The Lowest ESR, Surface-Mount, High-CV Capacitor

In the never-ending quest to improve the performance of the tantalum capacitor, KEMET continues this effort with the T530 surface-mount capacitor. With the focus on reducing the ESR of these capacitors, the T530 combines technologies introduced with the T510 (multiple anode, tantalum anodes with MnO₂), and the T520 (replacing the MnO₂ with a conductive polymer), to create a 1000 uF chip capacitor with typical ESR below 7 milliohms.

The RC-Ladder, cathode materials, and geometry

The capacitive elements within the tantalum pellet structure offer the cumulative charge storage for the capacitor (the total capacitance). The cathode material and the geometry of these paths dominate the resistive magnitude connecting these elements. The deepest capacitive element defines the worst or highest resistive connection to these elements. The loss of capacitance with increasing frequency begins with these deepest elements (Cn). These are the first elements to stop responding to the circuit’s current stimulus. As frequency increases, the next deepest elements stop responding, and this continues with increasing frequency, until the outermost capacitive elements are the only elements responding (C1, C2).

Reducing this effect and moving the response to a higher frequency is simply a matter of reducing the resistance connecting these capacitive elements to the external contacts of the device. We can accomplish this with two proven methods: first, we can change the geometry of the pellet to reduce the length of the connection to the deepest capacitive element; and secondly, we can reduce the resistivity by changing the cathode material.

Both of these factors have been implemented, independently, in prior designs. The T510 utilized multiple-anode designs to reduce the effective ESR. These devices were, effectively, multiple low-ESR pellets (T495 pellets), with manganese dioxide cathode systems, packaged into three and six-pellet chip designs. This design in the three-pellet structure reduced the penetration depth to the deepest capacitive element by one-third compared to the single anode structure. In addition, the three pellets are in parallel and like resistors in parallel, offer an effective resistance of one-third of each individual element. The six-pellet structure offered one-sixth the penetration depth, and one-sixth effective resistance in parallel when replacing the same effective volume attainable in a larger, single anode structure. At the time they were first released, these capacitors offered the lowest ESR in the industry.

With the introduction of the conductive polymers in the T520 series as a replacement material for the manganese dioxide cathode systems, the lower resistivity of this material realized single pellet tantalum capacitors with ESR levels approaching those of the T510. The material change alone nearly duplicated the parallel pellet effect.

The next step is to combine the polymer with the parallel pellet structure.
T530 – Parallel pellets with polymer cathodes

We were able to achieve a 1000 uF chip structure with the “X” case dimension (7.3mm x 4.3mm x 4.3mm), using three pellets in place of the single pellet. This offering at 3 VDC is a deviation from the T510 as that 1000 uF chip is in an “E” case structure (7.3mm x 6.0mm x 3.8mm) but rated at 4 VDC. Yet, because of the derating recommendations, the polymer T530X may be used at 2.4 VDC (80%Vr) versus the T510E usage limited to 2.0 VDC (50%Vr).

From the attached graph, the ESR at 100 kHz is around 6.0 milliohms for the T530X, 13 milliohms for the T510E, and 56 milliohms for the T491. The minimum ESR achieved by these devices is 4.3, 10.6, and 43 milliohms for the T530X, T510E, and T491E, respectively. The capacitance roll-off is affected by this difference in that the T491E has the most capacitance loss at 100 kHz (~93%), the T510E has a lower loss (~48%), while the T530X has the least amount of roll-off (~19%).

Both of these factors will allow the designer to require fewer capacitors of the T530X than any of these three. The piece count may be similar between the T510E and T530X, but keep in mind that these chips are very different in size (board real estate more efficient with the “X”), and cost (the “E” case uses six pellets instead of three, which has a huge impact on manufacturing efficiency).

Polymer benefit – no ignition

As with the T520 series, the polymer carries another effect that is important to designers—no ignition. The absence of the large amounts of oxygen found within the manganese dioxide materials eliminates the exothermic type of ignitions on failure. This failure mode usually increases with the volume of the anode in MnO2 systems, but the polymer eliminates this effect.

Unlike the T520 in which the standard offering was rated at +105°C, all of the T530 product will be processed to enable its maximum application temperature to be +125°C.

Applications

The leakage currents of the T530 will restrict some applications; like the T520, the leakage currents will be three times those typical of the manganese dioxide cathode system. In battery decoupling, this additional leakage can diminish the battery life and require more frequent charging. As a rule, tantalum capacitors should not be used in high-impedance circuits. Generally, for the MnO2 system devices, the self-healing can be severely affected if the currents are restricted to levels below 100 microamperes. For the polymer-based system, this current level must not be restricted to less than one millampere. In a 10-volt circuit, the MnO2 based systems should have less than 100 k-Ohms of series resistance, and the polymer should have less than 10 k-Ohms of series resistance.

This product is built for +125°C operation. It has the non-ignition characteristic of the polymer cathode system. It can handle much larger ripple currents, as its ESR is so much lower than conventional, single-anode structures. It is ideally suited for power supply (switch-mode power supplies, or SMPS) and regulator circuits. It approaches an “ideal” power decoupling capacitor.