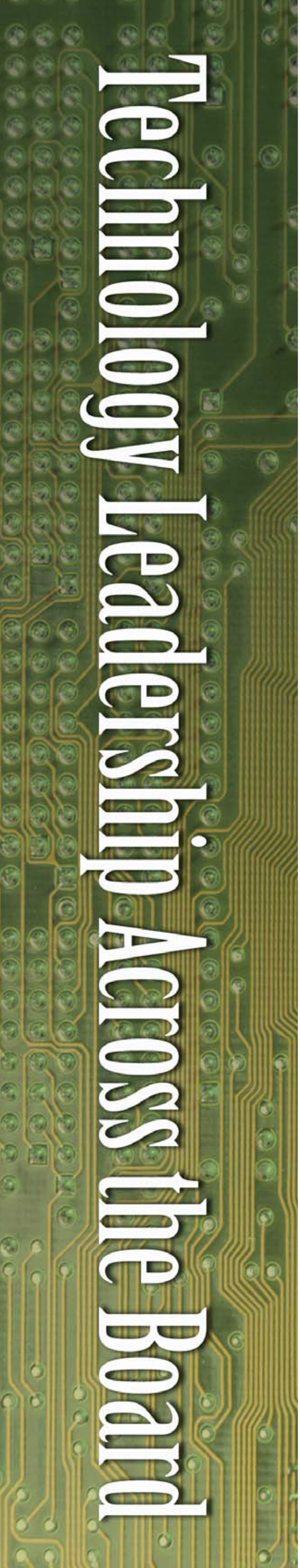

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SMD Tantalum Capacitors Break Limit of 200degC for Continuous Operation

R. Faltus, T. Zedníček

AVX Czech Republic s.r.o., Dvorakova 328, 563 01 Lanskroun, Czech Republic

email: techsales-tantalum@eur.avx.com

Abstract

Capacitors are one of the key parts of any electronic device and system. The main functions of capacitors include power supply voltage smoothing, supporting energy sources when high current pulse is demanded, blocking a DC voltage in signal pathes, filtering, etc. To assure required functionality of a system we cannot omit capacitors and it is valid for high temperature applications as well. In oil and gas mining industry a high temperature capacitors are needed for DC/DC converter of drilling heads that are subjected to rising ambient temperature with depth. Thus the higher permitted operating temperature of used capacitor and other passive and active parts, the deeper situated resources are accessible.

Solid tantalum capacitors have been known for their excellent reliability, robustness and stable parameters. Hence this is very suitable capacitor technology for further research and development targeting enhancing operating temperatures up to 200ºC. This paper describes a novel 200ºC capacitor concept and technical development & processes of enhancing operating temperature of solid tantalum capacitor. Stability of the main capacitor parameters at high ambient temperature is essential condition for valuable product.

INTRODUCTION

In oil and gas industry, high temperature capacitors are needed for the DC/DC converters used in drilling heads that experience rising ambient temperatures the deeper you drill. Simply, electronic components with a higher operating temperature will allow you to drill deeper, accessing harder-to-reach resources. Typical aerospace and defence applications include engines and turbo fans as well as control and sensing electronics placed near outer shells of rockets and space shuttles. A key requirement here is reliability under harsh conditions. Automotive applications such as small gearboxes or embedded alternators/starters also require reliability and long life at elevated temperatures.

HIGH TEMPERATURE APPLICATIONS PLACE HEAVY DEMANDS ON TANTALUM CAPACITORS

Operating temperature

Nowadays, the pressure to reach new natural oil and gas resources is increasing as worldwide consumption grows. Therefore, mining companies are forced to drill deeper to find new these reservoirs, the sensing and control electronic circuits that are mounted inside the drilling head - including tantalum capacitors - are required to withstand temperatures above 175°C.

The trends towards the integration of automotive electronic systems closer to mechanical parts, for example inside of gearboxes, also demands further capacitor development so that parts can operate at temperatures of up to 200°C.

Voltage rating

Oil drilling applications require capacitors for use in control circuits at 3.3V (digital) and 5V/15V (analog). Automotive applications require 12V and 24V for power lines. Allowing for derating, providing voltages from 15V upwards is a real challenge because it combines high voltage together with maximum temperatures.

Reliability

The oil industry has specific service interval requirements; the minimum-requested continuous operating time is 1000 hours at 200°C. Latest demands shifts the conditions even further to 2000 hours operating time at 215°C.

DEVELOPMENT CHALLENGES

The present state

Standard tantalum capacitor technologies have an operating temperature range of -55°C to +125°C which covers the needs of consumer electronics, computers, mobile phones and also in-cabin automotive electronics. There are a variety of automotive applications, specifically situated near the engine, which requirec components to work at higher operating temperatures. Mainly to satisfy the needs of the automotive industry, some producers have introduced Automotive product families, which expand the use of tantalum capacitors to engine compartment systems with operating temperatures of up to 175°C [1].

Material development

Higher operating temperatures affect the stability of all materials used in the production of capacitors from both a chemical and mechanical viewpoint. Materials have to be designed to survive both high temperature operational stress as well as storage.

Maximum operating material temperatures have been studied in laboratories to prove the long term stability of materials at elevated temperatures. These findings have then been confirmed by testing the electrical and mechanical performance of finished capacitors.

The extension of operating temperatures to 200°C requires that special attention must be paid, mainly to three groups of materials – the tantalum anode, encapsulant and terminations.

The real challenge when moving from 175°C to 200°C is dealing with the epoxy-based materials used in capacitor manufacture, ie moulding resin, silver adhesives etc. These materials have glass transient temperature of around 175°C. The value of the coefficient is significantly higher at the temperatures above the glass transient temperature than under this level, which could cause cracks and delaminations in the capacitor layers. Thus the selection of suitable materials is very important.

Tantalum anode

Reliability testing has proved that tantalum capacitors with MnO_2 counter electrodes are capable of being stored at higher temperatures provided specific procedures are followed. Five years experience with 175°C capacitor production [1] and massive amounts of reliability data have provided enough information to make evaluation at increased temperatures worthwhile.

The type of tantalum powder is crucial for creating a robust anode. Powders from various producers differ marginally in terms of granularity, porosity and purity, factors which all influence capacitor reliability.

The forming of homogenous dielectrics with a maximum safety formation parameters, together with a robust anode wall structure results in a tantalum anode, which is able to absorb thermo-mechanical stresses and to survive adverse environmental conditions including high temperatures and high humidity.

Encapsulation

The encapsulation material must be able to reduce stresses from thermal shocks, to survive high temperature and to create an effective barrier to prevent penetration by moisture due to humidity.

The effects of thermal shocks can be reduced by selecting a moulding compound with a low thermal expansion and high glass transition temperature. High strength at high temperature and good adhesion to the leadframe reduces the chances of cracking the encapsulant and opening the way for humidity to penetrate. IPC level 2 is a minimum required level of cracking resistance. It requires zero cracks after 168 hours at 85°C in 85% relative humidity and three times 90 seconds solder immersion at 220°C. A low water absorption tendency of the encapsulant will further improve humidity resistance.

Today, lead-free solder is the most common assembly process. Lead-free process-compatible components must be able to withstand reflow at peak temperatures up to 260°C. They must also meet environmental standards which ban using Sb/Br compound as fire retardants.

Finally, encapsulants should be colour- stable and markings must remain legible after storage at 200°C.

Terminations

Conventional tin/tin-lead terminations have melting points between 183°C and 210°C - too low for reliable operation at 200°C. Among many applications, 200°C capacitors are used for hybrid circuit applications where they are hand soldered or mounted, so the most suitable terminations are gold plate - environmently-friendly, highly reliable and temperature stable.

Aging process

Leakage current (DCL) stability is important measurement for production process quality. When a standard aging process was used (capacitors are exposed to high temperature at the defined voltage for several hours, then failed capacitors are removed) certain leakage current “flyers” were noted after final life test (Fig.1). A new aging method had to be evolved to improve DCL stability.

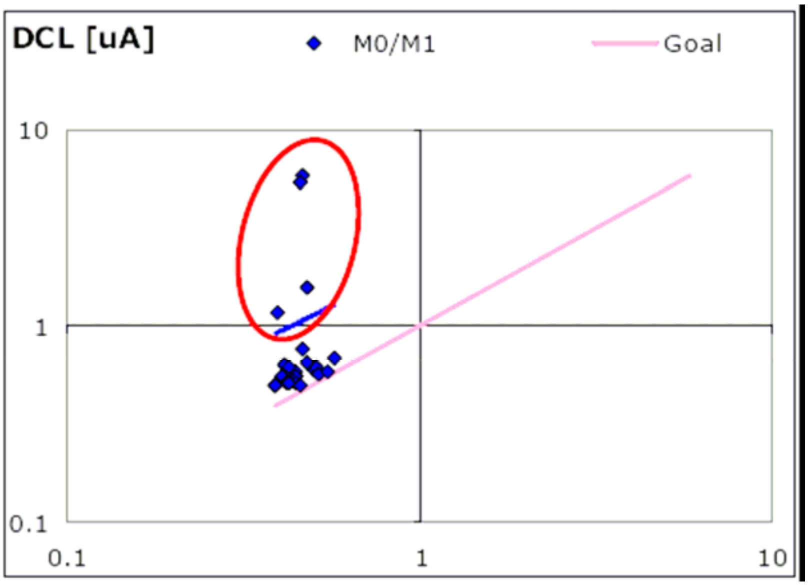

Fig.1. Leakage current flyers of E100µF/16V after 200°C, 1000 hours life test, (Standard aging)

DEVELOPMENT RESULTS AND CAPACITOR SPECIFICATION

Implemented processes

Long experience with 175°C capacitor production enabled AVX to specify materials (powder, silver, moulding resin, etc.), designs and procedures, which resulted in highly reliable capacitors even after storage or cycling at 200°C.

Tantalum capacitors are 100% screened during the production at accelerated conditions to eliminate potential failures. The capacitors are overstressed by combinations of high voltage and temperature, cyclic thermal shocks or current surges. Robust anode design allowed AVX to modify screening operations towards temperatures as high as 200°C. All capacitors experience the high temperature (200°C) at accelerated testing during production, guarantees reliability for end users.
To assure higher electric parameter stability, additional long term aging and further leakage current testing at capability limit with screening was incorporated into the production process. The improvement is demonstrated in Fig.2 versus Fig.1.

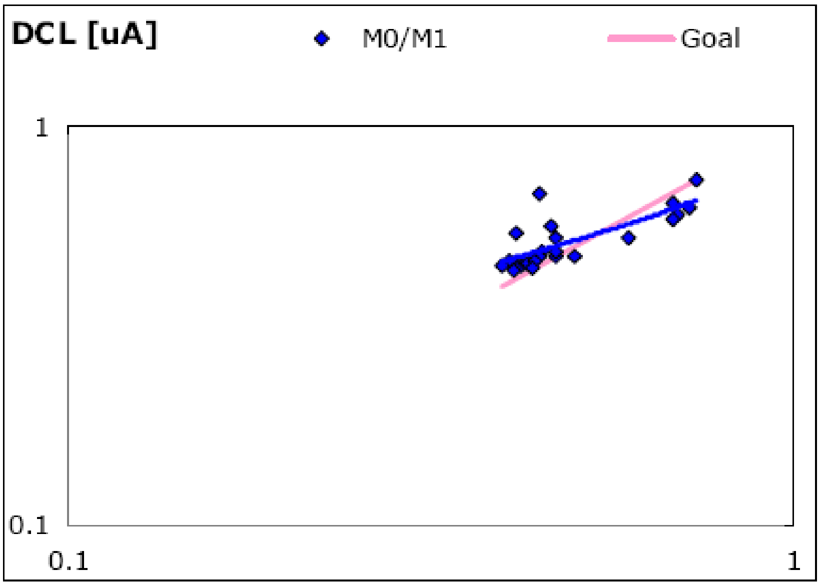

Fig.2. Leakage current stable, E100µF/16V after 200°C, 1000 hours life test, (Long term aging performed)

Results of stability tests

Newly developed capacitors reached a high stability of basic electrical parameters thanks to careful material selection and the new processes that was implemented. The stability can be seen in the long term test results – see Fig. 3, 4 and 5.

M0 is inital measurement of parameters; M1 is measurement after 1000 hours at 200°C and 0.3Ur (thirty percent of rated voltage); M2 is measurement after 2000 hours with the same conditions as M1. Part used is E 100µF/16V. No failures and no parametric rejects occured.

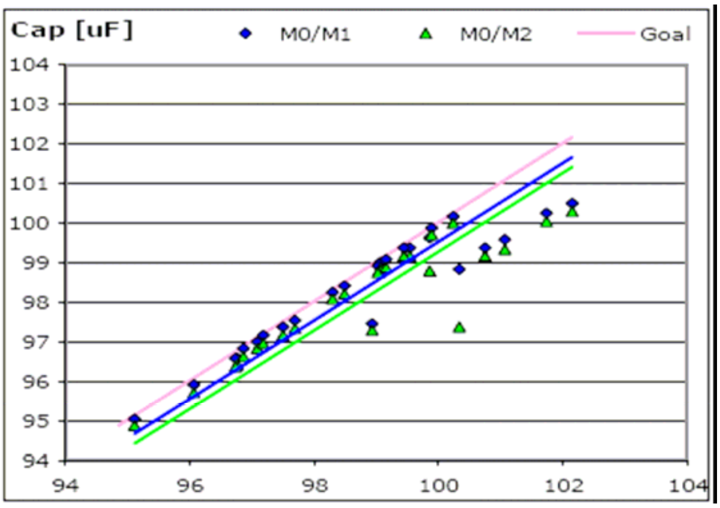

Fig.3. Stability of capacitance, E100µF/16V @200°C, 0.3Ur, M1 after 1000 hours, M2 after 2000 hours

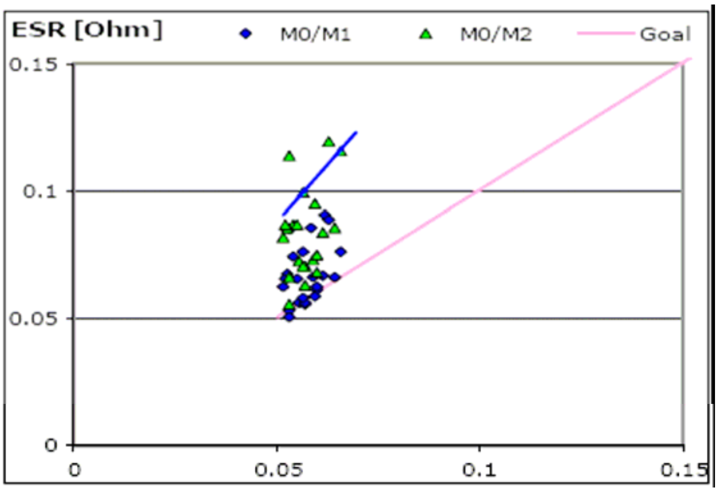

Fig.4. Stability of ESR, E100µF/16V @200°C, 0.3Ur, M1 after 1000 hours, M2 after 2000 hours

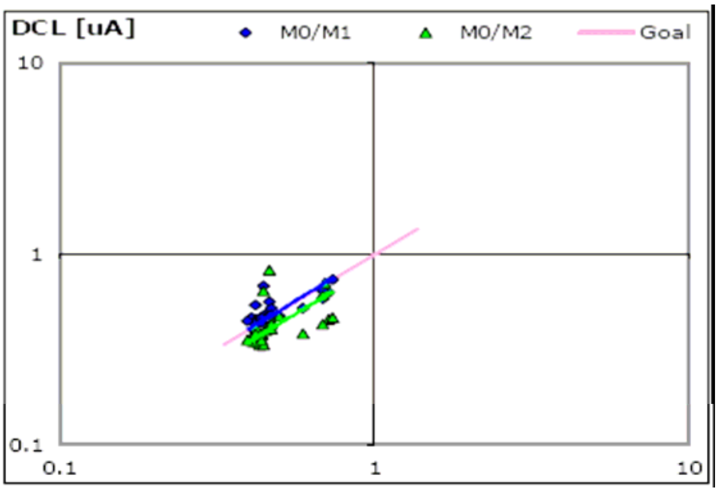

Fig.5. Stability of leakage current, E100µF/16V @200°C, 0.3Ur, M1 after 1000 hours, M2 after 2000 hours

200°C tantalum capacitors availability

The capacitors are initially available in two E-case (7.3 x 4.3 x 4.1 mm) sizes: E 220µF rated at 10V and E 100µF rated at 16V. Capacitors are specified for continuous operation at 200°C and are 3-times 260°C leadfree reflow compatible. Construction uses gold-plated terminations and black encapsulation which assures legibility of marking even after storage at 200°C.

Leakage current

Long term, low leakage current is a key attribute; the THJ 200°C capacitors have a DCL of less than 1mA even after 1000 hours of operation at 200°C.

Category voltage

The THJ 200°C capacitors require voltage derating to operate at high temperature. Maximum operating voltage considering actual operating temperature is called category voltage. Category voltage at 200°C is equal to 0.3xUr (thirty percent of rated voltage at room temperature). Considering this rule, the 16V capacitor is suitable for 5V analog circuits at 200°C and the 10V capacitor can be used for 2.5V and 3.3V digital circuits at 200°C in systems like a drilling heads. Figure 6 shows the dependence of category voltage on temperature.

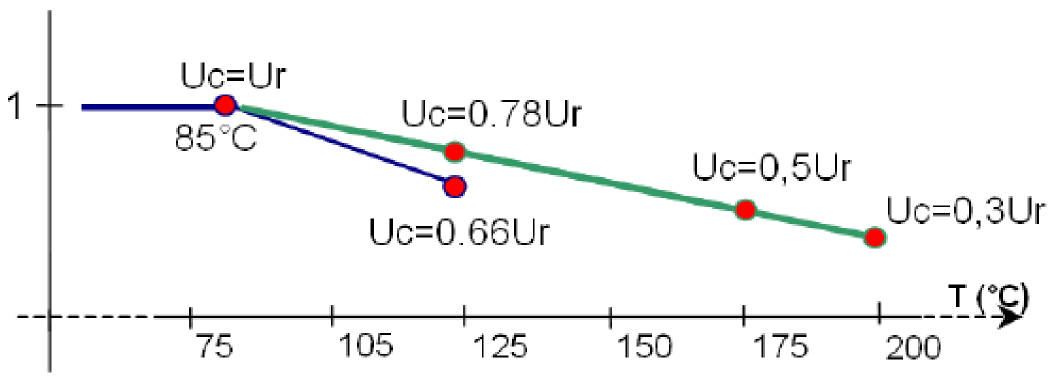

Fig.6. Category voltage vs temperature

Uc = 0.66Ur at 125°C for standard series

Uc = 0.78Ur at 125°C for all THJ series

Uc = 0.5Ur at 175°C for all THJ series

Uc = 0.3Ur at 200°C for special THJ 200°C

Reliability of THJ 200°C capacitors

The 200°C capacitor is developed from THJ family and inherited its increased reliability level which is two time better (0.5%/1000 hours) than in the case of standard families (1%/1000 hours) measured by failure rate defined at ambient temperature 85°C at full rated voltage.

CONCLUSION

New technological processes and materials have been implemented in order to enhance the operating temperature range of AVX's THJ family tantalum capacitors. Continuous operation at 200°C is now possible with specially improved capacitors. Their leakage current after 1000 hours of operating time at 200°C does not exceed limit 1mA. This opens new possibilities when used in oil and gas industry drilling systems.

More, the experience that AVX has gained concerning new materials' behaviour and new aging and screening processes promises to result in 200°C capacitors with even longer operational times and lower leakage currents in the future – which may be suitable to meet the demands of even the automotive and aerospace industries.

REFERENCES

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