POWER SCRAPING MODULE

Team: SDMAY 20-10

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Client: Honeywell

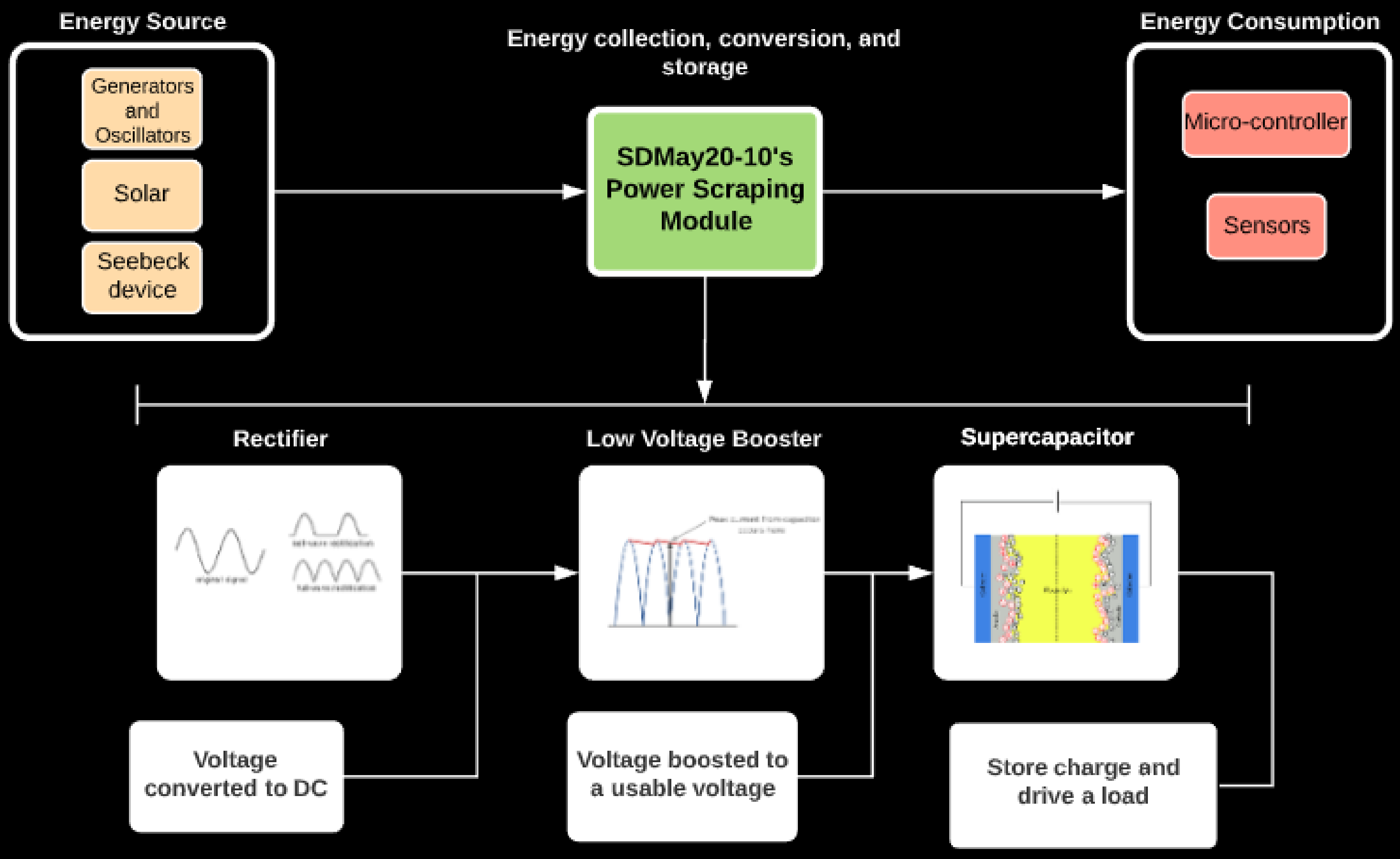
Faculty Advisor: Prof. Gary Tuttle

Website: https://sdmay20-10.sd.ece.iastate.edu/

Problem Statement

- Research and development of a device that will efficiently collect, convert, and store low voltage energy.
- The purpose is to provide an alternative self-powered source for devices.
- The goal of this project is to take a small, unusable AC voltage as a source and convert it to a usable DC voltage that can power various components in a system.
- The project can be used for many wireless applications like remote sensing, battery-free remote sensors for HVAC control and building automation etc.

High Level Overview



Market Survey

- There is a huge demand for Low Power Power Harvesting Devices in fields like Medicine and Engineering Industry.

- Most of these harvesting devices are used in hard to reach areas like:

    - Remote Control Monitoring Systems.
    - Implantable Devices.
    - Equipment Monitoring.

Functional Requirements

- Converting 1.1 V AC Peak to Peak Voltage to 3V DC.
- The input signal is the only power source for the device.
- Use a source or method that can be adjusted from 1.1 Vpp to 0.2 volts Vpp.
  - lowest possible input.
- Include a charge indicator in the output of the device.
- The entire device must be contained within a 6” by 6” space.

Technical Considerations and Constraints

- Finding diodes that have low barrier voltage.
- Use half-wave or full-wave rectifier accounting for voltage drop.
- Finding a boosting device that can utilize a very low input and achieve 3V or greater
- Determine necessary capacitance to allow for adequate charge time

Potential Risks

- Excessive signal loss during rectification
  - Using Schottky Diodes to reduce the impact of rectification on the already small input signal.
- Slow Charging Capability
  - Enough power may not be available to charge the capacitor.
- Booster Functionality Issues
  - Booster module may not work as specified from manufacturer
- Input signal variability (RF-type signal, solar applications, etc)
  - May fluctuate due to the choice of source.

Potential Mitigations

- Test the parts rigorously before including them in the system.
- Make sure that the signal generator can produce enough power.
    - Power limitations of the signal generators in Lab.
- Design or order a better booster design
- Order a large enough supercapacitor preferably 1 F.

Resources & Cost Estimate

Prototype Cost:

- Schottky Diodes.
- EH 4295 Booster Module.
- Supercapacitor.
- Capacitors.
- LED.
- Total Cost:$72.32

Total Project Cost:

- Two types of boosters tested.
- Spare parts
  - Diodes.
  - Capacitors.
  - Boosters.
- Misc. Circuit Components.
- Total Cost: $295.95

Main resources provided by Iowa State University: Power Supply, Oscilloscope, and Multimeter

Project Milestones & Schedule

Semester 1

- Researched Current Solutions
- Preliminary Schematic.
- Selected Initial Parts.
- Component Testing.

Semester 2

- Updated Design After Testing.
- Looked into Booster Alternatives.
- Selected New Booster Module.
- Booster Testing.
- System Testing.

DESIGN

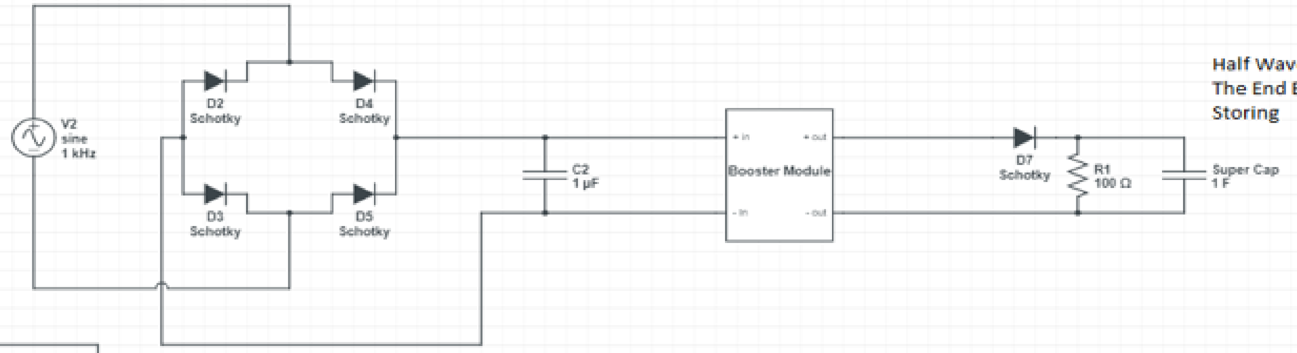
Non-Functional Requirements

- The system should be as efficient as possible.
  - Minimize loss.
  - Determine for every hour of energy scrapping, how many minutes will we be able to drive a 20mA LED.

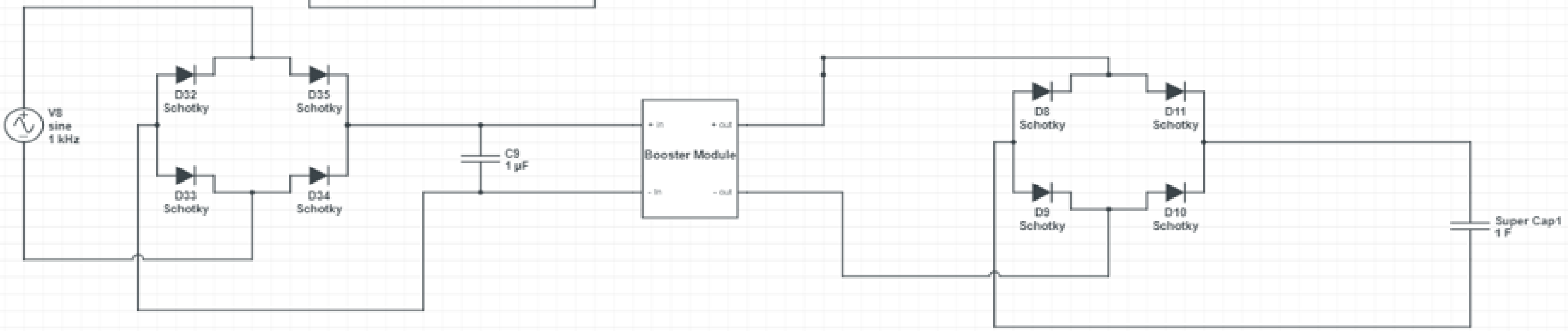
- Stretch goals:
  - Produce output of 5V
  - Use harvesting device as input

- Scalability

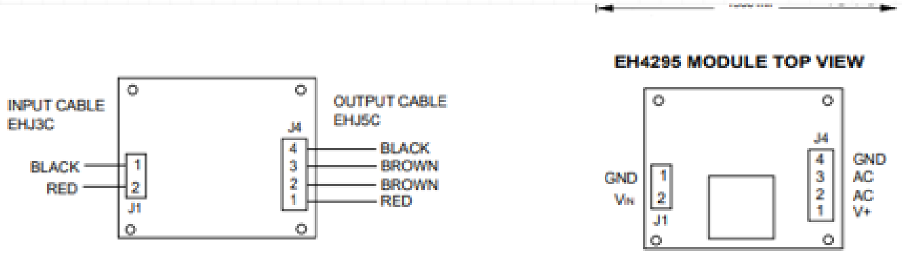
System Design



Half Wave Rectifier at
The End Before
Storing



Full Wave Rectifier at
the End before storing



Booster Module
Design

Notes: J1 pin 1: Ground, J1 pin 2: Positive Input V_{IN}
J4 pins 2/3: Standard AC Output
J4 pins 1/4: DC Output when optional full wave rectifier
is installed by user.

Functional Decomposition

1. Rectification - Using Schottky diodes to convert the AC input signal into a DC signal.
2. Voltage Boosting - Using a DC-DC booster, increase the low-level input to a higher voltage level.
3. Energy Storage - Store the charge into a long-term storage component (supercapacitor) so that it can be used when desired.
4. Charge Indicator - Add an indicator (LED) to signal that the energy storage device is being charged.

TESTING

Functional Test Plan

Component-Level

- Diode
  - Verify cutoff voltage
  - Rectification test

- Capacitor
  - Verify capacitance
  - Charge testing of capacitors

- Booster
  - Verify boosting effect

System-Level

- Output test
  - DC output
  - At least 3V

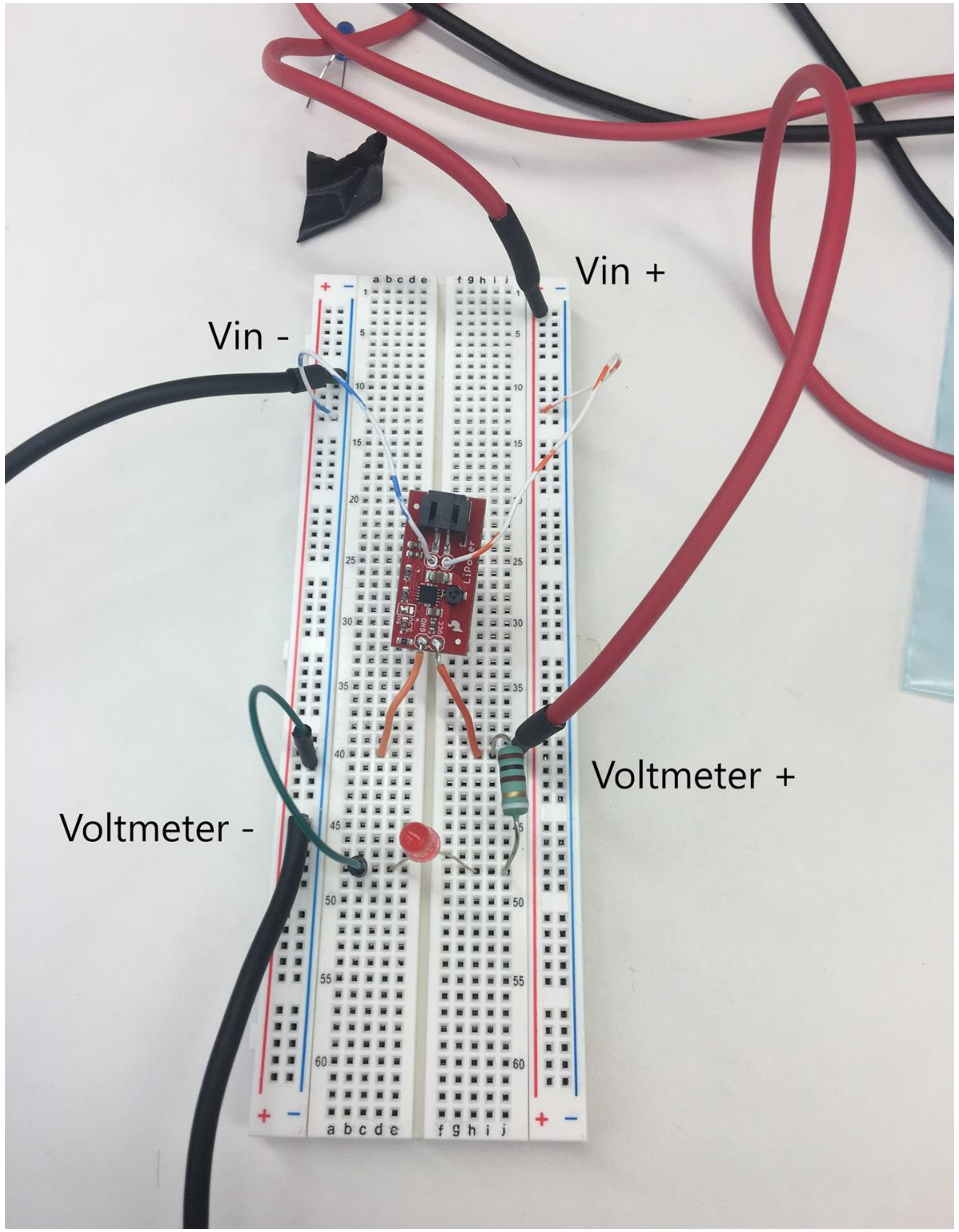
- Function test
  - Power LED
  - Verify LED time vs charge time

- Efficiency test
  - Energy out vs energy in

Booster Testing

In the booster testing stage we verified the functionality of the booster between 1.1V and 1.6V DC input. However the required input is below this range.

Measurement	Voltage	Output Boost
1	1.1	2.6
2	1.2	2.78
3	1.3	3
4	1.4	3.27
5	1.5	3.5
6	1.6	3.75 - 4 (between these values)
7	1.7	Starts Decaying again



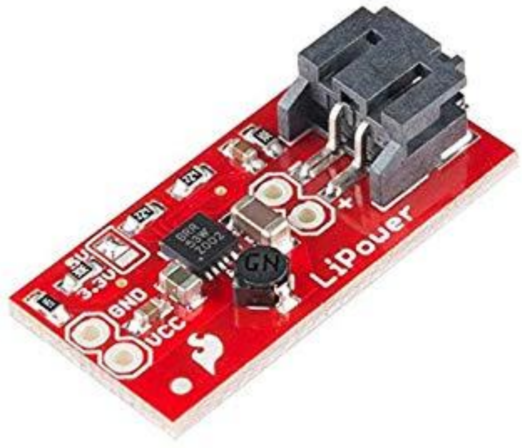
Voltage Boosters

Testing Yielded Several Issues:

- Failure to hold boost.
- Transient behavior.
- Inconsistent results.

Transition To a New Booster:

- Found EH-4295.
- Better Voltage Boost.
- Facilitates a Boost of 0.3V - 5V.

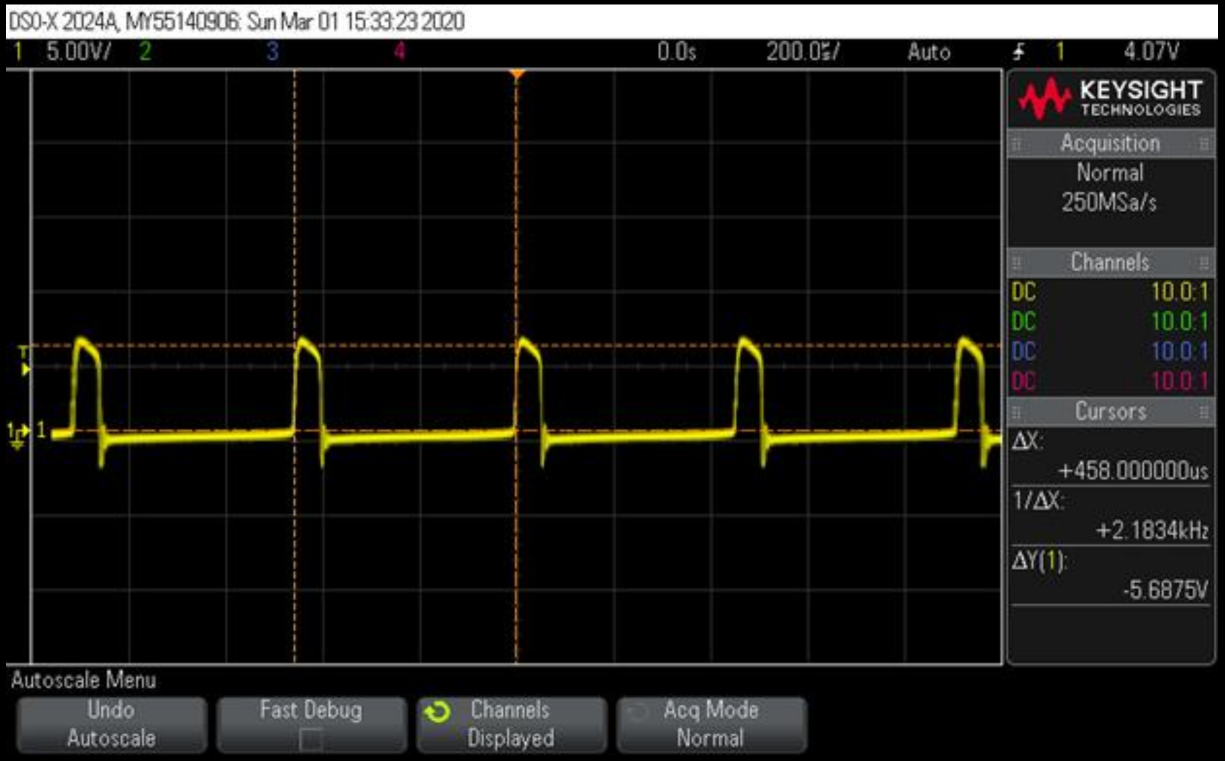


DC-DC Booster

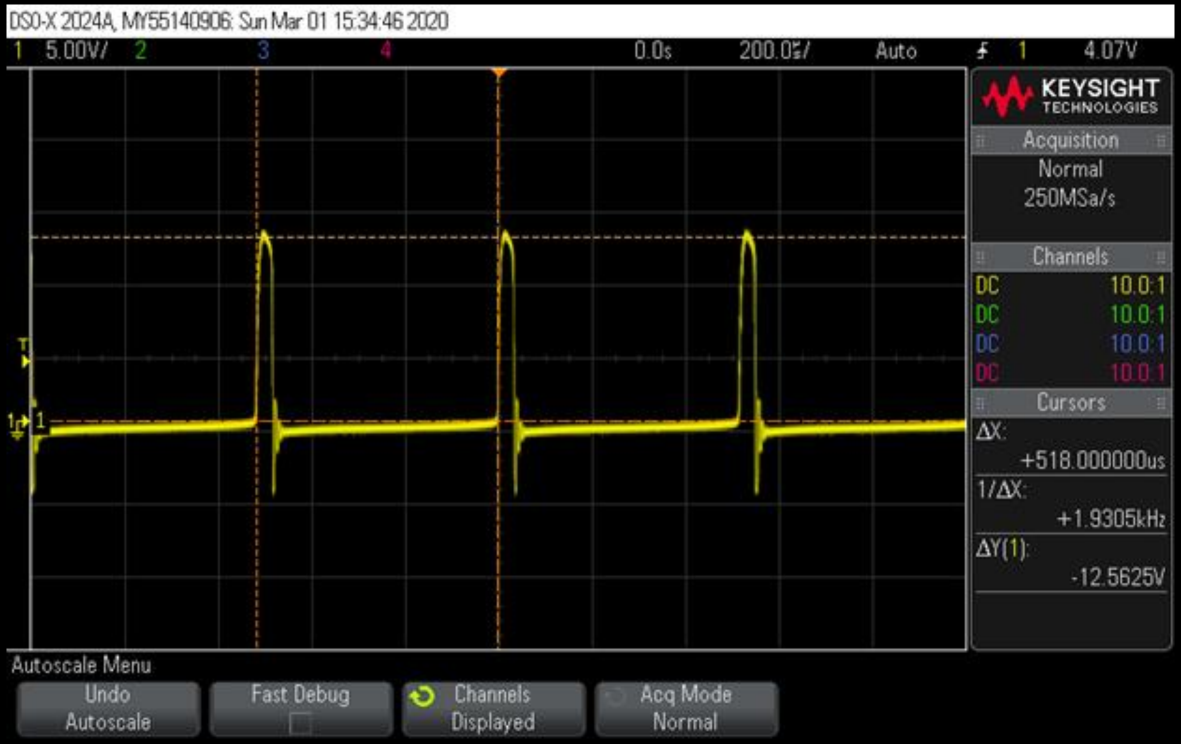
DC-AC Booster

Booster Testing (EH4295)

- DC power 0.35V, 10K ohms load.



- DC power 0.5V, 10K ohms load.



Capacitor Testing

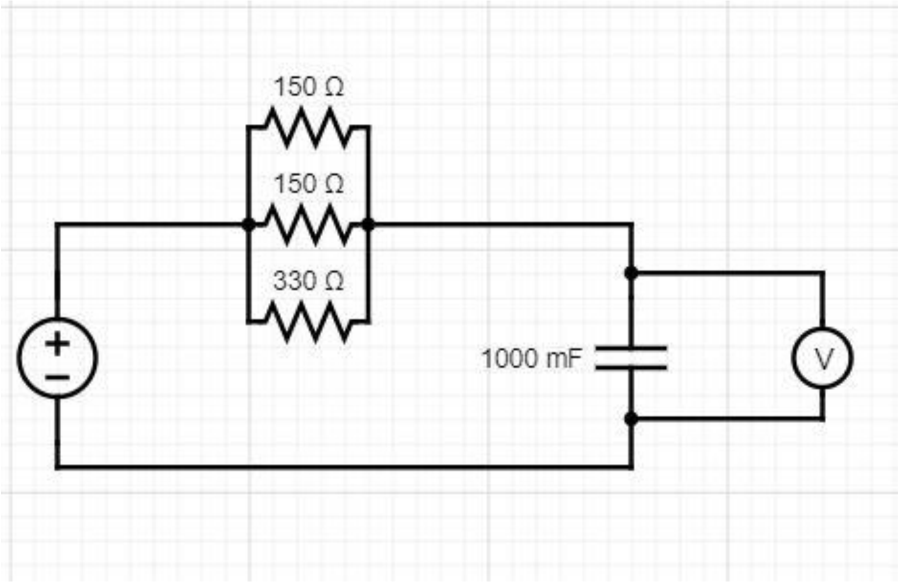
- The capacitors were tested with the circuits shown here.
- From the results, they are acceptable for use in or design.

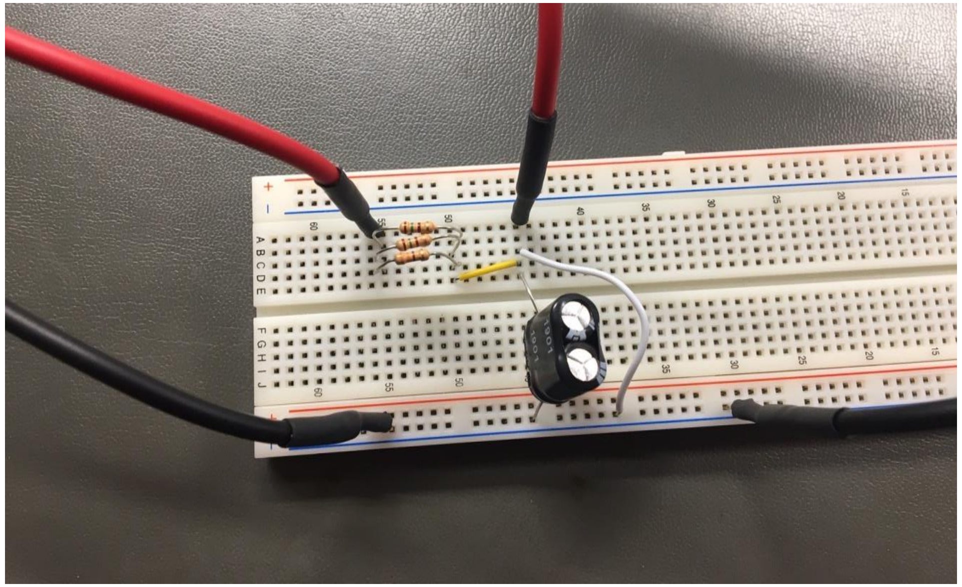
Testing Setup Information

Input Voltage	3 VDC
63.2 % Value	1.896 VDC
Calculated R_{EQ}	61.11 Ω
Measured R_{EQ}	65 Ω

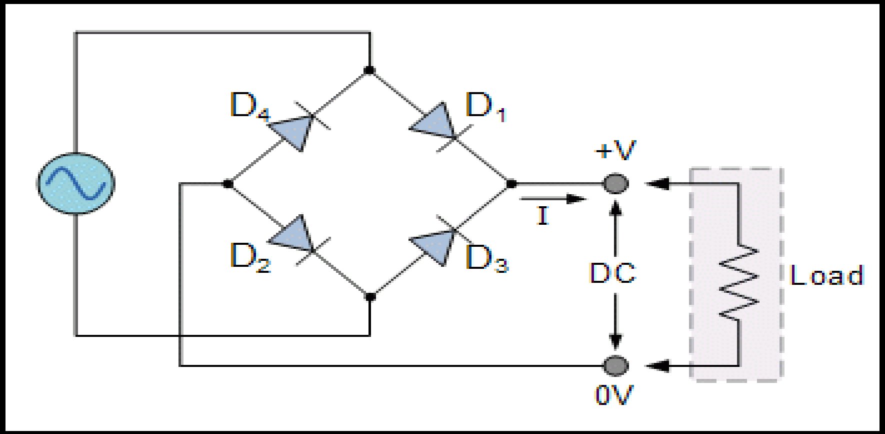
Capacitor Measurement Results

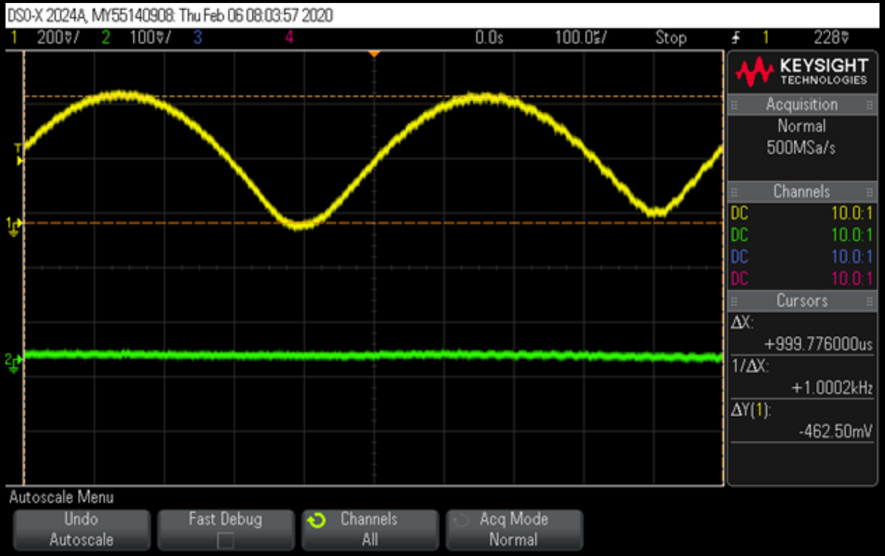
Capacitor	Measured Time Constant (seconds)	Calculated Capacitance (Farads), $C=\tau/R$	% Error
1	62.67	0.964	3.6
2	63.72	0.98	2
3	60.1	0.925	7.5
4	64.67	0.995	0.5
5	64.1	0.986	1.4



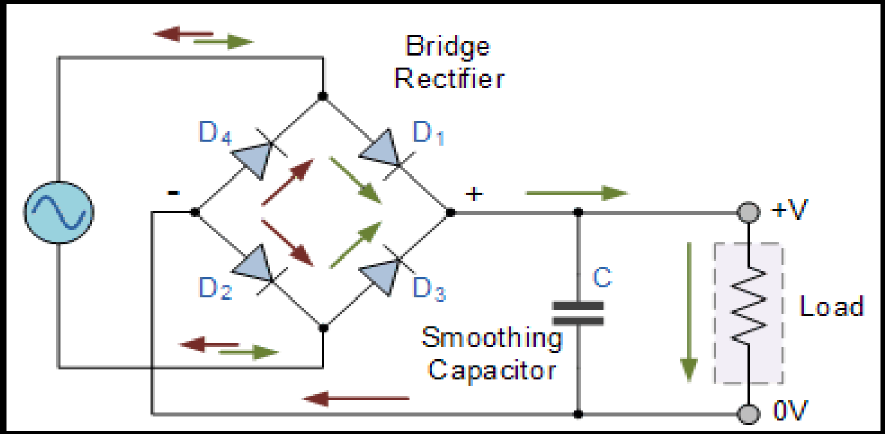


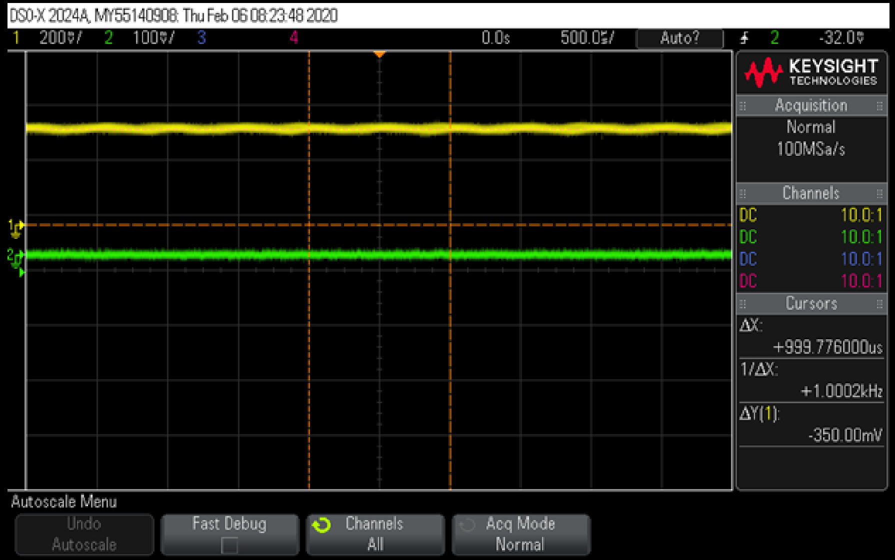
Rectification Circuit





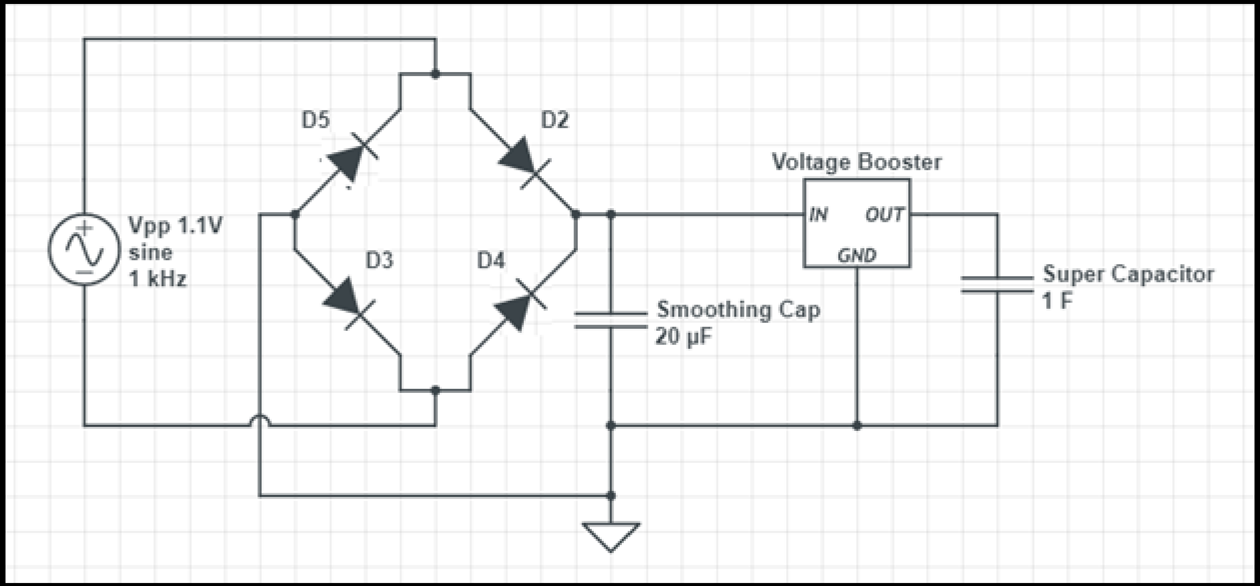
When applied with 1.1Vpp, 1KHz sine wave with 10K load resistor.



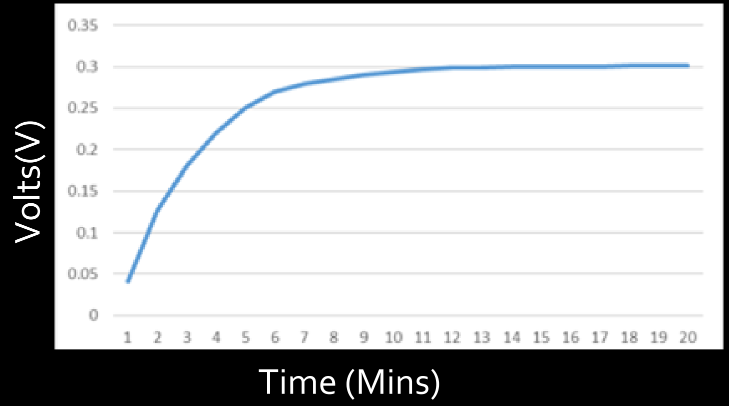


When applied with 1.1Vpp, 1KHz sine wave with 10K load resistor and 20uF smoothing capacitor.

System Testing

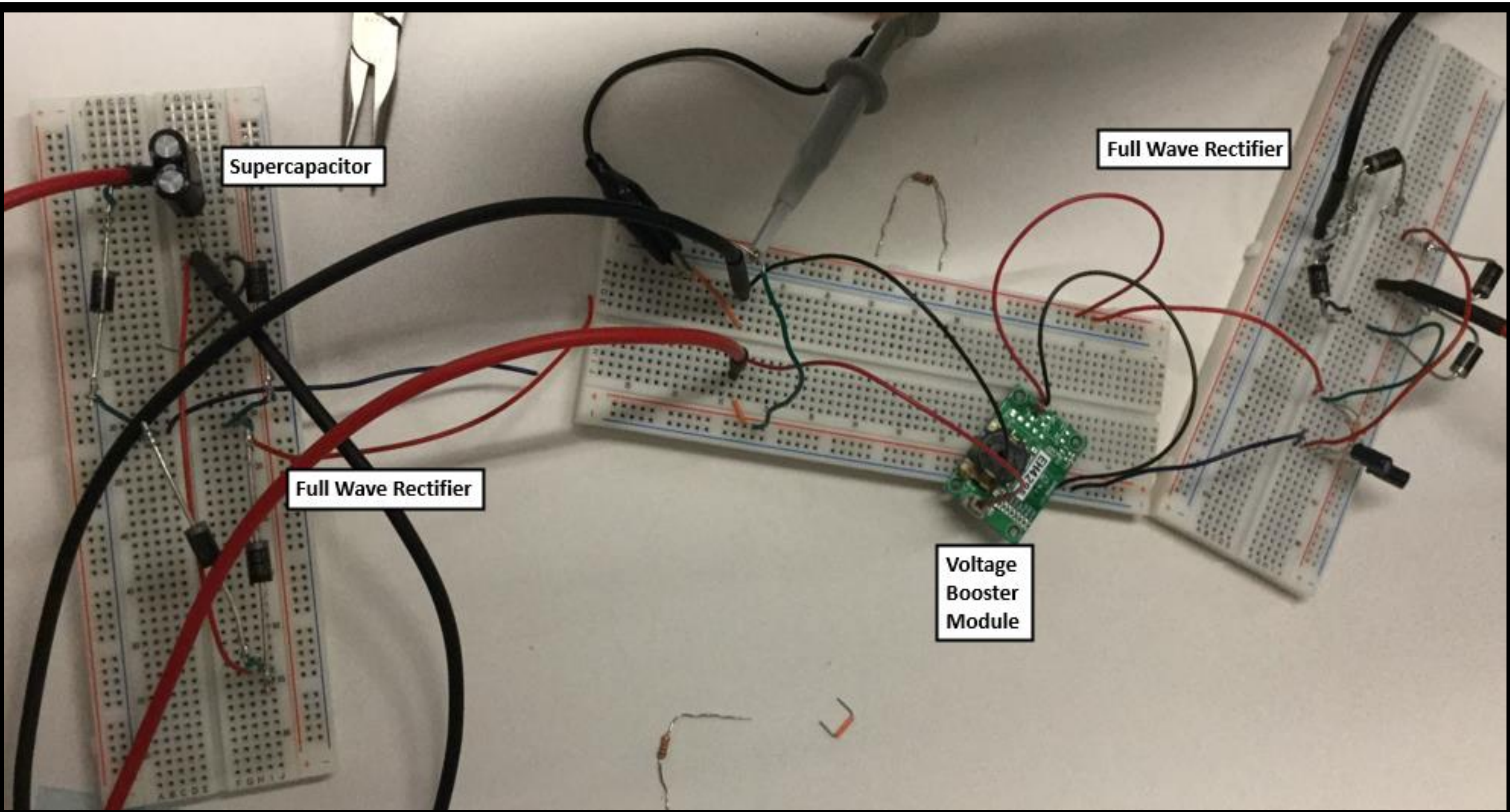


Time(minutes)	Voltage(V)	Time(minutes)	Voltage(V)
1	0.041	11	0.297
2	0.126	12	0.299
3	0.18	13	0.299
4	0.22	14	0.3
5	0.25	15	0.3
6	0.27	16	0.3
7	0.28	17	0.3
8	0.285	18	0.301
9	0.29	19	0.301
10	0.294	20	0.301



According to the results we obtained we verified that the system was successfully charging the supercapacitor. However the speed is relevently slow the charging process saturates fast.

Prototype Board



Engineering Standards and Design Practices

- Cadence simulated circuit testing.
- Readable circuit designs that follow design conventions.
- RoHS compliant circuit components
- Followed all electrical safety procedures.
- IEEE Code of Ethics

Member Responsibilities

- Shahzaib Shahid: Team Leader.
- Benjamin Yoko: Chief Engineer.
- Andesen Ande: Documentation Manager.
- Ahmed Salem: Test Engineer.
- Jordan Fox: Design Engineer.
- Xiangyu Cao: Test Engineer.

Summary

Accomplished

- Designed Energy Harvesting Unit Given Clients Constraints
- Explored Alternative Methods and Parts
- Component Testing
- Began System Testing

Planned

- Complete System Testing
- Detailed Analysis of Circuit Performance
- Explore Ways to Improve Performance
- Strive for Stretch Goals

Thank You