Towel Bacteria Detector

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1. Introduction

1.1 Objective

Bath towels are used every day often after a shower, but people rarely think about how often they should clean their bath towels. In fact, most people neglect to wash their towels just once a week. Because bath towels are often damp and left to air dry, they provide the perfect environment for unwanted bacteria to grow. This can lead to a buildup of substances like mold, mildew, or bacteria on the towel [1]. Furthermore, these can result in an unpleasant odor that makes the towel unsuitable for drying use. Knowing when a bath towel is beginning to exhibit signs of unwanted bacteria would provide insights into when a bath towel should be cleaned.

We propose building a detective device that lets users know when to wash their bath towels. Our unit could let towel users know this by monitoring the amount of emitted CO_2 from bacteria and mold. As mold develops it emits CO_2 as a byproduct. In mold-free environments, there are typically around 400 parts per million (ppm) of CO_2. With mold, CO_2 concentrations can spike to over 1,000 ppm [2]. If the towel is deemed moldy, the user is alerted via a red LED or green LED if the towel is deemed fine.

1.2 Background

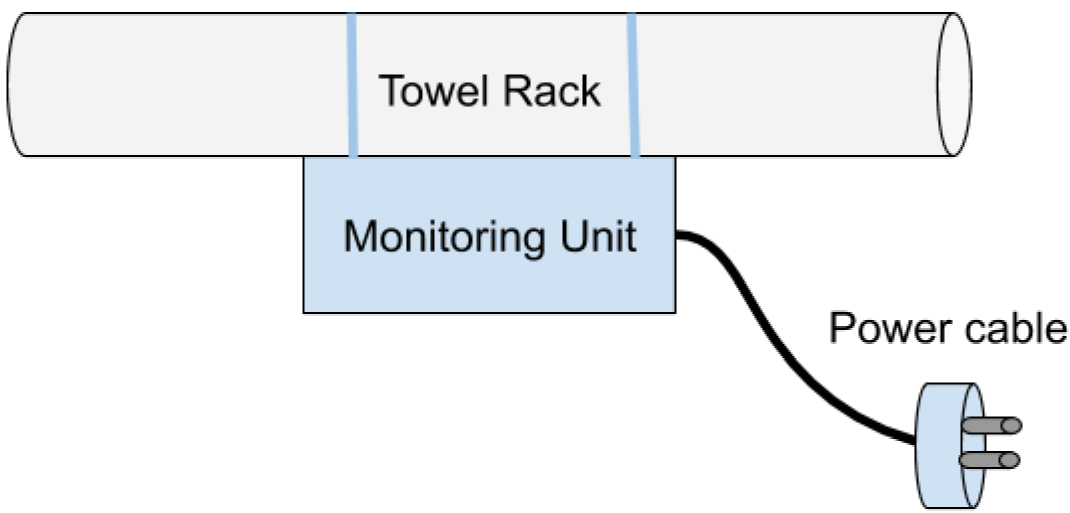
This project was originally done in Spring 2019 by team #25. However, their project extensively involved cleaning the towel with a moderately expensive UV LED solution. Rather than detecting the amount of bacteria, their UV cabinet was triggered on a timer and blasted the towel with disinfecting light regardless of if the towel actually needed cleaning or not. Their cleaning UV cabinet cost around $200.

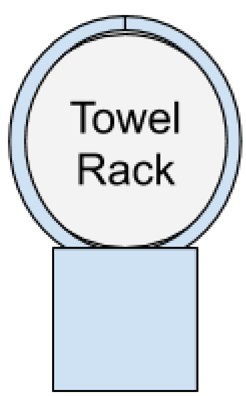
Our solution proposes simply identifying when a towel should be cleaned and alerting the user of this. Because towels can be cleaned using traditional washer and dryer units, we sought to eliminate the inclusion of expensive UV LEDs and a cleaning cabinet altogether. Rather, we can capitalize on the existing infrastructure (in-unit washers and dryers) as our cleaning mechanism and provide a monitoring solution for towel-bourne bacteria. Additionally, this will be beneficial if users are away from home when a bath towel would not be regularly used since unnecessary cleaning would not occur.

Other attempts at preventing towel bacteria growth have rarely been made yet there are a few consumer products that exist. Special towel detergents are available to be used in a washer unit. These work primarily to reduce odor from bath towels but don't objectively specify when a towel should be washed [3]. Salons also have heated cabinets designed to keep towels bacteria-free, but these units require a significant amount of energy since they are continuously operating. Our solution is the first to accurately identify when a bath towel should be washed.

1.3 Physical Design

Below is a drawing of the front and side views of the monitoring unit. It will be attached directly to a user's pre-existing towel rack and will reside under a hanging towel. It will be attached by a plastic connecting component that wraps around a towel rack.



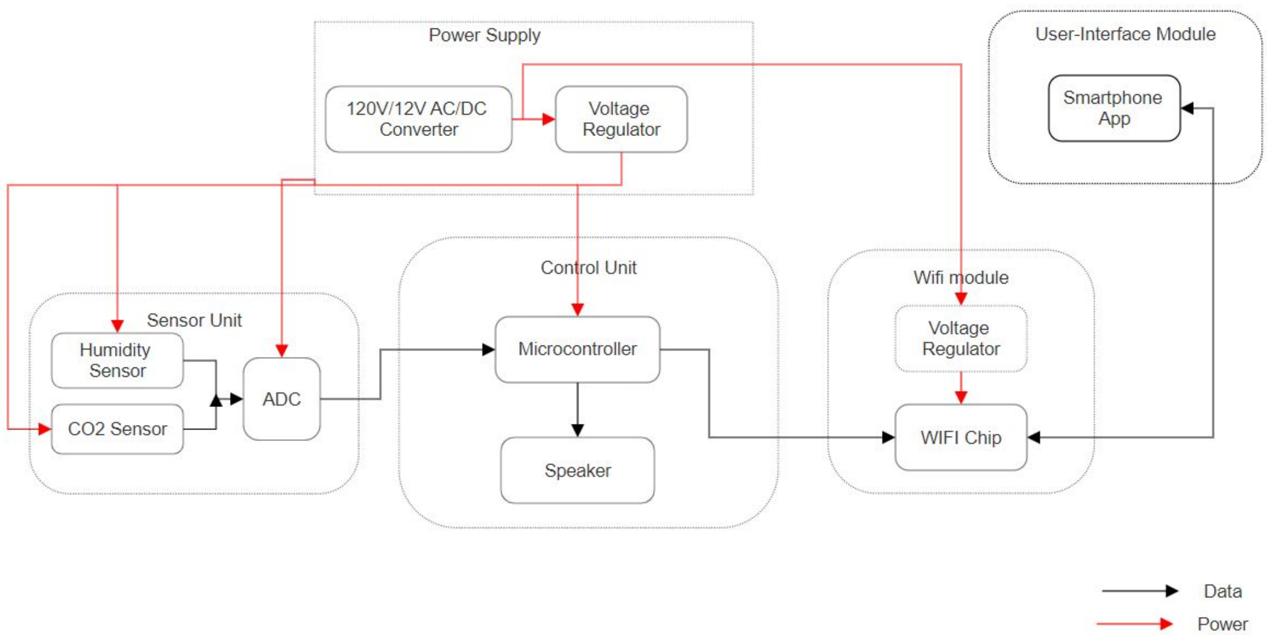


1.4 High-Level Requirements

- Detects CO_2 in the surrounding air in ppm with an accuracy of +/- 10%
- Alerts the user if a towel is good or bad based on if CO_2 concentration is at or above 800 ppm near the towel
- The unit can operate in a high humidity environment without resulting in faulty operation

2. Design

2.1 Block Diagram



2.2 Functional Overview

2.2.1 Power supply unit

The power supply will power the entire circuit and its components. It will also convert standard wall voltage into suitable voltages in order to power the hardware components.

120V/12V AC/DC Converter

The unit operates off of wall voltage and uses a standard 120V AC/ 12V DC converter that connects to the unit via barrel jack. The unit also has a switch that allows the user to power the unit on or off when operation is desired.

Voltage Regulator

The voltage regulator takes the input voltage from the battery and generates a constant 5V DC output. This 5V DC output is used to power the various components of the circuit including the humidity sensor, the CO2 sensor, and the microcontroller.

Requirements: The power supply unit must take a standard 120V AC wall voltage and outputs a 5V +/- 0.5V output with at least 250mA.

2.2.2 Control unit

The control unit will handle all data inputs from the sensors and send outputs to the WIFI module and speaker to alert the user.

Microcontroller

The microcontroller receives digital reading of the CO2 sensor and humidity sensor from the ADC and controls the output that is sent to the WIFI module and speaker. We expect two digital output pins connected from the ADC to the microcontroller.

Speaker
The speaker receives a signal from the microcontroller when the limit of CO2 level is reached.

Requirements: The microcontroller should be able to receive the data from the sensors and be able to output a signal to the speaker when the CO2 level limit is reached. The microcontroller must be robust enough to function in the humid environment in the long term. The microcontroller should be able to send data to the wifi module to communicate with the user.

2.2.3 WIFI module

The wifi module connects the device to the wifi router to get a direct communication with the smartphone app to control the sensors.

Voltage Regulator

The voltage regulator of the WIFI module takes in the 12V input and outputs a constant 3V output, which is the active range of the wifi chip.

Wifi chip

The wifi chip will receive data from the microcontroller and send the data to the user's smartphone. It will have to get a wifi connection, and it will be the primary network host for packaging information to send and to receive acknowledgements from the paired smartphone.

Requirements: The wifi module should receive data from the microcontroller and be able to send the data to a given destination. The module should be able to receive data from the smartphone whenever the smartphone sends data to the module.

2.2.4 Sensor unit

CO2 sensor
The CO2 sensor is the most important unit sense it detects the concentration of CO_2 in the surrounding air. This sensor's output voltage decreases as CO_2 concentration increases. This voltage goes to the ADC for digital conversion.

Humidity sensor
The humidity detector is necessary because the voltage response of the CO_2 detector is also dependent on the ambient air humidity. This sensor detects the humidity of the air around it and outputs a dependent voltage. This voltage goes to the ADC for digital conversion.

Analog-to-digital converter
The analog-to-digital converter takes the CO_2 and humidity sensor readings and converts them to a digital form that is suitable to be read by the microcontroller.

Requirements: The accuracy of both the CO_2 sensor and the humidity sensor should be within +/- 10%. The ADC should accurately translate an analog signal into a digital signal.

2.2.5 User interface module

The user interface module establishes a connection between the user and the microcontroller to retrieve data from the sensors and lets the user control the microcontroller.

Smartphone app
The smartphone app connects with the control unit by wifi connection. The app receives the data from the sensors and displays the CO_2 level. It displays the level of severity with specific colors for each level: red for off the limit, yellow for warning, green for safe. The app can reset the microcontroller to default setting, and start recalibration of the sensors. The app can enable and disable the speaker.

Requirements: The smartphone app should be able to establish a connection between the microcontroller and the user. The app should display the incoming sensor data, and manipulate the microcontroller settings.

2.3 Risk Analysis

One of biggest challenge of our project will be getting the accurate CO_2 level. The accuracy of a CO_2 sensor is directly correlated to the price of the sensor. Since our product requires to be affordable to draw demand from potential customers, we will have to test the right accuracy that will meet our need of detecting whether a towel needs to be cleaned. Another potential problem is detecting the CO_2 level in humid condition. We need to test how humidity could alter the detection sensitivity of CO_2 sensors, and find a right calculation method that accounts for the humidity level. We also need to test how humidity could damage our circuit and find how the electronics can be safe in the humid environment. Another risk is maintaining battery efficiency. We will have to find the right frequency that will be enough to detect CO_2 level effectively and achieve energy efficiency.

3. Ethics and Safety

Our product will certainly have associated safety and ethical concerns since it is operating in a humid environment with electrical components, detecting harmful CO_2, and preventing the spread of disease-causing bacteria. Operating in a humid and wet environment poses significant challenges to electrical components. Failure to properly secure and enclose a device in such an environment can result not only in electrical failure but also can pose a safety risk to those using the device. The IEEE Code of Ethics states as its first principle “to hold paramount the safety, health, and welfare of the public” [4]. In order to abide by this principle, we will enclose our device in a waterproof casing, spraying our most vulnerable components like our PCB with a hydrophobic coating, and providing caution labels on our packaging to prevent improper use like submerging the device in water.

Another key concern is how well our solution can detect CO_2 produced by bacteria and mold. CO_2 electrical sensors do have tolerance for error. As a result, we will provide a clear and honest description of these limitations on the product’s packaging. This is in line with the third IEEE principle “to be honest and realistic in stating claims” [4]. We view this as necessary since we don’t want our sensor to be interpreted solely as a live-saving CO_2 detector when it is not.

We also want a safe amount of voltage to be delivered to our device. This is of the utmost importance when operating in a wet and humid environment. Here, our voltage regulator will be key to mitigating any risk to users of this product. We will require a safe voltage step down from our power supply.

Finally, it is important to recognize that our product may provide the only indication of towel bacteria. Bacteria like E-Coli and mold can often grow on damp bath towels, and these substances can pose significant health risks to humans. Because of this, it is really important that our sensors work properly in detecting bacteria. Having disease-causing bacteria go undetected can be harmful to users especially if they have a high level of confidence in our device working. The risk of our device giving false positives can be lessened with extensive unit testing as well as cautionary labels on the product packaging.

4. References

[1] Abrams, A. (2017, September 21). Your Towels Are Way Dirtier Than You Think. Retrieved April 29, 2020, from http://time.com/4918624/wash-towels-bacteria/

[2] https://www.ars.usda.gov/plains-area/mhk/cgahr/spieru/news/modeling-erosion-of-particulate-matter/monitoring-mold-by-measuring-co2/

[3] https://www.amazon.com/Smelly-Washer-All-Natural-Laundry-Treatments/dp/B0032TW6I0

[4] “IEEE Code of Ethics.” IEEE.org. https://www.ieee.org/about/corporate/governance/p7-8.html (retrieved Feb. 13, 2020).