Home Appliance Energy Monitor

ECE 445 Design Document - Fall 2023

Project #

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Introduction

Problem

As a technologically modern world, we have a lot of home appliances that are consistently reliant on a lot of electricity. However, we tend to overuse these devices, thus leading to dangerously high electricity usage. An average of 34% percent of electricity at the household is wasted. This problem would become more apparent to users if they were able to visualize and track their electricity consumption for each home device because many users are unaware of their electricity consumption patterns and do not realize the extent of wastage that occurs.

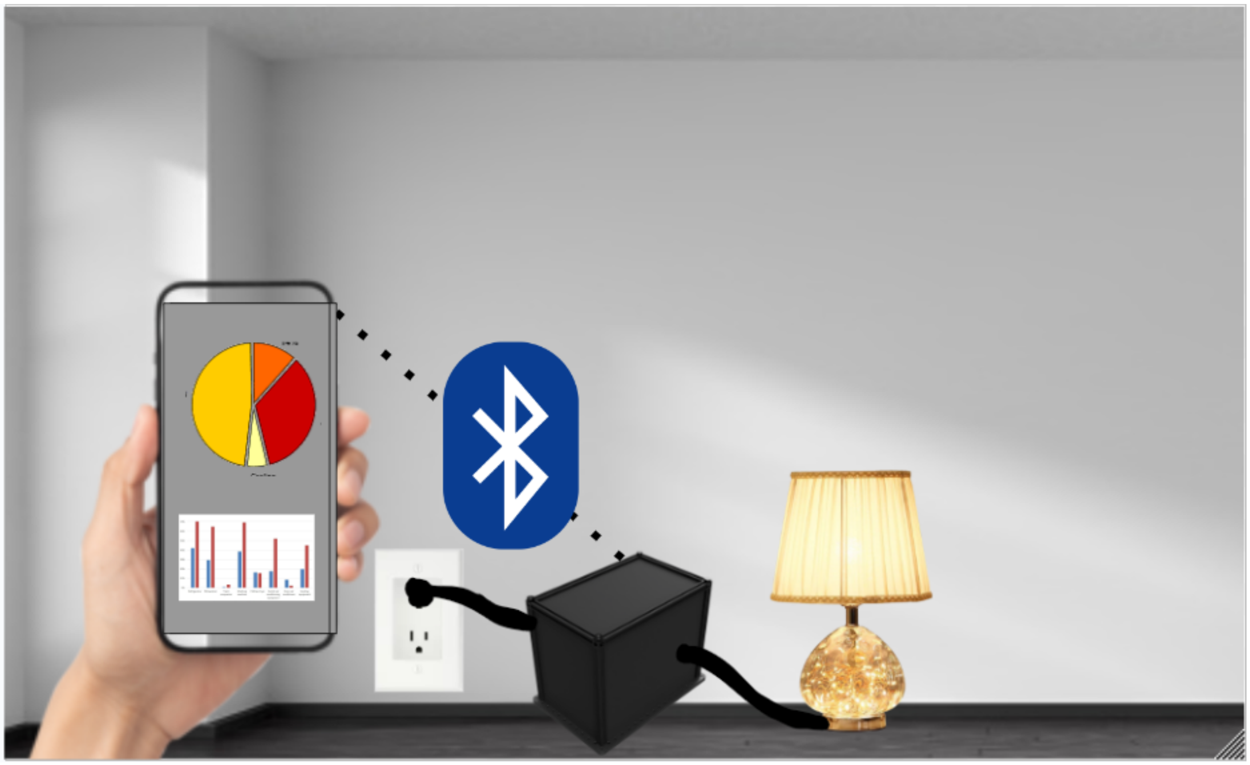
Due to convenience, entertainment, and forgetfulness, the average modern lifestyle does not spend time being more mindful about their electricity consumption. Even though there are quick actions that can be taken to reduce the consumption of electricity, individuals cannot make informed decisions. For example, homeowners may see high utility consumptions but don't exactly know what appliances are disproportionately contributing to the total electricity consumption amount.

Solution

To address the electricity consumption problem, a viable solution needs to enable better decision-making by users to better manage electricity consumption. The electricity usage of home appliances need to be tracked to understand how to make adjustments to how individuals consume electricity and understand patterns of usage.

The solution we will be implementing is a Bluetooth-enabled electricity monitor for home appliances. This monitor would track electricity consumption for the connected device over a period of time. There would be a microcontroller to process the values from the sensors and handle communication. An app would be made to display the results and send notifications to users if a certain device is consuming dangerously high amounts of power.

Visual Aid



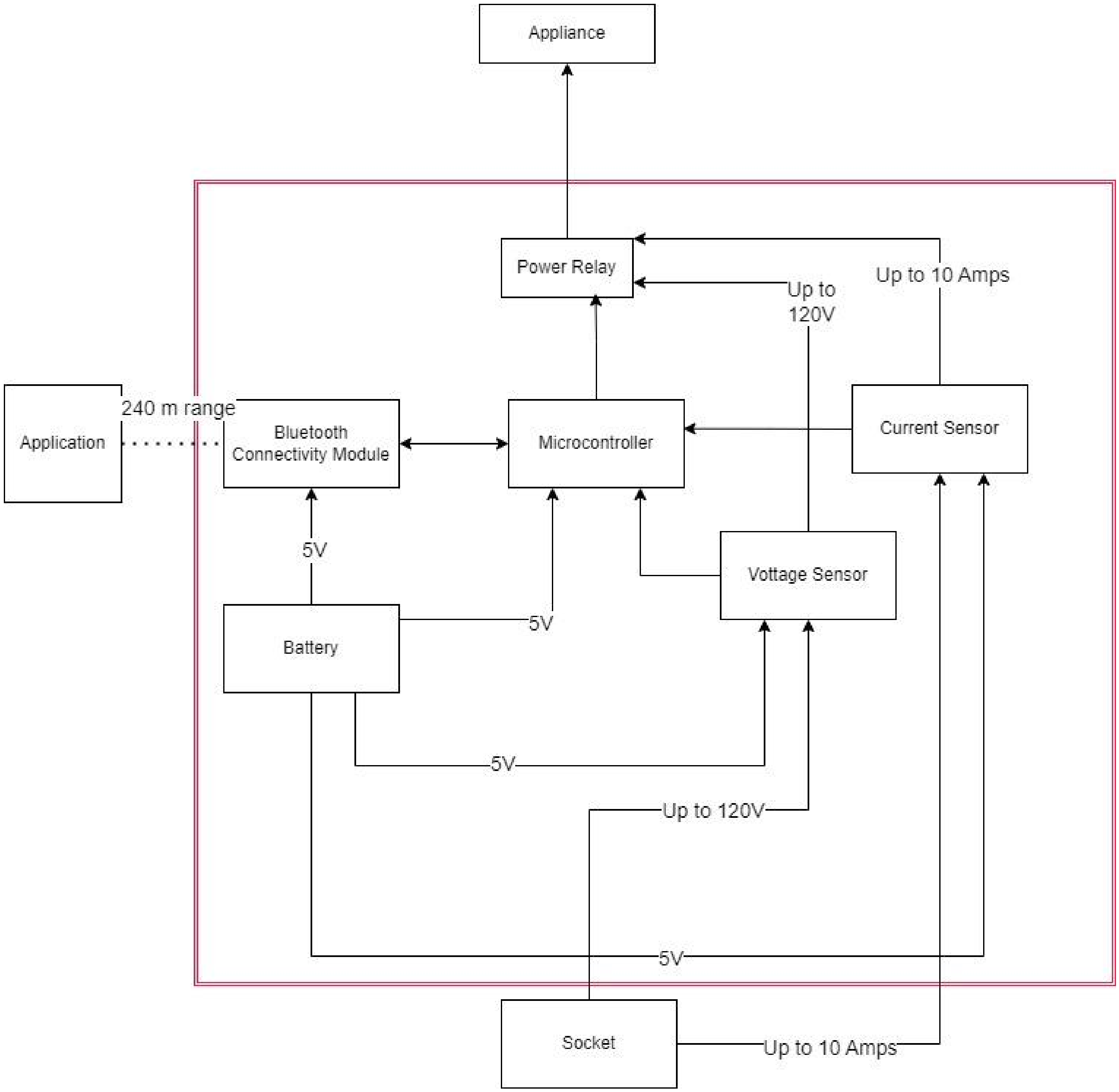
High-level requirements list

- A physical device that can handle a load of up to 250 Volts and 20 Amps as this is the maximum household socket output in most regions around the world.
- We have an application that is able to fetch data wirelessly that is visually appealing and easy to understand for the customer. This reach should be around 100 meters as this is the normal bluetooth range.
- We aim for an accuracy of +- 5%. The standard we will be referencing is IEEE-Standard 1459-2010. This standard defines terms, concepts, and test methods for the measurement of electric power quantities.

Design

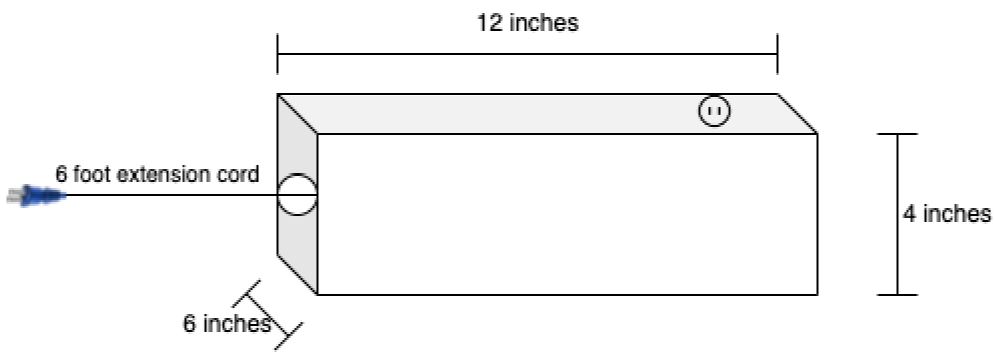
Block Diagram

A general block diagram of the design of your solution. Each block should be as modular as possible and represent a subsystem of your design. In other words, they can be implemented independently and re-assembled later. The block diagram should be accompanied by a brief (1 paragraph) description of the critical subsystems and what they do.



Our device is completely enclosed in the red box in the above figure. As shown in the block diagram, the device will be connected to the socket, the application, and the appliance. The current drawn from the device is measured and sent to the microcontroller and transmitted via the bluetooth module to the backend of our application.

Physical Design



Our physician design consists of a pcb board that will be in an enclosure above. The dimensions for the enclosure is available in the above image. This enclosure will be made of plastic as this will allow our bluetooth signal to pass through. An extension cord will go into the box as seen on the left of the diagram. This extension cord will be plugged into our wall socket that provides the electricity. We will also be having a socket on our enclosure that will allow our appliance to plug into our monitor.

Microcontroller

Manage functionality and interactions of all other subsystems. We will use this to handle data from sensors to be analyzed and output a signal to the power relay to turn on or off the appliance. It will also output to the bluetooth module the relevant data and get user input. Using data that is fed in from the sensors, we will use this to extract and send this data to our app by sending the data to the bluetooth module. This data that we get from the sensors will be recalibrated to match the real value of the voltage and current. This will be recalibrated using the graphs in the data sheet of the sensor that correlate the data sent to the microcontroller to the real value. The microcontroller will also accept data from the bluetooth module to control the power relay. The power relay will also be connected to the microcontroller and be controlled through it as well. Lastly, the microcontroller will take in data from the thermostat sensor as we can use this reading to read any dangerously high temperature reading which helps us notice high electricity use and in some cases electricity wastage. The operating voltage of the microcontroller is 2.7 to 3.6V and the I/O ports have a 5V tolerance. Since the battery will be a 5V battery, we will need to use a DC-to-DC step down converter to lower the voltage to the operating voltage.

Power Relay

Take care of turning devices on and off. Essentially used to control the power supply to the connected devices. Will receive input from the microcontroller whether the power relay should allow the appliance to receive voltage and current from the wall socket or not. The power relay will be able to handle up to 250 Volts and 20 Amps as these are the maximum household outputs from sockets in most regions of the world. Coil rating for this part is 5V therefore it will be connected directly to the battery to be powered.

Sensors
The necessary sensors are a current sensor and a voltage sensor that will connect to the microcontroller to use the data. The current sensor measures the current flowing through the socket's outlet, which will be used for power consumption calculations. The voltage sensor measures the voltage level of the power supply, which will be used for power consumption calculations. The voltage and current sensor will be connected to the energy metering IC to send it data to be extrapolated. The current and voltage that is used to power the appliance will also run through these sensors. Both sensors have a voltage supply rating of 5V so it will be connected directly to the battery.

Bluetooth Connectivity Module
Transfers data from sensors and metering IC to an application on a phone or laptop via Bluetooth. Will get fed data from the microcontroller to output to the user application. It will also input data from the user app to send to the microcontroller so control out the power relay. This module will use bluetooth 5.1 which has a range of 250 meters. Maximum voltage supply can be 3.6 V therefore we will be using a DC-to-DC step down converter to lower the voltage to the operating voltage.

Tolerance Analysis

- For voltage, we will be accepting a tolerance of ±5% as this is what is accepted in most residential applications. Since most appliances run 120 voltage, we expect to get voltage readings of 126 V to 114 V. This would mean our monitor is not disrupting by causing a voltage drop or spike between the socket and the appliance. A voltage drop may cause our appliance to shutdown, and a spike can cause device damage.
- For the current, we will be accepting a tolerance of ±1%. Since this is a smaller value, usually 10 Amps, we have less room for error. Therefore a tighter tolerance should be followed to avoid device damage or shutdown.

Cost and Schedule

Cost Analysis
Include a cost analysis of the project by following the outline below. Include a list of any non-standard parts, lab equipment, shop services, etc., which will be needed with an estimated cost for each.

Labor:
Guneet Sachdeva: ($52/hour) x 2.5 x 400 = $52,000

Om Patel: ($52/hour) x 2.5 x 400 = $52,000

Ravi Thakkar: ($52/hour) x 2.5 x 400 = $52,000

Parts:
Include a table listing all parts (description, manufacturer, part #, quantity and cost) and quoted machine shop labor hours that will be needed to complete the project.

Description	Manufacturer	Part #	Quantity	Cost
Microcontroller	Renesas Electronics	R7FA6M4AF 3CFP#AA0	1	$8.10
Current Sensor	Allegro Microsystems	ACS712ELCT R-20A-T	1	$3.79
Voltage Sensor	Noyito Technologies	ZMPT101B	1	$6.99
Bluetooth Module	Renesas Electronics	US159-DA145 31EVZ	1	$1.93
Power Relay	Omron Electronics	Omron g5le-1 5vdc	1	$1.52
Battery	N/A	N/A	1	$2
Extension Cord	N/A	N/A	1	$8
DC-to-DC Step Down Converter	Advanced Monolithic Systems	AMS1117	2	$4.33

Sum of Costs
Each Member Salary = $52,000
Number of Members = 3
Total Member Salary = $156,000
Total Parts = $59.06
Spare Parts = $59.06

Total = $156,118.15

Schedule

Tasks	Start Date	Goal Date
Finish Design Doc	9/24	9/28
Finalize Parts to be used	9/28	9/30
PCB first Draft	9/28	10/1
Review PCB/Container design with Machine Shop	10/4	10/8
Team Evaluation	10/10	10/11
Get first round PCB order in	10/6	10/10
Last machine shop revisions	10/9	10/13
Update PCB design	10/11	10/15
Review PCB design with Machine shop/TA	10/14	10/17
Begin Firmware	10/17	10/23
Solder/Test PCB	10/18	10/22
Review PCB design with Machine shop/TA	10/19	10/23
FINAL PCB ORDER	10/23	10/24
Individual Progress Reports	10/21	10/25
Solder/Testing	10/24	…
Firmware	10/24	…
Create App	10/24	…
Prepare draft demo	11/9	11/12
Mock Demo	11/13	11/17
Team Contract Fulfillment	11/15	11/17

Final Paper	11/17	12/6
Prepare Final Demo	11/15	11/29
Final Demo	11/27	11/29
Prepare mock presentation	11/28	11/30
Mock Presentation	11/30	12/1
Prepare Final presentation	11/29	12/3
Final Presentation	12/4	12/6
Lab Checkout	…	12/7
Lab Notebook due	…	12.7

Discussion of Ethics and Safety:

Ethical and Safety Concerns

- Safety Issue: Dealing with high voltage will require us to take extra precautions during testing and building of our appliance
  - Work on circuit when not plugged in
  - Sources are grounded when dealing with live wires
  - Have someone with you during lab work
- Safety Issue: Handling different tools in the lab
  - Never be in the lab alone
  - Follow tool handling procedures
- Electrical Safety- Design:
  - It is imperative that we are evaluating the device, constituent components, and the connections between the components and the socket/appliance. We would need to carefully read the components' ratings and take notes of the characteristics to make sure every component is compatible with each other.
  - The device should be designed with proper insulation, grounded, and compliant with electrical safety standards. Safety warnings and instructions should be clearly provided to the users.
- Wireless Communication/Bluetooth Safety:

    - We need to make sure that our components are compliant with regulations for wireless communication
- Application Safety
    - We need to make sure that any sort of data being used by the application is secure and protected.

Safety Manual

- High Voltage
    - General Precautions
        - Always assume you are dealing with high voltage
        - Follow the buddy system and make sure someone is with you
        - Keep workstation clean and organized
        - Comply with local electrical guidelines
        - Be ready for emergencies by having medical assistance of way of contacting for assistance nearby
    - Protective Equipment
        - Wear insulating shoes if dealing with live voltage
        - Wear insulating gloves
        - Wear safety goggle
    - Working on Project
        - Always make sure voltage is disconnected before working on device
        - Use insulated tools and gear
        - Have plan ready for emergencies
    - Emergency Protocols
        - Electrical Shock
            - Do not touch electrocuted area
            - Disconnect Power
            - Call for supervisor or medical assistance
        - Fire
            - Ensure own safety
            - Use Class C fire extinguisher for electrical fires
            - If caught on fire: Stop, Drop, and Roll

Citations

Any material obtained from websites, books, journal articles, or other sources not originally generated by the project team must be appropriately attributed with properly cited sources in a standardized style such as IEEE, ACM, APA, or MLA.

"IEEE Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions," in IEEE Std 1459-2010 (Revision of IEEE Std 1459-2000) , vol., no., pp.1-50, 19 March 2010, doi: 10.1109/IEEESTD.2010.5439063.

Estimating appliance and Home Electronic Energy use. Energy.gov. (n.d.). https://www.energy.gov/energysaver/estimating-appliance-and-home-electronic-energy-use

M. Mahith, D. S. B. Kumar, K. C. Prajwal and M. Dakshayini, "Bluetooth Home Automation," 2018 Second International Conference on Green Computing and Internet of Things (ICGCIoT), Bangalore, India, 2018, pp. 603-607, doi: 10.1109/ICGCIoT.2018.8753094.