High Temperature Ceramic and Tantalum Capacitors

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Abstract

The dielectric found in capacitors has two main functions. One function is to enhance the electric field created between the two plates, and a relative measure for this property is the dielectric constant and relates directly to the capacitance rating of the device. The second function of the dielectric is that it be insulative and suppress the loss of charge on the plates through the dielectric. In high temperature applications, both of these properties are challenged, but it is the insulative property of the dielectric that is most critical. Insulators become more conductive in higher temperatures, and the conductivity can become a degrading element of the dielectric.

Presentation of the capacitor to the circuit, or packaging presents another challenge for high temperature applications. Lead attachment methods that worked below a maximum temperature rating of 125°C no longer maintain a mechanical integrity at temperatures of 150°C and higher. The epoxy encapsulant used for the SMT tantalums present additional challenges.

High Temperature Ceramics

Ceramic capacitors are sintered at temperatures exceeding 900°C. Terminations applied to the outer face of the ceramic block are fired at temperatures near 900°C. These two elements present few problems in applications up to 260°C. The capacitance for an X7R material will remain within ±15% original value over the temperature range from -55°C to 125°C.

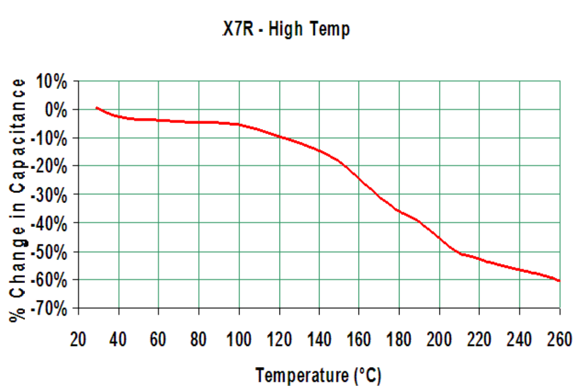

Figure 1. Capacitance change up to 260°C.

In Figure 1, the X7R dielectric tested to 260°C shows deviations well below -15%. At 200°C, the capacitance loss is 45%, and at 260°C, the capacitance loss is at 60%. Use of this capacitor at these temperatures will require compensating for these losses.

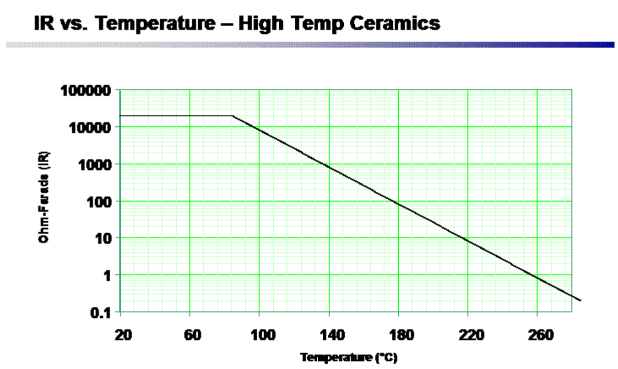

Figure 2. Insulation resistance versus temperature.

The insulation resistance at 125°C drops a decade from the 25°C requirement, as shown in Figure 2. Thereafter, for every 40°C rise, the requirement drops another decade. At 260°C, the requirement is less than 1/10000th of the 25°C requirement.

Ceramic packaging

High-temperature ceramic capacitors are specifically designed for applications in which the device is exposed to continuous operating temperatures of 200°C rated (with 220°C for short periods) and 260°C rated. The capability also includes process exposures up to 300°C during

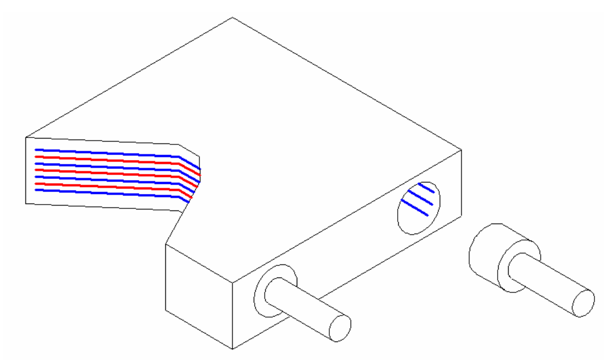

Figure 3. Radial lead with cavity/inserts for lead heads.

assembly[1].

The construction of this device utilizes a unique lead attachment to the ceramic body (Figure 3). A hole or cavity is created in the ceramic structure to allow a lead head to be fitted into the cavity with a high-temperature solder. The mechanical fit allows an attachment that stays true even when the solder reaches a plastic state that would normally allow a lift-off of the lead to the termination.

The device is typically a bare ceramic device, with capability for being coated with an epoxy or potted into a case. The potted case presents materials that do not match the coefficients of thermal expansion (CTE) of the ceramic and can be a limiting factor on thermal exposure. The elimination of the plastic case also allows greater volume to be utilized by the ceramic structure, creating a potential for higher capacitance.

The same cavity-attach method (as depicted for a radial-leaded device in the diagram) is applied to axial-leaded devices with the cavities located at opposite faces of the chip (termination faces). The devices are available with X7R and C0G dielectrics. Specially formulated X7R allows 40% retention of the 25°C capacitance at 200°C. The insulation resistance (IR) is specified at 25°C and +125°C, with the higher temperature rating being 1/10th that of the 25°C rating. The IR requirements from 25°C through 85°C are the same. For increasing temperatures beyond 85°C, there is a log-linear temperature-IR relationship such that the IR decay is equal to one decade per 40°C.

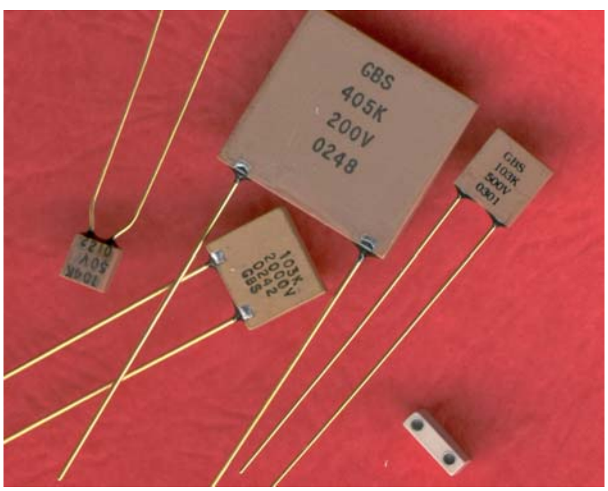

Figure 4. Radial-leaded, high-temperature, ceramic capacitors.

High Temperature Tantalums

The ceramic capacitors have the benefit that the capacitor structure can become part of the packaging. With tantalum capacitors, the device has to have one contact to the anode structure (the tantalum base material) and the other contact to the cathode structure (the MnO_2 structure here). Although replacement of the MnO_2 cathode with a conductive polymer has shown great success in lowering ESR, this material cannot be used for these high temperature applications at this time.

These contacts are brought out of the package by lead frame structures that enable a very efficient surface mount process.

The materials that will factor the ability for a high temperature application include the silver adhesive, the carbon, the MnO_2, the lead frame, and the epoxy coating.

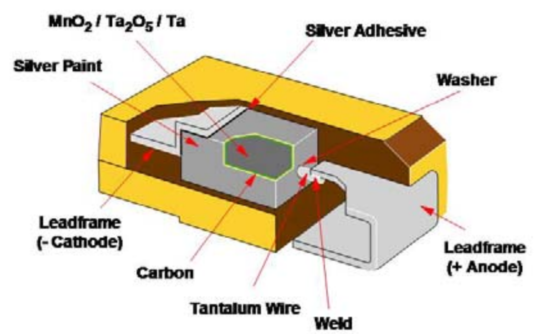

Figure 5. Tantalum surface mount capacitor.

Of these materials, the external case material is the most obvious change. The typical yellow or gold plastic has a heat sensitive characteristic such that high-speed laser marking is created with a quick flash through a template to create the marking characters as well as the termination band on the anode side of the chip. The heat turns the yellow epoxy brown.

With these capacitors exposed to temperatures at or above 150°C for extended periods, a full coloration of the surface will occur, obliterating the original mark-

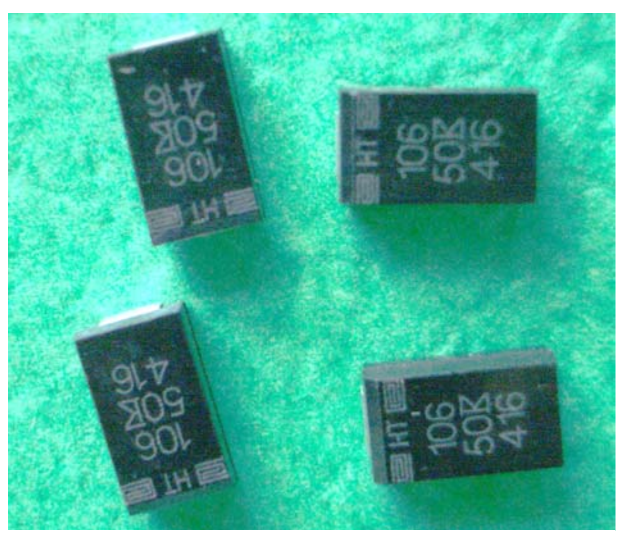

Figure 6. Black epoxy for the 175°C T499 capacitors.

ings. This discoloration will first appear on the corners and edges and create some concerns with the users. The solution will be to use a black molding compound for the 175°C rated components (T499).

High Temperature - Wet tantalums

There are still applications that demand wet tantalum capacitors. A subset of the hermetically sealed series (T197 & T198) is rated up to 200°C. The voltage derating for these capacitors is the same as the solid-tantalum: full rating up to 85°C, then in a linear fashion to 67% at 125°C, to 50% at 150°C, and continuing at 50% to 200°C.

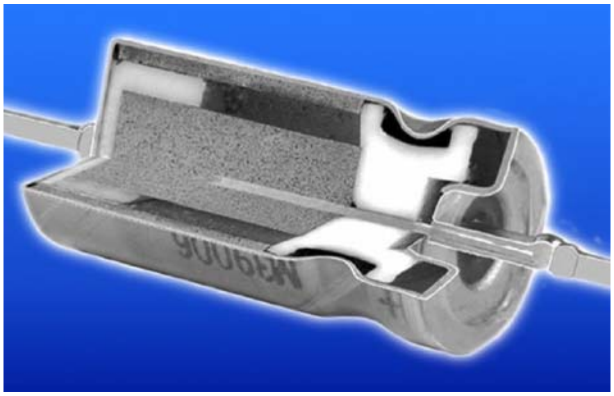

Figure 7. Hermetically sealed wet-tantalum capacitor.

Applications

These devices are intended for high temperature applications such as oil well logging (down-hole instrumentation), jet engine controls (on-engine control circuits rather than remote sensing), and geophysical probes. Increasing instances in automotive circuit designs are demanding the application of capacitors rated at 150°C (in oil) and 175°C (in exhaust system). Large characteristic changes in these applications (including capacitance, dissipation factor (ESR), and insulation resistance) must be accounted for in these environments.

The high temperature ceramic capacitors are available today as this line was picked up with the Sierra-KD purchase. The wet tantalums are available today as we re-entered that manufacturing line. The T499 high-temperature, surface-mount tantalums will be available early in 2005.

Bibliography

[1] KEMET Electronics Corp., "Product Update – High Temperature Capacitors", KEMET Technical Handout, November 2003