Smart Climate Control System
Project Proposal

Jeff Lawrence Johnny Watts Dan Whisman
TA: Mustafa Mukadam

September 28, 2013

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.

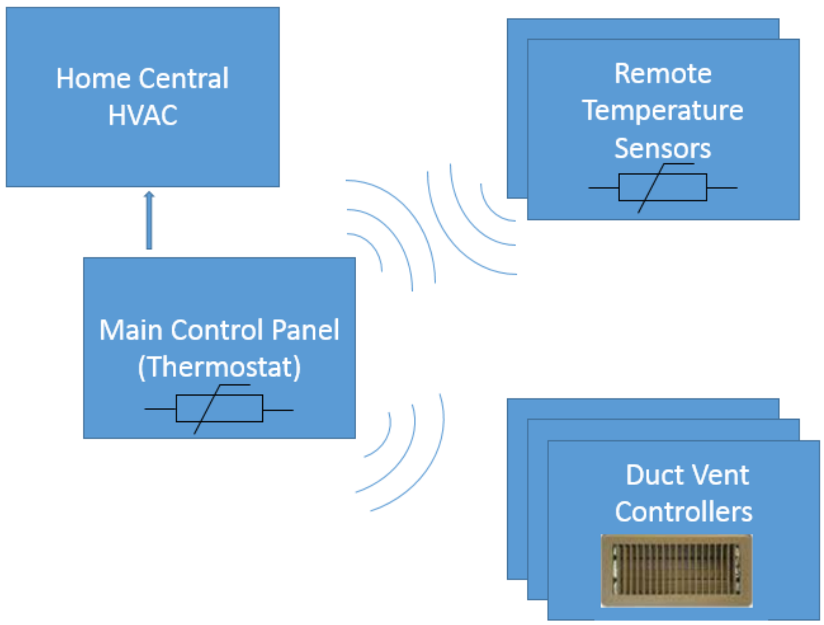

Figure 1: Top level system diagram.

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

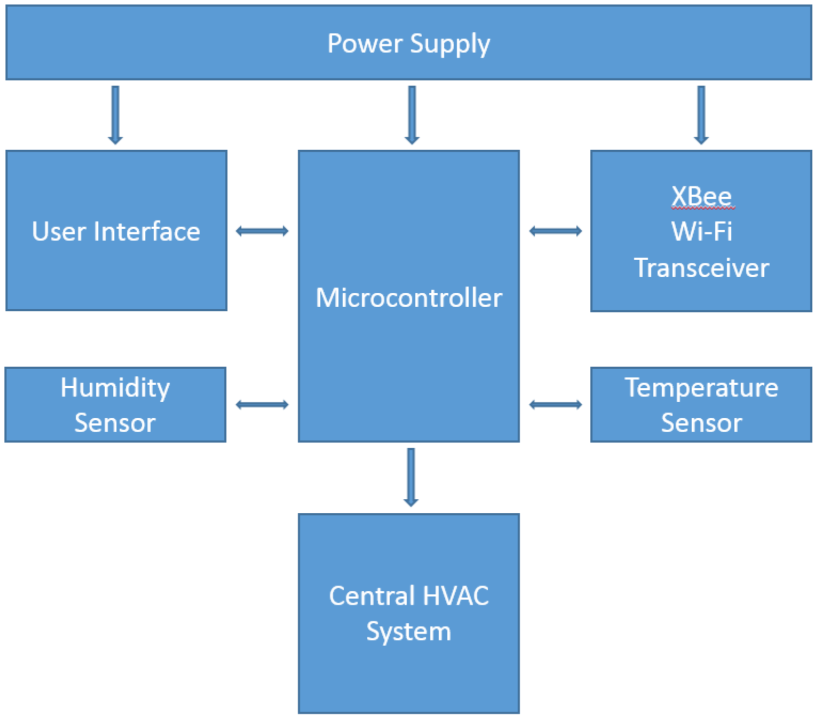

Figure 2: Main Control Panel component Diagram from Fig. 1.

to control air flow to desired rooms, but at least two are required to make the system work as intended.

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.

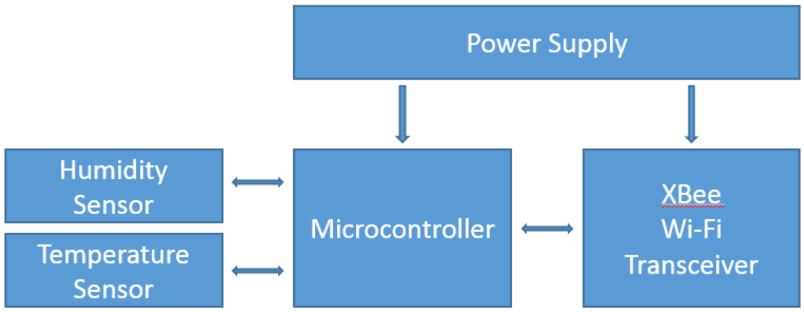

Figure 3: Remote Temperature Sensor component diagram from Fig. 1.

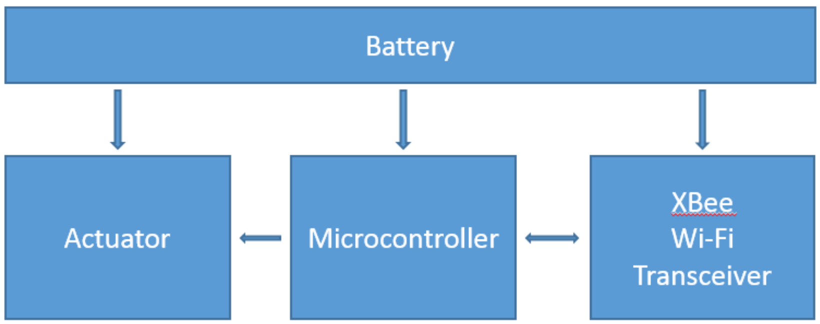

Figure 4: Vent Duct Controller component diagram from Fig. 1.

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. 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.

2.3 Schematics

2.3.1 Remote Temperature Sensor Schematics

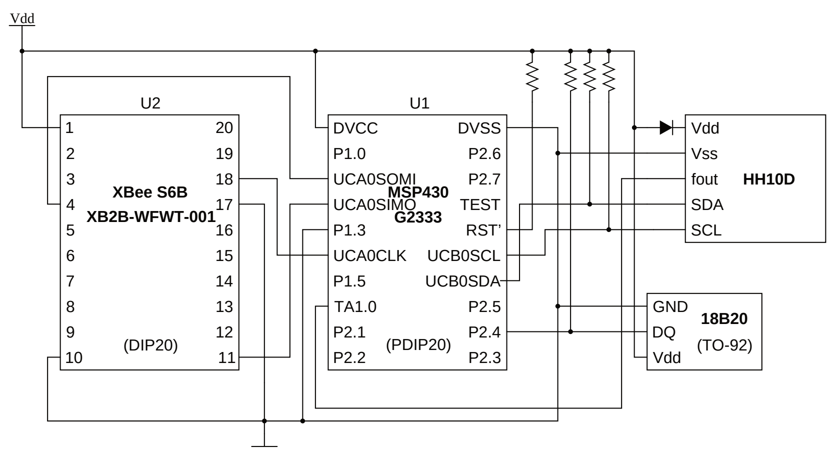

Figure 5: Remote Temperature Sensor Schematic

2.4 Simulations and Calculations

3 Requirements and Verifications

3.1 Remote Temperature Sensor Unit

3.1.1 Power Supply

Requirement	Verification
The output of the voltage regulator must be 3.3 V DC $\pm$ 0.1 V DC for an input of 5 V and an output of 500 mA.	Measure the output voltage with a load current of 500 mA (6.6 Ω at 3.3 V) and ensure it meets specifications.

3.1.2 Sensor Data Collection

Requirement	Verification
The MCU will read the ambient temperature data from an external sensor via a 1-wire protocol.	Ensure that the MCU communicates with the temperature sensor and a valid temperature value is read.
The MCU will convert the raw temperature data, as needed, to tenths of degrees Celsius (e.g., $T \times 10$).	Ensure the proper conversion of the raw data is taking place.
The MCU will read the calibration values for the humidity sensor via the I^2C bus, if needed.	Ensure that the MCU communicates with the humidity sensor and that valid calibration values are read.
The MCU will read the ambient relative humidity from the humidity sensor.	Ensure the MCU reads the output of the humidity sensor and that a valid relative humidity is read.

3.1.3 Sensor Accuracy

The exact accuracy requirements of the sensors, and hence the verification procedures, are not critical to the system's performance, and are meant only as general guidelines.

Requirement	Verification
The temperature sensor should output the ambient temperature with an error of no more than $\pm 0.5°$ C over a range of 10–32° C.	The data sheet of the temperature sensor should indicate an accuracy within specifications.
The humidity sensor should output the ambient relative humidity with an error of no more than $\pm 5\%$ RH. over a range of 10%–90% RH.	The data sheet of the RH sensor should indicate an accuracy within specifications.

3.1.4 Network

Requirement	Verification
The MCU will initialize the wireless transceiver with a pre-programmed SSID, password, and static IP address.	Ensure that the wireless transceiver is able to associate with the router.
The MCU will periodically transmit a packet to the central control unit containing the most recent temperature and humidity data along with a unique identification.	Ensure that a packet containing the necessary data is sent to the central control unit.

3.2 Vent Control Unit

3.2.1 Servo Control

Requirement	Verification
The MCU shall cause the servo motor to open the vent upon receipt of the appropriate packet.	Send the appropriate packet to the vent controller and the vent should open.
The MCU shall cause the servo motor to close the vent upon receipt of the appropriate packet.	Send the appropriate packet to the vent controller and the vent should close.

3.2.2 Network

Requirement	Verification
The MCU will initialize the wireless transceiver with a pre-programmed SSID, password, and static IP address.	Ensure that the wireless transceiver is able to associate with the router.
The MCU will listen for packets on the wireless network and take appropriate action when a command packet is received.	Send a command packet to the vent controller and the vent should take the appropriate action.
The MCU will acknowledge command packets by sending an ACK packet to the central control unit.	When a command packet is received at the vent controller, ensure an ACK is sent back to the central control unit.

3.3 Main Control Unit

3.3.1 Power Supply

Requirement	Verification
The output of the voltage regulator must be 3.3 V DC $\pm$ 0.1 V DC for an input of 5 V and an output of 500 mA.	Measure the output voltage with a load current of 500 mA (6.6 Ω at 3.3 V) and ensure it meets specifications.

3.3.2 Local Sensor Data Collection

See §3.1.2—the same requirements and verification procedures are used here.

3.3.3 Local Sensor Accuracy

See §3.1.3—the same requirements and verification procedures are used here.

3.3.4 Network

Requirement	Verification
The MCU will initialize the wireless transceiver with a pre-programmed SSID, password, and static IP address.	Ensure that the wireless transceiver is able to associate with the router.
The MCU will listen for packets from the remote sensor units and update the values for temperature and humidity.	When a packet from a remote sensor is received, the data corresponding to that sensor should be updated with the new values.
After the MCU sends a command packet to a vent controller, if an ACK is not received within a specified amount of time, the packet will be resent up to three times.	Send a command packet to a PC and listen for the initial packet and three resent packets.
When the MCU receives a command packet from the user, an acknowledgment will be sent to the sender of the packet.	Send a command packet to the central control unit and listen for an ACK packet.

3.4 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