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Design Consideration for Super NovaLed

Introduction

Electrical power dissipation and ambient temperature will affect the p-n junction temperature of LED. Change of junction temperature can induce some effects on LED's characteristics.

LEDs are typically encapsulated in an optical clear epoxy resin, the allowed operation temperature for the specific lifetime is limited by the glass-point of the resin, the temperature of the die inside must not exceed its p-n junction temperature, this is to avoid permanently change of the thermal expansion coefficient of epoxy resin, which will cause more displacement of wire bond and resulting wire bond breakage.

LEDs experience a degradation of light output as temperature increases. The junction temperature also affects dominant wavelength of LEDs. Changes of light output and dominant wavelength are varied on LED chip's technology and color.

American Bright's NovaLED provides a high light output at higher operating current. This is due to its thicker leadfreame and larger cathode lead, which provide better heat dissipation. In order to achieve reliability and optimal LEDs performance, additional thermal connections are required, which the LEDs are soldered toa metal core PCB to enhance the heat dissipation. A proper thermal design is imperative to keep it below its rated operating temperature to reduce the impact of temperature rise on the optical performance and avoid LED failure.

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Recommended Design for Proper Thermal Management

Thermal Modeling

A simplified thermal resistance model of the thermal path, as in Fig 1:

Fig 1a

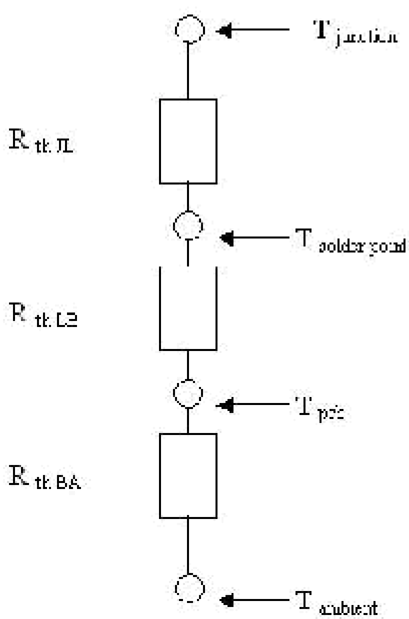
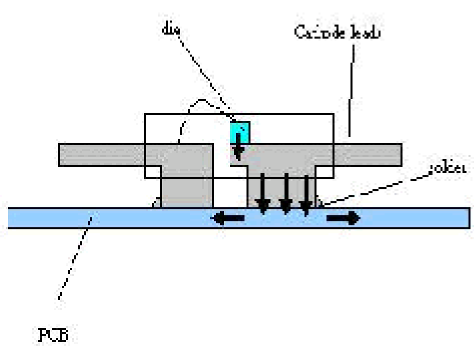


Fig 1b



The overall thermal resistance $R_{th\ JA}$ can be expressed as the sum of the individual resistance of the thermal path from junction to ambient.

$$R_{th\ JA} = R_{th\ JL} + R_{th\ LB} + R_{th\ BA}$$

Where,

$R_{th\ JL}$ = thermal resistance from junction to solder point

$R_{th\ LB}$ = thermal resistance from solder point to the pcb

$R_{th\ BA}$ = thermal resistance from pcb to ambient

The primary concern to evaluating the thermal characteristics of an LED assembly is to ensure that the temperature of LEDs always kept below its maximum value: 125^{o}C

$R_{th\ JA}$, power to LED and ambient temperature determined the LED junction temperature. To ensure the good thermal management, $R_{th\ JA}$ has to be optimized with consideration of proper LED package design and PCB design.

ii) Thermal resistance from junction to solder point

$R_{th\ JL}$ value is determined by the package construction, e.g. geometry, material used and chip size. American Bright NovaLed is optimized by using better thermal conductive material (copper), larger surface area and shorter heat transfer distance to solder point.

ii) Thermal resistance from solder point to the PCB

$R_{th\ LB}$ varies by solder pad design, component placement, PCB material and construction. To ensure the best efficiency of thermal dissipation, this resistance value has to be minimized.

IR reflow soldering method used to mount the NovaLed to ensure a good contact between the leadframe and the PCB.

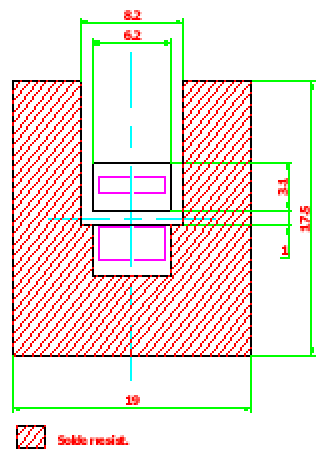
Larger solder pad area and thicker Cu are ideal to provide a better heat dissipation, fig. 2 shown a recommended solder pad dimension on FR4 PCB, with solder pad (17.5 mm x 19 mm) per lead, thickness of solder pads is 35 μmCu.

LED pitch-to-pitch should be designed as far as possible to allow more space for heat dissipation, which it helps to lower down PCB temperature. Our recommended minimum LEDs pitch-to-pitch is 25mm for NovaLED.

Other electrical components must keep at certain minimum distance away to avoid any additional heat sources that influence the thermal behavior of LEDs. The resistors should be distributed evenly along the PCB to distribute the heat generated. Prevent to locate resistors close/connected to cathode leads of LEDs too. If possible, the resistors and other components should be located in a separate PCB.

LED housing can be optimized to provide a conductive path from the backside of the PCB to an additional thermally conductive pad, it helps to increase contact area and improve the thermal performance, this can be done as FR4 PCB glued on an aluminum plate using standard pressure sensitive adhesive. Further improvement is possible by using Multi Copper Layer with array of thermal via (Fig. 3).

Fig. 2



iii) Thermal resistance from PCB to ambient

$R_{th\ BA}$, heat transfer from a solid body to a fluid can be enhanced by extending the surface of the solid body, one of the common methods to increase the surface area is the use of heat sinks (flat / finned). Larger surface / footprint area gives lower thermal resistance. The fanned heat sink further decreases the thermal resistance.

Orientation of PCB to gravity causes the thermal resistance to vary, too; vertical orientation provides better heat dissipation against horizontal orientation.

Substrate technology further enhances the thermal resistance. Metal core printed circuit board incorporate a base metal material as heat spreader as an integral part of circuit board. Its dielectric polymer layer has high thermal conductivity. This MCPCB provides a high thermally conductive base material for heat spreading. In case of LEDs pitch-to-pitch had to reduce to less than 25mm, we recommend using metal core printed circuit board and mounted it to a heat sink. The size of metal core PCB, size of heat sink and its thermal resistance (< 5 ^{o}C/W) have to be evaluate based on this general guideline; the temperature on the solder point should not excess 85 ^{o}C, this temperature can be measured by place a small thermocouple onto cathode lead of NovaLED.

Circuit Design

Constant current driver circuit is ideal circuit design, which supplies the same current to LEDs even with changing ambient temperature, battery voltage, and LEDs resistance.

If constant current drive circuit is not possible, circuit design has to consider more issues, such as variation of LED’s forward voltage requirement, current limiting resistors, etc. The primary approaches to driving large arrays are series string, parallel connections and multiplexing.

Series strings of LEDs provide the same current distribution and better power efficiency, its disadvantage is any LED

Failing open circuit will disable the entire string, or any LED shorted will affect current regulation. Usually number of LEDs in series is limited to the power supply constraint.

However, connecting LEDs in parallel will result in nonuniform current distribution due to variation in the forward voltage requirements of individual LEDs. To minimize this effect, individual current limiting resistors are used in the circuit.

The most common LED driver circuit consists of a current limiting resistos and connected series string of LEDs in parallel, which it averaging out the forward voltage over several LEDs.

Fig. 4.1

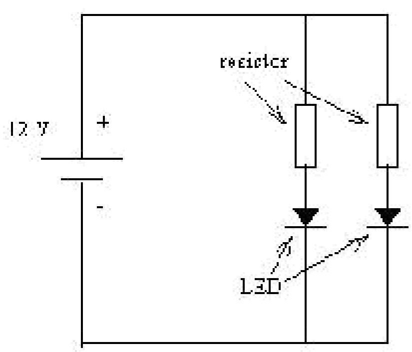
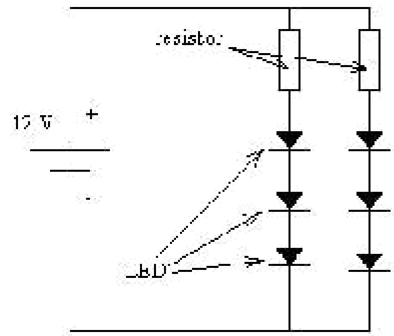


Fig 4.2



The current to LEDs are controlled by resistors, the current control characteristic improve as larger resistor are used and fewer LEDs in series, but mean time larger resistor generated greater heat in the circuit, so it is recommended to located resistors to the separate PCB or configured more LEDs in series. Circuit in figure 4.2 is recommended if compared to figure 4.1, it has a better power efficiency and less heat generation.

For most application with standard power supply of 12 – 13 V, we recommend connecting three and four LEDs in series for InGaN devices (blue and white) and AlInGaP devices, respectively.

Super NovaLed Reliability Test Setup

Our burn in setup used FR4 PCB with solder pad (17.5mm x 19mm) per lead, at 25mm pitch. (Refer to Figure 2). The material for solder pads is 35 μmCu.

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Product Reliability Qualification Plan

All units are to pre-conditioned before proceeding to the respective test.

	Conditions
- Pre-conditioning as per JEDEC L. - 2A requirement (JESD22A113-B) - IR re-flow soldering on FR4 board.	- Bake @ 125C, 24 hrs - Storage @ 60°C/60% RH, 120 hrs - 3 x IR reflow soldering at 235°C/10 sec. min (Jedec).

Failure Criteria:

Electrical failures:

Vf shift → 10 % Vt

Vt > 5V @ 100μA for InGaN

Light Output Degradation:

% Iv shift ← -50% max

← -35% average

Visual failures:

Broken or damaged package or lead

Solderability < 95% wetting

Dimension out of tolerance

Reliability Test Matrix

IR / Convective Reflow Process at Peak Temperature 235 oC for 10 – 20 sec

Pre-conditioned @ 60 oC / 60% RH for 120 hours

No	Test Type	Stress Condition	S/S	Test Point
1	Ambient life test (ALT)	a) Pre-conditioning b) IR re-flow soldering - T_a = 25°C, I_f = [illegible] mA	100	0 hrs 168 hrs 504 hrs 1000 hrs
2	High temperature humidity elevated life test (ELT)	a) Pre-conditioning b) IR re-flow soldering - T_a = 85°C, 85% RH, I_f = [illegible] mA	100	0 hrs 168 hrs 504 hrs 1000 hrs
3	Thermal shock (TSK)	a) Pre-conditioning b) IR re-flow soldering c) Liquid-to-liquid, -55°C to 100°C, 15 min dwell, < 10 sec transfer	100	0x, 50x, 100x, 500x, 1000x

Super NovaLed Reliability Test Result

No	Test Type	Stress Condition	S/S	Test Point	[illegible]	
					[illegible]	[illegible]
1	Ambient life test (ALT)	a) Pre-conditioning b) IR re-flow soldering - T_a = 25°C, I_f = [illegible] mA	100	0 hr	[illegible]	[illegible]
				168 hr	[illegible]	[illegible]
				504 hr	[illegible]	[illegible]
				1000 hr	[illegible]	[illegible]
2	High temperature humidity elevated life test (ELT)	a) Pre-conditioning b) IR re-flow soldering - T_a = 85°C, 85% RH, I_f = [illegible] mA	100	0 hr	[illegible]	[illegible]
				168 hr	[illegible]	[illegible]
				504 hr	[illegible]	[illegible]
				1000 hr	[illegible]	[illegible]
3	Thermal shock (TSK)	a) Pre-conditioning b) IR re-flow soldering c) Liquid to liquid, -55°C to 100°C, 15 min dwell, < 10 sec transfer	100	0X	[illegible]	[illegible]
				50X	[illegible]	[illegible]
				100X	[illegible]	[illegible]
				500X	[illegible]	[illegible]
				1,000X	[illegible]	[illegible]

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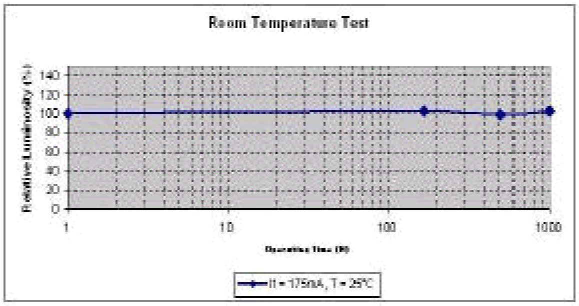

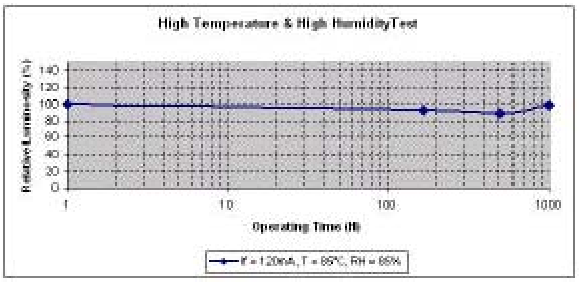

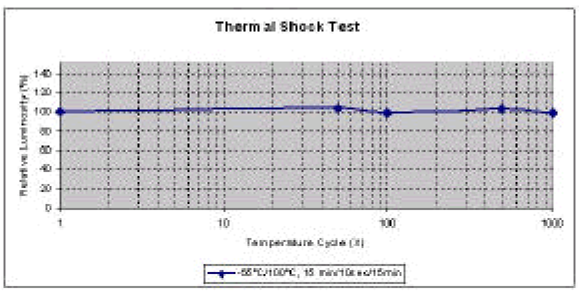

Conclusions:

The reliability tests were designed to evaluate both package integrity as well as workability of product performance over time.

The samples have completed ALT at 1000 hrs, ELT at 1000 hrs and TSK at 1000X with ZERO failure. Based on the good result shows on the above test, this product is qualified and released to market.

The intent of this application note is to provide a basic guideline for a good thermal management design. The recommended minimum LEDs pitch-to-pitch, minimum solders pad size; PCB substrate technology, heat sink design/selection, PCB orientation and the consideration of driving circuit should be able to provide sufficient cooling for Super NovaLed.

Note:

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