OSRAM
Opto Semiconductors

OSRAM OSTAR® Stage Evaluation Kit

Application Guide

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A. Description

The OSRAM OSTAR® Stage Evaluation Kit provides customers a convenient way to assess the performance of the OSRAM OSTAR® Stage LED. The kit provides the LED mounted to a high-performance PCB technology, heat sink, color mixing optic, and wire harness for an easy connection to a driver system. This kit includes all the items necessary items in order to start an evaluation of the OSRAM OSTAR® Stage LED component. The kit (see Figure 1) contains a light engine and 2 wire harnesses.

Figure 1: Light engine

Light engine with wire harnesses

Light engine without wire harnesses

The kit is designed so that a user can connect their driver board or power supply directly to the individual anode/cathode of different color die within the OSRAM OSTAR® Stage LED. This provides the user the ability to independently control the 4 different color die of the LED. The kit acts as a reference design for engineers in making selections for key design elements such as the optic and PCB technology. In addition, the heat sink and PCB technology used in these kits allow the LEDs to be driven near their rated peak forward current values.

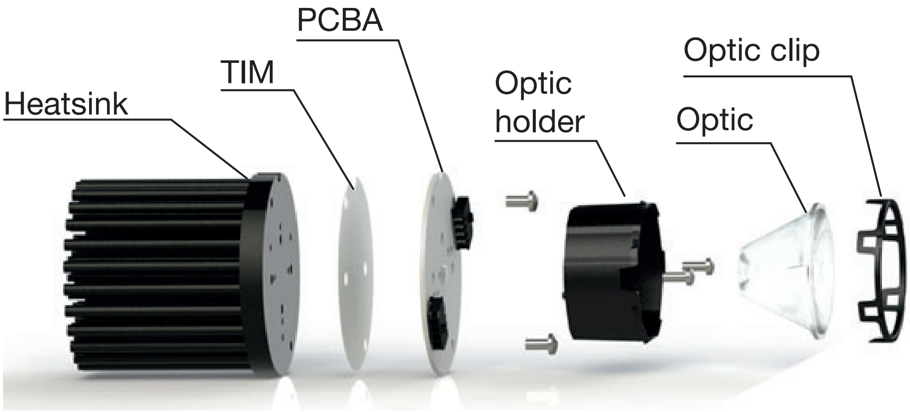
There are 3 variants of the kit available. Each variant uses a different OSRAM OSTAR® Stage LED. Table 1 provides a summary of the different kits available.

Table 1: Evaluation kit variants

Variant	Evaluation kit part number	Description
1	Demo_LE RTDUW S2WM_RGBW	20 W RGBW LED inside
2	Demo_LE RTDUW S2WN_RGBW	40 W RGBW LED inside
3	Demo_LE RTDCY S2WM_RGBA	40 W RGB Converted Yellow LED inside

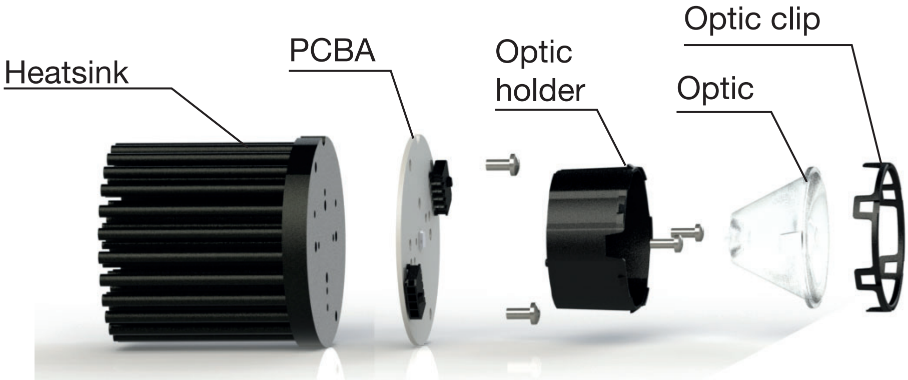
The different kit variants have slightly different assemblies. An exploded view of the light engine of the 20 W RGBW variant is shown in Figure 2. This light engine is comprised of a heat sink, thermal interface material, PCB assembly, optic holder, optic, optic clip, and mounting screws.

Figure 2: Exploded view of 20W RGBW kit



An exploded view of the light engine of the 40W RGBW and 40W RGWA variants is shown in Figure 3.

Figure 3: Exploded view of the 40W RGBW and RGBA kits



There are two primary differences between the 20 W and 40 W kits:

1. The PCB materials used are different between them.
2. The 20 W assembly uses a thermal interface material where the 40 W does not.

A summary of the key components used in the kits is shown in the Table 2 and 3.

Table 2: 20W RGBW kit components

#	Component	Description	Manufacturer	P/N
1	Heat sink	67mm Pin Style Black Anodized	Mechatronix	LPF6768-B-OST
2	PCB	FR-4 with Ceramic In-Lay	Rayben	MHE901
3	LED	20 W RGBW OSRAM OSTAR® Stage	OSRAM OS	LE RTDUW S2WM
4	Optic	45mm Color Mixing Optic with 10° FWHM Beam	Gaggione	LLC59C
5	TIM	Double sided adhesive, electrically insulating	HFC	HS060

Table 3: 40W RGBW and RGBA kit components

#	Component	Description	Manufacturer	P/N
1	Heat sink	67mm Pin Style Black Anodized	Mechatronix	LPF6768-B-OST
2	PCB	Copper substrate with direct connection to LED heat pad	Rayben	MHE301
3	LED	40 W RGBW OSRAM OSTAR® Stage	OSRAM OS	LE RTDUW S2WN or LE RTDCY S2WN
4	Optic	45mm Color Mixing Optic with 10° FWHM Beam	Gaggione	LLC59C

B. Connection, pinouts and identification

The OSRAM OSTAR® Stage Evaluation kit has two connectors on the light engine. One connector contains all the connections to anodes (+) of the LED and the other connector contains connections to the cathodes (-) of the LED. The pinout of the connectors will be different based which Evaluation Kit you have. To properly identify which kit you have, you can reference the kit indicator graphics on the light engine PCB assembly. See Figure 4 for where the kit markings are located on the PCB. Based on which circle is filled, you can identify which LED is populated on the PCB assembly by looking at the adjacent suffix of the LED part number. Table 4 explains this further.

Figure 4: Kit indicator and pinout markings

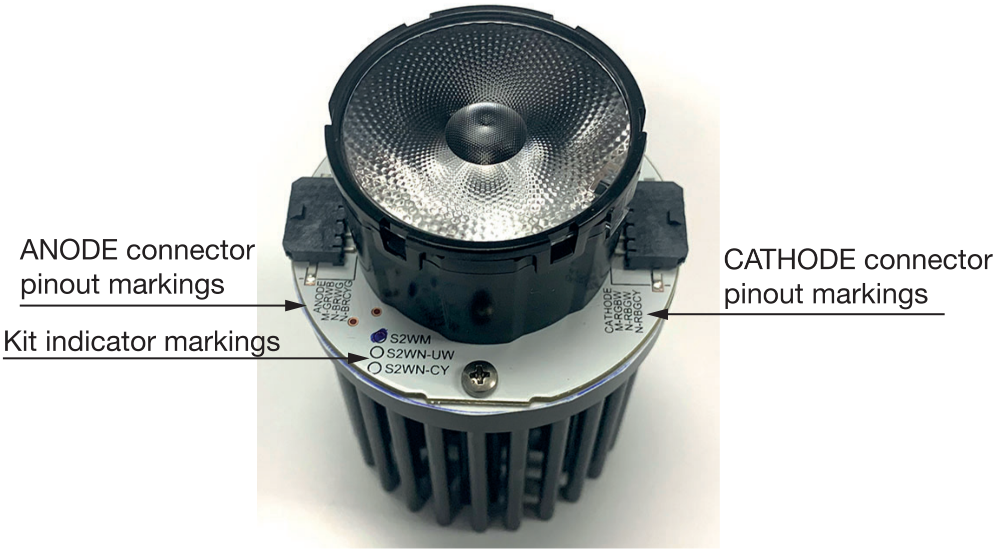
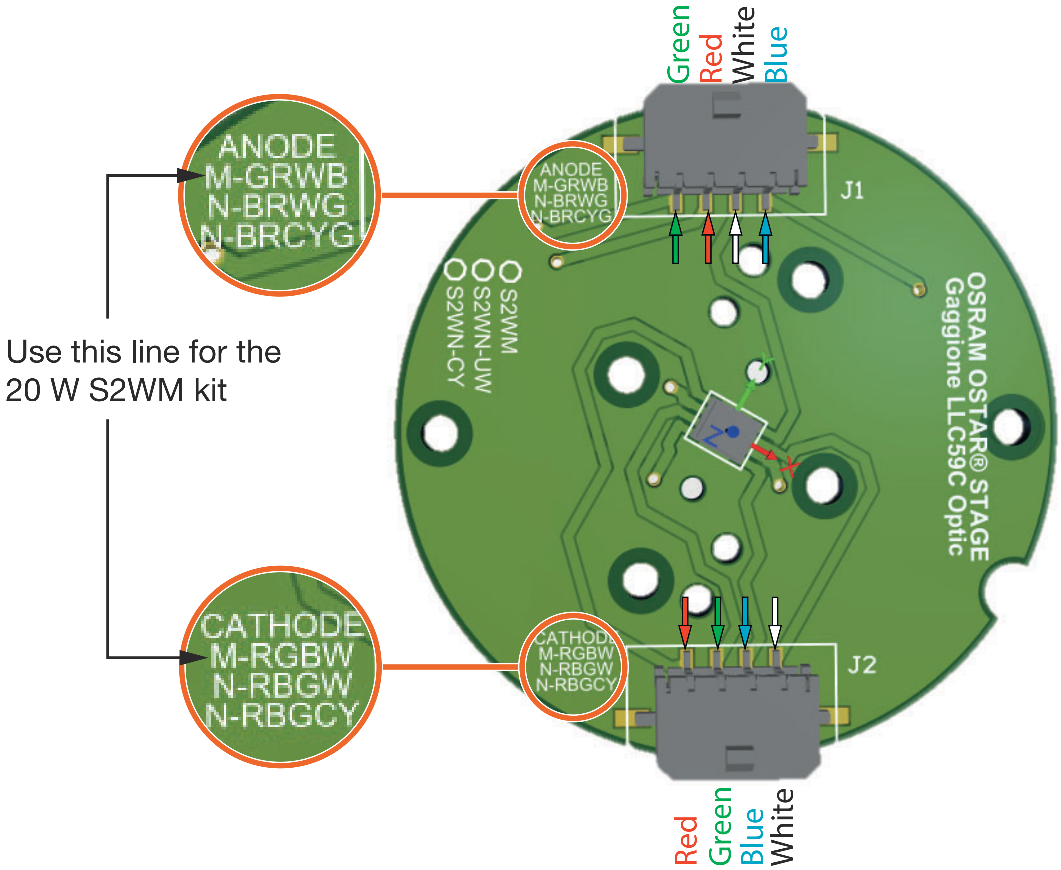


Table 4: Kit indicator markings

Indicator marking	Description
S2WM	This means the PCBA has the 20W RGBW LED installed
S2WN-UW	This means the PCBA has the 40W RGBW LED installed
S2WN-CY	This means the PCBA has the 40W RGBA LED installed

The light engine PCB assembly also indicates the pinout of the connectors based on which kit you have. Figure 4 identifies where you can find the ANODE and CATHODE connector pinout markings. The connector markings are arranged in a way that allows you to quickly identify which pin of the connector is connected to which die of the LED. The first letter denotes which power class you have. The M = 20 W and the N = 40 W. The next series of letters represent the pinout order. For the ANODE, M-GRWB label, the left most pin of the connector would be connected to the ANODE of the Green die, the next pin moving right would be connected to the ANODE of the Red die, the next pin would be connected to the ANODE of the White die, and the right most pin would be connected to the ANODE of the Blue die. Figure 4 below is an illustration of the PCB assembly that identifies the connector pinouts further as if you were to have the 20W RGBW S2WM kit variant.

Figure 5: Connector Pinout Markings



Use this line for the 20 W S2WM kit

The kit comes with wire harnesses; however, all the wires are black and are not color coded. Therefore, you need to take care to identify which wire is connected to which pin on the PCB assembly before connecting to your power supply or driver electronics.

The free ends of the wire harnesses already have a terminal crimped on to them. You can choose to either use the terminals with a compatible connector receptacle housing or you can simply cut the terminals off and strip the wires for a more generic connection option. Information regarding the connectors and wire harnesses is shown in Table 5 below.

Table 5: Connector and harness information

Item	Description	Manufacturer	Part number
J1, J2 PCBA connectors	3.0 mm male 4-Pin connector	Wurth Elektronik	662104145021
Mating harness connector	3.0 mm female 4-Pin receptacle housing	Wurth Elektronik	662004013322
Mating harness wires	3.0 mm pre-crimped cables, 20 AWG, 300 mm length Terminals used: 66200113722	Wurth Elektronik	662162120030

C. How to Use

This evaluation kit is intended to provide users a very easy way to get the OSRAM OSTAR® LED up and running with a color mixing optic and an appropriate heat sinking method. When driving the LED, it is important to understand the limits of the device. Table 6 below is a snapshot of the 3 different LEDs maximum DC forward drive currents.

Table 6: Maximum DC forward current

LED part number	Maximum DC forward current (mA)				
	Red	Green	Blue	White	CY or Amber
LE RTDUW S2WM	1000	1500	1500	1500	N/A
LE RTDUW S2WN	2500	3000	3000	3000	N/A
LE RTDCY S2WN	2500	3000	3000	N/A	3000

In order to properly drive the LEDs, you must have enough voltage to properly forward bias the LED. As LED forward voltage will change with current, it is important to have enough voltage at the LED in order to keep it properly forward biased. Table 7 below shows a snapshot of the forward voltage ranges of the different LEDs with respect to their binning current. As the current increases, so does the forward voltage of the LED. Please refer to the LED data sheet for details related to the performance characteristics.

Table 7: Forward voltage range

LED part number	Forward voltage range (V)				
	Red	Green	Blue	White	CY or Amber
LE RTDUW S2WM	2.10 - 2.90	2.80 - 4.00	2.70 - 3.70	2.70 - 3.70	N/A
LE RTDUW S2WN	1.85 - 2.80	3.00 - 4.10	2.70 - 3.40	2.70 - 3.40	N/A
LE RTDCY S2WN	1.85 - 2.80	3.00 - 4.10	2.70 - 3.40	N/A	2.70 - 3.40

It is recommended to drive these LEDs with a constant current source. A constant current source provides several advantages when driving an LED. Please refer to our Application Note “Dimming LEDs with respect to grouping current” which describes one of the advantages of using constant current with PWM for dimming LEDs. When using a constant current source, take care to set the voltage high enough to ensure proper forward bias of the LED. As a general guideline, you can take the maximum forward voltage value listed in Table 7 above and add 0.5 V to it to ensure proper forward bias across the forward current operating range.

When powering the device up for the first time, we recommend you try to drive each color independently at a forward current much lower than the maximum limit. For example, try using 350mA as a starting point. Observe that each color is working independently, and your driver or power supply is connected to the right wires of the kit. Once you confirm each color is operating properly, then you can start to mix the colors by activating different colors at the same time. The light is being projected out of the optic in a beam that is approximately 10° FWHM. If you point the kit towards a white wall, you should observe a nicely mixed color spot being projected onto the wall. If the wall is very close to the kit, then the colors may not be as well mixed. You need some distance between the optic and the wall you are shining it on to observe the well mixed colors.

D. Thermal Performance

The OSRAM OSTAR® Stage is a high-power multi-die LED component. The small package size, flat profile, and tight die placement allow for optimum color mixing and beam shaping applications such as stage lighting, architectural lighting, and entertainment lighting. With the high-power nature of this LED, thermal management is a key design element that needs proper attention. The LED component has been designed with a ceramic substrate in order to conduct heat away from the LED die efficiently. However, the LED alone cannot effectively dissipate the heat generated by the LED, therefore the system design needs to be considered. In this kit, several design elements have been implemented to aid in the thermal management of the LED. While this design is not the optimal design, it is effective and easy to implement. Furthermore, it provides the user with a reference for their system design choices.

Printed Circuit Board (PCB) Technology

The PCB is the first thermal interface that the LED has to the ambient air. Careful selection of the PCB material and stack-up is necessary when you want to drive high power LEDs.

The 20 W RGBW kit utilizes an FR-4 with ceramic in-lay PCB substrate. The PCB substrate is manufactured by Rayben, who specializes in high power PCB technology; the part number for this PCB substrate is MHE®901. The base of the board is FR-4, however, directly underneath the LED a ceramic block is inlaid to the FR-4 substrate. This provides a ceramic-to-ceramic interface (LED to PCB). The benefit of utilizing such an interface is to provide an good thermal conduction path from the LED to the PCB. In addition, the ceramic-to-ceramic interface provides reduced stress on the solder joint during thermal cycling as the Coefficient of Thermal Expansion will be similar between the LED substrate and the ceramic in-lay of the PCB. Since the substrate is FR-4 based and multi-layer, electrical vias can be implemented within the PCB for other electronic components. While IMS MCPCB (Insulated Metal Substrate Metal Core Printed Circuit Board) are widely found in high power LED applications, utilizing a multi-layer approach with electrical vias within the MCPCB is an expensive solution and not widely used. As an example, the 20 W RGBW kit has implemented the use of the multi-layer FR-4 substrate with electrical vias for some of the routing needs. One consideration to this approach is managing the backside PCB interface to the heat sink. In the case of the 20 W RGBW kit, there are exposed vias on the backside of the PCB, therefore, when connecting the PCB to a metal heatsink, you could cause a short circuit. In order to eliminate this situation, an electrically insulating thermal interface material has been used between the backside of the PCB and the heat sink. The drawback of this approach is the thermal conduction to the heatsink is now limited by the performance of the thermal interface material. On the other hand, one could remove the electrical vias from the PCB design and allow the PCB to make a direct connection to the heat sink.

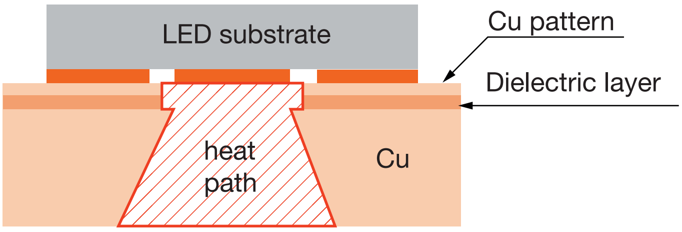
The 40 W RGBW and RGBA kits utilize a different PCB substrate from the 20 W RGBW kit. The 40 W kit utilizes a copper substrate PCB which has a direct connection to the heat pad of the LED. This provides a high thermal conductive path from the LED to the heat sink. Instead of using a ceramic material as in the 20 W kit, this kit uses copper as the primary heat transfer material. Typical AlN material has a thermal conductivity of ~170 W/mK whereas Cu material has a thermal conductivity of ~400 W/mK. This PCB substrate is also manufactured by Rayben and the part number for this substrate is MHE®301. A higher performing PCB was selected for the 40 W kits because the power is two times the 20 W kit.

A simple illustration of the two different PCB technologies is shown in Figure 6 below.

Figure 6: PCB Substrate Illustration

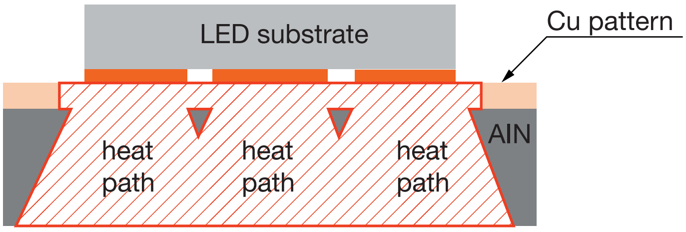
MHE®301

MHE®301 Layers:
- 1 sided PCB
- 70 µm Cu Top Layer
- 180 µm Dielectric Layer
- 1.25 mm Cu Base Layer
- Total Thickness = 1.5 mm
- Cu (400 W/mK)



MHE®901

MHE®901 Layers:
- 4-layer FR4 PCB
- 70 µm Cu Top Layer
- 70 µm Cu Middle Layers
- 1.5 mm FR4
- 70 µm Cu Bottom Layer
- Total Thickness = 1.65 mm
- AIN (170-200 W/mK)



Thermal Interface Material (TIM)

The thermal interface material used in the 20 W RGBW kit is the HS060 series from HFC. It is an electrically insulating, thermally conductive double-sided adhesive which is assembled between the PCB and the heatsink. As previously mentioned, the 40 W RGBW and RGBCY kits do not include a TIM layer.

Heatsink

The heat sink used in the all three kits is a 67 mm diameter black anodized pin cooler from MechaTronix. The heat sink can be purchased from MechaTronix in various mounting options. For these evaluation kits, we used the LPF6768 heat sink with custom holes drilled into it for our kit purposes.

Thermal Simulations

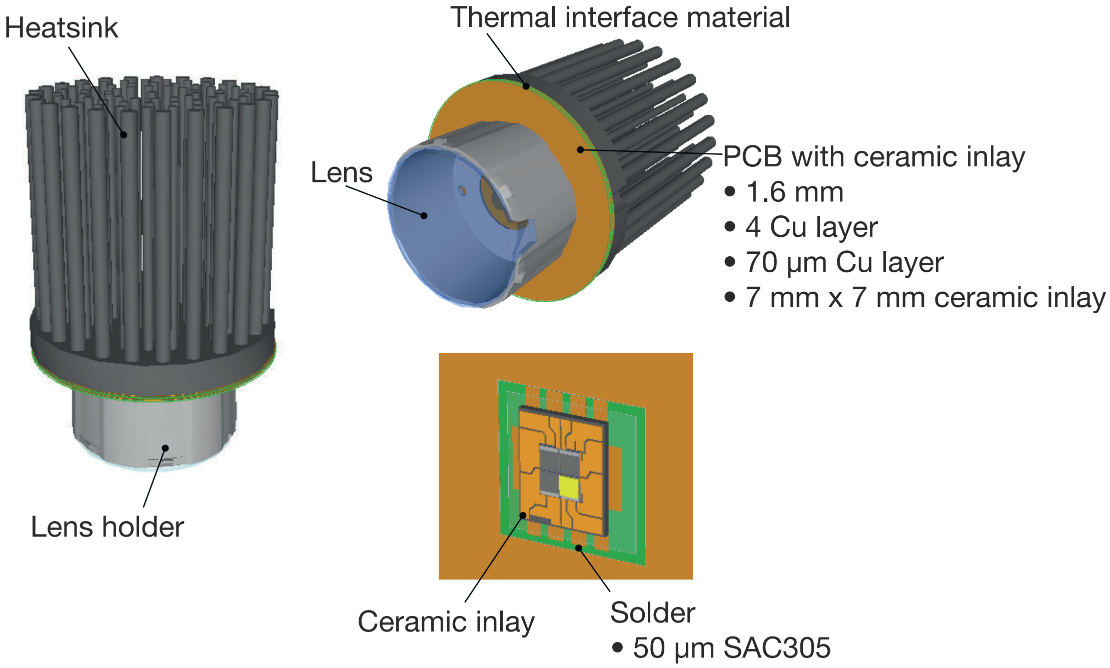
20 W RGBW Evaluation Kit:

A thermal simulation of the 20 W RGBW kit was executed to show the thermal performance under an example operating condition. The simulation setup used the following assumptions:

- Ambient air temperature = 25 °C
- All 4 LED die operating simultaneously at 1 A each
- Total heat power = 8.7 W
- Conjugate heat transfer and steady state operating
- The unit was mounted with the light pointing in a downward direction.
- All thermal interfaces between the LED and the ambient air were modeled in this simulation.

Figure 7 below shows the thermal simulation setup and conditions.

Figure 7: Thermal simulation setup 20 W RGBW kit

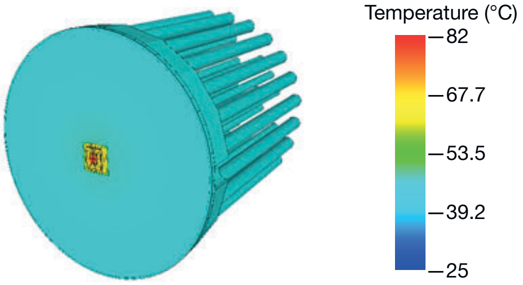


The simulation results show that the resultant LED junction temperature is under the rated maximum junction temperature of the LED. This means that you can operate all 4 die at 1 A simultaneously in a room temperature environment with no concerns related to heat. The results are shown in Figure 8.

Figure 8: Thermal simulation results 20 W RGBW kit

Junction temperature:

Red	T_J: 77.0 °C
True Green	T_J: 82.0 °C
Deep Blue	T_J: 77.5 °C
White	T_J: 76.6 °C

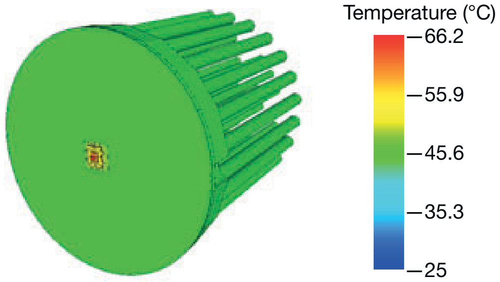


As it was discussed in the Printed Circuit Board section of this document, the PCB utilizes electrical vias for some of the electrical routing within the PCB. If the design of the PCB were to be changed, such that the electrical vias were removed and 0 ohm jumper resistors were used in lieu of the vias, then the PCB can make a direct connection to the heat sink. This would allow removal of the thermal interface material and create an even better path for the heat to flow away from the LED. As an example, a second thermal simulation was executed with the same conditions as previously noted, but the thermal interface material was removed. The results are shown in Figure 9.

Figure 9: Thermal simulation results 20 W RGBW kit without thermal interface material

Junction temperature:

Red	T_J: 61.3 °C
True Green	T_J: 66.2 °C
Deep Blue	T_J: 61.8 °C
White	T_J: 60.9 °C



You can observe that the resultant junction temperature is ~15 °C cooler than the design with the thermal interface material. You can also observe that the heatsink temperature is hotter in the second simulation; this is an indication that the heat is moving into and out of the heat sink in a more efficient manner then in the first simulation.

This information can be used as a reference when considering how to design your system using OSRAM OSTAR® Stage high-power LED components.

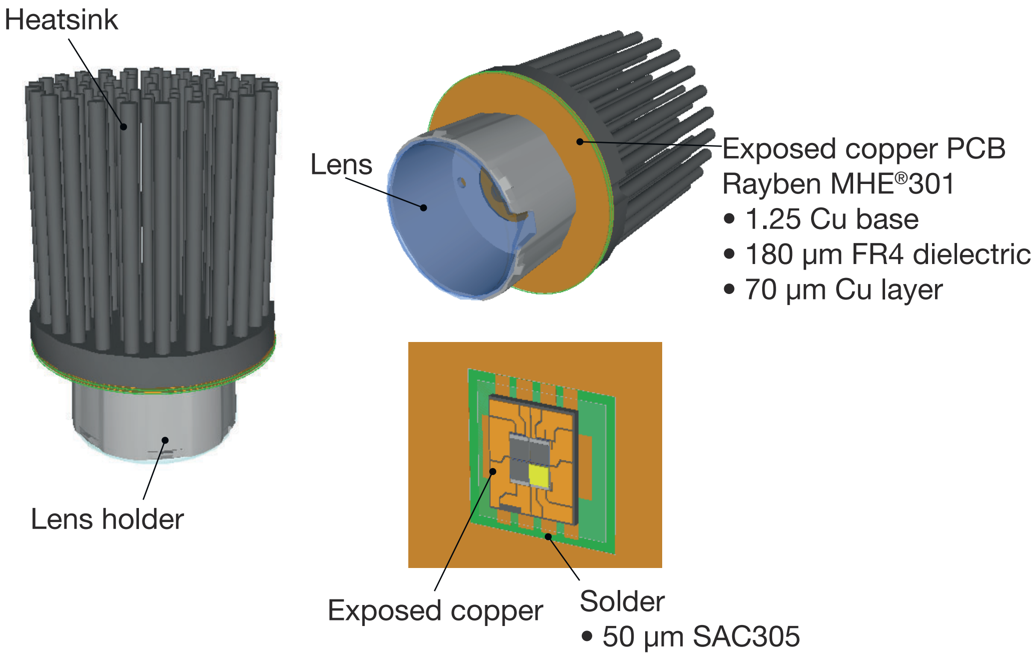
40 W RGBW Evaluation Kit:

A thermal simulation was also executed using the 40 W RGBW kit. The assumptions were as follows:

- Ambient air temperature = 25 °C
- All 4 LED die operating simultaneously at 2 A each
- Total heat power = 19.4 W
- Conjugate heat transfer and steady state operating
- The unit was mounted with the light pointing in a downward direction.
- All thermal interfaces between the LED and the ambient air were modeled in this

simulation

Figure 10: Thermal simulation setup 40 W RGBW kit

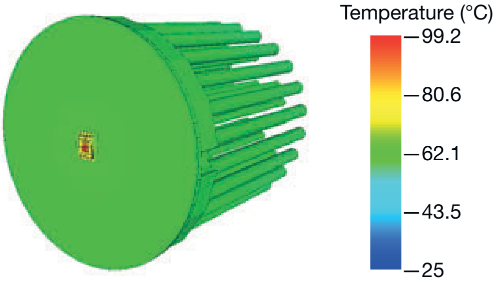


The simulation results show that the resultant LED junction temperature is under the rated maximum junction temperature of the LED. This means that you can operate all 4 die at 2 A simultaneously in a room temperature environment with no concerns related to heat. The results are shown in Figure 11

Figure 11: Thermal simulation results 40 W RGBW kit

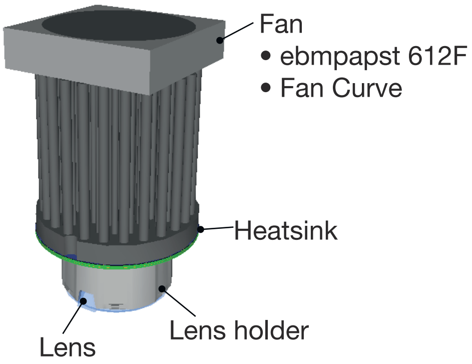
Junction temperature:

Red	T_J: 92.0 °C
True Green	T_J: 99.2 °C
Deep Blue	T_J: 90.2 °C
White	T_J: 93.0 °C



For some additional insight to operating this evaluation kit, we have included an additional analysis showing if there was some active cooling used. By utilizing a fan to force air across the heat sink, you can cool the LED even further. Figure 12 below shows the setup with a fan placed on the heat sink pushing air across it.

Figure 12: 40W RGBW thermal Simulation with fan



We have selected an operating point based on the fan's characteristics and used this as a basis for the simulation – see Figure 13 for the assumed operating point of the fan. The results of the simulation are shown in Figure 14.

Figure 13: Fan operating point

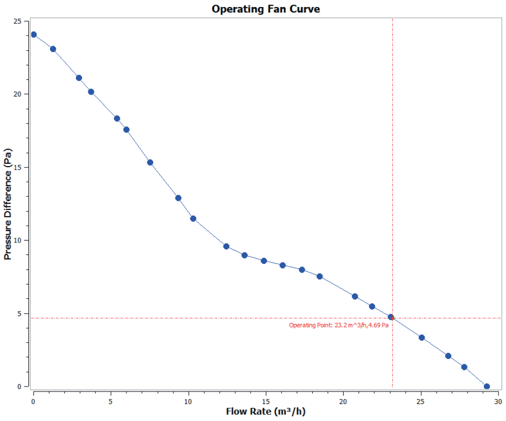
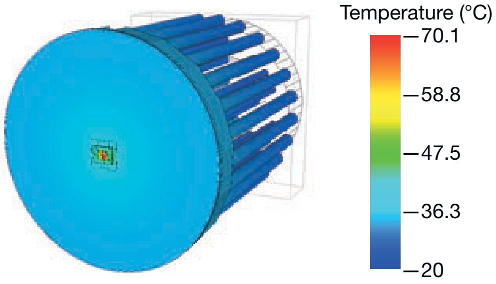


Figure 14: Thermal simulation results 40 W RGBW kit with fan

<u>Junction temperature:</u>

Red	T_J: 62.9 °C
True Green	T_J: 70.1 °C
Deep Blue	T_J: 61.2 °C
White	T_J: 64.0 °C



Additional simulations were conducted using the same setup to show some of the tradeoffs between the PCB technology, addition of TIM, and use of a fan. Table 8 summarizes the results.

Table 8: Thermal simulation summary

	20 W RGBW	**20 W RGBW**	**40 W RGBW**	**40 W RGBW**	**40 W RGBW**	**40 W RGBW**
P_{heat}	8.7 W	8.7 W	19.4 W	19.4 W	19.4 W	19.4 W
PCB	MHE®901	MHE®901	MHE®301	MHE®901	MHE®301	MHE®901
TIM	Yes	No	No	No	No	No
Fan	No	No	No	No	Yes	Yes
			Results			
Red T_J	76.9 °C	61.1 °C	92.0 °C	97.9 °C	62.9 °C	69.2 °C
Green T_J	81.5 °C	65.5 °C	99.2 °C	105.4 °C	70.1 °C	76.5 °C
Blue T_J	77.3 °C	61.4 °C	90.2 °C	96.2 °C	61.2 °C	67.6 °C
White T_J	76.3 °C	60.5 °C	93.0 °C	99.1 °C	64.0 °C	70.4 °C

Important observations can be made from the simulations:

1. By removing the TIM in the 20 W RGBW variants, the T_J of the LED can be reduced by 15 °C.
2. By moving from MHE®901 to MHE®301 in the 40 W RGBW variant, the T_J of the LED can be reduced by 6 °C
3. By applying a fan in the 40 W RGBW variant, the T_J of the LED can be reduced by 30 °C.

When designing your system using high power LEDs such as the OSRAM OSTAR® Stage, careful consideration of thermal management should be made. The lower you can keep the junction temperature of the LED, the more efficient the LED will be and the lifetime of the LED will be extended. When considering PCB options, it is easy to recognize that copper has a higher thermal conductivity than ceramic material; 400 W/mK vs 170 W/mK, so the copper material will be a better performer strictly in terms of thermal conduction. However, when selecting a PCB technology for your system, consideration should be made based on the cost, environmental requirements, and reliability in addition to the thermal performance. Utilization of PCB technologies with high thermal conductivity, such as the MHE®901 or MHE®301, should be considered.

E. Optics

All three kits come assembled with a 45 mm PMMA color mixing collimating optic from Gaggione. The optic is the LLC59C (see Figure 15) and the corresponding optic holder with clip is the LLH59SPB00. The LLC59C optic used in combination with the OSRAM OSTAR® Stage LED demonstrate an excellent color mixed beam in a 10° FWHM angle. You can achieve a high intensity beam that exhibits well mixed light on a surface. From a system design perspective, this gives customers an advantage from a cost and timing perspective as no custom optic development is needed.

Figure 15: LLC59C optic

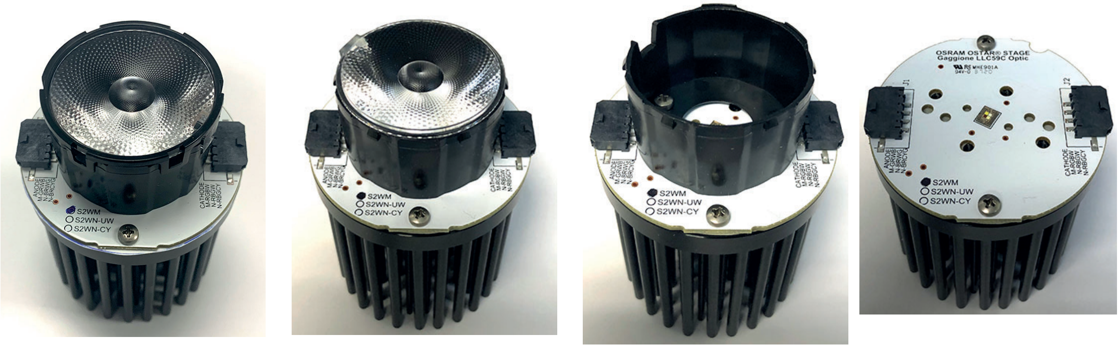
The light engines have also been designed to accept a smaller, alternate 32 mm color mixing optic, that is not included in the demo kit. The smaller optic is the Gaggione LLC25C, 32 mm color mixing optic (see Figure 16). The corresponding optic holder is the LLH02HEL. Please contact Gaggione in order to obtain samples of this optic and holder combination.

Figure 16: LLC25C optic

The smaller optic offers designers an alternate option for packaging while still getting good color mixing capability. In order to remove the existing 45 mm optic from the Evaluation Kit, you will need to follow 4 steps (see also Figure 17):

1. Remove the optic holding clip on the top of the optic
2. Remove the optic out of the holder by gently lifting it out of the holder
3. Remove the 2 screws that are holding the optic holder to the light engine
4. Remove the optic holder from the light engine

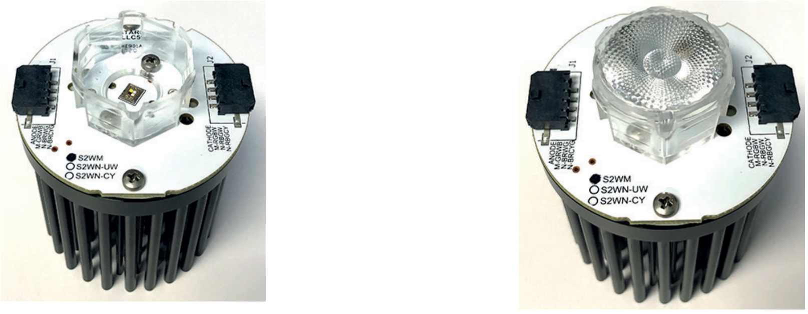
Figure 17: Removing the existing 45 mm optic from the Evaluation Kit



20 W RGBW Kit Optic clip removed Optic removed Optic holder removed

To mount the new optic and holder, simply place the new holder on top of the light engine and find the corresponding alignment and screw holes. Screw the holder into the light engine in the two available holes and then snap the optic into place within the holder. The holder is keyed so that optic can only go in one way. Figure 18 shows the mounting of the new optic and holder.

Figure 18: Mounting the new holder to the Evaluation Kit



LLC25C optic holder installed LLC25C optic installed

F. Summary

This kit provides you with information to help you with your success in using the OSRAM OSTAR® Stage LED component in your application. It provides:

- Easy connectivity between your driver and the LED component for fast time to evaluation
- Compatible heat sink which allows you to operate the device under high power conditions
- A compatible color mixing optic and a reference to a second color mixing optic
- High power PCB technology options
- Thermal performance analysis

The optical performance of this kit will be dependent on your operating conditions and any additional system impacts (i.e. fans, enclosures, additional electronic components, etc.). Figure 19 shows some example pictures of the kit in operation.

Figure 19: Example pictures of the kit in operation