Theremin

Pedro Brito - David Gomez - Patrick McCabe

Overview

A Theremin is a musical instrument played without contact that sounds like a cello from the future

Two antennas control the pitch and volume

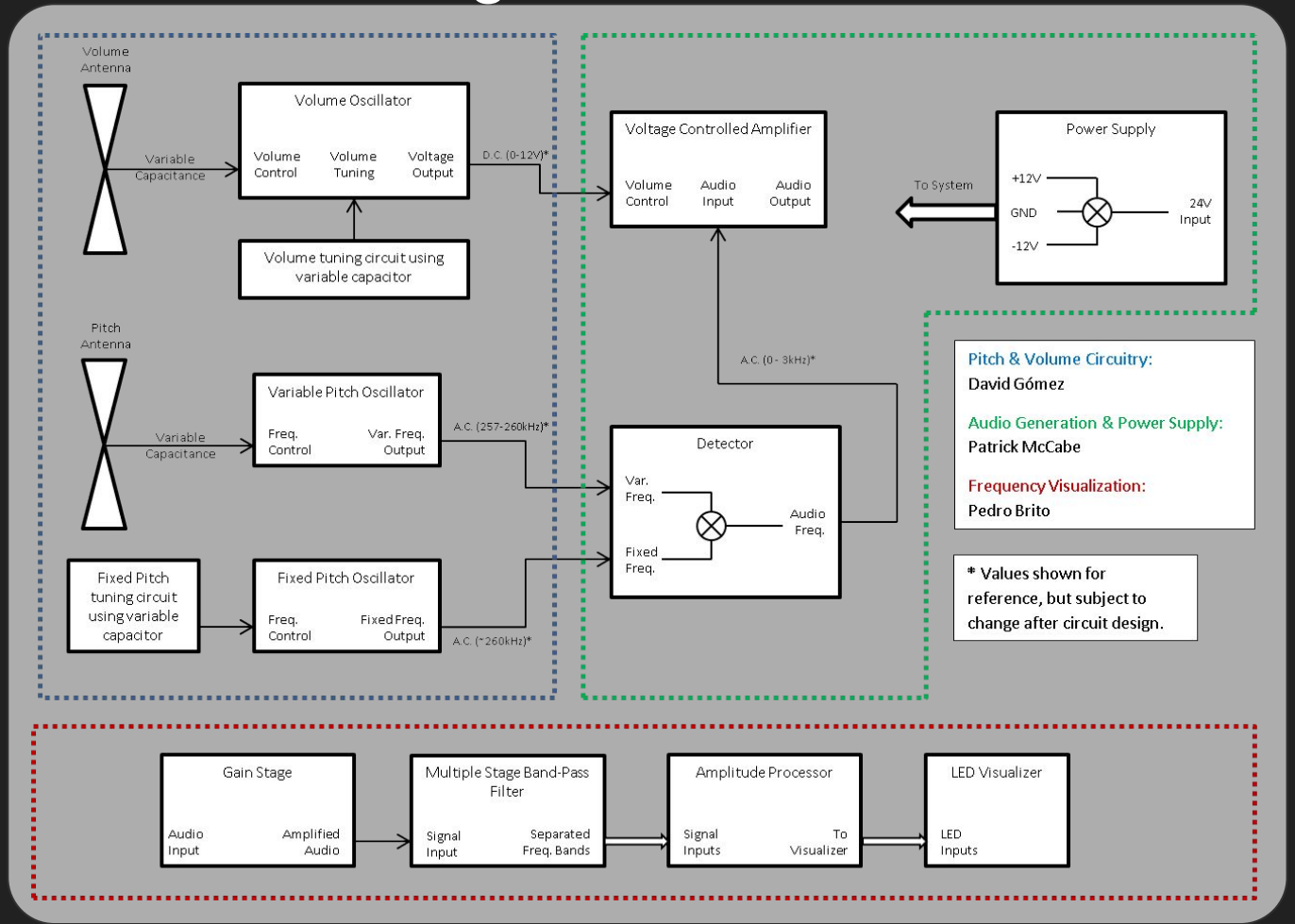
Varying your hand’s distance to the antennas changes the capacitance of them which is used as the control input

Motivation

Theremins are inherently all analog and require some interesting oscillators and signal processing techniques

Not just cool but practical, the capacitive measuring techniques used have many real applications like cell phone touch screens

High Level Block Diagram

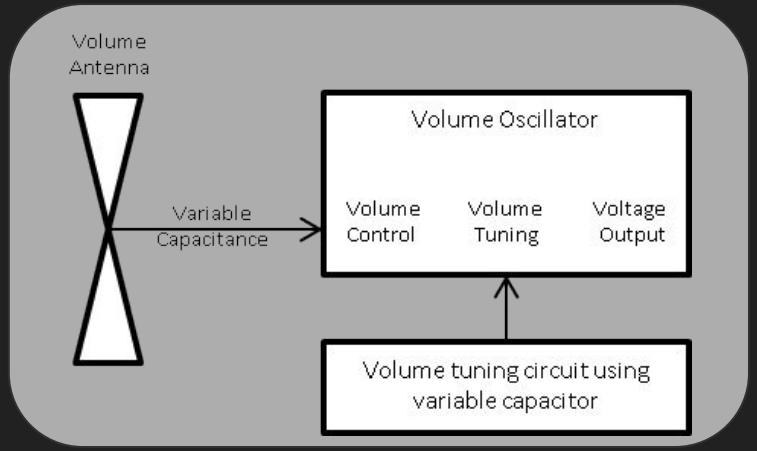


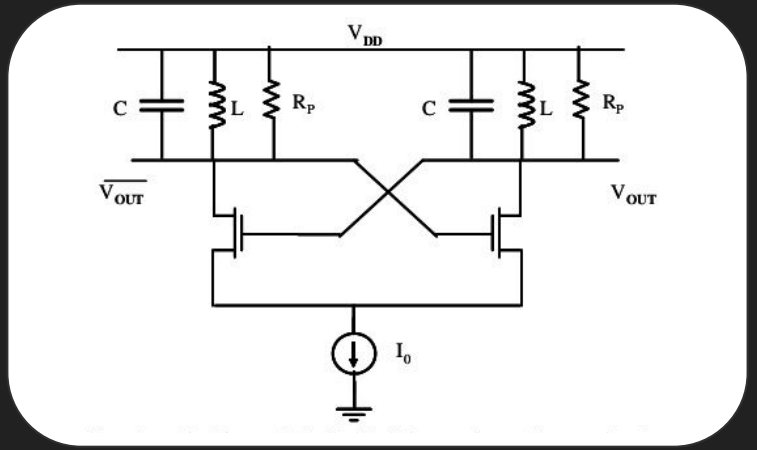
Volume Circuit

Volume antenna changes the capacitance in a LC resonant tank

Changing LC changes frequency of a sine wave oscillator

Oscillator topology potentially a cross coupled pair with series capacitance and inductance of antenna changing LC



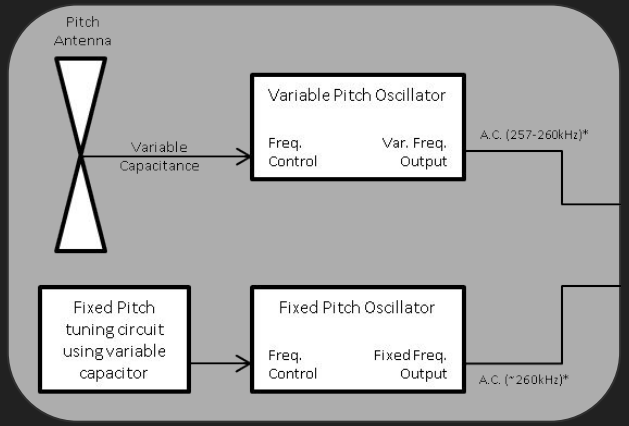


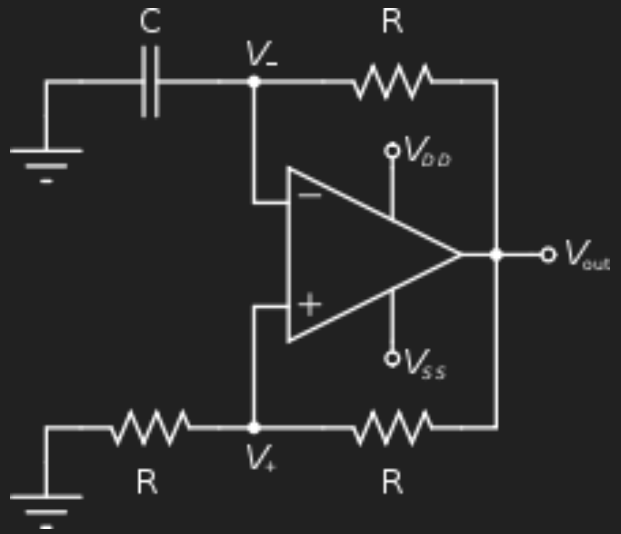
Pitch Circuit

Two oscillators: one fixed, one changed by capacitor
The frequency difference can be turned into audio

Variable pitch oscillator can be essentially identical to volume oscillator

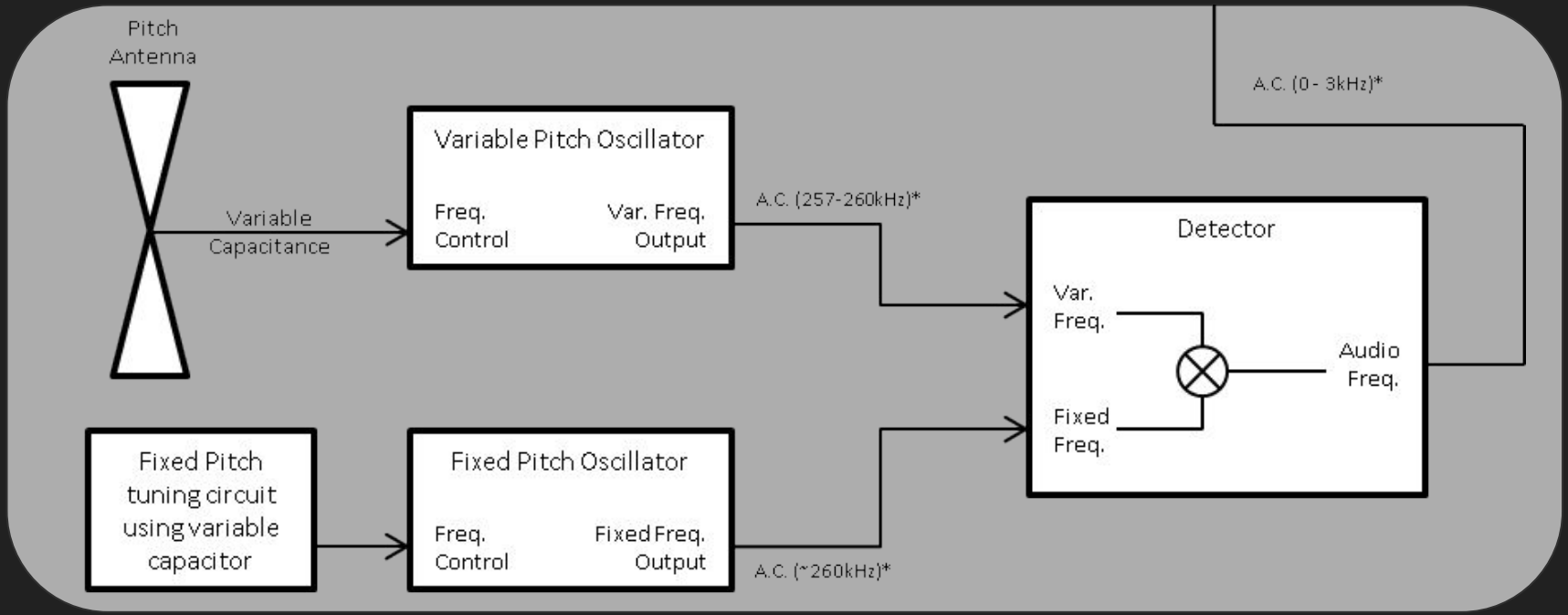
Fixed pitch oscillator can produce a square wave output for the mixer, a simple relaxation oscillator will work.





Mixer Overview

- Two inputs with frequency f1 and f2
- Produces output sine wave with frequency f1-f2



Mixer Math

$$y(t) = \sin(w_v t)$$

$$x(t) = \frac{4}{\pi}\left(\sin(w_o t) + \frac{1}{3}\sin(3w_o t) + \frac{1}{5}\sin(5w_o t) + \ldots\right)$$

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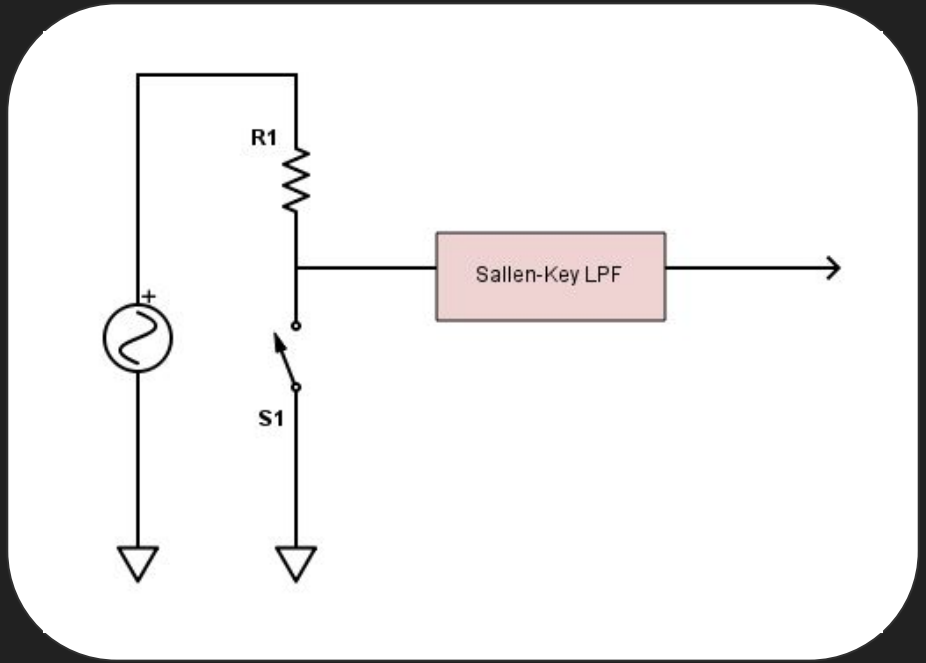
$$y(t) * x(t) = \frac{4}{\pi}\frac{1}{2}\left(\cos((w_v - w_o)t) - \cos((w_v + w_o)t) + \frac{1}{3}(\cos((w_v - 3w_o)t) - \cos((w_v + 3w_o)t)) + \dots\right)$$

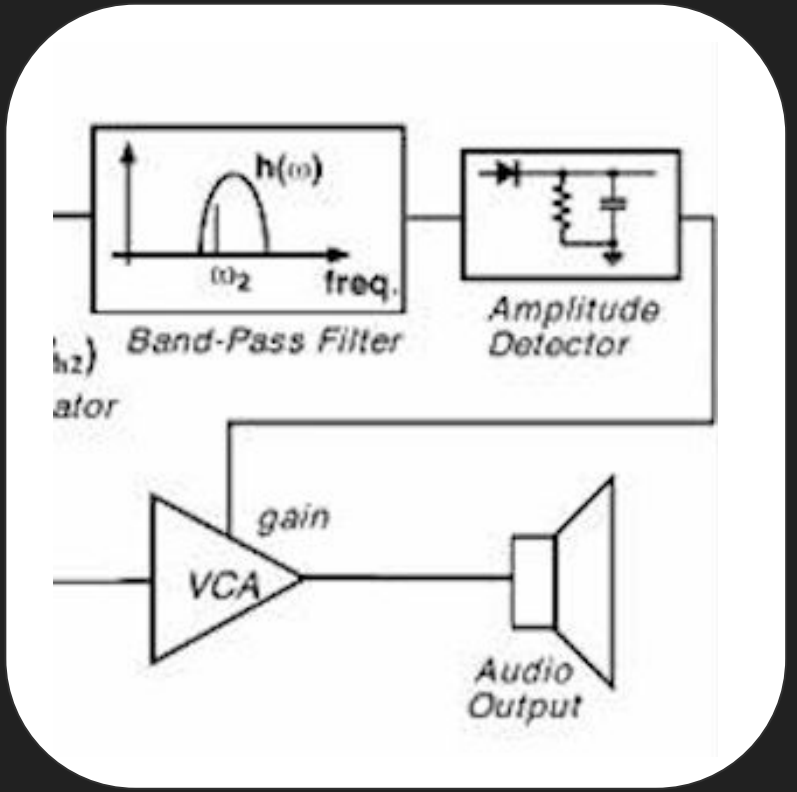
Mixer Circuit

- Multiply a sine wave and a square wave
- Low pass filter the output of the multiplication



Volume Control

- Need a DC control voltage for the VCA
- Bandpass the volume oscillator
- Perform amplitude detection on the filtered signal
- This will give a relation between frequency and the DC voltage



Voltage Controlled Amplifier

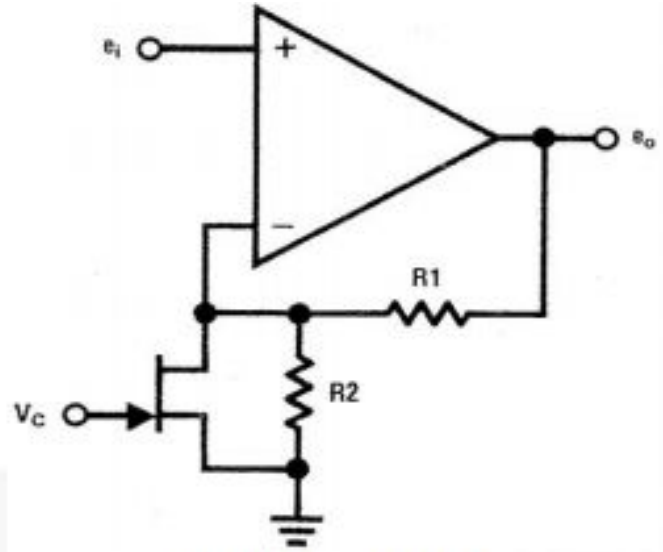


Figure 7. A_{VMIN} >1

$$A_V = 1 + \frac{R1}{R2\ r_o\ (V_P/V_C)}$$

$$R2 + r_o(V_P/V_C)$$

$$= \frac{1 + [R2 + r_o\ (V_P\ /\ V_C)]}{R2\ r_o(V_P/V_C)}$$

$$A_V = 1 + \frac{R1}{R2} + \frac{R1\ V_C}{r_o V_P}$$

Voltage Controlled Amplifier

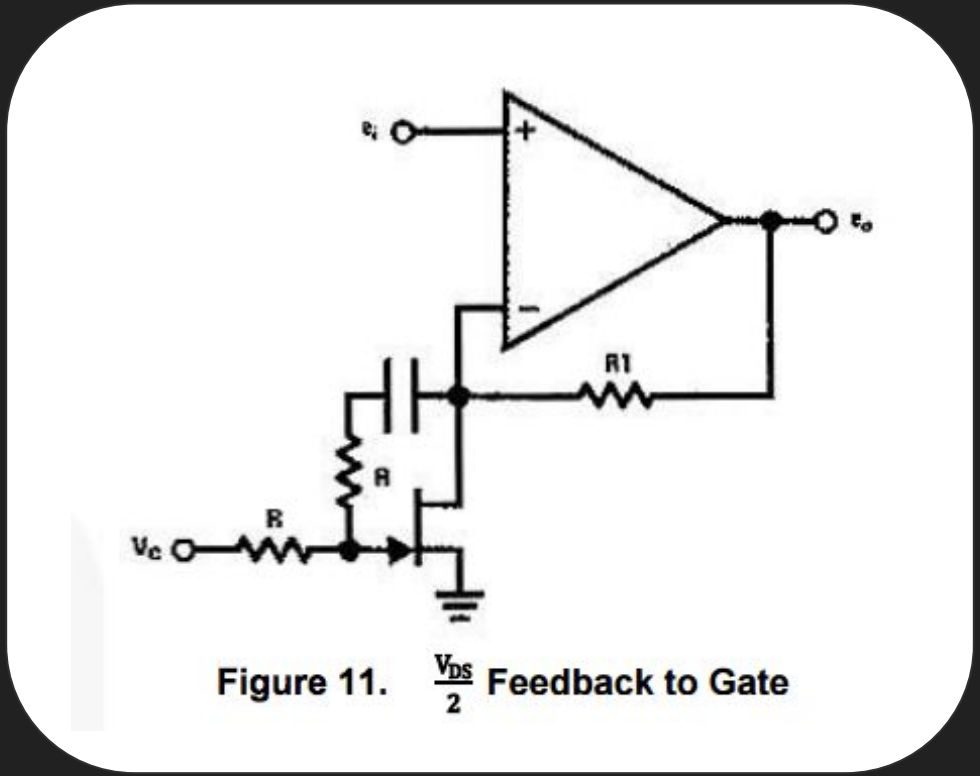
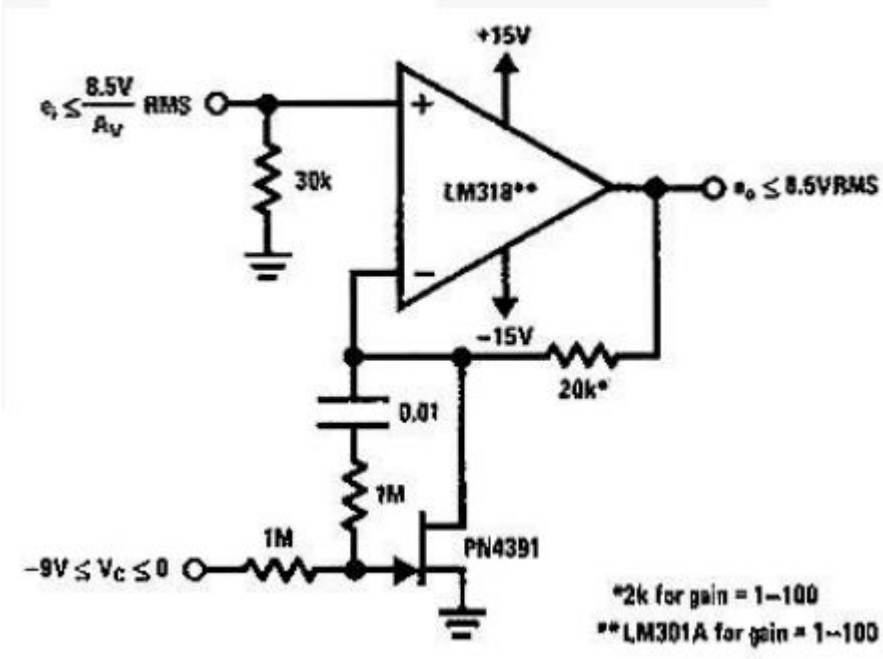
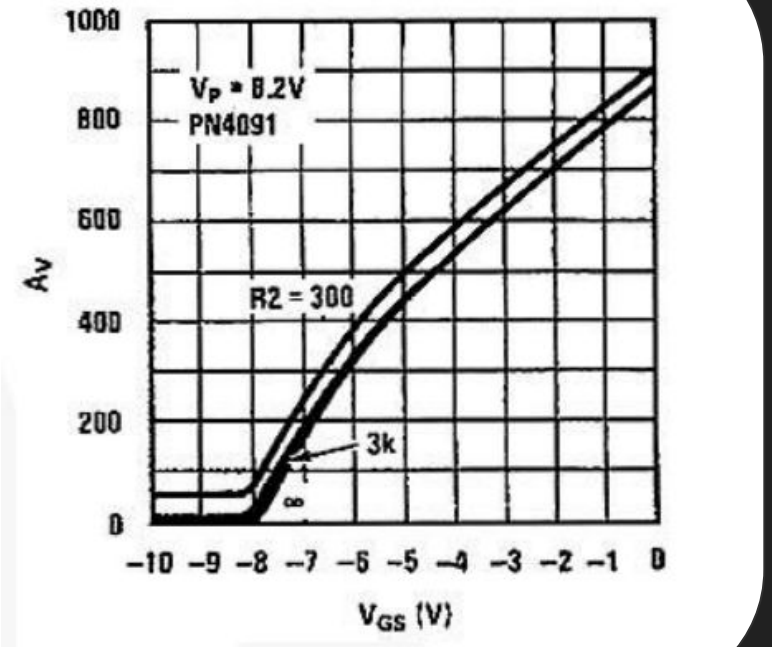


Figure 11. $\frac{V_{DS}}{2}$ Feedback to Gate

Voltage Controlled Amplifier

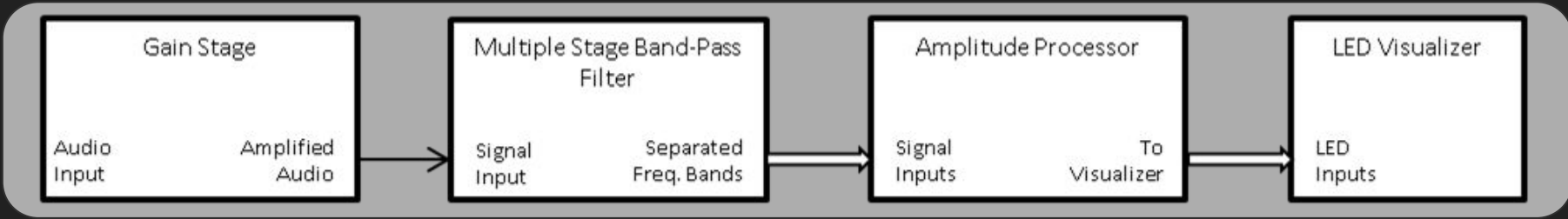




Frequency Visualization

Purpose:

- Have a visual representation of what note the Theremin is playing
- Aid in Theremin calibration

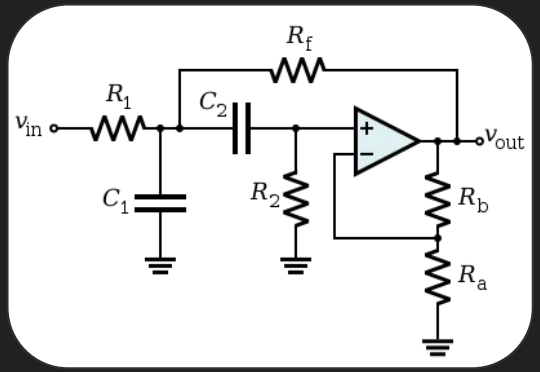


Stages:

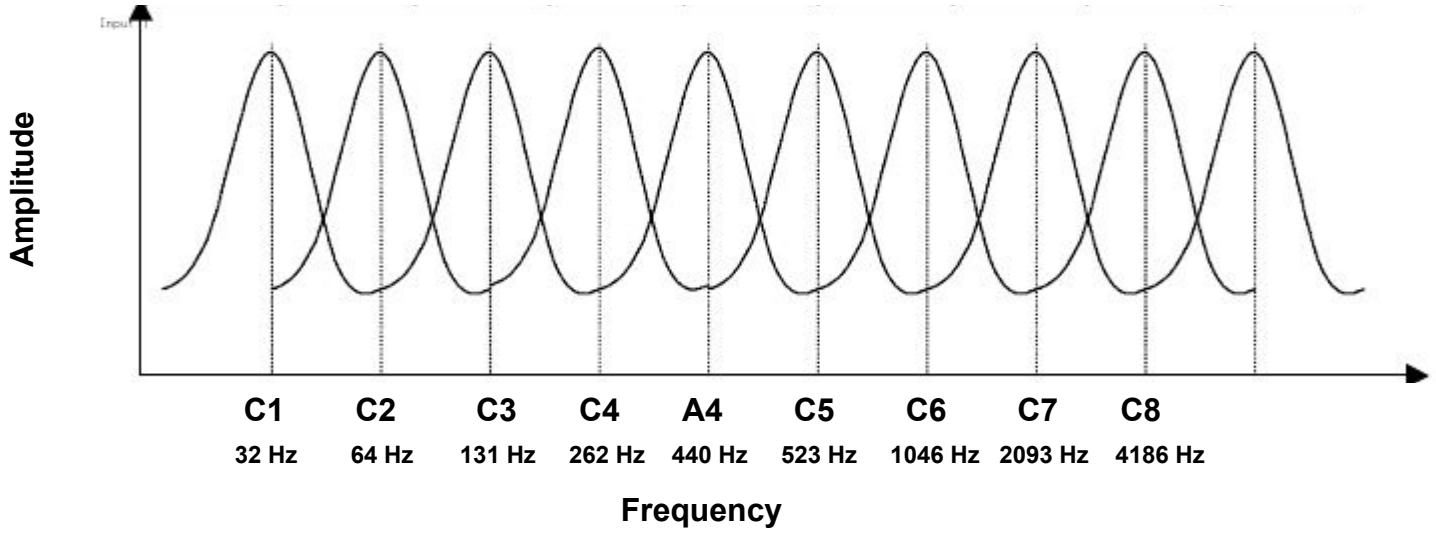
- Gain: receives the audio output from the detector and amplifies it
- Band-Pass: detects how close the output frequency is to different reference frequencies
- Amplitude Processor: takes the amplitude of each Band-Pass output and turns on LED's incrementally
- LED Visualizer: an array of LEDs properly organized to orient the player and tune the theremin

Sallen-Key Band-Pass Filter

Uses a low-pass and high-pass filter in conjunction.

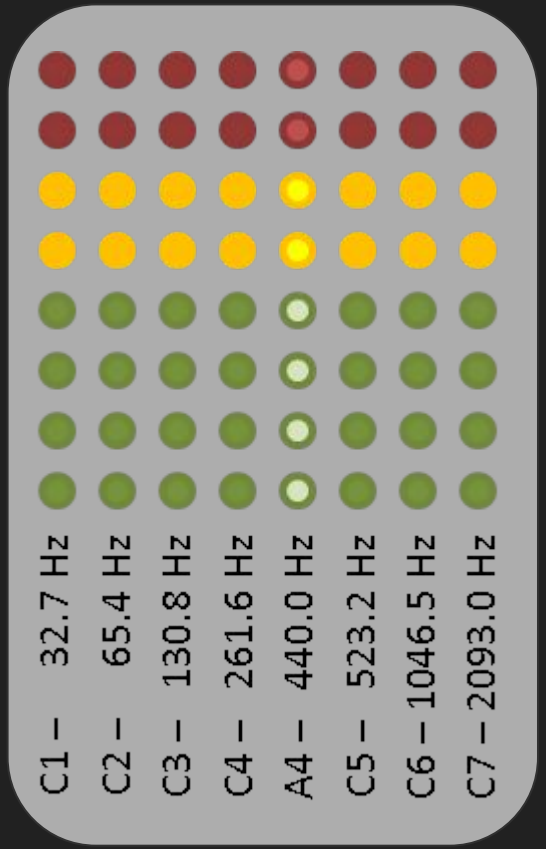


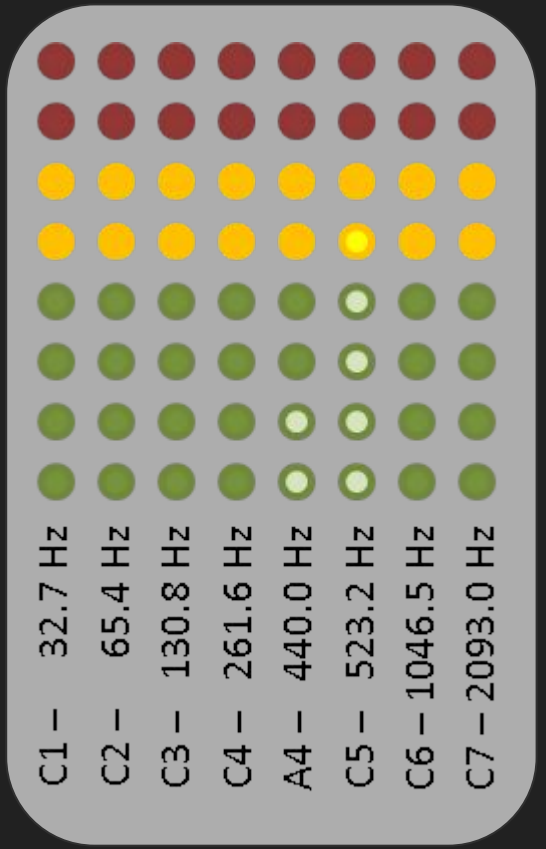
Bode Plot:



Visualizer

By properly adjusting the bandwidth of every band-pass filter, LED arrays overlap to let the player know within what frequency range he or she is playing.





Timeline

Weeks-> Members || V	April 04	April 11	April 18	April 25	May 02
All	Order/make antennas	----	----	Integration Testing and Refining	DONE!
David	Make FPO with Tuning	Make/test VPO with antenna	Design/make stretch goal component		
Patrick	Mixer	VCA / Power supply	Design/make stretch goal component		
Pedro	Working Schematic on LTSpice	Gain Stage Band-Pass	Amp. Proc. Visualization		

Conclusion and Challenges

Dealing with low capacitance change of antennas

Non-linearity of pitch antenna response

Making something that sounds good.

Questions?