UV Sensor and Alert System for Skin Protection

Team 6

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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
Functionality

Exposure Button

Sunscreen Button
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
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

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

Verifications

- Gain is within 5%
Tested on breakout board with different gain than actual system (less than 5% error still seen)
Challenges
Sensor LED Testing

Sensor Output Voltage vs Distance from LED at 10 mW

Output Voltage (mV)

Sensor Distance from LED (cm)

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

expected: \( y = 740.07 x^{-2} \)

\( y = 2151.7x^{1.774} \)
Expected vs Seen Sensor Data

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

Gavin Chan
Software Flowchart - Main Operating Modes

- Active Mode
- Skin Type Mode
- Low Power Mode
Microcontroller

Time Accuracy of Microcontroller

<table>
<thead>
<tr>
<th>Expected Time</th>
<th>Actual Time</th>
<th>Percent Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 minute</td>
<td>1 minute, 1.37 seconds</td>
<td>2.280%</td>
</tr>
<tr>
<td>1 minute, 10 seconds</td>
<td>1 minute, 9.85 seconds</td>
<td>0.214%</td>
</tr>
<tr>
<td>6 minutes, 10 seconds</td>
<td>6 minutes, 10.08 seconds</td>
<td>0.022%</td>
</tr>
<tr>
<td>12 minutes</td>
<td>12 minutes, 0.26 seconds</td>
<td>0.036%</td>
</tr>
<tr>
<td>30 minutes</td>
<td>30 minutes, 2.5 seconds</td>
<td>0.140%</td>
</tr>
<tr>
<td>3 hours</td>
<td>3 hours, 1.41 seconds</td>
<td>0.013%</td>
</tr>
</tbody>
</table>

Current Draw of Microcontroller

<table>
<thead>
<tr>
<th>Microcontroller State</th>
<th>Current Draw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>4.42 mA</td>
</tr>
<tr>
<td>Sleep</td>
<td>55 μA</td>
</tr>
</tbody>
</table>

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
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

Getting Started with RTC, Microchip 2018
Power

Jimmy Huh
Battery

- Energy Dense
- Small Volume
- Rechargable

Verification

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

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

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
LDO Linear Voltage Regulator

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

Verification

- Constant output voltage of $3.3 \text{ V}_{\text{DC}} \pm 5\%$
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
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
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
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?