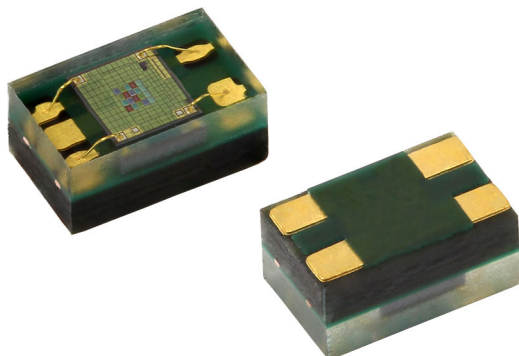




## RGBW Color Sensor With I<sup>2</sup>C Interface



### 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 $\Lambda_{0.5}$ (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

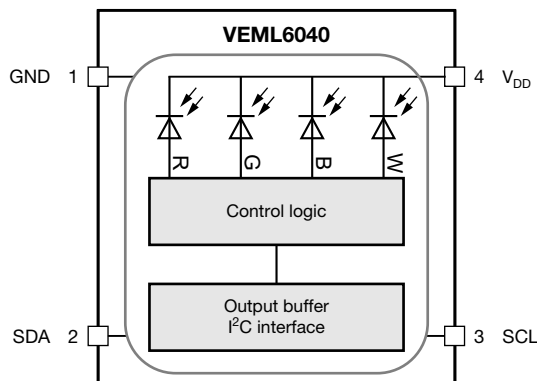


| <b>ABSOLUTE MAXIMUM RATINGS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |                |           |      |      |                    |
|--|----------------|-----------|------|------|--------------------|
| PARAMETER  | TEST CONDITION | SYMBOL    | MIN. | MAX. | UNIT               |
| Supply voltage   |                | $V_{DD}$  | 0    | 3.6  | V                  |
| Operation temperature range  |                | $T_{amb}$ | -40  | +85  | $^{\circ}\text{C}$ |
| Storage temperature range  |                | $T_{stg}$ | -40  | +85  | $^{\circ}\text{C}$ |

| <b>RECOMMENDED OPERATING CONDITIONS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |                |                |      |      |                    |
|--|----------------|----------------|------|------|--------------------|
| PARAMETER  | TEST CONDITION | SYMBOL         | MIN. | MAX. | UNIT               |
| Supply voltage   |                | $V_{DD}$       | 2.5  | 3.6  | V                  |
| Operation temperature range  |                | $T_{amb}$      | -40  | +85  | $^{\circ}\text{C}$ |
| I <sup>2</sup> C bus operating frequency   |                | $f_{(I2CCLK)}$ | 10   | 400  | kHz                |

| <b>PIN DESCRIPTIONS</b> |          |                    |   |
|-------------------------|----------|--------------------|---|
| 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                       | $V_{DD}$ | I                  | Power supply input                            |

**BLOCK DIAGRAM**





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

**Notes**

- (1) Test condition: V<sub>DD</sub> = 3.3 V, temperature: 25 °C
- (2) Light source: white LED
- (3) LED spectrum given in fig. 1; I<sub>T</sub> = 160 ms

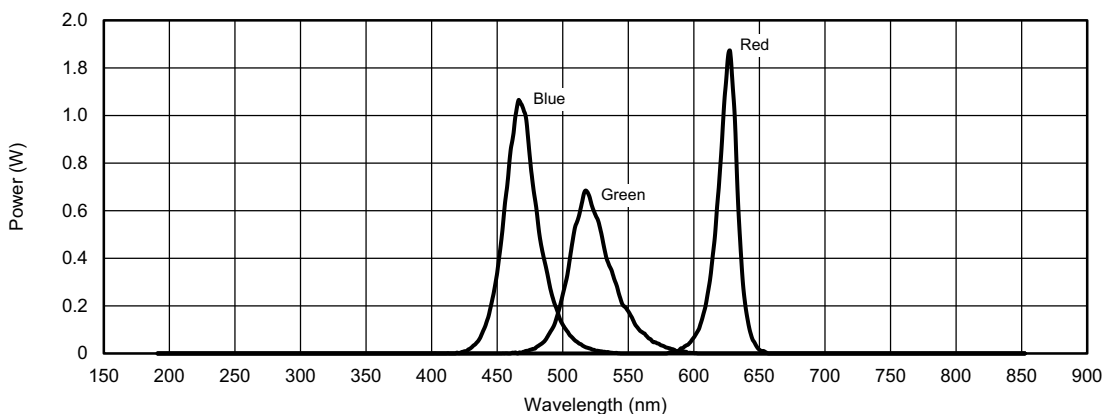


Fig. 1 - Normalized Spectral Response of Used LEDs for Measuring the Irradiance Responsivity



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

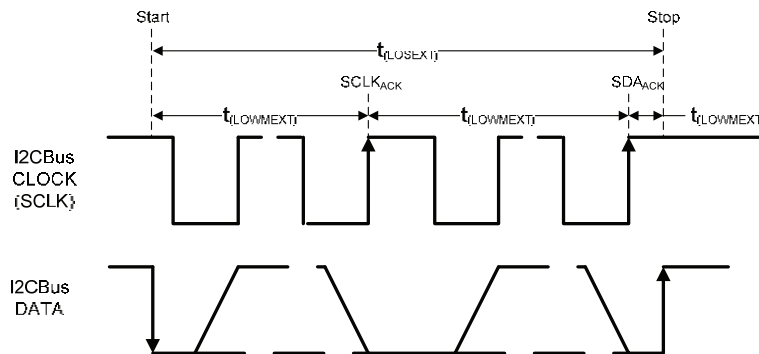
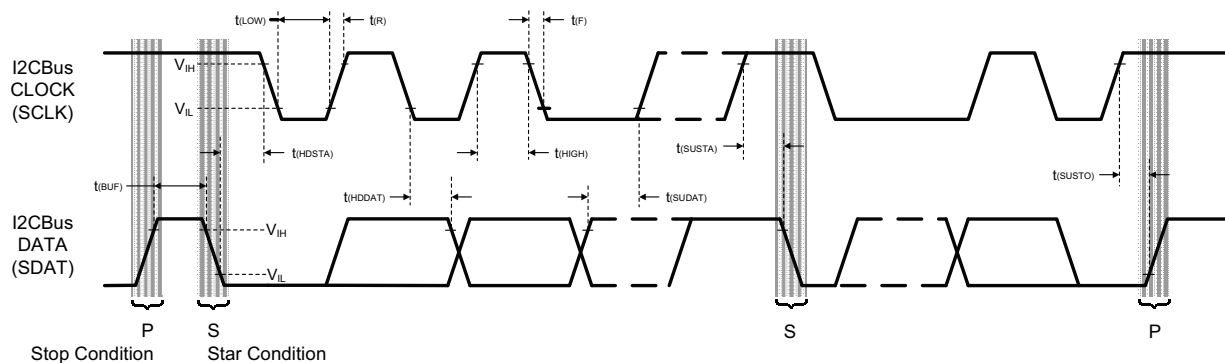


Fig. 2 - I<sup>2</sup>C Bus Timing Diagram



**PARAMETER TIMING INFORMATION**

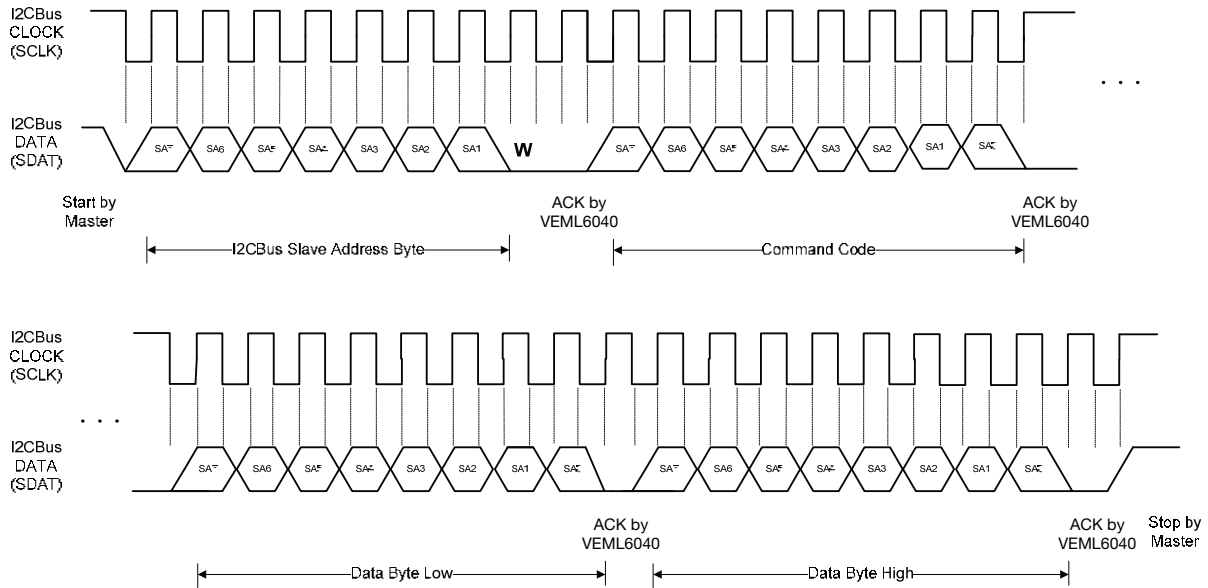


Fig. 3 - I<sup>2</sup>C Bus Timing for Sending Word Command Format

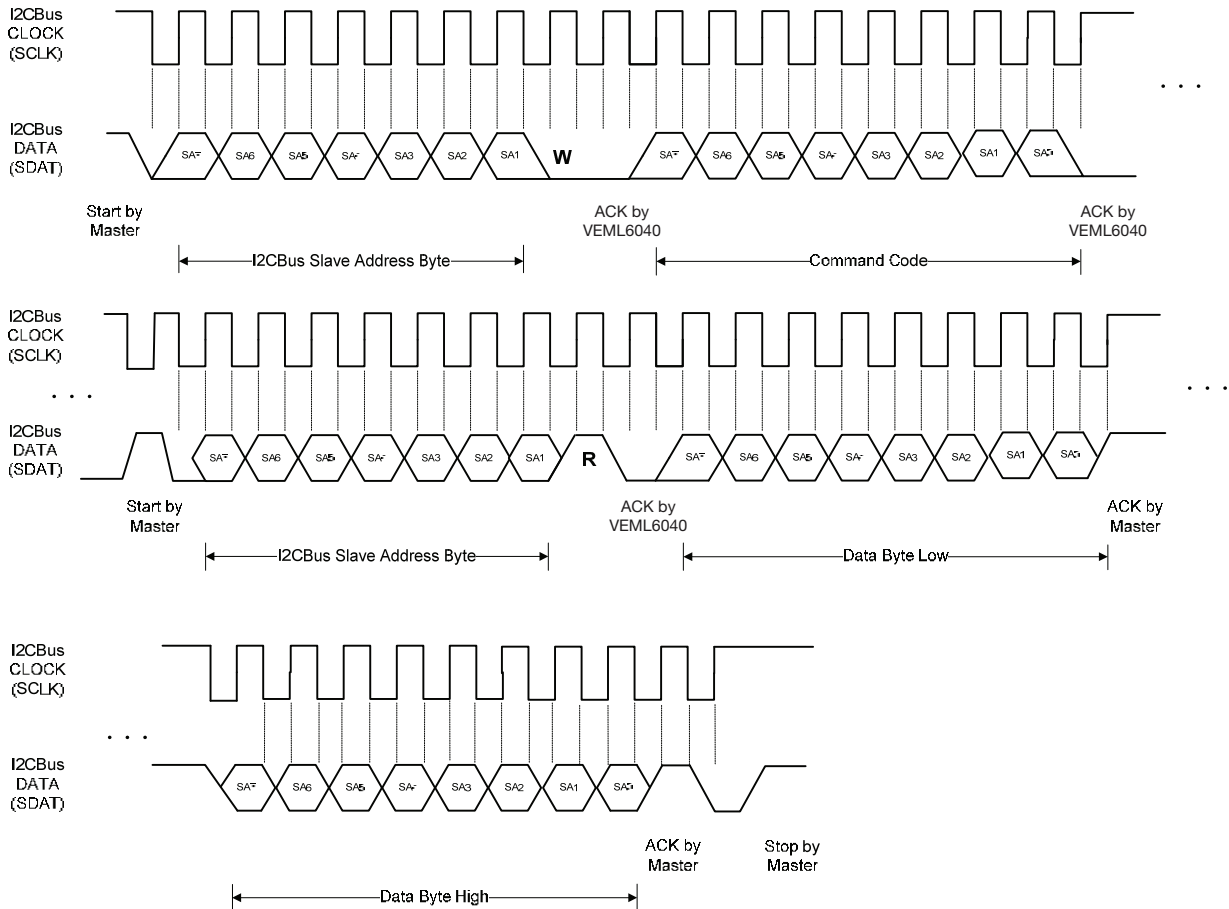


Fig. 4 - I<sup>2</sup>C Bus Timing for Receiving Word Command Format

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

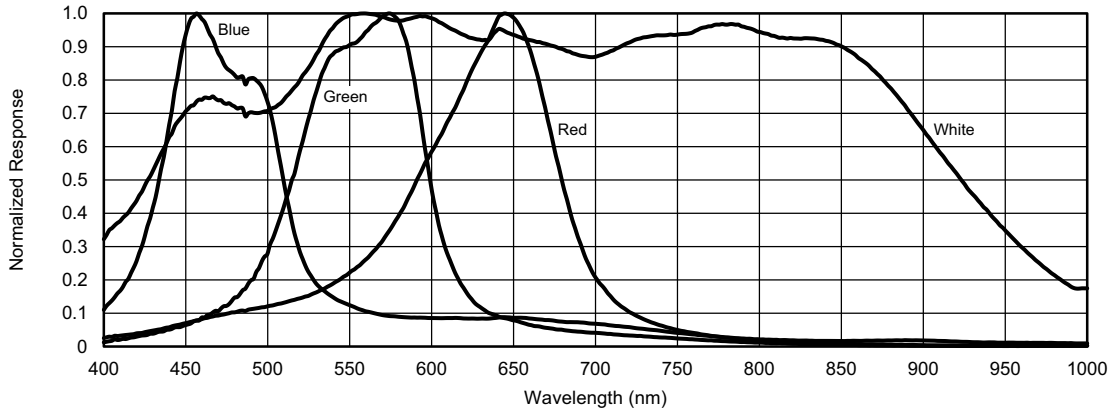


Fig. 5 - Normalized Spectral Response

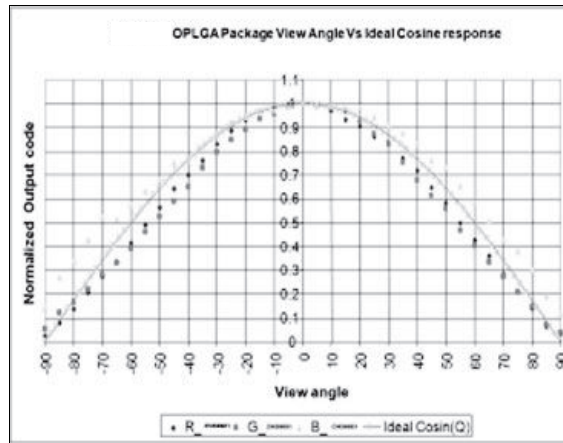


Fig. 6 - Normalized Output vs. View Angle

**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.

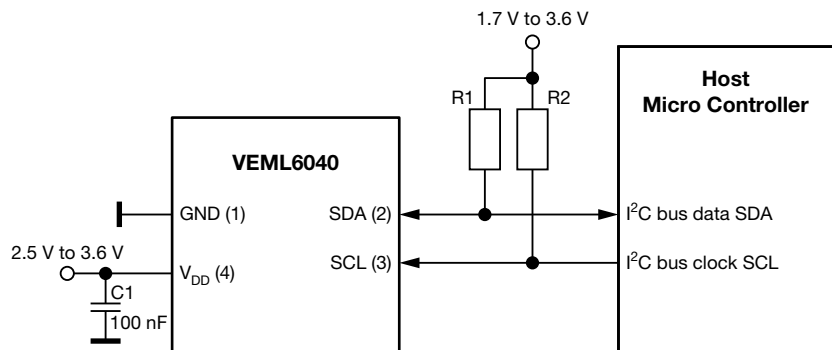


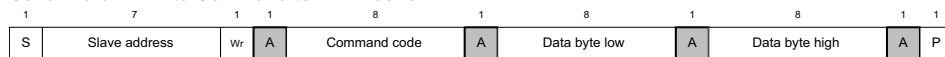
Fig. 7 - Hardware Pin Connection Diagram



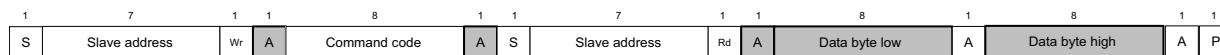
**Digital Interface**

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 I<sup>2</sup>C communication. Figure 8 shows the basic I<sup>2</sup>C 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 I<sup>2</sup>C interface is compatible with I<sup>2</sup>C 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 I<sup>2</sup>C 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                                   |                      |               |       |                 |            |   |   |   |      |    |    |
| COMMAND CODE   | DATE BYTE LOW / HIGH | REGISTER NAME | R / W | BIT             |            |   |   |   |      |    |    |
|  |                      |               |       | 7               | 6          | 5 | 4 | 3 | 2    | 1  | 0  |
| 00h  | L                    | CONF          | R / W | 0               | IT (2 : 0) |   |   | 0 | TRIG | AF | SD |
|  | H                    | Reserved      | R / W | Reserved        |            |   |   |   |      |    |    |
| 01h to 07h   | L                    | Reserved      | R / W | Reserved        |            |   |   |   |      |    |    |
|  | H                    | Reserved      | R / W | Reserved        |            |   |   |   |      |    |    |
| 08h  | L                    | R_DATA        | R     | R_Data (7 : 0)  |            |   |   |   |      |    |    |
|  | H                    | R_DATA        | R     | R_Data (15 : 8) |            |   |   |   |      |    |    |
| 09h  | L                    | G_DATA        | R     | G_Data (7 : 0)  |            |   |   |   |      |    |    |
|  | H                    | G_DATA        | R     | G_Data (15 : 8) |            |   |   |   |      |    |    |
| 0Ah  | L                    | B_DATA        | R     | B_Data (7 : 0)  |            |   |   |   |      |    |    |
|  | H                    | B_DATA        | R     | B_Data (15 : 8) |            |   |   |   |      |    |    |
| 0Bh  | L                    | W_DATA        | R     | W_Data (7 : 0)  |            |   |   |   |      |    |    |
|  | H                    | W_DATA        | R     | W_Data (15 : 8) |            |   |   |   |      |    |    |

**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<br>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<br>TRIG                     |  |
|  |  | 0 = no trigger                    |  |
|  |  | 1 = trigger one time detect cycle |  |
|  |  | BIT 1<br>AF                       |  |
|  |  | 0 = auto mode                     |  |
|  |  | 1 = force mode                    |  |
|  |  | BIT 0<br>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

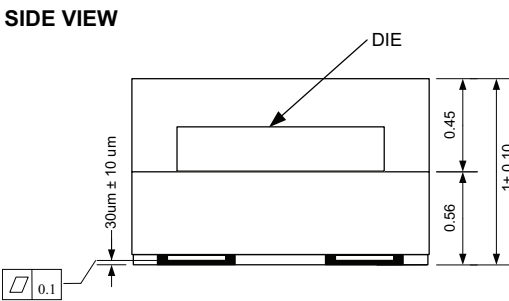
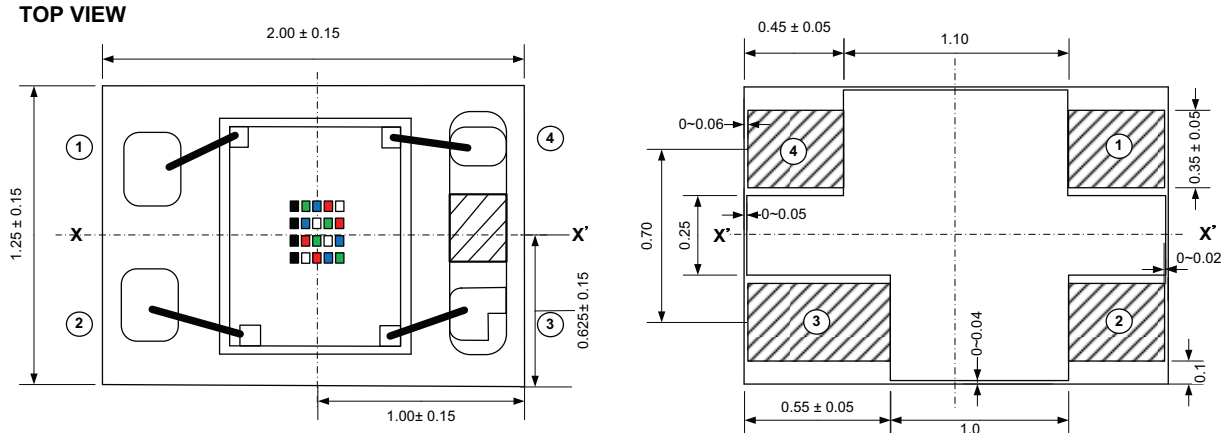


Fig. 9 - VEML6040 A3OG Package Dimensions

**LAYOUT NOTICE AND REFERENCE CIRCUIT** in millimeters

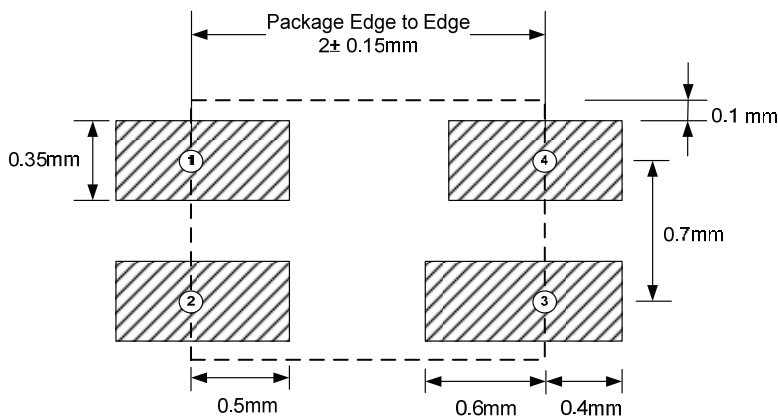


Fig. 10 - VEML6040 PCB Layout Footprint

| 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

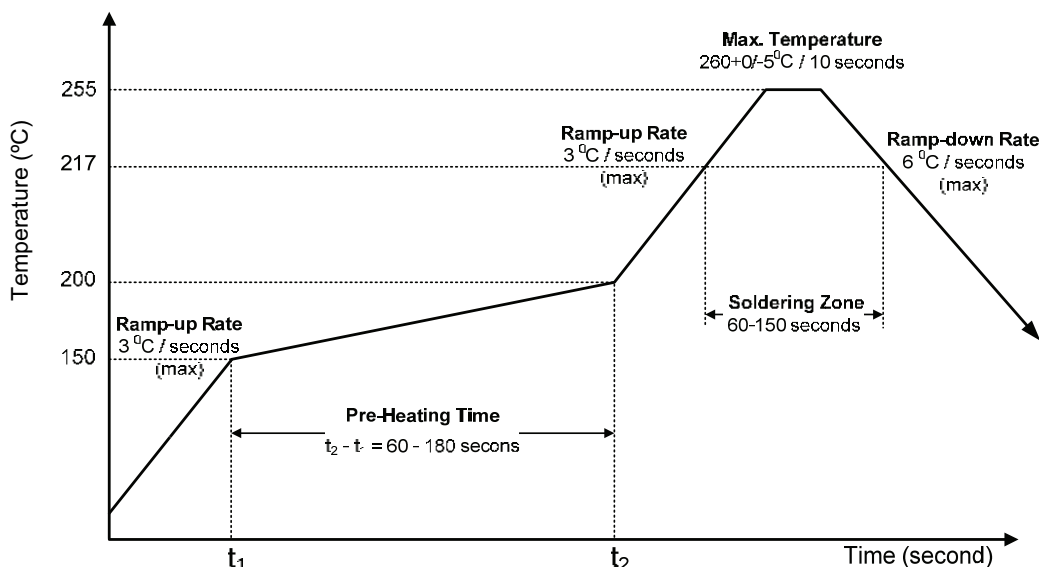


Fig. 11 - VEML6040 OPLGA Solder Reflow Profile Chart

**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.)



**TAPE PACKAGING INFORMATION** in millimeters

**DIMENSION OF CARRIER TAPE**

SIDE VIEW

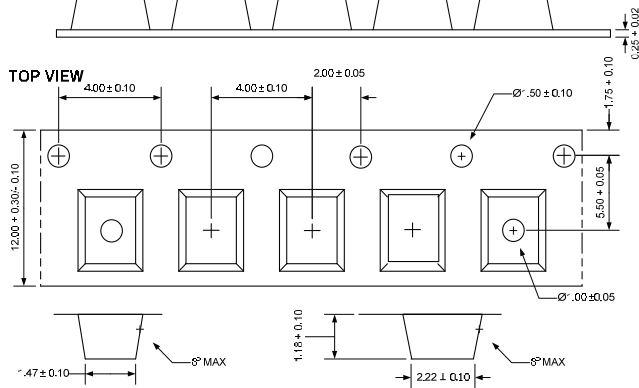


Fig. 12 - VEML6040 A3OG Package Carrier Tape

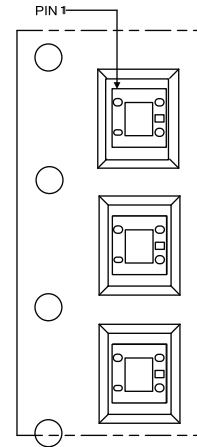


Fig. 13 - Taping Direction

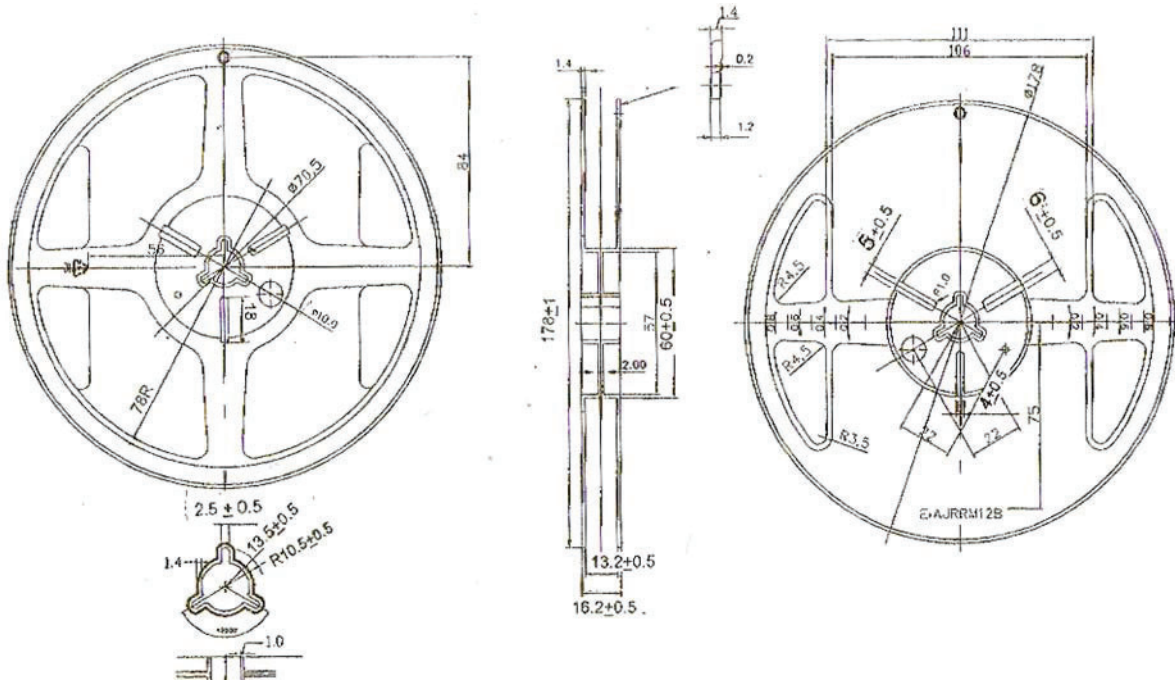


Fig. 14 - Reel Dimensions



## Disclaimer

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