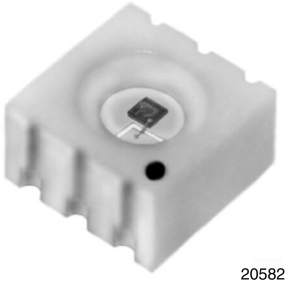
VISHAY SEMICONDUCTORS

LEDs

Application Note CLCC6

# High Power LED, Ceramic Base SMD, VLMxxx Series



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## Introduction

Highest performance and reliability are fulfilled with these ceramic package for high power LED's.

By the high demand of power to optical efficiency ration while maintaining the highest possible heat dissipation. Our CLCC6 is the devices of choice in applications were stability, performance, and reliability can not be compromised.

The high efficiency on heat dissipation (18 W/mK) makes this product a must for clustered or matrix designs were the cumulative heat should be take into serious consideration and must be maintained at a minimum to reduce profound wavelength deviations caused by the excessive heat resulting in unwanted effects such as a severe reduction of luminous intensity and luminance homogeneity.

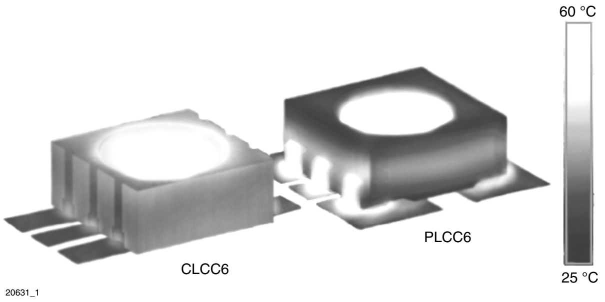


Fig. 1

Unlike plastic/resin packages, a ceramic material offers lesser resistance to a heat source, thus effectively serving as a cooling mass as well as a robust packaging. Fig. 1 shows a thermal graphic representation of heat conductance in a ceramic CLCC6 package as it compares to a standard PLCC6 plastic/resin package.

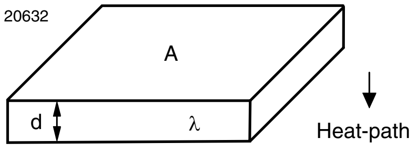
Both samples have the same LED (thermal simulation Fig. 1) and are driven with the same $I_F$ current, soldered on same type of pc-board material. It can be observed that the heat generated at PLCC6 is sustained within the package due to its high heat resistance and can only find its dissipation path via the leads and onto the pc-board.

With plastic/resin packages, the designer must provide for larger solder-pads to help in dissipating the heat forcing larger distances between the LED's. The ceramic CLCC6 package is a cooler approach, although the same heat is been generated at the chip heat source, the LED package operates just a little over the room temperature. The ceramic efficiently conducts the heat, serving as an ideal cooling body maintaining the heat source lower and avoiding having to have large solder-pads to dissipate the heat.

Plain and simple; driving high power LED's while minimizing lowest possible heat for any given $I_F$, provides you not only with the advantages of efficiency on its electro-optic properties but would also extends its service-life.

## Thermal Management

Our high power LED's VLMxxx series have been designed specifically with the thermal-effect consideration in mind. Ceramic, with its high thermal conductivity properties, ensures an efficient heat dissipation medium to the embodied heat source at the semiconductor junction.



d = Thickness of the plate
A = Area
λ = Thermal conductivity (W/mK)
$R_{th} = d/\lambda A$

APPLICATION NOTE

## High Power LED, Ceramic Base SMD, VLMxxx Series

Typical thermal conductivity:

Plastics: 0.5 W/mK or 0.5 W/m°C

Ceramic: 18 W/mK or 18 W/m°C

Cu: 300 W/mK or 300 W/m°C

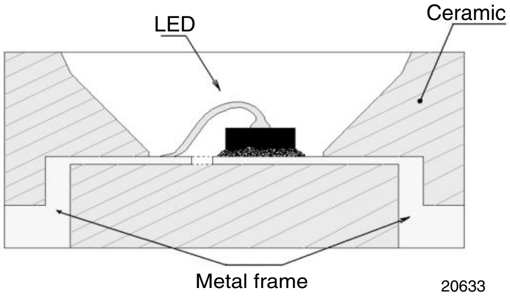


Fig. 2

Whether in automotive or heavily clustered applications, the advantages of low thermal resistance will be reflected in the simplicity and compactness of a design, thus the thermal management considerations for a given case are far more simplified.

The junction temperature (source of heat) should be maintained below the maximum specified value. If the temperature between two points (junction and ambient) is known, the amount of heat that moves from the junction to the ambient is determined by the thermal resistance.

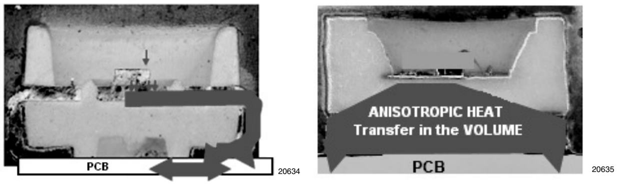
Material parameter:

Material: λ (W/mK)

Cu: 300

Ceramic: 18

Plastic: 0.5 to 1.3



**PLCC6**
- Heat transfer via lead-frame Cu lead-frame with high thermal conductivity
- Long distance for heat transfer low cross section for heat transfer

**CLCC6**
- Anisotropic heat transfer within high cross-cut
- Low thermal conductivity compared to Cu
- No thermal behavior of thermal conductivity

Fig. 3

In most semiconductors, the two thermal resistance values between the source and the ambient are typically given in the form of $R_{thJP}$ and $R_{thJA}$, providing the basic values from which thermal management can be applied. Thus, the total power dissipation must flow between these two points and their relationship can be described as follow:

$$\theta_{JA} = T_J - T_A/P_D$$

…theta junction ambient equals the temperature at the junction-ambient temperature dived by the power dissipation.

$$\theta_{JC} = T_J - T_C/P_D$$

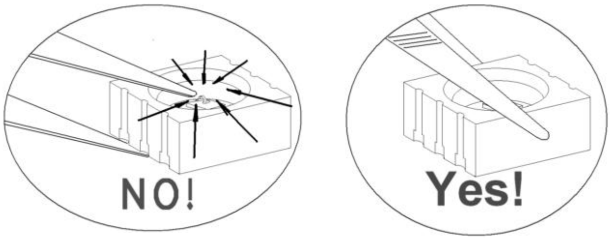
… theta junction case equals the temperature at the junction-case temperature dived by the power dissipation.

Then.. $T_J = \theta J_A \text{ x } P_D + T_A$

Because of the thermal stable nature of ceramic packages, the thermal resistance associated at the application level via the soldering pad is the only significant consideration to evaluate. Here, the thermal dissipation specification for the pcboard's material as well as the soldering pad layout considerations will improve the total thermal management approach.

## Handling

The reflector is covered with a silicone base compound. It is very important to avoid scratching the surface with sharp objects tweezers and pointed utensils.



Caution: On automatic pick-n-place equipment, caution should be taken that the picking tool "die" is so designed that when placed over the LED, it does not scratch the silicone surface.

## Source of Light

LED's are the most popular and commonly used solid-state semiconductor, so widely used that it creates an application world of its own. This "renaissance" of the LED imposes upon the designer a new set of faculties and considerations in building and excellent application. The color that is emitted from an LED is defined by its $\lambda_d$ dominant wavelength measured in (nm) nanometer units (one billionth of a meter). The thermal laws as well as the laws of optics, in particular chromaticity for white LED's are increasingly playing a mayor role in each and every new design.

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| MOST POPULAR AREAS OF APPLICATION | | |
|---|---|---|
| **AUTOMOTIVE AND TRANSPORT** | **CONSUMER** | **GENERAL ILLUMINATION** |
| Instrument panels | Household appliances | Retail and window displays |
| Courtesy lighting | VCR/DVD/audio | Signage and graphics |
| Center high mounted stop lamps | Toys and games | Emergency lighting and signs |
| Rear stop/turn and tail | Instrumentation | Accent and pathways lightings |
| Marker lights | Security | Machine vision |
| Traffic routing signal | | |
| Railways | General backlight | |
| Aviation (interior) | Handheld lighting | |
| Emergency vehicle | | |
| Perimeter lightings | | |

## General Consideration

Although one of the main basic objectives for LED chip designers is to get the highest possible light output with the smallest chip side while reducing junction temperature. It does not necessarily means that the application designer must also design for the highest possible light output from a single source at the risk of performances and degradation. There should be a balance between the amount of light required and the number of LED's that are applicable for a given space to fulfill a specific lighting requirement.

Data sheets are the prime basic source on product specifications as well as operating range and conditions. A datasheet is specific to a product and has been compiled based on analysis results from a controlled environment. The designer should be well familiarized with the product specifications and be aware that it is impossible for a manufacturer's lab to simulate or foreseen any and all possible electrical scenarios and environmental conditions to which this product may be subjected to. The application designer is responsible to consider the technical specifications of a product and its suitability or adaptability for a given job.

### The Light that we see:

The "inverse square law" as a property to light radiation (Fig. 4), is a behavior that a designer should be familiarized with; It estates that the illumination is inversely proportional to the square of the distance between a source and an illuminated surface.

In addition to requirements concerning the luminous intensity to cover a given area at a given distance, the color wavelength as well as the chromaticity value are becoming increasingly critical as the conventional application of LED's is emerging into new fields such as automotive, architecture, showrooms and entertainment.

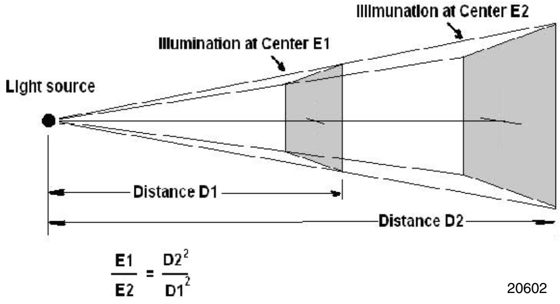

Fig. 4

The human eye sensors perceive colors based on the perceptibility of dual criteria. One relates to sensitivity and is responsible in quantifying the intensity of a source and the second, more complex responds to the wavelength. What we perceive as color is basically depending on characteristics relating to brightness, hue and saturation.  We regard the basic colors as Red, Green and Blue and a mixture of these three can represent all other colors.

Any given color can be expressed by its trichromatic coefficient based on the tristimulus x, y, z, values respectively as contained within the CIE diagram.

$\mathbf{x = X/(X + Y + Z)}$ and $\mathbf{y = Y/(X + Y + Z)}$ thus;
$\mathbf{1 = x + y + z}$

The CIE (International Commission on Illuminant) chromaticity diagram is a standard at defining the normalized amount of colors on an x, y range within the visible spectrum.

The diagram gives color composition as a function of x (red) and y (green) with the amount of z being determined from z = 1 - (x + y). The locus or outer ring represents the spectral energy wavelength in nanometers.

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For color LED's in addition to luminous intensity $I_v$ (measured in cd or mcd), the wavelength definition is of particular interest, specially when a design involves an array of same color LED's, in which case the highest color homogeneity is desired. When specifying the color of an LED, two main specifications are generally used;

1. **Peak wavelength** $\lambda_p$: The maximal point of the spectral curve
2. **Dominant wavelength** $\lambda_d$: Given as a range and in accordance with DIN 5033 part 3, relating to the measure of the hue perceived by the human eye

In addition to Luminous intensity, Peak wavelength and Dominant wavelength grouping, LED's are also grouped according to forward voltage $V_F$, all under a specific electric and ambient condition.

For white LED's, there is (example) a chromaticity coordinate grouping:

| | WHITE | |
|---|---|---|
| **GROUP** | **Cx** | **Cy** |
| **3L** | 0.266 | 0.232 |
| | 0.258 | 0.239 |
| | 0.273 | 0.261 |
| | 0.280 | 0.252 |
| **3K** | 0.273 | 0.227 |
| | 0.266 | 0.232 |
| | 0.280 | 0.252 |
| | 0.286 | 0.244 |

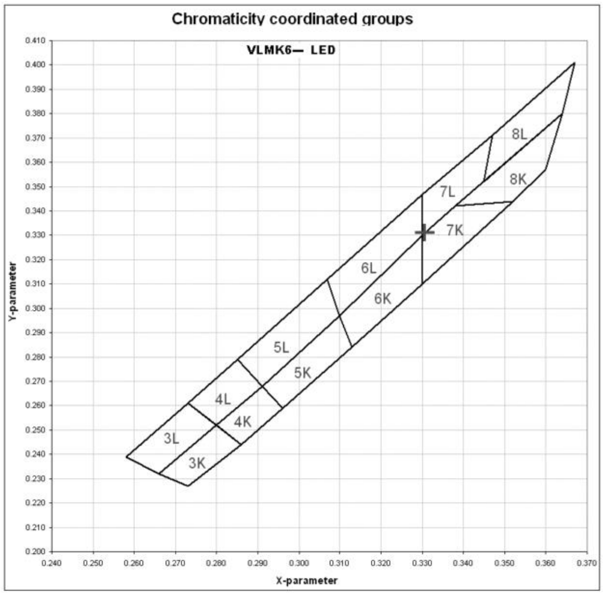

Fig. 5

The twelve chromaticity groups (Fig. 5) are generally suited to match grouping schemas that are compatible with other manufacturers. This gives the designer additional flexibility by the direct grouping comparison and selection from various sources while the focus could be more centered towards electrical characteristics as well as the very important thermal considerations necessary for a robust design.

For the designer, the color group selection within a given color, depends very much on the level of homogeneity that is required. An array of LED serving as an automotive blinker or a similar intermittent function, would be less critical to homogeneity as for example the LED array used on stop or breaking lights were the intensity as well as the color homogeneity is of paramount importance.

Applications associated with automotive backlighting as well as message boards are affected by extreme external contrast, were influences may range from daylight to night ambient lighting. The designer may consider providing a mechanism that would dim the LED's intensity proportionally to the external ambient light. There are various techniques available for this task such as the use of time-of-day signals, or alternatively the use of a dynamic feedback method by using latest intelligent ambient light sensors such as the Vishay's TMT6000.

**TABLE 1- LED TYPICAL CHARACTERISTICS AT $I_F$ 10 mA**

| COLOR | TECHNOLOGY | $\lambda_p$ | $\lambda_d$ | $\Delta\lambda$ | $\phi_v$ | $\phi_e$ | $V_F$ | $t_r$ | $t_f$ | COMPERATIVE |
|---|---|---|---|---|---|---|---|---|---|---|
| | | nm | nm | nm | mlm | mW | V | ns | ns | EFFICIENCY: m/W |
| Red | GaAlAs on GaAs | 650 | 648 | 20 | 60 | 0.82 | 1.80 | 100 | 100 | 3.3 |
| Red | GaAsP on GaP | 635 | 620 | 38 | 30 | 0.20 | 2.00 | 300 | 150 | 1.5 |
| Red | AlInGaP on GaAs | 643 | 630 | 15 | 150 | 1.44 | 1.90 | 45 | 30 | 7.9 |
| Red | AlInGaP on GaAs | 620 | 618 | 20 | 300 | 1.15 | 1.85 | 45 | 30 | 16.2 |
| Softorange | AlInGaP on GaAs | 610 | 605 | 17 | 300 | 0.92 | 1.90 | 45 | 30 | 15.8 |
| Softorange | GaAlAs on GaP | 610 | 605 | 36 | 25 | 0.06 | 2.00 | 300 | 150 | 1.3 |
| Yellow | AlInGaP on GaAs | 590 | 588 | 20 | 200 | 0.39 | 1.90 | 45 | 30 | 10.5 |
| Yellow | GaAsP on GaP | 585 | 590 | 38 | 30 | 0.05 | 2.00 | 300 | 150 | 1.5 |
| Green | GaP on GaP | 565 | 570 | 38 | 35 | 0.05 | 2.00 | 450 | 200 | 1.8 |
| Pure Green | GaP on GaP | 555 | 560 | 22 | 12 | 0.02 | 2.00 | 450 | 200 | 0.6 |
| True Green | InGaN on SiC | 518 | 523 | 35 | 250 | 0.55 | 3.10 | 30 | 30 | 8.1 |
| Blue Green | InGaN on SiC | 503 | 505 | 30 | 200 | 0.79 | 3.20 | 30 | 30 | 6.3 |
| Blue | InGaN on SiC | 463 | 470 | 25 | 75 | 1.21 | 3.60 | 30 | 30 | 2.1 |
| Blue | GaN on SiC | 428 | 466 | 65 | 25 | 0.96 | 3.70 | 30 | 30 | 0.7 |
| White | InGaN/YAG on SiC | 5500 K<br>x = 0.33/y = 0.33 | | not defined | 220 | 1.21 | 3.60 | 30 | 30 | 6.1 |

## LED' Present The Ideal Solution to a Large Number of Lighting Applications

### Automotive, Railway and Aviation (Signal Application)

- Courtesy lighting
- CHMSL (center high mounted stop lamps)
- Rear stop/turn/tail
- Instrument panels and switches
- New turn/tail/marker lights
- Retrofits
- Emergency/police vehicle lighting
- Traffic
- Rail and railroad crossing indicators
- Aviation
- Tower and periphery lights

### Consumer Electronics, Mobile and General Indication

- Household appliances
- Toys/games
- VCR/DVD/stereo/audio/video devices
- Switches
- Instrumentation
- Security equipment
- Digital cameras
- Backlighting
- Laptops

### Illumination and Sensing with LED's

- Signage (channel letters)
- Emergency lighting (exit signs)
- Machine vision
- Retail displays
- Neon and bulb replacement
- Accent lighting - pathways, marker lights
- Flashlights
- Medical instrumentation
- Color and money sensors
- Fiber optic communication
- Encoders
- Bar code readers
- Optical switches

### LED Sign Applications

- Transportation - passenger information
- Traffic/VMS
- Full color video
- Monochrome message boards

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## Driving the LED

As the LED is becoming a dominant source of light, it must be designed to meet optical requirements under specific electrical and environmental conditions. The practical and conventional usage of LED's with a current limiting resistor as stand-alone indicator used to dominates most of all applications. In applications were we have a variance of voltage and were the LED's are not placed side by side but merely as signal indicators, an external current limiting resistor would be acceptable. The current limiting resistor can be calculated by R = $V_{cc}$ - $V_F/I_F$.

An ever increasing number of new areas of applications, such as backlighting, large LED-Arrays, general illumination and automotive, is posing totally new concepts and new challenges to the designer.

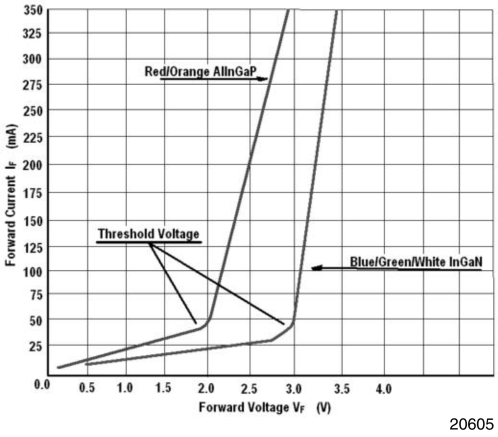

Fig. 6

Very much like common diodes, LED's voltages vs. current (Fig. 6 characteristics are typically exponentially associated, were a small voltage change (threshold voltage) results in a large change in current. Overdriving the LED will immediately increase its junction temperature that may be worsened by higher ambient temperatures. As the junction temperature increases so that the current too, turning it into a destructive cycle that would have the first impact in its optical homogeneity and a shorter operating-life.

In optically demanding applications, were the optimal performance and operating life are of greater relevance, the designer should take into consideration that the voltage is logarithmic to the current, the power can be considered as to be almost proportional to the current. Thus the ideal method to maintain power relatively constant as well as the LED's characteristics, while avoiding the adverse effects of fluctuating voltage, it is to drive the LED with a constant current source.

Backlight applications as well as matrixes are very demanding on optical homogeneity as well as power conservation. Mostly used on portable equipment were the power availability is a mayor issue. A simplified approach is the use of dedicated IC LED's drivers; most of them use current driven outputs as well as automatic compensation via a sense input. A typical example of a popular boost-controller (Fig. 7) requiring minimum of external components is the SiP12401 from Siliconix.

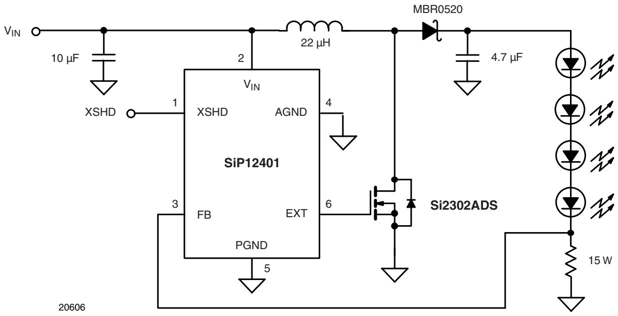

Fig. 7 SiP12401 is ideal for portable applications

Power drive: Applications that require maximum allowed power drive, thus driving the LED to the maximum ratings as indicated in the data sheet, should consider external elements such as humidity and heat, which can reduce the useful life for the component. Worse case scenarios as far maximum ambient temperature must be taking into consideration to avoid operating the LED beyond its maximum junction temperature. The easiness is in the numbers, in achieving a given demand in illumination, the designer should considered splitting available current into additional LED's instead of driving to their limit a smaller number of LED's providing little allowance for external environmental influences that would degraded and reduce operating life of the light source.

Because the human eye does not perceive pulses at frequencies beyond 70 Hz, it is frequently adopted to pulse the LED to reduce consumption while maintaining an acceptable intensity. Other applications require the possibility to dim the LED. The variable power supply adjustment may work fine until it reaches the non-linear threshold, at that point the LED would flicker, an effect not frequently desired. The best approach is to pulse the LED with a PWM signal where by adjusting the duty cycle, the intensity can be increased or decreased. Typical example for this approach, are LCD's on mobile phones were the intensity for daylight usage varies to nighttime.

Small portable application that depend on LiIon or NiMH cells, should considerer the use of readily available buck-boost regulator such as Vishay's SiP1759. The basic

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buck topology if frequently found on drivers, dedicated for high-power LED applications for their efficiency and very low pricing.

Driving LED's with a pulse modulated signal is a frequent approach at increasing the intensity beyond its DC or static characteristics. Caution should be taken in not exceeding the max $V_F$ and ideally a constant current source should be used were the average effective $I_F$ should not exceed 2/3 of the maximum $I_F$. For large LED matrixes, the designer is presented with a very large selection of available controllers; most are programmable using latch or constant current controlled outputs that in most cases do not exceed single output current of 100 mA. For most backlighting application as well as large LED panels it is adequately sufficient.

When a small number of high power LED's is required, a dedicated IC's capable of driving up to 2 A such as Vishay's FX5959G701 is highly recommended.

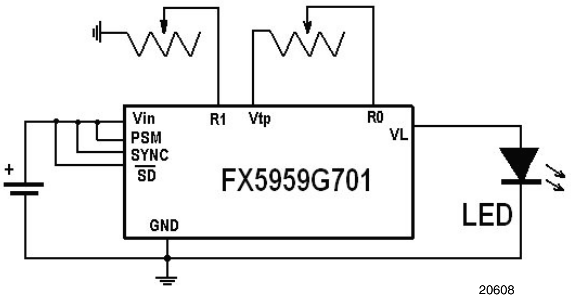

Fig. 8

The conveniences of having a torch function together with a flash effect for small cameras build in mobiles phones are simplified by the use of dedicated IC's (Fig. 9) that provide a relative high forward current while boosting the demand in flash mode.

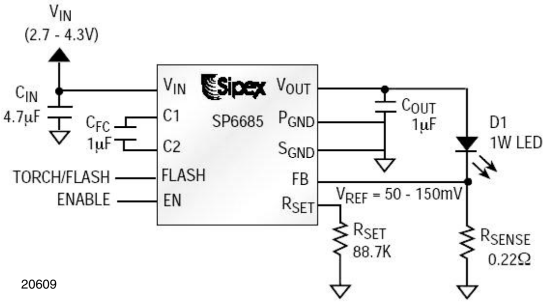

Fig. 9

## Symbols, Terminologies and Abbreviations

| | |
|---|---|
| A | Anode |
| cd | Candela (unit luminous intensity) |
| $C_j$ | Junction capacitance |
| $E_v$ | Iluminance |
| $I_F$ | Forward current (continuous) |
| $I_{FM}$ | Peak forward current |
| $I_R$ | Reverse current (reverse bias) |
| $I_V$ | Luminous intensity |
| lm | Lumen (luminous flux) |
| lx | Lux |
| $P_{tot}$ | Total power dissipation |
| $P_V$ | Power dissipation general |
| $R_{thJA}$ | Thermal resistance (junction ambient) |
| $R_{thJC}$ | Thermal resistance (junction case) |
| $T_{amb}$ | Temperature ambient |
| $T_j$ | Junction temperature |
| $V_{(BR)}$ | Breakdown voltage (reverse bias) |
| $V_F$ | Forward voltage |
| $V_S$, $V_{CC}$ | Supply voltage |
| $\lambda$ | Wavelength |
| $\lambda_d$ | Dominant wavelength |
| $\lambda_p$ | Peak wavelength |
| $\Delta\lambda$ | Spectral half bandwidth |
| $\phi_V$ | Liminous flux |

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## Conversion Tables

**CORRESPONDING RADIOMETRIC AND PHOTOMETRIC DEFINITIONS, SYMBOLS AND UNITS**

| | RADIOMETRY | | | PHOTOMETRY | | |
|---|---|---|---|---|---|---|
| **DEFINITION** | | **SYMBOL** | **UNIT** | | **SYMBOL** | **UNIT** |
| Power | Radiant flux (radiant power) | $\phi_e$ | W | Luminous flux (luminous power) | $\phi_V$ | lm |
| Output power per unit area | Radiant emittance/exitance | Me | W/m$^2$ | Luminous exitance | Mv | lm/m$^2$ |
| Output power per unit solid angle | Radiant intensity | Ie | W/sr | Luminous intensity | Iv | cd |
| Output power per unit solid angle and unit emitting area | Radiance | Le | W/m$^2$ x sr | Luminance | Lv | cd/m$^2$ |
| Input power per unit area | Irradiance | Ee | W/m$^2$ | Illuminance | Ev | lx,<br>lx = lm/m$^2$ |
| Energy | Radiant energy | Qe | Ws | Luminous energy (quantity of light) | Qv | lm x s |
| Energy per unit area | Radiant exposure (irradiation) | He | (W x s)/m$^2$ | Light exposure | Hv | lm x s/m$^2$ |

**CORRESPONDING RADIOMETRIC AND PHOTOMETRIC DEFINITIONS, SYMBOLS AND UNITS**

| UNIT | cd x m$^2$ | asb | sb | L | cd x ft$^2$ | fL | cd x in$^2$ | NOTES |
|---|---|---|---|---|---|---|---|---|
| 1 cd x m$^{-2}$ | 1 | p | 10-4 | p x 10-4 | 9.29 x 10-2 | 0.2919 | 6.45 x 10-4 | |
| 1 asb (Apostilb) | 1/p | 1 | 1/p x 10-4 | 10-4 | 2.957 x 10-2 | 0.0929 | 2.054 x 10-4 | |
| 1 sb (Stilb) | 104 | p x 104 | 1 | p | 929 | 2919 | 6.452 | |
| 1 L (Lambert) | 1/p x 104 | 104 | 1/p | 1 | 2.957 x 102 | 929 | 2.054 | |
| 1 cd x ft$^{-2}$ | 10.764 | 33.82 | 1.076 x 10-3 | 3.382 x 10-3 | 1 | p | 6.94 x 10-3 | ft = foot |
| 1 fl (Footlambert) | 3.426 | 10.764 | 3.426 x 10-4 | 1.0764 x 10-3 | 1/p | 1 | 2.211 x 10-3 | |
| 1 cd x in$^{-2}$ | 1550 | 4869 | 0.155 | 0.4869 | 144 | 452.4 | 1 | in = inch |

**ILLUMINANCE CONVERSION UNITS**

| UNIT | lx | lm x cm$^{-2}$ | fc | NOTES |
|---|---|---|---|---|
| 1 lx | 1 | 10$^{-4}$ | 0.0929 | |
| 1 lm x cm$^{-2}$ | 104 | 1 | 929 | 2 instead of lm x cm$^{-2}$, formerly Phot (ph) y |
| 1 fc (footcandle) | 10.764 | 10.764 x 10$^{-4}$ | 1 | |

Vishay Semiconductors, GmbH

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