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Free convective heat transfer for the wire-bonded and low powered QFN64b electronic device☆

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ABSTRACT

The aim of this study is to quantify the natural convective heat transfer concerning the wire-bonded version of the Quad flat non-lead with 64 leads denoted as QFN64b. This active package generates during operation low powers corresponding to the partial operation of the electronic equipments. In this power range, the thermal state of such device is entirely different from that of the higher power conditions corresponding to normal operation. To size the low-powered QFN64b component while increasing its reliability, it is necessary to know the natural convective heat transfer coefficient. This is the main objective of the present survey which presents the details of this parameter in five specific areas of the assembly constituted by a Printed Circuit Board (PCB) on which is welded the active package. It generates a power varying between 0.01 W and 0.1 W by steps of 0.01 W and it may be inclined with respect to horizontal plane by an angle ranging from 0 to 90° corresponding to the horizontal and vertical position respectively, by steps of 15°. The average convective heat transfer is quantified by means of original correlations allowing its determination in any area of the considered assembly, according to the generated power and inclination angle. They allow better sizing of the QFN64b device which is widely used in the modern electronic assemblies for specific applications. They contribute to improve their reliability while saving energy.

1. Introduction

The substantial increase of electronic equipments in the domestic and industrial sectors over the last years requires a solution to reduce energy consumption and increase the reliability. Partial activity of these facilities correspond to their operation in a low power range. Given their excellent thermal and electrical performance, the Quad flat non-lead (QFN) electronic devices are increasingly used in electronics. Their reliability is nevertheless very dependent on their thermal state, hence special attention is required for their correct dimensioning, especially when they are subjected to natural convective phenomena often preferred in electronics. The technical specifications of the QFN are available in many documents including [1]. The wire-bonded versions are integrated into modern arrangements as they improve their basic versions' performance. The wire-bonding technique described in several documents as [2] consists in connecting the QFN source to their leads by means of wires of high thermal conductivity materials as gold, aluminum, copper, silver and nickel. This increases the pure conductive source-leads heat transfer through the wires. The heat drained from the component to the PCB is then exchanged with the environment by the surface natural convection and thermal radiation phenomena. The device temperature is thus lowered, and it deviates from the maximum allowable by the manufacturers. This enables a broader range of power generated by the device while improving its performance and reliability. This applies to all available QFN and especially to the wire-bonded version of the model with 64 leads denoted as QFN64b examined in this study. Natural convection is widely treated in the literature for many engineering fields, geometry of the cavity and thermal boundary conditions, [3–12]. This heat transfer phenomenon is favored in electronics given its well-known advantages in this domain [13–17]. Specific studies deal with the quality of the convective fluid improving the heat exchange. Nanofluids are the subject of many interesting studies [18–20].

The QFN64b is used in specific applications given its characteristics that distinguish it from its basic version without wire bonding and other QFN models. The QFN with 16 and 32 leads denoted as QFN16 and QFN32 respectively were recently examined in [21,22]. Natural convective heat transfer has been quantified in these surveys by means of correlations allowing calculation of the average convective heat transfer convection. This study has been carried out according to the QFN's generated power and its inclination angle with respect to the horizontal plane. The unique work [23] quantifying this parameter for the low-powered basic model QFN64 concerns only a limited tilt angles of the device. To the knowledge of the author, natural convective heat transfer concerning the wire-bonded version QFN64b has not been quantified and thus motivates the present work. The studied case is a QFN64b device generating a power varying between 0.01 W and 0.1 W by steps of

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Nomenclature

A_i	area of the i^{th} element (m^2)
g	gravity acceleration ($m\ s^{-2}$)
h_i	local convective heat transfer coefficient ($Wm^{-2}\ K^{-1}$)
$\overline{h}$	average convective heat transfer coefficient ($Wm^{-2}\ K^{-1}$)
m	number of elements of the considered area (−)
P	generated power (W)
P'	natural convective power (W)
P^*	ratio defined by $P^* = P'/P$ (−)
P_R	radiative power (W)
P_R^*	ratio defined by $P_R^* = P_R/P$ (−)
T_c	cold temperature and initial temperature of the whole system (K)
T_i	local temperature of the i^{th} element (K)

Greek symbols

α	inclination angle with respect to the horizontal (°)
λ	air thermal conductivity ($Wm^{-1}\ K^{-1}$)
λ_m	thermal conductivity of the assembly's materials ($Wm^{-1}\ K^{-1}$)

0.01 W. It is welded on a Printed Circuit Board (PCB) which can be inclined by an angle ranging from 0 to 90° corresponding to the horizontal and vertical position respectively, by steps of 15°. The numerical approach done with the finite volume method shows that the surface temperature field of the assembly equipped with the wire-bonded device version is different from that containing the basic component. The study also shows that the heat transfer by radiation calculated by varying the global infrared surface emissivity is very low. The predominant natural convection is quantified by means of correlations allowing determination of the average free convective heat transfer coefficient for all the treated configurations in five specific areas of the assembly.

2. The considered configurations

The external appearance of the considered wire bonded QFN64b device is presented in Fig. 1(a) and detailed in Fig. 1(b). The materials constituting the device are assumed as isotropic from the thermal conductive phenomena point of vue. The Table 1 provides the values of their thermal conductivity λ_m considered as constant and temperature-independent. The connections between the source and the leads are done by means of 64 high conductive wires of 25 μm diameter. The parallelepipedic QFN64b (square of 9 mm side, 1 mm thick) is welded in the center of a square Printed Circuit Board (PCB, 40 mm side, 1.6 mm thick) presented in Fig. 1(c). Its equivalent thermal conductivity is of 0.35 $Wm^{-1}\ K^{-1}$ in its thickness and 20 $Wm^{-1}\ K^{-1}$ in its plane corresponding to an average density of the copper tracks network. The entire electronics assembly could be tilted by an angle α varying between 0° (horizontal position) and 90° (vertical position) by steps of 15° as presented in Fig. 1(d). The walls of the air-filled parallelepipedic box (48 mm × 32 mm × 8 mm) containing this assembly are maintained at temperature T_c = 293.15K. During operation, the device generates a volumetric heat flux assumed to be constant, corresponding to a power ranging from 0.01 W to 0.1 W. The study covers five specific areas detailed in Fig. 1(c):

* the top face (Q_T) of the device;
* the 4 sides of the device grouped into a single area (Q_S);
* the top face of the PCB, (except the (Q_T)'s mark) (B_T);
* the 4 sides of the PCB grouped into a single area (B_S);
* the back face of the PCB (B_B).

To facilitate the presentation of the results, the surfaces (B_B) and (B_S) are grouped into a single area denoted as ($B_B + B_S$). Otherwise, the (Q_B) back face is introduced for modeling the QFN64b without the PCB.

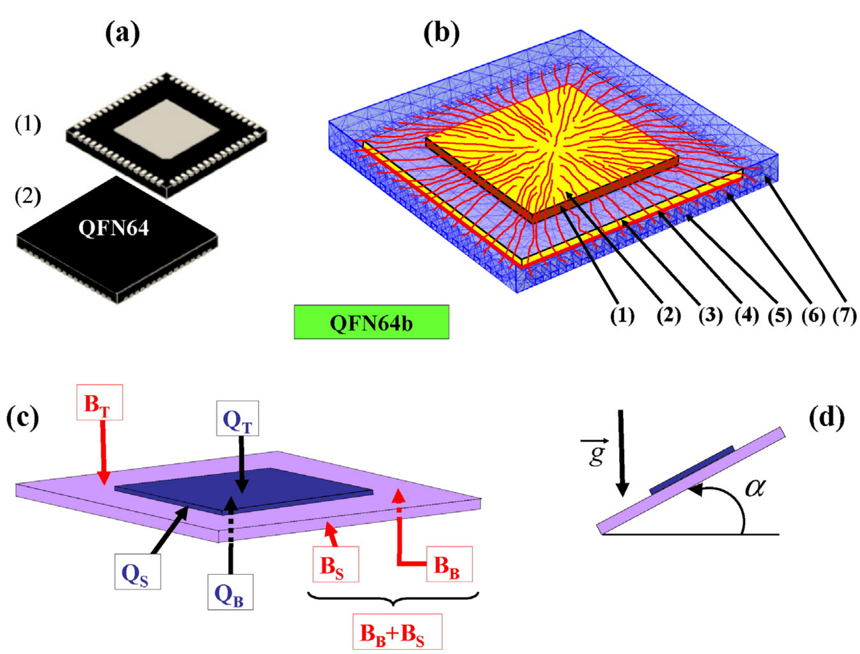

Fig. 1. (a) External appearance of the back (1) and top (2) faces of the considered QFN64b package; (b) the wire bonded QFN64b package and the adopted mesh (c) the device welded on the PCB and the areas of the assembly; (c) the inclination angle α with respect to the horizontal plane.