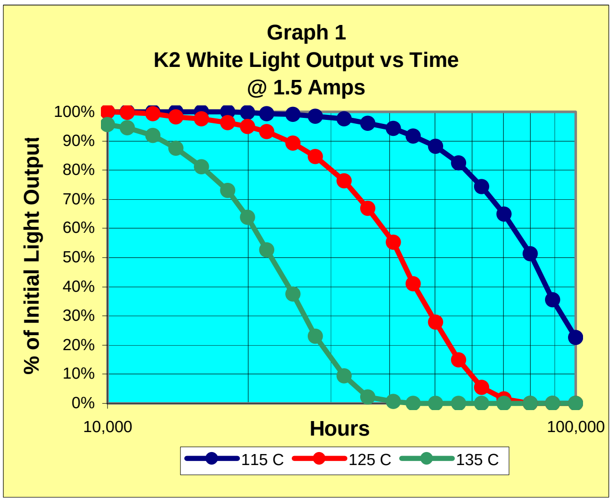
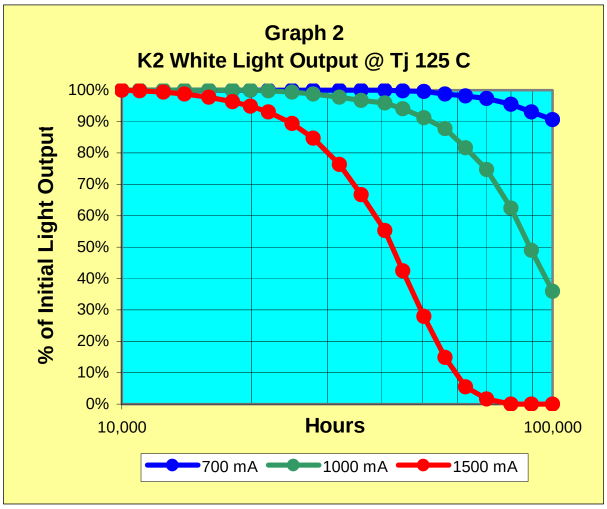
# LED Light Lifetime
# As Affected by Temperature

Philips LumiLEDs published a seminal paper, "Understanding Power LED Lifetime" in early 2007. It is the first work that shows the effects of junction temperature [$T_J$] and LED forward current [$I_F$] on LED light output degradation over time. It will become a standard that will be used by the LED industry to understand the operation of LEDs in lighting applications.In this application note, we will take the LumiLEDs reported data in that paper and analyze it to uncover some interesting points. There are two major graphs that they present and they are inter-related.

In Graph 1, the power level is held constant. Using LumiLEDs data sheet, an $I_F$ of 1.5 Amps has a $V_F$ of 3.86 volts. The power dissipated is 5.79 Watts. The junction temperature is varied [115 $^0$ C, 125 $^0$ C and 135 $^0$ C]. We would assume that the case or ambient temperature is allowed to move up or down to achieve these junctions temperatures.




The 50 % light output degradation is greatly affected by a small change in junction temperature.

| K2 White Light Output Lifetime | | | |
|---|---|---|---|
| JUNCTION TEMP. | 115 $^0$ C | 125 $^0$ C | 135 $^0$ C |
| 50% DEGRADATION | 80k hrs. | 43k hrs. | 22k hrs |

In Graph 2, the LED junction temperature is held constant and the forward current [IF] is varied [.7 A, 1.0 A and 1.5 A]. Again, using the LumiLEDs data sheet, this gives:

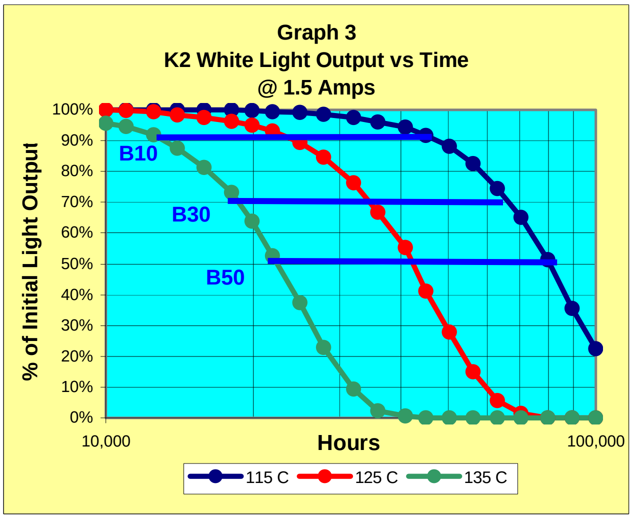
| $I_F$ | $V_F$ | Power |
|---|---|---|
| 700 mA | 3.61 V | 2.53 Watts |
| 1,000 mA | 3.72 V | 3.72 Watts |
| 1,500 mA | 3.86 V | 5.79 Watts |

By combining the results of the two graphs we can make some interesting discoveries.Using 10% [B10], 30% [B30] and 50% [B50] light output degradation across the temperature [Graph 3], we can develop equations for the degradation at 3 specific percentages. We do this by plotting junction temperature versus time for the three degradation rates. We can see the result of this in Graph 4below.

By doing a curve fit, we have equations for the degradation of the light output over time for the three rates: B10, B30 & B50.

- $T_J$ [B10] = -15.822Ln[t] + 284.73
- $T_J$ [B30] = -15.593Ln[t] + 288.12
- $T_J$ [B50] = -15.491Ln[t] + 289.9

where y = junction temperature $T_J$, x = time. [These equations are only good for the 1.5 Amp stuation]

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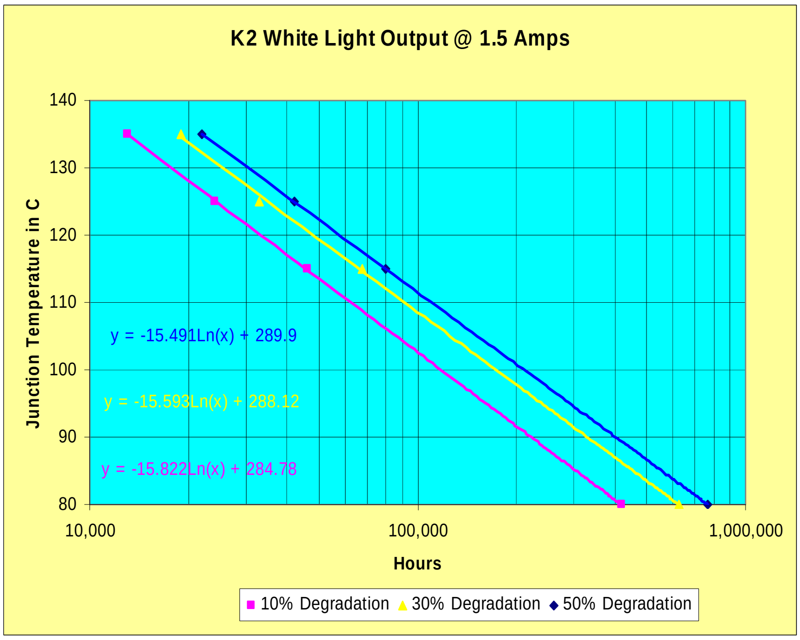
These equations can be used to evaluate the effects of thermal resistance on the light output degradation. For the purposes of this application note, we will use 30 % degradation, or B30. The K2 thermal resistance is 9 $^0$ C/Watt. So, if we were to change the thermal resistance of the package, then we would change the junction temperature for a set of conditions. The conditions we will use are IF = 1.5 Amps and 5.79 Watts being dissipated.

Using 6, 7, 8, and 10 $^0$ C/Watt packages, lets look at the effects on the lifetime of the light output. If we have the K2 at a junction temperature [TJ] of 125 $^0$ C, then the corresponding junction temperatures for the other packages would be:

**Graph 4**

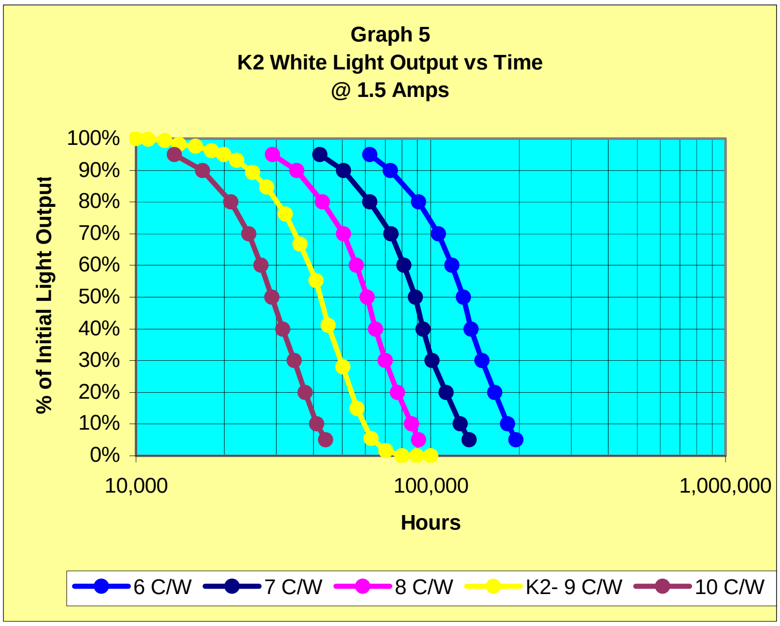



| Thermal Resistance | 6 $^0$ C/W | 7 $^0$ C/W | 8 $^0$ C/W | 9 $^0$ C/W | 10 $^0$ C/W |
|---|---|---|---|---|---|
| Junction Temperature | 107.6 $^0$ C | 113.4 $^0$ C | 119.2 $^0$ C | 125 $^0$ C | 130.8 $^0$ C |

From all of this we can plot Graph 5 using Light Output versus time for the different thermal resistances. The 9 $^0$ C/Watt is the LumiLEDs K2 package.This assumes that the packages are all heat sunk at the same case temperature. Looking at the 30 % degradation, B30, we can see the following effects in the table below.

If you want long lifetime, thermal resistance is key. Even the method for attaching the LED chip to the package is crucial. Eutectic methods should be used rather than the historical epoxy ones. A second benefit of lower thermal resistance is that the LED light output is increased. This is explained in application note AN-102.

As LED manufacturers understand the principles discussed above, they will migrate away from ceramic and metal core board technology to copper based packages because of the thermal resistance differences.




| Thermal Resistance | 6 $^0$ C/W | 7 $^0$ C/W | 8 $^0$ C/W | 9 $^0$ C/W | 10 $^0$ C/W |
|---|---|---|---|---|---|
| Lifetime in hours | 106k hrs. | 73k hrs | 51k hrs. | 43k hrs | 24k hrs. |