Web Based Weather Responsive Window

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Contents

1 Introduction

1.1 Background

Windows are an essential part of our home. Sometimes we open windows to let fresh air come inside the house or to adjust the room temperature; sometimes we close them because of bad weather, like rain, snow, heat or cold, etc. One of the problems is that people are not always staying in the house, so people cannot always control the windows. And weather is sometimes unpredictable. For example, rain damages our treasures through open windows; sunlight and fresh air cannot go into the house on a nice weather day because of closed windows.

In order to solve this problem, we want to design a web-based responsive window system, which can open the windows to different levels, according to remote instructions from the user and weather conditions from the Internet. Our system has many novelties: First, the window can be adjusted both by user remotely through Internet or by the system. Second, compared to other weather-responsive windows using sensors, the system uses weather from Internet as the information source, which makes the information more accurate. Last but not least, the system supports different levels of opening and a LED denoting whether the air conditioner should be turned on. The complexity will make the system quite powerful.

1.2 Objective

Goals and benefits to the end customer of the responding system include:

- Users can open the window to different levels remotely through a web server or through physical buttons.
- Users input the city they live in, and the desired temperature of the room through the temperature button physically or through the web remotely.
- The system will open the window to different levels in order to avoid bad weather, like rain and snow, and to adjust the room temperature to the desired one.
- When the temperature adjustment is impossible through the window, the LED should be turned on denoting air that conditioner should be turned on.
- If the buttons that change the desired temperature is pushed, the display screen will display the desired temperature in the next five seconds. Otherwise, the display screen will display the current room temperature.

1.3 Features

- When moving the window, if there are any objects in the way, the window will stop moving.
- In order to save energy, the system will only update the status of the window and the AC periodically unless there are extreme weather conditions or direction instructions from users.

2 Design

2.1 Block Diagram

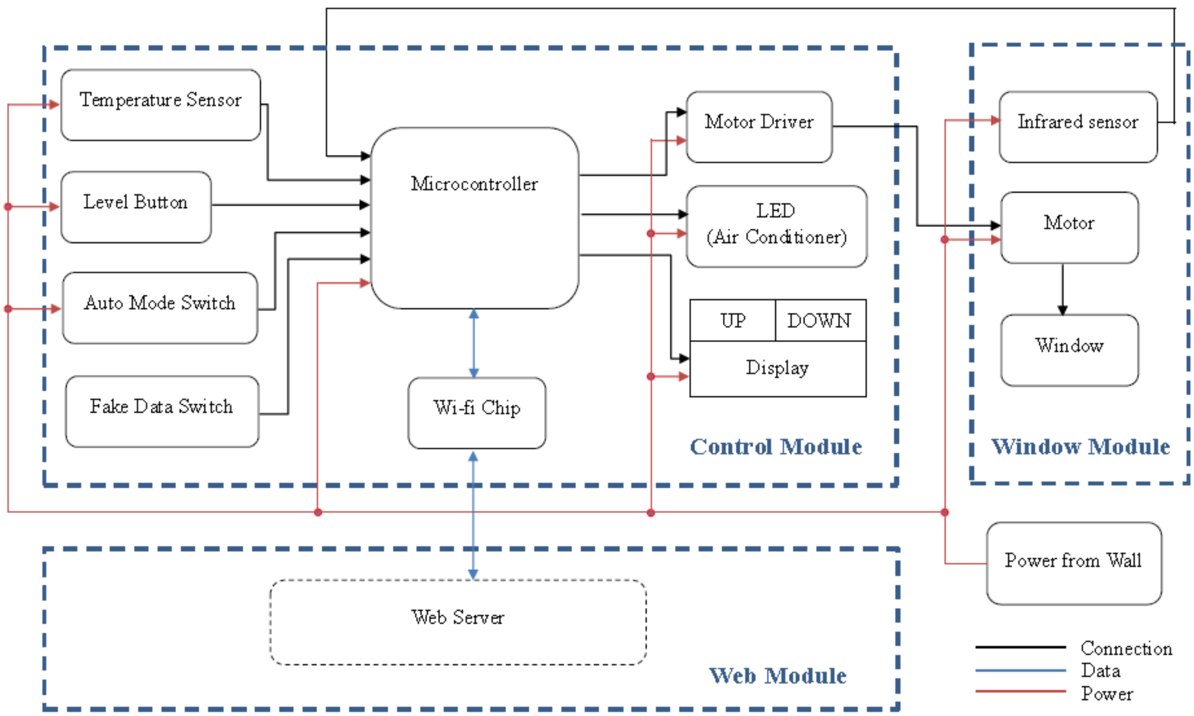

Figure 1: Block diagram with three modules and power supply.

Our project will be composed of three essential modules and power supply. The Web Module will be a web server with complete front end and back end, which can get weather information and room temperature, and give useful information to the Control Module. The Window Module will be composed of an actuator and a small window model. The actuator will drive the window model to different open levels according to the signal it receives from the microcontroller. The IR(object) sensor will also be placed in this module because of physical location. The Control Module will be composed of a microcontroller with WiFi, which controls the project; a WiFi Chip(ESP8266), which provides WiFi connection between the chip and the web server; a temperature sensor, which measures the room temperature; an LED, which denotes the status of the Air Conditioner(AC); and a motor driver, which drives the linear actuator and several buttons and a seven-segment-display of 2-digit temperature. The power supply will provide power to everything in the project except the weather web server, which will run on a cloud server. The power will come from the wall. There will be regulators converting the 110V from wall to 5V, 3.3V, and 12V.

2.2 Circuit Schematic

We have separated the schematic into four sheets below for modularity and clarity. All four sheets combined together contribute to our whole schematic design. The ATMEGA328 appears as the main chip in every sheet. Each sheet has different components connecting to different pins in ATMEGA328. The first sheet has power components, LED for AC, and ESP8266 WiFi chip connected to ATMEGA328; the second sheet has temperature sensor and object sensor; the third sheet has H-Bridge and motor; the fourth sheet has switches, level button, and temperature display.

Note: The power supply (+5V VCC) for the ATMEGA328 is provided in sheet 1, the rest of the sheets don't include this power supply.

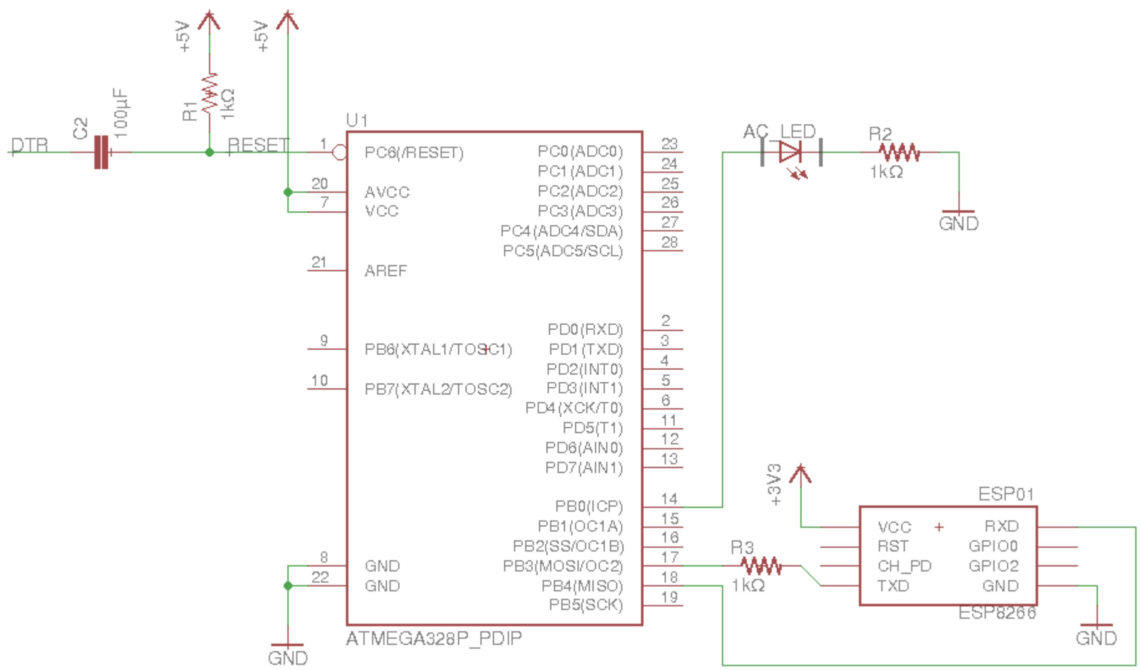

Figure 2: Schematic sheet 1: ATMEGA328 with power components, LED for AC, and ESP8266 WiFi chip

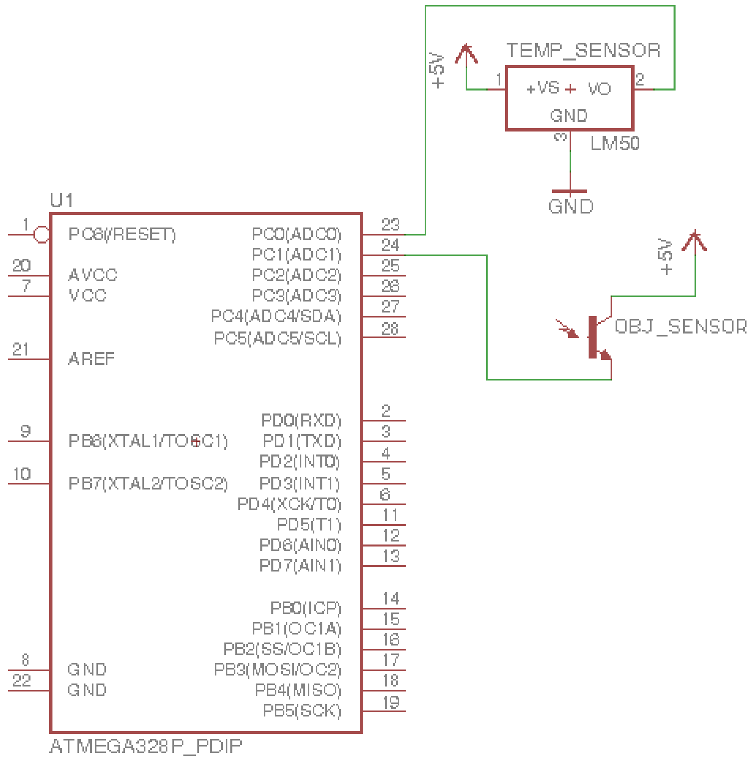

Figure 3: Schematic sheet 2: ATMEGA328 with temperature sensor and object sensor

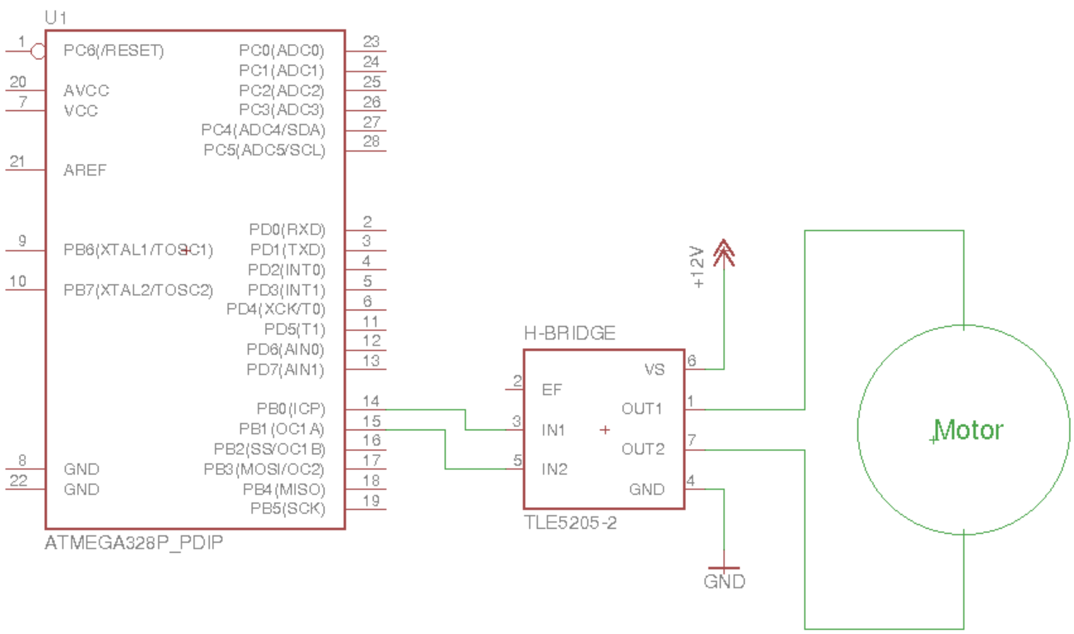

Figure 4: Schematic sheet 3: ATMEGA328 with H-Bridge and motor

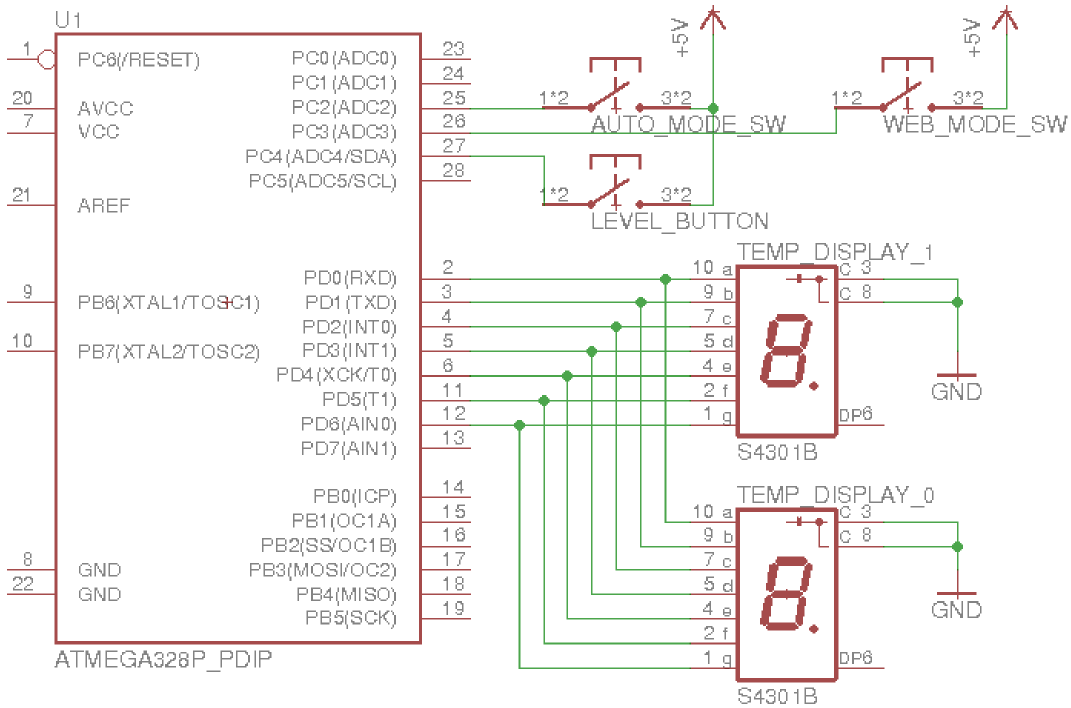

Figure 5: Schematic sheet 4: ATMEGA328 with switches, level button, and temperature display

2.3 Physical Design

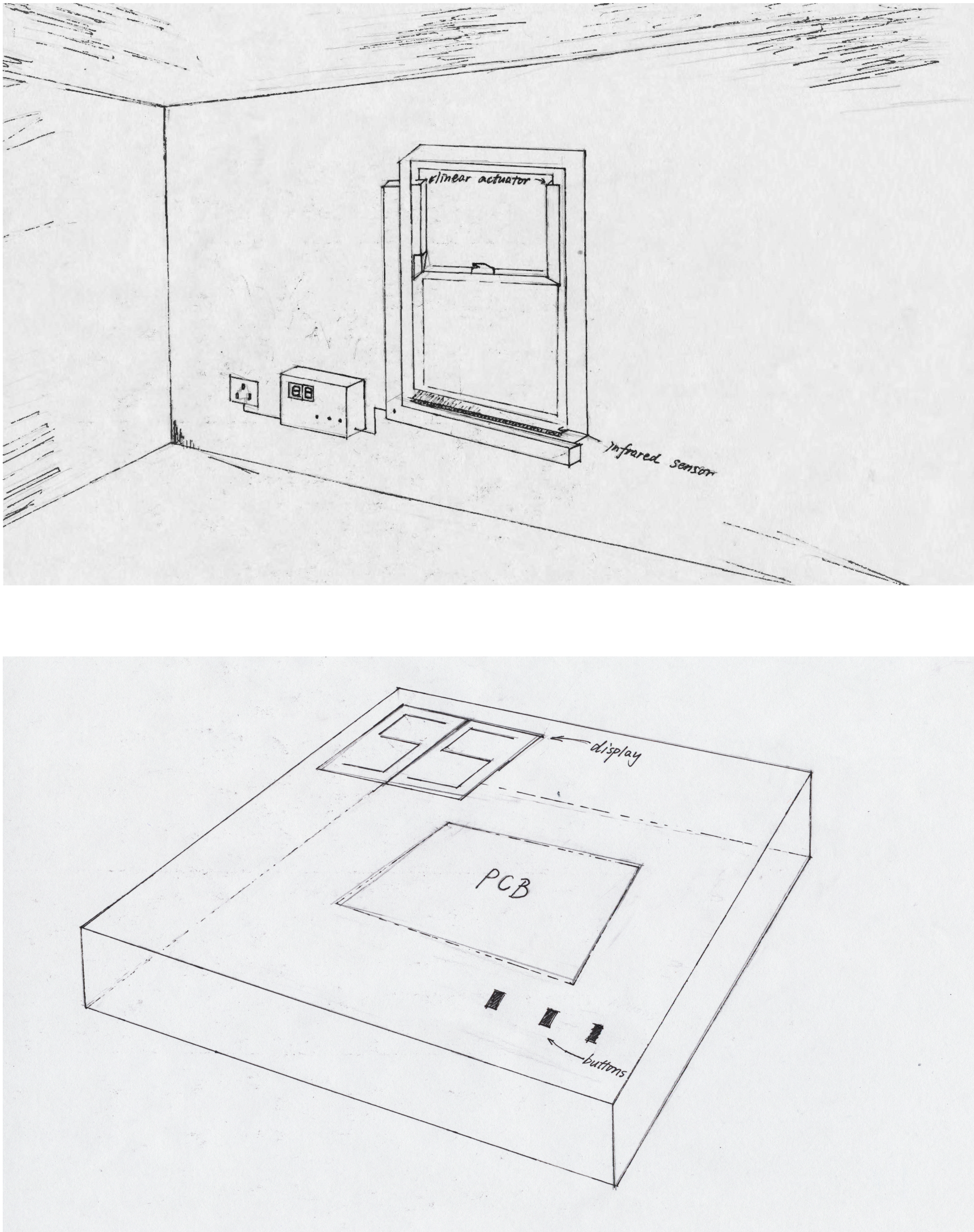

Figure 6: General Scratch & Control Unit

2.4 Power Supply

Our application will be directly plugged into wall, so the original power source will always be the 120V and 60Hz AC electricity. Then we convert the power through a AC-to-DC converter to transform it into a lower DC voltage which can be applied to our motor, microcontroller, sensors and LED.

2.4.1 AC-to-DC Converter

The real power supply into each component comes from the AC to DC converter. The converter takes in normal alternating current and outputs a lower DC voltage.

2.5 Control Module

2.5.1 Microcontroller

The Control Module will have following components. The AUTO Switch is used to decide whether the system should make decision by itself. The level button can be used to adjust the window to different oepn levels. The Fake Switch is used to simulate outside temperature when the Internet connection is lost. In particular, it simulates $40°$ when the switch is on and $0°$ when the switch is off. The UP and DOWN button can be used to adjust the desired temperature. The seven segment display is used to show the desired temperature and the room temperature. The temperature sensor will measure the room temperature, and provide its voltage to the microcontroller chip. The microcontroller chip will receive the information from the web server every minute, it will decide, to what level should the window be opened, and whether the Air Conditioner (LED) should be turned on/off. It will then cope with the LED and drive the linear actuator. It will stop the motor when the IR sensor detects anything in the way. The more detailed implementation can be found in the flowchart.

Requirement	Verification	Max points
1. The program should be able to convert analog input from the temperature and IR sensor into a temperature format, with an accuracy of 95%. 2. The microcontroller should turn the window and the AC to desired status every minute, and have a response time of less than 1 second for safety halt. 3. The microcontroller should get the temperature from Internet successfully. 4. when there's no Network or the Fake Data Mode is on, the microcontroller logic should be based on the physical sensors. 5. The microcontroller should send window level and sensor temperature info periodically to the server.	1. Measure the output voltage from sensors with a multimeter. Write code to display voltage of sensors. Compare the two results to calculate accuracy. For example temperature input can be digitized as follows: $\frac{analog_{in}}{1024} \cdot V_{cc}$. 2. Write unit test to the code and debug it on the computer. 3. Send temperature from the server and see if the microcontroller displays the temperature received on seven-segment LEDs. 4. Let server ignore request from microcontroller intentionally to simulate no Networks situation, or with Fake Data Mode on, see if the micontroller behaves expectedly based on the physical sensors. 5. Send window level and sensor temperature from the microcontroller to server, see if the server receives the data.	4

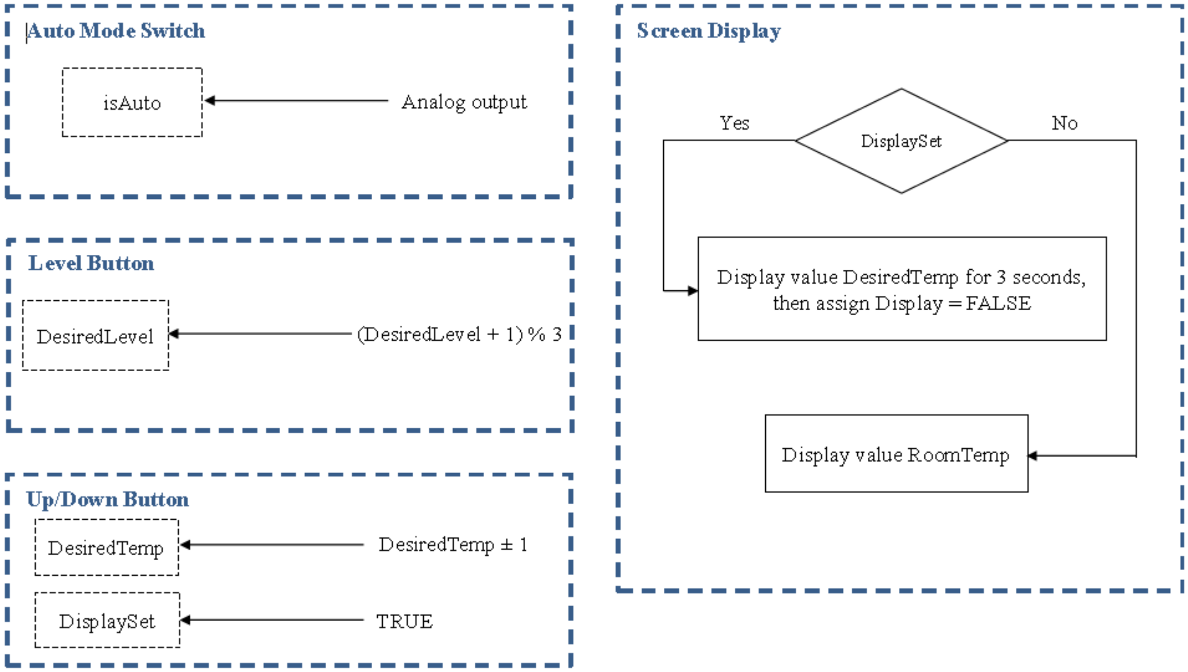

Figure 7: Chip Logic Flow Chart 1

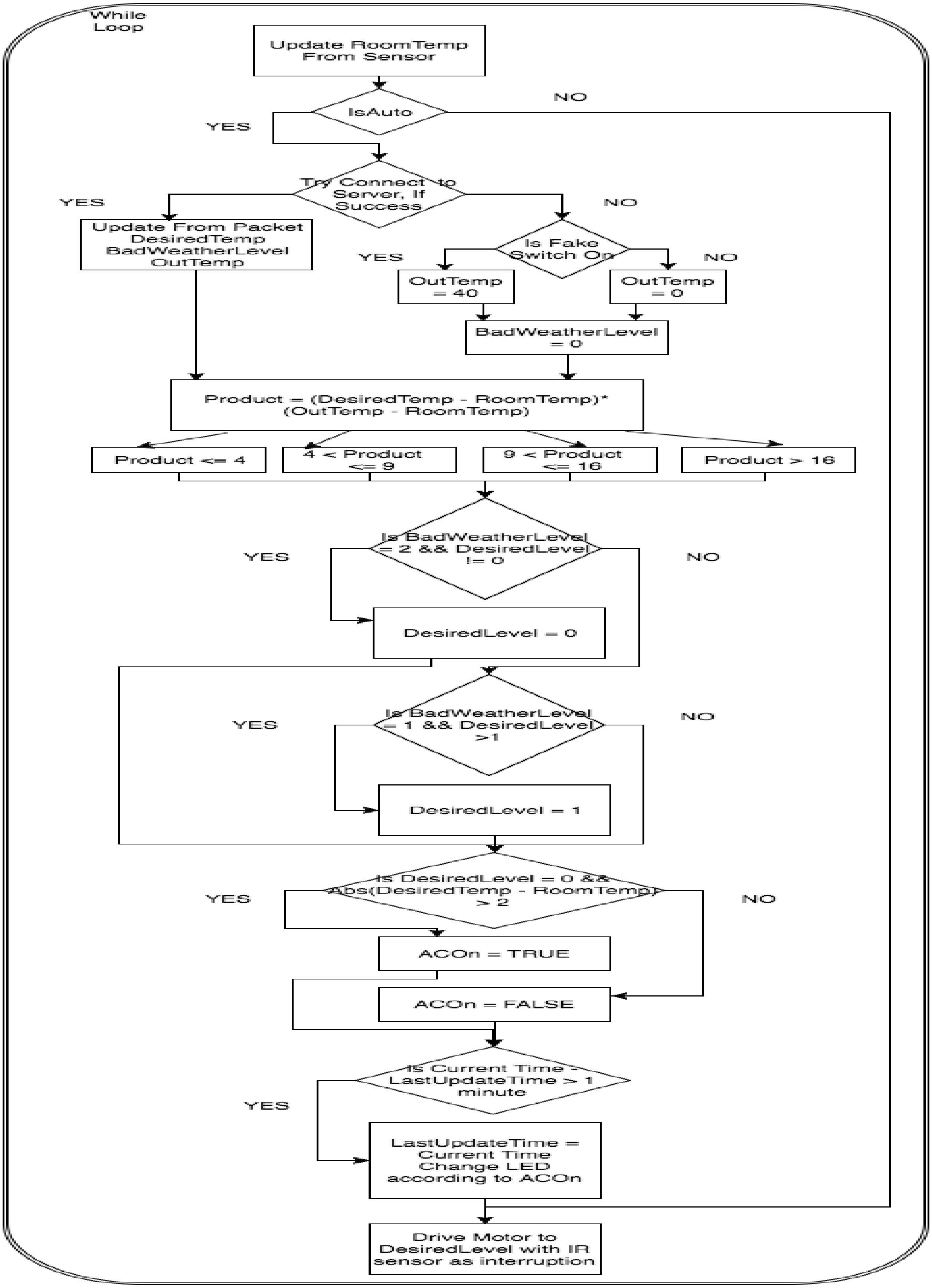

Figure 8: Chip Logic Flow Chart 2

2.5.2 H-Bridge Motor Driver

The motor driver DRV8833 receives signal from microcontroller and drivers the linear actuator. It can be powered with supply from 2.7V to 10.8V and we will provide it with 10V. Its maximum output current is 1.5A. According to the motor driver's data sheet, the device includes a low-power sleep mode, which lets the system save power when not driving the motor [1].

2.5.3 Other components

Requirement	Verification	Max points
1. Temperature Sensor (LM35) [2] (a) The sensor should be able to display temperature within a range of 32°F to 100°F.	1. Temperature Sensor (LM35) (a) Place the sensor in a room, and adjust the room temperature with an AC. Connect the sensor to an Arduino board and display the result on PC. Compare the result to the value from a well functioned thermometer.	2
2. LED (denoting AC) (a) The LED can be turned on if the window is at level 0 and the difference between room temperature and desired temperature is more than 2 deg.	2. LED (denoting AC) (a) Set window level 0 and the difference between room temperature and desired temperature to more than 2 deg in the program, and see if the LED will be turned on in 1 minute. And change the variable to meet the condition which will turn of the AC, and see if the LED will be turned off in 1 minute.	2

Continued on next page

Table 2 – continued from previous page

Requirement	Verification	Max points
3. Seven Segment Display (5261BS) [3] (a) The display of temperature must be the same value as the one generated from temperature sensor. (b) The display shows the current temperature if the temperature button is not pressed, and shows the desired temperature if the temperature button is pressed.	3. Seven Segment Display (5261BS) (a) Use Arduino to read temperature value from the temperature sensor and compare the value with the display. (b) Let current temperature be different from the desired temperature. Check if the current temperature is correct with temp button off and if the desired is temperature is correct with temp buttons on. Verification that the desired temperature has been reached will be apparent by seeing that the temperature is indeed increasing according to the display.	2
4. WIFI Chip (ESP8266) [4] (a) Provide IEEE 802.11 b/g/n Wi-Fi (b) Connect to UIUC Device WiFi successfully. (c) Ensure communications between the microcontroller IP and the server IP with AUTO switch on.	4. WIFI Chip (ESP8266) Test the functionality of the chip with test code from *https://www.exploreembedded.com/wiki/Arduino_Support_for_ESP8266_with_simple_test_code*.	2

2.6 Web Module

2.6.1 Web Server

The web server will get information from two ways: first, user input about level desired, temperature desired, city chosen; second, weather information from google weather api. The server will decide whether it is in a bad weather, and send these information to the microcontroller every minute. The web server will be implemented on a free web hosting called biz.nf.

Requirement	Verification	Max points
1. The web server should be able to communicate with the microcontroller through TCP and HTTP. The Web server should be able to receive request from the microcontroller every 10 seconds. 2. As for the front end, the web server should be able to read in the city that user has entered, and fetch the weather information from other weather web server. The web server should be able to read in the desired temperature and desired window level. 3. The back end should update the current weather information every 1 minute. The back end should be able to send packets with correct information about following fields: whether it is bad weather outside, the desired room temperature and outside temperature every 1 minute. 4. If the web server hasn't received any packages from the micro controller for 3 minutes, user should see that the connection is lost on the web page.	1. Write a simple python client to simulate the micro controller and connect to the server. The server will print a log file every 10 seconds for a continuous 5-minute-period. 2. This will be tested by manually clicking on different buttons. And the server will print internal variable on the screen. 3. Use curl command to receive the packet, and check the content if it is same as expected. 4. Disconnect anything from the server for 3 minutes, and see if the web page shows the correct information.	5

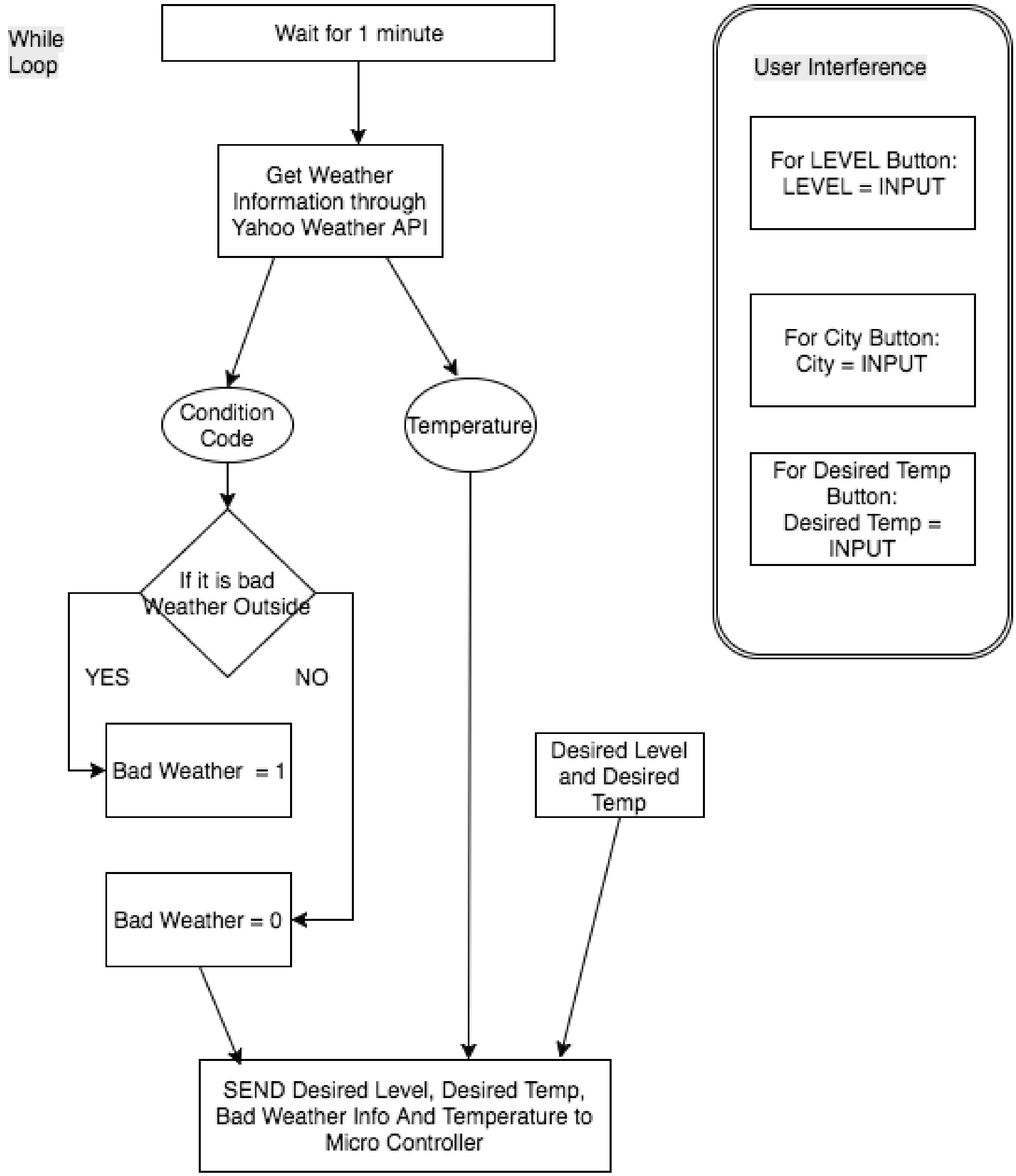

Figure 9: Backend Logic Flow Chart

2.7 Window Module

2.7.1 Passive Infrared Sensor

Passive infrared sensor is used to detect if there happen to be any person staying close to the window. To protect user's safety, the window will stop working in this situation.

Requirement	Verification	Max points
1. The IR sensor should be able to detect objects within distance of 10cm. 2. Window stops moving when object is detected, regardless of however microconteoller was trying to move the window.	1. (a) Put no infrared source within 10 cm ahead from the sensor, and read the output voltage from multimeter. Repeat 20 times, and calculate the accuracy. (b) Put human hand within 10 cm ahead from the sensor, and read the output voltage from multimeter. Repeat 20 times with human hand at different distances, and calculate the accuracy. (c) Put no infrared source within 10 cm ahead from the sensor, and read the output voltage from multimeter. Move human hand ahead of it and record time. Record the time when the output voltage become more than 3 V, and record the time. Calculate and see if the time lapse is less than 1 second. 2. Simulate situations such that microcontroller will move the window. While the window is moving, place object within 10cm range and see if the window stops.	5

2.7.2 Motor

We will place two linear actuators on each side of the window respectively to pull up the bottom half window and place them. The linear actuators take in 12V voltage as input, so our converted power supply just satisfy the requirement.

Requirement	Verification	Max points
1. The motors should be able to move steadily	1. (a) Connect the motor driver with the microcontroller and connect the motor with the motor driver (b) Send simulation data which indicates a rise in temperature into the microcontroller. Let microcontroller analyze the data and send out corresponding order to the motor driver (c) Use ruler and timer to record the distance the bottom half window moved in a certain time interval. (d) Plot a diagram or set up an equation to see if the distance, h is linearly dependent on time, t.	3

2.8 Power Calculation

Part Name	Volatage	Current (Active)	Current (Sleep)	Power Consumption (Active)	Power Consumption (Sleep)
ATmega 328P[5]	5 V	6.8 mA @8 MHZ	1.6 mA @8 MHZ	6.8 mA * 5 V = 34 mW	1.6 mA * 5 V = 9 mW
ESP8266 Wifi Module[4]	5 V	80 mA (Avg)	0.9 uA	80 mA * 5 V = 400 mW	<1.0 mW
LM35 Temp Sensor[2]	5 V	10 mA	0 A	5V * 10mA= 50mW	0
HC-SR501 IR Sensor[6]	5 V	50uA	50 uA	5V*50uA = 250uW	0
PA-14-12-35 Linear Actuator[7]	12 V	5A	0 A	12V * 5A = 60 W	0
5261BS Seven Segment Display[3]	2.4 V	83 mA	0 A	2.4V * 83mA = 220mW	0
drv8833 H-Bridge motor driver[8]	10 V	1.5 A	0 A	10V * 1.5A = 15W	0
Total (Without Motor)				700 mW	10 mW
Total (With Motor)				75 W	10 mW

Table 6: Power Calculation for each hardware component

3 Ethics and Safety

Since our objective is to control the window to react to incoming weather changes properly, we will take in weather forecasting data. Some numbers and descriptions we obtain may not be raw records, for example, accurate history temperature or hourly precipitation. What we get is already predictions based on some raw data which we dont know their resources. The website may hire mathematicians and programmers to design a unique algorithm to perform predictions. The algorithm can include an invented regression model. The website may also collaborate with an observatory to get precise measurements and collect massive data over a long time period. These procedures involve a lot of intellectual properties and copyrights which are not explicitly claimed.

We should respect other peoples professional creation. Per Imperative 1.6 in the ACM Code of Ethics, Specifically, one must not take credit for other's ideas or work, even in cases where the work has not been explicitly protected by copyright, patent, etc. [9].

More hazards may come when our project is misused by people who dont know how to manipulate it, or when people trigger any sensors without realization. A possible safety issue we may encounter is that the window will probably take a series of subsequent actions which can bring harm to the user. Imagine a situation like a kid watching a beautiful scenery outside through a slightly open window. Then a strong wind blew by and the window was shutting up; however, the kid didnt notice the changing because the windows motion is slow and steady. At that moment, the kid would have danger of being hurt by the window.

Number 9 of the IEEE Code of Ethics has requirement of, avoiding injuring others, their property, reputation [10]. We should protect a user's safety in many ways to the greatest extent. We thought of what we learned in another ECE course to be a great analogy to this kind of problems solution. Inside a computer, when user mode programs try to modify things in kernel which is of higher priority, the CPU will generate interruptions to inhibit any detrimental actions going further. Inspired by this way, we have decided to arrange the priority of sensors in a proper order to make sure that people will not be physically hurt at any time. The infrared sensor for detecting human and animal bodies will be set at the highest priority among all the sensors. We will also install a manual emergency brake handle beside the window to allow the user to take control of the window under any urgent circumstances.

3.1 Tolerance Analysis

3.1.1 Microcontroller

From the data sheets: the ATMEGA328 chip has an output accuracy of around 90%. For the inputs to the ATMEGA328, we have two sensors and three switches/buttons. The accuracy of temperature sensor (LM35) is 90%; the object sensor accuracy is not specified because it varies by different objects and distance, so let's assume it to be 90% optimistically; since switches are discrete binary input, we assume they are almost 100% accurate. So with the AUTO mode off (microcontroller's behavior independent of the WiFi data), we have 90% * 90% = 81% accuracy, which means the fault tolerance is 0 to 0.19. With AUTO mode on, we now consider the accuracy of the ESP8266, which we have almost no way to find. Empirically it's not a stable WiFi chip. So we do expect increase in the fault tolerance of microcontroller with the AUTO mode on.

4 Cost and Schedule

4.1 Cost Analysis

Labor:

Name	Hourly Rate	Total Hours Invested	Total
Kaishen Wang	30	220	16500
Fengling Wang	30	220	16500
Hanyu Wang	30	220	16500
Total	30	660	49500

Part:

Item	Unit Cost	Quantity	Total
LM35 Temperature sensor	$5	1	$5
HC-SR501 IR sensor	$5	1	$5
WiFi Module - ESP8266	$7	1	$7
ATmega328P-PU	$25	1	$25
Linear Actuator	$60	1	$60
PCB Integrated board for WiFi and sensor	$10	1	$10
Seven Segment Display (5261BS)	$1	1	$1
Solderable Breadboard	$10	1	$10
Total			$123

Total:

Section	Total
Labor	$49500
Parts	$123
Total	$49623

4.2 Schedule

Week	Member	Task
2/13	Kaishen Wang	Decide on the main funcationalities of our window
	Fengling Wang	Meet with machine shop to talk about the components needed in our project
	Hanyu Wang	Confirm more details in design and power supply; meet with machine shop
2/20	Kaishen Wang	Design Document R&V part
	Fengling Wang	Design Document schematics part
	Hanyu Wang	Design Document physical design part
2/27	Kaishen Wang	Build/Test Web Server
	Fengling Wang	Schematic Design
	Hanyu Wang	PCB Design
3/6	Kaishen Wang	Program Embedded Software
	Fengling Wang	Schematic Design
	Hanyu Wang	PCB Design
3/13	Kaishen Wang	Test Embedded Software with Server
	Fengling Wang	Test server with weather api input
	Hanyu Wang	Module test linear actuator
3/20	Kaishen Wang	Breadboard circuit components
	Fengling Wang	Module test functionality of each component
	Hanyu Wang	Revise PCB design
3/27	Kaishen Wang	Assemble components
	Fengling Wang	Solder components (microcontroller)
	Hanyu Wang	Fix Physical Issues
4/3	Kaishen Wang	Test and Fix Remaining Issues
	Fengling Wang	Revise schematic design
	Hanyu Wang	Test performance of power supply
4/10	Kaishen Wang	Prepare for Mock Demo WiFi part
	Fengling Wang	Prepare for Mock Demo Server part
	Hanyu Wang	Prepare for Mock Demo sensors and physical design part
4/17	Kaishen Wang	Mock Demo, Write Final Paper Web server part
	Fengling Wang	Mock Demo, Write Final Paper Schematic part
	Hanyu Wang	Mock Demo, Write Final Paper PCB part
4/24	Kaishen Wang	Test window application with real data and simulated data; get prepared for demonstration
	Fengling Wang	Record demo video and get prepared for demonstration
	Hanyu Wang	Record demo video if needed and revise the paper
5/1	Kaishen Wang	Refine final paper's portions on web module and sensors
	Fengling Wang	Refine final paper's portion on microcontroller
	Hanyu Wang	Check the paper's grammar; refine the portions on power and simulation

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