Duke
PRATT SCHOOL of ENGINEERING

Liquid Level Detection System

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In collaboration with Makerere University

DUKE ENGINEERING
DESIGN POD

Problem Statement

Due to understaffing, nurses at Makerere University in Uganda need a solution for sensing low water level in bCPAP respiratory assistance devices and notifying medical staff

Motivation

- Nurses are understaffed at the university, and have busy schedules and routines
- An alert system would streamline the nurses' routines, and ensure that bCPAPs are refilled as needed

Design Blocks

- **Sensing** liquid level using a capacitive sensor
- **Alerting** nurses using an alarm and LED lights
- **Attaching** to the bCPAP with adjustable Velcro® strap
  - Electronics are contained in a water-resistant wooden box
- **Powered** using a 4.5 volt battery
  - With battery level indicator
  - Battery life is conserved with alternating current
  - Compatible with rechargeable lithium-ion batteries

Final Solution

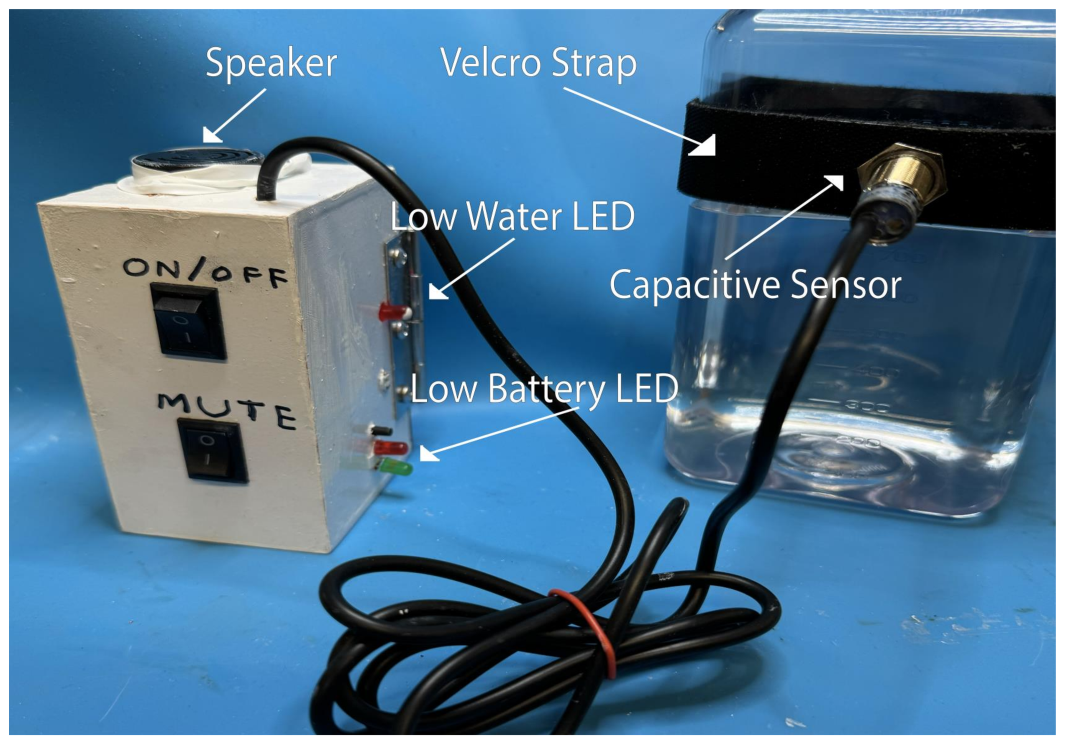

Fig. A: Liquid Level Detector

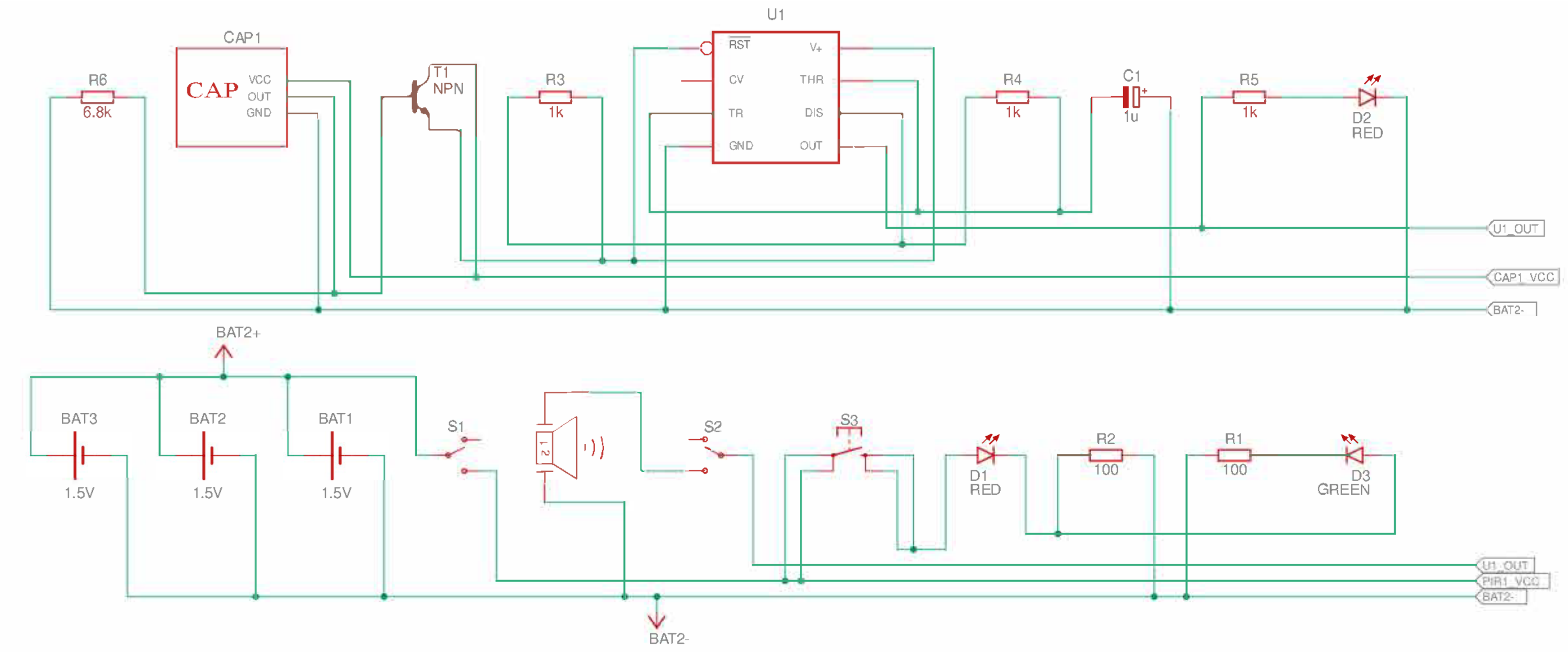

Fig. B: Circuit Schematic

1. **Sensing System**

The **capacitive sensor** is attached to the bCPAP container with an adjustable **Velcro® strap**. The capacitive sensor measures the difference in capacitance between water and air. When the water level falls below the capacitive sensor, it sends a high voltage signal to the alert system circuit.

2. Alert System

The alert system is activated when the water level falls below the capacitive sensor. An **LED** flashes, and the user can adjust the frequency of the flashing. A **speaker** also emits a beep to provide an auditory notification for nurses. The speaker has a a mute switch.

3. Power Supply

Three **AA batteries** supply 4.5V to the device. The battery life is estimated to last 8.5 days. The user can check the battery life by pressing a button; a powered green LED indicates sufficient battery life, while a powered red LED indicates low battery. The power supply system is compatible with both disposable AA batteries and rechargeable 14500 lithium-ion batteries.

Design Criteria & Testing

Objectives, Constraints	Performance Criteria	Justification for Performance Criteria	Test	Target Value for Test	Results
Cost (objective)	Cost ≤ $10	Given criteria from consultation with client	Look up cost of parts in Uganda	Cost < $10	Cost ~ $23.11 X
Portable (objective)	Weight ≤ 35 lbs.	Referenced OSHA safe patient handling protocol for nurses	Time people moving device	Takes 0-7 seconds to move	Weight = 0.537lbs ✓
Durable (objective)	Last for ≥ 500 patients	Given criteria from consultation with client	Simulate 500 uses of the device	Maintains functionality for 500 uses	Lasted > 500 uses ✓
	Battery life > 30 days	ISO 60601-1 Medical Electrical Equipment Standard	Two-day voltage drop test	Battery life > 30 days	Battery life ~ 8.5 days X
Intuitive (objective)	Learn time < 5 minutes	Given criteria from consultation with client	Time people to set up device (15 test subjects)	Average learn time < 5 minutes	Average learn time = 70 sec ✓
	Response time < 5 minutes	The Joint Commision response time standard	Time to react to alarm (15 test subjects)	Average response time < 5 minutes	Average response time = 12 sec ✓
Local manufacturability (objective)	80%-100% of parts found in/delivered to Uganda	Device must be able to be replicated and repaired locally	Look up part availability in Uganda	80%-100% local parts	100% local parts ✓
Aesthetic (Objective)	Complies with ISO 13485 Medical Design Standard	Given criteria from consultation with client	Survey 15 people to rate device's design (15 test subjects)	Average rating is >4 out of 5	Average rating = 3.5 out of 5 X

Conclusion & Future Work

Following our testing, we are pleased to report that our device 6/8 of our tests. It costs $23.11 and weights 0.537 lbs. The device lasts greater than 500 uses and has an 8.5-day battery life. Users took 70 seconds to learn how to use the device and 12 seconds to respond to the alarm. 100% of the parts are locally manufactured, and peers rates the device 3.9/5 on aesthetics. Based on our testing, we suggest our device is a **successful proof-of-concept** as an affordable capacitive-based water level detection system for bCPAP respiratory assistance devices in Uganda.

Moving forward, we hope to:

- Meet IEC 60601 medical **noise fatigue** standard
- Improve **battery life** by reducing sensing duration

We remain uncertain as to the practical intuitiveness of our device given that we were unable to test the device with nurses. Further testing would be required to ensure the implementation and use of the device in the hospital setting.

References & Acknowledgements

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