TECHNICAL PAPER

Low Leakage Current Aspect of Designing with Tantalum and Niobium Oxide Capacitors

Radovan Faltus
AVX Czech Republic s.r.o., Dvorakova 328,
563 01 Lanskroun, Czech Republic

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Leakage current (DCL) is common effect of all capacitors and its value and dependencies on electrical and environmental conditions are related to capacitor technology. Leakage current of tantalum and niobium oxide capacitors consists of dielectric absorption current and fault current affected by impurities and irregularities of a dielectric. Characteristic value of the leakage current is measured at rated DC voltage applied and at room temperature 25°C. Circuit operation currents are significantly higher than the leakage current of used capacitors, so functionality of such apllication in “run” mode stays unaffected. The other case is battery circuit of an application in standby mode, where DCL value directly influence standby time as it directly discharges energy from the battery. There are consumer applications like mobile phones, communicators, mp3/mp4 players, DVD players, walkie-talkies, etc. using battery circuits with tantalum or OxiCap® capacitors. In automotive industry tyre pressure monitoring systems often accommodate capacitors in battery operated transmitter.

Battery operated handhelds (Fig. 1) use capacitors connected to the most usual lithium-ion rechargeable 3.7V battery in order to:

- backup data and settings when battery is being replaced and charger is unpluged
- smooth the voltage and current peak in the moment of battery inserting and charger pluging/unpluging
- support the battery by stored energy when increased current is demanded by circuits

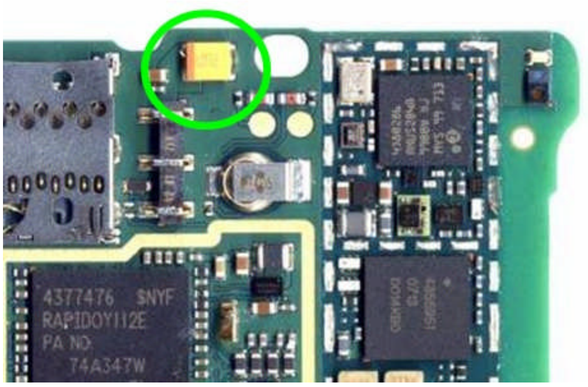

Figure 1: Battery circuit tantalum capacitor in handheld device

Direct TPM systems use in-wheel sensors (Fig. 2) typically powered by a 3V lithium coin battery. Pressure and temperature data are wirelessly transmitted to a central control unit which provides informations and warning alerts to the driver and are displayed on the dashboard or the rearview mirror.

Figure 2: Direct TPMS transmitter

Lithium batteries are often prefered thanks to their exceptional shelf life over ten years. Lithium batteries also function well at low temperatures, however in such conditions they exhibit increased internal resistance resulting in a higher voltage drop. The purpose of the bulk (parallel) capacitor used in conjunction with the remote wheel tyre pressure sensor is to deliver an energy pulse when the measurement and transmission sequence is initiated, especially at very low ambient temperatures.

Capacitor requirements

The suitable nominal capacitance for battery circuits is typically in the range of 22 to 220µF, and a small footprint and low profile is a common requirement to match the small size of the device. Excellent performance at low and very low temperatures is an obvious necessity to ensure reliable functionality. Therefore, tantalum and niobium oxide capacitors are best suited for this application.

Standby power consumption must be minimized to assure maximal battery life in the battery operated units. Both active parts and passive functions must be considered, and the leakage current (DCL) of the bulk capacitor is an effect which directly drains a battery so reducing DCL is important.

There are some major possible methods which may be combined to minimize the leakage current of the bulk capacitor. Selection of the right tantalum or niobium oxide capacitor is the first method. Different formulas exist for different AVX product families to determine the basic DCL (maximal guaranteed value specified at full rated voltage, 25°C):

Equations 1

TAJ series: DCL = 0.01*C*Vr,

TRJ series: DCL = 0.0075*C*Vr,

NOJ series: DCL = 0.02*C*Vr,

where C = nominal capacitance; Vr = rated voltage.

Tantalum TRJ professional series capacitors have lower DCL in similar conditions than standard TAJ products. Niobium oxide NOJ OxiCap® devices exhibit higher DCL. However ambient temperature and voltage derating are very important factors to consider when calculating DCL – see Figure 3 and 4. Special version of tantalum

TAJ series capacitors have been developed to further reduce the DCL values shown in *Equations 1*. Voltage derating is the second method to control leakage current.

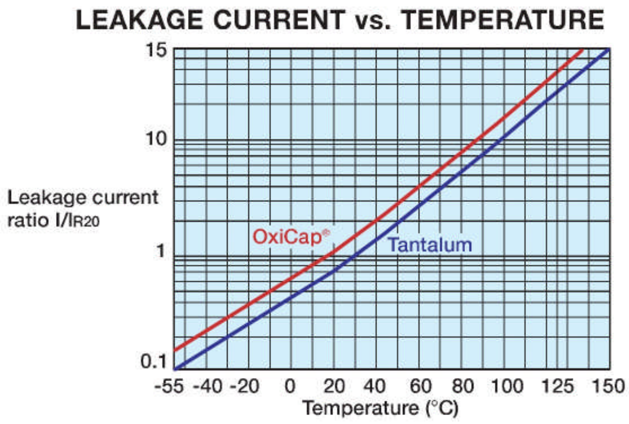

Figure 3: Temperature dependence of DCL

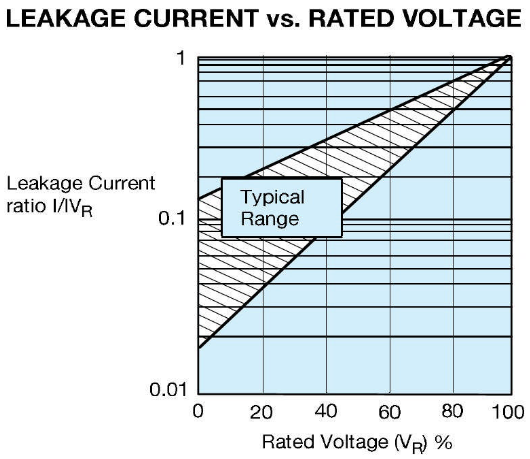

Figure 4: Effect of voltage derating on DCL

The typical range of DCL versus rated voltage can be seen in Figure 4. This relationship can be approximated in linear measure by reverse decimal logarithmical function with offset – see Figure 5.

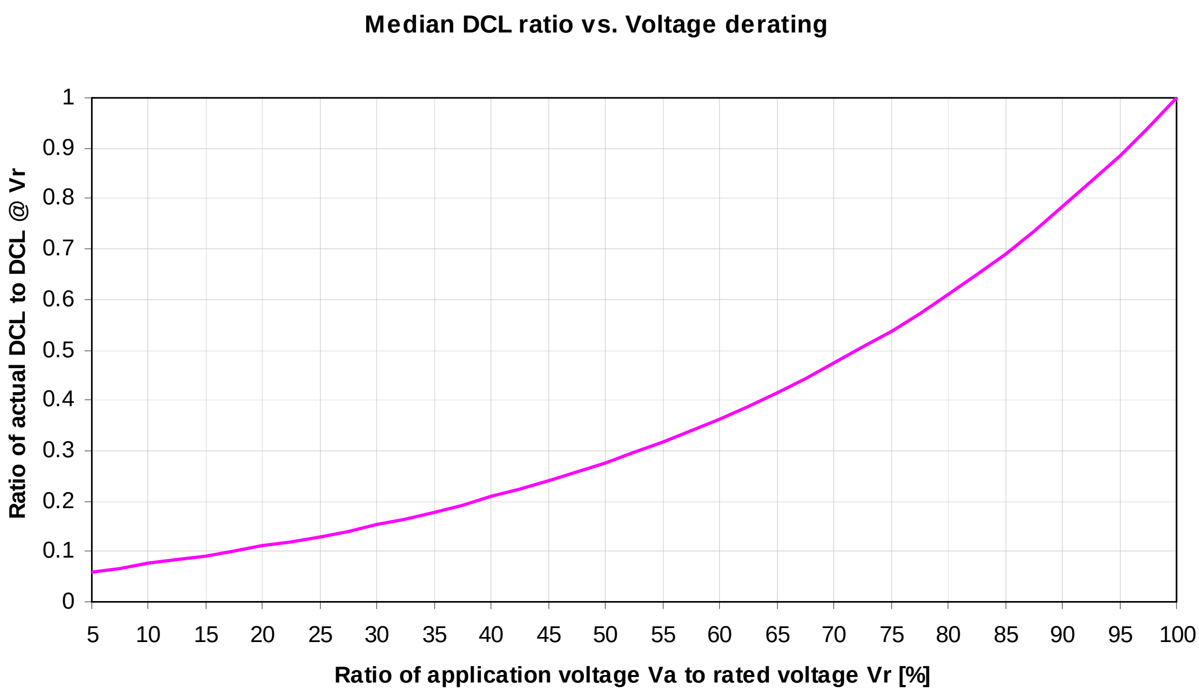

Figure 5: Median curve of typical range of DCL vs Voltage derating from Figure 4

Optimal voltage derating for minimal DCL

To achieve the optimal leakage current ratings for the application (DCLa) at room temperature we need to consider two factors. One is the calculation of basic DCL defined at rated voltage Vr as in *Equations 1*; the second calculation is DCL ratio vs Voltage derating – Figure 5.

Equations 2:

TAJ series:	DCLa = 0.01*C*Vr*Ri,
TRJ series:	DCLa = 0.0075*C*Vr*Ri,
NOJ series:	DCLa = 0.02*C*Vr*Ri,

where Ri = ratio of DCLa/DCL (at Vr) – Figure 5.

The maximal DCL multiplier vs Va/Vr for fixed application voltage Va is displayed in Figure 6.

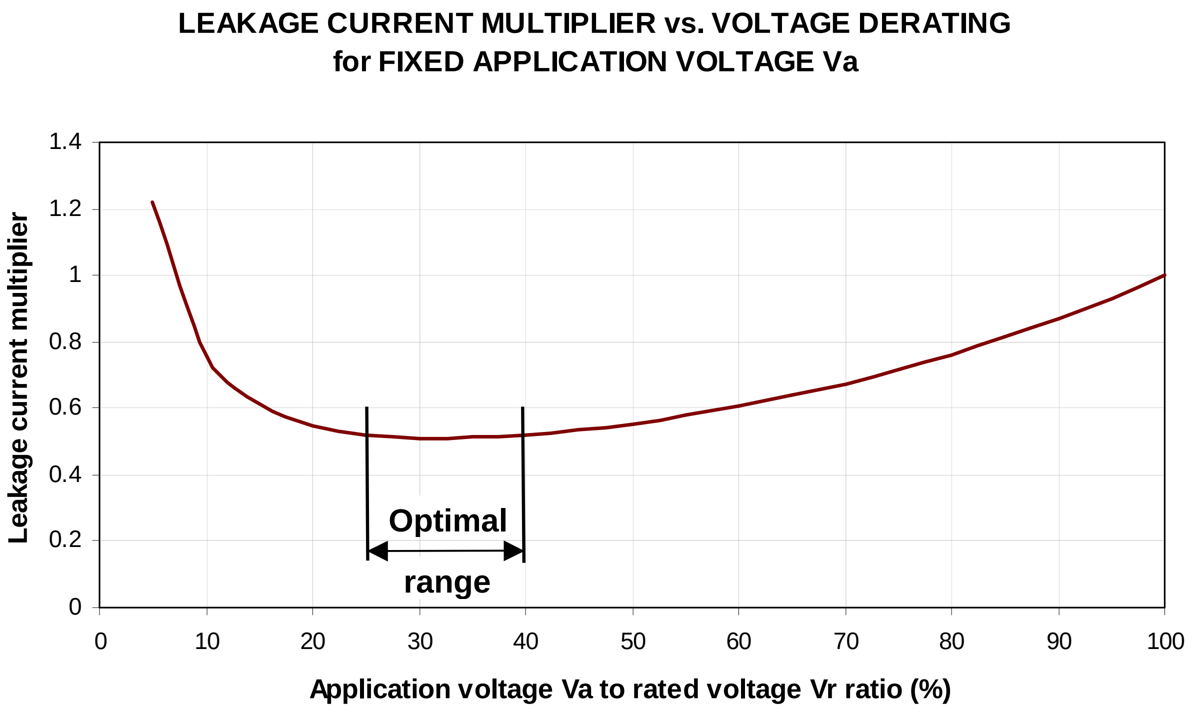

Figure 6: Graph of maximal actual DCL vs voltage derating

The value of maximal actual DCL varies with different input conditions (chosen capacitor serie, nominal capacitance and rated voltage), however shape of the graph (Fig. 6) will be the same. So we can identify the range of Va/Vr (derating) values with minimum actual DCL as the “optimal” range. Therefore the minimum DCL is obtained when capacitor is used at 25 to 40 % of the rated voltage - when the rated voltage of the capacitor is 2.5 to 4 times higher than actual application voltage.

Comparison of capacitor DCL performance in a typical battery circuit application

As we have said, the typical energy source of a handheld device is a lithium-ion rechargeable battery with a nominal voltage Va = 3.7V. To support device functionality, designers can choose from several different capacitor series which are available with different rated voltages. Figure 7 compares the maximal DCL of different capacitor series all with nominal capacitance of 47µF.

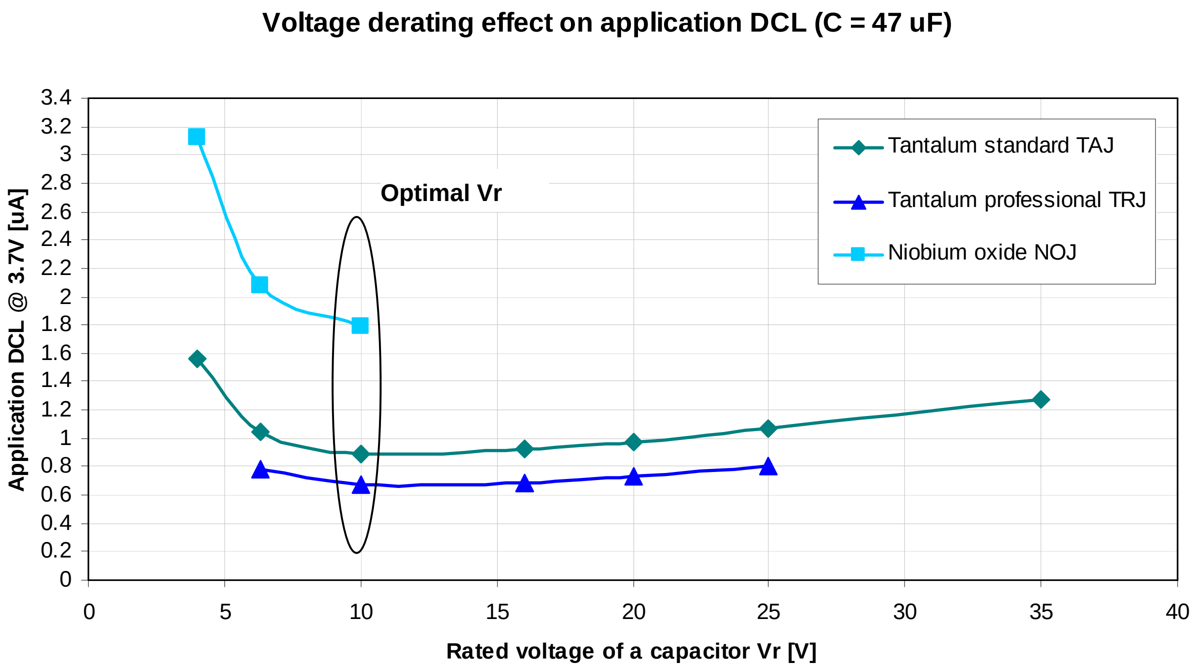

Figure 7: Benchmark of maximal actual DCL of different capacitor series

In this example where the Va is 3.7V, the optimal rated voltage (Vr) = 10V (Fig. 7), which means the optimal operating voltage is 37% of the rated voltage (see Fig. 6). For different capacitances the optimal rated voltage will be also 10V.

Summary and conclusion

Among tantalum and niobium oxide series – AVX's TRJ, TAJ and NOJ capacitor series are suitable to support the battery in handheld and TPMS transmitter applications. These parts exhibit different basic leakage currents (DCL@Vr – Equations 1), TRJ serie capacitors have the lowest catalogue DCL value. However, voltage derating can be applied to further optimize the application DCL, to less than the catalogue value defined at rated voltage Vr. The optimal condition for minimal application DCL is to use the capacitor at the voltage between 25 and 40% of the rated voltage – Figure 6. For 3.7V applications, the optimal rated voltage is 10V – Figure 7 and the device benchmark (Fig. 7) shows the best choice available from AVX is to use TRJ capacitor with Vr = 10V, closely followed by a TAJ device with the same rating. Also special TAJ, *LE suffixed tantalum capacitors exist with even significantly lower guaranteed maximal DCL.

A KYOCERA GROUP COMPANY

NORTH AMERICA
Tel: +1 864-967-2150

ASIA
Tel: +65 6286-7555

CENTRAL AMERICA
Tel: +55 11-46881960

EUROPE
Tel: +44 1276-697000

JAPAN
Tel: +81 740-321250

WWW.AVX.COM