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Next Generation of High Voltage, Low ESR SMD Tantalum Conductive Polymer Capacitors Exceeds 100V Milestone

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INTRODUCTION

Tantalum capacitors designed for high voltage applications (above 25V) have been used for many years in telecommunication, industrial, automotive or other high reliability applications. The conventional high voltage tantalum capacitor design is using a manganese dioxide cathode that provides good reliability, stability and robustness. Nevertheless there are certain limitations. First of all it is the operating voltage – even with optimized processes of dielectric formation, rated voltages of such parts are mostly limited to 50 or 63V. The other limitation is ESR. Very low ESR values have been achieved by using special anode shape designs such as multianodes or fluted anodes, but further ESR decrease is limited by low conductivity of manganese dioxide. Also a thermal runaway failure mode of the conventional MnO_2 tantalum capacitors is a concern for some surge current intensive circuits. Thus higher voltage derating 50% minimum is recommended in surge current intensive circuits that further limit the maximum operating voltage of conventional tantalum capacitors.

Conductive polymer cathode material has been proved to provide a solution that addresses ESR reduction and reduces ignition failure mode. Nevertheless, until recently, working voltage of tantalum conductive polymer capacitors was limited to approximately 20V due to the maximum achievable breakdown voltage of such capacitors. Reasons for this limitation have been discussed in [1], where authors suggested hypothesis based on the reduction of effective dielectric thickness. Cracks in dielectric can be filled by in situ produced conductive polymer what makes the final thickness of dielectric and thus the breakdown voltage lower. The other referenced paper [2] brought explanation based on the metal-insulator-semiconductor theory, where the metal is the tantalum anode, insulator tantalum pentoxide and the semiconductor is a conductive polymer (like PEDOT). Authors anticipate diode like behavior. The current flow, in an ideal state, at normal polarity is suppressed by a potential energy barrier that increases with applied voltage. Authors also suggested that in the case of in-situ polymerized capacitor the potential barrier at the interface between dielectric and PEDOT is deteriorated by a charge deposited on the dielectric during polymerization. This leads to elevated DCL and lower BDV.

The latest development on polymer materials and introduction of dispersed pre-polymerized intrinsically conductive polymer [1,3,4] has successfully addressed the issues with low BDV and high DCL. New application techniques, completely different compared to in-situ polymerization had to be also developed in order to utilize the potentials of the new materials. Testing results of tantalum polymer capacitors made by the advanced polymerization process can be found in [5]. Besides the fact that there are no polymerization reactions taking place during polymer application, there are much less thermal stresses compared to MnO_2 processes where high temperature is used during formation of MnO_2 electrode. As the result, the new polymer technology can offer not only low ESR and reduced ignition failure mode benefits, but also higher working voltages compared to the conventional MnO_2 technologies [6]. Due to the nature of polymer capacitors surge robustness and reduced ignition failure mode, lower derating 20% can be used. This significantly widen the working range of tantalum capacitors to the new applications such as telecommunications, LED TVs, Notebook power supplies, Industrial applications etc using higher rail voltages.

This article presents potentials and roadmap of the next generation tantalum polymer capacitors expanding its capability towards the high voltage, ultra low ESR capacitors and thus opens a way for new designs with improved power capability within a smaller package, higher output and safer designs.

ULTRA LOW ESR HIGH VOLTAGE SOLUTION

Besides the conductivity of cathode material, keeping the interfaces resistivity as low as possible, optimized design of anode, the overall surface area of a tantalum capacitor anode is one of the most important parameters. Particularly its surface-to-volume ratio defines its ESR value – the higher the overall surface area, the lower the ESR [7]. The high voltage conductive polymer series has been launched and a special focus is paid to ESR minimization. The development effort yielded a brand new category of low ESR high rated voltage tantalum capacitors. Frequency characteristic of E (7343-43) case

22µF 35V polymer multianode capacitor - see Figure 1. The ESR value at 100kHz is about 15mOhms. Such low ESR in combination with high capacitance and small case size has not been achievable by any other technology so far. This may enable to develop a new generation of power supplies with the same power within small dimensions or higher power in the same design as it is available nowadays.

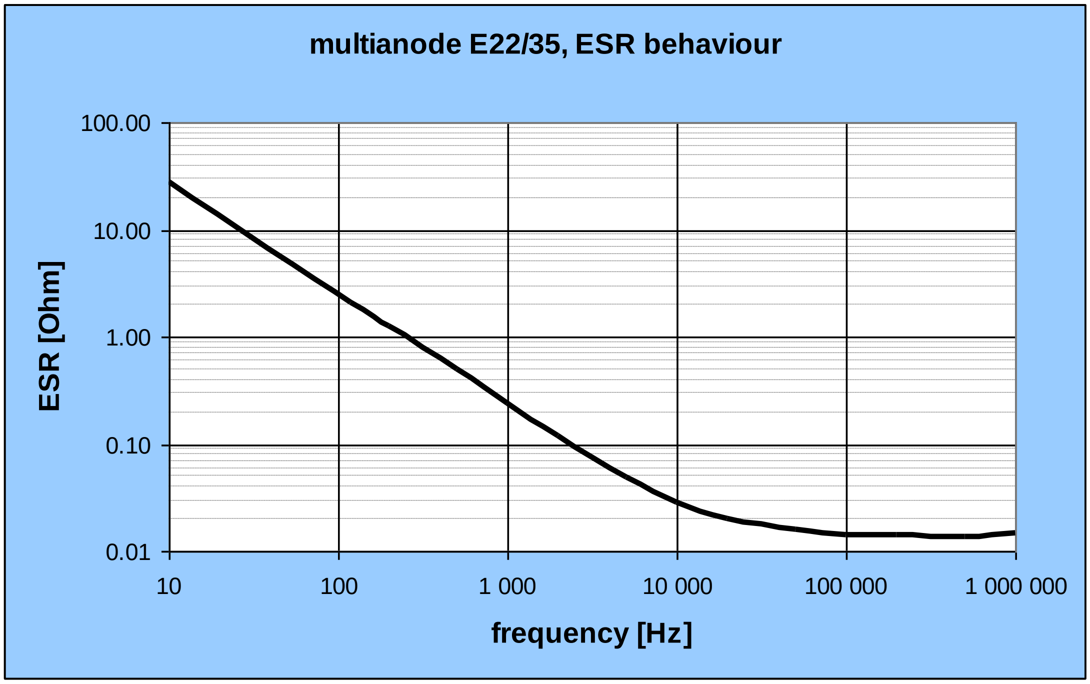

Figure 1: ESR median vs frequency E 22µF / 35 V multianode polymer tantalum capacitors.

INCREASING THE LIMITS OF WORKING VOLTAGE

First 50V rated polymer capacitors have been launched recently, nevertheless there are studies under process to evaluate potential of the new polymer technology for development even higher voltage ratings. 3.3µF 50V conductive polymer single anodes molded in Y (7343-20) case were tested under accelerated conditions. Breakdown voltage of such capacitors in evaluation measurement was in a high range from 130 to 180V. The life tests were carried at elevated temperatures (105 or 125°C) and voltages 50, 75 or 100V (at 105°C), or 33, 49.5 or 66V (at 125°C) on 25 samples of capacitors from every group. Measurements at 50, 75 or 100V of electrical parameters were recorded after 500, 1000 and 2000 hours. DCL distributions are presented at Figures 2 and 3. Values of DCL dropped during the first 500 hours, then slightly grew during the next 500 hours, but no further significant increase was observed during consequent 1000 hours. No failures were observed during the testing, and the DCL shift was significantly below the limit calculated on the basis of rules commonly used for tantalum polymer capacitors. Higher spread of DCL values after 2000 hours at 125°C, 66V and measured at 100V is probably connected with wider breakdown voltage distribution of original parts and thus under such extreme conditions parts with lower breakdown voltage exhibit higher DCL. It is possible to make conclusion based on this life and breakdown voltage data that tested parts could be rated as 50, 63 or even 75V parts. High current surges were applied on 100 parts at 95V and low impedance circuit where peak current recorded reached levels of 200A in order to test the surge robustness of the parts. None of the tested capacitors exhibited failure.

ESR frequency characteristic of E case (7343-43) 10µF 63V are presented in Fig. 4. Furthermore temperature dependency of ESR at 100kHz of multianode parts E (7343-43) case 22µF 35V and 10µF 50V polymer and manganized capacitors are compared at Fig. 5. Very low ESR is typical for broad scale of temperatures in comparison with standard manganized product.

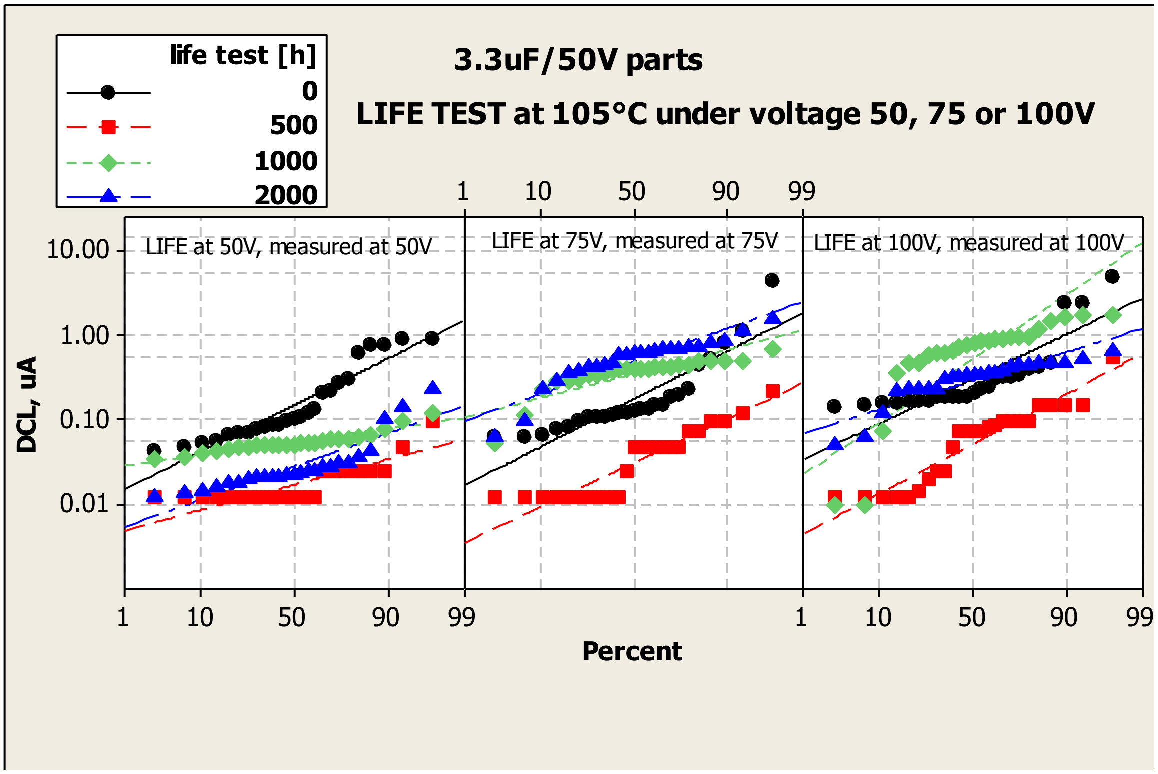

Figure 2: DCL leakage of 3.3µF 50V polymer parts after storage at 105°C and voltage 50, 75 or 100V

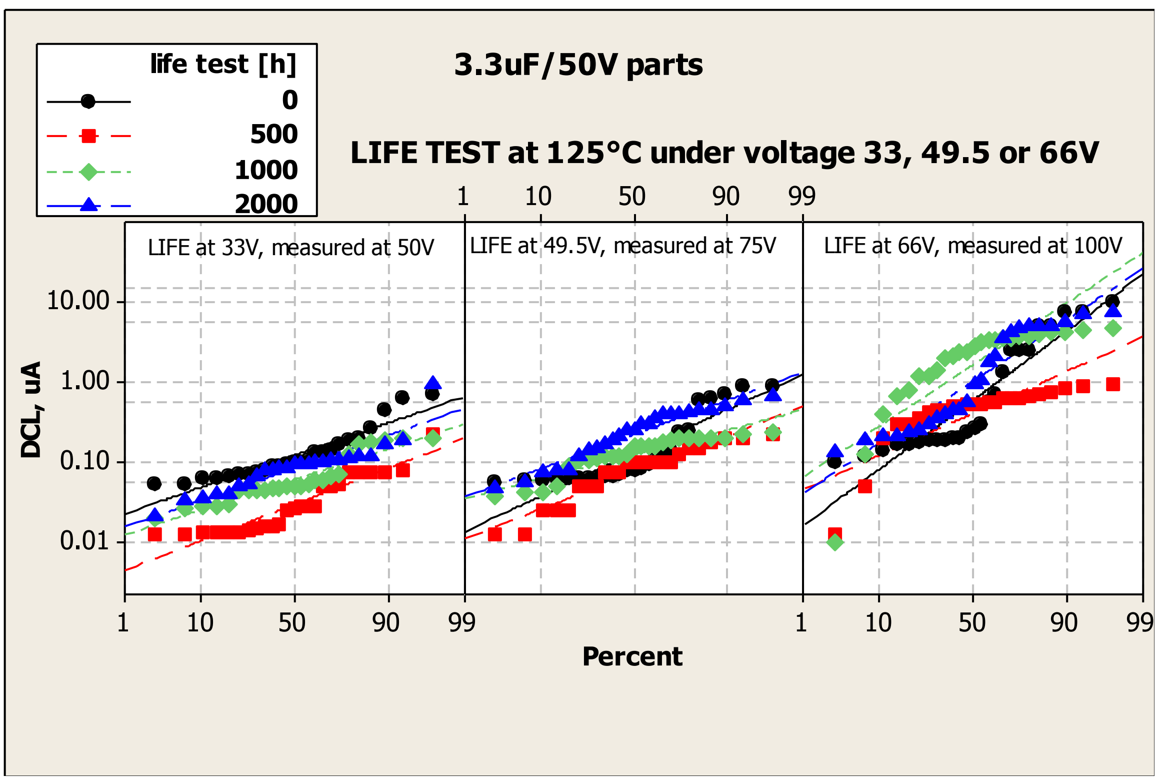

Figure 3: DCL leakage of 3.3µF 50V polymer parts after storage at 125°C and voltage 33, 49.5 or 66 V

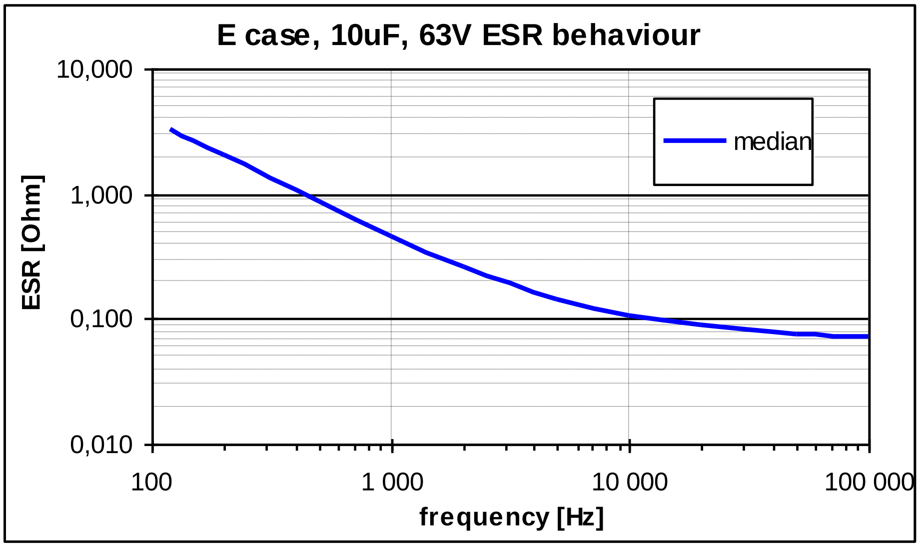

Figure 4: ESR median vs frequency E 10μF / 63V SMD polymer tantalum capacitors.

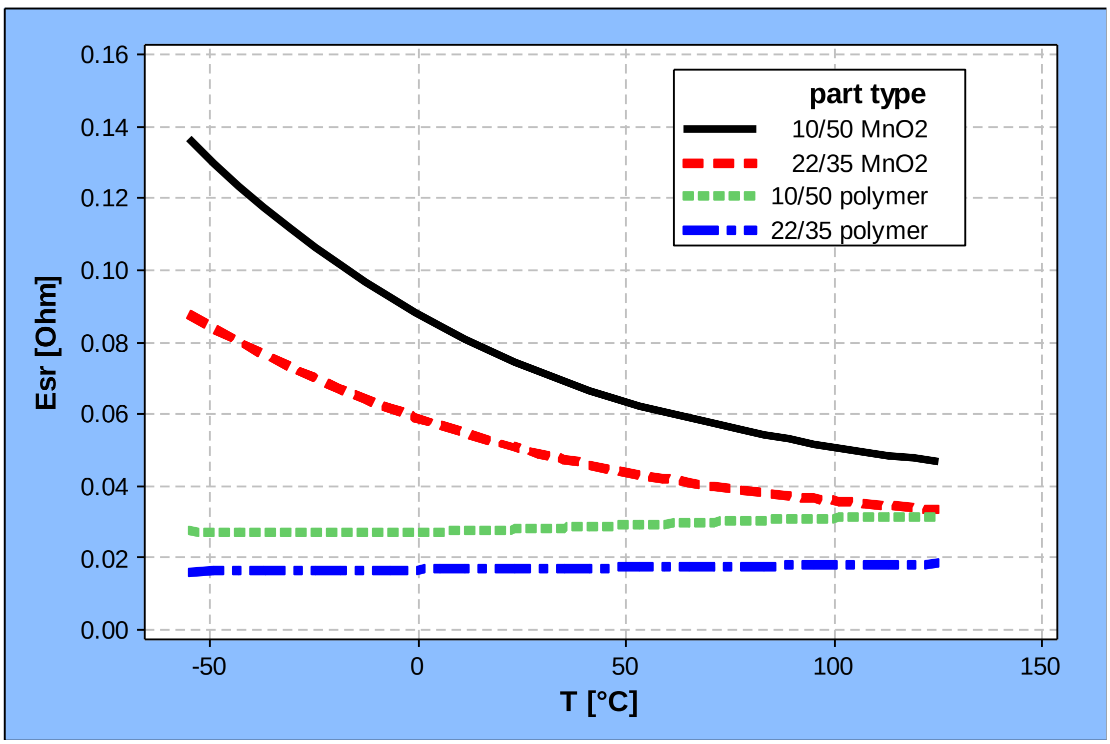

Figure 5: Temperature characteristics of ESR measured at 100kHz

BREAK DOWN VOLTAGE INCREASE

The key parameter that reflects potentially improved quality and increase of working voltage is break down voltage. The increase in uniform distribution of breakdown voltage is a key parameter that reflects an enhanced ability to withstand higher working voltage. An example can be seen in Figure 2 where 3.3µF, 125V rated tantalum polymer capacitors are shown to achieve VBD values higher than 220V.

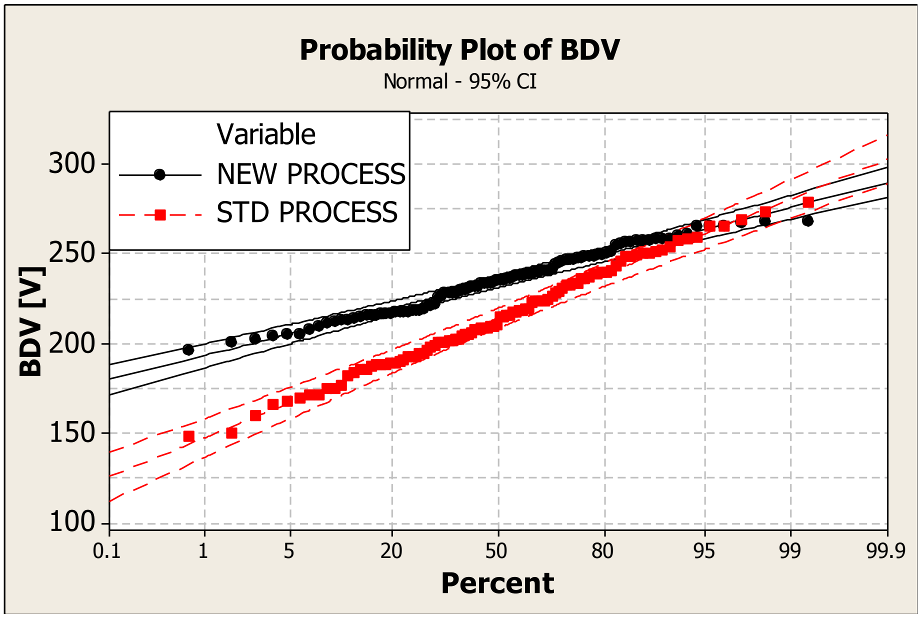

Figure 6 BDV distribution of capacitors 3.3µF prepared by standard and improved processes

Due to the ability of polymer capacitors to withstand surge currents, derating can be maintained at 20%; therefore 63V rated tantalum polymer capacitors are suitable for 48V rails, commonly used in telecomms systems, LED drivers and medium voltage power supplies.

AVX's new 125V tantalum polymer capacitors are available from April 2013. Following the award winning 50V TCJ series capacitor released in 2010 and the 63V and 75V version launched only in spring 2012, the new components offer the benefits of great capacitance, high voltage, and low ESR technology in a small case size. Maintaining 20% recommended voltage derating; TCJ series capacitors significantly extend the usable voltage range.

APPLICATIONS

LED lighting drivers
A wide range of lighting applications use LED technology. For high and medium power applications, constant-current mode driver topology with LEDs connected in series is preferred, as this approach delivers high overall system efficiency and enables PWM dimming. Light levels can be easily matched to the needs of the environment by turning the LED chips on and off at low frequency, starting from 120Hz. The voltage rail in this application is typically in the range of 28-60 VDC. High voltage tantalum polymer capacitors are well suited for such application voltage as 63V rated devices can be used up to 50V; 75V products are suitable for use up to 60V. Additionally, tantalum polymer devices do not exhibit any piezo effect and thus avoid the typical short-comings of ceramics capacitors at such low frequencies. Another advantage that polymer tantalum capacitors have over their ceramic counterparts is an improved mechanical robustness. As rated voltages increase, tantalum polymer devices may also be suitable as input capacitors, as they are more reliable than aluminium electrolytic devices (E-caps) and have no wear out mechanism. This would make them more suitable to match the increasing life expectancy of power supplies in LED lightning systems.

LCD TV

Lower and medium voltage tantalum polymer capacitors are well established in Notebooks and LCD TVs, with D (7343-31) and Y (7343-20) being the favourite case sizes used in DC/DC converters and backlight LED drivers. However, some modern LCD TV architectures with LED backlighting now require a higher output voltage. Typically, a 5V output is dedicated for the microprocessor and the logic circuitry, 12V supplies the TV panel, 24V is used for the audio power amplifiers, and 24V and higher voltages for the backlight.

Telecommunications

Currently-available 63V rated tantalum polymer capacitors with a capacitance range of 0.47 to 15μF and ESR ratings as low as 100mΩ ideally suit applications in telecommunications systems which often use 48V rails and where long lifetime, low ESR and high ripple current capability are the key requirements. Some manufactures of industrial long operational life devices still prefer to use 50% derating safety margin on 48V line, in this case up to 125V SMD tantalum capacitors have been introduced to the market in 2013.

CONCLUSIONS

Conventional conductive polymer CP processes or even MnO_2 processes used in today's manufacturing of tantalum capacitors limit the breakdown voltage to lower level than theoretically achievable. The new CP materials and processes have been developed and proved in its ability to increase the rated voltage up to 125V voltage that was released to market in April 2013. The key for such improvement is utilization and optimization of processes that lead to uniformly distributed higher breakdown voltage. The recommended derating policy will be maintained to 20% and thus the 63V polymer capacitors will present a solution for 48V rail voltages commonly used in many industrial and telecom applications.

The increasing capability of tantalum polymer capacitors to operate at higher voltages delivers a combination of highest capacitance and smallest case size at these voltage ranges; this has not previously been possible using other capacitor technologies. These and other benefits, including high stability and excellent reliability, are opening up opportunities for designers to shrink the size of their products and add new functionality in wide range of applications. Additionally, tantalum polymer devices can eliminate the shortcomings associated with conventional capacitor technologies that operate in similar voltage ranges by eliminating the piezo effect and offering better mechanical robustness than ceramic capacitors, achieving higher capacitance and voltage per volume than film capacitors and better reliability and lifetime than aluminium polymer technology devices.

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