Application Note 02_01 TELUX

Vishay Semiconductors

Specification, Thermal management and design-in

1. Introduction

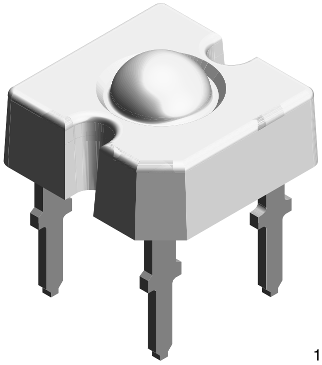
The performance and reliability of TELUX® LED are mainly determined by a proper thermal management of the complete lamp system. The thermal management is a critical part in the design in of high power LEDs

The following application note details the product specification in the corresponding data sheets for the different TELUX® series .

Thermal management of optical systems with LEDs and the influence of temperature on electrical and optical parameters are covered.

2. Data sheet informations

The data sheet presents the performance of the TELUX® LED in tables and diagrams.



The type name contains ,,brightness series; colour and emission angle plus customer specific information's.

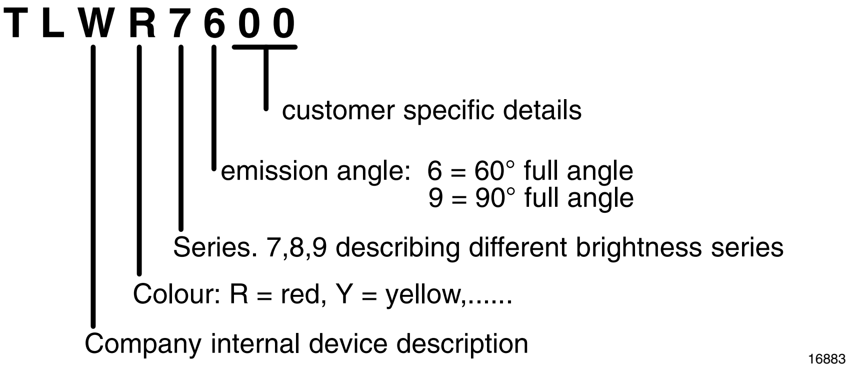


Figure 1. Description of Type Name

2.1 Structure of the datasheet:

Colour emission angle and Chip technology are described in the first table. For luminous flux, wavelengths and forward voltage a special grouping is done. This grouping scheme can be found in the general part of our data book. The grouping system is compatible to the systems used by main competitors. (Figure 2)

The paragraphs Description, Features and Applications are giving a general introduction about the design, technology, features and applications of the device.

Group	Luminous Flux [mlm] @I_F = 70mA, T_A = 25°C, R_{thJA} = 200°C/W (Steady State)	
	Min.	Max.
5	200	320
4	250	400
3	320	500
2	400	630
1	500	800
0	630	1000
A	800	1250
B	1000	1800
C	1500	2400
D	2000	3000
E	2500	3600
F	3000	4200

Group	dominante wavelenghts [nm] @I_F = 70mA, T_A = 25°C, R_{thJA} = 200°C/W (Steady State)	
	Min.	Max.
1	611	618
2	614	622
3	616	634

Group	Forward Voltage [V]	
	Min.	Max.
Y	1.83	2.07
Z	1.95	2.19
0	2.07	2.31
1	2.19	2.43
2	2.31	2.55
3	2.43	2.67
4	2.55	2.79

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Figure 2. TELUX® grouping scheme for luminous flux , forward voltage and wavelengths for red.

The second table "Absolute maximum rating" is very important for the thermal properties of the TELUX®. The reverse voltage, the max. DC forward and surge current, the maximum power dissipation and junction temperature, operation and storage temperature range, solder temperature and the thermal resistance (junction/ambient & junction pin) are listed in this table.

The last table " Optical and electrical characteristics" contains the optical parameters and the corresponding electrical parameters of the lamp. The optical parameters as well as the electrical parameters are more or less a function of the temperature.

The data sheet contains also graphs illustrating the operational conditions. The relevant graphs for the thermal management are described below.

3. Non thermal characteristics of the TELUX® LED

3.1. Emission characteristic of the TELUX® LED

The angle of half is the typical criteria of the different TELUX® type versions.The luminous flux vs. angular displacement and the percentage of the luminous flux covered by different angles are describing the light emission in detail.

This typical emission characteristic is a nearly temperature independent feature of the LED.

Typical charts are in Fig. 3 - 6. The 60 degree type is showing a typical double peak while the 90 degree version is showing a more sharp peak

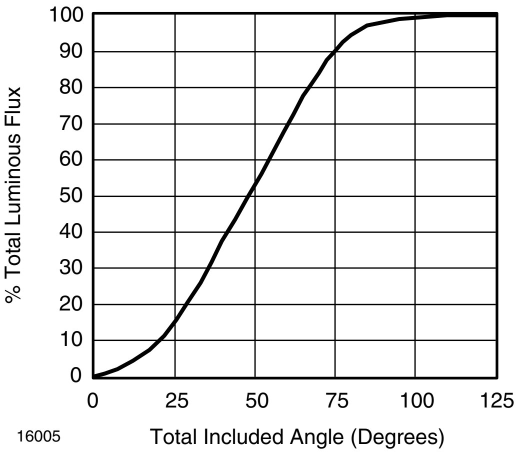

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Figure 3. Percentage Total Luminous Flux vs. Total Included Angle for 60 ° emission angle

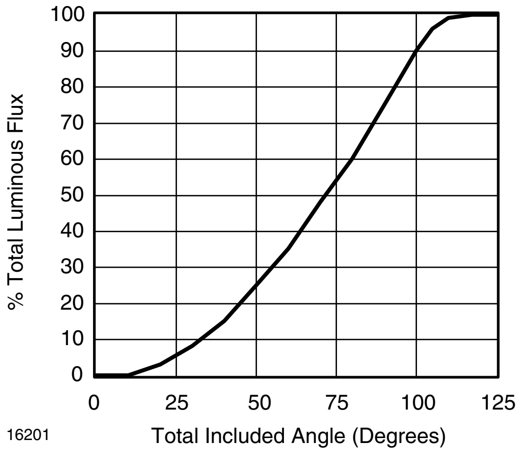

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Figure 4. Percentage Total Luminous Flux vs. Total Included Angle for 90 ° emission angle

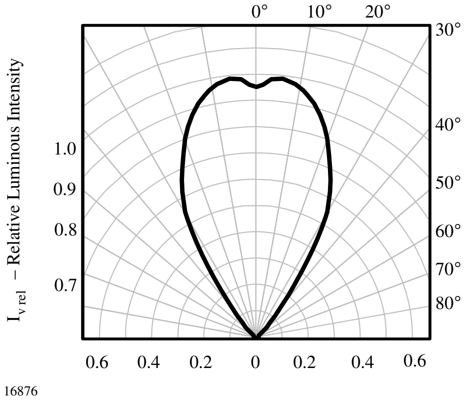


Figure 5. Rel. Luminous Intensity vs. Angular Displacement for 60 ° emission angle

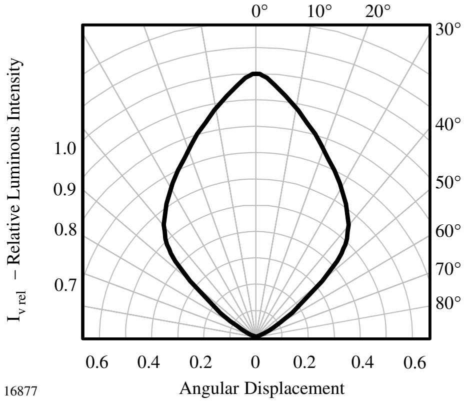


Figure 6. Rel. Luminous Intensity vs. Angular Displacement for 90 ° Emission Angle

4. Thermal limitations of the TELUX LED

The junction temperature mainly affects the luminous flux, the wavelengths and the forward voltage of the TELUX® LED. The junction temperature itself will be affected by ambient temperature and self heating due to electrical power dissipation. Approximately only 5 to 10 % of the power is dissipated optically, the main portion is heating up the device.

4.1. Dominant wavelengths

The dominant wavelength is a linear function of the junction temperature and can be described by the following equation:

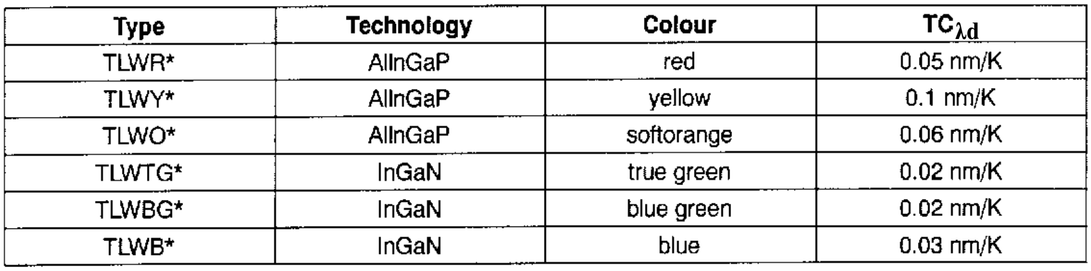
$\lambda_d(T_j) = \lambda_d(Tjo) + TC\lambda_d * \Delta T_j$ (1)

The coefficient $TC\lambda_d$ is a material specific parameter and listed in fig. 7

$\lambda_d(Tj)$ = dominant wavelength as a function of temperature

$\lambda_d(Tj0)$ = dominant wavelength at a certain temperature T_0

ΔT_j = temperature difference (T_j - T_{j0})



Type	Technology	Colour	$TC_{\lambda d}$
TLWR*	AllnGaP	red	0.05 nm/K
TLWY*	AllnGaP	yellow	0.1 nm/K
TLWO*	AllnGaP	softorange	0.06 nm/K
TLWTG*	InGaN	true green	0.02 nm/K
TLWBG*	InGaN	blue green	0.02 nm/K
TLWB*	InGaN	blue	0.03 nm/K

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Figure 7. Temperature Coefficient of λ_d

4.2. Luminous flux

The luminous flux is an exponential function of the of the junction temperature and can be described as:

$\phi_v(T_j) = \phi_v(T_{j0}) * e^{-k\Delta T}$ (2)

$\phi_v(T_j)$ = luminous flux as a function of temperature

$\phi_v(T_{j0})$ = luminous flux at a certain temperature T_0

k = material specific parameter (typical $1,1 * 10^{-2}$ for AS AllnGaP red)

ΔT = temperature difference (T_j - T_{j0})

For application the $\phi_V(T_a)$ is measured (Fig. 8 and Fig. 9). In generally the junction temperature is determined by $T_a + \Delta T$ from electrical power dissipation. The calibration is done after a stabilisation of the parameter, to eliminate short time effects.

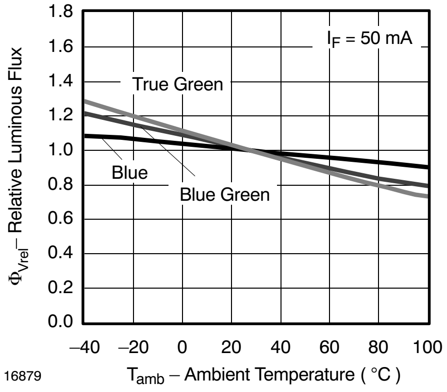


Figure 8. Luminous Flux as a Function of T_{amb} for InGaN

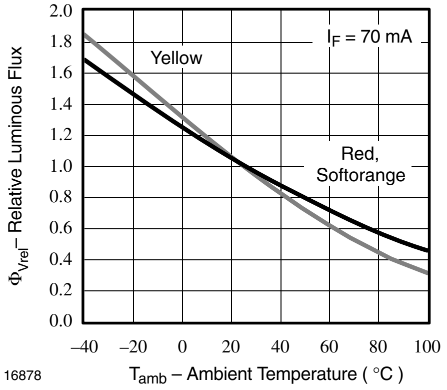
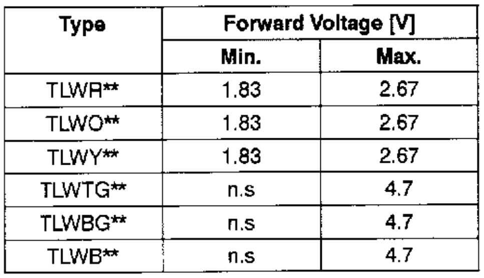


Figure 9. Luminous Flux as a Function of T_{amb} for AlInGaP

4.3. Forward voltage.

The forward voltage is a function of current and junction temperature(Fig.10 - 12). For the specification at max. current at 25 °C, the junction temperature is defined by the thermal resistance (R_{thja} = 200 K/W). This will be described in the next chapter and in combination with the thermal resistance it is a function of T_{amb}, due to linear shift by a selfheating effect of $\Delta T = R_{thja} * P$. (Fig. 14)



Type	Forward Voltage [V]	
	Min.	Max.
TLWR**	1.83	2.67
TLWO**	1.83	2.67
TLWY**	1.83	2.67
TLWTG**	n.s	4.7
TLWBG**	n.s	4.7
TLWB**	n.s	4.7

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Figure 10. Forward Voltage

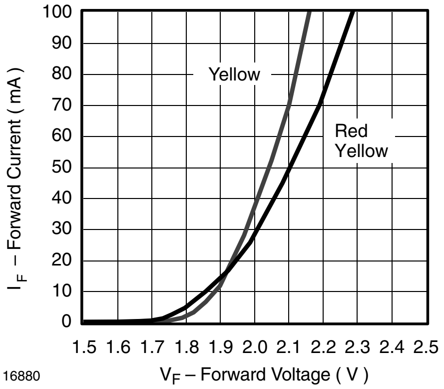

Figure 11. Forward Current vs. Forward Voltage for AlInGaP

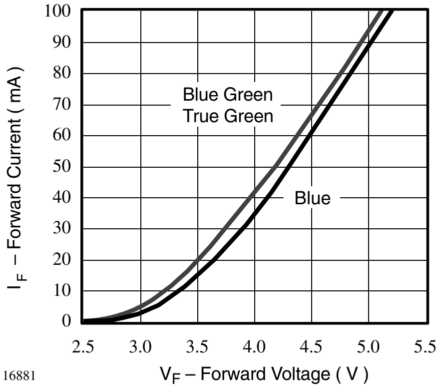

Figure 12. Forward Current vs. Forward Voltage for InGaN

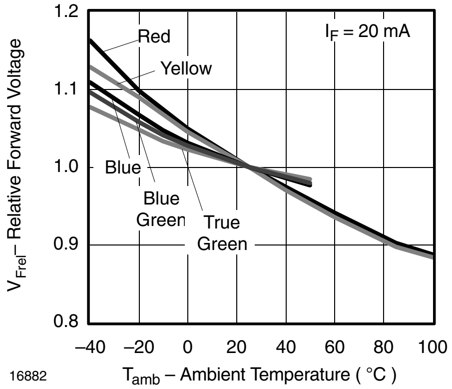

Figure 13. Forward Voltage vs. Ambient Temperature for AlInGaP und InGaN

In a first approximation from Fig. 13 a linear temp. coefficient for V_f can be defined in the temperature range above - 25 °C. (Fig. 13)
This temp. coefficient is only typical for one V_f group because the $V_f(T)$ is also a function of the V_f group itself as shown in Fig. 15 for AlInGaP red.

Type	TC_{VF}/mV/K
TLWR	− 4.5 (70 mA)
TLWY	− 4.1 (70 mA)
TLWB	− 6.2 (50 mA)
TLWTG	− 4.7 (50 mA)
TLWBG	− 5.6 (50 mA)

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Figure 14. Temperature Coefficient of V_F

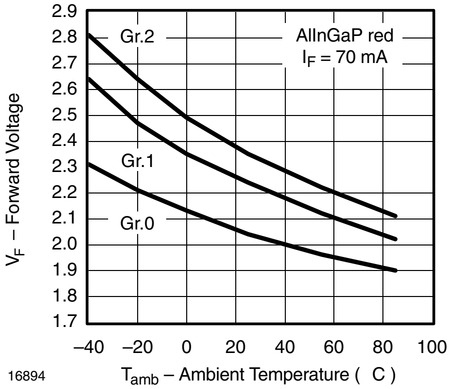


Figure 15. Forward Voltage against T_{amb} for Different V_FGroups

4.4. Thermal resistance

Similar to electrical resistance, which is associated to the conduction of electricity, the thermal resistance is associated to the conduction of heat. Defining resistance as the ratio of driving potential to the corresponding transfer rate, the thermal resistance for conduction can be defined as:

$R_{th} = \Delta T/q_x$ (3)

where ΔT = temperature difference between the 2 points, q_x = rate of heat transfer between those 2 points.

The thermal resistance of LED lamp where the LED is mounted on a PCB as illustrated in Fig. 16 can be divided into 2 parts.

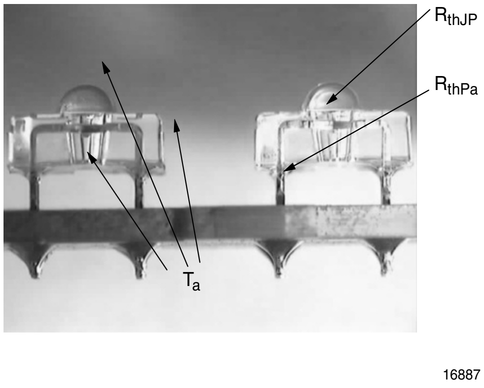


Figure 16. Components of Thermal Resistance

1. thermal resistance of the LED package (junction to pin thermal resistance or R_{thjp})

2. thermal resistance of the lamp housing (pin to ambient thermal resistance or R_{thpa}).These two components are adding up to the thermal resistance junction to ambient

$R_{thja} = R_{thjp} + R_{thpa}$ (4)

Based on the assumption that the electrical power is dissipated mainly as heat, the junction to pin thermal resistance of an LED can be defined in the following equation:

$R_{thja} = (T_j - T_a)/P = ((\Delta T_j + T_a) - T_a)/P = \Delta T_j/P$ (5)
where $T_j = \Delta T_j + T_a$

The electrical power can easily be determined by multiplying forward current and forward voltage. The rise in junction temperature can be determined by measuring the change in forward voltage of the LED.

There are different possibilities to measure the thermal resistance "junction to ambient". A simple method is to assume that R_{thjp} for the tested device is known from data sheet. Solder a very thin thermocouple on one cathode pin of the hottest LED in your PCB. The solder point should be close to the surface. After measuring the pin temperature, the ambient temperature and the power, the R_{thpa} can be calculated as: R_{thpa}= (Tp-Ta)/P. With equation (4) the thermal resistance junction to ambient can be calculated. The thermal resistance junction to ambient vs. cathode padsize is shown in Figure 17, $T_j = T_{ak} + R_{thjp} * P$. The anode pad is not contributing to heat dissipation.

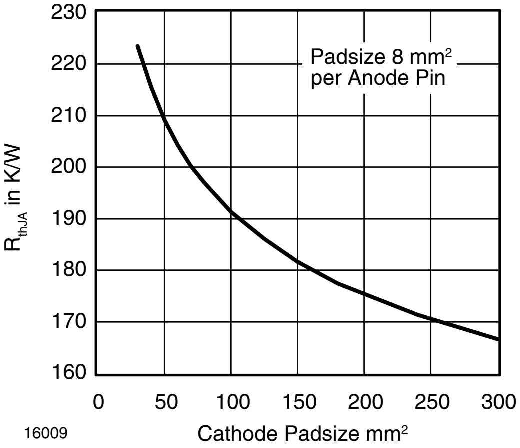


Figure 17. Thermal Resistance Junction Ambient vs. Cathode Padsize

4.5. Maximum power, maximum current and maximum junction temperature

The maximum junction temperature is limited mainly by the chip

Actual: T_{jmax} = 125 °C for TELUX with AlInGaP chip
T_{jmax} = 100 °C for TELUX with InGaN chip

The thermal resistance junction to pin R_{thjp} is 90 K/W. The optical and electrical Parameters are specified based on a cathode heat sink of 70 mm^2. The thermal resistance junction to ambient for 70 mm^2 heat sink on cathode side (both pins are connected) R_{thja} is 200 K/W.

From equation (5)

$R_{thja} = (T_{jmax}-T_{amax})$ /Pmax
with $P_{max} = V_{fmax} \times I_{max}$
$T_{jmax} = R_{thja} * V_{fmax} * I_{max}$ (6)

From this equation the derating diagram forward current via temperature for R_{thja} = 200 K/W can be calculated. The charts for TELUX AlInGaP and InGaN are shown below in Figure 18 and 19.

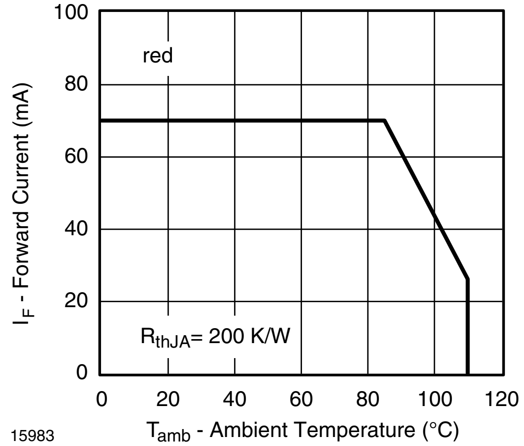


Figure 18. Forward Current vs. Ambient Temperature

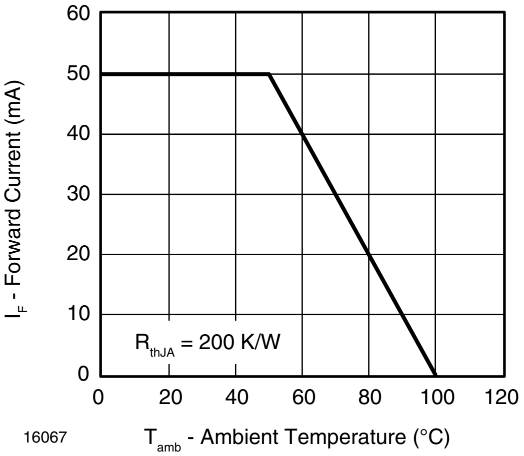


Figure 19. Forward Current vs. Ambient Temperature for InGaN

4.6. Ambient Temperature and thermal resistance of the enclosure

The LED's on the PCB are often mounted into an enclosure as shown in Fig. 20. It is very important to realise that the ambient temperature is the temperature of the air surrounding the LED. This means that the real ambient temperature inside the enclosure is higher than the temperature outside the enclosure due to heat generated by the LED, the other electronic parts and in some applications extremely by the sun illumination.

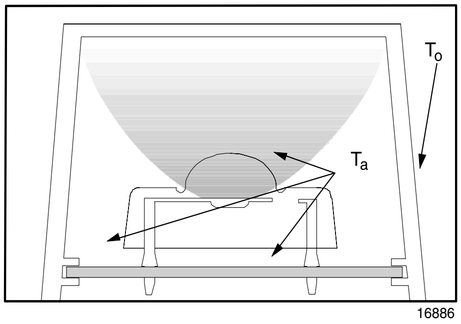


Figure 20. Thermal Resistance of the Enclosure

Following the definition of the thermal resistance in equation (5), the thermal resistance of the enclosure can be written as below:

$R_{thao} = (T_a - T_o)/P_T$ (7)

where: R_{thao} = thermal resistance of the enclosure

T_a = temperature inside the enclosure closest to the LED

T_o = temperature outside the enclosure

P_T = power consumption of all devices inside the enclosure

The junction temperature can be estimated as:

$T_j = T_o + (P_{LED} \times R_{thja}) + \Delta T_D + P_T R_{thao}$ (8)

where: ΔT_D = temperature evaluation due to power density of the PCB

5. PCB design

Proper PCB design can reduce the R_{thja} of a lamp assembly and finally this will lower the junction temperature of the LED chip.The Thermal resistance "junction to ambient" as a function of cathode pad size is shown in Fig 17. Since the most of the electrical power in the LED is dissipated as heat, the LED's should be spaced as far as packaging and optical constrains will allow. 10 mm and 15 mm are ideal in x, y and it is helpful to design large metal pads to keep the temperature on the PCB on a low level.

Resistors and other electronic parts which contribute to the heat should be distributed on the PCB at largest possible distance from the LED's. For thermal management as well as for current control it is better to use more than only one resistor to achieve a better distribution of the generated heat.

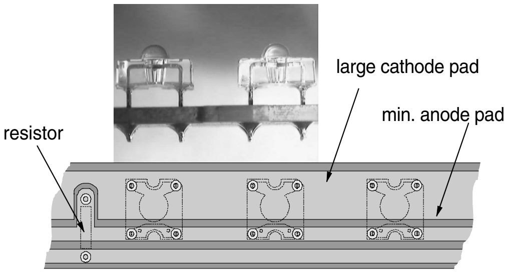
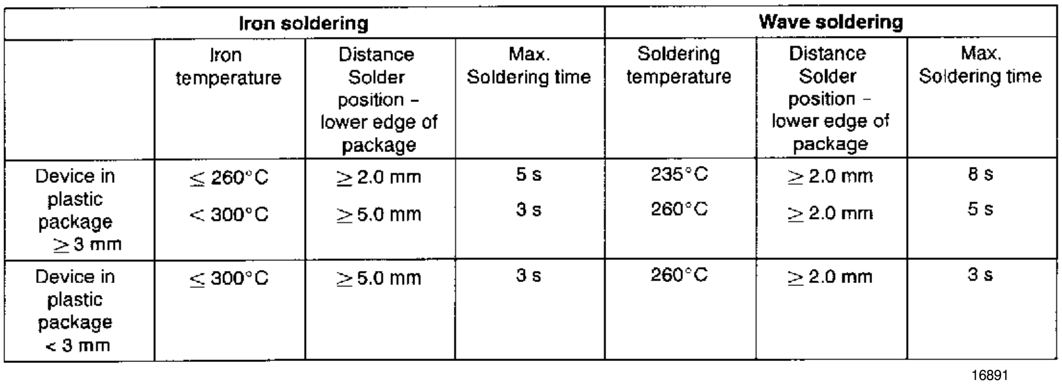


Figure 21. PBC Design with Proper Metallization and Device Placement

6. Soldering

Solder-method recommendation

The TELUX LED is not released for reflow soldering



	Iron soldering			Wave soldering		
	Iron temperature	Distance Solder position - lower edge of package	Max. Soldering time	Soldering temperature	Distance Solder position - lower edge of package	Max. Soldering time
Device in plastic package ≥ 3 mm	≤ 260°C < 300°C	≥ 2.0 mm ≥ 5.0 mm	5 s 3 s	235°C 260°C	≥ 2.0 mm ≥ 2.0 mm	8 s 5 s
Device in plastic package < 3 mm	≤ 300°C	≥ 5.0 mm	3 s	260°C	≥ 2.0 mm	3 s

Figure 22. Soldering Conditions

- Double wave profile
  As per CECC00802 (5s peak)

- Hand soldering
  260 °C for 5 sec 2 mm from body of the device

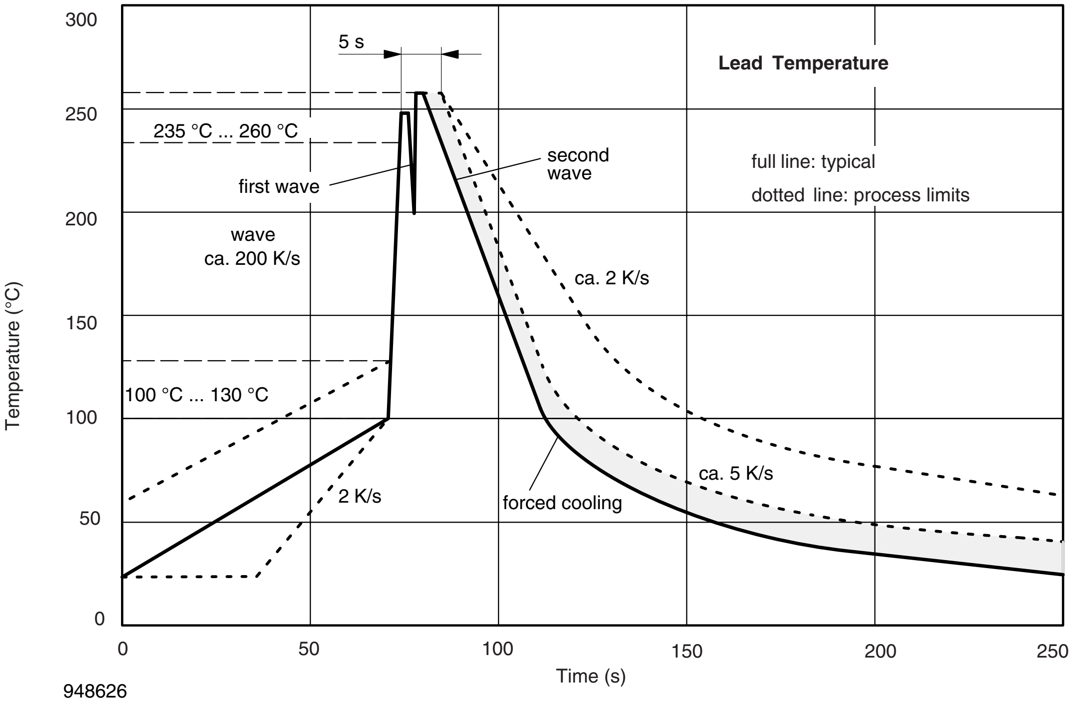


Figure 23. Double Wave Solder Profile

- Most critical part of the profile is the preheating. It is recommended to keep the preheating temperature on a maximum level of 100 °C for 30 sec. As defined in the "Absolute maximum ratings" for the product.

Ozone Depleting Substances Policy Statement

It is the policy of Vishay Semiconductor GmbH to

1. Meet all present and future national and international statutory requirements.
2. Regularly and continuously improve the performance of our products, processes, distribution and operatingsystems with respect to their impact on the health and safety of our employees and the public, as well as their impact on the environment.

It is particular concern to control or eliminate releases of those substances into the atmosphere which are known as ozone depleting substances (ODSs).

The Montreal Protocol (1987) and its London Amendments (1990) intend to severely restrict the use of ODSs and forbid their use within the next ten years. Various national and international initiatives are pressing for an earlier ban on these substances.

Vishay Semiconductor GmbH has been able to use its policy of continuous improvements to eliminate the use of ODSs listed in the following documents.

1. Annex A, B and list of transitional substances of the Montreal Protocol and the London Amendments respectively
2. Class I and II ozone depleting substances in the Clean Air Act Amendments of 1990 by the Environmental Protection Agency (EPA) in the USA
3. Council Decision 88/540/EEC and 91/690/EEC Annex A, B and C (transitional substances) respectively.

Vishay Semiconductor GmbH can certify that our semiconductors are not manufactured with ozone depleting substances and do not contain such substances.

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