Arduino based Portable System for Real-time Sensing of Visible Wavelengths

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Abstract- A new approach of sensing the wavelength of visible light is presented here. A low cost, rugged and compact system has been realized and demonstrated in the laboratory. The technique involves the use of a color sensor TCS230 interfaced with the ARDUINO UNO board. Using the detected RGB color constituents the incident light wavelength has been sensed with help of RGB to wavelength converter. The variations due to distance and time are also presented here.

Key words: Arduino, Color sensor, RGB color coding, Wavelength sensor

I. INTRODUCTION

Sensing visible light wavelengths has several applications. They are employed in a variety of commercial, industrial, scientific and forensic applications such as automatic detection of food quality, packaging faults, process monitoring, quality control, environmental monitoring, spectrum analysis etc. [1-10]. Although various techniques are available for detecting wavelength quite accurately and reliably, their utility is limited due to high level of sophistication, fragileness and high cost of implementation. In most of the applications, a low cost color sensing system with small size, weight and power (SWaP) is required to realize efficient, compact and robust system.

In this paper we present the implementation of visible light wavelength sensor using Arduino UNO board and TCS230 color sensor [11, 12]. We also present its calibration and investigation of variations w.r.t. the time and distance of measurements.

II. EXPERIMENTAL SETUP

2.1 Components Used

Arduino UNO board, which is the most robust microcontroller board, has been used here to receive and process the color signal output from TCS230 color sensor. TCS230 is a well known color sensor board that has the capability of sensing a very wide range of color shades.

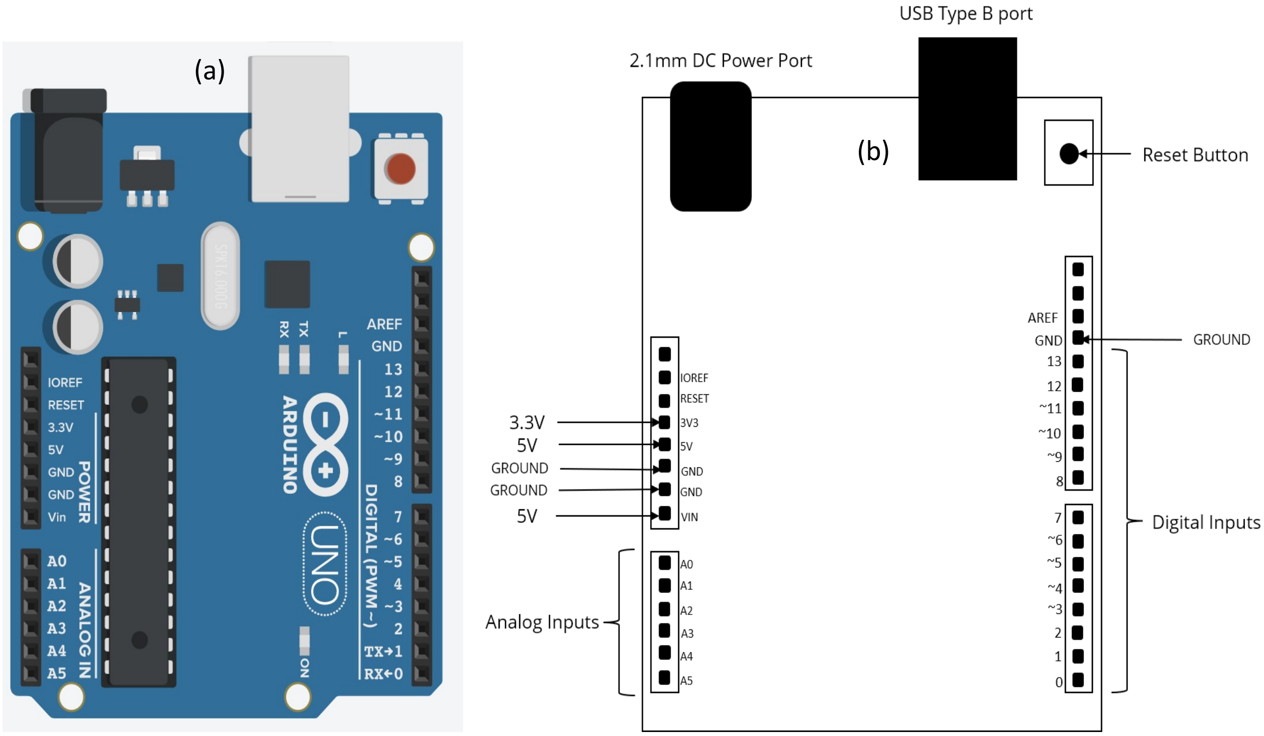


Figure 1: (a) Photographs of an Arduino UNO board, (b) Pinout of Arduino board

A photograph of the Arduino UNO board (revision 3) along with its pin-out diagram is shown in Fig. 1 (a) and (b). It may be seen that the board contains a 28-pin microcontroller chip, ATmega328P, input/output ports and power supply port. It has also got a push button for hard reset.

The photograph of the color sensor board TCS230 and its pinout are shown in Fig. 2(a) and (b). It consists of color sensor chip surrounded by the four white light emitting diodes (LED). These LEDs illuminate the target and the reflected light that falls on the sensor chip is used to detect the color of the target. The sensor chip contains 64 photodiodes with four different filters. There are 16 filtered photodiodes of each RED, GREEN and BLUE colors to sense their corresponding intensity, rest 16 photodiodes have clear filters to sense the white light intensity. These four types of filter can be selected using S1 and S2 inputs and the output in terms of voltage pulse is obtained the intensity is proportional to the pulse width which is sensed by the external circuit or the microcontroller as done in our experiment. Output frequency may be scaled to 2%, 20% or 100% by S0 and S1 pins of sensor board. With frequency selection, one may control the accuracy of color intensity

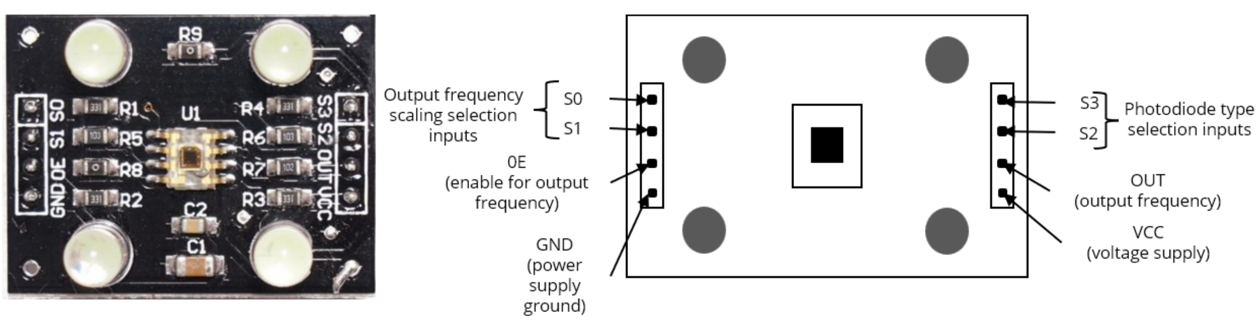


Figure 2: (a) Photographs of color sensor TCS230, (b) Pinout of Color sensor board

2.2 Circuit Interconnection

The Arduino and color sensor boards have been interconnected in a specific configuration. None of the critical pins on Arduino are required while wiring the TCS230 color sensor. As the arrangement doesn't make use of any pin specific functions, it is possible to use any pin of our choice. The interconnections between the two boards are shown schematically in Fig. 3.

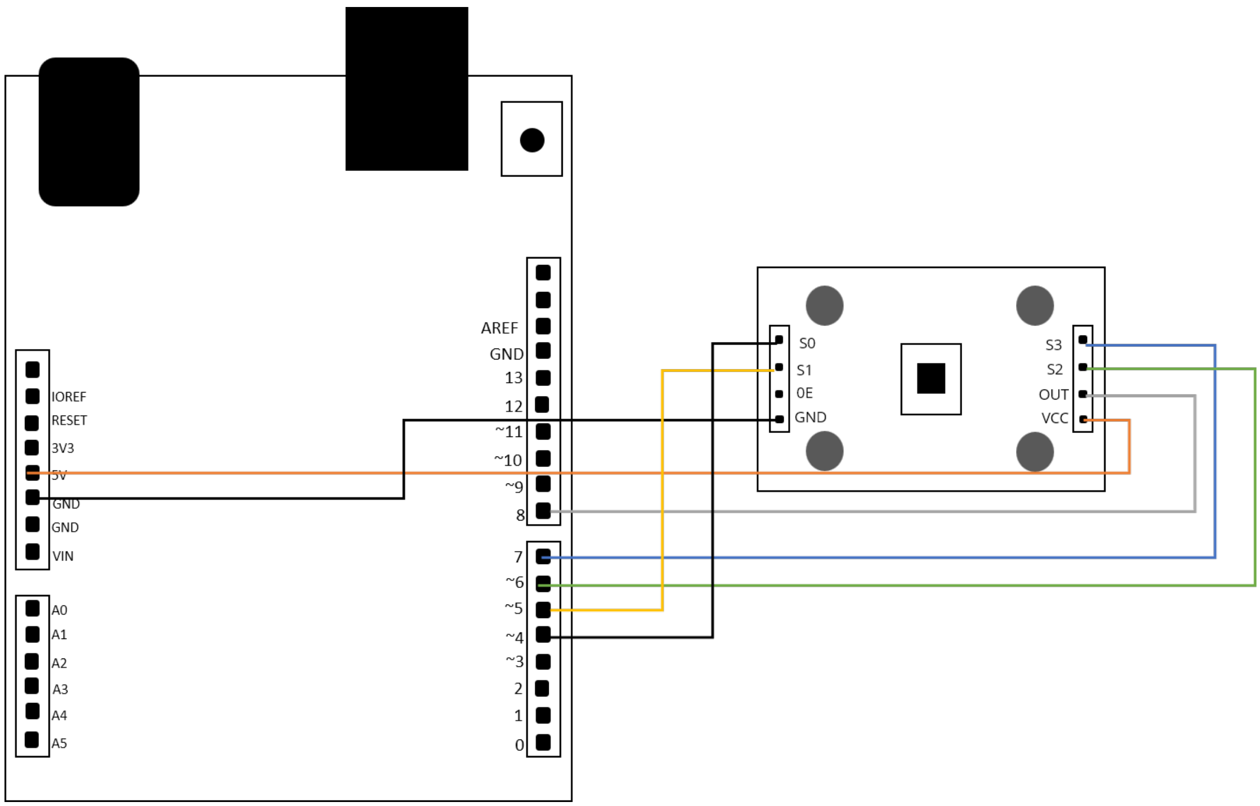


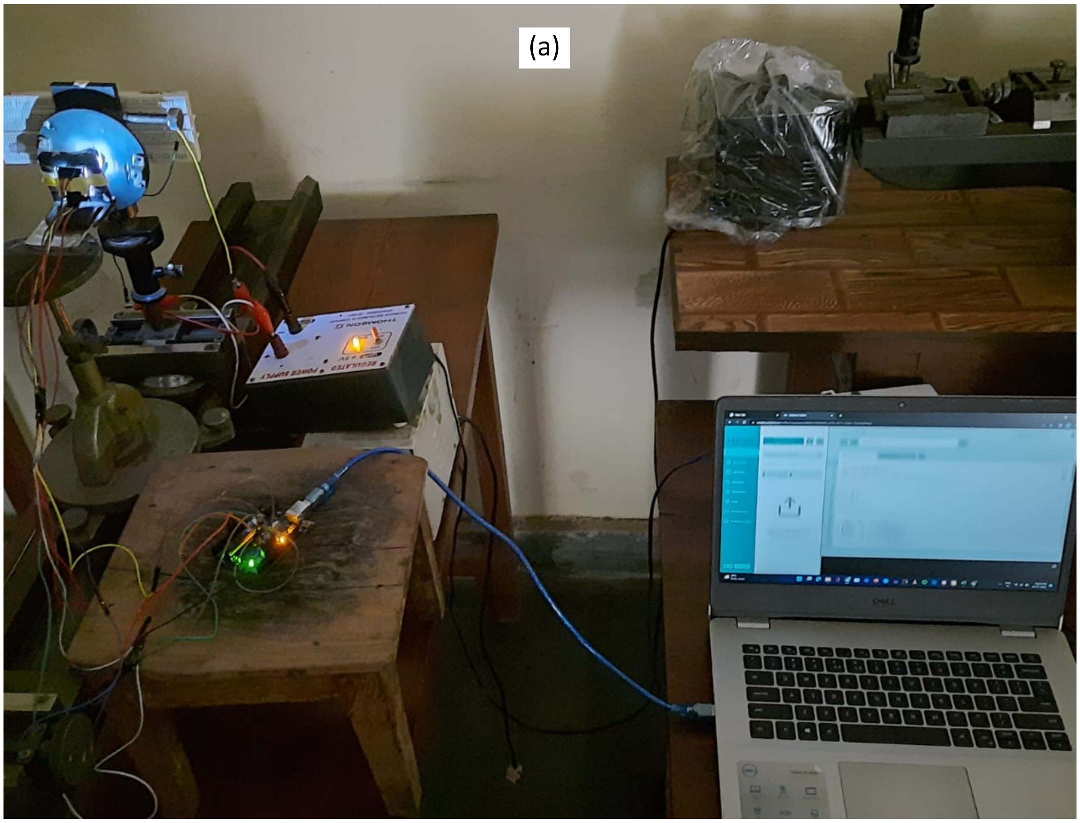
Figure 3: Schematic view of the interconnection between Arduino UNO and Color sensor boards

The S0 and S1 pins of TCS230 responsible for scaling the output frequency have been connected to the digital pins 4 and 5 of the Arduino, respectively. Likewise S2 and S3 pins of TCS230, connected respectively with pins 6 and 7 are responsible for selecting the colors detected by the photodiode within the sensor. The OUT pin is terminated at pin 8 of the Arduino.

2.3 The measurement setup

The source LED whose wavelength is to be assessed is connected to 5 Volt power supply through a resistor on a breadboard. The breadboard is set on the mounting stand such that the LED is placed right in front of the TCS230 sensor mounted in a similar manner.

The sensor chip of TCS230 has been enclosed in a non-reflecting black cylinder to isolate it from the four surrounding LED's to ensure that only the source light is received by the chip. The output pins of TCS230 have been connected to the specified input ports of Arduino UNO, as discussed in previous section. The Arduino board has been interfaced with the computer through USB port so that the data may be grabbed directly on the computer for further analysis. The whole setup is shown in Fig. 4(a) along with its schematic in Fig. 4(b).



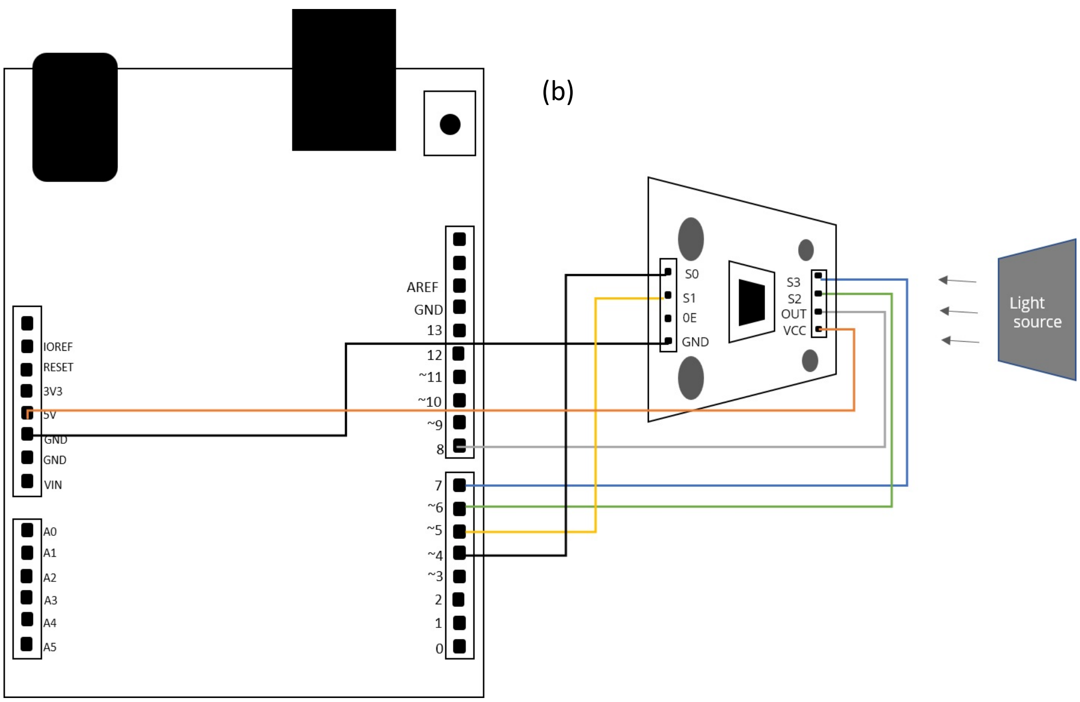


Figure 4: (a) The picture of measurement setup, (b) Schematic of the measurement setup

III. THE METHOD AND ALGORITHM

The TCS230 sensor is capable of grabbing the source light intensity in terms of RGB color components. The pulse width obtained for each color component is read by the Arduino, which is connected to the output terminals of TCS230 sensor. The output connections of the color sensor have been defined and set as the Arduino's input. Pins S1 and S2 have been set to obtain 20 percent scaling of the frequency / pulse width and the serial monitor has been activated. The flow chart of the setup code is shown in Fig. 5. Once the code is initiated, the arduino starts reading the pulse width for each color in the sequence defined in the code. A delay of 200 ms has been maintained between two consecutive readings allowing the sensor to stabilize. The loop is repeated for a specified period.

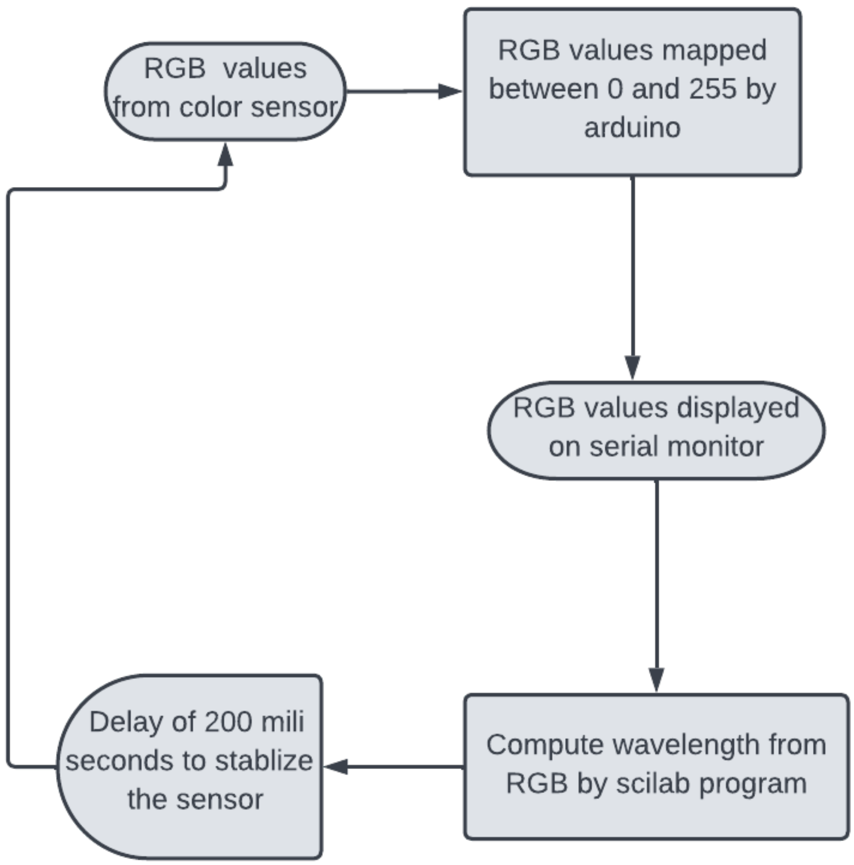


Figure 5: Flow chart of the experimental setup functioning

Arduino requires a calibration code to obtain the raw data and identify the limits on both extremes. The pulse width readings corresponding to the calibration source has been analyzed to identify the upper and lower data points for each color. For all the three colors the range has been set from 0 to 255. Each of the pulse width read by the system is mapped in accordance to the calibrated end values to obtain the RGB values corresponding to the input color light. Another code utilized to map this data to the equivalent wavelength is described in flowchart shown in Fig, 6.

The RGB values displayed on the serial monitor have been recorded as data arrays and provided as input values to the Arduino. The corresponding wavelength has been computed using functions defining the relation between RGB-Hue and Hue-Wavelength [13, 14].

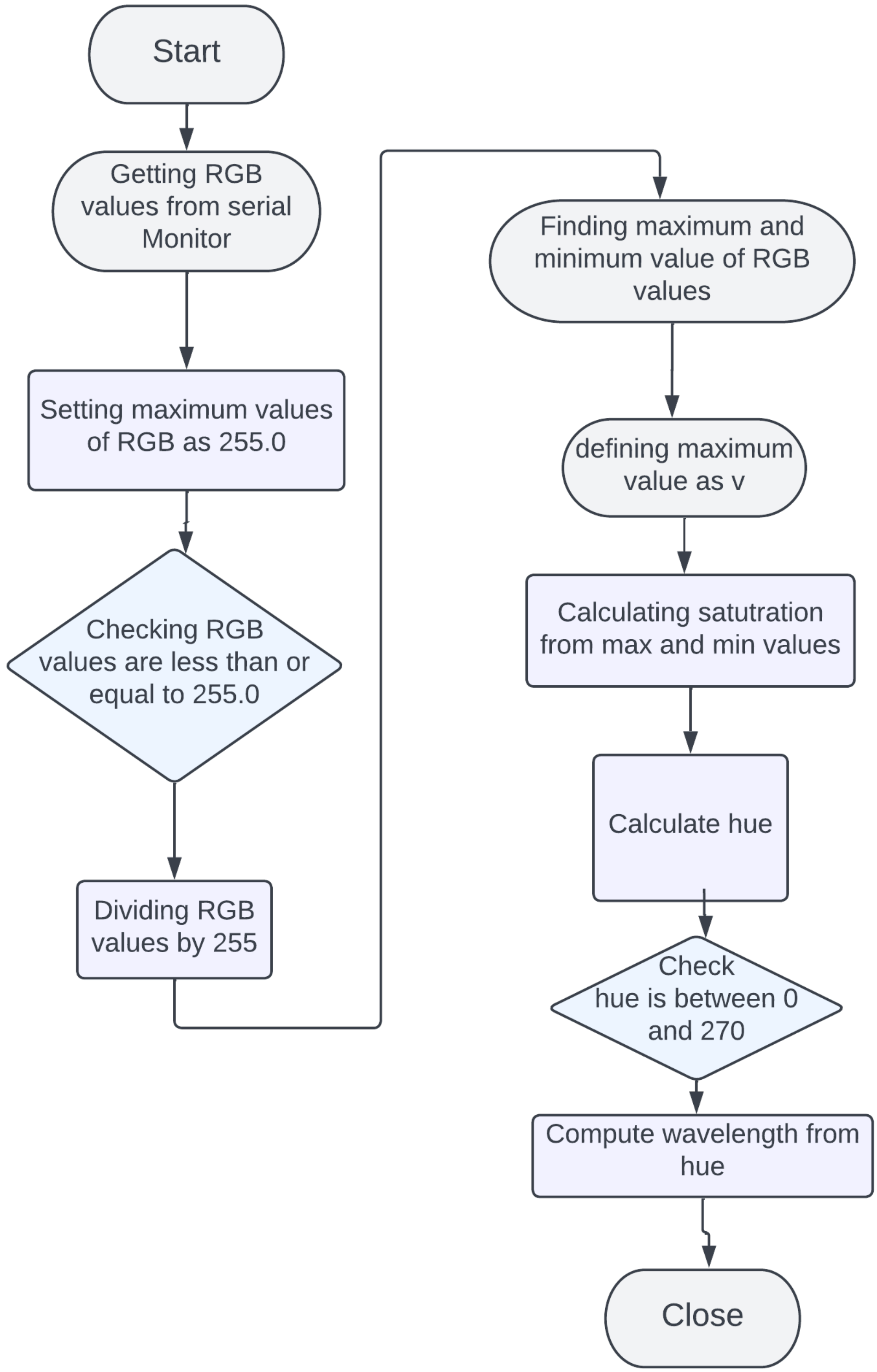
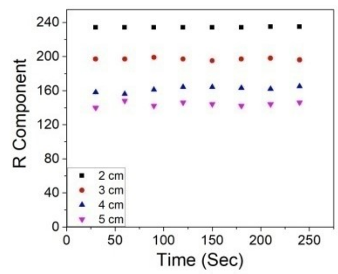
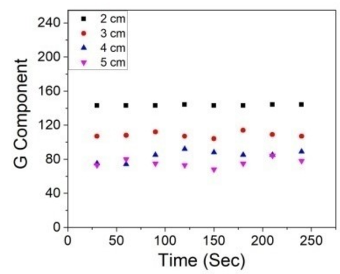
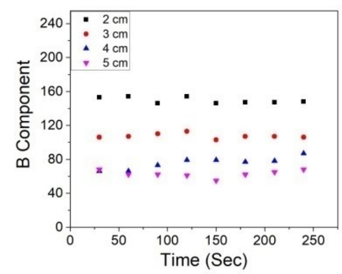


Figure 6: Flow chart describing the algorithm

IV. RESULTS AND DISCUSSION

The TCS230 is a very sensitive to the light condition and distance. Therefore, a detailed study of the influence of distance has been carried out by taking multiple samples with a period of 30 seconds. This study was carried out with papers of different colors, such as Green, Blue, Orange and Yellow, as illustrated in Fig. 4(a) and (b) in previous section. The results in terms of R, G and B components of the resulting RGB data is summarized in Table-I.

Table-I: The results of calibration experiment performed on objects (papers) of different colors

<table>
<tr><th></th><th>R component</th><th>G component</th><th>B component</th></tr>
<tr><td>Red Object</td><td>
</td><td>
</td><td>
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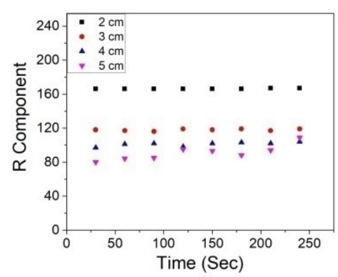
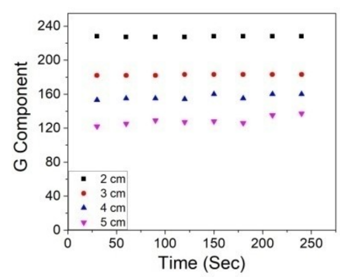
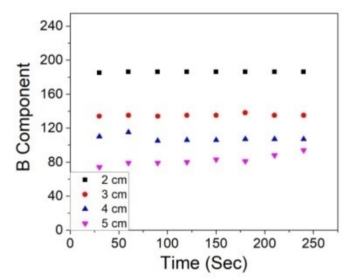
<tr><td>Green Object</td><td>
</td><td>
</td><td>
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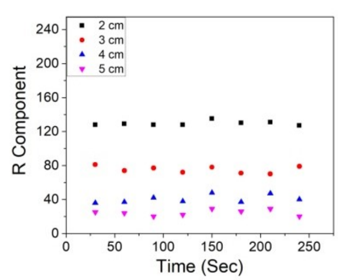
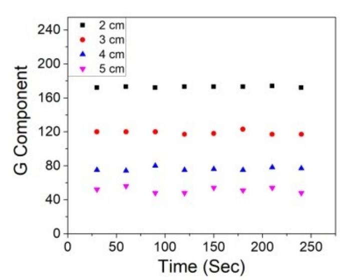
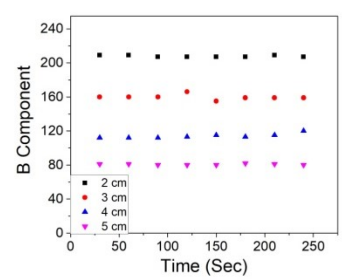
<tr><td>Blue Object</td><td>
</td><td>
</td><td>
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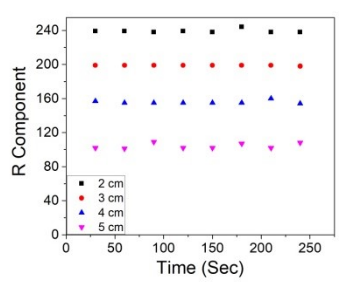
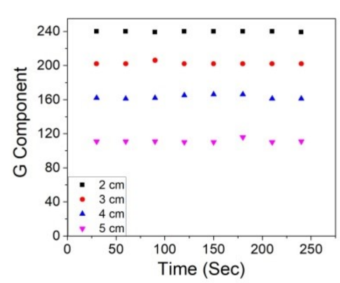
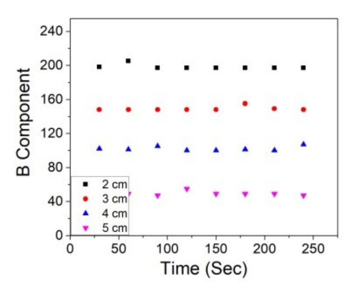
<tr><td>Yellow Object</td><td>
</td><td>
</td><td>
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Based on the RGB data, the corresponding wavelengths have been computed for each sample. The averages of the computed wavelengths along with the standard deviations in the results are summarized in Table-II for respective objects.

Table-II: Wavelength and standard deviation obtained for different colored papers with varying distances.

Object color	Wavelength attributes	Distance between object and sensor (cm)			
		2	3	4	5
Green	Mean (nm)	576.18	577.19	579.92	585.83
	Standard deviation (nm)	0.16	0.32	1.54	1.80
Orange	Mean (nm)	507.91	619.55	618.15	617.03
	Standard deviation (nm)	0.76	0.46	0.72	0.97
Blue	Mean (nm)	554.88	554.22	553.60	553.52
	Standard deviation (nm)	0.24	0.70	0.73	0.69
Yellow	Mean (nm)	600.80	599.84	598.89	598.92
	Standard deviation (nm)	0.80	0.43	0.97	0.92

It may be inferred from the table-I and table-II that increasing the distance beyond 3 cm results in more scatter in the data. At small distance of 2 cm we get small scatter in the data but the wavelength accuracy is less. Therefore, based on this experiment, we conclude that 3 cm distance is the optimum distance to measure the wavelength of a light source. The further experiments of determining the wavelength of incoming light have therefore been conducted by keeping the distance of 3 cm from sensor to light source in dark room as shown in Fig 7. The experiments on different colored visible light sources of known wavelengths have been conducted and the results are depicted in Fig. 8. The extracted wavelengths of the multiple samples of the light with time interval of 30 seconds have been recorded. Based on the mean and standard deviation of the data, 99.5% confidence intervals of the measured wavelengths of different light sources have been computed that are shown in Table-III. The deviation from the expected values of the wavelength may be attributed to the measurement inaccuracy and the fact that all combinations of R, G and B do not have unique equivalent wavelength and the conversion from RGB values to wavelength itself has some error. Thus, within the reasonable and acceptable error, we could perform the wavelength measurement of the light sources.

Table-III: The 99.5% confidence interval of the measured wavelengths of different colored light

Light source	Verified wavelength (nm)	Measured Wavelength Range (nm)
Cyan LED	520	558.66 - 561.68
Green LED	570	569.38 - 576.18
Yellow LED	590	605.96 - 607.11
Sodium Lamp	589	600.34 - 620.04

Figure 7: Experimental setup for determining the wavelength of light sources

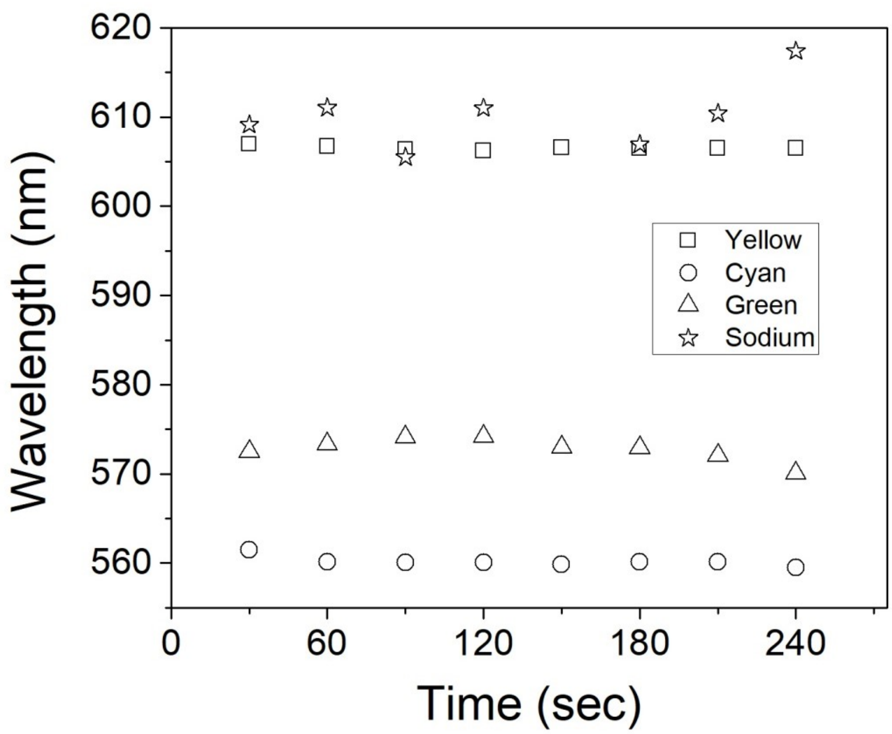

Figure 8: Samples of extracted wavelengths of different light sources kept 3 cm apart from sensor

V. CONCLUSIONS

We have demonstrated the color sensing in our laboratory using Arduino based compact and rugged color sensor. We have calibrated the sensor with the colored objects and then used the calibrated algorithm to determine the wavelengths of the visible light sources of different colors. This type of arrangement can be utilized for a variety of low cost color sensing applications.

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