International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-3, Issue-3, March 2015

Thermal Design And Analysis Of HSDB System

Uma ravindra M, Rajendran P, Laxminarayana P

Abstract— **Thermal management of high power dissipation PCB plays a vital role in design and development of electronic systems for military applications. This paper describes about the enhancement of conduction heat transfer for high power electronics components placed on multilayer PCB of High Speed Digital Board** (HSDB) **system. It further makes clear about the location of components, establishment of low thermal resistance path, importance of vias and copper deposition on conductive layers of the PCB.** HSDB **comprises of different components such as FPGAs (U1, U2), ADCs (U3, U4) and memory modules (U8-U17) are varying power levels from 0.33W to 19W. Different components have their own temperature limitations based on material construction, layout and type of packaging characteristics.**

Thermal analysis is carried out with 50% of copper deposition in the PCB layers using Electronics cooling software "FloTHERM". Results indicated that introduction of thermal enhanced conductive path along with location of critical components at the edges of the board gives better thermal performance.

Index Terms—**Conduction heat transfer, Thermal analysis and Thermal ladder**

I. INTRODUCTION

HSDB is used to perform analysis, accurate parameter measurement, classification, identification and determination of technical parameters of different types of radars. HSDB system as is designed to monitor RF emissions from the earth.

This system is developed as independent entity that contains multi layer PCB with different types of components. Active components consume more power and needs thermal attention for safe operation of the system.

HSDB system comprises of different ICs function at varying power levels populated on PCB. The PCB in-turn fixed in the protective housing that has provision for connectarization for data transfer with other module of the pay load. The total power consumed by those electronics components get dissipated into heat in the absence of RF power [2].

In order to operate the electronics for its intended performance and reliability, thermal management plays a crucial role. Thermal management of high power dissipation PCB is a vital and challenging aspect for thermal engineers [3]. As the PCBs dissipate the heat non-uniformly for entire its volume; it is a tough task to find the way for getting rid of the generated heat. Different components have their own temperature limitations based on material of construction, layout and packaging characteristics.

II. DESIGN INPUTS

HSDB system is a rectangular box made of AA6351-T6 having dimensions of 364 mm (length) x 200mm (width) x 30 mm (height) as shown in Fig.1. It has 14 layers PCB of 233.4 mm x 160 mm x 2.4 mm and 0.5 ounce of copper deposition with 50 percent coverage in each layer.

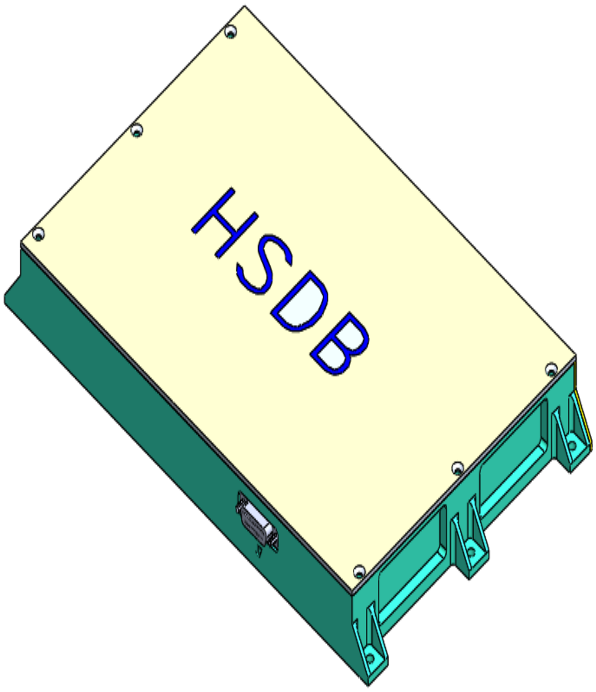

Fig.1. Isometric view of the HSDB system

The PCB is populated with different type of components such as dip packages like ADCs (U3,U4), surface mount packages like FPGAs (U1,U2) and Memory modules (U8-U17) and their nomenclatures from U1 to U28 attributing to 60W heat dissipation as shown in Table 1.

All heat dissipating electronic components are mounted on the both sides of PCB as shown in Fig.2 and Fig.3. Most critical components are placed on bottom side of the PCB. HSDB system will be mounted on surface panel of Antenna Head Unit (AHU)

Manuscript received March 09, 2015.
Uma Ravindra Maddipati, Defence Electronics Resarch Lab, Hyderabad, India, +919490969059.

Rajendran P, Defence Electronics Resarch Lab, Hyderabad, India, +919440884756.

Laxminarayana P, Department of Mechanical Engineering, UCE, Osmania University, Hyderabad, India, +914027071759.

Table 1. Component wise dimensions and power values

S.No	Power (W)	Theta JB	Theta JC	T_J (^{0}C)	T_C (^{0}C)	Package
U1	17.6	2.21	0.1	125	-	CF1752 Ceramic Flip Chip CGA
U2	19.0	2.21	0.1	125	-	CF1752 Ceramic Flip Chip CGA
U3	0.858	34.6	0.85	150	-	52 pin ceramic QFP
U4	4.37	3.2	0.5	-	125	376 ceramic CGA
U5	1.49	66.5	63.8	150	-	8 Lead Plastic Small-outline Package
U6	0.33	51.2	12.5	-	85	SOP-54
U7	0.33	18.7	10	150	-	48 Lead Flat Pack
U8 TO U17	0.53	51.2	12.5	85	-	74 pin SOP
U18	0.18	-	-	-	130	8-Lead Dual Flat Pack
U19	1.7	-	12	150	-	36-Lead Flat Pack
U20	3	-	7.6	150	-	78-Pin Ceramic Flat Pack
U21	0.33	51.2	12.5	-	85	SOP-54
U22	0.5	-	19	150	-	DIP
U23	0.7	1.5	-	150	-	CQFP
U24	0.7	1.5	-	150	-	CQFP
U25	0.6	1.5	-	150	-	CQFP
U26	0.33	1.5	-	150	-	CQFP
U27	1.3	1.5	-	150	-	CQFP
U28	1.38	51.2	4	175	-	CDFP

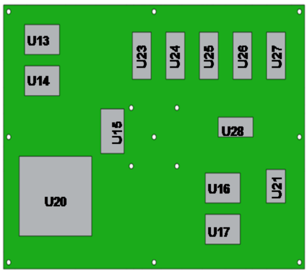

Fig.2. Top side Components

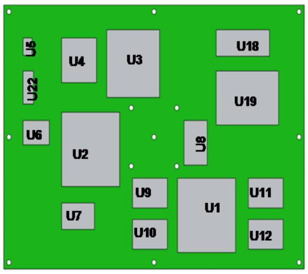

Fig.3. Bottom sides Components

III. THERMAL DESIGN

HSDB system consists of metallic housing, 14 layers PCB with components and connectors. Each layer of PCB made of 0.7 Mil thicknesses with 50% copper coverage on it. Thermal design is done in such a way that all the low thermal resistance from junction to case (theta JC) components are having contact with metallic body, edges of PCB is gold plated and made to place on 8mm width of side walls of housing then fixed the PCB by thermal screws at 17 different locations including 5 projected column of housing. This thermal design arrangement is shown in Fig.4.

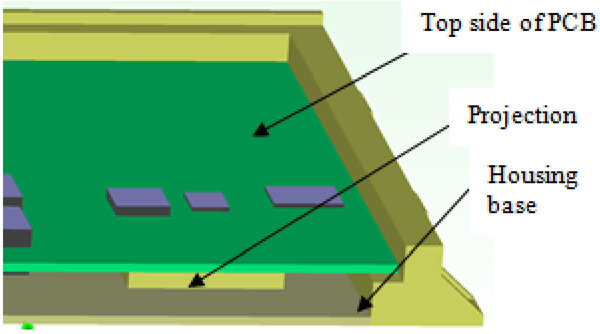

Fig.4. Projections on base of housing

Most of the components placed on PCB are low theta JC which are having physical contact with housing, all high mass components are placed at edges of the PCB and it is enclosed in a small volume which reduces convection heat transfer. Radiation heat transfer generally dominates at elevated temperatures. Hence, conduction heat transfer is predominating by nature, which will transfer the heat from component to housing. A proper thermal path/ ladder are ensured for low theta JC components and its heat flow path is shown in Fig.5.

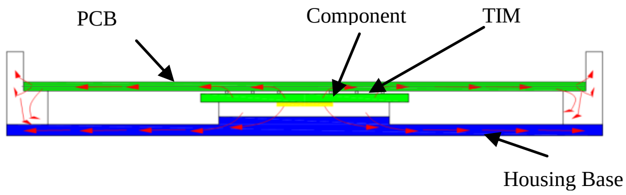

Fig.5. Low theta JC Components heat path

For other electronics components heat travels from components through copper layers to edges of board. In this regard, more copper conducting layers are preferred for transmitting of generated heat energy from components to the housing via edges of the board. Solder and copper greatly enhance thermal performance of the FR4. Multiple vias under are provided under high heat flux components to reduce hot spots on the PCB. The heat flow path of high theta JC component is shown in Fig.6.

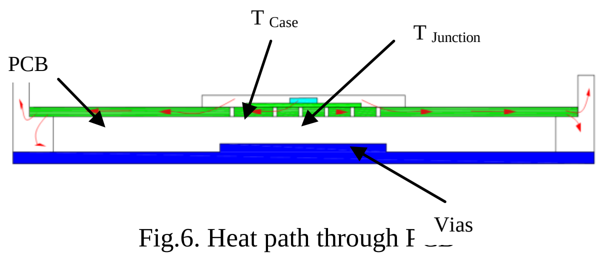

Fig.6. Heat path through F

Cho-Therm 1671 is used as Thermal Interface Material

(TIM) between two contact interfaces of critical PCB components and housing. CHO-THERM 1671 insulators are silicone elastomers, precisely filled with a controlled dispersion of boron nitride particles to provide superior thermal and electrical performance characteristics. The thermal interface impedance of an interface depends greatly on a number of different parameters, including the flatness and smoothness of the mating surfaces forming the interface and the contact pressure between them, as well as thickness of the interface material, its thermal conductivity and conformability [4]. PCB components such as U1, U2, U3, U4 and U19 are having contact with the housing of the HSDB system. It is assumed in the analysis that board having perfect contact on 4 sides with the housing.

IV. NUMERICAL ANALYSIS

A temperature boundary condition of 40^0 C is applied to the surface panel of AHU. The constituent materials of HSDB with its properties are listed in Table 2; these properties are considered for FloTHERM thermal analysis.

Table 2. Material Used and their Properties

Part Name	Material		Density (m3/kg)	Thermal cond. (W/ mK)	Specific Heat (J/ Kg K)
Housing	AA 6351-T6		2800	180	963
Closing Cover	AA 6351-T6		2800	180	963
PCB	Di-electric	FR-4	1200	0.3	880
	Conductor	Cu.	8930	385	385
				In-Plane	Normal
				20	0.3
TIM	Cho-Therm 1671		1550	2.6	

Two-Resistance Model is used for modeling PCB components in which theta JC and theta JB values are used. Theta JB value for the few components are not available in the data sheets, hence high theta JB resistance value of 51.2°C/W is considered in the thermal analysis. The thermal impedance (R surf-solid) of 0.230C-in^2/W (0.00041 K-m^2/W) is applied between the surface of the components and housing. Conduction and radiation modes of heat transfer are considered with ambient temperature of 40°C. Emissivity of all the surfaces of the sub-system is considered as 0.9.

V. NUMERICAL ANALYSIS RESULTS

Over all sub-system temperature contours are shown in Fig. 7. The estimation of steady state temperature distribution by numerical simulation using the software FloTHERM 10.0 is shown in Fig.8 and Fig.9 for the top side of PCB and bottom side of PCB respectively. U20 is attaining maximum temperature of 75.6°C at its junction. High heat dissipation components such as U1 and U2 are lesser than their junction temperature limitation due to its low junction to case thermal resistance Component wise maximum temperatures against its limit are presented in Table 3.

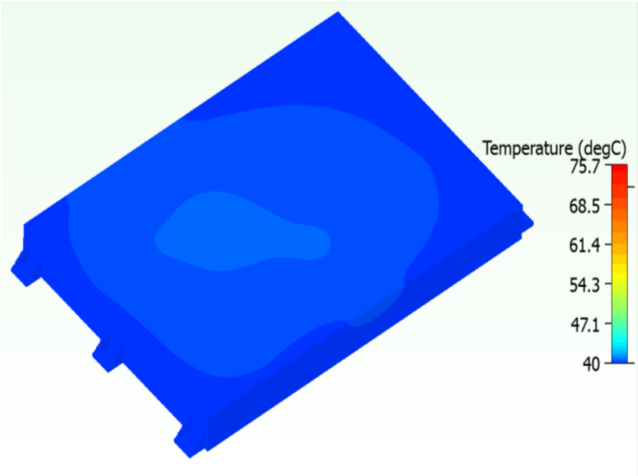

Fig.7. Temperature distribution on HSDB system

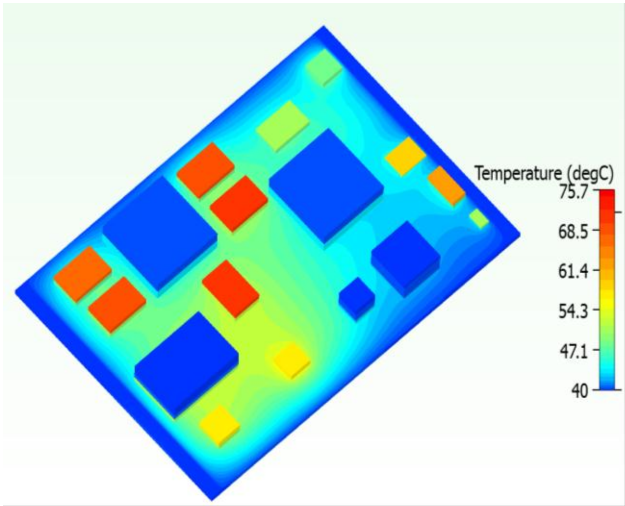

Fig.8. Temperature distributions on the bottom side of PCB

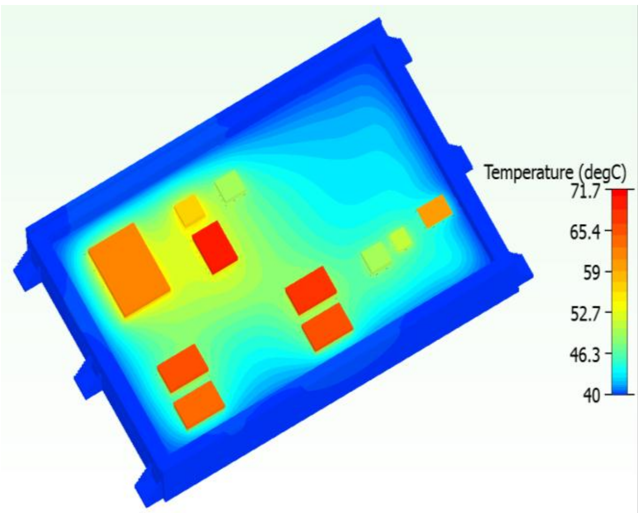

Fig.9. Temperature distributions on the top side of PCB

Table3. Maximum temperature values of components

S.No	Power (W)	T_J allowable (^0C)	T_C allowable (^0C)	Max. Temp. attained (^0C)
U1	17.6	150	-	41.96
U2	19.0	150	-	42.10
U3	0.85	150	125	42.84
U4	4.37		125	42.51
U5	1.49	150	-	50.93
U6	0.33	-	85	59.22
U7	0.33	150	-	51.86
U8 to U17	0.53	85	-	66.46 to 73.32
U18	0.18	-	130	57.63
U19	1.7	150	-	58.89
U20	3	150	-	75.65
U21	0.33	-	85	59.91
U22	0.5	150	-	64.46
U23	0.7	150	-	58.06
U24	0.7	150	-	49.31
U25	0.6	150	-	57.75
U26	0.33	150	-	50.56
U27	1.3	150	-	49.50
U28	1.38	175	-	51.68

VI. CONCLUSIONS

Thermal design and simulation of HSDB system with its PCB components is carried out and observed all components temperature value is less than 85°C. Results shows that effect of thermal ladder of low theta JC components such as U1, U2, U3, U4 and U19 are having contact through TIM with the housing and effect of location, thermal screws for high theta JC components such as U23 to U28 are having heat path through the PCB of the HSDB system. Hence, proper thermal vias are placed underneath of the IC in the PCB enhanced the conductive heat transfer and reduced the hot spots on the PCB. As the more amount of the copper percentage deposition, higher heat transfer rates are possible through PCB to housing. Hence, it is recommended to use more than six ounce of copper for better heat transfer and safety of the components.

NOMENCLATURE

T temperature ^oC
Theta JB thermal resistance junction to board $^oC/W$
Theta JC thermal resistance junction to case $^oC/W$

Subscripts
J junction
C case

ACKNOWLEDGMENT

Authors are thankful to Dr. C.G Balaji, Outstanding Scientist, and Director, DLRL for providing opportunity and giving acceptance to publish the paper. Authors are grateful to Shri C.V.H.Prasad, Scientist ‘F’ and Dr. Lachiram, Scientist ‘F’ for their constant support.

REFERENCES

[1] Avram Bar-cohen, Allan D. Kraus, "Advances in thermal modeling of electronic components and systems", volume 3, pp 94-101, ASME press, New York, 1993.

[2] Jerry E. Sergent, "Thermal Management Hand Book for electronic assemblies", chapter 2, McGraw-Hill, New Delhi, 1998

[3] Bo Chen,“Thermal Design and analysis of a satellite borne electronics PCB" Advanced Materials Research Vols 199-200 (2011) pp 1551-1554.

[4]Yunus. A. Cengel, "Heat Transfer"; A practical approach, 2nd edition, Tata McGraw-Hill Publishing Company limited, chapter 3, pp138-141.