Building a Theremin

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Outline

Task

- As part of 2nd year Physics labs we had to choose a project to implement over a period of 11 weeks.
- We had to work in teams of 2 students
- The project which I chose was to "Build a Theremin"

Implementation

First steps included;

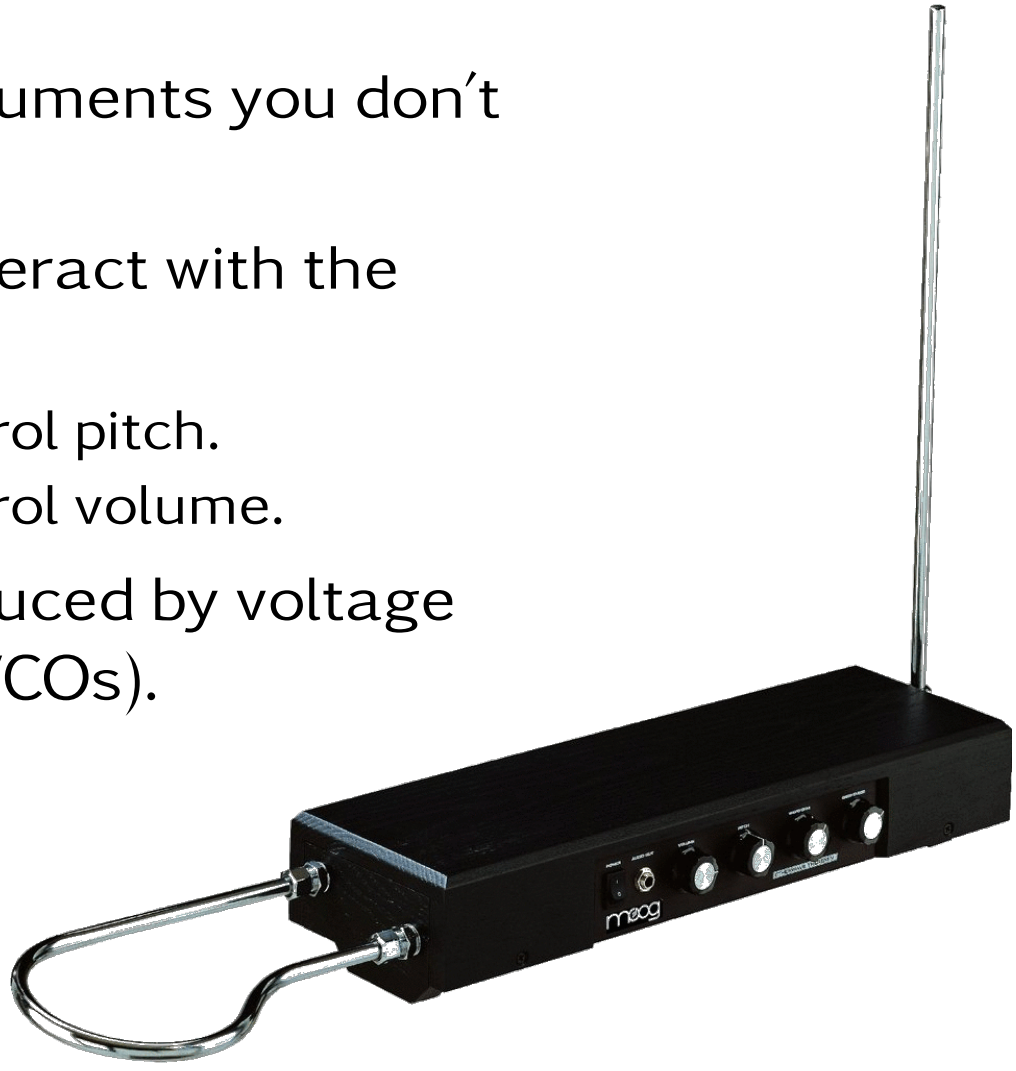
- Research
  - Complex circuits in commercial theremin
- First ideas
- Concept designs
  - Started from scratch
  - Modular design to allow testing separately
- Ordering parts

History

- Developed by Leon Termen, known in Europe as Leon Theremin.
- Invented in October 1920.
- By product of proximity sensor development.
- Shown to Lenin who dismissed it's usefulness but enjoyed the sound.
- Toured Europe to showcase the height of Russian technology.

Basic Concept

- One of the only instruments you don't touch to play.
- Use two hands to interact with the instrument;
  - One hand to control pitch.
  - One hand to control volume.
- The signals are produced by voltage control oscillators (VCOs).



Basic Theory

The electronics for each hand;

- Involves 2 VCOs
  - 1 as a control, remains fixed.
  - 1 is varied by the user
- 2 signals added and subtracted by a mixer circuit to produce final signal.

Signal Generator

- As proof of concept, use a signal generator to output sinusoidal waveform.
- Send this wave through control method then to speaker to test.
- Can vary between sinusoidal, triangle and square waves.
- Test mixer when using two signals from the generator.

Parallel Plate Capacitor

- User acts as a grounded plate of parallel plate capacitor.
- Moving closer decreases the capacitance.
- When further away, the capacitance increases.
- Can make rough estimate of capacitance from the following capacitor equation;

Capacitor Equation

$$C = \frac{k\epsilon_0 A}{d}$$

where

- $k =$ relative permeability of the dielectric material between the plates, in this case air =1,
- $\epsilon_0 =$ permittivity of free space $= 8.854 \times 10^{-12} Fm^{-1}$,
- $A =$ area of the plates,
- $d =$ separation of the plates, in this case the distance from the plate to the user's hand.

555 Timer Chip

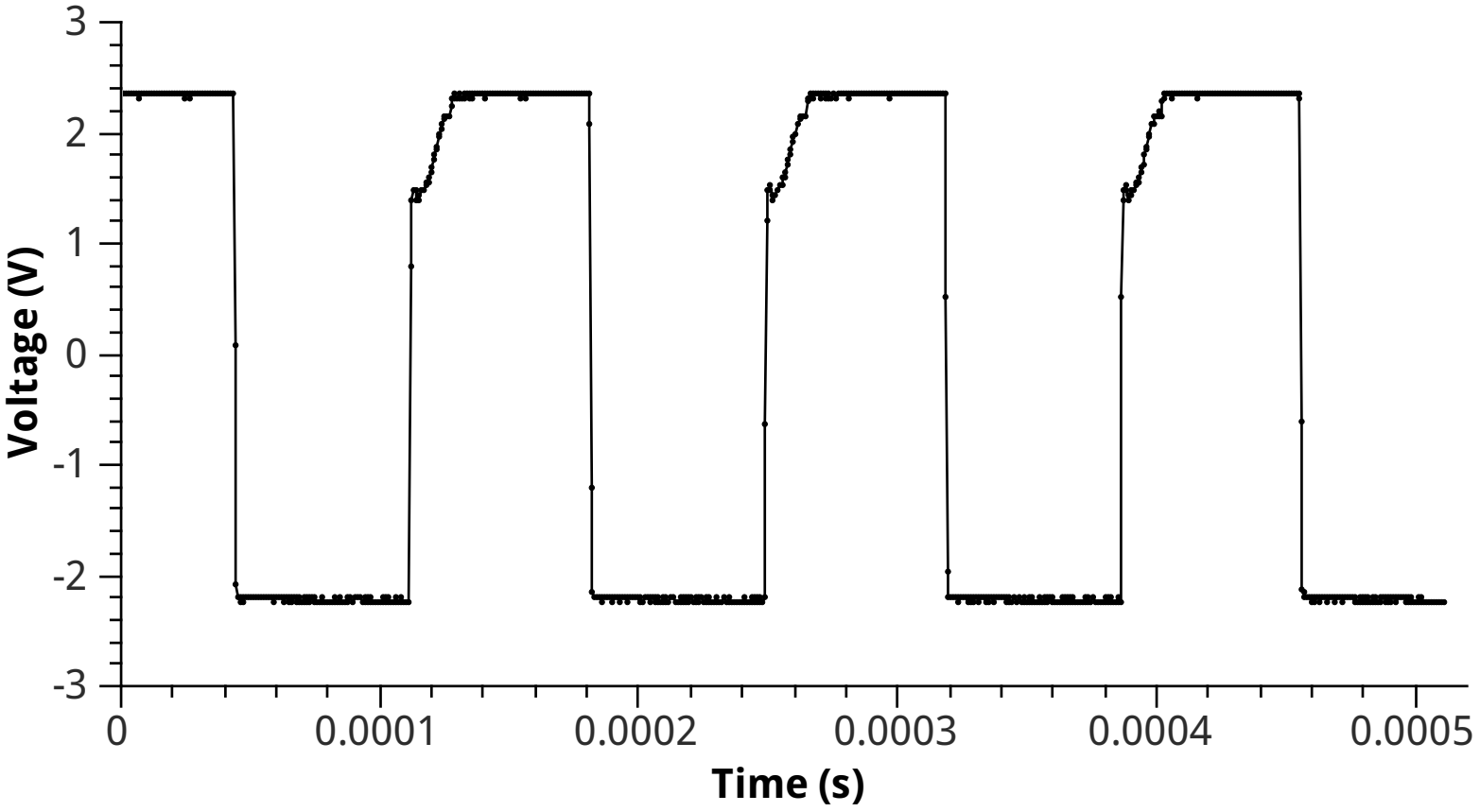
- The 555 timer IC outputs a square wave with frequency depending on the input voltage.
- Can be used as a VCO, changing the resistances changes the input voltage - voltage divider theorem.
- Characteristics of produced wave controlled by the equations;

$$\text{Frequency, } f = \frac{1}{\ln(2)C(R_1 + R_2)}$$

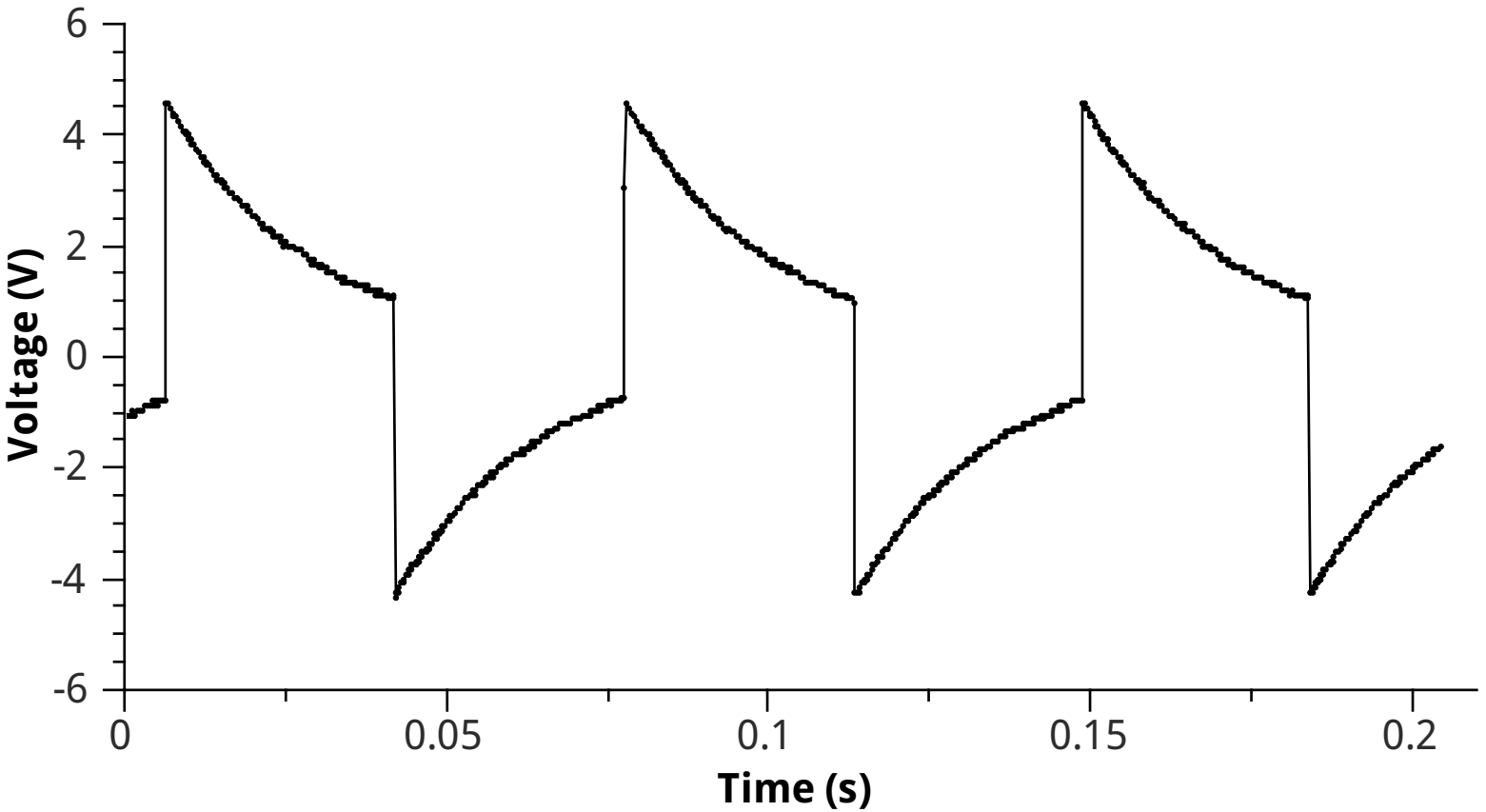
$$\text{Low time, } \tau_l = \ln(2)R_2C$$

$$\text{High time, } \tau_h = \ln(2)(R_1 + R_2)C$$

High Frequency



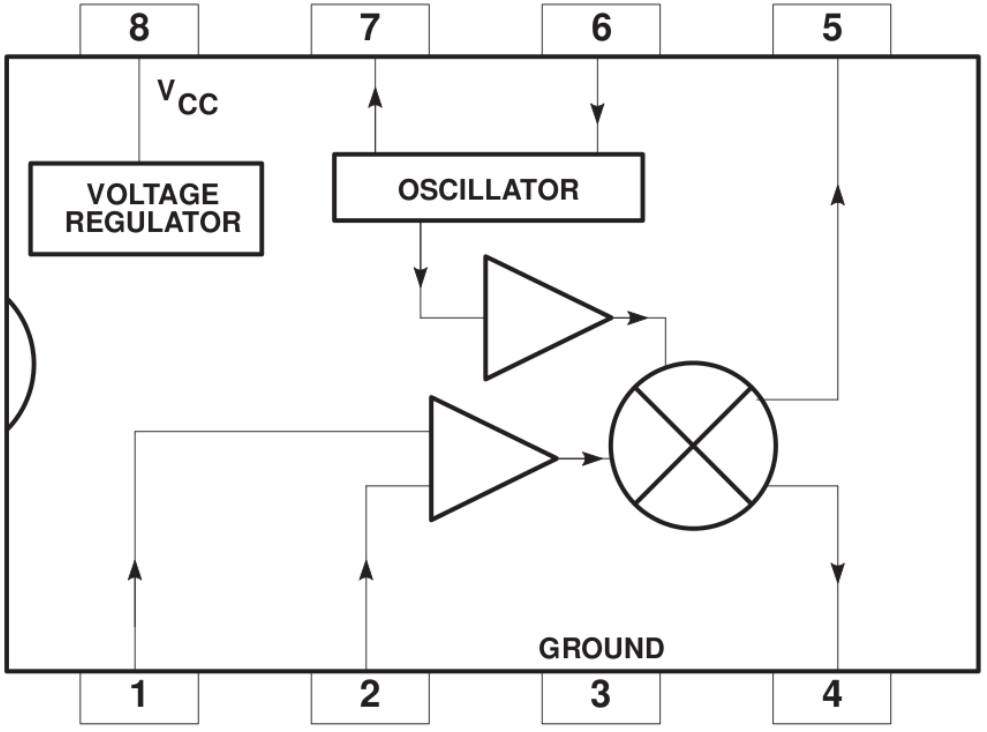
Low Frequency



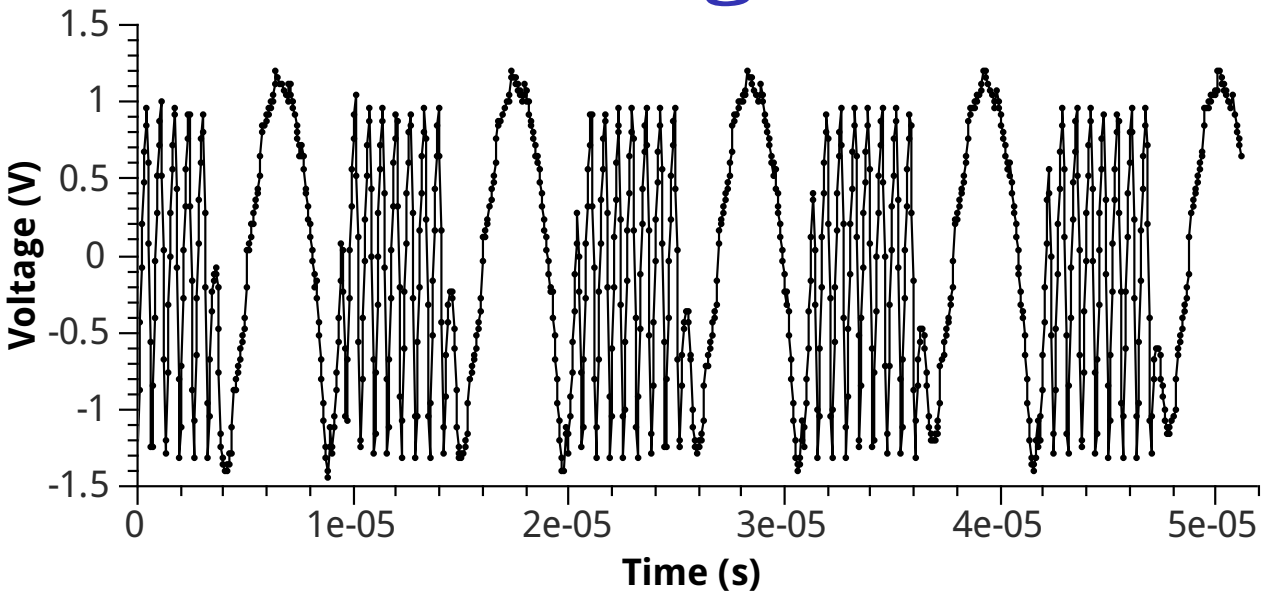
Mixer Circuit

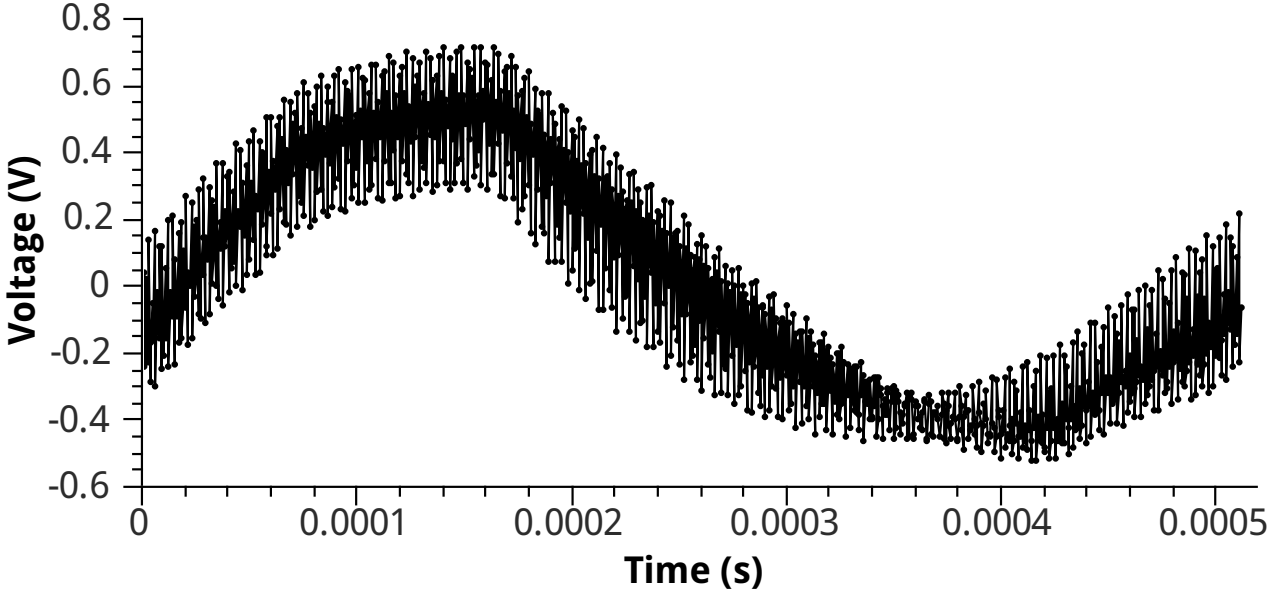
The SA612A mixer chip is used for the mixer circuit.

- Takes 2 input signals and outputs both the addition and subtraction of them.
- Contains internal oscillator, but not used for this purpose.



Mixer Signal

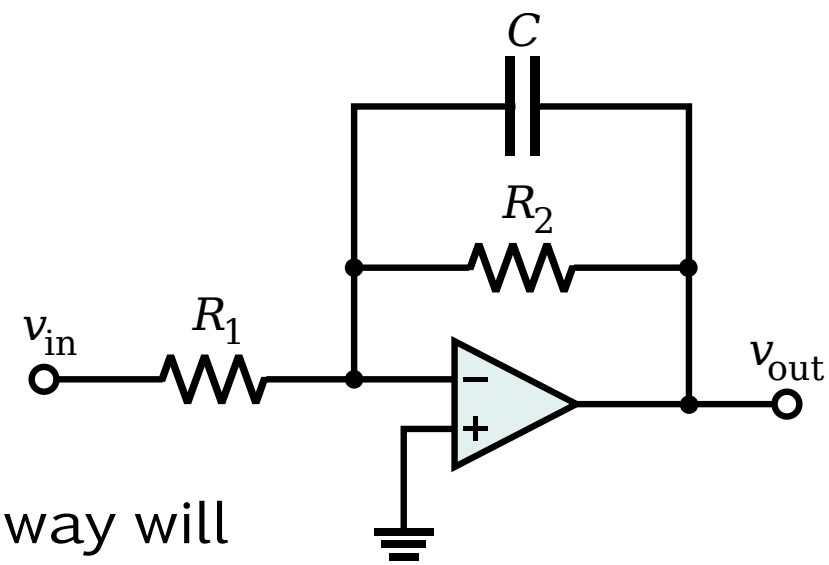




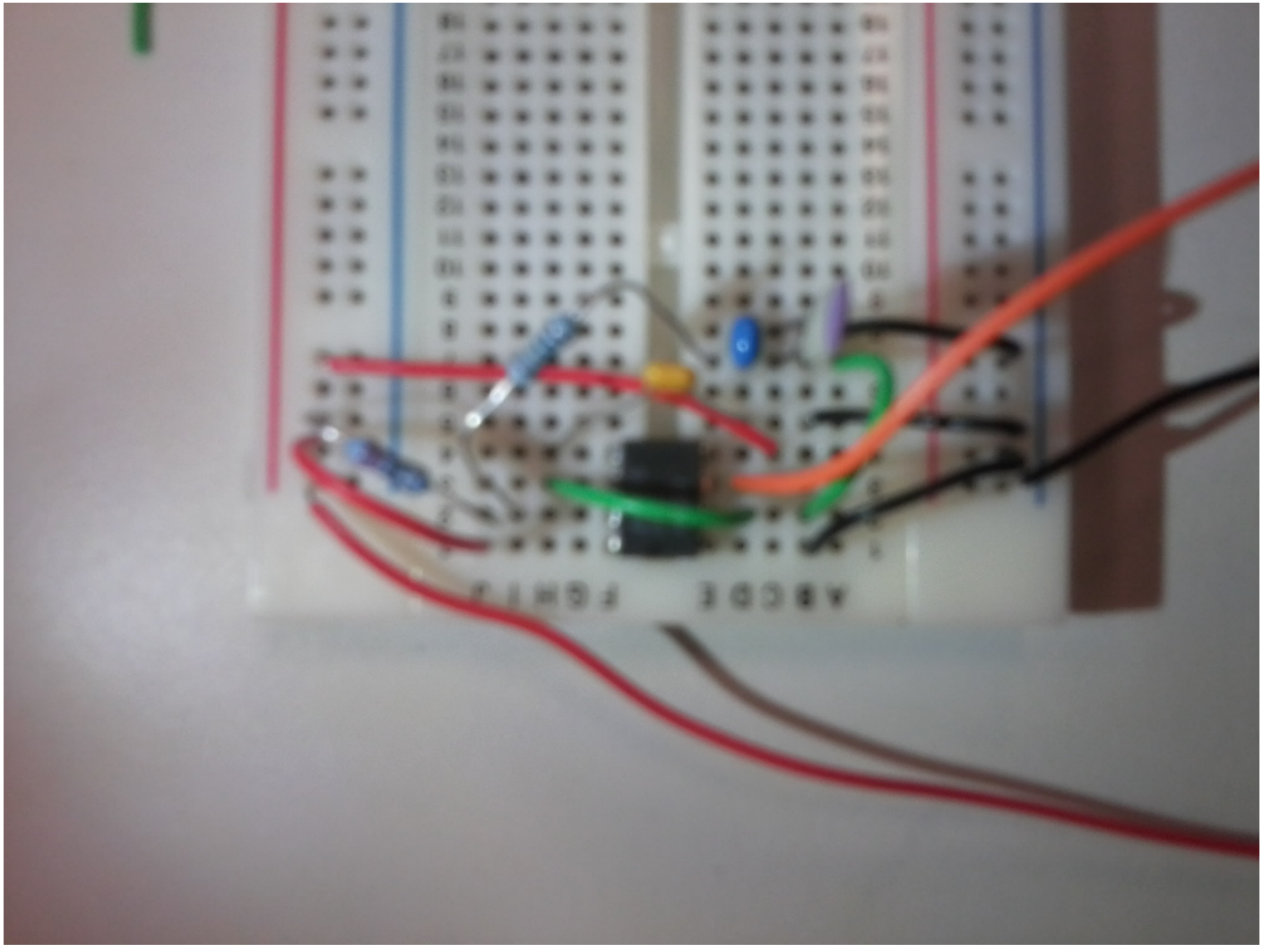
Low Pass Filter

Low pass filter - electronic filter that passes low-frequency signals but reduces the amplitude of signals with frequencies higher than the cutoff frequency.

- Use to remove the high frequency oscillations in waveform
- Consists of simple cheap components;
  - Resistors
  - Capacitor
  - Op-amp
- When arranged in the right way will give large control over frequencies blocked.



Progress



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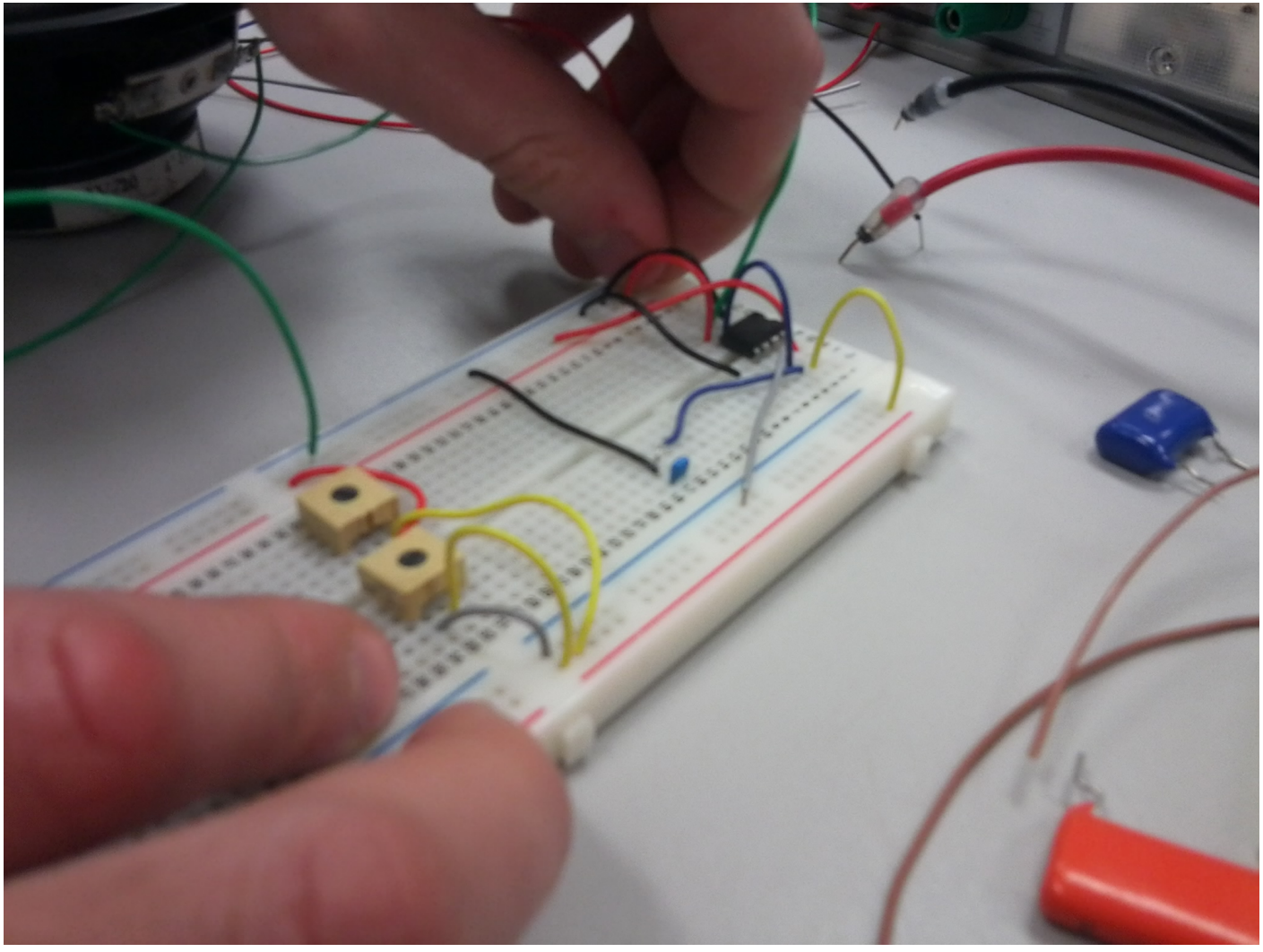

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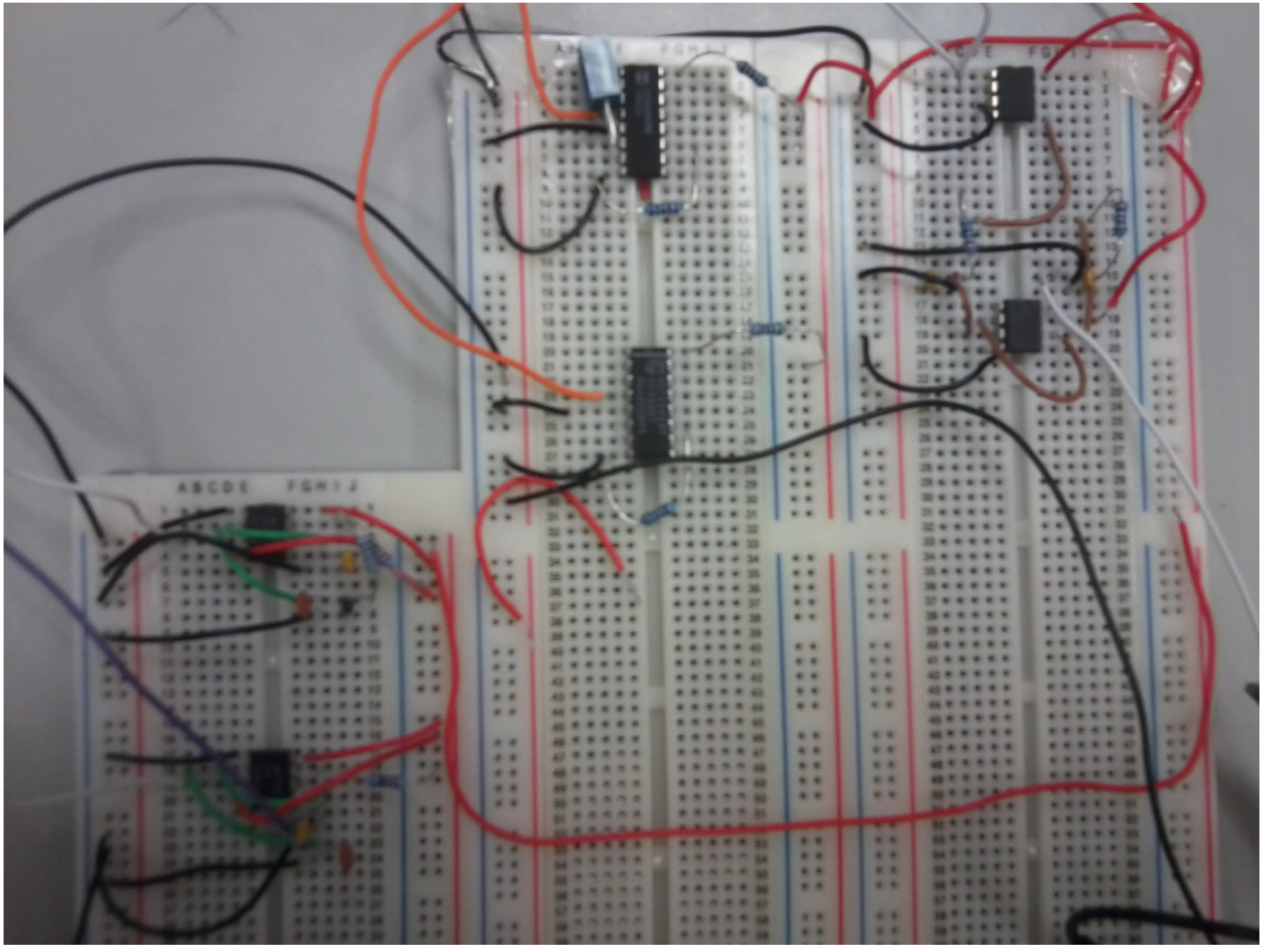

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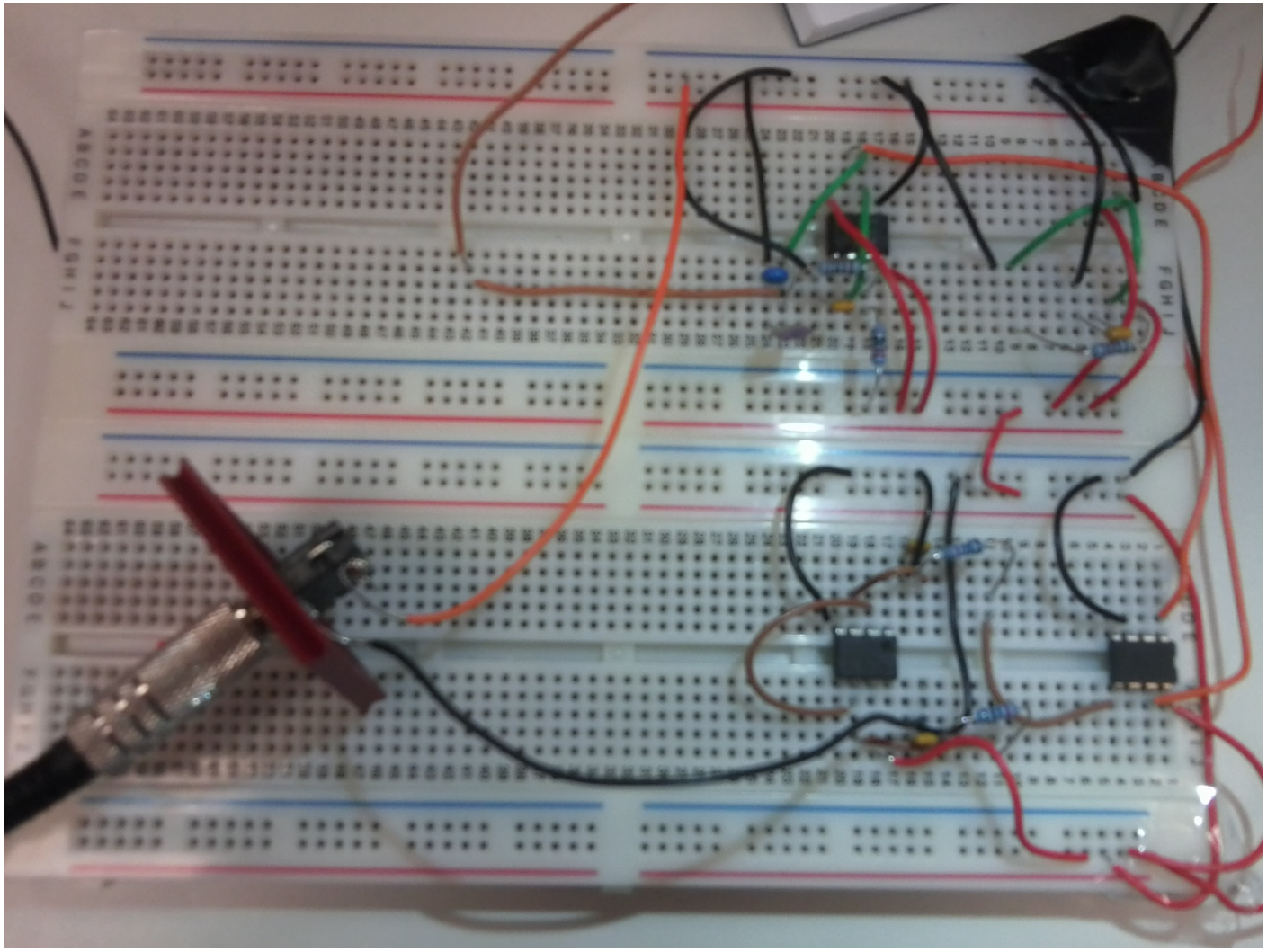

Summary

- Building a theremin in 11 weeks from scratch.
- Using commonly available components and resources.

- Outlook
  - Testing to improve quality and performance.
  - Reduce size and power requirements for commercialisation.