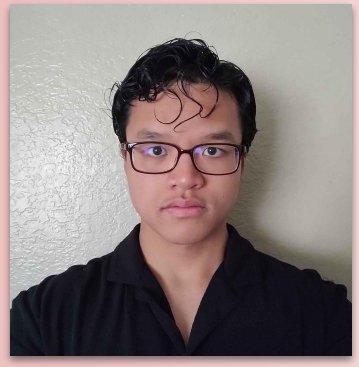
EASE : Notifying Feminine Hygiene Pad

Senior Design Group 29

The Team



Alexander Nguyen

Electrical Engineer

Matthew Poole

Electrical Engineer

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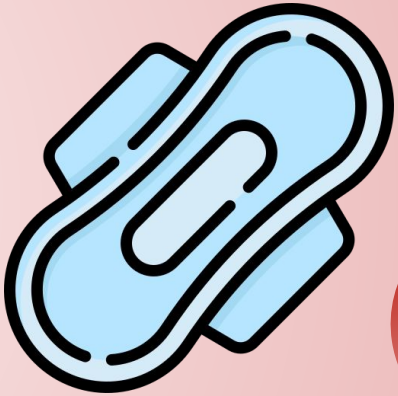
Motivation and Background

- Some menstrual cycles can be unpredictable which makes it difficult to determine
  - **When** to replace a fully used hygiene product
  - **How often** to replace such products
- Can lead to leakage
  - Embarrassment
  - Inconvenience
  - Messy
  - Ruins clothing
- Presented to us by **Gabriela Mercado** , a finance student at the University of Central Florida
  - Developed the concept for this project when she was 16
  - Resulted from having multiple leakages herself, leading to embarrassment and stained clothing
  - Saw the lack of products currently on the market that addressed these problems
- Our team is motivated to positively impact and directly improve the daily lives of everyday people through the development of this product

Goals and Objectives

- **Basic Goals**
  - Accurately detect when the user's menstrual product is at or nearing capacity with an accuracy of 75% or higher.
  - Reliably sends data between the sensor and alert system.
  - Comfortable and discrete form factor.
- **Advanced Goals**
  - Fully reusable sensor.
  - Can communicate between both Android and IOS devices.
  - Provides current sensor readouts and updates at the users request.
- **Stretch Goals**
  - Additional health sensors such as pH level, blood iron levels, or any other useful data that can be effectively measured through the blood.
  - Communicated with our own wearable implementation of the alert system

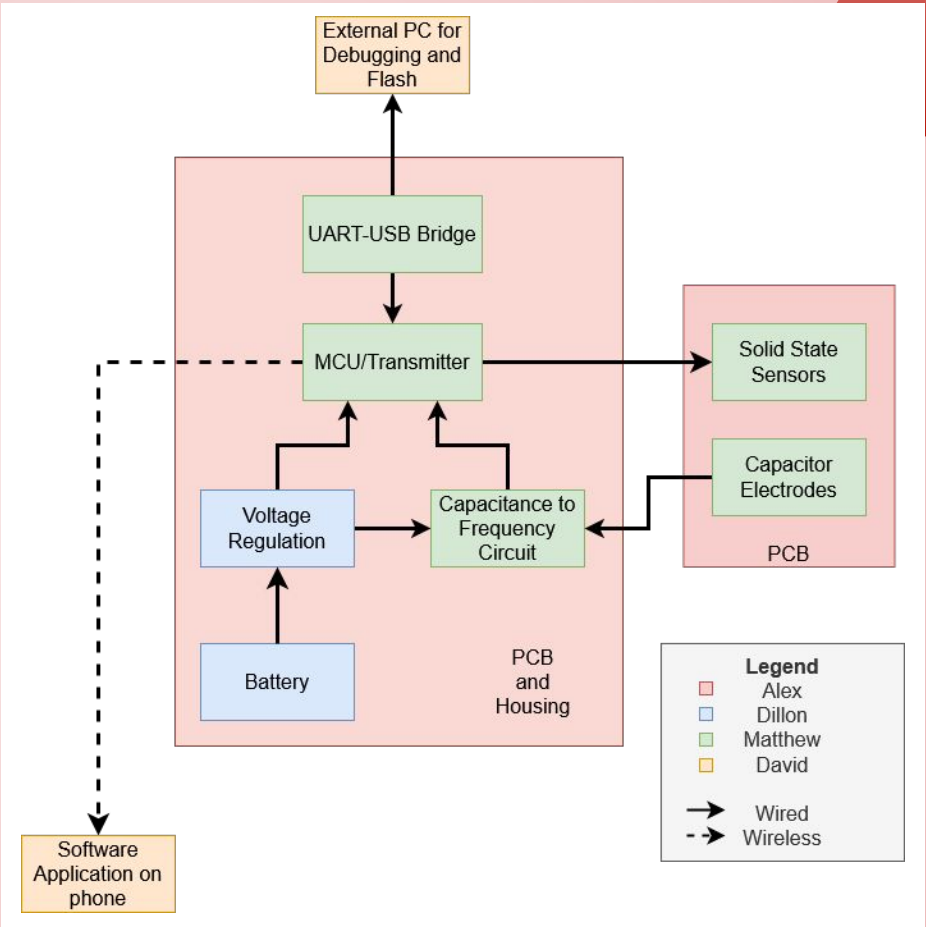


Engineering Specifications

EASE Notifying Feminine Hygiene Pad	
Quantitative Metrics	
Max. Surface Area	125 cm^3
Max. Weight	10 g
Temperature Limitations	Up to 46℃ [3]
Environmental Rating	IP 35 [4]
Volume Accuracy	1 mL
Response Time	Transmits within ~1 s of product reaching ~75% and 95% capacity
Battery Life	7 Days
Performance Reliability	Provides an accurate notification 90% of the time

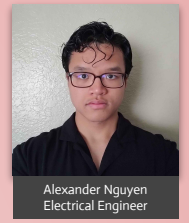
Block Diagram

- Small subsystem count for miniaturization purposes
- Separation of sensor and data processing PCBs to achieve size specifications



Hardware Selection

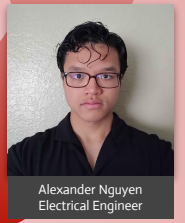
MCU Part Selection



- ESP32-WROOM-32 Module for prototyping
- Surface Mount QFN and VQFN Packaging

	TI CC2640R2L	**STM** STM32WBA54KGU6	**Infineon** CYW207
Cost	$4.17	$7.39	$6.56
Packages	VQFN, QFN	UFQFPN	QFN
Size	5.1x5.1 mm	5x5 mm	5x5 mm
Total Pin and GPIO Count	32, 15	32, 18	40, 16
Development Environment	Code Composer Studio IDE	STM32CubeIDE 3rd Party IDEs	Support Discontinued

Sensor Technology

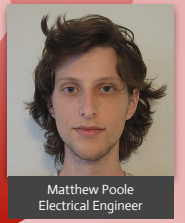


Feature	Time of Flight Sensors	Capacitance Sensors	Pressure Sensors	Float Level Sensors	Solid State Sensors
Accuracy	High in controlled environments	Less accurate, needs calibration	Versatile and reliable	Needs defined, static fluid container	Discrete data, less continuous accuracy
Simplicity	Complex setup required	Simple, easy to use unconventionally	Varies by type (e.g., piston, capacitive, piezoelectric)	Simple but needs auxiliary sensor	Very simple implementation
Environmental Dependency	Sensitive to environment	Needs dielectric constant of liquid	Can work with varied environments	Limited to specific container setups	Requires conductive liquid
Best Use Case	Controlled environments	Small, defined environments	Versatile applications	Large, defined fluid containers	Flexible applications
Drawbacks	Needs controlled environment, large	Less accurate, needs calibration	Can be large, difficult in small spaces	Not intuitive for small scale	Discrete data, susceptible to wear

Capacitance to Digital Converter (CDC)

Parameter	TI FDC1004	AD AD7746	TI FDC2214	ADI AD7156
Resolution	16-bit	24-bit	28-bit	12-bit
Range	±15 pF	±4 pF	Up to 250 pF	Automatic Calibration
Baseline	0 - 100 pF	0 - 17 pF	N/A	
Interface	I^2C	I^2C	I^2C	I^2C
Conversion Rate	100 samples/sec	45 Hz	High-Speed	Fast
Package	TSSOP-16	TSSOP-16	QFN-16	MSOP-8
Temperature Compensation	✓	✓	✓	✓

UART to USB Bridge IC



	Microchip MCP2221A	Silicon Labs CP2102	FTDI FT230X	FTDI FT260
Baud Range	300-460800 bps	300-100000 bps	300-3000000 bps	1200-12000000 bps
Voltage Range	3.0 to 5.5V	3.0 to 5.25V	3.3 to 5.25V	1.8 to 3.3V
Package	TSSOP-14	QFN-28	SSOP-16	TSSOP-28
Price	$2.53	$5.59	$2.26	$1.99

Battery Selection

	Attribute			
Type of Battery	Size	Safety	Rechargeable	Output Voltage
Lithium Ion	Varies	Prone to exploding if not handled correctly	Yes	3.7V / cell
NiMH	Varies	Generally safe	Yes	1.2V
Coin Cell	⌀ 20 mm x 3.2 mm	Safe	No	3-3.6V
Alkaline	Varies	Safe	No	1.5V
9V	48.8 mm x 26 mm x 16.9 mm	Safe	No	9V

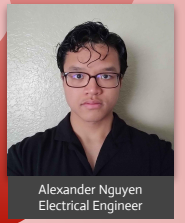
Voltage Regulator Technology

	Linear	Switching Regulators		
Specifications	**LDO**	**Buck**	**Boost**	**Buck-Boost**
Efficiency	Moderate (60-90%)	High (up to 95%)	High (up to 95%)	High (up to 95%)
Heat	Moderate	Low	Low	Low
Step-up or Step-down	Step-down	Step-down	Step-up	Both
Complexity	Simple	Complex	Complex	Complex

Voltage Regulator Part Selection

	LDO			Boost		
Voltage Regulator	**MCP1700**	**TPS 783**	**NCP 1117**	**TPS61023**	**Comidox Boost Converter**	**LTC1682-3.3**
Voltage Output	1.8, 2.5, 3.0, 3.3, 5.0V options	1.8, 1.9, 2.6, 3, 4.2V options	1.5, 1.8, 1.9, 2.0, 2.5, 2.85, 3.3, 5.0, and 12 V options	5V at 1 amp	5V at 480 mA	3.3V at 50 mA
Quiescent Current	1.6 microamps	0.5 microamps	6 mA	N/A	N/A	N/A
Dropout Voltage	178 mV at full load	175 mV at full load	1V	N/A	N/A	75-120 mV
Size	4.62 x 4.71 x 3.62 mm	8.12 mm² 2.9 x 2.8	6.5 mm x 7 mm x 1.8 mm	17.8 x 11.3 x 5.6 mm	11 x 10.5 x 7.5 mm	5.01 x 6.18 x 1.44 mm

PCB Selection



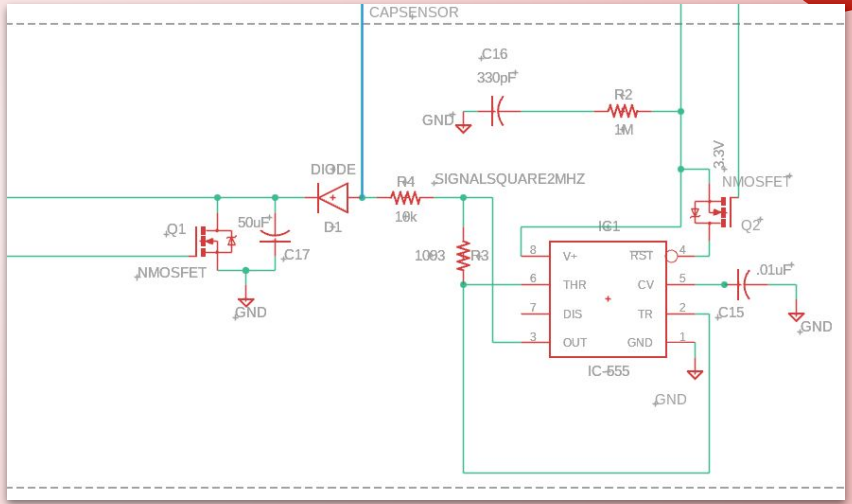
Flex PCB Capabilities
- Flexion
- Torque
- Compactness
  - Single Sided
    - 0.11 mm
  - Double Sided
    - 0.2 mm

	Circuit Complexity	Cost	Unique Attribute
Single	Low	Low	-
Double	Medium	Low	-
Rigid	-	Low	Increased stability and durability
Flex	-	Medium	Allows significant flexion
Rigid-Flex	-	High	Allows some flexion while maintaining some stability
Multilayer	High	High	High compactness and complexity
Aluminum	-	High	Thermal management
High Density Interconnect	High	High	Extremely high compactness and complexity

Sensor Design V1

Lowpass Filter Capacitive Sensor

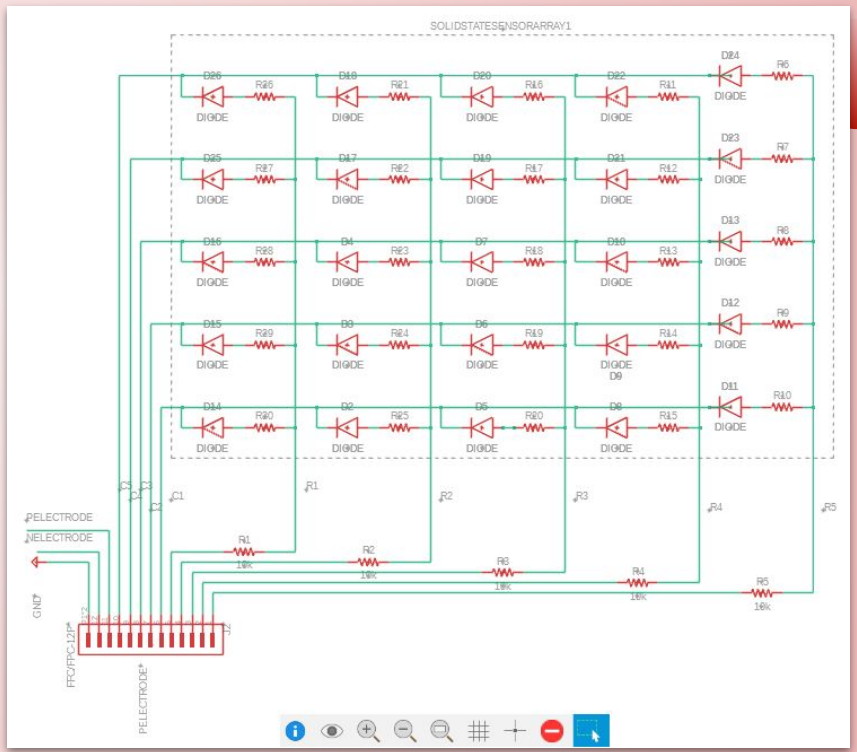
- Utilized an astable oscillator and a lowpass filter controlled by our capacitor electrode.
- The lowpass output is then captured by a peak detector and the analog signal is fed to an analog pin on the MCU.



Electrode PCB

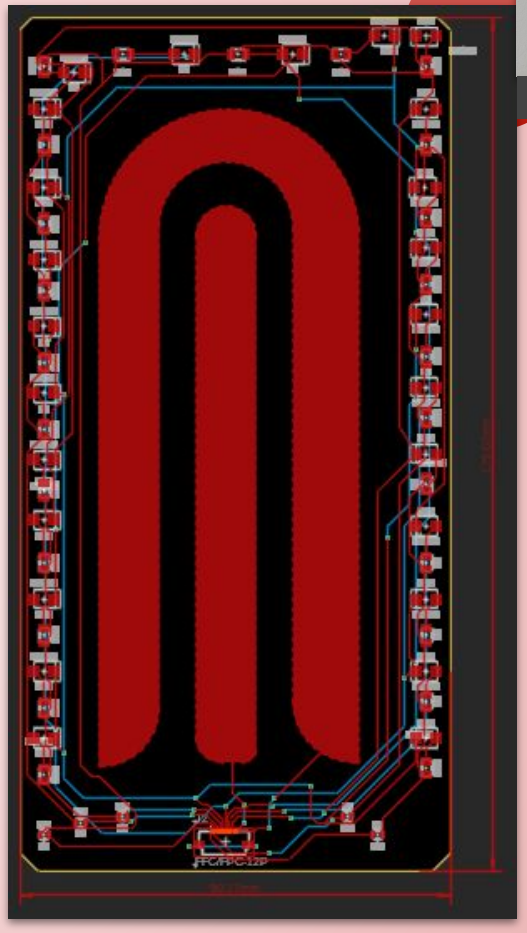
- The solid state sensors are setup in an array similar to a keyboard matrix. This way we can maximize our GPIO usage.

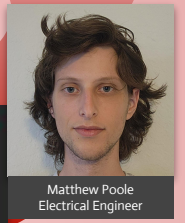
- The solid state array is accompanied by the fringing field capacitor electrodes.



Electrode PCB Layout V1

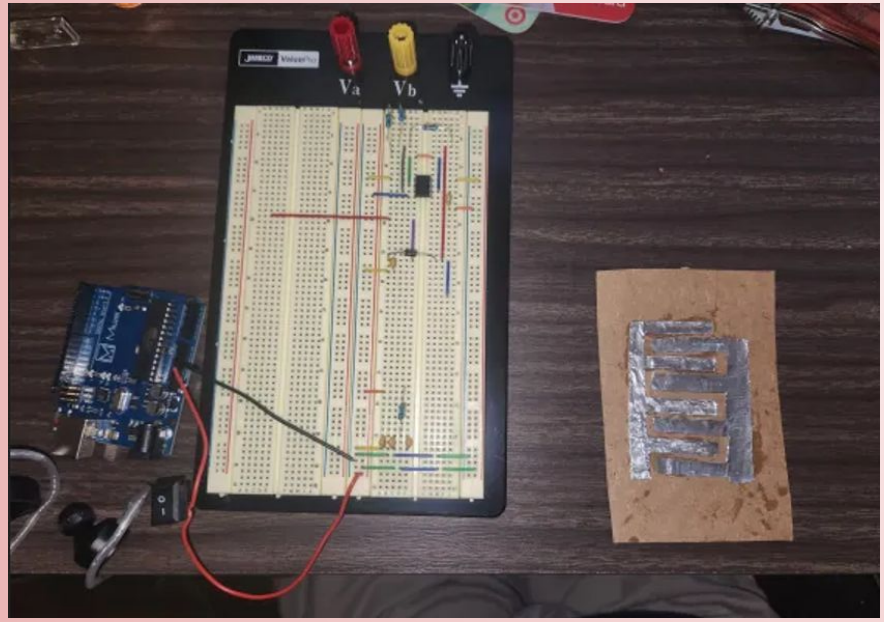
- The matrix array sits in a ring along the outside of the capacitor electrodes. This way the solid state sensors provide supplemental data to the capacitive sensor.
- The capacitor electrodes use the fringing field for contactless sensing. A copper pour polygon is used here and effort is made to keep bottom layer traces way from the electrodes to reduce noise.
- The capacitor electrodes and diodes all need to be waterproofed while the resistor pads need to stay exposed.

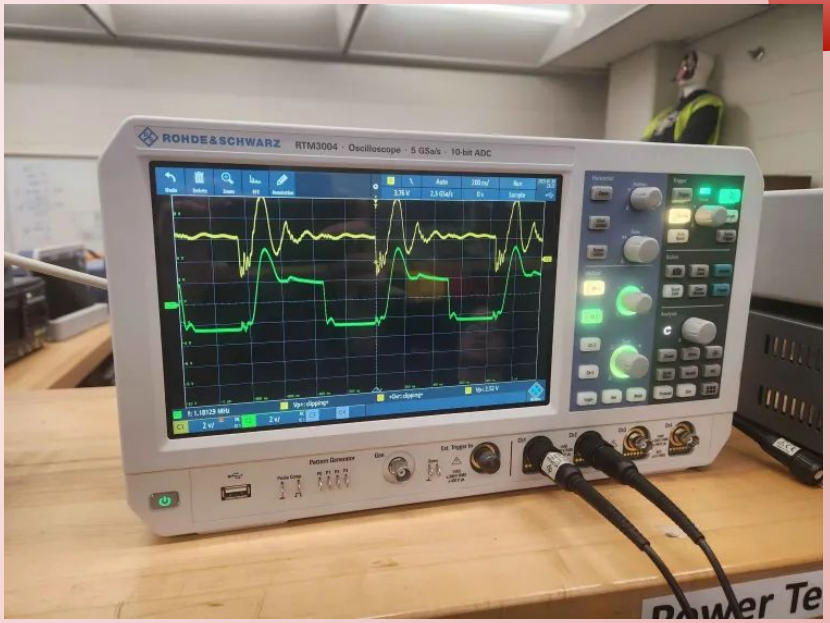


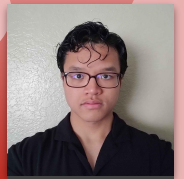


Matthew Poole
Electrical Engineer

Initial Breadboarding



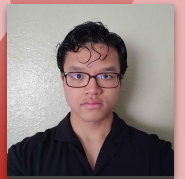


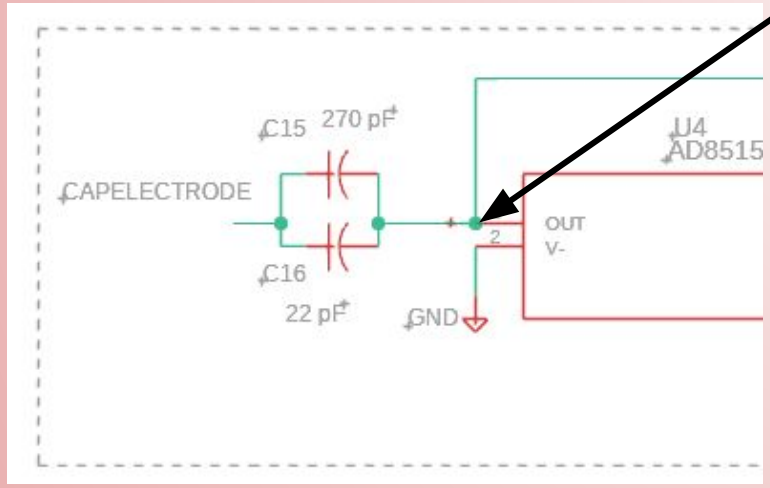


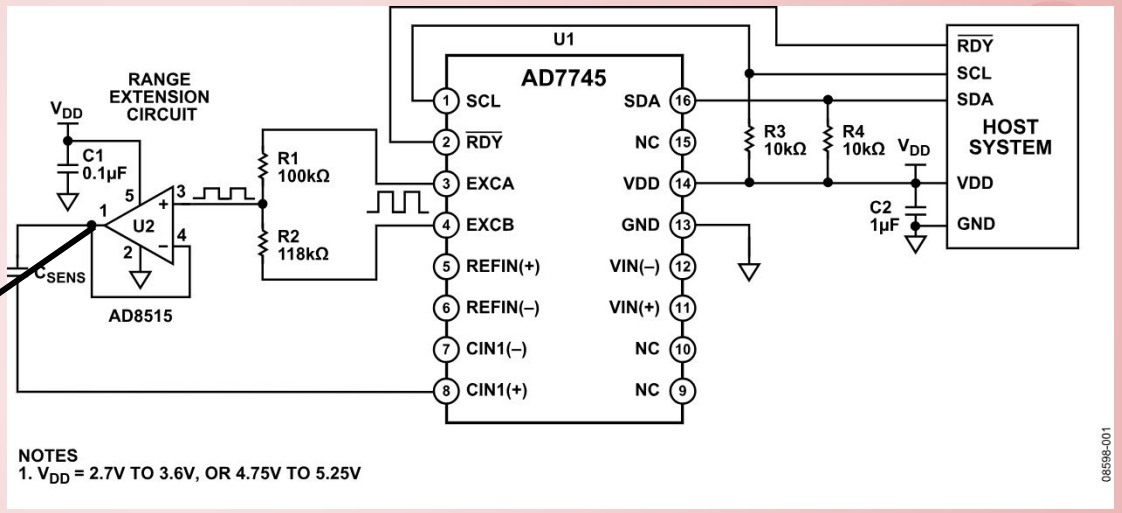
Alexander Nguyen
Electrical Engineer

Sensor Design V2

Capacitance to Digital Converter

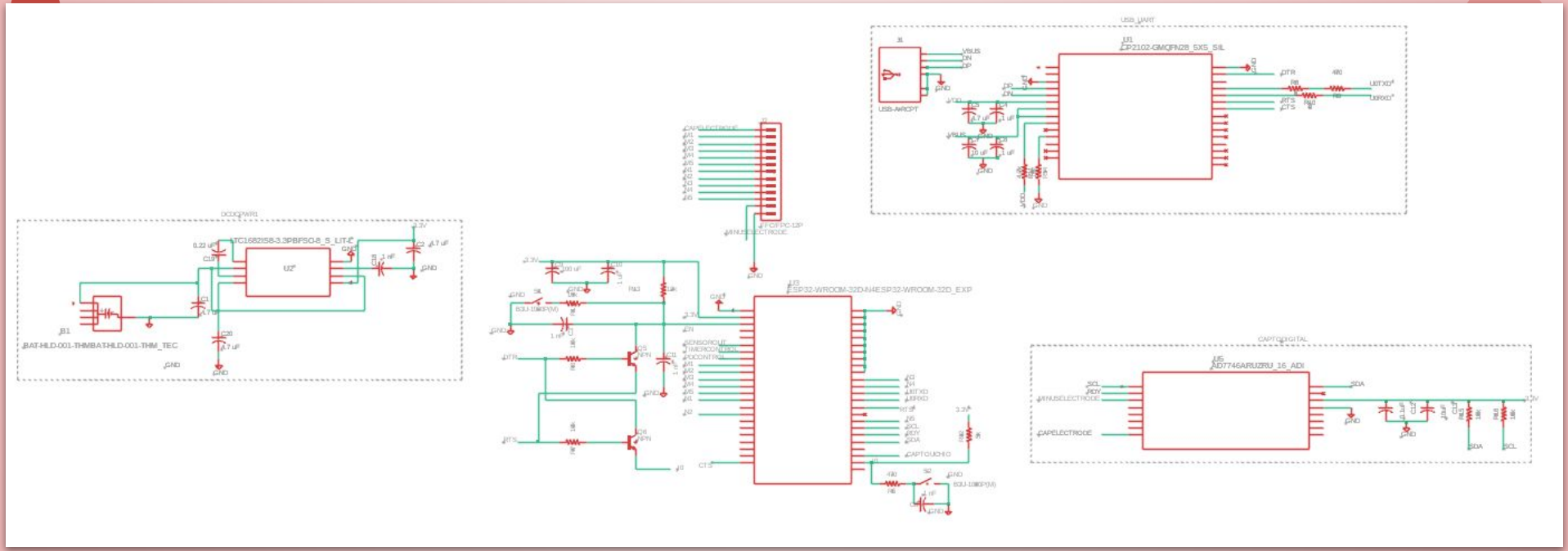






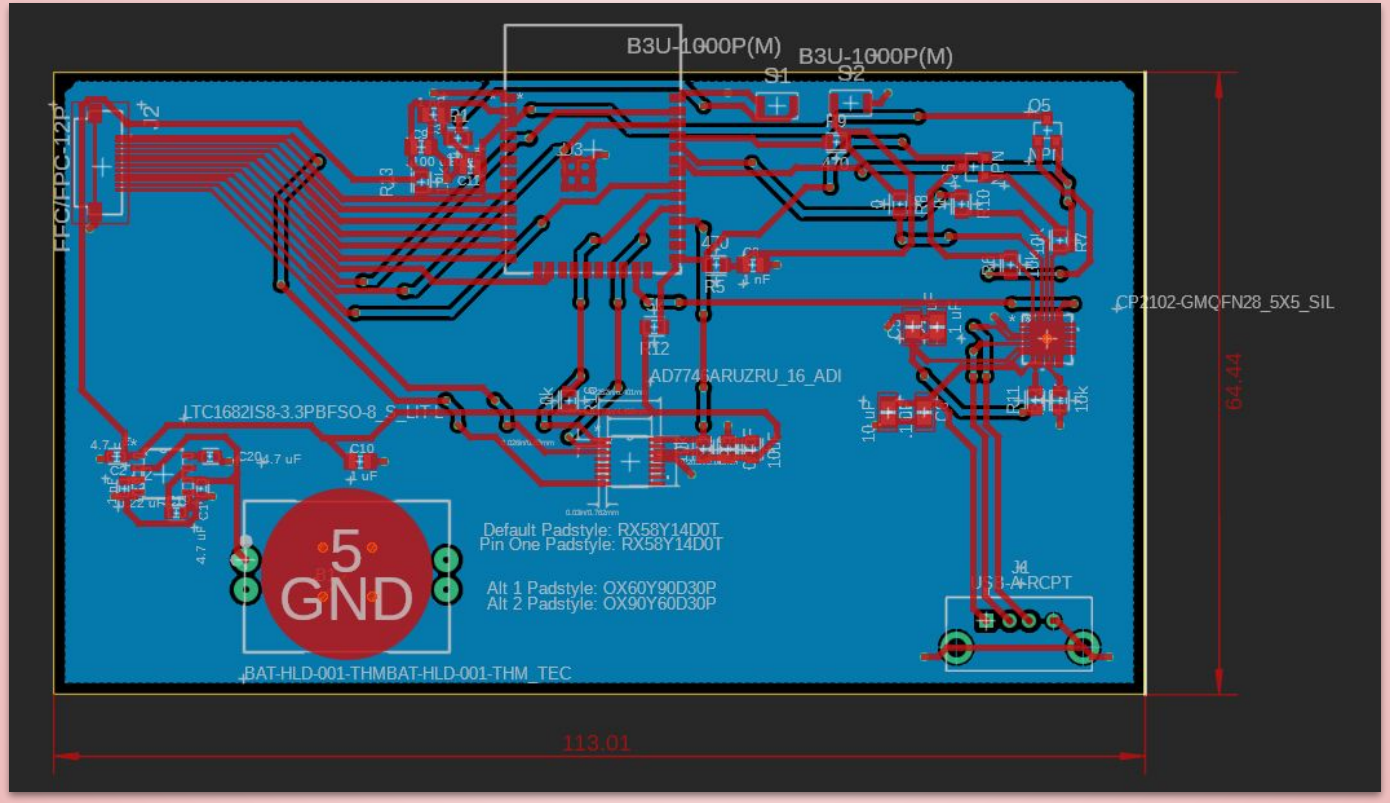
Main PCB Schematic

Matthew Poole
Electrical Engineer

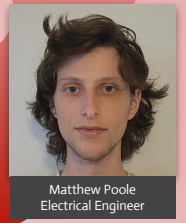


Main PCB Layout

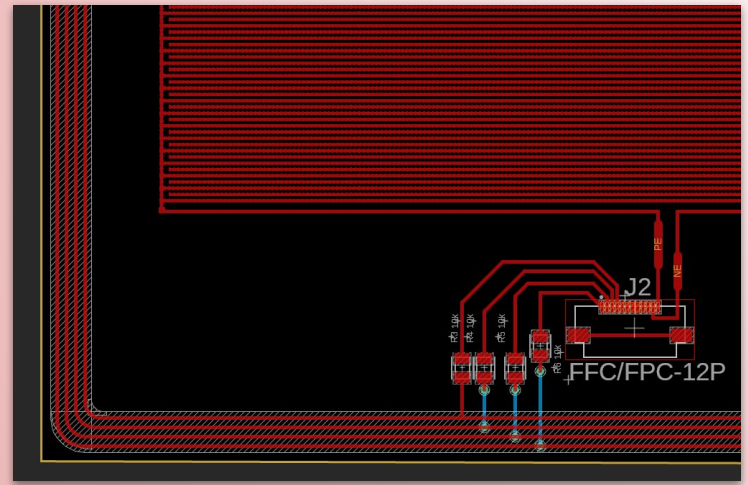
Matthew Poole
Electrical Engineer

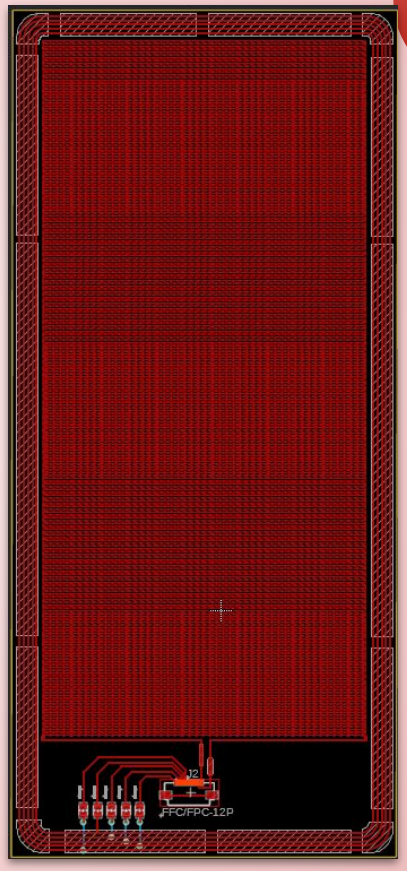


Electrode PCB layout V2



- Solid state array removed in favor of concentric rings.
- Capacitor electrode design can utilize the extra space and achieve more precision with an interdigitated design.





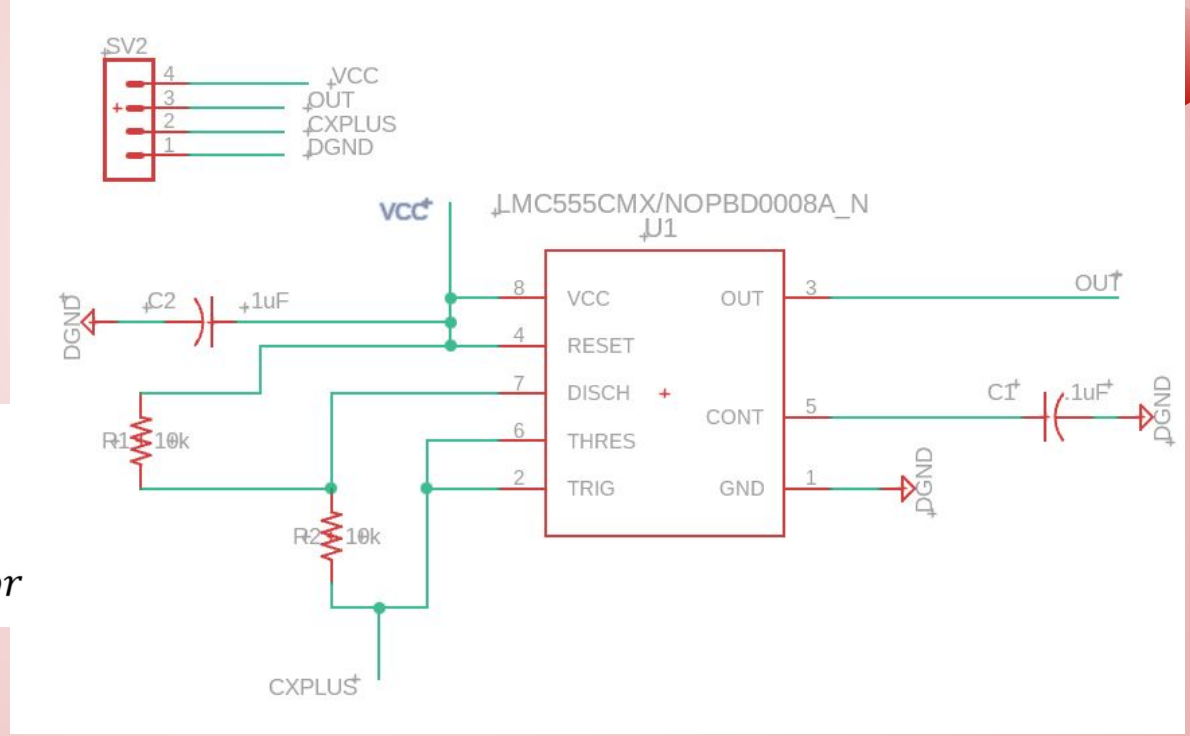
Sensor Design V3

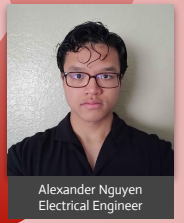
555 Timer: Frequency

- Change in capacitance results in change in frequency
- Threshold capacity determined by frequency

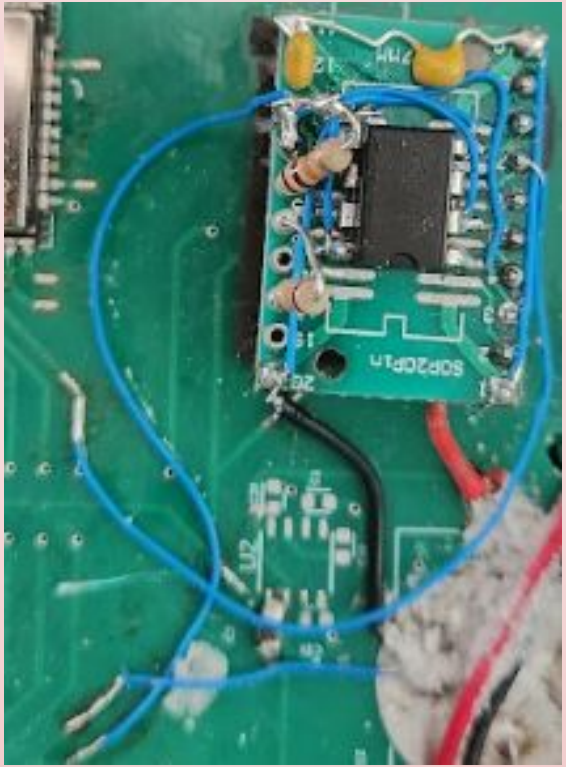
$$f_c = \frac{1}{0.639\,(Ra+2Rb)\,C}$$

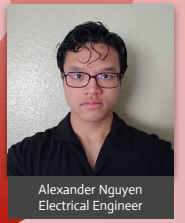
$$C = Capacitive\ Input\ of\ Sensor$$





555 Timer Breakout Board

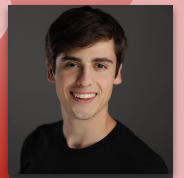




Alexander Nguyen
Electrical Engineer

Software Selection

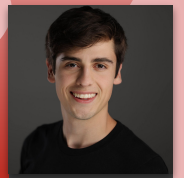
Development Environment Selection



In order to select our development environment for the ESP32, we must compare our options:

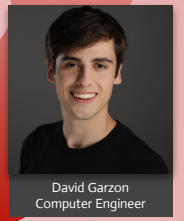
IDE	Arduino IDE	VS Code + PlatformIO Extension	Espressif IDE (Eclipse based)	Eclipse + ESP-IDF Plugin
Ease of Use	Beginner-friendly	Intermediate	Advanced	Advanced
Setup Complexity	Minimal	Moderate	High	High
Supported Languages	C, C++	C, C++, Python	C, C++	C, C++
Debugging Support	Limited	Advanced (JTAG, GDB)	Full Debugging (JTAG, OpenOCD)	Full Debugging (JTAG, OpenOCD)
Code Intellisense	Basic	Advanced	Advanced	Advanced
RTOS Support	Limited (via libraries)	Yes (ESP-IDF, FreeRTOS)	Yes (ESP-IDF, FreeRTOS)	Yes (ESP-IDF, FreeRTOS)
Integration	Basic (via board support)	Full (via PlatformIO)	Native	Native
Best For	Quick prototyping	More flexible with multi-board support and debugging	Official ESP32 IDE with deep integration of ESP-IDF	Similar to Espressif IDE but with manual setup

Development Environment Selection



In order to select our app related development environment, we must understand our needs:

- We want to build a mobile app for both iOS and Android devices
  - Ideally, our development environment should natively allow cross-platform development
- We want to be able to test our app easily and with multiple different devices
  - If local simulation is possible, then this brings a huge advantage instead of needing a local device at all times
- We want to be able to take in the BLE communication given by the ESP32 and perform actions based on that communication
- We want to be able to send a push notification to the device after certain actions are met

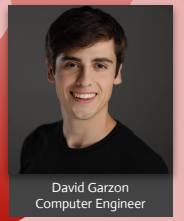


Development Environment Selection

In order to select our app related development environment, we must compare our options:

Environment	Flutter	React Native	Swift	Kotlin
Primary Language	Dart	JavaScript / TypeScript	Swift	Kotlin
Target Platforms	Android, iOS, Web, Desktop	Android, iOS, Web	iOS only	Android only
UI Framework	Flutter Widgets	React Native Components	SwiftUI / UIKit	Jetpack Compose / XML
Performance	Near-native	Good	Native	Native
Live Preview	Yes	Yes	Yes	Yes
IDE Options	VS Code, Android Studio, etc	VS Code, WebStorm	Xcode	Android Studio
Ease of Learning	Moderate	Easy (if familiar with JS)	Moderate	Moderate
Best For	Cross-platform UI, High Performance	JavaScript developers, hybrid applications	iOS-only applications	Android-only applications

Development Environment Selection

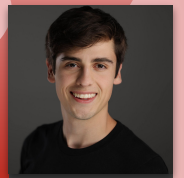


We finalized our development environment to the following choices:

- Embedded Development
  - Arduino IDE
  - C++ as our coding language

- App Development
  - Visual Studio Code as our IDE
  - Flutter framework used for cross-platform development
  - Dart as our coding language
  - iOS and Android development tested with simulator and live on actual devices

Programming Language Selection

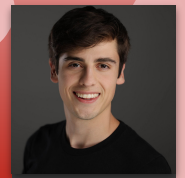


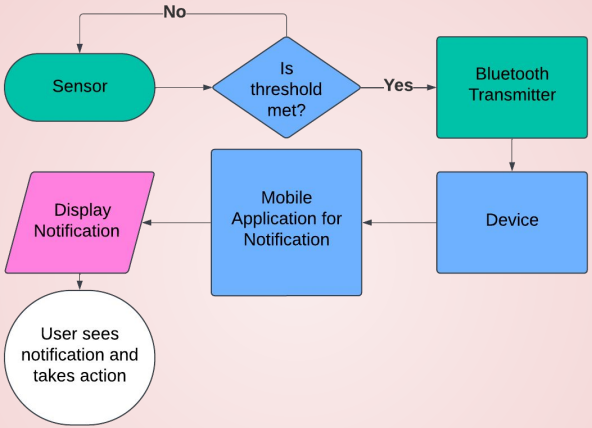
We had several programming language options to select from based on our Development Environment but the chosen programming languages are below:

- Embedded Development
  - C++ as our programming language
    - Has the most native support for Arduino IDE and most code examples are given in C++.
- App Development
  - Flutter framework
    - Chosen for cross-platform development and chosen over React Native for BLE testing simplicity
  - Dart as our programming language
    - Native supported language for Flutter development.

Software Design

System-level Flowchart

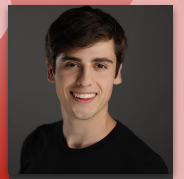


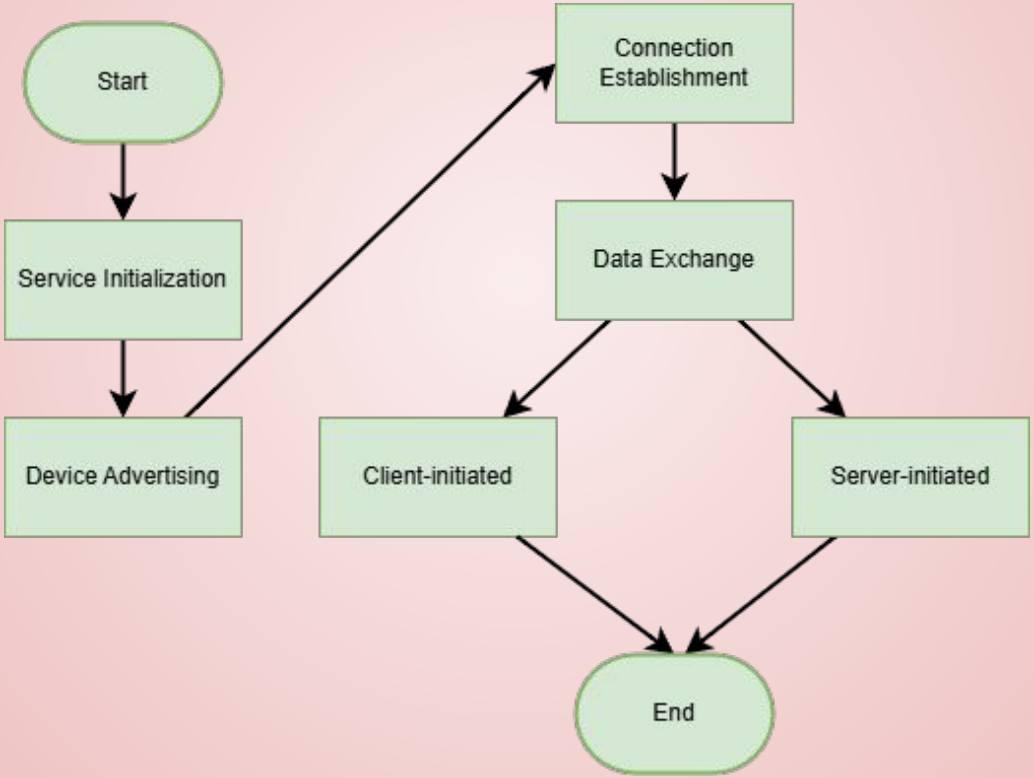


Flowchart Legend

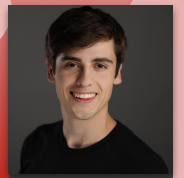
- Hardware (Alex, Dillon, Matthew)
- Backend Software (David)
- User Facing Software (David)

Bluetooth (BLE) Flowchart

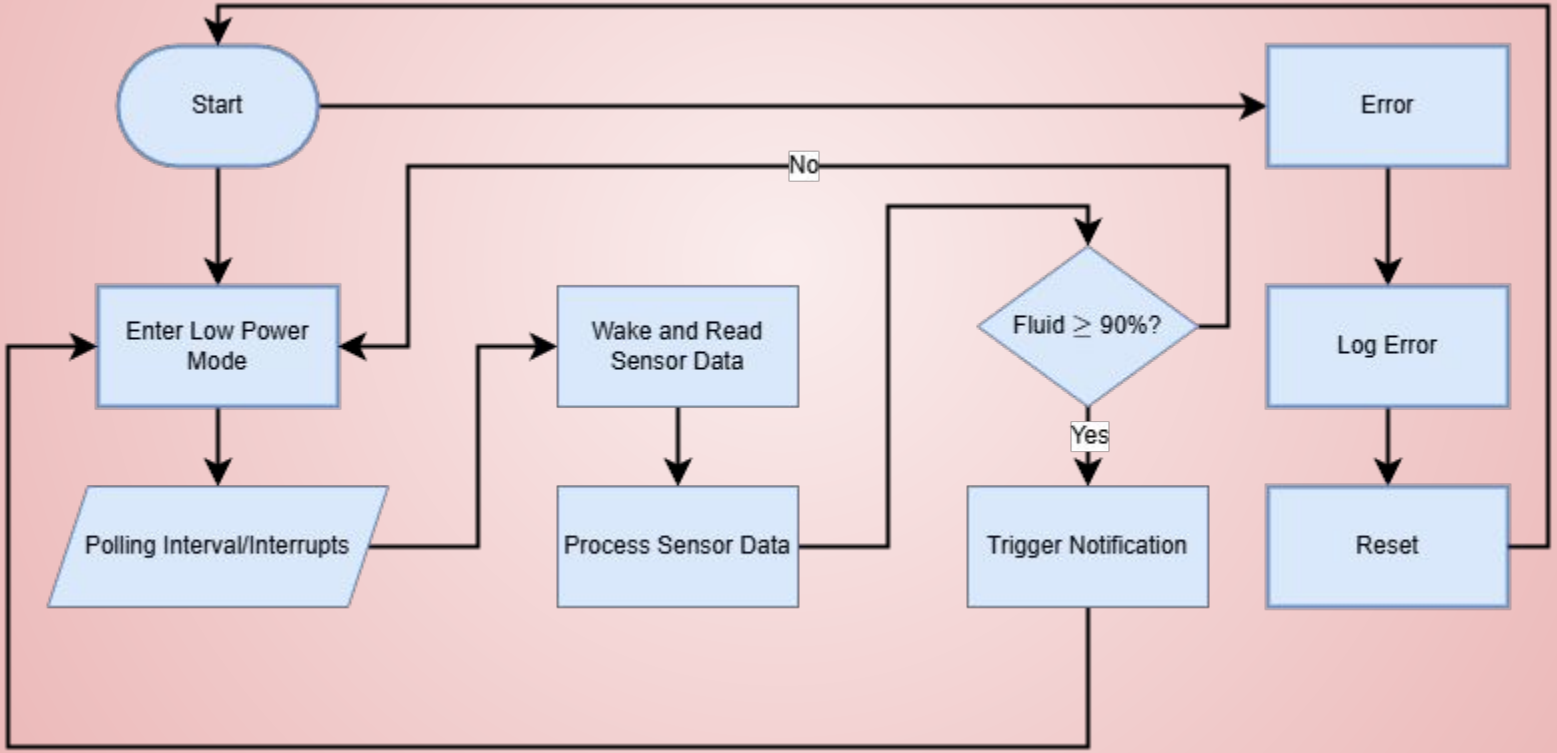




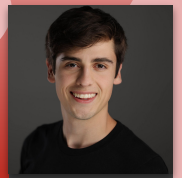
Sensor Code Flowchart



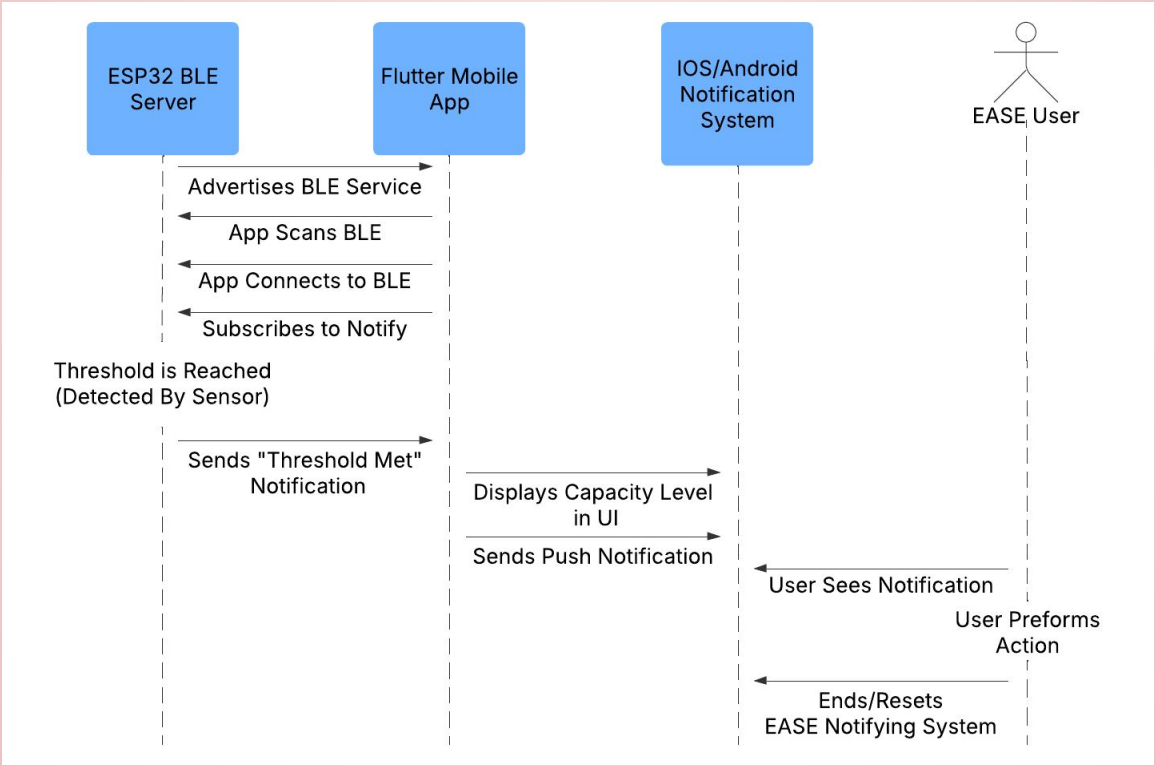
David Garzon
Computer Engineer



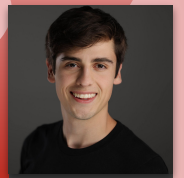
Notification Sequence Diagram

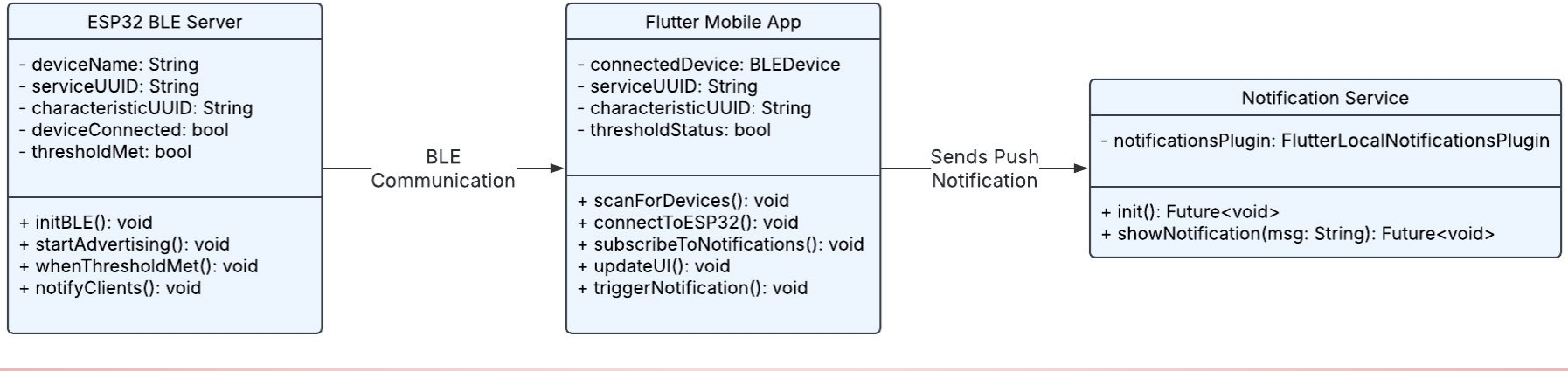


David Garzon
Computer Engineer



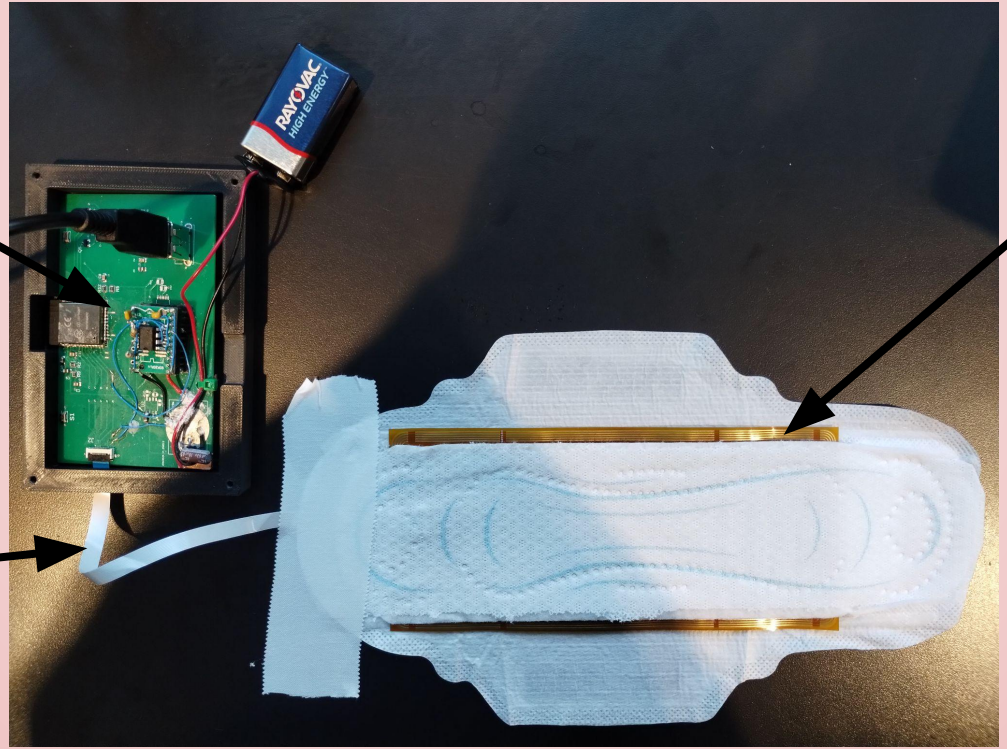
Notification Class Diagram

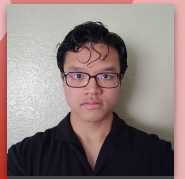




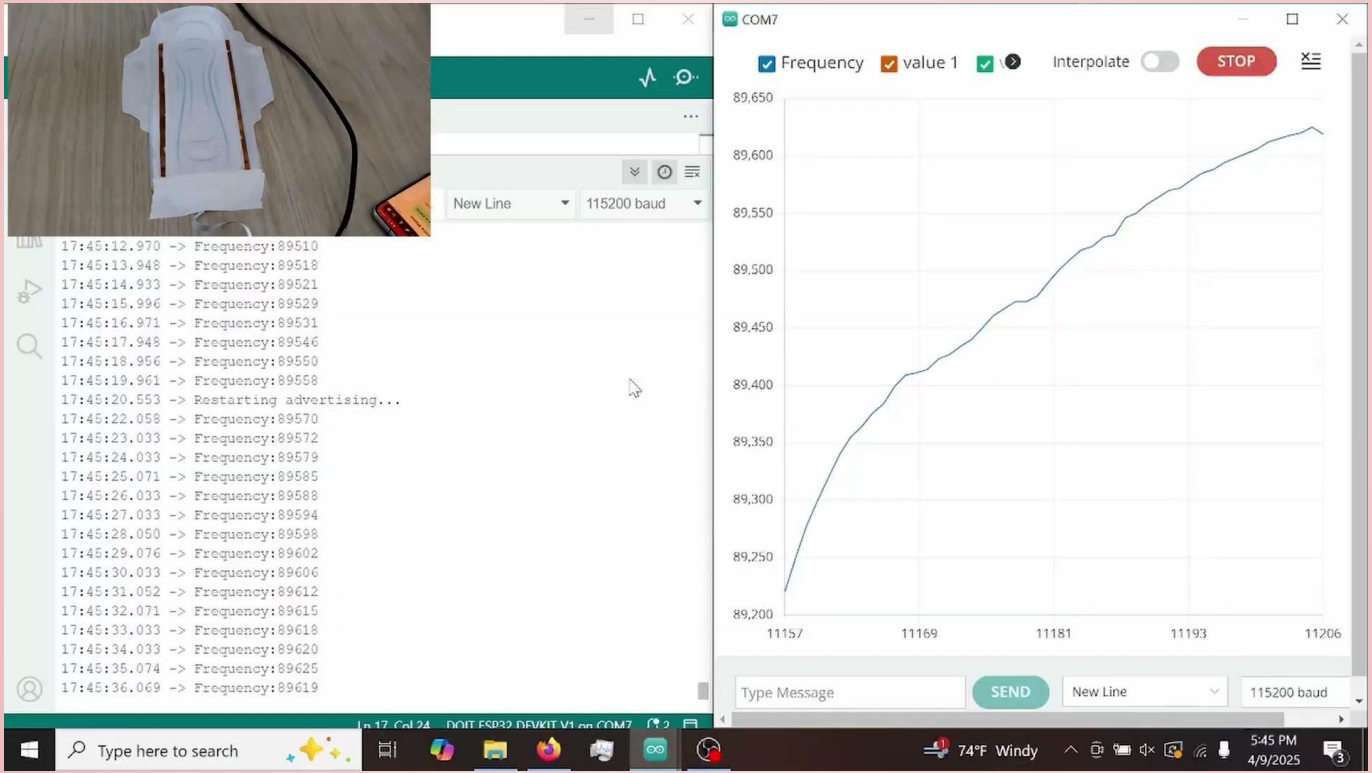
Prototyping & Testing

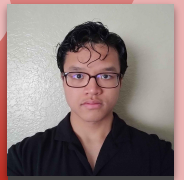
System Integration





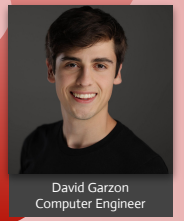
Hardware Testing





Alexander Nguyen
Electrical Engineer

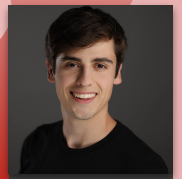
Software Testing



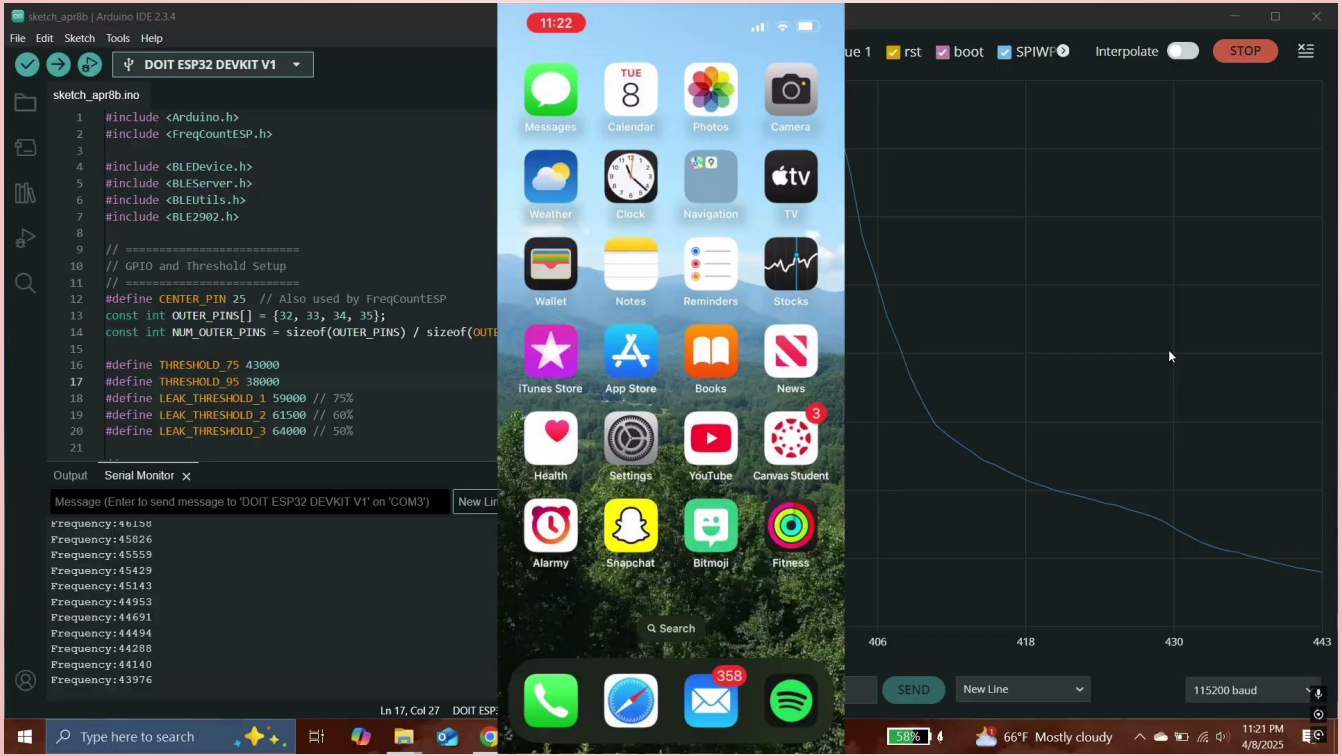
- Embedded Development
  - We need to ensure the ESP32 can be found as a Bluetooth server for pairing on different platform devices. This can be tested locally with different devices like iOS and Android mobile devices.
  - We need to ensure the threshold sensor notifier works consistently and accurately by repeated local testing.

- App Development
  - We need to ensure cross-platform front-end styling is consistent among devices by simulation testing and live demo on different local devices.
  - We need to ensure BLE (Bluetooth Low Energy) features work on different devices with a smooth set-up.
  - We need to ensure post-notifications appear on different platform which can be tested via simulation and locally with different devices.

Software Testing Example



David Garzon
Computer Engineer



Challenges and Troubleshooting

- Microcontroller not receiving enough current
  - Switched to AA batteries
- Capacitance to Digital IC always reading the max value or zero because of parasitic capacitance in the traces
  - Switched to 555 timer to calculate capacitance
- Inaccurate frequency readings
  - Resoldered ESP32 and shortened cable wires
- ESP 32 browning out when adding bluetooth functionality
  - Switched to a different voltage regulator and 9V battery
- Difficulty sending notifications
  - Sent a string instead of a json to ensure correct data formatting
  - Insuring the pCharacteristic has the matching data types between the arduino and the app code

Administrative Content

Budget and BOM

Number	Part	Cost	Quantity	Subtotal	Budget
1	Voltage Regulator	$1.17	1	$1.17	$2.00
2	Buttons	$0.70	2	$1.40	$2.00
3	Battery Holder	$0.61	1	$0.61	$1.00
4	Flex Cable Connector	$0.53	2	$1.06	$2.00
5	USB Connector	$1.30	1	$1.30	$2.00
6	555 Timer	$0.85	1	$0.85	$1.00
7	NPN Transistor	$0.03	2	$0.06	$1.00
8	6 Inch Ribbon Cable	$3.84	1	$3.84	$5.00
10	SMD Resistors and Capacitors	$0.03	1	$0.03	$1.00
11	Rigid PCB	$1.60	1	$1.60	$3.00
12	Flexible PCB	$6.78	1	$6.78	$10.00
13	Battery	$1.50	1	$1.50	$5.00
14	ESP 32	$5.00	1	$5.00	$5.00
				$25.20	$40.00

Work Distribution

Component	Primary Responsibility	Secondary Responsibility
Sensor	Matthew Poole	Alexander Nguyen
Capacitance to Digital Converter	Alexander Nguyen	Matthew Poole
Software Application	David Garzon	Dillon Sardarsingh
MCU	Matthew Poole	David Garzon
Power Supply	Dillon Sardarsingh	Alexander Nguyen
Housing Unit / PCB	Alexander Nguyen	Matthew Poole
Administrative	Alexander Nguyen	

Thank you!

This project was sponsored by JLC PCB

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