Dryer Temperature Probe

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1. Introduction

1.1 Objective

Improper use and maintenance of laundry dryers lead to the accumulation of lint and fabric softener in the dryer vent. Without the removal of this debris, the internal temperature of the dryer would be too high, resulting in dryer fires that could cause substantial property damage and potential bodily harm. A thermocouple could be used to measure the internal temperature of a dryer during its operation and a temperature above 250°F indicates a large accumulation of lint that must be cleaned out. However, such a solution is rather pricy with units costing about $100.

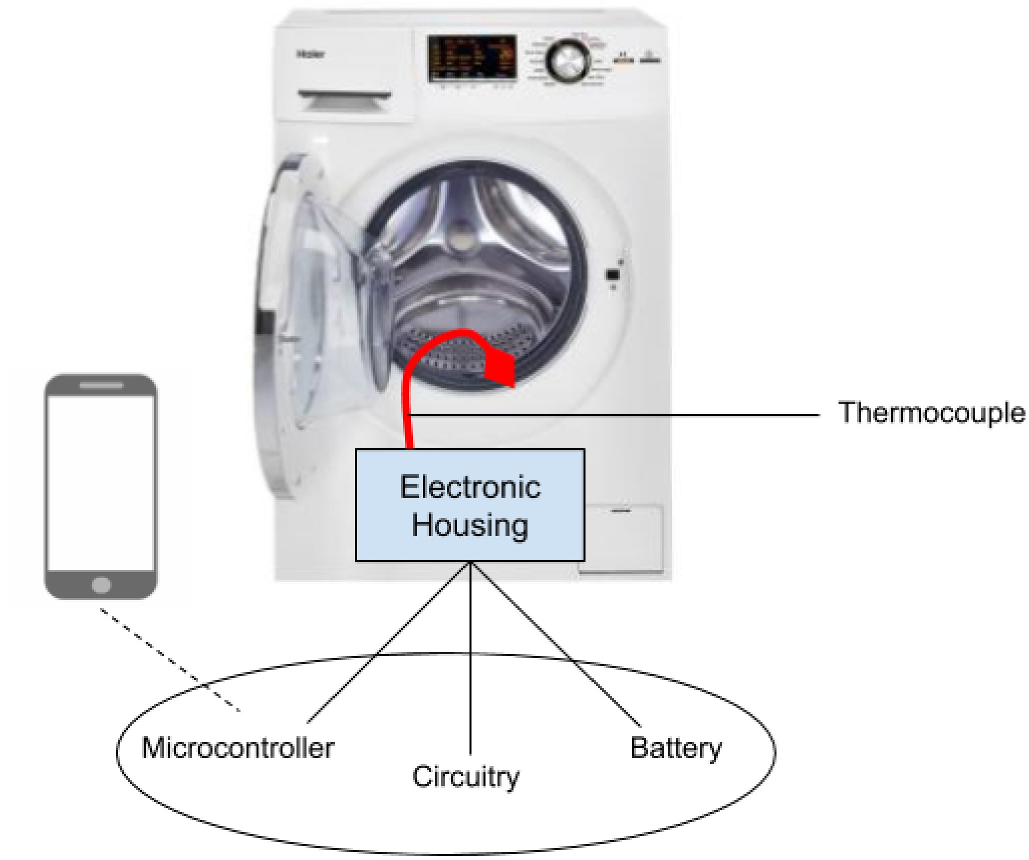
A more cost-effective user-friendly dryer temperature probe can be created by utilizing three components. The temperature probe would be a k-type thermocouple that can withstand and measure temperatures of up to 350°F inside the dryer while it is running. The hardware unit would physically be placed on top of the dryer while it is running to read the data, convert it from analog to digital, and transmit the data via wireless communication. A smartphone would then be used to view the temperature data in real-time and indicate whether or not the temperature is potentially dangerous. This interface would be more user-friendly compared to the LCD display commonly found on handheld thermocouple temperature sensors.

1.2 Background

Home appliances like dryer units are used several times a week by American consumers, and they serve a major function in one’s everyday life. Yet, they are not always perfectly made, and improper use or lack of maintenance can cause malfunction. Excess lint from clothing and fabric softener from dryer sheets can accumulate in various areas of the dryer. This can then lead to air vents becoming clogged, and eventually, this excess lint may even cause overheating. When air temperatures exceed 250 degrees Fahrenheit, a fire hazard may occur since cotton and wool burn at those temperatures. Our goal is to accurately detect the current dryer air temperature and alert a homeowner or resident when the air temperature has exceeded the 250-degree threshold. By doing this, fires and property damage may be avoided.

1.3 Physical Design

Our solution will be mounted on the front of a dryer unit in a protective box. It will have an opening for the thermocouple sensor to extend outside of the box and into the dryer’s lint trap through the dryer’s main door. The computational components will also connect wirelessly to a designated smartphone.

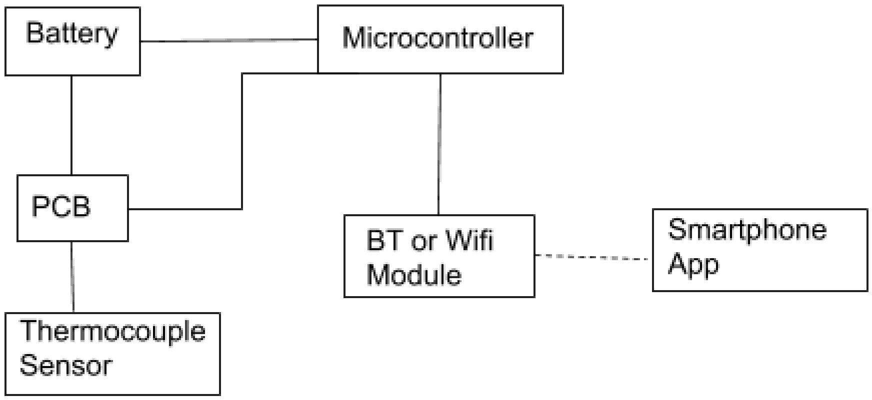


1.4 High-Level Requirements

- The probe must be able to accurately detect the current temperature in the lint trap within a tolerance of 1-2 degrees Celsius.
- Our prototype must easily connect with a user's smartphone either via Bluetooth or wifi. It should provide a close to real-time (no more than a 2-minute delay) temperature reading.
- The smartphone app should display results and recommendations to the user in an easy-to-understand and intuitive manner using temperature zones. It should indicate whether the dryer temperature is too low, just right, at a cautiously high temperature, or is at risk of starting a dryer fire.

2. Design

2.1 Block Diagram



The above block diagram depicts our entire unit. Each component is necessary to properly fulfill the high-level requirements. A thermocouple is the most essential sensor, and it will be used to identify the current air temperature. A PCB component will be used to properly read the analog values from the thermocouple and deliver them to the microcontroller. The microcontroller will tie everything together by sending temperature readings to a smartphone via a wireless connection (Bluetooth or wifi). This will be possible only with the additional BT/Wifi module attached to the microcontroller. A basic smartphone app will display the current temperature readings in a human-readable interface. Finally, the battery will power the microcontroller, module, and sensor allowing the entire unit to function.

2.2 Functional Overview

2.2.1 Battery

The battery will power the entire unit. It consists of a battery holder for an alkaline disposable battery and a voltage regulator. It provides power directly to the microcontroller. This, in turn, will divert power to the wireless connection module, allowing for information to be sent to a smartphone. The battery will also directly power our circuit. This will allow for the cold junction compensation to operate and properly bias the thermocouple temperature which will be filtered and amplified through other elements and the resulting values will be sent to the microcontroller for processing. Each component is directly reliant on the battery as a main power source.

The PCB and microcontroller will interface with the battery through direct-connection wires. With the microcontroller, there may be some very basic circuitry needed to modify voltage and current. This will lie in between the battery and microcontroller. However, it is important to note that the specific battery and microcontroller have not yet been decided upon. So it is possible for a direct wire connection from the battery to the microcontroller.

2.2.2 Thermocouple

The thermocouple captures unique and real-time temperature readings from the dryer unit's lint trap. This directly satisfies the first high-level requirement of being able to read the temperature, and it helps satisfy the second and third high-level requirements since temperature readings are needed as a basis for additional functionality. The thermocouple will be interfaced directly through the PCB which will deliver the appropriate voltages needed to interpret temperature values.

2.2.3 Microcontroller

The microcontroller will serve to process the incoming temperature values and send output information through the wireless module to the smartphone application. It will serve to convert analog resistance values into understandable temperature values. The PCB will be interfaced by direct wires plugged into the microcontroller. It will then send the current temperature reading as well as some additional information based on conditional logic to the smartphone. It will do this by interfacing with the wireless module through a device driver and software code.

2.2.4 BT/Wifi Module

The Bluetooth/wifi module is responsible for wirelessly communicating with the user's smartphone. It will be interfaced through a device driver on the microcontroller. This will allow the incorporation of conditional logic through software to send specific information to a smartphone device. This module is essential for real-time data to be transmitted to a device that is not physically connected to the unit. Overall, this allows for much quicker identification of potential fire hazards.

2.2.5 PCB

The PCB consists of various circuit components that assist in the processing of the thermocouple voltage signal. A cold junction compensation IC is required to bias the cold junction of the thermocouple since it measures the temperature difference between the hot junction in the dryer and the cold junction on the PCB. The cold junction compensation IC makes the thermocouple behave as if the cold junction were at 0 degrees Celsius, resulting in a more accurate reading. An analog filter must be implemented to filter out random noise from the thermocouple signal. An amplifier is necessary for the signal to be legible to the microprocessor since the voltage generated by the thermocouple is around 4mV at 100 degrees Celsius. The processed analog signal is sent to the microcontroller for analog to digital conversion and subsequent wireless transmission.

2.2.6 Smartphone App

The app installed on the user's smartphone acts as the wireless communication between the probe and the user. It displays color coded warning messages based on the temperature detected by the probe. Below 185 degrees Fahrenheit it would be too low of a temperature to adequately dry clothes, rendering service necessary to restore normal operation, represented by a blue color code. Between 185 and 210 degrees Fahrenheit the dryer operates normally, requiring no additional action from the user, represented by a green color code. Between 220 and 250 degrees Fahrenheit the dryer is a bit warmer than normal, maybe requiring service, represented by a yellow color code. Above 250 degrees Fahrenheit the dryer is operating at too high of a temperature at which cotton and wool can start to burn, causing a potential dryer fire, represented by a red color code.

2.3 Block Requirements

- Battery
  - Must step down 9V battery input to 5V +/- 0.5V voltage regulator output.
- Thermocouple
  - Must generate a voltage within +/- 82 μV of expected voltage based on ambient operating temperature.
- Microcontroller
  - Analog-to-digital converter must have high enough resolution to distinguish between what is equivalent to 1 degree Celsius.
- BT/Wifi Module
  - The wireless communication module must be able to communicate and transmit data to a user's smartphone within 15 feet in the same room.
- PCB
  - The low pass filter circuit must demonstrate a characteristic of -20db/decade for signals above 30Hz.
  - The amplifier circuit must amplify filtered thermocouple signal with a DC gain of at least 100 times.
- Smartphone App
  - The application must properly display temperature data and warn user if a potentially high temperature occurs with appropriate color codes for different temperature regions.

2.4 Risk Analysis

The block that poses the biggest risk to proper implementation of the project is the PCB unit. The voltage that comes from the thermocouple is on the order of μV and even the slightest change would result in a large change in the associated temperature value. The cold junction compensation IC, filter, and amplifier are all integral in the processing in the analog signal of the thermocouple voltage. Any one of these components implemented incorrectly could result in a total incorrect thermocouple voltage reading and a completely incorrect temperature reading which results in complete failure of the purpose of the project.

3. Ethics and Safety

3.1 Ethics

There is one main ethical concern in the operation of this device. We must ensure that the temperature reading is accurate since the IEEE code of ethics states "to avoid injuring others, their property, reputation, or employment by false or malicious action." [1] Displaying false information could result in bodily or property damage. A false low temperature could drop a person's guard, letting them touch a dangerously hot thermocouple without letting it cool down. A false low temperature could also persuade them not to have their dryer properly maintenanced, resulting in a higher probability of dryer fires, a situation that the aim of this device is attempting to reduce the likelihood of.

3.2 Safety

There exists various safety hazards to the user during the operation of the dyer probe. There is a risk that the temperature unit may be used incorrectly, either placing the electronics housing in the dryer itself instead of keeping it outside of the dryer during operation or utilizing any part of the circuit with a washing machine. This will at the very least cause damage to the thermocouple sensor, the physical circuitry, and possibly the laundry machine itself. Warnings on the packaging will be essential to avoid this risk. The thermocouple may also be at a very high temperature after a dryer cycle and may result in burns if it is touched by the user quickly after measuring temperature and not allowing it to properly cool. A warning for this problem would also be apparent on the packaging to whoever uses the device.

4. References

[1] "IEEE Code of Ethics." IEEE.org. https://www.ieee.org/about/corporate/governance/p7-8.html (retrieved Feb. 13, 2020).