Design Guide
for T8 Application rev1.0

Samsung Electronics

LM561X, LM231X

SAMSUNG ELECTRONICS
LED Business

SAMSUNG

1. Introduction

With incandescent lamp, fluorescent lamp has become a main lighting source of residential life and industrial filed. For energy savings and protection of the environment, new light source has to be required and LED is a major candidate of replacing that role. In this design guide, it is shown how LED component could be used as the lighting source of these traditional lamp and what main design factors are. Especially samsung LED components, LM5631X, LM231X, are introduced as a light source and several technical guide is presented in terms of thermal and optical properties.

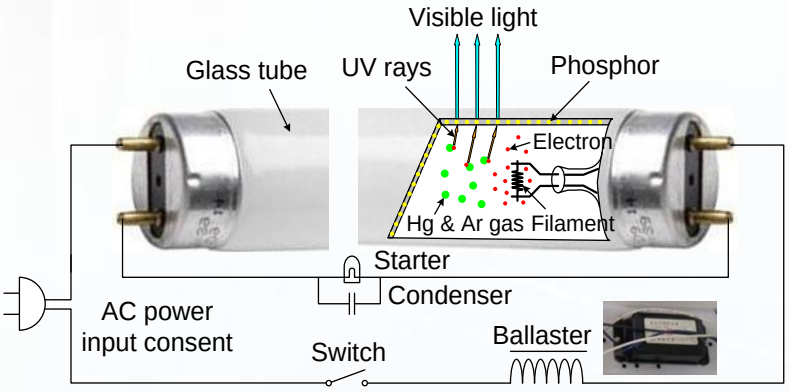
T8 specification could be designed - total luminous flux, power dissipation, beam angle and the number of LEDs. From these specification, expected performances could be estimated through the design support tool. For accuracy, we made entire T8 LED-tube implementation and showed comparison with estimated performance and realized results.

This design guide is made for providing several design information for T8 LED-tube replacement and is not any warranty or a specification.

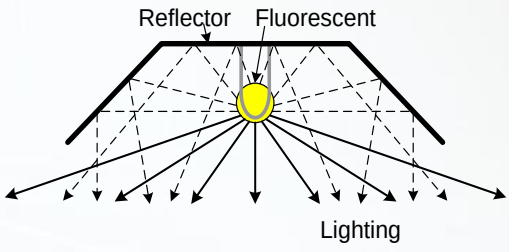
1. Introduction

1.1 T8 Description

1.1.1 Fluorescent

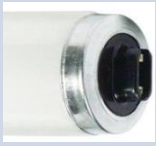


[Fluorescent structure & circuit]



[360´ beam angle & reflector]

Fluorescent has developed nearly 60 years ago and nowadays so many lighting application adopted this light source. Brief theory is that electrons emitted from filament meets Hg & Ar gas and then generate UV rays which makes visible light with phosphor coated inside of glass tube. Less optical glare is a great merit of fluorescent. On the other hand, adopted Hg and Ar gas is anti-ecologies and normally reflector which could reduce efficiency of system is basic essential combination for it's 360 beam angle features.

	Bi pin		Single pin	Double contact
Base (Socket)	 G5	 G13	 Fa8	 R17d
Tube (Diameter /Length)	T-5 (16㎜ / 2ft)	T-8 (26㎜ / 2ft, 4ft, 8ft) T-10 (32㎜ / 2ft, 4ft, 8ft) T-12 (38㎜ / 2ft, 4ft, 8ft)	T-6 T-8 T-12	T-10 T-12
Application	Regular type		High output / Very high output	

[Fluorescent socket type & tube diameter]

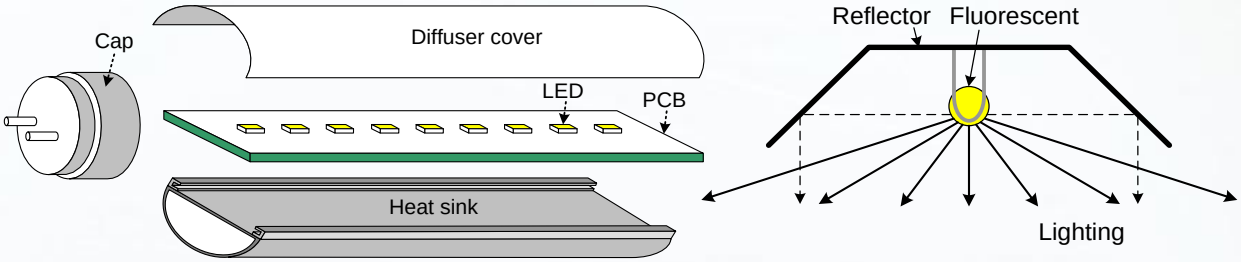
Fluorescent has several different pin type. G13 socket is largely used in T-8, T-10 and T-12. G5 is used in T-5 which has higher optical efficiency rather than T-8 due to shorter diameter. Single pin and double contact pin is used partially.

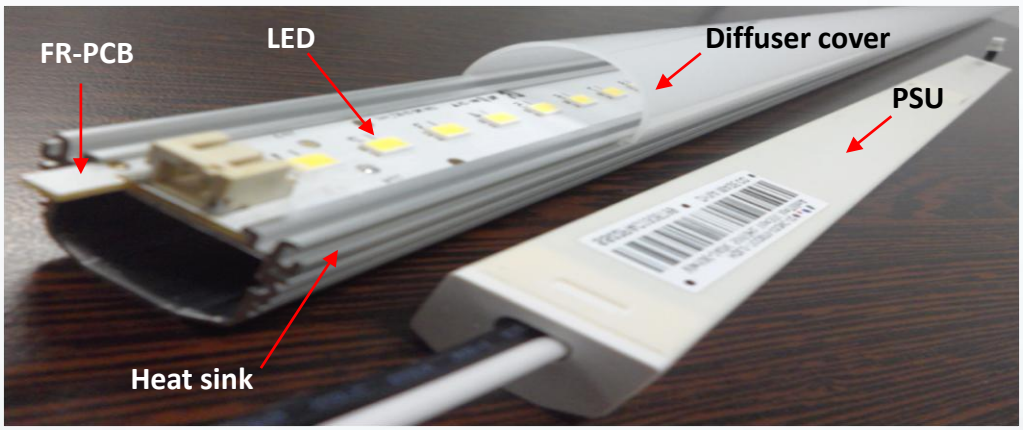
1. Introduction

1.1 T8 Description

1.1.2 The structure of LED-tube

LED-tube have begun to replace fluorescent light source for high optical efficiency, energy saving, eco-friendly material and long lifetime. Especially as for LED-tube's long lifetime, demand of LED-tube has been requested from garage lighting application of large market and storage. After early time, many indoor application start to replace fluorescent lamp with LED-tube as a main lighting source.





[Structure of LED-tube]

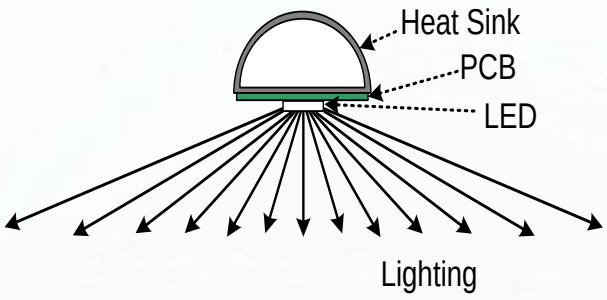
General structure of the LED-tube consists of LED, PCB, heat sink, diffuser cover, socket and power supply unit(PSU) instead of ballast in fluorescent. LED emit optical light directionally, therefore actually reflector doesn't be required as much as fluorescent lamp. This makes LED-tube has less optical loss rather than fluorescent. But LED-tube needs function of scattering directional light characteristics through the diffuser cover which could reduce glare property also.

1. Introduction

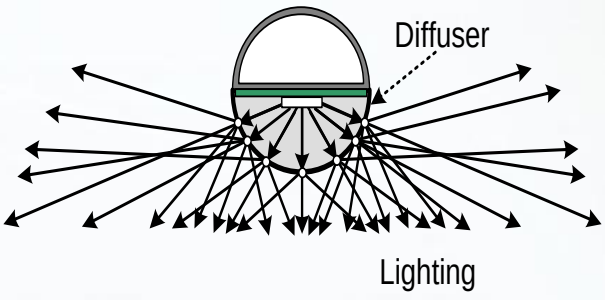
1.1 T8 Description

1.1.3 The effects of diffuser

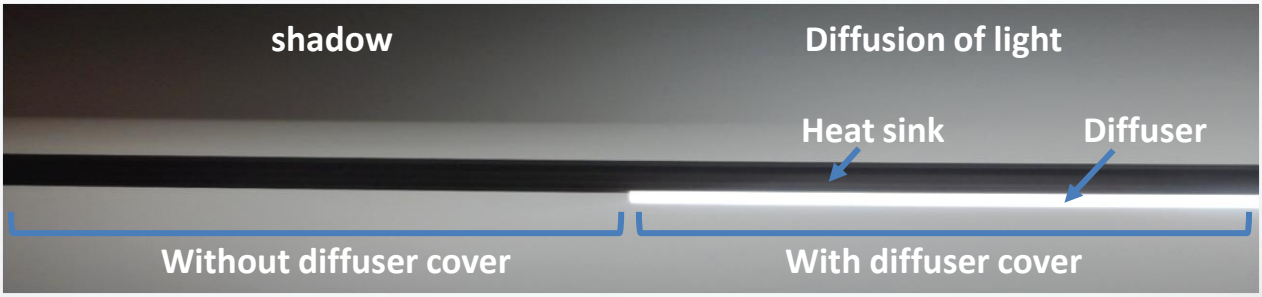
LED has a directional optic property and needs to adopt heat sink, large PCB which makes longish beam angle of T8. In order to increase viewing angle more wider, diffuser cover could be used and additionally this cover also makes less glare level.



[Without diffuser cover]



[With diffuser cover]



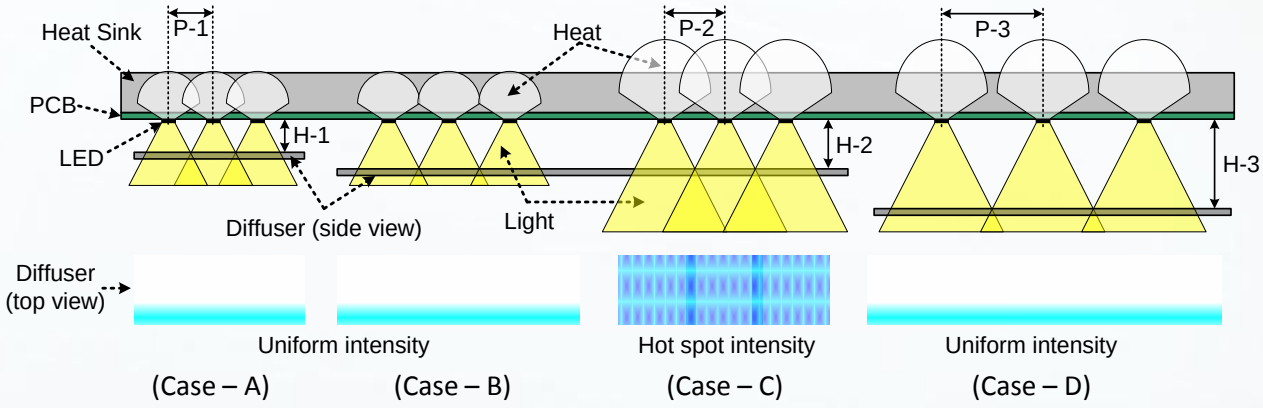
[The difference of beam angle between without and with diffuser @ side view]

In above picture, we can observe shadow line from heat sink edge (without diffuser) and also could see more wide diffused light performance (with diffuser).

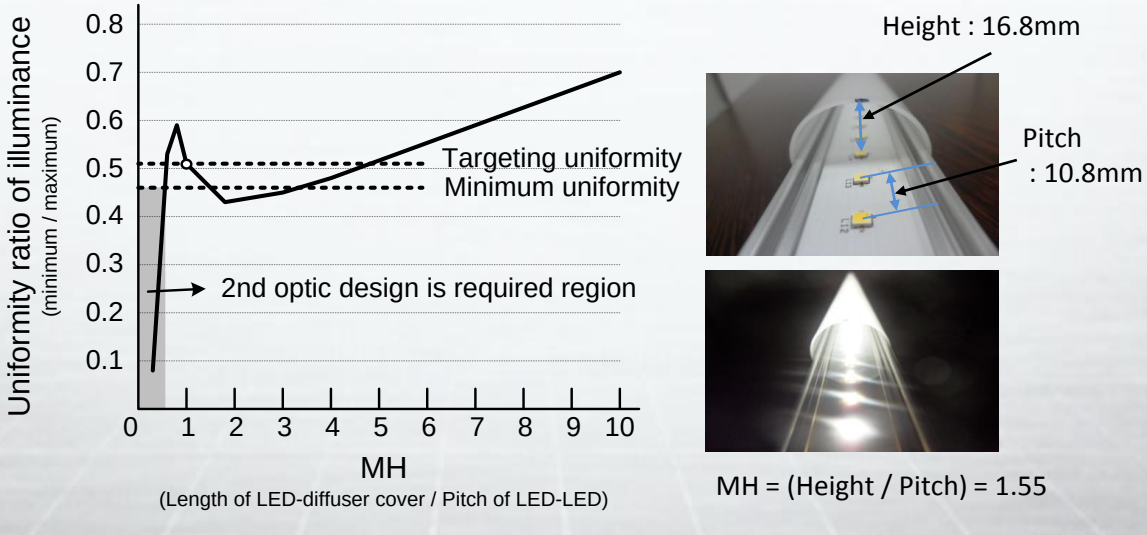
1.1 T8 Description

1.1.4 The effects of LED pitch

There are some relations between LED pitch and cover height from LED to diffuser for illuminance uniformity. If LED power consumption is increased to emit higher luminance flux, heat sink might be designed more carefully and could be appeared hot spot through diffuser cover (Case-C). To prevent hot spot, the height of diffuser cover should be larger and the diameter should be considered by T8 specification (Case-D). To reduce cover diameter of LED-tube, LED pitch and LED light output should be optimized to T8 system and then thermal management should be optimized (Case-A or Case-B). The index of illuminance uniformity ratio could be presented in terms of MH value.



[The relation of pitch and cover height for illuminance uniformity]



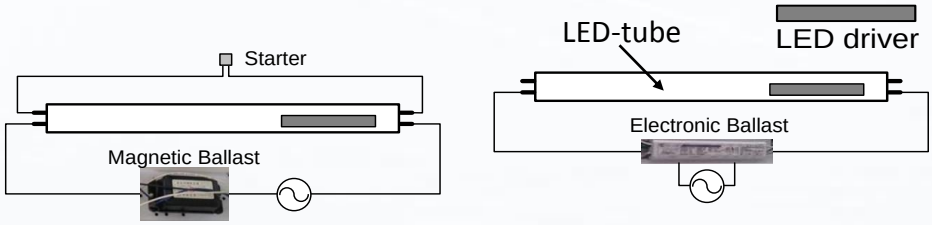
[Uniformity ratio of illuminance]

1.1 T8 Description

1.1.5 Ballast connection of LED-tube

Traditional fluorescent lamp is driven by ballast which is divided into magnetic ballast and electronic ballast. The work of these ballast is AC charging and discharging not the conversion of AC to DC power(SMPS). But LED –tube should be driven by constant current mode. Therefore AC to DC power converter is generally required as a ballast of LED-tube.

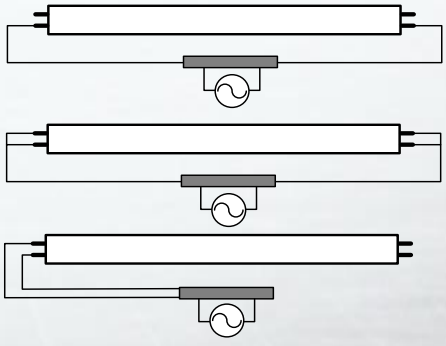
At first, for the compatibility between already installed magnetic or electronic ballast of traditional T8 lamp and LED-tube, compatible converter should be required for LED-tube.



[compatible converter type with installed ballast of fluorescent]

The exclusive converter for LED-tube is divided into interior type and exterior type. Interior converter type is embedded in LED-tube body and tube socket is connected to AC plug directly. And another is exterior type which is separated with LED-tube body like as fluorescent ballast.

[Interior converter type]



[Exterior converter type]

2.1 T8 Implementation

2.1.1 Calculated table (estimation)

System estimation and compare tool of samsung led is supported for user convenience. First, user could sellect LED type and detail rank information (CCT, VF, Flux rank). Then optical and electrical efficiency of system information could be inserted. If there's non information of system level, then just board level results might be shown.

Second, target driving current and the number of LEDs should be inserted. After this, unit LED performance(Flux, VF) and system expected value(total flux, power consumption, lumen per watt) could be shown. And this value is just only relevant to 25℃ solder point temperature case(Ts). If user want real value at operating condition, for example when Ts is 70℃ or 85℃ etc,. do the next stage.

Third, insert expected Ts temperature to tool. Then LED performance might be changed as to inserted Ts information and system results might be changed also. Furthermore the thermal resistance of system could be known. From these system information, allowable current level related with derating curve is shown and some comments would be presented and expected lifetime becomes to be shown.

LM231A		Efficiency of PSU	0~100	78%		LED	Vf : AZ,A1,A2,A3,A4	A3		(Datasheet) TJ_max. = 110℃
sellect : LM231A,LM231B,LM561A,LM561B,LM362A		Efficiency of Optical	0~100	89%		Rank	Flux : S1,S2,S3	S2		(Datasheet) IF_max. = 150mA

CASE	Input filed					LED performances at operating			Estimations of system			Derating performance			
	CCT [K]	I_F_driving (A)	# of LED	Ts (℃)	Ta (℃)	V_F (V)	Flux (lm)	T_J (℃)	Flux (lm)	Power (W)	Efficacy (Lm/W)	R_{th}(J-a)	I_F_max. (A)	I_F_margin (A)	Comment
A	2700	0.056	110	51	25	2.95	20.4	54.3	1997	23.30	85.7	256	0.150	0.094	inside of derating curve
		0.063	100	55	25	2.97	22.7	58.7	2020	23.99	84.2	258.2	0.150	0.087	inside of derating curve
		0.071	90	59	25	2.99	25.2	63.2	2019	24.50	82.4	256.1	0.150	0.079	inside of derating curve
B	5000	0.056	110	51	25	2.95	20.9	54.3	2046	23.30	87.8	256	0.150	0.094	inside of derating curve
		0.100	110	75	25	3.05	34.8	81.1	3407	43.01	79.2	255.5	0.150	0.050	inside of derating curve
		0.150	110	105	25	3.13	46.2	114.4	4523	66.21	68.3	255.6	0.143	-0.007	Out of current range
C	5000	0.056	110	64	25	2.92	20.4	67.3	1997	23.06	86.6	373.1	0.113	0.057	inside of derating curve
		0.100	110	99	25	2.99	32.2	105.0	3152	42.17	74.7	371.5	0.106	0.006	Warning for current
		0.114	110	111	25	3.03	36.0	117.9	3524	48.71	72.3	370	0.104	-0.010	Out of current range

2700~6500	0.04~0.15	Input #	measured data

※ derating characteristics is based on Ts (LED solder temperature)
※ IF_margin = IF_max.-IF_driving

LM561B		Efficiency of PSU	0~100	78%		LED	Vf : AZ,A1,A2,A3,A4	A3		(Datasheet) TJ_max. = 110℃
sellect : LM231A,LM231B,LM561A,LM561B,LM362A		Efficiency of Optical	0~100	89%		Rank	Flux : S1,S2,S3	S2		(Datasheet) IF_max. = 150mA

CASE	Input filed					LED performances at operating			Estimations of system			Derating performance			
	CCT [K]	I_F_driving (A)	# of LED	Ts (℃)	Ta (℃)	V_F (V)	Flux (lm)	T_J (℃)	Flux (lm)	Power (W)	Efficacy (Lm/W)	R_{th}(J-a)	I_F_max. (A)	I_F_margin (A)	Comment
D	2700	0.056	110	52	25	2.96	22.4	54.7	2193	23.38	93.8	258.2	0.150	0.094	inside of derating curve
		0.063	100	56	25	2.98	24.9	59.0	2216	24.07	92.1	259.3	0.150	0.087	inside of derating curve
		0.071	90	60	25	3.00	27.7	63.4	2219	24.58	90.3	256.3	0.150	0.079	inside of derating curve
E	5000	0.056	110	52	25	2.96	24.9	54.7	2438	23.38	104.3	258.2	0.150	0.094	inside of derating curve
		0.100	110	77	25	3.07	41.0	81.9	4014	43.29	92.7	257.5	0.149	0.049	inside of derating curve
		0.150	110	109	25	3.18	56.0	116.6	5482	67.27	81.5	257.9	0.139	-0.011	Out of current range
F	5000	0.056	110	65	25	2.94	24.3	67.6	2379	23.22	102.5	373.8	0.112	0.056	inside of derating curve
		0.100	110	102	25	3.03	39.0	106.8	3818	42.73	89.4	375.2	0.104	0.004	Warning for current
		0.114	110	115	25	3.07	43.7	120.6	4278	49.36	86.7	375.7	0.101	-0.013	Out of current range

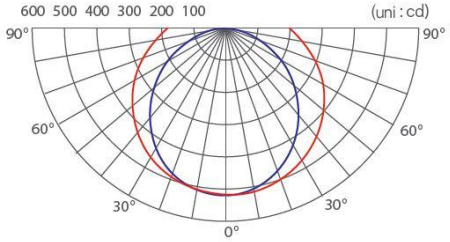
2700~6500	0.04~0.15	Input #	measured data

2. Implementation

2.1 T8 Implementation

2.1.2 Implementation (realization)

Real implementation of LED-tube is made for 4ft T8 replacement. Adopted LED components are LM561B and LM231A and 110 number of LEDs are used respectively.



2.1.3 Comparison with estimation vs. realization

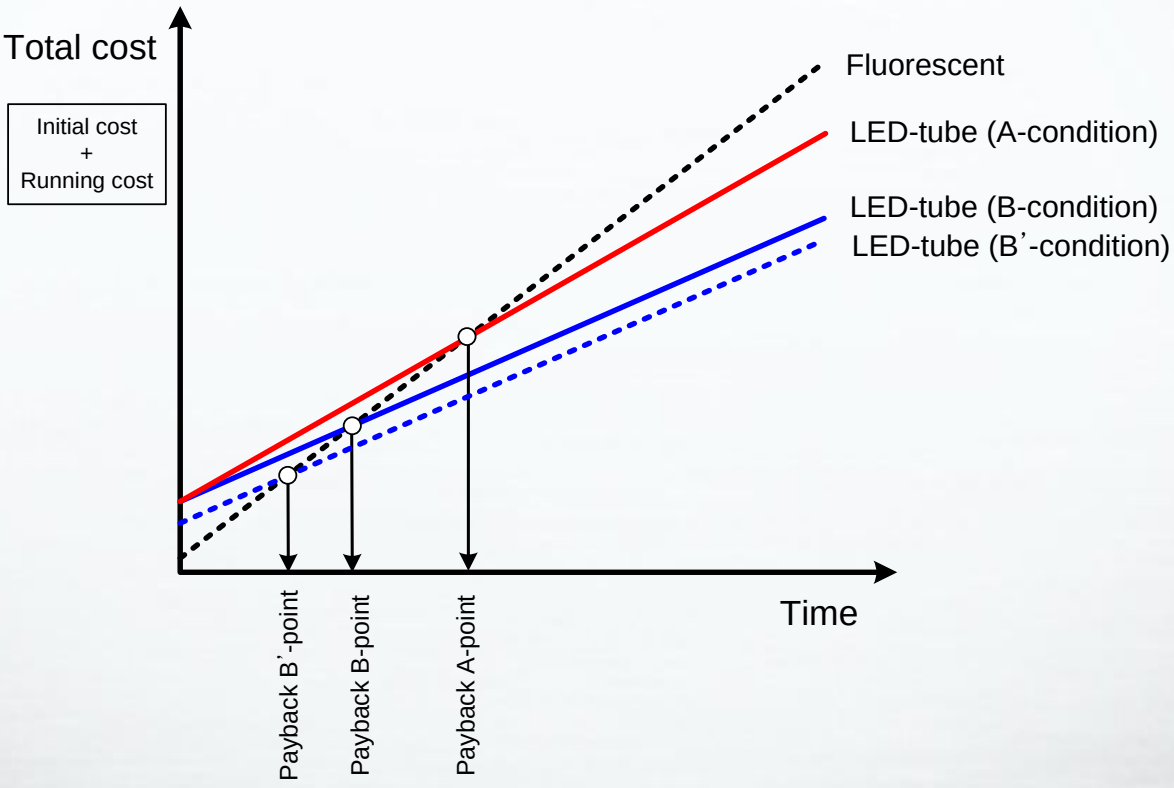
The measured value of LED-tube implementation and the estimated value from estimation software tool is compared as below table.

LED Rank (V_F : A3, Flux : S2)	LM561B		LM231A		LM561B		LM231A	
	Estim.	Imple.	Estim.	Imple.	Estim.	Imple.	Estim.	Imple.
CCT (K)	2700				5000			
# of LED	110				110			
Total lumen (lm)	2193	2242	1997	1994	2438	2442	2046	2162
	(102.2%)		(99.8%)		(100.2%)		(105.6%)	
Total power (W)	23.4	23.9	23.3	23.8	23.4	23.5	23.3	24.0
	(102.1%		(102.1%)		(100.4%)		(103.0%)	
Set efficacy (lm/W)	93.8	93.8	85.7	83.8	104.3	104.1	87.8	90.2
	(100.0%)		(97.8%)		(99.8%)		(102.7%)	

※ ( ) : ratio of 'implementation value / estimation value'

3. Epilogue

The market price of LED-tube falls down rapidly year by year. But actually the cost of LED-tube is still expensive compared with fluorescent lamp. Therefore manufacturer should consider 2 kind of main factor. One is initial price of LED-tube itself and install cost. Another is running cost related with electric bill and this cost is closely correlated with LED-tube efficiency. From these relations, the concept of payback becomes important.
Below graph show a simple payback curve. Both of A-condition and B-condition has same initial price. But LED-tube efficiency or electric bill might be different. Therefore payback time could be different like as below graph(payback A-point and B-point, the efficiency of B is more higher than A). Surely as initial cost falls down, payback time could be advanced like B'-condition.
Therefore LED-tube could have various market positioning according to each country and installed site .



[Example of payback]

4. Revision History

Date	Revision History	Writer	
		Drawn	Approved
2013.03.21	New Version	Y.J. Lee	D.M. Jeon