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ECE 416 Senior Design Project

Team number # 1

Project Title: Vent Booster

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Abstract

This project introduces a vent booster system designed to optimize central air conditioning efficiency. Using mechanical and electrical components, it enhances duct airflow, ensuring temperature balance. Featuring a user-friendly interface and smart home integration potential, it caters to comfort-seeking homeowners and energy-conscious consumers.Addressing the need for cost-effective, energy-efficient climate control, it boosts existing HVAC airflow. This device improves HVAC efficiency and reduces energy consumption.

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Introduction

The centralized air conditioning systems have become a very integral part of modern life, providing homeowners and residents the ability to control climate in their homes, offices, factories and commercial buildings. These systems offer us very efficient cooling and heating solutions. However these systems can be traced back to several thousands of years. Many civilizations have attempted and formed their own manner of climate systems. The ancient Egyptians used several methods to cool indoor spaces. The Egyptians used reeds hung in windows soaked with water to cool incoming air through evaporation[2]. Although the ancient civilizations used their methods to cool their homes. Modern centralized air conditioning is more centered around the 19th and early 20th centuries.

Willis Harvard Carrier is generally attributed to centralized air conditioning. In 1902, Carrier invented the very first electrical air conditioning system that both controls temperature and humidity [1]. Modern day air conditioning systems work together with the refrigeration cycle to provide indoor cooling. This cycle operates by managing the energy state of the system's refrigerant: Certain components of the system contain refrigerant with a high energy content, poised to discharge heat, while other components contain refrigerant with low energy levels, primed to soak up heat[3].

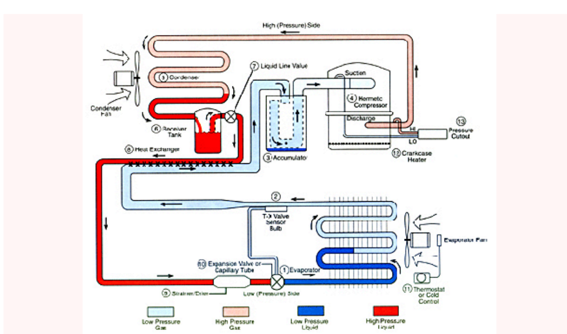


Figure 1. The Refrigeration Cycle

The modern air conditioning system emphasizes sustainability. Engineers and manufacturers are working on systems that use renewable energy to explore ways to lower global warming potential.

The vent booster we are trying to produce addresses several problems in a centralized air conditioning system. Some of these problems can be address below:

- No power to the air conditioner - Faulty wiring can disrupt the unit proper functioning and be a safety hazard[7].
- The outdoor unit doesn't switch on - there might be problems with the breaker or wire, or there might be a defective thermostat[7].
- Fans don't run - there can be problems with the grounded compressor or the fan motor, a weak breaker, or a defective contactor[7].
- Compressors stop working - there can be problems with the thermostat settings, or blown fuses[7].
- Air Conditioning leaks water - this problem is addressed more mechanically, where there can be a clogged drain or ice buildup on the unit. There might be a need for a replaced evaporator coil pan[7].
- The AC unit runs continuously - this indicates there might be low refrigerant levels, reducing efficiency[7].

These are some of the general issues most central air conditioners face, and result in an unpleasant experience for the consumer.

The AirTap Series Register Booster Fan System is a specific type of vent booster designed to improve airflow to individual rooms by boosting the output of existing HVAC registers (floor or wall vents). Here's an overview of the adopted approach when installing an AirTap Series Register Booster Fan System:

A vent booster, also known as a booster fan or duct booster fan, is used to improve the airflow in a ventilation system. The objective of a vent booster is to increase the efficiency of air circulation in a specific area or room within a building. Here are other uses for a vent booster:

1. **Improve Airflow:** Vent boosters are used when there is not enough airflow in certain areas of a building, such as rooms with not enough defusers or areas with poor ventilation. They help push or pull air to these spaces, improving comfort and air quality.

2. **Temperature Regulation:** In cases where some rooms are warmer or cooler than wanted, vent boosters can help distribute air more evenly, reducing undesired temperatures.

3. **Balancing Air Distribution:** In large buildings with complex ductwork, it can be challenging to achieve a balanced distribution of air. Vent boosters can be strategically placed to make sure that each area receives the appropriate amount of airflow.

4. **Economical Operation:** By improving airflow to areas, vent boosters can help reduce the need for running the central HVAC system at a higher capacity, saving energy and lowering costs.

5. **Addressing Dead Zones:** Certain areas of a building may have stagnant air or dead zones where contaminants or odors accumulate. Vent boosters can help remove stagnant air pockets and improve air quality.

6. **Enhance Ventilation:** In kitchens and bathrooms, vent boosters can be used to increase the effectiveness of exhaust fans, making sure that moisture, odors, and pollutants are vented to the outside.

7. **Solving Pressure Imbalances:** In commercial and industrial settings, vent boosters can be used to address pressure imbalances caused by a variety of factors, such as HVAC system changes, exhaust equipment, or building layout changes.

8. **Supporting HVAC System:** Vent boosters can alleviate strain on the central HVAC system by reducing the need for it to work harder to distribute air throughout the building.

It's important to note that vent boosters should be used carefully. Improperly sized or placed booster fans can potentially create issues such as noise, increased energy consumption, or imbalances in the ventilation system.

The vent booster we are designing is to improve airflow in individual rooms by boosting the output of existing HVAC registers (floor or wall vents). Here's an overview of the adopted approach when installing the vent booster:

1. **Assessment of Airflow Issues:**
    - Identify the specific rooms or areas in the building where poor airflow or temperature imbalances are occurring.

- Determine the cause of the airflow issues, which could be due to long duct runs, restricted airflow, or inadequate HVAC system capacity.

2. **Selection of Register Locations:**
    - Decide which HVAC registers (floor or wall vents) in the affected areas will benefit from booster fans. Usually, installing booster fans in the registers farthest from the central HVAC system or in areas where airflow is insufficient.
3. **Sizing and Installation:**
    - Choosing the appropriate Booster Fan models based on the size and type of registers in the selected locations. These booster fans are available in various sizes to fit different register dimensions.
    - Install the booster fans in the chosen registers. The installation process usually involves securing the booster fan in place, connecting it to a power source, and attaching the included sensor to the register grille.
4. **Wiring and Control:**
    - Connecting the booster fans to a power source. Some models may require hardwiring, while others can plug into a standard electrical outlet.
    - Configure the control settings for the booster fans. Most models come with a built-in thermostat and fan speed control. You can set the desired temperature and fan speed to activate the booster fan when needed.
    - Writing a C++ program to control the vent booster operations to ensure vent booster is automated.
5. **Testing and Adjustment:**

    - Test the booster fans to ensure they activate as intended when the temperature in the room falls below the set threshold.
    - Adjust the thermostat settings and fan speed as needed to achieve the desired comfort level and airflow.
6. **Regular Maintenance:**
    - Periodically clean the booster fan blades and registers to prevent dust and debris buildup, which can reduce efficiency.
    - Check for any loose connections or issues with the booster fans and address them quickly.
7. **Monitoring and Optimization:**
    - Monitor the performance of the Booster Fan System over time to ensure it continues to address airflow issues.
    - Make adjustments as necessary to optimize the system's performance, such as changing the thermostat settings or relocating booster fans if needed.

The most prominent trend within the HVAC field is the integration of smart HVAC systems with automated home technology and the Internet of Things. This integration will allow homeowners to control their vent booster systems remotely using their smartphones or other devices. Along with comfort and convenience, we can achieve energy savings by setting triggers to activate HVAC units exactly when we need them [4]. With the help of AI and IoT within smart HVAC systems, owners will be more aware of important factors that can affect their systems. Data on air quality and equipment status can be detected early so any problems can be fixed before severe damage occurs [4]. Along with households, smart HVAC systems are also made to benefit workplaces. Temperature is one of the major complaints from workers who have to show up in person. Smart HVAC systems provide a solution to this problem as employees can now report their comfort level so that facilities can see where the problem is and make adjustments to the HVAC system settings [5]. This can also help find hot or cold spots within the building, notifying management that there might be an issue with the level of insulation. Utilizing these smart systems, users can set specific settings and track their energy usage, enhancing overall efficiency and providing greater convenience.

Another trend in central air conditioning efficiency revolves around zone control systems. These systems use dampers distributed throughout the building, blocking or releasing hot or cold air. Users can set the temperature on thermostats connected to a central control panel for a specific zone and the system will apply those settings [6]. This system allows users to set different rooms to different temperature settings since there are many factors that affect indoor temperature. Zone control systems can give users full control over their home's temperature level, solving the problem of excessively heating or cooling rooms to compensate for rooms that are too warm or too cool, or rooms that are unoccupied at different times of the day [6]. This system provides high energy efficiency for users, saving their money along the way.

Vent booster systems in HVAC have several related real-world systems such as air handling units and variable air volume (VAV) systems. Air handling units are responsible for producing clean and healthy indoor air quality. If poorly maintained, they can negatively impact the room occupants. This system is also very costly as there are initial investments, including components and installation, and other long term investments such as maintenance and filter replacements. In order to keep AHUs for a long time, owners have to be willing to spend often. Variable air volume systems optimize energy-efficient HVAC system distribution by optimizing the amount and temperature of distributed air [8]. The VAV system can have greater maintenance intensity due to the additional components of dampers, sensors, actuators, and filters, depending on the VAV box type [8]. Since there has to be more maintenance for a more efficient system, the cost would increase. There are also issues with research developing artificial intelligence and smart control systems that can be integrated into the variable air volume system. Researchers are working on maintaining comfort by creating control strategies that can respond to factors affecting the indoor air. Both of these systems are related to vent booster systems as they are used to improve ventilation and airflow in any area or room desired. It is important to take these issues into consideration to improve the performance of vent booster systems, enhancing their ability to keep their users comfortable, making them more energy-efficient, and increasing their life span while also keeping maintenance requirements to a minimum.

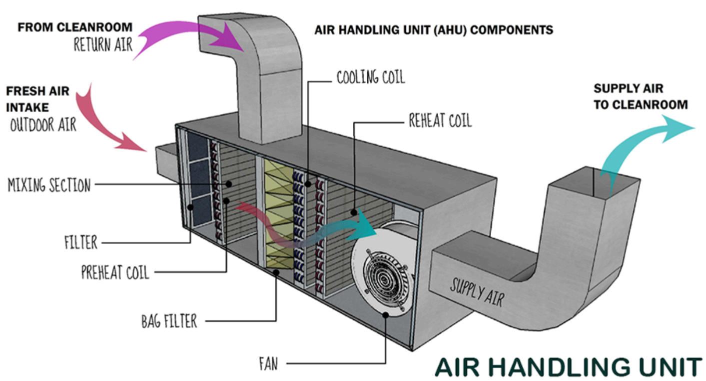


Figure 2: Air Handling Unit (AHUs)

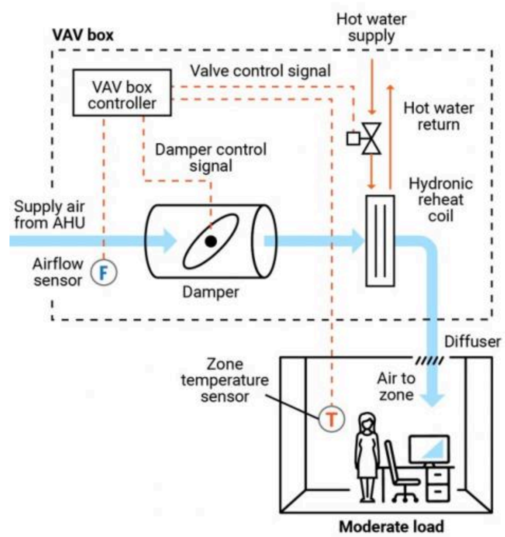


Figure 3: Variable Air Volum

2. Project Accomplishments:

2.1 Technical goals:

1-Designing energy-efficient electrical systems. The electrical engineers will focus on selecting energy-efficient components, optimizing circuit designs, and minimizing power losses. Additionally, we may explore the use of energy storage solutions.

2- Designing and optimizing control systems that manage electrical components. We will focus on creating efficient control algorithms, fine-tuning control parameters, and ensuring that the system responds accurately to inputs.

3- involves software control, a software engineer may be responsible for developing and maintaining the control software. He should ensure that the software is reliable, bug-free, and capable of handling various control scenarios.

2.2 Testing And Performance Measures

Time (Hours)	Temp without Fans (°F)	Temp with Fans (°F)
0	78	78
1	78	77
2	78	76
3	78	76
4	78	75
5	78	75
6	78	74
7	78	74
8	78	73

Figure 4. Data values for the functionality of the Vent Booster

2.3 Specifications

The specifications desired for this project are:

- Maintain constant temperature regulation in the room of the consumers desire
- Make sure and monitor that the temperature and the code is working as desired for a large period of time.
- Make sure that the vent booster can turn off on it own while the temperature is desired for the room set by parameter

2.4 Engineering Standards

Relevant engineering standards, project constraints, risk and uncertainty.

1. IEEE # 21451-2-2010, "Smart transducer interface for sensors and actuators -- Part 2: Transducer to microprocessor communication protocols and Transducer Electronic Data Sheet (TEDS) formats"

   Abstract:

   A digital interface for connecting transducers to microprocessors is defined. A TEDS and its data formats are described. An electrical interface, read and write logic functions to access the TEDS and a wide variety of transducers are defined. This standard does not specify signal conditioning, signal conversion, or how the TEDS data is used in applications.

   -This standard projects any concerns we may have using and understanding the microcontroller in our project
2. IEEE # C37.92-2023, "IEEE Standard for Low-Energy Analog Interfaces between Protective Relays and Power System Signal Sources"

   Abstract:

   Electronic devices that develop or utilize analog signals are not presently covered by standards. Interface connectivity of modern power-system signal transducers based on electronics, such as magneto-optic current transducers and electronic relays, are provided in this standard. The existing standardized levels from familiar magnetic current and voltage transformers are not readily generated by new types of electronic signal transducers.

-This standard describes a transducer which is commonly used for thermostats and can be useful for installing and programming the thermostat in the project.

3. IEEE # 484-2019, "IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications"

   Abstract:

   Recommended design practices and procedures for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of vented lead-acid batteries are provided. Required safety practices are also included. These recommended practices are applicable to all stationary applications. Specific applications, such as emergency lighting units, semi portable equipment, and alternate energy applications, may have other appropriate practices and are beyond the scope of this recommended practice.

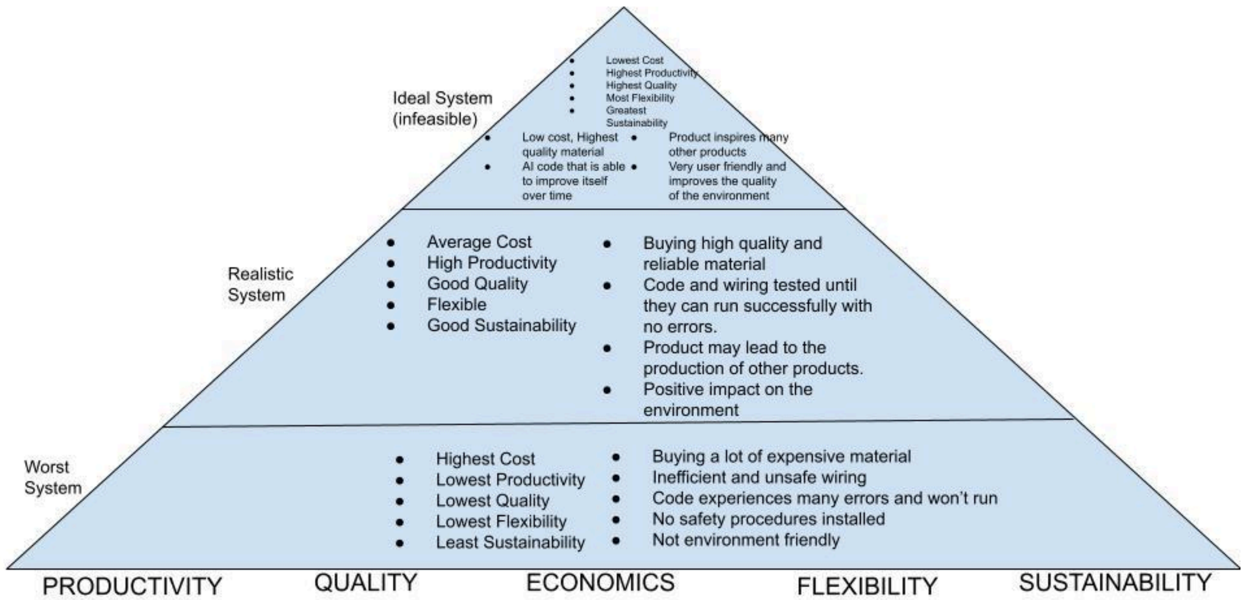
   -This standard is important as we are working with vents and fans, and we will need to take into consideration installation of vents.

2.5 Budget

Vent Booster Budget	
Materials	Price
Fan axial(2)	$20.00
Breadboard Wire kit	$11.36
components(NPN Mosfet,Potentiometer, Sensor, LCD Module Display)	$14.90
Vent frame	$15.00
Arduino R3	$14.99
12V Battery	$23.80
Total	$100.05

2.6 Summary Of the Project Accomplishments and the Future Potential

- Use of Mosfets to enhance and accomplish the desired performance of the project
- Code for microcontroller was accomplished and was used as the main core for the entire project.
- Design of the project hardware design was concise and detailed for easy assembly and understanding.
- Smart Home Interface
- Smart Home Application Via Bluetooth
- Mass production for homeowners, and rental spaces.
- More compact design
- Marketability



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3. Learning Experience

Throughout the course of this project, we gained significant insights into several key technological components. Firstly, we observed the practical application of MOSFETs, particularly N-type MOSFETs, which we utilized to amplify signals from a microcontroller to power 12V fans effectively. Additionally, we learned that temperature sensors are delicate and prone to damage from physical contact, highlighting the need for careful handling. Furthermore, our exploration into wireless communication revealed that Bluetooth applications tend to perform more optimally with Android devices compared to Apple products. This project not only enhanced our understanding of these elements but also provided valuable hands-on experience.

4. Analysis of constraints, risk and uncertainty.

4.1 Projected community impact and relevant ethical issues:

The vent booster, designed to enhance ventilation efficiency and air quality, is expected to have several positive impacts on the community:

Improved Indoor Air Quality: By effectively circulating and ventilating indoor air, the vent booster can help reduce pollutants, allergens, and odors, leading to healthier living and working environments for community members.

Energy Efficiency: Enhancing ventilation efficiency can result in reduced energy consumption for heating and cooling, leading to lower utility bills and reduced carbon emissions, contributing to energy conservation and sustainability efforts.

Enhanced Comfort: Better ventilation can create more comfortable living and working spaces, promoting overall well-being and productivity among community members.

Emergency Response Support: In emergency situations, such as fires or chemical spills, the vent booster can aid first responders by quickly clearing smoke or toxins from buildings, improving safety during rescue operations.

Relevant Ethical Issues:

Several ethical considerations surround the development and deployment of the vent booster to ensure its responsible and beneficial use:

Safety and Reliability: Ensuring the vent booster's reliability and safety is paramount, especially in emergency scenarios. Ethical concerns include rigorous testing, maintenance protocols, and compliance with safety standards to prevent malfunctions or accidents.

Inclusivity and Accessibility: Designing the vent booster control interface to be accessible and user-friendly for individuals with disabilities is an ethical imperative to ensure equitable benefits for all community members.

Environmental Responsibility: Minimizing the environmental impact of the vent booster's manufacturing and operation is essential. Ethical practices include using eco-friendly materials, energy-efficient components, and promoting recycling or responsible disposal of system components.

Data Privacy and Security: If the vent booster collects and processes data, safeguarding user privacy and data security is vital. Ethical concerns involve transparent data usage policies, consent mechanisms, and protection against data breaches.

Resource Allocation: Ethical considerations also encompass equitable access to the benefits of the vent booster. Ensuring that the technology is affordable and accessible to a broad spectrum of the community helps avoid exacerbating social inequalities.

Transparency and Accountability: Providing clear information about the vent booster's capabilities, limitations, and potential risks is essential. Ethical practices include transparent marketing and clear instructions for users.

4.2 Relevant engineering standards

4. IEEE # 21451-2-2010, “Smart transducer interface for sensors and actuators -- Part 2: Transducer to microprocessor communication protocols and Transducer Electronic Data Sheet (TEDS) formats”

   Abstract:

   A digital interface for connecting transducers to microprocessors is defined. A TEDS and its data formats are described. An electrical interface, read and write logic functions to access the TEDS and a wide variety of transducers are defined. This standard does not specify signal conditioning, signal conversion, or how the TEDS data is used in applications.

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   -This standard is important as we are working with vents and fans, and we will need to take into consideration installation of vents.

4.3 Constraints

There are different constraints with these devices, including technical, safety, and operational constraints. Here are three of them:

1. **Technical Constraint**: Motor and Fan Size Limitations
   - Vent boosters have motors and fans that come in different sizes and capacities. One technical constraint is the limitation on the size and capacity of the motor and fan. This constraint depends on the available power supply and space for installation. Selecting a motor and fan that are too large for the space can lead to issues like excessive noise and power consumption. On the other hand, using a motor and fan that are too small might not provide enough ventilation.
2. **Safety Constraint**: Fire and Electrical Safety Regulations
   - Vent boosters being electrical devices must comply with safety regulations. There are strict guidelines regarding the electrical components, wiring, and fire safety. For instance, the materials used in the construction of the booster must be fire-resistant and the wiring should be done to prevent electrical hazards such as short circuits or overheating. Not abiding fire compliances can result in electrical fires.
3. **Operational Constraint**: Noise and Vibration Control
   - Noise and vibration control are major operational constraints. Excessive noise generated by the booster fan can be disruptive and uncomfortable for occupants. Moreover, vibrations can lead to structural issues over time. Therefore, designing and installing the vent booster with noise and vibration control measures, such as

isolating the fan from the structure or using sound-absorbing materials, is vital to ensure smooth and quiet operation.

Addressing these constraints is critical to the effective and safe operation of vent boosters while ensuring that they meet the required ventilation and air circulation needs.

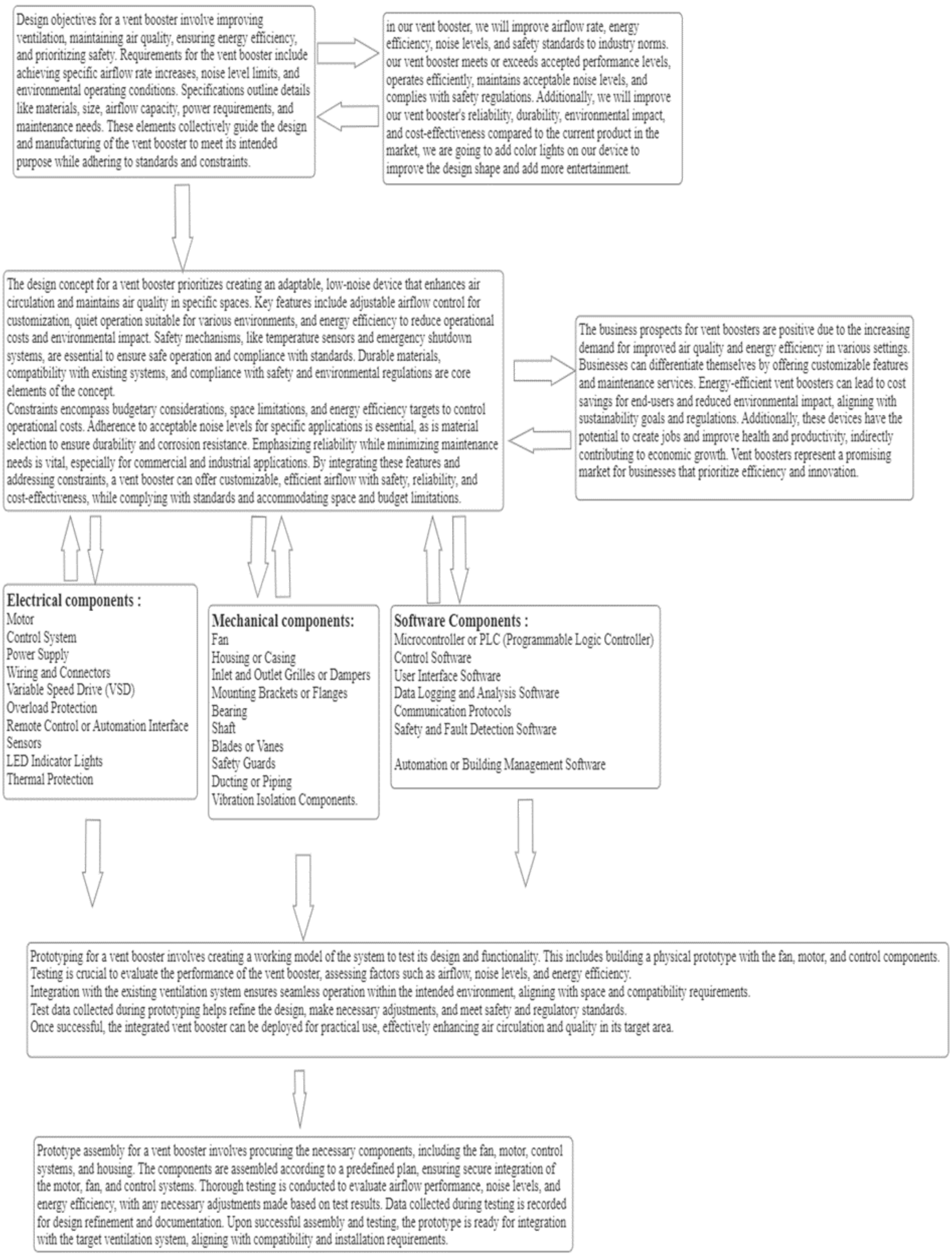
4.4 Risk Assessment

Risk Table

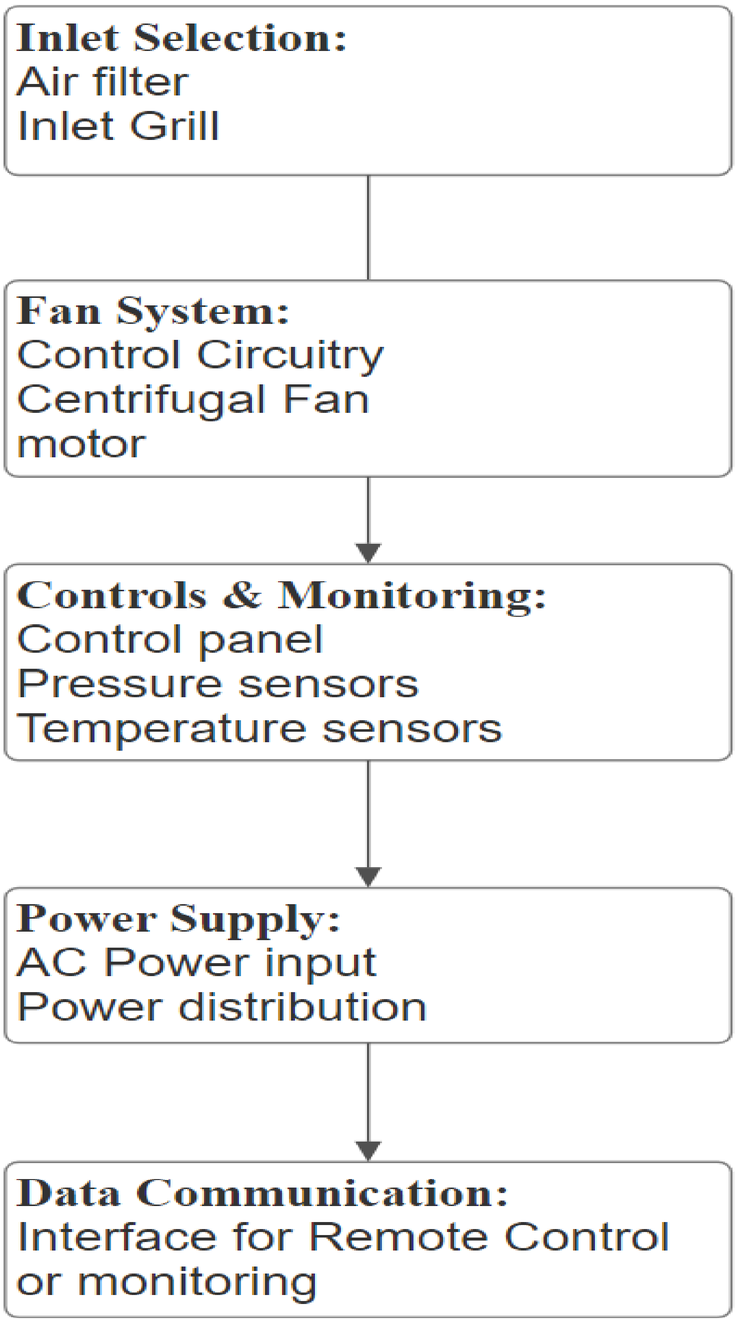
Technical Goals	**Low**	**Moderate**	**High**
Designing Energy-Efficient Electrical Systems			X
Designing and Optimizing Control Systems That Manage Electrical Components		X	
Developing and Maintaining the Control Software		X	

Design methodology, prototyping and validation, hardware block diagram.

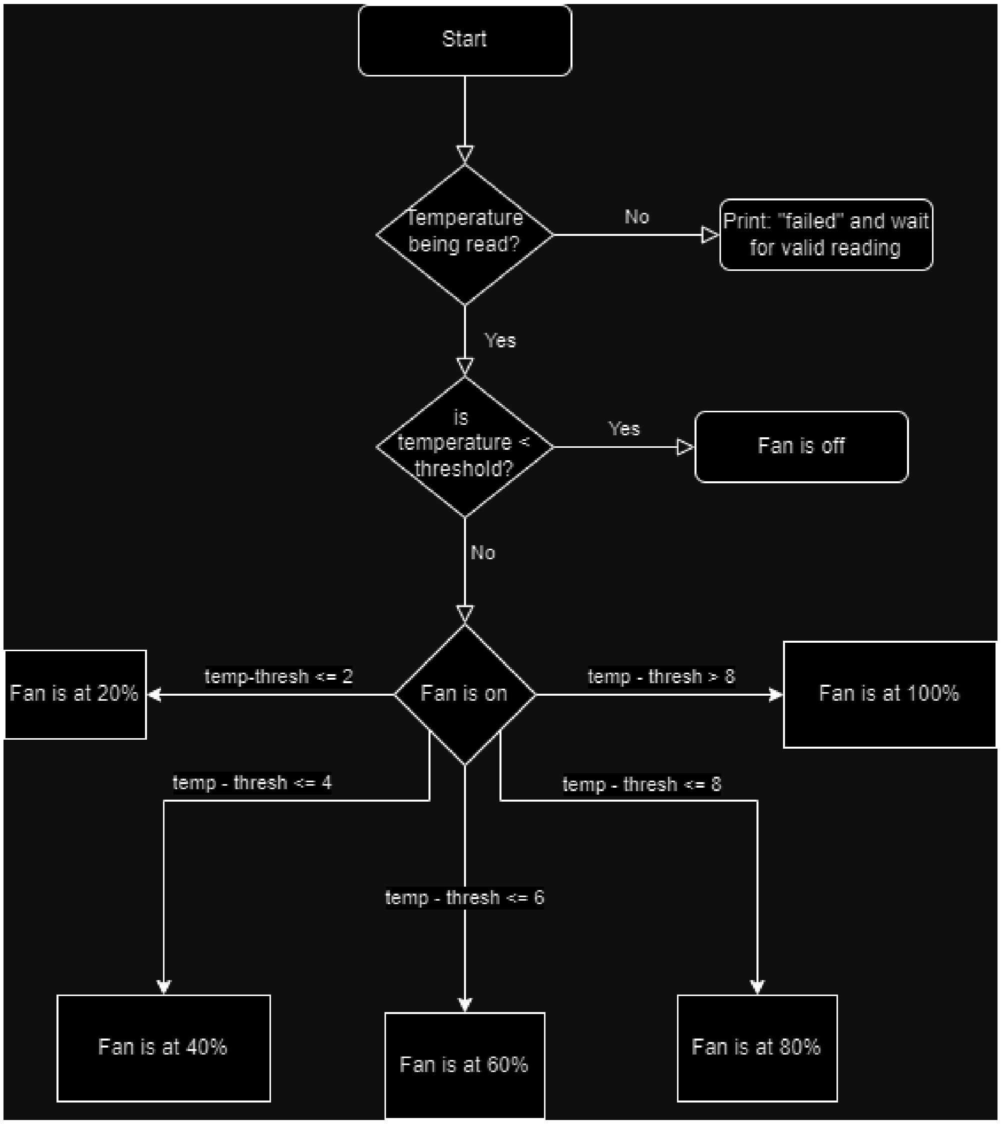
Flow Chart:



Block Diagram:



Software Flow Chart.



Timeline and Milestones

Date	Start	Finish
September 15, 2023	1:00pm	3:00pm
September 22, 2023	1:00pm	3:00pm
September 29, 2023	1:00pm	3:00pm
October 4, 2023	7:00pm	10:00pm
October 6, 2023	1:00pm	3:00pm
October 13, 2023	1:00pm	3:00pm
October 20, 2023	1:00pm	3:00pm
October 26, 2023	7:00pm	9:00pm
October 27, 2023	1:00pm	3:00pm
November 3, 2023	1:00pm	3:00pm
November 10, 2023	1:00pm	3:00pm
November 17, 2023	1:00pm	3:00pm
November 24, 2023	1:00pm	3:00pm
December 1, 2023	1:00pm	3:00pm
December 8, 2023	1:00pm	3:00pm
January 2, 2024	5:00pm	7:00pm
January 5, 2024	5:00pm	7:00pm
January 8, 2024	5:00pm	7:00pm
January 12, 2024	5:00pm	7:00pm
January 15, 2024	5:00pm	7:00pm
January 19, 2024	2:00pm	5:00pm
January 22, 2024	2:00pm	5:00pm

Date	Start	Finish
September 15, 2023	1:00pm	3:00pm
September 22, 2023	1:00pm	3:00pm
September 29, 2023	1:00pm	3:00pm
October 4, 2023	7:00pm	10:00pm
October 6, 2023	1:00pm	3:00pm
October 13, 2023	1:00pm	3:00pm
October 20, 2023	1:00pm	3:00pm
January 26, 2024	2:00pm	5:00pm
January 29, 2024	2:00pm	5:00pm
February 2, 2024	2:00pm	5:00pm
February 5, 2024	2:00pm	5:00pm
February 9, 2024	2:00pm	5:00pm
February 12, 2024	2:00pm	5:00pm
February 16, 2024	2:00pm	5:00pm
February 19, 2024	2:00pm	5:00pm
February 23, 2024	2:00pm	5:00pm
February 26, 2024	2:00pm	5:00pm
March 1, 2024	2:00pm	5:00pm
March 4, 2024	2:00pm	5:00pm
March 8, 2024	2:00pm	5:00pm
March 11, 2024	2:00pm	5:00pm
March 15, 2024	2:00pm	5:00pm
March 18, 2024	2:00pm	5:00pm

March 22, 2024	2:00pm	5:00pm
March 25, 2024	2:00pm	5:00pm
March 29, 2024	2:00pm	5:00pm
April 1, 2024	2:00pm	5:00pm
April 5, 2024	2:00pm	5:00pm
April 8, 2024	2:00pm	5:00pm
April 12, 2024	2:00pm	5:00pm
April 15, 2024	2:00pm	5:00pm

Conclusion

In our collaborative effort to design and propose a vent booster, we successfully completed several crucial tasks that laid the foundation for our project. Our initial focus was on researching the necessary parts and software required for the construction of the vent booster. This involved thorough investigation and discussions to identify the most suitable components and tools for our project.

The face-to-face meetings were instrumental in fostering a comprehensive understanding of our individual strengths and areas of expertise, leading to a more effective division of tasks. The collaborative brainstorming sessions facilitated a creative exchange of ideas and ensured that we were aligned in our vision for the vent booster.

Simultaneously, we delved into researching the budget and costs associated with the project. This phase required meticulous planning and financial analysis to ensure that our proposal was not only technically sound but also financially feasible. By gaining a comprehensive understanding of the costs involved, we laid the groundwork for making informed decisions about resource allocation.

Furthermore, we were able to take advantage of the time allotted to work on our idea. Consequently we built a project that worked and completed our objectives as a team. We learned to work with our individual strengths and overcome our weaknesses.

8. References:

[1]“Global Cooling: The History of Air Conditioning.” *ASME*, www.asme.org/topics-resources/content/global-cooling-the-history-of-air-conditioning#:~:text=Willis%20Carrier%3A%20The%20Father%20of,printing%20plant%20in%20Brooklyn%2C%20NY. Accessed 25 Sept. 2023.

[2]Mohamed, Mady. (2010). Traditional Ways of Dealing with Climate in Egypt. Accessed 25 September 2023.

[3]“Global Cooling: The History of Air Conditioning.” *ASME*, www.asme.org/topics-resources/content/global-cooling-the-history-of-air-conditioning#:~:text=Willis%20Carrier%3A%20The%20Father%20of,printing%20plant%20in%20Brooklyn%2C%20NY. Accessed 25 Sept. 2023.

[4]Editorial, T. (2022, September 30). *Automation is the way forward for Smart hvac*. Thermal Control Business Update | HVAC-R Industry. https://thermalcontrolmagazine.com/lets-talk/automation-is-the-way-forward-for-smart-hvac/. Accessed 25 Sept. 2023

[5]Rosone, M. C. (2022, August 4). *Smart Hvac & Sensor Technology for smart buildings*. Arista. https://aristair.com/smart-hvac-sensor-technology-for-smart-buildings/. Accessed 25 Sept. 2023

[6](Grafton), K. K. (2021, June 15). *Zone control systems: The works and benefits: Grafton*. K Komfort Heating & Cooling. https://kkomfort.com/residential/zone-control-systems/#:~:text=A%20zone%20control%20system%20uses,of%20the%20work%20for%20you. Accessed 25 Sept. 2023.

[7]“Central Air Conditioning Problems and Solutions: Jennings HVAC4.” *Jennings Heating & Cooling Co.*, 6 Apr. 2021, jenningsheating.com/central-air-conditioning-problems-and-solutions/.

[8](Grafton), K. K. (2021, June 15). *Zone control systems: The works and benefits: Grafton*. K Komfort Heating & Cooling. https://kkomfort.com/residential/zone-control-systems/#:~:text=A%20zone%20control%20system%20uses,of%20the%20work%20for%20you.

[8]"ISO/IEC/IEEE International Standard for Information technology -- Smart transducer interface for sensors and actuators -- Part 2: Transducer to microprocessor communication protocols and Transducer Electronic Data Sheet (TEDS) formats," in *ISO/IEC/IEEE 21451-2:2010(E)* , vol., no., pp.1-130, 15 May 2010, doi: 10.1109/IEEESTD.2010.5668463.

[9]"IEEE Standard for Low-Energy Analog Interfaces between Protective Relays and Power System Signal Sources," in IEEE Std C37.92-2023 (Revision of IEEE Std C37.92-2005) , vol., no., pp.1-32, 25 April 2023, doi: 10.1109/IEEESTD.2023.10106648.

[10]"IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications," in IEEE Std 484-2019 (Revision of IEEE Std 484-2002) , vol., no., pp.1-29, 17 July 2020, doi: 10.1109/IEEESTD.2020.9141541.

[11] Hamza, Mohannad, Omer Bafail, and Hisham Alidrisi. "HVAC Systems Evaluation and Selection for Sustainable Office Buildings: An Integrated MCDM Approach." *Buildings* 13.7 (2023): 1847.