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ECE 198

Design Document

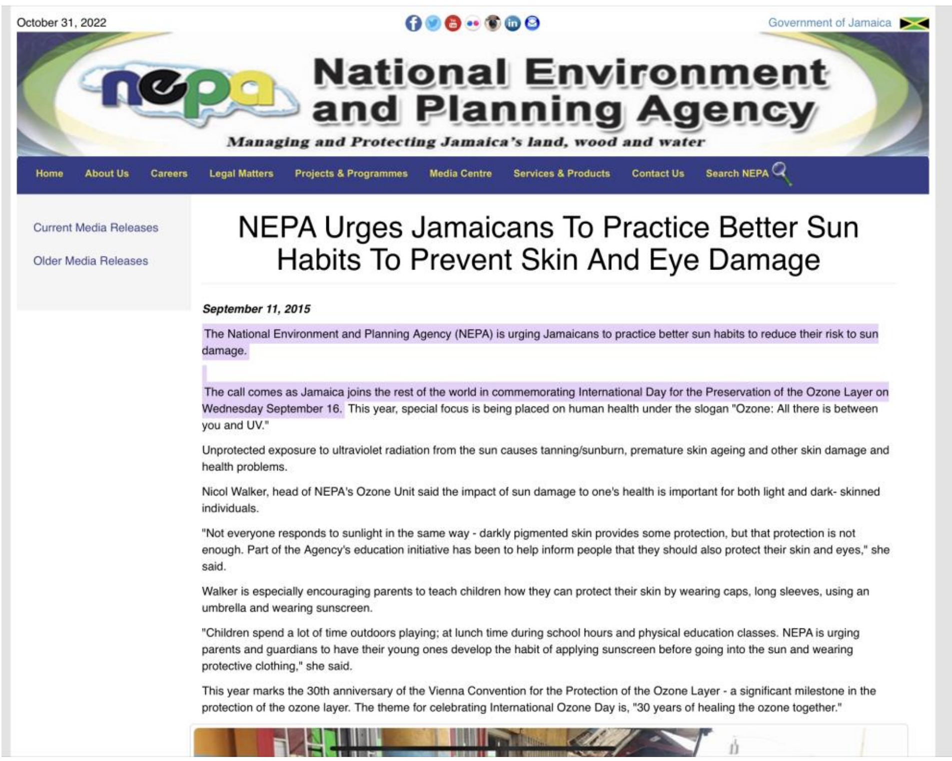
Needs Assessment

Client/Customer Definition

The Customer for which the product is being built is an Electrical Engineer from Kingston Jamaica, who spends a lot of time outside the in the sun when on jobsites, for example inspecting solar panel installations done by his company. Jamaica is known for its tropical climate; however, the temperatures can get exceedingly high, especially in the summer months. This puts him as well as his employees at a high risk of overexposure to UV radiation, which can have multiple adverse health effects. The UV protection device designed is intended to reduce the possibility of these health effects by measuring the UV radiation index and giving a recommendation for the level of protection needed to safely work in these environments. The age of the customer as well as his employees also puts them at an increased risk of these health effects, thus it is vital that this device can give a good idea of the protection level needed in order to work safely. The customer also suggested that the total cost of the device should not exceed 100 CAD, making it accessible to a wider demographic to ensure the safety of all those who work in the sun.

Sources Cited

Walker, N. (2015, September 11). *NEPA urges Jamaicans to practice better sun habits to prevent skin and eye damage*. NEPA. Retrieved October 31, 2022, from https://websitearchive2020.nepa.gov.jm/new/media_centre/press_releases/releases/2015/PR20150911-nepa_urges_jamaicans_to_practice_better_sun_habits.php



October 31, 2022

Government of Jamaica

National Environment and Planning Agency

Managing and Protecting Jamaica's land, wood and water

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NEPA Urges Jamaicans To Practice Better Sun Habits To Prevent Skin And Eye Damage

September 11, 2015

The National Environment and Planning Agency (NEPA) is urging Jamaicans to practice better sun habits to reduce their risk to sun damage.

The call comes as Jamaica joins the rest of the world in commemorating International Day for the Preservation of the Ozone Layer on Wednesday September 16. This year, special focus is being placed on human health under the slogan "Ozone: All there is between you and UV."

Unprotected exposure to ultraviolet radiation from the sun causes tanning/sunburn, premature skin ageing and other skin damage and health problems.

Nicol Walker, head of NEPA's Ozone Unit said the impact of sun damage to one's health is important for both light and dark- skinned individuals.

"Not everyone responds to sunlight in the same way - darkly pigmented skin provides some protection, but that protection is not enough. Part of the Agency's education initiative has been to help inform people that they should also protect their skin and eyes," she said.

Walker is especially encouraging parents to teach children how they can protect their skin by wearing caps, long sleeves, using an umbrella and wearing sunscreen.

"Children spend a lot of time outdoors playing; at lunch time during school hours and physical education classes. NEPA is urging parents and guardians to have their young ones develop the habit of applying sunscreen before going into the sun and wearing protective clothing," she said.

This year marks the 30th anniversary of the Vienna Convention for the Protection of the Ozone Layer - a significant milestone in the protection of the ozone layer. The theme for celebrating International Ozone Day is, "30 years of healing the ozone together."

websitearchive2020.nepa.gov.jm

umbrella and wearing sunscreen.

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Nicol Walker, head of the National Environment and Planning Agency's (NEPA) Ozone Unit engages a student about what he can do to protect himself from the sun's UV rays. She also presented tokens that included drawstring bags, exercise books, sun visors, and sunscreen."

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National Environment and Planning Agency (NEPA)
10 & 11 Caledonia Avenue, Kingston 5

Last modified: January 16, 2021 | Sitemap

Rostant, H. (2001, July). *Enjoy the fun, beware the sun*. Caribbean Beat Magazine. Retrieved October 31, 2022, from https://www.caribbean-beat.com/issue-50/enjoy-the-fun-beware-the-sun#axzz7ifx9yx3c

LIFESTYLE ● SCIENCE

Enjoy the fun, beware the sun

Heidi Rostant reminds readers to protect their skin from the harmful rays of the sun. Use sunscreen and tan wisely

BY HEIDI ROSTANT | ISSUE 50 (JULY/AUGUST 2003)

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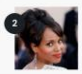
2 
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Sunburn

Ultraviolet rays are the invisible “burning” rays that cause sunburn and even cancer. There are three types of UV rays:

• UV-A: Besides sunburn, these rays contribute to premature aging, wrinkling and skin cancer.

• UV-B: These are stronger than UV-A rays and contribute to premature aging, cataracts and skin cancer, and can even alter your immune system. They are felt mostly in the summer months, at higher altitudes, and by people who live or vacation in countries closest to the equator.

• UV-C: The strongest and most dangerous of UV rays. Luckily, they are normally filtered by the ozone layer and never reach Earth.

The amount of UV you are exposed to changes with the time of day, seasons, weather and location. In the Caribbean, the time of day affects us most, since UV is greatest when the sun is highest in the sky (between the hours of 10 a.m. and 2 p.m.). It is important to know that the longer we are exposed to the sun, even during the course of our daily activities, the more likely we are of being sunburned.

Sun Damage

The sun is responsible for at least 90% of the appearance of skin aging. It is the most destructive as well as the most preventable of the causes of wrinkles. It causes the skin to take on a leathery texture, with permanently etched deep creases. No one wants their face to look and feel like a thickened hide! You can prevent these deep sun-induced wrinkles by applying a high-protection sunscreen and by always wearing a hat.

How Sunscreens Work

Sunscreens either block or absorb ultraviolet light. All sunscreens are labelled with an SPF, or Sun Protection Factor. The SPF acts like a multiplying factor. If you would normally be fine in the sun for 10 minutes and you apply an SPF 10 sunscreen, you will be fine in the sun for 100 minutes. In order for the sunscreen to work, however, you have to apply a lot of the product, which has to stay on. You should apply it about half an hour before going out in the sun (or the water) so it can bind to your skin. If you don’t, then it is very easy for the sunscreen to wash off.

Sunscreen Guidelines

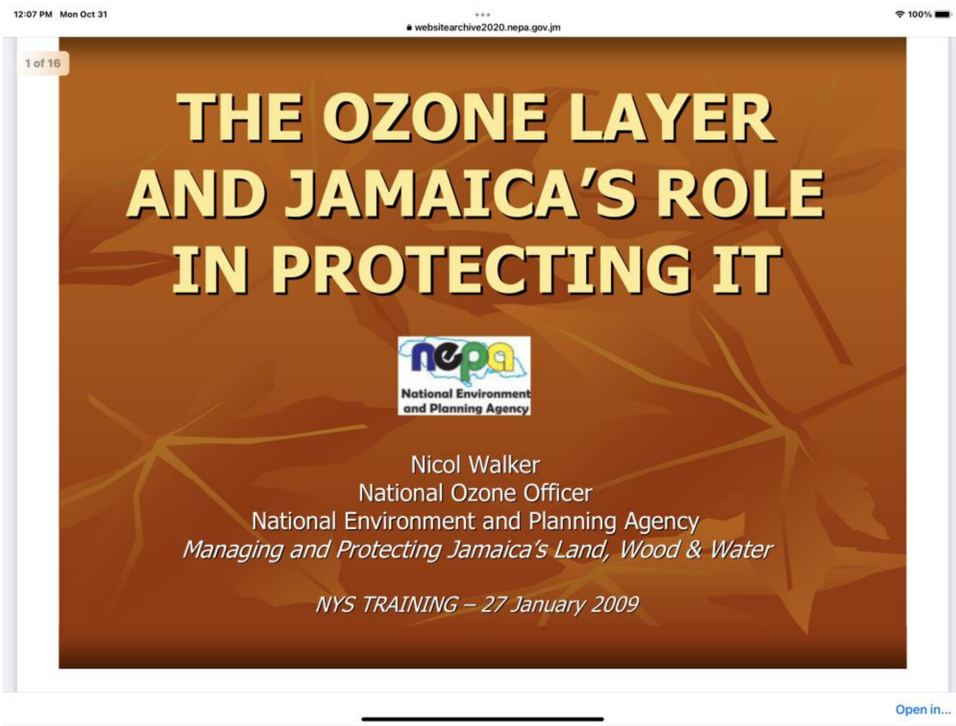
• Choose a sunscreen of at least SPF 25 to 30, especially in bright sunlight

• Be sure that the sunscreen you use is water-proof, particularly if you swim or perspire a lot

• Be sure your sunscreen protects against UVA as well as UVB

• Reapply your sunscreen every 1 $^1/_2$ to 2 hours when outdoors.

Walker, N. (2009, January 27). *The Ozone Layer and Jamaica's Role in Protecting It*. National Environment Planning Agency. Retrieved October 31, 2022, from https://websitearchive2020.nepa.gov.jm/student/resource-material/pdf/The_Ozone_Layer_and_Jamaica's_%20Role_in_Protecting_it.pdf



RESULTS OF OZONE LAYER DEPLETION….UV-B EXPOSURE

- Increased risk of skin cancers
- Increased risk of cataracts
- Decreased resistance to disease
- Lower crop yields
- Affects phytoplankton, zooplankton
- Increased degradation of plastics and paints

PROTECT YOURSELF FROM THE SUN….HOW?

- Limit exposure during midday
- Wear protective clothing
- Wear broad rimmed hat to protect eyes, face, neck
- Protect eyes with wrap around/side panel sunglasses
- Use sunscreen with SPF 15 and above
- Protect young children

Competitive Landscape

Technological System 1 (UV Global App)

The SunSmart UV Global app provides the customer with daily forecasts of UV radiation and weather for different locations around the world. The app provides time intervals during the day when sun protection is required, for the purpose of reducing the amount of global skin cancer and eye damage.

The shortcoming of this system is based around the accuracy of the readings on the app. Due to fluctuations with cloud coverage within the same general area, this app might not be able to provide the correct UV index for the precise location the customer is in. Moreover, this app might not update as frequently as a customer might need when moving from one area to another in the same general location.

Haysmith, S. E. (2022, June 21). *SunSmart Global UV app helps protect you from the dangers of the Sun and promotes public health*. World Health Organization. Retrieved October 31, 2022, from https://www.who.int/news/item/21-06-2022-sunsmart-global-uv-app-helps-protect-you-from-the-dangers-of-the-sun-and-promotes-public-health#:~:text=The%20SunSmart%20Global%20UV%20app,and%20UV%2Drelated%20eye%20damage.

Technological System 2 (Arduino UV Index Meter Created by Abid Hossain)

The Arduino UV Index Meter created by Abid Hossain, solves most of the challenges presented. It uses a UV index sensor along with an Arduino and a display to read and output the numeric value of the UV index along with a relative measurement.

This solution seems viable, however, when taking a closer look, we can see that the formfactor is not one that makes the device portable. The two breadboards along with the need for an external power supply do not allow for the device to be used easily in a work environment. This along with the fact that it is not protected within an enclosure does not make it a suitable solution.

Hossain, A. (2021, May 28). *Arduino UV index meter*. Arduino Project Hub. Retrieved October 31, 2022, from https://create.arduino.cc/projecthub/abid_hossain/arduino-uv-index-meter-f03b4e

Technological System 3 (UV Index Meter created by DroneBot Workshop)

The UV index meter created by DroneBot Workshop is another solution that encompasses most of the requirements specified by the customer, namely measuring and outputting the UV index to a display, as well as the integration of a portable power source. In addition, it is also able to read the temperature and humidity, which was not specified as a requirement from the customer.

As with the last design this one also has a few drawbacks. The device is again not enclosed which results in it being more difficult to use and not adequately protecting the components. The additional components that are also added allowing for the temperature and humidity to be measured also use more of the microcontroller's memory and add more complexity to the system. The lack of a rechargeable power source may also be a disadvantage in the eyes of the customer.

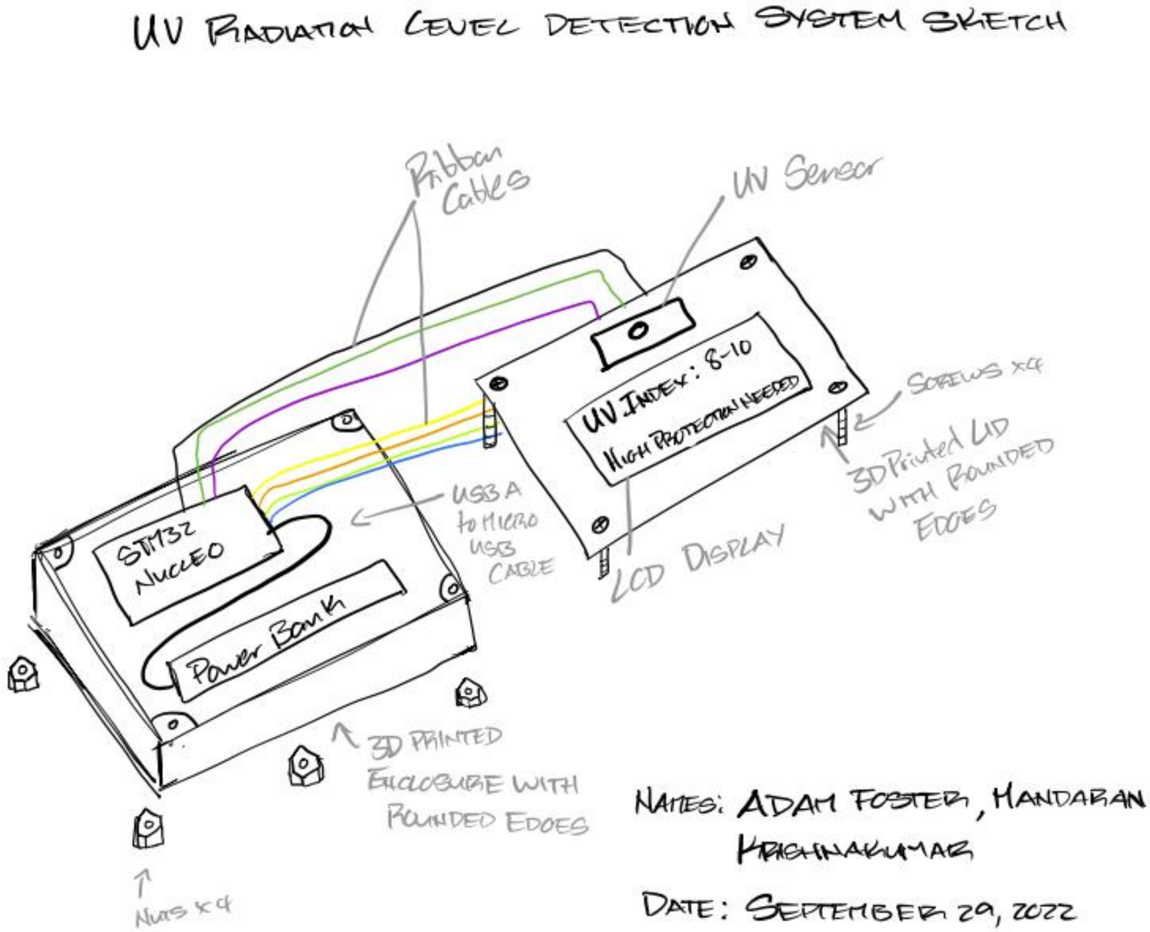
Workshop, D. B. (2018, September 5). *Build an Arduino UV index meter*. DroneBot Workshop. Retrieved October 31, 2022, from https://dronebotworkshop.com/arduino-uv-index-meter/

Requirement Specification

- The device should feature the ability to calculate and output the UV index of the ultraviolet radiation (using the GUVA S12SD UV Light Sensor Breakout) which is initially measured in voltage then converted to a UV index value ranging from 1 – 11.
- The device should refresh the reading of the UV index and the required protection every 5000 ms.
- The device should read the sun's UV radiation level in terms of a value from 1 – 11, and output the UV Index value and the necessary level of protection to prevent overexposure to high UV radiation levels.
- The device should boot up and display the UV rating and necessary protection needed within 2000 ms of the power switch being turned on.
- The software should have the ability to convert the voltage value recorded by the UV sensor to a UV index value by dividing the output voltage by 0.1V.

<u>Analysis</u>

Design

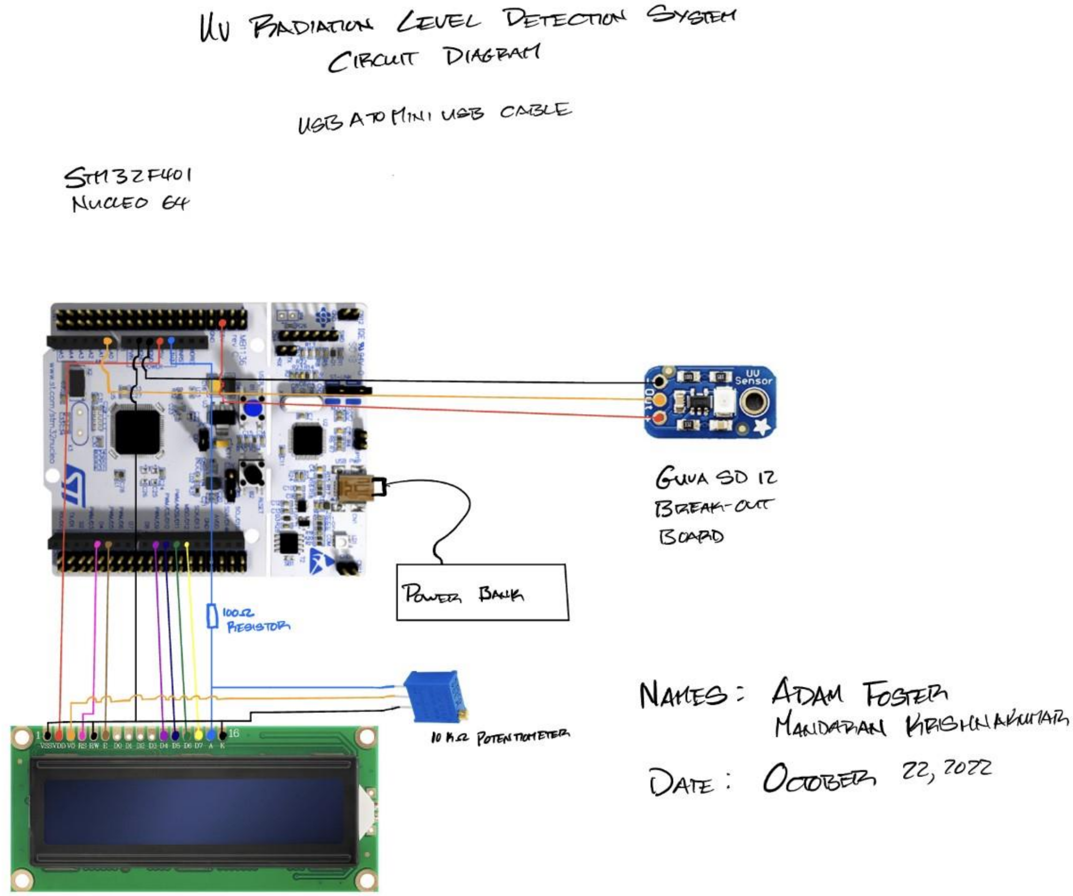


The Design of the UV index measurement device comprises of 18 main parts. These include:

- The STM 32 Nucleo 64 Board
- The 3D Printed Enclosure
- The 3D Printed Lid
- The UV sensor

- The LCD Display
- The Connecting Wires
- The Power Bank
- The Mini USB to USB A cable
- The Four bolts
- The Four nuts
- 10k Potentiometer
- 100 ohm resistor

The device is assembled by first making the connections using the connecting wires based on the wiring diagram illustrated below.



Next the components can be placed into the 3D printed enclosure. The LCD screen and the UV sensor can then be attached to the lid of the enclosure using low temperature hot glue.

To complete the assembly of the device, the lid can be placed on top of the enclosure with the display and UV sensor facing outward and the four bolts can be passed through the lid and the through the enclosure. The entire assembly is held together using four nuts, one on each bolt passed though the enclosure.

To operate the device, the power bank must first be switched on. At this point the microcontroller will boot up and numerical values for the UV index and the corresponding amount of protection that will be needed to remain safe will be displayed. This value will update every 5000 ms. It is important to ensure that the device is not placed in a shaded area to ensure the accuracy of the readings received. Once the user has collected adequate readings, the device can be powered down by turning off the power bank.

Scientific or Mathematical Principles

Arithmetic

- Fundamental theorem of arithmetic: The UV sensor output voltage will be divided by a factor of 0.1 to calculate the equivalent UV index value.

  Equation: UV index = output voltage / 0.1 V

Industries, A. (n.d.). *Analog UV light sensor breakout - guva-S12SD*. adafruit industries blog RSS. Retrieved October 31, 2022, from https://www.adafruit.com/product/1918

Electromagnetism

- Electric Potential: The device’s UV sensor will output an electric potential value that can be used to calculate the UV index value.

  Equation: UV index value = output electric potential / 0.1 V

Industries, A. (n.d.). *Analog UV light sensor breakout - guva-S12SD*. adafruit industries blog RSS. Retrieved October 31, 2022, from https://www.adafruit.com/product/1918

Statistics

- Statistical Distribution: The device will be able to record UV index values over time and output the maximum and minimum values recorded, as well as the median UV index. This will give an idea of the variation in solar radiation.

  Maximum UV Index = highest voltage / 0.1 V

  Minimum UV Index = lowest voltage / 0.1 V

  Median UV Index = (Maximum UV Index + Minimum UV Index) / 2

Brooks, D. R. (2021). *Arduino-based UV Measurements Institute for earth ... - instesre.org*. Arduino-Based UV Measurements. Retrieved October 31, 2022, from https://instesre.org/ArduinoBook/UVmeasurements.pdf

Costs

Manufacturing Costs

In manufacturing the UV Index measurement device, there were many costs associated with manufacturing the final product. As far as the manufacturer locations are concerned, the UV index sensor is made by Adafruit Industries located in New York City, the power bank is manufactured by Shenzhen Firstar Battery Co., Limited located in Shenzhen China, the 3D printer used was manufactured by Prusa Research located in Prague, Czech Republic, the nuts and bolts were manufactured by Home Builder a Home Hardware Brand which is located in

Waterloo, Ontario and the other electronic components were manufactured by Elegoo, located in Shenzhen China.

Most of the items used in the project are available on Amazon, which allows for them to be easily shipped to most parts of the world allowing for the device to be easily replicated. The only exceptions are the 3D printer and printing material as well as the nuts and bolts. The 3D printer is available from Prusa Research directly. This may be less accessible due to the company being located in the Czech Republic, and the device itself being very costly however there are companies that are making 3D printing more accessible, with cheaper printers being available on Amazon, as well as printing services that are a fraction of the cost of a 3D printer. The bolts although manufactured by a company based in Ontario can be found at any local hardware store in most parts of the world.

Implementation Costs

To operate the UV Index Measurement device:

- Place it on a level surface with the UV sensor facing directly upward.
- Power on the device using the button located on the back.
- Read the UV index value and the relative protection measurement and ensure that the necessary protection is used while in the sun
- To recharge the battery, remove the four nuts from the bottom of the device and remove the lid.
- Use the included micro USB cable to charge the power bank.

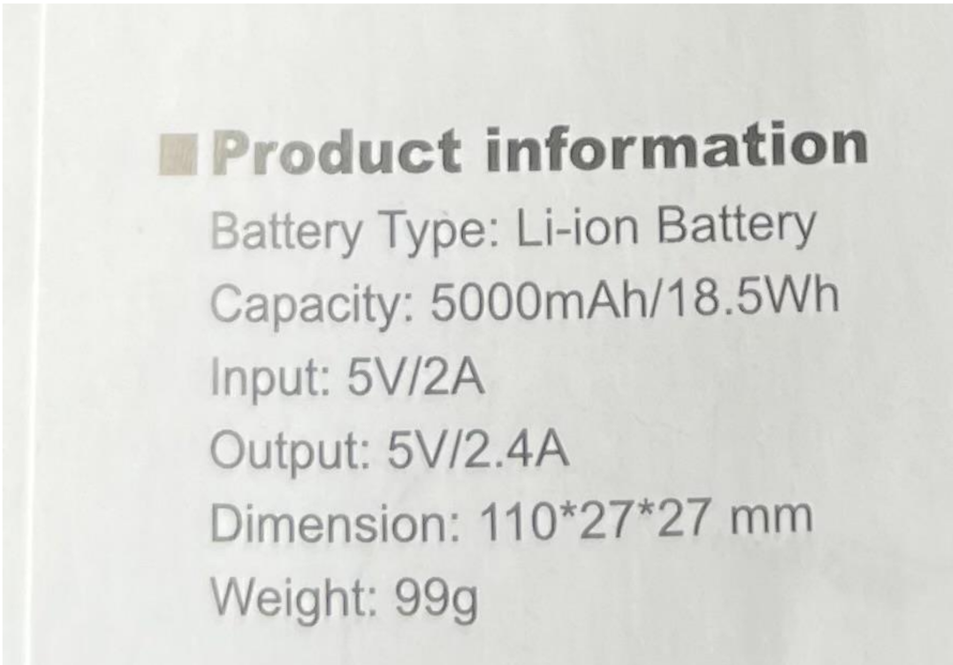
- Once charged, unplug the power bank and reassemble the device by replacing the lid with the four bolts and fastening the nuts on the bottom of the device.
- To make any changes to the program, disassemble the device using the steps above, plug the included mini USB cable into the STM 32 Nucleo 64 board and the other end into a computer.
- Make any necessary changes using the STM Cube IDE.

Risks

Energy Analysis

Based on the requirements given in the project requirements document, the design must not consume, transfer discharge or otherwise expend more than 30W of power at any point in time and the design must also not store or otherwise contain more than 500 mJ of energy at any point in time.

The device is powered by a power bank that supplies 5V at 2.4A to the STM 32 microcontroller. This therefore means that the output power of the power bank is 12W, which is well below the 30W threshold. The input power needed to charge the power bank is 10W which is also below the 30W threshold. Although a 110V AC power adapter can be used to charge the power bank, by connecting it to the included micro-USB cable, it is recommended that a laptop's USB port is used to charge the power bank as it is much safer than using an AC power supply due to the voltages being much lower. Although the power bank stores approximately 67 KJ of energy, this could be considered an external component, because the STM 32 along with all the other components within the circuit do not allow for more than 500 mJ of energy to be stored.



Product information

Battery Type: Li-ion Battery
Capacity: 5000mAh/18.5Wh
Input: 5V/2A
Output: 5V/2.4A
Dimension: 110*27*27 mm
Weight: 99g

Image taken from Energy QC Power Bank Manual

Since there are no mechanical moving parts, there is no storage of mechanical energy. There are also no capacitors or other energy storage devices, apart from the power bank, that would allow for the build up of energy greater than 500 mJ in the internal system of the device. The UV sensor can sense up to a UV index of 11, which equates to 1.1 V.

If this corresponds to a photocurrent of 1uA and is stored for 1 second, then the energy stored would be 1.1×10^{-6} J

which is well below the 500 mJ threshold.

Table 7. Power supply capabilities

Input Power	Connector pins	Voltage range	Max current	Limitation
5V_USB_STLK	CN2 PIN1	4.75 V to 5.25 V	500 mA	Max current depends on the USB enumeration: – 100 mA without enumeration – 500 mA with enumeration OK
VIN	CN6 pin 8 CN7 pin 24	7 V to 12 V	800 mA	From 7 V to 12 V only and input current capability is linked to input voltage: – 800 mA input current when VIN=7 V – 450 mA input current when 7 V<VIN<9 V – 300 mA input current when 10 V>VIN>9 V – less than 300 mA input current when VIN>10 V
E5V	CN7 pin 6	4.75 V to 5.25 V	500 mA	
5V_USB_CHG	CN2 pin 1	4.75 V to 5.25 V	500 mA	Max current depends on the USB wall charger used to power the Nucleo board
3V3	CN6 pin 4 CN7 pin 16 JP3 pin 1	3 V to 3.6 V	-	Used when ST-LINK part of PCB not used or remove SB1 and SB19

Image taken from STM 32 Nucleo 64 Manual

Risk Analysis

1. If the design is used as intended, the only negative consequence that may occur is the usage of energy to recharge the battery within the device.
2. If the design is not used as intended, there is the possibility of a short circuit being created by introducing moisture to the system or placing bare wires directly on a metal surface which could cause damage to the components and potentially electrocute the user.
3. The device could overheat and potentially shut down if exposed to very high temperatures for an extended period. This could also cause the battery to overheat and even explode causing harm to people near the device.

4. The design could malfunction by one or several of the internal connections becoming loose. This could result in the display not working correctly or the UV index measurement being inaccurate.
5. If the internal connections become loose, this could cause a short circuit and potentially a fire. It could also cause an incorrect measurement to be displayed which could result in the overexposure of the user to UV radiation.

Testing and Validation

Test Plan

Requirement:

- The device should feature the ability to calculate and output the UV index of the ultraviolet radiation (using the GUVA S12SD UV Light Sensor Breakout) which is initially measured in voltage then converted to a UV index value.

Test:

- The test is set up by powering on the UV index measurement device and placing it on a horizontal surface in the sun that has no shading. The environmental parameter being measured is the UV index. The test input is the sunshine which will be converted to a voltage value that can be understood by the microcontroller. The value output by the display can be compared to that of another UV index meter that is set up in the same place. Once the values are within 1.0 unit of each other, the test has been passed.

Requirement:

- The device should refresh the reading of the UV index and the required protection every 5000 ms.

Test:

- The test is set up by powering on the UV index measurement device and placing it on a horizontal surface in the sun that has no shading. Using a stopwatch, for three readings, measure the time between each update and find the average of three time readings. The environmental parameter being measured is the time between the output of the UV index readings. The test input is the sunshine that is converted to a UV index reading and displayed to the screen. Once the value is within 500 ms of 5000 ms, to account for reaction time, then the test has been passed.

Requirement:

- The device should read the sun's UV radiation level and output the UV rating and the necessary level of protection to prevent overexposure to high UV radiation levels.

Test:

- The test is set up by powering on the UV index measurement device and placing it on a horizontal surface in the sun that has no shading. The environmental parameter being measured is the relative UV protection needed. The test input is the sunshine which can be converted to voltages that can be understood by the microcontroller. Using an app that gives the relative protection value needed to keep safe, record the measurement that is displayed. Once the necessary protection is similar in a relative sense then the test has been passed.

Requirement:

- The device should boot up and display the UV index measurement and necessary protection needed within 2000 ms of the power switch being turned on.

Test:

- The test is set up by powering on the UV index measurement device and placing it on a horizontal surface in the sun that has no shading. The environmental parameter being measured is the time taken for the device to boot up and display the UV index value and necessary protection needed. The test input is the sunshine which is converted to a voltage value that can be understood by the microcontroller. If the UV index device is able to boot up and display the UV index and the relative protection value in less than 2000ms then the test has been passed.

Requirement:

- The software should have the ability to convert the voltage value recorded by the UV sensor to a UV index value by dividing the output voltage by 0.1V.

Test:

- The test is set up by powering on the UV index measurement device and placing it on a horizontal surface in the sun that has no shading. The environmental parameter being measured is the UV index value. The test input is the sunshine and the UV index value output before it is divided by 0.1 V. Three measurements can be recorded by outputting the raw value from the UV index sensor to the display by modifying the code. Another UV index measurement device can be set up in the same location and the values output by it recorded. If the output when divided by 0.1V manually is within 1.0 of that of the other UV index measurement device, then the test has been passed.