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# Development of Smart Electrochromic Film Device

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**Abstract**: The demands for smart devices are increasing exponentially nowadays. This project presents the invention of a new, low-cost, and user-controlled electrochromic film device for home safety and privacy purpose. The development of this system focuses on windows where electrochromism materials as a film had been layered for the safety and privacy plan. Excessive exposure to UV radiation over 15 minutes causes acute and chronic long-term skin effects. Meanwhile, the high cost of cutting precise glass appliances due to the high volume of heat trapped during daylight causes the application of this device to be crucial. This invention is equipped with IoT (Internet of Things) which helps users to control it remotely via Blynk Apps in smartphones and displays all the sensor's output. The system comprised of Arduino UNO as the main controller, NodeMCU ESP8266 for IoT platform, solar battery as a power source, UV sensor together with PIR sensor to enhance safety purpose and DHT11 for monitoring temperature and humidity.

**Keywords**: electrochromic film, UV radiation, UV sensor, automation, IoT

## 1. Introduction

Smart materials are capable of sensing and reacting with environmental conditions or stimulation such as mechanical, chemical, electrical, and even magnetic signals [1]. In the construction industry, glass is one of the main elements that had been used widely for houses and buildings leading to high demand from manufacturers for construction companies. According to Ho Sai Woo, the chairman of the Malaysia Glass Association (MGA), the glass industry is currently booming with RM3 billion turnover for the manufacturing and processing streams [2]. One type of glass that has the characteristics of smart material is called as electrochromic glass. These electrochromic materials will change their optical properties once some amount of voltages is applied across them [3]. Normal transparent glass does not assist in keeping privacy and safety. It is also incapable of blocking the UV radiation from the sunlight and facing high prices in which require individual installation which increases construction cost [4]. According to NOAA's Climate Prediction Center (CPC), January 2020 had a temperature departure of 1.14°C, which is 2.05°F above the 20$^{th}$-century average and the highest surface temperature of the Earth's land and sea in 141 years [5]. Meanwhile, the Meteorological Department stated that Malaysia's UV index reading varies and could reach 15 in the afternoon on a clear day [6].

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Dermatologist Dr. Nurashikin Ahmad said that long exposure to extreme UV radiation causes acute and chronic long-term skin effects. People with sensitive skin experiences itchiness and sunburns while its long-term effect leads to photo-aging effects like wrinkles or skin cancer [7].

Thus, a solution has been figured out to develop a prototype of a smart house by using electrochromic film [8, 9] to control the amount of UV light that passes through the house/building by providing safety and privacy as well to the residents. The electrochromic film was chosen instead of the electrochromic mirror for its cost-effectiveness with much lower price, convenient properties which are more versatile, and installable to any pre-existing glass available. To achieve the intention of the project, three steps were designed. At first, Arduino based system powered by a solar source was developed. Next, a solar battery charger for the ardu-electrochromic film device was constructed, and lastly, the evolution of an electrochromic film device that is remotely controlled by Arduino via Blynk Apps. The project focuses on the development of the electrochromic film to be attached to houses. The electrochromic film was chosen instead of the electrochromic mirror due to its stick-on concept and ability to change its state from transparent to opaque. The efficiency of the electrochromic film was measured experimentally at different voltages. The size of the electrochromic film was estimated at 15cm x 10cm. A solar panel with a battery charger was implemented as the power source of the project. By embedding an infrared (IR) sensor to identify the motion of surrounding, ultraviolet (UV) sensor to measure the amount of UV light, DHT11 for monitoring temperature and humidity, this system not only fosters a privacy plan but the safety as well.

## 2. Materials and Methods

### 2.1 Materials

This section describes the specifications and properties of materials, equipment, and other resources used in this current work. The materials that have been used in this project were divided into three main categories:

- Hardware Implementation : NodeMCU (ESP8266), Arduino UNO
- Software Implementation : Blynk Application, Arduino IDE
- Sensing Implementation : UV sensor, PIR sensor, DHT11

### 2.2 Methods

The procedures that were applied in the process were presented in the form of a block diagram. The circuit diagrams of the whole system have also been illustrated in this section. Two microcontrollers development board with wifi capacity had been implemented together with Arduino UNO. The output data translated into the buzzer, Blnyk Apps, LED and electrochromic film itself.

#### 2.2.1 Block Diagram and Flowchart

The block diagram of the device consists of five separate parts combined into one system to be constructed as one completed device. It consists of a solar battery charger, PIR sensor [10], DHT11, UV sensor [11], and smart control as shown in **Figure 1**. Meanwhile **Figure 2** (a) (b) (c) depicted the flowchart of all output sensors used in the system.

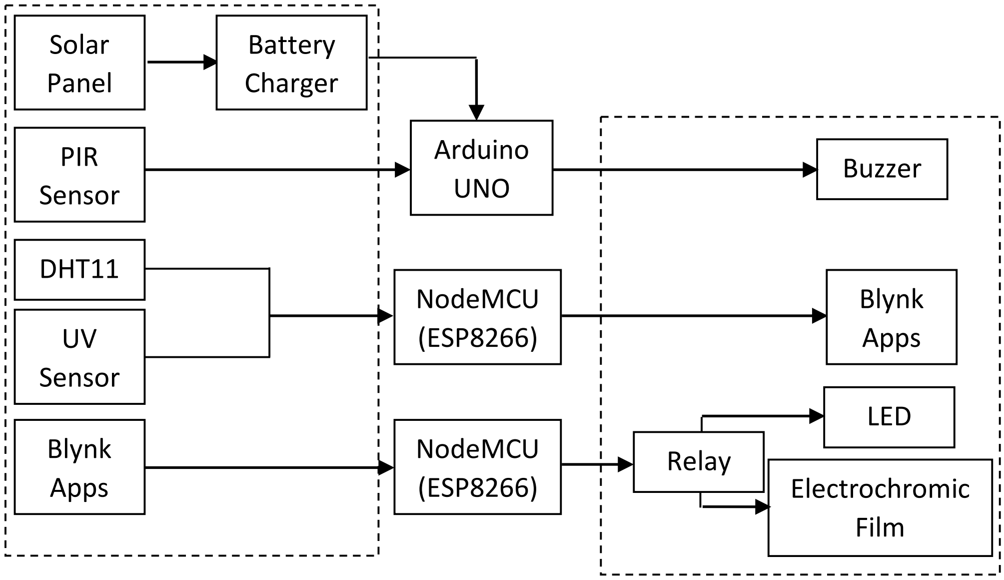
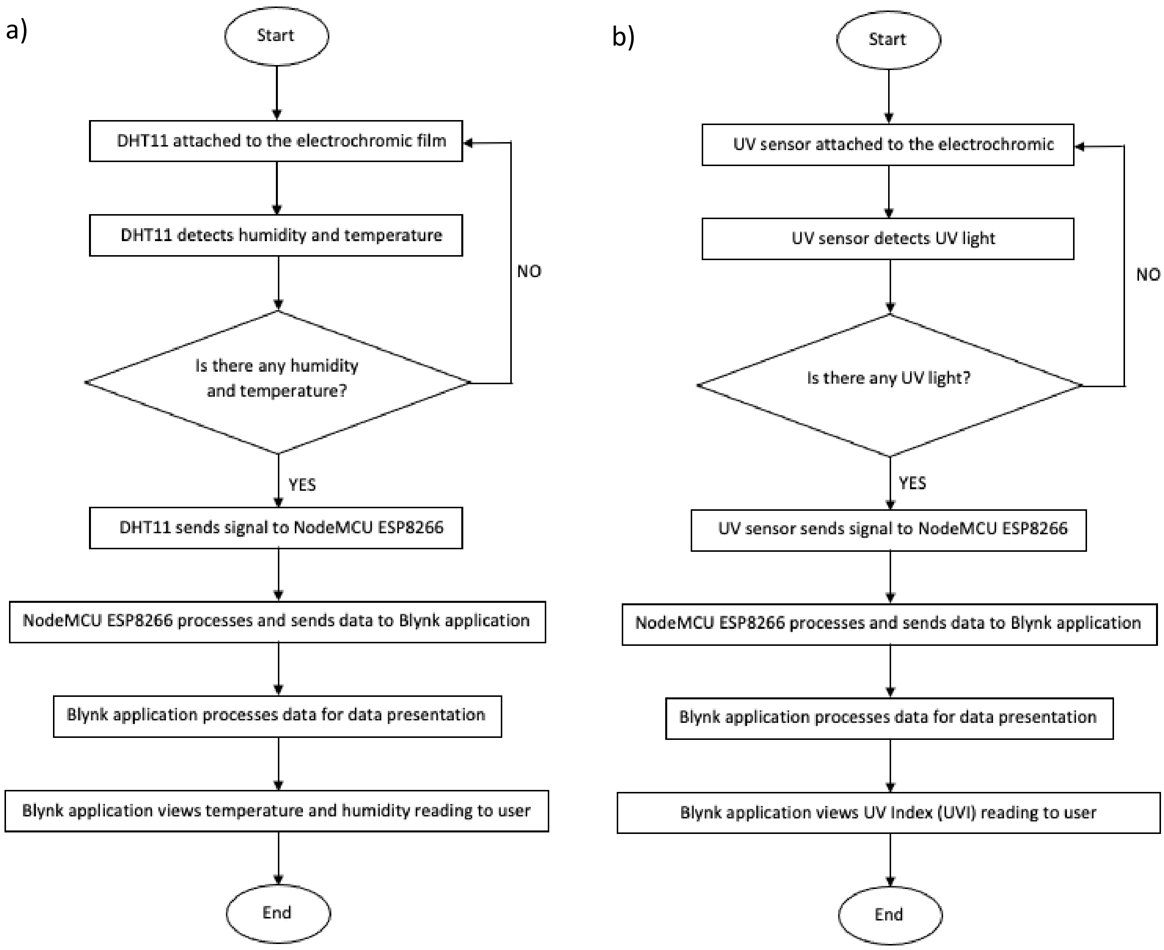



**Figure 1: Block diagram of the smart electrochromic film device**



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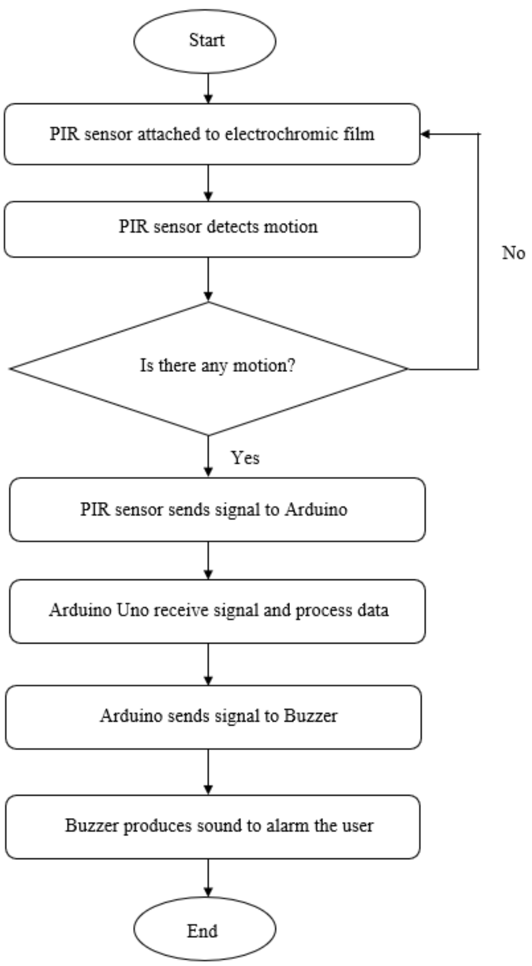


**Figure 2: Flowchart of (a) Temperature and Humidity sensor (b) UV sensor (c) Security alarm**

### 2.2.2 Circuit Diagram

The circuit diagram of the device consists of four parts: The solar battery charger, security alarm, lights and film control, and temperature and humidity monitoring. The security alarm uses Arduino Uno as the controller meanwhile ESP8266 is used for the lights and film control and temperature humidity monitoring.

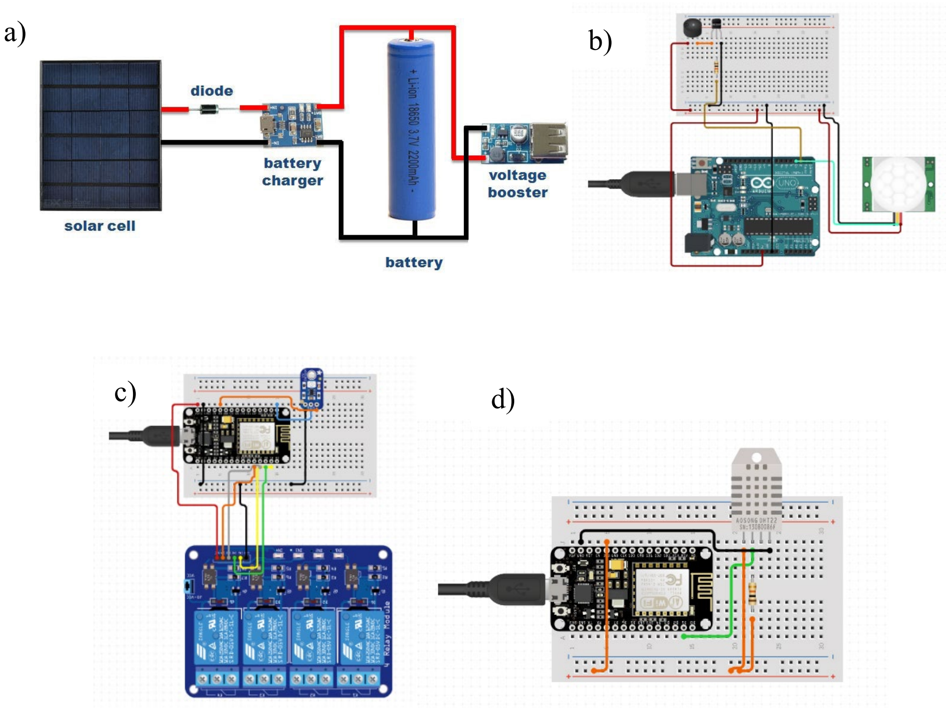


**Figure 3: Circuit diagram of the device (a) solar battery charger (b) security alarm (c) lights & film control (d) temperature & humidity monitoring**

## 3. Results and Discussion

In this section, the final output of the prototype was presented at various angle of view. Some experiments were conducted to investigate the efficiency of the smart electrochromic film device.

### 3.1 Prototype of the device

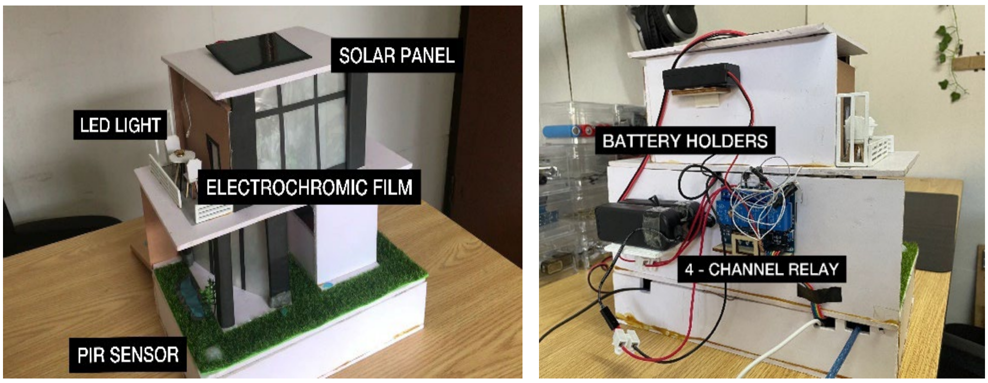


**Figure 4: The smart house prototype (a) Front view (b) Back view**

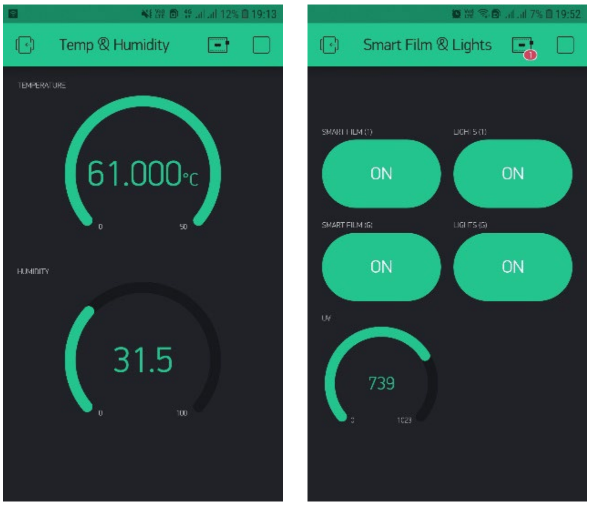


**Figure 5: Electrochromic film control, UV light, temperature, and humidity monitoring through the Blynk application**

3.2 The efficiency of the solar battery charger

The efficiency of the solar battery charger was measured and calculated by measuring the voltages, currents and calculating its power [12]. **Figure 6** shows the consistent amount of voltage captured from the solar battery charger at different weather conditions.

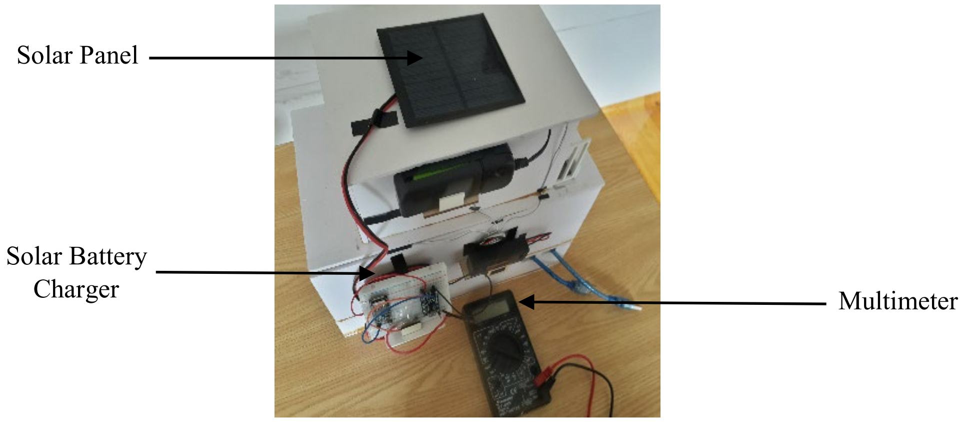


**Figure 6: Measuring voltage and current using a multimeter**

**Table 1: Table for The Efficiency of the Solar Battery Charger**

| Weather Conditions | $V_{in}$ (Volts) | $V_{out}$ (Volts) | $I_{in}$ (Amps) | $I_{out}$ (Amps) | $P_{in}$ (Watts) | $P_{out}$ (Watts) |
|---|---|---|---|---|---|---|
| Night | 0.08 | 4.27 | 1.08 | 1.55 | 0.08 | 6.62 |
| Morning | 1.69 | 4.26 | 1.21 | 1.76 | 2.04 | 7.50 |
| Cloudy | 4.23 | 4.27 | 1.44 | 1.75 | 6.09 | 7.47 |
| Sunny | 4.91 | 4.27 | 0.90 | 1.56 | 4.42 | 6.66 |

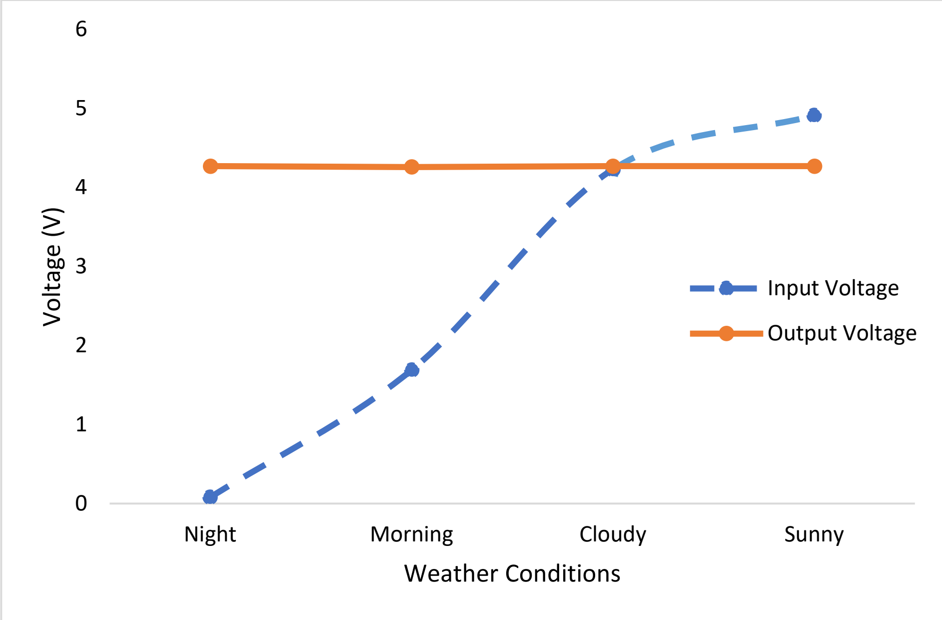


**Figure 7: Graph of voltage (V) against different weather conditions**

3.3 Range of PIR sensor detection

The range of detection of the PIR sensor was measured to identify the sensing strength of the PIR sensor. It was placed on the housing prototype and an object was used as a tester for the PIR sensor.

**Table 2: Range of PIR Sensor Detection**

| Distance of object from PIR sensor (m) | Detection of motion by PIR sensor |
|---|---|
| 0.2 | Motion detected |
| 0.4 | Motion detected |
| 0.6 | Motion detected |
| 0.8 | Motion detected |
| 1.0 | Motion detected |
| 1.2 | Motion detected |
| 1.4 | Motion detected |
| 1.6 | Motion detected |
| 1.8 | Unable to detect motion |
| 2.0 | Unable to detect motion |

3.4 The efficiency of the electrochromic film

The efficiency of the electrochromic film was determined by measuring the amount of sunlight passing through the device when the electrochromic film is at a transparent and opaque state by using a pyranometer. The manual of using a pyranometer was referred to in [13-15]. The solar radiation was measured from 1.00 pm until 4.00 pm every 10 minutes.

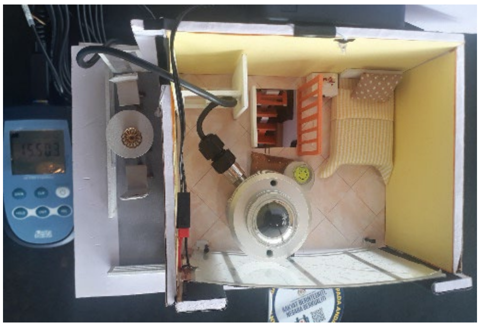

**Figure 8: Measuring the solar radiation inside the house using a pyranometer**

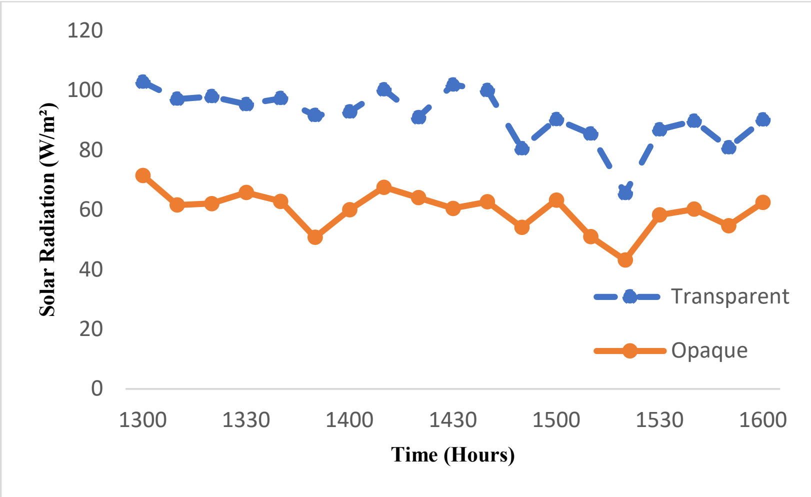


**Figure 9: Graph of solar radiation at transparent and opaque state against time**

## 4. Conclusion

The smart switchable electrochromic film device was successfully developed and was validated electronically by a smart house prototype. Based on the data collected, the electrochromic film device was proven to block the amount of UV light directly entering the house/building by 66%. In addition, the solar battery charger showed a constant and efficient amount of power to the ardu-electrochromic film device regardless of time and weather conditions. All the sensor systems also exposed good functionality.

### Acknowledgement

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