WHITE PAPER

PC-5 EVALUATION

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Introduction

The Parts Analysis and Assurance (PA&A) group at the Johnson Space Center (JSC) evaluated the PowerCache Ultracapacitor, part number PC5, from Maxwell Technology. These capacitors are used in the ISS PEEK (Portable Electrical Equipment Kit). The PEEK hardware provides electrical power extension cables and outlets as well as 120 to 28Vdc converter units to power portable electrical hardware on the ISS.

Ultracapacitors, also known as double-layer capacitors, incorporate new technology and material not used in other capacitors. The ultracapacitor stores electrostatic energy by polarizing the electrolytic solution and can be charged and discharged hundreds of thousands of times. An electrode-electrolyte interface with activated carbon fibers allows obtaining extremely high capacitance per unit area. There are several methods of construction, but JSC tested one where an insulator separates two activated carbon electrodes. These electrodes consist of an aluminum foil with a carbon binder mixture deposited in it. The set is tightly rolled with leads attached to the aluminum foils. An electrolyte is added and the component is sealed.

This technology is suited for applications where there is a need of providing large bursts of power, for fractions of seconds up to several minutes, with the ability of rapid recharge. During a power outage, power levels from the ultracapacitor can be held until power returns. Due to their large energy storage capability, ultracapacitors have found applications in the electric vehicle industry, memory back-up devices in appliances such as videocassette recorders, typewriters, wristwatches, and measuring devices. The advantage of ultracapacitors is that they are smaller in size than other capacitors of the same value. This allows for greater packaging efficiency. The typical voltage rating for a single ultracapacitor is 2.3Vdc. The components can be stacked in series to achieve the proper operating voltage for any specific application.

Space Application

The PEEK project had the J SC RITF (Receiving and Inspection Test Facility) evaluate these commercial capacitors to determine their suitability in space flight hardware. The evaluation consisted of a series of tests to determine their performance across a range of environmental stress conditions. The following tests were conducted:

- Visual Inspection
- Fine Leak Test
- Accelerated Life (Six tests)
- Static Burn-in (five tests)
- Reverse Bias

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• Self-Heat via Rapid Charge-Discharge (three tests)
• Over Voltage Pulse (eleven tests)
• Thermal Shock (one test)
• Destructive Physical Analysis
• Electrical Parameter testing at periodic intervals

The RITF test results demonstrate that the ultracapacitor is suitable for use in the ISS PEEK hardware, as well as in other equipment that is used in ISS manned pressurized modules. Ultracapacitor pedigree in military or aerospace applications is presently not available and no specific standard has been developed for screening and testing purposes. However, the PowerCache ultracapacitor survived the environmental tests in MIL-STD-810 "Environmental Engineering Considerations and Laboratory Tests". A series of tests were performed at JSC Receiving Inspection and Test Facility (RITF) to determine the reliability of the ultracapacitor under different conditions. The PC5 ultracapacitor is rated at 4 Farads at 2.7Vdc maximum and the operating temperature is between -20ºC to +70ºC.

Investigation

Fifteen ultracapacitors were tested, all receiving the fine leak test and visual inspection. The ultracapacitors are hermetic ally sealed; therefore, the fine leak test was performed in accordance with MIL-STD-883 test method 1014 during initial inspection and at the completion of all tests. The ultracapacitors did not exceed the leakage limit imposed by the tes t method.

The ultracapacitors were divided into groups of five and ten. Ten ultracapacitors received accelerated life tests, which consisted of six dynamic tests. The ultracapacitors were charged-discharged cycled 6000 times, at three different temperatures (-20ºC, +25ºC and 65ºC). They were first cycled 1000 times and then 5000 times. The charge voltage was 2.3V and each cycle was approximately 1.5 minutes in duration. They were subjected to a total of 18000 cycles. The monitored parameters (C, ESR, and LC) did not change significantly as a result of these tests.

A total of 480 hours of static burn-in while charged at 2.5V was performed on the ten ultracapacitors. The burn-in consisted of 96 hours at +60ºC, 48 hours at –20ºC, 48 hours at –5ºC, 48 hours at 0ºC and 240 hours at +85ºC. The 240 hours of burn-in resulted in a change in capacitance, ESR and LC. However, the parameters remained within the manufacturer's specification.

For the reverse bias test 5 ultracapacitors were connected in reverse polarity. They operated this way for 5000 charge-discharge cycles at 65ºC. The duration of the cycles was approximately 1.5 minutes in duration. After 5000 cycles, the capacitance of the 5 ultracapacitors was reduced to almost half and the ESR almost tripled.

Ten ultracapacitors were subjected to 100 cycles of thermal shock between –55ºC to 85ºC. The ultracapacitors were not connected to any circuit or power for this test. No significant change in the parameters resulted at the completion of the test.

Two ultracapacitors were tested for self-heat via rapid charge-discharge. The test consisted of charge-discharge at a rate fast enough to cause internal heating. When the desired temperature was reached, the ultracapacitors continued to be cycled for five minutes at that temperature. No significant change in the parameters resulted from the test.

Two ultracapacitors were subjected to over voltage pulse test. The test consisted of voltage pulses of varying amplitude and of varying duration. The test did not result insignificant change in the parameters.

Destructive Physical Analysis (DPA) was performed in accordance to MIL-STD-1580 on a sample. The sample was a representation of the 15 ultracapacitors. The sample was examined externally and internally. No anomalies were found.

Conclusion

One test, the reverse bias test, caused damage to the ultracapacitor as expected. These are polarized devices and are not to be used in reverse polarity. In all the other tests, the ultracapacitors continue to work as advertised within the specification. The 240 hours of burn-in at 85ºC, resulted in drift of capacitance, ESR and LC. However, this change was never beyond the specification and the capacitor continued to work properly. Two of the tests designed to overstress the part, self-heat via rapid charge-discharge and the over voltage pulse, did not cause any damage.

The results of these tests show that the PowerCache ultracapacitor from Maxwell is highly reliable when used within the manufacturer's specification. The series of tests performed on the ultracapacitor showed the suitability of the device in the space flight crew compartment. The ultracapacitor demonstrated that it could operate beyond the manufacturer's operating parameters. However, care must be taken in the operating temperature. The ultracapacitor operating temperature is –20ºC to +70ºC but the space and military operating temperatures exceed this range.