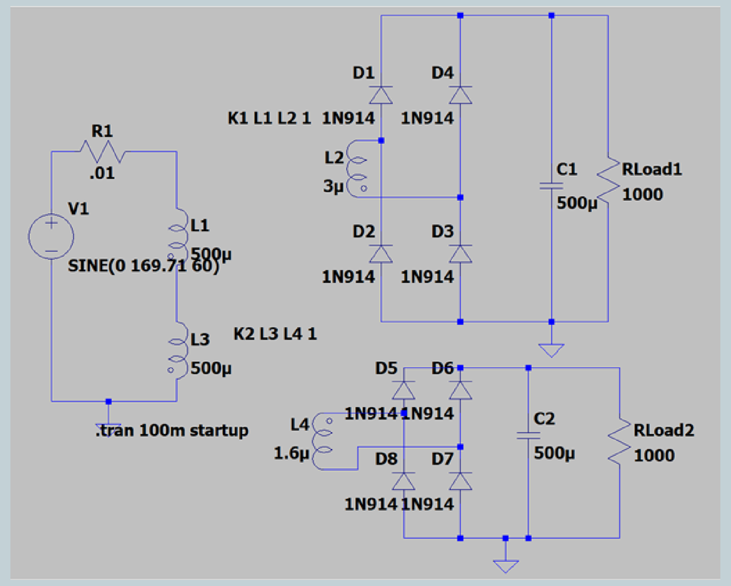
Modular Smart Power Bar

Group 7 - Martin Anderson - Jasmin Ford - Darian Langeler - Nathan Lawko - Jack Yeo
University of Victoria - BME/ECE 499 - Design Project II

POWER SYSTEM

The power system was designed to offer 3 different voltage options from the 120VAC source from the wall outlet. The Source is transformed into:

- 120V AC source for power usage
- 5VDC source for the microcontroller and USB ports
- 3.3VDC source for the microcontroller and current sensors



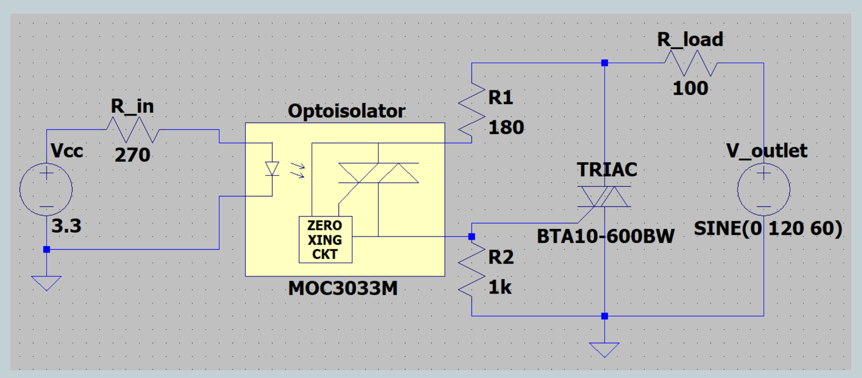
Power system model in LT spice

CONTROL SYSTEM

The control system was designed to provide current sensing and power-switching capabilities to give the user customizable control over the state of each individual outlet module while also receiving updates and information regarding the power usage of the connected loads.

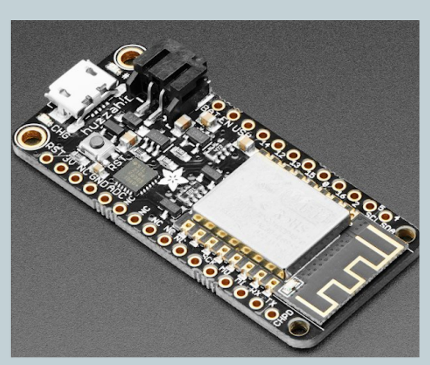
The control system features:

- Differential Hall effect sensors that utilize I2C protocol and perform internal power calculations
- TRIAC-driven opto-isolator solid state relay for controlling 120VAC output
- Current-limited power distribution switch for USB outlet control



TRIAC-driven opto-isolator switch model in LT spice

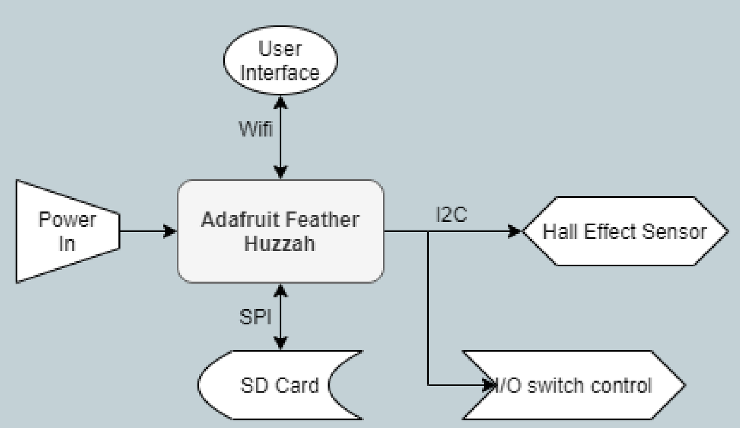
MICROCONTROLLER



The microcontroller subsystem was designed to be the communication hub for the system. Many factors were taken into consideration for selecting the controller and the communication systems including bus complexity, ports available, wifi chip integration, storage speed and size, and price.

The final system can be seen on the right and includes:

- Adafruit Feather Huzzah w/ ESP8266 WiFi Module (20.89$CAD)
- I2C communication to modules
- SPI to external 16GB uSD card for storage

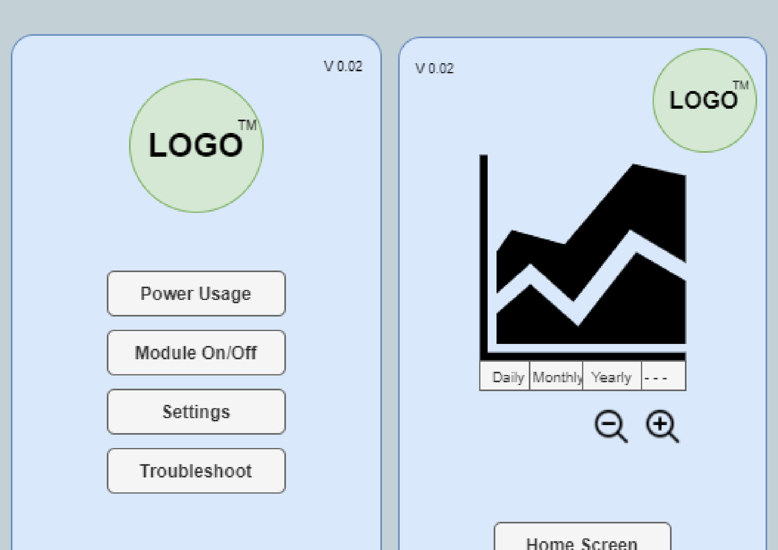


USER INTERFACE

The user interface was designed to be informative and user friendly offering ample customization features as well as descriptive power usage data.

Through the app, users can:

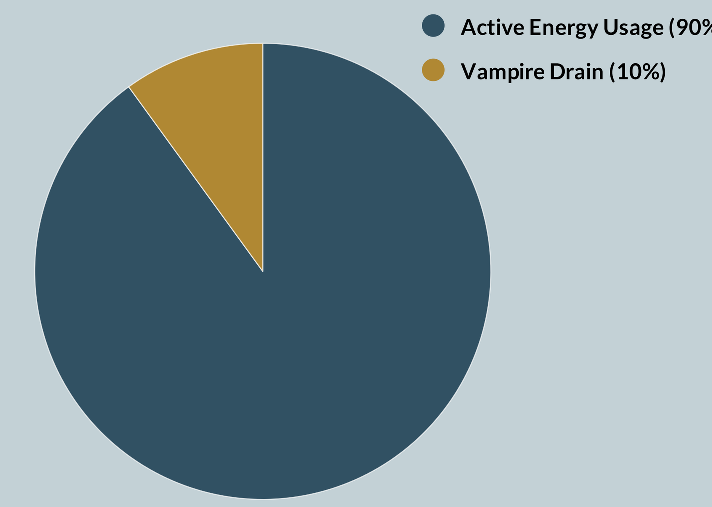
- View power usage for over a year for individual outlets or entire device
- Turn on/off individual outlets or slaves settings on command
- Configure master/slave, timer, and inactivity settings



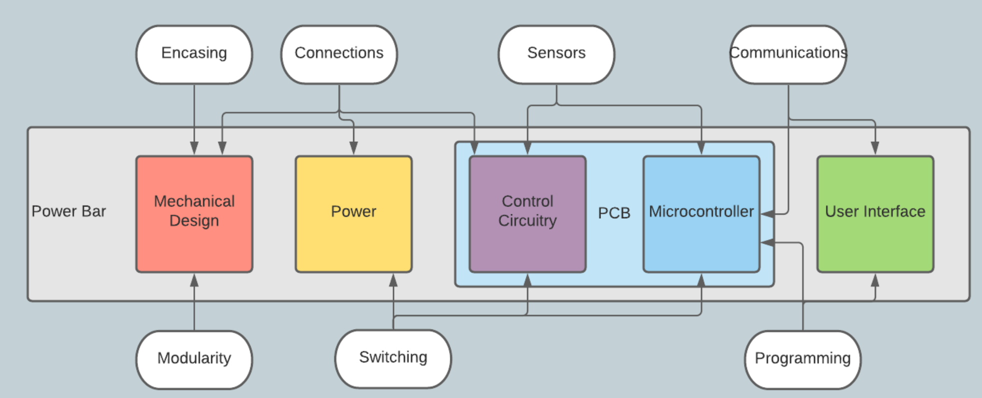
Prototype design for user interface

BACKGROUND INFORMATION

- Unknown to users of many electronics, energy is drained by these devices while they are "off"; in standby mode; this is known as "phantom load" or "vampire load" and can account for drawing between 0.5 and 30 Watts of power when not in use
- Products exist to limit power waste but holes in the market exist with lack of power tracking
- This project aims to reduce the wasted energy from these devices while they are idle



PROJECT GOALS

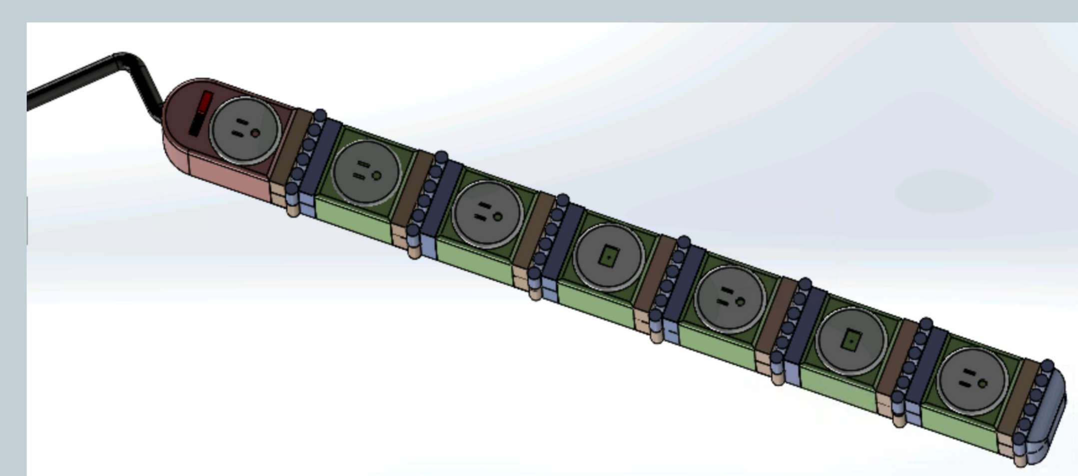


Block diagram showing interconnection of subsystems for the project

1. Design and test a prototype for a user-friendly smart power bar which provides details and automated control over residential energy usage
2. Provide users with customizable modular outlets with master/slave configurability and power data collection
3. Target environmentally conscious consumers with an interest in learning about and reducing their residential energy footprint and electrical bills by providing an accessible solution

ENCLOSURE

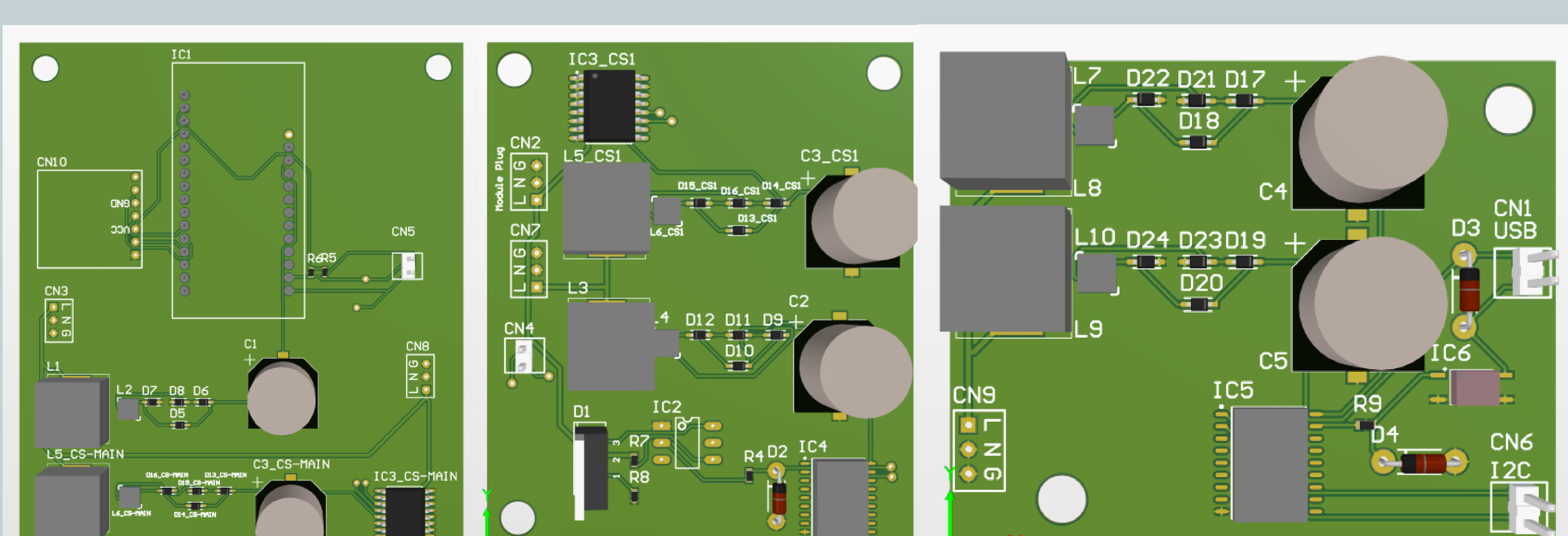
- The design of the enclosure was completed using an iterative process.
- Two module types were designed to meet the modularity requirement: NEMA-5 plug and USB outlet.
- A removable terminal closes the I2C circuitry and protects the outside environment from the 120V hot rails.
- Modules can be added on or removed in whatever order desired by the user.



Prototype of modular power bar: one-dimensional modularity

PCB

- The PCB was designed to be a simple 2-layer board in order to keep the fabrication costs of the device as low as possible
- Large ground planes are used for added heat dissipation
- I2C lines were placed as far away from the mains inputs and voltage transformers in order to reduce the chance of potential interference and noise



PCBs for each of the modules designed in Altium. From left to right, it is the main module, high-voltage module, and USB module

RESULTS & DISCUSSION

- Due to the artistic and subjective nature of UI, a final design was not chosen; however, a wireframe design with the intended features was developed
- The microcontroller system selected utilizes a low cost, efficient Adafruit Feather Huzzah which has an internal ESP8266 WiFi Module for wireless communications
- The I2C protocol will be used to communicate with each outlet module's sensor and switch
- An SPI SD card is used for storing upwards of three years of power data for long term usage
- The power system has been able to properly recreate the voltage; however, there are some current issues that would need to be refined in future work
- The power-switching control circuitry provided favourable results from simulation testing; however, there are some current issues that were not able to be fully addressed given the time constraints
- The PCBs designed enable each module to meet the predetermined requirements, with room to improve the design further

CONCLUSIONS

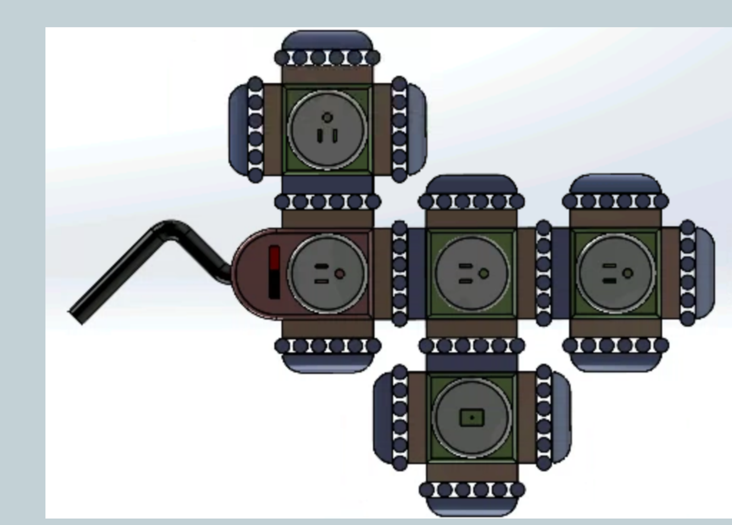
The final design solution sufficiently meets the listed design objectives. We created a design to address the problem of phantom load from devices that are continuously consuming power in standby mode, targeting environmentally aware consumers who are interested in reducing their energy footprint. The power bar utilizes a microcontroller with the capability for a user interface to better the consumer's experience with the product with improved feedback and understanding on residential energy use. To achieve a better share of the market, a modular system was adopted to provide flexibility to match the user's needs.

Though a physical prototype was not feasible for this endeavour, the performed tests and simulations provide the confidence and validation that the presented solution will be successful with some future work to improve current issues.

RECOMMENDATIONS

For future work, now that the Covid-19 restrictions are being alleviated, having the team meet together on the physical prototype is the next important step. Developing the PCB and ordering parts and components for assembly will be required for further electrical testing when applying modules together. Further, on the communications side, the next steps will be making the already designed user interface into a Graphical User Interface and programming the microcontroller and complementary application for smart devices such as tablets or smart phones to handle the functionality.

Once the electronics meet the required standards, creating the casing and enclosure can be done. 3D printing would be effective for rapid iterative prototyping. Also, the group would need to work on producing a better current value and reducing the power usage for the power system.



Potential future design with multiple directions to add modules

REFERENCES

[1] G. of Canada. (2018). "*Standby power and "smart" devices.*" [Accessed: July 29, 2021], [Online]. Available:https://www.nrcan.gc.ca/energy/products/categories/electronics/14195
[2] *Espressif smart connectivity platform: Esp8266*, Espressif Systems, 2013. [Online]. Available:https://cdn-shop.adafruit.com/datasheets/ESP8266_Specifications_English.pdf
[3] F. Leens, "*An introduction to i2c and spi protocols*,"IEEE Instrumentation & MeasurementMagazine, vol. 12, 1 2009, [Accessed: 2021-07-28],issn: 1941-0123. [Online]. Available:https://ieeexplore-ieee-org.ezproxy.library.uvic.ca/document/4762946.