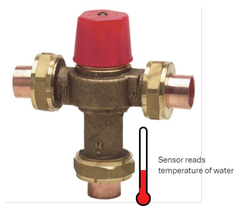
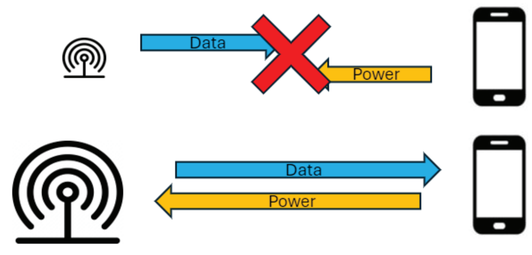
Failure Mode Analysis of NFC Near Plumbing Infrastructure

We have worked on developing a sensing system that is powered by and transmits data using Near Field Communication (NFC), enabling users to gather data wirelessly using only their phone. In plumbing contexts, this enables users to read water temperature faster and easier.

Problem Set

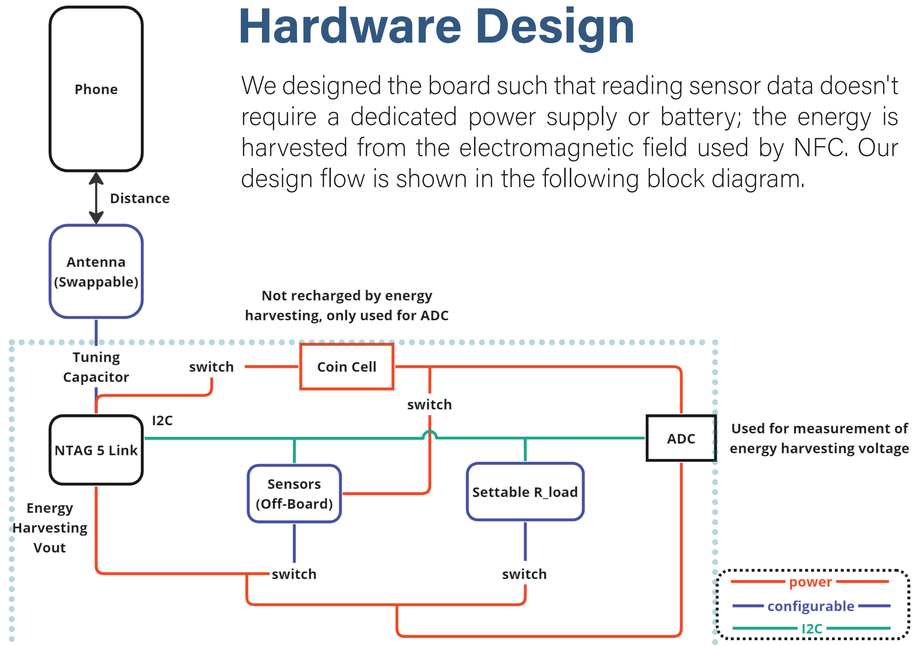
Mixing valves are used to mix hot and cold water together. These valves often have an analog knob on them that can be turned to adjust the ratio of hot water to cold water. These knobs don't have any feedback mechanism besides turning on the sink they might be attached to and measuring the temperature of the output flow. Users need to climb under their sink, adjust the knob, get out from under the sink, and then measure the output temperature. If the temperature isn't correct, then they would have to repeat this process multiple times. The goal of our project is to test failure modes an limitations of NFC that could be used to help make a reliable device to solve this problem

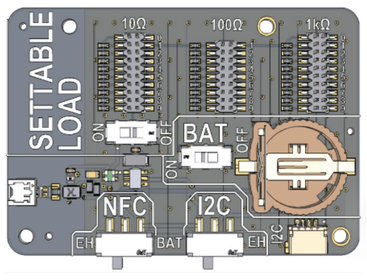


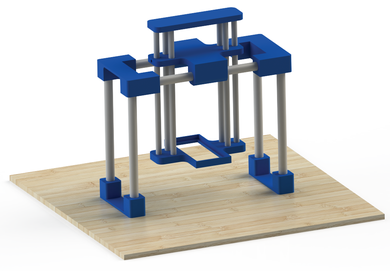


Hardware Design

We designed the board such that reading sensor data doesn't require a dedicated power supply or battery; the energy is harvested from the electromagnetic field used by NFC. Our design flow is shown in the following block diagram.



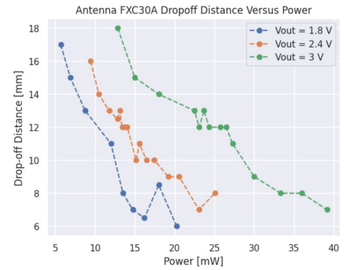




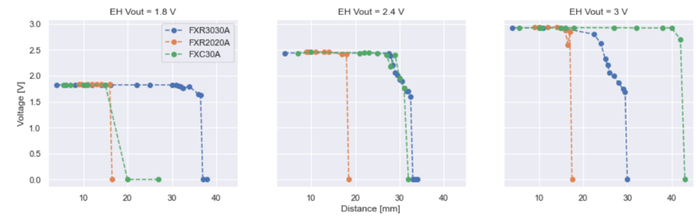
We are aiming to read data from and power the sensor via a smartphone. We are evaluating characteristics of the on-board NFC chip, antenna sizes, and the distances between the phone and the antenna to determine the limits of how this goal can be achieved.

Data and Findings

The distances where the voltages drop off show us the maximum operating distance between a particular antenna and target output voltage (regulated by the NFC chip). We saw a trend of increasing drop-off distances as we increased the antennae sizes and reduced the power harvested by the board.



The graph to the left shows the change in drop-off distance depending on the amount of power consumed by the system when using the 30 mm circular antenna. We found that many temperature sensors use between 0.5 and 5 mW of power.



These graphs show the varying drop-off distances of three of the antennas we decided to test at 1.8, 2.4, and 3 V outputs. We find that at the 3 V output setting, the 30 mm circular antenna is able to transmit data at the furthest distance.

According to our test results, we would recommend using circular-shaped antennae with maximal sizes. The distance between the phone and the antenna should generally be kept within the range of 0-35 mm for ideal performance, and we found that there is negligible interference from other plumbing, electronics, and metals.

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