A new approach to the current regulator design of LED strings based on current mirror

Pu-Jin Kim*,Min-Ki Yoo,Rok-Hee Lee,Koo-Hwa Lee,Kyeong-Kun Jang and Sin-Ho Kang
R&D center, LG display
642-3, Jinpyung-dong, Gumi-City, Kyungbuk, 730-360, Korea
TEL:82-54-478-5621, e-mail:allforone@lgdisplay.com.
Keywords : LCD, LED, Current Regulator, LED Array

Abstract

This paper studies the current regulator of LED Backlighting system for LCD. The proposed regulator and a typical regulator are introduced. To find out the characteristics of two regulators, Prototype samples of LED Backlighting system are made. Both the proposed regulator and a typical regulator are compared with electrical, thermal and optical characteristics each viewpoint.

1. Introduction

LED Backlighting System is composed of LED, driving circuit and mechanical and optical components. Therefore, when we evaluate the performance level of LED Backlighting system, we need to consider electrical, thermal and optical characteristics all together. In that respect, LED driving circuit and LED Array are key component of LED Backlighting system.

A current regulator is required to control the LED current constantly to control luminance and color coordinate of LED backlighting system for LCD. Therefore, we normally called the driving circuit of LED is *constant current regulator* or is simply *regulator*.

A typical regulator is made of boost converter, current regulator. An output voltage of boost converter is connected with the common anode of LED strings and feedback line is connected with each current regulator within driving circuit board.

The structure of a typical regulator as Fig. 1. is a current sink block at each LED string. In this case, a typical regulator is limited to dissipate the thermal amount of LED package because thermal dissipation path is so complicated.

The proposed regulator based on current mirror is implemented to simplify thermal conduction path. This current mirror circuit has been used for current source of IC normally but It can be used for current balancing circuit after modification.

The proposed regulator is made of boost converter, current regulator and balancing circuit using current mirror circuit. An output voltage of boost converter and LED strings are connected through balancing circuit. The last cathodes of LED strings except bias current channel can be connected with ground directly and can be connected with ground through mechanical chassis(normally aluminum plate).

In this case, we can use aluminum plate usefully as thermal dissipation plate because thermal conduction path and electrical conduction path is formed simultaneously.

2. Design

2.1. LED current regulator

Target design specification is,
Input voltage – 12V(typical) ;
Output voltage – 34V(typical) ;
Output current – 120mA(20mA per string, 6strings);
Output power consumption – 4.08Watt(typical);
Power conversion efficiency – 85%(typical);
Input power consumption – 4.8Watt(typical);

a. A typical regulator

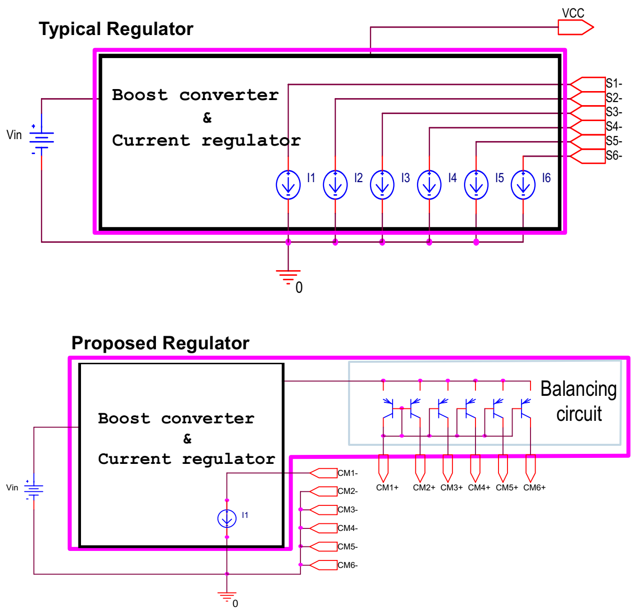
A typical regulator is implemented with Boost Converter and Current Sink within IC. Boost Converter supplies the energy to meet demanded voltage of LED strings. Normally, a needed voltage of LED strings is decided by the maximum forward voltage among strings at same current. Current Sink Block regulates the target LED current of each string.

b. The proposed regulator

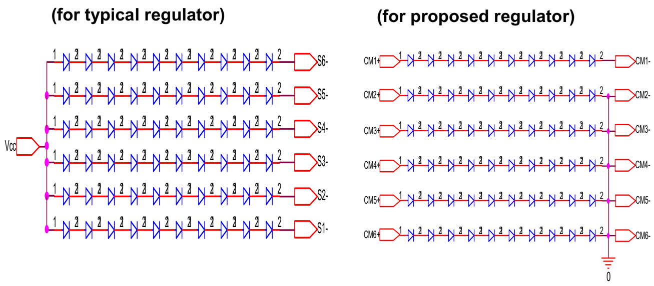
The proposed regulator is implemented with Boost Converter and Balancing Circuit using PNP dual transistor. At balancing circuit, one of 6channels is used as bias current channel to control the LED current and the each current of the others' strings follows bias current according to current mirror circuit.

c. LED Array

LED Array depends on the type of regulator. LED quantity is totally 60pieces and the 10pieces are connected serially per string. LED is mounted on Flexible Printed Circuit.



(a) Regulator circuit block diagram

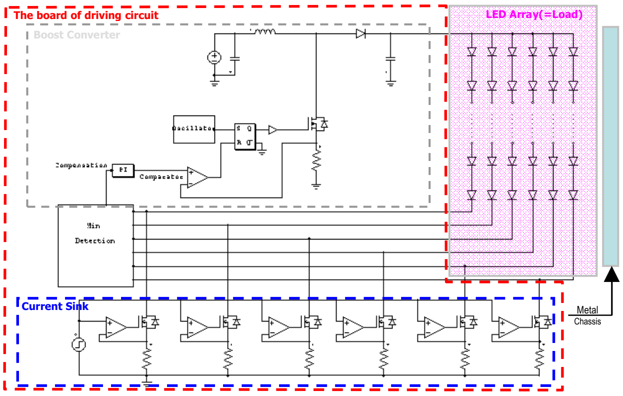


(b) LED Array schematic

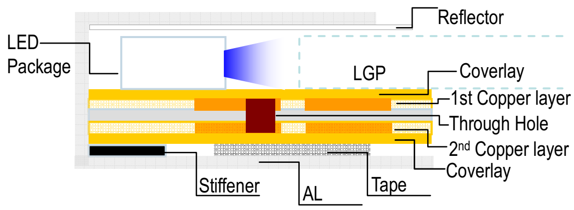
Fig. 1. Block diagram and LED Array schematic

2.2. Prototype Assembly

Assembly method is different. This is depends on regulator type. The most different thing is an assembly method between LED Array and metal chassis. An LED Array for a typical regulator is attached on metal chassis with double side bonding tape otherwise an LED Array for the proposed regulator is attached on metal chassis with screw. The other components such as Panel, optical sheet and Light Guide Panel are totally common. Fig. 2. and Fig. 3. show the electrical and mechanical composition of each prototype sample.

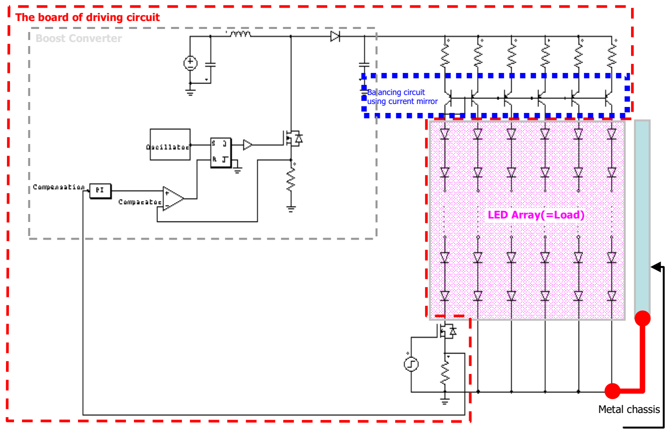


(a) Typical regulator , LED Array and Metal chassis

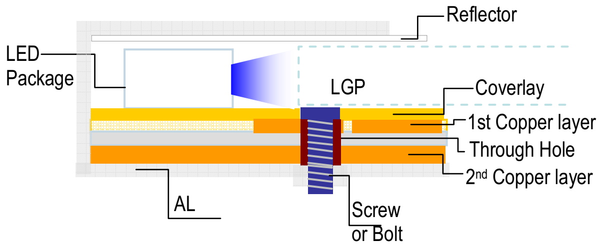


(b) Assembly–LED Array and Metal chassis

Fig. 2. Prototype1 structure



(a) Proposed regulator, LED Array and Metal chassis

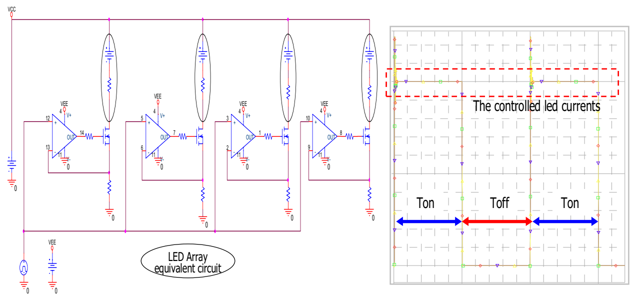


(b) Assembly –LED Array and Metal chassis

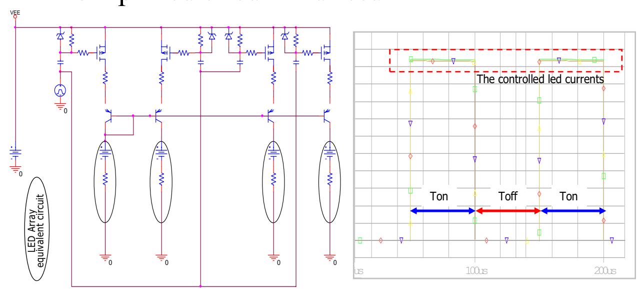
Fig. 3. Prototype2 structure

2.3. A simulation of each regulator type

The circuit simulation of two types of regulator is implemented. It is validated that the operation of current regulation is correct using simulation. Fig. 4. (a) and (b). show the LED current regulated per sting.



(a) Prototype1, Current Sink simulation
– simplified circuit and result



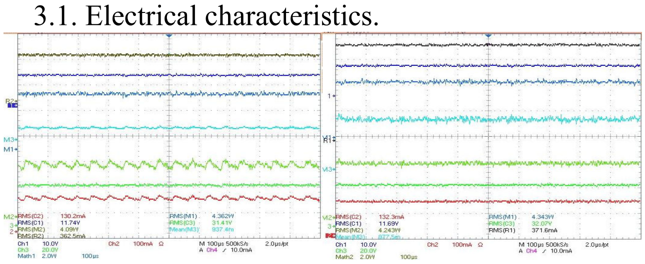
(b) Prototype2, Balancing Cicuit simulation
– simplified circuit and result

Fig. 4. Regulator Simulation of main block

3. Experimental Results

All experiments are executed with a 15.4inch Notebook LCD Module.

3.1. Electrical characteristics.



(a) Prototype1 (b)Prototype2

		Prototype1	Prototype2
Ch1	Input voltage	11.74Vrms	11.69Vrms
R1(R2)	Input Current	362.5mA	371.6mA
Ch2	Output current	130.2mA	132.3mA
Ch3	Output voltage	31.41Vrms	32.07Vrms
M1	Input Power	4.362Watt	4.343Watt
M2	Output Power	4.09Watt	4.243Watt
M3 (=M2/M1)	Power conversion efficiency(%)	93.70%	97.70%

Fig. 5. Electrical Waveform

The performance of two regulators is compared in Fig. 5. The operation of both regulators' current control is right and Pototype2 at power conversion efficiency is same or better level.

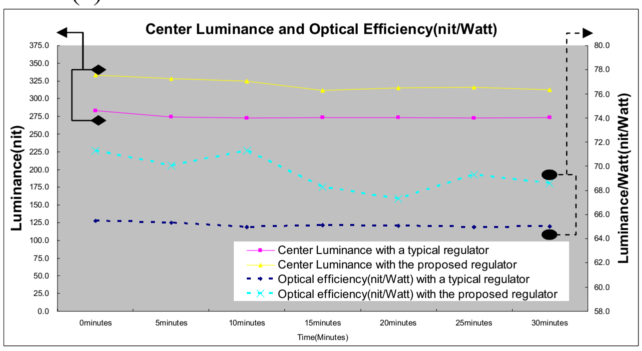
3.2. Optical characteristics

Luminance(nit), color coordinate at CIE1931 and optical efficiency(nit/Watt) is tested on LCD Panel with CA210. Fig. 6.(b) shows that Prototype2 is 10% higher luminance than a Prototype1 and optical efficiency is also better performance level around 5(nit/Watt). Optical efficiency is defined as the center luminance of LCD per input power. The value is Color coordinate is same level between two Prototype samples.

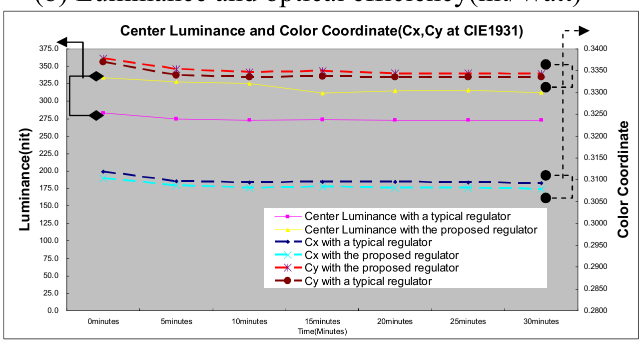
TABLE 1. Center Luminance, color coordinate and Power consumption data

	Time	0minutes	5minutes	10minutes	15minutes	20minutes	25minutes	30minutes
Prototype1 (Typical)	Pin(Watt)	4.32	4.2	4.2	4.2	4.2	4.2	4.2
	Lv(center,nit)	283	274.3	273	273.5	273.3	272.9	273.2
	Nit/Watt	65.51	65.31	65.00	65.12	65.07	64.98	65.05
	Cx	0.3118	0.3096	0.3094	0.3095	0.3095	0.3094	0.3093
	Cy	0.337	0.3339	0.3336	0.3337	0.3336	0.3336	0.3335
Prototype2 (Proposed)	Pin(Watt)	4.68	4.68	4.56	4.56	4.68	4.56	4.56
	Lv(center,nit)	333.7	328	325	311.3	315	316	312.7
	Nit/Watt	71.30	70.09	71.27	68.27	67.31	69.30	68.57
	Cx	0.3103	0.3087	0.3082	0.3084	0.3081	0.3081	0.3079
	Cy	0.3378	0.3353	0.3346	0.3349	0.3344	0.3344	0.3342

(a) Front and Rear side of LCD Module



(b) Luminance and optical efficiency(nit/Watt)



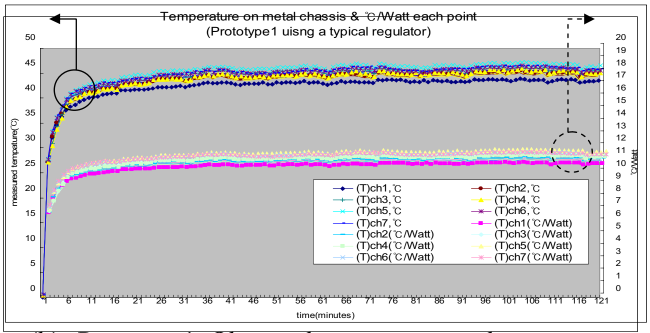
(c) Luminance and Color coordinate

Fig. 6. Luminance, Color coordinate and optical efficiency(nit/Watt) data

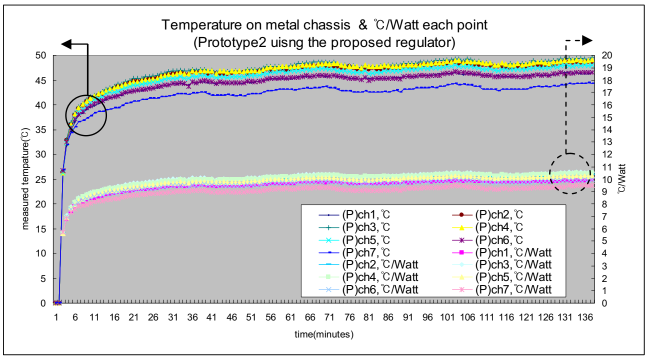
3.3. Thermal characteristics

The thermal level of two prototypes is compared with the measured data using thermometer, GL450(GRAPHTECH).

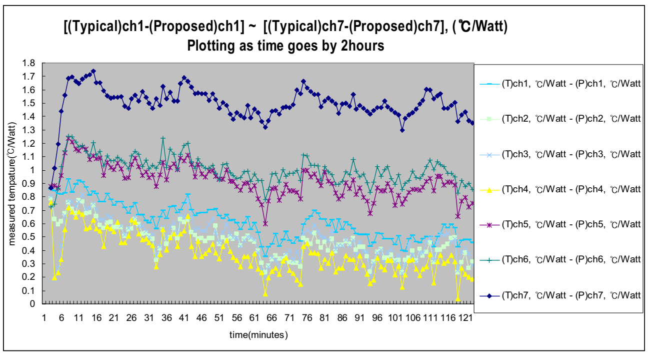
(a) Test point of rear side of LCD Module



(b) Prototype1, Observed temperature and Observed temperature per input power(℃/Watt)



(c) Prototype2, Observed temperature and Observed temperature per input power(℃/Watt)



(d) "Prototype1(℃/Watt)-Prototype2(℃/Watt)" at each measurement point.

Fig. 7. Temperature measurement and Analysis

Fig. 7.(b) and (c) shows that the measured temperature data on metal chassis of a Prototype1 and a Prototype2. From temperature per input power point of view, Fig. 7(d) shows that a Prototype2 is better than a Prototype1 and the difference value is from around 0.3(℃/Watt) to around 1.5(℃/Watt).

(2 line spacing)

4. Summary

A new approach to the regulator design is executed. the control accuracy of LED current regulation is same level as a typical regulator otherwise the optical and thermal performance of the proposed regulator are better than a typical regulator at the Backlighting System.

5. References

1. Osaka-fu, "Light-emitting drive circuit, and optical transmission system using the circuit" US Patent 6,728,494(2004).
2. Koyto, "LED drive circuit", US Patent No. 6,628,252(2003).
3. Ahmed Masood, "Driving Schemes for LED Backlighting Large-area LCD Displays", SID Digest, pp308~311, 2007.