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... THE LEADING EDGE

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This edition of Tech Topics…The Leading Edge is devoted to KEMET's design of a fused surface mount tantalum capacitor. The author, Barry Neal, is the inventor and project manager for the development. The capacitor described is the subject of U. S. Patent 4,907,131 and numerous foreign patent applications.

Dr. John Piper
Vice President, Technology

DEVELOPMENT OF FUSED SURFACE MOUNT TANTALUM CAPACITORS

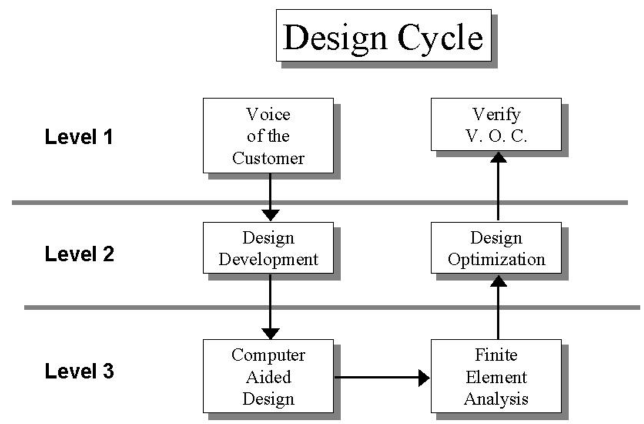
ABSTRACT

Tantalum capacitors have long been recognized for their volumetric efficiency, reliability, and stability in electronic circuits. Error rates in the Parts-per-Million (PPM) are quickly being pushed toward Parts-per-Billion (PPB) requiring that designs and design techniques change to achieve world class quality and reliability levels.

Two major factors affecting product design today are the conversion of the world's factories to Surface Mount Technology (SMT) and increased demand for high levels of quality and reliability. The harsher mounting environments of SMT place greater stress on the component, while the demands on quality and reliability are increasing. ***Passive components require non-passive engineering and technology to achieve the goals of electronics manufacturers in the 90's and beyond.***

A major concern over the years has been dielectric breakdown caused either by part reversal or high surge currents. An extreme dielectric breakdown condition could cause component ignition resulting in damage to the printed circuit board. *Fused* tantalum chip capacitors allow the device to fail open when current levels reach the actuation point of the fusing element, thereby eliminating the short circuit failure mode and the resulting catastrophic damage.

The following is an overview of the design process (Figure 1) showing the considerations and technology used to develop the fused surface mount tantalum capacitors. The design process includes tools such as Quality Function Deployment, Computer Aided Design, Statistical Process Control, and Design of Experiments and Finite Elemental Analysis.



VOICE OF THE CUSTOMER

The first step in any successful design is to determine the voice of the customer. If customer wants and needs are understood and satisfied, then ultimately the product will have success in the marketplace. Key requirements were identified by talking directly with our users. These were then translated into design goals using Quality Function Deployment techniques.

Some of the key points that came out in the discussions:

- The capacitance values must be equal to the values of non-fused surface mount tantalums.
- Package sizes should meet the EIA standards.
- Soldering could be by infrared reflow, vapor phase reflow, or wave solder techniques.
- Cost is a major concern.
- Fuses must actuate fast enough to eliminate the probability of the anode igniting and must not blow during turn on currents.
- Resistance of the part must not substantially change.
- After the fuse actuates the part must have a resistance of greater than 10 megohms.

DESIGN DEVELOPMENT

Fuse Design

Fuse wire materials were evaluated to find the best properties for this application:

- Exothermic and reactive materials were tested and several proved to be alternatives. One of the most promising alternatives was an exothermic wire used in the munitions industry.
- Endothermic, non-reactive materials such as lead and solder were rejected because fuse actuation times varied widely and testing showed that there was a great probability that the melted materials could rejoin causing the part to eventually ignite.

Attach Methods

Many fuse attach methods were analyzed:

- Soldering of the fine wires was rejected because of reliability problems.

- Laser welding was explored but could ignite the exothermic wire unless very tightly controlled.
- Silver epoxy attach was rejected after it was discovered that the epoxy caused localized heating. This could cause the wire to blow inside the silver epoxy.
- Resistance welding had the same problems as laser welding, along with providing great difficulties in equipment design because of the tight space constraints.
- Ultrasonic bonding was chosen as the preferred method. Ultrasonic bonding has been used in the semiconductor industry for many years.

Wire Coating

A material had to be developed to coat the fuse wire and prevent organic materials from coming in contact with it. Organic material in contact with the fuse during the exothermic reaction would leave a carbonaceous trail that could have a resistance as low as a few ohms.

COMPUTER AIDED DESIGN

Computer Aided Design was used so that the whole component could be built layer by layer on the computer.

- The case could not increase in size so the design had to take advantage of available space. The fuse was designed on the positive end of the anode, using space that cannot be used by the anode due to processing limitations.
- The tantalum pellet was optimized to give the largest possible size, thereby increasing the capacitance and de-creasing the resistance of the part.
- Wall thicknesses were designed to maximize mold flow, minimize wire sweep, increase moisture resistance, and maximize strength.
- The leadframe was designed to maximize the pull strength of the terminations while providing for the ultra-sonic bonding of the fuse. The goal was to eliminate the possibility that the surface mounting process could damage the fuse resulting in failure.
- Leadframe material was selected to optimize solderability, weldability, strength, thermal conductivity, and electrical conductivity.

FINITE ELEMENTAL MODELING

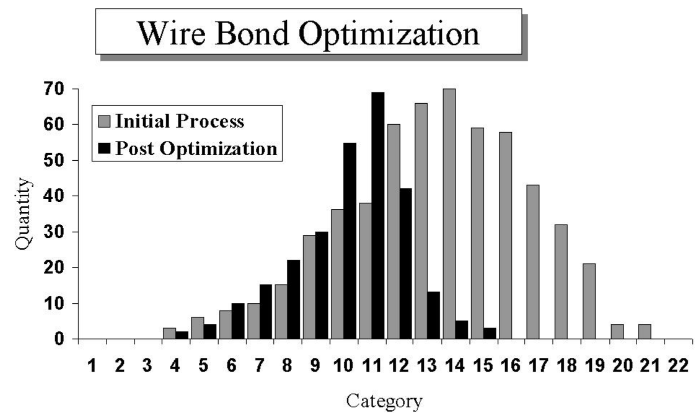
The design was modeled using Finite Elemental Analysis. A design capable of producing Parts per Billion defective rates cannot be achieved using trial and error methods. The quantity of parts required to get a statistically valid sample would be prohibitive through cost increases and delays in product shipments.

The component was modeled in 3D and evaluated using the board mount process stress levels provided by our customers. Von Mises stress, normal shear, principal stresses and displacements were studied under various temperature gradients to look for potential problems. Areas of concern, such as the fuse, were modeled separately to gain more insight into changes that could be required.

PROCESS/DESIGN OPTIMIZATION

The fuse wire diameter and gap length then had to be optimized to guarantee actuation within the specified limits. The addition of molding compounds, leadframe and anode provide heatsinks which can offset the fusing characteristics. The ultrasonic bonding process had to be refined to guarantee reliability and productivity. These goals were accomplished using Design of Experiments. In this way many factors were considered at once while focusing in on the best process window with the fewest steps possible.

Experiments were performed to look at relationships between wire diameter, wire composition, bond time, power, loop height, loop length, head load, bonding tools, platen temperature and bonder velocity. Upon completion of this experimental series and subsequent verification runs, the wire composition and bonding tool were defined. Another series of orthogonal arrays were run to optimize the bonding process, minimize process variation, and maximize productivity. The orthogonal arrays contained relationships between bonding parameters only. The result was a dramatic improvement in the pull strengths of the wires.



DESIGN VERIFICATION

Design Goal	Measure	Result
Capacitance Range	Full range	Yes
Fuse Minimum Current	0.75 amps continuous	Yes
Fuse Actuation	5 amps	Yes
	5 sec. Max.	<10 mS
Post Actuation Resistance	> 10 megohms	Yes
Added ESR	<0.10 ohms at 100kHz	Yes
Case Sizes	Standard EIA	Yes
Cost	Low cost adder	Yes
Solderability	Mil spec.	Yes
Solder Mount	260 degrees C, 10 sec.	Yes

SUMMARY

Component design is a complex task requiring changes to methods and technologies to keep up with the accelerating pace of product offerings and quality. The designer must understand his customer and form partnerships for their mutual success. New tools must be employed that provide him with an expanded information base. Product designs must be developed by simultaneous engineering intermeshing product quality, reliability and manufacturability. The result is a product that meets and exceeds customer expectations.