



2023-2024 Reverse Engineering Challenge
Kidde Firex i4618 Smoke Alarm



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1. Introduction

Our team consists of eight hardworking and dedicated members. To prepare for VRC competitions, we often meet at our school workshop and team members' houses. During one meeting, a smoke alarm was triggered, which turned out to be a battery replacement notification. This prompted us to perform further research on a malfunctioning smoke alarm, leading to the completion of this challenge.



Safety has always played an integral role in the security and stability of buildings. One risk in these buildings is fires, which is combated by the use of smoke detectors. This summary provides a full teardown and analysis of the Kidde Firex i4618 Smoke Alarm, including descriptions and lessons learned.

2. Smoke Alarm History



1890
Francis Upton created the first electric automated fire alarm

1930s
Walter Jaeger "accidentally" created the first smoke alarm when his cigarette set off a prototype poison gas detector



1965
First household smoke detector patented, titled "SmokeGard 700"

1972
Donald Steele and Robert Emmark created the optical smoke alarm, which receives infrared smoke light



1995
10-year lasting lithium battery smoke alarm was patented

1902
George Darby patented first heat sensor and detector



1939
Ernst Meili created the first ionization chamber usable for smoke alarms

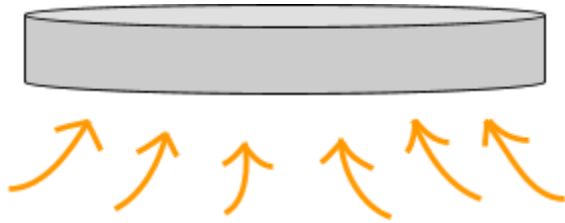


1969
BRK Electronics launches the first battery-powered smoke alarm

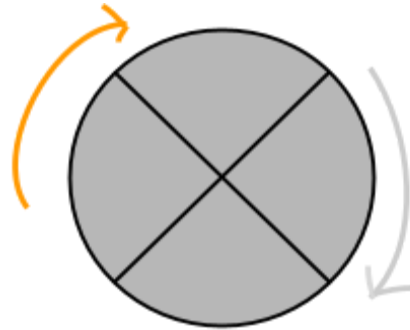
1976
USA passed the "Life Safety Code" mandating smoke alarms in every household



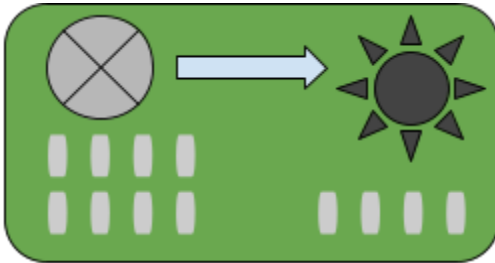
3. Hypothesis



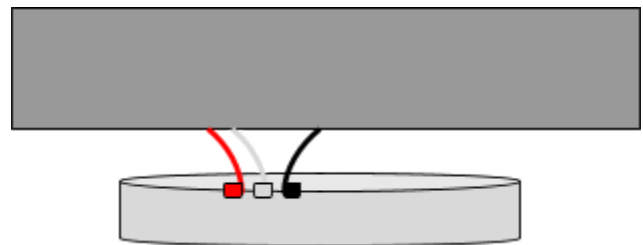
1. Smoke alarm is able to intake surrounding air



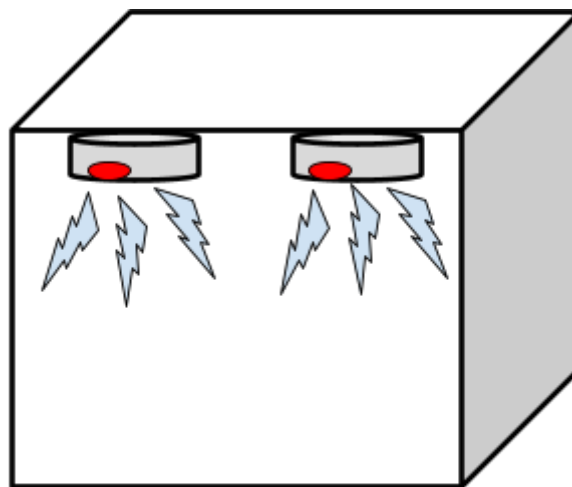
2. Chemicals within the ionization chamber detect presence of fire/smoke



3. This detection sends signals through the circuit, into the sounder



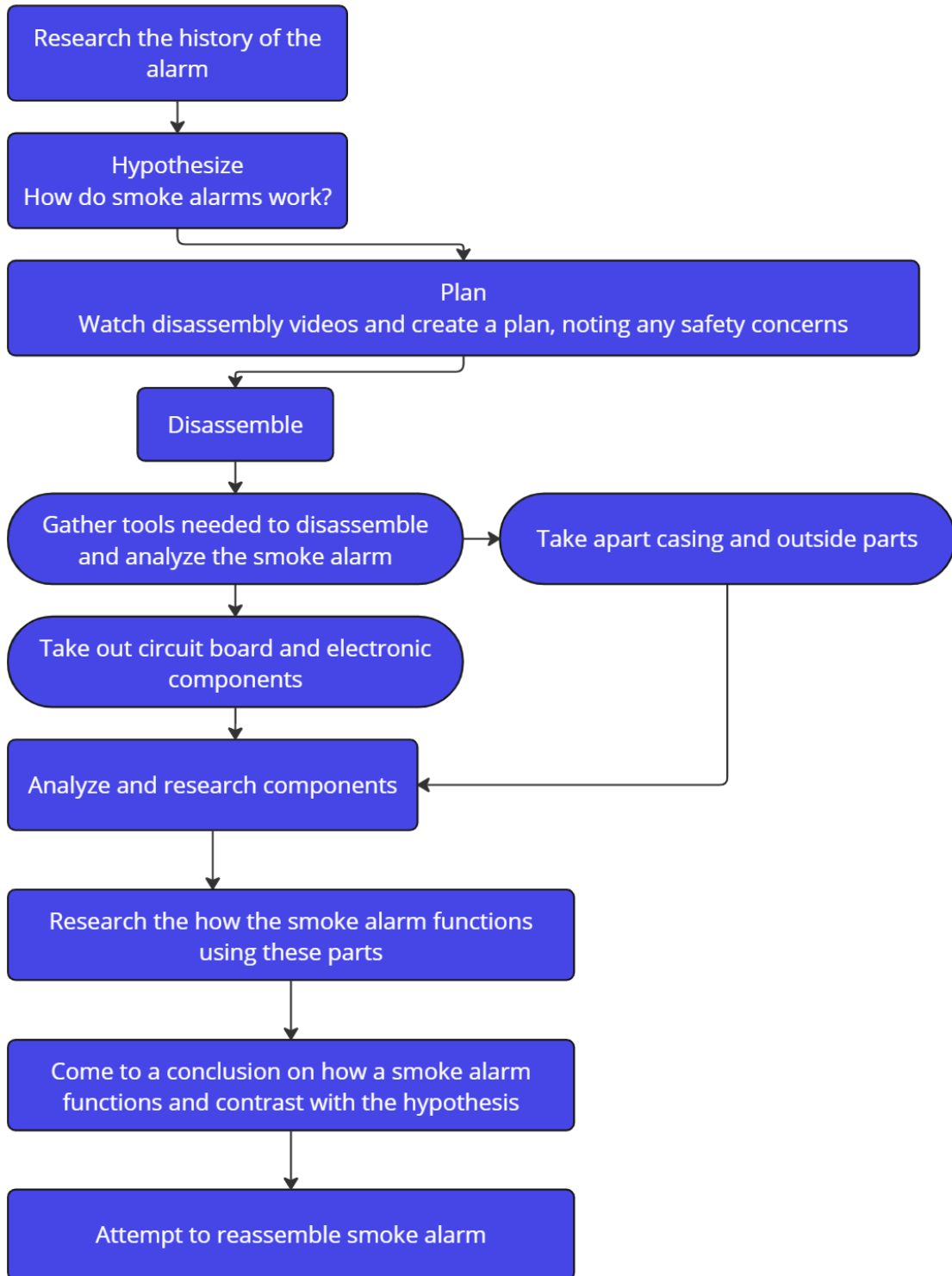
4. Signal is also sent through the circuit into wires connecting the alarm to the building



5. Sounders in each alarm are connected, creating sound throughout an area

4. Plan

Before beginning, we developed a plan.

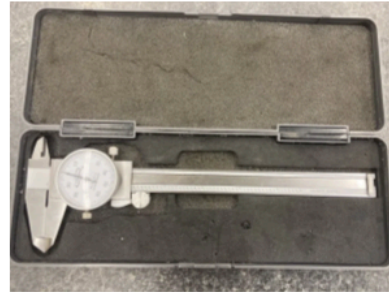


5. Disassembly

5.1 - Tools Used



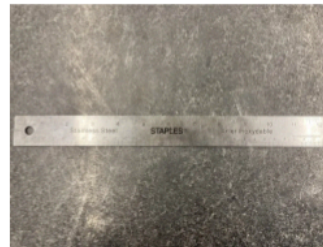
Safety goggles (ft. Kian's dog)



Dial Caliper



Ratchet Screwdriver Set from Ratchet Tools



Ruler

5.2 - Safety Preparations

To be safe, we made sure to research before disassembling.

Resources :

<https://youtu.be/VHGSHf40tI?si=dj-j17h4905Nnk5R>
[Smoke Alarm Kidde i4618A Teardown](#)

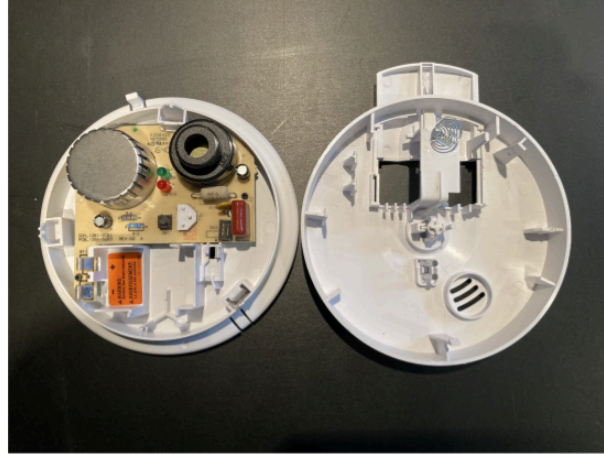
As the ionization chamber contains radioactive material, we cannot open it.
All energy sources are removed.

5.3 - Execution

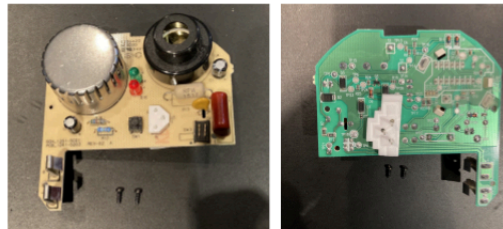
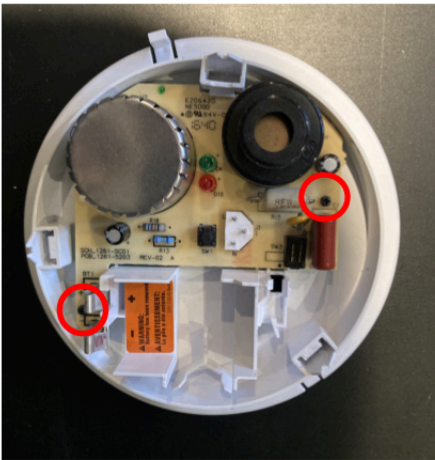
Step 1 - Separate the top and bottom casing



We used a flathead screwdriver and wedged the space in between the casing to separate them.

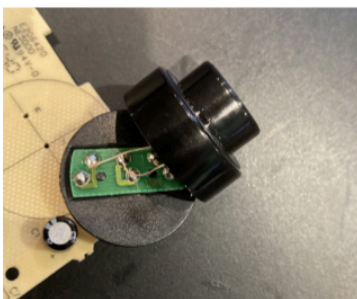


Step 2 - Remove the circuit board



We removed the screws that attach the circuit board to the casing.

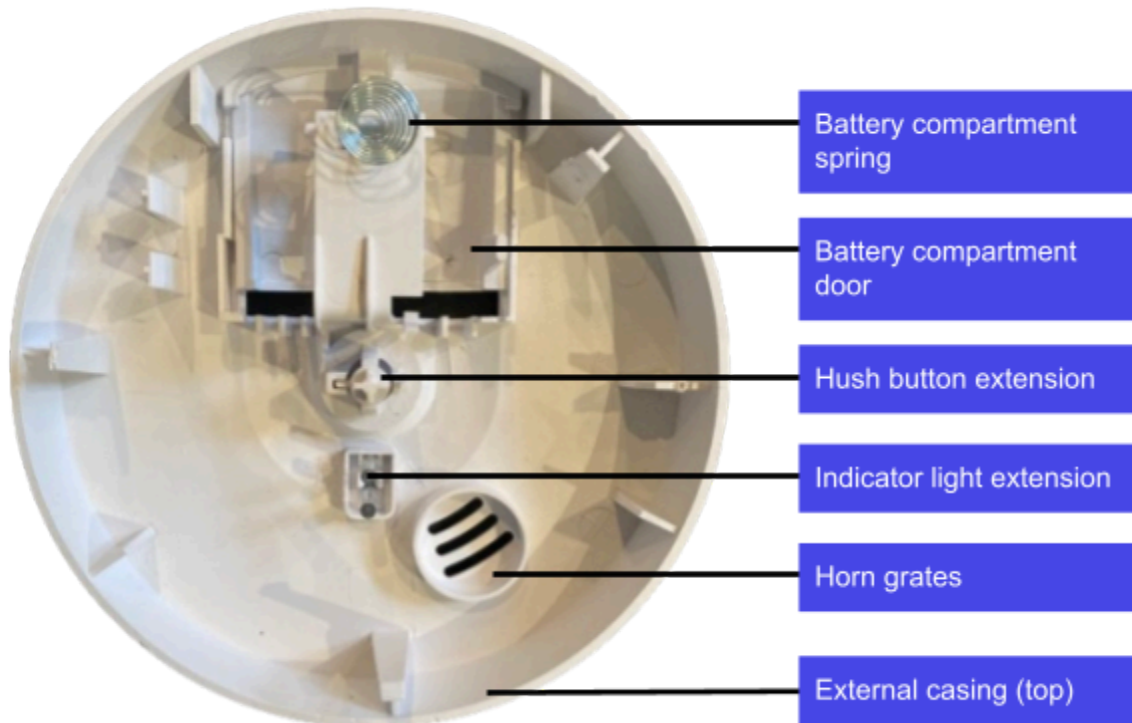
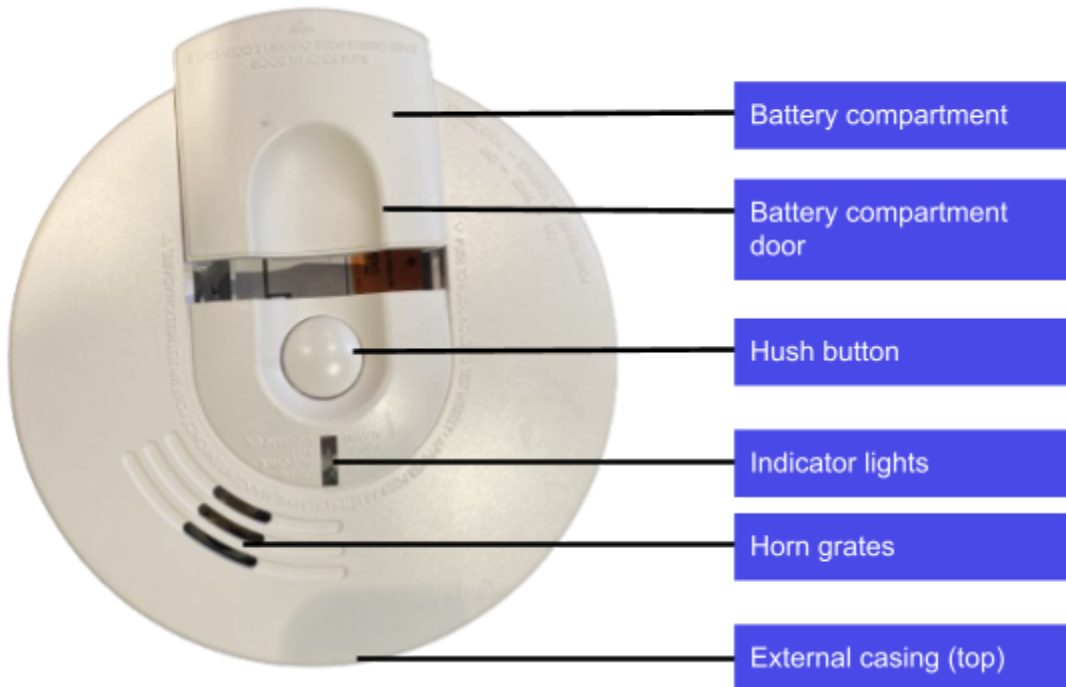
Step 3 - Remove the sounder

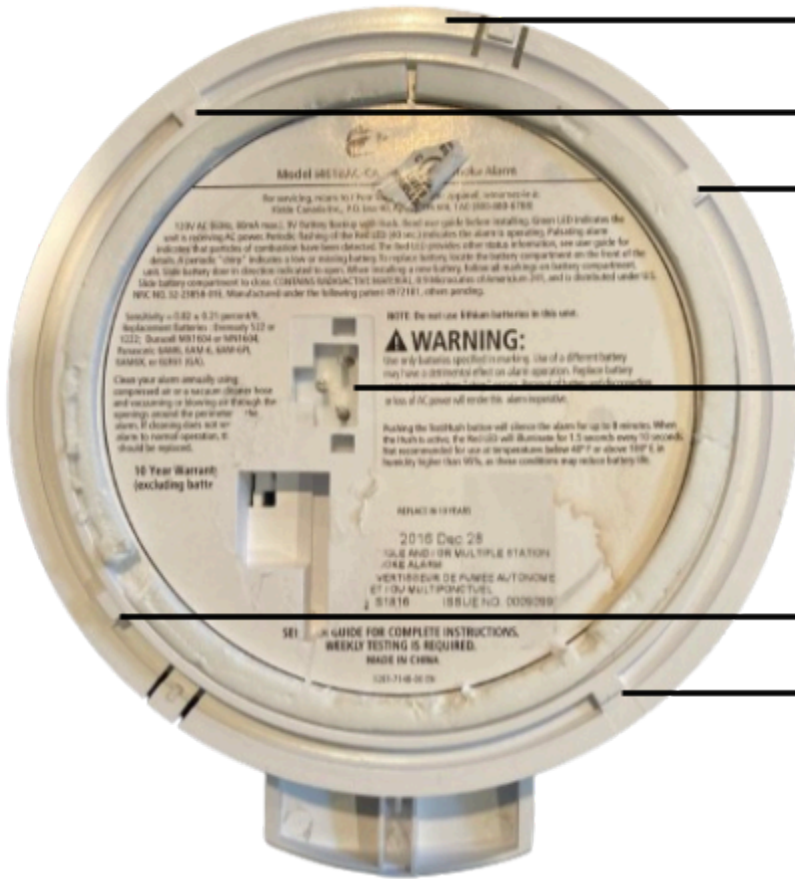


Using a flathead, we wedged the sounder off the board in order to examine the insides

6. Diagrams

6.1 - External Features





External casing (bottom)

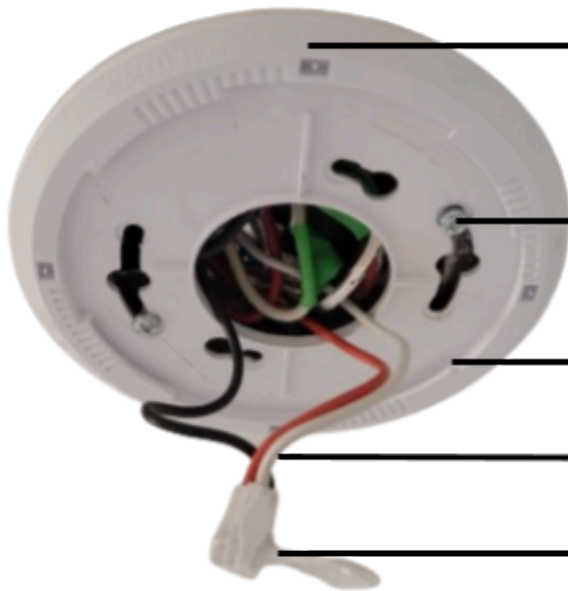
Mounting notch

Mounting notch

3-way switch

Mounting notch

Mounting notch



Plastic mount

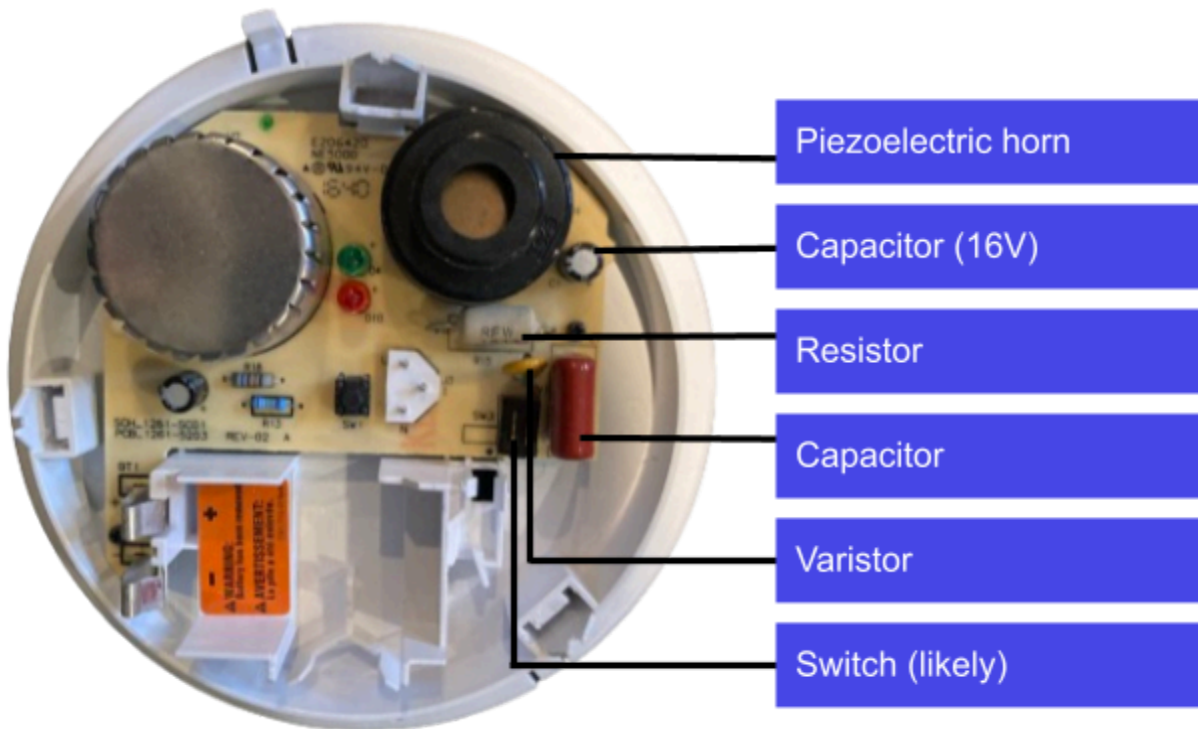
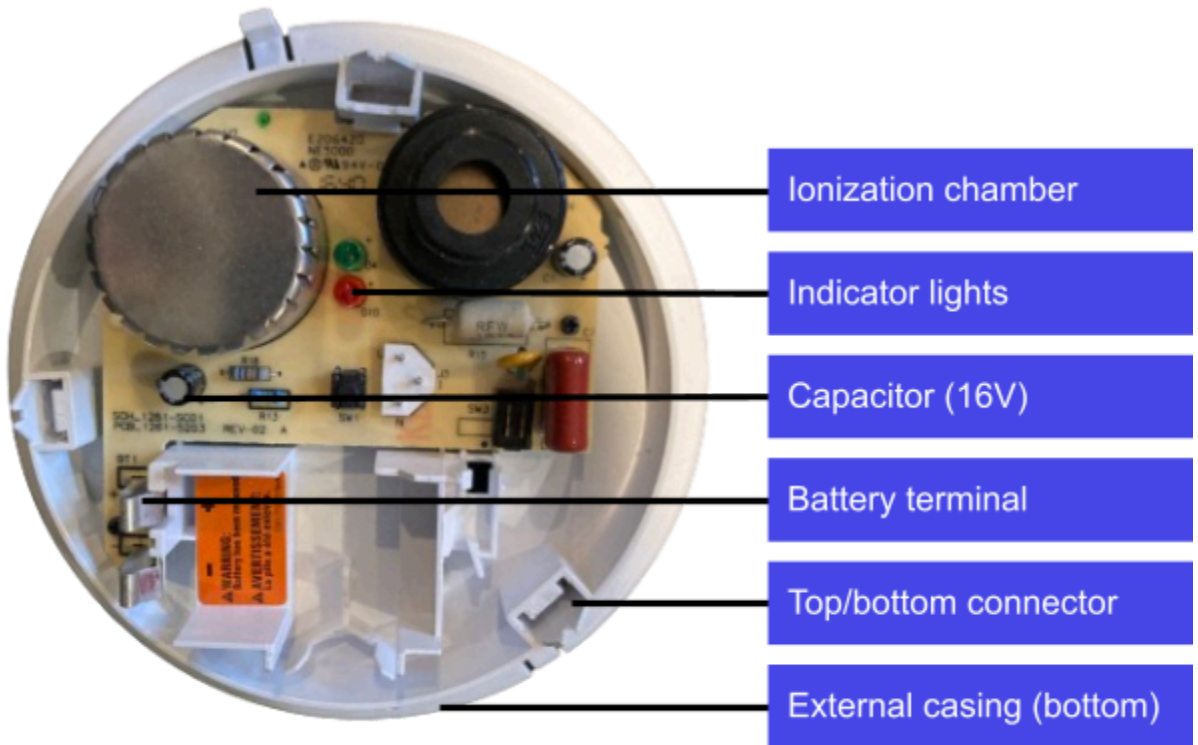
Screw holes for house

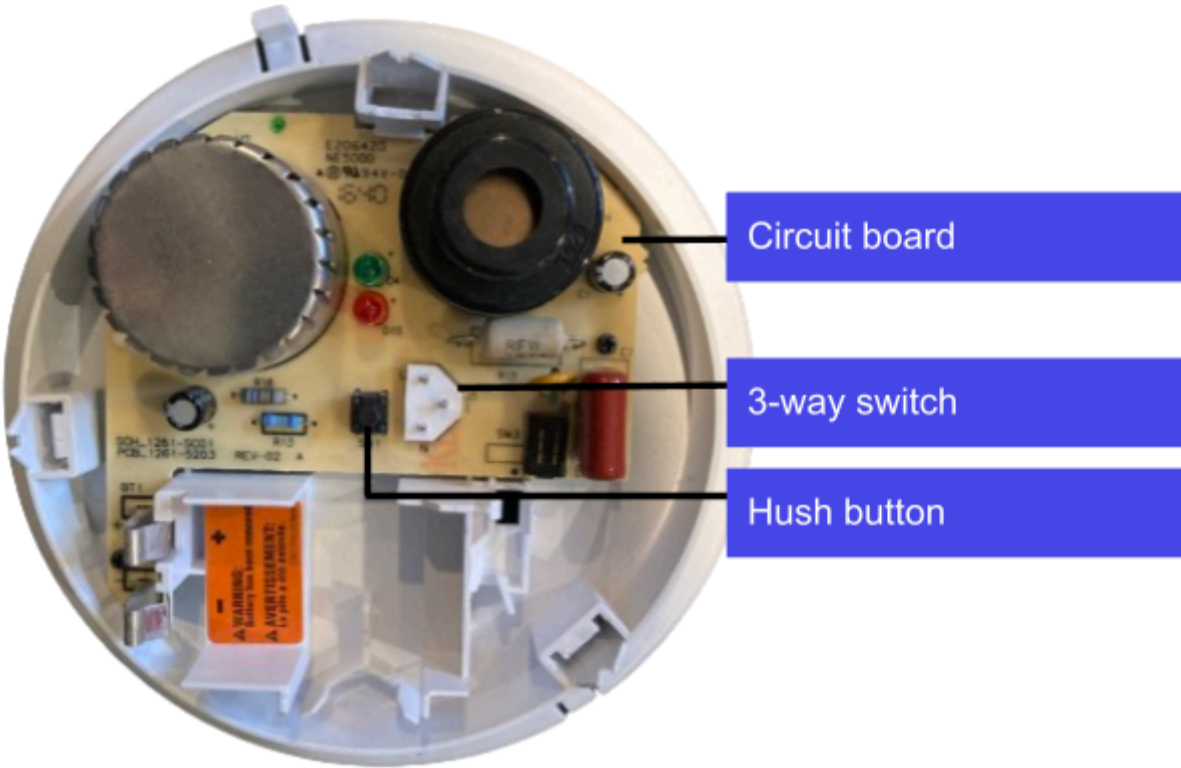
Notch hole

Home wires

Alarm socket

6.2 - Internal Features





Circuit board

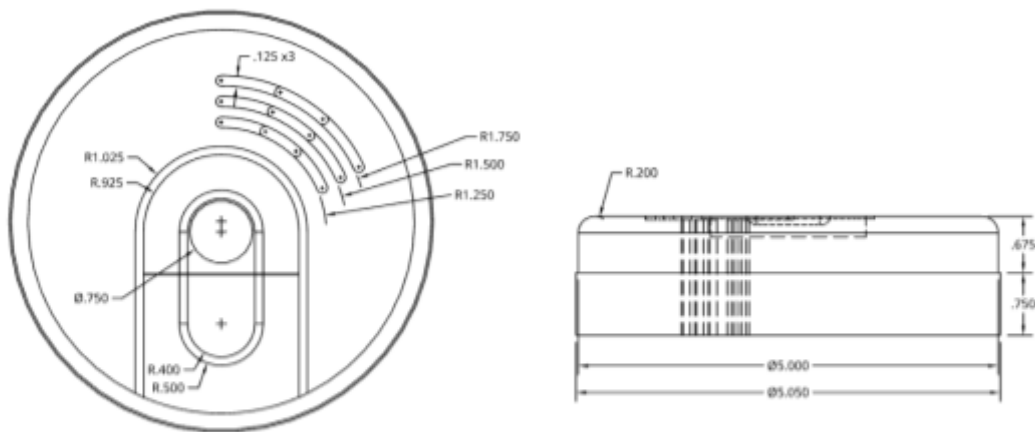
3-way switch

Hush button

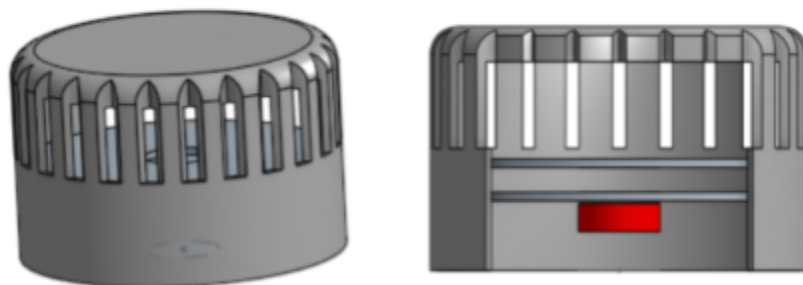
6.3 - CAD Modelling (Onshape)



3D Model of the Smoke Alarm Assembly



Orthographic Drawing of the Smoke Alarm Assembly
(All Dimensions are Imperial)





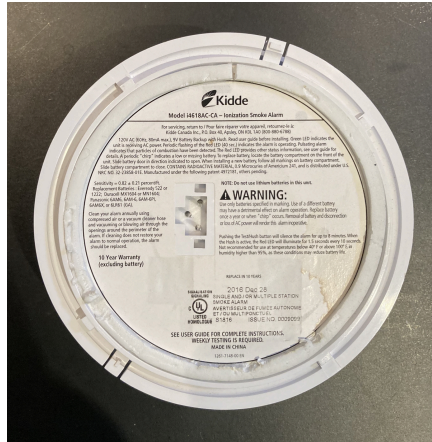
3D Model of the Ionization Chamber
(Includes Cutout View of Interior)

7. Parts List

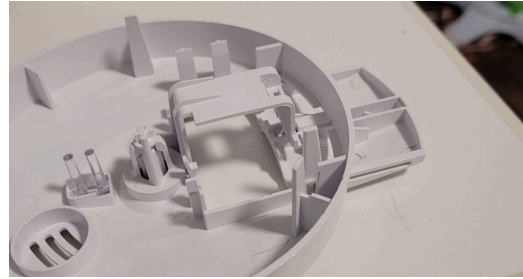
All parts and dimensions can be found here :

https://docs.google.com/spreadsheets/d/1FlaAZxCaBjYZ64qzyX1hr30avl-nN4OP3_CKPDP_dUU/edit#gid=0

7.1 - Non-electronic Components

Part	Picture
<p>1. Mounting plate</p>	
<p>2. Outer shell (top)</p>	
<p>3. Outer shell (bottom)</p>	

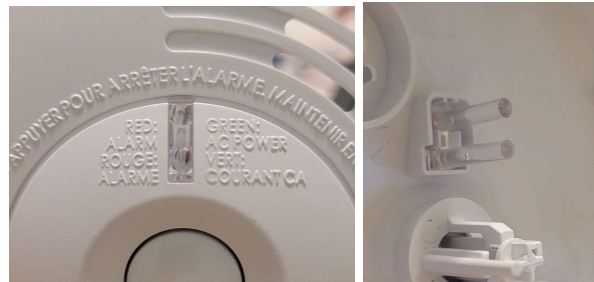
4. Battery Compartment





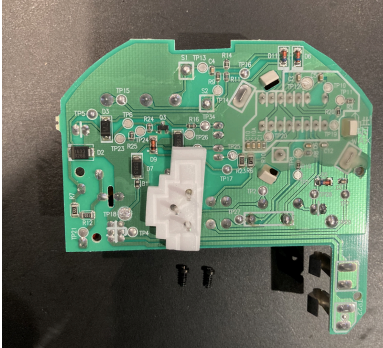


5. Hush Button

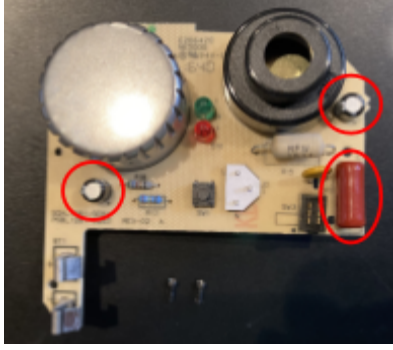




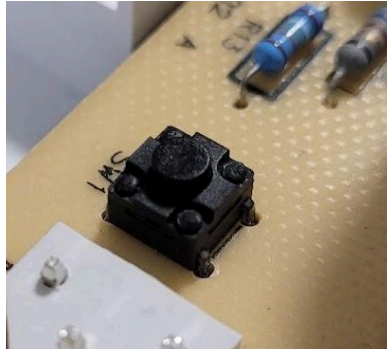



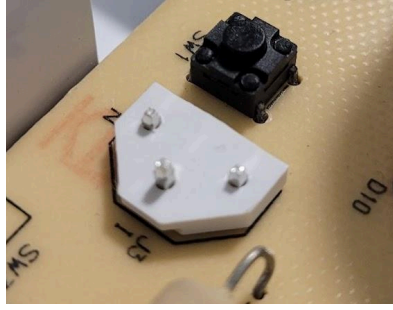

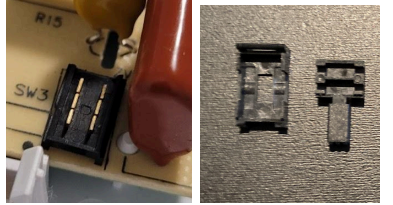



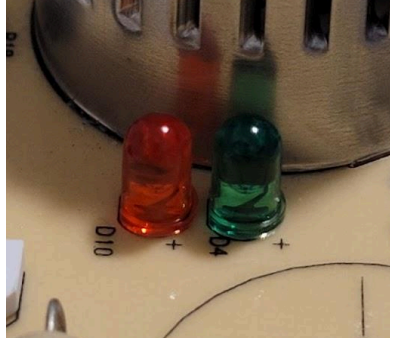
6. Alarm Lights



7.2 - Electronic Components

Part	Location	Picture
7. Circuit Board		 
8. Battery Terminal		

<p>9. Capacitors (x3)</p>	 A photograph of the main PCB showing three capacitors circled in red: a large electrolytic capacitor on the left, a small ceramic capacitor in the center, and a red electrolytic capacitor on the right.	 Two close-up photographs. The top one shows a small ceramic capacitor and a red electrolytic capacitor. The bottom one shows a red electrolytic capacitor with 'RFW 15' printed on it.
<p>10. Resistors (x3)</p>	 A photograph of the main PCB showing three resistors circled in red: a small blue resistor in the center, a larger tan resistor on the right, and a small black resistor on the left.	 Two close-up photographs. The top one shows a blue resistor labeled 'R13' and a black resistor labeled 'R12'. The bottom one shows a tan resistor labeled 'R14'.
<p>11. Hush Button</p>	 A photograph of the main PCB showing a black hush button circled in red.	 A close-up photograph of the black hush button, showing its four pins and the label 'LMS' on the PCB.

<p>12. 3-Way Switch</p>		
<p>13. Switch (likely)</p>		
<p>14. Varistor</p>		
<p>15. Indicator Lights</p>		

16. Piezoelectric
Sounder

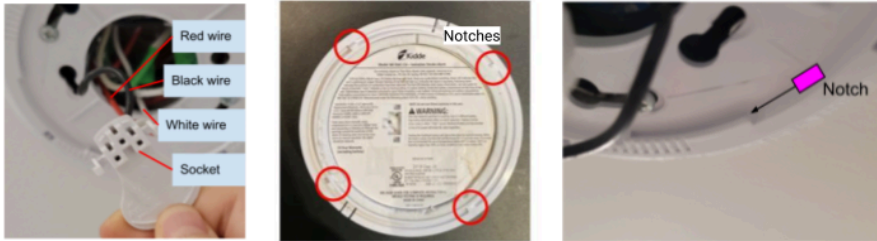


17. Ionization
Chamber



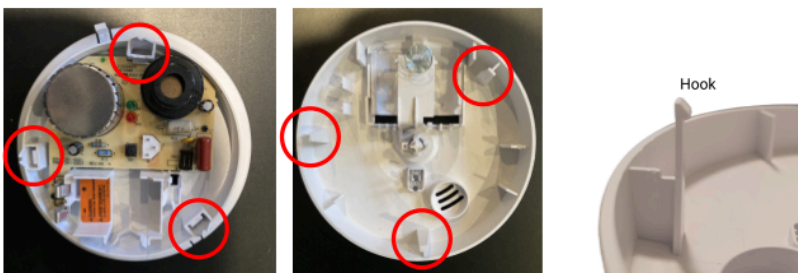
8. Part Description

Mounting Plate and External Casing (bottom)



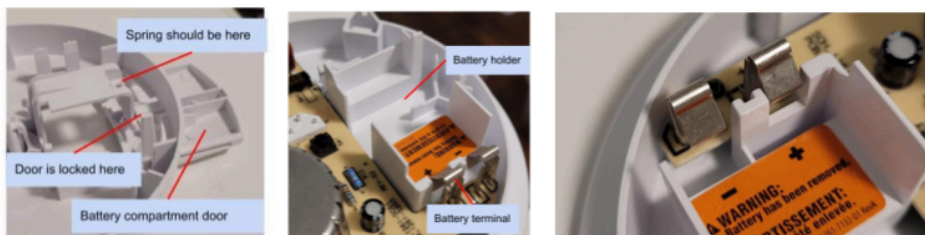
The smoke alarm attaches to the ceiling through notches, which slide into holes in the mounting plate. The wires in the mounting plate connect to a 3-way switch on the back of the alarm. The black wire supplies electricity, while the red is used to communicate with other smoke alarms and the white is neutral.

External Casing



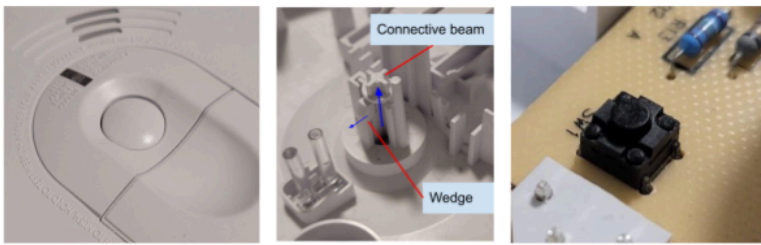
The case is exposed to consumers, and features 2 interactive components – the indicator light and the hush button. The top and bottom section are connected by plastic “hooks” on the top that latch onto the bottom hole.

Battery Holder and Terminal



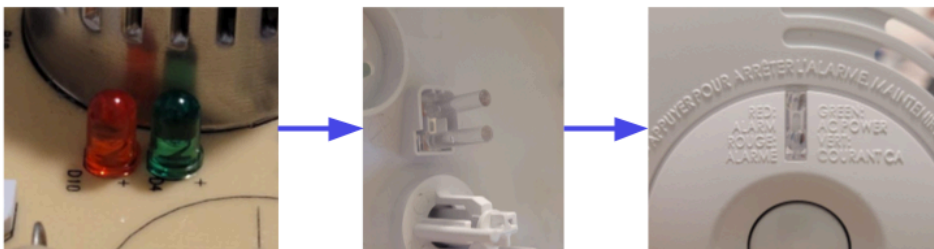
Holds battery to power the alarm. The spring underneath the compartment pushes up onto the door and prevents it from closing unless the compartment is weighed down by a battery. Battery terminals transfer the electricity from the battery to the circuit through a negative and positive terminal.

Hush button



The hush button can be pushed by consumers to temporarily silence an alarm. When the button is pressed, a beam below the button is pushed down, which presses a switch on the circuit.

Indicator lights



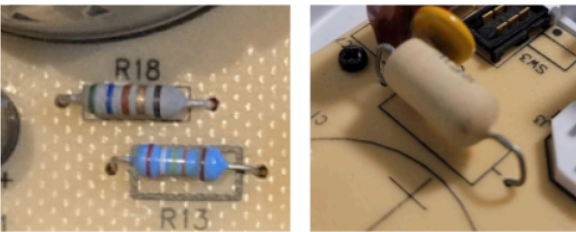
The indicator lights consist of 2 LEDs that are green and red respectively. When the alarm is properly working, the green LED is turned on, with its light transferred through a plastic beam to the outside of the casing.

Capacitors



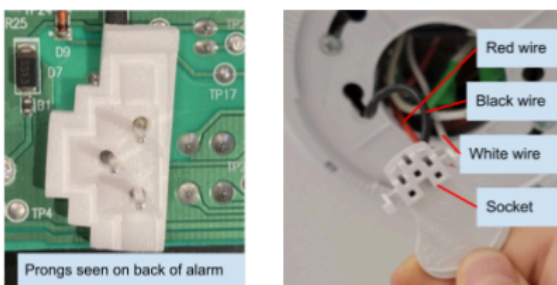
The circuit contains 3 capacitors, 2 that hold 16V and 1 that holds 250V. Capacitors store electricity when there is a surplus, and release electrons when there is a shortage, which regulates the flow of the circuit.

Resistors



Visibly, there are 3 resistors on the circuit, 2 small and 1 large. Resistors can reduce the current in a circuit. The small beige resistor has a resistance of 56.2 Ohms, while the bottom one has a resistance of 295 K Ohms. The resistance of the large beige resistor is unknown.

Three-way Switch



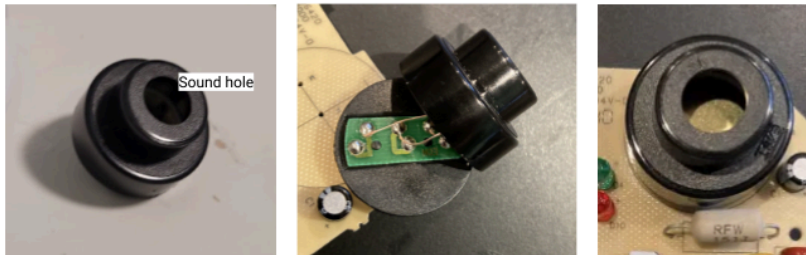
The 3 prongs on the alarm is a 3-way switch. Typically, the alarm is connected to the black (normal) wire. When it detects a fire, the alarm sends a message down the red wire, which is connected to other smoke alarms. This causes them to also be triggered.

Varistor

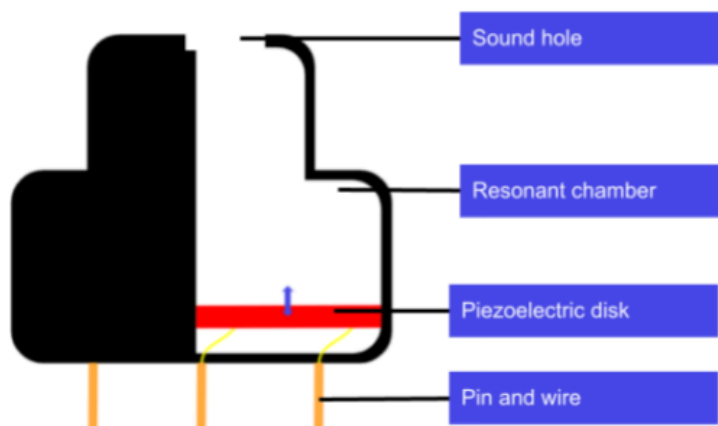


A varistor (voltage dependent resistor) is a resistor that changes depending on the voltage level. As the voltage increases, the resistance decreases. This is able to protect the circuit from random surges in voltage.

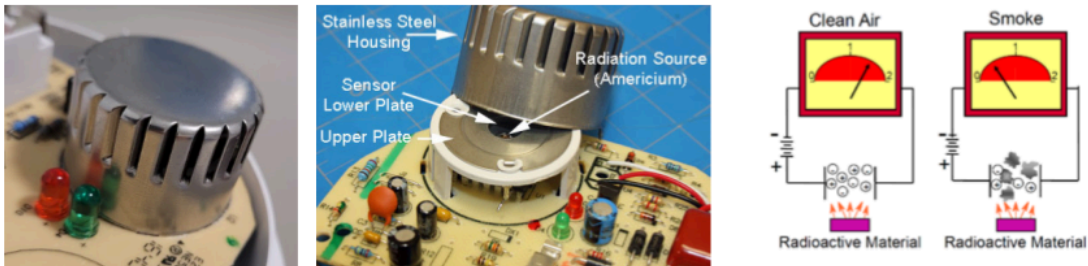
Piezoelectric Sounder



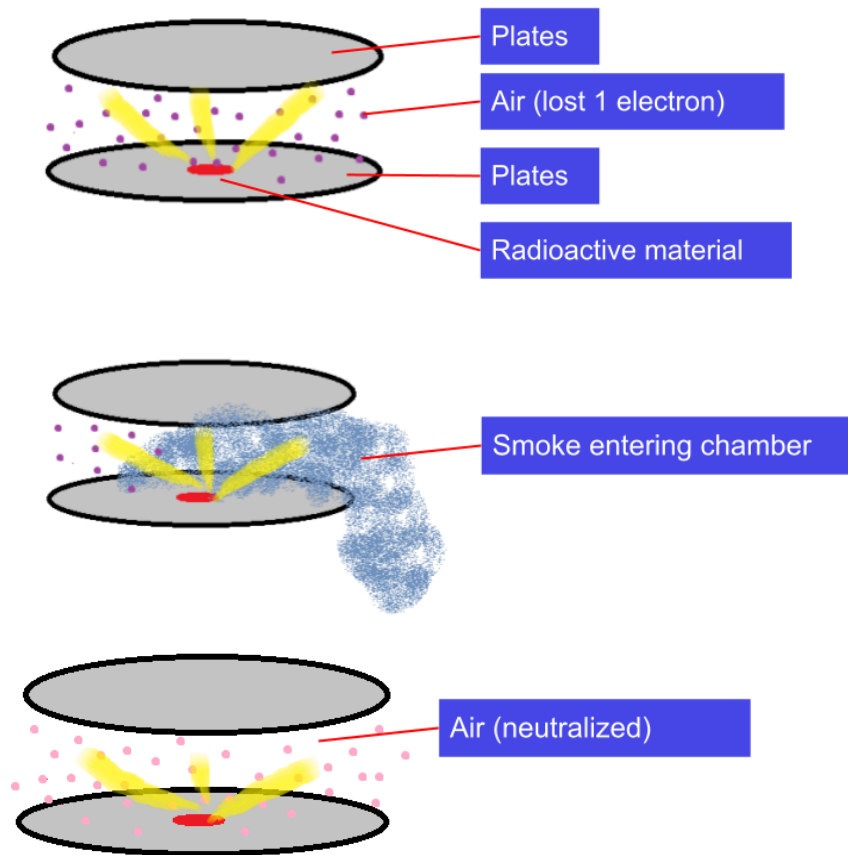
A piezoelectric sander creates the alarm to alert if there is smoke. When given electricity, this device vibrates a disk inside the sander, which creates the noise. This is then amplified by the empty space which serves as a resonance chamber.



Ionization Chamber



Inside the metal casing, there is 2 plates that have electricity flowing through them. Below them, Americanum emits alpha particles, which causes the air between the 2 plates to lose an electron. When smoke enters in between these plates, it neutralizes the particles in the chamber, causing a change in current to the plates. This is detected by the smoke alarm. (second image not ours)



The plates detect the change in current and alert the user of a fire.

9. Findings

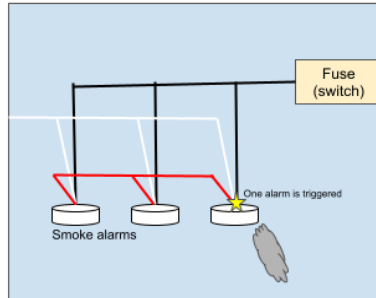
After looking at the parts, we researched home wiring and documented the steps from the smoke to the alarm.

Home Wiring

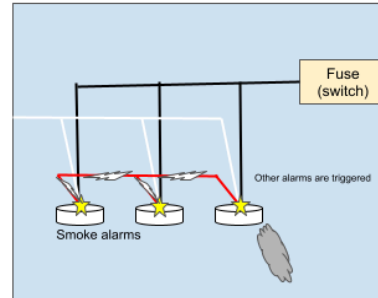
If one smoke alarm is triggered, the other ones in a house will be activated too. This is due to the internal house wiring, which allows the smoke detectors to “communicate.”



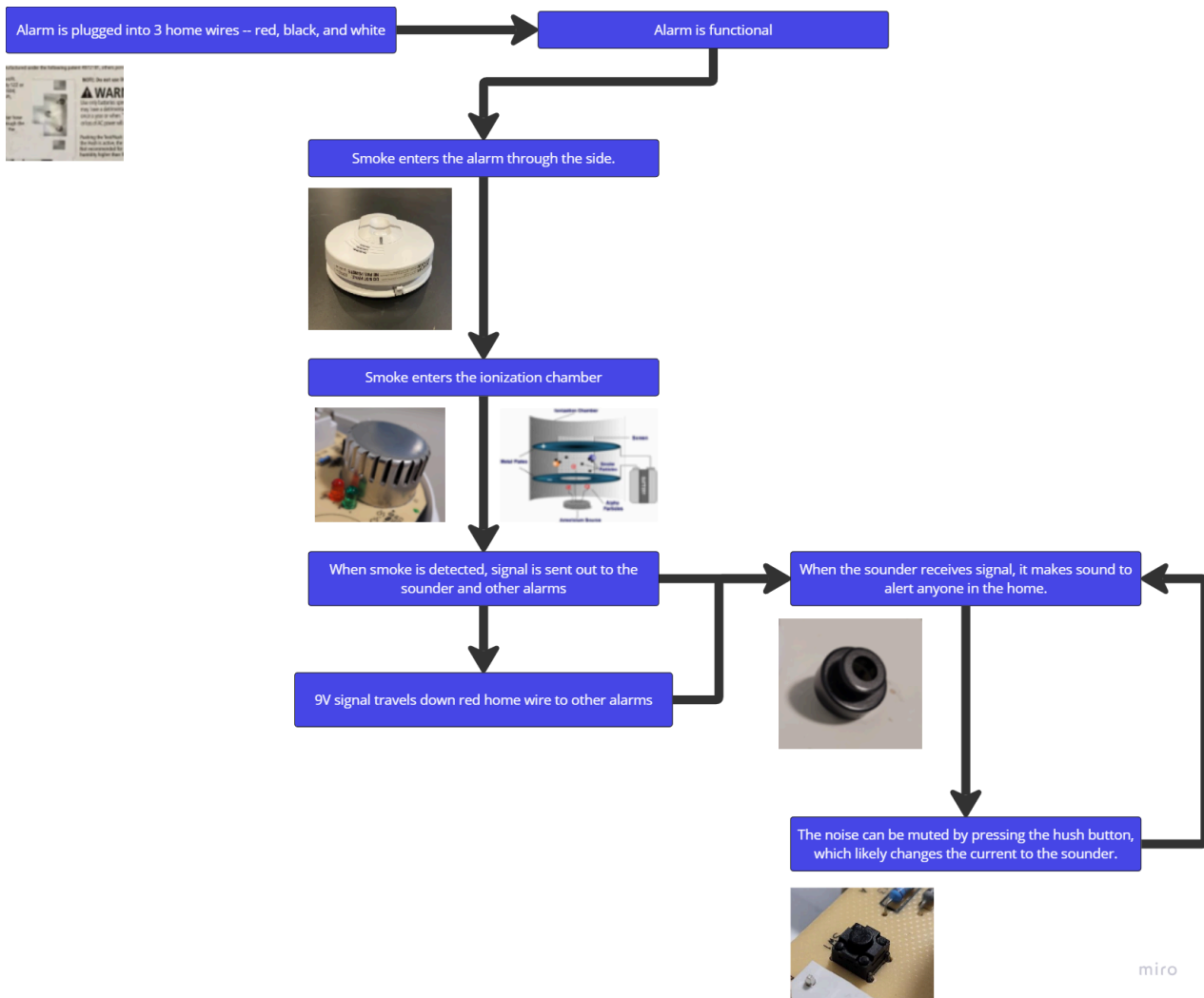
The smoke detector is connected by a 3-way switch to the house, which has a red, white, and black wire.



The black wire supplies 120V to the smoke alarms and is normally connected, while the red wires allow the smoke detectors to communicate. The white wire is neutral.



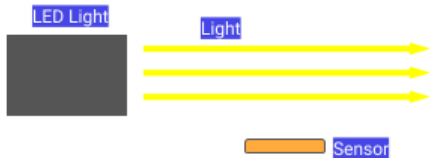
When one alarm detects smoke, it sends a 9V signal down the red wire. When the other smoke alarms connected to this wire sense the message, they also go off.



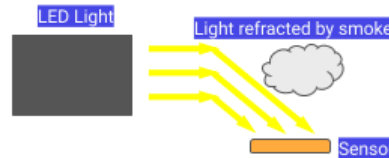
10. Extensions

Other Technology

Although our smoke detector contains an ionization chamber, there are 2 majorly used types -- ionization and photoelectric.



Normal photoelectric chamber

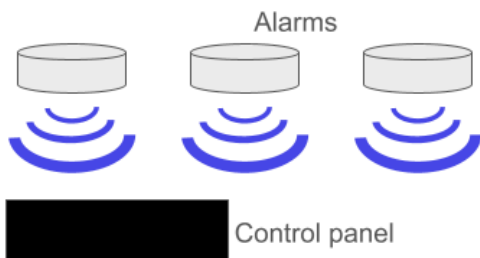


Photoelectric chamber detects smoke when light is refracted into the sensor.

While ionization typically detects sudden fires better, photoelectric sensors are able to pick up on slower, smoldering fires earlier. Photoelectric sensors are extremely helpful in safety, as many of the deaths from fires result from inhaling toxic fumes. In general, photoelectric alarms are shown to be more consistent.

Other Technology - Wiring

Although most smoke alarms rely on wires that connect them to one another, some new technology relies on wifi to communicate with other alarms. This allows logs of where the fire originated, as well as provides more accurate documentation. In places where wiring may be difficult, this technology is very helpful.



Wireless System



Wired System

11. Conclusion

Over the course of this project, we learned many aspects of engineering and about the smoke detector's anatomy, which can also apply to everyday life and VEX. Despite the simple circuitry that is used, smoke detectors play a crucial role in everyday safety.

Lessons Learned:

- Effective research strategies to gather valuable information
- How to safely and effectively take apart an everyday object
- What occurs within the smoke detector
- Analyzing circuit features
- Creating CAD modelling based on measurements taken
- Writing summaries to convey and express information
- Differences between types of smoke detectors
- What goes on behind the scenes of a safe home

12. References

References can be found below:

https://docs.google.com/document/d/1V6mls_8248qInxpMBiPmOISUJtIB3KAocf_GJeygr4Y/edit?usp=sharing