Needs Assessment

Client and Customer Definition

The individuals who are at the center of this specific scenario are the residents of Bozeman, Montana. However, the region has been confronted with a significant problem, an alarmingly disproportionate rate of incidents involving alcohol-impaired driving. Despite its relatively modest population, Bozeman has earned the unfavourable reputation of being one of the most problematic cities in the United States in terms of DUI (Driving Under the Influence) incidents [10]. Residents are confronted with the daunting issue of the widespread danger posed by those who drive under the influence of alcohol, thereby jeopardizing their safety as well as that of others on the road.

The proposed intervention, a breathalyzer, presents a potential opportunity for minimizing this problem. The breathalyzer device offers a quick and effective method for assessing blood alcohol levels. Its availability enables individuals to utilize responsible judgment before driving a vehicle, consequently diminishing the occurrence of driving under the influence. This, in turn, fosters improved road safety for all Bozeman residents, transforming the town into a more secure and protected community.

Geographic

Bozeman is a municipality situated within the region known as Yellowstone Country in the state of Montana. With a population of 57,494 (2023), the city is seeing a yearly growth rate of 2.67%, an approximately 8% increase from 2020 [11]. The prevalence of personal vehicles is notably higher in rural areas such as Bozeman due to the restricted availability of public transit choices. This reliance, while essential for daily life and work, can inadvertently exacerbate the issue of Driving under the influence of alcohol.

Demographic

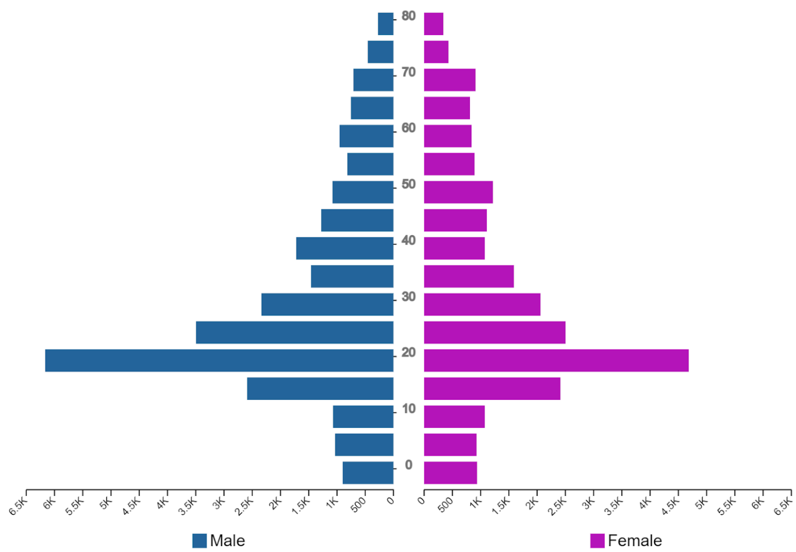


Figure 1 - Bozeman Gender/Age Population Pyramid 2023

This population pyramid is a visual depiction that illustrates the distribution of the population of age and gender within the city of Bozeman. The visual representation comprises a pair of bar graphs, whereby one graph depicts the data about males, while the other graph portrays the information related to females in the city of Bozeman. These graphs are positioned adjacent to each other. The x-axis represents the number of age groupings of the population, usually in intervals of half a thousand, while the y-axis represents the age or count of individuals within each age group. The median age in the city of Bozeman is reported to be 28.2 years, with a slightly lower median age of 27.6 years for males and a little higher median age of 29.3 years for females [11].

Economic

According to data from 2021, the median property value in Bozeman, Montana stood at $466,400, while the rate of homeownership was recorded at 44.6% [12]. In terms of salary, among the highest-paying industries in the region are Management of Companies and Enterprises, Quarrying, Mining, Oil and Gas Extraction, and Utilities, offering average annual salaries of $250,001, $73,393, and $64,050, respectively [12]. Drunk driving in Bozeman, Montana is mostly caused by its economy. Bozeman, a growing metropolitan area that promotes tourism, has a strong hospitality and service economy, including several pubs and restaurants. This industry is important to the local economy, but it also raises worries about alcohol-related incidents like DUIs. Tourists and temporary workers may not know the region's transportation infrastructure and rules, exacerbating this issue.

Challenges the Clients Face

The residents of Bozeman, Montana have been dealing with a big problem for a long time that needs instant attention: the worryingly high number of people who drive while drunk. It was clear how bad things were in Montana when it was named the worst state for drunk driving in 2023. *"The Big Sky Country topped the list with sobering statistics like 8.39 drunk drivers were involved in a fatal crash for every 100,000 licensed drivers, and 6.92 people were killed in a crash involving a drunk driver for every 100,000 state residents. Those are both the highest in the country [13]."* This widespread issue additionally impacts specific municipalities in Montana, as shown by the city of Bozeman, which has a population of around 57,494 inhabitants. Bozeman has the most drunk driving accidents in the state, with a frightening 5.587% of those accidents involving alcohol. [10]. Within the framework of increasing concerns over road safety issues associated with alcohol consumption, our project group aims to provide a comprehensive approach to effectively tackle these challenges within the state, with a particular emphasis on Bozeman, Montana.

Competitive Landscape

Social System: Ridesharing Services and Community-Based Designated Drivers Programs

Ridesharing apps like Uber and Lyft have helped reduce drunk driving in Bozeman, Montana. These platforms provide a simple alternative to driving drunk. A study by Brad Greenwood and Sunil Wattal found that ridesharing services reduce alcohol-related accidents [14]. Several firms in Bozeman provide safe and reliable transportation for people leaving bars or alcohol-filled events. Some downsides must be noted. During peak demand, the service is limited, especially in rural Bozeman. A price rise during high demand may prevent some users from using the service.

One additional social structure aimed at tackling the issue of drunk driving in Bozeman, Montana, involves the implementation of community-based designated driver programs. These efforts depend on the assistance of either volunteers or hired drivers to guarantee that those who have drunk alcohol have a safe means of transportation to their residences.

These programs cultivate a collective sense of responsibility in addressing the issue of drunk driving. In the city of Bozeman, many groups, such as “Montana Car” have implemented effective designated driver initiatives, which have demonstrated a significant reduction in occurrences of driving under the influence [15]. Nevertheless, a significant drawback lies in the dependence on volunteerism, which can result in irregular availability and insufficient coverage for all regions or periods of peak demand, especially on weekends or holidays when there is a surge in activities.

Economic System: Alcohol Taxation and Regulation

The economic approach implemented to tackle the issue of drunk driving in Bozeman encompasses the implementation of alcohol pricing and regulation. The implementation of elevated taxes on alcoholic beverages can increase the overall cost associated with drinking, hence potentially discouraging the consumption of alcohol in excessive quantities. Research conducted by Randy Elder has demonstrated that the implementation of alcohol-taxing measures has the potential to successfully reduce the rate of alcohol-related traffic deaths [16].

Furthermore, the implementation of strict laws, such as the establishment of limitations on the hours of alcohol sales, can successfully regulate the availability of alcohol during periods of greater danger. Even so, the economic system exhibits several problems, namely the tendency for unlawful alcohol production and consumption as a result of excessive taxes and laws, alongside the necessity for diligent oversight to mitigate unintentional repercussions, such as the development of underground alcohol marketplaces.

Technological System: Mobile Breathalyzer Apps

Mobile breathalyzer apps are used in Bozeman to combat drunk driving. These mobile apps let people check their blood alcohol levels before driving. Apps like BACtrack Mobile Pro are popular because they make self-evaluation easy. By helping drivers assess their safety, mobile breathalyzers promote responsible drinking.

University College of London conducted a study that showcased the potential effectiveness of these applications in mitigating instances of drunk driving [18]. However, this system has limitations. Its voluntary participation, the likelihood of blood alcohol content measurement errors, and the need for public education to promote its implementation are its drawbacks.

Requirement Specification

Accuracy

Given Montana's strict alcohol and driving laws, breathalyzer accuracy is crucial. Montana follows the majority of US states by setting a 0.08% Blood Alcohol Concentration limit [19]. Driving over this limit can result in fines, suspension of driving privileges, and jail for repeat offenders.

These criteria ensure that equipment tests blood alcohol concentration accurately and within a predetermined error range of 15% to 20% [20]. For our case, when testing for no alcohol in the air and with alcohol in the air, the values must be well within this range for our device to be viable.

Response Time

The response time of the breathalyzer is a key factor to take into account, especially in circumstances where fast and dependable outcomes are of the greatest significance. To effectively combat the problem of drunk driving in Bozeman, Montana, the breathalyzer device must be capable of providing rapid blood alcohol content readings. Ideally, these readings should be obtained within a timeframe of 10 seconds or less from the moment the user exhales into the device. A prompt reaction time is crucial in enabling users to quickly access their Blood Alcohol Concentration values, enabling informed judgments regarding their capacity to operate a vehicle safely.

Calibration Time

The majority of commonly used breathalyzers use sensors that require some time to warm up to optimal functioning conditions. Unfortunately, most sources don't specify a specific calibration time and state simply to "Let it warm up a few minutes" [17]. So as an estimate, we propose approximately 10 minutes. The objective is to establish the reliability and trustworthiness of the measurements and data obtained from the breathalyzer, ensuring their suitability for their designated objectives.

Portability

The portability of a breathalyzer device is an important aspect that greatly affects its usability and efficiency, particularly in the context of addressing the problem of alcohol-impaired driving in Bozeman, Montana. For portability, the gadget must be compact and lightweight, with dimensions of 15 cm x 10 cm x 3 cm and a weight of 150 grams. The breathalyzer may be carried in wallets, purses, or bags due to its portability, ensuring its availability when needed. Mobility helps people make sober decisions before driving in social situations, bars, and alcohol-related activities.

A portable breathalyzer allows drivers to take responsibility for their safety and make responsible drinking choices. This measure is practical for people who don't want to rely just on their subjective disability evaluation. Portability makes the item easy to share and use in countless social settings.

Battery Life

Lastly, the battery longevity of a breathalyzer holds a high value, particularly within the framework of United States of America legislation about alcohol use and operating a motor vehicle. In the context of the United States, where surpassing the legally established threshold of 0.08% blood alcohol concentration can result in substantial legal consequences, a breathalyzer device must possess a durable battery that can sustain a minimum of 100 tests on a singular charge or battery set. The prolonged duration of battery life is of utmost importance to guarantee the device's dependability in providing correct blood alcohol concentration measurements.

Analysis

Design

The overall design of our system is outlined in *Fig. 2,3 and 4*. *Figure two* includes the CAD drawing of the case of the breathalyzer with labels representing where the various components will belong. *Figures three and four* are the circuit diagram and schematic view of our system, exhibiting how the microcontroller, sensor, button, and LCD screen are all connected through a breadboard. Since a breathalyzer is meant to be a portable device, our design includes a battery, but for the actual implementation demo, we will use a USB connected as a power source. The simulation software utilized didn't have an exact 5V power source, so we opted for a 9V with a resistor to obtain the same result. Below is a step-by-step explanation of how our system will operate.

1. The button will be pressed to start the breathalyzer
    - The MQ-3 sensor requires heat to function, so the system will heat the sensor appropriately [7]. During this time, there will be text on the LCD screen saying "Calibrating System" to notify the user of the wait.

2. After the sensor is fully calibrated, there will be text on the LCD screen saying "Calibration complete. Please blow into the mouthpiece". This is when the user is meant to blow into the mouthpiece.
    - Since human testing is prohibited, we will use rubbing alcohol and paper towels to simulate this. The MQ-3 sensor has a SnO_2 film that when heated, "becomes highly resistive and prevents electric current flow" within the sensor. However, with alcohol present, the oxygen is more attracted to the alcohol rather than the film, allowing more current flow to occur within the sensor [7]. As the sensor only requires alcohol particles to be within the air to function, our method of utilizing rubbing alcohol is applicable.

3. Once the user blows into the mouthpiece sufficiently, the microcontroller will then read this change in current and using the code embedded, compute the blood alcohol concentration.
    - This computation requires the initial resistance of the sensor, the resistance with alcohol present in the air and the evaluation of the following formula: Concentration = $10^{(A*\log(Rs/R) + B)}$.

4. Lastly, the result from the computations will be displayed on the screen.
    - "BAC is _____ "
    - The buzzer will vibrate if the %BAC is above the legal limit in the USA (0.08%)

5. When the system is idle for more than 30 seconds, it will automatically shut down to avoid unnecessary energy consumption.

6. By pressing the button twice consecutively, the system will shut down.

Design Figures

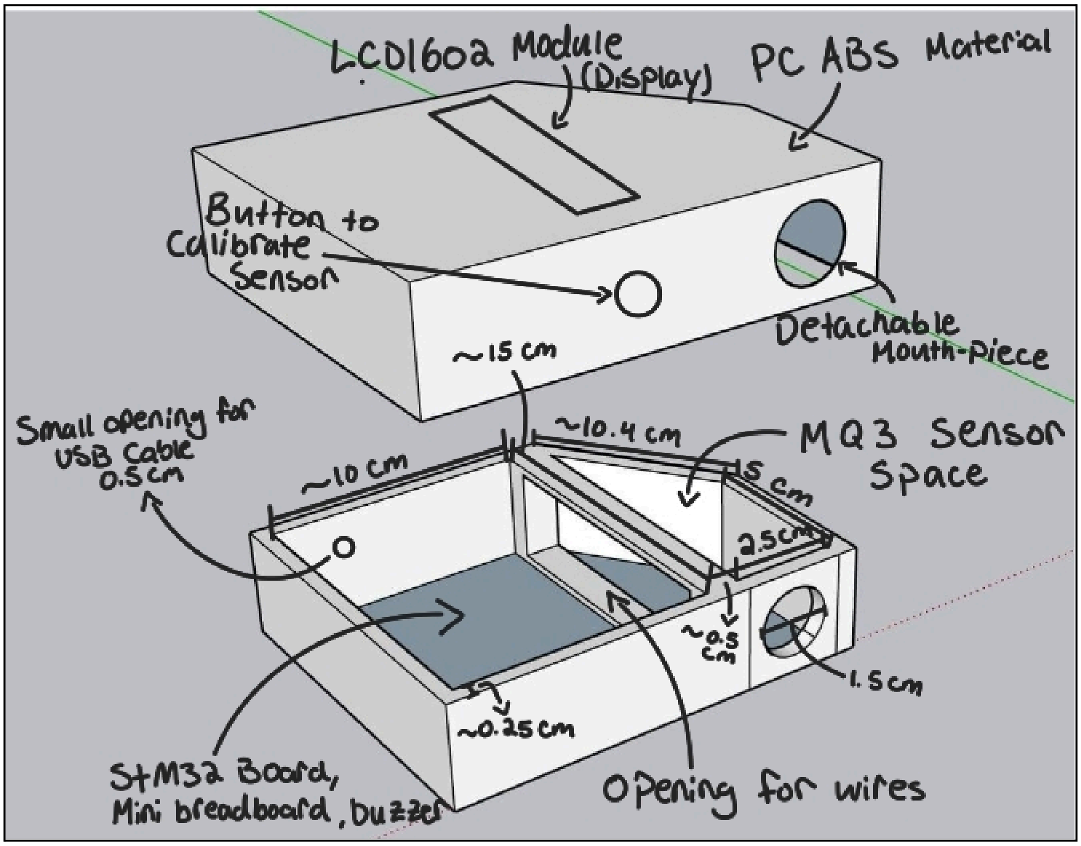


Figure 2: CAD View of Case

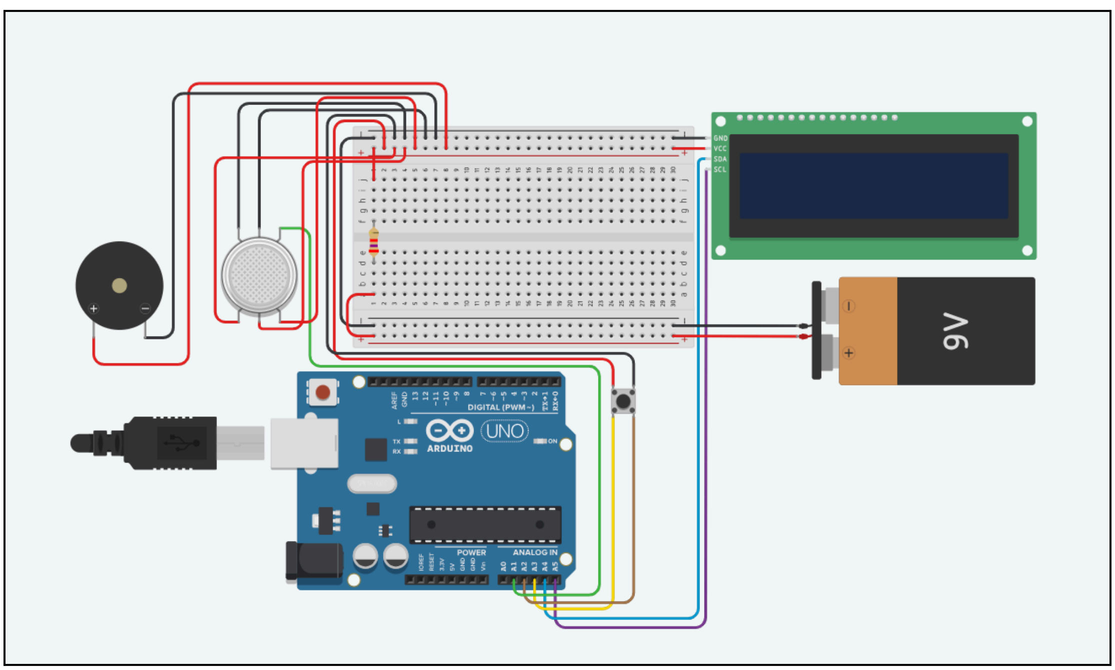


Figure 3 - Circuit Diagram of System Powered by a Battery

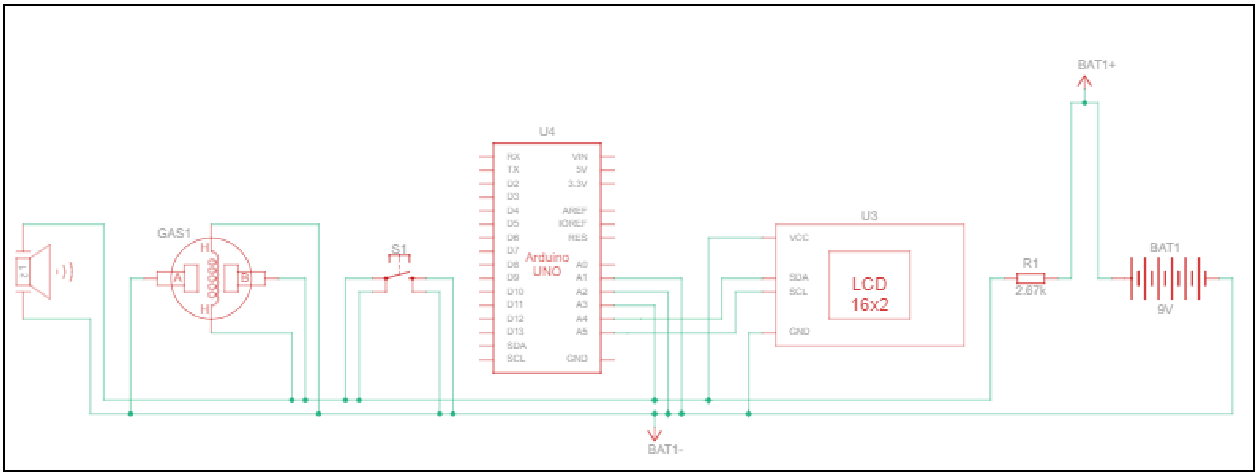


Figure 4 - Schematic Diagram of System Powered by a Battery

Scientific and Mathematical Principles

Ohm's Law

Because mindlessly testing various voltages is a safety hazard, we will do computations using Ohm's law before ensuring our safety. Ohm's law is an equation of the direct relationship between Voltage, Current and resistance. By doing calculations relating to our system, we can guarantee that the correct amount of voltage is being supplied to the sensor and that our system will always stay within the bounds of the safety requirements by adding resistors where necessary. Furthermore, we will prevent short-circuiting our sensors and other electronic components.

First, we must determine whether our system has a DC or AC. To do this, we use an oscilloscope, a device that can display voltage signals in waveforms that then can be used to interpret whether the current is AC or DC [9]. Using the simulation software as shown in *Fig 5*, the oscilloscope reads a straight line. DC means "unidirectional" flow of current; current only flows in one direction", or in other words, constant voltage [5]. By graphing something constant over time, the result is a straight line, therefore by using the oscilloscope, we can conclude that our system is DC.

This is important in determining the internal resistance of the battery being used. DC currents utilize battery internal resistance while AC currents have internal impedance. You can find this by searching the battery datasheet. For example, if using a Duracell battery, the impedance will be 1700mΩ or 1.7Ω. This means that if the current is AC, the actual output will be 9/1.7 amperes rather than 9A.

In the case of the simulation, the internal resistance of the battery is approximately 1.5Ω. This means the output current will be 9/1.5 = 6A. Assuming the breadboard yields zero resistance, the voltage at this point being supplied will be 9V, way too high for the sensor, meaning resistors must be added. To compute how much resistance is required, use Ohm's law, where the current is 9A and the voltage is 5V. We use 5V because that is the desired voltage output.

$V = IR$

$5 = 6R$

$5/6 = R$ $\rightarrow$ Therefore 0.8333333Ω of resistance are required.

Our design will utilize the Duracell 9V battery. Its impedance is 1.7Ω, but since we have DC current, we must use internal resistance [2]. Its actual internal resistance cannot be computed as it varies from battery to battery. Luckily, we can approximate the resistance required as a normal 9V battery has an internal resistance of 1Ω to 2Ω [3].

Use the middle value for the lower bound. If the internal resistance is 1.5Ω, the outputted amperes will be 9/1.5 = 6A
Because the internal impedance is 1.7Ω, we can use this as our upper bound for our approximation. 9/1.7 = 5.294A.

Plugging both amperes values into Ohm's law, we get:

$V = IR$

$5 = 9R$

$5/6 = R \rightarrow$ Therefore 0.833333Ω of resistance is required.

$V = IR$

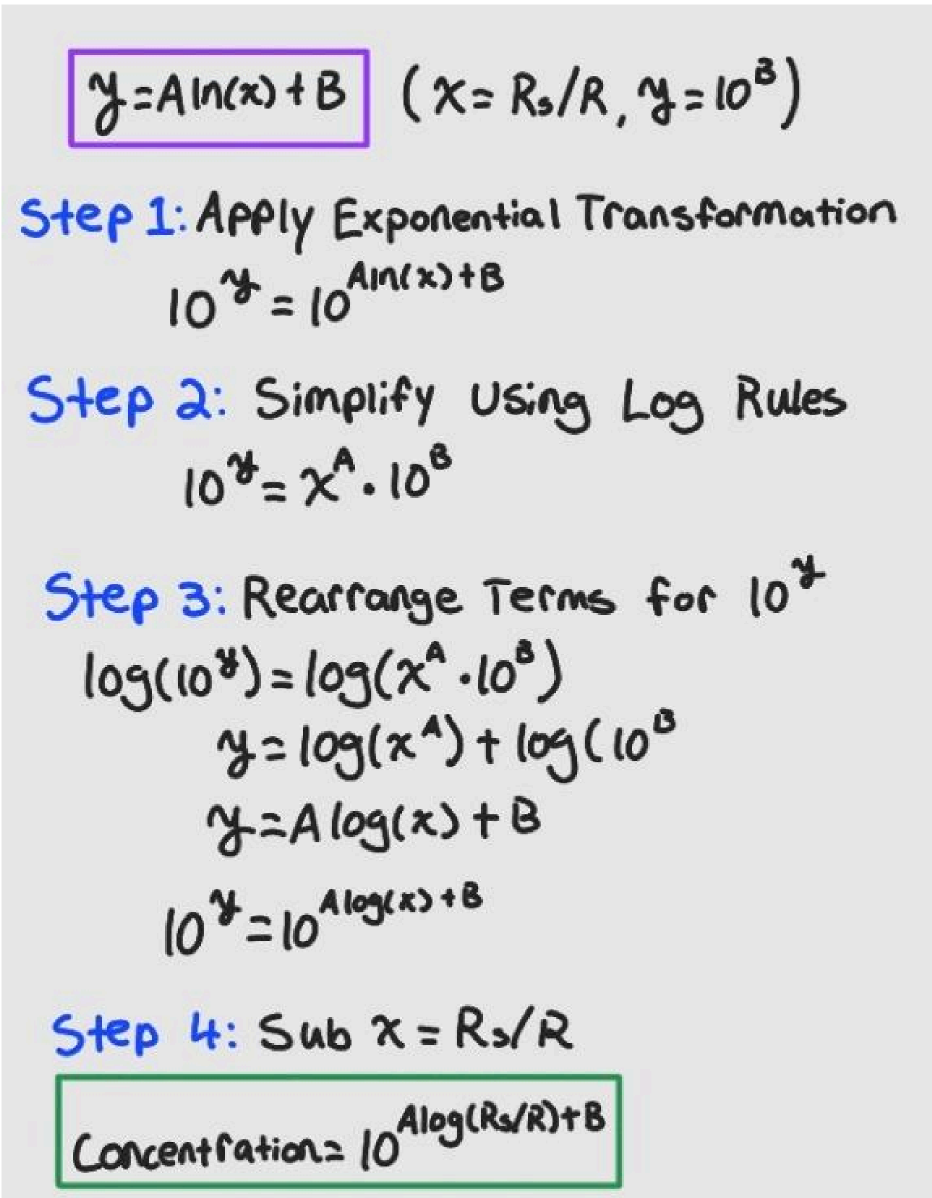
$5 = 5.294R$

$5/5.294 = R \rightarrow$ Therefore 0.9444Ω of resistance is required.

So our bounds for the resistance required are 0.83333Ω < R < 0.9444Ω
Or simply use the average, 0.88Ω

Slope Formula

To derive a formula for the concentration, first analyze the data provided in *Fig 6* and its graph. By inspection, we can see that the data follows a logarithmic pattern. Next, we plot this into Excel and apply a log regression, as seen in *Fig 7*. This gives us an equation of the line, $y = -0.066ln(x) + 0.4071$, following the general formula of $y = Aln(x) + B$, where $x = Rs/R$ and $y = 10^B$. Because a log regression is applied, the following calculations can be made to derive a formula for concentration:



Concentration = $10^{(A*\log(Rs/R) + B)}$. Rs is the initial resistance and R is the resistance with alcohol. The datasheet has a graph and a method to derive the values for A and B. A is the slope of the graph below, and B is the y=-intercept. To acquire this, the principle of slope calculation is required to obtain the value of *A*. From this, we can compute *B (calculations are on the next page)*

Calculations:

Step 1: Choose 2 points on graph

$P_1 = (\underset{x_1}{50}, \underset{y_1}{0.18})$ $P_2 = (\underset{x_2}{500}, \underset{y_2}{0.012})$

Step 2: Apply Slope Formula

$$\text{Slope} = A = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.012 - 0.18}{500 - 50}$$

$$A = -0.00037\overline{3}$$

Step 3: Re-arrange line equation for B

$$y_1 = A \cdot x_1 + B$$

$$y_1 - A \cdot x_1 = B$$

$$0.18 - \left(\frac{0.012 - 0.18}{500 - 50}\right) \cdot 50 = B$$

$$B = 0.198\overline{6}$$

Code Implementation:

```
double Rs{};
double R{};
double A = (0.012 - 0.18) / (500 - 50);
double B = 0.18 - (A * 50);
double concentration = pow(10, (A * log(Rs / R) + B));
```

Rs and R are uninitialized as we haven't found their values through testing yet

The third line computes the value of A as shown in *step 2* of the calculations

The fourth line computes the value of B using the value of A as shown in *step 3* of the calculations

The last line computes the concentration using the formula $10^{(A*\log(Rs/R) + B)}$

PPM (Parts Per Million) to %BAC (Blood Alcohol Concentration)

The MQ3 sensor being used measures the alcohol content in the air in PPM and the standard breathalyzer measures in %BAC in accordance with federal law, we must convert between these units. Furthermore, we must implement this conversion into code so that the output is the desired value. To do this, some research on this conversion must be done, all within the standards of the laws within the United States. The Breath to Blood Alcohol ratio in the United States is 2100:1 [1]. Furthermore, it is widely considered that BAC should be reported to 2 digits after the decimal places, so we will also need to include this within our code implementation [8].

1. First, get the PPM from the sensor input
2. Divide this value by 2100 to get the %BAC
    a. %BAC = PPM / 2100
3. Display the result to the 2nd digit after the decimal place

Code Implementation:

```
double PPM{concentration};
float BAC{round((concentration / 2100) * 100.0) / 100.0};
```

The first line initializes a variable PPM with the concentration, a value computed in a previous segment.

The second line converts the concentration from PPM to %BAC and rounds it to two decimal places using a function *round* from the *cmath* library in C++

Scientific/Mathematical Principles Figures

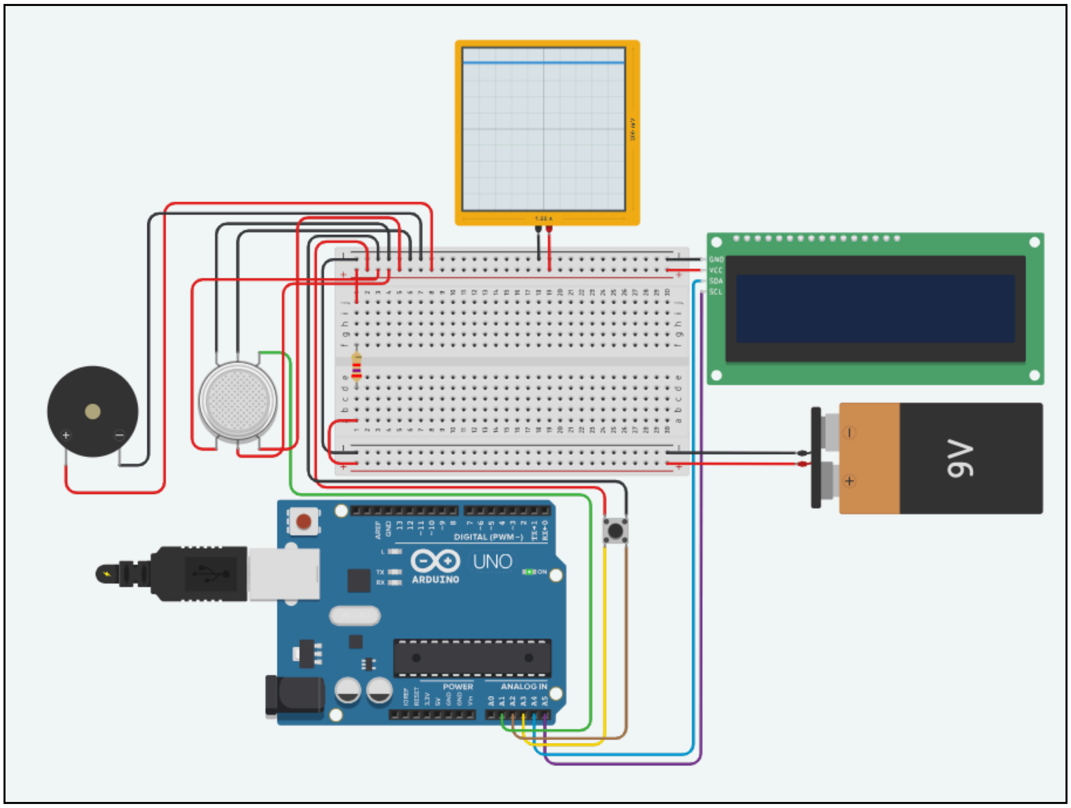


Figure 5 - Circuit Diagram with an Oscilloscope Attached Reading a Straight Line

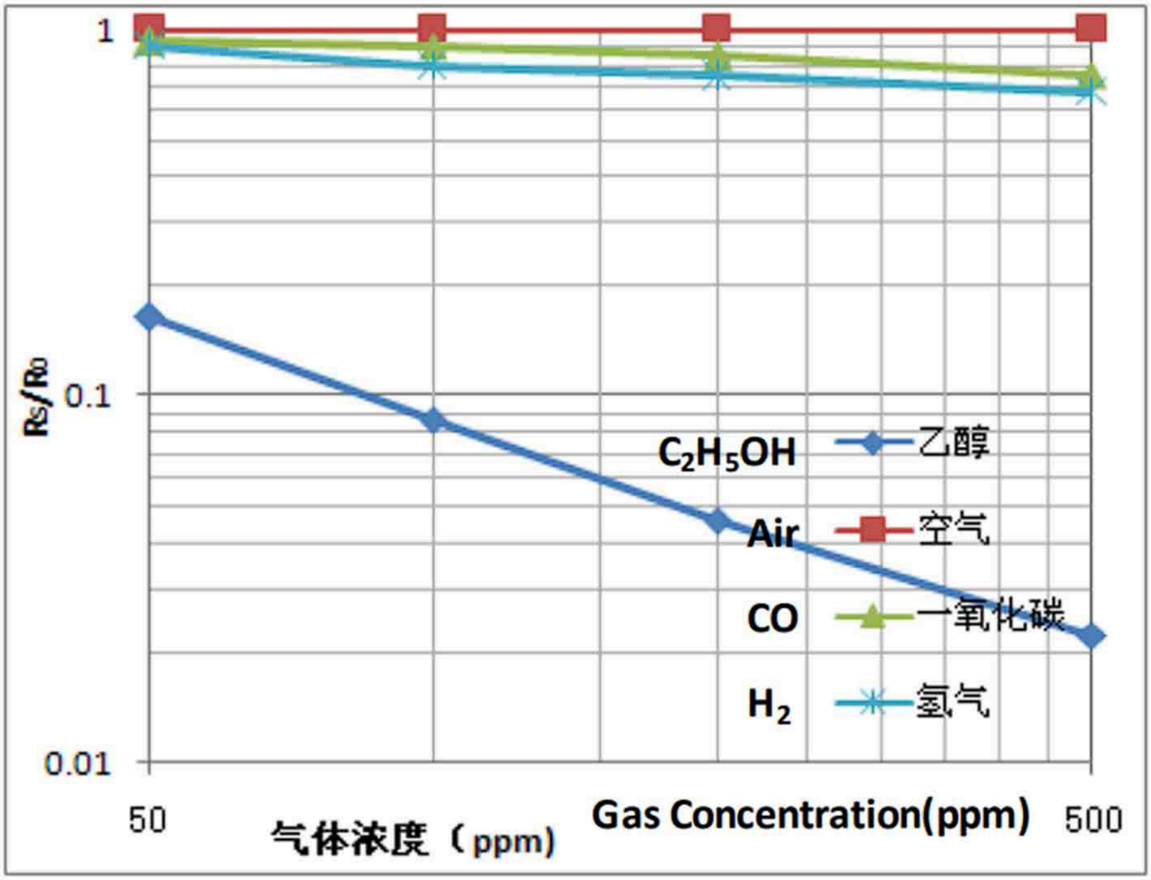


Figure 6 - Gas Concentration in PPM Graph from MQ3 Sensor Datasheet

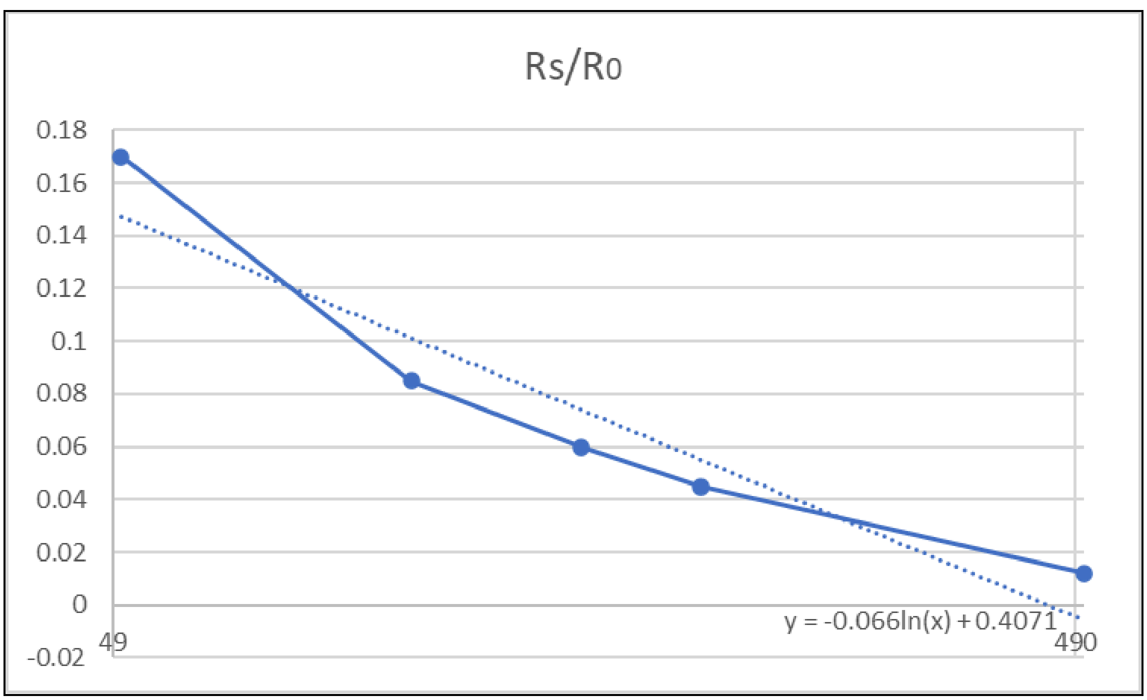


Figure 7 - Graph from Applying Log Regression to Graph in Datasheet

Costs

Manufacturing Costs

Components:	Quantity:	Cost (CAD$):	Manufacturer:	Manufacturer Location:
STM 32 NUCLEO F401RE Microcontroller	1	$34.99	STMicroelectronics	Geneva, Switzerland
LAMPVPATH Mini Small Solderless Breadboard	1	$1.10	LAMPVPATH	Fuzhou, China
LCD 1602 Component	1	$11.56	SunFounder	Shenzhen, China
9V Duracell Battery	1	$1.50	Duracell	USA, Cleveland, Tennessee
MQ-3 Alcohol Sensor	1	$4.20	Wendeekun	Shenzhen, China
Mini Piezo Buzzers Speaker	1	$1.25	Kecheng Wei Electronic Component Supplier	Zhejiang, China
3-D Printed Case	1	$3.50	University of Waterloo	Waterloo, Canada
BACtrack Professional Breathalyzer Mouthpiece	1	$0.99	BACtrack	San Francisco, California, USA

Installation Manual and User Guide

Thank you for choosing our Breathalyzer! This Installation Manual and User Guide offers detailed instructions relating to the setup and utilization of our breathalyzer device. These instructions aim at promoting precise and user-friendly operation. This guide has been intentionally crafted to be precise and educational, with the aim of enhancing the efficiency of installation and utilization processes, hence reducing expenses and exertion for the user. The next section provides explicit guidelines, visual representations, and schematic designs to provide a seamless user experience.

Installation Manual:

1. Unboxing And Setup:

When opening the Breathalyzer package, make sure it contains:
- Breathalyzer Device (Pre-Assembled + Mouthpiece)
- Batteries

Insert the batteries, following along with the User Guide. Power on the Breathalyzer, and allow the device to warm up. This should take a few seconds.

2. Calibration:

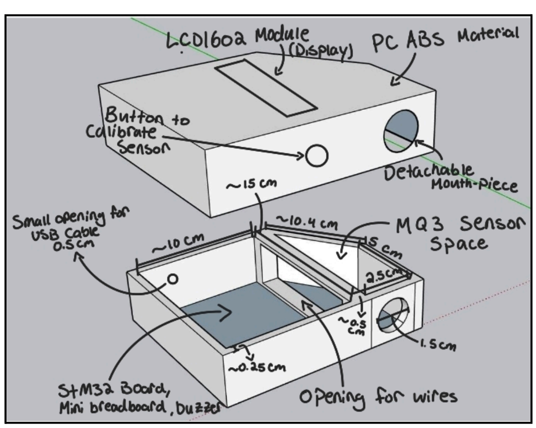
In order to ensure precision, it may be necessary to calibrate the gadget. Please refer to the User Guide for more information on calibration. The process of calibration is essential in order to obtain accurate and exact outcomes.

3. Device Placement:

Position the breathalyzer device on a level and secure platform. It is important to ensure that the area is adequately ventilated.

4. Initialization:

After the completion of the setup process, the Breathalyzer is prepared for use. For full guidance on usage, please refer to the User Guide.



User Guide

1. Getting Started:

Activate the Breathalyzer device by pressing the start button on the front. Please be patient till the device has finished its warm-up procedure. Once set up, you are ready to conduct a test.

2. Taking A Test:

It is important to make sure that the individual undergoing testing has refrained from alcohol consumption for a minimum duration of 15 minutes. The user should be instructed to engage in gentle exhalation through the mouthpiece for a duration of more than five seconds for accurate results. After the user has finished exhaling, the results will be visible on the screen.

3. Interpreting Results:

- Sober: 0.0 percent Blood Alcohol Concentration (BAC).
- Legally intoxicated: 0.08 percent BAC. Unable to legally drive if the alcohol level is 0.08 or higher.
- Very impaired: 0.08–0.40 percent BAC. At this blood alcohol level, you may have difficulty walking and speaking. Other symptoms may include confusion, nausea, and drowsiness.
- At risk for serious complications: Above 0.40 percent Blood Alcohol Concentration. At this blood alcohol level, you may be at risk for coma or death.

4. Maintenance And Care:

It is recommended to clean the mouthpiece following each usage. It is suggested to store the breathalyzer in a location that is cool and dry. It is necessary to maintain a clean and debris-free sensor area.

5. Troubleshooting:

Please contact our customer service for breathalyzer concerns.

6. Safety Precautions:

Use the breathalyzer only as intended. Do not use the device if it is broken. Keep it away from kids. Do not use it right after drinking or eating. Use in a well-ventilated location.

Risks

Energy Analysis

Our design using the simulation utilized a 9V battery that was the only choice of battery type with the software. With this arrangement, we expect a voltage supply of 9V. However, because an LCD screen requires 5 to 5.5V to operate, the power supply could potentially be slightly lower [24]. Using Ohm's Law, we can compute the lowest amount of voltage required so that the system can still maintain 5V for the LCD screen. Assuming we use the same resistance calculated from the *Scientific/Mathematical Principles Calculations*, R = 0.88Ω.

$V = IR$

$5 = 0.88*I$

$5.68\ A = I$

Therefore the lowest amount of current possible to work with our system is 5.68A. To determine the voltage in the battery, we must first consider the battery's internal resistance. So V = 5.68*R, where R is the battery's internal resistance. By first determining the internal resistance of the battery and checking the voltage, you can determine if the battery is suitable for our system.

Assuming that our power source for our actual device is 5V and that the current is equal to I = V/R, where V is the voltage of the source and R is the internal resistance. However as our power source is through USB, there will be zero internal resistance since it isn't a battery. Therefore, the current will be 5A. Now, compute the power using the known voltage and current values:

$$P = V \times I$$
$$P = 5 \times 5$$
$$P = 25W$$

Therefore the maximum power in our system is 25W. The power cannot be higher since we never use any components which increase the current or voltage within the system, meaning the highest power will be the circuit coming directly from the power source.

By utilizing the power achieved from the formula to find the power in the system and the formula E = V x I x t, where E is energy in joules, V is voltage in volts, I is current in amperes and t is the duration in seconds estimated for our breathalyzer to give a reading [21]. We estimate the reading to be approximately 10 minutes with 4.5 minutes of processing time [22]. Because there is already a complete calculation for the power to be used by the sensor, 570 mW, we time this by the number of seconds and divide by 1000 to convert to mJ [23]. In doing so, we get the total energy of the system to be approximately 496 mJ, just within the energy limit.

Risk Analysis

Possible Negative Consequences From Using The Design As Intended:

Safety Concern: If the breathalyzer yields incorrect readings or exhibits flaws in accurately detecting alcohol levels, users may be prone to make poor decisions and perhaps partake in hazardous behaviours, such as operating a vehicle while under the influence. This could result in accidents and subsequent harm.

Environment Concern: Although breathalyzers are typically considered environmentally harmless, the inadequate recycling of batteries or electronic parts could potentially exacerbate the issue of electronic waste.

Possible Negative Consequences Of Using The Design Incorrectly:

Safety Concern: Safety risks may arise from improper operation of the device, such as excessive force when blowing or failure to adhere strictly to the provided instructions. These actions have the potential to yield erroneous findings, which could lead persons to underestimate their alcohol levels.

Environment Concern: The environmental consequences arising from the improper use of electronic devices, which may lead to their damage, might manifest in the form of environmental issues related to electronic trash if these devices are not disposed of in an environmentally responsible manner.

Possible Negative Consequences From Misusing The Design Or Using It In An Unintended Manner:

Safety Hazard: The intentional misuse of the device, such as engaging in manipulating actions, has the potential to yield inaccurate readings and promote irresponsible conduct.

Environmental Impacts: The deliberate infliction of harm or acts of vandalism have the potential to result in poor disposal practices, hence giving rise to environmental issues.

Possible Ways The Design Could Malfunction:

Electronics Malfunction: Inaccurate or inconsistent measurements may arise due to component failures or malfunctions in the internal circuitry.

Sensor Failure: The sensors housed within the breathalyzer device may see a decline in performance or encounter operational issues as they age, resulting in a series of unreliable measurements.

Calibration Errors: If the device is not appropriately calibrated or if the calibration has exceeded the recommended timeframe, it is possible that the obtained measurements may lack precision.

Battery Issues: In the event of a power source failure or malfunction, the device may become non-functional.

Consequences On Safety Or The Environment For Each Failure Mechanism:

Sensor Failure: Imprecise measurements can result in poor decision-making and, perhaps, jeopardize safety, particularly if an individual mistakenly assumes they have the capability to operate a vehicle.

Electronics Malfunction: Errors in the functioning of the breathalyzer can lead to readings that lack reliability, giving rise to safety concerns and potentially impacting law enforcement activities.

Battery Issues: The item may become unusable due to a failing power source, which could have implications for safety since the device is relied upon for making crucial judgments.

Calibration Errors: Failure to properly calibrate the equipment in accordance with the prescribed guidelines may give rise to inaccurate measurements, hence potentially exposing those with impairments to hazardous situations.

While breathalyzers are an important part of supporting safety as well as responsible drinking, it's important to be aware of the risks and bad effects they could have on both safety and the environment. Proper use, and maintenance, along with disposal, as well as frequent calibration and maintenance of the gadget, can help ease these worries.

Testing And Validation

1. Accuracy

Test Setup: Make sure there is no scent of alcohol in the air, to ensure that the device can accurately detect alcohol in room temperature humidity range. Set up the system according to the Installation Manual.

Environmental Parameters: The test setting must be at room temperature, approximately 22 degrees Celsius, and approximately 50 percent humidity. There should be no alcohol present in the surrounding area including people.

Test Inputs: There will be two test inputs. The first input is the control case with zero alcohol around the sensor. Test this five times and find the median. The second case would be using rubbing alcohol with paper towels to simulate alcohol on the person's breath. Lightly put the paper towel in the alcohol and wave it around the breathalyzer mouthpiece. Wait for an output. Repeat five times with a 10-minute interval within each time and compute the median.

Quantifiable Measurement Standards: Measurements will be read from the LCD Screen on the breathalyzer in terms of percent BAC.

Pass Criteria: For the first case with no alcohol, the median should be zero. The second case should be well above the legal percent BAC in America, which is 0.08%.

2. Response Time

Test Setup: Set up the system accordingly with a stopwatch. Record once the test has been conducted.

Environmental Parameters: A room temperature of 22 degrees Celsius and 50% humidity is required for the test. Have an abled body person press the stopwatch with sufficient reaction time

Test Inputs: Start the timer when the paper towel-dipped alcohol is waved around the mouthpiece. Stop the timer when the device gives you an output. Turn off the device and let rest for 15 minutes. Repeat five times and compute the median.

Quantifiable Measurement Standards: Measurements will be read in seconds on the stopwatch.

Pass Criteria: The median should be under 10 seconds.

3. Calibration Time

Test Setup: For accurate breathalyzer results, use a controlled atmosphere. Start the breathalyzer calibration by pressing the button on the device.

Environmental Parameters: Test room temperature must be 22°C and 50% humidity.

Test Inputs: Press the button to begin calibrating the breathalyzer. At the same time, press start on the stopwatch. When the LCD screen says calibration complete, stop the stopwatch. Then turn off the system by pressing the button twice. Let the system rest for 10 to 15 minutes. Repeat 5 times and compute the median of the times recorded.

Quantifiable Measurement Standards: The test should be measured quantitatively using a stopwatch in minutes as the unit of measurement.

Pass Criteria: As long as the calibration median time is within ten minutes, then it has passed the criteria.

4. Portability

Test Setup: The weight of the plastic case should be 150 grams, with the dimensions of 15 cm x 10 cm x 3 cm.

Environmental Parameters: On Earth, where gravity is the gravitational constant, $g = 9.81\ m/s^2$

Test Inputs: Have a ruler with adequate precision (5mm) to measure the dimensions of the width, length, and height of the case, and measure the weight of the object with a kitchen scale.

Quantifiable Measurement Standards: Measured in grams for the weight, measured in cm for the dimensions of the case.

Pass Criteria: If the dimensions are within 15 cm x 10 cm x 3 cm and the weight of the box is under 150 grams, it passes the test.

5. Battery Lifetime

Test Setup: Have a stopwatch ready and start as soon as you turn on the breathalyzer with a new battery. Stop the timer when the breathalyzer can run anymore.

Environmental Parameters: The test requires 22ºC and 50% humidity. Give a capable individual enough time to press the stopwatch.

Test Inputs: You would have to test this case five times to find the median, which should show the most accurate result for the battery lifetime of the breathalyzer. Have the device at a battery lifetime of 100%, and start the timer when you turn the device on. Stop the timer when the battery reaches zero percent, do this five times and record the time to compute the median.

Quantifiable Measurement Standards: The quantifiable measurement for this test should be in minutes. It should be around an 80-minute run time.

Pass Criteria: The battery lifetime of the breathalyzer runs for 80 minutes or longer. If it meets this requirement, it passes the test.

Citations

[1] The University of Toledo, “Counseling center,” The University of Toledo, https://www.utoledo.edu/studentaffairs/counseling/selfhelp/substanceuse/bac.html.

[2] Duracell, “Alkaline-Manganese Dioxide Battery,” MN1604 Datasheet, https://www.duracell.com/wp-content/uploads/2016/03/MN1604_US_CT1.pdf.

[3] Learning About Electronics, “Battery Internal Resistance,” Learning About Electronics, https://www.learningaboutelectronics.com/Articles/Battery-internal-resistance.

[4] Fluke, “What is battery impedance?,” Fluke, https://www.fluke.com/en-ca/learn/blog/energy-efficiency/battery-impedance.

[5] S. Hymel, “Alternating current (AC) vs. Direct Current (DC),” Alternating Current (AC) vs. Direct Current (DC), https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc/all.

[6] Zhengzhou Winsen Electronics Technology Co., Ltd, “Alcohol Gas Sensor,” MQ-3 Datasheet Version 1.4, May 2014, https://www.tme.com/Document/080c1276ad5de7bf1ca208a2b4f9454d/MQ-3.pdf.

[7] Last Minute Engineers, “In-depth: How MQ3 alcohol sensor works? & interface it with Arduino,” Last Minute Engineers, https://lastminuteengineers.com/mq3-alcohol-sensor-arduino-tutorial/.

[8] Alco Prévention Canada, “Questions about Breathalysers and alcohol testers, we have the answers.,” Alco Prévention Canada, https://alcoprevention.com/en/faq/.

[9] Fluke, “Basic oscilloscope functions,” Fluke, https://www.fluke.com/en-ca/learn/blog/oscilloscopes/basic-oscilloscope-functions

[10] “Gordon River Road: A journey through Tasmania’s wilderness,” World’s greatest driving roads, https://www.dangerousroads.org/north-america/usa/10833-the-10-cities-with-the-most-drunk-driving-incidents.html (accessed Sep. 20, 2023).

[11] WorldPopulationReview, “Bozeman, Montana Population 2023 (Demographics, Maps, Graphs),” *worldpopulationreview.com*, 2023. https://worldpopulationreview.com/us-cities/bozeman-mt-population

[12] DataUSA, “Bozeman, MT | Data USA,” *datausa.io*, 2021. https://datausa.io/profile/geo/bozeman-mt

[13] L. Masterson, “Worst States for Drunk Driving, ranked,” Forbes, https://www.forbes.com/advisor/car-insurance/worst-states-for-drunk-driving/ (accessed Sep. 20, 2023).

[14] B. N. Greenwood and S. Wattal, “Show Me the Way to Go Home: An Empirical Investigation of Ride-Sharing and Alcohol Related Motor Vehicle Fatalities,” *MIS Quarterly*, vol. 41, no. 1, pp. 163–187, Jan. 2017, doi: https://doi.org/10.25300/misq/2017/41.1.08.

[15] MontanaCar, “*Montana Car Service”*, 2021. https://www.montanacarservice.com/about (accessed Oct. 31, 2023).

[16] R. W. Elder *et al.*, “The Effectiveness of Tax Policy Interventions for Reducing Excessive Alcohol Consumption and Related Harms,” *American Journal of Preventive Medicine*, vol. 38, no. 2, pp. 217–229, Feb. 2010, doi: https://doi.org/10.1016/j.amepre.2009.11.005.

[17] “Self-Test for Breath Alcohol | HealthLink BC,” *Healthlinkbc.ca*, 2022. https://www.healthlinkbc.ca/medical-tests/self-test-breath-alcohol.

[18] C. Garnett, D. Crane, S. Michie, R. West, and J. Brown, “Evaluating the effectiveness of a smartphone app to reduce excessive alcohol consumption: protocol for a factorial randomised control trial,” *BMC Public Health*, vol. 16, no. 1, Jul. 2016, doi: https://doi.org/10.1186/s12889-016-3140-8.

[19] Montana University, “Bozeman Alcohol Policy - Office of Health Advancement | Montana State University,” *www.montana.edu*, 2018. https://www.montana.edu/oha/alcohol_drugs/policy.html#:~:text=Driving%20under%20the%20influence%20of%20alcohol%20or%20drugs%E2%80%94DUI&text=It%20is%20illegal%20to%20drive (accessed Oct. 31, 2023).

[20] EvokeWellness, “How Accurate is a Breathalyzer for Measuring Levels of Intoxication?,” *Evoke Wellness FL*, Jun. 04, 2021. https://evokewellnessfl.com/blog/how-accurate-breathalyzer-for-measuring-levels-intoxication/

[21] PhysicsNet, “Energy & Power in Circuits,” PhysicsNet, http://physicsnet.co.uk/a-level-physics-as-a2/current-electricity/energy-power-in-circuits/ (accessed Sep. 25, 2023). \

[22] “Arduino breathalyzer using MQ3 gas sensor and OLED display,” Electronics, https://www.electronics-lab.com/project/arduino-breathalyzer-using-mq3-gas-sensor-oled-display/ (accessed Sep. 29, 2023).

[23] W. Storr, “OHMS law tutorial and power in Electrical Circuits,” Basic Electronics Tutorials, https://www.electronics-tutorials.ws/dccircuits/dcp_2.html (accessed Sep. 29, 2023).

[24] Focus LCDs, “LCD Voltage Pins Explained,” Focus LCDs, https://focuslcds.com/lcd-voltage-inputs-explained/ (accessed Oct. 31, 2023).