LUXEON Rubix

AB309C Thermal Design Guideline

LUMILEDS

Introduction

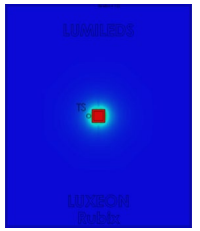
- The AB309C application note discusses the thermal considerations necessary when operating the LUXEON Rubix up to max DC Rated current.
  - PCB design, assembly (thermal stack up) and operating ambient condition are important factors for consideration.

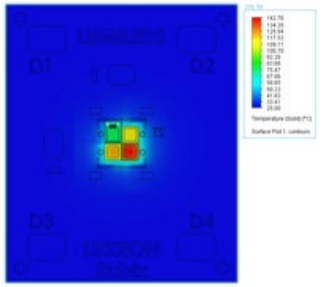
- In this guideline, three types of PCB designs are simulated.
  - Al-MCPCB (**standard**) 1.6mm thick, 2oz copper, dielectric thermal conductivity of 2$Wm^{-1}K^{-1}$ 100µm thick. This is a standard Al-MCPCB that is widely available.
  - Al-MCPCB (**premium**) 1.6mm thick, 2oz copper, dielectric thermal conductivity of 3$Wm^{-1}K^{-1}$ 38µm thick. For example, Bergquist HPL-03015.
  - Aluminum nitride (AlN) ceramic 1mm thick, 2oz copper, thermal conductivity of 170 $Wm^{-1}K^{-1}$. For example, Maruwa AlN AN-170 substrate.

- To further improve the thermal stack-up, Hitherm HT-2505 thermal interface material (TIM) with 127µm thick, 16$Wm^{-1}K^{-1}$ through-plane thermal conductivity is used between PCB and heat sink.

- Derating curves and typical Rth tables are provided.

Simulation Setup Assumptions



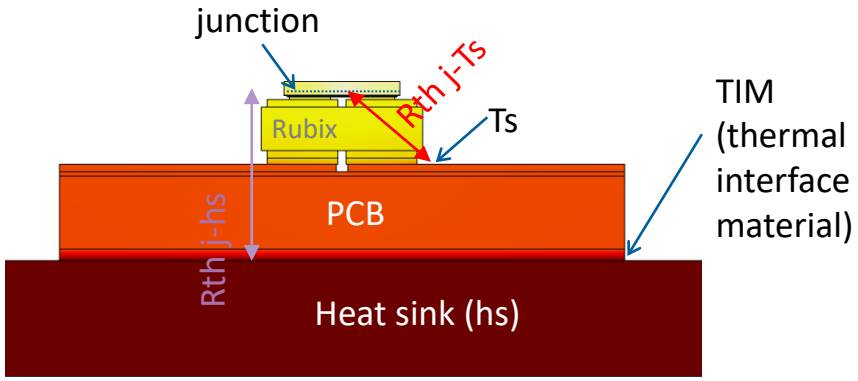


- Two scenarios with three PCB designs
  - 4-up board layout consisting of one LUXEON Rubix red, green, blue and white LEDs (LED spacing – 100um) and
  - 1-up board layout are investigated.
- The board is secured to a heatsink maintained at 25˚C.
  - Both ambient (air) and heatsink are always at 25˚C
- Run thermal simulation conditions as shown in table below. This provides boundary operating limits in interpolating the junction temperature.
- Typical LUXEON Rubix Vf at 1.5A, 85˚C are used.

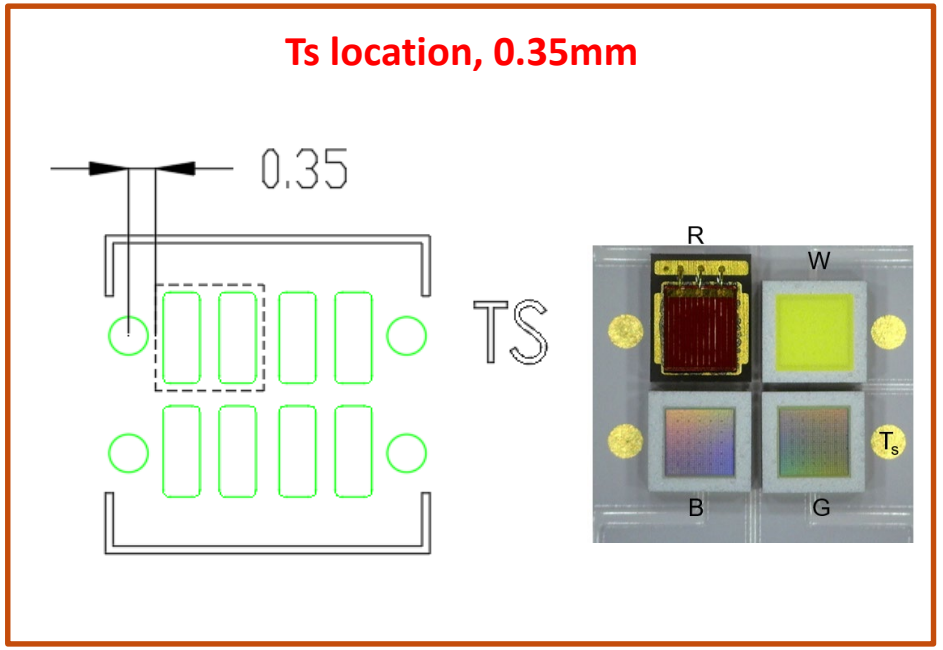
PCB Designs	4-on (4-up)		1-up	
	R, G, B, W 1.5A ea	G, B, W 3A ea, R at 2.2A	1.5A	2.2A/3.0A
Al-MCPCB, 2$Wm^{-1}K^{-1}$, 100µm (standard)	✓	✓	✓	✓
Al-MCPCB, 3$Wm^{-1}K^{-1}$, 38µm (premium)	✓	✓	✓	✓
AlN 1mm	✓	✓	✓	✓

Rth and Ts Definition

- Definition of Rth parameters:
  - Rth j-Ts: refers to thermal resistance from junction to Ts point which is located at 0.35mm away from the edge of LUXEON Rubix package
  - Rth j-hs: refers to thermal resistance from junction to heat sink[1]



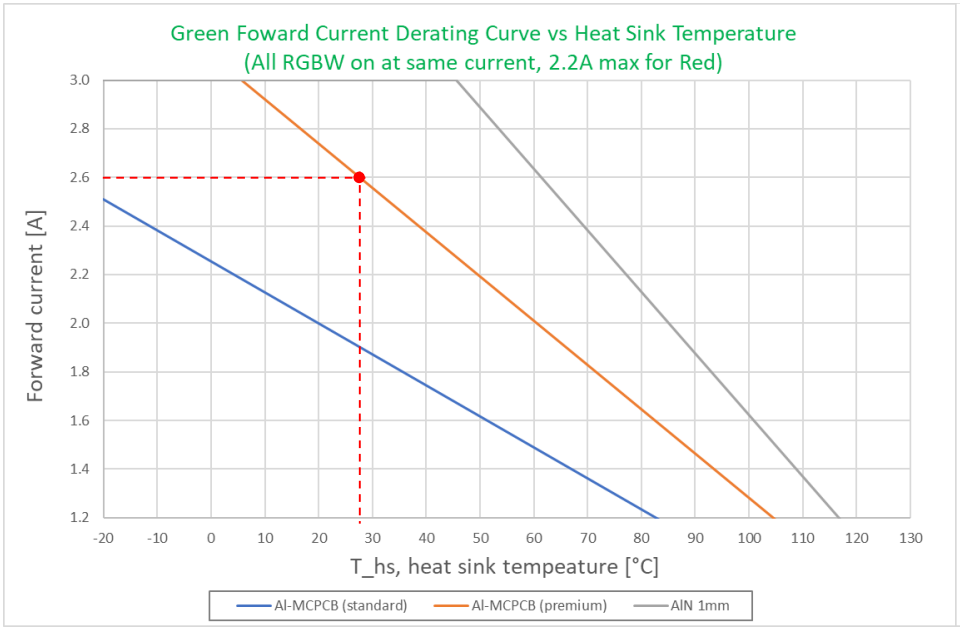
Cross section of the thermal stack

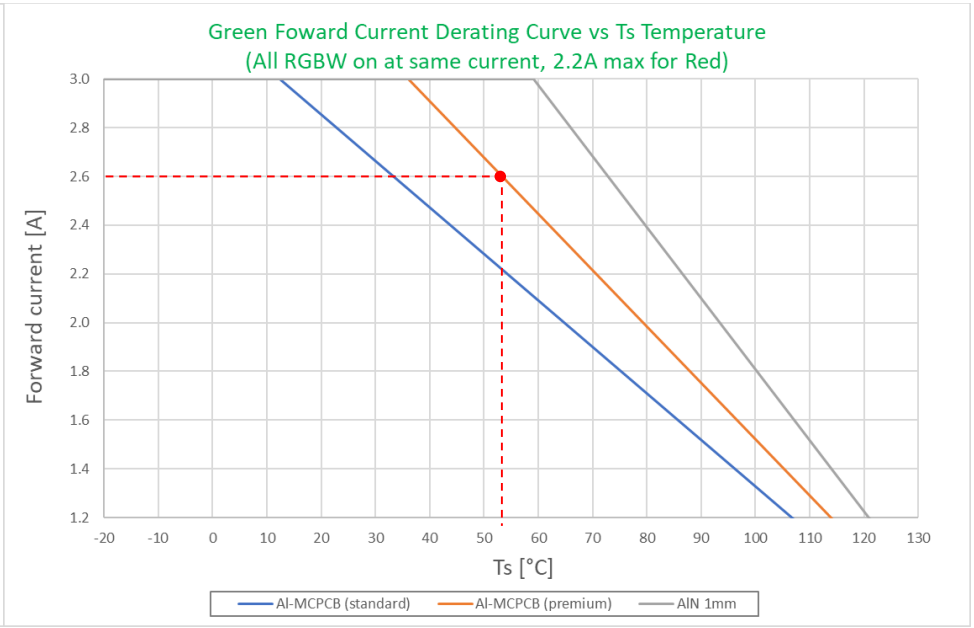


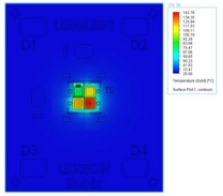
[1] In reality, the heat sink temperature varies spatially depending on the geometry unlike Ts which is defined at a fixed location on the PCB

Derating Curves Results

Derating Curve for the 3 PCB Boards in 4-up RGBW Configuration, $T_{jmax\ GREEN}$ = 150°C





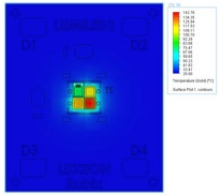


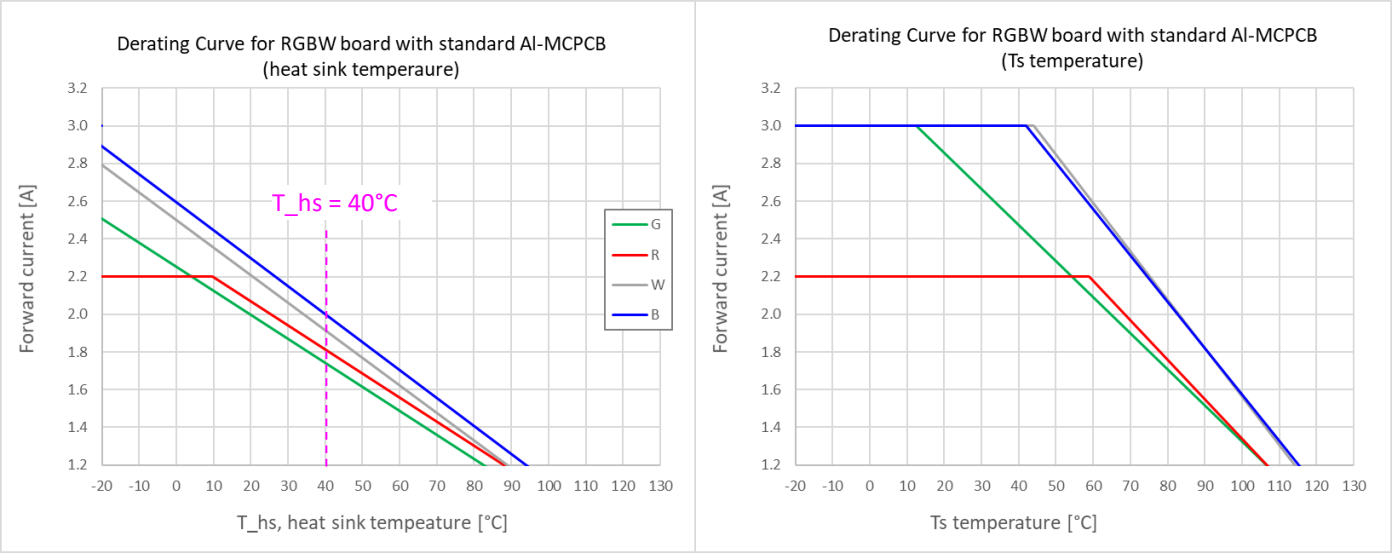
For example, using premium Al-MCPCB in RGBW configuration, one can operate the green at 2.6A with heatsink temperature of 27°C or Ts temperature of 53°C, when operating the remainder colors at 2.6A and red at 2.2A (limited by datasheet)

- Clearly the AlN board allows the highest forward current operation and the highest heatsink or Ts temperature, follows by premium and standard Al-MCPCB.

Derating Curves for each Colors in RGBW Configuration with Standard Al-MCPCB , T_{Jmax} = 150°C

In RGBW configuration with each colors operating at the same current (red limited at 2.2A). Green is the limiting factor.

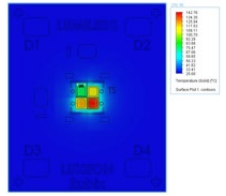


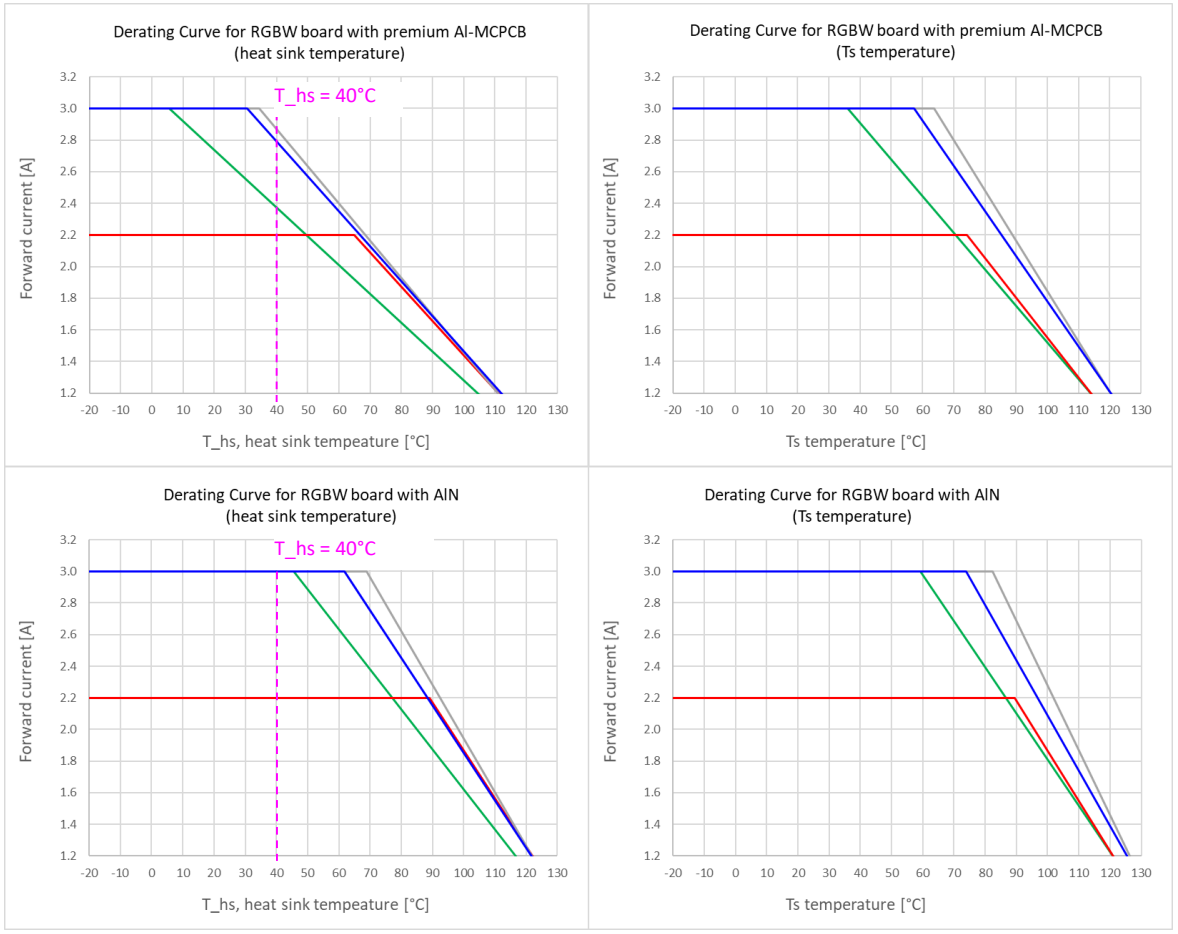


For illustration purpose, at 40°C heat sink temperature, green can be operated at about 1.7A, red at 1.8A, white at 1.9A and blue at 2.0A with standard Al-MCPCB. **We recommend measuring the Ts temperature as this location is clearly defined while heat sink temperature varies spatially depending on the heat sink geometry. See "Typical Rth Table" for typical thermal resistance values to use when doing thermal calculations.**

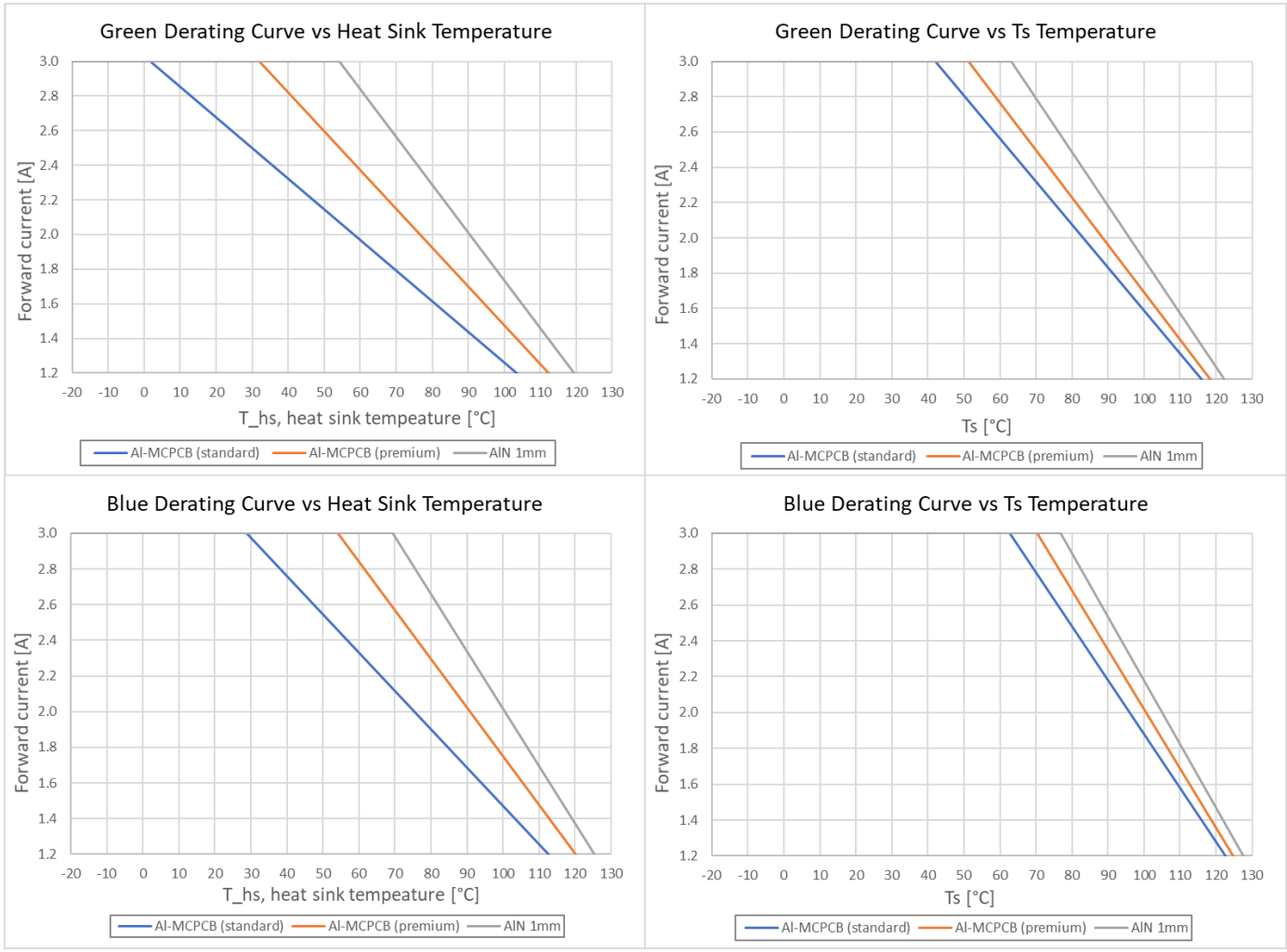
Derating Curves for each Colors in RGBW Configuration with Premium Al-MCPCB and AlN Boards

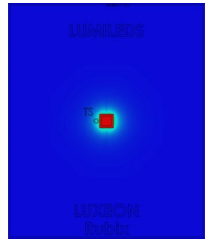
With AlN board, if heat sink temperature is kept at 40°C, can run all colors at max current.



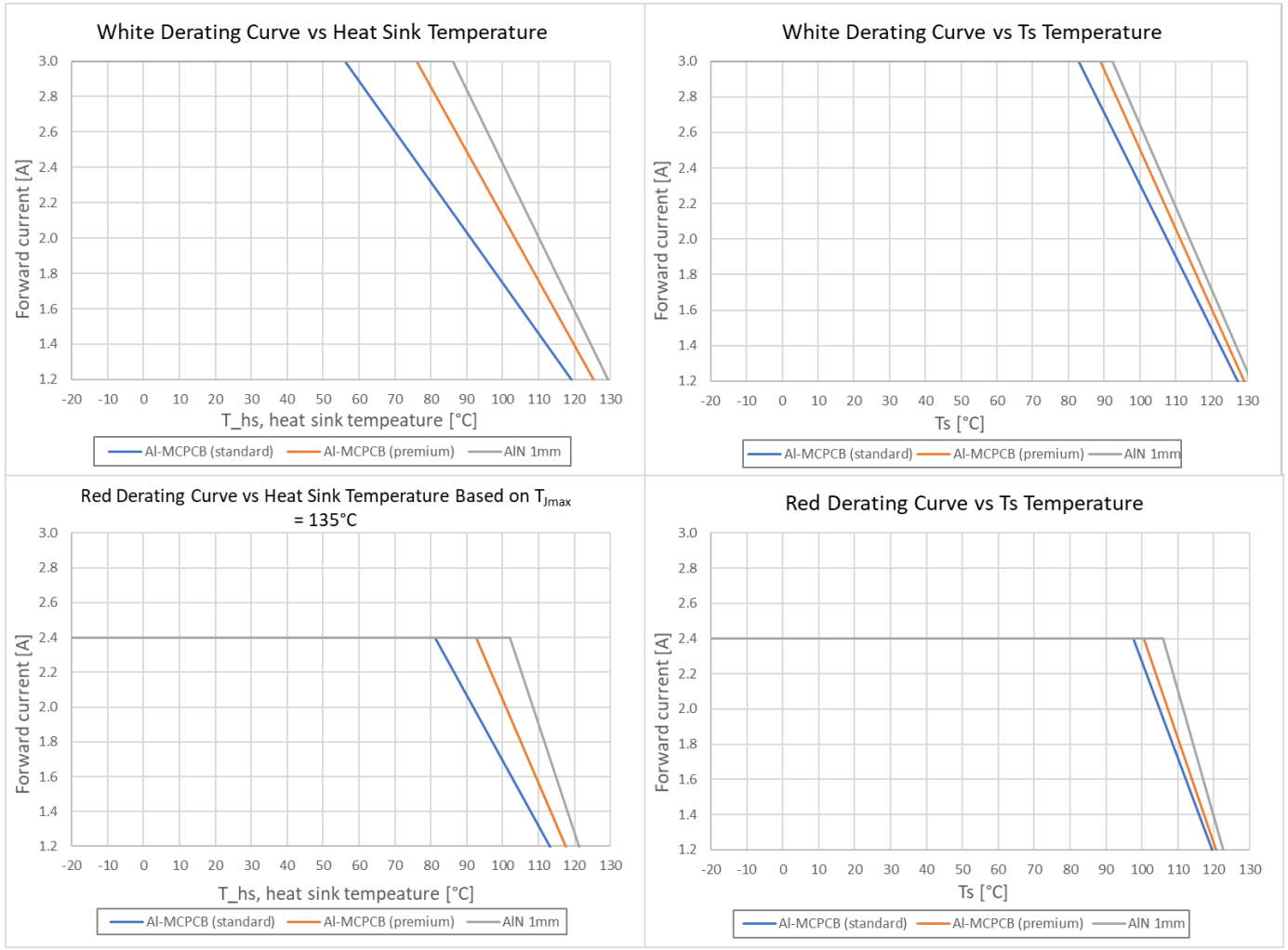


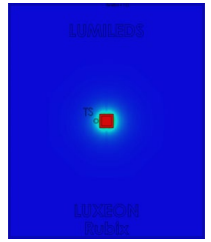
Green & Blue Derating Curve for 1-up Board, $T_{J\ max}$ = 150°C



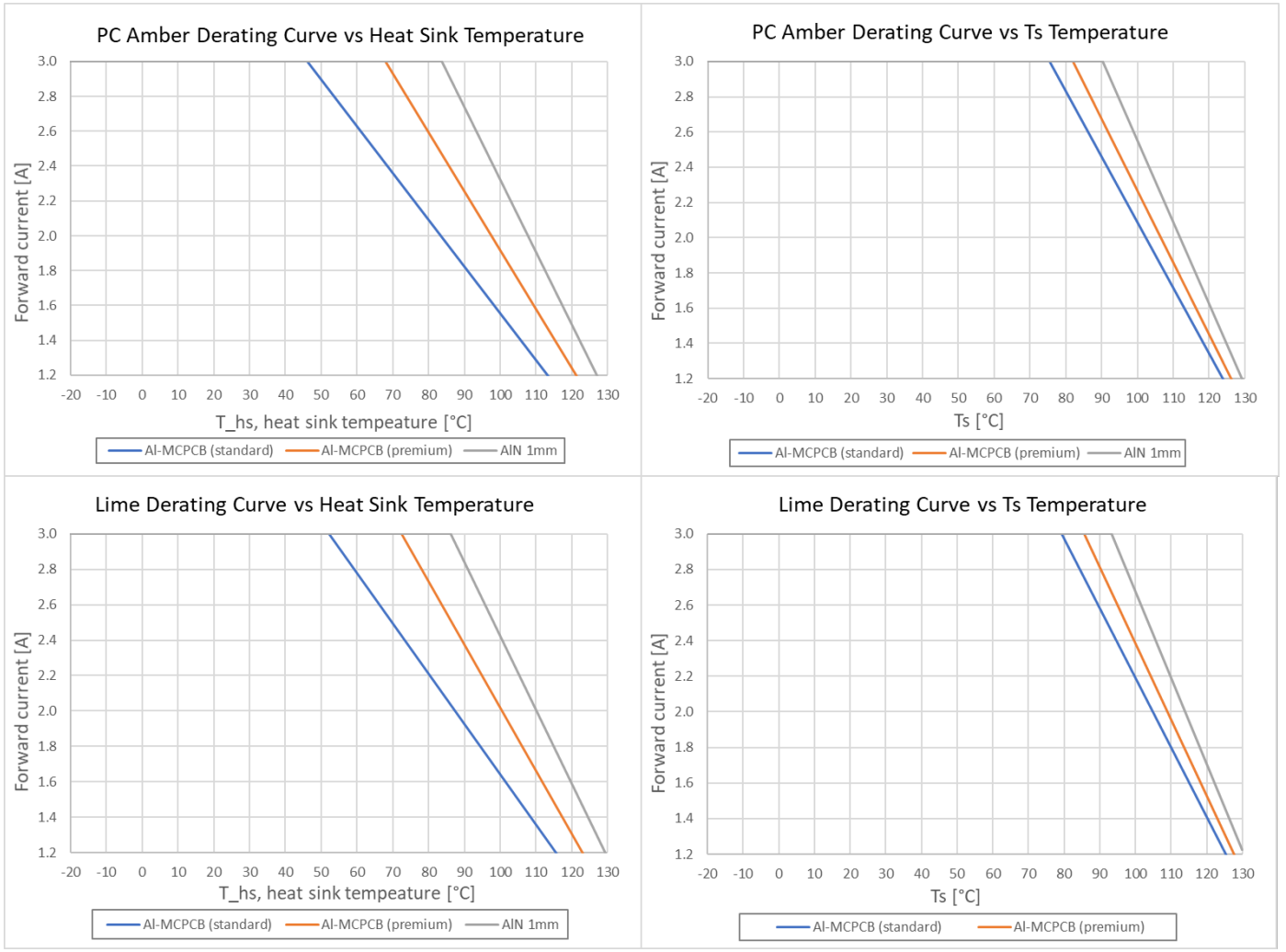


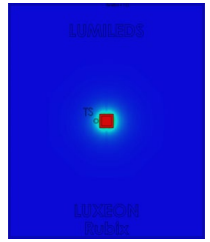
White & Red Derating Curve for 1-up Board, Red T_{Jmax} = 135°C



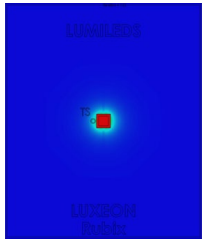


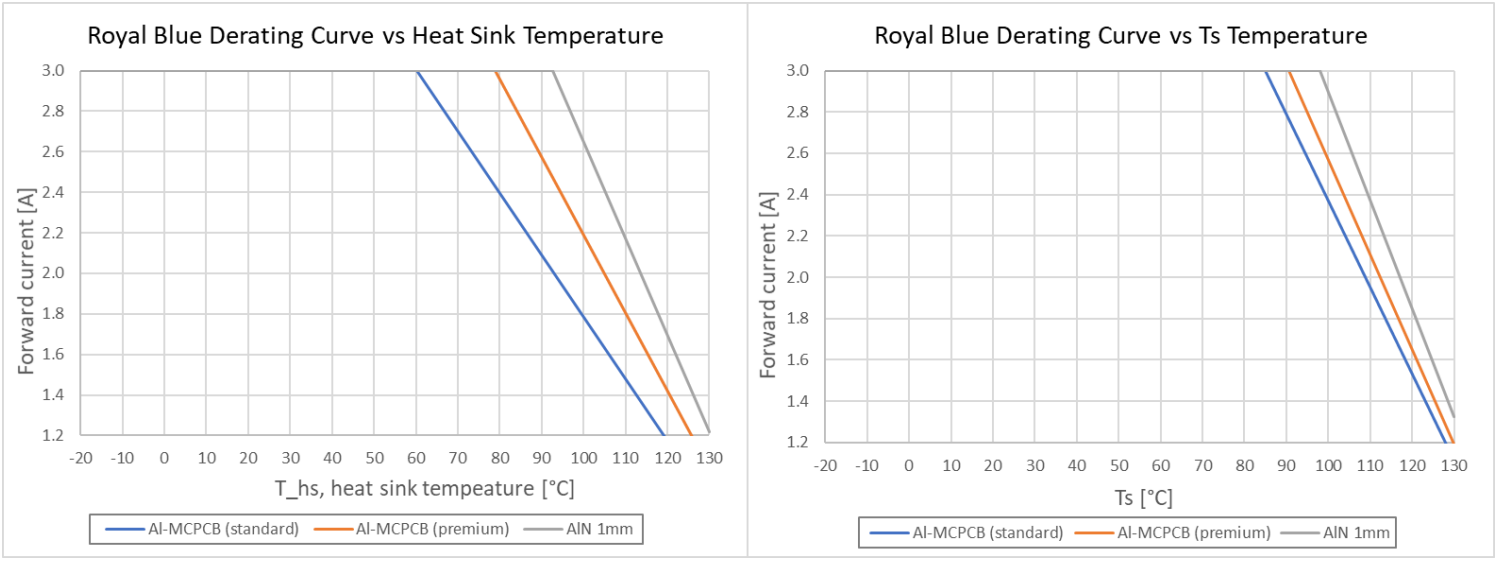
PC Amber and Lime Derating Curve for 1-up Board, $T_{J\ max}$ = 150°C





Royal Blue Derating Curve for 1-up Board, $T_{J\ max}$ = 150°C





Discussion and General Recommendations

- LUXEON Rubix Green is the limiting factor as it has the lowest typical wall plug efficiency (WPE) and thus generating the most heat at the same drive current as the rest of the colors. This limitation should be considered first in any thermal design.
- Other factors that can affect the derating curves shown here are:
  - LUXEON Rubix Vf
  - Improper TIM mounting
  - Solder void
  - Insufficient PCB copper trace width, causing resistive heating
  - Ts measurement (see below)
- When attaching thermocouple (TC) wire to the Ts point, it is important to put the soldered tip of the TC wire as close as possible to the LUXEON Rubix package and with direct contact to the PCB top copper layer. If the TC tip is placed far away (exceeding 0.35mm as recommended here), the Ts temperature recorded will be lower and thus underestimate the junction temperature.
- To keep heat sink temperature to the required target, active cooling of the heat sink such as forced air convection (with fan) or liquid cooling should be considered.

Typical Rth Tables

Electrical versus Heat Resistance Definition

Recap:

$$\text{Electrical Rth} = \frac{\Delta\, temperature}{P_{electrical}}$$

$$\text{Heat Rth} = \frac{\Delta\, temperature}{P_{heat}}$$

Where $P_{electrical}$ is the LED electrical power input (If_{LED} x Vf_{LED})

P_{heat} = $P_{electrical}$ x (1 – WPE), WPE = LED wall plug efficiency in %

Simulated 4-up, RGBW Electrical Rth j-Ts and Rth j-hs

- Based on RGBW configuration and LUXEON Rubix typical Vf as described.

PCB Designs	RGBW: Simulated Rth j-Ts electrical [K/W]							
	R		W		B		G	
	1.5A	2.2A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A
Al-MCPCB standard	8.5	9.5	8.3	8.8	8.4	8.6	10.5	10.7
Al-MCPCB premium	6.8	7.3	6.9	7.2	7.2	7.4	8.7	8.9
AlN 1mm	5.4	5.7	5.5	5.6	5.9	6.1	7.0	7.1

PCB Designs	RGBW: Simulated Rth j-hs electrical at 25°C heat sink [K/W]							
	R		W		B		G	
	1.5A	2.2A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A
Al-MCPCB standard	14.8	17.0	14.3	15.3	13.6	14.1	16.3	16.9
Al-MCPCB premium	9.2	10.2	9.1	9.6	9.2	9.5	11.0	11.3
AlN 1mm	6.6	7.3	6.5	6.7	6.9	7.0	8.0	8.1

Simulated 1-up Electrical Rth j-Ts and Rth j-hs

- 1-up configuration operating at the drive current indicated
- Assume LUXEON Rubix typical Vf at 1.5A, 85˚C binning condition

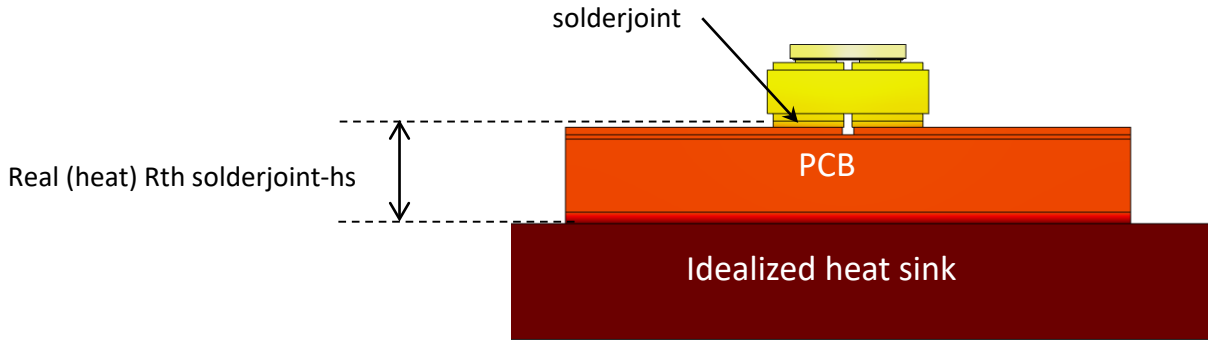
Description	1-up: Simulated Rth j-Ts [K/W]													
	R		W		B		G		RB		PCA		Lime	
	1.5A	2.2A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A
Al-MCPCB, 3Wm-1K-1, 38µm, 1-up board	5.7	5.8	5.9	6.0	6.4	6.6	7.6	7.7	5.7	5.9	6.8	7.0	6.4	6.5
Al-MCPCB, 2Wm-1K-1, 100µm, 1-up board	6.1	6.2	6.4	6.6	6.9	7.2	8.3	8.4	6.2	6.5	7.5	7.7	6.9	7.2
AlN 1mm, 1-up board	4.8	4.9	5.3	5.7	5.7	6.0	6.7	6.8	5.1	5.2	6.0	6.2	5.6	5.7

Description	1-up: Simulated Rth j-hs at 25°C heat sink [K/W]													
	R		W		B		G		RB		PCA		Lime	
	1.5A	2.2A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A	1.5A	3.0A
Al-MCPCB, 3Wm-1K-1, 38µm, 1-up board	6.9	7.1	7.0	7.3	7.6	7.9	9.1	9.2	6.7	7.1	8.2	8.4	7.6	7.8
Al-MCPCB, 2Wm-1K-1, 100µm, 1-up board	8.7	8.9	8.8	9.3	9.4	10.0	11.3	11.6	8.3	8.9	10.2	10.7	9.5	9.9
AlN 1mm, 1-up board	5.4	5.5	5.9	6.3	6.2	6.6	7.4	7.5	5.5	5.7	6.7	6.8	6.2	6.4

Simulated 4-up RGBW Real (Heat) Rth solderjoint-hs

Description	RGBW: Simulated real (heat) Rth solderjoint[1]-hs at 25°C heat sink [K/W]			
	R	W	B	G
Al-MCPCB standard	15.3	14.2	11.8	12.2
Al-MCPCB premium	7.5	7.0	6.1	6.3
AlN 1mm	4.1	3.4	3.1	2.9

[1] SAC305



- This information is provided to estimate the 4-up RGBW real (heat) Rth of the PCB system consisting of SAC305 solder with HT-2505 TIM.
- One can then consider a suitable heatsink such as Mechatronics Moduled Giga 15250-B with 0.7 K/W thermal resistance to determine if the solution works.
- For example: RGWB at 2.0A operation with Al-MCPCB premium has Rth solderjoint-hs = 6.3 K/W for green. Enter this value into the Lumileds Design Tools LED System Calculator in the field “Rth pad – heat sink”. Let’s assume the Rth of Mechatronics 15250-B heat sink to ambient = 0.7 K/W. So enter this value in the field “Rth heat sink – ambient”. Note: The Rth from heat sink to ambient which can be affected by system orientation in air, forced air cooling, etc. Consult with heat sink manufacturer on further details.

Simulated 1-up Real (Heat) Rth solderjoint-hs

Description	1-up: Simulated real (heat) Rth solderjoint[1]-hs at 25°C heat sink [K/W]
	R/G/B/W/RB/PCA/Lime
Al-MCPCB standard	6.6
Al-MCPCB premium	4.1
AlN 1mm	2.2

[1] SAC305