Remotely Connected Electric Field Generator for Particle Separation in a Fluid

Timothy Dee, Justin Long, & Brandon McDonnell

Team May1612

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This project is sponsored by Minnetronix, a health care company based in St. Paul, Minnesota, founded in 1996. Minnetronix continues to innovate landscape of health care technology with an emphasis on device development and commercialization of medical technologies. This project is apart of this effort.

Problem Statement

This project is part of a larger design to exploit the dielectrophoresis phenomenon for use in medical equipment. There are many medical applications which utilize a method of separation. Centrifuging blood and testing spinal fluids are two examples of such systems. Current testing equipment is expensive therefore a cheaper device utilizing DEP would have a large competitive advantage if constructed.

Dielectrophoresis Phenomenon:

- separate particles in a fluid.
- involves applying an electric field to a fluid.
- field applied over long period of time.
- particle separation depends on electric field characteristics.
- adjusting the voltage and frequency used to generate the field varies its characteristics.

Requirements

This device will need to be capable of operating in a laboratory environment. It is also beneficial if this device is portable. Given these constraints, the proposed solution seeks to create a device which is:

- of small form factor
- having little cost
- capable of separating particles in a fluid utilizing DEP
  - produces 1 to 60_{Vpp}
  - produces 10_{Khz} to 1_{Mhz}

Solution

A number of circuit components connected to the the Raspberry Pi GPIO pins.

- Voltage Control
  - Utilizes three Programmable Gain Amplifiers(PGA)
  - Summing Amplifier to sum the output of PGA's
- Frequency Control
  - Minigen Function Generator
  - Communicates with Raspberry Pi through SPI
- Web Interface
  - Apache 2 web server hosted on Raspberry Pi
  - provides user ability to set voltage and frequency output

Testing

A typical testing environment includes:

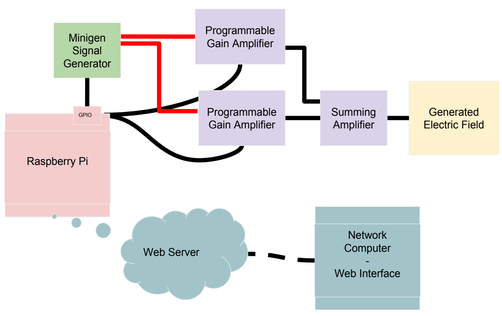
- Oscilloscope
- Raspberry Pi
  - Connected for monitor for web interface access
  - Connected to circuit to control Minigen, PGA's
- Multiple breadboards
  - Minigen Function Generator
  - PGA's
  - Summing amplifier

Testing this project involved and iterative process of:

1. Theorize a design
2. Acquire necessary components
3. Construct design
4. Understand problems
5. Return to step 1

Many times we found that designs would not work and thus this process began at the beginning.

Block Diagram

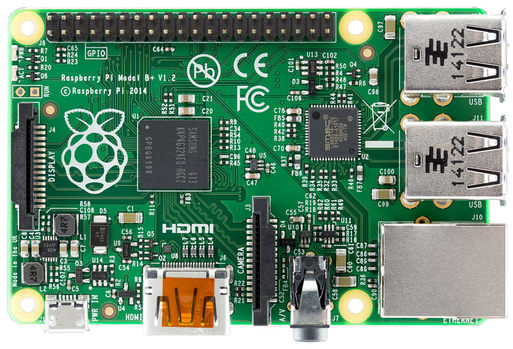


Functional Blocks

- Raspberry Pi
  - web server
  - voltage, frequency control scripts
- MiniGen
- Amplifier Circuit

Raspberry Pi

The Raspberry Pi acts like a bridge between the user and the electronic circuit. From the perspective of the Pi, there are two interfaces, a web server to interact with the human user and GPIO Pins to interact with the electronic circuit.



Raspberry Pi:

- Approximately 5.6cm x 8.5cm
- Running Linux operating system
- Has 40 General Purpose Input Output (GPIO) pins

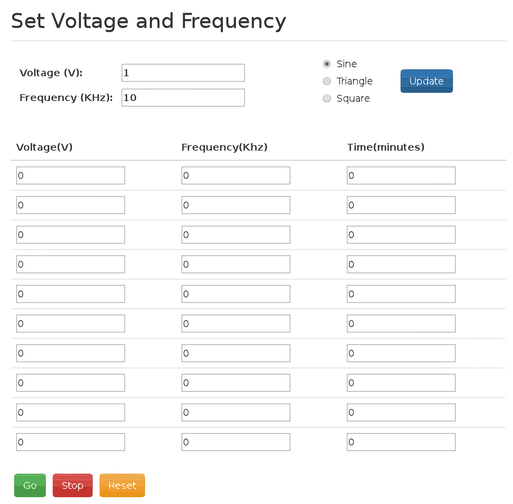
Web Server

- Implemented using Apache 2 web server.
- Updates GPIO state using python and bash scripts

General Purpose Input Output (GPIO) Pins

- Connected to PGA's and Minigen
- SPI communications with Minigen
- Simple 3-bit interactions with PGA's

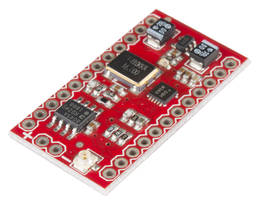
Web Interface



Interface Specifications

- Displayed using Apache 2 web server
- Provides functionalities
  - set voltage
  - set frequency
  - adjust signal type, sine, square, and triangle
  - table allows voltage, frequency for time duration in series
- Implemented using cgi-scripts.

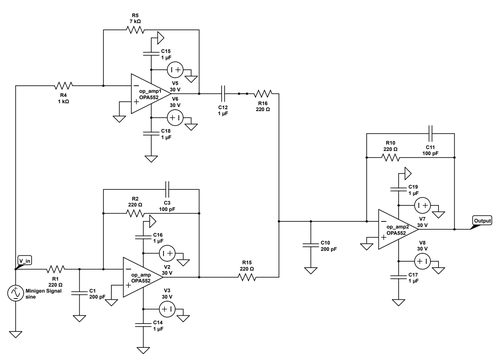
Minigen



Specifications

- Variable frequency integrated circuit device
- Interconnections
  - Frequency set over SPI by Raspberry Pi
  - Output supplies PGA's input
- Output waveform
  - can output sine, square, triangle waveforms
  - amplitude $1V_{pp}$
  - from $-0.5V$ to $0.5V$
- Register Interactions
  - 2 frequency registers
  - 1 control register
    - set output waveform
- Small form factor

Amplifier



Components

- Programmable Gain Amplifiers (PGA's)
  - Take input from output of Minigen
  - Input to Amplification Stage
- Amplification Stages
  - 3 stages
  - each additional stage gives $\frac{previous\_stage\_step\_size}{7}$
  - takes output of PGA as input
  - outputs to summing amplifier
- Summing Amplifier
  - takes input from amplification stages
  - output is overall circuit output
  - gain of $1V_{pp}$