March 9th, 2011

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Design Specification for Color Deficiency Aid Device *ColorAid*

Dear Dr. Rawicz:

The Alnair Innovations document attached describes the actual implementation of the color deficiency aid device, *ColorAid*. The document includes the methods of design and choices made.

We are currently developing a handheld device that can determine colors of objects. The device can be used for people of varying occupational and personal needs, above all, by those with color deficiency. We are designing and implementing a device that will sense and alert colors in question to the user, to help the user better communicate with the surrounding world. *ColorAid* will minimize the need to ask for help when questioning regarding colors.

The purpose of this design specification is to have clear objectives and specific requirements set in place so as to enhance the product development process. Every constituents of the company will refer to the document to help them guide along the project.

Alnair Innovations consists of five students with backgrounds in engineering physics and electronics engineering: Arash Ahmadi, Henry Chan, Jun Hong, Claret Ramos and William Seo. For further inquires about our company and proposal contact our CEO Claret Ramos via email at ckr@sfu.ca, or by phone at (604) 839-9322.
Sincerely,

Claret Ramos
Chief Executive Officer
Alnair Innovations

Enclosure: *Design Specification for Color Deficiency Aid Device ColorAid*

# DESIGN SPECIFICATION FOR COLOR DEFICIENCY AID DEVICE
## *COLORAID*

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## Executive Summary

Colorimetry is the science that specifies the color of physically defined visual stimulus numerically when viewed by an observer with normal color vision [1]. The need to communicate colors gave rise to the CIE color system, which characterizes colors through tristimulus values, representing all the colors visible to humans [1]. The use of this knowledge can help us design systems to aid those with color deficiencies, which is inability to distinguish hues of colors and possibly to even recognize color at all. Alnair Innovation's product *ColorAid* seeks to give color support by displaying on an LCD the name of the color of the objects sampled with a high sensitivity reflective color sensor.

This document will provide detailed information about the design specifications of the product. From the proof-of-concept to final production, these requirements are needed to identify the design goals and verify the functionality of the device. The design specification provides not only justification for the design choices made, but also is means of ensuring and assessing that all requirements have been met.

Our device consists of three main units: the color sensing unit, the central control unit and the user interface unit. Avago ADJD-S311 digital color sensor is the main component of the sensing unit; it converts the light reflected from the surface of objects into RGB values by means of filter coated photodiode array. The user will visualize the process data by means of a mini color LCD screen, and it will operate the device by means of three push buttons. They will allow the user to toggle through the menu, access different options and go back. The central control unit will control interaction between the two units.

*ColorAid* is intended to be used by individuals that need help with distinguishing colors. The prototype will not only display in text the name of the color, but it will also display the RGB values of the color detected. It will also enable the user to save the color sampled, allowing them to access this information at any time. The final device will also provide *ColorWizard* application, which will give assistance with color matching. The application will allow the user to view the name and RGB values of the analog, complementary and triad components of the color sampled.

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## Glossary

**CPU**    Central Processing Unit

**CS**    Chip Select

**DIO**    Digital Input Output

**GND**    Ground

**HEX**    Hexadecimal

**LCD**    Liquid Crystal Display

**LED**    Light Emitting Diode

**MCU**    Microcontroller Unit

**RBG**    RGB color model (Red, Green, Blue)

**SCL**    Serial Interface Clock

**SDA**    Serial Data

**SCK**    Serial  Clock

**TWI**    Two wire Interface

**XCLK**    External clock input

**XRST**    Reset Pin

# 1. Introduction

*ColorAid* is a device that detects colors. The device first senses the color of surface in question, then outputs the obtained data in a recognizable format to those who have difficulty recognizing the color by mere visual inspection of the surface. *ColorAid* provides the accuracy for those who need precision of color, and the recognition for those who have color deficiency. The device would be square shaped, with a sensor at one corner and an LCD on a surface. The name of the color and the RGB values would be displayed on the screen. The actual implementation requirements for *ColorAid,* as proposed by Alnair Innovations, are described in this design specification.

The sensor has capability to store the color read in a 30-bit format, meaning recognition of over 1 billion different colors.

## 1.1. Scope

This document outlines the design requirements that must be met by a functioning *ColorAid* and explains how the design meets the functional requirements as described in *Functional Specification for Color Deficiency Aid Device Coloraid* [2]. The design specification includes all the requirements for a proof-of-concept system and a portion of the requirements for the final production model. Only the functional requirements labeled I or II will be considered.

The overall system consists of three major portions, the color-sensing unit, the central control unit, and the user interface unit. In the color-sensing unit section, electronic design, sensor specifications, and light source specifications will be discussed. In the central control unit section, the use and the specifics of the microcontroller, and the control software will be discussed. The user interface portion of the document will detail specifics for the display unit used.

## 1.2. Intended Audience

The design specification is intended for the use by the members of Alnair Innovations. The chief executive officer shall refer to the design requirements as a concrete measure of progress throughout the development phase. Our hardware officers and software officers shall refer to the requirements as the overall design goals to be kept in mind during the implementation process. This document shall again be used to assist with the assessment of the produced device. This document will be used to aid in the design of user test trials.

## 2. System Specifications

*ColorAid* will detect the color in question and alert the user by displaying the name of the color. The device will detect the color of the surface where the sensor is on, upon requested by the user through the push of a button. The user will also have options to save, delete, and view RGB values.

## 3. Overall System Design

An overview of the system design will be discussed in this section. The main goal that Alnair Innovations Inc. wants to achieve is to provide a convenience platform for people to identify colors. A system block diagram showing the inputs and outputs along with the relationship is described in Figure 1.
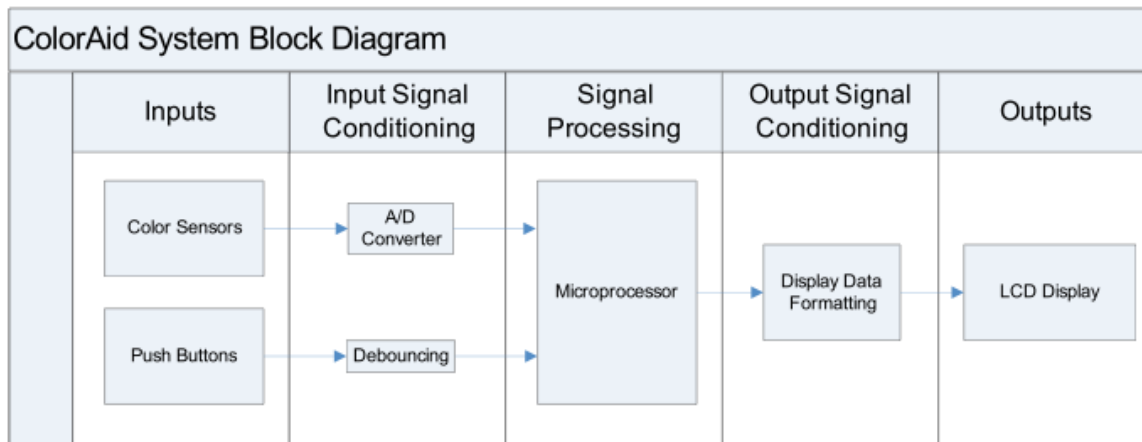


**Figure 1 System Block Diagram**

There will be two types of inputs including the color sensors and the push buttons. These inputs will be generating signals which will then be conditioned for processing. During the input signal being conditioned, the signals will undergo process through the A/D conversion and debouncing stages. After the signals have been conditioned, they will be fed into the signal processing stage.

The data sent to the signal processing stage will be processed by the microprocessor. The LCD data is first formatted in the output signal conditioning stage. After the process, the formatted LCD data will be transmitted to the LCD display and the user will be able to see changes on the LCD display according to the inputs.

# 4. Central Processor Unit

## 4.1. Overview

The central processing unit (CPU) takes serial data from the sensor unit and sends processed data to the user interface unit to display (LCD). ATmega2560 is used for our project to meet the design criteria.

## 4.2. MCU Criteria

The microcontroller unit (MCU) has to read the serial data from the sensor unit and send the parallel data to the user interface unit. The MCU requires faster data transfer rate than the sensor, and enough number of output pins to connect to the display unit of the user interface unit. Since the data will be saved on the MCU, the storage capacity is also considered in the choice of the MCU. In summary, these factors are considered:

Data Storage: Enough space to store the result of color reading and the instruction code

I/O Interface: More than 20 digital connections to make the display, the sensor and the switch connections

$I^2C$: support $I^2C$ (TWI) communication to interact with ADJD-S311 RGB digital color sensor

Transfer Rate: Equivalent or faster than the serial data transfer rate of 100kbit/s

## 4.3. Arduino Mega 2560

Arduino Mega 2560 is a microcontroller board based on ATmega2560. It has 54 bidirectional digital pins, 16 analog input pins, a two-wire serial pin and a 16MHz crystal oscillator. There are two power options: USB powered and external DC voltage supply with the range between 7 to 12V. The on board memory size is 256KB along with 8KB SRAM and 4KB EEPROM. The Clock frequency is 16MHz. For the two-wire interface connection, ATmega2560 can transfer data up to 400kbit/s [3]

There is Arduino software for Arduino board. The software language is compatible with C language. After the compilation, Arduino board can be downloaded with the instruction through the USB port connection.

## 4.4. I/O Pin Connections

All the signals from the sensor unit and the user interface unit are digital signals. The output of the SDA is again, a series of digital signal. The connection lay out diagram can be seen in figure 2 below. There are three blocks, sensing, control and displaying blocks.
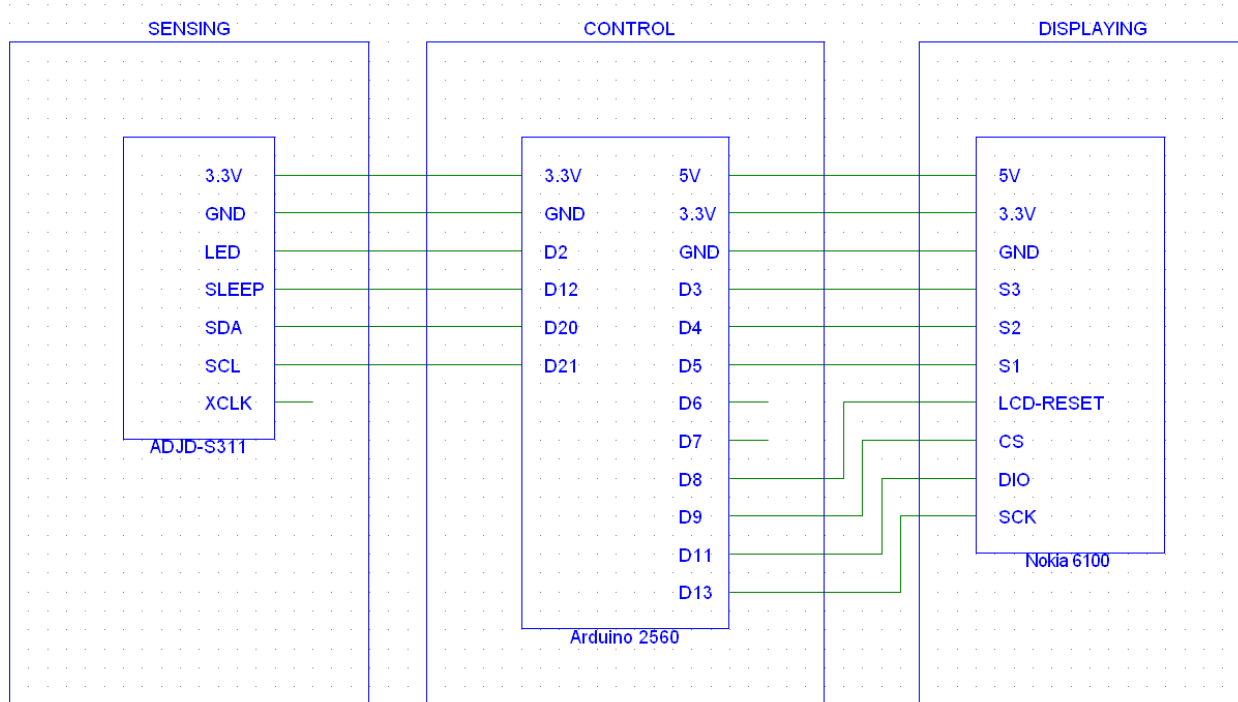


**Figure 2 Pin connection of Arduino 2560**

### 4.4.1. MCU to the Sensor unit Connection

The 3.3V pin supplies power to the sensor unit. The reference GND is connected to GND of the sensor unit. The pin labelled D2 in figure 2, Digital 2, controls the sensor LED. The sensor unit can be in the sleep mode by setting SLEEP to low. The pin D12 controls sleep mode of the sensor. The pins D20 and D21 are designated for TWI connection.

### 4.4.2. MCU to the User Interface unit Connection

The user interface unit requires two different voltage levels, 5V and 3.3V. The power pin is connected as shown in figure 2. The pins S1, S2, S3 of the display unit are for the push button switches mounted on the display. The pins D3, D4, D5 are connected to the pins S3, S2, S1 respectively just for the testing purpose. Later these pin connections will be replaced by the

push button switches. The DIO of the display unit is bidirectional data in/out controlled by CS. The SCK is the external signal clock terminal. Arduino pins 9, 11, and 13 are connected to CS, DIO, SCK respectively.

## 4.5. Instruction Flowchart

Arduino code template provided by the manufacturer consists of the initial setup of the microprocessor and simple loop state.

In the setup state, the global variables are defined and *ColorAid* logo is displayed on the screen. After the setup, the system loops through various system menus indefinitely until the interrupt event occurs. Figure 3 shows the sequences after the boot up and of the menu selection.
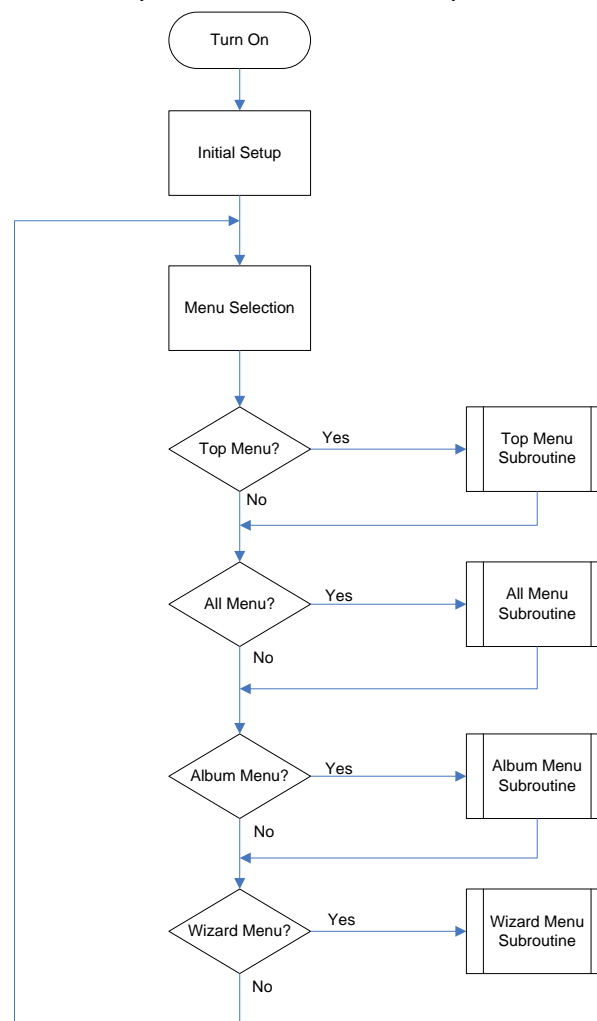


**Figure 3 Overall menu flow chart**

Once the process ends up in one of the subroutines, appropriate function will be called to perform various actions required to capture the color of the object and to display the name of the color and the color of the object on the screen. Figure 4 shows an example of the operation of one of the subroutines, Top Menu Subroutine. The top menu subroutine always ends up in the sample function or in the album menu function since the top menu is part of the boot up sequence.
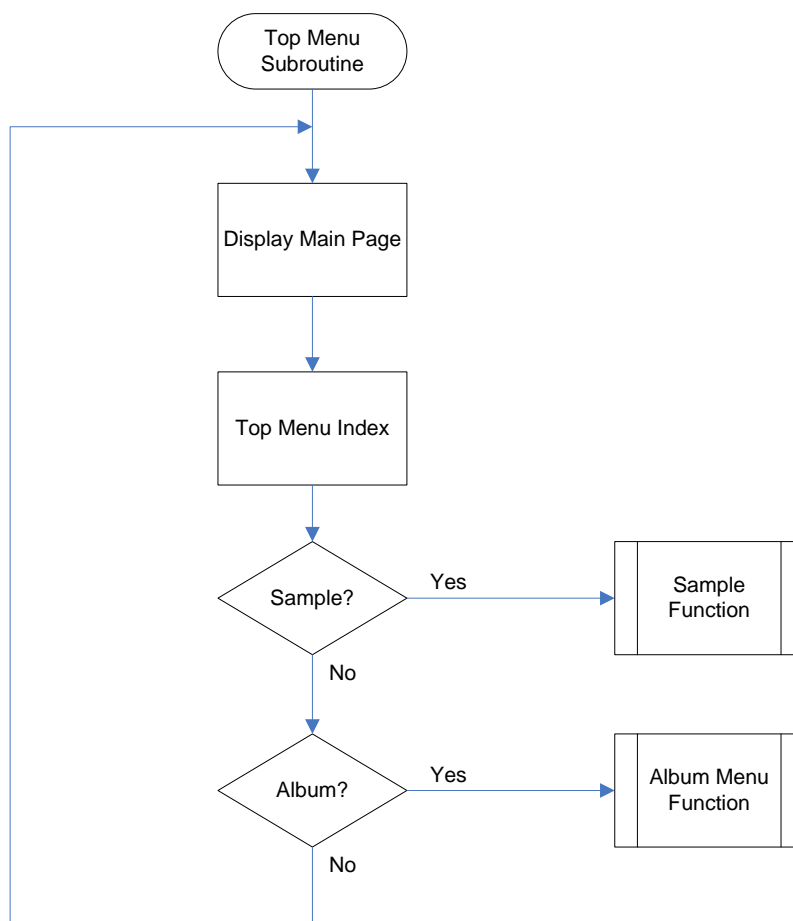


**Figure 4 Top menu subroutine**

## 4.6. Bit Scaling

In order to read color and display the color without any discrepancy, both the sensor unit and the user interface unit need to have a same color convention. However, the sensor, ADJD-S311 and the display screen, Nokia-6100 have different color scale. The color data from the sensor

are of the data length of 40 bits: 10 bits for red, 10 bits for green, 10 bits for blue and 10 bits for clear, whereas the display screen only accepts 12 bits of data length: 4 bits for red, 4 bits for green and 4 bits for blue (there is no clear bit to display). To accommodate both units in the overall integration process, an arithmetic scale down from 10 bit to 4 bit will be implemented in our code just before saving the color data.

## 4.7. Color Table Chart

After the scaling of the data from the sensor, a color chart that matches a digital value to a color will be used to determine the color of the object. Table 1 shows a few basic color definitions in 12 bit hexadecimal number.

Table 1 12 bit color definition

| COLOR | RGB (HEXADECIMAL) |
|---|---|
| White | FFF |
| Black | 000 |
| Red | F00 |
| Green | 0F0 |
| Blue | 00F |
| Cyan | 0FF |
| Magenta | F0F |
| Yellow | FF0 |
| Brown | B22 |
| Orange | FA0 |
| Pink | F6A |

## 5. Color Sensing Unit

## 5.1. Overview

The color sensing unit is responsible for the actual color detection. The main component of this portion of the device is ADJD-S311-CR999 RGB digital color sensor module. This device operates via reflective color sensing, which means that the color sensor will detect the light reflected from the surface of the object sampled in order to recognize the color.

## 5.2. Avago ADJD-S311-CR999 RGB Digital Color Sensor Module

ADJD-S311-CR999 is a miniature surface mount device (SMD) with four channel integrated light to digital converter for RGBC (Red, Green, Blue, and Clear) and an integrated LED. Figure 5 is the functional block diagram of the sensor module [3].
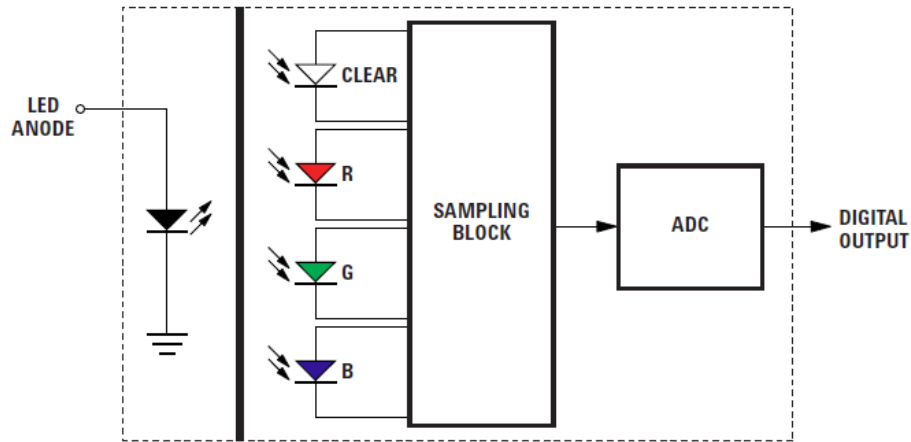


**Figure 5 ADJD-S311_CR999 Functional Block Diagram [4]**

Each channel (RGB and C) has 10 bit output resolution. Figure 6 shows the color sensor, along with its components, and its physical dimensions (3.9 x 4.5 x 1.8 mm) from the side and from the top [3]. Table 2 shows the pin assignment of ADJD-S311-CR999. Figure 7 shows the actual location of the pins on the sensor.
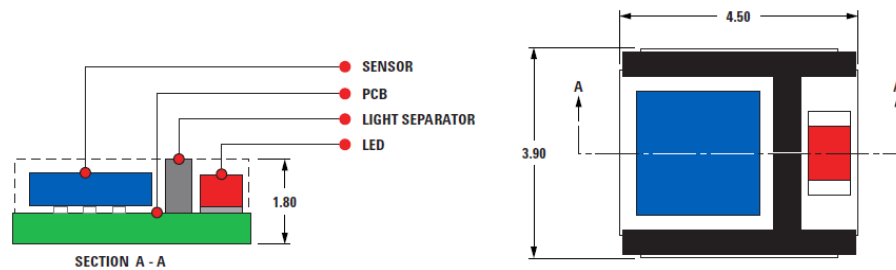


**Figure 6 ADJD-S311_CR999 device and Dimensions in mm [4]**
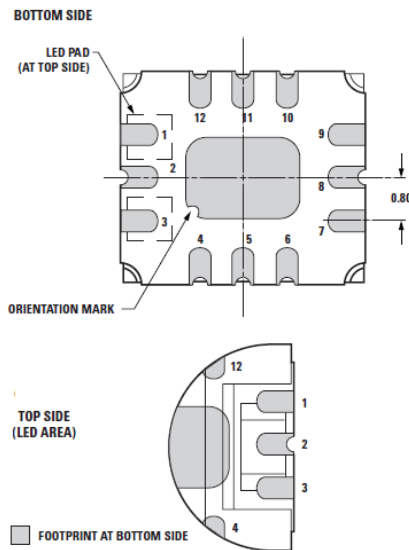
**Figure 7 Pin Assignment [4]**

| Pin | Name | Description |
|-----|------|-------------|
| 1 | LED_VE | LED Cathode |
| 2 | NC | No Connection |
| 3 | LED+VE | LED Anode |
| 4 | SDA | Bidirectional Serial Data Pin |
| 5 | DVDD | Digital Power On |
| 6 | SCL | Serial Interface clock |
| 7 | AVDD | Analog Power On |
| 8 | SLEEP | Sleep (active high) |
| 9 | AGND | Analog Ground |
| 10 | XRST | Reset |
| 11 | DGND | Digital Ground |
| 12 | XCLK | External clock input |

Avago's ADJD-S311-CR999 color sensor module specifications are found in the following tables. Table 3 shows the electrical specifications for the absolute maximum ratings. Table 4 shows DC electrical over recommended operating Conditions. Table 5 shows the minimum sensitivity of the sensor.

**Table 3 Electrical Specifications Absolute Maximum Ratings**

| Parameter | Symbol | Minimum | Maximum | Units |
|---|---|---|---|---|
| Storage Temperature | $T_{STG\_ABS}$ | -40 | 85 | °C |
| Digital Supply Voltage, $D_{VDD}$ to $D_{VSS}$ | $V_{DDD\_ABS}$ | 2.5 | 3.6 | V |
| Analog Supply Voltage, $A_{VDD}$ to $A_{VSS}$ | $V_{DDA\_ABS}$ | 2.5 | 3.6 | V |
| Input Voltage | $V_{IN\_ANS}$ | 2.5 | 3.6 | V |
| Human Body Model ESD Rating | $ESD_{HBM\_ABS}$ | | 2 | kV |

**Table 4 DC Electrical Over Recommended Operating Conditions**

| Parameter | Symbol | Minimum | Typical | Maximum | Units |
|---|---|---|---|---|---|
| Supply Current | $I_{DD\_STATIC}$ | - | 3.8 | 5 | mA |
| Sleep-Mode Supply Current | $I_{DD\_SLP}$ | - | 2 | - | µA |
| Input Leakage Current | $I_{LEAKS}$ | -10 | - | 10 | µA |

**Table 5 Minimum Sensitivity**

| Parameter | Symbol | Conditions | RGBC | Minimum Sensitivity | Maximum Sensitivity | Unit |
|---|---|---|---|---|---|---|
| Irradiance Responsivity | Re | $\lambda_p$= 460 nm | R | 152 | 3796 | LSB/(mW cm$^{-2}$) |
| | | $\lambda_p$= 542 nm | G | 178 | 4725 | |
| | | $\lambda_p$= 645 nm | B | 254 | 6288 | |
| | | $\lambda_p$= 645 nm | C | 264 | 6590 | |

The sensor module has wide sensitivity coverage of 0.1 klux – 100 klux. Figure 8 shows the spectral response when the gains for all the color channels are set equal [3]. As described in Table 5, the peaks for red, green, blue and clear are 460 nm, 542 nm, 645 nm and 645 nm respectively. Also notice that the spectral response of the sensor is favorable since it has a wide bell shape.
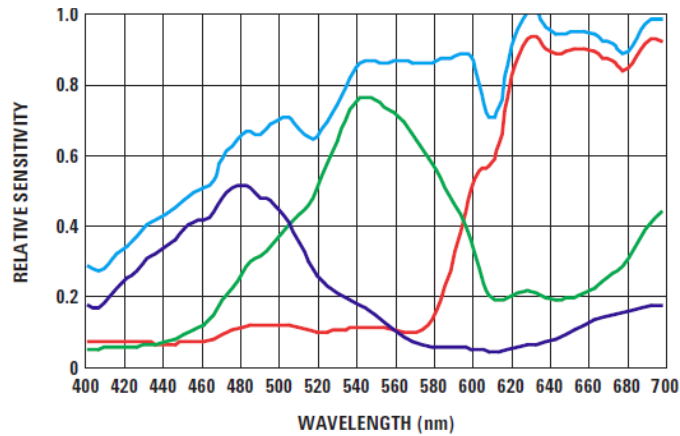
**Figure 8 Spectral response when the gains for all the color channels are set equal [4]**

ADJD-S311-CR999 color sensor module operates with 2-wire serial communication, which allows the chip to interface with the central processing unit. The bus consists of a serial clock (SCL) and a bidirectional serial data line (SDA). The sensor module acts as the slave, while the Arduino microcontroller acts as the master.

In order to set the gain of each channel, the module provides two independent gain parameters that can be adjusted: number of capacitor and integration time. Table 6 has show the addresses of the registers reserved for these parameters. The number of capacitor controls the number of capacitors selected for each channel, and it can be set up with values raging from 0 to 15 (The higher the number of capacitor, the lower the sensitivity). The integration time slots can be setup from 0 to 4095 (low integration times corresponds to low time to sense, as longer time will result more photons to be sensed). These two parameters are adjusted through the sensor calibration process.

**Table 6 Gain Setting Registers**

| Address (Hex) | Register | Description |
|---|---|---|
| 6 | CAP_RED | Number of red channel capacitors |
| 7 | CAP_GREEN | Number of green channel capacitors |
| 8 | CAP_BLUE | Number of blue channel capacitors |
| 9 | CAP_CLEAR | Number of clear channel capacitors |
| A | INT_RED | Number of red channel integration time slots |
| C | INT_GREEN | Number of green channel integration time slots |
| E | INT_BLUE | Number of blue channel integration time slots |
| 10 | INT_CLEAR | Number of clear channel integration time slots |

In order for the sensor to acquire digital values of the light reflected from the object surface, the master uses the Control register CTRL (address 0x00). To activate the sensor, the control register must be set to 01 hex. The sensor module will then acquire digital data and store it in the 10 bit data registers for each channel, and once this process is completed the register will read 00 (which indicated data is ready to be read from the Data registers). Addresses 40H to 47H correspond to the data registers as shown in table 7.

**Table 7 Channel ADC Data Registers**

| Address (Hex) | Register | Description |
|---|---|---|
| 40 | DATA_RED_LO | Red channel ADC data  – low byte |
| 41 | DATA_RED_HI | Red channel ADC data  – high byte |
| 42 | DATA_GREEN_LO | Green channel ADC data – low byte |
| 43 | DATA_GREEN_HI | Green channel ADC data – high byte |
| 44 | DATA_BLUE_LO | Blue channel ADC data  – low byte |
| 45 | DATA_BLUE_HI | Blue channel ADC data  – high byte |
| 46 | DATA_CLEAR_LO | Clear channel ADC data  – low byte |
| 47 | DATA_CLEAR_HI | Clear channel ADC data  – high byte |

## 5.3. Sensor Operation

ADJD-S311 color sensor module needs to execute two main procedures for correct sampling of color and they are: sensor gain optimization procedure and sensor operation procedure.

### 5.3.1. Sensor Gain Optimization Procedure

The gain optimization procedure is executed in order to select and set the gain values for each channel that will result in correct reading of the color. This is done using a special sorting algorithm that will allow rapid finding of the optimum value of gain for the calibrating source with known data of repeatability and stability.

First a value of the gain is assigned, then the color of the object is acquired and the digital values are stored in the data registers. An optimum digital value must not exceed 1000. If the value exceeds 1000, new gain must be selected and new sampling must be done.

When executing this calibration procedure, the module's LED must be turned on and a light source of known RGB values must be used. Another way of calibrating is by placing a white surface in front of the sensor module and executing the Gain Optimization Procedure, instead of using a continuous light source. Figure 9 shows the flow chart of the optimization procedure.
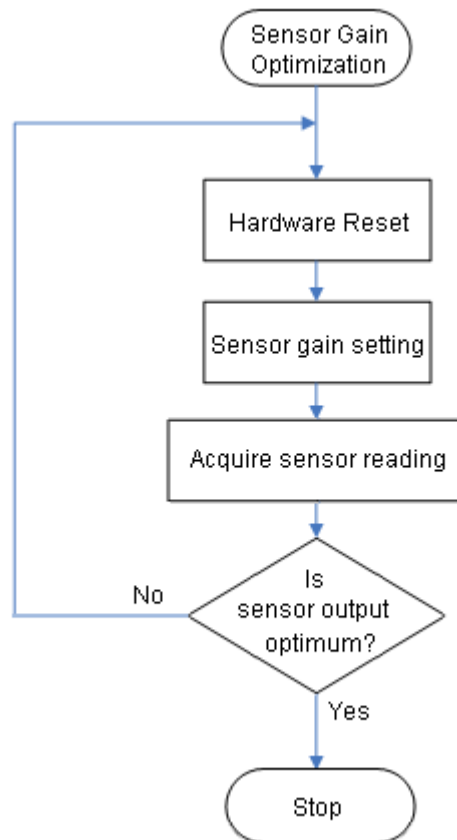
**Figure 9 Sensor Gain Optimization Procedure [5]**

## 5.3.2. Sensor Operation Procedure

Once the calibration is successfully completed for the optimal gain, the sensor operation procedure is implemented. First, a power on reset is executed, setting all registers to zero. Then the values of integration time and number of capacitor for each channel obtained in the optimization procedure are stored in the corresponding registers. In order to obtain the data of the normal operation environment, an offset sampling is executed with the light source turned off. The offset data is automatically stored in the 8 bit OFFSET registers for each channel (address 47 hex to 4B hex). Figure 10 shows the flow chart of the sensor operation procedure.
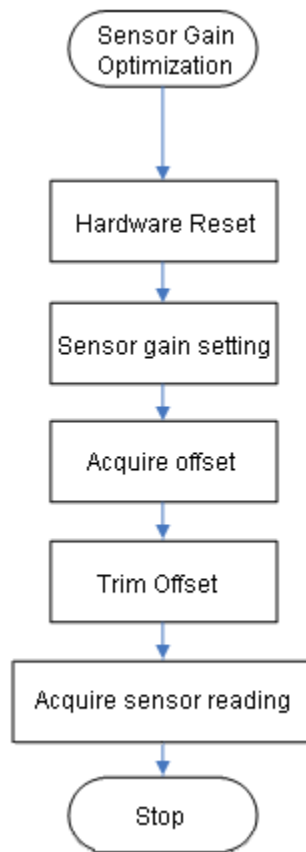
Figure 10 Sensor Operation Procedure [5]

## 5.4. Color Sensor Circuit Implementation

ADJD-S311CR999 circuitry design for its use can be in figure 11 below. Arduino microcontroller will then communicate to the sensor module through the following inputs, found in table 8.

Table 8 Input of Color Sensor Board

| Input Pin | Description |
|---|---|
| SDA | Bidirectioanl Serial Data Pin |
| SCL | Serial Interface Clock |
| SLEEP | Sleep (active high) |
| XRST | Reset Pin (active high) |
| XCLK | External Clock Input |

Figure 11 Color Sensor Circuit Implementation

The PCD board shown in figure 11 will be placed at the upper side of the device. The color sensor module must be placed at a distance of approximately 2 to 3 mm away from the surface of the object to scan as shown in figure 12.
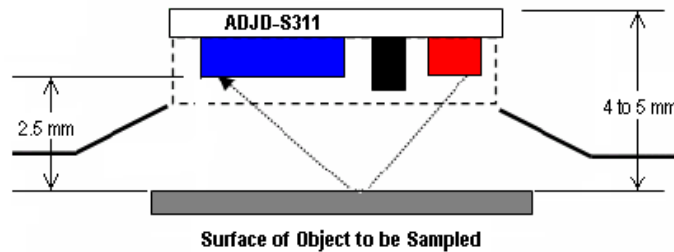


Figure 12 Distance of operation [4]

# 6. User Interface

## 6.1. Overview

The user interface unit consists of a power switch, a color LCD, and three push-buttons. The power switch is used to turn the unit on or off. The color LCD is the main feature for the interaction between the user and the per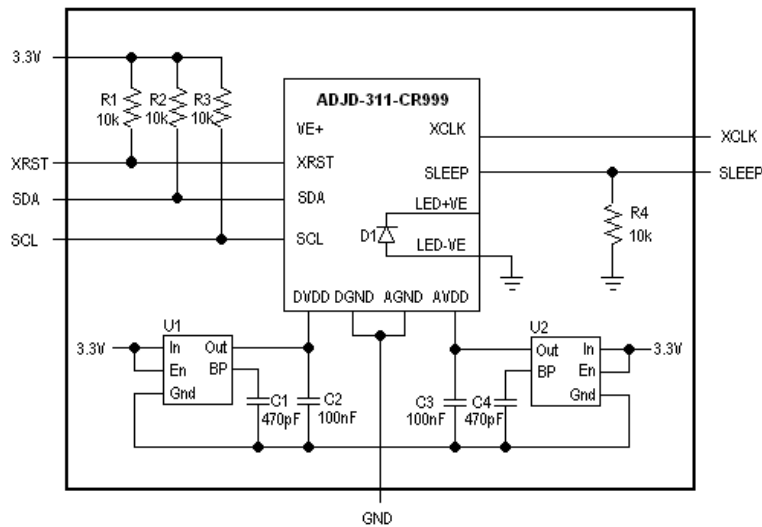ceived data. The color LCD displays the menu to allow the users to choose different options such as sampling the color of an object, accessing the album of saved colors, reviewing the color data, and etc. The three push-buttons are the following: "OK" button, "MODE" button, and "BACK" button. "MODE" button is used to toggle between different options. "OK" button is used to select the desired option in order to either execute a command or step into a sub-menu of choices. "BACK" button is used to go back to the previous menu.

## 6.2. User Interface Hardware

### 6.2.1. Power Switch

A single pole, single throw (SPST) rocker switch is used as the power switch of the device. SPST rocker switches are popular on-off switches due to their simplicity, light weight, and low cost. The switch dimensions and circuit diagram are shown in figure 13 and figure 14 respectively:



Figure 13 SPST Rocker Switch Dimensions in mm [6]

Figure 14 SPST Rocker Switch Circuit Diagram

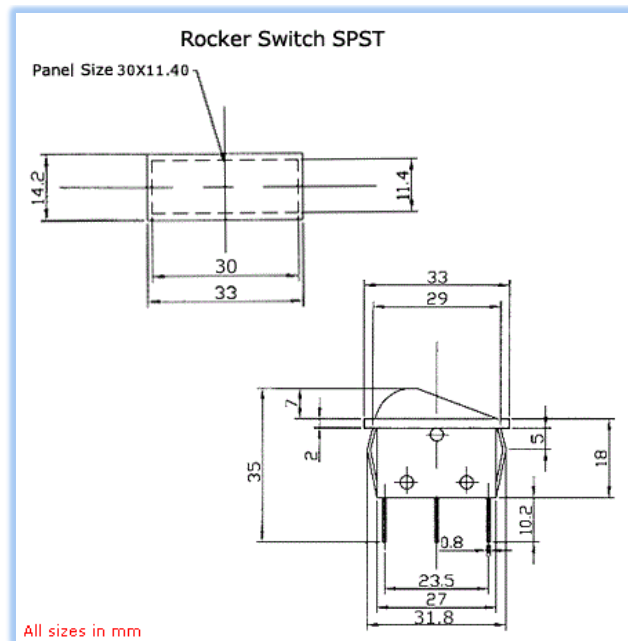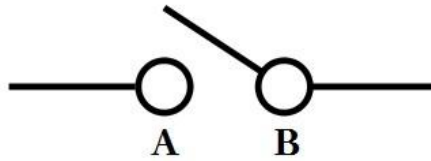The SPST switch has two sides as shown in figure 14: when two white dots are connected, it means "on" and when they are not connected, it means "off". This implies the switch has two states: on, and off. The initial state of the power switch is "off," where it creates an open loop circuit within the device's circuit. As soon as the user presses down the switch, B terminal will be shorted to A terminal and a closed loop circuit will be created to power on the device. Each state will be active by just pressing the switch once on its desired side.

## 6.2.2. LCD

Nokia-6100 LCD is used as the display unit for interaction between the user and the device. The LCD displays a list of options in color to the user to choose from. This LCD is power efficient and compatible with Arduino microcontrollers.

This LCD has 132 × 132 pixels, where each pixel has 12-bits color (4 bits for red, 4 bits for green, and 4 bits for blue). 12-bit color coding allows us to display 4096 different colors on the LCD. However, due to poor contrast and resolution of the LCD, it will be very difficult and pointless to distinguish some similar colors from each other. For example, it will be very difficult to distinguish the following two colors from each other (The following RGB values are in binary):

Case1: Red = 1000, Green = 1000, Blue = 1000

Case2: Red = 1000, Green = 1000, Blue = 1001

Therefore, we have decided to create a library that displays 64 colors on the LCD.
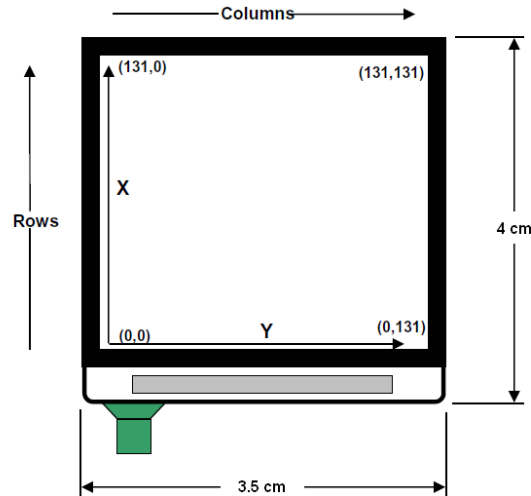
Figure 15 shows the physical dimensions of Nokia 6100 LCD. The LCD is connected to the microcontroller through 9 pins, where 5 pins are used to transfer data from the micro-controller to the LCD and 4 pins are used for power connection. A complete pin assignment for data transferring can be seen in table 10 with its corresponding diagram in figure 16.

**Table 9 Data Pin Assignment**

| Digital Data Pin | Symbol | Name | Function |
|---|---|---|---|
| D8 | RES | Reset | LCD Reset (set to low to reset) |
| D9 | CS | Chip Select | LCD chip select (set to low to select the LCD chip) |
| D11 | DIO | Data I/O | SPIO_MOSI Master Out – Slave In pin (Serial Data to LCD slave) |
| D12 | VOLCTR | Backlight | Backlight control (normally PWM control, 1 = full on) |
| D13 | SCK | Serial Clock | SPIO_SPCK Serial Clock (to LCD slave) |
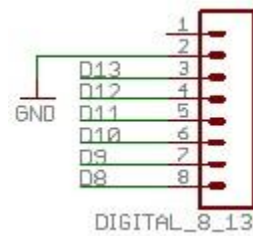
Figure 16 Data Pin Assignment [8]

This LCD uses a two-wire serial SPI interface and is connected to the microcontroller through a 9-bit SPI serial interface (clock/data signals). The microcontroller SPI peripheral generates the clock and data signals, and the display acts solely as a slave device. The ninth bit of SPI serial interface indicates whether a command byte or a data type is being transmitted. Although the SPI interface can be run at 16MHz, but it is safe to run it at 6MHz since the board's master clock has a period of 166 nanoseconds. Figure 17 shows the diagram of SPI serial interface.
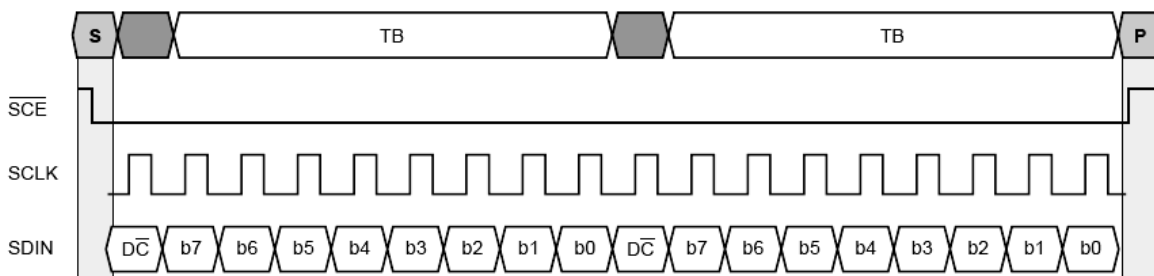


Figure 17 SPI Serial Interface for Nokia-6100 [7]

Since the operating voltage of the LCD is only 3.3V, it can be powered on through Arduino microcontroller. Pin 3V3 provides a maximum of 50mA to the LCD. A complete pin assignment for power connection can be seen in table 10 with its corresponding diagram in figure 18

**Table 10 Power Pin Assignment**

| Power Pin | Function |
|-----------|----------|
| **3V3** | Provides 3.3V by the on-board regulator |
| **5V** | The regulated power supply used to power the micro-controller and other components on the board |
| **GND** | Ground pin |
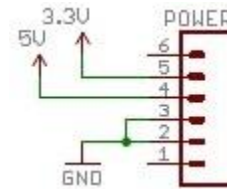


Figure 18 Power Pin Assignment [8]

## 6.2.3. Push-buttons

There are three push-buttons supplied for navigating through menus. They are "OK" button, "MODE" button, and "BACK" button. The "MODE" button is used to toggle between different options and the "OK" button is used to select the desired option in order to either execute a command or step into a sub-menu of choices. The "BACK" button is used to go back to the previous menu. These push-buttons are small, cheap, and have a life time of at least 100,000 cycles.

As shown in figure 19, when a button is pressed, terminals 1 and 2 will be shorted with terminals 3 and 4, respectively. As soon as the button is released, it returns to its original state. The three push-buttons share the same board as the LCD and they are tied through a jumper to pins D3-5 of the board. A complete pin assignment for push-button connections can be seen in table 11 with its corresponding diagram in figure 19, where S1, S2, and S3 serve as the "BACK", "MODE", and "OK" buttons respectively.

**Table 11 Push-Button Pin Assignment**

| Digital Data Pin | Symbol | Name | Function |
|------------------|--------|------|----------|
| **D3** | S3 | "OK" Button | Serves as confirming a choice from the menu |
| **D4** | S2 | "MODE" Button | Toggles between choices in the menu |
| **D5** | S1 | "BACK" Button | Goes back to the previous menu |

## 6.3. User Interface Menu

Once the device is turned on, the company logo will be displayed first, then the main menu appears after three seconds. While in the main menu, the user can toggle between five different sub-menus to choose the desired option. The five different sub-menus are the following: Sample, Album, Color, Save, and Wizard (Wizard option not included in prototype).

### 6.3.1. Sample

When in the sample menu, the user can point the device at the desired object and sample color by pressing the "OK" button. The system will call the function in charge of color calibration and color sensing immediately. Once the color is sampled, it will make this information accessible so the LCD can show the color name on the screen with its corresponding RGB values. At this point the user has the option to either save the sampled color or discard it. If the user decides to save the sampled color, then it will be automatically saved in the Album. Figure 20 shows current LCD display of Sample option (still in development).



Figure 20 LCD displaying Sample Option

### 6.3.2. Album

Album is a place where the user can save up to 5 sampled colors. At this menu the user can view or delete any of the sampled colors. Figure 21 shows current LCD display of Album option (still in development).



Figure 21 LCD displaying Sample Option

### 6.3.3. Color

Color menu is a library of various colors. At this menu the user can get familiar with different color names and view corresponding RGB values if needed. Figure 22 shows current LCD display of Color option (still in development).



**Figure 22 LCD displaying Color option**

### 6.3.4. Save

This option allows the user to store the color information of the sampled object. Figure 23 shows current LCD display of Save option (still in development).



**Figure 23 LCD displaying Save option**

### 6.3.5. Wizard

The Wizard feature will not be included in our prototype but is one of the features for the final product of the device. This option is a Color Wizard which will allow the user to view different options for color matching. This is a useful feature sine most of us have a hard time color matching, especially if the user is colorblind. The Wizard option provides three types of color matching: Analog, Complementary and Triad.

**Analog:** Analog colors are those that lie on either side of any given color. Analog colors are harmonious and give a natural feel.

**Complement:** Complementary colors those located opposites in the color wheel. They are contrasting and usually used to highlight.

**Triad:** Triad colors are three hues equidistant in the color wheel, which provide a balanced and colorful combination of colors.
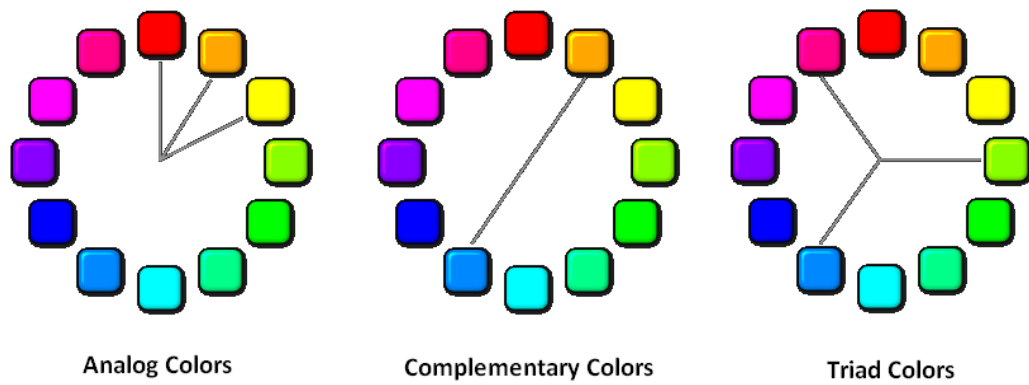
**Analog Colors**　　**Complementary Colors**　　**Triad Colors**

**Figure 24 Color Wheel pointing Color Combination: Analog, Complementary and Triad Colors [9]**

# 7. System Test Plan

## 7. 1. Objective

The main goal of having a system test plan is to ensure strong confidence and quality assurance of our device, *ColorAid*. To achieve as accurate and reliable performance data as possible, comprehensive testing in different areas will be performed throughout the development process.

In the development stage, tests will be conducted on different unit components to ensure accurate functionalities for the proof-of-concept device. In the proof-of-concept device, hardware test cases will also be required for the project demo. However, there will be very limited hardware requirements before all the components are being integrated into one device. Therefore, hardware testing will not be as comprehensive as the software testing in the development stage.

Some test cases are intended to be performed on the final product to ensure a trustworthy and reliable device, so they will not be conducted before the integration of different components occurs.

This test plan is not intended to restrict further testing; however, it is to ensure the prototype's performance and functionalities that were specified.

## 7.2. Approach

Through unit testing, individual components of *ColorAid* will be tested separately. The components will then be integrated into one, and the integrated device will be tested as a whole. Testing in the purpose of validation from the end users will also be performed.

The purport of unit tests conduction is to ensure that each individual component works as expected and performs its tasks reliably before the device is integrated. Members will be divided into teams to perform unit testing on different components on which they have contributed work. By splitting up into teams, members will have more time to spend on unit testing which they are familiar with.

After all the unit tests have passed on, every component, the subsystems will be integrated and eventually form a complete system. The connections between each subsystem have been established in a laboratory environment. With the complete system, the integration testing will be performed. All members will be involved in the integration testing, so as to enable their insights of different components to be optimized for troubleshooting problems that may arise.

Once the integration tests have passed, acceptance testing will be conducted. All members as well as their families and friends will be invited to participate in the acceptance testing. During the acceptance testing, the testers will not have detailed knowledge on how the device works; therefore, their advices and feedbacks will be unbiased after the usage of the product and developers can modify the product accordingly.

## 7.3. Unit Testing

Unit testing consists of the testing of the color sensors and the LCD screen. To perform tests of each subsystem, the steps below should be executed. All unit testings will be conducted under normal performing condition, which means normal atmospheric pressure, normal humidity, and room temperature.

### 7.3.1. Color Sensors

1. Connect the color sensors to the microprocessor.
2. Power up the subsystem.
3. Calibrate the sensor
4. Place the color sensors to an object once calibration is completed.

Expected Observation: The data read should be accurate in RGB readings

### 7.3.2. LCD Screen

4. Connect the LCD screen to the microprocessor.
5. Power up the subsystem
6. Push buttons to access each and every single one of the options available in the menu.

Before performing the above test steps, testers are allowed to pre-set RGB readings in order to access all screen designs since some pages are accessible only after the first sampling of data.

Expected Observation: Buttons should operate as intended and all pages should be displayed the respective pre assigned data.

## 7.4. Integration Testing

Before conducting the integration tests, all components will be connected in a laboratory environment; therefore, modifications on the connections can be performed to make correct connections between subsystems. Test steps that should be followed are listed below.

1. Connect every component together.
2. Power up the complete system.
3. Toggle through the menu using the three push buttons Mode, Ok and Back.
4. Ensure user can access each option and that they work accordingly:
   a. Sample Option: follow the instructions (place the color sensors to an object and press okay)
      i. Check that calibration process is being executed by viewing message on the LCD screen.
      ii. Check that the sensor is obtaining the color of the object executed by viewing message on the LCD screen.
      iii. Once the sampling process is completed, the LCD should display the "Color" option which will show the name of the color and the RGB value.

   b. Album Option: select a color saved
      i. View color data which were previously saved.
      ii. Ensure the saved color data is accurately retrieved in the "Color" option.
      iii. Delete data and ensure the deleted data does not show up in the album menu list.

   c. Color Option: view color data
      i. LCD should display this option after sampled a color, selected a color saved in the "Album" option, or pushed back in the main menu.
      ii. Ensure the color displayed is accurately with the name of the color and the RGB value.

   d. Save Option: save the current color displayed on the LCD screen to the "Album" option
      i. Ensure the availability of this option (only available when a new color is sampled.)
      ii. Ensure the saved color display in the "Album" option.

   e. Wizard Option*: view the analogous, complementary,  and triad relationships of the current color displayed on the LCD screen
      i. Ensure the availability of this option (only available when viewing a color.)
      ii. Ensure the accuracy of the three relationships of the color.

*The wizard option will be integrated only if the other requirements can be met within the limited timeline.

In the integration tests, testers should not pre-set RGB readings as testing the LCD screen since RGB readings should be read from the sensors in this case.

Expected Observation:  All pages should be displayed as designed, and RGB readings showed on the screen should be accurate.

## 7.5. Acceptance Testing

The device will be integrated into a compact case as if it's a final product before performing the acceptance testing. The acceptance tests are intended to collect feedbacks from non-experienced users; therefore, the developers will be able to make final changes before the mass production occurs.

An integrated device will be provided for the testers to perform the acceptance testing to verify the following functionalities.

- Start-up
    o Company logo displayed
    o Limited menu selections before any samplings
- Samplings
    o Full menu selections after samplings
    o Samplings accuracy
- Album
    o Accessibility to the saved colors
    o Deletion of the saved colors
- Color View
    o RGB readings displayed on LCD
    o Color names displayed on LCD
    o Color displayed on LCD
- Saving
    o Ability to save colors and view later in the album function
- Wizard*
    o Capability to view Analogous, Complementary, and Triad relationships of the sampled colors

Other than verifying the above functionalities, testers are expected to ensure that the LCD display pages flow smoothly.

*The wizard function will be integrated only if the other requirements can be met within the limited timeline.

## Conclusion

The design solutions to meet the functional specifications, the details of the device design and implementation are proposed in this document. These design specifications will be referred to and adhered to meet the functional specifications. Implementing the test plans included, the device will be ensured of all the required functionality. The design specification provides clear goals for the development of the device prototype.

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# Appendix: ColorAid Menu Options

## Main Page



## Sample Option



| Album Option | Album Submenu |
|---|---|

## Color Option

COLOR

RED

RGB: 255, 255, 0
SHL: 60,100,50

Sample
Color
Wizard
Save
Album

Mode

OK

Back

Sensor

## Save Option

SAVE

File name: RED

Mode

OK

Back

Sensor

## Wizard Option

WIZARD

- Analog
- Complement
- Triad

Mode

OK

Back

Sensor

## Wizard Submenu: Analog



**WIZARD**

Analog: Teal

- Teal
- Green
- Blue
- Light Blue
- Purple

## Wizard Submenu: Complement



**WIZARD**
Complementary: Teal

- Teal
- Blue
- Red

## Wizard Submenu: Triad



**WIZARD**
Triad: Teal

- Teal
- Purple
- Olive Green