



## Avago HDJD-JD02 Development Kit

### ICM Program User Guide

***WARNING: This product is non RoHS compliant***

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#### Warning

By connecting the HDJD-JD02 development kit to the parallel port using the I<sup>2</sup>C adapter, you are operating these two circuits together WITHOUT GALVANIC ISOLATION. DO NOT CONNECT OR DISCONNECT ANYTHING WHILE THE HDJD-JD02 DEVELOPMENT KIT OR THE PC IS SWITCHED ON!!! Doing so anyway may damage your PC and/or the HDJD-JD02 Development Kit permanently. Make sure power is off while interfacing with the Color Reader Board. DO NOT & never switch off power from color reader board while program is running.

#### Credits

CIE xy chart – Prof. Geoff Hoffman (<http://www.fhoden.de/~hoffmann/>)

HunterLab application note, “CIE L\*a\*b\* Color Scale.”

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## 1.0 Introduction

Being able to accurately and consistently 'name' a color, the Avago color sensor opens up opportunities to manipulate and control color. It is ideal for color detection, differentiation and control in both open and closed loop systems. Potential areas of application are office automation, quality control and color coding in such industries as food, textile, paint, assembly and packaging, environmental lighting, consumer good, pharmaceutical, medical and research and automotive.

The Avago sensor development kit is used to demonstrate the principle of color sensing in reflective and transmissive context.

A reflective color sensing system comprises of three main elements namely illuminant, non-emissive object and observer/sensor. The illuminant, as the name implies, will illuminate the object under observation and reflected light will be captured by the system's sensor. The resultant color information will be governed by the illuminant spectrum, object surface reflectance and sensor/observer spectral response.

The  $45^\circ/0^\circ$  directional measurement method is adopted in Avago sensor development kit. Avago white phosphor LED is used as the illuminant at the incident angle of approximately  $45^\circ$  while sensor at  $0^\circ$ . At a distance of 20mm along the surface orthogonal, diffusely reflected light is detected by Avago color sensor and digitized by A/D board. The development kit program reads the digitized sensor data from A/D board via parallel interface and performs various color information computation.

Unlike reflective color sensing system, a transmissive color sensing system only comprises of two elements namely observer/sensor and emissive object. The light emitted from the object will be captured by the system's sensor. The resultant color information will be governed by the emission spectrum and sensor/observer spectral response.

Avago sensor development kit serves an exemplary circuit application for composing other simple reflective and transmissive color detection system with Avago color sensors.

## 2.0 Startup

### Included in Delivery

Standard Avago Sensor Development Kit includes the following components:

- One sensor module – Reflective Sensor Kit (RSK)
- One sensor module – Transmissive Sensor Kit (TSK)
- One A/D board – Color Reader Board (CRB)
- One LPT parallel cable
- One USB cable
- One CD with installation software

(For details, please refer to table 2.0 below.)

	<b>(1) RSK (Reflective Sensor Kit)</b> <i>* Built with HDJD-S722-QR999</i>		<b>(4) LPT Parallel Cable</b> <i>* For data communication</i>
	<b>(2) TSK (Transmissive Sensor Kit)</b> <i>* Built with HDJD-S722-QR999</i>		<b>(5) USB Cable</b> <i>* For +5VDC supply only</i>
	<b>(3) CRB (Color Reader Board)</b>		<b>(6) CD with Software installation</b> <i>* For HDJD-JD02 use only</i> <i>* User guide inside</i>

Table 2.0

### 3.0 Color Sensor Module

Avago color sensor is a high performance, small in size, cost-effective, light-to-voltage converting sensor. The sensor combines a photodiode array and three trans-impedance amplifiers in a single monolithic CMOS IC solution. With a Red (R), Green (G) and Blue (B) color filters coated over the photodiode array, the sensor converts RGB light to analog voltage outputs, denoted by VROUT, VGOUT and VBOUT, respectively. The sensor is packaged in a 5x5x1 [mm] surface mount QFN-16 package.

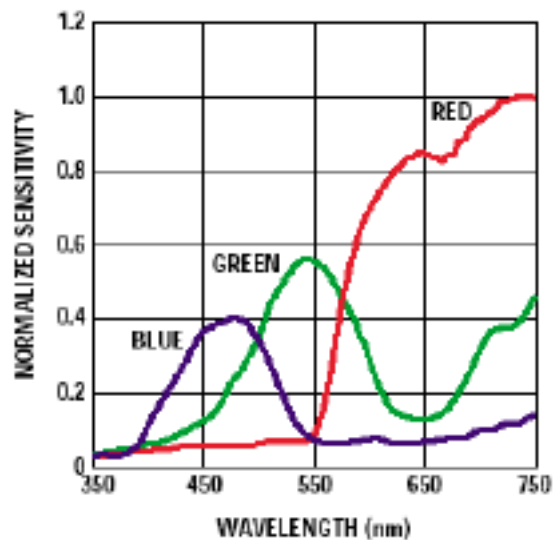


Figure 3.0 Spectral responsivity.

Reflective color sensing kit comprises an illuminant, color sensor and post filtering circuitry. The Avago white phosphor LED is used as the illuminant/light source and Avago's color sensor (HDJD-S722-QR999) as the detector. Optical lens is also added to focus reflected light onto the color sensor. The kit also features an alignment gauge for maintaining an optimum gap between sensor and the targeted surface.

## Reflective Color Sensing Theory of Operation

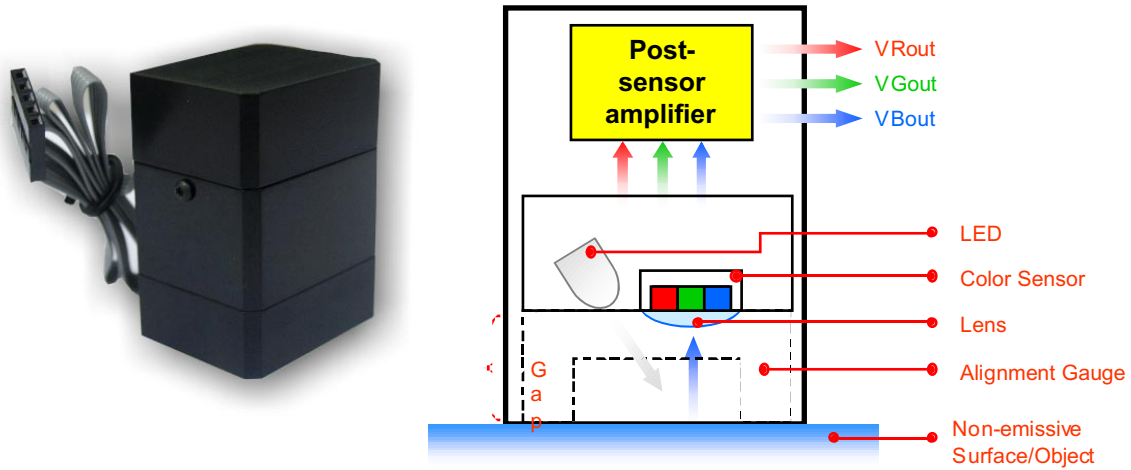


Figure 3.1 Schematic of reflective color sensor Reflective Sensing Kit (RSK).

By definition of reflective sensing, the color sensor detects light reflected from a surface or an object. The sensor module is designed in such a way that both the light source and the color sensor are placed closed to the target surface/object. Light coming from the LED is bounced off a surface/object and measured by the sensor. For a given light source, the color of light reflected off a surface/object is a function of the surface/object color. For example, white light incident onto a red surface is reflected as red. Since any color is uniquely represented by its **R**, **G** and **B** components, the sensor module effectively measures the color of a surface/object by converting the **R**, **G** and **B** components of the reflected light to analog voltages. In addition, given that the outputs increase linearly with the intensity of reflected light, the sensor also measures the reflectivity of a surface/object.

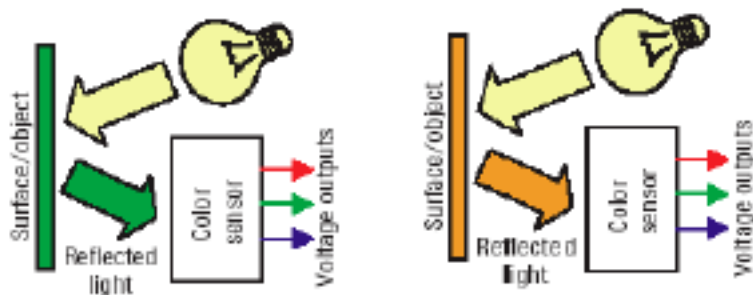


Figure 3.2 For a given light source, color of reflected light depends on surface/object color.

### Transmissive Color Sensing Theory of Operation

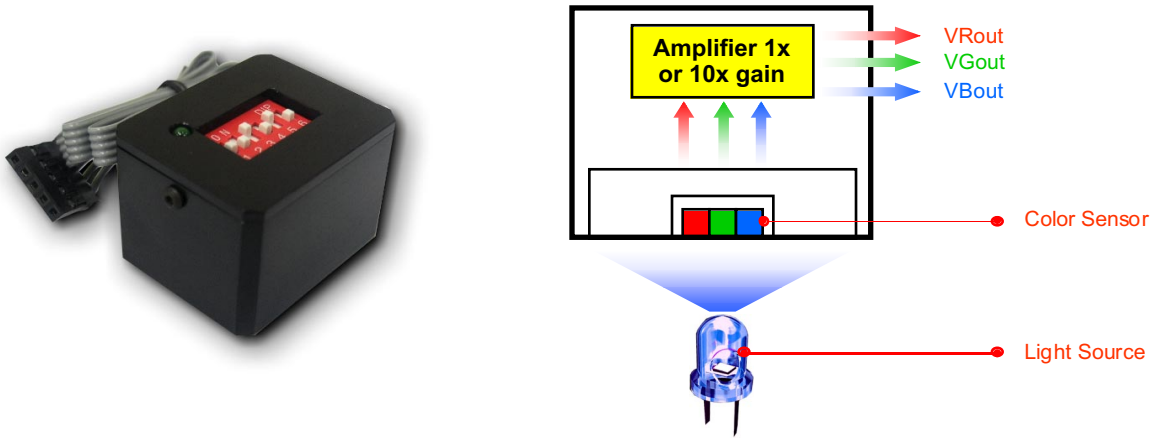


Figure 3.3 Schematic of Transmissive Sensing Kit (TSK).

By transmissive, it means the application kit is placed facing the light source being measured. The filter-coated photodiode array of the color sensor converts the R, G, B components of light falling on it into photocurrent, which is then amplified and turned into analogue voltages for each of the primary component. Given that any colored light is uniquely represented by the ratio of the primary colors, the color sensor provides a definite manner of measuring color. In addition, the sensor is also responsive to light intensity where its outputs increase linearly with increasing light intensity. For a given light source, the application kit can also be used to determine the color of transparent medium through which the light is passed before reaching the sensor. For example, the medium could be glass, plastic or liquid.

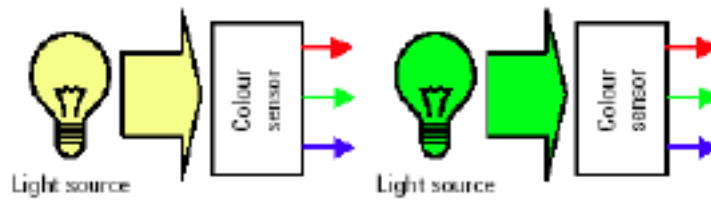


Figure 3.4 R,G,B outputs of sensor are determined by color of light falling on sensor.

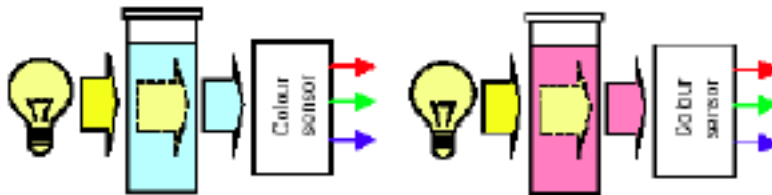


Figure 3.5 Apply color sensor on media such as color filter, liquid and gas.

## Analog to Digital Converter Board

The Analog to digital converter board comprises of the following components:

- (1) Avago color controller
- (2) Line/power supply filtering circuit
- (3) USB power supply connector
- (4) Parallel port connector
- (5) Resistors and capacitors

As the name implies, its function is to perform A/D conversion with 10-bit resolution. Upon power up, the color controller will start taking in 3-channel color sensor output ( $V_r, V_g, V_b$ ) and perform A/D conversion. The digitized value will be read by the Avago sensor development kit program via parallel upon completion of each round of conversion.

Shown in the following Figure 3.6 is the diagram of the A/D board:

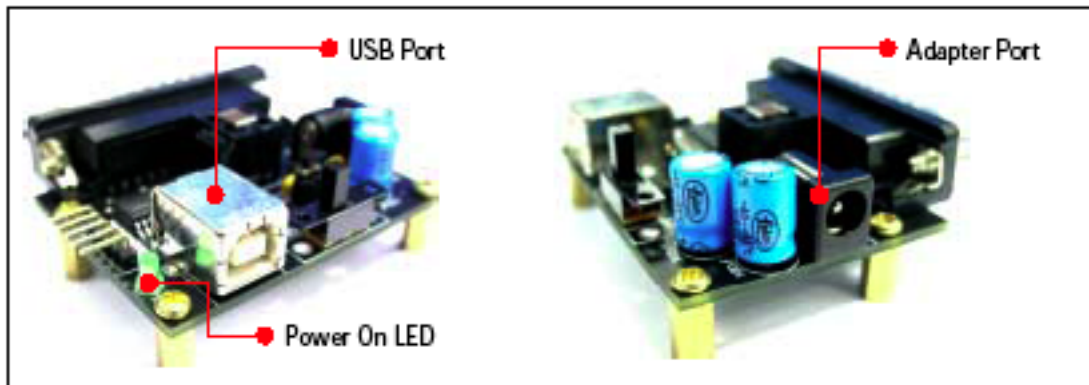


Figure 3.6 A/D board (Color Reader Board).



## 4.0 Hardware Setup and Configuration

### To Select +5VDC Supply

This CRB (Color Reader Board) as designed comes with 2 different selections to obtain +5VDC. User may either select USB Port or Adapter Port as its +5VDC supply with respect to the changes of the “Jumper.”

#### By selecting USB port as +5VDC supply

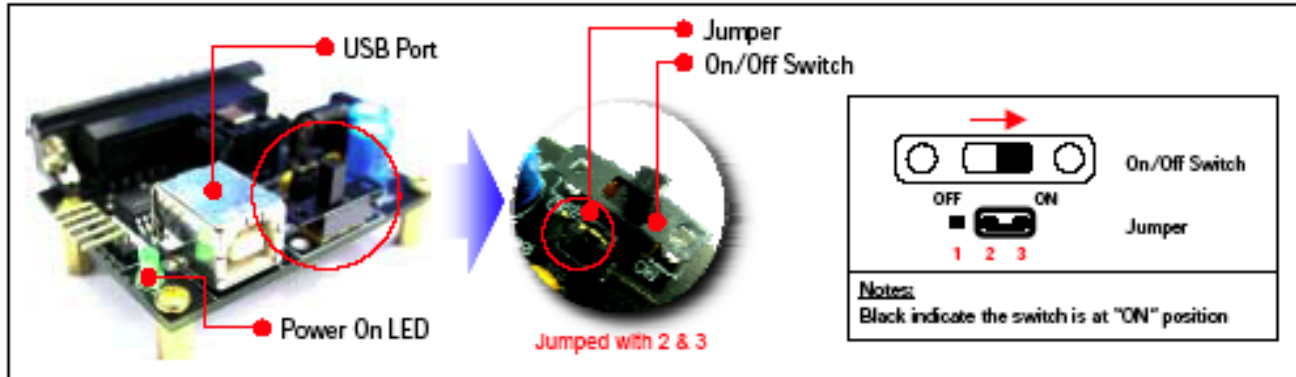


Figure 4.0

- (1) To select USB Port as +5VDC supply, use the Jumper to connect up both “2” & “3” as shown in figure above.
- (2) Next, interface the CRB and computer with USB cable.
- (3) Push the On/Off Switch to ON position and make sure the Power On LED is lit up.

#### By selecting Adapter port as +5VDC supply

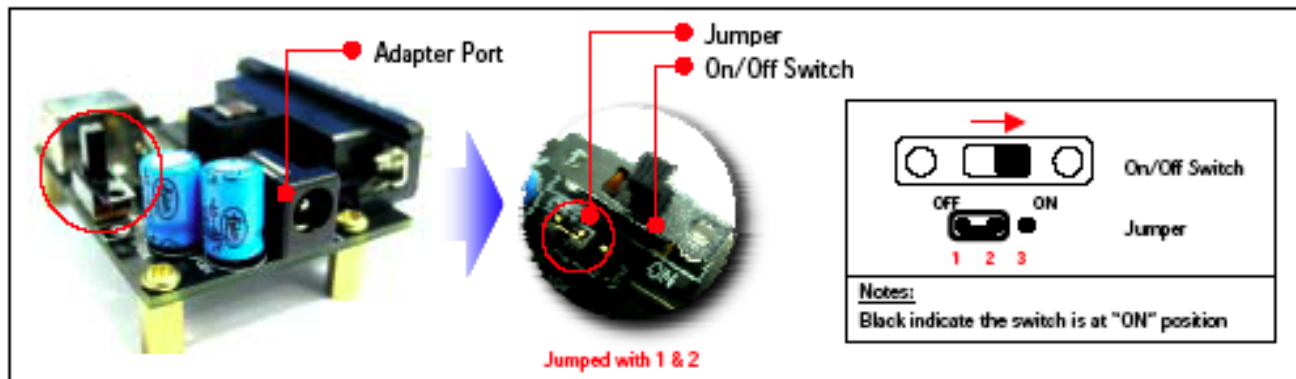


Figure 4.1

- (1) To select Adapter Port as +5VDC supply, use the Jumper to connect up both “1” & “2” as shown in figure above.
- (2) Next, interface the CRB and computer with +5VDC Adapter.
- (3) Push the On/Off Switch to ON position and make sure the Power On LED is lit up.

## To Interface the Hardware

Plug in USB cable, LPT parallel cable and the RSK (Reflective Sensor Kit) or TSK (Transmissive Sensor Kit) onto the CRB (Color Reader Board) as shown below.

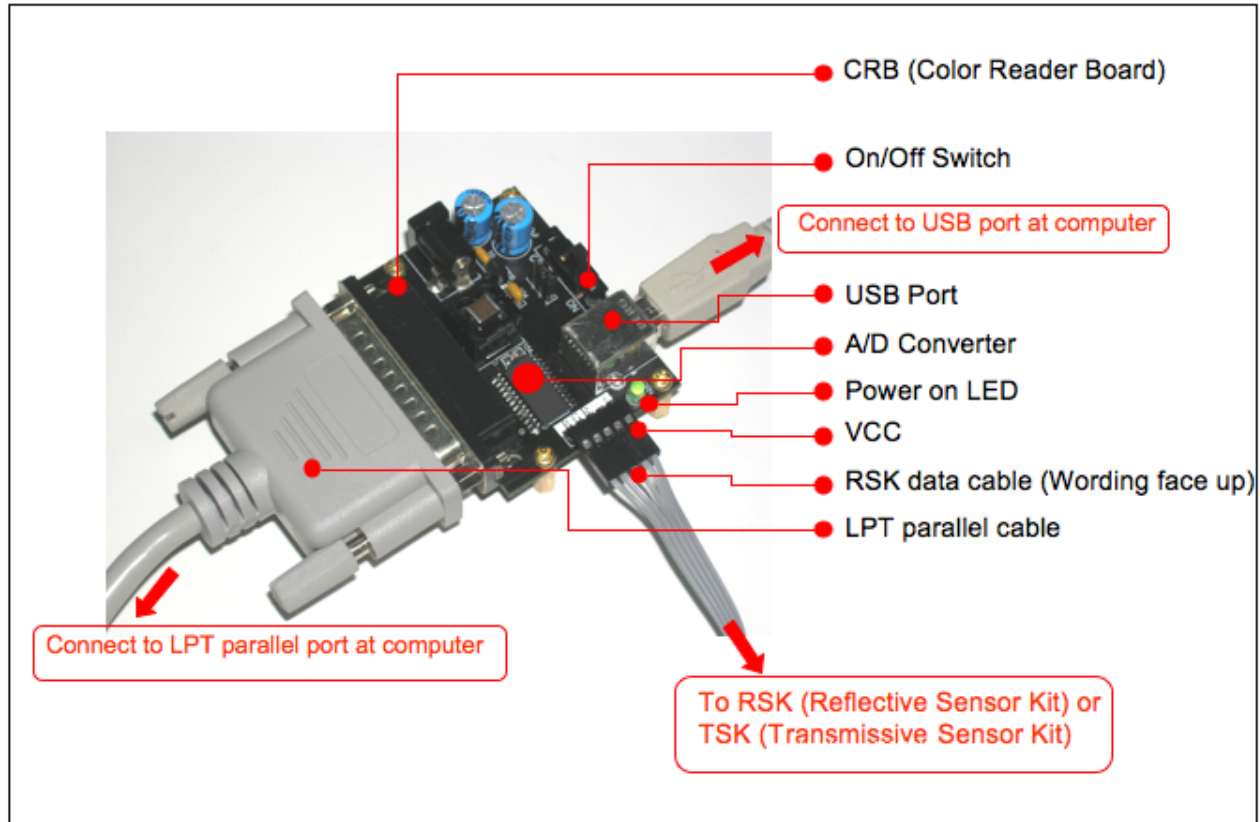


Figure 4.2

## 5.0 PC Software Description

Avago Color Sensor Development Kit software is developed to be a tool for user to acquire knowledge on how color sensor can be applied and various types of standard color space system. It is also equipped with a basic color differentiation tool that allows user to have a visual understanding on how color control is performed nowadays. The interactive graphical user interface has made the software to be user friendly and easy to use. This software allows user to select either in Transmissive or Reflective mode. For Transmissive mode program user may obtain Analogue & Digital output as shown in Figure 6.1. The program for reflective sensor kit as shown in Figure 7.1 comprises 4 main sections i.e.,

- (1) Sensor RGB Data
- (2) Color Differentiation
- (3) Color Interpretation
- (4) Numerical Data Log and Chart Viewing

### Software Installation

To begin the software installation, user has to run “Setup.exe” then follow the guided steps.

- (1) Unzip “Package (Devkit+transmissive)zip.”
- (2) Run “Setup.exe” to install the program.
- (3) Plug in USB cable, LPT parallel cable and the RSK (Reflective Sensor Kit) or TSK (Transmissive Sensor Kit) onto the CRB (Color Reader Board) as shown below.

### Starting the Software

To start PC software, select or double click the icon shown below to initiate the program.



HDJD JD02 Software

Figure 5.0

## 6.0 PC Software Operation – for Transmissive only

### Selection Window

User makes selection on Transmissive Application Kit to initiate applications.

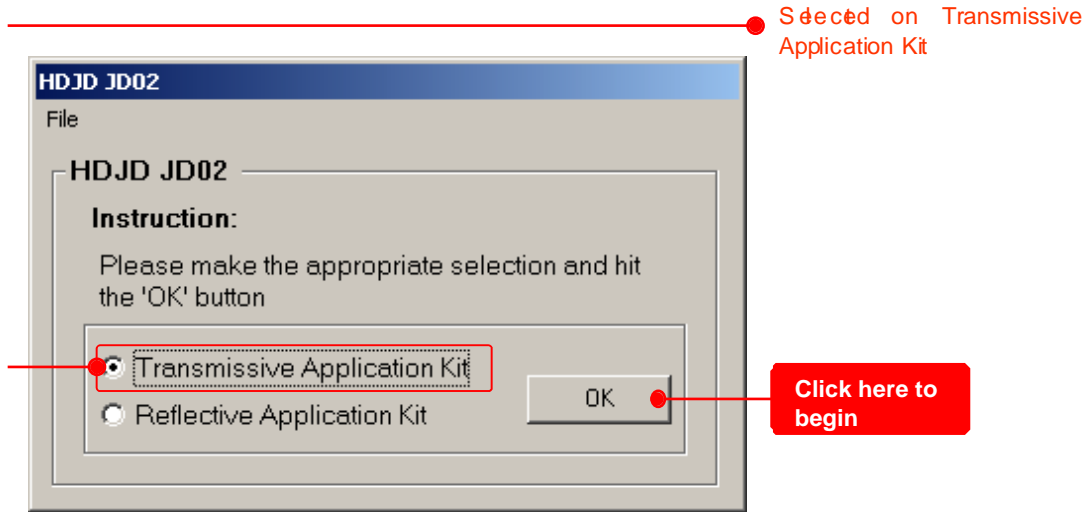


Figure 6.0

### User Screen

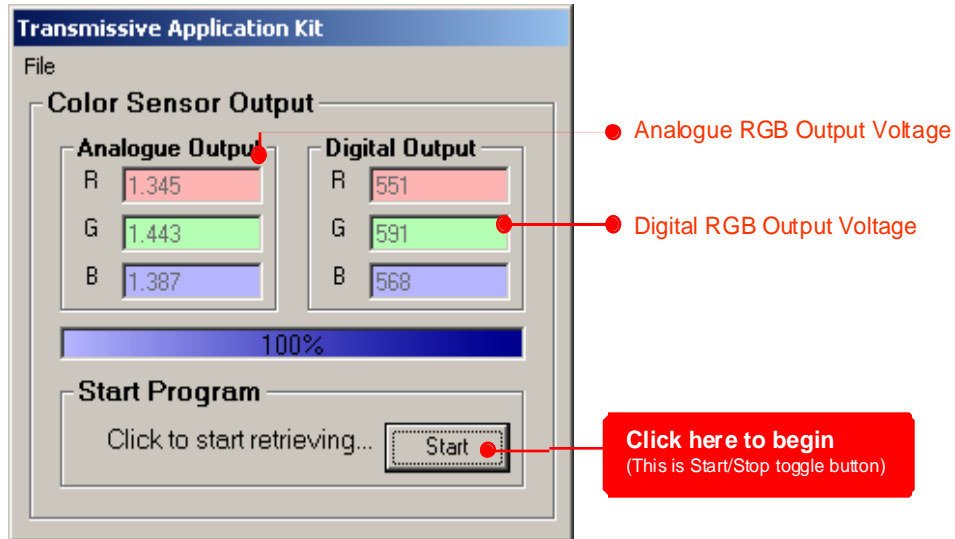


Figure 6.1

## Starting Light Source Color Detection

- Position Transmissive Sensing Kit (TSK) on assigned color LED as shown in Figure 6.2.
- Then click on “Start” button to trigger data acquisition in which RGB analogue & digital voltages are continuously read and displayed in Color Sensor Output section. Each color is broken down into its RGB portions; it is displayed in a mixed color generation field. By having this Color Sensor Output section able to let user identify the color differences from one LED to another LED.

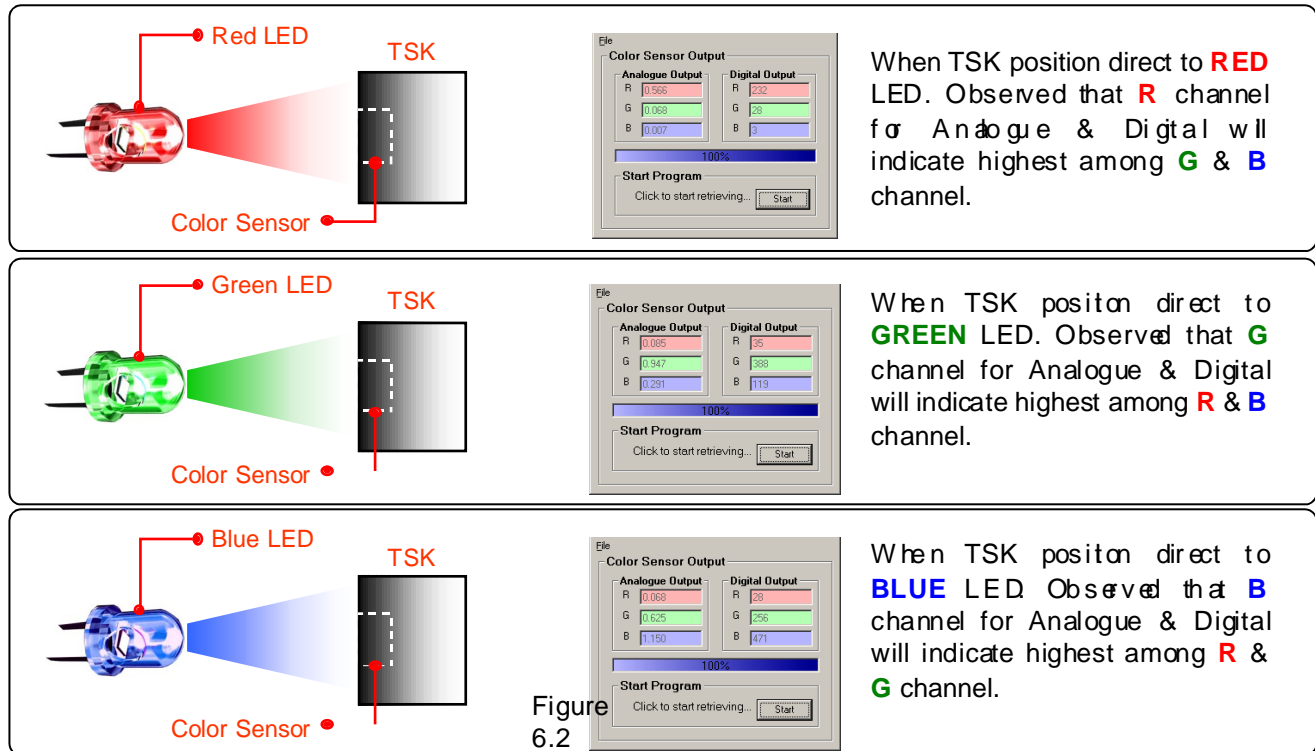


Figure 6.2

### Notes:

1. Refer to Appendix for transmissive sensing kit gain selection guide.
2. The figures above only show a few examples of the LEDs, distance is not specified & undefined.

## 7.0 PC Software Operation – for Reflective only

### Selection Window

User makes selection on Reflective Application Kit to initiate applications.

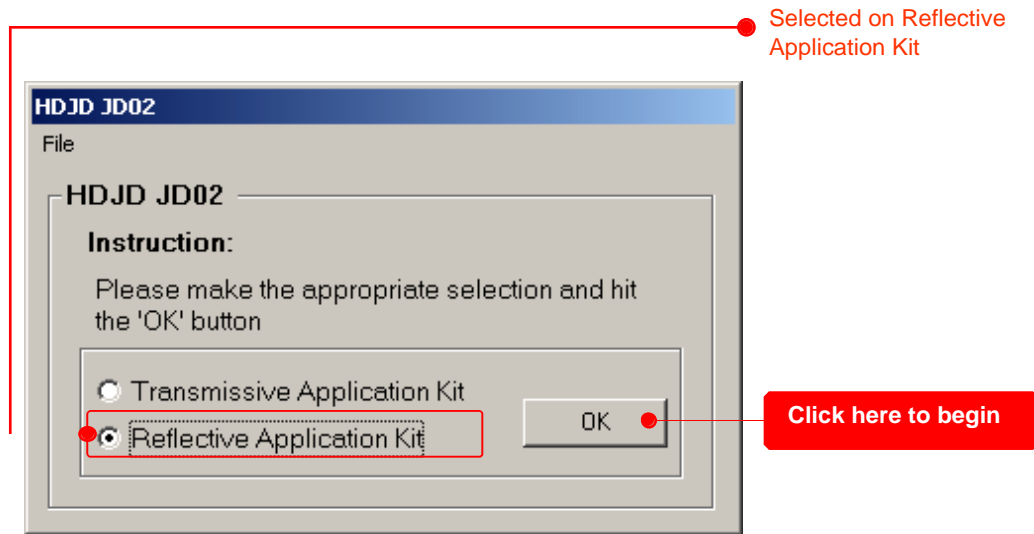


Figure 7.0

# User Screen

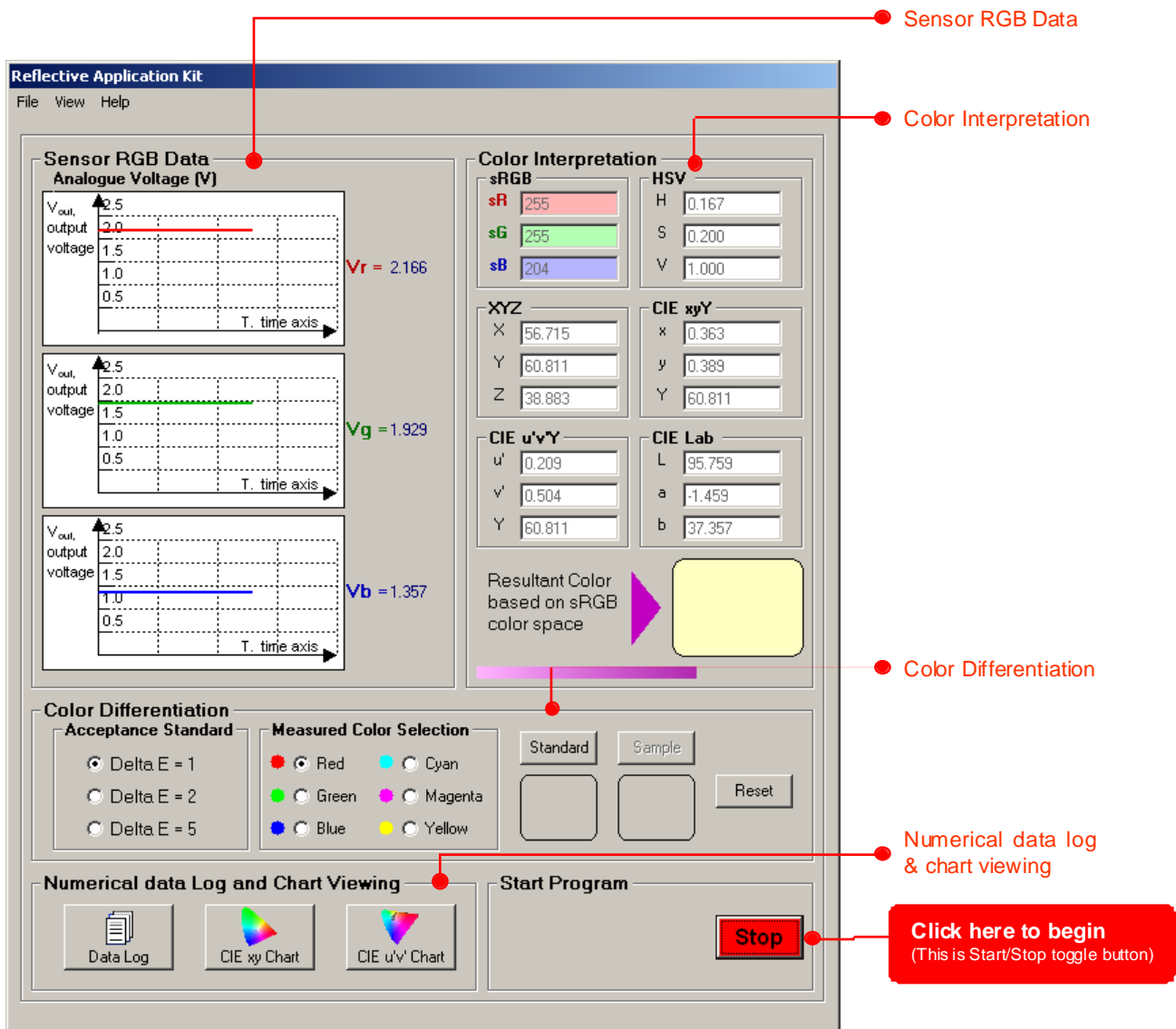


Figure 7.1

## Starting Color Measurement

- Place Reflective Sensing Kit (RSK) on assigned color as shown in Figure 7.2.
- Then click on “Start” button to trigger data acquisition in which RGB analogue voltages are continuously read and display in sensor RGB data section. Each color is broken down into its RGB portions (with 3-channel real-time oscilloscope); it is displayed in a concurrently changing graphic and a mixed color generation field. Timing indicated in x-axis whereas output voltages indicated in y-axis. With these 3-Channel real-time oscilloscope able to let user identify the consistency and repeatability of the color sensing.

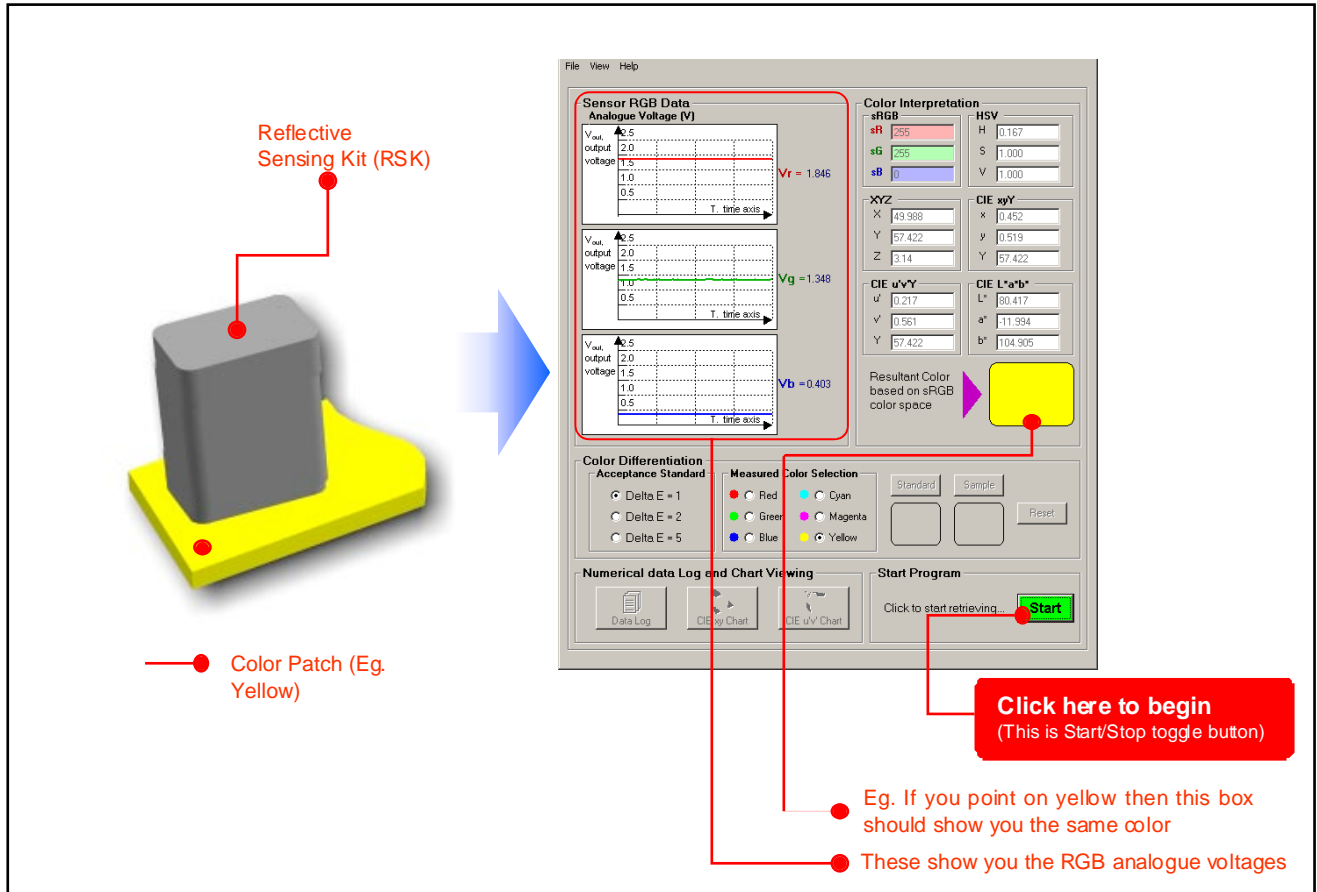


Figure 7.2



## Color Sensing

Combination of various RGB portions into a mixed color may produce mismatches with the actual sample color. These circumstances can be corrected with the aid of complex mathematical algorithms.

## Color Differentiation

CIELAB color space is one of the most popular color space for measuring object color and is widely used in virtually all fields. It is one of the uniform color spaces defined by CIE to reduce the problem of non-linearity in the original xyY color space (the equal distances on the x,y chromaticity diagram did not correspond to equal perceived color differences).

In this color space,  $L^*$  indicates lightness and  $a^*$  and  $b^*$  are the chromaticity coordinate. Figure 7.3 shows the  $a^*, b^*$  chromaticity information diagram.

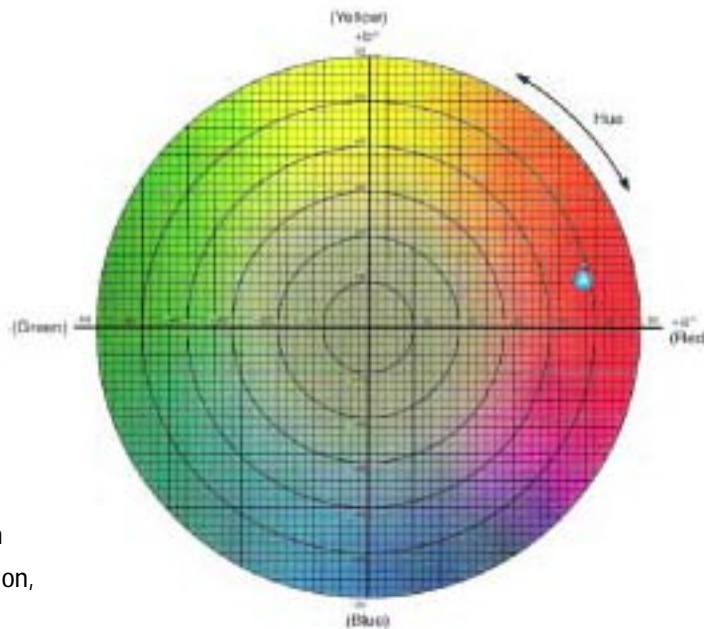


Figure 7.3

In this diagram,

- $+a^*$  is the red direction,
- $-a^*$  is the green direction
- $+b^*$  is the yellow direction,
- $-b^*$  is the blue direction

There are delta values associated with this color scale.  $L^*$ ,  $a^*$ , and  $b^*$  indicate how much a standard and sample differ from one another in  $L^*$ ,  $a^*$ , and  $b^*$ . These delta values are often used for quality control or formula adjustment. Tolerances may be set for the delta values. Delta values that are out of the tolerances indicate that there is too much difference between the standard and the sample. The type of correction needed may be determined by which delta value is out of tolerance. For example, if  $a^*$  is out of tolerance, the redness/greenness needs to be adjusted. Whether the sample is redder or greener than the sign of the delta value indicates the standard.

For example, if  $a^*$  is positive, the sample is redder than the standard. The total color difference,  $E^*$ , may also be calculated. The  $E^*$  is a single value which takes into account the differences between the  $L^*$ ,  $a^*$ , and  $b^*$  of the sample and standard. It does not indicate which parameter(s) ( $L^*$ ,  $a^*$ , and/or  $b^*$ ) are out of tolerances if  $E^*$  is out of tolerance.

The CIELAB color scale may be used on any object whose color may be measured. It is used extensively in many industries. As was intended, it provides a standard scale for comparison of color values.

## Starting Color Differentiation

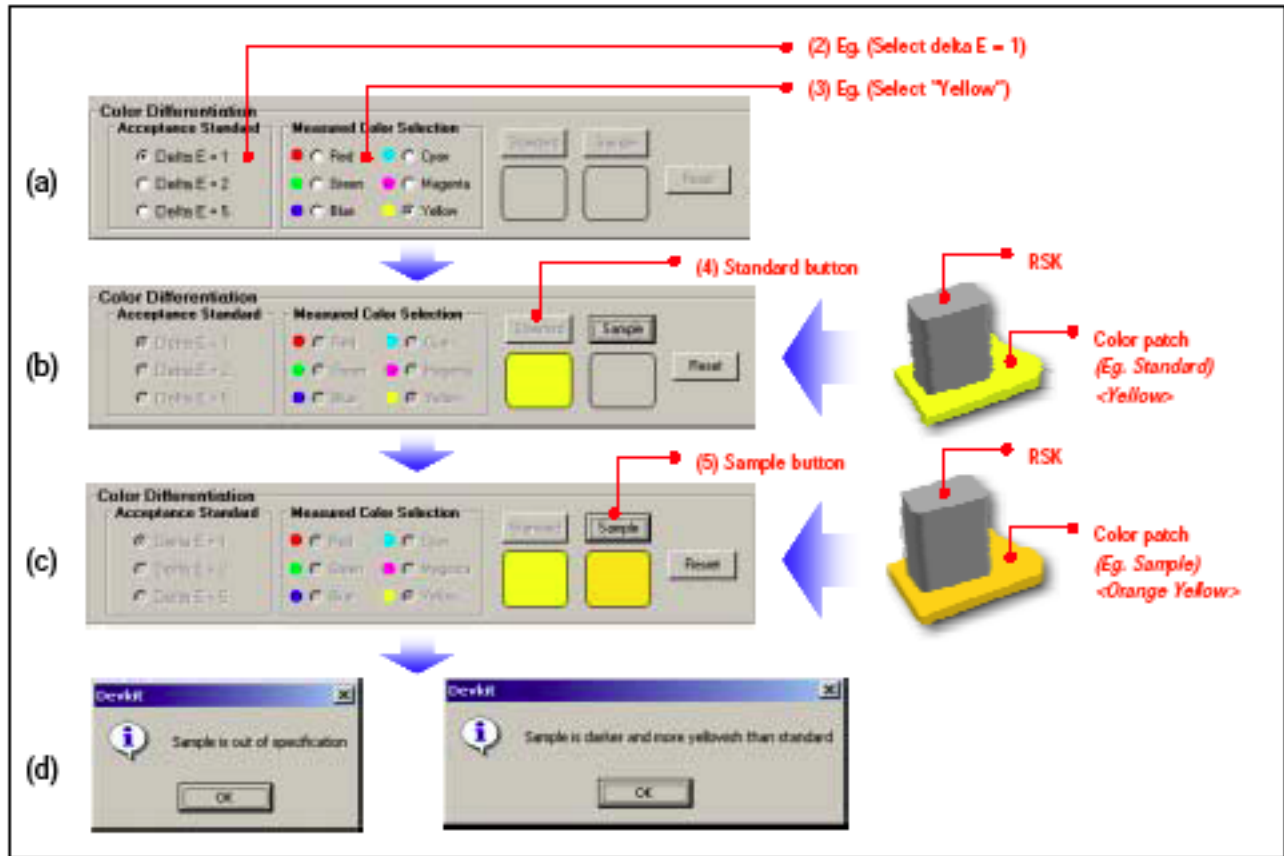


Figure 7.4

### Procedures:

1. Make sure to click once at "Start" button to run the program.
2. Select the acceptance standard (e.g., delta E = 1), as shown in Figure 7.4(a).
3. Select the types of color to be measured (e.g., Yellow), as shown in Figure 7.4(a).
4. Place RSK on standard color patch and click once at the "Standard" button to store chromaticity and lightness information into database. Refer to Figure 7.4(b).
5. Next, place RSK on sample color patch and click once at the "Sample" button to store chromaticity and lightness information into database. Refer to Figure 7.4(c).
6. System will compare the sample with the standard color patch.
7. User will be prompted with a message box of the result of comparison i.e., either within or out of specification, as well as prompting the L\*a\*b\* color space information. Refer to Figure 7.4(d). (e.g., In this case, Yellow is a Standard whereas Orange Yellow is a Sample, so identify that sample is yellowish than standard.)

## Interpretation of Colorimetric System

### RGB -> XYZ

- With the digitized value of RGB the system will further interpret and convert it into XYZ color space and XYZ values are displayed.

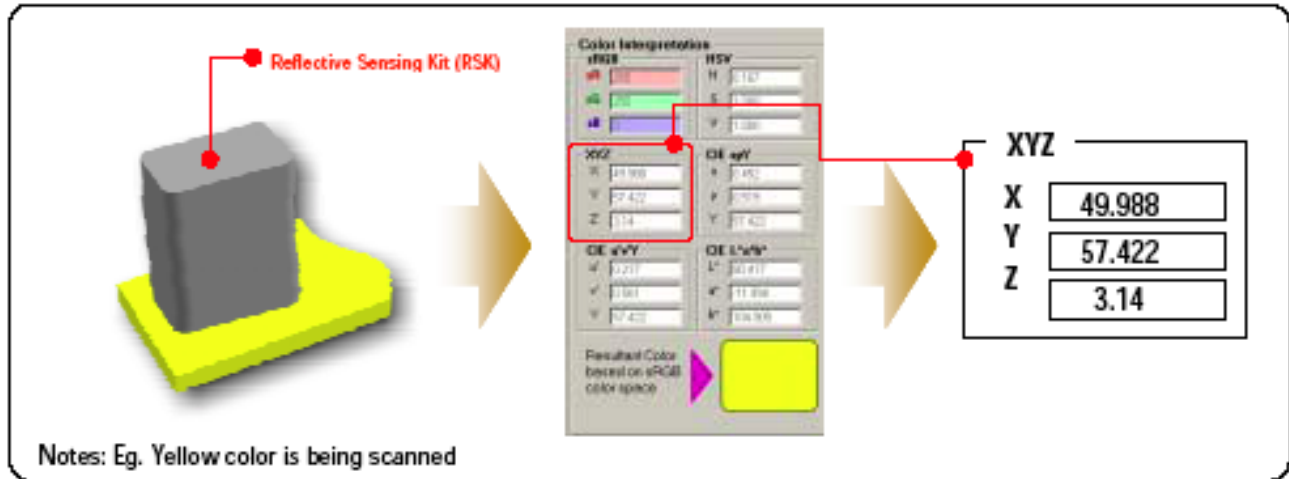


Figure 7.5

### XYZ -> sRGB

- Color space tristimulus XYZ values will then be converted with complex mathematical algorithm to sRGB value whereby sRGB is the standard color gamut for monitor.

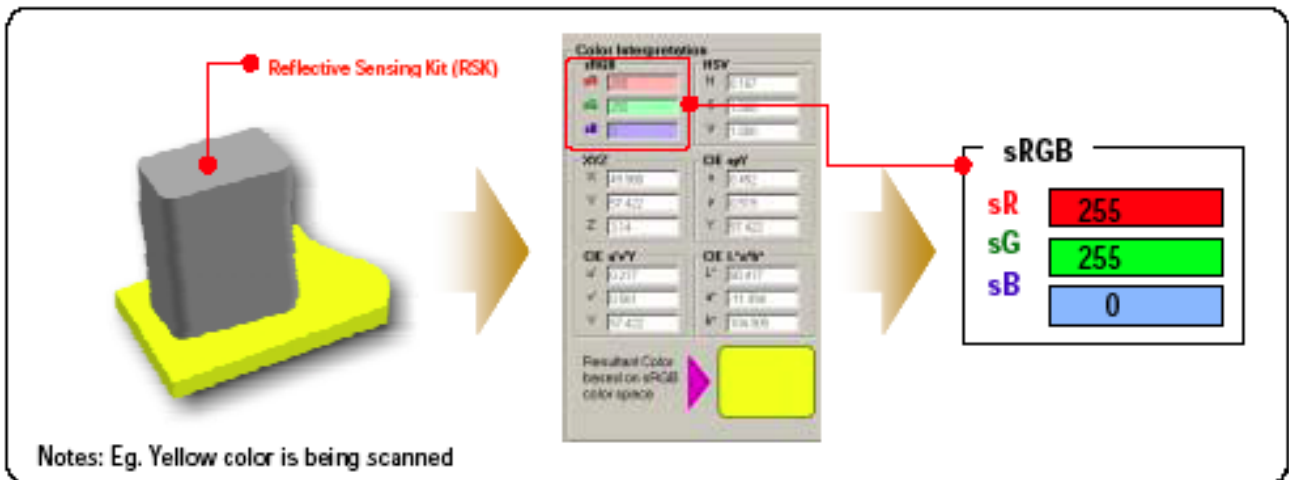


Figure 7.6

sRGB -> HSV

- HSV is a non-linear transformation of the RGB color space. The Hue Saturation & Value (or HSV) model defines a **color space** in terms of three constituent components; hue, saturation, and value. HSV is shown in color interpretation section as well. The system will convert sRGB value with special mathematical algorithm to obtain HSV data.

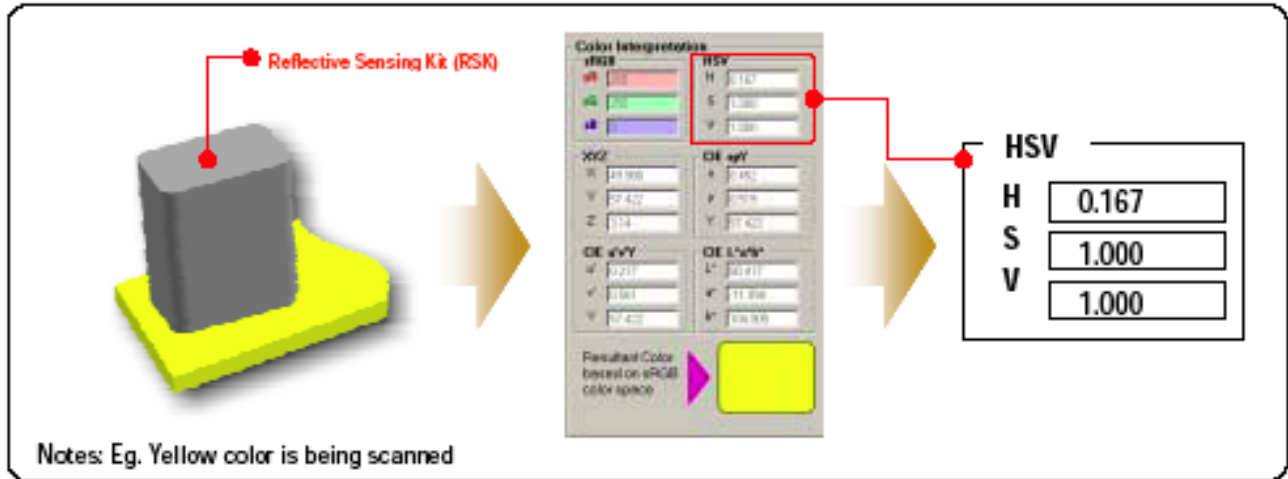


Figure 7.7

XYZ -> xy Y

- The tristimulus values X, Y and Z define a color in the CIE XYZ space. The CIE XYZ is a 3D linear color space, and it is quite awkward to work in it directly. It is common to project this space to the X+Y+Z=1 plane. The result is a 2D space known as the CIE chromaticity diagram. The coordinates in this space are usually called xyY and they are derived from XYZ. Color is usually described by xyY coordinates, where x and y determine the chromaticity and Y the lightness component of color. These xyY values can be refer to Color Interpretation section.

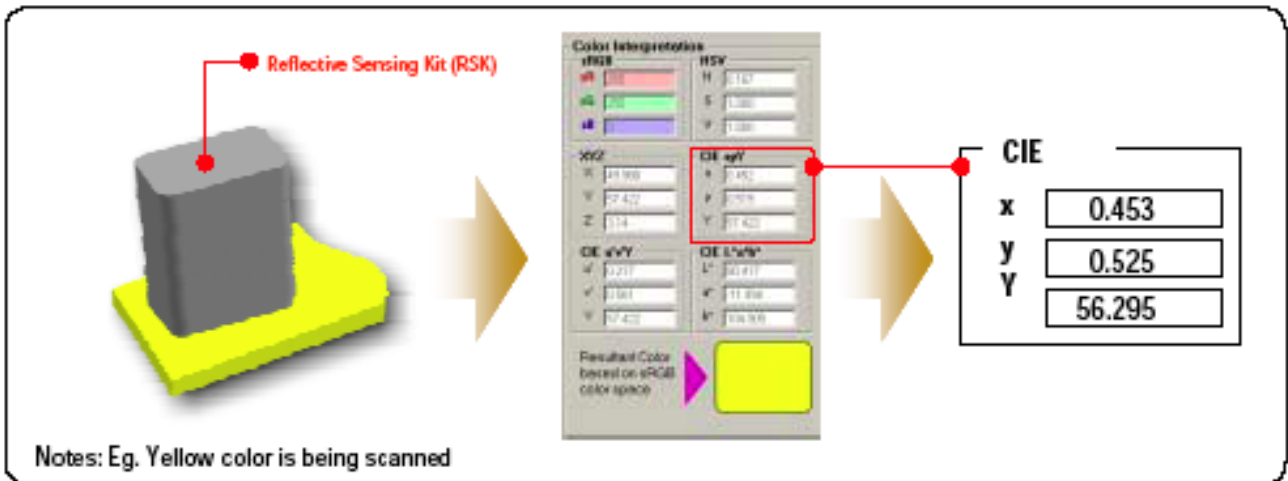


Figure 7.8

XYZ -> u'v'Y

- u'v'Y are device-independent color spaces. CIE u' and v' are for uniform perceived color difference as a function of lightness and chromaticity of the surrounding. User can obtain the u'v'Y values from Color Interpretation.

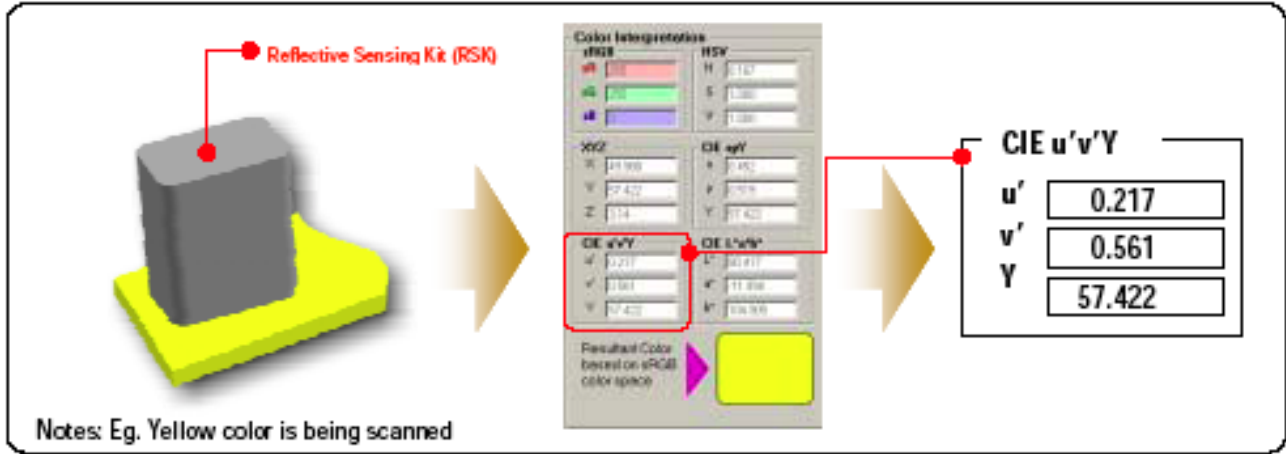


Figure 7.9

XYZ -> L\*a\*b\*

- A color model using lightness (L\*) and two color values (a\* & b\*). The “a” value defining a red-green axis and the “b” value defining the blue-yellow axis. The “L” value adds a third dimension to the color space. Values of L\*a\*b\* are also displayed in Color Interpretation section.

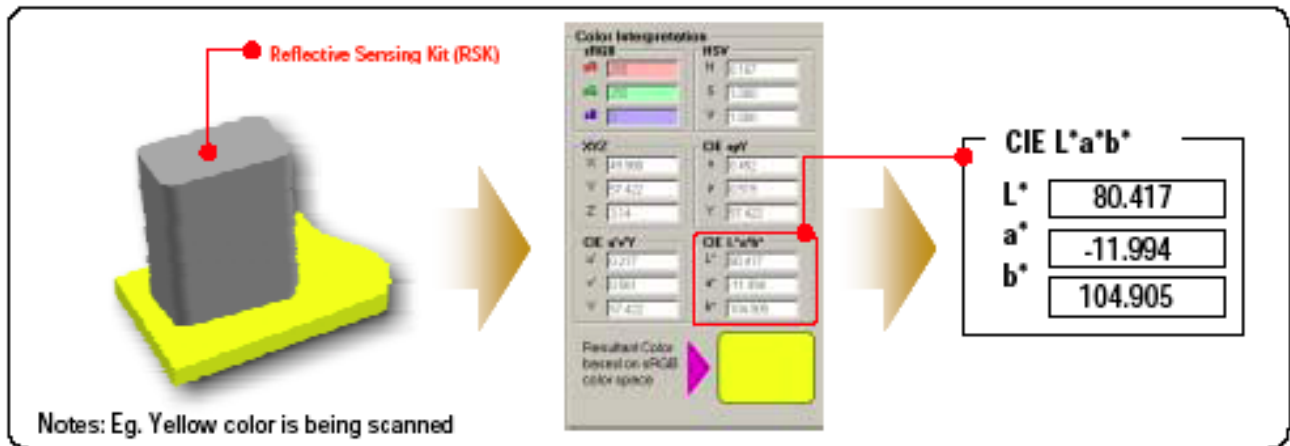


Figure 7.10

## Chart Viewing (CIE xy and CIE u'v')

### CIE xy Chart

- It is possible to represent the detected color in xyY colorimetric system. From the digitized RGB color values are computed the graphical x, y and Y values and represented in the CIE xy chart.

To view the real time CIE xy chart user may click on the “CIE xy Chart” button then the chart will be shown. The circle on CIE xy chart shows the color location in term of CIE color space coordinate and the xy coordinate displayed at the right hand top corner simultaneously.

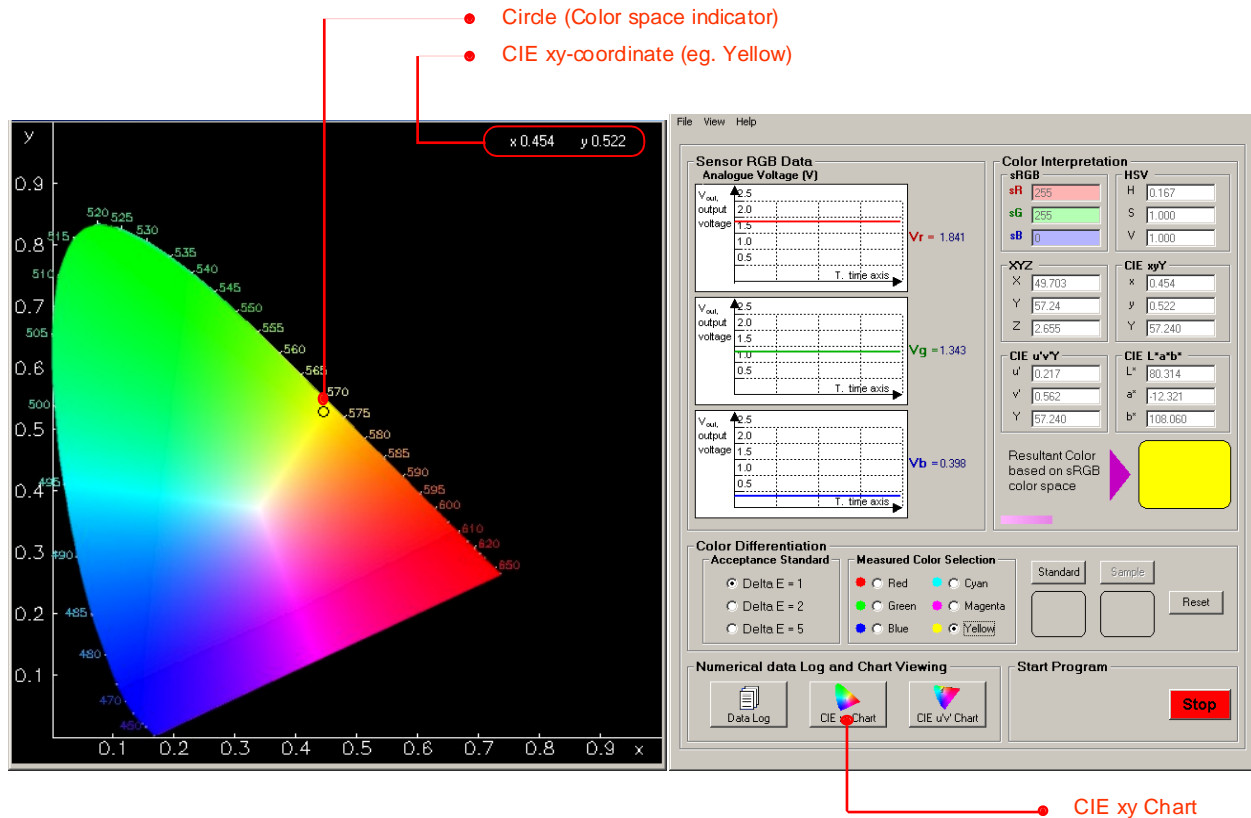


Figure 7.11

## CIE u'v' Chart

- The u'v' chromaticity co-ordinates were derived to aid the prediction of the magnitude of the perceived color difference between two objects that are found to mismatch in color. These modify the x and y chromaticity co-ordinates so that the color difference anywhere in the diagram will have the same appearance of difference.

User may click on the “CIE u'v' chart” button to view the real time CIE u'v' chart. The square on CIE u'v' chart shows the color location in term of CIE color space coordinate and the u'v'coordinate displayed at the right hand top corner simultaneously.

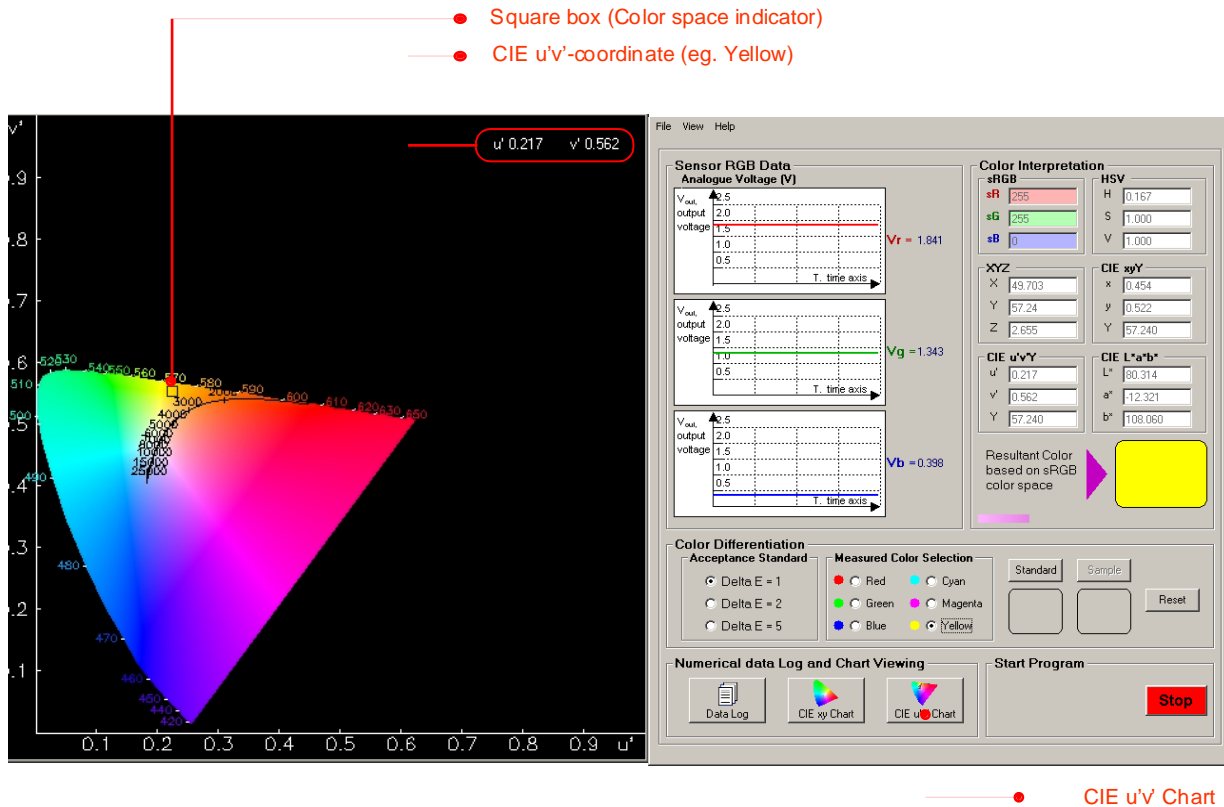
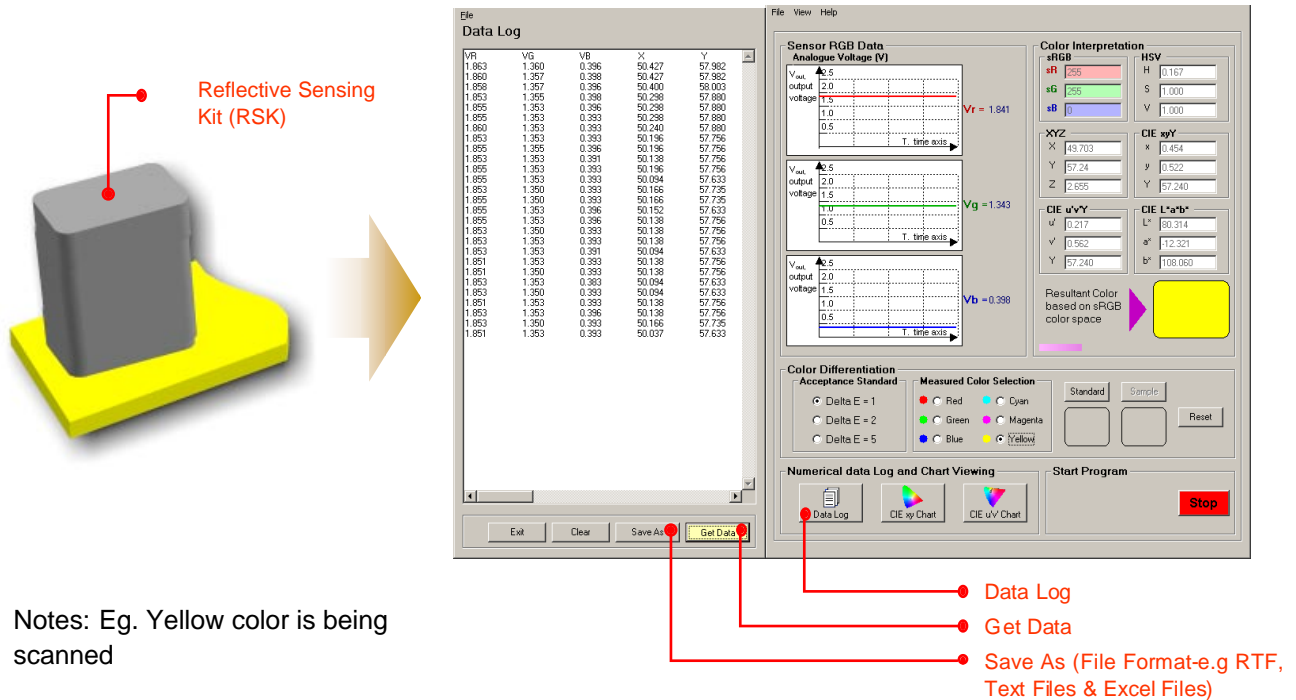


Figure 7.12

## Numerical Data Log

With this numerical data log feature, the user is able to identify and keep track of the consistency and repeatability of the color being scanned. The detected RGB values as well as other color space values can be stored separately or as sequence. User must position the RSK onto color patch (e.g., Yellow) and make sure the program is in running mode, then click once on “Data Log” button as shown in Figure 7.13 to launch the “Sensor Data Log” window. Then, user may proceed to obtain data by clicking the “Get Data” button.

In order to store data log, user may click “Save As” button. User may also save file as several different types of format (e.g., RTF, Text Files or Excel Files).



Notes: Eg. Yellow color is being scanned

Figure 7.13



## 8.0 APPENDIX - Transmissive Sensing Kit Gain Selection Guide

### Features

- 2 selectable gains, to cater for different level of amplification
- Portable and small housing for easier handling and testing

### Description

The transmissive kit has three types of gain selection, GS00, GS01 and GS10. Please follow the instructions below on how to use the sample.

### Instructions

#### 1) Pin configurations

There are 5 pin outs for the sample:

Pin 1 VDD (+5V DC)

Pin 2 GND

Pin 3 Red

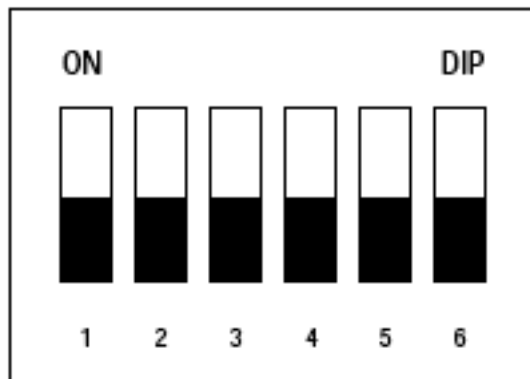
Pin 4 Green

Pin 5 Blue

It will be stated clearly on the connector itself.

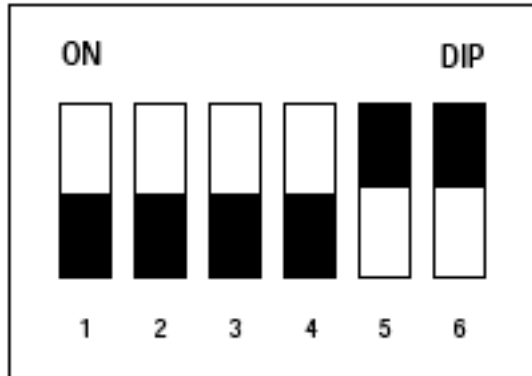
#### 2) DIP Switches

At the back of the sample, there will be a 6-way DIP switch. This is for the selection of gain.

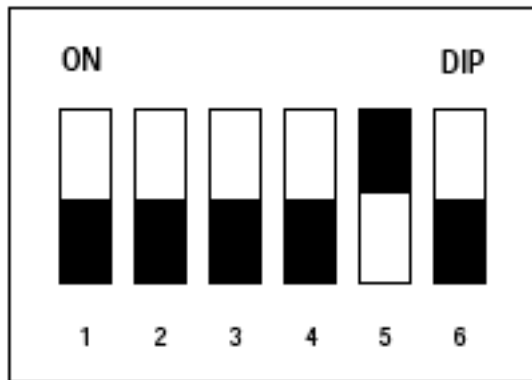


- Pin 1: Blue Gain Selection bit 1
- Pin 2: Blue Gain Selection bit 0
- Pin 3: Green Gain Selection bit 1
- Pin 4: Green Gain Selection bit 0
- Pin 5: Red Gain Selection bit 1
- Pin 6: Red Gain Selection bit 0

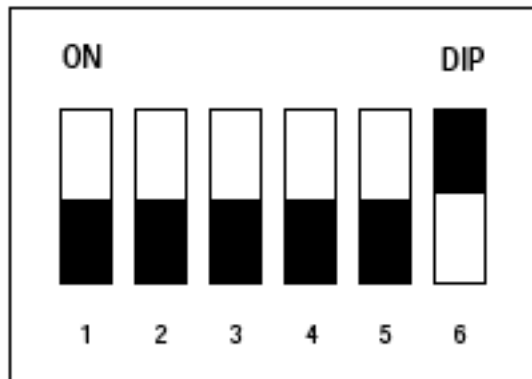
For Red Channel



Red channel: GS00

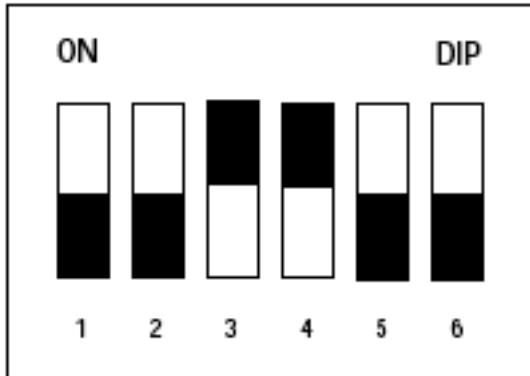


Red channel: GS01

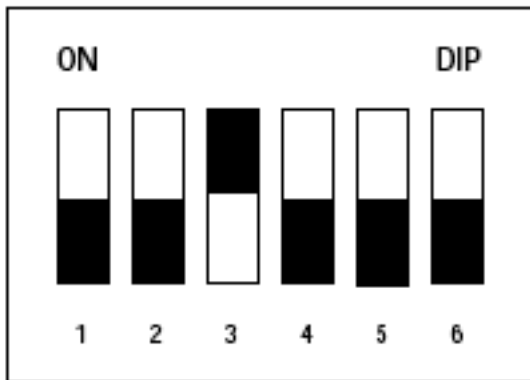


Red channel: GS10

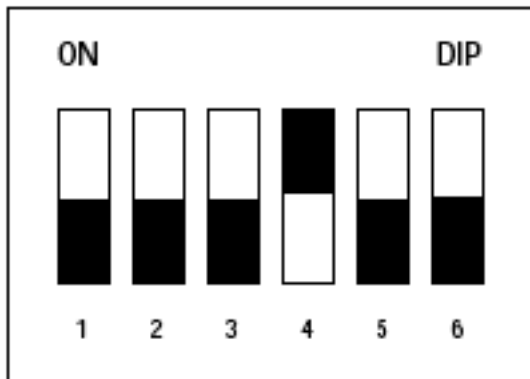
For Green Channel



Green channel: GS00



Green channel: GS01

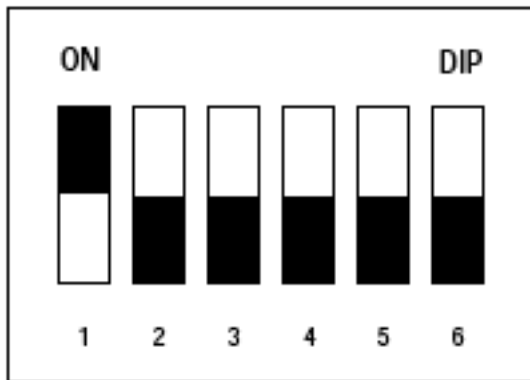


Green channel: GS10

For Blue Channel



Blue channel: GS00



Blue channel: GS01



Blue channel: GS10

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