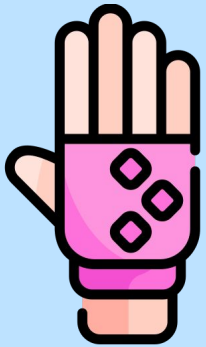
PROJECT N.I.H.M.S

(Non-Invasive Health Monitoring System)



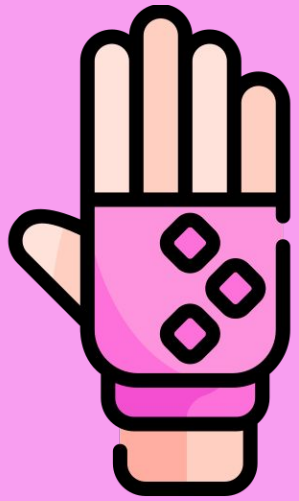
Group E - Senior Design Fall 2021

Gabriela Pinedo *(Computer Engineering)*
Schneider Maxime *(Computer Engineering)*
George Michael Ruiz *(Electrical Engineering)*
Nicole Fossenier *(Photonic Science and Engineering)*

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO

Agenda

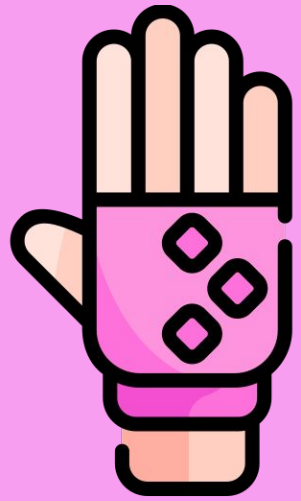


1. Introduction
2. Motivation
3. Requirements and Specifications
4. Standards and Constraints
5. Block Diagrams
6. Hardware
7. Software and Hardware Integration
8. Software
9. Challenges
10. Project Cost and Responsibilities

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO

Introduction

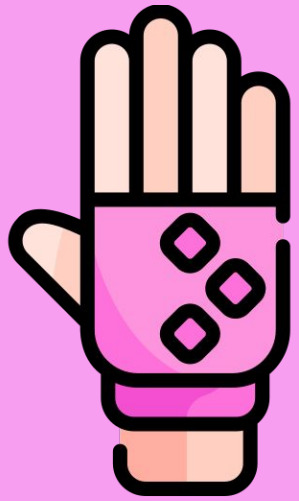


- Project N.I.H.M.S is a non- invasive wearable device that is meant to be an alternative way to measure and track daily vitals such as **heart rate, pulse oxygenation, skin temperature.**
- Transmits vitals taken to a medical professional without needing to visit them in person.
- Using a mobile application, users would be able to view/obtain current vitals, past vitals, as well as be able to immediately call emergency services if there were any abnormal readings present.
- Users would be able to export their results as a PDF document, which they can send to whoever they want, straight from their mobile device.

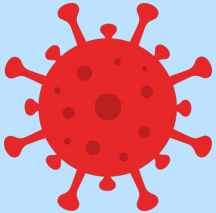
PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

Motivation



Beneficial and to be potentially used in the medical field.



To help make it easier for those who are unable to reach or check into a hospital and need their vitals checked immediately.

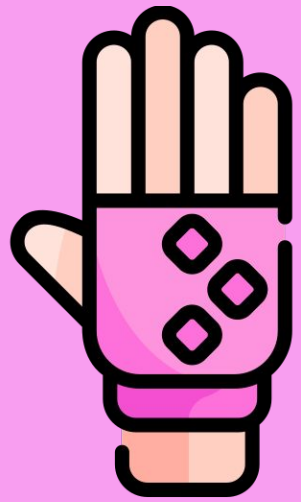
Especially in the midst of a pandemic!

Provide transparency to users on their health.

PROJECT N.I.H.M.S

SPEAKING: SCHNIEDER MAXIME

Requirements & Specifications

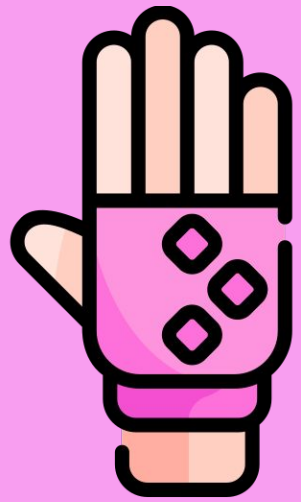


#	Requirement and Specification Description	Unit
1	The device will boot and begin connect to Wi-Fi within a specific time frame.	10 seconds
2	**Fast data transfer to allow for a more continuous view of vitals shown on the database, time taken for each reading should be less than the time listed.**	**20 seconds**
3	Overall weight of device should be less than the amount listed in order to allow users to not struggle with the device while in use.	2 pounds
4	Goal for overall battery life of the device.	8 hours
5	Listed is the size of hand that should be able to fit as it is also known to be the size of the hand of the average user, proving the wearability of the device.	7.6 inches
6	Time to teach users on how to use the product and application are less than the time mentioned.	2 minutes
7	**Mobile application shows overall user results before the time listed.**	**45 seconds**
8	**Alert to call proper authorities is triggered if the product detects major irregularity in data within specified time period.**	**60 seconds**

PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

Constraints & Standards



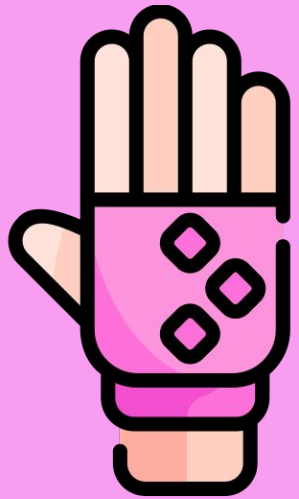
Constraints

- Time
  - 2 semesters:
    - 1 for research, 1 for development and testing
- Economic
  - <$300 for overall project cost
- Manufacturability
  - Lightweight, accurate, durable

Standards

- Wireless Communication
  - IEEE 802.15.1
- Dart programming language
  - ECMA-408

HARDWARE

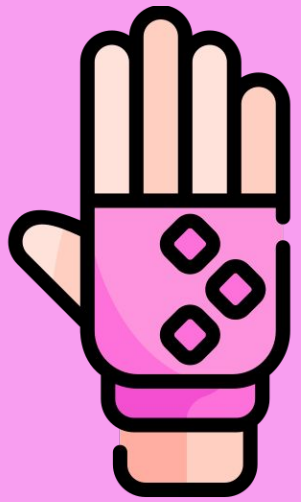


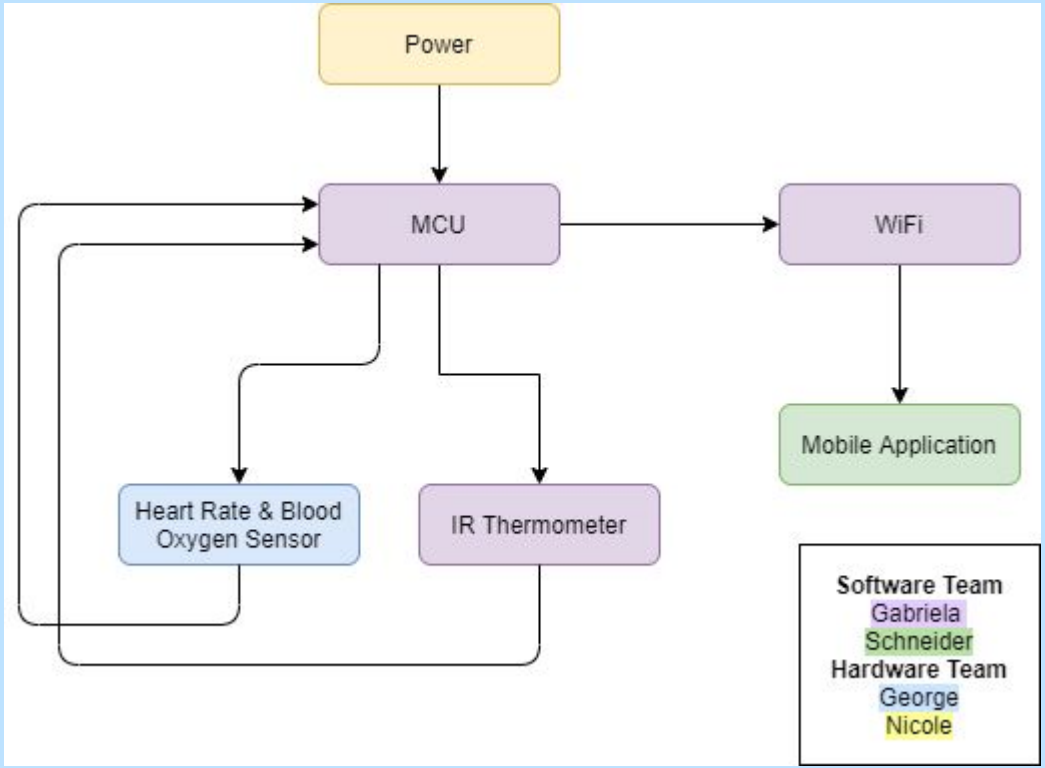
SPEAKING: GEORGE RUIZ

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

Block Diagram
(Hardware)





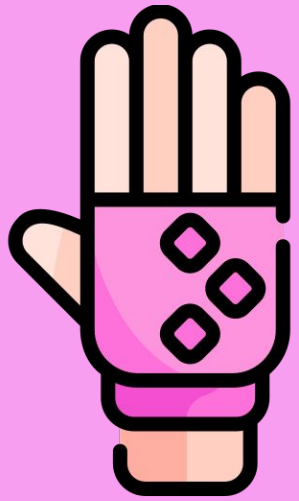
PROJECT N.I.H.M.S

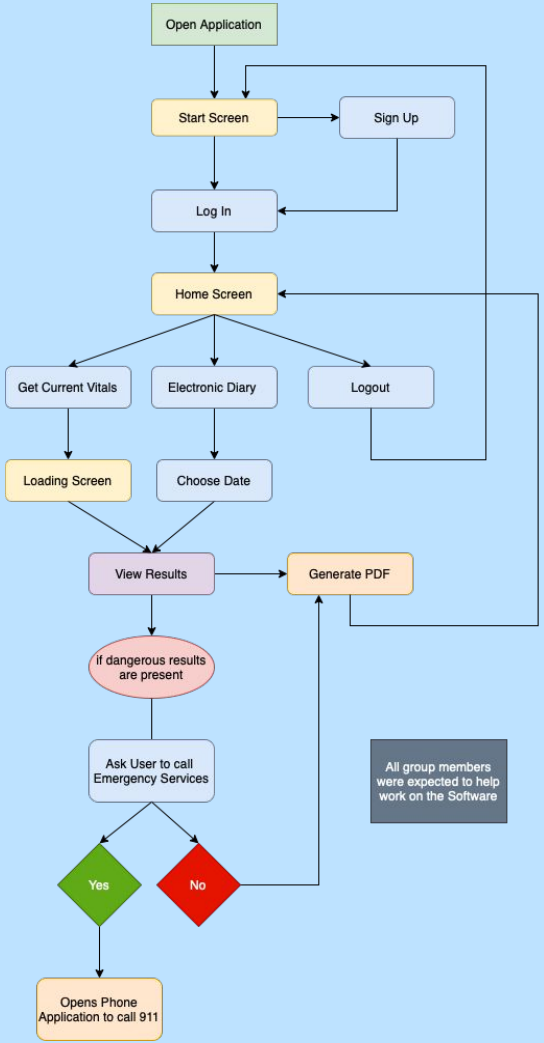
SPEAKING: SCHNIEDER MAXIME

Block Diagram

(Software)

aka Mobile Application



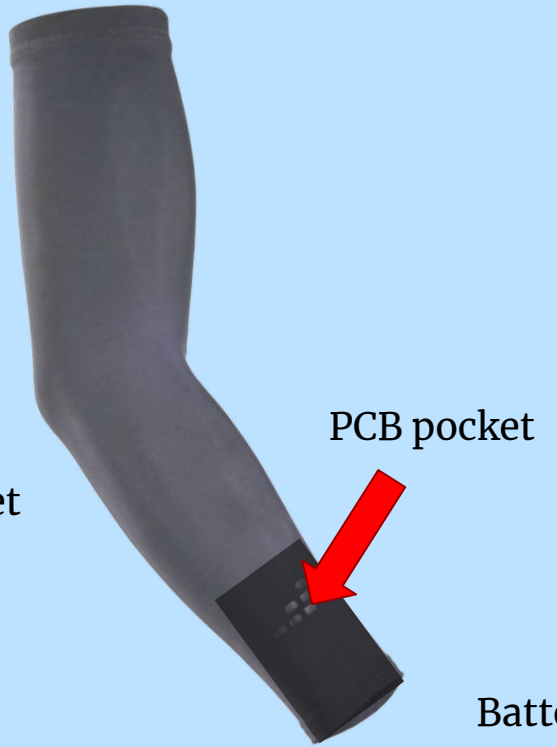


Glove

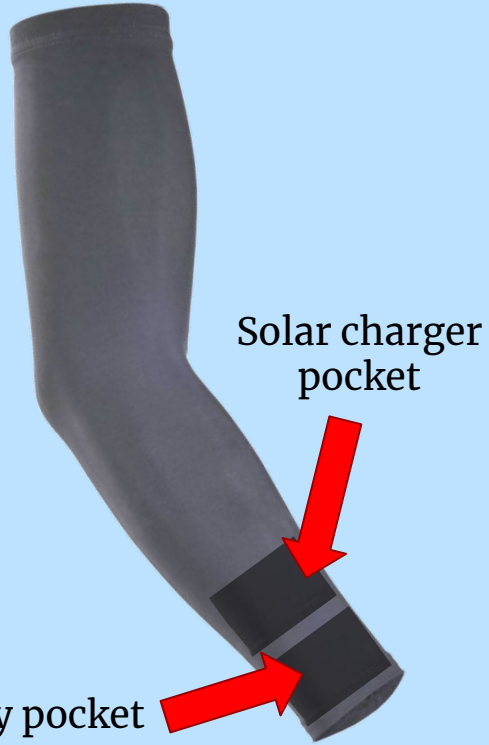
PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

Top View



Bottom View



Solar Cell Principles

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

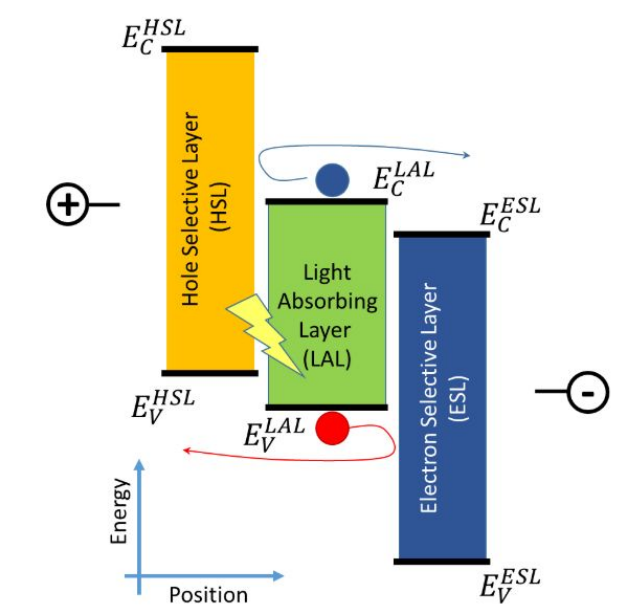


Fig. 4. Schematic diagram of key elements for solar cells. EC and EV represent the conduction and valence bands of the layers

Any technology designed to convert light energy into electrical energy must fulfill two requirements:

- Be able to absorb photons and generate electron-hole pairs in the conduction and valence bands
- Electrons and holes must be sent to their selective contact

Consists of three layers:

- a hole-selective layer
- a light absorbing layer
- an electron-selective layer

Solar Panel Comparisons

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

Specs	Amorton (AM-5412CAR)	SunPower Maxeon Gen III Je3A	IXOLAR (SM730K12TF)	IXOLAR (SM850K12TF)
Fill Factor (%)	60	74	70	70
Solar cell efficiency (%)	8	22	25	25
Max. Peak Power (mW)	87.6	330	188.6	220.5
Size [L×W×H] (mm^3)	$33 \times 50 \times 1.8$	$52 \times 52 \times 2.9$	$33 \times 32 \times 1.5$	$38.5 \times 33 \times 1.5$
Cell type	Amorphous silicon	Monocrystalline	Monocrystalline silicon	Monocrystalline silicon
Cost (USD)	8.01	5.50	7.23	8.49

Solar Panel Final Selection

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

Fig. 5. IXOLAR series solar panel SM850K12TF by Anysolar

Solar Panel we chose:

SM850K12TF

By AnySolar

Cost: **$8.49**

- Relatively cheap
- Excellent fill factor and efficiency
- Small enough to fit on back of hand
- P_{MPP} = 221 mW
  - V_{MPP} = 6.70 V
  - I_{MPP} = 32.9 mA

Used for: Powering the device

Solar Panel Properties

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

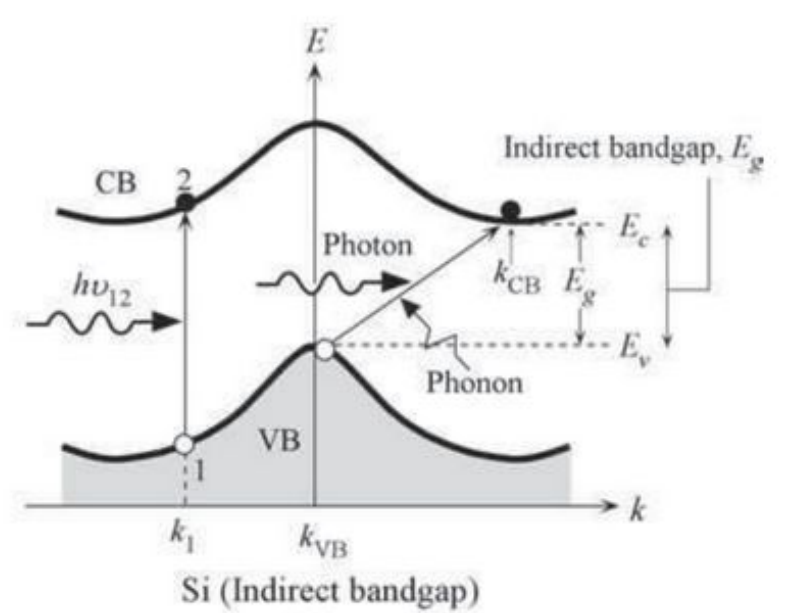


Fig. 6. Photon absorption in a silicon indirect bandgap semiconductor. VB is the valence band and CB is the conduction band

Material qualities of silicon

- **Indirect bandgap.** To absorb photons, it requires absorption and emission of lattice vibrations (phonons).
- **Band gap energy.** 1.11 eV at 300 K and 1.13 eV at 274 K
- **Spectral range.** Threshold wavelength of 1,110 nm. Range of 300 nm to 1,100 nm

Selective layer creation

- The electron selective layer has been n-doped
- The hole selective layer has been p-doped

Battery Comparisons

PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

Specs	J.Flex	ICR18650	LIPO785060
Nominal Voltage	3.8 V	3.7 V	3.7 V
Capacity	10 mAh - 5Ah	2200 mAh	2500 mAh
Charging time	~1 hour	~4 hour	~4 hour
Cost	N/A	$9.95	$14.95

Battery Final Selection

PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

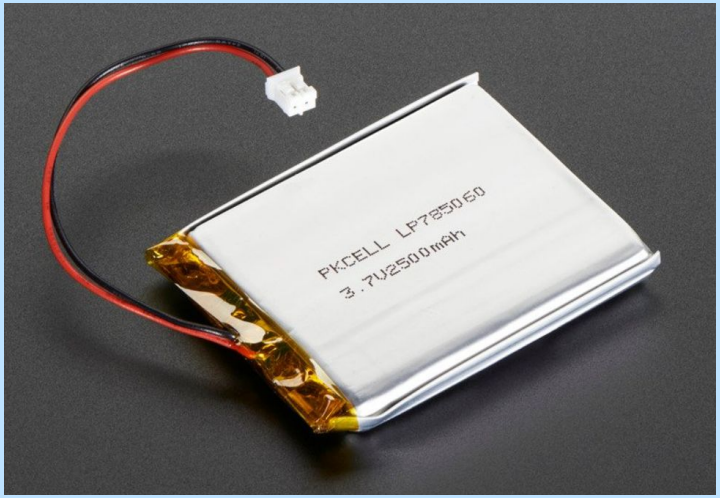


Fig. 7. Image of the LIPO785060 battery by PKCell

Battery we chose:

LIPO785060

By Pkcell

Cost: **$14.95**

- Has a slightly longer charging time to reach full capacity, about 4 hours, but is sustainable
- Has a large charge capacity of 2500 mAh
- Flat shape for better user comfort

Used for: Storing power, especially power converted from light, and powering the device

Solar Cell Charger Comparisons

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

Specs	MCP73871	BQ24074
Maximum Solar Cell Input Voltage	6 V	10 V
Type of Charger	Lithium Ion/Polymer	Lithium Ion/Polymer
Max Charge Rate	500 mA	1.5 A
Cost	$18	$10

Solar Cell Charger Final Selection

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

Fig. 8. Image of the BQ24074 Solar charger by Adafruit

Connections:

- USB type C port
- DC jack
- 2-pin JST cable

Solar Cell Charger we chose:

BQ24074

By Adafruit

Cost: **$9.95**

- Fully compliant USB charger
- Can sustain a higher input voltage from solar cells, 10 V
- High maximum charge rate of 1.5 A

Used for: Supplying energy to the battery

Microcontroller Comparisons

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO

Specs	MAX32666	STM32WB55	QN9090THN	ESP8266EX
Storage	1MB	256 KB	152 KB	16 MB
Memory	560 KB Flash	1MB Flash	640KB Flash	128 KB Flash
Speed	Up to 96 MHz	Up to 48MHz	Up to 48MHz	160 MHz
Data Bus	32 bit	32 bit	16 bit	32 bit
Cost	$176 (Digikey)	$56 (Digikey)	$40 (Mouser)	$2.75 (Digikey)

Microcontroller Final Selection

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO

Important pins:

3.3V

GND

D1 (GPIO 5) **USED FOR SCL**

D2 (GPIO 4) **USED FOR SDA**

MCU we chose:

ESP8266EX

By ExpressIF

Cost: **$2.75**

- Cheap and Effective
- Lightweight (*useful for small PCB design*)
- Easy to program, Useful Libraries Available
- Uses UART to USB Bridge to send program to Flash Memory
- Very well documented
- Programmed on a 8266 NODEMCU module

Used for: Receiving sensor data, sending sensor data to the database via Wi-Fi

Wireless Communication Module Comparisons

PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

Specs	Adafruit Flora	BLE112-A-V1	Laird Connectivity 453-00006	ESP-12E	Quectel YC0011AA
Wireless Connection	BLE - 802.15.1	BLE - 802.15.1	BLE - 802.15.1	802.11 b/g/n	BLE - 802.15.1
Memory	256 KB Flash	256 KB Flash	192KB	N/A	N/A
Interface Type(s)	UART	UART, SPI, I2C	Serial, UART, SPI, I2C	UART, I2C, SPI, I2S	I2C
Cost	$18	$13	$8	$2	$0.75

Wireless Communication Module Final Selection

PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

Fig. 10. Image of the YC0011AA Wireless Communication Module by Quectel

Important pins:

- NC
- Input
- GND

Wireless Communication Module we chose:

YC0011AA

By Quectel

Cost: **$0.75**

- Cheap
- BLE - 802.15.1
- Uses I2C Communication Protocol
- High efficiency
- Small and lightweight

Used For: Wireless application

Infrared Thermometer

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

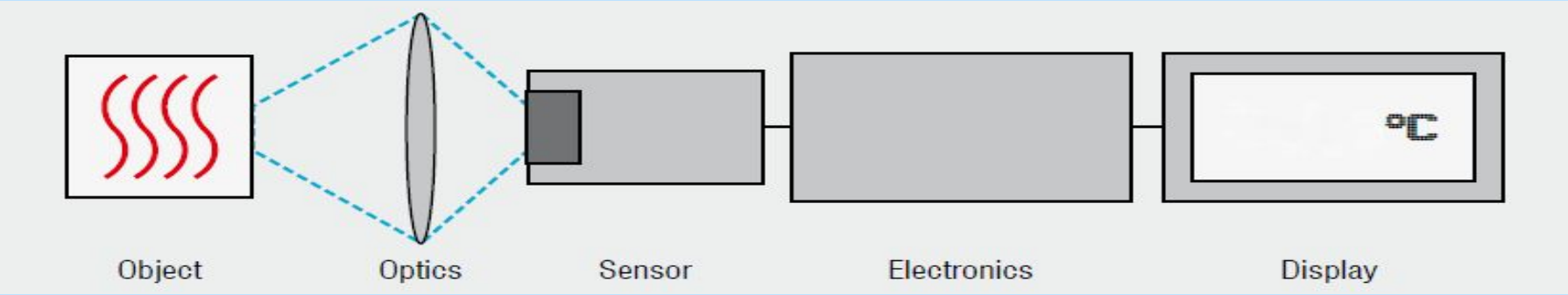


Fig. 11. Diagram of the working principle for an infrared thermometer.

- Turns infrared light into electrical signals by gathering it through a lens onto thermopiles
- A long-wave pass filter filters unneeded wavelengths
- Generally uses a signal amplifier and analog-to-digital converter

IR Thermometer Comparisons

PROJECT N.I.H.M.S

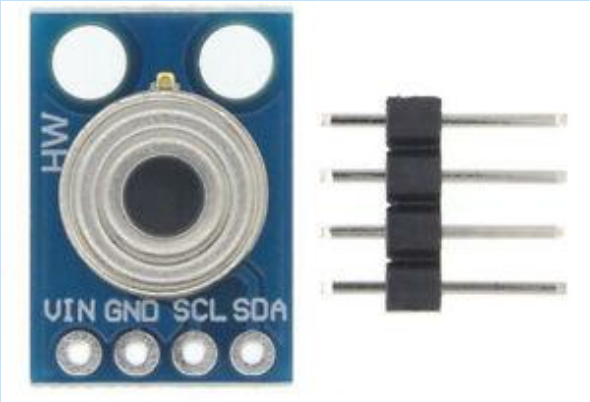
SPEAKING: GABRIELA PINEDO

Specs	MLX90615	MAX6627	MLX90632	MLX90614
Mounting Style	Through Hole	Surface Mount	Surface Mount	Through Hole
Interface Type	PWM, SMBus	SPI	I2C	I2C
Supply Voltage	2.6V-3.4V	3V-5.5V	3V-3.6V	2.6V-3.6V
Cost	$15.89	$5.46	$15.27	$12.59

IR Thermometer Final Selection

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO



IR Thermometer we chose:

MLX90614

By Melexis

Cost: **$12.59**

- Lightweight (*useful for small PCB design*)
- Accuracy of ±0.2°C in a limited temperature range around human body temperature
- Uses I2C Communication Protocol
- Compatible with ESP8266EX
- Reads ambient temperature (*room temperature*) and object temperature (*what is hovering over the sensor*)
- Wavelength pass band is from 5.5 to 14 µm

Used For: Measuring skin temperature of the user

Connections to MCU:

MLX90614 .... ESP8266EX

VIN → VCC (3.3V)
GND → GND
SCL → D1
SDA → D2

Shared I2C Bus with MAX30100

Photoplethysmography

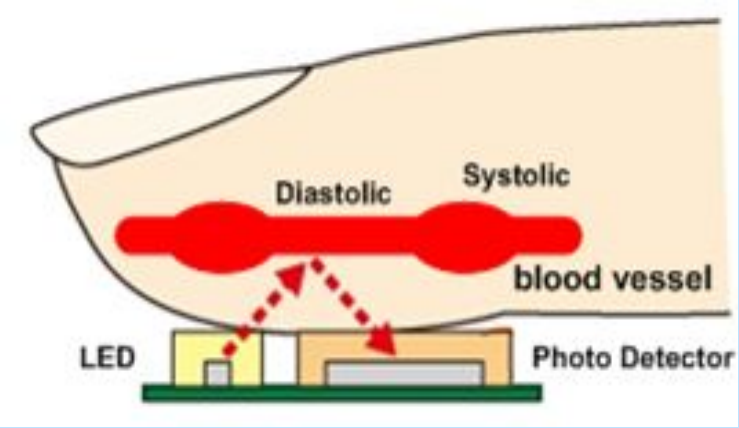


Fig. 13. Representation of how the module works and what is being measured.

The user's heart rate is measured using reflective mode photoplethysmography (PPG). The main components of the PPG are the IR LED and photodiode. The LED illuminates the skin and the photodiode detects changes in the reflected light; the intensity varies due to the change in blood volume.

PPG Sensor Comparisons

PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

Specs	RT1025	MAX86150	TIDA-01580	MAX30100
Interface Used	I2C	I2C	SPI	I2C
Voltage Supply	1.62 V - 3.3 V	1.7 V - 2 V	1.8 V - 3 V	1.8V - 3.3V
Cost	$15	$44	N/A	$11

PPG Sensor Final Selection

PROJECT N.I.H.M.S

SPEAKING: GEORGE RUIZ

PPG Sensor we chose:

MAX30100

By Maxim Integrated

Cost: **$11**

- Lightweight *(useful for small PCB design)*
- Uses I2C Communication
- Two LEDs, 660 nm and 880 nm

Used For: Measuring Blood Oxygen Levels and Heart Rate of the user.

Connections to MCU:

MAX30100 .... ESP8266EX

VIN → VCC (3.3V)
SCL → D1
SDA → D2
INT → VCC (3.3V)
GND → GND

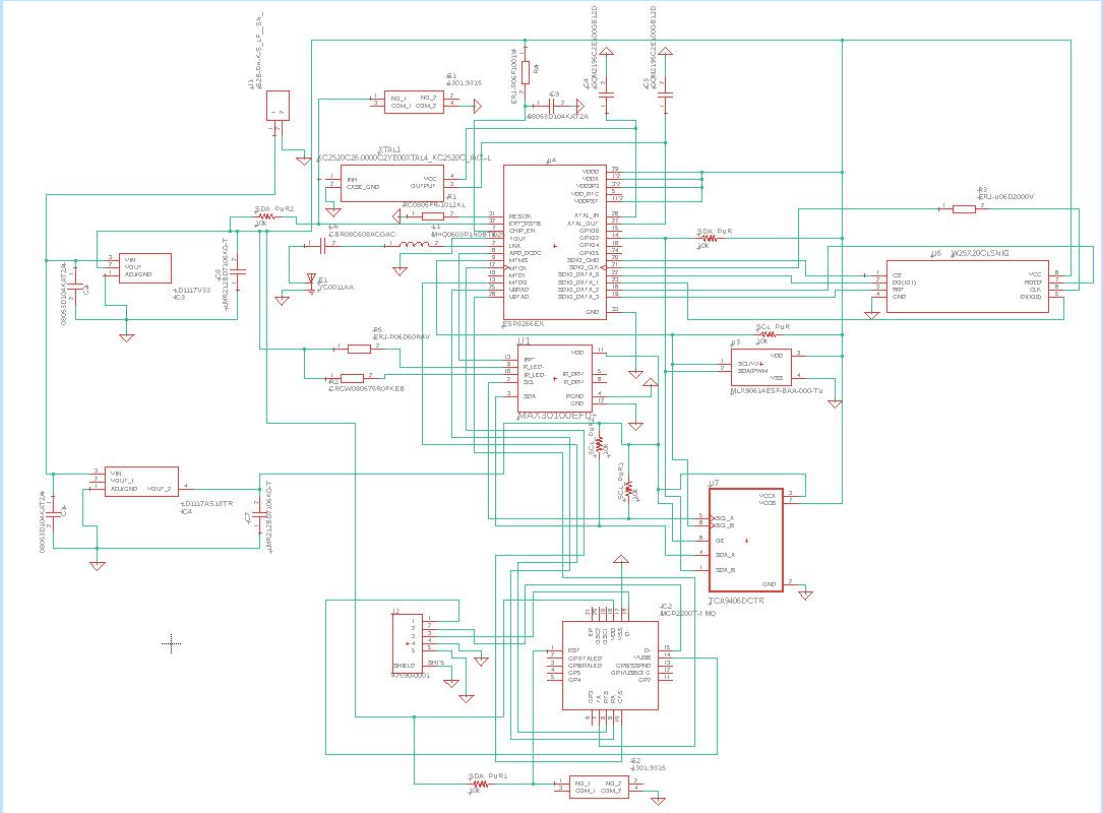
Shared I2C Bus with MLX90614

Not Connected: **IRD, RD**

PCB Design Overview – *Schematics*

PROJECT N.I.H.M.S

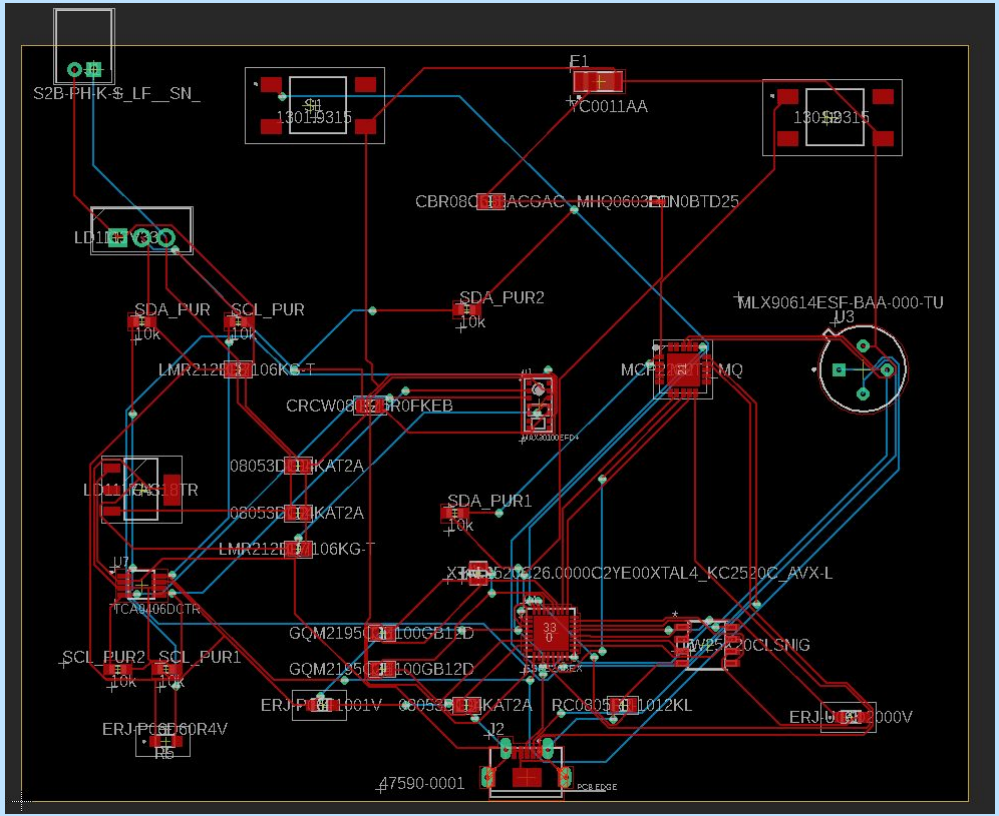
SPEAKING: GEORGE RUIZ



PCB Design Overview
– *Board Layout*

PROJECT N.I.H.M.S

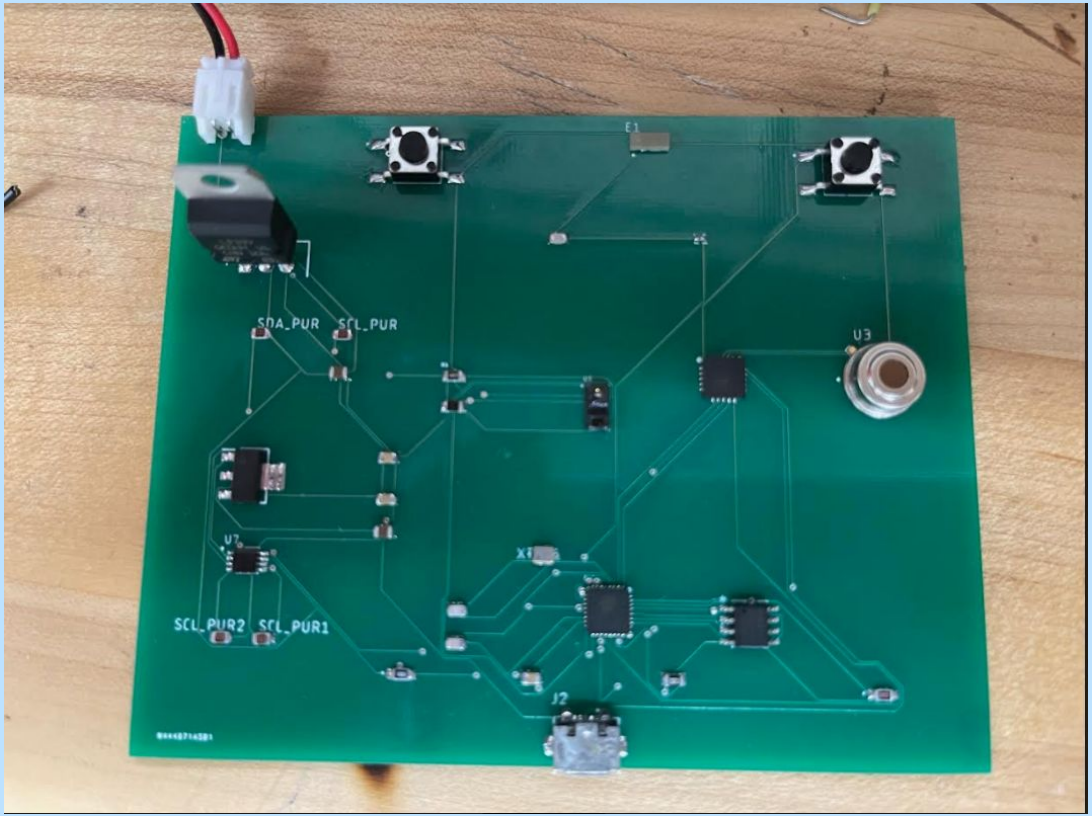
SPEAKING: GEORGE RUIZ



PCB Components

PROJECT N.I.H.M.S

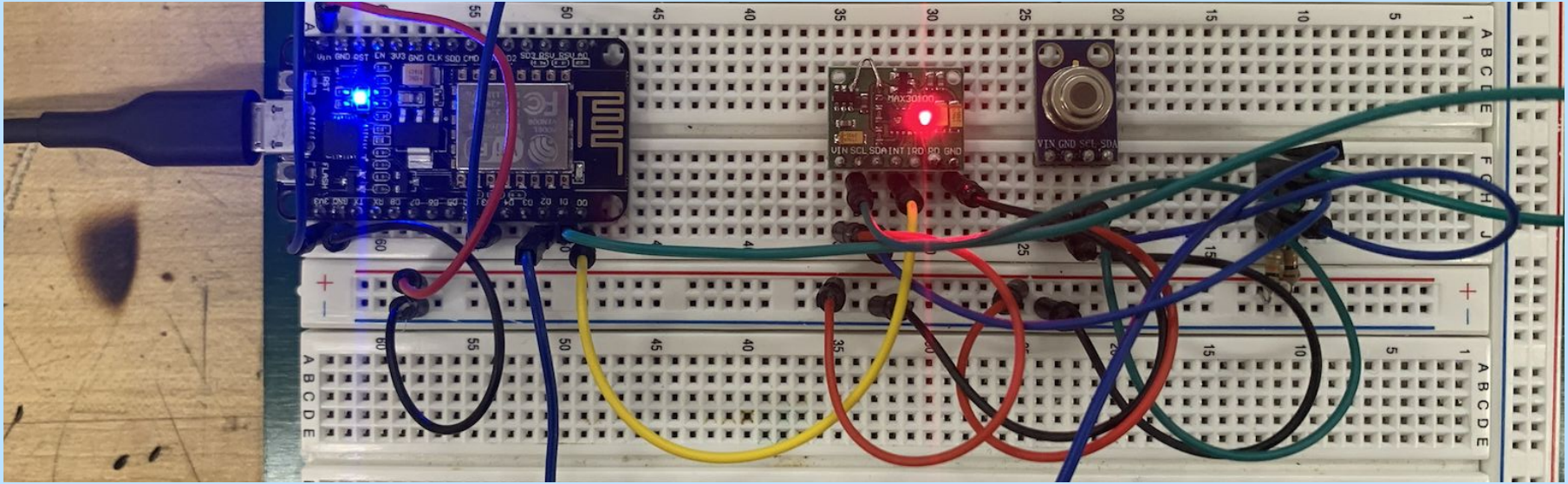
SPEAKING: GEORGE RUIZ



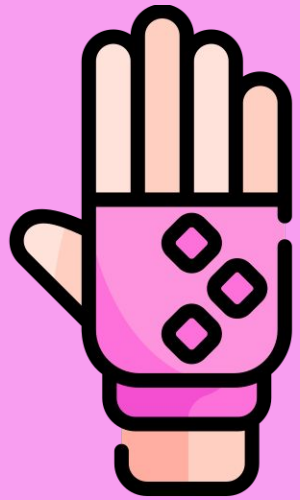
Prototype

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO



SOFTWARE



SPEAKING: GABRIELA PINEDO

Mobile App - *Development Selection*

PROJECT N.I.H.M.S

SPEAKING: SCHNIEDER MAXIME

Spec	IOS (Native)	React Native (Cross-Platform)	Flutter (Cross-Platform)
Programming Language	Swift	JavaScript	Javascript
Development	Fast	Fast	Fast
Performance	Fast	Fast	Fast
Flexibility	Limited	Open-Source	Open-Source
Testing	Limited	Moderate	Moderate

Mobile App - *Database Selection*

PROJECT N.I.H.M.S

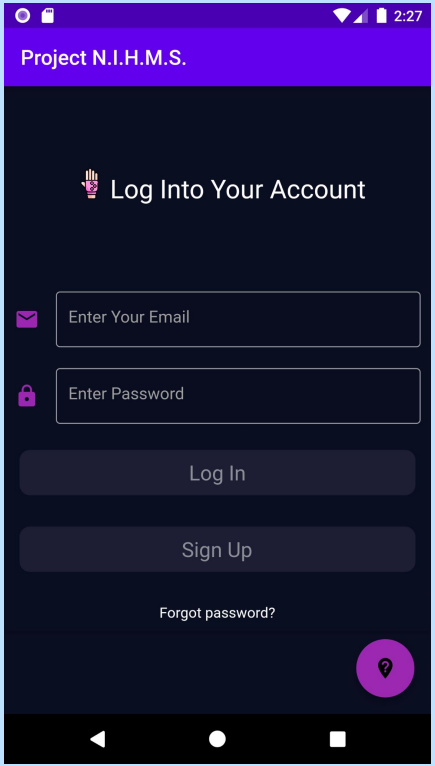
SPEAKING: SCHNIEDER MAXIME

Spec	AWS	Azure	Firebase
Cost	Free 5 GB stored/month, 15 GB served/month	Free 1 GB Disk Space Up to 10 apps	**Free Hosting Up to 1 GB 5 GB storage**
Ease of Use	Easy to learn	Requires some prior knowledge	**Easy to learn**
Performance	Medium	Fast	**Fast**
Support	Large	Large	**Moderate**
Updates and Maintenance	Limited	Moderate	**Large**

Mobile App - *User Login & Sign Up*

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO



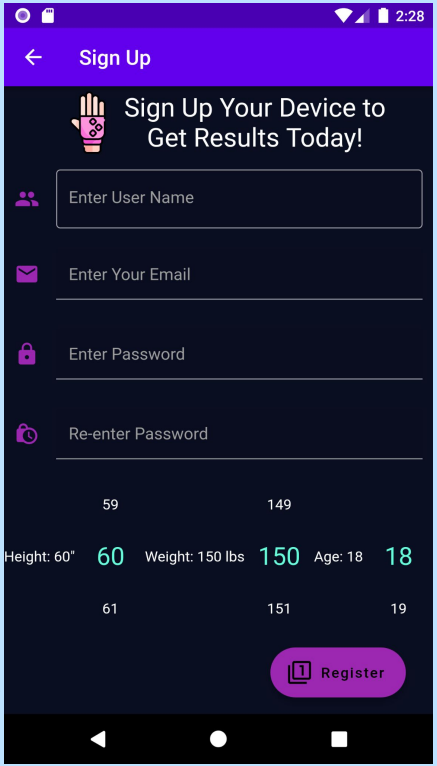
Login Screen

Purpose

To allow user to sign in to their account to utilize device and get past or present vitals.

Test Cases:

- Incorrect Username or Password
- Attempt of use of Username of Password that does not exist
- Clicking on the help button or sign up link and not getting the proper screen



Sign up Screen

Purpose

To allow user to provide their personal information in order to register with an account if they are using the device for the first time.

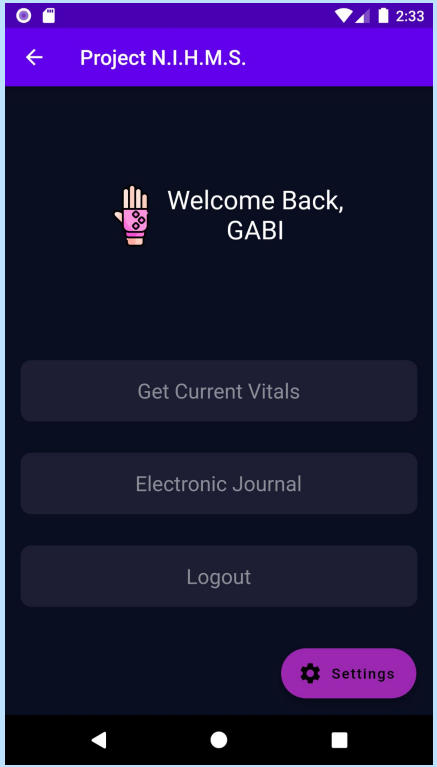
Test Cases:

- Password and reentry of password do not match
- Username has already been taken by another account
- Missing entry on one of the required boxes
- Password not meeting the required character amount

Mobile App - *Home & Connection Check*

PROJECT N.I.H.M.S

SPEAKING: SCHNIEDER MAXIME



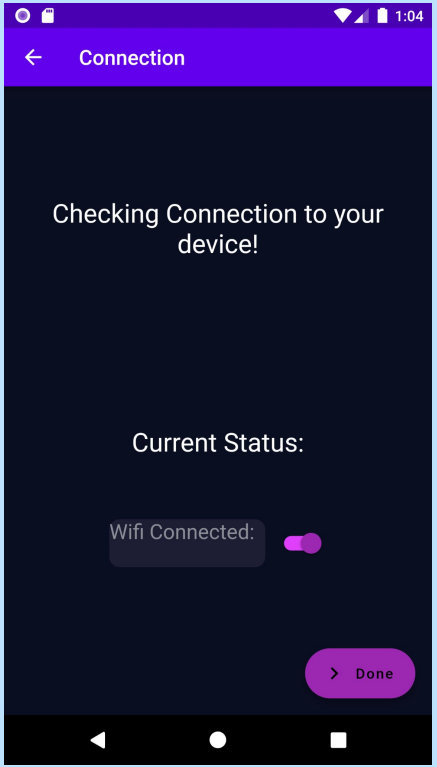
Home Screen

Purpose

To allow user to choose to check current vitals or check for past vitals

Test Cases:

- Correctly display username
- Clicking on either vitals or electronic journal routes you to the correct page
- Logout button logs the current user out and back to the login page



Connection Screen

Purpose

To allow user to check their connection between their phone and our device

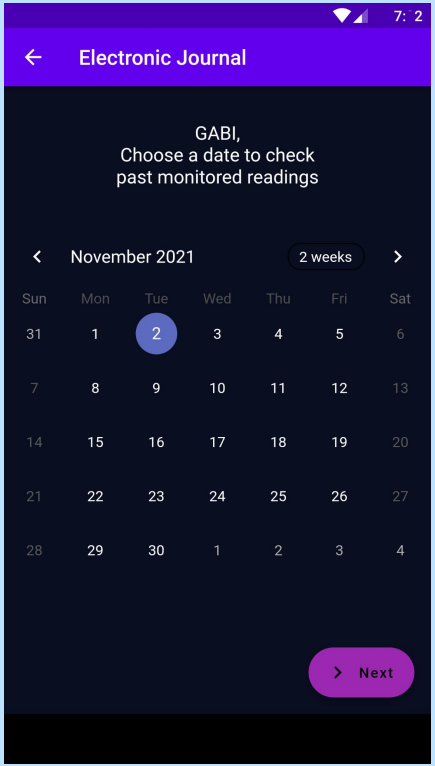
Test Cases:

- Checks if the user phone has wifi
- Checks if their bluetooth is on
- Displays our device bluetooth name

Mobile App – *Electronic Journal & Loading Screen*

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO



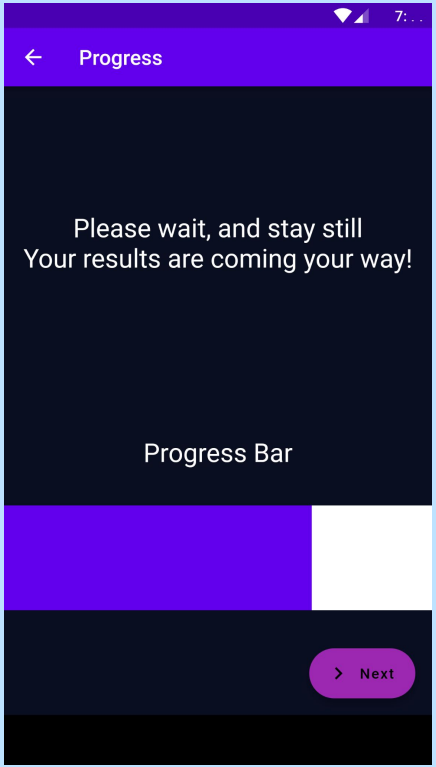
Electronic Journal Screen

Purpose

To allow user to check their past monitored vitals up to a year

Test Cases:

- Correctly display username
- Ability to check a range of selected dates
- Correctly display monitored readings



Loading Screen

Purpose

Visual aid to let the user know that the device is currently on and gathering their vitals

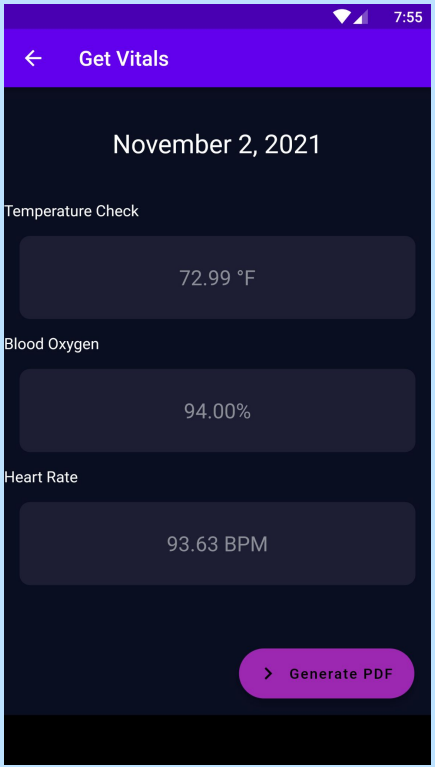
Test Cases:

- Correctly displays a progress bar that signifies how much time is left until the device has completed the vital readings

Mobile App – *Get Vitals & Generate PDF*

PROJECT N.I.H.M.S

SPEAKING: SCHNIEDER MAXIME



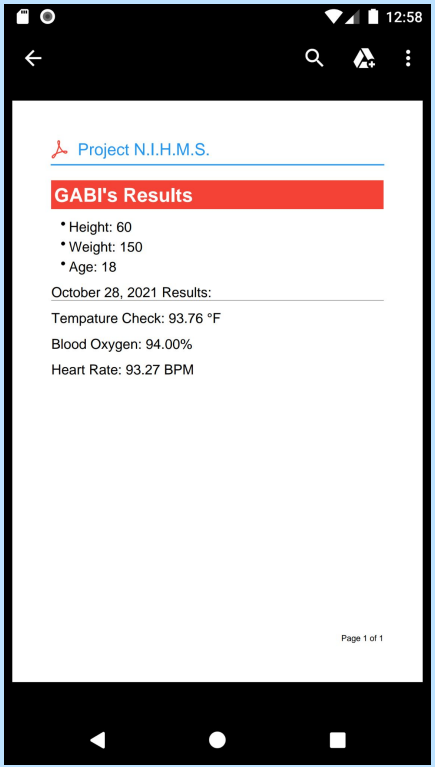
Get Vitals Screen

Purpose

To allow user to view their current vitals

Test Cases:

- Correctly display username and today's date
- Correctly displays all vitals recorded from device



PDF Screen

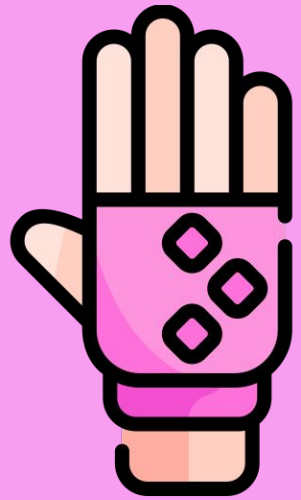
Purpose

To allow user to view a pdf version of any range of dates of vital readings

Test Cases:

- Correctly display user selected date ranges
- Correctly displays all vitals recorded from device

HARDWARE & SOFTWARE INTEGRATION

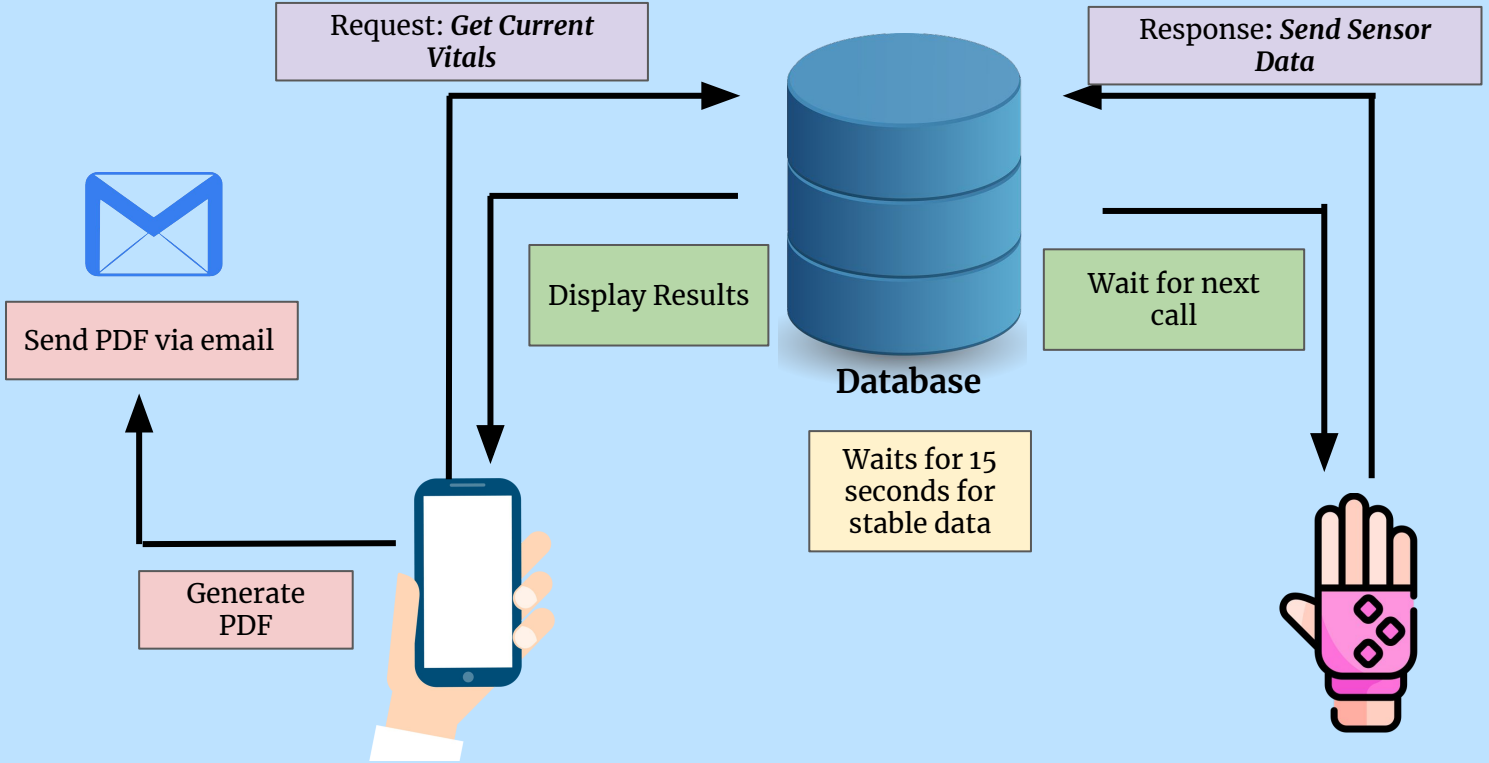


SPEAKING: GABRIELA PINEDO

Glove - Firebase - Mobile App Integration

PROJECT N.I.H.M.S

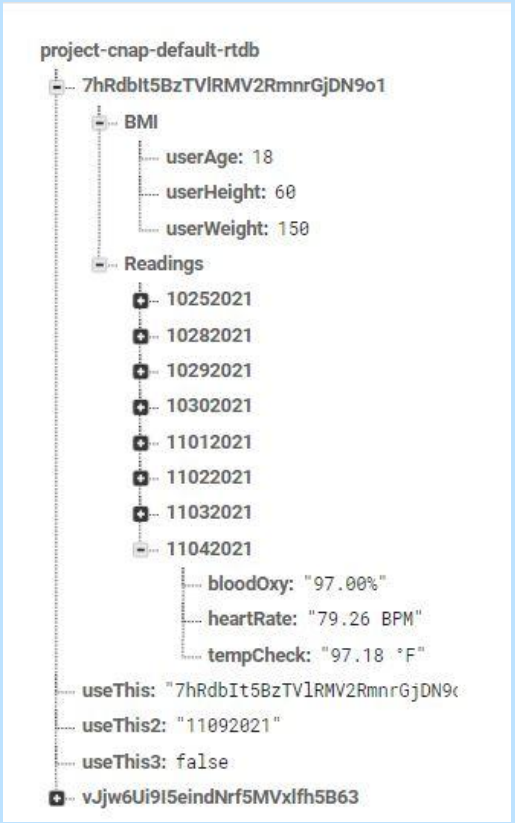
SPEAKING: GABRIELA PINEDO



Backend - Firebase

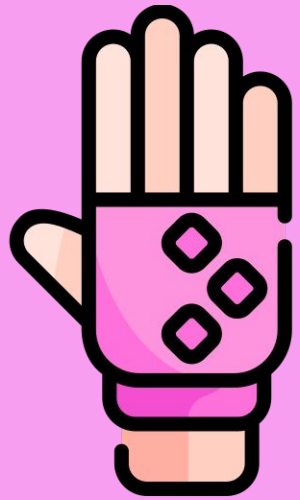
PROJECT N.I.H.M.S

SPEAKING: SCHNIEDER MAXIME



- Google's Firebase will be handling the data with real time database
- Hardware device sends the monitored vital readings to the database within the required fields
- userGetter() function retrieves the unique user ID generate by the Firebase
- updateCurrent() function updates the database to change the predetermined values of the hardware device (User ID, Current Date, True/False)

CHALLENGES



SPEAKING: GABRIELA PINEDO

Project Challenges - Hardware

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO

Challenge	Solution
Issues with PPG Sensor not turning on	Googled a solution on an edit we had to make to the development board. Allowed for it to get the proper power needed for it to work after soldering the edit.
Shipping Delays	Constantly ordered extra parts in case a part we worked with was damaged during testing. Having backup parts as a way cancel out the delays as much as possible.
Issues with USB to UART communication	A pull up resistor was added to ensure that an external reset of the device would be possible.

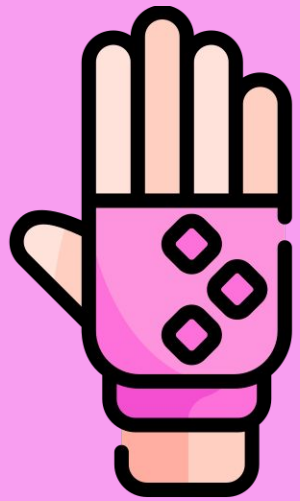
Project Challenges - Software

PROJECT N.I.H.M.S

SPEAKING: SCHNIEDER MAXIME

Challenge	Solution
Application Emulator	Used Android Studio as main sources of emulation
Implementing APIs between front end and back end	Used Google Firebase documentation to understand how to full use realtime database and its features
Design and Feature Priority	Identified the most critical features outlined in the requirements and implemented them
Debugging Errors	Used Google and friends
Creating and implementing unique user ID upon sign up	Used Google Firebase documentation in order to implement a different approach of adding new user Firebase ability of creating unique user ID values

PROJECT COST & RESPONSIBILITIES



SPEAKING: NICOLE FOSSENIER

Project Cost

PROJECT N.I.H.M.S

SPEAKING: NICOLE FOSSENIER

Item Description	Manufacturer	Part No.	Quantities	Unit Cost	Total Cost
IR Thermometer	Melexis	MLX90614	6	$12.59	$75.54
Solar Panel	AnySolar	SM850K12TF	1	$22.45	$22.45
PCB	JLCPCB	-	1	$20.00	$20.00
Wifi Antenna	Mouser	Quectel YC0011AA	1	$0.75	$0.75
PPG Sensor	Maxim Integrated	MAX30100	6	$11.00	$66.00
Microcontroller	Espressif	ESP8266EX	3	$2.75	$8.25
Fingerless Glove	Amazon	-	2	$12.00	$24.00
Arm Sleeve	BCG	158851	1	$21.29	$21.29
Solar Cell Charger	Adafruit	BQ24074	1	$9.95	$9.95
Battery	Pkcell	LIPO785060	1	$14.95	$14.95
Total					$263.18

Project Responsibilities

PROJECT N.I.H.M.S

SPEAKING: GABRIELA PINEDO

Work Distribution							
Group Member	**PCB**	**MCU**	**Wi-Fi**	**Power**	**IR Thermometer**	**PPG Sensor**	**Mobile App**
George	Primary			Secondary		Secondary	
Nicole	Secondary			Primary		Primary	
Gabriela		Primary	Primary		Primary		Secondary
Schneider		Secondary	Secondary		Secondary		Primary

SPEAKING: GABRIELA PINEDO

Thanks for watching!