The Heart of the Matter

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Overview

Photoplethysmography (PPG) optically measures changes in blood volume by the absorption and reflection of red and infrared light in hemoglobin. These changes are measured by capturing the reflected light with a photodiode. The project aims at creating a PPG instrument to observe detailed changes in the pulse wave using the properties of light, providing a doctor with a noninvasive way to gain insight into cardiac health. A microcontroller controls a pulse oximetry analog-to-digital converter, which runs the flashing of red and infrared LEDs. Deoxygenated and oxygenated blood absorb some of the light from the LEDs and reflect excess light to a photodiode, which sends an analog current signal back to the pulse oximetry analog-to-digital converter. The microcontroller receives a digital signal from the ADC and sends the data to a storage card. Finally, an external MATLAB processor analyzes the data.

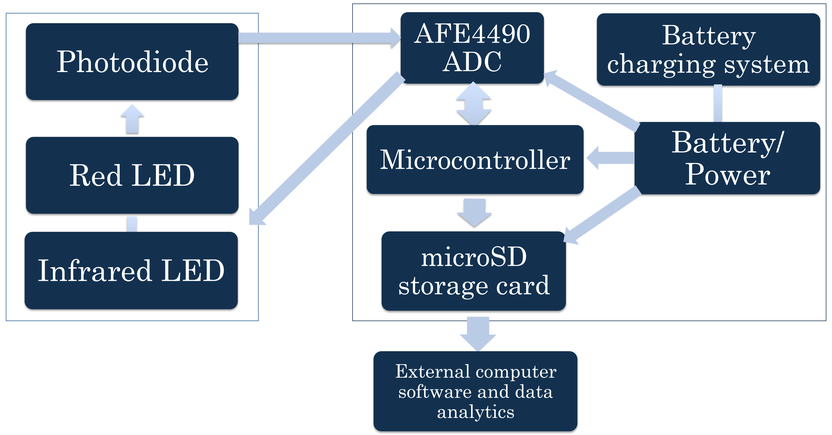
Development Process

- A Texas Instruments evaluation board and software allowed for the testing of the AFE4490 pulse oximetry digital-to-analog converter and creation of the LEDs/Photodiode external subsystem.
- Using Eagle software, a unique board was designed to include a PIC32MX270F256D microcontroller, AFE4490 ADC, microSD card, and power regulating system.
- Software programming on MPLAB allows for SPI communication between the MC and ADC and MC and storage card.
- MATLAB software on an external computer analyzes the data.

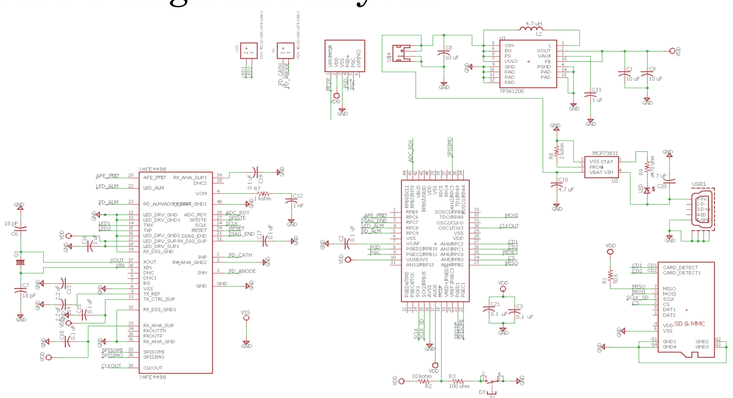
Subsystem Functionality

1. Microcontroller to AFE4490 communication
   - SPI communication
   - MC controls AFE to control LEDs
   - AFE sends a digital signal back to MC
2. LEDs/Photodiode external system
   - Blood absorbs red and infrared light
   - Photodiode captures reflected light
   - Photodiode sends current to AFE
3. Microcontroller to storage card communication
   - SPI communication
   - MC sends data to microSD card
4. Power management
   - Battery charging system uses USB port for external power supply
   - Li-Ion battery
   - Charge management controller outputs a constant 3.3 V
5. External data processing and analysis
   - Receives data from microSD card
   - MATLAB software and GUI analyzes data

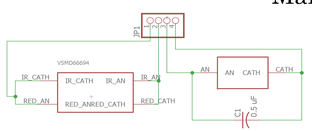
System Diagram



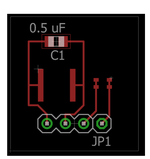
Board Design and Layout



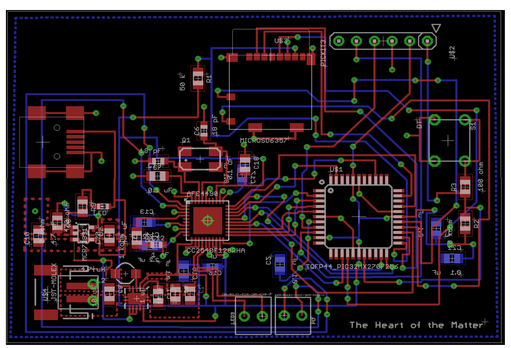
Main board schematic



LEDs/Photodiode system schematic

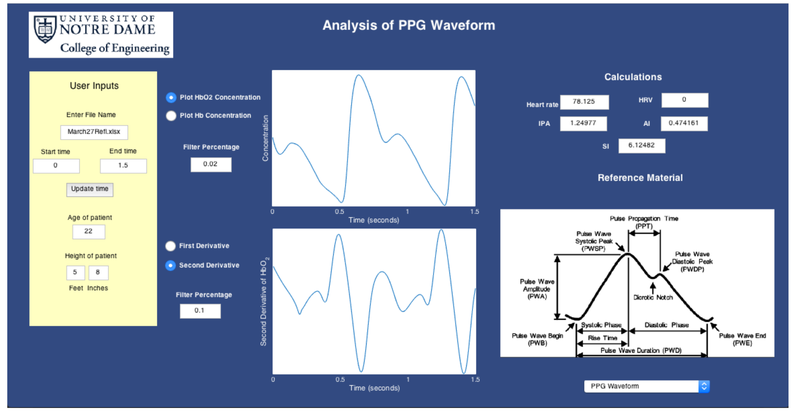


LEDs/Photodiode board layout



Main board layout

Pulse Waveform and Data Analysis



- The MATLAB GUI shows the measured PPG wave from the index finger of the user.
- It plots the relative concentration changes of Hb and HbO_2 in the blood.
- The program finds the peaks in the HbO_2 waveform and locates parameters such as the dicrotic notch and systolic peak.
- Utilizing this information, the program calculates the heart rate, heart rate variability (HRV in SDNN), inflection point area, augmentation index, and arterial stiffness index.
- The first and second derivatives of the pulse waveform are plotted with variable loss filter smoothing.
- Reference images for comparison with the data can be selected from a popup menu.

Future Development

- Automatic transfer of data from main board to computer via wifi or bluetooth
- Smaller packaging with a more compact board layout
- Phone application to analyze data and output usable information

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