Heat Dissipation Designs for LED Backlight System: Simulation and Experiment

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Abstract

The LED light source has many excellent advantages for the application of LCD backlight module. As we know, the operational temperature can significantly influence the characteristics of LEDs. Heat can damage the LED's quality, and decrease its lifetime and output light intensity. In this paper, we perform computer software, Flomerics CFD (Computational Fluid Dynamics), to simulate heat distribution of the 20.1" LED backlight module we designing, and realize how the different heat sinks can solve the serious heat problem in practice.

I. Introduction

LED (Light emitting diode) is a solid state light source featuring the merits of super long life span, power saving, low voltage, high color rendering, low temperature operation, quick responding speed, and conformity to EPA requirements (no Hg content), which are all superior to the current CCFL light source[1, 2]. Now this LED light source is currently being used for many lighting apparatuses and small size cell phone backlight applications. It is obvious that LEDs will take place of CCFL as the large-scale TFT-LCD backlight source in the near future.

Although LEDs have a lot of advantages, most semiconductor devices have a common big problem about heat generation during operation. The operational temperature arises as heat is accumulated, and high operational temperature will decrease LED's output light intensity and shorten its lifetime. Moreover the behavior of TFT-LCD's color temperature and colorimetry strongly depend on the relation between the individual intensity of RGB LEDs. The relative luminous light outputs of RGB LEDs changed by floated operational temperatures was shown in **Fig. (1)**. As temperature rises, the output intensity of R LED diminishes more dramatically than that of GB LED, not only the brightness of LCD module is also decreasing but the color temperature is also changed toward high field (blue-shift). The safety operation LED junction temperature is about 85 ^{o}C; however, the module temperature should be under 70 ^{o}C.

II. Experiment

1. Assembly

We demonstrated several heat-sink designs for 20.1 inches LED-LCD module to decrease the module operational temperature and improve LED device performance and lifetime. This LED backlight module of 20.1" TFT-LCD TV was equipped with Lumileds Luxeon (1W) RGB LEDs (total 122 pcs), which are mounted on a Cu-based substrate, and driven by Delta Electronics' power supply. The layout of LEDs is shown in **Fig. (2).**

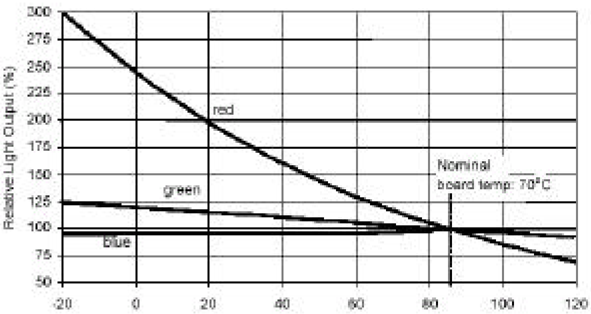

Fig. 1. Relative Luminous light output vs. Junction Temperature for Lumileds Luxeon Emitter.

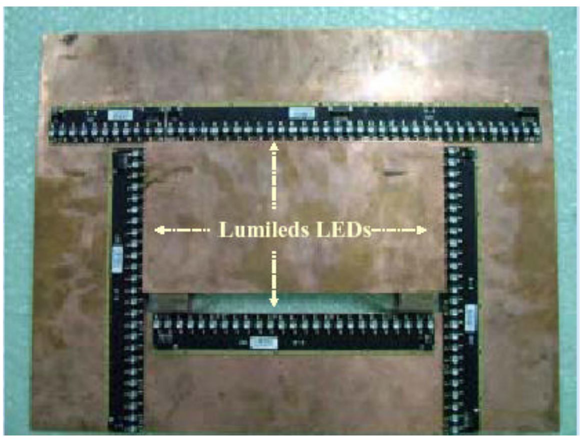

Fig. 2. The layout of LED strips mounted on the front of Cu-based board.

The LED backlight structure we designing is two layers integration. One is white light mixing layer and the other is main light guiding layer [1, 2]. The R-LED is applied a DC voltage about 2.3 V@ 420 mA, and G, B-LEDs are applied a DC voltage about 3.2 V @350mA. The total power consumption is about 100 W in order to reach the TV brightness of 500 nit. These parameters are measured by power meter and Tektronix Scope.

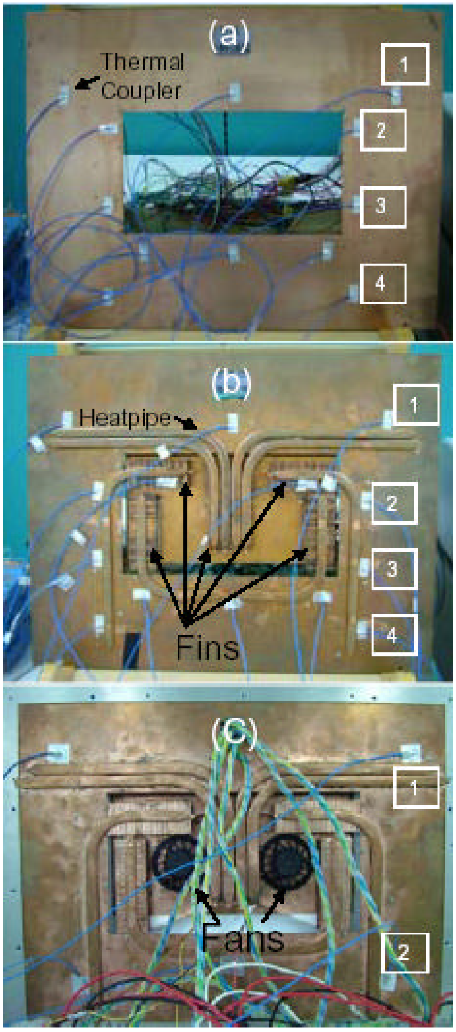

Fig. 3. Three heat dissipation designs (a) the back of Cu-based board, (b) Cu-based board with heatpipes and fins, (c) Cu-based board with heatpipes, fins, and two fans. The probe points of thermal couples are also marked "1, 2, 3, and 4".

2. Simulation

In the beginning, we consider that E-O conversion efficiency is about 30 %, electric power consumption is 1 W, and the heat generation is about 0.7 W for each LED in the following stimulations. Three different heat dissipation cases were designed, and shown in **Fig. (3).** The first case is LEDs on Cu-based substrate without any other heat dissipation apparatus. The second one is heatsinks and heatpipes are mounted on the back of Cu-based substrate. And the third one is 2-fan-equipped version of the second one (rotation rate is 5000 rpm). These three LED backlight modules are operated under 25 °C environment. When LED backlight is turned on, all of the LEDs can produce the total 85.4 W heat.

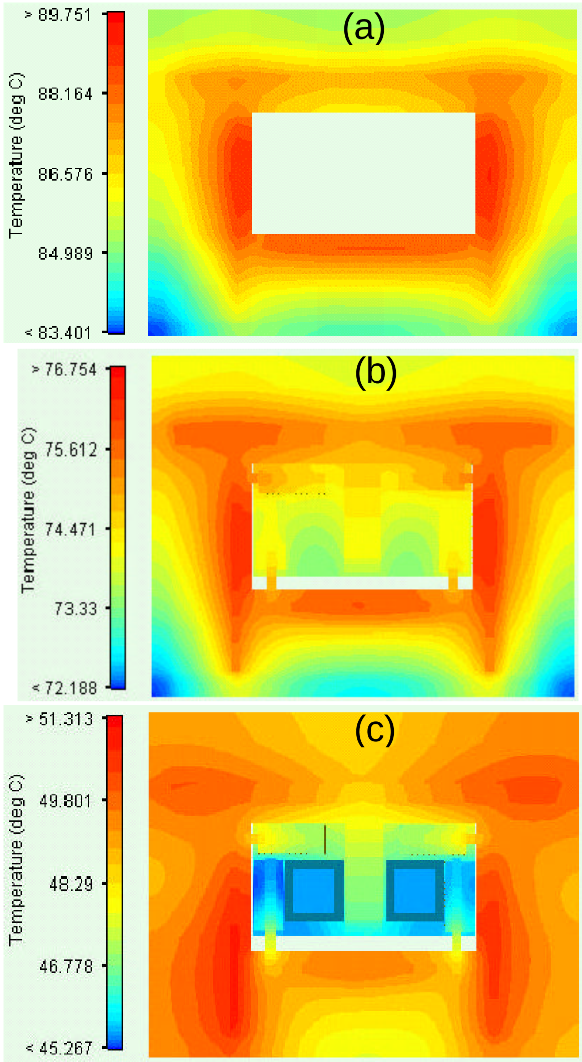

Fig. 4. The CFD simulation results for Fig. 3(a), 3(b), and 3(c). Their maximum operational temperatures are about 89 °C, 76 °C and 51 °C, respectively.

We put all parameters into CFD software, and **Fig. 4(a)** shows the simulation result of the temperature distribution on the back of Cu board of **Fig. 3(a)**. The maximum temperature is 89.75 °C, which is over Lumileds LEDs' specification 70 °C. If LED-LCD module is operated under this condition, we can make sure its lifetime will be shortened abruptly. According to the result of simulation, heat is generated from LED junction layer, diffuse to Cu board, and then spread to all Cu board. Finally it will be transferred into environmental air. In order to protect LED device, the new design with fins is fabricated as shown in **Fig. 3(b**). The simulation result is displayed in **Fig. 4(b),** and the maximumtemperature is 76.75 ^{o}C. Compared with the **Fig. 3(a)**, fins can increase 1.5 times heat dissipation area, and help reduce 13 ^{o}C operational temperature; however, it still cannot achieve Lumileds LEDs' specification. Thus, accelerating the speed of heat interchange with environment is necessary. The final solution of our LED backlight module as shown in **Fig. 3(c)**. The forced convection can be generated by two fans. The simulation results are shown in **Fig. 4(c),** and the maximum temperature 51.31 ^{o}C is very appropriate for the operation of LED backlight module.

III. Results and discussions

To realize the real function of these three designs, we attach several thermal couplers on the back of Cu board to probe the real temperature changes when all LEDs are turned on. The front of Cu board is mounted by LED strips as shown in **Fig. (2),** and the main highest temperature area is behind LED strips. Due to symmetric structure, we only collect data from 4 points on the right side of **Fig. 3(a)**, **3(b),** and 2 points on the right side of **Fig. 3(c).** The measured results are shown in **Fig. (6).** The maximum stable operational temperatures occur at position 4 of **Fig. 3(a)** and **3(b)**,

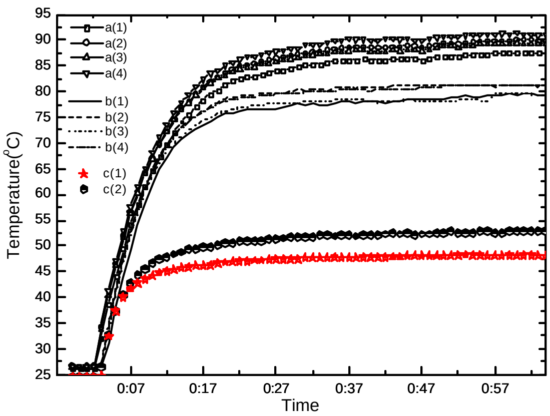

Fig. 5. The measured results for the three systems of Fig. 3(a), 3(b) and 3(c). The perfect condition is the design of Fig. 3(c), and its operational temperature is under 52 ^{o}C.

and position 2 of **Fig. 3(c).** The minimumstable operational temperature occurs at position 1 of **Fig. 3(a)** and **3(b),** and position 1 of **Fig. 3(c).** In the same system, the individual temperature difference is within 10 ^{o}C.

All of the measured results are very similar to the simulations in these three different systems. Therefore, the heat dissipation apparatus composed of heatsinks, heatpipes, fins, and fans is necessary for standard LED backlight module with 8000 nit brightness.

IV. Conclusion

We successfully demonstrate appropriate heat sink design can solve the heat problem by using fins, heatpipes and fans to increase heat dissipation area and to carry heat out via forcing wind. The maximumoperational temperature can be predicted and detected from simulation and experiment, respectively. We use heatpipes to guide heat to fins due to heatpipes can carry heat form high temperature to low temperature quickly. The main heat dissipation mechanism in this case is the speed of heat interchange with air. The lowest operational temperature of 20.1" LED-LCD TV module can be achieved at 51 ^{o}C.

V. Acknowledge

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Reference:

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