2226 Midwest

A Net Zero Emission Strategy for Building

Heat Exchange System

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Abstract

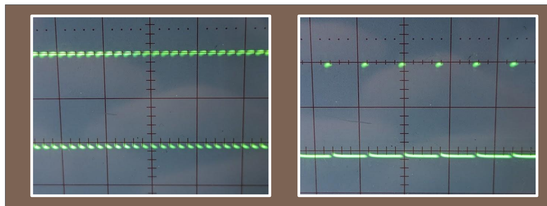
Climate change is one of the most pressing issues of today, and it is directly driven by our energy usage globally. Heating and cooling our built environment is a major contributor to that energy use. Many technologies, systems, and ideas have been proposed to reduce energy consumption in our homes, offices, and schools. We've elected to explore a modified version of a previous project called 2226, in which an office's thermal needs were met exclusively with passive technologies that allowed for ample fresh air circulation. However, this project needs extensive modifications to adapt it to the harsher climates. This is where the 2226 Midwest project comes in which strives to introduce small active components to achieve similar performance to the original project. Our component of the overarching project specifically focused on developing a heat exchanger system that allowed fresh air into the house to also uptake heat from the air being expelled. The project produced a partial prototype that demonstrates the concept and produces partial functionality. Overall, it fits into the broader scope of the project as a vital component to achieving high efficiency in difficult climates



The Original 2226 Project

Introduction

With the advent of high R-value insulations and advancements in window technologies, the concept of passive homes emerged. These homes leveraged these technologies to remove their need for traditional HVAC systems by being extremely efficient in their capture and retention of heat. With such tight envelopes, however, buildings start to run into a new problem. One of increased CO_2 concentrations—a problem traditional homes mitigated through their inherent porous nature. This problem was what the original 2226 Project set out to resolve. Using various natural ventilation and facade improvements, the goals of passive homes were able to be achieved while allowing ample fresh air. This, however, was very reliant on the climate of the environment it was built in, making it difficult to adapt to more extreme climates. This is the goal of the 2226 Midwest Project, where the high humidity of Midwest summers and the extreme cold of our winters are tackled through the minimal addition of active thermal management. One specific aspect is how we handle introducing fresh air into the building even when we're experiencing cold conditions. This is our active heat recovery system, where fresh air enters a corrugated material that allows exiting air to exchange heat with incoming air. This requires explicit control based on interior CO_2 concentrations. This project (a component of the whole 2226 Midwest Project) focused on implementing the embedded system and fan controller to manage this airflow into the heat exchanger.

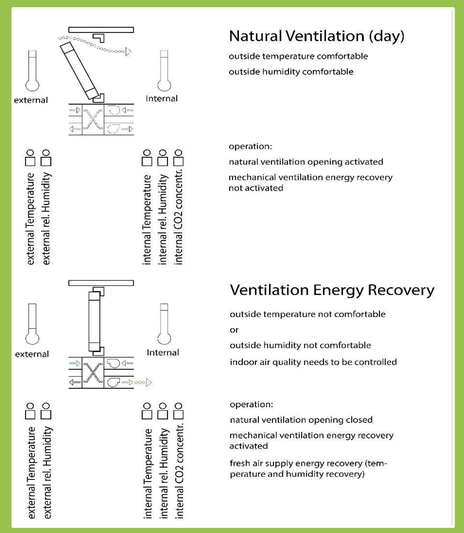


PWM Control Signals

Methods & Design

The design methodologies of the embedded system that governed the heat exchanger were one of trade-offs, power concerns, and fault tolerance. The whole of the project utilizes various Raspberry PIs as nodes, each collecting environmental data, coordinating commands, or executing actions. The software side of the system was broken into, the communication, the hardware abstraction, and the controller which sat between them. The communication between these nodes was selected to be MQTT, a protocol that operates on TCP. This decision was made against lower-level abstractions such as our own protocol implemented on top of TCP or much higher-level abstractions such as node-red. We elected to use MQTT as provided the greatest flexibility while allowing the quickest implementation. From there considerable attention was paid to how the hardware of the Raspberry Pi would be interacted with, such as how to access the hardware PWM (pulse width modulation) implementation, which controls fan speed. Often this can be done in software but that can be subject to operating system interrupts and can increase wear and tear on the fan itself. Thus pi-gpio was selected, because the library allowed for hardware-level PWM, and was controlled through a simple C program.

On the hardware side, two major design decisions were made on what microcontroller to use and what fans to use. The Raspberry Pi Zero 2 was selected as it gave us the advantage of having an operating system while having a very low power utilization. For fans, considerable emphasis was placed on quietness. This led us to utilize Noctua fans which gave us excellent performance, silent performance, and supported PWM.





Natural Ventilation Unit



Air Exchange Unit

Results & Conclusions

As the heat exchanger and its controller are a prototype and have plenty of potential for improvements and have some major flaws. The circuit design of the prototype lacks a functioning power-off system. It doesn't handle reconnecting to the network after power outages. The whole of the system lacks an easy setup and installation process. Some interesting improvements though would be how the system handles itself when the network is down for extended periods, and what decisions it should make locality with its limited information—perhaps utilizing local past actions to inform future actions or other more complex predictions. A tighter embedded system, on a single circuit board rather than the breadboard prototype.

Ultimately the heat exchanger system functioned with a network-supplied variable fan settings that was received over MQTT. The exchanger itself is still awaiting validation and testing. Developing the methodologies, technologies, and testing equipment is still in the works. Also, work is being done on a testing chamber to allow for accurate temperature conditions to be tested. However, the prototype system provides a promising glimpse into what is possible with these technologies.

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