

SCHOOL *of* BUSINESS AND TECHNOLOGY

Department of Engineering and Aviation Sciences

**The Design of a**

**Smart Fire Detection System**

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2/24/2019

The Design of a Smart Fire Detection System

By

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Submitted to the Department of Engineering and Aviation Sciences in partial fulfillment of the requirements for the degree of Bachelor of Science in Engineering at the

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Authors Israel Akinsoyinu, David Goslee, Dedrick McCoy

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**Table of Contents**

[**List of Contents 2**](#_30j0zll)

[**List of Figures 4**](#_1fob9te)

[**List of Tables 5**](#_3znysh7)

[**Abstract 6**](#_2et92p0)

[**1.0**](#_tyjcwt) **Introduction 7**

[**1.1**](#_3dy6vkm) **Backgound/Motivation 7**

[**1.2**](#_1t3h5sf) **Objective 7**

[**1.3**](#_4d34og8) **Design Requirements 7**

[**1.4**](#_2s8eyo1) **Design Constraints 7**

[**1.5**](#_17dp8vu) **Design Methods 7**

[**2.0**](#_26in1rg) **Project Description 9**

[**2.1**](#_lnxbz9) **System Description 9**

[**2.2**](#_35nkun2) **System Diagram 9**

[**2.3**](#_44sinio) **System Functions 9**

[**3.0**](#_2jxsxqh) **Implementation Plan 11**

[**3.1**](#_z337ya) **Tasks 11**

[**3.2**](#_3j2qqm3) **Team Organization 12**

[3.2.1.](#_1y810tw) Responsibility of Team Member 1. 12

[3.2.2.](#_4i7ojhp) Responsibility of Team Member 2. 12

[**3.3**](#_2xcytpi) **Timeline/Milestones/Delivery Plan 12**

[**4.0**](#_3whwml4) **Implementation 13**

[**4.1**](#_2bn6wsx) **Implementation of Task 1. 13**

[4.1.1.](#_qsh70q) Implementation of Subtask 1.1 13

[**4.2**](#_3as4poj) **Implementation of Task 1. 13**

[**5.**](#_1pxezwc) **Conclusion (Discussion and Future Plans) 14**

[**Acknowledgment 15**](#_49x2ik5)

[**Appendix 16**](#_2p2csry)

[**A.**](#_147n2zr) **Component Specs 16**

[1.](#_3o7alnk) Specs of Arduino Due 16

[2.](#_23ckvvd) Specs of Raspberry Pi 16

[**B.**](#_ihv636) **Source Code. 16**

[1.](#_32hioqz) Source Code of Graphic User Interface 16

[2.](#_1hmsyys) Source Code of Robotic Arm 16

[**REFERENCES 17**](#_41mghml)

**List of Figures**

Figure [1.](#_1ci93xb) System Diagram 11

**List of Tables**

**Abstract**

By the end of the project, summarize the project into short text and put here.

1. **Introduction**

This project will be the design, development, and implementation of a smart fire detection system. This system will utilize modern sensor and network technologies to help notify firefighters and building occupants of an impending or life threatening situation.

## Background/Motivation

This project is the design of a smart fire detection system, with the consideration that there are other systems that already exist. The goal is to make improvements to these devices and add features that set this product apart from the others. With this design the goal is to take out all the issues seen previous systems and to make it user friendly as possible. This will allow individuals to have a thorough understanding of the product and its functions. The design of this product will include a smoke sensor, carbon monoxide sensor, and a temperature sensor. The system will be connected to a webpage that will display the data that is read from each of the sensor nodes in real time. When a problem is detected the webpage will display what the cause of the alarm is and highlight the area of the building in which the problem is located. With this design the plan is to have an SMS message that will inform building occupants and dispatch of what the problem is and where it is located within the building. This will then activate the alarm system and the webpage will display possible escape routes for individuals that are in the structure at that time. This system will be controlled by a Raspberry Pi that will use a built in program call PIVLO that will generate and autonomous phone call to 911 operators that will let them know where the problem is located in the building and the exact nature of the problem at hand. The sensor data will be transmitted via a node network known as a wireless sensor network (WSN). This feature will allow the system to retain its functionality as an alarm based system even if the power is out and there is no WIFI connection.

Upon researching other designs that related to this particular idea, one found an idea for a mini fire detection system on a website called newton projects. It detected potential fire threats using a thermistor, with a simple led that flashes as an alert and a piezo buzzer for the alarm notification. This idea was a great starting point because it presented a good idea but left a lot to be desired. One looked at this mini project and thought of how to make this simple detection system more elaborate and something that can actually serve as a replacement for devices that are already installed. Upon doing further research one found another system on Amazon called the nest smart detector. This smart detector uses a photoelectric sensor and a split-spectrum sensor to detect potential fire threats. This gave the project team the first idea to use a photoelectric sensor in our earlier design plan, which was later scrapped due to the dramatic increase in the cost of the overall system. The objective of this project is to keep the design within affordable price range. This means that one does not want to exceed the cost of existing detectors on the market. It was found that cheaper sensors exist that offer the same measurement precession for half the price. The Nest smart detector is equipped and offered to customers with its own app, which informs the individual who owns it if a problem is detected. This idea was very interesting and the team decided to add this as a feature for this particular project. However, it was realized that this was actually not needed and in fact was overkill for this particular project. In turn a decision was made to alert occupants in the form of an SMS message. The processes of the SMS message transmission will be done using a software called PIVLO. The nest system had a built in function within the app that allowed the user to shut the detector off in case of a false alarm. With this consideration taken into account it could be something this smart fire detection system could encounter. Thus, an executive decision was made afford the users of this system the ability to turn of the system if a false alarm occurs.

One found another similar system on Amazon. It is the Alexa enabled smoke detector and CO monitor that uses a photoelectric sensor, compatible with both Apple and Android devices. The price range is more excessive than what this project plans to charge. That particular monitor is listed around 180 dollars, where this system will only cost around 100 dollars. This being one of the most expensive systems on the market, one compared this detector to the detector mentioned earlier which was the Nest Smart Detector to find a baseline for the price range of where this product should fall.

The inspiration behind this project stemmed from the background experience from two of its group members. Two out of the three group members are volunteer firefighters and have direct experience in the field. This led to the thought, what would a first responder want to see and what one believe could make the response time quicker, safer and more efficient. One also employed the ideas of other first responders to see what their thoughts on this device were. This product aims to limit casualties of civilians as well a fellow firemen. One has witnessed casualties caused by flashovers, and other dire situations caused by high temperatures. By having the system relay the temperature to the building occupants and dispatch, the goal is to greatly decrease casualties caused by flashovers. There are many signs of a flashover in which firefighters are thought to be aware of but inevitably due to human error these can be missed. With this product the objective is to have a drastic effect on that. This system will inform dispatch of the location of the threat in the building and floor it is located on. This will afford first responders the ability to pinpoint and isolate their plan of attack without having to assess the situation on scene.

When conducting research on this particular product idea one realized that people often do not have the same reaction to fire alarms, based on the simple premise that they think it is either system testing or a false alarm. This in turn causes individuals to sit idle and wait for the reactions of others. The issue with that particular situation is not the alarm system but the psychological component of the civilians themselves. The plan of this project is to eliminate this component by having a SMS message that will be sent to the occupants of the building. This SMS message will inform the building occupant’s weather or not the alarm is a test or an actual threat. Another hurdle is the problem that can arise when individuals are trying to exit the structure as soon as possible. This project plans to attach this problem by having a website that will show individuals possible escape routes, corresponding to their location within the building. The overall objective of our system is the safety and protection of life for both the civilians and first responders.

Another reason for the creation of this product is one realized the inherent need in fire detection and co monitors, between January 1, 2019 and March 4, 2019 a total of 427 civilian home fire fatalities were reported by the U.S. media, not to mention the fatalities that were not on record. One knows that they cannot completely eradicate the issue but with this system the overall goal is to have an impact on that number and have it decrease it in the future. In recent systems have improved and afforded a decrease in the number of casualties. However, the number of casualties are still too high and one must not be complacent with the systems currently in place. This is one of the main drivers for the idea for the design of a smart fire detection system, to have an impact as in the local and national community.

## Objective:

The project objective is to design a smart fire detection system that can be implemented for commercial and in home use this system will be able to determine the fires location, notify 911 operators of the fire location, and alert building occupants of the potential threats location.

## Design Requirements:

1. The system will have an autonomous 911 call that will notify dispatch of the fire and its location within the building.
2. System should monitor the temperature of the fire and determine if it is at flash point.
3. The system will monitor carbon monoxide levels and alert occupants if level is above acceptable threshold.
4. Send out a SMS message to registered occupants of the structure of the fire and its location.
5. Must provide output signals for PPE systems.
6. In home fire detector should mount to existing detectors base plate.

## Design Constraints

1. Detector should be less than 200 dollars.
2. System must have voice alarm notification for building occupants.
3. Wireless nodes must be no more than 60 feet apart.

## Design Method (Approach)

The first step for this design method is to select the appropriate sensors for smoke, carbon monoxide, and temperature detection. The second step is to program each of these sensors for their perspective measurement thresholds and if these thresholds are passed issues a warning signal. The third step is to interface these sensors with a microcontroller that will drive each of these sensors processes and transmit their data to the CPU. The fourth step in this project is to program the RF transmitter, RF receiver, and logic level converter for the interface between the microcontroller and raspberry pi. The fifth step is to download PIVLO onto the raspberry pi and program the pi to make autonomous phone calls to emergency services. The sixth step is to implement reference ID’s for each node and assign them to their proper autonomous emergency call. The seventh step is to create a website that will allow the building administrator to see a virtual map of the building and location of where a potential problem will be located. The eighth step will be to again use PIVLO to send SMS warning messages to all registered building occupants of potential problem. The tenth step is to create a printed circuit board that will house contain the sensors, alarm module, and microcontroller. The eleventh step is to design and print a 3D housing that will contain the PCB. The twelfth step is to connect raspberry pi with display and test the administrative web page. Finally the thirteenth step is to interface the entire project and test the system as a whole.

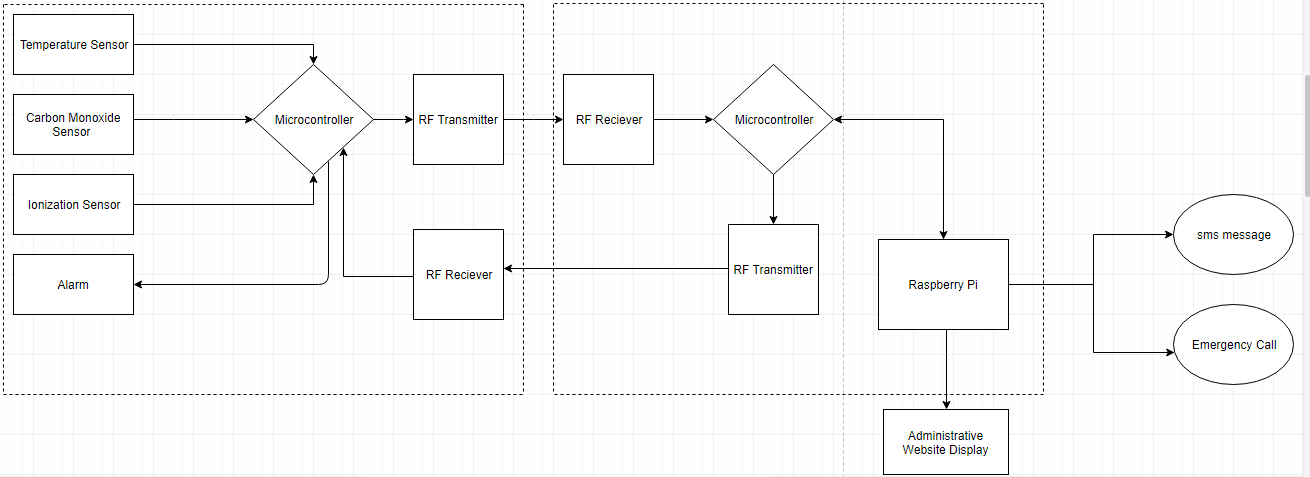
## Standards

1. The initiation function provides the input signal to the system. (NFPA 101, 9.6.1.7).
2. The notification function is the means by which the system advises that human action is required in response to a particular condition. (NFPA 101, 9.6.1.7).
3. The control function provides outputs to control building equipment to enhance protection of life. (NFPA 101, 9.6.1.7).
4. Occupant notification shall be by means of voice announcements. (NFPA 101, 9.6.1.7).
5. Fire alarm circuits shall be installed in a neat workmanlike manner. (NFPA 70 Art. 760.24).
6. Cables and conductors installed exposed on the surface of ceilings and sidewalls shall be supported by the building structure in such a manner that the cable will not be damaged by normal building use. (NFPA 70 Art. 760.24).
7. All fire alarm drawings shall use symbols described in NFPA 170, Standard for Fire Safety and Emergency Symbols.
8. With every new system, a documentation cabinet shall be installed at the system control unit or at another approved location at the protected premises.
9. Smoke detector must be replaced every ten years in accordance to Maryland Smoke Alarm Law.
10. The smoke alarm requirements for existing older homes are based upon when the house was built.
11. The Law heavily emphasizes the use of sealed smoke alarms with long life batteries and silence/hush buttons.
12. Any new home in Maryland constructed after January 1, 1989 required at least one hardwired electric smoke alarm on every level of the home, including the basement.
13. The units must be interconnected in order that activation of any one of the required smoke alarms resulted in the sounding all of the required smoke alarms.
14. The time from the detector’s issuing a fire alarm signal to the controller’s receiving should be controlled within the 10 seconds (GB4717-2005 Fire Alarm Control Units).
15. If any module in the system fails, fire alarm controller should detect the fault in 100 seconds (GB4717-2005 Fire Alarm Control Units).
16. **Project Description**

## System Description

The fire detector is going to consist of three core sensors, a temperature sensor, carbon monoxide sensor, and an ionization sensor. The sensor data will be transmitted over a wireless sensor network made up of a series of RF transmitters and receivers. The sensors. RF transmitter, and RF receivers will be controlled by a microcontroller (Arduino). The detector will transmit sensor data to a RF receiver that will be connected to a logic level converter. This logic level converter will step the microcontroller’s voltage up from 3.3 volts to 5 volts. This will allow communication between the microcontroller and microprocessor (raspberry pi). The raspberry pi will process the data contiguously and if a problem is detected will use a program called PIVLO to transmit an autonomous emergency call that is specific to the ID of the sensor that identified a problem. The raspberry pi will transmit a warning message to any numbers programmed in the occupant network alerting building occupants of the potential problem and its location. The microprocessor will also send a warning signal back through the system and activate an alarm in the detector.

## System Diagram



1. System Flow Chart

## System Functions

1. When either of the sensor thresholds is tripped it will transmit a message signal that will be processed by the Arduino.
2. The Arduino will process this signal and transmit it via the RF transmitter module and also activate a Piezo buzzer as an instant alert notification.
3. This will signal will be received by the RF receiver that will pass this information through a second Arduino and then pass the signal through a logic level converter.
4. The signal will then be passed to the raspberry pi which will interoperate the data signal, determine its node ID, and determine the exact nature and origin of the problem within the building.
5. This will then instantiate the PIVLO program and transmit an autonomous phone call to emergency services notifying them of the nature and origin of the problem within the structure. While this process is occurring the raspberry pi will send out a SMS warning message to all registered occupant phone numbers within the database.
6. The potential threat will be updated to the administrative web page, its location within the building will be highlighted, and possible escape routes will be calculated and displayed.
7. **Implementation Plan**

## Tasks

* Task 1. Sensor Design
  + Subtask 1. Design program for Temperature Sensor
  + Subtask 2. Design program for Ionization Sensor
  + Subtask 3. Design program for Carbon Monoxide Sensor
  + Subtask 4. Configure microcontroller with all three sensors.
  + Subtask 5. Design PCB for transmitter.
  + Subtask 6. Design PCB for receiver.
* Task 2. Wireless Sensor Network Design
  + Subtask 1. Configure microcontroller and RF transmitter interface
  + Subtask 2. Program microcontroller and RF transmitter.
  + Subtask 3. Configure microcontroller and RF receiver interface
  + Subtask 4. Program microcontroller and RF receiver interface.
  + Subtask 5. Design a data structure that will hold all sensor data.
  + Subtask 6. Configure microcontroller and raspberry pi.
  + Subtask 7. Configure raspberry pi to retrieve, display, and store node data.
  + Subtask 8. Design a program that will interpret node data and transfer it to the webpage.
  + Subtask 9. Configure raspberry pi and website for node data processing and storage.
* Task 3. Website Design
  + Subtask 1. Design background and layout of website.
  + Subtask 2. Design login for administrator and user access.
  + Subtask 3. Program a grid that will establish compartments for each room in building.
  + Subtask 4. Design a program that will interface the raspberry pi and website.
  + Subtask 5. Design a program that will pair node ID with corresponding room on the grid plan.
  + Subtask 6. Program grid to highlight room where potential threat arises.
* Task 4. Configure raspberry pi and website.
  + Subtask 1. Design program that will transmit and display WSN data on webpage.
  + Subtask 2. Design program that will display warning messages from pi on webpage.
  + Subtask 3. Configure node ID data from raspberry pi with website.
  + Subtask 4. Program alarm system shut off for administrative use.
  + Subtask 5.Program administrative link for admin to upload floor plan to website.
* Task 5. Design Automated Emergency Phone Call
  + Subtask 1. Setup PIVLO account and install corresponding software on raspberry pi.
  + Subtask 2. Configure PIVLO with wireless sensor network.
  + Subtask 2. Design a virtual autonomous alert message for each specific node ID.
  + Subtask 3. Design program that will allocate voice node ID numbers to specific automated dispatch message.
  + Subtask 4. Program each specific node ID for a specific SMS message transmission.
  + Subtask 4. Configure raspberry pi for SMS data transmission.
* Task 6. Design SMS Warning Message Database
  + Subtask 1. Design database for building occupant phone number storage.
  + Subtask 2. Design program to send link to the webpage.
  + Subtask 3. Test SMS warning message for building occupants
* Task 7. Design 3-D printed housings for transmitter and receiver modules
  + Subtask 1. Design cad model for transmitter housing.
  + Subtask 2. Design cad model for receiver housing.
  + Subtask 3. Print transmitter and receiver housings.
* Task 8. Complete System Assembly and Testing
  + Subtask 1. Assemble entire system.
  + Subtask 2. Test full platform with nodes placed in their desired positions.
  + Subtask 3. Test all warning message software and assure they work properly.

## Team Organization

### Responsibility of Team Member 1 (David Goslee).

Task 1, Subtask 1.1, 1.2, 1.3, 1.5

Task 2, Subtask 2.8, 2.9

Task 4, Subtask 4.1, 4.2, 4.3, 4.4

Task 5, Subtask 5.3, 5.4

Task 8, Subtask 8.1, 8.2, 8.3

### Responsibility of Team Member 2 (Israel Akinsoyinu).

Task 1, Subtask 1.6

Task 2, Subtask 2.1, 2.2, 2.3, 2.4, 2.6, 2.7

Task 5, Subtask 5.1, 5.2

Task 7, Subtask 7.1, 7.2, 7.3

Task 7, Subtask 8.1, 8.2, 8.3

### Responsibility of Team Member 3 (Dedrick McCoy).

Task 3, Subtask 3.1, 3.2, 3.3, 3.4, 3.5

Task 4, Subtask 4.1, 4.2, 4.3, 4.4

Task 6, Subtask 8.1, 8.2, 8.3

## Timeline/Milestones/Delivery Plan

1. **Project Timeline and Delivery Plan**

|  |  |  |  |
| --- | --- | --- | --- |
| **Time** | **David** | **Dedrick** | **Israel** |
| **Week 5** | Subtask 1.1-1.3 (two weeks needed) | Subtask 3.1-3.2 (two weeks needed) | Subtask 2.1-2.4 (two weeks needed) |
| **Week 6** | Subtask 1.1-1.3 | Subtask 3.1-3.2 | Subtask 2.1-2.4 |
| **Week 7** | Subtask 2.5 (two weeks needed) | Subtask 3.3 (two weeks needed). | Subtask 2.6-2.7 (two weeks needed) |
| **Week 8** | Subtask 2.5 | Subtask 3.3 | Subtask 2.6-2.7 |
| **Week 9** | Subtask 1.5 (four weeks needed) | Subtask 3.4 (three weeks needed) | Subtask 1.6 (four weeks needed) |
| **Week 10** | Subtask 1.5 | Subtask 3.4 | Subtask 1.6 |
| **Week 11** | Subtask 1.5 | Subtask 3.4 | Subtask 1.6 |
| **Week 12** | Subtask 1.5 | Subtask 3.5 (three weeks needed) | Subtask 1.6 |
| **Week 13** | Subtask 5.4-5.5 (three weeks needed) | Subtask 3.5 | Subtask 5.1-5.2 (two weeks needed) |
| **Week 14** | 5.4-5.5 | Subtask 3.5 | 5.1-5.2 |
| **Week 15** | 5.4-5.5 | Subtask 4.1-4.2 (three weeks needed) | Subtask 5.3 (one week needed) |
| **Week 16** | Subtask 6.1 (three weeks needed) | Subtask 4.1-4.2 | Subtask 6.2-6.3 (three weeks needed) |
| **Week 17** | Subtask 6.1 | Subtask 4.1-4.2 | Subtask 6.2-6.3 |
| **Week 18** | Subtask 6.1 | Subtask 4.3-4.4 (five weeks needed) | Subtask 6.2-6.3 |
| **Week 19** | Subtask 2.8 (two weeks needed) | Subtask 4.3-4.4 | Subtask 7.1-7.3 (two weeks needed) |
| **Week 20** | Subtask 2.8 | Subtask 4.3-4.4 | Subtask 7.1-7.3 |
| **Week 21** | Subtask 8.1-8.3 (two weeks needed) | Subtask 8.1-8.3 (two weeks needed) | Subtask 8.1-8.3 (two weeks needed) |
| **Week 22** | Subtask 8.1-8.3 | Subtask 8.1-8.3 | Subtask 8.1-8.3 |

1. **Implementation**

## Implementation of Task 1 Sensor Design.

### Implementation of Subtask 1.1

The implementation of subtask 1.1 is the design of program and circuit for a temperature sensor. The sensor that was chosen for this part of the project is the Adafruit DHT22 Temperature and Humidity Sensor. To implement this task first the Adafruit DHT source file must be downloaded and extracted into your project folder. It is imperative that this file be extracted into the proper folder so that the libraries can be utilized for the DHT22 program code. If this is not done properly all definition statements written for the DHT22 sensor will cause the Arduino IDE compiler to throw an error when attempting to upload the code to the board.

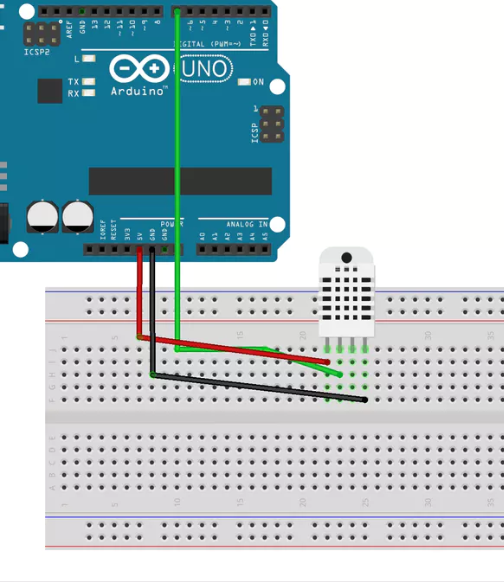


Figure 2: Adafruit DHT22 Circuit Diagram.

* + 1. ***Implementation of Subtask 1.2***

The implementation of subtask 1.2 is the design of a program and circuit for the flying fish MQ-7 carbon monoxide detector. This sensor was chosen for the implementation of this part of the project because of its precise calibration for the detection of harmful and poisonous gases. The MQ-7 fluctuates between a high and low voltage process that allows the device to clean its base plate before each reading thus affording a more accurate value for its user. No libraries are needed for this particular sensor only the program and circuit have to be built for complete operation. There are two ways to achieve this task the first is to build a complex circuit using capacitors, a NPN transistor, and multiple resistors to fluctuate the input voltage from 5V to 1.4V thus achieving the proper cleaning process for an accurate reading. The second is to hard code the voltage drop within the Arduino code itself. This will allow the microcontroller to fluctuate its own voltage over a specified range of time. The cleaning process needs to occur for a sixty second period and the reading must be taken directly after this process takes place to ensure that the device obtains an accurate reading. This sensor must be read using the analog pins of the Arduino because it does not contain a digital chip on its own board. The A0 pin on the Arduino must be utilized as a constant reference pin so that the device can differentiate between its high and low voltage fluctuations to achieve an accurate data reading.

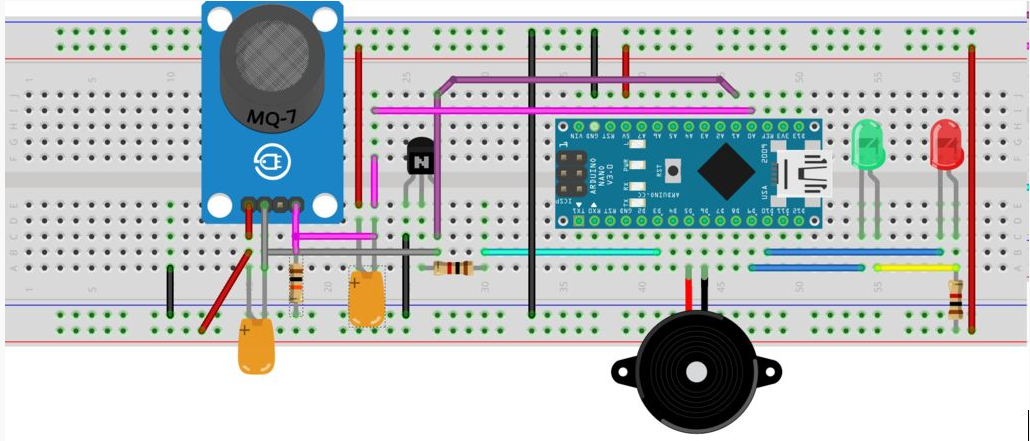


Figure 3(a): First Flying Fish MQ-7 circuit diagram.

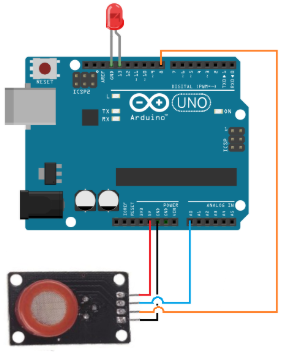


Figure 3(b): Second Flying Fish MQ-7 circuit diagram.

* + 1. ***Implementation of Subtask 1.3***

The implementation of subtask 1.3 is the design of a program and circuit for the Flying Fish MQ-2 ionization sensor. This sensor was chosen because of its high accuracy for detecting air born particulate which is a major benefit for detecting smoldering fires. For this sensor no libraries are needed to ensure that the sensor functions properly only the code and a proper circuit need be implemented. The MQ-2 input must be read using the analog pins because there is no chip on its board to convert the reading into a digital signal. This sensor does not require any special calibration technique to achieve proper measurement.

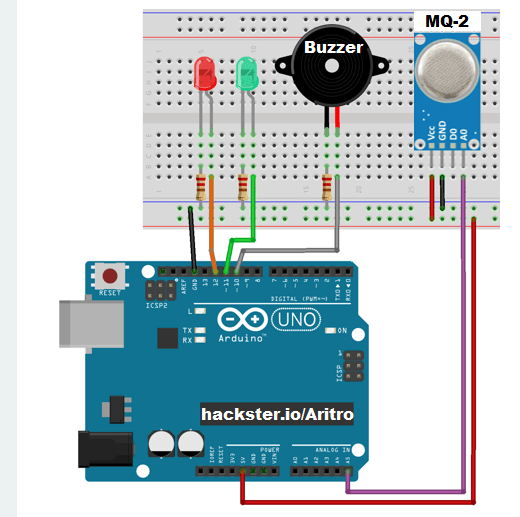


Figure 4: Flying Fish MQ-2 Circuit Diagram.

* + 1. ***Implementation of Subtask 1.4***

The implementation of subtask 1.4 is the complete integration of all three sensors with the alarm circuit. The most critical component of this task is the proper integration of all code for each of these sensors into one contiguous block of code that functions for them all. For this the adafruit libraries must be present in the project directory to ensure the definition statements for the DHT22 temperature and humidity sensor do not cause a compilation error. Careful consideration is needed for the integration of this circuit and it is imperative that all wires are connected to their proper input pins.

## Implementation of Task 2 Wireless Sensor Network Design.

1. **Conclusion (Discussion and Future Plans)**

**Acknowledgment**

**Appendix**

You can put reference info here, including: i) specs of components used in the system, ii) source code (must be here but not in the body text), iii) CAD figures, etc.

1. **Component Specs**
2. ***Specs of Arduino Due***

...

1. ***Specs of Raspberry Pi***

…

1. **Source Code.**
2. ***Source Code of Graphic User Interface***

…

1. ***Source Code of Robotic Arm***

…

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