Bioelectric Generator

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Abstract

Pacemakers revolutionized long-term healthcare for individuals suffering from irregular and slow heartbeats. These devices are battery powered, and after 5-15 years these batteries must be replaced via surgery. The scope of this project is to design, build, and test a fully implantable electric generating/charging system designed to recharge pacemaker-type implants to prevent the need for surgical battery replacement. The electric generating/charging system that we designed is an array of photodiodes powered by NIR (Near-Infrared) light. It will be placed beneath the skin near the chest. An IC (Integrated Circuit) that manages the energy produced by the infrared diodes will be placed in a 3D printed case which would be placed under the skin near the pacemaker.

Requirements

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- The device cannot be powered via any form of coupling or inductance.
- The device must charge a pacemaker battery in a safe manner for both the client and the battery.
- The charging must stop when the battery is full.

System Overview

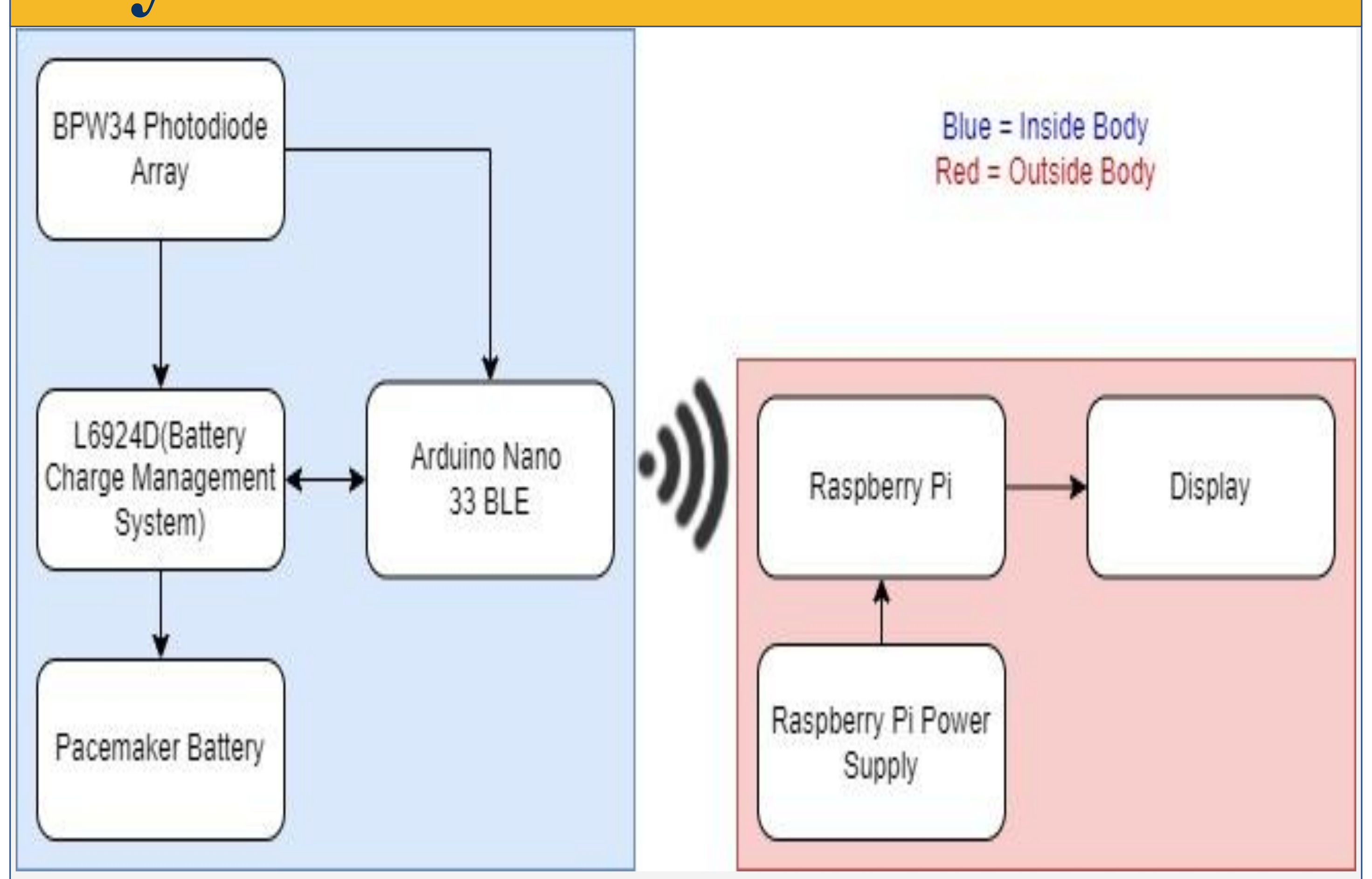

Figure 1: System Architecture

Our plan to successfully meet the requirements of the system was to use near-infrared (NIR) light to charge the pacemaker battery. The power generated from the NIR light will also power our other components e.g., the Arduino Nano 33 BLE, Raspberry Pi 3, and the Raspberry Pi display. In *Figure 1*, it shows our system architecture and what each component will be communicating with to properly charge the battery and communicate to the user the current state of the battery and its charging status.

Design Process

The method of charging we selected used BPW34 photodiodes (5.4x4.3x3.2mm) to generate power. Designing an array of these photodiodes consisted of experimenting with connecting the photodiodes in various combinations of series or parallel which gave us different voltage and current values. Our first prototype that we built to test if these photodiodes could generate the needed power to run our system is shown in *Figure 2*. It has a layout of 60 photodiodes altogether. The connection between each photodiode consists of 3 columns of 20 photodiodes in series and each column are connected in parallel together.

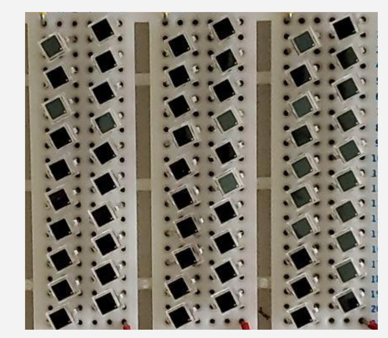

Figure 2: Prototype Photodiode Array

Figure 3: Near Infrared Lamp

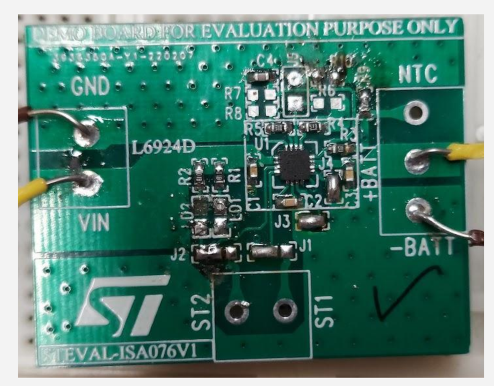

Figure 4: L6924D PCB

Figure 5: Arduino Nano BLE

To manage our power generation, an Arduino Nano 33 BLE and L6924D IC were used. We chose these components due to their miniscule size and the innate charge management and Bluetooth capabilities they have. For the IC to function properly, it must be placed on a PCB with connecting resistors and capacitors. Then, it can shut off the charging when the battery is full. The Arduino is used to monitor the battery level and charge rate. With Bluetooth, the Arduino can send that data to a Raspberry Pi 3 A+ that will display said data.

In order to serve as a substitute for a biocompatible material, the case was 3D printed using PLA for ease of design and testing. For the case we needed to keep this as small as possible since this device would need to be placed in the body. The dimensions of this case was 7.7cm x 9.2cm x 1.1cm

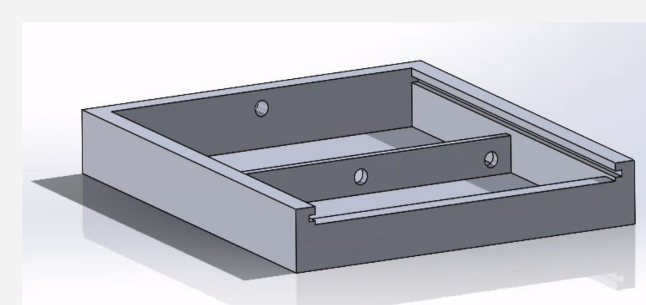

Figure 6: 3D Final Case Design

Figure 7: Raspberry Pi 3

Outside of the implanted device, the Raspberry Pi receives the data being sent front the Arduino and displays it on the screen in *Figure 8*. The data transferred is updated every 1 second as the battery is charging, and deactivated should the battery be fully charged.

Figure 8: Raspberry Pi Display

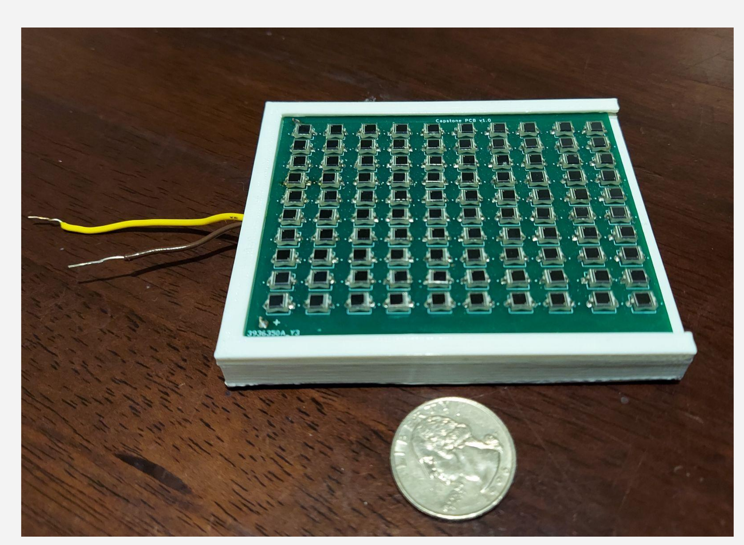

Figure 9: Completed inserted device

Results

- Implant size is 7.7x9.2x1.1 cm
- Display is 7" LCD 800x480
- Bluetooth transmitter in plastic case
- Uses an external display connected to a Raspberry Pi 3
- Two wires lead outside the case to attach to pacemaker battery
- The lid of the case is the photodiode array PCB

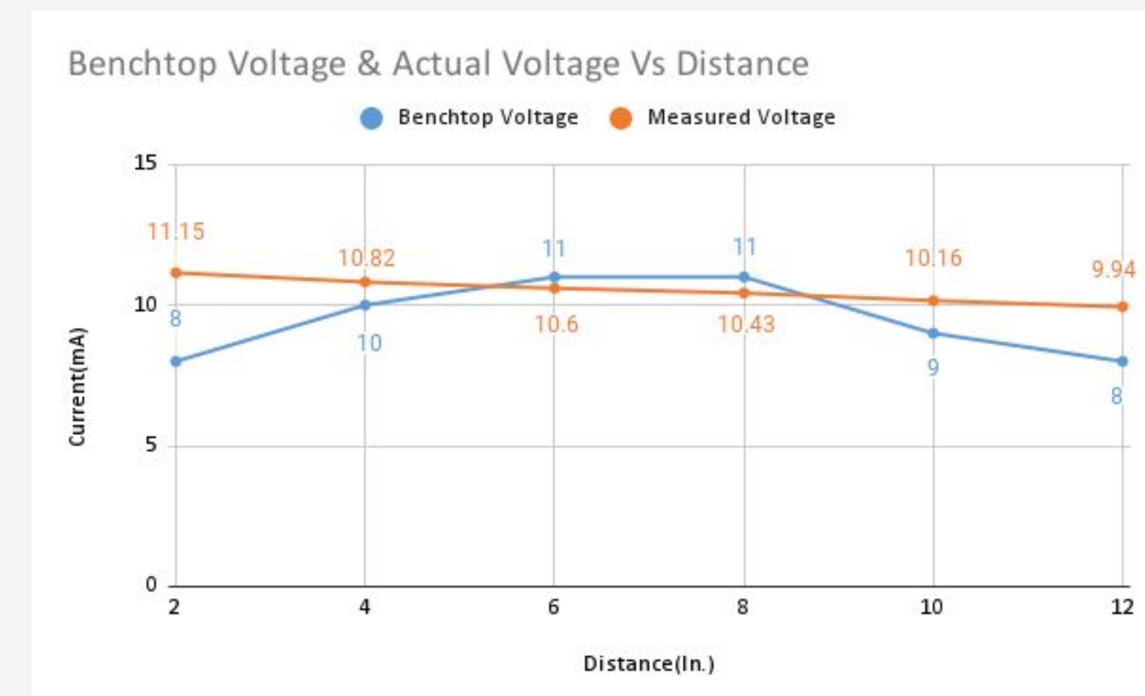

Figure 10: Benchtop Voltage & Actual Voltage Vs Distance

Figure 11: Benchtop Current & Actual Current Vs Distance

The photodiode array PCB produced approximately 11V and 12mA at a 4 inch distance from the NIR light source. This was capable of charging a LiPo battery from dead to 3V in 20 minutes before ceasing to charge the battery. Distances less than 6 inches are preferred due to the charge speed decreasing with a slower current, according to *Figure 11*,

Acknowledgements

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