Remotely Connected Electric Field Generator

for Particle Separation in a Fluid

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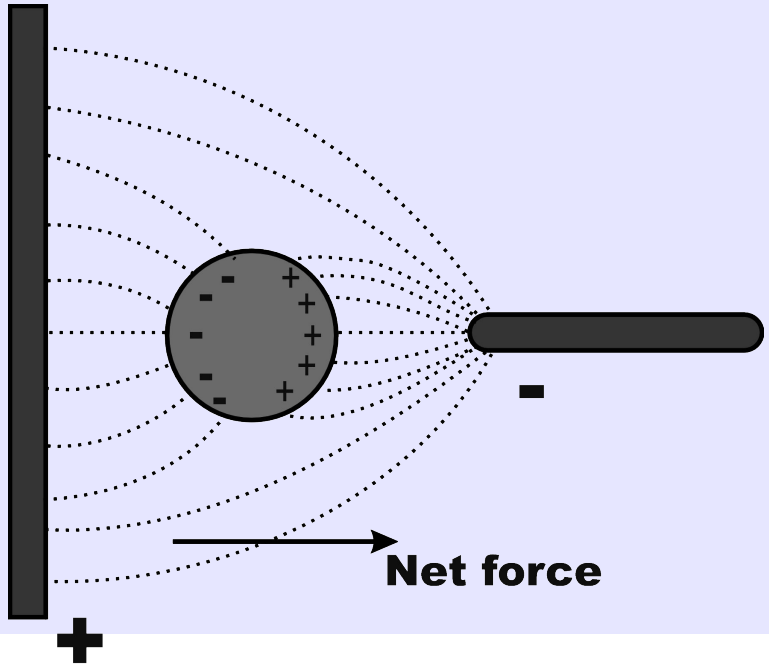
Dielectrophoresis (DEP)

- A dielectric particle in a non uniform electric field experiences a force
- Different potential fields and frequencies has an effect on the net force
- First studied in 1950s by Herbert Pohl



Real World Application

Dielectrophoresis

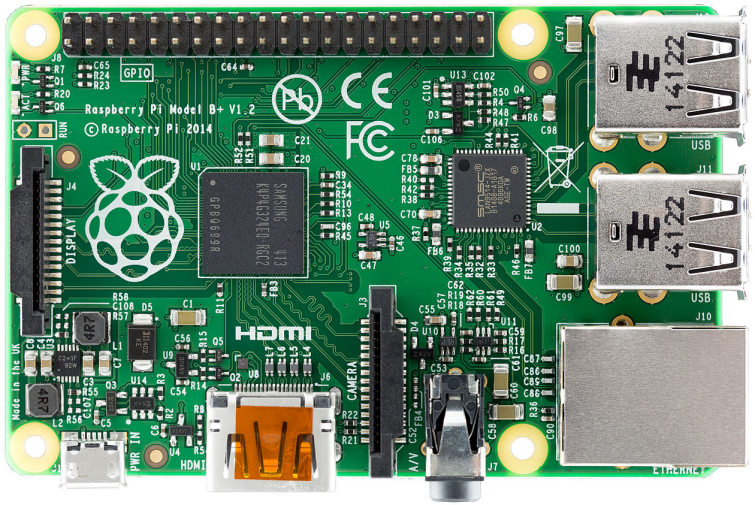
- Recently revived due to the ability to manipulate micro-particles and cells.
- Potential to separate particles in spinal fluid
- Act as filter
- Research in separating cancerous cells from healthy cells
- Separate platelets from whole blood
- Separate red and white blood cells
- Separate Strains of bacteria and viruses from living cells

Project Description

- A system to aid in of DEP research
- Allow for quicker setup times
- Control Voltage and Frequency via the web
  - 1 to 60 VPP
  - 10k to 1Mhz
- Hold output for long time periods
- Small Form Factor
- Easy to use
- Plug and play

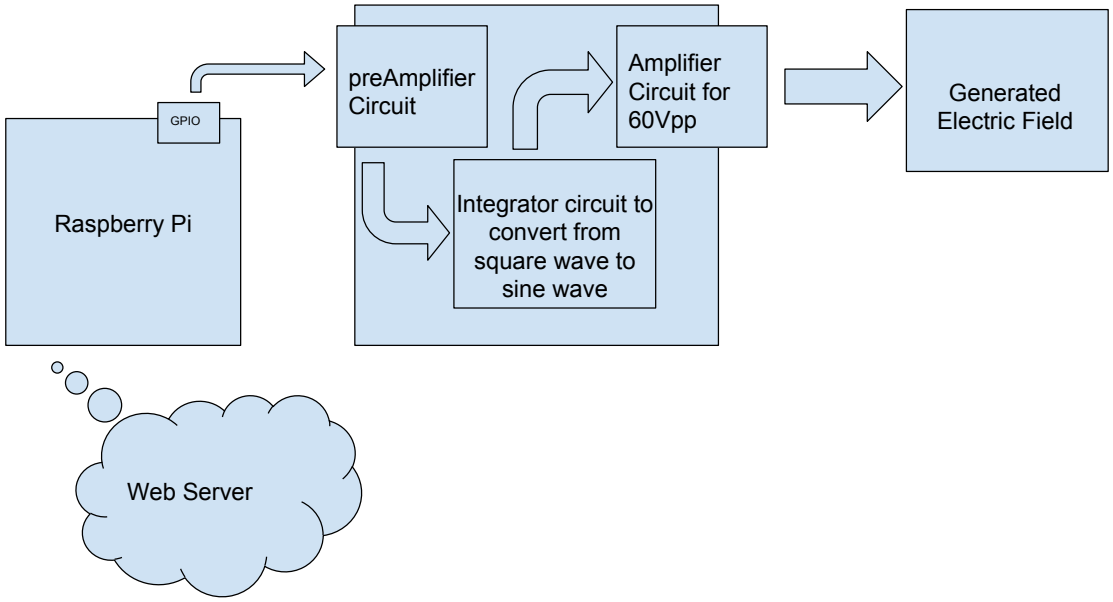
Project Structure

- Raspberry Pi
- Web Interface
- Web Server
- Frequency Control Solution
- Voltage Control Solution



Initial Implementation

- Raspberry Pi
  - Host web server
  - Remote manipulation of circuit output
  - Web interface can provide additional functionality
  - GPIO pins input to circuit
- Circuit Output
  - Frequency generated by GPIO pin
  - GPIO waveform integrated to get sine wave
  - Sine wave amplified to form output

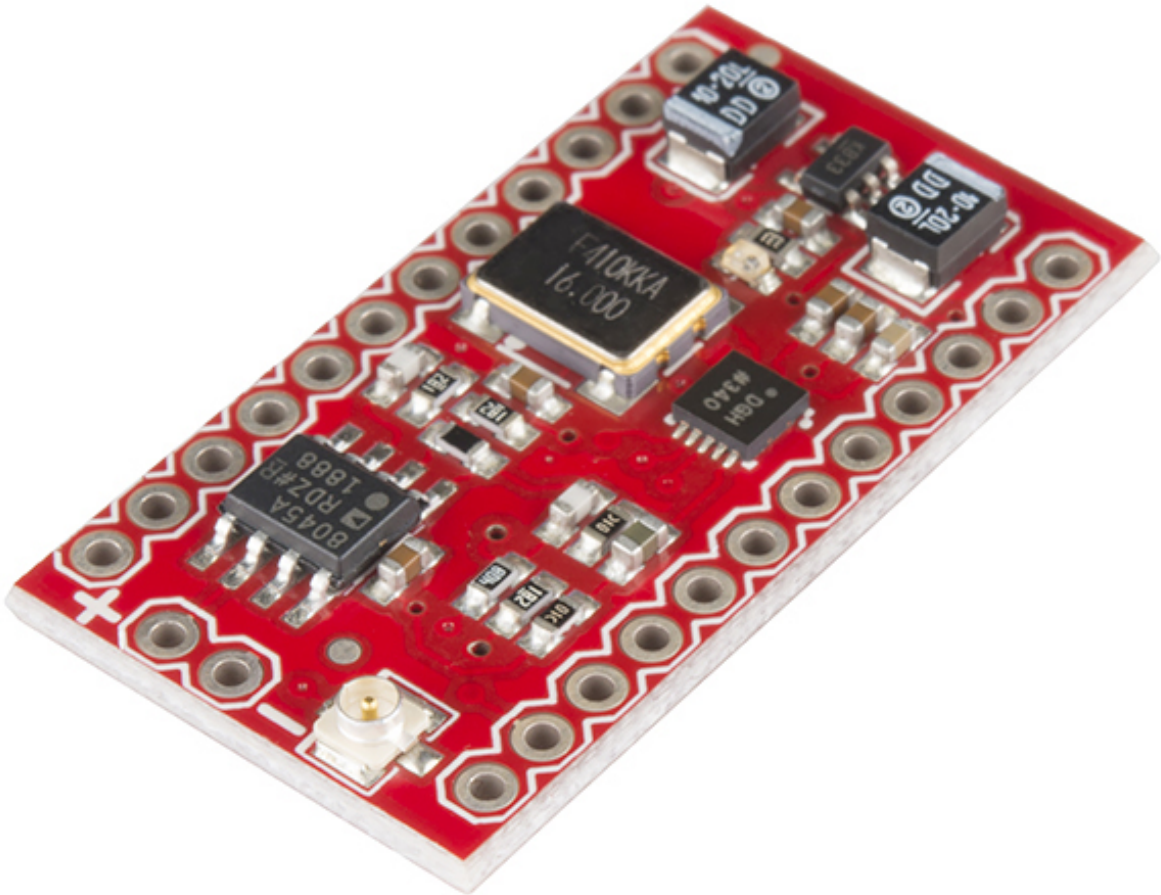


Concerns

- Raspberry Pi
  - Complexity of programming
  - GPIO pins may only be turned on and off
  - On-off mechanism must be used to generate waveform
  - Current load
- Circuit Output
  - Complexity of construction
  - No guarantees about cleanliness of GPIO pin waveform
  - High risk of failure

Minigen Function Generator

- SPI communications
- Small form factor
- Output programmable frequency
- Produces 1 Khz to 4 Mhz waveforms



Intermediate Design

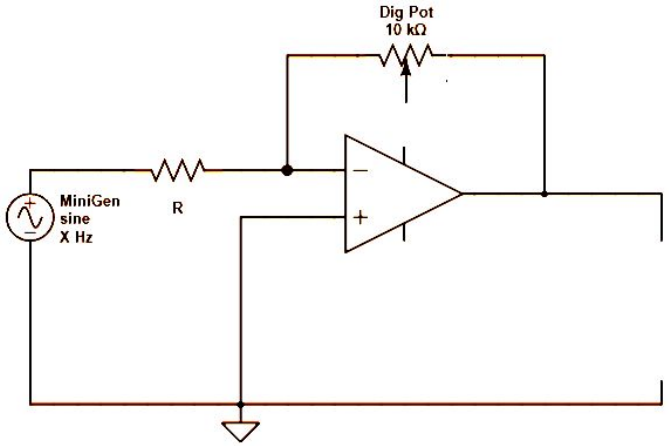
- Raspberry Pi controls Integrated circuit components
- Minigen used to produce frequency
- Digital Potentiometers
  - SPI communications
  - Vary resistance to control amplifier
- Amplifier controls voltage output from circuit

Digital Potentiometer Amplifier Circuit

Properties

- Utilizes digital potentiometer as feedback resistor

$$V_{out} = \frac{-R_F}{R_{IN}} * Minigen_{SIGNAL}$$



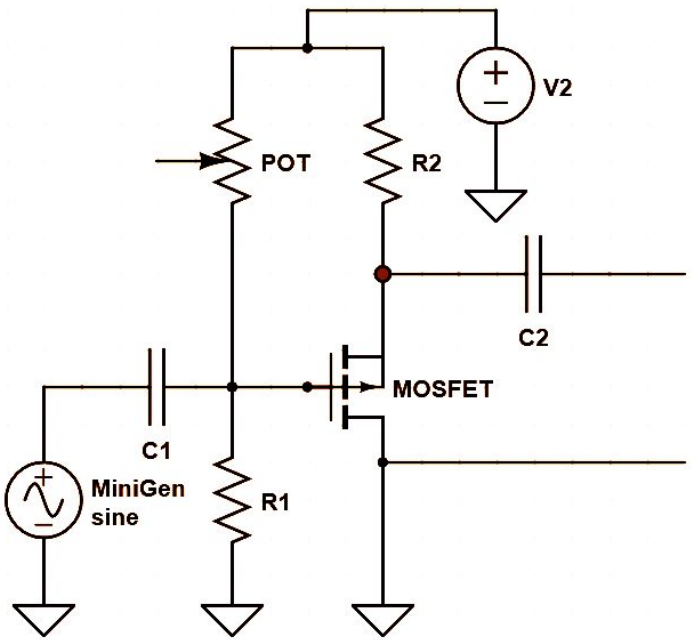
Problems

- Distortion of signal
- Very low resistance with AC signal

MOSFET Amplifier

Properties

- Utilizes digital pot in a different way
- Amplification utilizes transistor



- Suggested by Minnetronix
- Distortion of signal remains
- Concluded digital potentiometer is source of problem

Redesign Amplifier

Idea Overview

- Previous problems stem from voltage modification solutions
- Solution: Use integrated circuit component to modify voltage

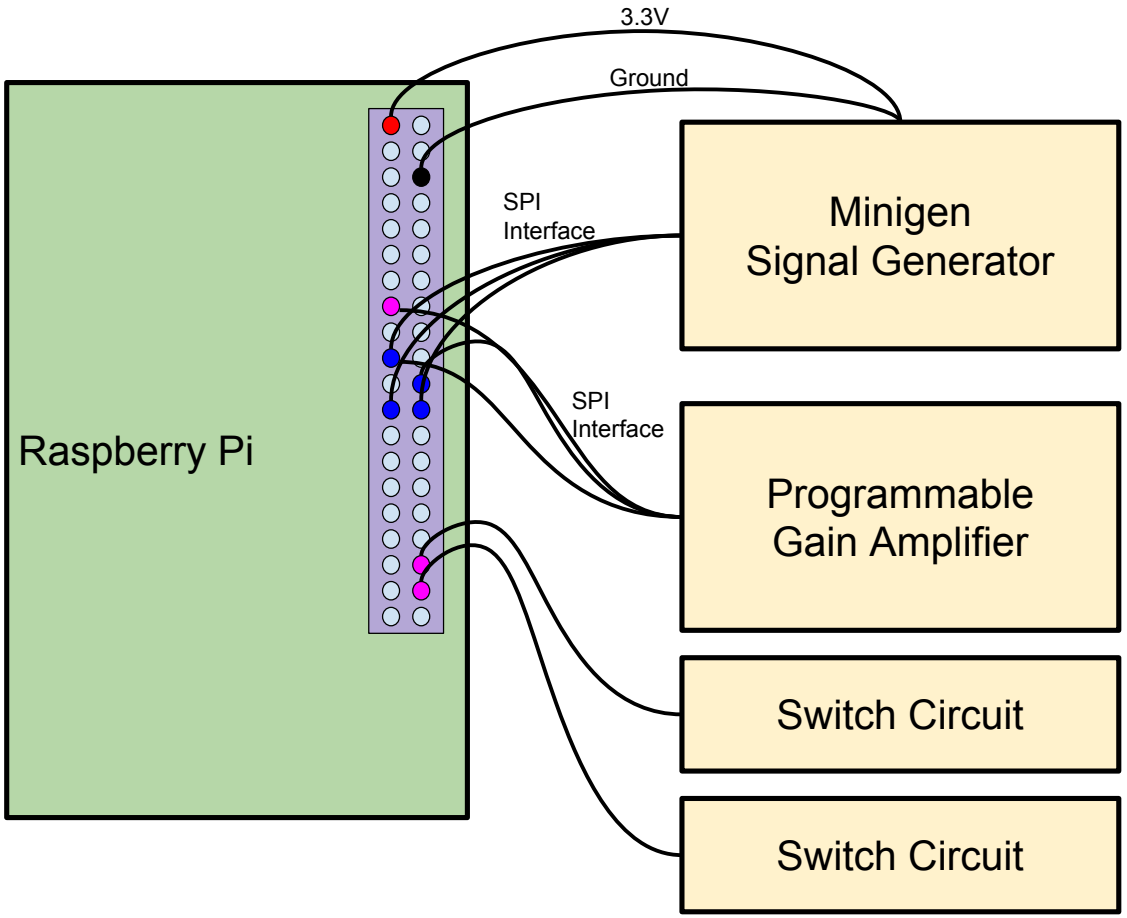
Amplifier Properties

- Three stages of amplification
- One PGA and two stages with constant gain
  - $20\,V_{pp}$ per stage
  - Summing amplifier sums stages
  - PGA achieves 8 steps within one stage
  - Switches increase output by $20\,V_{pp}$
- Use transistors as switches flipped using GPIO pins

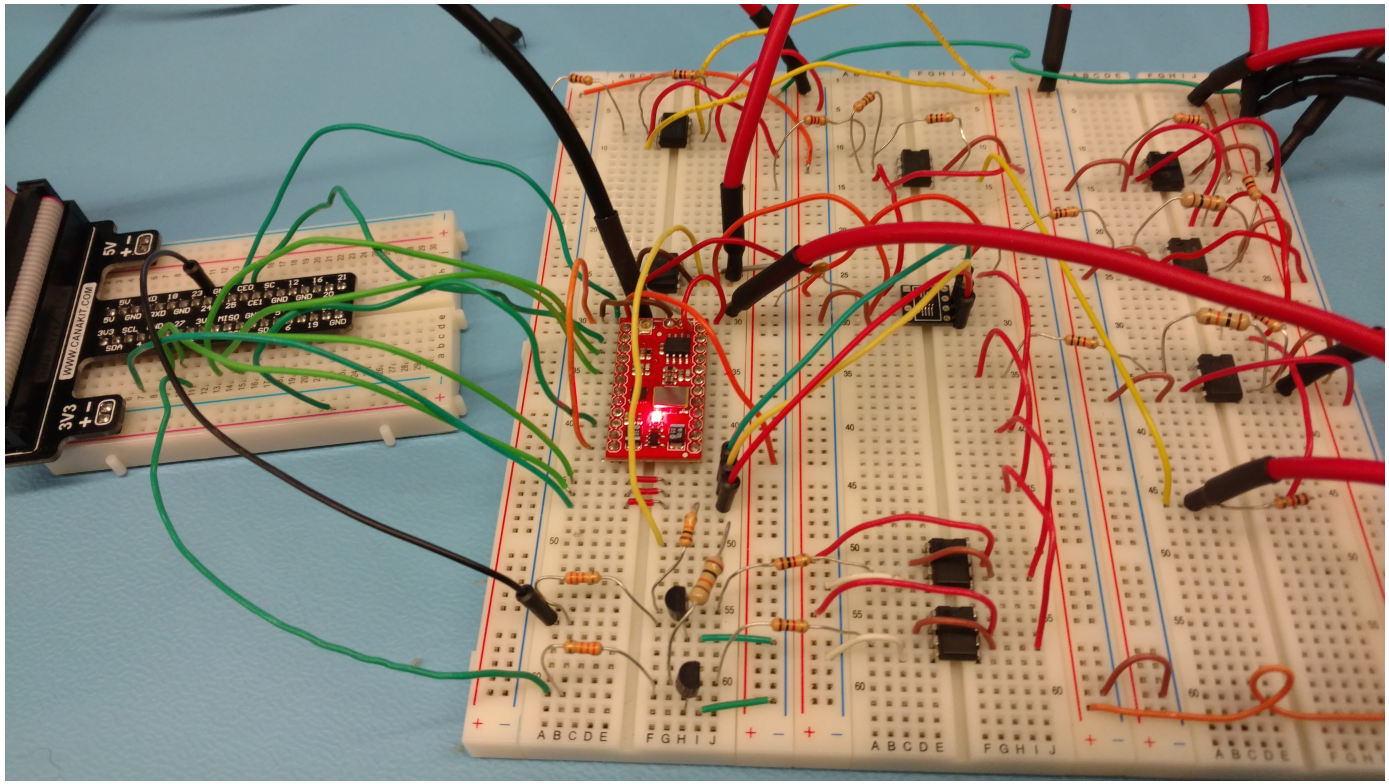
Configuration

Programmable Gain Amplifier(PGA)

- Three pins encode gain
- 8 Gain Options from 0 to 7



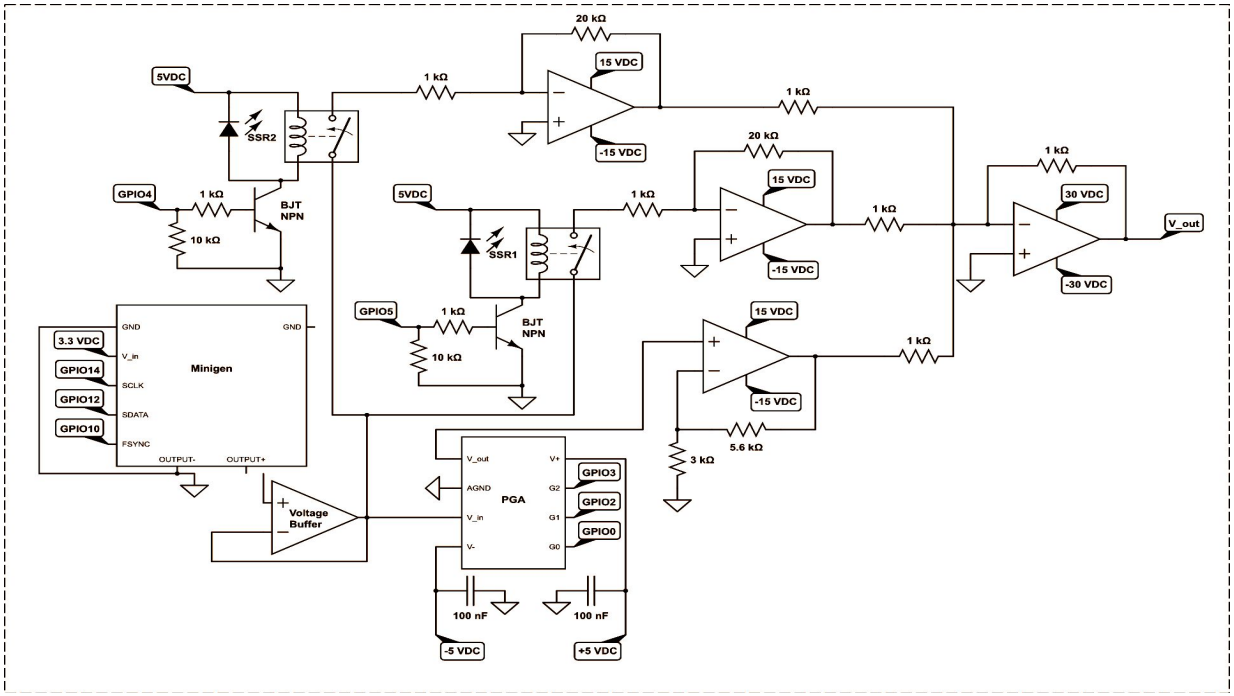
Layout



Connections Description

- Raspberry Pi connected to components
- Output of Minigen goes to input of PGA
- All three stages input to summing amplifier

SSR Circuit Implementation



Solid State Relay (SSR)

- Uses LED and photo-resistor to allow current though
- Hoped to fix waveform distortion issues

Problems

Programmable Gain Amplifier(PGA)

- Easy to destroy
- Functionally works well

Transistor Switch Circuit

- BJT Leaks when logically off

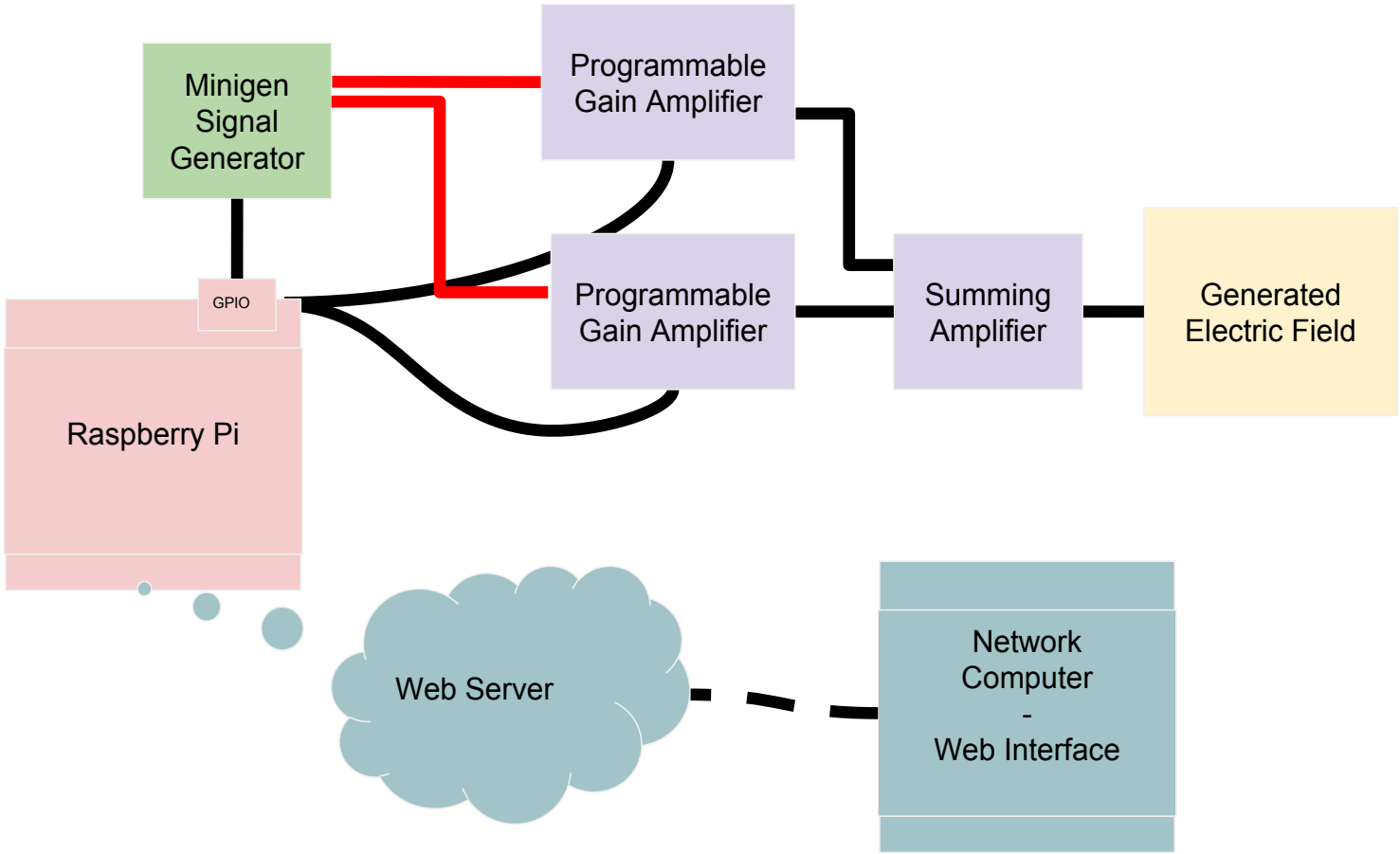
Solid State Relay

- Could not function at high enough frequency
- Even moderately high AC signals at input cause output of 0

Overview

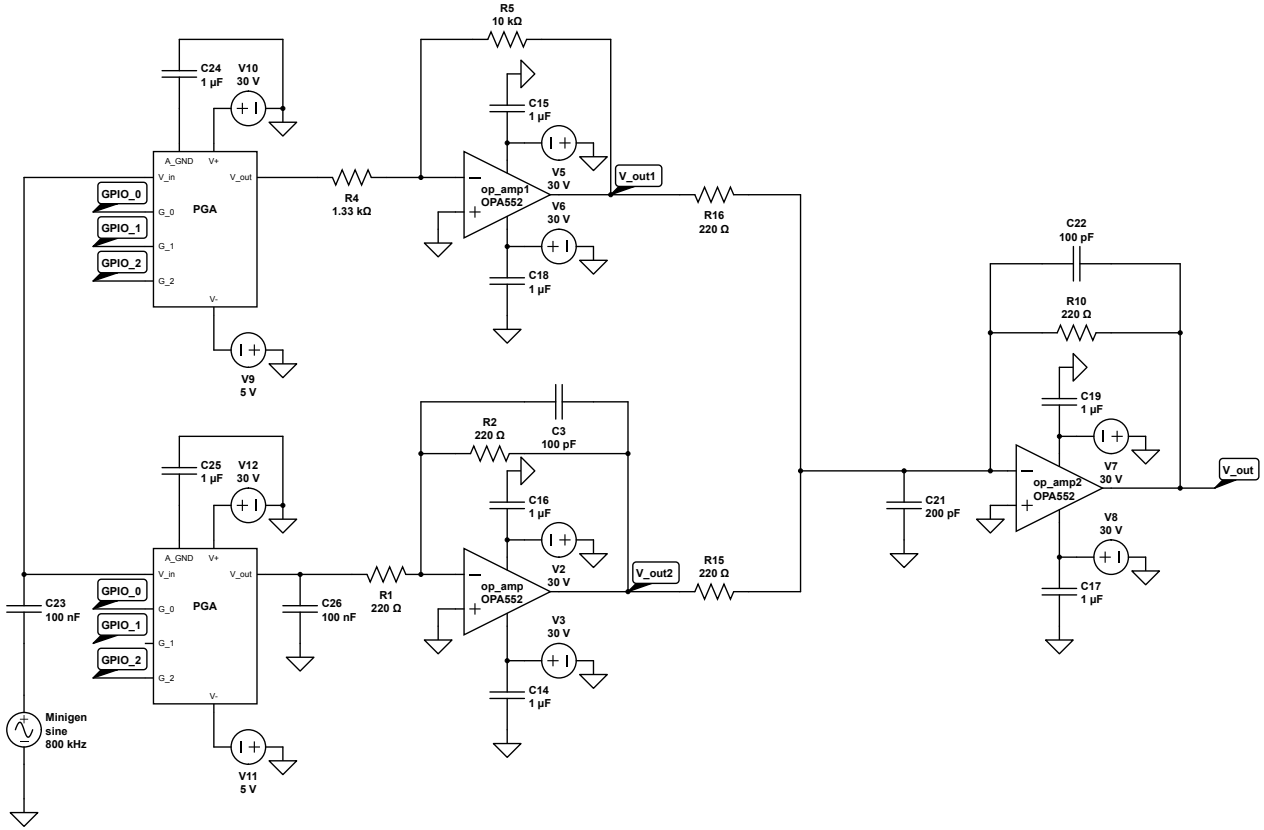
- Raspberry Pi controls integrated circuit components
- Minigen Function Generator
  - SPI communications
  - Produces frequency 10 Khz - 4 Mhz
- Programmable Gain Amplifier(PGA)
  - GPIO communications
  - 8 voltage options (0-7)
- Two-stage amplification
- Summing Amplifier
  - Sums output from amplification stages

Systems Diagram

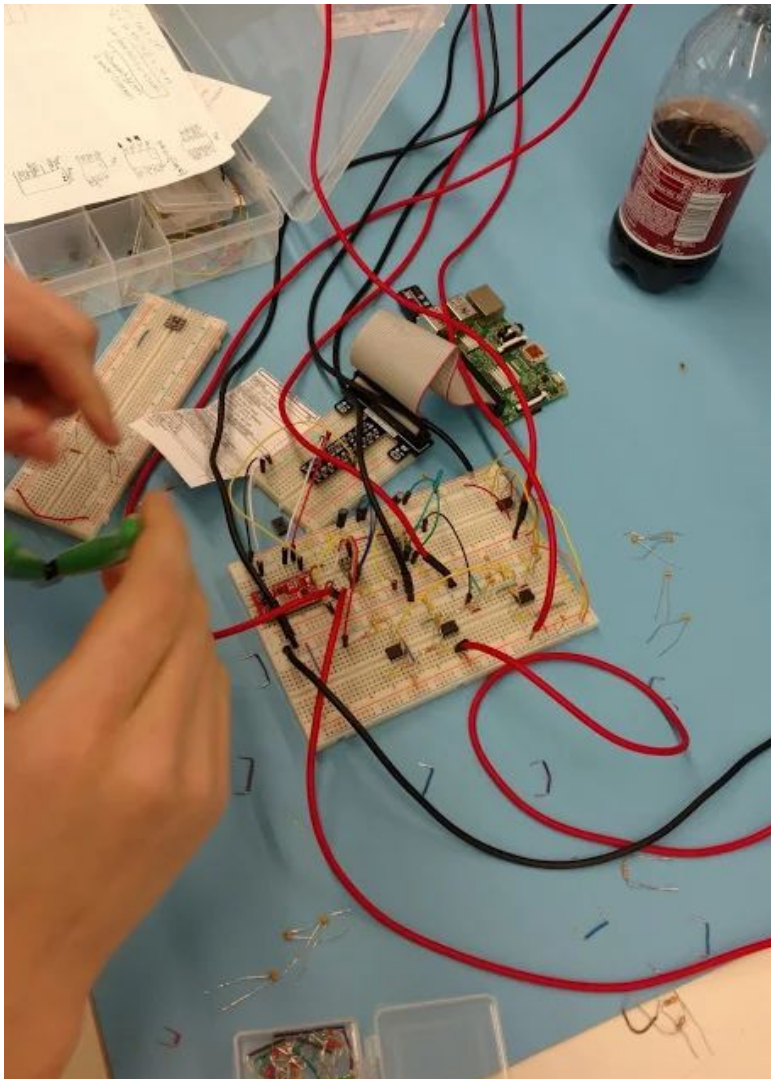


Amplifier Circuit

- Two stages with PGA and constant gain amplifiers
  - Upper stage constant amplifier Gain 7.5
  - Lower stage constant amplifier Gain 1.07
  - PGA's both having variable gain
- Summing amplifier



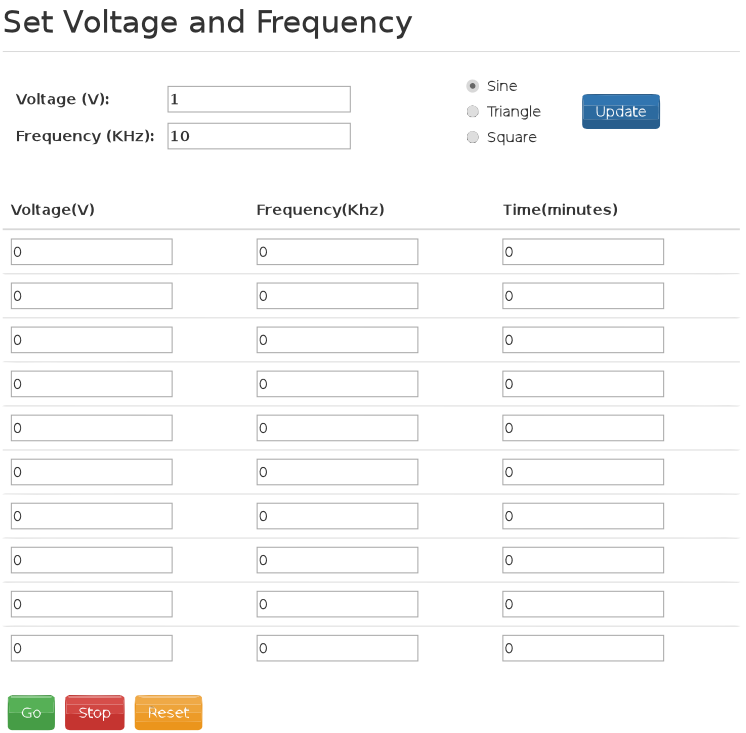
Physical Implementation



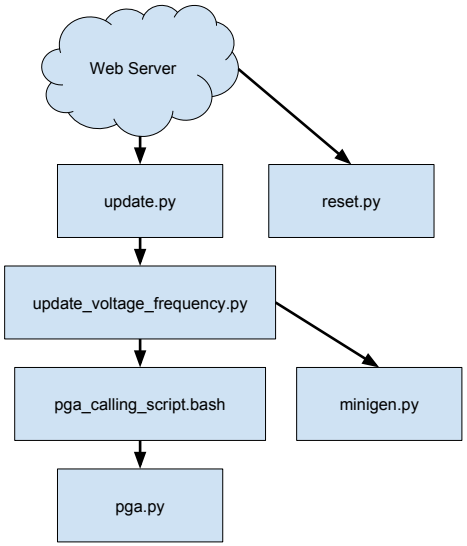
- Raspberry Pi connected to break-out board
- Break-out board connection GPIO pins to
  - PGA
  - Minigen
- Minigen output to PGA
- PGA output to constant gain amplifier within same stage
- Constant gain amplifiers output to summing amplifier

Web Interface

- Hosted Locally
- Able to be seen on intranet
- Voltage and Frequency controls
- Provides Additional Functionality



Software Components



- Script organization of the Raspberry Pi
- Delegation of Responsibility
- Scripts correspond to hardware components

Current State

Problems

1. Current op-amps
   1. have insufficient Gain-Bandwidth Product
   2. Slew rate too low
2. Current draw from Raspberry Pi

Solutions

1. An op-amp with necessary specifications exists, 598-1449-ND
2. Ensure few additional components connected to the Pi

Cost

Itemized Expenditures

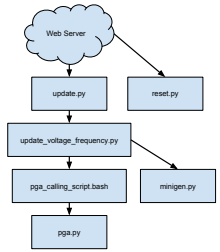
Item	Quantity	Price($)
Raspberry Pi 3 Kit	1	49.99
Micro SD card	1	9.99
Minigen Function Generator	1	29.95
Op Amps	3	4.41
PGA	2	8.00
Miscellaneous Components	-	10.5
Total	-	112.84

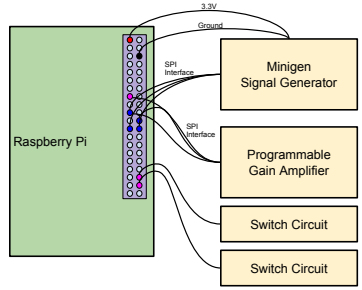
Logistical Setbacks

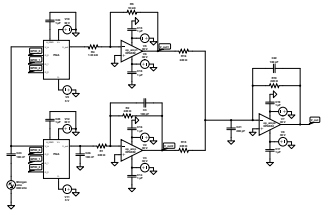
- Lack of manpower
- Loss of a team member at semester break
- Point of contact left company

Deliverables

- Raspberry Pi loaded with controlling code
- User manual
- Current circuit implementation
- PCB design
- Simulation files







Questions?

Discussion Points

- Dielectrophoresis (DEP)
- Circuit Design
- Digital Potentiometer/ Operation Amplifier
- MOSFET/ Programmable Gain Amplifiers (PGA)
- Web Interface
- Final Documentation

Work Breakdown

Items

- Initial Planning
- Project Website
- Reports and documentation
- Circuit Design
- Web Server
- SOC Communications
- PCB Design