

# HIGH PERFORMANCE WET TANTALUM CAPACITORS FOR SPACE APPLICATIONS

**Michael L. Mosier**

*Vishay Intertechnology*  
2813 West Road  
Bennington, VT 05201 U.S.A.  
1-317-341-3714  
mike.mosier@vishay.com

## Overview

Wet tantalum capacitors have been used in space applications for over 40 years, from the very early days of the manned space flight programs. The original devices were axial leaded, hermetically sealed, silver case capacitors. The all tantalum case CLR79 series was developed specifically for space applications, to provide a reverse voltage and increased ripple capability. Subsequently several extended capacitance styles were developed, but they lacked the overall performance of the early all tantalum design. Vishay has now developed and introduced the T16 series which provides the high capacitance values needed for new designs, while incorporating the higher performance requirements needed for avionics and space applications.

## Background

The wet electrolytic tantalum capacitor was the first tantalum capacitor. It is in reality two electrochemical capacitors in series. It consists of a porous sintered tantalum anode, upon which has been grown a thin film of tantalum oxide ( $Ta_2O_5$ ) which becomes the dielectric. The secondary capacitor plate is a combination of three materials. The first two are the “wet” liquid electrolyte and the actual metal case which contains the liquid. The critical component however is the “cathode plate” which is attached internally to the case wall. The two capacitor components in series are represented by the formula

$$C_T = 1 / (1/C_1 + 1/C_2)$$

where  $C_T$  = total or rated unit capacitance,  $C_1$  = anode capacitance, and  $C_2$  = cathode/case capacitance.

To achieve the maximum capacitance from the anode, the cathode/case capacitance must be as large as possible.

The original wet tantalum capacitors, developed by Mallory and Sprague, were non-hermetic or elastomer sealed designs provided in axial leaded or through-hole silver cases. The designs incorporated a sintered tantalum anode or pellet with a cathode which was plated or deposited upon the internal case wall. In almost all designs, the electrolyte is a 55 % sulfuric acid solution. The case must be a material which is impervious to this electrolyte.

While this electrolyte provides the excellent performance achieved by the wet tantalum, it also makes it critical to have a superior seal. While the non-hermetic designs were acceptable in many applications, they could lose capacitance due to electrolyte loss/evaporation over a long period of time. The next generation incorporated a high quality hermetic glass-to-metal seal. This design generally provided very good electrical performance. It was able to achieve long term established reliability as the MIL-PRF-39006 “CLR65” and “CLR69” styles. It was approved to meet all avionics and aerospace requirements specified at that time. Unfortunately, it had an internal performance flaw. When subjected to any reverse bias voltage or excess ripple current over long time periods, particles from the “negative cathode” silver case would migrate or plate themselves on the “positive tantalum anode.” This would result in increased DC leakage or even a short circuit condition under extreme conditions.

In 1975 under the direction of the Marshall Space Flight Center, Sprague Electric Company developed the CLR79 series. This tantalum case design provided a true 3 V reverse capability, as well as increased ripple current handling. The structurally superior all tantalum case provided increased thermal shock, mechanical shock, and vibration characteristics. Following its introduction, the CLR79 design rapidly became the wet tantalum capacitor of choice for

ALL TANTALUM HERMETIC SEAL  
(MILITARY SPECIFICATION MIL-PRF-39006)

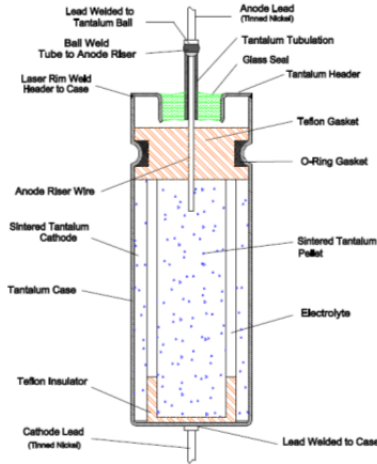


Fig. 1. 135D and MIL style CLR 78/81/90/91 capacitor construction

AMS (avionics, military, and space) applications. Then the technology roadmap stalled. This all- tantalum case design, with its tantalum powder cathode sleeve, had a capacitance limitation. Future increases were impossible to achieve due to a cathode design which took-up all the internal case space (see Fig. 1). The CLR79 remained a very good capacitor, but with nowhere to “grow.”

In 1988, Tansitor Electronic, Inc. introduced the SuperTan® series of all tantalum case wet tantalum capacitors. The ST and STE series, with their proprietary palladium cathode system, provide extremely high capacitance values, up to 10 000  $\mu\text{F}$ . In the industry standard T4 case size, a 75 V CLR79 capacitor can achieve a rating of 110  $\mu\text{F}$ . The CLR81 doubled this capacitance value to 220  $\mu\text{F}$  at 75 V. The ST or DLA Drawing 93026 moved the capacitance upward to 470  $\mu\text{F}$ , while the STE extended it further to 750  $\mu\text{F}$  at 75 V. See Table 1.

Table 1. Capacitance growth of T4, 75 V wet tantalum capacitors

Style	CLR79	CLR81	ST / DLA 93026	ST / DLA 10011
Capacitance	100 $\mu\text{F}$	200 $\mu\text{F}$	470 $\mu\text{F}$	750 $\mu\text{F}$

These hybrid designs which incorporate a tantalum anode with a non-tantalum cathode provided a significant step forward in wet tantalum capacitor technology (see Fig. 2).

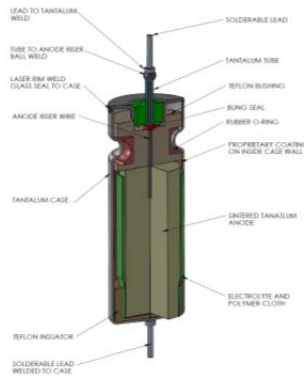


Fig. 2.

Much higher CV (capacitance-voltage) ratings were now available within the same industry standard case sizes. These designs provided reverse voltage (1 V) capability and the mechanical shock/vibration levels match the industry base levels of 100 g shock and 20 g sine vibration. These designs are widely accepted and used in many ground-based and avionics applications. These are very good capacitors for many applications, but Vishay wasn't satisfied.

In 2008, Vishay began a development program for a new wet tantalum capacitor design. Utilizing technology available as a broad based supplier of many types of electronic components, Vishay developed and recently released the T16 series of wet tantalum capacitors. The T16 combines many of the attributes of the CLR79 capacitor but with the extended capacitance of the Vishay SuperTan® series. The T16 has high capacitance values but with a true reverse voltage characteristic, similar to that of the CLR79. It is also has the ability to withstand higher vibration levels, along with 300 thermal shocks. In this paper, I will outline the development, testing, and high performance of this state-of-art all tantalum case wet tantalum capacitor designed specifically for avionics and space applications.

### T16 Development

The T16 series of wet tantalum capacitors was the direct result of ongoing customer requests for an improved performance capacitor from our SuperTan® or ST series. The major area of performance improvement most often requested was a higher vibration characteristic, to include random vibration.

In the past three years, Vishay initiated several wet tantalum development projects. One project was to continue to expand or increase the capacitance values available in our ST series. This project was and continues to be successful, resulting in the STE series which now offers the higher capacitance in the industry standard axial T4 case size. An example is the newly released 240µF/125V STE, which more than doubles the 82µF/125V found in the MIL-PRF-39006/25 or CLR81 series.

A second project was to continue the growth of the Vishay 134D series, which is a high-temperature (+200°C) version of the SuperTan® capacitor. This has also been successful with the addition of many of the STE ratings, such as the 1000µF/60V, to the 134D datasheet for use in high-temperature applications.

The third project was to improve the environmental and mechanical performance of the extended capacitance all tantalum case wet tantalum capacitors. The baseline performance was listed as shown in Table 2.

Table 2. Comparison of “hybrid capacitors” versus CLR79/81 series.

Test	Axial	Large Can	CLR79/81 “H”
Thermal shock	30 cycles	5 cycles	300 cycles
Reverse voltage	< 1 V	0	3 V
Shock	100 g	50 g	500 g
Vibration, high frequency	20 g	20 g	80 g
Vibration, random	None	12 g	54.4 g

The project goal was to provide an all tantalum, wet tantalum capacitor which would provide a true reverse and random vibration capability, as well as improve all other attributes as much as reasonably possible within time and cost guidelines established.

While the tantalum case with a GTMS seal and tantalum anode was a given, all other design factors were reviewed. The key factor was identified as the cathode material. As a long term wet tantalum manufacturer, Vishay had several options to review. While the tantalum powder sleeve used in the CLR79 is the best option, it would not allow the increased anode size needed to extend the capacitance value significantly. The older carbon dag and palladium cathodes did not provide the series capacitance required. Deposited platinum and ruthenium provide high capacitance, but cannot withstand the reverse voltage and vibration profiles. In the end, we knew it had to be a tantalum anode and tantalum cathode combination.

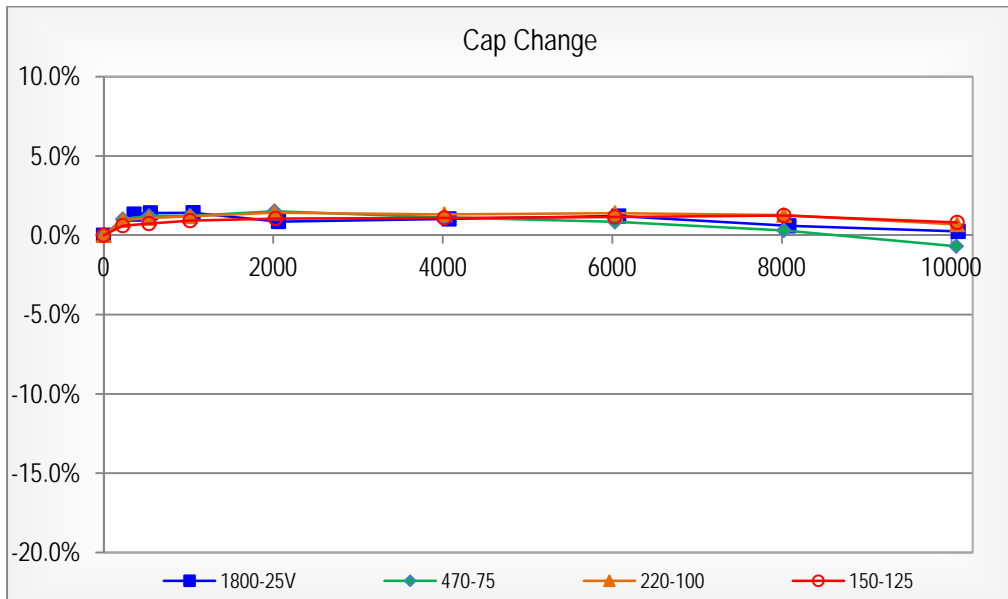
In 2009, Vishay developed a proprietary process to deposit a tantalum powder layer on the internal case wall. This resulted in a structurally thin, but extremely strongly adhered, high capacitance cathode. To eliminate any excess experimental design factors, initial development and testing was limited to the historically largest or T4 case

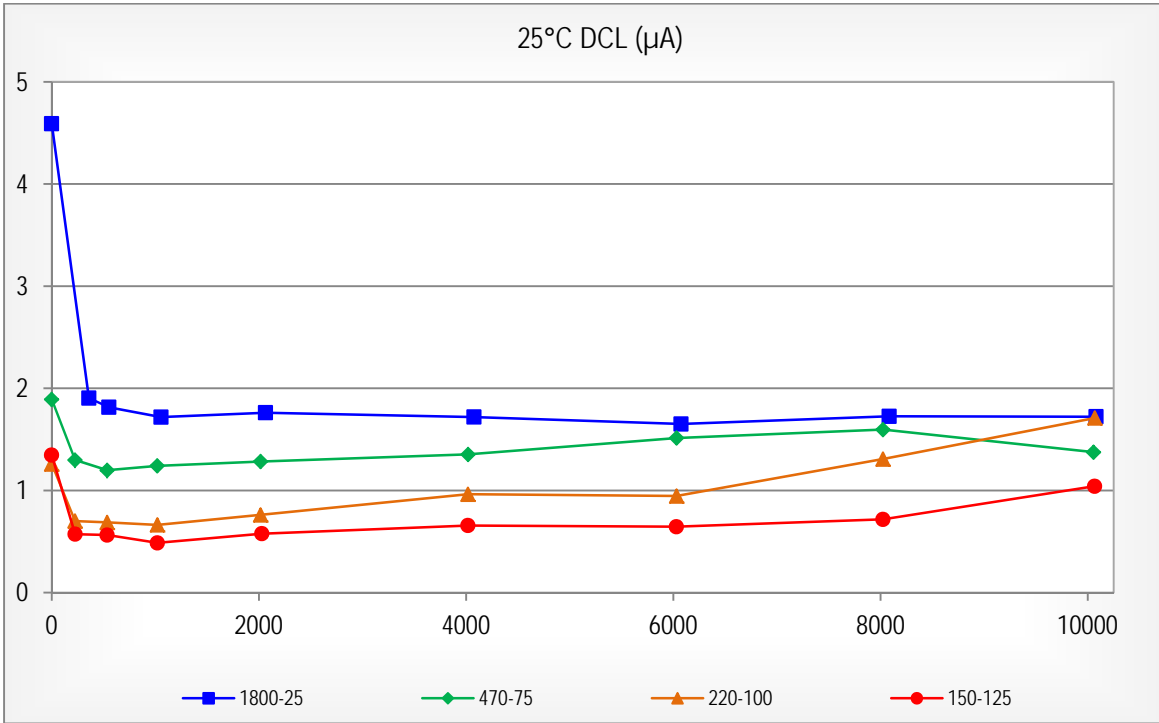
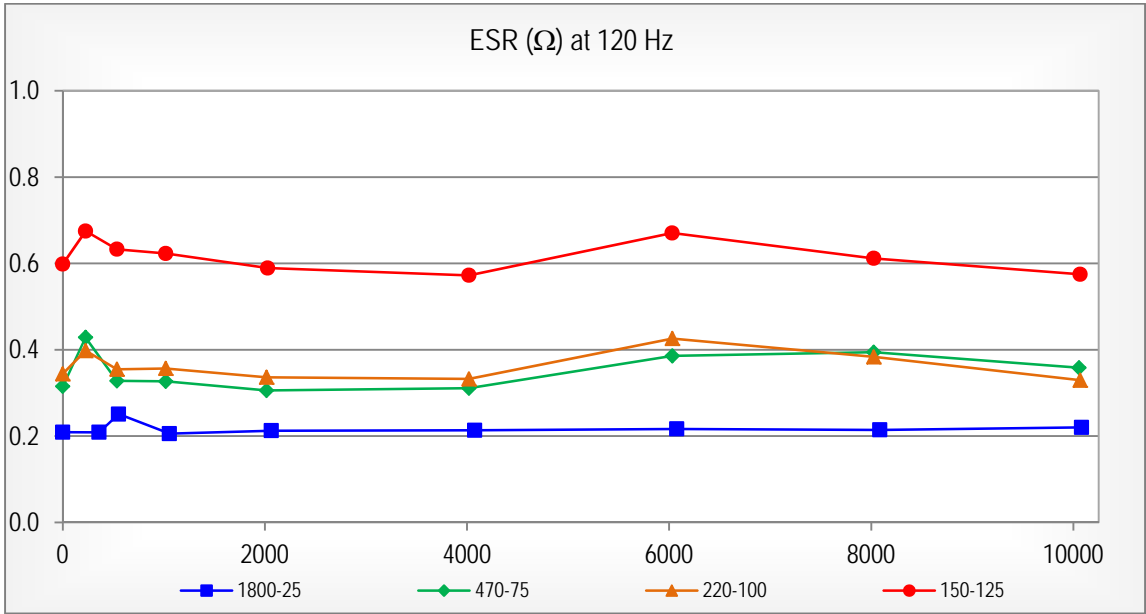
SuperTan® sizes ratings. Initial testing of the four T4 case size ratings showed that it could withstand a 1.5 V reverse bias without any degradation of the capacitor. The new design could also withstand 300 thermal cycles and a random vibration level of 27.7 g RMS. A summary of test results are shown below in Table 3.

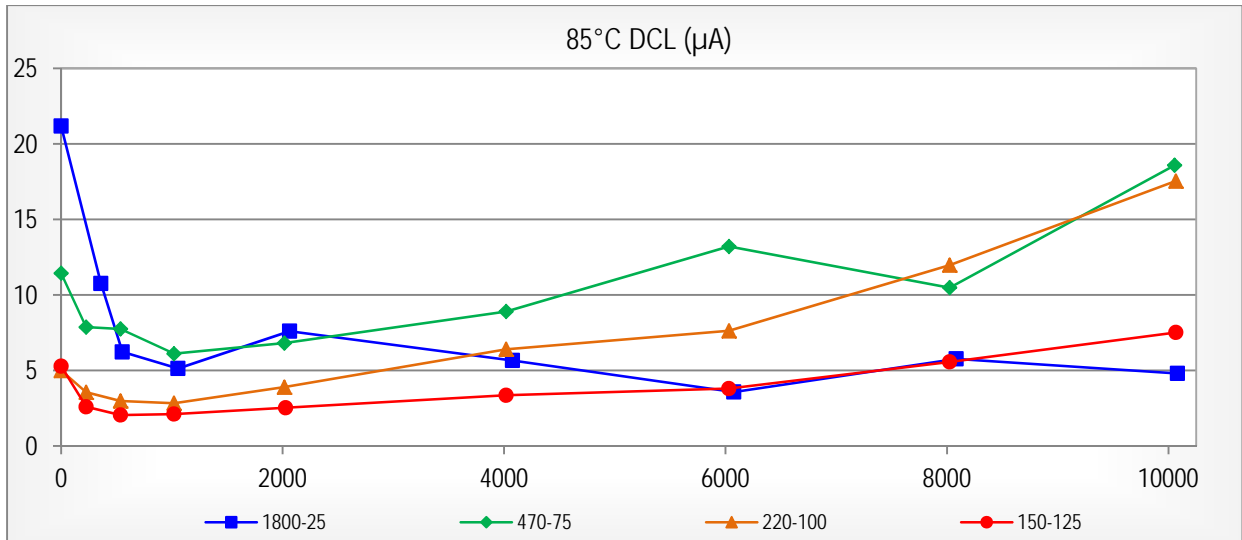
Table 3. Tabulated test results

Test/Conditions				1800µF-25V		470µF-75V		220µF-100V		150µF-125V	
				#	Pass	#	Pass	#	Pass	#	Pass
Group 1	Constant Voltage Conditioning	DSCC Dwg 93026	Table 1		✓		✓		✓		✓
	DC Leakage				✓		✓		✓		✓
	Capacitance				✓		✓		✓		✓
	DF/ESR				✓		✓		✓		✓
				30	23	27	27				
Group 3	Shock (Specified pulse)	ML-STD-202 (method 213)	Condition I (100g)		✓		✓		✓		✓
	Vibration (high frequency)	ML-STD-202 (method 204)	Condition D (20g)		✓		✓		✓		✓
	Random vibration	ML-STD-202 (method 214)	Condition II-G (27.78g)	4	✓	4	✓	4	✓	4	✓
	Thermal Shock	ML-STD-202 (method 107)	Condition A (300 cycles)		✓		✓		✓		✓
Group 4	Low temperature storage	ML-STD-810 (method 502)	--	3	✓	--	✓	--	✓	3	✓
Group 5	Temperature stability	--	Table 1	13	✓	13	✓	13	✓	13	✓
	Reverse voltage	As for CLR 79/81	1.5V	3	✓	3	✓	3	✓	--	✓
Group 6	85°C life test	ML-STD-202 (method 108)	2,000 hours	13	✓	13	✓	13	✓	13	✓
Group 8	125°C life test		2,000 hours	5	✓	5	✓	5	✓	5	✓

Samples were then placed upon life test at both +85 °C and +125 °C. As can be seen from the +85 °C data, the capacitance and ESR remained extremely stable for the entire 10,000 hours. The DC leakage tends to increase slightly over time, but remains well below the specified limits when measured at both +25 °C and +85 °C.

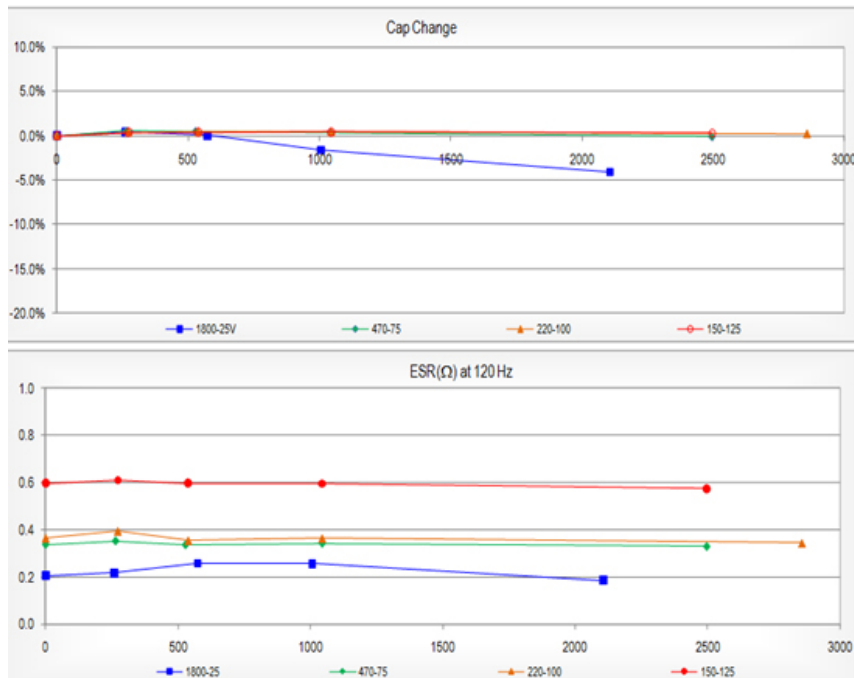




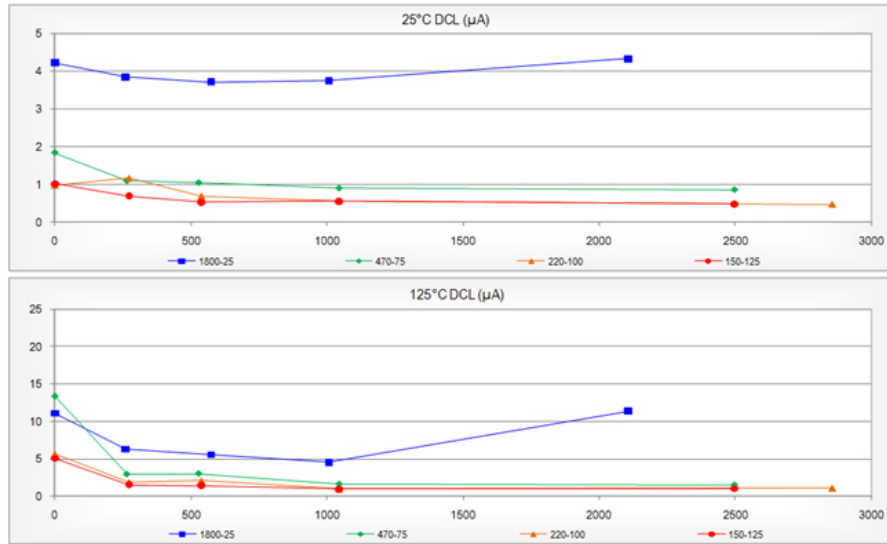


The +125 °C life test results are also very good. All four ratings tested stayed within 5 % of initial capacitance measurements over the 2000 hours of test. Three ratings stayed within a 1 % range. The ESR values also were very stable over the entire test period. DC leakage measurements were once again well below the specified maximum limits for all ratings at the end of test.

### 125°C Life Test Results



## 125°C Life Test Results



While the T16 design met initial project goals, we wanted to continue testing to establish design capability.

Additional lots were built and samples re-submitted for the vibration sub-group of MIL-PRF-39006. While initially we tested to only 20 g high frequency “sine wave” vibration, the objective now was to push higher. Initial testing at 80 g found acceptable results. Ongoing testing, however, found some random failures. We are continuing our development. Testing at the 50 g level, however, found that all test samples were acceptable, and results were repeatable.

Table 4. 50 g Test Results

Rating / Case		680µF-50V / D	470µF-75V / D	220µF-100V / D	150µF-125V / D
Date Code		1131DJ	1131DG	1115DD	1131DH
Sample Size		4	4	4	4
<b>TEST SEQUENCE</b>	MIL-PRF-39006 Req. Paragraph				
Shock (specified pulse)	3.11	pass	pass	pass	pass
Vibration (sine) / <b>50 g</b>	3.12	pass	pass	pass	pass
Random vibration	3.26	pass	pass	pass	pass
Thermal shock	3.13	pass	pass	pass	pass

Testing has also continued on the reverse voltage characteristic. Some preliminary results show that we capable of 3 V. Samples of new lots have been submitted for testing to confirm capability and repeatability.

### Summary

Utilizing technology available as a broad based supplier of many types of electronic components, Vishay developed and recently released the T16 series of wet tantalum capacitors. The T16 combines many of the attributes of the CLR79 capacitor but with the extended capacitance of the Vishay SuperTan® series. The T16 has high capacitance values but with a true reverse voltage characteristic, similar to that of the CLR79. It is also has the ability to withstand higher vibration levels, along with 300 thermal shocks. This state-of-art all tantalum case wet tantalum capacitor was designed specifically for avionics and space applications.

The T16 series of all tantalum case wet tantalum capacitor can provide the extended capacitance and voltage ratings, along with the high performance required for tomorrow’s avionics and space applications. The T16, T4 case size,

provides 150  $\mu\text{F}$  at 125 V, with a true 1.5 V reverse potential. It also is rated for 300 thermal shocks, 100 g of mechanical shock, 27 g RMS of random vibration, and 50 g of sine vibration. The T16 design is also available today to the requirements of the DLA drawing 13017.

## References

- [1] Stuart Libby, "Wet Tantalum Electrolytic Capacitors in Energy Storage Applications". C.T.T., Inc. 1995.
- [2] A.M. Holladay, "History of the CLR79 All-Tantalum Wet Slug Electrolytic Capacitor".
- [3] Walter F. England, "Tantalum-Cased Wet-Slug Tantalum Capacitor". Sprague Electric Bulletin TP 77-4, 1977.
- [4] John D. Moynihan, "The Tantalum-Cased Tantalum Capacitor". Sprague Electric Bulletin TP 77-5, 1977.
- [5] W.M. Rowe and P.H. Eisenberg, "Factors Affecting the Reliability of Wet Tantalum Capacitors". Reliability Physics Symposium, 1967.