Journal of Electronics and Information Science (2019) 4: 8-16
Clausius Scientific Press, Canada
DOI: 10.23977/jeis.2019.41012
ISSN 2371-9524

Novel Thermal Solution for Low Profile 1U Horizontal Box with Passive Cooling

Lian-Tuu Yeh, ASME Fellow

Dallas, Texas, USA
jjyeh2@aol.com

Keywords: Low profile; Novel thermal solution; 1U horizontal box; Passive cooling

Abstract: The 1U (1.75” thick) horizontal box under the natural convection is typically applied to the low power systems in the past. With increasing speeds and functionalities, the system power for a 1U box has been increased significantly in the recent years. Because of the increasing demands on the system performance and reliability, the thermal design is also becoming even more critical and important. A novel design concept is developed for the 1U horizontal box. The key technologies of this concept are (a) openings (holes) for ambient air flowing through the internal of the box and (b) large common heat sinks (each heat sink serving a group of components). The extended fins of heat sinks over the holes are cooled directly by the ambient air flowing through the openings (holes) of the box. This cooling scheme significantly reduces the length of thermal paths from the components to the ambient. Another feature of this novel design concept is divided the box into two upper and lower sections as presented in order to increase the system capacity and also to meet various types of system configurations. This innovative design concept enables to support the system power up to 75 watts with the ambient at 55 °C.

1. Introduction

Heat transfer by natural (or free) convection has long been considered as one of the most cost effective and reliable cooling methods. Natural convection with air has many practical engineering applications and is of special interest to the cooling of electronic equipment. The advantages of air cooling by natural convection are simple, reliable and cost effective.

The overall dimensions of a typical 1U box are 17.5” (444.5 mm) (width) x 1.75” (44.5 mm) (thickness) with the depth ranging from 8.67” to 10” (220 mm to 254 mm). Though the box can be placed on a table, however, the box is typically installed into an open telecommunication rack as illustrated in Figure 1. The ambient temperature is assumed to be at 55 °C and at the sea level conditions.

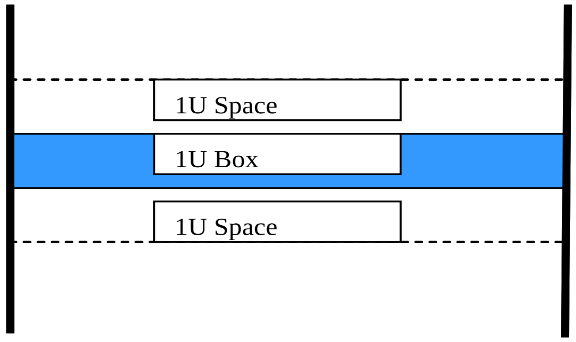


Figure 1 1U box in Telecommunication Rack

The survey of the current market status for the 1U horizontal box in telecommunication industry listed in Table 1 indicates that the system power is typically around 50 Watts

Table 1 Various Products of 1U box in Current Market

Products	Overall Dimensions (W x D x H) (mm)	Power (Watts)	Power Density (W/L)	Ambient (°C)
Ericsson Mini-Link HC	483 x 280 x 44.45	45.0	7.49	-20 to 60
NEC Pasolink	482 x 240 x 44.45	47.0	9.14	-5 to 50
Fujitsu Flashwave 4020	444.5 x 228.6 x 44.45	43.5	9.63	0 to 50
Huawei RBN GigaEdge 8200	482.6 x 304.8 x 44.45	60.0	9.17	-40 to 65
Huawei RTN610	442 x 215x 44.45	57.0	13.50	-0 to 55

Most of products mentioned in the above table are in a sealed box environment with a few exceptions which have some venting holes on the top surface of the box. Therefore, heat generated by components is first transferred to the all surface of the box and heat is then dumped to the outside ambient by natural convection and radiation. The radiation heat transfer must always include in the case of natural convection.

2. System Description

A novel design concept as illustrated in Figure 2 is developed for the 1U horizontal box. The key technologies of this concept are (a) openings (holes) for ambient air flowing through the internal of the box and (b) large common heat sinks (each heat sink serving a group of components). The extended fins of heat sinks over the holes are cooled directly by the ambient air flowing through the openings (holes) of the box. This cooling scheme significantly reduces the thermal paths from the components to the ambient.

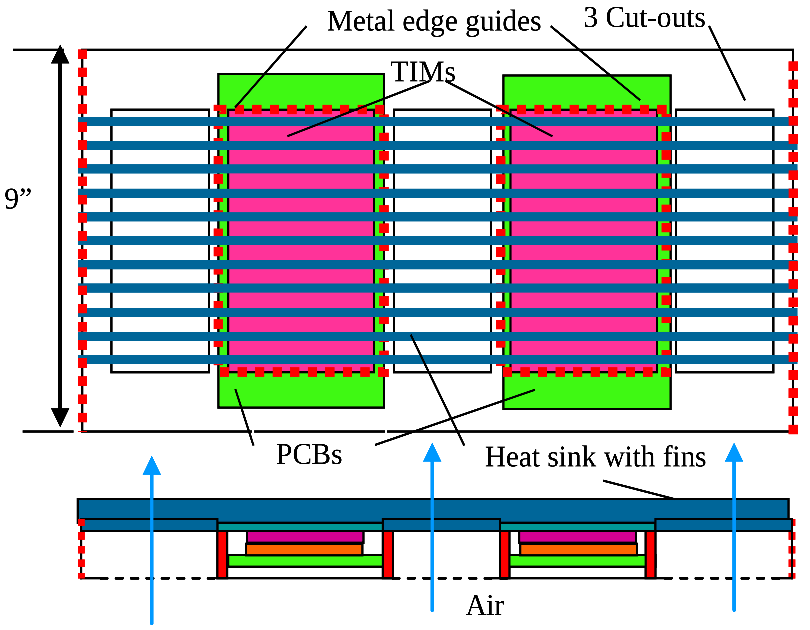
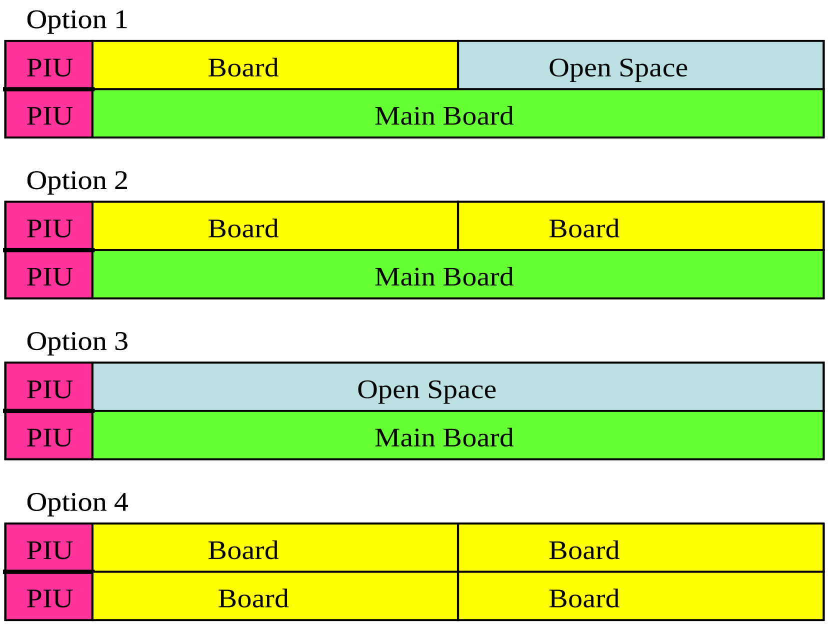


Figure 2 Novel Design concept of 1U Box

Another feature of this novel design concept is divided the box into two upper and lower sections in order to increase the system capacity and also to meet various types of system configurations. Figure 3 shows four different system configurations inside the box are under consideration the cross section view of Option 4 is given in Figure 4.



Option 1

PIU	Board	Open Space
PIU	Main Board	

Option 2

PIU	Board	Board
PIU	Main Board	

Option 3

PIU	Open Space
PIU	Main Board

Option 4

PIU	Board	Board
PIU	Board	Board

Figure 3 Various System Configurations

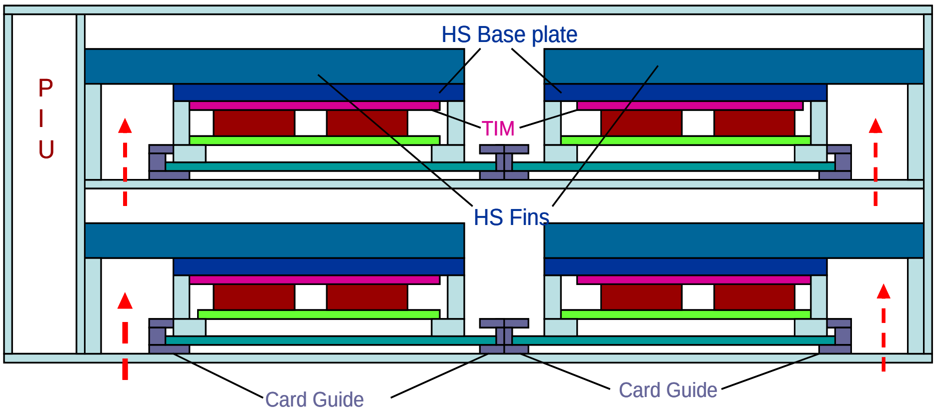


Figure 4 Cross Section View of Option 4 Configuration

The large heat sink is supported by the metal (aluminum) structures along the edges of the printed circuit board and at the same time, the end of fins is also supported by additional structures as shown in Figure 4. The components on the board are enclosed by the metal structures along the edges of the board and the heat sink base. Therefore, the metal structures provide not only the structural supports to the heat sink but also the electric magnetic insulation (EMI) protection to all components on the board as illustrated in Figures 2 and 4. The entire assembly given in Figure 4 is referred to as the board assembly that includes the heat sink, the thermal interface material (TIM) and the board. The base plate which supports the assembly is attached to the faceplate. This special feature of the design makes the board assembly easily be removed or plugged in. In other words, the board can be moved in and out, and it an also be replaced in the field.

Another special feature of this design is to apply the large heat sink and the single TIM over the group of active components on the board. This approach greatly simplifies manufacturing process. Conventionally, the individual small heat sinks along with the small pieces of the TIM are mounted to the individual components as needed.

3. Thermal Analysis

The ultimate goal of the thermal design is to maintain the temperatures of all electronics below the respective temperature limits in order to achieve the desired system reliability and performance. This innovative design concept is to utilize the large heat sinks to transfer heat generated from the components to the ambient air streams directly entering from two air holes at the bottom. The hot air is then exited through the air holes at the top plates of the box. Some of the heat generated by the components heat up the top and the bottom plates of the box. The heat is then transferred to the ambient through the box surfaces by the natural convection and radiation. The radiation must always be included in the case of the natural convection environments. To enhance the radiation heat transfer, a high emissivity coating/paint is applied to the internal and external surfaces of the box. The anodized aluminum with the emissivity of 0.81 is adopted in the present design.

The component temperature limits which are also the thermal design limits are presented as follows:

a) The junction temperature of the FPGA, Tj, is 100 °C for the industry grade part
b) The junction temperature for other microelectronics, Tj is 125 °C for the industry grade parts
c) The case temperature of SFP, Tc is 85 °C (industry grade part)
d) Internal air temperature, Tair is 85 °C in most of locations, especially in the location near the oscillators.

e) The thermal resistances for the junction to case, ɵj-c and the junction to board, ɵj-b are 3.1 and 8.0 °C/W, respectively.

In addition, the following assumptions are made to facilitate the thermal analysis

a) The box is suspended in an open air space
b) The ambient air is at 55 °C and at the sea level condition
c) The box is limited to passive cooling with natural convection and radiation
d) The box is made from anodized aluminum with emissivity of 0.81

Item (a) actually implies that effects from other equipment above and below the current system under consideration are small and can be omitted. This may not be always true in the actual installation.

The analysis has been performed on various configurations with aids of Flotherm software (1). It will be not possible to include the results from all cases analyzed in the report. The basic physical dimensions of parts inside the box are shown in Figure 5. The small boards if existed are in the upper section of the box.

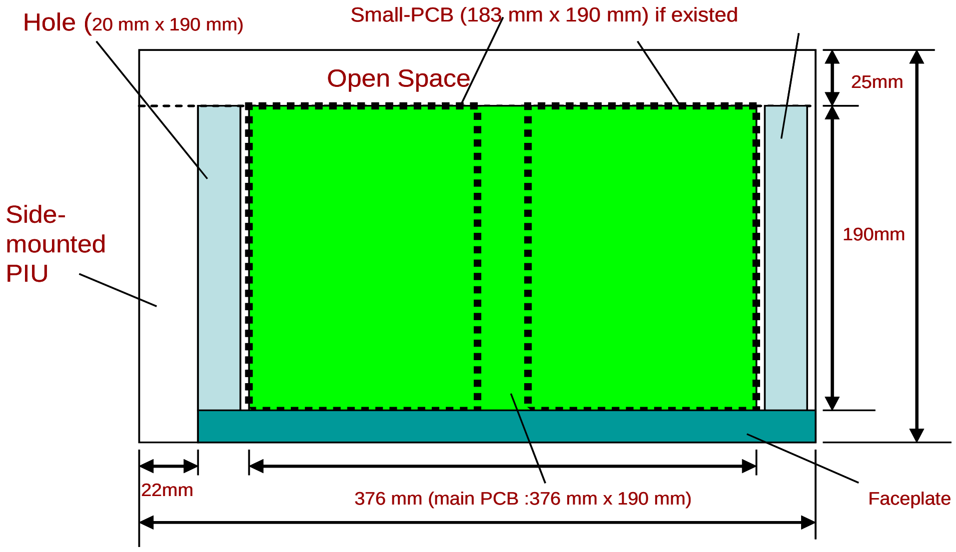


Figure 5 Box Internal Layout

The CFD thermal analysis is performed on Option 1 configuration which includes one main board (58.13W) in the lower section and one small board (16W) in the left side of the upper section of the box. The total system power is 74.13 watts. Various heat sinks in the lower section are shown in Figure 6. The components under the respective heat sinks are also listed in the figure. The heat sink for the small board in the upper section is shown in Figure 7

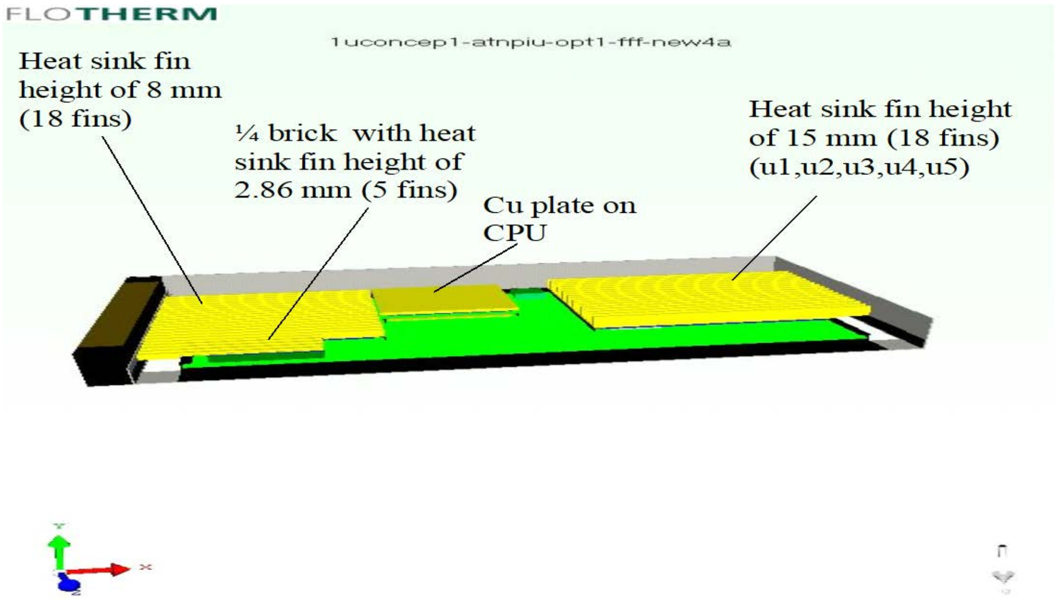


Figure 6 Various Heat Sinks on Main Board (Lower Section) of Box

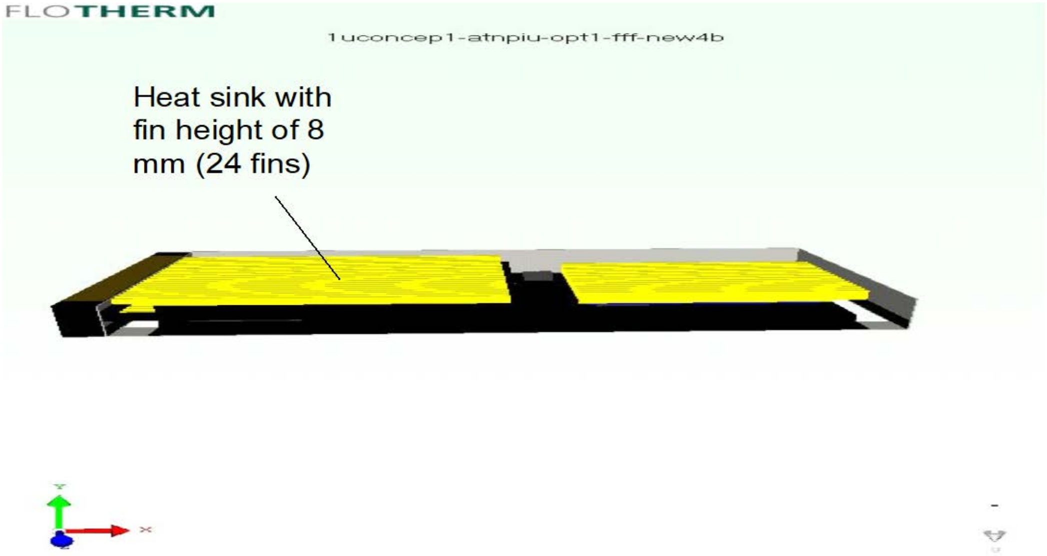


Figure 7 Heat sink for Small Board in Upper Section

4. Results and Discussion

The velocity over the box is given in Figure 8 and the box top surface temperature is presented in Figure 9. The component temperatures for the main board are presented in Figure 10. This figure also includes the power of the individual components. Similarly, the component temperatures for the small board are given in Figure 11. As given in Figures 10 and 11, all components have met the respective temperature limits. It should be noted that the open space in the rear of the box has little impact on the temperature inside the box. Therefore, the box depth actually can be reduced to 220 mm.

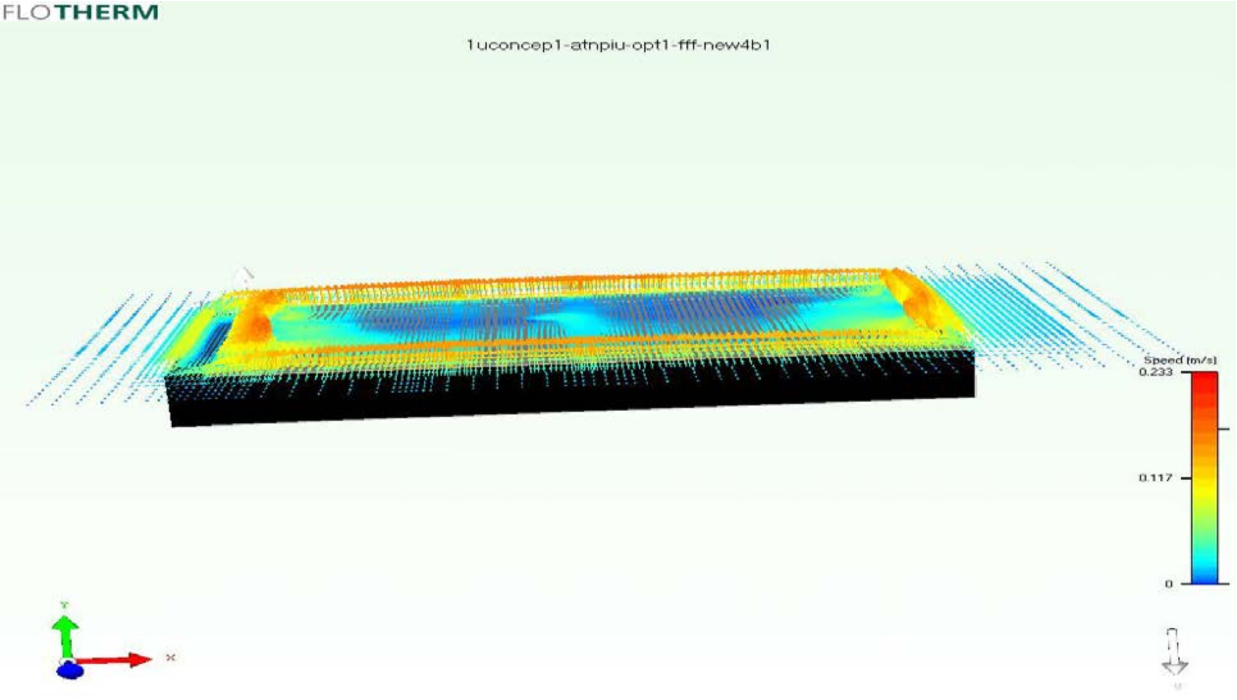


Figure 8 Velocity Profile over Box

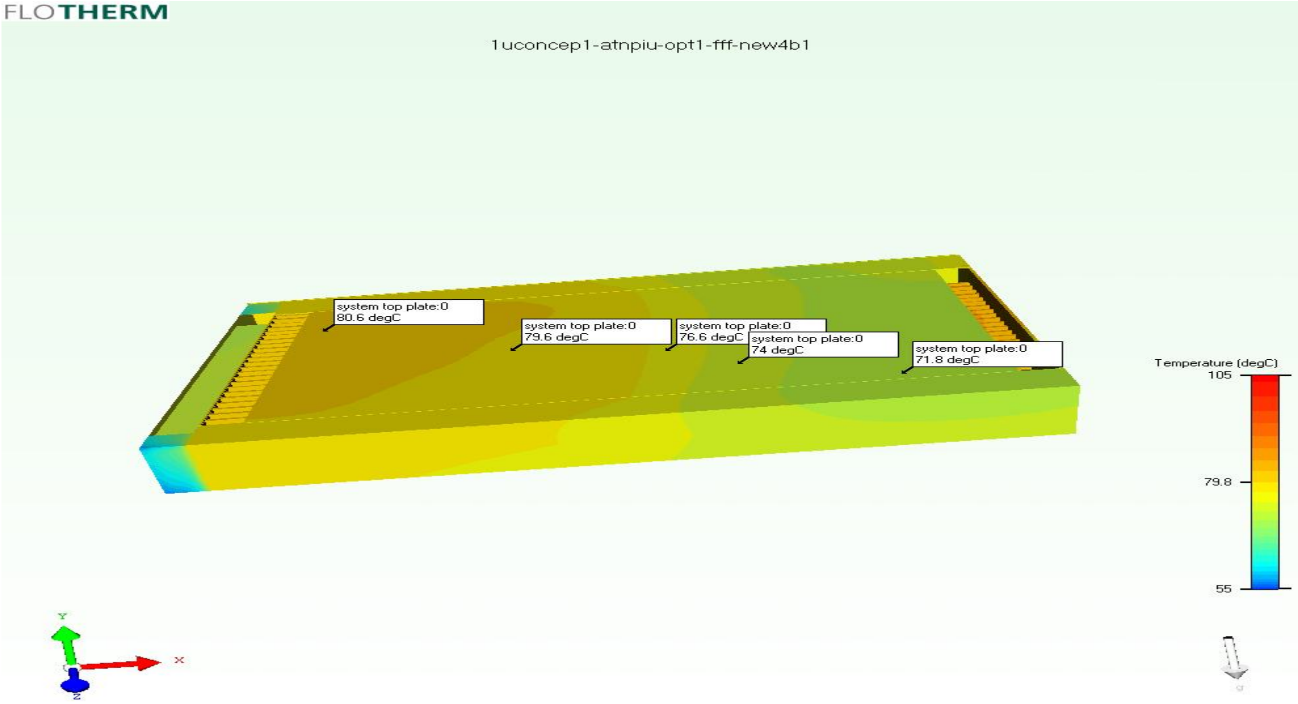


Figure 9 Temperature Distribution over Top Surface of Box

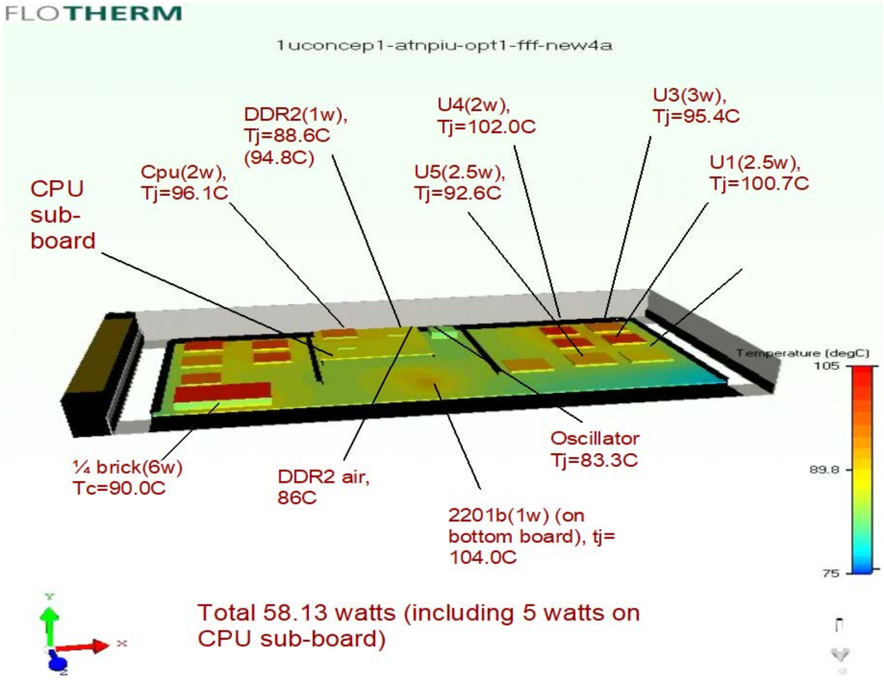


Figure 10 Component Temperatures on Main Board

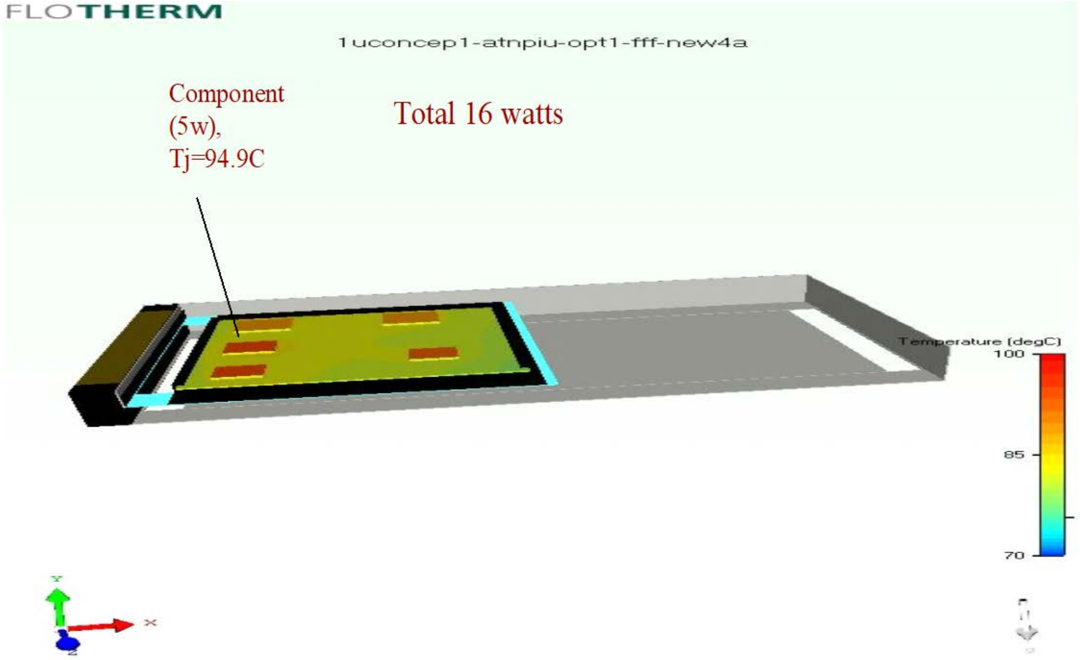


Figure 11 Component Temperatures on Sub Board

5. Summary and Conclusion

The overall thermal design goal is to utilize the passive cooling schemes in support of the 1U horizontal box with the system power greater than 60 watts and also to make the boards moveable. To achieve the goal, an innovative thermal design concept with the following special features is developed.

a) Ambient air flows through internal box though holes at various locations

b) The design is based on board assembly that includes the printed circuit board (PCB) and the associated the heat sink and the thermal interface materials (TIM).
c) The assembly is mounted to the base plate which is attached to the fact plate with the ejectors so the assembly can be removed or plugged in as needed.
d) All electronic components on the board are enclosed by the metal structures that provide the supports to the heat sinks as well as the electrical and magnetic insulation (EMI) protection.
e) A single large TIM is applied to a group of electronics in order to simplify assembly and manufacture processes. Generally, one heat sink requires one piece of the TIM.

In conclusion, the present thermal results have demonstrated that the proposed technology enables to support the system power of 75W which is far exceeding the any 1U box currently available in the market The maximum sustainable system power depends on the types of components on the board as well as the power of the individual components.

References

[1] Flotherm software by Mentor Graphics.
[2] Thermal Management of Microelectronic Equipment, Lian-Tuu Yeh and Richard C Chu, ASME Press, New York, NY, 2002