Introduction of New KAVX Low Inductance Polymer Tantalum Capacitors

13-16 October 2026
ESA/ESTEC, Noordwijk, The Netherlands

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ABSTRACT

Introduction of new Kyocera AVX polymer tantalum capacitors: Low Inductance Bulk Capacitors (LIBC) provide noise attenuation in electronic circuits, signal filtering and electromagnetic interference (EMI) suppression.

LIBC have advantageous properties such as low inductance, high attenuation in a wide frequency range, high signal and ripple current capability. These capacitors utilize polymer tantalum technology with benefits such as high capacitance and energy density, high reliability and electrical parameters stability over wide temperature range. Parts will be available in 2.5 - 50V voltage range and capacitance up to 330 μF in low profile face down case (size 7343-15).

These capacitors can be used in power supply lines and signal lines for EMI suppression, broadband I/O filtering, and/or power supply line conditioning. In applications such as micro power supplies, micro-DC-DC converters, switched-mode power supplies, microswitches and decoupling on FPGA. They can replace MLCCs in such cases to achieve smaller footprints and reduced electronic circuit design.

INTRODUCTION

Since earliest days of radiocommunication, it was apparent that Electromagnetic Interference (EMI) is one of the issues that needs to be targeted [1]. EMI refers to disturbing signal emitted by an external or internal source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction. Today with miniaturization of semiconductors, denser pcb designs and high frequencies EMI needs to be a key design consideration. There are various ways to prevent this unwanted phenomenon from promoting in electronic circuits such as shielding, robust grounding, filtering or mentioned pcb design that can include all above.

To get only wanted signal in electronic circuits filtering, coupling, decoupling or bypass capacitors can be used. To achieve wide frequency filtering multiple components are usually used such as combination of capacitors/inductors/resistors [2]. Those can be ideally replaced by single low Q filter such as capacitor with high capacitance and low inductance.

This can be achieved with new Kyocera AVX patented product Low Inductance Bulk Capacitor (LIBC) [3] based on polymer tantalum technology. This solution provides low frequency filtering due to high energy density, thus high capacitance. High frequency filtering is achieved by optimized construction with low inductance.

Hand-made proof of concept samples were tested by Teverovsky who recommended them for space applications [4], although proper screening for those parts was recommended. Which is based on the hand-made nature of those samples. In this paper we are presenting results of qualifying engineering samples manufactured on final production line.

CONSTRUCTION OF LIBC

LIBC utilizes a lot from polymer tantalum technology where construction of standard parts begins with a sintered pellet of powdered tantalum submerged in an acid bath with a DC voltage applied across it. As a result, an oxide layer on tantalum pentoxide quickly forms on the contoured surface of the pellet, the thickness of which is proportional to the voltage applied. This oxide acts as the dielectric insulator in the final capacitor structure, and its large effective area and high breakdown voltage yield high reliability and high-density devices. A cathode terminal is formed using a conductive polymer to sufficiently contact the oxide layer, either pre-polymerized dispersions or in-situ polymerization can be used. Most Tantalum electrolytics are packaged as surface-mounted devices [5]. The difference for LIBC is that tantalum wire goes through the anode and is connected to positive terminals on each side, with a negative terminal connected to the cathode in the middle see Fig. 1. (a). First LIBC series TCF will be released in SMD form with three terminal case size 7343-15 see Fig. 1. (b). This creates favorable geometry of feedthrough capacitors where DC signal goes through that part between positive terminals and AC can be separated through low inductance negative terminal. See electrical scheme on Fig. 1. (c).

MATERIALS AND METHODS

All testing was performed on TCFZ336M035R0150E parts manufactured on final production line.

Basic electrical parameters

Effect of DC bias on Capacitance was evaluated at levels from 0 V up to 35 V. LIBC were measured in custom jig. Capacitance measurements were performed on Wayne Kerr 6500B Precision Impedance Analyzer 20 Hz – 1 GHz at room temperature of 25 °C with AC measurement signal 1V. Measured on ten parts. Bias measurements were done in order from the lowest to the highest voltage.

Effect of temperature on basic electrical parameters was evaluated in the range -55 °C – 125 °C. Parts were mounted on custom FR5 testing board. Capacitance and DF measurements were performed on Agilent E4980A 20 Hz – 2 MHz Precision LCR Meter, frequency of 120 Hz with AC measurement signal 1 V and DC bias 2 V. ESR measurements were done on the same device, frequency 100 kHz, AC measurement signal 1 V, no DC bias. Direct current leakage was measured on Agilent 6634B System DC Power Supply with 1 kΩ series resistance with reading after 300 seconds. Testing temperature was secured by entering parts in Vötsch VT 7004 temperature test chamber with minimum 10 minutes for each temperature stabilization. Order of measurement was from -55 °C to 125 °C measured on 24 parts.

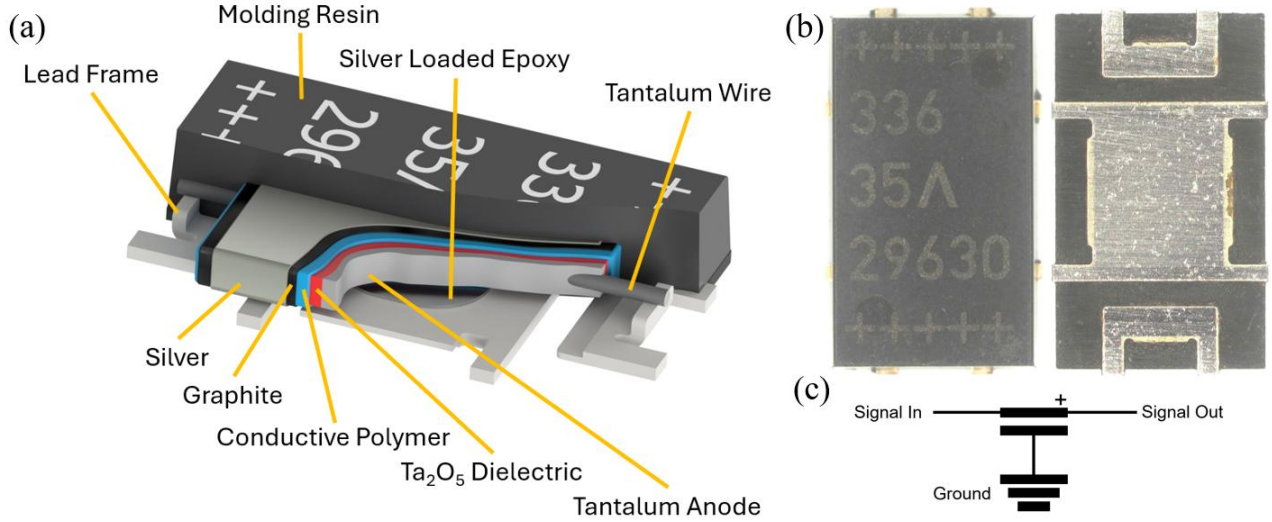


Fig. 1. (a) LIBC construction, (b) Marking and termination view of LIBC, (c) Feedthrough capacitor circuit diagram.

Basic reliability tests

Basic reliability testing was performed on parts with all electrical measurements on parts before and after test performed on 25 parts each. Parts were mounted on custom FR5 testing board. Capacitance and DF measurements were performed on Agilent E4980A 20 Hz – 2 MHz Precision LCR Meter, frequency of 120 Hz with AC measurement signal 1 V and DC bias 2 V. ESR measurements were done on the same device, frequency 100 kHz, AC measurement signal 1 V, no DC bias. Direct current leakage was measured on Agilent 6634B System DC Power Supply with 1 kΩ series resistance with reading after 300 seconds.

Dry heat test was done in Memmert UF110M Universal Oven. Test duration 2000 hours and test temperature 105 °C.

Dry heat test with applied voltage was performed in Memmert UF110M Universal Oven, voltage was applied from Power Supply EA-PS 5200-10A, total circuit impedance was < 3 Ω and each capacitor was connected in series with 1 A fuse. Test duration 2000 hours, test temperature 105 °C and applied voltage 35 V. Testing voltage gradually applied during the time of 300 seconds.

Temperature cycling test was performed in Weiss Technik ShockEvent T/60/V2 - Thermal shock. Each cycle consisted of test temperatures -55 °C and 105 °C with stabilization time on each temperature 15 minutes. Total number of cycles 1000.

Surge voltage test was performed in Memmert UF110M Universal Oven with custom testing device. Total impedance of testing circuit < 33 Ω and testing temperature 85 °C. Each cycle consists of charging from 0 V up to 1.3xUr = 45.5 V and discharging to 0 V with 30 seconds delay at each voltage. Total number of cycles 2000.

Attenuation characteristics

Tested part was mounted on custom FR4 testing boards, see Fig. 2 (a). Measurements were performed on Keysight ENA Network Analyzer E5061B 5 Hz – 3 GHz (impedance 50 Ω). Testing temperature was secured by entering part in ATS-750-M Thermostreamer with minimum 10 minutes for each temperature stabilization.

Direct current measurements

DC resistance was measured with Keithley 2461 SourceMeter on custom jig. Five parts tested.

DC current testing was done with Xantrex XPD18-30 DC Power Supply, parts were mounted on custom FR4 testing board and maximum temperature on part surface was monitored by FLIR A500 Thermal Camera connected to control computer see Fig. 2 (b). For measurements at elevated temperature custom FR4 testing board with part was heated up by hot plate for 15 minutes. DC current was applied gradually from 0 to 8 A in 1 A steps with 5 minutes stabilization at each condition before temperature reading. With four parts tested. One part was tested up to destruction with DC current applied gradually from 0 A in 1 A steps with 5 minutes stabilization at each condition before temperature reading.

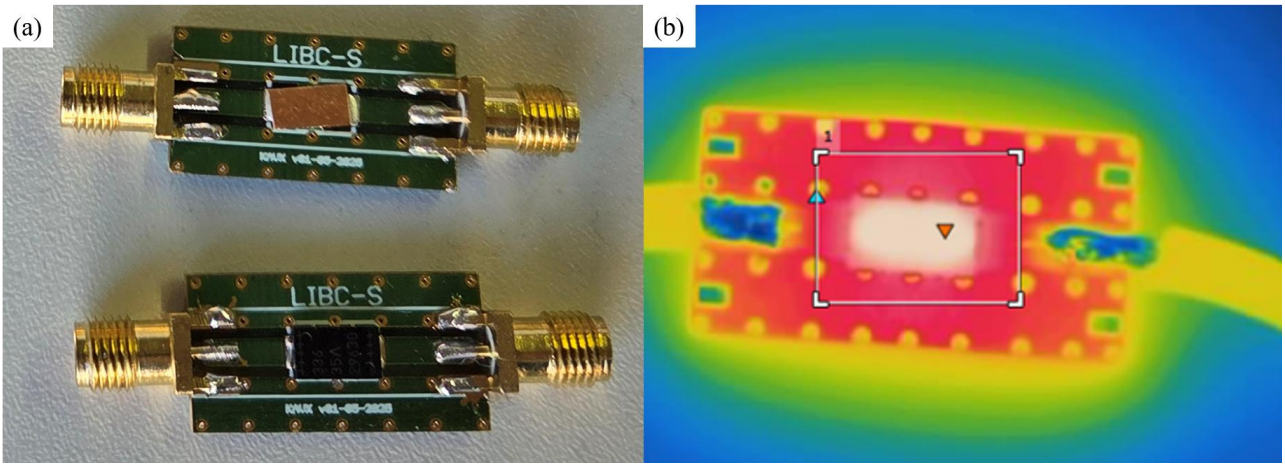


Fig. 2. (a) Testing board for S21 parameters with mounted short circuit (top) and tested unit (bottom), (b) Direct current testing thermal camera view of experimental set-up.

RESULTS AND DISCUSSION

Electrical characteristics of LIBC can be evaluated from multiple views. First, basic electrical parameters of polymer tantalum capacitors such as capacitance, DF, ESR and DCL and reliability such as biased high temperature test, surge voltage testing…. Then there are parameters that have more focus here than on standard polymer tantalum capacitors such as attenuation. And at the latest there are completely new parameters of applicable DC current through capacitor. All those are being evaluated in the following chapter.

LIBC showed excellent stability of electrical parameters with frequency and temperature, good stability in basic reliability tests, wide frequency filtering capabilities and capability to transfer high DC current through.

Basic electrical parameters

Effect of DC bias on Capacitance mean results showed in Fig.3. (a). Standard catalog values are provided with 2 V bias and 120 Hz. LIBC parts show excellent capacitance stability. Maximum relative change of capacitance with applied bias compared to 0 V bias was < 0.5 % at 120 Hz and < 3.5 % at 20 Hz. Difference in capacitance for different levels of voltage bias was negligible.

Effect of temperature on Capacitance Results shown in Fig. 3. (b). Parts showed growing capacitance with high temperatures and small capacitance decrease with low temperature. With high temperatures, capacitance at 120 Hz grows relatively to capacitance at 25 °C by 8 % at 85 °C, 11 % at 105 °C and 21 % at 125 °C. For low temperature capacitance at 120 Hz decreases by -3 % at -55 °C.

Basic reliability tests

LIBC parts showed good stability in basic reliability test see Fig. 4. All parameters in all tests are in proposed catalog limits that will be derived from standard polymer tantalum SMD capacitors.

Dry heat test caused slight ESR shift. Other parameters stayed stable. ESR increase is connected to thermal oxidation of polymer cathode.

Dry heat test with applied voltage caused ESR and DF shift, DCL and CAP stayed stable. These shifts are caused by thermal oxidation of polymer cathode and applied voltage bias effect.

Temperature cycling test caused ESR shift, other parameters stayed stable. This shift is caused by different thermal expansion coefficients of used materials lead frame, molding resin, anode and cathode layers.

Charge discharge test caused DF shift and CAP decrease, ESR and DCL stayed stable. These shifts are due to cathode degradation caused by fast charging/discharging that is connected to local heating of cathode.

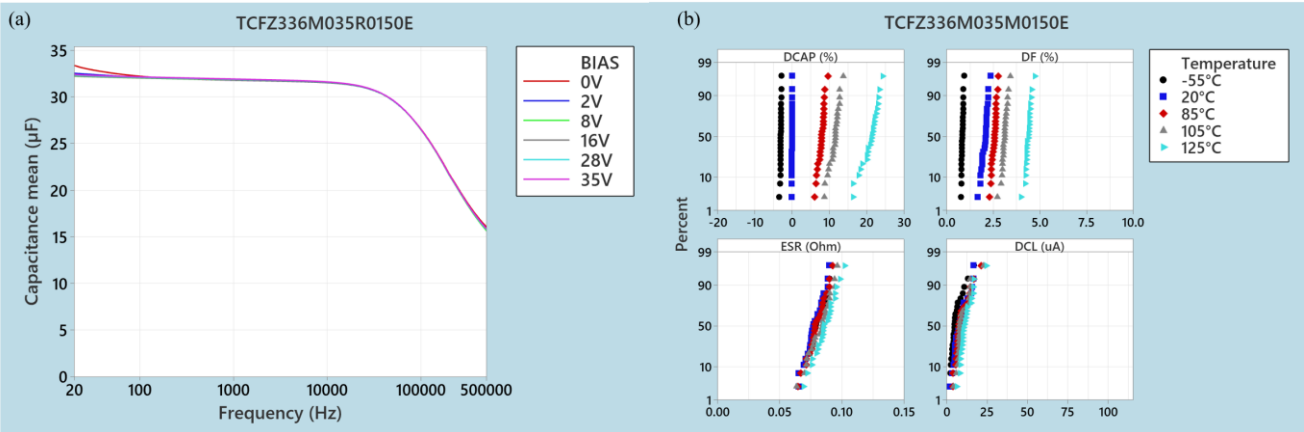


Fig. 3. (a) Capacitance means of TCFZ336M035R0150E dependency on DC bias, (b) Electrical parameters of TCFZ336M035R0150E dependency on temperature.

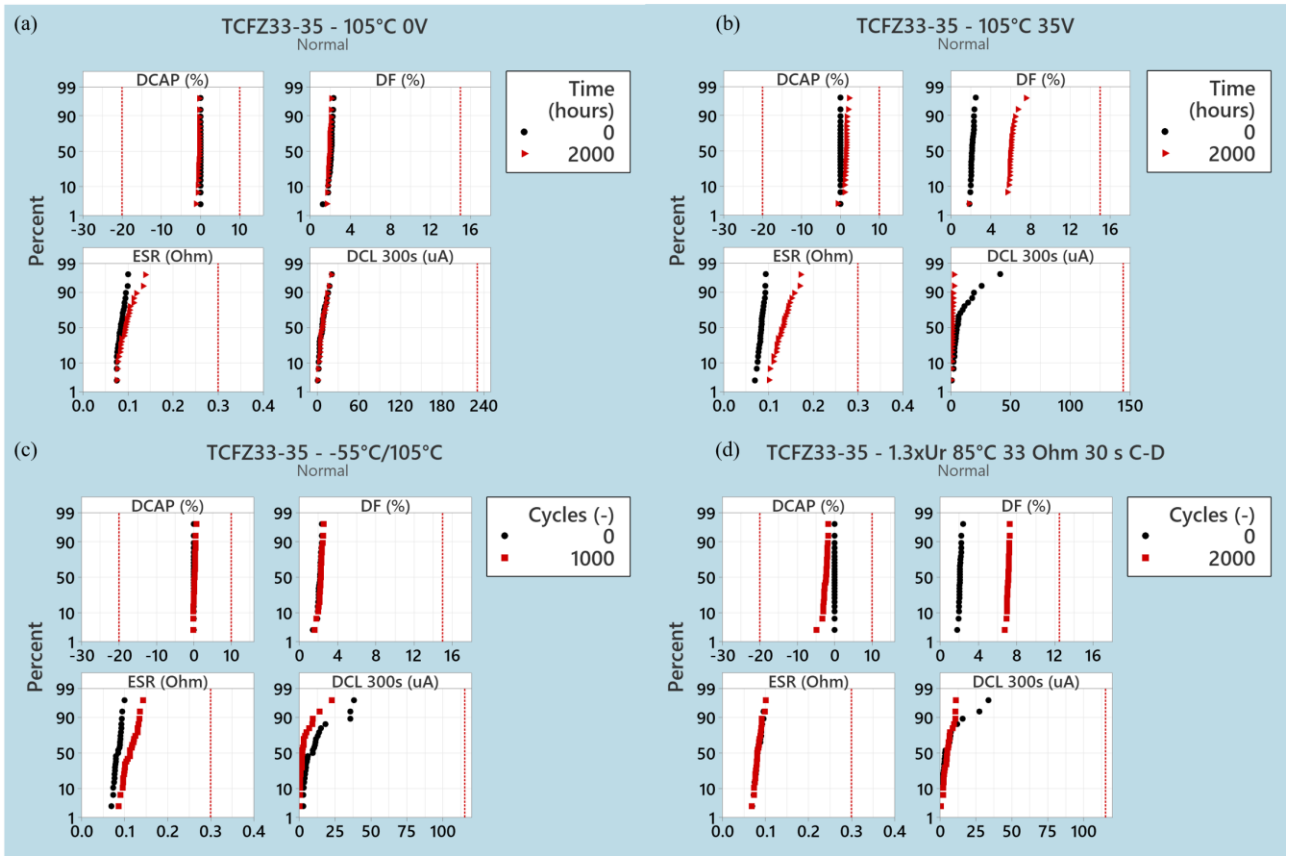


Fig. 4. Results of basic electrical parameters in reliability testing of TCFZ336M035R0150E (a) Dry heat test 105 °C, (b) Dry heat test with applied voltage 105 °C 35V, (c) Temperature cycling test -55 – 105 °C, (d) Charge discharge test 85 °C 45.5V 33 Ohm 30 seconds charge-discharge.

Attenuation characteristics

High frequency filtering performance of LIBC can be demonstrated by attenuation and Impedance frequency characteristics. There is capability of wide frequency filtering of LIBC parts with S21 attenuation below -30 dB from 6 kHz up to 3 GHz see Fig. 5. Attenuation is stable in wide temperature range as well. With temperatures ranging from -55 °C up to 125 °C, there are small differences in attenuation at frequencies below 10 kHz due to capacitance dependency on temperature which was discussed above, see Fig. 3 (b).

Direct current measurements

Construction with wire through gives LIBC new parameters: DC resistance and maximum DC current, both measured between two positive terminals.

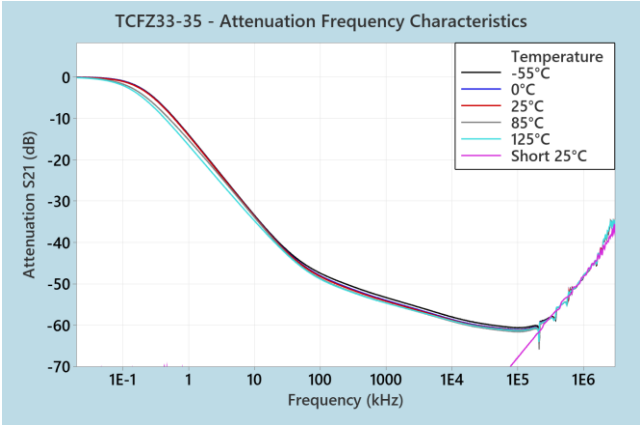


Fig. 5. S21 attenuation frequency characteristics of TCFZ336M035R0150E at multiple temperatures.

Flowing DC current is heating up every component which it flows through. Maximum value for exact component is given based on its resistance, temperature stability of materials (when the part melts, loses its shape/function) and heat conductivity that provides cooling.

On LIBC parts maximum allowed heating of part by DC current will be limited to 30 °C same as AC ripple current specification [6]. This is affected by a DC resistance of the part between two positive terminals and heat dissipation performance which is connected to materials, case size and construction of part.

Experimentally measured values of DC resistance of parts between two positive terminals is (26.5 +- 0.2) mΩ. Theoretical resistance of the tantalum wire through the part with radius r = 0.12 mm and length of L = 6.6 mm is calculated in (1). Resistivity of tantalum $(1.337 \pm 0.003) \cdot 10^{-7}$ Ω · m [7].

$$R_t = \rho \frac{L}{\pi r^2} = 1.337 \cdot 10^{-7} \frac{6.6 \cdot 10^{-3}}{\pi (1.2 \cdot 10^{-4})^2} = 19.5 \text{ m}\Omega \tag{1}$$

Difference between theoretical value of 19.5 mΩ. and measured value (26.5 +- 0.2) mΩ. can be explained by omission of copper lead frame and lead frame – wire connection contributions.

Direct current measurement data are presented on Fig. 6. Temperature change was below 10 °C up to 3 A. In regard to expected limitation of maximum temperature change 30 °C of the component average change of 33.7 °C was recorded with applied current of 6 A. Result for part pre-heated on the hot plate were comparable near identical to parts tested at 25 °C, see Fig. 6. One part was tested to destruction at 25 °C and it failed at 13 A and maximum surface temperature of 260 °C. Withstanding 5 minutes on each amperage step previously.

By using thicker 0.5 mm wire DC resistance of part could be theoretically lowered by approximately 15 mΩ, when all the other variables such as lead frame and welding would stay the same. This could result in 52 % higher applicable DC current. Making future designs even more capable handling DC load.

SUMMARY

New product of Kyocera AVX LIBC based on tantalum polymer technology proved its excellent electrical performance in this paper. They showed good parameters stability with bias and temperature in compact SMD design, together with high DC current capabilities. This can be preferred option in applications where size and weight of the system are crucial such as portable devices or even military and space applications.

With LIBC designers are getting new powerful tools for wide frequency AC signal filtering with very low attenuation. These capacitors can be used in power supply lines and signal lines for EMI suppression, broadband I/O filtering, and/or power supply line conditioning. In applications such as micro power supplies, micro-DC-DC converters, switched-mode power supplies, microswitches and decoupling on FPGA. They can replace multiple component network of MLCCs with resistors and inductors with single chip solution, improving system reliability, size and weight.

As we are at an early stage of adoption and utilization of LIBC parts we expect further improvement of performance and wider portfolio in the future both to the lower voltage with high capacitance and higher voltage. Together with possibility of higher DC current ratings on future designs. Tantalum polymer LIBC are definitely products to watch.

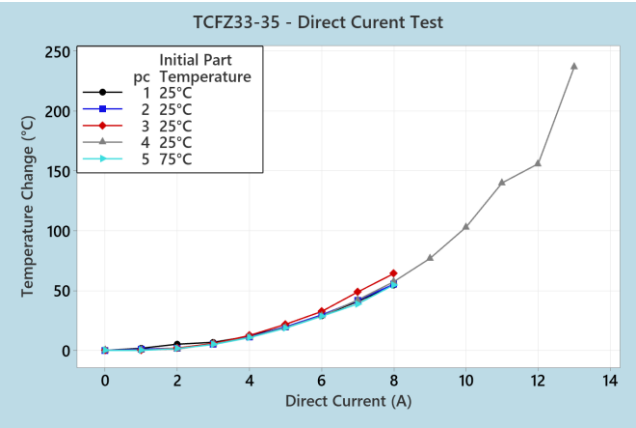


Fig. 6. Results of direct current testing of TCFZ336M035R0150E.

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