Light Guide Solar Concentrator

Group C

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Project Goals

1. Design a compact concentrated photovoltaic system suitable for rooftop or on ground mounting

2. Create an attractive design that system owners will be proud of

3. Provide a way for owners to clearly understand the benefits of their system by providing a software interface

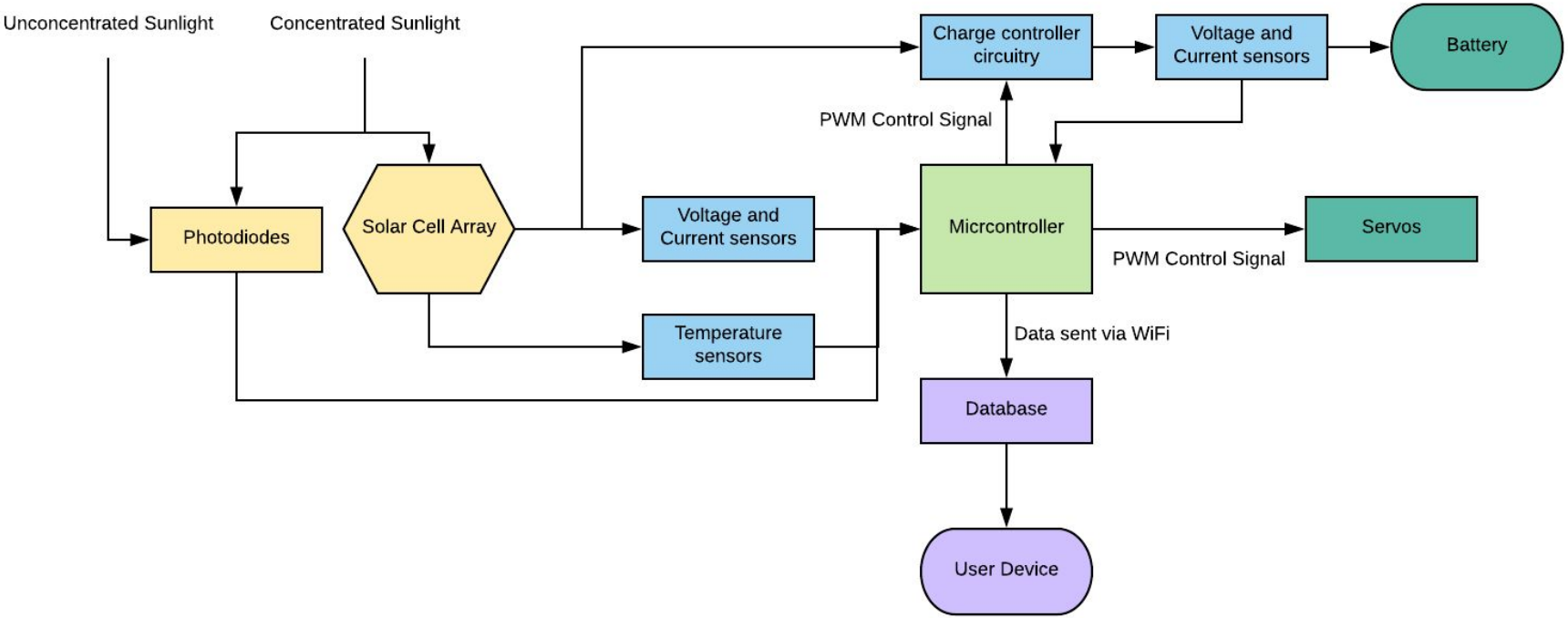
Overall Design

- Solar Concentrator
- Tracking System
- Energy Transfer and Battery
- Android Application

Specifications and Requirements

- Less than 5 cm thick
- Tracking angle: -60 degrees to 60 degrees
- Concentration factor: 2.5x
- Optical system efficiency: 70%
- Electronics system efficiency: 85%
- Android app must be easy to use and provide high utility

Block Diagram



Solar Concentrator

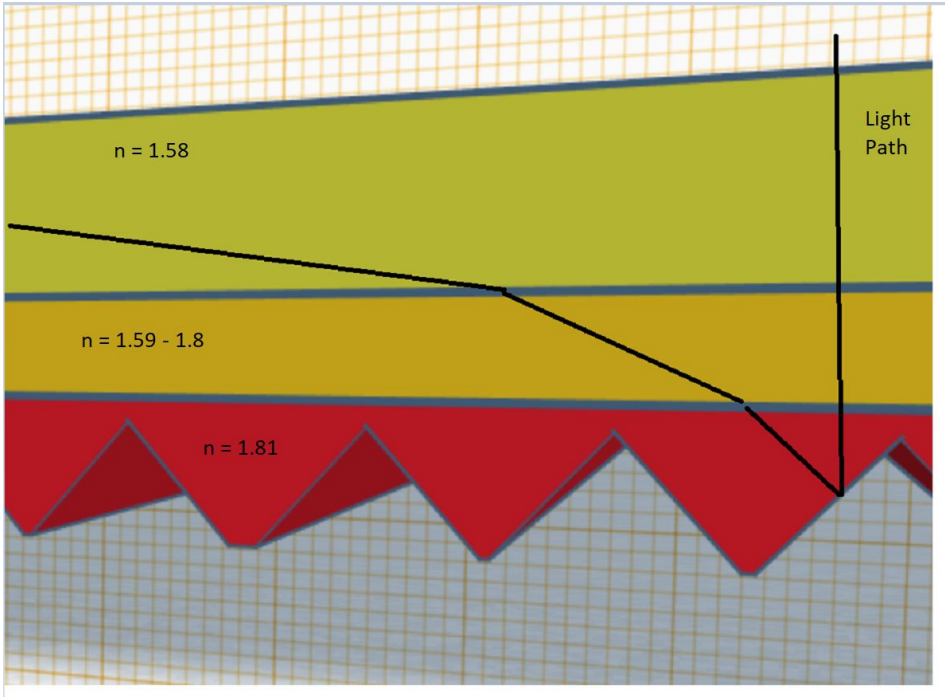
Weight: 0.6 kg

Expected Loss Factor: 8%

Excitation plane: Top

Emission plane: 2 sides

Next steps: practice bonding layers and test for losses and cut plexiglass



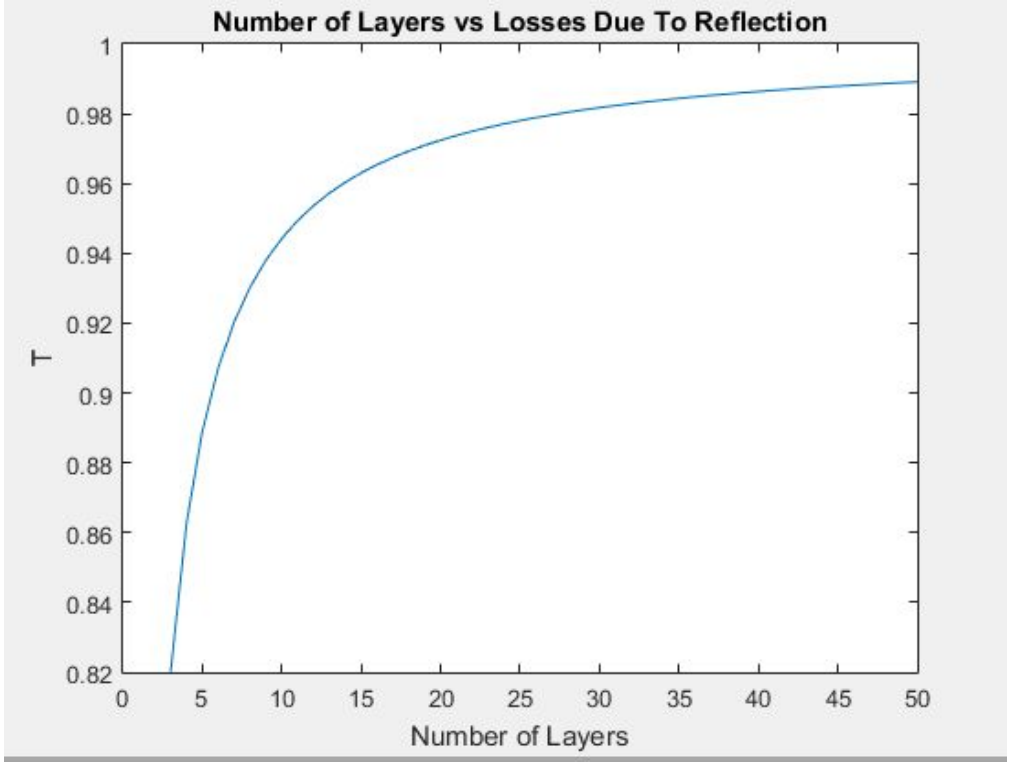
Optical Device Characterization

Predicted Sources of Optical Loss

Fresnel Reflection - 2% to 12%

Mirror Surface - 4%

Matlab script was used to characterize



Tracking Mechanism

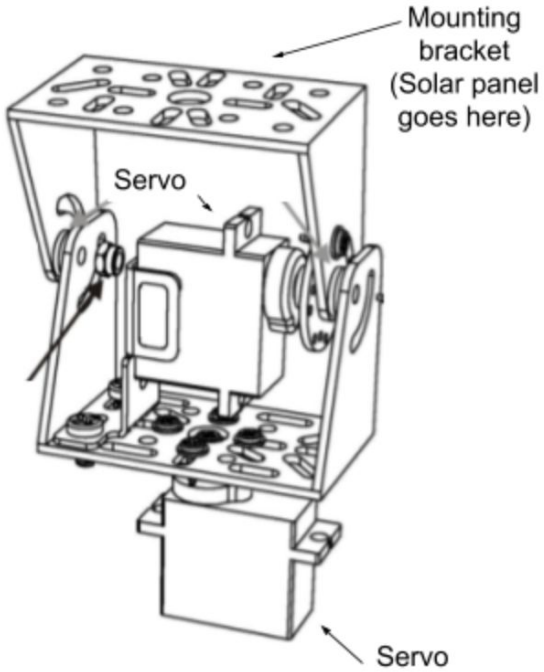
Prototype will be a scale model

Premade frame

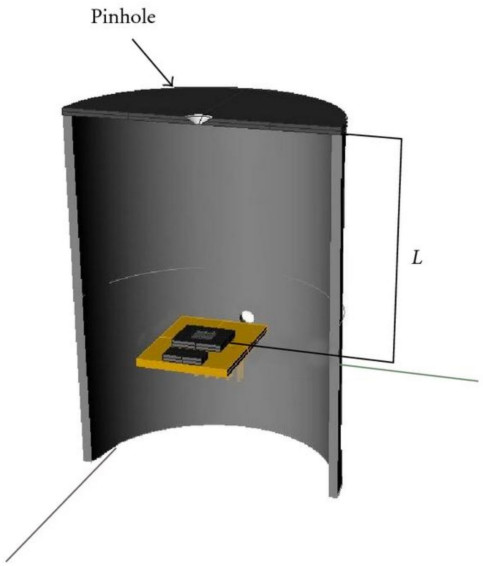
Easily controlled servos

Servo torque: 1.4 km/cm

Next step: Test servos with a test weight



Solar Direction Sensor

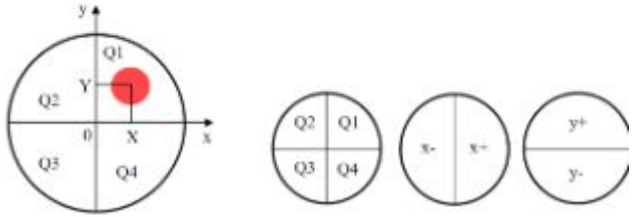


Quadrant Photodiode and Pinhole

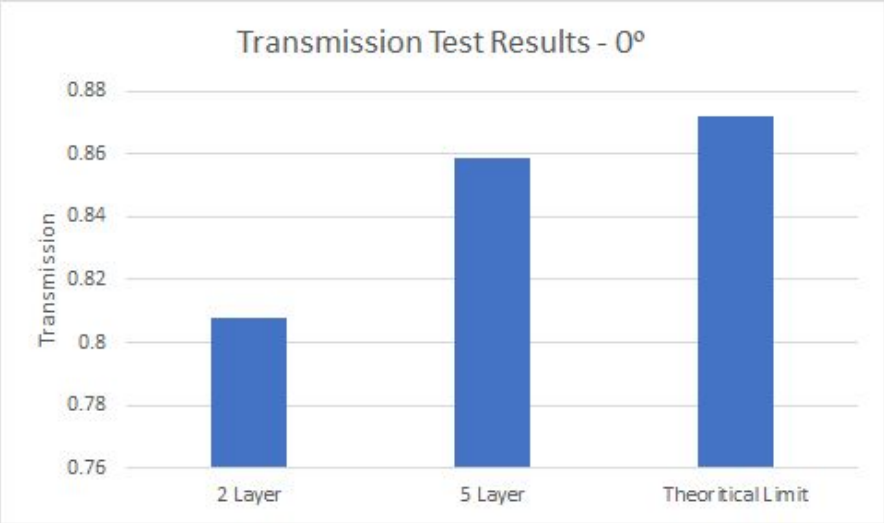
Scanning Mode and Sensing Mode

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

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



Optical Loss Test Results



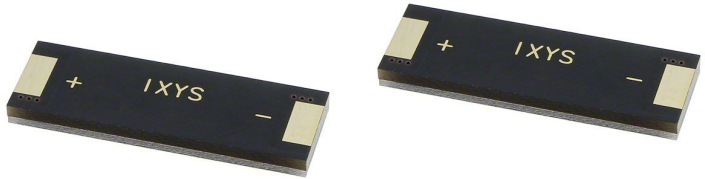
Tests performed with 532 nm laser diode, without the prisms attached

Electrical System and Sensors

- MPPT - PWM
  - DC-DC Buck Circuit
  - Reduce voltage, increase current
- Servos
  - Adafruit high torque, metal gear
- 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

Next Step: Test breadboard version in lab

Solar Cells



Model: IXYS KXOB22-01X8F

Output: **3.4V, 3.8mA**

3 cells connected in parallel to form combined output of **3.4V, 11.4mA**

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

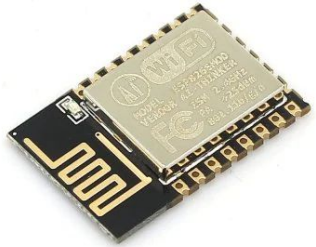
Microcontroller

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**
- Temperature Range (C): -40 to 125
- Operating Voltage Range (V): 1.8 to 5.5

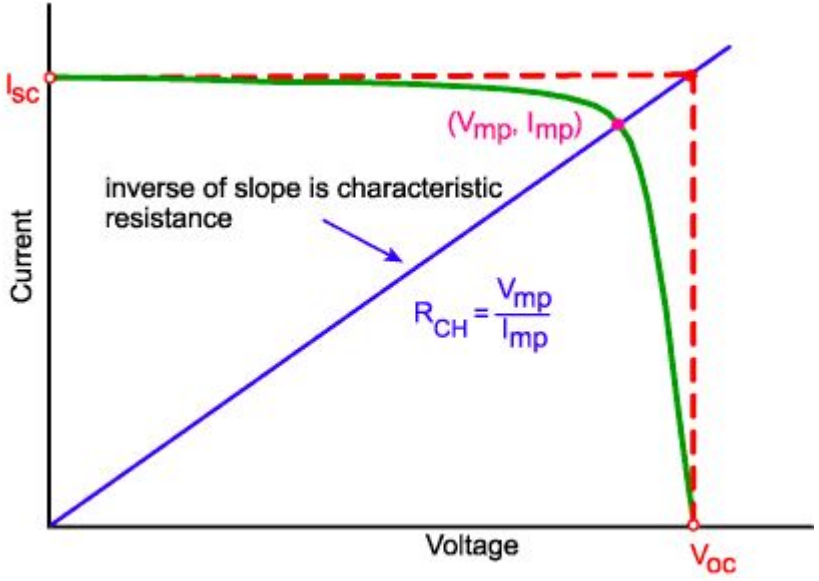
ESP8266-12

- Interfaces: I²C, SDIO, SPI, UART
- Data Transfer Rate: 54Mbps
- Frequency: 2.4GHz

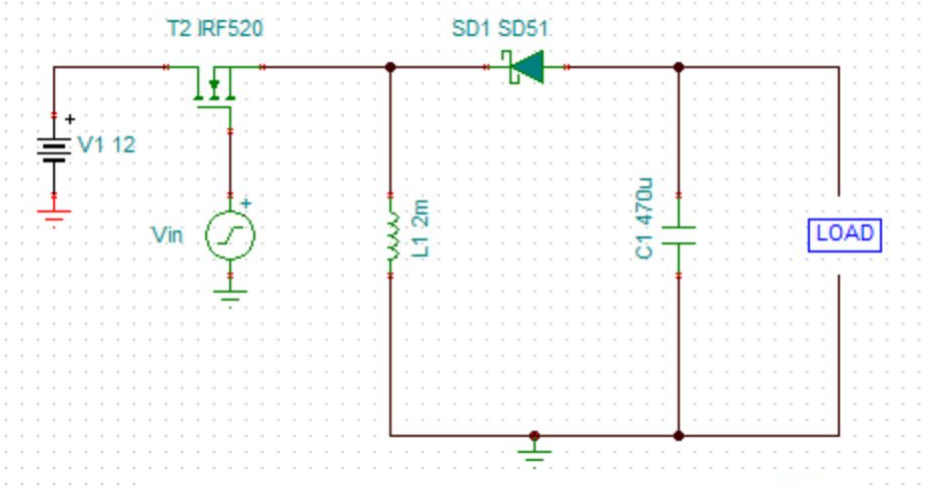


MPPT - PWM Control

Utilizes “Hill-climbing” Algorithm



Buck Converter Circuit



$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{\Delta I_L \times f_S \times V_{IN}}$$

Voltage Regulators

Needed for step-up DC-DC conversion between low-voltage microcontroller and servo motors.

LM2621 Low Input Voltage, Step-Up DC-DC Converter

- 1.2V-14V Input Voltage
- 1.24V-14V Adjustable Output Voltage

Servo Reference	
Speed	4.8V: 60 degrees in 0.2 sec
	6.0V: 60 degrees in 0.16 sec
Torque	4.8V: 8.5 kg-cm / 120 oz-in
	6.0V: 10 kg-cm / 140 oz-in

Temperature Sensors

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

- Resistance @ 0°C: 1 kOhms
- 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
- Tolerances: class F0.3 (B): ± (0.3+0.005*|T/°C|) °C (-50 ... +600 °C)

Battery

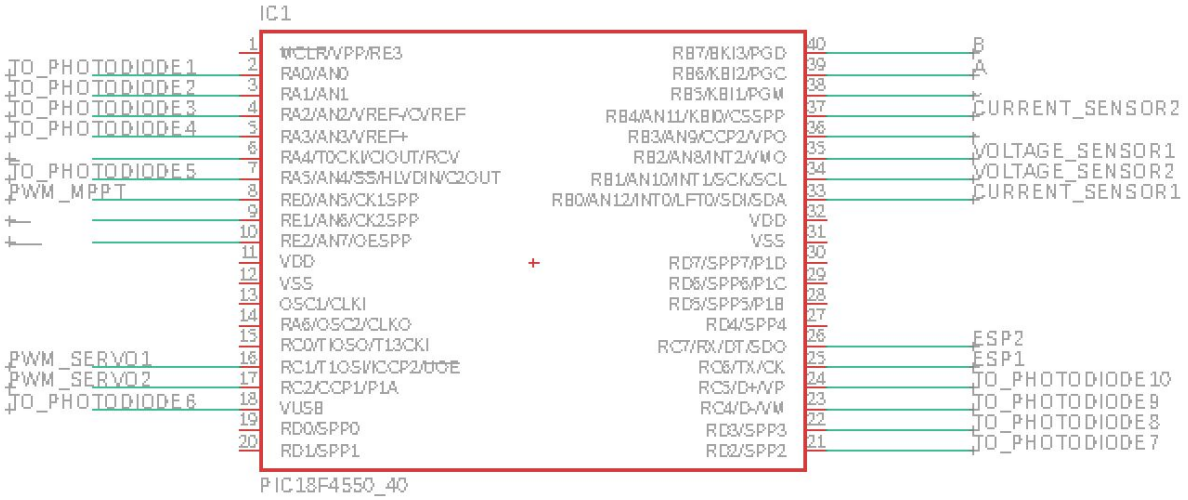
502030 Li-Poly Battery

- Nominal Voltage: 3.7V
- Nominal Capacity: 240mAh
- Operating Temperature: -20~+60C
- Discharged Voltage 3.4V

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

With our excess voltage, we will utilize the buck circuitry to increase current and reduce voltage.

Schematic



Next steps: Test breakout demo in lab before finalizing PCB

Microcontroller Code Flow Diagram

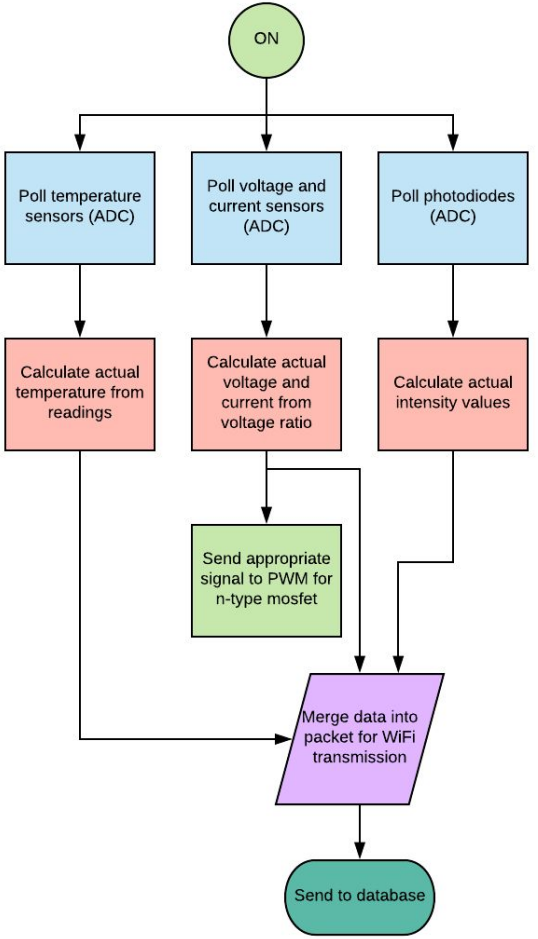
ADC Calculations

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)

Give user control over their device

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

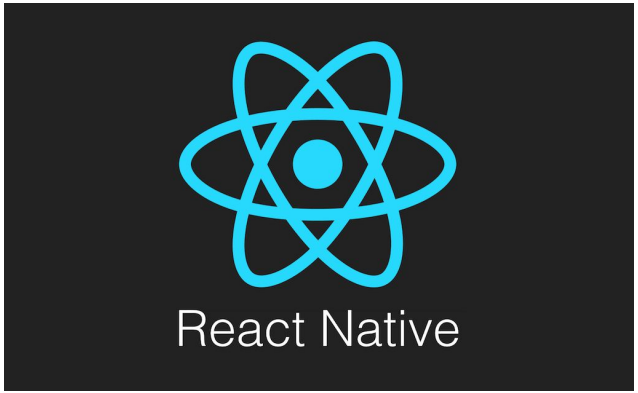
React Native

JavaScript Library

Native Mobile Application

Live Reload

Future: Development Across Platforms



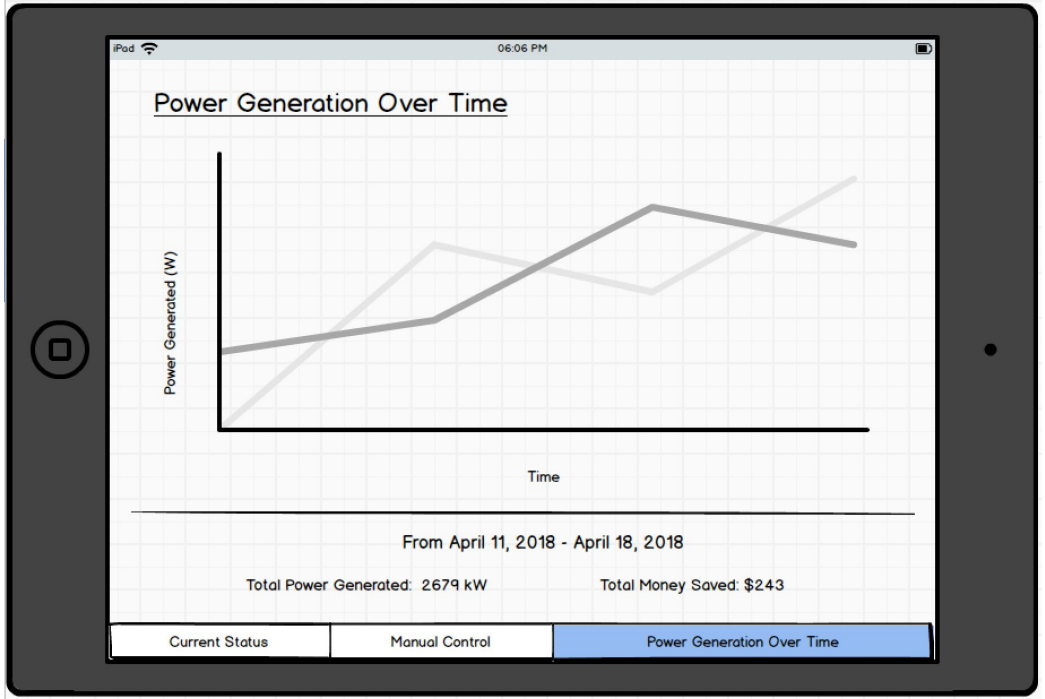
Firebase

Realtime database

Allow integration with Android Applications

Primary Features

- Solar Power Generation
  - Current Status
  - Total Power Generated
  - Power Generated vs. Time

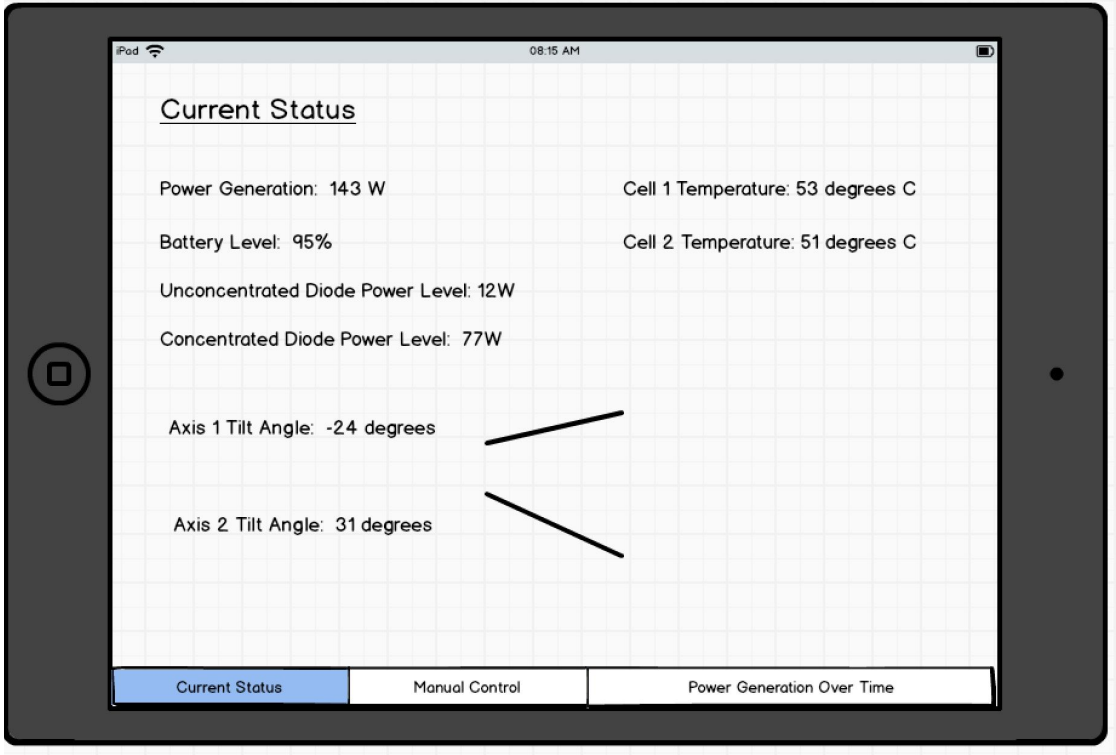


- Battery Charge
  - Current Charge Level

$$battery\ charge = \frac{current\ charge\ level}{capacity\ of\ battery}$$

Secondary Features

- Current Tilt Status
  - Tilt Angle
  - Rotation Angle
- Temperature of Solar Cells
- Cell Efficiency

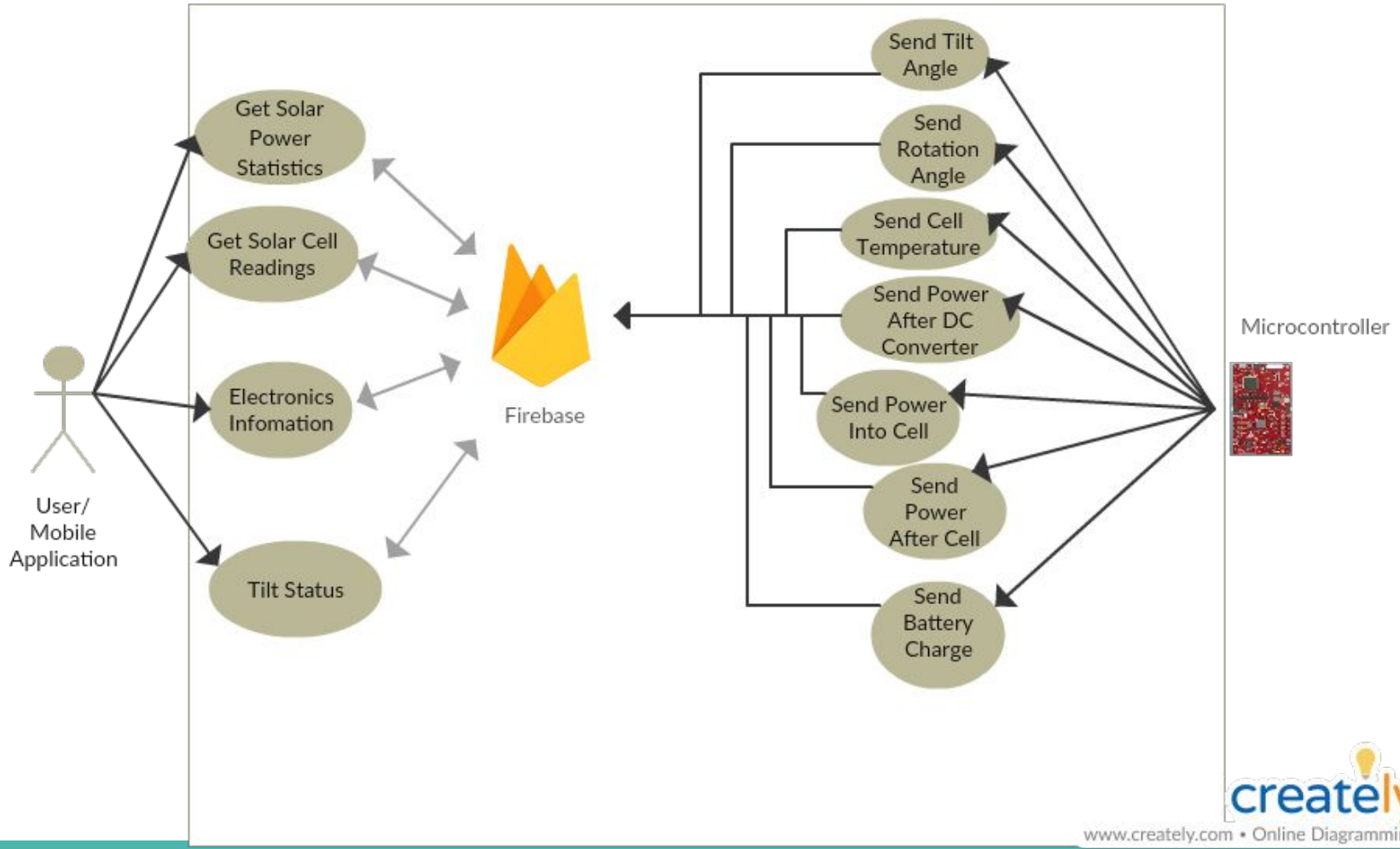


Firebase Data Structure

Data Packet Standard

```
[{
  "timePolled":"DateTime",
  "batteryCharge":"number",
  "powerIntoCell":"number",
  "powerAfterCell":"number",
  "powerAfterDC":"number",
  "tiltAngle":"number",
  "rotationAngle":"number",
  "cellTemperature":"number" },
...
]
```

Use Case Diagram



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	$50

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 nitrate salt	100g	$60
TOTAL		~1,505

Percentage Complete

Concentrator: 30%

Electrical: 20%

Software: 20%

Overall: 20%

Questions?