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STRUCTURAL DESIGN METHODOLOGY OF SPACEBORNE ELECTRONICS FOR IMPLEMENTING LIGHTWEIGHT AND LOW-COST SMALL SATELLITE APPLICATIONS

Abstract

According to the new space trend, small satellites are being actively developed in space industries around the world for implementing various constellation missions owing to its cost-effectiveness, short construction period and availability of mass production. As a demand for higher performance of small satellite is getting increased, one of the technical challenges is to enhance performance of on-board electronics while minimizing its mass and volume to be affordable in small satellite platform. Thus, highly integrated electronic packages have recently been applied in small satellite electronics. For successful space mission, one important task is reliable evaluation on mechanical safety on solder joint between package and PCB to prevent its fatigue failure under severe launch random vibration environment. To date, Steinberg's theory has been widely used for the mechanical safety evaluation on spaceborne electronics. This theory guarantees fatigue life of solder joint more than 20 million cycles of random vibration if the maximum PCB displacement does not exceed allowable value estimated by Steinberg's empirical formula. However, 20 million cycles of design criteria provides excessive margin compared with that accumulated during on-ground vibration tests and actual lift-off. This makes mass and volume of electronics to be bulky due to the unnecessary structural reinforcement by applying additional stiffeners and fixation points on the PCB. In addition, this theory has theoretical limitations due to the assumption of rectangular PCB with simply supported boundary conditions on the board edges, having an ideal mode shape of half-sine wave. This produces error in estimated allowable displacement when PCB exhibits complex mode shape owing to asymmetric board configurations, irregular constraints, or presence of stiffeners. For achieving low-cost and lightweight of the small satellites, the limitations of conventional methodology for electronics design shall be solved. This paper proposes a structural design methodology based on margin of safety (MoS) calculation with respect to critical PCB strain. An important feature of this methodology is that a safety factor in MoS calculation is estimated based on damage accumulated during on-ground tests and actual lift-off. This approach enables to minimize the unnecessary structural reinforcement of electronics. In addition, it ensures more reliable evaluation results of mechanical safety because the theoretical limitations of Steinberg's theory is eliminated by using critical PCB strain. To validate the effectiveness of the proposed methodology, random vibration fatigue tests on various types of packages and configurations of PCB were performed and the results were compared with those of MoS calculations.