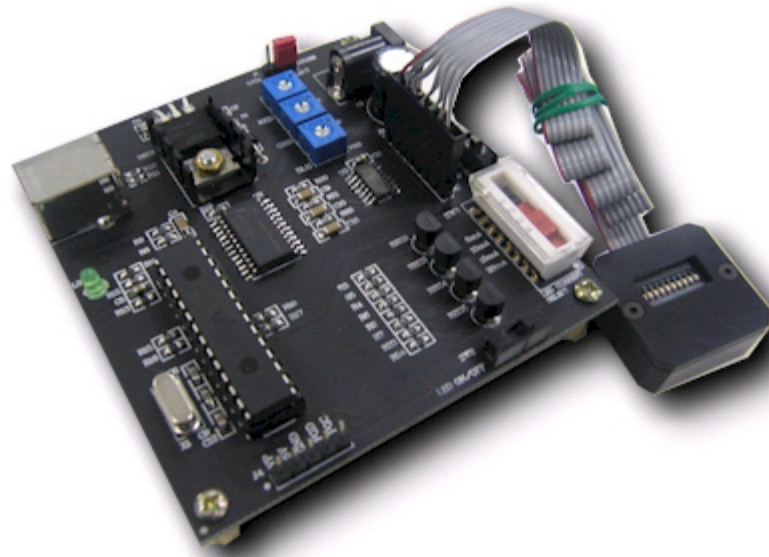


User Guide



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Warning

DO NOT CONNECT OR DISCONNECT ANYTHING WHILE THE HDJD-JD06 DEVELOPMENT KIT OR THE PC IS SWITCHED ON!!! Doing so anyway may damage your PC and/or the HDJD-JD06 Development Kit permanently. Make sure power is off while interfacing with the Controller Board. DO NOT & never switch off power from controller board while program is running.

Credits

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

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1.0 Introduction

Avago Technologies has introduced a new color sensor ADJD-E622-QR999, designed specifically for automotive applications. It is built to meet the Automobile Electronics Council AEC-Q100 standards. This RGB color sensor combines a photodiode array and three trans-impedance amplifiers in a single monolithic CMOS IC solution.

The sensor is packaged in a 5x5x0.75 [mm] surface mount QFN-16 package. 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. The photodiode arranged in 3x3 array design to minimize the effect of contamination and optical aperture misalignment. There are independent gain selection options for each R,G and B channel.

ADJD-E622-QR999 is an ideal choice of light sensor in automotive applications such as dashboard lighting, automotive interior lighting, infotainment and navigational panel. Other potential applications are such as environmental lighting, cabin lighting, decorative lighting, general color detection, industrial process, etc.

The Avago sensor development kit, HDJD-JD06 is used as a guide to the application of ADJD-E622-QR999 besides demonstrating the principle of color sensing. The color sensor development kit can be used for both transmissive and reflective sensing.

Some of the HDJD-JD06 features:

Easily connected to PC via standard USB port which is compatible with most IBM PC.

User-friendly software with displays of output analogue voltage, digital RGB readings, conversion to standard color format, datalog and CIE color chart features.

Color sensor controller board consists of post amplifier, filters and LED current selection features.

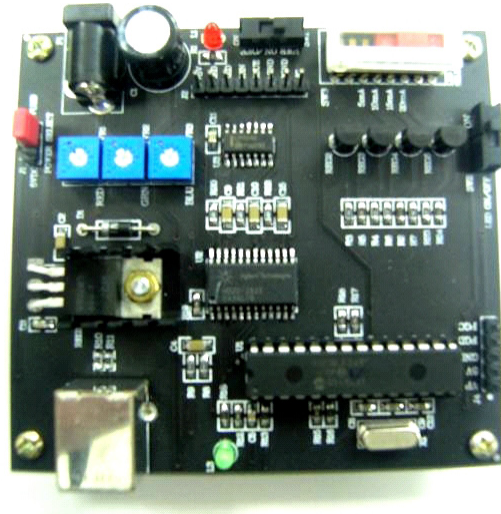
Avago HDJD-JD06 serves an exemplary circuit application for composing other simple reflective and transmissive color detection system with Avago color sensor.

2.0 Startup

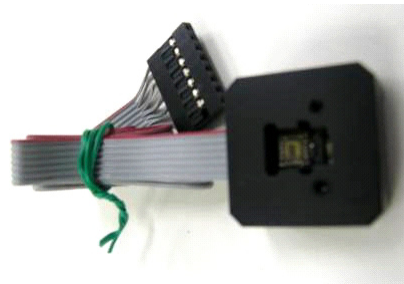
Include in delivery

Standard Avago HDJD-JD06 includes the following components:

- One sensor module
- One Controller Board (CB)
- One USB cable
- One CD with installation software



Color Sensor Controller Board



Sensor Module



CD with installation software



USB cable

3.0 Color Sensor Module

The color sensor module comprises an illuminant, RGB color sensor and the mechanical block. The Avago white LED (HSMW-C191) is used as the illuminant/light source and RGB color sensor in QFN Package (ADJD-E622-QR999) as the detector. The mechanical block not only acts as the casing but also features an alignment gauge for maintaining an optimum gap between sensor and the targeted surface.

ADJD-E622-QR999 is a high performance, small in size, cost effective light to voltage converting sensor. The sensor combines a photodiode array and three transimpedance 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 VR_{OUT}, VG_{OUT} and VB_{OUT}, respectively. The sensor is packaged in a 5x5x0.75 [mm] surface mount QFN-16 package.

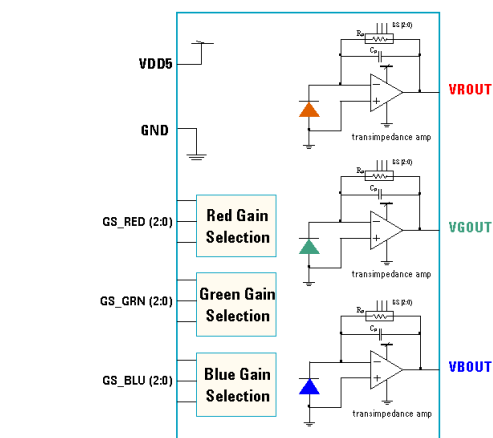
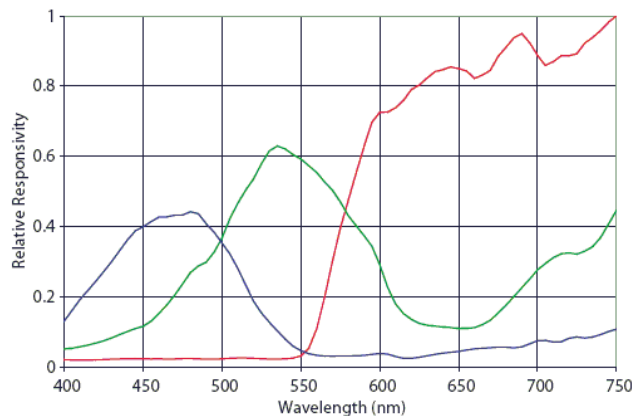


Figure 3.0: Spectral Responsivity and Block Diagram of ADJD-E622-QR999

Avago HSMW-C191 is a small white ChipLED in a standard footprint (1.6mm x 0.8mm x 0.6mm). The typical luminous intensity is 200mcd @ 20mA with typical viewing angle at 140 degrees. For more details of ADJD-E622-QR999 and HSMW-C191 specifications, please refer to the datasheet which can be download at www.avagotech.com.

Reflective Color Sensing Theory of Operation

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 analogue 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.

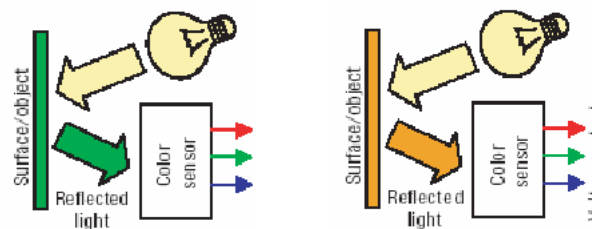


Figure 3.1: For a given light source, the color of reflected depends on surface/object color

Transmissive Color Sensing Theory of Operation

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 converted into digital values 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.

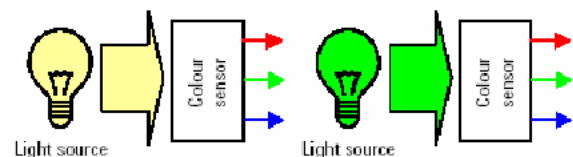


Figure 3.2: R, G, B outputs of the sensor is determined by color of light falling on the sensor

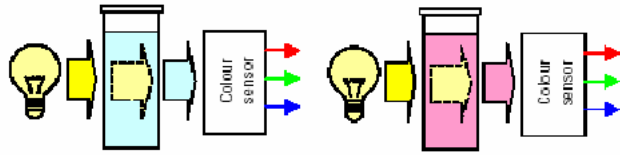


Figure 3.3: Apply color sensor on media such as color filter, gas or liquid

To use HDJD-JD06 in transmissive mode, the white LED should be turned off with the slider switch at the color sensor controller board.

3.1 Color Sensor Controller Board

The color sensor controller board consists of the following modules:

- Color reading and interface Module
- Power Supply Module
- LED Constant Current Module
- Color Reading and Interface Module

This module converts the analogue voltage to digital output, and then from 2-wire serial interface to USB protocol that can be easily interfaced with the computer. The ADC has 10-bit resolution. Upon power up, the ADC 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 microcontroller via the 2-wire serial interface which is then sent to Avago sensor development kit program via USB upon completion of each round of conversion.

The main components of this module are HDJD-J822 as

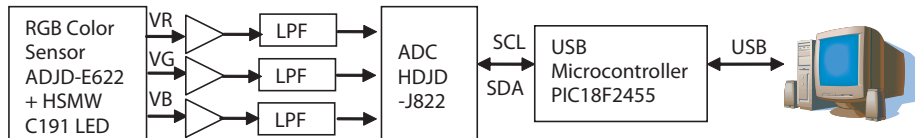


Figure 3.4: Color Reading and Interface Module Block Diagram

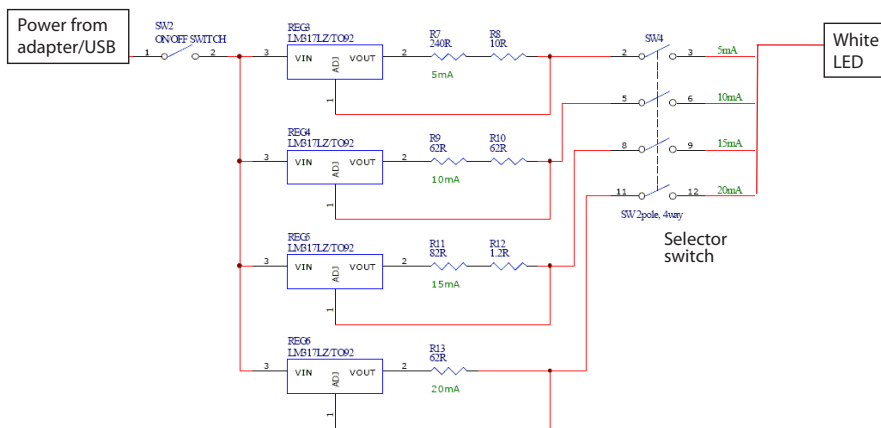


Figure 3.6: LED Constant Current Block Diagram

analogue to digital converter, amplifier and RC low pass filter using LM324 and USB microcontroller, PIC18F2455 to interface the 2-wire serial interface to USB.

Power Supply Module

The power supply module provides regulated voltage 5V for the ADC, microcontroller, op-amp, LED and color sensor. The power source can be selected from the USB or the power adapter.

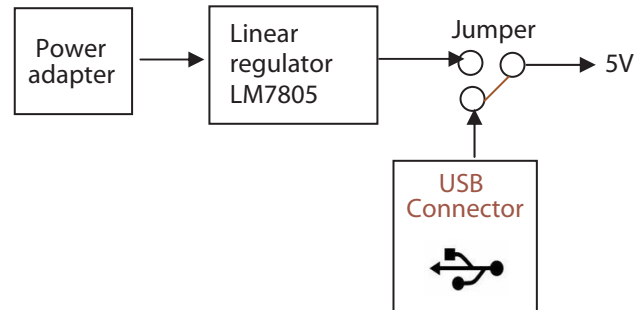


Figure 3.5: Power Module Block Diagram

LED Constant Current Module

This module provides four selectable current 5mA, 10mA, 15mA and 20mA to the white LED.

4.0 Hardware Setup & Configuration

Setup:

This HDJD-JD06 has designed 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".

Connect the USB cable from the computer to the controller board.

Select the jumper to the power source to use. If power from adapter is chosen, connect the adapter to the adapter socket.

Precaution: Please make sure that the adapter voltage is between 9V to 20V.

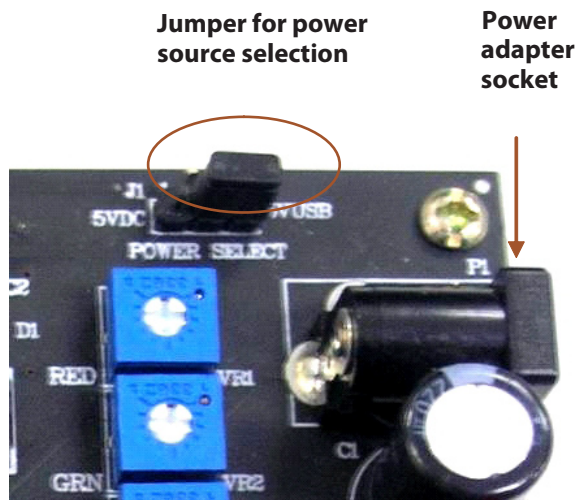


Figure 4.0: Selecting the power supply

Connect the sensor module to the controller board. Make sure the orientation is correct by checking the pin 10 that is without cable is connected to NC.

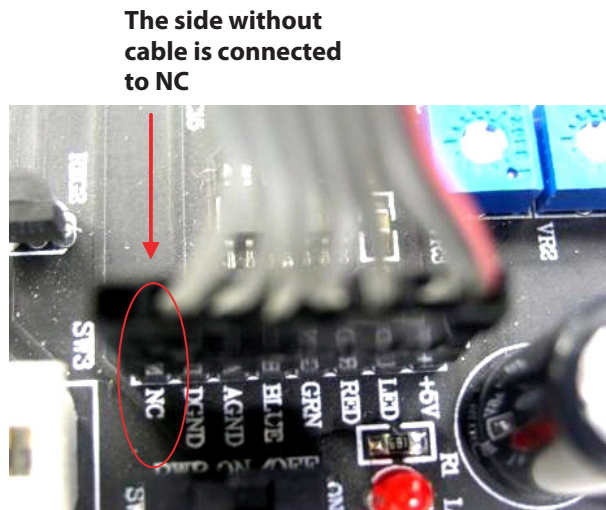


Figure 4.1: The right orientation to connect the sensor module to controller board

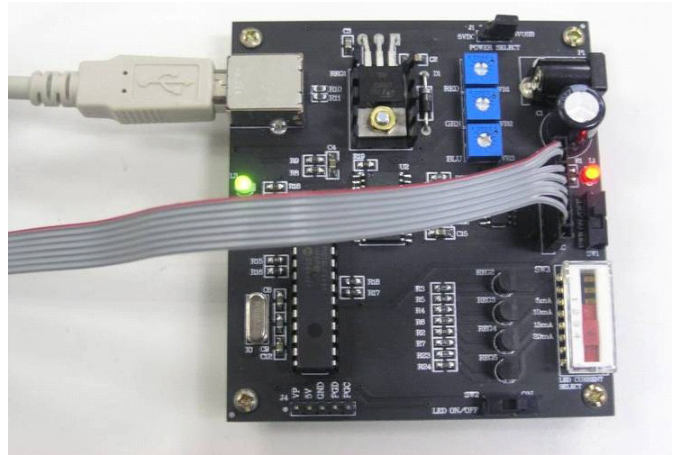


Figure 4.2: Controller board with all interface connected

To power on:

Turn on the power switch (SW1). The red LED will light up to indicate there is power supply to the board.

The green LED will light up if the USB cable is connected indicating there are communication between the controller board and the computer.

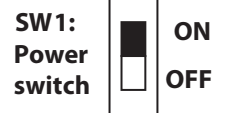
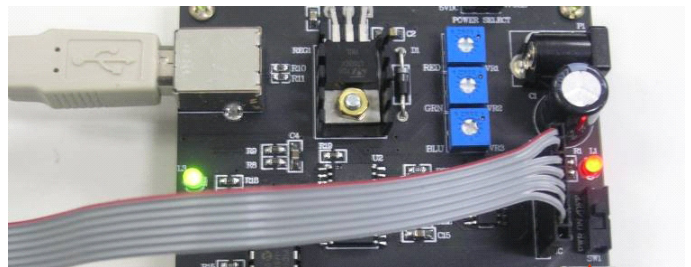


Figure 4.3

LED switches:

Turn on the white LED for reflective sensing using SW2. Turn off the LED for transmissive sensing or during calibration.

The LED current can be selected between 5mA, 10mA, 15mA or 20mA by switching SW3.

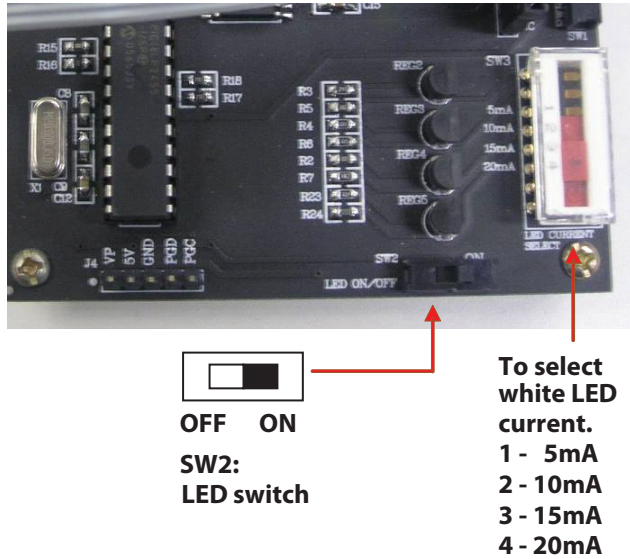
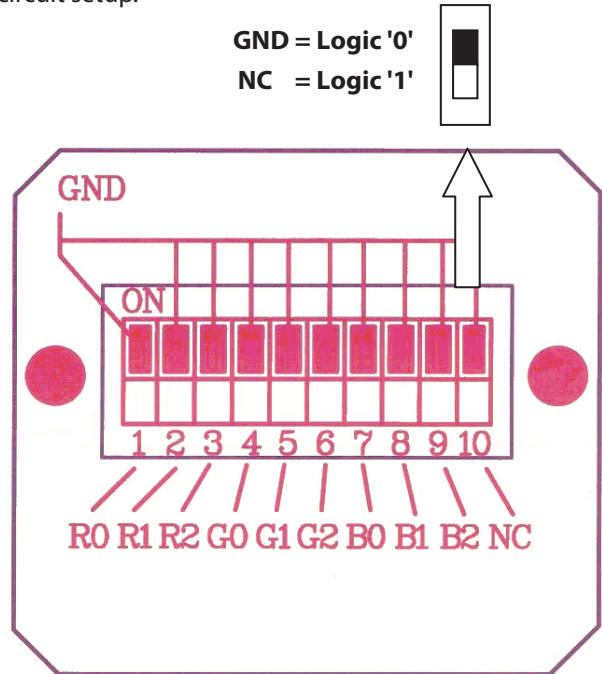


Figure 4.4: LED switches

Dip Switch:

The dip switch is used to select the gain of the color sensor. Please refer to the datasheet and application note for details on the gain feedback resistor table, the responsivity correspond to the feedback resistor and circuit setup.



- Pin 1 - R0: Gain Selection Red Bit '0'
- Pin 2 - R1: Gain Selection Red Bit '1'
- Pin 3 - R2: Gain Selection Red Bit '2'
- Pin 4 - G0: Gain Selection Green Bit '0'
- Pin 5 - G1: Gain Selection Green Bit '1'
- Pin 6 - G2: Gain Selection Green Bit '2'
- Pin 7 - B0: Gain Selection Blue Bit '0'
- Pin 8 - B1: Gain Selection Blue Bit '1'
- Pin 9 - B2: Gain Selection Blue Bit '2'

Figure 4.5: Gain Selection Diagram

Table 4.0: Gain Selection Feedback Resistor Table

GS: Bit 2	GS: Bit 1	Bit 0	Feedback Resistor, R
0	0	0	1.9 MΩ
0	0	1	2.5 MΩ
0	1	0	3.2 MΩ
0	1	1	4.1 MΩ

5.0 PC Software Guide

Avago HDJD-JD06 Color Sensor Development Kit software is developed to be a tool for user to acquire knowledge on how to use ADJD-E622-QR999 and how color sensor can be applied. The interactive graphical user interface has made the software to be user friendly and easy to use. The same software can be used for both reflective and transmissive mode.

Software Installation

To install the software to the PC:

Insert the installation CD to the CD-ROM drive

Click Start, then click Run

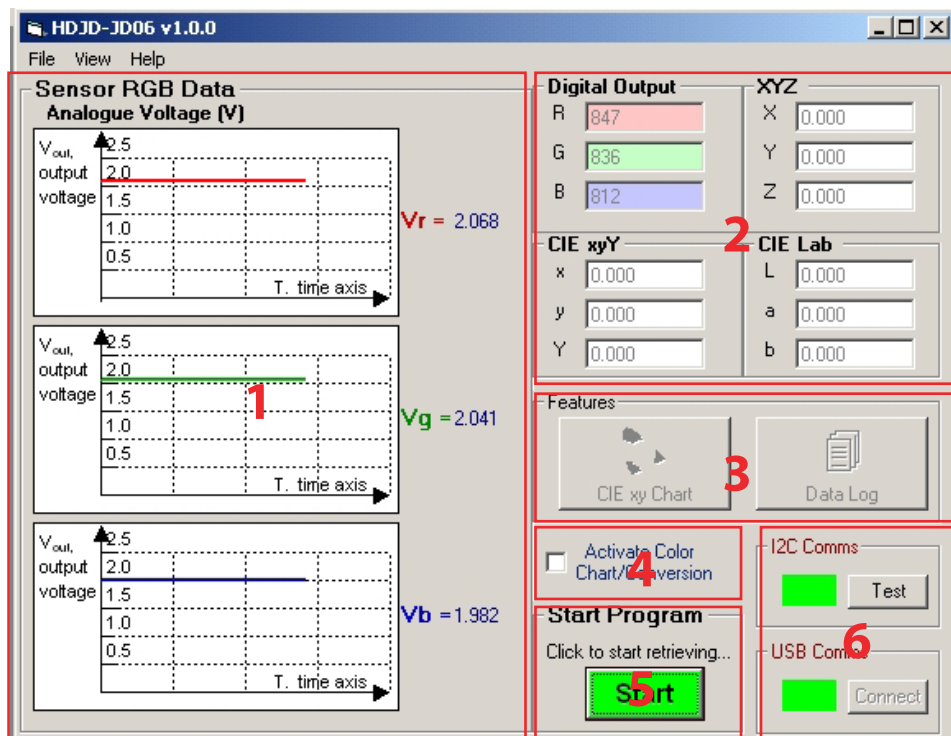
Type D:\setup and press Enter.

IMPORTANT: Use the appropriate drive letter in the above command to install the software. CD-ROMs are commonly "D:".

The installation program will guide you through the software installation.

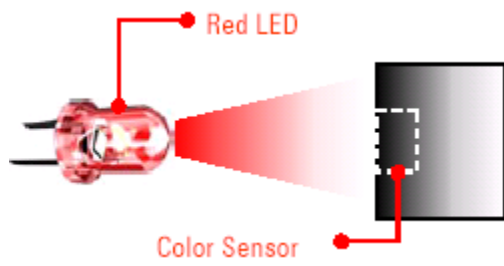
User Interface

- Sensor RGB Data – Analogue Voltage**
Display the sensor RGB analogue voltage in graphical and numerical form. The RGB voltage will range from 0V to 2.5V.
- Sensor Reading in Standard Color Format**
Display the sensor readings in digital RGB readings, XYZ tristimulus values, CIE Yxy color space and L*a*b* Color space. The XYZ, Yxy and Lab value will only be shown if the checkbox for "Activate Color Chart/Conversion" is checked.
- Features**
Includes the button to launch the CIE xy chart and datalog window.
- Activate Color Chart/ Conversion**
When the box is checked, the RGB readings will be converted to XYZ, Yxy and Lab color space. A circle will appear at the CIE xy chart to show the color point of the color measured. Unchecked the box to disable the color conversion and color chart function.
- Start Program**
Click to start color measurement. The measurement will be continuous until the button is click again.
- Comms**
The user needs to check the communication between the software and the board before using the software by pressing the test button. Red means the comms test failed. Green means it passed.



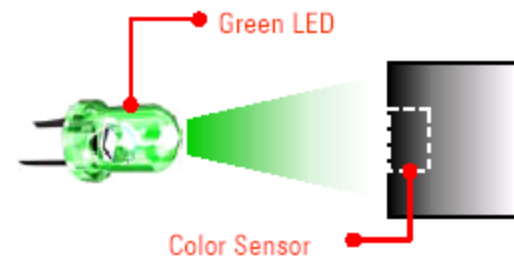
Sensor Reading Interpretation.

The sensor readings obtained is processed to yield color information. Below is the example of detecting LED color in transmissive mode.



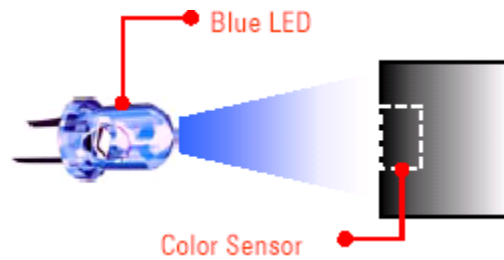
Digital Output	
R	319
G	149
B	75

When sensor module position direct to RED LED. Observed that sensor reading for R channel will indicate highest compared to G & B channel.



Digital Output	
R	105
G	230
B	24

When sensor module position direct to GREEN LED. Observed that sensor reading for G channel will indicate highest compared to R & B channel.



Digital Output	
R	22
G	198
B	611

When sensor module position direct to BLUE LED. Observed that sensor reading for B channel will indicate highest compared to R & G channel.

Color Conversion

RGB -> XYZ

With the digitized value of RGB obtained from the sensor and ADC, the system will further interpret and convert it into XYZ color space and XYZ values are displayed.

CIE XYZ color space is special, because it is based on direct measurements of the human eye, and serves as the basis from which many other color spaces are defined. XYZ tristimulus values are calculated using the CIE Standard Observer color matching functions shown in Figure 5.0.

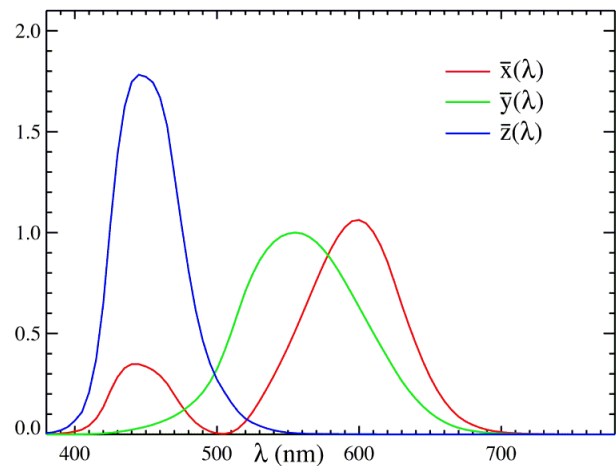


Figure 5.0: Spectral sensitivity corresponding to human eye

XYZ -> Yxy

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 the results are not easily visualized. Because of this, CIE also defined a color space in 1931 for graphing color in 2D independent of lightness, the Yxy color space. The Y is the lightness component of color while the xy are the chromaticity coordinates calculated from the XYZ tristimulus values. The concept of color can be divided into two parts: brightness and chromaticity. For example, the color white is a bright color, while the color grey is considered to be a less bright version of that same white. In other words, the chromaticity of white and grey are the same while their brightness differs.

The x and y are calculated based on the following formula:

$$x = \frac{X}{X + Y + Z},$$

$$y = \frac{Y}{X + Y + Z}.$$

Y is identical to tristimulus value Y.

XYZ -> L*a*b*

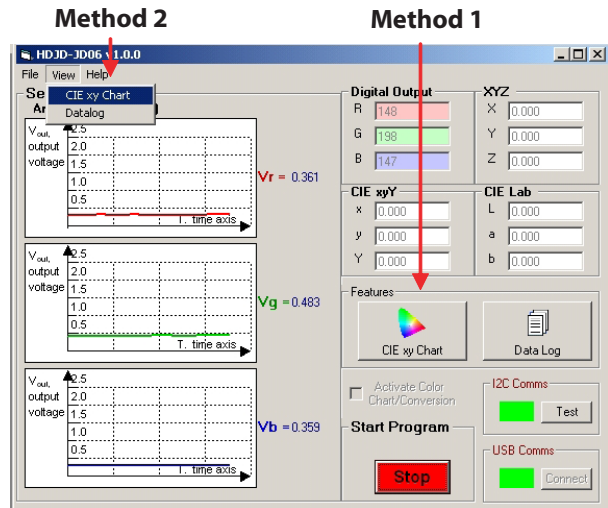
CIE L*a*b* (CIELAB) is the most complete color model used conventionally to describe all the colors visible to the human eye. The three parameters in the model represent the lightness of the color (L*, L*=0 yields black and L*=100 indicates white), its position between magenta and green (a*, negative values indicate green while positive values indicate magenta) and its position between yellow and blue (b*, negative values indicate blue and positive values indicate yellow).

CIE 1976 L*a*b* is based directly on the CIE 1931 XYZ color space as an attempt to linearize the perceptibility of color differences, using the color difference metric described by the MacAdam ellipse. The non-linear relations for L*, a*, and b* are intended to mimic the logarithmic response of the eye.

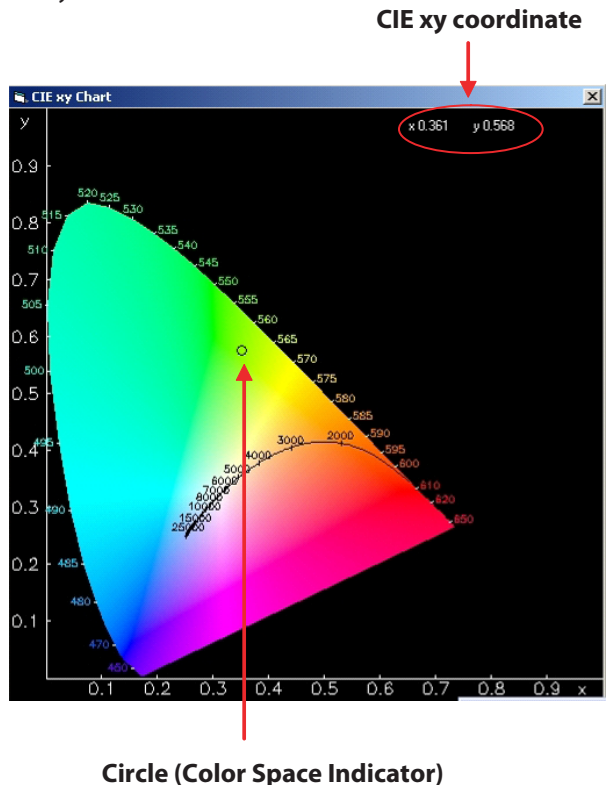
CIE xy chart

The CIE xy chart can be accessed in the following 2 ways:

1. Click on CIE xy Chart button at features section at the main GUI.
2. Click menu View -> CIE xy Chart.



To view the CIE xy chart real time, user had to activate the color chart/ conversion. Then a circle will appear showing the color measured by the color sensor at the CIE xy chart.



Numerical Data Log

With this numerical data log feature, the user can identify and keep track the consistency and repeatability of the color being scanned. The user can also save the data so that it can easily be retrieved later. The data log can be access in the following 2 ways:

1. Click on Datalog button at features section at the main GUI.
2. Click menu View -> Datalog.

Buttons function at Data log windows:

Get data: Transfer the analogue and digital readings measured and displayed at the main GUI to the data log windows.

SaveAs: Save file as several different types of format (e.g. RTF, Text Files or Excel Files).

Clear: Clear the display screen of data log windows.

Exit: Close the data log window.

The screenshot displays the HDJD-JD06 v1.0.0 software interface. The main window is titled "Sensor RGB Data" and contains three graphs showing "Analogue Voltage (V)" for Red (Vr), Green (Vg), and Blue (Vb) channels. Each graph plots "V_{out} output voltage" (0.5 to 2.5) against "T. time axis". The current readings are Vr = 2.334, Vg = 2.324, and Vb = 2.334. To the right of these graphs are sections for "Digital Output" (R: 956, G: 952, B: 956), "CIE xyY" (x: 0.000, y: 0.000, Y: 0.000), and "CIE Lab" (L: 0.000, a: 0.000, b: 0.000). Below these are "Features" (CIE xy Chart, Data Log), "I2C Comms" (Test), and "USB Comms" (Connect). A "Start Program" section has a red "Stop" button. A "Sensor Data Log" window is open on the right, showing a table of data points.

VR	VG	VB	R	G	B
0.437	0.300	0.217	179	123	89
1.406	0.869	0.684	576	356	280
0.442	0.576	0.845	181	236	346
0.308	0.347	0.215	126	142	88
0.708	0.706	1.055	290	289	432
0.620	1.096	1.150	254	449	471
0.144	0.251	0.632	59	103	259
0.359	0.586	0.320	147	240	131
1.121	0.342	0.188	459	140	77
2.332	2.322	2.329	955	951	954

At the bottom of the "Sensor Data Log" window, there are buttons for "Get Data", "Save As", "Clear", and "Exit".

5.1 Activation of Color Chart/ Conversion

The following is the step by step procedure to activate the color chart and color conversion. To make sure that the conversion is correct, the procedure should be strictly followed.

1. First, select the LED current to 20mA. Refer to section 4.0 on how to select the LED current.
2. Select all the sensor gains to '1' which means put the dip switch to the position as shown in the picture below. (Refer to section 4.0 for how to select the gain)

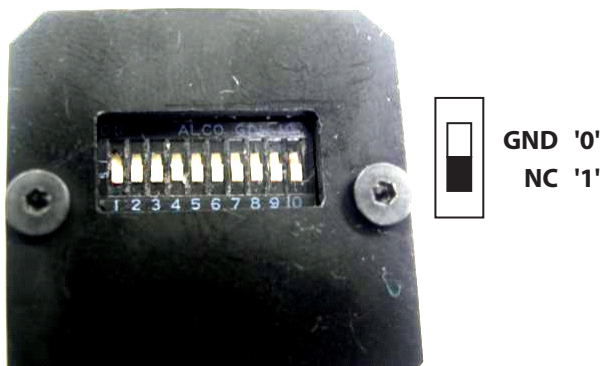
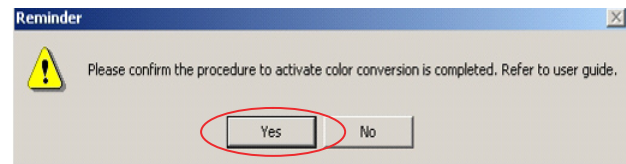
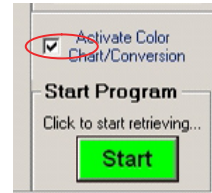


Figure 5.1: Select all sensor gain to '1'

3. Check the checkbox "Activate color chart/ conversion" and then click "Start" button. A message box will appear, click Yes to confirm all procedure correctly done. The color conversion and real time CIE xy chart is now activated.



Note: Do not adjust the trimmers at the controller board. The trimmers are calibrated at the factory for optimum color conversion.

For product information and a complete list of distributors, please go to our web site:

www.avagotech.com

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