Designing the VEML3235 Into an Application

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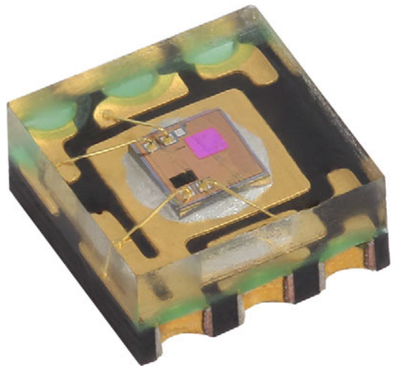
HIGH ACCURACY AMBIENT LIGHT SENSOR: VEML3235

The VEML3235 is a very high sensitivity, high accuracy ambient light sensor in a miniature transparent 2 mm by 2 mm package. It includes a highly sensitive photodiode, low noise amplifier, 16-bit A/D converter, and supports an easy to use I^2C bus communication interface and additional interrupt feature.

The ambient light read-out is available as a digital value, and the built-in photodiode response is near that of the human eye. The 16-bit dynamic range for ambient light detection is 0 lx to ~ 18 klx, with resolution down to 0.0021 lx/counts.

In addition to 100 Hz and 120 Hz flicker noise rejection and a low temperature coefficient, the device consumes just 1 μA in shutdown mode. The device operates within a temperature range of -25 °C to +85 °C.

The VEML3235's very high sensitivity of just 0.0021 lx allows the sensor to be placed behind very dark cover glasses that will dramatically reduce the total light reaching it. The sensor will also work behind clear cover glass, because even very high illumination will not saturate the device and read-outs up to about 18 klx are possible.



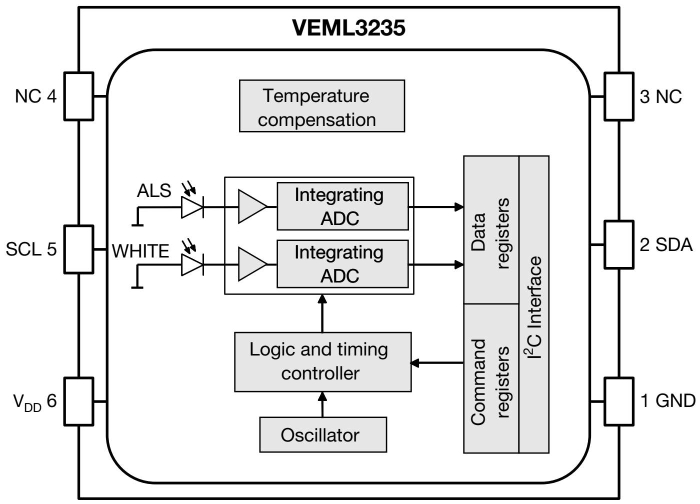


Fig. 1 - VEML3235 Block Diagram

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APPLICATION CIRCUITRY FOR THE VEML3235

The VEML3235 can be connected to a power supply ranging from 2.6 V to 3.6 V. The pull-up resistors at the I²C bus lines may also be connected to a power supply between 1.7 V to 3.6 V, allowing them to be at the same level needed for the microcontroller.

Proposed values for the pull-up resistors should be > 1 kΩ, e.g.: 2.2 kΩ to 4.7 kΩ for the R1 and R2 resistors (at SDA and SCL).

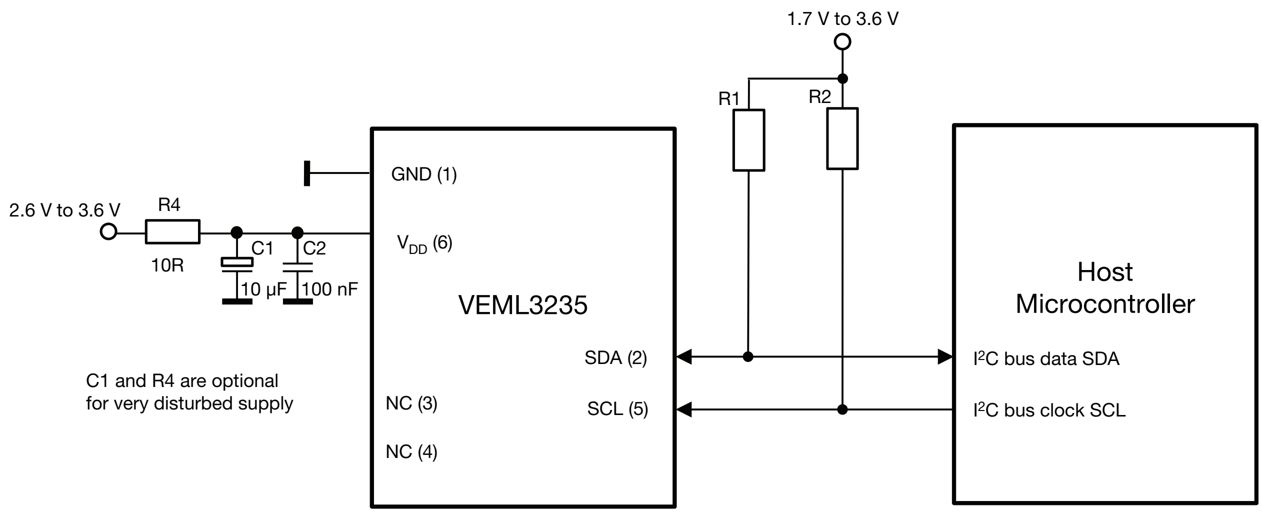

Fig. 2 - VEML3235 Application Circuit

The VEML3235 is insensitive to any kind of disturbances, so a small ceramic capacitor at its supply pin will be enough. Only if the power supply line can be very noisy and the voltage range close to the lower limit of 2.6 V should a R-C decoupler, as shown in the above circuitry, be used.

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REGISTERS OF THE VEML3235

The VEML3235 has six user-accessible 16-bit command codes. The addresses are 00h to 06h (03h not defined / reserved).

TABLE 1 - COMMAND CODE DESCRIPTION

COMMAND CODE	REGISTER NAME	DATE BYTE LOW / HIGH	BIT	FUNCTION DESCRIPTION	R / W
0x00	Reserved	L	7	Set 0	R / W
	ALS/W_IT		6 : 4	ALS/W integration time setting (0 : 0 : 0) = 50 ms (0 : 0 : 1) = 100 ms (0 : 1 : 0) = 200 ms (0 : 1 : 1) = 400 ms (1 : 0 : 0) = 800 ms	
	Reserved		3 : 1	Set 0	
	SD		0	Shutdown BG and LDO with SD = 1 (default)	
	SD0	H	7	Shutdown ALS and white channel with SD0 = 1 (default)	
	Reserved		6	Set 0	
	DG		5	0 = x 1, 1 = x 2	
	Gain		4 : 3	(0 : 0) = x 1 (0 : 1) = x 2 (1 : 0) = reserved (1 : 1) = x 4	
	Reserved		2 : 1	Set 0	
	Reserved		0	Set 1	
0x02	Reserved	L	7 : 0	Set 0	
	Reserved	H	7 : 0	Set 0	
0x04	W_LSB	L	7 : 0	W LSB data	R
	W_MSB	H	7 : 0	W MSB data	
0x05	ALS_LSB	L	7 : 0	ALS LSB data	
	ALS_MSB	H	7 : 0	ALS MSB data	
0x09	ID_L	L	7 : 0	ID part number: 3235 = 0011 0101	
	Reserved	H	7 : 0	Reserved	

WAKE-UP OF THE VEML3235

For random measurements, e.g. once per second, the sensor may be switched to shutdown mode, where power consumption is lowest.

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
Supply voltage		V_{DD}	2.6	3.3	3.6	V
Shutdown current	V_{DD} is 3.3 V	I_{sd}	-	1	-	μA

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There are two shutdown bits: SD and SD0. SD set to “1” shuts down the sensor so that only the specified 1 μA will be consumed. With both set to “0” the measurement will be started.

COMMAND REGISTER FORMAT				
COMMAND CODE	**REGISTER NAME**	**BIT**	**FUNCTION / DESCRIPTION**	**R / W**
0x00_L	SD	0	Shutdown BG and LDO with SD = 1 (default)	R / W
0x00_H	SD0	7	Shutdown ALS and white channel with SD0 = 1 (default)	R / W

When activating the sensor, setting bit 0 of the command register to “0”, a wait time of 4 ms should be observed before the first measurement is picked up, to allow for a correct start of the signal processor and oscillator.

RESOLUTION AND GAIN SETTINGS OF THE VEML3235

The VEML3235 is specified with a resolution of 0.0021 lx/counts. This high resolution is only available for a smaller light range of approximately 0 lx to 140 lx. For this range a high gain factor can be selected and the integration time needs to be set to 800 ms. For light levels up to about 18 000 lx, both gains need to be reduced: DG = 1 and GAIN = 1, which would then lead to a possible resolution of 0.017 lx/counts (with an integration time of 800 ms), respective of 0.2726 lx/counts (with IT = 50 ms).

Command Code 0x00_H

Bits 5, 4 to 3

COMMAND REGISTER FORMAT			
REGISTER NAME	**BIT**	**FUNCTION / DESCRIPTION**	**R / W**
DG	5	0 = x 1, 1 = x 2	W
Gain	4 : 3	(0 : 0) = x 1, (0 : 1) = x 2, (1 : 0) = reserved, (1 : 1) = x 4	W

Remark: to avoid possible saturation / overflow effects, application software should always start with low gain: DG = x 1, gain = x 1. DG = x 2 shows the highest resolution and should only be used with very low illumination values, e.g. if sensor is placed below a very “dark” cover allowing only low light levels to reach the photodiode.

Command Code 0x00_L

Bits 6 to 4

COMMAND REGISTER FORMAT			
REGISTER NAME	**BIT**	**FUNCTION / DESCRIPTION**	**R / W**
ALS/W_IT	6 : 4	(0 : 0 : 0) = 50 ms, (0 : 0 : 1) = 100 ms, (0 : 1 : 0) = 200 ms, (0 : 1 : 1) = 400 ms, (1 : 0 : 0) = 800 ms	W

Remark: the standard integration time is 100 ms. If a very high resolution is needed, one may increase this integration time up to 800 ms. If faster measurement results are needed, it can be decreased down to 50 ms.

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READ-OUT OF ALS MEASUREMENT RESULTS

The VEML3235 stores the measurement results within the command code 0x05. The most significant bits are stored to bits 15 : 8 and the least significant bits to bits 7 : 0.

Command Code ALS

Command code: 0x05, bits 15 : 8 (MSB), bits 7 : 0 (LSB)

COMMAND REGISTER FORMAT			
REGISTER NAME	BIT	FUNCTION / DESCRIPTION	R / W
ALS	15 : 8	MSB 8 bits data of whole ALS 16 bits	R
	7 : 0	LSB 8 bits data of whole ALS 16 bits	R

TRANSFERRING ALS MEASUREMENT RESULTS INTO A DECIMAL VALUE

Command code 0x05 contains the results of the ALS measurement. This 16-bit code needs to be converted to a decimal value to determine the corresponding lux value. The calculation of the corresponding lux level is dependent on the programmed gain setting and the chosen integration time.

CALCULATING THE LUX LEVEL

With the standard integration time of 100 ms, one has to just calculate the corresponding light level according to the programmed gain and corresponding resolution. This resolution is most sensitive with DG = 2 and gain = x 4 and an integration time of 800 ms, specified to 0.0021 lx/step. For each shorter integration time by half, the resolution value is doubled.

The same principle is valid for the gain. For gain = x 2 and x 1 it is doubled and again doubled, and for DG = 1 the digital gain is not active.

The table below show this factor of “2” for the gains, as well as integration times values:

RESOLUTION AND MAXIMUM DETECTION RANGE AT DG = 1							
	GAIN: x 4	GAIN: x 2	GAIN: x 1		GAIN: x 4	GAIN: x 2	GAIN: x 1
IT (ms)	TYPICAL RESOLUTION (lx/cnt)				MAXIMUM POSSIBLE ILLUMINATION (lx)		
800	0.00426	0.00852	0.01704		279	558	1117
400	0.00852	0.01704	0.03408		558	1117	2233
200	0.01704	0.03408	0.06816		1117	2233	4467
100	0.03408	0.06816	0.13632		2233	4467	8934
50	0.06816	0.13632	0.27264		4467	8934	17 867

RESOLUTION AND MAXIMUM DETECTION RANGE AT DG = 2							
	GAIN: x 4	GAIN: x 2	GAIN: x 1		GAIN: x 4	GAIN: x 2	GAIN: x 1
IT (ms)	TYPICAL RESOLUTION (lx/cnt)				MAXIMUM POSSIBLE ILLUMINATION (lx)		
800	0.00213	0.00426	0.00852		140	279	558
400	0.00426	0.00852	0.01704		279	558	1117
200	0.00852	0.01704	0.03408		558	1117	2233
100	0.01704	0.03408	0.06816		1117	2233	4467
50	0.03408	0.06816	0.13632		2233	4467	8934

Example:

If the 16-bit word of the ALS data shows: 0000 0101 1100 1000 = 1480 (dec.), the programmed gain = x 1, the digital gain DG = x 1, and the integration time is 100 ms, the corresponding lux level is: light level [lx] = 1480 x 0.13632 = 202 lx.

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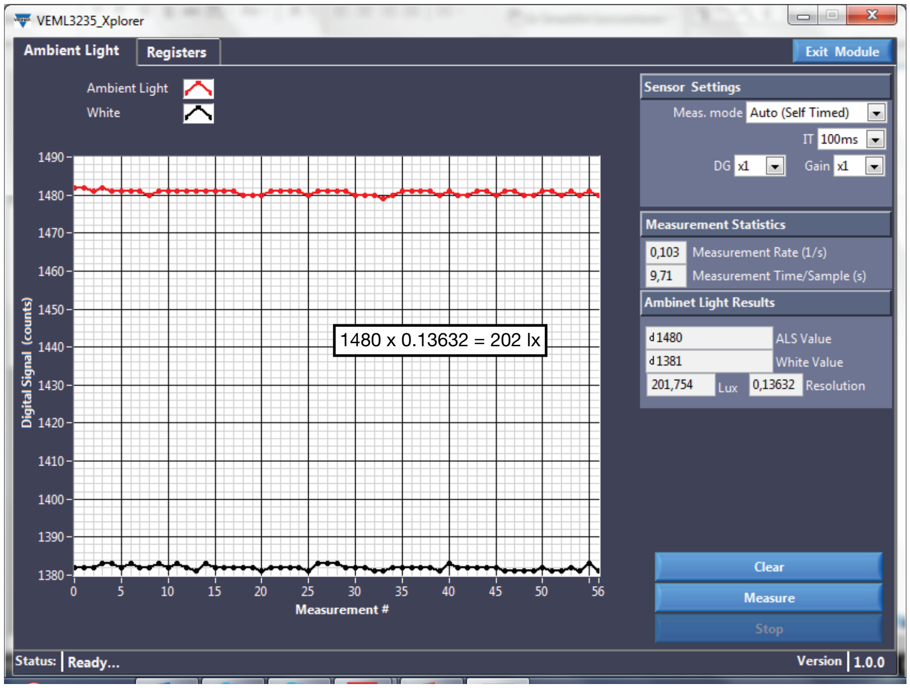

Fig. 1 Calculation of Lux Level

The screen shot below shows the linearity for the four gain factors.

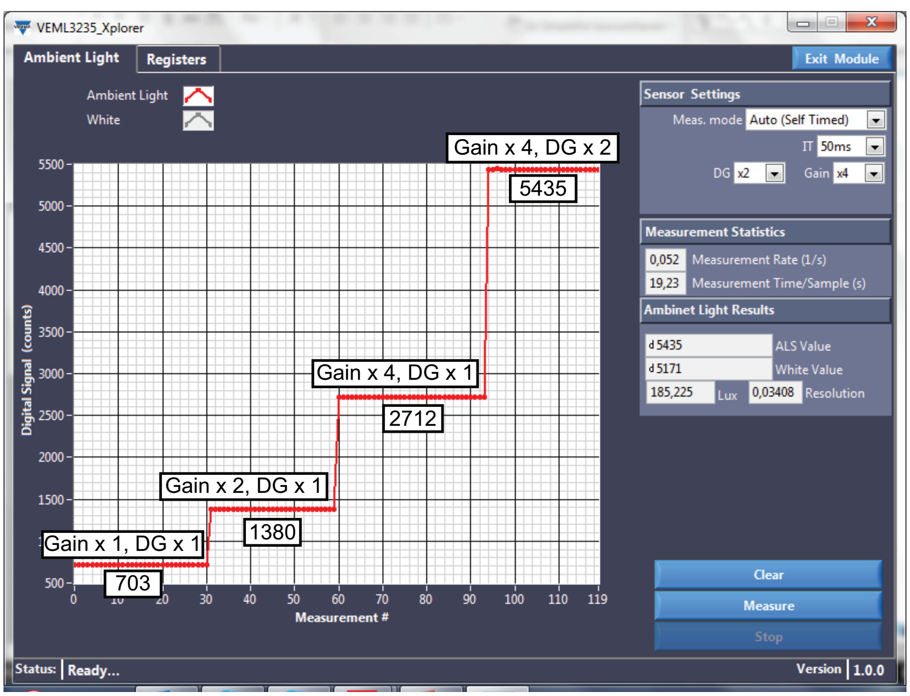

Fig. 3 - Linearity of Gain Steps

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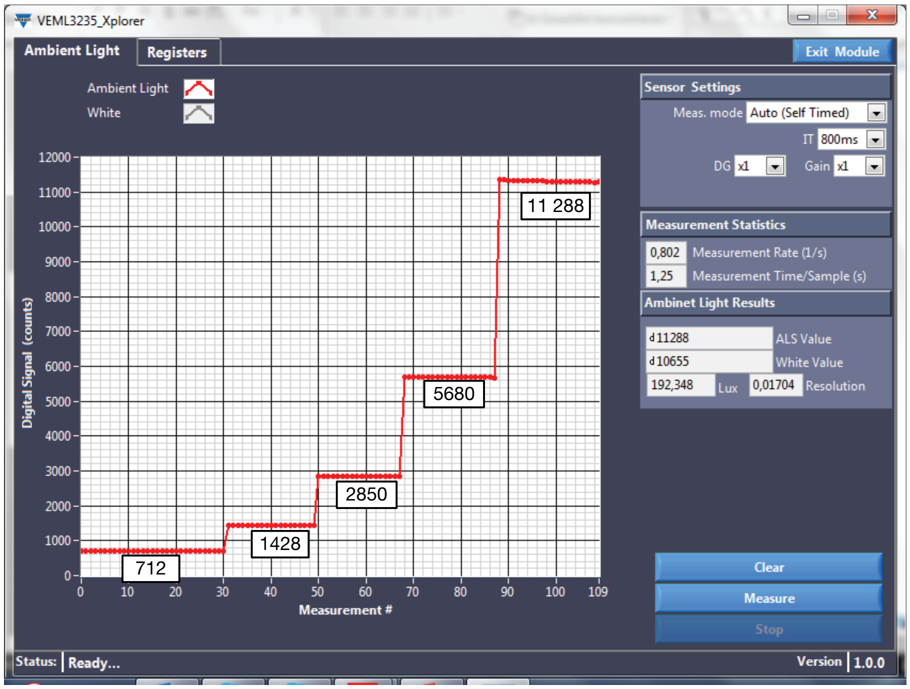

Fig. 4 - Linearity of Integration Times from 50 ms to 800 ms

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If the light level is very low, or if just a small percentage of outside light reaches the sensor, a higher integration time will need to be chosen.

For just 1 lx, 35 counts are enough with both gain modes set to max.: “gain x 4” and “DG x 2”, but for 0.1 lx just 3.5 counts will remain. With an integration time of 200 ms, this will be doubled to 7 counts, and with 800 ms 28 counts are shown.

This also means that with this high integration time, together with the highest gain, even 0.00426 lx will deliver 2 digital counts, resulting in a high resolution of 0.00213 lx/counts.

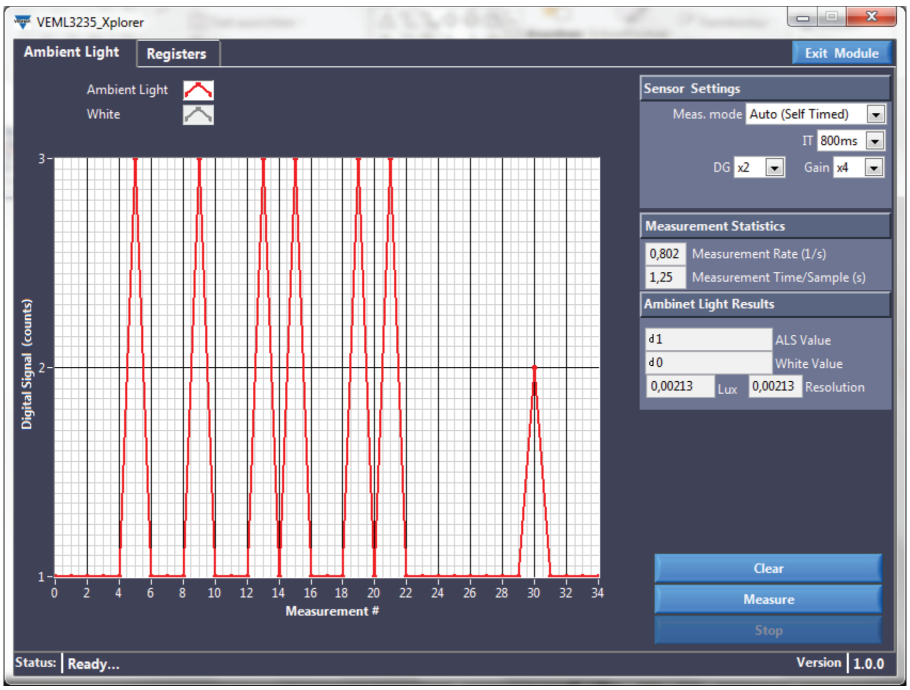

Fig. 5 - VEML3235 Highest Sensitivity

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LUX LEVEL MATCHING FOR DIFFERENT LIGHT SOURCES

The VEML3235 shows very good matching for all kinds of light sources. LED light, fluorescent light, normal daylight, as well as halogen or incandescent light show about the same results in a close tolerance range of just ± 10 %.

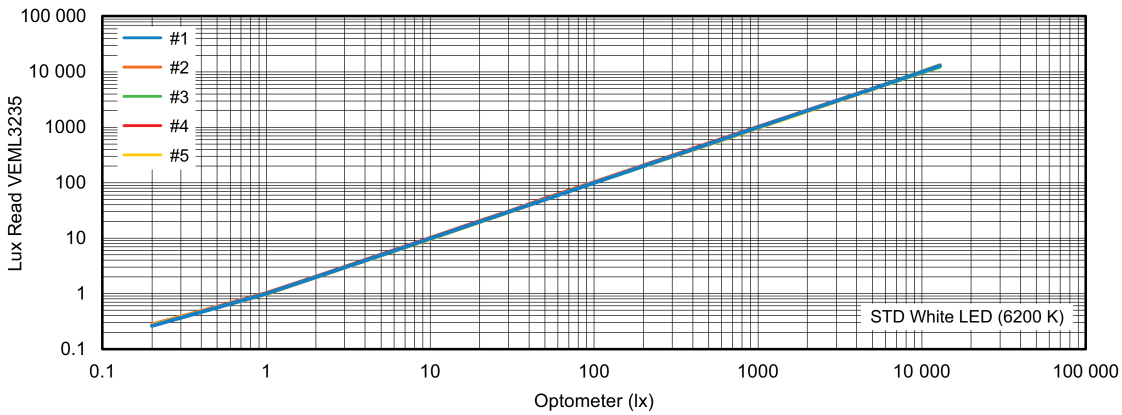

Fig. 6 - VEML3235 Lux Value vs. Optometer Lux Value for White LED

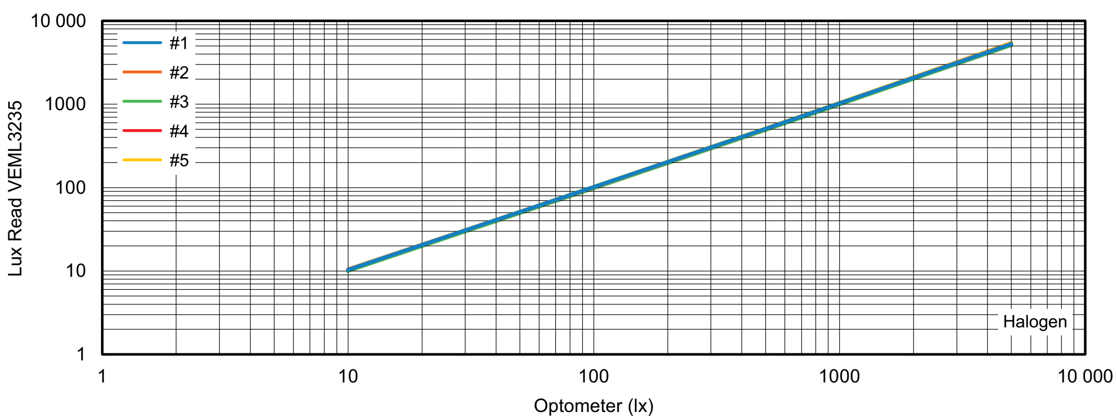

Fig. 7 - VEML3235 Lux Value vs. Optometer Lux Value for Halogen Lamp

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APPLICATION-DEPENDENT LUX CALCULATION

If the application uses a darkened / tinted cover glass, just 10 % - or even just 1 % - of the ambient light will reach the sensor. For a tinted cover glass where there is 1 lx up to 100 klx of light outside, just 0.01 lx to 1 klx is reaching the sensor, and the application software may always stay with gain x 4.

If the application uses a clear cover glass, nearly all ambient light will reach the sensor. This means even > 10 klx may be possible. For this clear cover where < 1 lx to ≥ 10 klx is possible, the application software will need to adapt the gain steps according to light conditions.

As explained before, with analog gain x 4, digital gain DG x 1, and IT = 50 ms, a maximum of 4467 lx will be possible before saturation occurs.

For unknown brightness conditions, the application should always start with the lowest gain: DG = 1 and gain x 1. This avoids possible overload / saturation if, for example, strong sunlight suddenly reaches the sensor. To show this high value, an even lower integration time than 100 ms may be needed.

WHITE CHANNEL

In addition to the ALS channel that follows the so-called human eye curve very well, there is also a second channel available called the white channel, which offers a much higher responsivity for a much wider wavelength spectrum.

This white channel could be used to distinguish between different light sources, as e.g. LED or fluorescent light and halogen or incandescent light.

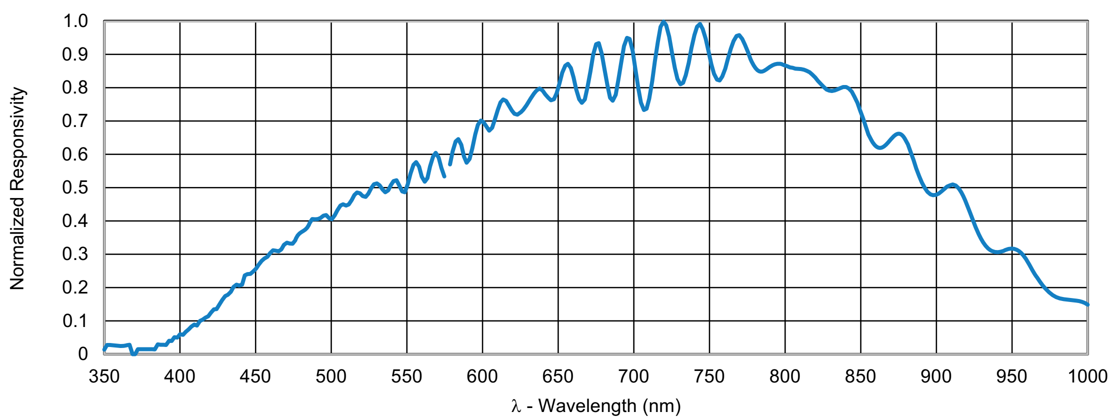

Fig. 8 - Spectral Response White Channel

COMMAND REGISTER FORMAT				
COMMAND CODE	REGISTER NAME	BIT	FUNCTION / DESCRIPTION	R / W
0x04	WHITE	15 : 8	MSB 8 bits data of whole white 16 bits	R
		7 : 0	LSB 8 bits data of whole white 16 bits	R

The data for this channel is available within the command code 0x04.

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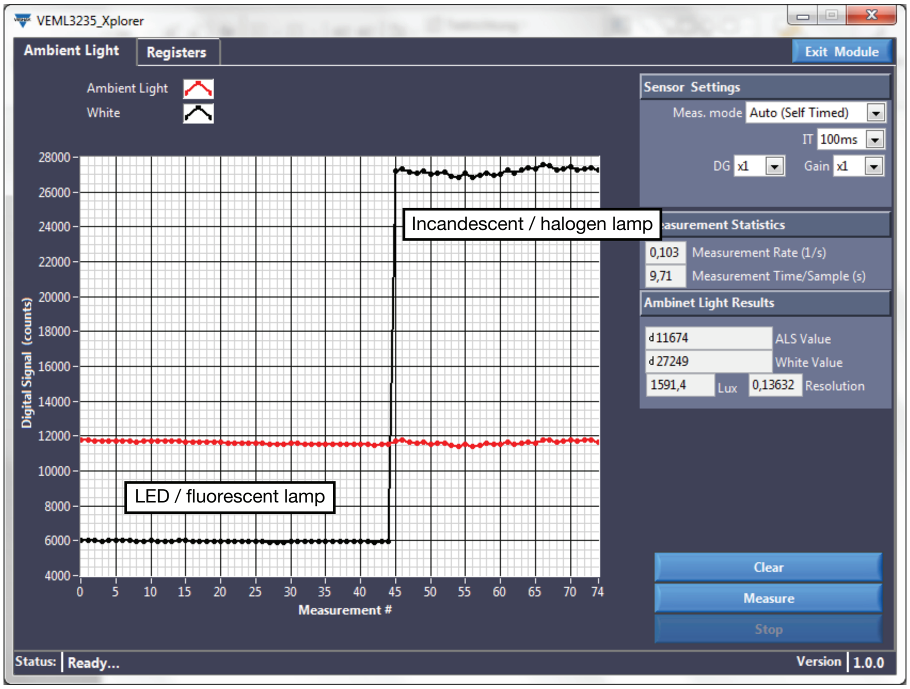

Fig. 9 - White Channel and ALS Channel for Different Lamp Spectra

Knowing that light sources with strong infrared content deliver about > 2 times higher output data at the white channel than all other light sources, which show a maximum factor of about 2, one may use it to differentiate between.

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MECHANICAL CONSIDERATIONS AND WINDOW CALCULATION FOR THE VEML3235

The ambient light sensor will be placed behind a window or cover. The window material should be completely transmissive to visible light (400 nm to 700 nm). 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 VEML3235 has an angle of half sensitivity of about ± 55°, as shown in the figure below.

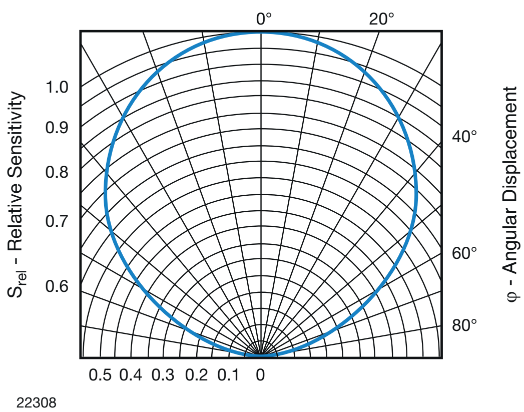

Fig. 10 - Relative Sensitivity vs. Angular Displacement

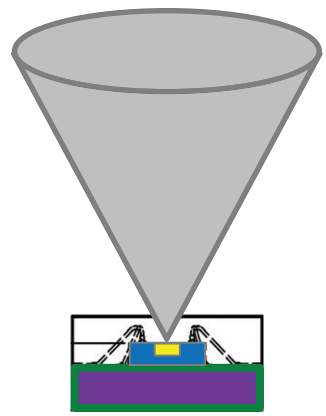

Fig. 11 - Angle of Half Sensitivity: Cone

Remark:

This wide angle and the placement of the sensor as close as possible to the cover is needed if it should show comparable results to an optometer, which also detects light reflections from the complete surroundings.

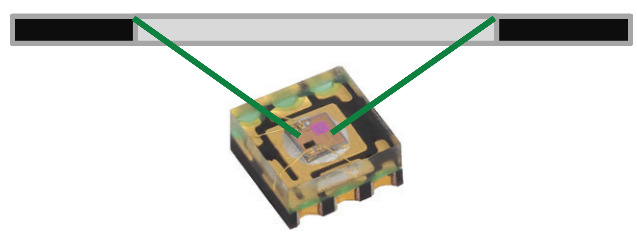

Fig. 12 - Windows Above Sensitive Area

The size of the window is simply calculated according to triangular rules. The dimensions of the device are shown within the datasheet, and with the known distance below the window's upper surface and the specified angle below the given window diameter (w), the best results are achieved.

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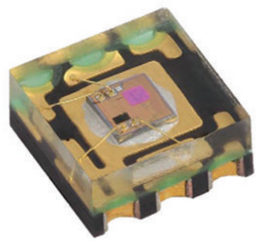
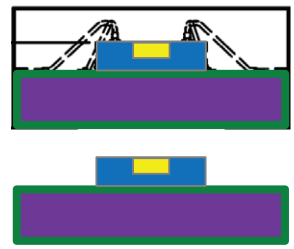
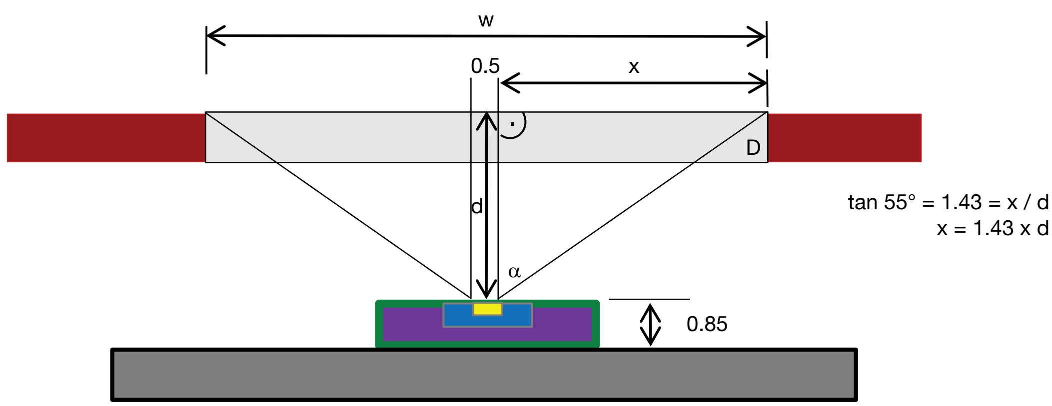
VEML3235





Dimensions (L x W x H in mm): 2 x 2 x 0.87



Dimensions in mm

Here in drawing α = 55°

Fig. 13 - Window Area for an Opening Angle of ± 55°

The calculation is then: tan α = x / d → with α = 55° and tan 55° 1.43 = x / d → x = 1.43 x d

Then the total width is w = 0.5 mm + 2 x x.

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

A smaller window is also sufficient if reference measurements can be done and / or if the output result does not need to be as exact as an optometer.

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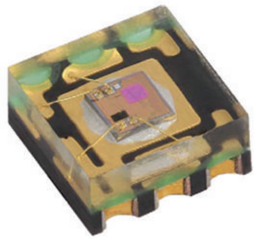

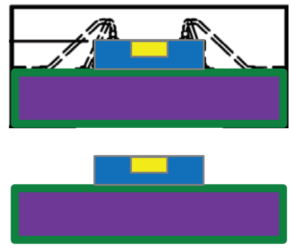

Dimensions (L x W x H in mm): 2 x 2 x 0.87

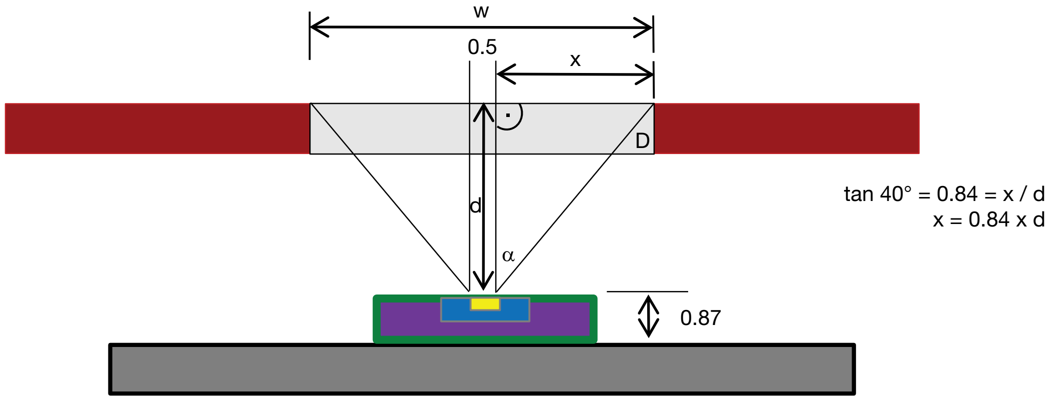

Fig. 14 - Window Area for an Opening Angle of ± 40°

The calculation is then: tan α = x / d → with α = 40° and tan 40° 0.84 = x / d → x = 0.84 x d

Then the total width is w = 0.5 mm + 2 x x.

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

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TYPICAL SOFTWARE FLOW CHART

For a wide light detection range of more than six decades (from 0.0021 lx to 17.8 klx), it is necessary to adjust the sensor. This is done with the help of four gain steps and five steps for the integration time.

Whereas the programmed gain begins with the lowest possible value, in order to avoid any saturation effect the integration time starts with 100 ms.

With this up to about 18 klx is possible. If this is not enough due to the sensor being exposed to direct bright sunlight, one may use a dedicated tinted cover that comes with reduced transmissivity, e.g. allowing just 10 % or even just 1 % of the light to reach the sensor.

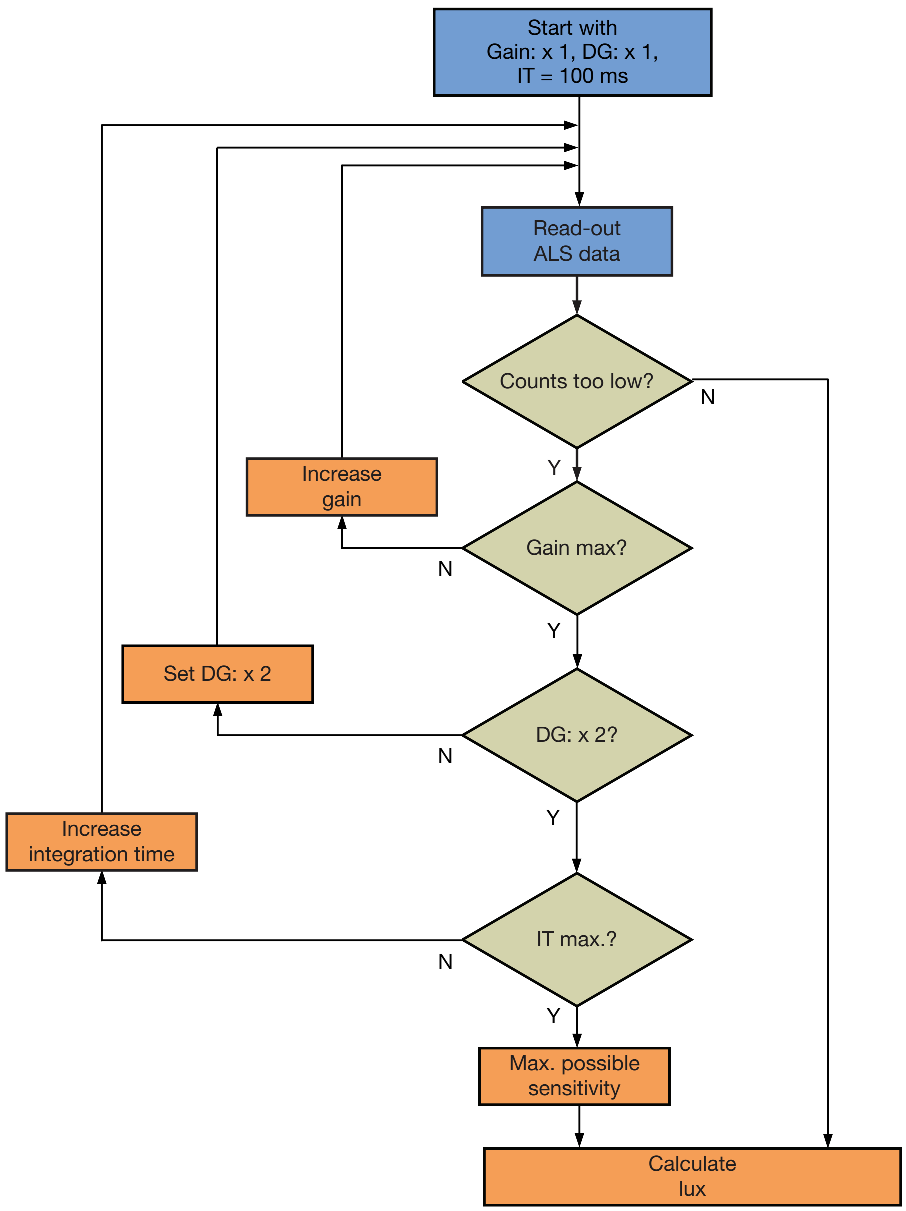

Fig. 15 - Simple Flow Chart View

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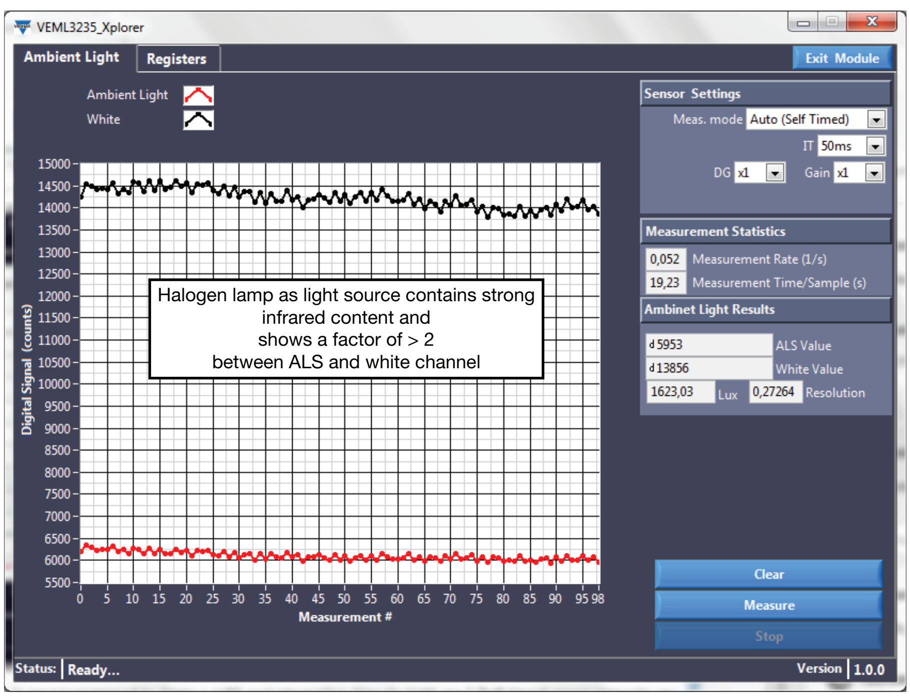
TYPICAL LUMINANCE VALUES

Luminance	Example
10^{-5} lx	Light from Sirius, the brightest star in the night sky
10^{-4} lx	Total starlight, overcast sky
0.002 lx	Moonless clear night sky with airglow
0.01 lx	Quarter moon, 0.27 lx; full moon on a clear night
1 lx	Full moon overhead at tropical latitudes
3.4 lx	Dark limit of civil twilight under a clear sky
50 lx	Family living room
80 lx	Hallway / bathroom
100 lx	Very dark overcast day
320 lx to 500 lx	Office lighting
400 lx	Sunrise or sunset on a clear day
1000 lx	Overcast day; typical TV studio lighting
10 000 lx to 25 000 lx	Full daylight (not direct sun)
32 000 lx to 130 000 lx	Direct sunlight

VEML3235 SENSOR BOARD AND DEMO SOFTWARE

The small blue VEML3235 sensor board is compatible with the SensorXplorer™.
Please also see www.vishay.com/optoelectronics/SensorXplorer.

After plugging in the VEML3235 sensor board to the SensorXplorer and activating with the "VEML3235.exe" file, the "Ambient Light" menu appears.



The ALS sensitivity mode is preprogrammed to gain x 1 and DG x 1 and integration time to "50 ms". Self-timed measurements are started by clicking the measure button.