NoctiSense

Final Presentation
Group 1

Meet the team

Mason Miles

Computer Engineering

Jose Ojeda

Computer Engineering

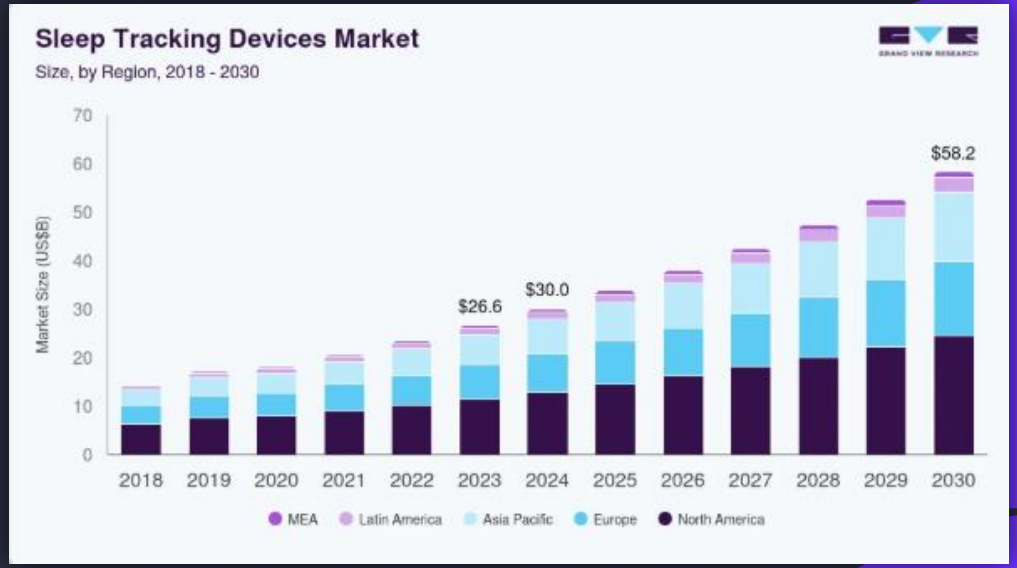
Colby Toner

Electrical Engineering

Edward Perez

Photonic Science and Engineering

Motivation & Background



Price: $249 – $1,399
Requires iPhone
Trains "AI" on data

Subscription: $199 - $359 per year
Trains "AI" on data

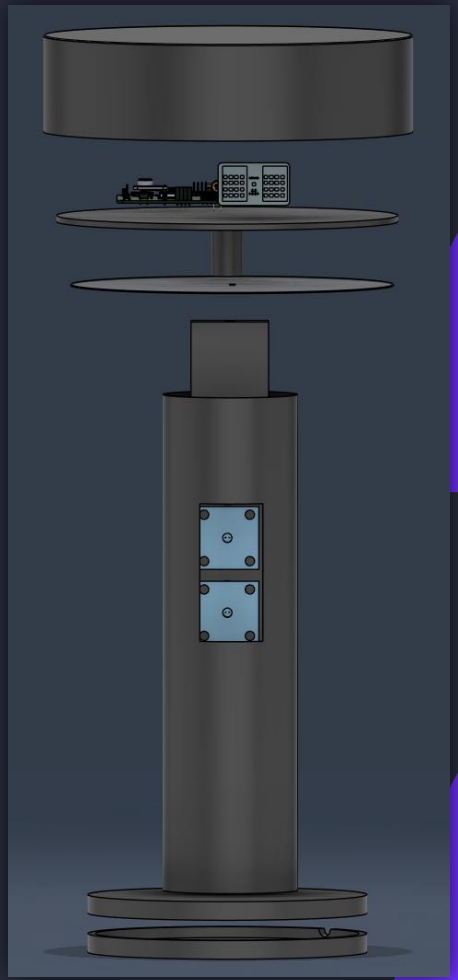
Price: $399 – $499
Subscription: $70 per year
Trains "AI" on data

Price: $2,849 – $5,899
Subscription: $199 - $399 per year
Trains "AI" on data

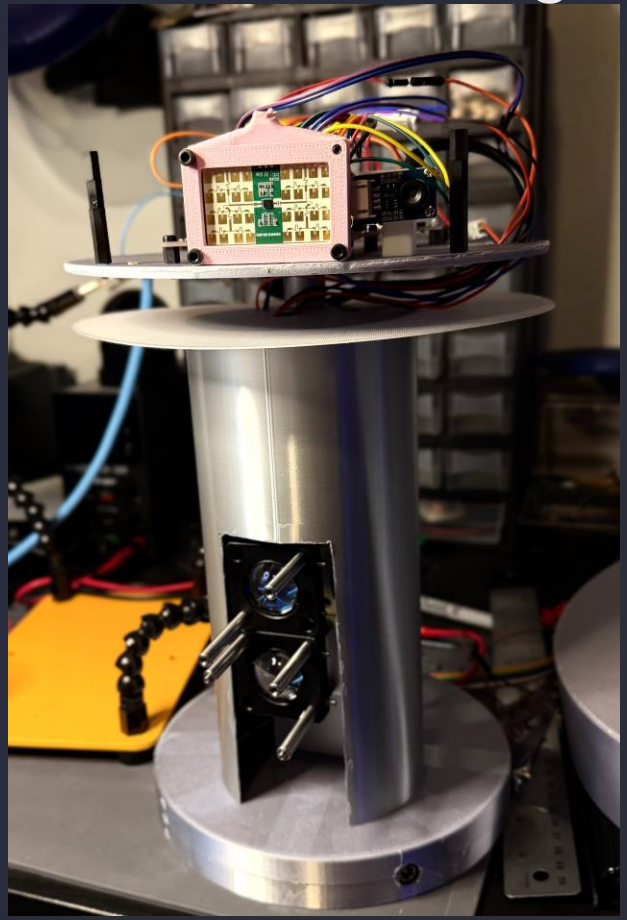
Goals & Objectives

- Measure meaningful data to help people track their sleep hygiene
- Digest and display this data in a meaningful way to the end-user
- Consistent, accurate data measurements
- Reliable, safe hardware

Project Conceptualization



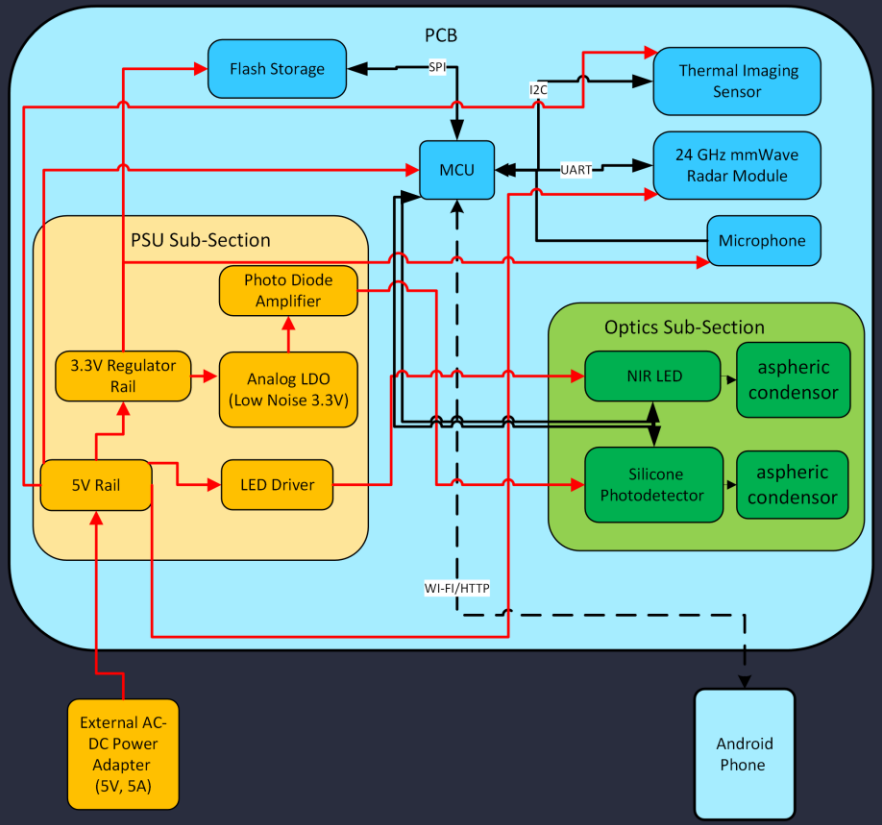
Final Product Design



Engineering Specifications

Parameter	Description	Target Value
Monitoring Area	Maximum tracking distance	2850 in^2
Lamp Housing Footprint	Overall dimensions of the lamp housing	19.7 in W x 23.6 in H
Operation/Setup	Time it takes to setup device and start receiving Data	Data should be in application within 1 minute of boot up
Operating Voltage	Device voltage under which it will operate nominally	5V
Usability	Low friction between the amount of time and effort it takes to initially set up the system including the application	10 minutes
Optical Detection Distance	Minimum Distance to send and receive optical signal	1.5 m ≥

Hardware Block Diagram

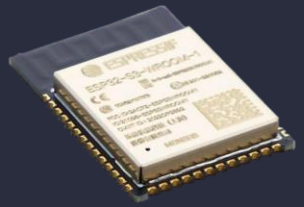


Blue: Mason Miles & Jose Ojeda

Orange: Colby Toner

Green: Edward Perez

MCU Selection



ESP32-S3

- Dual-core up to 240 MHz
- 8MB flash memory
- Plethora of IO & Wi-Fi.
- $5

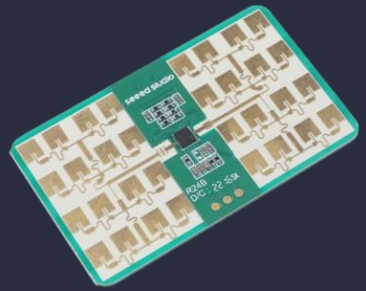
Arm Cortex-M4 (Arduino Nano Series)

- Up to 48 MHz
- 256KB flash memory
- Plethora of IO, no Wi-Fi
- $13

Key Points:

- Fast/efficient processing
- Sufficient PSRAM/Flash memory
- Vast GPIO/Wi-Fi
- Well-documented community support/tools

Movement Tracking



Radar Sensor

- Fast sampling
- Moderate range
- Sensitive enough for respiratory/heart rate
- Through-obstacle operation
- $25-$35

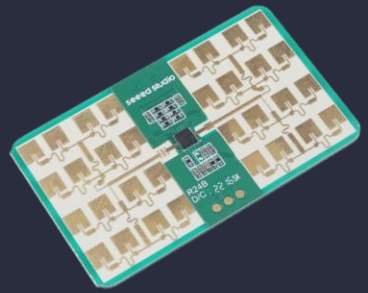
PIR Sensor

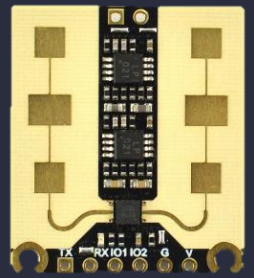
- Low sampling
- Far range
- Binary detection event data
- No through-obstacle detection
- $5-$10

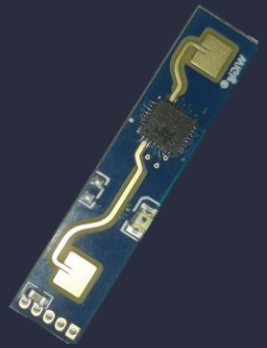
RGBD Sensor

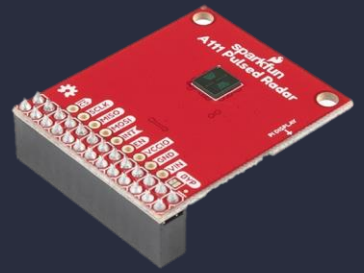
- High sampling/data rate
- Far range
- Requires external processing
- $100+

Radar Selection









Seeed Studio MR24BSD1

- 24 GHz
- Developed for sleep tracking
- Built in DSP/Libraries
- Low data rate
- $25-$35

DFRobot SEN0395

- 24 GHz
- Developed for presence detection
- Built in DSP/Libraries
- Low data rate
- $20-$30

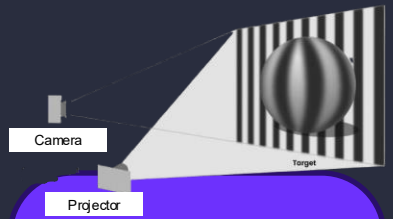
Hi-Link HLK-LD2410

- 24 GHz
- Developed for presence detection
- Community DSP tools
- Moderate data rate
- $10-$20

Acconeer A111

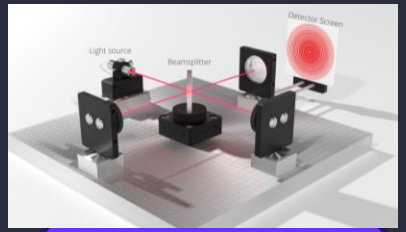
- 60 GHz
- Multi-Purpose
- No built-in DSP
- High data rate
- $50-$100

Optical Measuring Technology



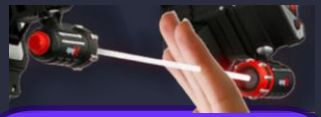
Structured Light Camera

- Triangulation
- 0.5 – 3m range
- Struggles in sunlight
- $150-$500



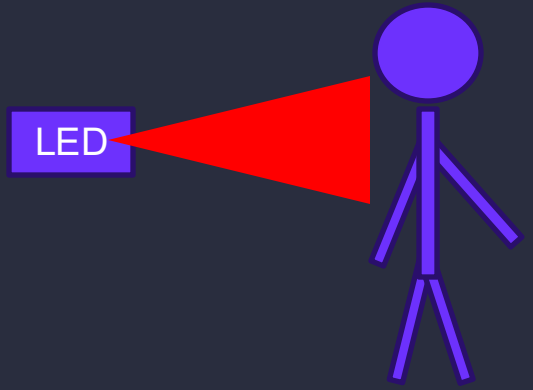
Michelson Interferometer

- Phase difference
- ~mm-cm displacement only
- Vibration stability < λ/10 (~100 nm)
- +$1000 (optics + mounts)

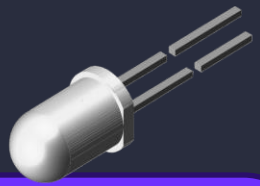


Light Tripwire

- Intensity difference
- 0.5 – 3m range (our design)
- Sufficient return power (~μW–nW detection)
- $20-$150



Optical Hardware Comparison



TSAL6400 IR LED

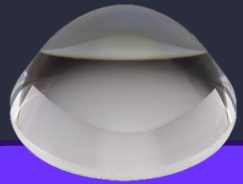
- ~0.04 W Peak Power
- ~ 15 ns Pulse Capability
- Beam Divergence of 200 mm
- Drive of 100 mA
- $0.48
- Class 1

SPL TL90AT03 Laser Diode

- 24 GHz
- 1-100 ns Pulse Capability
- Beam Divergence 9 mm
- Drive of ~ 3 A
- ~$17
- Class 1-2

KPA18AR.16 Aspheric Lens

- ~Ø 25 mm
- *f* = 16 – 25 mm
- NA ≤ 0.79
- AR coating (600 -1050 nm)
- Precision polished aspheric
- $455



ACL25416U-B Aspheric Lens

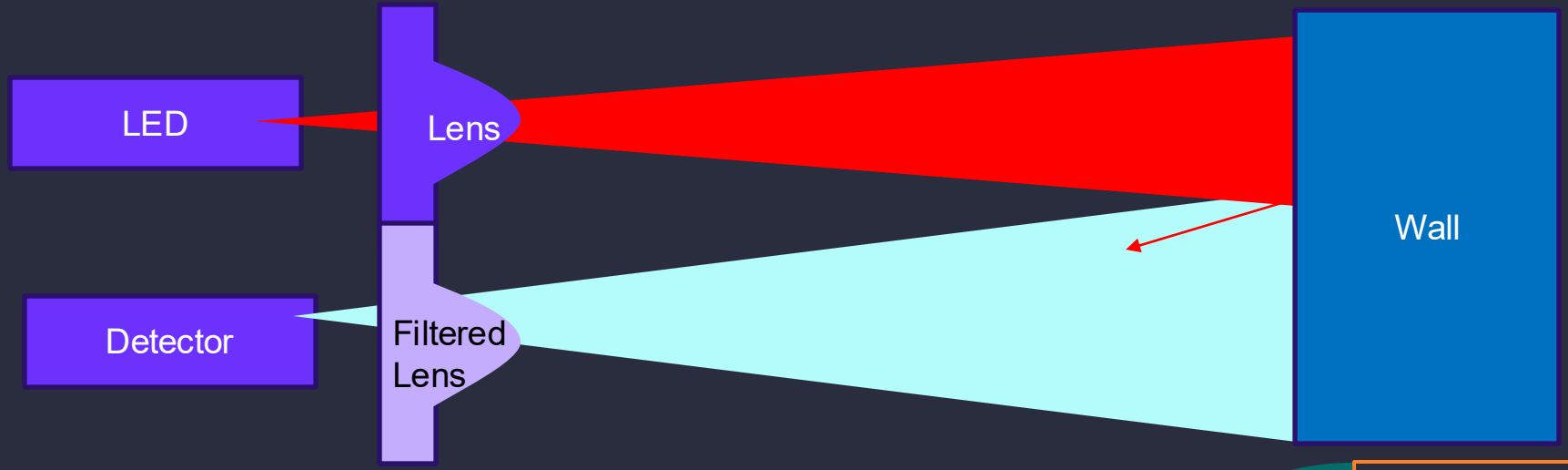
- ~Ø 25.4 mm
- *f* = 20.1 mm
- NA ~ 0.79
- AR coating (650 -1050 nm)
- Molded Aspheric
- $34.33

Optical Design Case

3.3 nW at 1.5 meters with no lens, at the wall.

3.3 uW at 1.5 meters with lens, at the wall

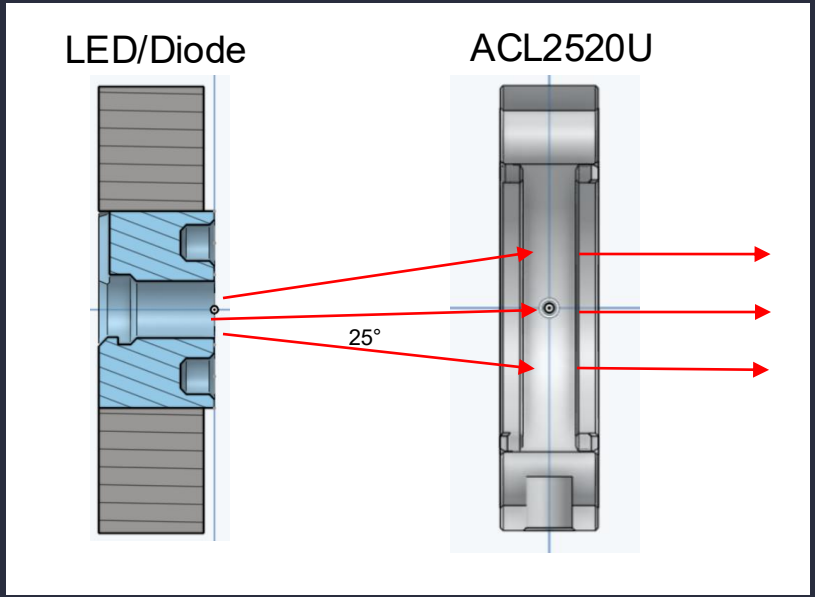
Optical Design



1.5 pW at 1.5 meters with no lens, at the wall.

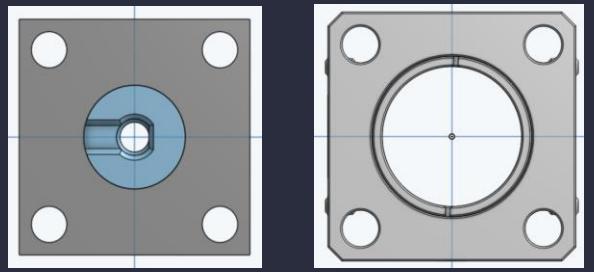
1.5 uW at 1.5 meters with lens, at the wall

Opto-Mechanical



Side View

Top View



Temperature Monitoring Hardware

RGB Camera

- Captures Visible Light
- High Resolution
- Needs Ambient Light
- Privacy Concerns

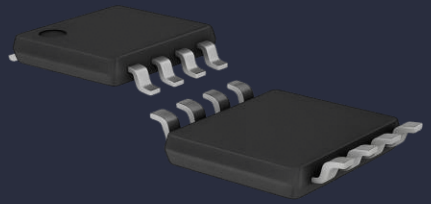
NIR Camera

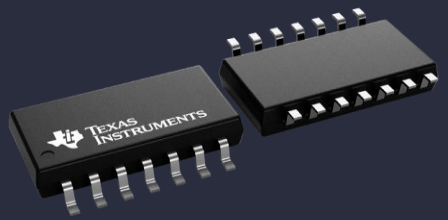
- Captures Near-Infrared
- Works in the Dark
- Better at Capturing Shapes
- Provides Poor Temp Data

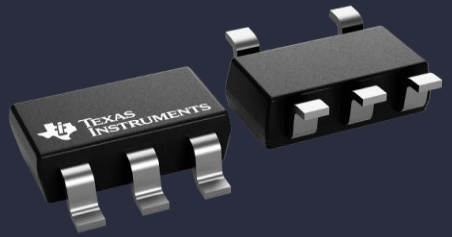
FIR Camera

- Passively Detect Heat
- Far range
- Lower Resolution
- Captures in the Dark
- Ideal for Capturing Core Temperatures

Transimpedence Amplifier







OPA380

- $6 per unit
- 5.8 nV/√Hz Input Voltage Noise
- 80 V/µs Slew Rate
- 90 MHZ GBW

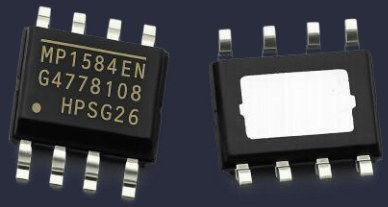
TL084

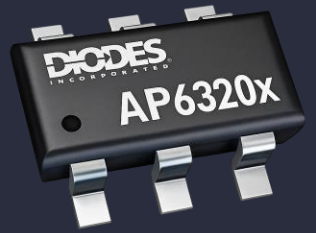
- $0.50 per unit
- 18 nV/√Hz Input Voltage Noise
- 80 V/µs Slew Rate
- 3 MHZ GBW

OPA320

- $2.50 per unit
- 7 nV/√Hz Input Voltage Noise
- 10 V/µs Slew Rate
- 20 MHZ GBW

Switching Regulators





MP1584EN

- $3 per unit
- 0.8V - 20V Input Voltage
- 100 µA Q-Current
- 3A Max Output Current
- 92% Efficient
- 1.5 MHz Switching Frequency

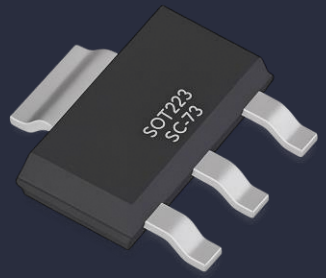
LMR33620

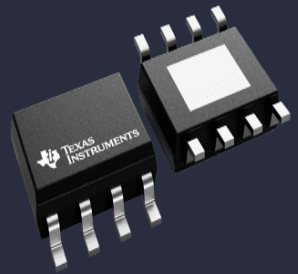
- $3 per unit
- 3.8V - 36V Input Voltage
- 25 µA Q-Current
- 2A Max Output Current
- 95% Efficient
- 400 K-2.1 M HZ Switching Frequency

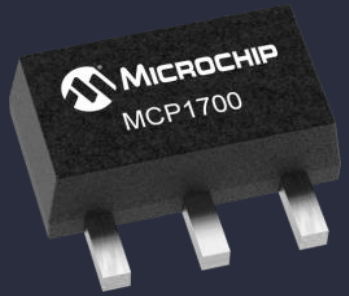
AP63201

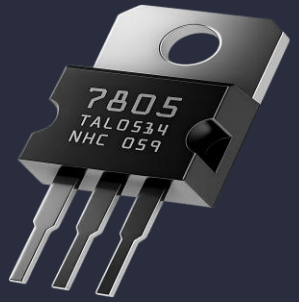
- $1 per unit
- 0.8V - 20V Input Voltage
- 22 µA Q-Current
- 2A Max Output Current
- 95% Efficient
- 1.1 MHz Switching Frequency

Linear Regulators









LT3080

- $3 per unit
- 1.2V - 36V Input Voltage
- 100µA Q-Current
- 1.1A Max Output Current
- 40 µVRMS Output Noise

LP2985

- $0.54 per unit
- 2.1V - 16V Input Voltage
- 75 µA Q-Current
- 0.15 A Max Output Current
- 30 µVRMS Output Noise

MCP1700

- $0.50 per unit
- 2.3V - 6V Input Voltage
- 1.6µA Q-Current
- 0.25 A Max Output Current
- 125 µVRMS Output Noise

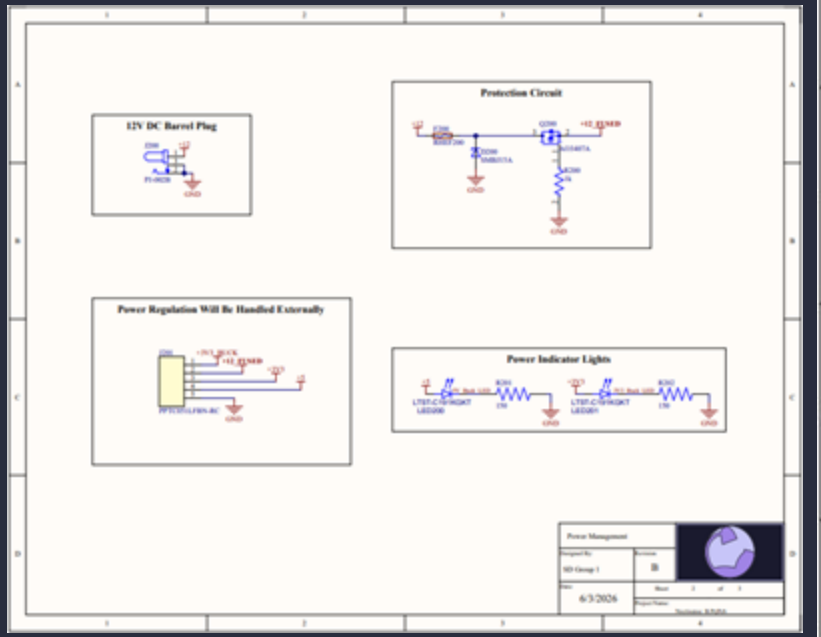
LM7805

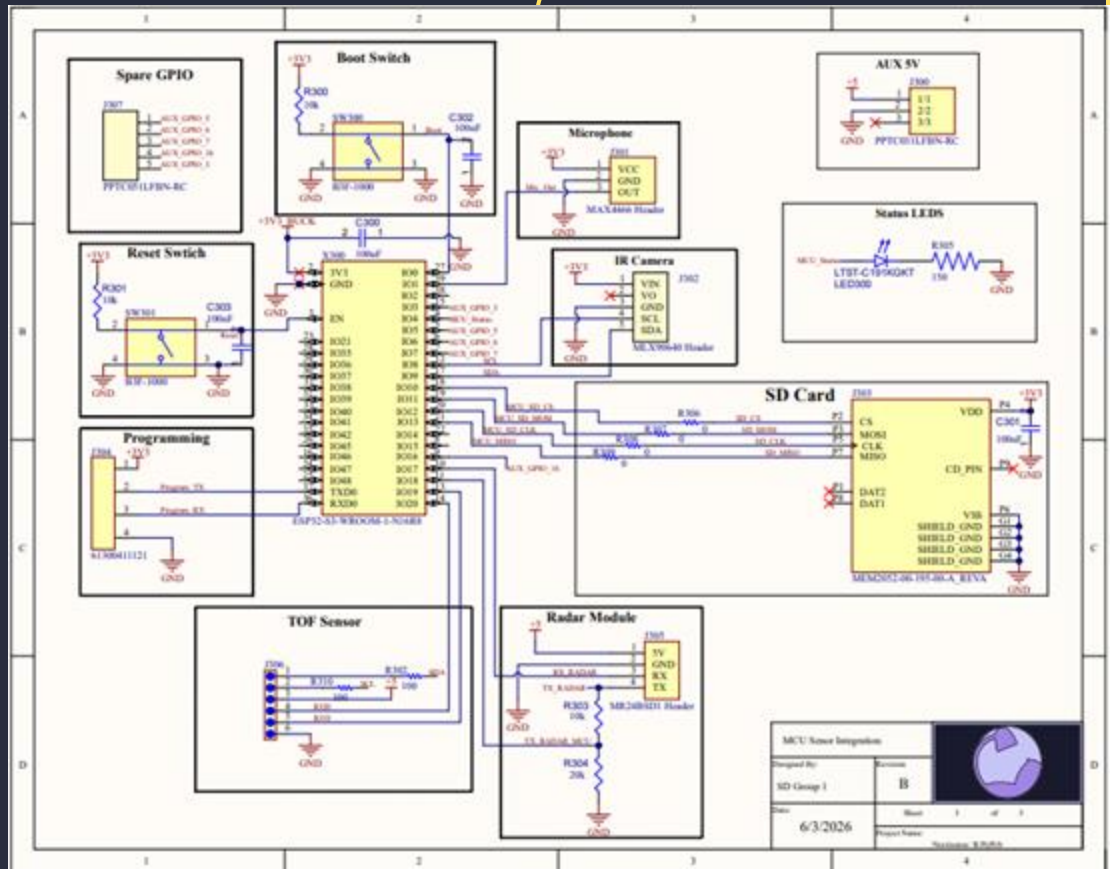
- $2 per unit
- 7V - 35V Input Voltage
- 6 µA Q-Current
- 1.5 A Max Output Current
- 80 µVRMS Output Noise

Regulator Thermal Calculations

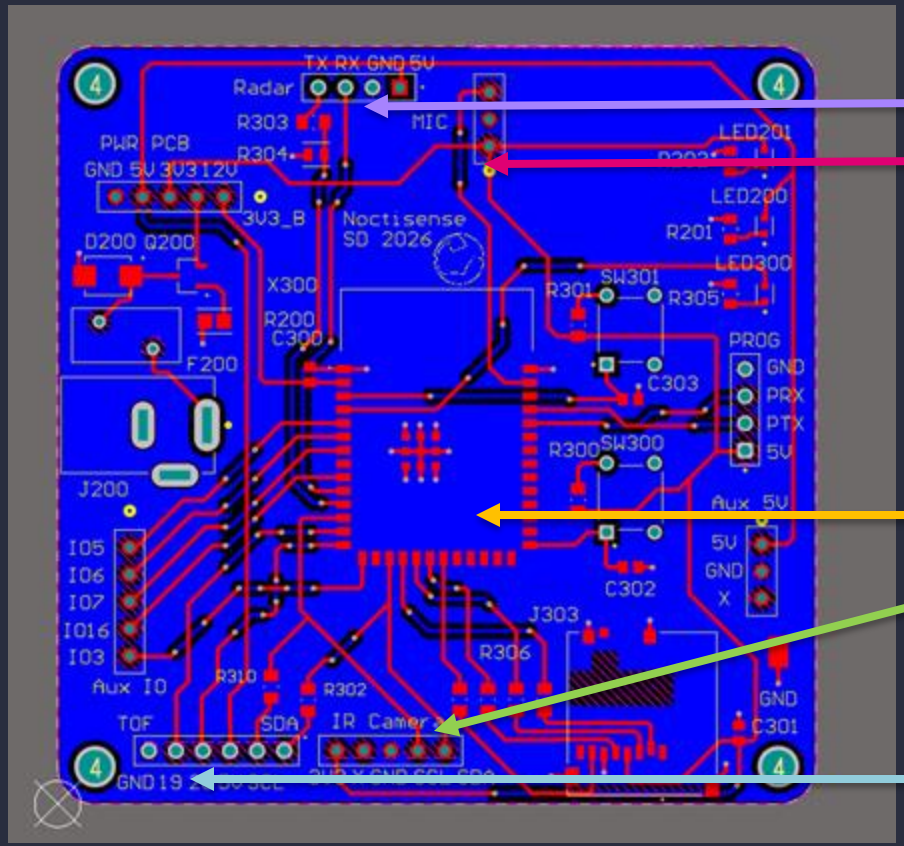
Regulator	Type	Dissipated Power	Rated (°C/W)	Junction Temperature
AP63201	5V Switching	0.67 W	40	51.8 °C
AP63201	7V Switching	0.12 W	40	30 °C
LT3080	3.3V Linear Regulators	1.02 W	50	76 °C
LT3080	5V Linear Regulator	0.4 W	50	45 °C

MCU Board Schematic





MCU PCB Layout



Dimensions:
2.8 in X 2.8 in (71.12 mm X 71.12 mm)

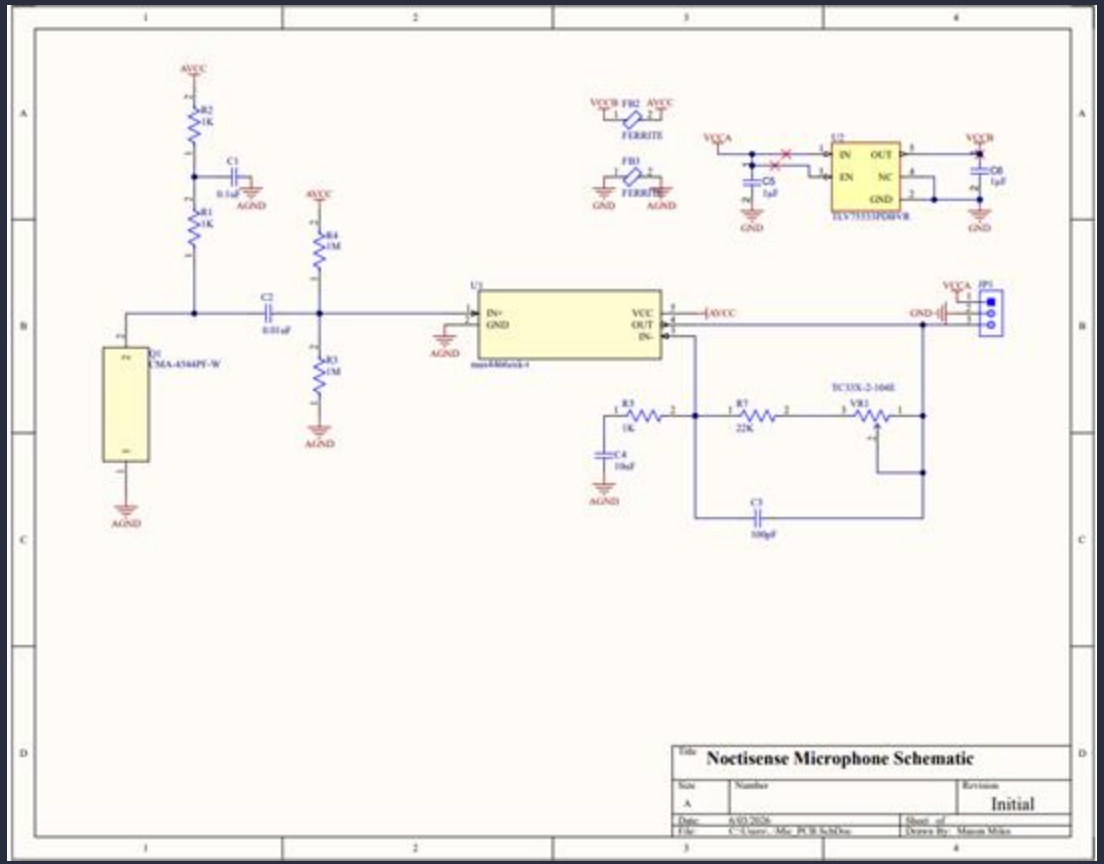
Properties:

2 Layer 1 oz Stackup

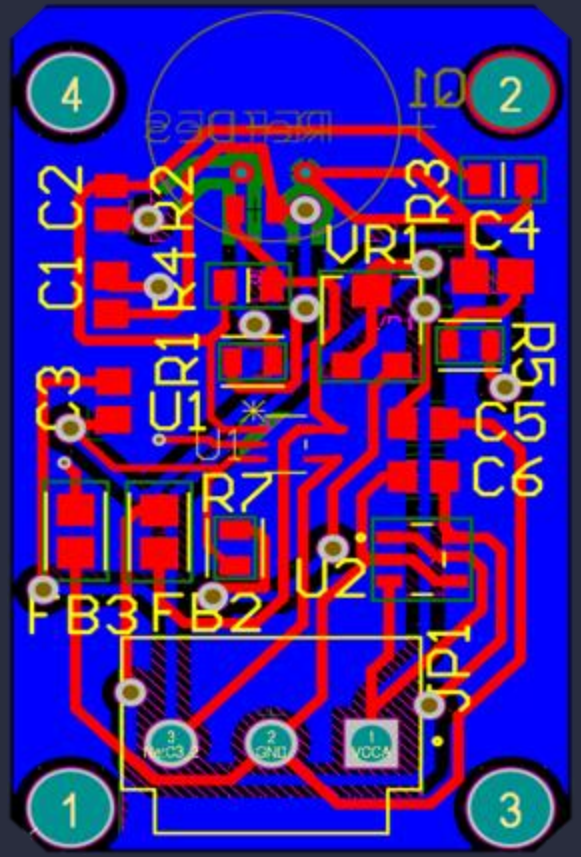
Ensured DFMA Compliance:

- Adhered strictly to JLC manufacturing constraints.
- Maintained 1mm minimum component spacing.

Mic Board Schematic



Mic PCB Layout

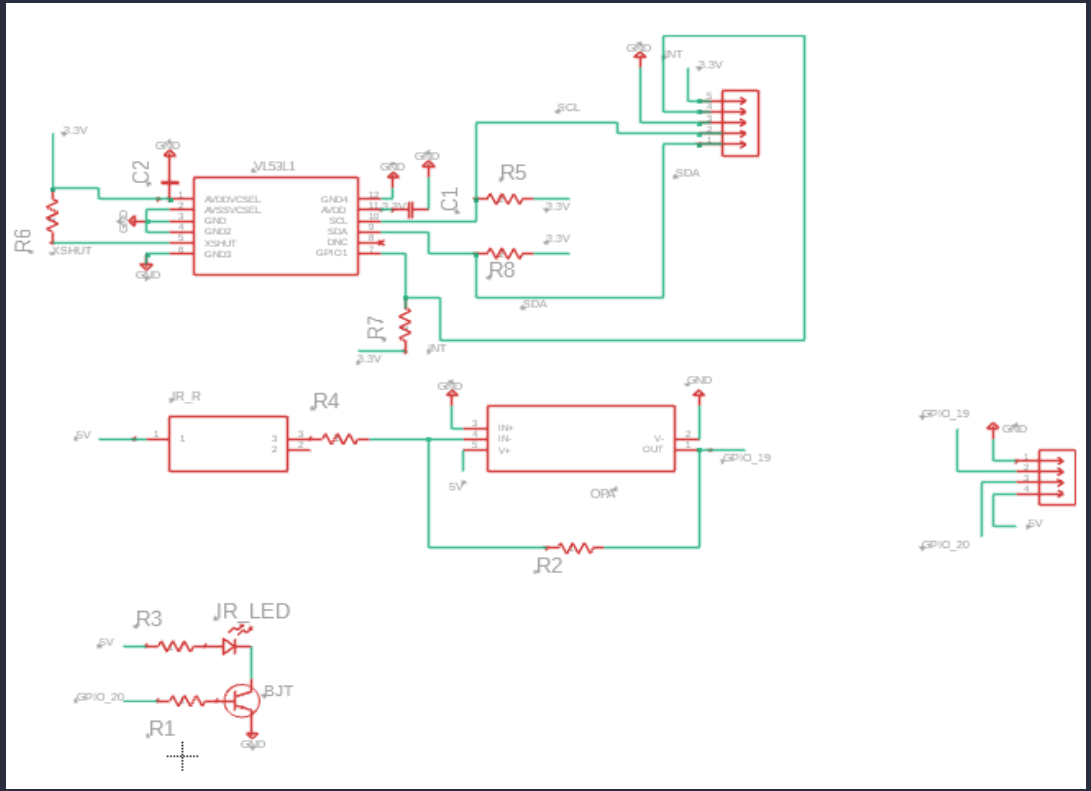


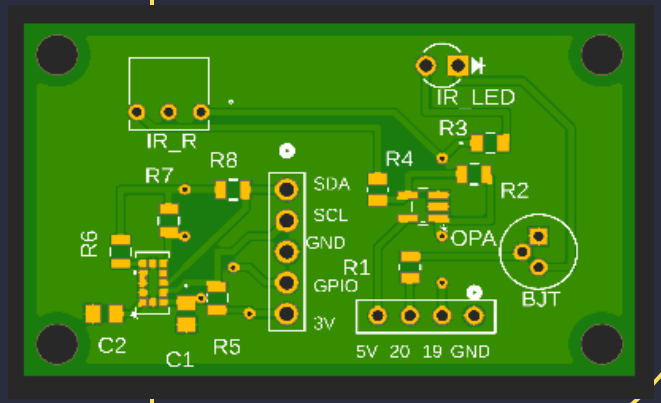
Dimensions:

0.9 in X 1.5 in (22.4 mm X 37 mm)

Utilizes a 3.3V LDO

Optical Schematic & PCB

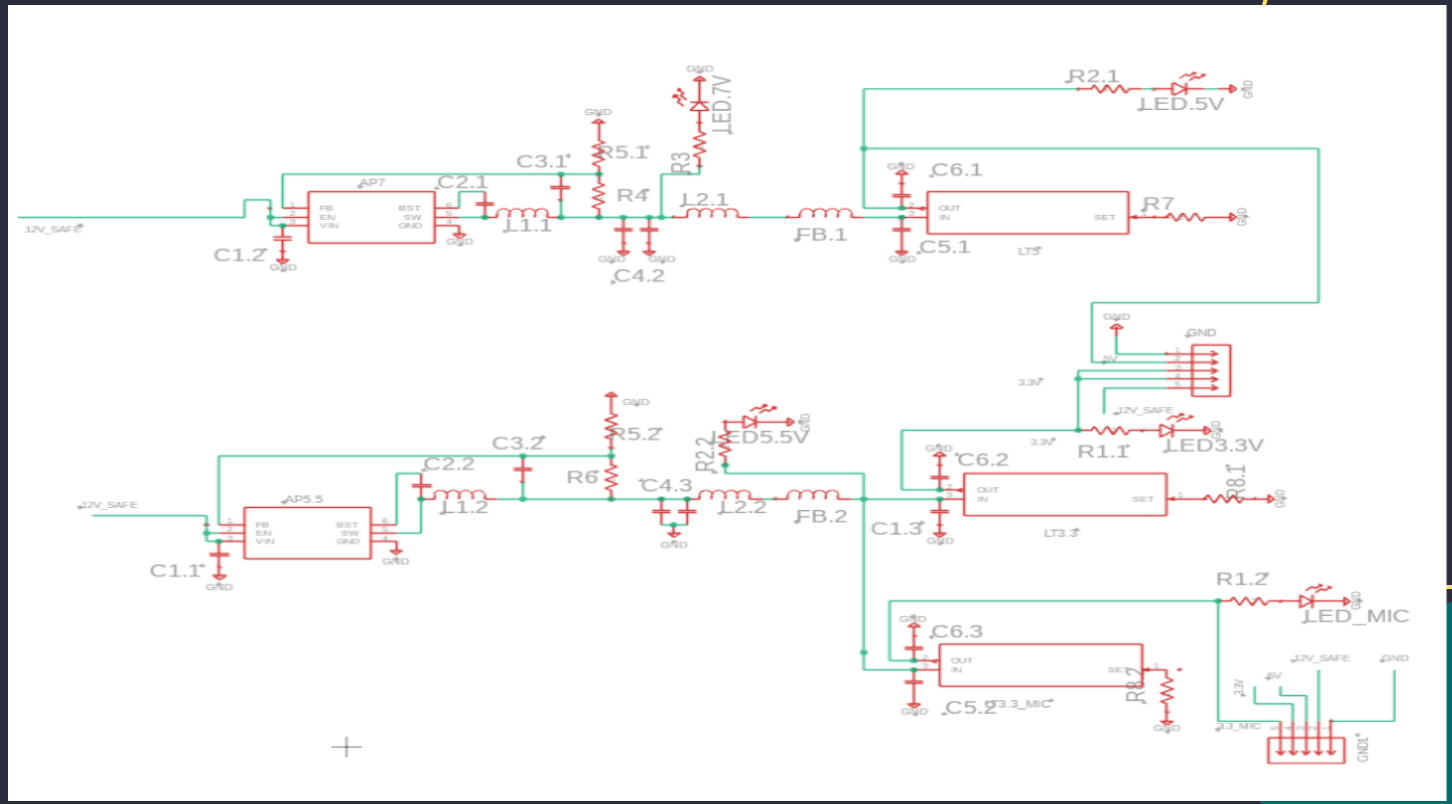




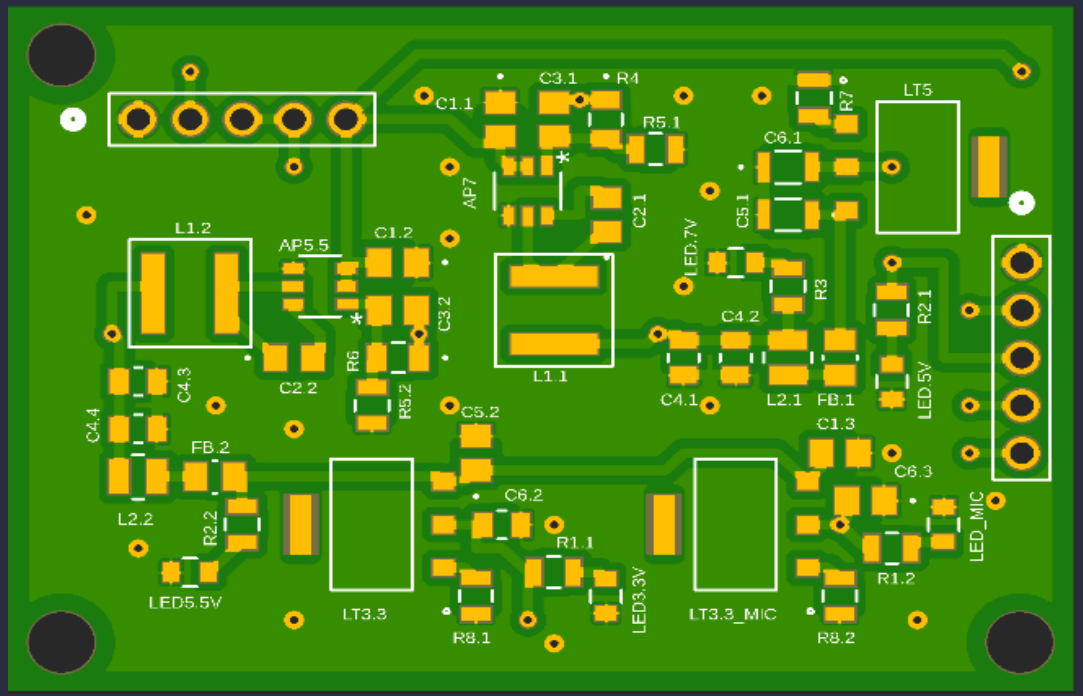
Dimensions:

1.9 in X 1.15 in (48.26 mm X 29.21 mm)

Regulator Board Schematic



Regulator PCB Layout

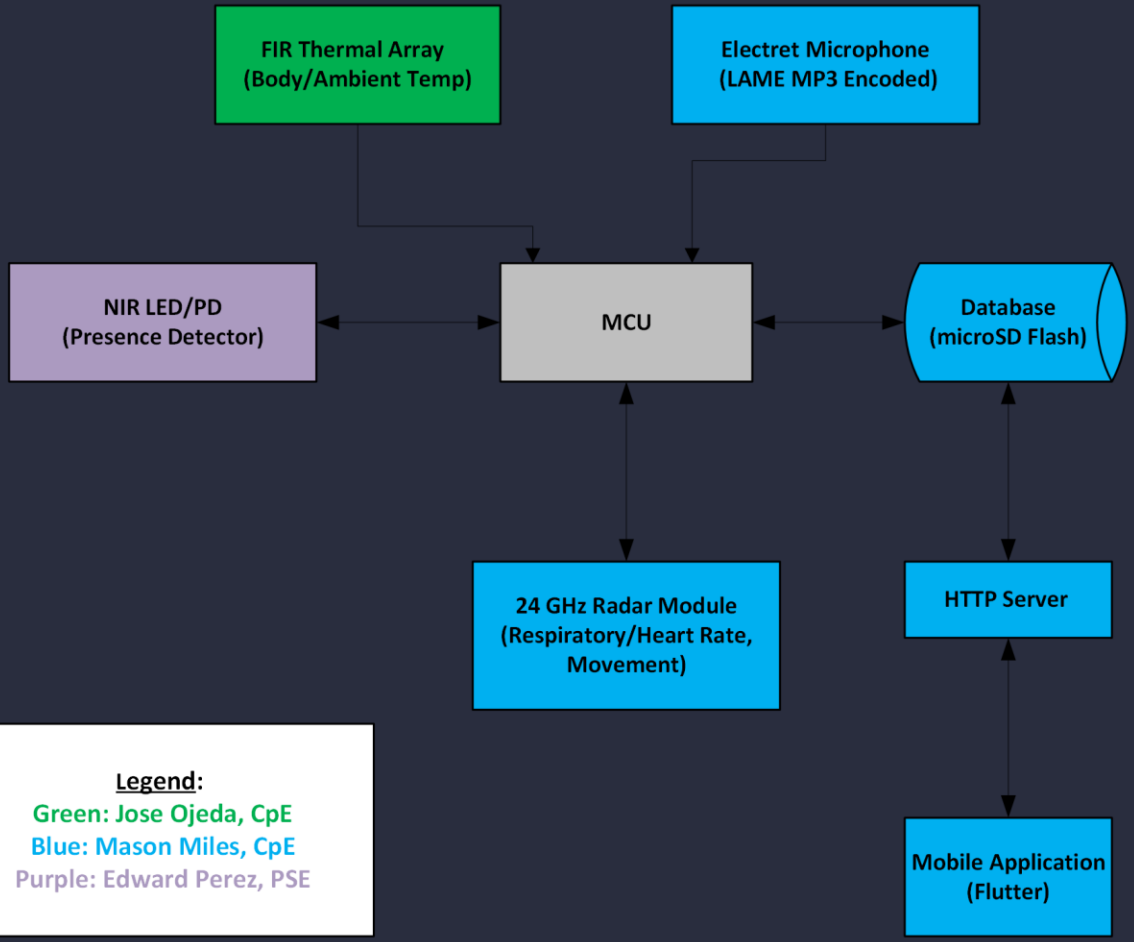


Dimensions:

2.05 in X 1.43 in (52.07 mm X 36.38 mm)

2 oz Copper Pour

Software Block Diagram



Legend:
Green: Jose Ojeda, CpE
Blue: Mason Miles, CpE
Purple: Edward Perez, PSE

Application Software

Native iOS/Android

- Swift for iOS, Kotlin for Android.
- Maximum performance and deep hardware access.
- Requires two entirely separate codebases, doubling development time.
- Development overhead is too high for the project timeline.

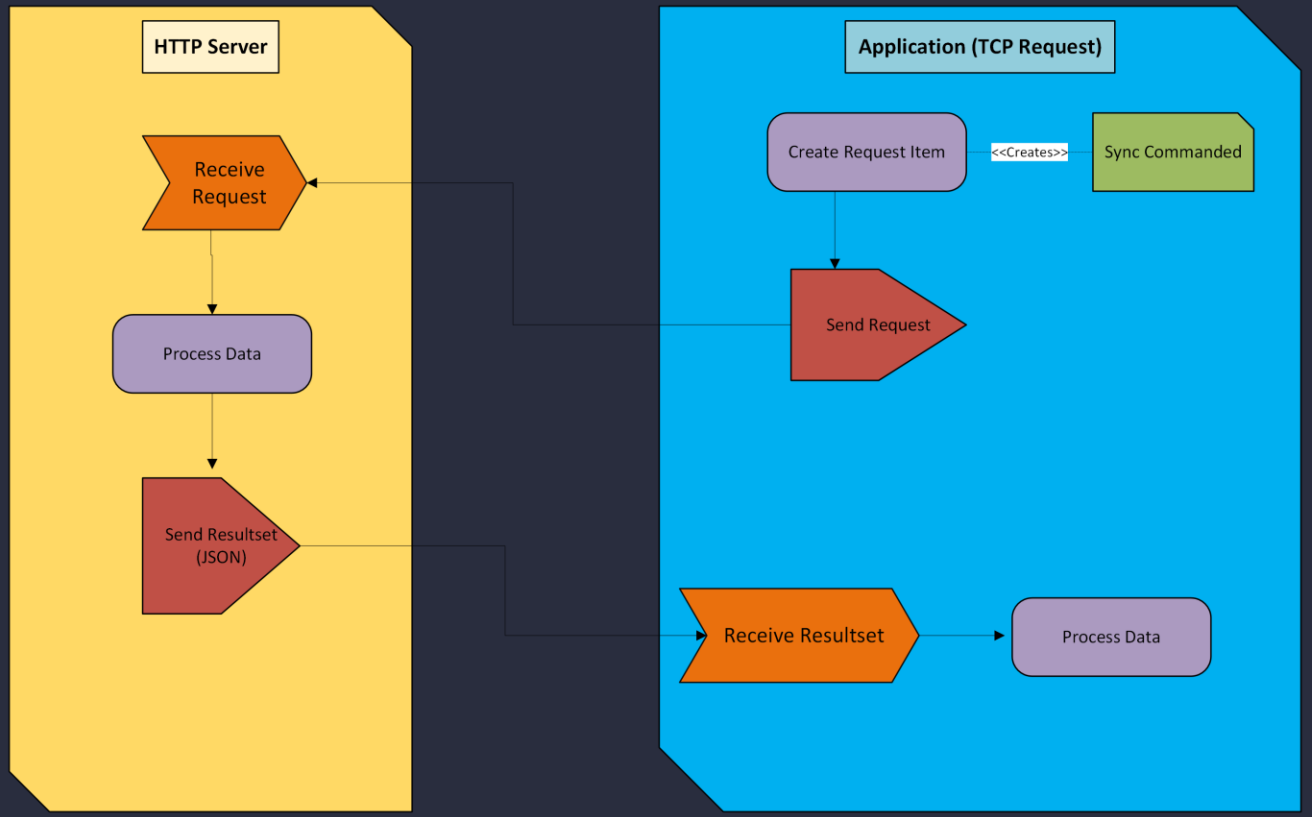
React Native

- JavaScript bridge rendering native UI components.
- Single codebase and massive web-developer community.
- JS bridge can introduce bottlenecks when parsing large JSON data arrays.
- Parsing efficiency is critical for handling the ESP32's dense sleep telemetry.

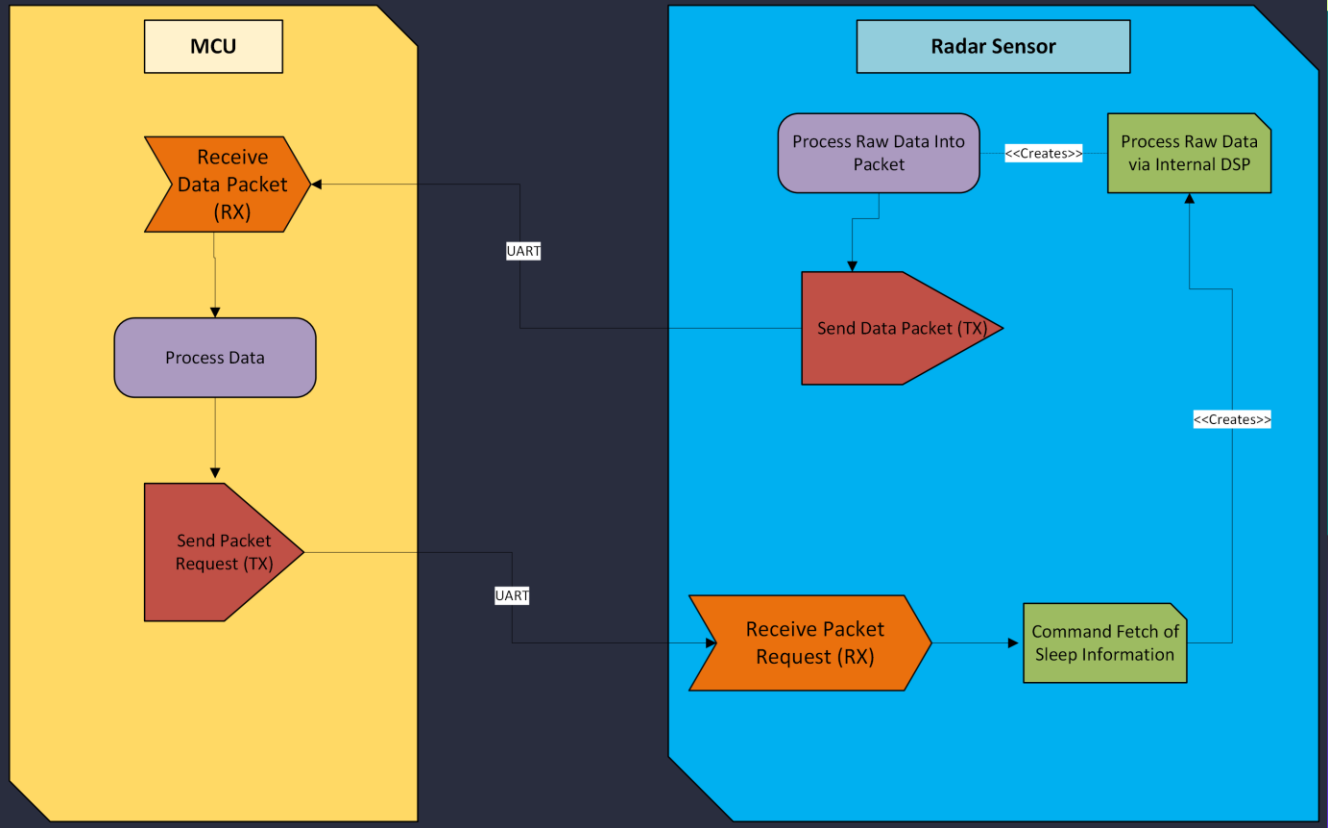
Flutter

- Dart codebase compiled directly to native ARM via custom engine.
- Fast execution, consistent UI across platforms, excellent background parsing.
- Slightly larger compiled app size.
- Cuts development time and boosts familiarity across the team

Application-to-HTTP Server - Activity Diagram



Movement, Respiratory/Heart Rate – Activity Diagram



Thermal Data Processing Algorithms

Ambient Calibration

- Sorts thermal pixels into temperature zones for precise room readings.

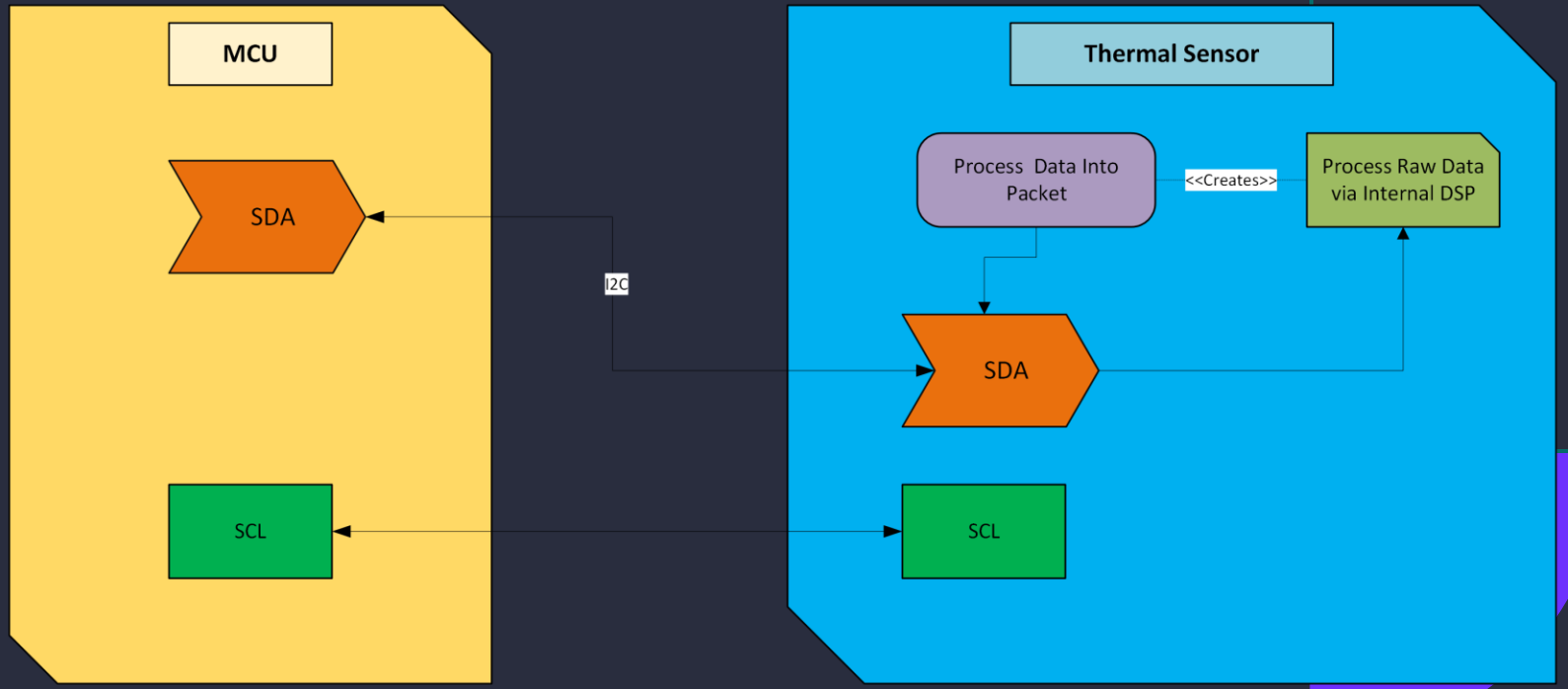
Hot Spot Tracking

- Uses sorted thermal data to isolate max temperature

Physiological Sleep Detection

- Detects sleep by measuring temperature drops against baseline

Thermal Imaging Activity Diagram



Audio Analysis Software

Uncompressed WAV

- Negligible processing power
- Massive storage demand
- Heavyweight file for SD writes & app transfer
- Low memory consumption

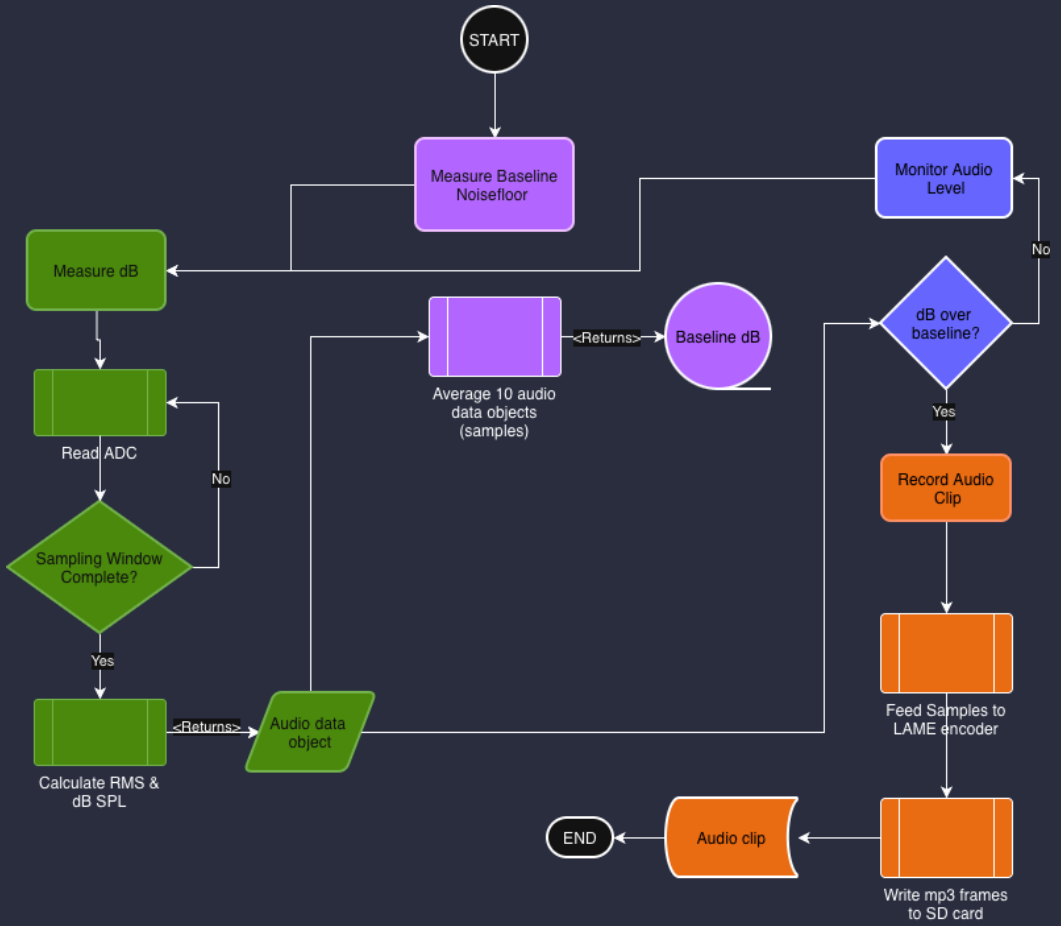
LAME MP3

- Real-time CPU encoding
- Low storage demand
- Lightweight for file transfer to application
- Moderate memory consumption

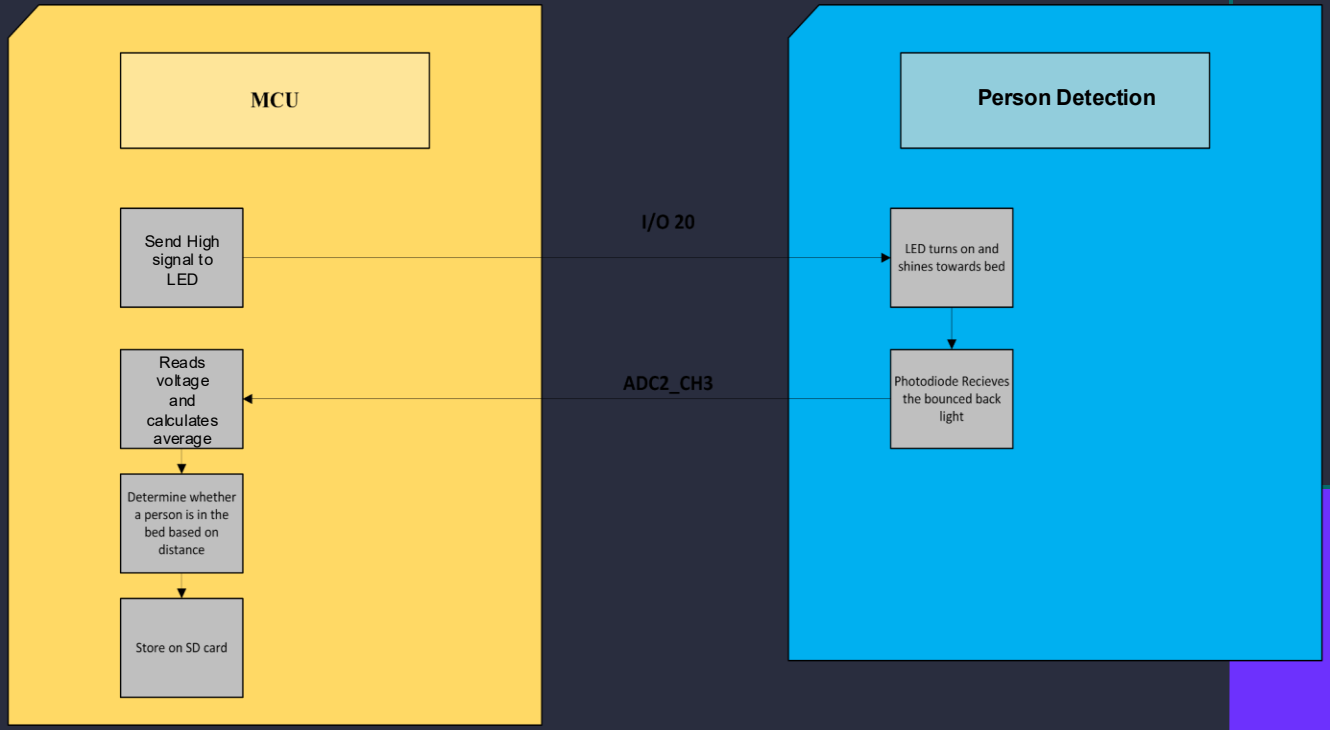
AAC

- Very high processing power
- High memory usage
- Low storage consumption
- Efficient file type for write & transfer

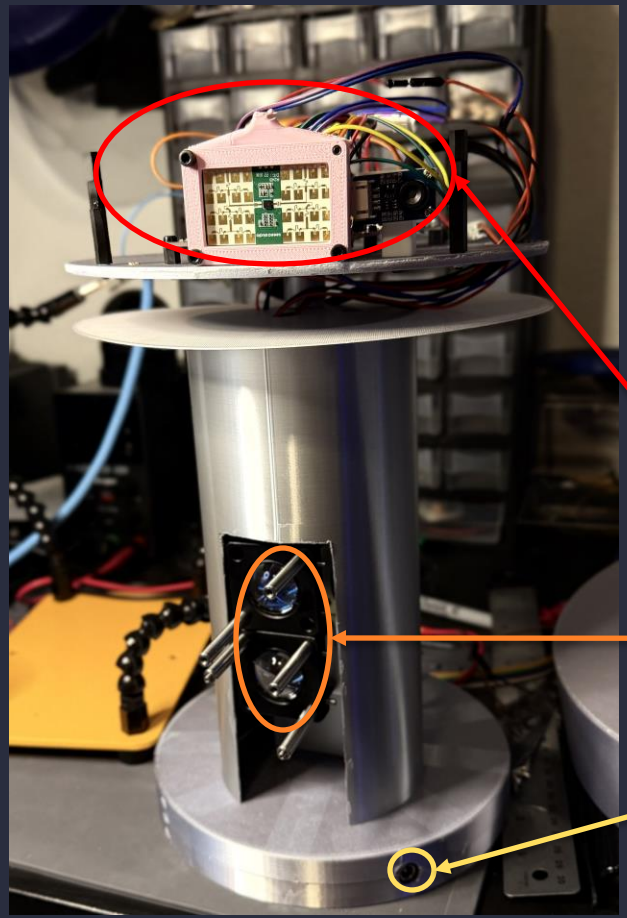
Audio Tracking Activity Diagram



In-Bed Detection Activity Diagram



Final Hardware Design



PCB(s) Mounted to an inner plate

IRLED/Photodiode Mounted to inner pillar & covered by shroud with window

12VDC barrel connector wired through shroud from top housing

Software Design

Finalized Application:

- Single unified dashboard displaying:

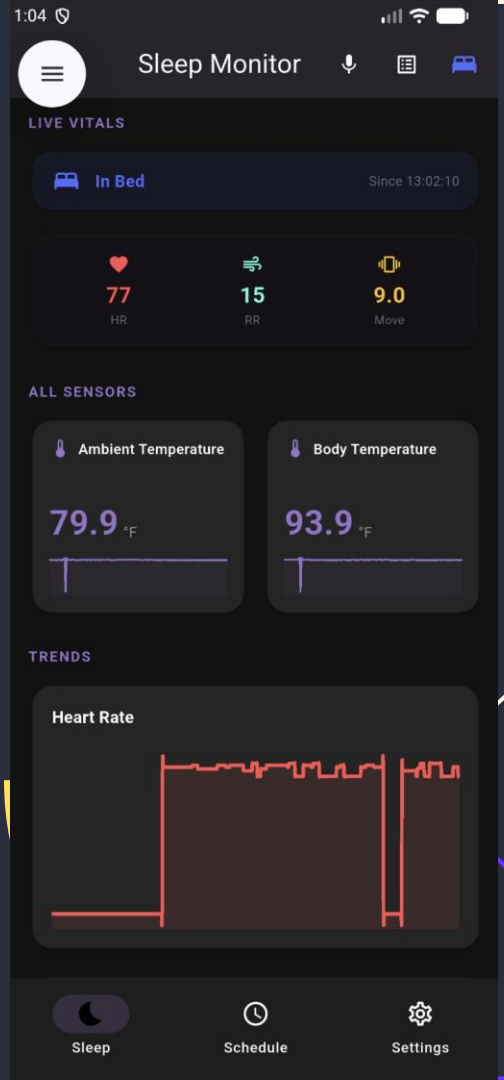
  - Overall sleep score

  - Average vital measurements (entire period)

  - Shortcut to audio clip screen for user audio clip playback

  - Live bed-presence status & vitals

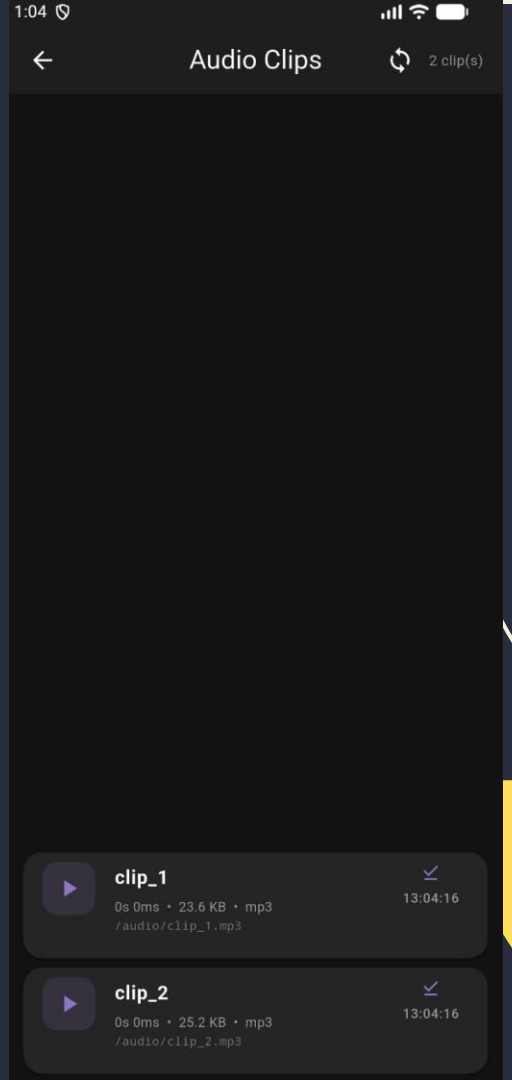
  - Live graphs of temperature, heart rate, & respiratory rate

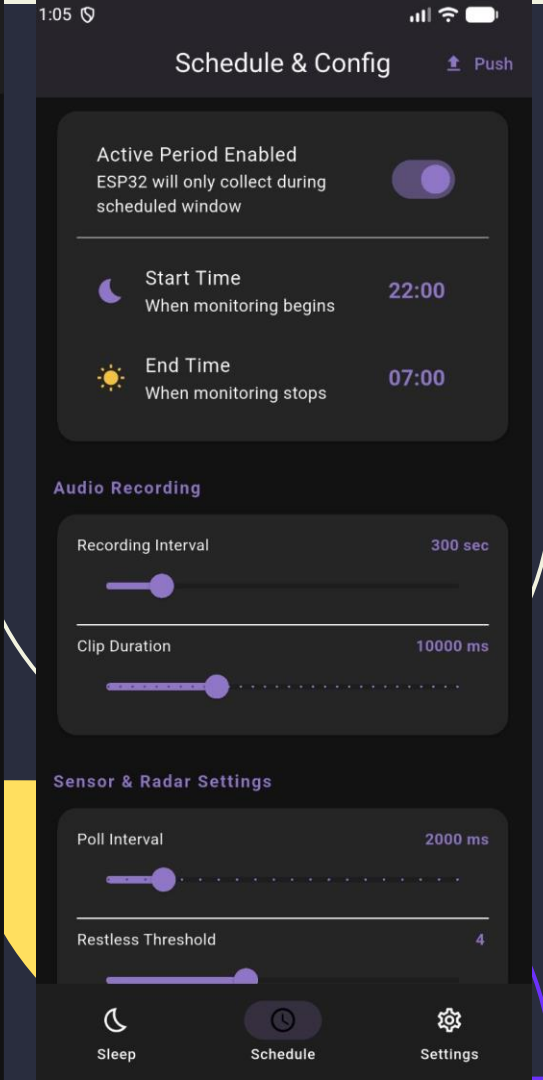


Software Design (Cont.)

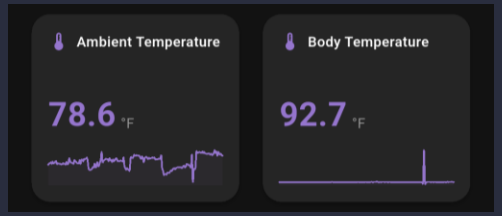
Finalized Application:

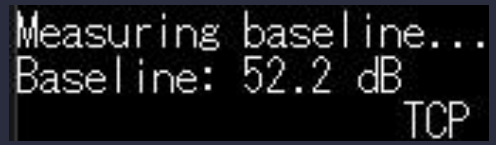
- Audio clip menu displays recorded audio events the analyzer found over the normalized threshold.
- Schedule & Config menu gives the user the ability to set a sleep/wake time for accurate system tracking, as well as fine-tuning adjustments for sensors based on their unique experience within their environment.

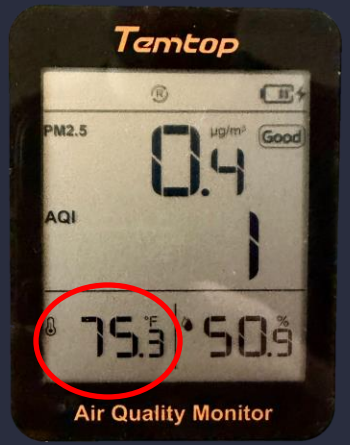




Performance Evaluation



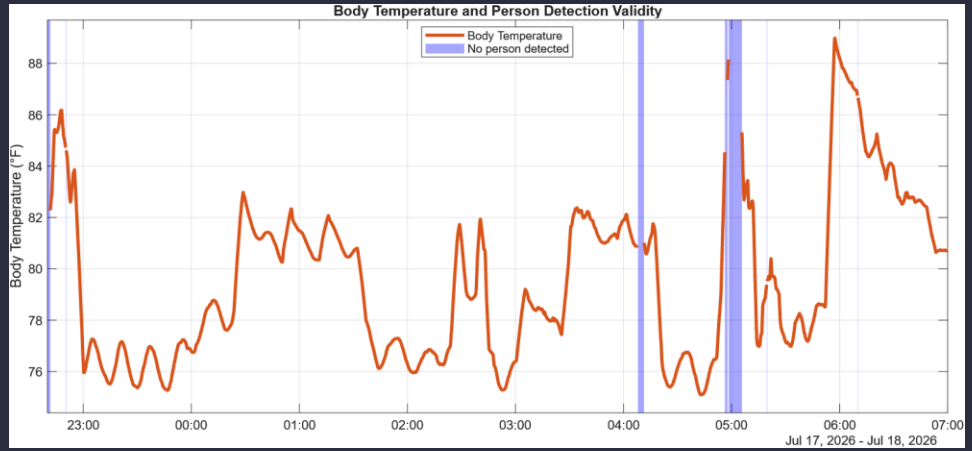




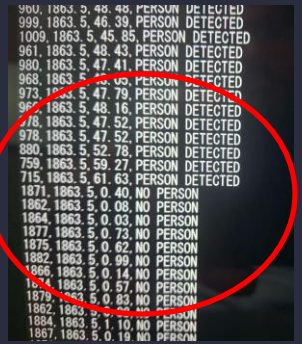
Other testing:

- Respiratory rate was measured against manually counted breaths within one minute taken at several sampling periods to within 1BPM.
- Heart rate was measured against wrist-worn monitor, this was within 2BPM.
- Body temperature was measured against a consumer body thermometer to within 6°F.
- Presence detection was compared to the response rate of ToF sensor

Performance Evaluation



2026-07-18T04:57:47Z	TRUE
2026-07-18T04:57:51Z	TRUE
2026-07-18T04:57:53Z	TRUE
2026-07-18T04:57:57Z	TRUE
2026-07-18T04:57:59Z	TRUE
2026-07-18T04:58:03Z	TRUE
2026-07-18T04:58:05Z	TRUE
2026-07-18T04:58:10Z	TRUE
2026-07-18T04:58:11Z	TRUE
2026-07-18T04:58:16Z	TRUE
2026-07-18T04:58:18Z	TRUE
2026-07-18T04:58:22Z	FALSE
2026-07-18T04:58:24Z	FALSE
2026-07-18T04:58:28Z	FALSE
2026-07-18T04:58:30Z	FALSE
2026-07-18T04:58:34Z	FALSE
2026-07-18T04:58:36Z	FALSE
2026-07-18T04:58:40Z	FALSE
2026-07-18T04:58:42Z	FALSE
2026-07-18T04:58:46Z	FALSE
2026-07-18T04:58:48Z	FALSE
2026-07-18T04:58:52Z	FALSE
2026-07-18T04:58:54Z	FALSE



Other testing:

- Presence detection was compared to the response of the IR camera module in addition to the ToF (VL531X).
- Overlapping both optics and Body Temperature – Blue shade presents No person detection
- ToF and optical prove person detection with same code

Budget

Subsystem	Major Components	Cost
PSE (Optical Hardware)	TSAL6400 IR LEDs (×8), Photodiodes (×5), Aspheric Condenser Lenses (×2), Miscellaneous	**$232.67**
EE (Electronics)	Photodiode Amplifier, 12 V Power Adapter, Barrel Jack, Buck Regulators, Linear Regulators, Capacitors, Inductors, Protection Circuitry, LEDs/Misc., PCB Fabrication	**$134.01**
CPE (Embedded System)	Storage, MCU, Radar Module, Microphone, MLX90640 Thermal Camera, SD Card Interface, PCB Fabrication, Miscellaneous/Safety Net	**$208.43**
Contingency & Additional Costs	Budget Reserve	**$170.34**
Total Estimated Cost		**≈ $745.45**

Work Distribution

Mason Miles

- Primary System Architecture, & Firmware
- System/Application Software
- Radar Software Library
- Audio Analysis Library
- Microphone PCB Design
- System housing 3D modeling/manufacturing

Jose Ojeda

- MCU PCB Design
- Temp Sensor Software Library
- Application Software
- MCU/Microphone PCB assembly

Colby Toner

- Regulator PCB Design/Assembly
- Optical PCB Design/Assembly
- Power System Design
- Power Supply Protection Design

Edward Perez

- Optical presence detection system design
- LED mount 3D model
- Optical presence detection software and hardware
- Design Optical Circuit

Thank You