Gas Stove Safety Device

ECE 445 Design Document

Joey Sun, Derek Cernek, Jared Trupp

Group 25

TA: Bonhyun Ku

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1. Introduction

1.1. Objective

Each year, 172,900 homes burn down due to cooking-related fires, the leading cause being unattended stoves. Additionally, many gas leaks in a home are not caused by broken pipes. Rather, it is also because of these unattended stoves boiling over and putting out the flames, causing gas to start leaking from the now-unlit stove. Based on studies performed by the NFPA (National Fire Prevention Association), about 39% of the fires per year are attributable to human negligence (unattended or unintentionally turned on/not turned off) of the stove itself, while 36% of the fires can be attributed to human negligence of materials around the stove, and only a very small percentage are various forms of failures. However, human negligence of the stove itself is by far the most costly, totalling $620 million dollars in property damage (52% of the total property damage caused in a year), as well as the deadliest, totalling in at 340 deaths (61% of the total deaths) that home cooking fires cause [1].

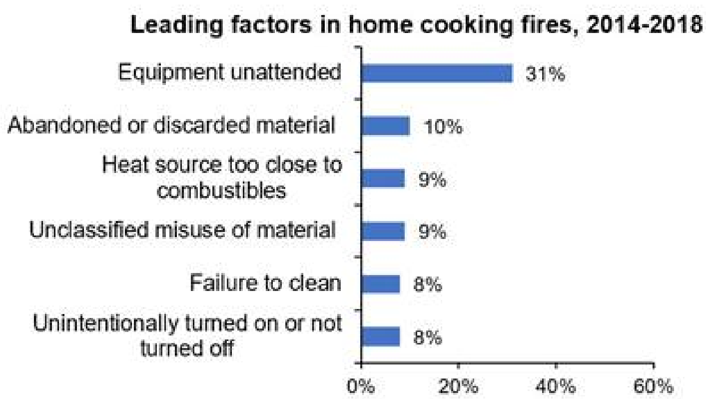

Figure 1: Chart of leading factors of home cooking fires. Two factors exist that can be solved through a clever device: Unattended equipment and unintentionally turned on.

Clearly, we cannot depart from gas stoves any time soon. Our goal is to make stoves safer to use by the creation of a safety device. This safety device must alert the user in the event of a fire risk rather than an actual fire, because then it is too late. In order to determine when a risky scenario is occurring, the device must alert the user periodically that the stove is on, alert the user when the user walks away too far, and alert the user when the stove's flame is put out but the stove is still running.

1.2. Background

While there exist many safety measures for electrical appliances, very few devices exist for gas stoves [2], [3], [4]. Only two electric safety devices concerned with gas stove saftey were found in the popular market. The ones that do exist also require professional installation as they attempt to shut off the flow of gas, and as a result they are often costly to install. Additionally, it is very unlikely that people will give up on using gas stoves, whether it is due to the instantaneous and controllable nature of the heat, or the commonly stated anecdote of “food cooked on gas stoves just tastes better.”

With this information, we have concluded that our device must be easy to install and maintain. Many stove customers will likely have the funds necessary to purchase a $200 appliance that keeps their homes safe, but they may not have the physique, skill, or patience necessary to install something directly into their gas lines. They also may prefer immediate installation of a system that is immediately usable rather than waiting for a complex system to be installed.

1.3. Visual Aid

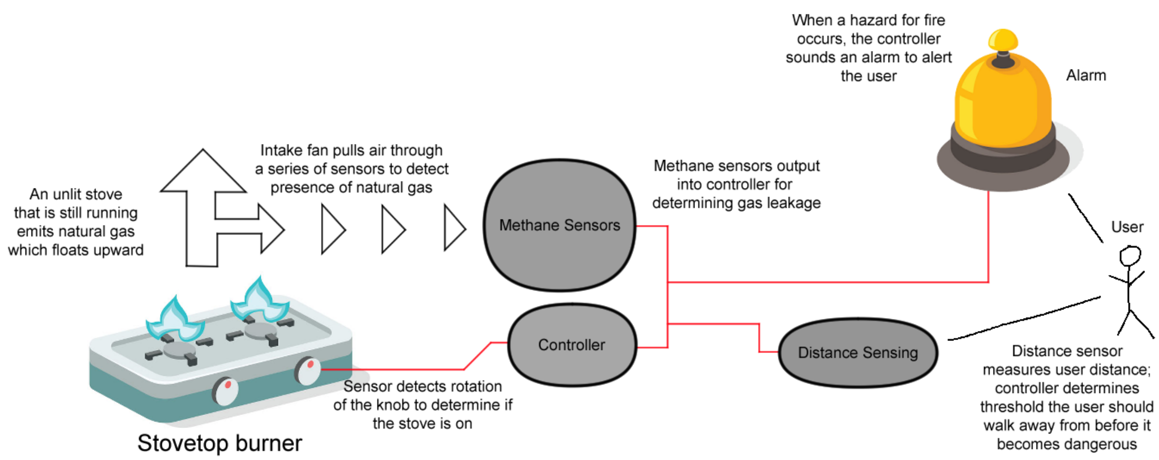

Figure 2: Visual aid for understanding the solution. As seen, the device we aim to build can solve three common fire hazards in cooking: Gas leakage, unattended device, and accidentally turning the stove on, or forgetting to turn the stove off. Vector art provided by VectorPortal.com licensed under the Creative Commons (CC BY 4.0) license.

1.4. High-Level Requirements

- The device must be able to detect when the stove is on, issuing a short alert that it is on to the user.
- The device must be able to detect the distance between the stove and the user, issuing an alert when the user walks 5 to 15 meters away.
- The device must be able to detect the presence of a gas leak from the burners. If there is no flame, but the stove is on due to the detection of gas, the device must issue a critical alert of the potentially high risk of a gas leak or a gas explosion, especially if other stoves are on.

2. Design

2.1. Block Diagram

Our device needs two separate units, divided into the sensor box and a personal alarm, as seen in Figure 3. The sensor box serves as the hub, and the alarm unit, carried by the user, serves as the method the main sensor box uses to determine how far the user is from the stove via Bluetooth.

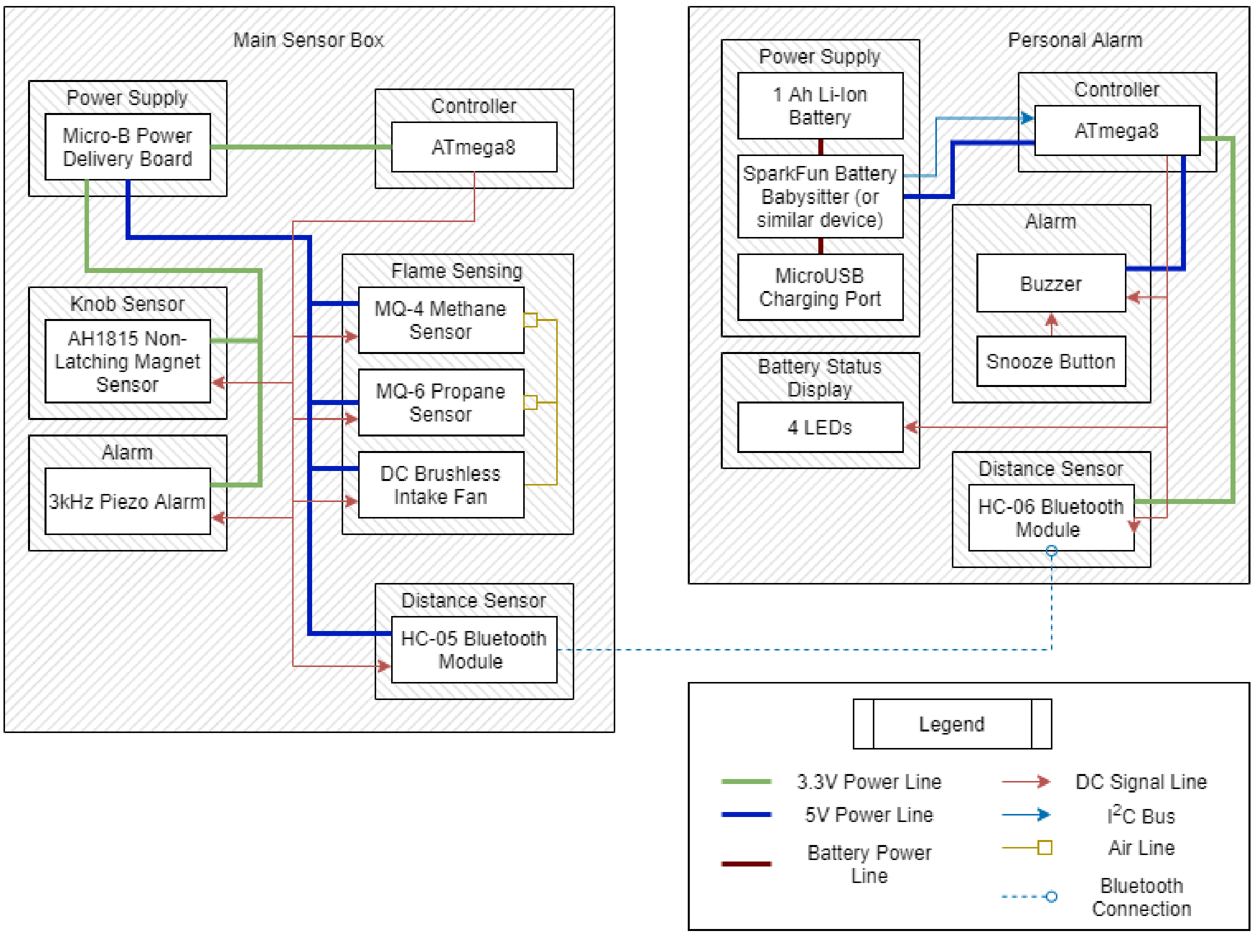

Figure 3: Block diagram of the system in its entirety.

The sensor box consists of six modules: a power supply, an alarm unit, a controller, a knob sensor, a gas sensor, and a distance sensor. The power supply plugs into the standard 120V AC wall outlet and delivers 5V power to the controller, which serves a double purpose as a power distributor. The knob sensor detects whether or not the user has turned on the stove through sensing rotation. The gas sensor detects propane and methane, two common gases used for fuel in stoves. The distance sensor utilizes a Bluetooth signal, which supports RSSI (Received Signal Strength Intensity) and can send a notification if the connection is lost. We use both of these properties to detect approximately how far the user is from the sensor box.

The controller then takes all the data from the sensors. Using all the given data, the controller decides whether or not to sound the alarm module.

The small alarm unit has five modules, all of which emphasize compactness and portability. The power supply must supply a constant 3.3V to the entire small alarm unit for many hours on end between recharges. The power supply also must output the amount of charge left in the battery. The distance sensor once again functions similarly to the one found in the main sensor box, utilizing RSSI and the connection state (connected/not connected) to determine how far the user is from the main control box. The controller takes input both from the distance sensor and the power supply's charge sensor. It then outputs the distance sensor's processed information to the alarm, notifying the user when they have walked too far away from the stove. It also outputs information about how much charge remains to four LEDs, which light up with the corresponding charge level remaining on a button press.

2.2. Physical Design

2.2.1. Sensor Box

The physical design of the sensor box, as seen in Figure 4, consists of a 3D-printed plastic casing. The lower component serves as a tray that holds the microcontroller, antenna, gas sensors, and alarm. An intake loop comprises most of the upper exterior, used to feed air through the gas sensors, with the remaining upper keeping air and dirt out. A sealant is applied to keep air out, and a fine mesh will be placed between the upper and lower component. The sensor box has a footprint smaller than an A5 sheet of paper and stands a little over four inches tall, as seen in Figure 5.

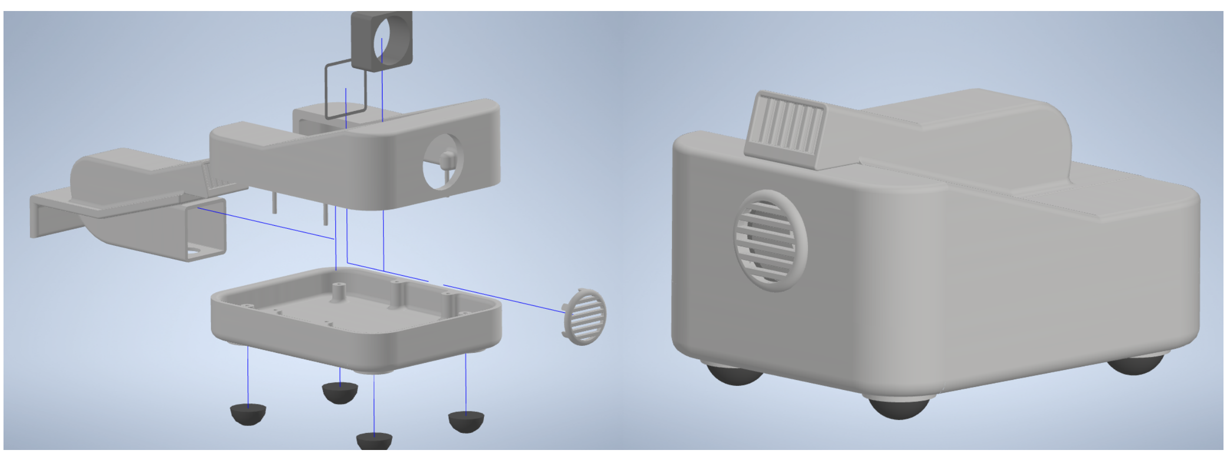

Figure 4: Sensor Box (Exploded View and Put Together View)

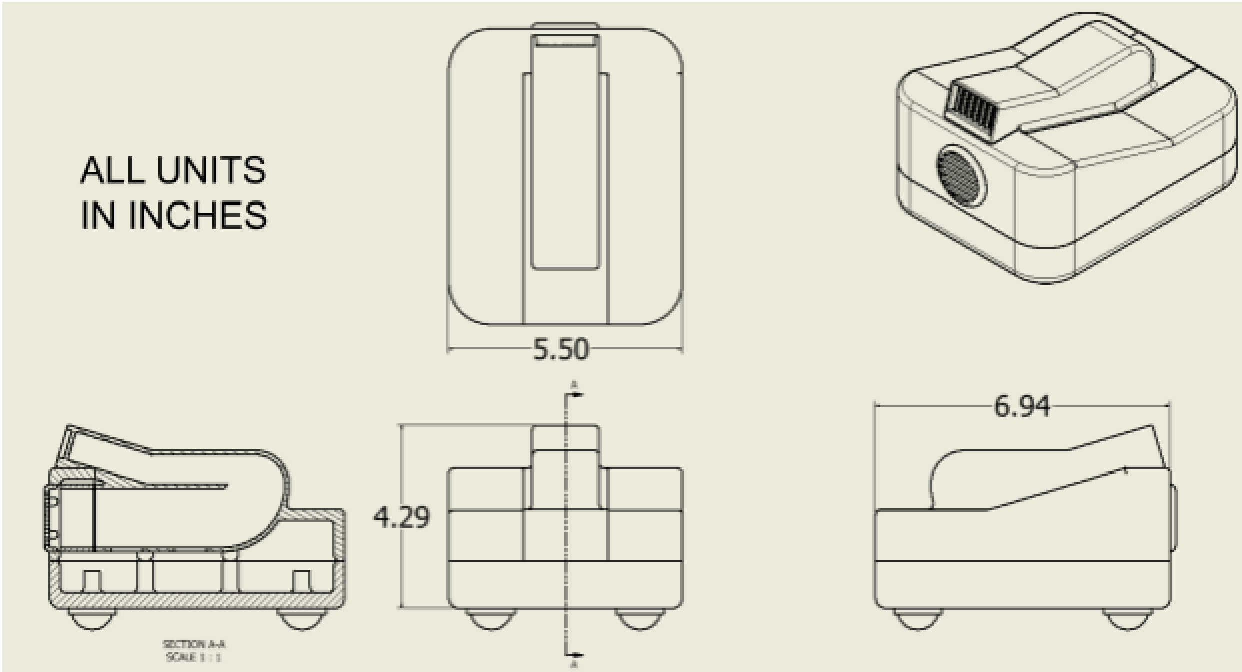

Figure 5: Sensor Box Dimensions. All images to scale.

2.2.2. Personal Alarm

The physical design of the personal alarm, as seen in Figure 6, also consists of a 3D-printed casing. The lower case holds the LiPo battery and the LiPo battery management PCB (white rectangle and red square), with holes in the back to vent excess heat produced by the LiPo battery. The divider doubles as a tray for the logic and sensor PCB, holding two buttons, a microcontroller, a Bluetooth antenna, and a buzzer. The upper case uses button actuators to press the buttons on the logic PCB due to its distance from the two buttons. The upper case also has four LEDs embedded, used for displaying how much power is remaining in the LiPo battery. These LEDs are not color-specific.

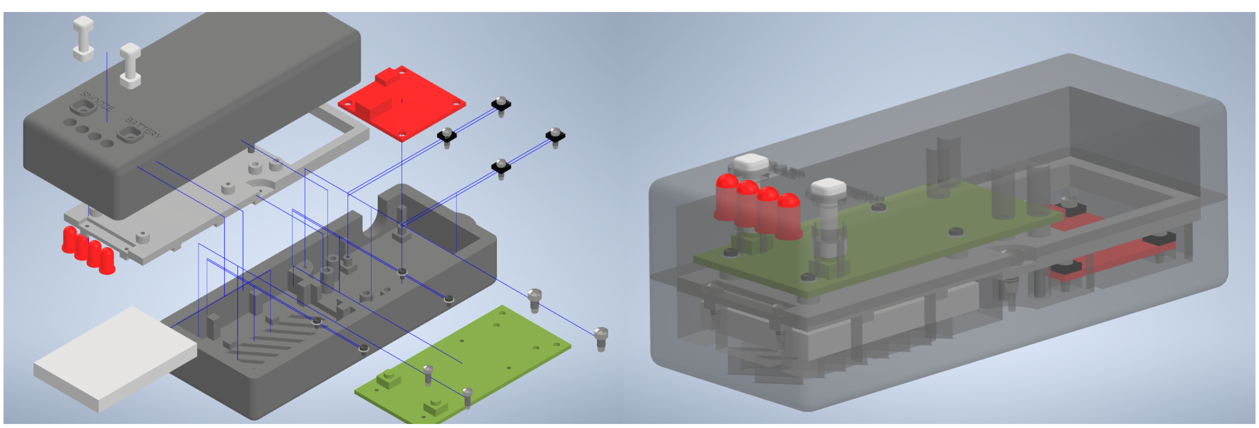

Figure 6: Personal Alarm (Exploded View and Put Together View). The exterior of the Put Together View has been made more transparent to show the interior.

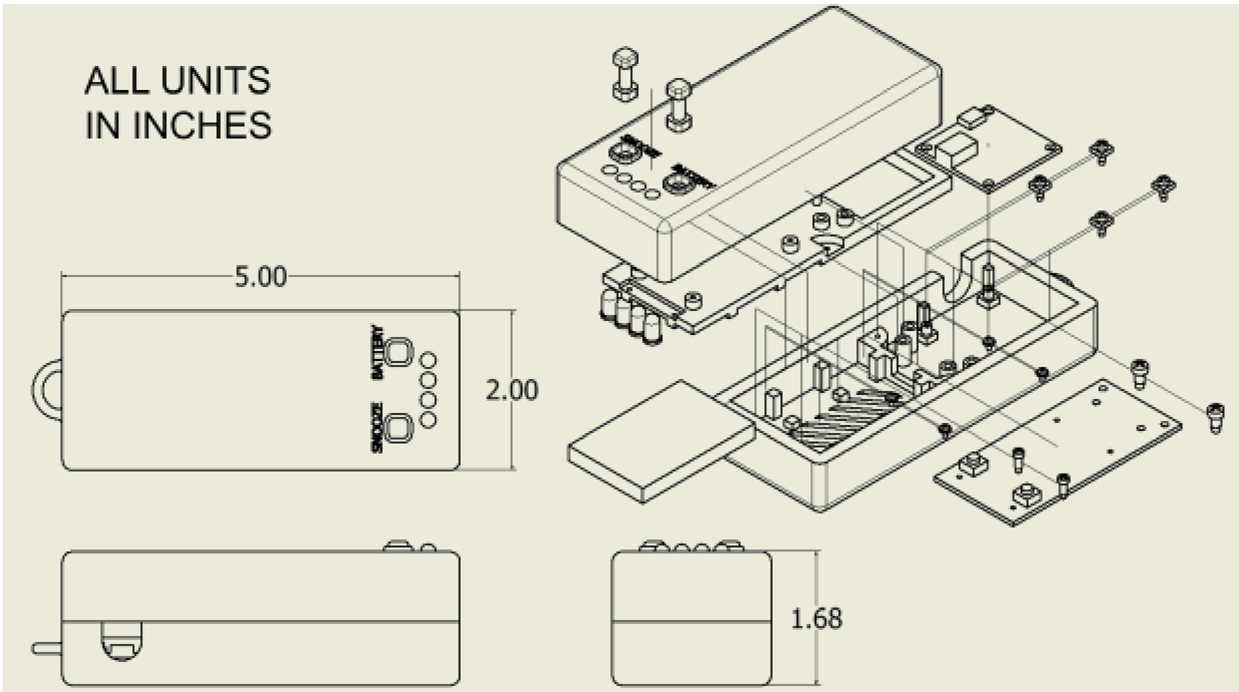

Figure 7: Dimensions of the Personal Alarm. All images to scale.

2.3 Sensor Box

The sensor box (Figure 3) is a standalone unit and provides its primary purpose as a sensor package. It holds the capability to detect propane and methane gas, sense the rotation of the stove's knob, and provides the distance sensor's reference anchor. It will not hold any capability to charge the personal alarm.

2.3.1 Power Supply

The power supply (Figure 8) provides the circuit with 3.3V and 5V at all times. It intakes a regulated 5V current from a Micro-B port, supplied by a wall power converter, ensuring that the sensor box can reliably stay on at all times. Our 3.3V line requires 47mA, broken down between the knob sensor (12mA), siren (5mA), and the distance sensor (30mA), which we achieve through a 5V/3.3V DC-DC converter. The 3.3V line also powers the Controller PCB, with an expected current draw below 100mA. Our 5V line powers the gas sensors (150mA per sensor), and the intake fan (140~330mA, variable), all in total requiring upwards of 630mA.

Since we can perform power-saving using MOSFET transistors and logic gates, we can say that we will need upwards of 800mA, safely within the bounds of a Micro-B port.

Requirement	Verification For Both
1. 3.3V bus outputs 147-160mA between 3V-3.7V below 85°C 2. 5V bus outputs 630-700mA between 4.5-5.5V below 85°C	1. Plug the power circuit into a Micro-B port. 2. Measure all open-circuit voltages with a voltmeter, ensuring the 3.3V bus is 3.7V or below and the 5V bus is 5.5V or below. 3. Terminate the buses with a resistive load such that the 3.3V bus is reading out its maximum rated 160mA and the 5V bus is reading 700mA. 4. Ensure that the voltages of the buses are above 3V and 4.5 respectively. We do not care about their minimum beyond the rated current draws. 5. Leave the device on for 30 minutes. Measure the temperature of the components using a thermometer, ensuring they do not exceed 85°C.

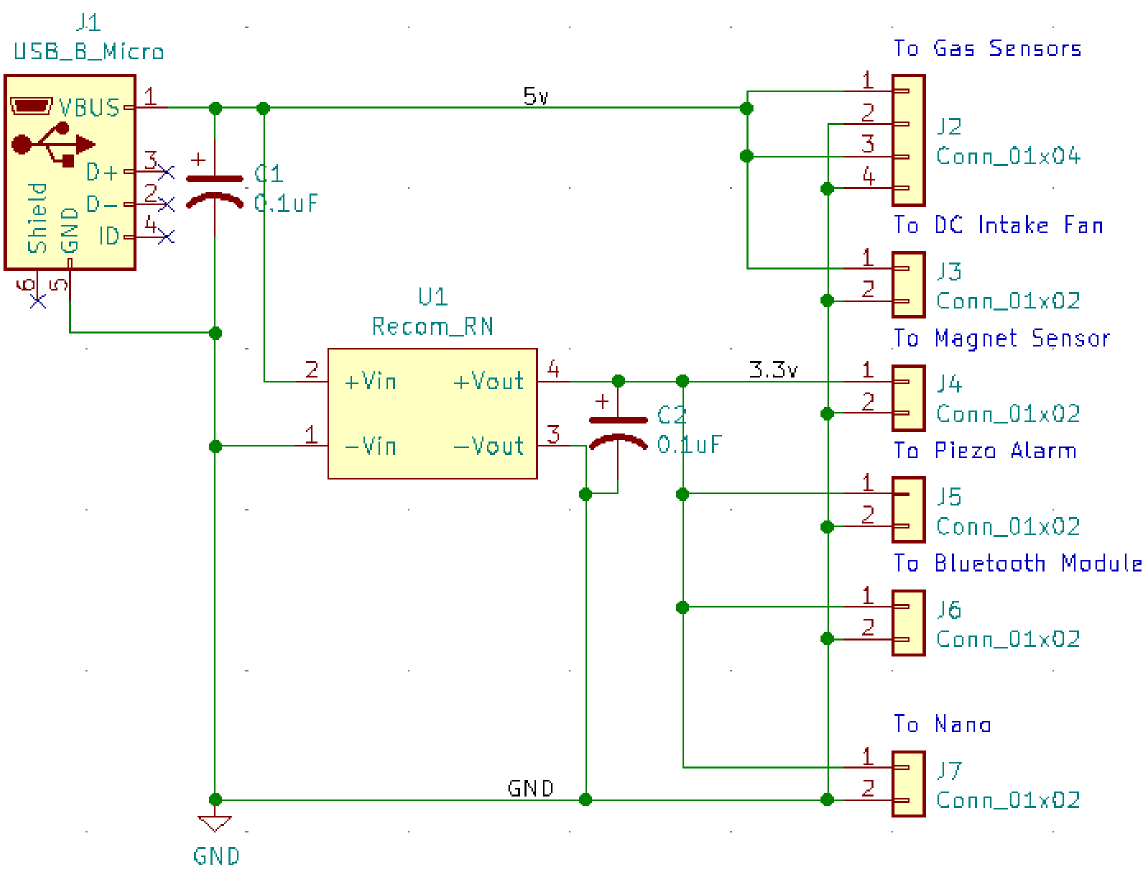

Figure 8: Power Supply and Conversion PCB schematic.

2.3.2 Controller

The controller, an ATmega328, handles logic and signals from all the sensors. It takes in analog and digital data, processes the data, and uses the information received to determine whether to trigger the alarm. Two conditions merit an alert:

1. The user is reminded once per minute if the knob is on.
2. The user must be alerted immediately if the fire goes out while the knob is on.

The ATmega328 is perfect for its compact size and its affordability. The ATmega328 can be programmed through an Arduino board interface as a burner, which are readily available from the ECE supply store.

Requirements	Verification
1. Can read input signals from the various sensors 2. Can drive a MOSFET controlling the siren from the 3.3V bus at 5mA 3. Can drive a MOSFET controlling the intake fan from the 5V at 330mA	1. Read Input Signal: a. Create two circuits where a 5V line and a 3.3V line connect into an input pin on the ATmega328 through a push button. By the entry of an input signal, the ATmega328 will drive an LED to turn on. b. Write a script that constantly displays whether the respective pins are receiving HI or LO input. Run the script. c. Press the push buttons and see if the appropriate LED turns on. 2. Driving MOSFETs: a. Write a script that switches an output pin between HI and LO. b. Create two circuits where a 5V line and a 3.3V line connect through two MOSFET transistors. Place an adequate resistor for the 3.3V line to achieve 5-10mA drain current, and for the 5V line to achieve 330-350mA drain current. c. Connect the output pins to the gates of both MOSFETs. Run the script and use an ammeter to measure the current across the drain to ground. If the current is within bounds, verification is satisfactory.

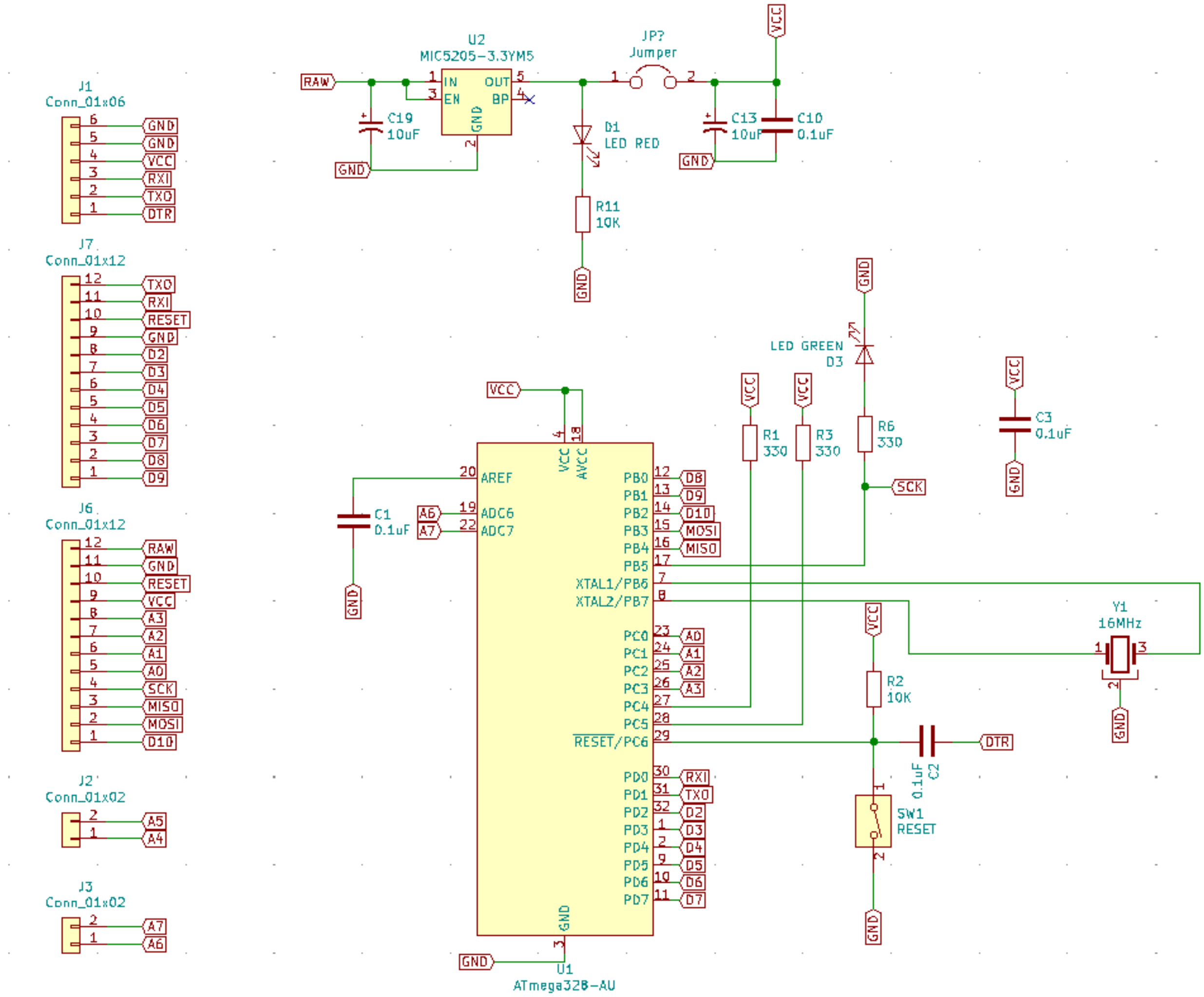

Figure 9: ATmega328 ControllerPCB Schematic

2.3.3 Flame Sensing

We know methane or propane will power most consumer stoves across the world. Occasionally, such as in the United Kingdom, butane is the fuel. Instead of detecting the presence of a flame, we instead detect the presence of hazardous gases. In this way, we perform a more direct function of why we are looking for a fire in the first place, which is to detect possible hazardous gas leakage.

To detect these fuels, we use the MQ-4 Methane Sensor and the MQ-6 Flammable Gas Sensors. We find the immediate danger to life or health concentration (IDLH) or 10% of the lower explosive limit (LEL) of methane, propane, and butane to be 5,000 ppm, 2,100 ppm, and 1,600 ppm, which we must calibrate our sensors to detect [7].

Requirements	Verification For All Sensors
1. MQ-4 can detect 5,000 ppm methane. 2. MQ-6 can detect 2,100 ppm propane. 3. MQ-6 can detect 1,600 ppm butane.	1. Create a circuit and script using the microcontroller where if the respective sensor has detected the adequate threshold, the microcontroller will signal an LED to flash. 2. Place the circuit into a chemistry glove box, or failing that, an airtight vacuum box, and allow the sensor adequate warmup time. 3. Fill the box with pure nitrogen at first; then add in the respective testing gas until the proper ppm has been reached. Look for LED flashing.

2.3.4 Knob Sensing

We decided to use a non-latching Hall Effect Sensor (AH1815) and a sticky neodymium magnet to detect whether the knob is on. The AH1815 outputs HI when it senses a perpendicular magnetic field and outputs LO when the magnetic field angles past a certain threshold. Due to the low sensitivity of the AH1815, we can trust that it will not pick up a stray magnetic field from any source. We then place the magnet on the knob, lined up with the sensor in the OFF position. When the user turns on the stove, the sensor no longer reads the perpendicular magnetic field, deducing that the user has turned on the stove.
Physically, the AH1815 will be on the end of a long, stain-proof tether that sheaths its wires.

Requirements	Verification
1. The sensor must be able to output HI when the knob is in the OFF position, and output LO when the knob is turned 30 degrees away from the OFF position with minimal noise from the magnet.	1. Stick a small magnet onto a cylindrical object, roughly the same size as a stove knob. A small cylinder made of wood can be used due to lab restrictions. 2. Set up a circuit that powers the AH1815 with 3.3V. Feed the output pin into an LED and place the AH1815 a testing distance from the magnet. The LED should be on. 3. Slowly rotate the wooden cylinder. Mark where the LED turns off. 4. Use a protractor to measure whether or not the knob has turned 30 degrees or less.

2.3.5 Alarm

The alarm is a 3kHz piezo alarm that adjusts its volume depending on the voltage put into it. As the 3.3V rail is the most easily accessible and closest to its minimum threshold of 3V, we power the device using 3.3VDC, which should be around 80dB of sound.

Requirements	Verification
1. The alarm must be able to output at least 60dB of sound when standing 40 feet away. 2. The alarm must not exceed 90dB of sound when standing 1 foot away..	1. Build a circuit using the alarm with an adjustable voltage. This can be done using an ADALM1000. 2. Turn the circuit on and measure the amount of decibels the alarm produces at 3.3V. Damp the alarm with cotton and foam until the sound reaches 60dB of sound at a distance of 40 feet. To achieve this measurement, use a mobile app. The person damping must wear ear protection. 3. Move the measuring device next to the alarm. Measure the decibels and ensure the amount is below 90dB of sound.

2.3.6 Distance Sensing

To detect a distance threshold, we instead rely on the rated range of the HC-05 Bluetooth chip. The HC-05 on the sensor box serves as a reference point for the personal alarm's Bluetooth module to connect to and performs no other functions.

Requirements	Verification
1. The HC-05 Bluetooth module must automatically disconnect after at most 15 meters of distance in an open room.	1. Build a circuit using the HC-05 and power it on. 2. Using a mobile phone, connect to the HC-05 and slowly walk away until the Bluetooth connection drops. 3. Measure the distance and check to see if it is equal to or less than 15 meters.

2.4 Personal Alarm

The personal alarm (Figure 3) is the other standalone unit. Its primary function is as a portable extension of the distance sensor on the main sensor box. The personal alarm comes with a few secondary features made to support the primary function. One of the main issues with this submodule is the need to save as much power as possible. As such, low power dissipation is a priority in the choice of components.

2.4.1 Power Supply

Due to the portability requirement, the personal alarm is to be powered using a rechargeable Li-Ion battery. To safely manage the Li-Ion battery, we chose to take no risks and use the Sparkfun Battery Babysitter board, which allows us to monitor the remaining charge and temperature. The battery doctor also supports bi-directional charging and discharging of the Li-Ion battery, allowing functionality even when connected to power.

We have a single 3.3V rail from which everything functions, supported by the Battery Babysitter.

From some back-of-the-envelope calculations, the Battery Babysitter will consume under 3mA of current. With the same math, the microcontroller will draw a maximum of 200mA, although this requires every output pin to be active. As such, we can rely more on the experimentally proven amount of 5mA draw. The alarm will draw a maximum of 20mA, but not consistently. The distance sensor will draw a maximum of 30mA, even accounting for a necessary 3.3V/5V DC-DC converter. All other components have a negligible current draw. Therefore, the entire system will take a maximum of around 60mA, which a 1Ah Li-Ion battery should handle easily for 16 hours. As a safety margin, we say the system actually consumes 80mA due to various fluctuations and unknowns, which means our 1Ah battery can power the entire system for 12.5 hours.

Requirements	Verification
1. The power supply can output a consistent 3.0-3.7V at 80mA while on battery power.	1. Set up a circuit where the voltage and current of the LiPo battery can be measured across the 3.3V terminal. 2. Charge LiPo battery and plug into the Battery Babysitter. Ensure voltage is within bounds. 3. Place a resistor across 3.3V terminal to ground that gets the current as close as possible to 80mA. Measure voltage and ensure it is within bounds.

2.4.2 Controller

The controller is an ATmega328. It only takes digital data from the STATE pin of the distance sensor and the SNOOZE button from the alarm module. The controller has one function involving the distance sensor, listed below:

1. When the STATE pin of the HC-05 becomes LO (disconnected), a countdown timer begins for 1 minute.

2. If the timer runs out, the controller sends a signal for the buzzer to sound until the user presses the SNOOZE button.
3. The SNOOZE button cycles power to the HC-05, allowing it to begin searching for its paired Bluetooth chip again. In the meantime, the countdown timer resets to 1 minute.
4. Repeat steps 2-3 until the HC-05 reconnects (STATE pin becomes HI).

Because the Battery Babysitter outputs the battery charge value on an I^2C bus, which the ATmega328 supports, we also need to make the controller process that I^2C signal. After processing, the controller outputs four signals to the battery display module, showing how much power remains.

Requirement	Verification
1. The controller must be able to start a 1-minute countdown timer when it receives a LO signal, reset the timer when it receives a button signal pulse, and stop the countdown when the LO signal becomes a HI signal. 2. The controller must be able to process an I^2C signal that comes in the form of a percentage, convert it into a 25/50/75/100% format, and output it across four signals.	1. Timer a. Connect the output pin for the timer's alarm to an LED. Power on the controller. b. Feed HI into the STATE pin input signal and the SNOOZE signal to simulate a pull-up signal. The LED should not be on. c. Turn the STATE signal to LO and time 1 minute. The LED should light up. d. Flick the SNOOZE signal quickly once between LO and HI. The LED should go out, lighting up after 1 minute. e. Flick the SNOOZE signal again and turn the STATE signal to HI. The LED should not light up after 1 minute. 2. Battery Display a. Connect the Battery Babysitter to the controller with the proper I^2C setup. Connect the battery in. b. Observe the signals on HI and the amount on LO. c. Wire up the 3.3V output to a resistive load that allows for 50mA theoretical current and discharge the battery slowly, turning the resistive load off every 30 minutes for 5 minutes to let the battery cool. Keep an eye on the output signals. After a few hours, a few

	signals should toggle. d. Plug a charging cord into the Battery Babysitter and watch the output signals. After a few minutes, a few signals should toggle.

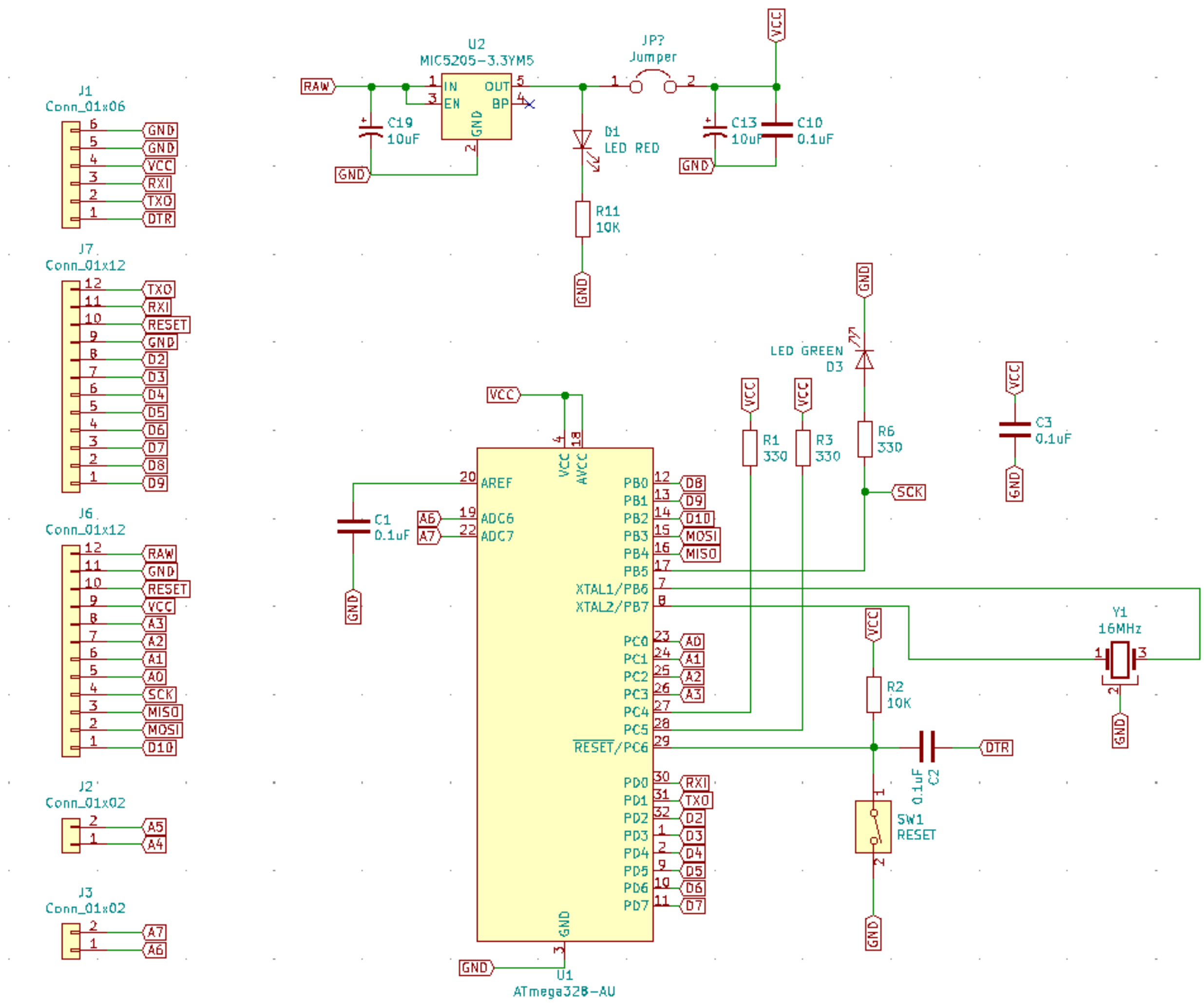

Figure 10: ATmega328 ControllerPCB Schematic

2.4.3 Alarm

The alarm consists partially of a COM-16092 buzzer, capable of producing a minimum of 58dB and a maximum of 77dB of sound. The buzzer takes in a square wave with a duty cycle of ½ at 3.3V. From the datasheet, we find that in order to produce 58dB of sound, a 100Hz square wave is required. With the buzzer, we need a button that sends a signal to the controller. This button's purpose is to activate the SNOOZE function, resetting the one-minute timer.

Requirement	Verification
1. The alarm must be at least 50dB in volume when placed in an insulated jacket pocket worn on the person. 2. The alarm must be at most 75dB in volume when worn around the neck. 3. The button must output a signal when pressed. This triggers the SNOOZE function in the controller, which is tested separately.	1. Alarm Volume a. Connect the buzzer to a breadboard and ready a waveform generator. b. Place the buzzer in an insulated parka pocket. If none is available, wrapping it in a jacket to a loosely-packed thickness of about 1 inch is enough. c. Stand 3 feet away with a sound decibel measurement device and connect the buzzer to the waveform generator. Sweep frequencies from 100Hz-10kHz until we measure 50dB of sound. d. Take the buzzer out of the pocket or jacket and move the device 1 foot away from the buzzer. Ensure the sound is below 75dB. 2. Button Signal a. Wire up a button in a pull-up or pull-down configuration with an LED as the signal recipient. Press the button to ensure functionality.

2.4.4 Battery Status Display

The battery status display consists of four LEDs and a push-button that turns on the LEDs. Each LED connects to a MOSFET which receives a signal from the microcontroller, corresponding to battery status. If the battery is above 75% charge, all lights will be on. For every 25% of the full capacity the battery drops by, one LED will no longer light, down to a minimum of one LED. The MOSFET is switched into its active state through the push button in the pull-up configuration. By pressing the button, 3.3V is input into each MOSFET, driving them into saturation and lighting the LEDs.

Requirement	Verification
1. The push-button must turn on the LEDs.	1. Set up a circuit where 4 LEDs are in parallel, driven by 4 P-MOSFETs. The

	gates of all MOSFETs are driven by a push button in a pull-up configuration. 2. Press the push button and ensure all LEDs turn on.

2.4.5 Distance Sensing

The distance sensor is an HC-06 Bluetooth Module, although it can interchangeably be an HC-05 Bluetooth Module set in Receive Connections Only mode. The Bluetooth Module is connected to a MOSFET capacitor, used for performing hard resets on the Bluetooth Module. From above, the Bluetooth Module has a rated range of ten meters, although this range is not definite.

As we could not find evidence that the HC-05 and HC-06 automatically reconnect when in range while still being on, we may not need the MOSFET. In the case that they do not, we know the HC-05 and HC-06 automatically reconnect if their power is cycled. We also know that they include a STATE pin, which outputs a LO signal when the connection is cut, and a HI signal when the connection is established.

We take advantage of the rated range and the STATE pin to make this distance sensor function through this algorithm that will be coded into the microcontroller:

1. The microcontroller reads the STATE pin. If the STATE signal is LO, continue to step 2.
2. Begin the internal countdown timer for 1 minute.
3. When the minute is up, the alarm will sound. At this time, we assume the user pushes the SNOOZE button. This sends a signal to the microcontroller, which outputs a signal that deactivates the MOSFET, turning the power off. Note that this means we will have to implement a pull-up or pull-down resistor on the STATE pin.
4. When the SNOOZE button is released, the MOSFET powers back on. This allows the Bluetooth Module to begin scanning for a connection again. Go back to step 2, unless the Bluetooth Module reconnects to the sensor box. Then go back to step 1.

Requirements	Verification
1. The distance sensor must be able to reconnect to the distance sensor on the sensor box.	1. Create two separate circuits with two Bluetooth chips. One of them is rigged up to a MOSFET that cycles the power. Let both connect. 2. Walk out of the room with one, twenty meters away. Check connection status to see if they are disconnected. 3. Walk back into the room to see if they automatically reconnect. 4. If this fails, cycle the power to the one with the MOSFET. Check to see if they automatically reconnect.

2.5 Casings

The cases, shown in Figures 4 through 7, protect the internal electronics from dust and contaminants. The greatest danger with the sensor box is exposed electronics catching fire from gas leakage. A fine metal mesh will be placed over the electronics to stop a spark causing a gas explosion, with the methane sensors poking through to detect the volatile gases. Both sensors will have their electrical terminals sealed using an airtight sealant. The mesh is the theory behind Davy lamps, which were historically used in coal mines to prevent a lantern flame from igniting coal dust and methane. Due to the nature of the device itself, we must make sure the device passes IP54 environmental standards due to random splashes.

The greatest danger with the personal alarm is dirt, dust, and oil, as we assume the user will secure the device in their pocket, on a lanyard, or clipped on their belt to prevent accidental dropping into water. As a result, we must make sure the device passes IP51 environmental standards.

Requirements	Verification
1. Sensor box passes IP54 Protection 2. Sensor box does not spark fires 3. Personal alarm passes IP51 Protection	1. Sensor Box IP54 a. Enclose box and seal with hot glue, a stand-in for a better sealant during production. Ensure the holes built for the methane/propane sensors have them put and sealed in as well. Place a brick inside to weigh it down. b. Using a hose, spray water at the device for 10 minutes from all angles from a distance of 1 meter away. c. Dry device exterior and remove sealants. Examine interior for water by tactile examination. If water leaked in but only trickled to the bottom, this is not a concern as the PCB will be elevated. 2. Sensor Box Fire Sparking a. Place a lit candle in the lower compartment of the sensor box. Cover the lower compartment with a fine mesh and secure it. b. Place the lower compartment into an airtight chamber and seal the chamber. Through a hole in the side, puff some

	methane into the chamber and observe the flame. 3. Personal Alarm IP51 a. Enclose box and seal with hot glue, a stand-in for a better sealant during production. b. Place the box upright under a dripping source of water (a faucet will do if the surface is flat) for ten minutes. c. Remove the box and look for signs of water entering using tactile examination.

2.6 Tolerance Analysis

The most important tolerance we must maintain is the gas sensor. While tuning the sensor, it is easy to note that while we can very easily test a steady-state gas inside a box, the real-world environment will be a flowing, mobile gas that floats upwards. There may even be a fume hood sucking away measurement gas, which further complicates our tolerances. As we have no experience nor knowledge of how to perform calculation with fluid dynamics, we cannot by ourselves identify an adequate threshold for the gas volume.

However, the Occupational Safety and Health Administration (OSHA) also had to deal with this problem when writing Standard 1915 Subpart B App A [8]. In it, OSHA details these exact specifications, under Section 1915.12(b)(3):

> Atmospheres with a concentration of flammable vapors at or above 10 percent of the lower explosive limit (LEL) are considered hazardous when located in confined spaces. However, atmospheres with flammable vapors below 10 percent of the LEL are not necessarily safe.
>
> Such atmospheres are too lean to burn. Nevertheless, when a space contains or produces measurable flammable vapors below the 10 percent LEL, it might indicate that flammable vapors are being released or introduced into the space and could present a hazard in time. Therefore, the cause of the vapors should be investigated and, if possible, eliminated prior to entry.
>
> Some situations that have produced measurable concentrations of flammable vapors that could exceed 10 percent of the LEL in time are:

1. Pipelines that should have been blanked or disconnected have opened, allowing product into the space.

2. The vessel may have shifted, allowing product not previously cleaned and removed during washing to move into other areas of the vessel.

3. Residues may be producing the atmosphere by releasing flammable vapor.

As OSHA has more resources than we do, we trust OSHA has performed many calculations and proved that 10% of the LEL is the optimal threshold.

Therefore, we are using the same reasoning detailed here by OSHA, in that our tolerances for the gas sensors are set to 10% of the LEL for all of the gases. Specifically, we find that the LEL for n-Butane, Iso-Butane, Methane, and Propane to be 1.8%, 1.8%, 5%, and 2.2% respectively [9].

We then use equation 1 to calculate parts per million of the corresponding gas levels we need to detect.

$$\frac{LEL}{100} \cdot \frac{1}{10} \cdot 10^6 = PPM$$

Equation 1: Converting the LEL to necessary PPM to detect according to OSHA standards.

This gives us our totals of needing to have our sensor sensitive enough to detect at most 1,800 ppm butane, 5,000 ppm methane, and 2,200 ppm propane.

3 Cost and Schedule

3.1 Cost Analysis

Our fixed development costs are estimated to be at $30/hour, 10 hours/week for three people. 100% of our design will be completed by the end of this semester, consisting of work during the next 9 week period.

$$3 \ * \ \frac{\$30}{hour} * \frac{10\ hours}{week} * 9\ weeks \ * \ 2.5 \ = \ \$20,250$$

Equation 2: Development costs for all members of the project.

The parts costs below contain the rest of the expected costs for this project.

Part	Cost (Prototype)
AC/DC Wall Adapter, 30W (B01N2K48HR, Amazon)	$14.99
Methane CNG Gas Sensor (SEN-09404, Sparkfun)	$4.95
LPG Gas Sensor (SEN-09405, Sparkfun)	$4.95
Wireless Bluetooth Transceiver * 2 (B07VL725T8, Amazon)	$12.59
Non-Latching Hall Effect Sensor (SEN-14709, Sparkfun)	$0.95
Piezo Alarm (COM-13940, Sparkfun)	$2.95
DC Brushless Fan (COM-15504, Sparkfun)	$9.95
ATmega328 * 2	$3.84
PCBs (PCBcart)	$4.46
1AH Li-ion Battery (PRT-13813, Sparkfun)	$9.95
LiPo Battery Manager (PRT-13777, Sparkfun)	$19.95
Green Diffused Ice 5mm LED * 4 (XSDG43MB, Digikey)	$2.64
Magnetic Buzzer Transducer (COM-16092, Sparkfun)	$2.95

3-D Printed Casing (est.)	$70.00
Assorted resistors, capacitors, ICs, crystals, mosfets, etc. (Digikey; est.)	$10.00
Total	$175.12

This yields a total development cost of $20,425. Manufacturing costs of PCB and 3-D Printed Casing are factored into the expected prototyping cost. We expect to manufacture one assembly.

3.2 Schedule

Week	Joey	Derek	Jared
3/8	Order proposed parts and contact MakerLab Work on simulation assignment	Finish Power and Controller PCB Layout Design Sensor Arrangement	Design Personal Alarm schematics
3/15	Start on controller firmware	Finalize version 2 schematics and layout for Sensor Box Assembly First Order Sensor Box PCB	Finalize Schematics and PCB layout of Alarm Box First Order Personal AlarmBox PCB
3/22	Continue controller firmware	Component Testing with Mock Assembly Second Order Sensor Box PCB if necessary	Component Testing Second Order Personal Alarm Box PCB if necessary
3/29	Hand code over; begin work on final project presentation slideshow	Prepare Sensor Box Case Assembly	Start PCB Soldering and Assembly
4/5	Continue working on final presentation slideshow	Debug and Revise Sensor Box Assembly Third Order Sensor	Start Debugging of Alarm Box Third Order Personal

		Box PCB if necessary	Alarm PCB if necessary
4/12	Finish final presentation slideshow	Prepare and Revise Sensor Box Assembly for Mock Demo	Continue Debugging and prepare for Mock Demo
4/19		Refine Sensor Box Assembly for Demo	Mock Demo Prep.
4/26	Work on Final Paper	Work on Final Paper	Work on Final Paper
5/3	Work on Final Paper	Work on Final Paper	Work on Final Paper

4 Safety and Ethics

4.1 Ethics

Since the first proposal of this project, safety has been the most important aspect of the design. This device is designed to improve the safety of gas stoves by making sure that the operator does not leave them unattended. With safety as the focus, the device must be safe to use around a stove. This includes the dangerous cases where there is a gas leak, or the stove flame went out with the gas still flowing. The devices must be designed and created so that it has the smallest possible chance of igniting anything. Safety is the most important and applicable Ethics code that this design must follow [4].

To help reduce the chance of the devices from igniting any gas potentially in the air, the devices will be surrounded by a flame arrester, which is a fine wire mesh that would contain any flame from spreading outside the enclosed area. This idea has been applied to lamps used in mines to stop the lamps from igniting a flammable atmosphere. With that in mind, it will help a significant amount to help minimize the chance of the devices from igniting anything.

As for the other main part of the ethics code, they do not apply to the devices themselves, but to us working on it. We must strive to work together respectfully, with this code of ethics to be understood and practiced by every engineer.

4.2 Testing Safety Procedures

Due to the nature of this project, it is important to come up with specific testing procedures for safety reasons. The device is meant to be for fixed gas stoves, but testing the device on an actual stove would be difficult to test in ECEB. So, as an alternative, a small portable camping stove will be used as a substitute. This will make it portable and make it easier for non-flame testing. Propane is not needed for many parts of the testing, so for those parts, we can just use the stove with no propane. For testing the gas sensors, testing cannot be done in ECEB. The building does not have the facilities to be running open flames with the possibility of small gas leaks. Using a fume hood would allow for safe testing with the stove. This would require access to fume hood used in other college departments, such as the chemistry department. If this permission is not given, the flame testing would be held outside in a large, empty area, such as a parking lot. A 10-meter radius clear area will be enforced to ensure that a gas leak cannot catch fire due to nearby objects. With the air currents of the outdoors, we have a suitable gas dispersion method. For more safety, while testing it, a fire extinguisher would be on standby just in case a fire breaks out. For the safety of the person conducting the flame testing, safety goggles, flame-resistant clothing, and gloves should be worn.

4.2.1 In Case of Accident

When doing testing with actual gas, the primary goal is the safety of people around. While natural gas and propane can be extremely dangerous when it builds up in a confined space. This could be put into the explosive range, but this will not happen with testing outside, so the primary concern is just an unwanted fire that is not the burner. In the case of a fire, the first step of action is putting out the fire. This would be done with the use of a fire extinguisher that will be on standby for all tests using propane. After the fire is put out, the next step would be turning off the gas knob if it is on. After these two steps are completed, the devices and stove should be monitored and left to cool off before inspected closer.

4.3 Regulations

The primary regulations that this device must follow at FCC regulations. With the uses of Bluetooth receivers and transmitters, it must be ensured that it follows the relevant FCC regulations. To make this easier, a Bluetooth board that is already FCC compliant is used. This makes it easier to use the devices in more ways than just as an experimental prototype.

5 References

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