SMART VENTS

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Abstract

The design problem was to develop a budget-friendly and energy efficient smart vent system for a residential home, and to test the 20% energy efficiency claim set by manufacturers. The smart vent was designed using SolidWorks and was 3D printed using PLA and PTEG filaments. The smart vent control components include temperature and pressure sensors, and a microcontroller for regulating the functionality of the vent. Six smart vents were manufactured for testing in a residential home. Data was acquired for 2 weeks (1 for inactive testing and 1 for active testing) in order to compare energy consumption data. In the tested rooms, the amount of energy savings reached an average of 14%.

Introduction

Design Problem:

- To design, develop, and manufacture a smart vent system that is budget friendly for a residential home.
- To test the 20% energy efficiency claim set by existing manufacturers.

Project Components:

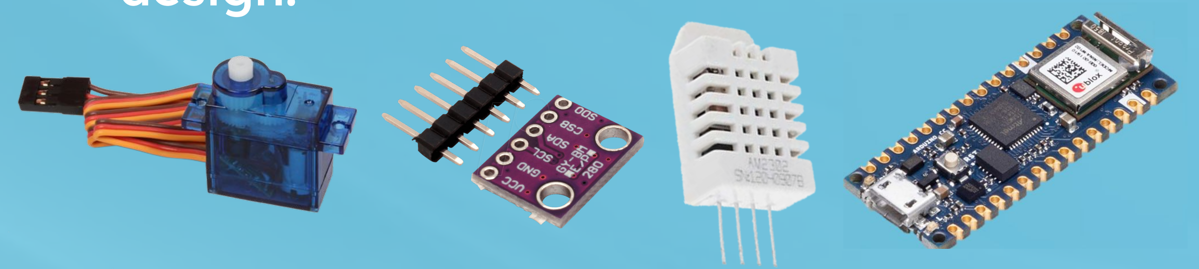
- Smart Vent Model
- Control System
- Physical Prototype
- User Interface
- Residential Testing / Simulation

Smart Vent System Benefits:

- Increased air distribution efficiency
- Customizable for different lifestyles
- Automation and remote control

Methods

- Several design concepts for the open/close mechanism and flap design were modelled in Solidworks.
- The most feasible option was chosen by analyzing the required vent space for the control system components and implementing a Solidworks airflow simulation and ANSYS stress analysis.
- The control system was further developed by programming the microcontroller to adjust the vent actuations based on user input and to collect pressure sensor and temperature sensor data for the post testing stage, using Arduino code.
- The user is able to control the vent using Bluetooth connectivity or by the physical push button built into the smart vent design.



- Calculations included:

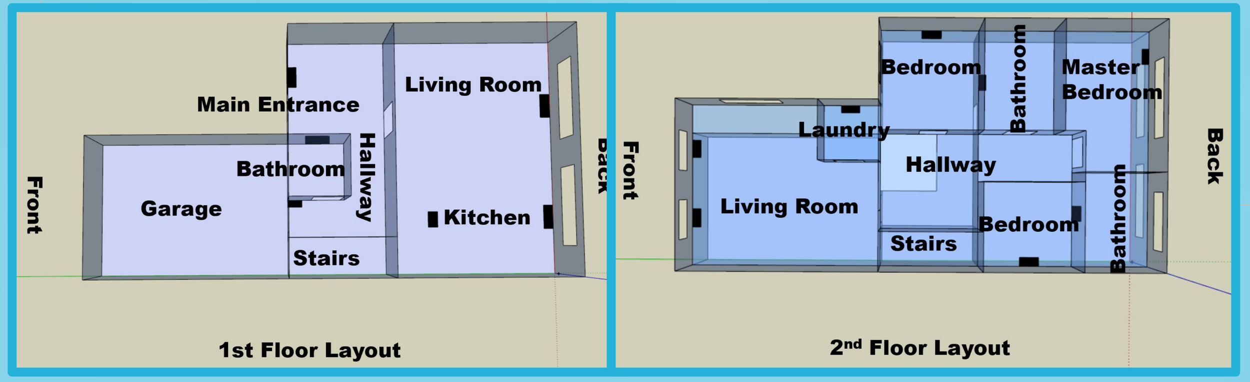
Motor actuation = 0.0507 mAh/actuation

$$1\ \text{Actuation} = \frac{(\text{Stall Current} - \text{Running Current})}{(\text{Stall Torque})} \times \text{Max Torque} + \text{Running Current}$$

Battery life = 415 days (5 actuations/day)

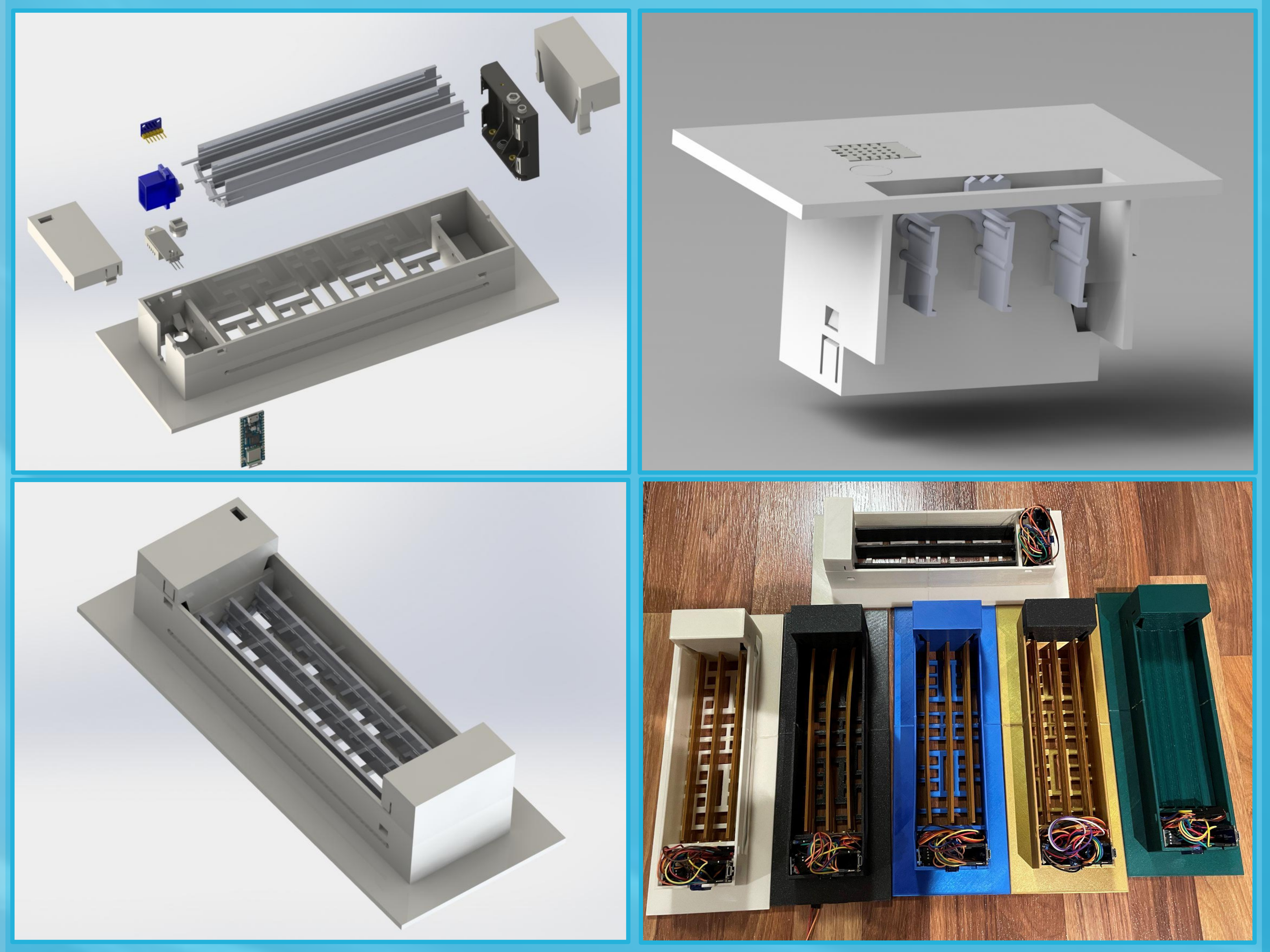
$$\text{Battery Life (days)} = \frac{\text{Battery Capacity}}{(\text{Actuation Consumption} * \text{Actuations/day}) + (\text{Controls Consumption})}$$

- The physical prototype was manufactured using 3D printers for the vent body, flaps and covers. PLA and PTEG filament was used.
- Six smart vents were manufactured for the residential testing process.
- Residential home testing procedure:
  - 1 week of inactive testing
  - 1 week of active testing

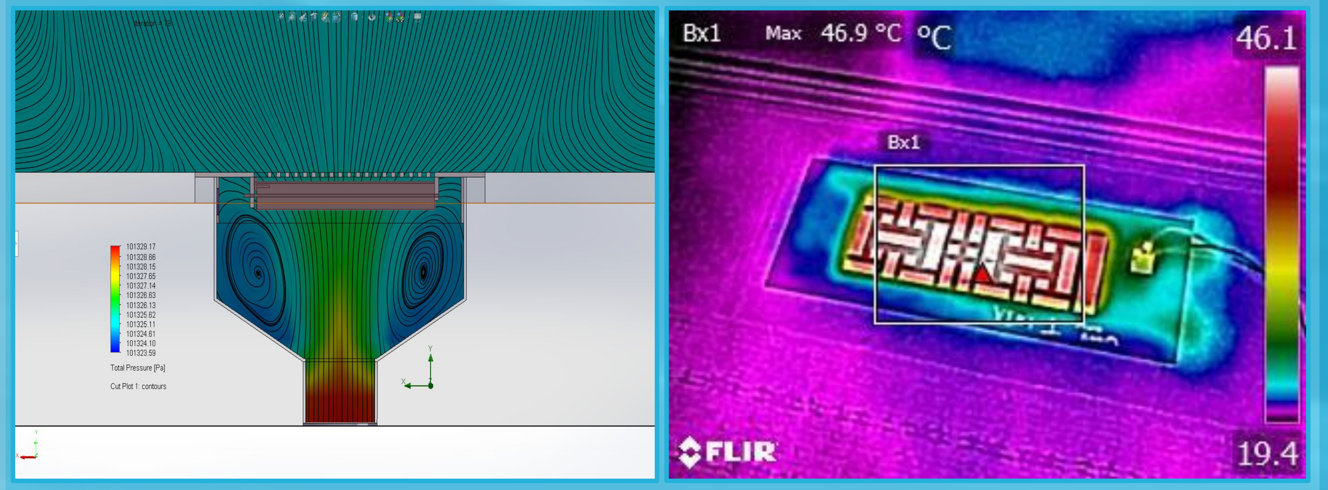


Design

Smart Vent Design (3D-Model & Prototype)

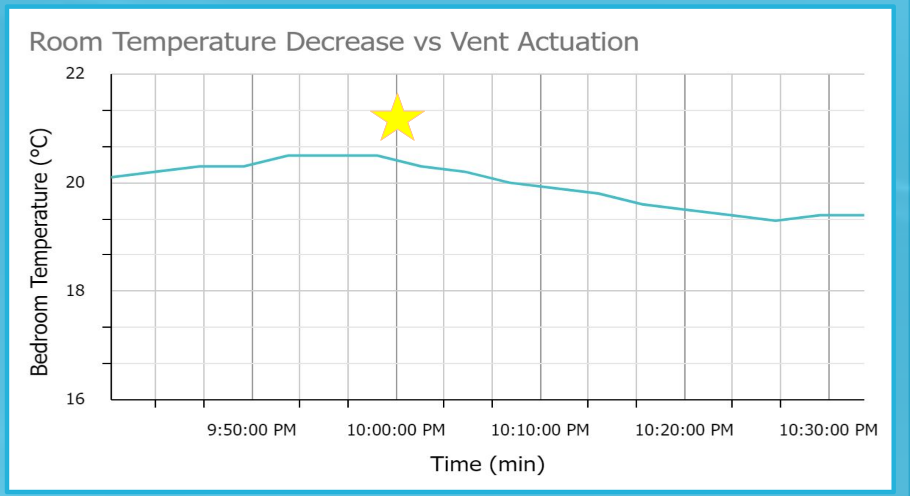


Airflow Simulation & Thermal Imaging

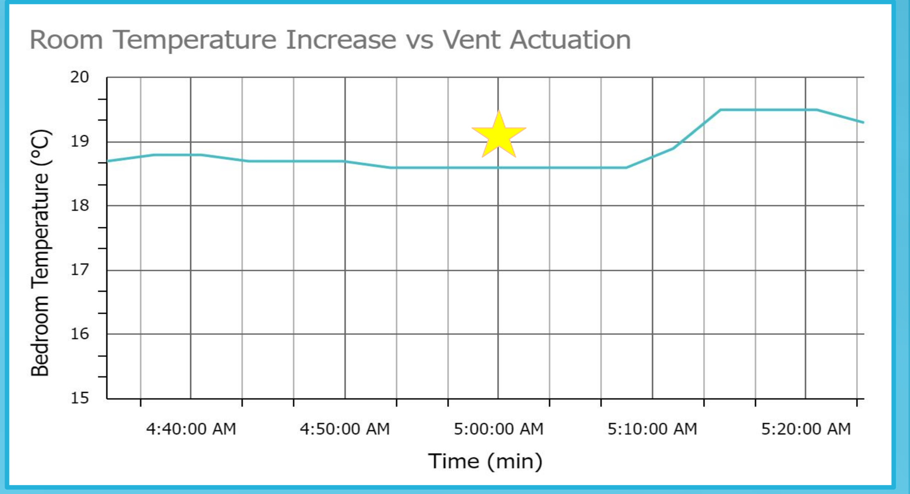


Results & Discussion

1. User defined temperature decrease



2. User defined temperature increase

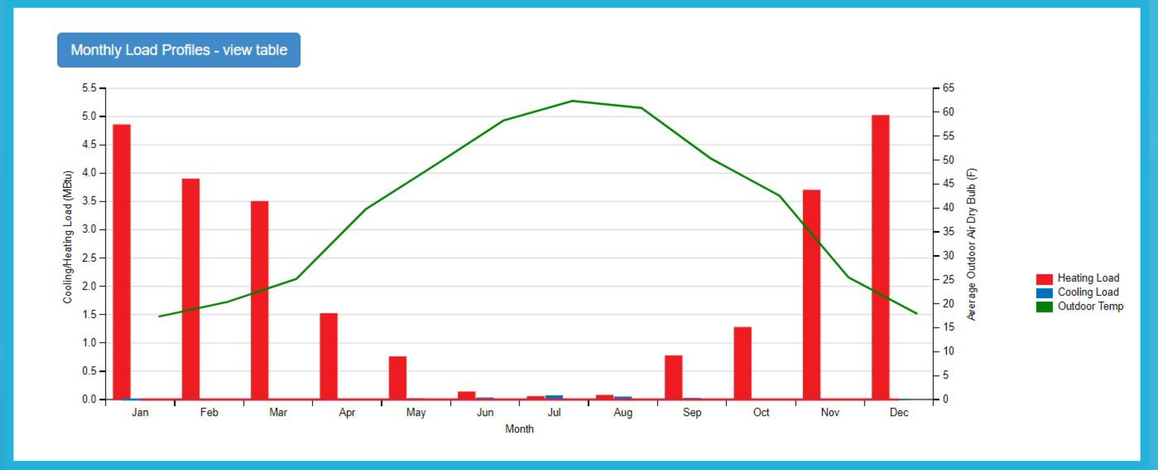


- Climate control: As seen from the room temperature/actuation graphs, the smart vents offer climate control. A temperature change of **+/- 1 °C** can be seen within **30 minutes** of vent actuation.

Active Testing Data			
Date	Heat Loss (kWh) Bedroom	Heat Loss (kWh) Spare Bedroom	Daily High/Low Temp (°C)
2023-03-24*	2.33	2.84	1, -6
2023-03-23	3.62	4.32	8, -6
2023-03-22	4.05	5.11	8, -9
2023-03-21	4.98	5.80	-2, -8
2023-03-20	4.34	5.12	2, -9
2023-03-19	4.58	5.37	4, -8
2023-03-18	4.35	5.20	4, -7

Inactive Testing Data			
Date	Heat Loss (kWh) Bedroom	Heat Loss (kWh) Spare Bedroom	Daily High/Low Temp (°C)
2023-03-15*	4.29	4.79	0, -11
2023-03-14	4.90	6.10	1, -11
2023-03-13*	6.46	4.63	-1, -16
2023-03-12	6.80	6.94	-11, -17
2023-03-11	7.30	7.88	-10, -17
2023-03-10	7.24	8.42	-12, -14
2023-03-09	5.14	8.36	-12, -19

- Energy savings: After comparing energy consumption results from both weeks of testing, a **14%** energy savings was found.



- Simulation results: OpenStudio was used to get a yearly estimate of the energy consumption. The model of the test house yielded a value of 66,925 kBtu, which is within 15% of the value obtained from the inactive testing.
- A simulation of the active testing was attempted on OpenStudio, and it showed a yearly savings of 10%, compared to 14% seen from testing.

Conclusions

- The smart vents yielded an energy savings of 14% for the rooms in which they were deployed. This was validated by our OpenStudio model.
- Rooms equipped with smart vents can expect to see temperature changes of **+/- 1 °C** within **30 minutes** of vent actuation.
- The smart vents fit inside a residential home and were able to be used for continuous testing for 7 days.
- The control system fit inside the vent and functioned accordingly.