Proposed Solution to the Problem of Thermal Stress Induced Failures in Medical Electronic Systems

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ABSTRACT

The concept of miniaturization has propagated to all types of electronic applications. The complexity of electronic systems has been increasing due to increase in the number of functions and features offered to the users. At the same time the number of devices working per unit volume of the system has increased enormously, due to which the power density per unit volume has increased. Dissipating high power in small volumes has increased the thermal problems in all types of electronic systems, including medical gadgets. Thermal stress has been identified to be the major cause of failure of electronic devices in electronic systems, based on the analysis of failures, based on research work. The causative mechanism of failure of semiconductor device package due to thermal overstress in medical electronic systems is the differential expansion between plastic and metal parts of the device which causes a differential strain and package failure. Selection of materials with similar coefficient of thermal expansion is important to prevent thermal overstress caused failures. In this paper, the authors discuss a technique which uses mathematical analysis to provide a solution to this problem of selecting the suitable material to prevent differential thermal stress failures in medical electronics systems.

Keywords: Medical Gadgets, Optimization, Perturbation, Semiconductor Devices, Stability, Thermal Stress Failure

1. INTRODUCTION

Miniaturization in medical electronic devices has increased the complexity, device density and power dissipation per unit volume. This is as a result of increase in the number of functions offered by the system to the users. Heat is generated in medical electronic systems just as in the case of other electronic products and cooling methods are used to control the same. Semiconductor devices used in electronic systems are highly sensitive to temperature.
Based on the research carried out by various users it has been found that among the various failure mechanisms occurring in semiconductor devices, thermally induced failures constitute a large percentage of the total as mentioned in Renesas Electronics (2010) and Electronic Design (2015). Hence there is a need to address this major problem to reduce failures in electronic systems Reliability Handbook (2000). Thermal stress could arise in a system for various reasons such as higher ambient temperature, thermal shocks (subjecting the device to extremes of temperature within a short time), over-loads, high power density due to system complexity, malfunctioning of components having a secondary effect leading to electrical overstress (EOS) and then thermal overstress, component defects, assembly faults, lack of proper cooling arrangements, and such reasons.

Temperature ranges of operation are defined for electronic components used in various applications. For example: commercial: 0° to +70°C, extended commercial: -10°C to +70°C, industrial: -40°C to + 85°C, automotive: -40°C to +125°C and the like. The junction temperature of a device depends on the following factors during its operation:

1. Power dissipated in the device
2. Ambient temperature
3. Thermal resistance from the junction to the ambient

The junction temperature of the semiconductor device should be kept within the limit depending on the material, within these operating temperature ranges.

2. MATERIALS AND METHODS

2.1. Definition of the Problem

Medical electronic systems range in size and complexity from miniature probes, sensors, diagnosis tools, laser appliances, implantable devices, pace-makers, hearing aids, etc. on the lower end of the size scale to MRI scanners, X-ray machines, large diagnostic equipment, physiotherapy apparatus such as ultra-sound, diathermy equipment, robotic surgery tools, etc. on the large-size end of the scale. Irrespective of the size, thermal stress and temperature control of medical electronic systems has certain unique requirements. Some of the special requirements in medical electronic systems are:

1. **Dust and Noise are to be Avoided:** Cooling accessories and materials such as metals including Al, Copper, etc. are not biocompatible and are not preferred. Cooling fans will collect dust, smoke, greasy dirt, fumes, chemical contaminants, etc. over time which will cause fungi, yeast, mould-growth, bacteria, etc. to collect over it. This will contaminate the equipment and spread infections, which should be avoided. In the environments in which such medical equipment are used, such causes of infections cannot be permitted. Noise is unwelcome everywhere, especially in medical equipment.

2. **Active vs Passive Coolers:** Active cooling methods may cause problems described in (i) above. In addition, problems of size, power consumption, noise, sudden failure and its consequences in the case of active cooler are a big negative factor. Passive coolers may be expensive, but quiet, have no moving parts like cooling fans, need no power and are more reliable. The commonly used passive cooling devices in medical electronic systems are heat sinks, heat pipes, heat spreaders, special materials, etc. Passive cooling accessories mounted along with the component to be cooled have the advantage that the medical part of the equipment is away from the electronics and cooling accessories which may have dust, bacteria, etc. and may affect the patient.

The problem of thermally induced failures affects medical electronics just as any other types of electronic systems and it is necessary to understand the root cause of the problem...
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