# Application Note rev1.8

**Samsung Electronics**

**LM231A (2323L)**

SAMSUNG ELECTRONICS

LED Business

SAMSUNG

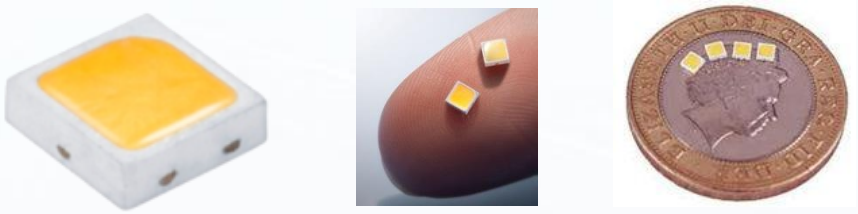
# Index

# 1. Introduction

## 1.1 Product Description

### 1.1.1 Compact & reliable light source (LM231A)

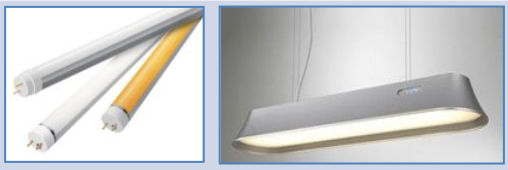
High brightness LED, LM231A, has extremely compact size of 2.3x2.3x0.7㎜ and passed harsh reliability testing regarding mechanical and lifetime tests. LM231A could be operated at 0.2~0.5W power consumption and emit 20~65 lumens of white luminance outputs.



[ LM231A]

LM231A LED package could be adopted for numerous illumination field widely. Retrofit lamps like as bulb, LED-tube need the high energy efficiency and the uniformity of color properties and especially low-cost solution for their light source. LM231A is very attractive solution for these lamps and for the various illumination fixtures due to it's performance, size and reliability.

The data of this application note is made especially for giving some reference information about LM231A characteristics, not for any warranty.

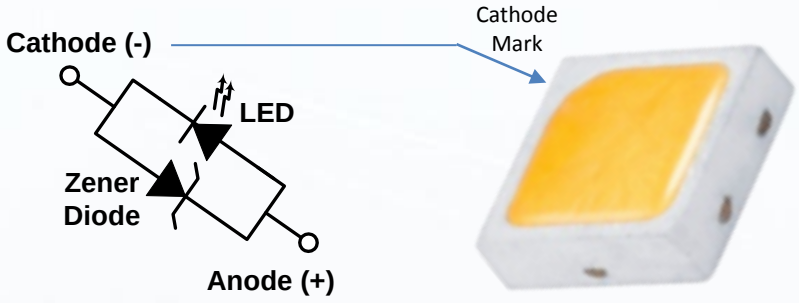
| Application | Illumination |
|---|---|
| LED Tube |   |
| Flat panel |   |
| Down light & Pendant |   |

## 1.2 Product Information

### 1.2.1 Feature and dimension

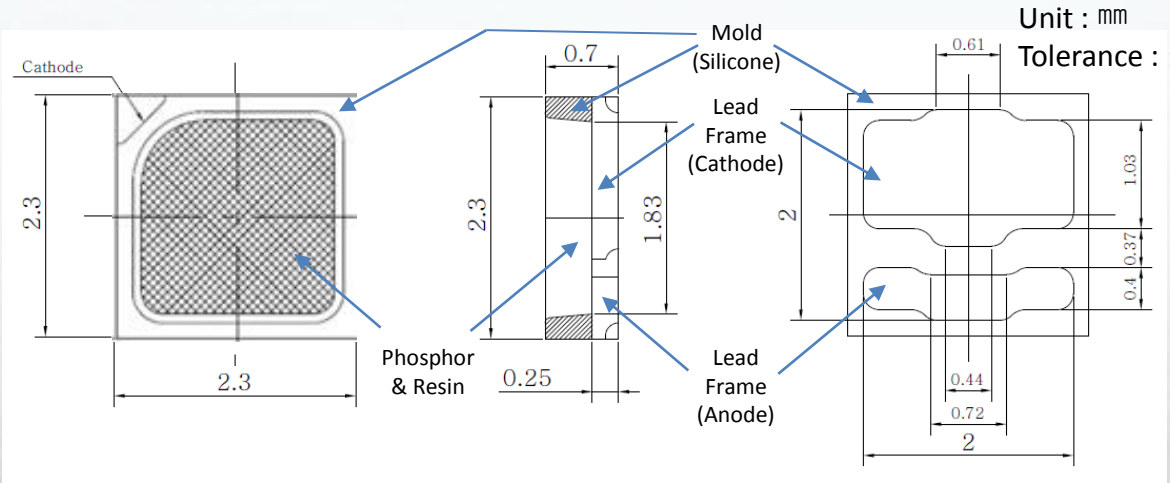
LM231A has a compact dimension.

- SMD Type LED Package : 2.3 x 2.3 x 0.7t mm
- Electrically cathode pad plays a key role as a main thermal pad




LM231A is a very attractive solution for reliability.

- GaN / $Al_2O_3$ Chip & SMD type package
- Robust of silicone mold material
- Eco-friendly : RoHS compliant
- Maximum compressing force is 15N on the silicone mold




Top View Side View Bottom View

[ LM231A Package Dimension ]

# 1. Introduction

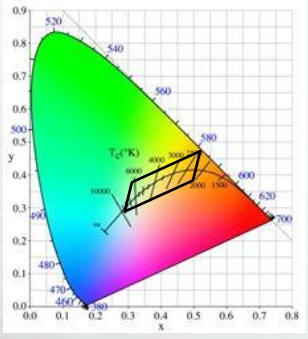
## 1.2 Product Information

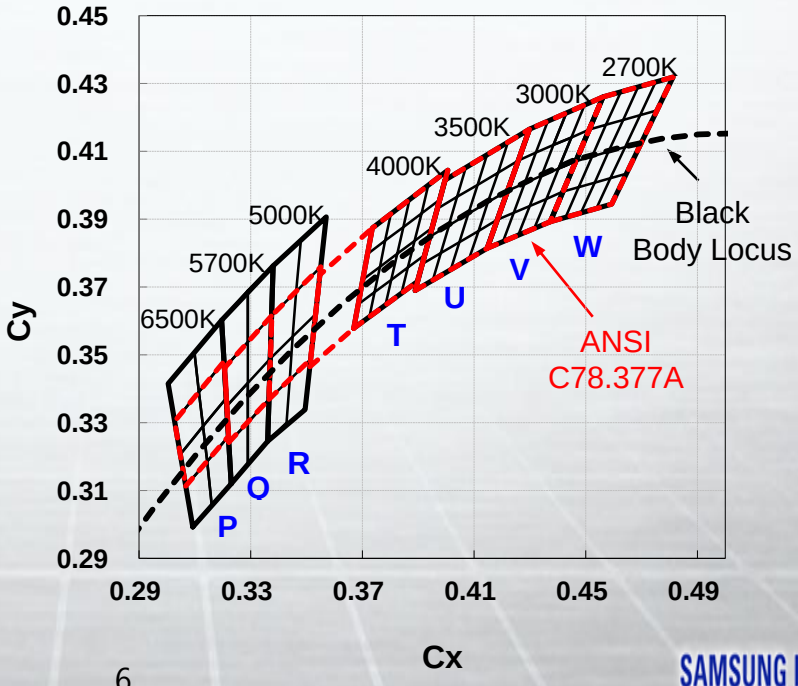
### 1.2.2 Product code and binning

LM231A has basic full color line-up.

| Basic Product Code | CCT [K] | CRI (Min.) | Quarter Bin | Kitting Bin |
|---|---|---|---|---|
| SPMWHT221MD5 WA**W**0S0 | 2700 | 80 | Available | Available |
| SPMWHT221MD5 WA**V**0S0 | 3000 | 80 | Available | Available |
| SPMWHT221MD5 WA**U**0S0 | 3500 | 80 | Available | Available |
| SPMWHT221MD5 WA**T**0S0 | 4000 | 80 | Available | Available |
| SPMWHT221MD5 WA**R**0S0 | 5000 | 80 | Available | Available |
| SPMWHT221MD5 WA**Q**0S0 | 5700 | 80 | Available | Available |
| SPMWHT221MD5 WA**P**0S0 | 6500 | 80 | Available | Available |

- Color CIE binning is according to ANSI bin and suitable for lighting application.
- As for 5000K, 5700K, 6500K, 8 elementary sub bins are operated.
  As for 2700K, 3000K, 3500K, 4000K, 16 elementary sub bins are operated.
- LM231A is provided by various selection of sub-bins. For more detail information of quarter bin and kitting bin, refer to datasheet of LM231A.



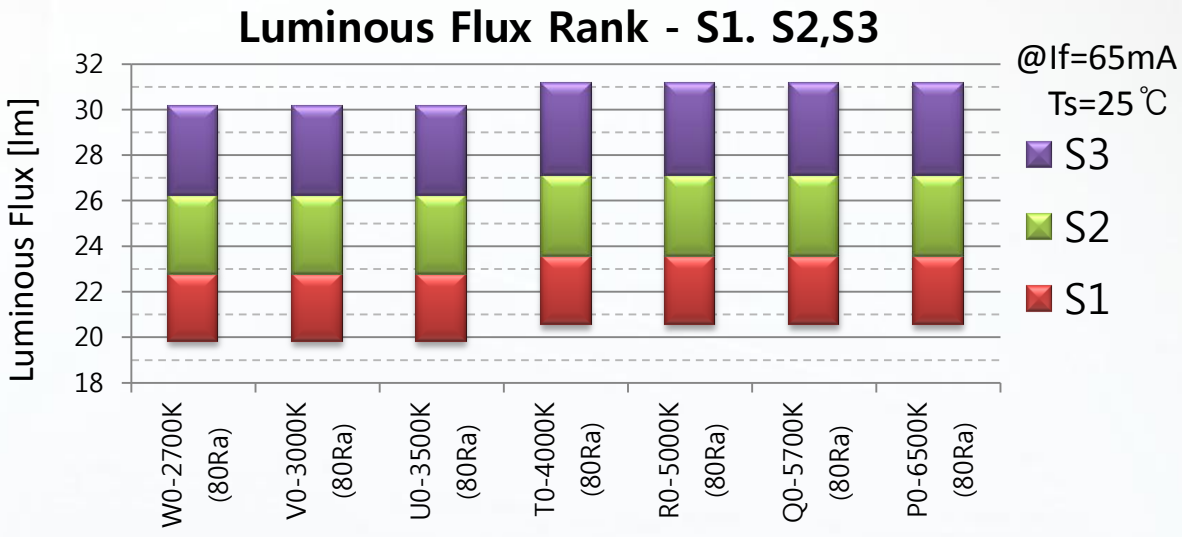




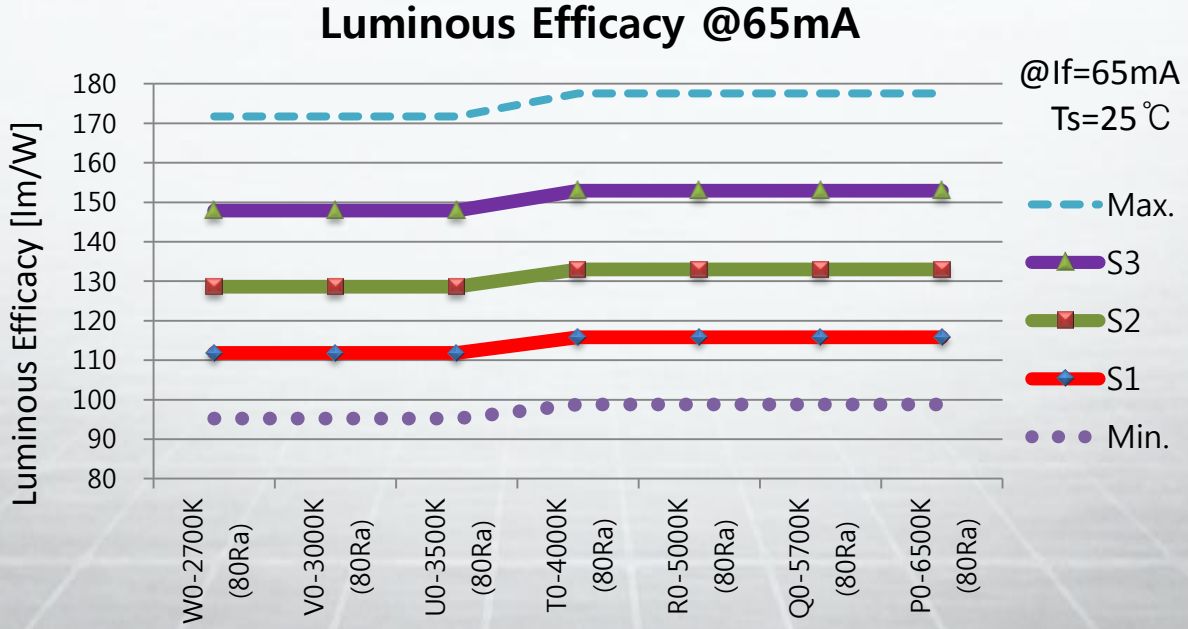

SAMSUNG LED

# 1. Introduction

LM231A has 3 kinds of fundamental binning, - Voltage, Flux, Color
- Luminous flux (Iv (Φv)) is divided by 3 rank – S1, S2, S3
- sorting current and ambient temperature is 65mA and 25℃ respectively.



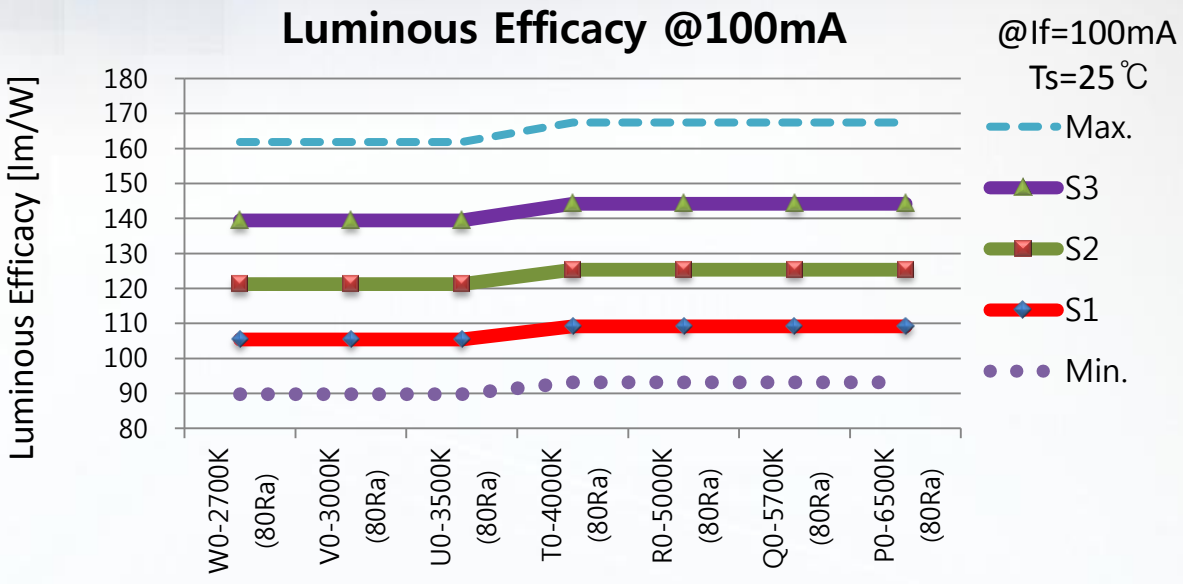

With the same typical forward voltage,2.95V, luminous efficacy (lm/W) at each flux rank are shown in below graph. From datasheet, highest and lowest luminous efficacy could be expected by considering highest luminous rank with lowest forward voltage rank and vice versa.

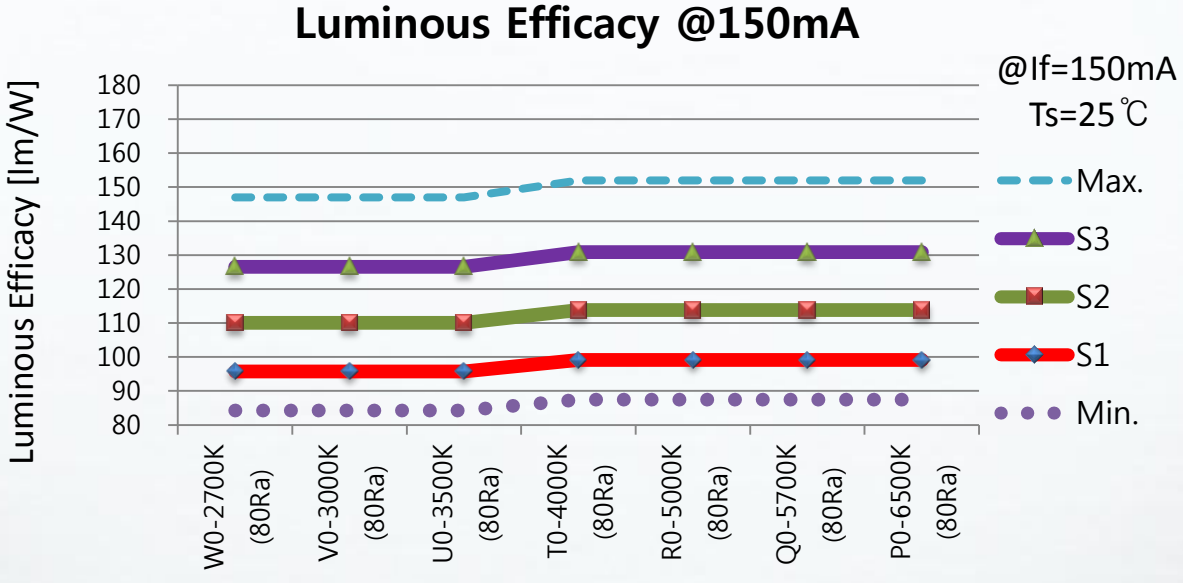




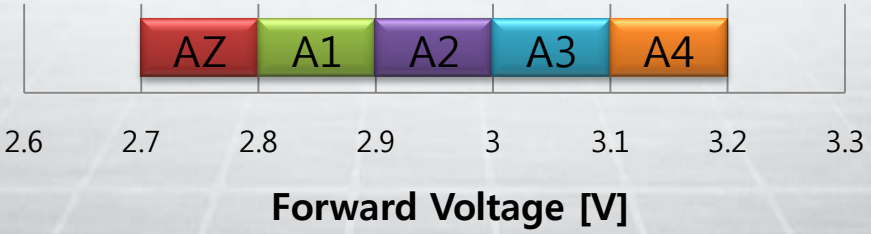

SAMSUNG LED

# 1. Introduction



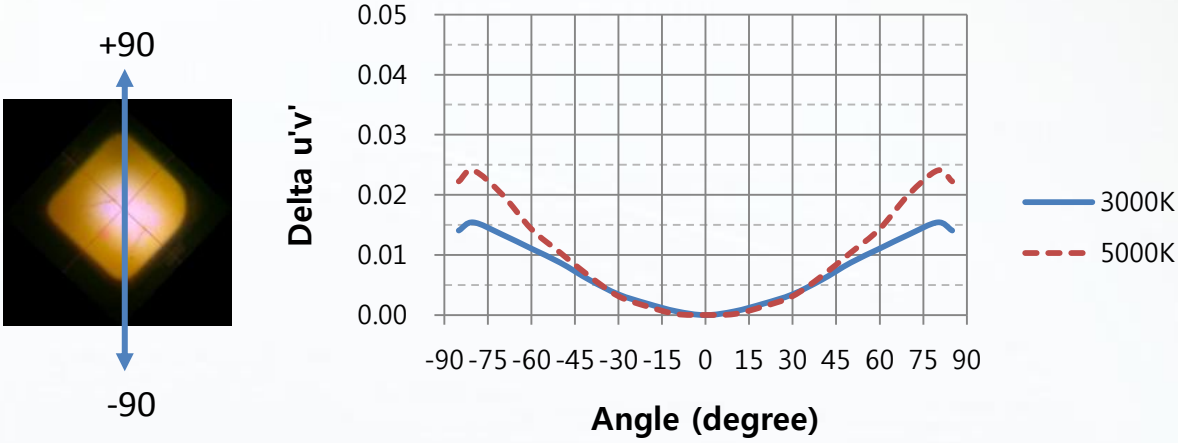

- Forward voltage($V_F$) is divided to 5 rank - A1,A2,A3,A4,A5



## 1.2 Product Information

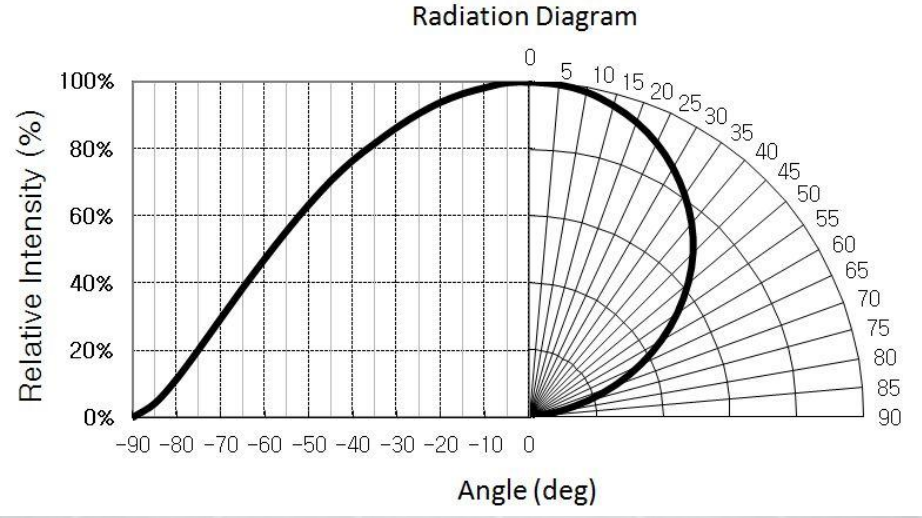
### 1.2.3 Beam angle vs. color shift (delta u'v')

Optical spectra of LM231A are shown like as below graph at each CCT 3000K and 5000K. Measured data is just for representative reference only.



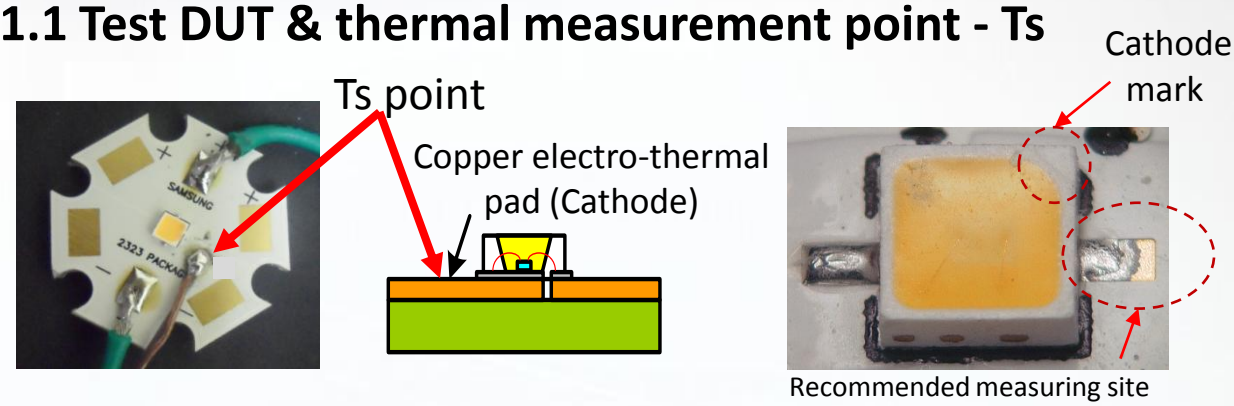

### 1.2.4 Polar intensity diagram

Viewing angle describes the spatial distribution and the value is 120°(FWHM, Full width at half maximum), FWHM is the difference between the angles corresponding to 50% of the maximum intensity.



## 2.1 Thermal Characteristics

### 2.1.1 Test DUT & thermal measurement point - Ts

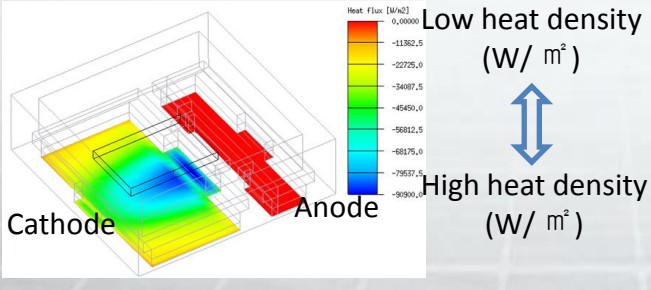



[ DUT (Device under Test) & Ts point ]

The typical value of LM231A is well presented on datasheet. But in case of the real design domain, typical value might be changeable as to operating conditions(current, voltage), product structure (Effects on thermal dissipation) and environment conditions. And performance objectives in product newly developed should be considered in various point of important factors. Most of all design factor, the thermal factor is the main key of expecting the target of LED performance. Basically the main LED properties of luminous flux(lm), forward voltage($V_F$) and color (Cx, Cy chromaticity) is depending on the thermal condition.

In this note, we show that how the characteristics of LED is changed with variation of temperature. First, the reference temperature should be clearly defined as solder temperature of cathode pad, which is expressed as 'Ts' and is measurement point for a reference temperature.

LED chip is usually mounted on cathode side where the most of heat can release. For measuring 'Ts', the thermo couple cable have to be connected with the cathode pad as shown in above figure.



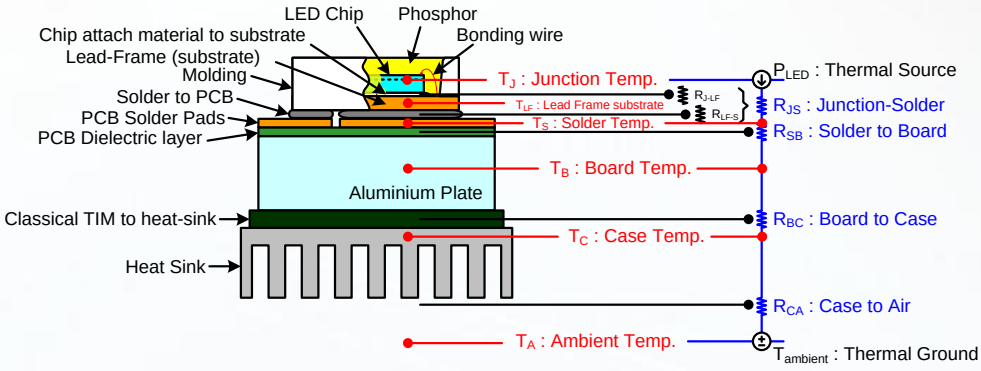

- condition : 50mA, 25℃
- Cu pad of Cathode
  : 44,400 W/㎡ (99.5%)
- Cu pad of Anode
  : 210 W/㎡ (0.5%)

[ Heat dissipation simulation ]

# 2. Package Characteristics

## 2.1 Thermal Characteristics

### 2.1.2 Thermal resistance

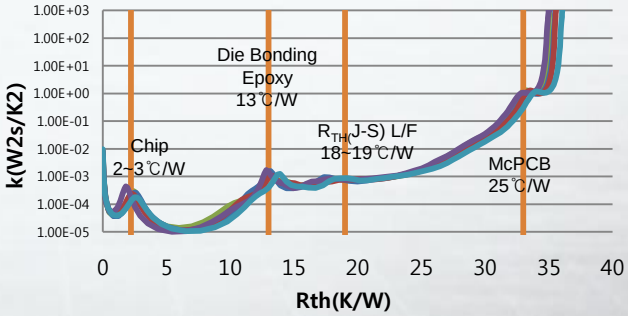



[ Thermal system - vertical diagram ]

It is not easy to measure LED chip temperature, $T_J$, directly. But most of lighting designer need LED chip temperature information to confirm their final product reliability. For these reason, designer use thermal resistance of LED package, $R_{TH}$ , to estimate chip temperature. Solder temperature, $T_S$, of Led package could be easily measured and then add delta temperature between solder and chip, $R_{TH}$ (J-S) x $P_{LED}$ , on $T_S$. See equation (1), (2). Finally designer could recognize how degree LED junction temperature can rise-up from these steps.

$$R_{TH} = \frac{T_J - T_S}{Power_{LED}} \quad \text{------ (1)} \qquad T_J = T_S + R_{TH} * Power_{LED} \quad \text{------ (2)}$$

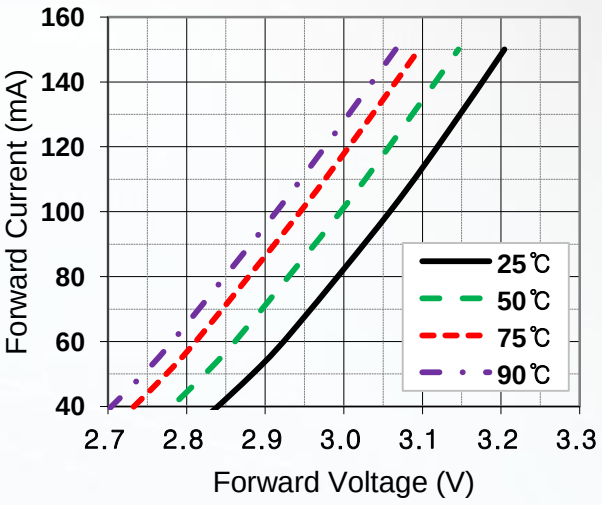
$R_{TH}$ is measured according to JEDEC Standards, JESD51-1, 51-14.
We use T3Ster to evaluate thermal resistance.




Average value of $R_{TH}$ (J-S) : 18.8
- Number of samples : 11ea
- sigma value : 1.5

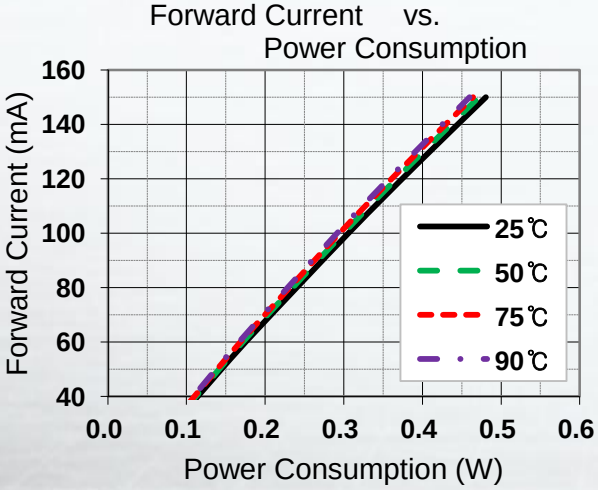
## 2.2 Electrical Characteristics

If constant current is driven into LED package, forward voltage of the LED would be dropped as temperature goes up, therefore IV curve would shift to the left side. In right side graph, IV curve of LM231A is shown at various $T_S$ temperature. Let us consider about power consumption. From IV curve, power consumption could be represented by forward current or forward voltage. Below two graphs show these relations. And these graphs show very meaningful point of LED operation.

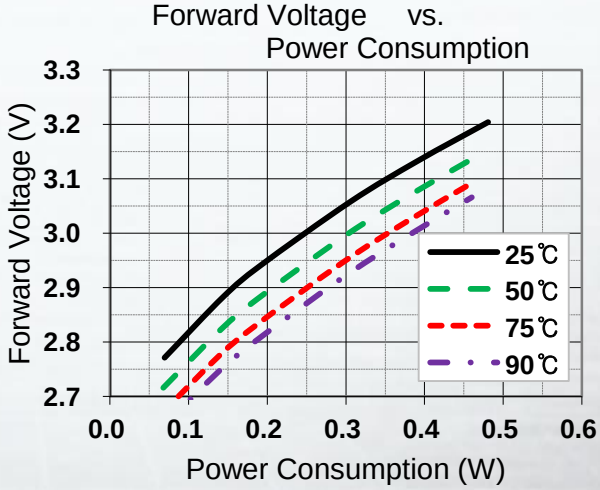



**[Forward Current vs. Forward Voltage]**

As shown in below figure, If driving mode is set by constant current(C-C) mode, the variation of power consumption becomes more less than constant voltage (C-V) mode over Ts temperature. In order to get stable lighting output, LED should be driven by constant current driving method.



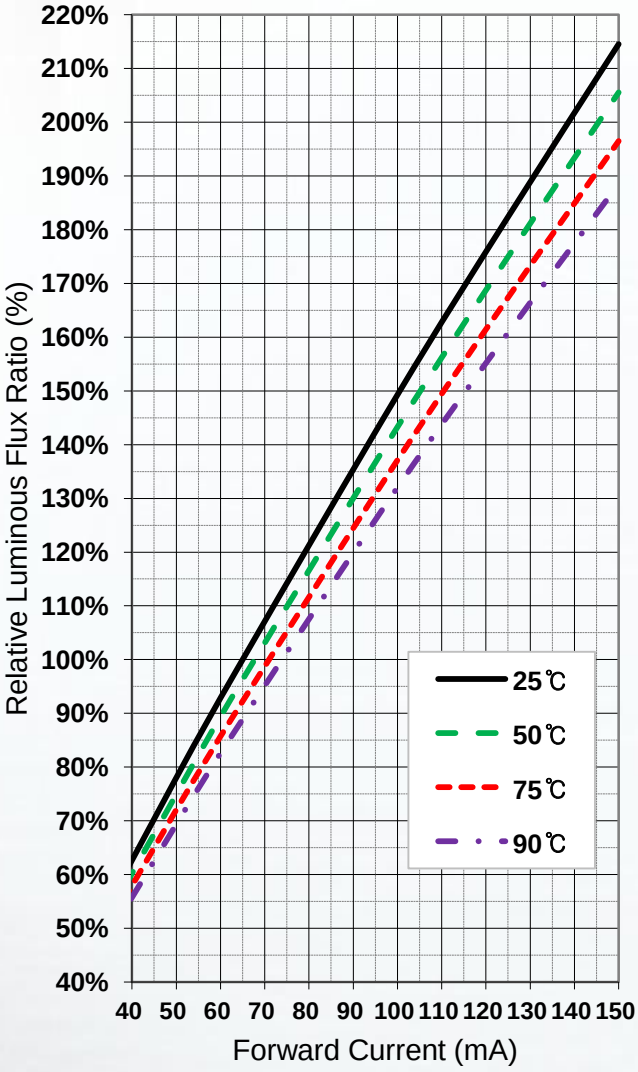

**[Power consumption with constant current mode]**



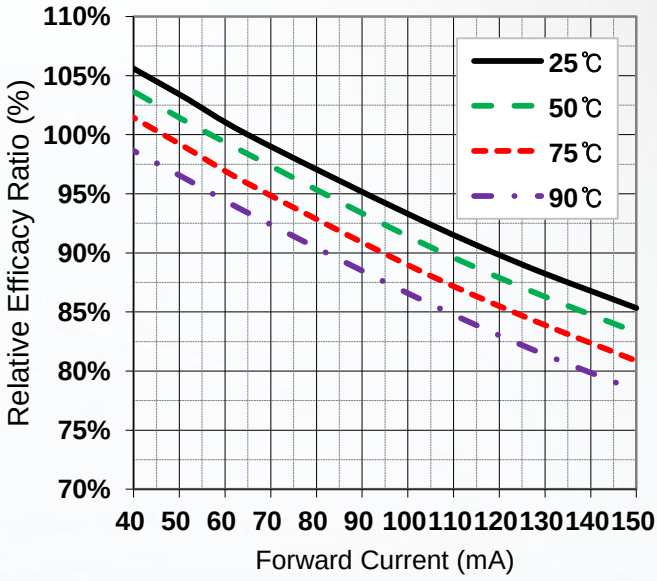

**[Power consumption with constant voltage mode]**

## 2.3 Optical Characteristics

### 2.3.1 Luminous flux & efficacy ratio vs. current & Ts




**[Relative Luminous Flux Ratio vs. Forward Current]**



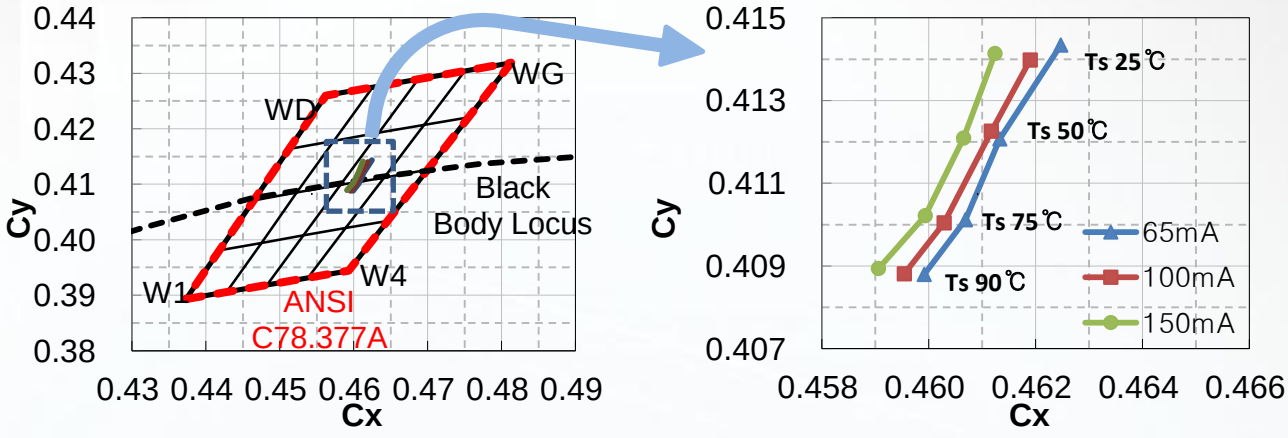

**[Relative Efficacy Ratio vs. Forward Current]**

At datasheet, luminous flux of each rank is presented in detail. In left graph, relative luminous flux ratio is presented depending on each $T_S$ temperature. Each color CCT has similar flux ratio between 2700K and 5000K. The reference point of flux ratio is set at the operation current of 65mA. Therefore we can estimate 185% luminous flux ratio at 140mA and Ts of 75 ℃ respectively.

Voltage binning is also presented at datasheet. If under the same typical voltage of 2.95V, relative luminous efficacy ratio could be presented like as right side graph. At Ts of 75℃, and driving current of 100mA, efficacy ratio of 89% could be roughly expected.

## 2.3 Optical Characteristics

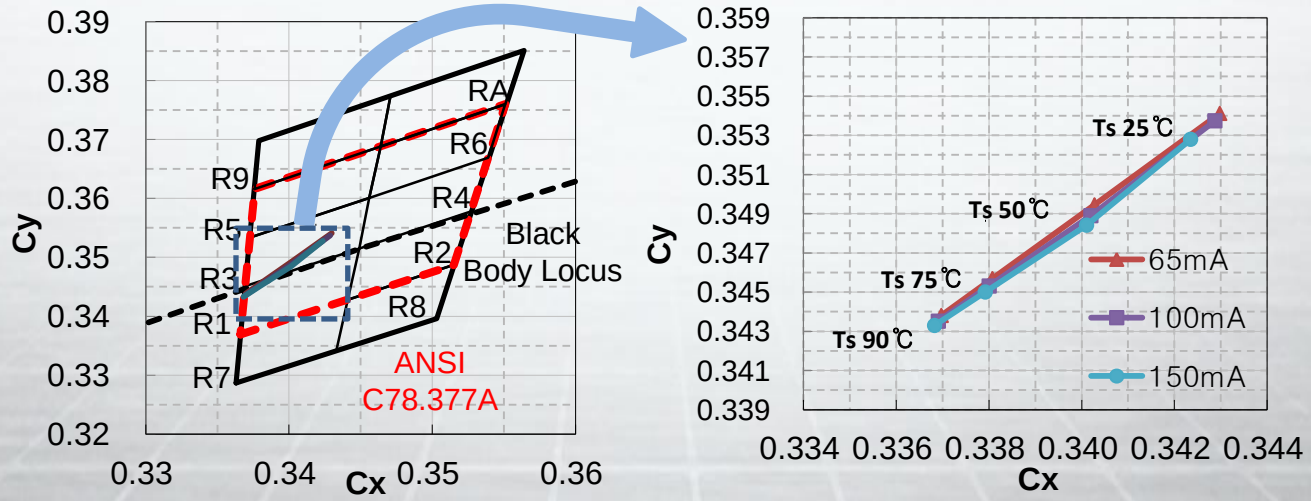
### 2.3.2 Color shift vs. current & Ts




**[2700K color shift vs. current & Ts]**

At datasheet, the variation of Cx, Cy coordination over current is presented. In this note, the variation is shown on CIE coordination with current and Ts temperature. As driving current and Ts temperature increase, each color coordination becomes shift. These tendencies are brought from the thermal effects on the blue chip wavelength and the conversion efficiency of phosphors.

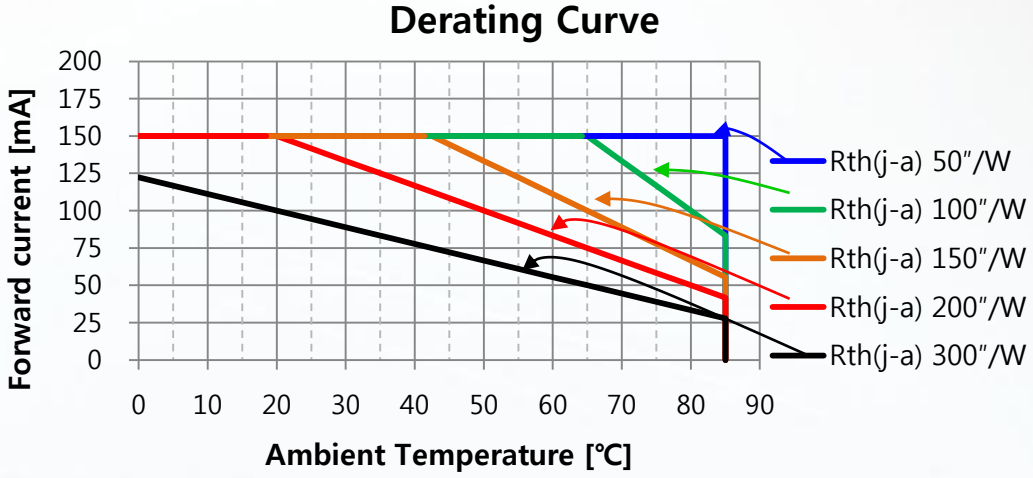
Therefore, design for lighting have to be consider the color shift, which depends on the operation conditions(current, temperature) as well as the characteristics of diffuser like as a diffuser thickness and material. 65mA and 25℃ is just sorting current and temperature which doesn't meaning always makes same properties at any conditions.




**[5000K color shift vs. current & Ts]**

## 2.4 Mechanical Characteristics

### 2.4.1 Derating curve




Max current for design LED lighting can be changeable with illumination systems. In case of LM231A, the max current doesn't equal in every conditions. The performance in LM231A is dependent on the thermal resistance that is closely related with the total power consumption, ambient temperature, kinds of material and mechanical assembly structure. In the worst case, the max current should be limited to the lower level in operation current for the LED. Therefore the user needs a design guide line for applying optimal operation current. Usually derating curve is used for these objectives.

In a LED module, the thermal resistance of system might be mathematically expressed like as (A). If the thermal resistance ($R_{TH}$ j-a), the max junction temperature ($T_J$, 110℃) and the max operating current ($I_f$-max, 150mA) are known, we can find out a linear function (D). As shown in above graph, X-axis is ambient temperature ($T_a$) and Y-axis is permitted forward current($I_f$).

$$R_{j-a} = \frac{T_j - T_a}{P} = \frac{T_j - T_a}{I_f \cdot V_f} \quad \text{------ (A)} \qquad I_f \cdot V_f \cdot R_{j-a} = T_f - T_a \quad \text{------ (B)}$$

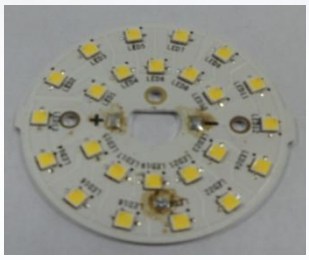
$$I_f = \frac{T_j - T_a}{V_f \cdot R_{j-a}} = -\frac{1}{V_f \cdot R_{j-a}} T_a + \frac{T_j}{V_f \cdot R_{j-a}} \quad \text{------ (C)}$$

$$\left( \frac{1}{V_f \cdot R_{j-a}} = constant = a, \quad \frac{T_j}{V_f \cdot R_{j-a}} = constant = b \right)$$

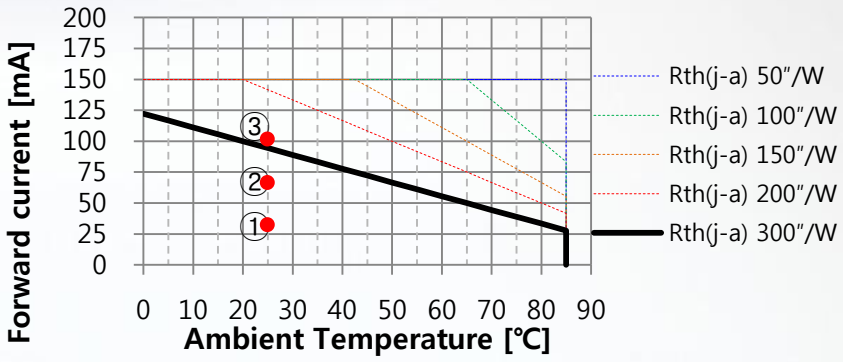
$$I_f = -a \cdot T_a + b \quad \text{------ (D)}$$

# 2. Package Characteristics

## Example 1) 12series X 2parallel circuit, metal PCB, without heat/sink system



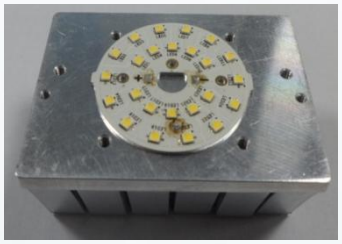
[ 12S X 2P McPCB without Heat Sink ]



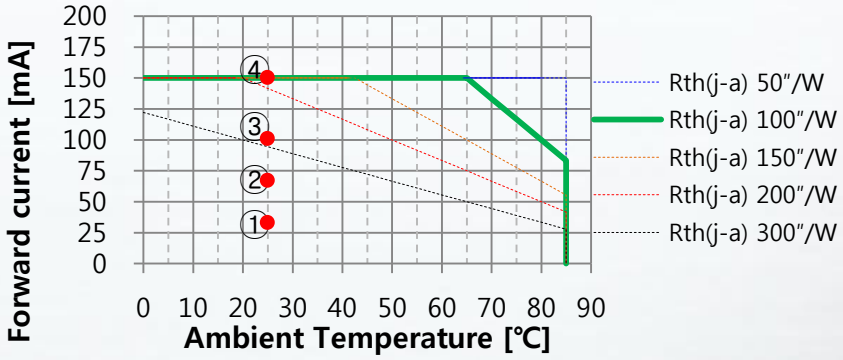

| Case | $I_F$[mA]/LED | P[W]/LED | $T_J$[℃] | $T_s$[℃] | $T_a$[℃] | $R_{J-a}$ [℃/W] |
|---|---|---|---|---|---|---|
| ① | 30 | 0.08 | 49 | 47.4 | 25 | 300 |
| ② | 65 | 0.19 | 82 | 78.2 | 25 | 300 |
| ③ | 100 | 0.3 | 115 | 109 | 25 | 300 |

In case of driving on metal PCB without any heat sink, system thermal resistance is 300℃/W. 100mA driving point is out of bounds and junction temperature, $T_J$, also goes over the maximum value - 110℃.

## Example 2) 12series X 2parallel circuit, metal PCB, with heat/sink system



[ 12S X 2P McPCB with Heat Sink ]



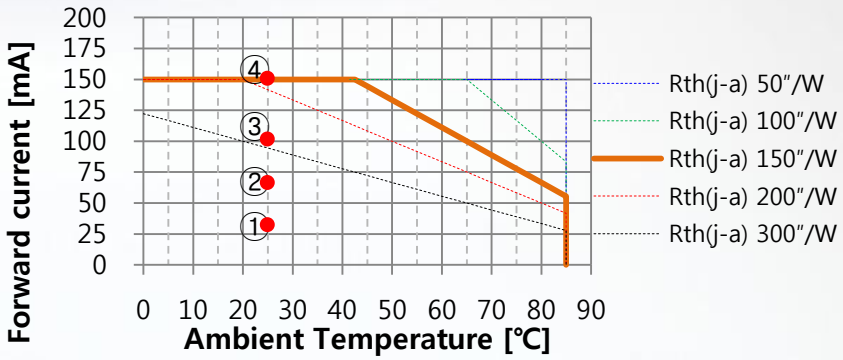

| Case | $I_F$[mA]/LED | P[W]/LED | $T_J$[℃] | $T_s$[℃] | $T_a$[℃] | $R_{J-a}$ [℃/W] |
|---|---|---|---|---|---|---|
| ① | 30 | 0.08 | 33 | 31.4 | 25 | 100 |
| ② | 65 | 0.19 | 44 | 40.2 | 25 | 100 |
| ③ | 100 | 0.3 | 55 | 49 | 25 | 100 |
| ④ | 150 | 0.45 | 70 | 61 | 25 | 100 |

If heat sink is added to metal PCB, system thermal resistance could be lower like as 100℃/W and 150mA driving current is inside of the derating curve.

# 2. Package Characteristics

## Example 3) 6series X 1parallel circuit, FR PCB, without heat/sink system

[ 6S X 1P FR-PCB
without Heat Sink ]




| Case | $I_F$[mA]/LED | P[W]/LED | $T_J$[℃] | $T_s$[℃] | $T_a$[℃] | $R_{J-a}$ [℃/W] |
|---|---|---|---|---|---|---|
| ① | 30 | 0.08 | 37 | 35.4 | 25 | 150 |
| ② | 65 | 0.19 | 53.5 | 49.7 | 25 | 150 |
| ③ | 100 | 0.3 | 70 | 64 | 25 | 150 |
| ④ | 150 | 0.45 | 92.5 | 83.5 | 25 | 150 |

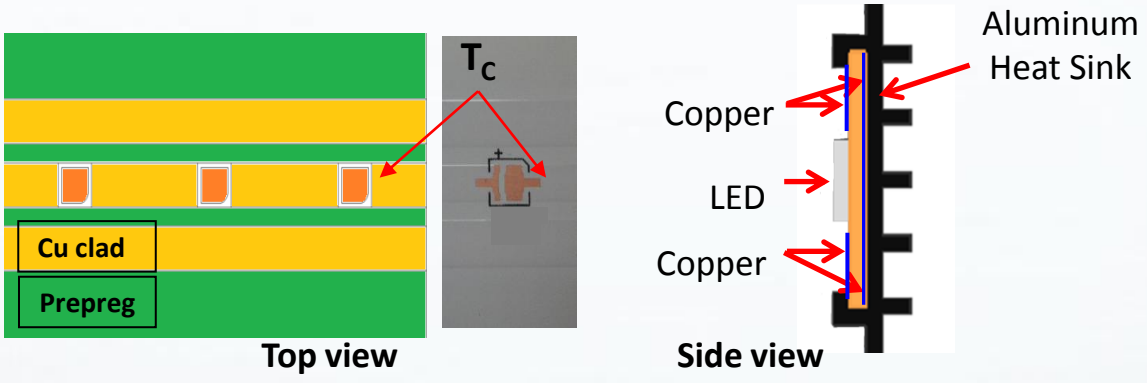
In case of driving on FR PCB without any heat sink, system thermal resistance is 150℃/W. It is shown that current of 4 cases are all under the derating curve.

## 2.5 Thermal Simulations

### 2.5.1 Reference PCB modeling

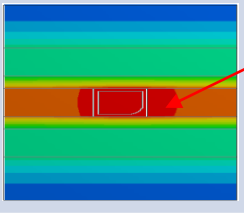
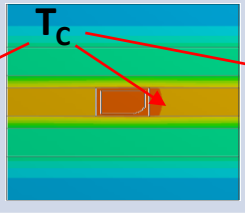
Through the thermal simulation of LM231A, we can consider how the PCB structure shall influence on $T_C$ (PCB case temperature). If $T_C$ is high, then we can expect high $T_J$ and the rapid degradation of luminous flux. And modeling DUT is bar-type PCB which is assembled on aluminum heat sink. In this note, we simulated thermal behaviors with 3kinds of PCBs. The key variables are the kinds of PCB material, the existence of via hole and copper pad thickness in PCB.

First of all, the effects of PCB material is the dominant factor for $T_C$ in high power applications, which can generate large heat. for example. For example, For LED bulb(which can replace 60W incandescent lamp), it should be recommended for using metal-core PCB board for normal operation condition.




[Reference PCB shape]

### 2.5.2 PCB material effects

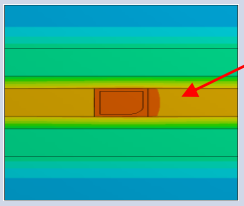
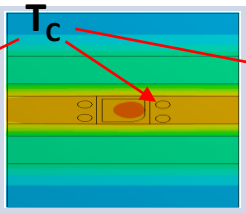
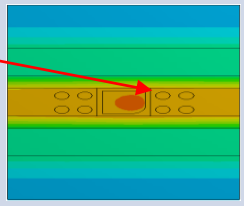
| Material | CEM-1 | FR-4 | McPCB |
|---|---|---|---|
| Cu 1.0 ounce 2-layer<br>PCB 1.0t<br>No via hole<br>65mA driving |  |  |  |
| $R_{TH}$ | 22.0℃/W | 17.8℃/W | 6.3℃/W |
| $T_C$ | 69.3℃ | 65.0℃ | 47.8℃ |



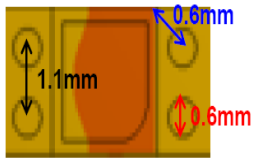
[ Comparison with PCB materials ]

## 2.5 Thermal Simulations

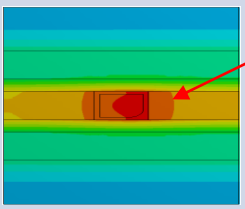
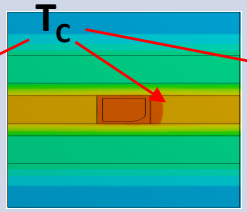
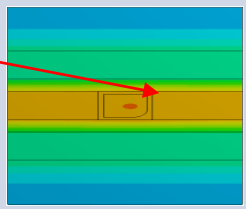
### 2.5.3 Via hole effects

| Number of via | Non via | 4 via | 8via |
|---|---|---|---|
| Cu 1.0 ounce 2-layer<br>FR-PCB 1.0t<br>65mA driving |  |  |  |
| $R_{TH}$ | 17.8℃/W | 10.5℃/W | 10.2℃/W |
| $T_C$ | 65.0℃ | 63.9℃ | 63.8℃ |

[ Comparison with via-hole ]



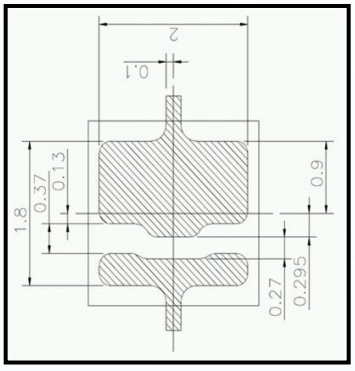

### 2.5.4 Copper pad thickness effects

| Cu thickness | ½ ounce (17.78㎛) | 1 ounce (35.56㎛) | 2ounce (71.12㎛) |
|---|---|---|---|
| 2-layer<br>FR-PCB 1.0t<br>No via hole<br>65mA driving |  |  |  |
| $R_{TH}$ | 25.4℃/W | 17.8℃/W | 12.7℃/W |
| $T_C$ | 66.8℃ | 65.0℃ | 63.7℃ |

[ Comparison with Cu pad thickness ]

## 2.6 S.M.T (Surface Mount Technology) guide

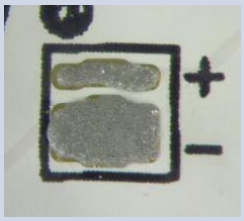
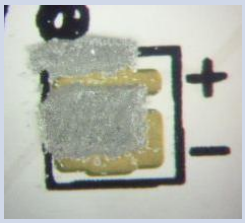
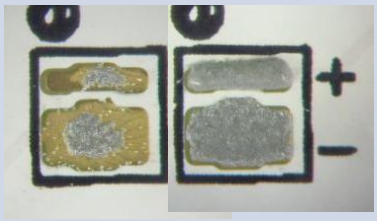
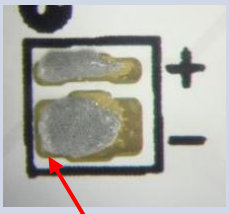
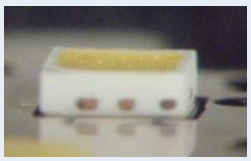
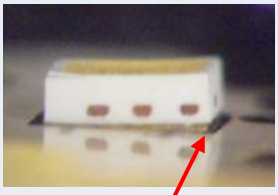
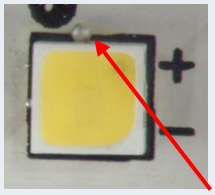
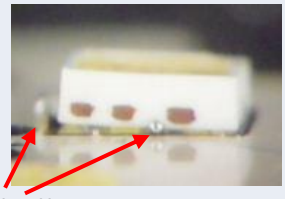
### 2.6.1 Recommended land pattern & solder paste




| LED | Thickness | Solder Alloy |
|---|---|---|
| LM231A | 100㎛ ~ 130㎛ | Sn 96.5<br>Ag 3.0<br>Cu 0.5 |

[ Recommended land pattern ] [ Solder paste components and thickness ]

In this note, it is emphasized that LED operating temperature is main design key of reliability and performance. Especially LM231A has been already verified to robust reliability test. But actually in the field of manufacturing site, most of failure issues are caused by SMT process. For example, allocation between pad and solder mask, incline, lack, and unbalance of solder amount are main quality factor of assembly.

| ( O ) | ( X ) | | |
|---|---|---|---|
|  |  |  |  |
| normal | misallocation | lack & over of amount | unbalance |
|  |  |  |  |
| normal | incline | Pb ball | |

[ Good or bad case - before & after reflow ]

## 2.6 S.M.T guide

### 2.6.2 Pick & Place

**- SMT Equipment process and its conditions**

| Process | Definition | Time (msec) | | Pressure (mmhg) |
|---|---|---|---|---|
| | | Sample | Mass Production | |
| Pick-up | Pick-up PKG from taping reel | 70 | 30 | 500 |
| Place | Place PKG to PCB | 40 | 30 | 60 |
| Blow | Press the PKG for fixing stably | 20 | 10 | - |
| Dump | Dump the faulty PKG | 50 | 50 | - |

※ Samsung SM411 mounter

**- Pick up tool (Collet)**

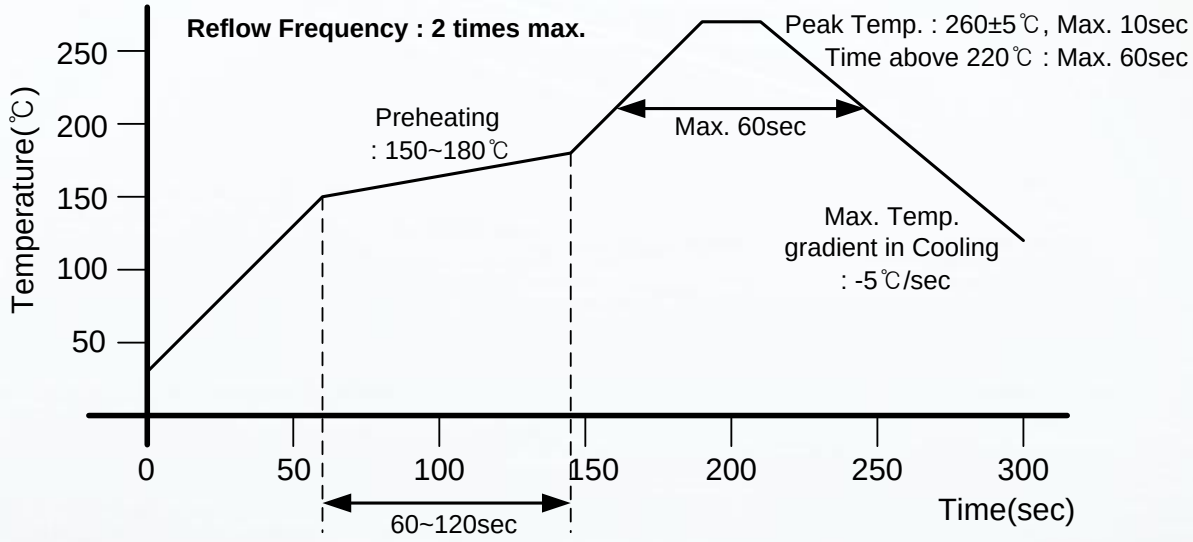
. LM231A PKG pick up section
Outside diameter : ϕ 2mm
Inside Diameter : ϕ 1.2mm


※ These reference value is information only and could be changeable with condition of assembly.

## 2.6 S.M.T guide

### 2.6.3 Reflow profile and conditions

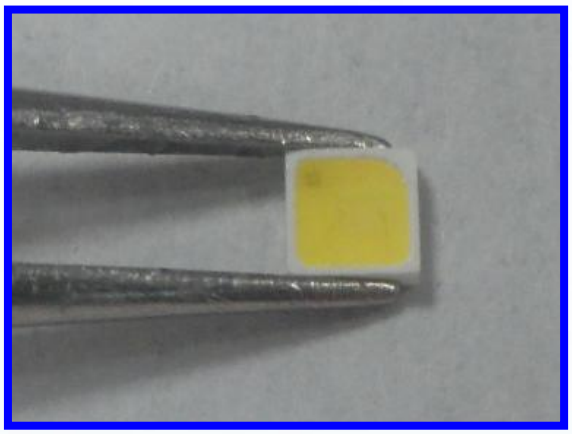
The below reflow profile is recommended for reflow soldering. Reflow conditions can be changed in various soldering equipment and PCB type. Also user should follow the reflow guide line of a solder manufacturer .
For Manual Soldering, no more than 5 seconds @MAX300 ℃, under soldering iron.



## 2.7 Mechanical consideration

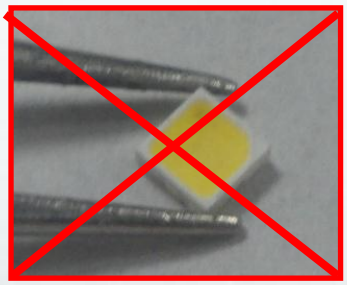
### 2.7.1 Handling guide

Please use tweezers to grab LM231A at the base. Do not touch the silicon mold side with the tweezers or fingers and the maximum compressing force is 15N on the silicone mold compound. Also don't place pressure on the encapsulation resin – phosphor.



**Correct Handling**

**Incorrect Handling**

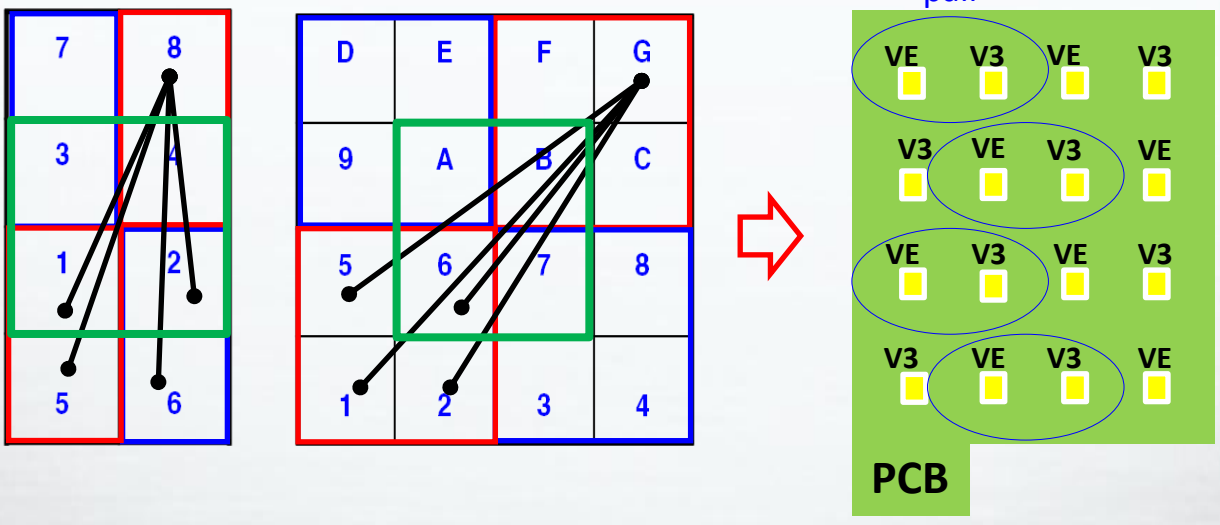


## 3.1 Kitting bin solution

### 3.1.1 Array solution for color uniformity

Samsung Kitting-Bin is purposed to maximize effective utilization in the production of Lighting applications. It is convenient to assemble LED modules in according to kitting-bin guide line.
For more information about kitting bin operation, refer to LM231A datasheet.

- **[Logic example] Basic Array Methods on PCB of LEDs**
  For target bin (green line)
  - Cool white : one LED in 4 upper bin(3,4,7,8) could be paired with any LED in 4 lower bins(1,2,5,6)
  - Warm white : one LED in 4 bins(B,C,F,G) could be paired with any LEDs in diagonal 4 bins(1,2,5,6)




[ 5000K, 5700K 6500K Sub-bin ]

[ 2700K, 3000K 3500K, 4000K Sub-bin ]

[SMT Pairing on board]

# 3.1 Kitting bin solution

## 3.1.2 Implementation of kitting bin application

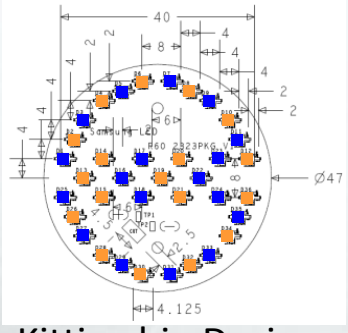
The test is planned to verify that the color gap between “TE rank” and “T3 rank” is not recognized when “Kitting-Bin” is applied.

### Test Information

- PKG information
  - LM231A **A1TES2** Rank - 18pcs
  - LM231A **A1T3S2** Rank - 18pcs
- Test Method
  - Measurement equipment
    : Gonio-photometer : NL 7000, Spectro-radiometer : CS 2000
  - Measured item
    : Cx,Cy, CCT, CRI
- Inspection with the bare eye
  : Color difference between “TE bin” and “T3 bin” was not found in the bare eye.

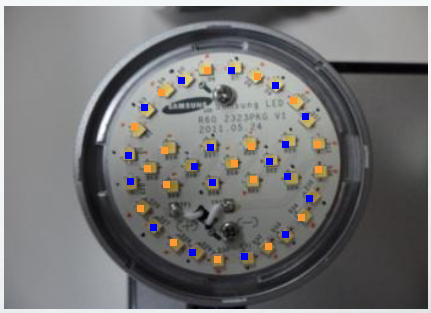
### Assembly Information

2 kind of rank, A1TES2 and A1T3S2, is picked and placed by turns when SMT processing.




Kitting bin Design

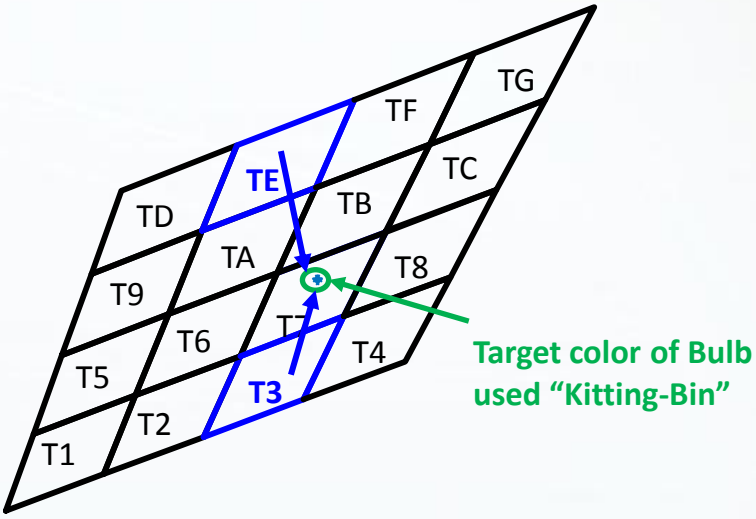
- LM231A - A1**TE**S2
- LM231A - A1**T3**S2



**60W Bulb**
**After SMT**

**Results**

In inspection with bare eye, color difference between “TE bin” and “T3 bin” was not found out.
The measured optical properties show that the color target of bulb is located within MacAdam 3 step binning.


[ Target color of bulb at chromaticity diagram ]

| Set | Current (A) | Voltage (Vac) | Cx | Cy | CCT(K) | CRI (Ra) |
|---|---|---|---|---|---|---|
| Bulb | 0.065 | 220 | 0.385 | 0.379 | 3900K | 83 |

# 4. Revision History

| Date | Revision History | Writer | |
|---|---|---|---|
| | | Drawn | Approved |
| 2013.02.19 | New Version | S. K. Park | D.M. Jeon |
| 2012.12.27 | -. Naming changed (MP23L → LM231A)<br>-. 10,000hr reliability test up-dated (P.39) | Y. J. Lee | D. M. Jeon |
| 2013.02.19 | 2nd revision<br>-. New datasheet generated (2012.11.30) | Y. J. Lee | D. M. Jeon |
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