In-Wall Smart Outlet
SENIOR DESIGN 1

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Department of Electrical Engineering and Computer Science

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Initial Project and Group Identification Document
- Divide and Conquer -

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Sponsors:
None

Project narrative

The past two years of covid have shown us the importance of being connected in this increasingly digital world. The ability to understand and communicate with each other effectively is increasing with each passing day. One area in which the disconnect is blatantly obvious is between a home owner and his power company. Every month you receive a bill for the overall usage of electricity within your house. This bill gives you no breakdown such as what has been consuming the most electricity or what rooms are consuming the most electricity. Of course each device has estimates of its yearly power consumption and how much it would cost, but estimates are not perfect, and in places with wholesale electricity like Texas, these averages end up being incorrect. Furthermore, with inflation happening in the U.S. at unprecedented levels, these averages are only as good as the day they were bought. We should not have to rely on estimates and averages in regards to our electricity consumption. What if this information was available to us at our fingertips in an easy to use system that you would be able to control. Our goal is to do this and more.

With our smart outlet, you would be able to measure the power draw of individual devices as well as set power limits for these devices within a given time frame. For example, let's say we had a gaming P.C. Due to the varied nature of gaming, the PC may require anywhere from 100 watts per hour to 330 watts per hour. You would be able to measure the exact energy usage from the P.C as well as get a warning when you were nearing a large number for the month. This would be multiplied by your Residential Electric Rate and thus you would be able to see how much money a particular device is costing you. In an apartment with roommates, you would be able to accurately compare energy usage between habitants and there would be no discussions regarding a mini fridge causing the electricity bill to go up a huge amount since it was plugged in.

Another feature of the smart outlet would be the ability to turn it off and on from the app. This would most likely be done through a relay. The user would be able to target specific outlets within his home instead of turning off the whole room through the breaker switches. This would also work in tandem with power limits. Take for instance the gaming P.C from before, if needed you could set an overall power cap for the P.C. based on usage or cost, and turn off the outlet. In locations with wholesale electricity, this would allow you to put a large cap on the outlets that if reached would save you a large amount of money. During the winter storms in Texas, electricity rates jumped up to 3.00 dollars per kWh. This led to customers paying excessive amounts of money without even knowing and without having any breakdown information on the energy usage. With our device, a user would be able to set a money limit such as $500 in which non essential devices would be powered off immediately to save cost. Now $500 is already a lot of money to pay for a bill but it is significantly better than the thousands some customers had to pay when rates spiked. Overall, a device like ours gives consumers knowledge and knowledge is power.

Electricity usage and monthly cost would be available through a companion application. Logs of usage throughout the month would help bill payers understand where their money is going. Furthermore, the user would be able to individually turn off each smart outlet from the app in desired situations, such as going on vacation.The goal is to allow the consumer access to specific information regarding their home instead of just having a single amount that they have to pay every month.

Currently there are a few other products on the market but there are only a few in wall smart outlets and those that do exist do not have all of the features we are trying to implement. The best in wall smart outlet according to the New York Times, is the Top Greener In-Wall Smart Wi-Fi USB Charging outlet but that one only has one controllable receptacle where-as we would like to be able to control both of the outlets. Our generation has shown a desire for everything to be minimal while having a visually pleasing aesthetic. Smart outlet boxes that go over the outlet create visual clutter and take up space in an economy where space is a premium. By having the outlet flush with the wall, you create a more cohesive environment as well as maintaining the usable space in your home or dwelling.

The market for this device would be everyone in a typical household. This includes anyone from homeowners to college students in a dorm. Measuring energy consumption is a vital tool that can be used by anyone. I know from personal experience how frustrating it is living in student housing, being told you went over the monthly electricity cap and being forced to pay extra money without having any info on what you could be doing. The user interface would be simple to use.

The Smart Outlet is meant to add power and knowledge to the consumer side instead of just having another bill to pay each month. Why should we not be able to break-down our monthly energy expenses into the devices or location we desire?

Requirement Specifications

The System Hardware will be able to:

1. Measure current accurately
2. Track power usage over time
3. Have a companion app to control the device
4. Visualize power data over time in the app
5. Set a power usage threshold to turn off the outlet
6. Connect to other copies of the device for networking
7. Indicate on/off state with an LED
8. Conform to safety standards
9. Fit into existing outlets without modifications needed
10. Keep accurate measurements no matter the temperature

The System Software will be able to:

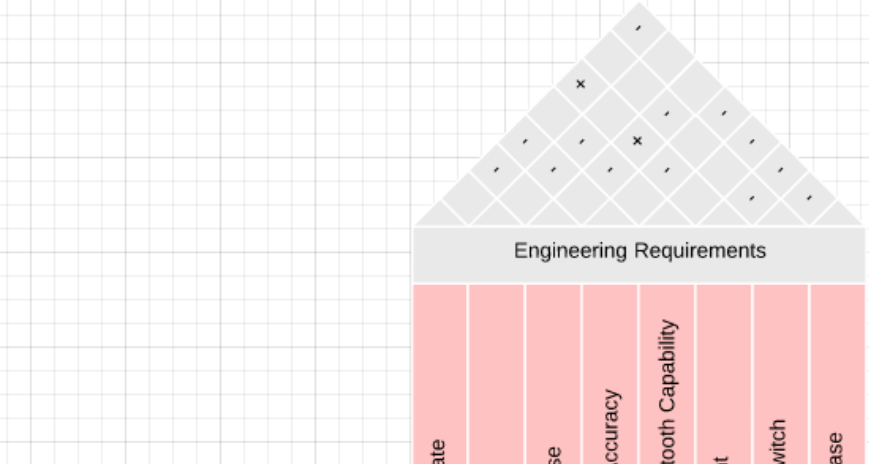
1. Be supported on both Apple and android devices
2. Connect to the app via wifi
3. Turn power on/off remotely
4. Set power usage limits
5. Connect to multiple smart power outlets at the same time
6. Have a constant refresh of the power usage every 30 seconds
7. Set a timer to turn off outlet

Possible Project Constraints

We are in the beginning of project planning so we will figure out more constraints as we go. The main constraint we see right now is the size. The bigger size, the more money it will cost to make and more power it might require. Also, if our plug is too big, it might not fit in the wall correctly. Another constraint is sturdiness. We would not want our plug to be in the wall and have it blow up whatever device is plugged into it and then possibly start a fire. To combat this, we will use quality components and make sure everything is up to common standards. Finally, we will use sturdy plastic to encase our components. This is what just about every other smart plug does so this will be no problem.

House of Quality

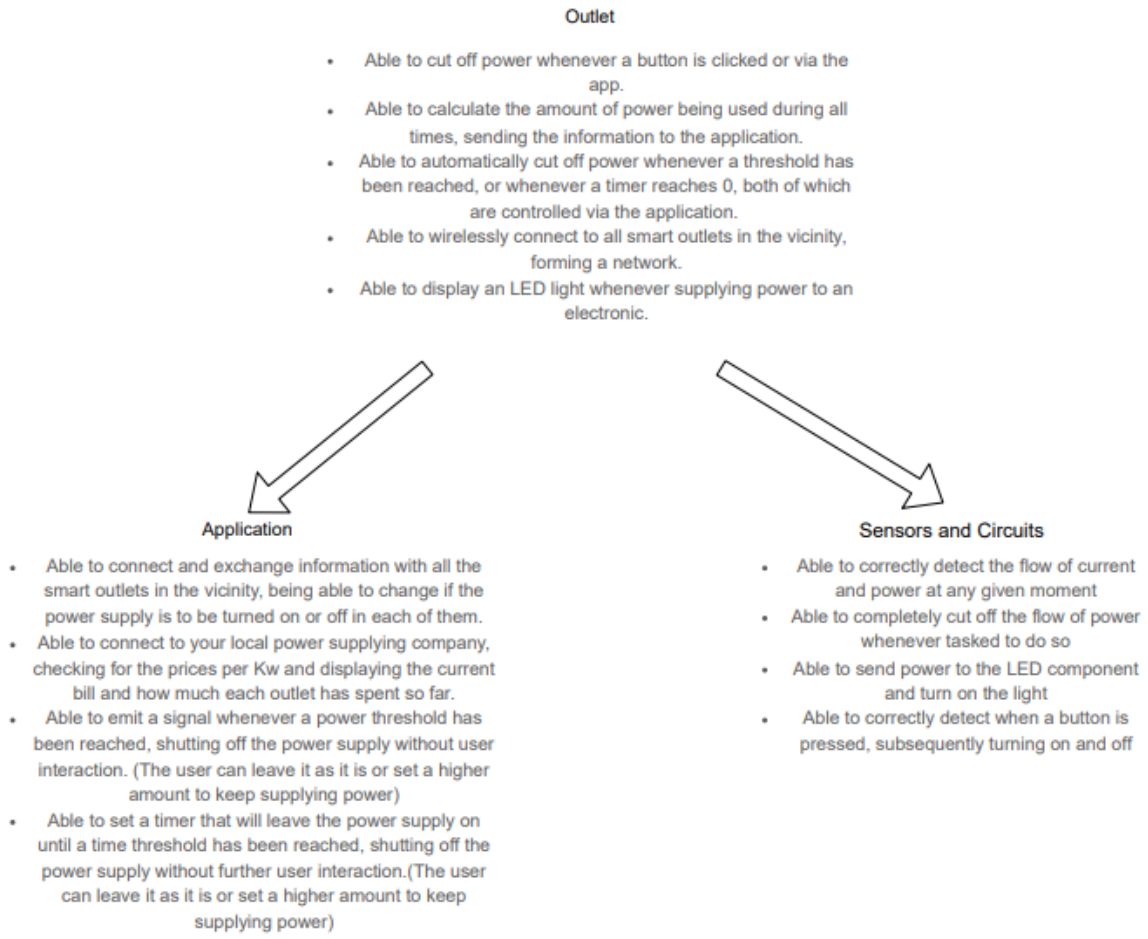
Key	
↑↑	Strong positive Correlation
↑	Positive Correlation
↓	Negative Correlation
↓↓	Strong negative Correlation
	No correlation
Positive Polarity	+
Negative Polarity	-



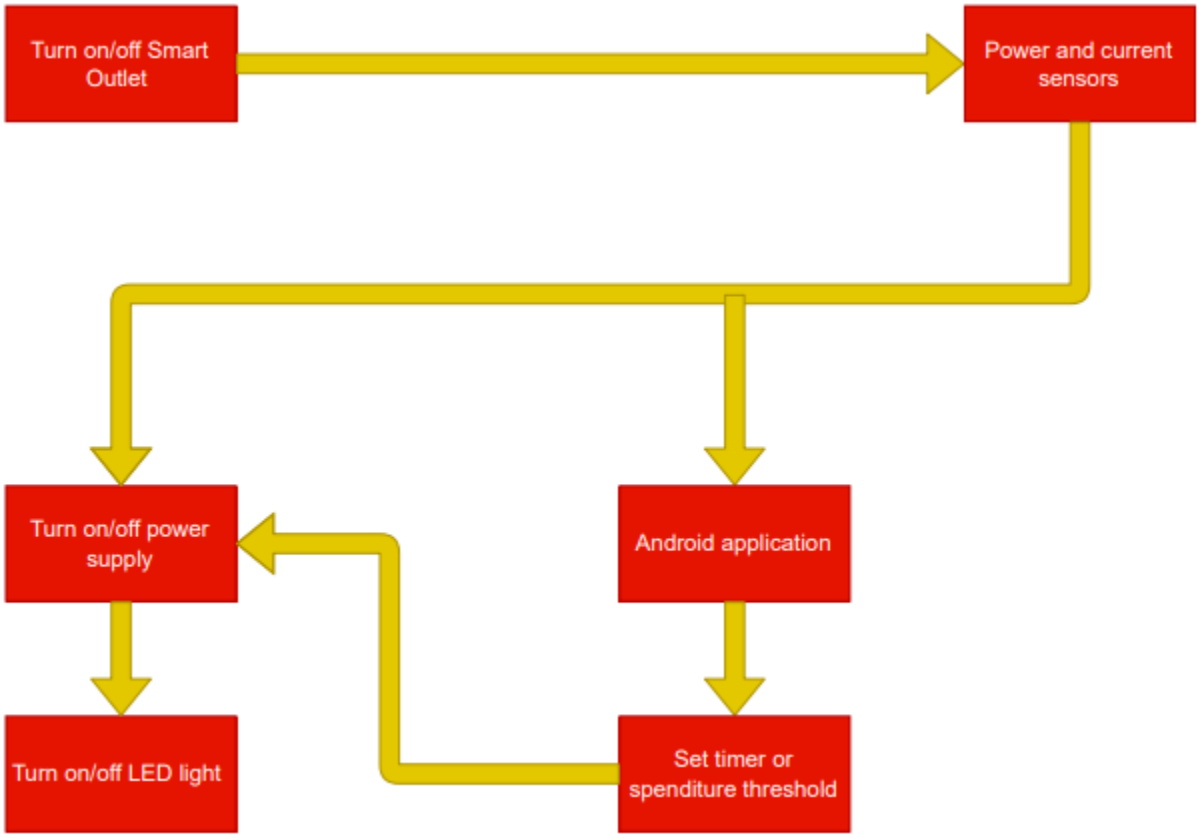
User Requirements			Power Rate	Cost	Power Use	Sensor Accuracy	Wifi/Bluetooth Capability	LED Light	Toggle Switch	Plastic Case
			+	-	-	+	+	+	+	+
	Cost	-	↓↓	↓↓	↓	↓↓	↓	↓	↓	↓
	Size	-	↓	↓	↓					
	Easy to use	+					↑↑	↑	↑	
	Reliable	+		↓↓		↑↑				
	Smart Phone App	+		↓			↑↑		↑	
	User Interface	+		↓			↑		↑	
	Power Use Reduction	+			↑	↑↑			↑	
			<1200Watts	<$500	<1200Watts	<20Watts	100ft Range	<1ms	<1ms	<$20

Project block diagrams

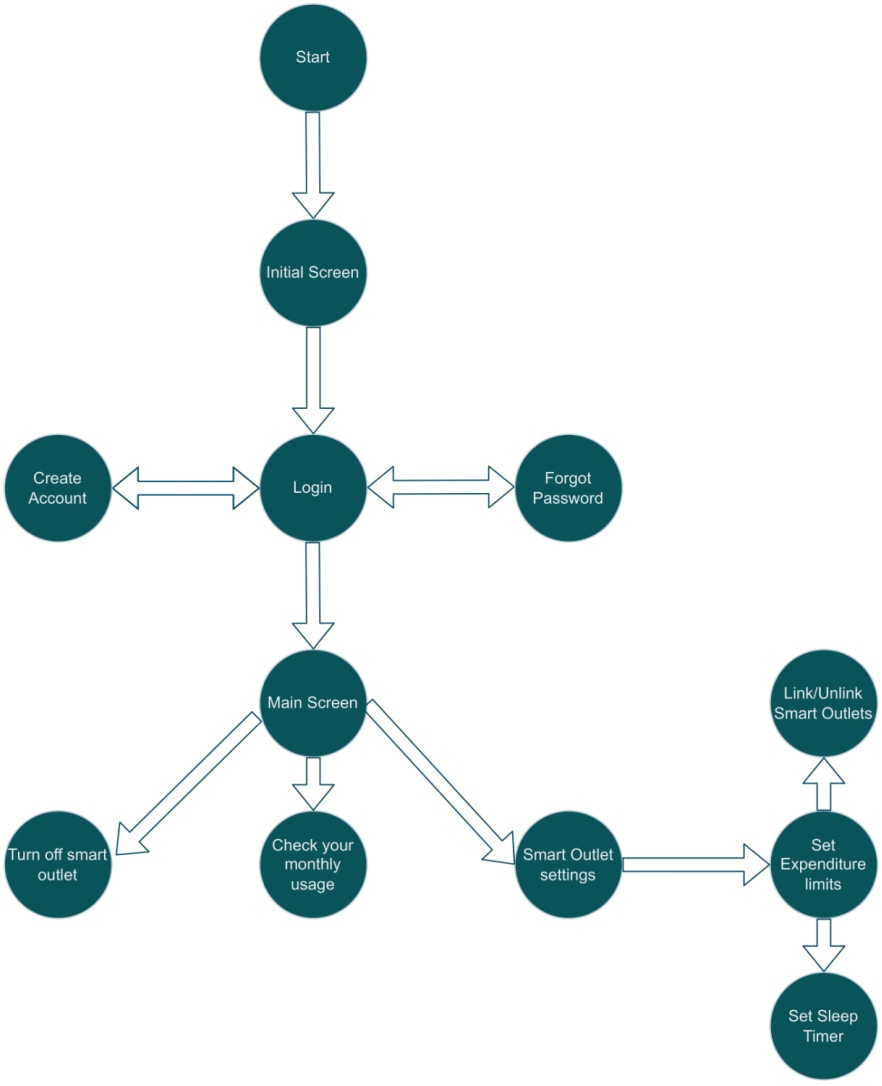
Hardware specifications



Hardware Flowchart



Application Flowchart



Estimated project budget and financing

Part Link	Name	Multiple of Order	Unit Price	Projected Amount	Vendor	Alt	Notes
Link	ESP32 Microcontroller	1	$10.99	$10.99	Amazon		
Link	Standard Outlet	1	$5.89	$5.89	Home Depot		
Link	AC Current Transformer	1	$10.99	$10.99	Amazon		
Link	Relay module	1	$6.99	$6.99	Amazon	Link	Parts will be moved to custom PCB
Link	Custom PCB	1	$10.00	$10.00	JLCPCB		Includes 2 week shipping
Link	External ADC	1	$12.76	$12.76	Amazon		Needed for higher precision and 1V max AC differential reading
Link	120V AC to 5V DC converter	1	$11.50	$11.50	Amazon		
	Additional support components	1	$30.00	$30.00			This should ideally account for any extra parts we need to order
			Total Cost	$99.12			

This outlines a general idea for what we need to purchase for our project. This is subject to change since we may learn that we need more through our research phases of the project, which is outlined in the project timeline below.

Milestone estimates

Weeks	Milestones
1	Come up with project idea
2 - 3	Create initial project documentation, requirements, and potential implementations. Discuss roles and tasks for implementing the project and dividing labor.
3 - 6	Research: Which microcontroller we need to use. How we can convert 120V AC to 5V DC in a small form factor for the microcontroller. How we can accurately use a split-core current sensor to read voltage. How to interpret the sensor data in a meaningful way for the user. What scheme we should use for developing our app. What our app should look like. How the app connects to the microcontroller.
6 - 7	Work on the PCB design
8 - 11	Write documentation to explain researched information
12	Delegate the build tasks among each project member
End of Spring Semester	
13 - 14	Hardware: Order all of the materials outlined in the current bill of materials. App: Start by importing boilerplate.
15 - 17	Hardware: Receive components and start assembling the system. Microcontroller: Begin writing code. App: Make several screens and connect them with simple buttons.
18 - 20	Hardware: Begin testing and make any adjustments to the circuit. Microcontroller: Work on wireless connection to the app (bi-directional). App: Populate each page with some core features, such as a dashboard, an on/off button, and a settings page to set thresholds and connect to other devices. Begin testing wireless connection.
21 - 23	Hardware: Begin modeling enclosure for all of the hardware, 3d print prototype versions. Microcontroller: Work on sending/receiving the data over the wireless connection. App: Finish making wireless connection, connect received data to visualization dashboard, connect button to transmitting data.
24 -26	Fine-tune the system to make sure it works properly during the presentation.
27	Present

Project Alternatives

Some of our backup projects include:

- Smart trash can, which is a project with the objective to fully automate a trash can, making it able to move around a set path, finding the most optimal way to the user whenever a button is pressed, or going around a random path, avoiding collisions at all times.
  This trash can is also going to be able to be connected to an app, where you can choose the type of trash (recyclable or non recyclable) being thrown in, opening the lid for the right compartment and incentivizing recycling for the user.

- Smart Beverage maker, which is a project to fully automate a smoothie machine, by utilizing a conveyor belt and taking the cup from one beverage dispenser to another.
  The user will have a choice to decide which beverage he wants via an application, and the machine should automatically decide how much of each liquid it should put on the cup for the correct recipe, leaving to the user only the job of placing and picking up his cup.

- AR Glasses, which is a project to fully build a pair of glasses with a built in HUD that would be able to be connected to your phone and show notifications. It would also have transition lenses, meaning the lenses would go darker whenever the user is in a place with higher luminosity and back to normal whenever the surrounding light fades.
  The goal of this project would be to improve on the currently existing smart glasses, by making them more interactive, with a built in voice control system, and a longer battery life.