UV Sensor and Alert System for Skin Protection

Team 6

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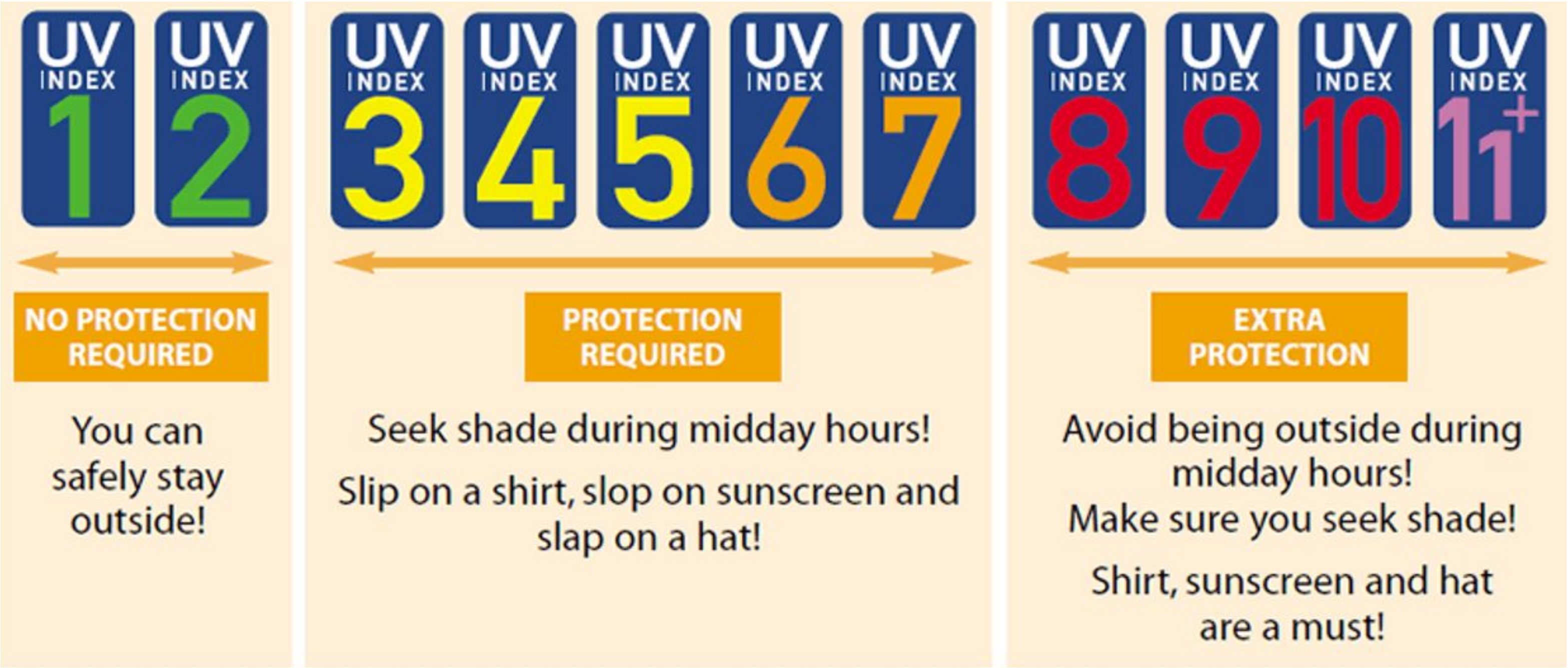
May 2, 2022

Problem of UV Light

- Sunburns
- Skin and Eye Damage
- Premature Skin Aging
- Skin Cancer

Problems of Existing Solutions

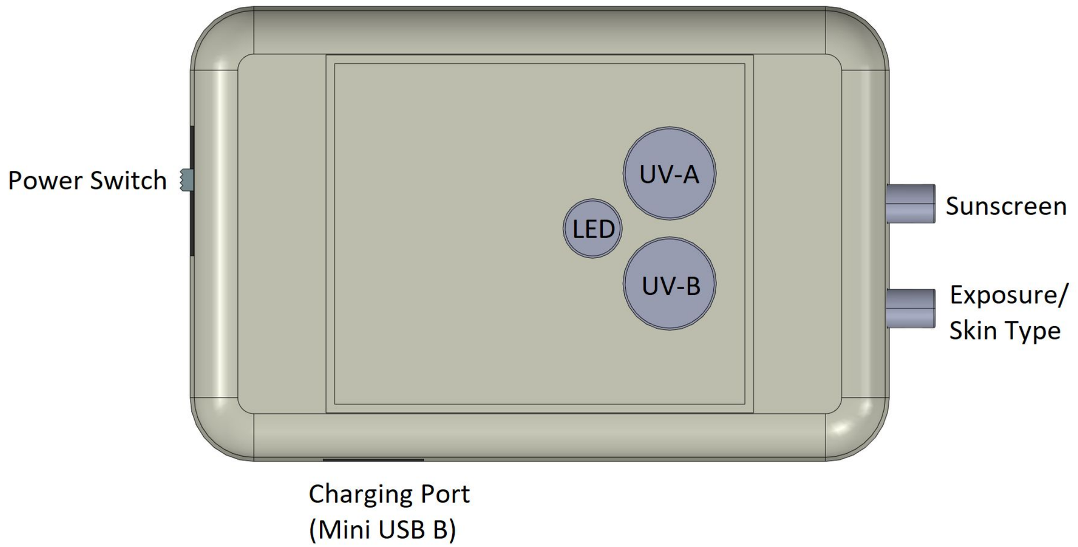
- Lack of Consumer Awareness
- Sunblock
    - Time Management
- Cover
    - Not Always Available



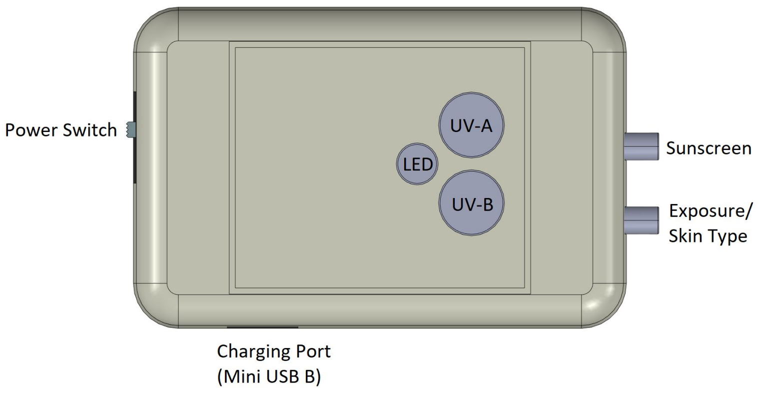
World Health Organization, 2002

High Level Requirements

- Battery lasts 16 hours per charge
- Measure UV exposure intensity (mW/cm^2)
- Timekeep for sunscreen reapplication
- Receive input from user through buttons
- Alert users through an LED and a vibration motor

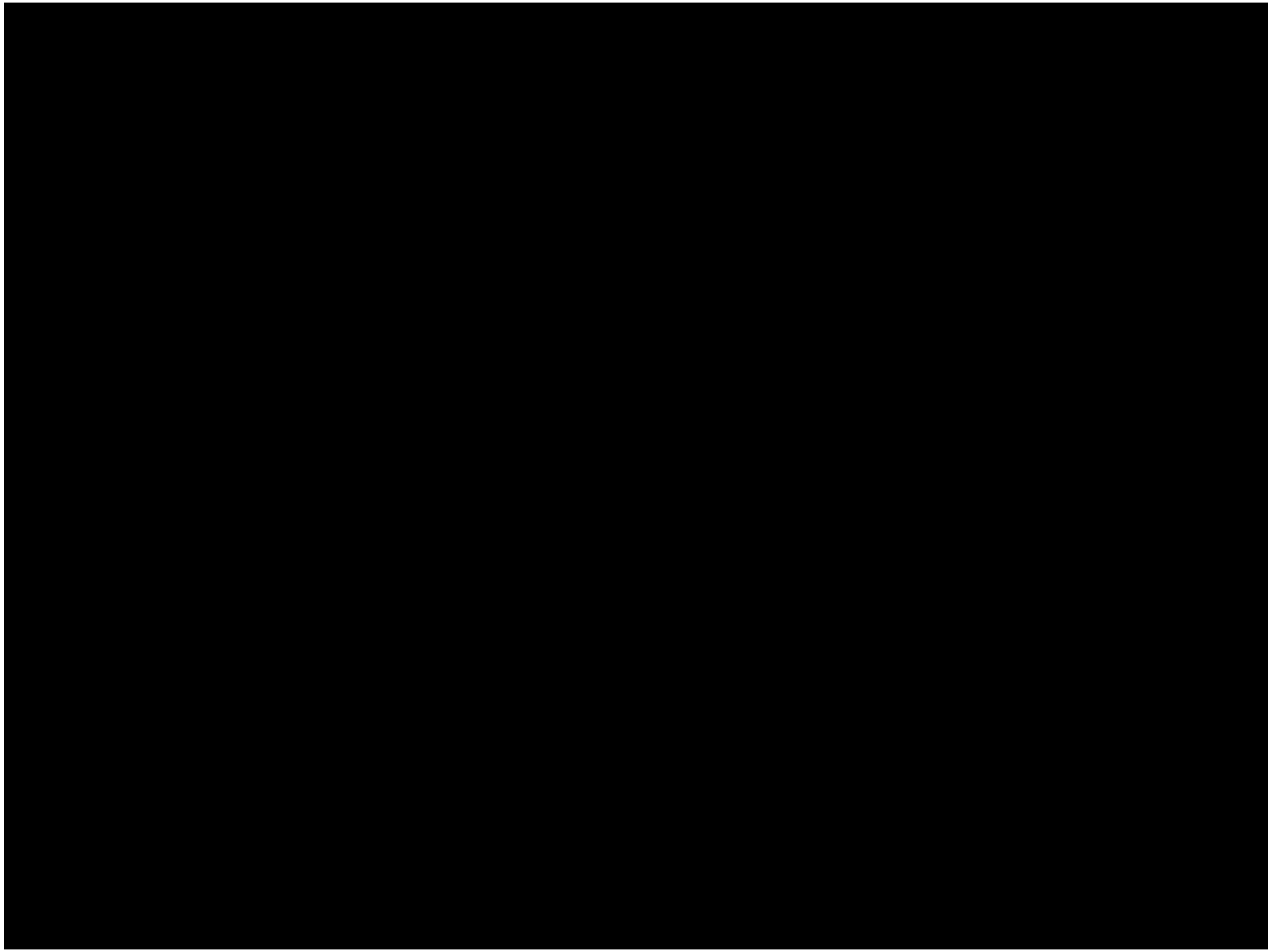


Project Images

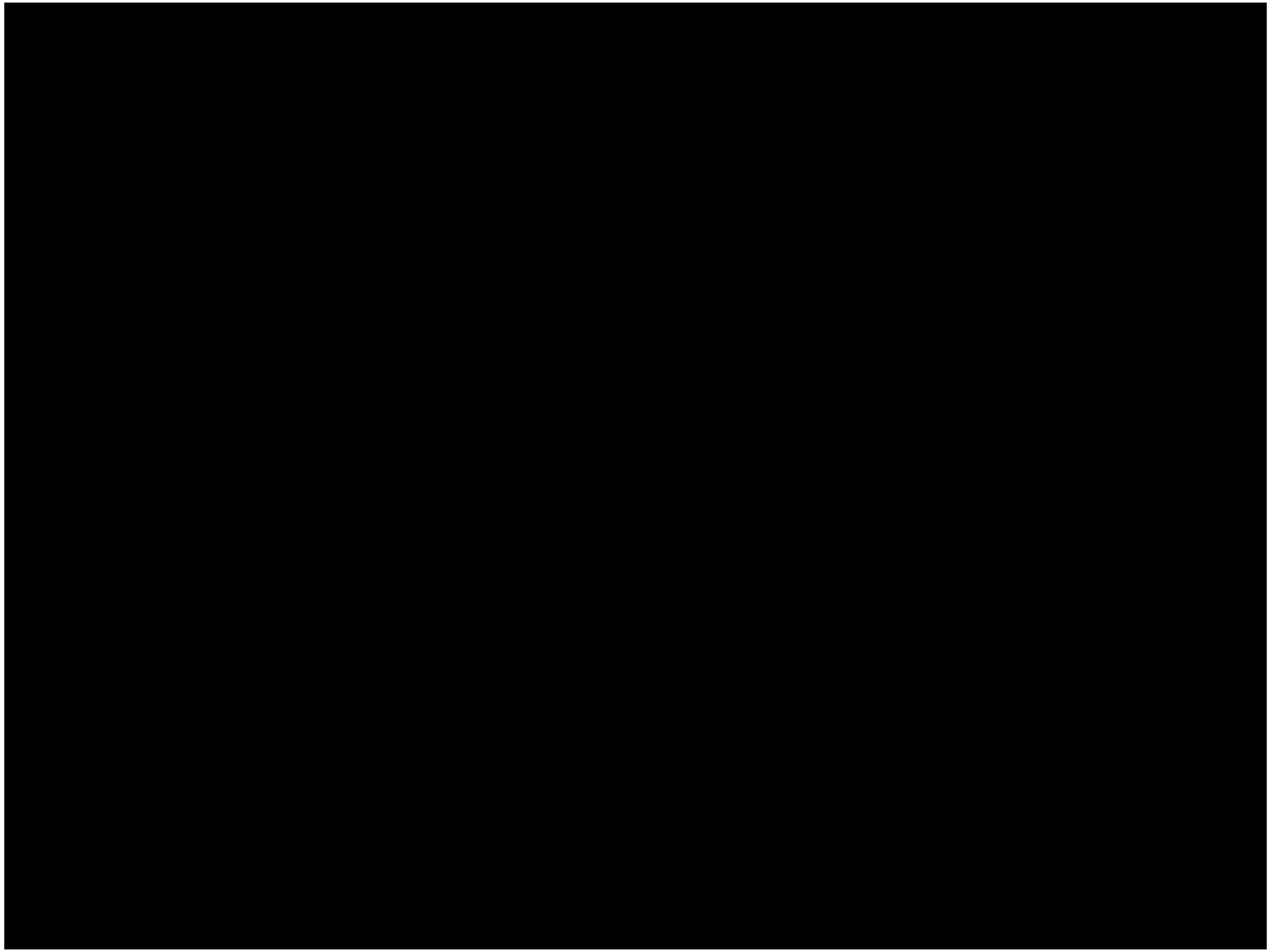


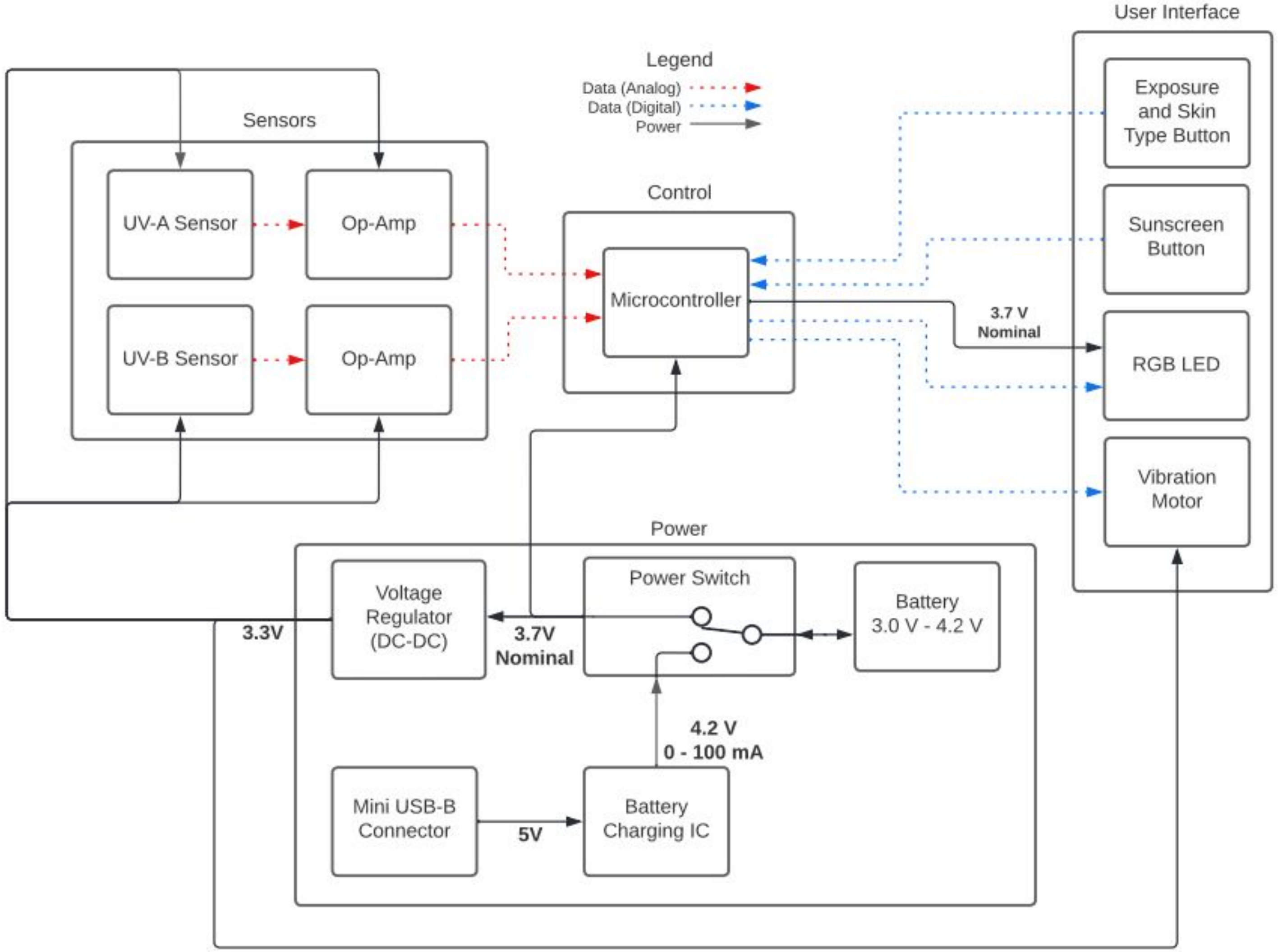
Functionality

Video - Skin Type



Video - UV Index and Time Test





Block Diagram

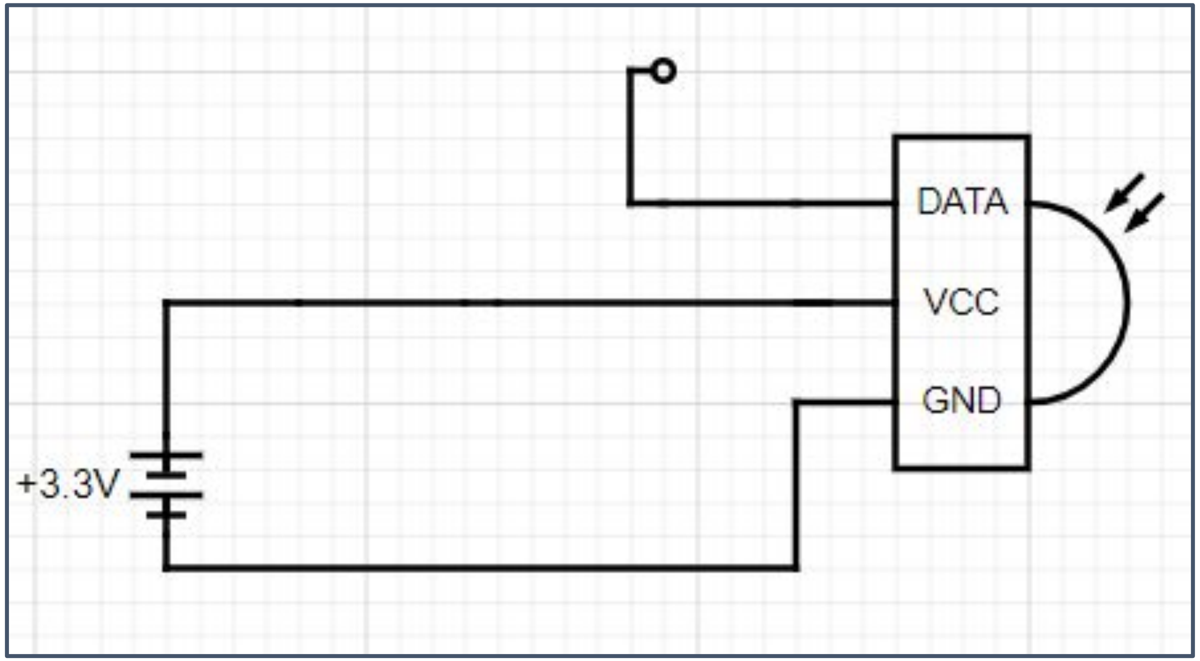
Four Subsystems: Control, Sensors, User Interface, and Power

Sensor Subsystem

Elizabeth Boehning

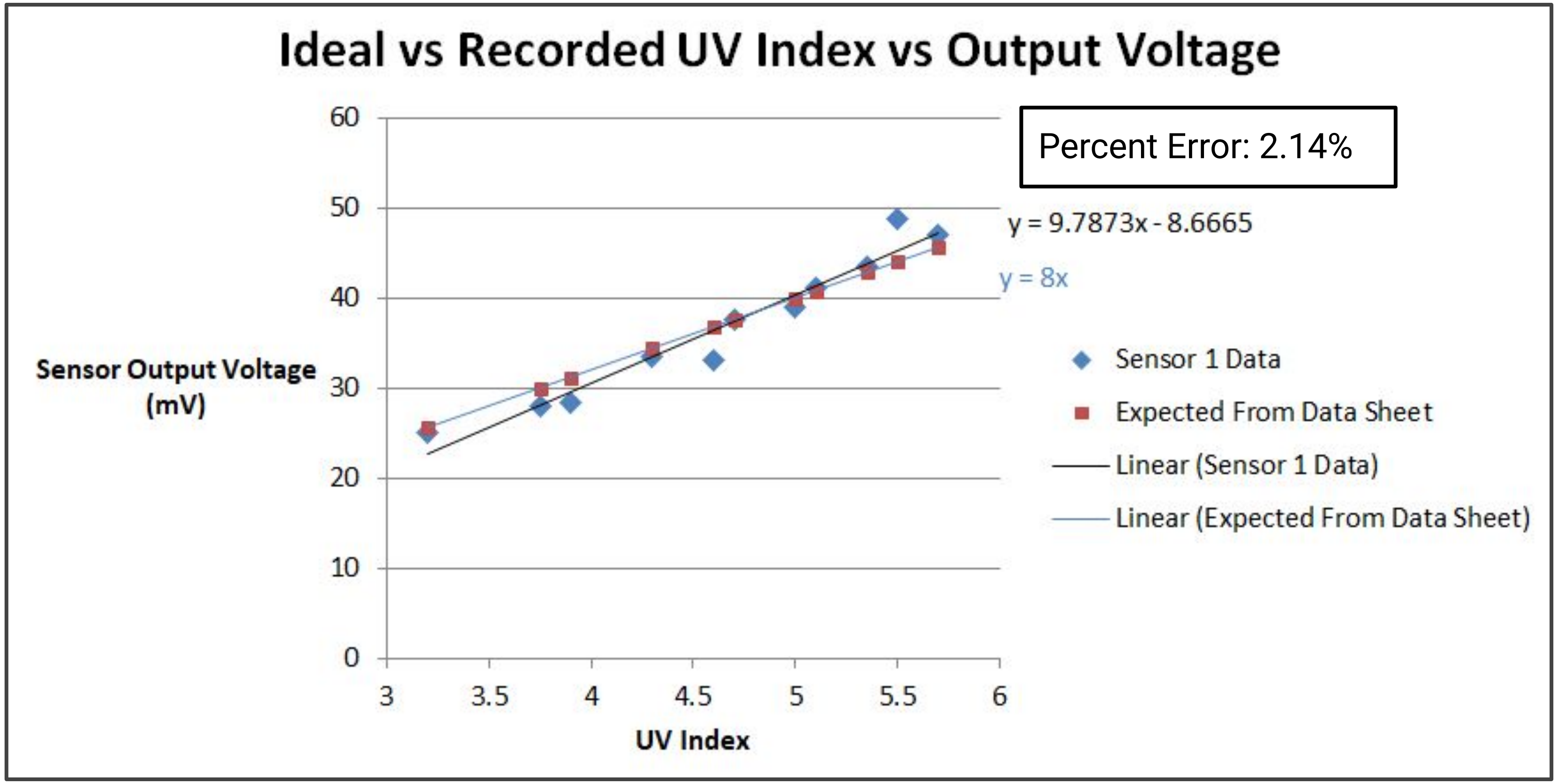
UV Sensors

- Supplied 3.3 V
- output voltage feeds directly to operational amplifier
- UV Index is directly calculated using UV-B Sensor output voltage
  - linear relationship with 8 mV slope
- UV-A Sensor not used for now
  - explained in challenges



Both sensors supplied with 3.3 V

Sensor Sunlight Testing



(Percent error is averaged over all points taken)
Amplification makes this slight error less important

UV-B Sensor

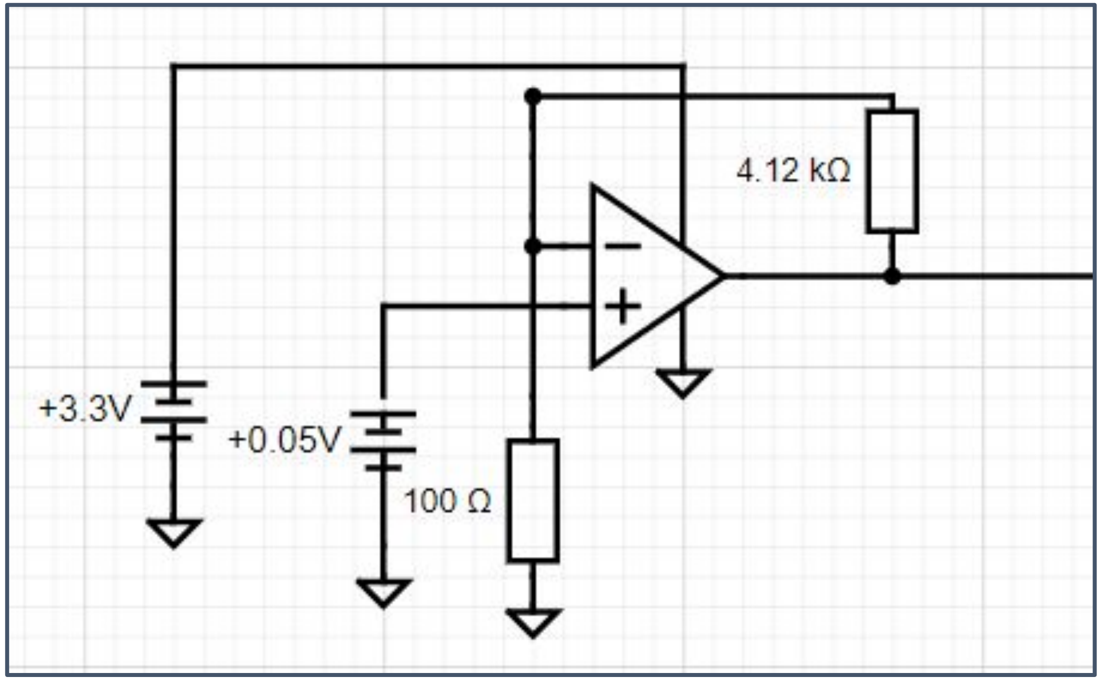
- Measures UV-B response in mV
- using National Weather Service UV Index in Champaign

Verifications

- Measure UV-B intensity within 10% error

UV Sensors - small output voltage in response to sunlight

- Microcontroller ADC is only 10 bits, so resolution is 3.2 mV
- Amplified to make maximum from sensors (80 mV) to maximum voltage (3.3 V)
- Desired gain of 42.2 using 100 ohm and 4.12 k ohm resistors

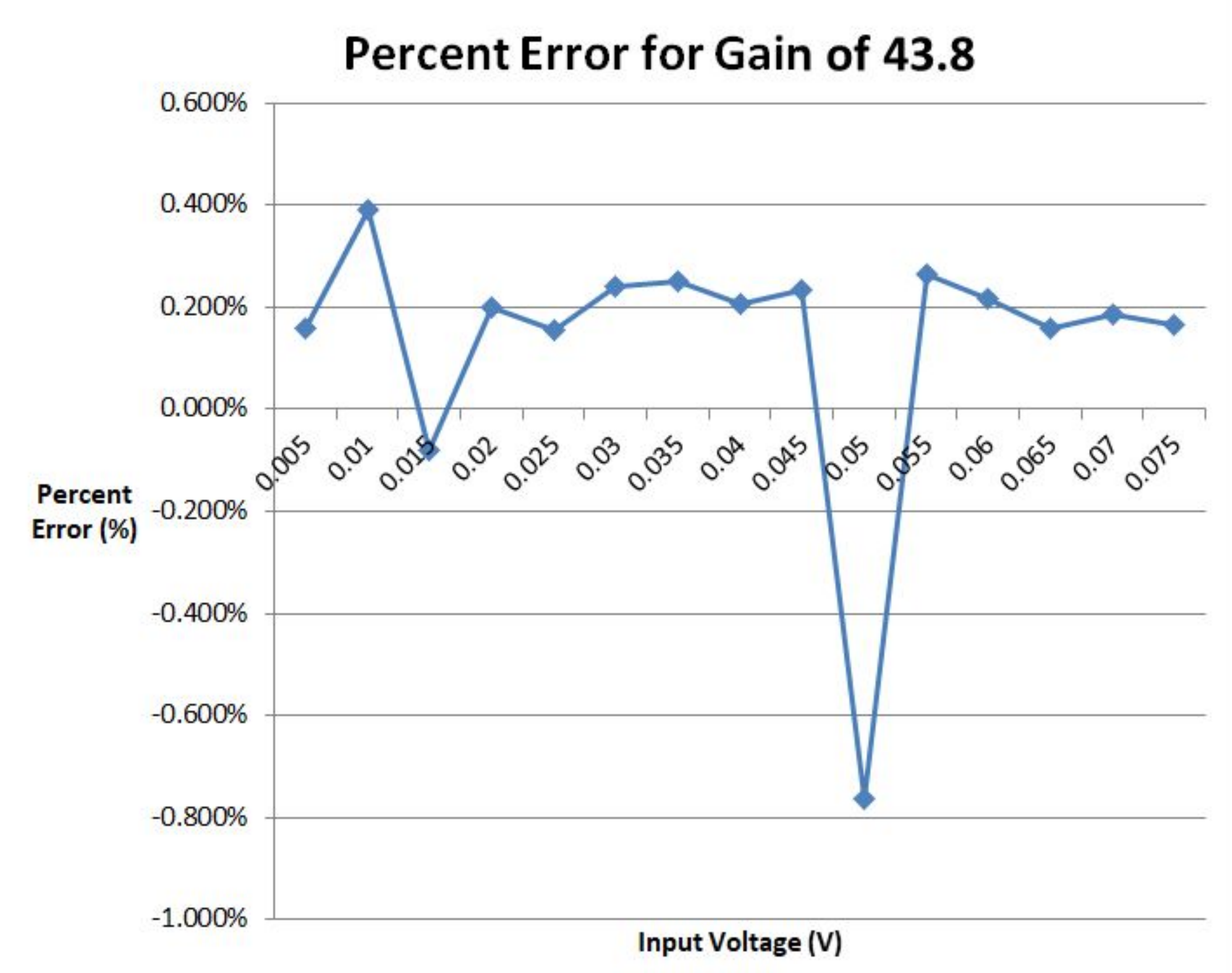


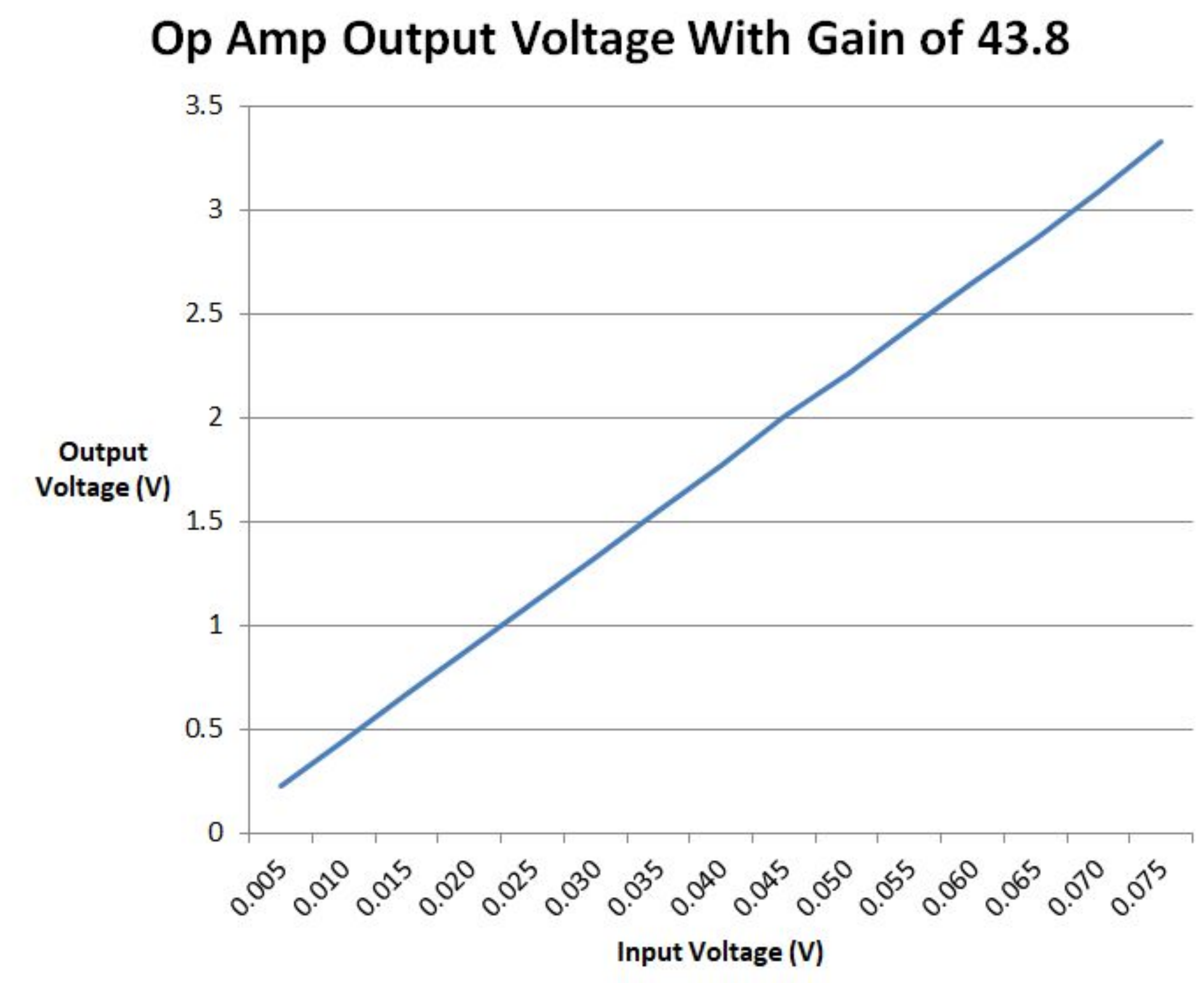
0.05 V represents sensor input voltage

Verifications

- Gain is within 5%

Operation Amplifier Error

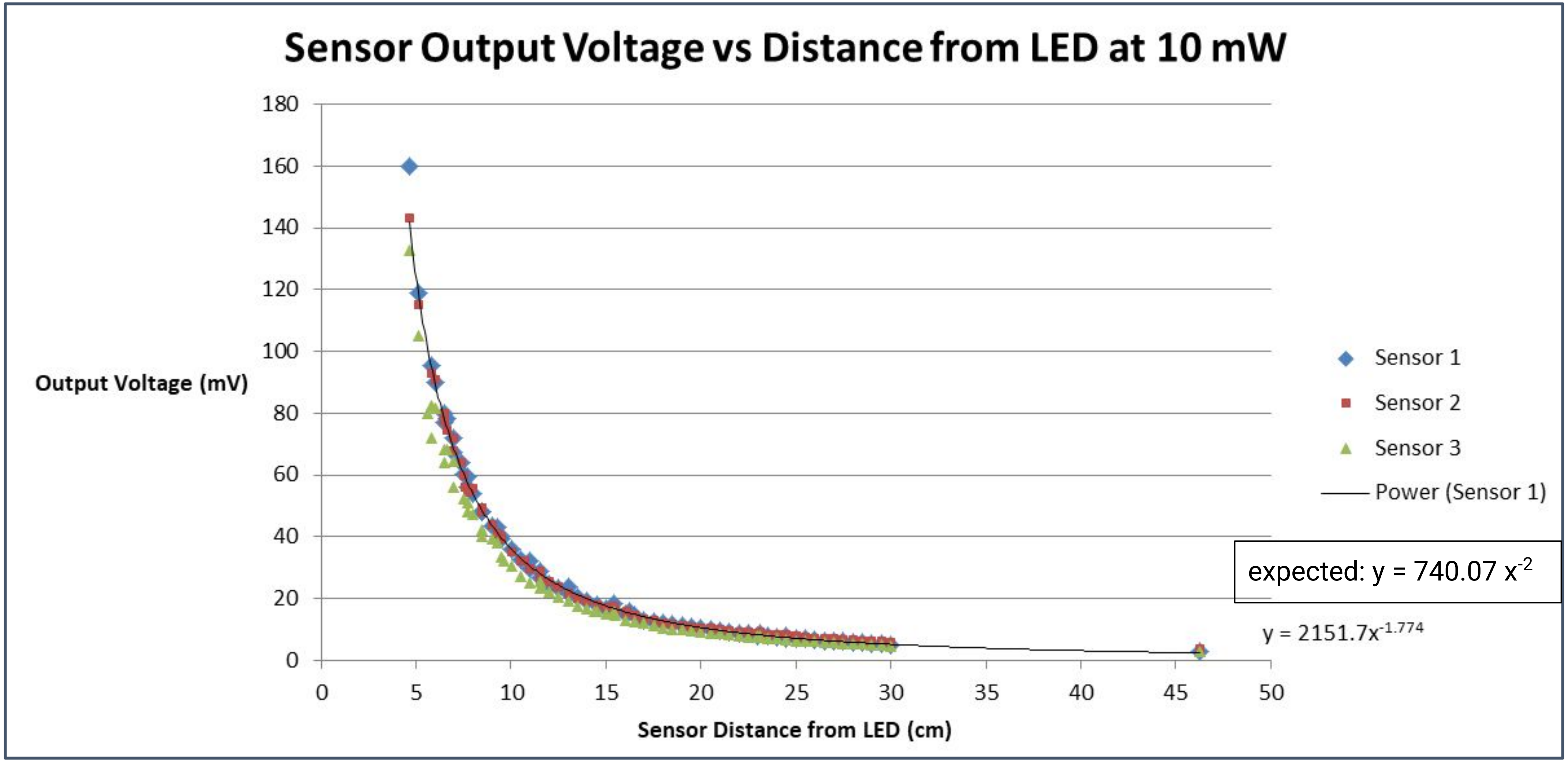




Tested on breakout board with different gain than actual system (less than 5% error still seen)

Challenges

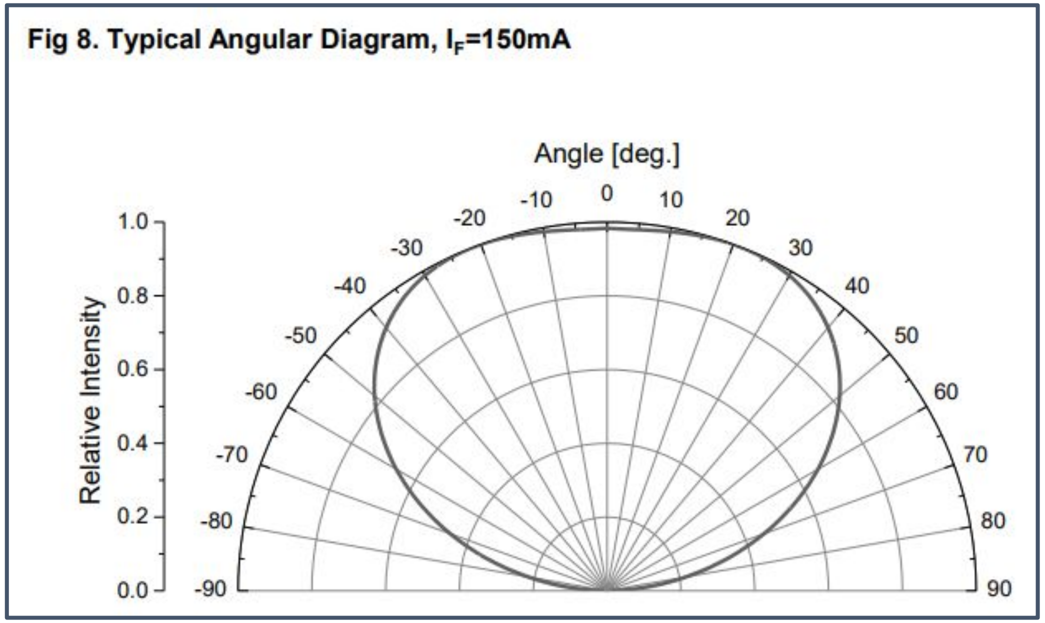
Sensor LED Testing



Taken using UV-B LED at maximum power, 10 mW (corresponding to 150 mA current)

Expected vs Seen Sensor Data

- Based on trendline: $2151.7\ x^{-1.774}$
- Expected: $y = 740.07\ x^{-2}$
  - using data sheet relationship: **output voltage = 0.93 * UV-B Intensity (mW/cm²)**
  - and relationship between output power and intensity of light: **intensity (mW/cm²) = power/(4*π*distance²)**
- Assuming difference is due to non-spherical emission of light
  - no explicit equation in data sheet



UV-B LED Data Sheet, Part Number: CUD8MN1A

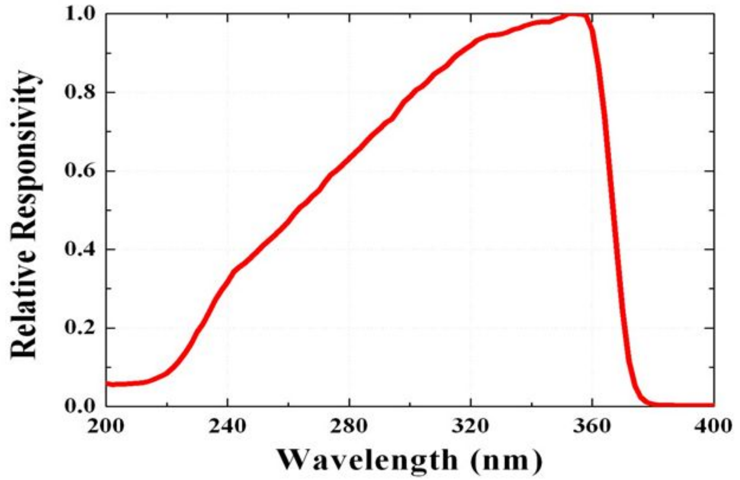
Equation for UV Index

- difficult to relate the UV-A sensor output voltage to each wavelength for the purpose of calculating the UV Index

- paper by Richard McKenzie notes that UV Index can be calculated within 10% using just UV-B intensity

$$UVI = \frac{1}{25\frac{mW}{m^2}} \int_{286.5nm}^{400nm} I(\lambda) \cdot w(\lambda) d\lambda$$

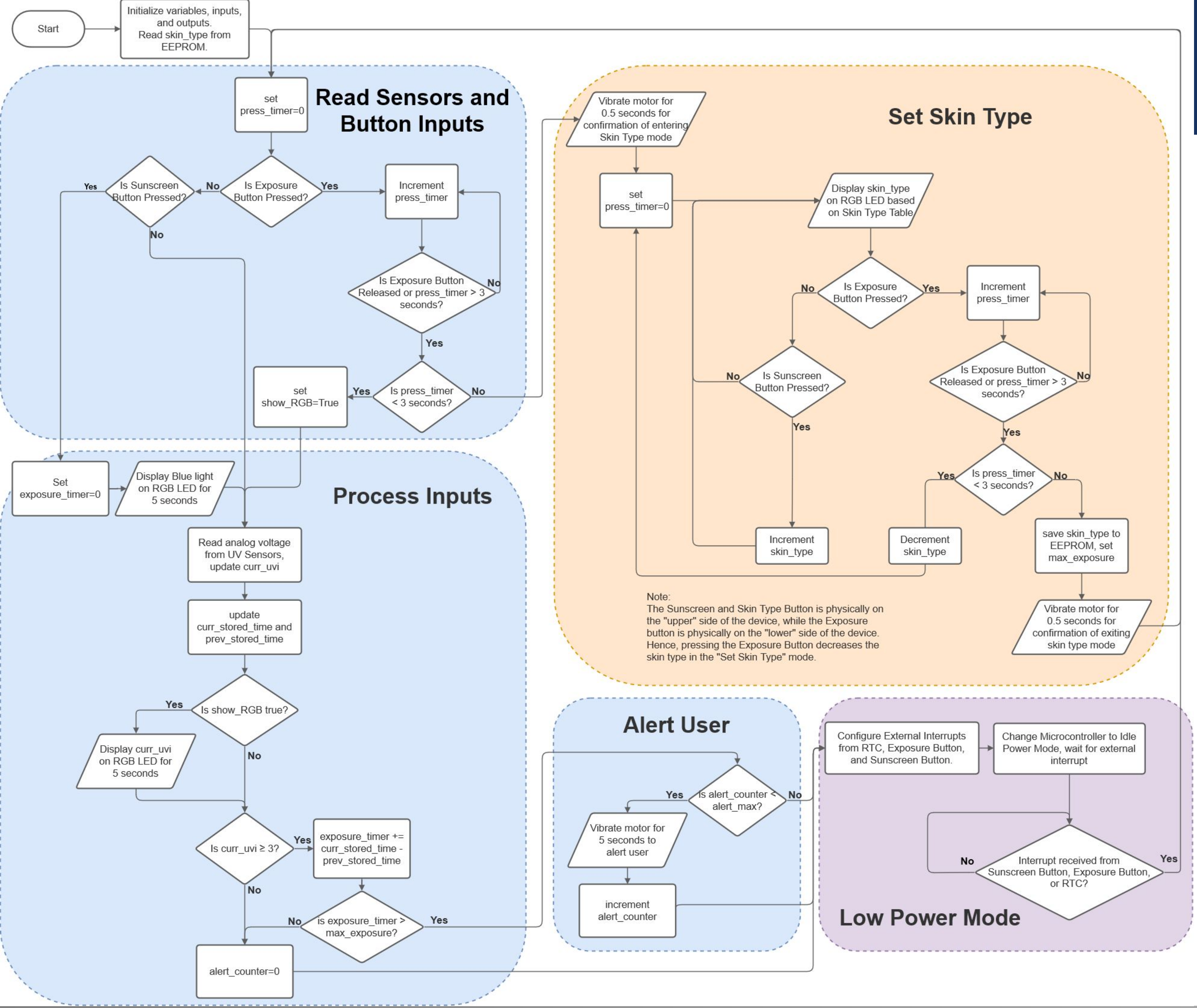
$$w(\lambda) = \begin{cases} 1 & 250 < \lambda \leq 298 \\ 10^{0.094 \cdot (298-\lambda)} & 298 < \lambda \leq 328 \\ 10^{0.015 \cdot (139-\lambda)} & 328 < \lambda \leq 400 \\ 0 & 400 < \lambda \end{cases}$$



UV-A Sensor Data Sheet, Part Number: GUVA-T21GH

Control

Gavin Chan



Software Flowchart - Main Operating Modes

- Active Mode
- Skin Type Mode
- Low Power Mode

Microcontroller

Time Accuracy of Microcontroller

Expected Time	Actual Time	Percent Error
1 minute	1 minute, 1.37 seconds	2.280%
1 minute, 10 seconds	1 minute, 9.85 seconds	0.214%
6 minutes, 10 seconds	6 minutes, 10.08 seconds	0.022%
12 minutes	12 minutes, 0.26 seconds	0.036%
30 minutes	30 minutes, 2.5 seconds	0.140%
3 hours	3 hours, 1.41 seconds	0.013%

Current Draw of Microcontroller

Microcontroller State	Current Draw
Active	4.42 mA
Sleep	55 μA

ATMega4808

- Internal Real-Time Counter (RTC) with External Crystal Oscillator
- Low Sleep Current
- Analog-to-Digital Converter (ADC)

Verifications

- Time accuracy of less than ±5% error
- Sleep current of 1 mA or less
- Capable of 6 mV vs. required 10 mV

Challenges

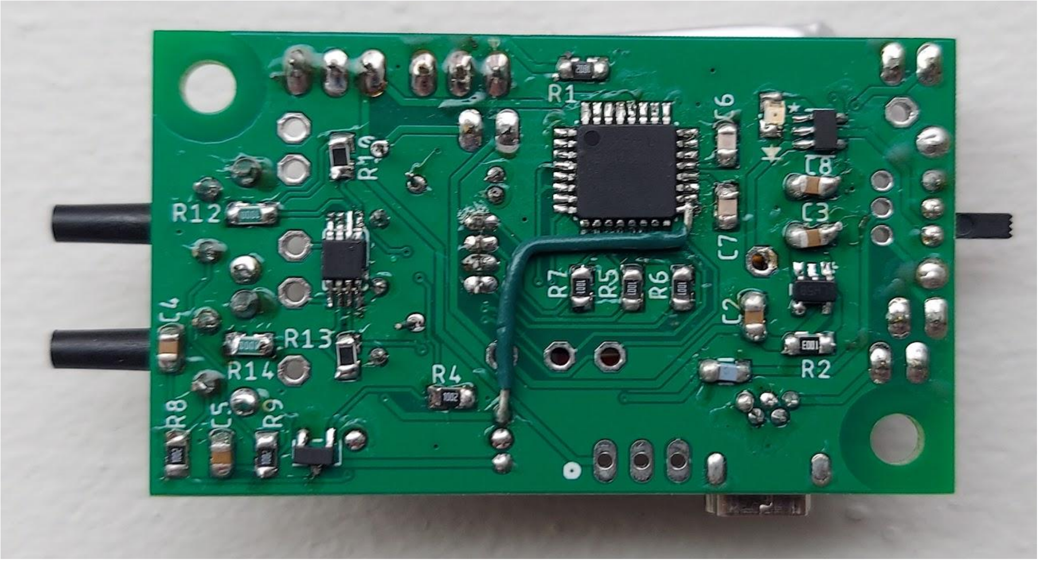
Hardware Challenges

Asynchronous Interrupts

- Only specific pins can wake microcontroller without main clock running

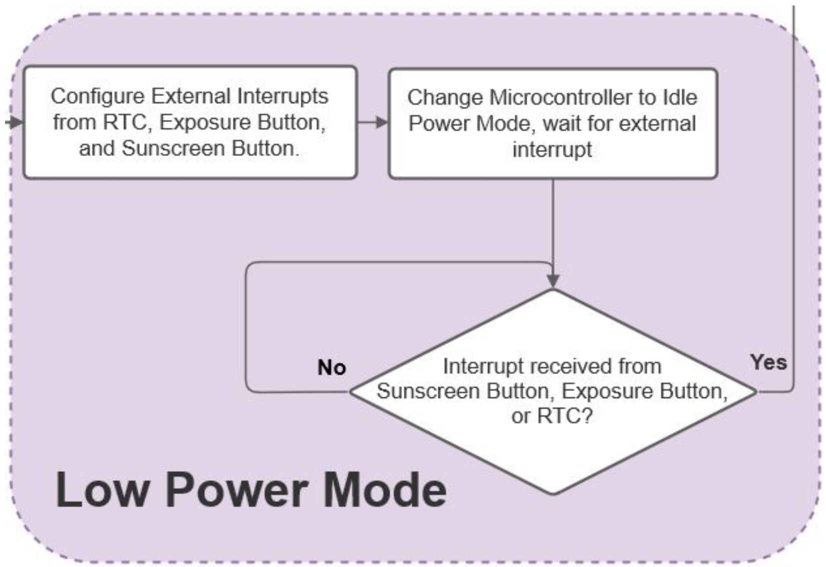
Analog Reference

- Battery voltage changing over time



Back Side of PCB

Software Challenges



RTC Functionality

- Setting internal registers

Accurate Timekeeping from Different Interrupt Sources

- Button Interrupt vs. RTC Interrupt

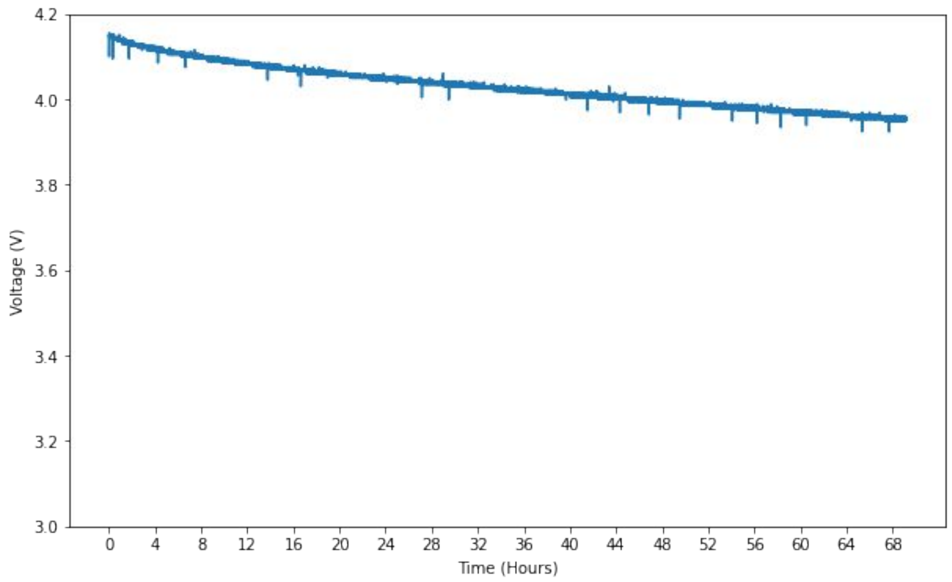
Figure 3-8. RTC.CTRLA – set Prescaler, RUNSTDBY bit, RTCEN bit

Bit	7	6	5	4	3	2	1	0
	RUNSTDBY	PRESCALER[3:0]				CORREN		RTCEN
Access	R/W	R/W	R/W	R/W	R/W	R/W		R/W
Reset	0	0	0	0	0	0		0

Getting Started with RTC, Microchip 2018

Power

Jimmy Huh



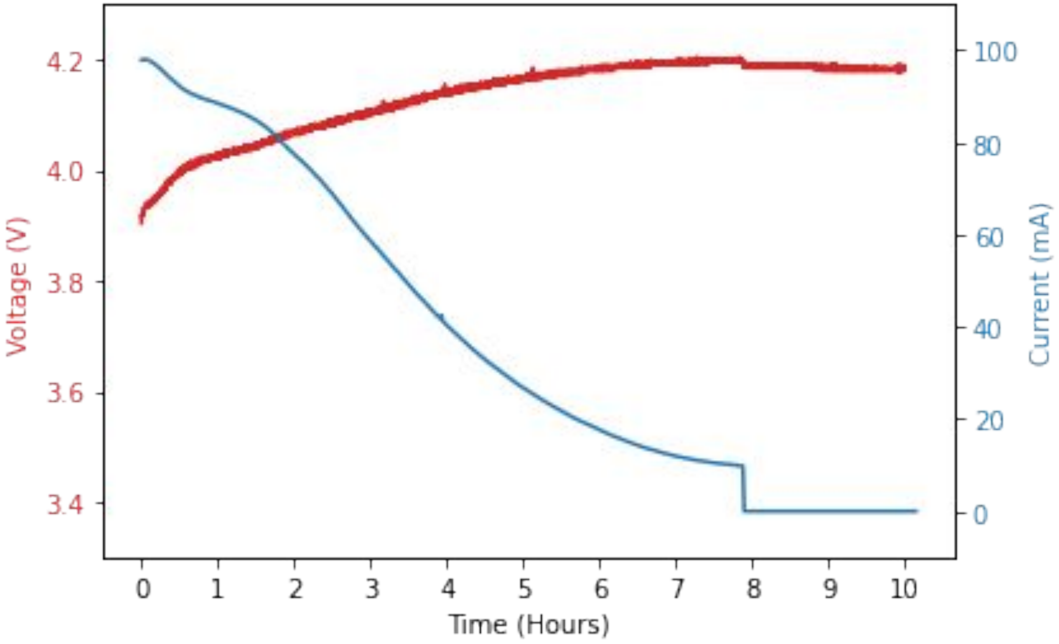
Device Discharging Characteristic
Discharge time = 69 hours, 11 minutes, 4 seconds
Voltage difference = 4.150 V to 3.954 V (0.196 V difference)

Battery

- Energy Dense
- Small Volume
- Rechargable

Verification

- Sustain a peak current of at least 110 mA for at least two seconds



Device Charging Characteristic
Voltage difference = 3.427 V to 4.185 V (0.758 V difference)
Charge time = 7 hours, 54 minutes
Voltage at 4 hours = 4.140 V

Charging Integrated Circuit

- Constant Current initially
- Constant Voltage near full capacity

Verification

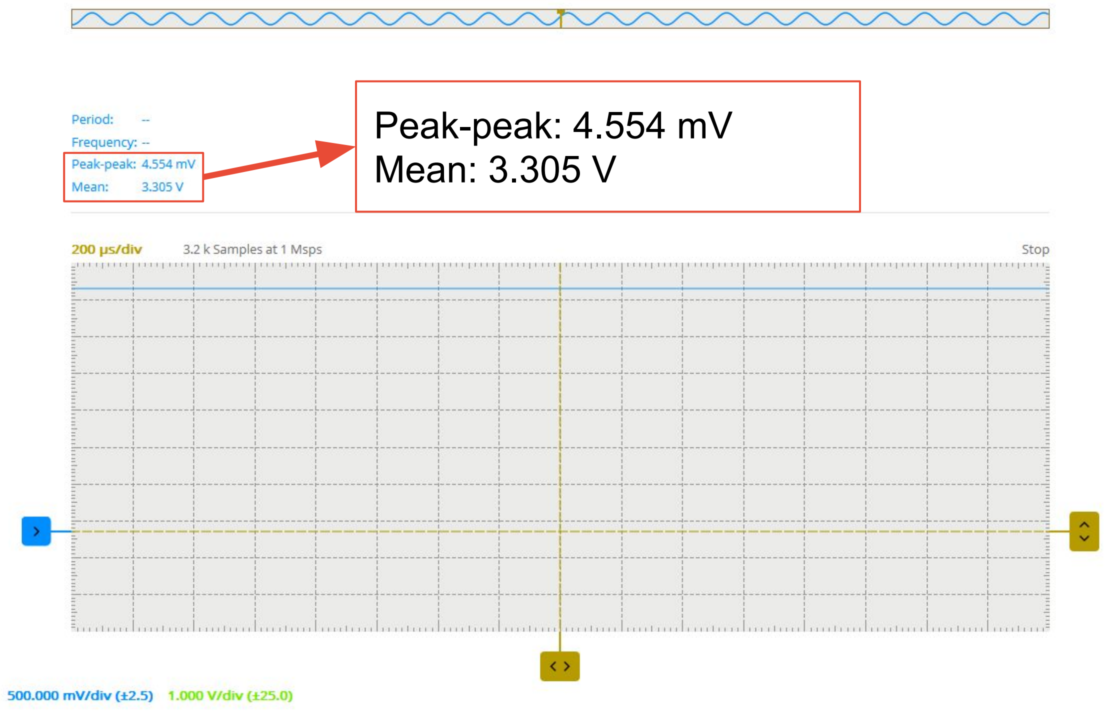
- Output of 4.2 V ±5% during constant voltage mode
- Output at most 200 mA during constant current

LDO Linear Voltage Regulator

- Low noise
- Low circuit complexity/component count
- High operating efficiency
- Fast transient response

Verification

- Constant output voltage of 3.3 V_{DC} ±5%



Linear Voltage Regulator Verification

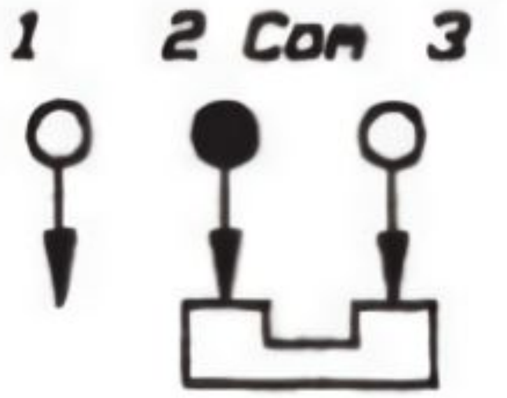
Miscellaneous Components

Power Switch

- Charging and device operation are mutually exclusive
- Prolongs battery health

Fuse

- Limits instantaneous current to 330 mA
- Limits hold current to 150 mA



Switch Schematic

User Interface

Elizabeth Boehning

Buttons

- Sunscreen Button (top)
  - records sunscreen has been applied
    - reflected by blue flash of LED
- Exposure/Skin Type Button (bottom)
  - short press:
    - shows current exposure on RGB LED
  - long press:
    - insert skin type mode, represented by vibration

Verifications

- button presses recorded and debounced
- short vs long press registered

RGB LED and Vibration Motor

- RGB LED
  - shows current UV Index color
  - shows current skin type following Fitzpatrick Scale
- Vibration Motor
  - alerts user of extra sun protection needed
  - represents moving into and out of Skin Type Mode

Verifications

- vibration motor runs when threshold is met
- RGB LED reflects exposure/skin type within one second of button press

Physical Design

Gavin Chan - Jimmy Huh

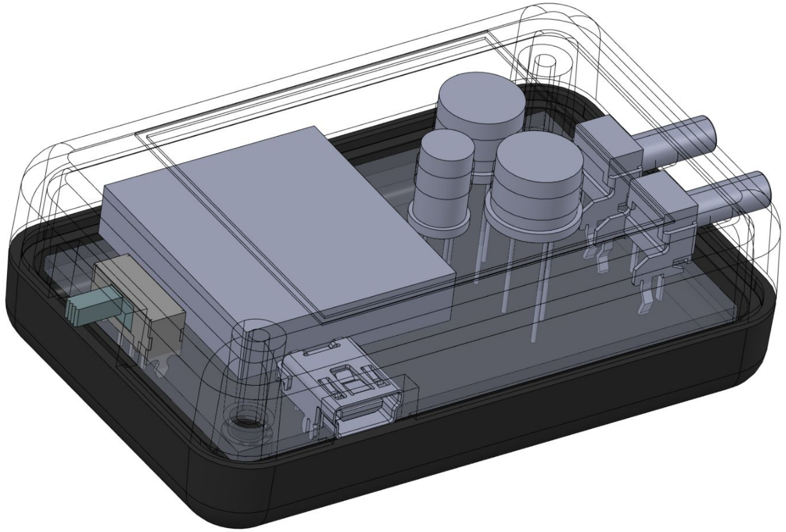
3D Modelling

Challenge

- Compact

Design Process

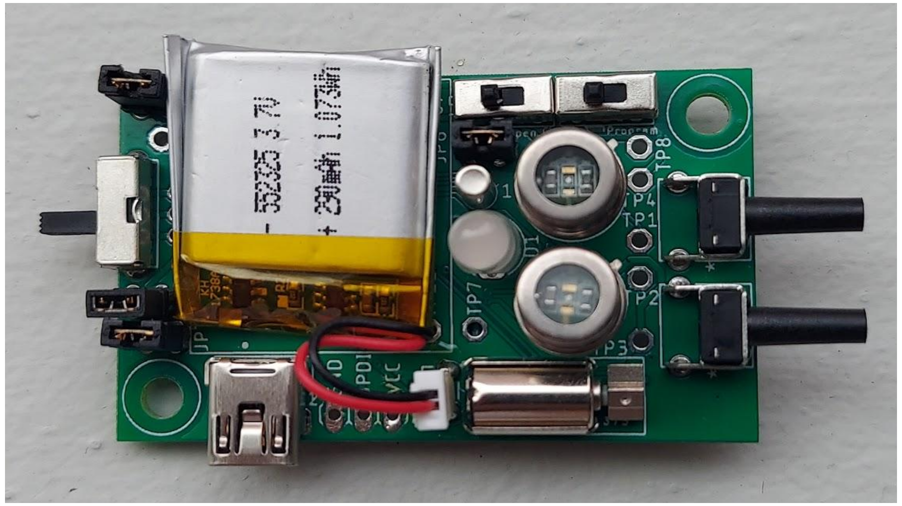
- 3D model of major components
- Mistakes caught
  - Overlapping placements
  - Switch pins piercing battery
- Machine Shop

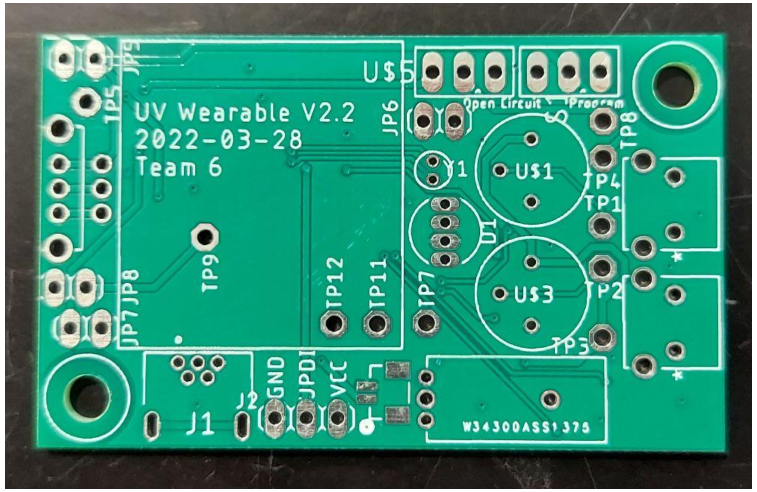


Model of Final Component Placement

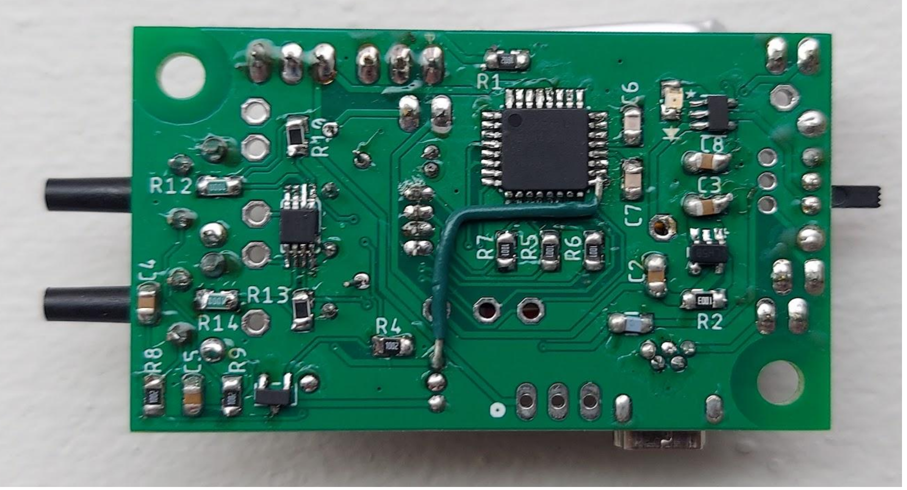
PCB Layout

- 55.5 mm x 33.5 mm
- Cutout for Battery
- Through-hole components on top, right side
- Surface-mount components on back side


Front Side of PCB



Unsoldered PCB


Back Side of PCB

Conclusion

What we learned and what future work can be done

Accomplishments

- Met all high level requirements, far exceeded some
- Small, wearable device
- Rechargable

Redesign Ideas

- Addition of phone app
- LCD display
- Time component

Recommendations for Further Work

- UV-A Intensity in UV Index
  - increased accuracy of UV Index
- Vitamin D tracking
  - UV-A exposure can be used to monitor Vitamin D levels
- Waterproof
  - Available to be worn in the water

Questions?

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