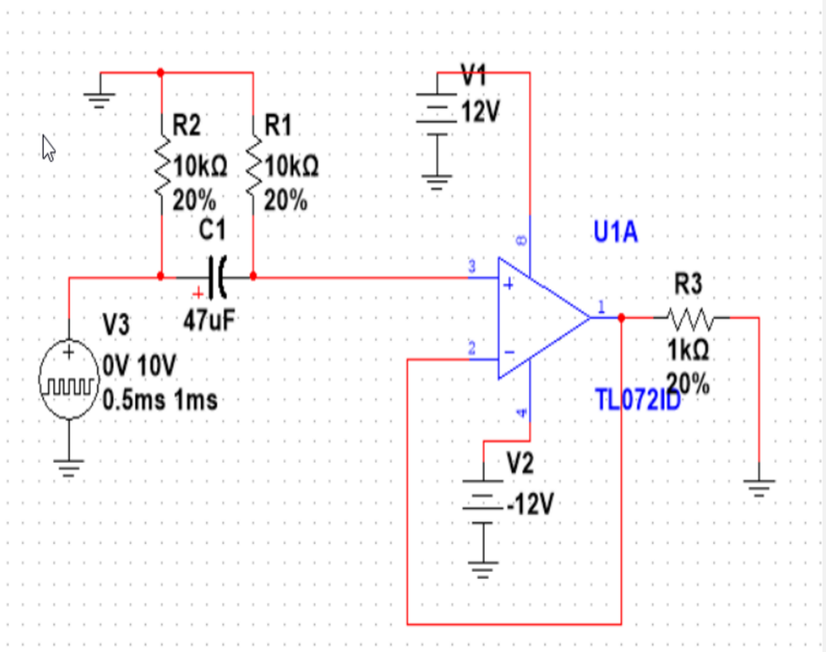


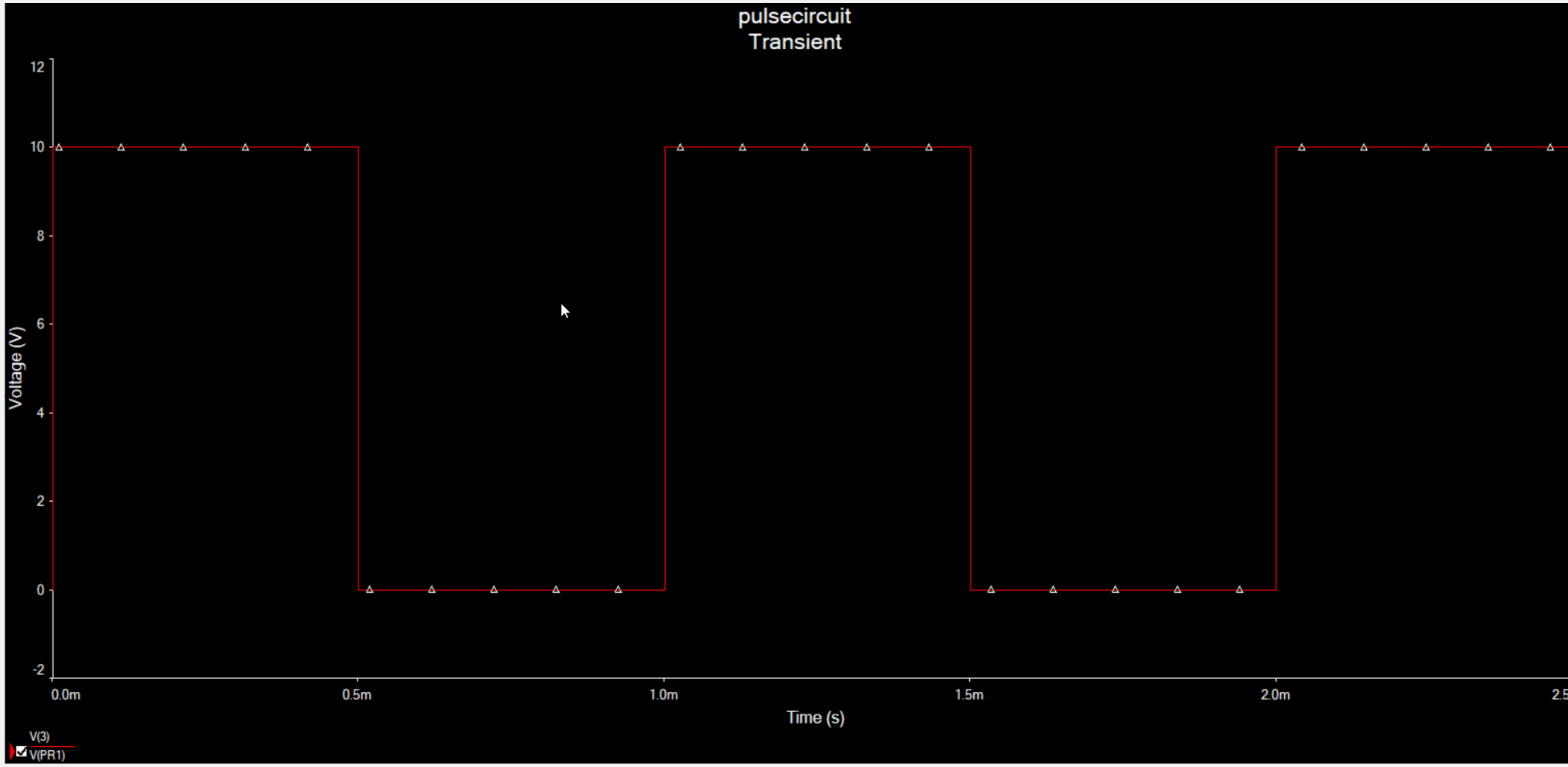


VCO ANALYSIS

Presented By: Rafael A Alvarez

Results	
Square Wave	10V

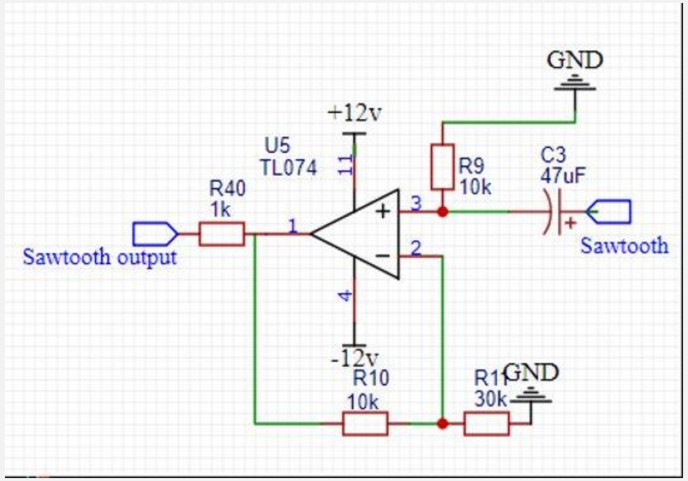


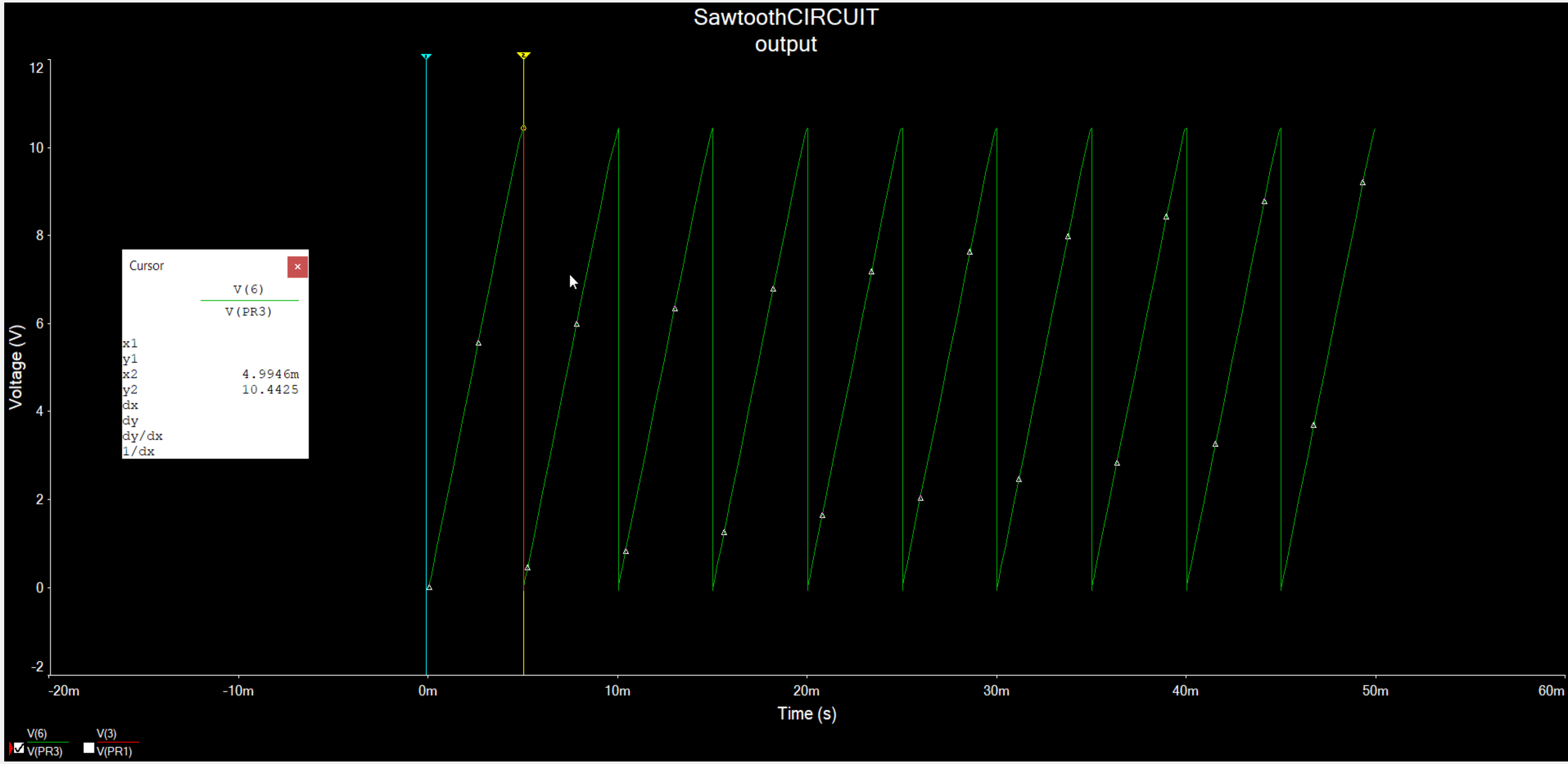


VCO ANALYSIS

Presented By: Rafael A Alvarez

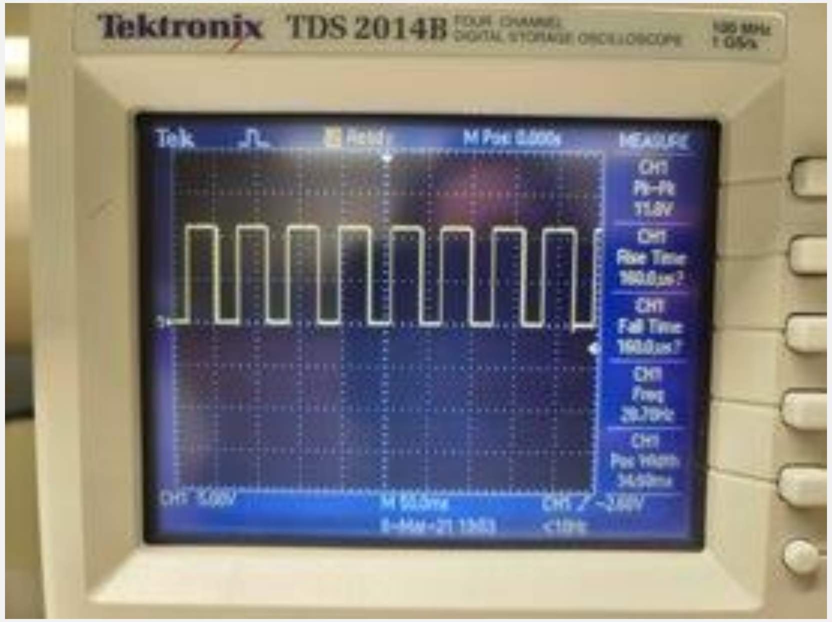
Results	
Saw Wave	10V



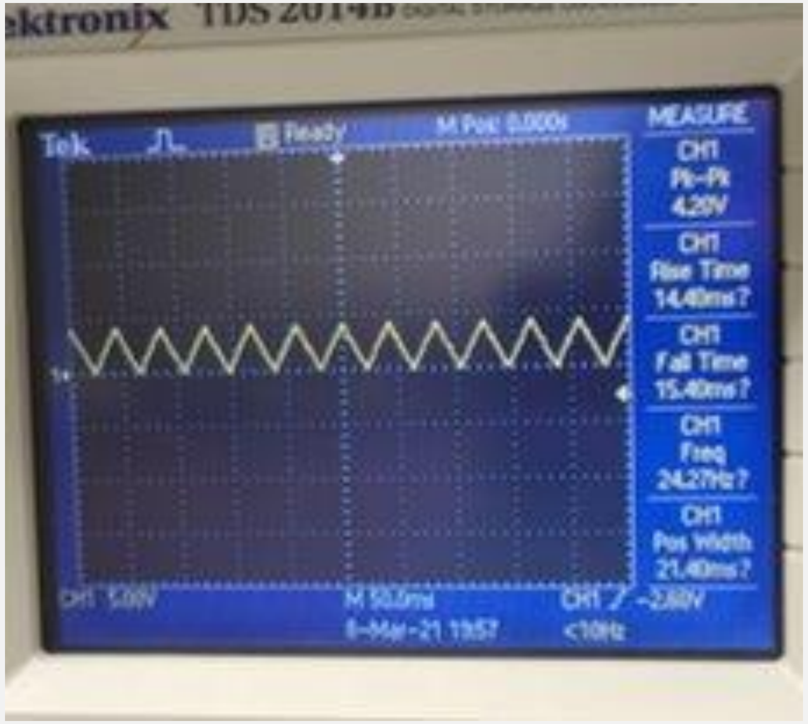


VCO
TESTING RESULTS

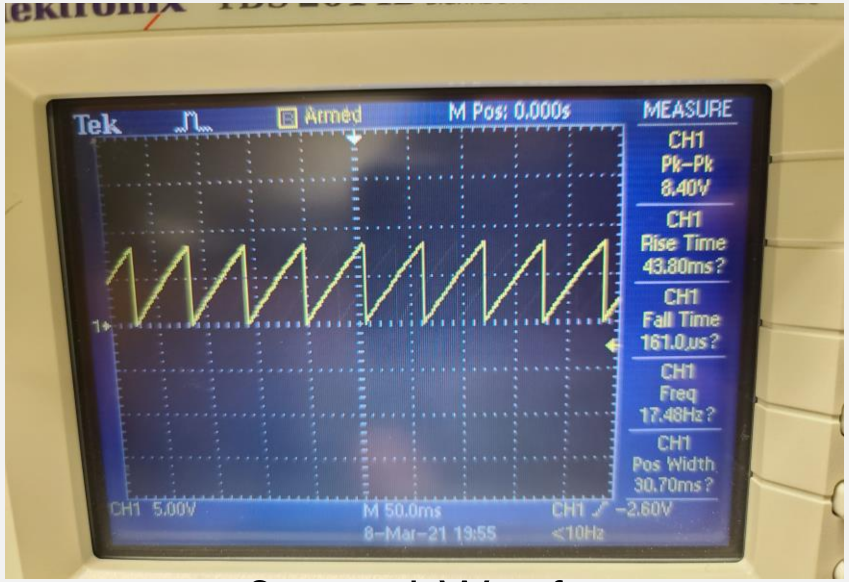
Data	Voltage
Square	11V
Triangle	4.2v
Sawtooth	8.4V



Square Waveform



Triangle Waveform



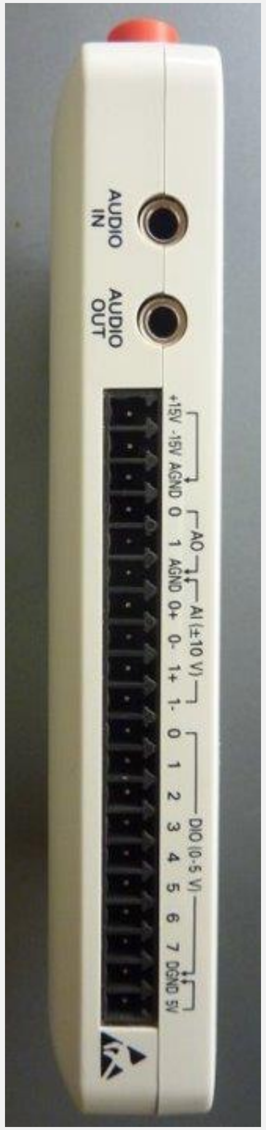
Sawtooth Waveform

Presented By: Rafael A Alvarez

LEVEL CONTROL MODULE (LCM)

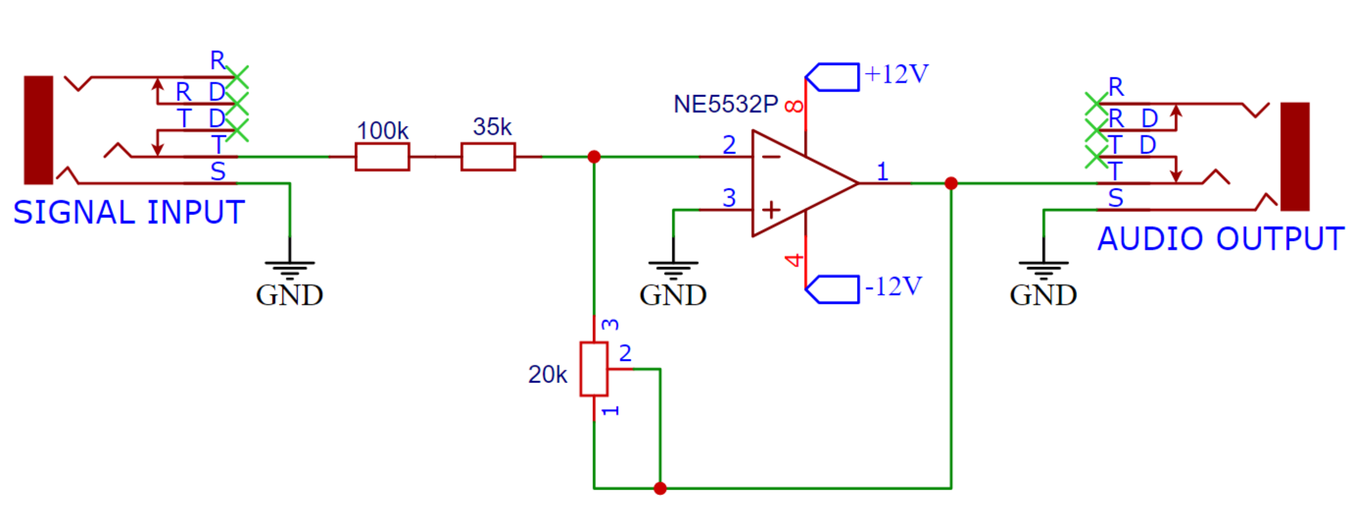
Purpose:
- Control volume level
- Attenuate signals, making it suitable to connect to a MyDAQ

Function:
Manipulate Signal Amplitude

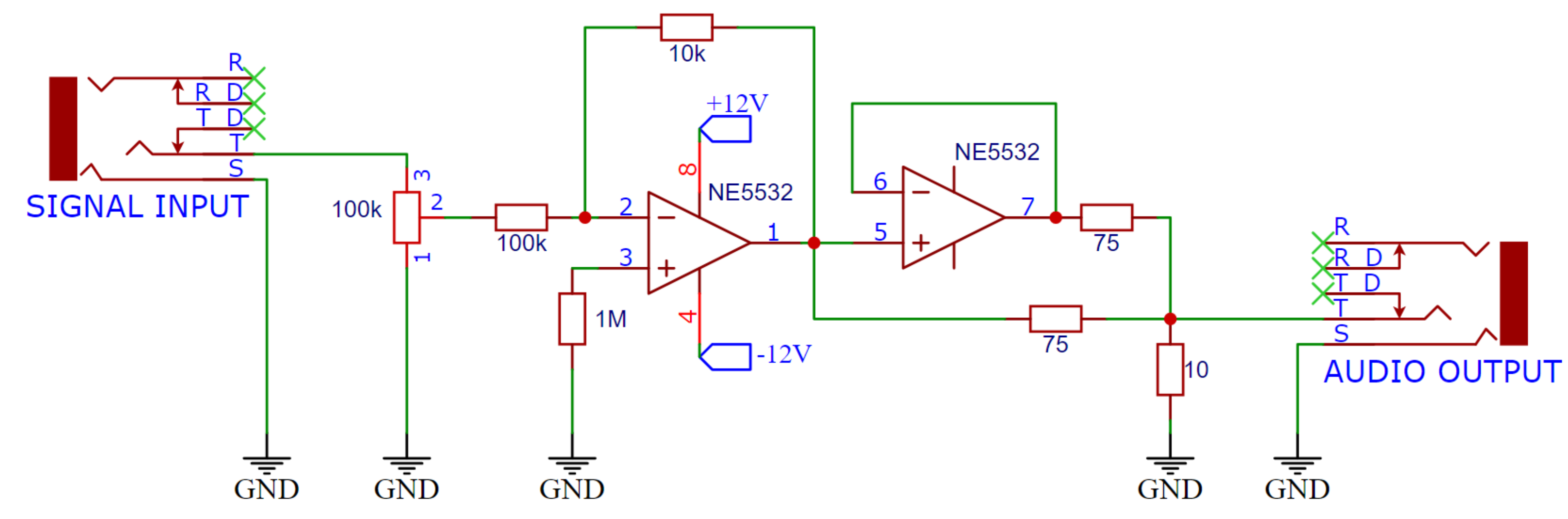


Presented By: Taylor LeBlanc

LCM ANALYSIS



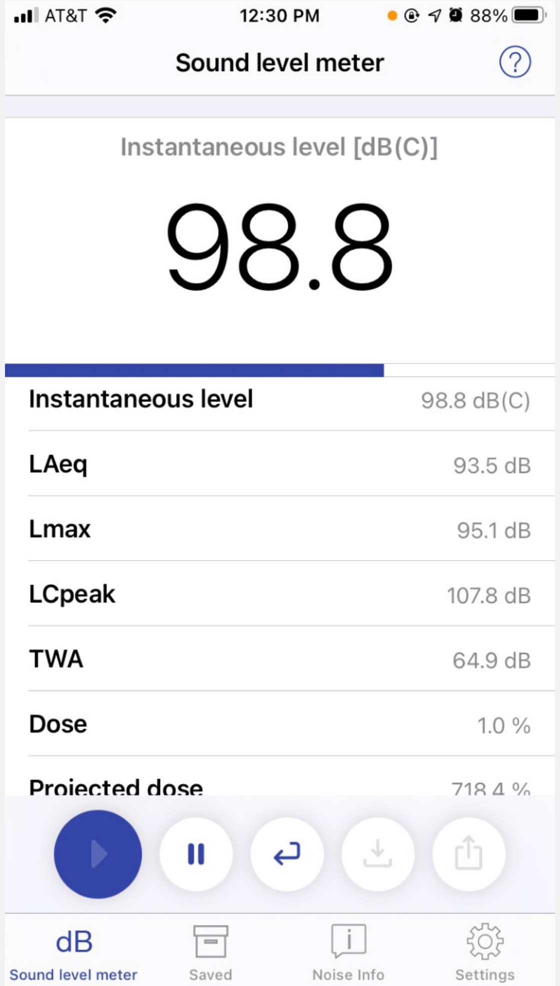
Original Volume Control



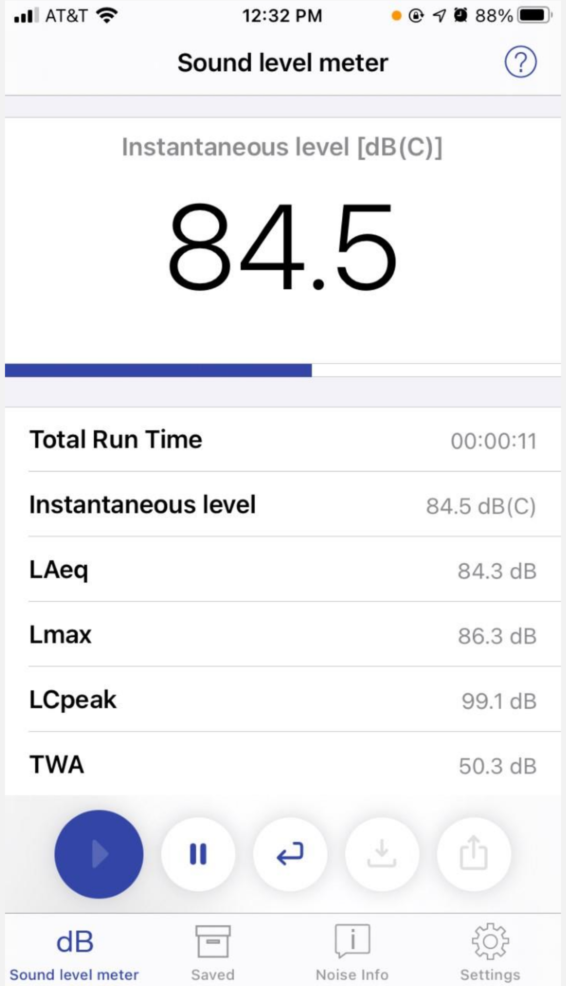
Final Volume Control

Presented By: Taylor LeBlanc

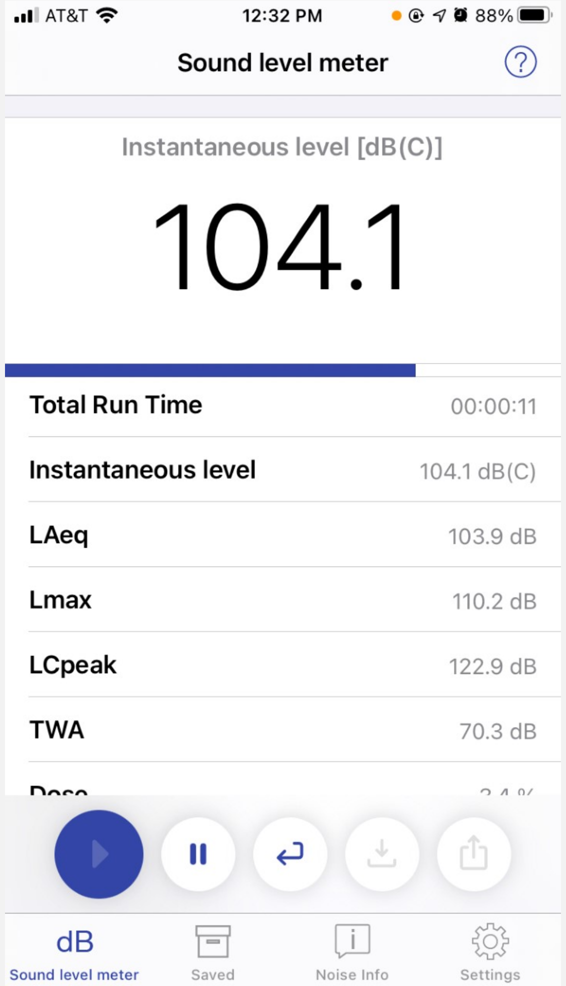
LCM
TESTING RESULTS



System Max Volume



Recommended Phone Volume

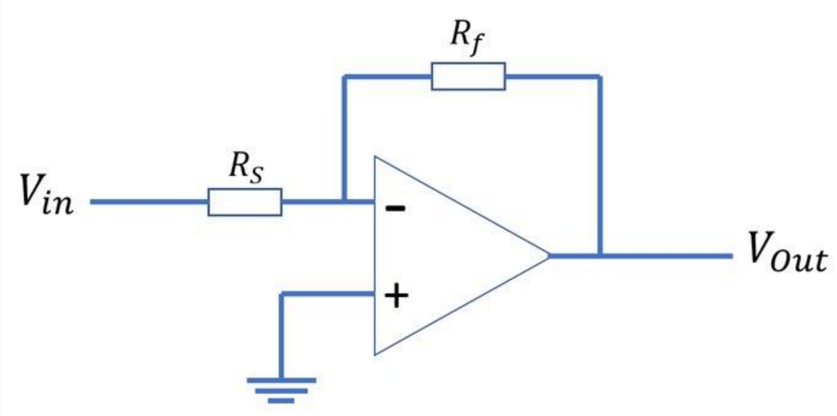


Max Phone Volume

http://static1.squarespace.com/static/54f4cf23e4b02841c1824db0/t/58ae6933f5e231d703dbd2da/1487825209334/NIOSH+Logo?format=1500w

Presented By: Taylor LeBlanc

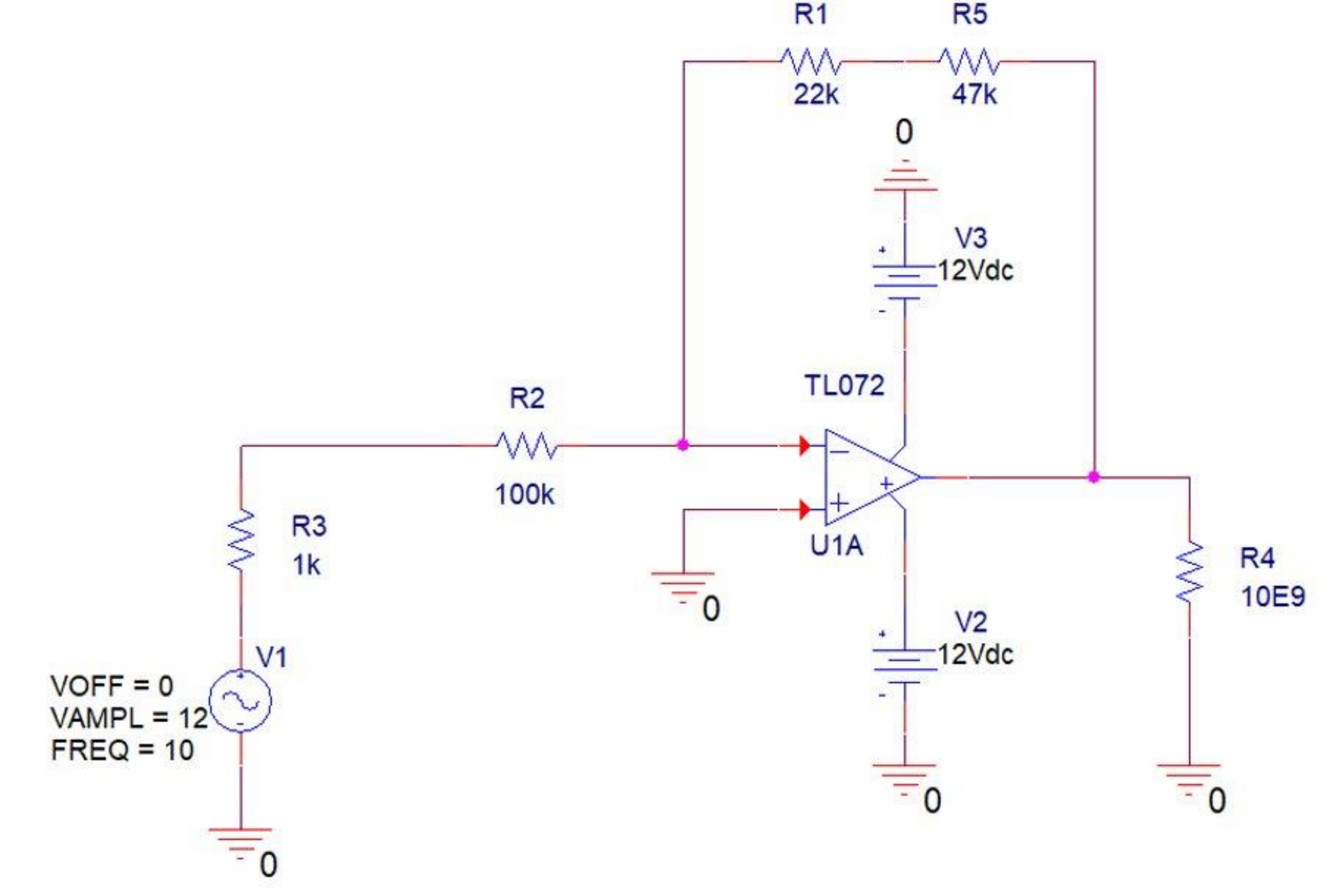
LCM ANALYSIS



Inverting Op-amp Attenuator

$$Gain = -\frac{R_f}{R_S}$$

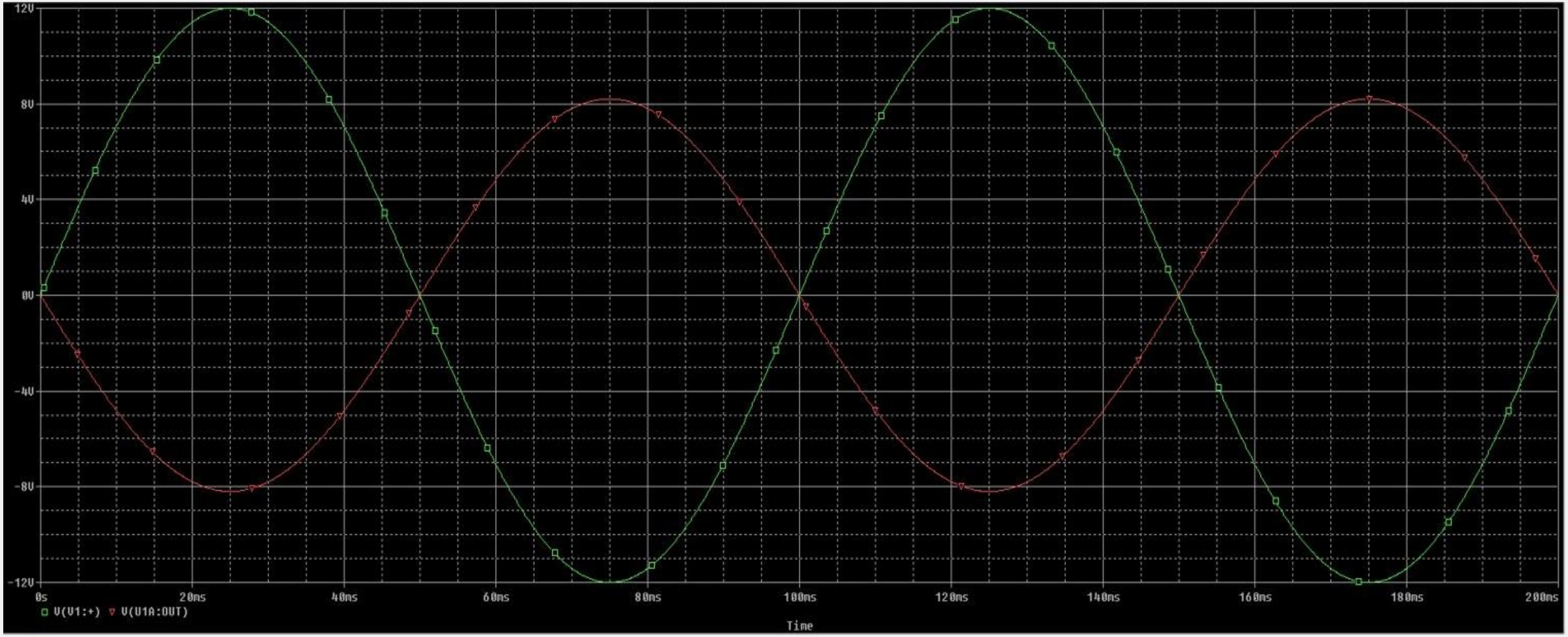
Inverting Op-amp Gain



Calculated Gain: -0.69

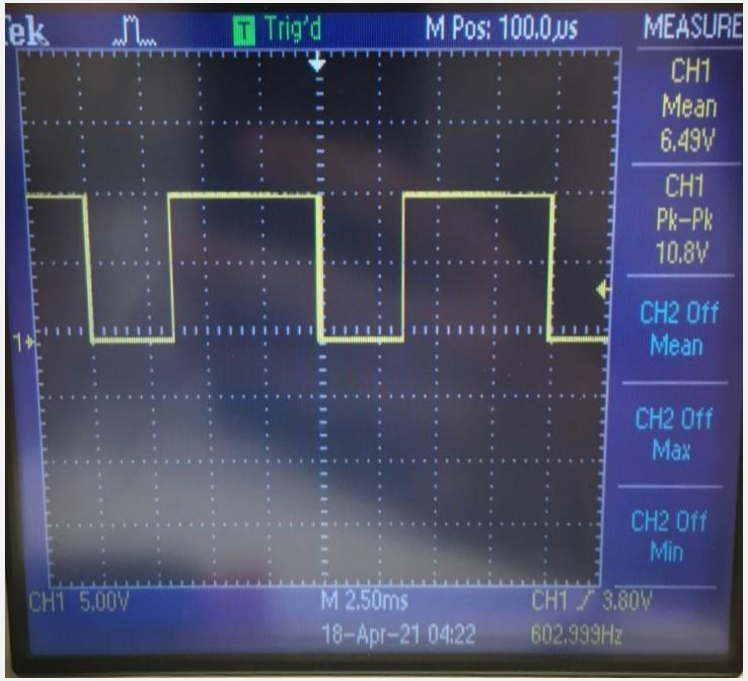
Presented By: Taylor LeBlanc

LCM ANALYSIS



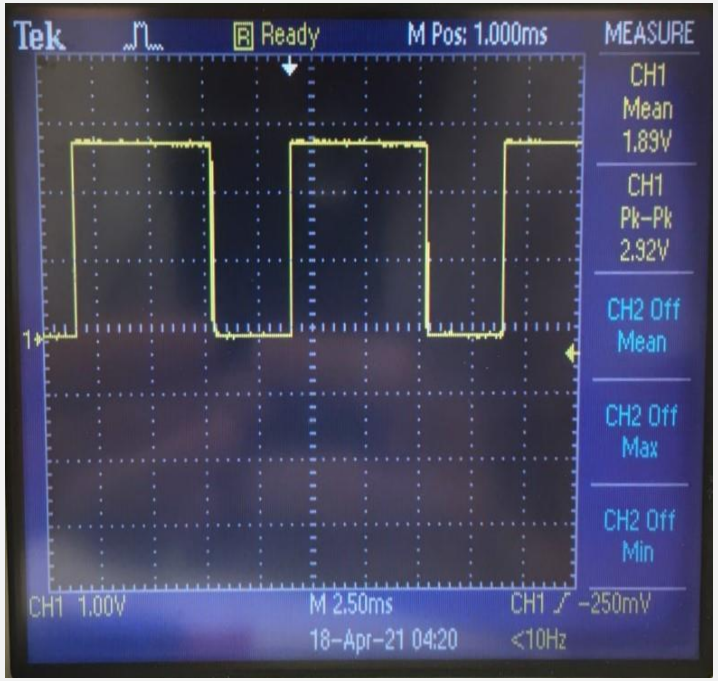
Presented By: Taylor LeBlanc

LCM TESTING RESULTS



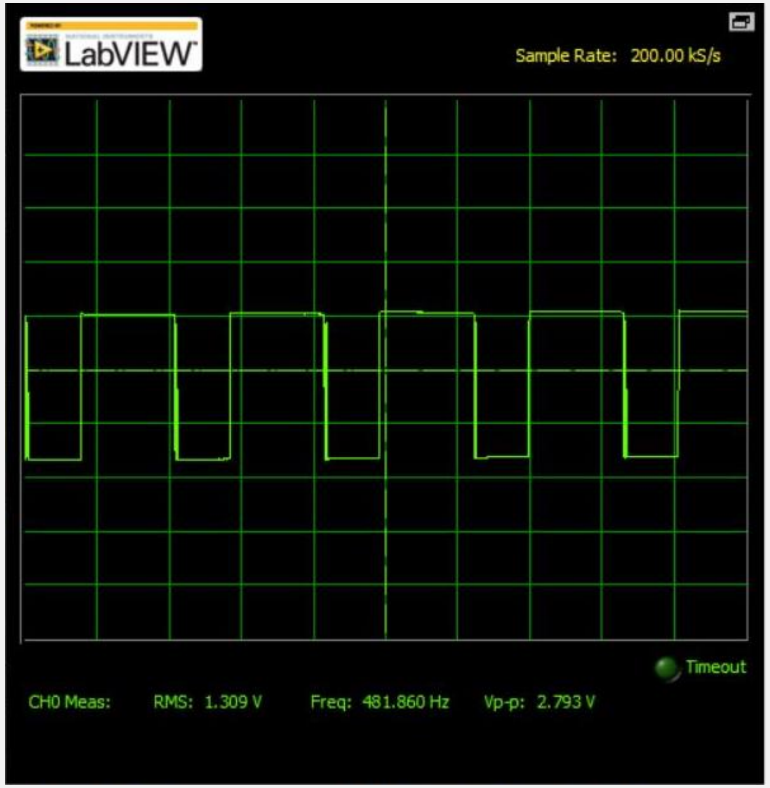
VCO direct reading

10.8V Peak-Peak



VCO passed through LCM

2.9V Peak-Peak



MyDAQ reading using LCM

2.8V Peak-Peak

Presented By: Taylor LeBlanc

VOLTAGE CONTROLLED FILTER (VCF)

Purpose:

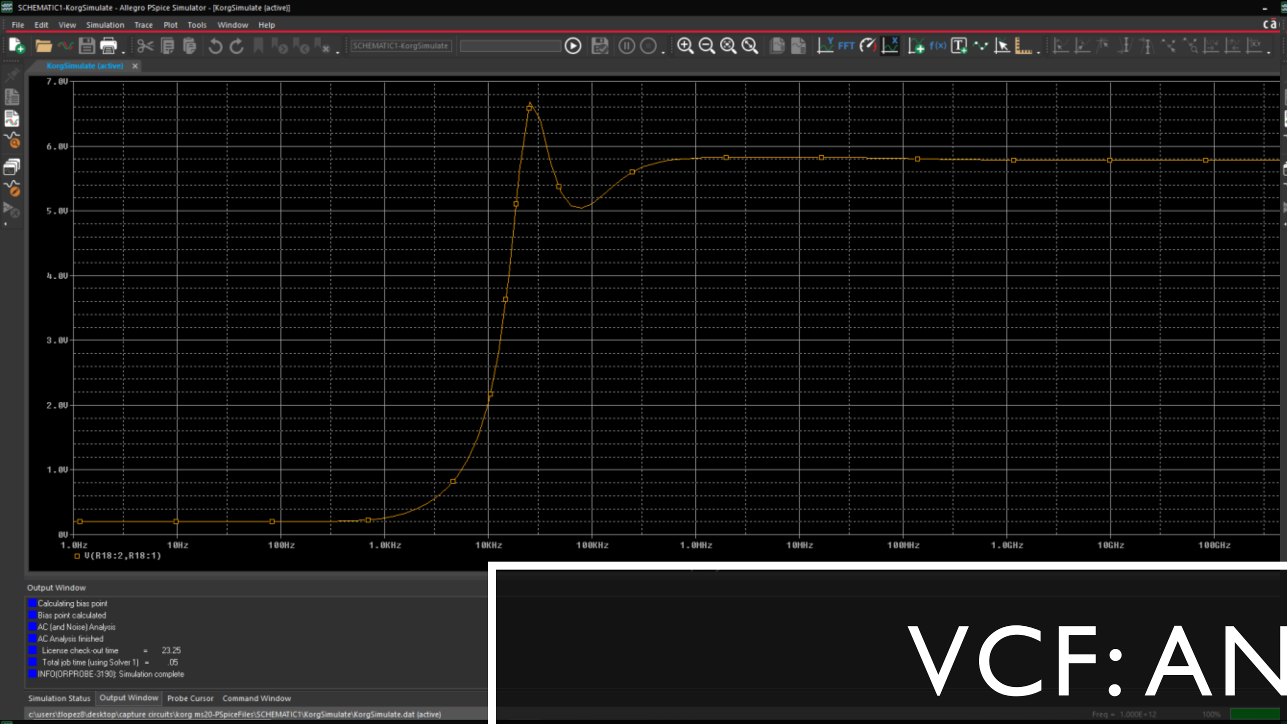
- Active Low-Pass Filter
- Active High-Pass Filter
- Resonance control
- Cutoff control

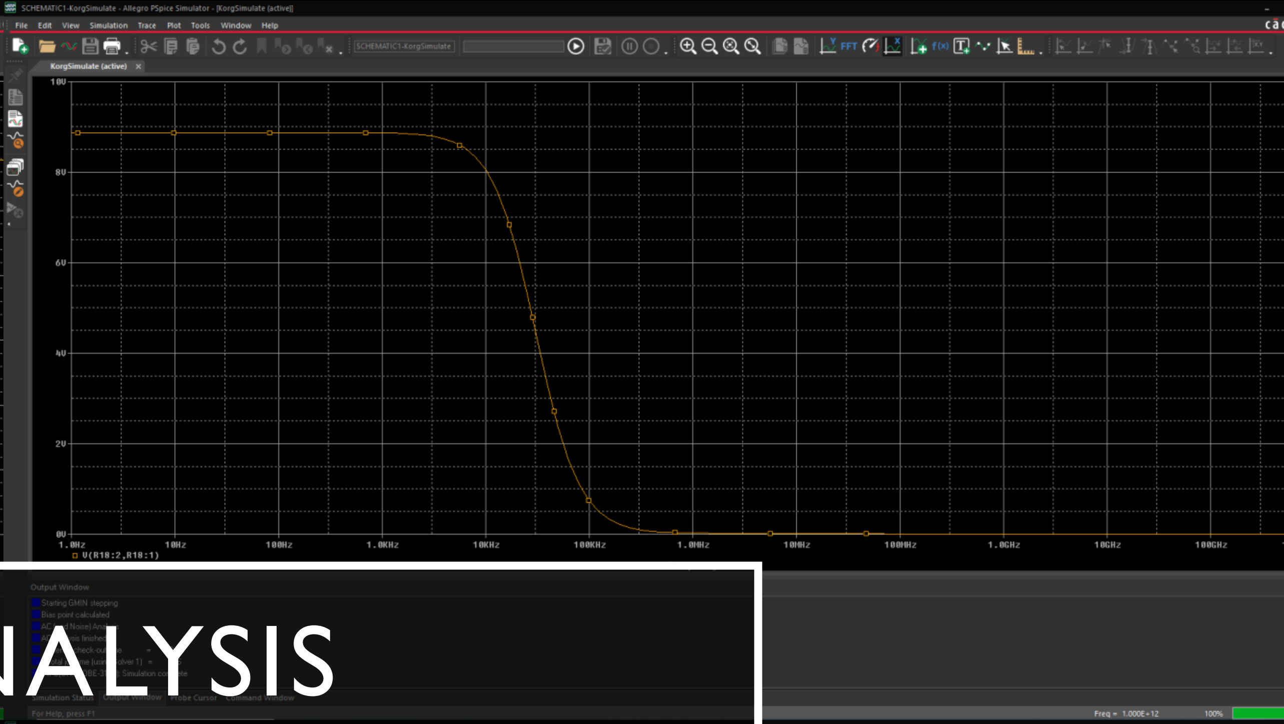
Functions:

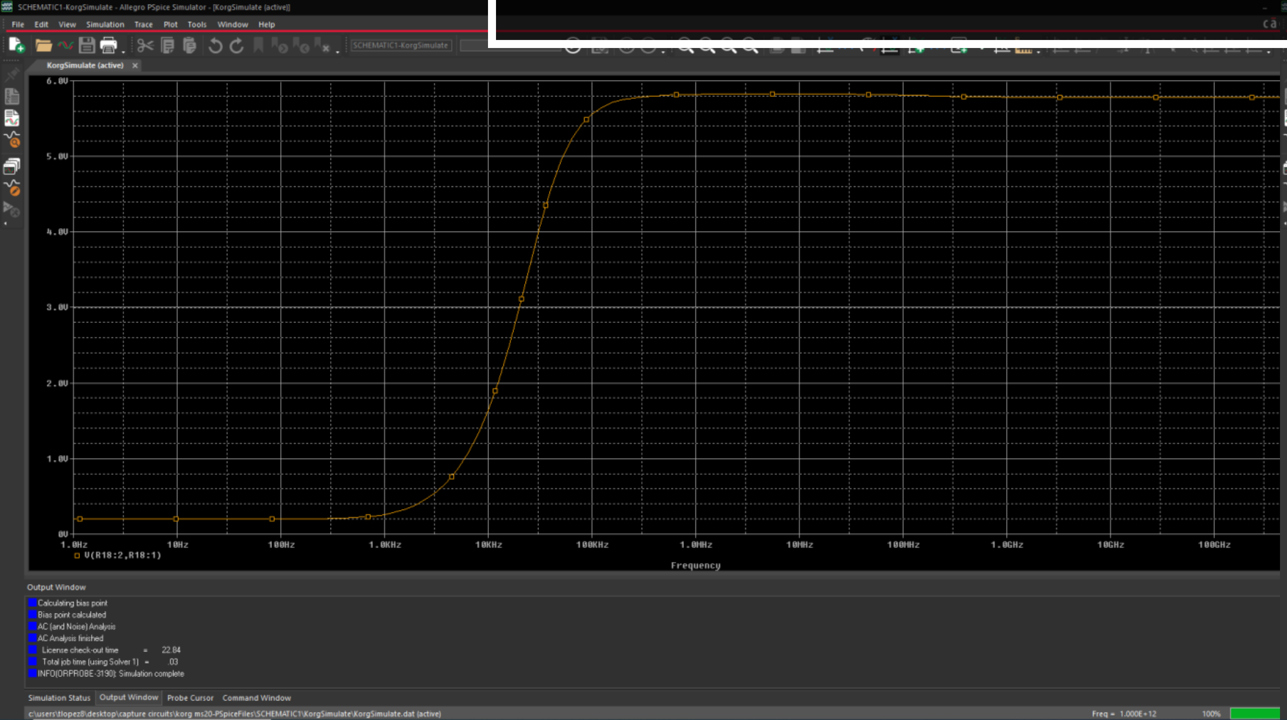
- Assist Course Syllabi
  - Electronic II
- Manipulate Signal Frequency
  - Cutoff Frequency
  - Resonance

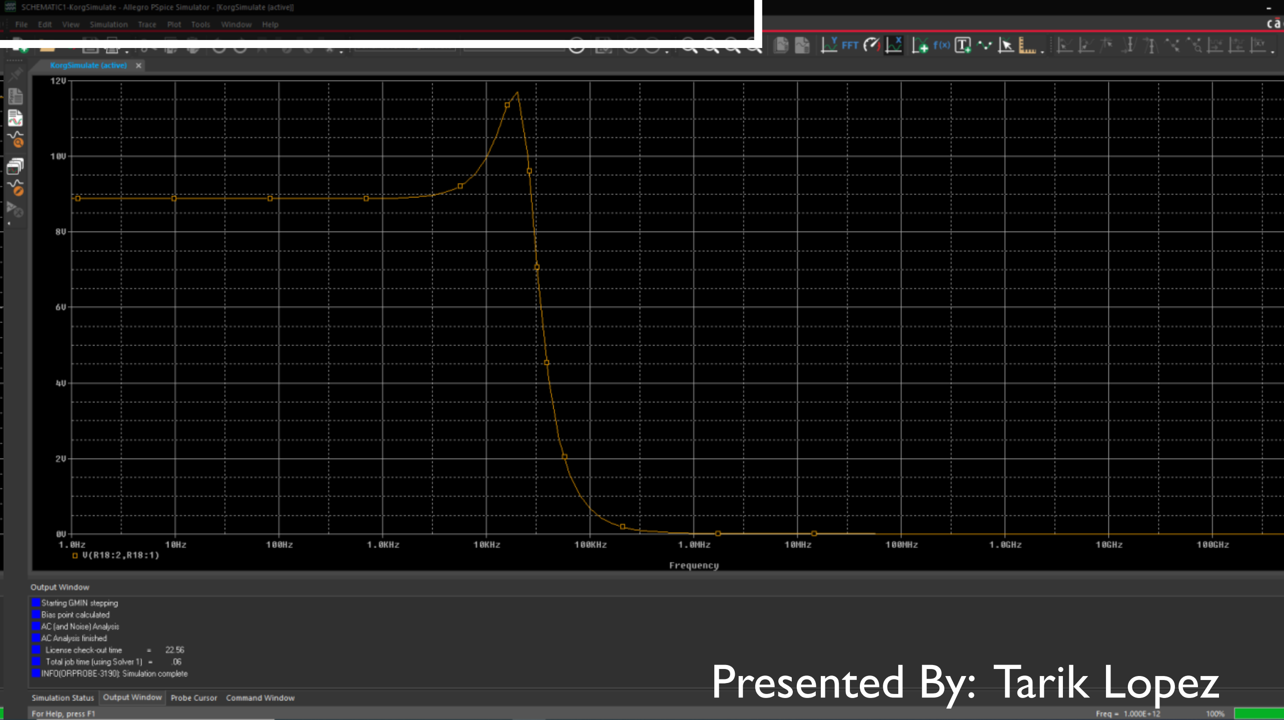
Presented By: Tarik Lopez

VCF: ANALYSIS



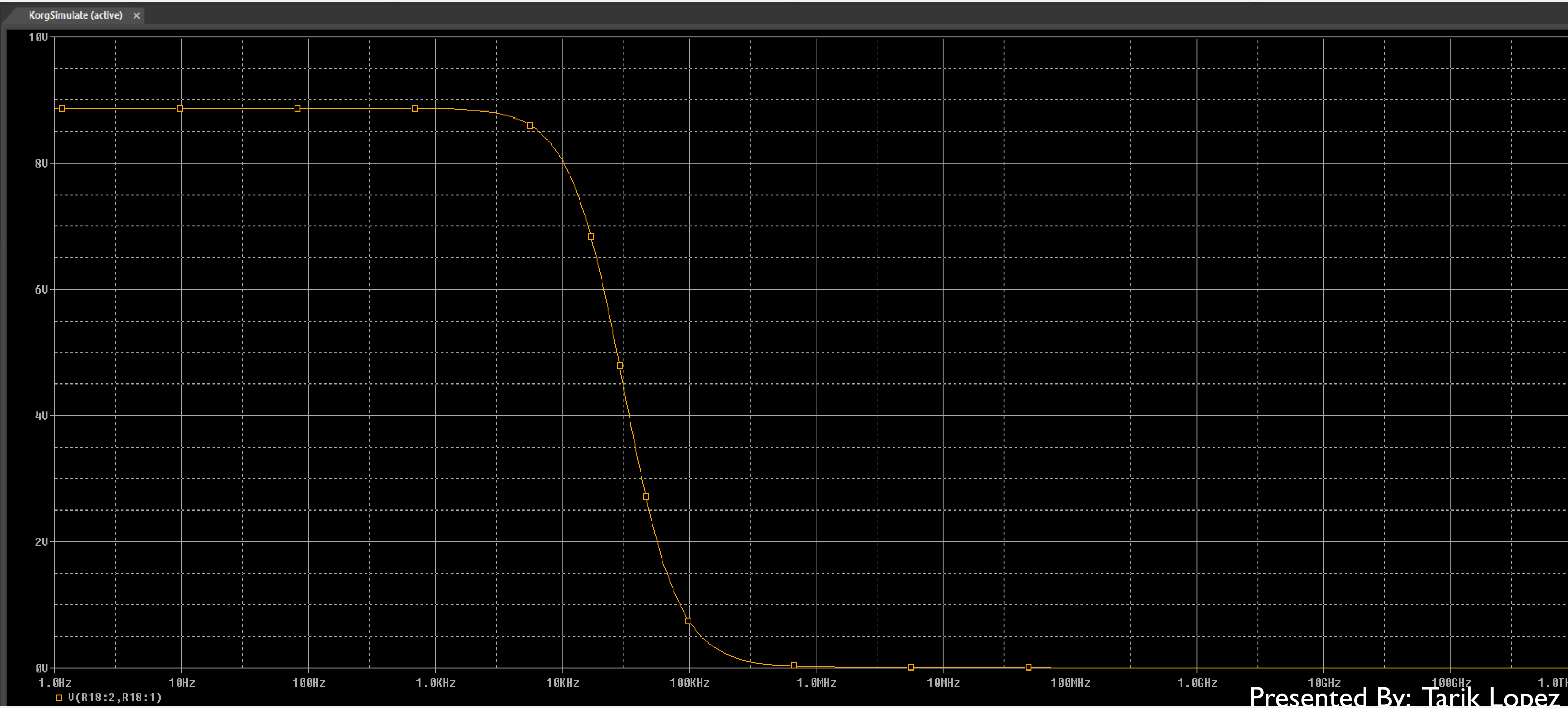






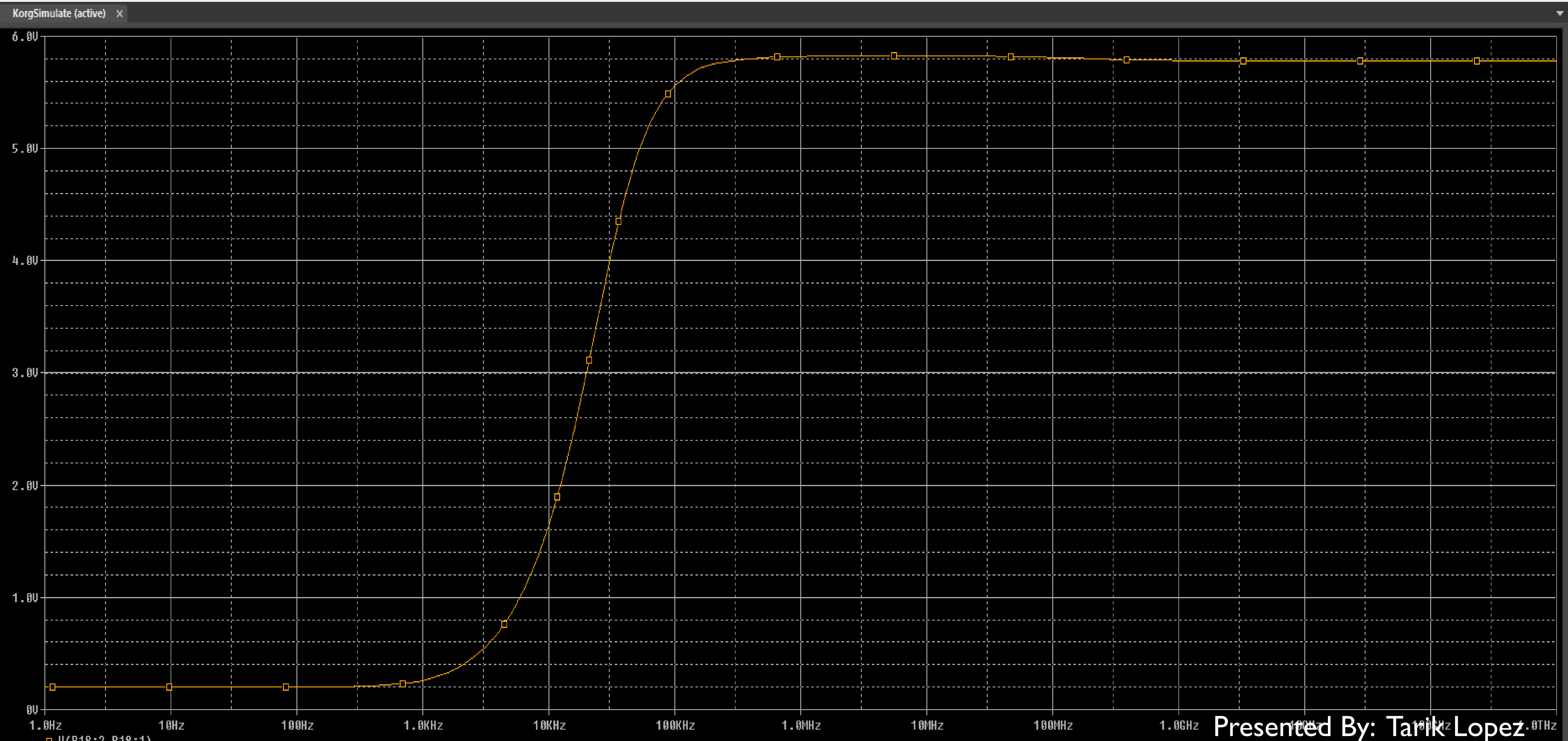
Presented By: Tarik Lopez

LOW-PASS FILTER



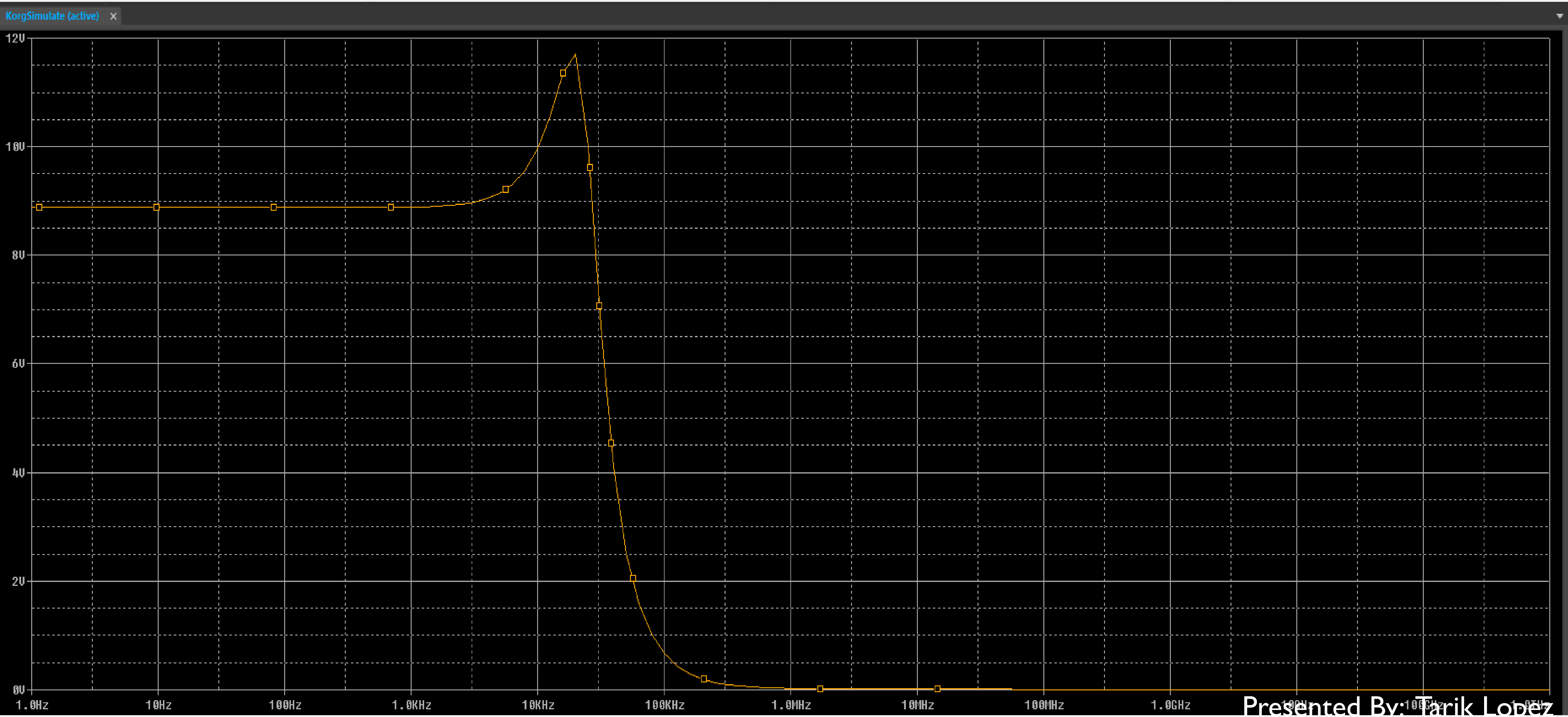
Presented By: Tarik Lopez

HIGH-PASS FILTER



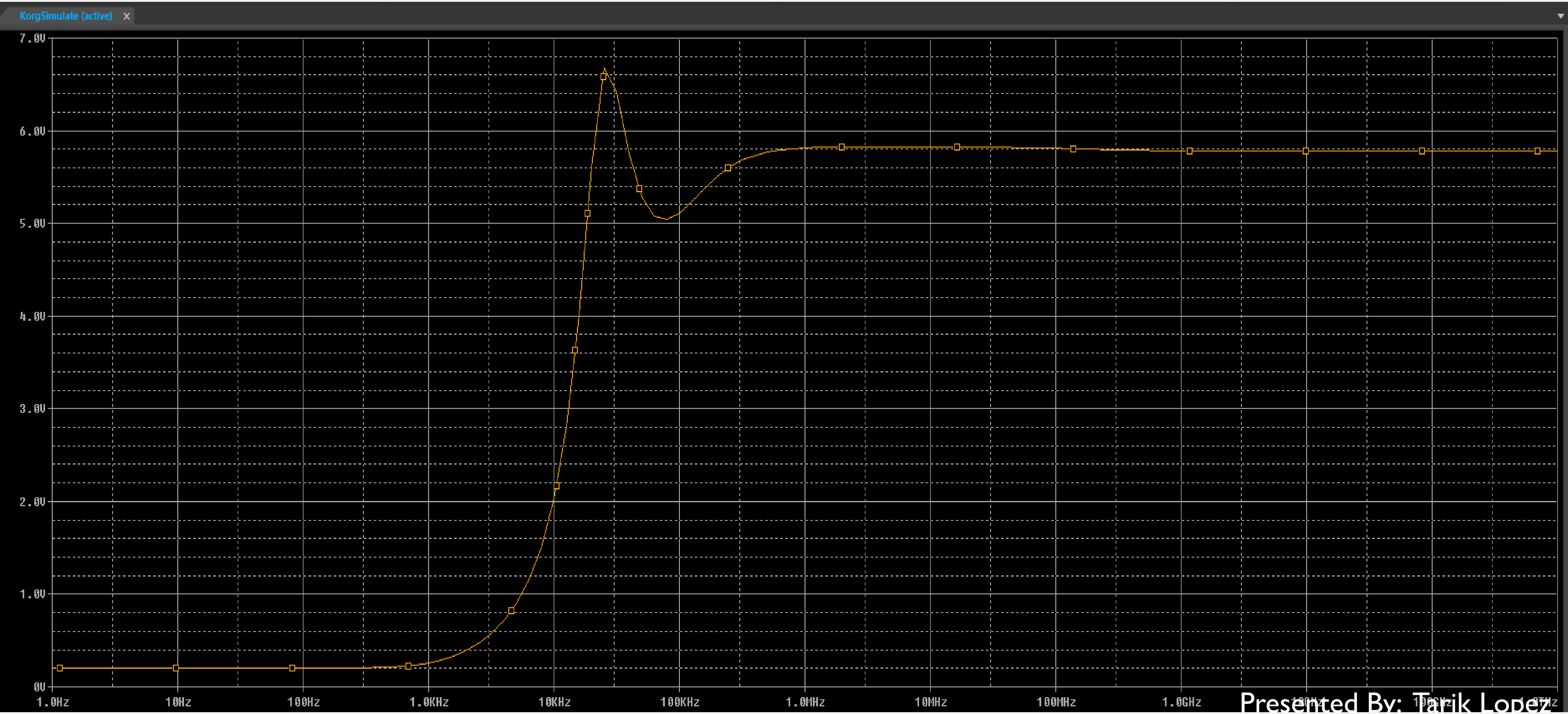
Presented By: Tarik Lopez

LOW-PASS FILTER WITH HIGH RESONANCE



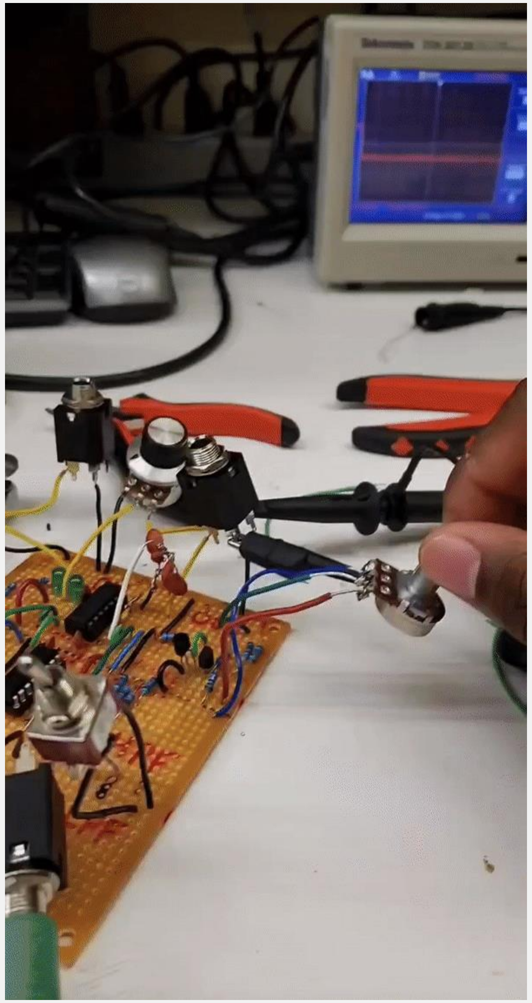
Presented By: Tarik Lopez

LOW-PASS FILTER WITH HIGH RESONANCE

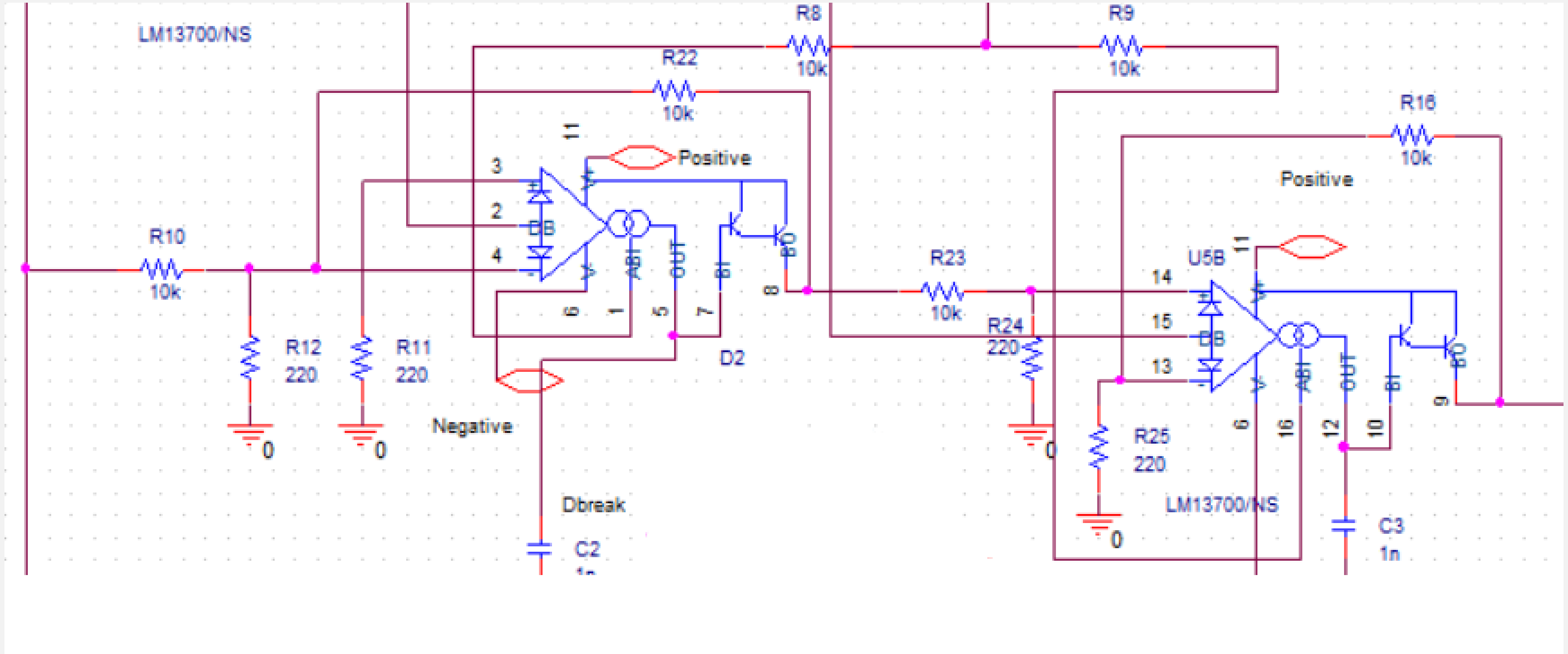


Presented By: Tarik Lopez

VCF: TESTING RESULTS

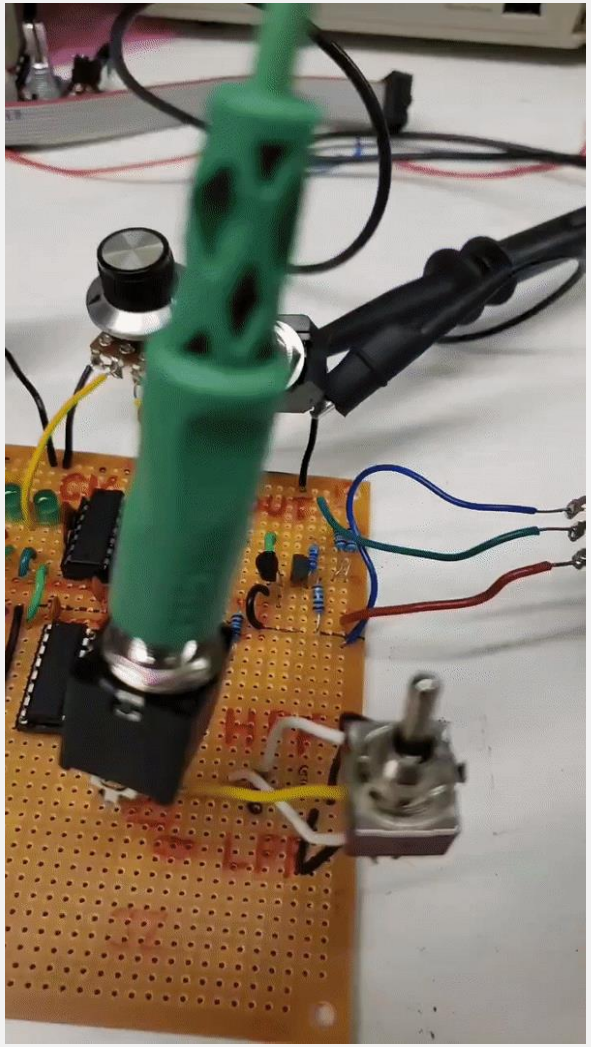


Filter	Frequency Range
Low-Pass	0 – 24.4kHz

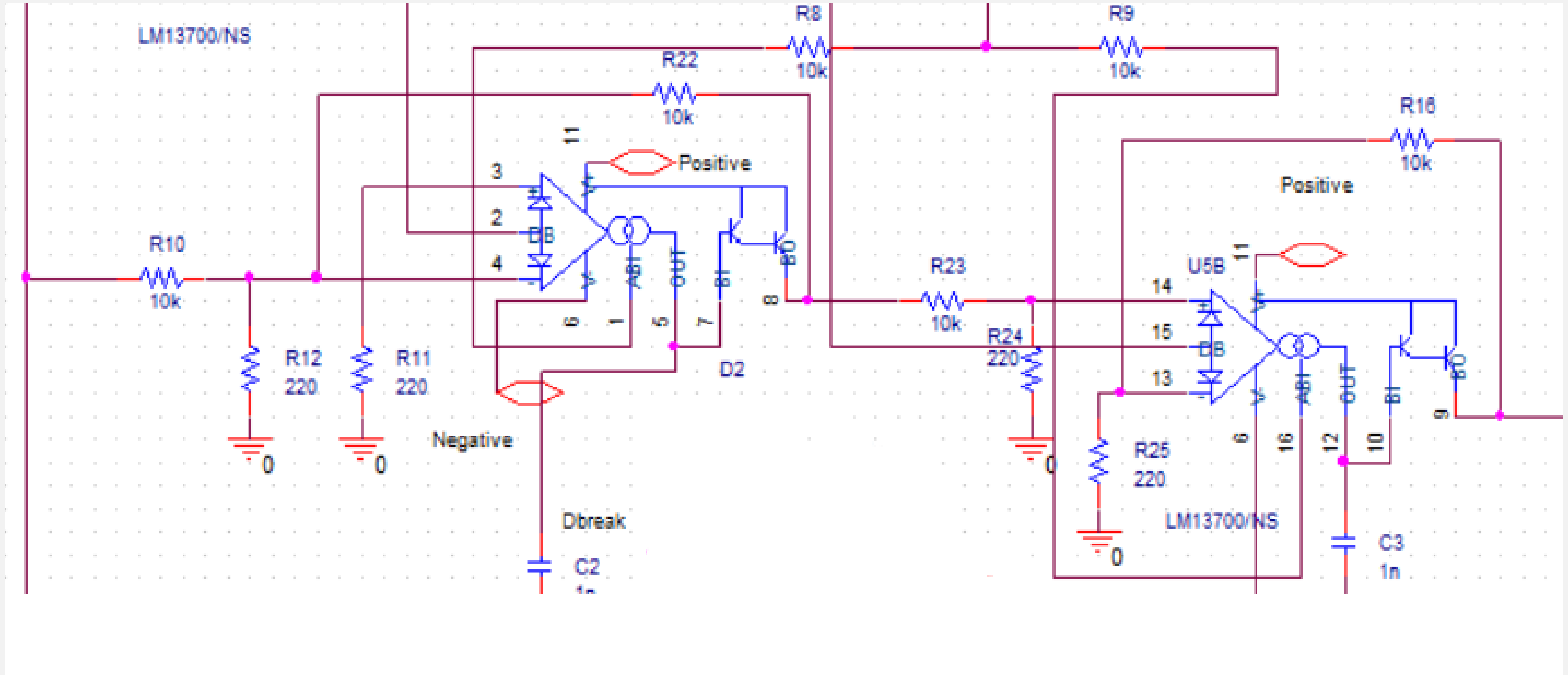


Presented By: Tarik Lopez

VCF: TESTING RESULTS

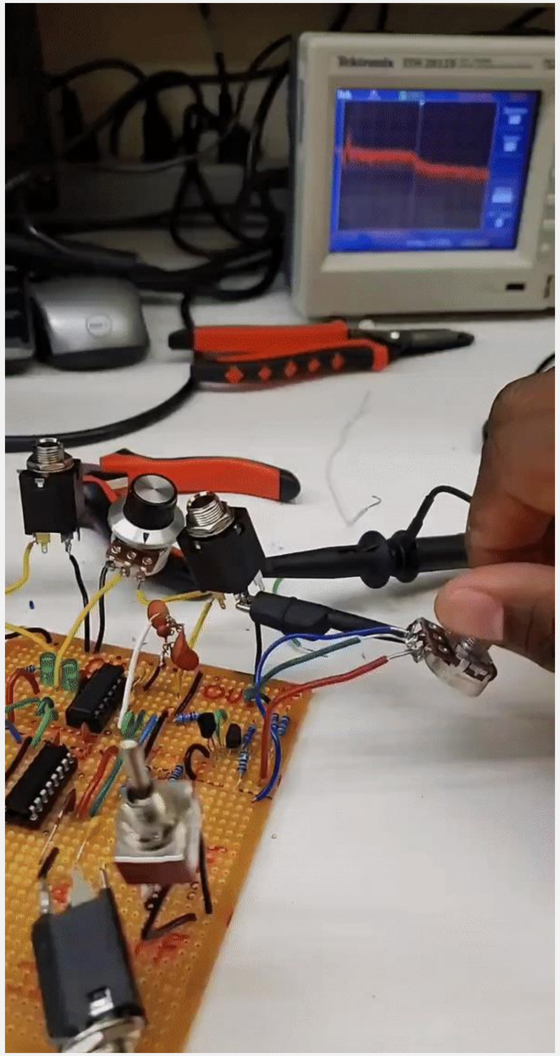


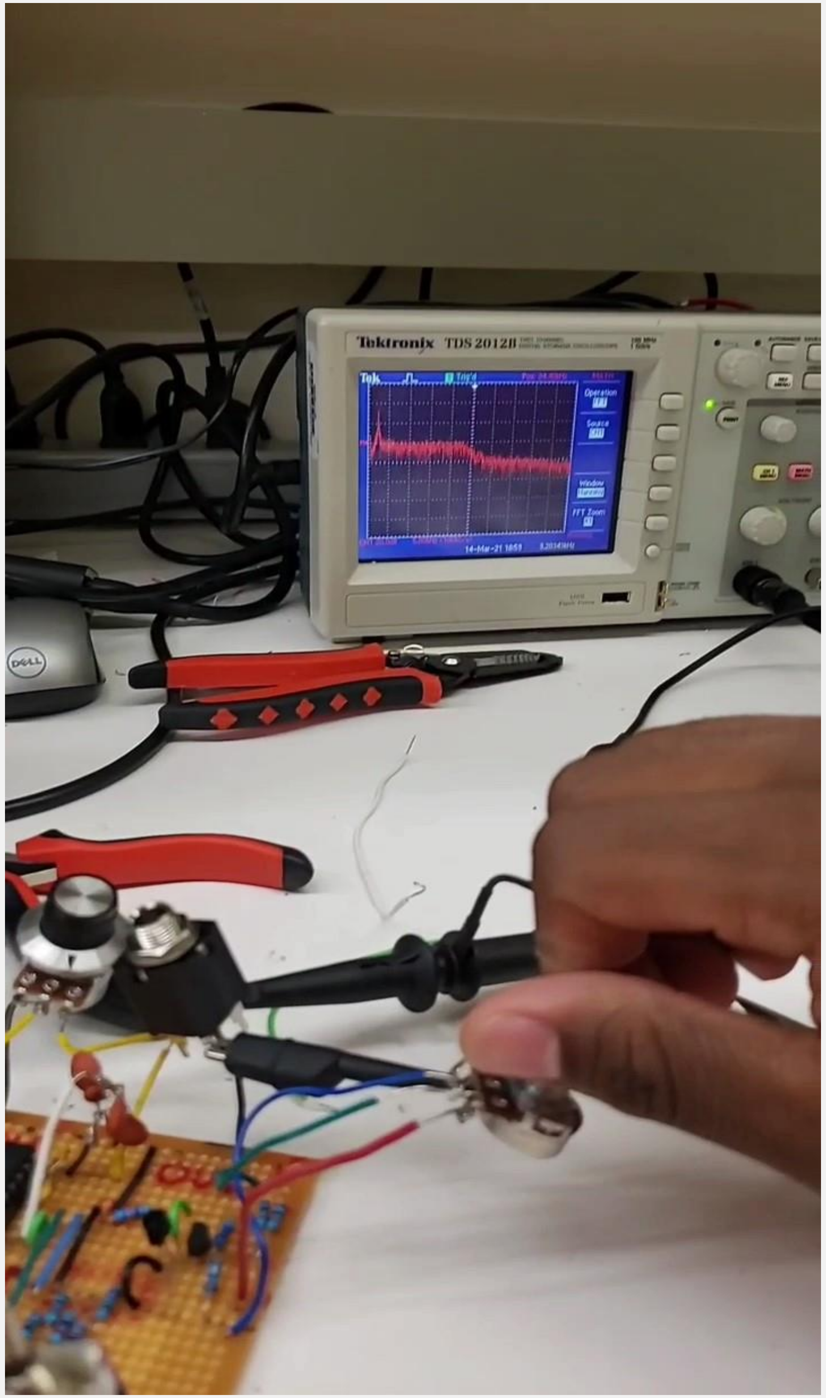
Filter	Frequency Range
High-Pass	24.4kHz – 0Hz

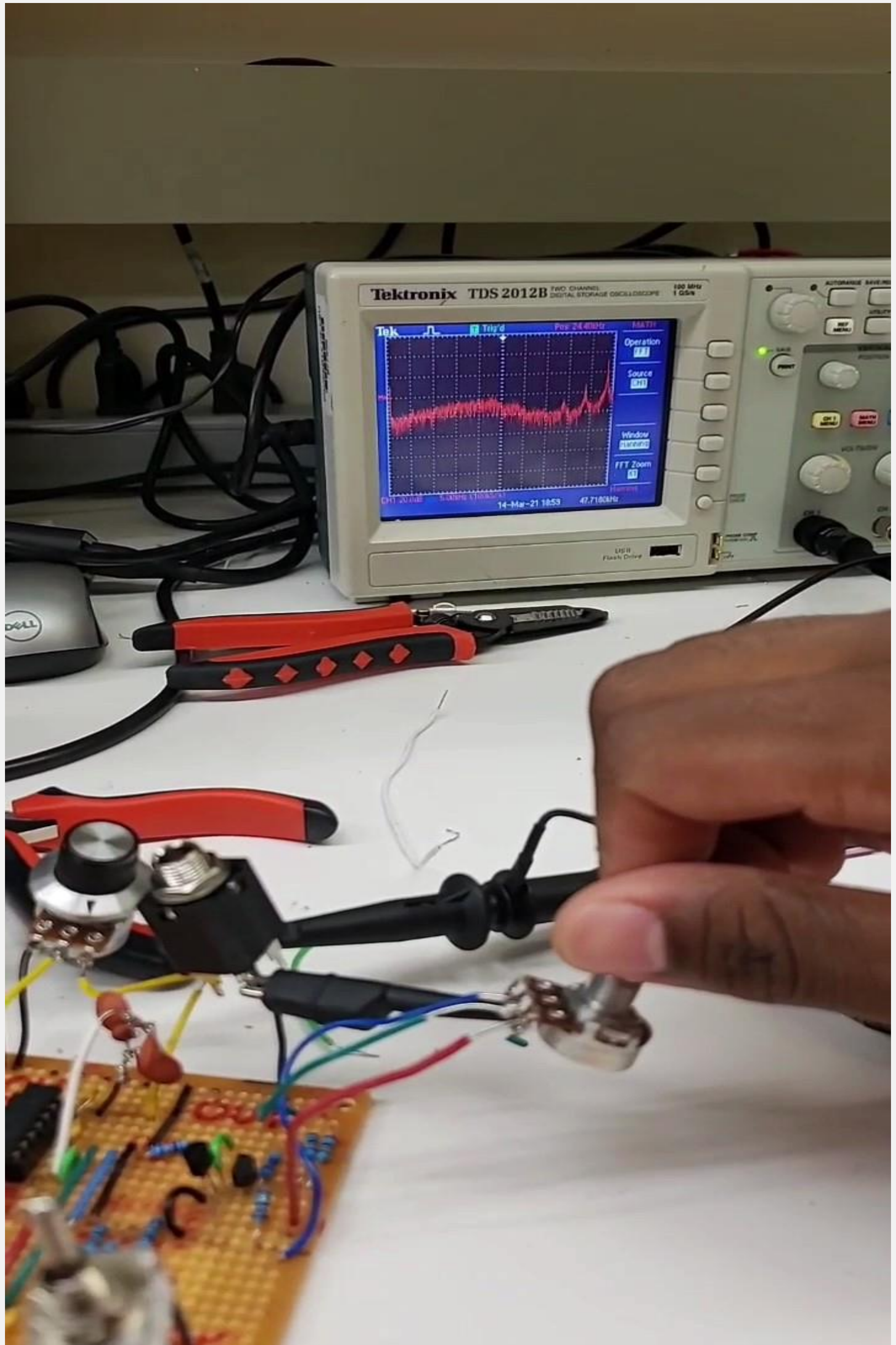


Presented By: Tarik Lopez

VCF: TESTING RESULTS







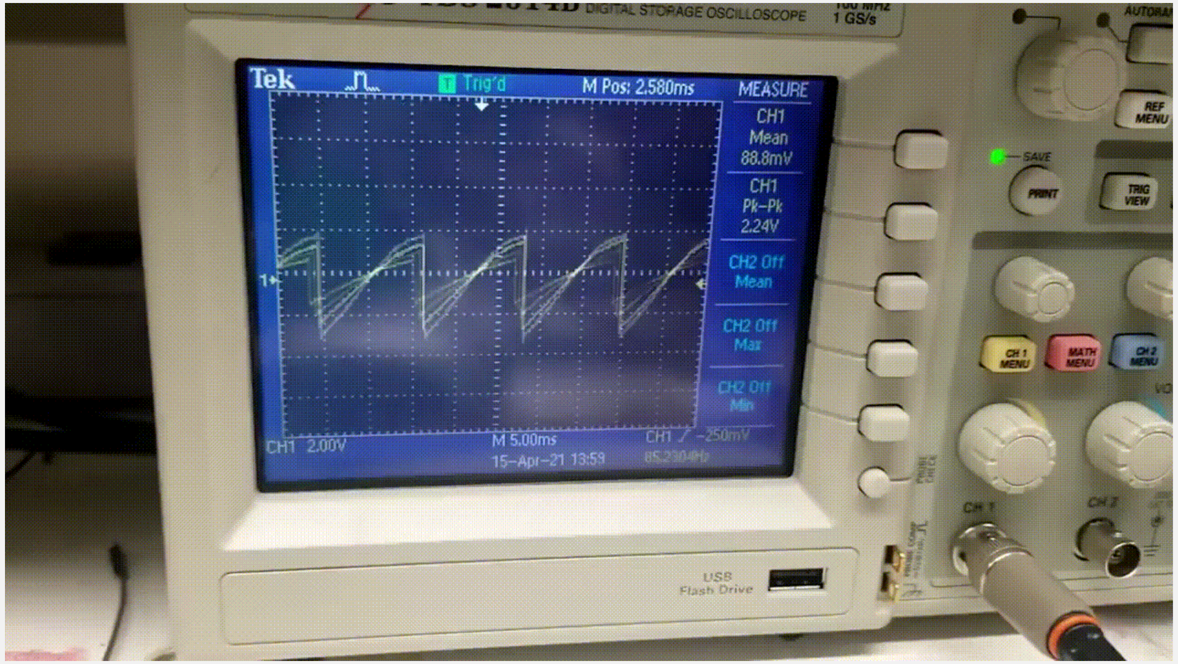
Presented By: Tarik Lopez

DIGITAL MULTI-EFFECTS (DME)

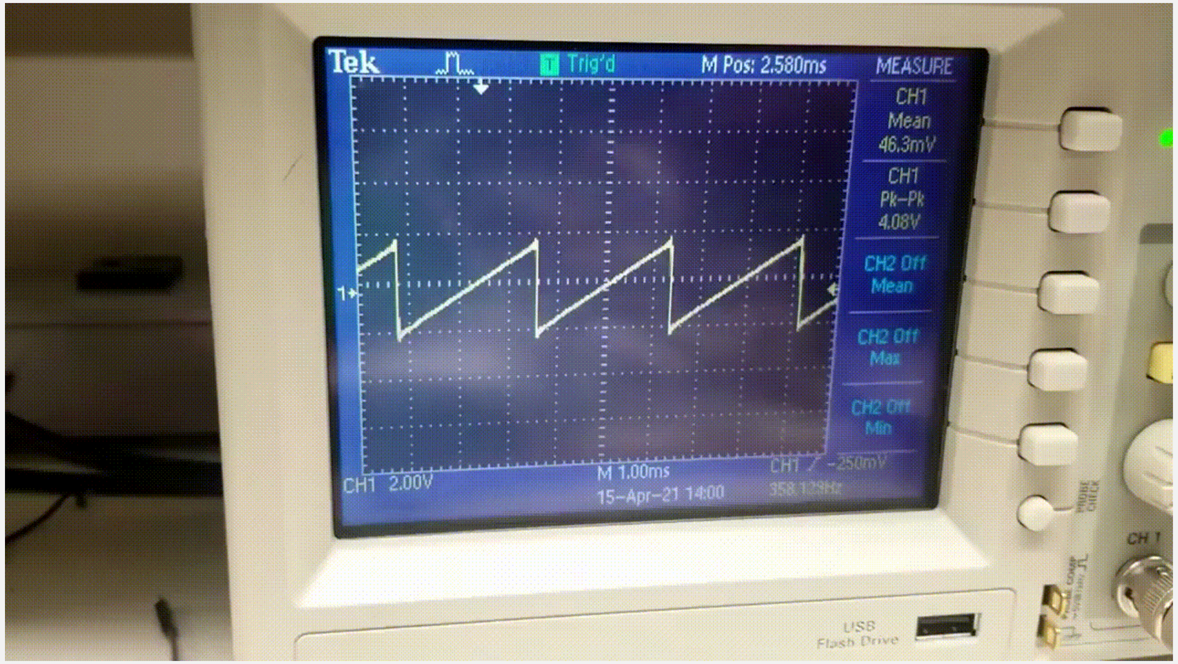
- Purpose:
  - Distortion
  - Bitcrusher
  - Delay
  - Reverb

- Functions:
  - Process Signals Digitally
  - Assist Course Syllabi

DME : EFFECTS DEMONSTRATION



Distortion



Bitcrusher

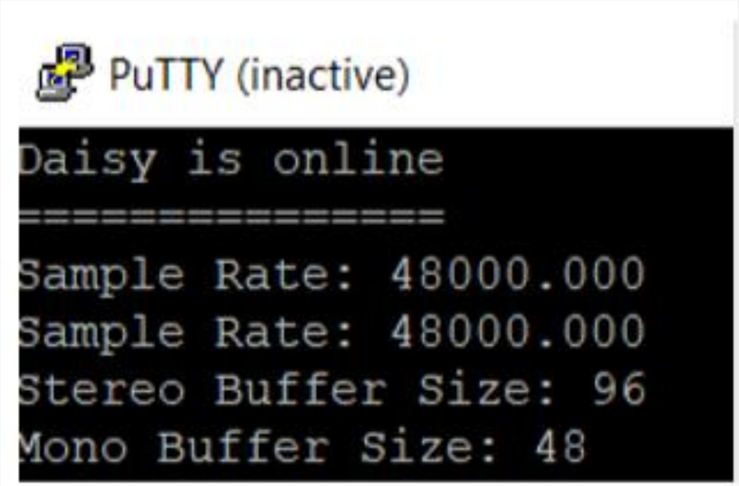
DME : QUANTITATIVE CONSTRAINTS

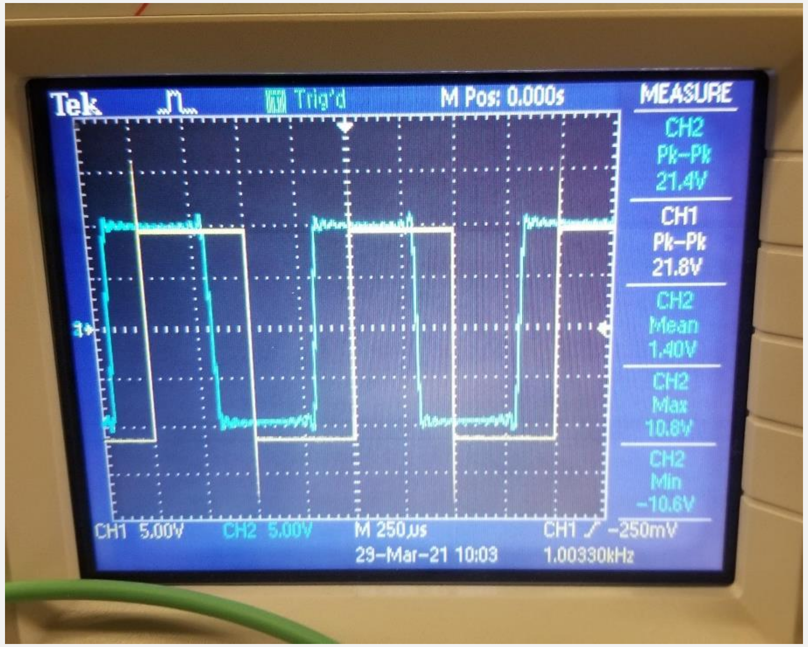
Sample Rate

Required	Actual
> 44100	48000

Digital Latency

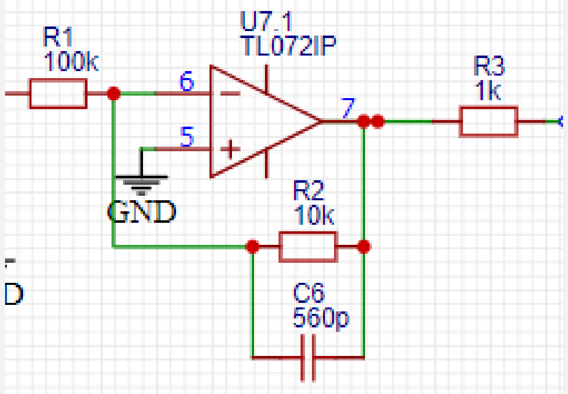
Required	Calculated	Actual
< 25ms	48 / 48000 = 1ms	2.6 ms

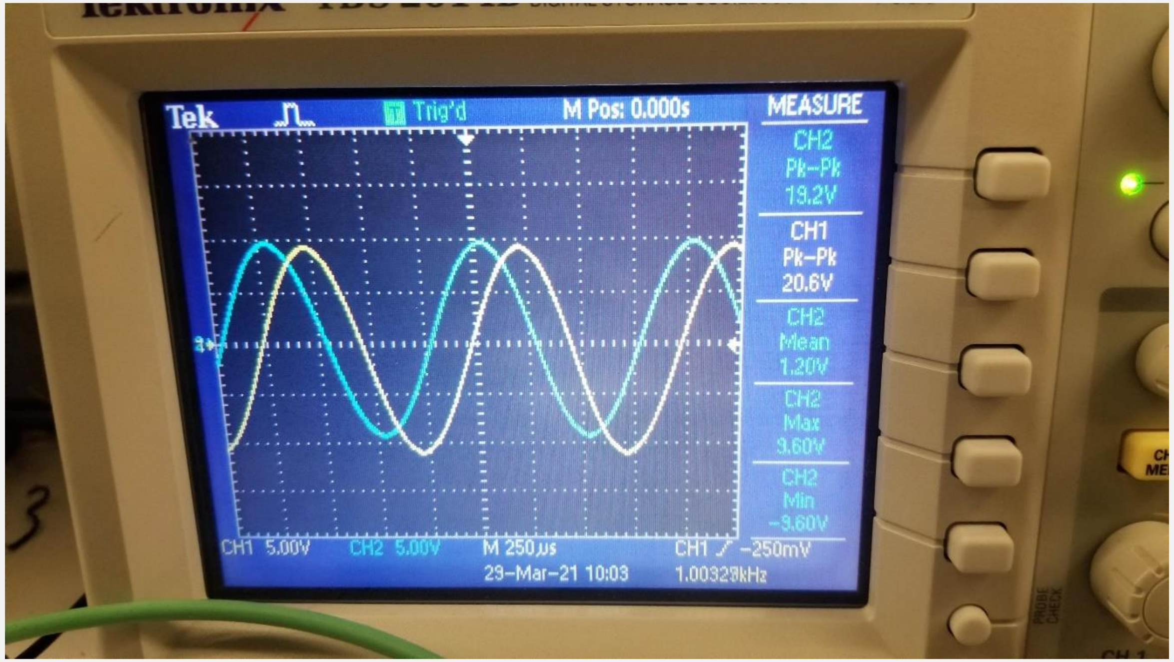




Input Output

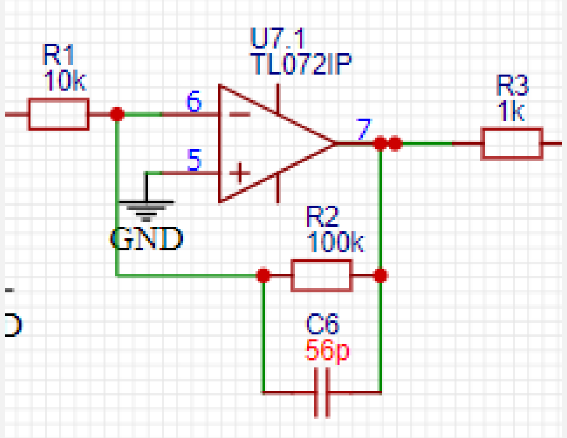
DME : AUDIO I/O ANALYSIS / TESTING



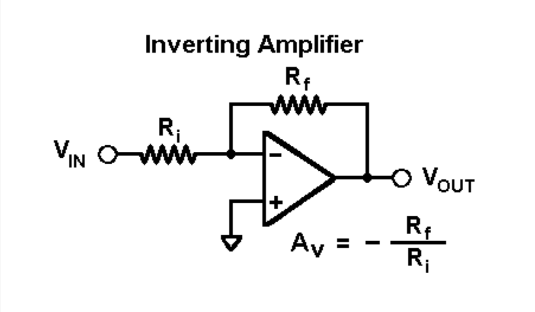


Input Gain = - 10 / 100 = -0.1

Actual Gain = 19.2 / 20.6 = 0.93



Total Gain = -0.1 * -10 = 1



Output Gain = - 100 / 10 = -10

CONTROL VOLTAGE

What is a **Control Voltage?**

A control voltage is a DC electrical signal with the ability to manipulate specified parts of an analog circuit.

How/Why Does Team 80 Use a CV?

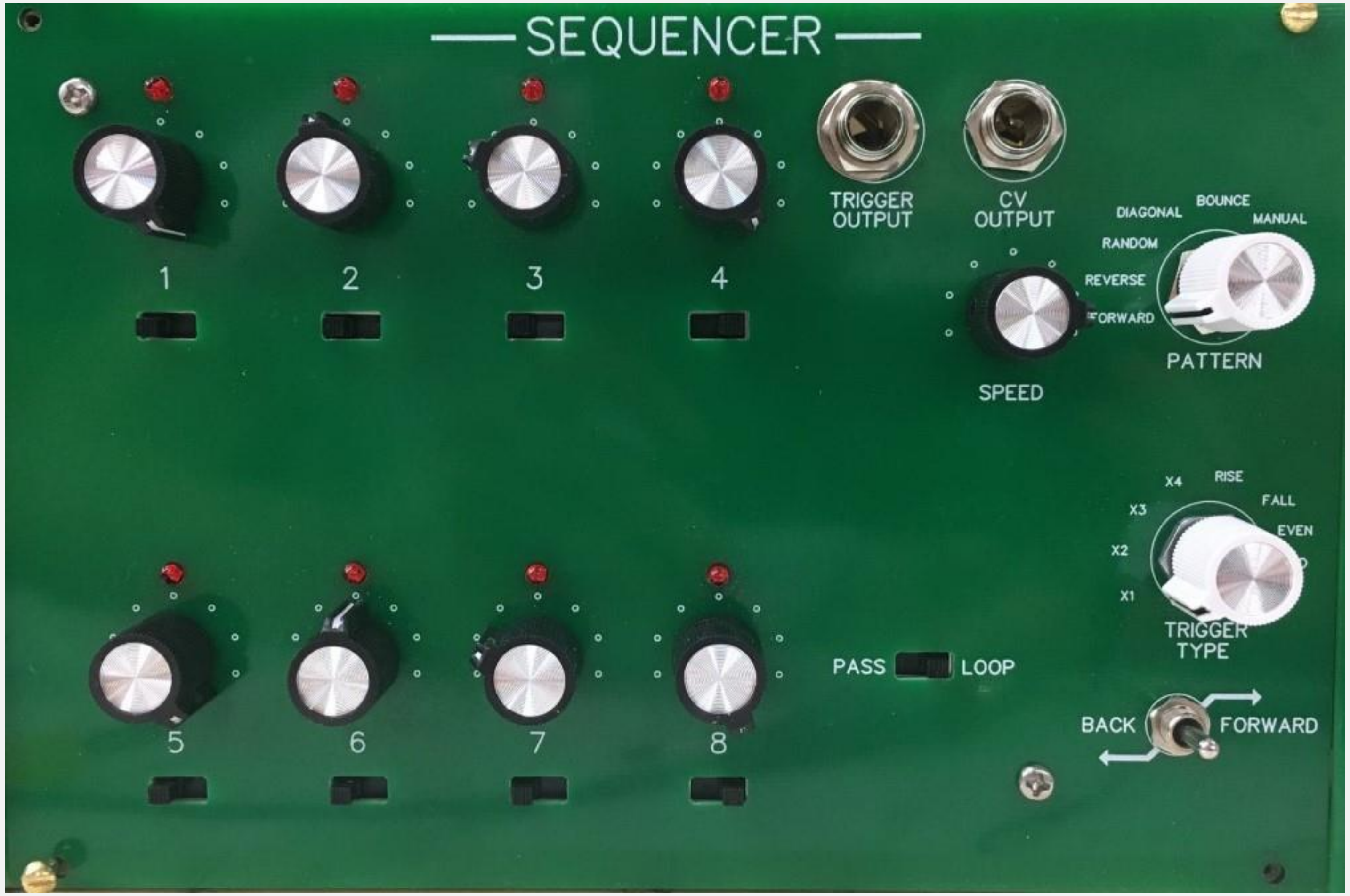
By design nature, some modules produce a control voltage at their output in order to affectively connect and manipulate the function of another module.

Three of Team 80's modules can produce a control Voltage. The **Envelope Generator, Sequencer,** and **Wireless Control Module**.

SEQUENCER

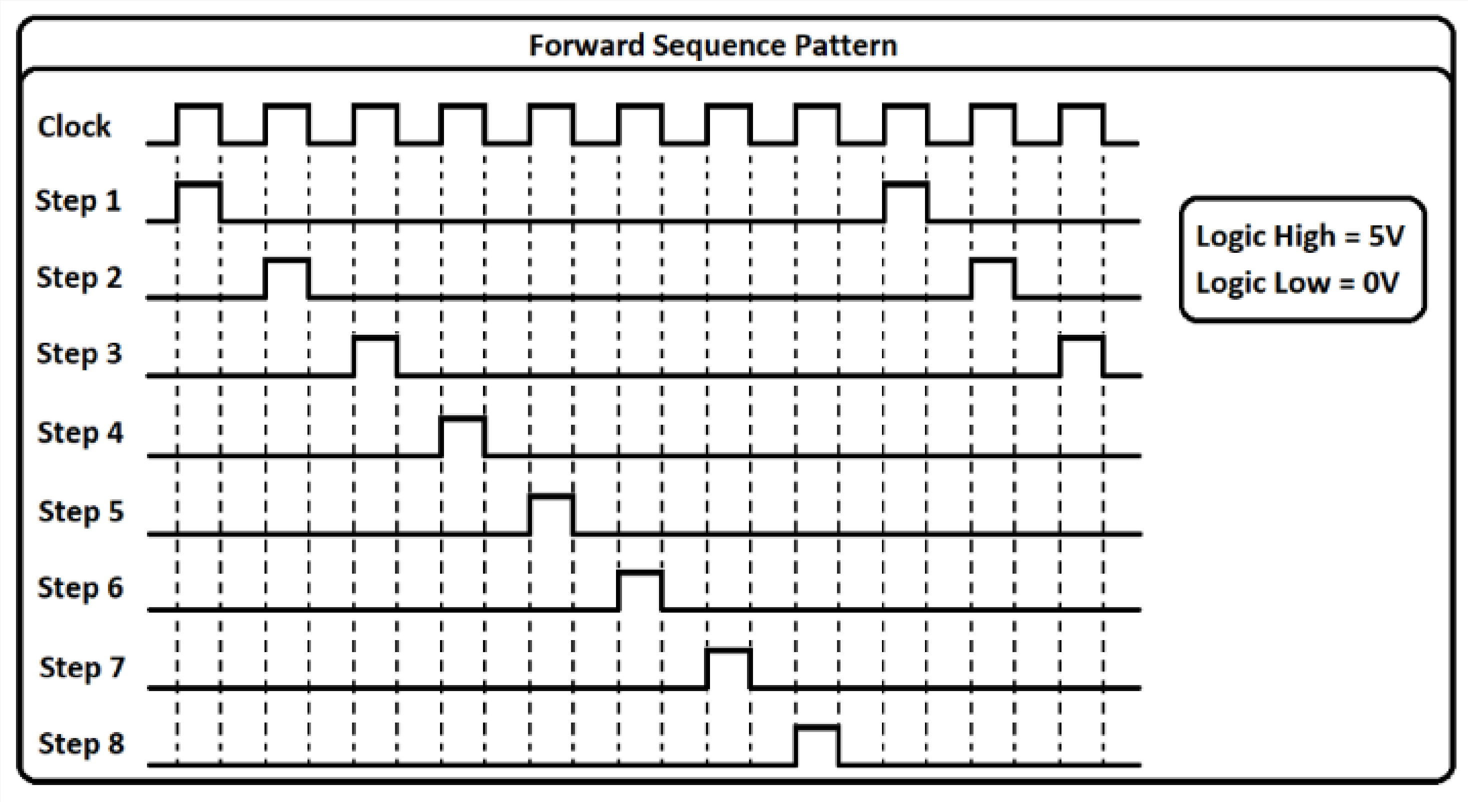
Purpose:
- Creates melodies and rhythms
  - Control Patterns
  - Control Speed
  - Toggle Steps On/Off

Functions:
- Generates Control Voltages



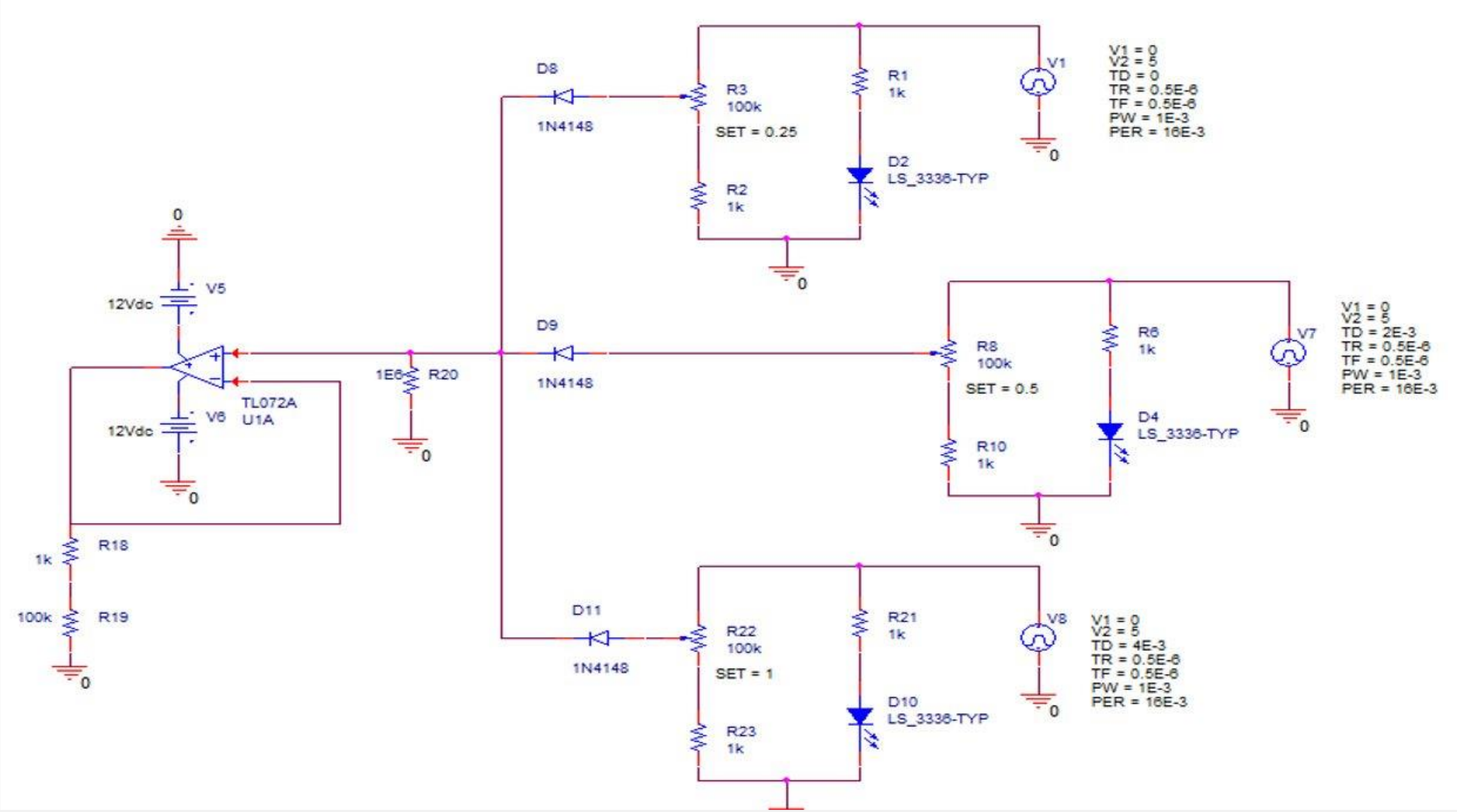
Presented By: Taylor LeBlanc

SEQUENCER ANALYSIS (OUTPUT STAGE)



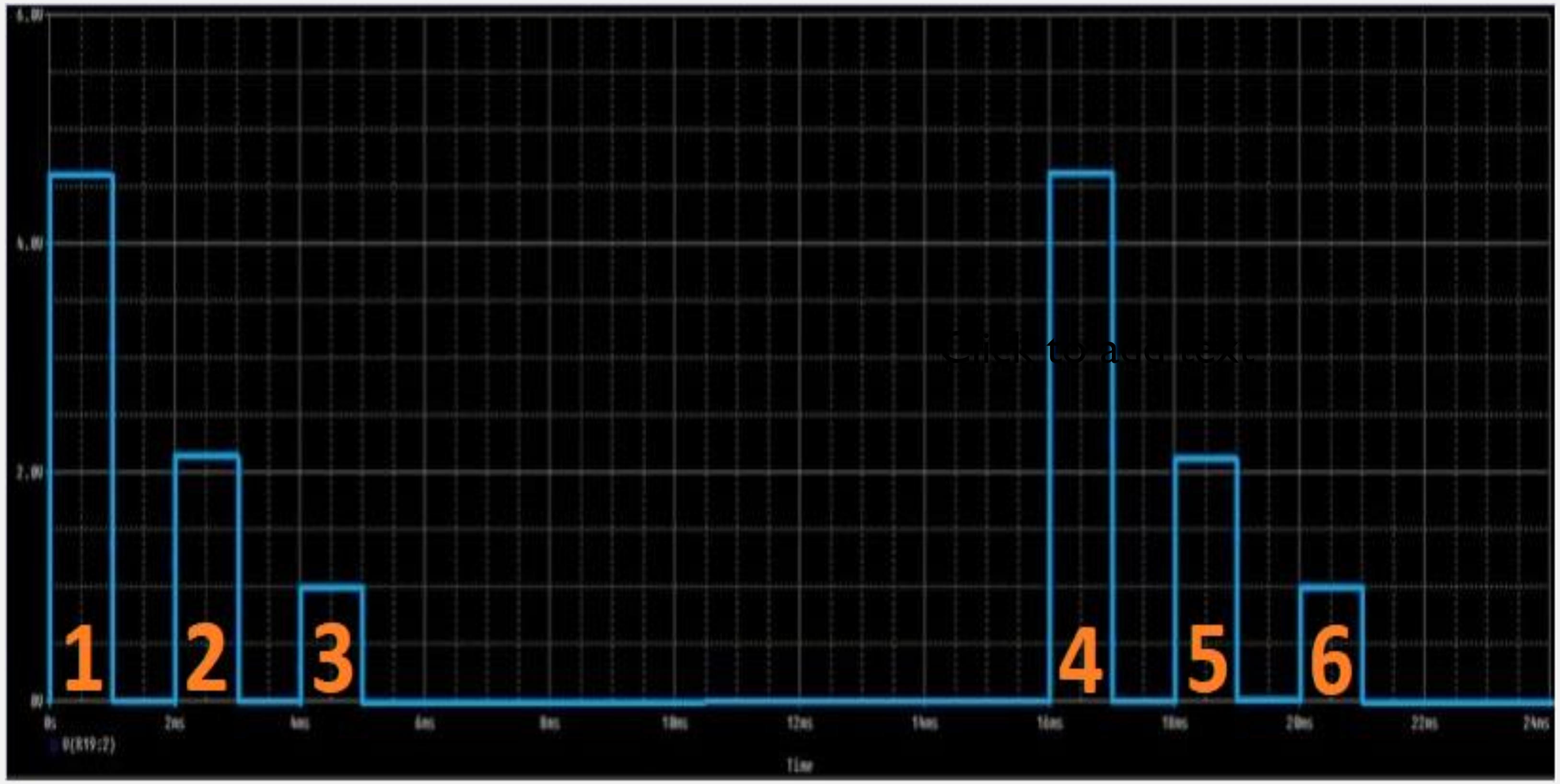
Presented By: Taylor LeBlanc

SEQUENCER ANALYSIS (OUTPUT STAGE)



Presented By: Taylor LeBlanc

SEQUENCER ANALYSIS



Step #	Voltage (V)
1	4.3
2	2.1
3	1
4	4.3
5	2.1
6	1

Presented By: Taylor LeBlanc

SEQUENCER TESTING RESULTS

Step #	Voltage (V)
1	4.3
2	2.1
3	1
4	4.3
5	2.1
6	1

Presented By: Taylor LeBlanc

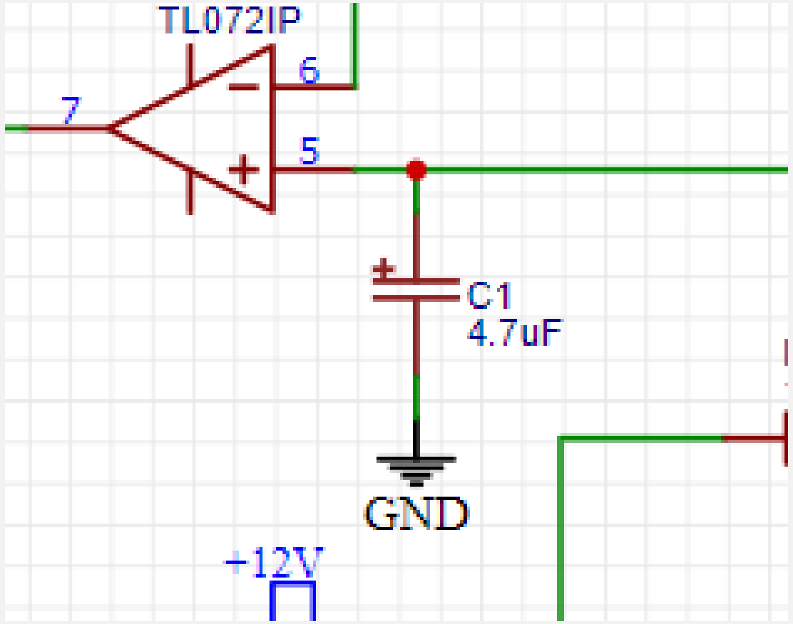
ENVELOPE GENERATOR

Purpose:
Modulation of amplitude over a user adjusted period of time.

Function:
Generates Control Voltages

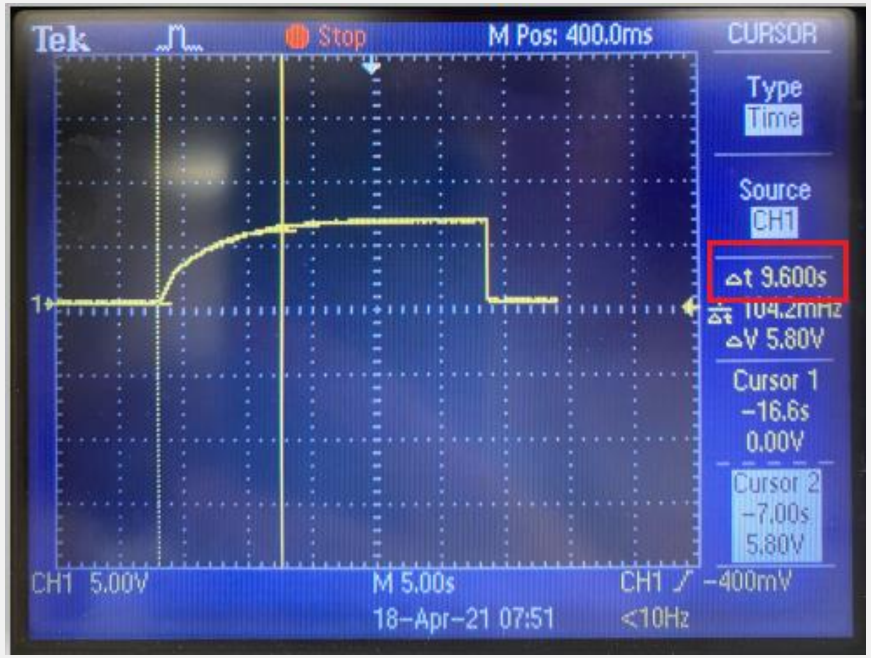
Presented by Keri Grevemberg

ENVELOPE GENERATOR ANALYSIS



$$\text{Simplify } (4.7 \cdot 10^{-6})(2000000): \quad 9.4$$

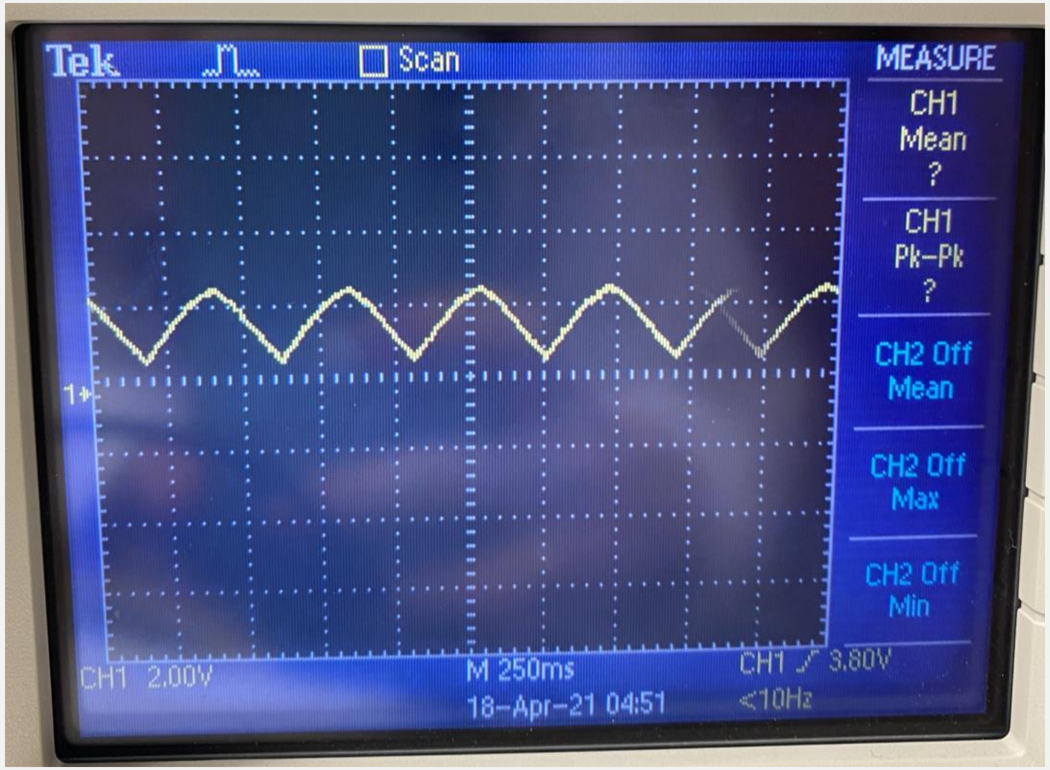
[T = R(C)]



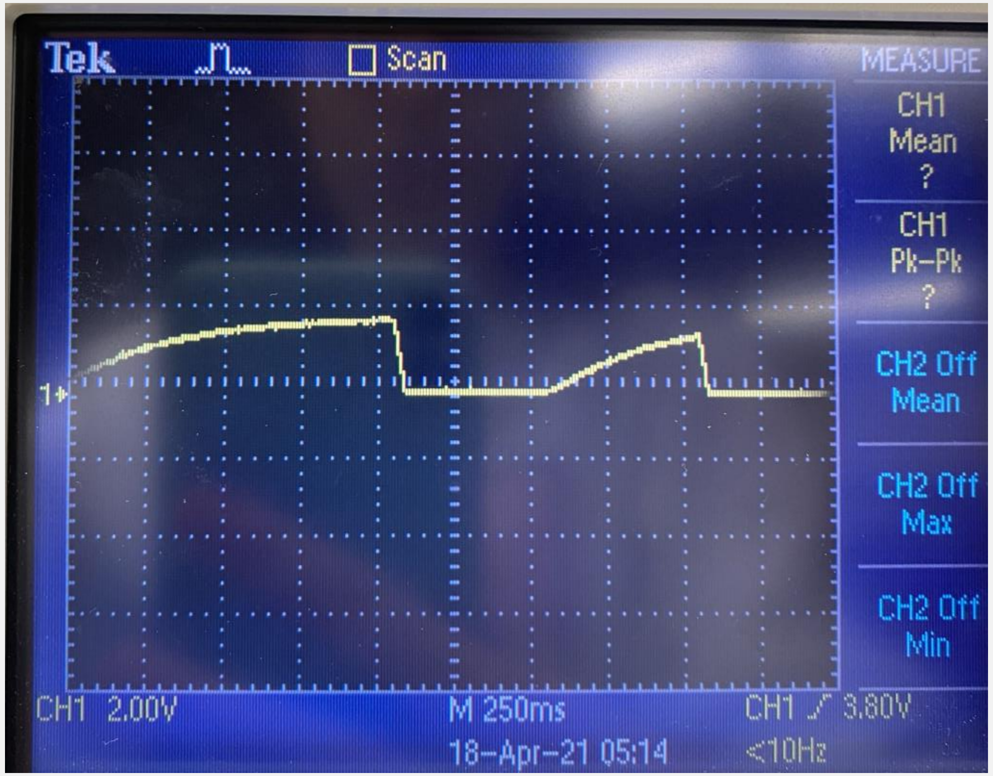
	MAXIMUM TIME
ATTACK	~9.4 seconds
RELEASE	±30 seconds (depends on gate length)
DECAY	~3.3 seconds

Presented by Keri Grevemberg

ENVELOPE GENERATOR TESTING RESULTS



AD Mode or Trigger Mode



AR Mode or Gate Mode

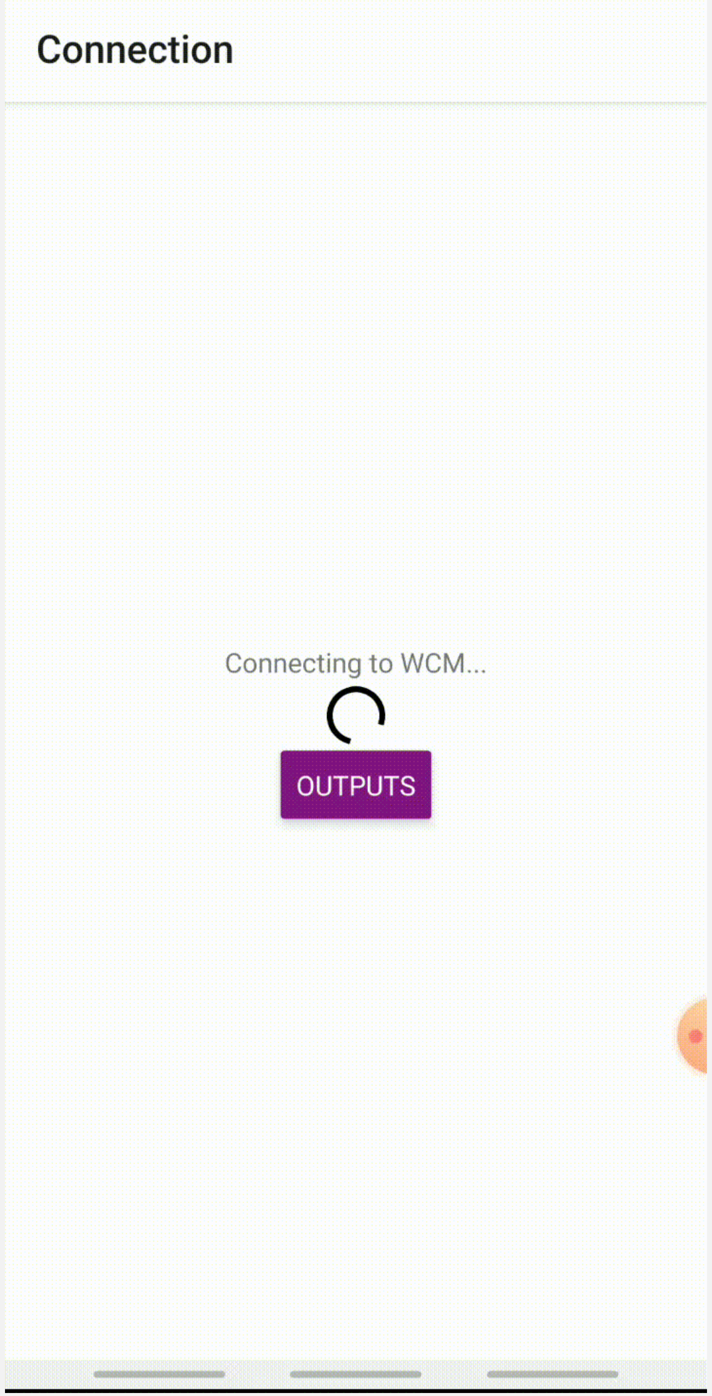
Presented by Keri Grevemberg

WIRELESS CONTROL MODULE (WCM)

- Purpose:
  - Allows users to interact with system from a distance
  - Expands Control Voltage Options

- Functions:
- Operate Remotely
  - Generates Control Voltages

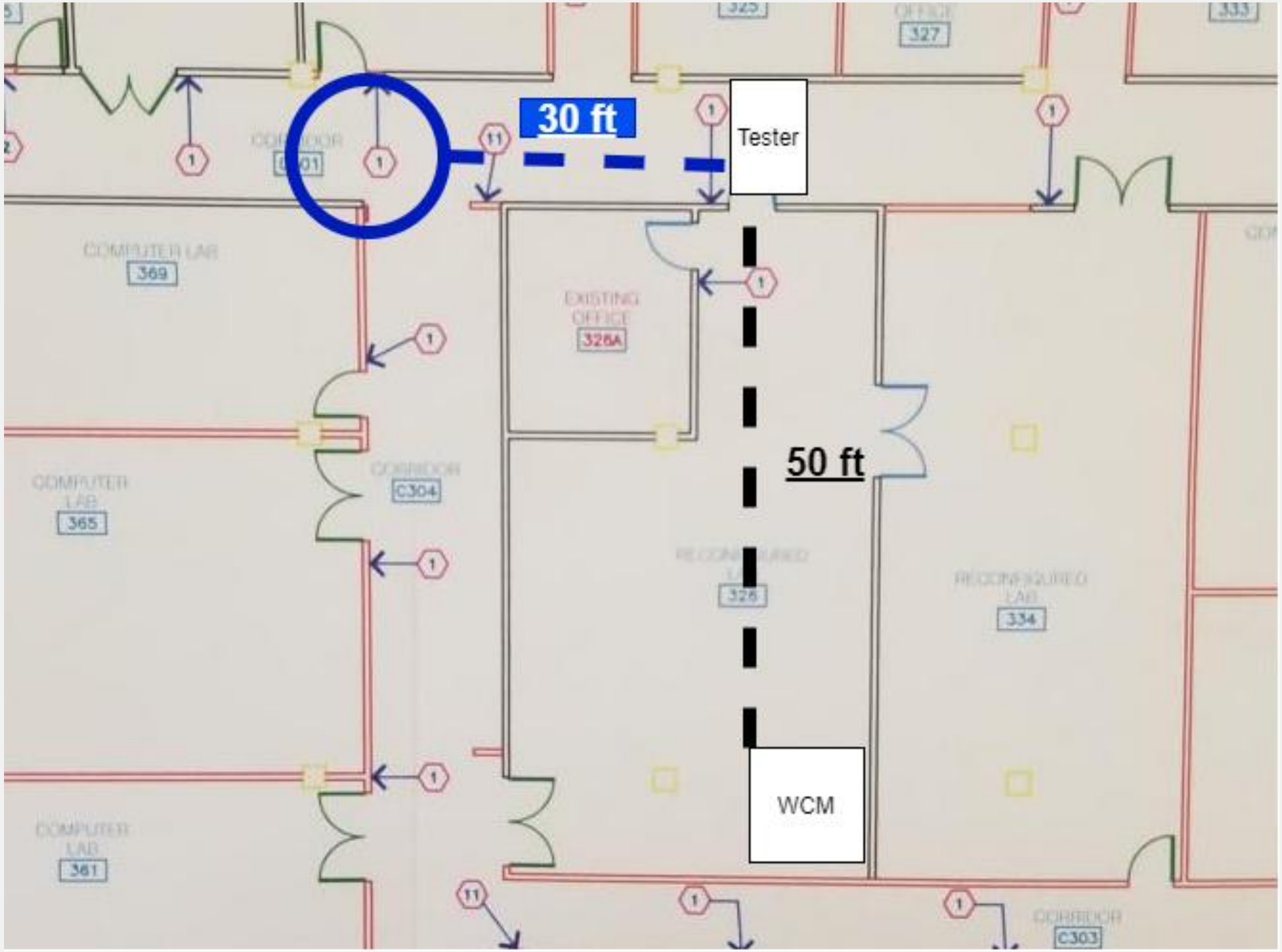
WCM : CONTROL APP



WCM : RANGE

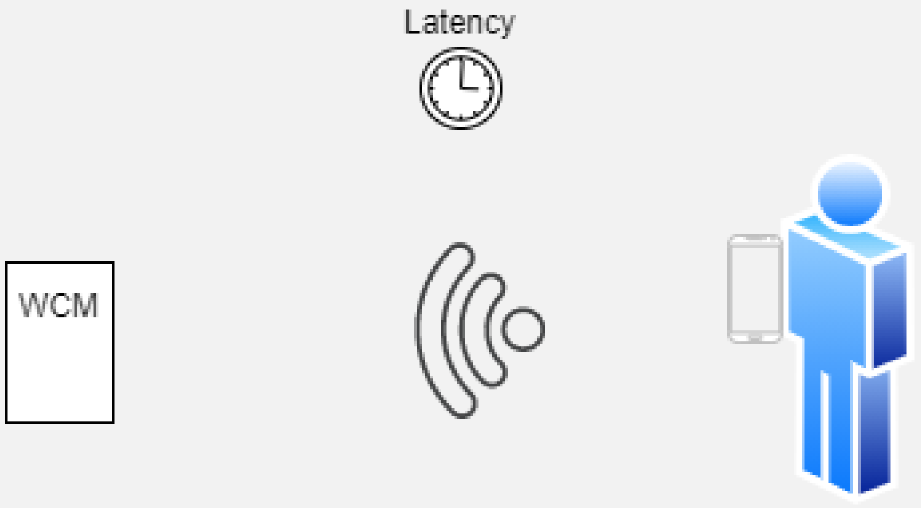
Required	Actual
> 10 ft	>50 ft

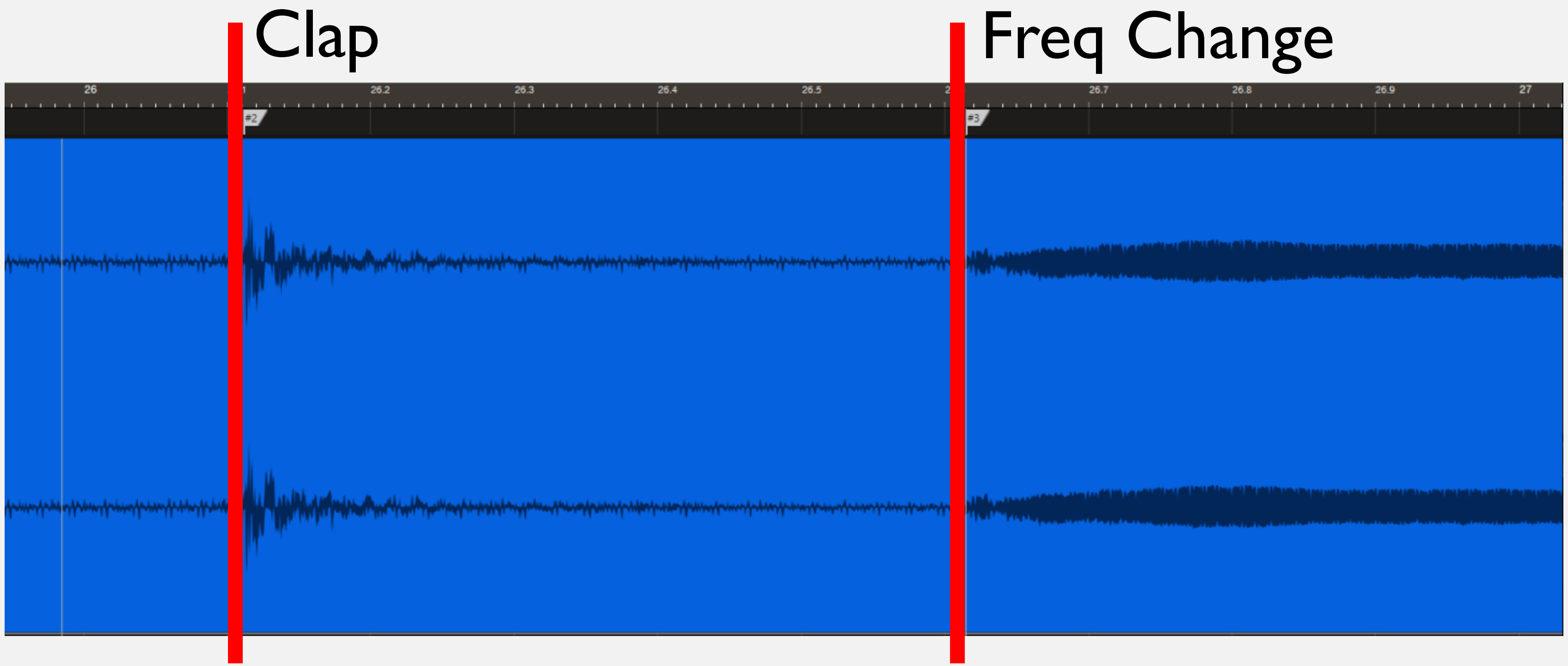
Actual Results:
58 ft through 2 walls



WCM : LATENCY

Required	Actual
< 100 ms	< 50 ms



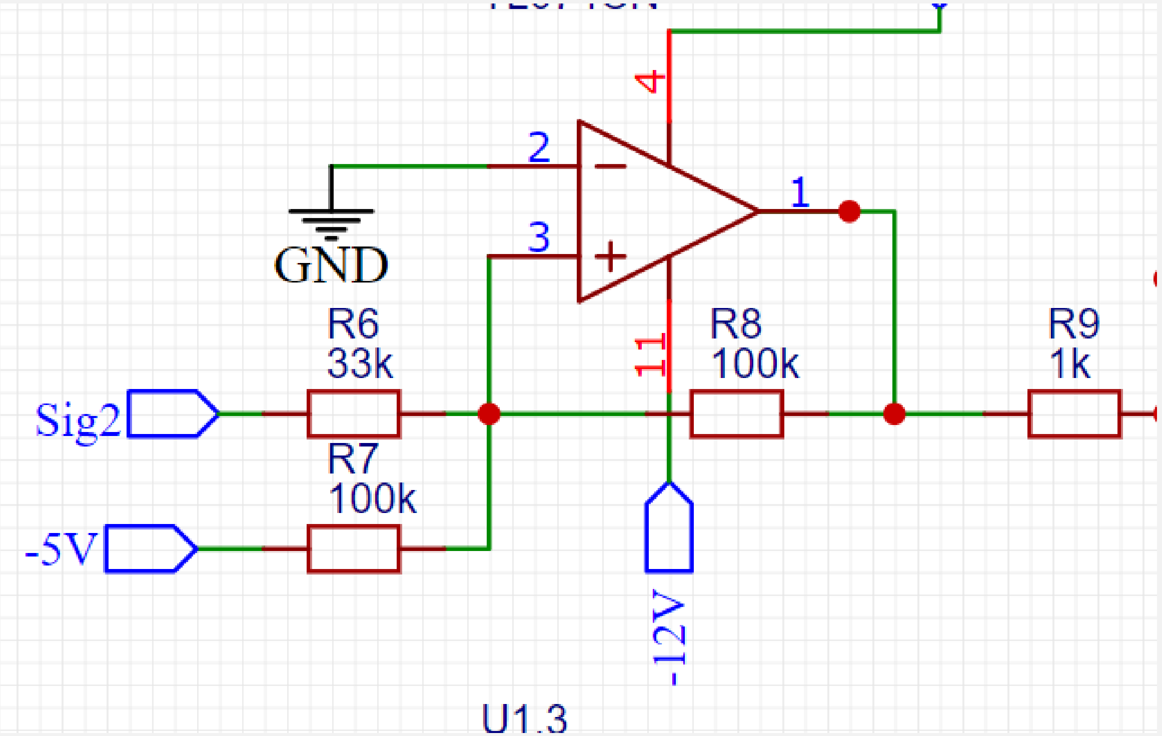


WCM : OUTPUT RANGE TESTING & VALIDATION

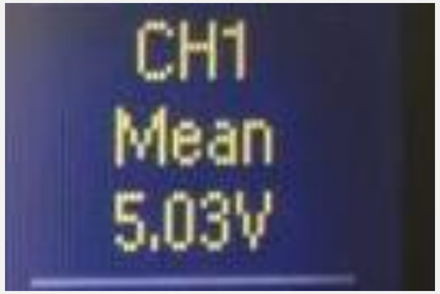
$$V_{out} = -\left(\left(\frac{100}{33}\right) * \text{Signal} + \left(\frac{100}{100}\right) * -5\right)$$

Signal = 0V -> Vout = 5 V

Signal = 3.3V -> Vout = -5V



Validation



Manufacturing Process

SYSTEM CASE MANUFACTURING

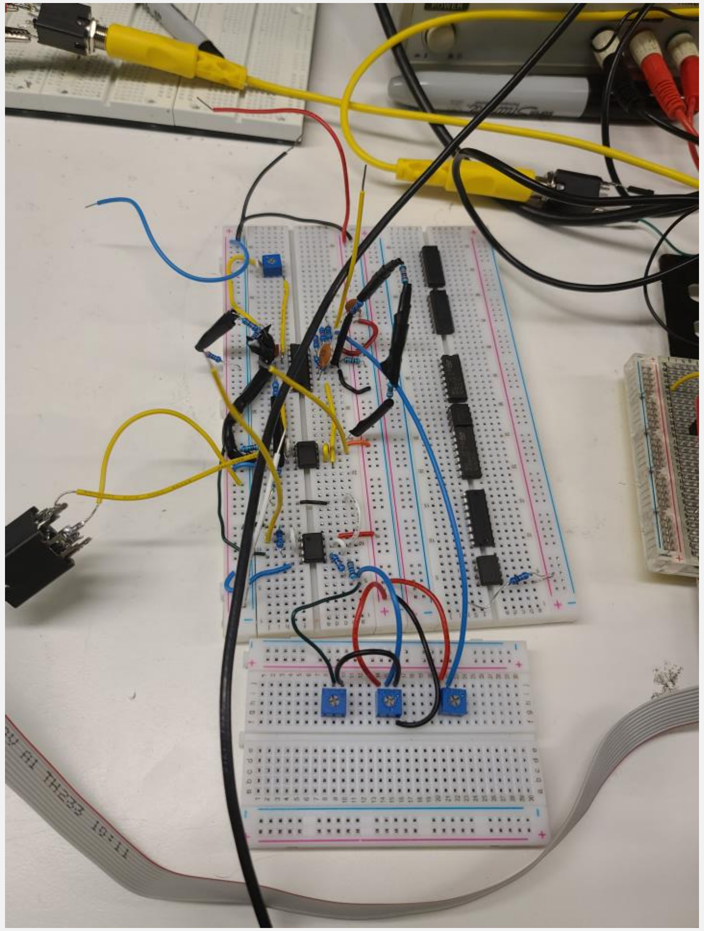
- Case Design
- Acquire material
- Cut sides
- Assemble Into Box
- Cut Rails
- Bevel Edges
- Mount Rails and PCB's

MANUFACTURING PROCESSES USED DURING PROJECT

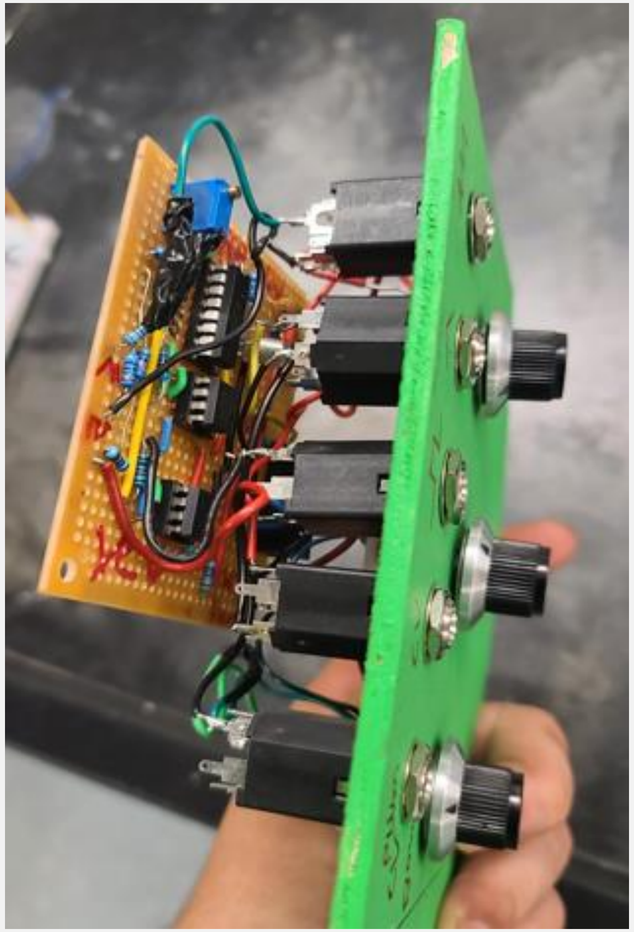
Team 80 followed a consistent process during manufacturing.

1. EasyEDA free online software to create schematic of each module.
2. PSpice software to analyze functionality of circuit before sending Gerber file to manufacturer.
3. JLC PCB was our chosen PCB manufacturer.
4. Circuit components were ordered mainly from Mouser and Tayda Electronics.
5. Team 80 utilized the IEEE Lab at the ERAD to solder, assemble, and test our final PCBs.

DESIGN PROGRESSION



VCO Breadboard Layout



VCO Stripboard Layout

VCO Final PCB Layout

Presented By: Rafael A Alvarez

Material Selection

Materials Selection: Case & Faceplates

Faceplate Material Considerations:

- Wood
- FR-4
- Aluminum
- Acrylic
- 3D Printed

https://store.lookmumnocomputer.com/collections/modules/products/1114-filter-grr

Selected: FR-4

Why?

- Ease of Manufacturing

Case Material Considerations:

- Wood
- Aluminum
- Acrylic
- 3D Printed

https://www.etsy.com/listing/178405852/synthrotek-6u-x-104hp-oak-plywood?gpla=1&gao=1&

Selected: Wood

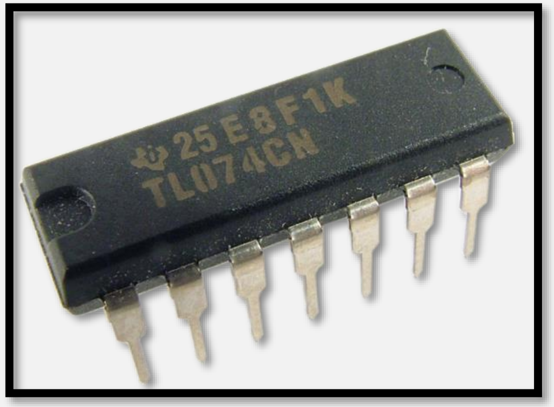
Why?

- Ease of Manufacturing
- Cost

Materials Selection: Electronics

Low Noise Op-Amp
Material Considerations:

- TL07xx
- NE-55xx



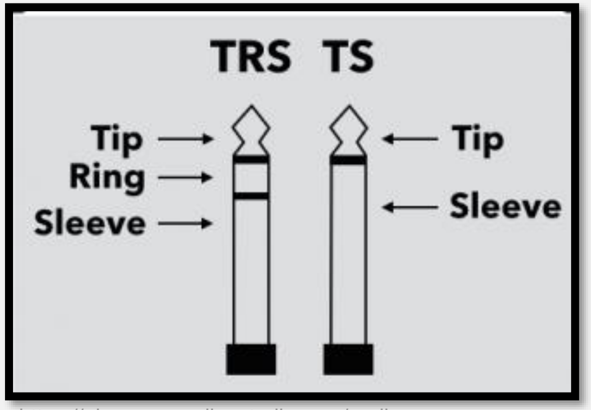
https://www.amplifiedparts.com/products/op-amp-tl074-quad-low-noise-jfet-input-14-pin-dip

Selected: TL07xx

Why?
•Lower Power Draw

Connector Jacks
Material Considerations:

- 1/4" TS
- 1/4" TRS
- 1/8” TS
- 1/8” TRS



https://ehomerecordingstudio.com/audio-cables-types/

Selected: 1/4” TS

Why?
•Safety
•Cost

SAFETY CONSIDERATIONS

TEMPERATURE REGULATION

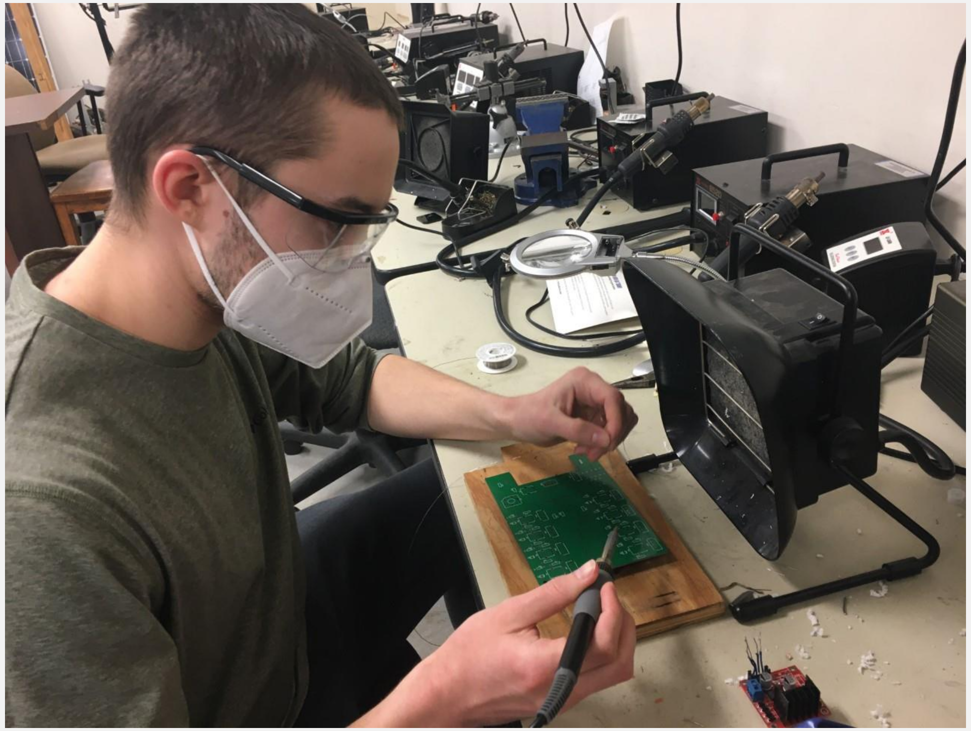
How Our Modular Synthesizer Stays Cool

- **Holes** found at the back exterior of the case to allow heat to escape.
- **Heat sinks** on the power supply board.
- Precise circuit component **placement** that separates components with the most power draw.

Module	Temp (*C)
Power Supply	37.3
WCM	32.9
DME	30
Sequencer	30.6
Ambient Case	26.7

LAB SAFETY

COVID-19 and OSHA recommended safety efforts were enforced in the lab when Team 80 was present.



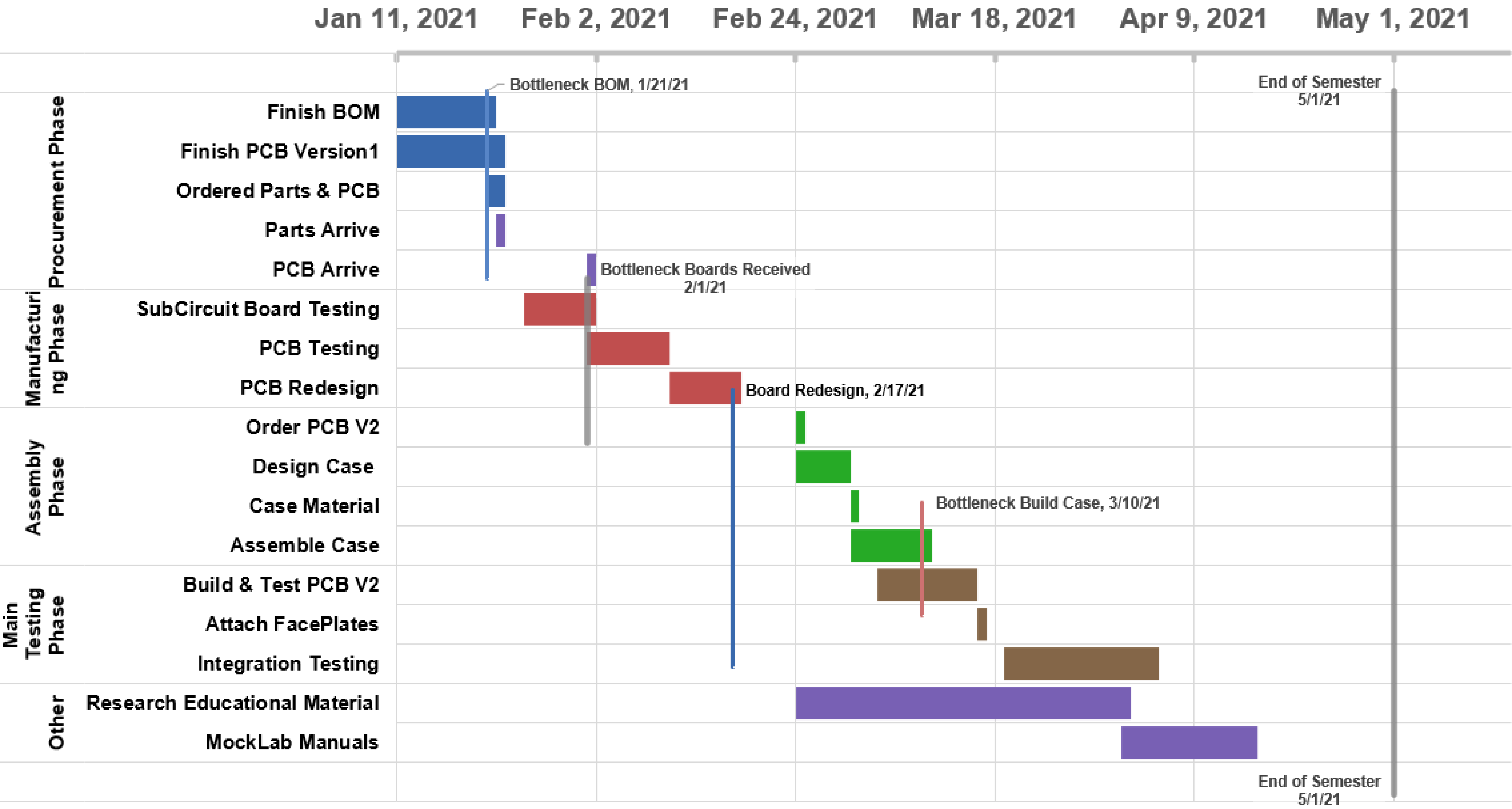
Project Management

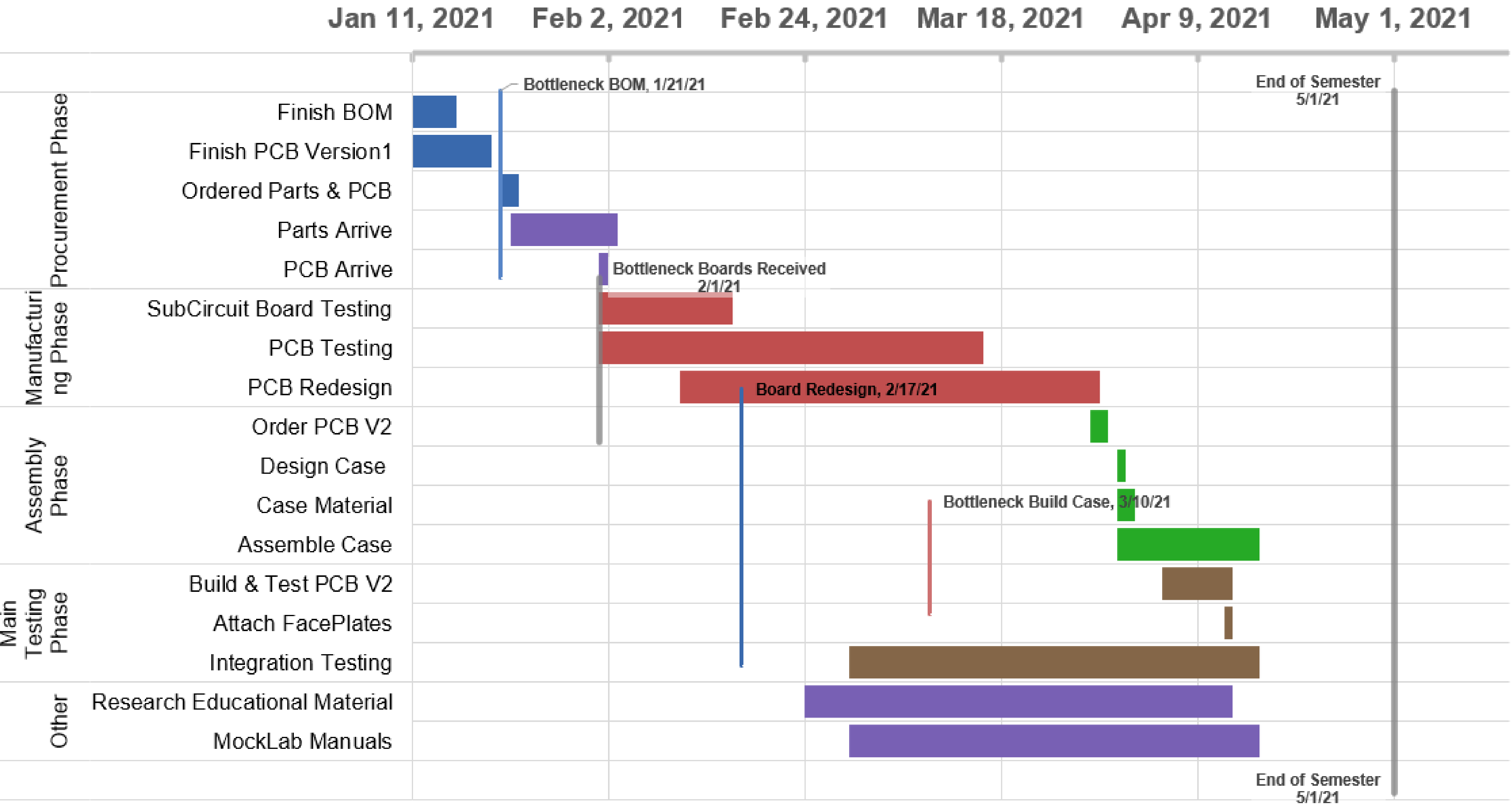
TEAM 80'S BUDGET

Expense Type	Ideal Budget	Final Spent	Per System Cost
Circuit Components	$400.00	$647.96	$414.09
PCBs	$75.00	$91.46	$13.07
Faceplates	$75.00	$124.91	$17.85
Case Material	$50.00	$35.00	$35.00
TOTAL	$600	$899.33	$479.85

Presented By: Rafael A Alvarez

Presented By: Rafael A Alvarez





Presented By: Rafael A Alvarez
Jan 11, 2021
Feb 2, 2021
Feb 24, 2021
Mar 18, 2021
Apr 9, 2021
May 1, 2021
Procurement Phase
Finish BOM
Finish PCB Version1
Ordered Parts & PCB
Parts Arrive
PCB Arrive
Manufacturing Phase
SubCircuit Board Testing
PCB Testing
PCB Redesign
Assembly Phase
Order PCB V2
Design Case
Case Material
Assemble Case
Main Testing Phase
Build & Test PCB V2
Attach FacePlates
Integration Testing
Other
Research Educational Material
MockLab Manuals
Bottleneck BOM, 1/21/21
Bottleneck Boards Received 2/1/21
Board Redesign, 2/17/21
Bottleneck Build Case, 3/10/21
End of Semester 5/1/21
End of Semester 5/1/21

QUESTIONS?

Modular Synthesizer for ECE Education

Team Members: Taylor LeBlanc Tarik Lopez Rafael Alvarez Kyle Sellers Keri Grevemberg

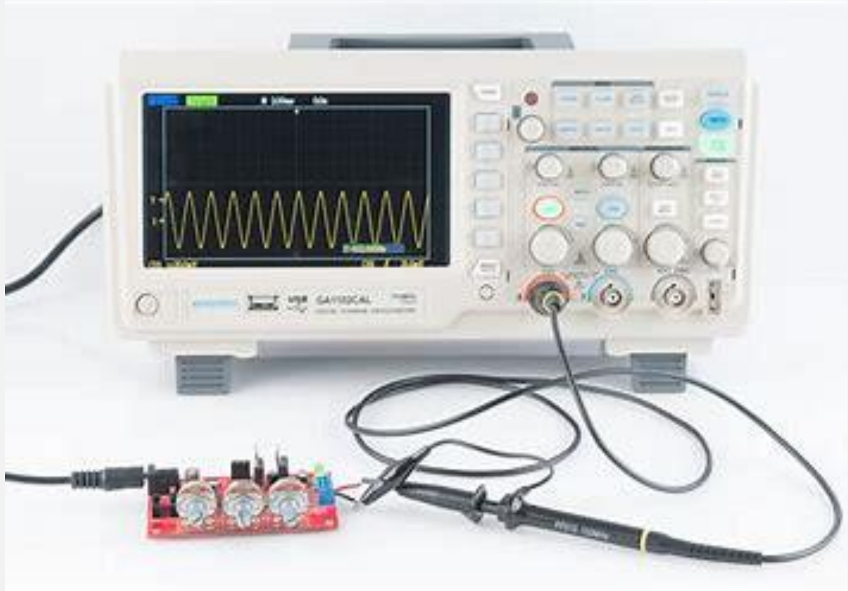
APPENDIX

Modular Synthesizer for ECE Education

FUNCTIONAL REQUIREMENTS

#	Function
F1	Assist Course Syllabi
F2	Generate Audio Signals
F3	Output Audio Signals
F4	Generate Control Voltages
F5	Manipulate Signal Frequency
F6	Manipulate Signal Amplitude
F7	Process Signals Digitally
F8	Operate Via Remote Control

TESTING TOOLS



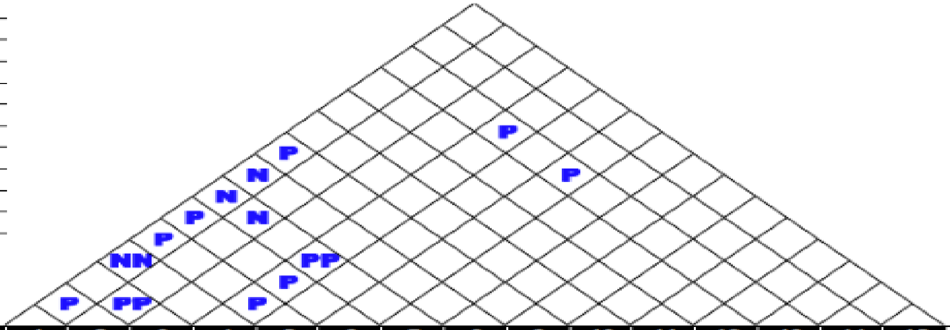
Oscilloscope

Multimeter for PCB continuity

Title: Modular Synthesis an Education Tool (Proj 80)
Author: Keri, Taylor, Tarik, Rafael, Kyle
Date: 10/15/2020
Notes:

Legend

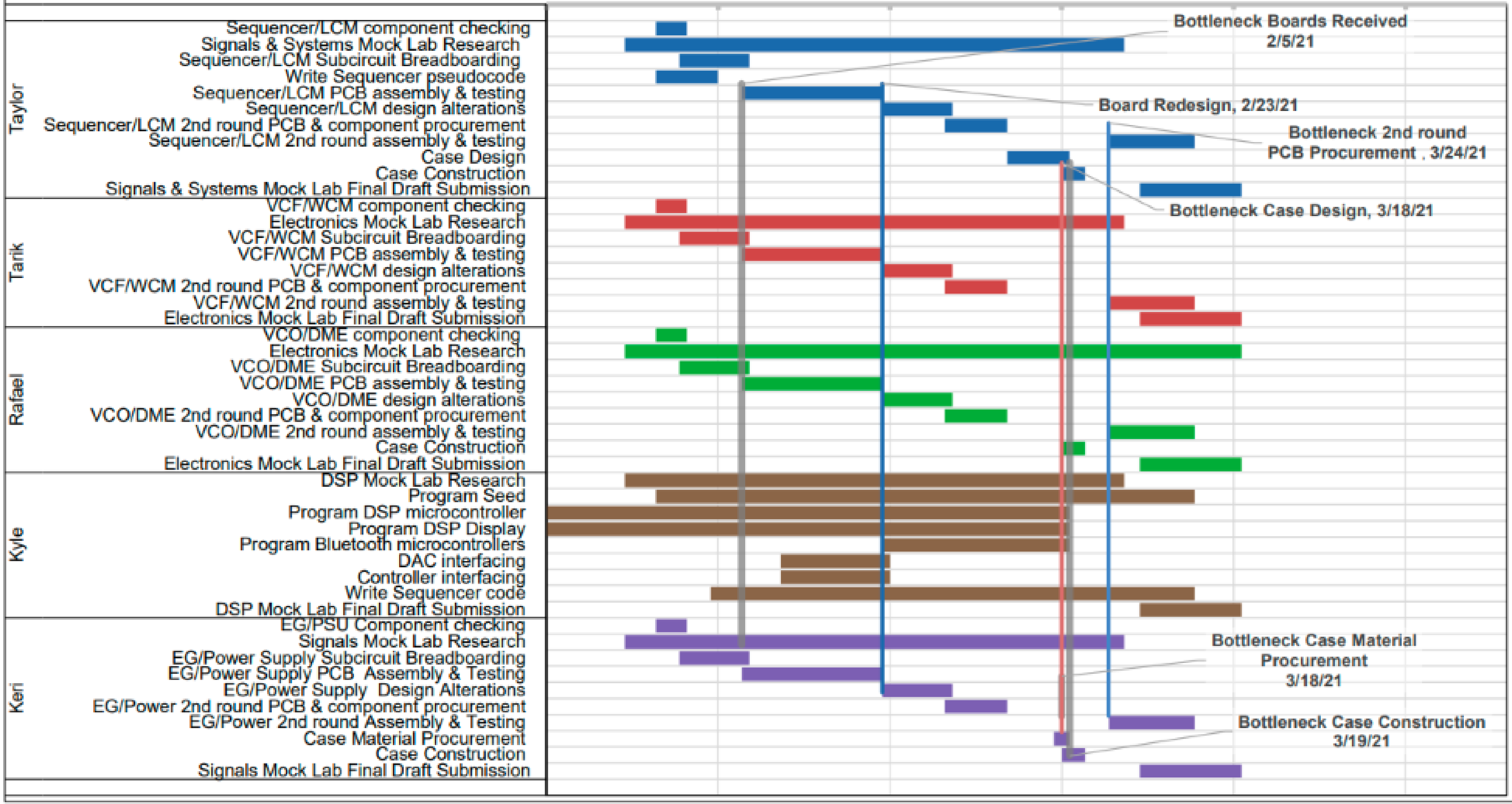
S	Strong Relationship	9
M	Moderate Relationship	3
W	Weak Relationship	1
PP	Strong Positive Correlation	
P	Positive Correlation	
N	Negative Correlation	
NN	Strong Negative Correlation	
↓	Objective Is To Minimize	
↑	Objective Is To Maximize	
⊕	Objective Is To Hit Target	



Row # 0	Max Relationship Value	Relative Weight	Weight / Importance	Column # 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
-1			-1	Direction of Improvement: Minimize (↓), Maximize (↑), or Target (⊕)	↓	⊕	↓	↓	⊕	↑	↓	↓	↑	↓	↑	↑	⊕			Competitive Analysis (0=Worst, 5=Best)					
				Functions & Qualitative Constraints ("Whats") / Quantitative Constraints with Units ("Hows")	Cost (USD)	Size of Case (Cubic Feet)	Weight (lbs)	Power Consumption (Watts)	Bandwidth (Hz)	Signal to Noise Ratio (dB)	Operating Temperature (°C)	Latency for wireless control (ms)	Range of wireless control (ft)	Latency of Digital Module (ms)	Sample Rate (Hz)	Instructional Material (# of Pages)	Degree of Loudness (dB)			Ours	littleBits Synth Kit	BASTL Instruments DIY	All About Circuits DIY Synth S	Moog Werkstatt	Pittsburgh Modular Microvolt
1	9	8.1	9.0	Assist Course Syllabi					M	W						S	W			5	3	0	4	2	1
2	3	8.1	9.0	Generate Audio Signals				M	M	W	W									2	1	5	0	3	4
3	9	8.1	9.0	Output Audio Signals					S	M	M						S			4	5	1	0	3	2
4	9	8.1	9.0	Generate Control Voltages				S			M									5	1	3	0	4	2
5	9	7.2	8.0	Manipulate Signal Frequency					S						M					3	2	5	0	1	4
6	9	7.2	8.0	Manipulate signal amplitude				S		W	M									4	2	5	0	1	3
7	9	5.4	6.0	Process Signals Digitally	M				W					S	S					5	4	0	0	0	0
8	9	5.4	6.0	Regulate Operating Temperature				S			S									1	5	2	0	3	4
9	9	7.2	8.0	Reroute Signal Path		S														3	2	4	0	1	5
10	9	5.4	6.0	Operate via Remote Control	M							S	S							5	0	0	0	0	0
11	3	4.5	5.0	Easy to Use		M										M				4	5	3	0	1	2
12	3	5.4	6.0	Stable Waveforms	W						M									4	2	1	0	3	5
13	3	4.5	5.0	Engaging/Fun to Use		M						M	W	W						4	3	1	0	2	5
14	9	6.3	7.0	Customizable	M	S	M	M								W				5	3	1	4	0	2
15	9	4.5	5.0	Good Sound Quality					S	S					M		S			3	0	4	1	2	5
16	9	4.5	5.0	Easy to DIY	W	M										S				2	4	0	1	3	5
17																									
18																									
19																									
20																									
21				Target or Limit Value for Quantitative Specs	600	4	20	2.5	20-20kHz	80	80	100	10	25	44100	5	80								
22				Difficulty (0=Easy, 10=Extremely Difficult)	3	5	5	8	7	7	6	7	4	7	2	4	3								
				Max Relationship Value	3	9	3	9	9	9	9	9	9	9	9	9	9								
				Weight / Importance	61.3	162.2	18.9	229.7	232.4	88.3	143.2	62.2	53.2	53.2	83.8	133.3	121.6								
				Relative Weight	4.2	11.2	1.3	15.9	16.1	6.1	9.9	4.3	3.7	3.7	5.8	9.2	8.4								

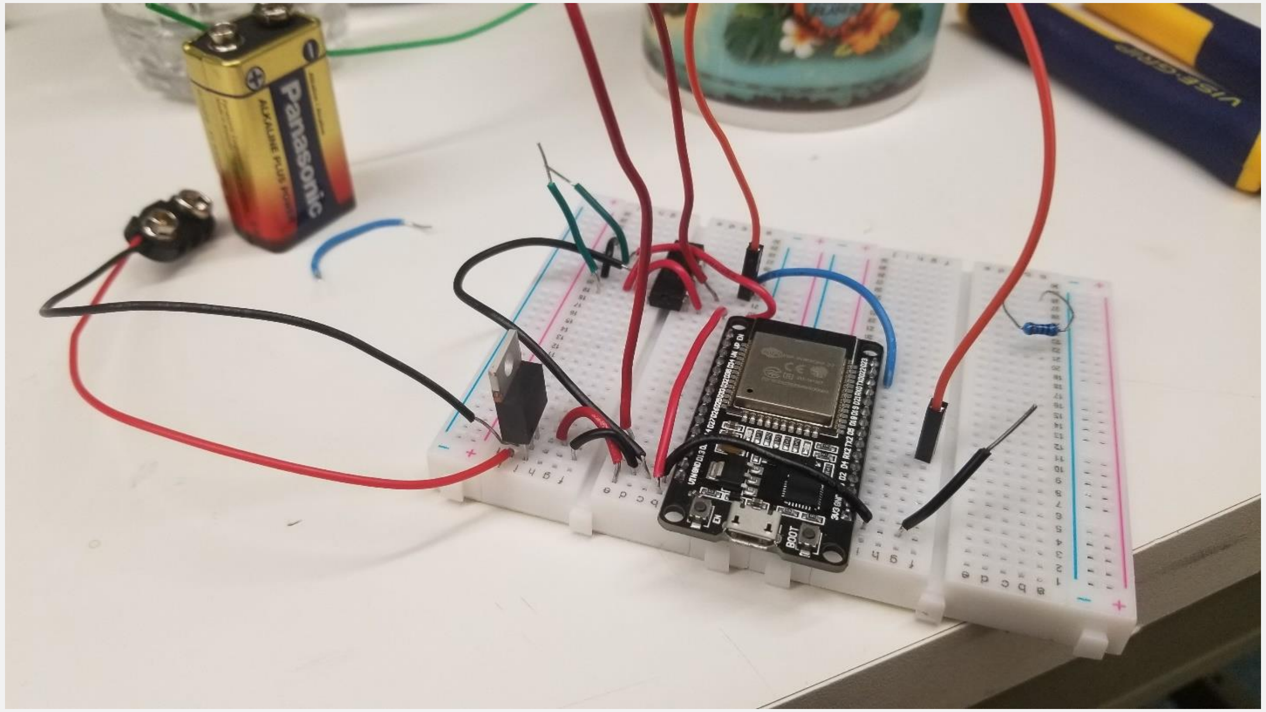
Modified from QFD Online (http://www.QFDOnline.com)

Project #80 Spring Timeline



GENERAL TESTING : BREADBOARDING

All subcircuits are breadboarded before soldering to PCB to ensure proper functionality



GENERAL TESTING : CONTINUITY

All PCBs are tested for proper net connections before soldering

Tool : Multimeter in connectivity mode

https://learn.adafruit.com/multimeters/continuity

WHAT WE LEARNED HARD SKILLS

- Footprint Analysis
- Efficient Soldering Techniques
- PCB Manufacturing (Include PCB Design & Trace Routing)
- OrCad PSpice Software
- Electronic Lab Equipment Operation

WHAT WE LEARNED
SOFT SKILLS

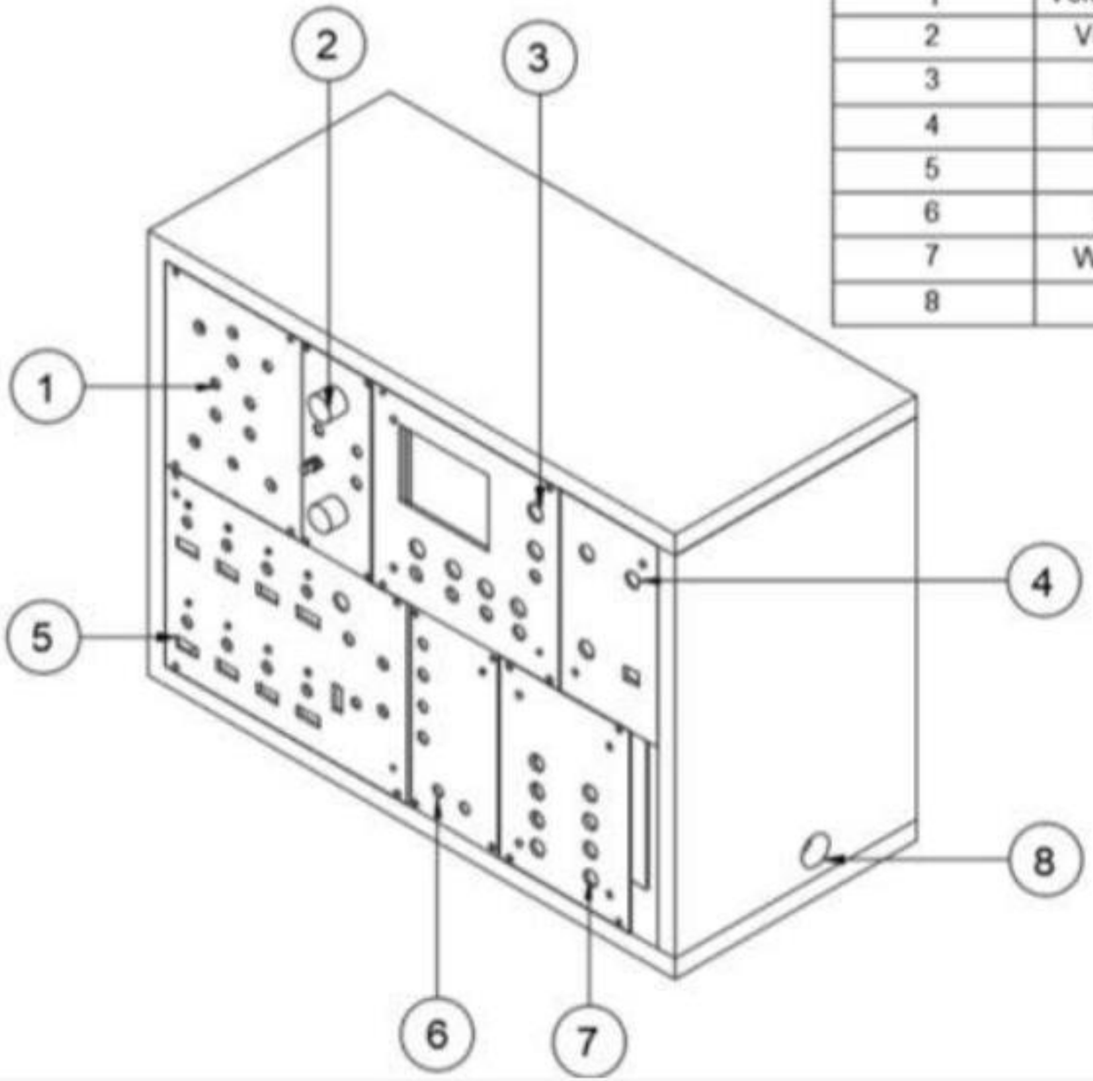
- Communication
- Time Management
- Scheduling
- Workload Allocation
- Datasheet / Documentation Familiarization

SYSTEMS AND SIGNALS MOCK LAB MANUAL

Slides (75-79)

THE FUNDAMENTAL FREQUENCY

Modular Synthesizer for Signals Education Lab



1	Voltage Controlled Oscillator
2	Voltage Controlled Filter
3	Digital Multi-Effects
4	Level Control Module
5	Sequencer
6	Envelope Generator
7	Wireless Control Module
8	Power Supply

OBJECTIVE

- Understand the fundamental frequency of a note.
- Learn how to find the fundamental frequency of a complex periodic waveform using a Voltage Controlled Oscillator and Voltage Controlled Filter.

DISCUSSION

The synthesizer, in practice, is a device that musicians can use to produce and manipulate sound. In other words, the system we are working with today is an instrument. The “modular” part of the system refers to the many individual working subsystems that can be connected in a variety of ways depending on the preference of the user. Some synthesizers work by adding sin waves of the same fundamental frequency together to produce a sound enjoyable to the musician. The synthesizer used in this lab is a Subtractive Synthesizer which produces a complex periodic waveform and then essentially “subtracts” parts of the waveform to produce a sound.

The two subsystems we will be learning about today are the Voltage Controlled Oscillator, the VCO, and the Voltage Controlled Filter, the VCF. The Level Control module will be used to aid in connecting the system to an oscilliscope. This system uses all of the concepts taught in electrical engineering to achieve the versatility of musical production. In this lab, we will explore the basic concepts of an oscillator and a filter, and what these modules offer to the system as a whole. Along the way, students will learn about the relevance of the fundamental frequency of a periodic waveform.

EQUIPMENT LIST

- Oscilliscope
- Voltage Controlled Filter, Voltage Controlled Oscillator, and LCM
- Patch cables

PROCEDURE

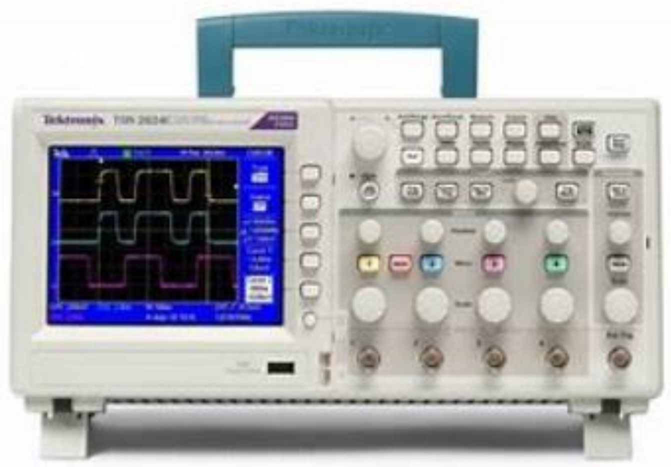
Connecting the Modules

Before powering the system on, connect a patch cable from the VCO terminal labeled “output” to the VCF terminal labeled “input”. The “output” of the VCF is then connected to the “Signal Input” of the Level Control Module. Ensure the VCF is switched to “Low Pass” before continuing.

Step 1: Selecting the VCO setting.

The VCO can produce a square wave, a triangle wave, and a sawtooth wave. In this step, we will connect the square, or “pulse” output of the VCO to the input of the VCF. Once the student has made that connection using patch cables, go ahead and connect an oscilliscope probe to the “Monitor” of the LCM.

Note: for the purpose of this lab, students should keep the “Course Tune” and “Pulse Width” adjusters on the VCO at about 50%, or halfway between minimum and maximum values.



Step 2: Fine Tuning the Oscilliscope

The Level Control Module includes an area where students can connect the signal and ground terminal of the probe to the system.

Do not connect a probe to any other area of the system while it is operating!!

Students will be using CH 1 on the oscilliscope. Once on, select “CH 1 MENU”. We want the “Coupling” set to AC and the “VOLTS/DIV” set to 2V per division. Students can verify this at the bottom of the oscilliscope display. A pulse wave should appear in yellow.

Note: If unable to distinguish a square wave due to a preset high frequency, try adjusting the “SEC/DIV” knob under “Horizontal Position” on the oscilliscope until a stable, clear square wave appears.

PICTURE OF OSCILLISCOPE SETTING BUTTONS

STEP 3: VCF Settings

Next, students will verify the VCF is operating in low pass mode. A low pass filter works to cut out high frequencies. The VCF allows users to select what the system considers a high frequency using the “Cut Off” knob. The knob at maximum turn allows all frequencies to pass, leaving the pulse waveform “unfiltered”. When the knob is at minimum value, the filter will cut out all frequencies above ********.

Note: make sure “Resonance” is set to zero. For now, students won’t need to worry about this parameter.

ADJUSTING THE FREQUENCY RESPONSE

Before Step 4, it is important students understand how the fundamental frequency of a periodic waveform is the backbone of subtractive synthesis. For the sake of this experiment, we are focusing on how one complex waveform is actually a compilation of multiple sine waves that have different multiples of the same frequency. Now, keep in mind that what allows this to remain true is that every waveform is within a fixed period. The sine wave with the lowest frequency is the Fundamental waveform. *Figure 5* shows this waveform in blue. Addition of the orange and green sine waves, having frequencies with multiples of the fundamental frequency, will result in a square wave. This same process can be used to create an infinite number of signals that sound different with each fundamental frequency adjustment.

In this experiment, students are beginning with the square wave, or pulse, and cutting out the frequencies higher than the frequency of the fundamental sine wave to prove that every complex periodic waveform starts from one simple sine wave.

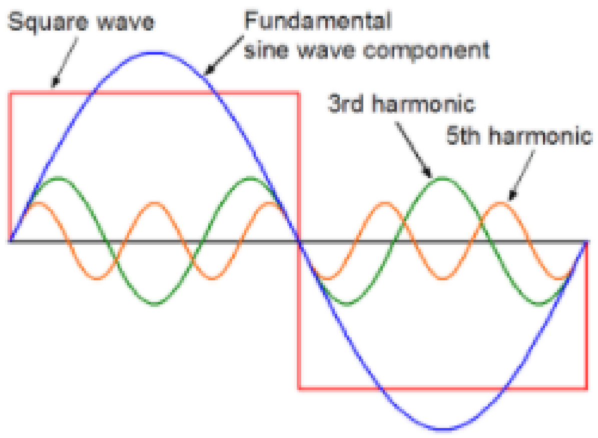


Figure 5.

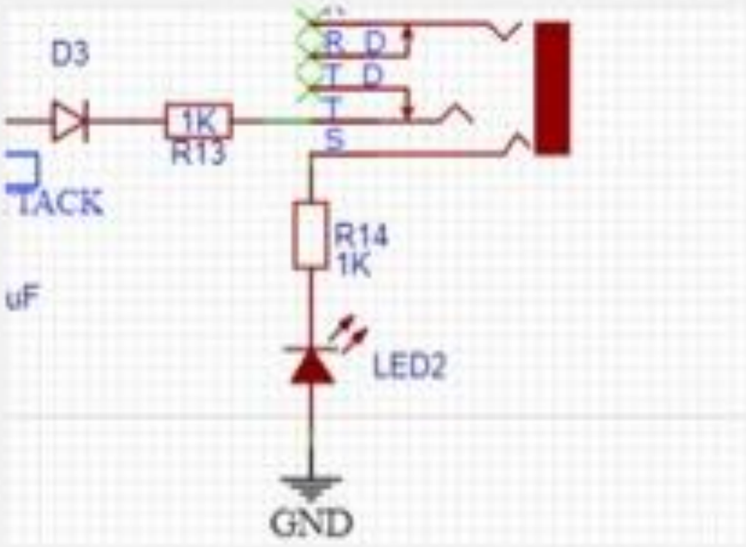
STEP 4: Using a Low Pass Filter to Identify the Fundamental Frequency

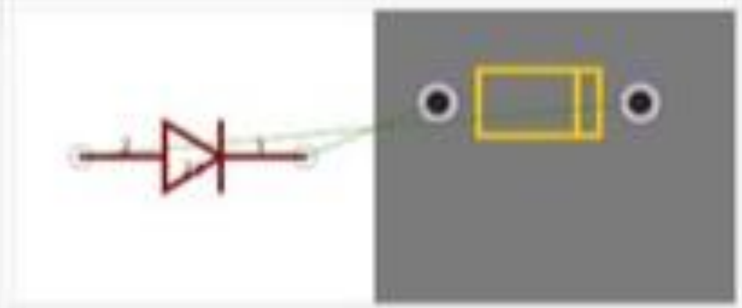
Next, students will use “MATH MENU” on the oscilliscope to read the frequency response. Under “Operation” setting, make sure the reading is under “FFT”, or fast Fourier transform. This measures the amplitude versus time in the frequency domain which allows students to see the effects of turning the “Cut Off” knob.

You should be able to clearly see the correlation of turning the “Cut Off” knob.

REPEATED CHALLENGES

Challenge	Solution
Faulty Components	Switch out/ reorder
De-soldering difficulties	Solder wick, heat gun
Incorrect PCB footprints	PCB reorder / swapping direction of components
Lack of Tools for Case Assembly	Completion off campus
Overheating of ICs	Double checking component placement before powering on

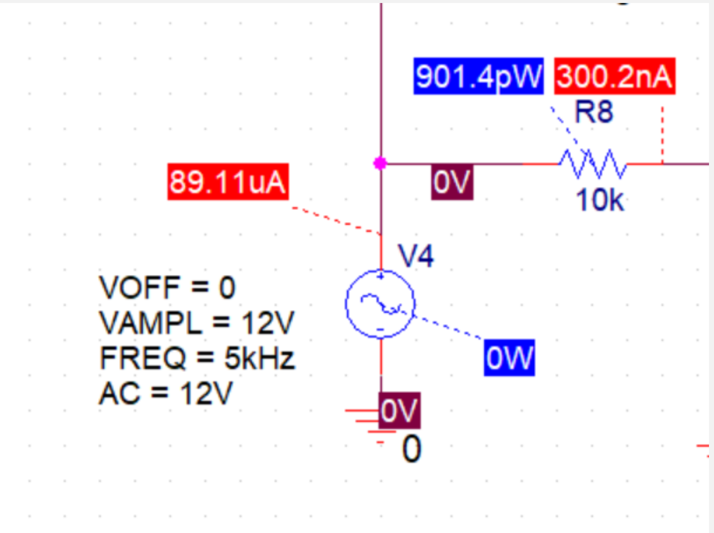


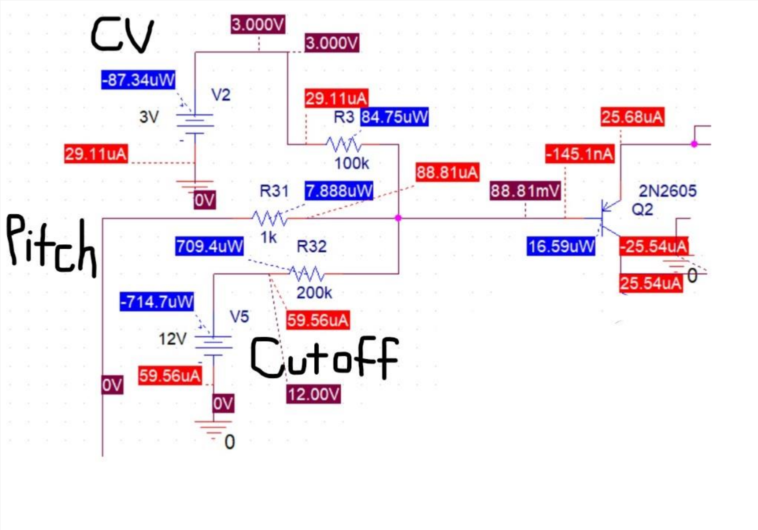


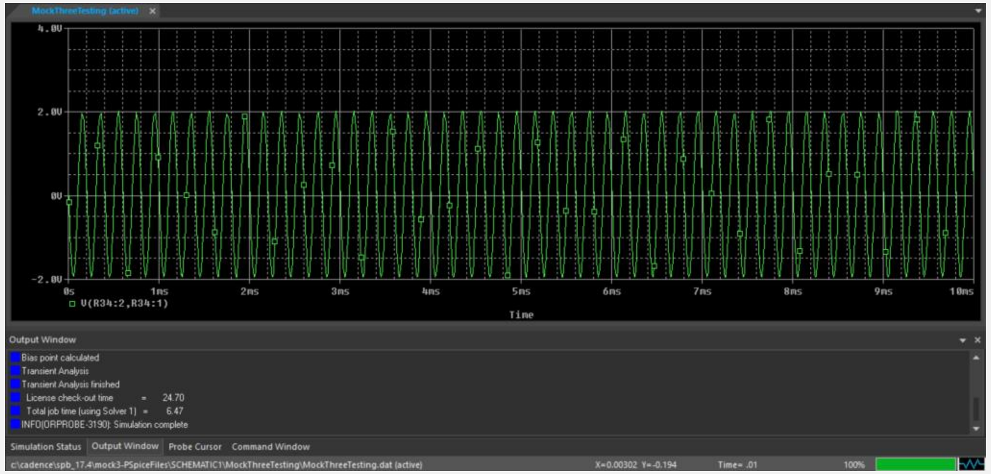
Diode with footprint backwards

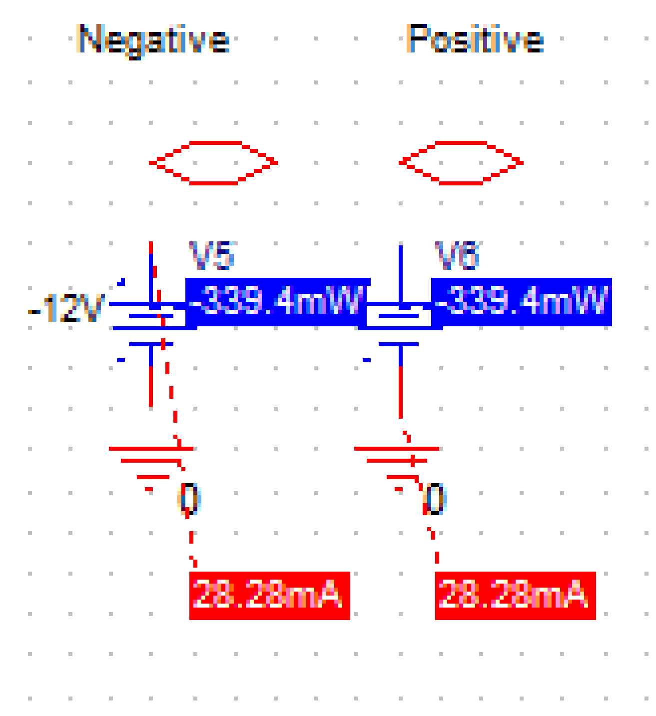
SYSTEM DEMO

VOLTAGE CONTROLLED FILTER (DME)



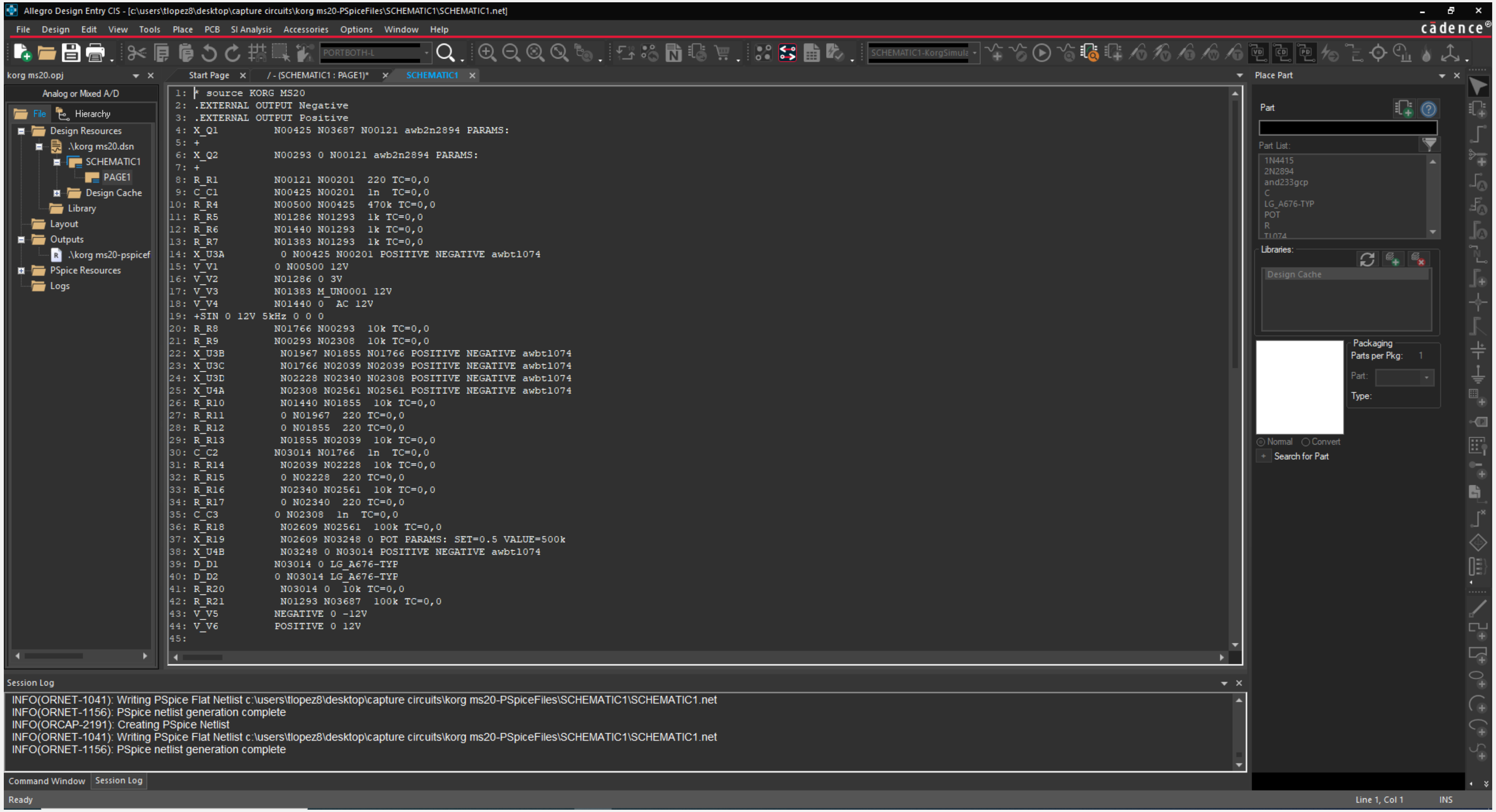




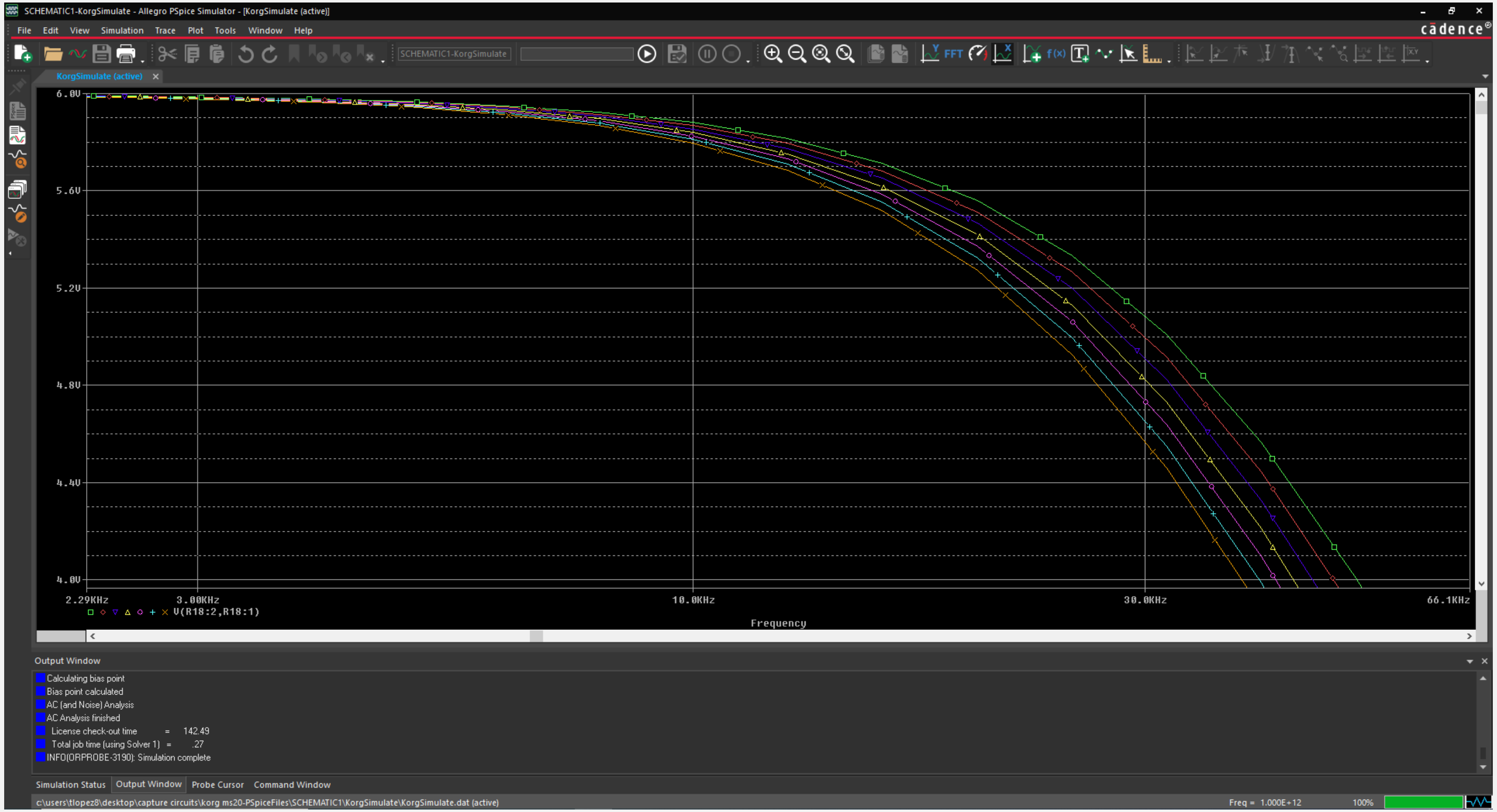


Power Analysis and Consumption

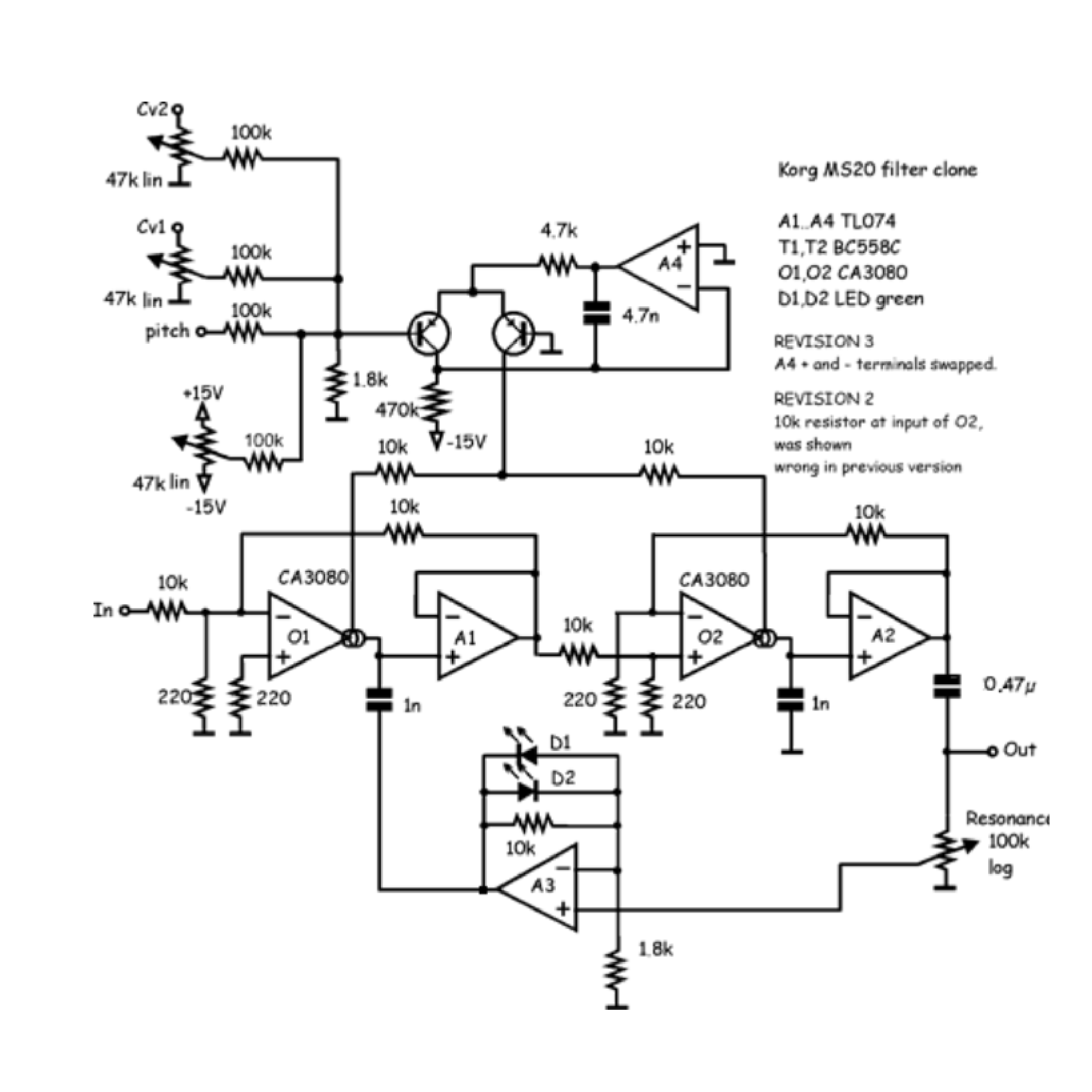
Sensitivity Analysis



Temperature Analysis

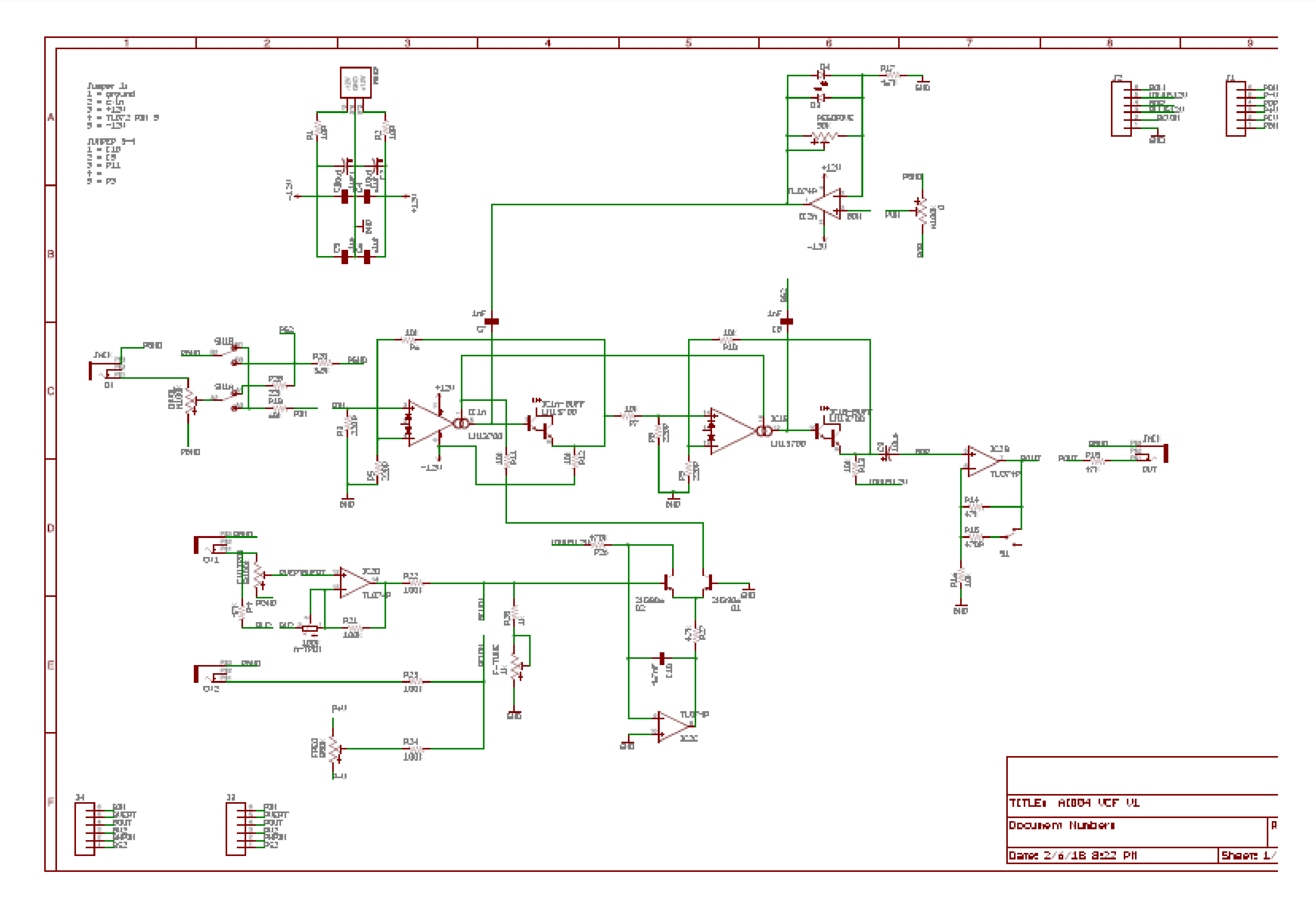


With a 6V output, the -3db mark sits at 4.2V and the temperature analysis is shown above.



Korg MS20 Filter Design

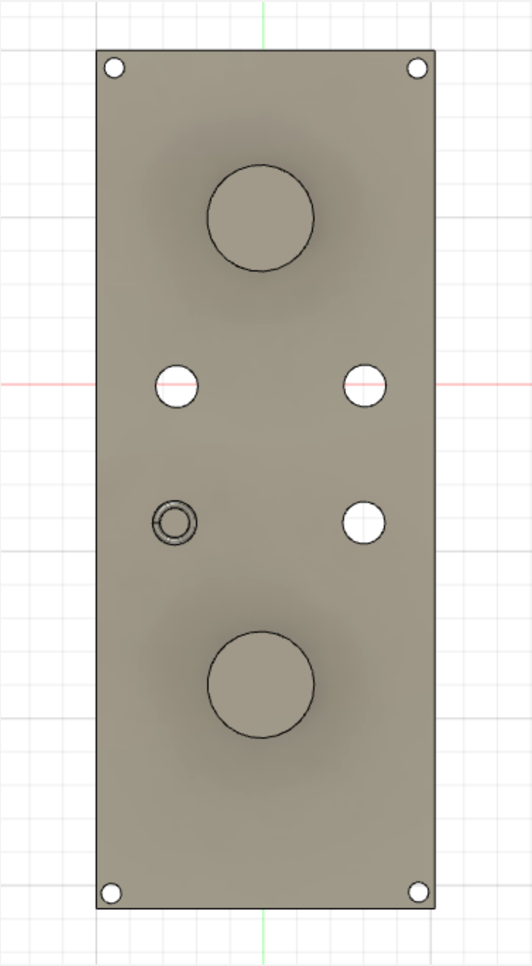
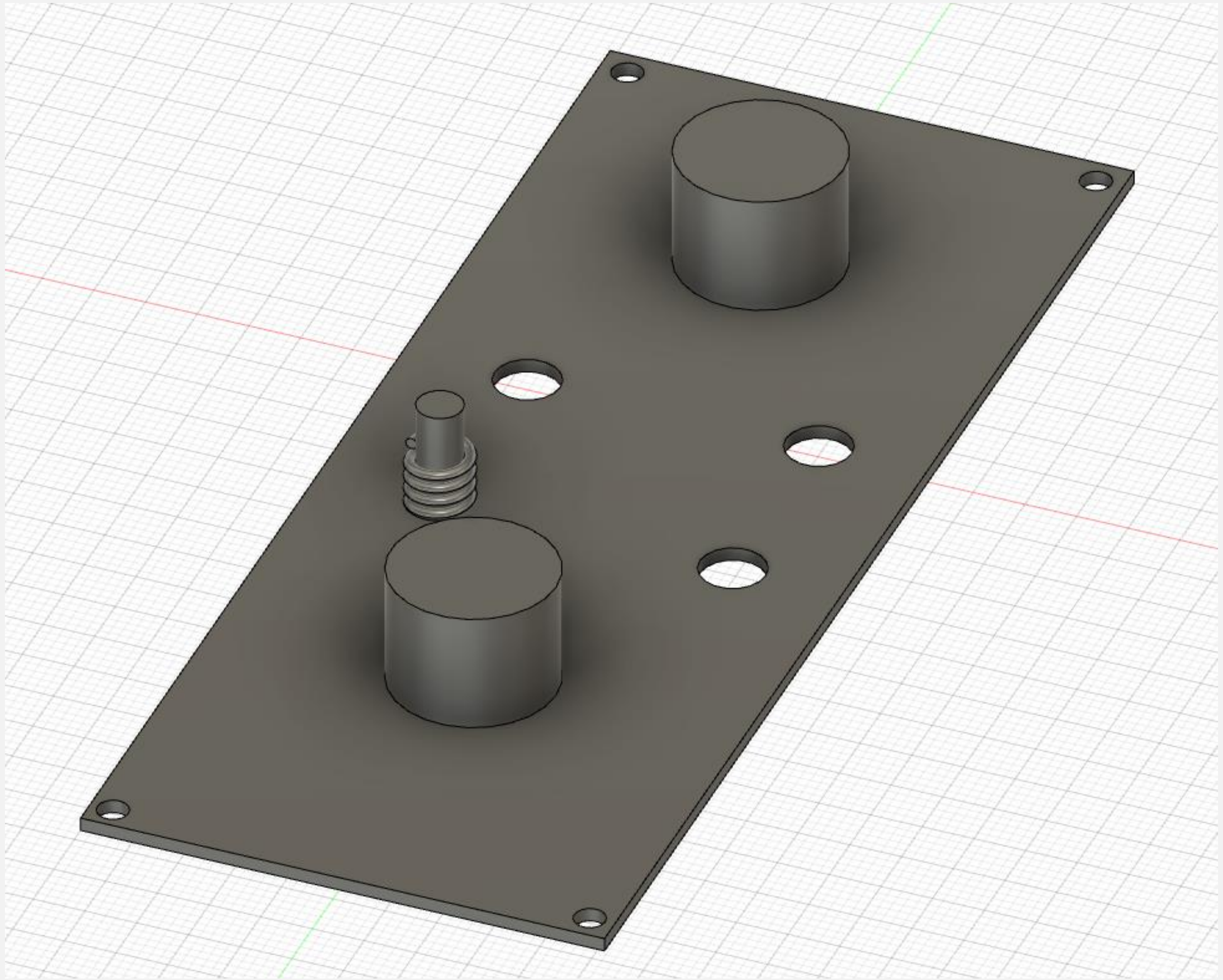
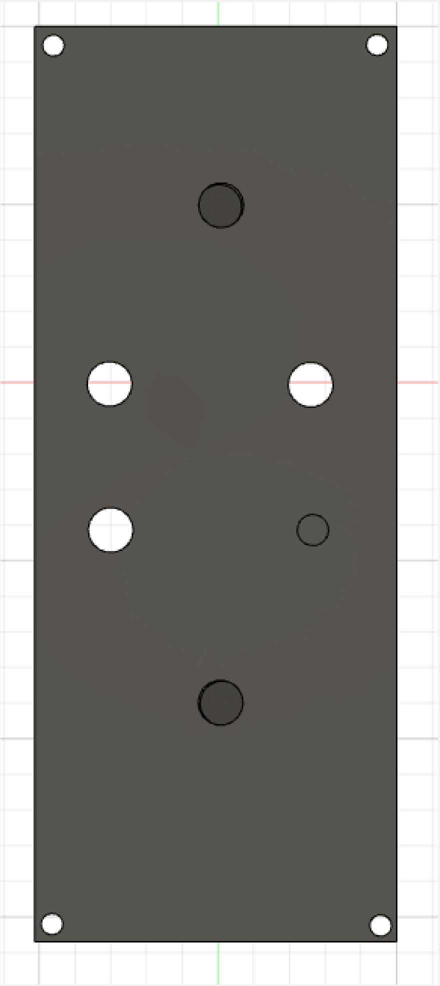
https://www.schmitzbits.de/ms20.html

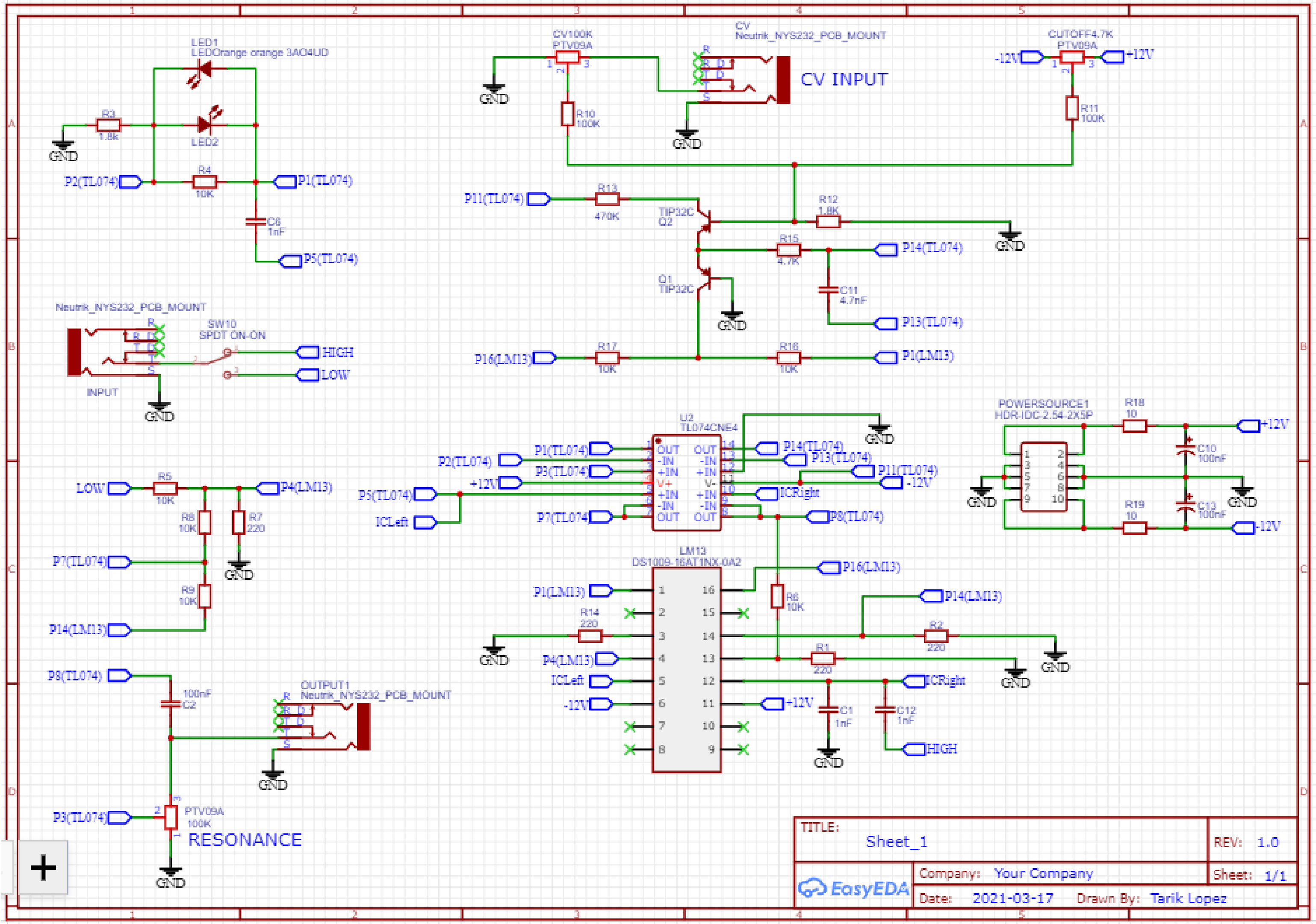


AI004 DIY Eurorack OTA Filter

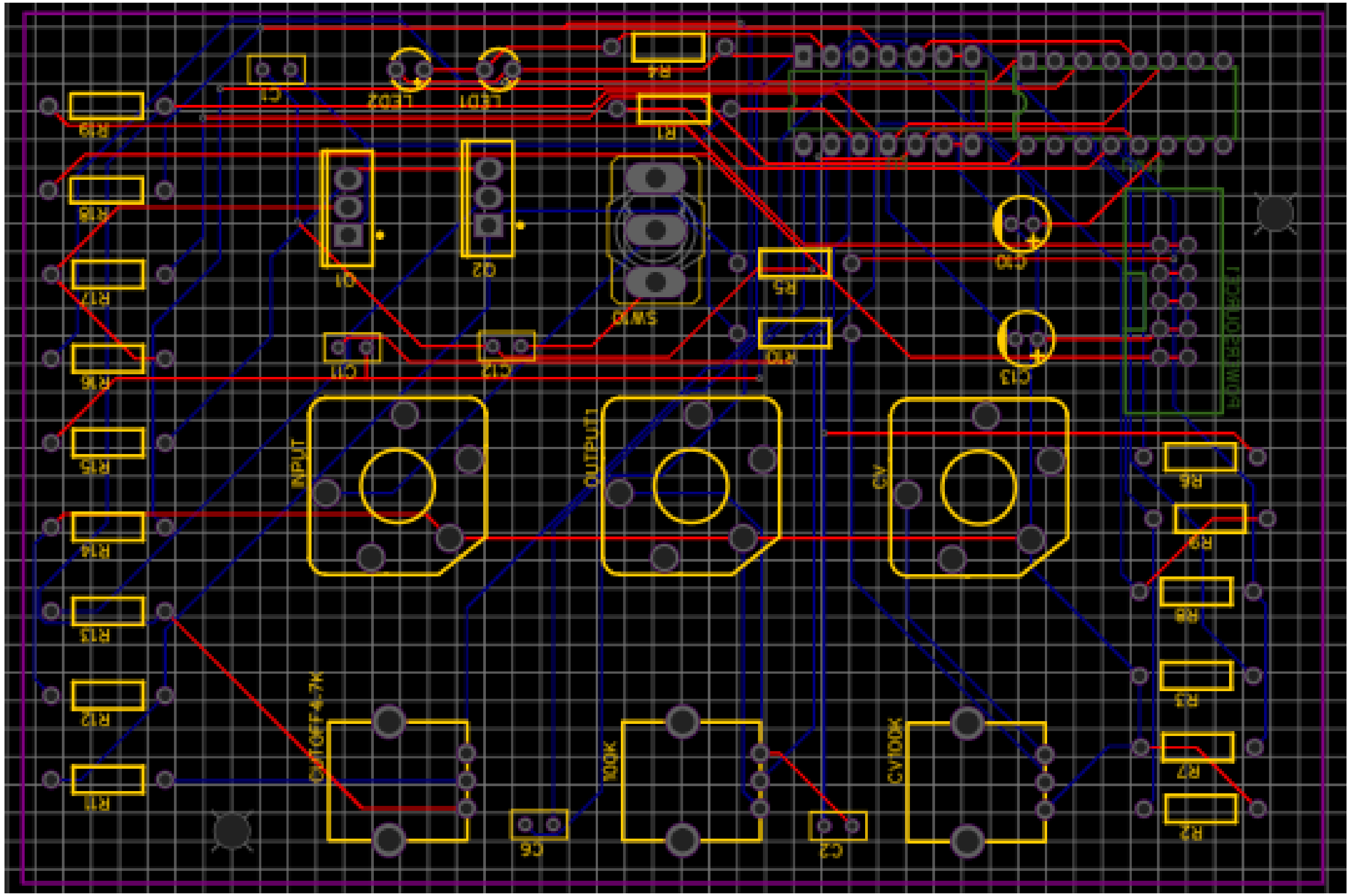
https://aisynthesis.com/how-to-build-ai004-diy-eurorack-ota-filter-vcf/

Rough Faceplate Fusion Model

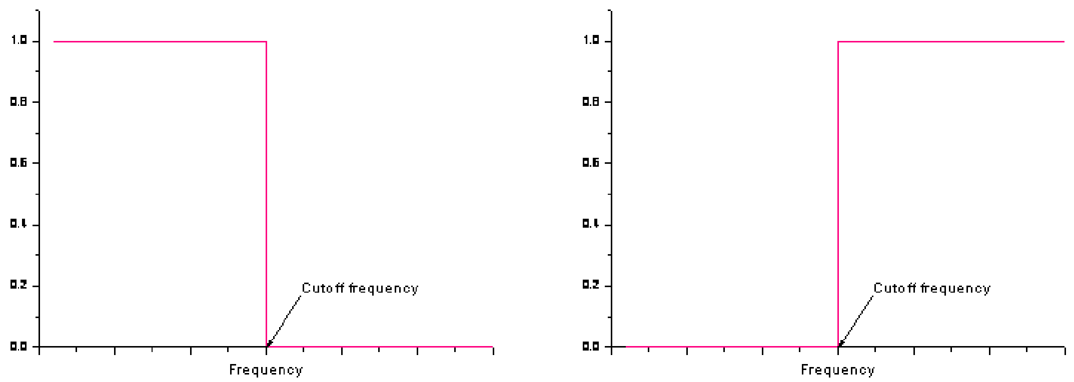


Final VCF Module Schematic



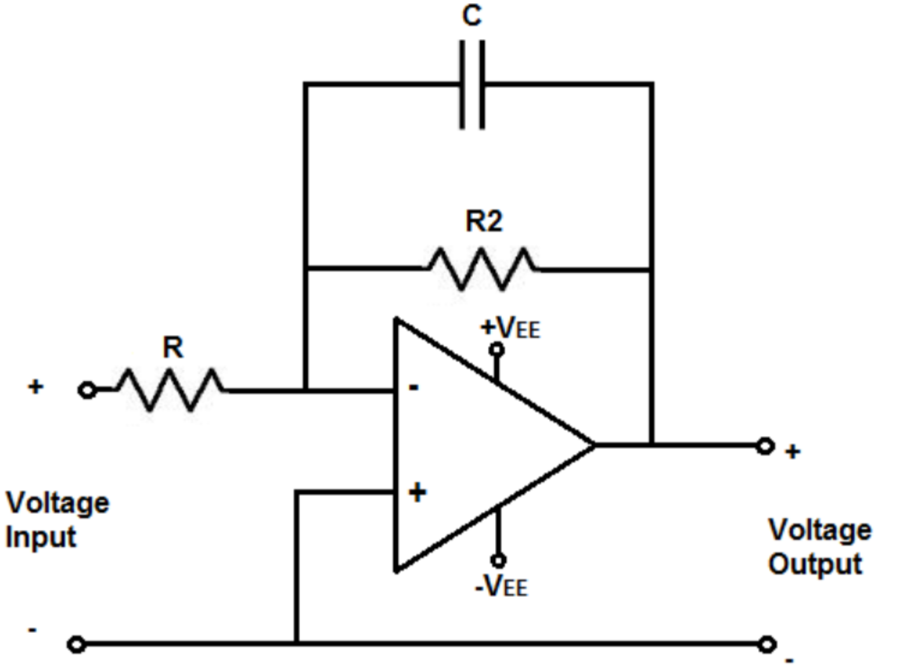
Final VCF Module Routed PCB Design

CALCULATIONS AND EQUATIONS



$$w(f) = \begin{cases} 1, & \text{if } f \le f_{c1} \\ 1 - \dfrac{(f - f_{c1})^2}{(f_{c2} - f_{c1})^2}, & \text{if } f_{c1} < f < f_{c2} \\ 0, & \text{if } f \ge f_{c2} \end{cases}$$

CALCULATIONS AND EQUATIONS (CONT.)



$$\text{Frequency Cutoff} = \frac{1}{2\pi R_2 C}$$

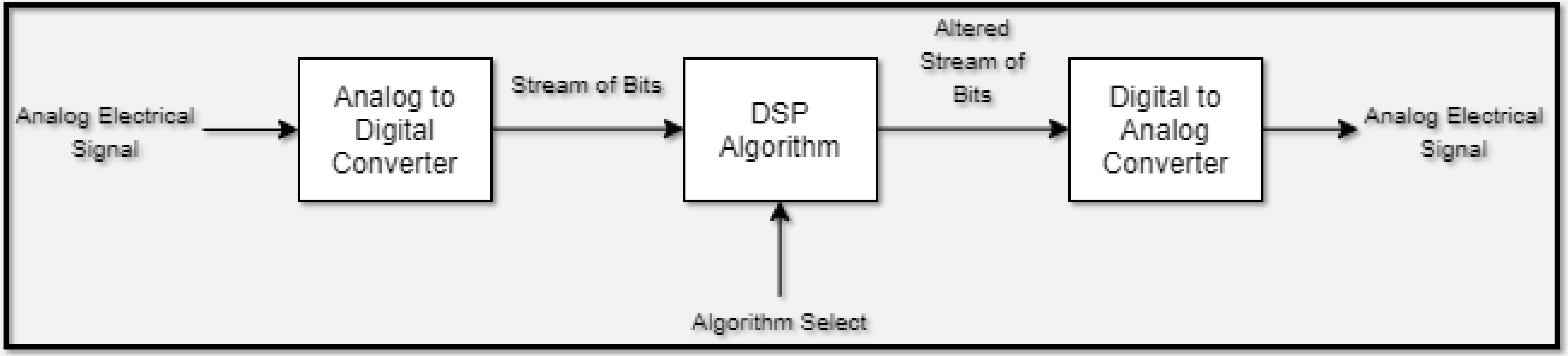
$$\text{Gain} = -\frac{R_2}{R}$$

MOCK LAB VCF RESONANCE LINK

https://docs.google.com/document/d/1hAaE2zSHt2OmR_1zOxF_C5R1qC0kocSc--IPfkO2wJY/edit?usp=sharing

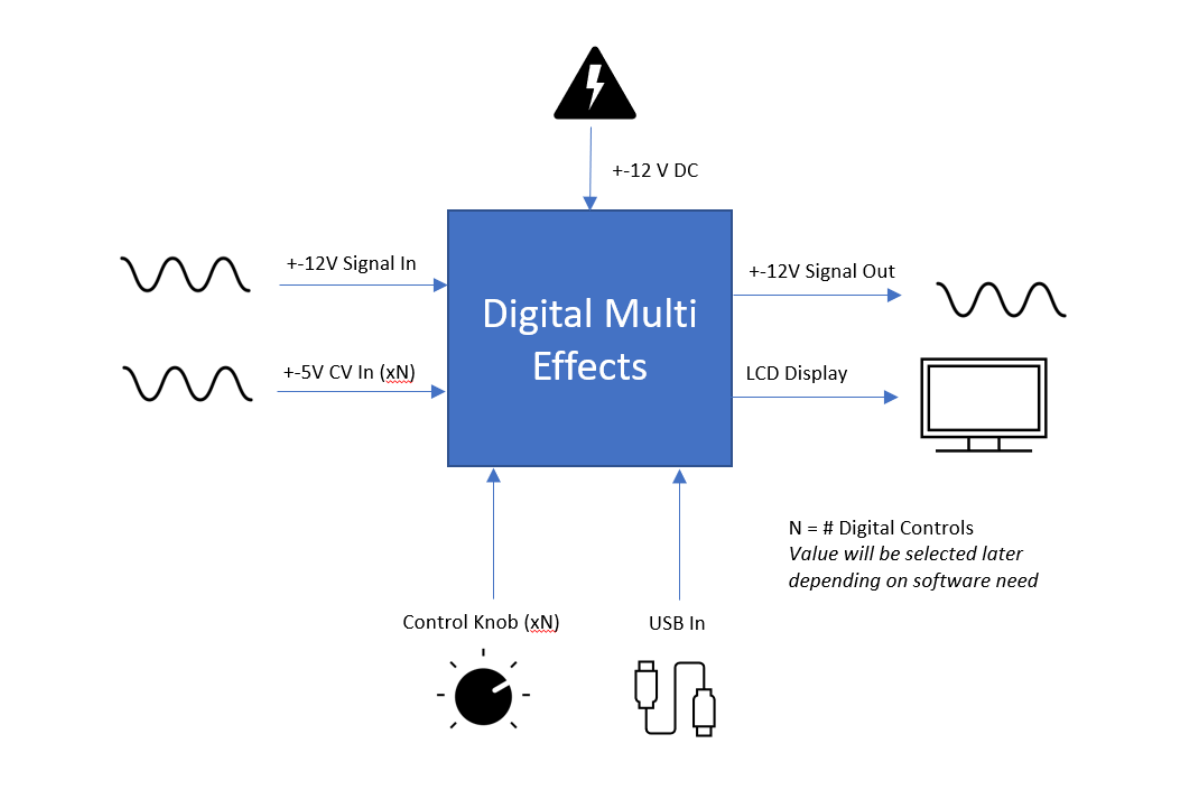
DIGITAL MULTI-EFFECTS (DME)

WHAT IT DOES


Analog Electrical Signal
Analog to Digital Converter
Stream of Bits
DSP Algorithm
Altered Stream of Bits
Digital to Analog Converter
Analog Electrical Signal
Algorithm Select

DESIGN INSPIRATION

LEVEL 0 DIAGRAM

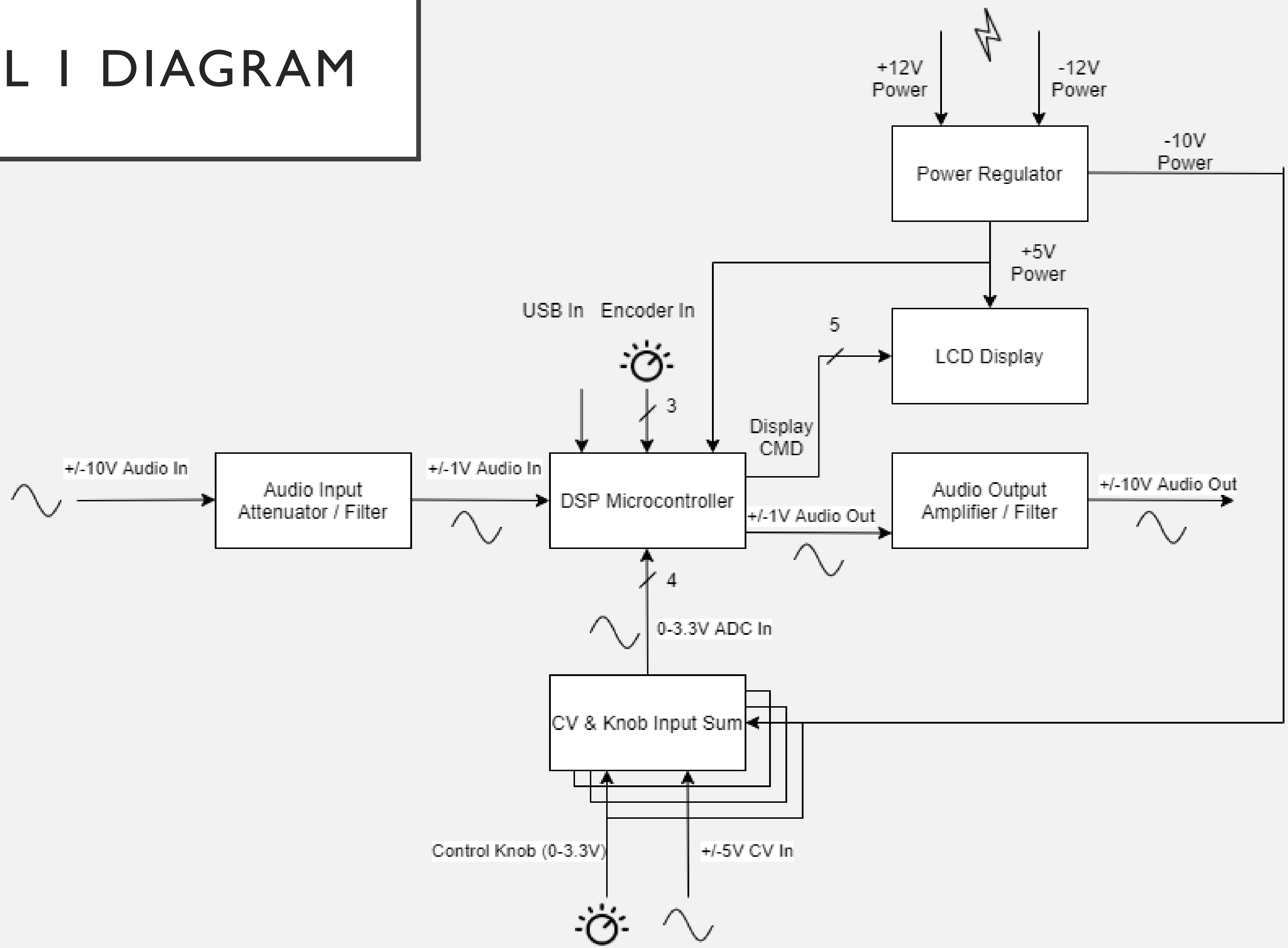


Module	Digital MultiEffects

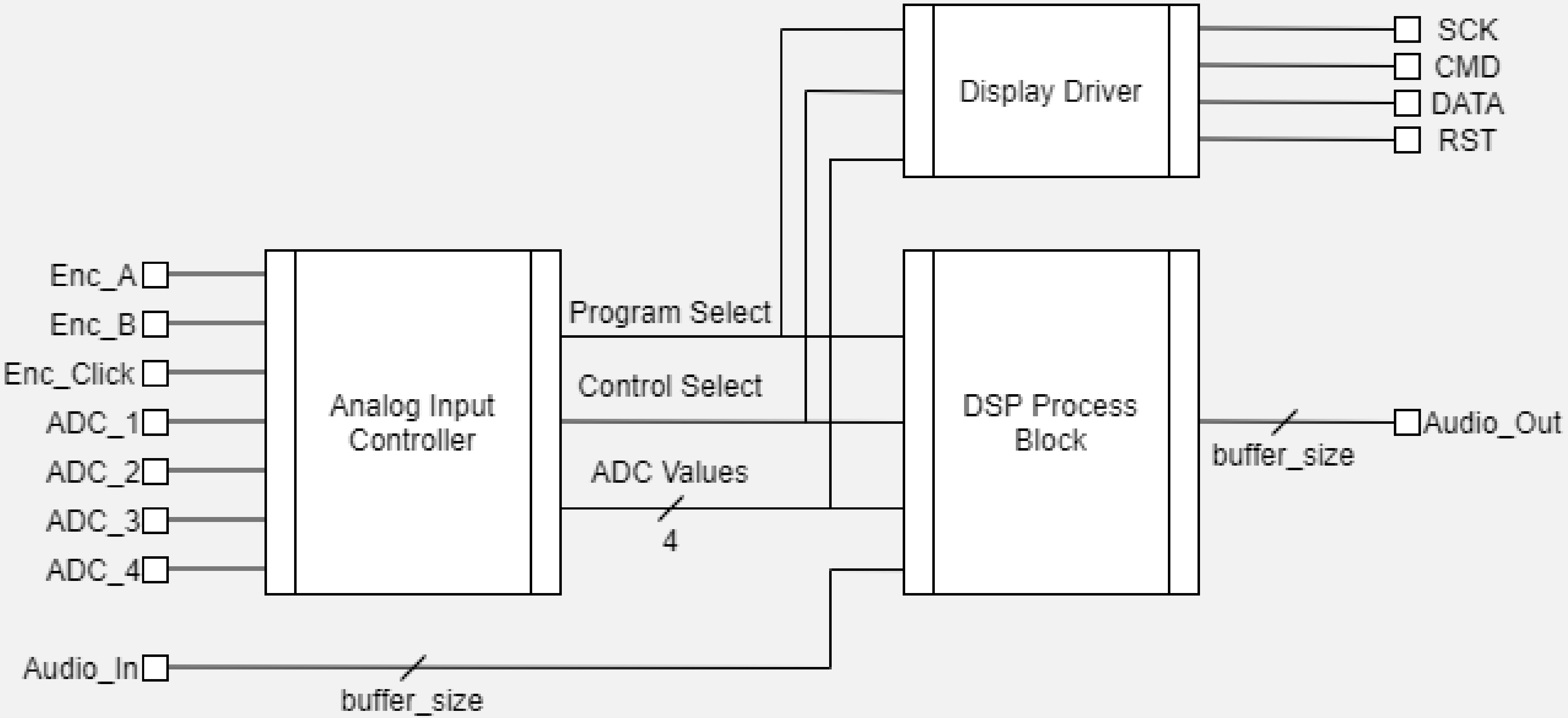
Inputs	• Signal In:
	  • Audio in: +-12 V @ 20-20kHz x1
	  • CV in: +- 5V @ 0-100Hz xN
	• Control: N number of analog knobs
	• USB: MicroUSB for uploading code

Outputs	• Audio Out: +-12V @20-20kHz x 1 • LCD Display: SPI output to a display
Functionality	Convert analog audio signals to digital signals, and perform DSP operations on them based upon uploaded programs, then convert back to analog audio signals. Interact with software parameters via knobs or CV, and display data to the user via an LCD

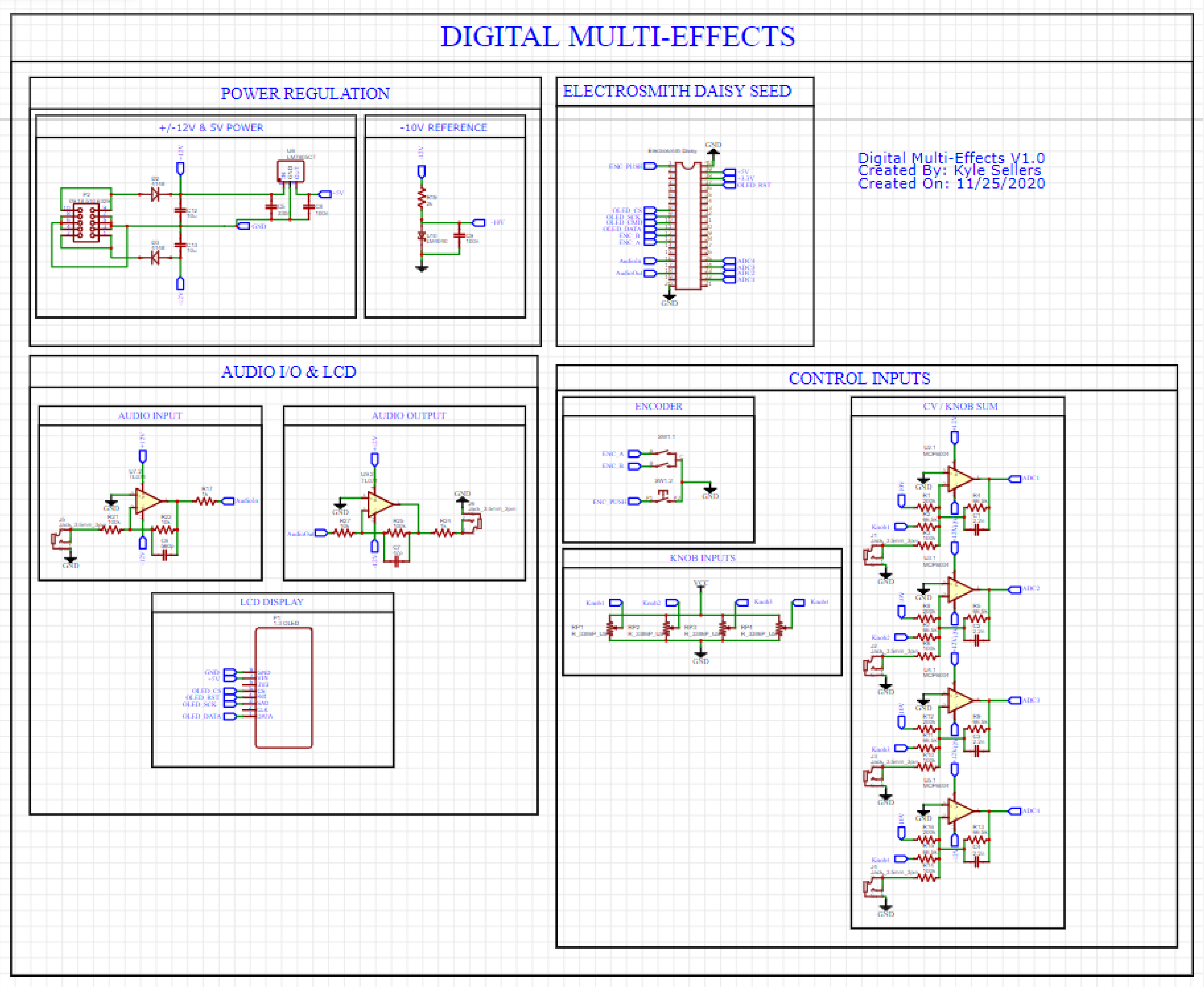
LEVEL 1 DIAGRAM



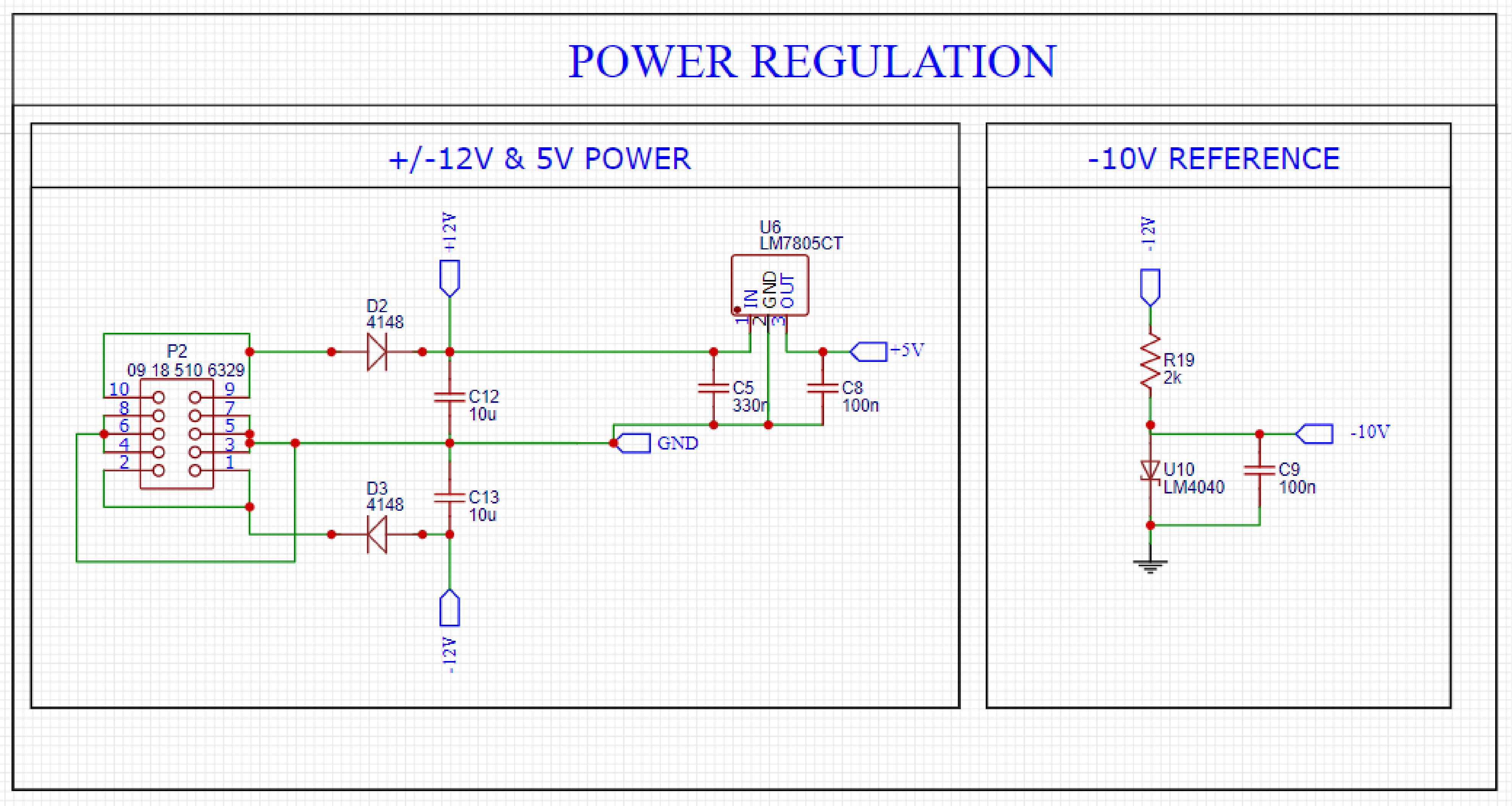
SOFTWARE DIAGRAM



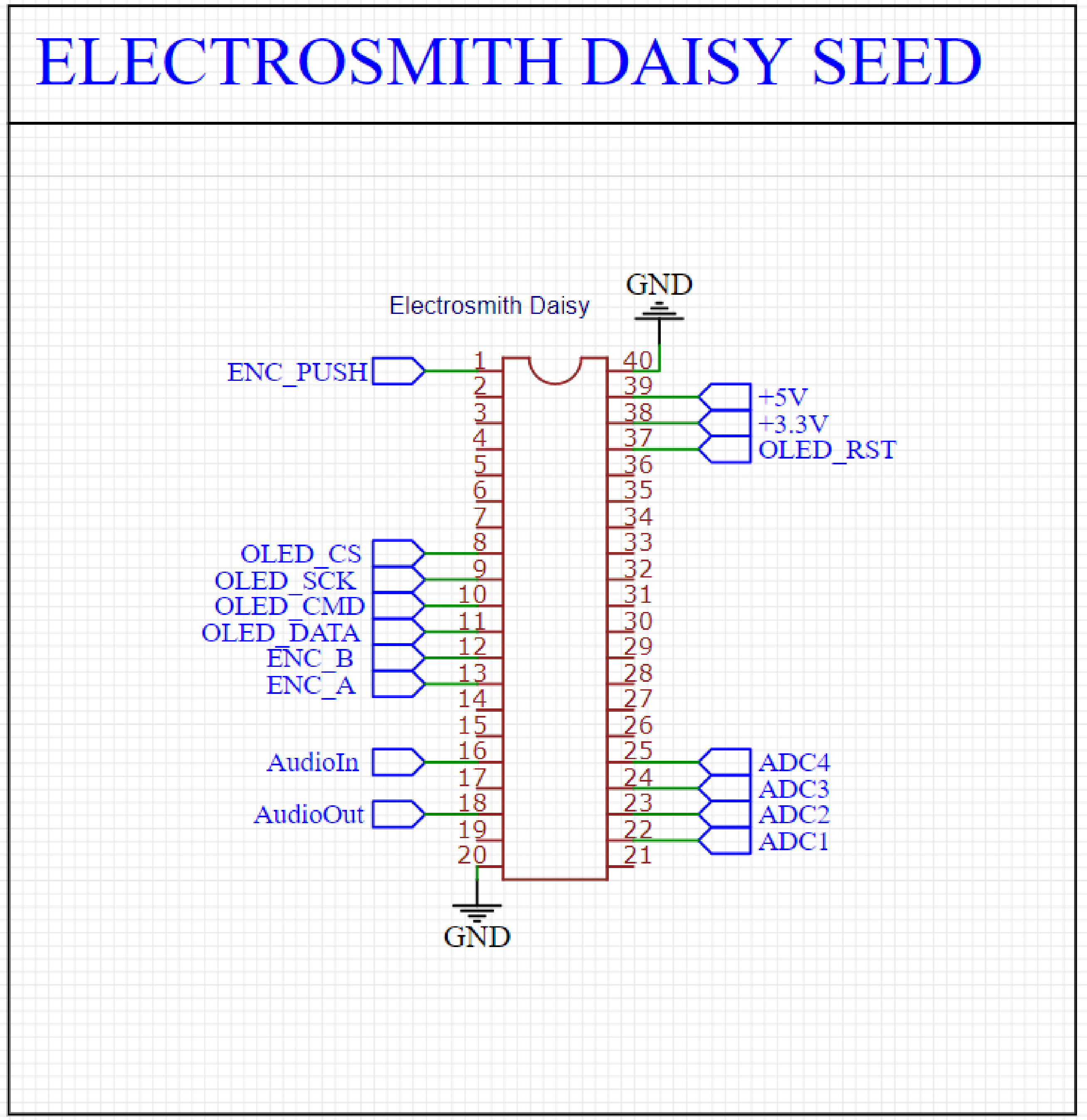
CIRCUIT DIAGRAM



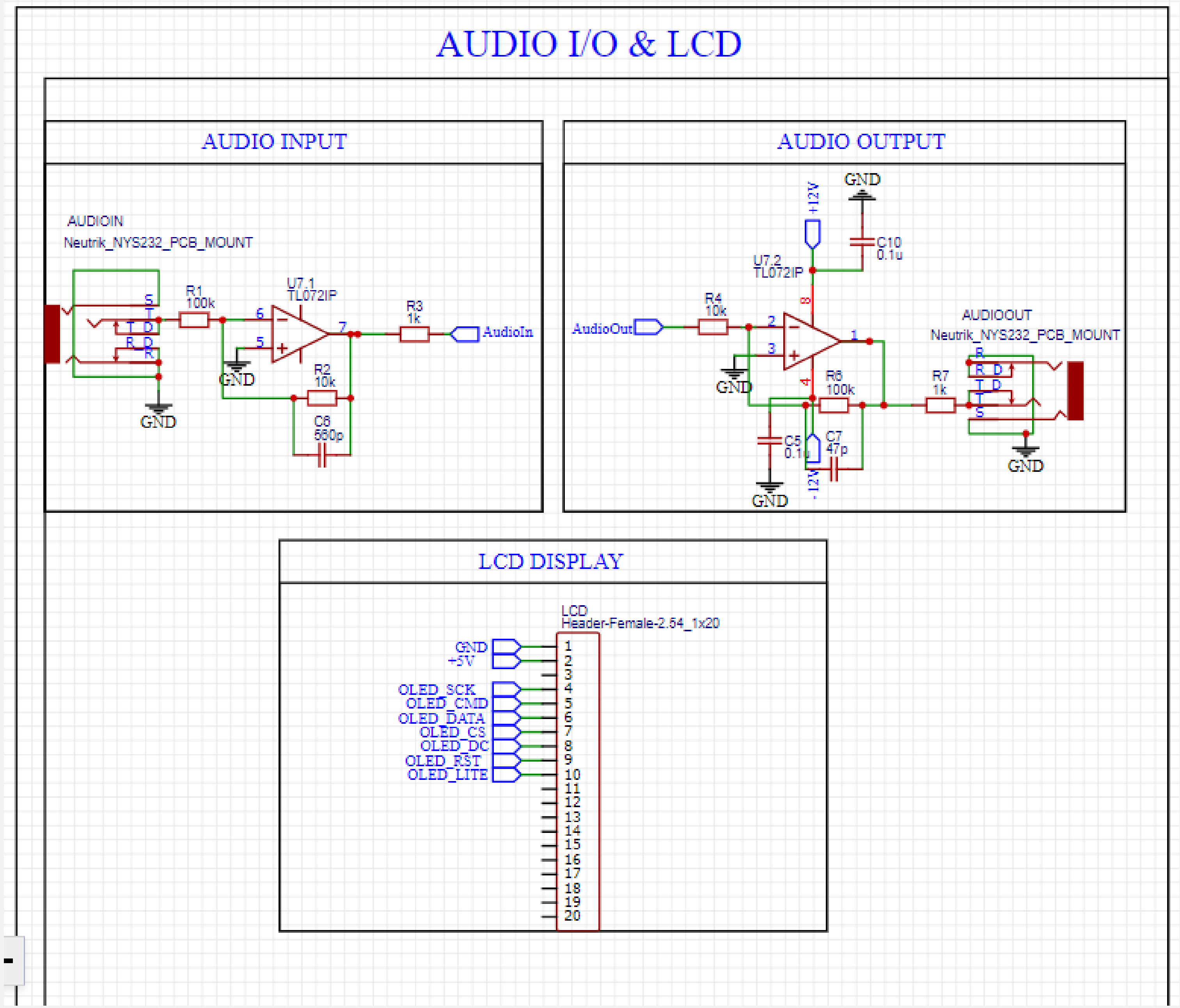
POWER REGULATION



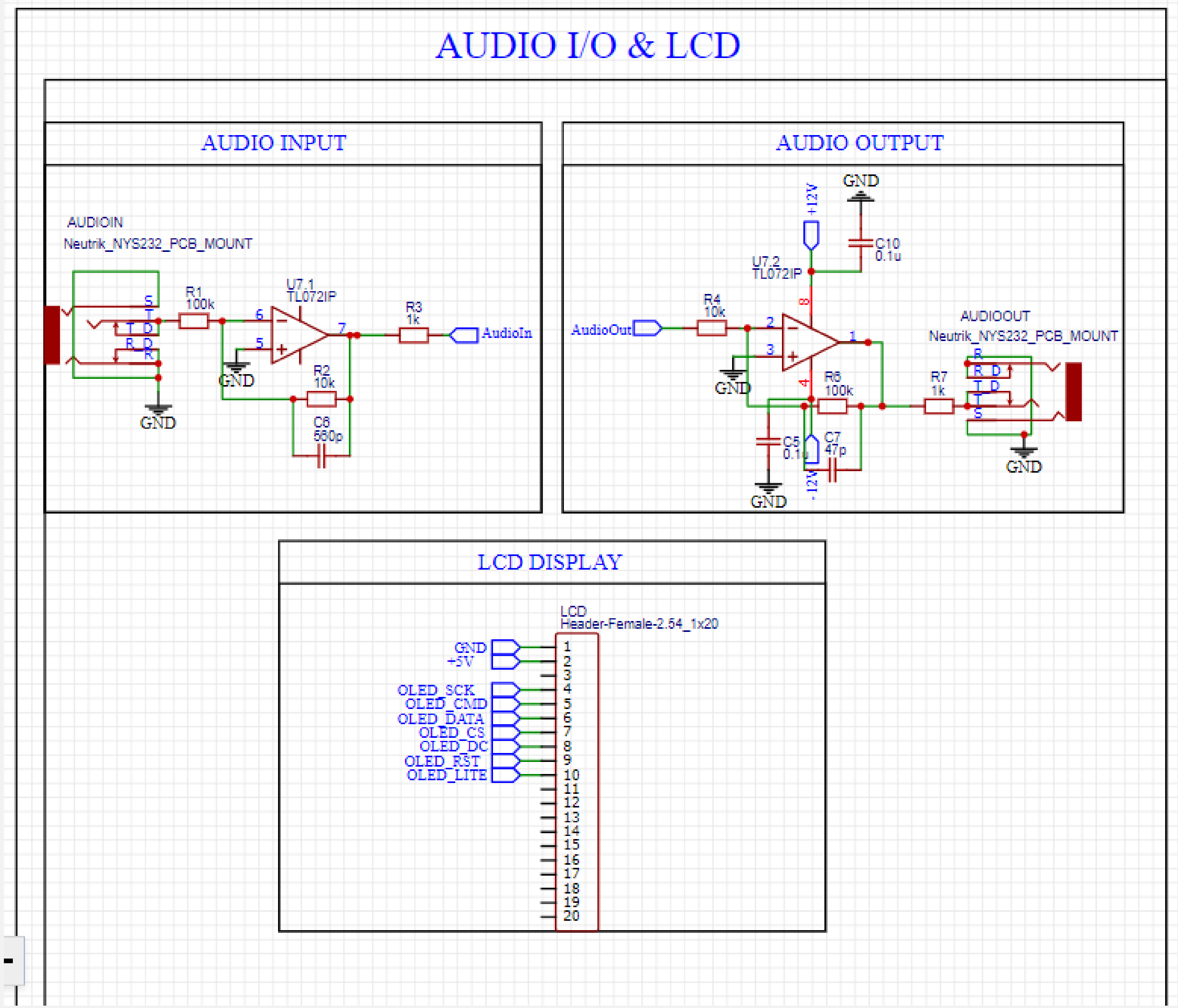
DAISY PINOUT



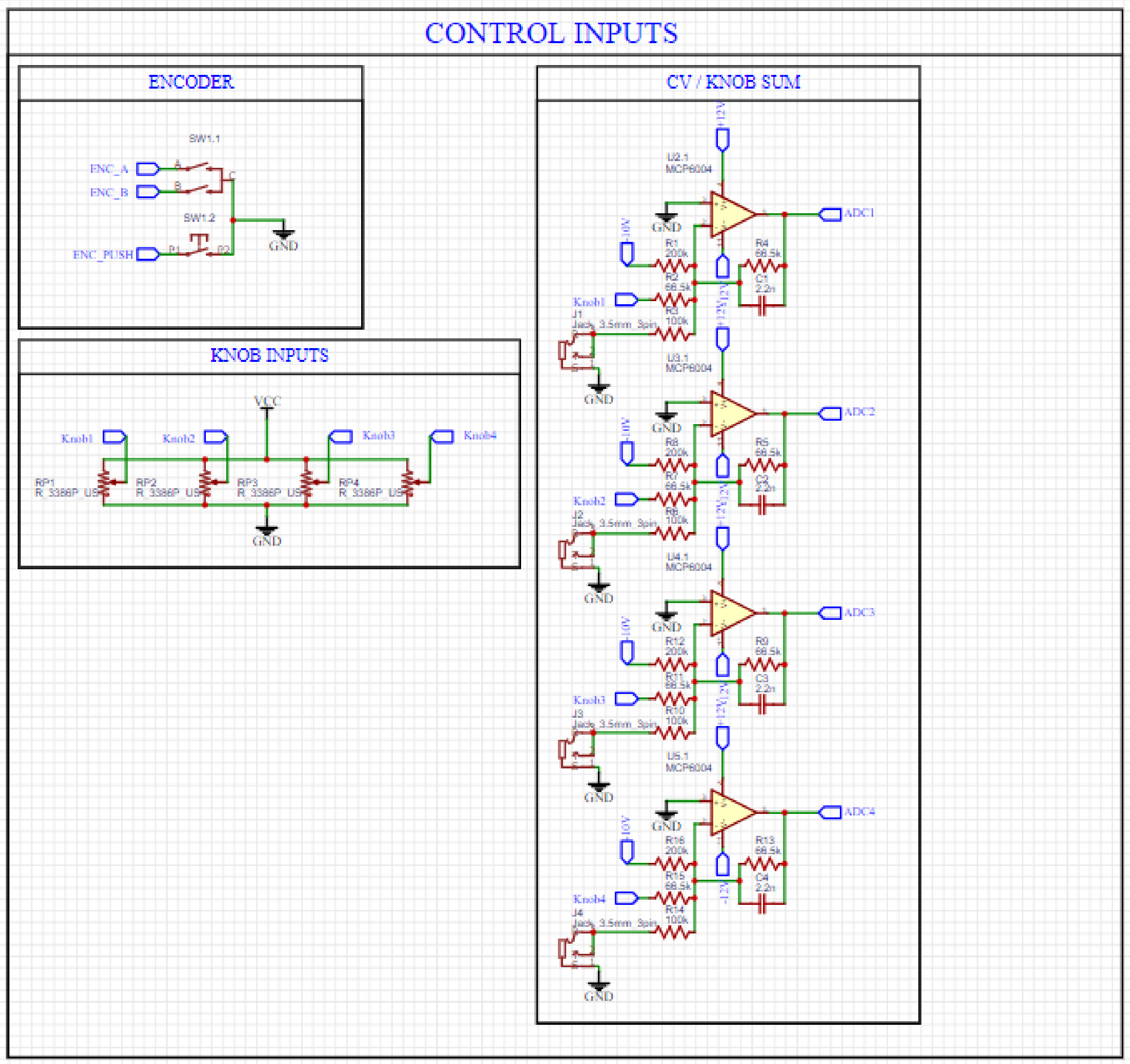
AUDIO I/O & SCREEN



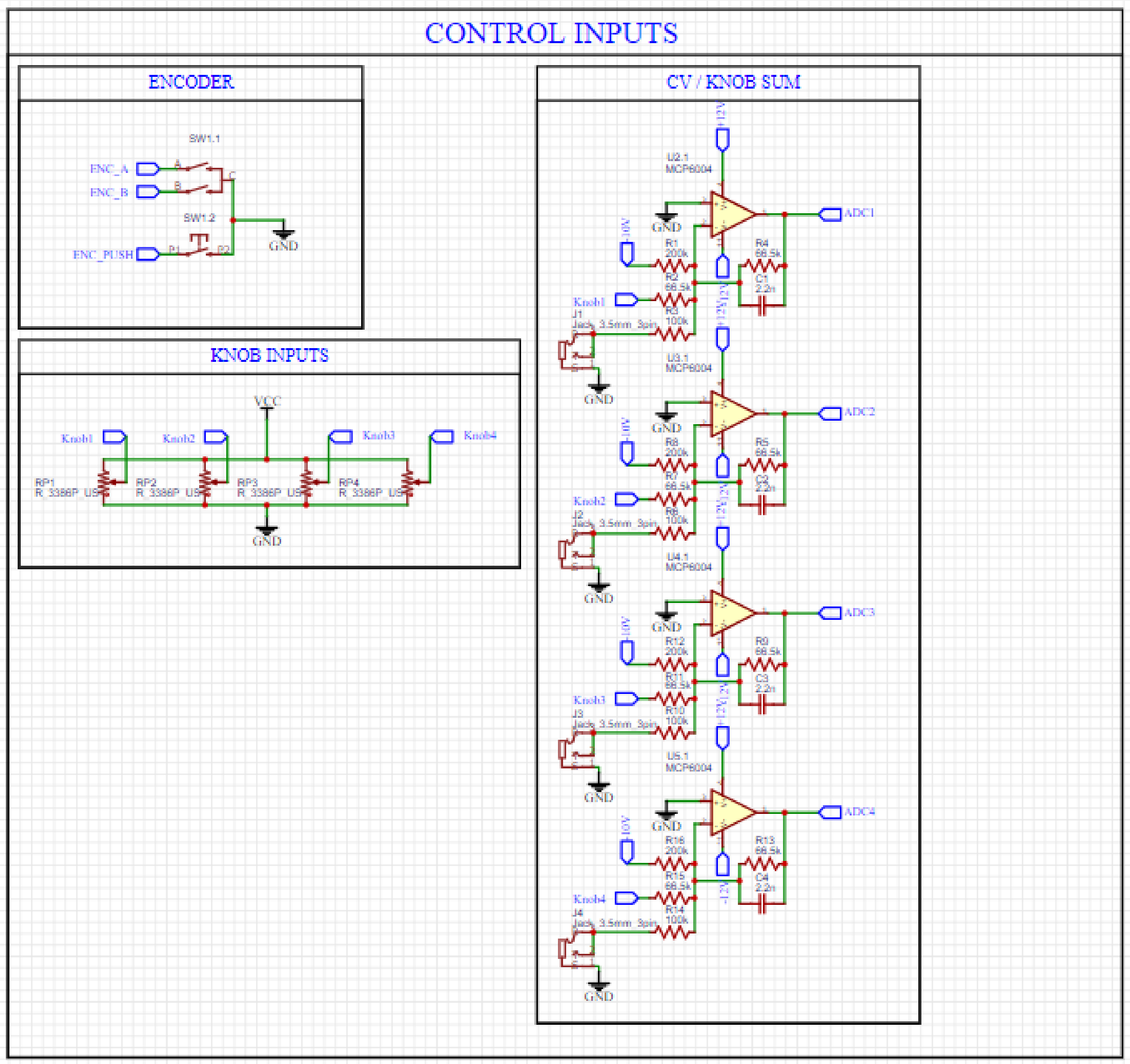
AUDIO I/O & SCREEN



CONTROL CONNECTIONS



CONTROL CONNECTIONS



EE 3610 INTRODUCTION TO DSP SYLLABUS

Course Description:

This course introduces basic knowledge and technology in digital signal processing (DSP). The fundamental concepts and topics include analog and digital signals, sampling and aliasing, discrete-time signals and systems, linear and time-invariant (LTI) systems, impulse response (IR), convolution, linear constant-coefficient difference equation, finite IR (FIR) and infinite IR (IIR) filters, z-transform, LTI system function, partial-fraction technique (PFT), time-frequency duality, Fourier transform (integral and series), frequency response of LTI systems, low-pass, high-pass, and bandpass filters, the sampling theorem, discrete Fourier transform (DFT), and fast Fourier transform (FFT) algorithms.

Outline:

1. Introduction (Chapter 1: 1.3, 1.4.1)
2. Discrete-time signals and systems (Chapter 2: 2.1, 2.2, 2.3, 2.4, 2.5)
3. z-transform and analysis of LTI systems (Chapter 3: 3.1.1, 3.2, 3.3.3, 3.4.3, 3.5.3, 3.6)
4. Frequency analysis of discrete-time signals (Chapter 4: 4.1, 4.2, 4.3, 4.4)
5. Frequency-domain analysis of LTI systems (Chapter 5: 5.1.1, 5.2, 5.4.1, 5.4.2, 5.5.1)
6. The sampling theorem (Chapter 1: 1.4.2 and Chapter 6: 6.1)
7. The discrete Fourier transform (DFT) (Chapter 7: 7.1.2, 7.1.3, 7.2 and Chapter 8: 8.1)

EE 4162 DSP ALGORITHMS AND IMPLEMENTATIONS SYLLABUS

Topics:

1. Discrete-Time and Digital Signals
    - Sampling
    - Quantization
    - Discrete-Time Fourier Transform and Discrete Fourier Transform
    - Linear Convolution and Circular Convolution
2. Discrete-Time Systems
    - Time-Domain Characterization
    - Transform-Domain Representation
3. Fast Fourier Transform
4. Digital Filter Design
    - IIR Filter
    - FIR Filter
5. Applications

Week	Lecture	Lab
1	Discrete-Time Signals -Time-Domain Representation	No Lab
2	Discrete-Time Signals -Elementary Operations and Basic Sequences	Lab1: Introduction to Digital Signal Processing using MATLAB
3	Sampling and Quantization	Lab 2: Introduction to eXperimenter Kit and Code Composer Studio
4	Discrete-Time Systems -Typical Systems and Classifications	Lab 3: Wavetable Generation and Sampling
5	Discrete-Time Systems -Convolution and Correlation	Lab 3 continued
6	Discrete-Time Fourier Transform	Lab 4: Signal Modulation
7	Discrete Fourier Transform and Fast Fourier Transform	Lab 4 continued
8	z-Transform	Lab 5: Fast Fourier Transform
9	Transform-Domain Systems -Frequency Response and Transfer Function	Lab 5 continued
10	Transform-Domain Systems -Concept of Filtering, Phase and Group Delays	Lab 6: Introduction to Filter Design
11	Ideal Filters and Linear-Phase FIR Transfer Functions	Lab 6 continued
12	Simple Filters and Implementation Structures	Project: Filtering and Digital Audio Effects
13	IIR Filter Design	Project continued
14	FIR Filter Design	Project continued

DSP CHIP SPECS

SPIN FV-1

Supply Voltage (maximum)	3.5V
Number of Effects	8
Applications	Effects IC
Number of Inputs	2
Number of Outputs	2

- Integrated stereo ADC and DAC
- 8 internal programs + 8 external programs
- Easy customization with external EEPROM
- 3 potentiometer inputs for real-time parameter adjustment
- 3.3V operation
- 6 MIPS operation at Fs=48KHz
- 128 instructions/sample clock
- 32K words of delay RAM
- Internal PLL for Fs input clock
- Integrated Power-On-Reset circuit
- LOG and EXP instructions for dynamics
- Green assembly/RoHS compliant

Electrosmith Daisy

Programmability: C++, Arduino, Max/MSP Gen~, Pure Data(export using Heavy)

Hardware: ARM Cortex-M7 MCU, High fidelity AKM stereo audio codec with up to 24-bit 192kHz, 64MB of SDRAM, and 8MB of flash memory

Pinouts include:

. 31 total GPIO pins which can be configured as standard GPIO or one of several alternate functions including 16-bit Analog to Digital Converters(x12)

. 12-bit Digital to Analog Converters(x2)

. SD Card interfaces

. PWM outputs

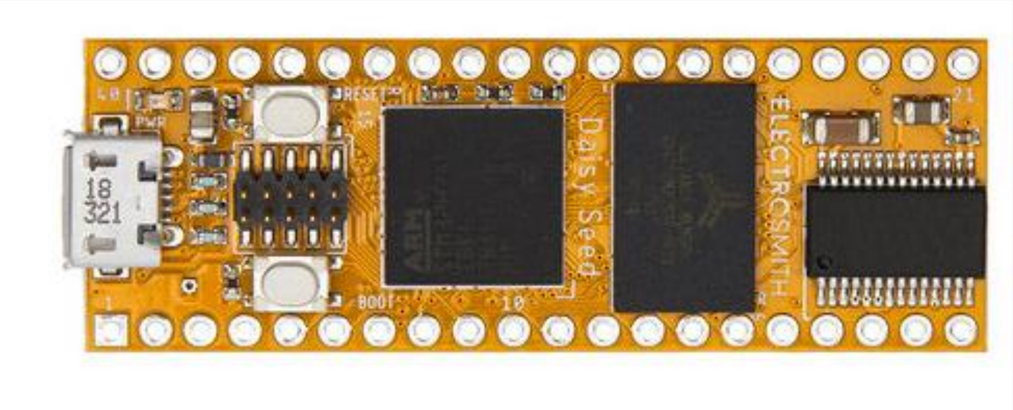
. Serial protocols for connecting to external sensors and devices including SPI, UART, I2S, and I2C

. Dedicated VIN pin for power (input range from 4v to 17v)

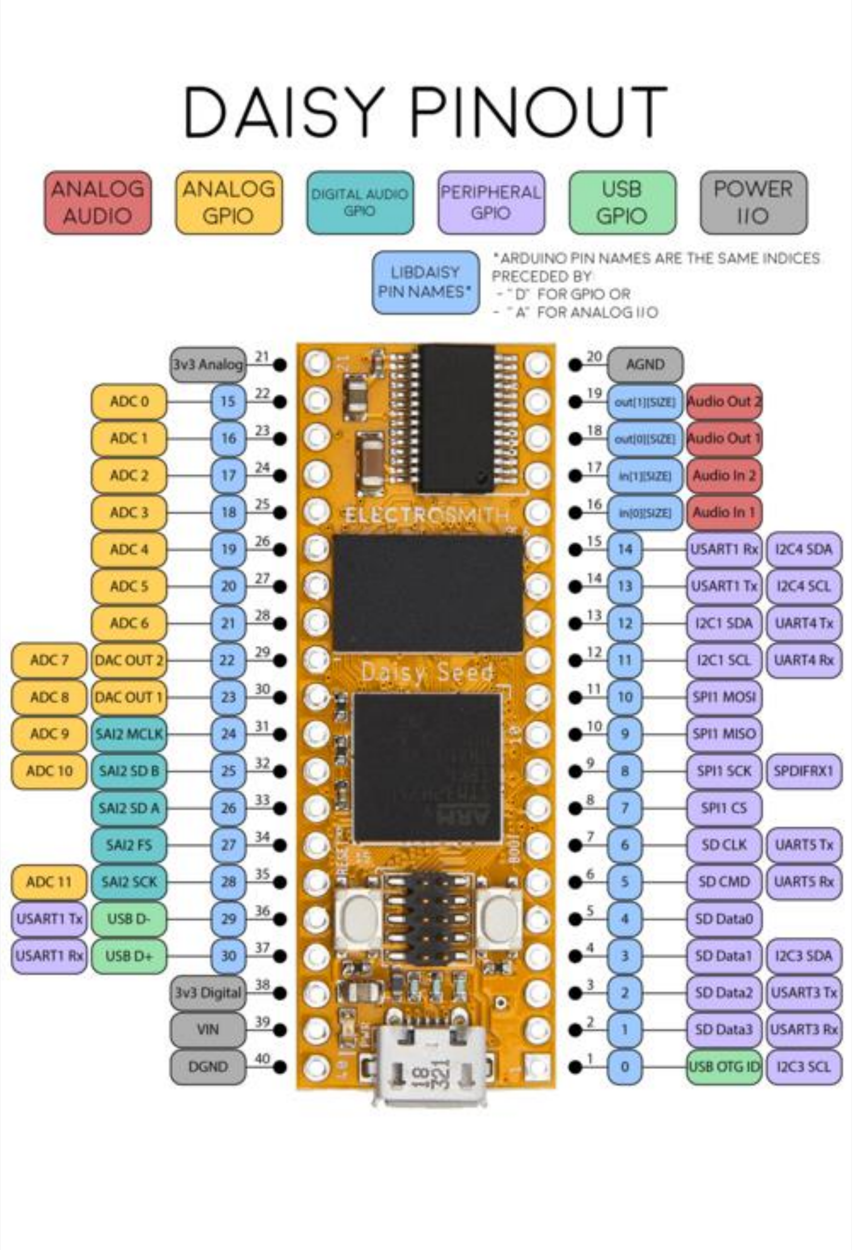
. Micro USB port along with additional USB pins for full OTG-support as host and device. Port can be used for power, firmware, and debugging.

DECISION MATRIX

	WEIGHT	DAISY	FV-1	WEIGHTED DAISY	WEIGHTED FV-1
Cost	0.2687	0.3280	0.6720	0.0881	0.1805
Ease of Programming	0.4463	0.7692	0.2308	0.3433	0.1030
Size	0.0343	0.8327	0.1673	0.0285	0.0057
Fidelity	0.0602	0.8000	0.2000	0.0482	0.0120
I/O	0.0754	0.9118	0.0882	0.0688	0.0067
Memory	0.1151	0.9995	0.0005	0.1150	0.0001
Total		**0.6920**	**0.3080**		



DAISY SEED PINOUT



DAISY SEED SPECS

- Programming Languages: C++, Arduino, Max/MSP Gen~
- RAM: 64 MB
- Memory: 8MB flash
- Sampling rate & bit depth: 24bit @ 192 kHZ
- Pinout info from website:
  - . 31 total GPIO pins which can be configured as standard GPIO or one of several alternate functions including 16-bit Analog to Digital Converters(x12)
  - . 12-bit Digital to Analog Converters(x2)
  - . SD Card interfaces
  - . PWM outputs
  - . Serial protocols for connecting to external sensors and devices including SPI, UART, I2S, and I2C
  - . Dedicated VIN pin for power (input range from 4v to 17v)
  - . Micro USB port along with additional USB pins for full OTG-support as host and device. Port can be used for power, firmware, and debugging.
- DaisySP included – an opensource DSP C++ library
- LibDaisy – Hardware abstraction lib for things such as ADCs & GPIO
- To upload programs, flash via microusb

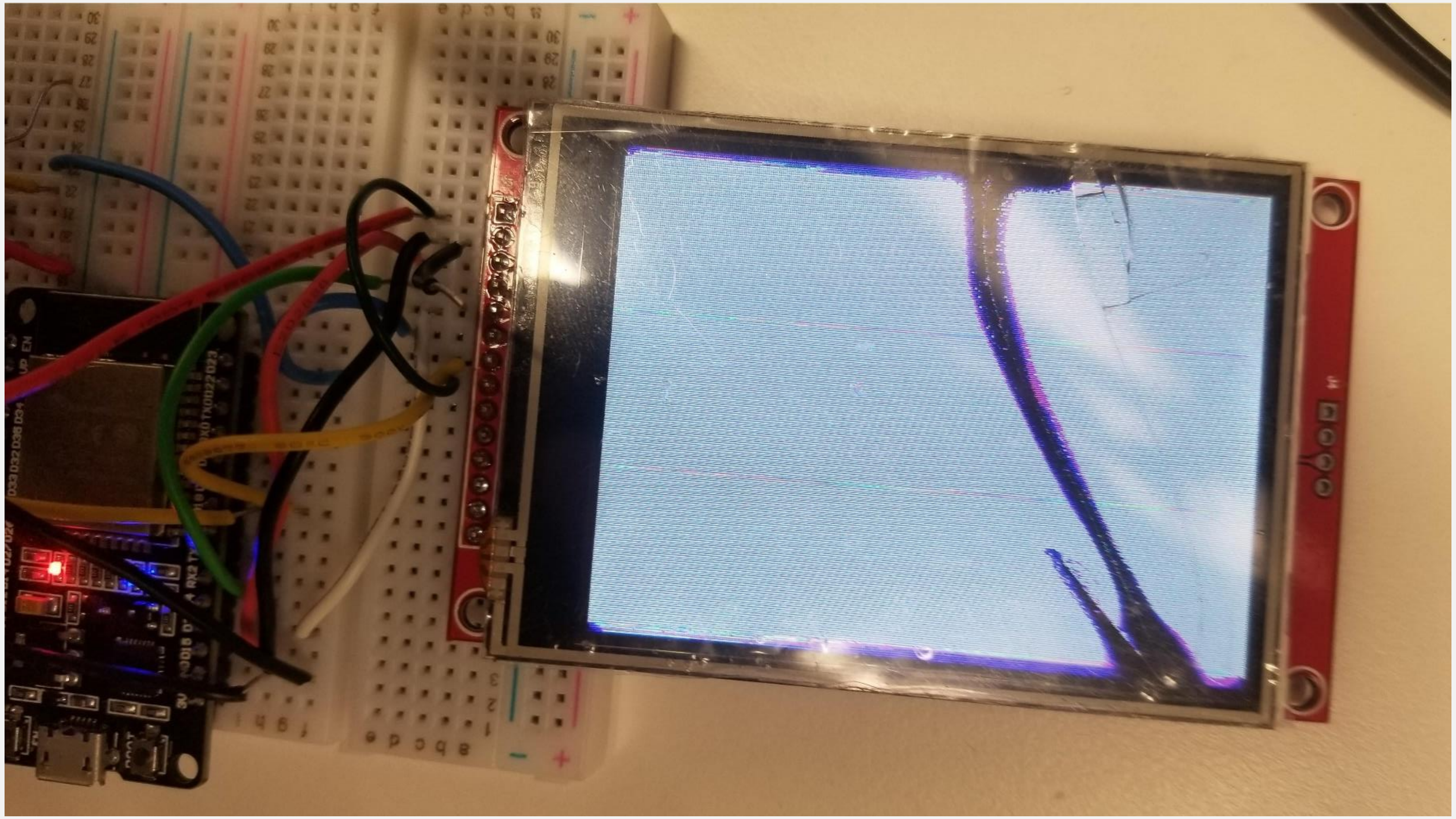
Digital Effects			
Name of Effect	Musical Function	Related DSP Concepts	Included
Delay*	Delays take a sound and repeats it at a lower volume at a set amount of time later, adding a sense of space or depth to a sound.	Delay Lines Circular Buffers	Yes
Reverb*	Artificially adds a sense of space by mixing in a delayed, blurred version of the sound at a later time.	All Pass Filters Feedback Comb filters	Yes
Bitcrusher	Reduces the bit depth and sampling rate of the sound, creating a "dirtier" and noisier signal.	Sample Rate Nyquist Frequency Aliasing Noise	Yes
Distortion	Adds harmonics to the signal by passing samples through a nonlinear function, making the signal sound richer.	Intro to programming DSP in C++ Linear vs Nonlinear Systems	Yes
Digital Filter	Like the analog filter, signals can have frequency content adjusted in the digital domain.	FIR Filter IIR Filter	No
FFT Inspired Effects	After performing an FFT, digital effects can be applied to frequency bands at differing amounts, such as delay, compression, reverb,.	FFT	No

DISPLAY: OLD

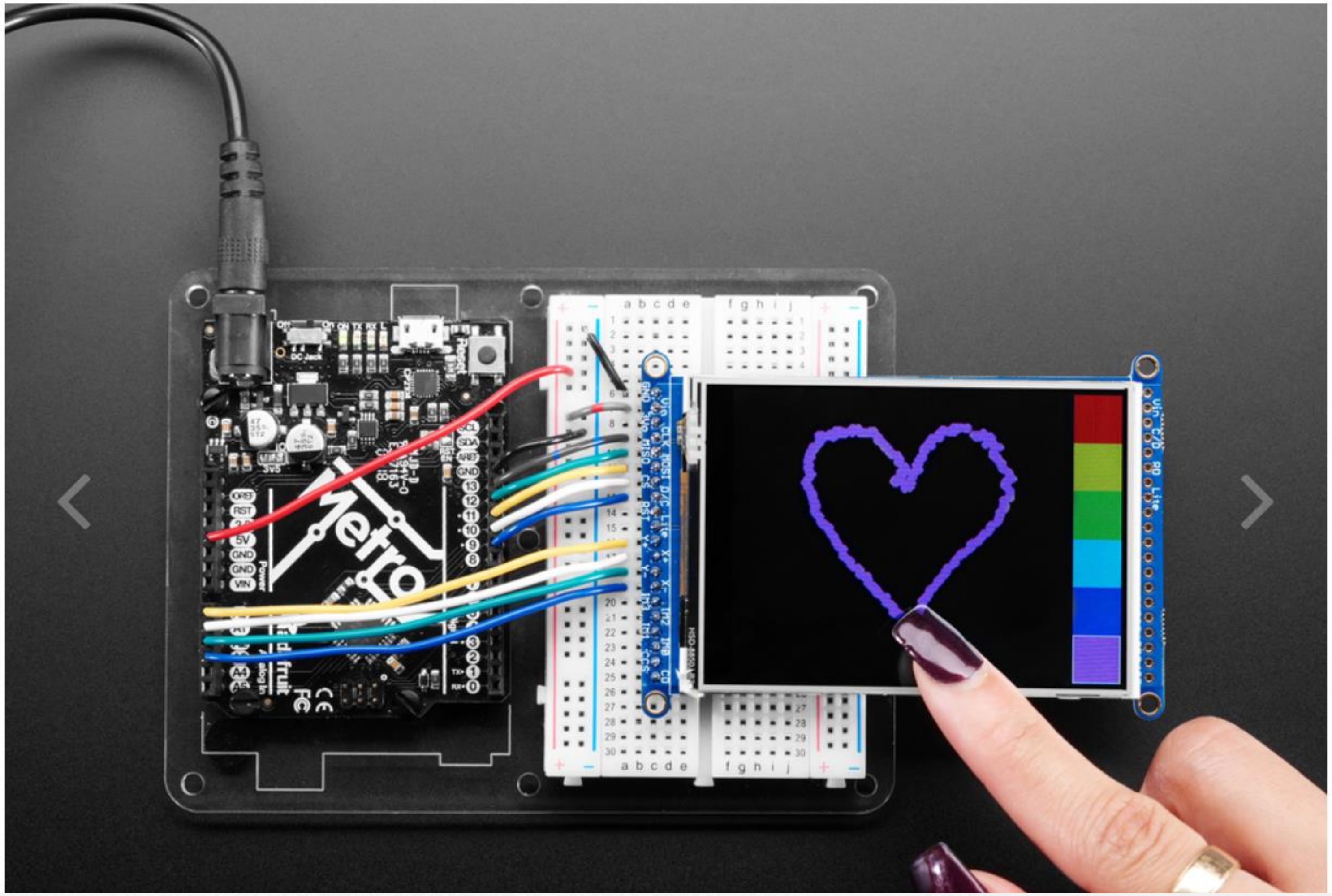
https://www.amazon.com/Display-Module-240320-4-Wire-Screen/dp/B07KPD4DHD

Specification:
Size: 3.2 inch
Type: with touch function, no touch function (optional)
Driver chip: ILI9341
Resolution: 320*240 (Pixel)
Module interface: 4-wire SPI interface
Effective display area: 48.6x64.8(mm)
Module PCB plate size: 55.04x89.3(mm)
VCC power supply voltage: 3.3v ~5V
Logical IO port voltage: 3.3v (TTL)
The power consumption: Approx. 90mA
Weight: Approx.42g/1.5oz
Interface definition: serial number label Pin description 1 VCC power input(3.3V~5V) 2

DISPLAY: OLD TEST



DISPLAY: NEW



3.2" TFT LCD with Touchscreen Breakout Board w/MicroSD Socket - ILI9341

PRODUCT ID: 1743

$29.95

6 IN STOCK

1 ADD TO CART

QTY	DISCOUNT
1-9	$29.95
10-99	$26.96
100+	$23.96

ADD TO WISHLIST

DESCRIPTION

TECHNICAL DETAILS

4.9 ★★★★★ Google Customer Review

https://www.adafruit.com/product/1743

DISPLAY: NEW TEST

DISPLAY DRIVER COMPLICATIONS

Kyle Sellers Mar 23rd at 10:48 A

Anyone have experience interfacing the Daisy Seed with a IL9341 TFT LCD screen? (edited)

2 replies

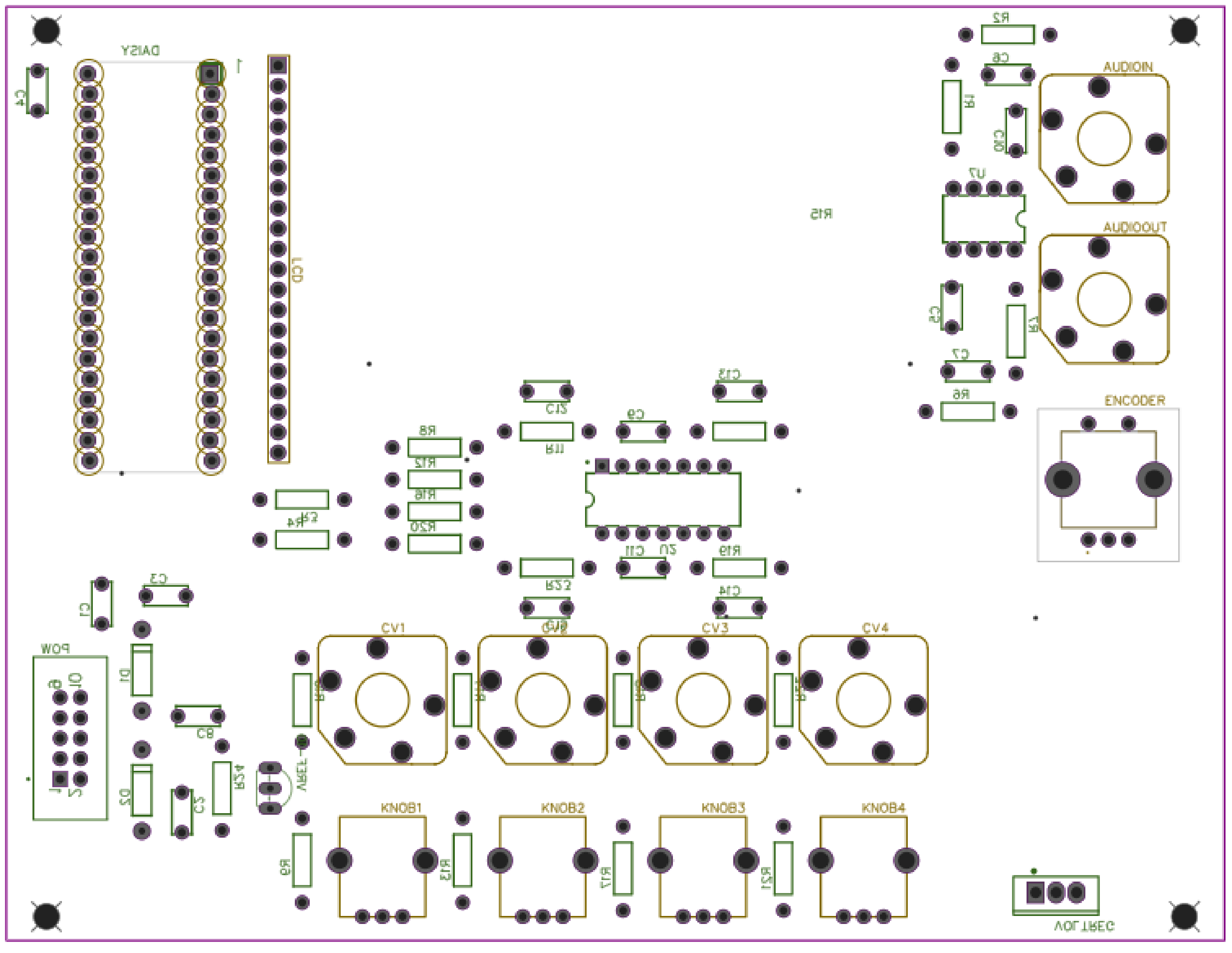
Kyle Sellers 23 days ago

looking at what was done for the patch, it seems thata the driver is /hid/oled_display.cpp in libDaisy. This seems to be only for the SSD1309 chip. ae there pre written libraries for this application, or will I have to write my own driver?

Stephen Hensley 11 days ago

I actually have a few of those sitting around here, but I haven't gotten around to writing a driver for libdaisy.

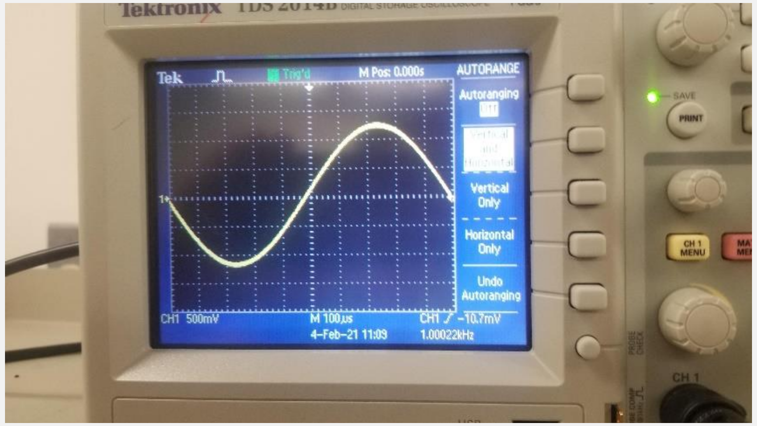
PCB


AUDIOIN
AUDIOOUT
ENCODER
CV1
CV3
CV4
KNOB1
KNOB2
KNOB3
KNOB4

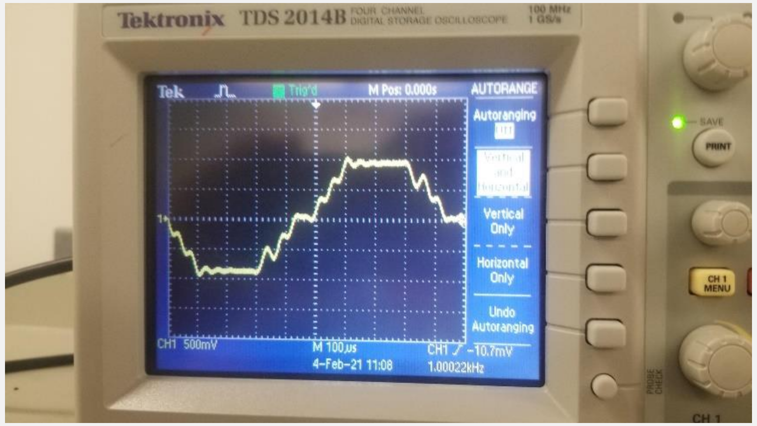
BITCRUSHER CODE

```
void AudioCallback(float *in, float *out,
size_t size)
{
knob1Val = hw.adc.GetFloat(0);
bitDepth = ((int)floor(knob1Val * 16)) + 1;
for(size_t i = 0; i < size; i += 2)
{

float totalQLevels = powf(2, bitDepth);
float val = out[i];
float remainder = fmodf(val, 1/totalQLevels);
// // Quantize ...
out[i] = val - remainder;
}
```

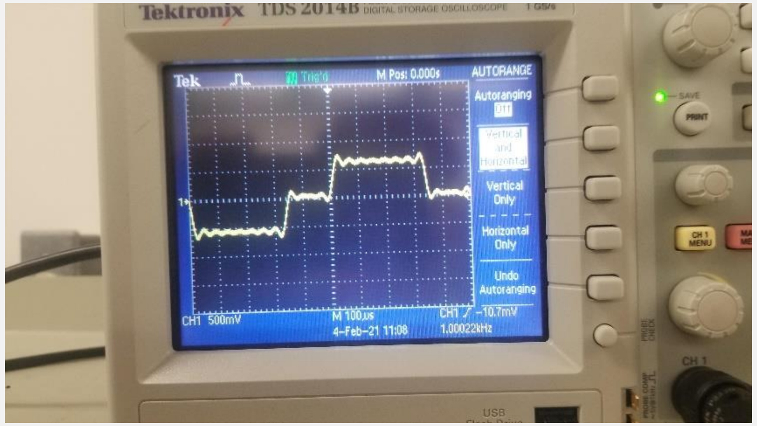
BITCRUSHER TEST



16 bit depth = 64k levels



2 bit depth = 4 levels

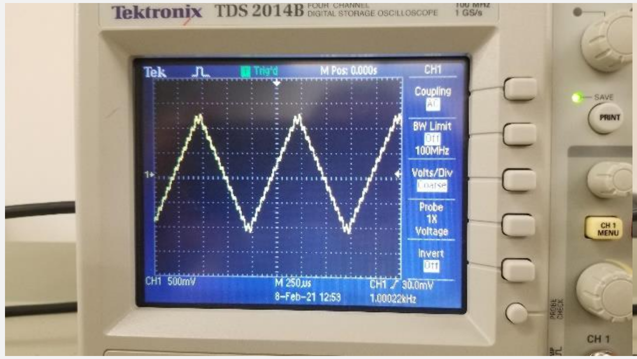


16 bit depth = 2 levels

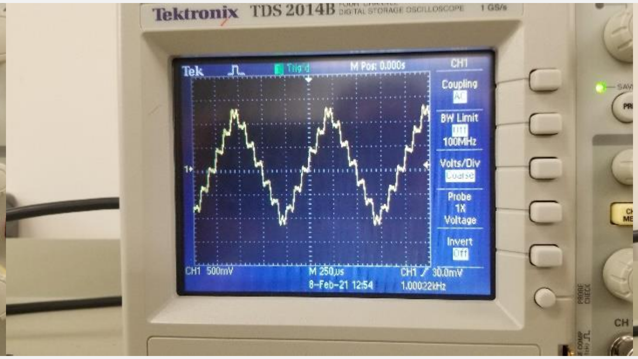
SAMPLE RATE REDUCE CODE

```
void AudioCallback(float *in, float *out, size_
t size)
{
    knob1Val = hw.adc.GetFloat(0);
    sampleRateReduce = ((int)floor(knob1Val * 1
6) + 1);
    for(size_t i = 0; i < size; i += 2)
    {
        out[i] = osc.Process();
        if (sampleRateReduce > 1)
        {
            //sample hold
             int index = i / 2;
             if (index%sampleRateReduce != 0) o
ut[i] = out[i - 2*(index%sampleRateReduce)];

        }

    }
    return;
}
```

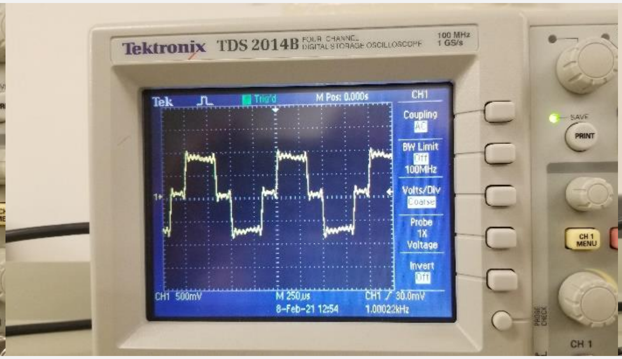
SAMPLE RATE REDUCE TEST



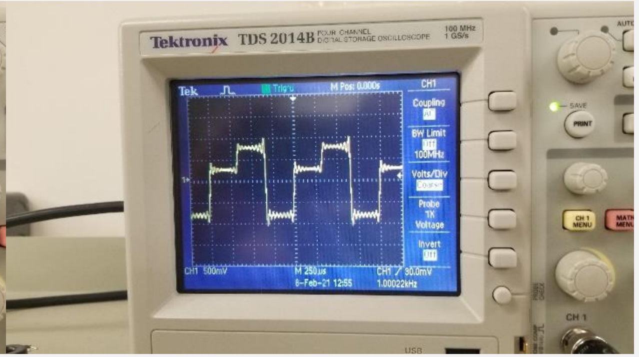
2x



4x



8x



16x

DELAY

- IIR Implementation
- Max Delay = 0.5 s due to memory constraints
- y[n] = 0.5 * x[n] + 0.5 * g * y[n-k]
  - g = Delay amount
  - k = # samples to delay
    - = floor(Delay time * 48000)

REVERB

Schroeder Reverberators

The subject of *artificial reverberation* was initiated in the early 1960s by Manfred Schroeder and Ben Logan [420,421,415]. Early Schroeder reverberators consisted of the following elements [415]:

- A series connection of several *allpass filters*
- A parallel bank of *feedback comb filters*
- A *mixing matrix*

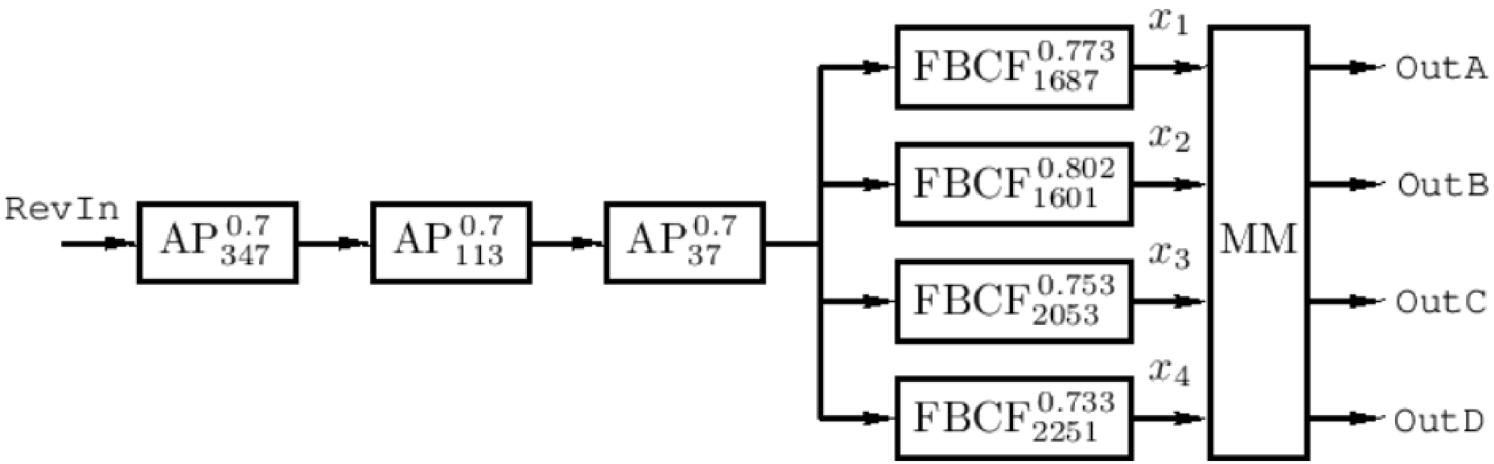
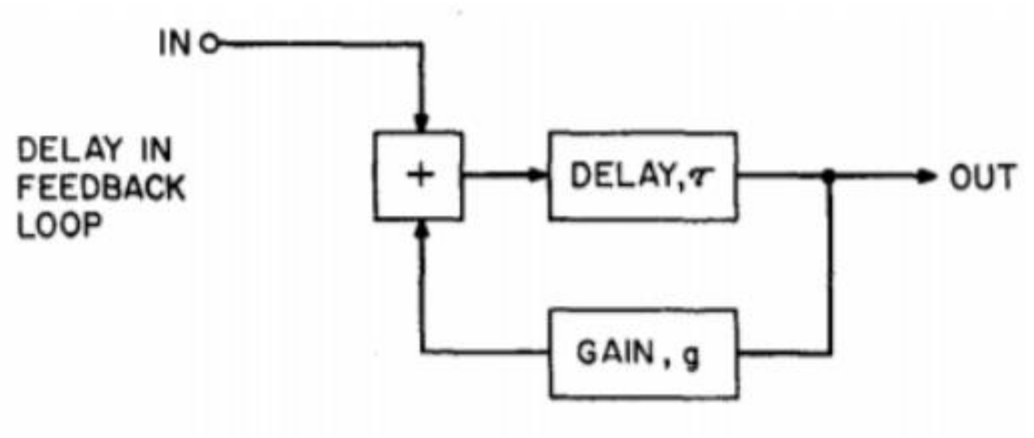


Figure: A Schroeder reverberator we will call JCREV developed by Prof. John Chowning, founding director of CCRMA (drawn from a 1972 MUS10 software listing, where MUS10 was an ``acoustic compiler'' language descended from Music V [308]).

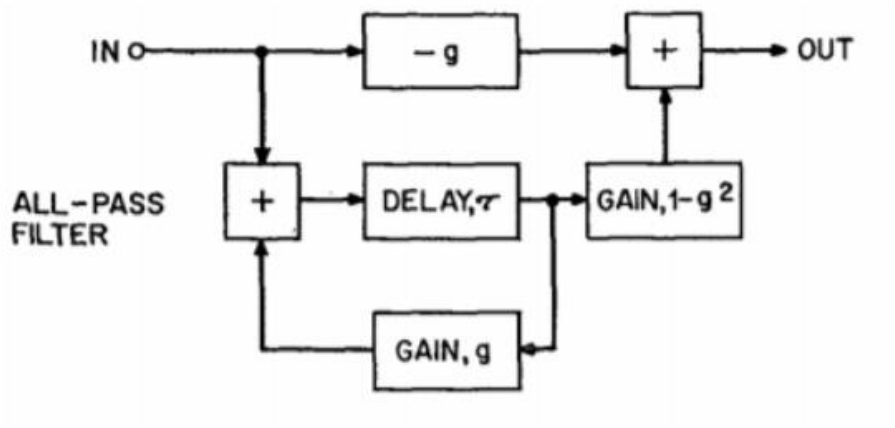
https://ccrma.stanford.edu/~jos/pasp/Schroeder_Reverberators.html

REVERB : COMPONENTS



Comb Filter structure

```
y[n] = x[n] + g·y[n−M]
```



All-pass filter structure

```
y[n] = (−g·x[n]) + x[n−M] + (g·y[n−M])
```

https://medium.com/the-seekers-project/coding-a-basic-reverb-algorithm-part-2-an-introduction-to-audio-programming-4db79dd4e325

DSP LAB 1 : INTRO TO AUDIO DSP

DSP MOCK LAB 1

INTRODUCTION TO AUDIO DSP

OBJECTIVE

To become familiar with how audio signals apply to DSP terminology and how these are represented digitally.

To introduce how to program DSP systems for processing real time audio.

BACKGROUND

Audio signals exist in the physical world in two forms: as compressions and rarefactions of particles in the air (Fig 1a), or as voltage signals varying with time (Fig 1b). As discussed in chapter 1, we convert continuous time analog signals into discrete time signals by sampling and quantiizing these real time signals. These concepts will be explored further in LAB 2.

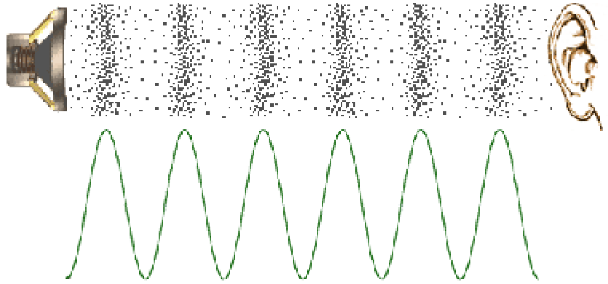


Fig 1a: Sound Waves in Air

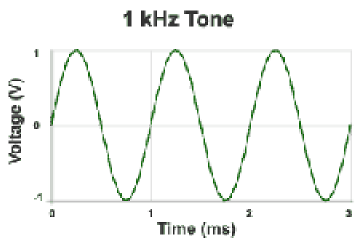


Fig 1b: Sound Waves as Voltages

DSP LAB 2: BITCRUSHER

DSP MOCK LAB 2

BITCRUSHER (NOISE, BIT DEPTH, & SAMPLE RATE)

OBJECTIVE

To explore artificial digital noise and its implementation.
To expose students to artificial bit reduction implementation.
To expose students to the simplest artificial sample rate implementation: sample and hold.

BACKGROUND

In chapter 1, we learned about sampling and quantization. If thinking about an audio signal (or any single dimension, single channel signal) on a 2D plane, the X-axis resolution is the sample rate (number of samples taken per second), and the Y-axis resolution is the bit depth (if the system has a bit depth of n, there are 2^n possible values the sample can take). This grid metaphor is visualized in Figure 2a.

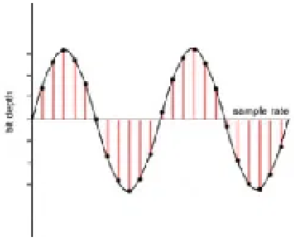


Fig 2a: Sample Rate and Bit Depth

To determine the required sample rate, we need to know the domain of signals being dealt with. The spectrum of human hearing is from about 20Hz to 20kHz, therefore 20kHz is the highest frequency we need to represent. Using the Nyquist Theorem, which states that the sample rate needs to be 2x the highest frequency we want to represent, we know our sample rate needs to be at least 40kHz to be able to cover the entire audible range for humans.

As for an appropriate bit depth, first refer to Fig 2b. For each sample, the closest multiple of 2^n, where n is the bit depth, is taken to approximate the real signal. This, as you know, is called quantization. The difference between the real value and the approximated value is known as quantization noise, and if this has a high enough amplitude, it becomes audible to whomever is listening to the signal.

DME LATENCY TEST CODE

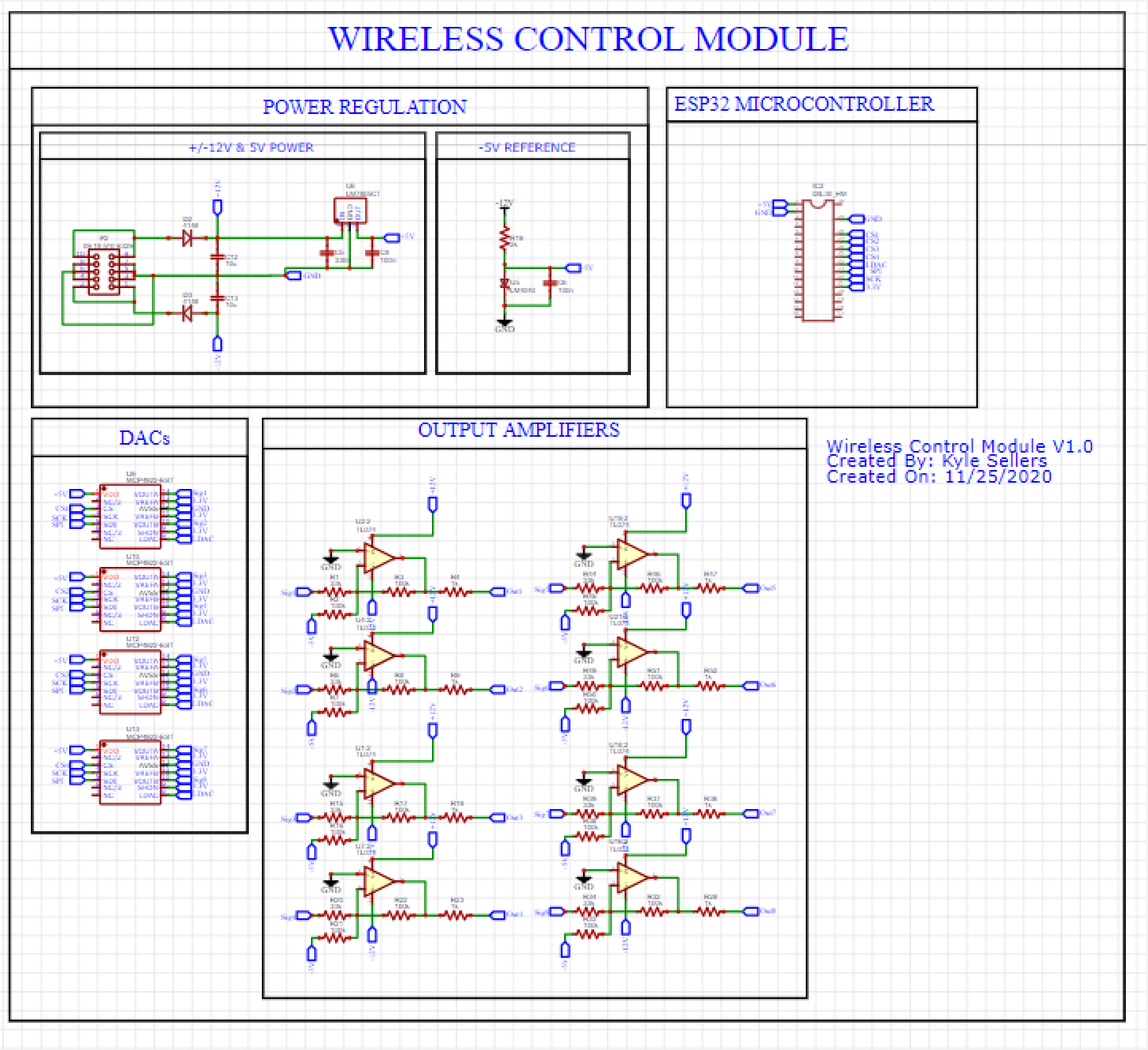
```
const int bufferSize = 48;
int counter = 0;
int numCycles = 22;
float HI = 1.0;
float LO = -1.0;
float newIn[bufferSize] = {};
float newOut[bufferSize] = {};

void MyAudioCallback(float *in, float *out, size_t size)
{
    if (counter % numCycles == 0)
    {
        for(size_t i = 0; i < size; i++)
        {
            float random = ((float) rand()) / (float) RAND_MAX;
            out[i] = (random * 2.0) - 1.0;
        }
    }
    else
    {
        for(size_t i = 0; i < size; i++)
        {
            out[i] = 0.0;
        }
    }
    counter++;
    counter = counter % numCycles;

}
```

DME LATENCY TEST CODE

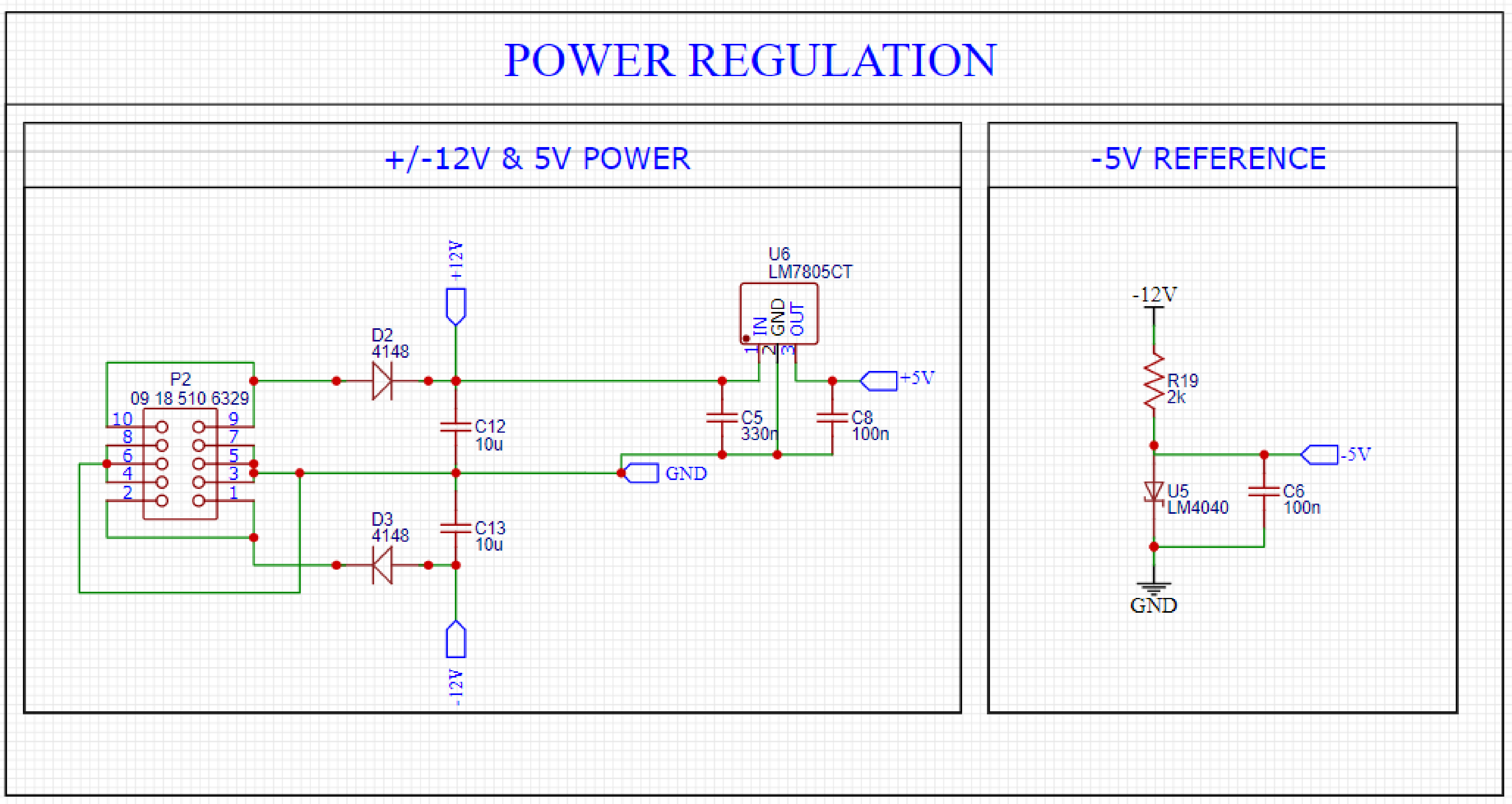
```
const int bufferSize = 48;
int counter = 0;
int numCycles = 22;
float HI = 1.0;
float LO = -1.0;
float newIn[bufferSize] = {};
float newOut[bufferSize] = {};

void MyAudioCallback(float *in, float *out, size_t size)
{
    if (counter % numCycles == 0)
    {
        for(size_t i = 0; i < size; i++)
        {
            float random = ((float) rand()) / (float) RAND_MAX;
            out[i] = (random * 2.0) - 1.0;
        }
    }
    else
    {
        for(size_t i = 0; i < size; i++)
        {
            out[i] = 0.0;
        }
    }
    counter++;
    counter = counter % numCycles;

}
```

WIRELESS CONTROL MODULE (WCM)

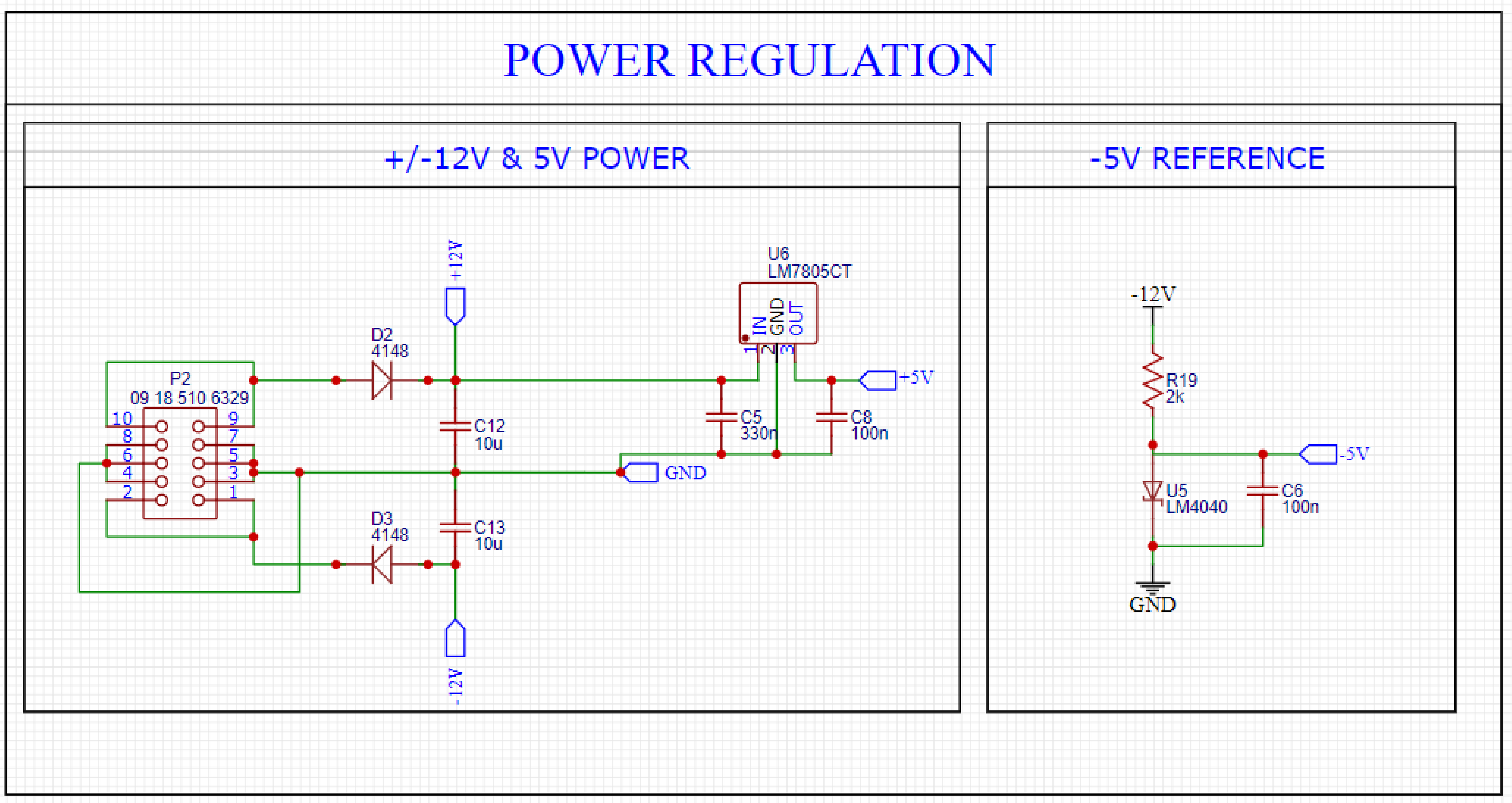
CIRCUIT DIAGRAM



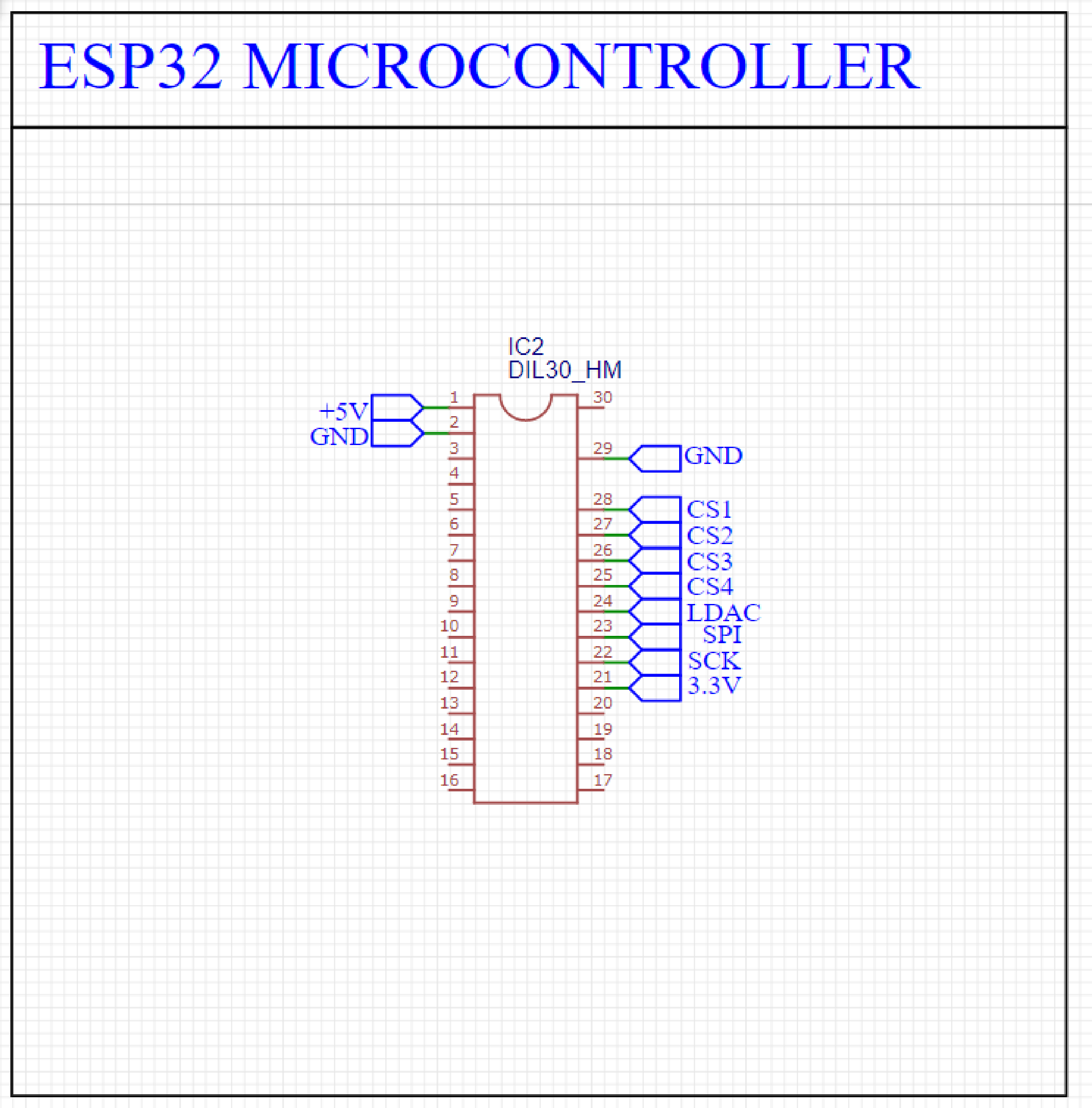
POWER REGULATION



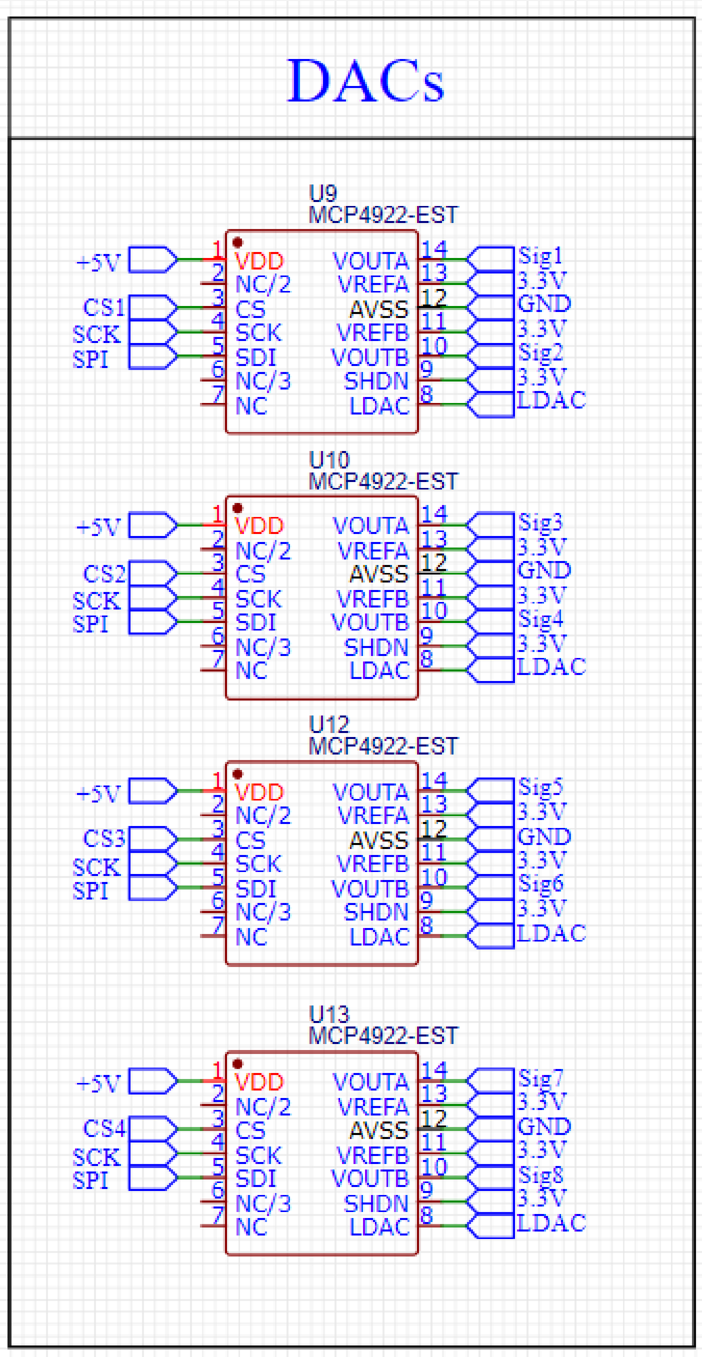
POWER REGULATION



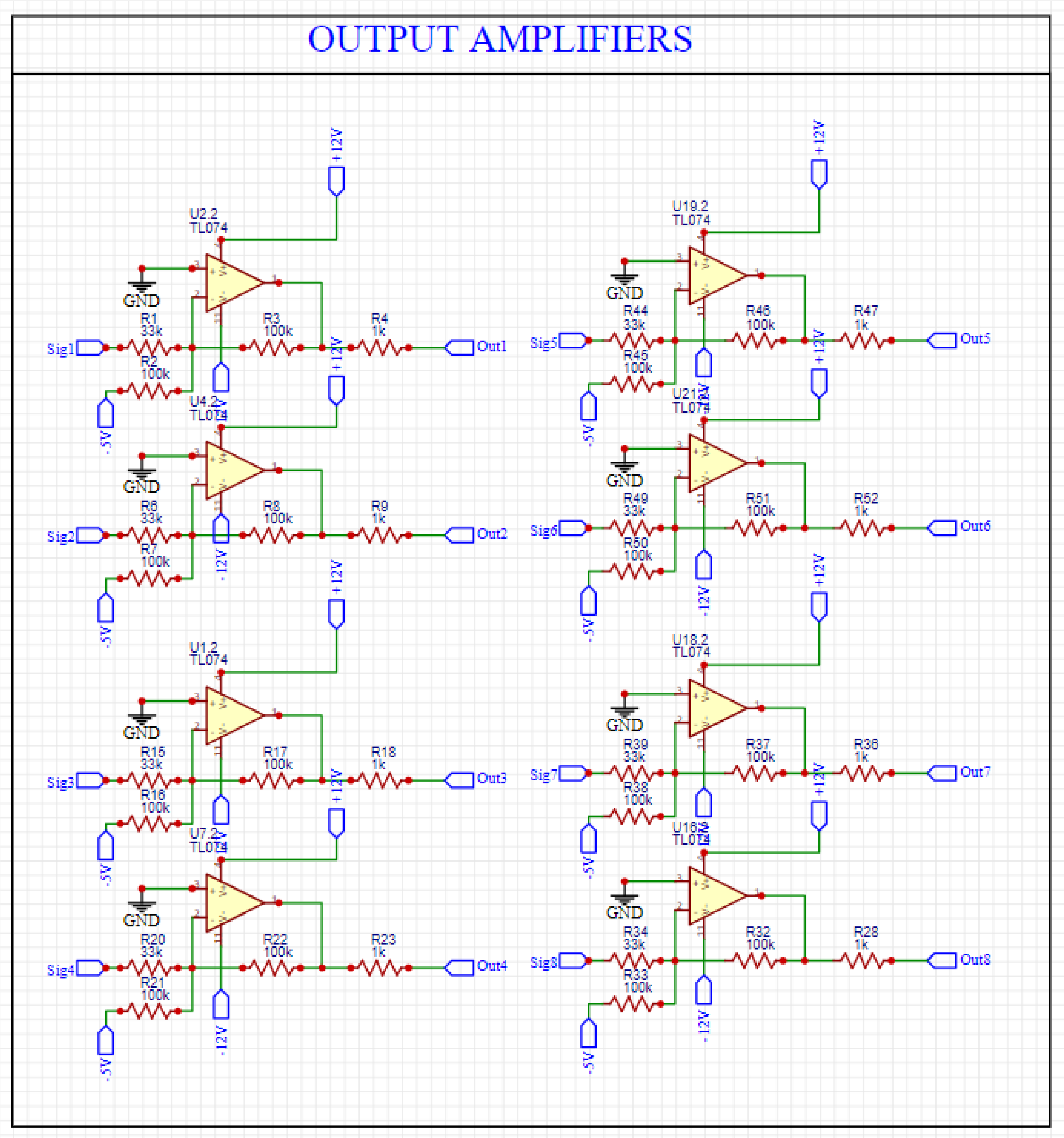
ESP32 PINOUT



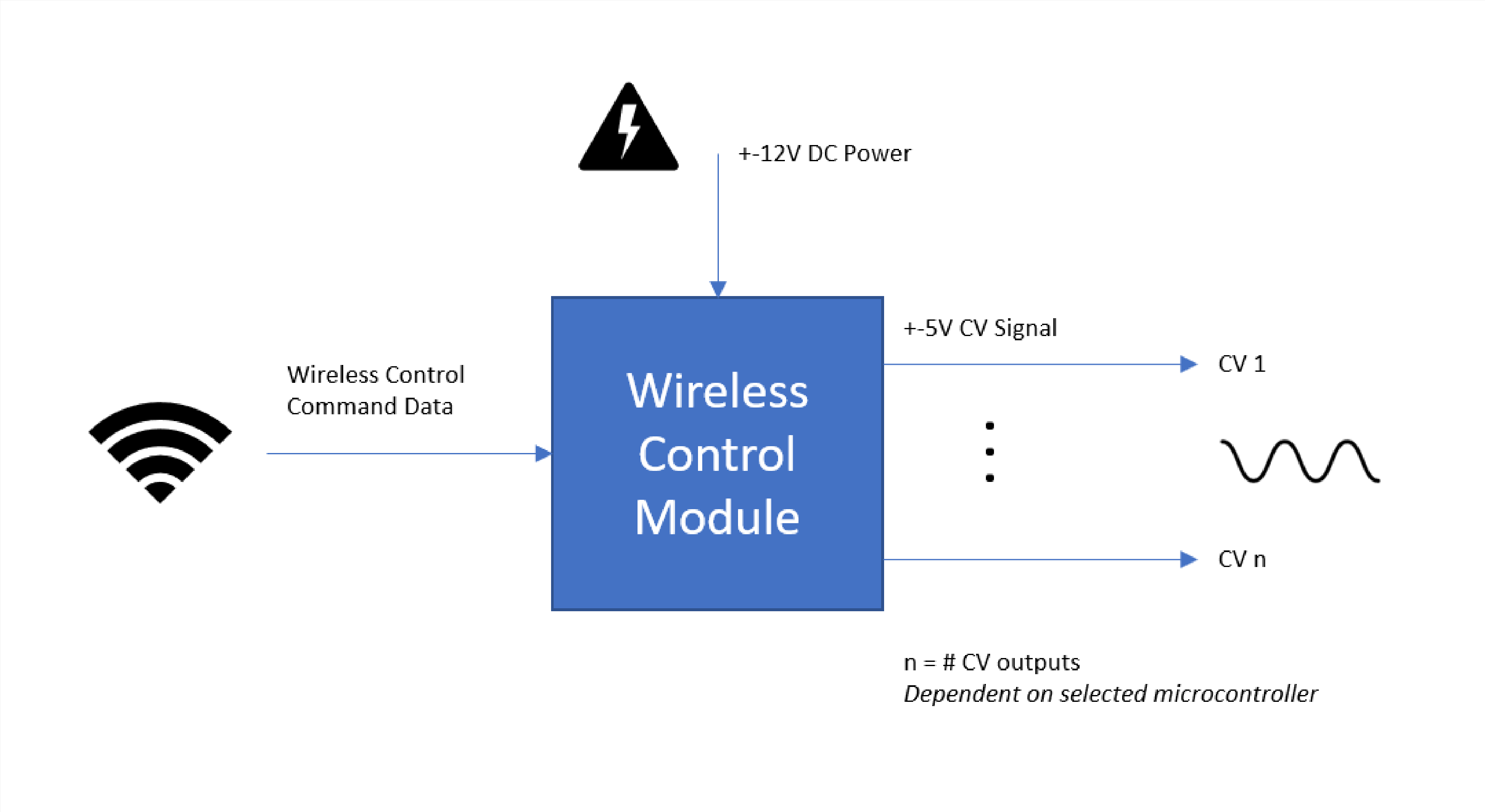
DACS


DACs
U9
MCP4922-EST
+5V
CS1
SCK
SPI
VDD
NC/2
CS
SCK
SDI
NC/3
NC
VOUTA
VREFA
AVSS
VREFB
VOUTB
SHDN
LDAC
Sig1
3.3V
GND
3.3V
Sig2
3.3V
LDAC
U10
MCP4922-EST
+5V
CS2
SCK
SPI
Sig3
3.3V
GND
3.3V
Sig4
3.3V
LDAC
U12
MCP4922-EST
+5V
CS3
SCK
SPI
Sig5
3.3V
GND
3.3V
Sig6
3.3V
LDAC
U13
MCP4922-EST
+5V
CS4
SCK
SPI
Sig7
3.3V
GND
3.3V
Sig8
3.3V
LDAC

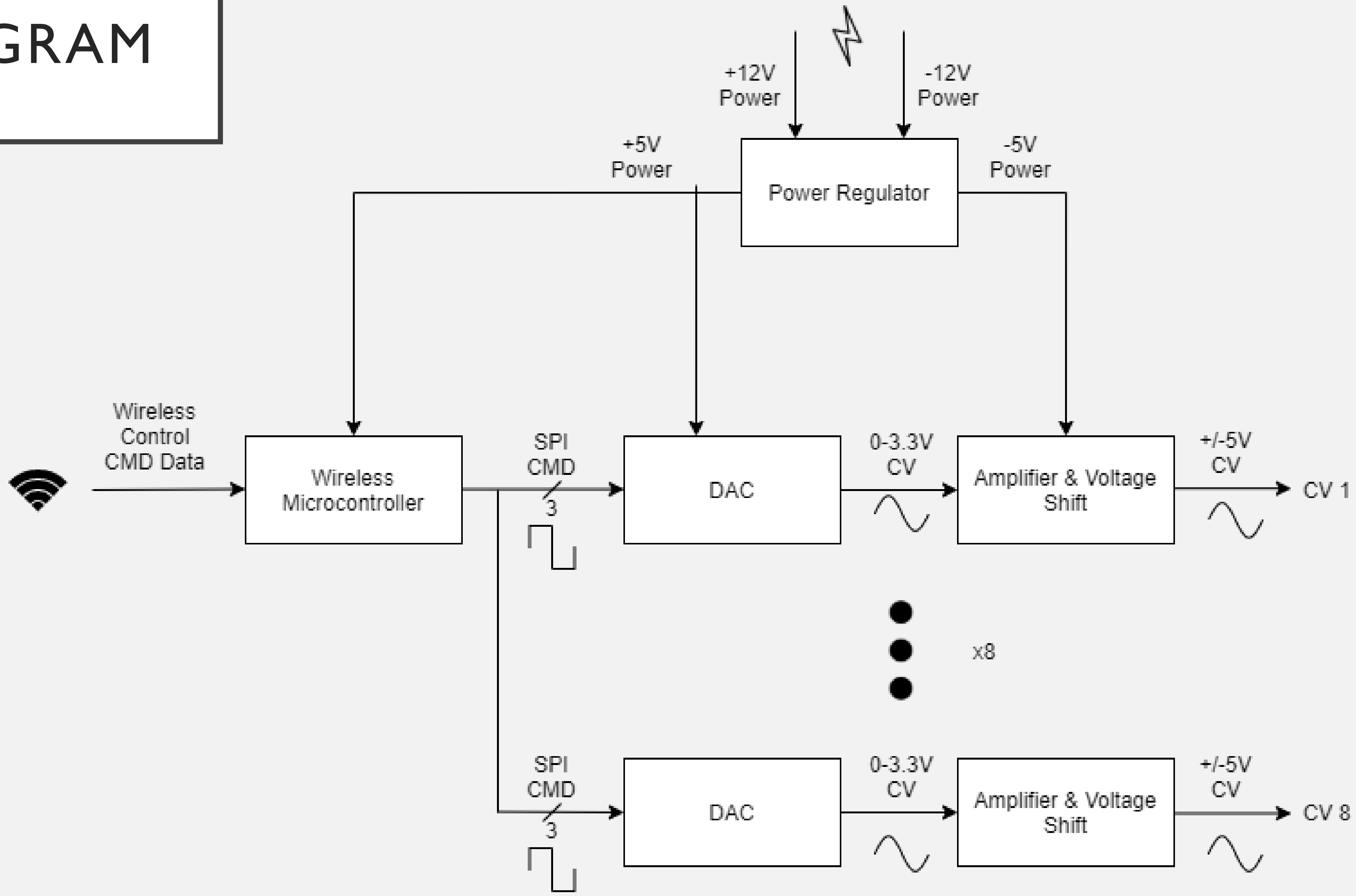
AMPLIFIER & VOLTAGE SHIFT



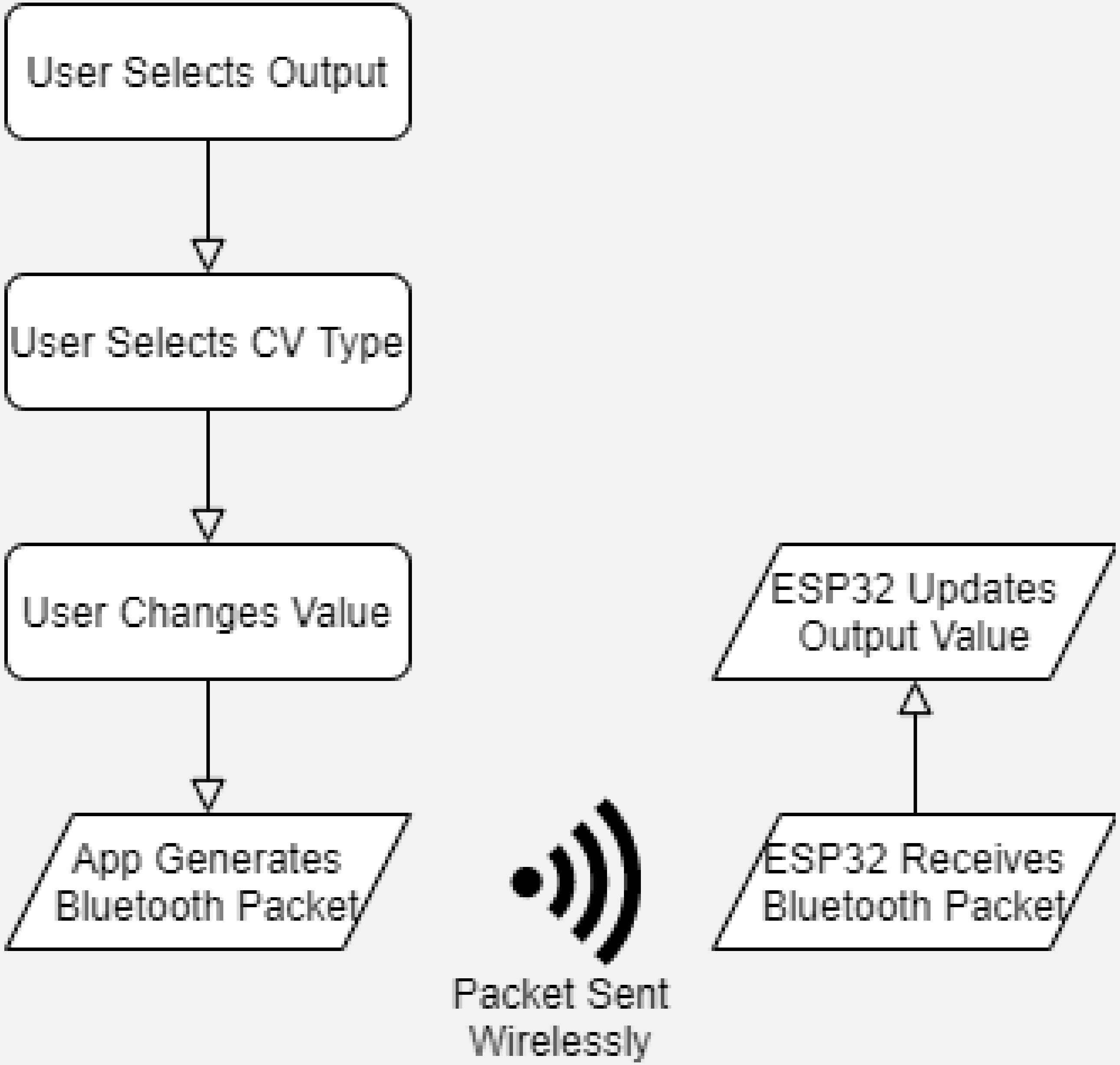
LEVEL 0 DIAGRAM



LEVEL 1 DIAGRAM

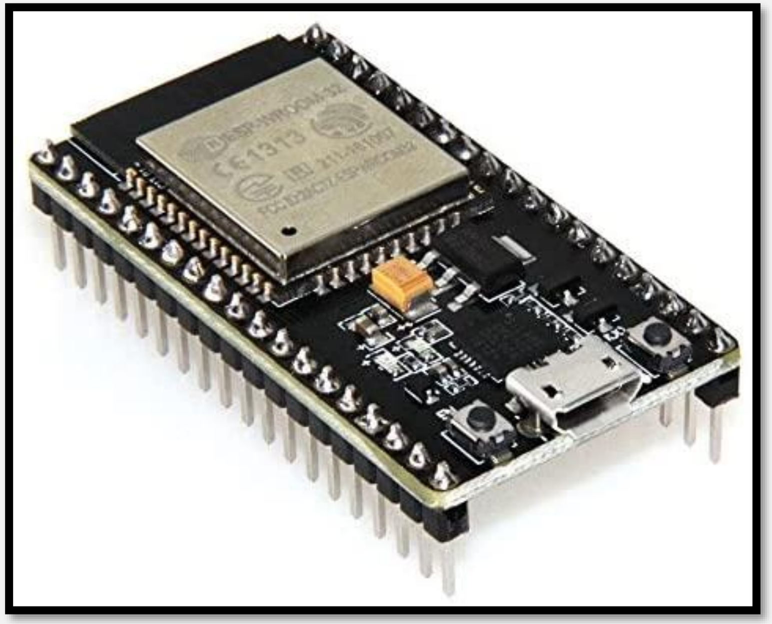


SOFTWARE DIAGRAM



WIRELESS TECH DECISION MATRIX

	Weight	Bluetooth	Wi-Fi	Zigbee	Weighted Bluetooth	Weighted Wi-Fi	Weighted Zigbee
Multiple Device Support	0.0436	0.1739	0.3913	0.4348	0.0076	0.0171	0.0190
Latency	0.3231	0.2000	0.4000	0.4000	0.0646	0.1293	0.1293
Documentation	0.2691	0.2353	0.5882	0.1765	0.0633	0.1583	0.0475
Range	0.1123	0.6250	0.3125	0.0625	0.0702	0.0351	0.0070
Power Consumption	0.0401	0.3373	0.2410	0.4217	0.0135	0.0097	0.0169
Security	0.2118	0.4762	0.2857	0.2381	0.1009	0.0605	0.0504
Total		0.3201	0.4099	0.2700			



WIRELESS TECH DECISION MATRIX

	Device Support	Latency	Documentation	Range	Power Consumption	Security		Geo Mean	Normalized
Device Support	1	1/7	1/5	1/3	1	1/5		0.35208	0.04361
Latency	7	1	3	3	5	1		2.60847	0.32313
Documentation	5	1/3	1	3	7	3		2.17203	0.26906
Range	3	1/3	1/3	1	5	1/3		0.90668	0.11232
Power Consumption	1	1/5	1/7	1/5	1	1/5		0.32334	0.04005
Security	5	1	1/3	3	5	1		1.70998	0.21183

WIRELESS TECH DECISION MATRIX

Technology	Device Support	DS / Max DS	Normalized
Bluetooth	4	0.4	0.173913043
Wi-Fi	9	0.9	0.391304348
Zigbee	10	1	0.434782609

Technology	Documentation	Doc / Max Doc	Normalized
Bluetooth	4	0.4	0.235294118
Wi-Fi	10	1	0.588235294
Zigbee	3	0.3	0.176470588

Technology	Latency	Min Latency / Latency	Normalized
Bluetooth	100	0.5	0.2
Wi-Fi	50	1	0.4
Zigbee	50	1	0.4

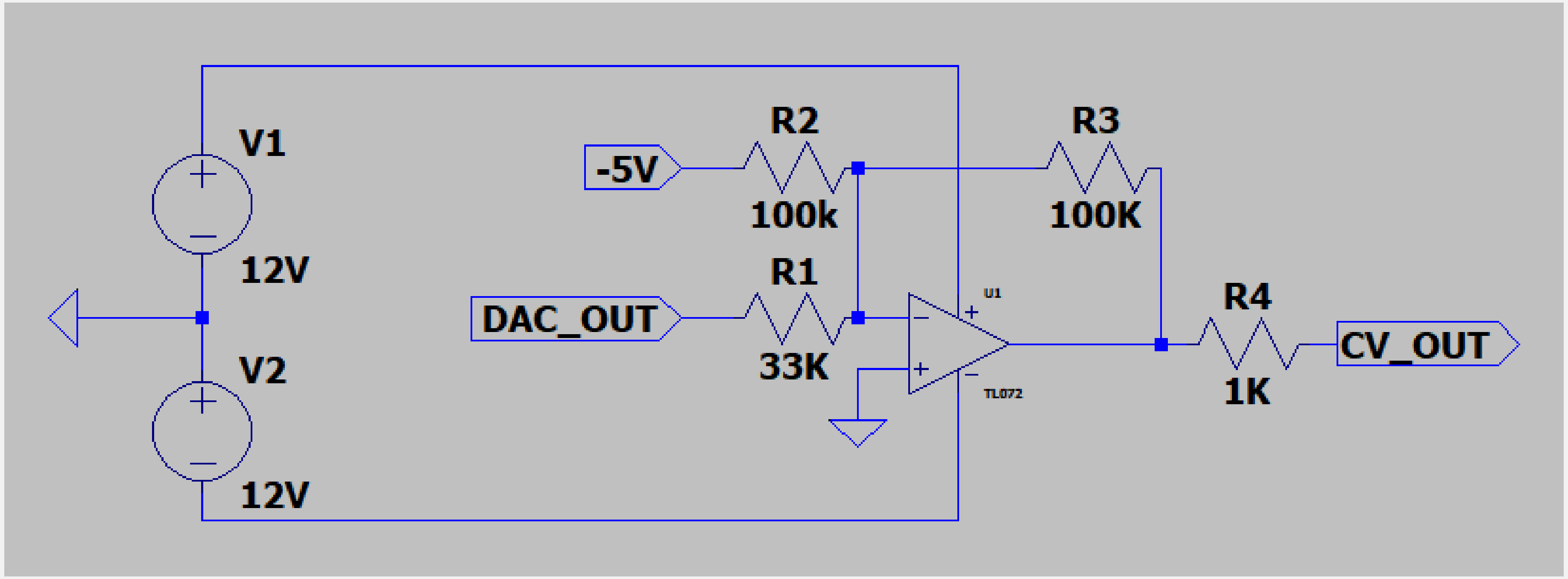
WIRELESS TECH DECISION MATRIX

Technology	Documentation	Doc / Max Doc	Normalized
Bluetooth	4	0.4	0.235294118
Wi-Fi	10	1	0.588235294
Zigbee	3	0.3	0.176470588

Technology	Cost	Min Cost / Cost	Normalized
Bluetooth	10	1	0.476190476
Wi-Fi	6	0.6	0.285714286
Zigbee	5	0.5	0.238095238

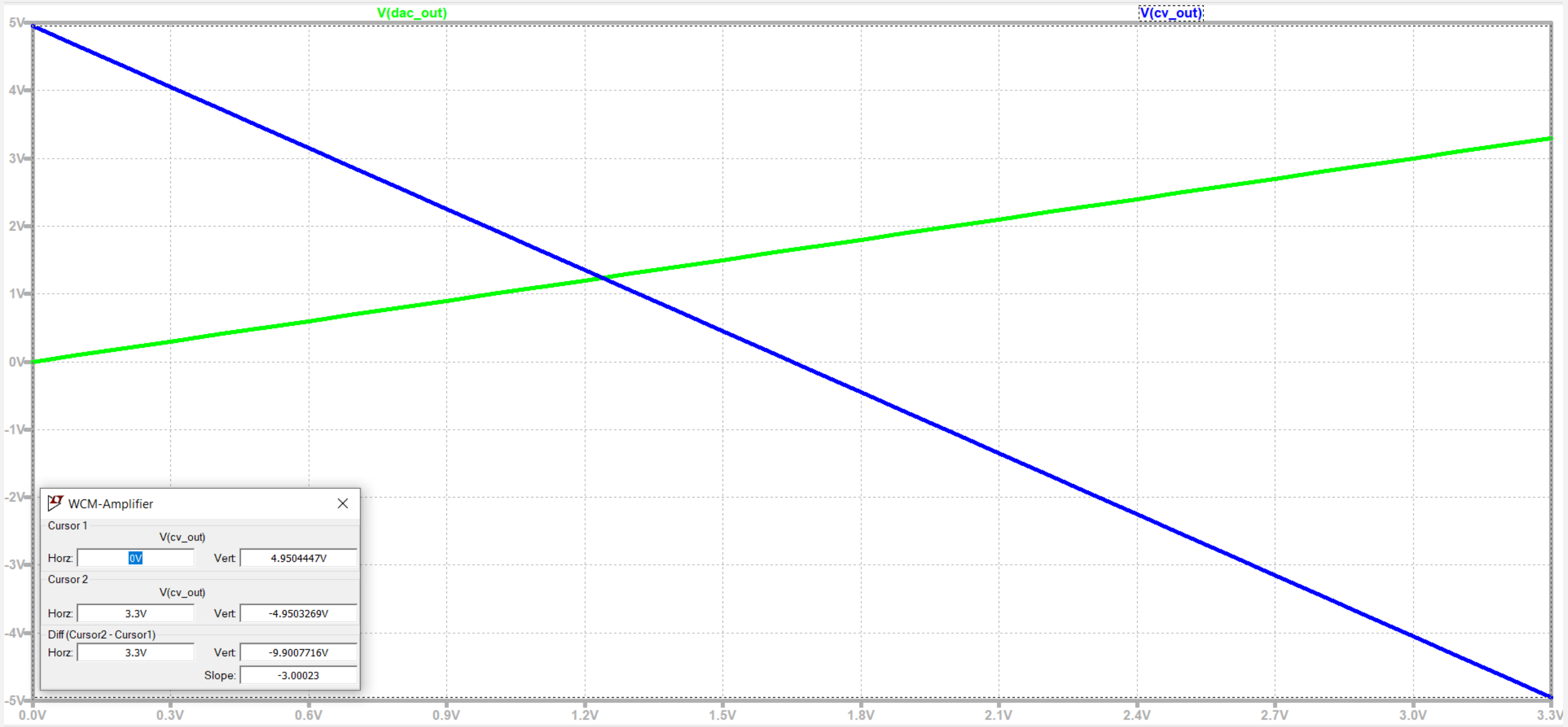
Technology	Power Consumption	Min PC / PC	Normalized
Bluetooth	50	0.8	0.337349398
Wi-Fi	70	0.571428571	0.240963855
Zigbee	40	1	0.421686747

AMPLIFIER SUBCIRCUIT



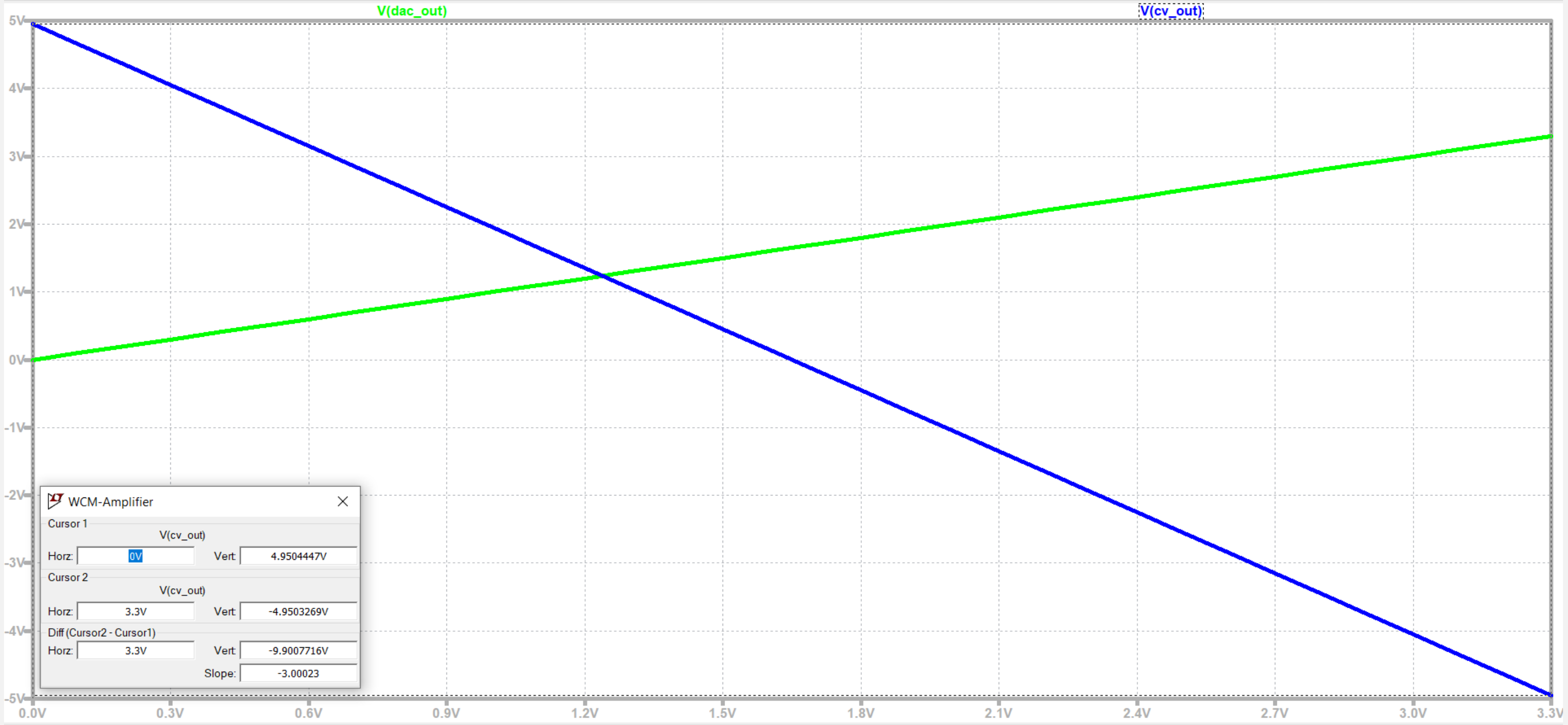
AMPLIFIER SUBCIRCUIT : DC SWEEP

- 0V to 3.3V In-> +5V to -5V Out

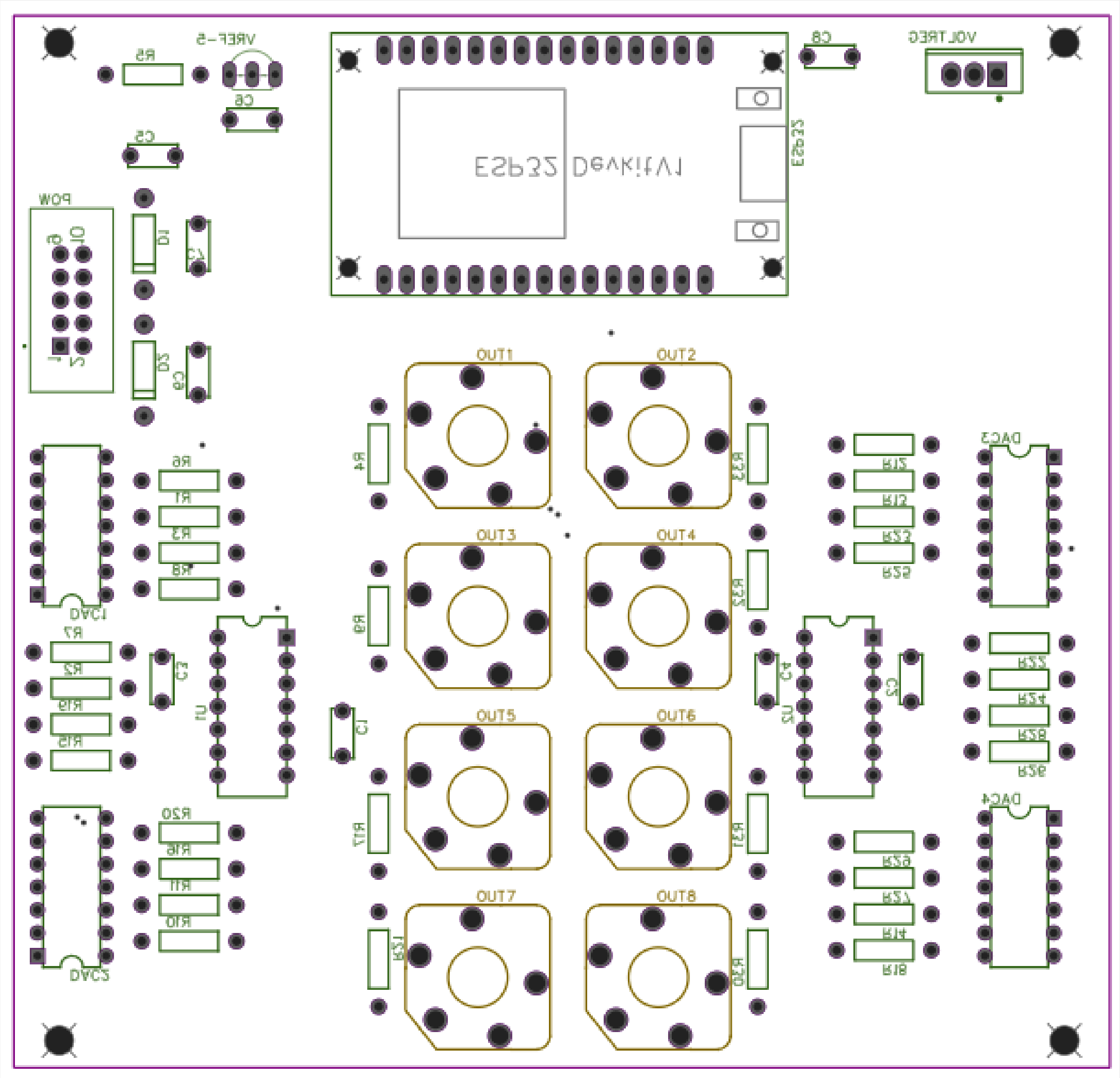


AMPLIFIER SUBCIRCUIT : DC SWEEP

- 0V to 3.3V In-> +5V to -5V Out



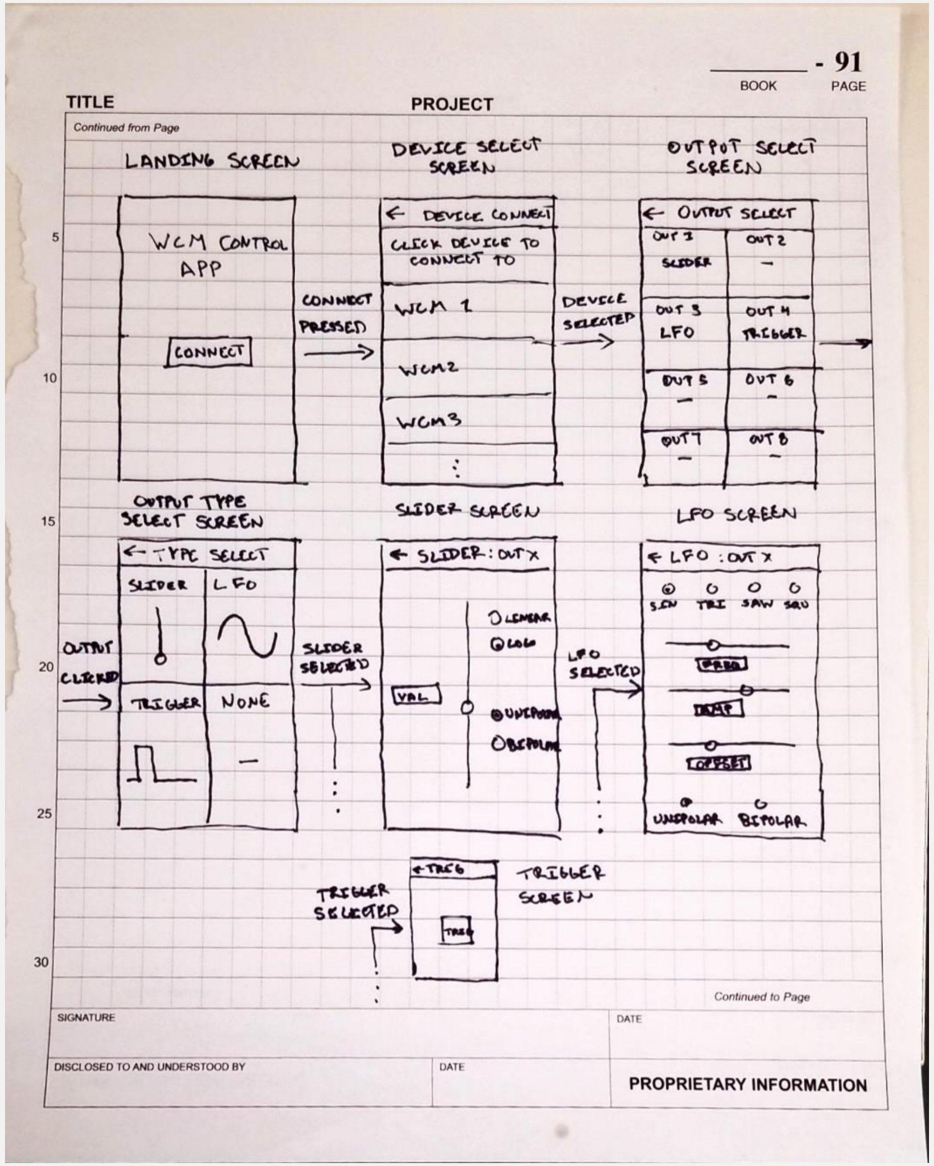
PCB



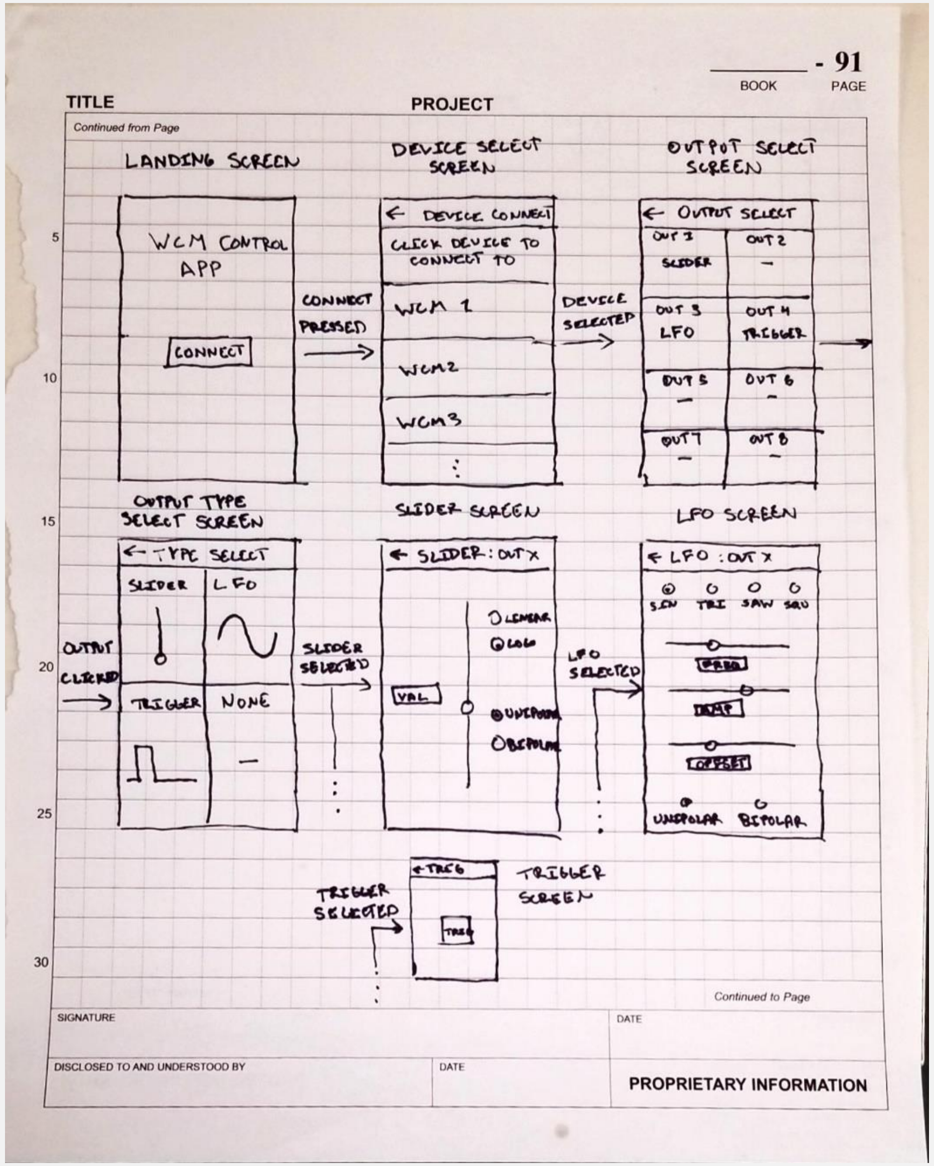
FACEPLATE

WCM
Wireless Control Module
OUT 1
OUT 2
OUT 3
OUT 4
OUT 5
OUT 6
OUT 7
OUT 8

APP UI MOCK UP

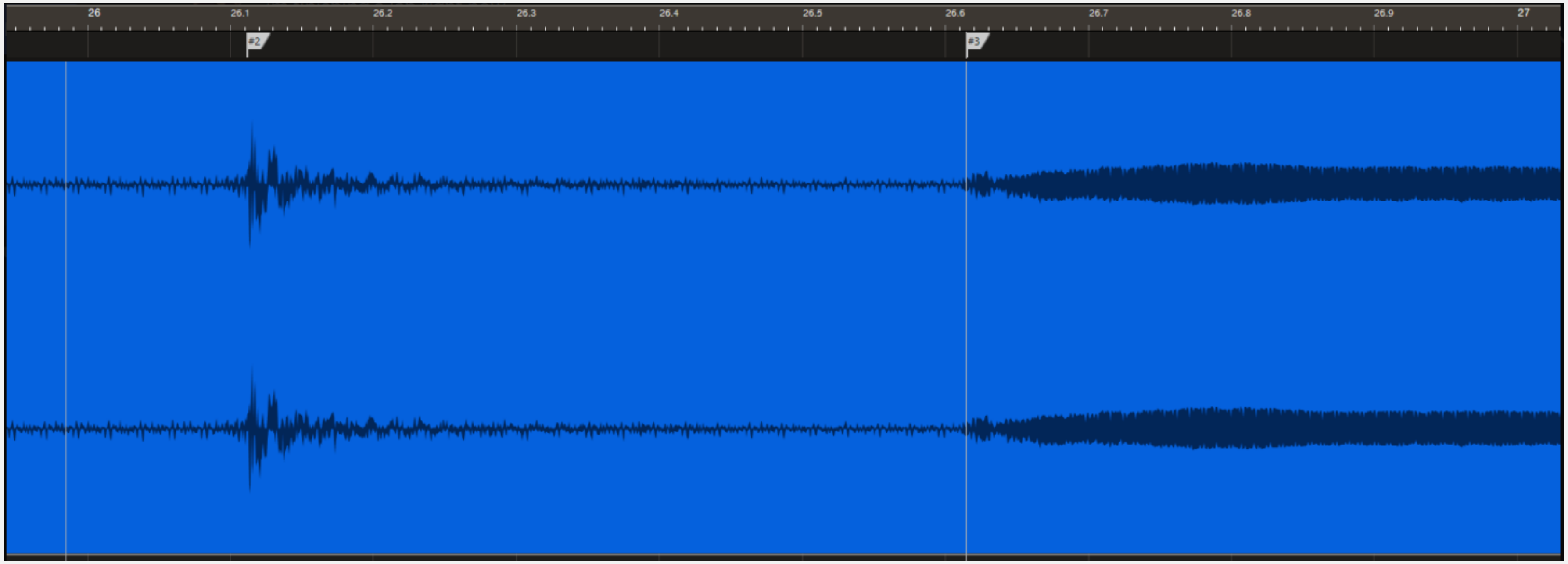


REALIZED UI


- 91
BOOK
PAGE
TITLE
PROJECT
Continued from Page
LANDING SCREEN
DEVICE SELECT SCREEN
OUTPUT SELECT SCREEN
WCM CONTROL APP
CONNECT
CONNECT PRESSED
← DEVICE CONNECT
CLICK DEVICE TO CONNECT TO
WCM 1
WCM2
WCM3
DEVICE SELECTED
← OUTPUT SELECT
OUT 1 SLIDER
OUT 2
OUT 3 LFO
OUT 4 TRIGGER
OUT 5
OUT 6
OUT 7
OUT 8
OUTPUT TYPE SELECT SCREEN
SLIDER SCREEN
LFO SCREEN
← TYPE SELECT
SLIDER
LFO
TRIGGER
NONE
OUTPUT CLICKED
SLIDER SELECTED
← SLIDER: OUT X
LINEAR
LOG
VAL
UNIPOLAR
BIPOLAR
LFO SELECTED
← LFO : OUT X
SIN
TRI
SAW
SQU
FREQ
AMP
OFFSET
UNIPOLAR
BIPOLAR
TRIGGER SELECTED
← TRIG
TRIG
TRIGGER SCREEN
Continued to Page
SIGNATURE
DATE
DISCLOSED TO AND UNDERSTOOD BY
DATE
PROPRIETARY INFORMATION

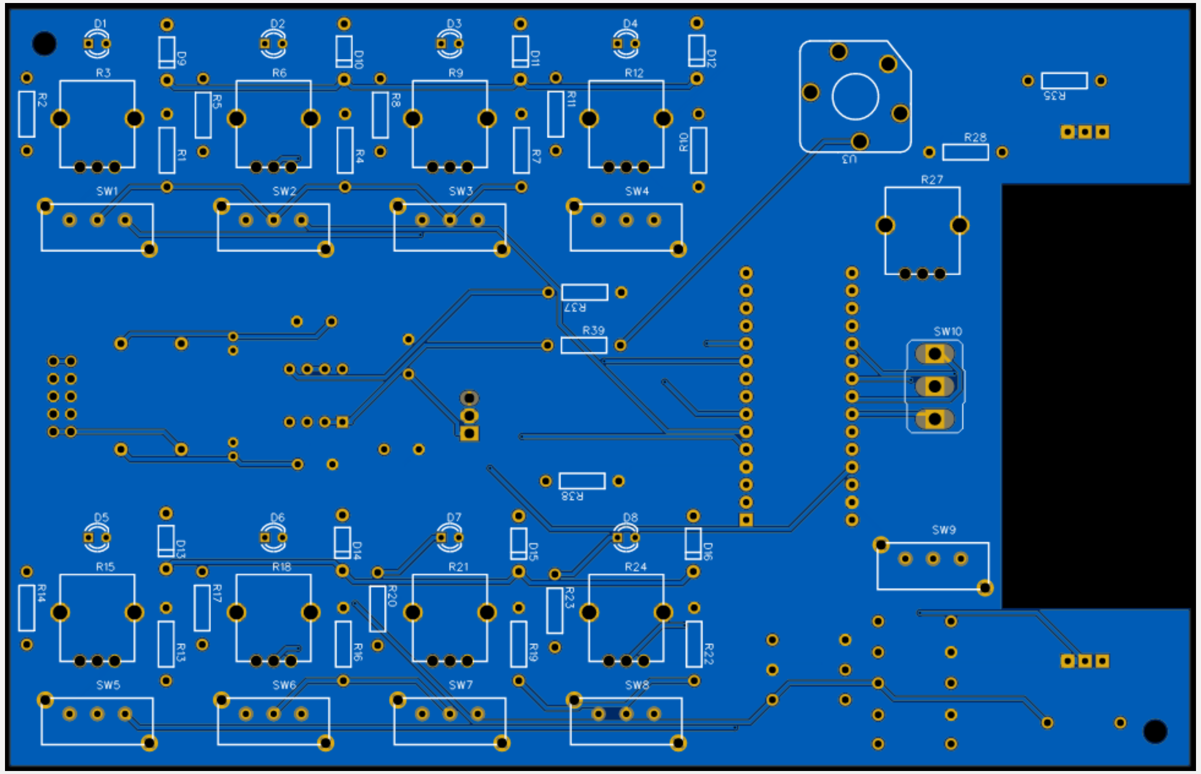
LATENCY TEST

Test#	Latency
1	0.3
2	0.256
3	0.319
4	0.354
5	0.256
6	0.23
Average	0.2858333333

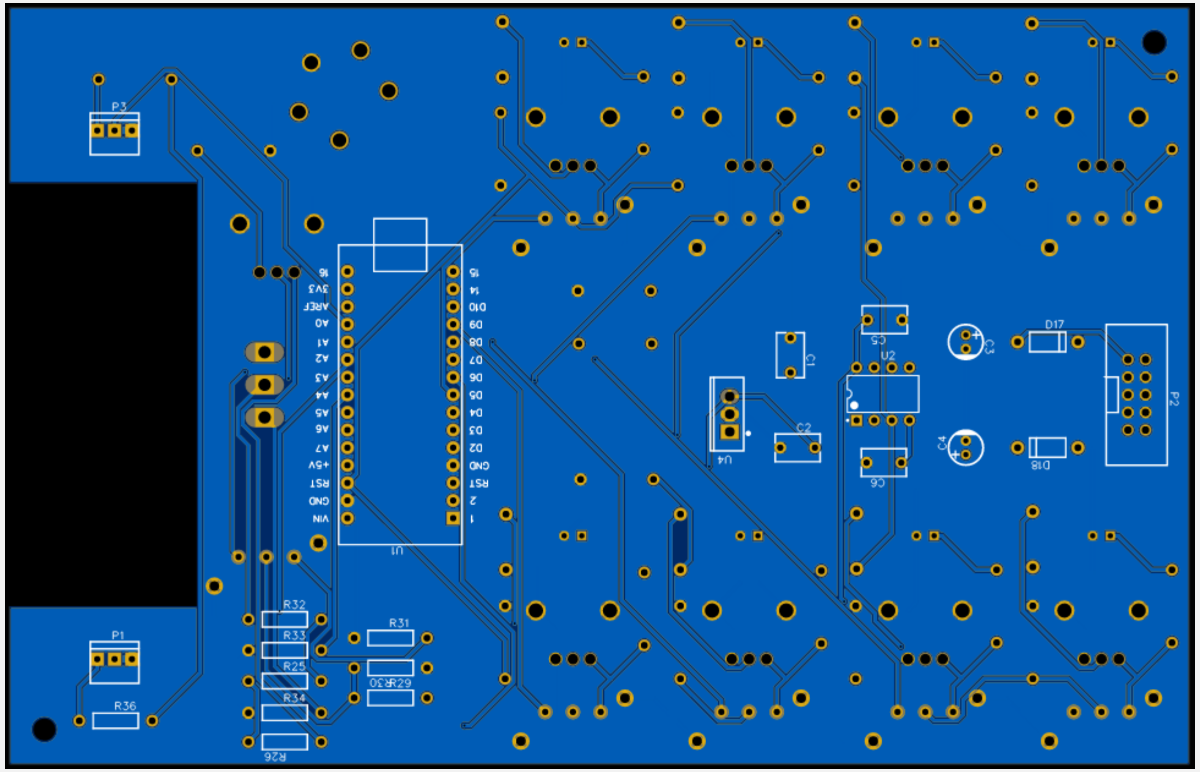


SEQUENCER

SEQUENCER PCB V1.0

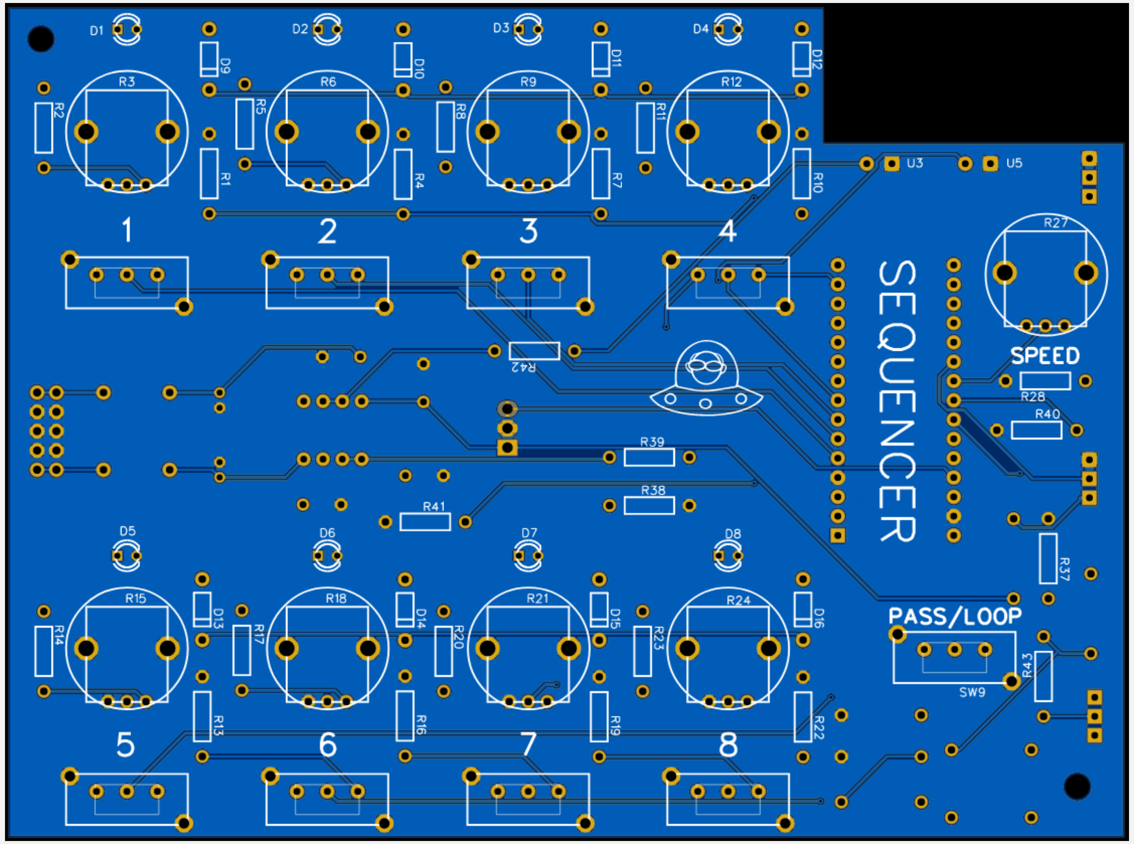


Front of PCB

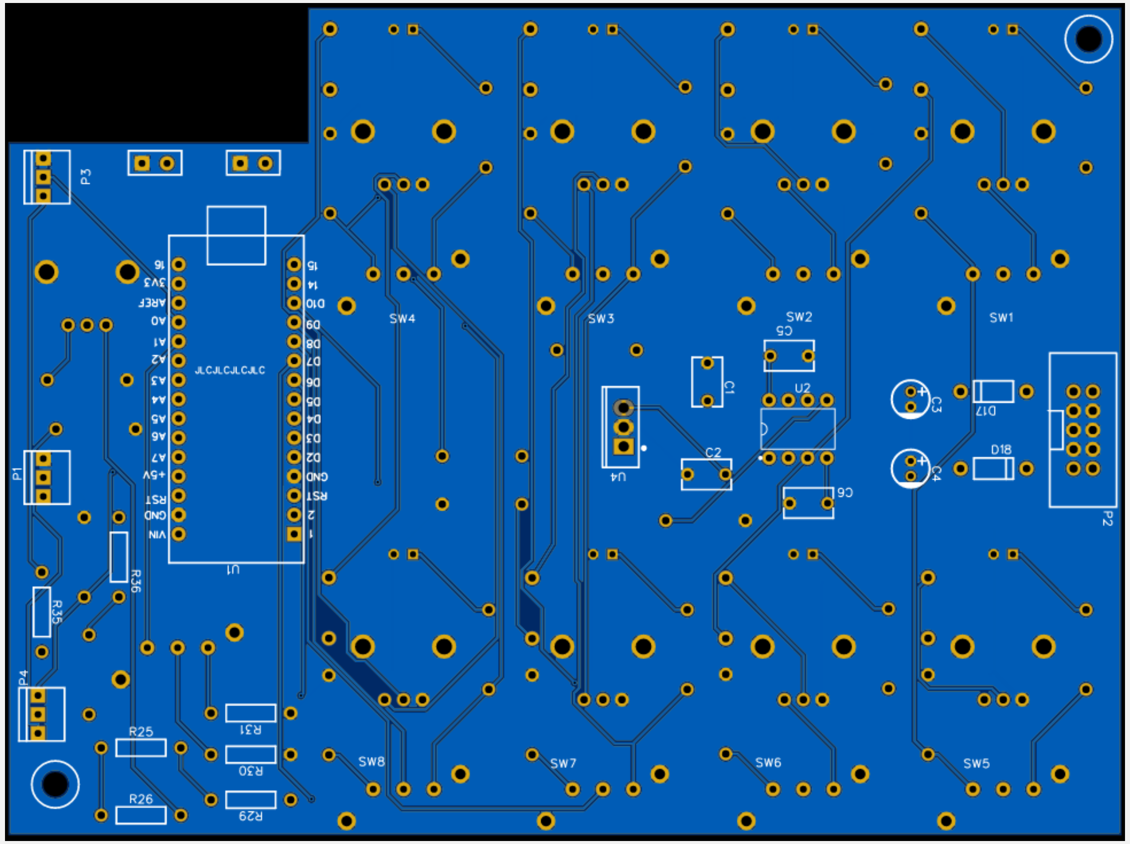


Back of PCB

SEQUENCER PCB V2.0

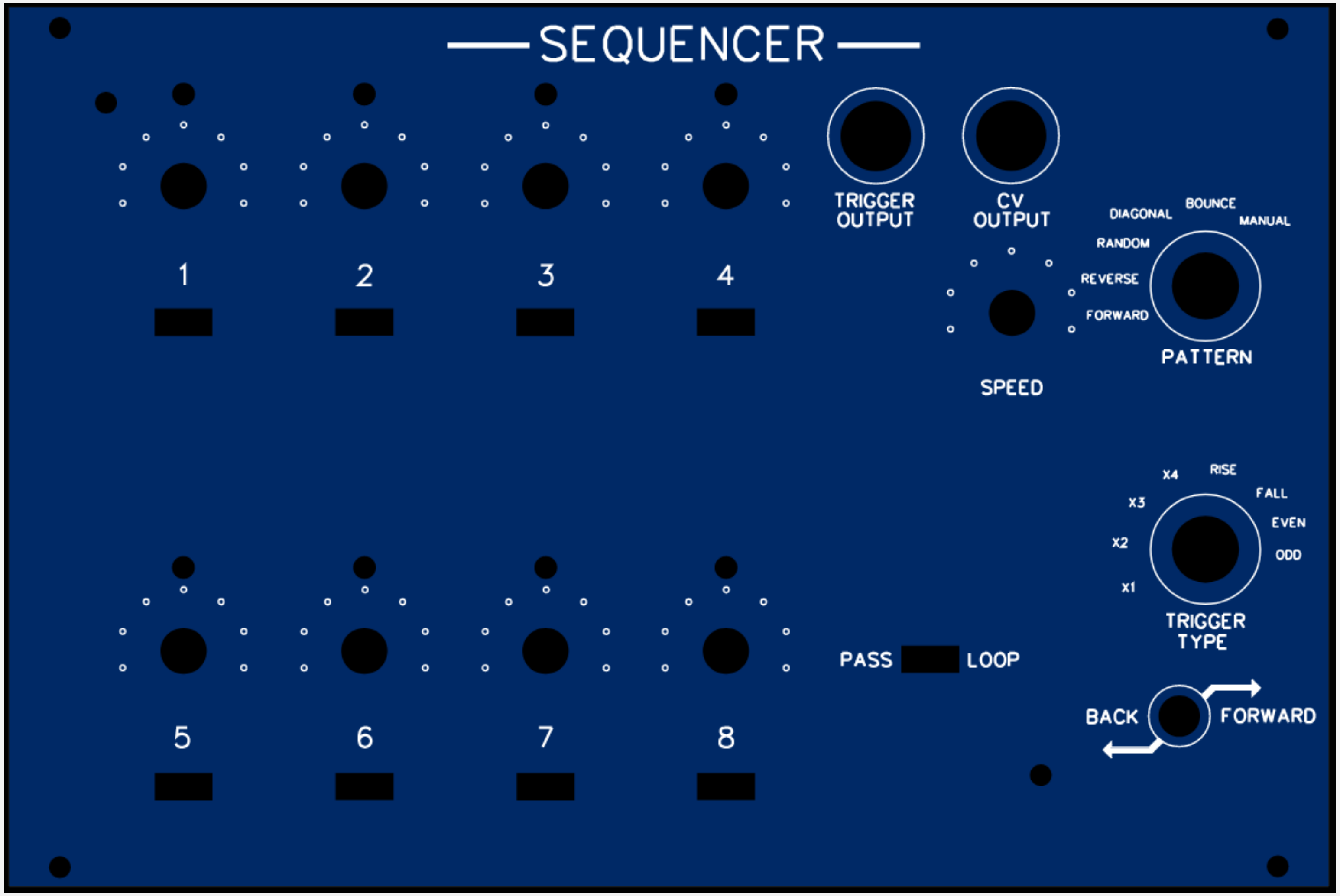


Front of PCB

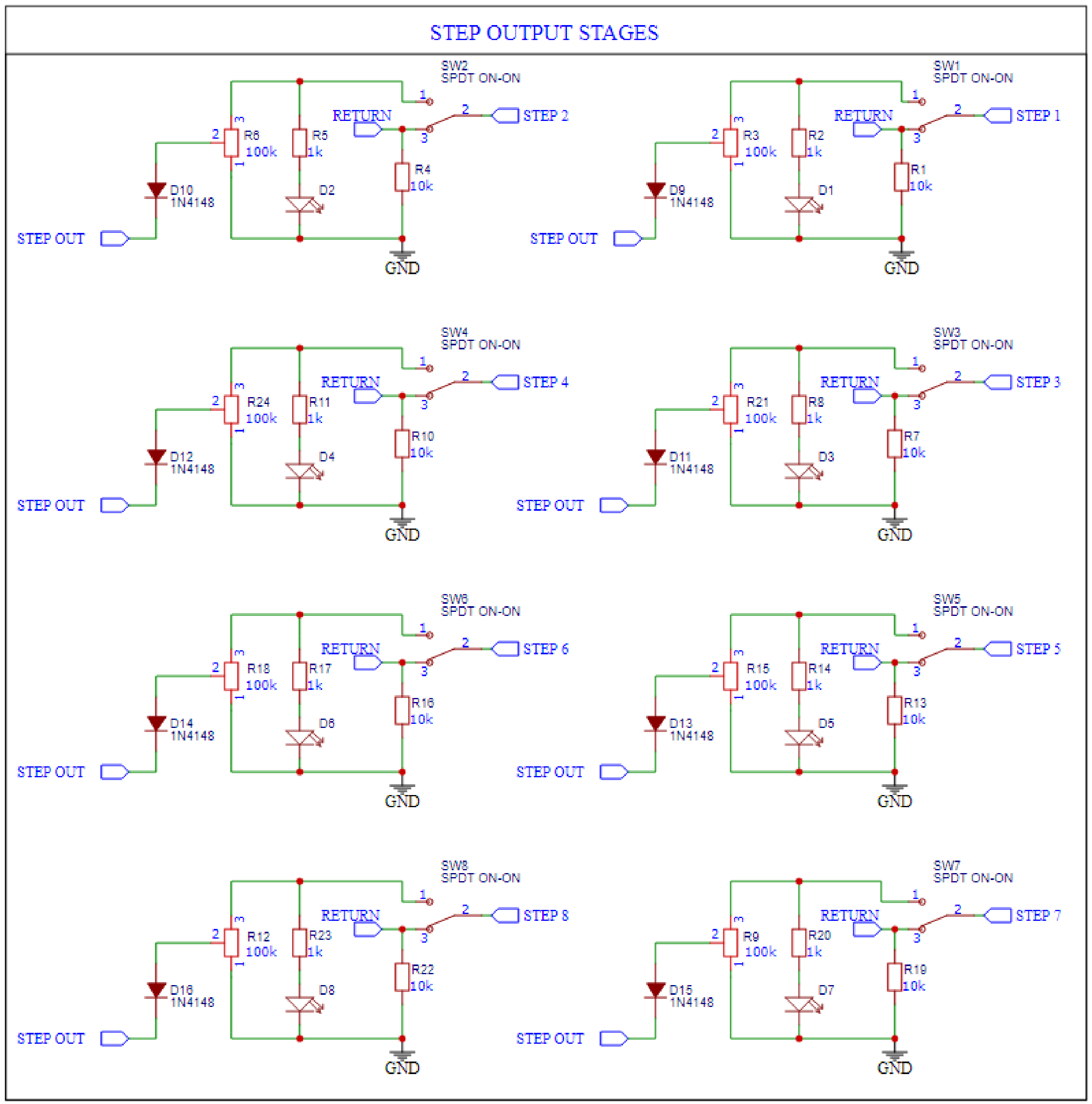


Back of PCB

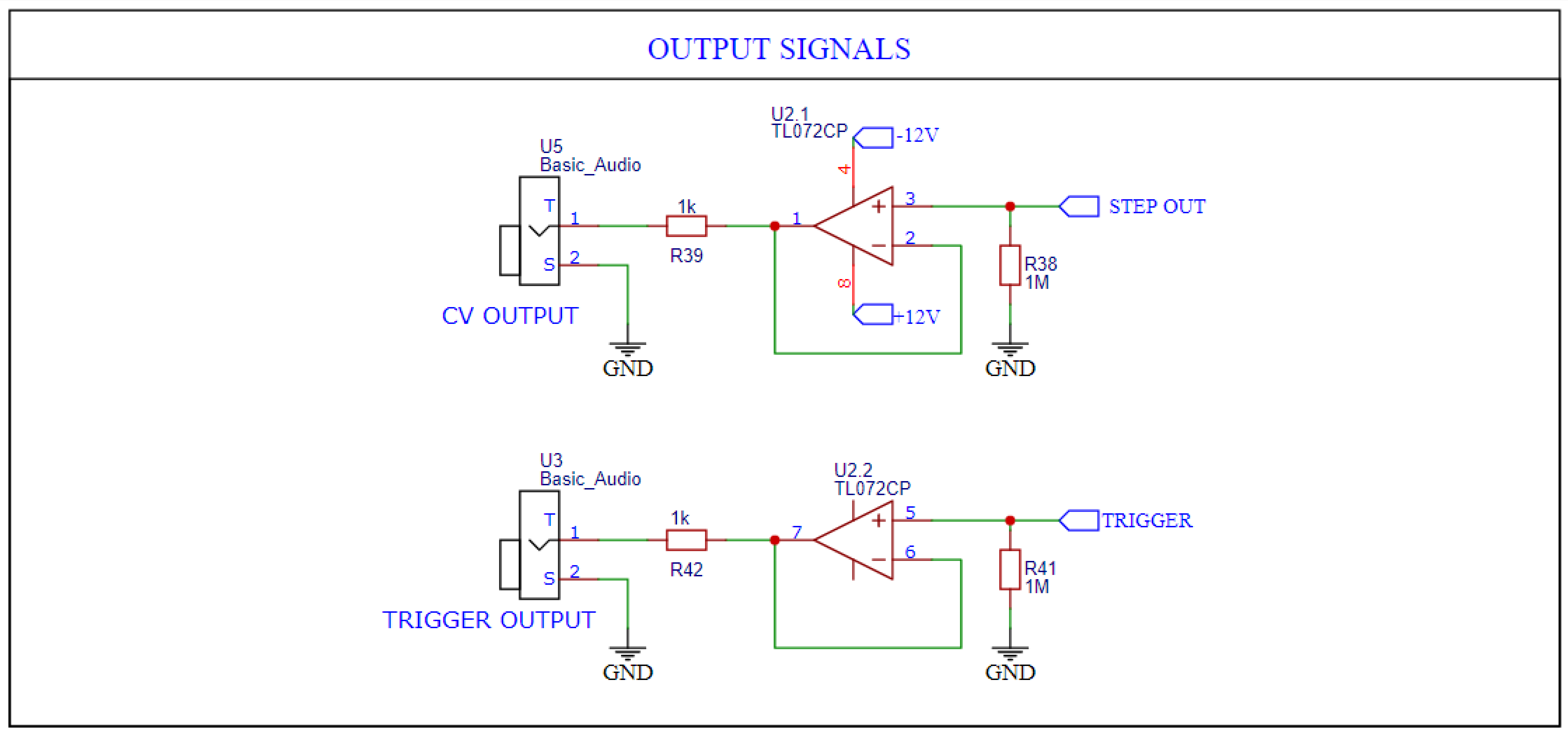
SEQUENCER
PCB V2.0 FACEPLATE



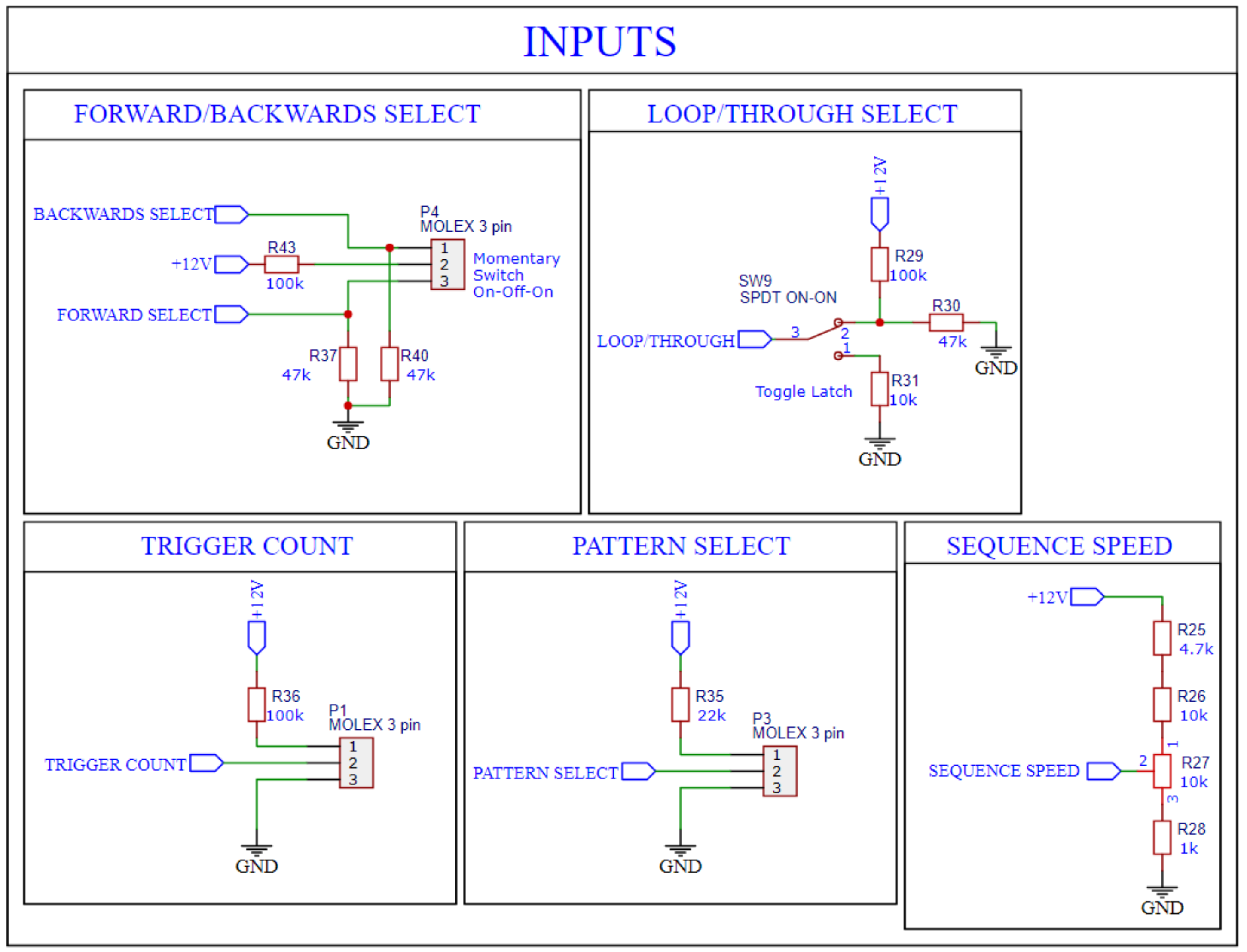
SEQUENCER
STEP OUTPUT STAGES



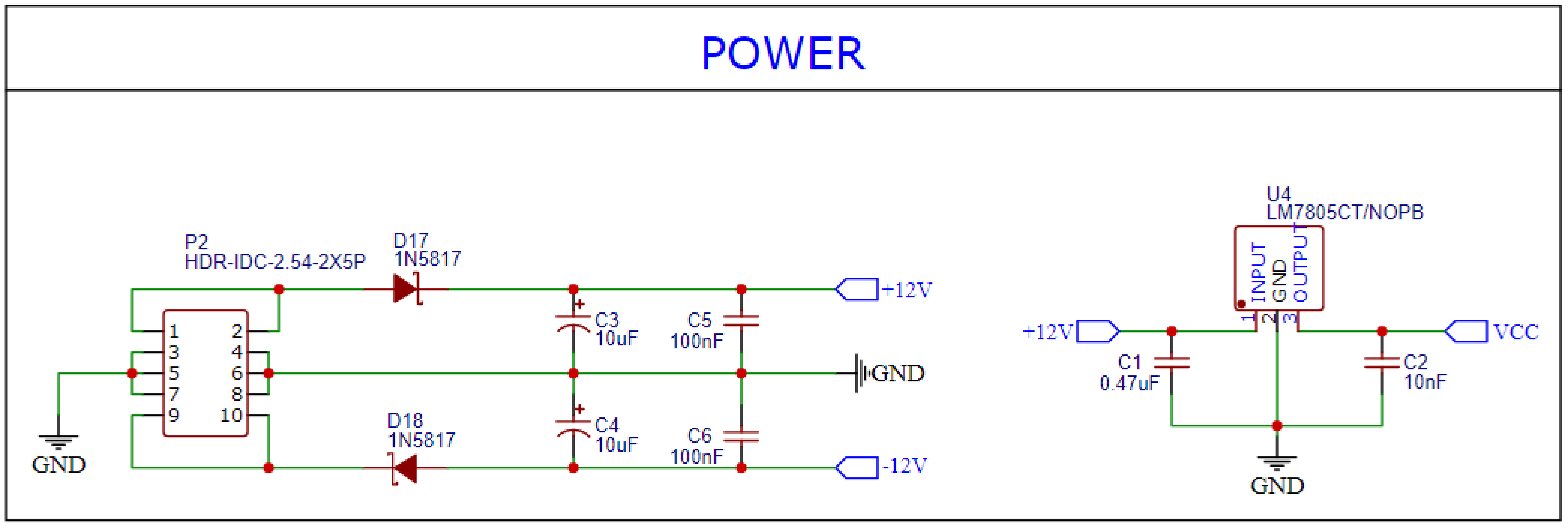
SEQUENCER OUTPUT BUFFERS



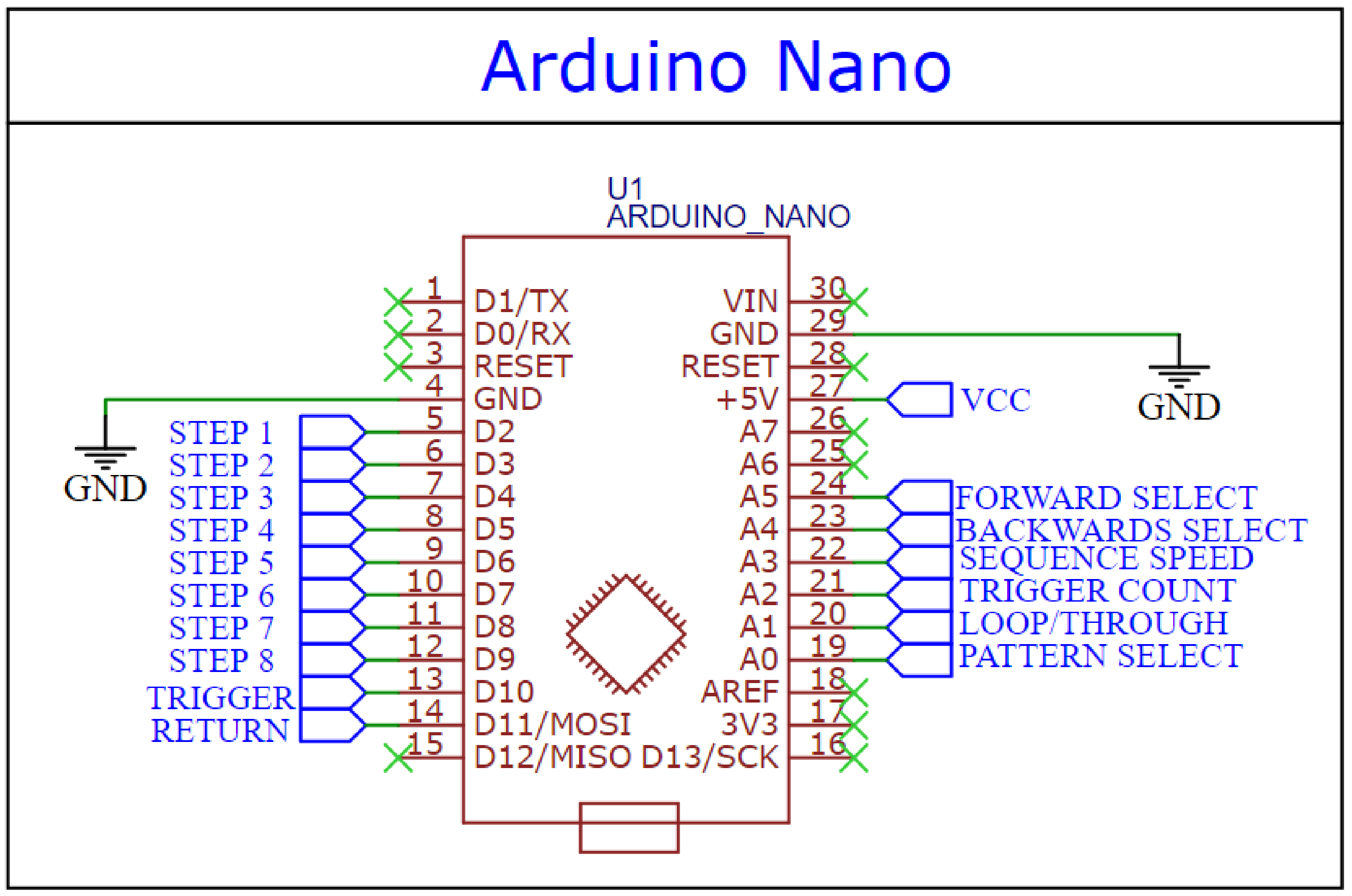
SEQUENCER INPUTS



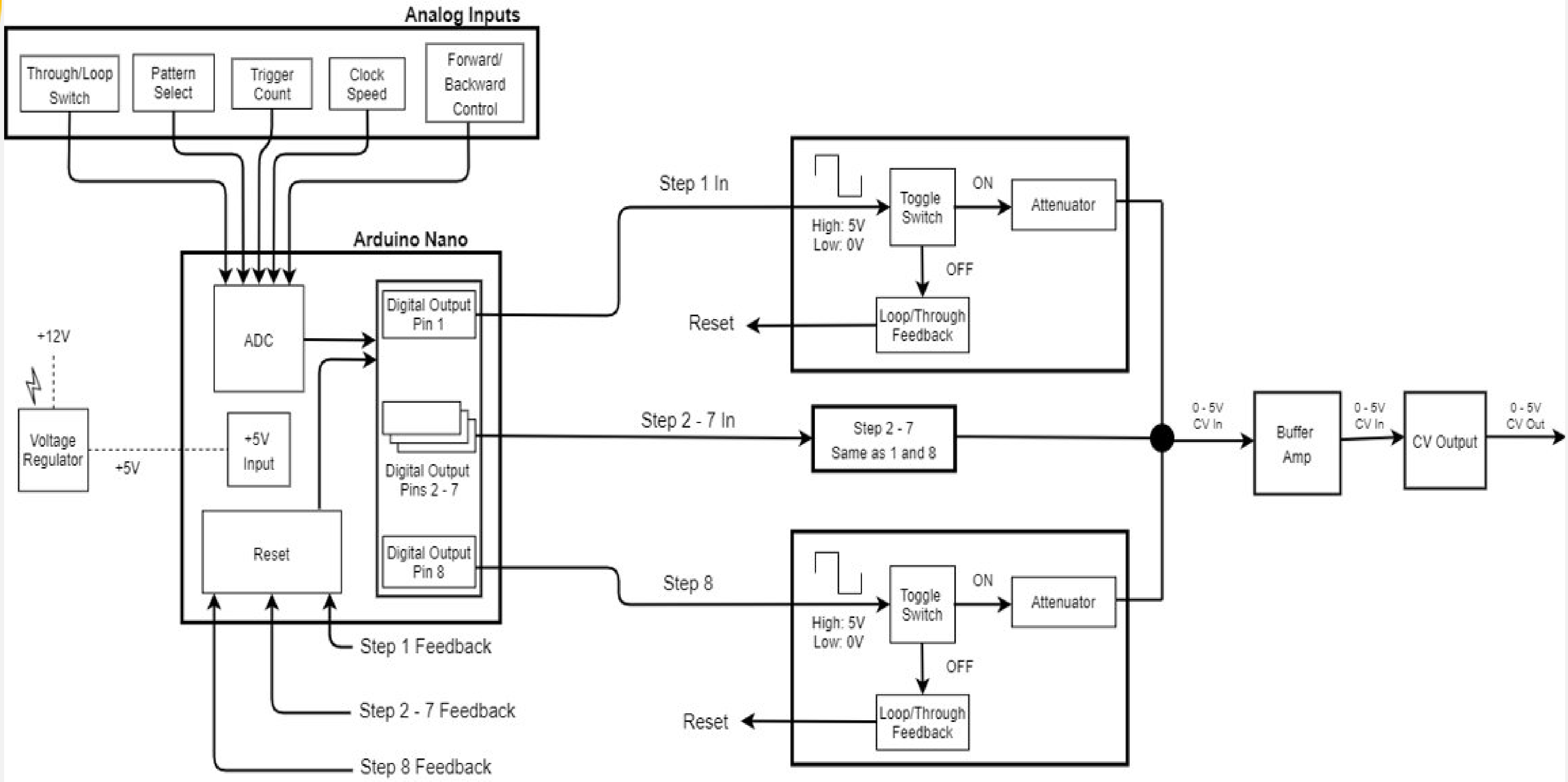
SEQUENCER POWER STAGE



SEQUENCER CONTROLLER STAGE

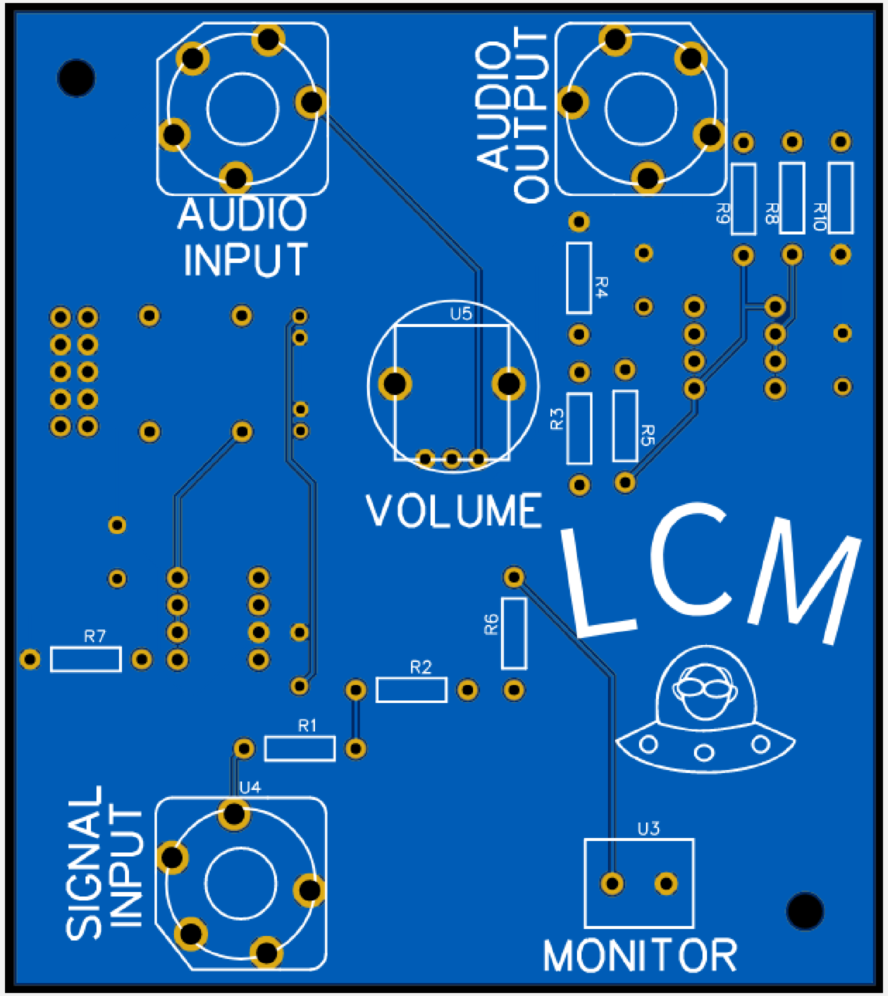


Sequencer: Level 1 Diagram

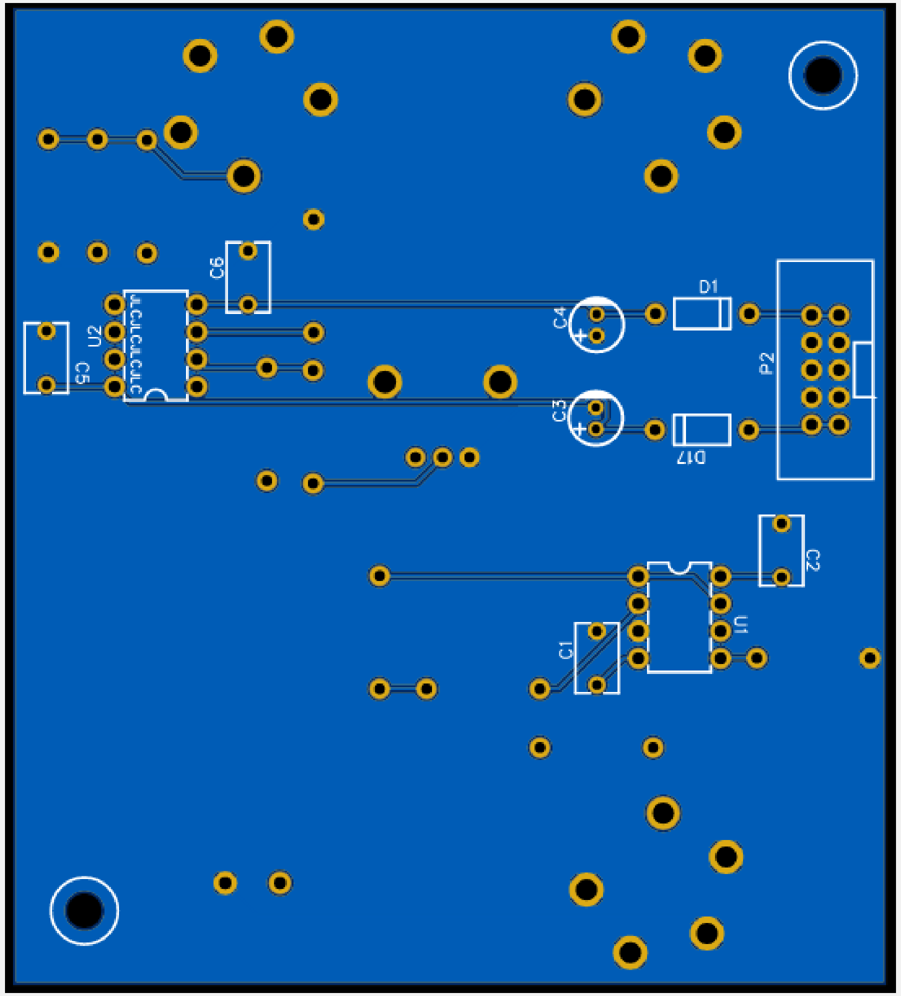


LEVEL CONTROL MODULE (LCM)

LCM V2.0 PCB

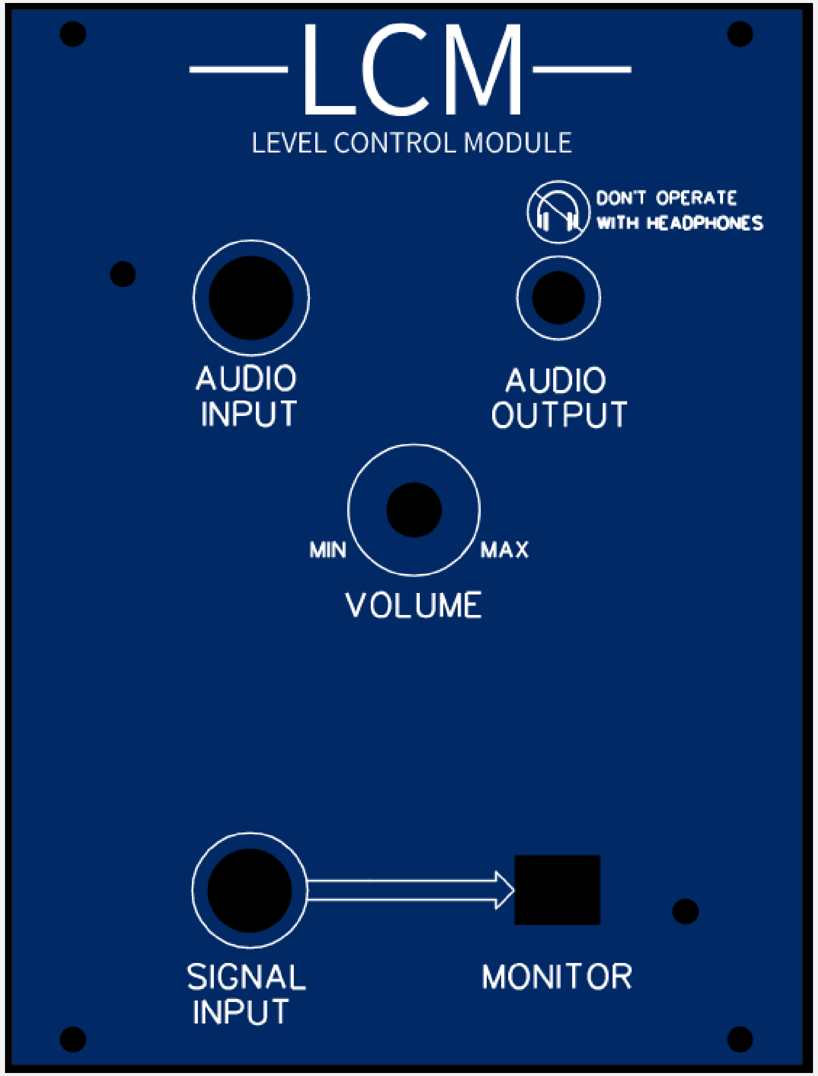


Front of PCB

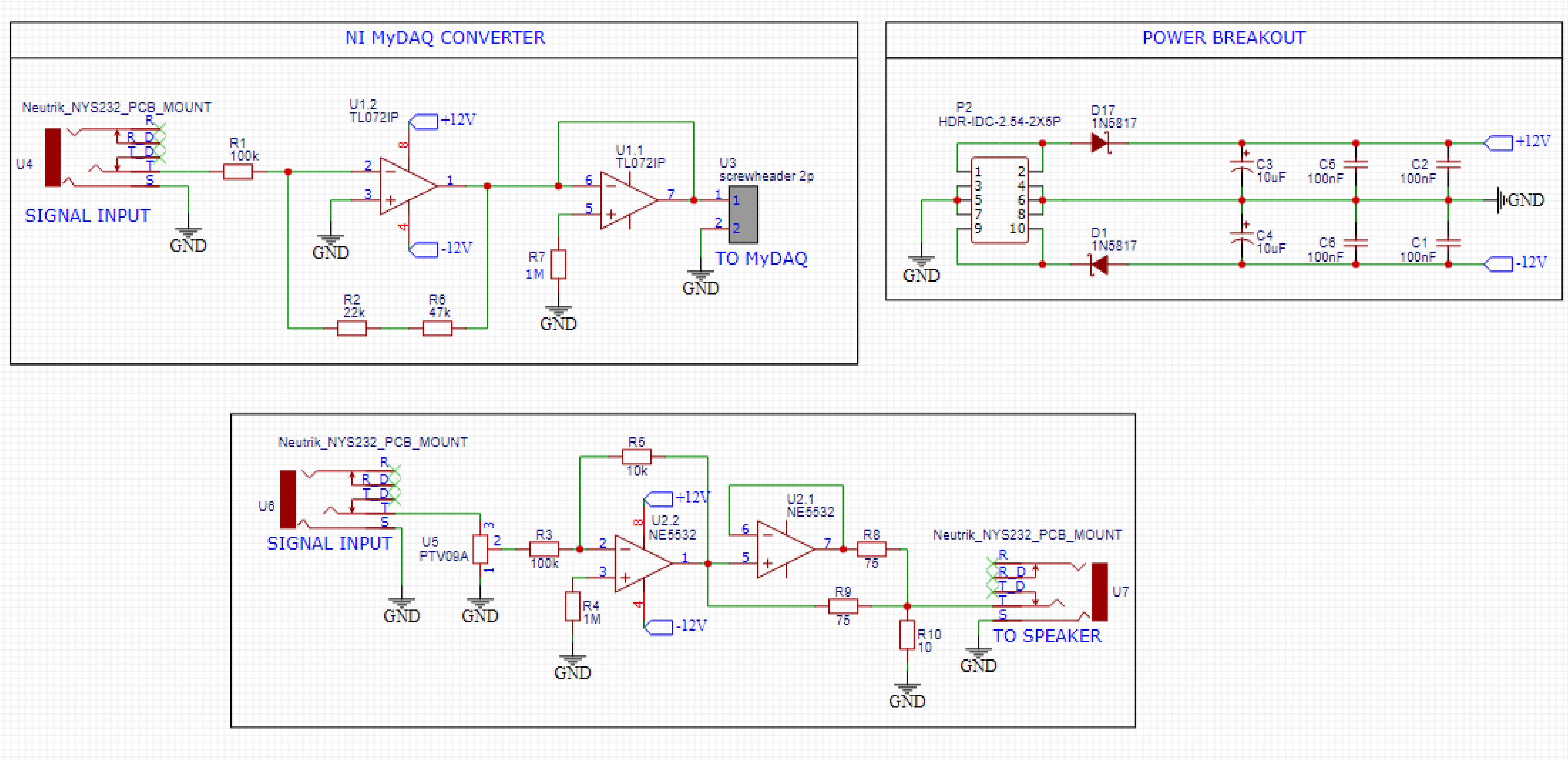


Back of PCB

LCM V2.0 FACEPLATE



LCM V2.0 CIRCUIT

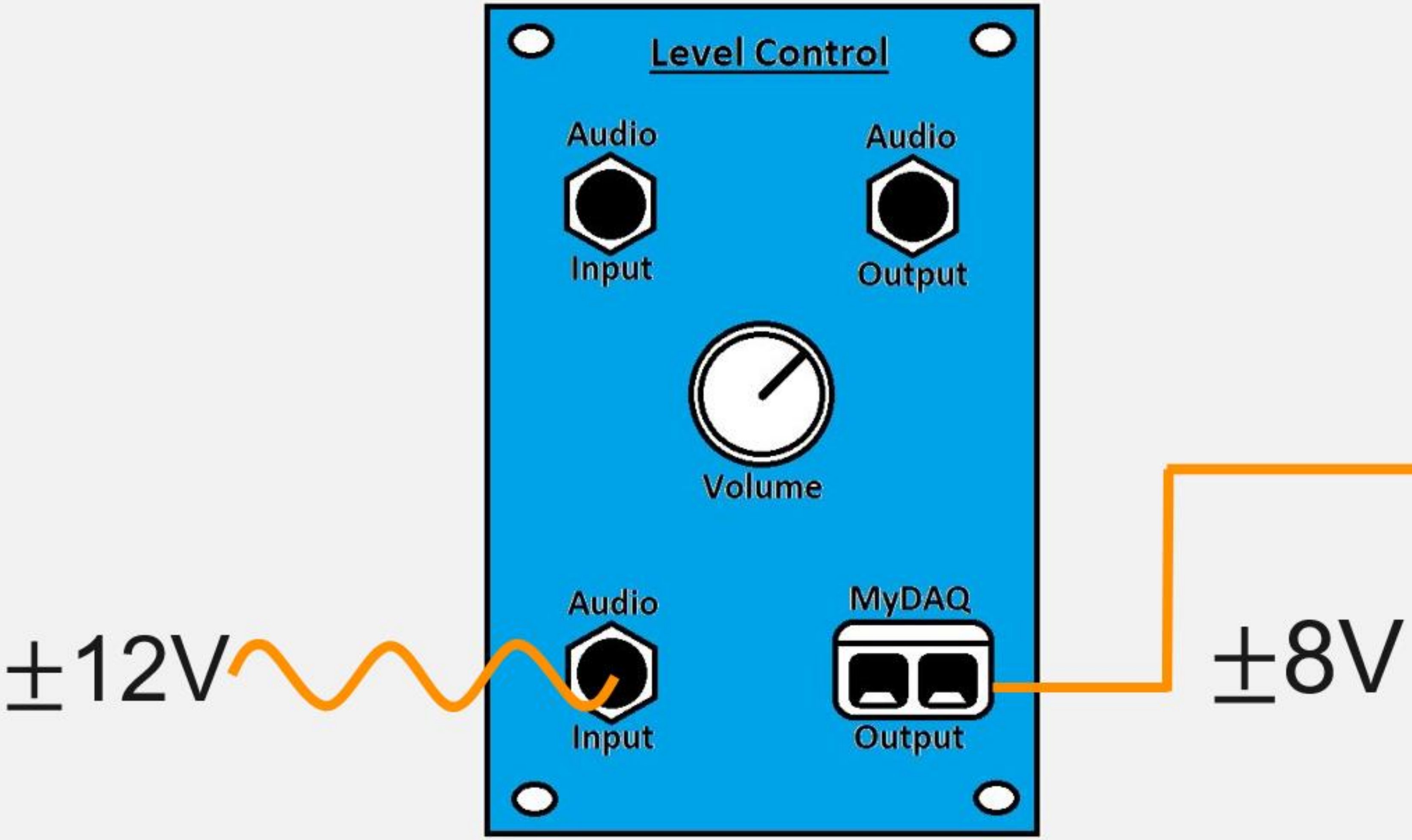


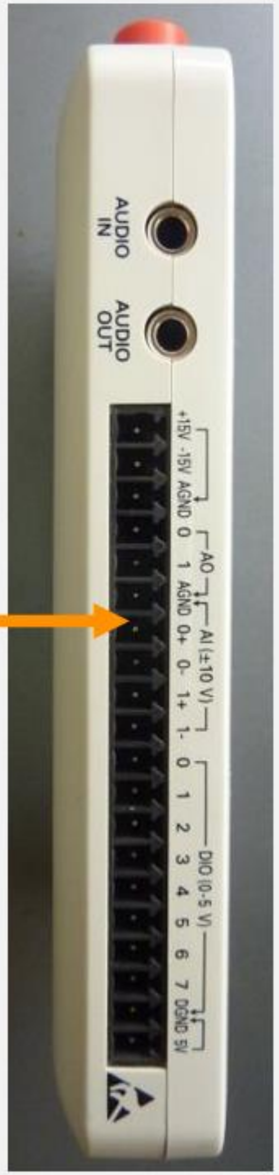
MyDAQ Hardware

https://www.yottavolt.com/shop/ni-mydaq/

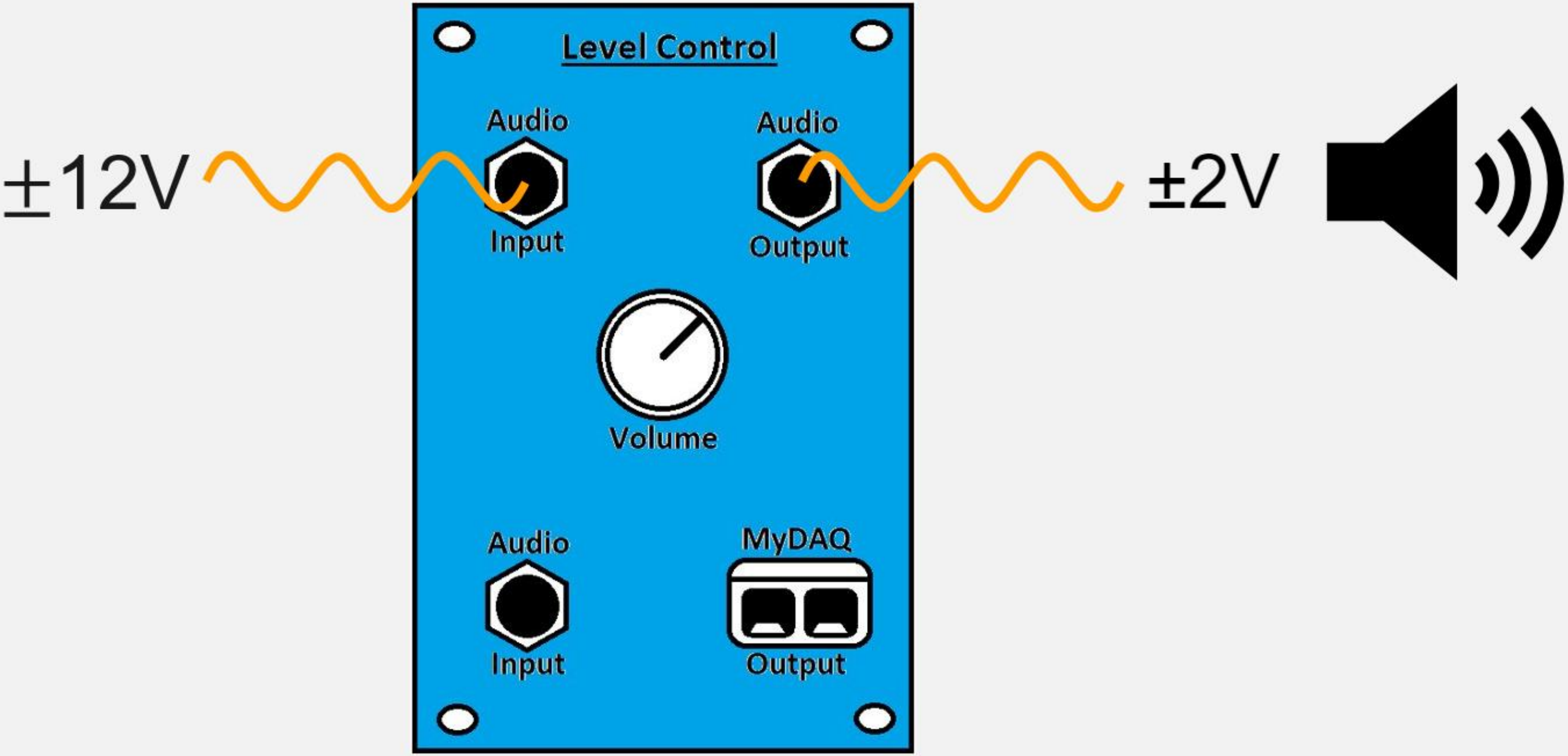
https://www.elektormagazine.com/magazine/elektor-201407/26907

MyDAQ Converter

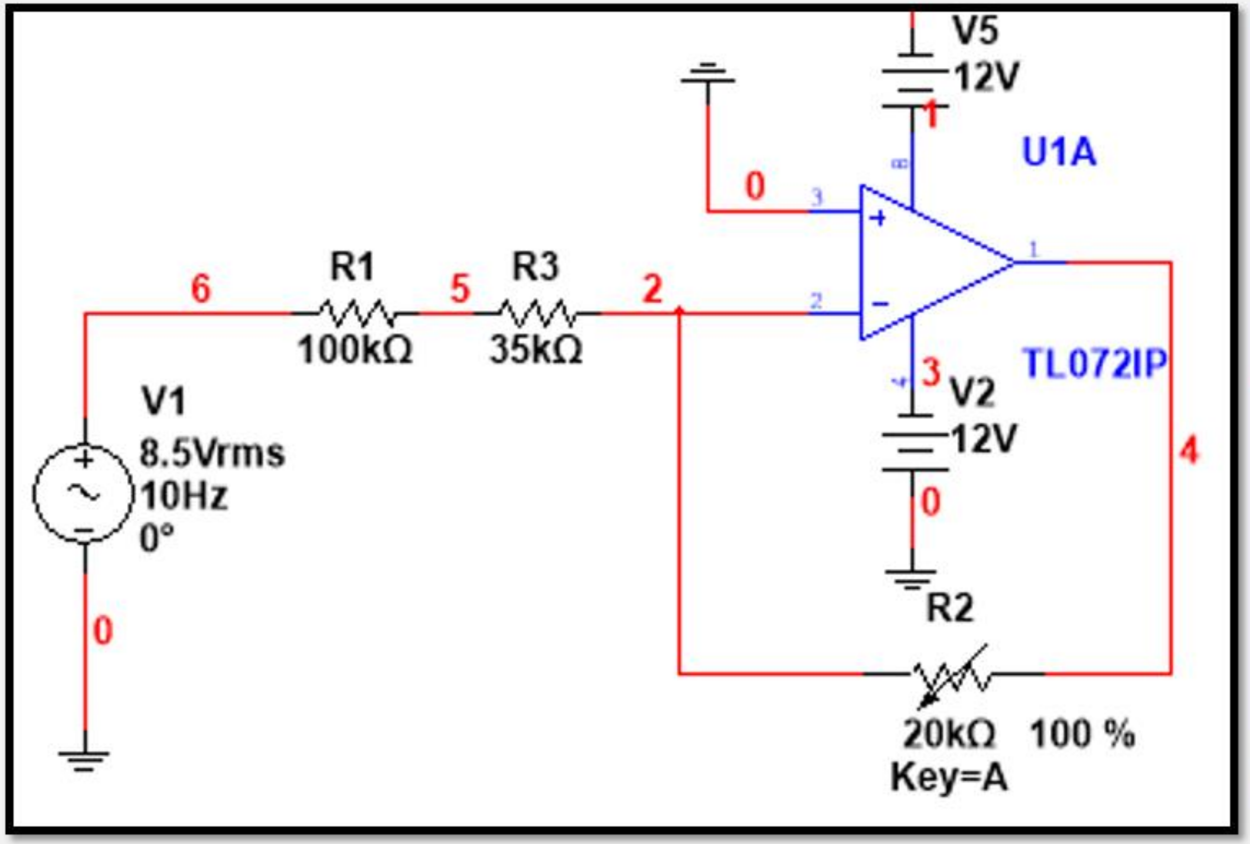


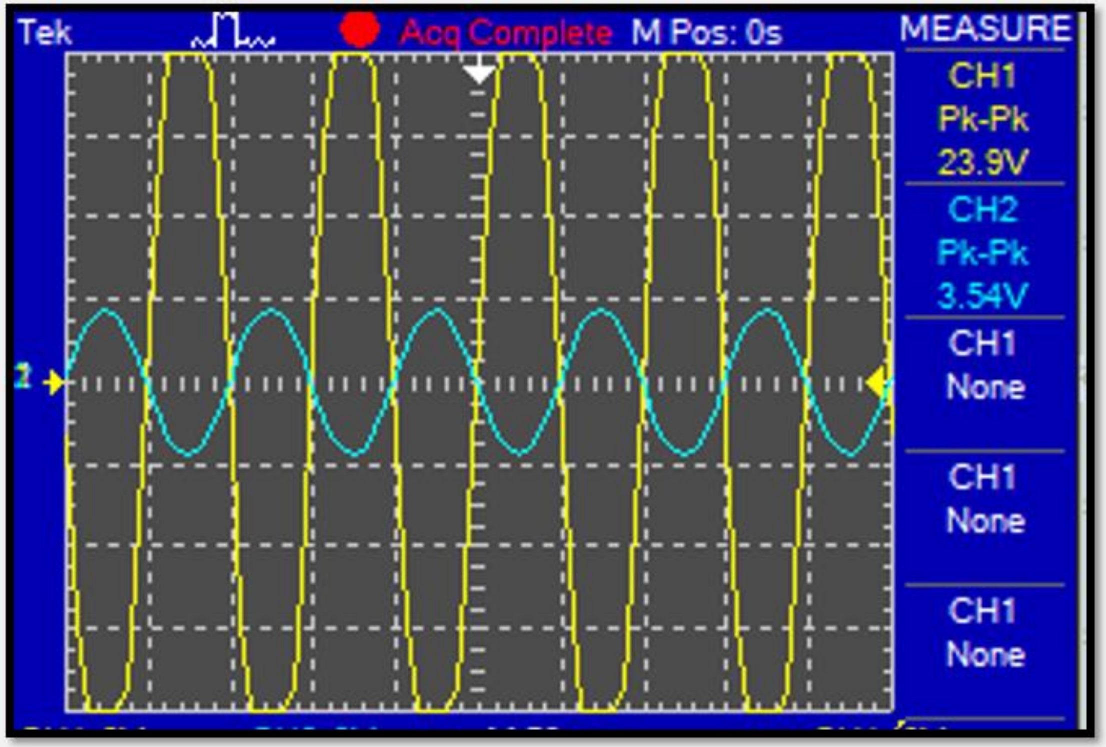


Volume Control



Volume Control





Input: Yellow Signal Output: Blue Signal Output

Variable Gain: $0 \leq A \leq 0.15$

VOLTAGE CONTROLLED OSCILLATOR (VCO)

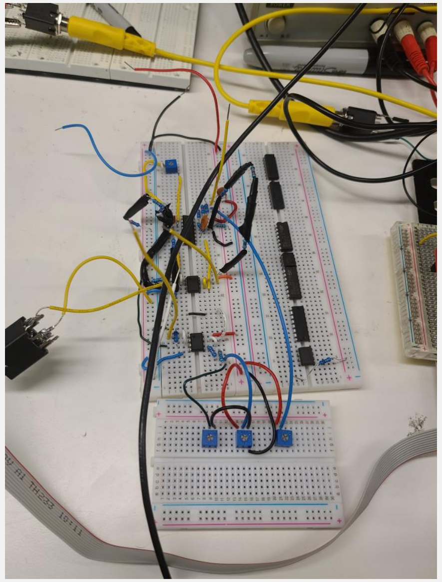
VOLTAGE CONTROLLED OSCILLATOR

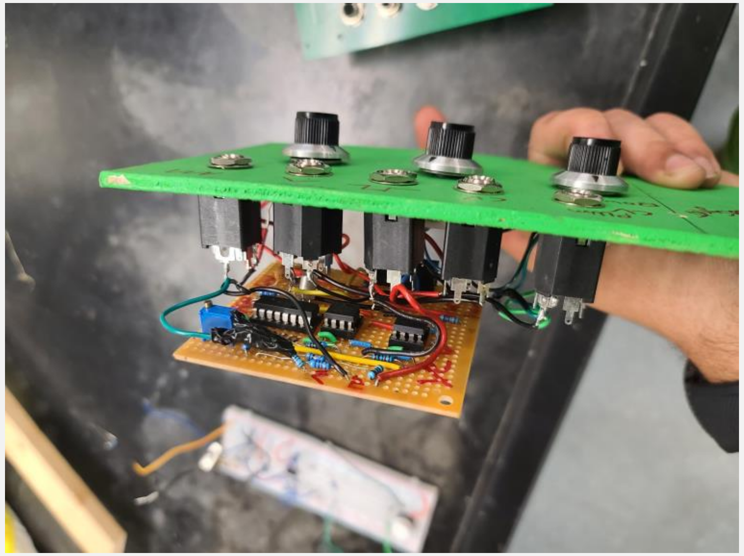
Team 80's **Voltage Controlled Oscillator** Module includes *insert two or three main circuit components that aids to audio generation* to effectively produce 3 stable waveforms.

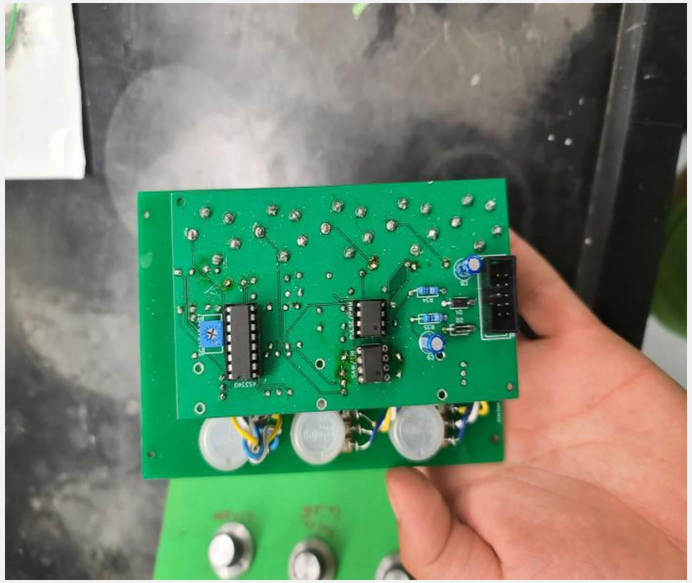
Waveforms Produced

- Pulse (square wave)
- Sawtooth
- Triangle

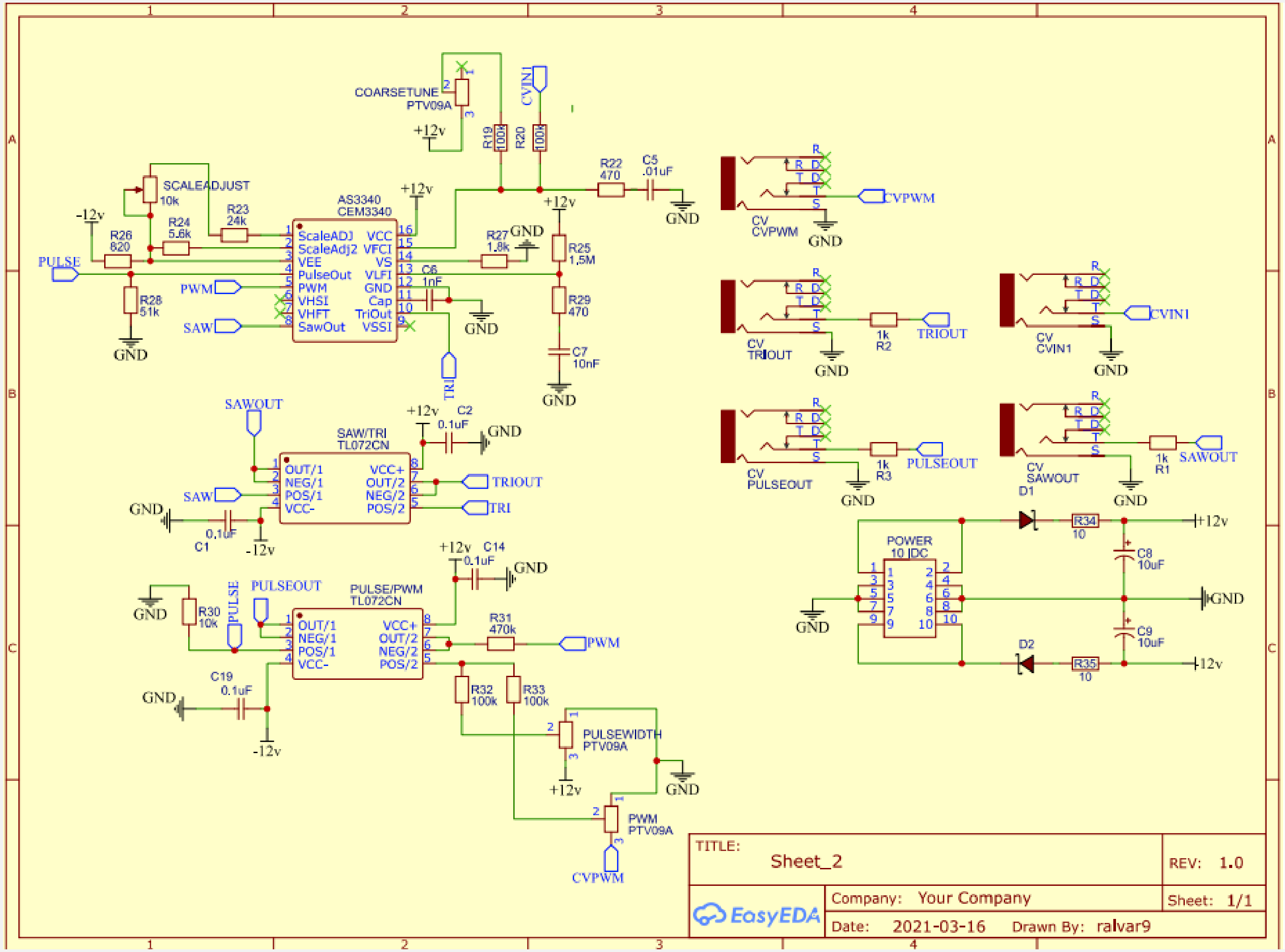
FUNCTION I EXECUTION BY STEP: AUDIO GENERATION







VCO SCHEMATIC

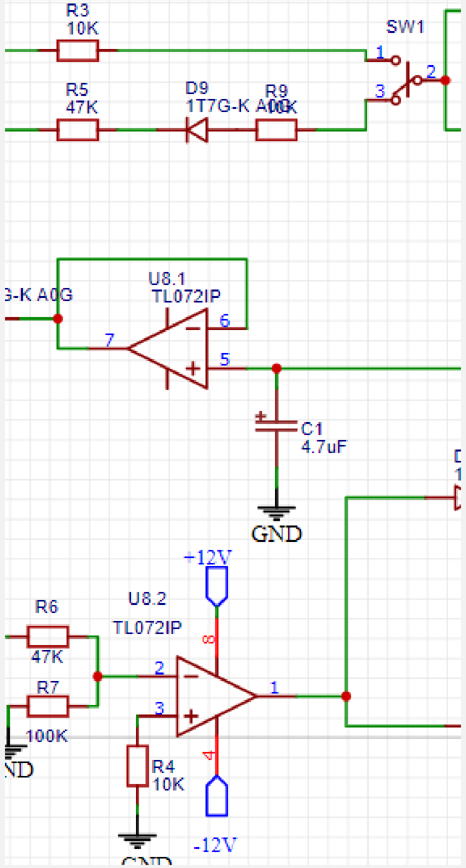


TESTING QE'S VCO

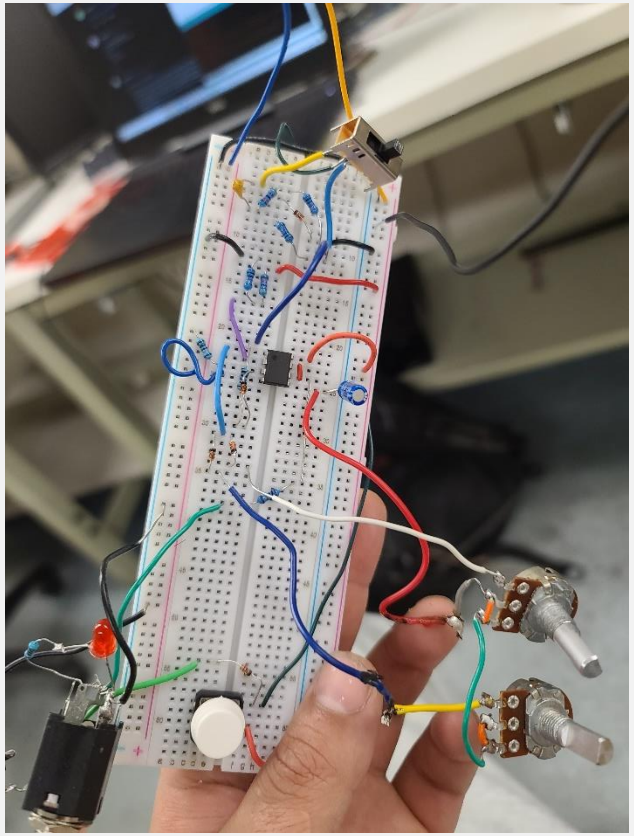
- Sawtooth Frequency Response (Web view)
- Triangle Wave Circuit (Web view)
- Pulse Circuit (Web view)

ENVELOPE GENERATOR

Slides (160-165)



Step 1. schematic design



Step 2. design breadboard

Step 3. PCB attached to faceplate

ENVELOPE GENERATOR DESIGN BY MAJOR STEP

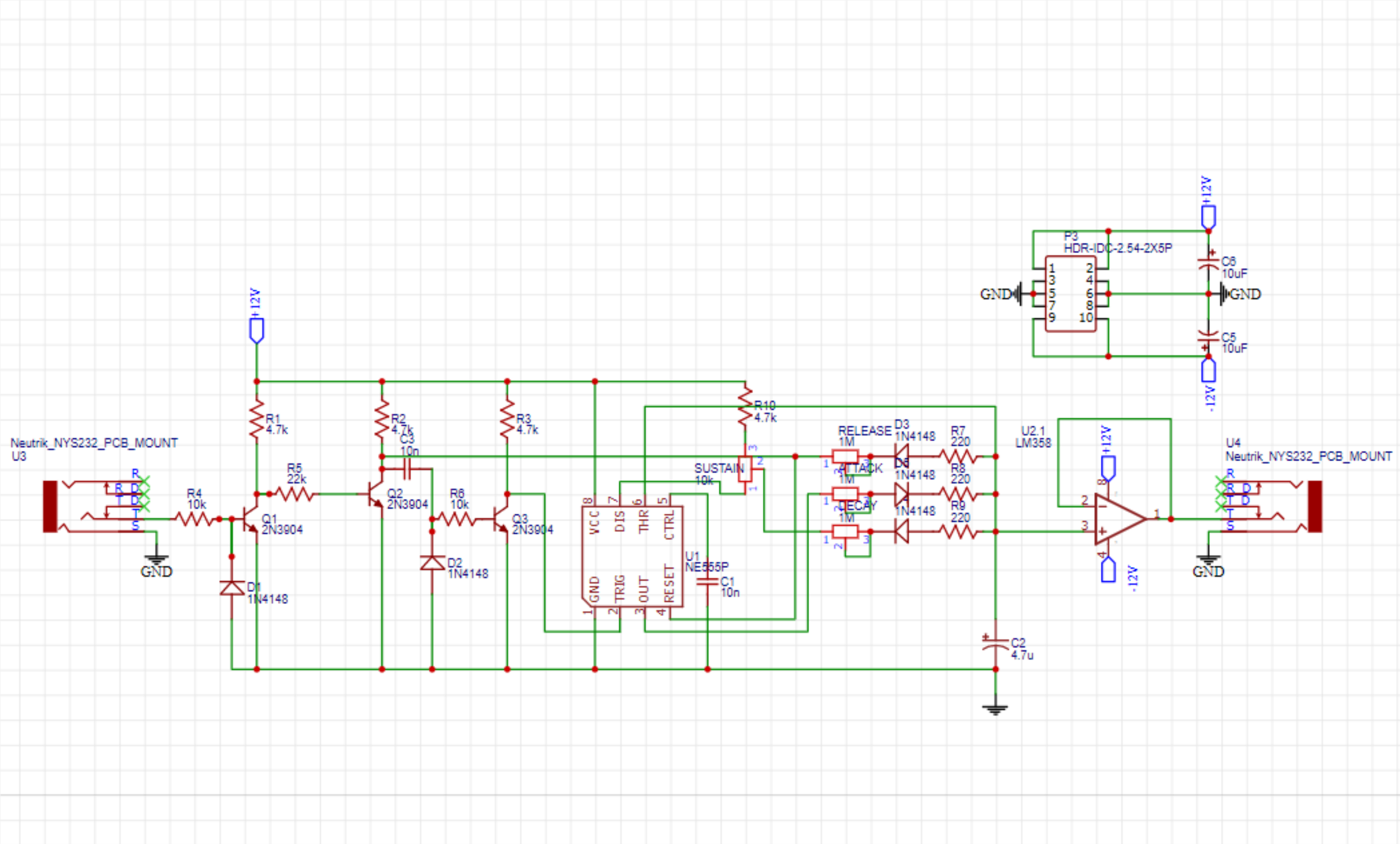
FUNCTION CHALLENGES: CONTROL VOLTAGE PRODUCTION

Envelope Generator (AD/AR)

Challenge	Solution
Accidental grounding during PCB design	Air wiring
Miscalculation of Power Consumption	New design that is compatible with +12V and –12V power levels
Component damage due to incorrect soldering	Soldering practice and component replacements
PCB silk screen mismatch of diodes	Placing diodes in opposite orientation of what silk screen shows

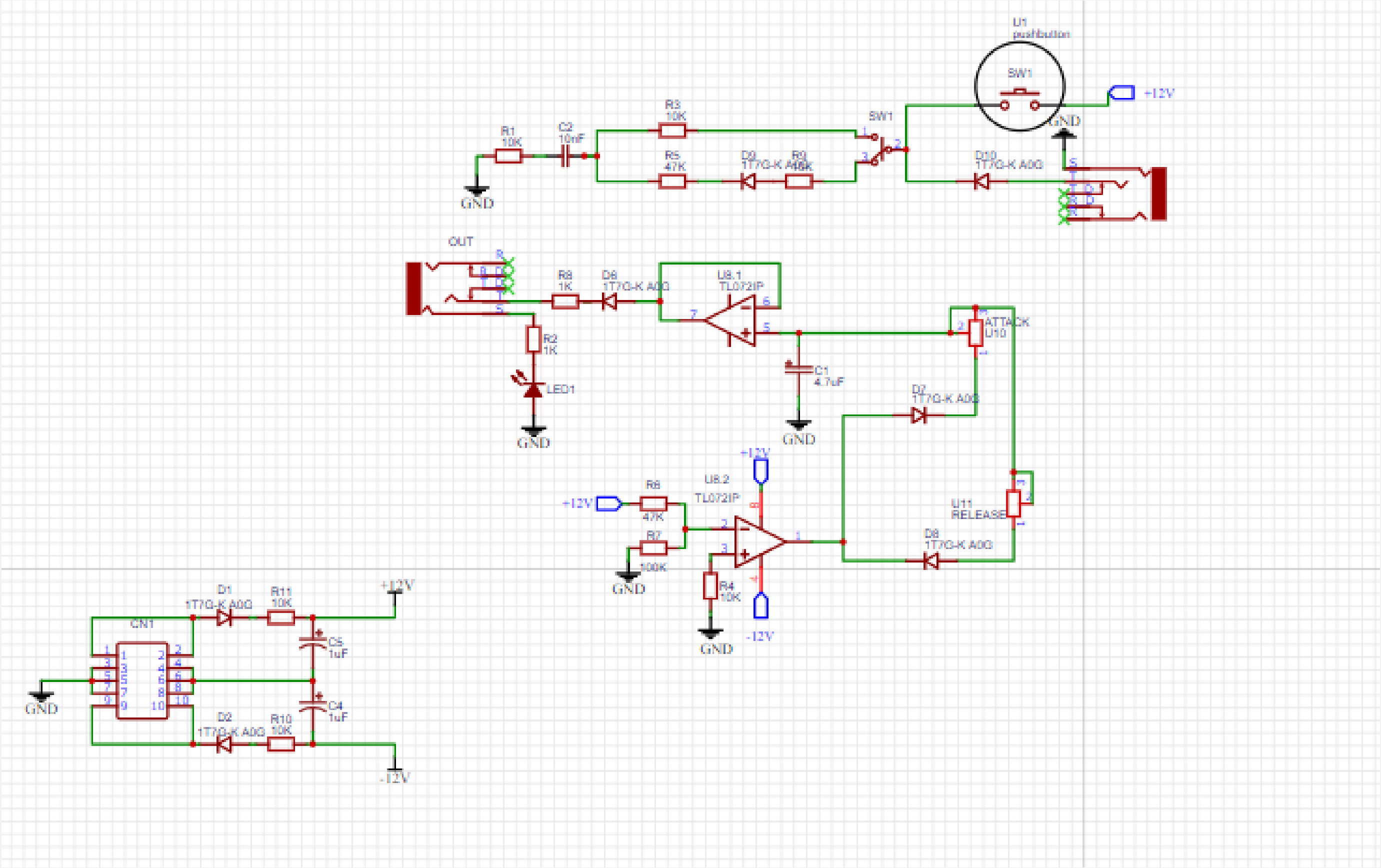
SPRING SCHEMATIC

After weeks of trying to get this design to work, we decided to start on an easier design for the Envelope Generator.



FINAL FALL SCHEMATIC

Schematic sent to PCB manufacturer. This design features less user control and no sustain knob.

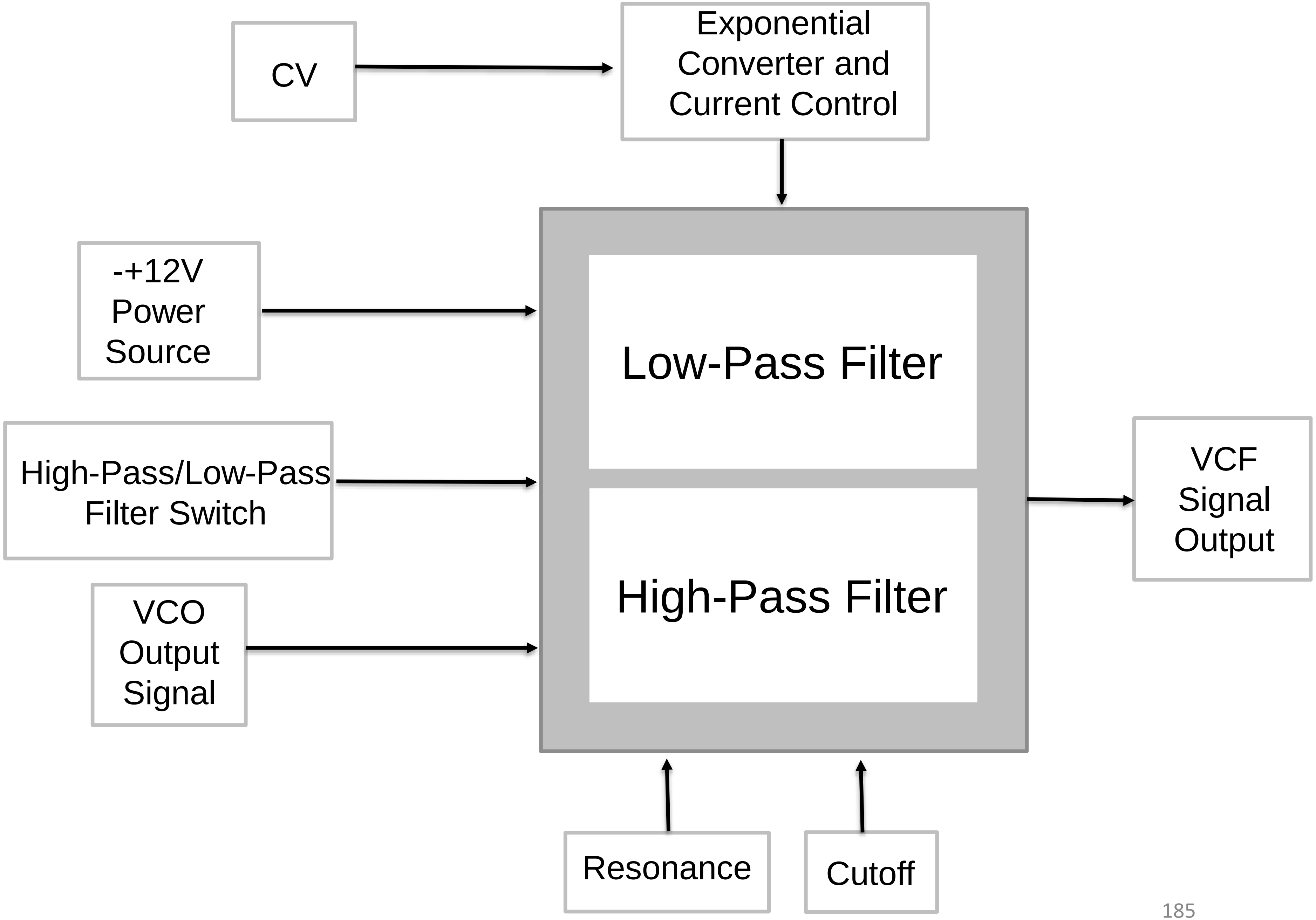


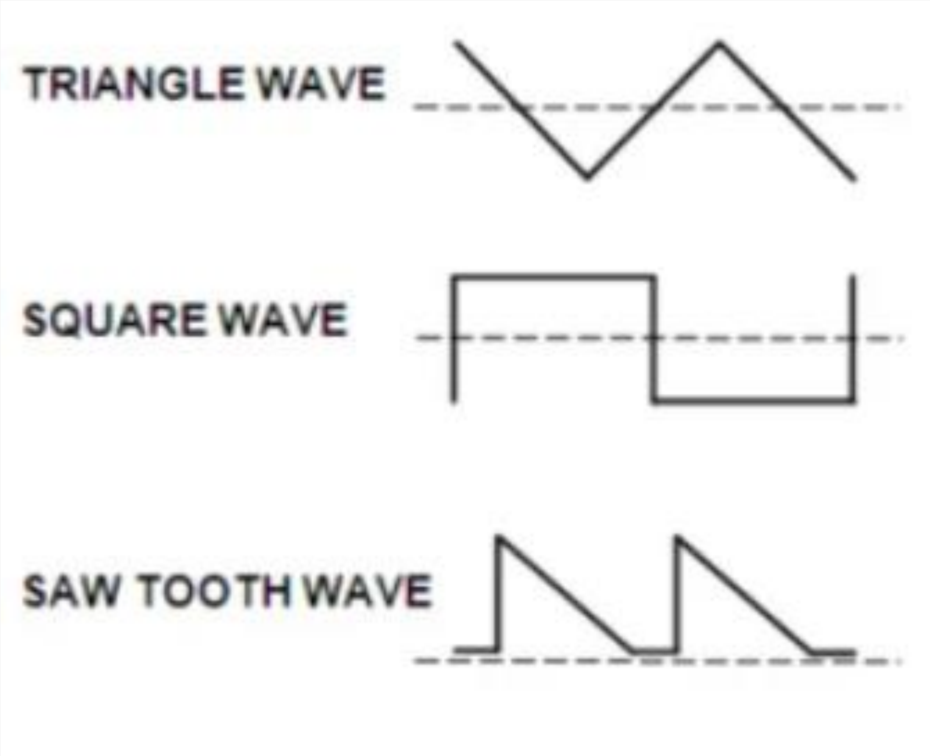
DIGITAL MULTI-EFFECTS (DME)

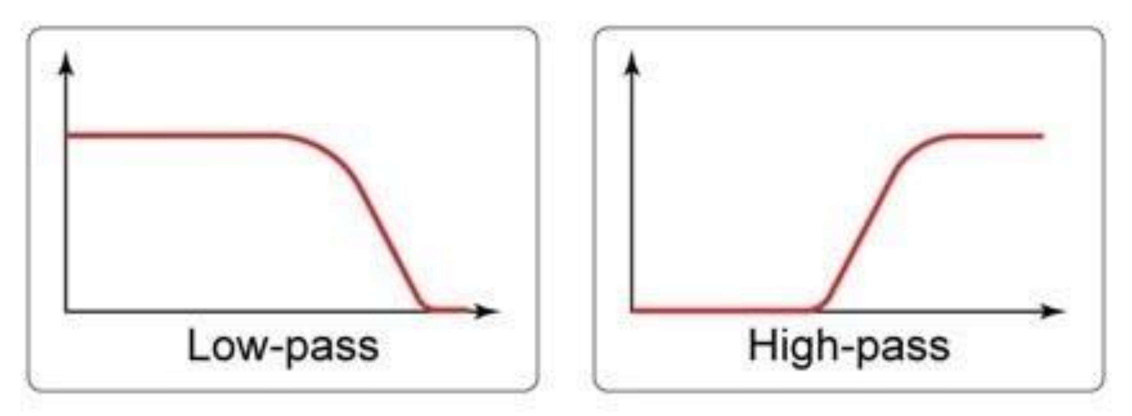
FUNCTION 3 MET: WIRELESS SYSTEM CONTROL

- Separates our system from others on the market
- Allows for easier performance by musicians
- Expands Control Options *

VCF: Level 1 Diagram





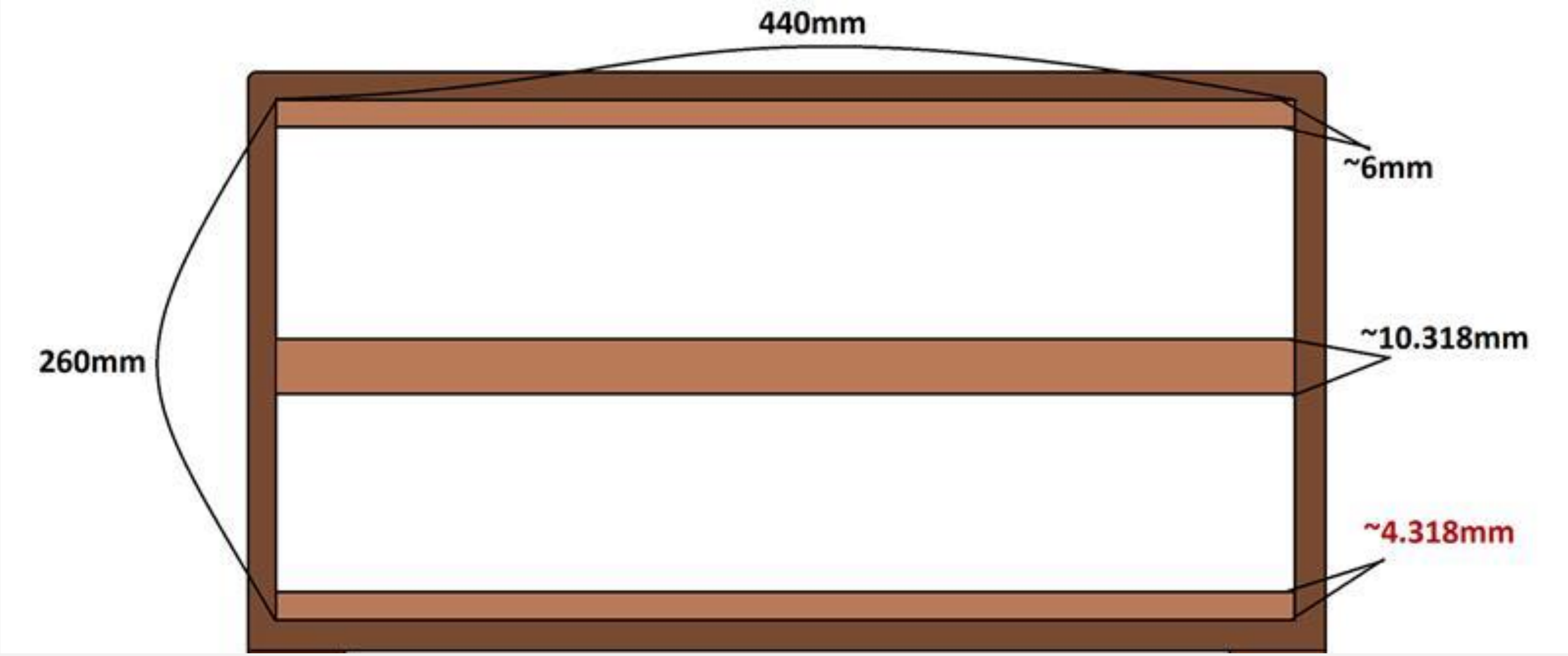


FUNCTION EXECUTION: WAVEFORMS AND FILTERS

FUNCTION CHALLENGES: FREQUENCY MANIPULATION

Challenge	Solution
Any Problems that had to do with VCO pace here	Something About the VCO Solution
Resonance & Cutoff	Switch out TL074s to LM13/700
Other Problem	Solution
Other Problem	Solution

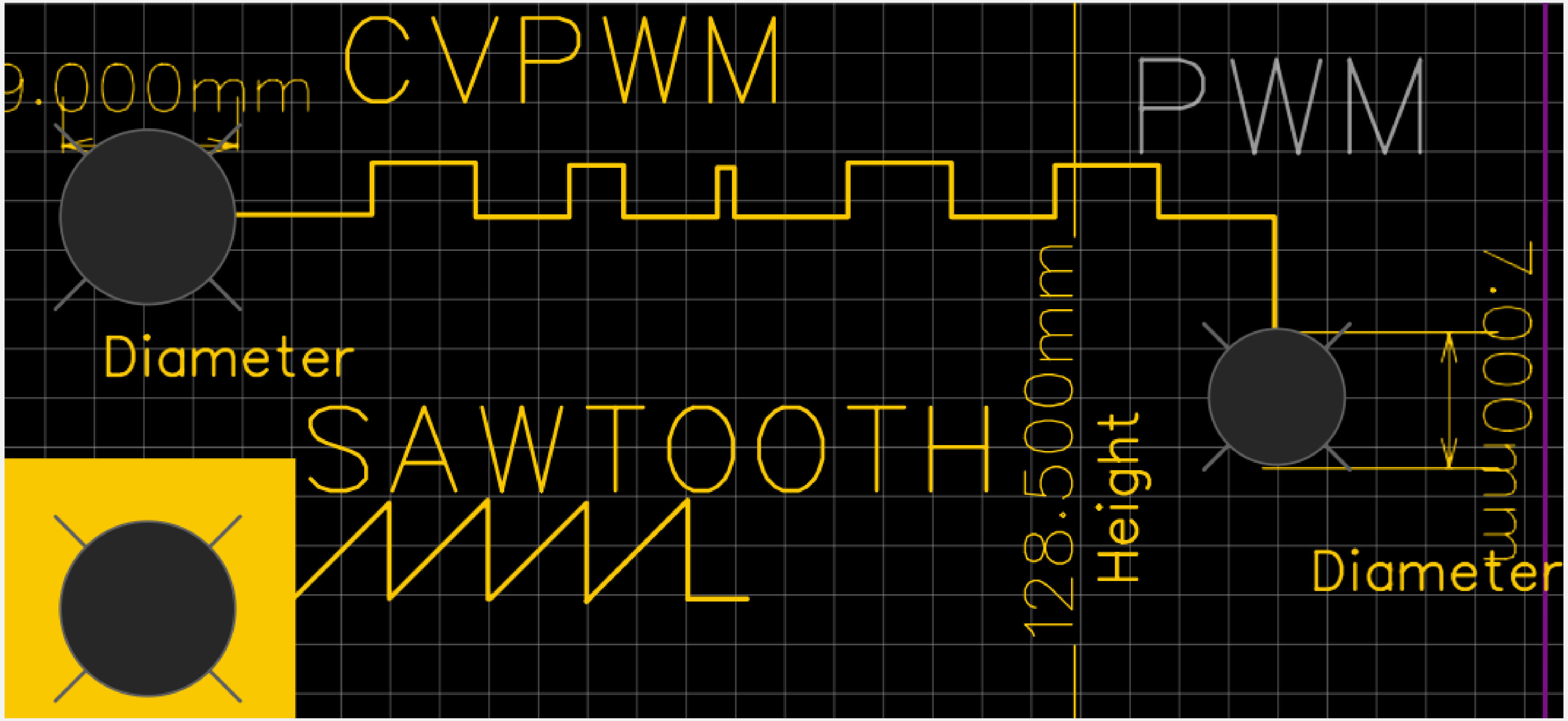
CASE SKETCH

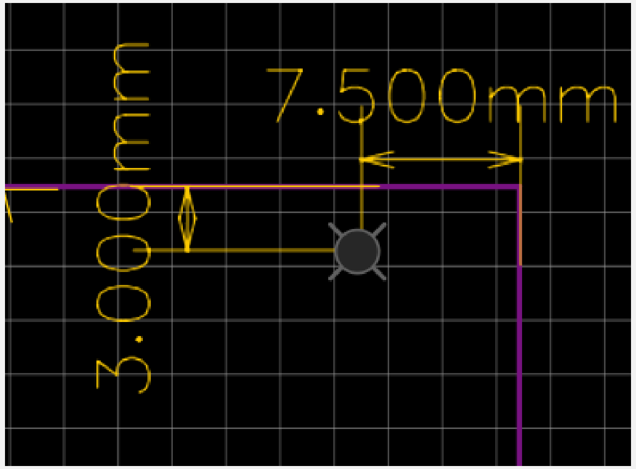


Depth

7 ¼ Inches

MODULE DIMENSIONS





Hole Diameters
Mounting 3mm
Phonejack 9mm
Potentiometer 7mm
Height of Faceplate 128.5mm
Mounting hole spacing 3mm from top of board and 7.5mm from wall

TEMPERATURE

- Average over 5 tests conducted over 20min intervals
- Case temp80.2
- Wcm 91.3
- Psu 99.2
- Dme86
- Sequencer 87.2[
- Ambient temp room76degeee
- Taken with temperature gun shown on the right (FLIR TG165)
- We let the case run 20mins and took a reading then waited 20more mins to take another reading.
- And then took the averages above.
- The expected Values were supposed ot be less than 80C and as you can see that's not even close