G12 PedalVision

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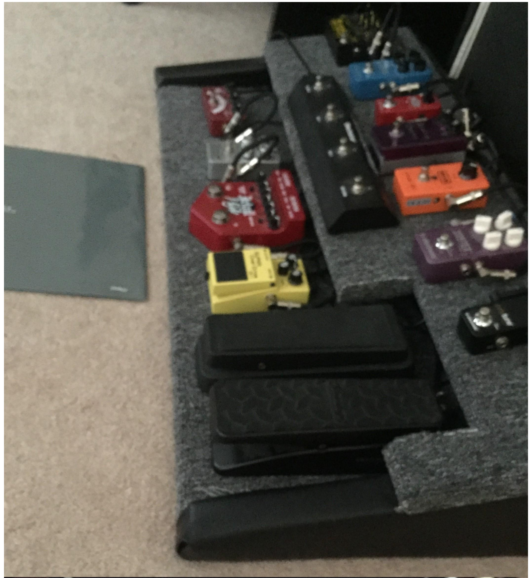
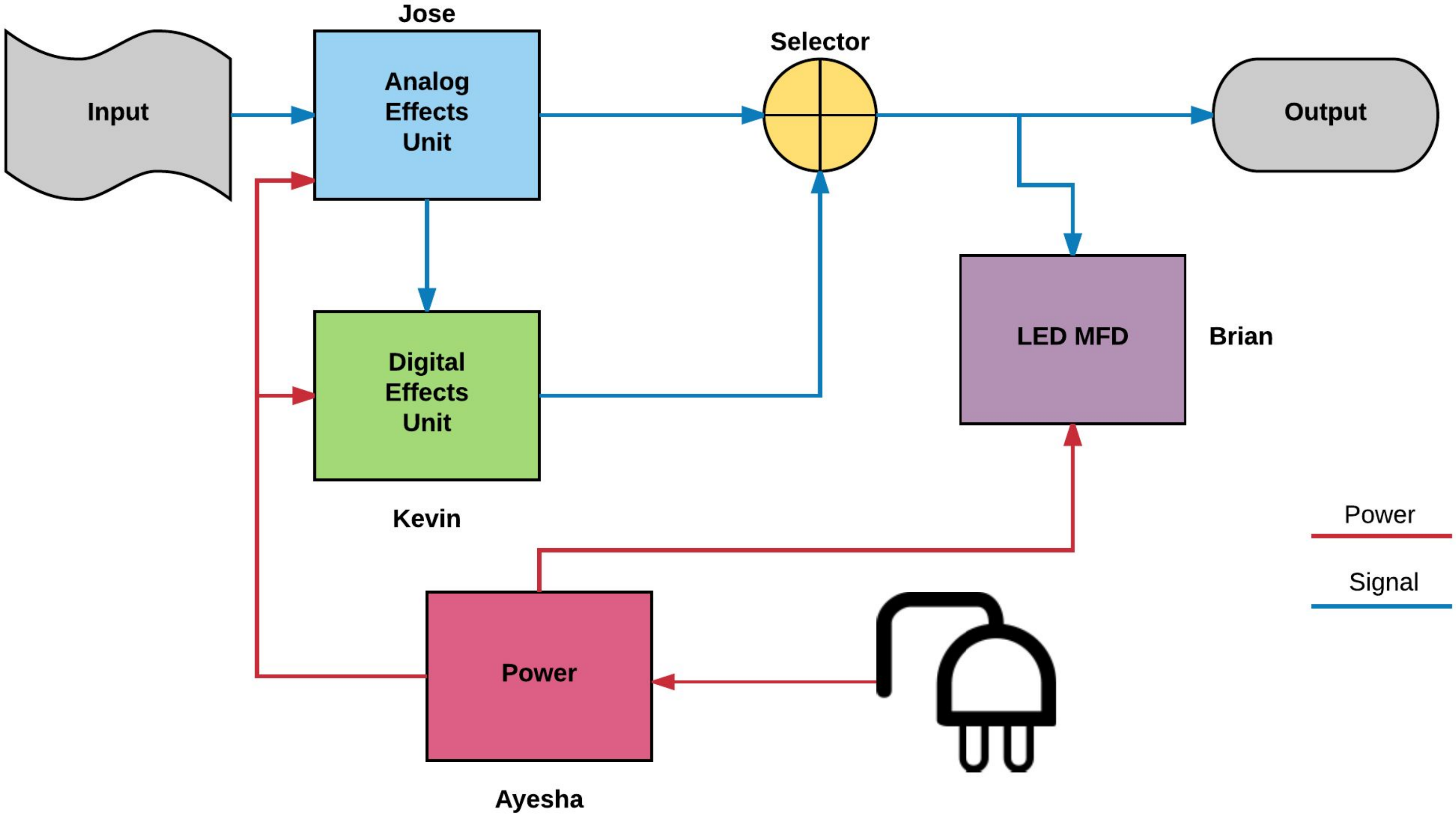
Motivation / Objectives

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 and engaging with LED matrix feedback display
5. More portable and less expensive

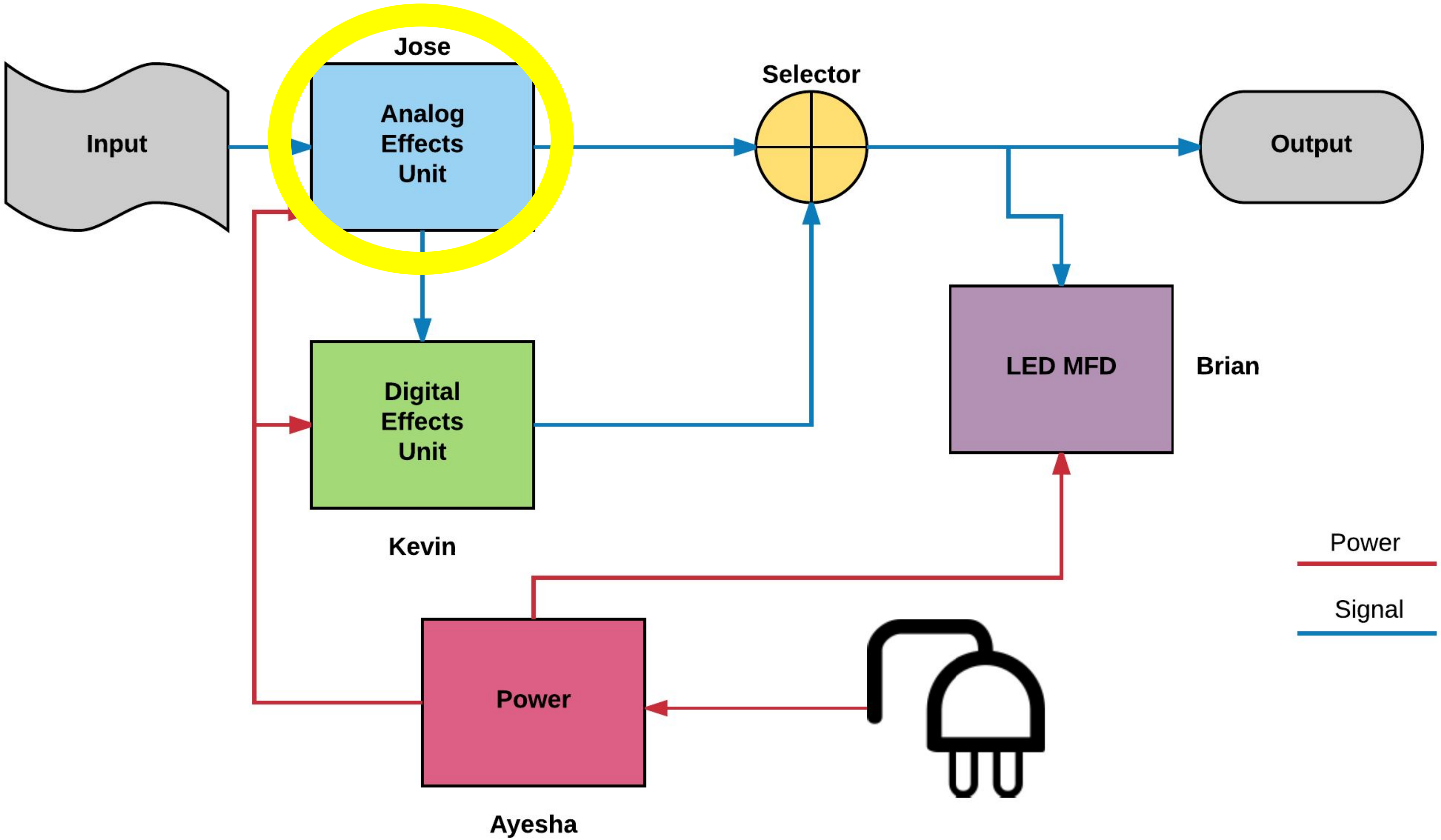


Project Overview



Requirement Specifications

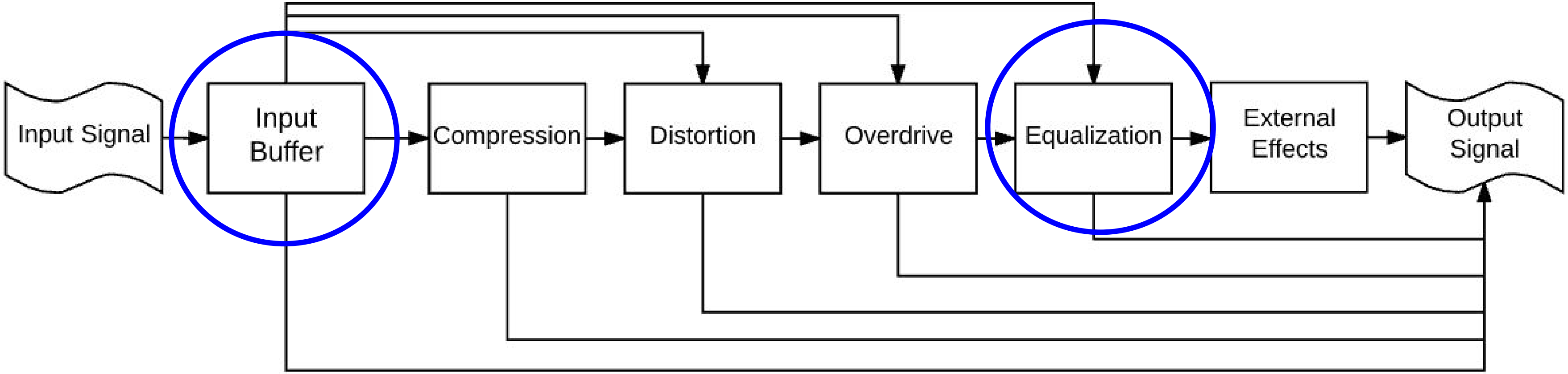
- Analog effects
  - Input impedance of at least 500K
  - Output impedance of no more than 10K
  - Bypass full frequency response from 20 Hz-20 KHz
  - Knobs to adjust volume, drive, and tone
  - Controls to toggle effect on and off
- Digital effects
  - DSP chip/microcontroller
  - LCD User interface
  - Knobs for adjusting digital values
  - 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 cm^3
  - $300 limit for audio
  - $200 limit for LED system



Jose
Input
Analog Effects Unit
Selector
Output
Digital Effects Unit
LED MFD
Brian
Kevin
Power
Signal
Power
Ayesha

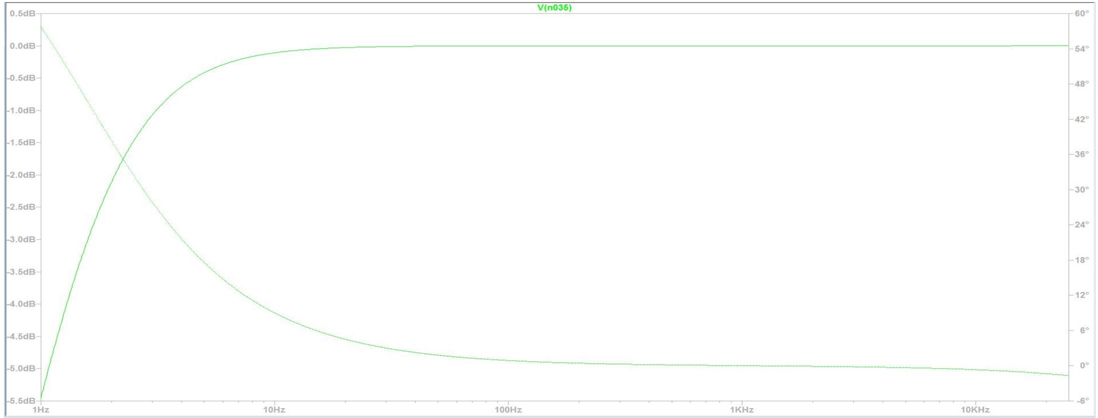
Analog Effects Signal Chain

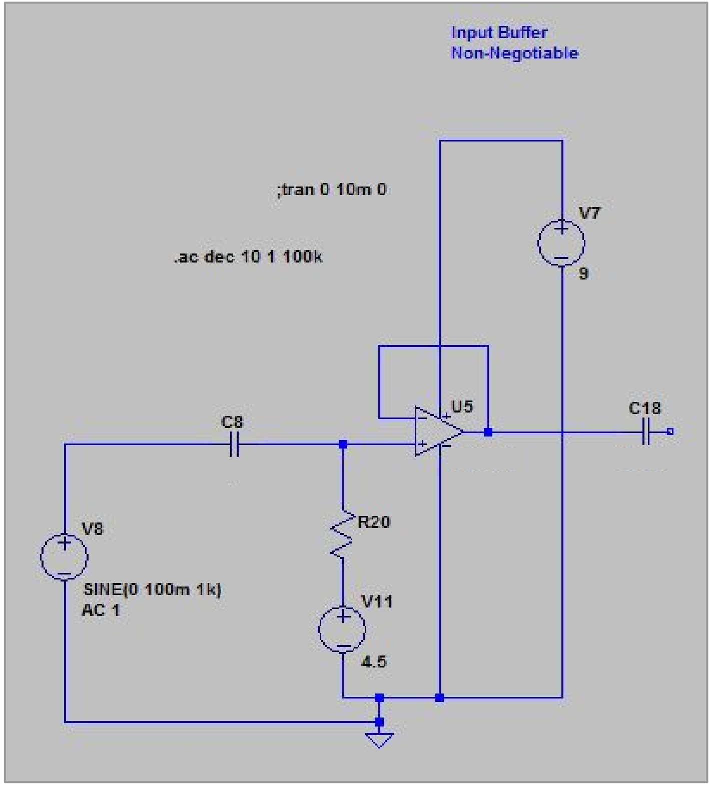
- Order Matters
- Why?



Input Buffer/ External Effects Interface

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



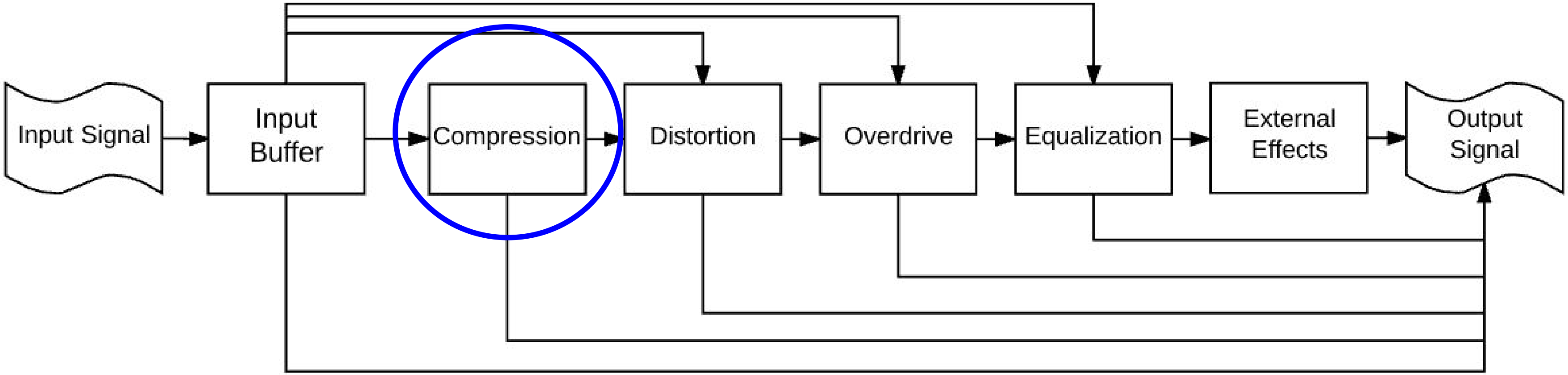


Op amp selection

- Why OPA164x?

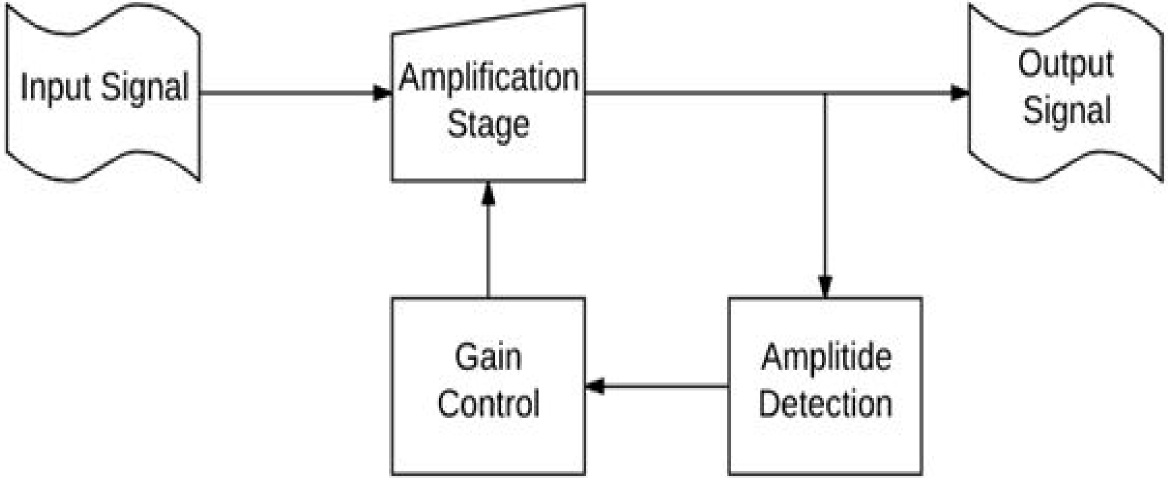
Op Amp Model	Input Impedance	Output Impedance @1k	Gain Bandwidth Product	Input Voltage Noise @ 1KHz	Total Harmonic Distortion	Price
TL07xx	10^12 Ω	Not in data sheet	3 MHz	18 nV/√Hz	0.003%	Not considered
OPA827	10^13 Ω	20 Ω	22 MHz	4 nV/√Hz	0.00004%	$10.13
OPA164x	10^13 Ω	10 Ω	11 MHz	5.1 nV/√Hz	0.00005%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

Analog Effects

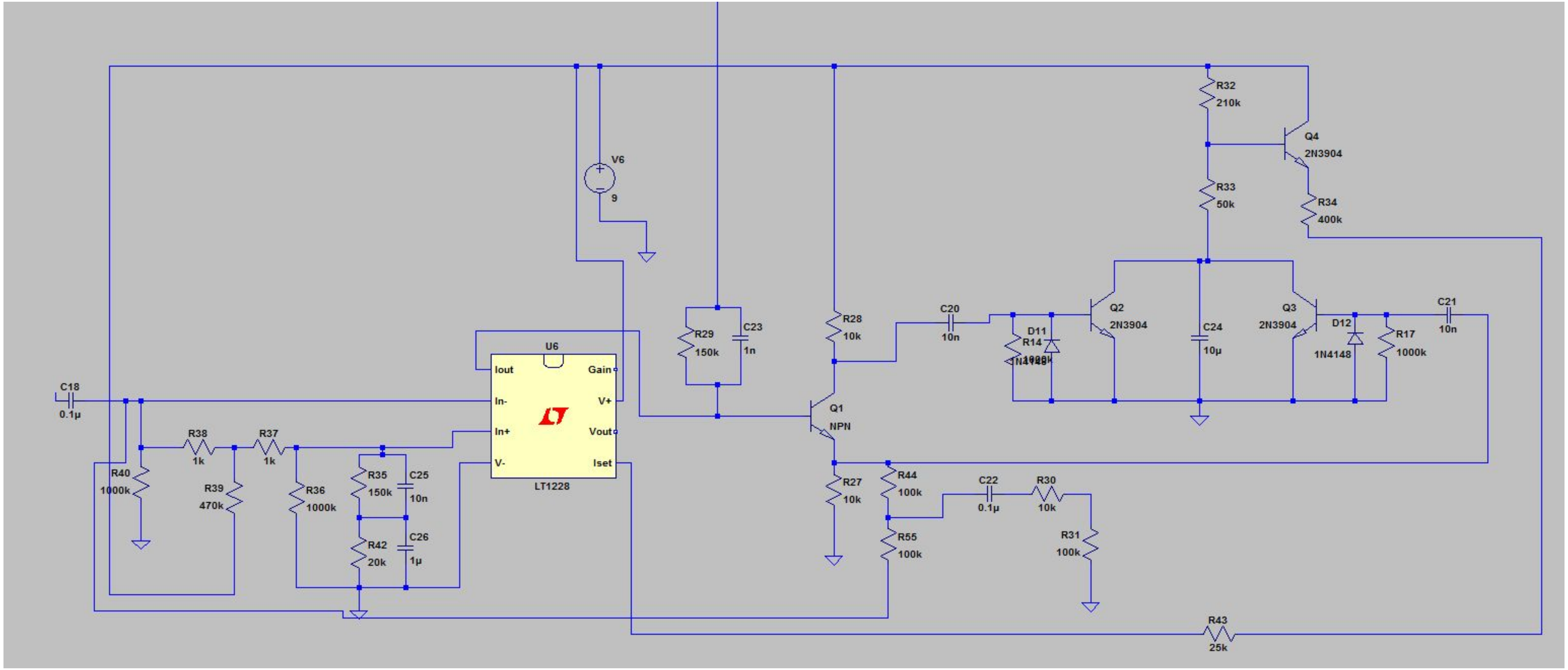


Compression

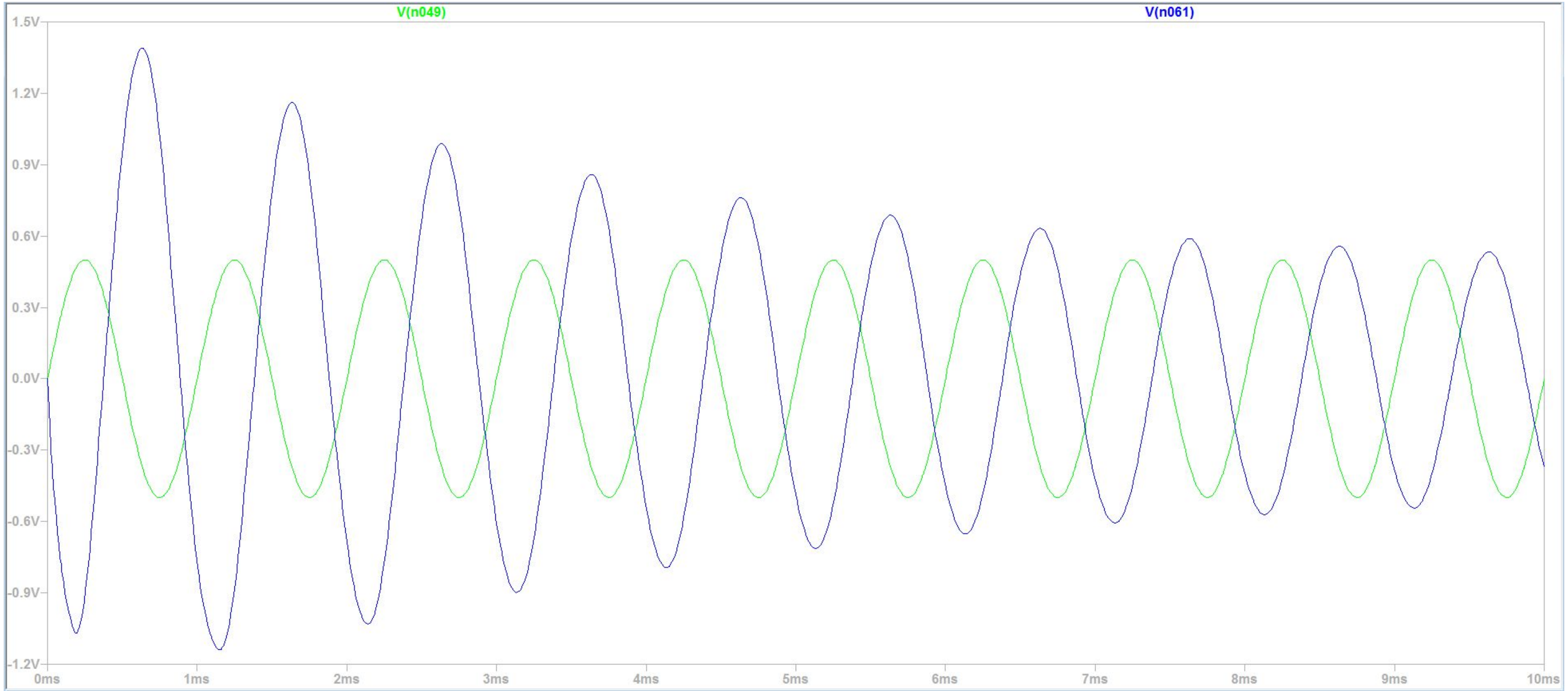
- LM13700
- Amplify softer signal
- “Compress” larger signal
- Add sustain



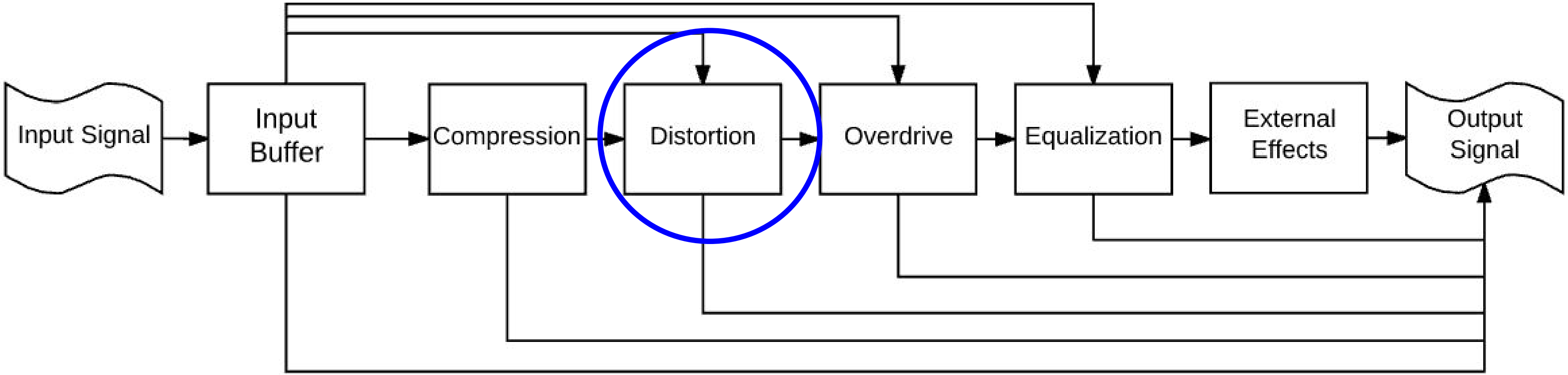
Compression



Compression Output

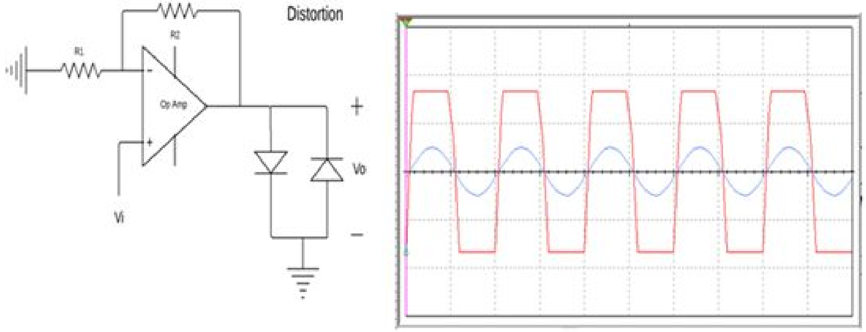


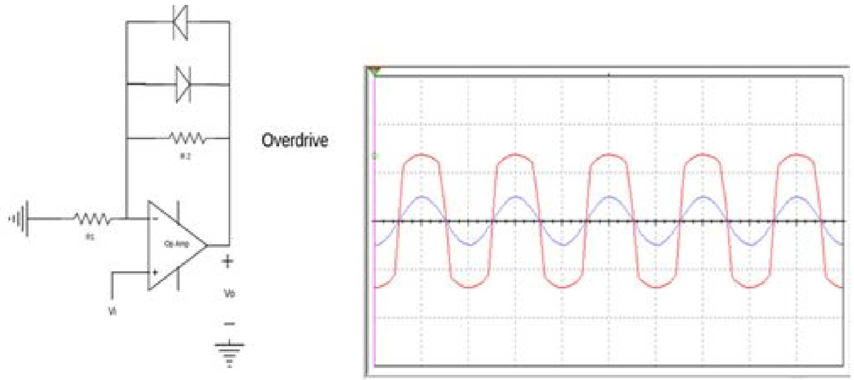
Analog Effects



Distortion and Overdrive

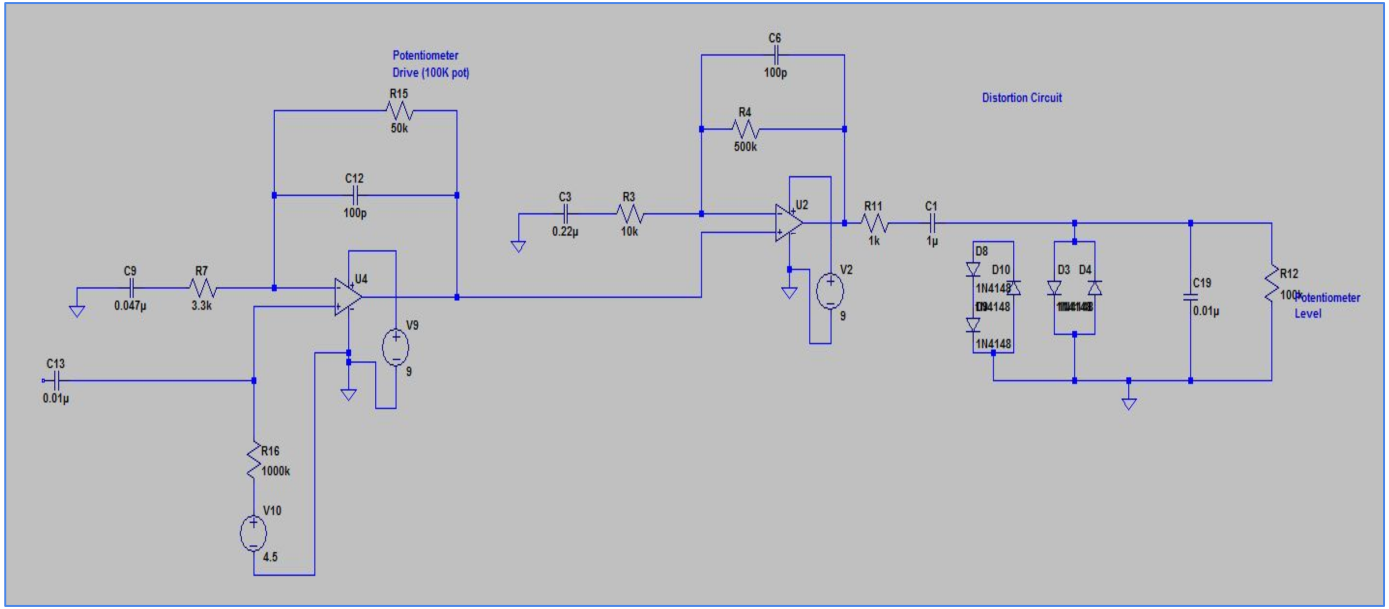
- Both use diodes to create clipping
- Symmetric vs Asymmetric clipping
- Why two amplification stages?



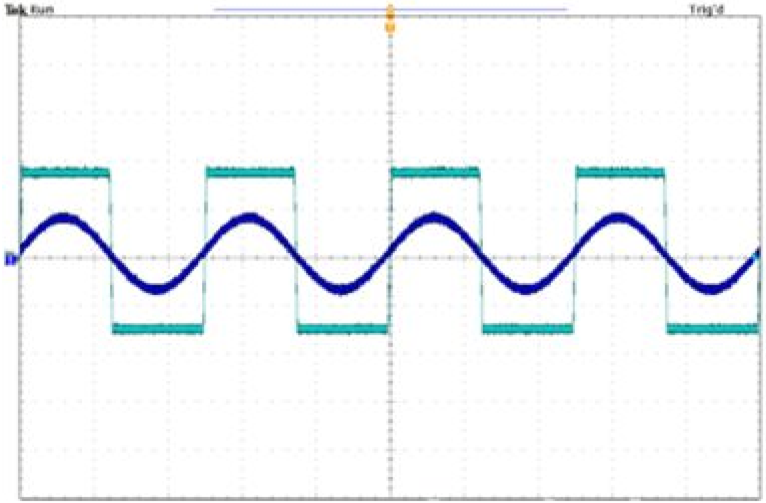


Distortion

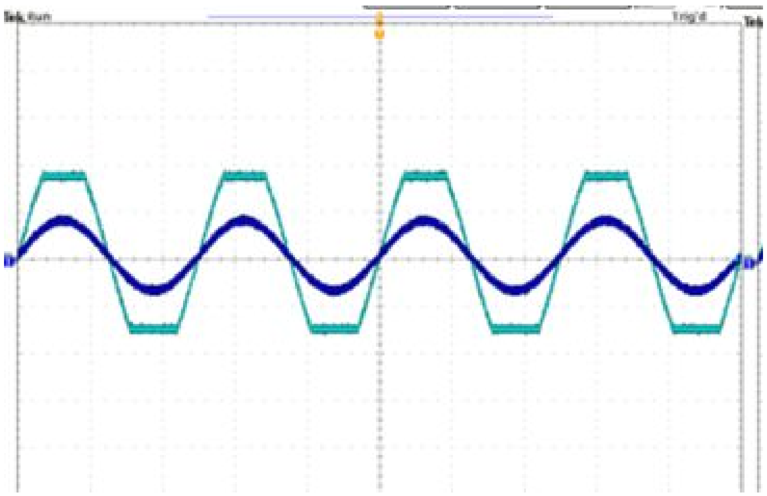
- Distortion at any volume level
- Hard clipping
- Adds some compression



Simplified Distortion Outputs

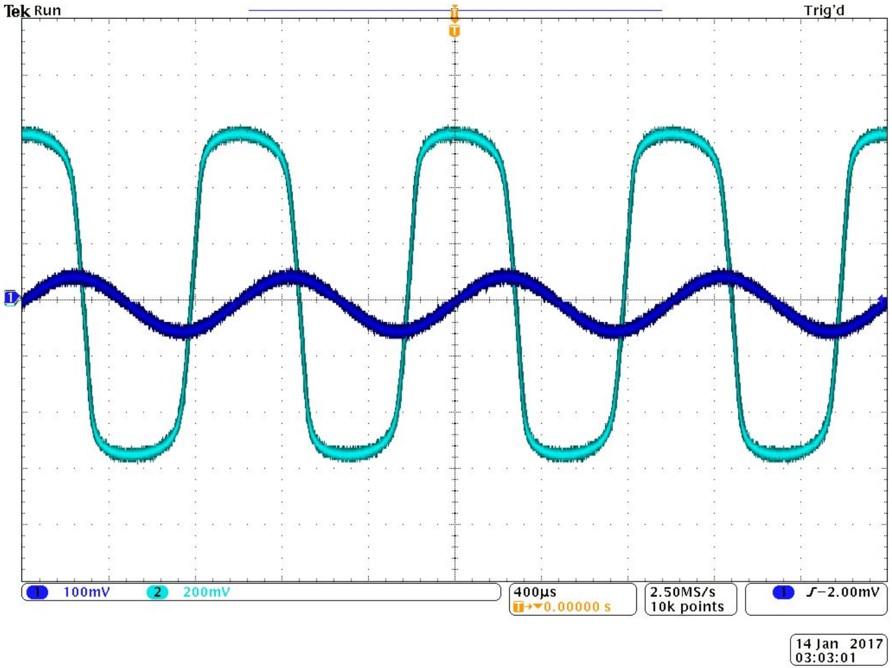


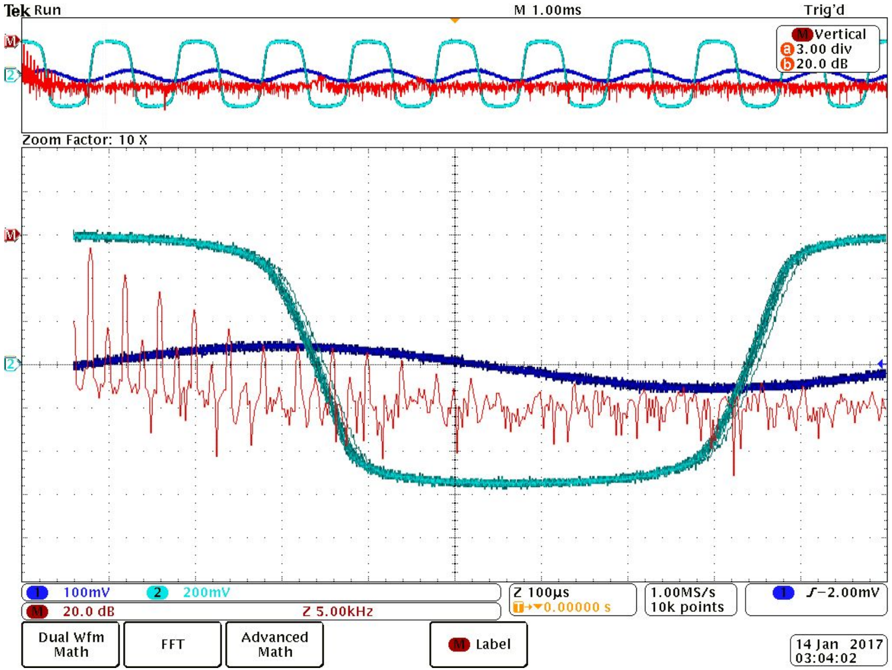
High Gain



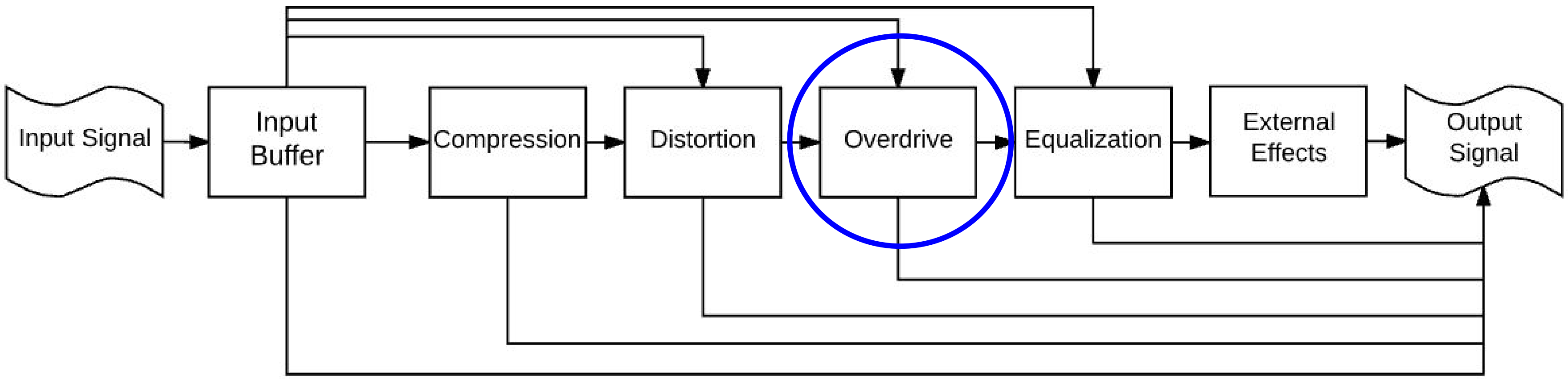
Low Gain

Actual Distortion Circuit Output



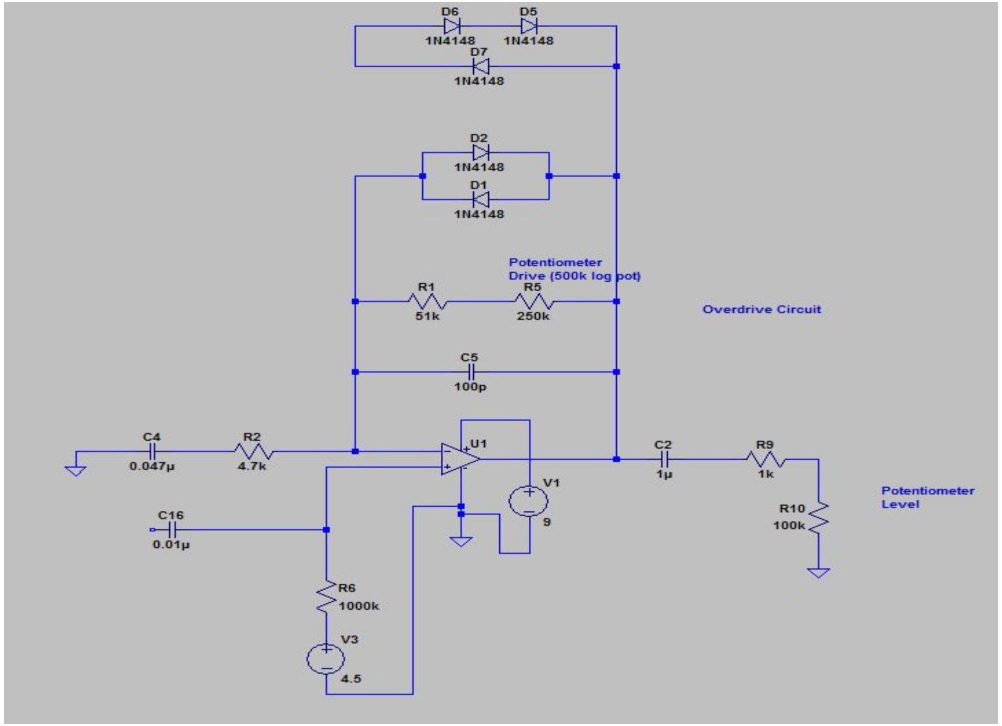


Analog Effects

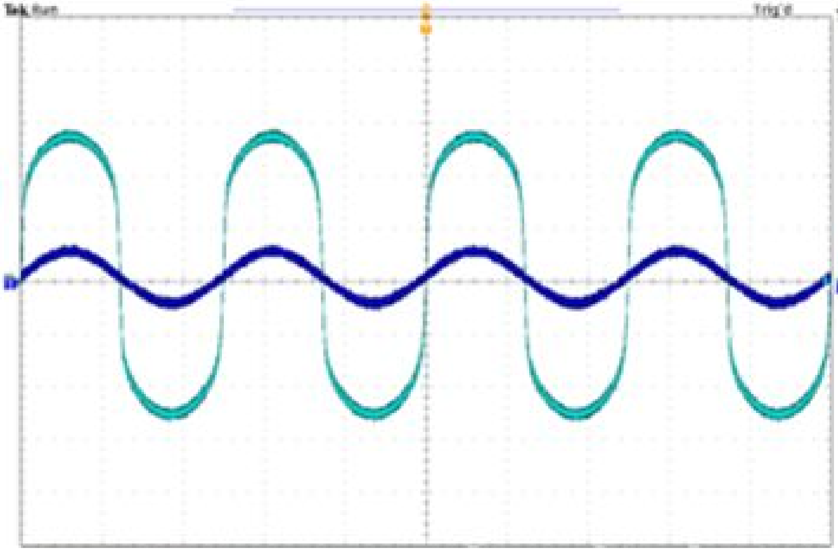


Overdrive

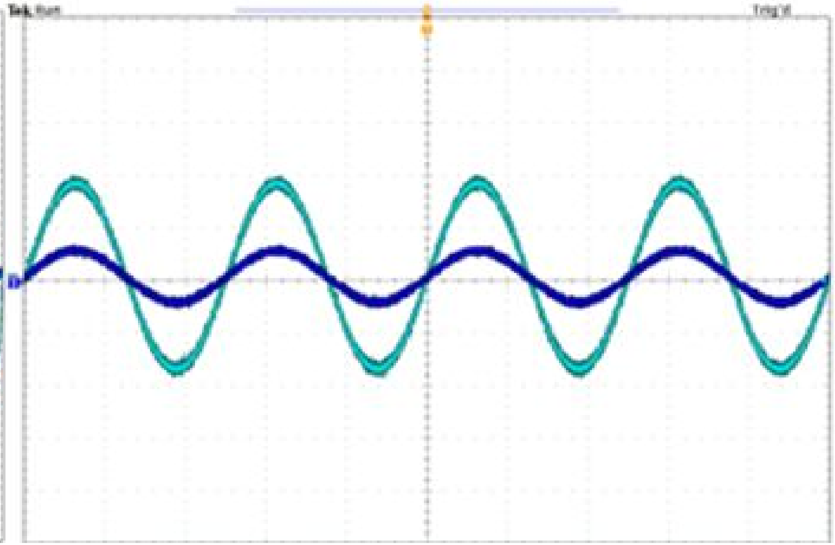
- More distortion as volume level increase
- Soft Clipping
- Can be used as a volume boost after other distortion effects



Simplified Overdrive Outputs

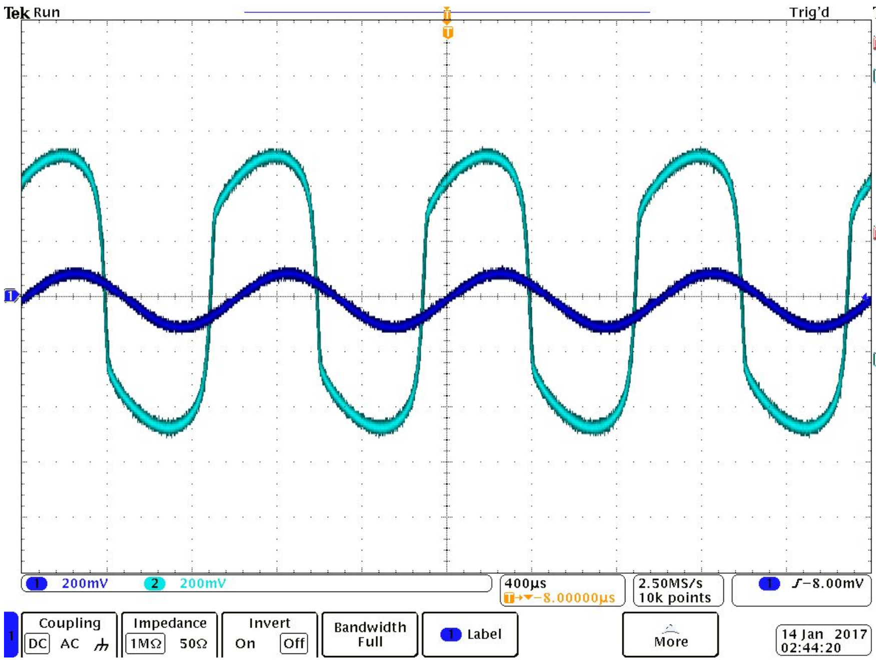


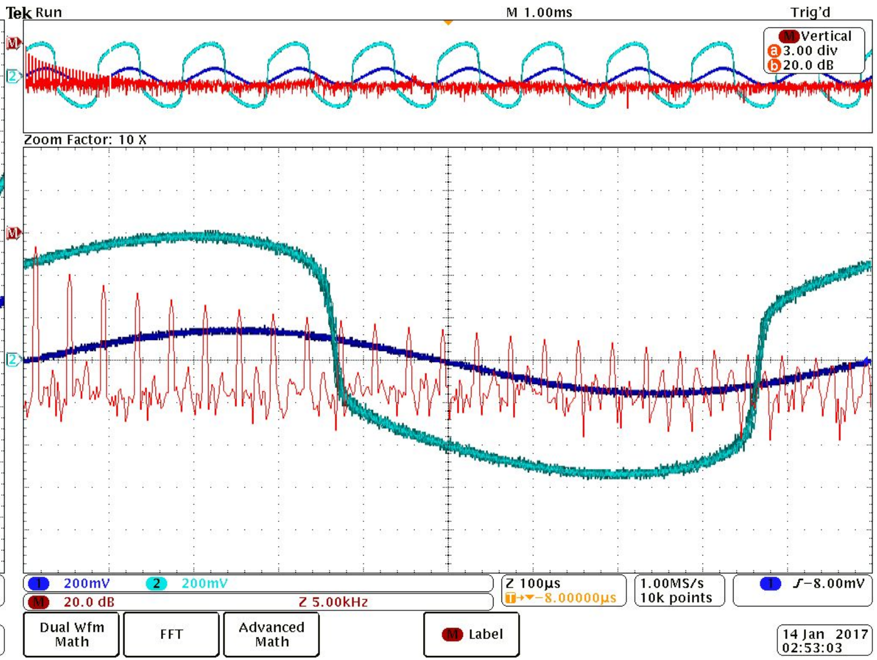
High Gain



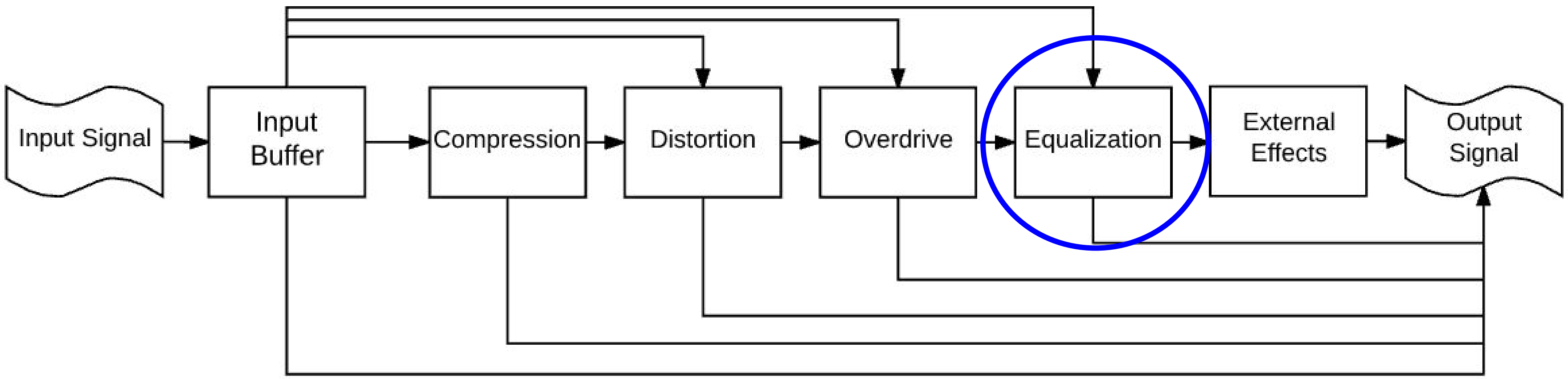
Low Gain

Actual Overdrive Circuit Output





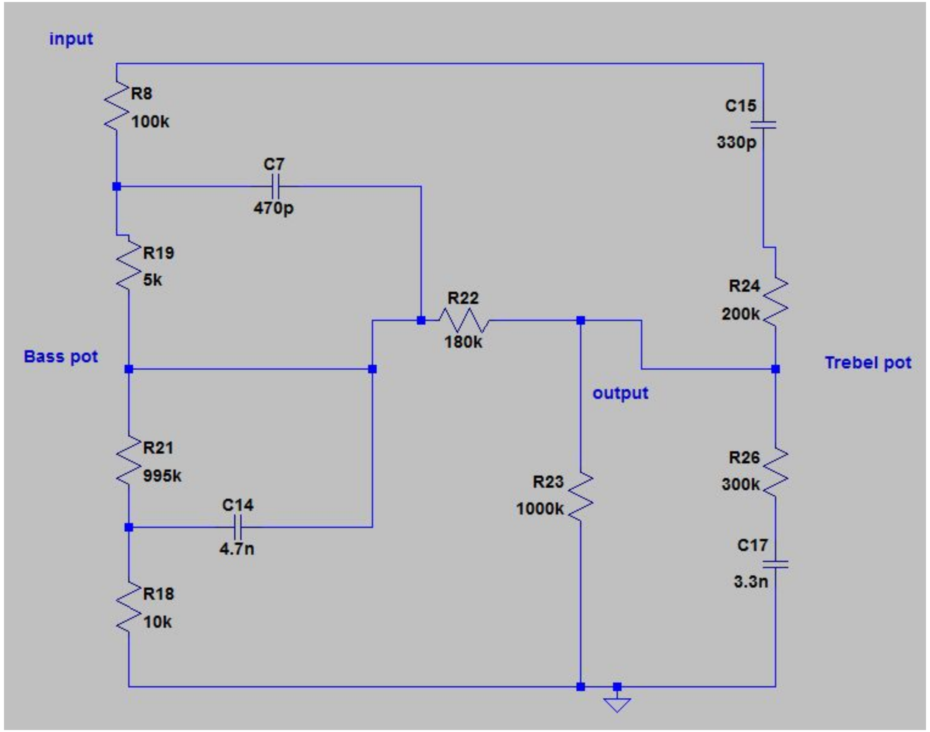
Analog Effects



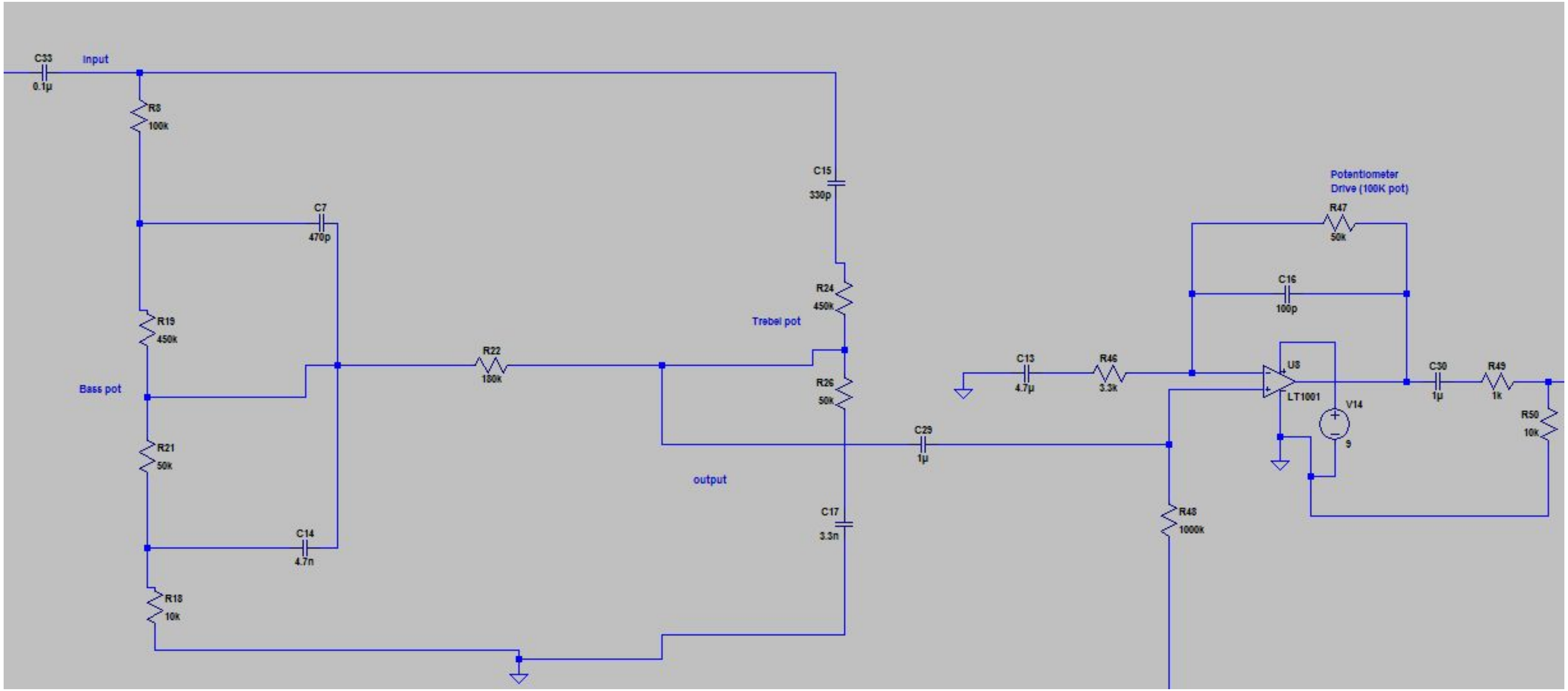
Tone Stack

- 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

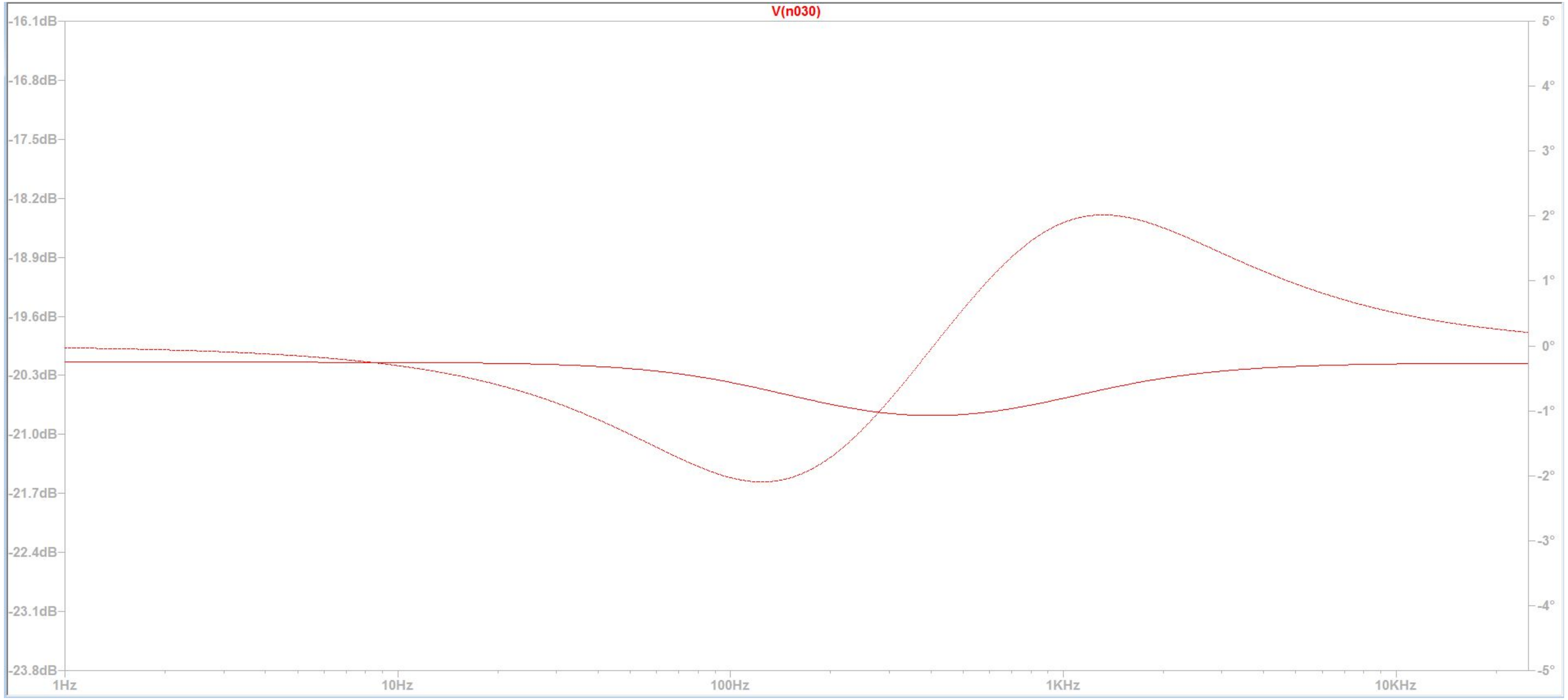


Complete Tone Stack



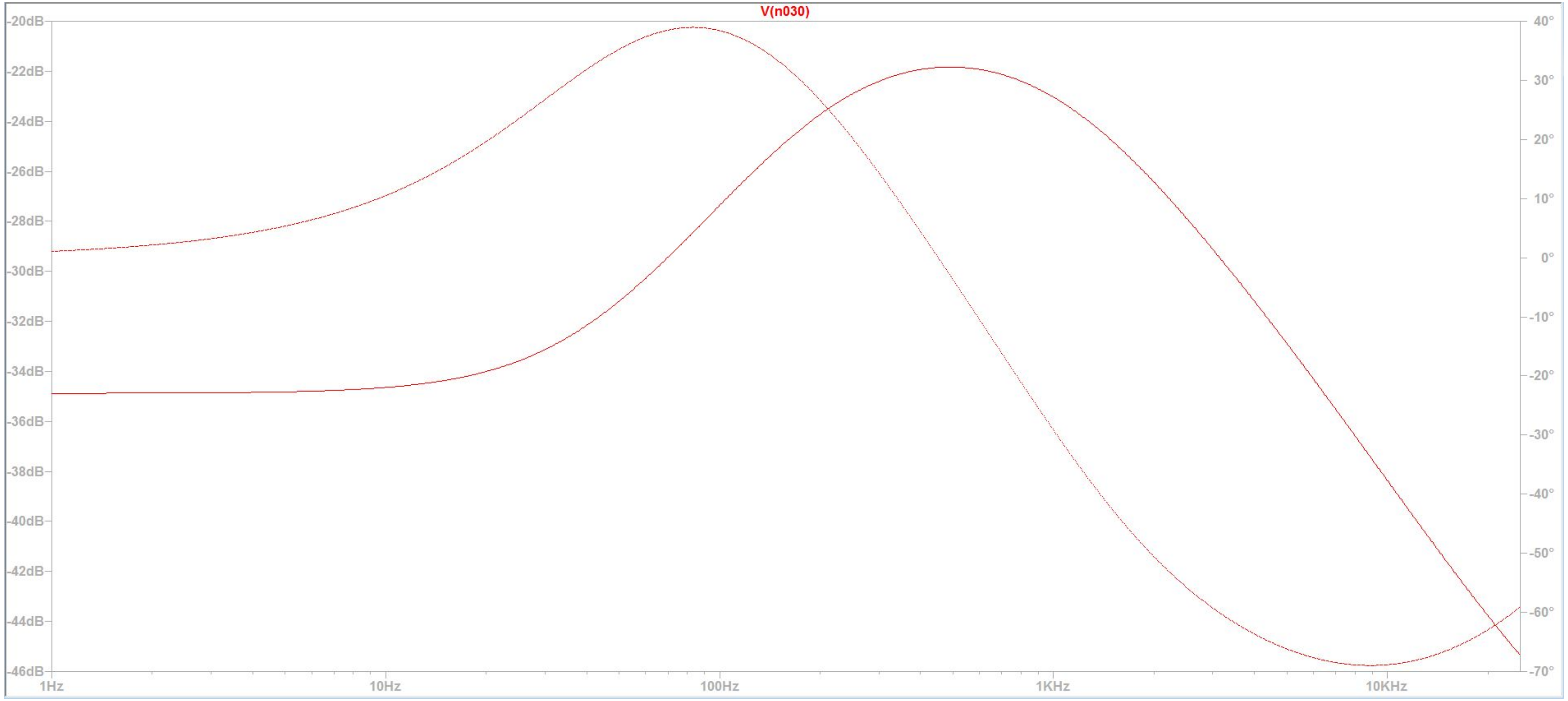
Tone Stack Simulation Frequency Sweep

Flat Band



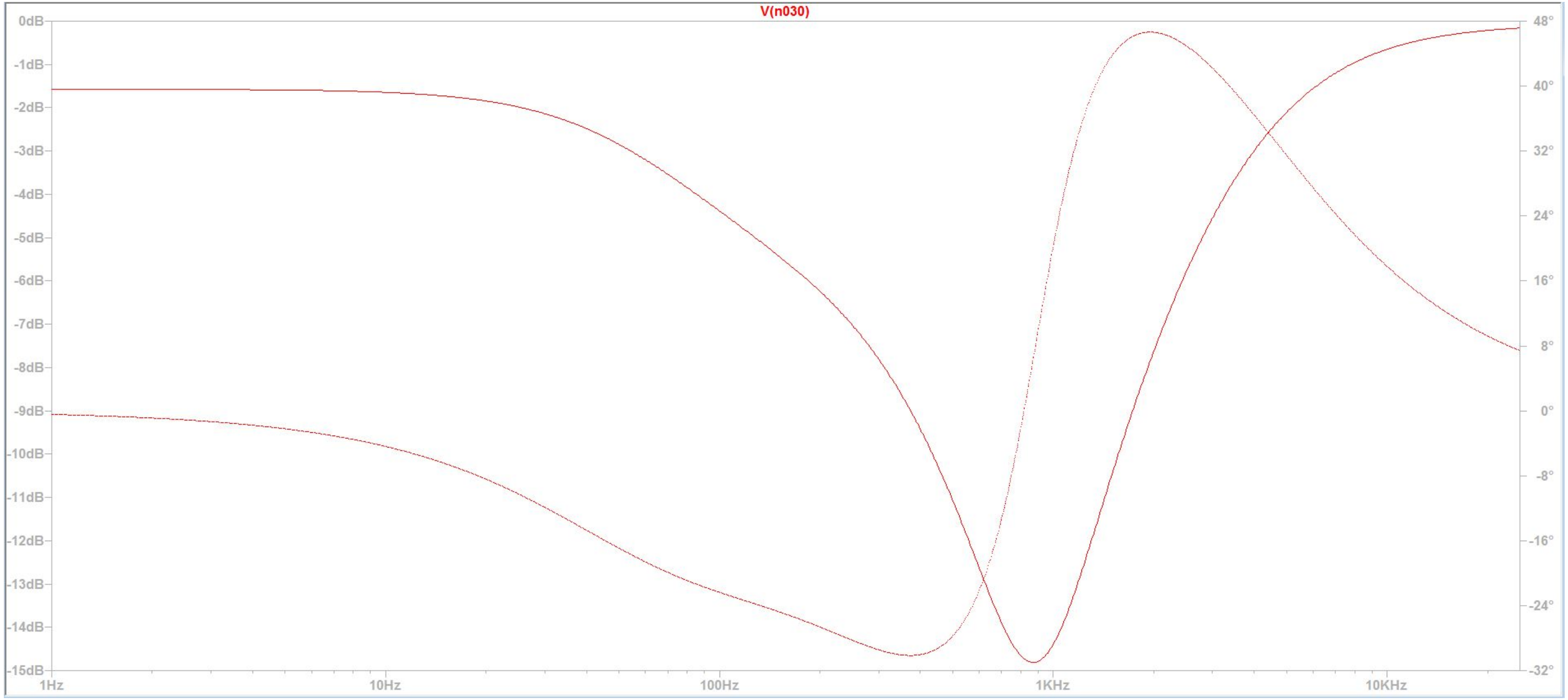
Tone Stack Simulation Frequency Sweep

- Mid Boost



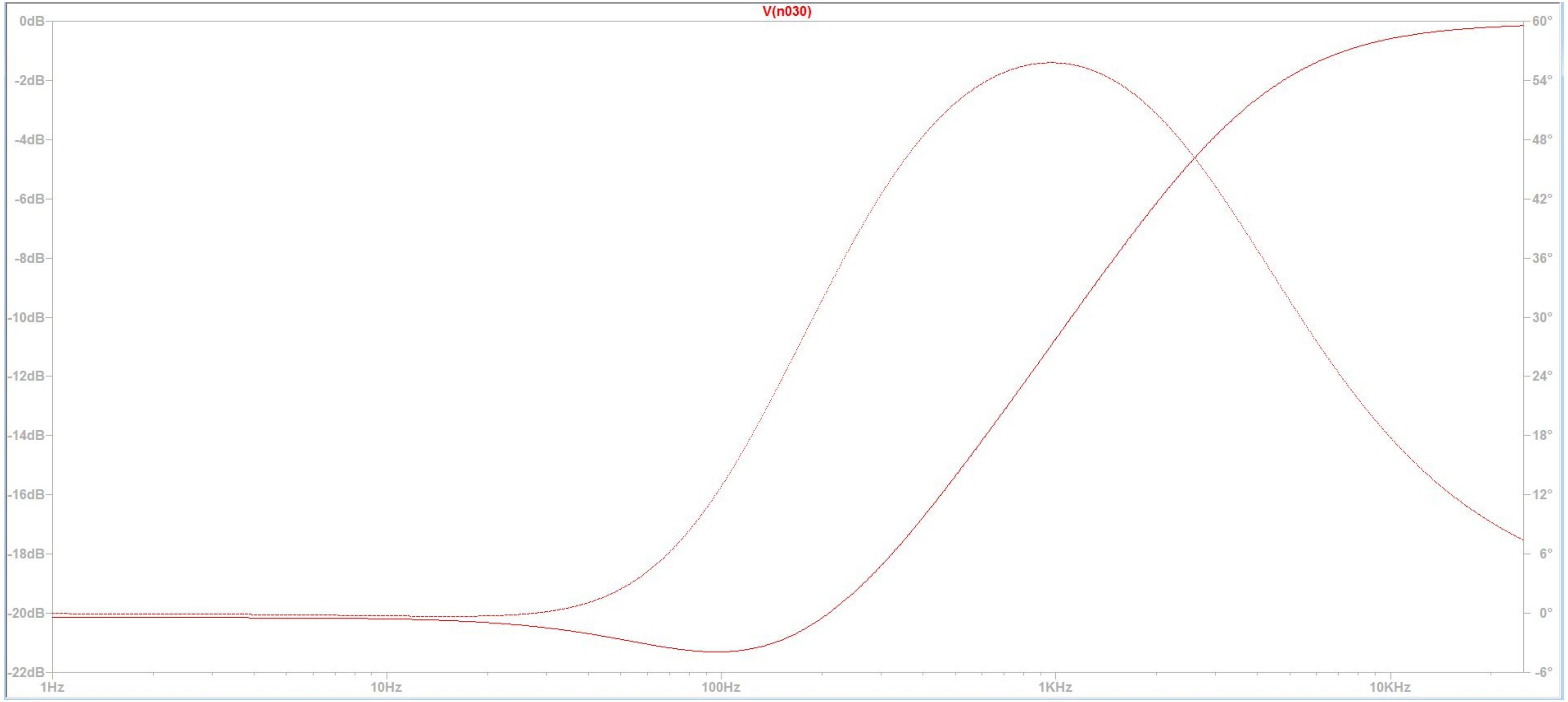
Tone Stack Simulation Frequency Sweep

- Mid Scoop



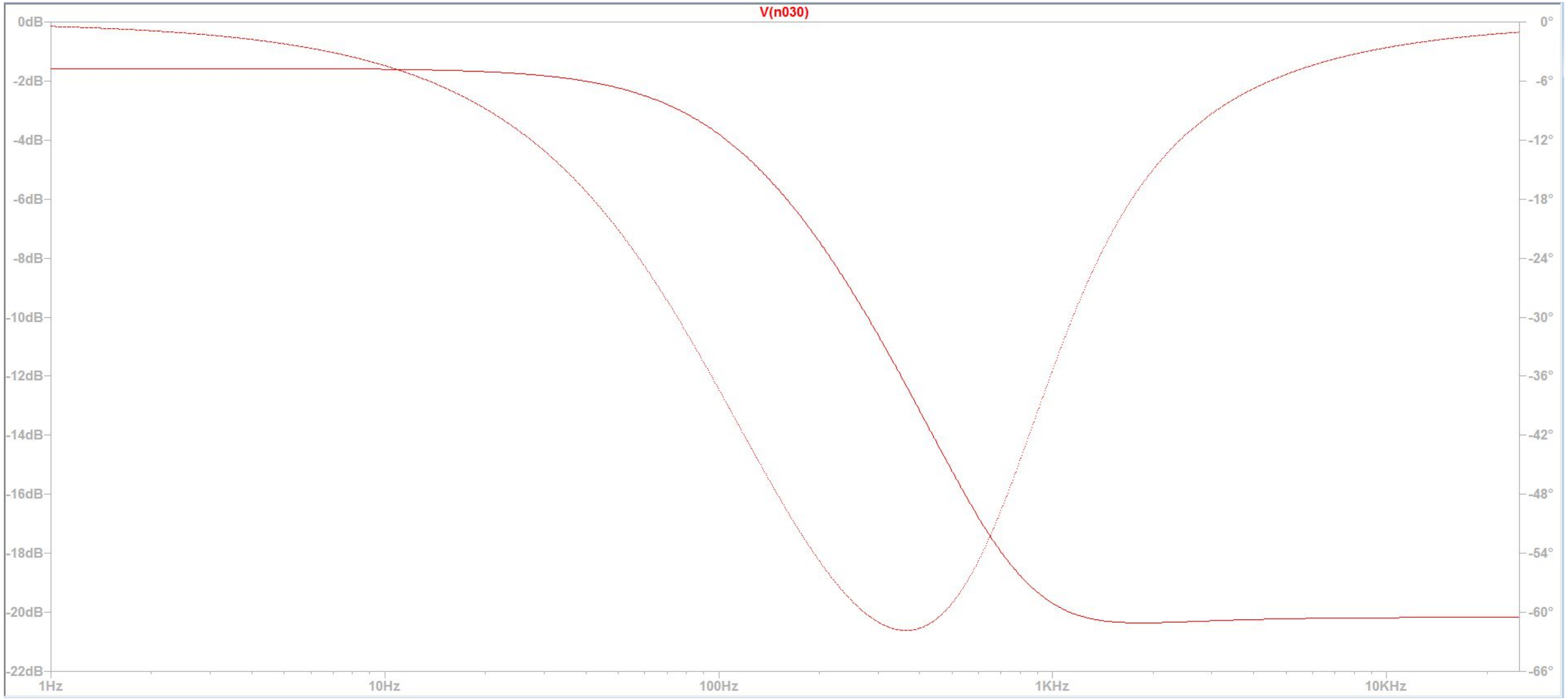
Tone Stack Simulation Frequency Sweep

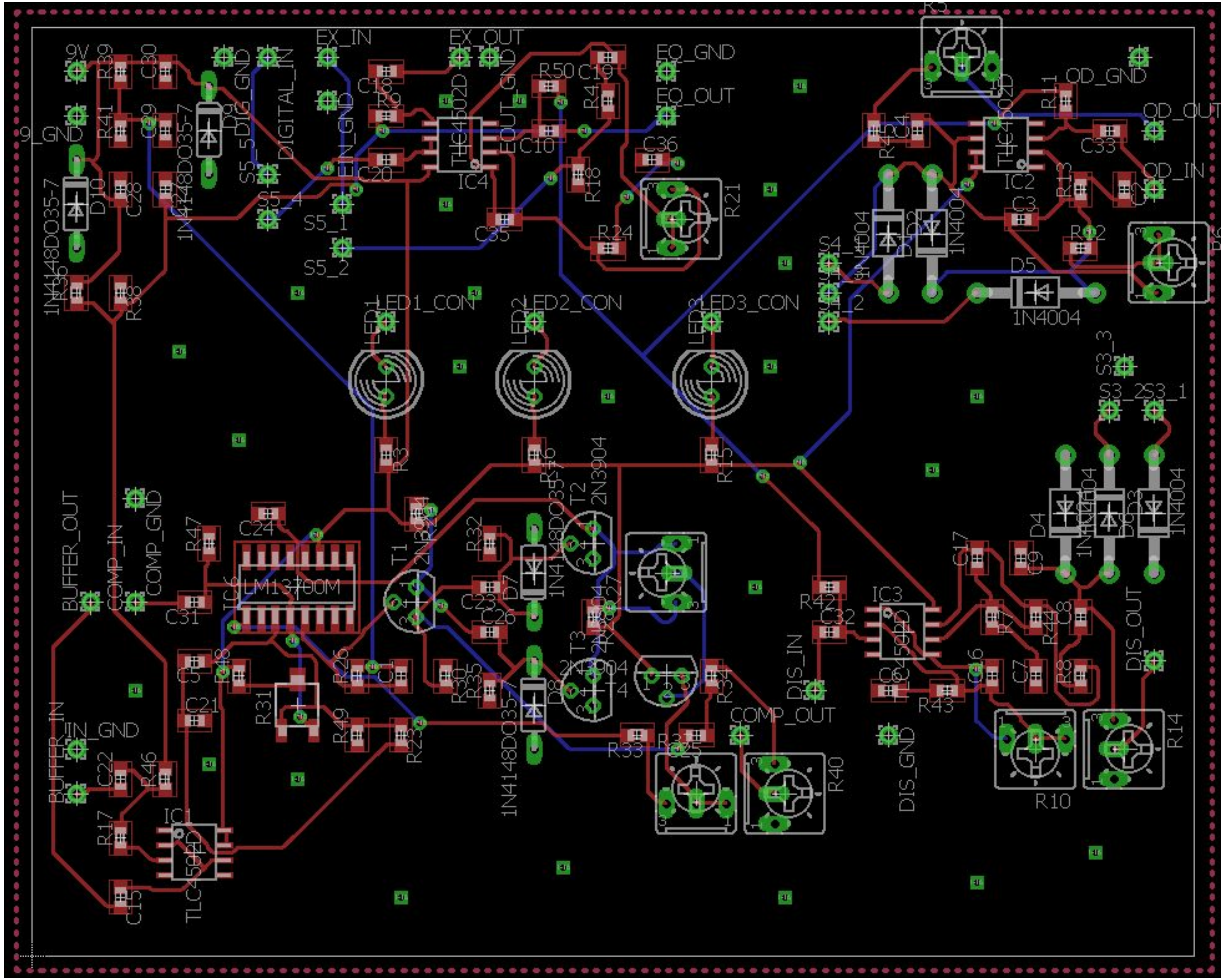
- Highpass



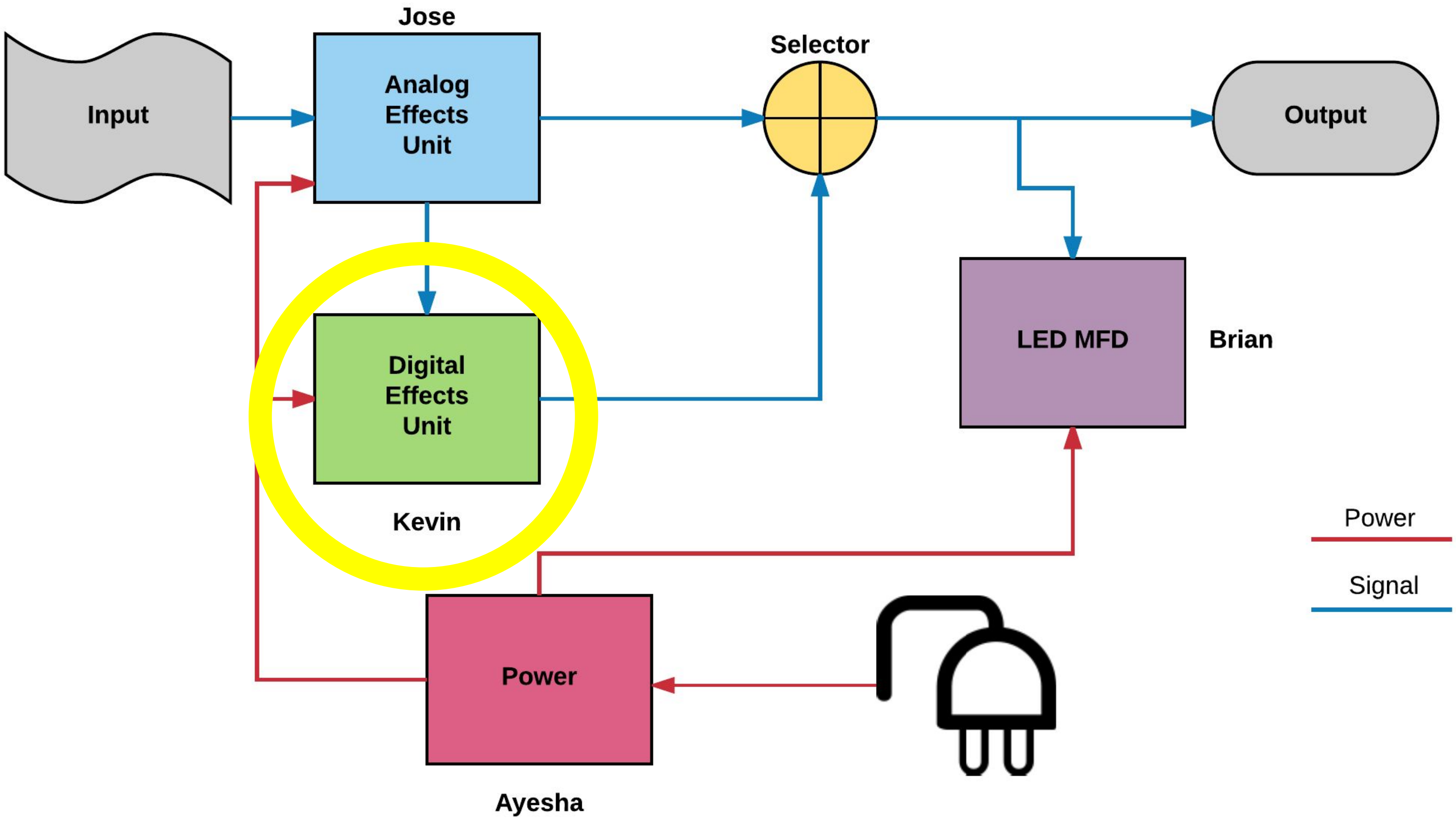
Tone Stack Simulation Frequency Sweep

- Lowpass

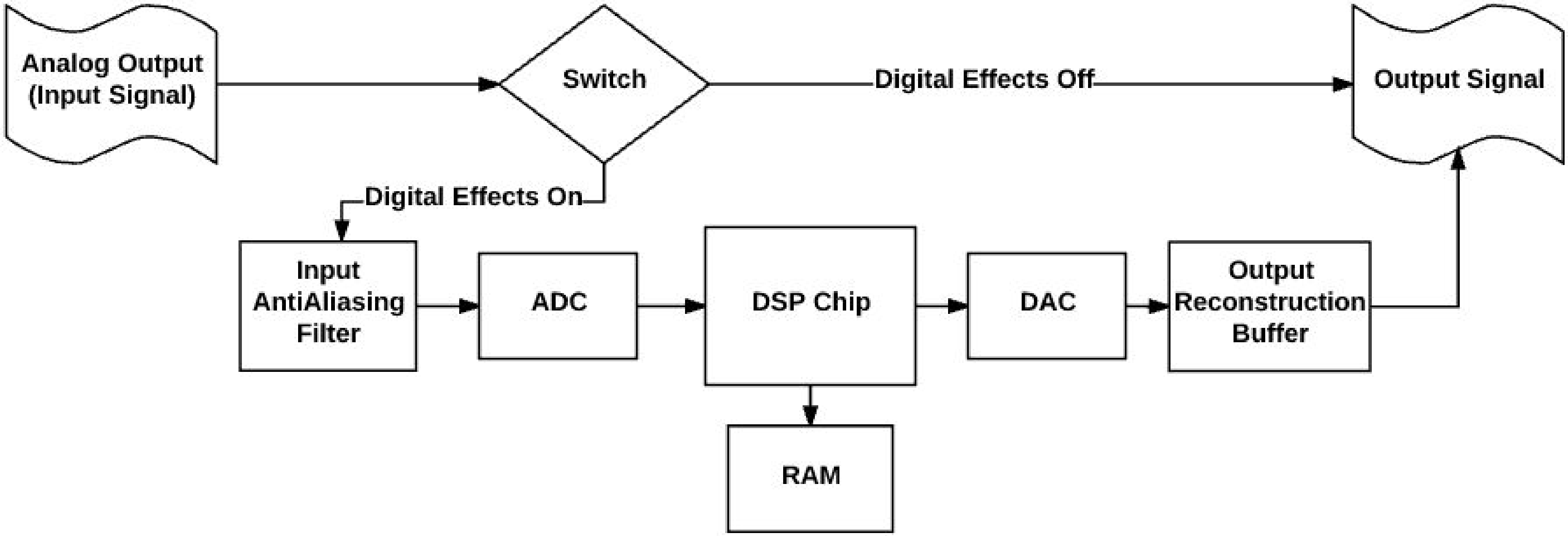




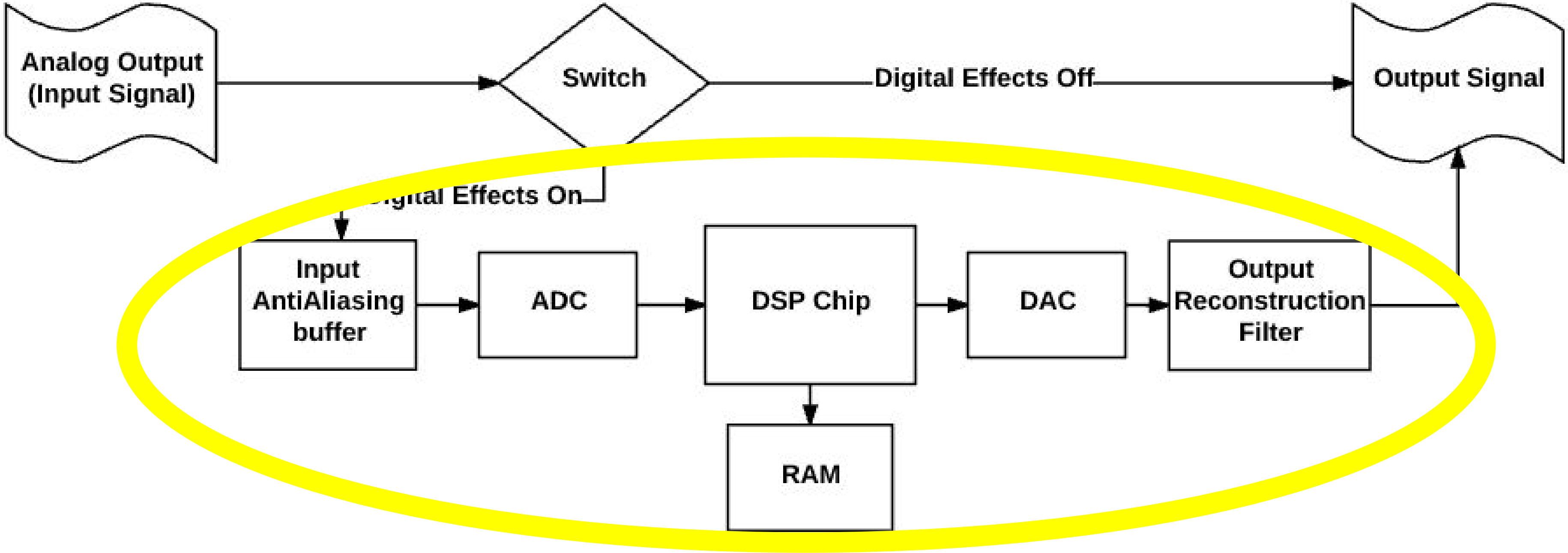
9V
EX_IN
EX_OUT
EQ_GND
EQ_OUT
DIGITAL_IN
IC4
IC2
OD_GND
OD_OUT
OD_IN
LED1_CON
LED2_CON
LED3_CON
1N4004
S3_3
S3_2S3_1
LM13700M
IC6
IC1
IC3
BUFFER_OUT
COMP_IN
COMP_GND
BUFFER_IN
IN_GND
COMP_OUT
DIS_IN
DIS_OUT
DIS_GND
2N3904
R10
R14
R40
R21
R24
R33
R43


Jose
Input
Analog
Effects
Unit
Selector
Output
Digital
Effects
Unit
Kevin
LED MFD
Brian
Power
Ayesha
Power
Signal

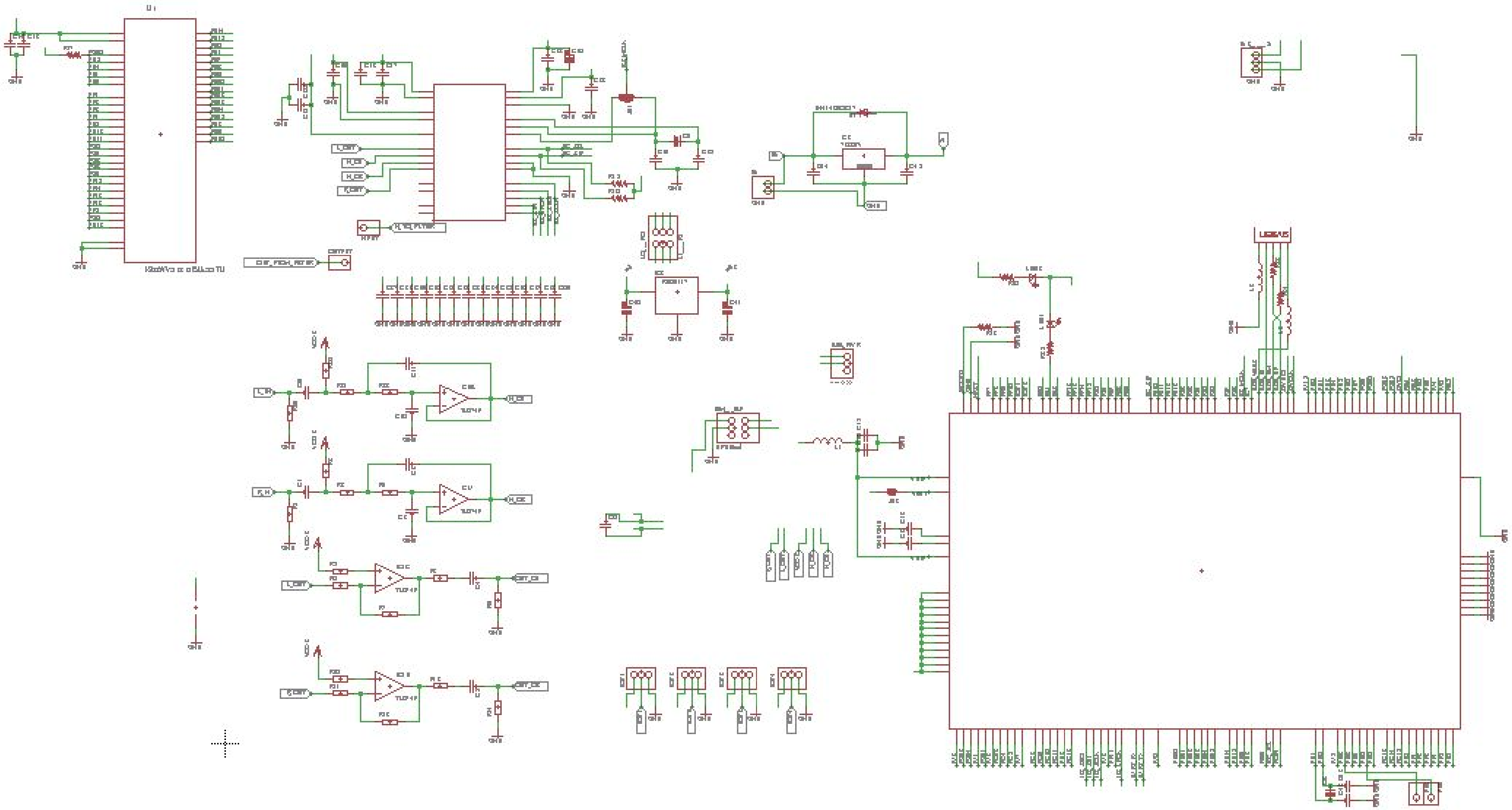
Digital Effects - Design Approach



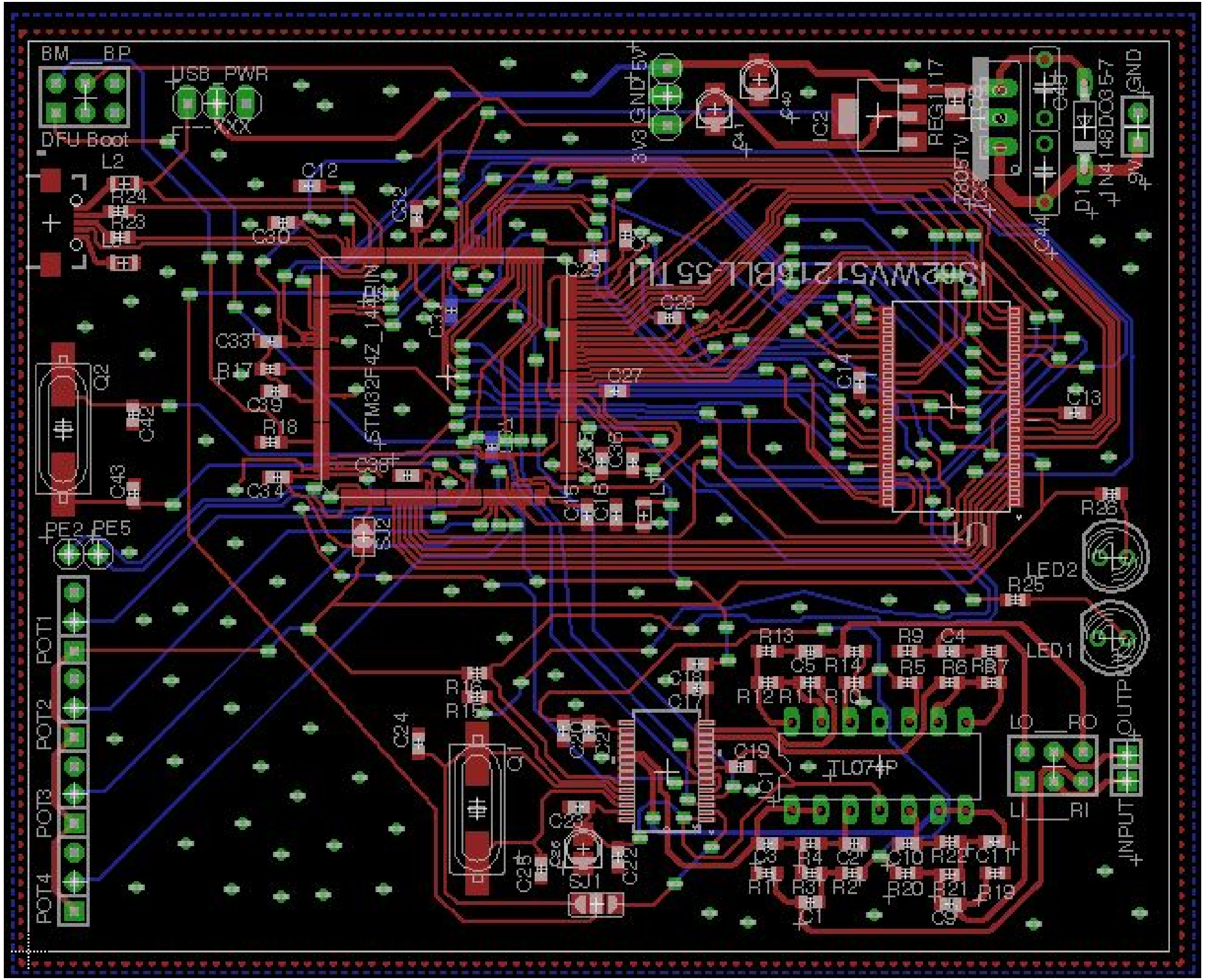
Digital Effects - Single Board



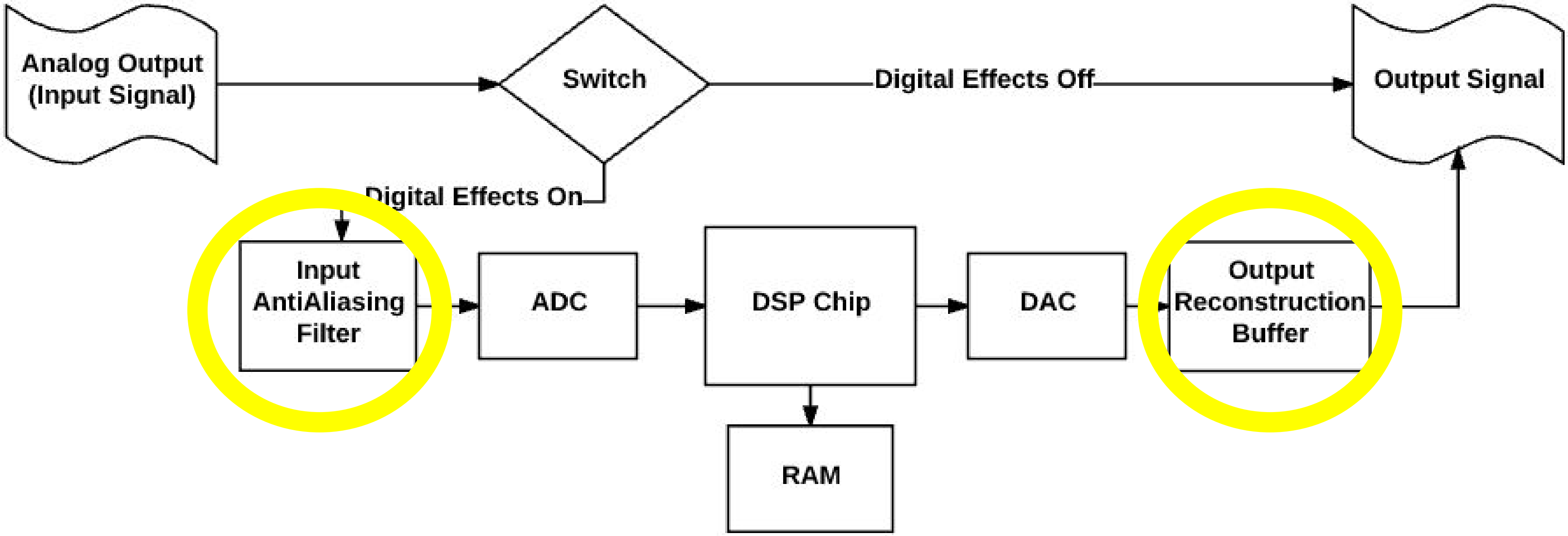
Schematic



Board

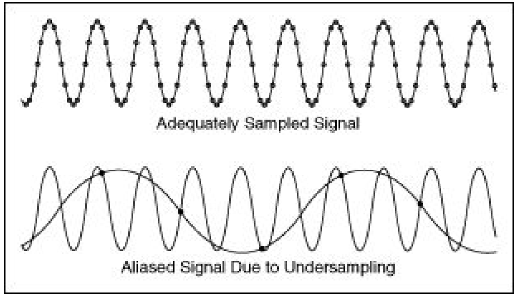

BM
BP
USB
PWR
DFU Boot
L2
R24
R23
C12
C30
C33
R17
C39
R18
C34
C38
C42
C43
Q2
PE2
PE5
POT1
POT2
POT3
POT4
C28
C27
C13
C14
R26
LED2
R25
LED1
R13
R9
C4
C5
R14
R5
R6
R12
R11
R10
LO
RO
LI
RI
TL074P
C19
R16
R15
C24
Q1
C23
C22
SJ1
C3
R4
C2
C10
R22
C11
R1
R3
R2
R20
R21
R19
C1
INPUT
REG1117
GND

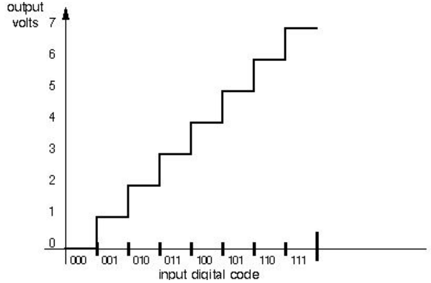
Digital Effects - Input and Output Filters

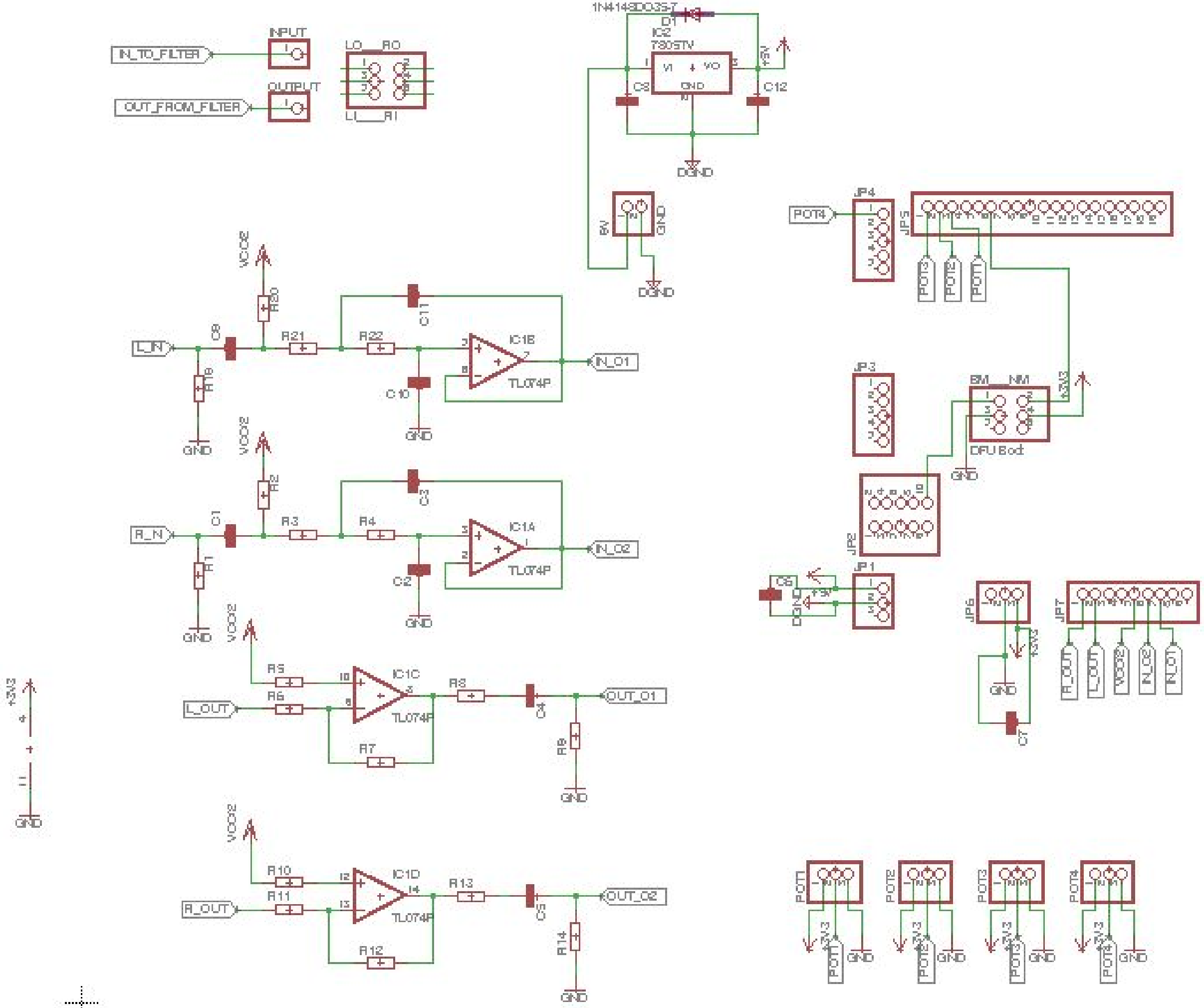


Schematic

- Anti-aliasing filter
- Reconstruction Filter
- Power Regulation
- Potentiometer Input







Component Selection

- Filters

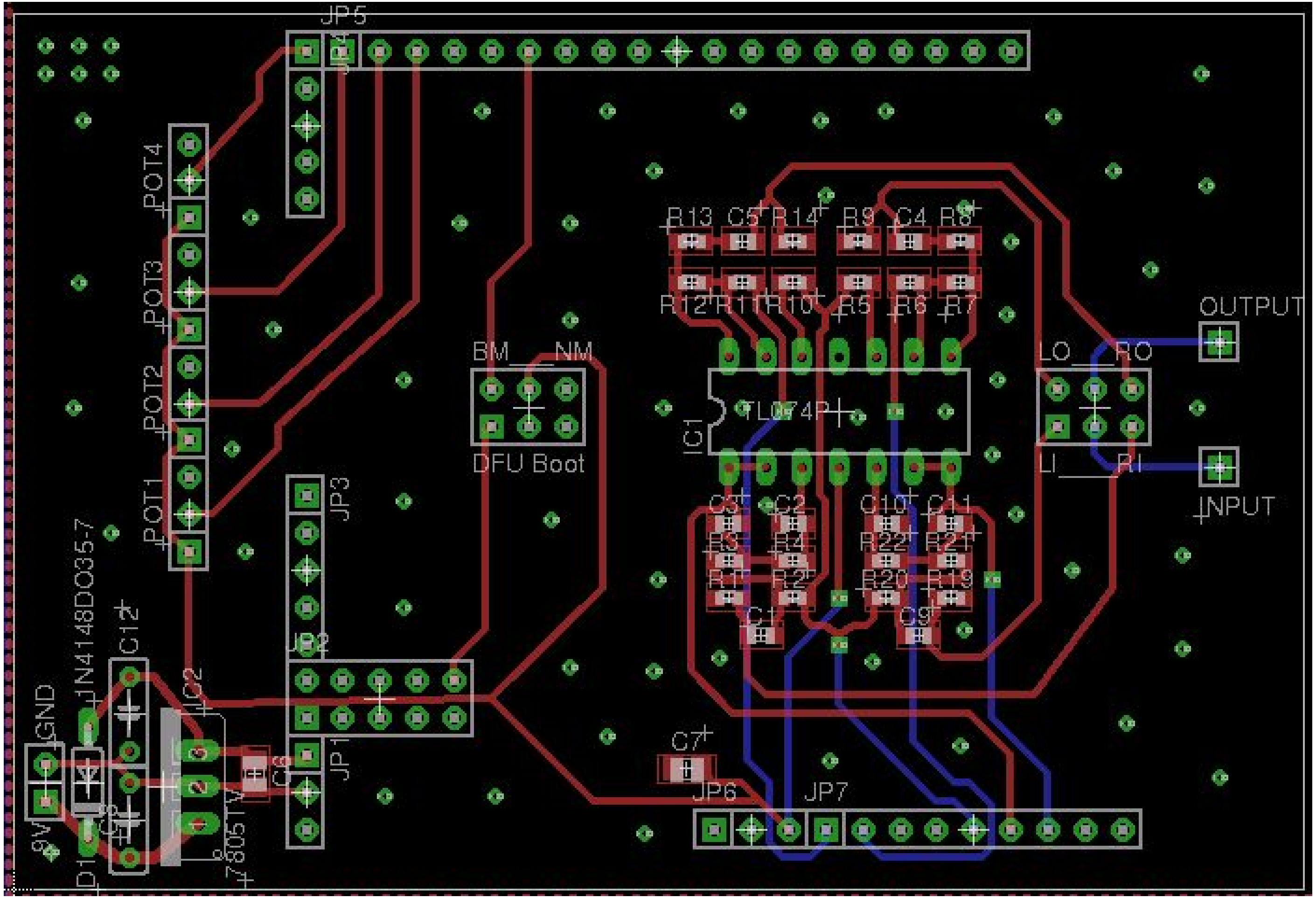
Op Amp	Advantage	Mouting Type	Cost
TL074	Low Noise, Enough Channels	Through Hole	$0.62
		Surface Mount	$0.82
TL084	Readily Available, Enough Channels	Through Hole	$0.00
		Surface Mount	$0.52

- Power Regulation

Regulator	Advantage	Mounting Type	Cost
MC79M05BDTRKG	Small footprint	Surface Mount	$0.64
LM7085	Readily Available	Through Hole	$0.00

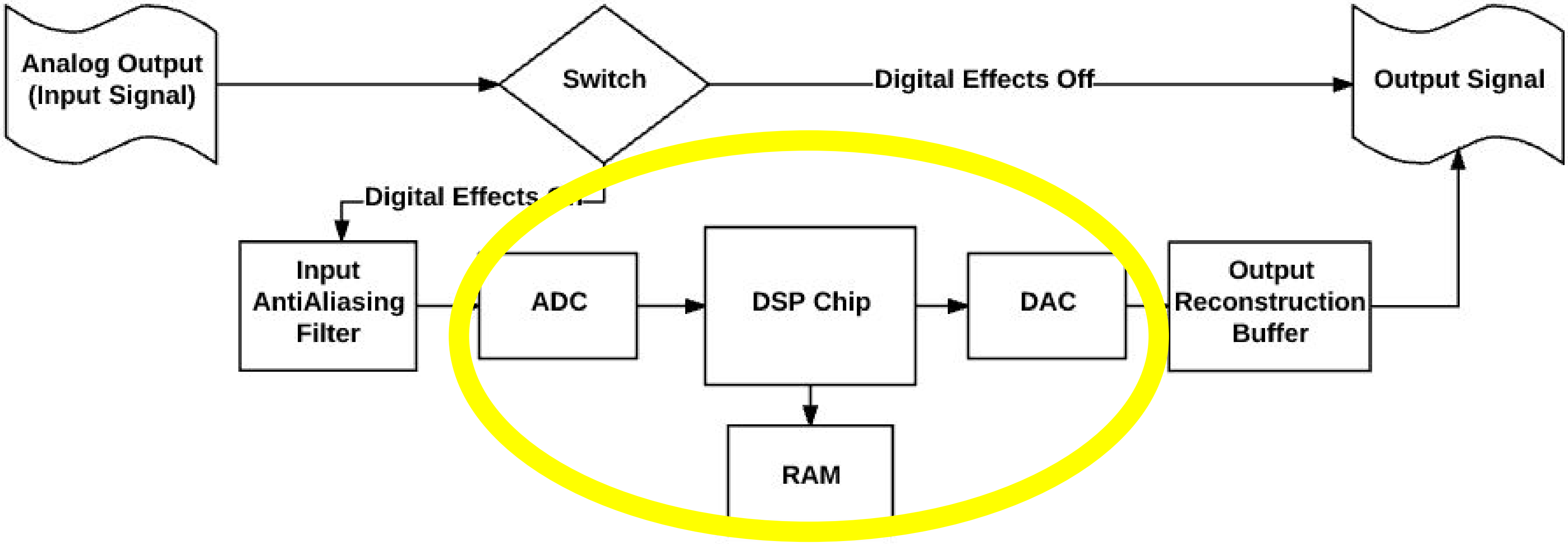
- Resistors/Capacitors/Diodes: Surface mount & Through Hole

Board



JP5
JP4
POT4
POT3
POT2
POT1
R13
C5
R14
R9
C4
R8
R12
R11
R10
R5
R6
R7
BM
NM
DFU Boot
TL074P
IC1
LO
RO
LI
RI
OUTPUT
INPUT
JP3
JP2
JP1
C3
C2
C10
C11
R3
R4
R22
R21
R1
R2
R20
R19
C1
C9
C7
JP6
JP7
1N4148DO35-7
C12
IC2
GND
9V
D1
7805TV
C8

Digital Effects - DSP



Digital Effects - DSP/MCU Chip

TMS320C6720

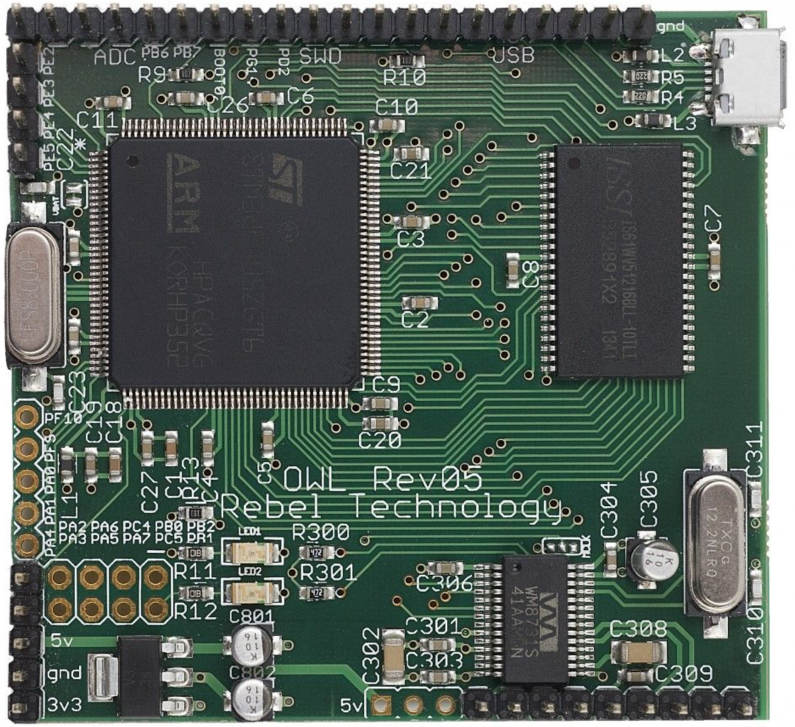
- Pros
  - High Speed/Quality
  - Faster and more accurate calculations
- Cons
  - High Cost Dev Board
  - Harder to code
  - Little documentation for guitar effects
  - Requires JTAG programmability

STM32F405ZGT6 (Hoxton Owl Based)

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

Digital Effects - Hoxton OWL Digital

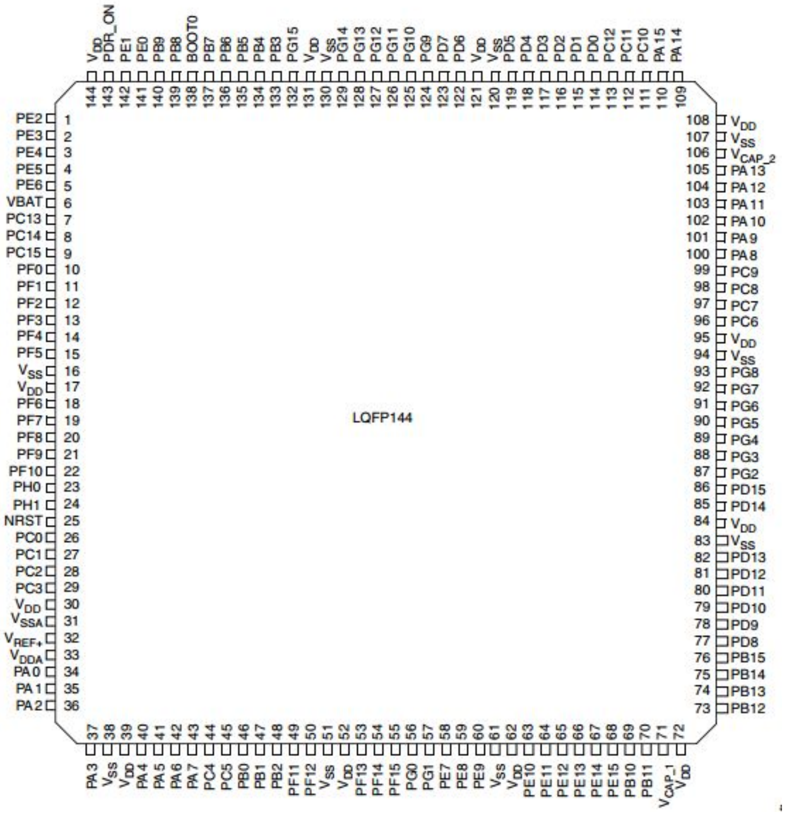
- Open source
  - Software
  - Hardware
    - Filter PCB design based on OWL
- Firmware available for modifications
- Helpful community
- Users will not be limited to the effects we create.
  - Online effect library and compiler
  - Plug and Play



Digital Effects - Components

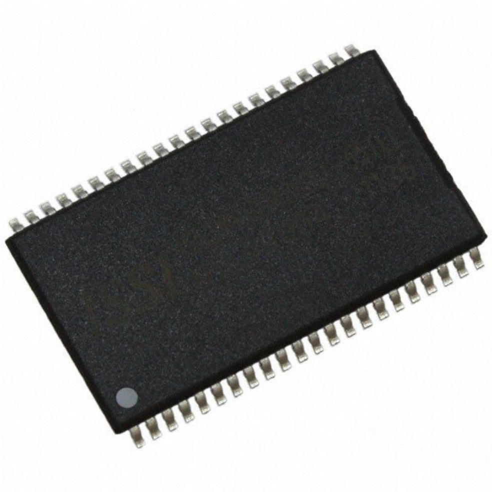
- STM32F405ZGT6 ARM Cortex M4 32bit
  - Up to 168 Mhz
  - Floating Point unit
  - On chip memory
    - Flash 512 MB
    - SRAM 192 kB
  - 15 Communication interfaces
  - Serial wire debug interface
  - Low power operation
  - Compatible with all ARM tools (including dsp libraries)

life.augmented



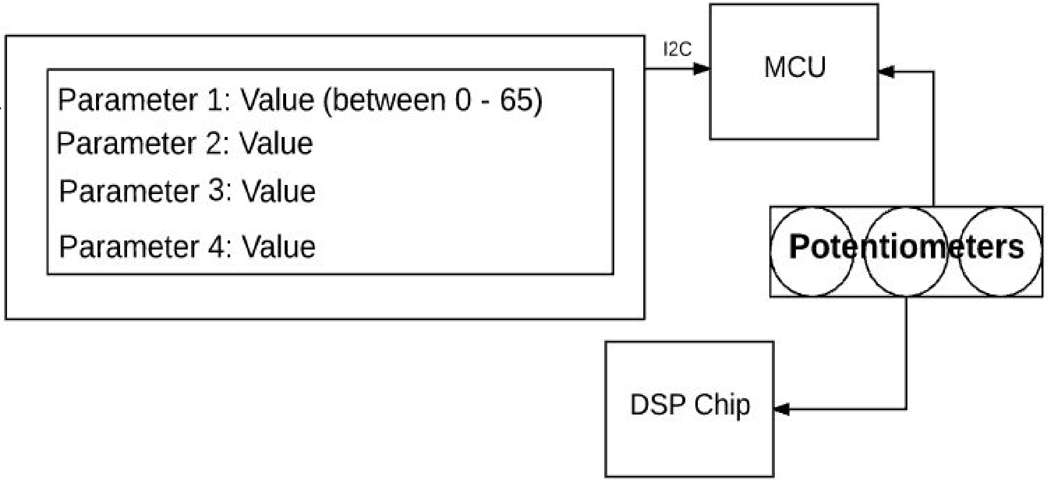
Digital Effects - Components

- 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
    - Up to 24 bit Delta-Sigma
    - Supported 8kHz to 96kHz
        - Used 48kHz



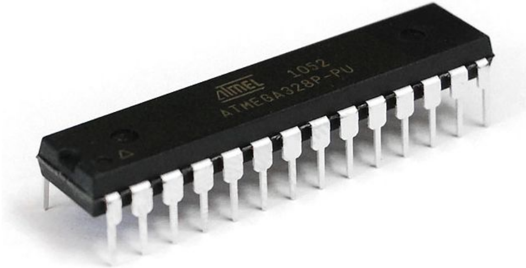
Digital Design Approach - Interface

- Very simple user interface
  - Anyone can easily use
  - Natural to Users
  - Footswitch to turn digital on or off
- Potentiometers for parameter changes
- I2C connection to LCD display

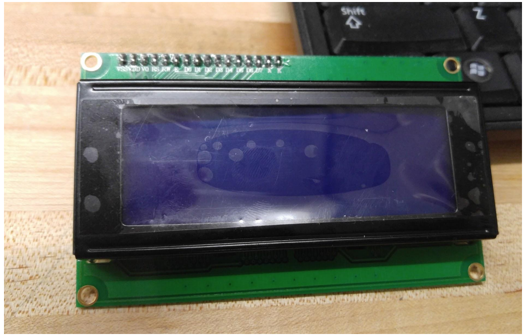


Digital Effects - Interface Components

- Atmega328p
  - Up to 20 MHz
  - Drive the LCD display
  - Display loaded effect and value
  - Used with Arduino Uno

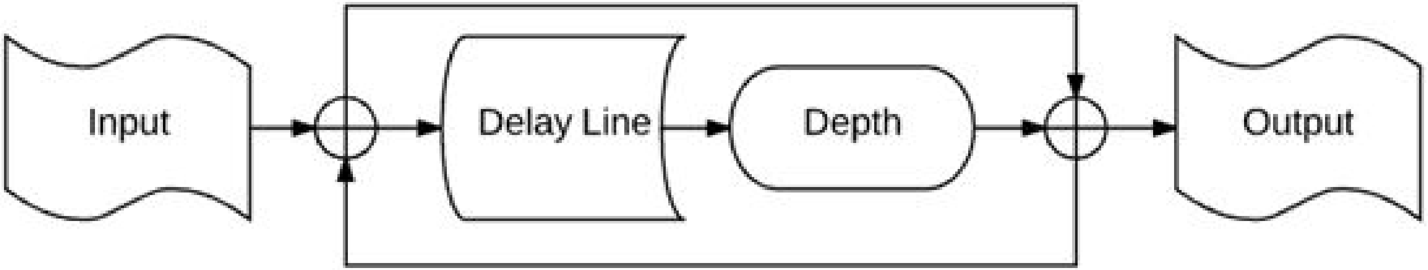


- LCD Display
  - 20x4 characters
  - I2C module for communication



Digital Design Approach - Echo

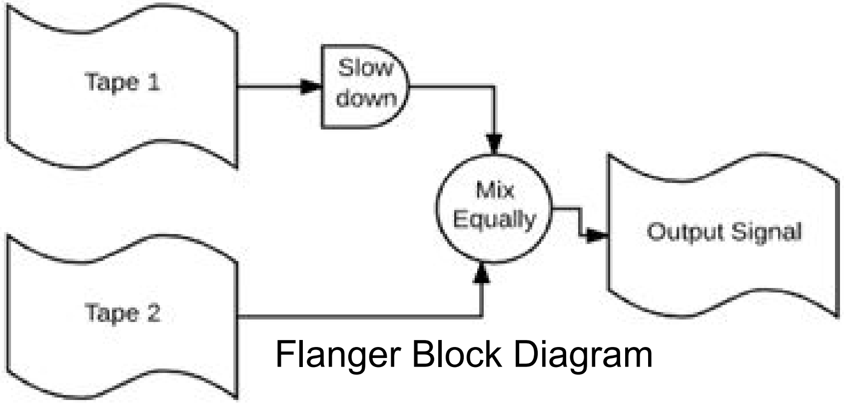
- Used to create a copy of the input and delay it slightly
    - Depth continues to decrease the impact of the copy the longer it continues
- Controls
    - Delay
    - Feedback
    - Level



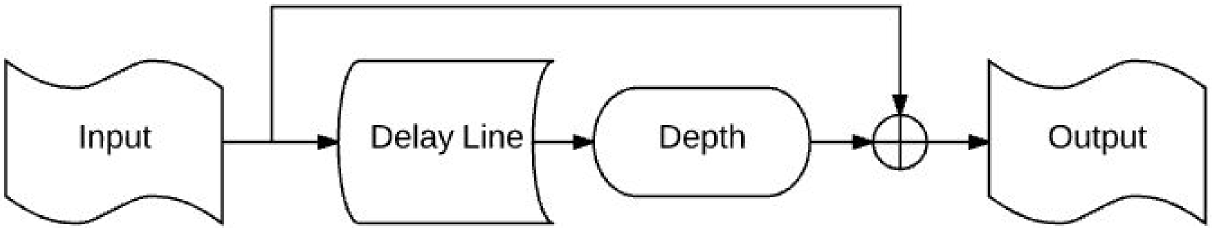
Echo Block Diagram

Digital Design Approach - 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



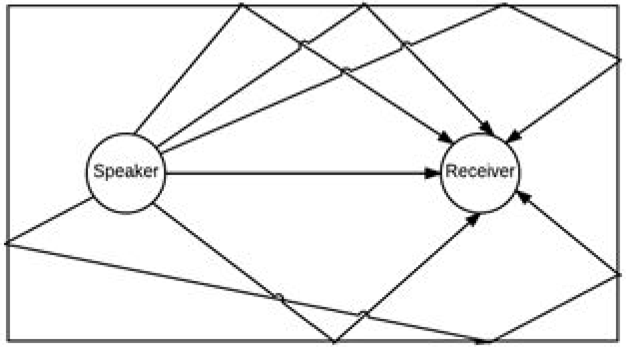
Flanger Block Diagram



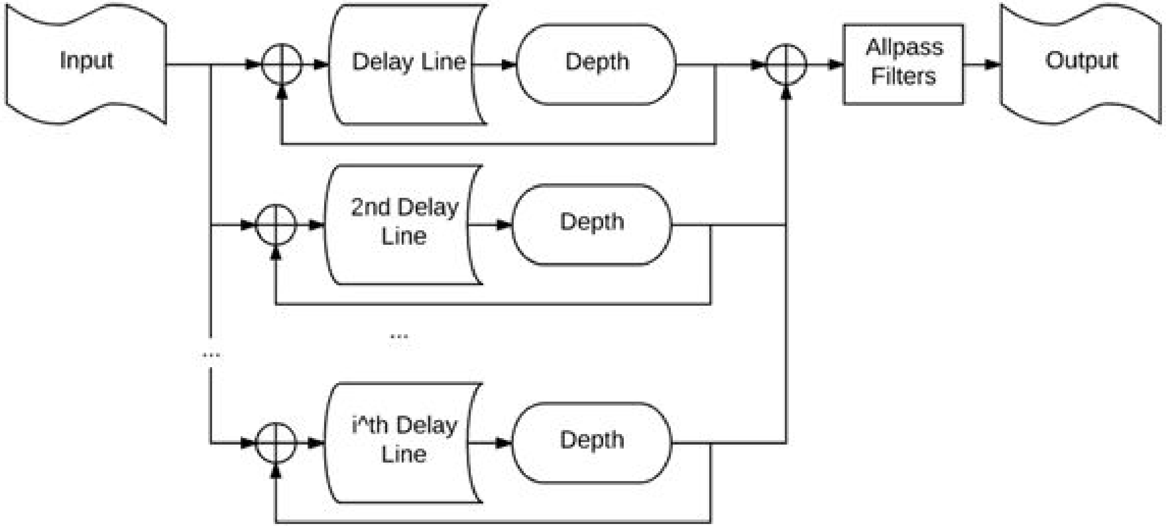
FeedForward Comb filter

Digital Design Approach - Reverb

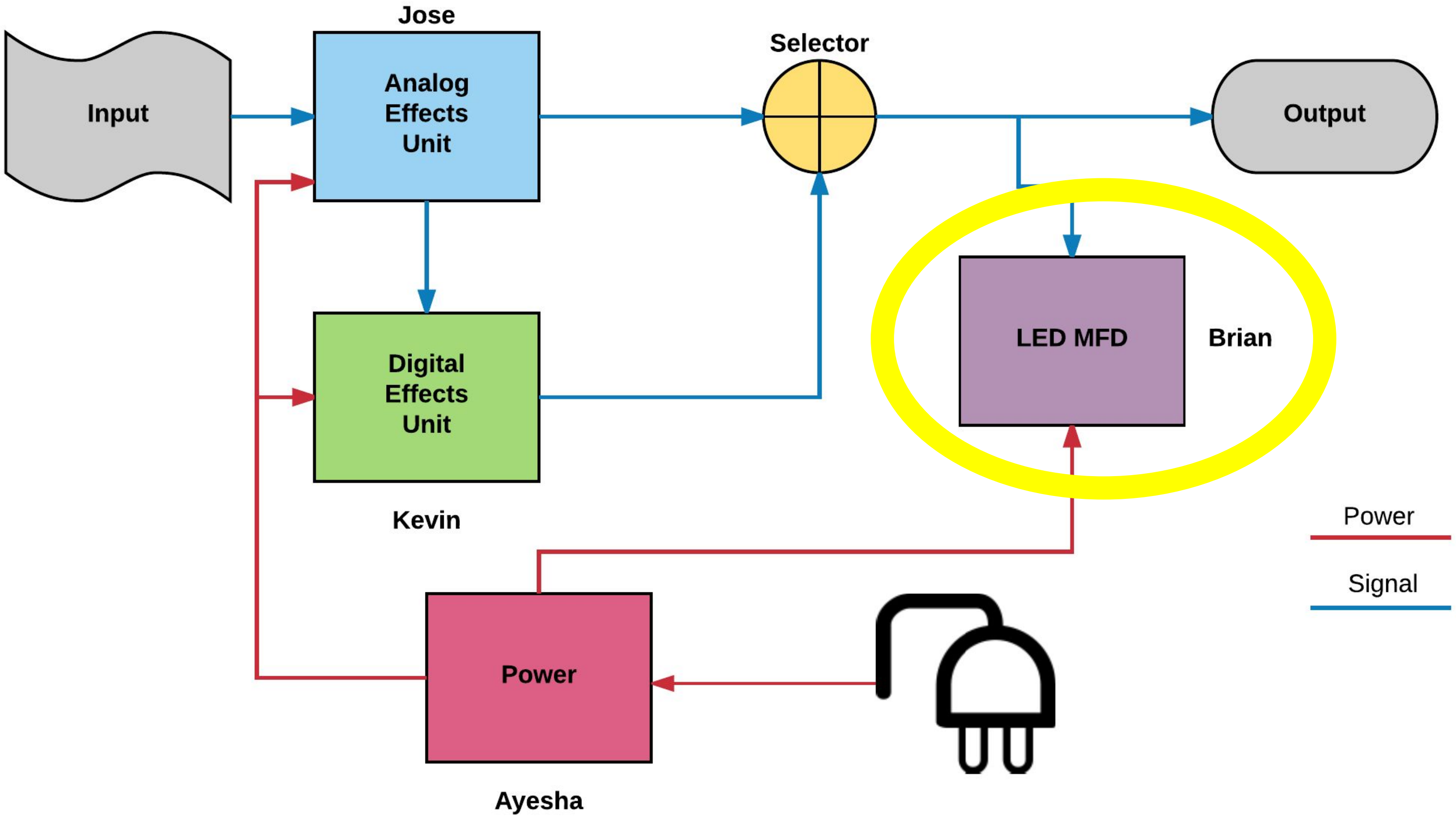
- Used to give the output sound the as if it was recorded in a large room
  - Achieved by overlaying multiple delays with comb filters, then passing through allpass filters.
- Controls
  - Room Size
  - Damp
  - Level



Natural Reverb



Schroeder Reverb Block Diagram

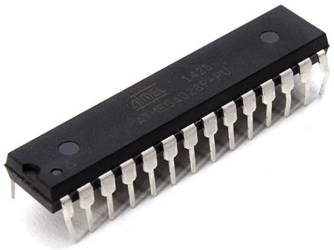

Jose
Input
Analog Effects Unit
Selector
Output
Digital Effects Unit
LED MFD
Brian
Kevin
Power
Signal
Power
Ayesha

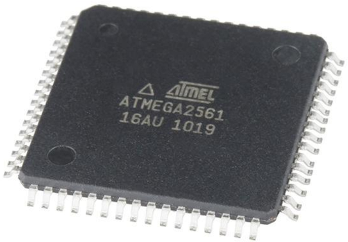
LED Matrix Feedback Display (LED MFD)

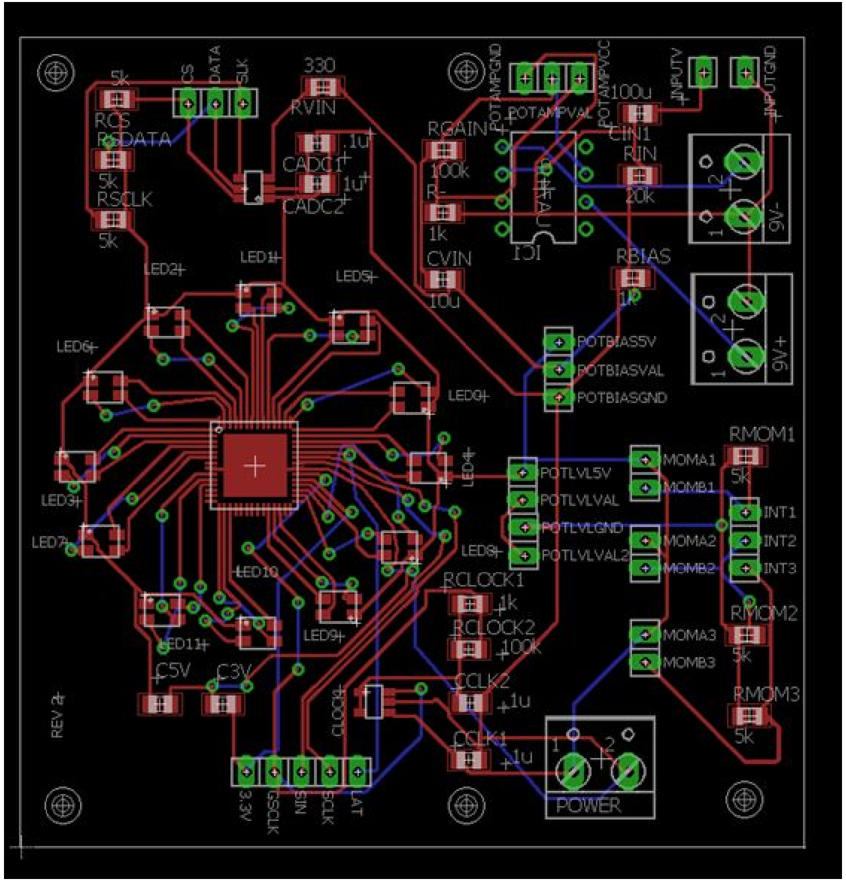
- General goals
  - Read the frequency of an input analog signal
  - Display frequency as a color
  - Introduce another way to enjoy the music you are playing

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



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CADC2
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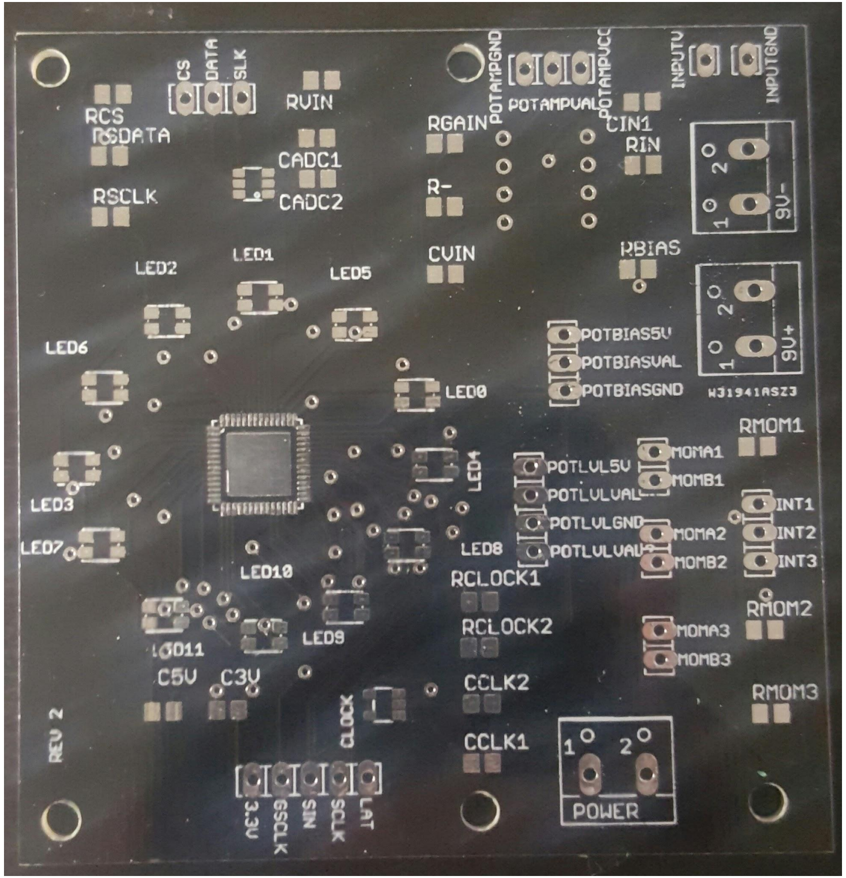
POTAMPVAL
POTAMPVCC
100u
CIN1
INPUTV
INPUTGND
RGAIN
100k
R-
1k
RIN
20k
IC1
9V-
CVIN
10u
RBIAS
1k
LED2
LED1
LED5
LED6
POTBIAS5V
POTBIASVAL
POTBIASGND
9V+
LED0
LED4
LED3
LED7
RMOM1
5k
MOMA1
MOMB1
POTLVL5V
POTLVLVAL
POTLVLGND
POTLVLVAL2
INT1
INT2
INT3
MOMA2
MOMB2
LED8
LED10
RCLOCK1
1k
RCLOCK2
100k
RMOM2
5k
MOMA3
MOMB3
LED11
LED9
C5V
C3V
CCLK2
1u
RMOM3
5k
REV 2
CLOCK
CCLK1
1u
POWER
3.3V
GSCLK
SIN
SCLK
LAT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CADC1
CADC2
RSCLK
R-
9V-
LED2
LED1
LED5
CVIN
RBIAS
LED6
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POTBIASVAL
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9V+
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RMOM1
MOMA1
MOMB1
LED4
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INT2
INT3
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MOMB2
LED3
LED7
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LED10
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RCLOCK2
RMOM2
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MOMB3
LED9
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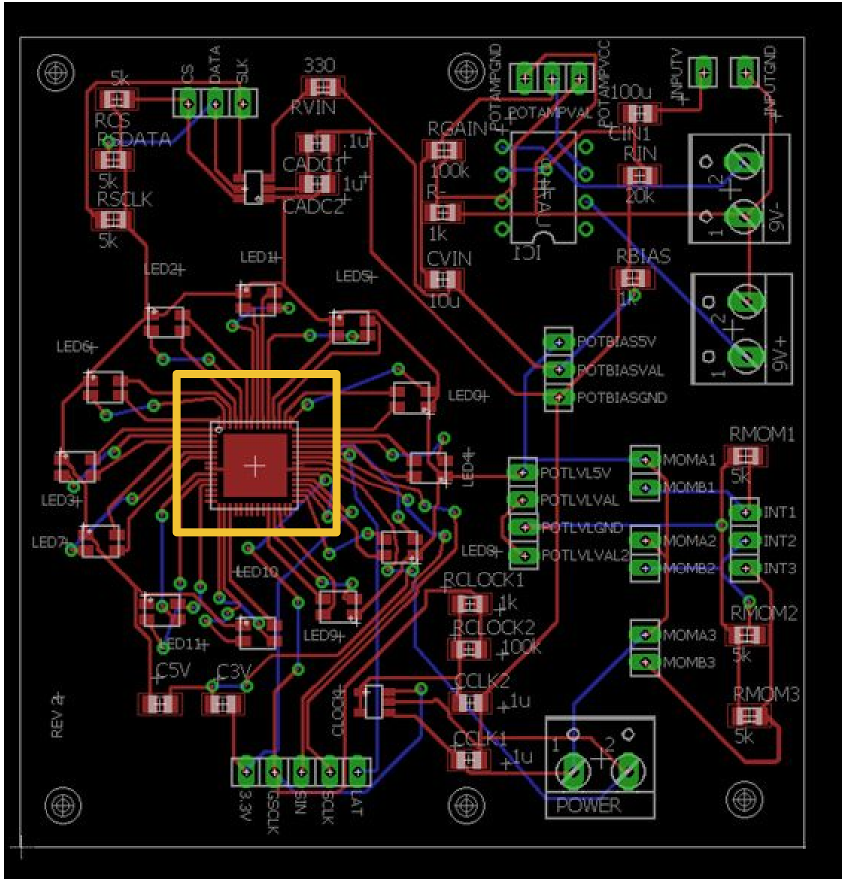

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R-
1k
CVIN
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POTAMPVCC
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CIN1
RIN
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IC1
INPUTV
INPUTGND
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RBIAS
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9V+
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MOMA1
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MOMB2
RCLOCK1
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RCLOCK2
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MOMA3
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GSCLK
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SCLK
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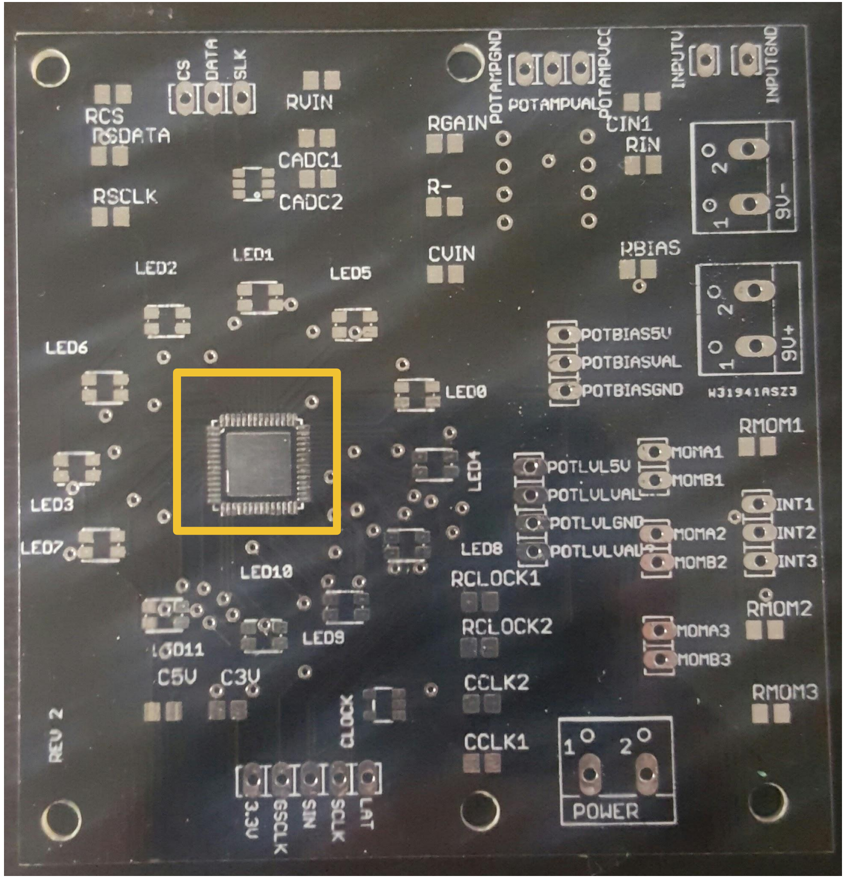
POWER



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POTLVLGND
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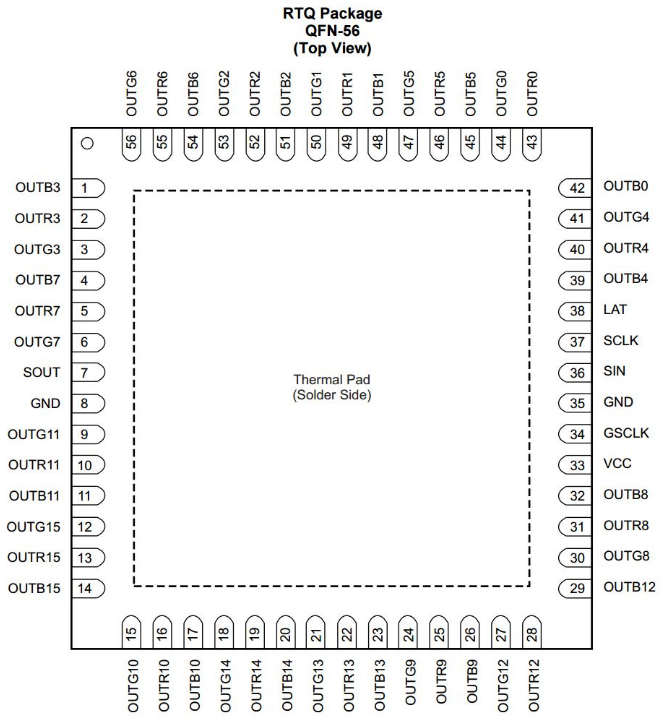
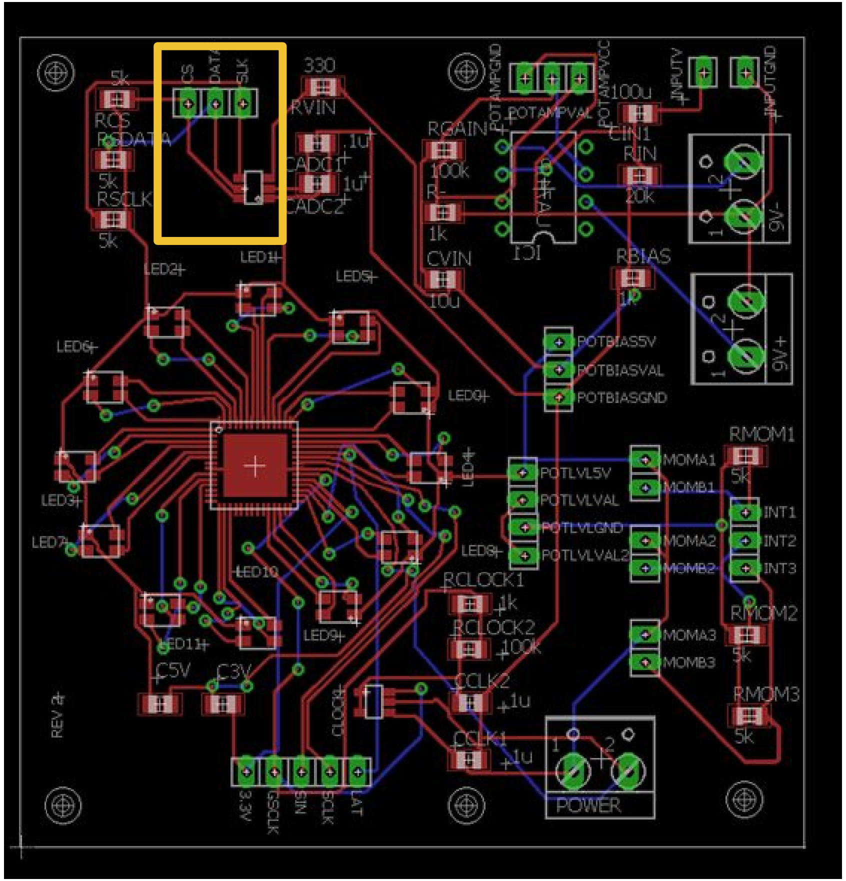
MOMB2
RCLOCK1
RCLOCK2
RMOM2
MOMA3
MOMB3
RMOM3
CCLK2
CCLK1
C5V
C3V
REV 2
CLOCK
3.3V
GSCLK
SIN
SCLK
LAT
POWER

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

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CVIN
10u
POTAMPGND
POTAMPVAL
POTAMPVCC
100u
CIN1
RIN
20k
INPUTV
INPUTGND
9V-
9V+
RBIAS
IC1
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LED11
POTBIAS5V
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POTBIASGND
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MOMA1
MOMB1
POTLVL5V
POTLVLVAL
POTLVLGND
POTLVLVAL2
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INT3
RMOM2
MOMA3
MOMB3
RMOM3
RCLOCK1
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CCLK1
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C3V
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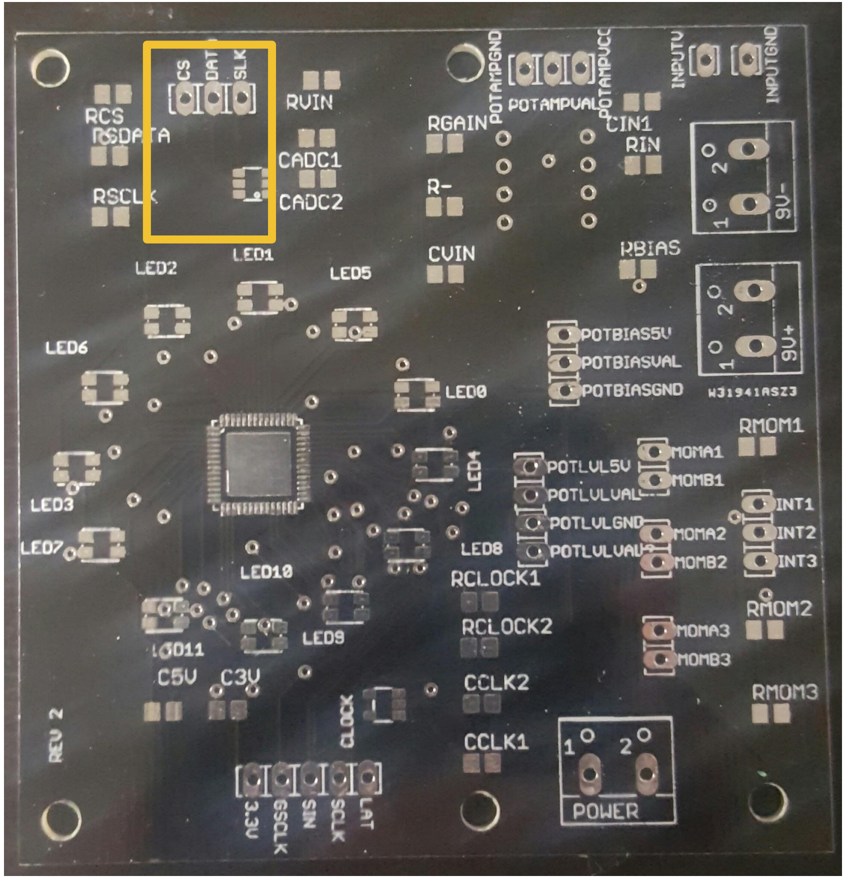
3.3V
GSCLK
SIN
SCLK
LAT
POWER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POTLVLVAL
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MOMB3
RMOM3
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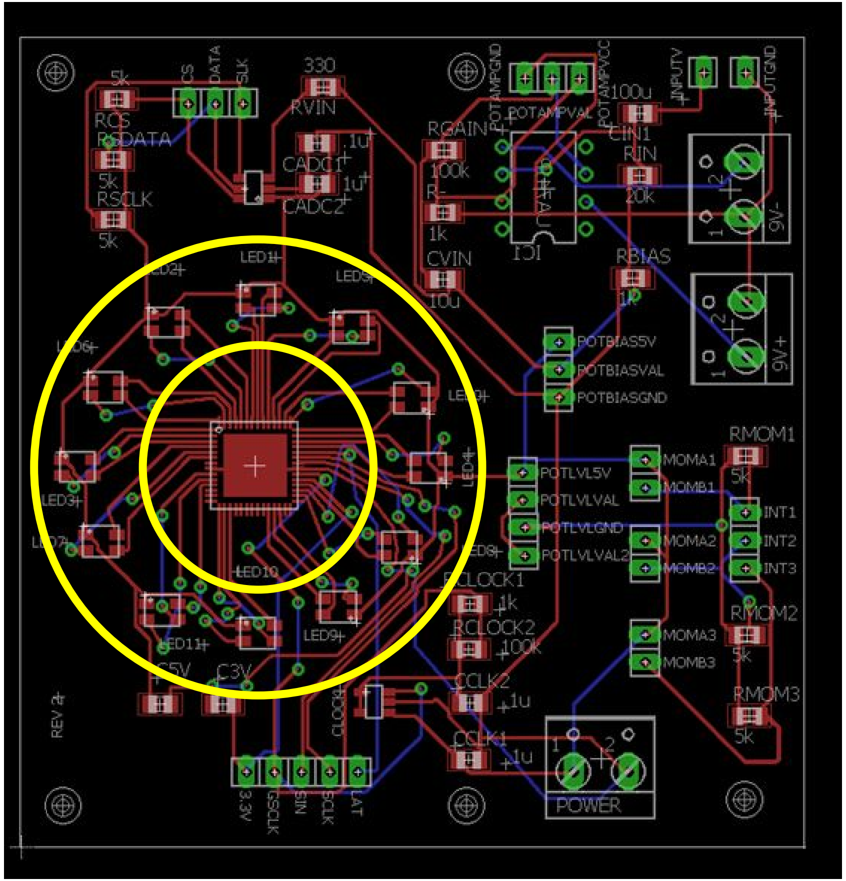
RCLOCK2
CCLK2
CCLK1
CLOCK
C5V
C3V
REV 2
3.3V
GSCLK
SIN
SCLK
LAT
POWER

ADC121s101: Analog to Digital Converter

- 12-bit ADC resolution
- Sampling rate of 1 MSPS
- Communicates serially
- SMD



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RMOM3
INT1
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SCLK
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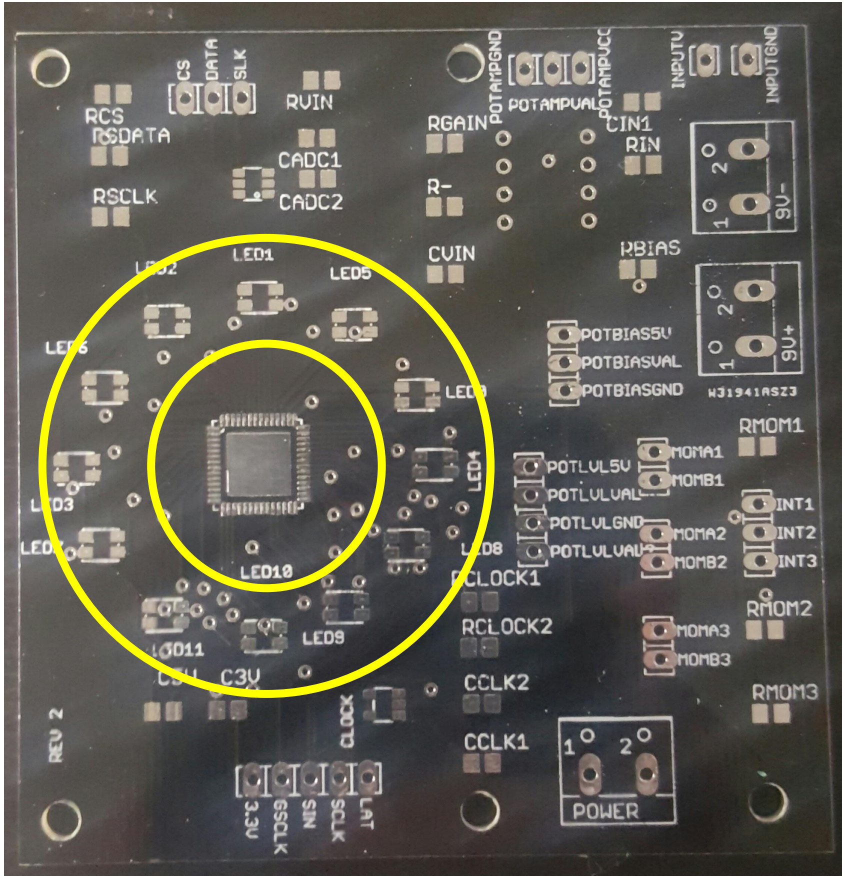
REV 2



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MOMA1
MOMB1
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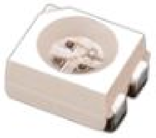
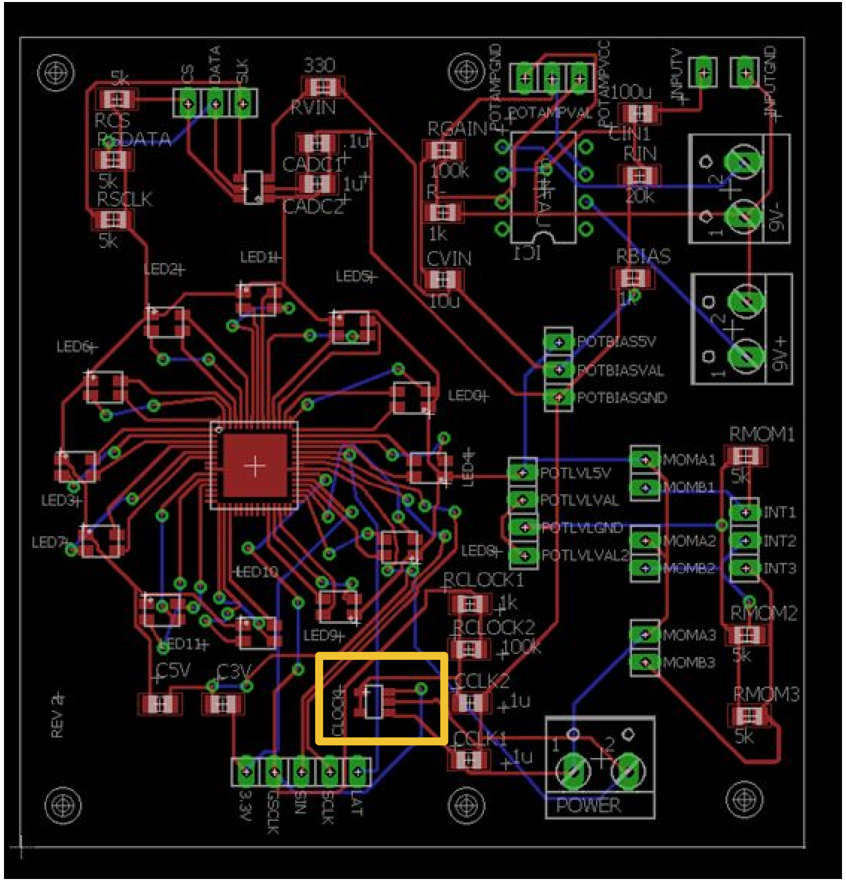
MOMB2
MOMA3
MOMB3
RMOM1
RMOM2
RMOM3
INT1
INT2
INT3
RCLOCK1
RCLOCK2
CCLK2
CCLK1
POWER
3.3V
GSCLK
SIN
SCLK
LAT
REV 2

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



CS
DATA
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330
RVIN
RCS
RSDATA
RSCLK
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CADC1
CADC2
1u
RGAIN
100k
R-
1k
CVIN
10u
POTAMPGND
POTAMPVAL
POTAMPVCC
100u
CIN1
RIN
20k
INPUTV
INPUTGND
IC1
RBIAS
1k
9V-
9V+
LED1
LED2
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LED4
LED5
LED6
LED7
LED8
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LED10
LED11
POTBIAS5V
POTBIASVAL
POTBIASGND
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MOMB1
MOMA2
MOMB2
MOMA3
MOMB3
POTLVL5V
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INT3
RCLOCK1
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CLOCK
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GSCLK
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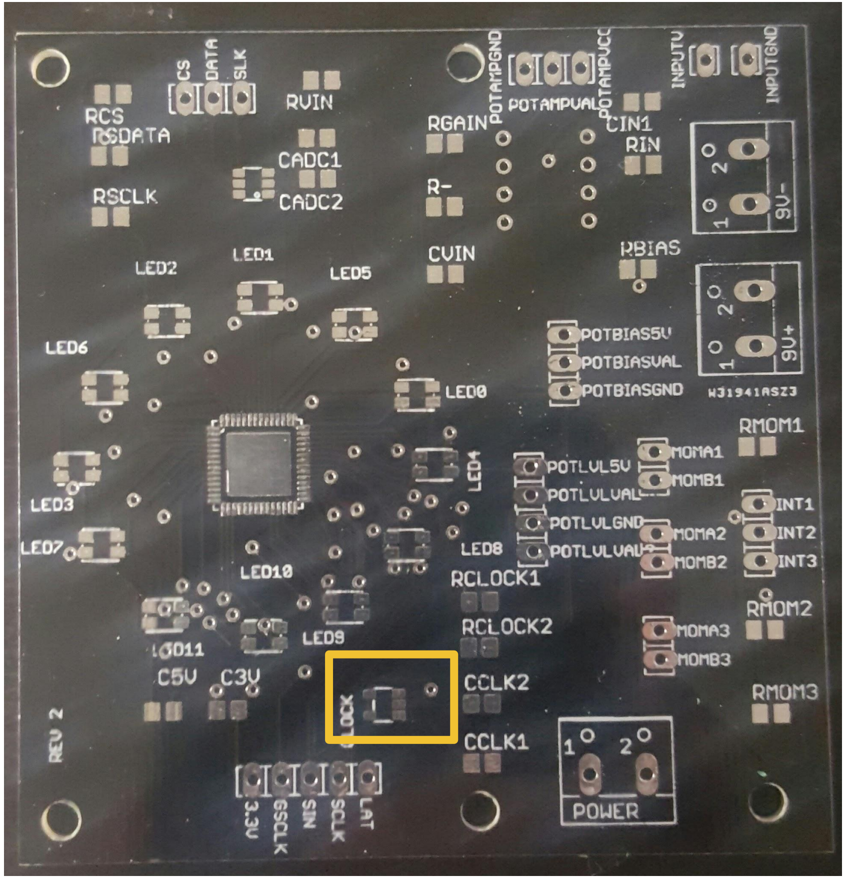
SCLK
LAT
POWER



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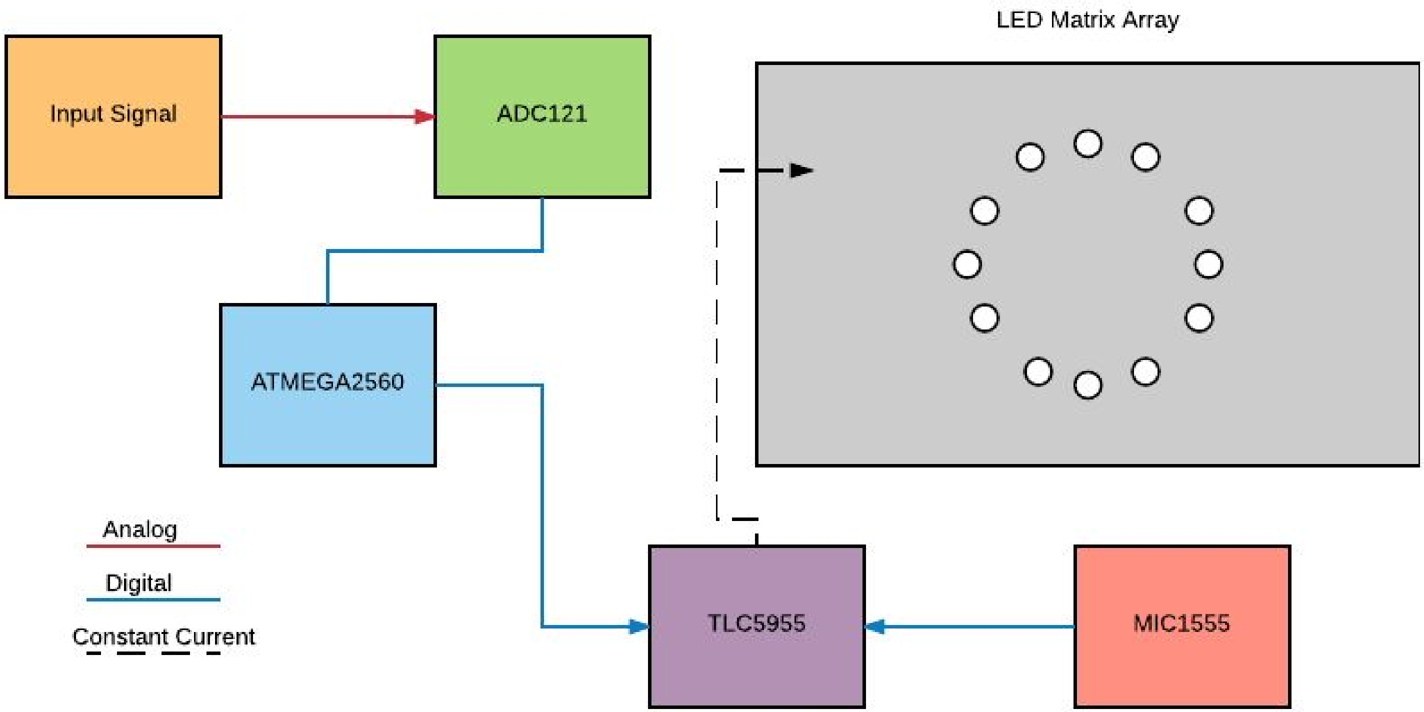
INT2
INT3
RCLOCK1
RCLOCK2
CCLK2
CCLK1
C5V
C3V
REV 2
3.3V
GSCLK
SIN
SCLK
LAT
POWER

MIC1555: Clock

- Clock speeds of up to 5 MHz
- Outputs a square wave with a 50% duty cycle
- SMD

Design of LED MFD



Design of LED MFD

1. ATMEGA 2560 makes request for voltage from ADC
2. ATMEGA 2560 interprets data using frequency Algorithm
3. ATMEGA 2560 outputs 769-bits serially to TLC 5955 to output color
4. MIC 1555 drives TLC 5955 GSCLK which is used to create the various colors available to the TLC 5955

Color Theory

- There will be 12 unique colors reserved for each of the 12 major notes recognized
- These frequencies are centered around the popular Western A4 = 440Hz principal

Frequency Capture Algorithm

1. ADC value is requested twice in succession and stored in A and then B
2. Values are checked to ensure that the slope is positive
3. Flag is checked to ensure that a reset cycle has occurred: reset = TRUE
4. A is checked to capture the time at which it crosses a threshold that is determined by the user, at which time the reset flag is set to False
5. System looks for a reset of the cycle to occur and then runs previous four steps
6. Both time stamps that are stored are used to calculate the period of the wave and thus frequency can be determined

Display Modes

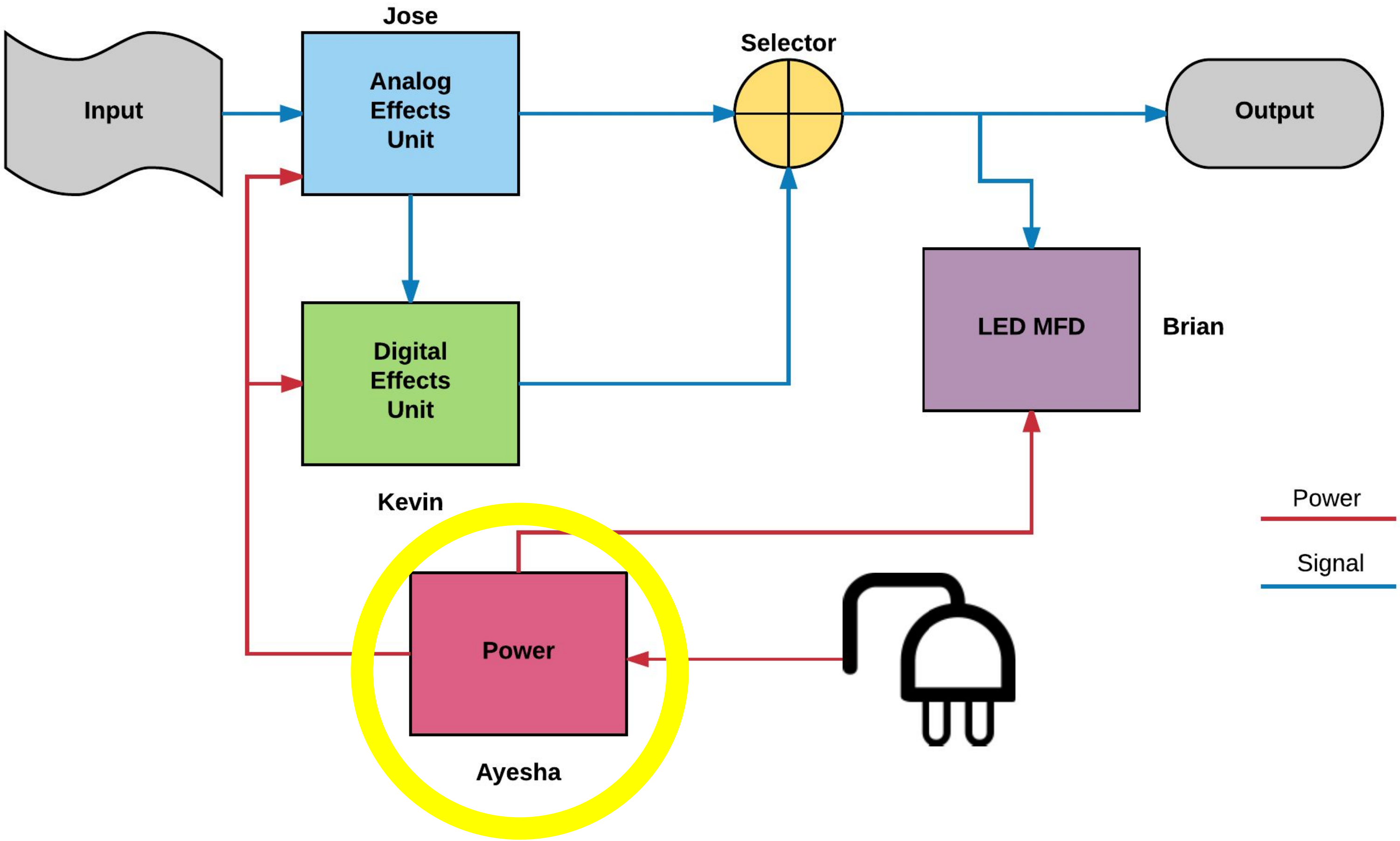
- Two display modes are currently available
- More modes can be added post production

Display Modes: Tune

- The note being played will be displayed at a unique position along with it’s uniquely mapped color
- Can be used during normal playing or during a “tuning” session
- Allows the user to visualize a “run” through the notes

Display Modes: All Flash

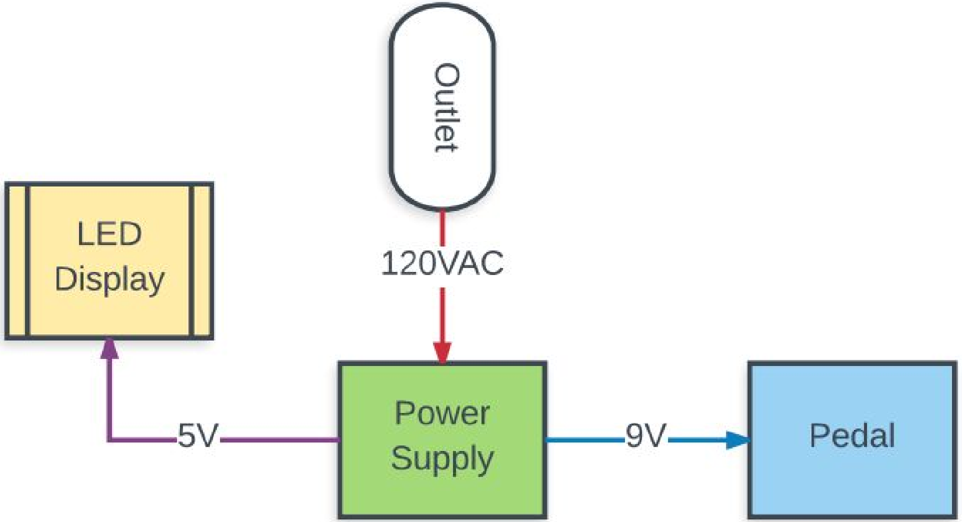
- All of the LEDs will display the same output color that is dependent on the input frequency at the same time.
- This mode is less reactive than the tune mode applying a check for stability before outputting a display.


Jose
Input
Analog Effects Unit
Selector
Output
Digital Effects Unit
LED MFD
Brian
Kevin
Power
Signal
Power
Ayesha

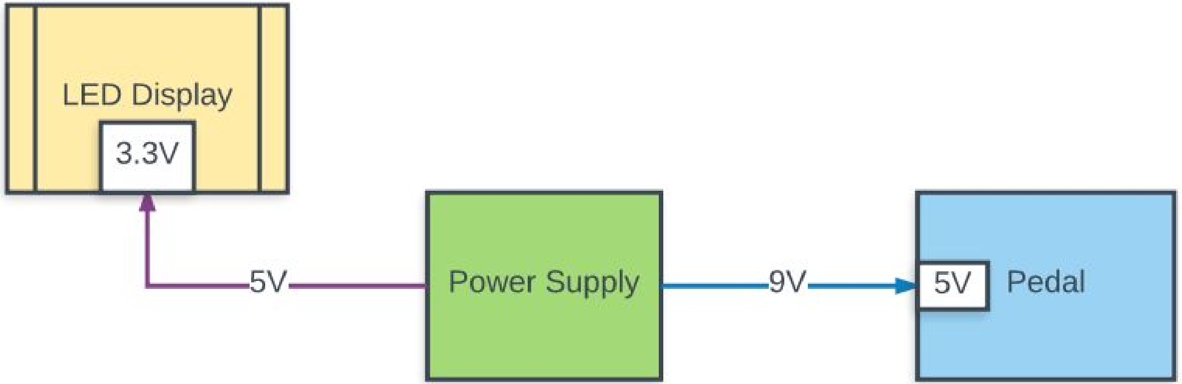
Design approach

- 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?



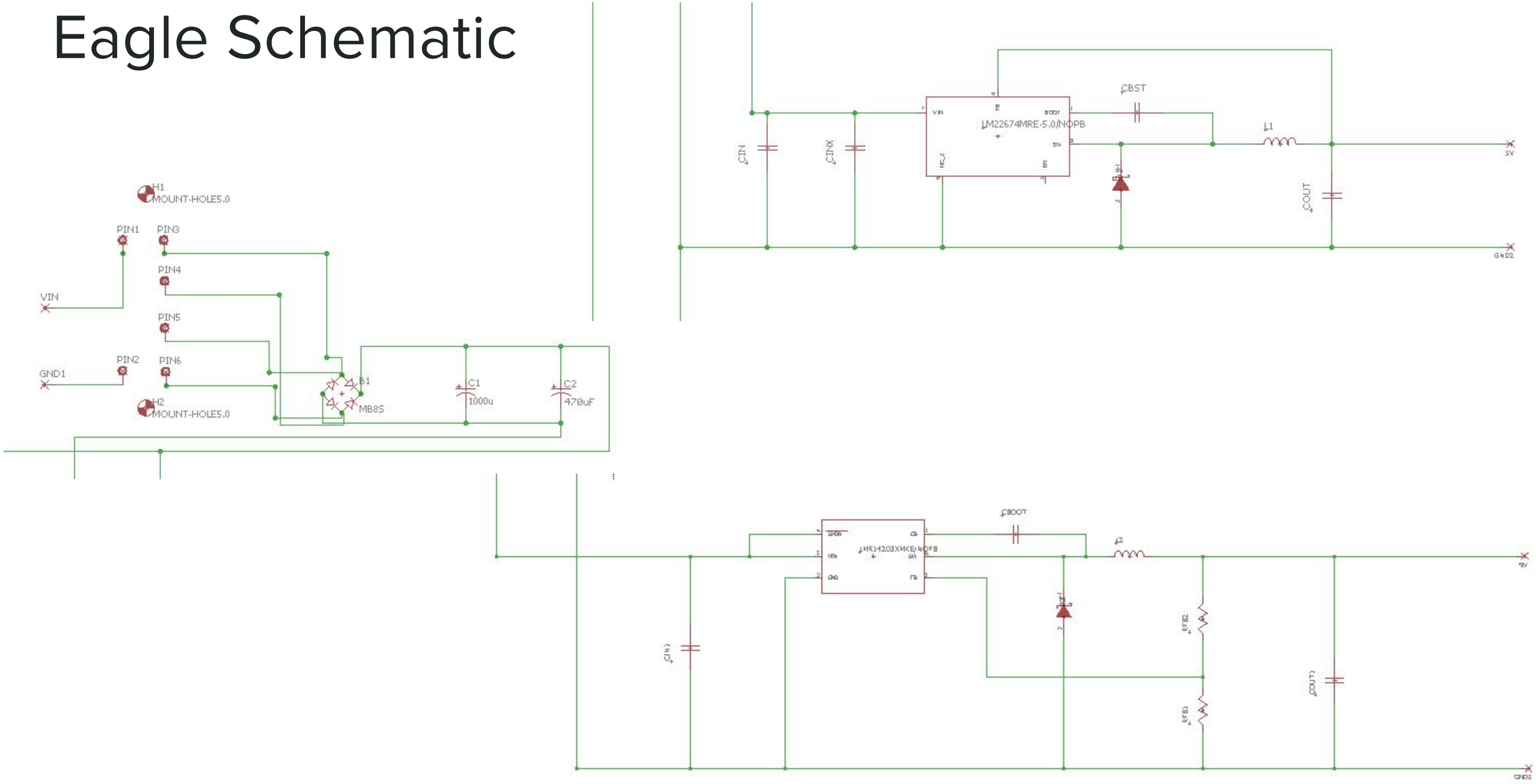
Power Distribution



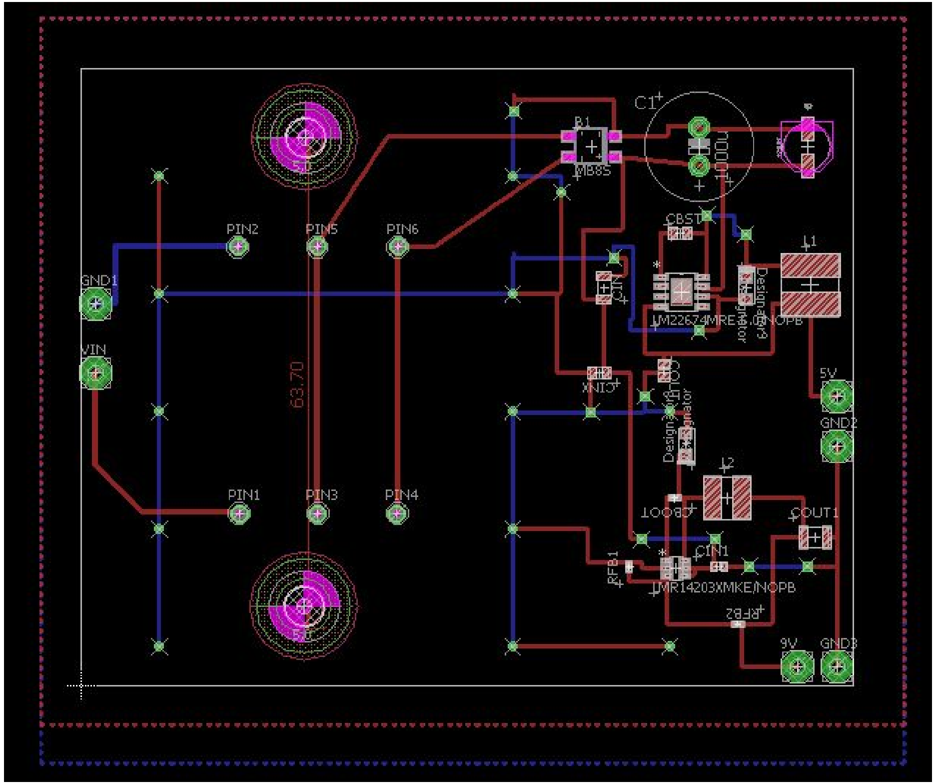
Step Down (Buck) Switching Regulators

- **LM22674** was chosen for the 5 V supply
  - Input Voltage Range : 4.5 V - 42 V
  - 5 V fixed output
  - Up to 500 mA
  - Switching frequency of 500 kHz
  - Current limiting for overloads
- **LMR14203** was chosen for the 9 V supply
  - Input Voltage Range : 4.5 V - 42 V
  - Up to 300 mA
  - Switching frequency of 1.25 MHz

Eagle Schematic



Board Layout



Current Build Budget

LED MFD Breakdown		
Part	Qty	Price
ADC121S101	1	$6.15
ATmega2560	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	$4
Total		$104.31

Responsibilities

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

Questions?