



# Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

By Reinhard Schaar

The VEML3328 is an advanced RGB-IR / ambient light sensor with an I<sup>2</sup>C protocol interface and designed with CMOS technology.

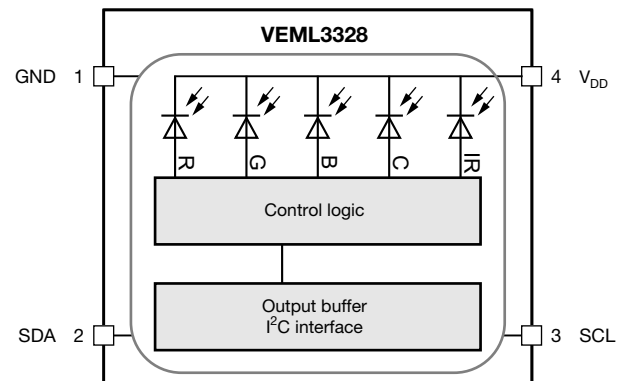
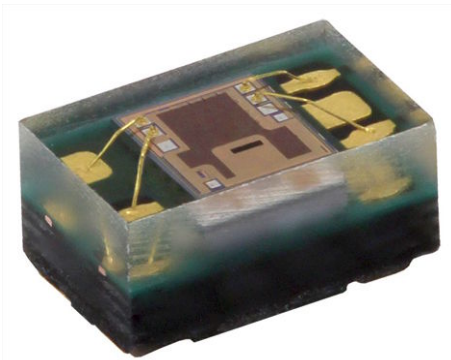


Fig. 1 - VEML3328 Block Diagram

The VEML3328 color sensor senses red, green, blue, infrared, and white light and incorporates photodiodes, amplifiers, and analog / digital circuits into a single CMOS chip. This digital RGB-IR-C information can be used in feedback control systems, among other things, to monitor and actively control a light source. For example, with the color sensor applied, the brightness and color temperature of a backlight can be adjusted, based on the ambient light conditions, in order to make the panel look more comfortable to the user's eyes. The VEML3328's adoption of the Filtron™ technology achieves an accurate response to the mid of each requested band for the red, green, and blue channel. Furthermore, it provides excellent temperature compensation, keeping the output stable under changing temperatures.

The VEML3328's functions are easily operated via simple commands sent over the I<sup>2</sup>C (SMBus compatible) bus.

The VEML3328 is packaged in a lead (Pb)-free 4-pin OPLGA package, which offers the best market-proven reliability.

The VEML3328 comes within a very small surface-mount package with dimensions of just 2.0 mm x 1.25 mm x 1.0 mm (L x W x H).

## VEML3328 RGB SENSOR APPLICATIONS

- Automatic white balancing of digital cameras
- Eliminate unsightly blue or orange color casts
- Adjust the backlight of an LCD display to provide a white balance in all ambient light conditions
- Actively monitor and control the color output of LEDs
- Differentiate indoor from outdoor lighting environments

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### APPLICATION CIRCUIT FOR THE VEML3328

The VEML3328 operates within a supply voltage range from 2.5 V to 3.6 V. The necessary pull-up resistors for the I<sup>2</sup>C lines can be connected to the same supply as the host micro controller, and have a range between 1.7 V and 3.6 V.

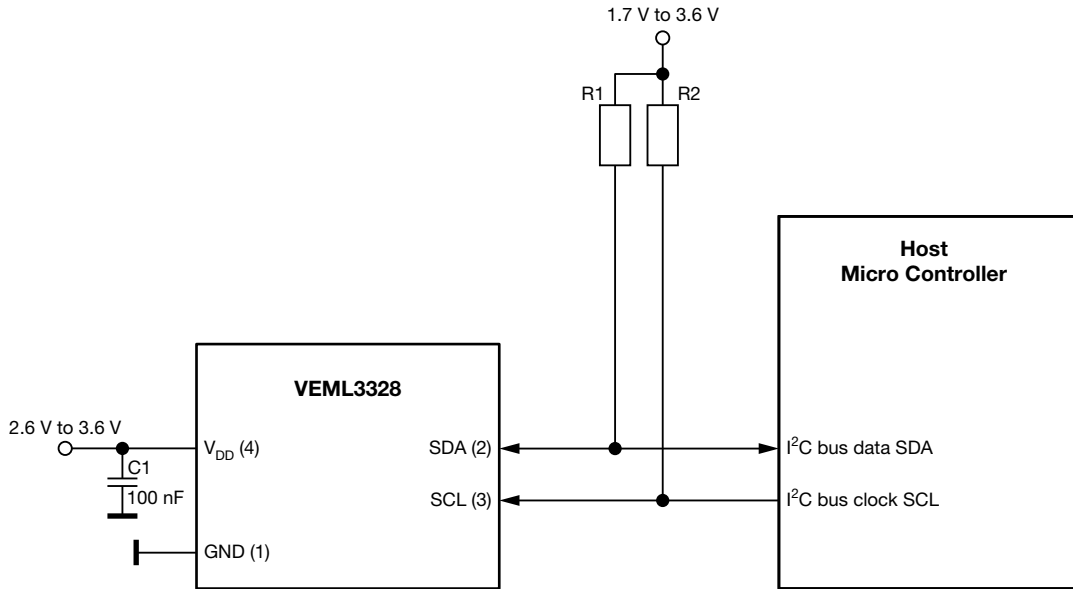


Fig. 2 - Hardware Pin Connection Diagram (slave address 0x10)

The value of the pull-up resistors should be from 2.2 kΩ to 4.7 kΩ.

The current consumption of the VEML3328 is typically 580 μA when measurements are being made. In the shut-down mode, which can always be chosen between any measurements (SD0 = 1 and SD1 = 1), the current consumption goes down to about 80 nA.

### SPECTRAL SENSITIVITY

The VEML3328 has peak sensitivities for red, green, blue, IR, and clear at 610 nm, 560 nm, 470 nm, 825 nm, and 590 nm respectively.

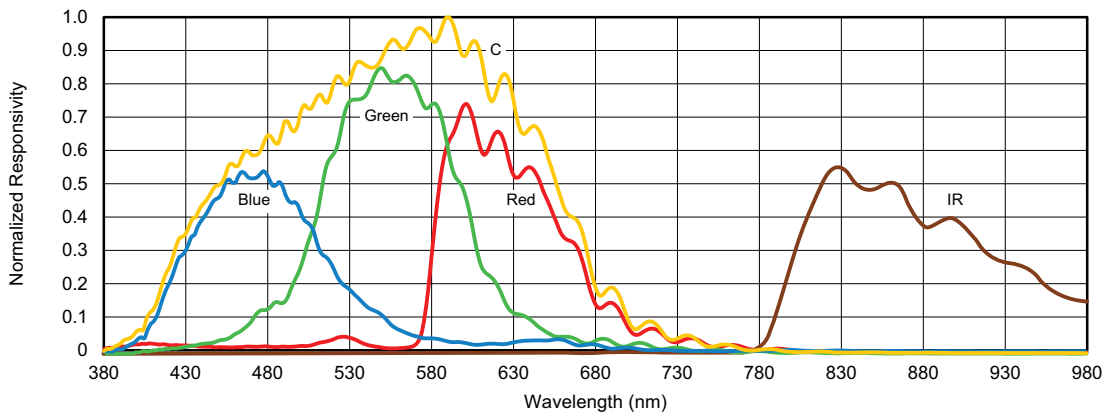


Fig. 3 - Normalized Responsivity vs. Wavelength



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### INITIALIZATION AND MEASUREMENT MODES

Set-up and initialization of the VEML3328 is done over the shutdown (SD0 and SD1) bits in register 0x00. Setting SD0 and SD1 to 0 enables the device and starts measurements in either auto (self-timed) mode or “Active Force” mode. Upon setting SD0 = 0 and SD1 = 0 with the bit AF = 0, the so-called “Auto” mode is started, and measurements are made continuously until SD0 and SD1 is set to 1. With AF = 1, only a single measurement is made, after which the component waits for the next command. This single measurement cycle is triggered by setting TRIG = 1.

### INTEGRATION TIME SETTINGS

The time over which the sensor integrates per measurement cycle can be set via the IT bits in the command register 0x00. The value set for IT defines the integration time and is set via bits 5 and 4 in the command register. From 0 : 0 to 1 : 1, four different integration times are selectable. The selectable integration times are shown within below Table 1.

TABLE 1 - COMMAND CODE DESCRIPTION				
COMMAND CODE	REGISTER NAME	BIT	FUNCTION DESCRIPTION	R / W
0x00	SD1	15	Shutdown setting <sup>(1)</sup> SD1 = 0 power on SD1 = 1 shutdown (default)	R / W
	SD_ALS only	14	0 = power on all channels (default) 1 = power on G, C, and IR (R, B shutdown)	
	DG	13 : 12	(0 : 0) = x 1 (default) (0 : 1) = x 2 (1 : 0) = x 4 (1 : 1) = reserved	
	GAIN	11 : 10	(1 : 1) = x 1/2 (0 : 0) = x 1 (default) (0 : 1) = x 2 (1 : 0) = x 4	
	Reserved	9 : 8	Set (0 : 0)	
	Reserved	7	Set 0	
	SENS	6	0 = high sensitivity (default) 1 = low sensitivity (1/3)	
	IT	5 : 4	Integration time setting (0 : 0) = 50 ms (default) (0 : 1) = 100 ms (1 : 0) = 200 ms (1 : 1) = 400 ms	
	AF	3	Auto / active force mode 0 = auto mode (default) 1 = active force mode	
	TRIG	2	Trigger a single measurement when in active force mode. This bit resets to “0” automatically when the measurement cycle is complete. 0 = no trigger (default) 1 = trigger one measurement cycle	
	Reserved	1	Set 0	
	SD0	0	Shutdown setting <sup>(1)</sup> SD0 = 0 power on SD0 = 1 shutdown (default)	

**Note**

<sup>(1)</sup> For power on, both SD0 and SD1 have to be set to 0; for shutdown, both SD0 and SD1 have to be set to 1



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The sensitivity of the component changes according to the set integration time and gain. With a set integration time of 100 ms, DG of x 1 and GAIN with x 4 the lux sensitivity of the green channel is 0.048 lux/step. Choosing a longer integration time will increase the sensitivity accordingly, with the longest integration time of 400 ms and also gain 1 set to x 4 leading to the highest sensitivity of 0.003 lux/step. The maximal detectable intensity is also derived from the set integration time. The sensitivity and detectable range for each of the selectable integration times is shown in Table 2.

<b>TABLE 2-1: RESOLUTION AND MAXIMUM DETECTION RANGE (FULL PD: SENS = 0)</b>									
	DG: x 4					DG: x 4			
	GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2		GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2
IT (ms)	TYPICAL RESOLUTION (lx/cnt)					MAXIMUM POSSIBLE ILLUMINATION (lx)			
400	0.003	0.006	0.012	0.024		197	393	786	1573
200	0.006	0.012	0.024	0.048		393	786	1573	3146
100	0.012	0.024	0.048	0.096		786	1573	3146	6291
50	0.024	0.048	0.096	0.192		1573	3146	6291	12 583
	DG: x 2					DG: x 2			
	GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2		GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2
IT (ms)	TYPICAL RESOLUTION (lx/cnt)					MAXIMUM POSSIBLE ILLUMINATION (lx)			
400	0.006	0.012	0.024	0.048		393	786	1573	3146
200	0.012	0.024	0.048	0.096		786	1573	3146	6291
100	0.024	0.048	0.096	0.192		1573	3146	6291	12 583
50	0.048	0.096	0.192	0.384		3146	6291	12 583	25 165
	DG: x 1					DG: x 1			
	GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2		GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2
IT (ms)	TYPICAL RESOLUTION (lx/cnt)					MAXIMUM POSSIBLE ILLUMINATION (lx)			
400	0.012	0.024	0.048	0.096		786	1573	3146	6291
200	0.024	0.048	0.096	0.192		1573	3146	6291	12 583
100	0.048	0.096	0.192	0.384		3146	6291	12 583	25 165
50	0.096	0.192	0.384	0.768		6291	12 583	25 165	50 331

For very high illuminations it may be needed to switch off to only 1 PD for each channel, then up to 150 klx is possible.

<b>TABLE 2-2: RESOLUTION AND MAXIMUM DETECTION RANGE (1/3 PD: SENS = 1)</b> (makes only sense for very high illumination)									
	DG: x 1					DG: x 1			
	GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2		GAIN: x 4	GAIN: x 2	GAIN: x 1	GAIN: x 1/2
IT (ms)	TYPICAL RESOLUTION (lx/cnt)					MAXIMUM POSSIBLE ILLUMINATION (lx)			
400	0.036	0.072	0.144	0.288		2359	4719	9437	18 874
200	0.072	0.144	0.288	0.576		4719	9437	18 874	37 748
100	0.144	0.288	0.576	1.152		9437	18 874	37 748	75 496
50	0.288	0.576	1.152	2.304		18 874	37 748	75 496	150 993

## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

### READ OUT OF RGB-IR-C RESULTS

The VEML3328 stores the 16-bit measurement results from the red, green, blue, clear, and IR channels in the registers 0x04 to 0x08. Each 16-bit result consists of a low and high byte, stored in the respective 8-bit registers as shown in the table below:

TABLE 3 - READ OUT COMMAND CODE DESCRIPTION				
COMMAND CODE	REGISTER NAME	DATE BYTE LOW / HIGH	BIT	FUNCTION DESCRIPTION
0x04	C_LSB	Low	7 : 0	Clear channel LSB data
	C_MSB	High	7 : 0	Clear channel MSB data
0x05	R_LSB	Low	7 : 0	Red channel LSB data
	R_MSB	High	7 : 0	Red channel MSB data
0x06	G_LSB	Low	7 : 0	Green channel LSB data
	G_MSB	High	7 : 0	Green channel MSB data
0x07	B_LSB	Low	7 : 0	Blue channel LSB data
	B_MSB	High	7 : 0	Blue channel MSB data
0x08	IR_LSB	Low	7 : 0	Infrared channel LSB data
	IR_MSB	High	7 : 0	Infrared channel MSB data
0x0C	ID_L	Low	7 : 0	Device ID 0x28
	Reserved	High	7 : 0	

The results will be updated after each measurement cycle, with each color channel being processed in parallel, so that red, green, blue, clear, and IR content of the light source is all measured at the same time. The amount of time taken for the completion of one measurement cycle depends on the IT setting in the command register. In self-timed mode the VEML3328 measures continuously; the host can poll the result registers. To ensure that the value read is current, an integration waiting period should be observed between readings. In “Active Force” mode, the VEML3328 executes one measurement cycle once the TRIG bit has been set. The result is updated after the measurement has completed, which remain in the result registers until a new measurement is made.

### VEML3328 “GREEN” CHANNEL USED AS AMBIENT LIGHT SENSOR

The spectral characteristics of the green channel match well to the so-called “Human Eye”  $v(\lambda)$  curve (fig. 5). Accordingly, reading the 16-bit green channel result data and multiplying this with the sensitivity factor, for the selected integration time, will lead to an accurate ALS result in lux. The lux sensitivity for every given integration time is shown in table 2.

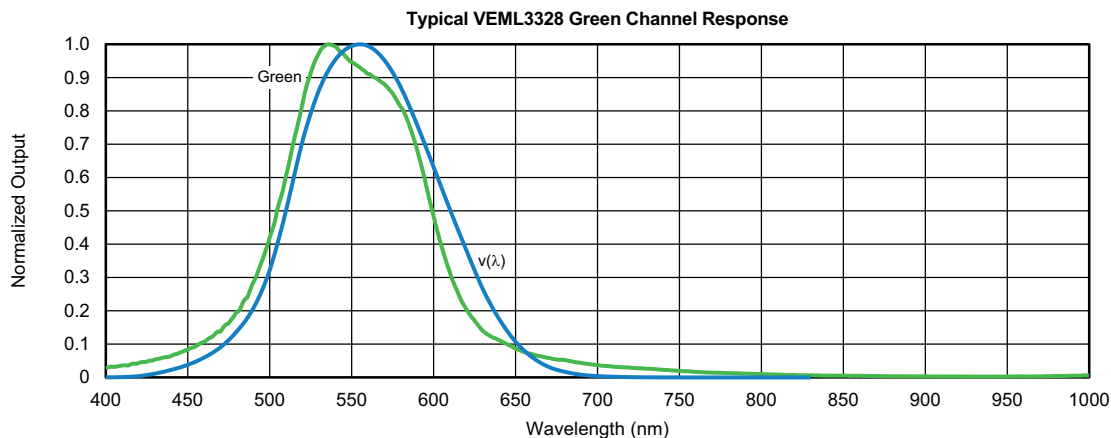


Fig. 4 - Normalized Green Channel Responsivity vs. Wavelength

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The corresponding ALS lux level is as follows: lux = G\_DATA x sensitivity.

**Example:**

For a selected integration time of 50 ms and GAIN = 1 and DG = 1, where sensitivity is 0.384 lux/count multiplied with a 16-bit green data value of 1254 counts (shown in Fig. 7), ALS (lux) = 1254 x 0.384 = 481.536 lux.

For a selected integration time of 100 ms and both gain set to “1”, the sensitivity is 0.192 lux/count. If the 16-bit green data value is 2508, the ALS (lux) = 2508 x 0.192 = 481.536 lux.

**CORRELATED COLOR TEMPERATURE (CCT)**

Another major application of an RGB sensor is to sense the correlated color temperature (CCT). This information can then be used in a feedback system to control a light source, such as a television backlight or an LED array. This can help to maintain the light sources’ output with reference to drifts associated with aging and temperature changes. Ambient light conditions in a room may also be monitored, so that backlights can be adjusted to make the screen appear more appealing to the human eye. The procedure for calculating the CCT from the sensors’ raw RGB channels is explained below.

**XYZ TRISTIMULUS VALUES AND THE COLOR GAMUT**

In order to help define a light source to specific common parameters, the International Commission on Illumination (CIE) has defined a color space called the XYZ color space. These XYZ values are called the “tristimulus” values. The color space calls upon a set of specified spectral sensitivity functions, called the color matching functions, from which the tristimulus values are derived. The tristimulus values are arrived at by integrating over the visible spectrum. The color matching functions and the corresponding tristimulus values are shown below:

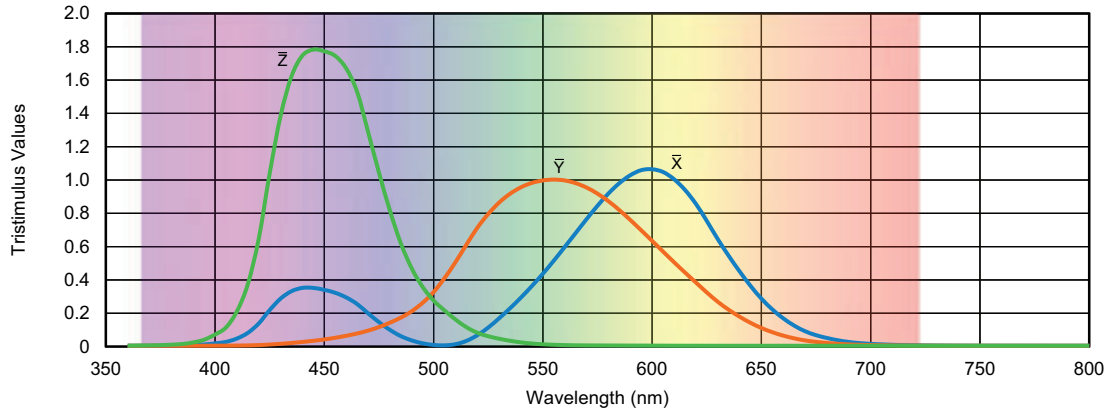


Fig. 5 - Color Matching Functions

$$X = \int_{360}^{780} \bar{X}(\lambda)d\lambda, \quad Y = \int_{360}^{780} \bar{Y}(\lambda)d\lambda, \quad Z = \int_{360}^{780} \bar{Z}(\lambda)d\lambda$$

The chromaticity coordinates (x, y) values can then be derived from the normalized XYZ values. This allows the color gamut (CIE 1931 chromaticity diagram) to be used to arrive at the color of the light and calculate the color temperature, for example, by using the McCamy formula. The process of calculating the CCT from the RGB sensor values is described in the next section. The color gamut and the corresponding equations to arrive at the (x, y) coordinates are shown below.

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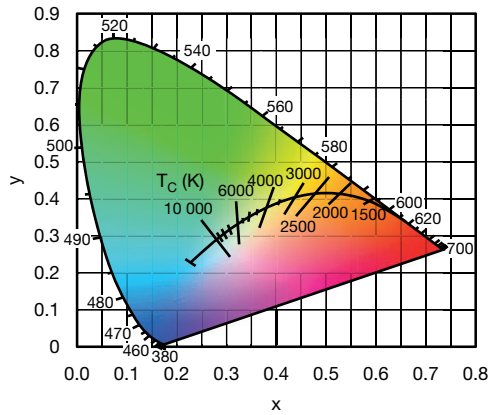


Fig. 6 - The CIE1931 (x, y) Chromaticity Space, also Showing the Chromaticities of Black-Body Light Sources of Various Temperatures (Planckian Locus), and Lines of Constant Correlated Color Temperature

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

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

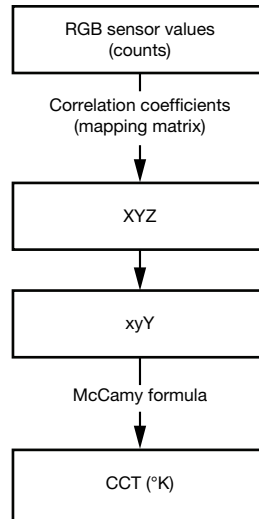
When converting between the XYZ color space and the xyY color space, the Y value (illuminance) is simply kept the same:

$$Y = Y$$

## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

### USING THE VEML3328 TO CALCULATE THE CCT (McCAMY FORMULA)

In order to calculate CCT values from the RGB values (counts) that are read by the VEML3328, the following steps can be taken:



As indicated by the first step, a so-called mapping matrix is required to convert the RGB values to XYZ values. The coefficients in this matrix map the RGB sensor values to the defined color matching functions, to then accurately arrive at the XYZ tristimulus values. Once the correlation coefficients of the mapping matrix are found, the following equation can be used to arrive at the XYZ values:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} M_1 & M_2 & M_3 \\ M_4 & M_5 & M_6 \\ M_7 & M_8 & M_9 \end{bmatrix} \times \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Where  $\begin{bmatrix} M_1 & M_2 & M_3 \\ M_4 & M_5 & M_6 \\ M_7 & M_8 & M_9 \end{bmatrix}$  is the mapping matrix and  $\begin{bmatrix} R \\ G \\ B \end{bmatrix}$  are the values read from the sensor.





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### CALCULATING THE MAPPING MATRIX

In order to get accurate results for the calculated XYZ values, accurate correlation coefficients need to be derived to fill the mapping matrix. This is done through a calibration procedure where values read from the sensor are mapped to XYZ values measured by a reference chroma meter or lux meter (e.g. Minolta CL-200). This is done over a range of different light sources in order to allow for a broad transformation. The light sources chosen for the calibration should be close enough to the desirable limits that are to be measured, as well as a light source that is very close to the conditions the application will be exposed to. Accurate results can be found by using at least three light sources. Typical choices here are:

- “A” light or 40 W incandescent - this light source has high IR content
- 6700 K compact fluorescent for cool color temperature
- 2700 K compact fluorescent for warm color temperature

The measurements taken during the calibration process are then used to populate the matrices of the following equation, to then arrive at the correlation coefficients matrix:

$$\text{Corr\_Coeff.} = \underbrace{\begin{bmatrix} X_{40\text{ W}} & X_{2700\text{ CF}} & X_{6700\text{ CF}} \\ Y_{40\text{ W}} & Y_{2700\text{ CF}} & Y_{6700\text{ CF}} \\ Z_{40\text{ W}} & Z_{2700\text{ CF}} & Z_{6700\text{ CF}} \end{bmatrix}}_{\text{Values from chroma meter}} \times \underbrace{\begin{bmatrix} R_{40\text{ W}} & R_{2700\text{ CF}} & R_{6700\text{ CF}} \\ G_{40\text{ W}} & G_{2700\text{ CF}} & G_{6700\text{ CF}} \\ B_{40\text{ W}} & B_{2700\text{ CF}} & B_{6700\text{ CF}} \end{bmatrix}}_{\text{Counts from VEML3328}}^{-1}$$

The calibration procedure is conducted as follows:

- Place the sensor and reference chroma meter side by side, so that they are exposed to the same light conditions throughout the calibration
- Warm up illuminant “A” light source to a stable brightness and color temperature condition. Use the chroma meter to measure the X, Y, and Z value of the illuminant “A” light source and use the VEML3328 to make a measurement, reading out the red, green, and blue channel
- Use these values to populate the first column in both matrices
- Warm up the 6700 K light source to a stable brightness and color temperature condition. Again take note of the X, Y, and Z values from the chroma meter and the red, green, and blue results from the VEML3328
- Use these values to populate the second column in both matrices
- Warm up the 2700 K light source to a stable brightness and color temperature. Again take note of the X, Y, and Z values from the chroma meter and the red, green, and blue results from the VEML3328
- Use these values to populate the third column in both matrices

Now that the matrices are complete, the equation can be solved and the correlation coefficient can be found. When the sensor is exposed to just typical open-air values, the correlation coefficients were found to be as follows:

$$\text{Corr\_Coeff.} = \begin{bmatrix} 0.000349 & 0.000380 & -0.000153 \\ 0.000140 & 0.000470 & -0.000073 \\ -0.000281 & 0.000183 & 0.000657 \end{bmatrix}$$

This can then be plugged into the XYZ equation to give the following:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.000349 & 0.000380 & -0.000153 \\ 0.000140 & 0.000470 & -0.000073 \\ -0.000281 & 0.000183 & 0.000657 \end{bmatrix} \times \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



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The following correlation matrix is created with different light sources and is perfectly suitable for mixed light, e.g. office light.

- “A” light or 40 W incandescent - this light source has high IR content
- 6700 K compact fluorescent for cool color temperature
- 6000 K white LED for cool color temperature

This correlation matrix is used in the following example calculation as well as in the demosoftware for the VEML3328-SB.

$$\text{Corr\_Coeff.} = \begin{bmatrix} 0.000419 & 0.000285 & -0.000069 \\ 0.000264 & 0.000301 & 0.000076 \\ -0.000299 & 0.000208 & 0.000635 \end{bmatrix}$$

### CALCULATING THE X, Y VALUES USING THE McCAMY FORMULA TO CALCULATE CCT

Once the XYZ have been found, these can be used to derive the (x, y) coordinates, which then denote a specific color, as depicted on the axes CIE color gamut on page 7. For this the following equations can be used:

$$x = X / (X + Y + Z)$$

$$y = Y / (X + Y + Z)$$

To give a sample calculation, the following RGB values will be used, which were measured with the VEML3328 sensor under the standard room lighting in our lab:

$$\begin{bmatrix} R = 698 \text{ counts} \\ G = 1207 \text{ counts} \\ B = 604 \text{ counts} \end{bmatrix}$$

Using the correlation matrix (created with a “A” light, 6700K compact fluorescent and 6000K white LED) stated above and solving for X, Y and Z gives the following:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.000419 & 0.000285 & -0.000069 \\ 0.000264 & 0.000301 & 0.000076 \\ -0.000299 & 0.000208 & 0.000635 \end{bmatrix} \times \begin{bmatrix} 698 \\ 1207 \\ 604 \end{bmatrix}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.59532 \\ 0.59273 \\ 0.42532 \end{bmatrix}$$

Having found the XYZ values, the (x, y) coordinates can be calculated using the equations above:

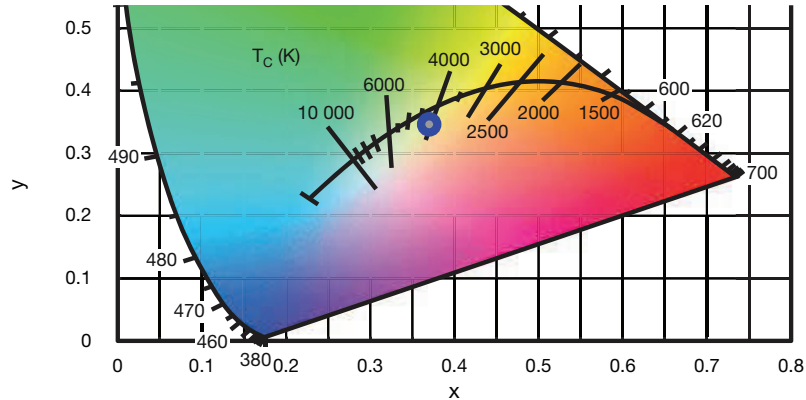
$$x = 0.59532 / (0.59532 + 0.59273 + 0.42532) = 0.36899$$

$$y = 0.59273 / (0.59532 + 0.59273 + 0.42532) = 0.36739$$

Plotting these coordinates on the CIE gamut chart shows that it is a white light source that is close to 4000 Kelvin, which is what we would have expected for our lab light lighting.

APPLICATION NOTE

## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications



The (x, y) coordinates can now be used to calculate the correlated color temperature (CCT). This can be done via the McCamy formula which is stated as follows:

$$CCT = 449.0 \times n^3 + 3525.0 \times n^2 + 6823.3 \times n + 5520.33$$

Where:

$$n = (x - X_e)/(Y_e - y)$$

$X_e$  and  $Y_e$  are constants:

$$X_e = 0.3320$$

$$Y_e = 0.1858$$

For our test this gives the following result for n:

$$n = (0.3689 - 0.3320)/(0.1858 - 0.36739) = -0.2037$$

This can now be inserted into the McCamy formula to calculate the CCT value:

$$CCT = 449.0 \times (-0.2037)^3 + 3525.0 \times (-0.2037)^2 + 6823.3 \times (-0.2037) + 5520.33 = 4272 \text{ K}$$

The comparison with the optometer which measures a CCT value of 4325 K shows that the calculated value is quite similar to the measured one.

### USING THE VEML3328 TO CALCULATE THE CCT (EMPIRICAL APPROACH)

A less accurate but less computationally intensive method of calculating CCT can be found using an empirical approach. This is based on the following estimation, which was derived by mapping CCT values calculated from the sensor results to CCT values measured by a chroma meter:

$$CCT = 11\,179 \times CCT_i^{-0.805}$$

For  $CCT_i$  calculation:

If the count level of the blue channel is lower than one

$$CCT_i = R + B$$

else

$$CCT_i = \left( \frac{R+G}{B} \right)$$

## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

### VEML3328 SENSOR BOARD AND DEMO SOFTWARE

With the help of the VEML3328 sensor board and the accompanying demo software, it is easy to test the RGB sensor. The four possible integration times as well as the 2 gain settings are selectable over the GUI (1), as shown in Fig. 7. As shown in this Fig. 7 and in Fig. 8, the output results of the sensor are strictly linear over the integration times and gain steps. A factor of 2 in the integration time and gain steps leads to a factor of 2 in the output data counts, shown on the graph and the color results section (3). Depending on the chosen integration time, the measurement rate will be affected accordingly (2). The resolution according selected integration time and gain settings is also shown (4).

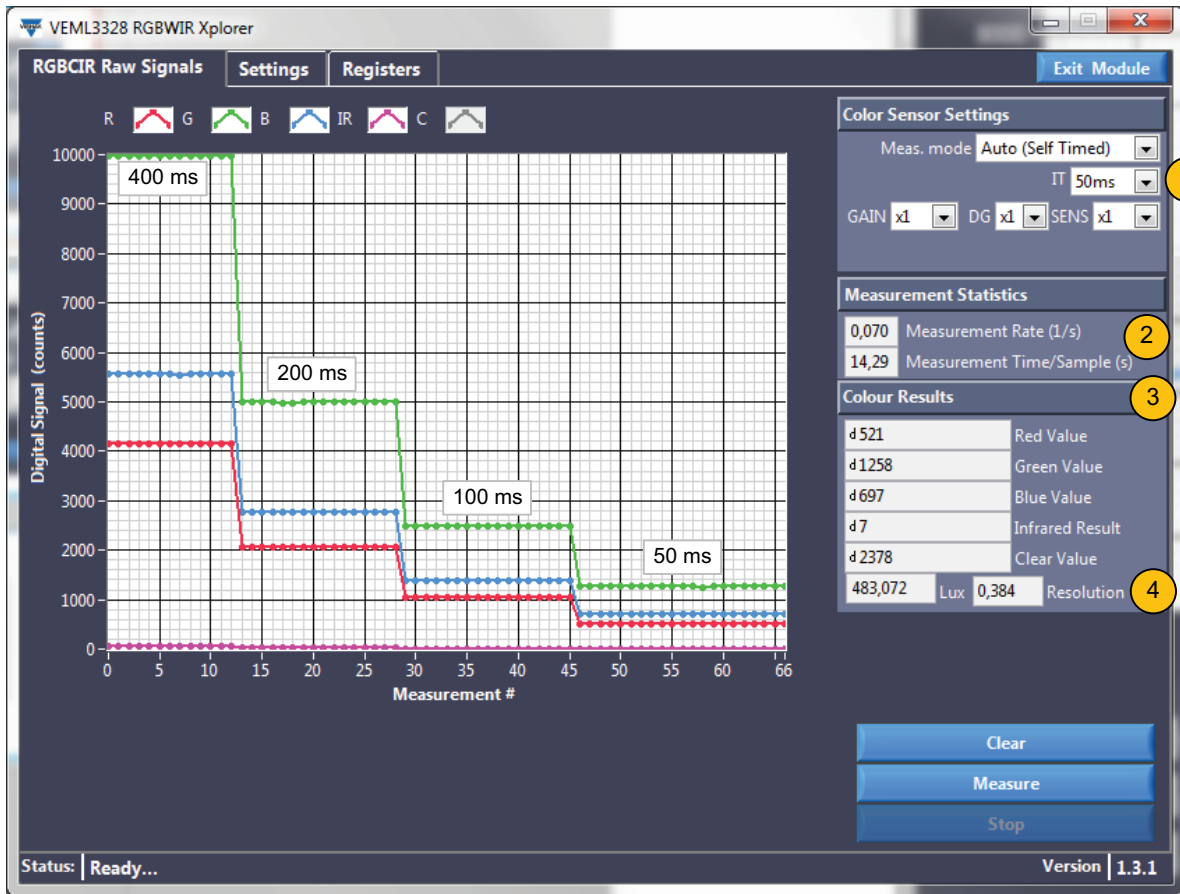


Fig. 7 - Linearity of the Integration Times

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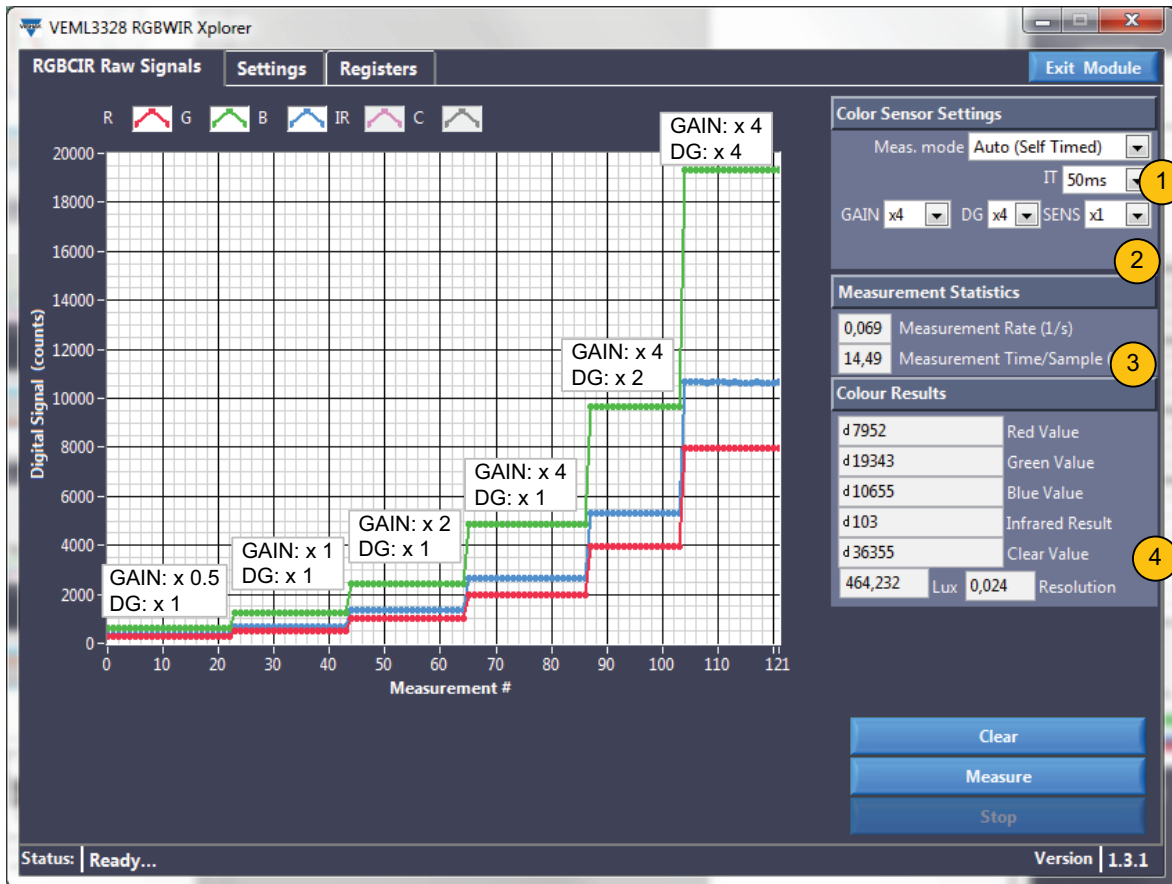


Fig. 8 - Linearity of the Gain Steps

## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

### MECHANICAL CONSIDERATIONS AND WINDOW CALCULATION FOR THE VEML3328

For optimal performance, the window size should be large enough to maximize the light irradiating the sensor. In calculating the window size, the only dimensions that the design engineer needs to consider are the distance from the top surface of the sensor to the outside surface of the window and the size of the window. These dimensions will determine the size of the detection zone.

First, the center of the sensor and center of the window should be aligned.

The VEML3328 has an angle of half sensitivity of about  $\pm 55^\circ$ , as shown in the figure below.

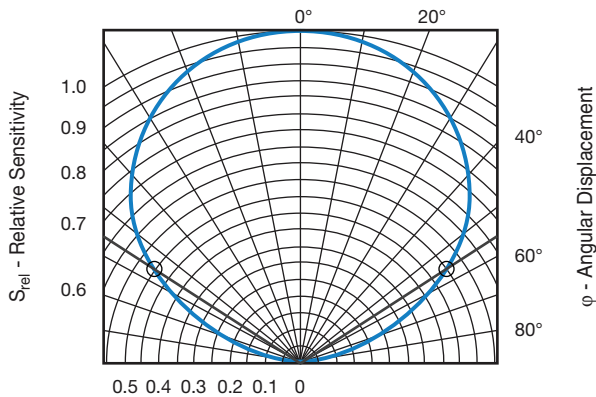


Fig. 9 - Relative Radiant Sensitivity vs. Angular Displacement

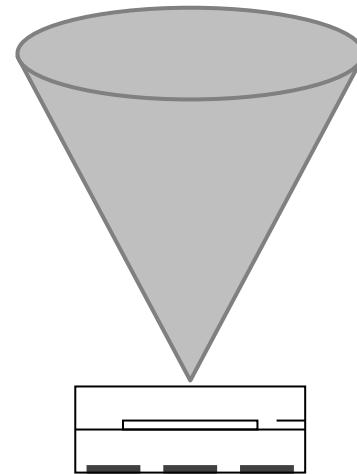


Fig. 10 - Angle of Half Sensitivity: Cone

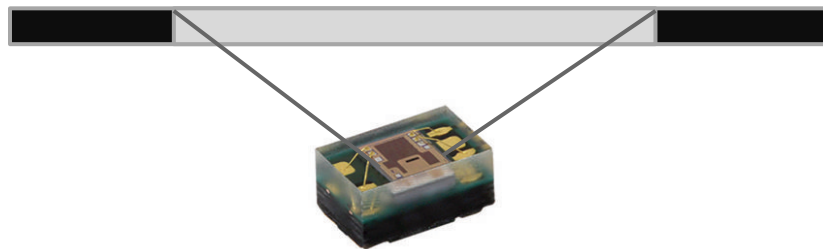


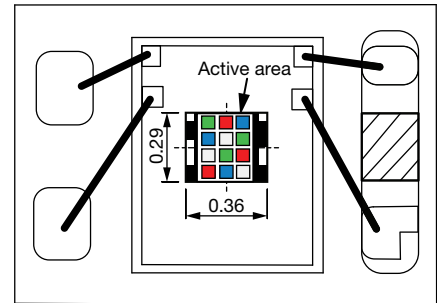
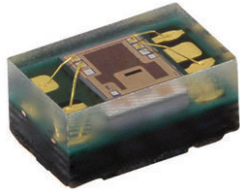
Fig. 11 - Window Above Sensitive Area

**Remark:**

This wide angle and the placement of the sensor as close as possible to the cover is needed to show good responsivity.

## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

The size of the window is simply calculated according to triangular rules. The dimensions of the device, as well as the sensitive area, is shown within the datasheet. Best results are achieved with a known distance below the windows, upper surface and the specified angle below the given window diameter (w).



Dimensions (L x W x H in mm): 2.0 x 1.25 x 1.0

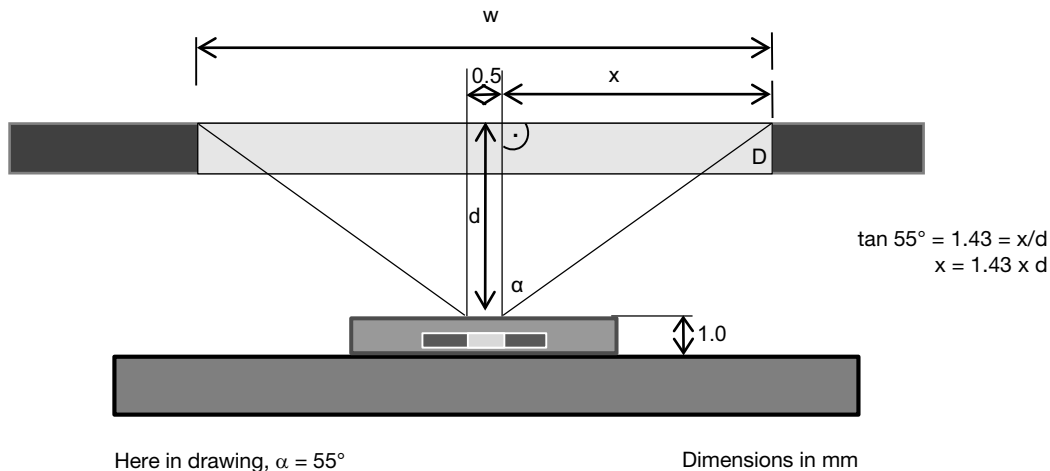


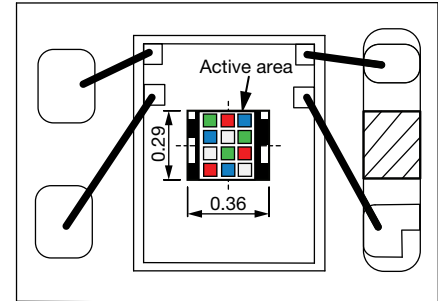
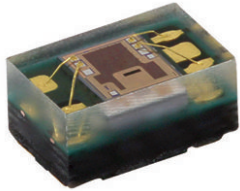
Fig. 12 - Window Area for an Opening Angle of  $\pm 55^\circ$

The calculation is then:  $\tan \alpha = x/d \rightarrow$  with  $\alpha = 55^\circ$  and  $\tan 55^\circ \ 1.43 = x/d \rightarrow x = 1.43 \times d$   
 Then the total width is  $w = 0.5 \text{ mm} + 2 \times x$ .

$d = 0.5 \text{ mm}$	$\rightarrow$	$x = 0.72 \text{ mm}$	$\rightarrow$	$w = 0.5 \text{ mm} + 1.44 \text{ mm}$	$=$	$1.94 \text{ mm}$
$d = 1.0 \text{ mm}$	$\rightarrow$	$x = 1.43 \text{ mm}$	$\rightarrow$	$w = 0.5 \text{ mm} + 2.86 \text{ mm}$	$=$	$3.36 \text{ mm}$
$d = 1.5 \text{ mm}$	$\rightarrow$	$x = 2.15 \text{ mm}$	$\rightarrow$	$w = 0.5 \text{ mm} + 4.30 \text{ mm}$	$=$	$4.80 \text{ mm}$
$d = 2.0 \text{ mm}$	$\rightarrow$	$x = 2.86 \text{ mm}$	$\rightarrow$	$w = 0.5 \text{ mm} + 5.72 \text{ mm}$	$=$	$6.22 \text{ mm}$
$d = 2.5 \text{ mm}$	$\rightarrow$	$x = 3.58 \text{ mm}$	$\rightarrow$	$w = 0.5 \text{ mm} + 7.16 \text{ mm}$	$=$	$7.66 \text{ mm}$
$d = 3.0 \text{ mm}$	$\rightarrow$	$x = 4.29 \text{ mm}$	$\rightarrow$	$w = 0.5 \text{ mm} + 8.58 \text{ mm}$	$=$	$9.08 \text{ mm}$

## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

A smaller window will also be sufficient, although it will reduce the total sensitivity of the sensor.



Dimensions (L x W x H in mm): 2.0 x 1.25 x 1.0

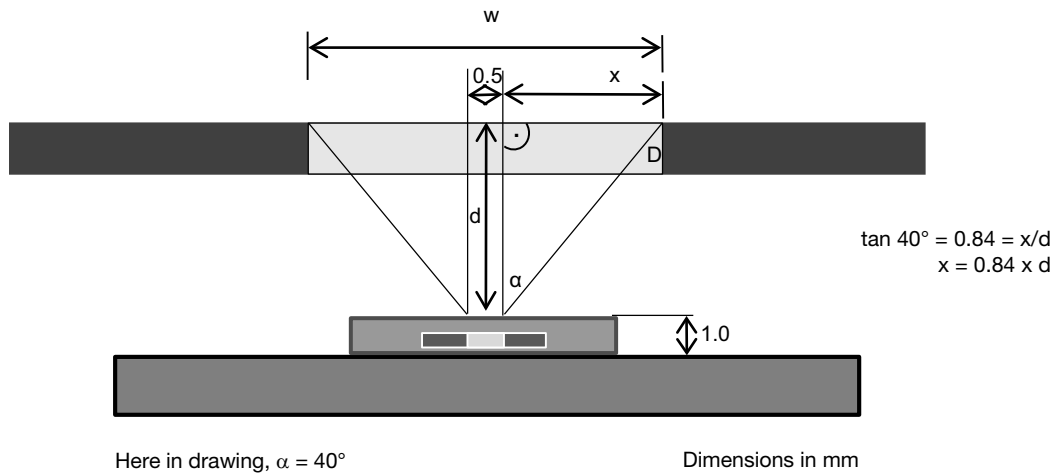


Fig. 13 - Window Area for an Opening Angle of  $\pm 40^\circ$

The calculation is then:  $\tan \alpha = x/d \rightarrow$  with  $\alpha = 40^\circ$  and  $\tan 40^\circ = 0.84 = x/d \rightarrow x = 0.84 \times d$   
 Then the total width is  $w = 0.5 \text{ mm} + 2 \times x$ .

$d = 0.5 \text{ mm}$	$\rightarrow x = 0.42 \text{ mm}$	$\rightarrow w = 0.5 \text{ mm} + 0.84 \text{ mm}$	$= 1.34 \text{ mm}$
$d = 1.0 \text{ mm}$	$\rightarrow x = 0.84 \text{ mm}$	$\rightarrow w = 0.5 \text{ mm} + 1.68 \text{ mm}$	$= 2.18 \text{ mm}$
$d = 1.5 \text{ mm}$	$\rightarrow x = 1.28 \text{ mm}$	$\rightarrow w = 0.5 \text{ mm} + 2.56 \text{ mm}$	$= 3.06 \text{ mm}$
$d = 2.0 \text{ mm}$	$\rightarrow x = 1.68 \text{ mm}$	$\rightarrow w = 0.5 \text{ mm} + 3.36 \text{ mm}$	$= 3.86 \text{ mm}$
$d = 2.5 \text{ mm}$	$\rightarrow x = 2.10 \text{ mm}$	$\rightarrow w = 0.5 \text{ mm} + 4.20 \text{ mm}$	$= 4.70 \text{ mm}$
$d = 3.0 \text{ mm}$	$\rightarrow x = 2.52 \text{ mm}$	$\rightarrow w = 0.5 \text{ mm} + 5.04 \text{ mm}$	$= 5.54 \text{ mm}$

### VEML3328 SENSOR BOARD AND DEMO SOFTWARE

The small blue VEML3328 sensor board is compatible with the SensorXplorer™. Please also see: [www.vishay.com/optoelectronic/SensorXplorer](http://www.vishay.com/optoelectronic/SensorXplorer).





## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

### VEML3328 REFERENCE CODE

```
//-----
// Global definition for VEML3328 registers
//-----

// 7bits SLAVE_ADD=0x10
#define VEML3328_SLAVE_ADD    0x10
#define CONF                  0x00
#define C_DATA                0x04
#define R_DATA                0x05
#define G_DATA                0x06
#define B_DATA                0x07
#define IR_DATA               0x08

//-----
// C main function
//-----
void main ()
{
    WORD VEML3328_DATA_C;
    WORD VEML3328_DATA_R;
    WORD VEML3328_DATA_G;
    WORD VEML3328_DATA_B;
    WORD VEML3328_DATA_IR;

//-----
// Write Shut Down Command to VEML3328
// Command Code: 0x00,
// Low Byte          0x11 (0001:0001)
// SENS=*1
// ALS = 100 ms
// TRIG = No trigger
// AF = Auto mode
// SD0 = 1: Enable

// High Byte          0x80 (1000:0000)
// SD1 = 1: Enable
// DG=*1, GAIN=*1
//-----
// Write Initial Command to VEML3328
// Command Code: 0x00,
// Low Byte          0x10 (0001:0000)
// SENS=*1
// ALS = 100 ms
// TRIG = No trigger
// AF = Auto mode
// SD0 = 0: Disable

// High Byte          0x00 (0000:0000)
// SD1 = 0: Disable
// DG=*1, GAIN=*1
//-----
```



## Designing the VEML3328 RGB, IR, C Color Sensor Into Applications

```
// Shut Down Color Sensor
WriteBytes(VEML3328 _SLAVE_ADD, CONF, 0x11, 0x80, 2);

// Enable Color Sensor
WriteBytes(VEML3328 _SLAVE_ADD, CONF, 0x10, 0x00, 2);

// Read VEML3328 Data Loop
while (1)
{
    Delay(150);

    // Read VEML3328 C Channel Data
    VEML3328 _DATA_C = read_ VEML3328 _data(C_DATA);

    // Read VEML3328 R Channel Data
    VEML3328 _DATA_R = read_ VEML3328 _data(R_DATA);

    // Read VEML3328 G Channel Data
    VEML3328 _DATA_G = read_ VEML3328 _data(G_DATA);

    // Read VEML3328 B Channel Data
    VEML3328 _DATA_B = read_ VEML3328 _data(B_DATA);

    // Read VEML3328 IR Channel Data
    VEML3328 _DATA_IR = read_ VEML3328 _data(IR_DATA);

}

//-----
// FUNCTION NAME: read_ VEML3328 _data
//
// DESCRIPTION:
//-----
WORD read_ VEML3328 _data(WORD channel)
{
    BYTE buff[2];
    BYTE lsb, msb;
    WORD channel_data;

    ReadBytes(VEML3328 _SLAVE_ADD, channel, buff, 2);
    lsb = buff[0];
    msb = buff[1];
    channel_data = ((WORD)msb << 8) | (WORD)lsb;
    return channel_data;
}
```