EEL 4914C Electrical Engineering Design

(Senior Design)

Preliminary Design Report with Diagram(s)

28 January 2008

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Project Title:

PAMELA:

Pulse Amplitude Monitoring Equipment for Living Applications

Team Name:

PULSERS

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Project Abstract:

The goal of our project is to measure three nearby heartbeats on the same test subject and be able to continuously chart/analyze the differences in amplitude among the heart beats. The continuous heart rate will be determined and displayed as well. With this data, numerous other plots can be displayed (trajectory, change in heart rate over time, etc.). Figure 1 demonstrates the simple process flow/overview of the PAMELA system.

This design is for a specific application. Its main function is to investigate how the differences in amplitudes of the three heart beats relate to the health condition of the test subject. A potential case study would be to collect data on a physically fit, healthy subject with no known organ deficiencies and to collect data on an unhealthy subject with known organ deficiencies. A general application of this product is to analyze one's heart rate and interpret the data accordingly. Existing products do not satisfy the needs of our specific application. Some current products on the market include hospital heart monitors which implement IR sensors, wrist watch BPM (beats per minute) monitors, etc.

Jones, *et. al* [1] provides a method for detecting one's heart rate via IR sensors and plotting the change in rate over time. This paper provides the foundation of understanding how to implement an electronic heart rate sensor.

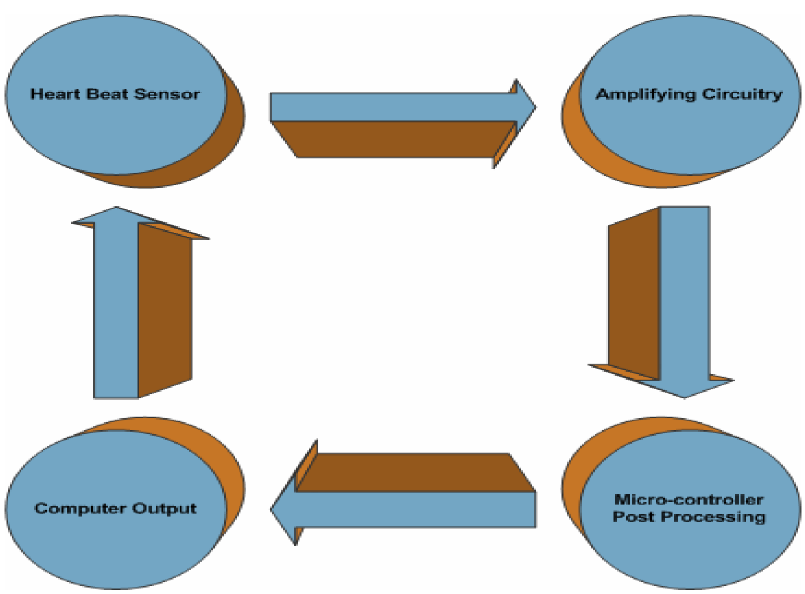


Figure 1. Overview of the PAMELA Process

Features:

The PAMELA system will provide a unique and accurate method for acquiring heart rate data for medical studies. The main features include:

- Three sensors detecting the pulse
- A fourth sensor used for software noise cancellation
- User friendly wristband with USB cable for easy access data acquisition
- Easy to read graphical displays with pertinent health information through computer based software
    - Differences in amplitude between the three different sensed pulses
    - Change in heart rate over time (duration: minutes)
    - Constant Beats per Minute (BPM) monitor

The Competition:

Our two competitors are the MITes (MIT Environmental Sensor) Heart Rate Monitor [5], Figure 2 and the COSY Digital Heart Beat Monitor [6], Figure 3. The MITes HRM (heart rate monitor) implements an industry standard Polar chest-strap transmitter and receiver. The transmitter sends out a beating pulse while the actual MITes generic board acknowledges this heart beat signal, calculates the BPM and sends it back to the MITes receiver. Voltage regulators are implemented to convert 5V down to 3V for the input of the device. This MITes unit is contained within a pillbox and costs $95.50 per 50 units. [5]

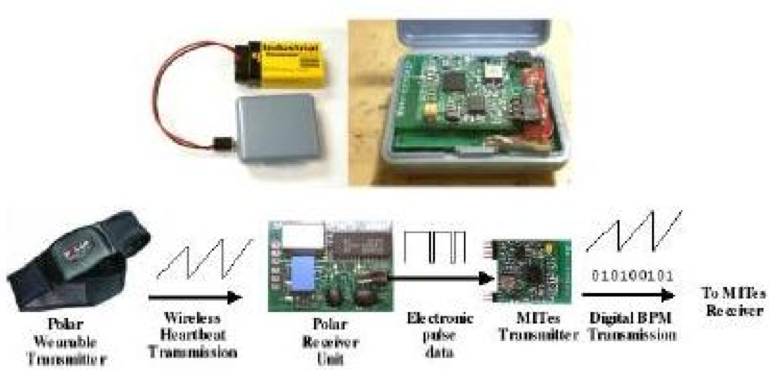


Figure 2. MITes Heart Beat Monitor
Source: http://web.media.mit.edu/~emunguia/html/mites.htm

The COSY Digital Heart Beat Monitor features an IR finger/earlobe clip sensor to monitor the heartbeat. It is a micro-controller based system which indicates the pulse via LED display and a piezoelectric beep. It features a bar graph to indicate the best sensor position on the finger/earlobe and costs $100 per unit. [6]

Figure 3. COSY Digital Heart Beat Monitor
Source: http://www.cosycommunications.com/Digitalpulsemonitorcatalogue.htm

Although both of these products are listed as competitors, they do not deliver the specific tasks that PAMELA offers. PAMELA acquires three heart beat pulses and analyzes the differences in these amplitudes for medical purposes. Instead of implementing an IR sensor, PAMELA features four force sensors, three of which capture the heart beat signal and the fourth serves to cancel noise in these signals. PAMELA is expected to cost nearly $170 per unit. Refer to the Features section above for further elaboration of PAMELA.

Technical Concepts:

The main objective of our project is to construct a product which can provide data which can be interpreted to diagnose the health condition of a test subject depending on the differences in amplitudes of three diverse heart beats. Preliminary testing consisted of attempting to detect the heart rate with an IR detector (LTR-301) and emitter (LTE-302). Unfortunately, the results were unacceptable and an alternative to IR sensors was sought out. An expert's opinion led to testing force sensors (102-1223-ND). It was determined that these force sensors would indeed detect a pulse. See Figure 4 for an annotated oscilloscope reading and Figure 5 for a graphical depiction of the application.

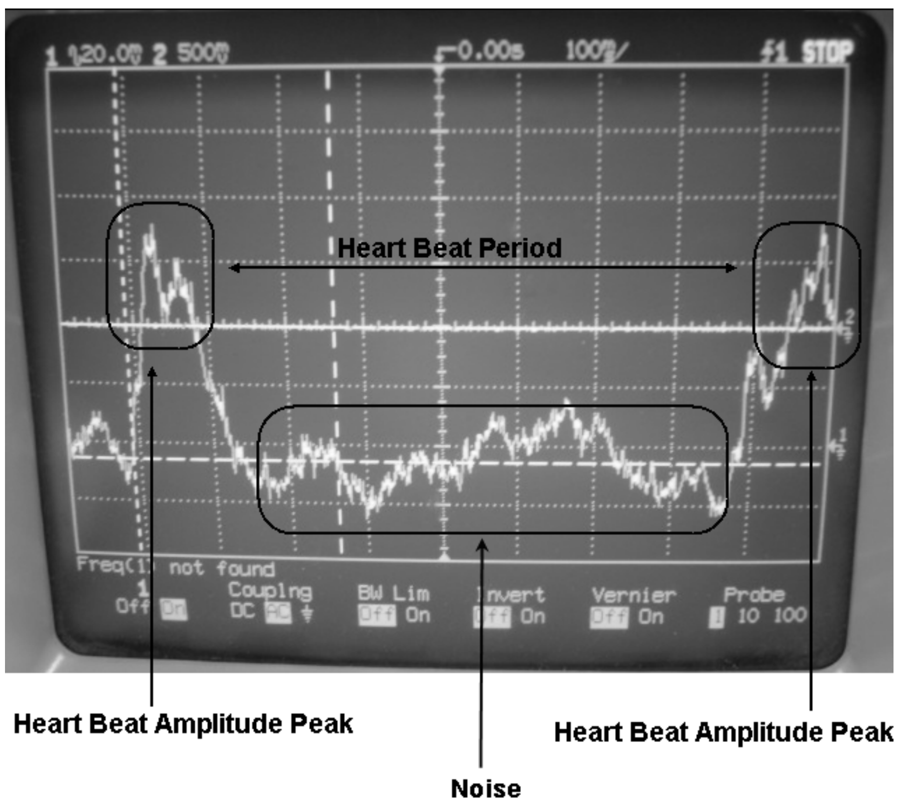


Figure 4. Annotated oscilloscope reading of a heartbeat via force sensor.

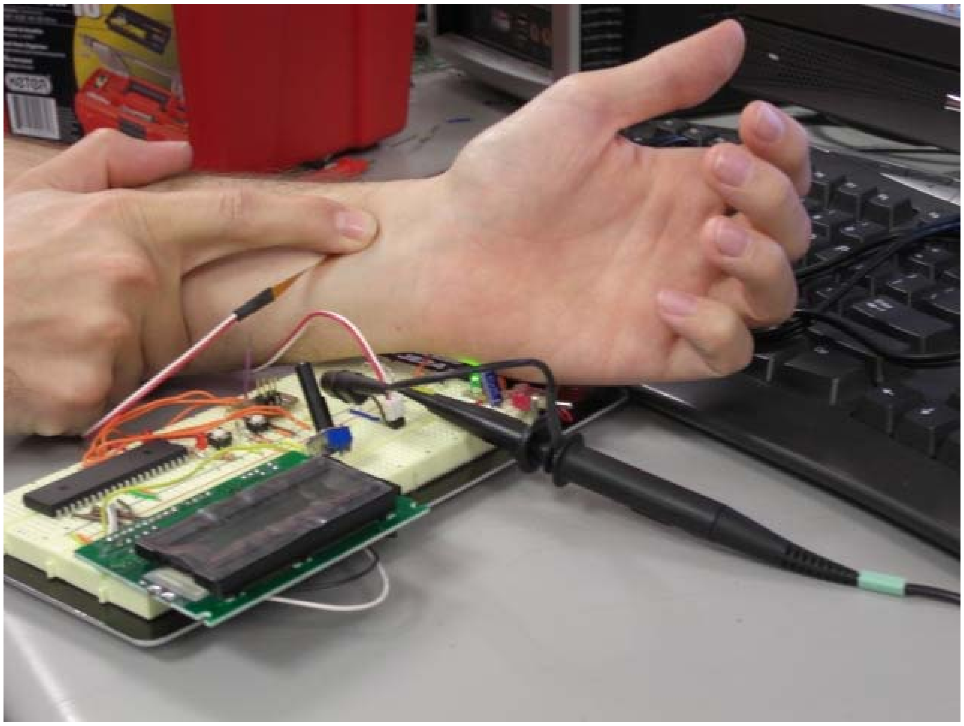


Figure 5. Proof of concept testing of force sensors connected to an oscilloscope.

As noted in Figure 4, the signal contains a consistent amount of noise. Essentially, the force sensor acts as a potentiometer with a resistance range of 100,000 kOhms (no force) down to nearly 1 kOhm (1.5 kg force) [2]. When placed in series with a 15kOhm resistor and a 5V DC source, as seen in Figure 6, the force sensor detects a pulse with amplitude of approximately 60 mV (see Figure 4). This signal will need to be amplified with an amplifying circuit prior to being read by an A/D converter.

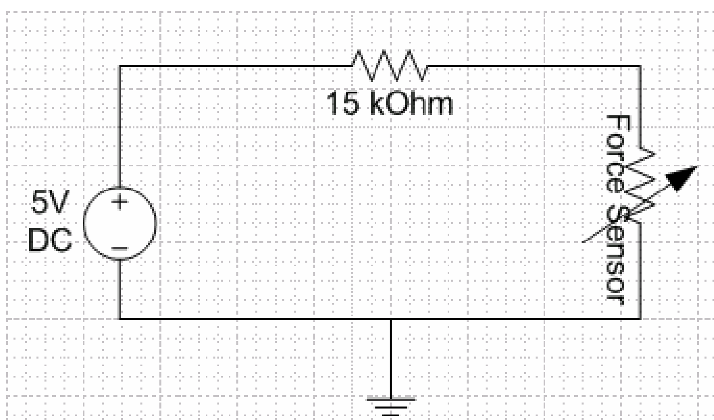


Figure 6. Simple test circuit for force sensor

In order to accommodate the project's goal, our preliminary design consists of four force sensors and supporting circuitry. Three of the force sensors will detect nearby heartbeats while the fourth force sensor will be placed on the subject's wrist near the other sensors yet not in the vicinity of a pulse. The purpose of this fourth sensor is to serve as a reference or baseline signal from which differences can be detected among the other three signals. Essentially, this will allow for noise cancellation with a differential noise reduction circuit (either through circuitry or in the microcontroller). As noted in Figure 4, the signal contains a consistent amount of noise. As of now, it is assumed that the differential noise reduction circuit will do the job. However, if the need arises to further reduce this noise then there are several solutions. One possible solution is to implement a low-pass RC filter to remove high frequencies from the circuit. Another, more precise method would be to implement a band-pass filter, thus further limiting the frequencies allowed through the circuit. One of these two solutions will be implemented if the circuit is found to be too noisy during further testing.

Figure 7 shows that the four analog signals will be converted to a digital signal via an A/D converter and will then be post processed by the microcontroller and provide the appropriate data for a computer output. The Atmega family is the microcontroller type chosen for this project. As of now, an Atmel Atmega 324P will supply enough A/D, I/O and UART ports for this application. Data will be sent to a computer via the microcontroller's UART output. It will then be fed to an FTDI Serial-to-USB converter (FT232RL) which attaches to the computer.

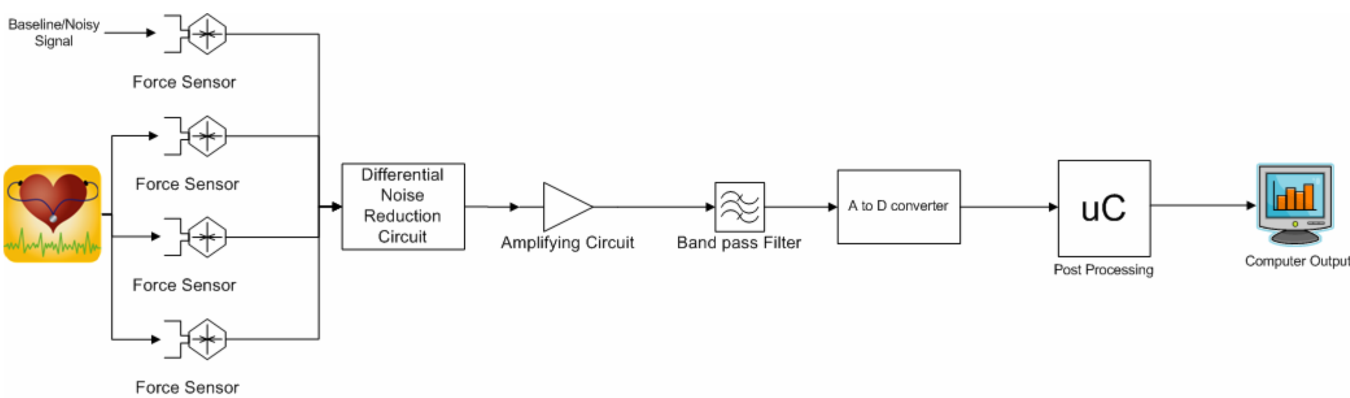


Figure 7. Technical Linear Schematic of Proposed PAMELA Architecture.

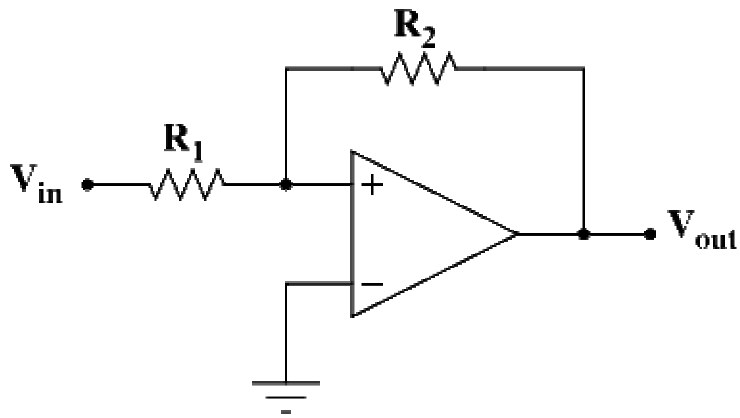


Figure 8. A simple op-amp schematic representation of a Schmidt Trigger.
Source: http://en.wikipedia.org/wiki/Schmidt_trigger [3]

We will be implementing the concept of a Schmidt trigger in the microcontroller code [3]. A Schmidt trigger is a comparator circuit (see Figure 8) which outputs a high voltage while the input voltage is higher than a designated high preset value. It outputs a low voltage while the input voltage falls below a designated low preset value. If the input voltage is between these two preset values, then the output is unaltered. This comparator concept will be used in software to determine the BPM (beats per minute) of the test subject.

National Instrument's LabVIEW will be used in the development of PAMELA. LabVIEW is a development environment which implements a graphical programming language to accomplish a task. Users can drag and drop block diagrams which serve as visual subroutines and interconnect them with wires. Data is input to each subroutine or interface and output through the wires towards the following block diagrams. [4]

Cost Objectives:

Expected costs are presented in the table below:

Product	Expected Cost
Atmega 324P	$8.00
Various Resistors	$0.00
Various Capacitors	$0.00
Force Sensors	$40.00
LabVIEW	$80.00
FT232RL	$10.00
USB Port	$5.00
Misc.	$25.00
Total Cost:	**$168.00**

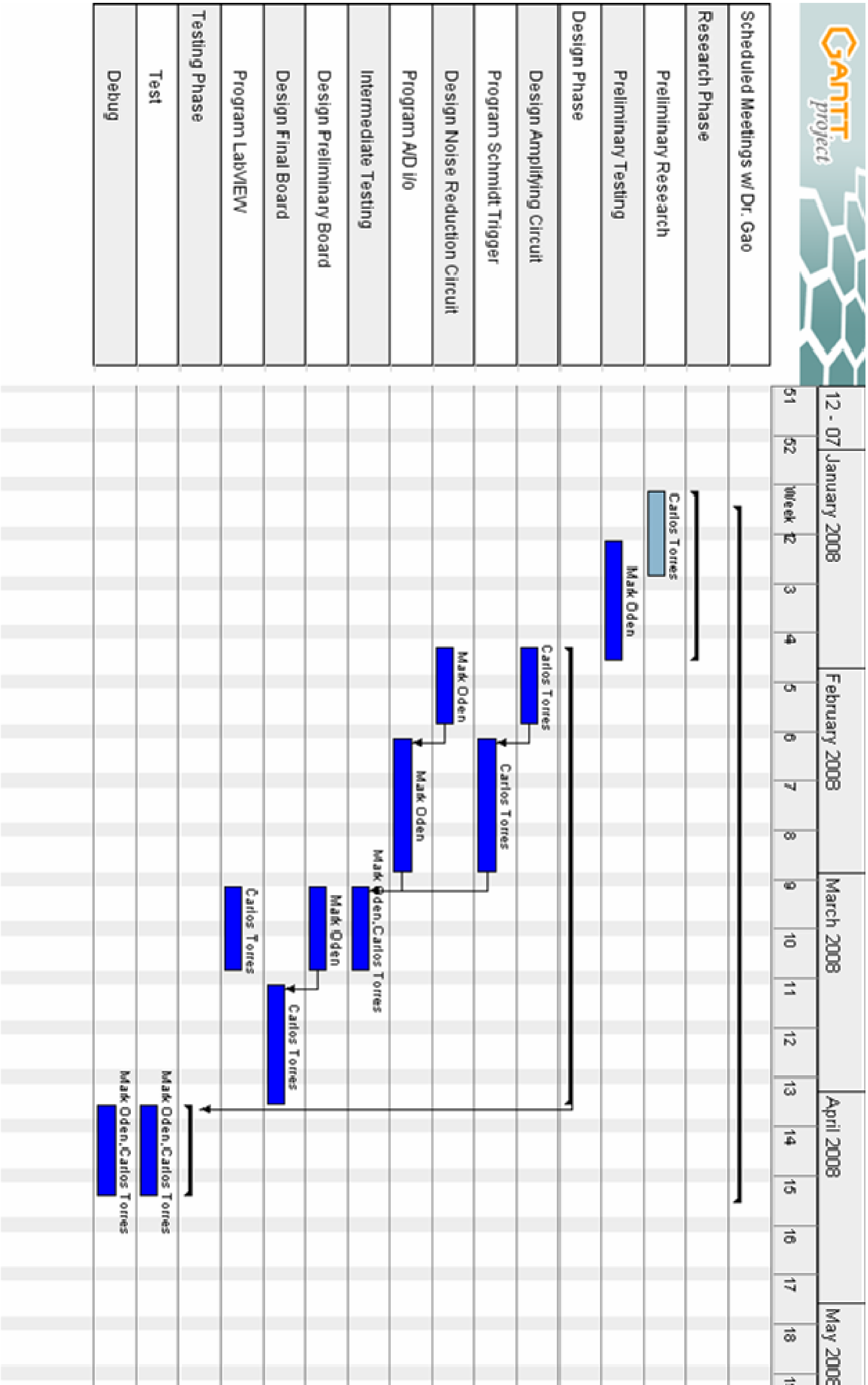
Table 1. Expected Cost Objectives

Division of Labor:

Carlos Manuel Torres Jr.	**Mark Oden**
Preliminary Research	Preliminary Testing
Design Amplifying Circuit	Design Noise Reduction Circuit(s)
Program LabVIEW & Schmidt Trigger	Program A/D input/output (microcontroller)
Design Final Board	Design Preliminary Board
Test/Debug	Test/Debug
Presentation, Documentation and Meetings	Presentation, Documentation and Meetings

Table 2. Division of Labor.

Timeline:


GANTT project
Scheduled Meetings w/ Dr. Gao
Research Phase
Preliminary Research
Preliminary Testing
Design Phase
Design Amplifying Circuit
Program Schmidt Trigger
Design Noise Reduction Circuit
Program A/D i/o
Intermediate Testing
Design Preliminary Board
Design Final Board
Program LabVIEW
Testing Phase
Test
Debug
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January 2008
February 2008
March 2008
April 2008
May 2008
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Week 2
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Carlos Torres
Mark Oden
Mark Oden,Carlos Torres

References:

[1] Lynette Jones, Nikhila Deo, Brett Lockyer, "Wireless Physiological Sensor System for Ambulatory Use," *bsn*, pp. 146-149, International Workshop on Wearable and Implantable Body Sensor Networks (BSN'06), 2006.

[2] CUI, Inc. SF-X-XX Part Specification Sheet. http://www.cui.com/pdffiles/SF-X.pdf.

[3] Schmidt Trigger - Wikipedia, the free encylopedia. http://en.wikipedia.org/wiki/Schmidt_trigger.

[4] LabVIEW - Wikipedia, the free encyclopedia. http://en.wikipedia.org/wiki/Labview

[5] MIT Media Lab - MITes (MIT Environmental Sensors), http://web.media.mit.edu/~emunguia/html/mites.htm

[6] COSY Digital Heartbeat Monitor, http://www.cosycommunications.com/Digitalpulsemonitorcatalogue.htm