QUESTIONS AND ANSWERS

Some commonly asked questions regarding Tantalum Capacitors:

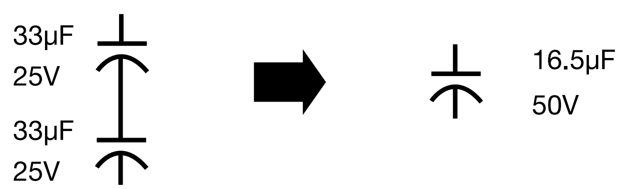
Question: If I use several tantalum capacitors in serial/ parallel combinations, how can I ensure equal current and voltage sharing?

Answer: Connecting two or more capacitors in series and parallel combinations allows almost any value and rating to be constructed for use in an application. For example, a capacitance of more than 60μF is required in a circuit for stable operation. The working voltage rail is 24 Volts dc with a superimposed ripple of 1.5 Volts at 120 Hz.

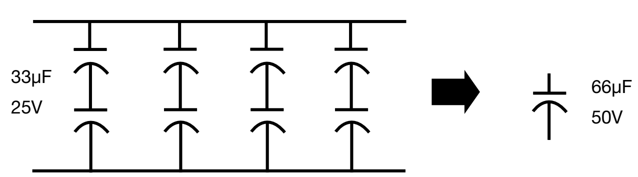
The maximum voltage seen by the capacitor is V_{dc} + V_{ac}=25.5V

Applying the 50% derate rule tells us that a 50V capacitor is required.

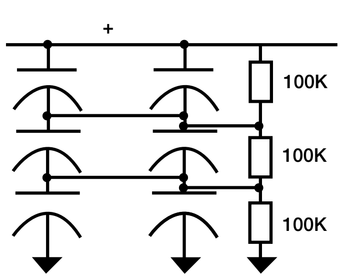
Connecting two 25V rated capacitors in series will give the required capacitance voltage rating, but the effective capacitance will be halved, so for greater than



60μF, four such series combinations are required, as shown.



In order to ensure reliable operation, the capacitors should be connected as shown below to allow current sharing of the ac noise and ripple signals. This prevents any one capacitor heating more than its neighbors and thus being the weak link in the chain.



The two resistors are used to ensure that the leakage currents of the capacitors does not affect the circuit reliability, by ensuring that all the capacitors have half the working voltage across them.

Question: What are the advantages of tantalum over other capacitor technologies?

Answer:

1. Tantalums have high volumetric efficiency.
2. Electrical performance over temperature is very stable.
3. They have a wide operating temperature range -55 degrees C to +125 degrees C.
4. They have better frequency characteristics than aluminum electrolytics.
5. No wear out mechanism. Because of their construction, solid tantalum capacitors do not degrade in performance or reliability over time.

Question: If the part is rated as a 25 volt part and you have current surged it, why can't I use it at 25 volts in a low impedance circuit?

Answer: The high volumetric efficiency obtained using tantalum technology is accomplished by using an extremely thin film of tantalum pentoxide as the dielectric. Even an application of the relatively low voltage of 25 volts will produce a large field strength as seen by the dielectric. As a result of this, derating has a significant impact on reliability as described under the reliability section. The following example uses a 22 microfarad capacitor rated at 25 volts to illustrate the point. The equation for determining the amount of surface area for a capacitor is as follows:

$C = ((E) (E_o) (A)) / d$

$A = ((C) (d)) /((E_o)(E))$

$A = ((22 \times 10^{-6}) (170 \times 10^{-9})) / ((8.85 \times 10^{-12}) (27))$

$A = 0.015$ square meters (150 square centimeters)

Where C = Capacitance in farads

A = Dielectric (Electrode) Surface Area (m^2)

d = Dielectric thickness (Space between dielectric) (m)

E = Dielectric constant (27 for tantalum)

E°= Dielectric Constant relative to a vacuum (8.855×10^{-12} Farads x m^{-1})

To compute the field voltage potential felt by the dielectric we use the following logic.

Dielectric formation potential = Formation Ratio x Working Voltage

= 4 x 25

Formation Potential = 100 volts

Dielectric (Ta_2O_5) Thickness (d) is 1.7×10^{-9} Meters Per Volt

d = 0.17 μ meters

Electric Field Strength = Working Voltage / d

= (25 / 0.17 μ meters)

= 147 Kilovolts per millimeter

= 147 Megavolts per meter

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No matter how pure the raw tantalum powder or the precision of processing, there will always be impurity sites in the dielectric. We attempt to stress these sites in the factory with overvoltage surges, and elevated temperature burn in so that components will fail in the factory and not in your product. Unfortunately, within this large area of tantalum pentoxide, impurity sites will exist in all capacitors. To minimize the possibility of providing enough activation energy for these impurity sites to turn from an amorphous state to a crystalline state that will conduct energy, series resistance and derating is recommended. By reducing the electric field within the anode at these sites, the tantalum capacitor has increased reliability. Tantalums differ from other electrolytics in that charge transients are carried by electronic conduction rather than absorption of ions.

Question: What negative transients can Solid Tantalum Capacitors operate under?

Answer: The reverse voltage ratings are designed to cover exceptional conditions of small level excursions into incorrect polarity. The values quoted are not intended to cover continuous reverse operation. The peak reverse voltage applied to the capacitor must not exceed:

10% of rated DC working voltage to a maximum of 1 volt at 25°C.

3% of rated DC working voltage to a maximum of 0.5 volt at 85°C.

1% of category DC working voltage to a maximum of 0.1 volt at 125°C.

Question: I have read that manufacturers recommend a series resistance of 0.1 ohm per working volt. You suggest we use 1 ohm per volt in a low impedance circuit. Why?

Answer: We are talking about two very different sets of circuit conditions for those recommendations. The 0.1 ohm per volt recommendation is for steady-state conditions. This level of resistance is used as a basis for the series resistance variable in a 1% / 1000 hours 60% confidence level reference. This is what steady-state life tests are based on. The 1 ohm per volt is recommended for dynamic conditions which include current in-rush applications such as inputs to power supply circuits. In many power supply topologies where the di / dt through the capacitor(s) is limited, (such as most implementations of buck (current mode), forward converter, and flyback), the requirement for series resistance is decreased.

Question: How long is the shelf life for a tantalum capacitor?

Answer: Solid tantalum capacitors have no limitation on shelf life. The dielectric is stable and no reformation is required. The only factors that affect future performance of the capacitors would be high humidity conditions and extreme storage temperatures. Solderability of solder coated surfaces may be affected by storage in excess of 2 years. Recommended storage conditions are: Temperature between -10ºC – +50ºC with humidity 75% RH maximum and atmospheric pressure 860 mbar-1060 mbar. Terminations should be checked for solderability in the event an oxidation develops on the solder plating.

Question: Are any recommendations/limitation for capacitor selection in parallel combination of capacitors?

Answer: Higher performance series CA45U are designed to provide lower ESR values and make the product more robust against current surges. The design differences make the better performance distribution of parameters, namely ESR is lower and tighter compared to the general purpose CA45 series. The surge current load in a parallel combination of capacitors is therefore shared more evenly amongst the capacitors and thus it is better suited for this application.

In a parallel combination is is strongly recommended to use the low ESR series of Tantalum Capacitors such as CA45U Do not combine different series of manufacturers within one parallel combination.

Question: What level of voltage derating is needed for Tantalum Capacitors?

Answer: For many years whenever people have asked a tantalum capacitor manufacturer about what were the safe guidelines for using their product, they spoke with one voice “a minimum of 50% voltage derating should be applied”. This message has since become ingrained and automatic. This article challenges this statement and explains why it is not necessarily the case.

The 50% rule came about when tantalum capacitors started to be used on low impedance sources. In such applications, the available current is high and therefore a risk of failure is inherent. Well established by empirical methods and covered in MIL-STD 317, was the fact that the amount of voltage derating has a major influence on the failure rate of a tantalum capacitor (Figure 1). Indeed, from rated voltage to 50% of rated voltage is an improvement in failure rate of more than 100.

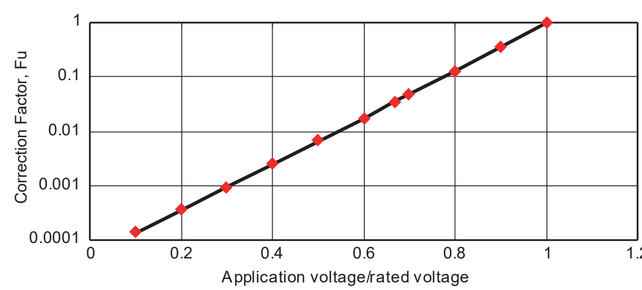
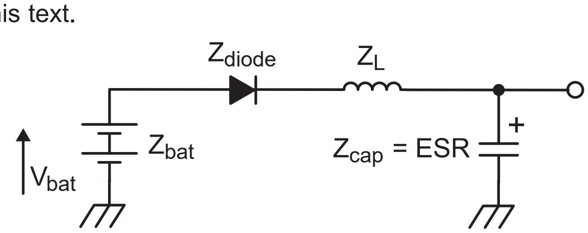


Figure 1

It was also proved that the same was true of dynamic, high current pulse conditions[1], hence the recommendation.

Now let us look more closely at the type of circuits in use. Below is a simple circuit which will be discussed further in this text.



Let us assume this is a 2 cell battery system, therefore

$V_{bat} = 3.2$ Volts

Also, let us assume

$Z_{bat} = 60\ m\Omega$, $Z_{diode} = 70\ m\Omega$, $Z_{cap} = 120\ m\Omega$, $Z_L = 70\ m\Omega$

If the "50% rule" was followed, the designer should chose a 6.3V rated capacitor.

The total circuit impedance of the system is 320 mΩ. So by Ohm's law the peak current would be 10 Amps.

This exceeds the test conditions used by Hongda to screen its product for high current pulses, so a risk of failure exists. Clearly a minimum of a 10 volt rate capacitor is required in this application.

As a general rule of thumb, the maximum current a tantalum capacitor can withstand (provided it has not been damaged by thermomechanical damage[2 3] or some other external influence) is given by the equation:

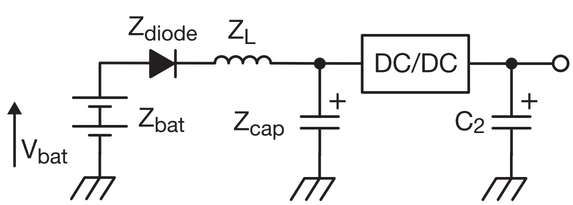
$I_{max} = V_{rated} / (1 + \text{Catalog ESR})$

So for example for a 100µF 10V D case capacitor (Catalog ESR = 0.9 Ohms), this would be:

$I_{max} = 10 / (1 + 0.9) = 5.2$ Amps

In some circuits, because of size restrictions, a tantalum capacitor may be the only option available. If this is the case, Hongda recommends a PFET integrator be used to slow the voltage ramp at turn on, which in effect reduces the peak current, and therefore reduces the risk of failure[4].

Now, let's consider a continuation of the circuit with the addition of an LDO or DC/DC convertor.



The risk of a high surge current being seen by the capacitor in location C_2 is very small. Therefore if we assume the voltage rail is 2.8 volts and the maximum current seen by C_2 is <1.5 Amps, a 4 volt capacitor could be able to be used in this application.

This all seems like good news, but as always, there are some downsides to using a part nearer to its rated voltage. The first is the steady-state life, or MTBF. The MTBF of a tantalum capacitor is easily calculated from MIL-STD 317 or the supplier's catalog data. An example is given below:

Assume operating temperature is 85°C and circuit impedance 0.1 Ohms/volt ($F_T = 1$).

For a 10 volt rated capacitor on a 5 volt rated line, the failure rate is:

$F_R = 1\%/1000 \text{ hours} \times F_T \times F_U \times F_R$

$= 1\%/1000 \text{ hours} \times 1 \times 0.007$ (from Figure 1) $\times 1$

$= 0.007\%/1000$ hours

$MTBF = 10^5 / F_R$

$= 14,285,238$ hours

$= 1,631$ years

For a 6.3 volt rated capacitor on a 5 volt rated line, the failure rate is:

$F_R = 1\%/1000 \text{ hours} \times F_T \text{ X } F_U \text{ X } F_R$

$= 1\%/1000 \text{ hours} \times 1 \times 0.12$ (from Figure 1) $\times 1$

$= 0.12\ \%/1000$ hours

$MTBF = 10^5 / F_R$

$= 833,333$ hours

$= 95$ years

The second factor to be considered is that the more derating applied to a tantalum capacitor, the lower the leakage current level (Figure 2). Therefore a part used at 50% of its rated voltage will have more than 3 times better leakage levels than one used at 80%.

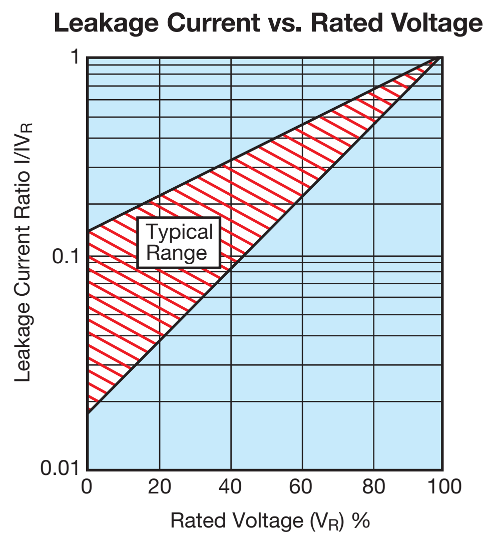


Figure 2

One final point worthy of mention with the introduction of higher reflow temperatures with the introduction of lead-free solders is that voltage derating can help to reduce the risk of failures due to thermomechanical damage during reflow.

To summarize, a tantalum capacitor is capable of being used at its rated voltage or close to it, provided that the user obeys the rules outlined in this document and is prepared for the reduced steady-state life performance and higher leakage current levels this would produce.