Why and how to use tantalum capacitors in Satellites secondary DC Bus?

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INTRODUCTION

In theory, each capacitor technology – including tantalum – has many advantages for use in satellites secondary BUS designs. This paper will detail what tantalum capacitors would bring to your design.

The global energy supply in satellites is usually powered by a big DC/DC converter composed of two buses. The first bus at the primary generally works at high voltages (you would typically find film capacitors such as Exxelia PM90). The other bus at the secondary works at lower voltages (10 to 100V). On the secondary, the most critical function ensured by capacitors is the general output filtering, where you basically have the choice between three technologies: ceramic, film and tantalum (solid or wet).

Ceramic and films have many interests, such as a low ESR, a capability to withstand reverse voltage and safe failure modes.

But tantalum capacitors have two major strengths that make them also an interesting solution:

- Energy density (see table1.),
- Price for the function.

Table 1. Technical characteristics by dielectric

	Ceramic	**Film**	**Solid tantalum**	**Wet tantalum**
Max capacitance value at 50V	3.3µF	27µF	47µF	750µF
Volume to achieve 10mF at 50V (mm^3)	881 664	1 980 000	160 325	35 412
Capacitance per volume at 50V (µF/cm^3)	11.3	5.03	62.14	281.3

Indeed, most of the time, output filtering are made of high value of capacitance (could be several 10mΩ for example), and so that means a lot of capacitors in film or ceramic, and also a high surface on the PCB. The function, in this configuration is becoming big and expensive.

TECHNOLOGICAL TRENDS WERE NOT OPTIMISTIC FOR TANTALUM MARKET

Two trends appeared these past few years for this type of applications and were not profitable to tantalum capacitors:

- Increase of the operating voltage: 50V or higher is becoming standard, sometimes up to 100V.
- Solid Tantalum failure mode has become a threat for some designers.

Regarding the first point: applying the standard derating rules for space, customers need to look for capacitors with a rated voltage of:

- 200V for solid tantalum
- 170 V for ceramic, film or wet tantalum.

That's where things got complicated, as today the existing voltage ranges for tantalum capacitors don't exceed 150V:

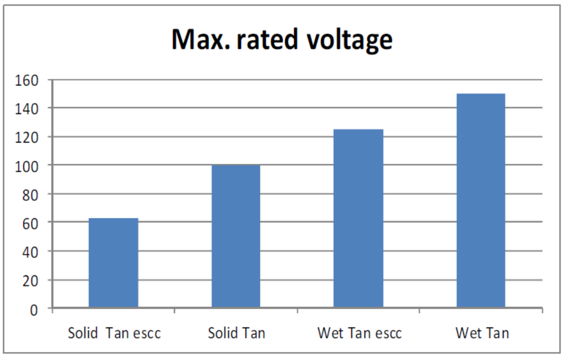

Fig 1. Max rated voltage per technology

So, the use of tantalum for this specific application is clearly compromised if this technical tendency continues

The second point is that solid tantalum failure mode can lead to thermal ignition, what allows to find nice pictures on the web, but can be scary for some designers.

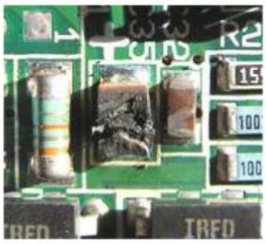

Fig 2. Burned tantalum capacitor on PCB

Fig 3. Failure appearing on a design

EXXELIA DEVELOPPED SOLUTIONS ALLOWING DESIGNERS TO USE TANTALUM CAPACITORS IN ALL SAFETY.

Technology hates emptiness. So the market needed tantalum technology at 170V. That's what Exxelia did with WT82.

Since 2014 EXXELIA-TANTALUM spent a big amount of time on this subject and found a way. Using the full knowledge of several business Units of the Exxelia group, they found a way to duplicate the performances they had at 150V at higher voltages under certain conditions (lower temperature ranges for example, but high enough for space usage). This has leaded to a few values in several case sizes, corresponding to the T3 and T4 of the MIL standards:

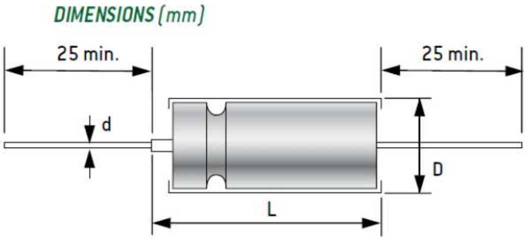

Fig 4. Tantalum case for WT82

Table 2. Case dimensions

Case code	Dimensions with insulating sleeve		
	L max	D max	D +10% -0.05
C	26	10.1	0.6
D	34	10.1	0.6

These values being:

33µF 160V in C case
47µF 160V in D case
82µF 160V in D case
82µF 170V in D case.

So with the deratings in voltages in space application, that allows designers to use them up to 100V.

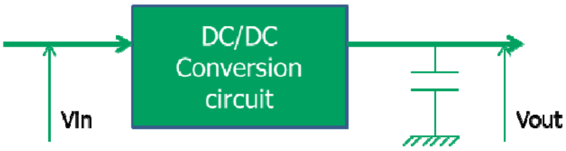

Fig 5. DC conversion schematic diagram

These performances are a first interesting step, but there was also a need of reliability for this kind of application. In this case, the tests made showed an excellent stability after 1000 hours in endurance.

	Before life test			**After life test**			
	Cap.(µF)	**TgD.(%)**	**Lc.(µA)**	**Cap.(µF)**	**dC/C(%)**	**TgD.(%)**	**Lc.(µA)**
Limits	65.6/98.4	40	5		10	60	10
Min.	87.93	7.64	1.02	81.73	-7.66	6.96	0.56
Max.	89.09	9.23	1.23	82.85	-6.84	8.14	0.62
Moy.	88.62	8.52	1.10	82.22	-7.21	7.40	0.58
Std	0.387	0.46	0.061	0.341	0.27	0.41	0.017

In addition of that, all the theoretical calculations are very interesting:
Indeed, if we use the formula given historically by the MIL standards, and also sometimes used in ESCC, we have a failure rate of:

$$FR = 3 \times \pi T \times \pi V \times \pi C \times \pi E \times \pi Q \times 10^{-9}/hour$$

With πT= influence of the temperature

πV= Influence of the voltage
πC= Influence of the capacitance
πE= Influence of the surrounding conditions
πQ= Influence of the qualification

In our case, let's consider a temperature of 70°C. We have then:

$\pi T=\exp(1.8x\ (T/Tmax)^2) = \exp(1.8) = 6.05$
$\pi V= \exp\ (Up/Ur)^2= \exp(0.6)^2=1.43$
$\pi C= 1.2$ at $82\mu F$
$\pi Q= 2$ because not space qualified product (0.5 if it is)
$\pi E = 0.5$ for a satellite in orbit/ 20 for a space launcher

What makes:
- FR= 31 x10^(-9)/ hour for a satellite in orbit
- FR= 12.4 x10^(-7)/hour for a launcher

This is corresponding to expected MTBF of
- 32.300.000 hours for a satellite in orbit
- 806.000 hours for a space launcher.

Of course these results are theoretical. It's difficult to prove such long ones, but still, these results are clearly a good sign of good behavior of these products in space applications.

Then to solve the concern about failure rate, the solution is to use conductive polymer. With CTP 21, Exxelia allows to use polymer on solid tantalum capacitors up to 100V with extremely low ESR.

The use of polymer (that does not include oxygen, contrary to MnO_2 standard solid tantalum cathode) avoids the risk of thermal ignition.

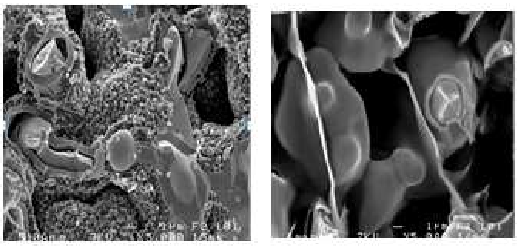

Fig 6. Internal structure of $Mn0_2$ and polymer

These products also have other benefits:
- Extremely low ESR
- High values of capacitance/ voltage (22µF 100V ; 47µF 80V ; 56µF 63V ; 330µF 25V)
- They are products you can stack to create a CTP42 (2x CTP 21)

Fig 7. Picture of CTP 21 and CTP42

We continue to innovate to give you the power of tantalum.

These products and also our future innovations are always made according to your needs, and we are more than happy to go with our customers to new innovative challenges leading to the space technologies of the future.

Don’t hesitate to visit our website for more information: www.exxelia.com