STUDIES ON BOARD LEVEL ELECTRONIC PACKAGES USED IN HAND HELD ELECTRONIC DEVICES SUBJECTED TO RANDOM VIBRATION AND DROP IMPACT LOADS

ABSTRACT
of the thesis

Submitted by

S.SARAVANAN

in fulfillment for the award of the degree

of

DOCTOR OF PHILOSOPHY

FACULTY OF MECHANICAL ENGINEERING
ANNA UNIVERSITY CHENNAI
CHENNAI - 600 025

DECEMBER 2009

ABSTRACT

Electronic equipments/devices are subjected to many different forms of vibration over wide frequency ranges and acceleration levels. It is probably safe to say that all electronic equipment will be subjected to some type of vibration at some time in life. The vibrations are induced on electronic equipments because of their active association with a machine or a moving vehicle or due to transporting the equipment from the manufacturer to the customer.

The handheld electronic equipments fit into the consumer and portable market segments. Handheld electronic equipments such as cameras, calculators, cell phones, palm size personal computers (PCs), personal digital assistants (PDAs) and other electronic equipments are conveniently stored in a pocket and used while held in user's hand.

The handheld electronic equipments are subjected to random vibrations and are prone to being dropped during their useful service life because of their size and weight. These random vibrations and dropping events can excite the natural frequencies of the printed circuit boards (PCBs) used in these equipments which may cause very high amplitudes of vibrations due to resonance conditions. This high amplitude of vibrations creates electronic failures in the PCB assemblies mounted inside the equipments due to transfer of energy through the PCB supports. The electronic failures may result from various failure modes such as cracking of circuit board, cracking of component lead wires used in the IC packages mounted on the PCBs or cracking of solder joints used to mount the IC packages on the PCBs.

The main objective of this research work is are the following:

1) To analyze the dynamic response characteristics of hand held electronic equipments when subjected to random vibration and drop impact loads.

2) To optimize the support locations of a PCB in order to increase its fundamental natural frequency.

The PCB used in this research is custom made as per JEDEC (Joint Electron Device Engineering Council) standard. The size of the PCB is 132 x 77 x 1.6 mm^3. Two such PCBs are used in this research. In one PCB there are 5 Small Outline Package (SOP) electronic packages are mounted on it and in the other, 5 Ball Grid Array (BGA) electronic packages are mounted. The locations at which the packages are mounted on the PCB are specified by JEDEC standard.

Initially, modal analysis was conducted on one of the PCB to determine its dynamic characteristics using both finite element (FE) method and experiments. The dynamic characteristics of the PCB determined using modal analysis are the natural frequencies, mode shapes and damping ratios. The results from the experiments were compared with that from the FE method to validate the FE model of the PCB. This validated FE model was used for further dynamic simulation studies.

Random vibration tests were conducted on the two PCBs with two different electronic packages mounted on them in order to determine their dynamic responses under these loads. Both FE method and experiments were used to analyze the dynamic responses of the PCBs. Critical elements in the packages vulnerable to failure under random vibration loads were identified by FE method and validated by experiments. Fatigue lives of the critical elements of the two packages were calculated to compare the responses of these two packages under random vibration loads. It was found that the SOP packages were able to with stand the random vibration loads better than BGA packages.

Free fall drop impact tests were conducted on the PCB using FE method and experiments. A full drop FE model of the PCB was developed and the dynamic responses of the PCB during free fall drop impact were analyzed. Tests were conducted using drop test apparatus. The dynamic responses measured from experiments were then compared with that from FE method. Critical areas in the packages vulnerable to failure under drop impact loads were identified from the FE model and validated by experiments. Two simplified FE methods proposed in the literature for drop impact analysis were used to analyze the dynamic characteristics of the PCB and the results from these two methods were compared with experiment results to identify a validated but simplified FE method for drop impact analysis. Using this validated FE method, the dynamic responses of the PCB was analyzed for three different mounting configurations. It was found that the electronic package mounted at the centre of the PCB were vulnerable to drop impact loads and the corner solder joints in these packages were prone to failure by cracking due to these loads. Further it was identified that the six screw corner mounting configuration of the PCB was able to withstand drop impact loads when compared to other configurations.

Optimization of support locations of a PCB used in typical electronic devices like personal computers (PCs) was carried out using FE method and experiments in order to increase the fundamental natural frequency of the PCB. The PCB used in this work has a size of 245 x 200 x 1.5 mm^3 and has several electronic components like Cooling fans, memory slots, I/O connectors, etc., mounted on it. The PCB was supported by six mounting screws at specific locations. Modal analysis technique was used to extract the fundamental natural frequency of the PCB. A FE model of the PCB with components mounted on it was developed and the fundamental natural frequency of the PCB was extracted from the FE model using modal analysis technique. Experimental modal analysis was conducted on the actual PCB supported at its six original support locations and fundamental natural frequency measured from experiment was compared with FE model. Using the FE model, the support locations were optimized by allowing each location to move within a predetermined area in the PCB. The optimized support locations from the FE method were verified by experiments by drilling holes on the actual PCB at its optimized support locations. Results revealed that there was a 51% increase in the fundamental natural frequency of the PCB after optimization by FE method and 54.35% increase in the fundamental natural frequency of the PCB after optimization by experiments.