EE 41430

SmartLint©

High Level Design

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1 Introduction

The members of our group are William Bailey, Aaron Diaz, Ryan Frost, Rene Frank Gahitira, Salvador Llort, Grayson Zinn. The purpose of this project is to apply the engineering skills we have learned over the past 3.5 years and use them to solve a common problem with a new, innovative idea. Our project came from the Elevator Pitch Presentations and is named SmartLint. Our project would solve a real-world problem and requires a variety of technologies, engineering techniques, and design ideas to accomplish it.

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2 Problem Statement and Proposed Solution

Problem Statement

Every year, over 15,000 clothes dryer fires are reported each year — causing an estimated 5 deaths, 100 injuries, and $35 million in property loss. An estimated 34% of these fires can be attributed to excess lint build-up in the dryer's ventilation system — making it the single largest cause of dryer accidents and related property damage. Older dryers are still prevalent in many homes and apartment buildings and have no mechanism for detecting and/or communicating if and when the lint trap in a dryer is full or if the ventilation pipe is clogged with lint. Cleaning the dryer lint trap regularly is necessary to decrease the risk of fires, but lint can also build up in the venting pipe and/or system without the owner's knowledge. This problem is further complicated by households and multi-family living arrangements in which many different people use the dryer and may not know when or where to check for lint build-up.

Proposed Solution

To solve this problem, we are interested in creating a device that will detect and alert the dryer's owner (whether it be a homeowner, landlord, or renting tenant) when it believes the lint in the dryer ventilation pipe is reaching a critical level. First, we have to design a method to indirectly measure the amount of lint (without seeing or collecting it) and then communicate to the user if there is a critical amount of lint that needs to be removed. The mechanisms to alert the user will consist of multiple communication mediums: visually with an LED, audibly via an alarm or buzzer, digitally via an email or other push notification, and recorded online with a log of notable system events. To detect a critical or problematic level of lint, we have two possible options: to sense the airflow through the ventilation pipe and to sense the temperature at the ventilation pipe's surface near the dryer.

Method 1:

Sense the temperature around the ventilation pipe (at the surface) in order to determine if it is heated up to a certain temperature above a threshold that may be indicative of a build-up of lint that leads to an increase in heat.

Materials needed:

- Temperature sensor, likely a variable resistor
- Circuit components for connectivity (i.e., resistors, capacitors, wires); will depend on specifications on sensor data sheet
- PIC microcontroller to interface with sensor and communicate via UART or SPI
- WiFi module or Bluetooth module

Method 2:

Measure the level of airflow in the ventilation pipe to determine if it has decreased beyond a threshold that is indicative of an accumulation of lint in the pipe that is potentially dangerous or combustible. This is accomplished by inserting the sensor into the pipe and sealing it off.

Materials needed:

- Airflow sensor, inserted into the pipe
- Circuit components for connectivity (i.e., resistors, capacitors, wires); will depend on specifications on sensor data sheet
- PIC microcontroller to interface with sensor and communicate via UART or SPI

- WiFi module or Bluetooth module

Method 3:

Measure the level of airflow in the ventilation pipe to determine if it has decreased beyond a threshold that is indicative of an accumulation of lint in the pipe that is potentially dangerous or combustible. This is accomplished by creating our own pipe fixture and attaching an airflow sensor within this fixture.

Materials needed:

- Airflow sensor, inserted into our own pipe fixture
- Aluminum dryer vent hose
- Circuit components for connectivity (i.e., resistors, capacitors, wires); will depend on specifications on sensor data sheet
- PIC microcontroller to interface with sensor and communicate via UART or SPI
- WiFi module or Bluetooth module

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3 System Requirements

We will judge our success off of the overall system's ability to reliably detect excessive amounts of lint in the pipes attached to the dryer and be able to alert the user. Our strategy is to detect when the level of lint in the dryer pipe or filter causes the dryer to be at risk of a fire as a result of the lint igniting. We will accomplish this by measuring the airflow through the dryer pipe as well as the temperature on the surface of the pipe near the entrance to the dryer. We expect that the temperature of the pipe would increase and the level of airflow would decrease by measurable amounts in the presence of excess lint. We will do this using a temperature sensor and an airflow sensor, which will live inside the vent pipe to sense and send data back to the microcontroller.

The board itself will need to take in the temperature and air flow readings and then decide if these are within a safe range. If the logic sees a problem with either, it will then begin the alert protocol which will entail flashing the LEDs, sounding the alarm, and sending out notifications. We intend to determine and develop thresholds that are conservative and alert the user when the lint trap or the pipe need to be cleaned out, as well as more dire thresholds that recommend the user refrain from running the dryer at all, for instance. This means the board will also need WiFi capabilities to send out an appropriate message to the user. The only physical user interface on the device will likely be a power on/off and a reset button for when the user wants to turn off the alarm. This could be a temporary reset to give the user a certain time period to have the alarm turn off and not turn back on again if they hear the message but are not able to clean out the lint at that moment. This way, they have time to recognize the problem, but the alarm will sound again if they forget to alleviate the problem or continue to run the dryer. The board and sensors will all be powered via a wall wart, so a transformer will be needed to convert the wall power into a lower voltage, suitable for the board. Another possibility is to power the device via a wall wart that converts the power to a USB mini or USB micro that can be easily taken to power a microcontroller, such as a PIC32.

Besides the interface on the actual casing to turn on and off and reset, there could also be a remote communication interface in which the user can “recognize” these alerts and disarm the microcontroller. Moreover, an added interface function could be to set the amount of time the reset makes the alarm inactive before it goes off again. For example, if the user is at work and plans to do it that night, they could set an 8 hour inactivity period. If they plan to do it after going to the store, they could set it for only 2 hours. This way, the user can adjust the alarm to remind them when it will be most convenient.

As mentioned, the device itself will be powered via a wall adapter. This will then interface with a protective casing, which will house the board, microcontroller, WiFi module, and other wires that protrude to connect to the sensors. It will ideally have a simple, convenient hardware user interface on the outside and display one or multiple LEDs and audible alarm. Out of the casing, wires will extend down to connect the temperature and airflow sensors that sit near the interface between the dryer unit and the ventilation pipe. These will run outside the dryer and the airflow sensor would need to be inserted inside the dryer sleeve through a cut. The airflow sensor insertion will need to be sealed off to prevent airflow from leaving the tubing, likely using bolts and a rubber sealant or another type of adhesive sealant. There should not be any safety hazards as the voltage from the wall will be heavily stepped down, but the power adapter in will have a grounding prong in case of shorts for added safety. In the case that we use batteries to power the device, it would all sit near the interface between the dryer and ventilation pipe and would share the same structure or encasing.

There are no weight requirements, as weight of the device will not likely be an issue as it is immobile and mounted on a relatively robust structure. The sensors, however, will have to be small and light to not interfere with the lint's ability to flow through the vent pipe. This size constraint should not be a problem since most sensors are already small, thus making our casing for the sensor small as well. The size requirement for the case will depend on how large the board is and which microcontroller and WiFi module we choose. However, we do not predict the size of the drive being a limiting factor. The LEDs and alarm will be mounted externally so they do not need to fit inside the case, just be visible and audible to the external world. Since our proposed design interacts with the dryer directly, all our materials and sensors should be able to withstand 250℉ without experiencing any malfunctions.

4 System Block Diagram

4.1 Overall System:

The whole system can be deconstructed into five main subsystems: Airflow Subsystem, Temperature Subsystem, Power Subsystem, Casing Subsystem and Communications Subsystem. The airflow subsystem is in charge of measuring the airflow within the ventilation pipe of the dryer and will be inserted therein; the level of airflow will hopefully be indicative of the level of lint present in the pipe. The temperature subsystem will measure the temperature of the ventilation pipe at its surface and will sit on the surface of the vent pipe nearest to the dryer unit, preferably inside the installation system of the airflow. The power subsystem is responsible for distributing power to the system and its peripheral devices (PIC microcontroller, WiFi module, temperature and airflow sensors). It will have an ON/OFF switch, a power reset button, and will be connected to a wall outlet using an adaptive wall wart. We are still evaluating the potential of powering the device using batteries and locating the entirety of the device near the ventilation pipe. The casing subsystem is what will hold all of the devices together and protect them from outside damage or interference. Once the size and dimensions of the board are clear, we will design a casing on a CAD software and 3D print and assemble the casing. Then, the power and communication subsystems will be installed therein, along with the associated connections to the sensors. Finally, the communications subsystem consists of the PIC microcontroller, which will be responsible for interfacing with and communicating with the airflow and temperature sensors via SPI, UART, or another two-way send/receive communications protocol. It will also include a

WiFi module which will interface with the microcontroller via UART and will enable communication to outside devices on a home-area network, or the Internet.

4.2 Subsystem and Interface Requirements:

Airflow:

The requirement for this system is to measure the airflow level of the ventilation pipe. We will accomplish this requirement by having a puncture in the vent pipe with a tube connected to and locked by a holding system that will not allow air to leak out. It will communicate measurements periodically back to the PIC microcontroller.

Temperature:

The requirement of this system is similar to the airflow system. This subsystem should be able to measure the temperature of the vent pipe. Whether or not we choose to create a custom connector piece, the temperature sensor will most likely sit on the outside of the connector or the ventilation pipe. Both the Temperature and Airflow subsystems have to work together within the installation unit so that both systems have no issues with each other and that the installation of them is not difficult. It will also communicate measurements periodically back to the PIC microcontroller.

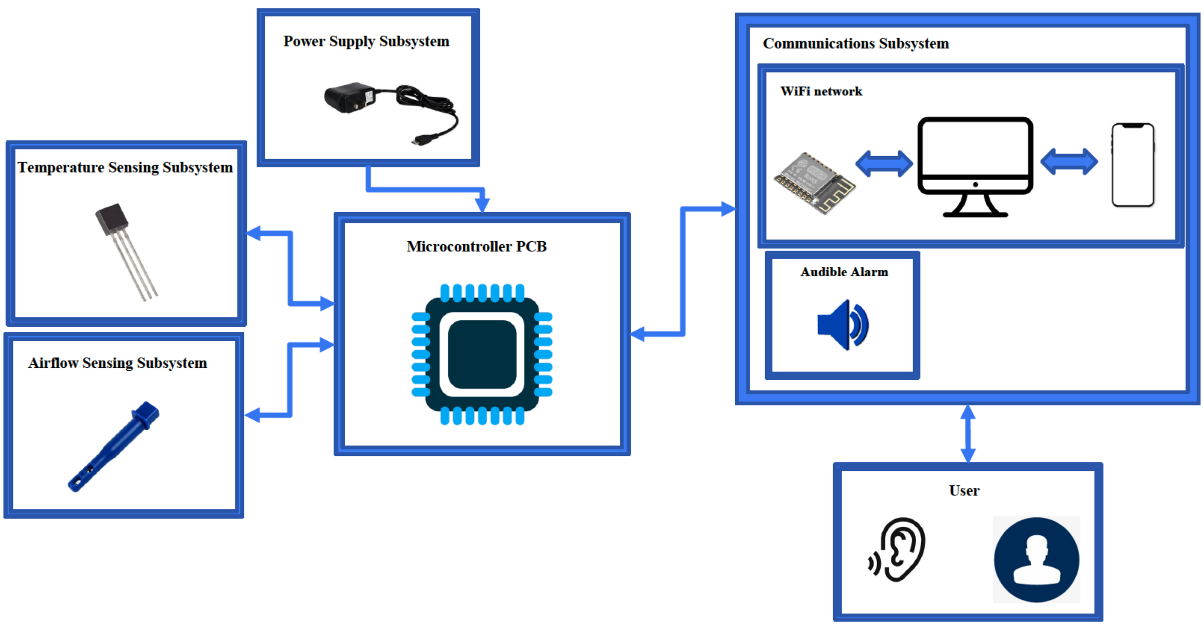
Power:

The main requirement of this subsystem is to power the devices. There are two viable options for our product: to use a wall wart that adapts to power the microcontroller via a USB mini or micro, or use batteries to power the system. Either way, the power subsystem should be responsible for providing power to the microcontroller, the sensors, the WiFi module, the alarm/buzzer, and any LEDs or other circuitry..

Board and Communication:

This will be the largest subsystem out of all. The PIC microcontroller will be at the heart of this subsystem, communicating and responding to the devices around it. This will include writing the code to receive data from the sensors, analyzing the data, and responding accordingly. Besides the microcontroller, the other main requirement of this system is to notify the user via a WiFi module that will interface with a home-area WiFi network. We will use LED (visual), speaker (auditory), and notifications (WiFi) to notify the user. These subsystems will be installed in the main component of the system.

SmartLint System Block Diagram



4.3 Future Enhancement Requirements

We had a couple of ideas that may not make it to the final iteration of our product. With more research and time, we would be able to enhance our product to perform even better under certain requirements.

The first one is developing an auto-shutoff system that operates like a circuit breaker that acts as the interface between the dryer plug and the wall outlet. If our sensors detect a highly dangerous level of lint (via increased temperature or lack of airflow), it would automatically cut off power from the dryer. We would need a circuit breaker within our product and there is too much of a potential fire hazard or risk of electrocution for us to safely develop this enhancement on our own without any knowledge of power electronics.

The second enhancement would be to make our product with different power adapters. There are many different types and variations of power adapters around the world, and if we make our product connected to the wall outlet we would have to ensure that the customer has the right power adapters to connect to. We would need multiple iterations of our product to accomplish this and, if we are assuming to target customers only in the US for the time being, we would only need one power adapter type for our final demonstration.

The last improvement we had in mind would be to improve the user experience of our product as it relates to the digital communication interfaces. For instance, thinking about the most useful way to communicate problems to the homeowner or user, we could allow it to interface with a device such as an Amazon Alexa or Google Home. We could create a digital log that uses data analytics to do predictive maintenance and predict the point at which the dryer would need to have its ventilation pipe cleaned or serviced. This could be useful for landlords planning maintenance in advance. We know that this would probably be where most of our time can be spent and there is always room for expanding the software and communications capabilities of our device.

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5 High Level Design Decisions

- Power Subsystem:
  - Function: provide power to the microcontroller and other peripheral devices via a wall wart (preferably adapted to USB mini or micro) to interface with the microcontroller. Alternatively, use batteries (Li-Ion) to power the associated devices.
  - Interface(s): N/A
  - Associated Device(s): PIC microcontroller, maybe WiFi or Bluetooth module (though this could siphon power from microcontroller most likely)
- Board and Communications Subsystem:
  - Function: provide processing power and communications to the product, power some peripheral devices such as the sensors, LED, and buzzer (alarm)
  - Interface(s): communicate w/ airflow sensor via SPI or UART, communicate w/ temperature sensor via SPI or UART, communicate w/ WiFi module via UART
  - Associated Device(s): PIC microcontroller, WiFi module, temperature sensor, airflow sensor, LED, piezoelectric buzzer
- Temperature Sensing Subsystem:
  - Function: sense heat on the dryer venting pipe, periodically communicating this back to the microcontroller. If the heat approaches or exceeds a given threshold, send a signal to the microcontroller.
  - Interface(s): communicate w/ microcontroller via SPI or UART protocols
  - Associated Device(s): PIC microcontroller
- Airflow Sensing Subsystem:

- Function: detect airflow in the dryer ventilation pipe
- Interface(s): communicate w/ microcontroller via SPI or UART protocols
- Associated Device(s): PIC microcontroller

- Casing Subsystem:
  - Function: contain the microcontroller and WiFi module from the environment and provide an appealing aesthetic to the device; wires will protrude from here to the respective sensors
  - Interface(s): contains the microcontroller, WiFi module, LEDs, and alarm (piezoelectric buzzer)
  - Associated Device(s): PIC microcontroller, WiFi module, LEDs, piezoelectric buzzer

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6 Open Questions

- There is still a question as to which method will be used to do the detection, or if both are determined necessary. There are two main options of detecting airflow and detecting temperature, thus more testing will be done to see what provides the best results. It should not be terribly difficult to prototype both of these, as airflow and temperature sensors are both commercially available.
- If we use each method of detection in our device, there is a question of determining and setting the threshold for an alarm or alert for both heat and airflow. If the threshold for heat is passed, but the threshold for airflow is not, or vice versa, how will the system respond and make recommendations? Should we have indicators to the users that

distinguish between these two? Which of these is a better indicator of an issue with the drier?

- Can either of these sensing mechanisms sense other problems with the dryer that would be potentially useful to communicate to the homeowner or user? For instance, can airflow or temperature at the drier pipe be an indicator that the drier is too full? If so, our device would need to be able to distinguish between this scenario and a scenario in which lint is in excess.
- What is the most effective way to test the efficacy of our device and simulate a real operating environment? It would be potentially dangerous to try and push a real dryer to the brink of starting a fire (reaching a threshold for temperature or airflow).
- What relevant regulations exist around the installation and usage of large appliances, such as dryers, that might impact or limit our device's capabilities? Are there any relevant sections of the fire code that might impact or limit what we intend to design in practice?
- What is the most feasible way for us to communicate the status of the dryer to a user remotely? If we utilize WiFi how do we create a server for our data and send that information to a user? If we utilize Bluetooth how do we make and monitor connections?

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7 Major Component Costs

- Board and PIC microcontroller (including fabrication/board house costs): ~ $50
- WiFi module: ~ $10
- Bluetooth module: ~ $10
- Air flow sensor: ~ $35
- Aluminum dryer vent hose: ~ $35
- Temperature sensor (wires, thermistor): ~ $5
- Materials to connect device to dryer and/or ventilation sleeve: ~ $10
- 3D Printed Casing: ~ $5
- LEDs and alarm: ~ $10
- Website hosting/ Data upload: Free - ~$20

Total Cost: ~ $190

Withstanding the current chip/microcontroller shortage, and if the product was produced at scale, we would anticipate the final price of our product to drop steeply.

8 Conclusions

In conclusion, we believe this project is feasible through multiple modes of sensing, powering, and communicating. An immediate question to answer is which method or perhaps both methods of sensing the presence of lint (albeit indirectly) is most viable. Testing will need to be done to determine what airflow and temperature cutoffs will need to be programmed in to alert the owner of a potential fire. The general design will be a powered board with sensors and a chip to run logic on when the alarm is triggered. The airflow sensor will then be inserted into the dryer sleeve through the side via a drilled hole. To alert the user when the lint buildup is potentially too high, there will be an LED indicator that changes color, a simple piezoelectric alarm that will sound off and alert the homeowner of an issue, and a digital notification to the user via a WiFi or Bluetooth communication.