Smart Energy Monitoring Network

May 1725
Adviser: Nathan Neihart
Client: Commercial Product

The Team






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Software Designer

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Hardware Designer

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Team Co-Lead

Hardware Designer

Mission statement:

To make a wireless power sensor that can monitor the power usage of different electronic devices and report that power usage back to the user via a user-friendly web application.

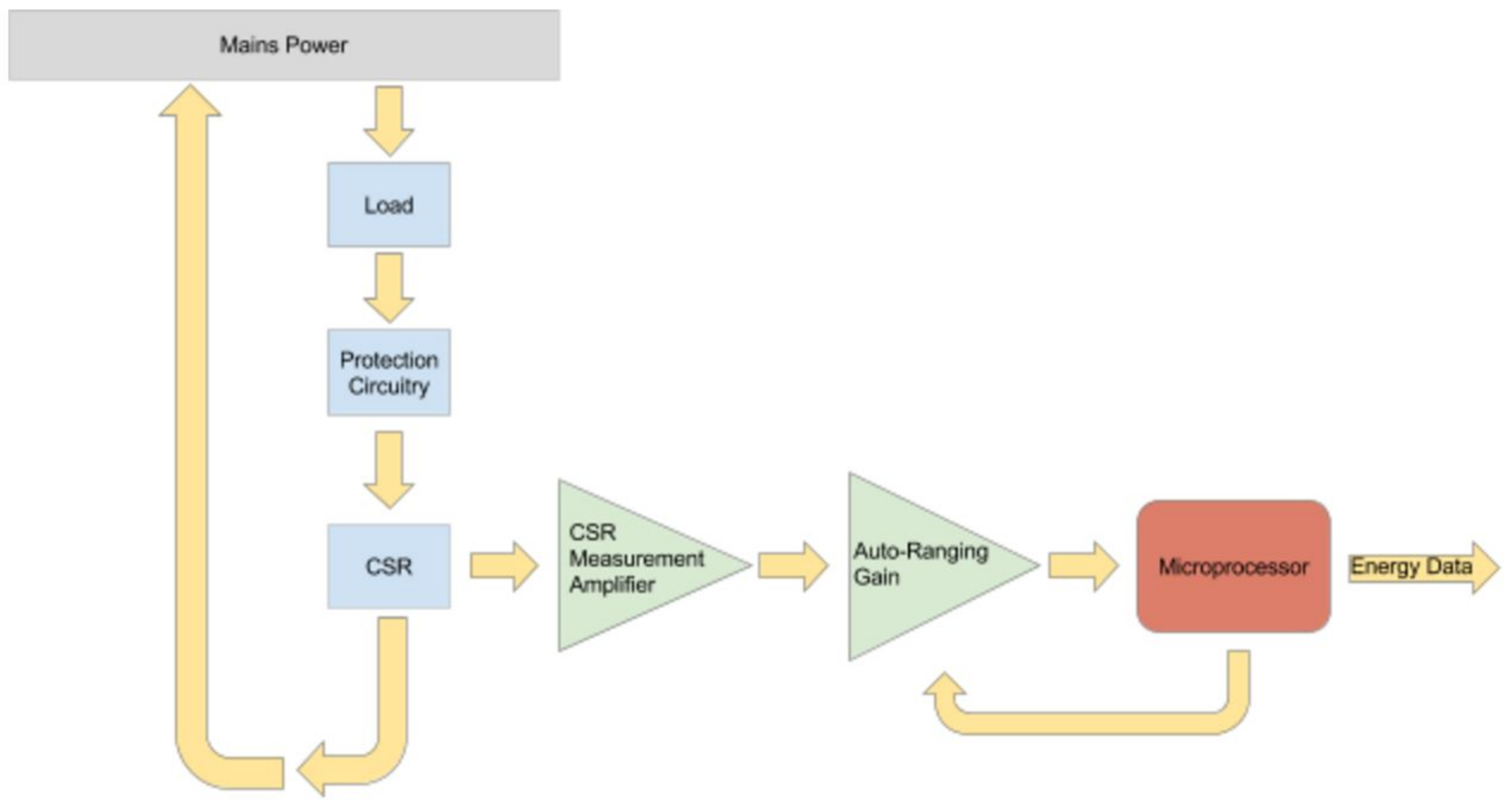
Hardware Requirements

Functional:

- Power Consumption Under 5W
- Operate with current magnitudes ranging from 100mA - 15A RMS
- Provide output with minimal frequency modulation

Non-Functional:

- NEMA 5, or equivalent housing
- Non-intrusive to other objects on the outlet
- Negligible Audible Noise
- Adequate Communication Range



Hardware Block Diagram

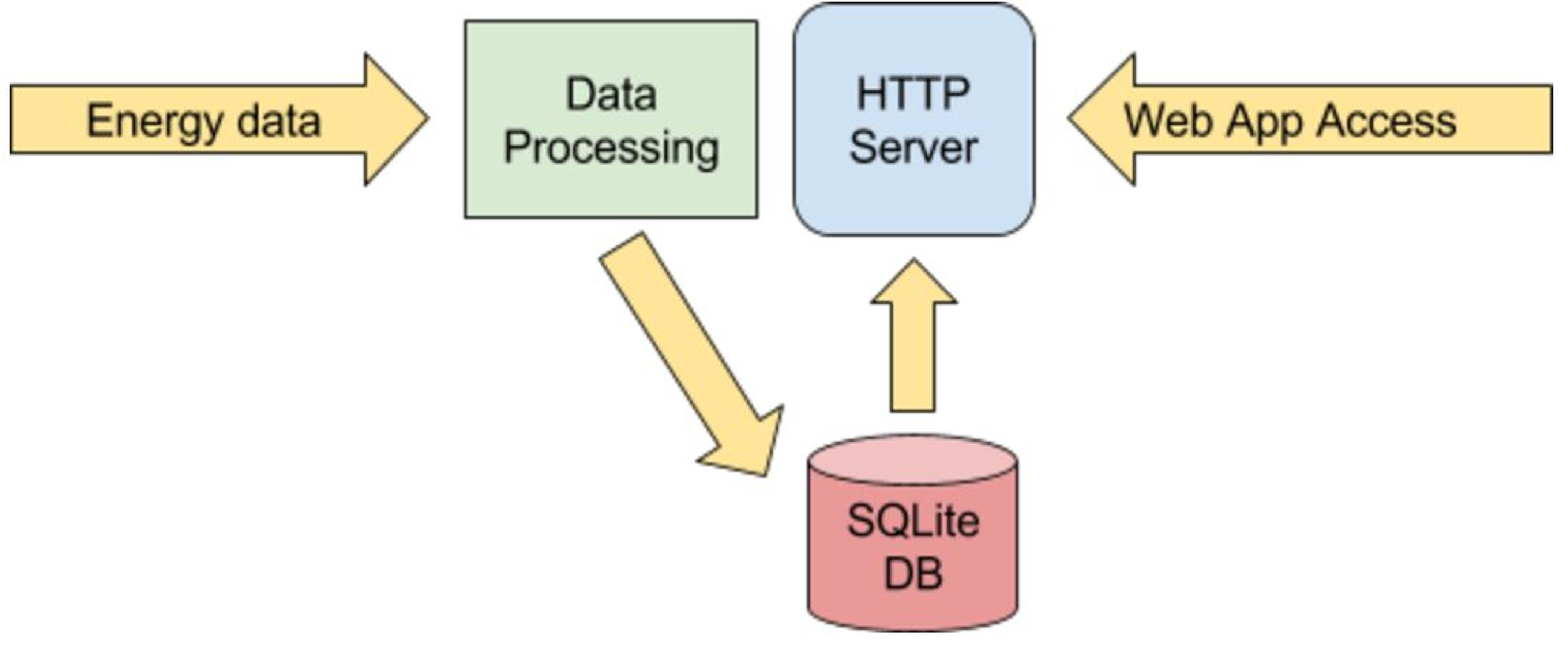
Software Requirements

Functional:

- Web application shall retrieve it's data from a central database.
- Web application shall allow the user to change the period of energy data collection
- Web application shall show a list of all connected monitoring systems
- Web application shall allow the user to give each station a user-friendly name
- Web application shall allow the user to turn off the AC power to individual energy monitoring systems.

Non-Functional:

- Web app should be modern and well-designed, with a sensible UI.
- Web app should have easy to use buttons and controls for the UI.
- Web app should have easy access to different monitoring stations.



Network Block Diagram

Software Design

- Each sensor has a WiFi enabled microcontroller
  - Texas Instruments CC3200
  - 32-bit ARM core
- Data is sent from each sensor to a central hub
  - Connection is UDP-based
  - Sensor samples are stored in a central database
- Central hub hosts a web server accessible from any device
  - Web application is mobile-friendly
  - User has the option to create graphs

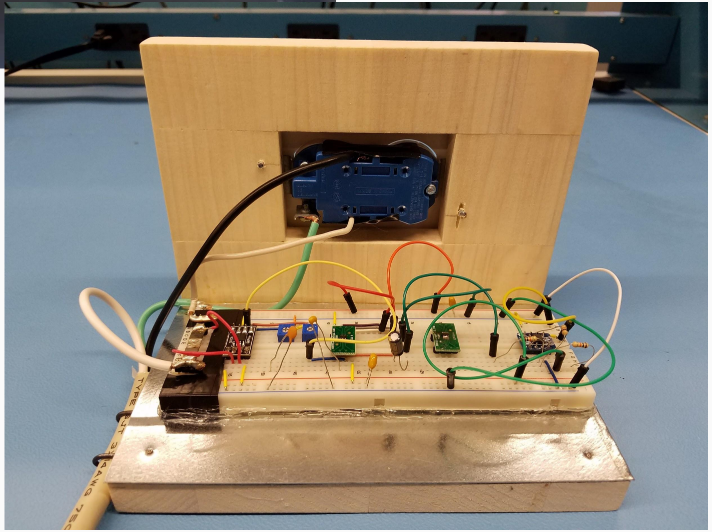
Software Technology Platforms

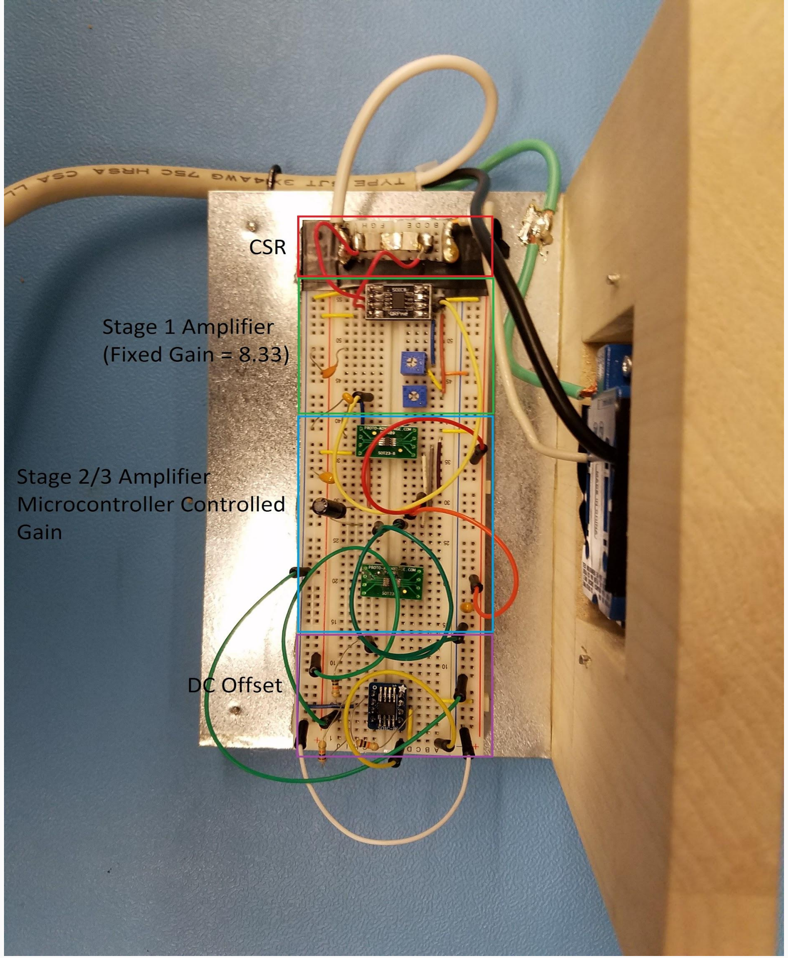
- Code Composer Studio
  - Free version of IDE from Texas Instruments
- SQLite
  - Connectionless database fits our lightweight model
  - Stores all past sensor measurements
- Python
  - Runs on central hub to provide sensor connection and web application

Current Hardware Status

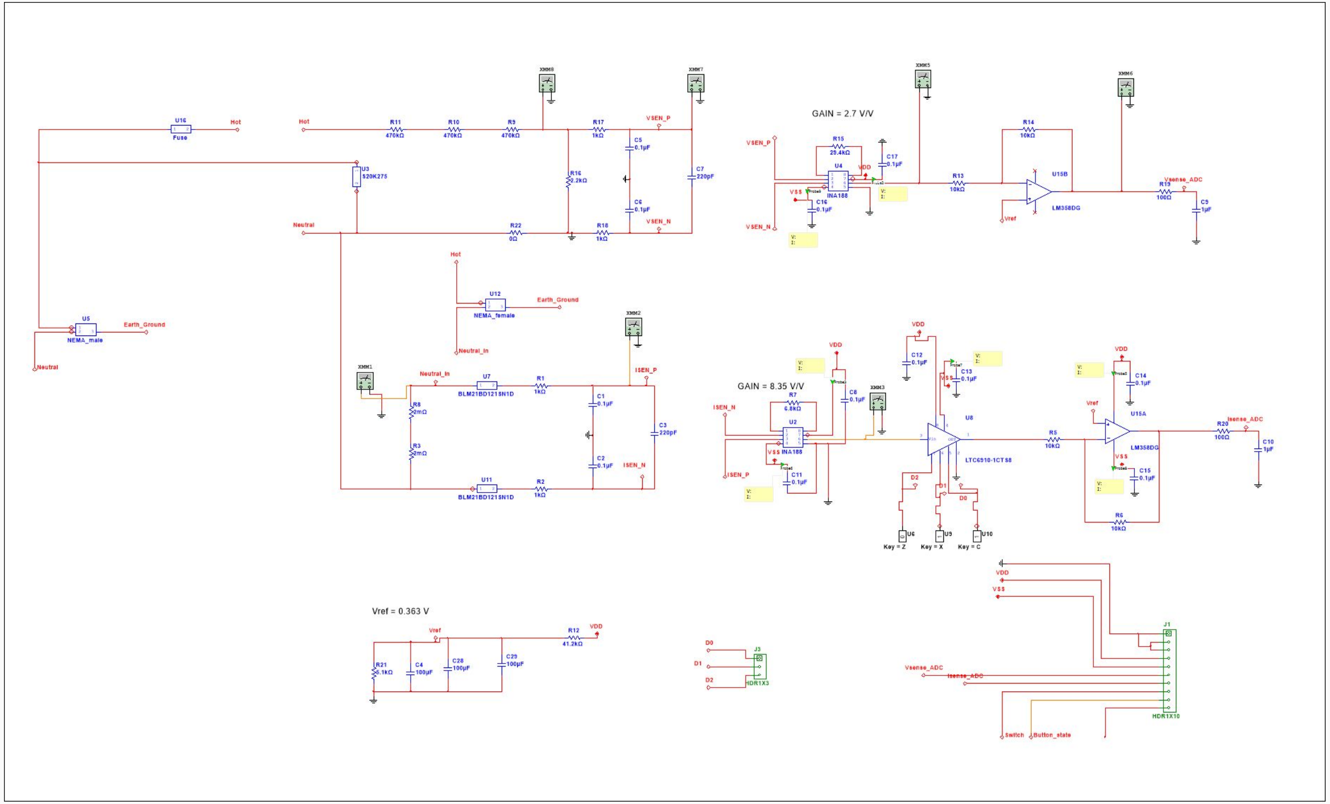
Hardware

- Refined Functional Prototype Circuit
- Finalized and Ordered Rev. 1 PCB
- Prepping For Conjunction With Software Circuit





Prototype Fixture

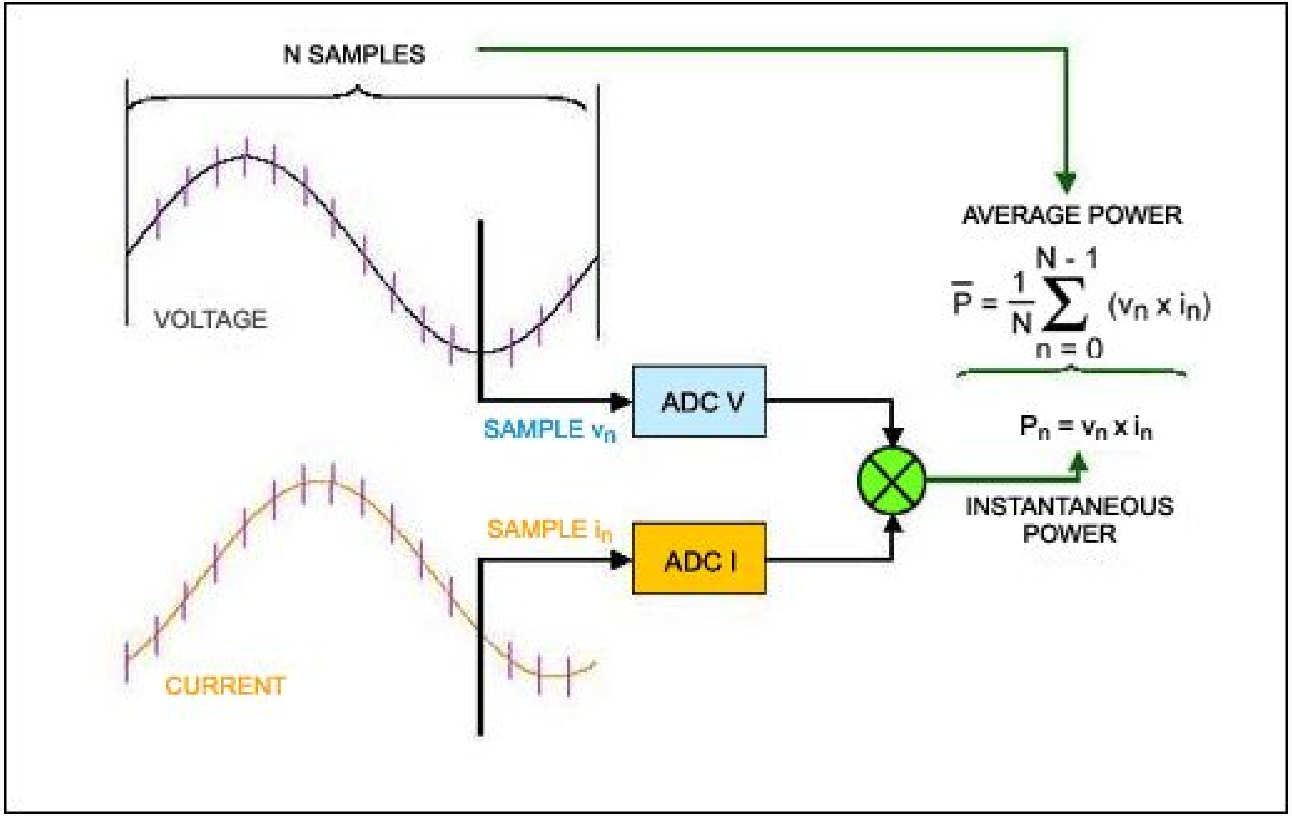


Sensing Challenge:

- Low current detection

Solution:

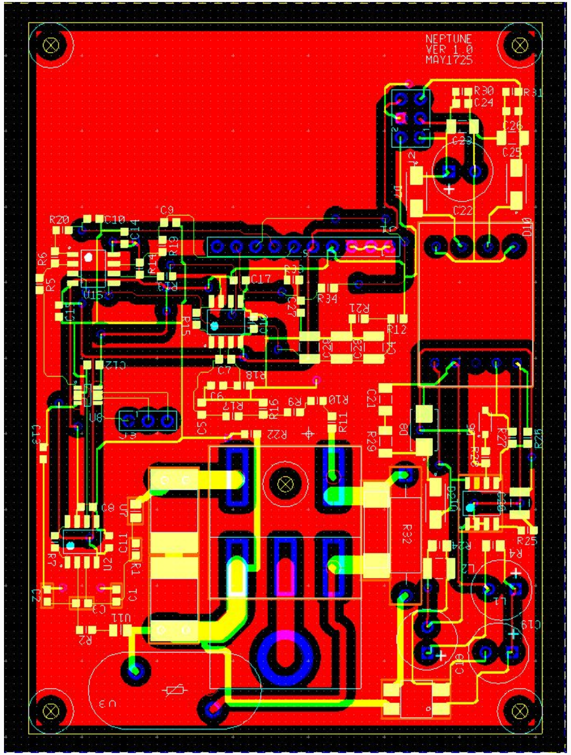
- Low-pass filter
- Programmable Amplifier for autoranging



Expected outputs

6.8 cm

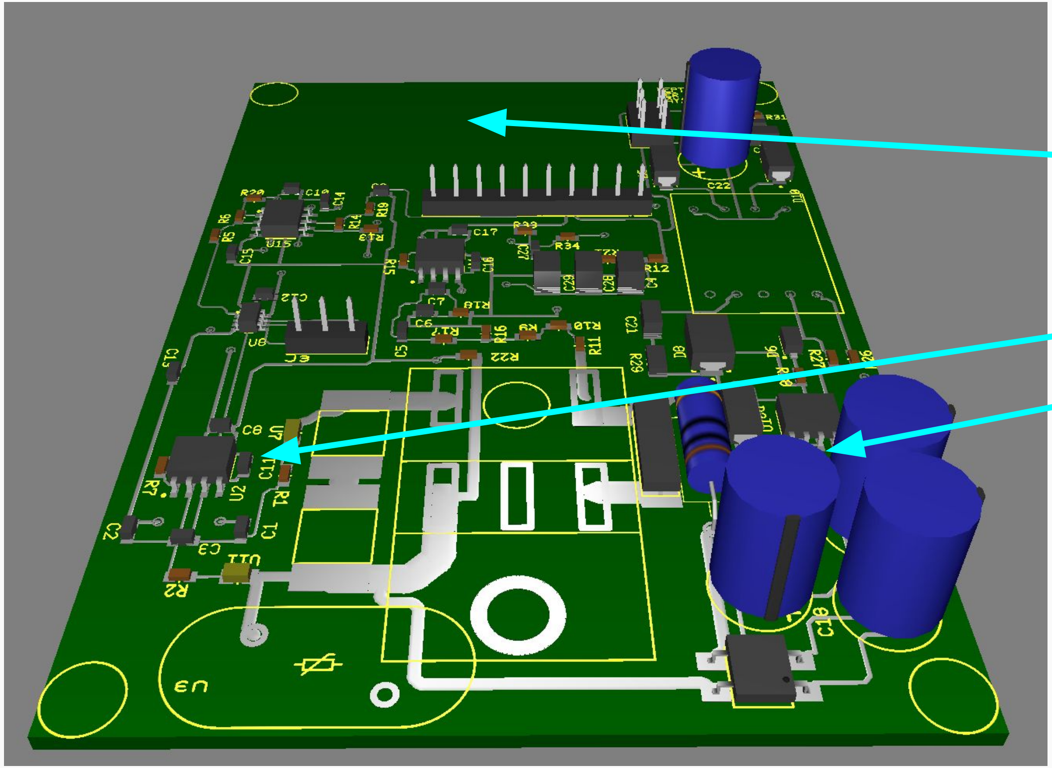
9.4 cm



PCB status:

- Board ordered (expect to arrive ~ 10 days)
- Transformer, amplifiers received
- All passive components received

PCB Layout



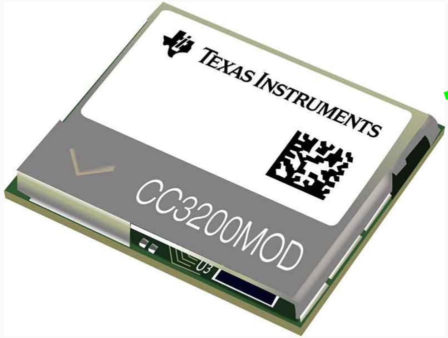
3 main areas:

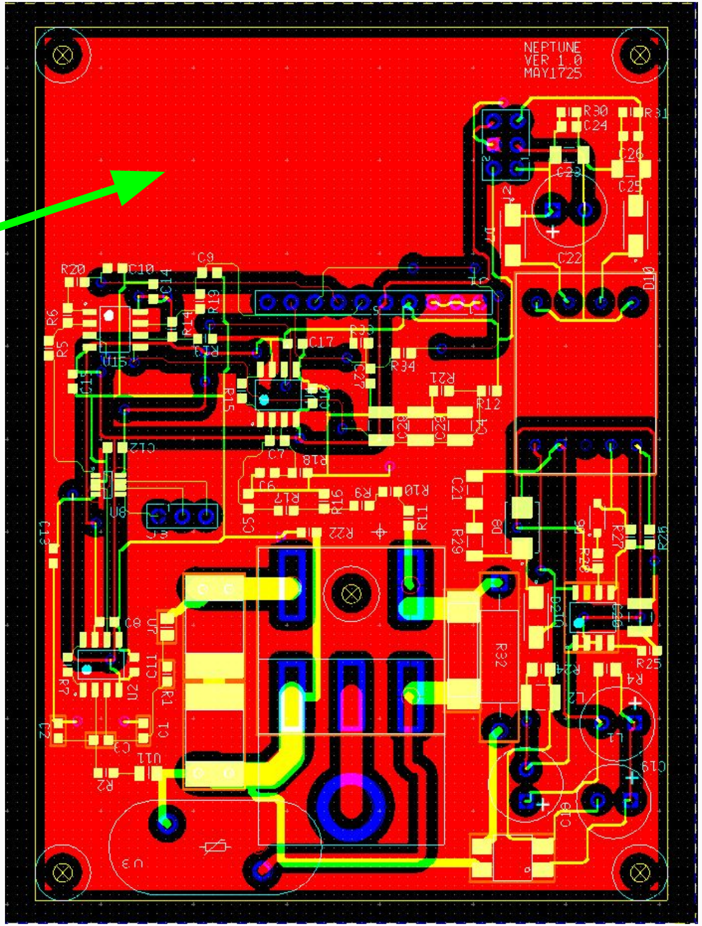
- CC3200 Microcontroller
- Sensing Circuits
- Power Supply

Hardware Challenge

MCU Challenge:

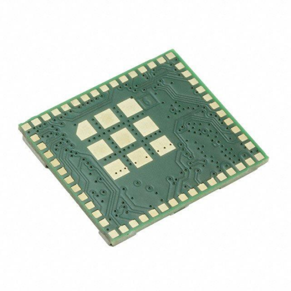
- Difficult to solder





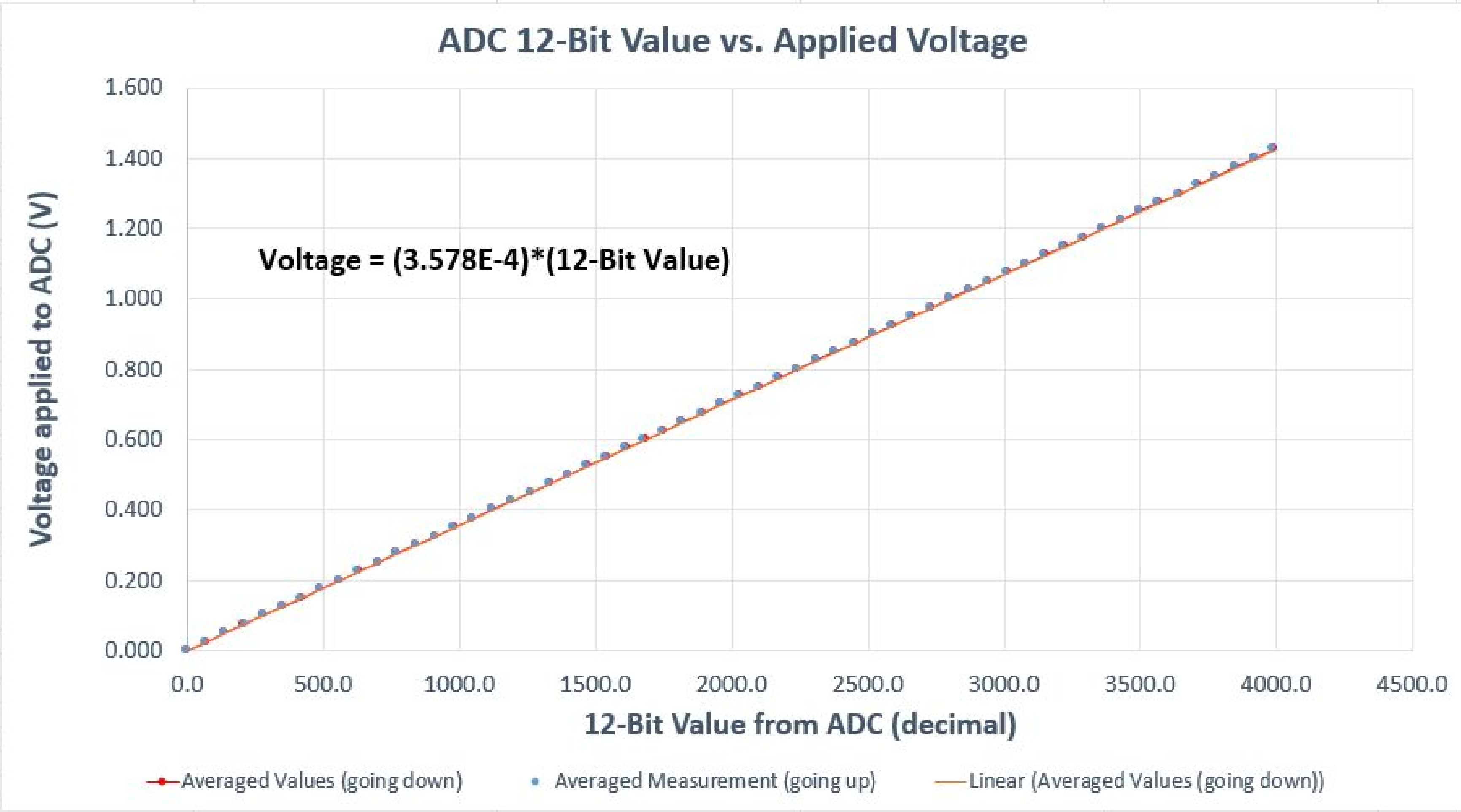
Solution:

- Reduce number of pin usage



Current Software Status

- CC3200 calculating RMS power data
  - Using function generator we have tested ADC linearity
  - Running-RMS algorithm implemented
- UDP Transmission of sensor data
  - CC3200 sends a UDP packet over the WiFi to the central hub
  - Packet is received by Python UDP server and inserted into the database
- Early version of website
  - REST API with dummy data
  - API feeds data to dynamic graphs


ADC 12-Bit Value vs. Applied Voltage
Voltage = (3.578E-4)*(12-Bit Value)
Voltage applied to ADC (V)
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
4500.0
12-Bit Value from ADC (decimal)
Averaged Values (going down)
Averaged Measurement (going up)
Linear (Averaged Values (going down))

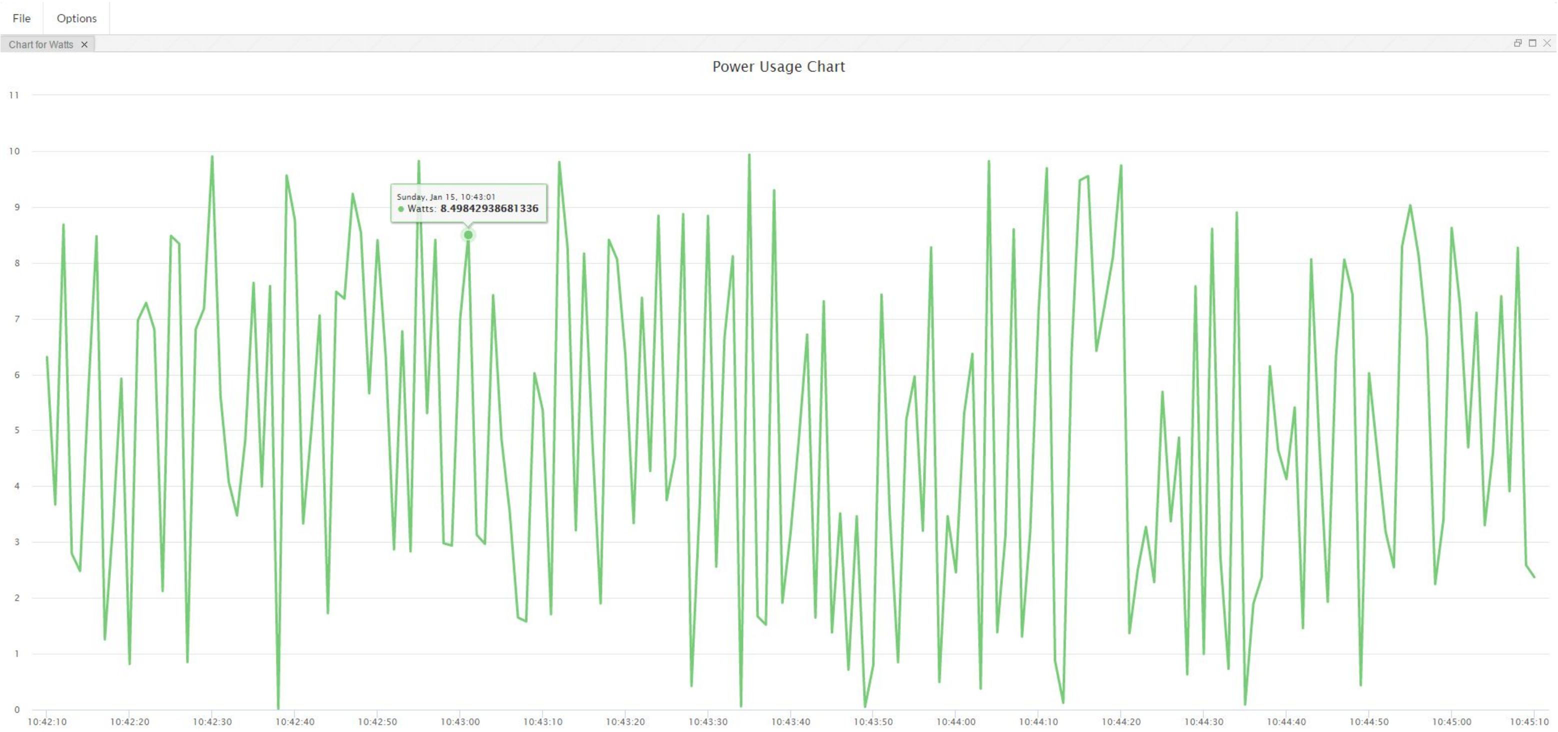
REST API


```
[
  - {
        power: 3.600853497959622,
        station_id: "1",
        timestamp: 0
    },
  - {
        power: 9.868210043072839,
        station_id: "1",
        timestamp: 1
    },
  - {
        power: 9.078286273047317,
        station_id: "1",
        timestamp: 2
    },
  - {
        power: 6.427535907109449,
        station_id: "1",
        timestamp: 3
    },
```

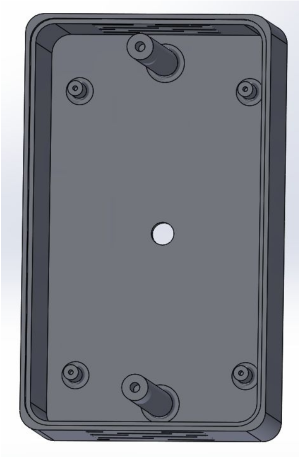


```
[
  - {
        id: 1,
        name: "Living Room"
    },
  - {
        id: 2,
        name: "Kitchen"
    },
  - {
        id: 3,
        name: "Garage"
    }
]
```

Website Screenshot



3D Enclosure



Milestones

Feb | Mar | Apr | May

Current Status
Functional Separate Prototypes

Mar 2016
Assembled Unit Prototype & Begin Testing

Apr 2016
Refinement/Debugging Complete

May 2016
Final Submission

Questions?

Appendix

Software Challenges

1. Website usability
2. Accuracy of ADC (noise)
3.

Hardware Challenges

1. Unwanted noise probably occur in real circuit
2. Integrate CC3200 onto the board

Bill of Materials

Part Number	Part Description	Quantity	Cost	Total
INA145	Difference Amplfier	1	$1.80	$1.80
LTC6910-1	Programmable Amplifier	2	$2.06	$4.12
PSR500HTQFJ2L00	Current Sense Resistor (2mOhms)	2	$1.68	$3.36
CC3200MOD	Microcontroller with Wifi	1	$9.99	$9.99
OPA344UA	Precision Op Amps	1	$0.61	$0.61
Capacitor	Varies	6	$0.10	$0.60
Resistor	0.25 W Carbon-Film Through Hole	5	$0.10	$0.50
Total Cost				$20.98

Project Neptune - Timeline

Month	AUG					SEP				OCT				NOV				DEC				
Year	2016																					
Week	W1	W2	W3	W4	W5	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W5
Week #	-	-	-	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Milestone											1		2		3			4				

Month	JAN				FEB				MAR				APR					MAY			
Year	2017																				
Week	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W5	W1	W2	W3	W4
Week #	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	-	-	-
Milestone				5																	

Deliverables		Duration
Plug-in Adapter to Measure Energy Usage		37w
Planning phase		**3 w**
Project Conception	Task I	2 w
Advisor Assignment	Task II	1w
Project Assignment/Approval	Task III	3 w
Research phase		**8 w**
Research Power Measurement	Task I	3 w
Research Components	Task II	5 w
Construct Block Diagram	Task III	3 w
Set Specifications	Task IV	2 w
Prototype phase (Analog)		**14 w**
Design PCB	Task I	4 w
Order Components	Task II	2 w
Fabricate	Task III	2 w
Test	Task IV	2 w
Prototype phase (Software)		**14 w**
Setup database schema	Task I	2 w
Setup HTTP Server	Task II	2 w
Develop data collection code	Task III	2 w
Develop UI (Front end)	Task IV	2 w
Closure phase		**3 w**
Documentation	Task I	3 w
Final Presentation Preparation		

Annotations

1 Project Plan Rev. 1 Due
2 Design Document Rev. 1 Due
3 Project Plan Rev. 2 Due
4 Final Project Plan & Design Documents Due
5 Functioning Prototype

Project Timeline

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	1 *	2 *	4	4X	5	6	6P	12	12K	13
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (falling dirt)	X	X	X	X	X	X	X	X	X	X
Ingress of water (Dripping and light splashing)	...	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (Circulating dust, lint, fibers, and flyings **)	...	...	X	X	...	X	X	X	X	X
Ingress of solid foreign objects (Settling airborne dust, lint, fibers, and flyings **)	...	...	X	X	X	X	X	X	X	X
Ingress of water (Hosedown and splashing water)	...	...	X	X	...	X	X	...	...	...
Oil and coolant seepage	...	...	...	..	...	...	...	X	X	X
Oil or coolant spraying and splashing	...	...	...	...	...	...	...	...	...	X
Corrosive agents	...	...	...	X	...	...	X	...	...	...
Ingress of water (Occasional temporary submersion)	...	...	...	...	...	X	X	...	...	...
Ingress of water (Occasional prolonged submersion)	...	...	...	...	...	...	X	...	...	...

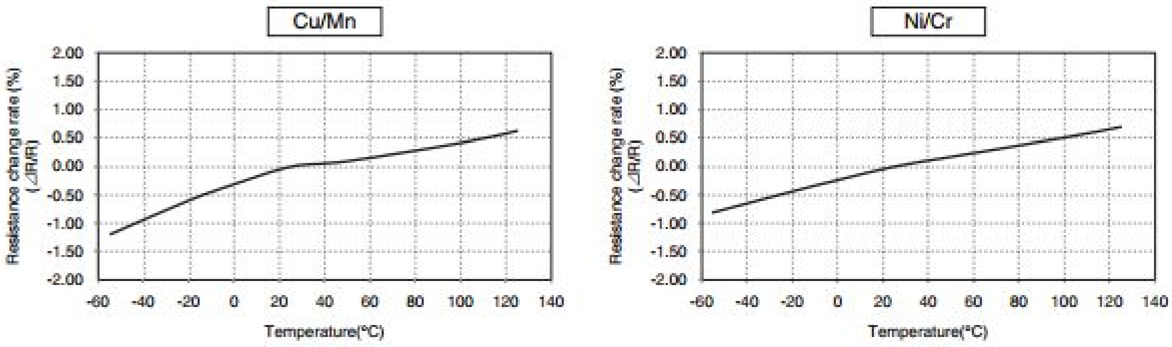
NEMA Rating Requirements

General		Comments
Dimensions	5 x 4 x 3 inches	Outlet faceplaces are 4-1/2" high x 2-3/4" wide
Plug options	US, 15 Amp	
Color	TBD	
Enclosure	NEMA 5 Rating	Consistent with Outlet Ratings
Operating Temprature (°C)	-20 < T < 70	
Storage Temprature (°C)	-40 < T <125	
Radio		
-Sensitivity	-74 dBm minimum	
-Output Power	14.5 dBm minimum	TX POWER & RX POWER
Power Supply	120 V(RMS)	Vcc = 2.3 - 3.6V DC
Power Consumption	TBD	3200_MAX = Vref*229mA =3.3V*229mA = 0.755mW?

Functions		Comments
Power Meter		
-Voltage Range	120 V(RMS)	
-Current Range	15A(RMS)	
-Current Floor	100mA(RMS)	
-Accuracy	Typ +/- 5.0%	
-Voltage Sensitivity	Varies	
-Optimum	TBD	
-Reported Resolution	TBD	
-Auto-Ranging Threshold	1.2 V	Voltage Floor Before Shifting Gain
Remote control		
-Max Switch Voltage	TBD	
-Max Switch Current	TBD	

Technical Specifications

●**Variation of resistance with temperature** (Reference temperature is 20°C)



Part No.	L	W	H	b	Resistance	t	Material
PSR400	10±0.3	5.2±0.3	0.5±0.1	2.0±0.6	0.3mΩ	1.85±0.15	Cu / Mn
					0.5mΩ	1.30±0.15	
					1.0mΩ	0.90±0.15	
					2.0mΩ	1.15±0.15	Ni / Cr
					3.0mΩ	0.90±0.15	

Vin (V)	V_resistor (V)	I_resistor (A)	R(Ω)	
0.001	0.000127	0.03	0.004233333	
0.01	0.000601	0.147	0.004088435	
0.02	0.00118	0.275	0.004290909	
0.03	0.001649	0.406	0.004061576	
0.04	0.00217	0.534	0.00406367	
0.05	0.002704	0.666	0.00406006	
			0.004132997	Average Resistance

Resistor Characterization

Risks

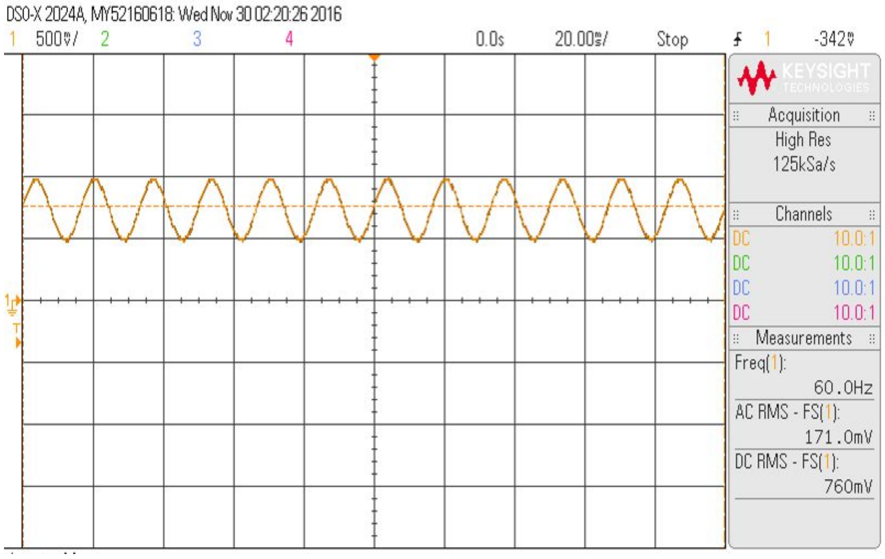
1. Electric Shock/Surges
2. Damaging Excessive Steady Current
3. Accuracy
4. Multi-Device Communication

Mitigations

1. Capacitive & Diode Protection Circuitry
2. Time Delayed 15A Fuses
3. Auto-Ranging Gain
4. UDP

Testing Known Load

Analog:
Weller WESD51



Results:

All RMS Values:

$$I = \frac{(171\ mV)}{10 * 8.3 * 0.004}$$

$$I = 516\ mA$$

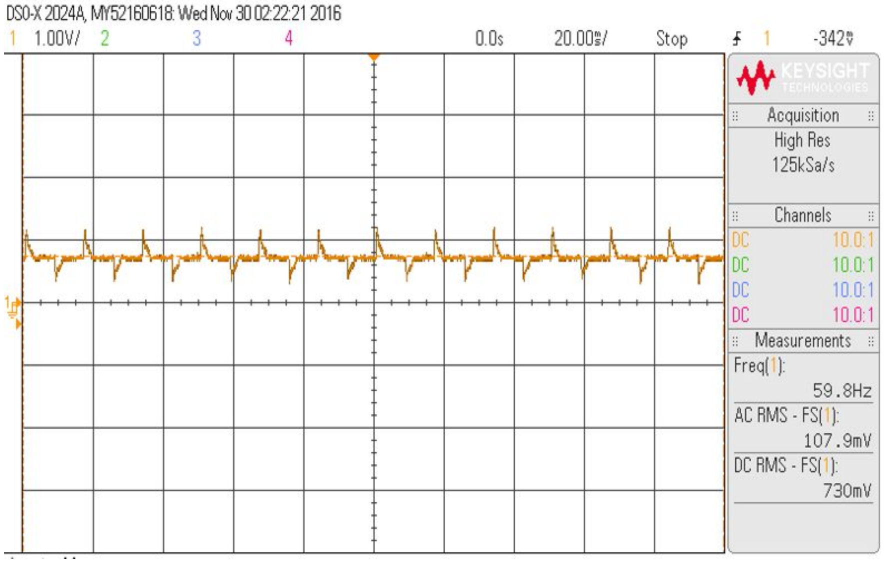
Using Multimeter

$$I = \sim 510\ mA$$

Testing Known Load

Digital:

Cell Phone Charger



Results:

All RMS Values:

$$I = \frac{(107.9\ mV)}{50 * 8.3 * 0.004}$$

$$I = 65\ mA$$

Using Multimeter:

$$I = \sim 61\ mA$$