THERAPEUTIC INCENTIVE SPIROMETER WITH E-FLEX

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Lung Technologies
The Digital Pre-Surgical Platform

Abstract

Surgical procedures requiring general anesthesia can collapse a patient's alveoli or even an entire lung lobe which can result in negative health outcomes including pneumonia and low blood oxygen levels.

Post-surgery, slow and deep breathing inhalation exercises – via volumetric incentive spirometers – serve to reopen the lung's air sacs and restore lung capacities. Thus, improving patient adherence and accuracy of sustained maximal inhalation data are key to rehabilitation.

This project aims to design an incentivizing monitoring device with a user display interface, attachable to the Voldyne 5000 spirometer model, and to improve the material efficiency and grip ergonomics of the model.

Background

Current Standard of Care & Challenges

- **Voldyne 5000** is the current standard of care for postoperative prevention for general anesthesia induced atelectasis
- **Limited patient adherence** due to pain upon inhalation and forgetfulness
- **Unreliable and inaccurate data** because inhalations are tracked on an honor system

Fig 1. Voldyne 5000

Deliverables

Enhanced Spirometer
- 4000 mL capacity
- Reduced height by 1 - 1-½ inches
- Ergonomic handle
- Rail system adjustable every 250 mL from 500 to 4000 mL's

Digital Interface
- Sensor to detect successful inhalation
- LCD screen displaying breath count
- Auditory and visual patient reminders every 10 minutes
- Motion activated device with sleep mode
- Wirelessly rechargeable battery, lasting a minimum of 3, 8-hour sessions

Printed Housing

Custom designed casing prioritizing:
- Clinical use
- Manufacturability
- Ease of cleaning

Fig 2. Concept of redesigned incentive spirometer with monitoring device

Monitoring System Design Choices

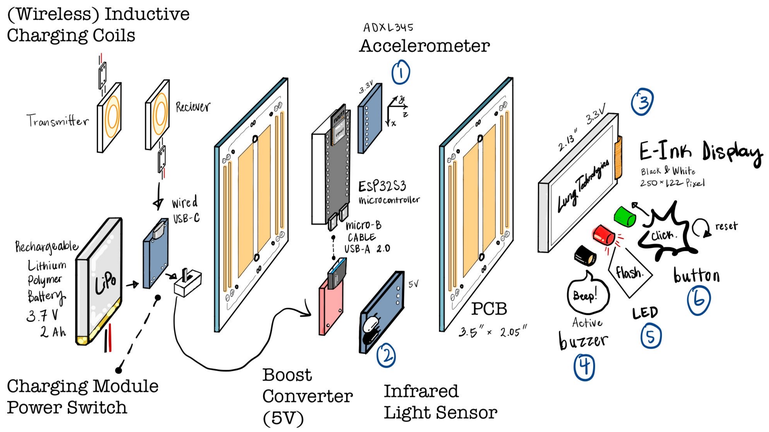
ESP32-S3 DevKitC-1 development board, equipped with a wireless communication module, comes with 5V and 3.3V power rails, sleep modes for power conservation, 36 GPIO pins, supports I2C and SPI communication protocols, and is compatible with Arduino IDE programming software.

ADXL345 accelerometer comes with two interrupt pins and functions as a motion sensor to detect the presence of the user, and automatically triggers sleep, and awake mode.

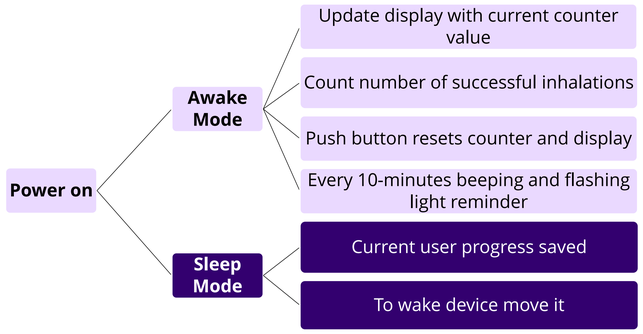
E-ink display with partial refresh only consumes power when the display information is updated and is ideal for a low power device.

Infrared light sensor is compact and can detect the float moving inside the inhalation chamber which is made from a semi-permeable plastic more resistive to visible light.

Monitoring System Architecture

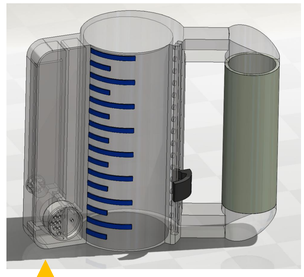


Monitoring System Firmware



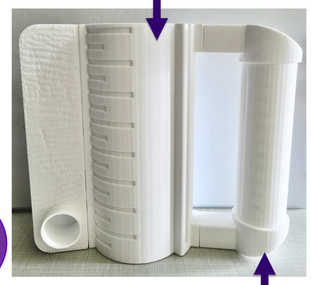
Enhanced Incentive Spirometer

Monitoring device to be attached to the sliding rail system equipped to the front or side of the inhalation-volume chamber



Combined inhalation-rate chamber with inhalation-tube connection port

compact
comfortable
compatible



Rounded and rubberized grip to suit the hand

Conclusion & Future Work

This project was successful in iteratively prototyping an incentive spirometer reduced in size and with an ergonomic design, in addition to a low power digital patient interface that tracks patient usage of the incentive spirometer.

Spirometer next steps
- Air volume calibration
- Stereolithography (SLA) fabrication with transparent material
- Administrate medicine

Monitor Hardware and Firmware next steps
- Design printed circuit board schematic and manufacture
- Custom silicone housing
- Multilingual or pictographic display

Testing to be completed
- Medical device safety regulations
- Power consumption of electronics
- Survey and incorporate user feedback

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