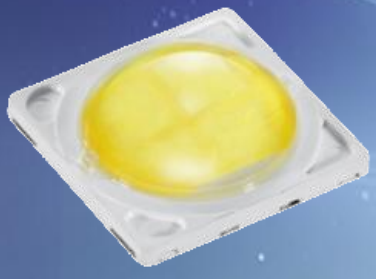


Application Note rev1.1

HA04J (HV-AC)

Samsung Electronics

Index

1.1 System Overview

1.1.1 Product Description

- HV-AC Product is directly connected to AC power source without any AC/DC converter
- Rectifier function merged in single bidirectional AC-LED die
- Unique monolithic LED die technology adopted
- Robust design : EMI/EMC, Surge, ESD
- High electrical performance : PF, THD*
- Available in various Voltage ranges:
  100~120Vac, 220~240Vac, 277Vac
- 100~120Hz current driving at AC source 50~60Hz
- Long life span and high reliability
- Available in white (2700K to 6500K CCT)
- Dimmable**
- Excellent color reproduction
- Eco-friendly light

* PF (Power Factor), THD(Total Harmonic Distortion)

** low voltage dimmer is suitable . See page. 4

1.1 System Overview

1.1.2 Benefits and Features

- Simple Design:

  Just connect infinitely parallel circuit connections without the trouble of making LED Arrays such as with DC LEDs.

- Compact Size & Low Weight:

  User can get space & weight saving in the fixture by eliminating the power supply unit.

- Longer System Life-time:

  Lighting Life-time of the fixture can be equivalent to the LED long life- time rather than relatively short power supply life-time.

- Low Cost solution:

  User can get benefits of saving power supply device cost.

- Eco friendly solution:

  There is no waste of electrical printed circuit board. etc.

- Wide operation range:

  Driving package power consumption range is 3.3W ~ 4.5W

1.2 Application

HV-AC solution can be used at various lighting applications

Lamp

Accent Lamp, GU10, Bulb
: small space solution




Ambient Lighting

Down Light, Ceiling Light
: simple assembly and low cost solution



High Bay

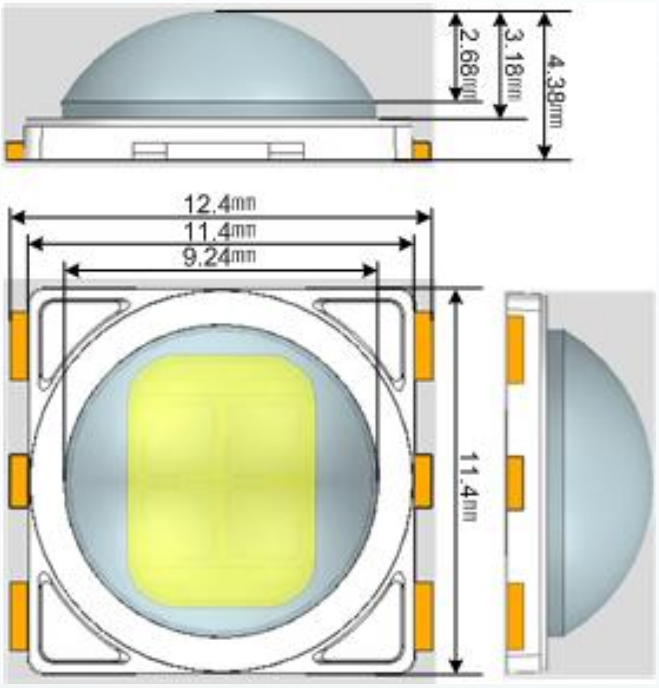
Garage, Warehouse, Street Light
: compact size and low cost solution



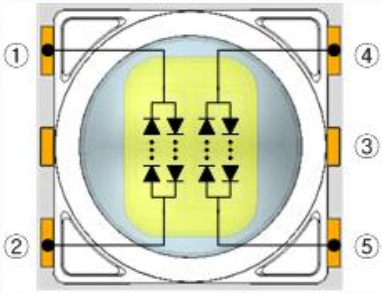
1.3 Package Information

1.3.1 Dimension and Pad Configuration

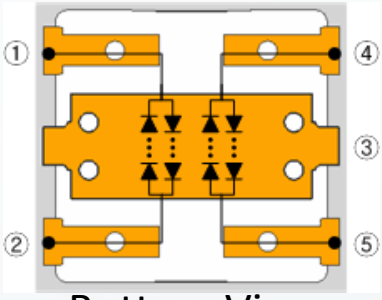
- Symmetric package with 4 electrical pads and 1 thermal pad
- 4 electrical pads are bi-polarity and 2-pair string (①-②, ④-⑤)
- 1 thermal pad(③) is non-polarity



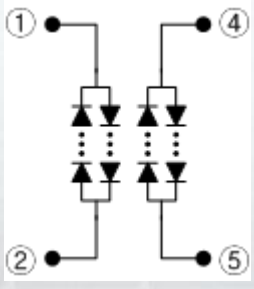
Dimension (12.4x11.4x4.38㎜)



Top View



Bottom View



LED Electrical Circuit

Pad	Function
①	Bi-polarity
②	Bi-polarity
③	Thermal Non-polarity (Electrically Isolated)
④	Bi-polarity
⑤	Bi-polarity

1.3 Package Information

1.3.2 Absolute Maximum Rating

- HV-AC absolute maximum ratings are shown in below table.
- When designing an application by using HV-AC, stay within margins to avoid exceeding the absolute maximum rating.

Parameter	Symbol	Rating	Conditions
Operating Temperature range	T_{op}	–40 ~ +85 ℃	-
Storage Temperature range	T_{stg}	–40 ~ +100 ℃	-
Power Dissipation*	W	4.5	
Junction Temperature	T_j	125 ℃	-
Forward Current	I_F	29 ㎃ (240Vac) ** 58 ㎃ (120Vac)	R.M.S*** value
Thermal Resistance, (Junction to Package Substrate)	R_{th}, JS	4.7 ℃/W	-
Assembly Process Temp.		260℃, < 10 sec	-
LED Operation Frequency	Hz	100~120Hz	50~60Hz****
ESD		± 3 kV	HBM
Surge		± 2 kV	@220Vac

* Average power dissipation of only LED component without any ballast components.
** Maximum current that can be feed into LEDs depends on their configuration
*** RMS (Root Mean Square) current indicates AC operation at 50~60Hz
**** Input AC source frequency

2.1 Warnings

1) For avoiding over-current, customers are recommended to apply resistors to prevent sudden change of the input current caused by slight shift of the voltage.

2) This device should not be used in any type of fluid such as water, oil, organic solvent, etc. If decontamination is required, IPA could be recommended to use.

3) When LEDs illuminate, operating current should be decided after considering the ambient maximum temperature(Refer to the maximum rating table).

4) LEDs must be stored in a clean environment.
If the LEDs are to be stored for 3 months or more after being shipped from S LED, they should be packed in a container sealed with nitrogen gas.
(Shelf life of sealed bags: 12 months, temp. 0~40 ℃, 20~70 % RH)

5) After bag is opened, device subjected to soldering, solder reflow, or other high temperature processes must be:
a. Mounted within 168 hours (7 days) at an assembly line with a condition of no more than 30 ℃/60 %RH,
b. Stored at <10 %RH.

6) Repack unused products with anti-moisture pack, seal pack to close any opening and then store in a dry place.

7) Devices require baking before mounting, if humidity card reading is >60 % at 23±5 ℃.

8) If baking is required, devices must be baked for 24 hours at 65±5 ℃.

9) The LEDs are sensitive to static electricity and surge current. It is recommended to use a wrist band or anti-electrostatic glove when handling the LEDs.

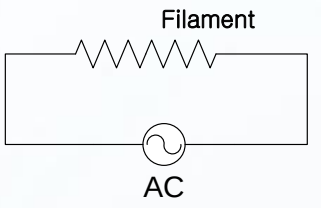
If voltage exceeding the absolute maximum rating is applied to LEDs, it may cause damage or even destruction of LED devices.

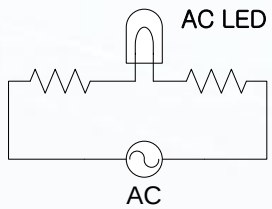
Damaged LEDs may show some unusual characteristics such as increase in leak current, lowered turn-on voltage, or abnormal lighting of LEDs at low current.

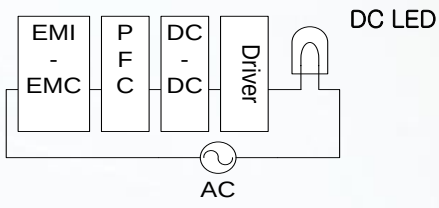
3. Basic AC Operation

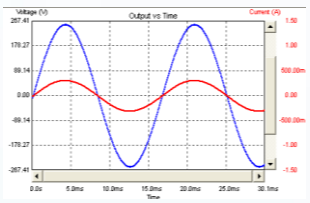
3.1 Incandescent Edison Lamp Concept for LED

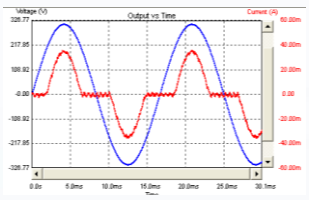
•AC LED is modeled after the incandescent Edison bulb

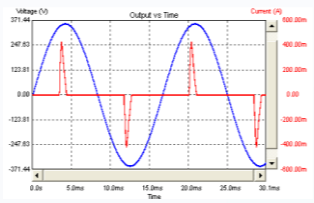












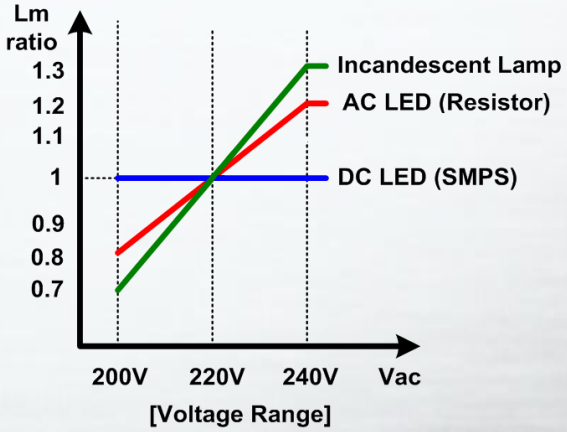
※Without PFC circuit

* AC Voltage Waves / Current Waves

[Edison Bulb] [AC-LED] [Normal DC Operation]

• Difference in lighting properties noticed by the human eye is small

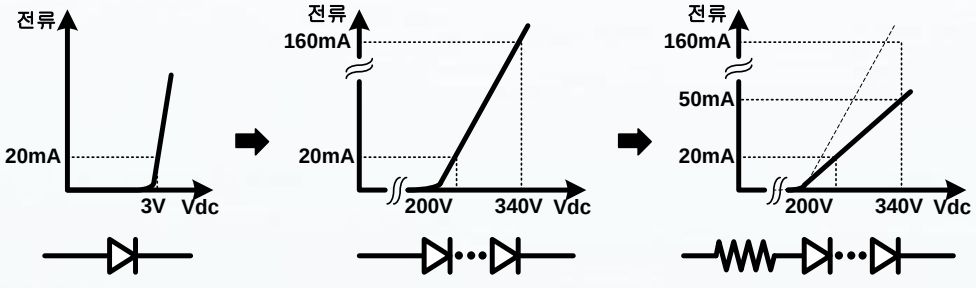
• Incandescent lamps emit their luminous output differently as input voltage sweep and AC-LED also has similar properties



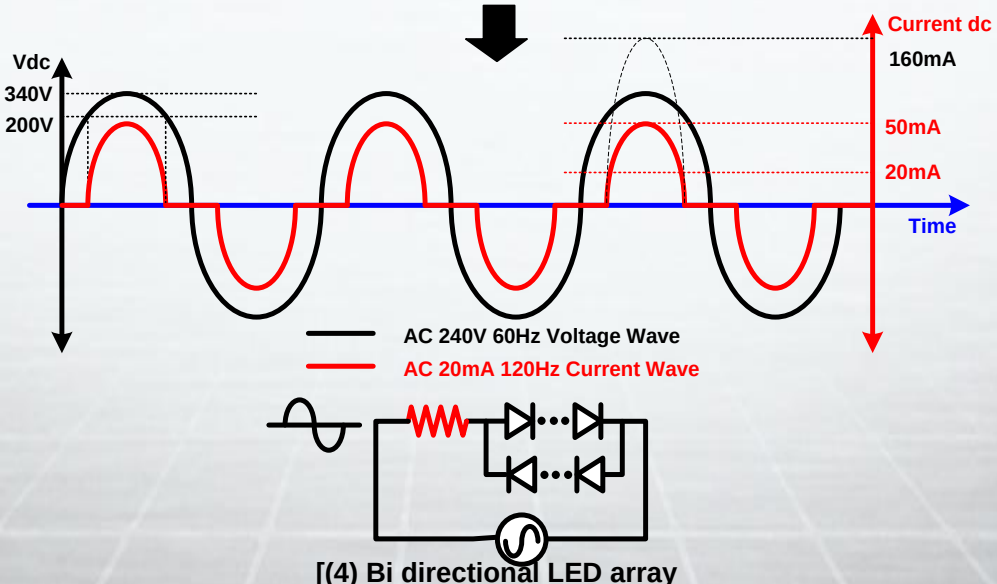
SAMSUNG LED

3.2 Normal AC Operation

- (1),(2) For driving LED under AC source directly, High Vf LED is needed
- (3) Current versus Voltage curve of LED is exponential function. Additional ballast is needed for attenuation of high Current at Peak Voltage
- (4) LED arrays are bi-directional. Current drive at 100~120Hz operation as 50~60Hz input AC source
- Power quality is poor. THD is 40~50% at 220Vac



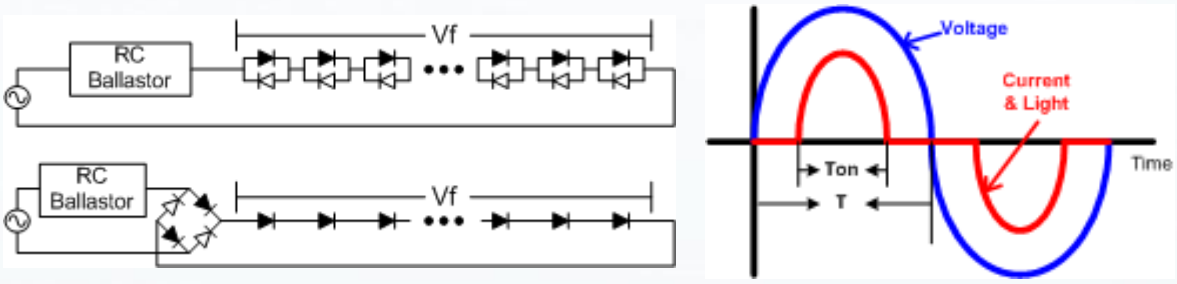
[(1) IV curve / Single LED] [(2) Multi Chip IV] [(3) Resistor add IV]



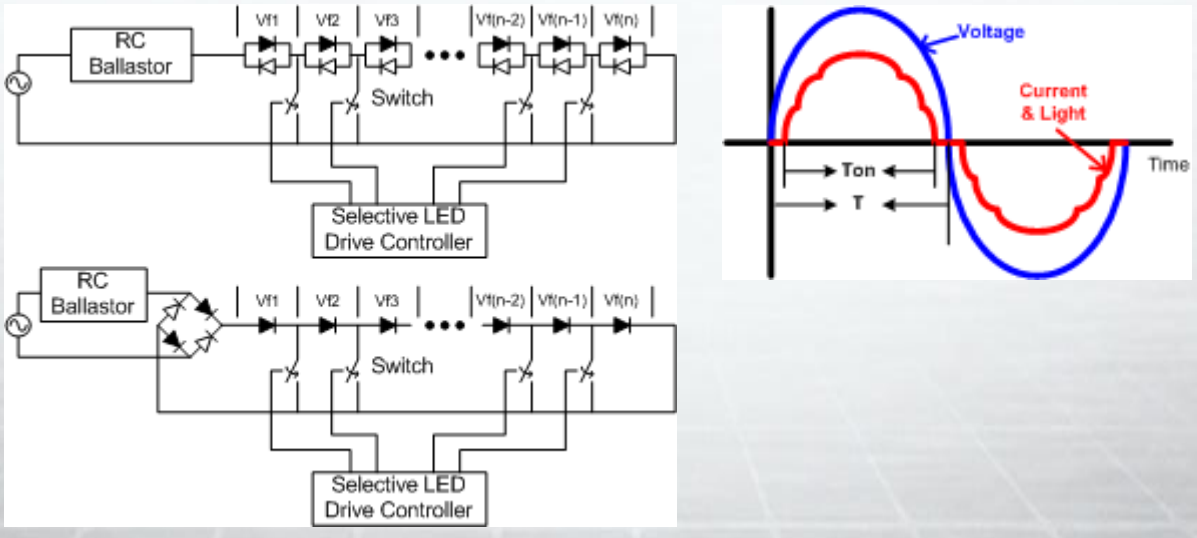
[(4) Bi directional LED array
(Rectifier merged function]

3.3 Advanced AC Operation

- The purpose of improving AC solution is to make narrow phase difference between Voltage and Current. Normal AC operation is very simple but has poor power quality and low flickering performance – turn on duty ratio (T_{on}/T) is 50~60%
- Some kind of solution like a switching logic controller could reduce phase difference and finally get advanced quality – THD, PFC, turn-on duty ratio(T_{on}/T) is about 80% which reduces flicker
- Complicated control system is not desirable for AC solution



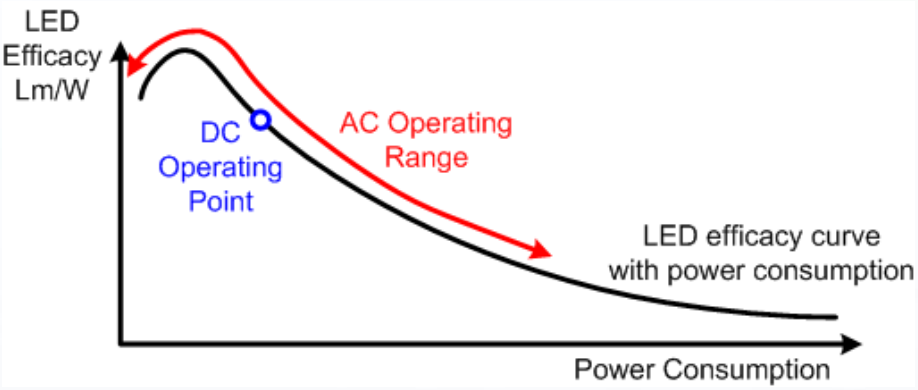
[Normal AC Operation]



[Advanced AC Operation]

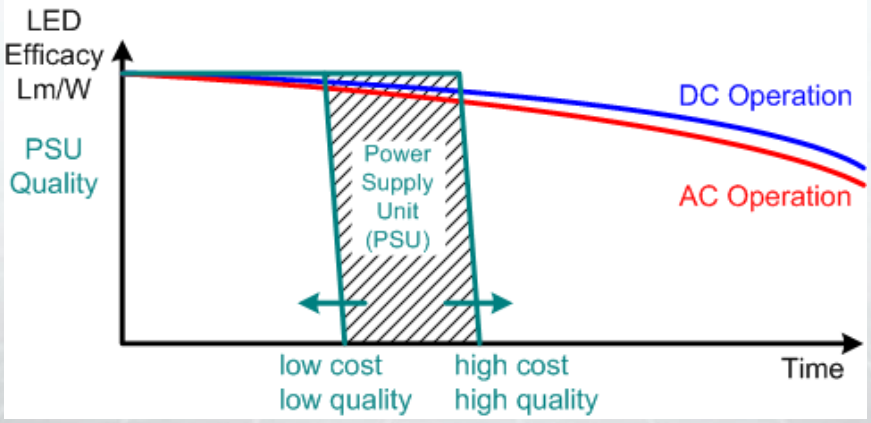
3.4 AC vs DC operation

• Usually LED is operated by constant current driving on one point according to LED efficacy curve. But AC operation is driven by AC voltage, therefore operation range is as wide as voltage alternately changes.



[Efficacy curve]

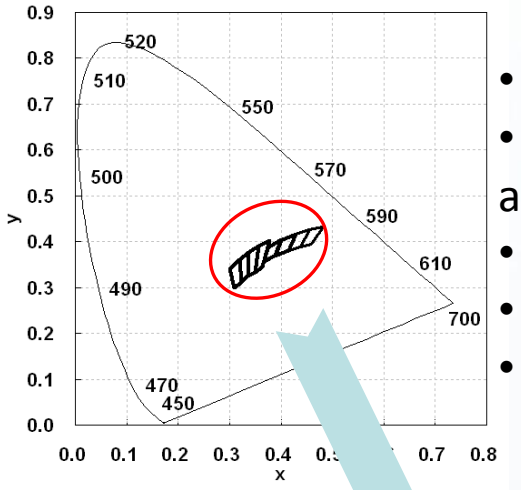
• When LED is driven by same power consumption under each driving method, AC driving method might cause more stress to LED lifetime rather than DC operation. From a different viewpoint at system level, PSU(power supply unit) is main factor to determine system lifetime.



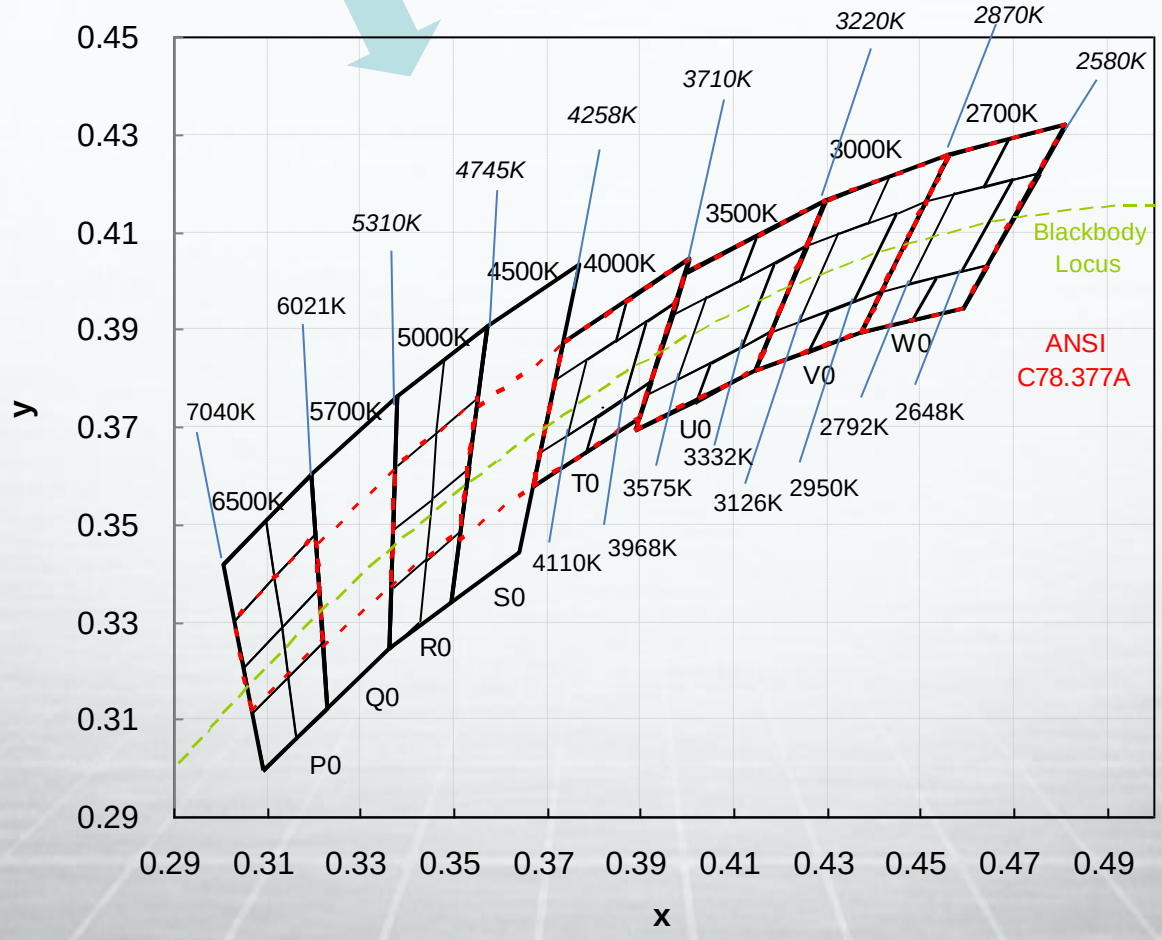
[Lifetime]

4.1 Optical Considerations

4.1.1 Chromaticity Bins



- HV-AC is supplied by ANSI standard.
- It should be suitable for lighting applications
- HV-AC is supplied from 2600K~7000K
- Those are divided to 6 ranks (W0~P0)
- Refer to below graph



SAMSUNG LED

4.1 Optical Considerations

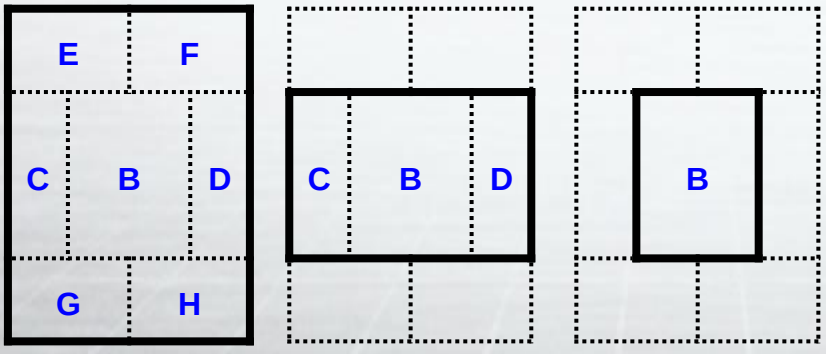
4.1.2 Product Code

- HV-AC has 6 CCTs – 2700K, 3000K, 3500K, 4000K, 5000K, 6500K
- Within DOE standard, 3 kind of bin (Whole, Half, Quarter) are available

CCT	Item Code			Properties	
	① Whole Bin	② Half Bin	③ Quarter Sub Bin	Lm typ. (3.3W / 4.5W)	CRI typ.
2700K	SPHWHTHAD605S0W0U4	SPHWHTHAD605S0WUU4	SPHWHTHAD605S0WPU4	280 / 355	83
3000K	SPHWHTHAD605S0V0VZ	SPHWHTHAD605S0VUVZ	SPHWHTHAD605S0VPVZ	290 / 365	83
3500K	SPHWHTHAD605S0U0VZ	SPHWHTHAD605S0UUVZ	SPHWHTHAD605S0UPVZ	290 / 365	83
4000K	SPHWHTHAD605S0T0WZ	SPHWHTHAD605S0TUWZ	SPHWHTHAD605S0TPWZ	300 / 375	83
5000K	SPHWHTHAD603S0R0MZ	-	SPHWHTHAD603S0RTMZ	360 / 460	75
6500K	SPHWHTHAD603S0P0LZ	-	SPHWHTHAD603S0PTLZ	330 / 430	75

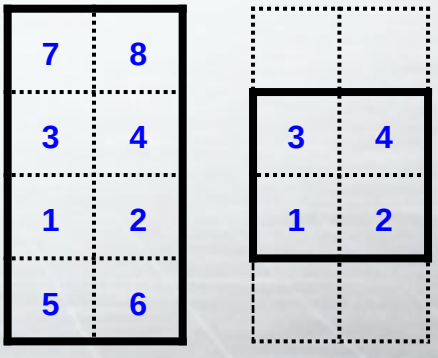
■ Warm White (2700K,3000K,3500K,4000K)

① Whole Bin ② Half Bin (1/2) ③ Quarter Bin (1/4)



■ Cool White (5000K,6500K)

① Whole Bin ③ Quarter Bin



* Warm White. B, C, D, E, F, G, H is sub bin
** Cool White, 1, 2, 3, 4, 5, 6, 7 is sub bin

4.1 Optical Considerations

4.1.3 Chromaticity Coordinates (T_a = 25℃)

• 2700K

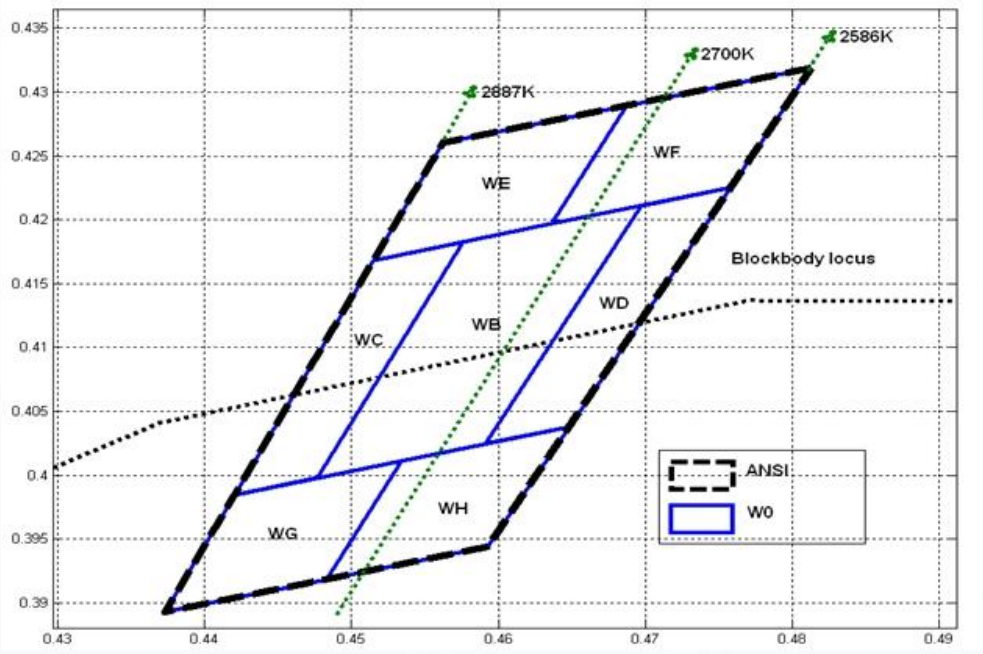


TABLE	Rank	CIE X	CIE Y	Rank	CIE X	CIE Y
2700K	WB	0.4697	0.4211	WF	0.4813	0.4319
		0.4576	0.4183		0.4688	0.4290
		0.4477	0.3998		0.4636	0.4196
		0.4591	0.4024		0.4758	0.4225
	WC	0.4576	0.4183	WG	0.4534	0.4012
		0.4515	0.4168		0.4420	0.3985
		0.4420	0.3985		0.4373	0.3893
		0.4477	0.3998		0.4483	0.3919
	WD	0.4758	0.4225	WH	0.4648	0.4038
		0.4697	0.4211		0.4534	0.4012
		0.4591	0.4024		0.4483	0.3919
		0.4648	0.4038		0.4593	0.3944
	WE	0.4688	0.4290	ANSI	0.4813	0.4319
		0.4562	0.4260		0.4562	0.4260
		0.4515	0.4168		0.4373	0.3944
		0.4636	0.4196		0.4593	0.4319

4.1 Optical Considerations

4.1.3 Chromaticity Coordinates (T_a = 25℃)

• 3000K

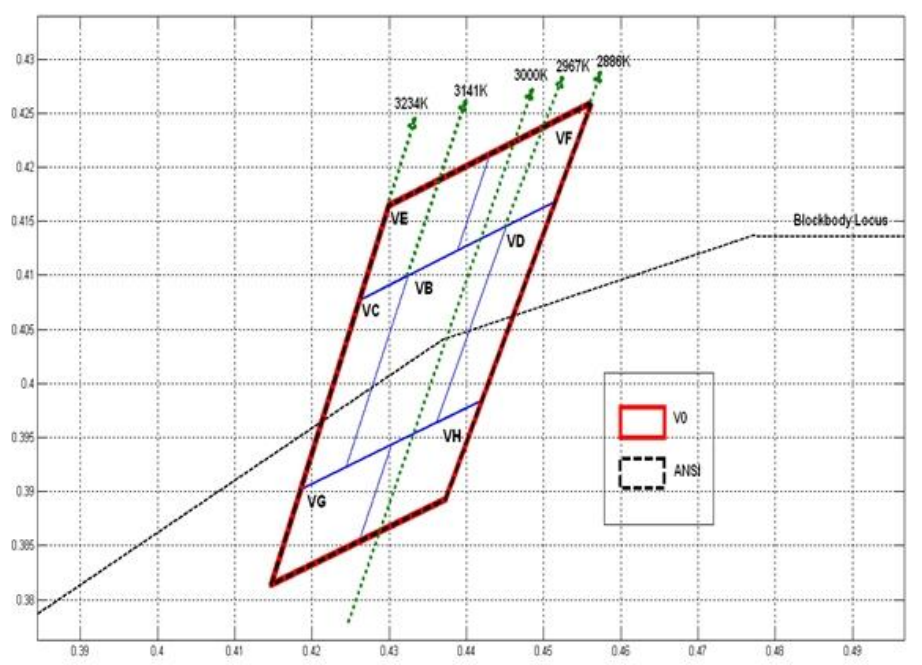


TABLE	Rank	CIE X	CIE Y	Rank	CIE X	CIE Y
3000K	VB	0.4451	0.4146	VF	0.4562	0.4260
		0.4324	0.4100		0.4431	0.4213
		0.4244	0.3922		0.4388	0.4122
		0.4361	0.3964		0.4515	0.4168
	VC	0.4324	0.4100	VG	0.4303	0.3944
		0.4261	0.4077		0.4185	0.3902
		0.4185	0.3902		0.4147	0.3814
		0.4244	0.3922		0.4260	0.3854
	VD	0.4515	0.4168	VH	0.4420	0.3985
		0.4451	0.4146		0.4303	0.3944
		0.4361	0.3964		0.4260	0.3854
		0.4420	0.3985		0.4373	0.3893
	VE	0.4431	0.4213	ANSI	0.4813	0.4319
		0.4299	0.4165		0.4562	0.4260
		0.4261	0.4077		0.4373	0.3893
		0.4388	0.4122		0.4593	0.3944

4.1 Optical Considerations

4.1.3 Chromaticity Coordinates (T_a = 25℃)

• 3500K

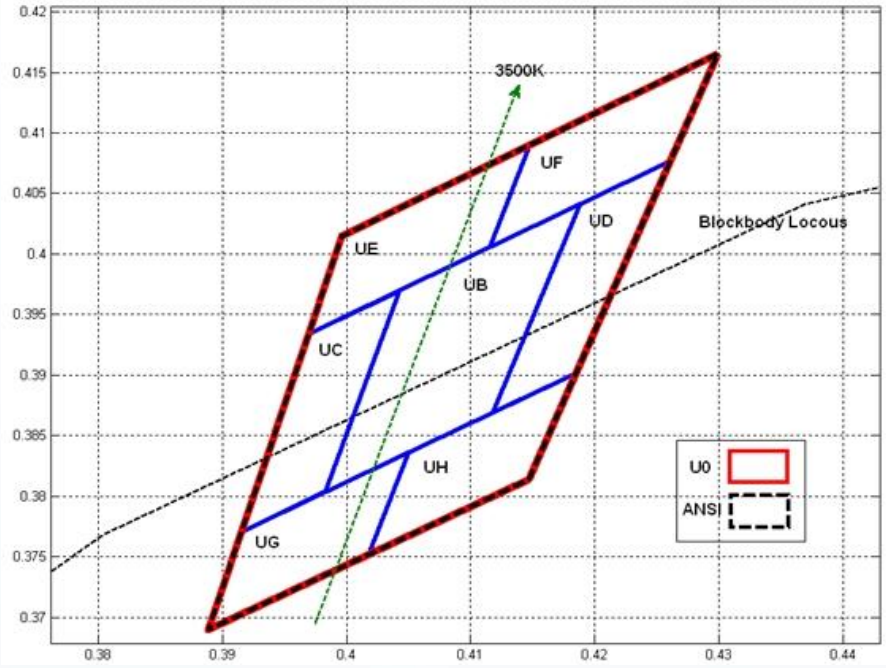


TABLE	Rank	CIE X	CIE Y	Rank	CIE X	CIE Y
3500K	UB	0.4188	0.4042	UF	0.4299	0.4165
		0.4042	0.3970		0.4148	0.4090
		0.3983	0.3803		0.4115	0.4005
		0.4118	0.3869		0.4261	0.4077
	UC	0.4042	0.3970	UG	0.4050	0.3837
		0.3969	0.3934		0.3916	0.3771
		0.3916	0.3771		0.3889	0.3690
		0.3983	0.3803		0.4018	0.3752
	UD	0.4261	0.4077	UH	0.4185	0.3902
		0.4188	0.4042		0.4050	0.3837
		0.4118	0.3869		0.4018	0.3752
		0.4185	0.3902		0.4147	0.3814
	UE	0.4148	0.4090	ANSI	0.4813	0.4319
		0.3996	0.4015		0.4562	0.4260
		0.3969	0.3934		0.4373	0.3944
		0.4115	0.4005		0.4593	0.4319

4.1 Optical Considerations

4.1.3 Chromaticity Coordinates (T_a = 25℃)

• 4000K

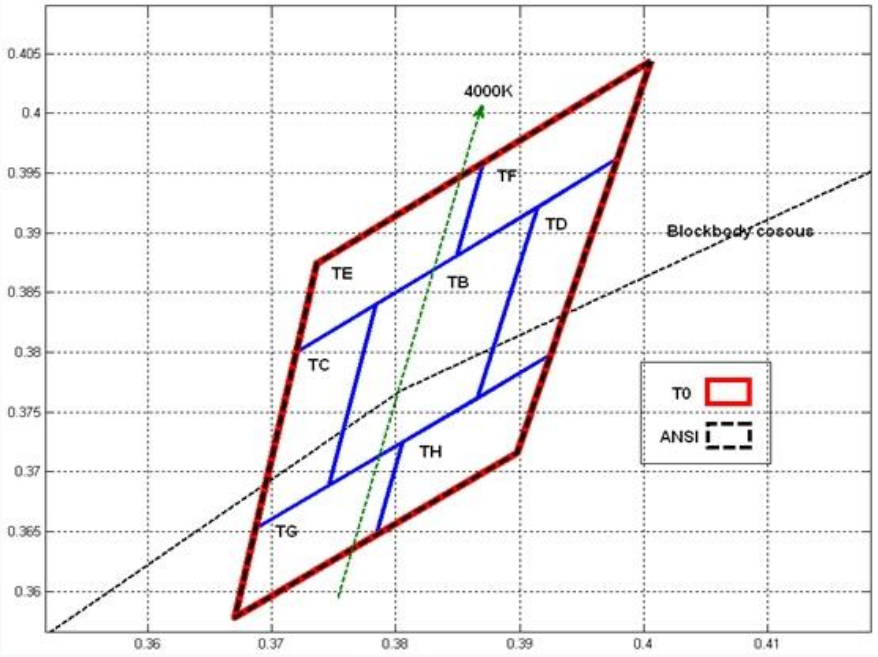


TABLE	Rank	CIE X	CIE Y	Rank	CIE X	CIE Y
4000K	TB	0.3914	0.3922	TF	0.4006	0.4044
		0.3784	0.3841		0.3871	0.3959
		0.3746	0.3688		0.3849	0.3880
		0.3865	0.3761		0.3979	0.3962
	TC	0.3784	0.3841	TG	0.3806	0.3726
		0.3720	0.3800		0.3687	0.3652
		0.3687	0.3652		0.3670	0.3578
		0.3746	0.3688		0.3784	0.3647
	TD	0.3979	0.3962	TH	0.3925	0.3798
		0.3914	0.3922		0.3806	0.3726
		0.3865	0.3761		0.3784	0.3647
		0.3925	0.3798		0.3898	0.3716
	TE	0.3871	0.3959	ANSI	0.4813	0.4319
		0.3736	0.3874		0.4562	0.4260
		0.3720	0.3800		0.4373	0.3944
		0.3849	0.3880		0.4593	0.4319

4.1 Optical Considerations

4.1.3 Chromaticity Coordinates (T_a = 25℃)

• 5000K

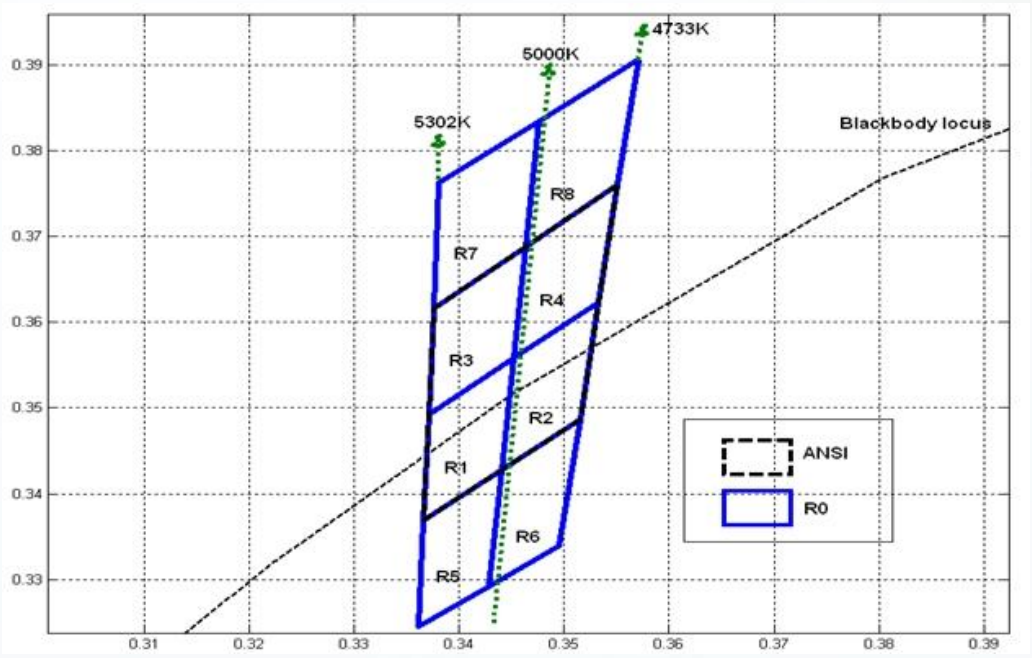


Table	Rank	CIE X	CIE Y	Rank	CIE X	CIE Y
5000K	R1	0.3452	0.3558	R5	0.3441	0.3428
		0.3371	0.3493		0.3366	0.3369
		0.3366	0.3369		0.3361	0.3245
		0.3441	0.3428		0.3428	0.3292
	R2	0.3533	0.3624	R6	0.3515	0.3487
		0.3452	0.3558		0.3441	0.3428
		0.3441	0.3428		0.3428	0.3292
		0.3515	0.3487		0.3495	0.3339
	R3	0.3464	0.3688	R7	0.3476	0.3835
		0.3376	0.3616		0.3381	0.3762
		0.3371	0.3493		0.3376	0.3616
		0.3452	0.3558		0.3464	0.3688
	R4	0.3551	0.3760	R8	0.3571	0.3907
		0.3464	0.3688		0.3476	0.3835
		0.3452	0.3558		0.3464	0.3688
		0.3533	0.3624		0.3551	0.3760

4.1 Optical Considerations

4.1.3 Chromaticity Coordinates (T_a = 25℃)

• 6500K

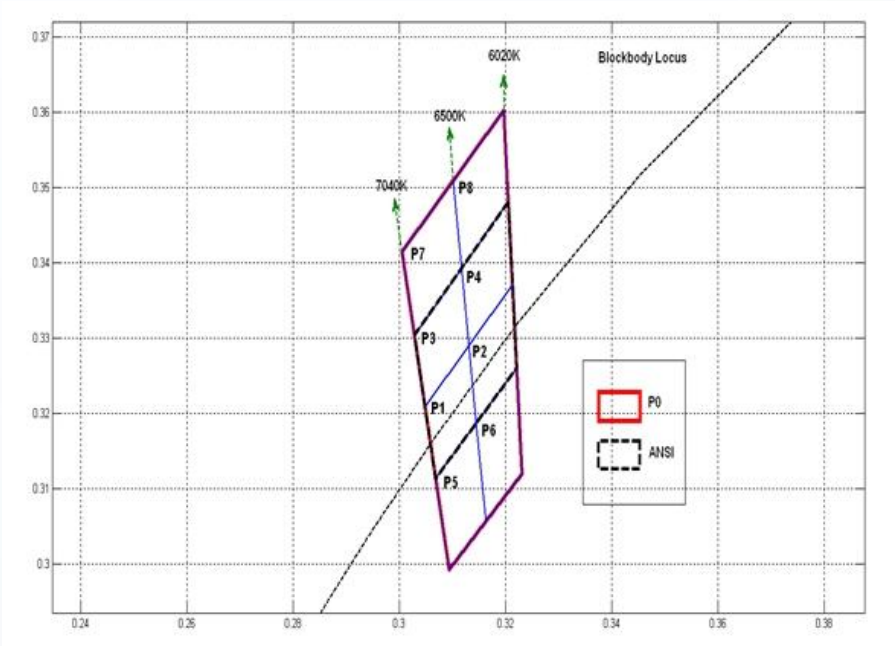


Table	Rank	CIE X	CIE Y	Rank	CIE X	CIE Y
6500K	P1	0.3131	0.3290	P5	0.3145	0.3187
		0.3048	0.3209		0.3068	0.3113
		0.3068	0.3113		0.3093	0.2993
		0.3145	0.3187		0.3162	0.3057
	P2	0.3213	0.3371	P6	0.3221	0.3261
		0.3131	0.3290		0.3145	0.3187
		0.3145	0.3187		0.3162	0.3057
		0.3221	0.3261		0.3231	0.3120
	P3	0.3117	0.3393	P7	0.3101	0.3509
		0.3028	0.3304		0.3005	0.3415
		0.3048	0.3209		0.3028	0.3304
		0.3131	0.3290		0.3117	0.3393
	P4	0.3205	0.3481	P8	0.3196	0.3602
		0.3117	0.3393		0.3101	0.3509
		0.3131	0.3290		0.3117	0.3393
		0.3213	0.3371		0.3205	0.3481

4.1 Optical Considerations

4.1.4 Luminous Flux (T_a = 25℃)

2700K (83Ra)		3.3W* 22mA(rms) / 220Vac 44mA(rms) / 110Vac			4.5W** 29mA(rms) / 220Vac 58mA(rms) / 110Vac		
		Min.	Typ.	Max.	Min.	Typ.	Max.
U4	U1	220	-	240	275	-	300
	V1	240	-	260	300	-	330
	W1	260	-	280	330	-	355
	X1	280	-	300	355	-	-

3000K (83Ra)		3.3W 22mA(rms) / 220Vac 44mA(rms) / 110Vac			4.5W 22mA(rms) / 220Vac 44mA(rms) / 110Vac		
		Min.	Typ.	Max.	Min.	Typ.	Max.
VZ	V1	240	-	260	285	-	310
	W1	260	-	280	310	-	340
	X1	280	-	300	340	-	365
	01	300	-	-	365	-	-

3500K (83Ra)		3.3W 22mA(rms) / 220Vac 44mA(rms) / 110Vac			4.5W 22mA(rms) / 220Vac 44mA(rms) / 110Vac		
		Min.	Typ.	Max.	Min.	Typ.	Max.
VZ	V1	240	-	260	285	-	310
	W1	260	-	280	310	-	340
	X1	280	-	300	340	-	365
	01	300	-	-	365	-	-

4000K (83Ra)		3.3W 22mA(rms) / 220Vac 44mA(rms) / 110Vac			4.5W 22mA(rms) / 220Vac 44mA(rms) / 110Vac		
		Min.	Typ.	Max.	Min.	Typ.	Max.
WZ	W1	260	-	280	310	-	340
	X1	280	-	300	340	-	365
	01	300	-	320	365	-	390
	11	320	-	-	390	-	-

5000K (75Ra)		3.3W 22mA(rms) / 220Vac 44mA(rms) / 110Vac			4.5W 22mA(rms) / 220Vac 44mA(rms) / 110Vac		
		Min.	Typ.	Max.	Min.	Typ.	Max.
MZ	M1	280	-	310	355	-	395
	N1	310	-	340	395	-	435
	P1	340	-	370	435	-	470
	Q1	370	-	-	470	-	-

6500K (75Ra)		3.3W 22mA(rms) / 220Vac 44mA(rms) / 110Vac			4.5W 22mA(rms) / 220Vac 44mA(rms) / 110Vac		
		Min.	Typ.	Max.	Min.	Typ.	Max.
LZ	L1	250	-	280	315	-	355
	M1	280	-	310	355	-	395
	N1	310	-	340	395	-	435
	P1	340	-	-	435	-	

※ Tolerance : ±10%

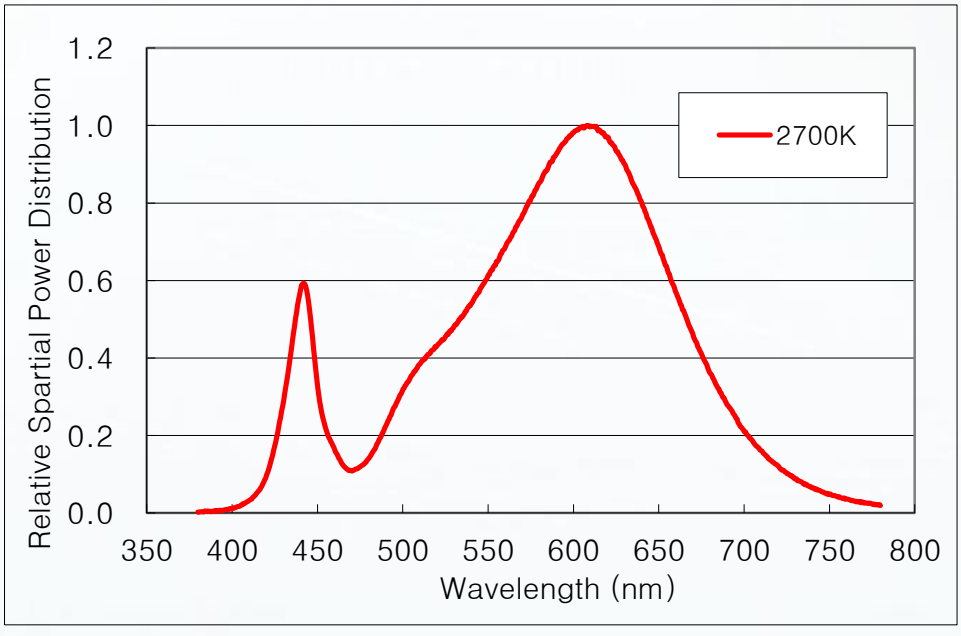
* Reference binning is done @ I_F=22mA(rms), 3.3W.

** Luminous flux at 4.5W operation is provided by statistical correlation with luminous flux at 3.3W operation.

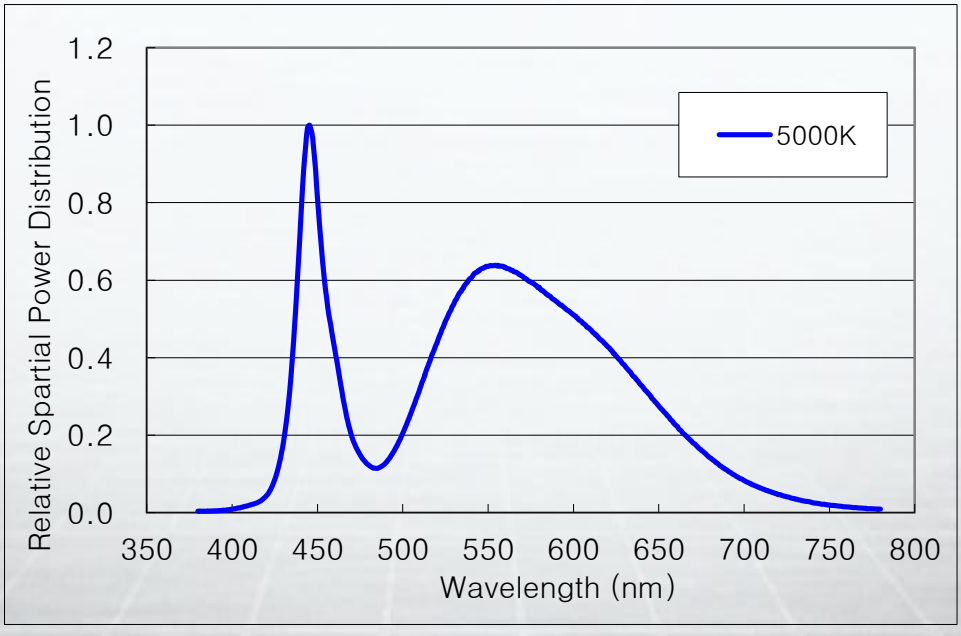
4.1 Optical Considerations

4.1.5 Spectrum

- 2700K (CRI typ. 83 / R9 typ. 20)



- 5000K (CRI typ. 75 / R9 typ. 3)

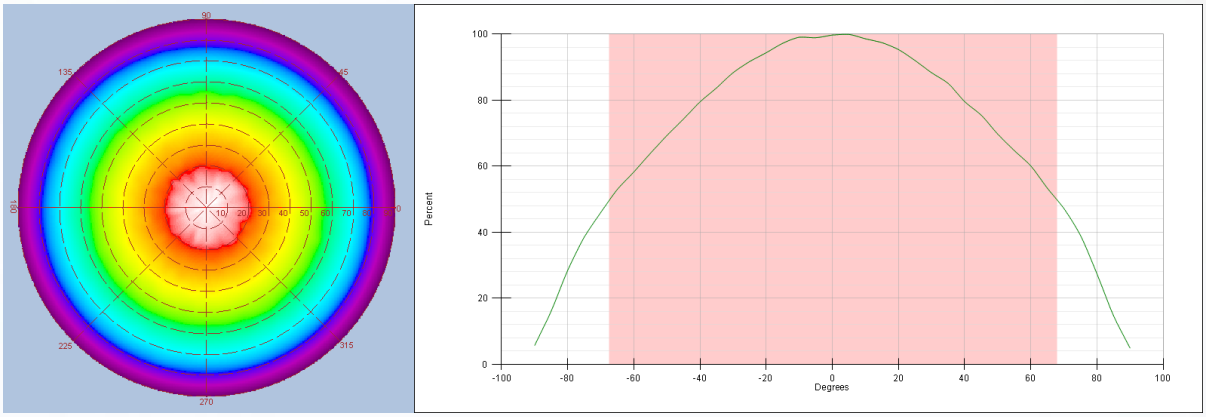


* This spectrum data is representative sampling data

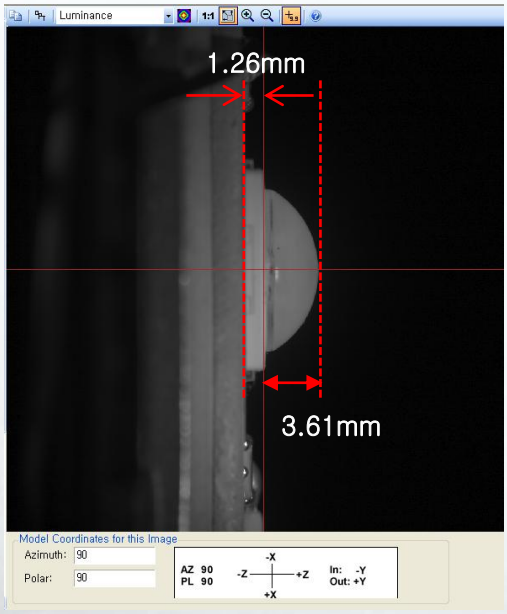
4.1 Optical Considerations

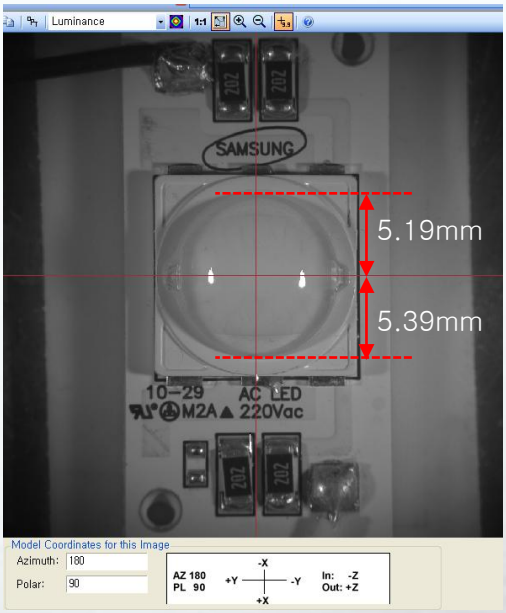
4.1.6 Polar Intensity Diagram

- HV-AC beam angle is 136° (FWHM).



[Measured Viewing Angle]





[Alignment]

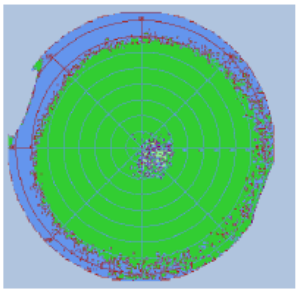
* View Angle describes the spatial intensity distribution and is the difference between the angles corresponding to 50% of the maximum intensity. (Full Width Half Maximum)

4.1 Optical Considerations

4.1.7 Coordinate variation test

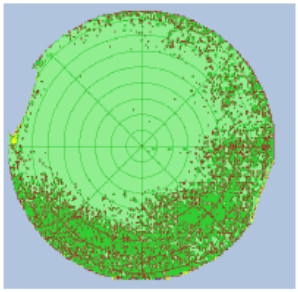
- Optical comparison with Single Package vs 2 Package
- 2Package optic dimension shows symmetric performance and there's no any hot spot

Single PKG 5000K



CCT
3,000 – 3,500
3,500 – 4,000
4,000 – 4,500
4,500 – 5,000
5,000 – 5,500
5,500 – 6,000
6,000 – 6,500

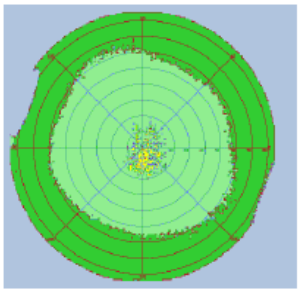
Single PKG 2700K



CCT
2,400 – 2,500
2,500 – 2,600
2,600 – 2,700
2,700 – 2,800
2,800 – 2,900
2,900 – 3,000
3,000 – 3,100

Single PKG Optic Dimension

2 PKG 5000K



CCT
3,000 – 3,500
3,500 – 4,000
4,000 – 4,500
4,500 – 5,000
5,000 – 5,500
5,500 – 6,000
6,000 – 6,500

Two PKG optical dimension is also Symmetric

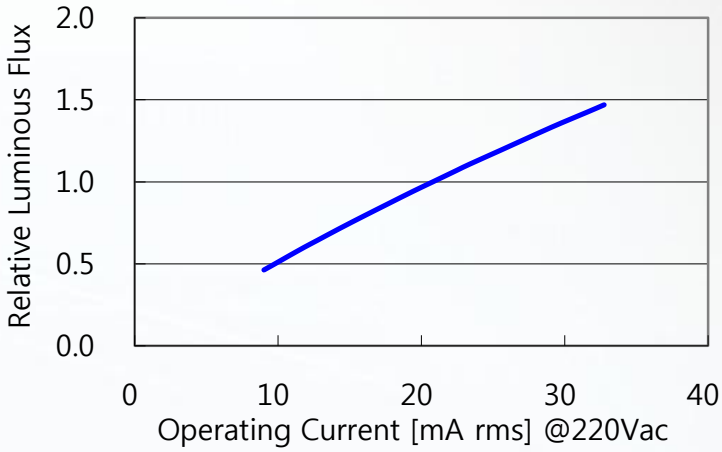
PKG Power	CW (5000K)		WW (2700K)	
	1PKG	2PKG	1PKG	2PKG
3.3W	360lm	720lm	280lm	560lm
4.5W	460lm	920lm	360lm	720lm

2 PKG Optic Dimension

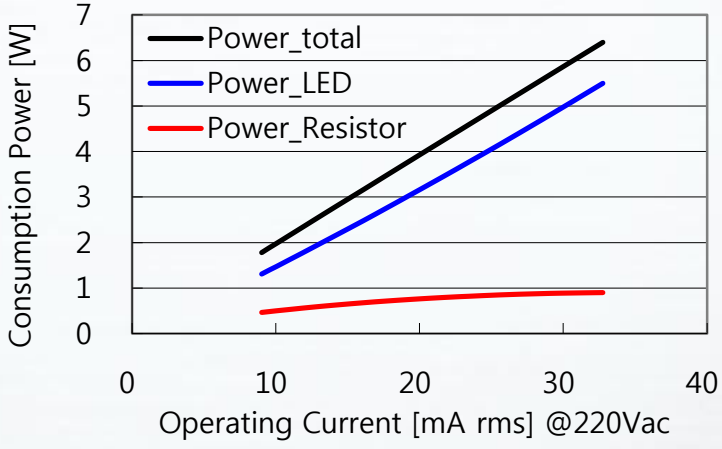
4.1 Optical Considerations

4.1.8 Characteristic Properties at Ts 25℃

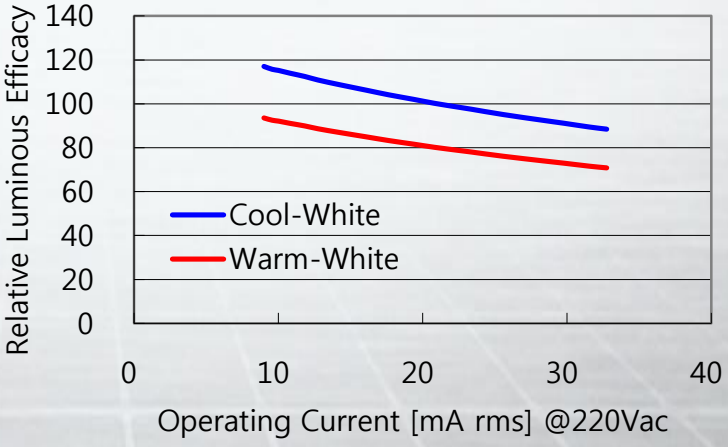
• Operating current is controlled by resistor value and as resistor value is changed, current rise and luminous flux also increase



• System total power consumption consist of resistor and LED power dissipation



• At the package level without resistor power, luminous efficacy is 100lm/W (cool white) and 80lm/W (warm white)



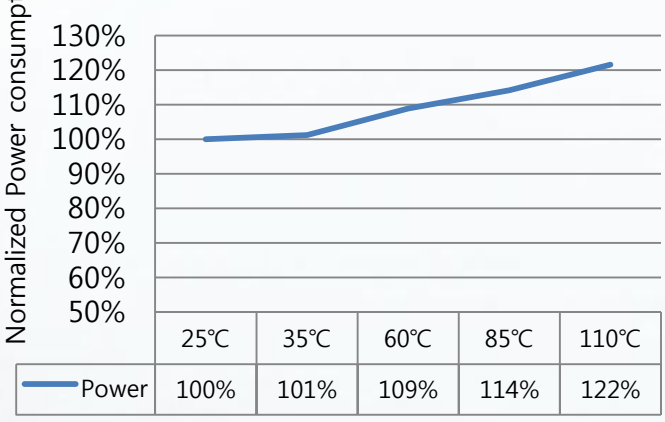
4.1 Optical Considerations

4.1.9 Operating properties vs Solder Temperature

• Basically AC operation is driven by AC Voltage directly. As Temperature increases, ower dissipation increases. This is caused by LED basic thermal properties that LED Vf becomes lower as junction temperature higher.

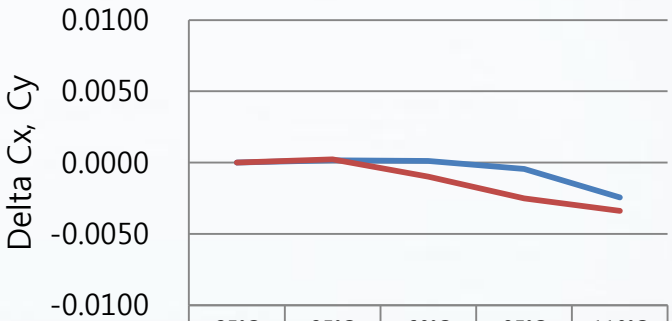
• Different than normal DC operation, power consumption increases and luminous flux maintains initial value as Temperature increases. Lumens per Watt becomes about 90% at 85℃ Solder Temperature vs Initial.

Consumption Power vs Ts



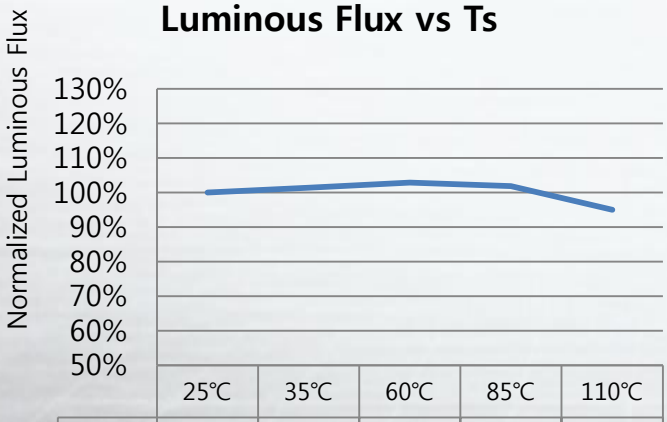
	25℃	35℃	60℃	85℃	110℃
Power	100%	101%	109%	114%	122%

△ Cx, Cy vs Ts



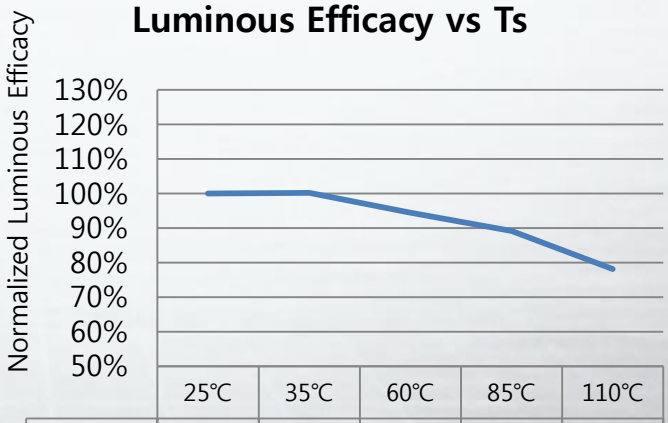
	25℃	35℃	60℃	85℃	110℃
△Cx	0.0000	0.0002	0.0001	-0.0004	-0.0024
△Cy	0.0000	0.0002	-0.0010	-0.0025	-0.0034

Luminous Flux vs Ts



	25℃	35℃	60℃	85℃	110℃
lm	100%	101%	103%	102%	95%

Luminous Efficacy vs Ts



	25℃	35℃	60℃	85℃	110℃
lm/W	100%	100%	94%	89%	78%

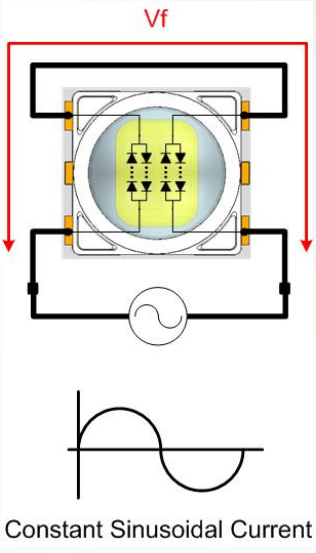
•Ts is solder temperature at package thermal pad. Refer to Page.7

• Measured data from 3000K sample for the reference

4.2 Electrical Considerations

4.2.1 Forward Voltage and Reverse Voltage

• The LED is directly connected with a test source without any additional components at measurement. LED is biased by the test source of sinusoidal current waves at 60Hz (22mA rms), and test circuit condition is series connected circuit which Vf is measured in RMS. There's 3 step Vf bin - F1, F3, F5.



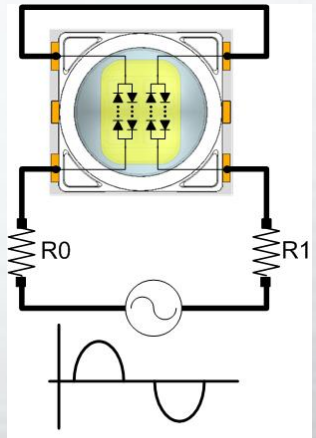
Constant Sinusoidal Current

• Vf of HV-AC LED is defined by constant sinusoidal current bias, and LED die is driven by bi-directional operation. Thus there is no reverse voltage concept.

※ Tolerance : ±5V

Symbol	Condition	Rank		Min.	Typ.	Max.	Unit
Vf	I_F = 22mA(rms)	S0	F1	185	-	195	Vac (rms)
			F3	195	-	200	
			F5	200	-	205	

• Actually real driving current is different with sinusoidal waves. As LED has a Vf, at the low input voltage, there's no current flows and the shape of wave also changes.



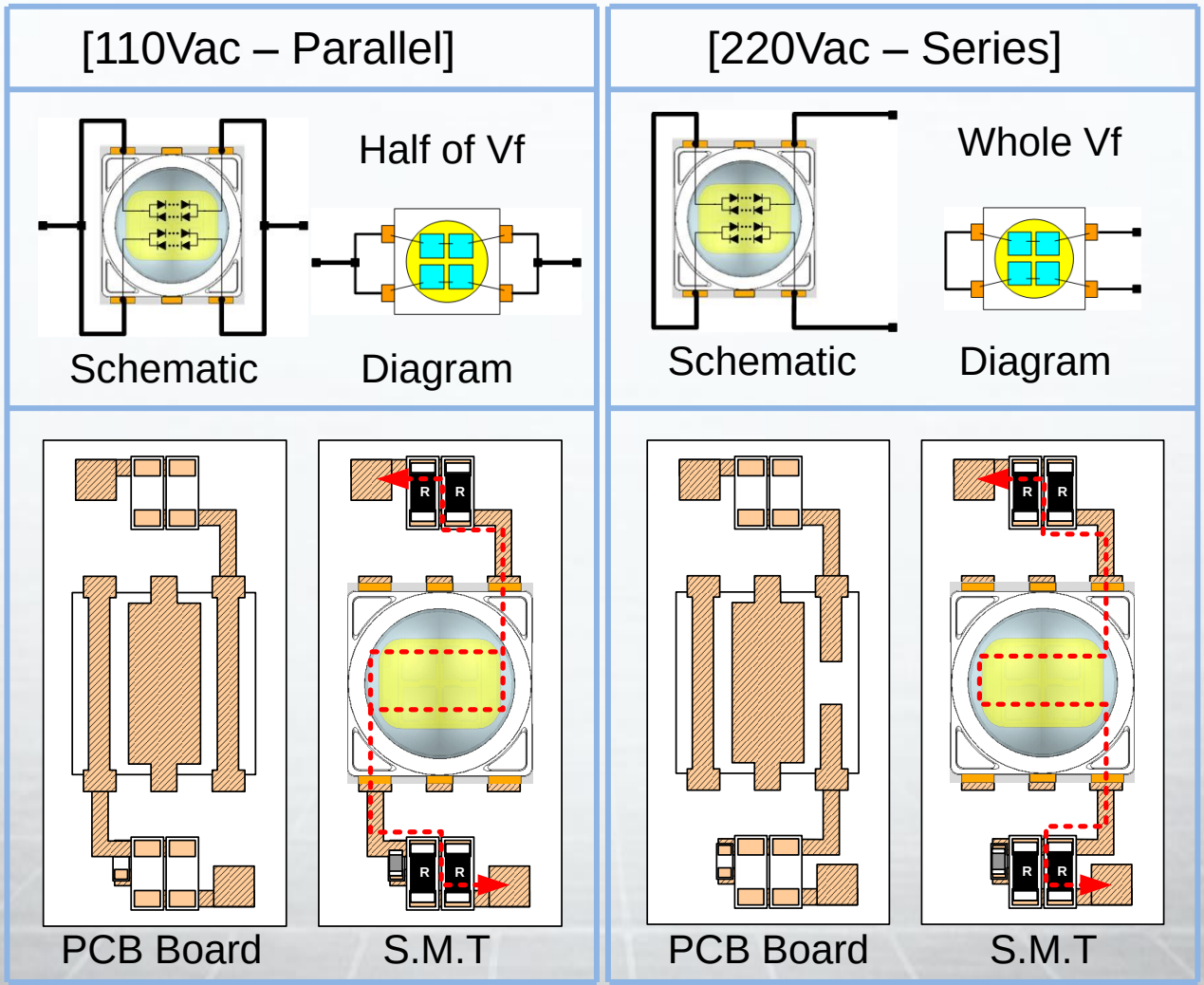
One of Real Driving Current

4.2 Electrical Considerations

4.2.2 100~120Vac vs 220~240Vac driving method

• HV-AC product is a single package type and common use is for 110Vac & 220Vac. HV-AC is designed for most of the input voltage ranges . Different pattern design of PCB will allow for use at 110Vac and 220Vac.

• HV-AC has 4 die and 2string array in single package. User can connect two electrical node at each side, then Vf becomes half of whole Vf suitable for 100~110Vac. And If user connect just only one side electrical node, then Vf becomes whole Vf suitable for 220~240Vac.

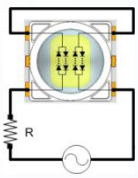


4.2 Electrical Considerations

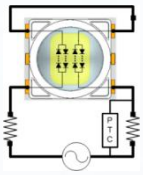
4.2.3 Driving method of HV-AC

- R (Resistor Load)

Most simple driving solution. Adjustable to small space application – candle, mini-lamp

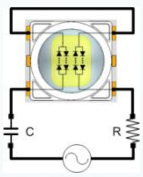


- R+PTC (Resistor + PTC Load)



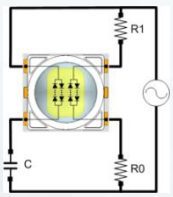
To limit current overflow, PTC(positive temperature coefficient) could be added in a row line with resistor

- RC (Capacitor Load)



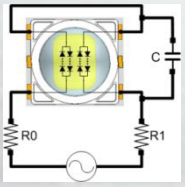
To maximize power dissipation efficiency, capacitor load recommendable for ballast. Resistor could be added in order to increase power quality

- RC Parallel (Resistor Capacitor Parallel Load 100/120Vac)



To get high quality of power(THD under 30% & PFC over 0.9), capacitor and resistor act as separate ballast. Most suitable to Bulb, Down Light, Outdoor in 120Vac market

- RC Switch (Resistor Capacitor Switch Load 220/230Vac)



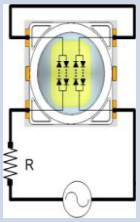
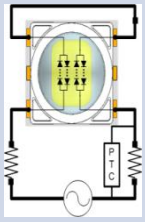
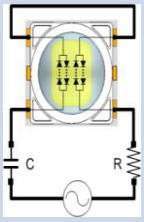
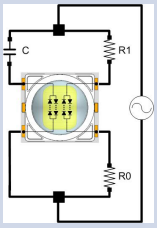
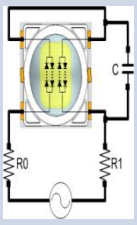
To get high quality of power(THD under 30% & PFC over 0.9), capacitor act as switch ballast. Most suitable to Bulb, Down Light, Outdoor in 220~230Vac market

4.2 Electrical Considerations

4.2.4 Summary of each driving method

As you drive differently, it shows different properties with same PKG!!!

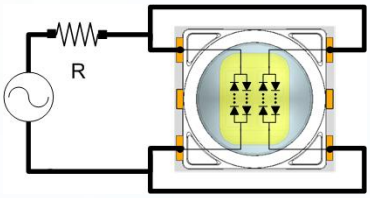
PKG property ; 3000K 4.5W(PKG) 220Vac, 120Vac

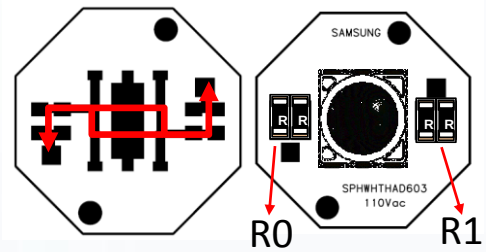
		Driving Method							
		1		2		3		4	5
		R		R+PTC		RC		RC parallel	RC switch
									
Electrical	Input Voltage[Vac]	120	220	120	220	120	220	120	220
	P.F.C	0.92	0.9	0.92	0.91	**0.78**	**0.79**	**0.91**	**0.95**
	T.H.D [%]	**40**	**43**	**38**	**42**	**46**	**50**	**27**	**25**
	Power [W] @Module	6.25	5.58	5.55	5.52	5.29	5.13	5.61	5.49
	Power [W] @PKG	4.61	4.47	-	-	4.48	4.59	-	-
	Power Efficiency [%]	74	80	-	-	85	90	-	-
Optical	Luminous Flux Ratio	417	400	345	352	385	385	409	374
	Efficacy [lm/W] @Module	**66.7**	**71.7**	**62.1**	**63.7**	**72.8**	**75**	**73**	68
	Efficacy [lm/W] @PKG	90.5	89.5	-	-	85.9	83.8	-	-
Feature		Simple		Temperature compensation		High efficacy		High power quality	High power quality

4.2 Electrical Considerations

4.2.5 Resistor Value Table & Properties

• 100~120Vac Input Voltage

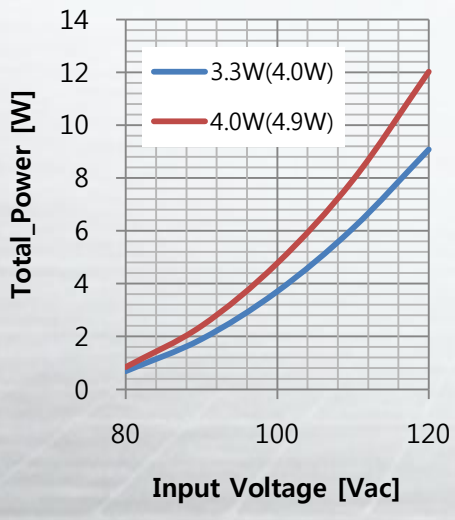


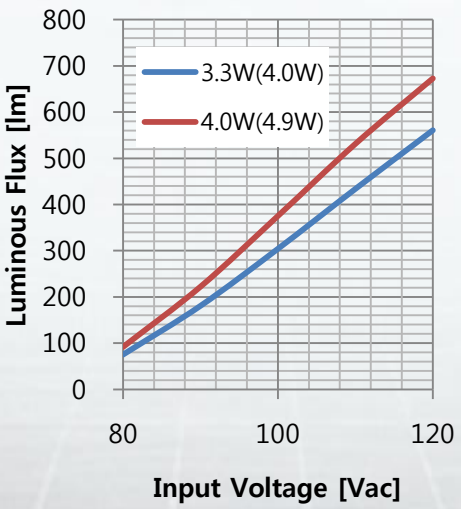


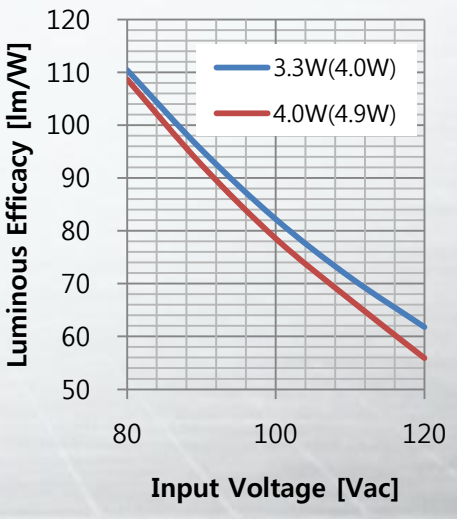
Total R = R0+R1

Vin (Vac) Typ.	Vf Bin	Target PKG Power Dissipation*		
		3.3W *(4.0W**) @ 44mA	4.0W(4.9W) @ 53mA	4.5W(5.5W) @ 58mA
		R [Ω]	R [Ω]	R [Ω]
100Vac	F1	330	240	200
	F3	300	230	190
	F5	270	220	180
110Vac	F1	560	430	360
	F3	510	410	360
	F5	460	390	360
120Vac	F1	800	620	560
	F3	750	620	545
	F5	700	620	530

• 100Vac Properties (3000K, THD:50, PFC : 0.87)





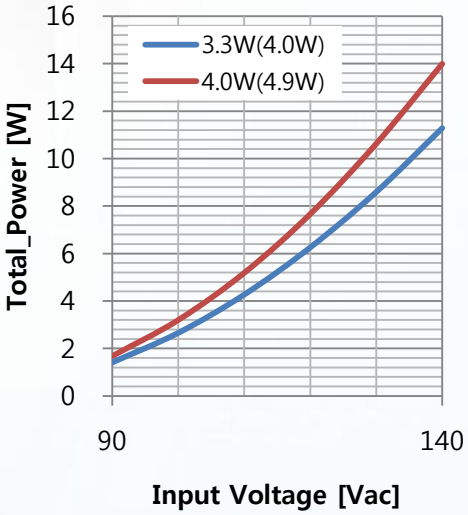


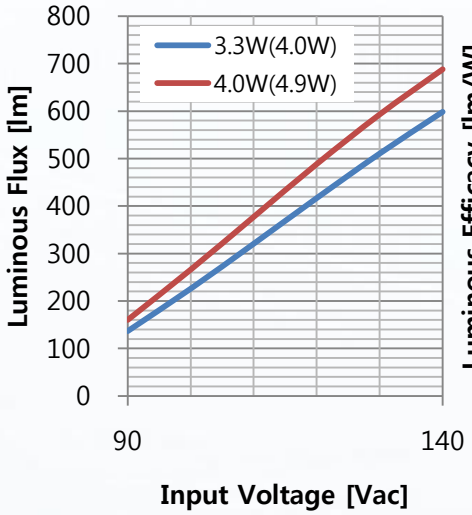
* LED Power Consumption
** Total Power Consumption

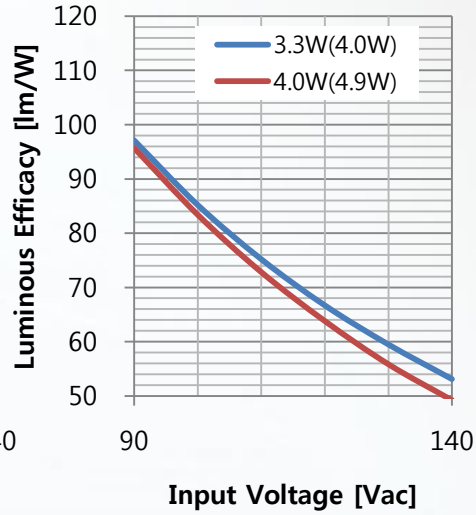
4.2 Electrical Considerations

4.2.5 Resistor Value Table & Properties continued

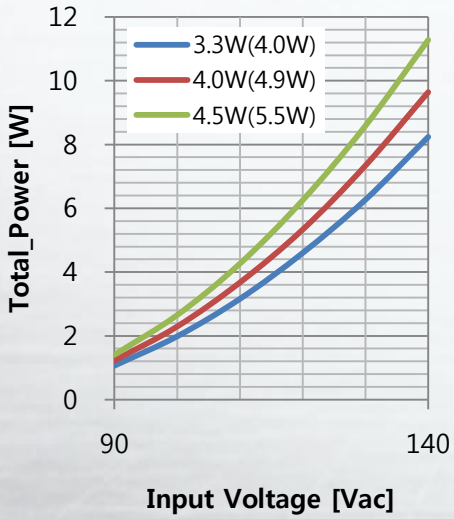
• 110Vac Properties (3000K, THD:43, PFC : 0.90)

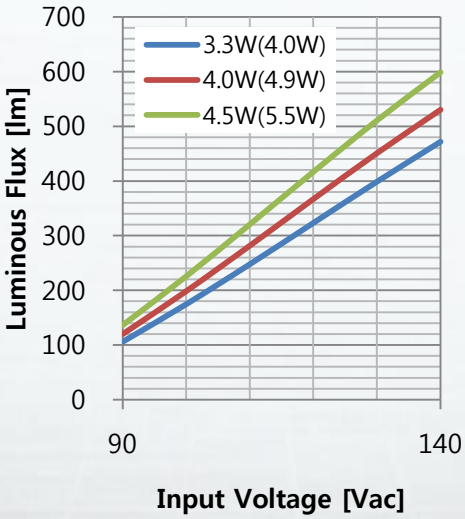


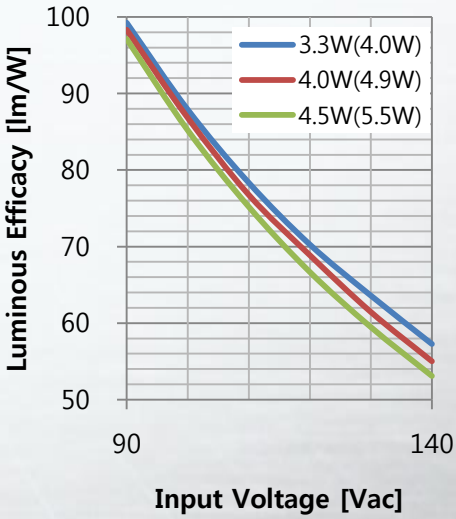




• 120Vac Properties (3000K, THD:40, PFC : 0.92)



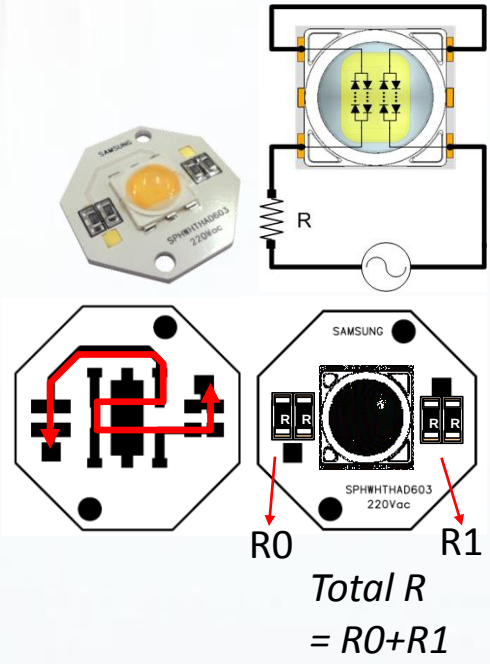




4.2 Electrical Considerations

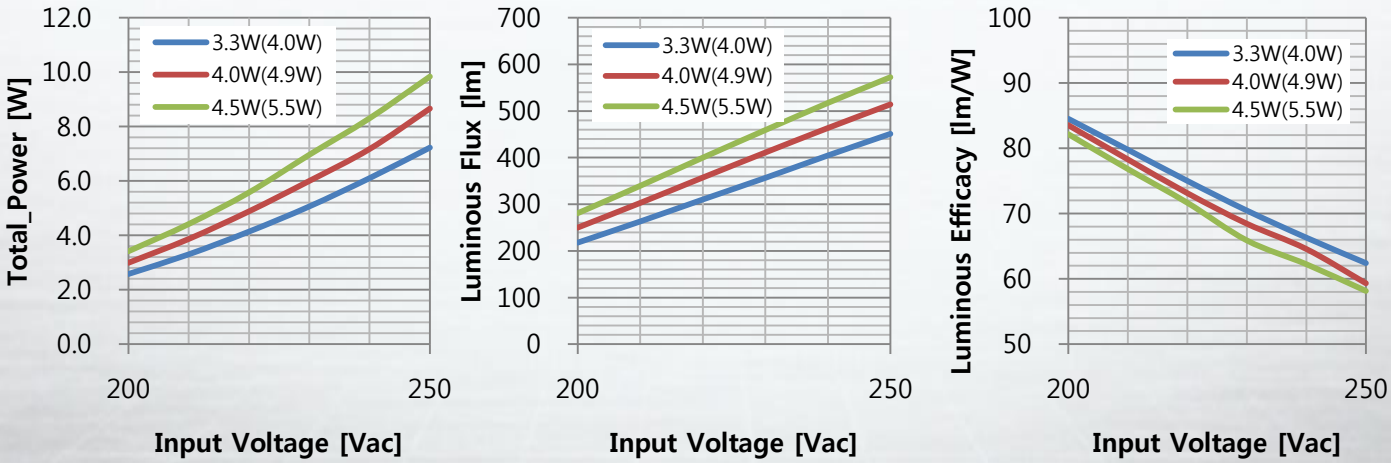
4.2.5 Resistor Value Table & Properties

• 220~240Vac Input Voltage Table



Vin (Vac) Typ.	Vf Bin	Target PKG Power Dissipation*		
		3.3W *(4.0W**) @ 44mA	4.0W(4.9W) @ 53mA	4.5W(5.5W) @ 58mA
		R [Ω]	R [Ω]	R [Ω]
220Vac	F1	2200	1700	1500
	F3	2100	1650	1460
	F5	2000	1600	1430
230Vac	F1	2620	2100	1900
	F3	2560	2050	1850
	F5	2500	2000	1800
240Vac	F1	3100	2500	2200
	F3	3000	2500	2200
	F5	2900	2500	2200

• 220Vac Properties (3000K, THD:43, PFC : 0.90)

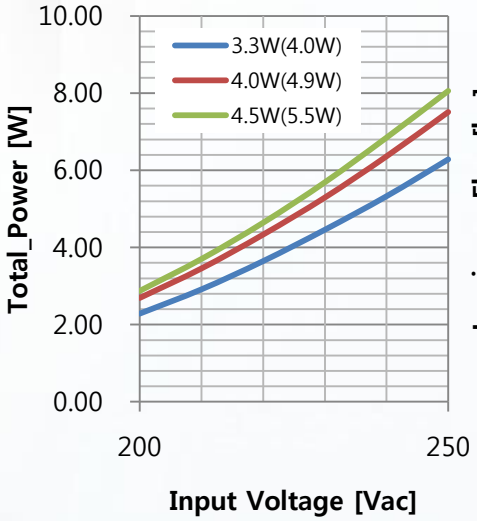


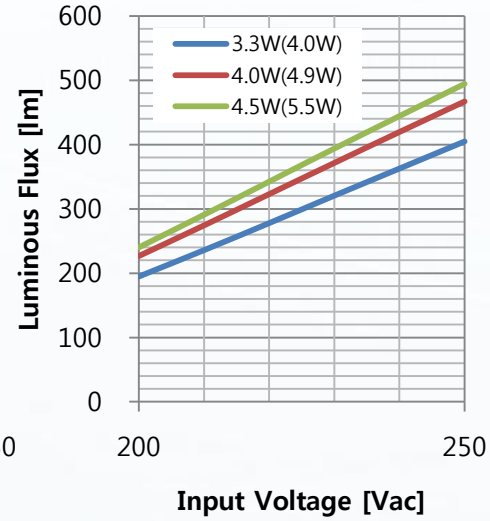
* LED Power Consumption
** Total Power Consumption

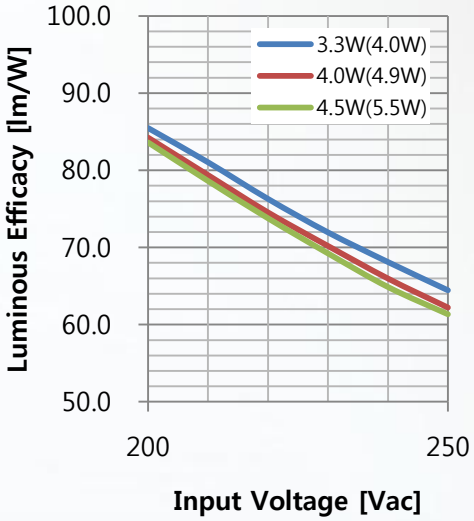
4.2 Electrical Considerations

4.2.5 Resistor Value Table & Properties continued

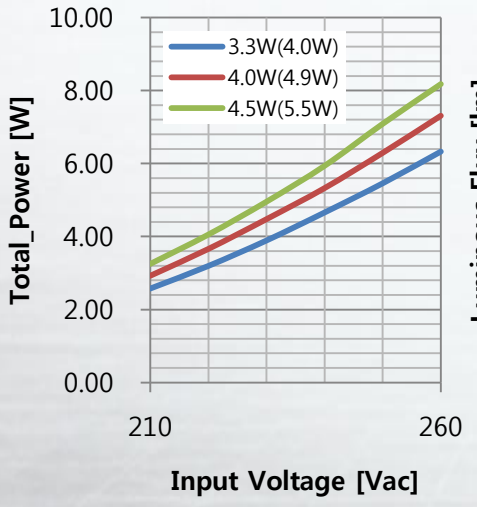
• 230Vac Properties (3000K, THD:40, PFC : 0.91)

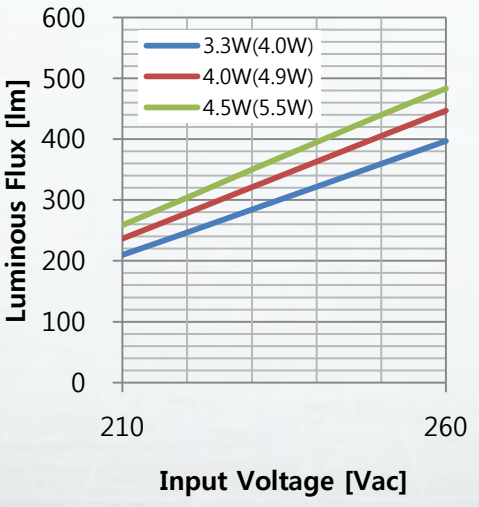


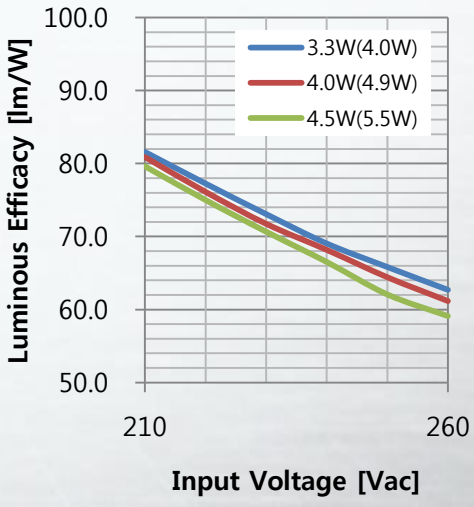




• 240Vac Properties (3000K, THD:38, PFC : 0.92)





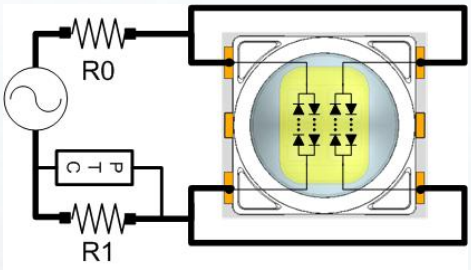


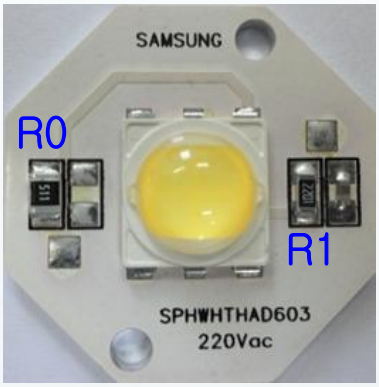
4.2 Electrical Considerations

4.2.6 Resistor Value and P.T.C*** Table & Properties

• 100~120Vac Input Voltage

Vin (Vac) Typ.	Vf Bin	3.3W* (4.0W**)			4.0W (4.9W)			4.5W (5.5W)		
		R0 [Ω]	R1 [Ω]	PTC	R0 [Ω]	R1 [Ω]	PTC	R0 [Ω]	R1 [Ω]	PTC
100	F1	400	510	470	300	510	330			
	F3	300			200					
	F5	200			100					
110	F1	600	510	470	500	510	470	500	510	330
	F3	500			400			400		
	F5	400			300			300		
120	F1	850	510	101	700	510	470	600	510	470
	F3	750			600			500		
	F5	650			500			400		





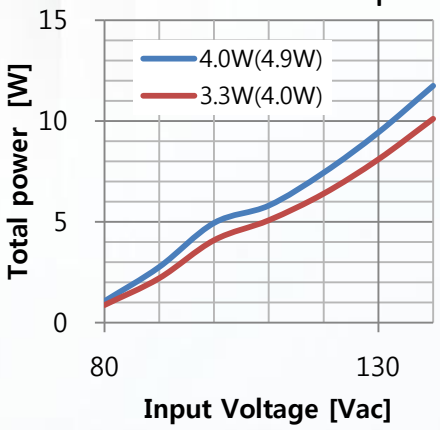
P.T.C	muRata Product
330	PRG18BB330MB1RB
470	PRG18BB470MB1RB
101	PRG18BB101MB1RB
221	PRG18BB221MB1RB
471	PRG18BB471MB1RB

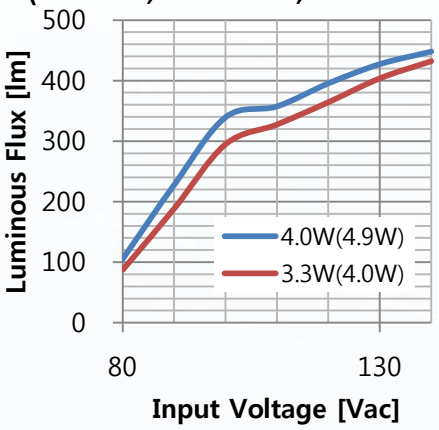
* LED Power Consumption
** Total Power Consumption
*** P.T.C (Positive Temperature Coefficient)

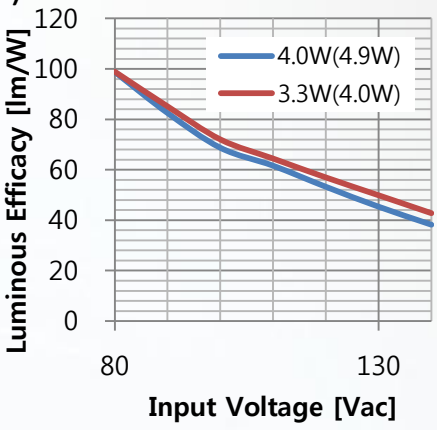
4.2 Electrical Considerations

4.2.6 Resistor Value and P.T.C*** Table & Properties

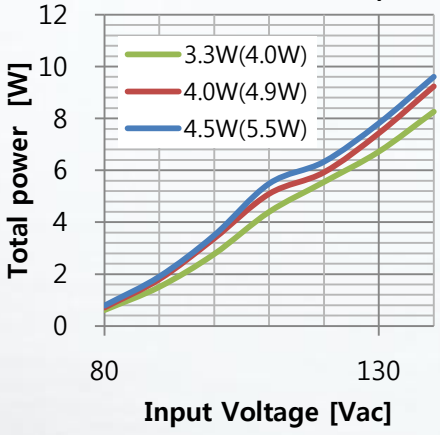
• 100Vac Properties (3000K, THD:48, PFC : 0.87)

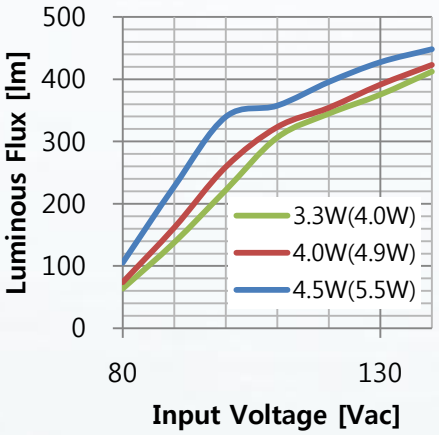


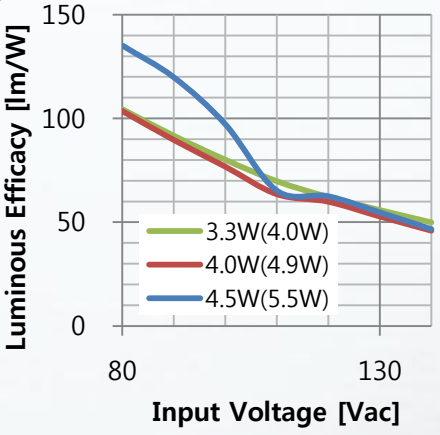




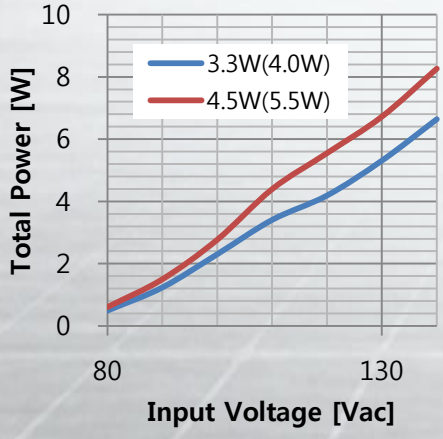
• 110Vac Properties (3000K, THD:43, PFC : 0.9)

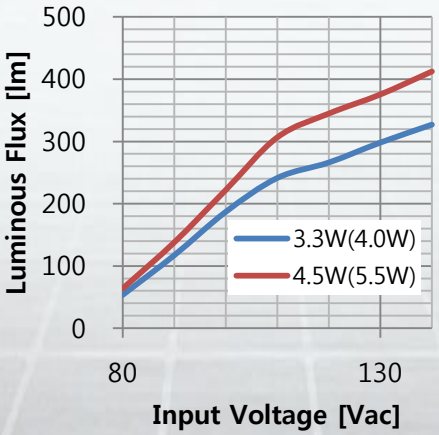


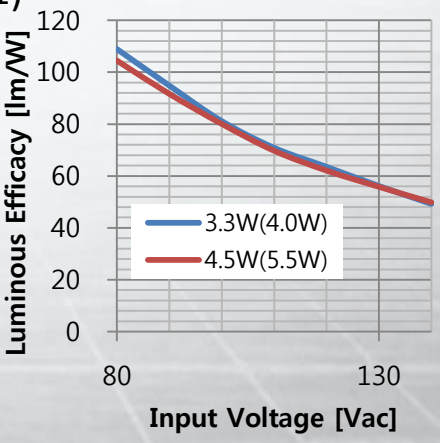




• 120Vac Properties (3000K, THD:39, PFC : 0.91)





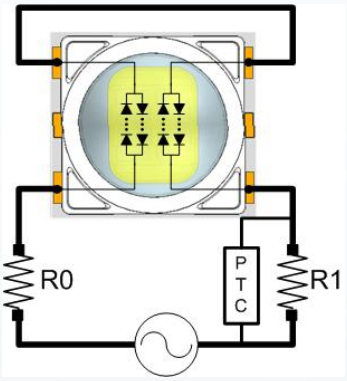


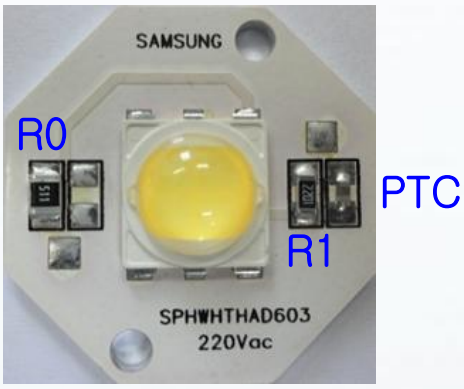
4.2 Electrical Considerations

4.2.6 Resistor Value and P.T.C*** Table & Properties

• 220~240Vac Input Voltage

Vin (Vac) Typ.	Vf Bin	3.3W* (4.0W**)			4.0W (4.9W)			4.5W (5.5W)		
		R0 [Ω]	R1 [Ω]	PTC	R0 [Ω]	R1 [Ω]	PTC	R0 [Ω]	R1 [Ω]	PTC
220	F1	2200	2000	471	1750	2000	221	1700	2000	101
	F3	2100			1650			1600		
	F5	2000			1550			1500		
230	F1	2800	2000	471	2300	2000	221	2100	2000	101
	F3	2700			2200			2000		
	F5	2600			2100			1900		





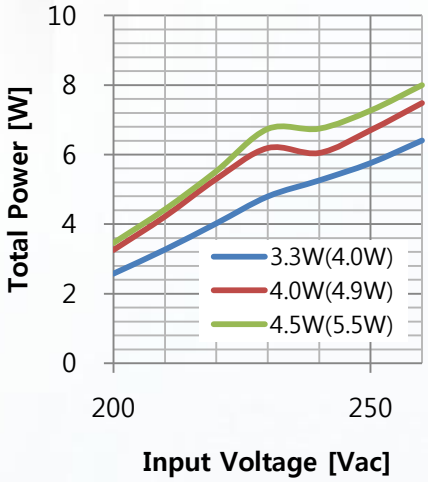
P.T.C	muRata Product
330	PRG18BB330MB1RB
470	PRG18BB470MB1RB
101	PRG18BB101MB1RB
221	PRG18BB221MB1RB
471	PRG18BB471MB1RB

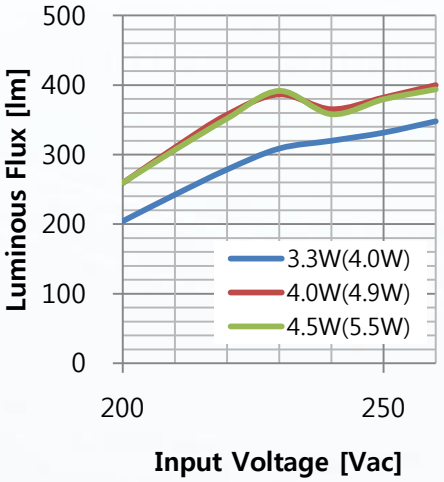
* LED Power Consumption
** Total Power Consumption
*** P.T.C (Positive Temperature Coefficient)

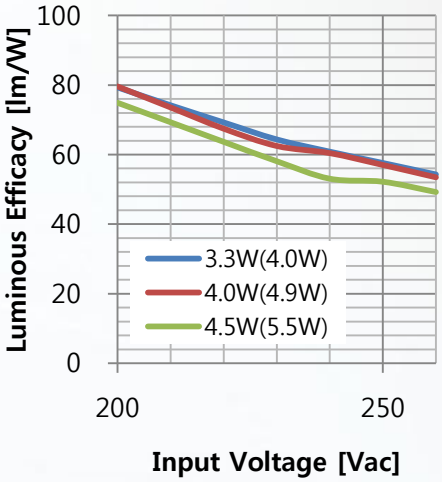
4.2 Electrical Considerations

4.2.6 Resistor Value and P.T.C*** Table & Properties

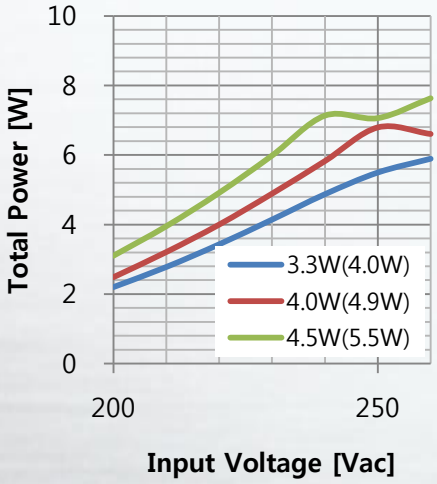
• 220Vac Properties (3000K, THD:40, PFC : 0.90)

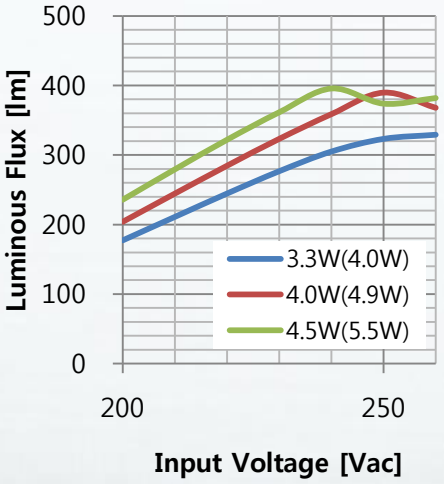


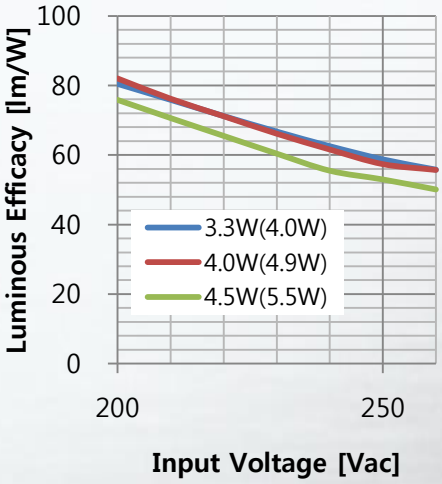




• 230Vac Properties (3000K, THD:40, PFC : 0.91)





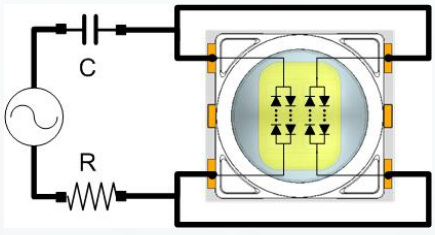


4.2 Electrical Considerations

4.2.7 Capacitor Value Table & Properties

• 100~120Vac Input Voltage

Vin.Typ (rms)	Vf Bin	3.3W* (4.0W**)		4.0W (4.9W)		4.5W (5.5W)	
		R [Ω]	C [F]***	R [Ω]	C [F]	R [Ω]	C [F]
100	F1	150	3200n	150	4400n	150	5700n
	F3	100		100		100	
	F5	50		50		50	
110	F1	150	2530n	150	3000n	150	3350n
	F3	100		100		100	
	F5	50		50		50	
120	F1	400	2420n	400	2900n	350	3000n
	F3	300		300		250	
	F5	200		200		150	

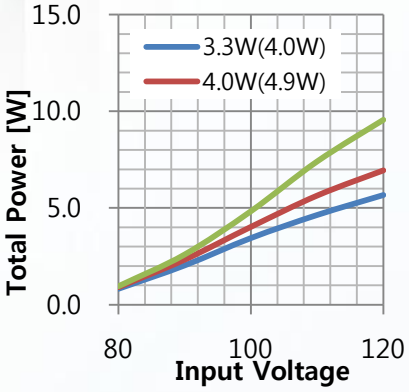


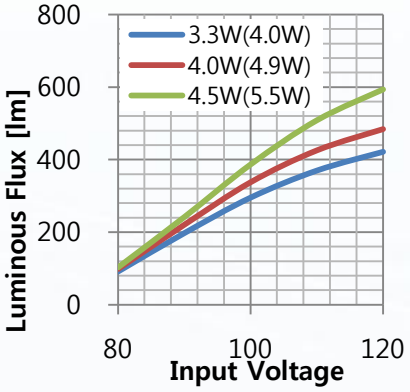
* LED Power Consumption
** Total Power Consumption
*** 100V withstanding voltage

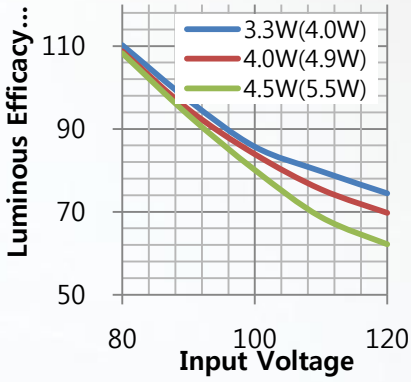
4.2 Electrical Considerations

4.2.7 Capacitor Value Table & Properties

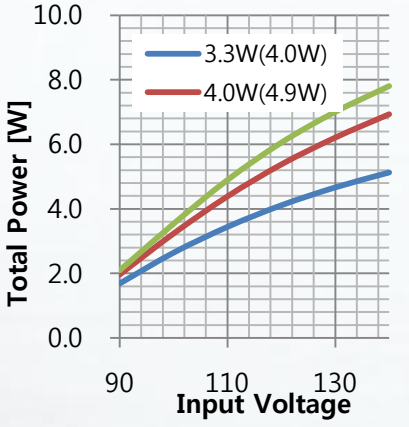
• 100Vac Input Voltage (3000K, THD:53, PFC : 0.75)

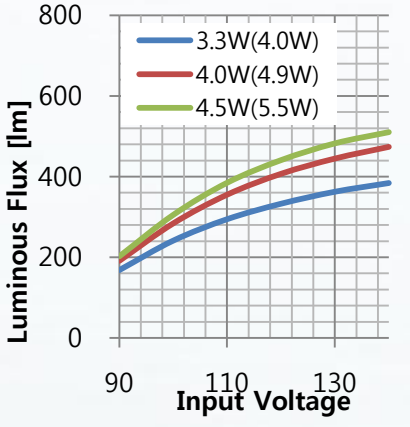


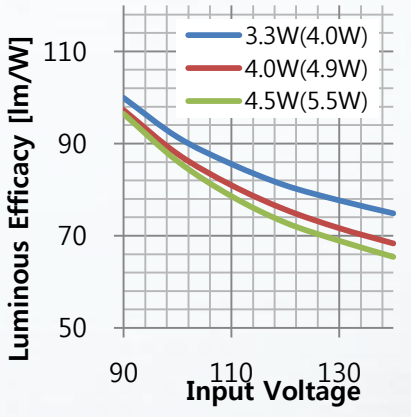




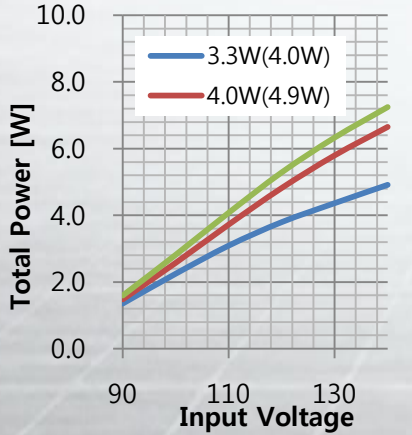
• 110Vac Input Voltage (3000K, THD:53, PFC : 0.75)

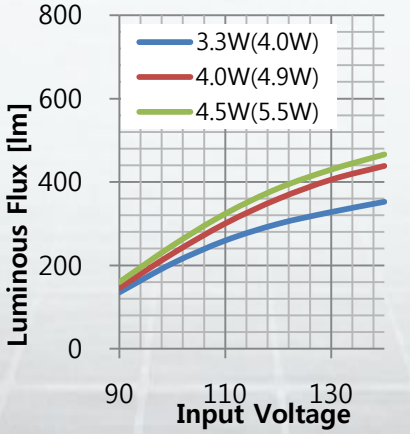


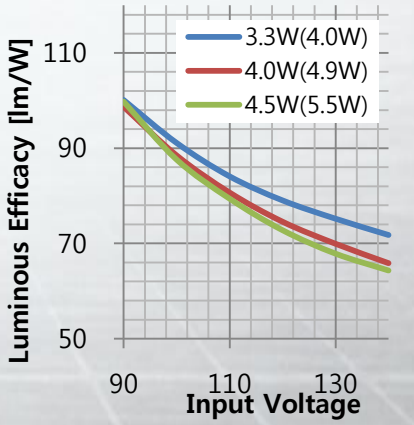




• 120Vac Input Voltage (3000K, THD:50, PFC : 0.78)





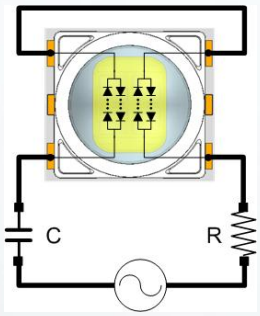


4.2 Electrical Considerations

4.2.7 Capacitor Value Table & Properties

• 220~230Vac Input Voltage

Vin.Typ (rms)	Vf Bin	3.3W* (4.0W**)		4.0W (4.9W)		4.5W (5.5W)	
		R [Ω]	C [F]***	R [Ω]	C [F]	R [Ω]	C [F]
220	F1	600	470n	500	700n	700	1000n
	F3	500		400		600	
	F5	400		300		500	
230	F1	1100	550n	500	570n	400	690n
	F3	1000		400		300	
	F5	900		300		200	
240	F1	900	550n	600	570n	500	690n
	F3	800		500		400	
	F5	700		400		300	

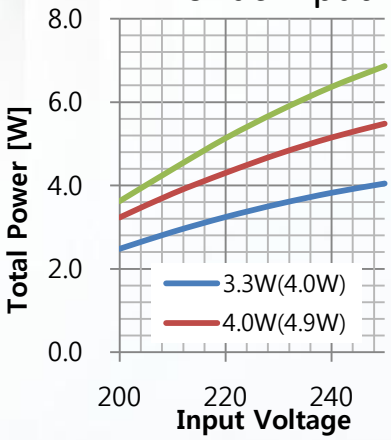


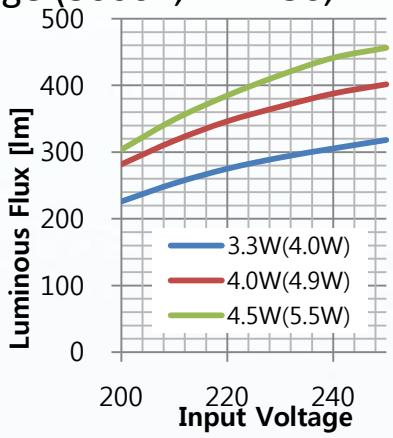
* LED Power Consumption
** Total Power Consumption
*** 100V withstanding voltage

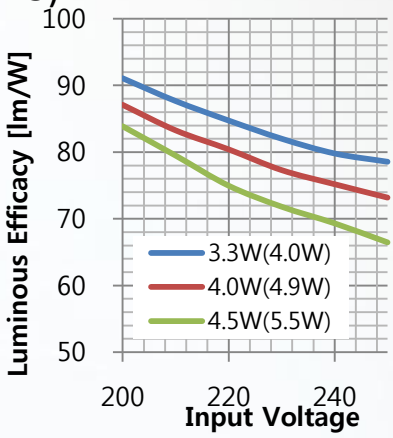
4.2 Electrical Considerations

4.2.7 Capacitor Value Table & Properties

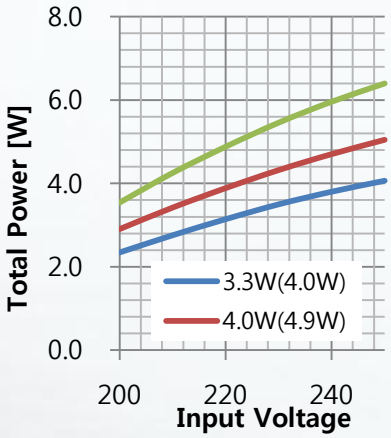
• 220Vac Input Voltage (3000K, THD:50, PFC : 0.73)

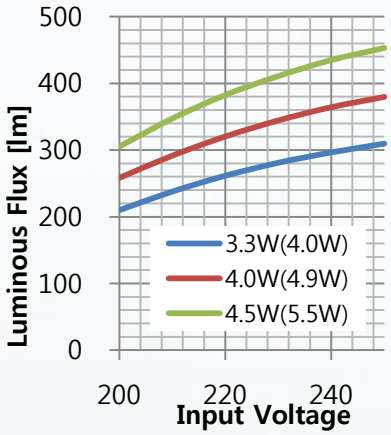


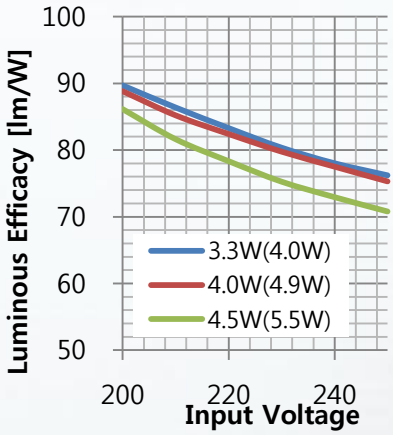




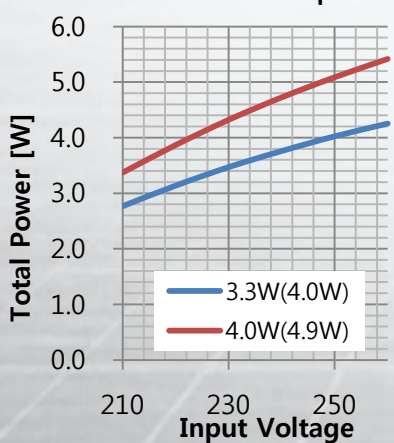
• 230Vac Input Voltage (3000K, THD:50, PFC : 0.73)

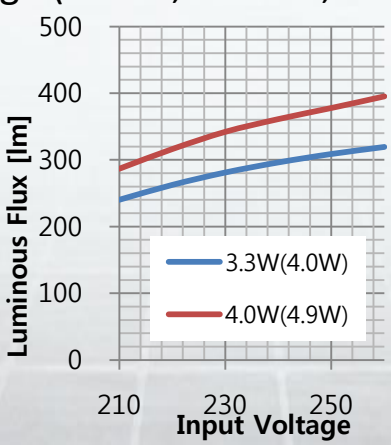


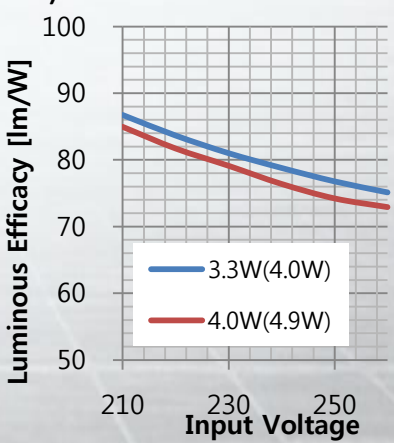




• 240Vac Input Voltage (3000K, THD:50, PFC : 0.73)





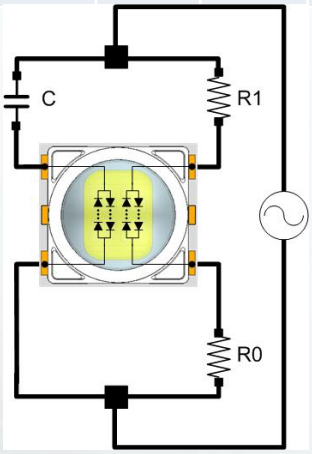


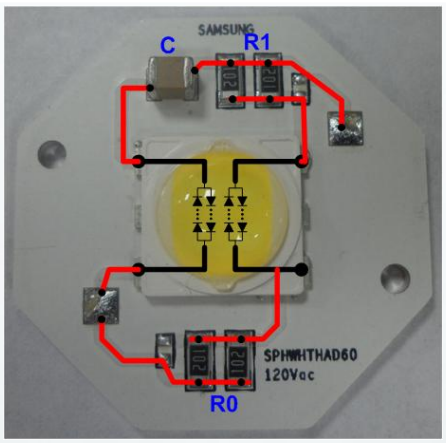
4.2 Electrical Considerations

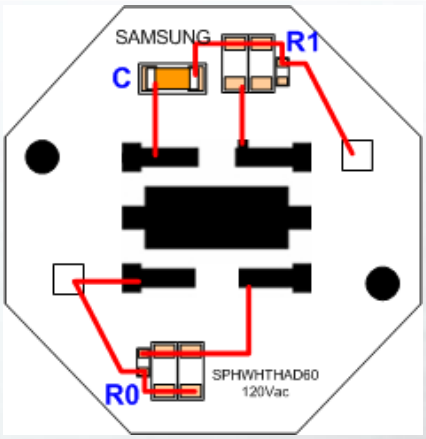
4.2.8 Parallel Capacitor and Resistor Values

• 100~120Vac Input Voltage

Vin (Vac) Typ	Vf Bin	3.3W* (4.0W**)			4.0W (4.9W)			4.5W (5.5W)		
		R0 [Ω]	R1 [Ω]	C[F] ***	R0 [Ω]	R1 [Ω]	C [F]	R0 [Ω]	R1 [Ω]	C [F]
100	F1	200	200	820n	100	100	1000n	100	100	1200n
	F3	150	150		50	50		50	50	
	F5	100	100		50	50		50	50	
110	F1	550	550	820n	300	300	1000n	250	250	1000n
	F3	500	500		250	250		200	200	
	F5	450	450		200	200		150	150	
120	F1	750	750	820n	600	600	1000n	450	450	1000n
	F3	700	700		550	550		400	400	
	F5	650	650		500	500		350	350	





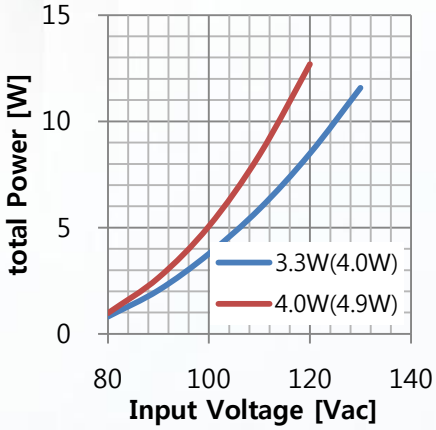


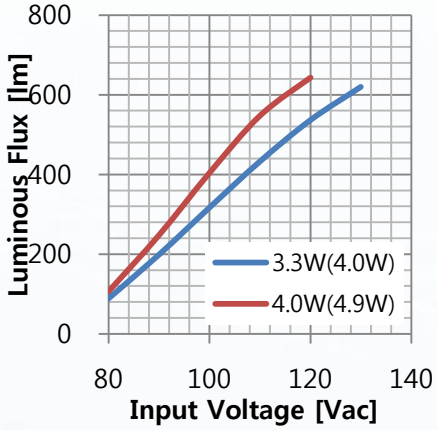
* LED Power Consumption
** Total Power Consumption
*** 100V withstanding voltage

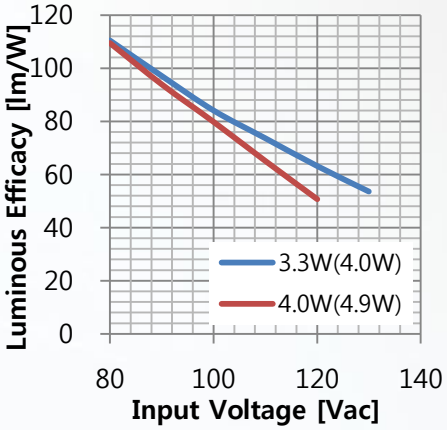
4.2 Electrical Considerations

4.2.8 Parallel Capacitor and Resistor Values

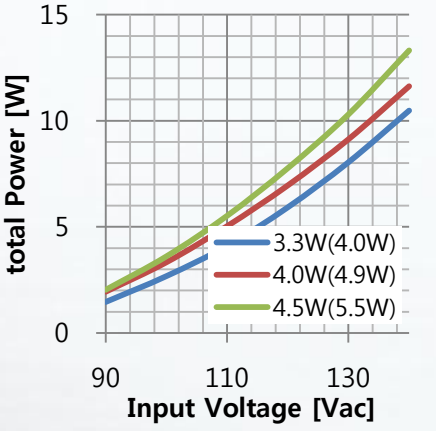
• 100Vac Input Voltage (3000K, THD:40, PFC : 0.90)

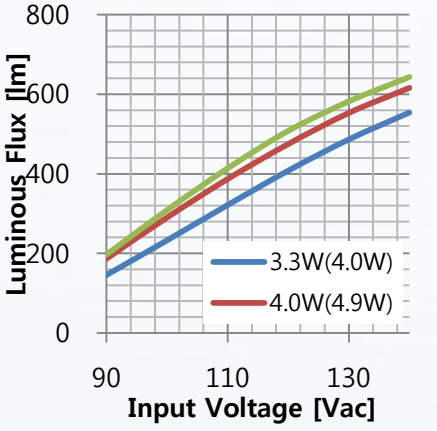


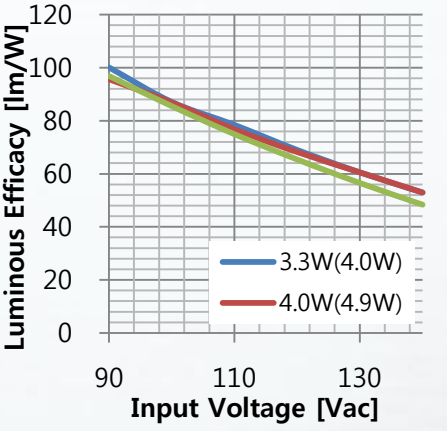




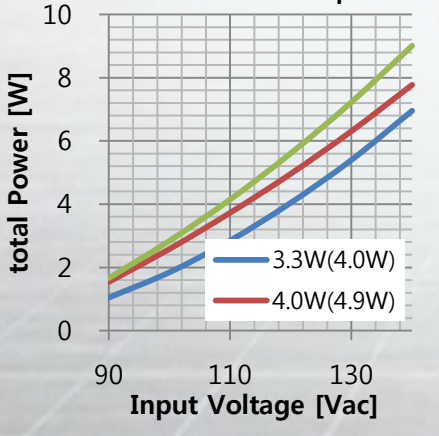
• 110Vac Input Voltage (3000K, THD:30, PFC : 0.91)

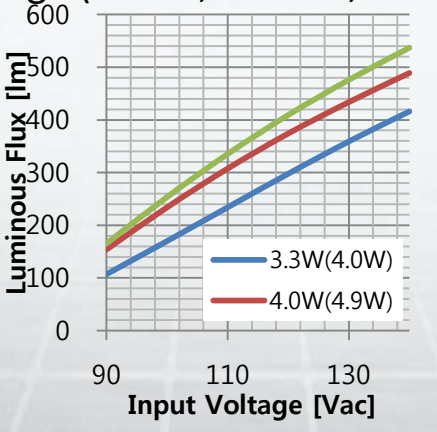


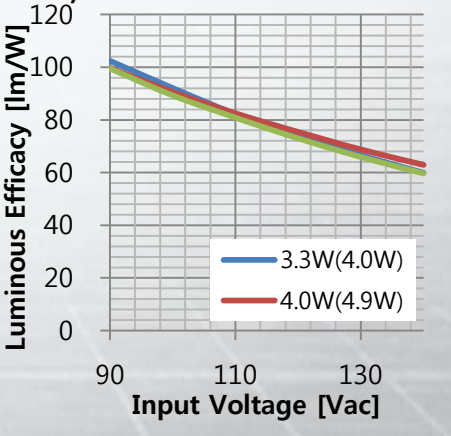




• 120Vac Input Voltage (3000K, THD:27, PFC : 0.91)





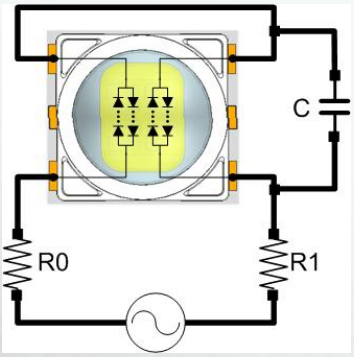


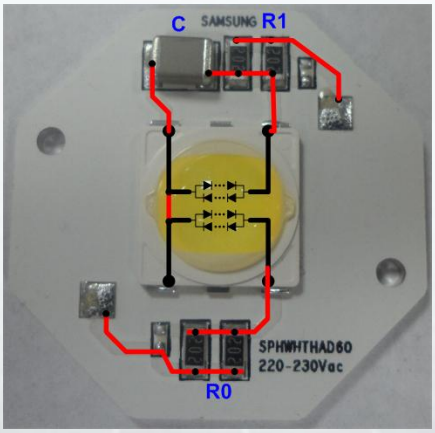
4.2 Electrical Considerations

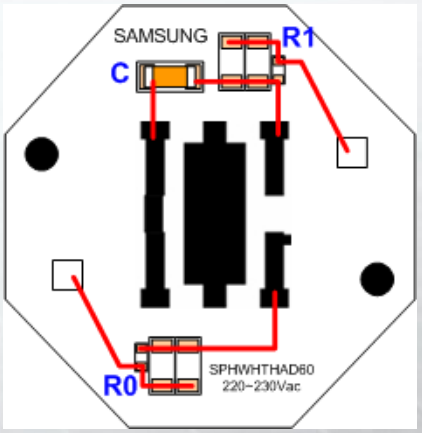
4.2.9 Capacitor Value Table & Properties

• 220~240Vac Input Voltage

Vin (Vac) Typ	Vf Bin	3.3W* (4.0W**)			4.0W (4.9W)			4.5W (5.5W)		
		R0 [Ω]	R1 [Ω]	C [F]	R0 [Ω]	R1 [Ω]	C [F]	R0 [Ω]	R1 [Ω]	C [F]
200	F1	900	800	200n	650	550	200n	550	450	200n
	F3	800			550			450		
	F5	700			450			350		
220	F1	1400	1300	200n	1100	1000	200n	900	1000	200n
	F3	1300			1000			800		
	F5	1200			900			700		
230	F1	1850	1750	200n	1350	1250	200n	1200	1100	200n
	F3	1750			1250			1100		
	F5	1650			1150			1000		
240	F1	2250	2150	200n	1650	1550	200n	1500	1400	200n
	F3	2150			1550			1400		
	F5	2050			1450			1300		





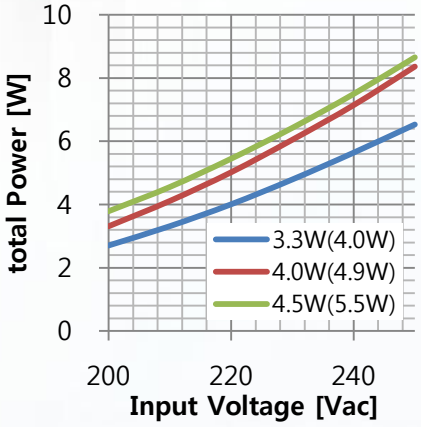


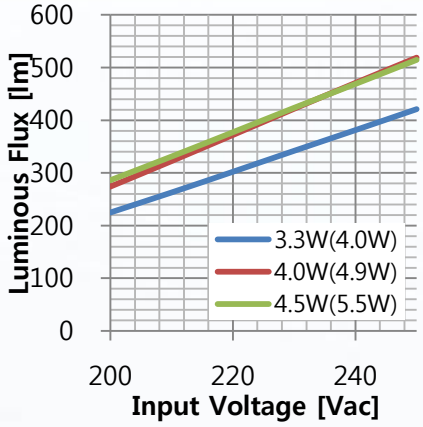
* LED Power Consumption
** Total Power Consumption
*** 250V withstanding voltage

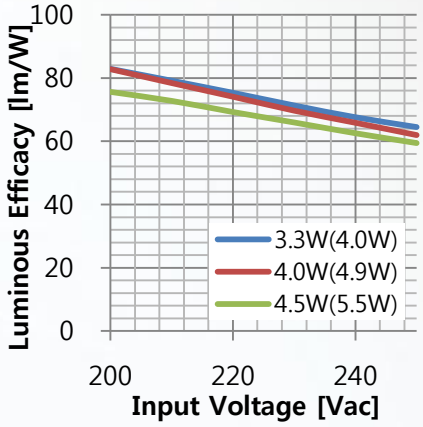
4.2 Electrical Considerations

4.2.9 Capacitor Value Table & Properties

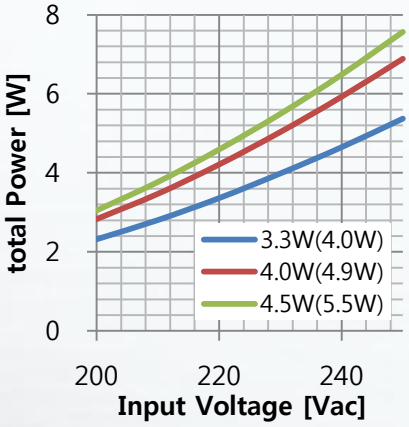
• 220Vac Input Voltage (3000K, THD:25, PFC : 0.95)

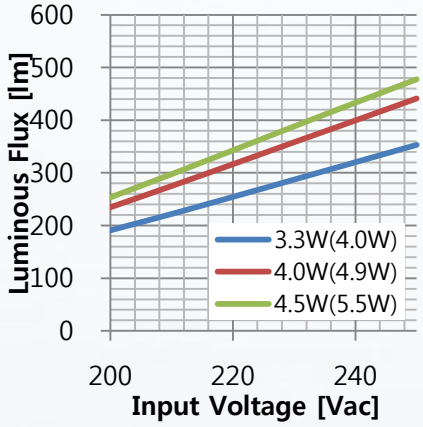


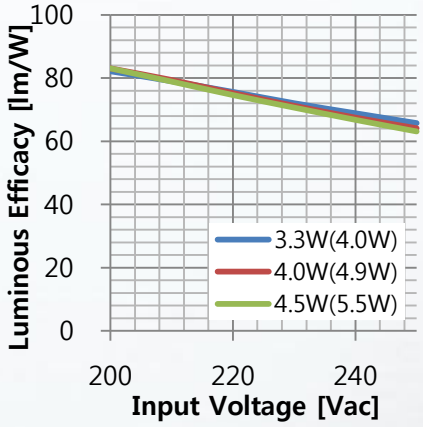




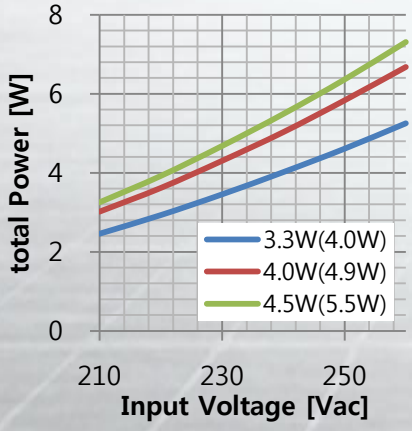
• 230Vac Input Voltage (3000K, THD:25, PFC : 0.95)

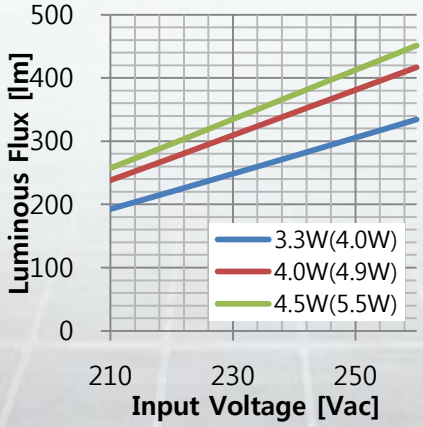


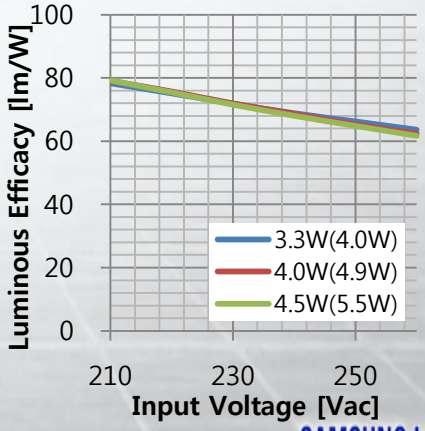




• 240Vac Input Voltage (3000K, THD:25, PFC : 0.95)



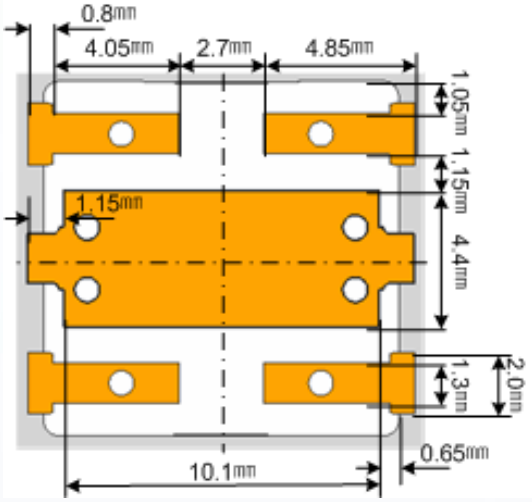




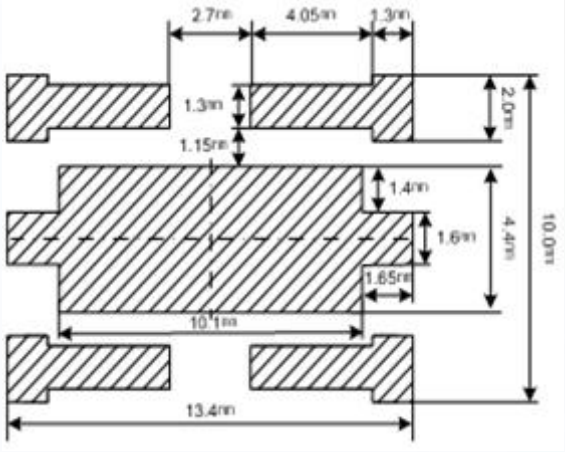
4.3 Mechanical Considerations

4.3.1 Mechanical Drawing

• Outline Dimension



• Recommended Land Pattern



• SMT nozzle pick up part

Outside diameter : ϕ 10mm
Inside Diameter : ϕ 5mm

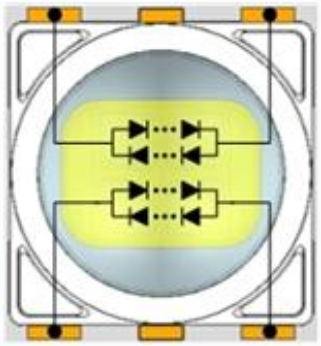
• Ts (Solder point of Temperature)

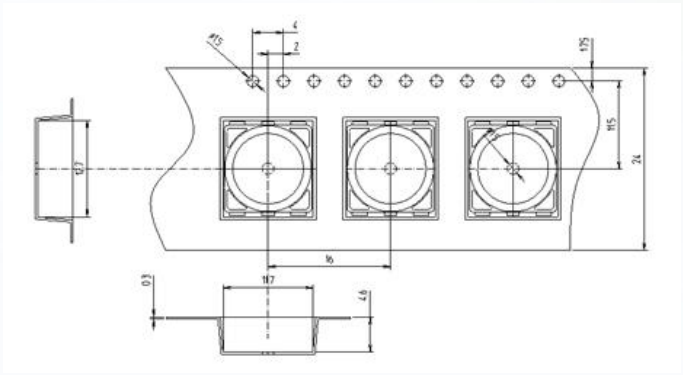
1. Tolerance is ±0.1 mm
2. The maximum compressing force is 15N on the silicone ⓐ
3. Do not place pressure on the encapsulation resin ⓑ

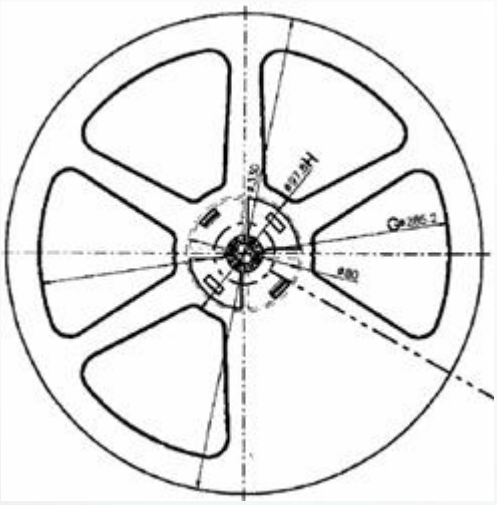
4.3 Mechanical Considerations

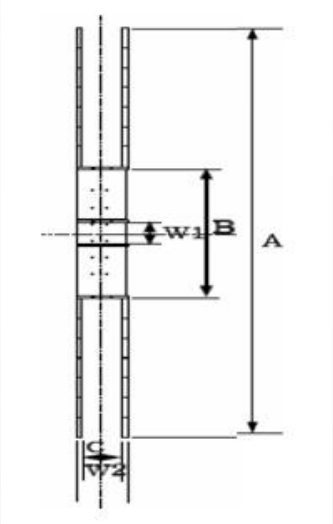
4.3.2 SMT Set

• Taping Dimension









Symbol	A	B	C	W1	W2
Dimension(㎜)	330 ± 1	80 ± 1	25 ± 0.5	13 ± 0.3	29.5 ± 1

(1) Quantity : 800 pcs / 13” Reel.
(2) Cumulative Tolerance : Cumulative tolerance/10 pitches to be ±0.2㎜
(3) Adhesion Strength of Cover Tape : Adhesion strength to be 0.1-0.7 N when the cover tape is turned off from the carrier tape at 10℃ angle to be the carrier tape.
(4) Packaging : P/N, Manufacturing data code no. and quantity to be indicated on a damp proof package

4.3 Mechanical Considerations

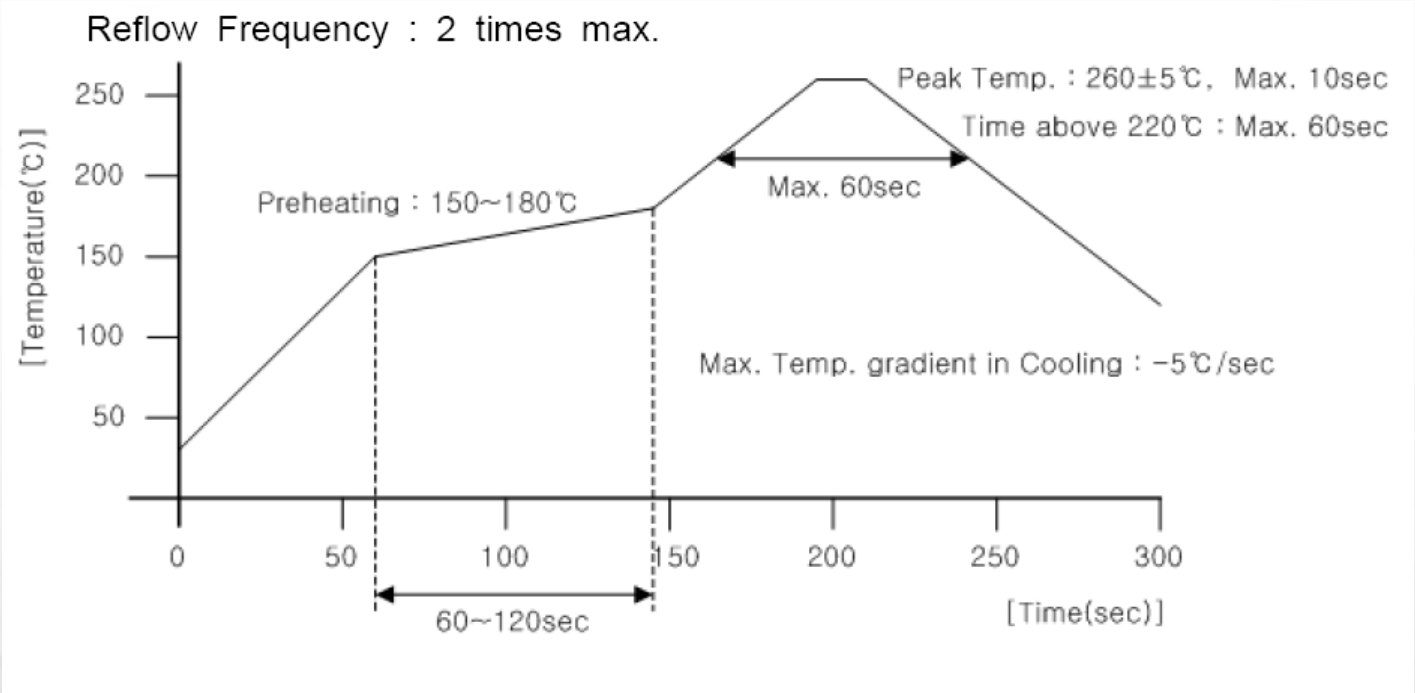
4.3.3 Reflow Profile

→ Reflow conditions and work guide

Below reflow profile is recommended for reflow soldering.

It may not apply for all PCB kinds and various soldering equipment.

It is recommended that users follow the recommended reflow profile of a solder manufacturer



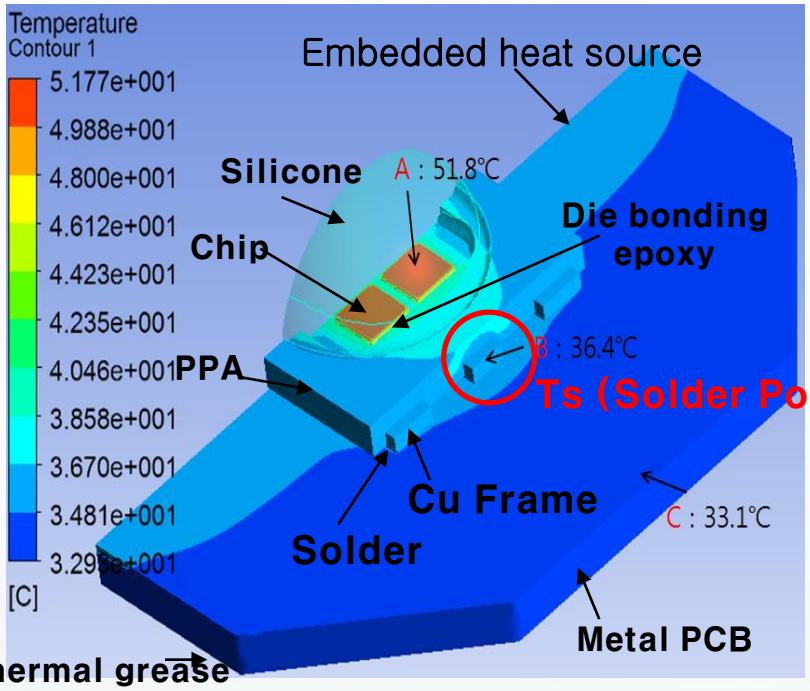
For Manual Soldering

Not more than 5 seconds @MAX300 ℃, under soldering iron.

4.4 Thermal Considerations

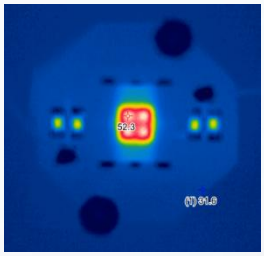
4.4.1 Thermal Resistance

- HV-AC solder point temperature(Ts) should be measured as close to the PCB land pattern as possible.
- Thermal resistance impossible to get from T3ster, which operates under DC operation condition



[Computational Simulation Model]

[Actual Image]



[IR Camera Image]

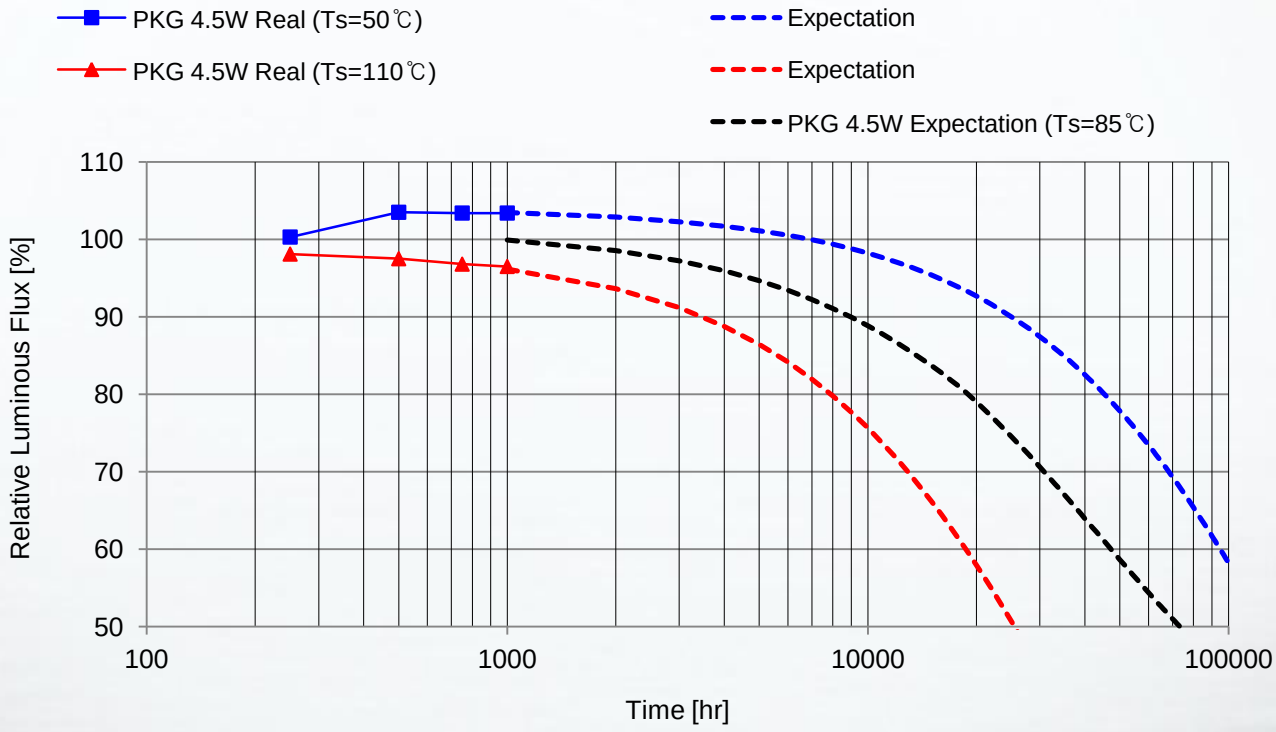
3.3W PKG Power Dissipation	Position		
	A	B	C
Thermo Couple	–	35℃	32℃
IR Camera	52℃	–	32℃
Simulation	52℃	36℃	33℃

R (j-s) = △T / W
= (51.8 – 36.4) / 3.3
= 4.7℃/W

5.1 Reliability

5.1.1 Test result

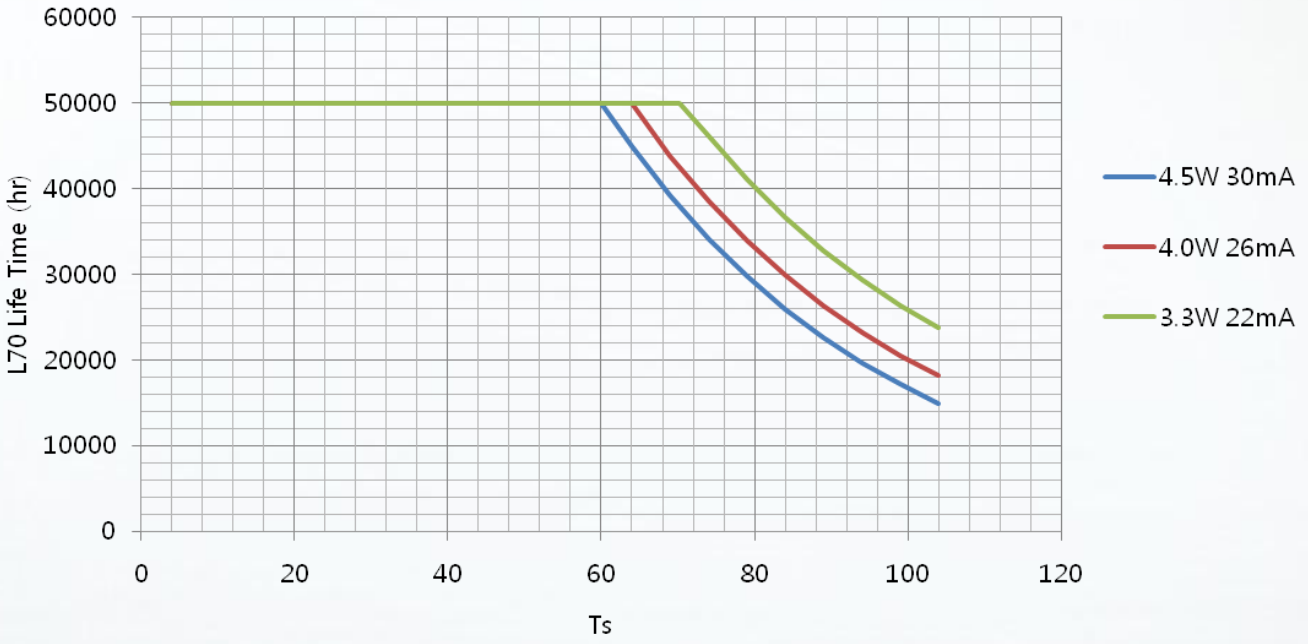
- This test was performed in-house at Samsung. There is currently no standard or reference of Energy Star lifetime test for AC direct operation.
- Solid lines are real test results and dotted lines are expected results



5.1 Lifetime

5.1.2 L_{70} Lifetime Prediction – MTTF (2700K)

- From real reliability test results at each different chamber condition, MTTF(Mean Time to Failure) curve could be obtained
- Ts point is recommended to maintain under 100℃



			L_{70} Lifetime (hours) & Ts Temperature					
	PKG Driving Condition	N	20℃	40℃	60℃	80℃	90℃	100℃
HV-AC	3.3W - If (22mA-rms)	Calculate	50,000+	50,000+	50,000+	41,108+	32,833+	26,393+
	4.0W - If (26mA-rms)	Calculate	50,000+	50,000+	50,000+	33,923+	26,349+	20,541+
	4.5W - If (30mA-rms)	21pcs *	50,000+	50,000+	50,000+	29,732+	22,566+	17,127+

This MTTF document is provided for informational purposes only and is not a warranty or a specification. The information in this document is subject to change without notice.

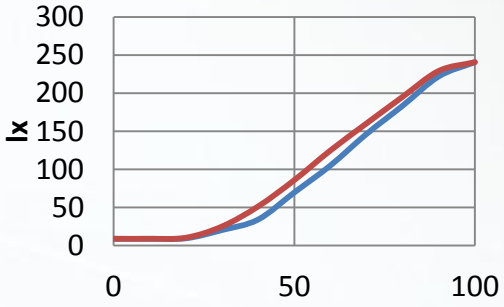
* Real test result

6.1 Dimming

6.1.1 Recommended Lutron Dimmer

- Low voltage dimmer is well matching with HV-AC

Lutron DVELV-300P



- Triac dimmer is not perfectly matching with HV-AC

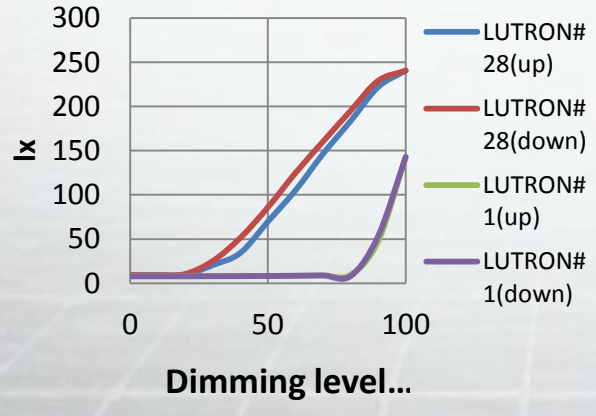
Lutron
NT-603P

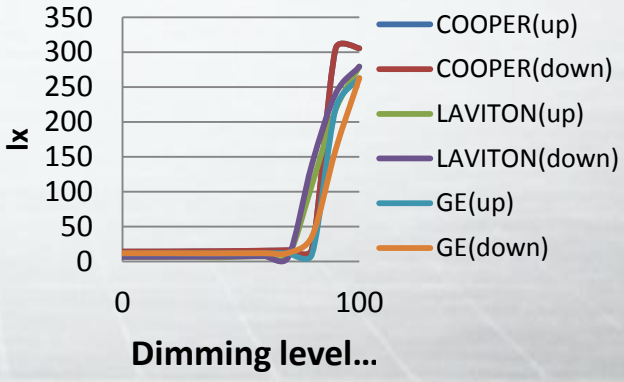
Lutron

Cooper

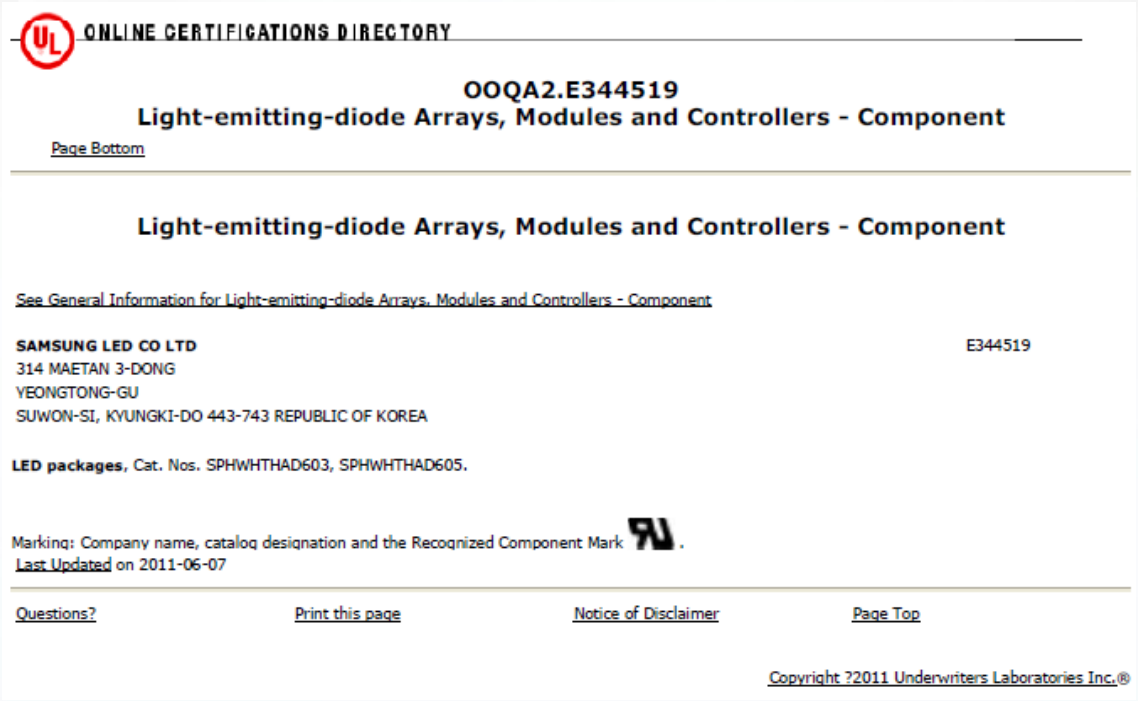
GE

Leviton
C20-6683





7.1 UL, cUL (Approved Jun '11)



ONLINE CERTIFICATIONS DIRECTORY

OOQA2.E344519
Light-emitting-diode Arrays, Modules and Controllers - Component

Page Bottom

Light-emitting-diode Arrays, Modules and Controllers - Component

See General Information for Light-emitting-diode Arrays, Modules and Controllers - Component

SAMSUNG LED CO LTD E344519
314 MAETAN 3-DONG
YEONGTONG-GU
SUWON-SI, KYUNGKI-DO 443-743 REPUBLIC OF KOREA

LED packages, Cat. Nos. SPHWHTHAD603, SPHWHTHAD605.

Marking: Company name, catalog designation and the Recognized Component Mark .
Last Updated on 2011-06-07

Questions? Print this page Notice of Disclaimer Page Top

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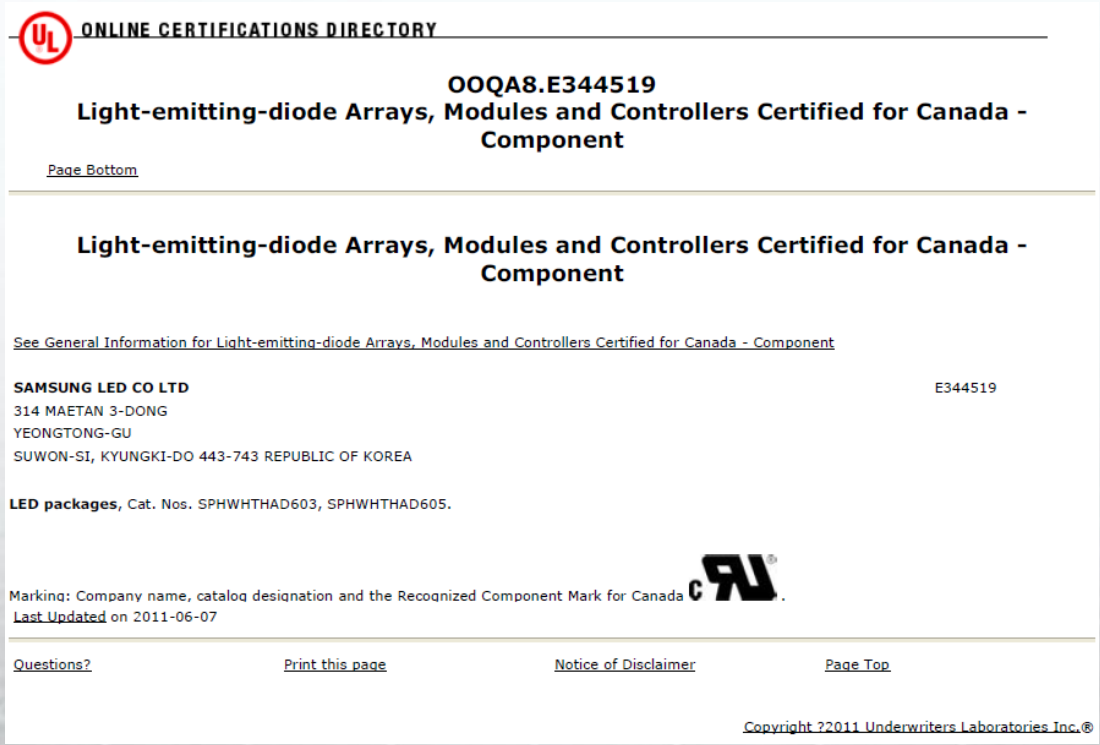

ONLINE CERTIFICATIONS DIRECTORY

OOQA8.E344519
Light-emitting-diode Arrays, Modules and Controllers Certified for Canada - Component

Page Bottom

Light-emitting-diode Arrays, Modules and Controllers Certified for Canada - Component

See General Information for Light-emitting-diode Arrays, Modules and Controllers Certified for Canada - Component

SAMSUNG LED CO LTD E344519
314 MAETAN 3-DONG
YEONGTONG-GU
SUWON-SI, KYUNGKI-DO 443-743 REPUBLIC OF KOREA

LED packages, Cat. Nos. SPHWHTHAD603, SPHWHTHAD605.

Marking: Company name, catalog designation and the Recognized Component Mark for Canada .
Last Updated on 2011-06-07

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** UL : Underwriters Laboratories*
** cUL : Canada UL*

7.2 CE, VDE (Approved April '11)

EC Declaration of Conformity

Issuer's name and address:

SAMSUNG LED Co., Ltd.
314 Maetan-3 Dong, Yeongtong-Gu
443-743 SUWON CITY, KYUNGKI-DO
SOUTH KOREA

Product: LED lamp

Type designation: SPHWHTHAD603; SPHWHTHAD605

The designated product is in conformity with the European Directive:

- Safety(LVD)
  - DIN EN 62031(VDE 0715 Teil5) LED modules for general lighting — Safety specifications
  - EN 62471 Photo Biological safety of lamps and lamp systems
- EMC
  - DIN EN 55015, EN 55015
  - DIN EN 61547, EN61547
  - DIN EN 61000-3-2, EN 61000-3-2
  - DIN EN 61000-3-3, EN 61000-3-3

7.3 Eye safety, EMC

Test Report issued under the responsibility of:

KTR
KOREA TESTING & RESEARCH INSTITUTE

TEST REPORT
IEC 62471
Photobiological safety of lamps and lamp systems

Report Reference No. ..... :	CEC2011-0118
Date of issue ..... :	2011.06.01
Total number of pages ..... :	19
CB Testing Laboratory ..... :	KTR (KOREA TESTING & RESEARCH INSTITUTE)
Address ..... :	66-6, Jeil-Ri, Yangji-Myun, Cheoin-Gu, Yongin, Gyeonggi-Do, Korea
Applicant's name ..... :	SAMSUNG LED CO., LTD.
Address ..... :	314, Maetan 3-dong, Yeongtong-gu, Suwon, Gyeonggi-do, Korea
Test specification:	
Standard ..... :	IEC 62471:2006 (First Edition) + European Group Difference and National differences
Test procedure ..... :	N/A
Non-standard test method ..... :	N/A
Test Report Form No. ..... :	IEC62471A
TRF Originator ..... :	VDE Testing and Certification Institute
Master TRF ..... :	Dated 2009-05

Test item description ..... :	LED Package
Trade Mark ..... :	SAMSUNG LED
Manufacturer ..... :	SAMSUNG LED CO., LTD.
Model/Type reference ..... :	HV-AC Cool White(SPHWHTAD)
Ratings ..... :	V_r=220 Vac, I_r=22 mA(rms)

☒ **CB Testing Laboratory:**	KTR (KOREA TESTING & RESEARCH INSTITUTE)
Testing location/ address ..... :	66-6, Jeil-Ri, Yangji-Myun, Cheoin-Gu, Yongin, Gyeonggi-Do, Korea
☐ **Associated CB Laboratory:**	
Testing location/ address ..... :	
Tested by (name + signature) ..... :	KYUNG-HO NOH
Approved by (+ signature) ..... :	JAE-JUN KO

7.4 RoHS, Hazard Substance Analysis

SGS

Test Report No. F690501/LF-CTSAYAA11-02161 Issued Date: January 21, 2011 Page 1 of 5

To: **SAMSUNG LED CO., LTD.**
314,Maetan-dong
Yeongtong-gu
Suwon-city
GYEONGGI-DO 443-370
Korea

The following merchandise was submitted and identified by the client as :

SGS File No.	: AYAA11-02161
Product Name	: HV_AC LED PKG
Item No./Part No.	: N/A
Received Date	: Jan 18, 2011
Test Period	: Jan 19, 2011 to Jan 20, 2011
Test Performed	: SGS Testing Korea tested the sample(s) selected by applicant with following results
Test Results	: For further details, please refer to following page(s)
Comments	: By the applicant's specific request, the sampling and testing was performed only for the part indicated in the photo without disassembly.

SGS Testing Korea Co. Ltd.

Timothy Jeon
Jinhee Kim
Cindy Park
Jerry Jung/ Testing Person

Jeff Jang / Chemical Lab Mgr

SGS Testing Korea Co.,Ltd.
322, The O valley, 656-9, Hogye-dong, Dongan-gu, Anyang-si, Gyeonggi-do, Korea 431-080
T +82 (0)31 4608 000 F +82 (0)31 4608 059 http://www.sgslab.co.kr ,www.kr.sgs.com/greenlab
Member of the SGS Group (Société Générale de Surveillance)

7.4 RoHS, Hazard Substance Analysis

SGS

Test Report No. F690501/LF-CTSAYAA11-02161 Issued Date: January 21, 2011 Page 2 of 5

Sample No. : AYAA11-02161.001
Sample Description : HV_AC LED PKG
Item No./Part No. : N/A
Comments : Materials are Copper, Silicone.

Heavy Metals

Test Items	Unit	Test Method	MDL	Results
Cadmium (Cd)	mg/kg	With reference to IEC 62321:2008, ICP	0.5	N.D.
Lead (Pb)	mg/kg	With reference to IEC 62321:2008, ICP	5	N.D.
Mercury (Hg)	mg/kg	With reference to IEC 62321:2008, ICP	2	N.D.
Hexavalent Chromium (Cr VI)	mg/kg	With reference to IEC 62321:2008, UV-VIS	1	N.D.

Flame Retardants-PBBs/PBDEs

Test Items	Unit	Test Method	MDL	Results
Monobromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Dibromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Tribromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Tetrabromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Pentabromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Hexabromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Octabromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Nonabromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Decabromobiphenyl	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Monobromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Dibromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Tribromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Tetrabromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Pentabromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Hexabromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Heptabromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Octabromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Nonabromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.
Decabromodiphenyl ether	mg/kg	With reference to IEC 62321:2008, GC-MS	5	N.D.

NOTE: (1) N.D. = Not detected.(<MDL)
(2) mg/kg = ppm
(3) MDL = Method Detection Limit
(4) - = No regulation
(5) ** = Qualitative analysis (No Unit)
(6) * = Boiling-water-extraction:
Negative = Absence of CrVI coating
Positive = Presence of CrVI coating; the detected concentration in boiling-water-extraction solution is equal or greater than 0.02 mg/kg with 50 cm2 sample surface area.

SGS Testing Korea Co.,Ltd.
322, The O valley, 855-9, Hogye-dong, Dongan-gu, Anyang-si, Gyeonggi-do, Korea 431-060
t +82 (0)31 4608 000 f +82 (0)31 4608 059 http://www.sgslab.co.kr ,www.kr.sgs.com/greenlab

7.4 RoHS, Hazard Substance Analysis

SGS

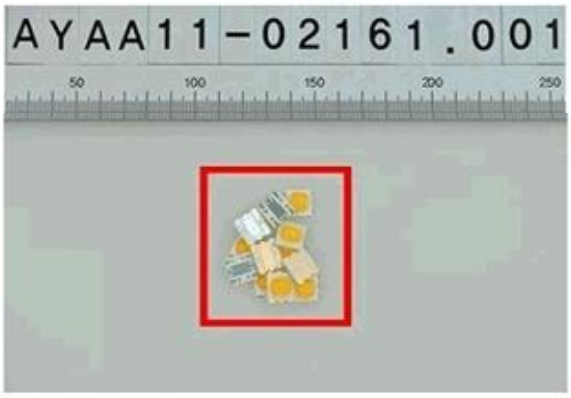
Test Report No. F690501/LF-CTSAYAA11-02161 Issued Date: January 21, 2011 Page 3 of 5

Sample No. : AYAA11-02161.001
Sample Description : HV_AC LED PKG
Item No./Part No. : N/A
Comments : Materials are Copper, Silicone.

Halogen Contents

Test Items	Unit	Test Method	MDL	Results
Bromine(Br)	mg/kg	BS EN 14582:2007 , IC	30	N.D.
Chlorine(Cl)	mg/kg	BS EN 14582:2007 , IC	30	N.D.
Fluorine(F)	mg/kg	BS EN 14582:2007 , IC	30	N.D.
Iodine(I)	mg/kg	BS EN 14582:2007 , IC	50	N.D.

Picture of Sample as Received:



NOTE: (1) N.D. = Not detected.(<MDL)
(2) mg/kg = ppm
(3) MDL = Method Detection Limit
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(5) ** = Qualitative analysis (No Unit)
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Negative = Absence of CrVI coating
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Member of the SGS Group (Société Générale de Surveillance)

8. Revision History

Date	Revision History	Writer	
		Drawn	Approved
2012.03.23	New Version	Y. J. Lee	D. M. Jeon
2012.04.13	Driving component table changes at 120Vac	Y. J. Lee	D. M. Jeon