ECE 445

Spring 2018

Home Energy Administration Tool (H.E.A.T.)

Project Proposal

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8 February 2018

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1. Introduction

1.1 Objective

According to the CIA World Factbook, the United States is the second largest energy consumer considering total use [1]. In the near future - estimated to be 2088 - we will run out of fossil fuels because energy reserves are clearly finite and the rate at which the world consumes them is increasing as the world's population increases. If we continue to use energy in this fashion, we will run out of energy eventually. We can stop pursuing fossil fuels by alternatively exploiting renewable energy sources, but this has to happen more quickly as energy resources dry up fast. While the world switches to renewable energy systems gradually, we can slow down the rate at which the energy is consumed at households. In order to slow down the energy consumption, it is first necessary that people become aware of how much energy they use daily, primarily because people tend to overuse energy unconsciously. However, it is often difficult to realize exactly how and how much energy they could save because they are uninformed of the specific amount of energy consumed by each appliance in their household.

The problem can be solved if residents at households can monitor in detail how much electricity they use daily. Furthermore, detailed statistical analysis of energy usage and remote power control can be very informative and handy towards solving the problem. From this, we expect people to grasp certain sense of how much each appliance at home takes up the total energy consumption and realize the necessity to economize energy.

1.2 Background

Our goal is to create a comprehensive administrative tool that provides detailed and quantitative information about each appliances' and electronics' energy consumption. The power of each appliance is going to be remotely controlled through a responsive web application we plan to develop. This web application is also going to include a timer feature where the user can schedule appliances to be turned on and off automatically. Most importantly, it is going to display detailed statistics that will help the user keep track of energy consumption and make decisions towards energy conservation. The information we plan to provide includes each appliances' energy consumption, elapsed time of usage, estimated bill, and periodic usage comparisons (ex. daily, weekly or monthly). This will be represented in forms of chart or table with filters, which will allow easier access to all the details.

Moreover, we aim to come up with the most desirable usage recommendations customized to each individual appropriately. For example, if the user's energy usage amount exceeds certain range of standards set from the average Americans', we can let the user know this fact and suggest decreasing the duration of usage. Indeed, energy conservation is important because it not only cuts down electricity bills but also saves the environment where we all live in.

1.3 High-Level Requirements List

- The current sensors should be able to measure up to 20 Amps, which we assume to be the maximum possible value of current that can be drawn by each household appliance.
- Current sensor must measure current with less than $\pm 5\%$ error so that energy consumption can be calculated as accurate as possible.
- The system must maintain stable connectivity at all time to achieve desired functionalities.

2. Design

2.1 Block Diagram

Figure 1 shows the block diagram for the design of our system. We have four big units - power unit, sensor unit, control unit, and server unit. The power unit consists of power source and voltage regulator which provides 120V AC and 5V DC, respectively to different parts in our system. The sensor unit is composed of a few current sensors which will measure the current flowing through each appliance or electronic device. Then we have a control unit which includes microcontroller and relays. This unit will control the entire power system as needed for our measurements. All the data is then collected through microcontroller and the server hosted by ESP32 module. Microcontroller will signal the relays in accordance with the data received on server. Finally, we are going to analyze and visualize statistics on our web application based on the database on the server.

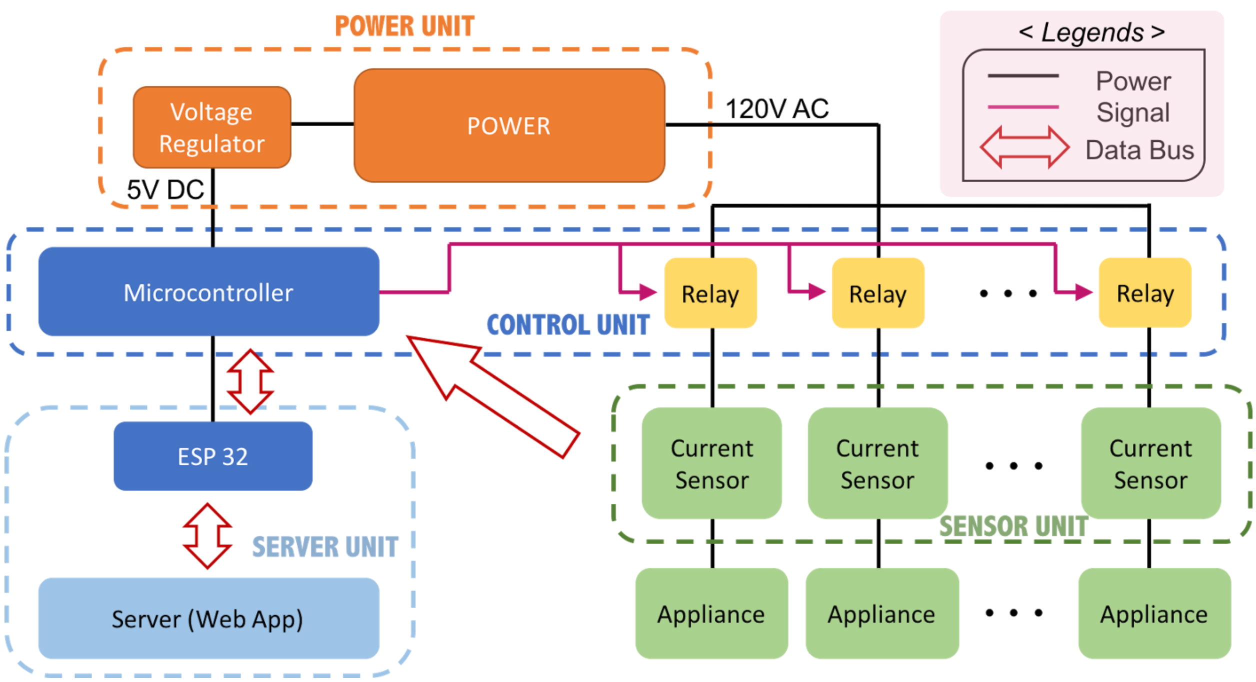

Figure 1. Block Diagram

2.2 Functional Overview

2.2.1 Power Supply

- The power supply, directly drawn from the wall outlet, will provide 120V AC to the entire system. Home appliances will be connected to this outlet with a few intermediate units such as relays and current sensors. Same amount of voltage will be loaded to each device by using the same kind of current sensors.

2.2.2 Voltage Regulator

- The voltage regulator steps down the 120V AC voltage to a 5V DC voltage to supply appropriate amount of stable voltage to the microcontroller.

2.2.3 Microcontroller

- The microcontroller is responsible for all power and signal controls. It will be embedded on the PCB board with ESP32. It is powered by 5V DC voltage to receive data from the current sensors and generally communicate with other units like ESP32 and relays. It sends and receives data to and from ESP32 to eventually manipulate the data for analysis or to decide on whether to signal the relays or not.

2.2.4 Relay

- The relay operates as a switch that connects/disconnects the current flowing through the appliances according to a signal received from the microcontroller.

2.2.5 ESP32

- The ESP32 hosts a web server where the data can be sent to and will work as an important medium for transmitting and receiving all the data to the web application we are going to deploy. This will be connected to the microcontroller on PCB board which will be able to obtain the current values to send over.

2.2.6 Current Sensor

- The current sensor measures the amount of current drawn by each appliance. The measured value will then be sent to the microcontroller and stored on the database.

2.2.7 Appliances

- Appliances in the model design represent the actual electronic devices, lightings and appliances at household.

2.2.8 Server (Web Application)

- Through the server hosted by ESP32, our web application transmits and receives data to and from the microcontroller. We are planning to use MongoDB to store and query the data. Our web application will be responsive so we can conveniently access through our smartphones and will display the detailed information regarding energy consumption, elapsed time of usage, estimated bill, and periodic usage comparisons represented in forms of charts and tables.

2.3 Block Requirements

2.2.1 Power Supply

- The power supply needs to provide sustainable 120V AC. This should be achieved by using any electric outlets on walls.

2.2.2 Voltage Regulator

- The voltage regulator must be able to handle 120V AC to step down to a stable 5V DC voltage independent of the load current.

2.2.3 Microcontroller

- The microcontroller should be able to provide 5V DC to the ESP32 and receive correct data from the current sensor. It should also be able to communicate with other components fast enough to handle data correctly. The microcontroller operates within 1.8V to 5.5V.

2.2.4 Relay

- The relays must be able to tolerate the 120V AC power we are providing. It should correctly work as a switch depending on the high/low signal sent from the microcontroller.

2.2.5 ESP32

- The ESP 32 must provide stable connection via WiFi at reasonable speed to transmit and receive will communicate through WiFi with 2.4GHZ (802.11n) [2].

2.2.6 Current Sensor

- Must be able to hold up and measure the current that is required to turn on the household appliances up 20 Amperes.

2.2.7 Appliances

- For the appliances we plan to connect with the power, the current flow should not exceed 20 Amperes. These appliances also must be able to normally operate on 120V AC.

2.2.8 Server (Web Application)

- The server must be able to store enough data of our interest, which we assume to be no larger than 0.5GB. Also, our data analysis should be updated as fast as possible, close to the real time. We also plan to use REACT to allow instant updates on the front-end. Last but not least, our server should respond and send data to the microcontroller as quickly as possible.

2.4 Risk Analysis

Failure to design the PCB board accurately can be the first possible risk we can encounter. It will need to be redesigned and reordered, which can be time-consuming. Time is a critical resource when working on the project, and to avoid wasting valuable time, it will be crucial to scrutinize the design before we place an order.

Since the design requires a power supply of 120V AC, there is a risk of electric shock when handling the modules and circuitry. We must always be careful when dealing with power cables and wires, and check if the power is turned off before we touch the circuit. It is also important to turn off the power whenever the system is not in use, even for a short period of time.

As we are using actual electronic devices to measure energy consumption, it is critical to examine the circuitry carefully before each trial so that it does not damage the electronics. Such mistakes will not only cause the tested electronics to malfunction, but also cause a fatal issue considering its real-world application.

3. Ethics and Safety

There are many aspects that must be concerned in the project. The critical safety issue is that the design uses 120V AC which results in high current and thus may cause fire hazard. We also need to use appropriate size of wire that can handle high current in order to prevent damage on circuit.

Security issue may arise as we are hosting a web server to store information that may be sensitive regarding to the household. We will have a web application to verify credentials of users to prevent others accessing the data.

We pledge to the IEEE code of ethics [3]. As the IEEE code 1 states, we will paramount the safety, health, and welfare of the public, to strive to comply with ethical design, and to be aware of the factors that might endanger the public or the environment [3]. As code 3 states, we will be honest and realistic with our data in measuring the energy consumption of each appliance and the cost of the electricity bill [3]. As code 7 and 10 states, we, as a group will accept our criticism and support each other as a team and always credit each members with their work and distribute work fairly [3].

4. References

[1] cia.gov, "The WORLD FACTBOOK", 2015. [Online]. Available: https://www.cia.gov/library/publications/the-world-factbook/rankorder/2233rank.html#us [Accessed: 04-FEB-2017]

[2]espressif.com, "ESP 32 Data Sheet", [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf [Accessed: 07-FEB-2017]

[3] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 05-FEB- 2017]