**SYSTEM IMPLEMENTATION, TESTING AND VALIDATION REPORT FOR THE NON-DISPERSIVE INFRARED ETHANOL DETECTOR SYSTEM**

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Document Approval

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# Chapter 1: Introduction

## Background and scope of the project

## **Overview of the document**

This document describes the implementation, testing and validation findings for the Non-Dispersive Infrared Ethanol Detector system (NDIRED). It is divided into the following sections:

**Section 1:** This section gives an overview of the above-mentioned system and the document as a whole.

**Section 2:** The section offers a brief overview of the system specifications, version of requirements and version control as well as the inputs and outputs of the NDIRED system.

The section as well entails the functionality, limitations and safety, default settings, assumptions, and special requirements of the system.

**Section 3:** In the section, a description of the design output in terms of the implementation, utilities for validation and testing is provided.

**Section 4:** The section is concerned with the inspection and testing of the system. A testing overview is provided, performances and test plans, test objectives are given.

**Section 5:** This section provides details about the installation and user system acceptance test where the input files, supplementary files, installed components, and installation qualification of the NDIRED system.

**Section 6:** This section outlines the Performance, operation and maintenance of the NDIRED system.

**Section 7:** This section provides the conclusion and recommendations of the NDIRED.

# SYSTEM SPECIFICATIONS

# 

This section describes and specifies the system to exhaustion as well as acting as a basis for system validation.

## Version Of Requirements And Version Control

### Controller Chip

The Atmega16 microcontroller was proposed in the first requirements version (1.0). However, we later switched to Arduino UNO R3 due to the that we did not want to reinvent the wheel given Arduino’s superior capabilities already built and encapsulated within Arduino libraries for most of the peripheral devices that we are using. Arduino comes with an IDE and already coded libraries encapsulated in C headers for most of the peripheral devices out there. It also has a large community of brilliant developers that have already solved some of the hardest problems and continue offering instant help to everyone using the open source Arduino project. Thus, for the general purpose of saving time by not re-inventing the wheel we switched to Arduino in a later version 2.0.

### Output (Display) Techniques

A 128X64 LCD display module had been proposed in the first version 1.0, but we have later decided to use a 16 X 2 LCD display module.

Display messages after ethanol measurement were also changed given the fact that the LCD changed, when a target is found to be drunk, we decided to switch from echoing a message *“You have passed the alcohol detection procedure, Have a safe Journey”* displayed three rows as displayed below:

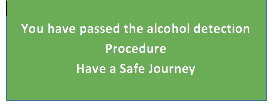


Figure 1: Earlier Display format after a positive test

We later switched to “*Ethanol % 0.005 Drunk”* using two rows on the LCD as displayed below.



Figure 2: New Display format after a measurement.

### Car Engine Integration

In the requirements version 1.0. the system was proposed to act as a mechanism to control the car engine by allowing it to start if the ethanol measurement turns out negative and locking it if it turns out positive. But due to feasibility analysis of this idea, we later changed the concept to just be an ethanol detector i.e. A non-invasive technique of finding out how much alcohol an individual has consumed just like the currently widely implemented breathalyzers do.

We switched because our earlier model did not sufficiently provide how the measurement is going to happen and who should oversee it. For example, it did not make sense at worst case, a drunk individual to check themselves without bias. So, the earlier model assumes a person overseeing this measurement is not biased for example a Traffic Law enforcement Officer. Thus, we are basically implementing a safer and easier electronic “breathalyzer” in the second requirements version.

We have Used GitHub as version control system for this project. We leveraged the usage of branches where every new modification on a requirement version was done on one branch which was later tested and merged to the main master branch which as we compile this document has the latest and final version of this system.

The GitHub link to the project is [***https://github.com/ekeeya/NDIRED***](https://github.com/ekeeya/NDIRED)

## Input

### Input to the Spectrometer module

When a known light intensity from the device is directed to the target individual skin, some of it is absorbed, some pass through and some is reflected back. The reflected light is then detected as analog signals by three tiny sensors on the spectrometer.

The first sensor detects Near Infrared, another detects Visible light and the third detects Ultraviolent light. All these are then converted and calibrated by the microcontroller inside the spectrometer module and later converted into digital values in a range of eighteen (18) light spectral bands (channels) depending onto their wave lengths.

### Input to Arduino

The above now digitally converted bands are sent to Arduino module as an array of 18 float values.

Using the standardized calibrations, we designed, Arduino will then try tell how much alcohol content an individual might have consumed. And signals the LCD to display a particular message, the buzzer to react accordingly then the GSM module to send a message to configured authorities if the ethanol detection results are positive.

## Output

### Powering

When the device is powered on successfully, the smaller red light at the back of the device will light up and a blue light.

### During measurement

When the take measurement button on the system is pressed (the device will take a shot at the target surface) and the following output lights will display.

A white led at the bark of the device will blink as a torch light similar to those of normal cameras when a shot is taken.

The blue light will go off during the shot to prevent expanding the already delicate error margin.

Once the short is taken the blue light will light up again.

### Results presentation

After the shot has been taken, Arduino will examine the values to find out if ethanol has been detected from the test surface.

#### If the measurement was positive (Target tested positive of ethanol)

The LCD 16X2 will display the percentage detected in row one. And a word “DRUNK” in the second row of the device as shown in Figure 2:

The red light at the front of the device will light as well and an SMS will be sent by the GSM module to the configured telephone number of the authorities.

#### If the measurement was negative (Target tested negative of ethanol)

The LCD display will display a 0.00% of ethanol in the first row and then displays “NOT DRUNK” in the second row as displayed below.



Figure 3: LCD display for a negative test

The green light at the front of the device will also light up.

## Functionality

### Ethanol Measurement.

The system provides a quick and easy mechanism for measuring ethanol content from a target under inspection.

The system provides the clearly marked ***Take measurement*** button which a user presses to acquire measurement. The total duration of the measurement only takes a second or two.

The system consists of an illumination mechanism which consists of three light emitters, the first emitter illuminates the target with invisible Infrared light, the second illuminates it with invisible ultra-violet light and the third illuminates the target with visible white light.

The system’s attached spectrometer which consists of three sensors then captures the reflected light from the illuminated target in their respective natures as shown above. The spectrometer then divides them in an array of 18 channels of different wave lengths that are then forwarded to Arduino for analysis via I2C enabled communication interface. All this happens in less than half a second.

### Result Analysis

The system provides automatic analysis of the measured data. The microcontroller on the Arduino board examines the data it receives from the spectrometer and then subject it to a standardized algorithm that is embedded within. This algorithm then can deduce how much alcohol content is detected given the deviations from standard model it uses.

Depending on the results Arduino instructs the rest of the output devices to act accordingly. The process of analysis almost happens in real time, so it is almost impossible to quote how long it takes but it is safe to say in microseconds.

### Result Display components

The system provides an easy and effective mechanism of communicating to the user and they are described below.

#### LED Lights

The system has two LED lights at the front for this purpose, the red light indicated ethanol measurement turned out positive and that the subject under examination has an ethanol composition in them.

The Green light indicates that measurement is negative and the target subject is free of ethanol.

#### LCD Display

The LCD displays results of the measurement to the user and the status of the target individual as far as ethanol composition is concerned.

After a positive measurement i.e. subject contains ethanol, the LCD displays percentage ethanol composition as per the total molecular composition of liquid substances in the subjects’ makeup (for a human blood) in the first row. The second row will display a word “DRUNK” (Refer to [Figure 2 in section 2.1.2](#_Output_(Display)_Techniques)).

After a negative measurement i.e. subject is free of ethanol, the LCD will display a 0.00 percentage in the first column and a word “NOT DRUNK” in the second row (Refer to [Figure 3 section 2.3.3.1](#_If_the_measurement_1) above)

#### SMS Notification

The system provides a mechanism of alerting the Unbiased User (Law Officer) via SMS that the target under inspection is Drunk.

The SIM card inside the GSM module sends an SMS to the only phone number saved in its phone book.

The SIM card can be removed and the SMS destination phone number saved to its storage. Note that only the first number shall be used if the phone book contains several numbers.

### Powering

The system comes with a powering mechanism, a power button is attached on the side of the device which toggles between the ON and OFF states of the system.

The system also provides a reset button which MUST be pressed every time a measurement is about to be taken, this clears out the previously measured values that may still be stack inside the system’s sensors’ memory and may introduce noise to the new measurement.

## Limitations and safety

The system has limitation of energy/power, it simply cannot work when it is not powered up with at least a 5.0V source. The system comes with a 9.0v which is then later stepped down by the Arduino board circuitry to allowed 5.0V, 3.0V for the spectrometer and GSM modules.

The system may not function as intended when the powering is insufficient (i.e. <5.0V) for all the components that require it. The system may fry when the powering is too much (i.e. >12V).

Since the system uses light for its measurements, this produces a limitation of excess noise from the surrounding environment, for example all objects at a temperature above absolute zero emit infrared radiation, the sun’s visible light and ultraviolet light during day time can also cause noise, but our model has noted all this noise and error and tries to minimize it. But the user should avoid taking measurements in highly lit environments e.g. during direct strong noon sun, or when other light sources have illuminated the object since they introduce an error in the incident light rays that hit the target’s surface.

Since the human body is carbon based and specifically consists of hydrocarbons like fats, ethanol being a hydrocarbon, this introduces a varying error for any given person under testing, so we have chosen taking the shot inside an open mouth since mouths do not vary so different in organic chemical composition.

The User should keep the devices dry and away from liquid contact, for example it should not be used under strong rains where water can easily enter inside it. Water being a good conductor easily destroys the system electronic components especially if the system is powered.

The transparent protective surface at the back of the device must not be scratched since this will reduce the surface area from which incident light leaves the emitters and reflected light reaches the sensors.

## Default settings

The SIM card in the GSM module has a default phone number attached to it which will act as the source when sending an SMS notification. On top of this there is a default phone number stored in the SIM card’s phonebook that will act as a destination of the SMS notification in case there is need for one.

## Special requirements

Some of crucial requirements include;

### Spectrometer and measuring

A dimly lit surrounding environment to minimize the margin of error introduced by other light sources.

### GSM Module

The device should be operated in an area with GSM network coverage i.e. at least a 2G enable cell tower close by to enable the GSM module connect to the service provider network (MTN, Airtel) in order to successfully send out SMSs.

The device should be kept out of reach of children for they may open it and swallow the easily detachable components or put try to ingest the poisonous lithium battery that powers the device.

## Errors and alarms

The system may fail to power on when the power button is pressed. This can be investigated by making sure the voltage supply is sufficient, i.e. at least 5.0V.

The sensors may fail to take measurements, this can be investigated by ensuring the right power supply is provided >=5.0V or making sure the LED lights at the back of the device i.e. Red and blue LEDs are lighting.

SMS may not be sent, the GSM module may fail to send an SMS only if it is disconnected, when the SIM in the module has no paid SMS plan, or when the GSM module fails to connect to the service provider network. Check using another device like a phone to confirm network coverage in the area of operation, and have a paid SMS plan on the SIM card under usage in the module.

# Chapter 3: Design output

## Implementation (coding and compilation)

The system uses a slave-master(I2C) architecture to allow communication between different components.

The system is further broken down into 3 modules, the Controller (Arduino), the Spectrometer module and the GSM module.

The Controller module uses Arduino UNO R3 that uses an. Atmega328 microcontroller soldered on its board. An LCD 16X2, LEDs and a Piezo Sounder are attached to this module.

The Spectrometer module uses a SparkFun Triad Spectroscopy Sensor - AS7265x (Qwiic) capable of detecting light from 410nm (UV) to 940nm (IR). In addition, 18 individual light frequencies can be measured with precision down to 28.6 nW/cm2 and accuracy of +/-12%.

The GSM module uses a SIM800L module that is connected to the Controller module.

### Arduino (Controller) Module

A component-based system engineering method is used to come up with the Arduino controller module. Components such as Piezo Sounder, LEDs, LCD display and an Atmega328 are all connected on an Arduino UNO R3 board. Each component has a pre-written library written in either C or C++ that is included as a header in the implementation code, these headers house all the control functions that these components require for operation. All these libraries are included or can be added to the Arduino open source software development kit (SDK) which can be customized using the integrated Arduino Development Environment (IDE).

The microcontroller on the Arduino board takes a hex file containing compiled code of the logic of the system that is then uploaded to it via the Arduino IDE.

### Spectrometer Module

This module uses a SparkFun Triad Spectroscopy Sensor - AS7265x (Qwiic) capable of detecting light from 410nm (UV) to 940nm (IR). The device has three LEDs that illuminate the target surface with the needed light bands i.e. Infrared, UV and visible light,

In addition to the above, the device comprises of three sensors, whereby each sensor detects light in a given band i.e. Near infrared, UV and Visible light in the above ranges.

Each sensor is governed by a small on-board embedded micro controller, which then reports to a master microcontroller also embedded onto this board. Th other three communicate to the master through I2C. When the master receives these measurements, it calibrates them into 18 individual light frequencies measured with a precision down to 28.6 nW/cm2 and accuracy of +/-12%. The master microcontroller then forwards these values to Arduino module via I2C (SCL and SDA pins).

In this setting, Arduino becomes the master, then the spectrometer module master controller and its slaves all logically become Arduino’s slaves.

### GSM Module

This uses a SIM800L module which operates in a GSM/2G enabled environments. This component is directly connected to Arduino board using digital pins for receiving commands.

## Utilities for Validation

System validation of the calibration model was derived from the following process,

Solutions of pure water combined with various volumes of 96% ethanol was used to come up with the calibration model, it was later observed that solutions with higher alcohol volumes registered lesser light frequencies from which a standard model using a solution of pure water as a standard combined with the calculated average error introduced due to noise from surrounding light sources was derived.

|  |
| --- |
| Inactive code Comments have been included within the code base for easier maintenance and understanding of the code. Documentation Software Requirement Document (SRS) for NDIRED which specifies all the system and user requirements for the NDIRED system.  Software Design Document (SDD) for NDIRED specifies the design consideration for the NDIRED system. |
|  |

Table 1: Design Details

| *Topics* | **Design output** | |
| --- | --- | --- |
| **Good programming practice** | Source code is...   * Modularized * Encapsulated * Functionally divided * Fail Safe (error handling) Strictly Compiled | Source code contains...   * Comments * Meaningful names * Readable Source code * Printable source code   Revision notes |
| **Dynamic testing** | * All statements have been executed at least once. * All functions have been executed at least once * All loops have been executed to their boundaries.   All case segments have been executed at least once.  Comments: code from library headers has not been tested. | |

# Chapter 4: Inspection and testing

## Introduction

The inspection and testing of the NDIRED system were planned and documented in the test plan. The extent of the testing was following the requirements, the system acceptance test specification, the approach, complexity, risks and the intended and expected use of the NDIRED.

Table 2: Inspection Plan and Performance

| **Topics** | **3.3.1 Inspection plan and performance** | **Date** |
| --- | --- | --- |
| **Design output** | * Program coding structure and source code * Evidence of good programming practice * Design verification and documented reviews * Change-control reviews and reports   **Comments:**  Inspection was done on the spectrometer module, the Control and display components, and finally to the GSM SMS sending module. | 12th September 2020  KEL  CNM |
| **Documentation** | * System documentation. * Test results * User manuals, online help, notes, etc. * Contents of user manuals approved   **Comments:** | 28th October 2020  GV  MGY  KEL |
| **Software development environment** | * Data integrity   File storage  Access rights   * Code protection * IDE   **Comments:**  The system does not require access control neither does it store any data. | 13th September 2020  KEL  CNM |
| **Result of inspection** | Inspection Approved | 29th October 2020  GV  MGY |

## Test plan and performance

The test plan was created during the development phase and all elements that are about to be

tested were identified. The test plan explicitly described what was tested, test scenarios, test cases and expected results were identified. Evidently the test plan confirmed what was done, what the result was, and if the result was approved.

Table 3: Test Plan and Performance

|  |  |  |  |
| --- | --- | --- | --- |
| **Test Scenario** | **Test case** | **Expected Results** | **Approve?** |
| Testing the system power. | Verifying device power up using the button. | The red, blue LEDs at the back of the device light up. | **Yes** |
| Testing spectrometer | Verifying whether the spectrometer takes the measurement correctly | The spectrometer successfully measures reflected light from the target. | **Yes** |
| Testing Output Devices | Verifying Output components when the measurement is positive. | LCD displays ethanol % content and the word “***DRUNK***”  Red LED lights  Buzzer continuously goes off. | **Yes** |
| Verify Output components when the measurement is negative | LCD displays “***NOT DRUNK***”  Green LED lights  Buzzer beeps once. | **Yes** |
| Testing GSM module | Verify whether the SMSs are sent when the measurement is positive. | SMS should be delivered to a destination number saved on the SIM card embedded in module | **Yes** |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Test objectives This section provides a prioritized list of verification/validation objectives for the NDIRED system.  The objectives have been grouped into the following categories.  **Functional correctness**  A demo was conducted to prove whether the NDIRED system conformed to the required functionality.  **Service Level**  Verification that the system supported the required service level of business. This included system availability and reliability, load and responsiveness.  **Usability**  Validating that the system met the required levels of usability.  Table 4: Test Categories and Objectives   |  |  |  | | --- | --- | --- | | **Category** | **Objective** | **Tested component(s)** | | **Functional Correctness** | * Ability to measure ethanol composition in a target using noninvasive means. * Ability to interact (communicate) with the user. * Ability to send SMS to authorities | Spectrometer  GSM module  Output devices (LCD, LEDS, Buzzer). | | **Service Level** | * Verify response time of less than 3 seconds for measuring, analysis and result output. | The entire device | | **Usability** | * The NDIRED can be used without a lot of effort and resources spent in training the users. * The system features and usage can easily be recalled. | The entire device and all the procedures. | |
| **Relevancy of tests** Validation tests were carried out to demonstrate to the developer and the system user that the NDIRED meets its requirements. Successful tests showed that the system operates as intended.  NDIRED also discovered defects in the software where its behavior was incorrect or not in conformance with its specification. Scope of tests This involves testing of individual components within each of the modules for example, spectrometer module, control and logic processing module, GSM module, the Output display module (LCD, buzzer, LEDs). Individual functions and each line of code in the codebase.  **Module Testing**  These tests were carried out on the 3 major modules of the NDIRED system; GSM module, Spectrometer module and Control and output module.  The purpose of these tests was to verify that the functionality of different components conforms to the specified and requirements.  **System testing**  This involved testing of the NDIRED as whole. This was done to verify all the requirements specified. |
|  |
| Levels of tests Table 5: Levels of Tests carried out on NDIRED   |  |  |  |  | | --- | --- | --- | --- | | **Testing Level** | **specification** | **General Scope** | **Opacity** | | unit | Low-level design: actual code | Files and modules | White box | | Integration | Low-level design: High level design | Multiple files and modules | White box, black box | | Functional | Requirements Analysis | Whole system (NDIRED) | Black box | | System acceptance | Requirements Analysis | Whole system in Environment | Black box | |
| Types of testsPerformance testing Software performance testing was carried to determine the speed or effectiveness of NDIRED. It was discovered that it took about 3seconds for the entire Ethanol measurement, analysis and feedback process to be completed. It was also noted that the results were reliable since they varied consistently depending on the different levels of composition of ethanol in our test subjects.  **Usability Testing**  First time users with experience of using the system were allowed to interact with the device by directing them on how to power on the device, take a measurement shot and interpret feedback. The reaction was very good since the second time to the user repeated process accurately without additional directions.  **Acceptance Testing**  A formal test was conducted to determine whether or not the NDDIRED satisfies its acceptance criteria and to enable the customer to determine whether or not to accept the system. The users were satisfied with the since it met its requirements.  **Conformance Testing**  The system was tested and given the test results, it was deduced that the implementation conformed to the specification on which it was based. This testing process was performed by testing team.  **Standardized measurement model Testing**  We also tested whether our standardized measurement model works for every person, since ethanol is a hydrocarbon in chemical nature, humans already possess hydrocarbons like fats, so we needed a model that works for at least most of the test subjects we examined. We later found out that the model works best for almost every one when we take the measurement shot inside an open human mouth. |
| **4.2.5 Sequence of tests**  Table 6: A Test Case for Powering Process   |  |  | | --- | --- | | **Test Case 1** | Powering process of the device | | **Purpose** | Verifying device power up using the power button. | | **Prerequisites** | Assumptions that the device is powered up using a >5.0V buttery. | | **Test Data** |  | | **Steps** | * Press the power button on the device. | | **Expected Results** | The red, blue LEDs at the back of the device light up. | |
| Table 7: A Test Case for Spectrometer successfully takes measurements   |  |  | | --- | --- | | **Test case 2** | Spectrometer successfully takes measurements. | | **Purpose** | Verifying whether the spectrometer takes the measurement and takes them correctly | | **Prerequisites** | Device is fully powered up. | | **Test Data** |  | | **Steps** | * Aim the back of the device in line with the target surface whose ethanol composition you want to measure. * Press the take measurement button. * Wait for the flash shot to complete * Wait for a second and observe the output on the LCD screen and LED lights | | **Expected Results** | The spectrometer successfully measures reflected light from the target. |   Table 8: A Test Case for Testing output components when measurement is positive   |  |  | | --- | --- | | **Test Case 3** | Testing Output components when the measurement is positive. | | **Purpose** | Verifying whether the output components give the right feedback upon a positive test | | **Prerequisites** | A measurement shot has been made. | | **Test Data** | Measured data | | **Steps** | * Take the measurement shot * Observe output devices | | **Expected Results** | LCD displays ethanol % content and the word “***DRUNK***”  Red LED lights  Buzzer continuously goes off. |   Table 9: A Test Case for output components when measurement is negative   |  |  | | --- | --- | | **Test Case 4** | Output components when the measurement is negative | | **Purpose** | Verifying whether the output components give the right feedback upon a negative test | | **Prerequisites** | A measurement shot has been made. | | **Test Data** | Measured data | | **Steps** | * Take the measurement shot * Observe output devices | | **Expected Results** | LCD displays “***NOT DRUNK***”  Green LED lights  Buzzer beeps once. |   Table 10: A Test Case for Testing GSM Module   |  |  | | --- | --- | | **Test case 5** | Testing GSM module. | | **Purpose** | Verify whether the SMSs are sent when the measurement is positive. | | **Prerequisites** | Device is fully powered up.  A positive test. | | **Test Data** | Measured data | | **Steps** | * Measure a target that will yield a positive test (Refer to Test case 2) | | **Expected Results** | SMS should be delivered to a destination number saved on the SIM card embedded in module. |  Configuration Tests During this test, we validated how well NDIRED supports on different types of hardware (SIM 800L, Sparkfun spectrometer, LEDs, LCD etc.). The result showed that the system was compatible to all the specified hardware and software. Calculation tests Calculation tests were made using test subjects who have consumed various ethanol contents, we observed that different all these yielded varying and consistent outputs. |
| Precautions |

### Anomalous conditions

Anomalous conditions my come up while the system is in use and this may affect the performance of the NDIRED.

Since the system uses light for its measurements, this produces a limitation of excess noise from the surrounding environment, for example all objects at a temperature above absolute zero emit infrared radiation, the sun’s visible light and ultraviolet light during day time can also cause noise

Since the human body is carbon based and specifically consists of hydrocarbons like fats, ethanol being a hydrocarbon, this introduces a varying error for any given person under testing, so we have chosen taking the shot inside an open mouth since mouths do not vary so different in organic chemical composition.

The GSM module is operated in an area with GSM network coverage i.e. at least a 2G enable cell tower close by to it connect to the service provider network (MTN, Airtel) in order to successfully send out SMSs. At times the network may be unavailable and hence a failure to send an SMS.

### Precautionary steps taken

Our standardized measurement model has noted all this noise and error and tries to minimize it. But the user should avoid taking measurements in highly lit environments e.g. during direct strong noon sun, or when other light sources have illuminated the object since they introduce an error in the incident light rays that hit the target’s surface.

We have chosen taking the shot inside an open mouth since mouths do not vary so different in organic chemical composition.

Use a normal cell phone to ensure the area in which the device is operated has a 2G/GSM network coverage.

# Chapter 5: Installation and system acceptance test

The validation of the installation process ensured that all system modules were properly fitted and installed in the host casing/ system and that the user obtained a safe and complete setup.

## Input files

All the logic that the system uses to operate was written in called “*project\_logic.ino*” which is an Arduino file. This was later compiled using Arduino IDE and uploaded to the on-board Atmega328 microcontroller of Arduino.

However, being an embedded system, we are likely to use pictures more to describe our setup.

**Arduino IDE**

Contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

|  |
| --- |
| Supplementary files **Proteus schematics**  The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards. This was used to simulate real devices during the debugging process.  We included a schematics image file in PNG (schematic.png) format and a Proteus project file “Ethanol detect.pdsprj” which can be opened using Proteus Version >8.6  A README file containing a full description and detailed instructions on how to install and operate the device.  We have used Arduino’s license distributed under GPL and sparkfun distributed under LGPL 2.1.  Spectrometer license. |
| Installation qualification The system does not require a complex installation process since it comes with all modules fitted in one casing.  Once the red and blue lights light up on pressing the power button, this means the setup is successful and the device is ready for usage.  If one happens to start from the source code, connect all the required components following the schematics, then when one clicks the upload button on the Arduino IDE that contains the cloned source code, and it displays a message “uploading files” the later “done” with no error messages in the console, then the software has been successfully installed on to the Arduino microcontroller. |

Table 11:Checklist of the Installation and system acceptance test

| **Topics** | **Installation summary** |
| --- | --- |
| **Installation method** | * Automatic – installation kit located on the installation media * Manual – Copy & Paste from the installation media |
| **Installation media** | * Download file from internet (GitHub)   Source disk folder (PC network)  Diskette(s) CD-ROM  Comments:  The project files are on our GitHub repo we provided at the begin of this document.  Arduino IDE and SDK can be downloaded from their official website. |
| **Installed files** | * HEX files * C files |

Table 12:Installation Procedure Check

| **Topics** | **Installation procedure** | **Date / Initials** |
| --- | --- | --- |
| **Authorization** | Person responsible: Development team | 28th October 2020 |
| **Installation test** | * Tested and approved in a test environment * Tested and approved in actual environment * Completed tested according to testing plan * Partly tested (known extent of update) | 29th October 2020 |

Table 13: System Acceptance Test

| **Topics** | **System Acceptance Test** | **Date / Initials** |
| --- | --- | --- |
| **Test Environment** | * The actual operating environment (site test) * A true copy of the actual environment * External environment (supplier factory test) | 30th October 2020 |
| **Test performance** | * Installation and version * Startup and shutdown * Selected or critical requirements * Selected inputs * Selected outputs * Selected functionality   Performance vs. user instructions | 31st October 2020 |
| **User level test** | * Tested on operator user level   Tested on super-user level  Tested on system administrator level  Tested on overall system manager level   * Education and training documented * System user manuals | 01st October 2020 |
| **Result of testing** | * Testing approved   Comments:  Not yet approved |  |

# Chapter 6: Performance, servicing, maintenance, and phase out

In this phase, the NDIRED was in use and subjected to the requirements for service, maintenance, performance, and support. All activities during performance resided and decisions about changes, upgrades, revalidation, and phase out were made.

## Service and maintenance

The device casing containing all the components firmly fitted with screws should not do not need servicing

The buttery should be continuously replaced preferably a 9.0V camera buttery.

Future Updates

We may update the system to fully be integrated with car engines. i.e. the system can be fitted in a car to measure an ethanol content in a driver’s breath and disables the engine if the driver is drunk or vice versa.

## Performance and Maintenance

The system is designed not the require a lot of maintenance, the user is required to continuously change the buttery for normal and maximum performance.

The system takes a total estimated time of 3 seconds to take a measurement shot, analyze the findings and provide feedback to the user. If the device takes way longer than that or does not respond at all, a buttery should be replaced it should be carefully opened to examine if no wires have been accidentally for some reason disconnected.

The system can be upgraded by opening the casing to access the Arduino board, then connect it to a PC installed with Arduino SDK connect the board to the PC using a USART cable compile the updated code and upload it to the Arduino microcontroller using Arduino IDE. Then put back the casing together.

The hardware may malfunction when exposed to liquids like water, the device should hence not be operated in liquid environments e.g. heavy rain falls.

Table 14: Performance and maintenance details

| **Topics** | **Performance and maintenance** | **Date / Initials** |
| --- | --- | --- |
| **Problem / solution** | The voltage required by the spectrometer was lower than we were producing. Lowering of this had to be done using resistors and we achieved a potential difference required.  Problem configuring varying SMS destination Phone number has been solved by saving it on the SIM phonebook. | 01/11/2020 |
| **Functional maintenance** | The GSM systems and services are described in a set of standards governed by ETSI. Hence the are must of operation will need to be situated with cell towers that support and conform to such standards. | 01/11/2020 |
| **Functional expansion and performance im­provement** | * Inclusion of support for car engine system integrations. * Make the setup smaller in size but more reliable | 01/11/2020 |

# Chapter 7: Conclusion and Recommendations

Due to the psychoactive effect of alcohol or ethanol in the human body or blood, car drivers should not use it as just before they drive, the commonest measure currently in place for detecting it includes a victim blowing just the right amount of breath in an alcohol breathalyzer.

This method though takes a bit longer and its inconveniencing, it also relies on the fact that the test subject provides the right amount of breath, and according to their lung capacity, and henceforth we sometimes end up with wrong results, in addition to making sure someone unbiased is around to do the test.

This project offers an easier alternative solution using NIR spectroscopy as described below.

Near-Infrared Spectroscopy is one of the most frequently used optical techniques used for detecting the presence of organic compounds in chemical substances. There is a very interesting behavior when an infrared ray of light is passed through a substance containing a hydrocarbon, a hydrocarbon a chemical compound composed of at least carbon and Hydrogen, and luckily enough, ethanol is one of them as clearly evident through its chemical equation CH3CH2OH.

Alcohol is an important substance in organic chemistry that may be amended from many other types of compounds. Ethanol or ethyl alcohol CH3CH2OH is a compound that can be found in alcoholic beverages.

Traffic Law enforcement officers need to be trained on how to the NDIRED functions in order to achieve the efficiency and effectiveness of its operation. The developer team does not confirm that the system will always give perfect results until a wide survey is conducted and the product is approved. But as per the tests we have conducted, I guess it is safe to say it is a big leap in the right direction.

During the course of this project, the developer team gained full understanding of the how to model, design and handle a serious software development project. We also learnt so much about embedded systems and how to work with them. We also explored and learnt a lot about the amazing capabilities of spectroscopy as a field of research and study.

Due to the effectiveness and time saving abilities of NDIRED we would like to request interested parties or individuals to fund this project to further more make research under this topic given the fact that this is currently no quick alternative alcohol detection method massively implemented, this hence can be a revolutionary break through idea once perfected.

**Appendix A: User Manual**

Below is the schematics set up of the Ethanol detector system

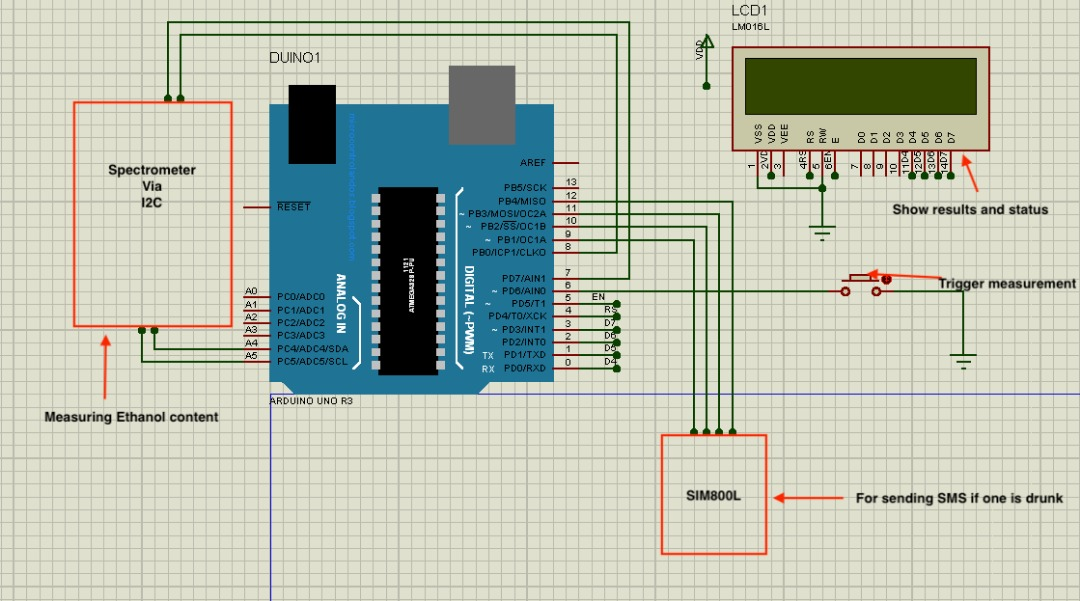
**

Figure 4: System Schematic

**Powering the device**

Fit the device with a 9.0v battery source similar to the one in the image below.



Figure 5: Power source

Power up the device by pressing the power button on the sides of the device.

The red and blue LEDs at the back of the device on a red board similar to the picture below will light up

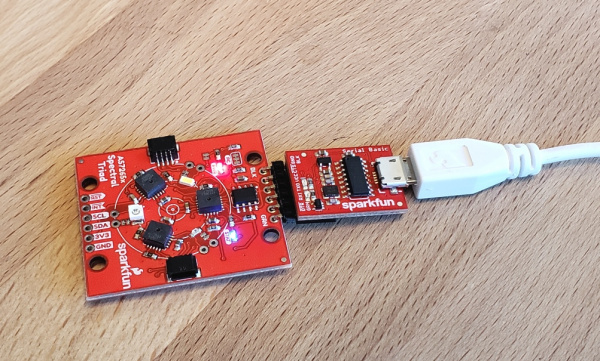


Figure 6:Red Sparkfun Board

Aim the back of the devices in line with the target whose ethanol composition you want to measure and press the big blue take measurement button once and release.

A flash shot at the back similar to that of a camera shutter will be observed.

Wait for one or two seconds and then check the LCD for feedback

**Intepreting feedback**

When the test positively detects ethanol composition, the following indicators confirm this;

* LCD displays ethanol % content and the word “**DRUNK**”
* Red LED lights
* Buzzer continuously goes off.
* An SMS notification is sent to the phone number saved in the phonebook of the SIM card embedded in the GSM module.

When the ethanol detection was negative the following indicators confirm this;

* LCD displays “***NOT DRUNK***” and **ethanol % 0.00**
* Green LED lights
* Buzzer beeps once.

**Resetting the device**

Resetting is required before every new measurement in order to clear out the results from the previous one from memory that may cause noise in the later.

| **Final approval for use** | | |
| --- | --- | --- |
| Identification: | |  |
| Responsible for validation: | |  |
| Remarks: | | |
| Date: | Signature: | |