Team Second Wind: Incentive Spirometer 2.0
DR 2.1 Presentation

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Restoring Lung Capacity

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Objective:

- **To create a more incentivized and engaging device that allows doctors to track a patient's progress while also providing a secondary function that eliminates the need for a second device.**
- **Provide Lung Technologies in collaboration with Northwest Orthopedics in Spokane with a new, improved incentive spirometers.**

Concept:

Find optimized arrangement of components and features so that the product can be more beneficial and reliable, while also being cost competitive.

Approach:

- **Redesign aesthetic features to improve the look**
- **Study existing OPEP technology and integrate into system**
- **Create a system of self-regulating valves that open/close based on the direction of air flow.**

Anticipated Costs and Runding Request:

- **$288.51 Spent so far**
  $371.18 Anticipated $ to-go
  $659.69 Total project Cost
- **-$750.00 Less internal funding**
- **$0 Additional amount requested**

Functional Specifications - Effectiveness

Incentive Spirometer 2.0 needs to be designed such that exhalations therapies performed by patient per doctor's prescription are digitally recorded and displayed for the doctor and patient. Our device will also be designed to be able to accommodate exhalation therapy if necessary.

ID	Spec	Threshold	Objective	Verification	Notes
E001	Record Patient Inhalation	Attained Inhalation level recorded in less than 1 second	Attained Inhalation level recorded in less than 0.5 seconds	Timing inhalation level	Minimize time delay from reaching inhalation goal and recording result
E002	Overlap Elimination	The sensor will accurately count the number of repetitions with 100% accuracy.	Confirm that the data being conveyed to the doctor and patient is accurate and can be trusted.	Visual verification through Observation	During inhalation therapy, the microcontroller will pause the count for 3s when prescribed level is reached. This pause is long enough to eliminate double counting.

Functional Specifications - Design

Incentive Spirometer 2.0 will be designed to accommodate an OPEP device, as well as remind the patient of when to use the device

ID	Spec	Threshold	Objective	Verification	Notes
D001	Amplitude of OPEP resistance	±10% maximum resistance pressure of the Aerobika OPEP device	±5% maximum resistance pressure of the Aerobika OPEP device	Recorded experimentation via a manometer	Flow and exhalation resistance must be strong enough for effective therapy and respiratory rehabilitation
D002	Levels of OPEP resistances that can be selected by the user	3 optional levels of exhalation resistance	5 optional levels of exhalation resistance	measured by experimentation via a manometer	Measurable, equally spaced levels of adjustable resistance
D003	Multi-Functional	N/A	Spirometer can function w/o electrical component	Testing and observation	The patient will take home the spirometer but not the electrical component
D004	Patient Reminder	Audible reminder for patients within 10 min	Audible reminder for patients within 5 min	Time reminder duration	Forgetful or tired users will be periodic

Functional Specifications - Efficiency

The incentive spirometer will read user inhalation volumes and display successful maximum inhalations to the user via OLED display. The device will be functional over 60 hours.

ID	Spec	Threshold	Objective	Verification	Notes
EF 001	Battery Life	The battery life will last between 60 and 70 hours of operation	The battery life needs to last for a few weeks without needing a battery change	Calculations and observation	None

Functional Specifications - Data Retention

The incentive spirometer will only retain data for a single patient at a time and delete it after the patient has completed their breathing exercises. Information will be displayed on a screen for the patient and attending physician to verify the patient's performance.

ID	Spec	Threshold	Objective	Verification	Notes
DR 001	Data Retention	The number of successful inhalation repetitions over the period of 1 hour will be recorded	To ensure that the patient's performance can be verified by an attending medical worker	Visually inspect and verify that the lcd display shows accurate count each time the laser gets interrupted.	The microcontroller stores and displays the current number of successes.
DR002	Information Display	Display different messages input from the microcontroller	Display information on patient's inhalation performance.	Screen dynamically outputs messages from microcontroller	The medical provider reads from the LCD display the number of successful inhalation therapies

Functional Specifications - Physical Characteristics

This device is likely to be handle by a large variety of people and therefore needs to be simple to use and aesthetically pleasing. The design of the spirometer also needs to be as compact as possible as it will be in a hospital setting where space is a limited resource.

ID	Spec	Threshold	Objective	Verification	Notes
PC001	Spirometer Dimension	Height: 11 in Width: 7 in Depth: 4 in	Height: 10 in Width: 6 in Depth: 3 in	Measured with calipers and CAD model	Our customer Kerry Curran requested that the new spirometer design remain similar in size to the original design.
PC002	ON/OFF switch	N/A	Preserve battery life while not in use	Simulation and code	None

Functional Specifications - Cost

Given that our product incorporates multiple devices the cost will be greater than other spirometers on the market. We aim to be competitive by increasing the functionality and lifetime of each subsystem on our device.

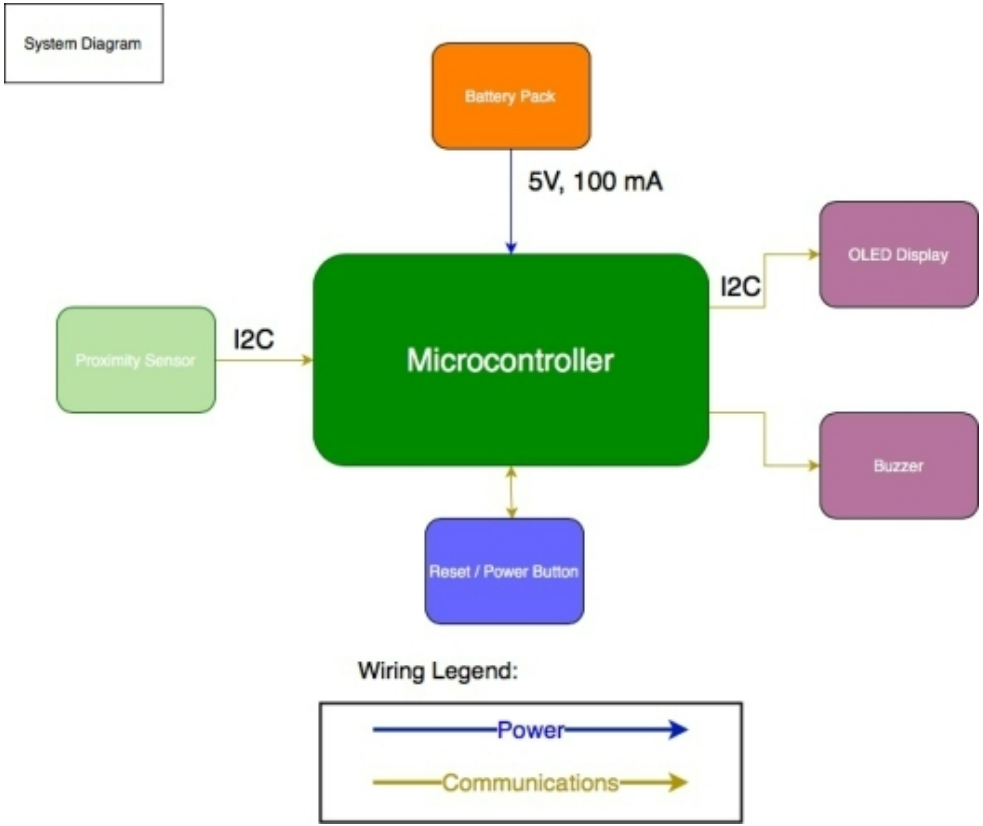
ID	Spec	Threshold	Objective	Verification	Notes
C001	Cost	Cost of the electrical components shall not exceed $75 and should not exceed $40	Keep the additional cost of the electrical component low to remain competitive with other models	Analysis of the bill of materials and the final cost	Since the electrical unit will be reused across multiple cheaper spirometer units, their cost is spread out over a massive volume of consumer-type product, the cost can remain competitive against forgoing our product.

Functional Specifications - Safety

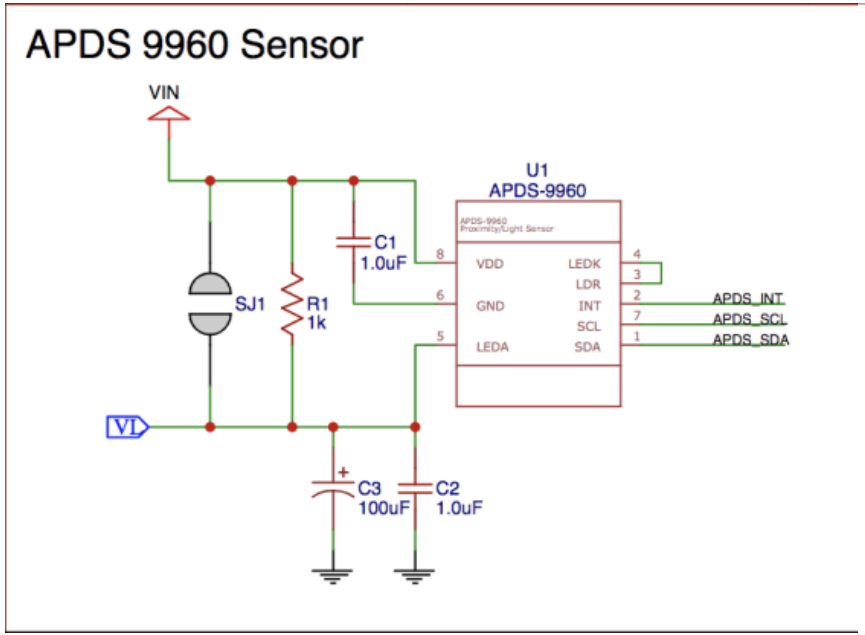
Since the device will be used for rehabilitation, it is essential for the electrical parts to stay hidden to account for overall safety. The device must not harm the user at all, be that from electrical shock or from other events.

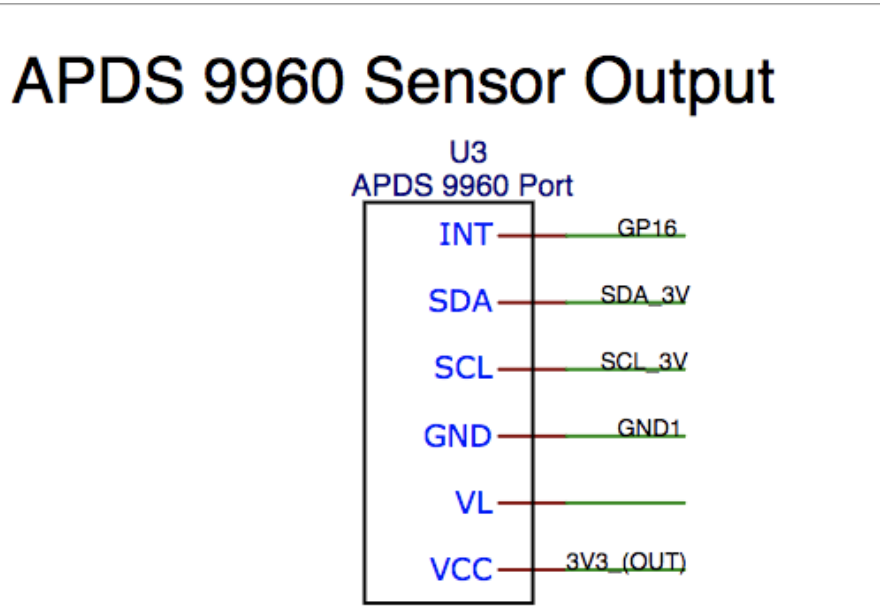
ID	Spec	Threshold	Objective	Verification	Notes
S001	Wire Exposure	N/A	No exposed wires	Visual Inspection	Keeping the wiring within the electrical housing will prevent damage to both user and the device
S002	Electrical Component Access	N/A	No user access to electrical components	Visual Inspection	Prevent access to all the electrical components besides the ON/OFF switch

Electrical Block Diagram

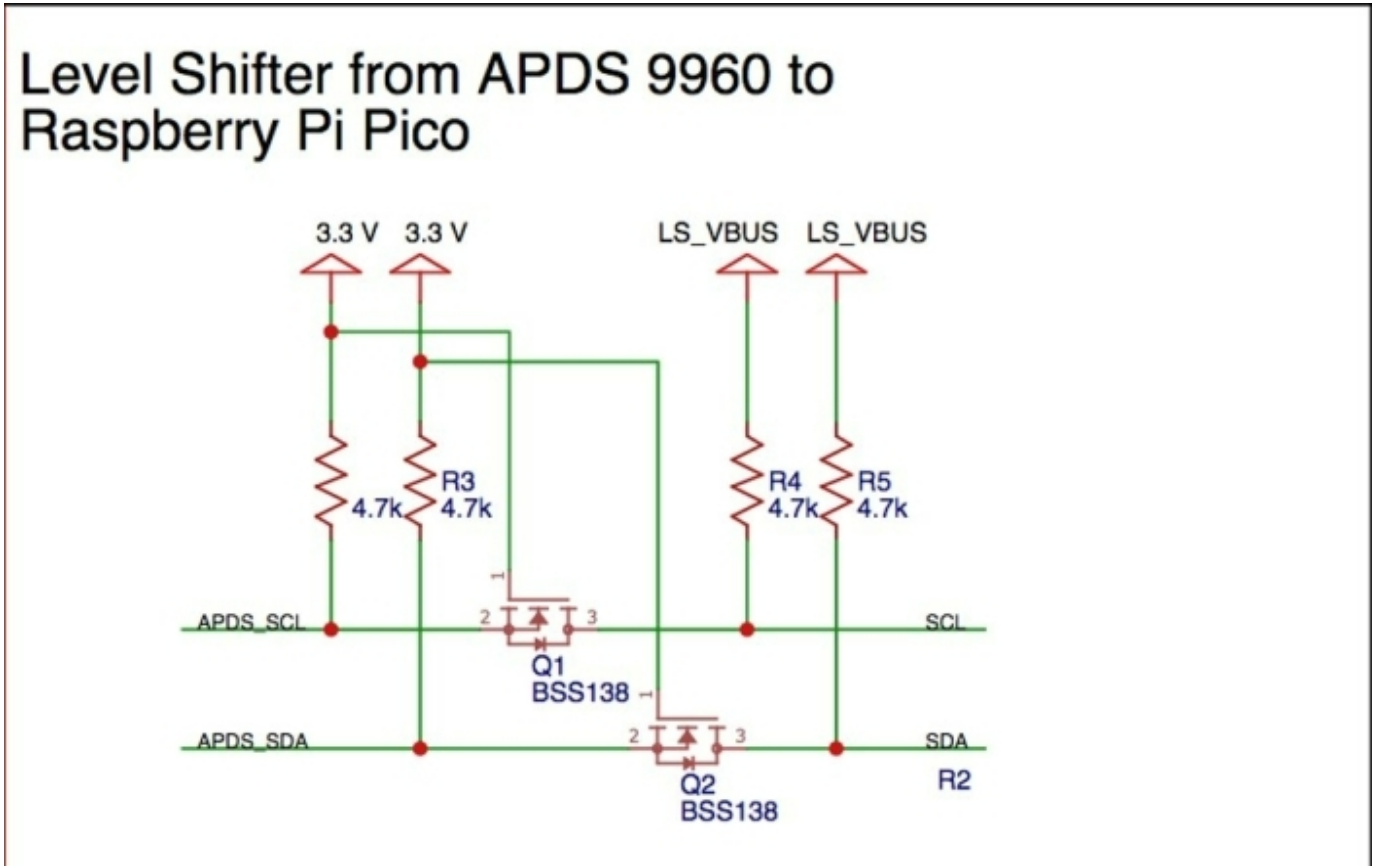


Electrical Schematic - IR Sensors

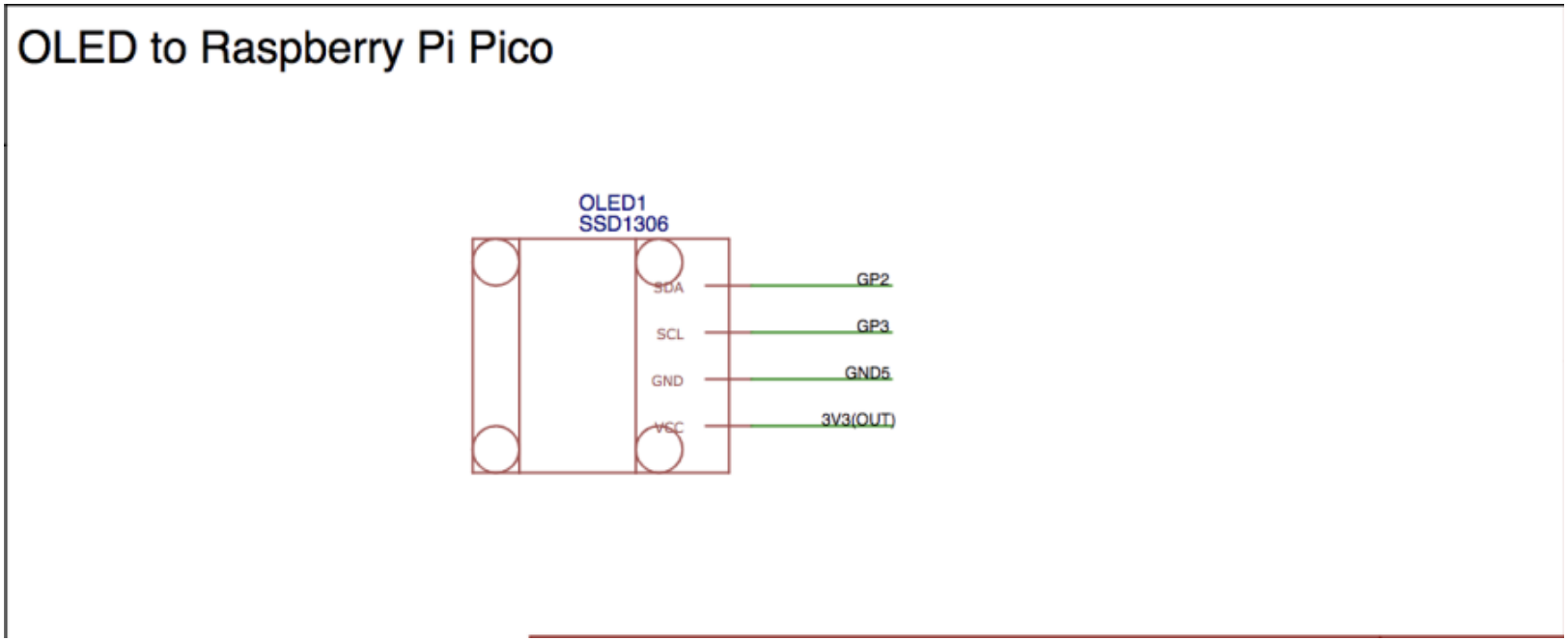




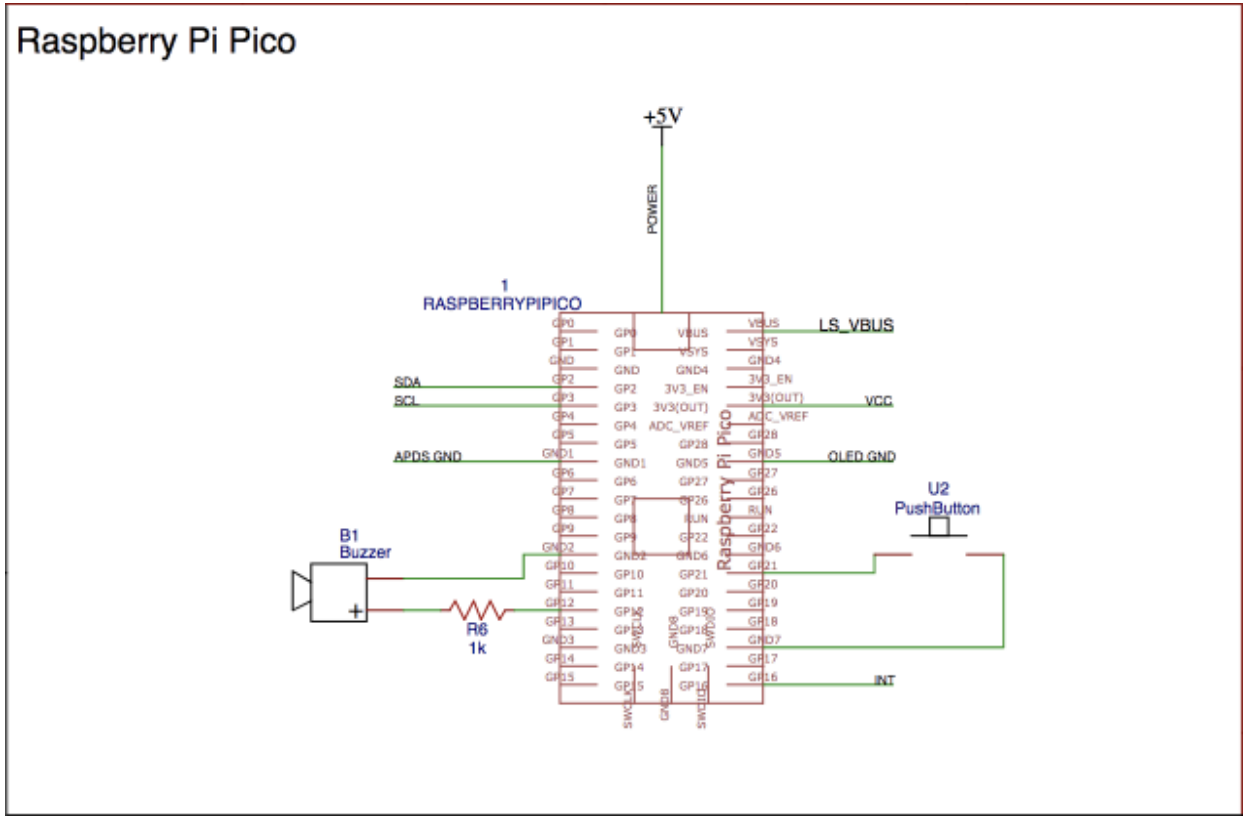
Electrical Schematic – Sensor to Microcontroller



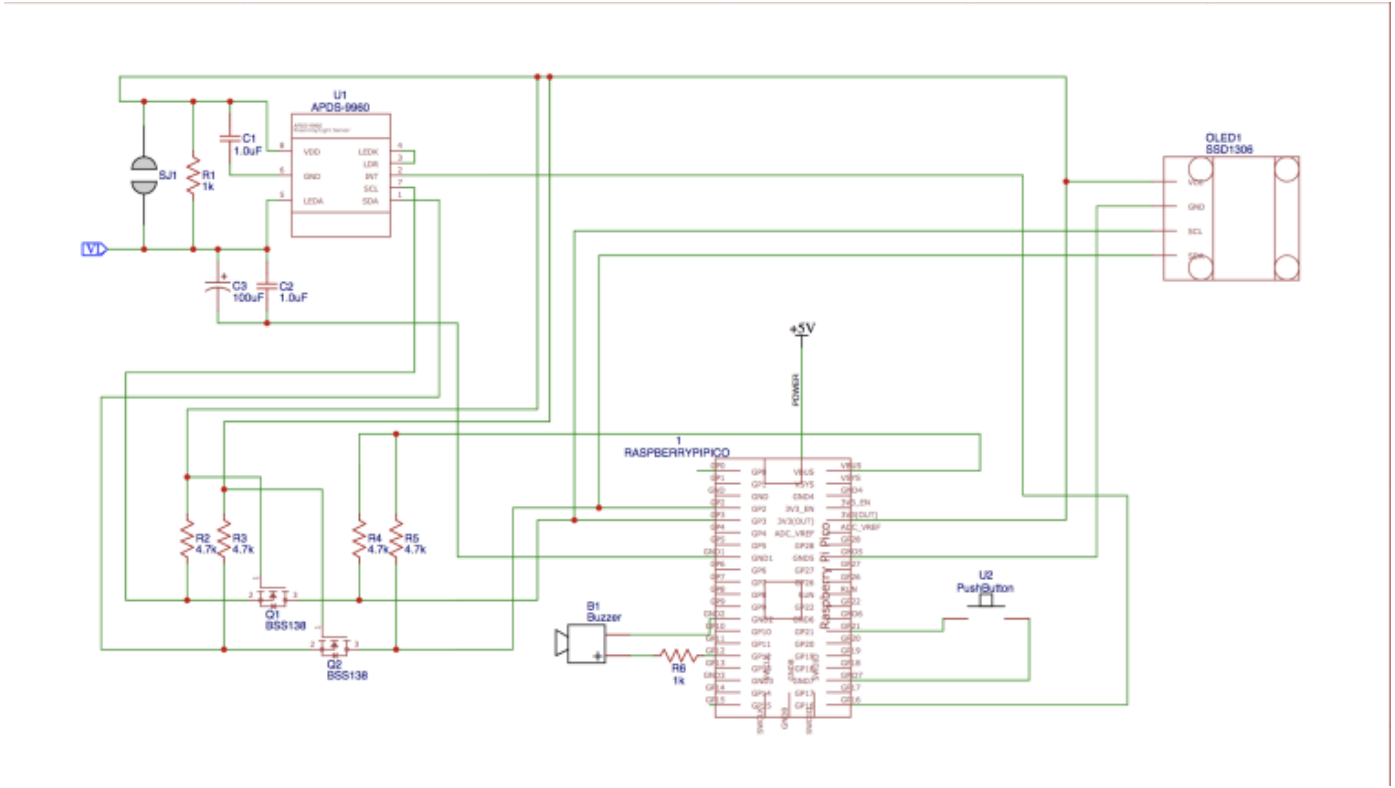
Electrical Schematic – OLED Display



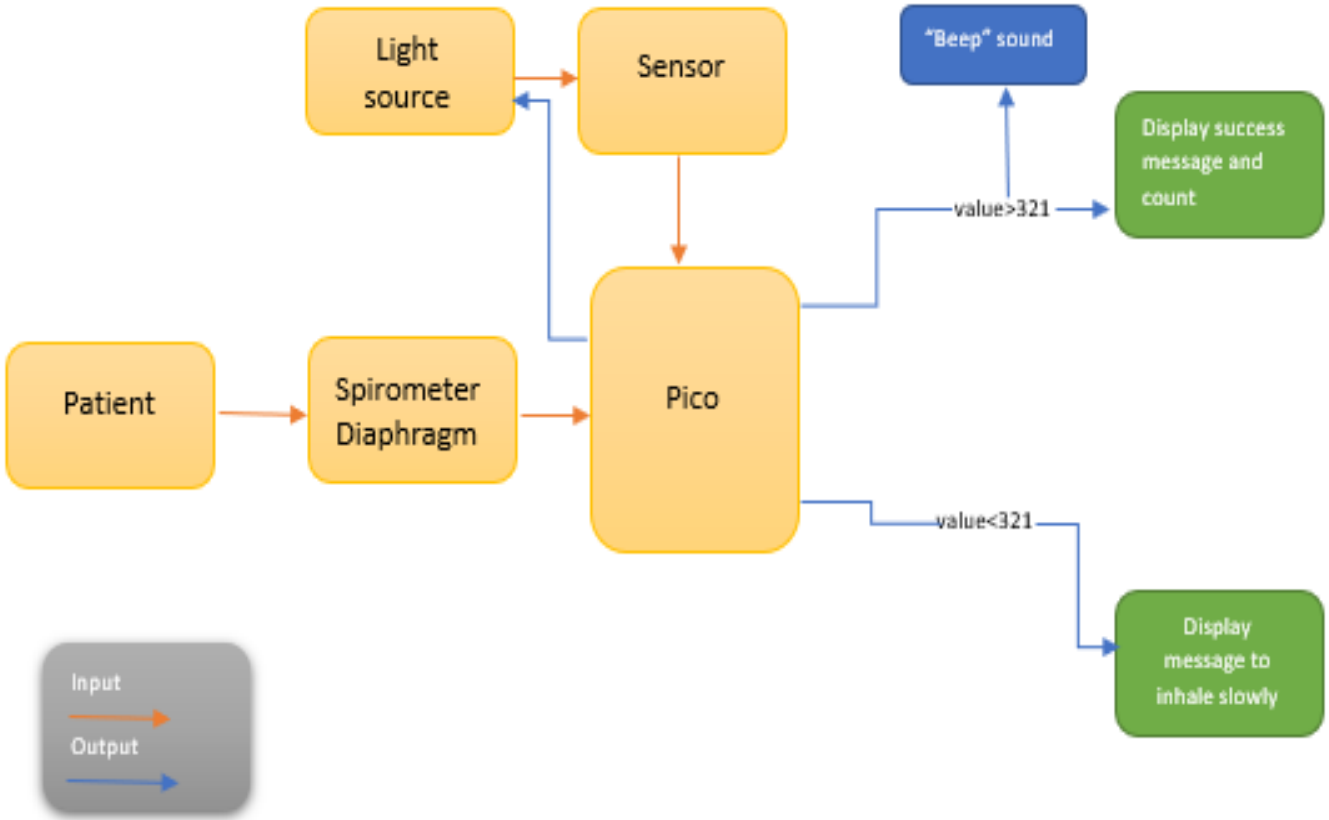
Electrical Schematic - Microcontroller



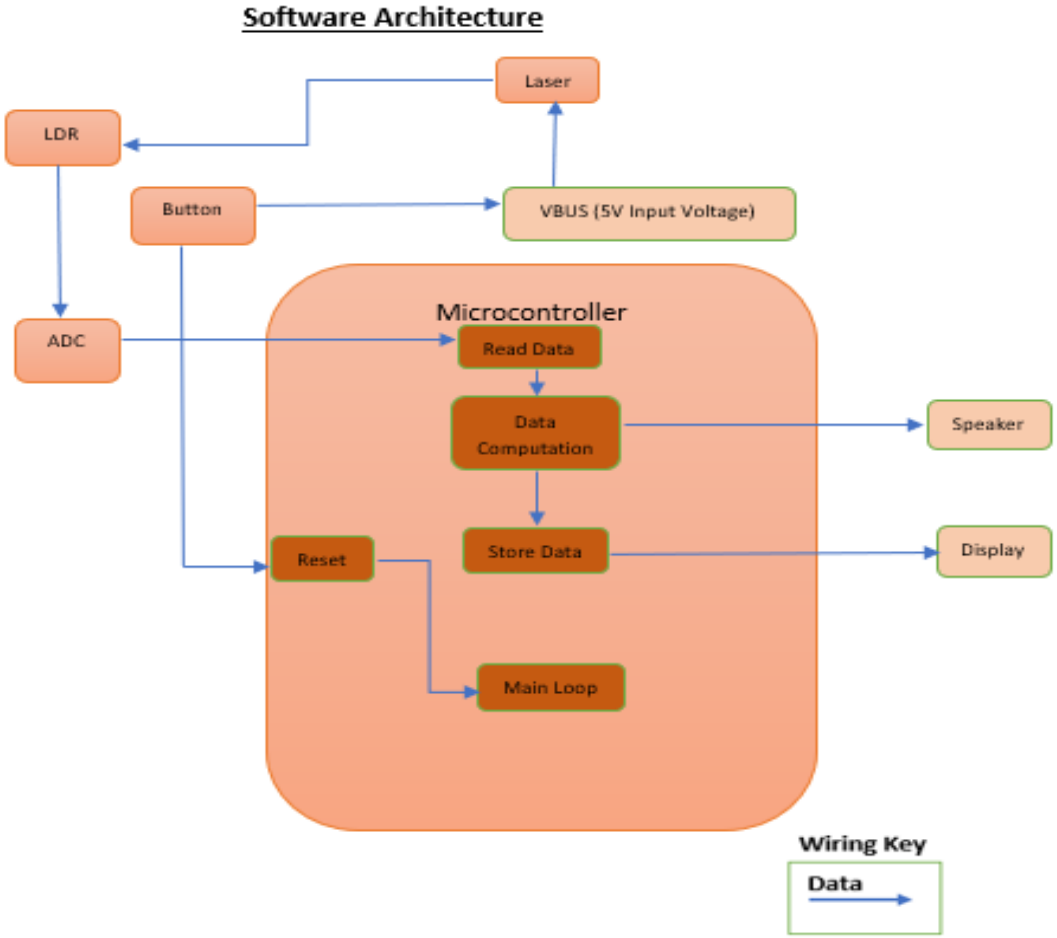
Electrical Wiring Diagram



Software Routine



SW / FW Block Diagram

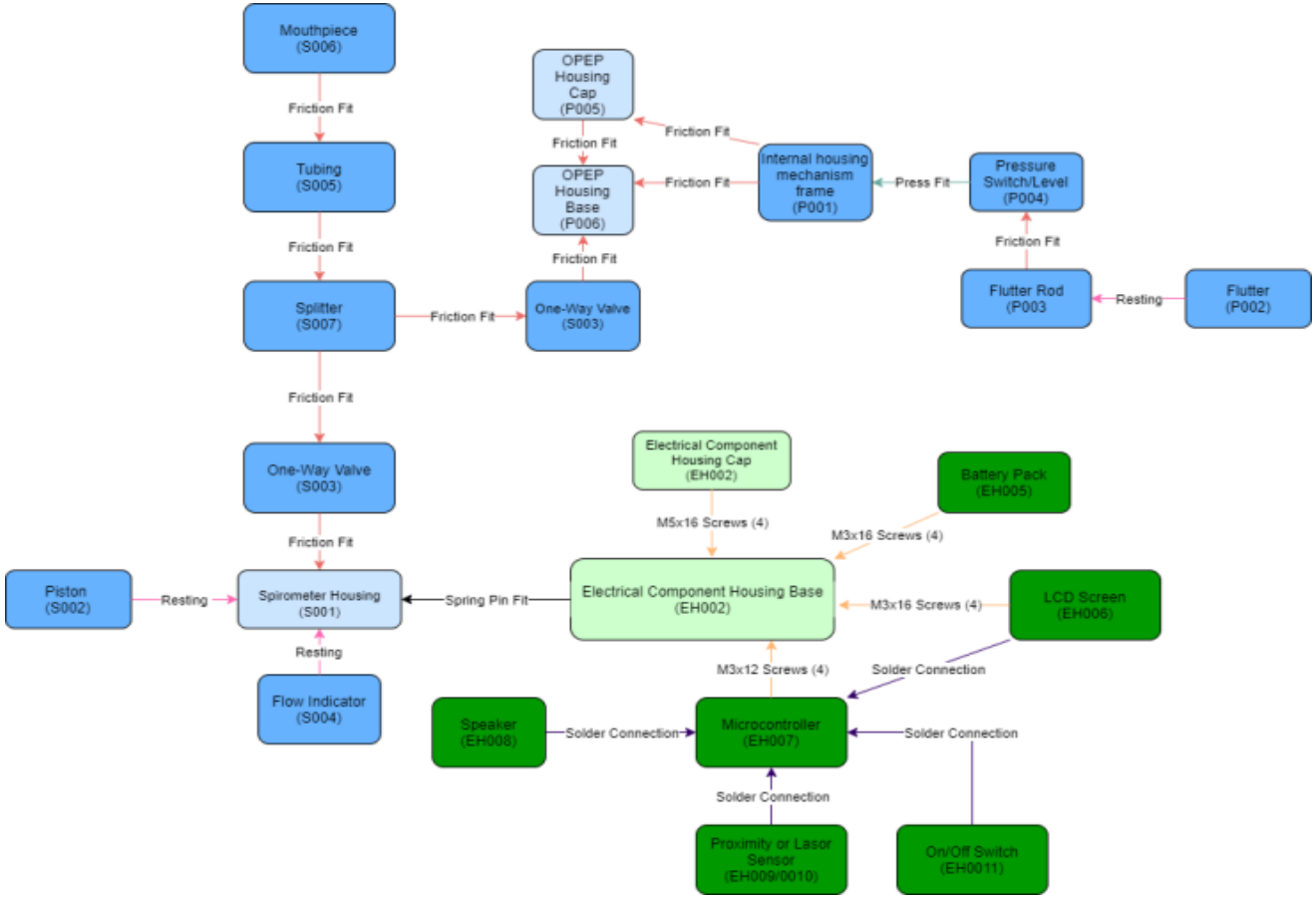


SW/FM Architect Context

Reading data from the Light Dependent Resistor (LDR) is very critical in providing a meaningful interpretation of patient inhalation therapy. Since the LDR is light dependent, we need to mitigate the issue of ambient lighting providing misleading data to the pulmonologist and it is why the use of a laser, for its directional and high consistent distribution compared to ambient light, becomes critical as our light source to the LDR. Our software is written such that the Raspberry Pi Pico, by shinning a laser to the LDR, accurately picks up data from the LDR. We then use the ADC on the Pico, because the LDR's values are in analog form, convert those values, and in our algorithm, we decide the commands we want to give to the Pico. For instance, if the LDR does not detect the laser when light from the laser is being blocked by the diaphragm of the Spirometer, the Pico will send an audible alert as a successful exhalation and prints a success message and count on our LCD display.

The reset feature in the SW/FM Architect block diagram is not a physical button to be pushed to reset the microcontroller. It is embedded in code such that every time the electrical component of Incentive Spirometer 2.0 is turned off and turned on, it will start a new count for a new patient.

Mechanical Block Diagram



Summary of Analyses

Completed during Q1

- **Design -** Maintain same spirometer functionality while making aesthetic improvements
- **OPEP Research** - Conducted research into which form of OPEP was best fitted for our customers desires.
- **GPIO Pins** – Communication between sensor, OLED, and microcontroller is necessary
- **Software IDE** - Software used to code microcontroller
- **Sensor Distance and Orientation Analysis** - placement of sensor in circuit and electrical housing for improving overall performance
- **APDS 9960 Module** – sensor in place to read volume of Incentive Spirometer 2.0

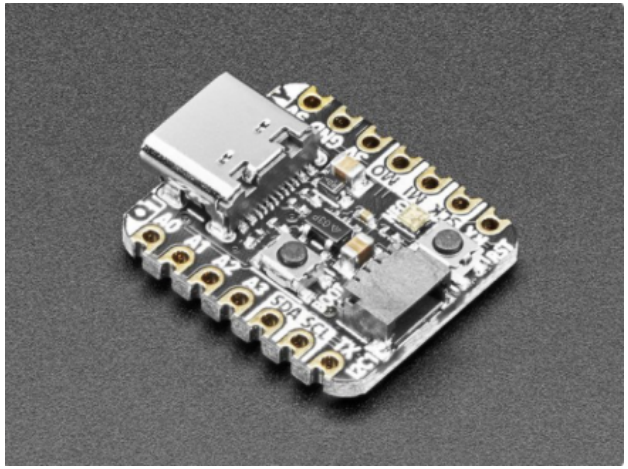
Additional analysis required

- **Microcontroller Selection –** Needed to record successful inhalations and display to user
- **OPEP Pressure Data –** Used manometer to collect data on Aerobika

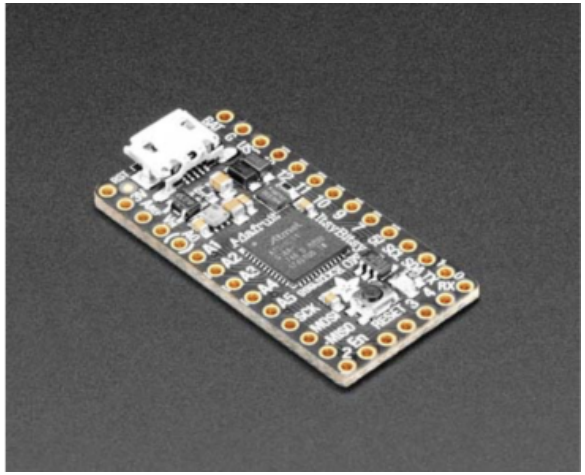
New analyses for Q2

- **Wire Routing**

Microcontroller Selection



<u>QT Py RP2040</u>
Size: 21.8mm x 17.8mm
I2C capability: Yes
Processing Speed: 125 MHz
Peak Current Draw: 16.6 mA



<u>ItsyBitsy M0 Express</u>
Size: 35.56mm x 17.78mm
I2C capability: Yes
Processing Speed: 48 MHz
Peak Current Draw: 112 mA

OPEP Pressure Readings

- To further understand how the airflow works within the OPEP we drilled a hole after the first air flow manipulation feature
- Using a manometer, we took pressure readings at different difficulty settings

Manometer setting	OPEP difficulty setting	Pressure (kpa)	Avg Pressure (kpa)	Avg Pressure Difference (kpa)
regular	5	1.59	1.56	0.32
		1.65		
		1.43		
	1	1.76	1.88	
		2.04		
		1.83		

Questions?