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The analysis of ion flow between the human body and local ground

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ECE 791H/792H Senior Honors Thesis

The Analysis of Ion Flow between the Human Body and Local Ground

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Other Advisors: Professor Wayne Smith

Project Completion date: May 18, 2012

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Abstract:

The project was designed to get a better sense of the phenomenon referred to as Earthing. Earthing is defined as the process where the human body is in contact with the earth and can freely transfer ions between the Earth and itself. Those promoting the idea of earthing say that this transfer of ions is important in maintaining a healthy immune system, and they claim that the recent increase in autoimmune diseases is the result of humans being insulated from the ground because of the shoes they wear and the places in which they live.

To better understand the degree to which ions are exchanged between the human body and ground, a circuit was developed to precisely measure ion flow. It was used to monitor that flow for a range of conditions. An experiment was run on distinguishing information from the noise that was inherent in the measurements. The purpose of this analysis was to see if there was any information embedded in the ion flow from the human body to ground, or if it was purely electrical noise. Multiple methods of analysis were used, including finding the frequency response, the probability density function, cross-correlations with breathing and heart rate, and finding the impulse response of the circuit.

The current versus time plots show the difference between a control and a person sleeping on a special bed sheet connected to ground. By comparing the two, it is shown that there is a charge exchange when a person is grounded. The frequency plots showed the frequency responses of the current versus time plots. By comparing the two, it is clear that having a human body connected to ground added more frequency components to the ion flow than was seen in the control.

The probability density function of charge exchange was looked at as well. The control showed an almost Gaussian distribution similar to white noise whereas the distribution of the person was shown to be a bivariate distribution. It was shown through cross correlation that breathing and heart rate were not the cause of this distribution.

It was proved that when a person is connected to ground, there is a charge exchange. This exchange has a current distribution that is bivariate in nature. It was proved that breathing and heart rate had little correlation with the data, and therefore did not cause the distribution. What exactly caused it was not found, along with what else might be contained in the signal.

Introduction:

This project was for the sole purpose of analyzing the effects of Earthing on the human body. The intent of the project was to measure the charge flow between the human body and the ground in order to understand the nature of the charge exchange. A circuit was developed to identify and analyze the ion flow from the human body to ground. Two main tests were conducted to analyze the human body and the rate of ion exchange over a period of time. The first trial involved the subject sleeping on a static bed pad that was connected to a battery operated amplifier. This amplifier transmitted the collected data to a local computer using a program called LabVIEW. The opposite end of the amplifier is connected to electric ground in the wall outlet. A picture of the setup of this experiment is provided below in Figure 1.
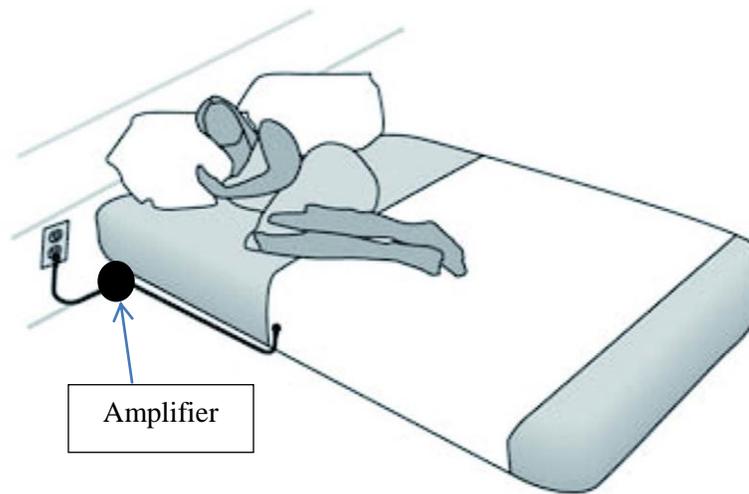

Figure 1 - Example of Bed Sheet Test Setup

The second test that was performed involved strapping the subject to ground during the day. This involved wearing a static wrist strap while the subject performs their normal daily activities. The static wrist strap was connected to the battery operated amplifier, which was then connected directly to electric ground in the wall outlet. This test limited the subject to a small area but still allowed them to go about their normal activities in order to get accurate data.

The thesis work, however, focused on distinguishing information from the noise. The signals in the data that was collected was analyzed. The purpose was to see if there was any information embedded in the ion flow from the human body to ground, or if it was just electrical noise. The inspiration came from The Search for Extra-Terrestrial Life (SETI). Multiple methods were used including finding the frequency response, the distribution of current, cross-correlations with breathing and heart rate, and finding the impulse response of the circuit.

Earthing is when the human body is in contact with the earth and has the ability to freely transfer ions between the Earth and itself. Through research, it was discovered that there seems to be a common belief that the human body continuously has a positive charge. This positive charge in the body cannot be balanced out, because nowadays people are mostly insulated from the Earth. In the past, activities performed during everyday life, such as walking barefoot and sleeping on the ground, were done without insulation. In other words, humans used to be constantly grounded. Today, the shoes that people wear insulate them from contact with ground, and all buildings are insulated from ground as well [1]. Being disconnected from the Earth seems to cause health problems since the body doesn't get the chance to exchange ions. These health problems include auto-immune deficiency, inflammatory diseases, etc. Hypothetically, by having a constant flow of ions, these health conditions are alleviated [2].

The idea of analyzing the data to see if there was information of not came from SETI. SETI is an organization that is actively searching out extra-terrestrial life. One program run by SETI was SETI@home, which was hosted by UC, Berkeley. The purpose of SETI@home was to use distributed computing to analyze radio signals to look for extra-terrestrial communication. Radio signals contain noise (from the environment and receiver) and manmade signals (satellites, TV, etc.). To look for other information in these signals, SETI@home employed analysis techniques such as looking for patterns in the signal power as a function of frequency and time. The program would look for narrowband signals or signal pulses that might indicate an attempt at communication [3]. Inspired by this, the project was designed to use digital signal processing techniques to look for any information buried in the Earthing data.

Before data could be captured by the circuit and analyzed, the linearity and frequency response of the circuit needed to be confirmed. The linearity plots were obtained by hooking the input and output of the circuit into an oscilloscope. The oscilloscope was set to X-Y mode to make a plot of the input vs. the output. If the oscilloscope showed a completely linear plot, as shown in Figure 2, it would mean the circuit added zero phase shift to the input.

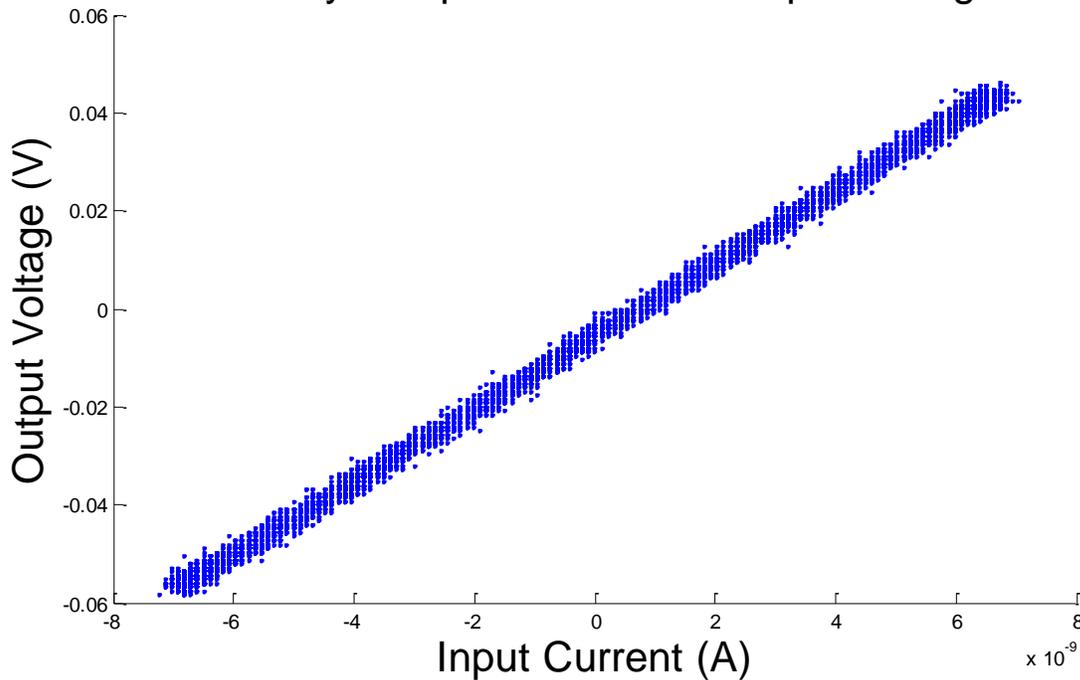## Linearity of Input Current vs Output Voltage

Figure 2 - Linearity of circuit before filters were added

Figure 2 above was obtained from the amplifier circuit before a 60 Hz notch filter and 250 Hz low pass filter was added. It is a plot of the input current versus the output voltage. It is linear, thus showing no phase shift. The thickness of the line shows how the noise level of the circuit. As can be distinguished, the line is very thin, demonstrating that the circuit captures little noise.

Apart from the linearity of the circuit, how it behaves in the frequency spectrum also affects the input signals. The 60 Hz notch filter was used to eliminate ubiquitous background noise. This noise is generated by electrical machinery and power cords. In the United States, power is transferred at a frequency of 60 Hz. The 250 Hz low pass filter was used to prevent aliasing (see Appendix A). To make sure that the circuit behaved as desired, the frequency response was checked by inputting a unit impulse. The output was the impulse response, as shown in Figure 3.
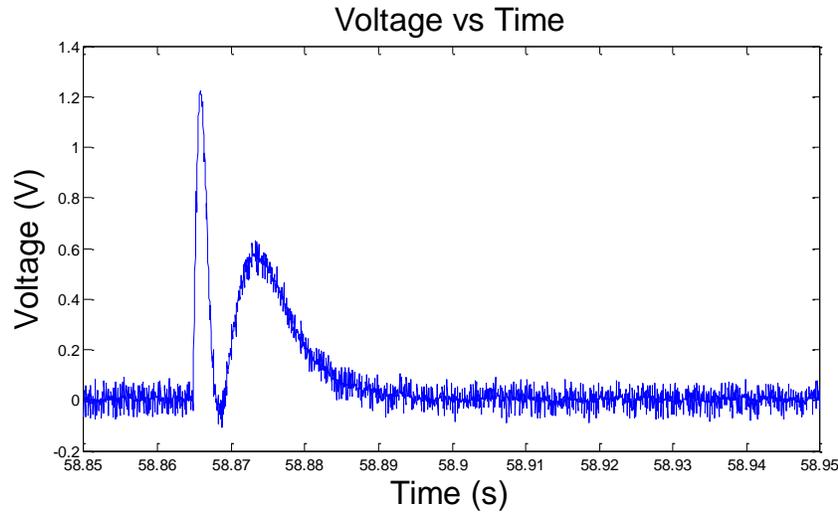
Voltage vs Time

Figure 3 - Impulse Response of the Circuit

The Impulse Response was found by having a person attached to the circuit while another person, who was carrying charge, tapped the first person. An impulse response is the output of a system when presented with a brief input signal, in this case a touch. By taking the Fourier Transform of the impulse response, the frequency characteristics of the circuit are obtained. The Fourier Transform of the impulse response is shown below in Figure 4. This shows the actual frequency response of the circuit. There is minor gain from 0 Hz to 50 Hz, a notch at 60 Hz, a gain of 1 from 70 Hz to about 150 Hz, and a slow drop off from there. Past 250 Hz, the signal is attenuated. This shows close to what was desired in the ideal case.
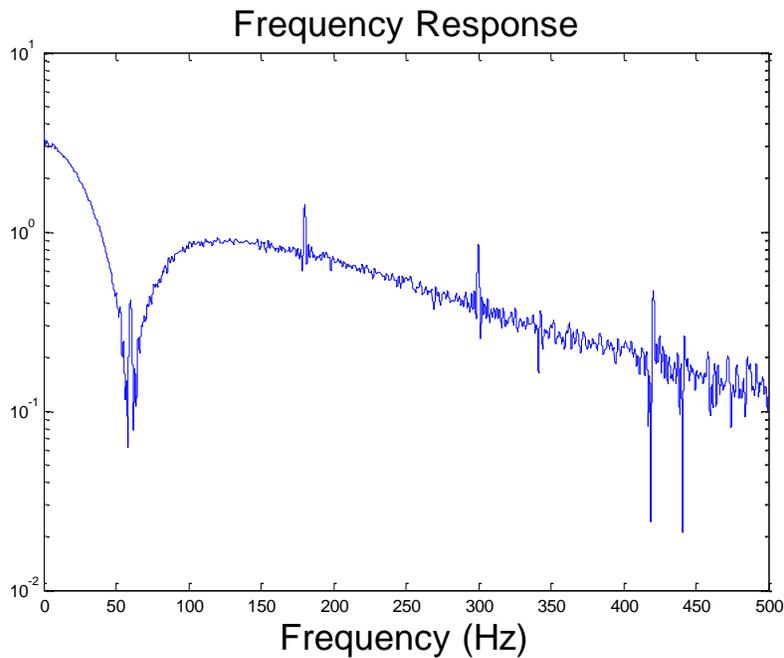

Frequency Response

Figure 4 - Actual Frequency Response of the Circuit

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The signals recorded through LabVIEW were stored in text files in 2.78 hour increments. At a sampling rate of 500 Hz, this meant 5,000,000 data points per file. All of the analysis of the data was run using a program called Matlab. After some experimenting, the number of data points per file was picked so Matlab did not run out of memory during the analysis. Matlab code was developed to open the text file and store the data into an array. The data was then converted from a voltage into a current and the direct current (DC) component was eliminated. This was done by taking the average value of the signal and subtracting it from the signal. The data was then put through a digital 60 Hz notch filter to better reduce noise.

There were multiple analyses attempted, but only four were used in the final design. These four were current versus time plots, frequency plots, probability density function plots, and the cross correlation between the data and breathing and heart rate. The plots needed to be prepared for comparison purposes by modifying the range of axis values. This was done by plotting multiple trials of tests run of a person sleeping on a bed sheet versus an empty bed sheet. A current range of -250 nA to 250 nA was decided to work the best for the current versus time and probability density plots. The probability density function plots, which were histograms, also needed to be set with a certain number of bins. After experimentation, it was decided 1000 bins for the 5,000,000 data points would be sufficient. After these steps, the data was ready for analysis. The code for the plots is below in Appendix C.

The first type of plot run is the current versus time plot. This plot shows up to 2.89 hours, or 10000 seconds, of a signal. This is done to compare a person being grounded, such as in Figure 5, to the control, such as in Figure 6. As the control, Figure 6 shows environmental noise levels. Figure 5 shows that there is an added current exchange when a human is grounded.
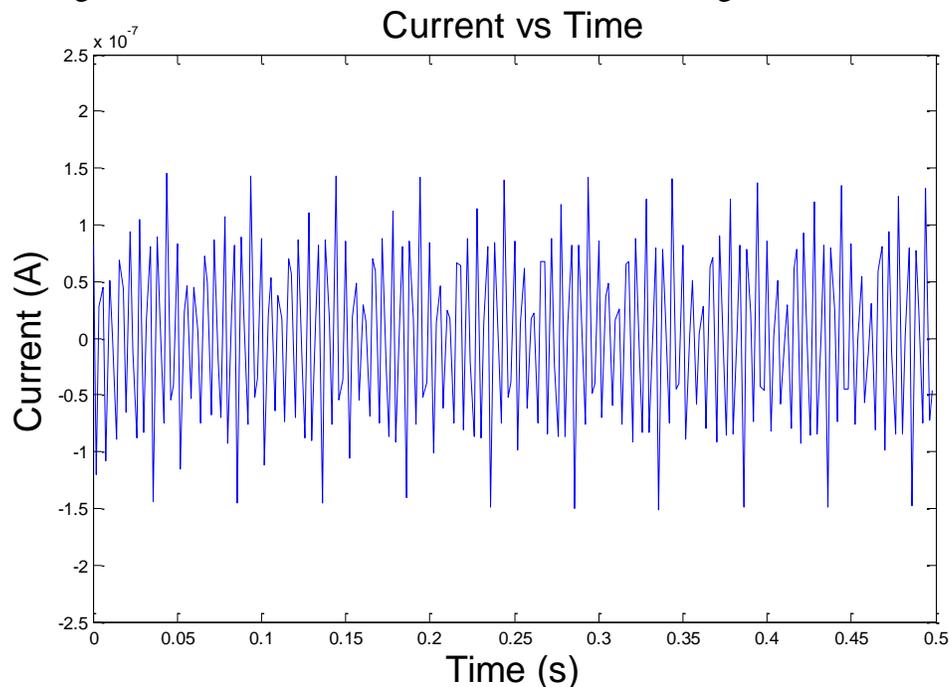

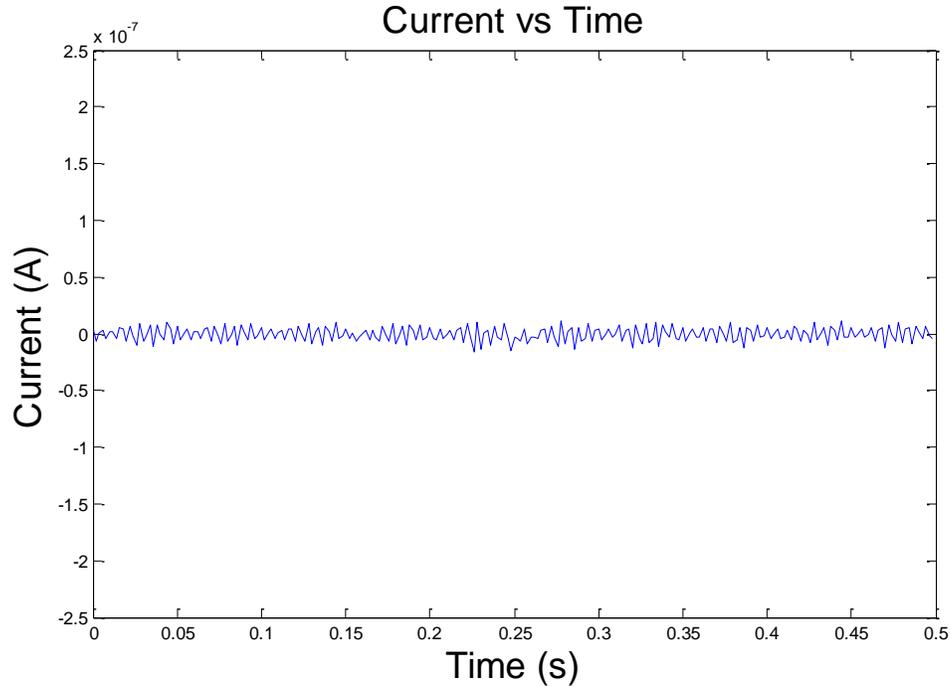Figure 5 - Current vs. Time of a Person Sleeping on the Bed Sheet

Figure 6 - Current vs. Time of the Control

The next type of plot run is a frequency plot. The Discrete Time Fourier Transform (DTFT) is taken of the data (see Appendix B) and plotted in a logarithmic plot using Matlab's semilogy() command. Figure 7 shows the frequency response of the empty bed sheet during an overnight sleep test. It shows a few strong frequency components at around 170 Hz and 200 Hz. Figure 8 shows the frequency response of a person being grounded. This shows a lot more frequency components are added when a subject is added to the bed sheet. These plots are acquired using Matlab's FFT() command.
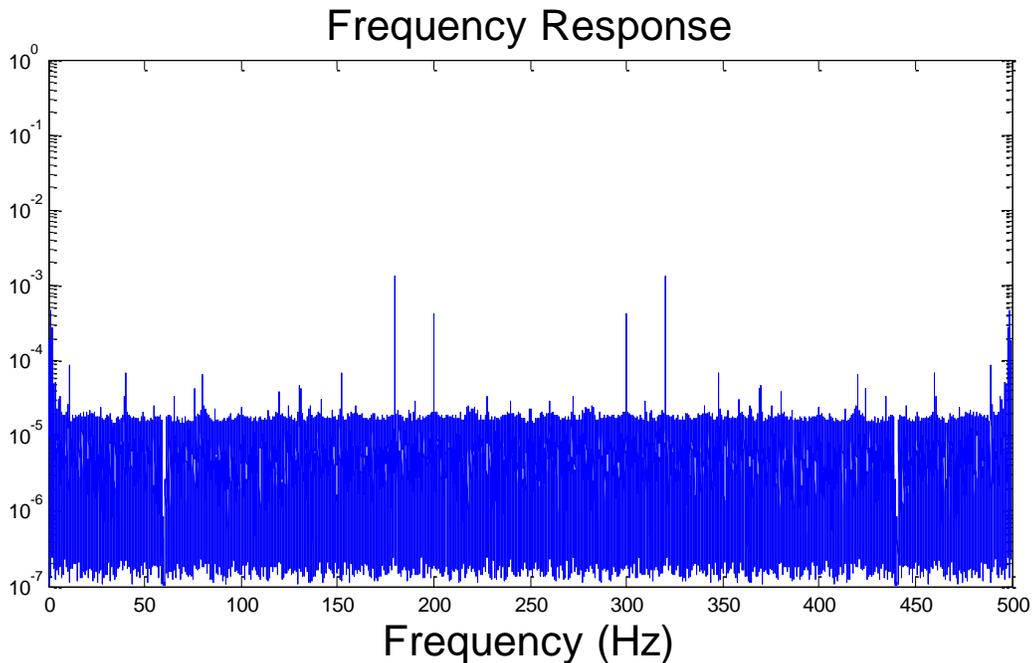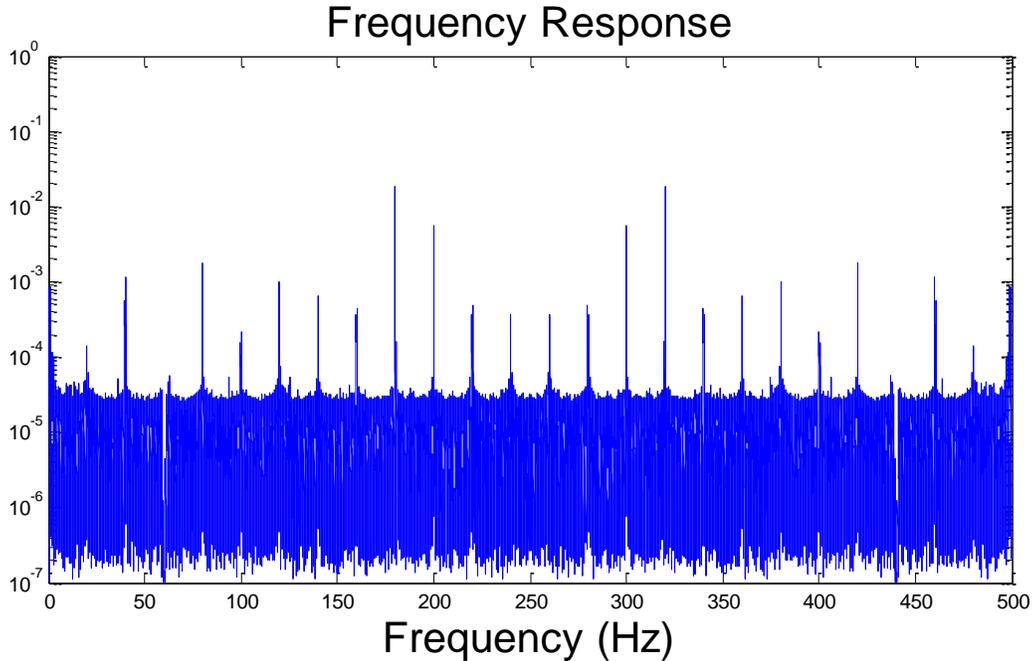

Figure 7 - Frequency Response of the Control

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Figure 8 - Frequency Response of a Person Sleeping on the Bed Sheet

To get a better view of the frequency response, a custom Fourier Transform command was created. The code is shown in Appendix D. This command was created to allow a better resolution of the frequency response than what Matlab's command could give. It also allowed the ability to look at any desired range of frequencies, rather than the entire range. The above data was rerun using this custom command. Figure 9 corresponds to Figure 7 and Figure 10 corresponds to Figure 8. This allows a cleaner view of the data's frequency response within a frequency range of 0 Hz to 250 Hz.
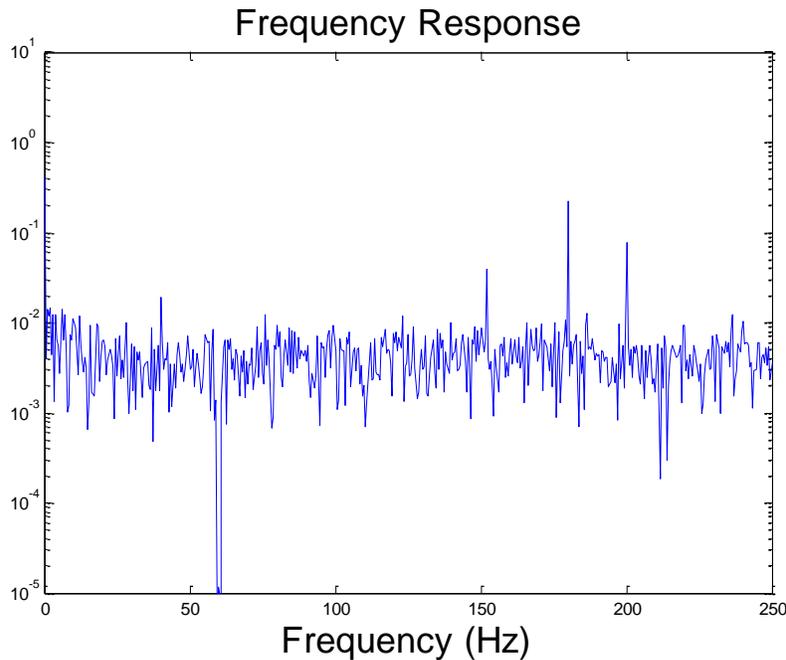

Figure 9 - Frequency Response of the Control using Custom Fourier Transform Command
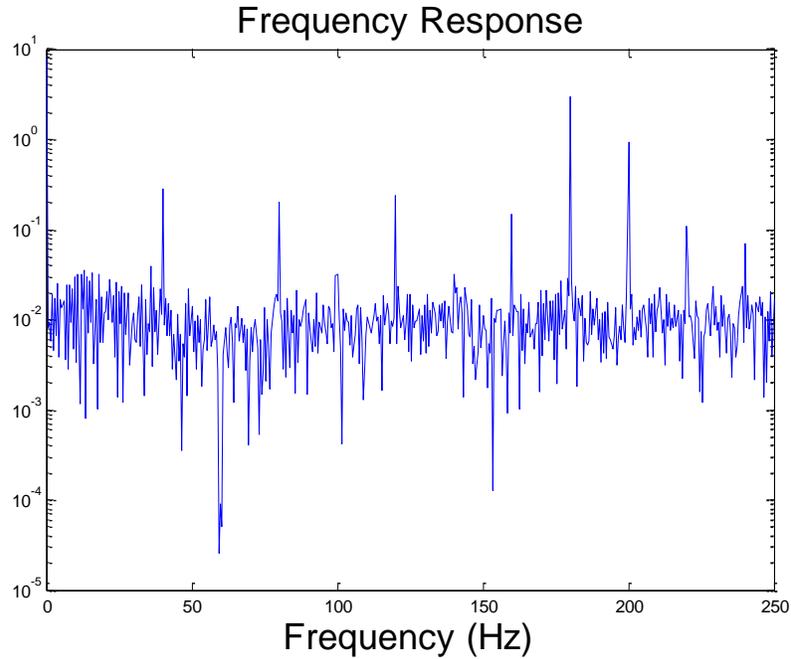
10

Figure 10 - Frequency Response of a Person Sleeping on the Bed Sheet using Custom Fourier Transform Command

The third type of plot run is the probability density function of charge exchange plot. The plots are obtained using Matlab's hist() command. Figure 11 shows the current distribution of the control. It shows a near Gaussian distribution of current. This reinforces the idea that the control is just environmental Gaussian noise.
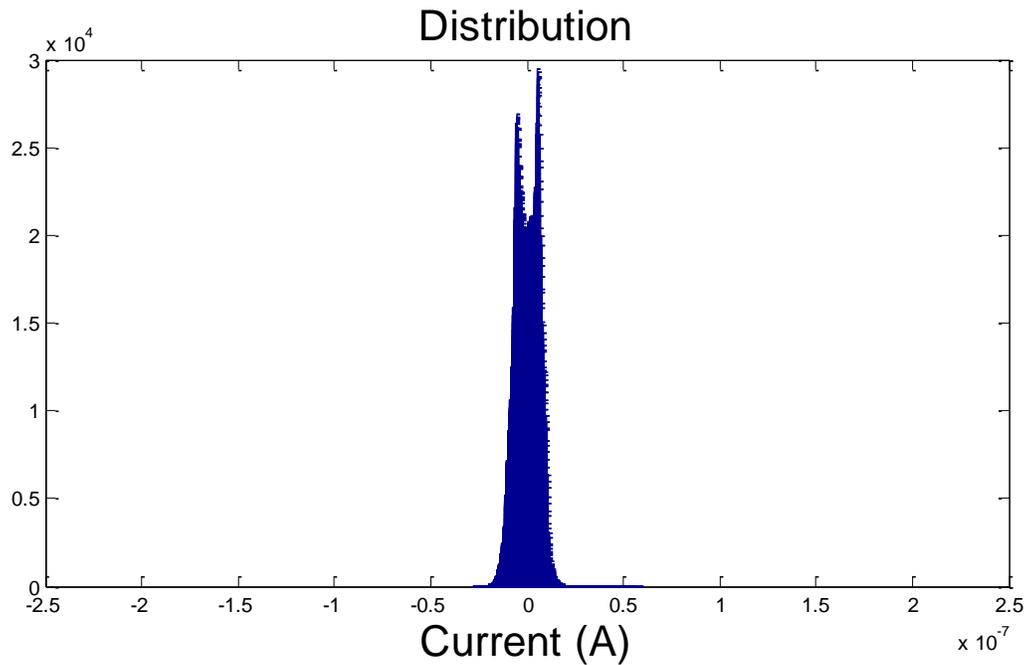

Figure 11 - Current Distribution of the Control

Figure 12 displays the current distribution of the subject laying on the bed sheet. It shows a wider, bivariate distribution. This indicates that when a person is being grounded, the ion flow cannot be ascribed to being just noise. Some hypotheses for this distribution were that breathing or heart rate could be the cause. The idea was that when the subject breathes in, the current might swing towards positive 100 nA, and when the subject breaths out, the current might swing toward negative 100 nA. This or the beating of the heart might cause the swing in current.
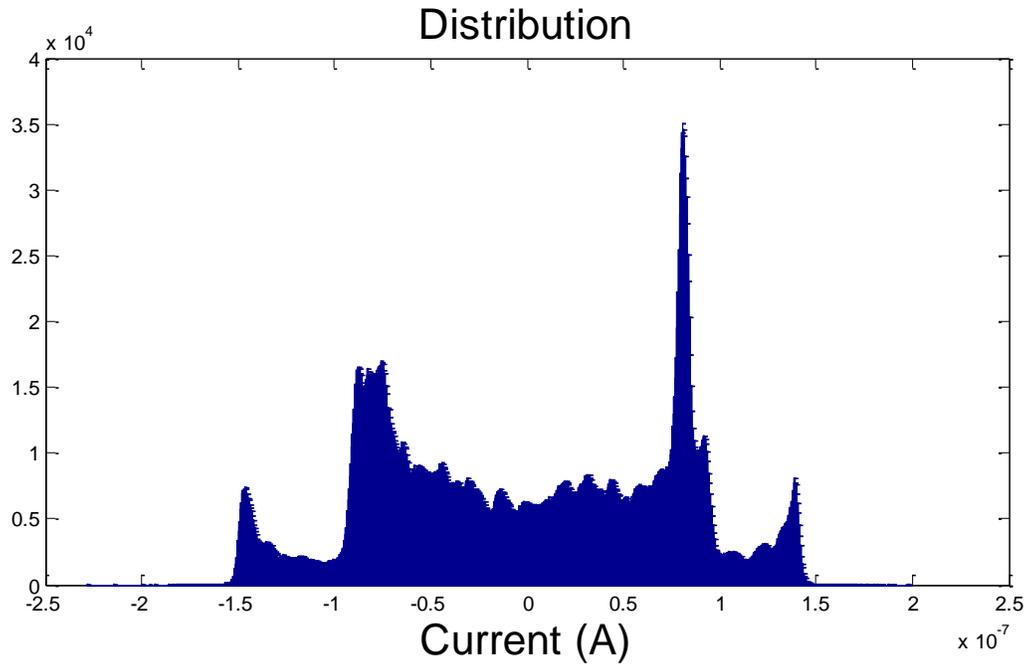

Figure 12 - Current Distribution of a Person Sleeping on the Bed Sheet

Both of the hypotheses, if true, should show up in the frequency response close to 0 Hz. Figure 13 shows the frequency response of Figure 5 from 0 Hz to 10 Hz. There appears to be no low frequency components that would indicate breathing or heart rate is responsible for the current distribution. To verify, a cross correlation (see Appendix E) was run between breathing while a person lays on their back and the data, breathing while a person lays on their stomach and the data, and heart rate and the data. The breathing data was obtained through an Electromyography (EMG) test and the heart rate data was obtained from an Electrocardiogram (ECG) test. The data from the EMG tests was obtained at a sampling rate of 25,000 Hz, and the data from the ECG test was obtained at a sampling rate of 50,000 Hz. They were then down sampled to 500 Hz to match the data of the person being grounded.
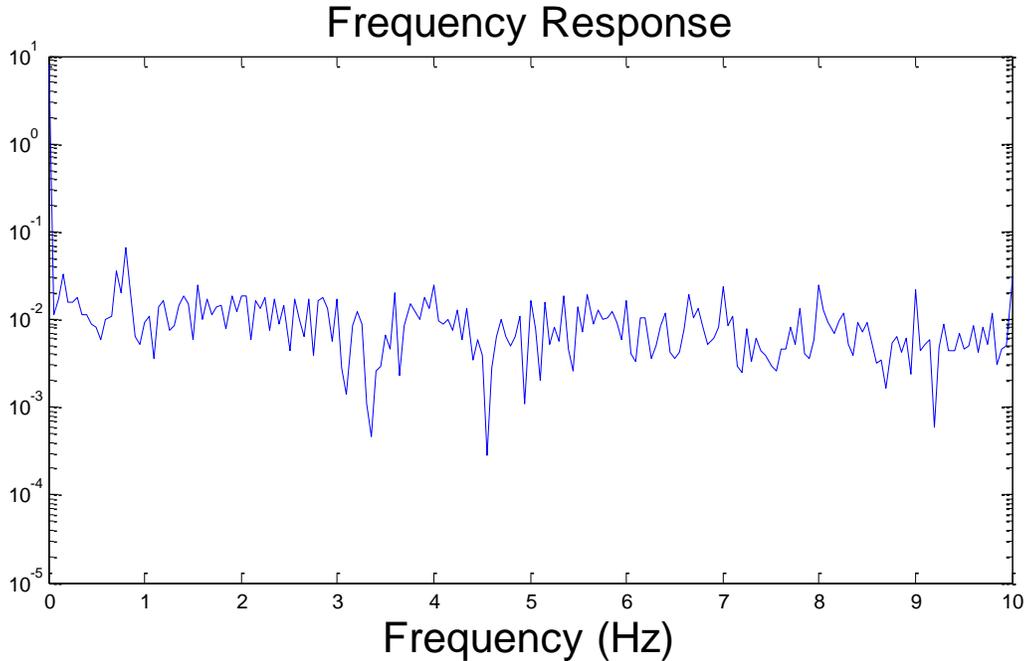
Frequency Response

The cross correlation was done using Matlab's corrcoef() command [4]. Heart rate and breathing data were cross correlated with four separate test runs of a person lying on a bed sheet. The results of the cross correlations are shown in Table 1. The values obtained from the corrcoef() function are the correlation of the data at zero lags. A correlation value of +1 would mean the signals being compared are perfectly similar, while a correlation of -1 would mean the signals are opposites of each other. A value of zero would indicate that the two signals are completely dissimilar.

Table 1 – Correlation between Test Runs and Breathing and Heart Rate

	ECG Data (Heart Rate)	EMG Data while Subject lay on Back	EMG Data while Subject lay on Stomach
Test Run 1	-0.0041	-0.0783	-0.0007
Test Run 2	0.0112	0.0511	0.0174
Test Run 3	0.0312	0.0014	-0.0342
Test Run 4	-0.0558	0.0080	0.0172

The table values are very close to zero for every test run, and show no correlation between the grounding data and a person's breathing (Figures 14 and 15), or between a person's heart rate (Figure 16) and the grounding data. This means neither breathing nor heart rate were caught in the signal exchange. The conclusion that breathing and heart rate did not play a major role in the data's current distribution was reached. It was then hypothesized that movement while sleeping caused the distribution.

Breathing while Person Lies on Back
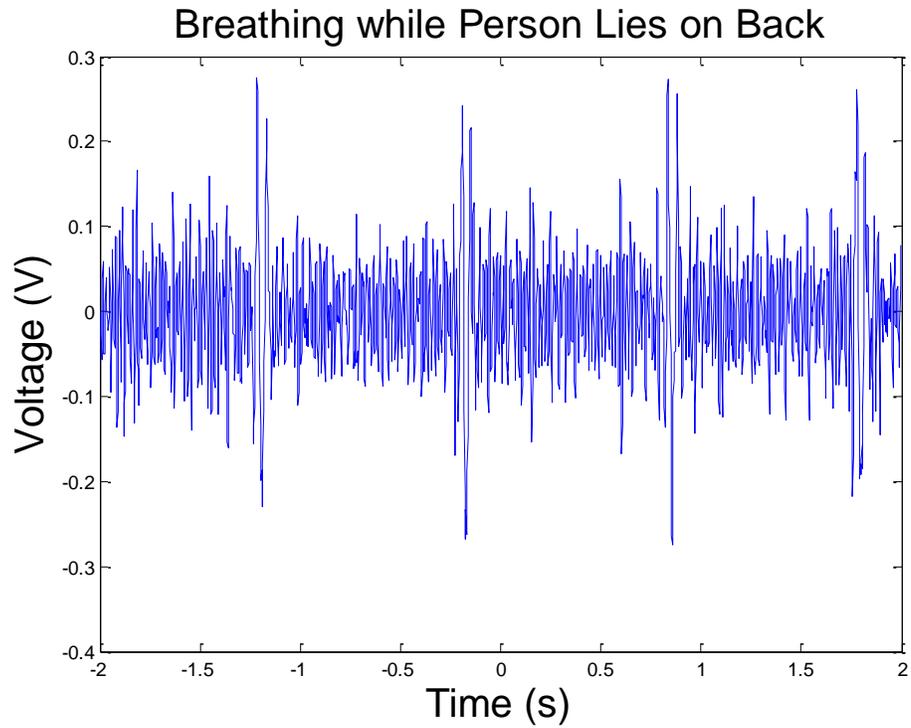
Figure 14 - EMG Data Representing Breathing while a Person Lies on their Back
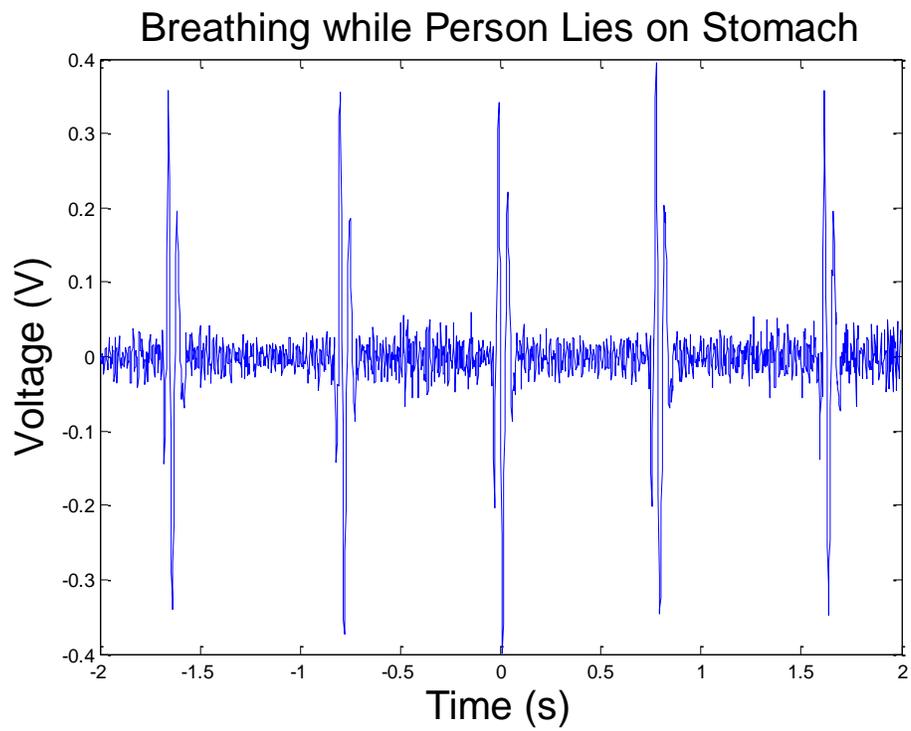
Breathing while Person Lies on Stomach

Figure 15 - EMG Data Representing Breathing while a Person Lies on their Stomach
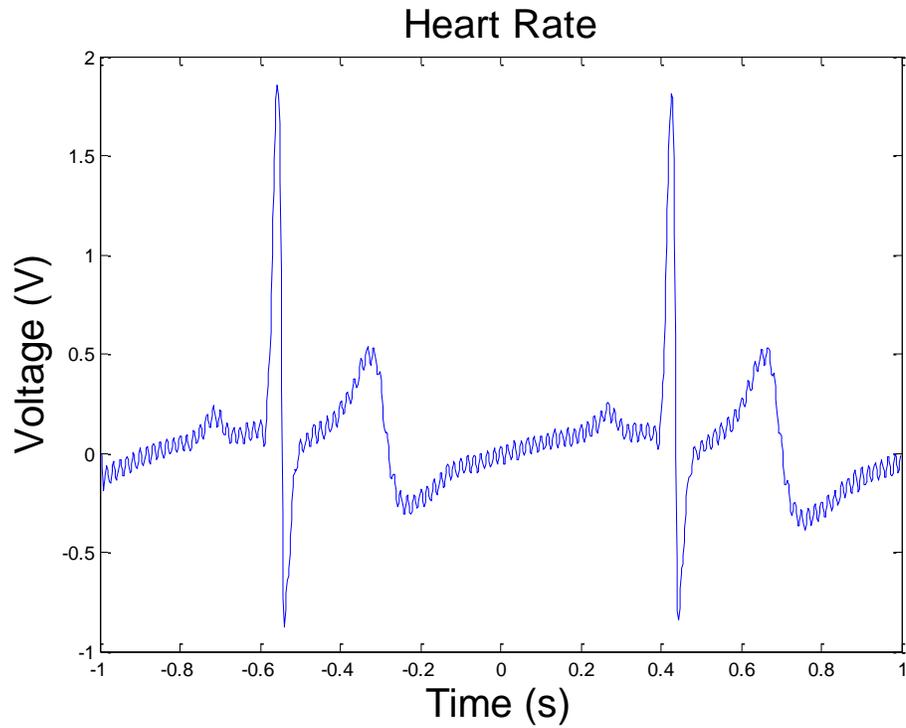
14

Figure 16 - ECG Data Representing a Person's Heart Rate

Evaluation:

The project was designed to get a better sense of the phenomenon referred to as Earthing. Earthing is defined as the process where the human body is in contact with the earth and can freely transfer ions between the Earth and itself. Those promoting the idea of earthing say that this transfer of ions is important in maintaining a healthy immune system, and they claim that the recent increase in autoimmune diseases is the result of humans being insulated from the ground because of the shoes they wear and the places in which they live.

To better understand the degree to which ions are exchanged between the human body and ground, a circuit was developed to precisely measure ion flow and we used that circuit to monitor that flow for a range of conditions. The thesis work focused on distinguishing information from the noise that was inherent in the measurements. The purpose of this analysis was to see if there was any information embedded in the ion flow from the human body to ground, or if it was purely electrical noise. Multiple methods of analysis were used, including finding the frequency response, the probability density function, cross-correlations with breathing and heart rate, and finding the impulse response of the circuit.

Figures 5 and 6 show the current versus time of a person connected to ground and the control, respectively. As the control, Figure 6 shows environmental noise levels. Figure 5 shows that there is an added current exchange when a human is grounded.

Figures 9 and 10 show the frequency response of a person connected to ground and the control, respectively. By comparing the two, it is clear that having a human body connected to ground added more frequency components to the ion flow than was seen in the control. Looking at the probability density function of charge exchange in Figure 12, these added frequency components may be the cause for the bivariate current distribution. Some hypotheses for the distribution were that breathing or heart rate could have caused the distribution. After running cross correlations as shown in Table 1, it appears that there was no correlation and they were not transmitted in the signal. It was then hypothesized that it was movement while sleeping, such as tossing and turning on one's side, which was caught in the signal. This was not able to be extensively tested.

Given more time, what exactly caused the wide, bivariate distribution could have been found. This could have told what information may be transmitted in the signal when grounded. This could be tested if this is picked up in the future. Along with what is contained in the charge exchange, building a basic electrical model of a human body connected to ground could be a future endeavor.

It was proved that when a person is connected to ground, there is a charge exchange. This exchange has a current distribution that is bivariate in nature. It was proved that breathing and heart rate had little correlation with the data, and therefore did not cause the distribution. What exactly caused it was not found, along with what else might be contained in the signal.

Paul Rioux	Christopher Chirgwin	Seshank Appasani
Background Research		
Progress Report		
LabVIEW Design	Design of Amplifier Circuit	
Matlab Code for Analysis		
Testing Subjects		
Undergraduate Research Conference Presentations		
Thesis		
Final Report		

References:

[1] C. Ober, S. T. Sinatra M.D., M. Zucker, "Electical You and Your Electrical Planet," in *Earthing The most important health discovery ever?,* Laguna Beach, CA: Basic Health Publications Inc., 2010, ch. 1, pp. 3-12.

[2] C. Ober, S. T. Sinatra M.D., M. Zucker, "The Disconnect Syndrome," in *Earthing The most important health discovery ever?,* Laguna Beach, CA: Basic Health Publications Inc., 2010, ch. 1, pp. 13-23.

[3] D.P. Anderson, J. Cobb, E. Korpela, M. Lebofsky, D. Werthimer. (November 2002). SETI@home: an experiment in public-resource computing. *Communications of the ACM* [Online]. pp. 56-61. Available: http://doi.acm.org/10.1145/581571.581573.

[4] MathWorks, "Product Documentation," 2012. [Online]. Available: http://www.mathworks.com/help/techdoc/ref/corrcoef.html. [Accessed 2012].

[5] R.G. Lyons, "The Discrete Fourier Transform," in Understanding *Digital Signal Processing,* 3rd ed. Boston, MA: Pearson Education, 2011, ch. 3, pp. 59-60.

A. Aliasing:

The data from the circuit was converted from an analog signal to a digital signal so it could easily be stored and analyzed. The analog-to-digital (D/A) converter sampled the signals at 500 samples per second (or 500 Hz). When the frequency response is computed from a discrete signal, the result will be mirrored over the sampling rate divided by 2 (or 250 Hz in this case) as seen in Figure 17.
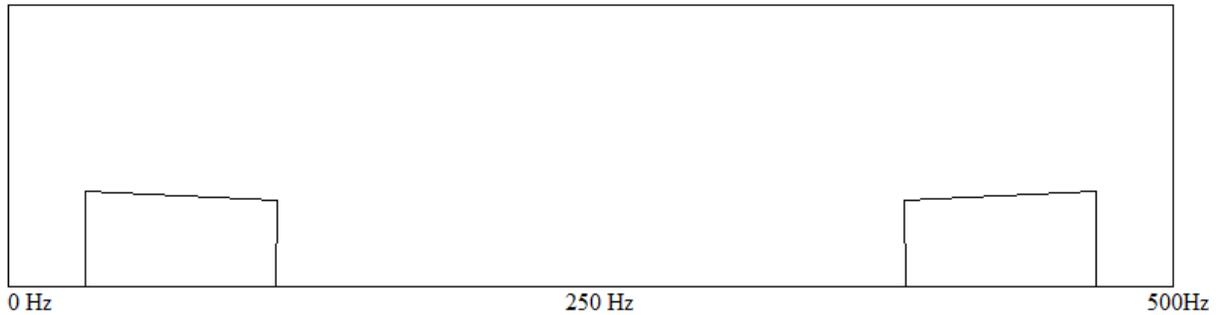

Figure 17 - Example of Replication of Frequency Components over Half the Sampling Rate

Aliasing occurs when a signal is sampled at too low of a sampling rate or the signal has a strong frequency component past the sampling rate. For example, say an analog signal as shown below in Figure 18 goes into the circuit without the 250 Hz low pass filter. When the Fourier Transform of the signal is taken, the result would look like Figure 19.
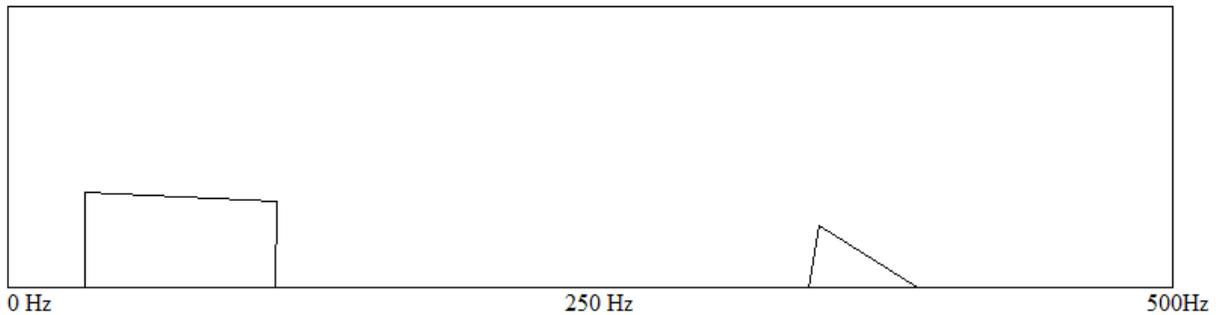

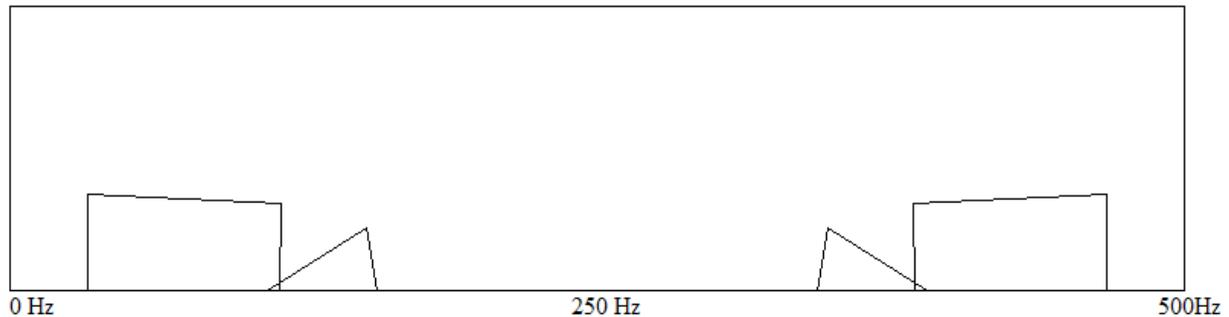**Figure 18 - Frequency Components of Analog Signal**

Figure 19 - Example of Aliasing

When the same signal is put through the circuit with the 250 Hz low pass filter, the result of the Fourier Transform would look like Figure 20 below. The filter is an anti-aliasing filter and is used to preserve the frequency components that we want to analyze.
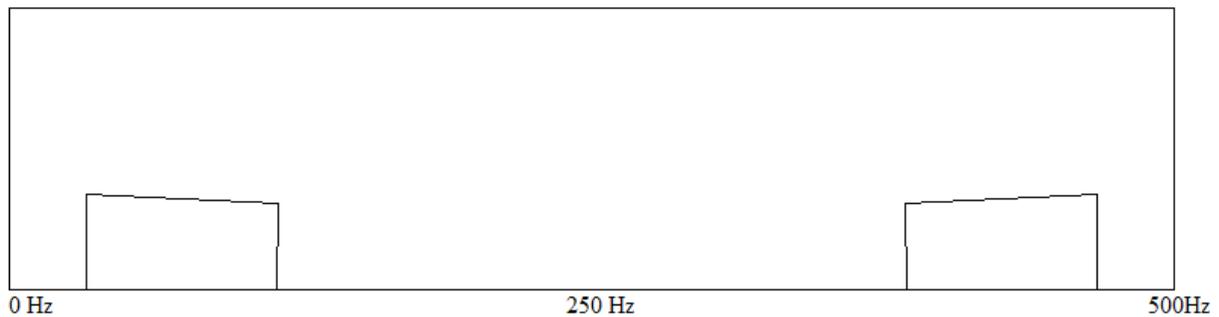

Figure 20 - Example of Aliasing Eliminated

B. As stated in [5], the Fourier transform of a signal is used to transform an expression of a continuous time-domain function into a continuous frequency-domain function. For discrete functions, the discrete Fourier Transform (DFT) is used. The DFT equation is:

$$X(m) = \sum_{n=0}^{N-1} x(n) * e^{-j2\pi nm/N}$$

This allows one the ability to see the frequency response of a discrete signal.

C. Matlab Code for Current versus Time, Frequency, and Current Distribution:

```
clear all;
clc;

%load 60Hz reject filter variables
load('60HZ_Bandreject.mat');

%Asks user for file to open
[filename, pathname] = uigetfile('*.txt', 'Select a file to open:');

if isequal(filename,0)
    disp('User selected Cancel')
else

    %Opens file and scans in 10000 points of data
    fid = fopen(fullfile(pathname, filename),'rt');
    S = fscanf(fid, '%g', [1 5000000]);
    fclose(fid);

    %Convert to current
    S = S / 7500000;
    S = S - mean(S);
    S = filter(B2,A2,S);

    %Plots frequency response
    figure
    semilogy(500*((0:length(S)-1)/length(S)),abs(fft(S))+10^-7);
```

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```matlab
    hold;
    title 'Frequency Response';
    xlabel 'Frequency (Hz)';

    %Plots voltage vs time
    figure;
    plot((0:length(S)-1)*0.002,S);
    hold;
    title 'Current vs Time';
    xlabel 'Time (s)';
    ylabel 'Current (A)';
    ylim([-2.5*10^-7 2.5*10^-7])

    %Plots current distribution
    figure
    hist(S,1000)
    title 'Distribution'
    xlabel 'Current (A)'
    xlim([-2.5*10^-7 2.5*10^-7])

end
```

D. The custom Fourier Transform code was based off the equation:

$$F(w) = \frac{1}{interval} * \sum_i f(t_i) * e^{jwt_i}$$

It was implemented in Matlab as the function FT():

```matlab
function F = FT( w, t, f )
%Custom Fourier Transform function for a high resolution Fourier Transform
%w is the frequency range in radians to compute the transform over
%t it the range of time values
%f is the function values
    F = w .* 0;

    for k=1:length(w)
        for l=1:length(t)
            F(k)= F(k) + f(l)*exp(1i*w(k)*t(l));
        end
    end

    F = F/t(length(t)-1);
end
```

It was called using the code below:

```matlab
fh=0:0.05:250;
w=2*pi*fh;
t=0:0.002:(length(S)/500)-0.002;
F = FT(w,t,S);
figure;
semilogy(fh,abs(F))
```

E. The cross correlation between two signals is a measure of the similarity between them as different time lags is applied to one of them. A correlation value of +1 would mean the signals being compared are perfectly similar, while a correlation of -1 would mean the signals are opposites of each other. A value of zero would indicate that the two signals are completely not similar.

The cross correlations were run using the following Matlab code:

```
%Correletion Matrix
X = S(5001:6000);
X2 = S(5001:7000);
R_ECG = corrcoef(X,ECG)
R_EMG_B = corrcoef(X2,EMG_B)
R_EMG_F = corrcoef(X2,EMG_F)
```

Corrcoef() returns a matrix of the correlation values of the two signals at zero time lags [4].