Research and Design of Biomedical Telemetry Device using Light Transmission

Mauricio Gallegos[1], Austin Mesa[2], Dr. Juan B. Gutierrez[3]

[1]Clemson University, [2] Florida International University, [3]Department of Mathematics, University of Georgia

Problem Statement

The goal of this project was to design and miniaturize an implantable biomedical telemetry sensor that provides continuous, long-term telemetry data that could, in turn, be used with predictive algorithms to pre-diagnose disease or predict the severity of an oncoming disease. Current sensors that accomplish the same goal are power-hungry due to radio transmission and bulky due to a large battery, making them poor implants. Our team designed a proof-of-concept device for telemetry data transmission that uses visible light instead of radio waves, which should theoretically reduce overall battery consumption and minimize size. The system features two components, one for data collection and transmission, and the other for data reception. These components work simultaneously to provide real-time telemetry data that can be analyzed further. For our particular transmission device, the sensors used were a 3-axis accelerometer, which detects the overall activity of the subject being studied, and a temperature sensor which provides a general measurement of biological health. This hardware along with code loaded to the microcontroller allows the system to transmit live data through an LED, which is instantaneously received by the photoresistor on the receiving end. By parsing and interpreting the binary data, it can be organized and plotted for further analysis.

Prototyping

Arduino is an open-source software and hardware microcontroller solution developed in Italy that provides a straightforward way of inputting or outputting data to hardware. The Arduino boards allowed for prototyping wiring schematics and developing code for our specific sensors. Further, the Arduino setup enables easy calibration of hardware to provide accurate readings as well as the ability to create multiple iterations without the permanence that printed circuit boards (PCB) bring.

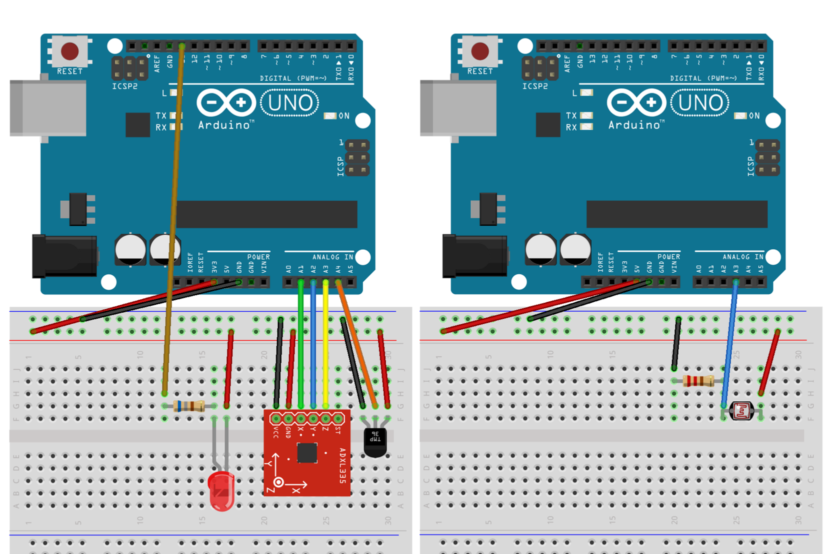

Figure 1: *Arduino Transmitter and Receiver*

Algorithm

Inputs are first gathered from the aforementioned sensors using analog inputs which are essentially voltage readings in 10-bits produced by the sensors. Using manufacturer and in-house conversion factors, the voltage readings are able to be converted to meaningful temperature and acceleration readings respectively. These new values are then converted back into 10-bit binary and transmitted by an LED through on-off signals corresponding to the 1's and 0's of binary preceded by an initialization code and a unique identifier for each sensor output. On the receiving end, the binary data is recorded, reconstructed, and stored using a parsing and interpretation algorithm in MATLAB. Meanwhile this data is simultaneously being logged and plotted in real-time. The QR code on the bottom right corner of the poster is a direct link to the three scripts and function developed to run the plotter.

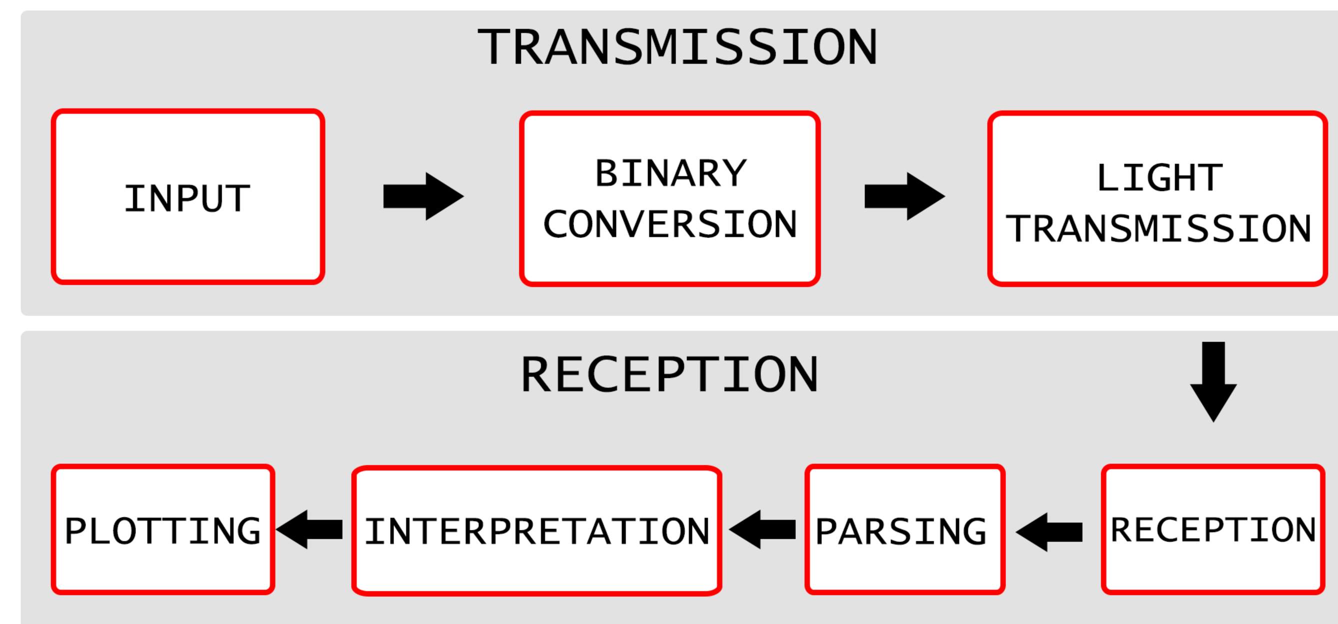

Figure 2: *Software Flowchart*

While plotting is used in the current version, simply storing all of the values into a spreadsheet for future analysis is also possible, and is a side-product of the current iteration. Further, the team has also had success in transmitting data using Bluetooth Low-Energy to mobile devices.

	1	2	3	4
1	'Tempera...	'accX'	'accY'	'accZ'
2	26	260	28	83
3	22	34	16	96
4	22	22	15	82
5	22	22	16	82
6	22	22	16	80
7	22	22	15	82
8	25	23	16	79
9	22	39	16	96

Figure 3: *Binary to Data*

PCB Development

The next step in the development of the telemetry device was transitioning from an Arduino prototype to a printed circuit board (PCB) prototype. All hardware components that are not essential for the functioning of the Arduino board were stripped and placed onto a schematic using Eagle PCB software. This included a bootloaded microcontroller, power supply, time crystal, and an ICSP system to be able to upload code to the microcontroller. Using manufacturer schematics and prior knowledge gained through the Arduino wiring, the schematic shown (Fig. 4 right) was able to designed and converted to a PCB (Fig. 4 left). This design process allowed for complete designing freedom, enabling the team to mold the design to fit any physical and electrical constraints, in our case making the device as small as possible while consuming low energy. The final board design was measured at 2056 x 1006 mil - roughly 2" x 1"; this was minimized from the Arduino and breadboard design that measured at nearly 6.5" x 2.5".

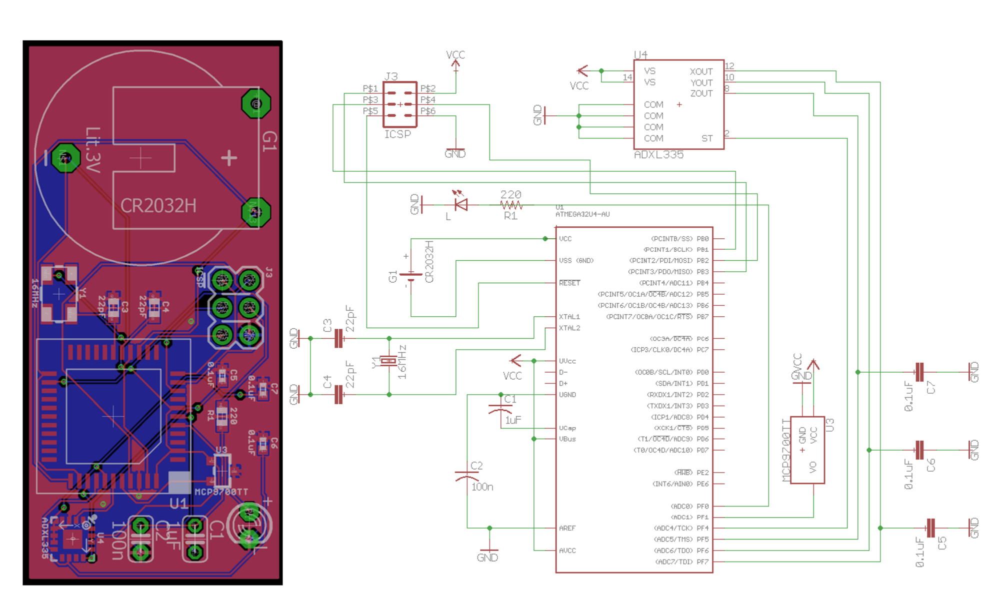

Figure 4: *Prototype 1 Schematic and Board*

Casing

The process of producing the casing for the telemetry device was divided into four stages spanning four mediums. Stage One consisted of creating a technical drawing of the casing design to be utilized as the fundamental design. The considerations taken included access to the necessary sensors and light as well as ergonomics in creating a relatively low profile and chamfered edges to reduce discomfort the implant may produce. The next stage, Stage Two, was designing the casing on a computer aided design (CAD) program, in this case SolidWorks. This design will then be exported as a file type recognized by MatterControl, the software used to connect to the 3D printer, and printed in Stage Three. The first physical iteration will then printed using ABS filament, chosen for its properties of strength, flexibility, and ease of printing. The final stage of the process will then be machining the metal casing also using an altered CAD design to be read by the CNC (Computer Numerical Control) Machine using aluminum as the material. In the future for animal and ultimately human trials, Titanium would be utilized instead of aluminum for its superior biomedical properties, and coated in a biologically friendly substance that mitigates the risk of a negative immune response against the device.

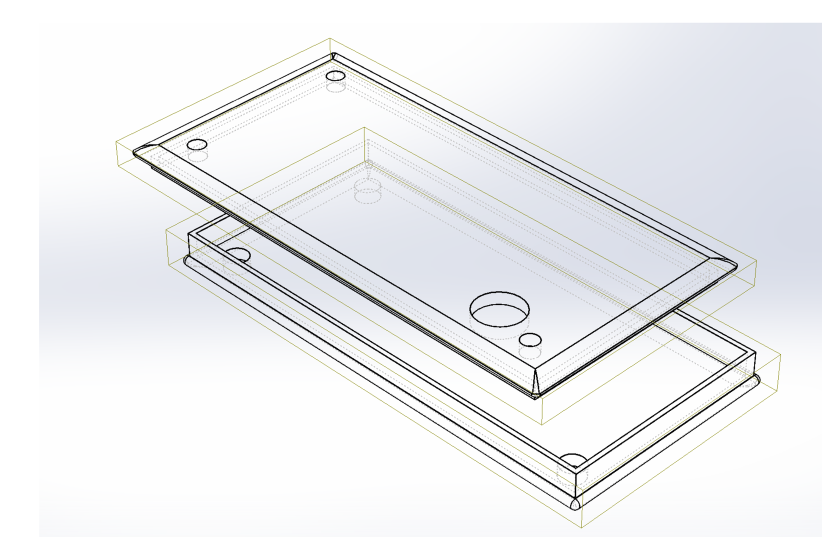

Figure 5: *Casing design model*

Future of Telemetry Technology

The role of continuous, long-term telemetry data can be powerful in providing baseline physiological data for individuals or groups and, with enough data, allows for the development of predictive algorithms used in the pre-diagnosis of diseases or conditions. Studying disease and how it deviates from baseline readings could be a groundbreaking preventative measure, specifically in examining diseases that have incubatory periods with little to no symptoms. For example, reading the slightest signs of an oncoming stroke by detecting inadvertent movements and changing physiological signals. In order for such methods to be feasible, minimization of telemetry sensors would have to increase much beyond the scope of our project, and frequency of readings would have to increase drastically. Our team recognizes the promise that telemetry data can provide not only in the realm of science, but in the everyday life of an individual as well.

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