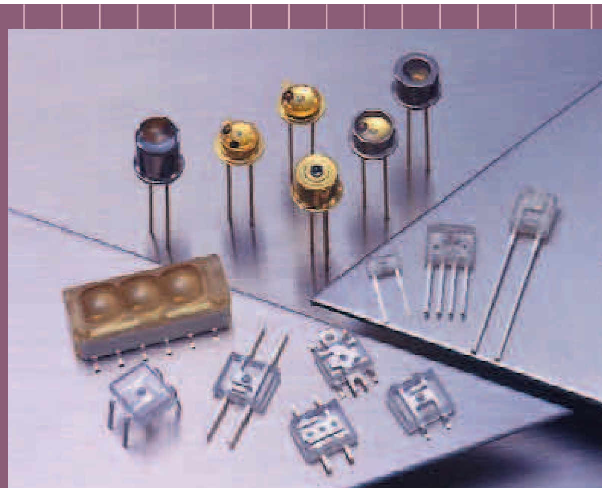
SOLID STATE DIVISION

LIGHT EMITTING DIODE



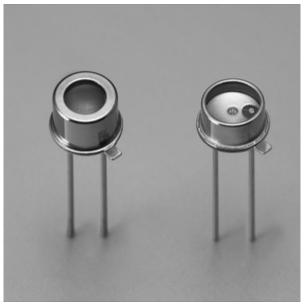
HAMAMATSU

LED
Light Emitting Diode

Light emitting diodes (LEDs) are opto-semiconductors that convert electric energy into light energy. Compared to semiconductor lasers (laser diodes or LD), LEDs offer advantages such as lower cost and longer service life.
Hamamatsu Photonics has developed and produced various types of LEDs that enhance emission efficiency via a high output power LED chip mounted in a reflector (mirror) at the package base, which makes the light emitted from the chip edges reflect towards the front.

■ Major applications

· Camera auto focus
· Optical switches
· Optical fiber communications
· Spatial light transmission
· Auxiliary light sources for CCD imaging



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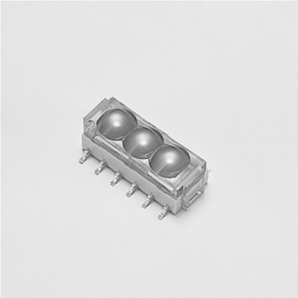
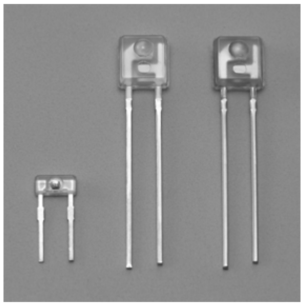
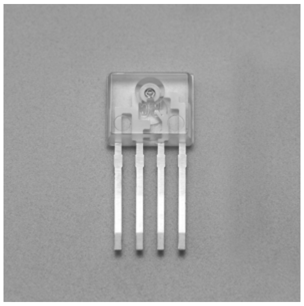


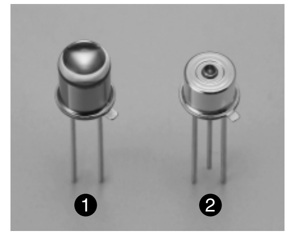




Selection guide

Metal package with lens

These LEDs have a metal package sealed with a lens cap that delivers narrow directivity. Hermetically sealed packages are reliable even in highly humid environments.



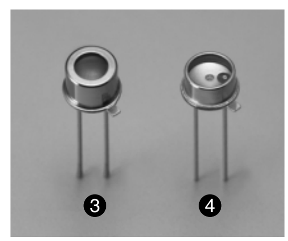
(Typ.)

Type No.	Photo	Peak emission wavelength (nm)	Spectral half width (nm)	Radiant flux (mW)	Forward voltage (V)	Cut-off frequency (V)	Measurement condition: Forward current (mA)	Feature
L6112-01		670	25	2.5	1.80	5	20	Red emission
L3989-01		830	40	3.6	1.45	30		High-speed response
L7558-01		850	50	7.0	1.45	50		High-speed response, high output power
L2791-02	❶	880	60	2.0	1.50	3		Uniform emission, narrow directivity
L1915-01 *		890	80	4.5	1.40	1	50	Multipurpose applications
L2656-03		890	50	9.0	1.45	1		High output power
L2690-02		890	50	9.0	1.45	1		High output power
L2388-01 *		945	45	3.4	1.30	0.3		GaAs LED
L7560	❷	850	50	0.65	1.80	100		For optical fiber communications

* LEDs using silicone resin for wire coating (potting) have higher resistance to temperature cycling.

Metal package

These LEDs are hermetically sealed in a metal package and can be used in highly humid environments. These metal package LEDs are ideal when characteristics similar to resin-potted package LEDs are required under environmental conditions requiring high resistance to humidity and temperature cycling.



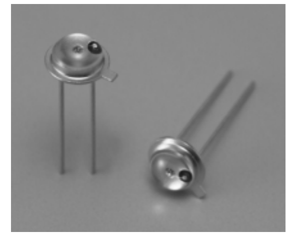
(Typ.)

Type No.	Photo	Emission size (mm)	Peak emission wavelength (nm)	Radiant flux (mW)	Forward voltage (V)	Cut-off frequency (MHz)	Measurement condition: Forward current (mA)	Feature
L6112-02	❸	ϕ1.2	670	2.5	1.80	5	20	Red emission
L3989-02	❹	ϕ0.8	830	5.8	1.45	30		High-speed response
L2791		ϕ0.4	880	2.0	1.50	30		Uniform emission, narrow directivity
L1915-02 *	❸	ϕ1.2	890	4.5	1.40	1	50	Multipurpose applications
L1939-04 *		ϕ0.3	890	2.8	1.40	1		Shadow of the wire does not appear emission pattern

* LEDs using silicone resin for wire coating (potting) have higher resistance to temperature cycling.

Resin-potted package (with reflector)

These are standard package LEDs potted with clear resin. A reflector (cavity) is provided on the metal stem (TO-46) to enhance the light extraction efficiency. The emission diameter is equal to the outer diameter of the reflector.

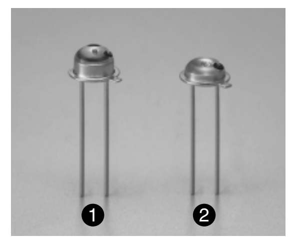


(Typ.)

Type No.	Emission size (mm)	Peak emission wavelength (nm)	Radiant flux (mW)	Forward voltage (V)	Cut-off frequency (MHz)	Measurement condition: Forward current (mA)	Feature
L3882	ϕ1.2	660	1.8	1.80	4	20	Red emission
L6112	ϕ1.2	670	5.5	1.80	5		Red high output power
L3989	ϕ0.8	830	8.0	1.45	30	50	High-speed response
L7558	ϕ0.8	850	14.0	1.45	50		High-speed response, high output power
L1909	ϕ0.8	890	10.0	1.40	1		Multipurpose applications
L1915	ϕ1.2	890	10.0	1.40	1		Multipurpose applications
L4100	ϕ0.65	890	14.0	1.45	1		Small reflector diameter
L2656	ϕ0.8	890	15.0	1.45	1		High output power
L2388	ϕ0.8	945	6.0	1.30	0.3		GaAs LED

Resin-potted package (without reflector)

These resin-potted package LEDs use a metal stem having no reflector and are suitable for applications requiring a small diameter light spot.



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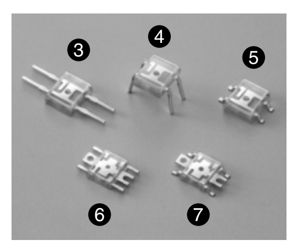
Type No.	Photo	Emission size (mm)	Peak emission wavelength (nm)	Radiant flux (mW)	Forward voltage (V)	Cut-off frequency (MHz)	Measurement condition: Forward current (mA)	Feature
L6108	❶	□0.25	670	5.5	1.80	5	20	Red high output power
L2791-03	❷	ϕ0.16	880	5.0	1.50	3	50	Current-confined type
L2690		□0.4	890	14.0	1.45	1		High output power
L1939		ϕ0.3	890	10.0	1.40	1		Shadow of the wire does not appear emission pattern

Plastic package

These plastic-molded package LEDs can be easily inserted into place on PC boards and are available at a lower cost than metal stem types. When higher accuracy is required for mounting on PC boards we recommend using types with a reference positioning hole.



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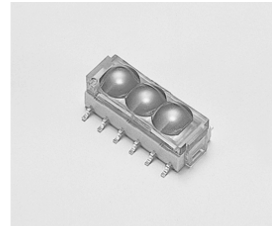
Type No.	Photo	Emission size (mm)	Peak emission wavelength (nm)	Radiant flux (mW)	Forward voltage (V)	Cut-off frequency (MHz)	Measurement condition: Forward current (mA)	Feature
L2402	❸	ϕ0.7	890	9.0	1.40	1	50	
L2402-01	❹			9.0	1.40	1		
L2402-02	❺			9.0	1.40	1		
L3458	❸			13.0	1.45	1		High output power
L3458-01	❹			13.0	1.45	1		High output power
L3458-03	❺			13.0	1.45	1		High output power
L6437	❻	ϕ0.75	940	10.0	1.35	0.3		With reference positioning hole
L6437-01	❼			10.0	1.35	0.3		With reference positioning hole
L2204	❸	ϕ0.7	945	6.0	1.30	0.3		GaAs LED
L2204-01	❹			6.0	1.30	0.3		GaAs LED
L2204-03	❺			6.0	1.30	0.3		GaAs LED

LED array for spatial light transmission

This is an LED array developed for automobile VICS. Applications also include spatial light transmission other than VICS.

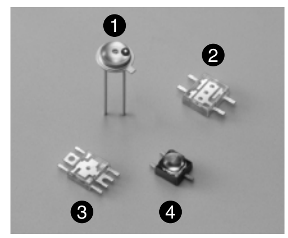


(Typ.)

Type No.	Peak emission wavelength (nm)	Radiant flux (mW)	Forward voltage (V)	Cut-off frequency (MHz)	Measurement condition: Forward current (mA)	Feature
L7022	870	78.0	4.60	10	100	High output power Small package Directivity ideal for automobile VICS

LED for camera auto focus

These are LEDs primarily developed for auto focus cameras. LED chips with a low forward current are used assuming that the camera is battery-driven. When operated at a constant voltage, a larger current flows in these LED than in normal LEDs, so higher output power can be obtained. We do not recommend using these LEDs for optical switches and other applications requiring reliability over long, continuous operation.



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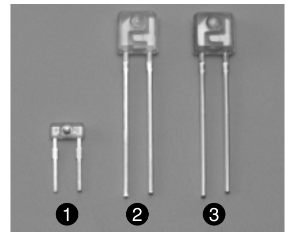
<table>
<tr><th>Type No.</th><th>Photo</th><th>Emission size (mm)</th><th>Peak emission wavelength (nm)</th><th>Radiant flux (mW)</th><th>Pulse * forward voltage (V)</th><th>Cut-off frequency (MHz)</th><th>Measurement condition: Forward current (mA)</th><th>Feature</th></tr>
<tr><td>L4492</td><td>❶</td><td>ϕ0.65</td><td rowspan="4">900</td><td>8.0</td><td rowspan="4">2.4</td><td rowspan="4">1</td><td rowspan="5">50</td><td>TO-46 Resin-potted package</td></tr>
<tr><td>L5128</td><td>❷</td><td>ϕ0.65</td><td>7.0</td><td>3 channel LED</td></tr>
<tr><td>L5871</td><td>❸</td><td>ϕ0.65</td><td>7.0</td><td>With reference positioning hole</td></tr>
<tr><td>L6486</td><td>❸</td><td>0.3 × 0.7</td><td>7.0</td><td>With reference positioning hole
Long, narrow emission pattern</td></tr>
<tr><td>L6007-01</td><td>❹</td><td>ϕ0.4</td><td>880</td><td>2.0</td><td>2.7</td><td>4</td><td>Current-confined structure inside chip, small emission diameter</td></tr>
</table>

* Forward current: 1.0 A

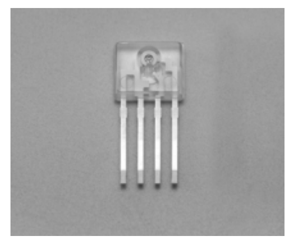
Miniature LED



(Typ., unless otherwise noted)

Type No.	Photo	Peak emission wavelength (nm)	Spectral half width (nm)	Forward voltage (V)	Radiant flux Min. (mW)	Measurement condition: Forward current (mA)	Feature
L5276	❶	880	60	1.3	1.0	20	
L5586		940	45	1.25	0.5	20	
L6286		940	45	1.25	0.8	20	
L5766	❷	660	20	2.0	0.5	20	
L6287		940	45	1.25	1.4	20	High output power
L6895-10	❸	940	45	1.25	1.2	20	High output power, Pd plated leads

For optical link



(Typ.)

Type No.	Peak emission wavelength (nm)	Spectral half width (nm)	Forward voltage (V)	Measurement condition: Forward current (mA)	Feature
L7140-10	650	20	1.9	20	For 50 Mbps optical link
L7726	650	10	2.3	30	For 156 Mbps optical link
L8045	650	20	1.9	20	For 50 Mbps optical link Wide operating temperature range: -40 to +85 ˚C

Description of terms

Term	Symbol	Unit	Description
Peak emission wavelength	λp	nm	Wavelength at which the maximum emission occurs.
Spectral half width	$\Delta\lambda$	nm	Full width at half maximum of emission spectrum, expressed in wavelength (nm).
Forward voltage	V_F	V	Voltage drop between the anode and cathode due to a current flowing in the forward direction.
Reverse current	I_R	μA	Current flowing in the reverse direction between the anode and cathode.
Radiant flux (Radiant output power)	ϕe	mW	Quantity of radiant energy per unit time.
Radiant flux density	P_E	mW/cm^2	Radiant flux per unit area measured at a specified distance *1 from the LED emission surface to the detector.
Cut-off frequency	fc	MHz	Response to sine wave modulation, defined as the frequency at which the modulated output decreases by 3 dB compared to a low frequency response.
Duty ratio	DR	%	The ratio of the ON period to the time period corresponding to one cycle of a pulsed current.
Forward current	I_F	mA	Current flowing in the forward direction between the anode and cathode.
Reverse voltage	V_R	V	Voltage applied between the anode and cathode in the reverse direction.
Pulsed forward current	I_{FP}	mA	Maximum forward current in pulsed operation specified by the pulse width and duty ratio.
Allowable power dissipation	P_D	mW	Maximum power dissipation that is allowed inside an element.
Operating temperature	Topr	˚C	Ambient temperature while device is in operation.
Storage Temperature	Tstg	˚C	Ambient temperature while device is not in operation.

* 20 mm in data sheets

Characteristic and use

The structures, characteristics and operation methods of Hamamatsu typical LEDs are explained below.

1. LED basic structure

The LED (Light Emitting Diode) chip has an internal P-N junction, and an electrode is provided on each surface of the chip to make ohmic contact. The P-N junction is formed by epitaxial growth using the substrate of a GaAs crystal. The crystal internal structure differs depending on the emission wavelength to be used, radiant power and cutoff frequency. The crystal undergoes diffusion and evaporation processes before manufacture into a complete LED chip.

Figure 1-1 LED chip structure

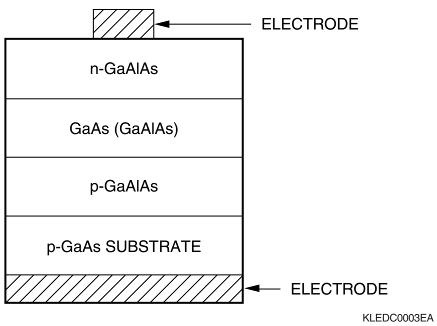
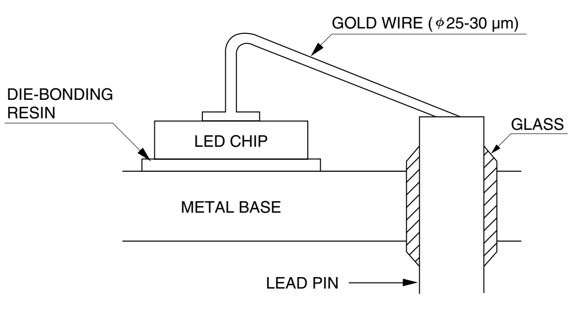


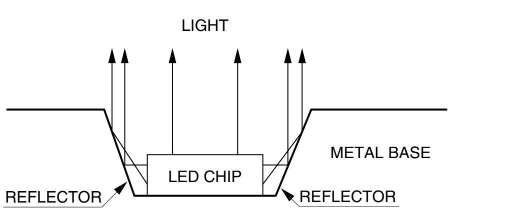
Figure 1-1 shows the structure of a high-power infrared LED. In general, an LED chip is mounted (die-bonded) on a gold-plated metal base or silver-plated lead frame. The electrode is connected to the lead pin using a gold wire which is resin-coated or sealed with metal cap for protection. Figure 1-2 shows the details of a chip assembled on a metal base.

Figure 1-2 LED chip assembly



To enhance radiant power, some LEDs use a metal base with a concave area which serves as a reflector, and the LED chip is mounted in it as shown in Figure 1-3.

Figure 1-3 LED chip mount example

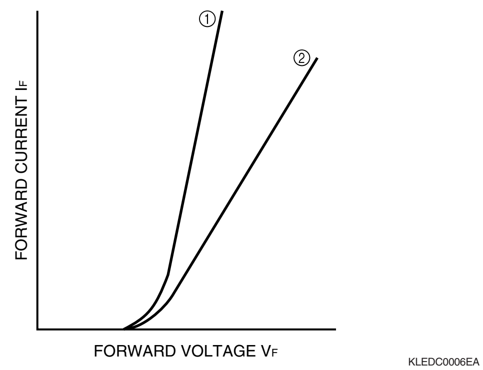


2. Characteristic

2-1 Forward current vs. forward voltage

The LED has forward current vs. forward voltage characteristics similar to those of rectifier diodes. The characteristic curves of individual LED types differ slightly, depending on the element structure and other factors. (See Figure 2-1 below.)

Figure 2-1 Forward current vs. forward voltage



Curve ① shows typical characteristics of a low-resistance LED. Compared to curve ② which is a normal LED, it is clear that the forward voltage (V_F) required to produce the same current value is lower. “Resistance” referred to here does not mean the term commonly used for “electrical resistance” but instead indicates the slope of a tangent for the characteristic curve at the specified current or voltage (differential resistance). In general, using an LED with a lower V_F allows easier circuit design. If the LED is operated at the same current value but a higher V_F is applied, the power consumption will be larger, causing a subsequent temperature rise. This results in detrimental effects such as a decrease in the output power, peak emission wavelength shift and deterioration of the LED.

2-2 Radiant output power vs. forward current

In DC operation, the radiant output power vs. forward current characteristics usually show a linear line up to the maximum rating. Likewise, nearly linear characteristics can be obtained with pulsed operation if the pulse width and duty ratio are selected properly. Therefore, if the power at a certain current value is measured, the approximate power at a different current value can be readily estimated. However, if the temperature of the emission area increases due to the ambient temperature and heat generated from the LED itself, the output power is reduced and saturation is seen in the characteristic graph.

3. Operation

3-1 DC drive

When using an LED in optical switch applications, the most common method is DC drive using a forward current. In this method, care should be taken not to allow the forward current to exceed its absolute maximum rating for the LED. If the ambient temperature of the LED is high, it is necessary to take into account the allowable forward current vs. ambient temperature characteristics.

Figure 3-1 Example of DC drive

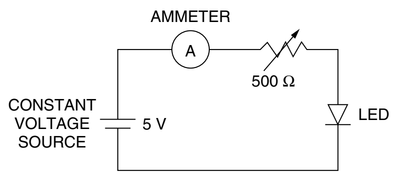
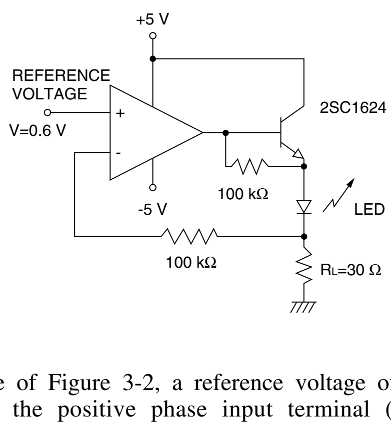


Figure 3-1 shows the simplest circuit. When a constant current of 20 mA is to flow in this circuit, first set the variable resistor to the maximum resistance position and apply the voltage. Then, observing the ammeter, gradually reduce the resistance of the variable resistor until the current reaches 20 mA. If no variable resistor is used, the resistance value should be calculated. For example, if the forward voltage at 20 mA is 1.4 V, the resistance R is given by: R = (5.0 V - 1.4 V)/0.02 A = 180 Ω. Thus a 180 Ω resistor should be used.

With the circuit shown in Figure 3-1, the forward current slightly varies according to fluctuations in the forward voltage of the LED. To prevent this, a constant current circuit using an op amp is suggested. Figure 3-2 shows a simple constant current circuit using an operational amplifier.

Figure 3-2 Example of constant current circuit using operational amplifier

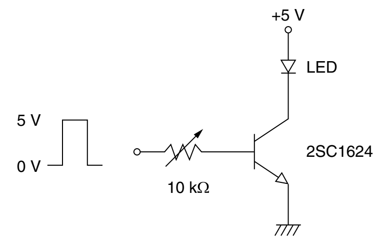


In the case of Figure 3-2, a reference voltage of 0.6 V is applied to the positive phase input terminal (+) of the operational amplifier. Because the potential of the negative phase input terminal (-) becomes nearly equal to this reference voltage, the voltage drop at both ends of load resistance RL will be 0.6 V, and a resultant current of 20 mA (0.6 V/30 Ω = 20 mA) flows through the LED. Thus it is possible to select the desired LED drive current by changing the value of RL.

3-2 Pulse drive

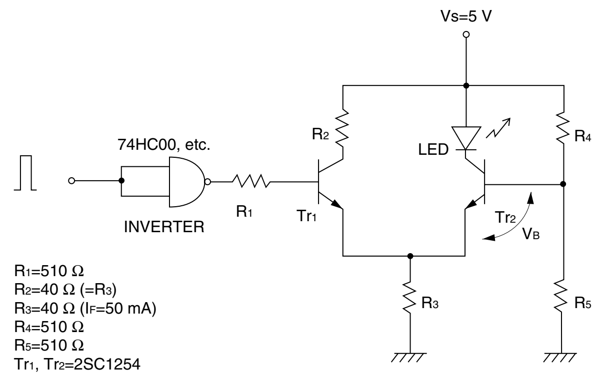
In pulse drive, the current value should not exceed the absolute maximum ratings. The simplest pulse drive is when the output from a pulse generator is directly fed into both ends of the LED. However, this method is usually insufficient in terms of current capacity. In such cases, the use of a transistor is recommended, as shown in Figure 3-3.

Figure 3-3 Example of pulse drive circuit



In addition, when the LED should be driven at high-speed, a high-speed driver is required. Figure 3-4 shows a typical circuit using a high-speed driver.

Figure 3-4 Example of high-speed pulse drive circuit



In the circuit shown in Figure 3-4, the LED turns on when the input is at the H level. The forward voltage IF which flows through the LED can be obtained in "$I_F = (V_s/2 - V_B)/R3$". [With this circuit, I_F = (5/2 - 0.5)/40 = 0.05 (A)] The response speed is determined by the time response of Tr1 and Tr2. It will be about 20 MHz if 2SC1815 is used, and about 100 MHz if 2SC1254 is used.

4. Performance deterioration

When an LED is used for long periods of time, performance deterioration may take place. Common deterioration phenomena include a decrease in the output power and variations of the forward voltage. It is thought that these deteriorations result from the crystal dislocation and shift caused by heat generation in the emission area. These can be observed as a dark line or dark spot in the emission pattern.
Deterioration may possibly occur from an external stress. If the LED is driven with a stress applied to the LED chip, its performance may unduly deteriorate. This stress may also issue from mechanical distortion on the package. Sufficient care must be exercised when mounting the LED.

Life expectancy

In general, the LED radiant output decrease exponentially with operating time, as expressed in the equation below.

$$P = Po \cdot \exp(-\beta t) \quad \text{............ (4-1)}$$

Po: Initial radiant output power
β : Deterioration factor
t : Operating time

The deterioration factor β depends on the element material, structure and operating conditions, and is usually assumed as follows:

$$\beta = \beta o \cdot I_F \cdot \exp(-Ea/kTj) \quad \text{............ (4-2)}$$

βo: Constant
I_F : Operating current
Ea: Activated energy
k : Boltzmann constant

In Equation (4-2), the deterioration factor β includes IF added to the Arrhenius equation which relates to the junction temperature. As stated, the deterioration is caused by the dislocation and shift in the crystal. Equation (4-2) is based on the assumption that the dislocation and shift result from recombination energy not contributing to emission as well as from the lattice vibration due to temperature.
The junction temperature Tj is given by the equation below.

$$Tj = Rth \cdot I_F \cdot V_F + Ta \quad \text{.......... (4-3)}$$

Rth: Thermal resistance
V_F : Forward voltage
Ta : Ambient temperature

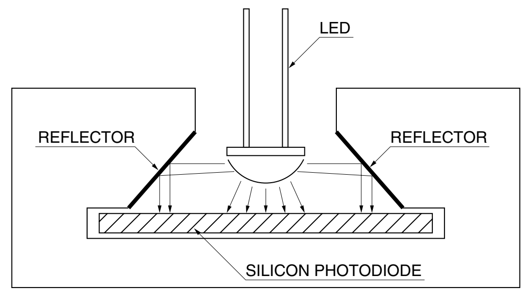
From the life test data measured under certain conditions, the deterioration factor under other conditions can be figured out using Equations (4-1), (4-2) and (4-3). For example, if we have the life test data measured at DC 50 mA for up to 3000 hours, β can be obtained using Equation (4-1). With this β and Equation (4-1), the extent of deterioration after 3000-hour operation under the same conditions can be estimated. In contrast, to calculate the life data of the same LED operated under different conditions, βo should be obtained by substituting both Tj obtained from Equation (4-3) and β obtained previously for Equation (4-2). Then substituting the test conditions for Equation (4-2) gives the deterioration factor β.
The activated energy Ea usually used is 0.5 to 0.8 eV and the thermal resistance ranges from 300 to 350 ˚C/W for a TO-18 (TO-46) package.

5. How to measure radiant output power

5-1 Radiant flux: ϕe

For fe measurement, the full radiant output power is measured when a specified forward current flows into the LED. To measure the radiant power emitted in the horizontal direction, a reflector is provided as shown in Figure 5-1, so that the entire radiant power emitted in every direction from the LED can be detected by a photodiode placed in front of the LED.

Figure 5-1 Measurement method for radiant output power



5-2 Radiant flux density: P_E

P_E is the quantity of radiant power per unit area (1 cm × 1 cm), measured at a distance of 2 cm away from the emission area of the LED. This measure can be satisfactorily used as a general guide for comparison of the radiant power of common LEDs, although LEDs with high directivity may sometimes show nonuniform distribution in the above measurement area.

6. Quality assurance

Reliability tests by Hamamatsu Photonics are generally performed in compliance with JEITA (Japan Electronic Information and Technology Association) standards. An example of major device reliability testing by Hamamatsu Photonics is shown below.

■ Major reliable testing

Tested item	Condition	ED-4701
Terminal strength	Pulling for 10 ± 1 seconds, 90-degree bending, 2 times	A-111
Vibration	100 to 2000 Hz, 200 m/s², 48 minutes	A-121
Shock	1000 m/s² for 6 ms, XYZ directions, 3 times each	A-122
Solderability	235 ± 5 ˚C for 5 or 2 seconds	A-131
Solder heat resistance	260 ± 5 ˚C for 10 seconds	A-132(except SMD)
	Reflow 235 ˚C, 10 seconds	A-133(SMD)
High-temperature storage	Tstg Max. 1000 hours	B-111
Low-temperature storage	Tstg Min. 1000 hours	B-112
High temperature and humidity storage	85 ˚C, 85 %RH, 1000 hours	B-121
Temperature cycling	Tstg Min. to Tstg Max. in air, 30 minutes each, 10 cycles	B-131
Continuous operation	25 ± 5 ˚C, IF Max. 1000 hours	D-511

Note) Test standards conform to ED-4701 "Environmental and Endurance Test Methods for Semiconductor Devices"

Precautions for use

1 Precautions for storage

To protect the terminal leads from oxidation and stain or prevent the package from absorbing moisture, always keep the light-emitting device in a desiccator (filled with nitrogen).

2 Precautions during transportation

Protect the light emitter from mechanical vibrations and shocks. The terminal leads might be deformed if they undergo strong vibrations and shocks. In particular, take great care in handling LEDs with micro-ball lenses (L2791 series and L7560).

3 Precautions for mounting

Do not allow any hard or sharp objects to touch the plastic package and epoxy-resin window as they are easily scratched.

(1) Lead forming

To form the leads, hold the roots of the leads securely and bend them so that no force is applied to the package. Lead forming should be done before soldering.

(2) Cutting off the leads

If leads are cut when still at a high temperature, this may cause an electrical discontinuity. Always cut off the leads when they are at room temperature. Never cut off the leads just after they have been soldered.

(3) Soldering

Using a low-temperature melting solder (below 200 ˚C), solder the leads at the temperature and dwell time specified in Table 1 below. If these conditions cannot be met, it is recommended that some form of heat sinking be used at the base of the lead so that the solder heat is not conducted to the package. Also be careful not to apply excessive force to the leads during soldering. Soldering at excessive temperatures and dwell times may cause the plastic package to melt or crack, resulting in performance deterioration. This sometimes leads to wiring breakage. If the leads are soldered while external force is applied to the device, the residual force tends to degrade the device performance. Care should also be taken not to apply force to the leads during soldering.

Do not use any flux which is highly acidic, alkaline or inorganic because it may cause the part leads to erode. Use a rosin flux.

4 Cleaning

Use alcohol for cleaning. When carrying out ultrasonic cleaning, acoustic forces applied to the device greatly depend on the size of the cleaning bath, the output of the vibrator, the size of the board to which the device is attached, and the attachment method of the device. Thus, take into account these factors to confirm the acoustic forces applied to the device prior to the actual cleaning.

5 Others

(1) Measures against static electricity

Static electricity charges from the human body or surge voltages from measuring equipment may degrade the performance of L2792 series LEDs, possibly leading to permanent damage. Therefore, the operator, worktable, and measuring equipment must be grounded to prevent such static electricity and surge voltage from being applied to the device.

(2) Driving the device

When driving a device, always observe the absolute maximum ratings. Most faulty device operation results from trouble associated with the drive current. Take sufficient care not to allow a forward current larger than the rated value to flow the device. Do not apply a reverse voltage larger than the rated value to the device. The device must also be protected against voltage surges from the power supply.

Product name	Maximum soldering temperature	Maximum soldering time
Plastic package LED	230 ˚C	5 seconds (1 second *)
Metal package LED	260 ˚C	5 seconds (1 second *)

* For devices having a lead length less than 2 mm

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HAMAMATSU PHOTONICS K.K., Solid State Division
1126-1, Ichino-cho, Hamamatsu City, 435-8558, Japan
Telephone: (81)53-434-3311, Fax: (81)53-434-5184

Homepage: http://www.hamamatsu.com

Main Products

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Sales Offices

ASIA:
HAMAMATSU PHOTONICS K.K.
325-6, Sunayama-cho,
Hamamatsu City, 430-8587, Japan
Telephone: (81)53-452-2141, Fax: (81)53-456-7889

U.S.A.:
HAMAMATSU CORPORATION
Main Office
360 Foothill Road, P.O. BOX 6910,
Bridgewater, N.J. 08807-0910, U.S.A.
Telephone: (1)908-231-0960, Fax: (1)908-231-1218
E-mail: usa@hamamatsu.com

Western U.S.A. Office:
Suite 110, 2875 Moorpark Avenue
San Jose, CA 95128, U.S.A.
Telephone: (1)408-261-2022, Fax: (1)408-261-2522
E-mail: usa@hamamatsu.com

United Kingdom:
Hamamatsu Photonics UK Limited
2 Howard Court, 10 Tewin Road, Welwyn Garden City,
Hertfordshire AL7 1BW, United Kingdom
Telephone: (44)1707-294888, Fax: (44)1707-325777
E-mail: info@hamamatsu.co.uk

France, Portugal, Belgium, Switzerland, Spain:
HAMAMATSU PHOTONICS FRANCE S.A.R.L.
8, Rue du Saule Trapu, Parc du Moulin de Massy,
91882 Massy Cedex, France
Telephone: (33)1 69 53 71 00
Fax: (33)1 69 53 71 10
E-mail: infos@hamamatsu.fr

Swiss Office:
Richtersmattweg 6a
CH-3054 Schüpfen, Switzerland
Telephone: (41)31/879 70 70,
Fax: (41)31/879 18 74
E-mail: swiss@hamamatsu.ch

Belgian Office:
7, Rue du Bosquet
B-1348 Louvain-La-Neuve, Belgium
Telephone: (32)10 45 63 34
Fax: (32)10 45 63 67
E-mail: epirson@hamamatsu.com

Spanish Office:
Centro de Empresas de Nuevas Tecnologies
Parque Tecnologico del Valles
08290 CERDANYOLA, (Barcelona) Spain
Telephone: (34)93 582 44 30
Fax: (34)93 582 44 31
E-mail: spain@hamamatsu.com

Germany, Denmark, Netherland, Poland:
HAMAMATSU PHOTONICS DEUTSCHLAND GmbH
Arzbergerstr. 10,
D-82211 Herrsching am Ammersee, Germany
Telephone: (49)8152-375-0, Fax: (49)8152-2658
E-mail: info@hamamatsu.de

Danish Office:
Erantisvej 5
DK-8381 Tilst, Denmark
Telephone: (45)4346/6333, Fax: (45)4346/6350
E-mail: lkoldbaek@hamamatsu.de

Netherlands Office:
PO BOX 50.075, 1305 AB ALMERE, The Netherlands
Telephone: (31)36-5382123, Fax: (31)36-5382124
E-mail: hamamatsu_NL@compuserve.com

Poland Office:
ul. Chodkiewicza 8
PL-02525 Warsaw, Poland
Telephone: (48)22-660-8340, Fax: (48)22-660-8352
E-mail: info@hamamatsu.de

North Europe:
HAMAMATSU PHOTONICS NORDEN AB
Smidesvägen 12
SE-171 41 Solna, Sweden
Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01
E-mail: info@hamamatsu.se

Italy:
HAMAMATSU PHOTONICS ITALIA S.R.L.
Strada della Moia, 1/E
20020 Arese, (Milano), Italy
Telephone: (39)02-935 81 733
Fax: (39)02-935 81 741
E-mail: info@hamamatsu.it

Rome Office:
Via Fosso del Torrino, 51
00144 Roma, Italy
Telephone: (39)06-52246492, Fax: (39)06-52246493
E-mail: inforoma@hamamatsu.it

Hong Kong:
HAKUTO ENTERPRISES LTD.
Room 404, Block B,
Seaview Estate, Watson Road,
North Point, Hong Kong
Telephone: (852)25125729, Fax: (852)28073155

Taiwan:
HAKUTO Taiwan Ltd.
3F-6, No. 188, Section 5, Nanking East Road
Taipei, Taiwan R.O.C.
Telephone: (886)2-2753-0188
Fax: (886)2-2746-5282

KORYO ELECTRONICS CO., LTD.
9F-7, No.79, Hsin Tai Wu Road
Sec.1, Hsi-Chih, Taipei, Taiwan, R.O.C.
Telephone: (886)2-2698-1143, Fax: (886)2-2698-1147

Republic of Korea:
SANGKI TRADING CO., LTD.
Suite 431, World Vision Bldg.,
24-2, Yoido-Dong, Youngdeungpo-ku,
Seoul, Republic of Korea
Telephone: (82)2-780-8515
Fax: (82)2-784-6062

Singapore:
HAKUTO SINGAPORE PTE LTD.
Block 2, Kaki Bukit Avenue 1, #04-01 to #04-04
Kaki Bukit Industrial Estate, Singapore 417938
Telephone: (65)7458910, Fax: (65)7418201

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