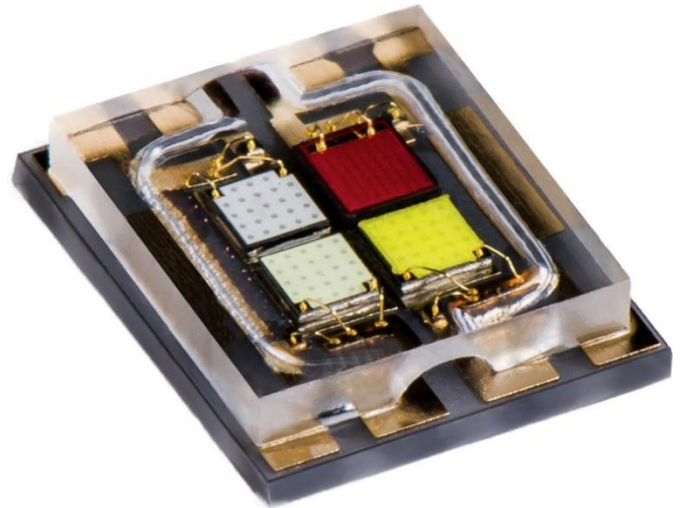


# Thermal Cross-Talk in Multi-Chip LED Packages



Designers using LEDs have to balance, among other factors, the lumen output of the LED and its lifetime. The two factors usually counteract each other—increased lumen output, achieved by increasing drive current, results in increased junction temperature ( $T_j$ ), which reduces lifetime. The median lifetime of an LED is dependent on  $T_j$ —typically, for a 10,000-hour median lifetime, the  $T_j$  of Blue, Green and White LEDs have to be 150 °C or lower, while the  $T_j$  of Red LEDs, because of their increased temperature sensitivity, should be maintained at 110 °C or lower. Additionally, flux, dominant wavelength and forward voltage are all parameters that vary with  $T_j$ . The significant impact of  $T_j$  on an LED’s lifetime and reliable operation thus necessitates its accurate determination.

In an individually addressable multi-chip module, the  $T_j$  of any chip is affected by both the power dissipated by the chip and the power dissipated by adjacent chips—both contributions have to be accounted for to accurately determine  $T_j$ . Multi-chip module such as the SBM-40 possesses individually addressable red, green, blue and white chips and allow the option of driving the chips individually, in combinations of 2 or 3, or all four simultaneously. When multiple chips are driven simultaneously, the rise in  $T_j$  of any individual chip is the sum of two components: the rise in  $T_j$  of the chip due to its drive current, and the rise in  $T_j$  due to the power dissipated by adjacent chips—a phenomenon known as thermal cross-talk. In such cases, a thermal cross-talk matrix is used to determine  $T_j$ . This application note illustrates the determination of  $T_j$  of any chip in the SBM-40 using the thermal cross-talk matrix; familiarity with the contents of “Thermal Management of Big Chip LEDs”, a Luminus Devices application note that describes the relationship between electrical power in, optical power out and the temperature at various points in the LED package is assumed.

Figure 1 depicts the cross-section of a multi-chip module mounted on an aluminum coreboard. Also shown are the temperatures of the junction ( $T_j$ ), case or substrate ( $T_c$ ), coreboard ( $T_b$ ), heat-sink ( $T_{hs}$ ) and thermistor ( $T_{ref}$ ). The junction temperature of any individual chip is calculated as follows:

1. The reference temperature ( $T_{ref}$ ) of the aluminum coreboard is first determined by the thermistor read-out.
2. The temperature rise from the thermistor to the ceramic substrate ( $T_c$ ) is the product of the thermistor-substrate thermal resistance ( $R_{\theta c-ref}$ ) and the total power dissipated by all the chips in the package.

$$\text{Temperature rise} = \{\sum P_a (1 - \eta_{rad,a})\} \times R_{\theta c-ref} \quad (1)$$

where a is R, G, B or W;  $P_a$  is the input power to an individual chip and  $\eta_a$  is the radiometric efficiency of the chip and takes into account the fraction of the input power that is converted to light.

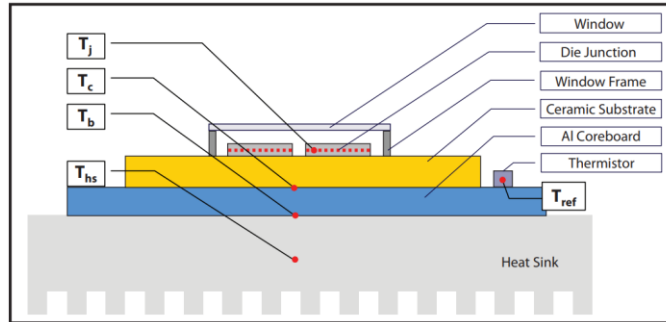


Figure 1: Cross-section of a multi-chip module mounted on an aluminum coreboard.

Note that, while Figure 1 shows a typical arrangement, the choice of coreboard, the location of the thermistor, and the solder used to mount the SBM-40 to the coreboard lies with the user, thus  $R_{\theta c-ref}$  is a reflection of those choices and can differ from the value listed in the SBM-40 data-sheet.

3. The temperature rise from the substrate to the junction of a chip is given by the product of two matrices as shown below—the thermal cross-talk matrix and the power dissipated by the chip.  $T_j$  rise for the SBM-40 is given by:

$$\begin{bmatrix} \Delta T_{jR} \\ \Delta T_{jG} \\ \Delta T_{jB} \\ \Delta T_{jW} \end{bmatrix} = \begin{bmatrix} 4.1 & 1.45 & 1.3 & 1.6 \\ 1.25 & 7.25 & 1.25 & 1.6 \\ 1.6 & 1.4 & 4.72 & 1.1 \\ 1.25 & 1.41 & 0.8 & 5.6 \end{bmatrix} \begin{bmatrix} P_R \times (1 - \eta_{rad,R}) \\ P_G \times (1 - \eta_{rad,G}) \\ P_B \times (1 - \eta_{rad,B}) \\ P_W \times (1 - \eta_{rad,W}) \end{bmatrix}$$

Actual junction temperature ( $T_{ja}$ ) of any chip in the SBM-40 is the sum of reference temperature ( $T_{ref}$ ), temperature gradient from reference to case  $\{\sum P_a (1 - \eta_{rad,a})\} \times R_{\theta c-ref}$  and temperature rise from case to junction ( $\Delta T_{ja}$ ).

$$T_{ja} = T_{ref} + \{\sum P_a (1 - \eta_{rad,a})\} \times R_{\theta c-ref} + \Delta T_{ja} \tag{2}$$

where a is R, G, B or W;  $P_a$  is the input power to an individual chip and  $\eta_a$  is the radiometric efficiency of the chip.

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