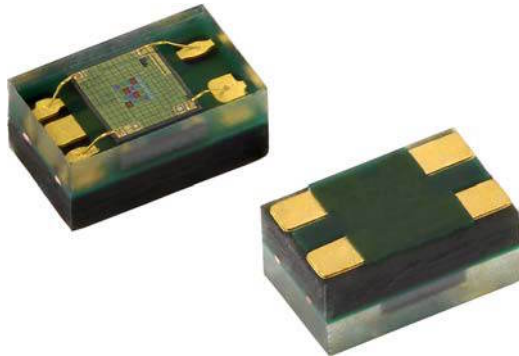


## RGBW Color Sensor with I<sup>2</sup>C Interface



### DESCRIPTION

VEML6040 color sensor senses red, green, blue, and white light and incorporates photodiodes, amplifiers, and analog / digital circuits into a single chip using CMOS process. With the color sensor applied, the brightness, and color temperature of backlight can be adjusted base on ambient light source that makes panel looks more comfortable for end user's eyes. VEML6040's adoption of Filtron™ technology achieves the closest ambient light spectral sensitivity to real human eye responses.

VEML6040 provides excellent temperature compensation capability for keeping the output stable under changing temperature. VEML6040's function are easily operated via the simple command format of I<sup>2</sup>C (SMBus compatible) interface protocol. VEML6040's operating voltage ranges from 2.5 V to 3.6 V. VEML6040 is packaged in a lead (Pb)-free 4 pin OPLGA package which offers the best market-proven reliability.

### FEATURES

- Package type: surface mount
- Dimensions (L x W x H in mm): 2.0 x 1.25 x 1.0
- Integrated modules: color sensor (RGBW) and signal conditioning IC
- Filtron™ technology provides a spectrum matching real human eye responses
- Supports low transmittance (dark) lens design
- Fluorescent light flicker immunity
- Provides 16-bit resolution for each channel (R, G, B, W)
- Selectable maximum detection range (515.4, 1031, 2062, 4124, 8248, or 16 496) lux with highest sensitivity 0.007865 lux/step
- Package: OPLGA
- Temperature compensation: -40 °C to +85 °C
- Low power consumption I<sup>2</sup>C (SMBus compatible) interface
- Floor life: 168 h, MSL 3, according to J-STD-020
- Output type: I<sup>2</sup>C bus
- Operation voltage: 2.5 V to 3.6 V
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



### APPLICATIONS

- Handheld device
- Notebook
- Consumer device
- Industrial and mechanical application

PRODUCT SUMMARY					
PART NUMBER	OPERATING VOLTAGE RANGE (V)	I <sup>2</sup> C BUS VOLTAGE RANGE (V)	PEAK SENSITIVITY (nm)	RANGE OF SPECTRAL BANDWIDTH λ <sub>0.5</sub> (nm)	OUTPUT CODE
VEML6040	2.5 to 3.6	1.7 to 3.6	650, 550, 450 (R, G, B)	± 35, ± 35, ± 40 (R, G, B)	16 bit, I <sup>2</sup> C

#### Note

(1) Adjustable through I<sup>2</sup>C interface

ORDERING INFORMATION			
ORDERING CODE	PACKAGING	VOLUME (1)	REMARKS
VEML6040A3OG	Tape and reel	MOQ: 2500 pcs	2.0 mm x 1.25 mm x 1.0 mm

#### Note

(1) MOQ: minimum order quantity

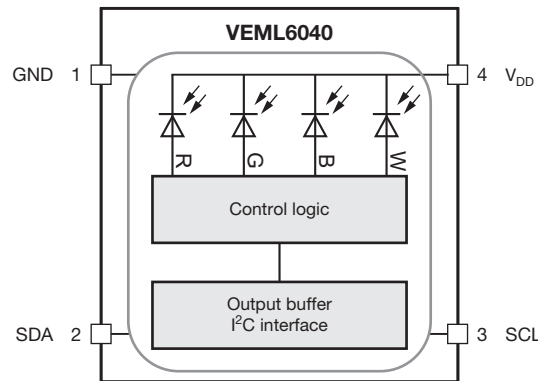


ABSOLUTE MAXIMUM RATINGS (T <sub>amb</sub> = 25 °C, unless otherwise specified)					
PARAMETER	TEST CONDITION	SYMBOL	MIN.	MAX.	UNIT
Supply voltage		V <sub>DD</sub>	0	3.6	V
Operation temperature range		T <sub>amb</sub>	-40	+85	°C
Storage temperature range		T <sub>stg</sub>	-40	+85	°C

RECOMMENDED OPERATING CONDITIONS (T <sub>amb</sub> = 25 °C, unless otherwise specified)					
PARAMETER	TEST CONDITION	SYMBOL	MIN.	MAX.	UNIT
Supply voltage		V <sub>DD</sub>	2.5	3.6	V
Operation temperature range		T <sub>amb</sub>	-40	+85	°C
I <sup>2</sup> C bus operating frequency		f <sub>(I2CCLK)</sub>	10	400	kHz

PIN DESCRIPTIONS			
PIN ASSIGNMENT	SYMBOL	TYPE	FUNCTION
1	GND	I	Ground
2	SDAT	I / O (open drain)	I <sup>2</sup> C data bus data input / output
3	SCLK	I	I <sup>2</sup> C digital bus clock input
4	V <sub>DD</sub>	I	Power supply input

**BLOCK DIAGRAM**



<b>BASIC CHARACTERISTICS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)							
PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT	
Supply voltage		$V_{DD}$	2.5	-	3.6	V	
Supply current		$I_{DD}$	-	200	-	$\mu\text{A}$	
I <sup>2</sup> C signal input	Logic high	$V_{DD} = 3.3\text{ V}$	$V_{IH}$	1.5	-	-	V
	Logic low		$V_{IL}$	-	-	0.8	
	Logic high	$V_{DD} = 2.6\text{ V}$	$V_{IH}$	1.4	-	-	V
	Logic low		$V_{IL}$	-	-	0.6	
Peak sensitivity wavelength		$\lambda_{PR}$	-	650	-	nm	
		$\lambda_{PG}$	-	550	-	nm	
		$\lambda_{PB}$	-	450	-	nm	
Irradiance responsivity	$\lambda_{PR} = 619\text{ nm}^{(3)}$		-	96	-	counts/ $(\mu\text{W}/\text{cm}^2)$	
	$\lambda_{PG} = 518\text{ nm}^{(3)}$		-	74	-		
	$\lambda_{PB} = 467\text{ nm}^{(3)}$		-	56	-		
Detectable intensity	Minimum	G channel, $I_T = 1280\text{ ms}^{(1)(2)}$	-	0.007865	-	lx	
	Maximum	G channel, $I_T = 40\text{ ms}^{(1)(2)}$	-	16 496	-		
Dark offset		G channel, $I_T = 80\text{ ms}^{(1)}$	0	-	3		
Operating temperature range		$T_{amb}$	-40	-	+85	$^{\circ}\text{C}$	
Shutdown current	Light condition = dark, $V_{DD} = 3.6\text{ V}$	$I_{DD}$	-	800	-	nA	

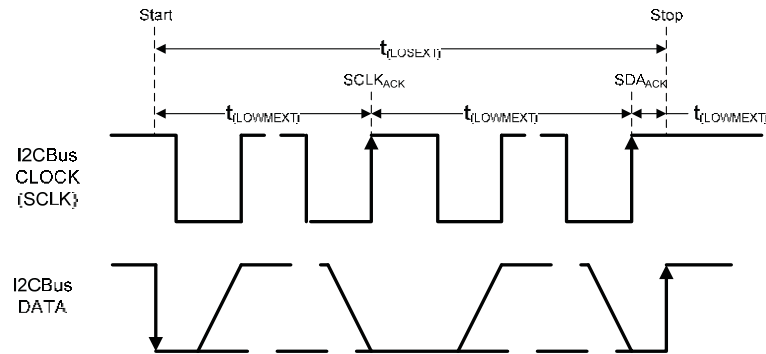
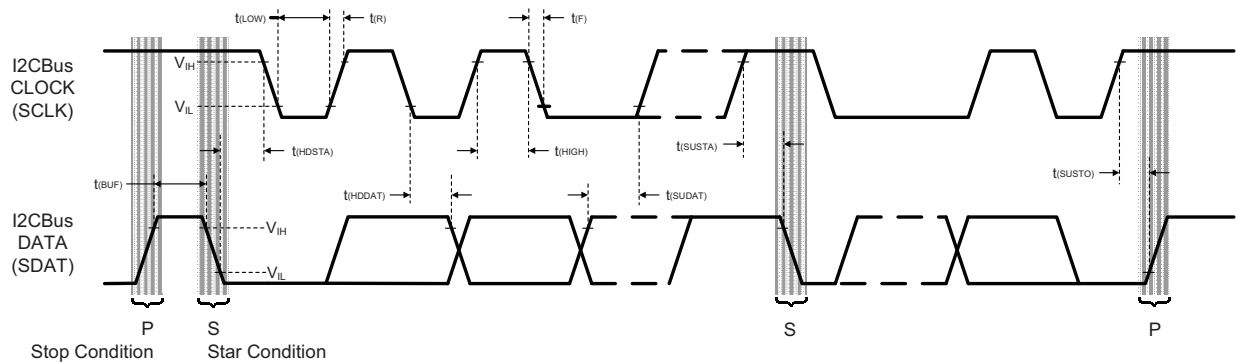
**Notes**

- (1) Test condition:  $V_{DD} = 3.3\text{ V}$ , temperature:  $25\text{ }^{\circ}\text{C}$   
 (2) Light source: white LED  
 (3) LED spectrum given in fig. 1;  $I_T = 160\text{ ms}$



Fig. 1 - Normalized Spectral Response of Used LEDs for Measuring the Irradiance Responsivity

<b>I<sup>2</sup>C BUS TIMING CHARACTERISTICS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)						
PARAMETER	SYMBOL	STANDARD MODE		FAST MODE		UNIT
		MIN.	MAX.	MIN.	MAX.	
Clock frequency	$f_{(SMBCLK)}$	10	100	10	400	kHz
Bus free time between start and stop condition	$t_{(BUF)}$	4.7	-	1.3	-	$\mu\text{s}$
Hold time after (repeated) start condition; after this period, the first clock is generated	$t_{(HDSTA)}$	4.0	-	0.6	-	$\mu\text{s}$
Repeated start condition setup time	$t_{(SUSTA)}$	4.7	-	0.6	-	$\mu\text{s}$
Stop condition setup time	$t_{(SUSTO)}$	4.0	-	0.6	-	$\mu\text{s}$
Data hold time	$t_{(HDDAT)}$	300	-	90	-	ns
Data setup time	$t_{(SUDAT)}$	250	-	100	-	ns
I <sup>2</sup> C clock (SCK) low period	$t_{(LOW)}$	4.7	-	1.3	-	$\mu\text{s}$
I <sup>2</sup> C clock (SCK) high period	$t_{(HIGH)}$	4.0	-	0.6	-	$\mu\text{s}$
Detect clock / data low timeout	$t_{(TIMEOUT)}$	25	35	-	-	ms
Clock / data fall time	$t_{(F)}$	-	300	-	300	ns
Clock / data rise time	$t_{(R)}$	-	1000	-	300	ns


 Fig. 2 - I<sup>2</sup>C Bus Timing Diagram

**PARAMETER TIMING INFORMATION**

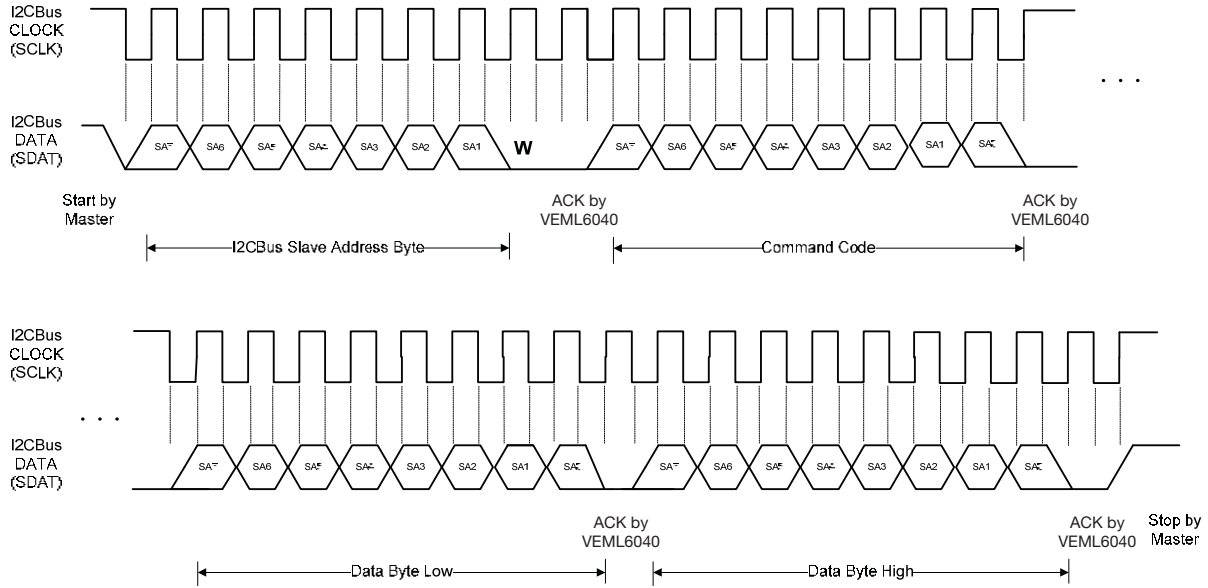


Fig. 3 - I<sup>2</sup>C Bus Timing for Sending Word Command Format

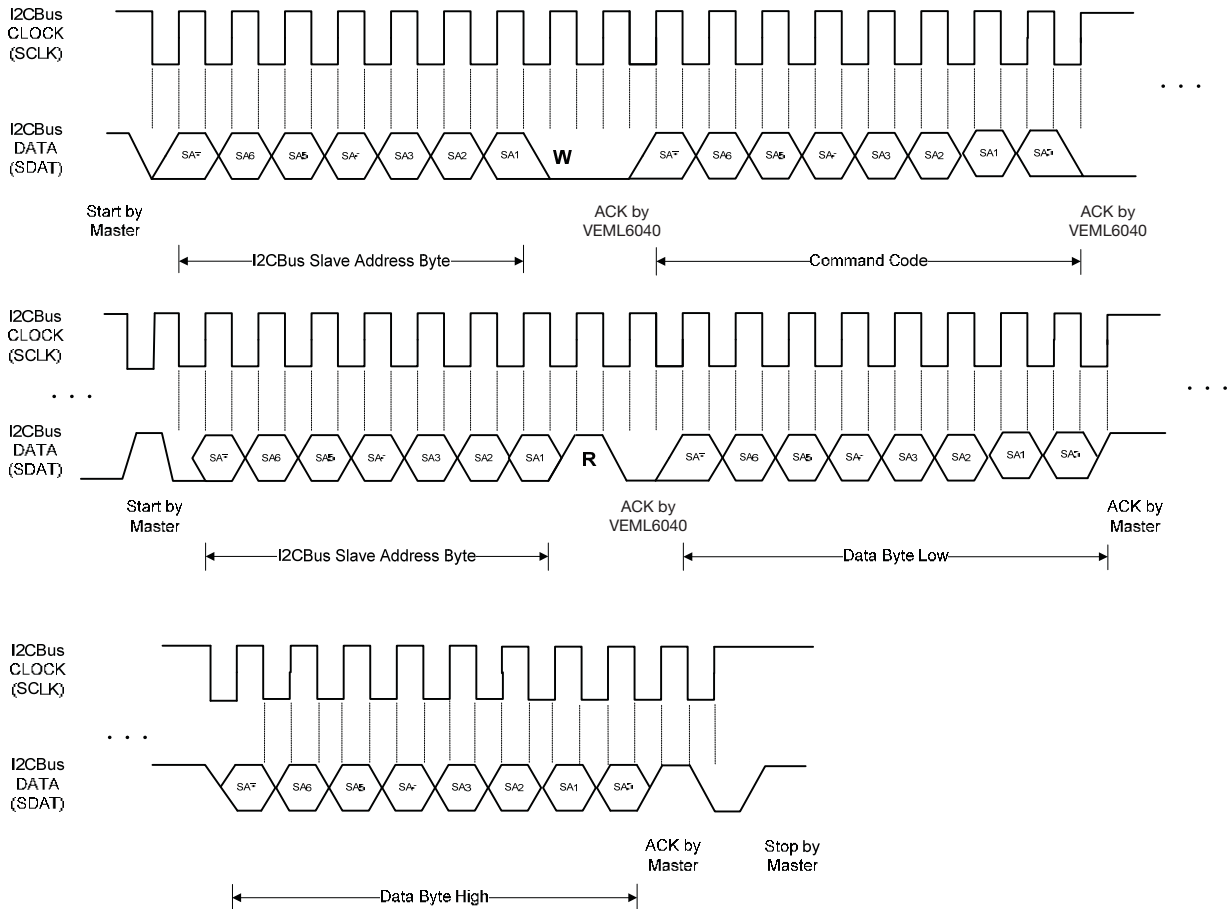


Fig. 4 - I<sup>2</sup>C Bus Timing for Receiving Word Command Format

**TYPICAL PERFORMANCE CHARACTERISTICS** ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)



Fig. 5 - Normalized Spectral Response

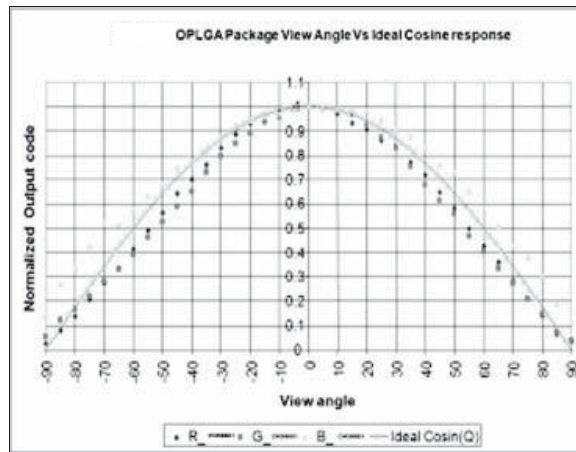


Fig. 6 - Normalized Output vs. View Angle

**APPLICATION INFORMATION**

**Pin Connection with the Host**

VEML6040 integrates R, G, B, and W sensor together with I<sup>2</sup>C interface. It is very easy for the baseband (CPU) to access VEML6040 output data via I<sup>2</sup>C interface without extra software algorithms. The hardware schematic is shown in the following diagram.

The 0.1  $\mu\text{F}$  capacitor near the V<sub>DD</sub> pin is used for power supply noise rejection. The 2.2 k $\Omega$ s are suitable for the pull-up resistors of I<sup>2</sup>C.

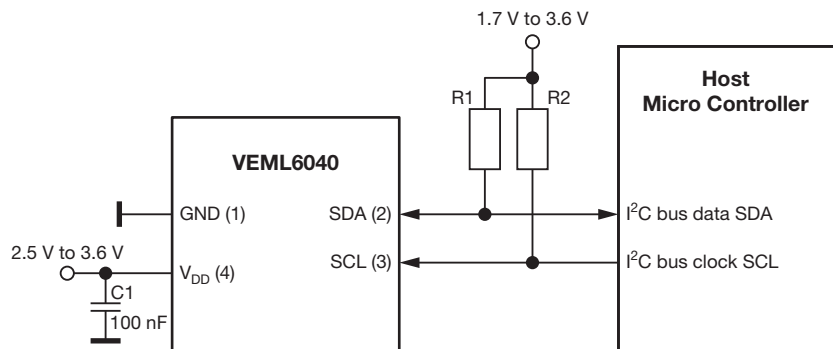


Fig. 7 - Hardware Pin Connection Diagram



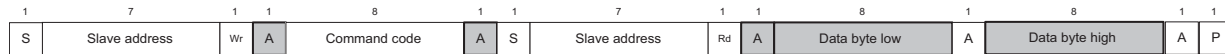
Digital Interface

The VEML6040 contains a CONF register (00h) used for operation control and parameter setup. Measurement results are stored in four separate registers, one each for red, green, blue, and white respectively (08h to 0Bh). All registers are accessible via I2C communication. Figure 8 shows the basic I2C communication with the VEML6040. Each of the registers in the VEML6040 are 16 bit wide, so 16 bit should be written when a write command is sent, and 16 bit should be read when a read command is sent. The built in I2C interface is compatible with I2C modes "standard" and "fast": 100 kHz to 400 kHz

Send Word → Write Command to VEML6040



Receive Word → Read Data from VEML6040



S = start condition
P = stop condition
A = acknowledge
Shaded area = VEML6040 acknowledge

Fig. 8 - Command Protocol Format

Note

- Please note the repeat start condition when data is read from the sensor. A stop condition should not be sent here.

Slave Address and Function Description

VEML6040 uses 10h slave address for 7-bit I2C addressing protocol. VEML6040 has 16-bit resolution for each channel (R, G, B, and W) that provides sensitivity up to 0.0056 lux/step for G, which is advantageous under a low transmittance lens design (dark lens).

TABLE 1 - SLAVE ADDRESS AND COMMAND CODE DESCRIPTION
SLAVE ADDRESS 0x10
Table with columns: COMMAND CODE, DATE BYTE LOW / HIGH, REGISTER NAME, R / W, BIT (7, 6, 5, 4, 3, 2, 1, 0)

Note

- Slave address is 7-bit addressing protocol

**Configuration Register Format**

VEML6040 has a 16-bit configuration register for controlling. The description of each command format is shown in the following tables.

<b>TABLE 2-1 - COMMAND CODE 00H BITS DESCRIPTION</b>							
SLAVE ADDRESS: 0x10; REGISTER NAME: CONF; COMMAND CODE: 00H / DATA BYTE LOW							
X	IT			X	TRIG	AF	SD
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0	IT2	IT1	IT0	0	TRIG	AF	SD
DESCRIPTION							
IT		Integration time setting					
TRIG		Proceed one detecting cycle at manual force mode					
AF		Auto / manual force mode					
SD		Chip shutdown setting					

<b>TABLE 2-2 - COMMAND CODE 00H REGISTER SETTING</b>			
BITS SETTING		DESCRIPTION	
BIT 7		Default = 0	
BIT 6, 5, 4 IT (2 : 0)		(0 : 0 : 0) = 40 ms	
		(0 : 0 : 1) = 80 ms	
		(0 : 1 : 0) = 160 ms	
		(0 : 1 : 1) = 320 ms	
		(1 : 0 : 0) = 640 ms	
		(1 : 0 : 1) = 1280 ms	
BIT 3		Default = 0	
BIT 2 TRIG		0 = no trigger 1 = trigger one time detect cycle	
BIT 1 AF		0 = auto mode 1 = force mode	
BIT 0 SD		0 = enable color sensor 1 = disable color sensor	

<b>TABLE 3-1 - RESERVE COMMAND CODE DESCRIPTION</b>		
RESERVED		COMMAND CODE: 00H / DATA BYTE HIGH
Command	Bit	Description
Reserved	7 : 0	Default = 0x00

<b>TABLE 3-2 - RESERVE COMMAND CODE DESCRIPTION</b>		
RESERVED		COMMAND CODE: 01H TO 07H
Command	Bit	Description
Reserved	7 : 0	Default = 0x00

<b>TABLE 4 - READ OUT COMMAND CODE DESCRIPTION</b>			
REGISTER	COMMAND CODE	BIT	DESCRIPTION
R_DATA	0x08_L (08H data byte low)	7 : 0	0x00 to 0xFF, R channel LSB output data
	0x08_H (08H data byte high)	7 : 0	0x00 to 0xFF, R channel MSB output data
G_DATA	0x09_L (09H data byte low)	7 : 0	0x00 to 0xFF, G channel LSB output data
	0x09_H (09H data byte high)	7 : 0	0x00 to 0xFF, G channel MSB output data
B_DATA	0x0A_L (0AH data byte low)	7 : 0	0x00 to 0xFF, B channel LSB output data
	0x0A_H (0AH data byte high)	7 : 0	0x00 to 0xFF, B channel MSB output data
W_DATA	0x0B_L (0BH data byte low)	7 : 0	0x00 to 0xFF, W channel LSB output data
	0x0B_H (0BH data byte high)	7 : 0	0x00 to 0xFF, W channel MSB output data





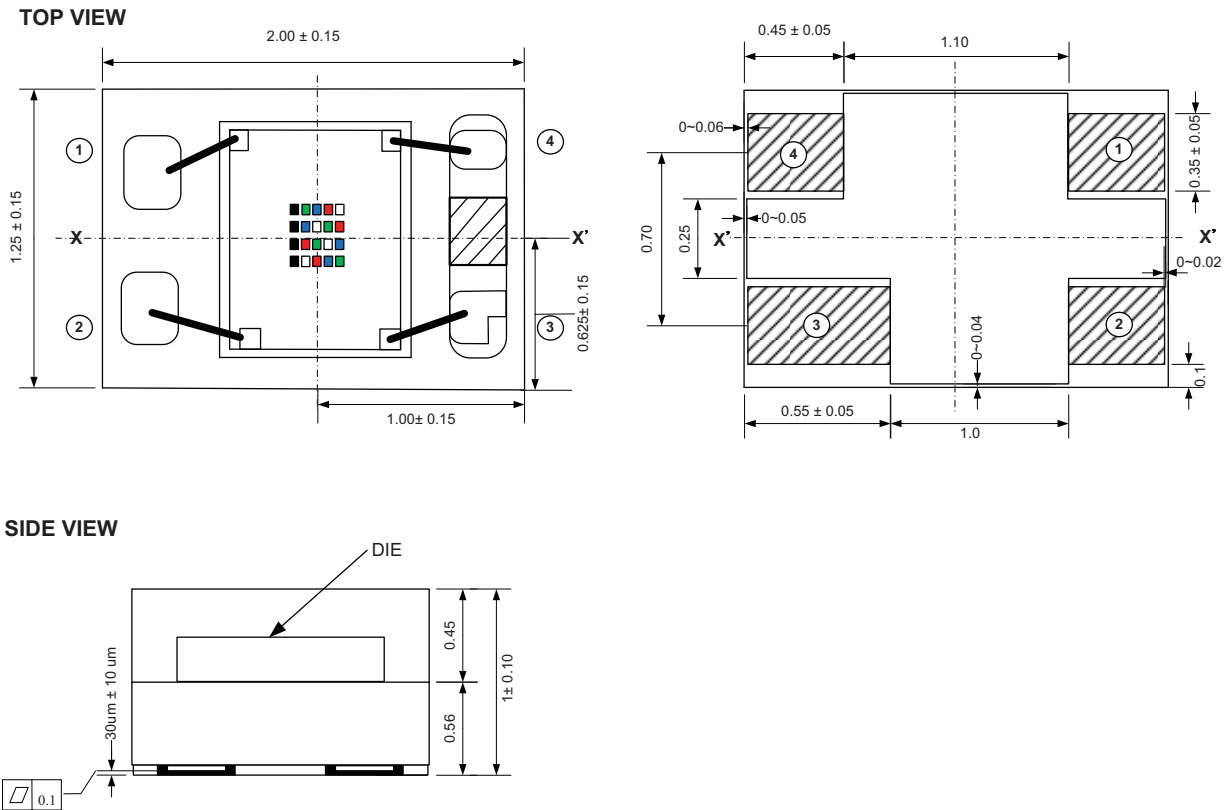
**PACKAGE INFORMATION** in millimeters


Fig. 9 - VEML6040 A3OG Package Dimensions

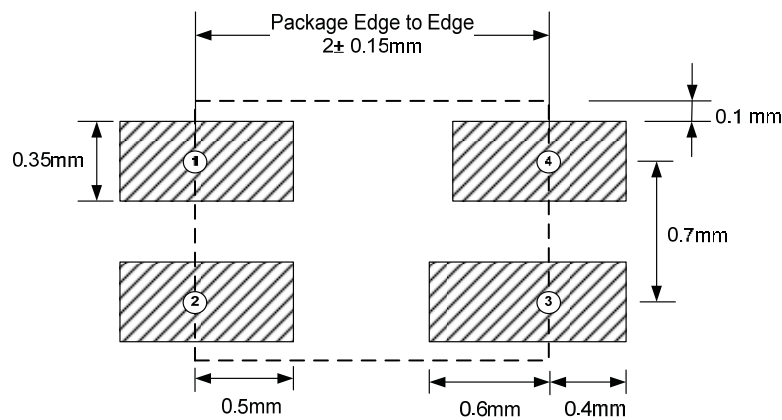
**LAYOUT NOTICE AND REFERENCE CIRCUIT** in millimeters


Fig. 10 - VEML6040 PCB Layout Footprint

RECOMMENDED STORAGE AND REBAKING CONDITIONS				
PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
Storage temperature		5	50	°C
Relative humidity		-	60	%
Open time		-	168	h
Total time	From the date code on the aluminized envelope (unopened)	-	12	months
Rebaking	Tape and reel: 60 °C	-	22	h
	Tube: 60 °C	-	22	h

**RECOMMENDED INFRARED REFLOW**

Soldering conditions which are based on J-STD-020 C

IR REFLOW PROFILE CONDITION			
PARAMETER	CONDITIONS	TEMPERATURE	TIME
Peak temperature		255 °C + 0 °C / - 5 °C (max.: 260 °C)	10 s
Preheat temperature range and timing		150 °C to 200 °C	60 s to 180 s
Timing within 5 °C to peak temperature		-	10 s to 30 s
Timing maintained above temperature / time		217 °C	60 s to 150 s
Timing from 25 °C to peak temperature		-	8 min (max.)
Ramp-up rate		3 °C/s (max.)	-
Ramp-down rate		6 °C/s (max.)	-

Recommend Normal Solder Reflow is 235 °C to 255 °C

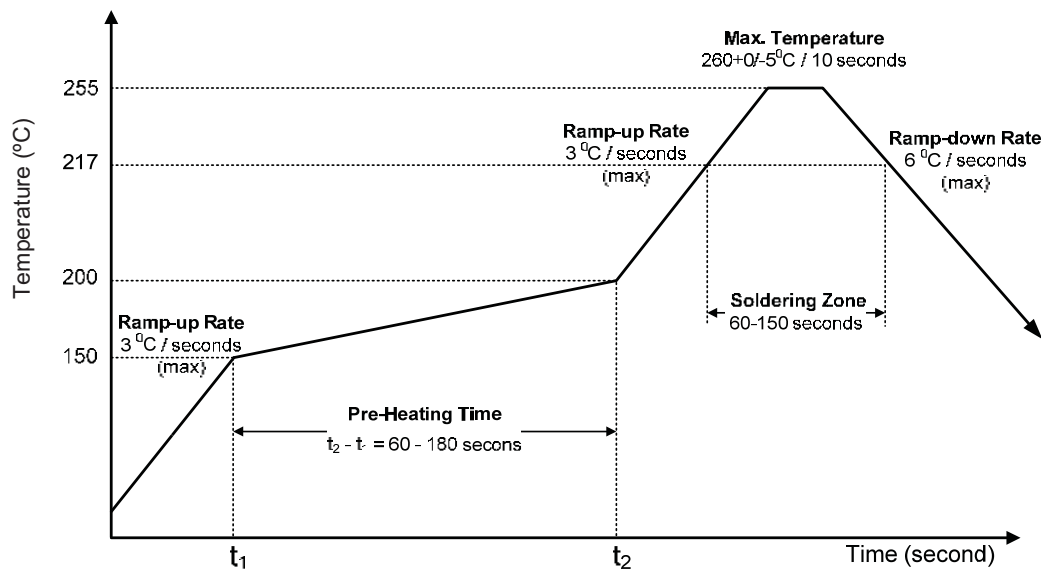


Fig. 11 - VEM6040 OPLGA Solder Reflow Profile Chart

**RECOMMENDED IRON TIP SOLDERING CONDITION AND WARNING HANDLING**

1. Solder the device with the following conditions:
  - 1.1. Soldering temperature: 400 °C (max.)
  - 1.2. Soldering time: 3 s (max.)
2. If the temperature of the method portion rises in addition to the residual stress between the leads, the possibility that an open or short circuit occurs due to the deformation or destruction of the resin increases.
3. The following methods: VPS and wave soldering, have not been suggested for the component assembly.
4. Cleaning method conditions:
  - 4.1. Solvent: methyl alcohol, ethyl alcohol, isopropyl alcohol
  - 4.2. Solvent temperature < 45 °C (max.)
  - 4.3. Time: 3 min (min.)





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