Carbon Control

Team 32

Department of Electrical and Computer Engineering

04/28/2022

Introduction

What is Carbon Control?

Carbon Control - An air quality monitoring solution that can determine room safety and ventilation effectiveness.

Some key device features:

- Wireless functionality
- Web Application for individual room monitoring
- Multi-zone deployment capabilities
- Highly integrated package and form-factor

Project Objective and Goals

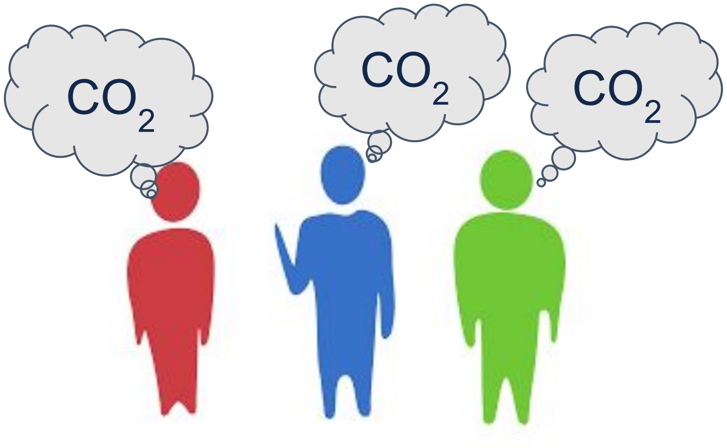
Our aim was to create a device that would:

1. Monitor the CO_2 concentration in ppm.
2. Alert occupants visually and audibly if a room is unsafe - high CO_2 levels.
3. Work with another Carbon Control device in a multi-zone configuration to detect local CO_2 hotspots in a large room.
4. Calculate an air exchange rate (ACH) for an empty room.
5. Provide an online interface for facilities personnel to monitor CO_2 levels and ACH rates for multiple rooms remotely.

Why CO_2?

Humans are contributors of indoor CO_2 above background.

(Satish et al., 2012)



"The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, specifies that indoor CO2 levels be less than 1000 ppm."

(Berardinelli & Christenberry, 1992)

What is ACH?

CDC estimates for time to remove airborne contaminants

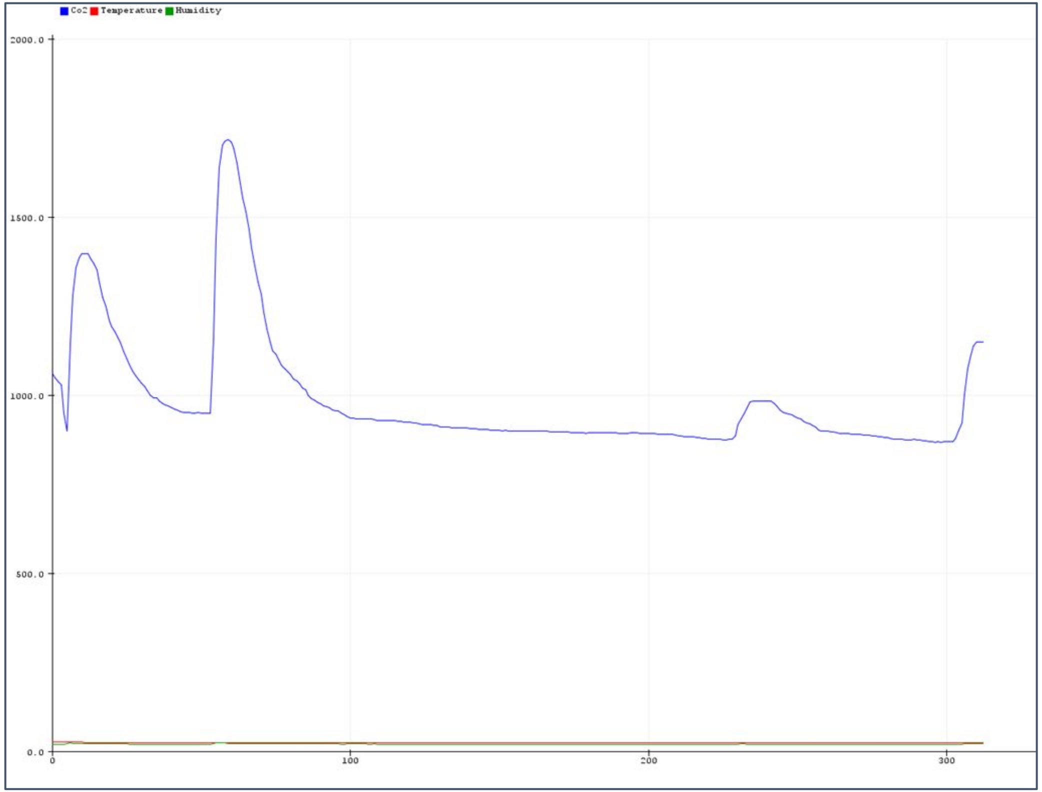
ACH (H^{-1})	Time required for 99% removal	Time required for 99.9% removal
2	138	207
6	46	69
10	28	41
50	6	8

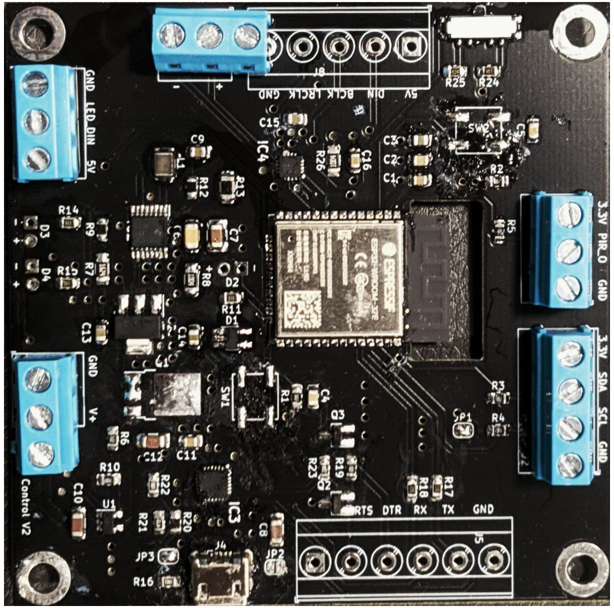
ACH is proportional to the rate of outdoor air entering an enclosed space.

Does not consider how many contaminants there are in the air, only how long it takes to remove them.

Excerpted from CDC Guidelines for Environmental Infection Control in Health-Care Facilities: Appendix B

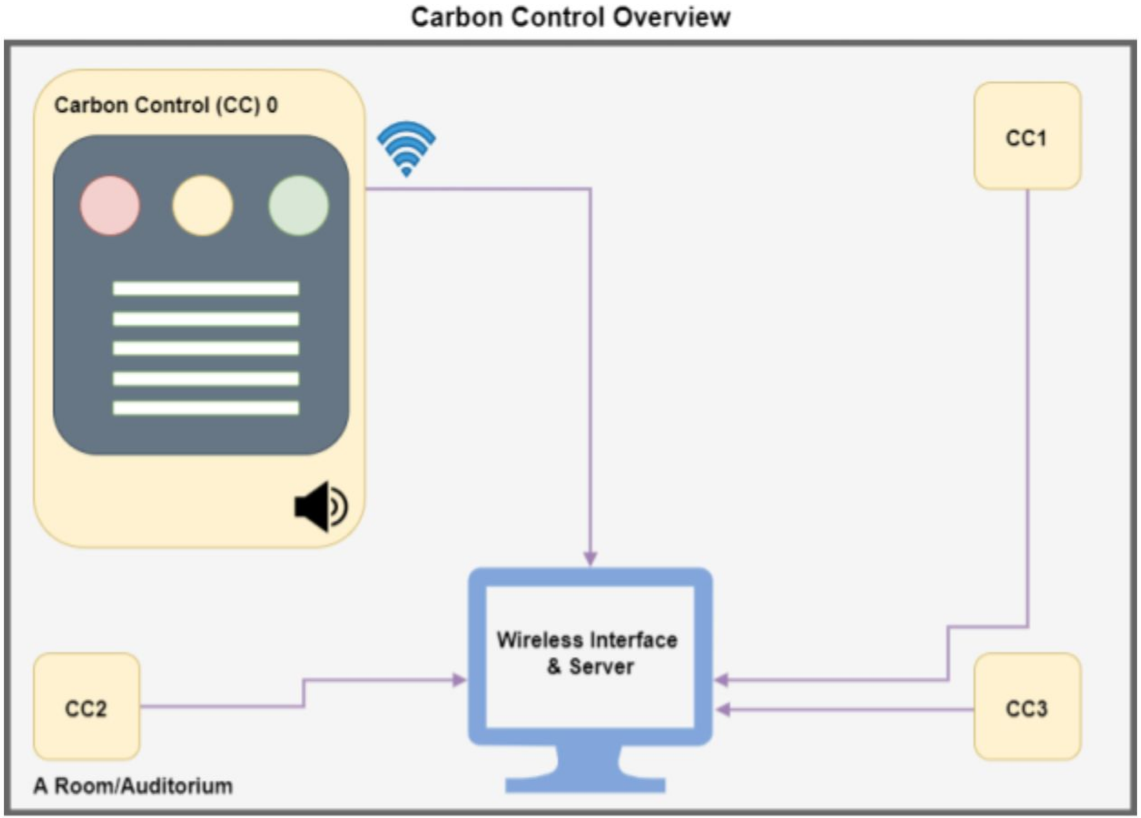
Carbon Control in Action



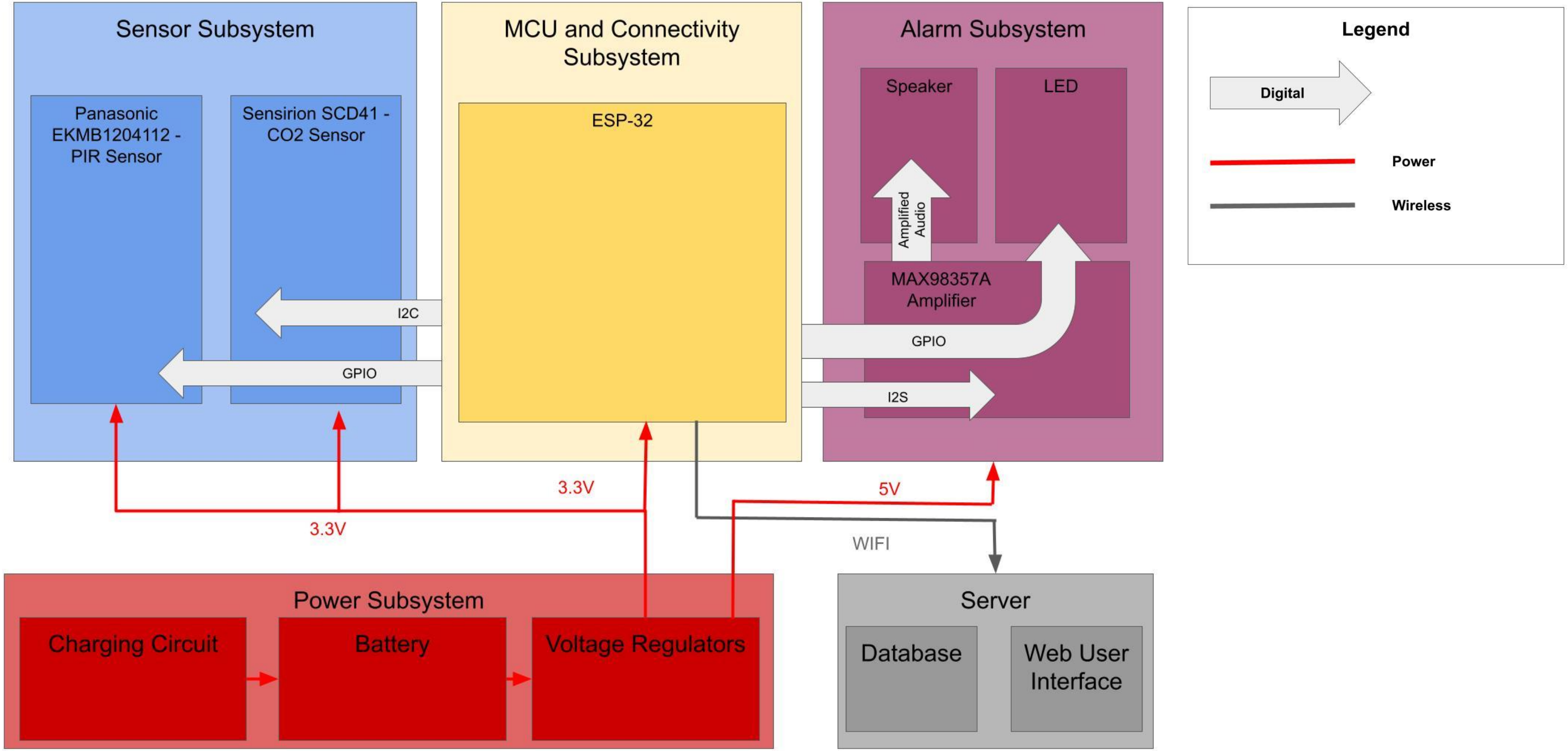


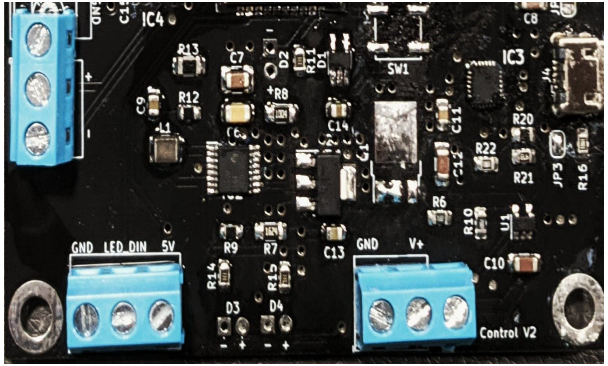
Technical Details & Subsystem Overview

Carbon Control Concept



Block Diagram





The power subsystem has two objectives:

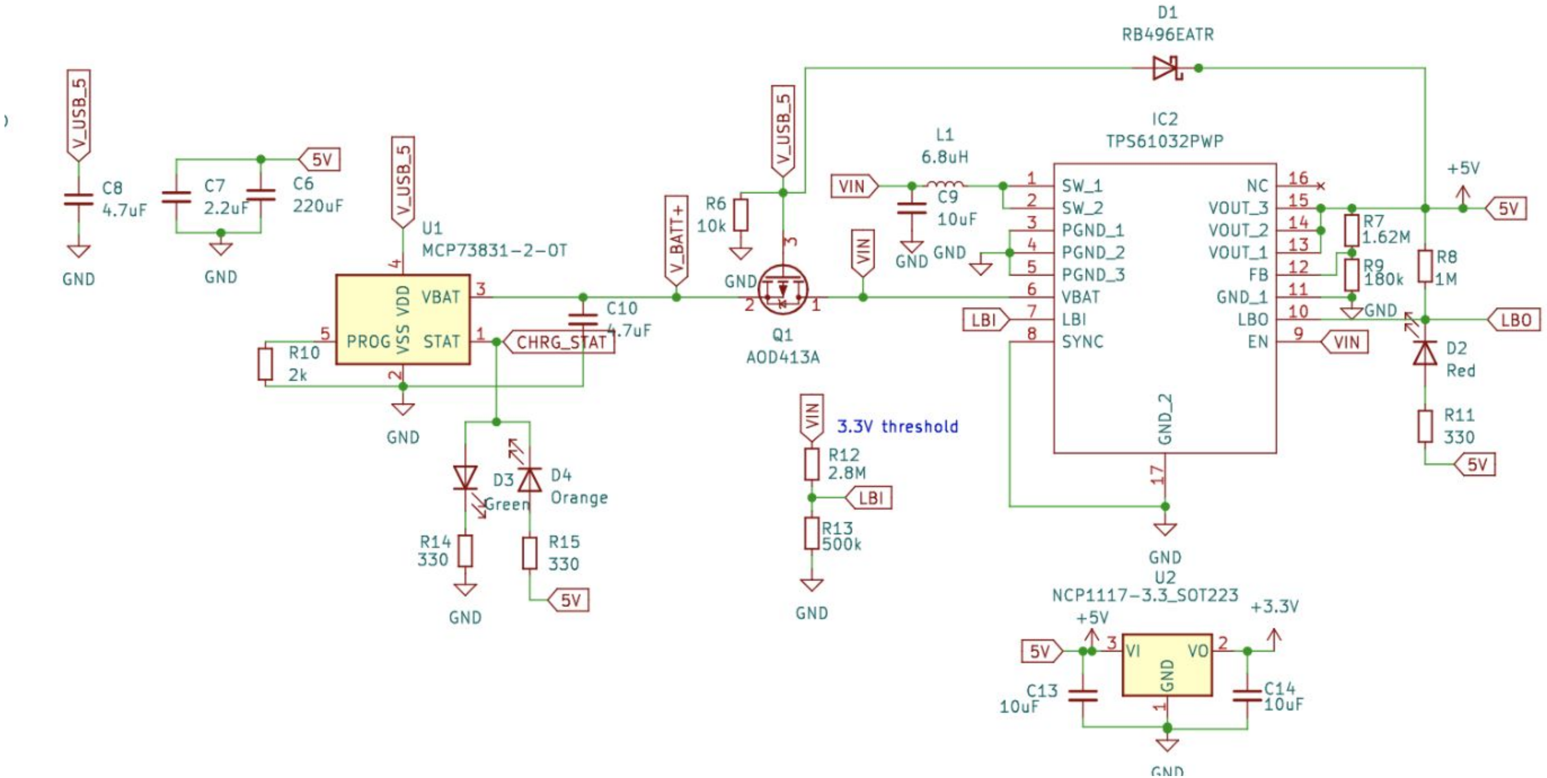
1. **Deliver stable voltages to our other subsystems.**

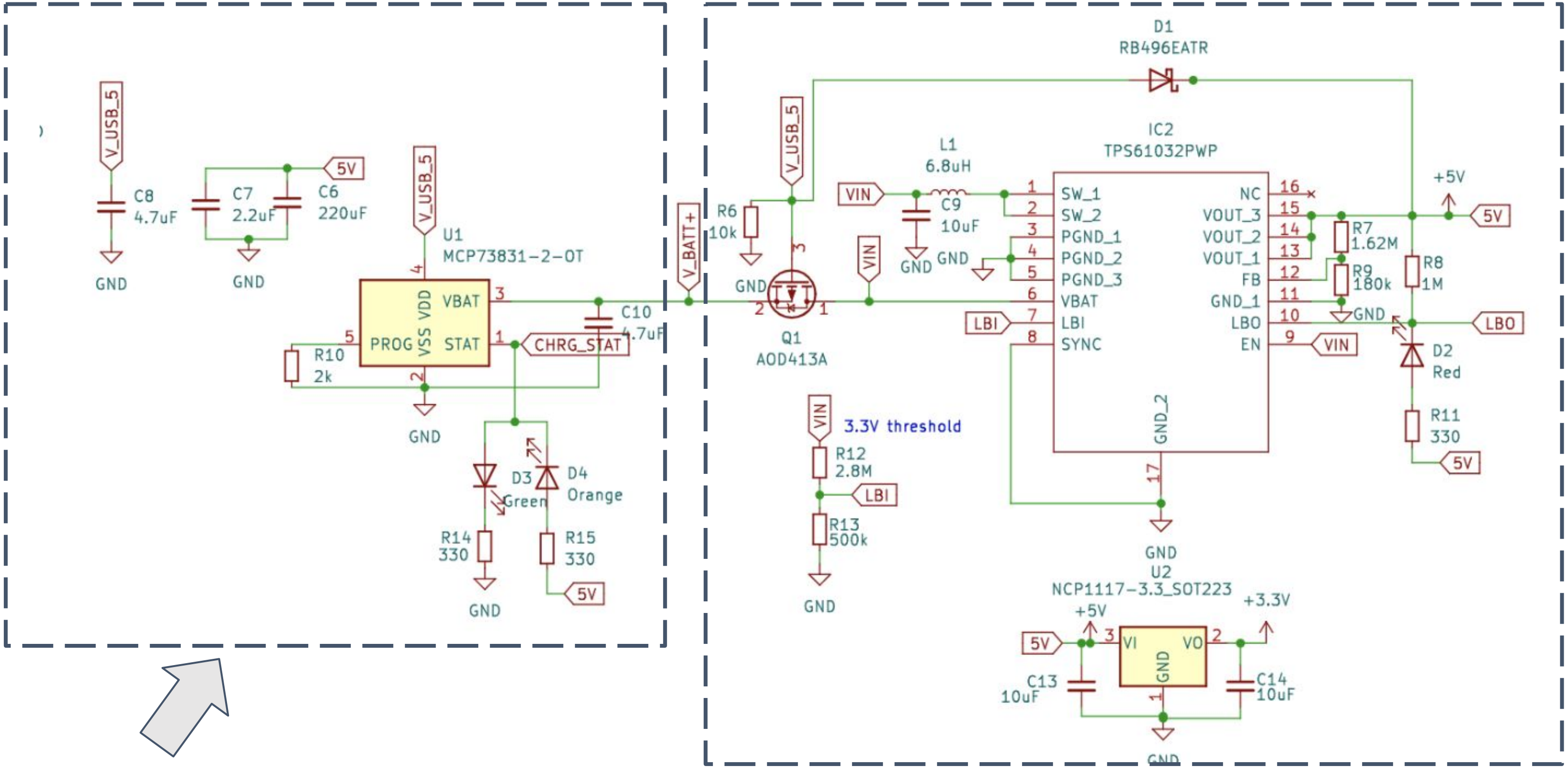
   Our system relies on two power rails: 3.3V and 5V. The 3.3V rail powers most low power ICs such as the MCU & Sensors. 5V are used to power the LED and Speaker.

2. **Charge our battery via USB connection.**

   Our battery charges from the USB 5V power line. The charging can take place while the device is operating normally. A battery charging IC is used to control the charging curve.

Power Subsystem





Battery Charger

Power Rails

Server Subsystem

The server subsystem stores, processes, and displays data.

1. **Store data in database.**

   Our server maintain a database with 6 attributes of past data. This is a MySQL database.

2. **Process data to compute ACH.**

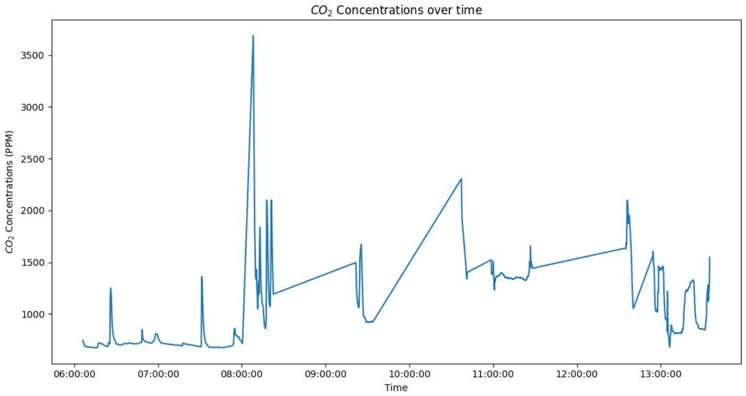
   Our server constantly evaluates the data to see if there is suitable data to compute ACH.

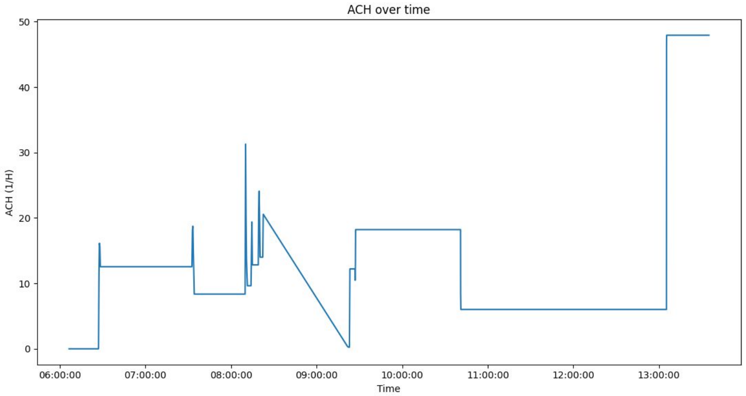
3. **Display data to user.**

   Our server displays two graphs showing the most recent CO2 and ACH.

Server Subsystem

Server Subsystem





Carbon Control Data

CO2	Temp	Humidity	Occupancy	Time	Sensor ID	Room ID
747	23.61	42.0	False	2022-04-25	1	ECEB 1002
738	23.39	42.52	False	2022-04-25	1	ECEB 1002
719	23.19	42.88	False	2022-04-25	1	ECEB 1002
710	23.03	43.19	False	2022-04-25	1	ECEB 1002
695	22.94	43.37	False	2022-04-25	1	ECEB 1002
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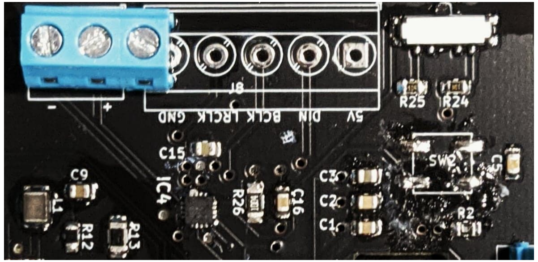
687	22.71	43.66	False	2022-04-25	1	ECEB 1002
684	22.67	43.64	False	2022-04-25	1	ECEB 1002

Alarm Subsystem



The alarm subsystem has two objectives:

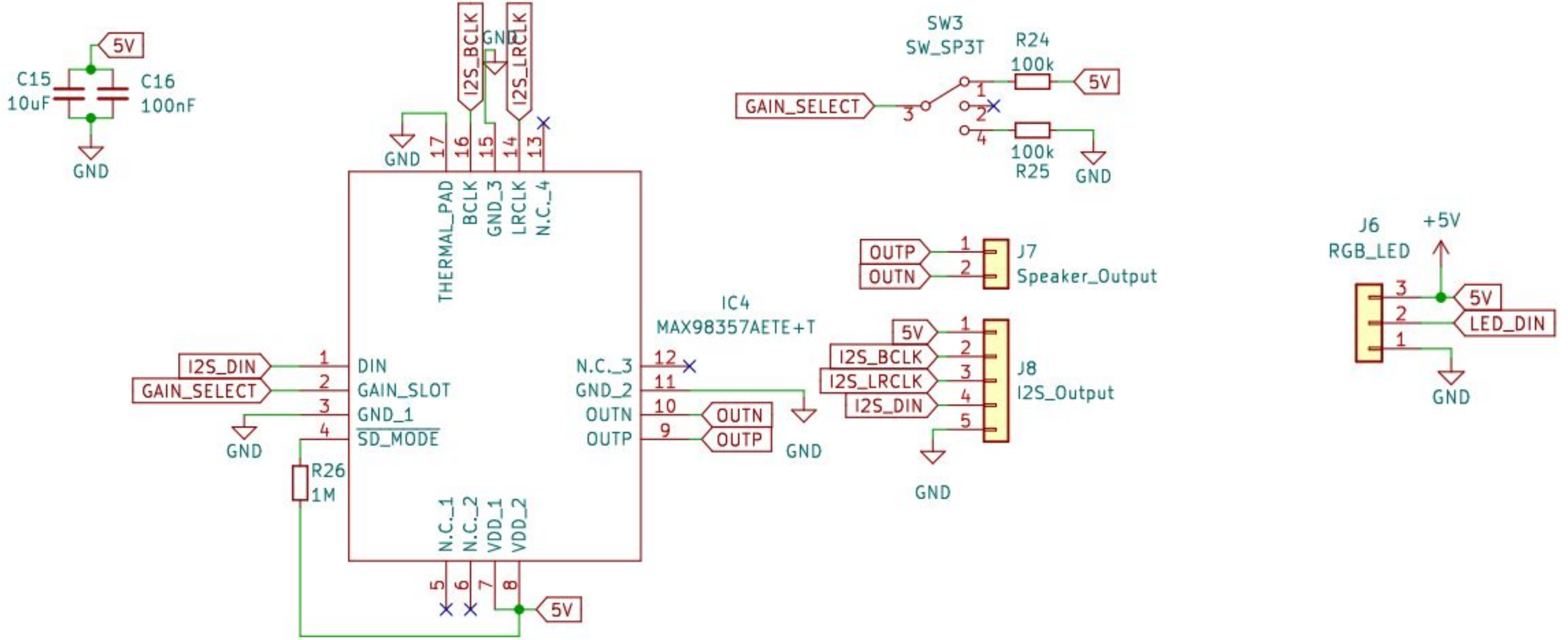
1. **Output green, yellow, and red colors onto an LED.**

   Our alarm subsystem notifies individuals in a room when the CO_2 levels in a room are low, medium or high through a traffic light LED system. The respective thresholds are 1000 and 1300 ppm.

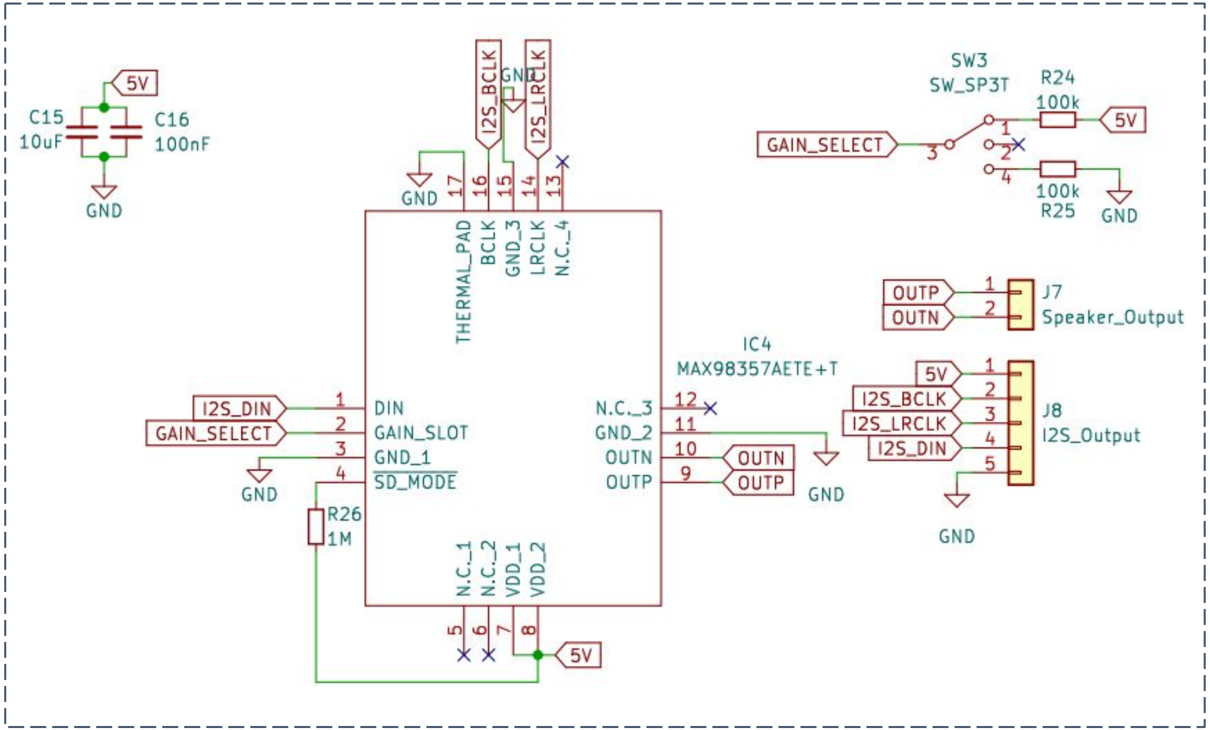
2. **Output an audible alarm through speakers.**

   When CO_2 concentrations are above 1400 ppm, an alarm will sound through the use of a speaker combined with a amplifier/DAC.

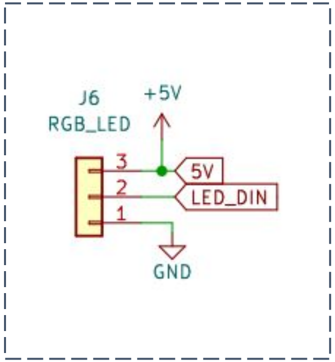
Alarm Subsystem



MAX98357 Amplifier with onboard DAC



Adafruit Flora RGB LED



The alarm subsystem requires power from the 5V rail

The MCU and sensor subsystems satisfy:

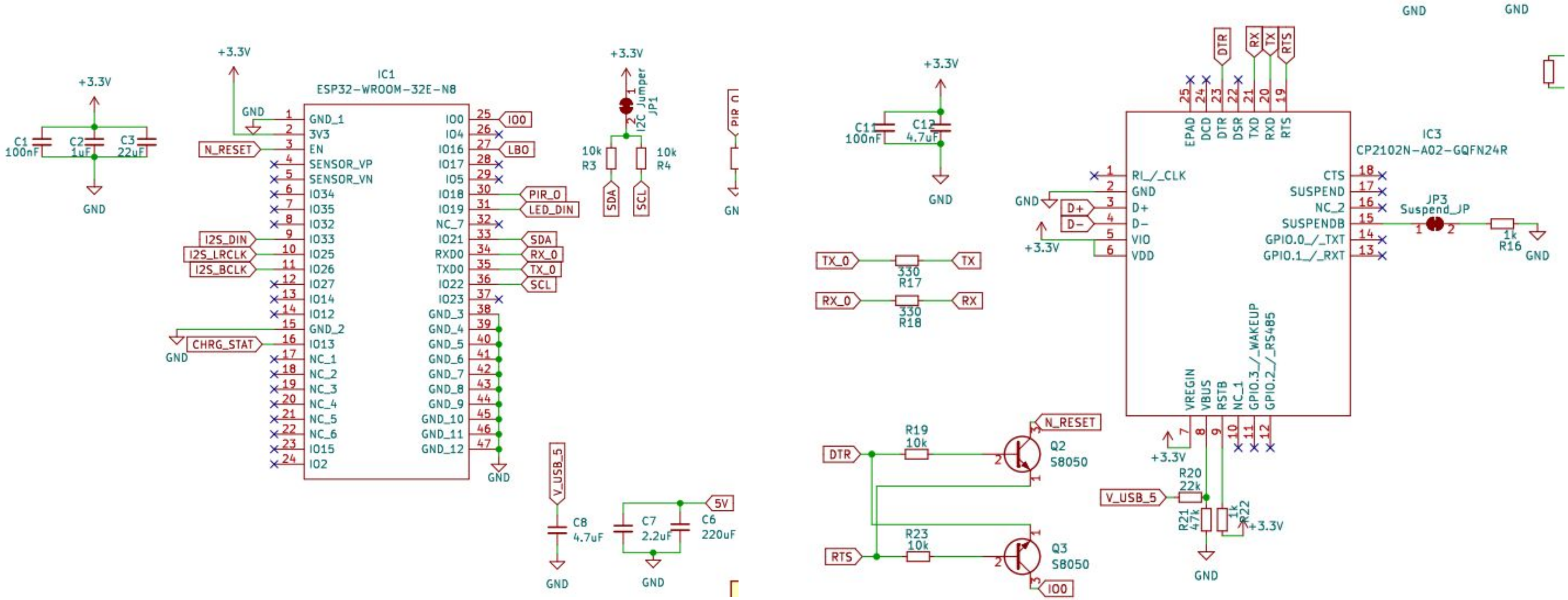
1. **The MCU must be WiFi capable and have sufficient I/O capabilities.**

   We chose the ESP32 WROOM module since it is WiFi capable and easily programmable through the Arduino IDE interface. The ESP32 also features many GPIO pins, so we were easily able to integrate all of our subsystems using a single unit.

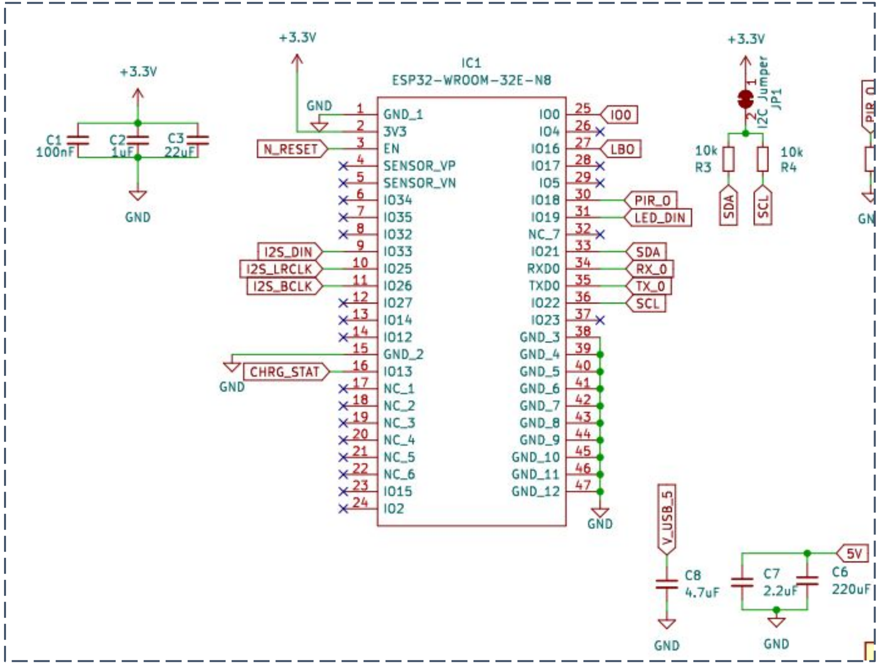
2. **CO_2 concentrations and room occupancies should be obtained via the sensors**

   We opted to use a Sensirion SCD41 CO_2 sensor and a Panasonic EKMB PIR sensor. Both sensors are able to connect to the ESP32 through simple interfaces to relay information to the other subsystems.

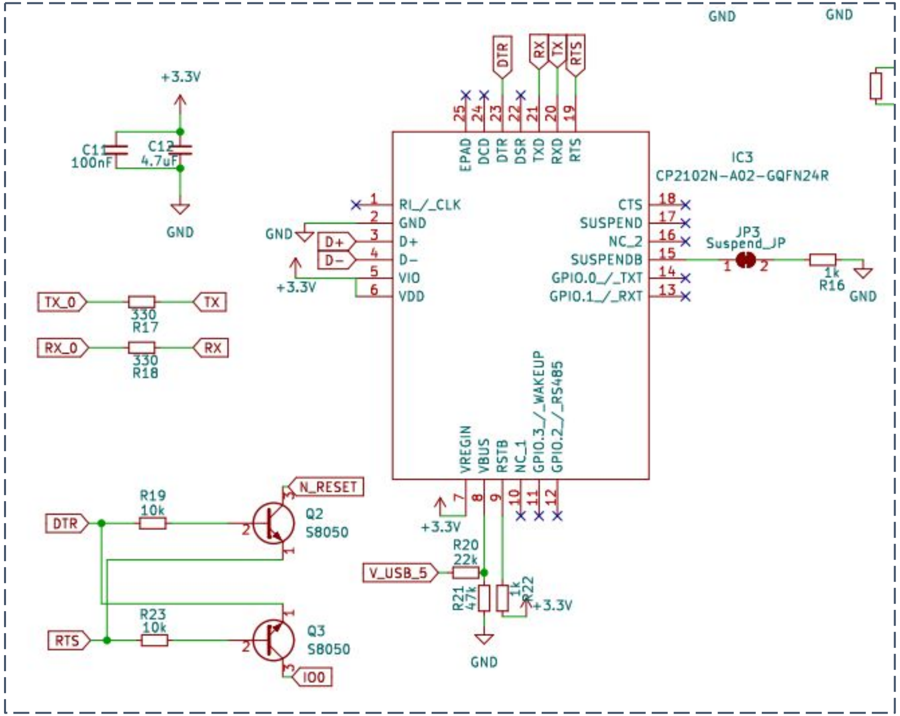
MCU and Sensor Subsystems



MCU and Sensor Subsystems



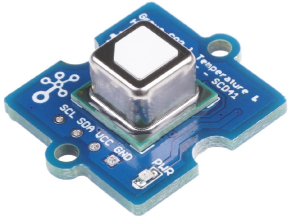
ESP32 WROOM Module



USB to UART - Circuit for Programming

MCU and Sensor Subsystems

Sensirion SCD41 - CO_2 sensor

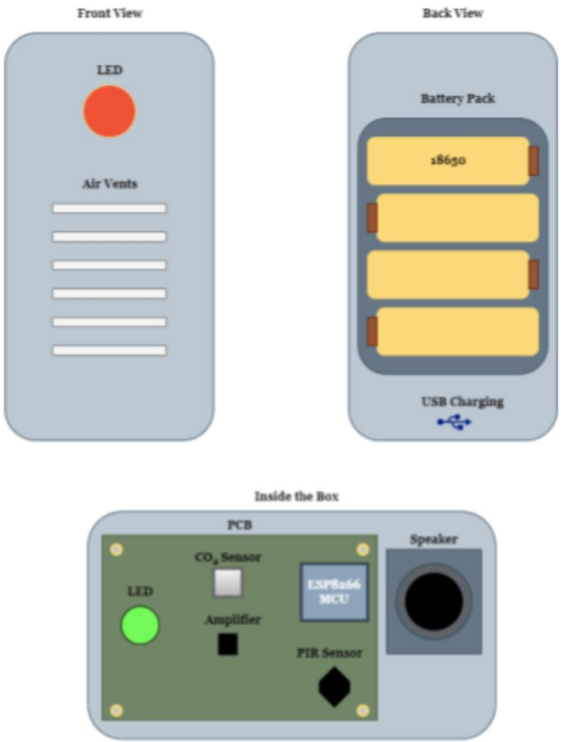


- 400 - 5000 ppm range.
- Response Time < 60 seconds.
- Simple I2C Interface.

Panasonic PIR Sensor

- Industrial-Grade PIR sensor
- Up to 12m detection range
- Wall-mounted type
- GPIO connection

Physical Design

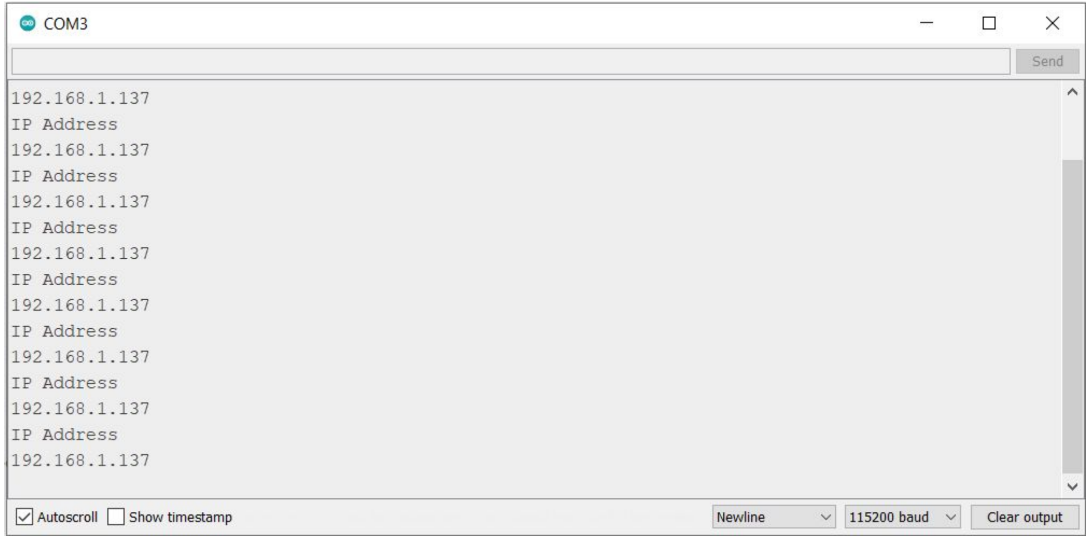


Concept

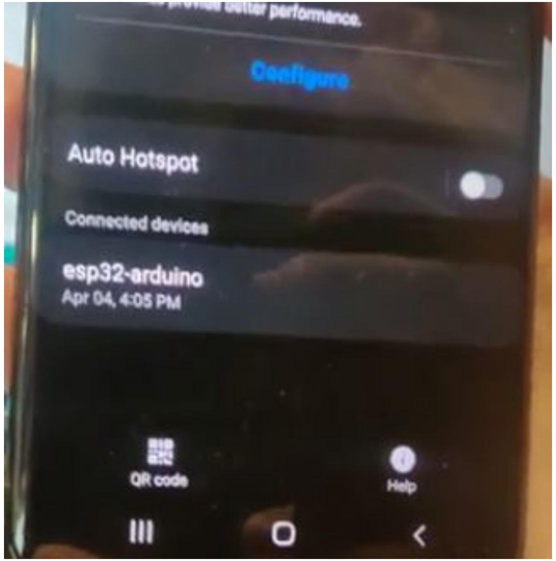
Actual

Subsystem Results

Successful Internet Connection

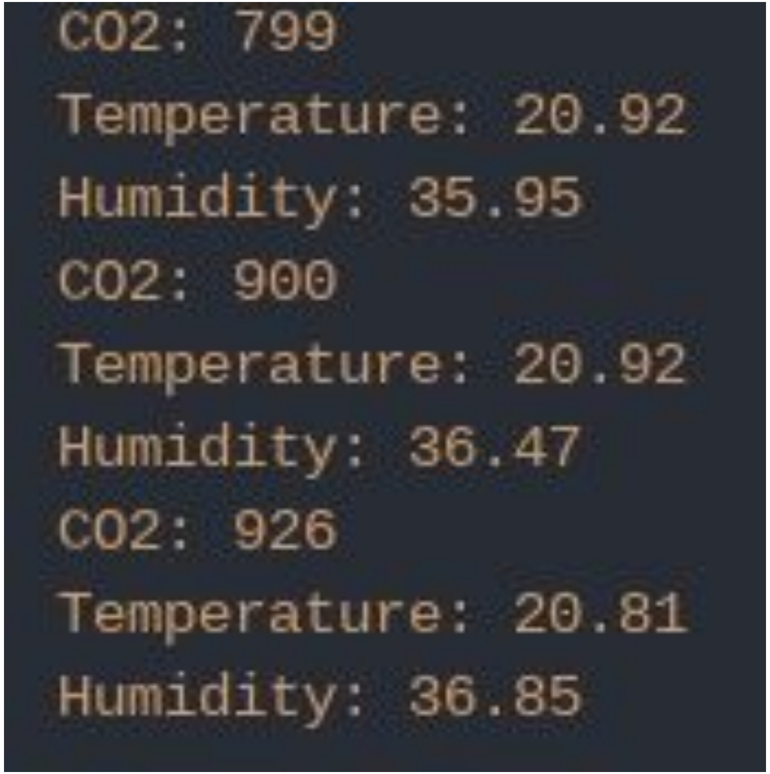


ESP32's IP Address

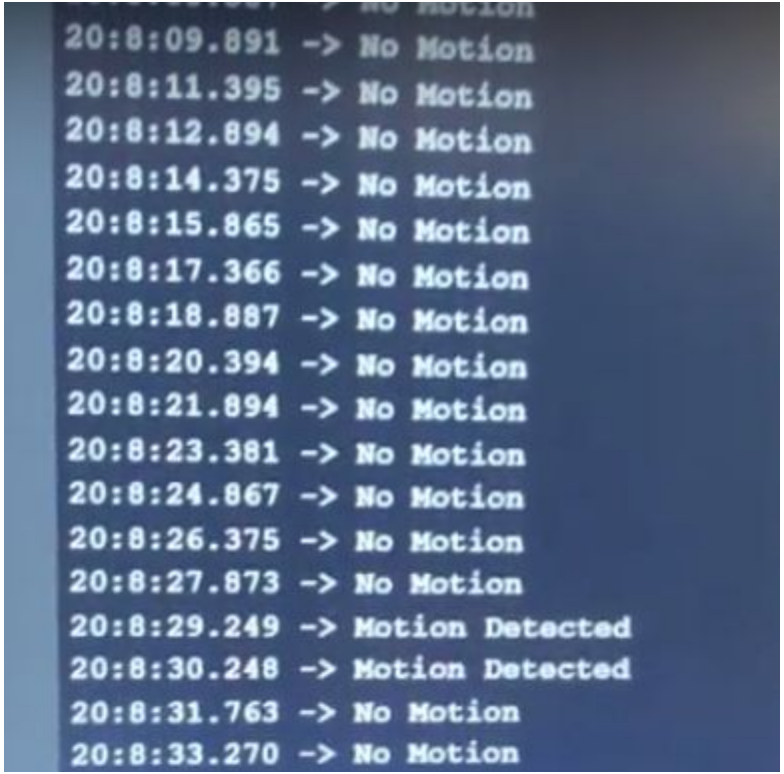


Hotspot showing ESP32

CO_2 and PIR Sensor Readings

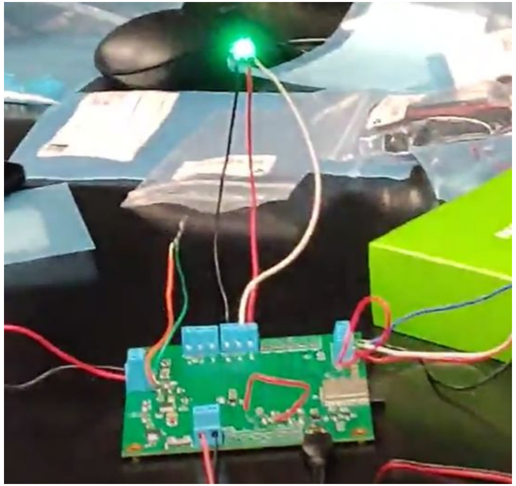


Co2 sensor

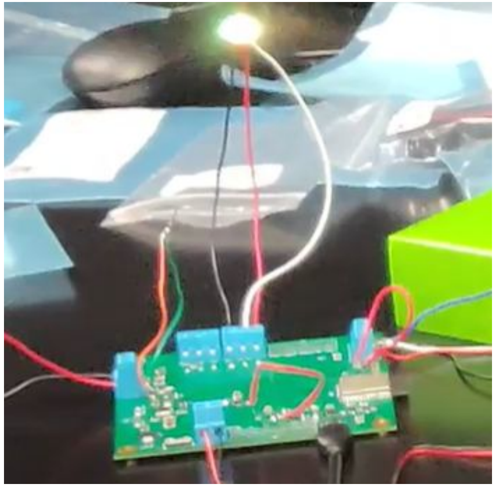


PIR sensor

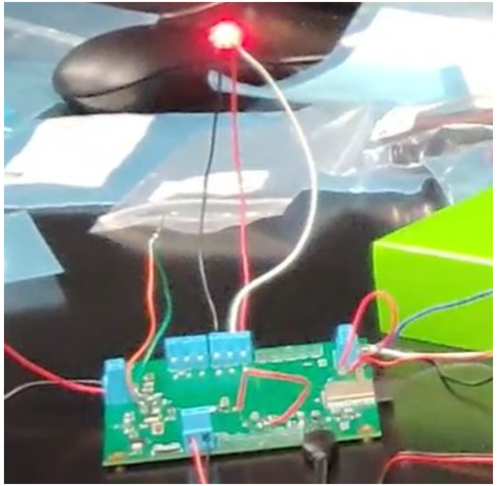
“Traffic Light” LEDs



Green

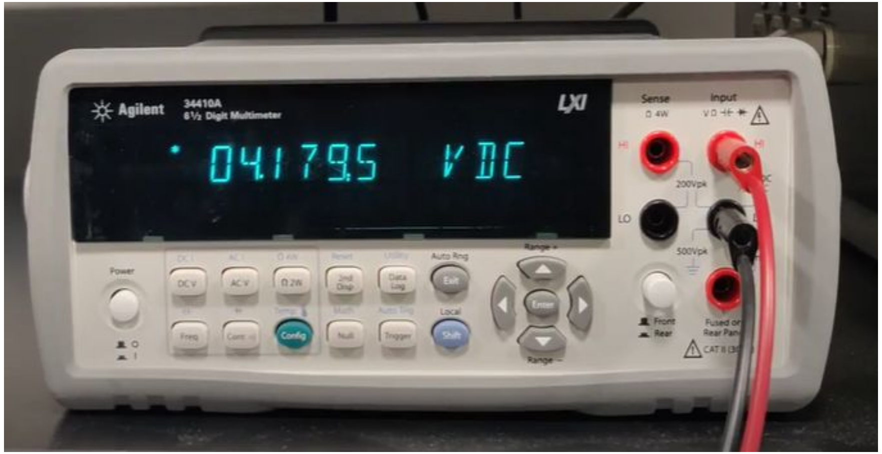


Yellow



Red

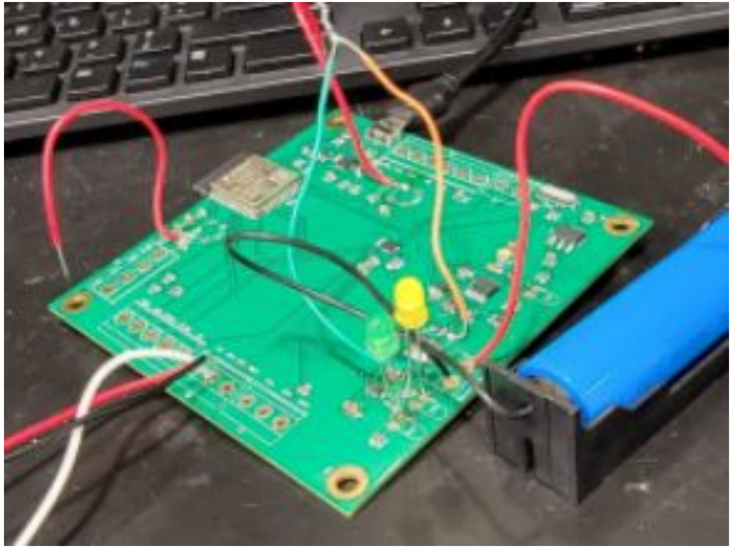
8 hour battery life



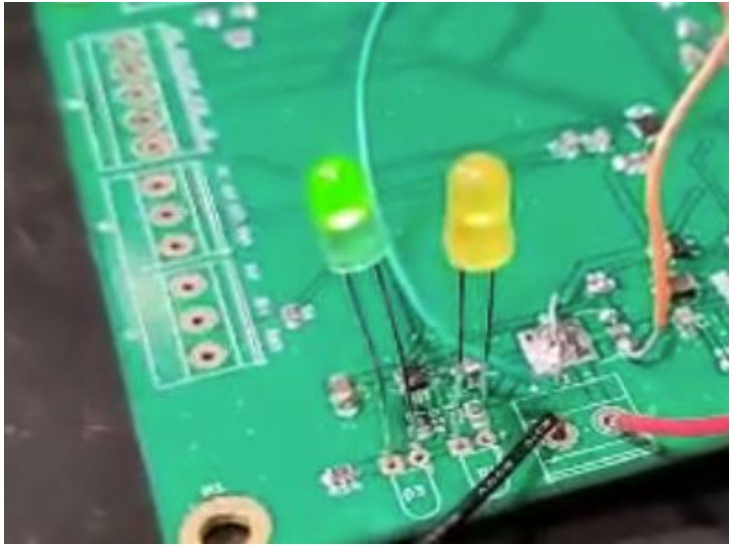
Fully charged battery

Battery after 8 hours

Charge Status Indicators

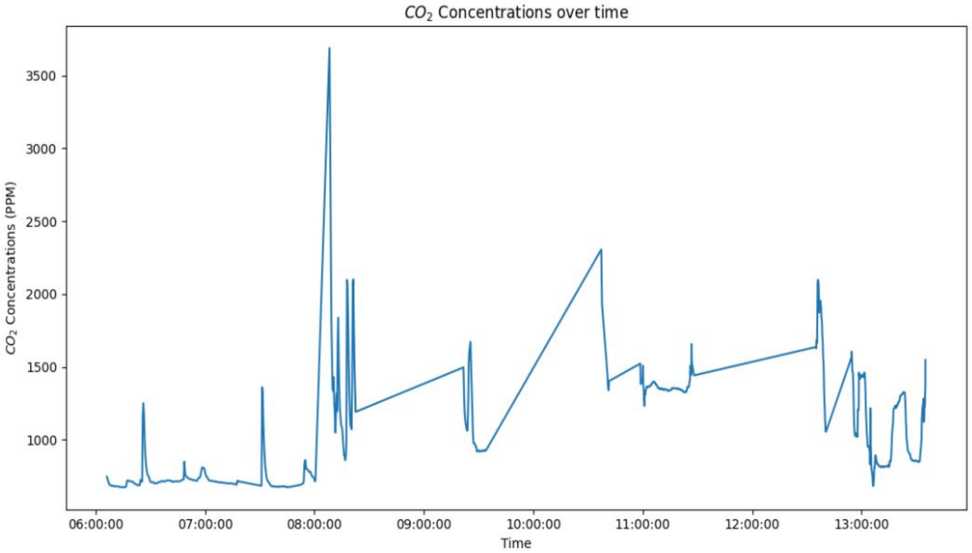


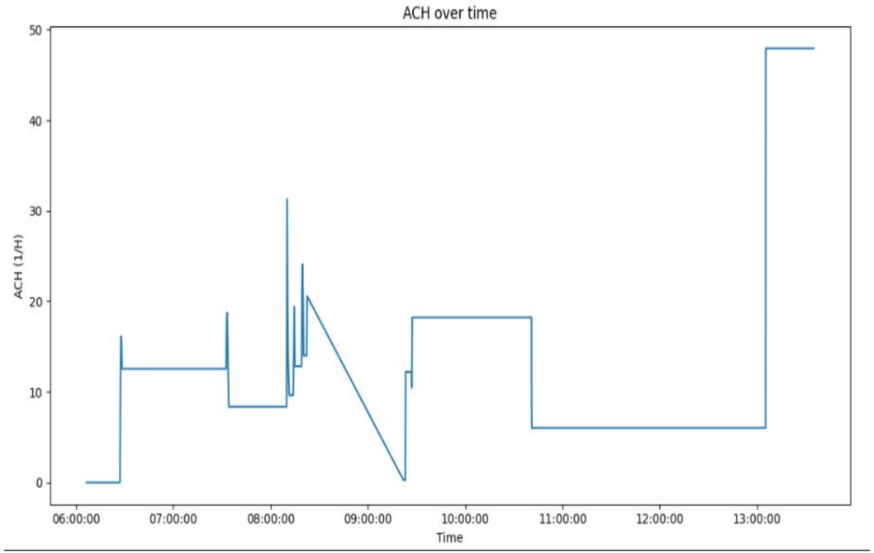
Yellow charging status LED



Green charged status LED

Live Graphs of CO_2 Concentration and ACH readings





Server Database Entries

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Concluding Remarks

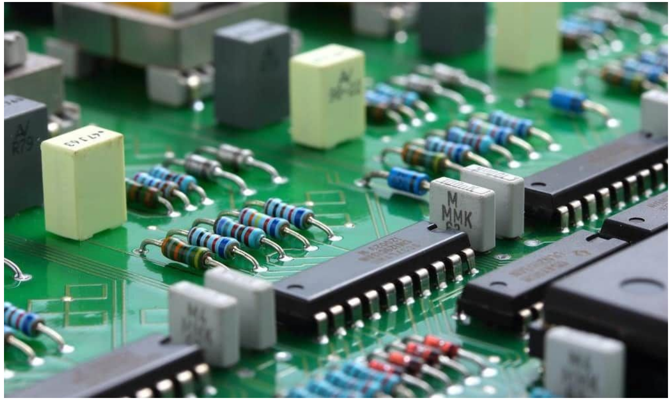
Knowledge Gained and Future Changes

What We Learned

- Product development lifecycle
- Reflow soldering techniques & manufacturing
- Schematic design and PCB layout
- Product costs and the global economy

What We Can Do Better

- Compact form factor
- Dynamic web-server
- Enhanced feature-set
  (mesh network or cellular)

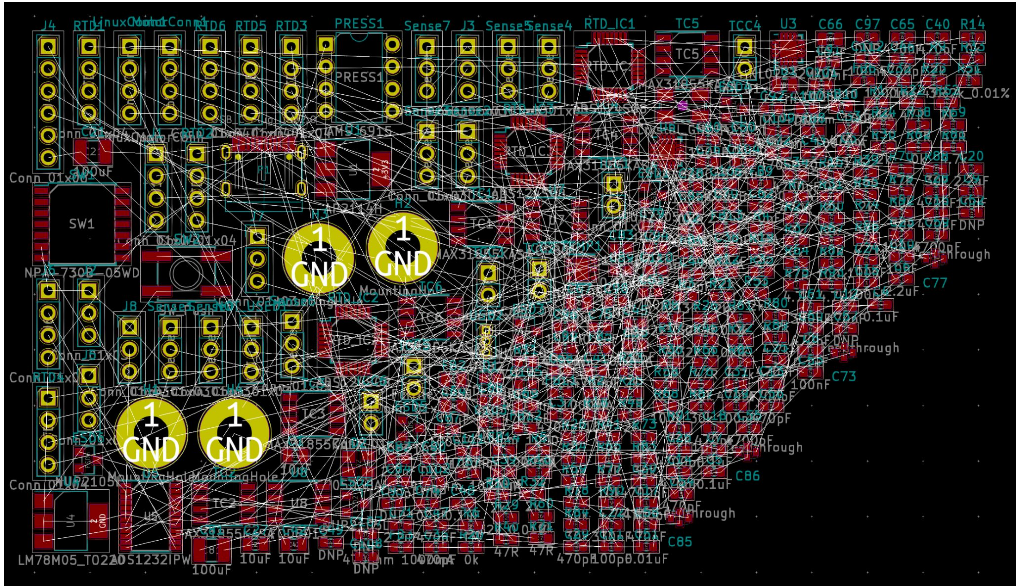


Challenges

Some Hardships We Faced

- Debugging a KiCad footprint error
- MCU programming configuration
- Impromptu design changes
- International Shipping

DHL EXPRESS



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