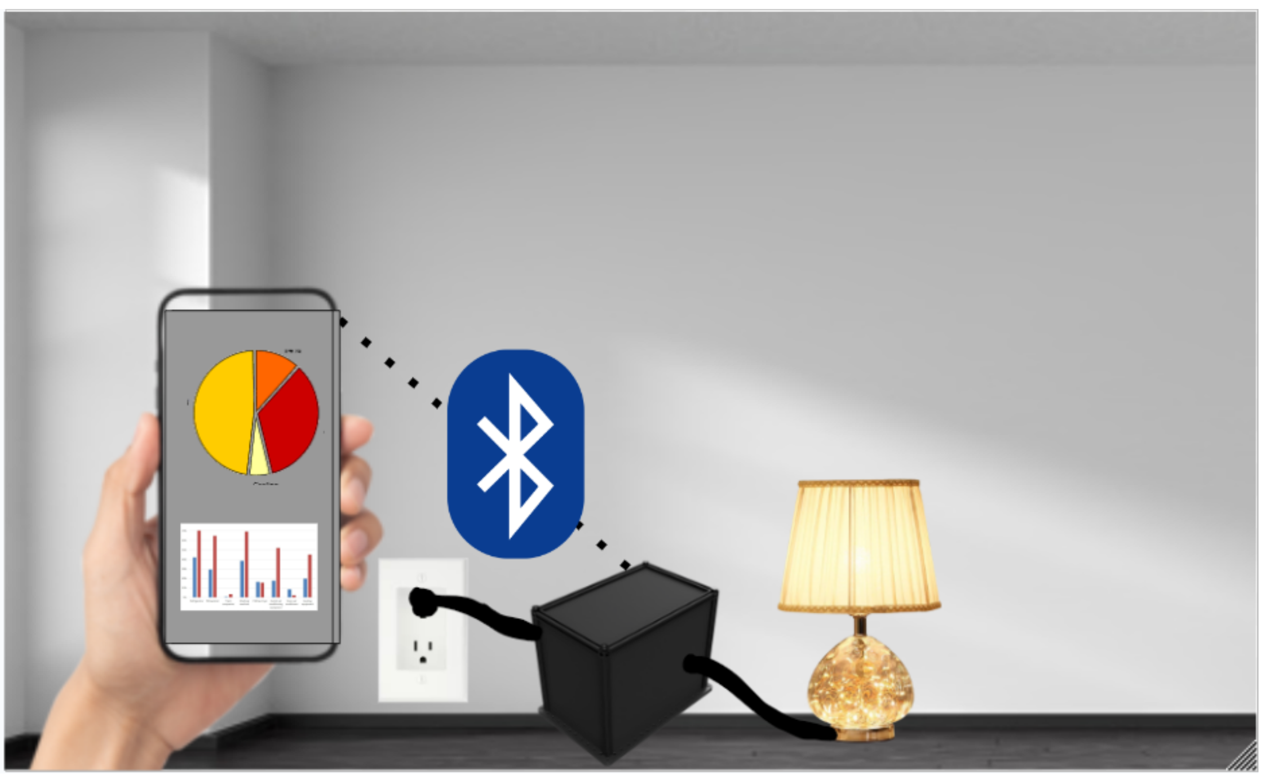
Introduction

- **Problem:** As a technologically modern world, we have a lot of home devices that are consistently reliant on a lot of energy. However, we tend to overuse these devices, thus leading to dangerously high energy 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 energy consumption for home devices.
- **Solution:** The solution for this problem would be to have a smart home energy monitor. This monitor would track energy 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.

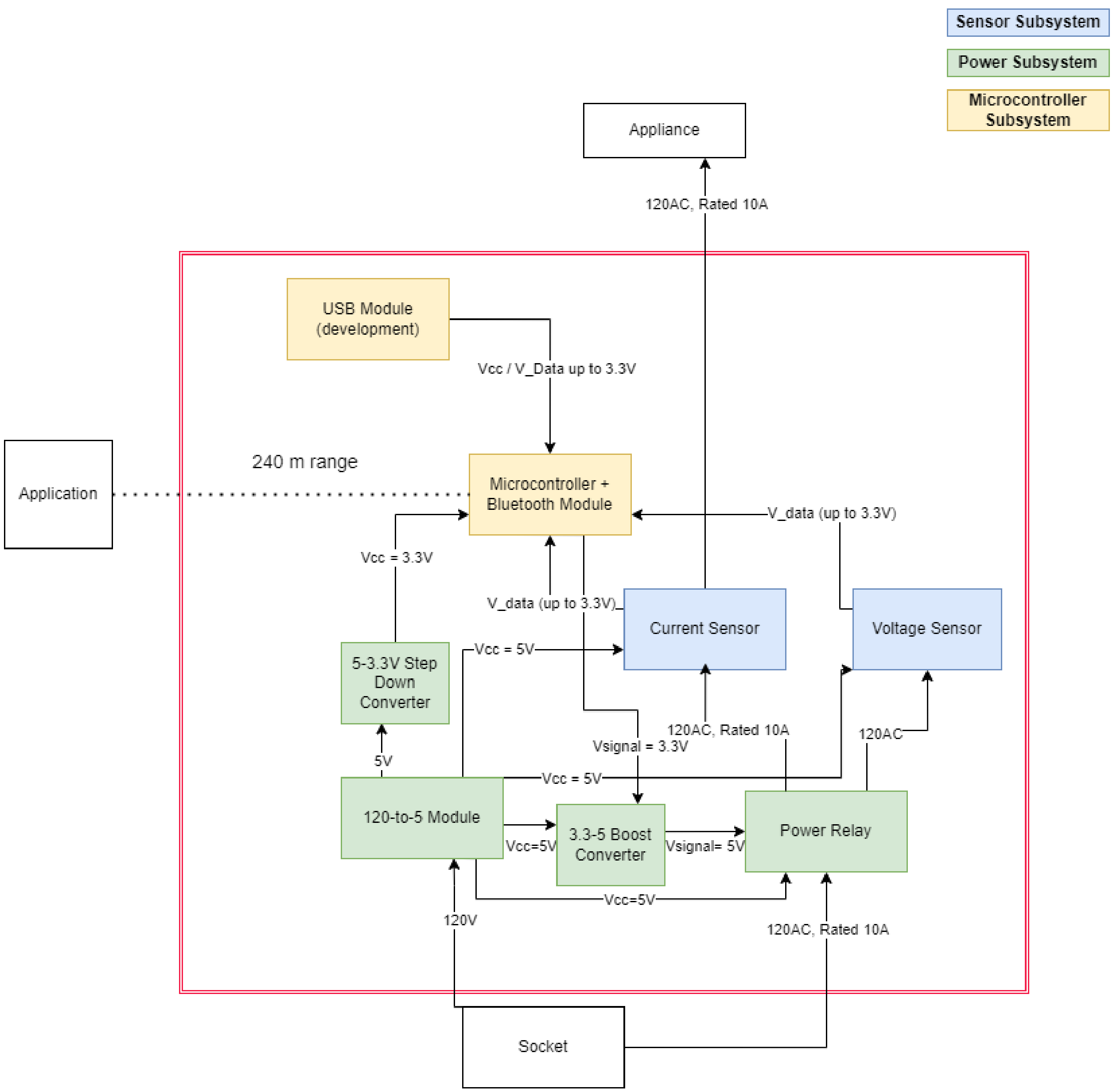
Visual Aid:



2. **High-level requirements list:**

- A durable physical device that can be plugged into wall outlets in the US (120VAC) and accurately measure and transmit power consumption to an application.
- The application 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.

3. **Design**
   - **Block Diagram:** Break your design down into blocks and assign these blocks into subsystems. Label voltages and data connections. Your microcontroller can live in multiple subsystems if you wish, as in the example below.



4. **Subsystem Overview:**
   - The first subsystem we have on our board is the **Microcontroller Subsystem**. This subsystem will be responsible for handling the turning on and off of the power relay, calculating the power value, and for relaying the power consumption information to our app via Bluetooth. The specific microcontroller we will be using for this subsystem is the ESP32. The microcontroller will be interacting with the power subsystem to receive 3.3 V to activate the enable pin. It will also interact with the power relay by telling the power relay to turn the power supply off if energy exceeds the user designated maximum power. The microcontroller

will be interacting with the sensor subsystem by reading in voltage and current values periodically to calculate how much energy is being consumed by the connected appliance.

- The second subsystem we have on our board is the **Power Subsystem**. This subsystem is responsible for powering the components on the board as well as controlling power supply to the appliance. The components in this subsystem are transformers and a power relay. There will be one 120 to 5 V transformer (LRS-35-5) to convert the voltage coming in from the socket to something that is apt for powering our sensors. There will be a 5 to 3.3 V (AMS1117-3.3V) transformer as well as a 3.3 to 5 V (Comidox 3.3 to 5 V transformer) transformer to control power going in and out of our microcontroller. Lastly, there is a power relay (Omron g5le-14 5vdc) that interacts with our microcontroller to determine if the connected appliance can continue to draw supply voltage or not.
- The last subsystem we have on our board is the **Sensors Subsystem**. This subsystem is responsible for measuring the voltage and current draw of the connected components. A voltage sensor (ZMPT101B) and a current sensor(ACS712ELCTR-20A-T) will be present in this subsystem. These sensors will be connected to the microcontroller subsystem as the microcontroller will be responsible for processing the values these sensors will be providing. These sensors will be receiving 5V of power from the 120 to 5 V transformer in the power subsystem.

5. **Subsystem Requirements:**
    - **Microcontroller Subsystem:** The first requirement for this subsystem is the ability to read in voltage and current sensor values. We want to be able to read in values every 5 seconds. This requirement can be confirmed via our front end app. If a new point appears on the energy graph (graph on the front end app) every 5 seconds, then our microcontroller is reading values according to our set period. The second requirement for this subsystem is the ability to control the power relay. If the power consumption exceeds the set safe limit, then the microcontroller should control the power relay to not let any voltage supply through. We can test this requirement by using a voltmeter to check the voltage going through the power relay. The last requirement is the ability for this microcontroller to alert users if power consumption is too high. We will have logic set in our firmware to determine if power consumption of the appliance is too high. To test this, the microcontroller should send users an alert on the user front end.If the alert is received appropriately, then our microcontroller subsystem has passed this requirement.
    - The **power subsystem** has quite simple requirements. We have transformers set in place to convert voltages to apt values. The requirement for the 120 V to 5 V transformer is to properly convert 120 Volts to 5 Volts and then power sensors

with the newly converted 5 volts/ The requirement for the 5 to 3.3 V transformer is to properly convert 5 volts to 3.3 volts and then power the microcontroller accordingly. The requirement for the 3.3 to 5 V transformer is to properly convert the 3.3 Volt output from the microcontroller to 5 volts. We can confirm all these values by using a voltmeter to test voltage values at different parts of our circuit. The power relay's requirement is to allow the voltage supply value through if the microcontroller allows such to happen and to not allow any voltage supply through if the microcontroller indicates that to happen. We can test this requirement through again using a voltmeter to test voltage values going through the power relay.

- **Sensors**: The requirements for the current and voltage sensor are to just the measured voltage and current values properly to the microcontroller. We can confirm this by seeing that whatever value is measured by the sensor is received by the microcontroller. One thing to keep in mind is the communication protocol between the sensors and microcontroller. To properly test this requirement, we would have to follow the procedure of the communication protocol between the microcontroller and the sensors.

Tolerance Analysis:

Our objective with tolerance analysis is to determine the worst-case tolerance of the power measurements based on the component tolerances to ensure that the overall error for power measurement does not exceed ±5%.

For the purposes of this document, we will demonstrate a simplified version of tolerance analysis. We will use 3 components' tolerances to calculate the worst case tolerance for measurement.

a. Voltage Sensor (ZMPT101B): ±X%

b. Current Sensor (ACS712ELCTR-20A-T): ±Y%

c. ADCwithin the microcontroller: ±Z%

For a worst-case scenario analysis, we will consider all components to be at their maximum tolerance at the same time.

To calculate the error to measure voltage and current, you can use the following formulas:

$E\_voltage = X + Z$

$E\_current = Y + Z$

And to measure the real power consumption, you use the formula: $P = I * V$. Therefore to measure E_power, it would be E_power = (X+Z) + (Y+Z). For our project, E_power must be under 5%.

This methodology can be expanded to fully consider all components in our schematic to provide a better understanding of the tolerance. This sort of tolerance analysis can also be used to ensure that the ratings of individual components are not exceeded, which is necessary to ensure the safety of our design.

6. **Ethics and Safety**
    - Safety Issue: Dealing with high voltage will require us to take extra precautions during testing and building of our appliance
        i. Work on circuit when not plugged in
        ii. Sources are grounded when dealing with live wires
        iii. Have someone with you during lab work
    - Safety Issue: Handling different tools in the lab
        i. Never be in the lab alone
        ii. 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.

1. **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