Automated Window Temperature Regulator

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I. Introduction

A. Objective

Most houses and buildings tend to drive a lot of energy in the form of electricity into the HVAC (Heating, Ventilating and Cooling) system. This system is used to regulate and maintain temperature and air quality at a comfortable level for the occupants. As the threat of climate change grows, new technology is emerging to curb the impact of energy consumption and find alternative and efficient methods to electricity. Efficient interior climate control can be used to limit the power consumption HVAC systems within apartments and homes. As an alternative to using the air conditioning system, we can harness the outside climate to help regulate the interior temperature and air quality. This will take the strain off the HVAC system, resulting in lower power consumption. A simple and common way for the outside climate to enter the feedback loop between the HVAC and room is to open a window! Opening the window a certain amount can dictate how much the exterior temperature changes the temperature inside. Using this natural diffusion of air and temperature allows for less electricity to be consumed as well as a natural cross-ventilation for the room.

Our proposed solution is to use a window that is attached to a motor that opens and closes accordingly when given a certain desired interior temperature. The window will have sensors that measure rain and temperature, which will be fed into a microcontroller, which will compute the size of the opening of the window so the outside temperature can help regulate the interior temperature. An IR sensor will be attached for safety reasons in case there is obstruction as well as be used to calculate the position of the window. Once the sensor data is calculated, the microcontroller will drive the motor to change the position of the window to efficiently maintain the desired temperature (cool or heat). The system will be powered by a wall adapter and will have multiple modules for the sensors, motor, microcontroller and user interface.

B. Background

For a typical homeowner, energy expenditure becomes a costly monthly fee. If people are looking to save money, most of the time they will turn off their thermostat or match it with the outside temperature. This does help, but using heating and cooling in a building can build up cost. The typical heating and cooling can make “up about 42% of your utility bill” [1]. Electricity is just one part of the utility bill, as there are water costs and sometimes natural gas costs as well. For reference, “The average monthly residential electricity bill in Illinois is $87… and is… less than the national average of $107 per month” [2]. By helping reduce the use of electricity and natural gas in temperature management, a homeowner could save hundreds of dollars a year.

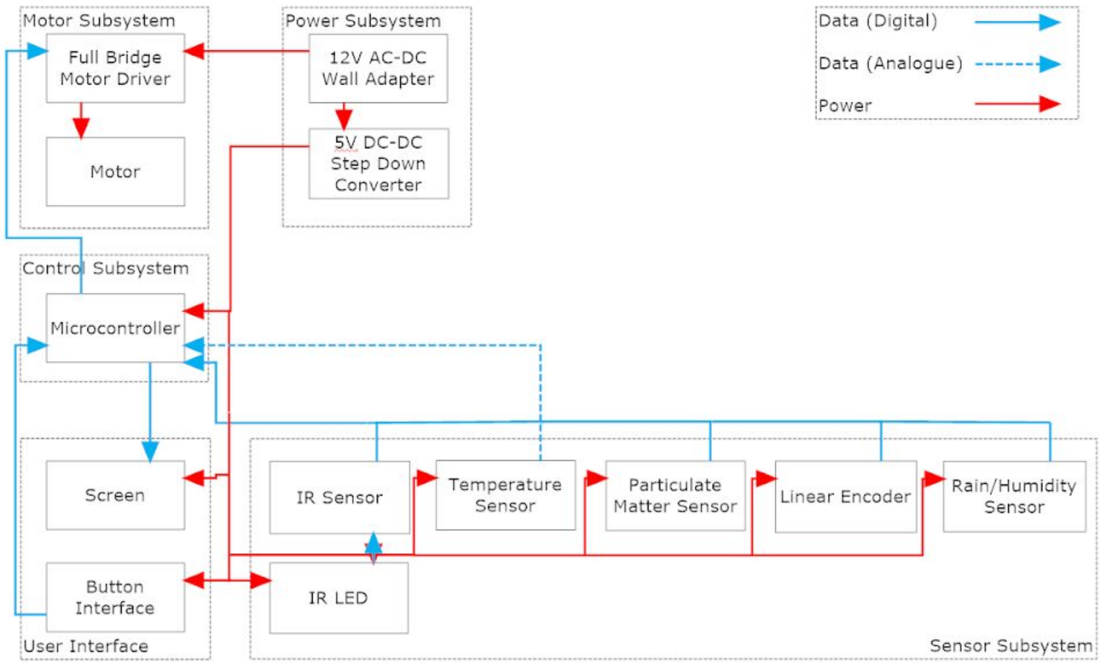
For cooling savings, the best time to open a window would be during the evenings and nights. If someone were to leave a window open at night, it could end up disastrous if there was a nighttime storm, high humidity, or a spike in a particulate matter like pollen. The consequences could be damaged furniture, damaged paper products, high AC unit work for humidity, or allergic reactions at night and in the morning. By having the window itself manage opening and closing, leaving a window open would be inconsequential as if conditions become undesirable, the window will close itself.

C. High-level Requirements List

1. Window should compare outside temperature and indoor temperature to open and close at proper times.
2. Window should stay open/closed based off of particulate matter in the air, humidity, and/or rain.
3. User should be able to adjust temperature threshold for the window.
4. System should incorporate a manual adjustment setting, so the user can override the automatic management

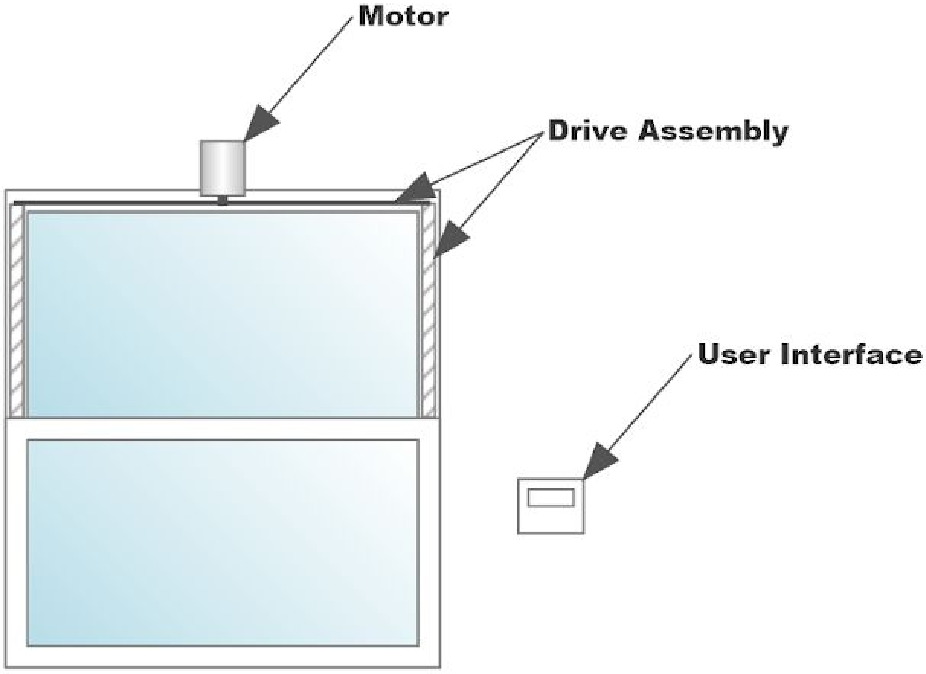
II. Design and Requirement

A. Block Diagram

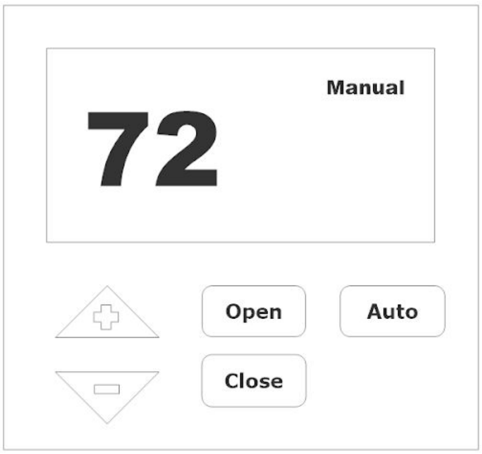


B. Physical Design

At a high level, the system will consist of 2 major components - the user interface and the window.



User Interface:



C. Modules

Power Module

The power module is required to run the motor when the control module requires the window to be open or closed and is needed to supply power to the microcontroller, user interface, and sensors. It consists of:

1. 12V AC-DC Wall adapter, to connect the system to the 120V AC mains power supply, and convert it to 12V, which is used to supply power to the motor, via the full bridge motor driver

Requirements:
- Output a steady 12V to power the system at a safe operating temperature, with minimal power loss
- Supply a high enough peak current to run the motors
2. 5V DC-DC Step down converter, which supplies 5V DC to the rest of the system. In order to maintain a steady output (thus smooth operation), we will use a buck converter, despite the power loss.
   Requirements:
   - Step down the 12 volts from the adapter to output a steady 5V to operate the microcontroller and peripheral devices

Control Module
The control module consists only of the microcontroller, which receives data from the peripheral devices, processes this information, then decides whether to activate the motor driver according to a set of predetermined parameters.

Motor Module
The motor module will be mechanically linked to the window, to open and close it when instructed to do so by the microcontroller. The module consists of two elements:
1. Full bridge motor driver - this will allow the microcontroller to operate the motor in both forward and reverse directions, to open and close the window. A full bridge driver also only requires a positive rail and ground connection, which saves on circuit complexity (as opposed to needing a negative rail as well).
   Requirements:
   - Supply power to the DC motor at opposite polarities to allow it to operate in both directions
2. 12V Brushed DC Motor - the motor will be mechanically coupled to the window, to open and close it. It will receive power from the full bridge motor driver.
   Requirements:
   - Have sufficient torque to open the window without difficulty
   - Open the window in less than 10 seconds
   - Operate quietly (around 30dB, or less)

User Interface Module
The user interface will allow the operator to either control the window position manually or set it to automatic mode, in which case the window will open and close according to the measurements made by the sensors. The interface will consist of:
1. LCD screen to display desired temperature, and operating mode
   Requirements:
   - Clearly display desired information
2. Buttons - Temperature up/down, automatic mode, open/close window (manual mode)

Requirements:

- Easily depressed; debounced to be as user friendly as possible

Sensor Module

The sensor module has all the sensors for our system and relays information back to the microcontroller. The information will come from a temperature sensor, IR sensors, a rain/humidity sensor, and a particle sensor.

1. Temperature Sensor
   The temperature sensor should monitor the outside and inside temperature and relay the information back to the microcontroller.
   Requirements:
   - Will be powered by 5 V.
   - An ADC coded into the microcontroller will be used to convert the information from the temperature sensor to digital information for the microcontroller to read.
   - Can accurately read temperature within 1C/1.8F
2. IR Sensors
   The IR Sensors will be positioned around the frame to send an alert if there is an obstruction at the window opening.
   Requirements:
   - Will be powered by 5 V.
   - Needs a source of infrared, which will be a high intensity IR LED.
   - The LED will be pulsed at a high frequency so an HPF will be used by coding one inside the microcontroller to only detect the IR LED.
   - IR sensors will be positioned equally along the window to cover a larger volume.
3. Rain/Humidity Detector
   The detector will give out information about the humidity and the presence of rain to the microcontroller.
   Requirements:
   - Will be powered by 5 V.
   - Needs to be able to detect slight presence of water like humidity.
4. Particulate Matter Sensor
   This sensor will give out a measured quantity of particulate matter to the microcontroller.
   Requirements:
   - Will be powered by 5 V.
   - Will need to be able to detect small particles like pollen and dust (down to 2.5 μm [4])
5. Linear Encoder
   The encode will measure the absolute position of the window to determine how far open it is at any time.
   Requirements:
   - Will be powered by 5 V
   - Provide window position to within 0.5mm

D. Risk Analysis

One of the bigger risks in this project is the reliability of the sensors we can find. It is hard to find a sensor that can do exactly what we want, especially sensors that can detect small particles and give us an accurate count. Also, a rain/humidity sensor is quite rare to find as many don't have a specific limit of moisture that we can adjust and come with a simple one-wire signal (low or high depending on the trigger). We feel most of the issues will come from sensors not functioning the way they were intended to, and much of the debugging will come from experimenting with sensor values and thresholds. Since we are working with so many variables, one bad sensor could derail our project a lot.

III. Ethics and Safety

We believe that our project does not have any ethical concerns. We will ensure that our project will take into account the safety and concerns of the user. Because this is an automated system which runs unsupervised, we want to be transparent with concerns we have ourselves and convey them to the user. As a notice, we will be transparent with safety issues we see and warn the user to follow the IEEE code of ethics; more specifically, the first point where we will "disclose promptly factors that might endanger the public or the environment," [3]. Another IEEE Code of Ethics point that we will follow is "avoid injuring others, their property, reputation, or employment by false or malicious action," [3]. As stated before, because of the unsupervised nature of this project, we will ensure that we the safety of the user is our first priority. We will ensure that the window will have sensors and overrides any action to stop movement in case of obstruction.

Another safety concern we have is the sensors we have are electronic and may be exposed to hazardous weather. Water can cause the circuitry to short circuit, which presents a fire hazard and risk of electrocution, which could cause damage to the home, window and anyone close by. We shall make sure that all circuits and sensors are properly shielded from any potential situations that could lead to this concern. Next, we also want to make sure that while working on the system, we take all the safety precautions in the lab. Working with power, circuits, and tools we could cause hazards like explosions and electrical fires if we are not careful. If we are careful and follow all lab procedures from the ECE 445 guidelines and ask for help on concerns we have, we will be protecting ourselves, classmates from any dangerous situations in the lab.

Finally, as a group of three, we will follow the Code of Ethics and hold each other accountable to follow these concerns of ethics and safety. Point nine states "assist colleagues and co-workers in their professional development and to support them in following this code of ethics," [3]. Working together to ensure we meet these standards will ensure that our project will be made without malicious intent and ensure that we take into account the safety of the user at all phases.

IV. References

[1] Energy.gov. (2019). *Home Heating Systems*. [online] Available at: https://www.energy.gov/energysaver/heat-and-cool/home-heating-systems [Accessed 12 Sep. 2019].

[2] Electricity Local. (2019). *Champaign, IL Electricity Rates*. [online] Available at: https://www.electricitylocal.com/states/illinois/champaign/ [Accessed 12 Sep. 2019].

[3] IEEE.org. (2019). *IEEE Code of Ethics*. [online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 13 Sep. 2019].

[4] US EPA. (2019). *Particulate Matter (PM) Basics* | *US EPA*. [online] Available at: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics [Accessed 16 Sep. 2019].