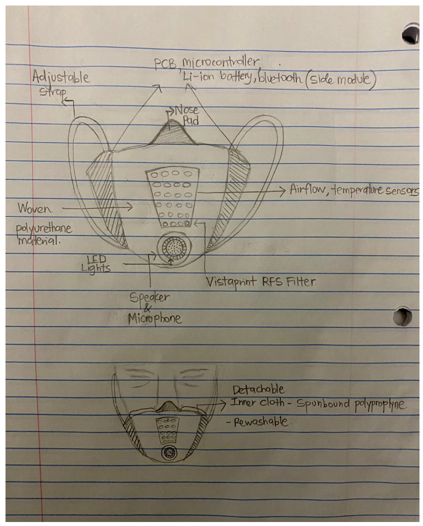
eAiR

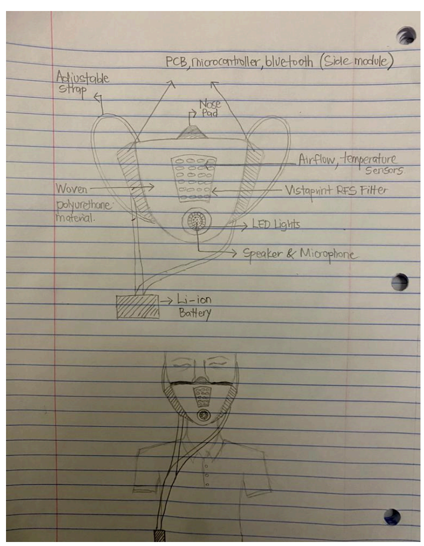
Team 14

Ryan Strefling, Yul Hee Cho, Dishawn Thiran, Shivendran Gandhi

Design Document - Rev. 2.0



PRODUCT SKETCH - ATTEMPT 1



PRODUCT SKETCH - ATTEMPT 2

TA: Matt Bliss

Professor: Peter Bermel

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Revision Log

Date	Revision	Changes
23-Jan-2021	1	Initial Release
25-Jan-2021	2	Added System level Activity Diagram & Team Structure
01-Feb-2021	3	Added System level Block Diagram
07-Feb-2021	4	• Added individual Subsystem Design, Modified Block and Activity Diagram • Updated Design requirements 5,6 and 7 and corresponding User story • Added bibliography
28-Mar-2021	5	• Updated Design Design requirements • Updated all individual subsystems content • Added new section - (PCB design) • Updated System Block diagram and added System Mechanical diagram
28-April-2021	6	• Added a Glossary • Updated Activity Diagram • Added new subsections under System Overview - (Integration Approach and System Photographs) • Updated all individual subsystems content • Added new section - (Final Status of Requirements)

Table 0.1: Revision Log

1 Introduction

1.1 Executive Description

A smart mask ensures everyday life experience to be easier compared to normal masks. It is for sure that life without a mask sounds better, but in this pandemic, if you have to choose one, a smart mask would definitely be a better option. A smart mask offers an auto-filtering sensor that would prevent the users from inhaling contaminated oxygen, a bluetooth connected communication system that would make it easier to interact with cell phones without taking off the mask. Moreover, the mask would enhance the quality of the voice coming through the mask by manipulating the amplitude that comes in as an input through the built-in microphone of the mask. Unlike other masks, the smart mask is a rechargeable device so multiple uses are allowed. Thinking about both economic and convenience aspects, the smart mask would be a reasonable pick.

1.2 User Story

Terry the entrepreneur and innovator has always been a social person. Due to the coronavirus pandemic, Terry was unable to drink with his friend, Cruise, in Cactus without exposing himself and others to the virus. Frustrated with not being able to celebrate in Cactus before it's closing, Terry decides to come up with a device idea that will allow him to party all night long with his friends without putting his friend and himself in risk. Terry dances in joy with his idea of a smart face mask that has safe rechargeable batteries to minimize waste. Terry takes it to the next level with battery life monitoring to inform him when to charge the mask as well as a battery protection unit to protect the battery source.

Terry's favourite movie is Iron Man and therefore, had a light bulb moment to include bluetooth communication in the smart face mask with your mobile phone, an audio feature that includes a microphone and speaker to prevent muffled speaking, sensors that detect breathing movement to inform him of filter changes. Terry wants to know if he has a fever, and therefore, includes sensors to inform him if his body temperature is higher than normal indicating a fever which he will be alerted with a red LED. Terry is going to invite everybody he knows to drink with him and sell his masks to them. He will make billions. Terry is now thinking of changing his legal name to Tony Stark.

2 Design Requirements

2.1 Requirements

1. Receive Audio by mask microphone, and send the data to the phone through bluetooth
2. Receive Audio through bluetooth from phone, and project the data through the mask speaker
3. Temperature sensors that can read the temperature of the person, and alert an LED when temperature resembles a fever
4. Airflow sensors that can read the airflow coming out of the filter, and if the airflow is too low, will alert an LED on the mask to replace the filter
5. A safe rechargeable power supply sufficient to power the mask for 8 hours at a time
6. A rechargeable power supply that outputs a regulated 3.3VDC
7. Monitor battery life constantly and informs the user, by alerting an LED when battery level is low
8. Battery management circuit to prevent battery failure
9. Informs user when input charging source is valid and when battery is charging through LED's
10. Mask Speaker should amplify the volume of the talking input received from the microphone and output an amplified volume talking output
11. Detachable inner cloth of the mask for washing purposes

2.2 Factors influencing requirements

1. Public health, safety, and welfare
    - In order to preserve the safety of people, these masks prevent germs from being spread which could potentially be lethal.
2. Global factors
    - Masks are required for global travel, which our masks will allow.
3. Cultural factors
    - Masks are increasing in popularity for when people are feeling sick. We want to design a mask that is both comfortable, and provides ease of life with using your phone.
4. Social factors
    - The masks allow for speech to no longer be muffled, and people to connect with their friends through phone connection
5. Environmental factors
    - The masks are designed with a rechargeable battery to eliminate e-waste from disposable batteries
6. Economic Factors
    - The masks are made with quality materials that will not degrade too much over time, making the mask affordable for all

3 System Overview

3.1 System Block Diagram

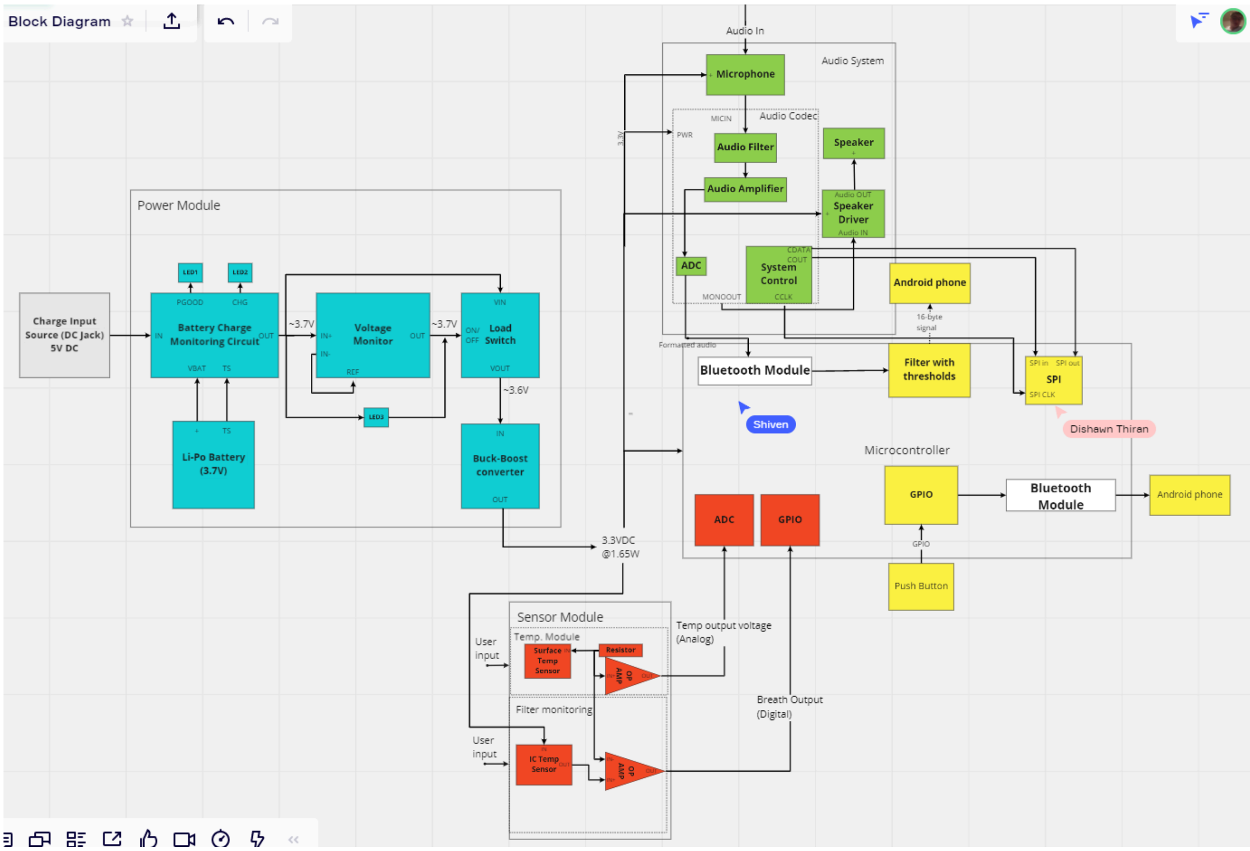

Figure 3.1: System level UML2 Block Diagram

3.2 System Activity Diagram

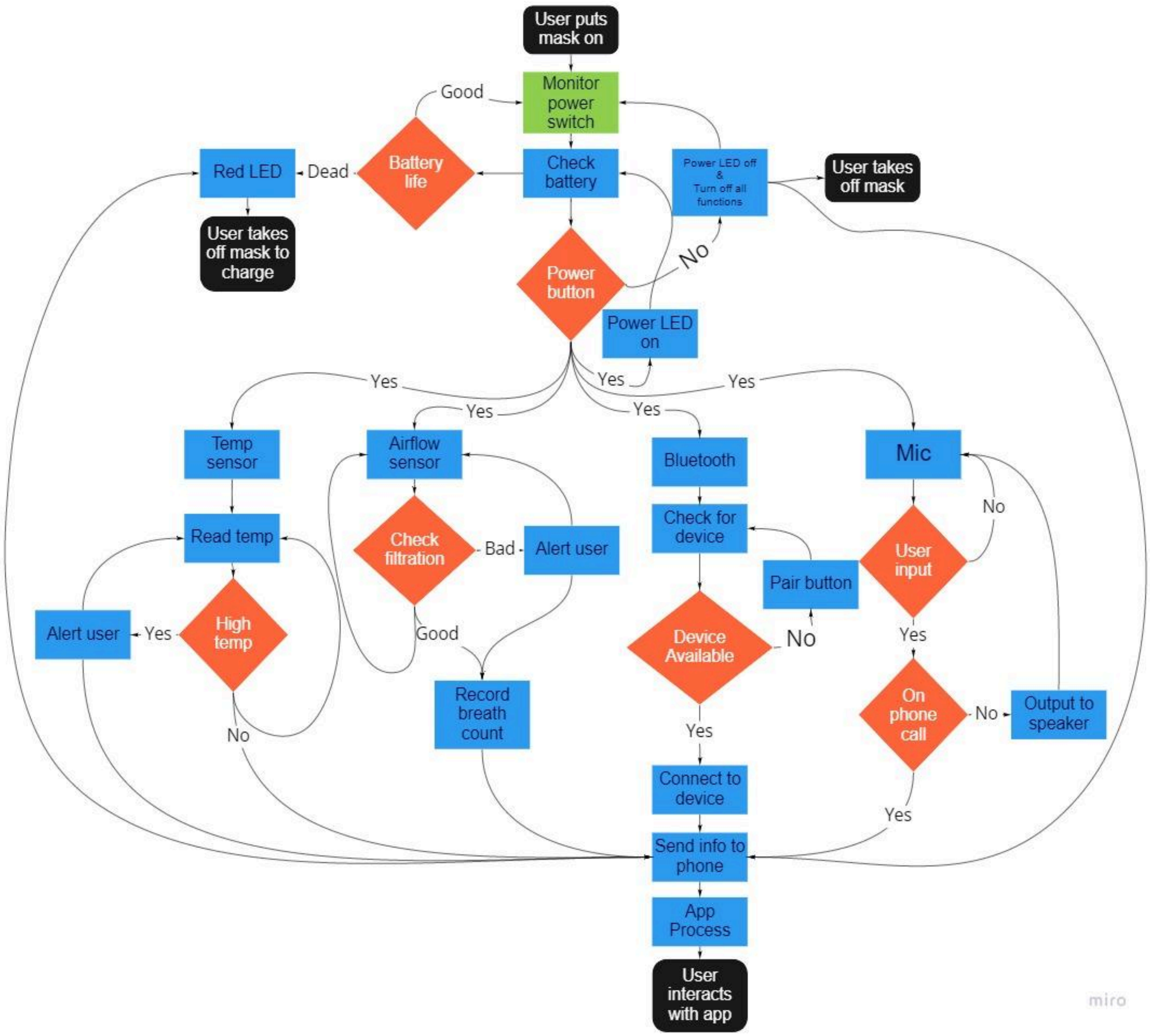

Figure 3.2: System level UML2 Activity Diagram

System activity description/diagram

- Monitor filter wear
  - Determines if the filter needs replacement. If the filter does need to be replaced the user will be alerted via phone app. Only works if the device is powered on.
- Monitor speech
  - Monitors if the user is talking and then determines whether to output the user's voice to the speaker or send it to the connected device if the user is on a phone call. Only works if the device is powered on.
- Monitor battery life
  - Continuous monitoring of battery life to ensure proper code functionality to minimize bugs. Always monitoring until battery life becomes too low.
- Monitor temperature
  - Monitors the user's temperature to determine if the user is running a fever or not. If the user is running a fever the mask will notify the user. Only works if the device is powered on.
- Monitor device connection
  - Will determine if there is a available device to connect to. If there is no available device the user will have to manually connect a device with a sync button. All data is processed in the mask and passed to an external device via bluetooth. This only works if the mask is powered on.

3.3 System Mechanical Design

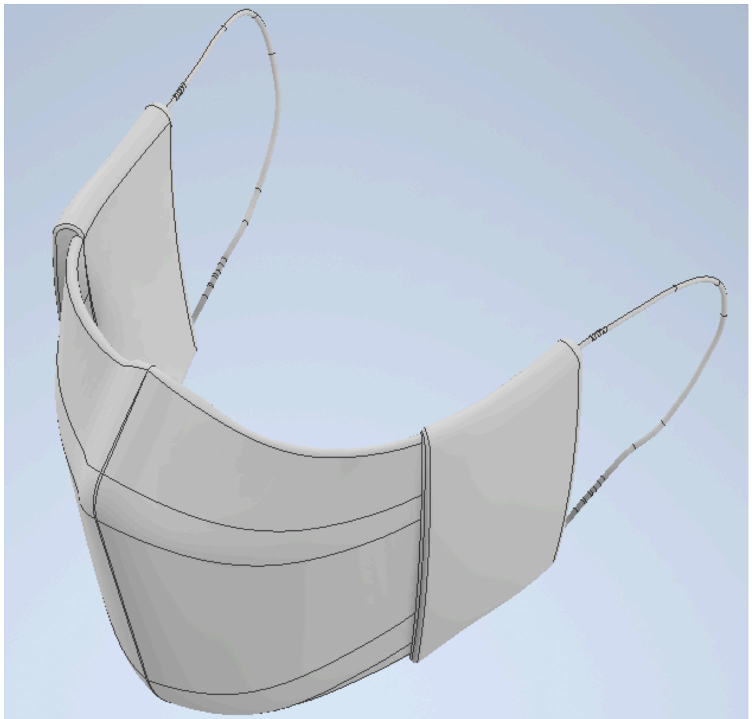

Figure 3.3: Orthographic View of Mechanical Design

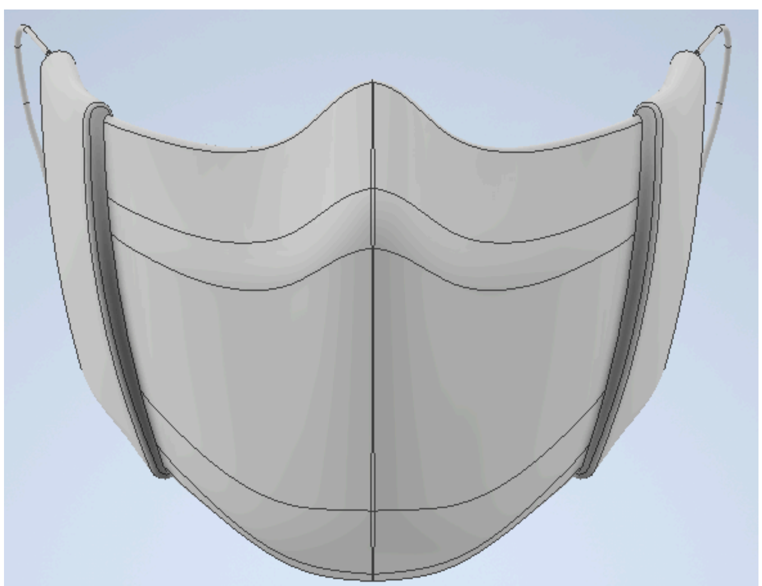

Figure 3.4: Front View of Mechanical Design

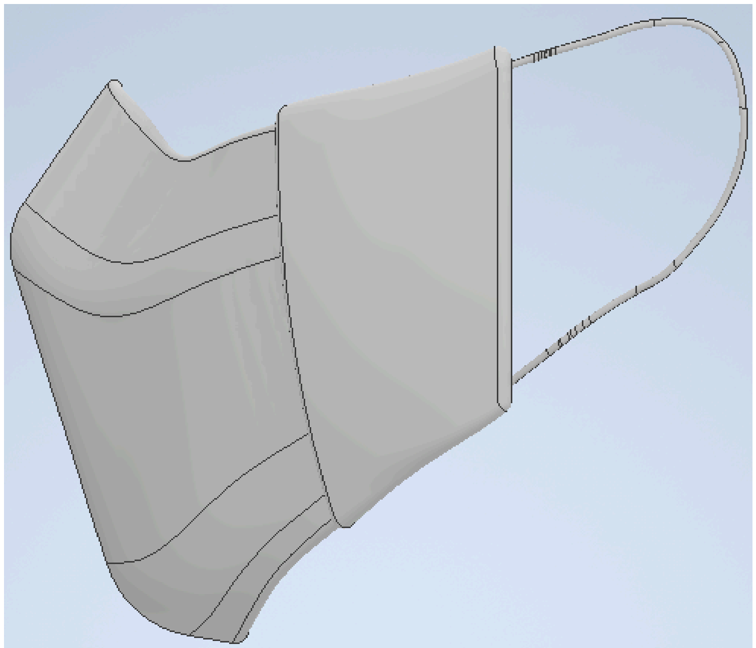

Figure 3.5: Side View of Mechanical Design

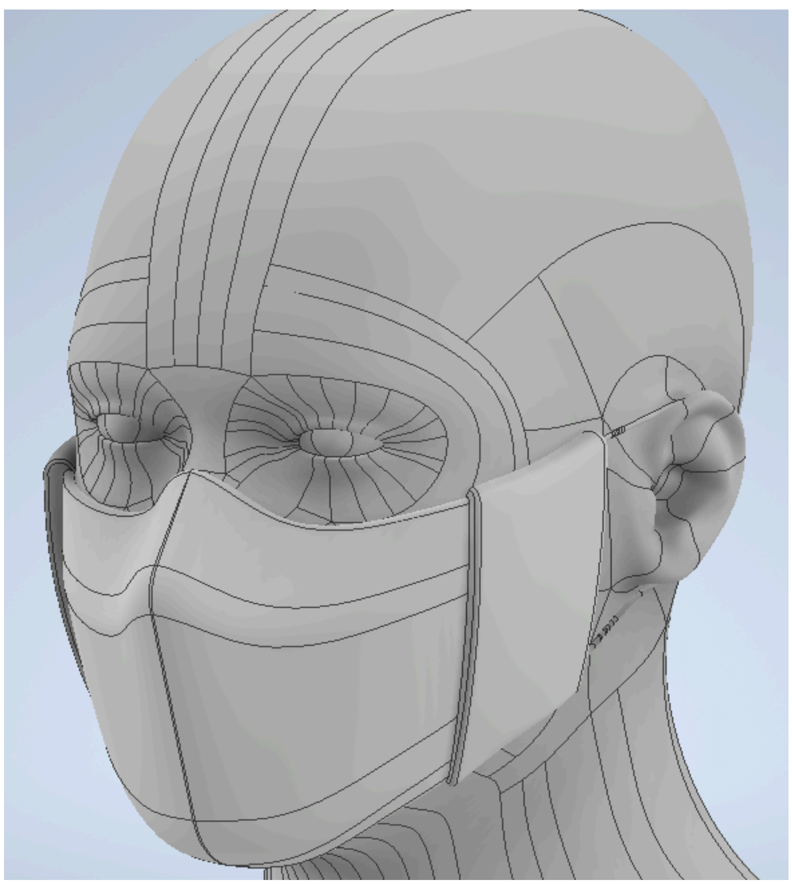

Figure 3.6: Modeled View of Mechanical Design

3.4 Integration Approach

The audio subsystem works with the communications of the microcontroller in converting analog audio input into a digitized signal to send to the bluetooth module in I2S audio format. This is accomplished by an ADC in the audio codec. Once the signal is digitized at a respective sampling rate, the data output is sent to the bluetooth module "data input" along with a bit clock to determine the clock for each bit in a frame, as well as a frame clock to be a measure of the frame speed. Each of these clocks can be set from programming and derive off the Master Clock signal on the audio Codec which derives off the oscillator included in the ESP32. The Audio Codec is loaded to sample at a specified rate(44.1kHz) to the ESP32. Audio in this format can be sent from the ESP32 to the Audio Codec as well and through its internal DAC, the codec can then output an analog signal to send to the speaker driver for playback. All of the audio subsystem draws power from a 3.3V line from the power subsystem.

The temperature sensor and breath sensor operate under 3.3V. The breath sensor needs the temperature sensor to function properly since the temperature sensor provides a base voltage for the breath sensor. The breath sensor communicates with the ESP32 via GPIO and the temp sensor communicates with the ESP32 via ADC. This data is then processed through the ESP32 and sent over bluetooth to be displayed by a mobile device.

The power module was chosen to sit on the right side of the mask and kept away from the rest of the circuit to prevent any interference. The filter, speaker, mic, and breathe sensor were mounted on the front of the mask for symmetry and direct flow of air and voice. The rest of the components were mounted on the left side of the mask and tightly consolidated to reduce bit error.

3.5 System Photograph

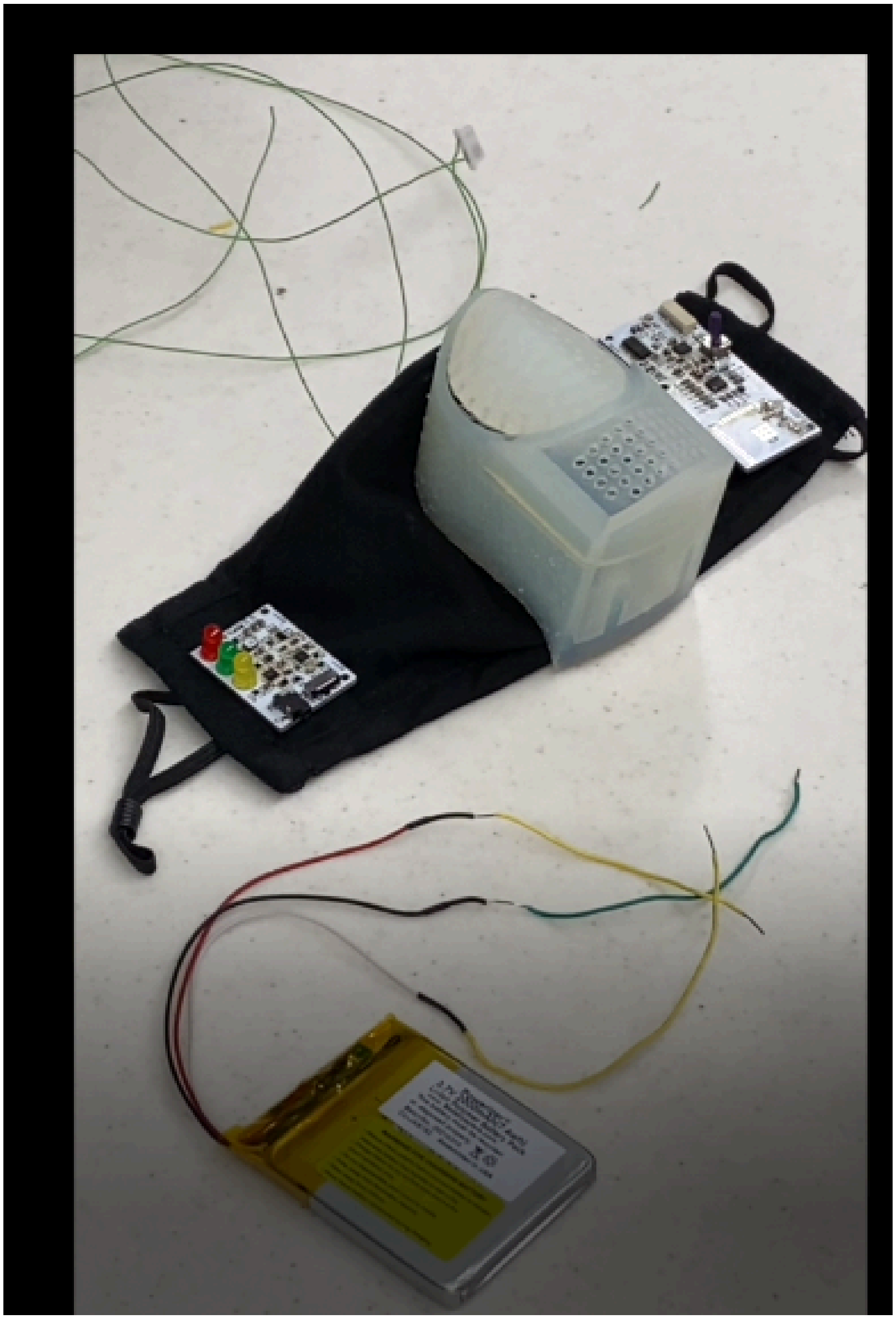

Figure 3.7: Outer View System Prototype

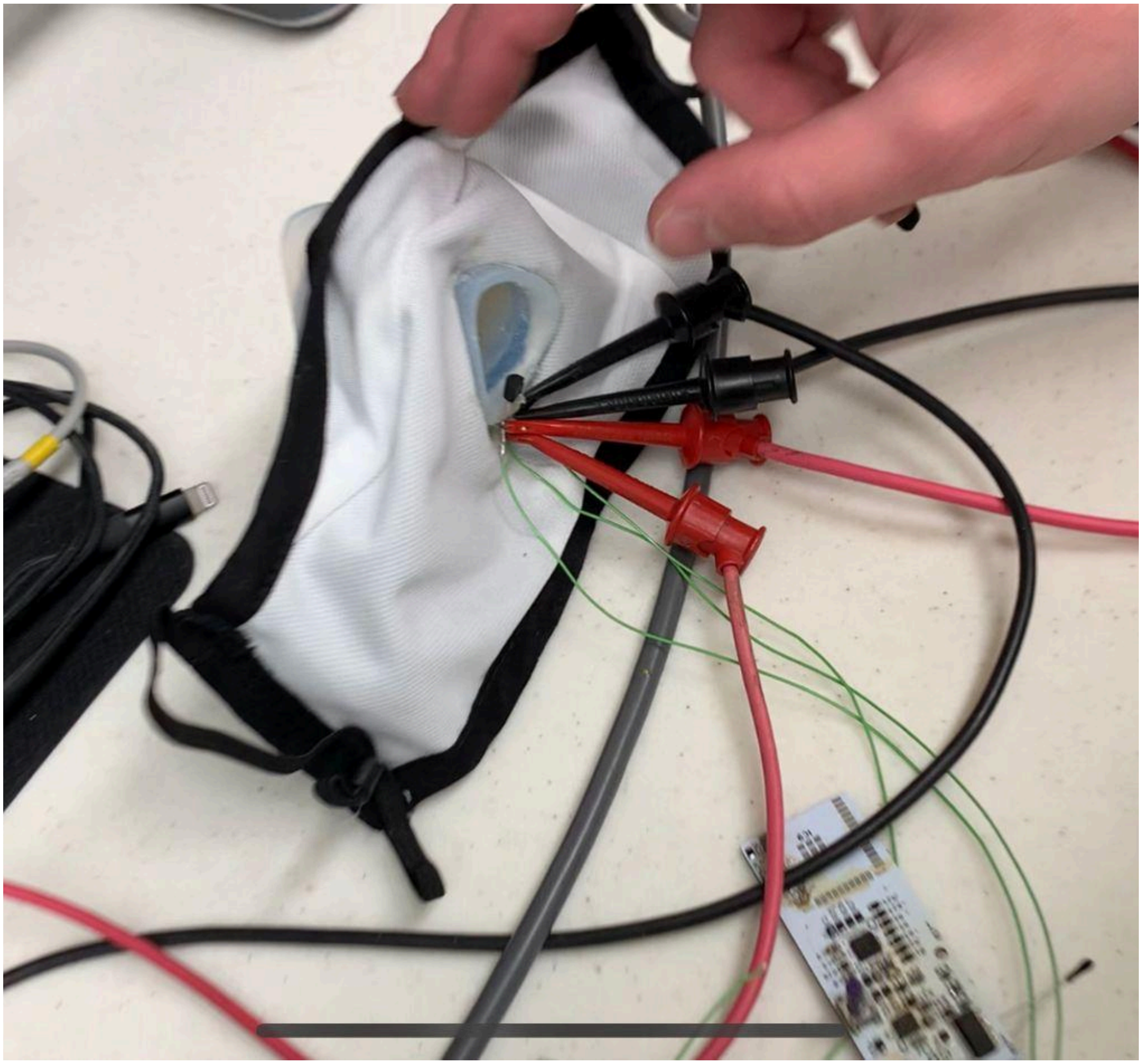

Figure 3.8: Inner View of System Prototype

4 Subsystem Design

4.1 Subsystem 1: Power Subsystem

Subsystem Owner: [Shivendran Gandhi]

Subsystem Design:

4.1.1 Subsystem Diagram

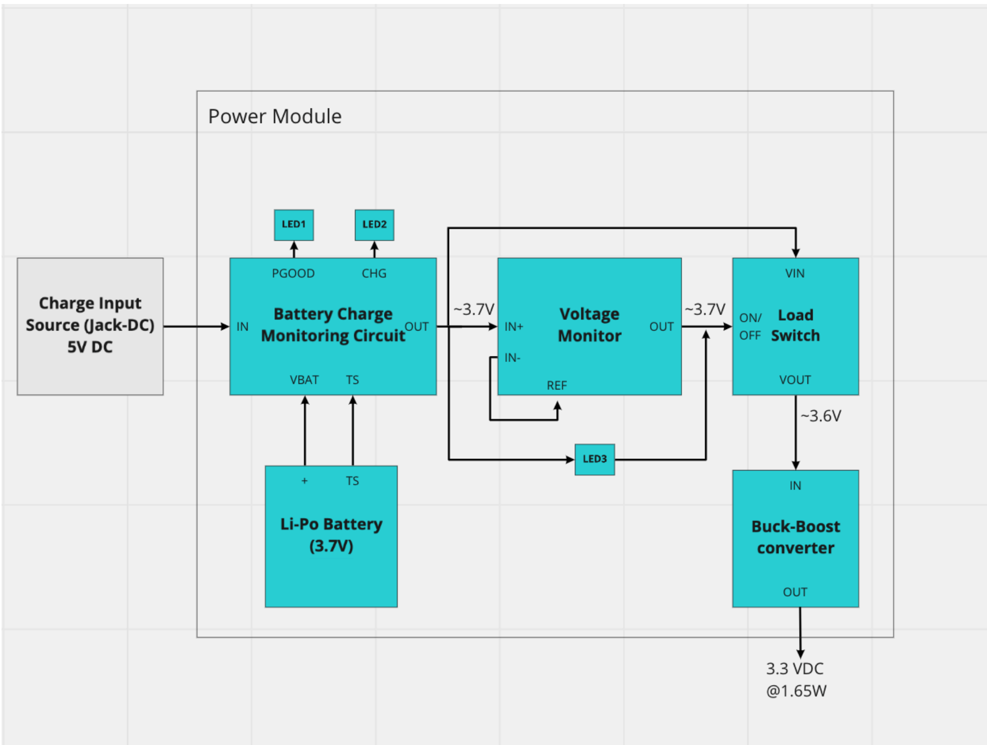

Figure 4.1.1: Subsystem 1 Block Diagram

4.1.2 Specifications

The power subsystem has to have a Li-Po battery to fulfill the requirement of a rechargeable battery. A 3.7V Lithium-Ion Polymer (Li-Po) battery with 2000mAh is used as it has higher battery power storage to fulfill the requirement of powering the mask 8 hours at the time. Lithium-Ion Polymer battery is used instead of a Lithium-ion battery to fulfill the requirement of a safe rechargeable battery (no explosion). Battery charge management circuit supports reverse current, short circuit, thermal protection and therefore, fulfills requirement of prevention of battery failure. Battery charge management circuit informs users if the input charging source is valid (LED1), battery in charging mode (LED2). Voltage monitoring circuit fulfills the requirement of monitoring battery life constantly by utilizing a comparator circuit and informs the user through a red LED (LED3) when the Li-Po battery voltage is below 2.8V stating that battery level is low. Buck boost converter is a DC-DC converter that steps down high-voltage DC to low-voltage when input voltage is of range 3.3V - 3.7V and steps up low voltage DC to high voltage DC when input voltage is 2.8V - 3.2V to ensure regulated output of 3.3V DC. The buck boost converter fulfills the requirement of regulated output voltage of 3.3V to provide for the sensor, audio and communication subsystems.

4.1.3 Subsystem interactions

The Power Subsystem will interact with the communication subsystem, sensor subsystem and the audio subsystem. The 3.3 VDC output will be used to power the microcontroller (ESP32) for the communication subsystem. The 3.3 VDC output will be used to power the audio codec, microphone, and speaker driver for the audio subsystem. The 3.3 VDC output will be used to power the NTC thermistor, temperature sensor (TMP35) and the 4 quadrant op-amp for the sensor subsystem.

4.1.4 Theory Of Operations/Algorithm

The Battery Management Circuit (BQ24075) has an NTC thermistor input that is used to monitor the temperature of the Li-Po battery through an internal 10kOhm thermistor. The max input current limit was set to 1A, battery capacity is 2000mAh, termination current set to 10%, setting charging current at 0.5C. With that, we were able to calculate R_{ISET} , R_{TERM} , R_{ILIM}. PGOOD pulls to ground when a valid input source is detected, therefore, LED1 lights up. CHG pulls to VSS when the battery is charging, therefore, LED2 lights up. Output of the BQ24075 will mirror the voltage of the Li-Po battery.

The Voltage monitoring circuit (LMP7300) is a combination comparator and reference with ideal specifications for precision threshold detection. The precision 2.048V reference comes with a 0.25% maximum error. The inverting input pin 2 is connected to the reference voltage pin 7 (REF) which is 2.048V. The non-inverting pin 1 is connected to a potential divider network comprising resistors. When the battery voltage decreases to below 2.8V, the voltage at pin 1 goes lower than the reference voltage at pin 2, which results in output of the comparator going low, thus glowing LED3 indicating low-battery status. Pull up resistor is placed at the output because the output of the comparator is open-drain.

The load switch (TPS27082) is a PFET load switch which will only switch on if its on/off pin (Pin 5) receives voltage of greater than 1V. Pin 5 is directly connected to the output pin of LMP7300. When the battery voltage decreases to below 2.8V, the output of the voltage monitoring circuit (LMP7300) goes low, pin 5 receives less than 1V and therefore, switches off the laid switch and no further discharging of the battery occurs. The voltage monitoring IC has a supply current of only 13uA and therefore, excess current will be delivered to the load switch.

Buck boost converter is a DC-DC converter that steps down high-voltage DC to low-voltage when input voltage is of range 3.3V - 3.7V and steps up low voltage DC to high voltage DC when input voltage is 2.8V - 3.2V to ensure regulated output of 3.3VDC. Inductor value of 1.5uH was chosen from the typical application schematic of the datasheet. The output voltage is adjustable and therefore, the output voltage of the TPS63036 of 3.3V is set by an external resistor divider. The resistor divider must be connected between VOUT, FB and GND. The typical value of the voltage at the FB pin is 500 mV. With that, we were able to calculate R19 and R20.

4.1.5 Core ECE design tasks

1. ECE 31032 - Elements of Power System Engineering knowledge will be used to analyze steady state and understanding of the power flow of the main components in the power module.
2. ECE 43300 - Power Electronics knowledge will be used to understand the principles of the buck boost converter used and calculate resistor, capacitor and inductor values to ensure an output voltage of 3.3V.
3. ECE 20007 & ECE 20008 - Electrical Engineering Fundamentals I & II knowledge will be used to understand and utilize the functions of the low-power comparator in the voltage monitoring circuit as well as calculations needed for resistors, LED's and etc for the entire subsystem.

4.1.6 Schematics/parts

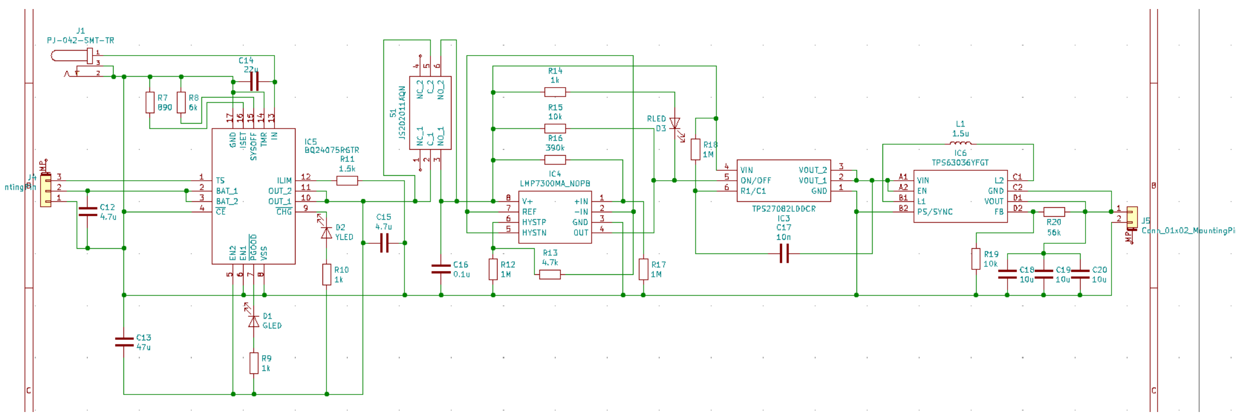

Figure 4.1.2: Circuit diagram of rechargeable power supply

Datasheet link for each IC used:

- Battery Charge Management Circuit(BQ24075): https://www.ti.com/lit/ds/symlink/bq24075.pdf?ts=1614280368460&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FBQ24075%253Fqgpn%253Dbq24075
- Voltage Monitor(LMP7300): https://www.ti.com/lit/ds/symlink/lmp7300.pdf?ts=1614287996460&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FLMP7300
- Load Switch(TPS27082): https://www.ti.com/lit/ds/symlink/tps27082l.pdf?HQS=dis-mous-null-mousermode-dsf-pf-null-wwe&ts=1614288039383
- Buck-Boost Converter(TPS63036):

https://www.ti.com/lit/ds/symlink/tps63036.pdf?ts=1614208248034&ref_url=https%253A%252F%252Fwww.google.com%252F

Purchase link for each component that needs to be ordered:

- Battery Charge Management Circuit(BQ24075):
https://www.mouser.com/ProductDetail/Texas-Instruments/BQ24075RGTR/?qs=XGzIaZb%2FFYKTADIJv746hA%3D%3D
- Voltage Monitor(LMP7300):
https://www.mouser.com/ProductDetail/Texas-Instruments/LMP7300MME-NOPB/?qs=7IkVKPoqpbbnV3EcFh3pgA%3D%3D
- Load Switch(TPS27082):
https://www.mouser.com/ProductDetail/Texas-Instruments/TPS27082LDDCR/?qs=%2Fha2pyFadug5Xy5oBhDTb906MP6VdEpY5KhIstyQfgQ%3D
- Buck-Boost Converter(TPS63036):
https://www.mouser.com/ProductDetail/Texas-Instruments/TPS63036YFGT/?qs=vnbNJPHmPnPNuSb49yxkAg%3D%3D
- 1.5uH Fixed Inductor for Buck-Boost Converter:
https://www.mouser.com/ProductDetail/?qs=MW2gS7wPCVyPIQaxlCsP7g%3D%3D
- 3.7 Li-Po Battery:
https://www.batteryspace.com/custom-polymer-li-ion-battery-3-7v-2000mah-7-4-wh-4a-rate-with-10k-thermistor.aspx
- DC-Jack:
https://www.mouser.com/ProductDetail/CUI-Devices/PJ-042-SMT-TR/?qs=%2Fha2pyFadujNJxKFkRzWw5H08uBuwVZtQWjBoq0oRku11STJqZjVQw%3D%3D

4.1.7 Specification Measurements

- Output of the BQ24075 IC will mirror the voltage of the Li-Po battery - The output of the BQ24075 IC is measured at 3.6995 V when the battery voltage is 3.7V.
- Monitor battery life constantly and inform the user, by alerting an LED when battery level is low- When the battery voltage is 2.85V, the tested output of the LM7300 is ~0V and the red LED (LED3) lights up indicating low battery status. The output of the LMP7300 IC is measured at 3.6991 V
- When using the power supply to be used as an input charging, we configure the power supply to output 4.9V and a 1A limit. Yellow LED (LED1) lights up when the input charging is valid and the green LED lights up to indicate the Li-Po battery is being charged.
- The output of the load switch is measured to be 3.7533V when the charged Li-Po battery is outputting 3.7540 indicating a small voltage drop across the 3 IC's.

4.1.8 Standards

Safety standard - Safety aspects are considered when selecting a battery for power supply. Decision matrix was used when choosing the battery based on safety, size and electric charge capabilities.

4.2 Subsystem 2: Communication Subsystem

Subsystem Owner: [Yul Hee Cho]

Subsystem Design:

4.2.1 Subsystem Diagram

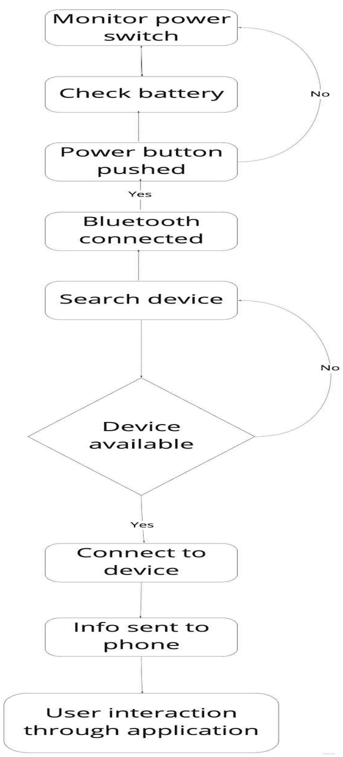

Figure 4.2.1: Subsystem 2 Activity Diagram

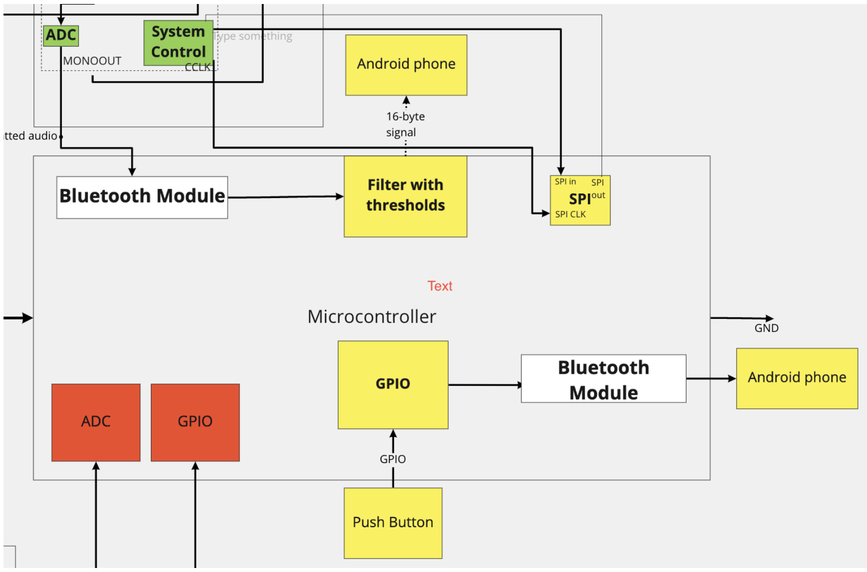

Figure 4.2.2: Subsystem 2 Block Diagram

4.2.2 Specifications

When Terry, our potential next generation Iron Man thought about the smart mask, he thought about connecting the mask with the portable device, such as an android phone. In order to accomplish this aspect, the bluetooth connection through microcontroller needs to be established. ESP32 bluetooth module is to be used, and version of at least 2.0 will be embedded. Currently the devices that would be used will only include android devices.

4.2.3 Subsystem interactions

By directing the communication system, the bluetooth module will help through the whole system's info, especially with the Sensor subsystem. Since the Sensor subsystem requires info in and out as well, it would be important to make sure that the right input and output are interacting. Moreover, with Audio subsystem, getting information from it and filtering through specified thresholds and sending out to the device would be the big picture. Finally, from the Power subsystem, getting power supply would make the whole subsystems work as a whole, including the Communication subsystem.

4.2.4 Theory Of Operations/Algorithm

ESP32 will be configured to act for DAC, ADC, SPI and GPIO pins. Also, the integrated BLE (Bluetooth Low Energy) will be used in order to establish the bluetooth connection. For SPI connection, ESP32 will let the CLATCH low three times in order to pop up the SPI mode in our audio codec, ADAU1361. After accomplishing the data transmission, it would manage the audio signal that goes into the codec. For DAC, ADC, and GPIO, the general GPIO pins are used for configuration. For signal handling, DAC and ADC would be used, and for the internal clock usage, GPIO pins would be used to activate the integrated ESP32 clock.

Libraries Usage:

In Eclipse IDE using C

- driver/gpio.h
- driver/spi_master.h
- esp_system.h
- freertos/FreeRTOS.h
- freertos/task.h

4.2.5 Core ECE design tasks

1. ECE 36200 - Microprocessor Systems and Interfacing. The course takes more deeply the knowledge of the microprocessor. Although the tools used in the class is STM32 which differs from ESP32, it still gives basic ideas where to start and skills about embedded C programming.

2. ECE 27000 - Introduction to Digital System Design. The course introduces the basic ideas about STM32, the basic microprocessor. Along with the basic ideas about the circuit, the course takes in the idea of embedded C programming. Although this course is the basic course for digital system design, it shows the start point for the ESP32 configuration.

4.2.6 Schematics/parts

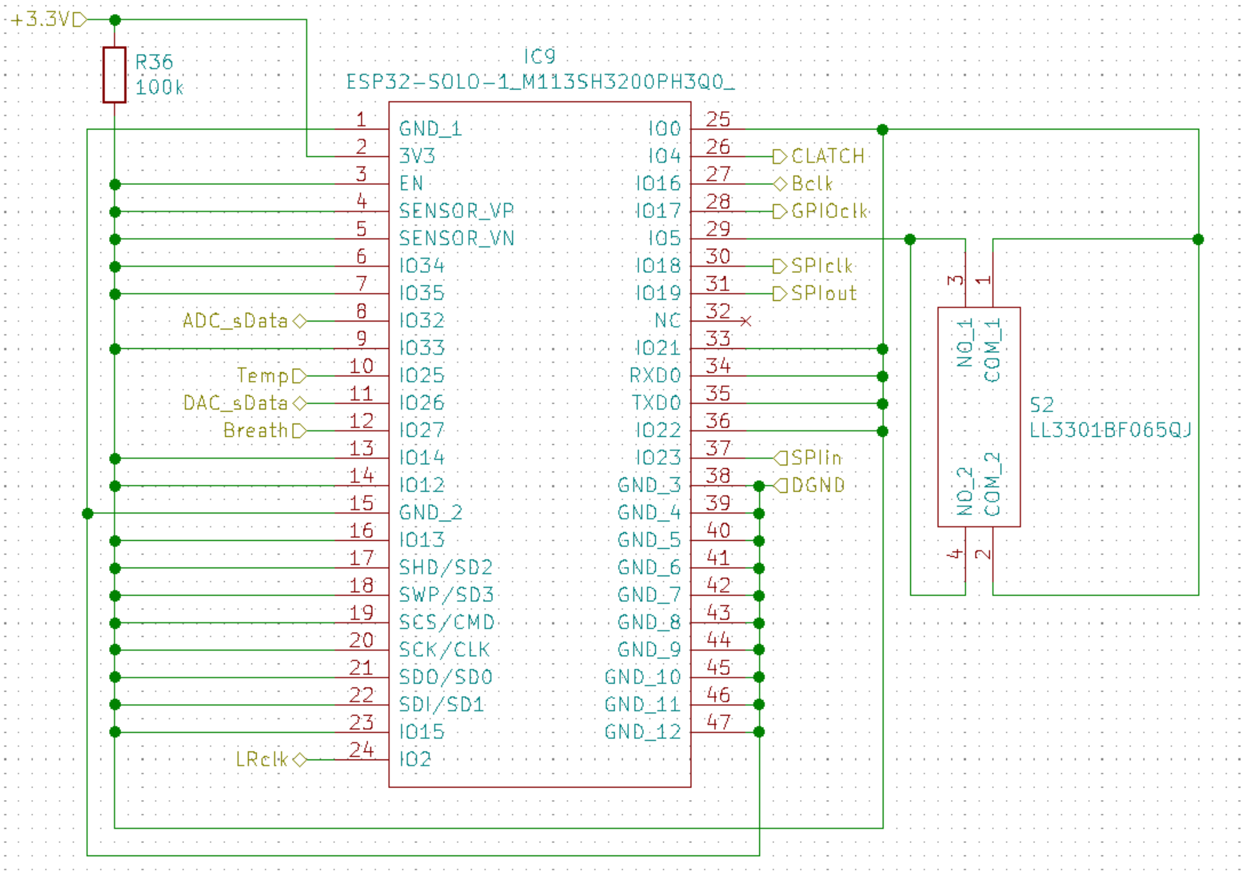

Figure 4.2.3: Subsystem 2 Schematic Diagram

4.2.7 Specification Measurements

BLE Connection through ESP32, by flashing in the compatibility test, the external iPhone(Version 14.4.1) was successfully connected. The external device needs an extra application LightBlue in it in order to detect the BLE connection. Moreover, SPI connection was established, but yet to be interacted with the audio codec in the audio sensor.

4.2.8 Standards

As in ECE 270 and ECE 362, the embedded programming skills through the microcontroller would be polished up. Also, by designing and building the smart mask that could possibly result in better lives of people in this pandemic, that would satisfy the fundamental purpose of doing engineering: make lives easier and better.

4.3 Subsystem 3: Audio Subsystem

Subsystem Owner: [Dishawn Thiran]

Subsystem Design:

4.3.1 Subsystem Diagram

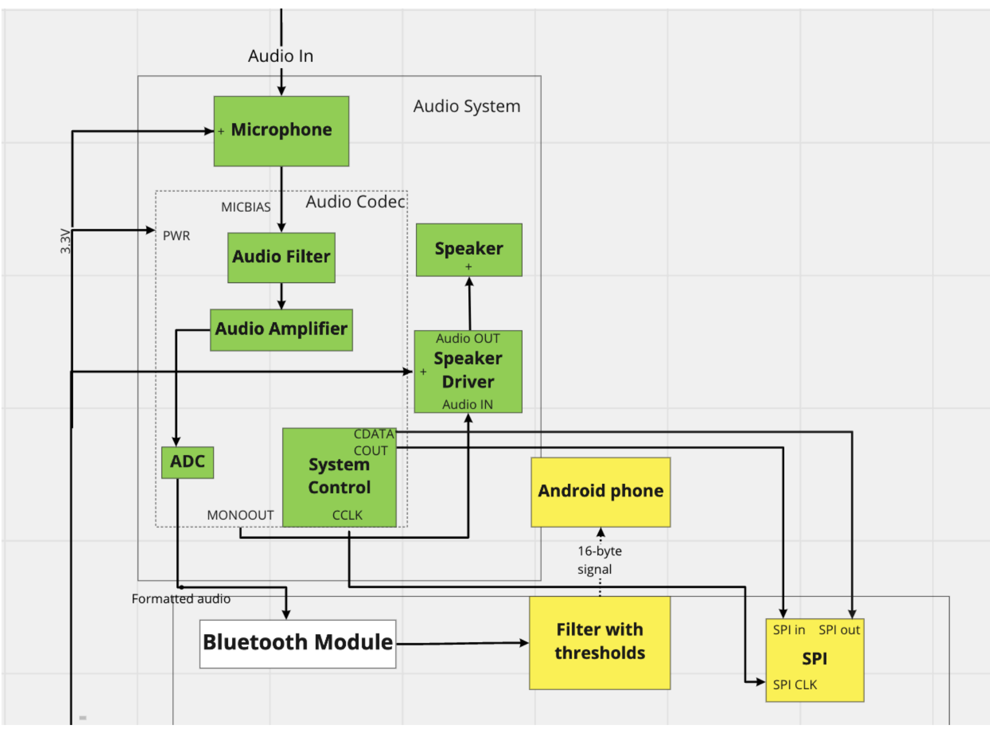

Figure 4.3.1: Subsystem 3 Diagram

4.3.2 Specifications

The audio in must be received by the microphone and filtered for noise with a high pass filter. If the Mask is on a phone call, the audio input shall be sent to the phone. If the mask is not, the audio input will just be sent to the speaker. The speaker will be able to play audio output at an audible volume.

4.3.3 Subsystem interactions

The Audio Subsystem will interact with the communications system in formatting an audio file for the correct bluetooth protocol and sending the audio file to the phone, as well as writing to the proper registers in the codec. The Audio Subsystem will attach to the power buses from the power system.

4.3.4 Theory Of Operations/Algorithm

The Microphone will oscillate a magnetic field to produce an electrical representation of audio. This will be sent through a high pass filter to filter out power supply noise as well as a series of amplifiers to toggle the gain of the signal. This will change the volume of the output signal. The audio is then run through an analog-to-digital converter to create a digitized signal which is sampled in frames and sent to the microcontroller. The final signal is sent to a speaker driver which will provide the power to drive a speaker to playback the amplified audio signal.

4.3.5 Core ECE design tasks

1. Filtering the Mic in signal and proper voltage biasing: ECE 201 and 301
2. Developing the App: ECE 39595, ECE 269
3. Using SPI to read and write registers, set IO, and ADC/DAC Theory: ECE 362, ECE 270

4.3.6 Schematics/Parts

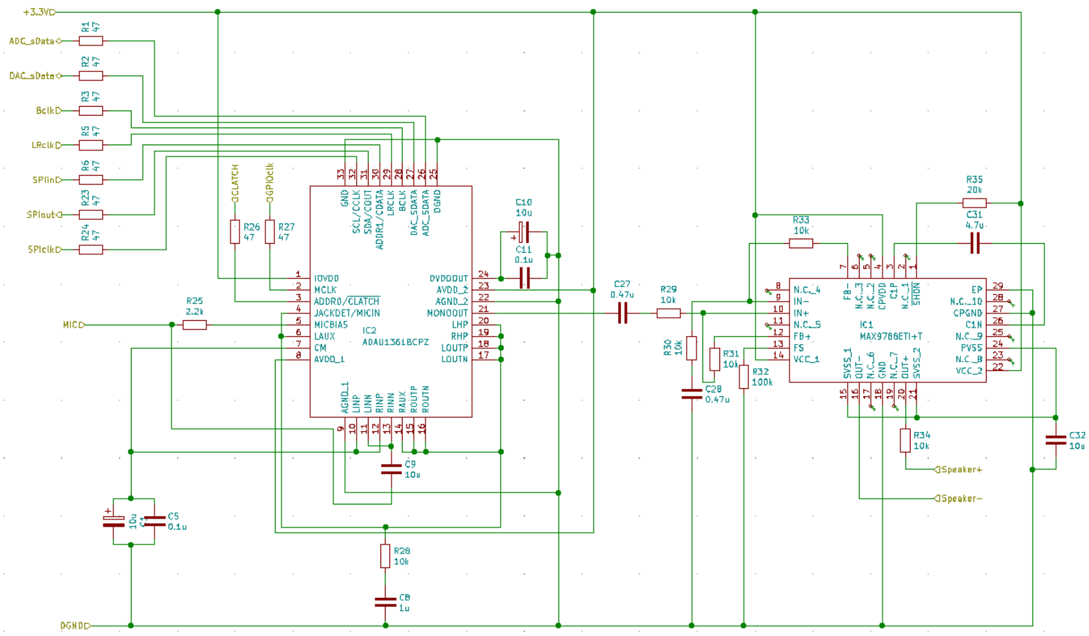

Figure 4.3.2: Subsystem 3 Schematic Diagram

Microphone: CMEJ-9745-37-P
Speaker: BF 37 - 8 Ohm
Audio Codec: ADAU1361BCPZ
Speaker Driver: MAX9788

4.3.7 Specification Measurements

-3dB level at 2Hz, Microphone oscillates about .3 volts at 3.3Volts bias, microphone worked successfully.

4.3.8 Standards

We will use SPI protocol to read and write registers in the ADAU1361.Due to the nature of our phones being android phones, we will use the android bluetooth protocol to connect the smart mask to the phone.

4.4 Subsystem 4: Sensor Subsystem

Subsystem Owner: [Ryan Strefling]

Subsystem Design:

4.4.1 Subsystem Diagram

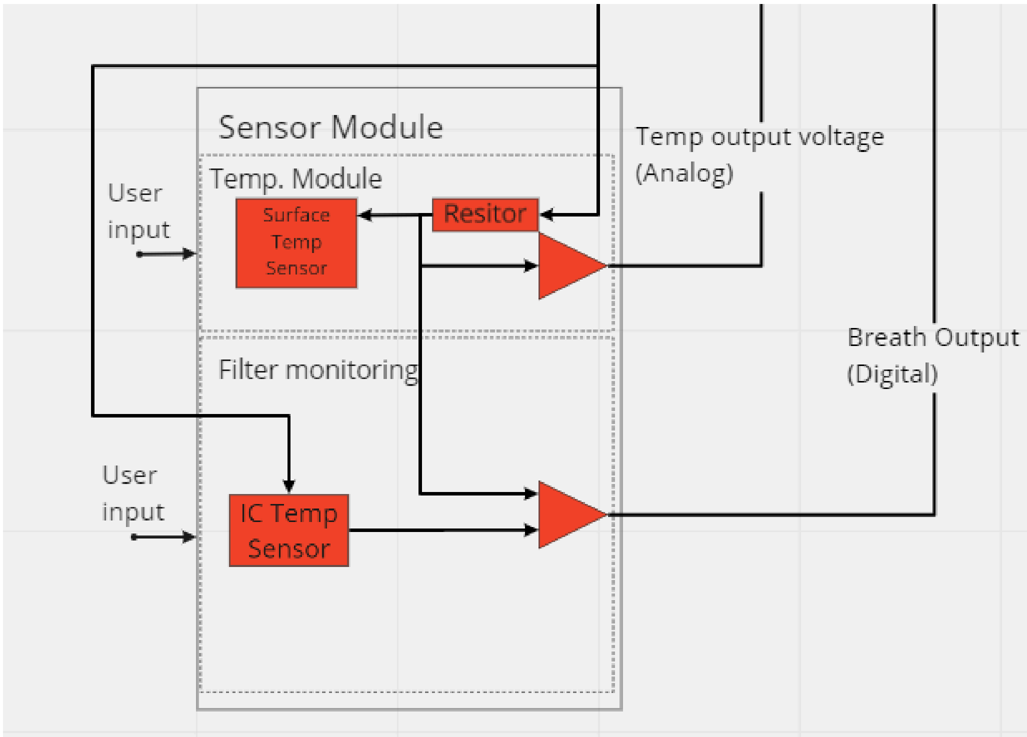

Figure 4.4.1: Subsystem 4 Diagram

4.4.2 Specifications

The Sensor Subsystem must have a sensor to monitor breath and a temperature sensor to monitor the users body temperature. If the user has a high temperature the MCU will report this to the bluetooth module. The breath sensor needs a baseline temperature in order to accurately measure quick fluctuations in breathing rate. The breath sensor must output a digital signal and the temperature sensor must output an analog signal.

4.4.3 Subsystem interactions

The Sensor Subsystem will directly interact with the user. The Sensor Subsystem will be tied into the power rails of the system and will interact with both the GPIO and ADC input of the MCU.

4.4.4 Theory Of Operations/Algorithm

This circuit operates at 3.3 VDC. A NTC thermistor in series with another resistor, value chosen to equate to room temperature resistance of the thermistor, will act as a voltage divider. The resistance of the thermistor goes down as the temperature on the thermistor increases. This causes a higher output voltage from the divider circuit. This output is then sent to the positive inputs of two operative amplifiers that are set up as voltage followers. This is to separate impedances of the circuit.

The output of the first voltage divider is directly sent to the analog to digital conversion register of the ESP32 solo. The ESP32 solo will then convert this signal into a binary value for analysis. The output of the second operative amplifier acting as a voltage follower is sent to another voltage divider that is designed to downscale and slightly lower the voltage for comparison with the breath sensor output voltage. The breath sensor is a fast response temperature sensor that outputs +-10mV per degree Celsius. The output of this temperature sensor is sent to the positive pin of a third operative amplifier. This operative amplifier is set up as a comparator.

The negative input to this comparator is tied to the second voltage divider that is downscaling this user's temperature. The reason for downscaling is due to the low voltage output of this temperature sensor. The downscaled voltage represents a slightly lower temperature than the user's body temperature which creates a baseline for the breath sensor.

When the user exhales, their breath, which is not exactly equal to body temperature but it is close to it, rises above the baseline voltage set by the second voltage divider and the comparator outputs a high signal. When the user inhales, this cools down the temperature sensor causing it to rapidly drop past the baseline voltage and the comparator outputs a low signal. This signal is then sent to a GPIO input pin of the ESP32 for analysis.

Body temperature varies from person to person and even the same individual can have fluctuating body temperature. With differences in body temperature an adaptive design needs to be implemented, which is exactly what this design is intended to be.

4.4.5 Core ECE design tasks

1. Operating a circuit linearly and operating the circuit blocks in isolation, along with figuring out the required voltage and current draw that will be necessary. - ECE 20100, ECE 20200, ECE 25500, and ECE 30500.

2. Technology that explains the functionality of the devices and how to best utilize each component. - ECE 25500 and ECE 30500.

3. Proper inputs and output along with understanding how to optimize a MCU and its coding. - ECE 27000 and ECE 36200.

4.4.6 Schematics/Parts

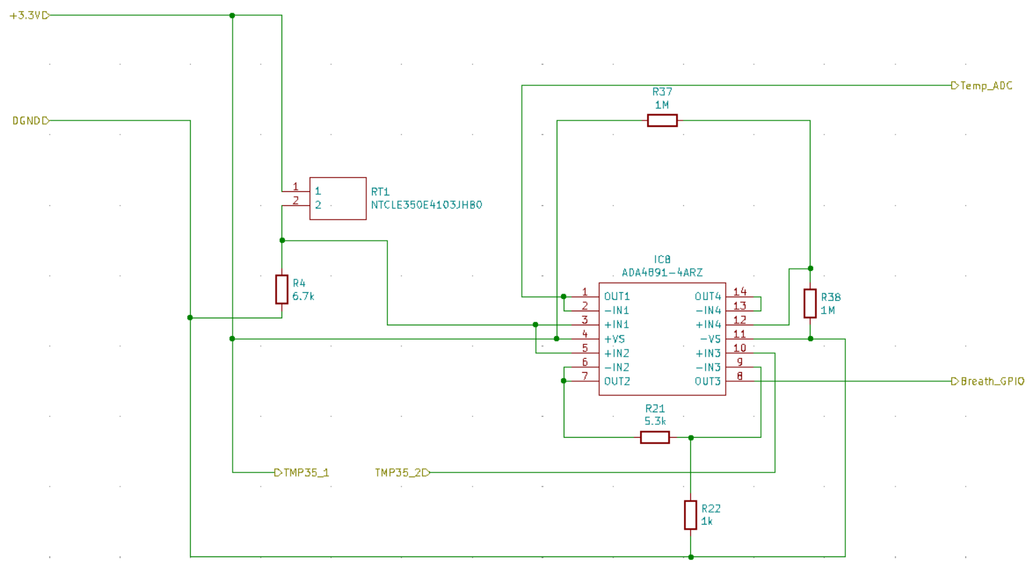

Figure 4.4.2: Subsystem 4 Schematic Diagram

Datasheet link for each IC used:

- NTC Thermistor(NTCLE350E4103JHB0): https://www.vishay.com/docs/29218/ntcle350e4.pdf
- Breath Sensor(TMP35GT9Z): https://componentsearchengine.com/Datasheets/2/TMP35GT9Z.pdf
- Four-quadrant Op-amp(ADA4891-4ARZ): http://www.analog.com/media/en/technical-documentation/data-sheets/ADA4891-1_4891-2_4891-3_4891-4.PDF

Purchase link for each component that needs to be ordered:

- NTC Thermistor(NTCLE350E4103JHB0): https://www.mouser.com/ProductDetail/594-NTCLE350E4103JHB
- Breath Sensor(TMP35GT9Z): https://www.mouser.com/ProductDetail/Analog-Devices/TMP35GT9Z/?qs=WIvQP4zGaniNVxMF5yKBpA%3D%3D
- Four-quadrant Op-amp(ADA4891-4ARZ): https://www.mouser.com/ProductDetail/Analog-Devices/ADA4891-4ARZ-R7?qs=BpaRKvA4VqFzauTFtudr%252Bw%3D%3D

4.4.7 Specification Measurements

- Voltage for the temperature sensor varies between 1.47V and 1.72V.
- Negative input of the comparator varies as temperature varies. Variation of 0.31V to 0.38V.
- Voltage from the breath sensor varies from 0.25V
- Voltage from the breath sensor has a +/-0.01V difference from downscaled input.
- Output voltage of the comparator is approximately 3.3V when the breath sensor voltage rises above the downscaled input.
- Output voltage of the comparator is approximately 0V when the breath sensor voltage is lower than the downscaled input.

4.4.6 Standards

Due to the nature of impedances the sensors must be isolated from the MCU. Both temperature sensors must have a precision of +/- 0.1 deg C.

5 Team Structure

Shivendran Gandhi - Power Subsystem

- B.S. in Electrical Engineering
- Co-leader in Electronics for EPICS IS - Mars Rover
- Co-leader in Electronics for EPICS EVEI - RC Kart
- Project Director for IndyGo Electric Bus Energy Consumption Reduction
- **Relevant Coursework:** Electromechanical Motion Devices & Systems, Electromagnetics, Microprocessor Systems & Interfacing, Feedback System Analysis Design, Python for Data Science, Digital System Design, Elements for Power System Engineering, Power Electronics.
- **Technical Skills:** Assembly X-86, MATLAB, Verilog, C-programming, Ki Cad, SPICE, Python, Microsoft Office (Word, PowerPoint and Outlook).

Yul Hee Cho - Communication Subsystem

- B.S. in Computer Engineering
- LED Matrix display and embedded computer programming project - Flappy bird
- C++ Compiler / Java Interpreter - Object Oriented Programming project
- Python - Data science trend prediction programming
- **Coursework:** OO Programming(C++ / Java), Microprocessor Systems & Interfacing, Python for Data Science, Fundamental C Programming, Advanced C Programming, Security, Operating Systems, Artificial Intelligence
- **Technical Skills:** MATLAB, Verilog, C++ / Java, C, Python, Assembly X-86, LT Spice

Dishawn Thiran - Audio Subsystem

- B.S in Electrical Engineering
- Co-op at GE Appliances, a Haier Company
- **Technical Skills:** PCB Design, Signal Processing Hardware, Software Validation design

Ryan Strefling - Sensor Subsystem

- B.S in Electrical Engineering
- Co-lead in Electronics for EPICS IS - Mars Rover
- Engineering internship for Starcraft Bus under Forest River
- Manufacturing and electrical engineer for Apertus Pharmaceuticals
- Project manager for Pageview Pharmaceuticals
- Repair and sales in chemical and pharmaceutical analytical equipment - self employed
- Co-owner and partner of several LLCs
- Growing entrepreneur
- 14+ years in automotive diagnostics and repair
- **Relevant Coursework:** Electromagnetics, Electromechanical Motion Devices & Systems, Feedback System Analysis, Microprocessor Systems & Interfacing, and Feedback System Analysis.
- **Technical Skills:** Autodesk Studio, C-programming, KiCad, MATLAB, Microsoft Office, Multisim, SPICE, Ultiboard, Verilog.

6 PCB Design

6.1 PCB Circuit Schematics

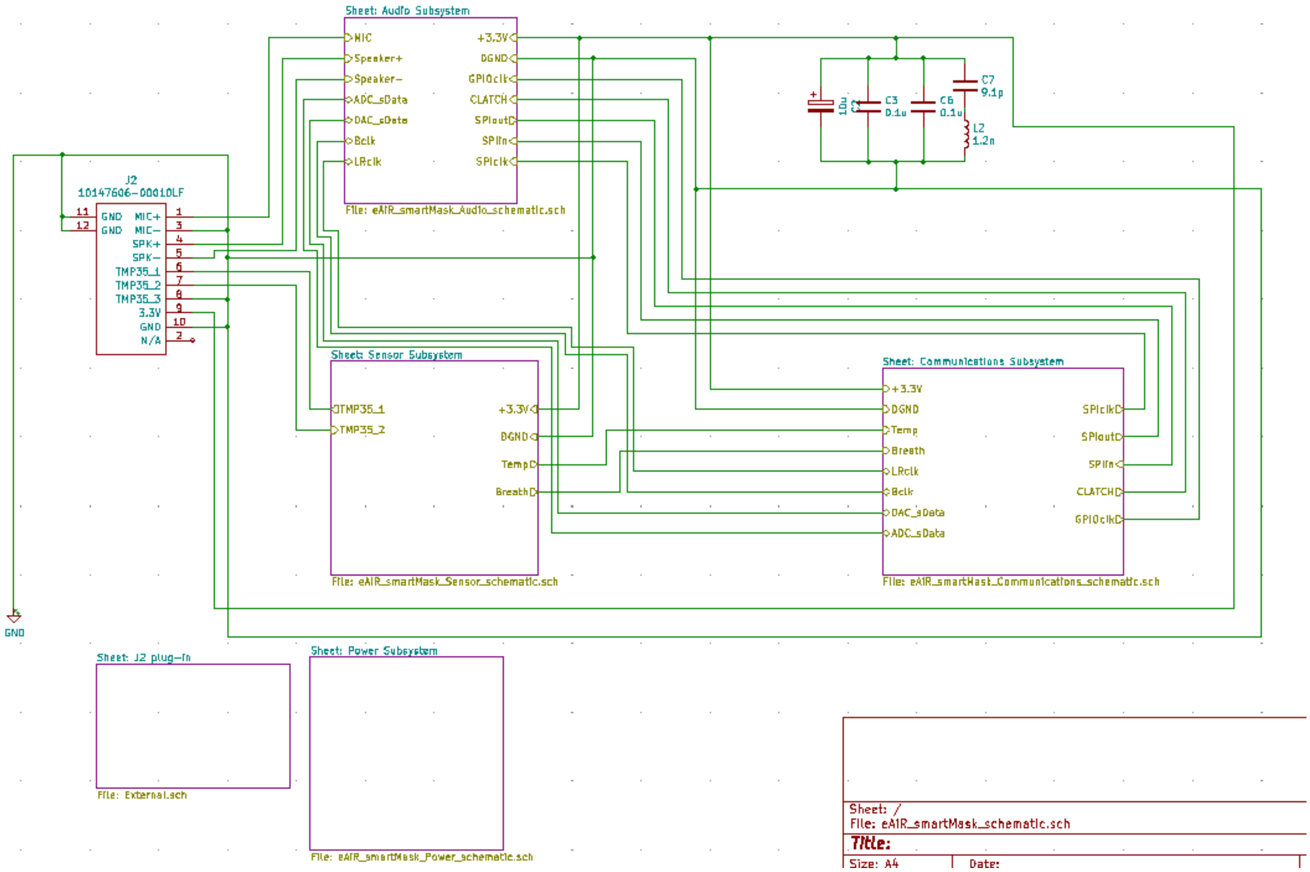

Figure 6.1.1: Entire circuit schematic

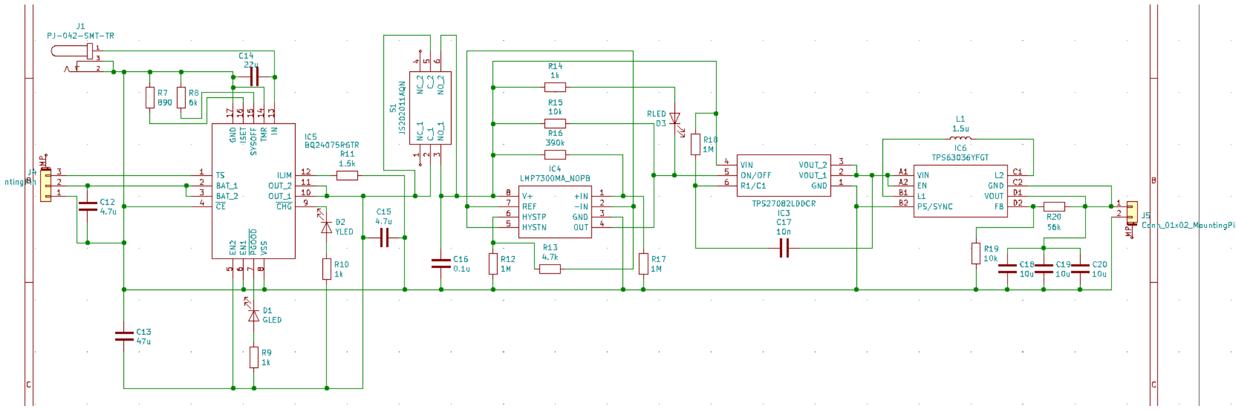

Figure 6.1.2: Power subsystem circuit schematic

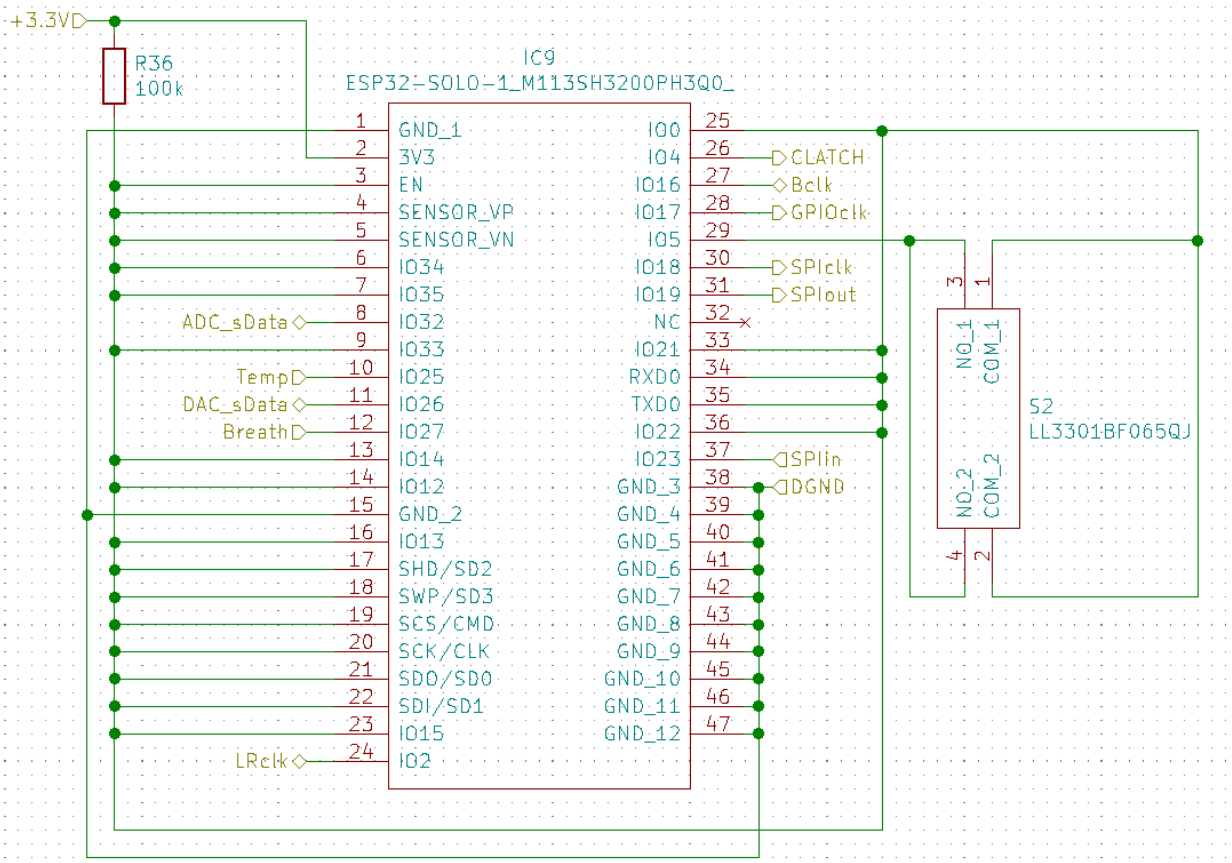

Figure 6.1.3: Communications subsystem circuit schematic

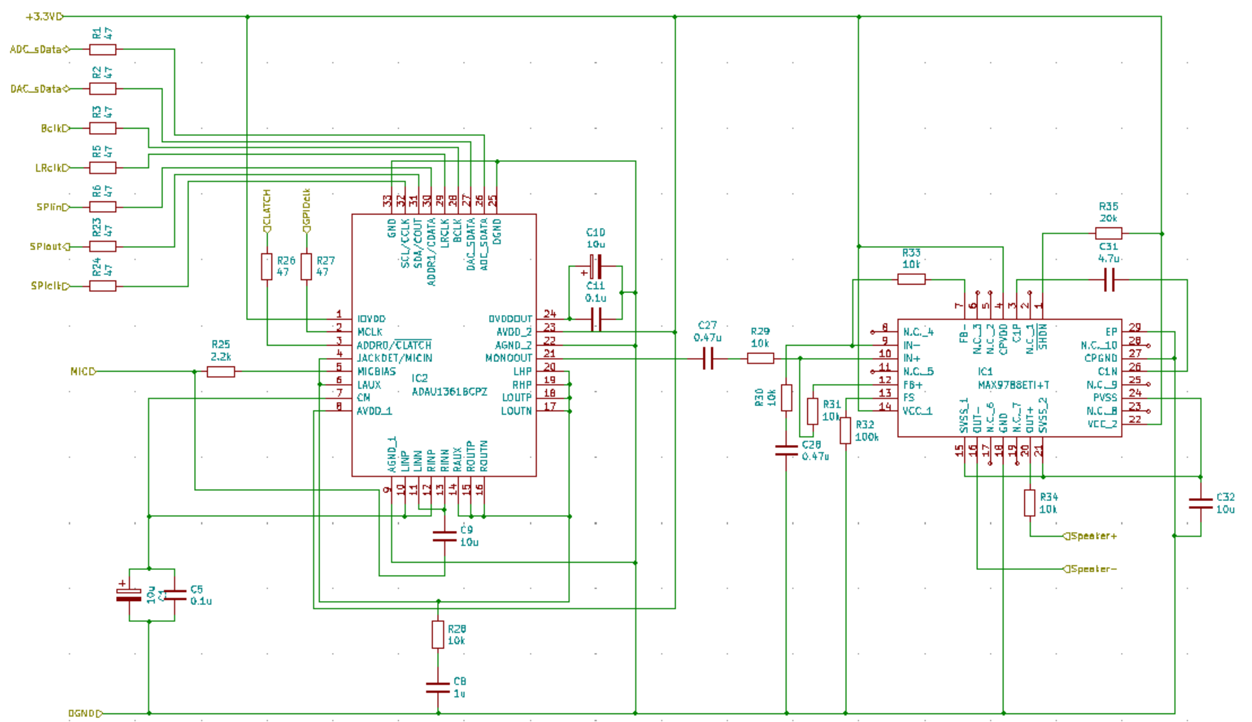

Figure 6.1.4: Audio subsystem circuit schematic

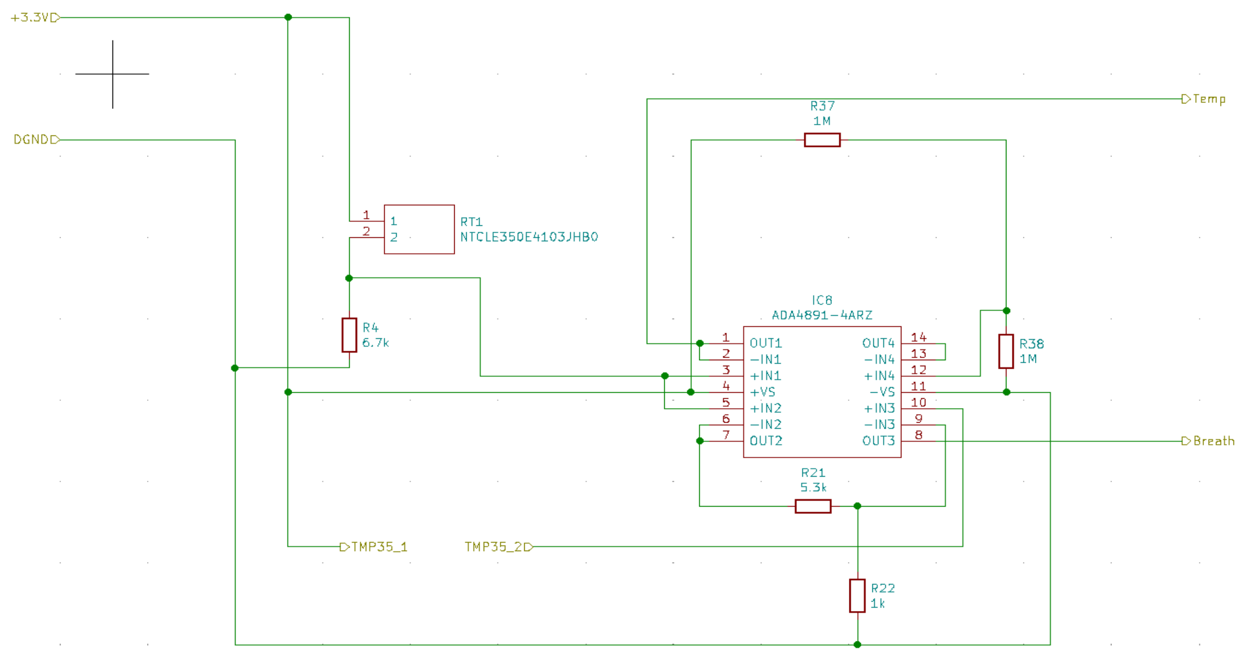

Figure 6.1.5: Sensor subsystem circuit schematic

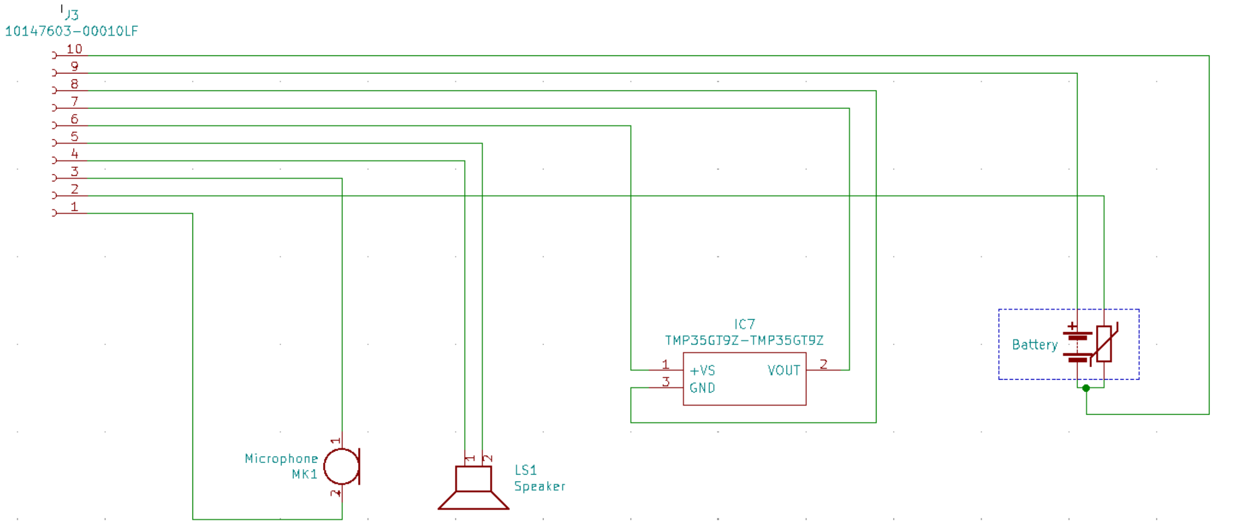

Figure 6.1.6: Off-board circuit schematic

6.2 PCB Physical Layout

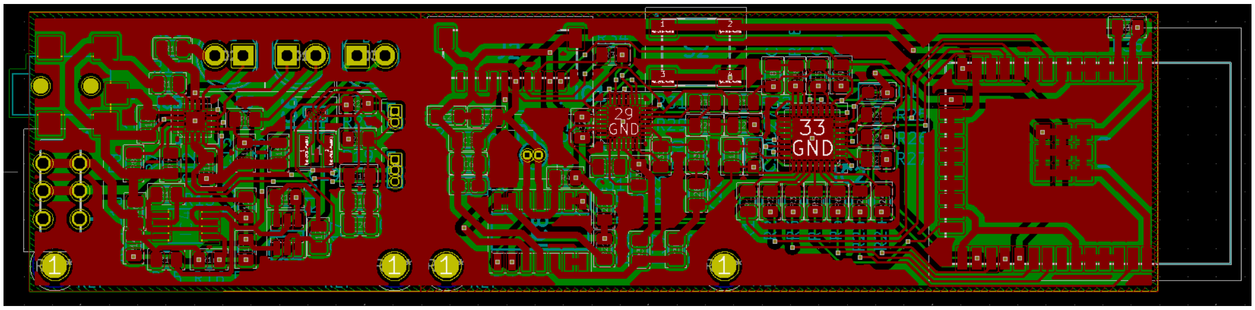

Figure 6.2.1: PCB layout

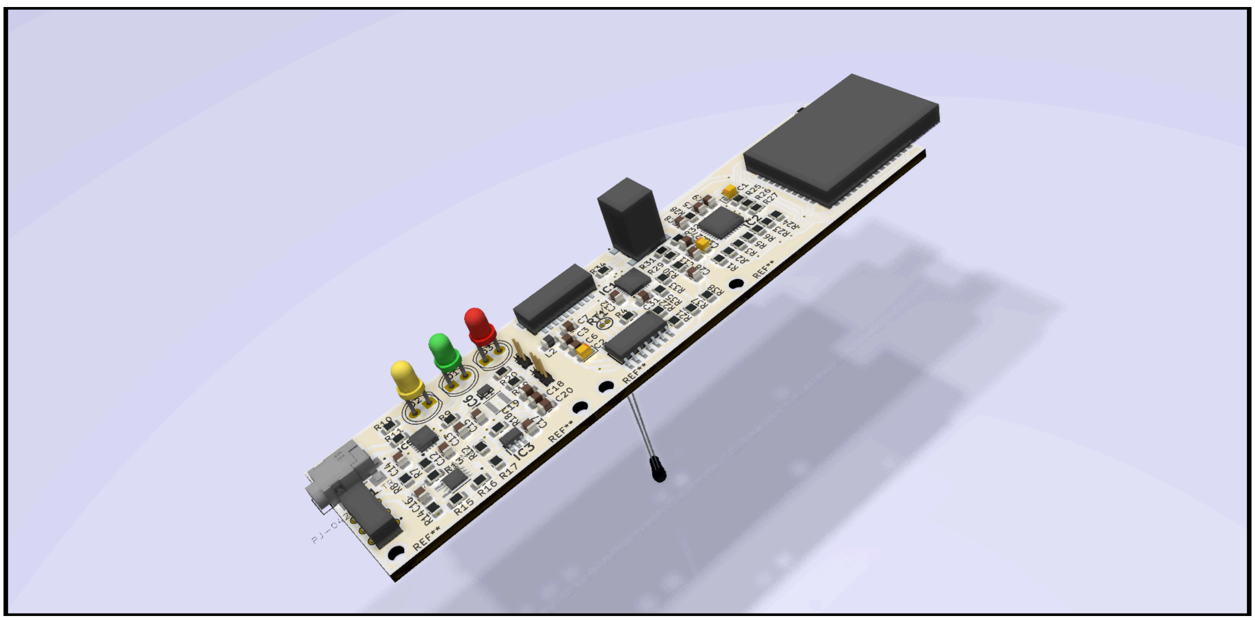

Figure 6.2.2: 3D model of PCB layout

7 Final Status of Requirements

- If met, give a detailed explanation of the Requirement. If partially met, mention what has been met and a reason for why the complete requirement couldn't be achieved. If not met, give an explanation for why the requirement couldn't be met in the product.

1. **Receive Audio by mask microphone, and send the data to the phone through bluetooth**

Partially Met - Audio was going through the audio codec and the signal was sending and receiving via ESP32 module, but the bluetooth module was not quite done except for the environmental parts setup and the simple data inputs transmission, therefore the requirement is only partially met.

2. **Receive Audio through bluetooth from phone, and project the data through the mask speaker**

Partially Met - ADC programming part was done, but had issues with flashing in the code into the module and interacting with the external devices. BLE was done by showing the data transmission between the bluetooth module and the phone. However, further complex data was not yet to be transmitted.

3. **Temperature sensors that can read the temperature of the person, and alert an LED when temperature resembles a fever**

Partially Met - The temperature sensor worked theoretically and on the breadboard prototype. Each sensor was quick at warming up and kept a steady and accurate temperature when in steady-state operation, but since this sensor was never fully mounted to the PCB and never showed proof of full operation in integration on the physical design.

4. **Airflow sensors that can read the airflow coming out of the filter, and if the airflow is too low, will alert an LED on the mask to replace the filter**

Partially Met - The breath sensor was mounted physically on the mask and would fluctuate from the slightest input from the user, but would not change from light breezes when moving around. The reason the was not fully met was the PCB has a solder mask flaw that prevented an solder contact with the body temperature sensor, thus meaning the circuit was never fully integrated. Also, the red LED was modified to output red numbers on the bluetooth device when displaying a body temp higher than 100degF.

5. A safe rechargeable power supply sufficient to power the mask for 8 hours at a time

Met - Using a Lithium-Polymer battery as the power supply fulfills the requirement of a safe rechargeable battery as Lithium Polymer batteries are rechargeable and they are safer to use compared to Lithium-Ion batteries as they have lesser tendencies to cause an explosion. The Li-Po battery that we chose has specifications of 3.7V and battery capacity rating of 2200mAh. The audio, sensor and communication subsystem require a cumulative maximum of 250mA of current to their respective subsystems. This means that the battery can supply 2200mA of current during its lifetime. The Li-Po battery can supply 250mA for 8.8 hours. Therefore, the requirement of powering the mask for 8 hours at a time is met.

6. A rechargeable power supply that outputs a regulated 3.3VDC

Partially Met - The power subsystem has 4 different IC's for different purposes. The buck-boost converter that we ordered is a high efficient Single inductor with 1A switches. The size of the converter is 0 mm^2 1.854 x 1.116. This made it extremely difficult for even experienced engineers to solder this IC onto our PCB. Through many trial and errors, we were unable to solder the buck boost converter IC to the PCB and be functional. Therefore, I tested the output of the load switch to give me a good idea of the voltage drop across the 3 IC's. The fully charged Li-Po battery outputted 3.7540V and the voltage at the load switch was measured to be 3.7533V. I tested the output of the load switch with a small load in the system and it is able to support current flow up to 0.75A. Theoretically, looking at the datasheet of this buck boost converter, the IC runs at an efficiency of 90+% even when outputting a high current of 250mA. This holds true when Vin of the IC is given to be 3.6V and outputs Vout of 3.3V which fits perfectly with our desire.

7. Monitor battery life constantly and informs the user, by alerting an LED when battery level is low

Met - The voltage monitoring circuit is run by the LMP7300 IC which is a combination comparator and has a precision reference of 2.048V with a 0.25% maximum error. The inverting input (pin 2) of the LMP7300 is connected to the reference voltage pin 7 which is 2.048V. The non-inverting input (pin 1) is connected to a potential divider network comprising resistors to reduce the input voltage relative to the built in reference voltage of 2.048 in order to achieve a desired reference voltage of 2.8V . When the battery voltage decreases to 2.8V and below, the voltage at pin 1 goes lower than the reference voltage at pin 2, which results in output of the comparator going low. Once the output pulls low, the red LED (LED3) lights as there is a potential difference across the positive and negative terminal of the LED. This requirement is met as I used a power supply to imitate the Li-Po battery voltage at 2.8V and below, indicating low battery status and the red LED lights up

8. Battery management circuit to prevent battery failure

Met - This requirement is met by the BQ24075 IC which is an integrated Li-Ion linear charger and has system power path management devices. The BQ24075 IC features dynamic power path management (DPPM) that powers the system while simultaneously and independently charging the battery. This IC is important in maintaining battery health. The BQ24075 IC has a charging input source which is important as directly charging the Li-Po batteries is detrimental as it may reduce the capacity of the battery and degrade it. The dynamic power path management feature monitors the charge current separately while supplying the system load continuously and this feature will reduce the charge and discharging cycles of the battery. The IC also has a TS pin which allows the IC to monitor the die temperature. By setting the charging current with specified calculated resistor values, the IC manages the input current charge to be below 1A to prevent battery failure. With that, the battery management circuit is functional and it prevents battery failure.

9. Informs user when input charging source is valid and when battery is charging through LED's

Met - This requirement was met and demonstrated using the BQ24075 IC with two LED's. The BQ24075 also known as the battery management circuit has pins PGOOD and CHG. PGOOD is an Open-drain Power Good Status Indication Output that pulls to ground when a valid input charge is detected. CHG is an Open-Drain Charging Status Indication Output. CHG pulls to ground when the battery is charging. We set limits on the input current, charging current and termination current using precisely calculated resistors. The input current to the power system was set to a max current of 1A and the max input voltage was set to 5V. With these parameters, we tested input charging of the system using a power supply to output 4.9V and a current limit of 1A. LED1(yellow LED) and LED2(green LED) of the power subsystem lit up when the Power supply was connected to the IN pinout of the BQ24075. Therefore, indication of the lit LEDs fulfills this requirement.

10. Mask Speaker should amplify the volume of the talking input received from the microphone and output an amplified volume talking output

Met - The microphone is an electret condenser microphone that requires a bias voltage. Using a dc-filter, just the oscillations are captured.This is sent into the speaker driver which is an IC with a current amplifier circuit in it to drive the speaker. This drives the speaker to run, outputting the audio signal for us to hear.

11. Detachable inner cloth of the mask for washing purposes

Met - This requirement is met and can be seen in the Final demo video showing the placement of the detachable inner cloth in the 3D printed front module of the mask. Dust proof Respirator which is Washable and reusable.

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[3] Id, Fcc. "CKH10101 Bluetooth Headset Block Diagram Chih-Kan Technology." *FCC ID*, 2019, https://fccid.io/Q2LCKH10101/Block-Diagram/Block-Diagram-319320

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