G12 PedalVision

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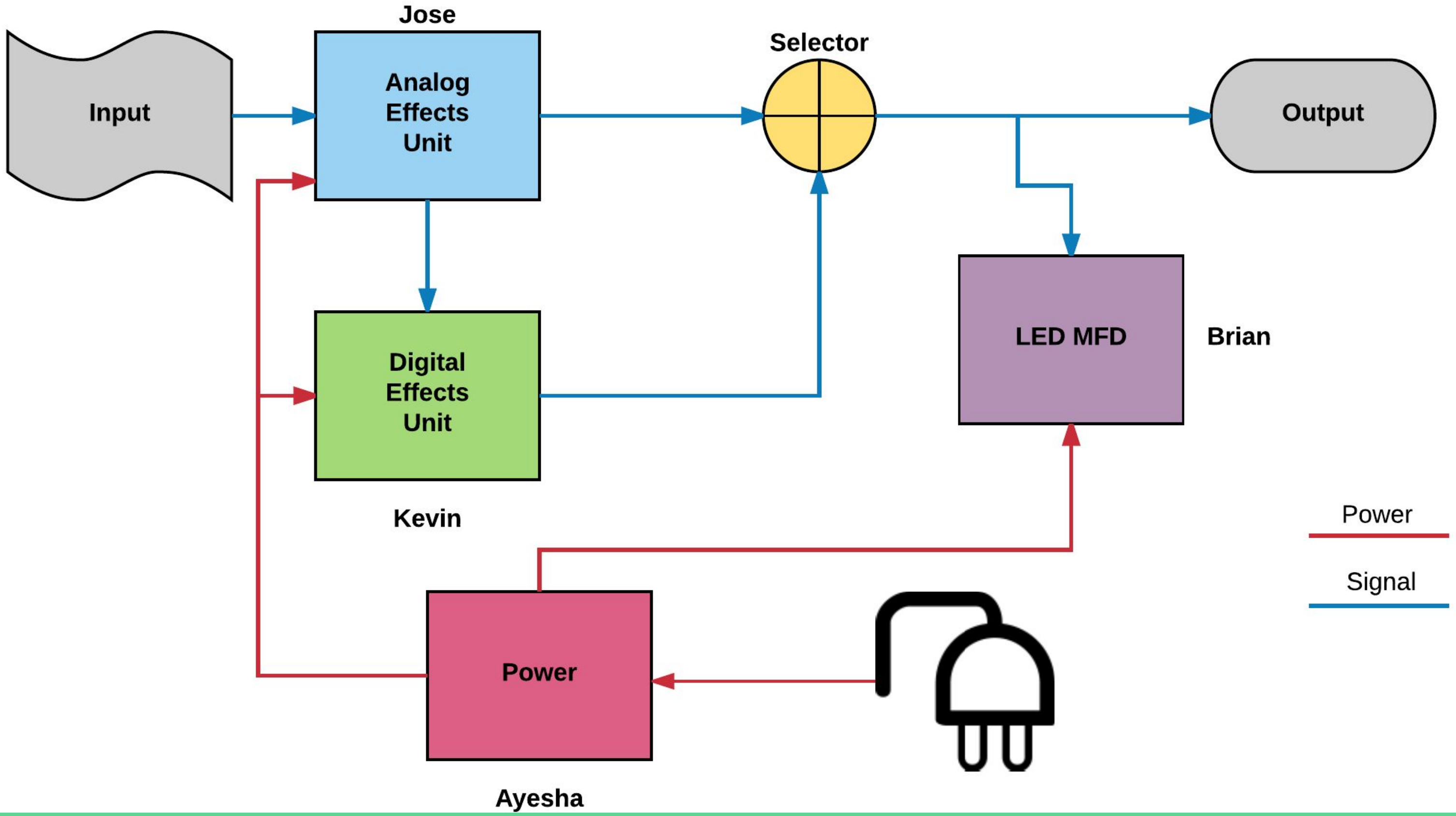
Jose Ramirez (EE)

Project Overview

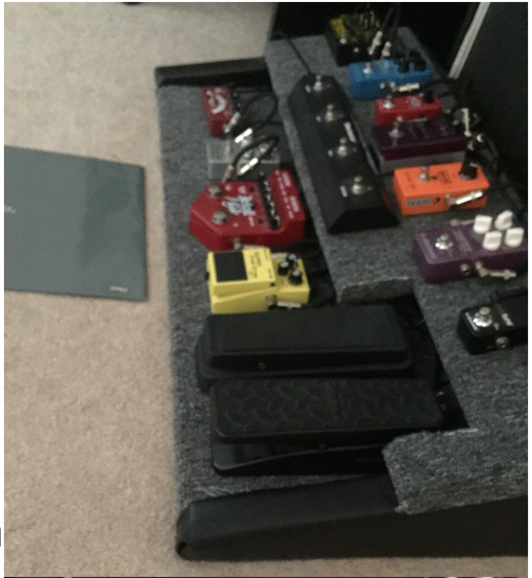


Responsibilities

	Primary	Secondary
Analog Effects	Jose	Ayesha
Digital Effects	Kevin	Jose
LED System	Brian	Kevin
Power Supply	Ayesha	Brian

Motivation / Objectives

1. Alternative to full digital unit
2. Alternative for expensive single analog effect
3. Remove user creative limitation due to digital effect programmability
4. Practice or performances will be more interesting an engaging with LED matrix feedback display
5. More portable and less expensive

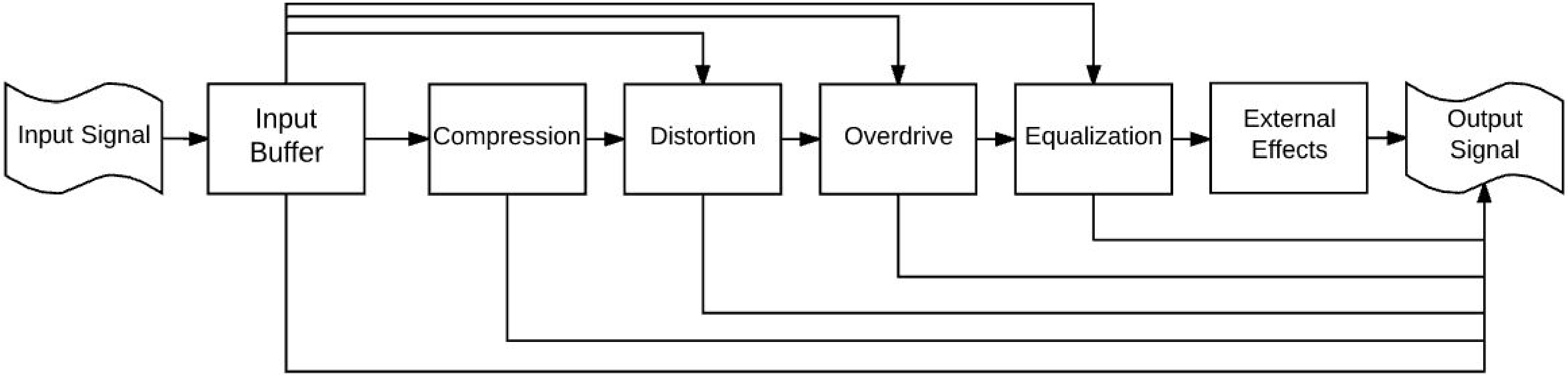


Requirement Specifications

- Analog effects
  - Input impedance of at least 500K
  - Output impedance of no more than 10K
  - Bypass full frequency response from 20 Hz-20 KHz
  - Knobs to adjust volume, drive, and tone
  - Foot controls to toggle effect on and off
- Digital effects
  - DSP chip/microcontroller
  - LCD User interface
  - Knobs for adjusting digital values
  - Foot control to toggle effect on and off
- LED display
  - Microcontroller for LED matrix operations
  - Multiple modes of operation
- Size, Weight, Cost
  - No more than 30 lbs
  - No larger than 15
  - $300 limit for audio
  - $200 limit for LED system

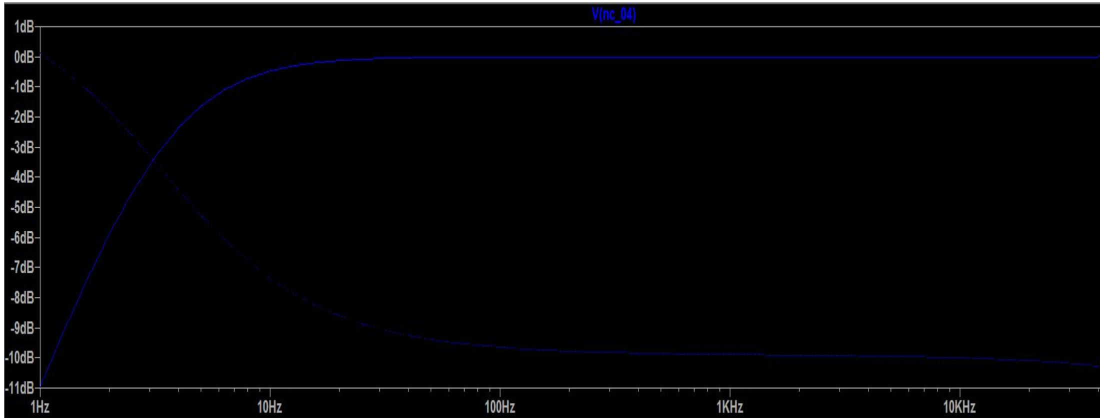
Analog Effects

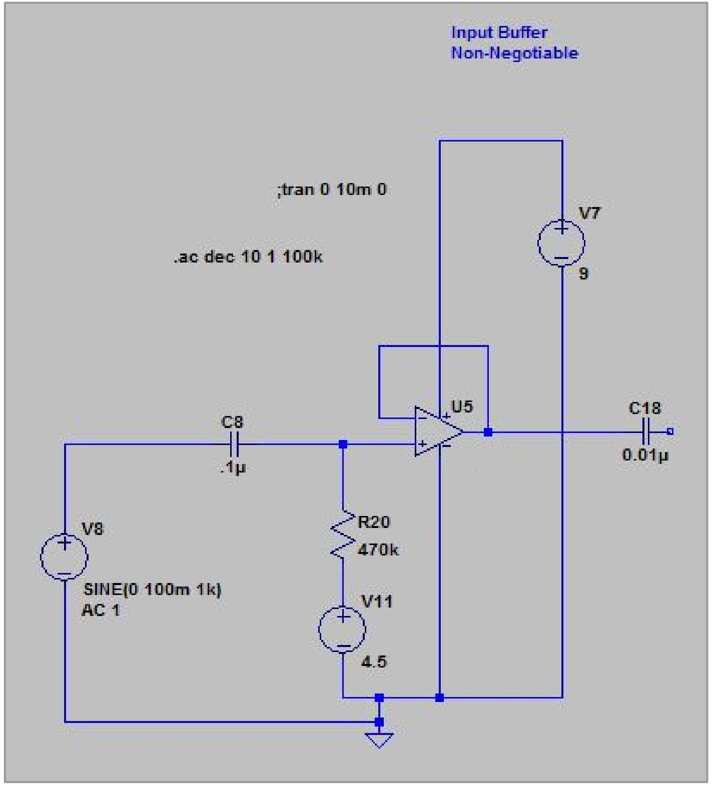
- Order matters
- Why?



Input Buffer/ External Effects Interface

- Unity gain buffer implemented using op amp
- Simple implementation
- Low part count
- Why not Emitter Follower Transistor buffer?





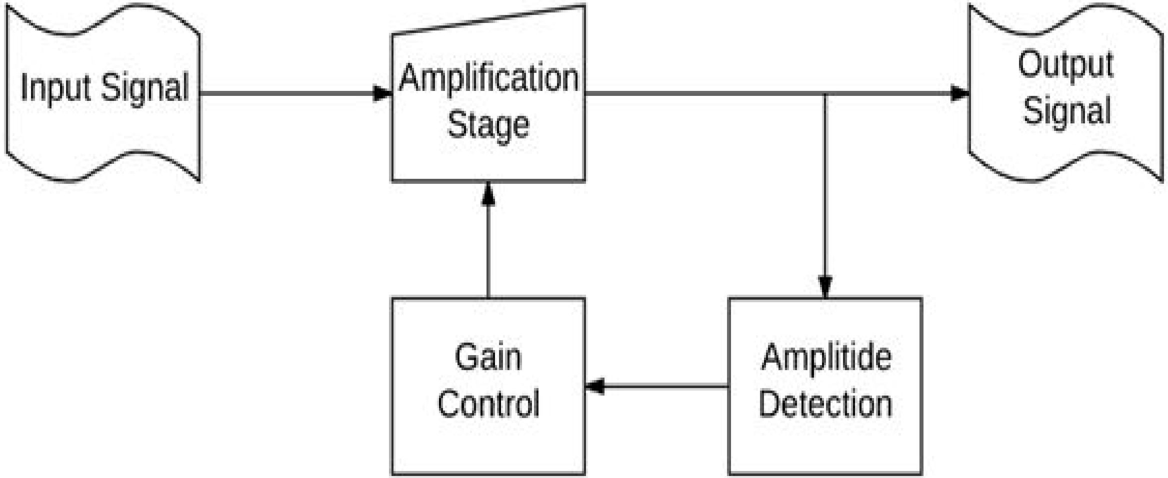
Op amp selection

- Why OPA164x?

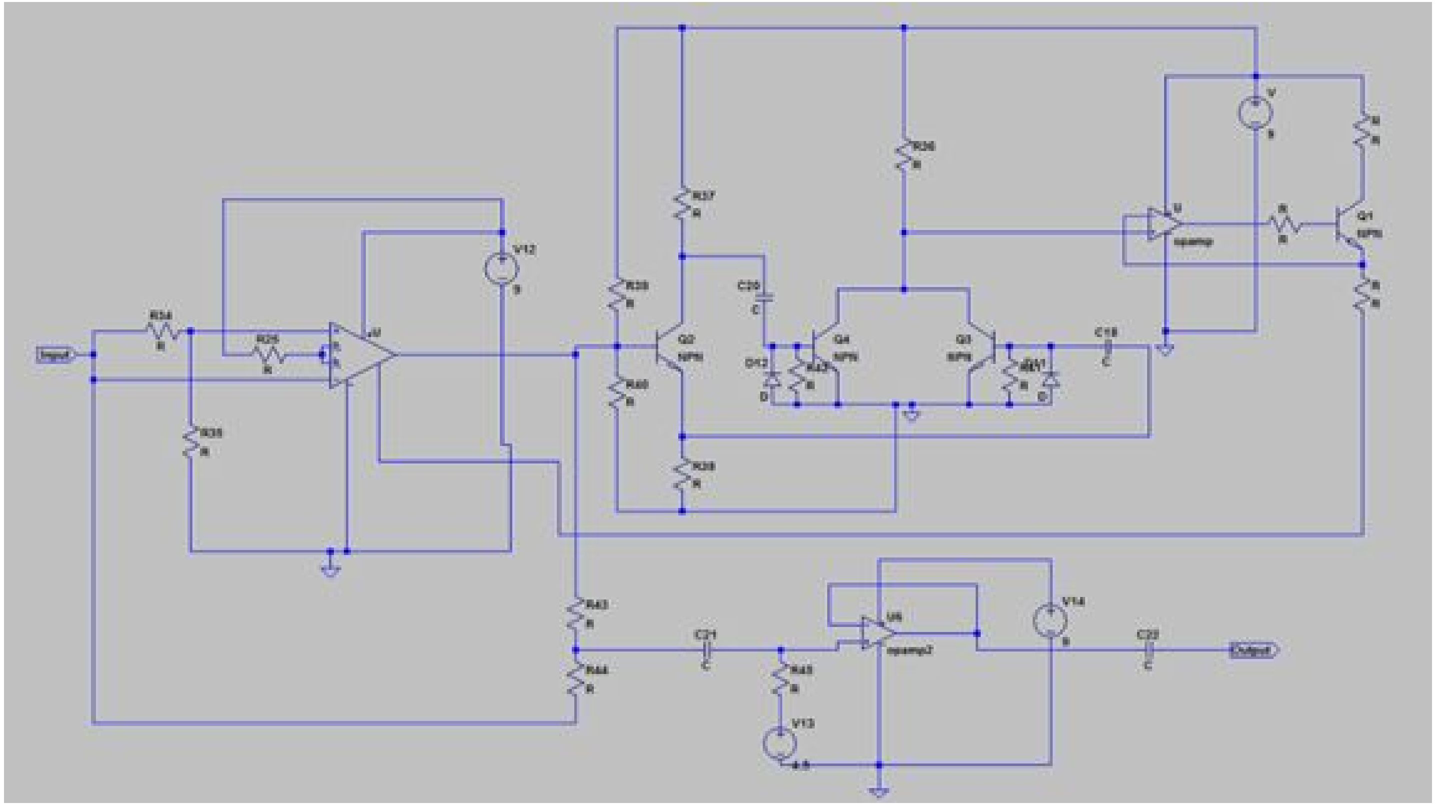
Op Amp Model	Input Impedance	Output Impedance @1k	Gain Bandwidth Product	Input Voltage Noise @ 1KHz	Total Harmonic Distortion	Price
TL07xx	10^12 Ω	Not in data sheet	3 MHz	18 nV/√Hz	0.003%	Not considered
OPA827	10^13 Ω	20 Ω	22 MHz	4 nV/√Hz	0.00004%	$10.13
OPA164x	10^13 Ω	10 Ω	11 MHz	5.1 nV/√Hz	0.00005%	$2.88

Compression

- LM13700
- Amplify softer signal
- “Compress” larger signal
- Add sustain

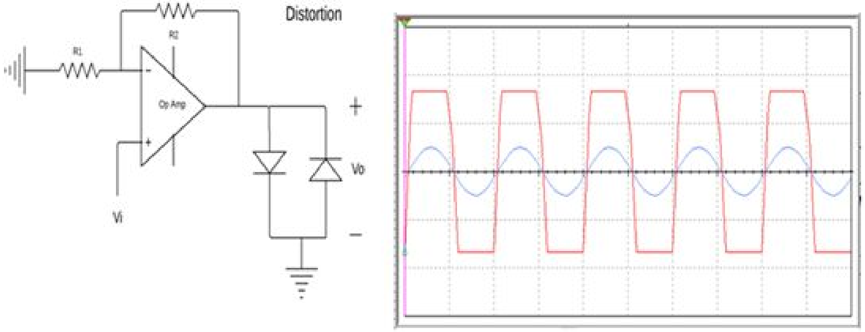


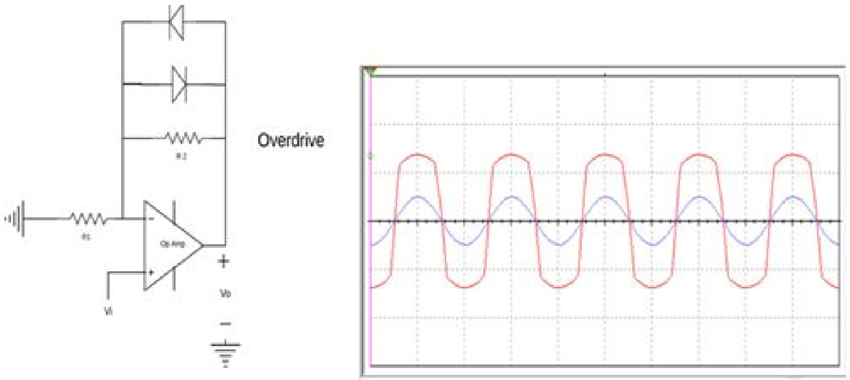
Compression



Distortion and Overdrive

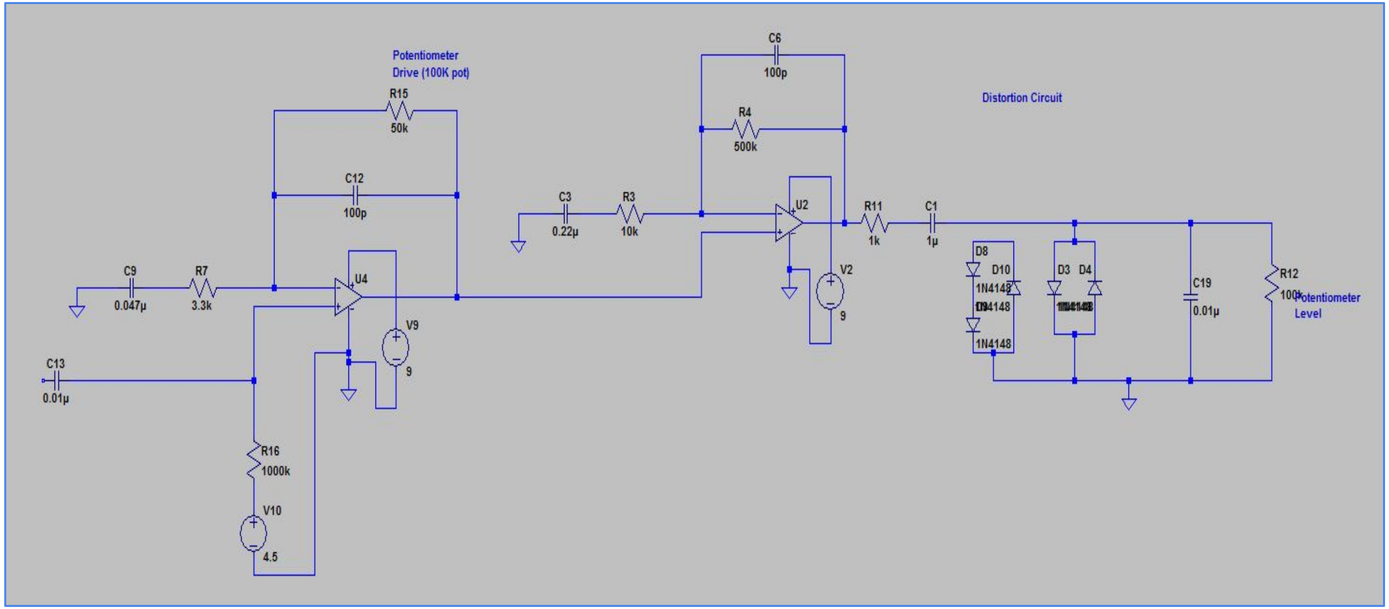
- Both use diodes to create clipping
- Symmetric vs Asymmetric clipping
- Why two amplification stages?



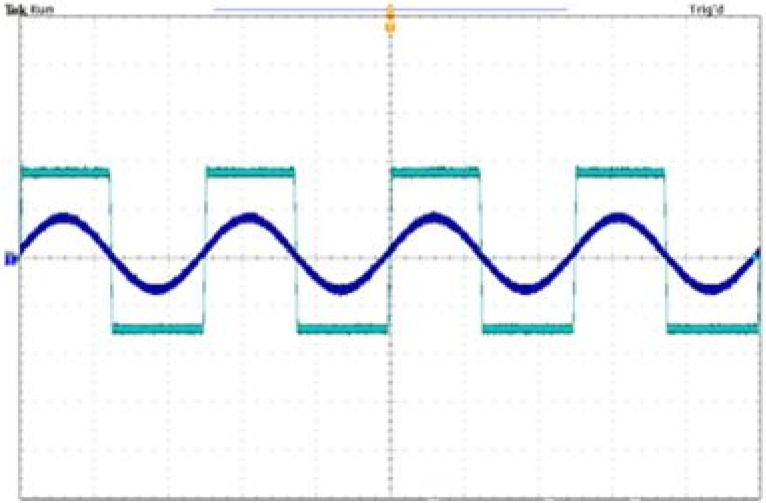


Distortion

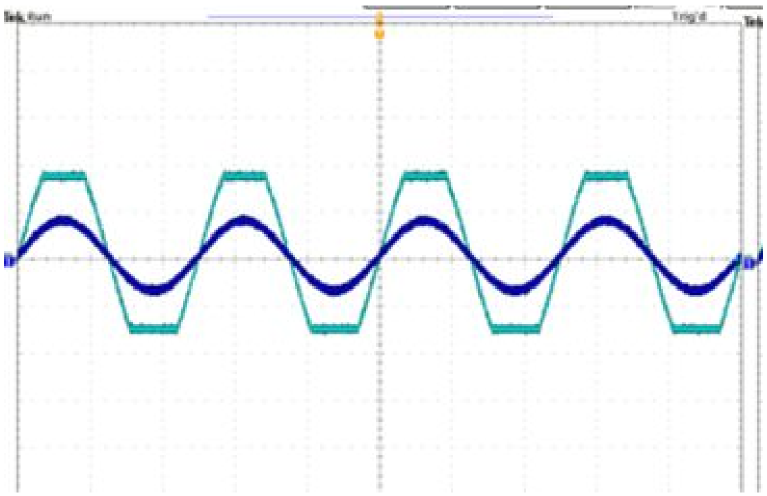
- Distortion at any volume level
- Hard clipping
- Adds some compression



Simplified Distortion Outputs

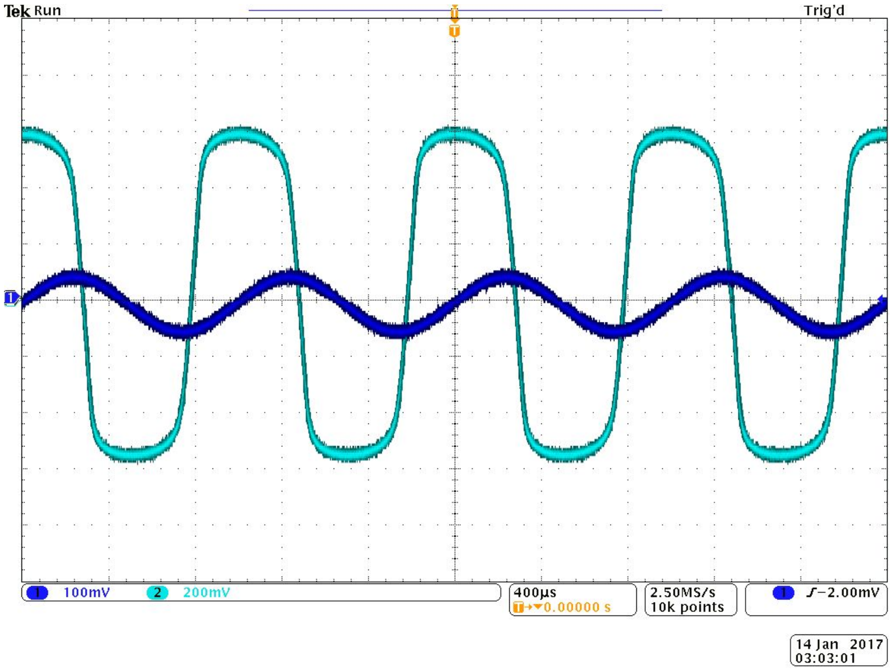


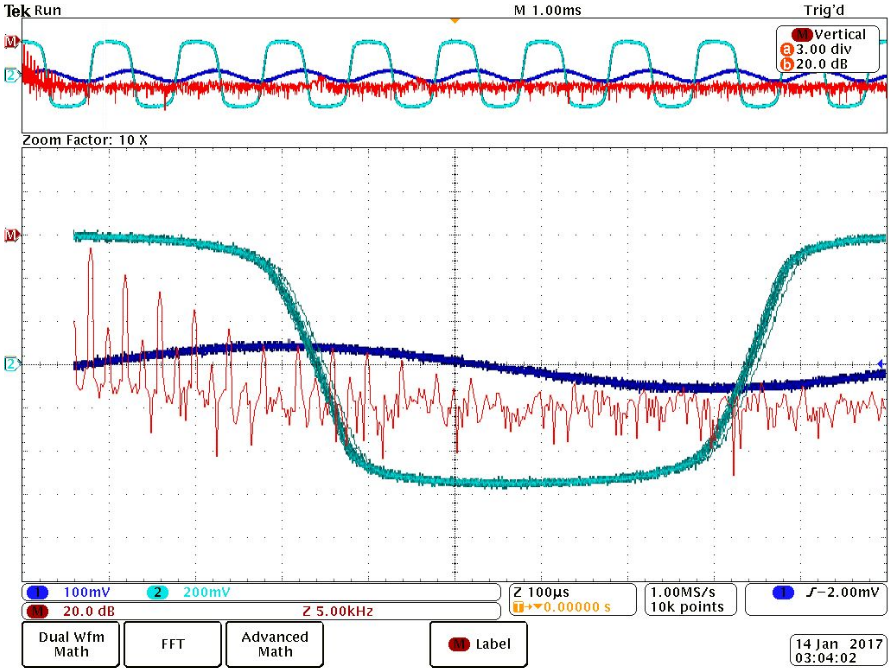
High Gain



Low Gain

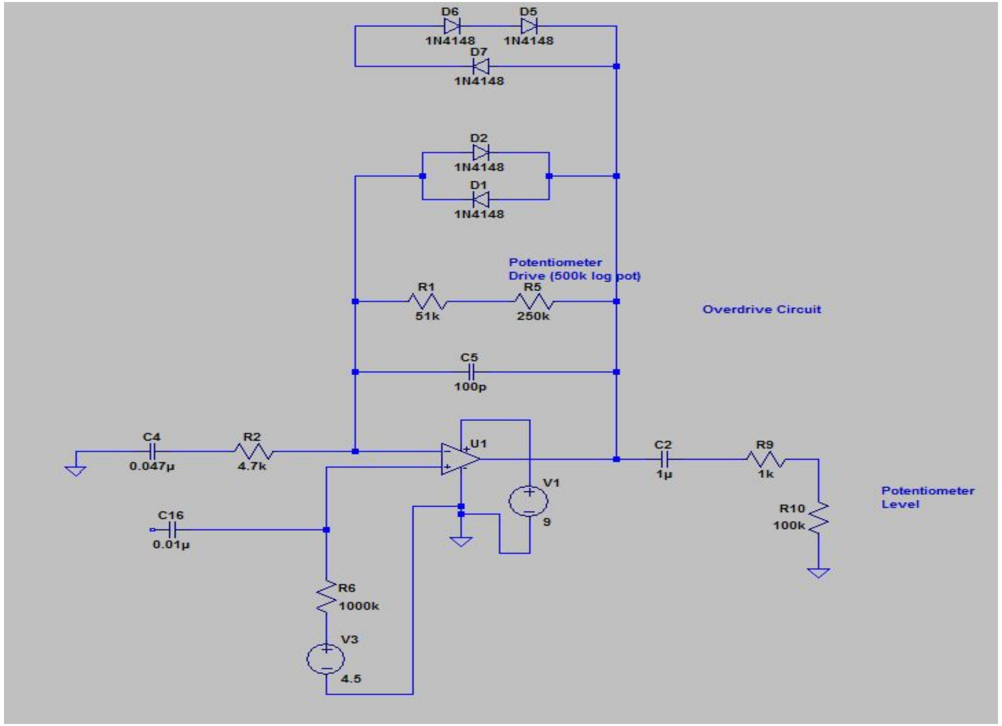
Actual Distortion Circuit Output



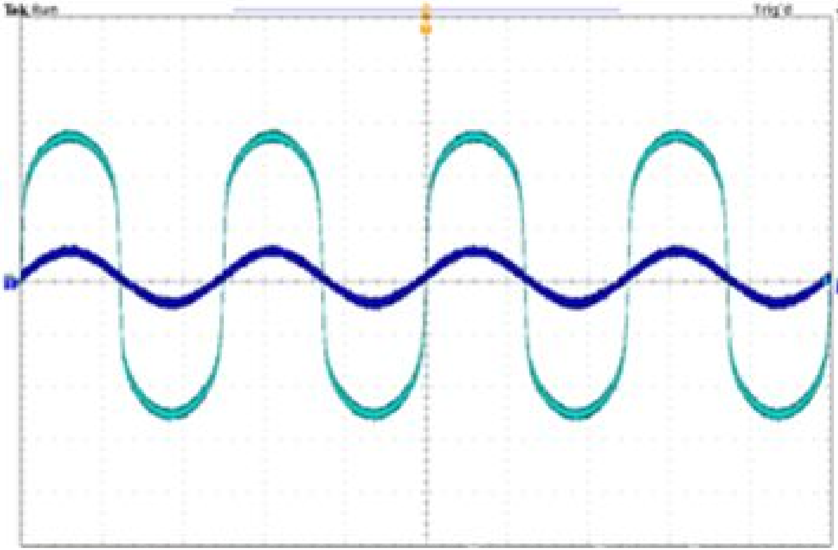


Overdrive

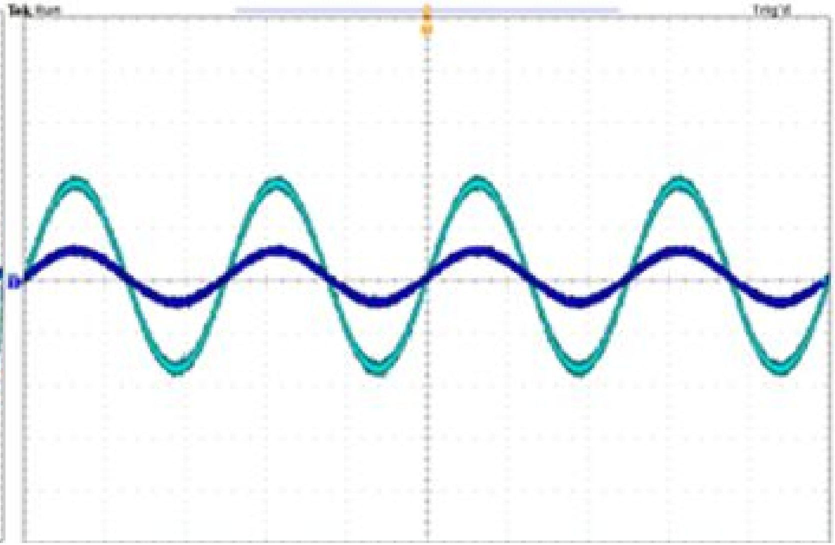
- More distortion as volume level increase
- Soft Clipping
- Can be used as a volume boost after other distortion effects



Simplified Overdrive Outputs

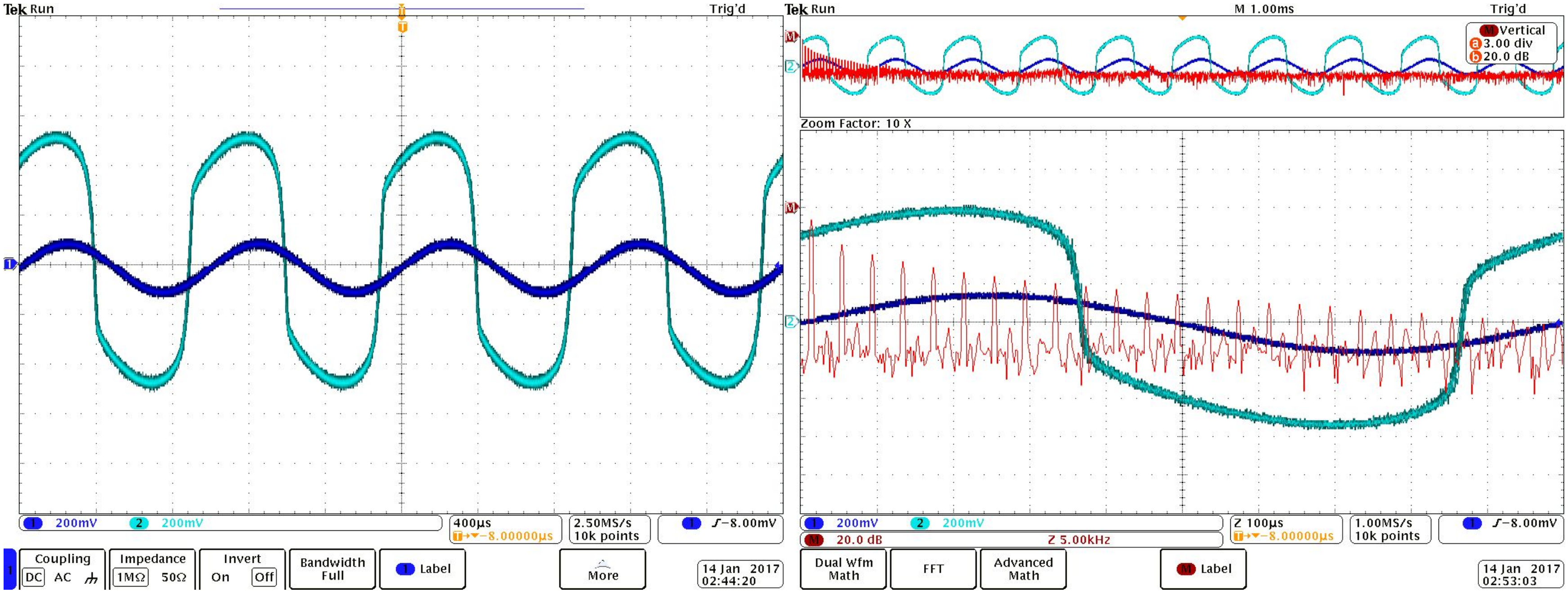


High Gain



Low Gain

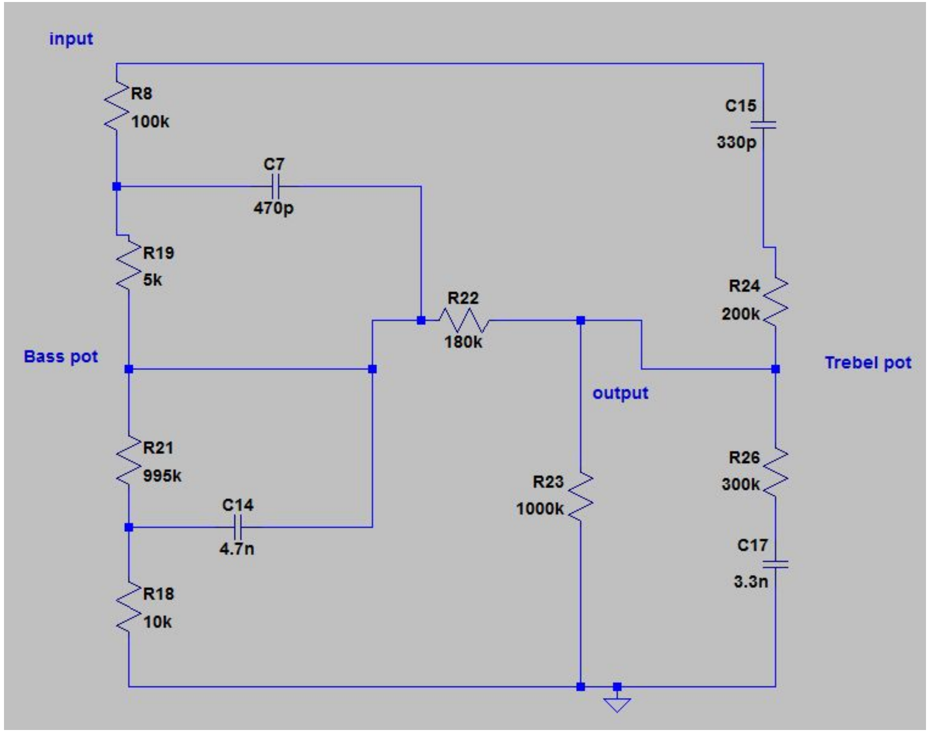
Actual Overdrive Circuit Output



Tone Stack

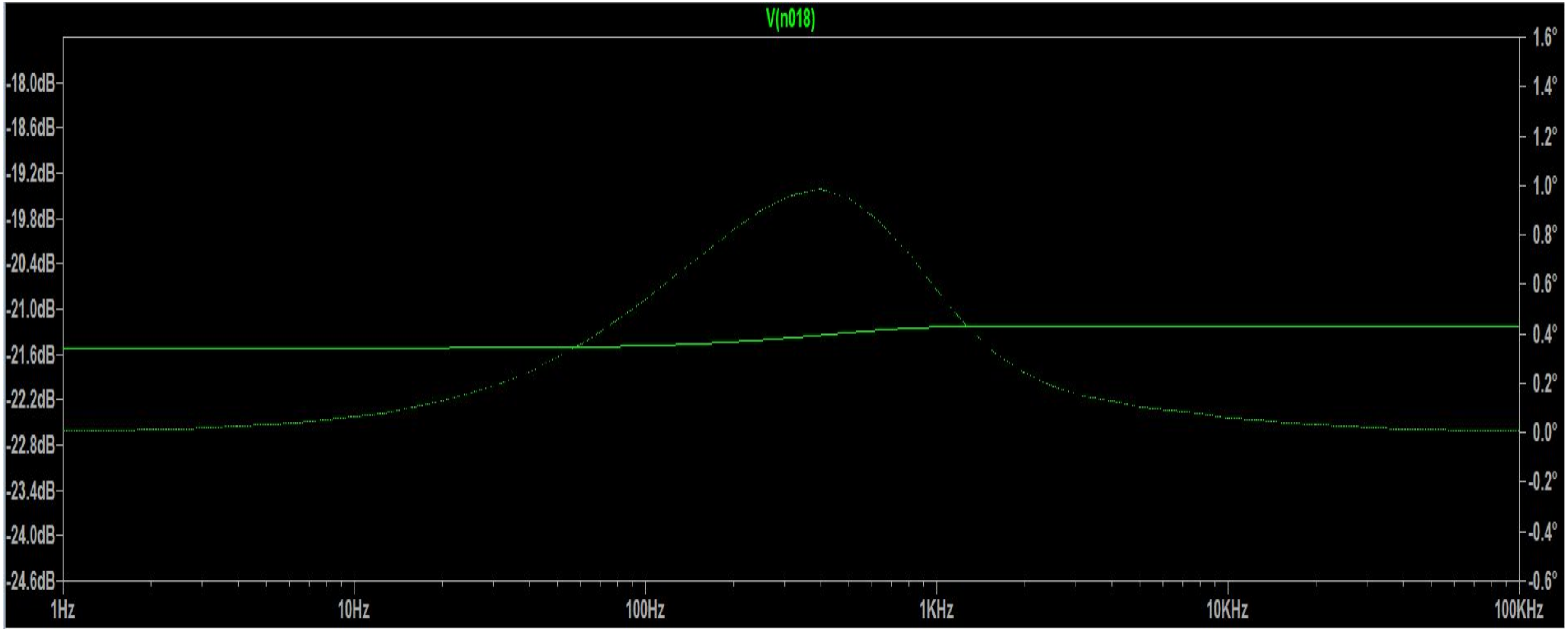
- Tone adjustment
- Versatile with only two controls

	Bass Control Position	Treble Control Position
Highpass	0	10
Lowpass	10	0
Mid boost	0	0
Mid Scoop	10	10
Flat band	5	5



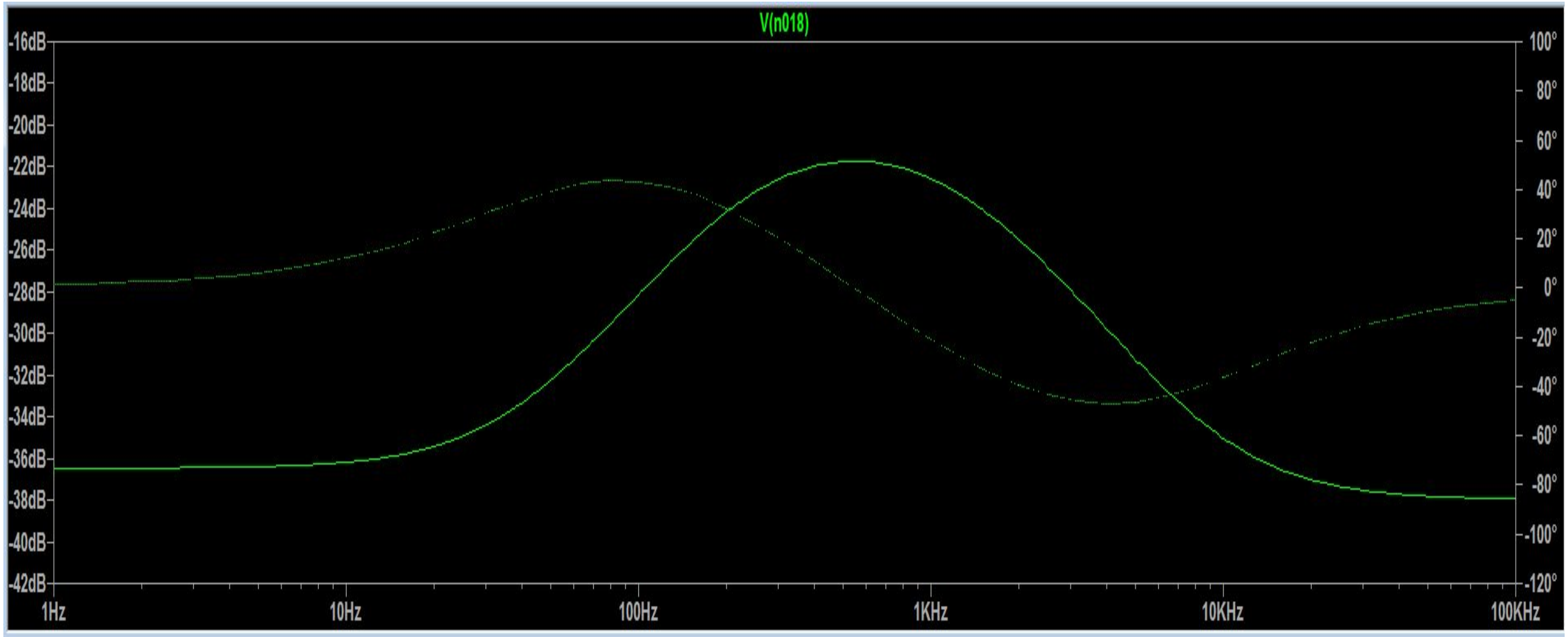
Tone Stack Simulation Frequency Sweep

- Flat Band



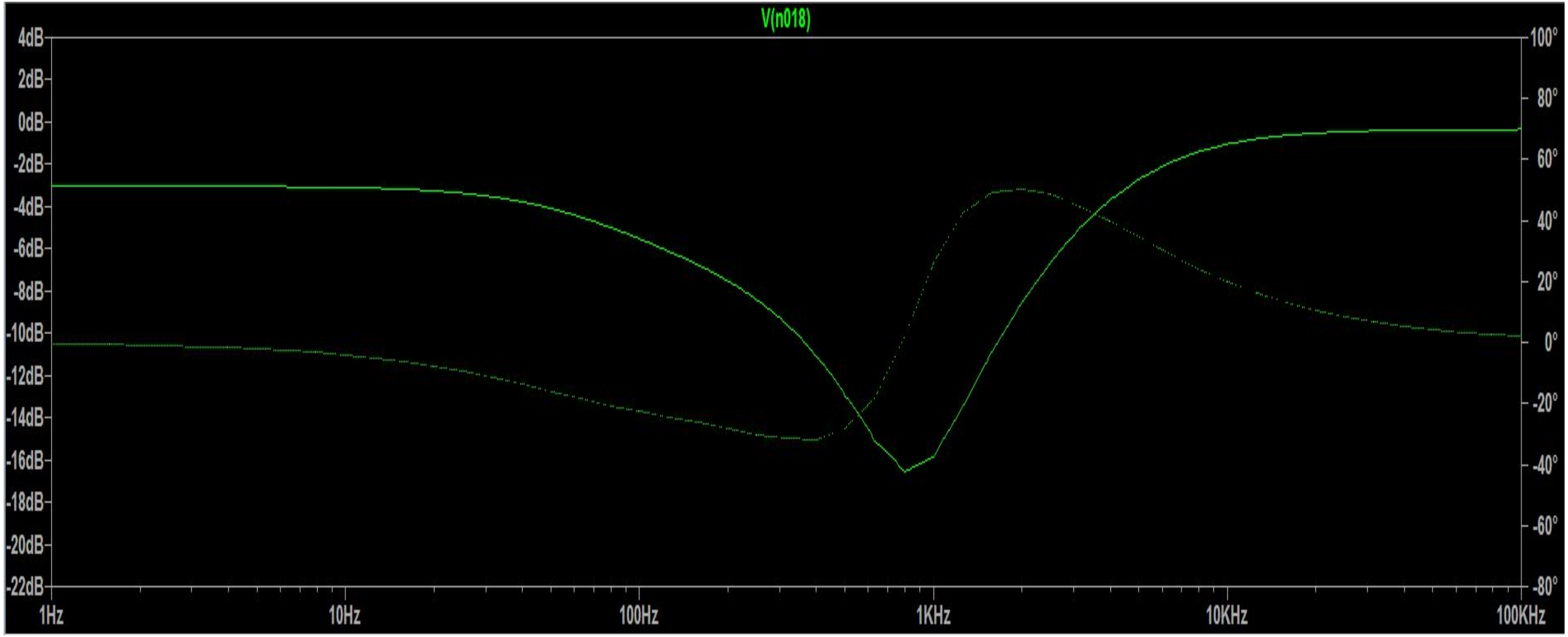
Tone Stack Simulation Frequency Sweep

- Mid Boost



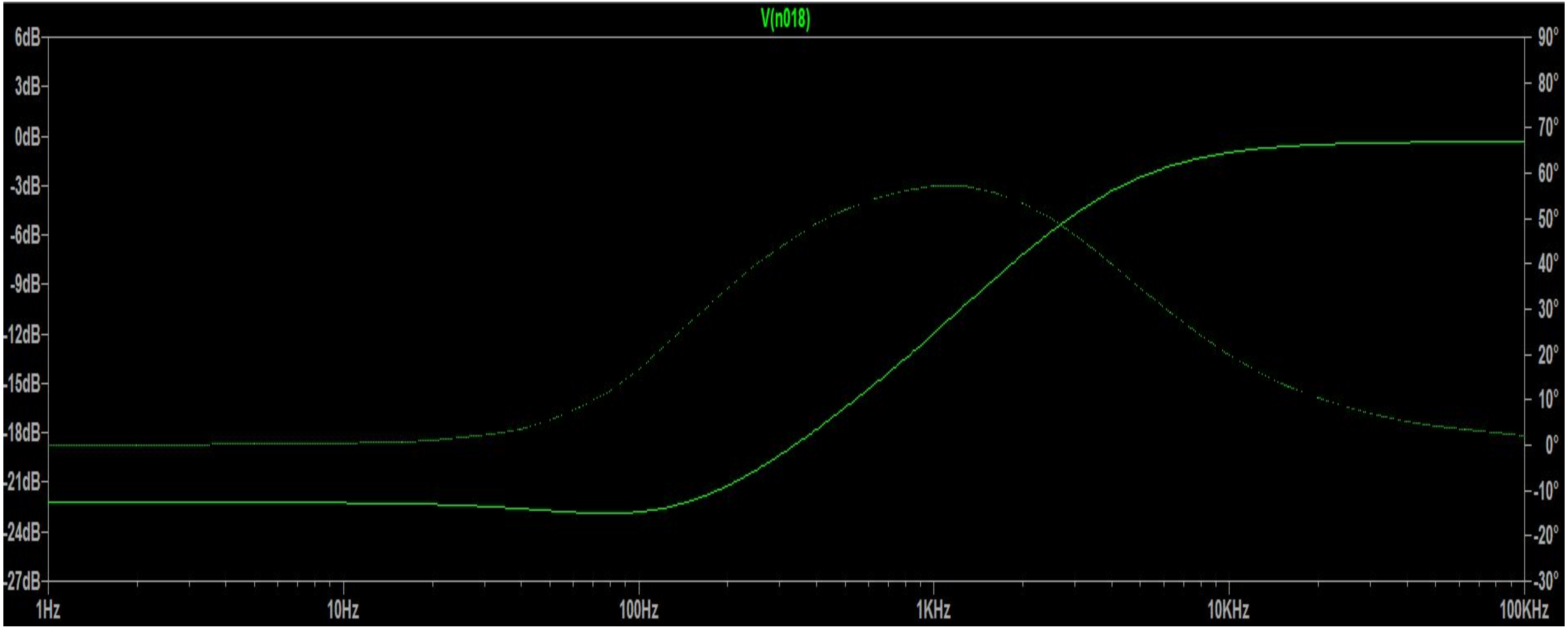
Tone Stack Simulation Frequency Sweep

- Mid Scoop



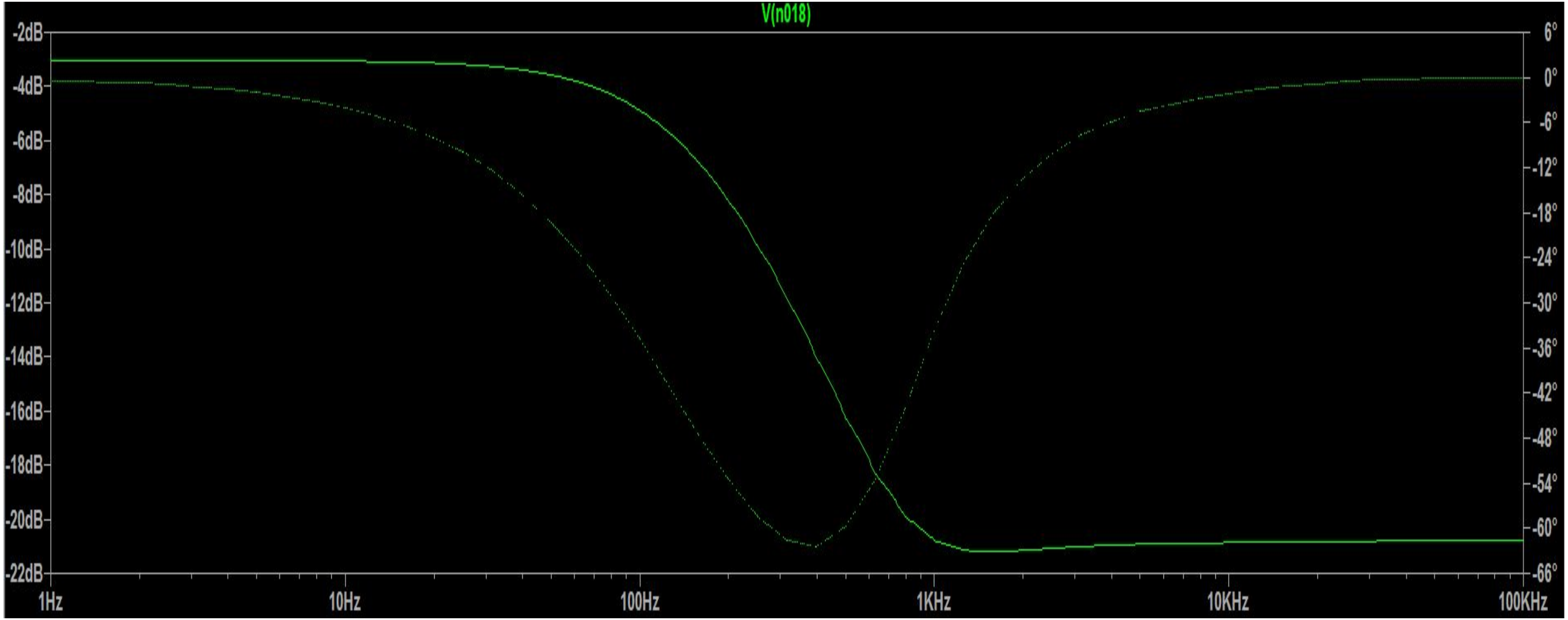
Tone Stack Simulation Frequency Sweep

- Highpass



Tone Stack Simulation Frequency Sweep

- Lowpass

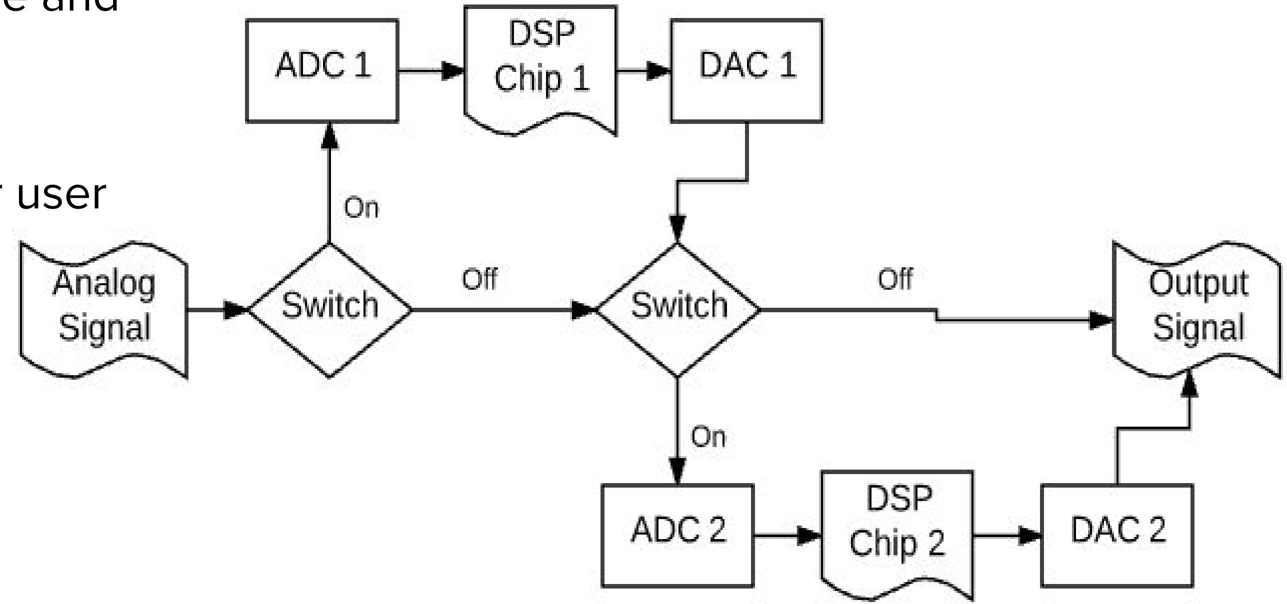


Results so far

- Successes
  - All effects have been implemented and function as expected.
  - All effects have been sound tested.
- Issues
  - Compression circuit has audible popping sound at output even when instrument is muted.
  - Tonestack may need a volume boost

Digital Effects - Design Approach

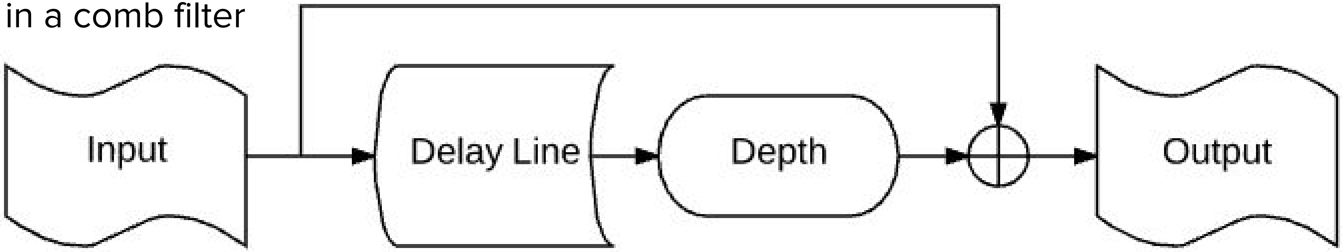
- Two digital effect chips (dependent on size and cost of product)
- Allows for more customizability for user



Digital Design Approach - Choices

- Delay Based Effects
    - Echo/Delay
        - Crisp echoing effect
    - Reverb
        - Spacious and full sound
    - Flanger
        - Jet like flanging adds dimension
- How to make these effects
    - Use delay lines in a comb filter

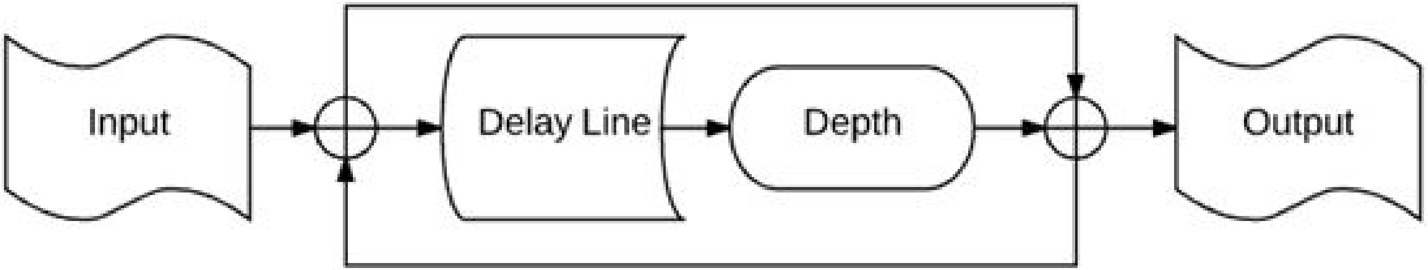
Delay Line



Comb Filter

Digital Design Approach - Echo

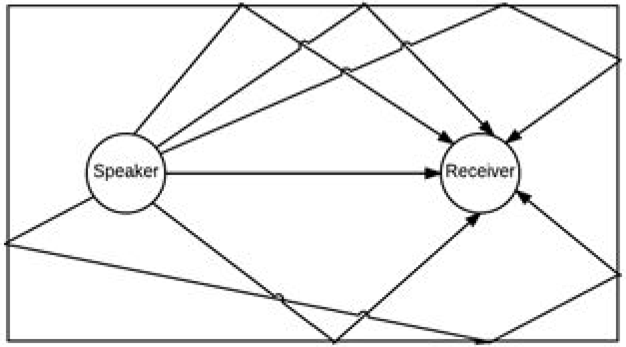
- Used to create a copy of the input and delay it slightly
  - Depth continues to decrease the impact of the copy the longer it continues
- Controls
  - Delay
  - Feedback
  - Level



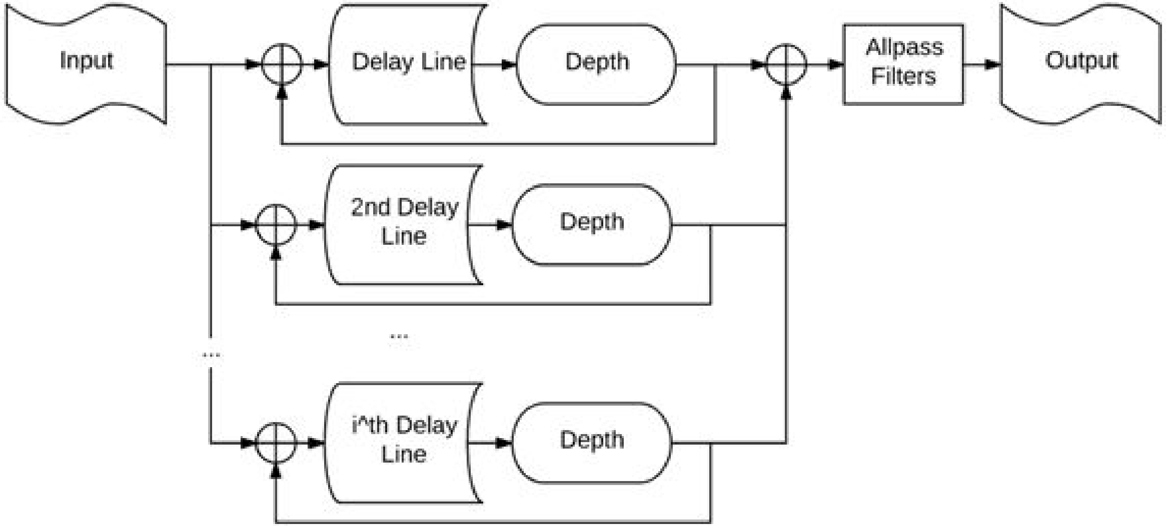
Echo Block Diagram

Digital Design Approach - Reverb

- Used to give the output sound the as if it was recorded in a large room
  - Achieved by overlaying multiple delays with comb filters, then passing through allpass filters.
- Controls
  - Decay
  - Tone
  - Level



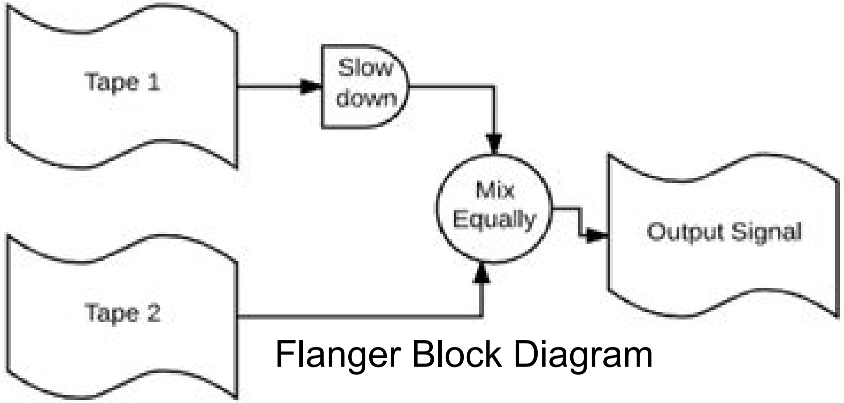
Natural Reverb



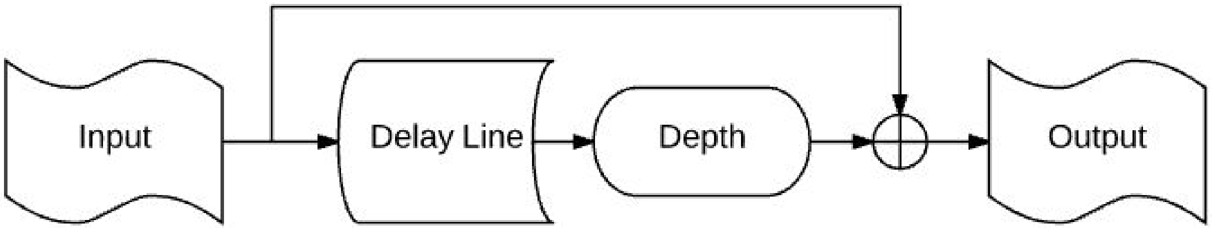
Schroeder Reverb Block Diagram

Digital Design Approach - Flanger

- Used to create a unique sweeping spacelike sound.
- Function: y(n) = x(n) + d * x(n - M(x))
  - y: Output Signal
  - x: Input Signal
  - d: depth
  - n: sample time step
  - M: Length of delay line
- Controls
  - Delay
  - Depth
  - Level



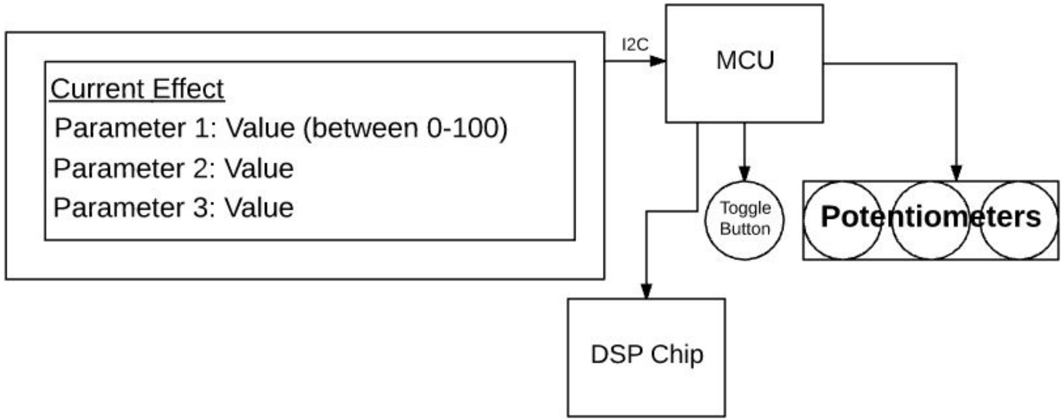
Flanger Block Diagram



FeedForward Comb filter

Digital Design Approach - Interface

- Very simple user interface
  - Benefits users who want to change effects quickly between songs
  - Anyone can easily use
- Potentiometers for parameter changes
- Button for cycling/choosing effect
- I2C connection to LCD display



Digital Effects - Component Decision

TMS320C6720

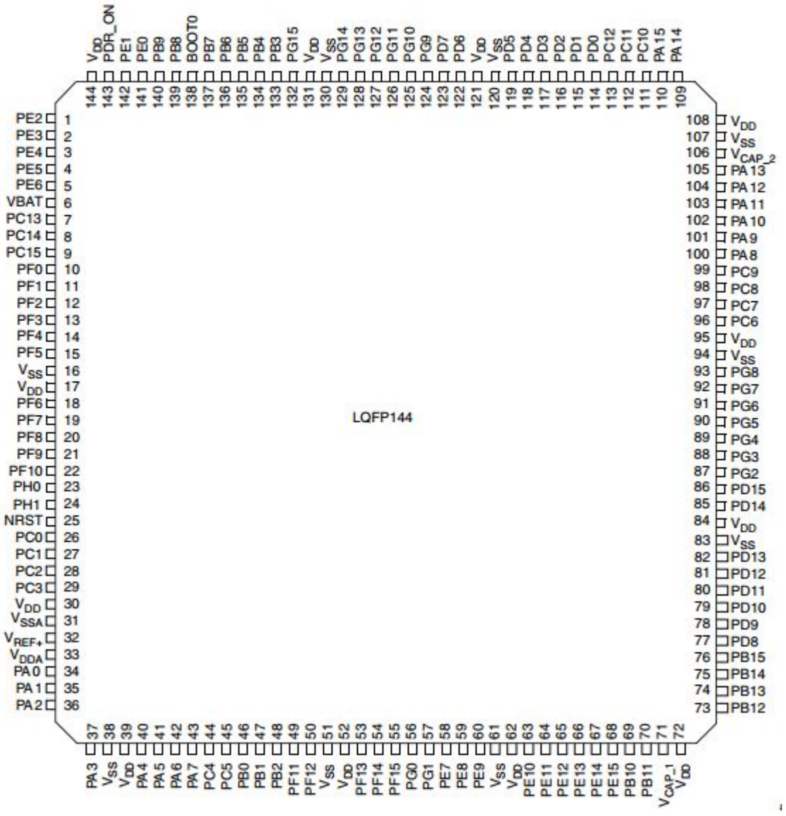
- Pros
  - High Speed/Quality
  - Faster and more accurate calculations
- Cons
  - High Cost Dev Board
  - High risk w/o dev board
  - Harder to code
  - Little documentation for guitar effects
  - Requires JTAG programmability

STM32F405ZGT6 (Hoxton Owl Based)

- Pros
  - Lots of documentation (HW & SW)
  - Cheaper Dev board for testing
  - Open source
  - ARM based DSP libraries
  - USB programmability
  - Owl Firmware
- Cons
  - Slower/lower quality

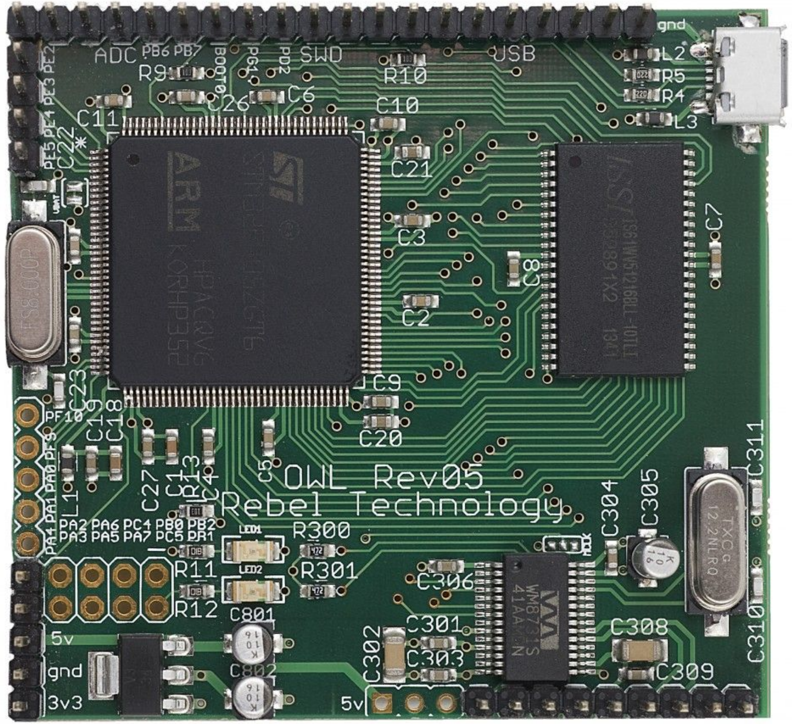
Digital Effects - Components

- STM32F405ZGT6 ARM Cortex M4 32bit
  - Up to 168 Mhz
  - Floating Point unit
  - On chip memory
    - Flash 512 MB
    - SRAM 192 kB
  - 15 Communication interfaces
  - Serial wire debug interface
  - Low power operation
  - Compatible with all ARM tools (including dsp libraries)



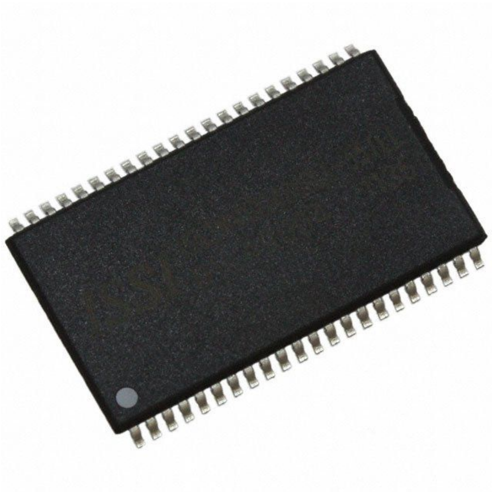
Digital Effects - OWL Digital

- Open source
  - Software
  - Hardware
- Bootloader available for custom builds
- Helpful community
- Users will not be limited to the effects we create.
  - Online effect library and compiler



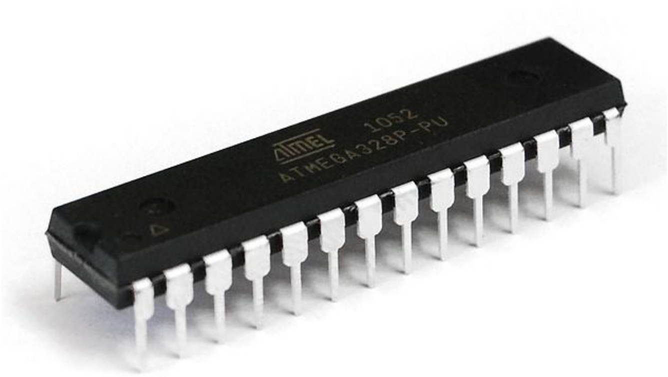
Digital Effects - Components

- SD Ram - IS61WV51216BLL-10TLI
  - Used to hold program memory
  - Also used for storing samples for effects
  - 8 MB
  - 10 nS access time
  - 100 MHz
- ADC/DAC - WM8731
  - ADC: Converts input signal from analog effects to digital values
  - DAC: Converts digital values back to an analog signal
  - 24 bit Sigma-Delta
  - Supported 8kHz to 96kHz



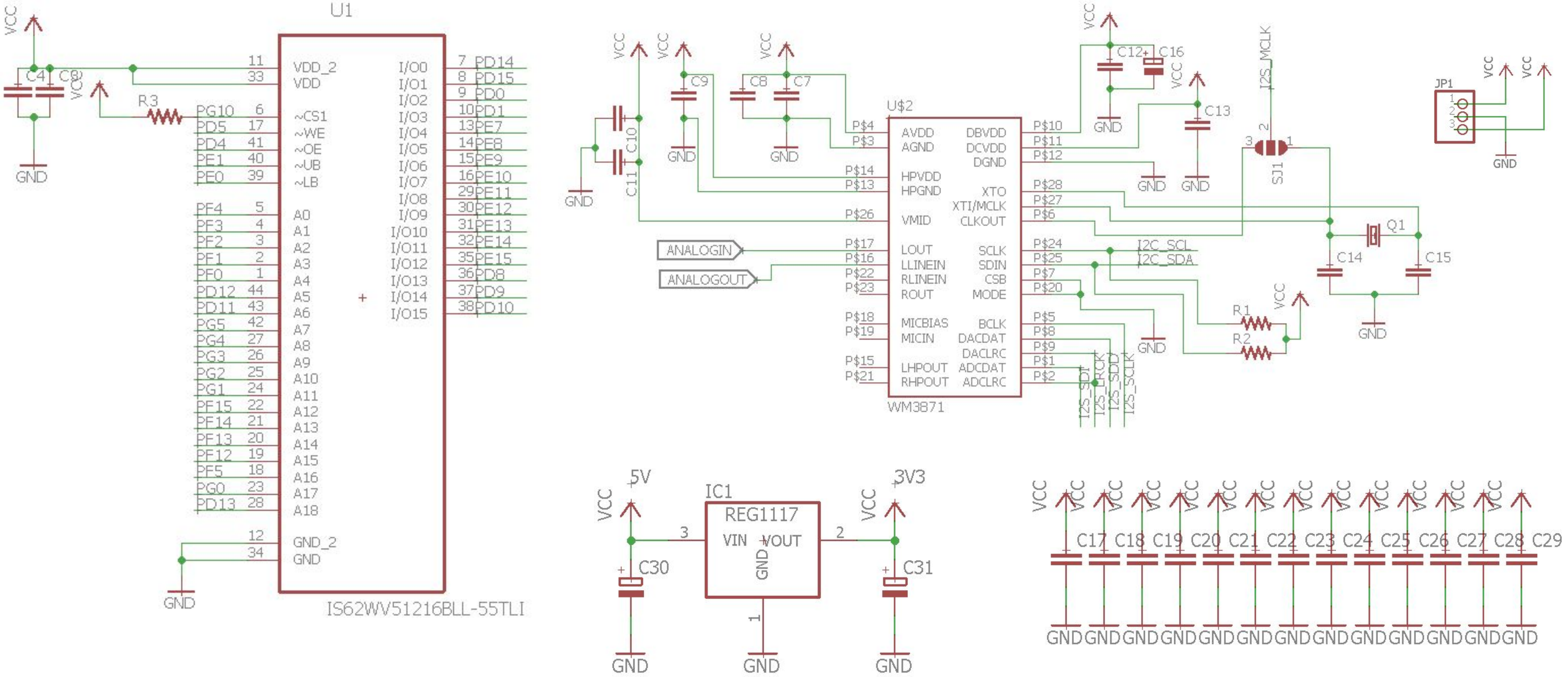
Digital Effects - Components

- Atmega328p
  - Drive the LCD display
  - Handle user interface controls
  - Display loaded effect and value

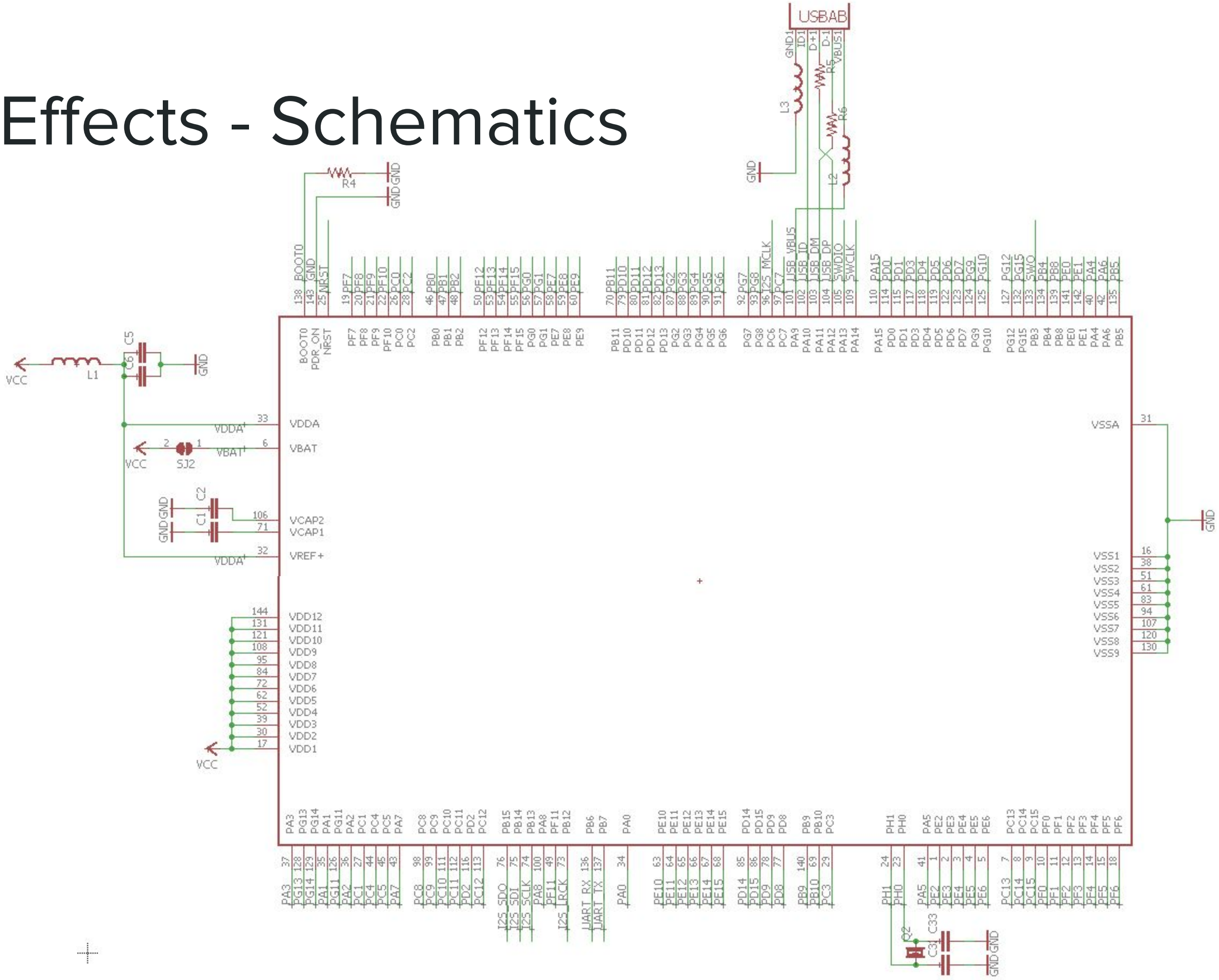


- LCD Display
  - 20x4 characters

Digital Effects - Schematics



Digital Effects - Schematics



Digital Effects - Difficulties

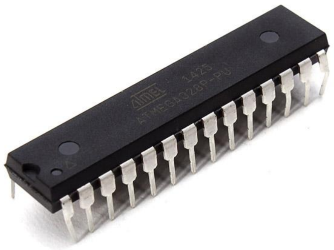
- Change of chip due to complications
- Waiting for shipping of parts
- Overall Cost

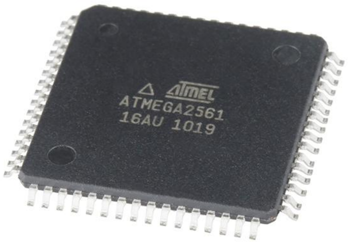
LED Matrix Feedback Display (LED MFD)

- General goals
  - Read a frequency and amplitude of an input analog signal
  - Display frequency as a color
  - Display amplitude as a brightness to the color
  - Introduce another way to enjoy the music you are playing

MCU

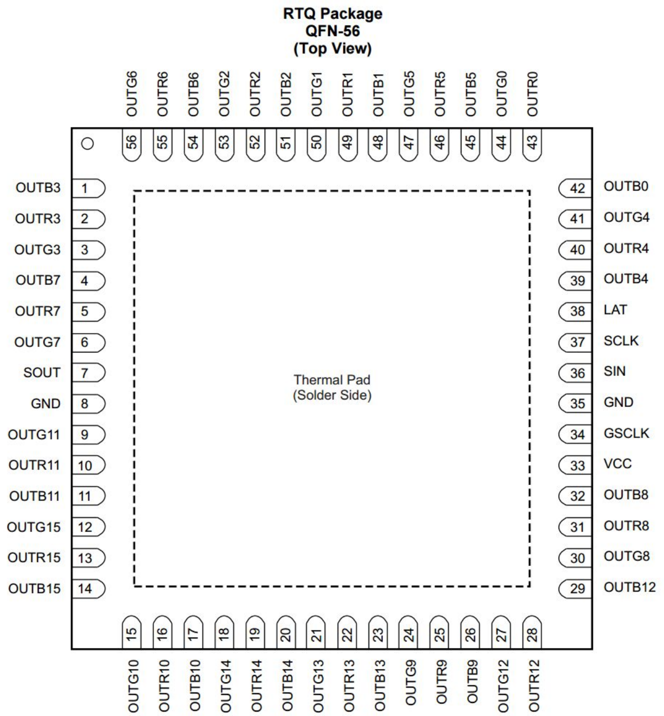
	Flash	EEPROM	RAM	Genral Purpose i/o	16-bit PWM	ADC Channels	Cost
ATMEGA328	32KB	1KB	2KB	23	6	8	$1.38
ATMEGA2560	256KB	4KB	8KB	86	12	16	$12.35
ATMEGA2561	256KB	4KB	8KB	54	6	8	$12.07





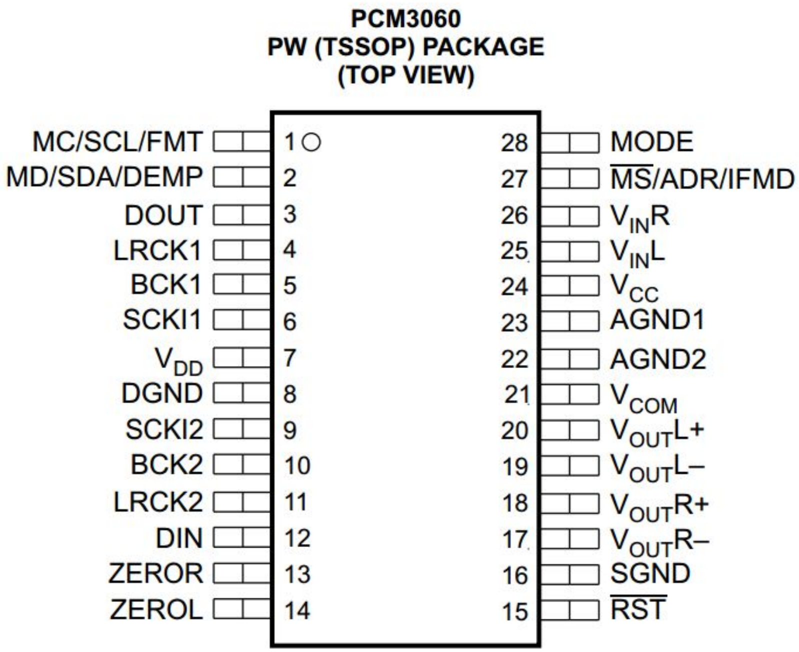
TLC5955: LED constant current driver

- 48-channel constant current output
- 281 trillion unique colors available
- 128 step current control per output
  - 2mA-31mA
- Fault flags
- GSCLK of 33MHz
- SCLK speed of 25MHz
- Ability to be daisy-chained

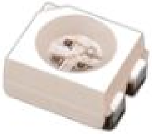


PCM3060: Analog to Digital Converter

- 24-bit ADC resolution
- Sampling rate of 16-96KHz
- Ability to communicate through...
  - 3-wire SPI
  - 2-wire I2C
- SMD
- Con: Wasted pins
- It was free

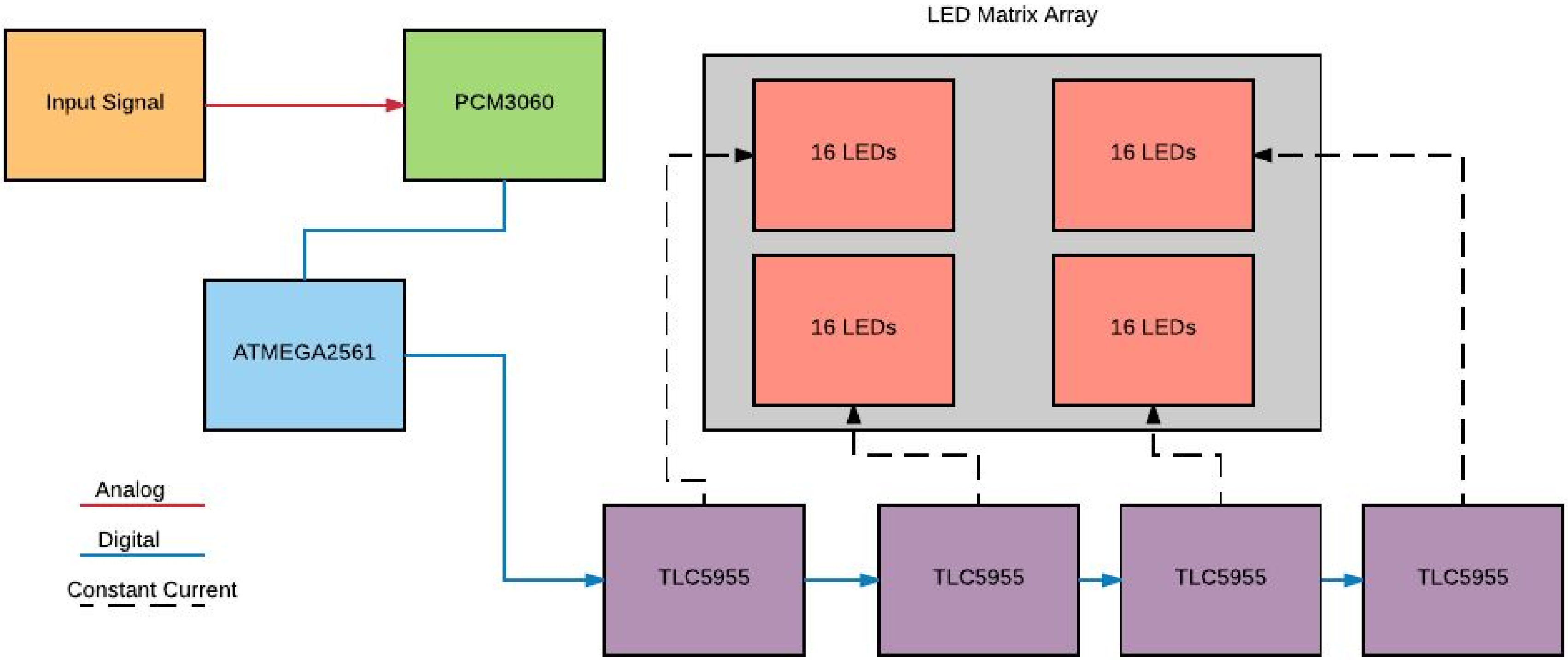


Kingsbright RGB LED

Photo	Part Number / Description	Wavelength / Color	Luminous Intensity			Viewing Angle
			Min.	Typ.	Unit	
	AAA3528BGRS/129/C3 *3.5X2.8MM RGB SMD LED*	470nm 525nm 621nm	200 1000 120	330 1600 220	mcd @20mA	120°

- 20 mA of current draw
- SMD
- Small in size
- Large viewing angle
- Cost: $0.38 a unit

Design of LED MFD



Color Theory

- There will be 12 unique colors reserved for each of the 12 major notes recognized
- These frequencies are centered around the A4 = 440Hz idea
- Amplitude of input signal will determine brightness of color

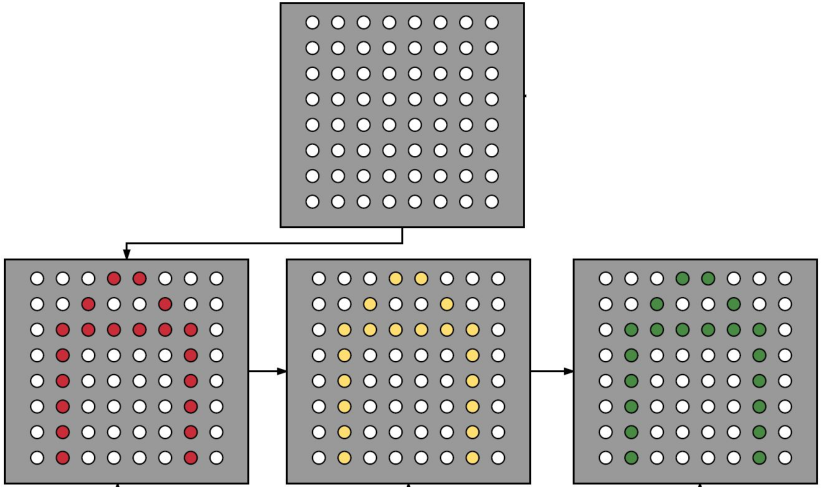
Display Modes

- Four display modes are currently being worked on
- More modes can be added post production

Display Modes: Tuning mode

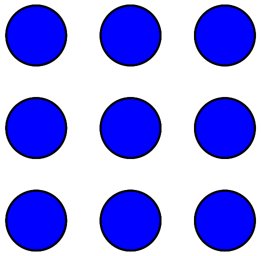
- The note being played read will be displayed
- Color will correlate with how far from the center of the frequency the user is
- Can be used during normal playing or during tuning

Figure 1



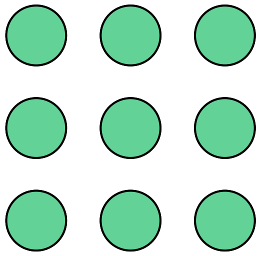
Display Modes: Unison mode

- All 64 of the LEDs change in unison to the same value



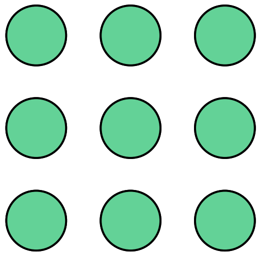
Display Modes: Segmented mode

- Each column from the left to the right changes in unison moving in time from left to right



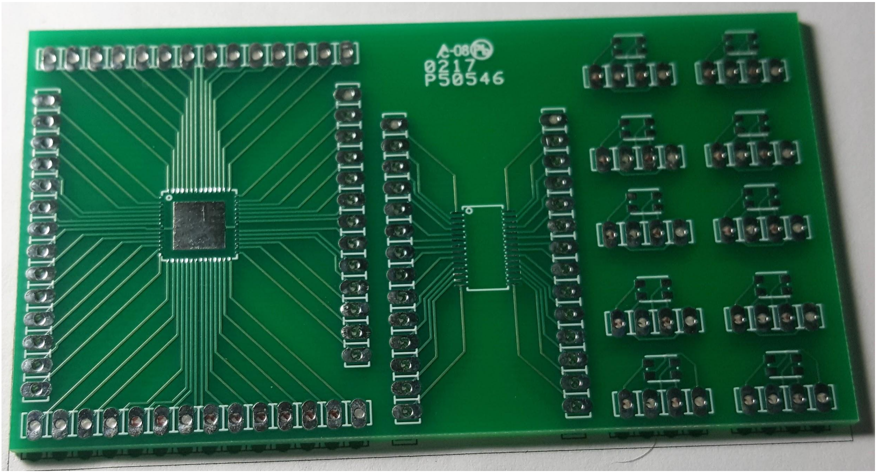
Display Modes: Continuous mode

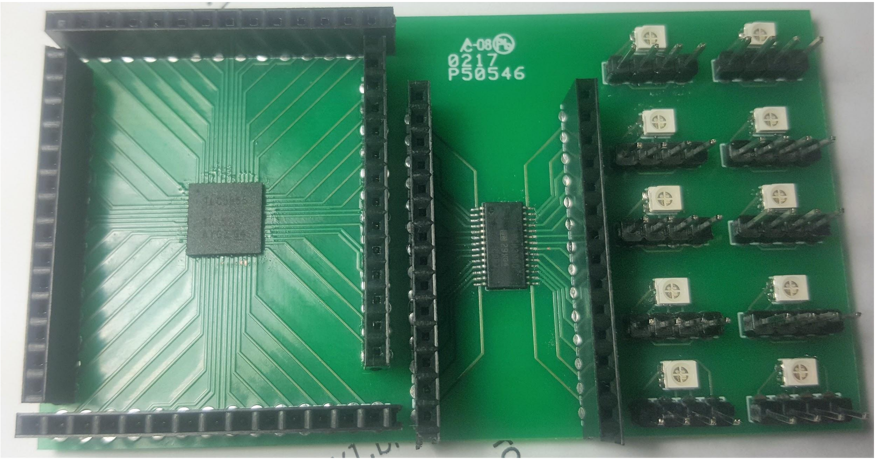
- Each LED holds it’s own value in time shifting in from the top left most LED
- The values shift to the right and then down one row adjusting to the left most LED when it reaches the farthest right it can go



Testing

- Created a breakout board
- Helped us understand our soldering limitations further
- Allowed for testing of individual components
- Allowed for testing of integration of components





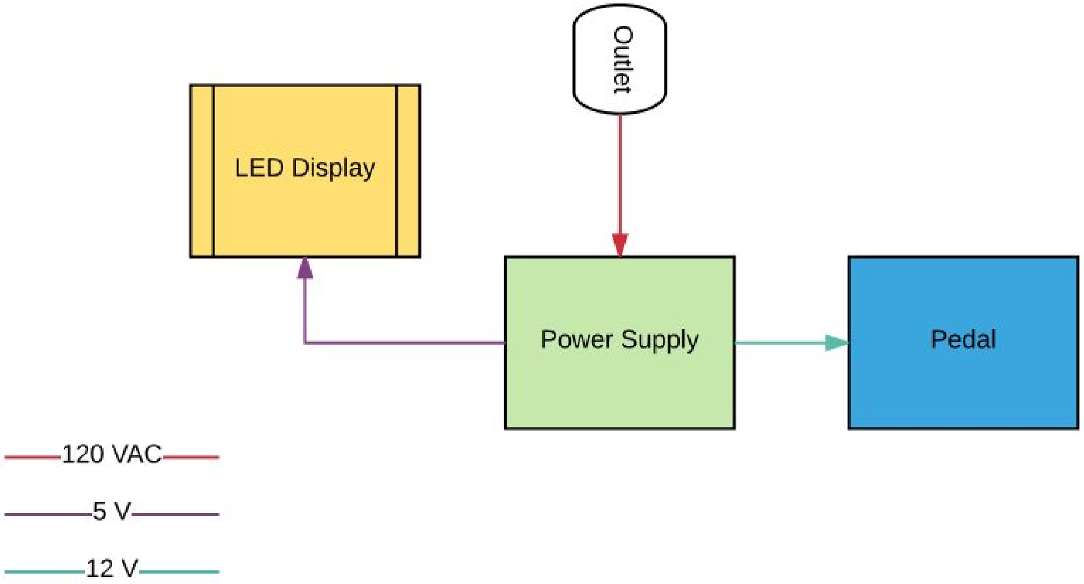
LED MFD Current Problems

- Timing
  - Time needed to capture frequency, interpret frequency, create lighting specific array and finally to output values in a time that isn’t noticeable
- Fast Frequency calculation
  - Accuracy of those readings
- Efficient Coding of Display Modes
- Analog to digital converter

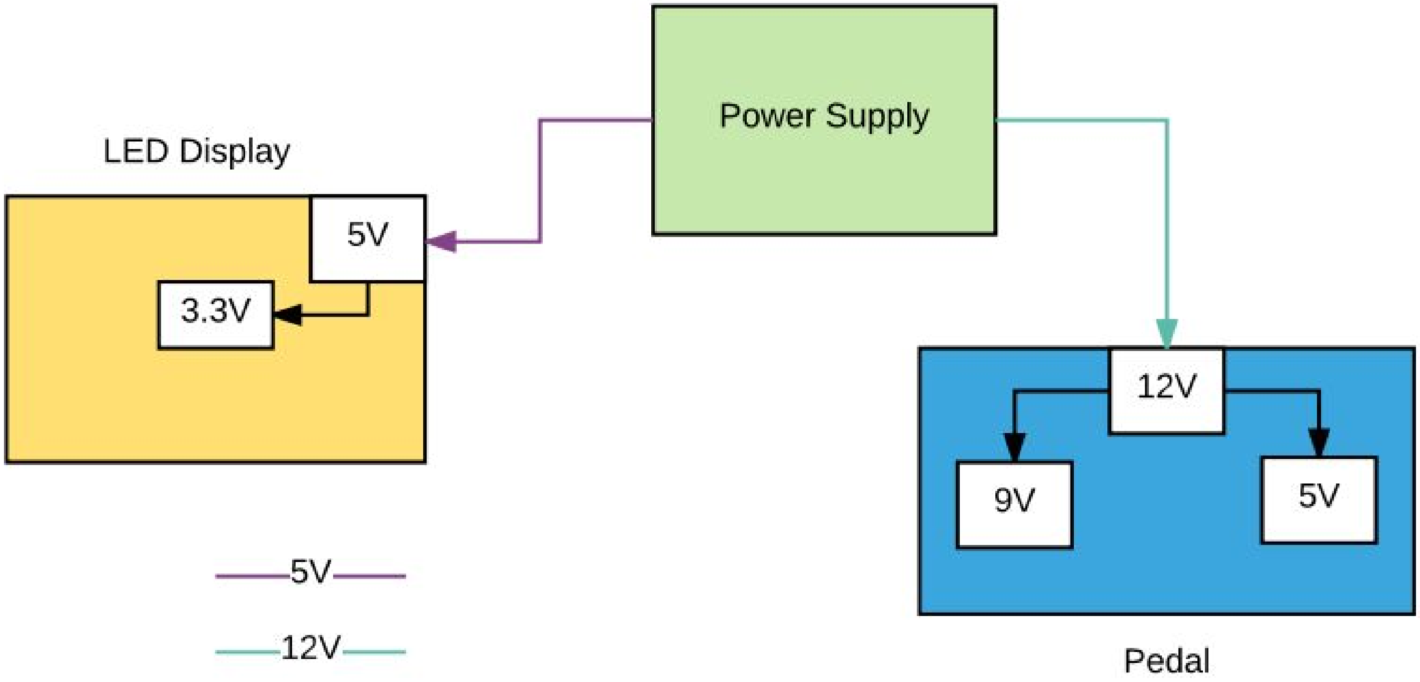
Design approach

- 1st idea: All inclusive PCB
- 2nd idea: Separate power PCB from analog and digital
- 3rd and Final idea: 3 separate PCB's

How to split the power?



Power Distribution



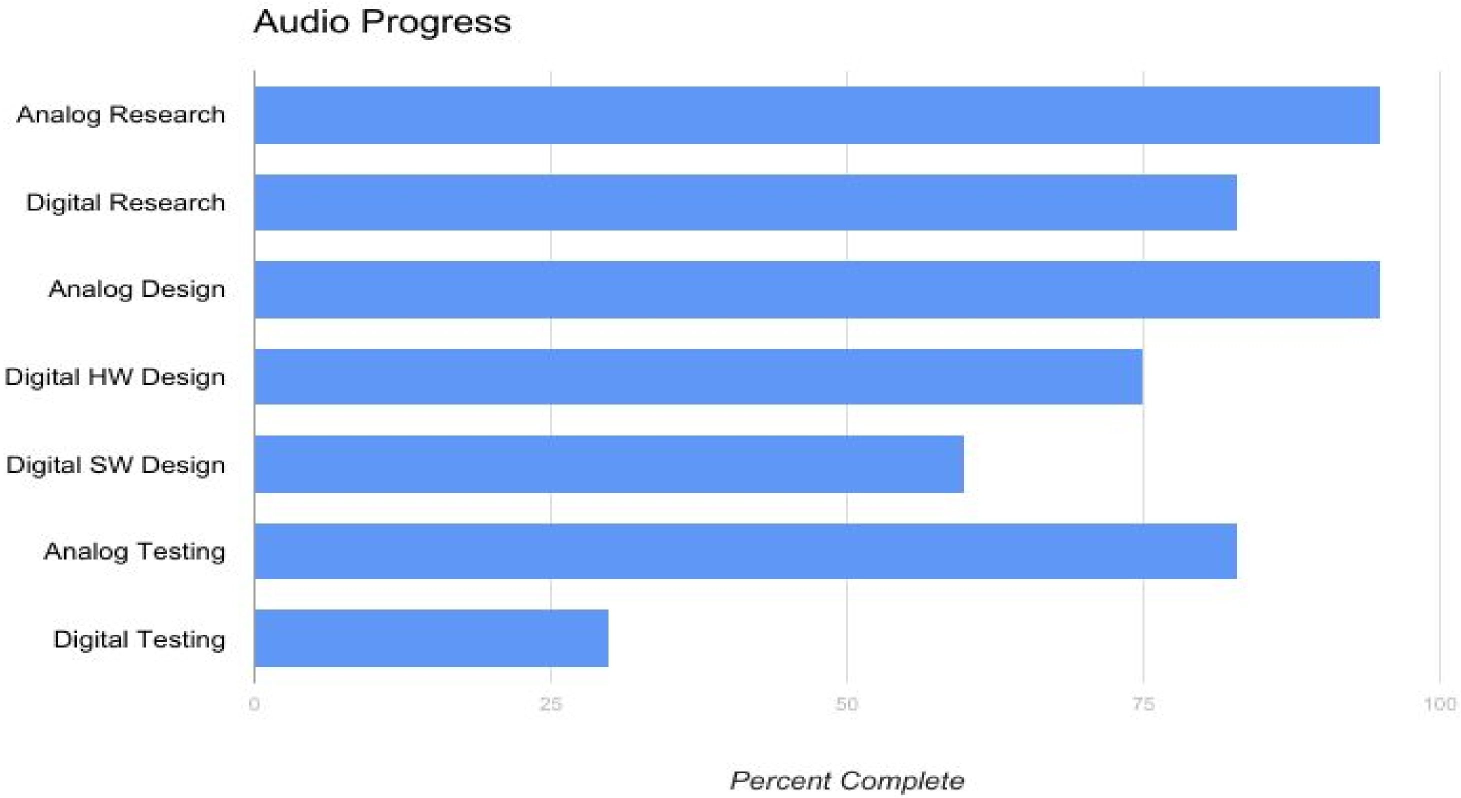
Linear Vs. Switching Regulator

- A switching regulator was chosen over a linear regulator because…
  - When switched off , it dissipates close to no power
  - Can be a boost, buck, or an inverter
  - Little heat loss, efficient
  - Can be used for DC to DC conversion
- MC34063 was chosen because ….
  - Capable of step-up/down/inverting
  - Has a wide voltage supply range
  - A full bridge rectifier circuit may still be used to help with noise

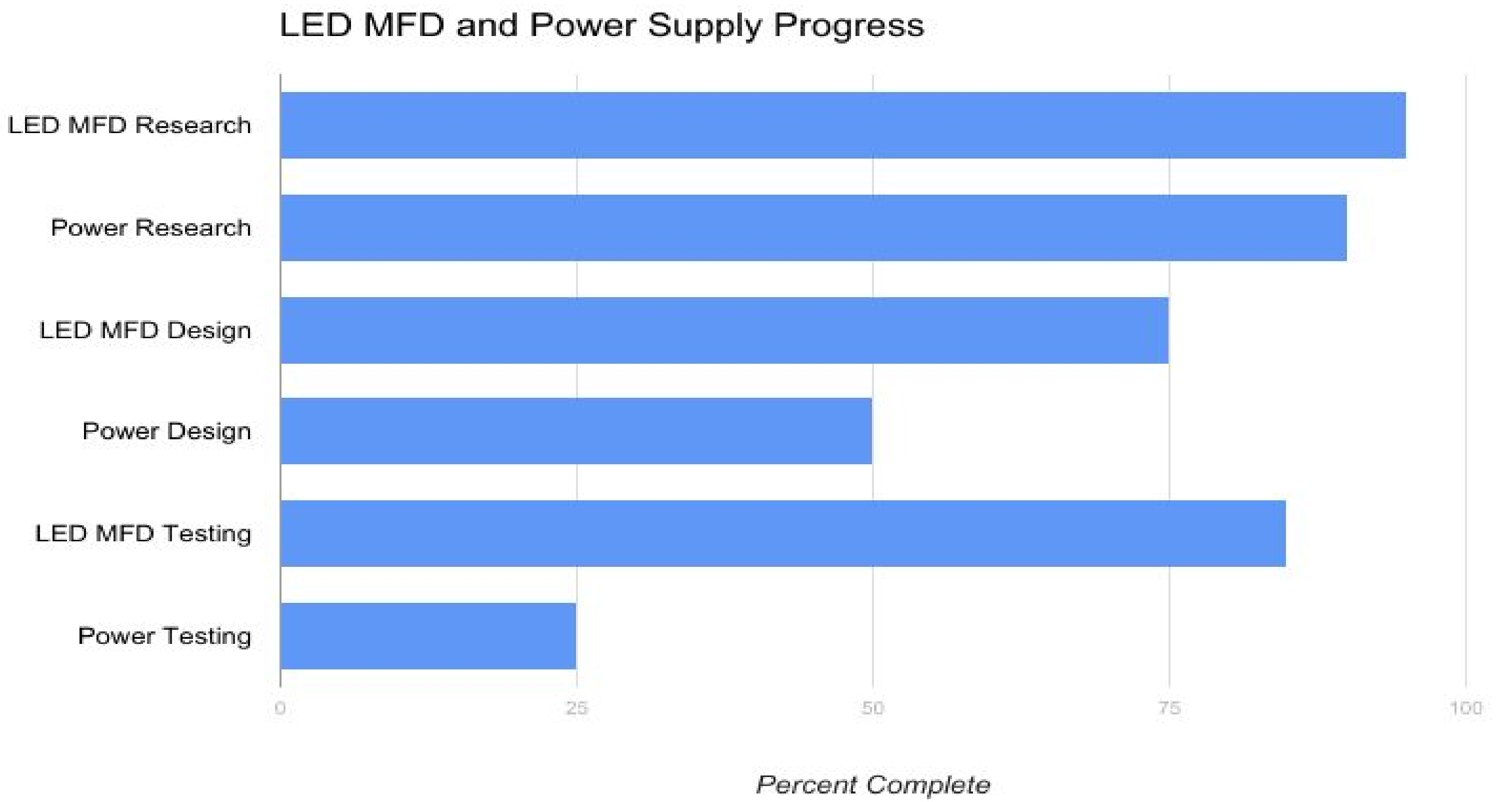
Success/Difficulties

- Difficulties
  - Design implementation
  - Power Distribution
  - PCB Design
  - Linear vs Switching ....
- Successes
  - Final Design idea
  - PCB Design close to completion

Administrative Content



Administrative Content



Current Build Budget

LED MFD Breakdown		
Part	Qty	Price
PCM3060	1	$6.15
ATmega2561	1	$12.07
TLC5955	4	$24.08
RGB LED	64	$24.32
PCB	1	$52
Total		$118.62

Audio Unit Breakdown		
Part	Qty	Price
OPA1641	4	$11.52
OPA1642	1	$4.20
LM13700	1	$1.36
R, C, & Diodes		≅$10
3PDT	4	$14.36
PCM3060	3	$18.45
STM32F405ZGT6	1	$12.29
IS61WV51216BLL-10TLI	1	$14.64
WM8731	1	$4.50
RRLCD204WB	1	$10.99
PCB	2	$70
Total		$172.28

Questions?