International Journal of Emerging Research in Management &Technology ISSN: 2278-9359 (Volume-5, Issue-7)

Research Article **July 2016**

Study the Behavoure of Several Types of LEDs Light with Designing Proper Heat Sinks for Each LED

Raaid R. Jassem[1, 2], Thamer Khalif Salem[1, 2], Mohammed K. Abbas[1, 3], Ibrahim Thamer Nazzal[1, 2]

[1] Ozyegin University, School of Engineering, Cekmekoy, Istanbul, Turkey

[2] TIKRIT University, Engineering College, Iraq

[3] Diyala University, Engineering College, Iraq

Abstract:

The Heatsinks play a role in the performance of light emitting diode (LED), because any rise in junction temperature above the design junction temperature leads to failure of the LED light. Hence, the Heatsinks design is very important factor to improve the performance of LEDs. LED light that gives 220 lm has been chosen to be the base of our design. Three typs of LEDs have been chosen to give this value of flux, and then suitable Heatsink for each type of LED has been design. EES program is used for both design and study the effect of some parameters on the LEDs flux, LEDs efficiency, Heat sink mass, and Heat sink cost.A 3D model of each type of LED is carried out by using ANSYS ICEPAK program, based on EES program results. There is agreement between theoretical results and numerical (EES, and ICEPAK results) According to the results, the fin lengths of heat sinks for the first, second, and third LEDs are 39, 47, and 52 mm, respectively. Fluxes of LEDS increase with fin lengths till specific length after that it still constant. The increasing of junction temperatures for each type LED light leads to decrease the flux of each LED. For instance, if junction temperatures increase by 20% for each LED's type, the fluxes of each LED decrease by 3%, 4.5%, and 7% respectively. The cost of heat sinks for each LED can be seen from figure-12 to be around 42, 51, and 57 US dollar for each LED, respectively.

Keywords: LEDs-Thermal management- Heat sink.

I. INTRODUCTİON

Proper thermal management is one of the most important aspects of LED system design. Since LEDs are temperature sensitive devices, their performance will depend on the thermal management system built around them. LED lifetime and reliability are highly dependent on LED junction temperature and operation at higher junction temperatures will result in reduced longevity of the product. Additionally, efficiency of LEDs will decrease with increased junction temperatures. Therefore, it is important to keep operating temperatures as low as possible. A well designed thermal system will have positive impacts on brightness, lifetime and reliability.

In order to ensure good performance and reliability, it is imperative to properly manage the heat generated by the device. In general, the design of a thermal system includes consideration of four factors. These include the thermal resistance of the LED module, the amount of power dissipated by the device, the thermal resistance of the heat sink and the ambient operating conditions of the system. Except for the thermal resistance of the LED module, the designer has control over the remainder of these factors. Different applications and designs will have a different balance of these factors, however the end goal is always the same - to minimize the junction temperature of the LED in operation[1].

The effect of chip packages on junction to board thermal resistance for both SiC and Sapphire chipswas studied by Arik M.[2].It is found that from the results, the higher thermal conductivity of the SiC chip provided about 2 times better thermal performance than the Sapphire chips .

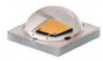
Sandy.K[3] developed several thermal interface materials and thermal management solutions for various power electronics PCBs used in LED lighting and find thermal management of electronic packaging has reached a crucial stage calling for immediate cooling solutions.

Nan Jiang [4] improvred advanced low CTE thermal management materials ,which have a CTE smaller than 7 ppm/K, thermal conductivity over 350-400 W/mK, and thermal diffusivity 2.5–3 times higher than that of Cu. The combination of high performance graphitic carbon-based materials and functionalized layerscan provide considerable reduction in total thermal interfaces in a power LED package.

In this paper three LEDs are chosen as they are shown in table (1). The main assignment is that design suitable heat sink for each LED and study the effect of that heat sink to the junction temperature and LEDs properties likes Flux and efficacy. 2200 luminous flux is assumed as required luminous and the number of LED's are calculated according to this value of luminous.

Table (1) shows the LEDs types and properties [5-7].

LED Type	Cree-Xlamp-XPLAWT-00-0000-000LV40E5	XPGWHT-L1-0000-00H53	XPEBWT-L1-0000-00CE4

Image			
Name	**LED1**	**LED2**	**LED3**
CCT(K)	**4000**	**6200**	**4500**
CRI	**75**	**70**	**75**
I(mA)	**1050**	**700**	**350**
V(Volt)	**2.95**	**2.9**	**2.9**
R(^{o}C/W)	**2.5**	**4**	**9**
P_max (watt)	**3.0975**	**2.03**	**1.02**
Flux(lm)	**440**	**220**	**104**
Color	**Neutral White**	**White ,cool**	**Neutral white**
T_J(^{o}C)	**85**	**85**	**85**
Viewing angle	**115**	**125**	**110**
LED dimension (mm)	**5*5**	**5*5**	**5*5**
LED number	**5**	**10**	**21**
LED Price ($)	**8.4**	**5.65**	**1.53**

II. ANALYTİCAL SOLUTİON

The main calculations of LEDs that are calculated are.

1. LED power.
2. Junction temperature.
3. LED flux.
4. LED efficacy.

First of all we assumed that we need LED light that provide 2200luminous flux and after that choosing three type of LED as they are shown in table (1).According to the luminous flux of each LED light the number of LED(NO_{LED}) can be calculated from equation(1) as follow

NO_{LED}= Total Flux/ LED_{Flux}………………..... (1)

The LEDs power can be calculated from following equation

$P_{LED} = I_{LED} \times V_{LED} \times NO_{LED}$ ……………....... (2)

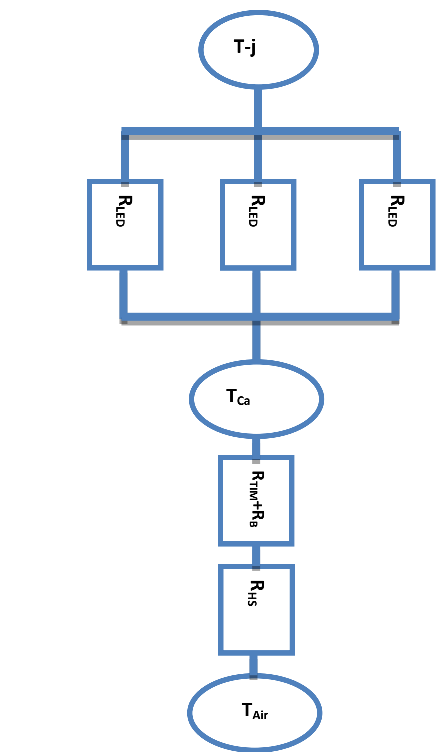


Figure 1 Thermal Resistances Network

From equation (2) we can calculate the power of each LED in (watt), and then the LED flux and LED efficacy changing are calculated with current and junction temperature according to catalogs of each LED[3]. In this catalog there are figures shows the relationshipbetween flux efficacy with current and junction temperature. By redrawing these figures and using the equations that we get to calculate them according to work data.

To determine the required dimensions of heatsink, its thermal resistance should be determined first. According to thermal resistance network as it is shown in figure (1), the LED resistance are known from table (1) and thermal resistance of board and interface material are determined before by choosing their material and properties. So from this network the total resistance can be determined as[8,9].

R_{LED} (From table-1)

$R_{TIM} = \frac{TIM_{thickness}}{A_{TIM} \times k_{TIM}}$ ……………………………………………………………………………(3)

$R_{PCB} = \frac{PCB_{thickness}}{A_{PCB} \times k_{PCB}}$ ……………………………………………………………………………(4)

$R_{base} = \frac{base_{thickness}}{A_{base} \times k_{base}}$ ……………………………………………………………………………(5)

In order to select the appropriate heat sink, the thermal designer must first determine the maximum allowable heat sink thermal resistance figure-2. To do this it is necessary to know the maximum allowable module temperature, T-junction, the module power dissipation, P_LED, and the total thermal resistance at the module-to-heat sink interface, R_total. The maximum allowable temperature at the heat sink attachment surface, T-junction, is given by

$T_{junction} = R_{total} * P_{LED} + T_{air}$. ………………………………………………………(6)

The maximum allowable resistance that dessipsted required power from the heat sink , $R_{dissip\text{-}require}$

$R_{dissip-required} = \frac{T_{junction} - T_{Air}}{P_{LED}}$ ……………………………………………………………(7)

From previos equations total resistance should not overtake the required resistance .

$\mathbf{R}_{total} \leq \mathbf{R}_{\_dissip\text{-}required}$

And

$R_{total} = \frac{R_{-LED}}{No_{LED}} + R_{TIM} + R_{PCB} + R_{base} + R_{HS}$ ……………………………………………………(8)

$R_{HS} = R_{total} - \frac{R_{-LED}}{No_{LED}} + R_{TIM} + R_{PCB} + R_{base}$ ……………………………………………………(9)

The thermal resistance of the heat sink is given by

$R_{fin} = \frac{1}{h * \eta_{fin} * A_{fin}}$, $R_{channel} = \frac{1}{(h * A_{channel})}$

$R_{HS} = \frac{1}{\frac{1}{R_{fin}} + \frac{1}{R_{channel}}}$ ……………………………………………………………………………(10)

Surface area for unfinned surface.

$$A_{channel} = (N_{fin} - 1) * S_{optimum}\ L$$

and the heat transfer area for fined surface

$$A_{fin} = 2 \times N_{fin}(t_{fin} + L) * H_{fin}$$

The Prandtl number is

$Pr = \frac{\mu \times cp}{k}$

Whereh is the heat transfer cofficient, μ is the dynamic viscosity of air, $\boldsymbol{c_p}$ is the specific heat of air at constant pressure, and k is the thermal conductivity of the air.

$Ra = \frac{g \times \beta \times \theta_{base} \times L^3}{\propto \times \vartheta_{Air}}$ ……………………………………………………………………………(11)

$h = \frac{k_{Air} \times 0.517 \times Ra^{0.25}}{L}$ ……………………………………………………………………………(12)

Now the optimum space between fins can be calculated ($S_{optimum}$)

$S_{optimum} = L \times 2.714 \times Ra^{-0.25}$

By assuming the fin's thickness and knowing the heat sink length, it is possible to determine the number of fins (N_{fin}).

$N_{fin} = \frac{L}{(fin_{thickness} + S_{optimum})}$ ……………………………………………………………(13)

After determining the value of $R_{\_dissip\text{-}required}$ and the known values L, S_{optimm},fin thickness, and heat transfer cofficient it is possible to calculated the fin's length or heat sink's height that exist the required resistance.

Finally the junction temperature can be determined as.

$T_{\_j} = T_{\_Air} + R_{\_total} * P_{\_LED} * NO_{LED}$ ……………………………………………………………(14)

Where (NO_{LED}=Number of LEDs)

From this equation it is obvious the heat sink and LEDs power are affect the junction temperature.

By using EES software the required heatsinks are designed and also determine the effects of these dimensions on the junction temperature, LED Flux, LED efficacy,and many variables that will discussed.

According to LEDs types there is a heat sink for each LED as they are shown in Table-2

Table-2 theheat sink dimensions

Heat Sink	LED1	LED2	LED3
Length, L(mm)	60	60	60
Width, W(mm)	30	30	30
Height ,H(mm)	39	47	52
N_{fin}	10	10	10
Fin_thickness (mm)	2	2	2
t_base(mm)	2	2	2

By using these dimensions and input LEDs power many results are calculated to explain their effect on different properties.

III. RESULT ANDDISCUSSION

Figure (2) shows the effect of fin's length on the junction temperature for each heatsink or LED. It is clear from the figure the sufficient height of heatsink for each LED. For example for LED1 the heatsink height or fin's length that achieves to dissipate required power is about 39 mm.

Figure (3) explains the power dissipated from heat sink with fin's length. The figure shows the increasing of power with increasing in fin's length and that happens because the heat sink resistance decreases with increasing of fin's length and that causes the increasing in power dissipated from it. It is clear from figure at design fin's length the dissipated power can be determined.

Fin's effectiveness is shown in **figure (4)** for heat sinkof each LED as it is clear the heat sinkof LED1 have the highest effectiveness because of its height.

The fin length affects the junction temperature, which affect the LED's flux. That can be seen in **figure (5)**. By increasing fin's length the heat sinkresistance will decrease and consequently the junction temperature will decrease too causing increasing in LED's flux. The gap between LED1,LED2 and LED3 is high because the flux of LED1 is 440 lm whereas the flux of LED2 and LED3 are 220 and 104 lm respectively.

Figures (6)and **(7)** shows the junction temperature effect on the LEDs flux and efficacy. It is clear the flux decrease with increasing the junction temperature and this relation according to manufacturing company catalogs for each LED. When the LED flux decrease, and the LED power remains constant the LED efficacy will decrease too as it is shown in figure(7).

Figures (8)and **(9)** show the LED current effect on the junction temperature and the LED's flux. In figure(8) the junction temperature increases, when the LED's current increase ,that happens only when Heat sink dimension still without any increasing, because Heat sink will not be able to dissipate power or heat more than that is designed to dissipate. Hence junction temperature decreases. While in figure (9) if the junction temperature still within the range or below 85^{o}C any increasing in current or in LED's power causing increasing in LED's Flux.

But what will happen if the junction temperature changes with current increasing. In this situation the junction temperature will increase and it may overtake 85^{o}C causing decreasing in LED's flux as it is clear in **figure (10).**

The mass of heat sinkand the total cost are shown in **figures (11)** and **(12)** respectively. The mass of heat sinks are identical for all LED's types because the power for all these LEDs are alike or equal. But the suitable heat sinkweight for each LED is cleared in the figure. Also the total costs that include the LED cost are shown in figure(12) and the difference is clear according to LED type that is used with heat sink.

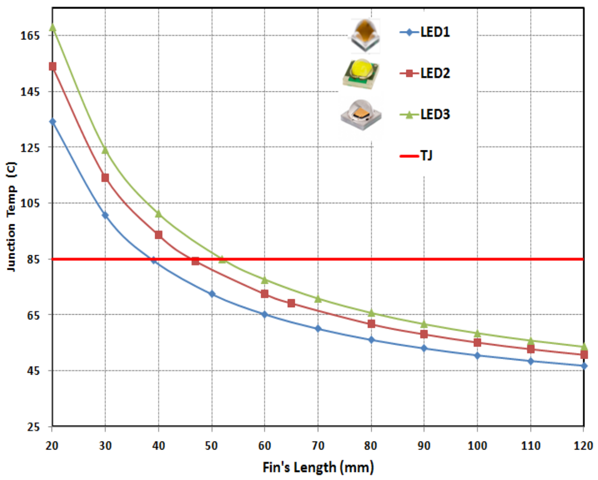


Figure-2 Fin's length for Heatsink with junction temperature for each LED

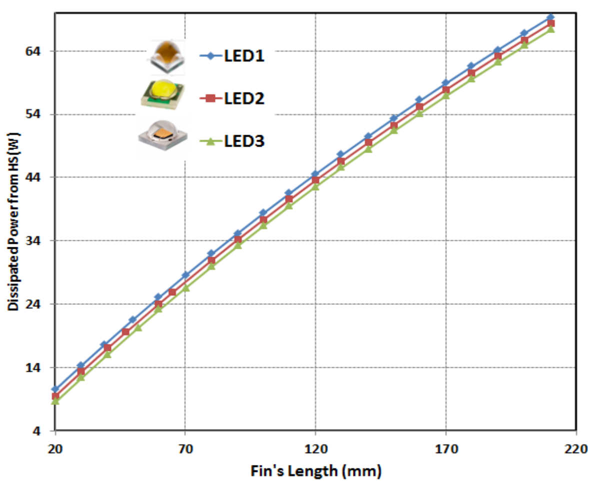


Figure-3 Fin's length for Heatsink with power dissipated from heatsink of each LED

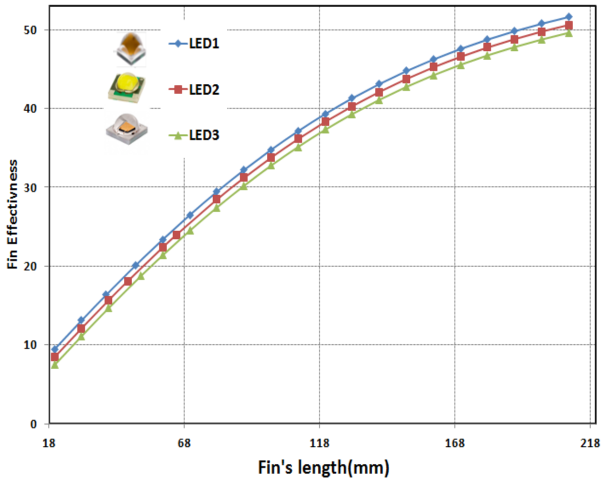


Figure-4 Fin's length for Heatsink vs fin's effectivness of each LED

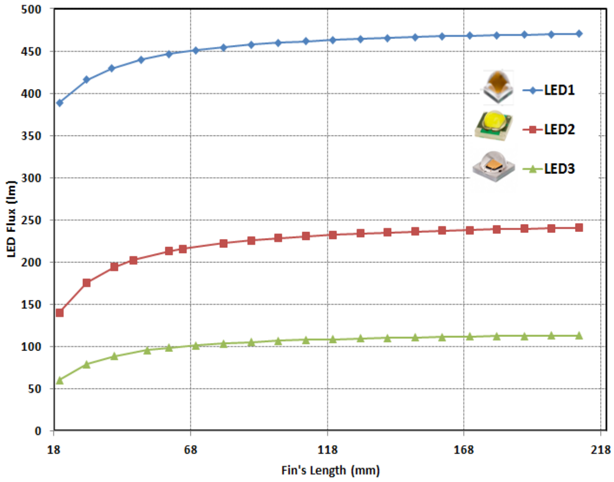


Figure-5 Fin's length for Heatsink fin's vs LED's Flux in(lm)

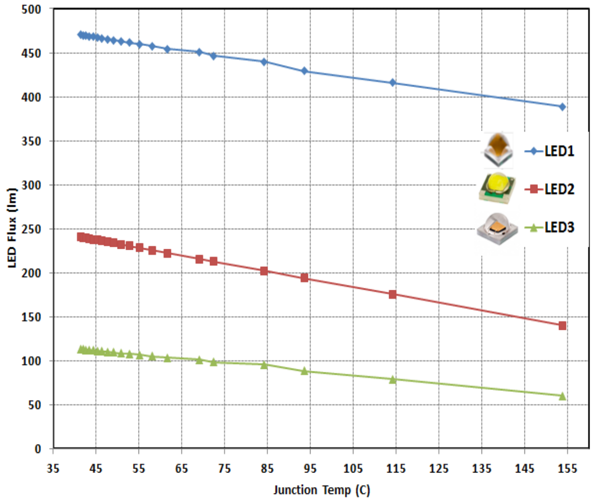


Figure-6 Junction temperature vs LED Flux for each LED

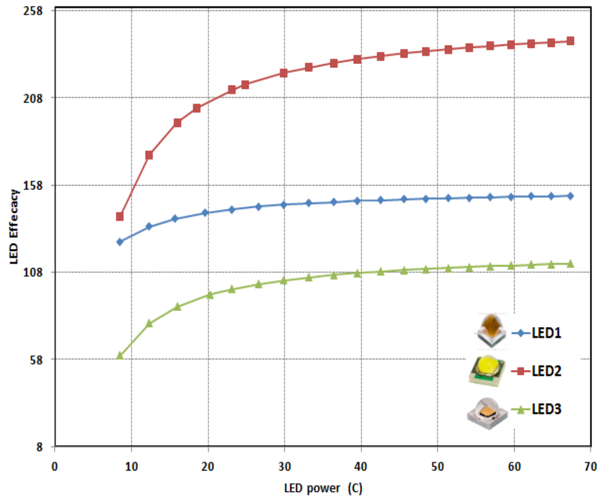


Figure-7 LED power vs LED Efficacy for each LED

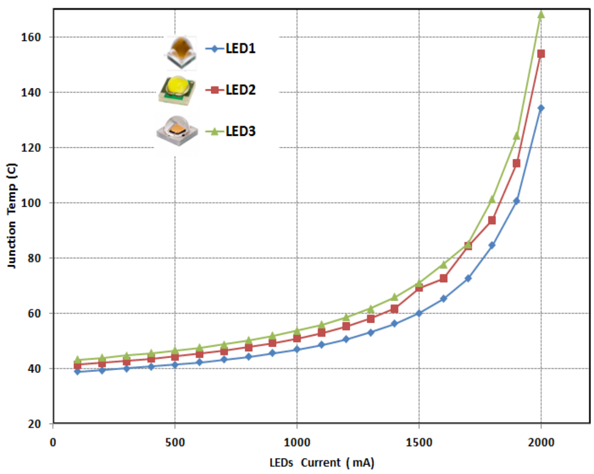


Figure-8 LED's current with junction temperature for each type of LED

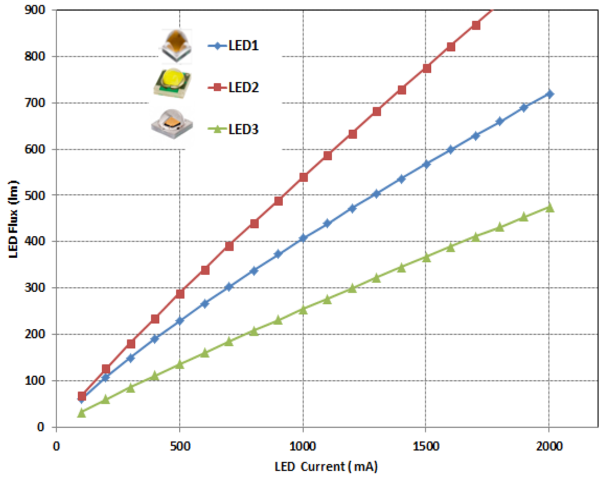


Figure-9 LED's current with LED's flux at constant Junction temperature and changing in electrical current for each type of LED

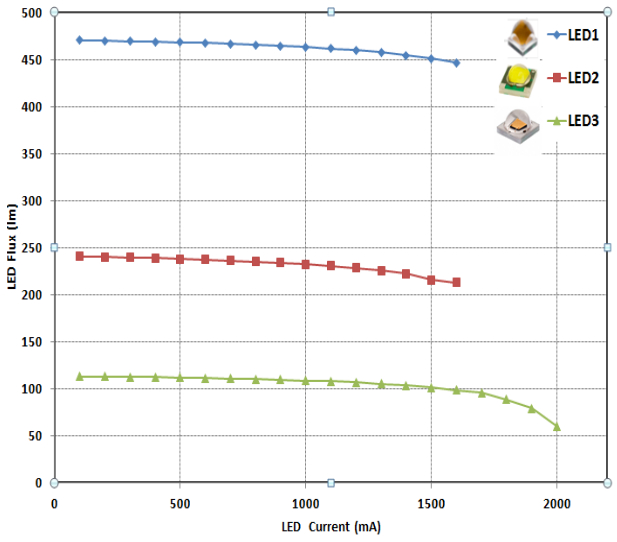


Figure-10 LED's current with LED's flux when Junction Temperarure changes with electrical current for each type of LED

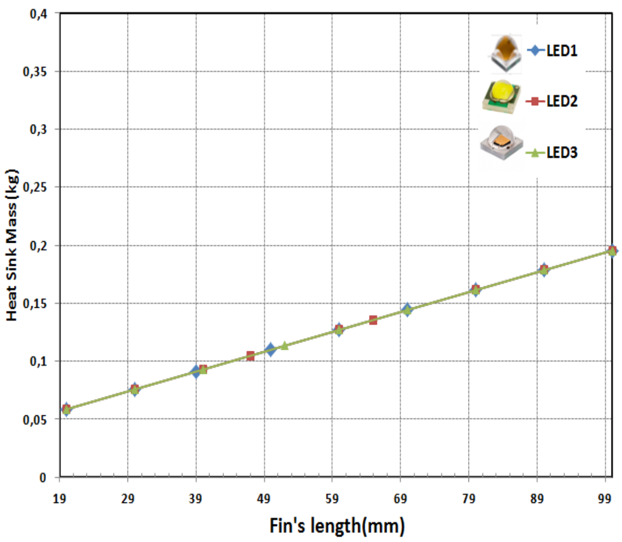


Figure-11 Heat sink mass in kg with its hieght .

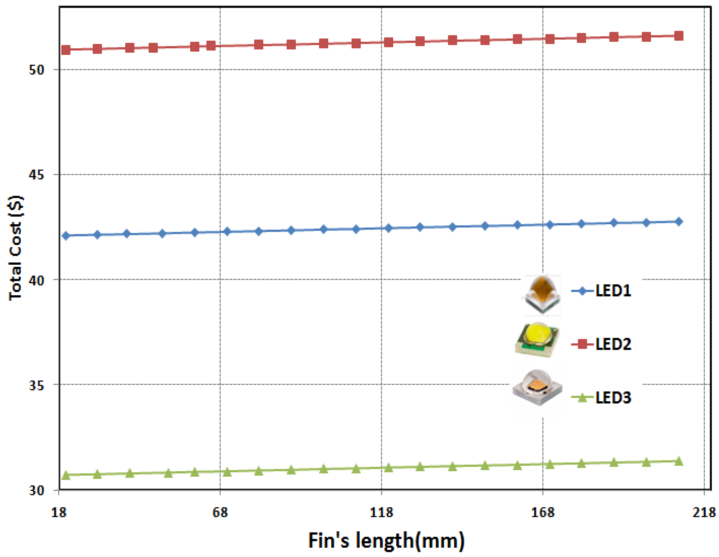


Figure-12 Total cost with fin's length

IV. NUMERICAL SOLUTON

ANSYS, ICEPAK 14.5used in this study[10-15]. The simulation results are compared with the theoretical heat sink temperatures in order to verify that the simulations are representing the conditions of the theoretical state. İn this study, three types of heat sink are designed in order to dissipate the amount of heat from the lighting emitted diode.Table (2) shows the heat sinkdimensions. Figures (13) shows the numerical results for varios LEDs.The maximum junction tempearture are84^{o}C ,84.4^{o}C and 84.7^{o}C For the LED type 1, LED type 2 and LED type 3, respectively . The mesh properties for each model explained in the table (3).

Table-3 Mesh values for each models

No.	LED type	Element Number	Node Number
1	LED1	256912	268637
2	LED2	326269	339536
3	LED3	363578	377610

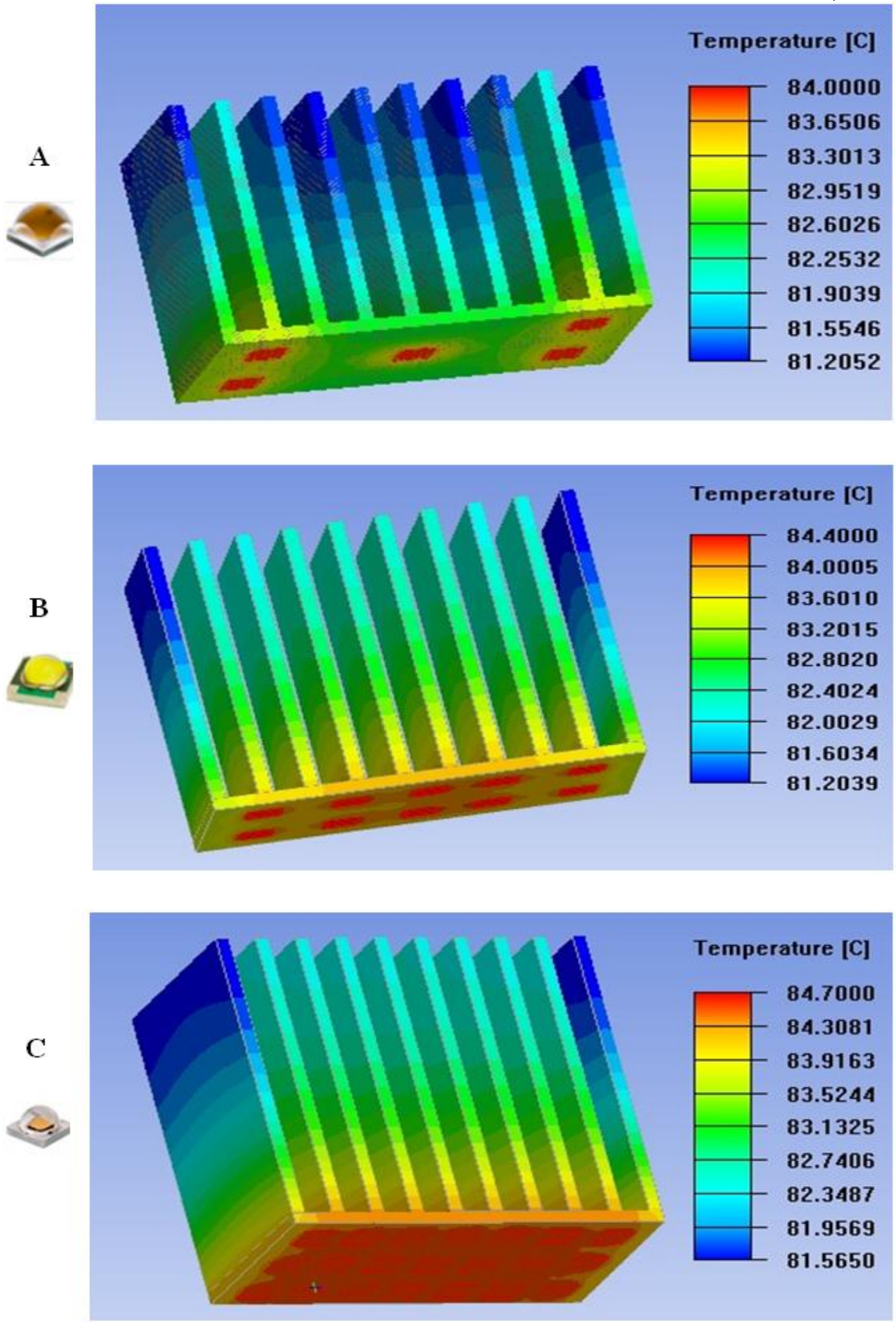


Figure (13) Temperature contour of heat sink for each LEDS. (A)LED1. (B) LED2 and (C)LED3

REFERENCE

[1] Billerica, MA, Thermal Management of Big Chip LEDs, Luminus Devices, Inc. • T 978.528.8000 • www.luminus.com.,2013.

[2] Arik,M, Thermal Management of LEDs: Package to System, Third International Conference on Solid State Lighting, edited by Ian T. Ferguson,Nadarajah Narendran, Steven P. Den Baars, John C. Carrano, Proc. of SPIE Vol. 5187(SPIE, Bellingham, WA, 2004).

[3] Sandy.K,thermal management materials for PcBs used in LED lighting systems, American standard circuits,Inc.2003.

[4] Nan.J,novel approaches to thermal management for power led packaging, ıssue 32 2012 © 2012 luger research e.u.

[5] Led packagıng for lıghtıng applıcatıons desıgn, manufacturıng and testıng sheng liu this edition first published 2011.

[6] Cree® XLamp LED,Thermal Management. -http://www.cree.com/xlamp
[7] http://en.wikipedia.org/wiki/Thermal_management_of_high-power leds
[8] Heat and mass transfer, Cengel.
[9] http://en.wikipedia.org/wiki/Heat_sink
[10] Arik, M, Petroski, J., and Weaver, S., "Thermal Challenges in the future generation solid-state lighting applications: Light Emitting Diodes", Pro. of the ASME/IEEE ITHERM-Conference, San Diego, 2002.
[11] Arik, M., Weaver, S., Becker, C., Hsing, M. and Srivastava, A, "Effects of Localized Heat Generations Due to The Color Conversion in Phosphor Particles and Layers of High Brightness Light Emitting Diodes",ASME/IEEE International Electronic Packaging Technical Conference and Exhibition - InterPACK'03, July 6-11, 2003, Hawaii, USA.
[12] Kraus, A.D., and Bar-Cohen, A., "Thermal Analysis and Control of Electronic Equipment", University of Minnesota Press, Minneapolis, MN, 1996.
[13] Holonyak, N. "John Bardeen and the Point-Contact Transistor", Physics Today, April 1992.
[14] Kraus, A. and Bar-Cohen, A., Design and Analysis of Heat Sinks, Wiley and Sons, NY, 1995.
[15] Lumileds, www.lumileds.com, 2003.
