



UNIVERSITY OF GEORGIA

CSEE 4630_3 Bioinstrumentation

Lab 1 - DIY Portable ECG (Heart Lab)

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Task A: Setup the Electrocardiogram Device	5%
Task B: ECG Digital Signal Processing	4%
Task C: Computing the Limb Leads & Augmented Leads	5%
Task D: Extraction of R Wave & Vectorcardiogram Conversion	6%
Task E: Stress Test Validation	1.6%

October 10, 2018

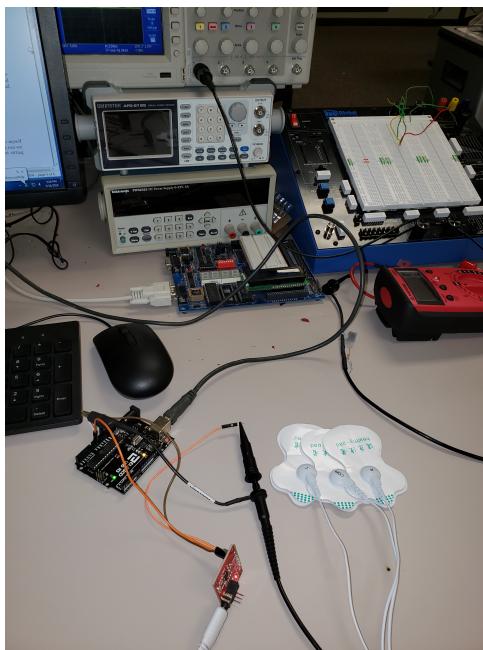
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1 Task A: Setup the Electrocardiogram Device

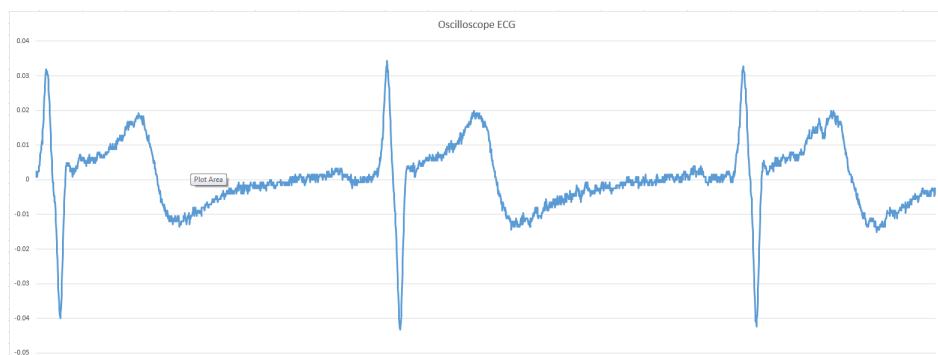
1.1 Assembling the Provided Kit

This year we were told that we were not going to solder the ECG because of difficulties in previous years so we just used some male to female wires to connect the ECG device to the oscilloscope and later the Arduino. Once I had the ECG device I used the arduino to power it, stuck the three leads to my chest and, connected the output to the oscilloscope just to verify that the device was producing a signal. The photo and data from the oscilloscope is included in the next section as it was more relevant to that section.



1.2 Obtaining From the ECG

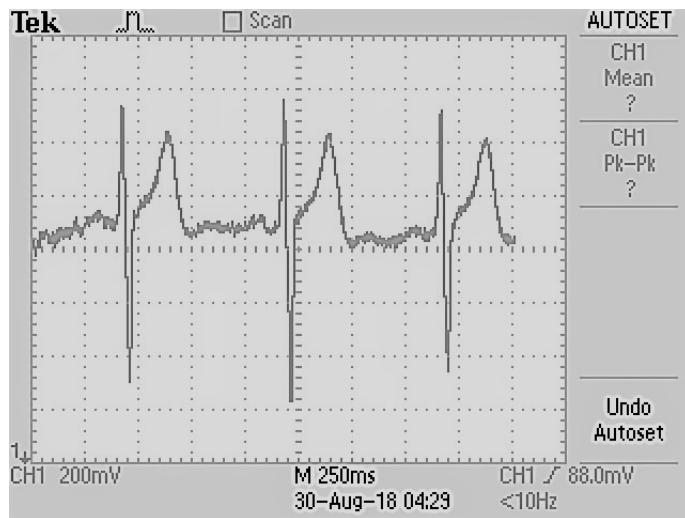
The following data was collected from the oscilloscope and the data points were saved to a flash drive. The oscilloscope was connected to the output of the ECG device which had its three leads connected to me. I took the data points from the oscilloscope into excel and plotted them to show the data.



2 Task B: ECG Digital Signal Processing

2.1 Connecting the ECG to the Oscilloscope

As I had done in the previous section I connected the ECG device input leads to myself and 3V and ground to the arduino and finally the output to the oscilloscope as you can see in the above picture. The following picture is the signal I could see while i was just sitting in a chair.



2.2 Connect the ECG to the Arduino for Real-Time ECG Display

Now that I have seen the ECG working the only thing that I changed in the setup was connecting the ECG devices output pin to the A0 pin on the Arduino. Then I was provided an Arduino program that I cleaned up a little so I could better understand what was happening. The program reads in the output sensor value from A0 pin and prints that value with a 2 ms delay.

```
///Electrocardiogram Device///
//Connect to A0//

//Defining Constants and Variables
const int analogInPin0 = A0;
int sensorValue0 = 0;

void setup() {
// initialize serial communications at 9600 bps:
Serial.begin(9600);
delay(500);
}
```

```

void loop() {
// read the analog in values:
sensorValue0 = analogRead(analogInPin0);

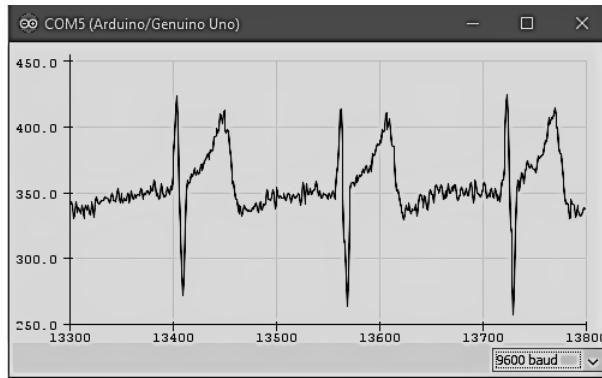
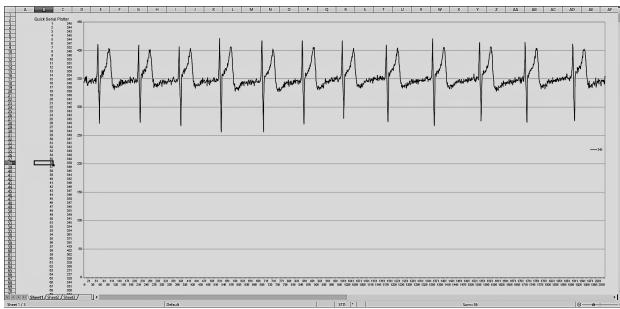
// print the results to the Serial Monitor:
//Serial.print("val ");

Serial.println(sensorValue0);

delay(2);
//delay(350);
}

```

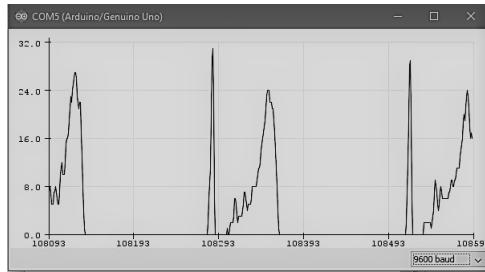
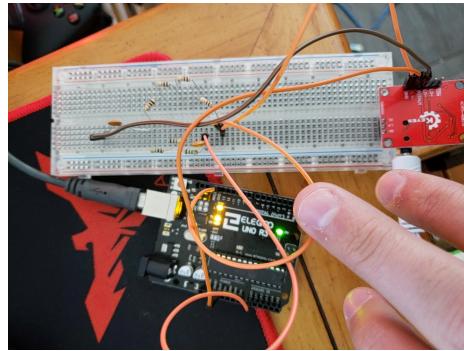
I can use the Arduino IDE to print the sensor output values to the serial monitor and plot the output data versus a time scale calculated using the baud rate of 9600 to see my real time ECG or use the serial plotter the actually view that data pre-plotted by the IDE. Both are shown below.



Now, in this task I am to take a 4 minute measurement of me increasing and decreasing my heart rate deliberately. The instructions are to exercise for two minutes measuring at various intervals and then do the same relaxing for two minutes. For my experiment I will continually be taking my ECG while exercising for two minutes then relaxing for two minutes. My 'exercise' consists of leg lifts and holding my breath as not to increase the noise of the signal. The resulting data was copied from the serial monitor and plotted using excel as before. The results are below.

2.3 Building A Band-Pass Filter for the ECG Signal

For this task I needed to make a simple band pass filter to apply to the ECG to cutoff excessively low and high frequencies from being plotted. All I needed to determine is the high and low cutoff frequencies, which I was able to find information on here. I then constructed the circuit below with a high pass cutoff frequency of 0.5 Hz and a low pass cutoff of 40 Hz using a 3 Mohm0.1 uF and 40 Kohm0.1 uF respectively. The results of the filter are shown below.



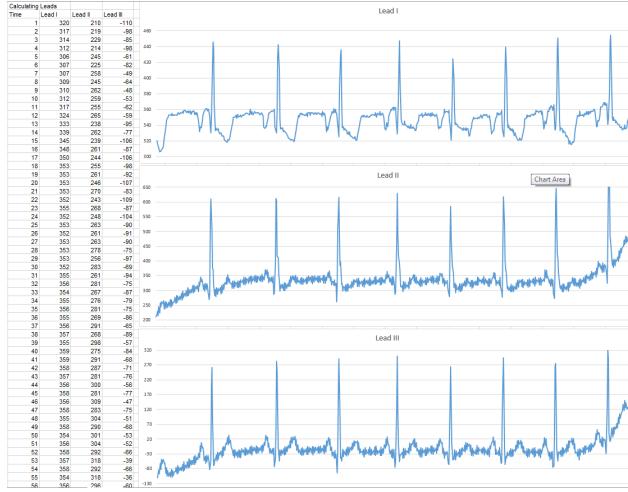
While the signal does look cleaner than the previous ones shown even though I used a high pass filter with a cutoff of essentially zero the P, Q, T, and U wave are getting cutoff. If I had the time I would instead use matlab to apply a software solution as I could more actually choose the cutoff frequencies and have yet and even cleaner solution.

3 Task C: Computing the Limb Leads & Augmented Leads

3.1 Computing the Voltages for Lead I, II, and III

For this part of the lab I needed to record the signal of lead I and lead II using the ECG device from the serial plotter simultaneously then I can subtract lead I from lead II the result being lead III. Finally I graphed all three leads to visualize and verify the data for comparison in excel which you can see below. It is worth mentioning that I needed to measure the voltages at both leads simultaneously to be able to calculate an accurate lead three, which means I was using multiple alligator clips on the pads making the signal slightly more noisy.

$$L_{III} = L_{II} - L_I \quad (1)$$



This is how the arduino source code had to be changed to allow for two analog inputs simultaneously. The two values are printed on one output line separated by a comma so they can easily be copied and formatted into excel to be graphed.

```
///Electrocardiogram Device///
//Connect to A0//
```

```
//Defining Constants and Variables
const int analogInPin0 = A0;
int sensorValue0 = 0;

const int analogInPin0 = A1;
int sensorValue1 = 0;

void setup() {
    // initialize serial communications at 9600 bps:
    Serial.begin(9600);
    delay(500);
}

void loop() {
    // read the analog in values:
    sensorValue0 = analogRead(analogInPin0);
    sensorValue1 = analogRead(analogInPin1);

    // print the results to the Serial Monitor:
    //Serial.print("val ");
}
```

```

Serial.print(sensorValue0);
Serial.print(",");
Serial.println(sensorValue1);

delay(2);
//delay(350);
}

```

3.2 Calculating aVL, aVR, and aVF

Now that we have the values of leads I, II, and III we can use three equations from Wilson's augmented leads to calculate the three augmented leads, which are shown here.

$$aV_L = \frac{2V_L - V_R - V_F}{3} \quad (2)$$

$$aV_R = \frac{2V_R - V_L - V_F}{3} \quad (3)$$

$$aV_F = \frac{2V_F - V_R - V_L}{3} \quad (4)$$

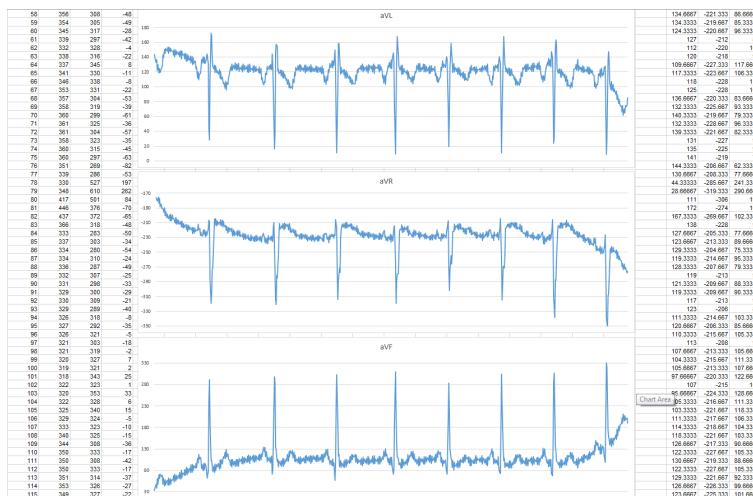
If I re-group the terms in terms of leads I, II, and III i can use the data i collected in the previous section to calculate all the augmented leads very easily.

$$aV_L = \frac{V_1 - V_3}{3} \quad (5)$$

$$aV_R = \frac{-V_1 - V_2}{3} \quad (6)$$

$$aV_F = \frac{V_2 + V_3}{3} \quad (7)$$

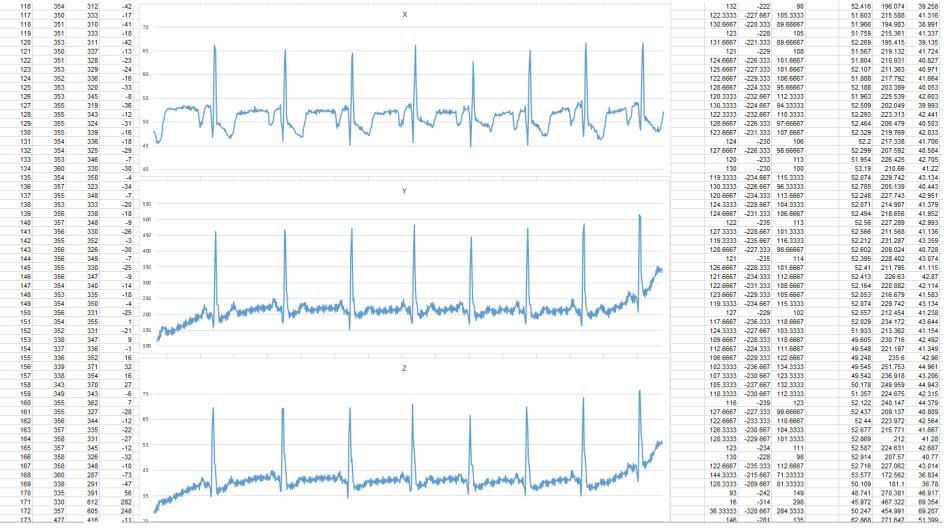
Now you can see the three graphs of each of the augmented leads that i calculated from the data i collected from lead I and lead II.



3.3 Computing a Vectorcardiogram in the Frontal Plane

For this section I need compute the three values of the vectorcardiogram. Now we can not reasonably collected data for the other 6 leads needed in a 12 lead ECG that will lets perfectly convert to a VCG but we do have lead I and II so we can convert to a VCG in the frontal plane. To do this we need to multiply the matrix of lead I and II with the matrix of dower coefficents that correlate to leads I and II. This will give us the values of X, Y and, Z, which I can then graph to show the VCG strictly in the frontal plane.

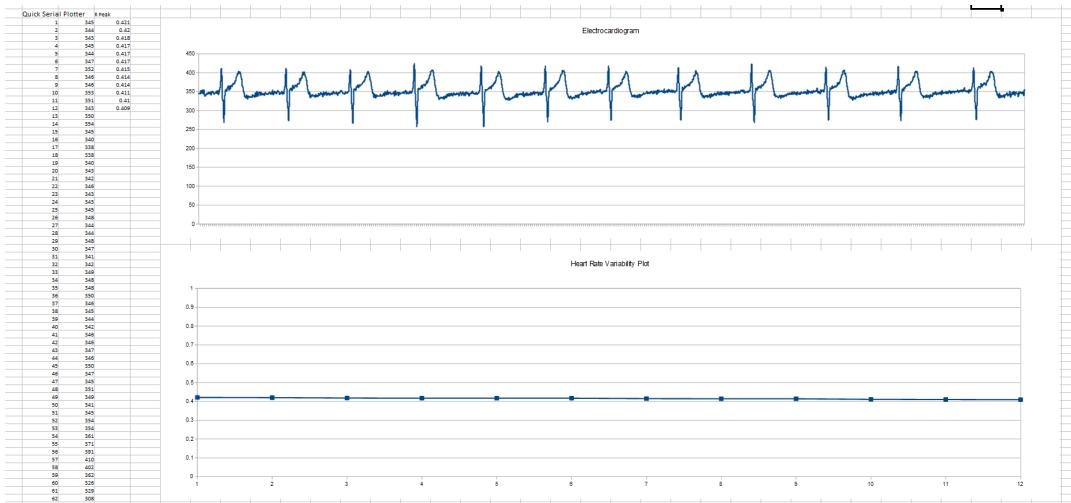
$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} I \\ II \end{pmatrix} * \begin{pmatrix} 0.156 & -0.009 \\ -0.227 & 0.886 \\ 0.021 & 0.102 \end{pmatrix}$$



It would appear that my conversion to a VCG is successful since X, Y, and, Z correlate with Lead I, II, and III respectively except for, of course the amplitude. In our case we only used two leads and some math to get to this point but with a VCG in the frontal plant we only need 2 leads rather than all three.

4 Task D: Extraction of R Wave & Vectorcardiogram Conversion

The purpose of this task is to learn and understand making an heart rate variability plot and practice measuring the R to R intervals on an ECG plot. To complete this i took the plot from section 2.2 and created a corresponding HRV plot. There are many ways to tackle this issue the most effective would be to have lines of code that save and print a max in a certain threshold but to create a plot once you already have the serial output data you could use matlab or other various programs but, I found that the easiest way was to use a vary simple excel function. Below is my resulting HRV and it seems to match the ECG plot and is relatively constant which is good as well.



5 Task E: Stress Test Validation

In the final section the goal is to exercise for three minutes then rest for three minutes then finally exercise for three more minutes and take measurement every minute on the oscilloscope. After i completed this i took all the data and complied it in excel and created a graph that shows each of the ten measurements stacked on top of each other and a legend of course. This was an interesting way to look at the data because you could compare the heart rates at the different times pretty directly, but admittedly with ten different measurements it can be pretty hard to read. That is why after that i created a heart rate variability graph to get an easier to see more full picture in the change in my heart rate.

