Automated Frozen Pipe Burst Prevention System

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Project #22

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1. Introduction

Problem:

Frigid temperatures like those during the winter here in Illinois run the risk of inducing frozen & thus burst pipes. Just this past winter break, my roommates and I got an email regarding several units on our floor that had unfortunately had their pipes burst as a result of the winter storm. This is an issue that plagues not only college students like us, but many residents across the country. An estimated average of over 250,000 homes each year will suffer damage from frozen and burst pipes. The damage is estimated to be in the $400-500 million each year. To further highlight the fragility of frozen pipes, even a rupture as small as an 1/8th of an inch can release up to 250 gallons of water per day.

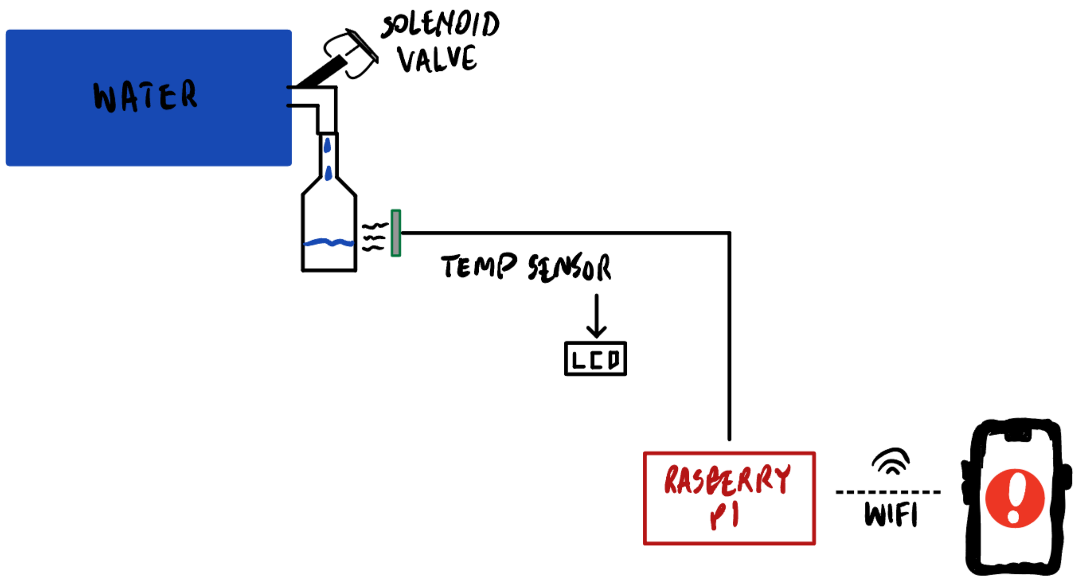
Solution:

Current methods to help alleviate this issue have proven insufficient and/or have left room for improvement. Common current methods to prevent frozen pipes include maintaining a set temperature of at least 55 degrees fahrenheit in the home, running a trickle of cold water from faucets with exposed pipelines, and adding insulation or heat cables along the pipelines. Other methods such as the use of antifreeze are considered harmful for the environment, wildlife, and humans.

The former 3 are a good place to start but what happens when a resident forgets to set the temperature or leave the faucets running? Even if the resident were to take these measures, the utilities costs that one would incur and energy wastage that would occur appears to be excessive and inefficient. In addition, situations where the resident is away from the residence for an extended period of time and cannot return in a timely manner further exasperate this issue.

Our proposed solution is creating an automated system that alerts the resident via a notification to their smartphone that a pipe is at risk of freezing and therefore further at risk bursting if left unattended. The notification subsystem will be triggered by the subsystem involving the temperature sensor. In addition, a third subsystem will be utilized to open a valve that would allow cold water to trickle through the pipe. The combination of these two features enables the resident the ability to take further action by buying them time as well as automating certain preventative measures such as allowing water to trickle through the pipe which helps prevent the pipe from freezing.

Visual Aid:

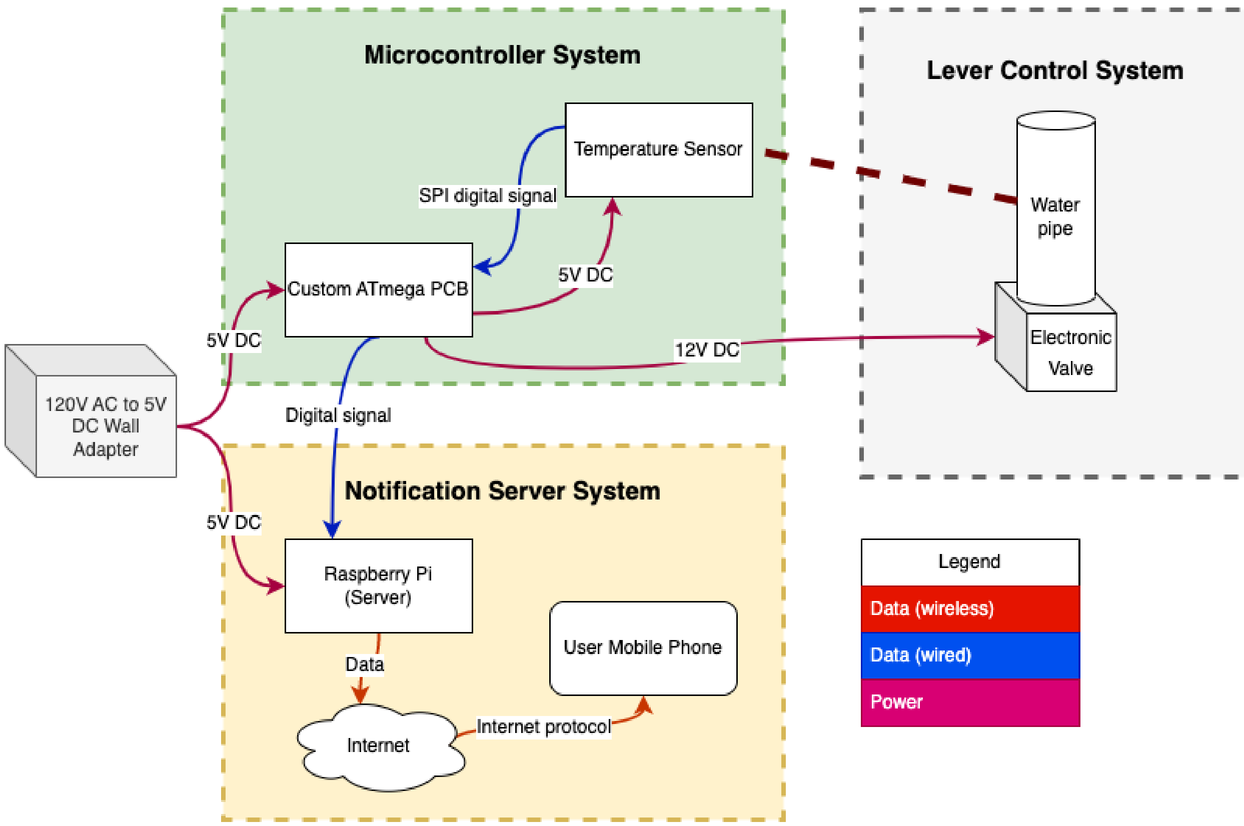


High-level requirements list:

1. System is not triggered until the temperature sensor output reads between 12.5 and 13.5 degrees Celsius.
2. 1 push notification is sent to the mobile device using wifi upon receiving low temperature reading.
3. Upon triggering, the valve opens, outputting approximately 77.22240 mL of water from the reservoir through the pipe for 0.1763 seconds.

2. Design

Block Diagram:



Subsystem Overview:

- ☐ **Microcontroller System:** For this subsystem we will be utilizing a Temperature & Humidity Sensor. The ATmega328 chip will be soldered to our custom PCB, with appropriate pins/leads for the connections to the sensors and the Raspberry Pi. This microcontroller unit will process the data from the sensor and determine whether or not the threshold temperature has been crossed (55 degrees fahrenheit). The data will be sent to the notification subsystem to alert the resident of the risk of the pipe freeze and to the I2C LCD Display so that the temperature can be visually monitored in real time.
- ☐ **Notification Server System:** The notification system will enable the device to send notifications via the Internet to the user's mobile device, in order to alert them that freezing is imminent and the valve has enacted safety measures. The Raspberry Pi will connect to the wifi network and act as a server, and the ATmega328 microcontroller PCB will plug into it via USB. When the PCB-connected sensors are triggered, it will

communicate with the Raspberry Pi, which will then send a text message (or push notification) to the user's mobile device.

- ☐ **Valve Control System:** To prevent the water from freezing, we plan to implement a motorized spigot that will release water into a pipe for a small duration of time. A non-conductive material is preferred as it allows for more accurate sensor readings. Online sources (How to Prevent Your Pipes From Freezing - Consumer Reports) suggest a safe temperature to avoid pipes bursting is 55° F. Using this as a threshold temperature, when the ATmega328 microcontroller receives output below 55° F from the Waterproof Temperature Sensor (DS18B20), the 12V DC solenoid valve will move to release water into the pipe for a set period of time (3-5 seconds). By doing so the water temperature in the pipe will be warmer and allow the user more time to implement a more assured method like turning up the thermostat. The user will be provided a warning (push notification) in the meantime.

Subsystem Requirements:

- ☐ **Microcontroller System:**
    1. The temperature sensor must be able to accurately detect that the water inside the pipe/surface of the pipe has reached the threshold temperature between 12.5 (54.5 degrees fahrenheit) and 13.5 (56.3 degrees fahrenheit) degrees celsius in accordance with +/- 0.5 degrees celsius accuracy of our DS18B20 Digital Thermometer.
    2. The ATmega328 microcontroller must communicate that the threshold temperature has been reached to both the notification subsystem and the valve control subsystem.
- ☐ **Notification System:**
    1. The raspberry pi must function as a server connected to the internet with a frequency of 2.4 GHz with a speed of 50-70 Mbps.
    2. The raspberry pi must send a push notification to the mobile device upon receiving the signal from the microcontroller system that the threshold temperature has been reached without having the mobile device connected to the same network.
- ☐ **Valve Control System:**
    1. Solenoid valve must be able to communicate with the ATmega328 microcontroller to release water into the pipe for 0.1763 seconds.
    2. Must be plugged into a 12V adapter connected to a 5V one-channel relay module that is also connected to the ATmega328 microcontroller. ATmega328(5V) alone is not powerful enough.

Tolerance Analysis:

- [ ] One-Channel Relay Module

Requirements	Verification
1. Provide 12 VDC +/- 10% from a 10.8 VDC-13.2 VDC 2. Can operate current within 0-200mA	1. Measure output voltage using an oscilloscope to ensure output voltage is within 10% of 12V. 2. Using a multimeter, connect leads to the coil terminals of the relay and measure. Output resistance should read 50-120Ω (Safe Relay Resistance).
1. Valve releases the correct amount of water. a. Volume of Pipe = $\pi * r^2 * h = \pi * (0.5)^2 * 6 = 0.7854 * 6 = 4.7124\ in^3 = 77.22240\ mL$ 2. Valve closes after enough water to fill the pipe has passed. a. Time it takes to free fall for 6 inches (not including air resistance or friction) = 0.1763 s	1. Measure the amount of water deposited into the bucket placed underneath the pipe. 2. Time the time it takes for the water to exit the pipe since being released from the valve.
1. System should only be triggered between a temperature of 12.5-13.5 degrees Celsius accounting for the +/- 0.5 accuracy of our DS18B20 Digital Thermometer	1. Measure the temperature of the water in the reservoir using a thermometer when the system is triggered to ensure that it is within this threshold range.

3. Ethics and Safety

Taking our project into consideration, one aspect that may be considered unsafe is the close proximity our electrical parts (PCB, Raspberry Pi) will need to be to the water reservoir and pipe for accurate measurements. We plan to mitigate this risk by utilizing waterproof/water-resistant components when possible and utilizing proper enclosures and encasing for components that are not (I.1. IEEE Code of Ethics).

We will be avoiding ethical breaches by abiding by the IEEE Code of Ethics throughout our development process. Our project inherently attempts to create a sustainable alternative to current frozen pipe prevention measures by minimizing the usage of resources such as water and heat to what is needed (I. 1. IEEE Code of Ethics). In addition, the three of us will be seeking the expertise and guidance of our professor, TA, as well as the faculty at the machine shop for constructive criticism of our technical work. The maintenance of our individual lab journals will serve as a basis for recording accurate measurements of our data which will serve as the basis for our claims (I. 5. IEEE Code of Ethics).