ECE 445

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Project Proposal

Wireless ECG (Bubz)

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Introduction

1. Problem

An electrocardiogram (ECG) is the electrical heart signals, and it is used to detect abnormal behavior of the heart. Conventional ECGs have 12 leads that measure electrical potentials and 10 of them are placed on the chest of a patient. However, the conventional ECGs involve wires, and it can be tedious to deal with in emergency situations where every second matters.

There are some products that have been developed to help resolve the issue. Apple watch can monitor the heart signal, but it can only monitor 1 lead, which makes it not suitable for medical purposes. Similarly, Zio Patch and BardyDx CAM can only measure ECG with 1 lead. Kardiomobile 6L monitors 6 leads, but it only monitors the frontal plane leads, meaning that it cannot monitor the horizontal view of the heart, which is essential for accurate clinical diagnosis. Therefore, having wireless ECGs that can monitor as the conventional ECGs does can reduce time of measuring ECGs in an emergency situation for early diagnosis.

2. Solution

In this project, we hope to implement 2-lead wireless ECG devices. The primary purpose of the devices is to be used in emergency situations, since a wireless design is advantageous in terms of the time it takes to put all the patches on the skin. This can be useful for early diagnosis.

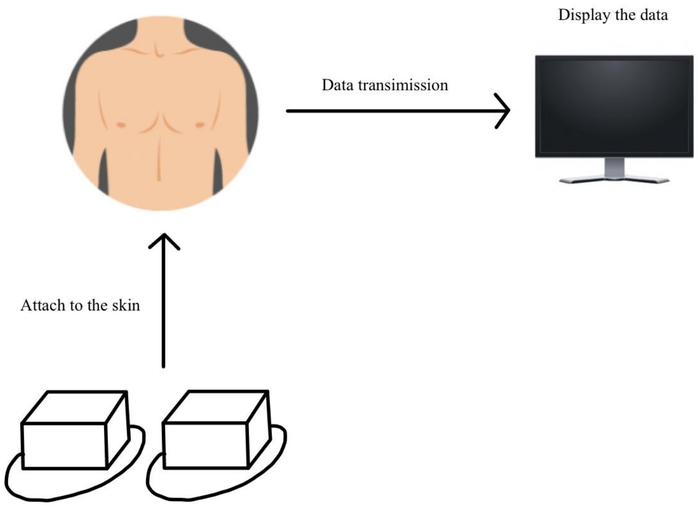
Each probe reads a voltage measurement from a reference point, which is usually about 1~10mV. The signal is then amplified and noise filtered. To achieve wireless transmission, the signal is converted from analog to digital through an ADC. Bluetooth protocol is used for wireless transmission of the information, and the monitor should display the data received like a normal ECG waveform. In essence, the circuit inside the device transmits the real-time health information to the computer, which can be easily read and monitored by people.

Voltage measurements are essentially relative measures, with a reference point being somewhere on the body. Hence using cables is inevitable to measure voltage across the body. In order to further prevent issues with cables, we intend to use retractable cables which are in a compact size when retracted, and can be pulled out and fixed to a certain length. Below is an audio retractable 3.5mm cable for reference.

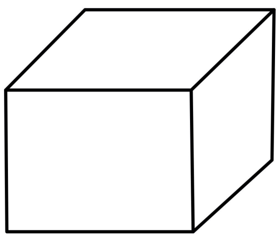
In essence, we can save time on both reading data and connecting the equipment. We hope that this solution provides a more timely and efficient means of obtaining ECG waveform.

3. Visual Aid

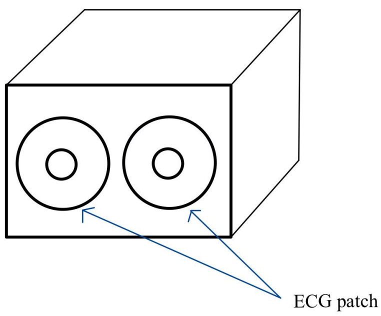
After connecting two patches to the patient's body, we mainly focus on using two bulbs to transmit the patient's health information wirelessly to the computer.



Functional Body

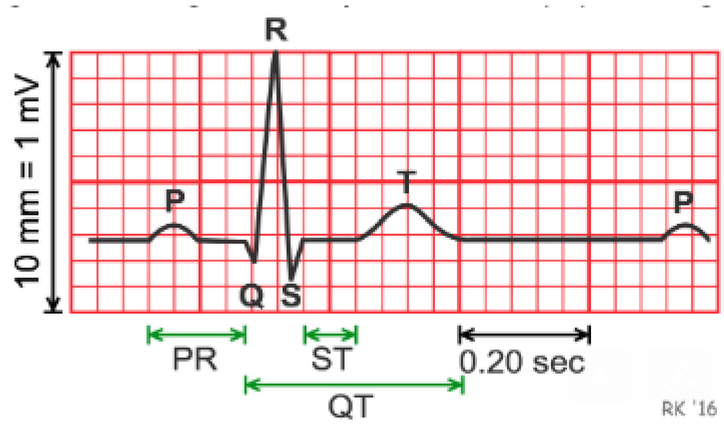


Bottom side view



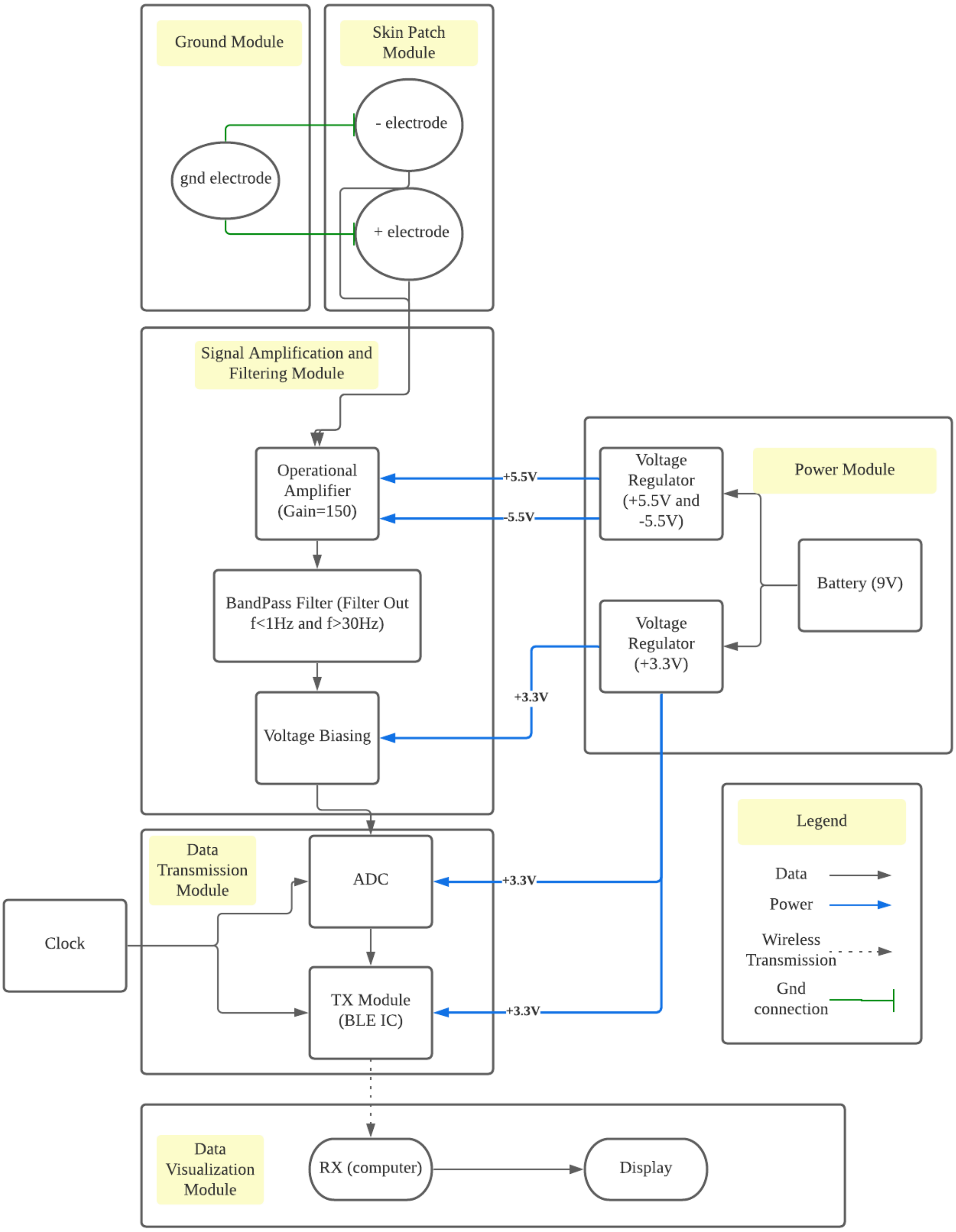
4. HIgh-level requirements list

1. **The device should successfully display ECG waveform on the computer, with accuracy not exceeding 0.1mV.**
2. **The data transmission rate should be within (500±50)Hz since the highest frequency of a common known heart rhythm problem (ventricular tachycardia) is up to 500 Hz. The data transmission delay time should be within 2 seconds.**
3. **The size of the device should be no larger than 12cm x 7cm x 6cm, which is the size of the device of the previous semester's design.**



Design

1. Block Diagram



2. Subsystem Overview and Requirements

Power Module Overview:

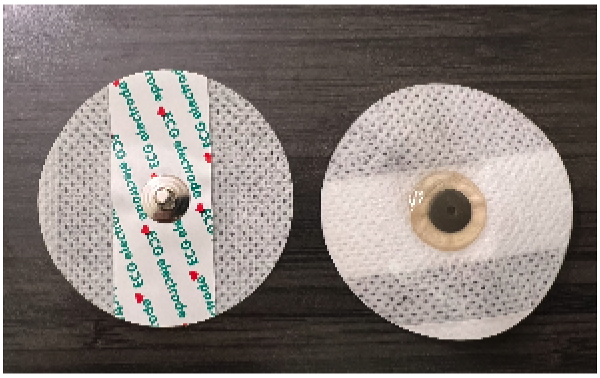
The power module supplies power to modules that require it. A battery (9V) is used to operate the entire system. It is distributed into two voltage regulators. One voltage regulator provides positive and negative voltage biases for the operational amplifier to operate. both positive and negative voltage biases, and they come from a voltage regulator microcontroller and the amplifier. Another voltage regulator provides voltage to voltage biasing, ADC, and the transceiver. A voltage divider can be used to divide power into the two voltage regulators. Voltage biasing is used to shift all the analog voltage readings in the positive region, since ADC can only read voltage larger than 0V.

The bias voltages illustrated in the block diagram are subject to change depending on the component that we decide to choose.

Subsystem Requirement: The power module should supply constant voltages that are required for components in different subsystems.

Skin Patch Module Overview:

The device is big enough to hold the necessary components, such as power supply and circuit board, and small enough to carry in an emergency situation. ECG electrode patches, which are already commercially available, will be used to ensure adhesion between the device and the skin.



This patch measures the voltage data that is to be processed by the rest of the subsystems.

Subsystem Requirement: The skin patch module should be attached to the skin along with the device, and it should be easily replaceable for repeated use on different people.

Signal Amplification and Filtering Overview:

For a typical EKG, the voltage reading ranges from 0.1mV to 10mV. In order to have these readings digitally, an amplifier should be designed. Moreover, research shows that data within the frequency range of 0 to 30Hz is desired, so a passive second-order low pass filter will be designed to filter out noises of the signal as well as noises from the power supply, which is typically around 60Hz. Since the cutoff realistically is not going to be steep, targeting a cutoff frequency of 30Hz should be sufficient to filter out 60Hz signals.
An oscilloscope will be used to determine the functionality of the filter.

Subsystem requirement: The functionality of the analog amplifier should work for the input range of -1mV to 1mV.

Data Transmission Module Overview:

We aim to use Bluetooth protocol to transmit data to the receiver. Each device should send the data measurements to the computer. It should keep the unit of transmission small enough for accurate and timely results (e.g, within 40 ms). One of the advantages of using Bluetooth is that the master receiving device can have multiple connections simultaneously.

Subsystem Requirement: The data transmission rate should be 500 Hz ± 50Hz.

Data Visualization Overview:

We will visualize the transmitted data (ideally in a form of the traditional EKG signal graph) after noise reduction. The data visualization part is divided into two parts: managing data and visualizing data. In the managing data part, once the computer receives the data from all the devices, the computer (or receiver) reduces the noise and does necessary steps to make the data be visualized (e.g., combines data from multiple devices and make it as one signal to display). Then, the visualizing data part visualizes the data in the user interface.

Subsystem Requirement:

- We should control the display time and when to display the data.
- The data should be accurate enough to display within the accuracy of 0.1mV on the computer.

3. Tolerance Analysis

One of the main purposes of designing this device is to eliminate the inconvenience caused by the wires having the possibility of tangling up, which hampers the process of the setup. It is also important to acknowledge that a ground node is necessary to have a voltage reading since voltage is a relative measure. Even though the wire connection to the monitor is eliminated, we would still need wire in order to read surface body potential to measure the voltage. We plan to eliminate such inconvenience by using retractable wires, which can be fixed at different lengths. By having the maximum length of the retractable wire to be approximately 30cm, we would be able to attach the ground patch (the reference point) on the body, considering people in different sizes.

We intend to improve the previous semester's design by eliminating the need for a suction component, which takes up more than half of the size of the device. We intend to use the standard ECG patches, which is good enough to make the device stay on skin. This implementation comes with another advantage that there is little to no need for sanitization for repeated use since simply replacing the ECG patches would suffice. Therefore, we would expect the size of the device to be smaller than 12cm*7cm*6cm, hence an improvement over the previous semester's work.

Ethics and Safety:

When doing our project, there are several ethical issues and safety problems that we need to consider. Since our devices are directly connected to the human body, we need to ensure that our circuit would not be too hot and our battery would not be damaged so that it would not hurt our users. All these are to follow the ethic rule: Avoid Harm.

We can expect minimal influence on the human body since the body surface potential reading is typically around 1~10mV, and the amplified signal should be in the range of valid inputs suitable for the ADC, typically maxing at 3.3V.

We do not expect any intentional misuse of our project, unless someone breaches into the collected data and takes away ECG waveform data of a person, which we believe is unlikely to happen. However, in order to prevent breaches of the data, we can disable wifi and only have bluetooth enabled while receiving data from the transceiver.

References:

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