ECE 445: Senior Design Spring 2017
Design Review

Wi-Fi Enabled Motorized Windows for Automatic Climate Control

Team 34
Trevor Bush (tsbush2)
Alex Casino (casino2)
Ryan Stark (rmstark3)

TA: Kexin Hui

1. Block Diagram

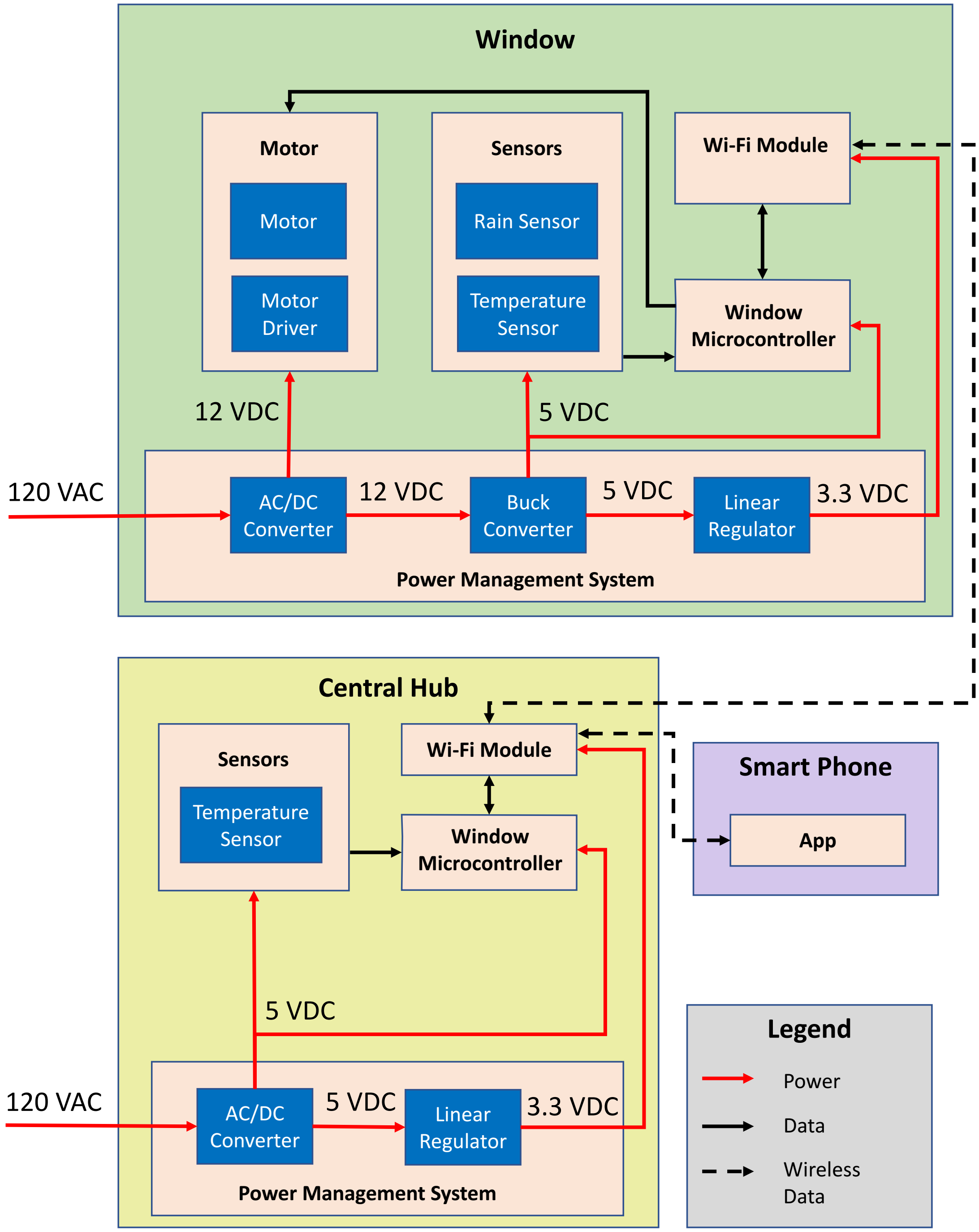

Figure 1: Block Diagram

2. Power Block Description

2.1 Power Supply

This module provides power to each area of the system. The power source for the controller will be from the power grid of the home. Since the different modules of the system require a variety of DC voltages, an AC-DC converter and multiple DC-DC converters will be used to supply each module with the necessary voltage.

2.2 AC-DC Conversion

We will use two AC-DC converters in our design. One will be for the window unit and will convert the 120VAC wall supply to 12VDC. The other will be for the central hub and will convert the wall supply directly to 5VDC since there is no motor in the hub module.

2.3 DC-DC Conversion

The window unit will require 12V, 5V and 3.3V DC supplies for the motor, microcontroller and sensors, and Wi-Fi module respectively. The TS30013 buck converter steps down the voltage from 12 to 5 volts. The inductor assists in the transfer of stored energy between 12 and 5 volts. The bootstrap capacitor allows the high-side FET gate driver to function properly. The PG pin outputs low when the voltage into the feedback pin is below the desired output. A pull-up resistor brings the voltage high when the output is at a satisfactory level and this will be monitored by the microcontroller. The 5-volt output powers the microcontroller, rain sensor, and temperature sensor in the window unit and powers the microcontroller and temperature sensor in the hub unit. The LM2937ET linear regulator steps down the voltage from 5 to 3.3 volts to power the WI-FI module. The capacitors on the input and output serve to filter out noise on the power lines as well improve the transient response of the system to sudden changes in load current.

3. Schematic

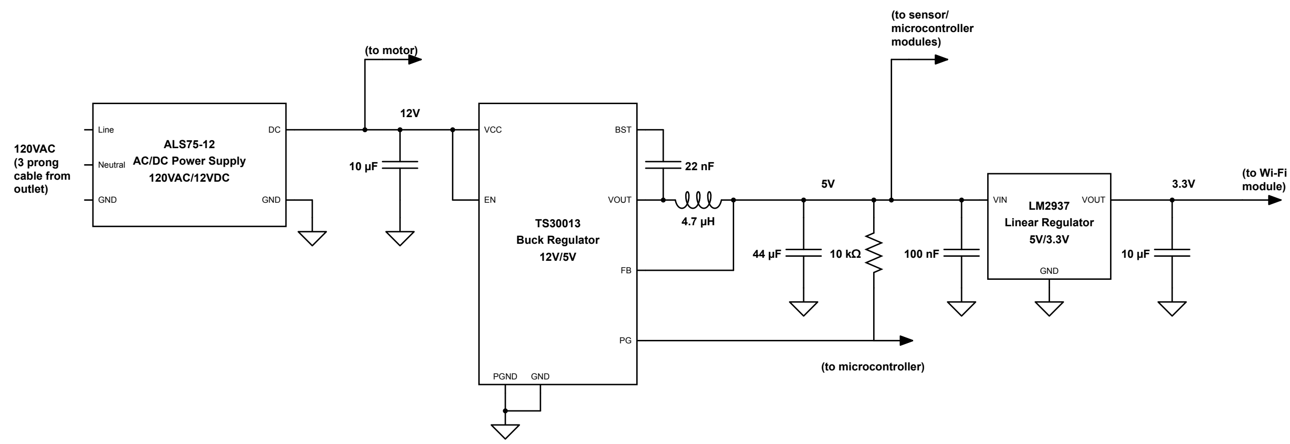

Figure 2: Window Power Circuit Schematic

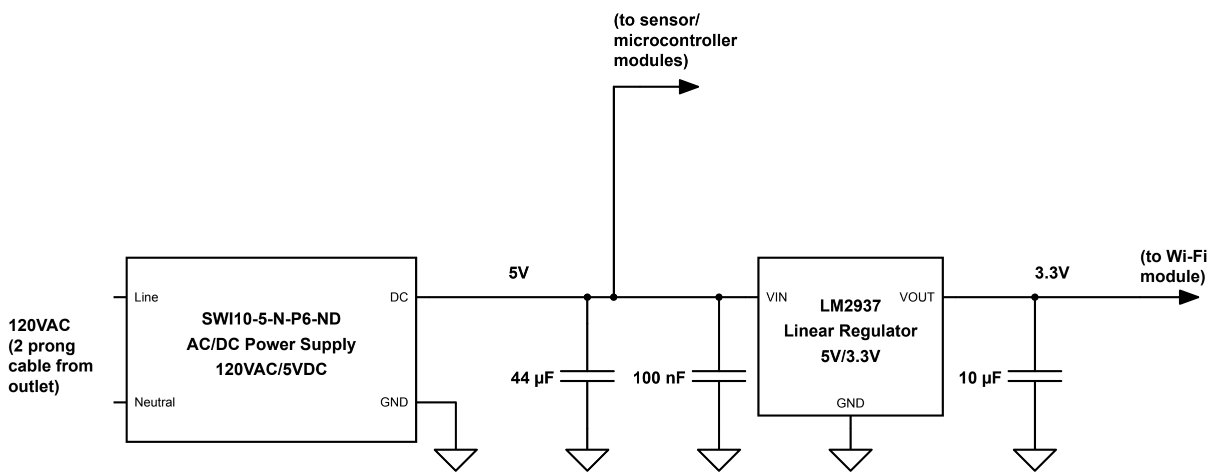

Figure 3: Central Hub Power Circuit Schematic

4. Requirements and Verification

Component	Requirements	Verification
AC-DC Converter (120VAC to 12VDC)	• Output 12V ± 2% DC consistently.	• Measure steady state output and compare with desired range. • Apply 2-amp load current and measure response.
AC-DC Converter (120VAC to 5VDC)	• Output 5V ± 2% DC consistently.	• Measure steady state output and compare with desired range. • Apply 1-amp load current and measure response.
Buck Converter	• Output 5V ± 2% DC. • PG signal indicates proper level of output voltage.	• Measure output and compare with desired range. • Induce fault on FB pin and ensure PG signal goes low.
Linear Regulator	• Output 3.3V ± 2% DC consistently.	• Measure steady state output voltage and compare to desired voltage range. • Apply 0.25-amp load current and measure response.

Table 1: Requirements and Verification

5. Calculation

The temperature sensor output voltage has a linear dependency on temperature as given by the relationship:

$$V_{out} = 10\left[\frac{mV}{°C}\right] * T[°C]$$

The temperature sensor has a measurement range of -55 to 150 C° making the range of measureable output voltages to be -0.55 to 1.5 volts [3]. The listed temperature sensitivity is 0.25C° which corresponds to a voltage change of 2.5mV.

The output of the temperature sensor is read by the microcontroller 10-bit analog-to-digital converter. With a reference voltage of 5 volts the sensitivity of the ADC is roughly

$$\frac{5}{2^{10}} \approx 5mV$$

Therefore, the system has a lower sensitivity than the temperature sensor itself. The sensitivity of the system is about 0.5°C from the temperature measured by the sensor. Since our requirement is only to measure a temperature difference of 1°C, this is not an issue. However, if noise or other circumstances causes this to be an issue, we will implement an amplifier and/or level shifter to fully utilize the input voltage range of the ADC.

6. Simulation

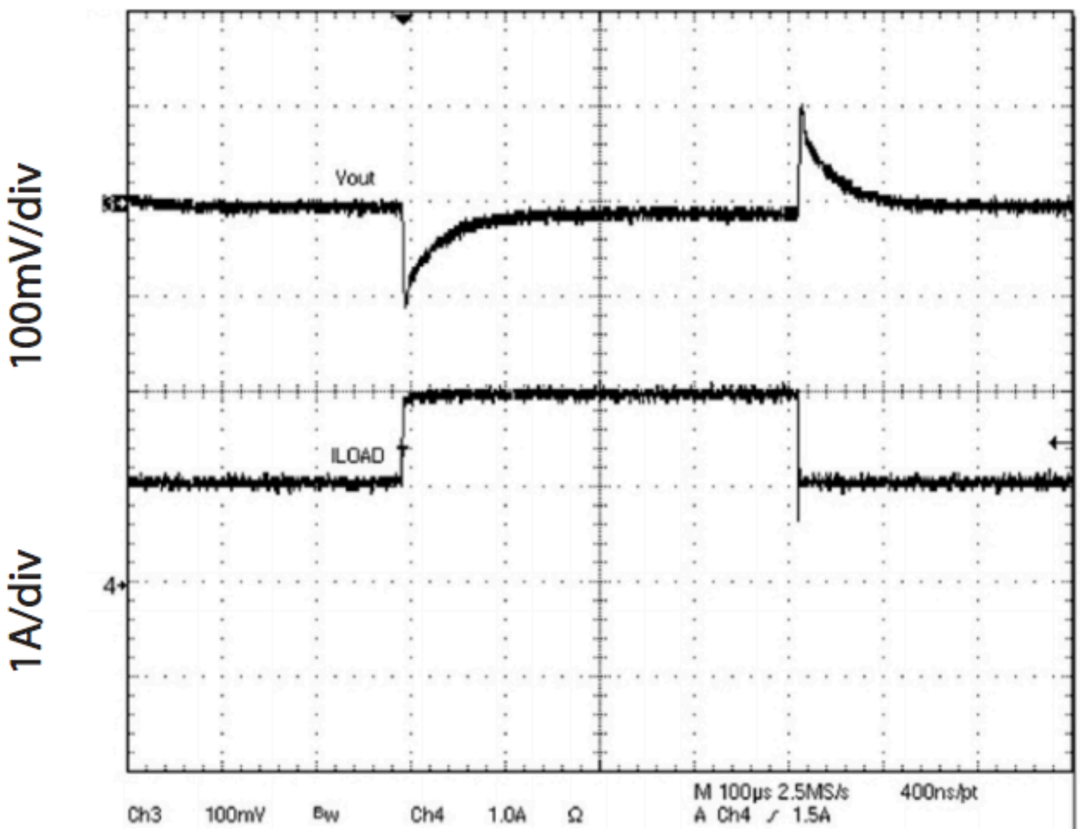

Figure 4: Buck Regulator Load Step (100mA to 1A) [1]

The buck regulator is powering the microcontroller, Wi-Fi modules, and sensors. The Wi-Fi module is a highly variable current load. It has an estimated max current input of 226mA, since it sinks 170mA for full power data transmission and 56mA to receive data [2]. We will assume that the microprocessor will have a similar magnitude of max current. According to the buck regulator datasheet, a load step increase from 100mA to 1A corresponds to a voltage sag of approximately 100mV, and a decrease from 1A to 100mA corresponds to a voltage spike of 100mV [1]. Our requirement for the 5V supply is 5V±0.1V which corresponds to this load step. Since our maximum load step will likely be much less (<500mA), our 5V supply will maintain proper voltage bounds for a load step.

7. Safety and Ethics

7.1 Ethics

Throughout our project, we plan to follow the IEEE code of ethics as closely as possible. This involves honesty, the acceptance of criticism, acknowledgment and correction of errors, fair treatment of everyone, and to hold each other accountable, as well as to give proper credit to the contributions of others [4]. Additionally, we will ensure that we make “decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment” [4]. Because of the nature of our product, there are a few specific safety concerns that we will encounter.

7.2 Safety

In terms of safety, there are a couple of primary concerns. First, the system could accidentally close on someone or something that it is not supposed to. Second, because the system is designed to be integrated into a window and wall and uses power from the grid, there are standard electrical risks such as shock and sparks that could be a fire hazard. These risks are largely preventable with correct installation of our product, and therefore we will recommend that the system be installed by a professional electrician. There are an estimated 52,500 electrical fires in US homes alone [5]. Third, someone could take advantage of the system to gain access to the house.

7.2.1 Physical Safety

Since the windows will have the capability of closing automatically, there is the potential that they will attempt to close while a hand, the tail of a pet, or some other appendage is in the window. To avoid this, we chose to use casement windows because these come with a screen on the inside of the window. This will prevent anyone or any pet from getting their hand or tail closed on.

7.2.2 Burglary

There are two main ways someone could break into a home because of our system. First, the system could automatically open the windows when the user isn’t home in order to regulate the temperature, which could allow an intruder to enter. Second, someone could hack into the central hub and open a window to gain access to the home.

7.2.2.1 Opening the window automatically when nobody is home

This problem can be solved by having a “keep all windows closed” setting (or maybe “keep all first story windows closed”). An idea that might be out of the scope for this semester would be to automatically detect if the user was home based on their phone and then only activate the system if they are home.

7.2.2.2 Allowing someone to hack in and open the window

The second problem can be solved by using password protection to ensure only the owner can open the window.

8. References

[1] Semtech, “TS30011/12/13 High Efficiency 1A/2A/3A Current-Mode Synchronous Buck DC/DC Converter, 1MHz,” TS30013 datasheet, Revised Aug. 2016.

[2] Espressif Systems, “ESP8266EX Datasheet”, ESP8266 Datasheet, Revised Jun. 2015

[3] Texas Instruments, “LM35 Precision Centigrade Temperature Sensors,” LM35 datasheet, Aug. 1999 [Revised Aug. 2016].

[4] Ieee.org, "IEEE IEEE Code of Ethics," 2017. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 16-Feb-2017].

[5] Pat Curry, “Find and Prevent Electrical Fire Dangers in Your Home,” Internet https://www.houselogic.com/organize-maintain/home-maintenance-tips/find-and-prevent-hidden-electrical-fire-dangers-in-your-home/ [Feb 20, 2017]