Smart Climate Control System
Project Proposal

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1 Introduction

1.1 Smart Climate Control System

Many homes and apartments suffer from large temperature differences from room to room. This can be due to many factors such as insulation, windows in the room, proximity to the kitchen, etc. The problem is that the current standard thermostat only senses one room or area to determine the temperature of the whole house. The Smart Climate Control System will allow anyone with a central heating and air conditioning (HVAC) system to have greater control over the temperatures in each room of the house. Each room will have a remote temperature sensor and vent actuator, controlled by a main thermostat unit via wireless network. The temperatures in each room of the house can then be dynamically controlled by the user interface much like standard thermostats.

1.2 Objectives

1.2.1 Goals

- Give user greater control over the climate in individual rooms in the building
- User can determine which room has priority so the temperature is more tightly controlled there
- Non-priority rooms can have a wider temperature range so as to conserve energy

1.2.2 Functions

- Ability to set preferred temperature and priority room from main control panel
- Wireless communication with sensors in each room
- Wireless communication with vent actuators
- Sense temperature and humidity of each room

1.2.3 Features

- Ability to prioritize rooms in the home as a reference for the thermostat
- Modular, scalable design
- Conserves energy by allowing a wider temperature range in non-priority rooms
- Sets temperature based on heat index to account for humidity

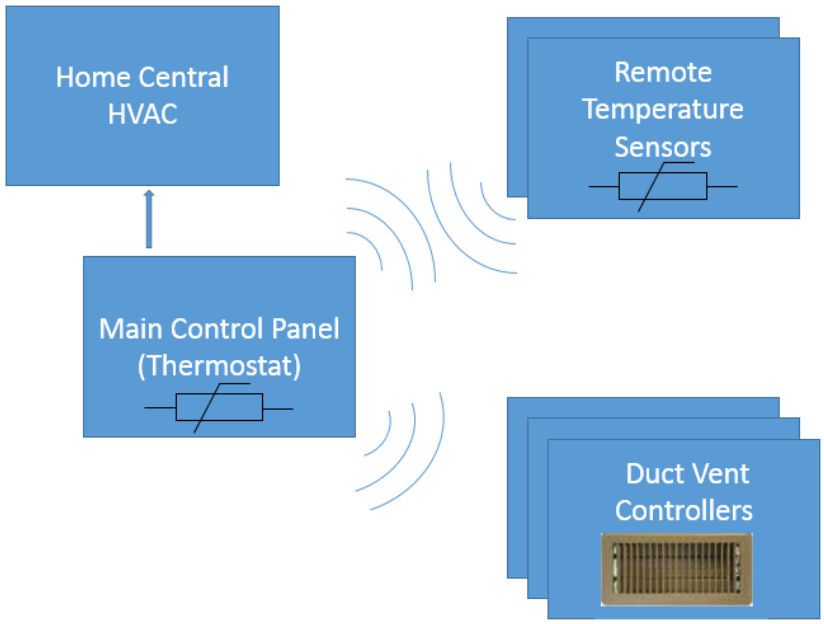

Figure 1: Top level system diagram.

2 Design

2.1 Block Diagrams

The design of this project is modular in nature. It is desired to have one main controller and multiple remote temperature sensors and vent controllers, as shown in Fig. 1. Fig. 2 will show the main control panel in more detail, while Fig. 3 will show the remote temperature sensors, and Fig. 3 will show the vent controllers. Each component will be described in further detail in §2.2.

2.2 Block Descriptions

2.2.1 Overall System Summary

The overall system will consist of one main control panel, a central HVAC system, and any number of remote temperature sensors and duct vent controllers. At least one remote temperature sensor is required for the system to be "smart", such that it will be able to detect temperatures in rooms other than where the normal thermostat (main control panel) is located. The duct vent controllers also follow a similar logic, as many duct controllers would be used as desired to control air flow to desired rooms, but at least two are required to make the system work as intended.

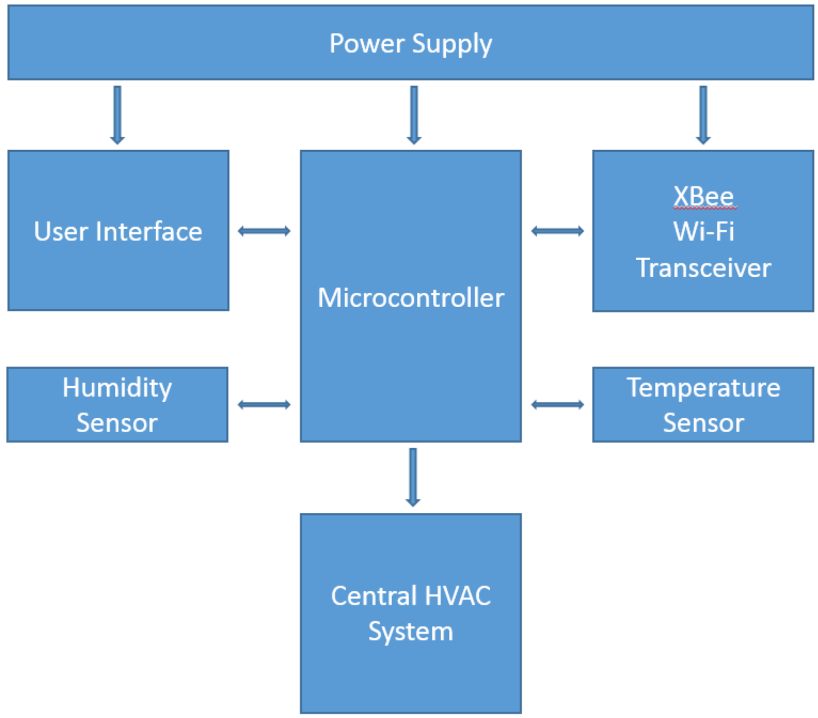

Figure 2: Main Control Panel component Diagram from Fig. 1.

2.2.1.1 Temperature Sensors An LM35 temperature sensor is used to get an accurate reading of temperature in all components. The sensors will be read by the microcontrollers and used along with humidity sensors to determine HVAC on/off state and vents open/closed state.

2.2.1.2 Humidity Sensors An HH10D humidity sensor will be used to measure the relative humidity around the sensor. The humidity reading will be used along with the temperature reading to set the temperatures in each room.

2.2.1.3 Central HVAC No modifications to a home's central HVAC system is desired. In the United States, most central HVAC systems supply a 24 VAC_{RMS}) power for a thermostat, and receive turn on and off signals from the thermostat. The main control panel must provide these signals to the HVAC system.

2.2.2 Main Control Panel

The main control panel acts as master to all other components. The main control panel can be broken down into several components as shown in Fig. 2.

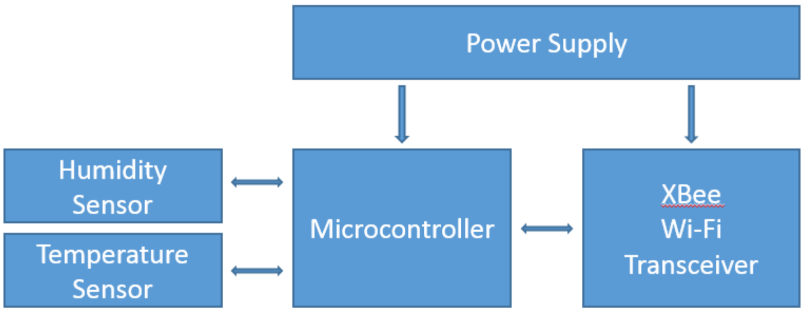

Figure 3: Remote Temperature Sensor component diagram from Fig. 1.

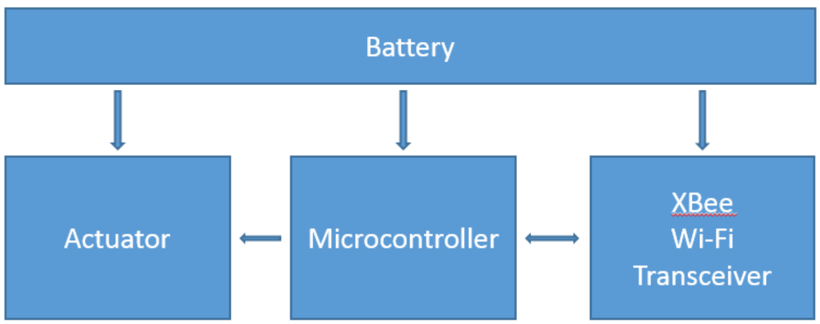

Figure 4: Vent Duct Controller component diagram from Fig. 1.

The housing for this main panel should be a plastic case similar to standard thermostats.

2.2.2.1 Main Panel Power Supply The power supply must convert the US standard 24 VAC_{RMS} low voltage wiring for most HVAC thermostat controllers into 3.3 VDC, as used by the microcontroller and transceiver. The Power supply will be a full-wave rectifier and a switched mode DC-DC converter.

2.2.2.2 Main Panel Microcontroller The microcontroller used will be an MSP430 microcontroller. The microcontroller must send and receive packets over the network via the wireless transceiver, read the temperature and humidity sensors, signal the central HVAC system on or off, and output to an LCD display for debugging and UI purposes. The main control panel will receive broadcast data from all of the remote temperature sensors on the network (including its own sensors). Once the microcontroller receives temperature information from each remote sensor, it determines which vents to open and close and sends data wirelessly to the desired vent controllers. The HVAC is controlled over a 2-3 wire system connected directly to the HVAC over existing house wiring.

2.2.2.3 XBee Wi-Fi Transceiver The Xbee transciever block is the main communication portion of the design. The transceivers will all be on a wireless network to allow each component to send/receive messages from the main control panel. Power for the transceiver is 3.3 VDC and comes from the power supply. The transciever connects to the microcontroller via serial port.

2.2.3 Remote Temperature Sensors

A remote temperature sensor consists of a power supply, microcontroller, sensors, and wireless tranceiver as shown in Fig. 3. Each remote temperature sensor will be identical, and will be housed in a small plastic case and plugged into an AC outlet.

2.2.3.1 Remote Temperature Sensor Power Supply The power source for this component is a standard AC outlet. Like the main controller, an AC-DC converter is required to convert the 120 VAC (RMS) into the 3.3 VDC required by the microcontroller and wireless transceiver. The conversion will be done using a standard "wall wart" style power supply.

2.2.3.2 Remote Temperature Sensor Microcontroller Again, the microcontroller for this component is an MSP430. The goal of this microcontroller is to read the sensors and output a message to the main control panel through the wireless device.

2.2.3.3 Remote Temperature Sensor XBee Transceiver The Xbee transceiver is used in the remote sensor to allow communication to the main control panel. It will be connected to the microcontroller via serial port.

2.2.4 Vent Controllers

The vent controller, shown in Fig. 4, will mount inside of a standard HVAC ventilation cover and control the opening and closing of the vent. Opening and closing of the vent will allow the system control over HVAC flow out of the desired vent, and by extension, the room. The vent controller will receive messages from the main control panel and open or close the vent using an actuator connected to the vent's existing closer. Each vent controller will be identical and can be replicated as desired.

2.2.4.1 Vent Controller Battery Since many homes have vents which are not near AC outlets, and it is not desirable to add a great deal of house wiring, the vent controllers will be battery powered. 9V batteries will be used to supply power to the microcontroller, transceiver, and actuator motor.

2.2.4.2 Vent Controller Microcontroller The MSP430 is used to receive messages from the main control panel via the wireless transceiver. Once a message is received, the controller will command a small DC actuator to open/close the vent.

2.2.4.3 Vent Controller XBee Transceiver The wireless transceiver in the vent controller will receive only. It will receive messages via the wireless network and forward the message over a serial connection.

2.2.4.4 Vent Controller Actuator The actuator will be a small DC servo motor controlled by the microcontroller. It will be powered by the 9 V batteries. It will operate in two directions and turn a shaft to two positions: $0°$ and $90°$. $0°$ will be the "Vent OFF" position and $90°$ will be the "Vent ON" position.

3 Requirements and Verification Procedures

3.1 Central Control Unit

Requirement	Verification
The unit must send the appropriate control signals to the HVAC system.	The appropriate system (heating or A/C) should be activated as necessary to control the environmental temperature.
The system will control the temperature of the priority rooms such that the temperature index is within $\pm 1.5°C$.	The temperature index of the priority rooms should be within the specified range.
The system will control the temperature of the non-priority rooms such that the temperature index is within $\pm 3.5°C$.	The temperature index of the non-priority rooms should be within the specified range.
The unit must receive the data from the individual sensor units.	The unit should take specified measures to control the temperature of the rooms.
The unit will send commands to the vent control units to open and close the vents as necessary to control the climate in each room.	The vent control units should open or close as directed by the central control unit.
The unit will display the desired temperature index.	The unit should display the user set temperature index.
The unit will have manual control to set a priority room and adjust the desired temperature.	The desired temperature should be displayed.
(If time permits) The unit will connect to a wireless network (802.11) to interface with a PC to set the desired temperature index and priority rooms.	The unit should acknowledge the packets sent to it over the network and adjust the climate accordingly.

Table 1: Requirements and verification procedures for central control unit.

3.2 Temperature Sensing Unit

Requirement	Verification
The unit will periodically read the temperature of its local environment within $\pm 0.5°C$.	The temperature output from the unit should correspond to the temperature of the local environment within the specified tolerance.
The unit will periodically read the relative humidity of its local environment within $\pm 5\%$ relative humidity.	The humidity output from the unit should correspond to the relative humidity of the local environment within the specified tolerance.
The unit will periodically broadcast the temperature and humidity data on the network on a regular interval.	The data should be transmitted on the network at a regular interval.

Table 2: Requirements and verification procedures for temperature sensing unit.

3.3 Vent Control Unit

Requirement	Verification
The unit must be able to open and close a vent with a motor.	The motor should turn by a sufficient amount to open and close the vent, but not enough to cause damage to the motor.
The unit must receive commands from the network to open and close the vent.	The vent should open or close when the respective command is received from the central control unit.

Table 3: Requirements and verification procedures for vent control unit.

3.4 Tolerance Analysis

The accuracy of the temperature sensor in the temperature sensing unit is critical to the performance of the system. The accuracy will be determined by comparing the output of the temperature sensor to that of a thermometer with a known error over a period of seven days. If the error of the temperature sensor is not within specifications, the analysis will fail.

4 Cost Analysis

4.1 Materials

Part	Quant.	Unit Price	Total Cost
XBee Wi-Fi S6B	4	≈35.00	135.00
TI MSP430 G2153	4	0.60	2.40
LM35 Temp. Sensor	2	1.57	3.14
HH10D Humidity Sensor	2	≈10.00	20.00
LCD Display	1	10.00	10.00
Assorted Circuit Components	–	–	20.00
5 V Power Adapter	1	3.95	3.95
9 V Batteries	2	2.00	4.00
Duct Vent	2	5.00	10.00
PCB	5	30.00	150.00
Servo Motor	2	≈5.00	10.00

4.2 Labor

Name	Hourly Rate	Hours	Total Cost
Jeff Lawrence	35.00	150	13125
Johnny Watts	35.00	150	13125
Dan Whisman	35.00	150	13125

Note: the total cost is calculated as $2.5 \times \text{Rate} \times \text{Hours}$.

4.3 Total

Section	Total ($)
Labor	39375.00
Parts	368.49
Total	**39743.49**

5 Schedule

Week	Johnny Watts	Dan Whisman	Jeff Lawrence
9/16	Proposal	Proposal	Proposal
9/23	Design Review — parts list for vent control units. Draft schematic of vent control unit.	Design Review — parts list for MCU, Wi-Fi, and sensors. Draft schematic of sensor units and main control unit.	Design Review — parts list for power supplies. Draft design for power supplies.
9/30	Finalize vent control schematic.	Design software for temperature sensors and vent controls.	Finalize schematic of power supplies
10/7	PCB layout for temperature sensors and vent controls. Purchase parts.	Design software for main control unit.	PCB layout of main control unit.
10/14	Implement main control on breadboard for testing.	Implement software and start debugging.	Implement vent control and sensor on breadboard for testing.
10/21	Finalize PCB designs for reveiw. Start on final report and presentation.	Finish debugging and interface with HVAC system.	Finalize PCB designs for reveiw. Start on final report and presentation.
10/28	Solder vent controllers and sensor module.	Prepare demonstration and presentation.	Solder main controller.
11/4	Mock demonstration — make any needed changes.		
11/11	Finalize PCB design.		
11/18	Final report and presentation.		
11/25	Thanksgiving Break		
12/2	Demo and Presentation.		