Smart Climate Control System
Project Proposal

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Contents

1 Introduction

1.1 Statement of Purpose

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 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.

1.3 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

1.4 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

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.

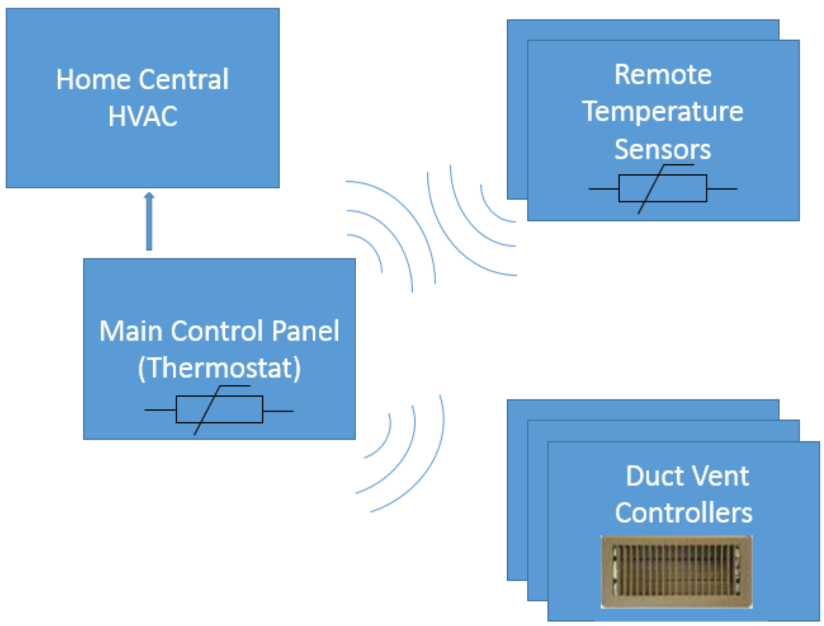

Figure 1: Top level system diagram.

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.

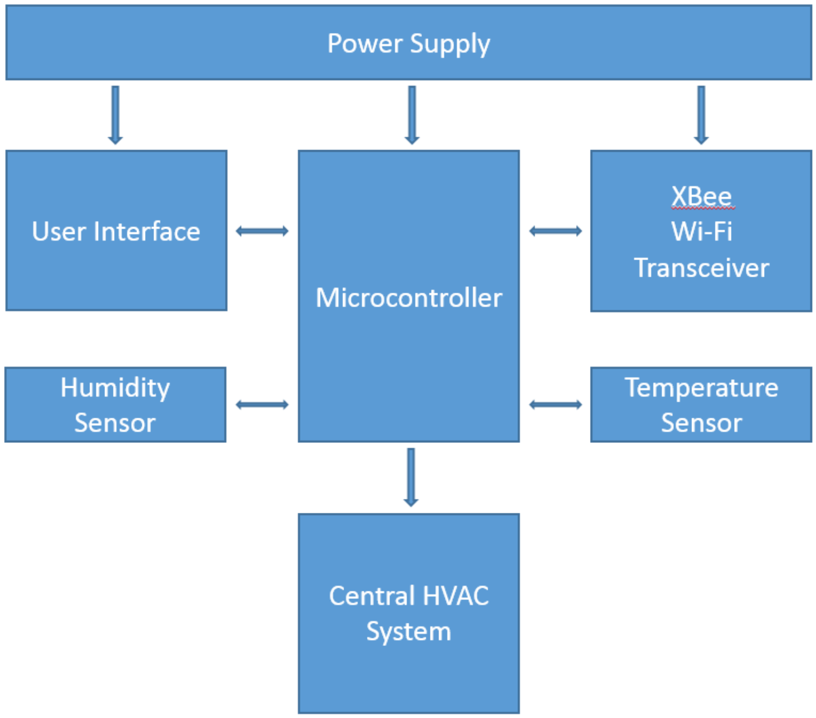

Figure 2: Main Control Panel component Diagram from Fig. 1.

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 $\mathrm{VAC_{RMS}}$ 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.

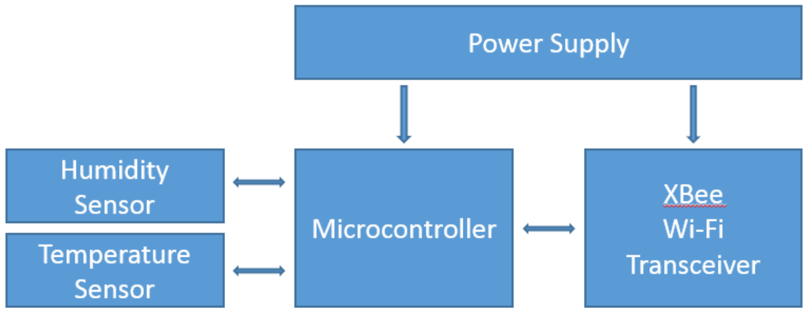

Figure 3: Remote Temperature Sensor component diagram from Fig. 1.

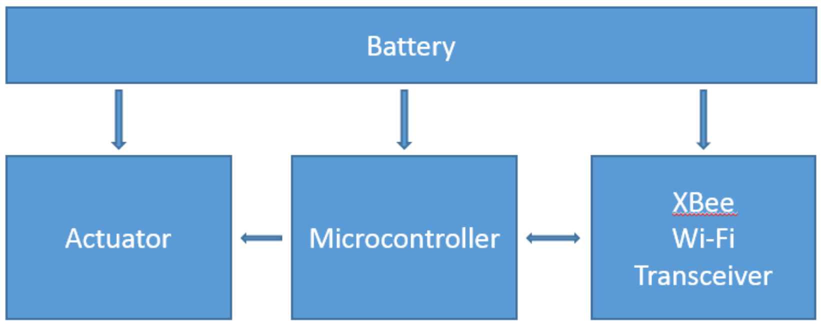

Figure 4: Vent Duct Controller component diagram from Fig. 1.

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 $\mathrm{VAC}_{\mathrm{RMS}}$ 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.

2.3 Schematics

2.3.1 Remote Temperature Sensor Schematics

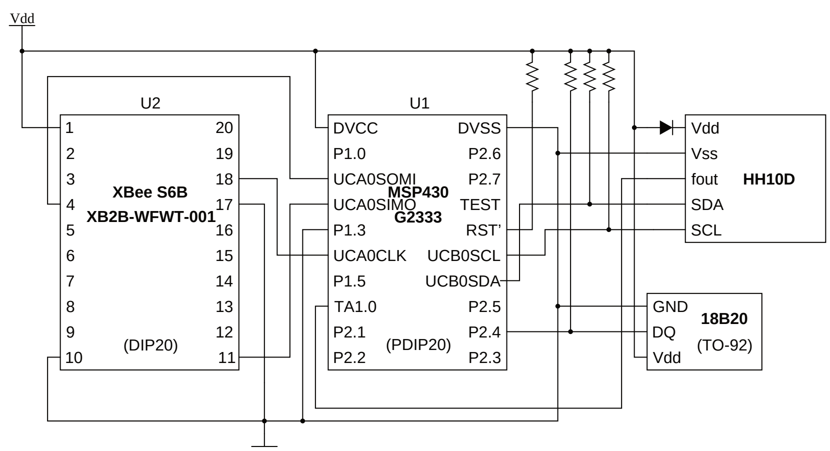

Figure 5: Remote Temperature Sensor Schematic

2.4 Simulations and Calculations

3 Requirements and Verifications

3.1 Remote Temperature Sensor

3.1.1 Power Supply

Power Supply Requirements	Verification
Power outlet must supply $120VAC \pm 10\%$ to the 5V power converter.	Use Voltmeter to check wall outlet for correct RMS voltage level.
Power Converter voltage output lies between LDO input voltage tolerance. $5-20VDC$ input requirement on LDO.	Use Voltmeter to check that output of power converter lies in tolerable range.
LDO output must be $3.3VDC \pm 5\%$ for components. LDO current output must be less than XA during circuit operation per XXXX datasheet maximum current output.	Use oscilloscope to monitor LDO output and ensure that output is properly regulated to 3.3VDC. After verifying voltage is within limits, measure current using oscilloscope current probe or ammeter with the LDO under load of components.

3.1.2 Microcontroller

Microcontroller Requirements	Verification
Input voltage to microcontroller is 3.3VDC on correct pins.	Use voltmeter to measure voltage at pins 1, and 16.
Microcontroller properly grounded.	Check board traces on pins 5 and 20 for continuity to power supply negative.
Temperature/Humidity sensor connected to digital input pins	Check traces/connections to ensure temperature sensor connected to pin 12.
Temperature/Humidity sensor messages properly received by microcontroller.	Monitor the messages sent by the microcontroller over Wi-Fi. The messages will contain the digital data received by the temperature sensor. Bump data with expected data.
XBee control and serial connections properly connected.	Check connections and ensure pins properly coded to match specification on schematic and data sheets.
MCU properly controls Xbee Wi-Fi.	Check that Wi-Fi is operating properly. Check that Xbee is sending messages by monitoring the port and reading the stream.

3.1.3 XBee Wifi Requirements

XBee Requirements	Verification
Xbee has 3.3VDC power input from power supply.	Check pin 1 for correct input voltage.
Xbee properly grounded.	Check board traces for pins 10 and 17 such that they are continuous to power supply negative.
XBee is transmitting.	Use a spectrum analyzer with an antenna connected. Monitor 2.4GHz while holding the XBee near the antenna; signal strength should be noticeably higher if device is transmitting.
Check that Xbee properly obtains its static IP address from local area network.	Use an accessable router to monitor connections.
Check that Xbee properly messages desired IP address.	Set up the XBee to message a local computer. Have the computer listen for messages and review the incoming data.

3.2 Tolerance Analysis

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.		

5.1 Contingency Plan

6 Ethics and Safety

6.1 Ethics

6.2 Safety

7 Appendix

7.1 References

7.2 Extra Figures