Light Guide Solar Concentrator

Group C

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Project Goals

1. Design a compact, scalable CPV system

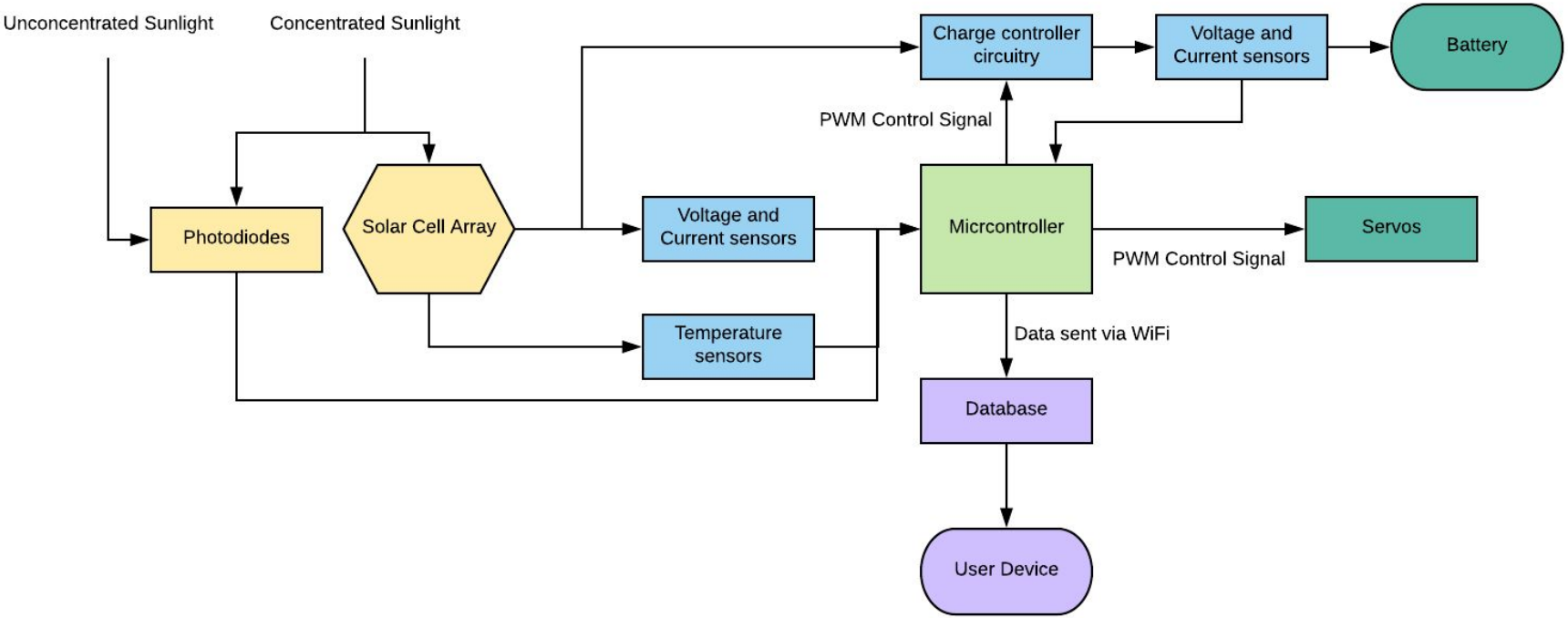
2. Create an attractive design

3. Simplify understanding the system status

Specifications and Requirements

- Concentrator should be less than 5 cm thick
- Tracking angle: -60 degrees to 60 degrees
- Concentration factor: 2.5x
- Optical system efficiency: 80%
- Electronics system efficiency: 85%
- Android app must be easy to use and provide high utility

Block Diagram



Solar Concentrator

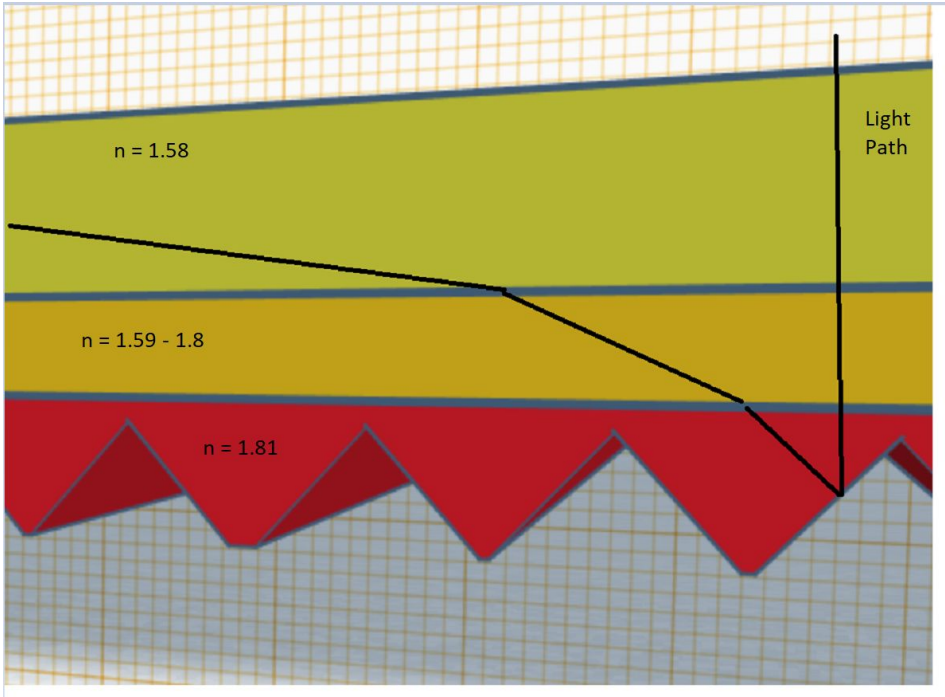
Weight: 0.6 kg

Expected Optical Losses: 20%

Excitation plane: Top

Emission plane: 2 sides

Index matching fluids



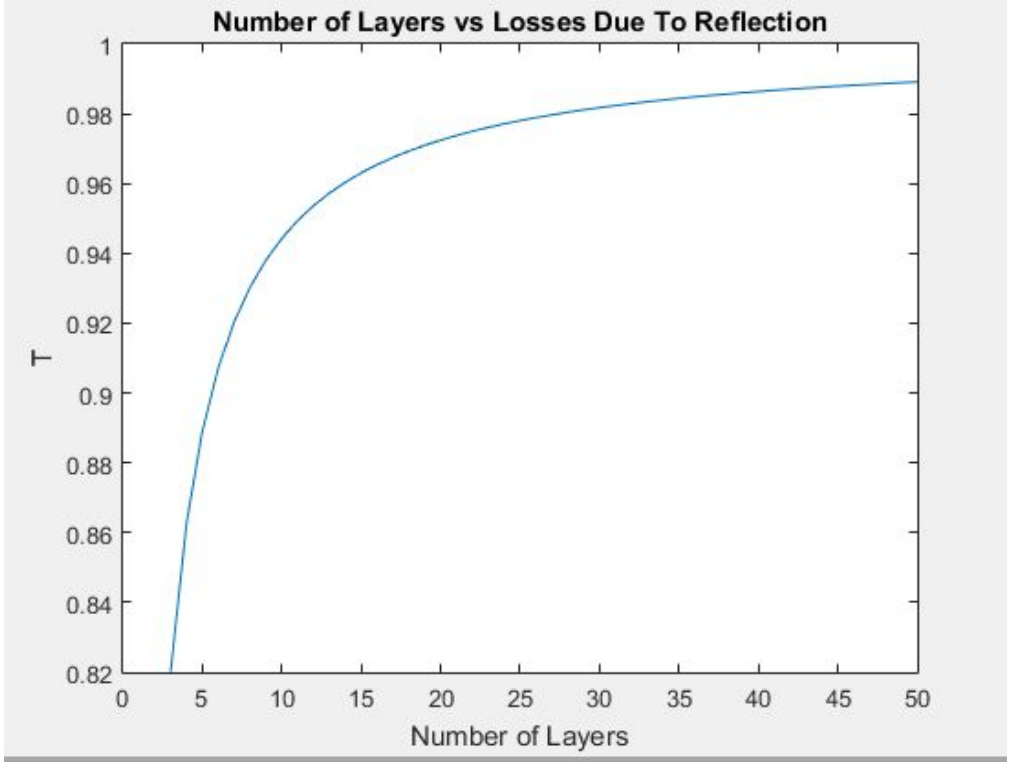
Optical Device Characterization

Predicted Sources of Optical Loss

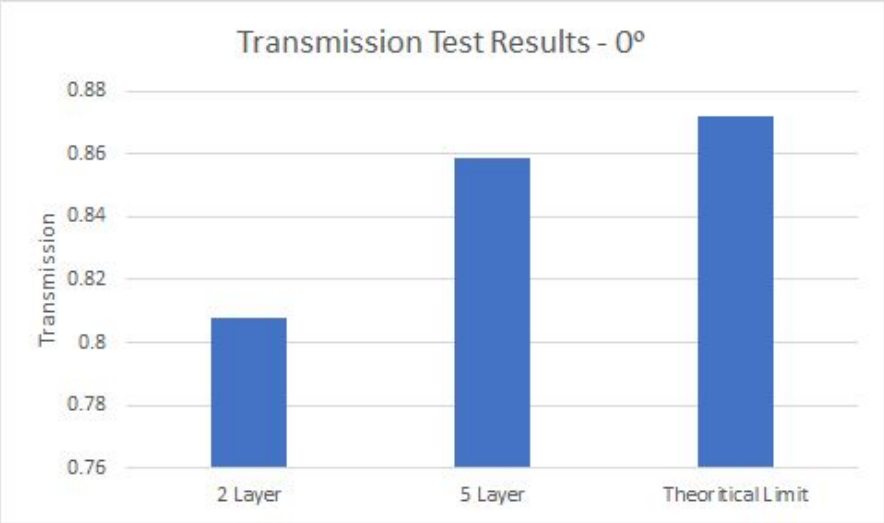
Fresnel Reflection - 2% to 12%

Mirror Surface - 4%

Matlab script was used to characterize

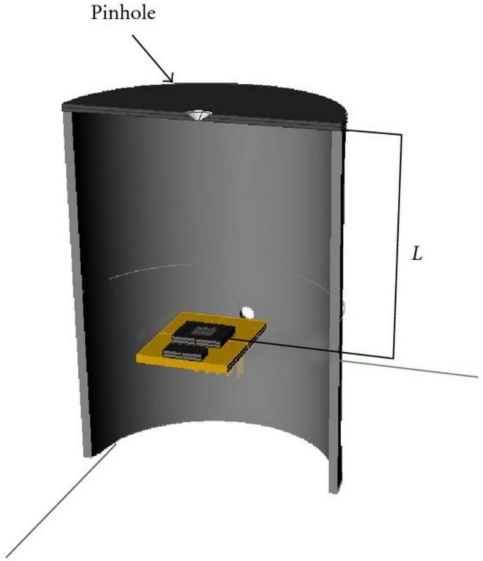


Optical Loss Test Results



Tests performed with 532 nm laser diode, without the prisms attached

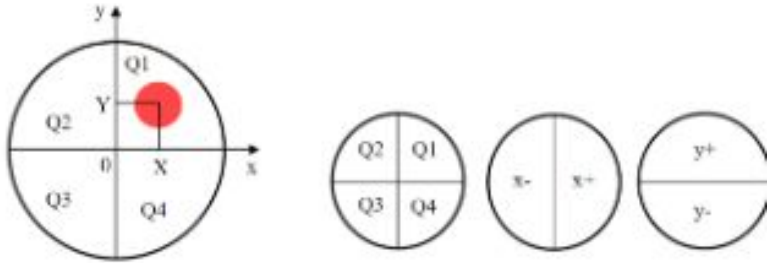
Tracking: Solar Direction Sensor



Quadrant Photodiode and Pinhole
Scanning Mode and Sensing Mode

$$X = \frac{(x+)-(x-)}{Q1+Q2+Q3+Q4} = \frac{(Q1+Q4)-(Q2+Q3)}{Q1+Q2+Q3+Q4} = \frac{X_{Diff}}{SUM}$$

$$Y = \frac{(y+)-(y-)}{Q1+Q2+Q3+Q4} = \frac{(Q1+Q2)-(Q3+Q4)}{Q1+Q2+Q3+Q4} = \frac{Y_{Diff}}{SUM}$$



Tracking: Physical Mechanism

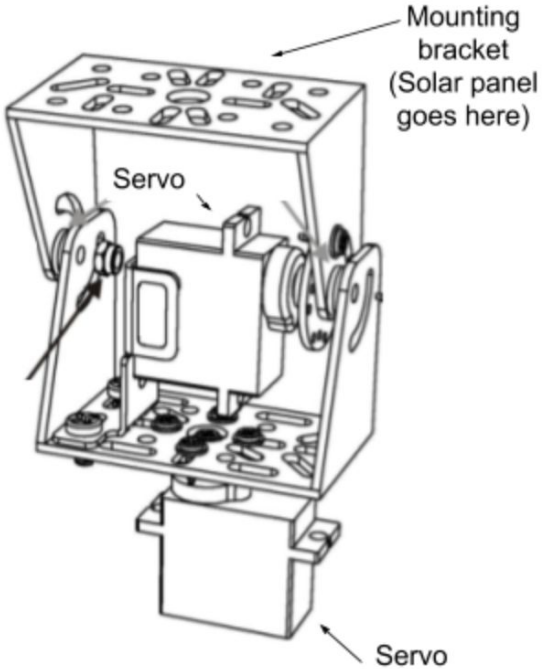
Prototype will be a scale model

Premade frame

Easily controlled servos

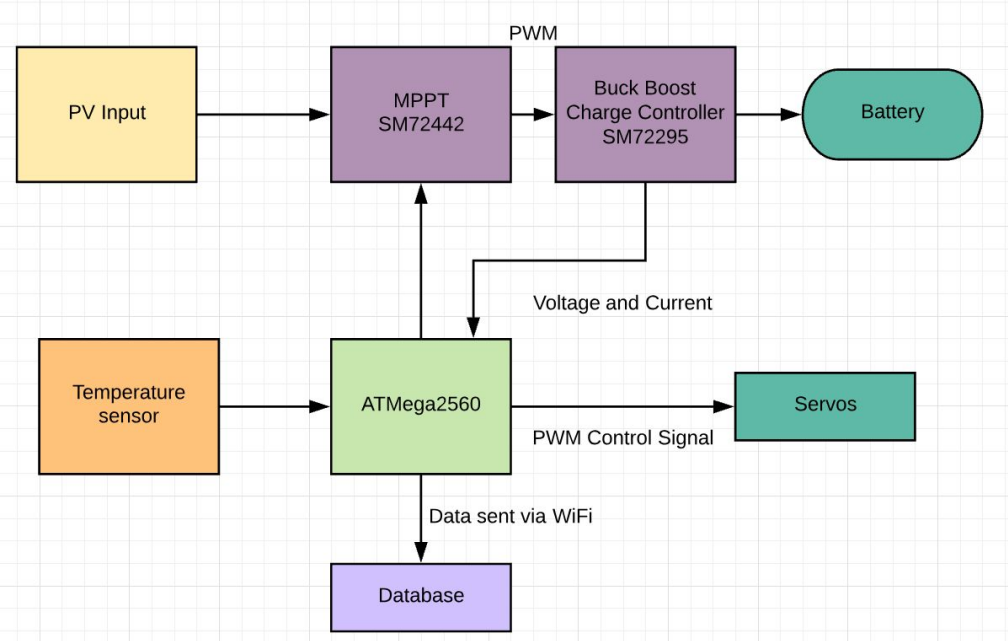
Servo torque: 5 km/cm

Had to swap kit servos with more powerful ones



Hardware Architecture

- MCU, MPPT, and Buck/Boost embedded onto single board design
- Traces for Serial and I2C communication for MCU/WiFi and MPPT/MCU respectively.
- Headers on board for longer distance sensor connections, tracking control, and reprogramming of MCU



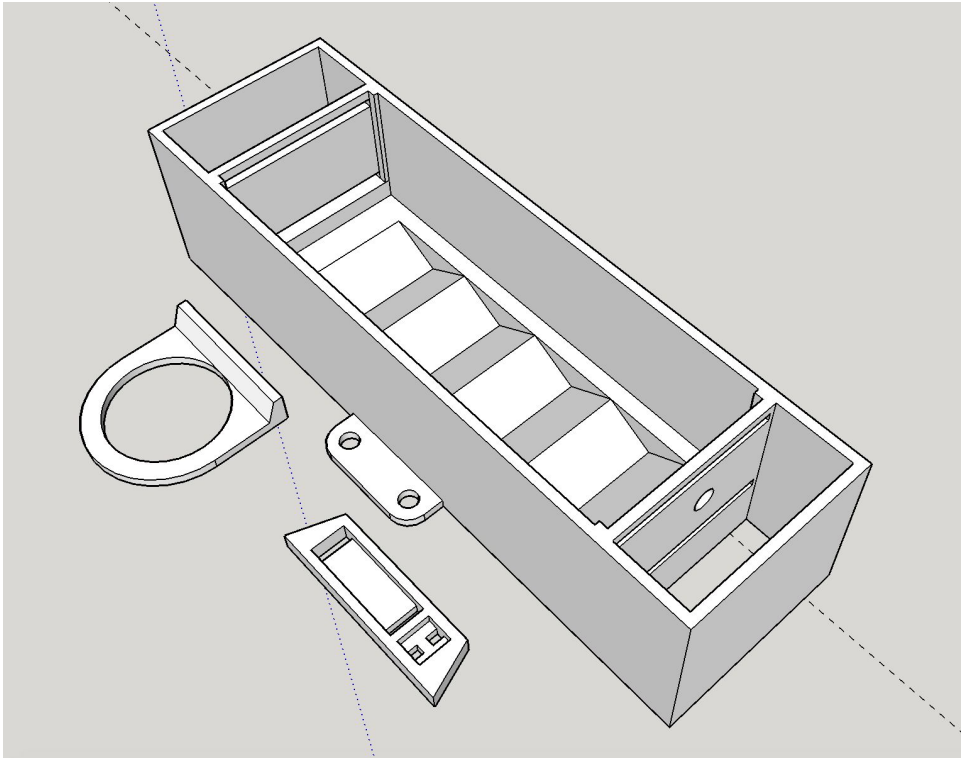
3D Printed Housing Unit

Unit Dimensions (mm):

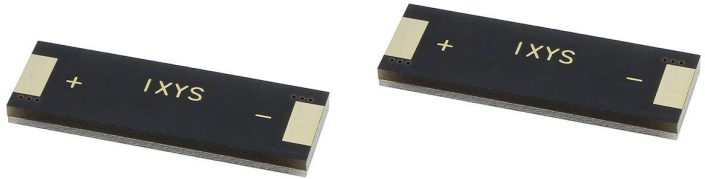
144.35 x 41.75 x 36.88

Active Concentration (mm):

86 x 30.25 x 24



Solar Cells Selection



Model: IXYS KXOB22-01X8F

Output: **3.4V, 3.8mA**

2 cells connected in series to form combined output of **6.8V, 3.8mA**

3 arrays in series to form combined output of **6.8V, 11.4mA**

Bypass and blocking diodes needed to prevent backflow of current from battery and ICs

Power Control System

- MCU - ATMega2560
  - Interfaces with servos via PWM signals
- MPPT - H-Bridge driven buck/boost topology
  - DC-DC Conversion
  - Reduce voltage, increase current
- Sensors: Temp, Sunlight, Voltage, Current
  - Analog to Digital conversion
  - Voltage and current values are required at solar cell array and battery to determine solar cell generation and battery intake.
- Sending data via WiFi
  - ESP8266 via serial communication

Microprocessor Selection

PIC18F46K22

- C Compiler optimized architecture
- Linear program memory addressing to 64 Kbytes
- Up to 16 MIPS operation
- **28 ch, 10-bit ADC Input**
- **Up to 4 PWM outputs**

CC3220

- ARM Cortex M4
- **WiFi module built into chip**
- Allows for I2C, SPI, SD and UART
- 1MB of Flash and 256KB of RAM
- Only 4 analog pins available, requires multiplexing

Microprocessor Selection

ATMega328

- Interfaces: I²C, Serial
  - Only one serial connection available
- Significant libraries for basic functions like servo control
- **Massively simplifies implementation and board design**
- Requires the use of multiplexing for analog signals

ATMega2560

- Interfaces: I²C, Serial
  - Up to three serial connections available
- Significant libraries for basic functions like servo control
- **Includes up to 16 analog pins, removing the need for multiplexing**

Temperature Sensor Selection

Texas Instruments: **SM72480**

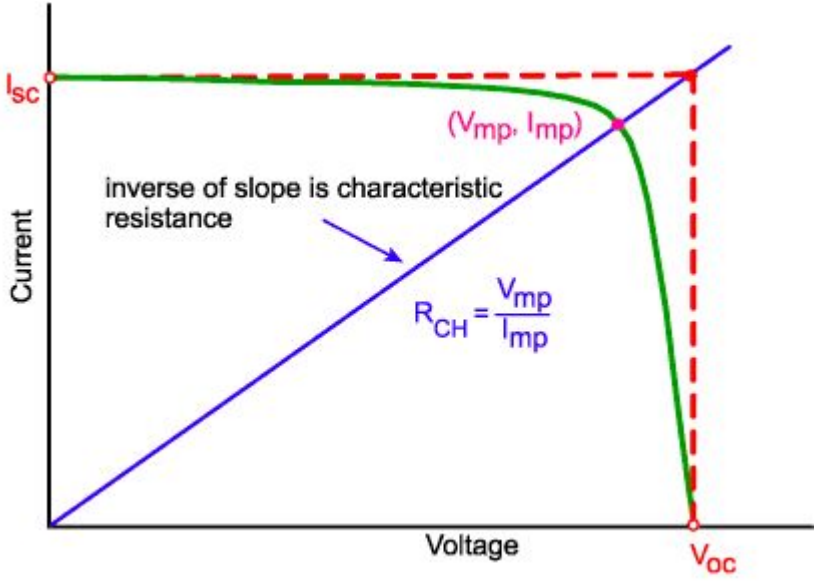
- Low 1.6V Operation
- Accuracy, Trip Point Temperature 0°C to 150°C ±2.2°C

TE Connectivity Measurement Specialties: **NB-PTCO-006**

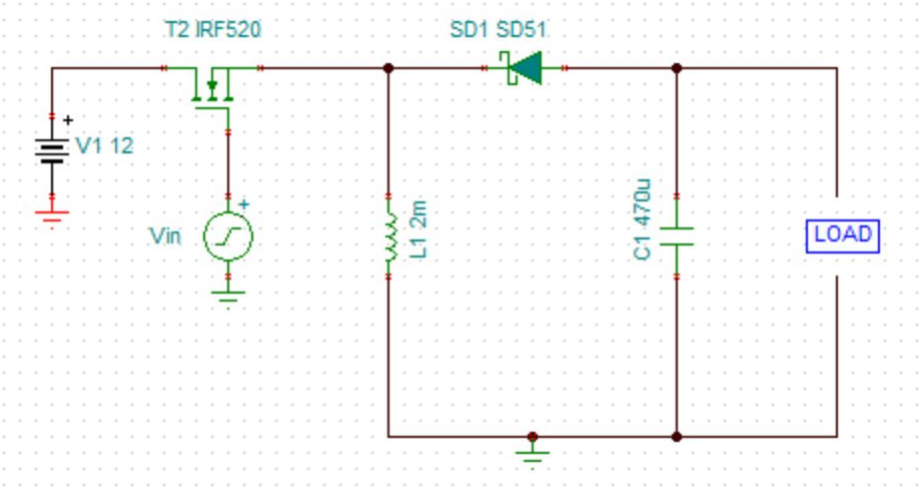
- Resistance @ 0°C: 1 kOhms
- Accuracy: ±0.3%
- For T ≥ 0 °C: R(T) = R(0) * (1+a * T + b * T 2)
- For T < 0 °C: R(T) = R(0) * [1+a * T + b * T2 + c * (T-100°C) * T3]
- Coefficients: a = 3.9083E-03 b = -5.775E-07 c = -4.183E-12

MPPT Method 1 - Single PWM Control

Utilizes “Hill-climbing” Algorithm

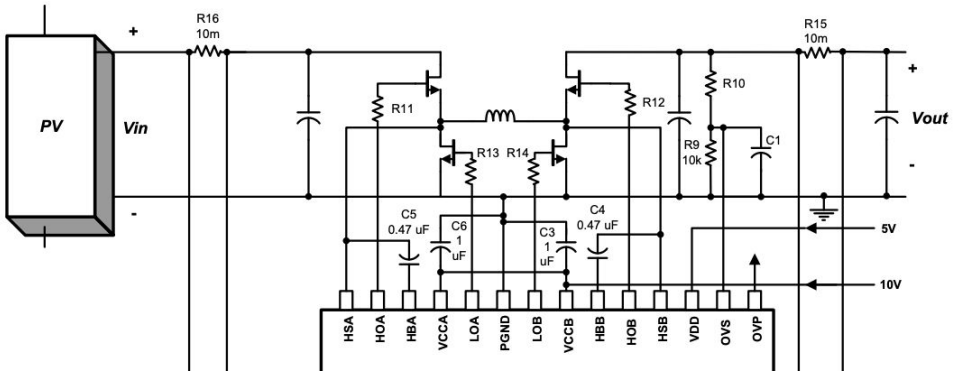


Buck Converter Circuit



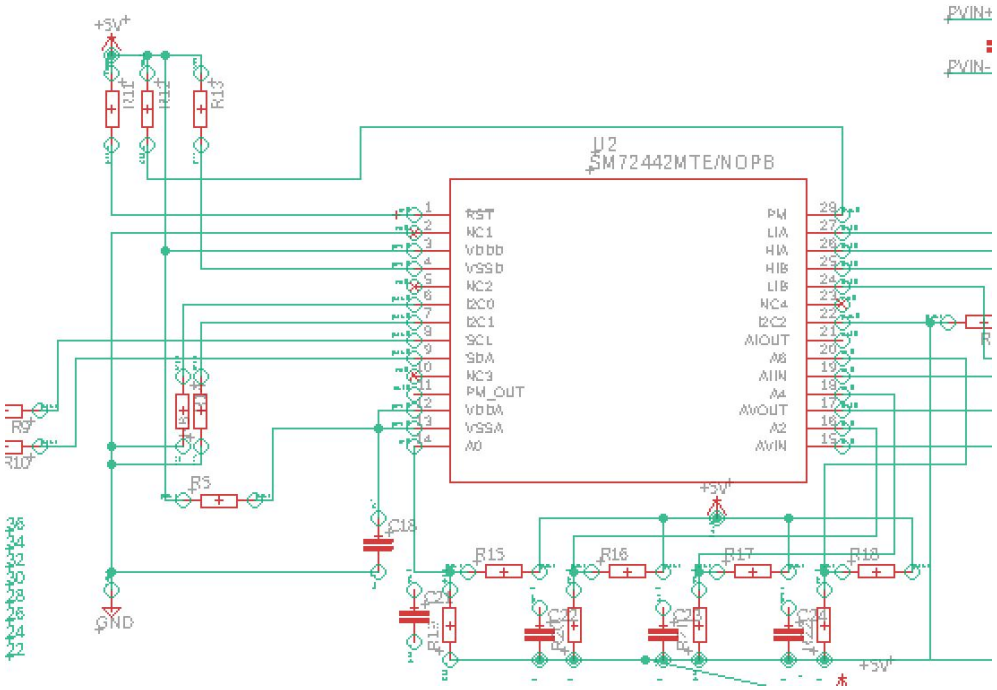
MPPT Method 2 - Buck/Boost Topology

- Four PWM control signals to switch four N-channel mosfets in order to allow or block current flow from the solar cells into the inductor
- PWM control signals are generated by adding a second feedback loop indicating resulting inductor current
- The driver signals are powered by 3A of peak current for fast switching
- Convergence to the MPPT typic
    - Switching Frequency: 100MHz



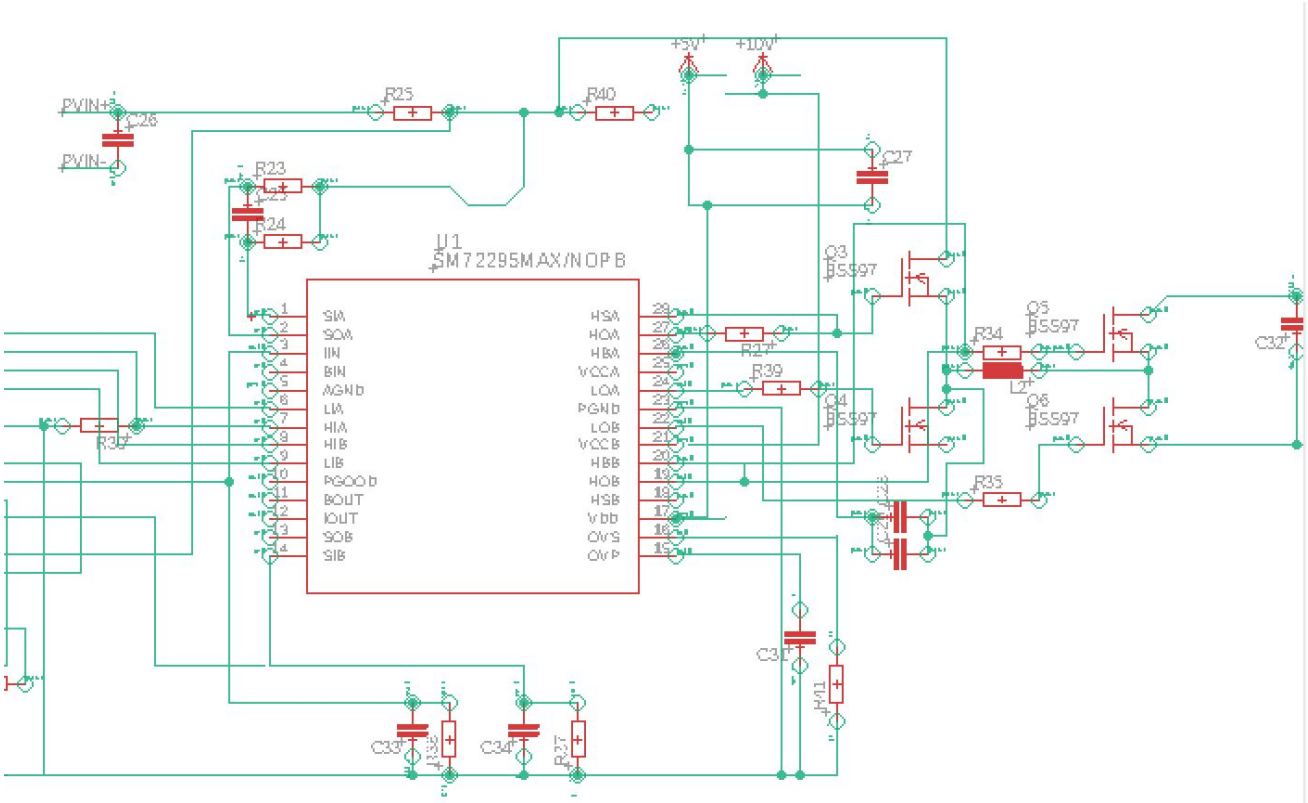
MPPT Schematic - MPPT Configuration (SM72442)

Voltage (V)	
Vo_max	5
V_A0	1.67
V_A2	1.55
V_A4	1.43
V_A6	0.30



Resistance (Ohms)	
RT1	10000
RB1	5000
RFB1	40000
RFB2	20000
RT2	4500
RB2	10000
RT3	4000
RB3	10000
RT4	4500
RB4	70000
SCL_R	2000
SDA_R	2000

MPPT Schematic - Buck Boost (SM72295)



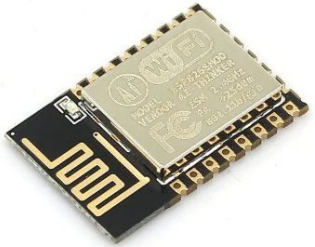
Battery Selection

Tattu Li-Poly Battery

- Nominal Voltage: 3.7V
- Nominal Capacity: 220mAh
- Discharged Voltage 3.2V
- Charged Voltage: 4.2V
- Typical applications: Remote Control Helicopters

Due to design constraints, the battery has a small capacity.

WiFi Module Selection



RN1810

- Communication via UART
- Protocol: 802.11 b/g/n
- Vin 3.3V
- Lacking support
- **Data rate: 54 Mb/s**

ESP8266-12E

- Communication via UART (Serial)
- Protocol: 802.11 b/g/n
- Vin: 3.3V
- **Data rate: 7 Mb/s**
- Significant support for implementation
- Pre-existing libraries for Firebase data manipulation

Microcontroller Code Flow Diagram

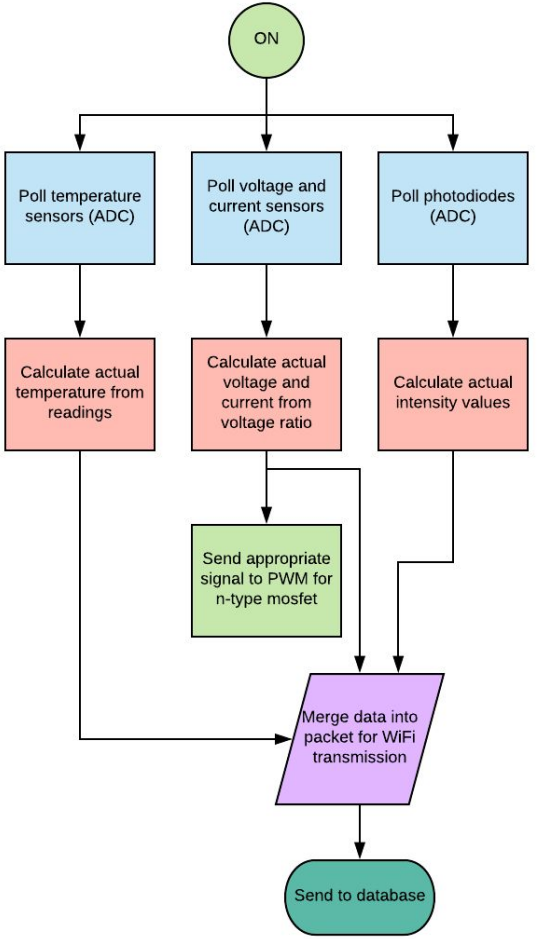
ADC Calculations

Calculating Temperature

Calculating PWM signal to servos

Calculating Voltage

Calculating Current



Motivation For Android App

Solar generation statistics not readily accessible to consumer

Desire to acquire data instantly (not wait for energy bill)

Analyze data in a way that’s comprehensible to non-technical user

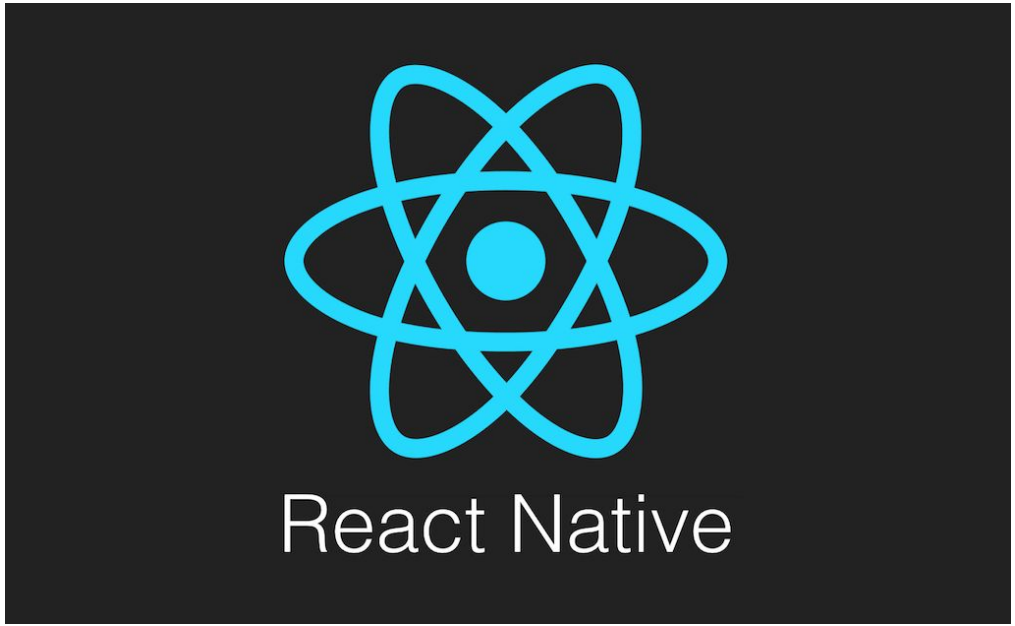
React Native

Native Mobile Application

JavaScript Library

SVG Charting Tool

Live Reload



Firebase

Realtime database

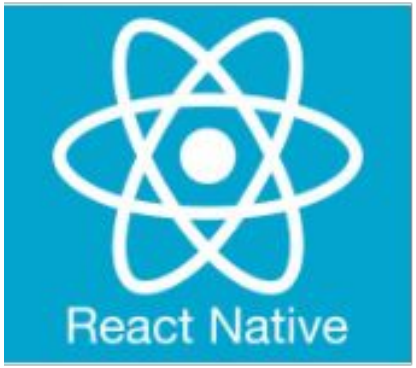
Allow integration with Android Applications

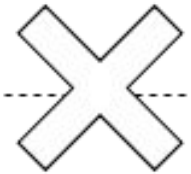
Much simpler than custom server

React API

Arduino API

Data Flow

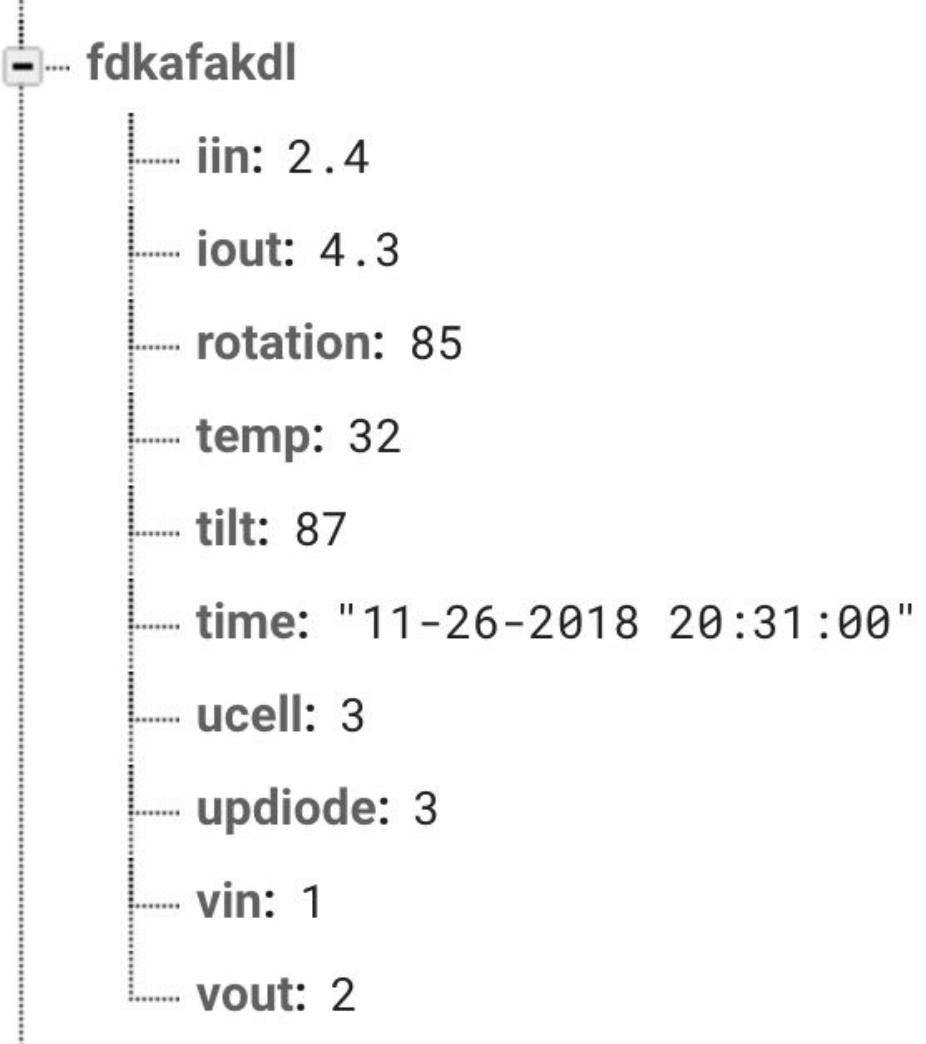




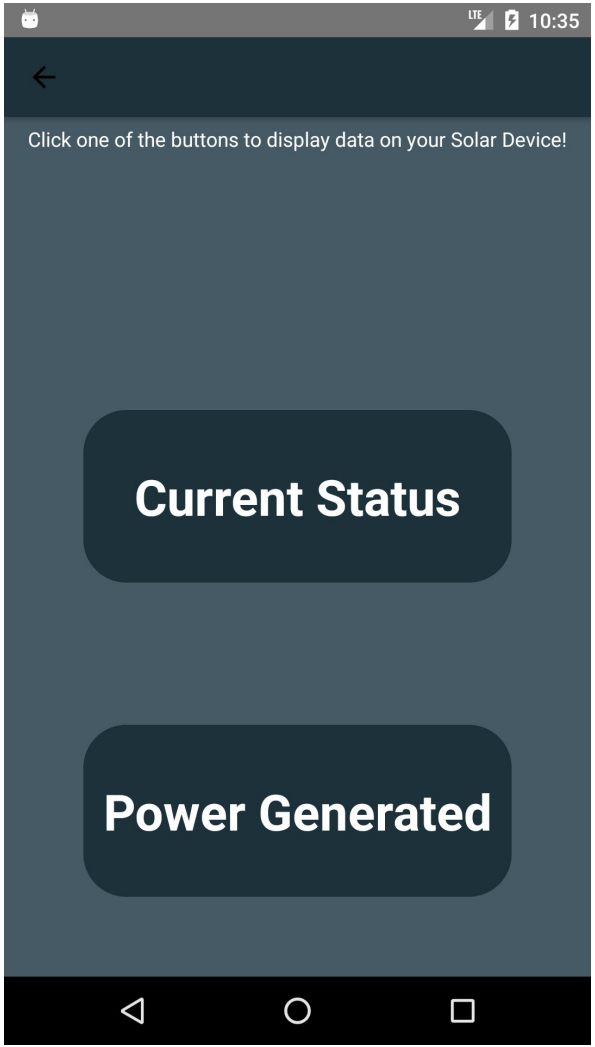
ESP8266-12E
Wifi Module

Firebase Data Structure

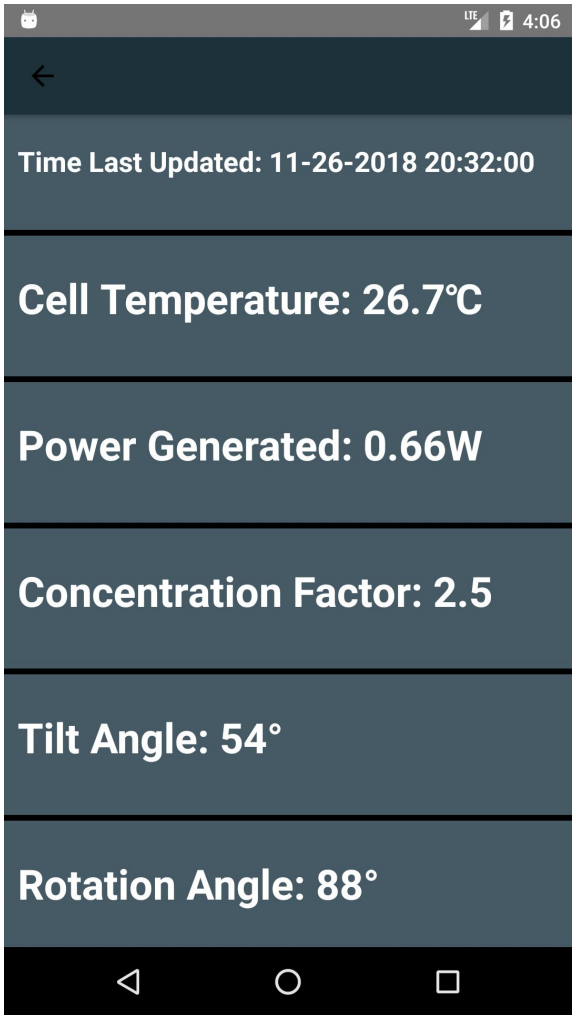
- String passed in from microcontroller
- Updates every minute




10:34
UCF
College of Engineering and Computer Science
Light Guide Solar Concentrator Mobile Application
Enter

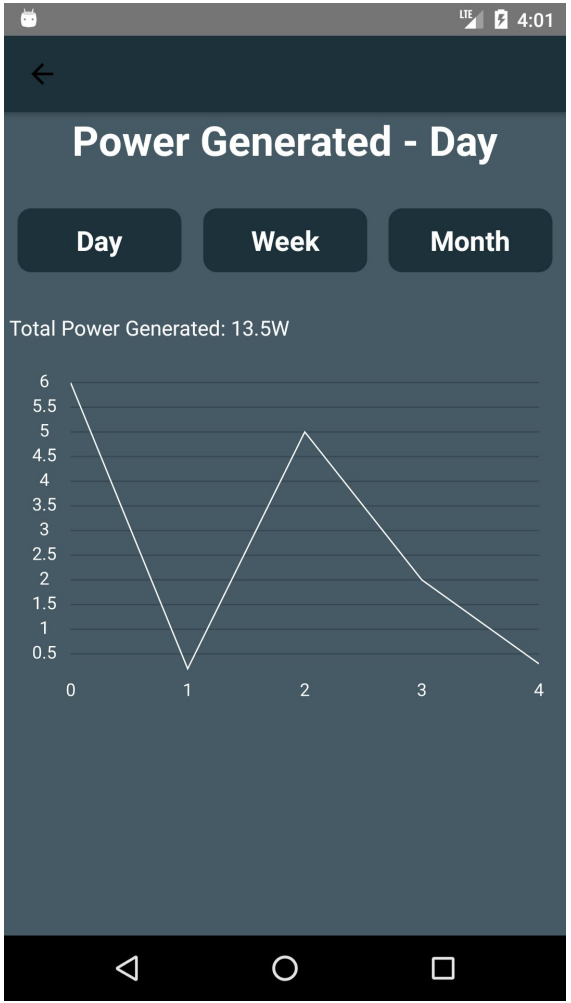

10:35
Click one of the buttons to display data on your Solar Device!
Current Status
Power Generated

Current Status



Power Generated

- Total Power Generated
- Power Generated vs. Time
  - Day
  - Week
  - Month



Project Budget and Financing

Item	Quantity	Price Estimate
Metal Framing Material	1	$20
Metal Support Material	1	$10
Resistance Temperature Detectors	2	$40
Quadrant Photodiode	1	$90
Tube with Pinhole for Quadrant Photodiode	1	$10
Servos	2	$30
Batteries	1	$100
Custom PCB	1	$30-$100
High index glass samples (~3cm^2)	5	$100

Item	Quantity	Price Estimate
PIC16F46K22	1	$20
Circuitry components	1	$25-$65
Buck Converter Components	1	$20
Microcontroller	1	$20
Microcontroller wifi chip	1	$15
Voltage regulators	2	$20
Gem Refractometer	1	$98
Gem Refractometer Liquid	2	$122
Various Tools for Glass Component Assembly	1	$60

Item	Quantity	Price Estimate
Large high index glass sheet	2	$200
Laser Diode for Testing Concentrator	1	$40
Optical Bench Setup for Testing Concentrator	1	$120
Anamorphic Prism Pairs	10	$550
Silver Deposition Kit	1	$75
TOTAL		~1,590

Questions?