Remotely Connected Electric Field Generator for Particle Separation in a Fluid

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Abstract

This document details the design and implementation of a remotely connected electric field generator. The goal of this design is to provide an easy interface for manipulating the output voltage and frequency of a circuit remotely in order to generate an electric field. This electric field, when applied to a fluid over a long period of time will cause particles in the fluid to separate. The hardware and software components used to accomplish the aforementioned goal are described in detail.

1 Introduction

New research has shown that certain particles may be separated from fluids through dielectrophoresis. This process involves applying an electric field to a fluid. The field may be manipulated in order to attract or repel certain particles. The particles the electric field will attract or repel depends on characteristics of the electric filed which may be controlled by varying the voltage and frequency of the electronics driving the field.

This technology has many useful applications in health care

2 Project Definition

In our implementation, an electric field is applied to two metal plates. by varying the voltage and frequency applied to these plates, the properties of the electric field can be changed.

Our job is to construct a system containing an electronic circuit capable of providing the necessary voltages and frequencies required to drive a pair of metal plates. This system must enable the circuit to be controllable through the use of a web interface. In addition, a small form factor must be maintained.

The system must be able to generate up to a 60 V peak-peak sine wave with user-controlled variable frequency from 10 kHz to 1 MHz.

2.1 Deliverables

There are four items which must be constructed for this project:

For the analog circuit components, functionality of the circuit will be tested using an oscilloscope to verify the requirements have been satisfied. This method can also be used to ensure the output signal contains minimal amounts of noise and distortion.

The construction of this device is the first phase of the project. After the completion of this component, the device will be used to experiment with particle separation in various fluid types. These experiments constitute the remainder of the project. For these experiments our advisor at Minetronix, John Pritchard, will be the main source of guidance and testable material.

2.2 Constraints

Constraints on this project fall within the size, voltage, and portability domains.

The size requirements of this project are directly related to the portability of the final design. The design requirements specify this system must be easily and quickly moved around from one workstation to another. The maximal allowed size is approximately the size of a backpack with smaller sizes being more desirable but not explicitly required. With the electronics currently being used, these requirements will easily be met.

Another constraint arises from the power supply requirements. The power supply must deliver at least 60V DC in order to feed the amplifier circuit. Due to this, the final design requires a power brick similar to one which would be used to charge a laptop. Importantly, this would require the device to be plugged into a wall outlet. This is not seen as an issue. Every location this device will operate will most likely have other equipment with similar power requirements.

In order to use this system, there are other items which are required apart from the device itself. The first requirement is a network connection between the device and a computer. This connection is necessary to be able to interact with the web server hosted on the Raspberry Pi. Without a computer to interact with this system there is no practical means of utilizing the device's functionality. The next requirement, as mentioned above, is a network connection to the Raspberry Pi. The third system requirement is a standard wall outlet to accommodate the power needs of the system.

2.3 System Analysis

A user will interface with this system though the web interface. This web interface may be accessed by typing the IP address of the device into a standard web browser. The interface will allow the user to choose the values for Voltage and Frequency. Once these values have been entered, update scripts on the Raspberry Pi will set the voltage and frequency output of the circuit according to the values entered.

3 Block Diagrams

4 Functional Decomposition

This system has four fundamental functional blocks. These include the Web Interface, Raspberry Pi, Minigen Signal Generator, and Amplifier Circuit. The project will be described in terms of these components and their interactions.

4.1 Web Interface

The web interface is hosted on the Raspberry Pi using an Apache web server. This web server displays an interface which allows the user to set a voltage and frequency output by the system. The interface is simple and interactive, implemented using cgi-scripts on the Apache web server.

4.2 Web Server

The primary function of the web server is to communicate with the Raspberry Pi. This is the primary method of control afforded to the user by the system. The web pages displayed by the server have the ability to control the voltage and frequency output by the circuit.

Displaying this interface is accomplished by running an Apache web server on the Raspberry Pi. When the user clicks update, the server could executes a cgi-script performing the update functionality.

4.3 Raspberry Pi

The Raspberry Pi will act as the bridge between the user and the circuit. The Raspberry Pi will host a web server allowing the user to interact with the system. Based on the results of this user interaction, the Raspberry Pi will update the state of the GPIO pins. The GPIO pins connect to a circuit causing the output to change based on their state.

In addition to hosting the web server the Raspberry pi is used to communicate with the Minigen Signal Generator and amplifier circuit. This communication is accomplished via the Raspberry Pi's SPI interface and GPIO pins respectively.

4.4 Minigen

The Minigen Function Generator device controls the frequency output by the circuit. Varying the frequency is accomplished by writing to registers present on the Minigen. This communication is completed over SPI between the Raspberry Pi and the Minigen. The frequency produced is a function of the values contained in the Minigen's frequency registers.

The Minigen outputs a waveform from -0.5V to 0.5V. This waveform may be a triangle, square, or sine wave. The voltage output by the Minigen is not variable. Given that the design specification requires a variable voltage, the voltage needs to be adjusted separately. Accordingly, the output of the Minigen is supplied to the input of the amplifier circuit.

The Minigen is controlled by setting five registers, two registers for frequency, two for phase shift and one as a control. There exists no need for phase shifting to meet the design requirements, however the frequency and control registers are needed. By having two frequency registers, data can be sent to one register while it is not in use, followed by a write to the control register to use this register. This allows for a nicer gradient, because the frequency will not change until the entire frequency register is written. The control register also allows for changing between sine, square and triangle waveforms. In the event that the frequency needs to be finely adjusted, this system utilizes the functionality of the control register to modify the way in which writes to the frequency registers are received. The way writes are received by the frequency registers can be varied between two modes. In one mode, two consecutive 14-bit writes to a frequency register are used. In the other mode, one write to the lower 14-bits of the 28-bit frequency register is used. This functionality affords the ability to accurately dial in small changes to the register values quickly.

Until this point, several functional benefits of the Minigen Signal Generator have been discussed. An additional benefit which increases the practicality of this solution is the Minigen's small form factor. The small chip size allows the Minigen to fit easily into a small case with the Raspberry Pi. This is consistent with the system's requisite small footprint.

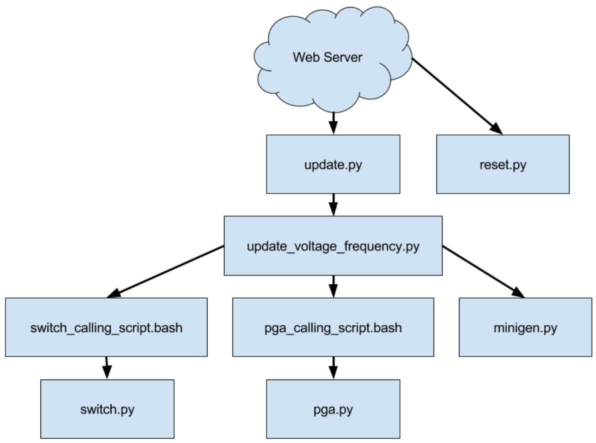
4.5 Amplifier Circuit

As mentioned in the previous section, the output of the Minigen Function Generator is applied to the amplifier circuit as input. The amplifier also receives input from the GPIO pins of the Raspberry Pi. These GPIO pins act as switches which help to control the output voltage. Based on these inputs the amplifier circuit manages the overall voltage and frequency output.

The project requirements state that the system must generate signals which range from $1V_{pp}$ to $60V_{pp}$. To accomplish this,

5 Software Components

The web interface displayed by the web server hosted on the Raspberry Pi is the user's window into the system. Through this interface, the user can seamlessly control various components of the system cause the desired voltage and frequency to be produced. Previously covered are the hardware components used to accomplish this. This section describes the software counterparts used to control the hardware.



5.1 Modifying Frequency

The frequency output by the circuit is controlled by the Minigen Function Generator. Thus the software components used to modify the output frequency are in essence a method of communication with the Minigen device.

The process begins when the user enters a new frequency value into the web interface and clicks the "update" button. The *update.py* script parses the parameters contained in the URL resulting from the user's update request. These parameters are than passed on to *update_voltage_frequency.py* which determines the appropriate update procedure with which to call *minigen.py*.

5.2 Controlling Voltage

6 Cost Considerations

The monetary cost of this project is fairly low. The precise costs of components in the future are unknown, but a table of current prices has been provided along with the necessary quantity of each component. The projected cost of op-amps and other electronic components is minimal. The largest expenditure of the project is the purchase of the Rasperry Pi 2 and Minigen Function Generator. The Raspberry Pi 2 package is currently priced at $99.95 and the Minigen cost at $29.95. Thinking conservatively the cost of the major hardware will be $129.90. In addition, the cost of a resistor kit, a capacitor kit, and a handful of op-amps must be included.

The Minigen Function Generator may be acquired from *http://www.sparkfun.com*. This website also provides a resistor kit for $7.95 which includes all necessary resistors. From this same website, individual capacitors may be purchased at a rate of $0.25 per capacitor. Operational amplifiers may also be purchased at a rate of $0.95 per amplifier. Given this, the total cost is approximated at $152.35. This is far below the maximum allotted funds of $1,000 specified in the project description.

Item	**Part Number**	**Quantity**	**Price**
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Total	-	-	**TODO**

Total Cost Raspberry Pi 2 Kit - $99.95 Minigen - $29.95 Resistors - $7.95 Capacitors - $5.00 Op Amps - $9.50 Estimated Total = $152.35

7 Redesigned Components

In an introductory economics class, it is common that students are taught about sunk costs. Sunk costs refer to those costs which have already been incurred and cannot be recovered. These classes teach that suck costs should not be considered in making future investments. In other words, one should not ask themselves the extent of current investment down a particular path. Rather, one should ask, given what is known now, which investment is more intelligent.

While economics classes teach about sunk costs in the context of monetary investment, the same logic may be applied to other domains. In the case of this project, the investment capital is time and energy. Regardless of how much energy has been invested in a particular design, it is necessary to evaluate alternatives to that design. If these alternatives than look better given what is known about both designs than the design should be modified accordingly to fit the alternative design.

Throughout the course of this project, several components needed to be redesigned. Below is some mention of these designs and the issues encountered which motivated deviation from them.

7.1 Frequency Control

The Raspberry pi is capable of producing square waves by turning the GPIO pins on and off rapidly. We can use this functionality to produce a wave of the frequency indicated by the user. The GPIO pins can also be used to set the voltage by communicating with the circuit how much the output waveform should be amplified. The downside to this approach is the analog circuit component will need to be more complex. The analog circuit needs to output a sine wave. With this approach we would need to integrate the square wave produced by the GPIO pin.

There exist alternatives to using the GPIO pins to generate a signal with a given frequency. We could instead use the GPIO pins on the raspberry pi to communicate with a small signal generator, such as sparkfun.com s Minigen. This would make programming the Raspberry pi more complex, but could lead to higher quality waveforms. Producing a sine wave using the Minigen signal generator is likely to to produce fewer distortions compared to integrating a square wave produced by the RPIs GPIO pin twice.

7.2 Voltage Control

7.2.1 Digital Potentiometer

The output of the digital potentiometer has 128 steps. This Translates into our ability to set 128 different gains on our amplifier. We will need multiple stages of amplifier to go between 1 and 60 Vpp. The most prominent reason for this is due to the gain bandwidth of the op-amps. We will not be able to have a large gain while still producing a frequency of 1Mhz.

One problem we foresee with the digital potentiometer is that it cannot handle a large amount of power. This may force us to come up with different amplifier configurations, or use the digital potentiometer in a different way. Another way we could possibly use this device is as an attenuator at the input to the amplifier.

Another problem which might arise with the digital potentiometer is the capacitance of the wiper. We dont have any context for understanding how much this will affect the output signal. According to some preliminary calculations, we have determined that the capacitance will not present a large problem.

8 Known Issues

9 Conclusion

10 Appendix

10.1 Project Timeline

Item	Completion Date	Description
Project Plan	01 Oct. 2015	Create a project plan which specifies the pieces of the project.
Project Design	15 Oct. 2015	Complete a detailed design of each component of our project. Assign people to work on the various pieces of the project.
Design Web Interface	01 Nov. 2015	Design and build web interface. Outline code for Communications with Minigen and Digital Potentiometers.
Hardware Communications and Design	15 Nov. 2015	Get communications working between Raspberry Pi, Minigen, and Digital Potentiometers.
Prototype Completion	01 Dec. 2015	Take final steps testing prototype. Device should be able to do everything in specification.
Senior Design I Presentation	15 Dec. 2015	Present a working prototype of our project.
Begin Experimentation Component	01 Jan. 2015	Begin working on Research component of the project.
Continue Experimentation	01 Feb. 2016 - 05 May. 2016	Use the project to perform research.

10.2 Graphical Comprehension Aides

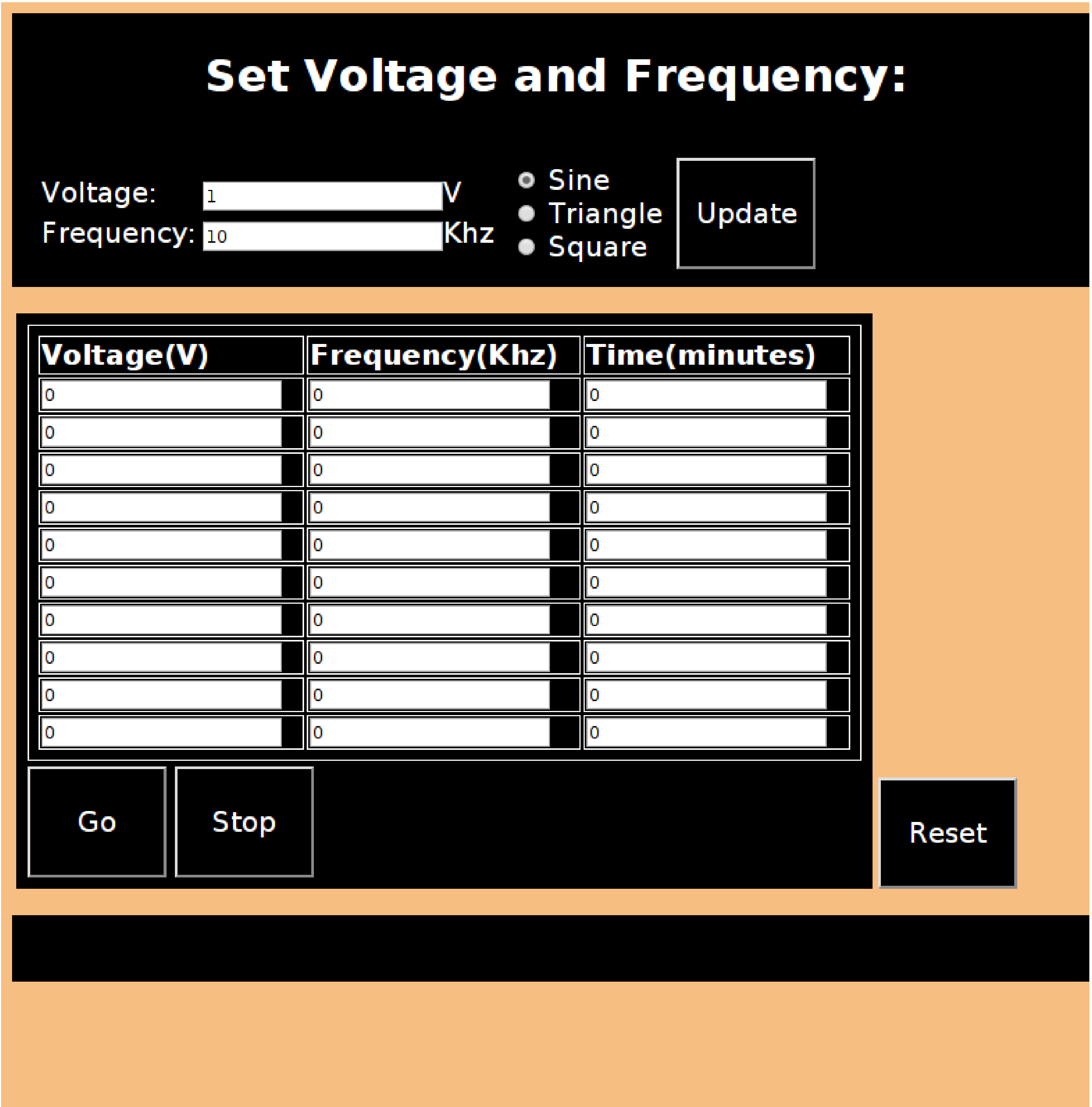


Figure 1: Web Interface