Insight Power™ Smart Outlet

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Team Roles

Hardware - **Kriss**

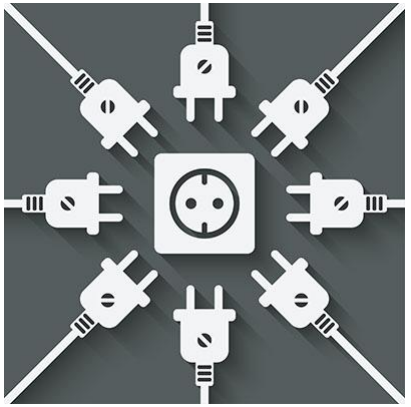
Software - **Garrett**

Classification Algorithm - **Mark**

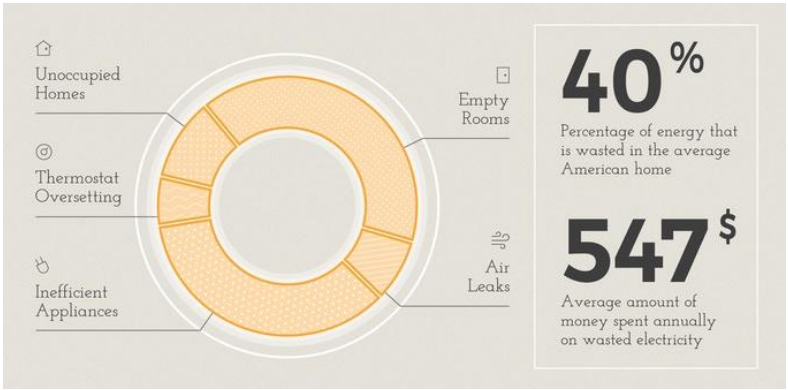
Companion App - **Brendon**

Website - **Collaborative**

Problem Statement



- 30-40% of energy in a home wasted on average.
- Alternatives difficult to manage/tedious to set up
- Difficult to track device-specific power usage
- Devices plugged in are not always the same



System Specification

- Plug easily into wall outlet
- Connect wirelessly to app
- Measure power usage in real-time
- Turn device on and off via app
- Continuous analysis of usage data
- Classify devices based on data
- Classification accurate >80% of the time
- User-Friendly companion app

Motivation

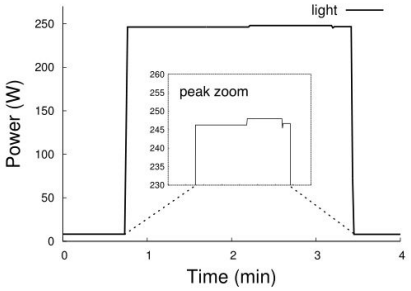
- Existing smart home hardware can control e.g. lighting when the user leaves the home or returns
- Smartphone indicates user has left home, turns off all lights
- On return, lights restore to previous on/off state

Motivation Cont.

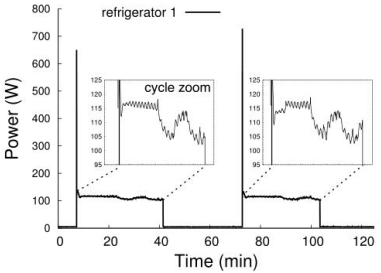
- Automatic tracking of devices is non-existent on the market
- Every time a device moves, the home automation program doesn't know
- Configuring an entire home with dozens of devices is difficult, time consuming
- If one device is moved, will have to update all of the existing outlets manually.

Solution

- Classify devices using time-series power analysis
- Resistive, inductive, and non-linear loads have distinct waveforms
- Identify features of these waveforms,
- Classify into categories: Lighting, Periodic Loads, Electronics



Light bulb



Refrigerator

Classification (Option 1)

- Look for specific features of AC power usage
- Ex. power spike with gradual decline
- Instantaneous, but some accuracy loss

Classification (Option 2)

- Train algorithm with power usage data (Tracebase)
- Classifies based on features such as average, standard deviation, duty cycle, periodicity, etc
- Slower identification for some devices, but more accurate
- Will need time to train algorithm.

Design Alternatives

Belkin WeMo Insight Smart Plug

- Uses Wifi and WeMo app
- Real-time reports of energy consumption
- Set schedules for devices.
- **Does not identify plugged in device**
- **Software label does not reflect unplugged/moved devices**

Design Alternatives

Amazon Smart Plug

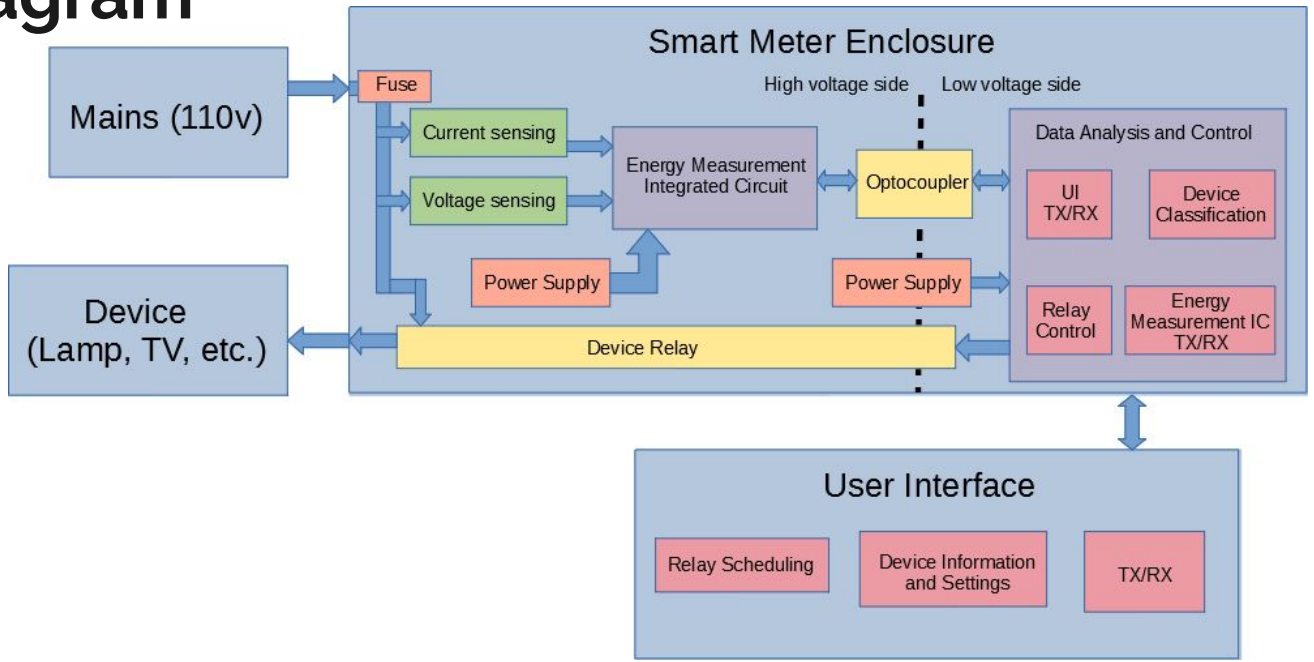
- Works with Amazon Alexa
- Uses Wifi and Alexa app
- Set schedules for devices
- **No power monitoring**
- **Outlets need names for voice commands**
- **Does not identify moved devices.**

Design Alternatives

Insteon iMeter Solo Power Meter

- Powerline only
- Software reporting on energy display
- **Does not identify plugged in device**
- **No companion app, complex software interface**

Block diagram



Hardware (Power Analysis)

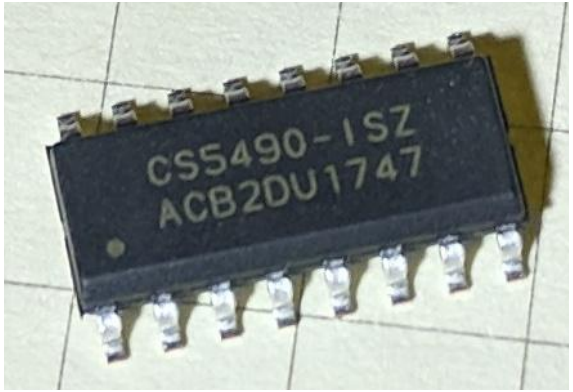
Cirrus Logic CS5490-ISZ

On-chip calculation of:

- Active, Reactive, and Apparent Power
- RMS Voltage and Current
- Power Factor and Line Frequency
- Instantaneous Voltage, Current, and Power

UART Serial Interface

Power calculated once per second by default, configurable to 40Hz



Hardware (Current/Voltage Sensing)

CS5490 supports several sensor types

Current: Current transformer, shunt resistor, or Rogowski coil

Voltage: Resistive divider or voltage transformer

We will choose to use a shunt resistor and resistive divider for their simplicity and reliability

Hardware (Device Connection/Case)

- 3D Printed Enclosure
- Male/female NEMA 5-15P standard wall outlet connectors
- One user device per smart outlet

Hardware (Network Connectivity)

Wifi: enables integration with existing networks

- Difficult to secure

Bluetooth: shorter-range, low power

- We are not power limited in this application and may require longer range

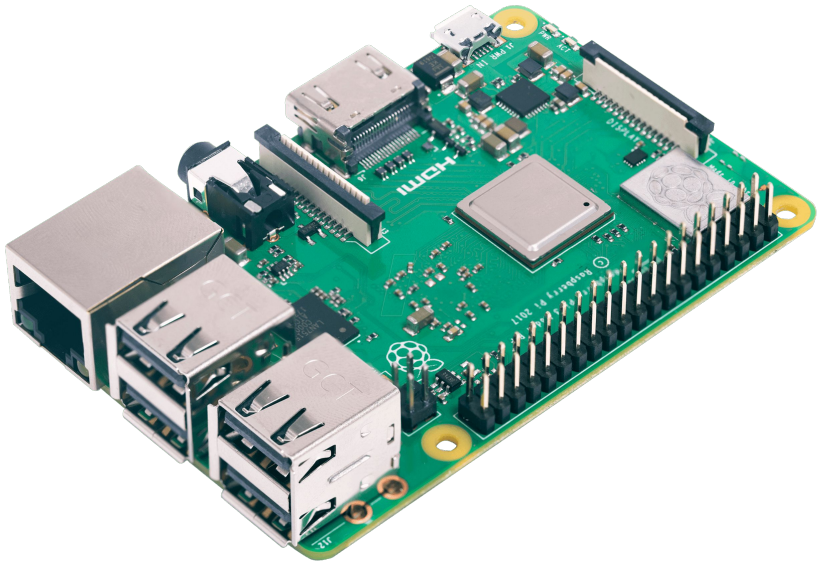
Powerline networking: less vulnerable to wireless attacks

- Requires less common hardware, dedicated hub for interface to an existing home network

We will choose a SoC with integrated wifi for its easy implementation.

Hardware (Raspberry Pi)

- Serial communication to retrieve stored power readings from the Cirrus Logic chip.
- Integrated 2.4Ghz 802.11n wifi for communication with companion Android app
- 4x ARM Cortex-A53 CPU cores for classification model execution



Software (Companion App)

- Java
- Android APK
- User-Friendly

Software (Classification Algorithm)

- Written in Python 3
- Will use the Scikit-learn library
- Will listen on a network port (TCP) for the companion app
- Classify devices into categories such as lighting, electronics, periodic devices, etc

MDR Deliverables

Smart outlet prototype

- Able to read power usage
- Able to turn on and off devices

Companion app

- Able to communicate with outlet

FPR and Demo Day

- 2-3 working prototypes
- Demonstrate ability to monitor power usage and turn device on/off
- Demonstrate ability to accurately identify a device
- Switch device to different outlet, identifies that device has moved,
- App UI reflects these changes in real-time
- Demonstrate ability to automatically turn off specified devices when user walks away

Budget

- Resistors and Capacitors packs ~ $30 ($0 if available in M5 or SDP lab)
- Power converters ~ $20
- Power Measurement IC ~ $4
- Optocouplers ~$1.50
- Raspberry Pi - $35
- Relay board ~ $5
- Outlet connector ~$5

Total: ~ $71/$101