OSTAR® Observation

Application Note

Summary

This application note provides an overview of the general handling and functionality of the OSTAR®-Observation from OSRAM OS. The important optical and electrical characteristics are described and the thermal requirements for stable operation of the IR LED light source are addressed.
In addition, the procedure for dimensioning an appropriate heat sink is illustrated by means of an example.

Applications of the IR light source OSTAR®-Observation

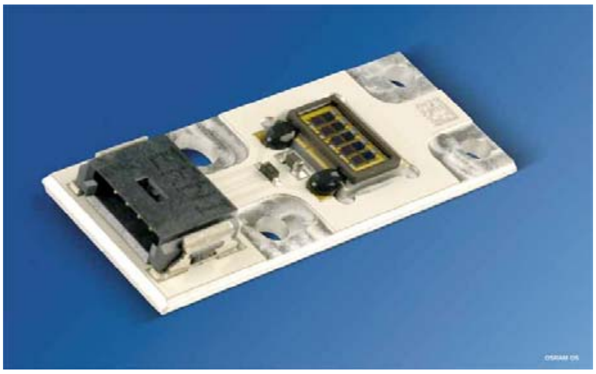
There are numerous possibilities for using the OSTAR®-Observation IR light source such as:

- Infrared illumination for CMOS cameras
- General monitoring systems
- IR data transfer
- Driver assistance systems.

Due to its compact and flat design together with its high radiance, the OSTAR®-Observation can be easily integrated in various applications. This opens up new application areas that were off limits to conventional IR devices.

Construction of the OSTAR®-Observation

During design of the OSTAR®-Observation, special attention was given to the thermal optimization of the module.



The module core is formed from ten highly efficient semiconductor chips mounted on ceramic. For optimal heat transfer, the ceramic is directly mounted to the aluminum of the insulated metal core circuit board (base plate). This results in optimal heat dissipation and additionally provides a sufficiently large area for a good thermal connection to the system heat sink where the OSTAR® module has to be attached to.
With this construction, the light source itself exhibits a very low thermal resistance (R_{thJB}) between junction and base plate of 2.8 K/W.

The frame surrounding the chips is available in black and white colour to enable a choice depending on the desired application.
The black frame minimizes scattered light, which is important in imaging systems, whereas the white frame optimizes the total optical output power.

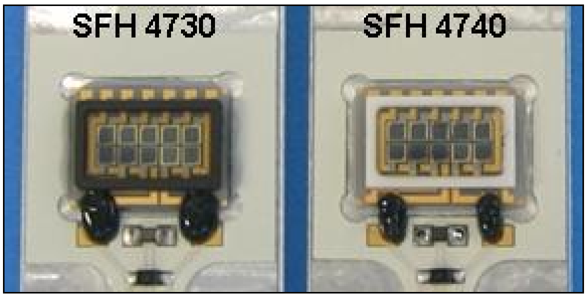


Figure 1: Two frame colours are available for the OSTAR®-Observation.

Equipped with an ESD protection diode, the OSTAR®-Observation possesses ESD protection up to 2 kV according to JESD22-A114-B.

A thermistor (NTC EPCOS 8502) mounted to the base plate serves as a sensor for determining the temperature of the metal core board. The NTC temperature provides a good approximation of the average temperature of the underside of the aluminum base plate. From this the junction temperature can be estimated (using R_{thJB}) and thus controlled.

As a light source, semiconductors of the latest highly efficient thin film technology based on AlGaAs are employed. This provides a nearly pure surface emitter with Lambertian radiation characteristics.
All semiconductor chips are wired in series to achieve a constant intensity for all emitting surfaces.

Tips for handling the OSTAR®-Observation

In order to protect the semiconductor chips from environmental influences such as moisture, they are encapsulated using a clear silicone.
In addition, the silicone encapsulant allows operation at a junction temperature of 145°C.
Since this encapsulant is very elastic and soft, mechanical damage to the silicone should be minimized or avoided if at all possible during processing (see also the application note "Handling of Silicone Resin LEDs").
This also applies to the black silicone encapsulant for the connection contacts. Excessive force on the cover can lead to spontaneous failure of the light source (damage to the contacts).

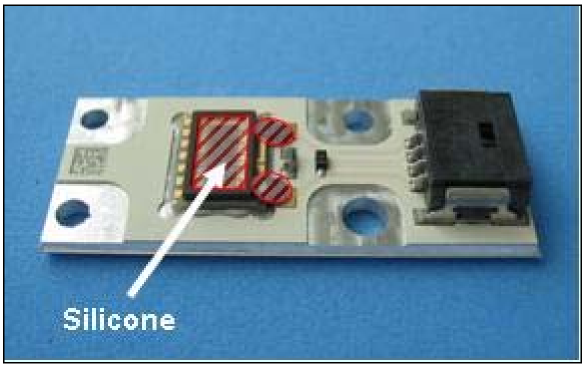


Figure 2: Areas of the silicone encapsulant of the OSTAR®-Observation (shown in red hatch marks), which must not be damaged.

In Figure 2, the corresponding locations are shown in red hatch marks.
To prevent damaging or puncturing the encapsulant the use of all types of sharp objects should be avoided.
Furthermore, it should be assured that the light source is provided with adequate cooling (see design example below) during operation. Even at low currents, prolonged operation without cooling can lead to overheating, damage or even failure of the module.

Electrical connection of the OSTAR®-Observation

For easy electrical connection, the OSTAR®-Observation is equipped with a 4-pin socket:

Pin Assignment:
Pin 1: Anode
Pin 2: Thermistor
Pin 3: Thermistor
Pin 4: Cathode

As a mating plug, the SMD plug from ERNI (SMD214025.4-pins) is recommended.

Mounting the OSTAR®-Observation

Several mounting methods can be used for attaching the IR light source.
When selecting an appropriate mounting method, make sure that a good heat transfer is provided between the OSTAR®-Observation and the heat sink and that this is also guaranteed during operation.
An insufficient or incorrect mounting can lead to thermal or mechanical problems during assembly.
Generally, screws should be used for mounting the OSTAR®-Observation.
When mounting the module with M2 screws, a torque of 0.2 - 0.3 Nm should be used. In order to achieve a good thermal connection, the contact pressure should typically be in the range of 0.35 MPa.

In addition to mounting with screws, the OSTAR®-Observation can also be attached by means of gluing or clamping.
When mounting with glue, care should be taken that the glue is both adhesive and thermally stable, and possesses a good thermal conductivity.

When mounting a component to a heat sink, it should generally be kept in mind that the two solid surfaces must be brought into physical contact.
Technical surfaces are never really flat or smooth, however, but have a certain roughness due to microscopic edges and depressions. When two such surfaces are joined together, contact occurs only at the surface peaks. The depressions remain separated and form air-filled cavities (Figure 3).

<table>
<tr><th>Description</th><th>Material</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Thermally conductive paste</td><td>Typically silicone based, with heat conductive particles</td><td rowspan="2">Thinnest connection with minimal pressure

High thermal conductivity

No delamination</td><td rowspan="2">Material discharge at the edges

Danger of contamination during mass production

Paste can escape and "creep" over time

Connections require curing process</td></tr>
<tr><td>Thermally conductive compounds</td><td>Improved thermally conductive paste – rubbery film after curing</td></tr>
<tr><td>Phase Change Materials (PCM)</td><td>Material of polyester or acrylic with lower glass transition temperature, filled with thermally conductive particles</td><td>Easy handling and mounting

No delamination

No curing</td><td>Contact pressure required

Heat pretreatment required</td></tr>
<tr><td>Thermally conductive elastomers</td><td>Silicone plastic washer pads
- filled with thermally conductive particles
- often strengthened with glass fibers or dielectric films</td><td rowspan="2">No leakage of material

Curing not required</td><td rowspan="2">Problem with delamination

Moderate thermal conductivity

Contact pressure required</td></tr>
<tr><td>Thermally conductive tape</td><td>Double sided tape filled with particles for uniform thermal and adhesive properties</td></tr>
</table>

Table 1: Thermal Interface Materials

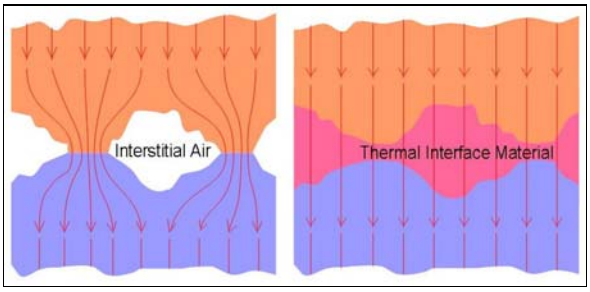


Figure 3: Heat flow with and without heat conductive material.

Since air is a poor conductor of heat, these cavities should be filled with a thermally conductive material in order to significantly reduce the thermal resistance and improve the heat flow between the two adjacent surfaces.

Without an appropriate, optimally effective interface, only a limited amount of heat exchange occurs between the two surfaces, eventually leading to overheating of the light source.
To improve the heat transfer capability and reduce the thermal contact resistance, several materials are suitable.
Thermally conductive pastes and compounds possess the lowest transfer resistance, but require a certain amount of care in handling.
Elastomers and foils/bands are easy to use. With pretreated surfaces and appropriate contact pressure, a good thermal transfer can be realized.
Table 1 shows an overview of the most commonly used thermally conductive materials along with their most important advantages and disadvantages.

Optical characteristics of the OSTAR®-Observation

When characterizing IR LEDs, the intensity is usually specified with two parameters - the total radiant flux Φ_e (units of mW) and the radiant intensity I_e (units of mW/sr).

The total radiant flux Φ_e of an LED describes the total radiated light power independent of direction. For the OSTAR®-Observation, this is shown in Figure 4, in relation to forward current.

In contrast, radiant intensity expresses the radiated power within a fixed solid angle (e.g. 0.01 sr ≙ ±3.2°) in the primary direction of radiation (optical axis).

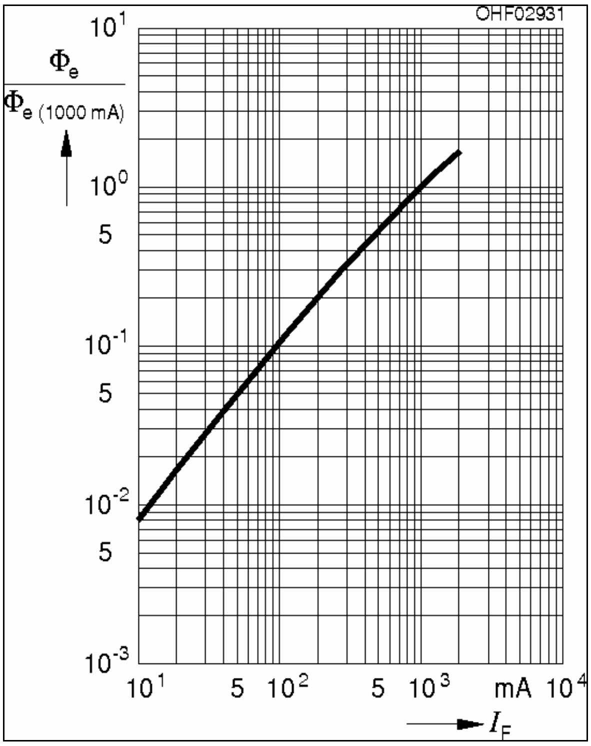


Figure 4: Relative total radiant flux in relation to forward current I_F.

The radiation characteristics (in the *far field*) show the distribution of intensity dependent on angle and are shown for the OSTAR®-Observation in Figure 5. This represents a good approximation of a Lambertian source with a radiation angle of ±60°.

In general, the brightness can be influenced with the help of appropriate secondary optics. That is, with the use of focusing optics, the light output within a particular angle can be significantly improved.

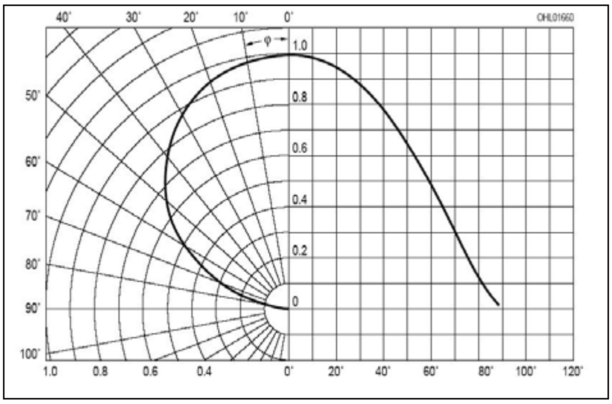


Figure 5: Radiation characteristics of the OSTAR®-Observation without optics.

The user should refrain from attempting to mount the primary optics to the silicone encapsulant. This can lead to damage to the chip and especially to the bonding wires, thereby voiding the warranty provided by OSRAM OS.

In the *near field* (at different operating currents), the OSTAR®-Observation exhibits the radiance images shown in Figure 6.

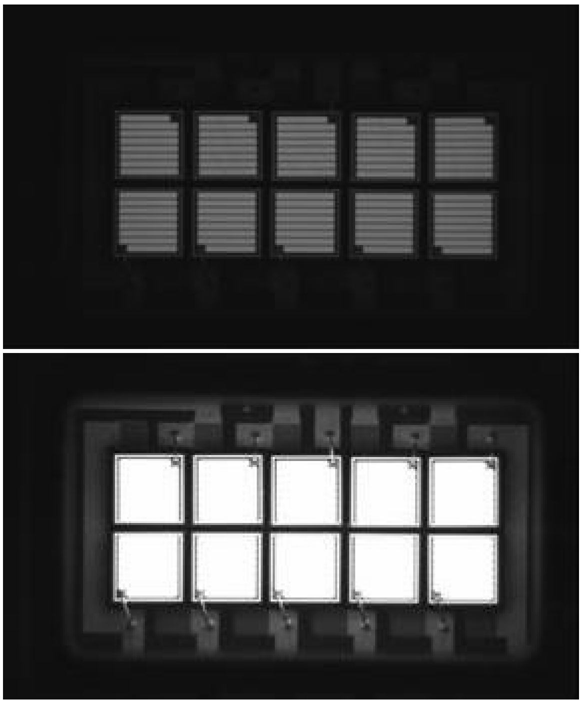


Figure 6: Radiance images of the OSTAR®-Observation in the near field at very low power (above) and at higher power (below).

An especially homogeneous radiance is achieved through the black frame of the module - a particular advantage when using imaging optics.

Optical safety regulations

Depending on the mode of operation, the OSTAR®-Observation emits highly concentrated, invisible infrared radiation, which can be dangerous for the human eye. Products which contain these components must be handled according to the guidelines specified in IEC Standard 60825-1 and CIE S009/ IEC 62471 "Photobiological Safety of Lamps and Lamp Systems".

At high currents, one should always avoid looking at the optical path through a focusing lens, since the limits imposed by Laser Class 1M can be exceeded.

Electrical characteristics and operation of the OSTAR®-Observation

In addition to optimized optical behavior, the new thin film AlGaAs technology also exhibits improved electrical characteristics, when compared to traditional standard chip technologies. These improvements lead to a significantly reduced forward voltage. It also enables higher forward currents for a given junction temperature.
A typical current-voltage characteristic is shown in Figure 7.

Care should be taken to observe the limiting conditions specified in the data sheet and at higher power, sufficient cooling should be provided.

The OSTAR®-Observation consists of a current-driven component, in which small voltage fluctuations at the input can lead to significant changes in current for the device and thus to changes in the emitted output power. When selecting or developing suitable driver circuitry, it is therefore recommended that appropriate current stabilization should also be provided. A selection of suitable components for this purpose is summarized in the appendix.

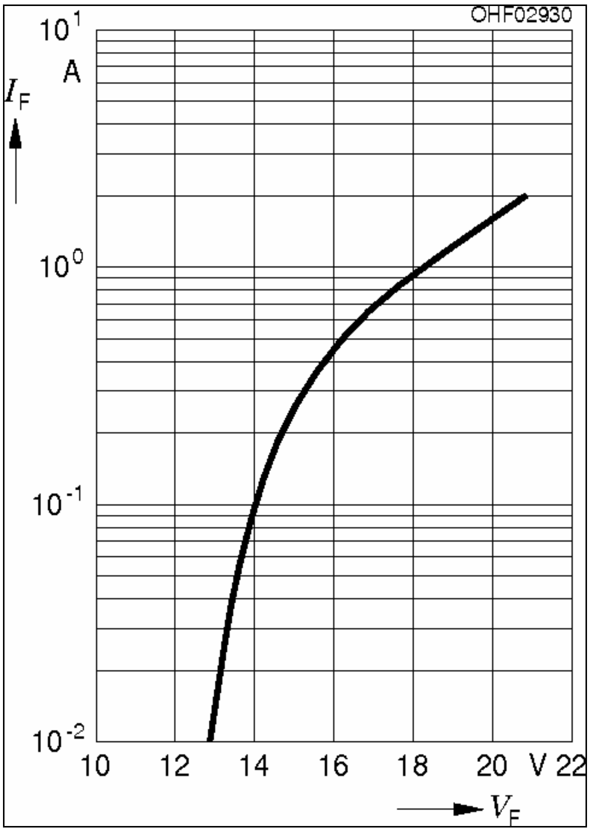


Figure 7: Current-Voltage characteristic of the OSTAR®-Observation.

The efficiency of the OSTAR®-Observation module which results from the total radiated light power Φ_e and the electrical power $P = V_f \times I_f$, is plotted in Figure 8.
It is optimal at around 100 mA and decreases at lower and higher currents.

This is especially true for pulse operation at I_f >100 mA, since the average optical power does not remain constant when the current is doubled and the duty cycle is halved.

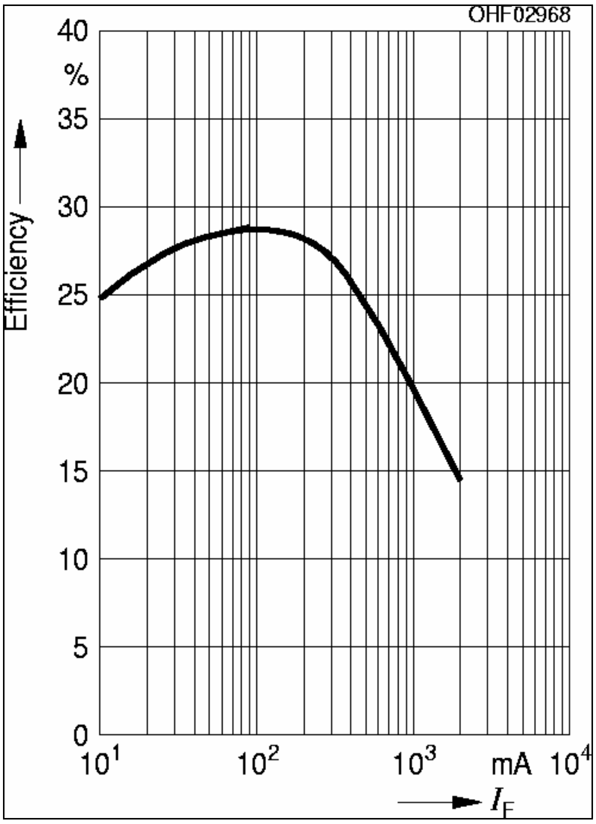


Figure 8: Efficiency in relation to forward current I_f; T_B = 25°C, t_p = 100µs.

Thermal Considerations

In order to achieve reliability and optimal performance for IR light sources such as the OSTAR®-Observation, appropriate thermal management is necessary.
Basically, there are two principle limitations for the maximum allowable temperature.
First of all, for the OSTAR®-Observation, the maximum allowable base plate temperature T_B of 125°C must not be exceeded. Secondly, the maximum junction temperature is specified to be 145°C. Since these temperatures are dependent on the operating current and mode of operation (constant current or pulsed mode), the maximum allowable currents listed in the data sheet specify a T_B of up to 125°C for DC operation and T_B = 85°C for various pulse modes. Thus, for example, the maximum allowable constant current is 1 A

for a base plate temperature T_B = 85°C and is 600 mA at 110°C.
Exceeding the maximum junction temperature of 145°C can lead to irreversible damage to the LED and to spontaneous failure of the device.

Due to underlying physical inter-dependencies associated with the functioning of light emitting diodes, a change in the junction temperature T_J - within the allowable temperature range - has an effect on several LED parameters.
As a result, the forward voltage, radiant flux, wavelength and lifetime of LEDs are influenced by the junction temperature.

Influence on forward voltage V_f and optical power Φ_e

For LEDs, an increase in junction temperature leads to both a reduction of forward voltage V_F (Figure 9), and a decrease in optical power Φ_e (Figure 10). The resulting changes are reversible. That is, the original default values return when the temperature change is reversed.

For the application, this means that the lower the temperature of the semiconductor, the higher the light output will be.

Influence on reliability and lifetime

In general, with respect to aging, reliability and performance, continually driving the LEDs at their maximum allowable junction temperature is not recommended, since with an increase in temperature, a reduction in lifetime can be observed.

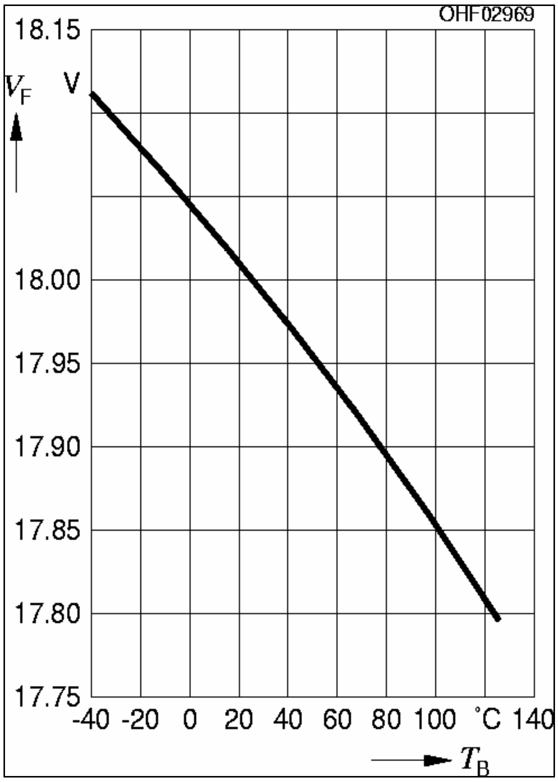


Figure 9: Typical forward voltage in relation to base plate temperature T_B (I_f = 1 A, t_p = 10 ms).

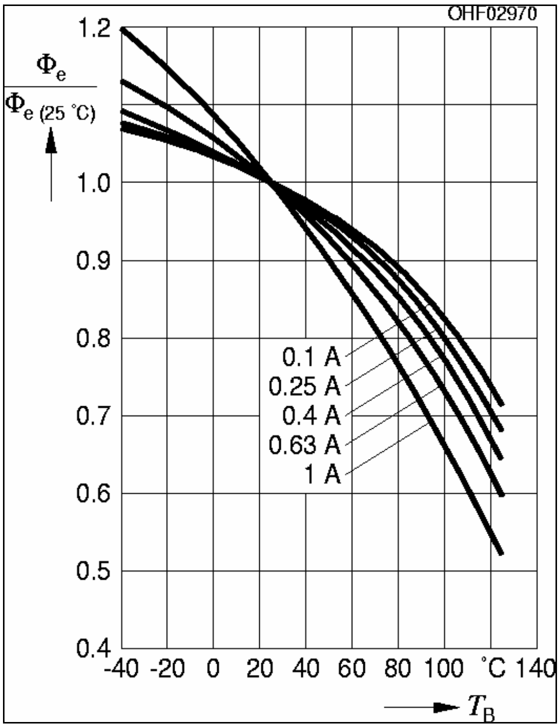


Figure 10: Relative optical power in relation to base plate temperature for various pulsed currents (t_p = 10 ms).

Determination of the module temperature with the integrated NTC

A good approximation of the base plate temperature T_B can be determined from the measured resistance of the NTC and the curve given in the reference table (Figure 12).
Depending on operating conditions, the corresponding junction temperature will be $\Delta T = R_{thJB} \times P_D$ (P_D = electrical power dissipation) higher. With appropriate feedback circuitry, T_B and thus the junction temperature can be regulated.

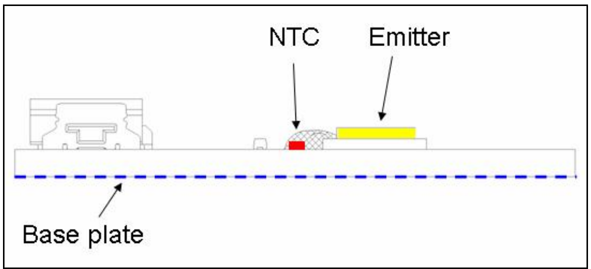


Figure 11: Cross section of the OSTAR®-Observation.

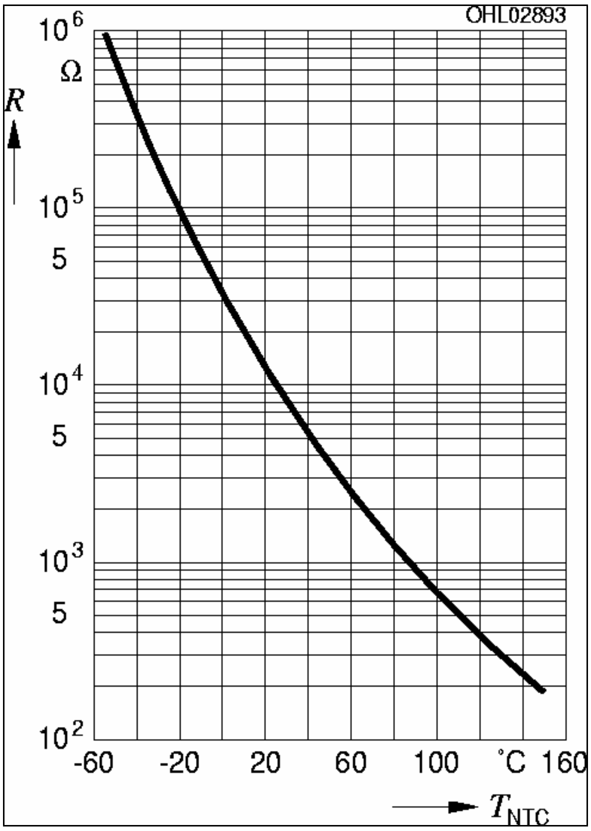


Figure 12: Typical thermistor characteristics for the OSTAR®-Observation (NTC EPCOS 8502).

Design Example

In the following example, the thermal requirements of the heat sink for the OSTAR®-Observation are examined. In Figure 13, an equivalent circuit for the different thermal resistances of the module is shown.
Additional information is contained in the application note "Thermal Management of OSTAR®-Projection Light Source".

As a starting point for the thermal evaluation, an OSTAR®-Observation module (10 Chips) is driven at an operating current of **I_f = 1000 mA** and a maximum ambient temperature of **T_A = 50°C**.
From the given data and information from the data sheet, the requirements for the necessary cooling can be found by means of the following formula:

$$\frac{\Delta T}{P_{D,\,Module}} - R_{th,Interface} - R_{th,\,JB} = R_{th,Heat\,sink}$$

Where

$$\Delta T\,[K] = T_{J\,(unction)} - T_{A(mbient)} - \Delta T_{Safety}$$

$$P_{D,Module}\,[W] \approx V_f\,[V] \cdot I_f\,[A]$$

With

$T_{J(unction)}$ = Max. Junction temperature (from data sheet: T_J = 145°C)

$T_{B(aseplate)}$ = Base plate temperature

$T_{A(mbient)}$ = Ambient temperature (T_A = 50°C)

ΔT_{Safety} = Safety temperature range (typ.10 – 20K)

V_f = Forward voltage (from data sheet: V_f = 18V)

I_f = Forward current (I_f = 1A) → typ. $P_{D,\,Module}$ = 18 W

ΔT = Temperature change due to $P_{D,Module}$

$R_{th,Interface}$ = Thermal resistance of the transition material between the OSTAR® base plate and the cooler/heat sink (e.g. thermally conductive paste ≈ 0.1 K/W)

$R_{th,JB}$ = Thermal resistance of the OSTAR®-Observation (from data sheet: $R_{th,JB}$ = 2.8 K/W)

$R_{th,Heat\ sink}$ = Thermal resistance from the cooler/heat sink to the environment

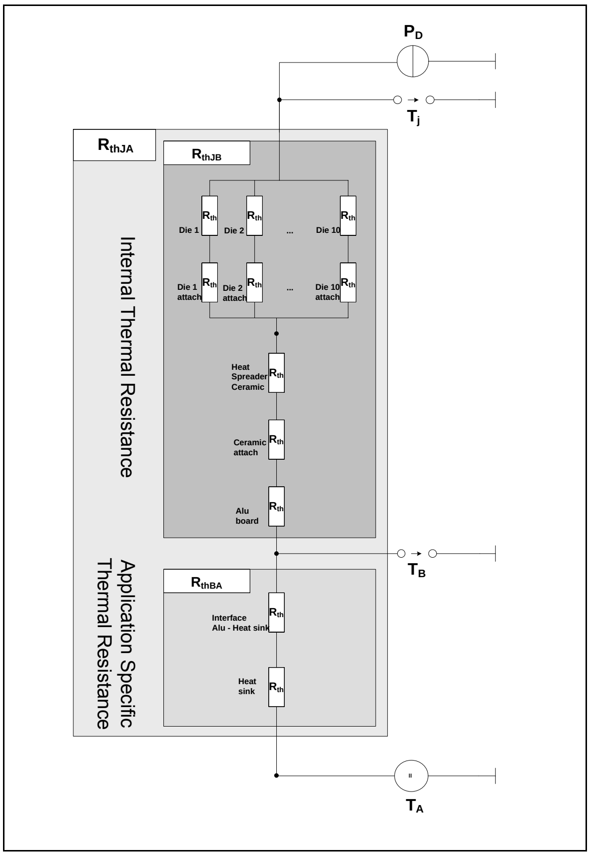


Figure 13: Equivalent circuit diagram for the thermal resistances.

In this example, the maximum thermal resistance required for cooling of the module can be found by:

$$R_{th,Heat\,sink} = \left(\frac{145-50-10}{18\times 1} - 0.1 - 2.8\right) K/W$$

$$R_{th,Heat\,sink} = 1.82\ K/W$$

With the calculated thermal resistance value at hand, a corresponding heat sink can be selected from a manufacturer (for a list of manufacturers, see appendix). Using this setup at the given operating conditions the junction temperature of the module will be at 135°C. If a lower T_J is desired, the safety temperature ΔT_{Safety} has to be increased accordingly.

In addition to a thermal evaluation by means of a simulation or a computed estimate, it is generally recommended to verify and safeguard the design with a prototype and thermal measurements.

Conclusion

Developed for high power operation with pulsed currents of up to two Amperes, the OSTAR®-Observation IR light source achieves a light output of several Watts, depending on operating parameters.

Due to operation at high power levels, appropriate thermal management is particularly necessary in order to dissipate the accumulated heat and to assure the optimal performance and reliability of the module.

When developing applications based on the OSTAR®-Observation, it is generally recommended that in addition to thermal simulations, the design should be verified and safeguarded by means of a prototype and thermal measurements.

Appendix

Manufacturer	Type	Voltage	Current (max.)
National	**LM3478**	V_{in} = 3 - 240 V	
	(DC/DC)	V_{out} = 1.24 - 36 V	I = 1 A
	LM5000	V_{in} = 3.1 - 40 V	
	(DC/DC)	V_{out} = 3.1 - 80 V	I = 2 A
	LM5010	V_{in} = 8 – 75 V	
	(DC/DC)	V_{out} = 2.5 - 60 V	I = 1 A
STMicroelectronics	**VIPer 53A**	V_{in} = 82 - 265 V	
	(AC/DC)	V_{out} = 5 - 40 V	I = 1 A
	L4976D	V_{in} = 8 - 55 V	
	(DC/DC)	V_{out} = 0.5 - 50 V	I = 1 A
	L5970D	V_{in} = 4.4 - 36 V	
	(DC/DC)	V_{out} = 0.5 - 35 V	I = 1 A
Supertex	**HV9910**	V_{in} = 8 - 450 V	
	(AC or DC)	$V_{out} < V_{in}$	I = 2 A
	HV9931	V_{in} = 8 - 450 V	
	(AC or DC)	V_{out} > 3 V	I = 1 A
	HV9930	V_{in} = 8 - 200 V	
	(DC/DC)	$V_{in} < V_{out} < V_{in}$	I = 1 A

Overview of possible driver devices for driving the OSTAR®-Observation.

Drivers

OSRAM	www.osram.com
National	www.national.com
STMicroelectronics	www.st.com
Supertex	www.supertex.com

Heat sinks

Aavid Thermalloy	www.aavidthermalloy.com
Alutronic Kühlkörper	www.alutronic.de
Fischer Elektronik	www.fischerelektronik.de

NTC (Thermal Resistors)

EPCOS (NTC 8502)	www.epcos.de

Customer Specific Optics

Fraen	www.fraen.com
LEDIL	www.ledil.com
L2 Optics	www.lumidrives.com

Thermal Interface Materials

3M	www.3m.com/conductive
Aavid Thermalloy	www.aavidthermalloy.com
Bergquist	www.bergquistcompany.com
Chomerics	www.chomerics.com
Fujipoly	www.fujipoly.com
Graftech Intl.	www.graftech.com
Universal-Science	www.universal-science.com

Thermal Adhesives

Emerson & Cuming	www.emersoncuming.com
Polytek	www.epotek.com
Loctite	www.loctite.com
Dowcorning	www.dowcorning.com
Panacol Elosol	www.panacol.com
Diemat	www.diemat.com

Connectors

ERNI	www.erni.com

Author: Claus Jäger, Andreas Stich

About Osram Opto Semiconductors

Osram Opto Semiconductors GmbH, Regensburg, is a wholly owned subsidiary of Osram GmbH, one of the world's three largest lamp manufacturers, and offers its customers a range of solutions based on semiconductor technology for lighting, sensor and visualisation applications. The company operates facilities in Regensburg (Germany), San José (USA) and Penang (Malaysia). Further information is available at www.osram-os.com.