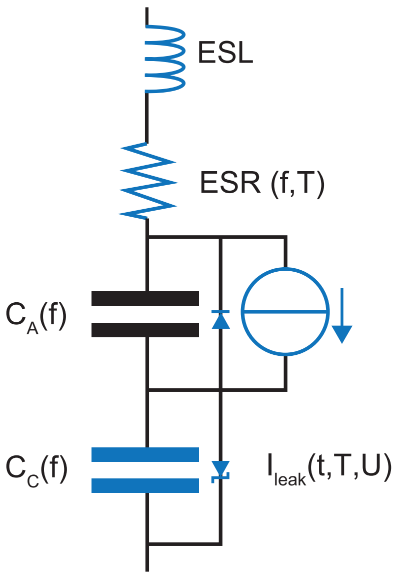
DID YOU KNOW?

CAPACITANCE AND ESR

THE ART AND SCIENCE OF USING ALUMINUM ELECTROLYTIC CAPACITORS

Aluminum electrolytic capacitors are prized for their low cost and large capacitance in small case sizes, designers need to keep in mind their ample parasitics when designing them into an application.



Unipolar Design

The figure on the left shows the equivalent electrical circuit of an aluminum electrolytic capacitor. The capacitor itself consists of two capacitors in series: the main anode capacitor and the series cathode capacitor. The cathode capacitor should be connected to the negative pole, and allows for reverse bias up to 1 V. Above this value, oxidation of the cathode foil will take place, creating internal gas pressure and an irreversible drop in total capacitance.

The anode is the positive terminal and allows for voltages up to the rated voltage. Above this voltage, the leakage current will start to rise quickly, ultimately giving rise to a short circuit once the voltage rises above the breakdown voltage of the electrolyte. The capacitor is clearly a unipolar design.

Equivalent Series Resistance (ESR)

Both capacitors consist of an aluminum sheet as an electrode, and an electrolyte as a counter-electrode. This electrolyte is a liquid with salts which is contained in the paper spacer present between the 2 layers of aluminum foil. It is conductive but with a high resistivity. This is the base for the series resistance (ESR). This ESR is typically dominated by the aluminum oxide resistance in the low frequency zone (typically up to 100 Hz) and by the paper / electrolyte in the mid and high frequency area (> 1 kHz).

Equivalent Series Inductance (ESL)

The two metal sheets forming the anode and cathode are nicely wound around each other in the winding of the electrolytic capacitor. As such, the self-inductance of the winding is negligible. But the two metal strips connecting the anode and cathode sheets with the outside world cannot be shielded properly, and the length of these so-called tabs defines the self-inductance (ESL) of the capacitor. Typically, values for the ESL are 5 nH to 25 nH and rise with the dimensions of the capacitor.

Impedance (Z)

The sum of the capacitance, ESR, and ESL yields to the impedance (Z) of the capacitor.

The value is $Z= \sqrt{ESR^2+\left(\omega L- \frac{1}{\omega C}\right) 2}$

with $\omega= 2\pi^*$ f, the frequency of the ripple current passing through the capacitor branch.

As a function of frequency, Z shows a bathtub kind of shape. Z drops with frequencies in the low frequency range ($Z \sim 1/\omega C$); it is relatively flat in the mid range frequencies ($Z \sim ESR$); and Z increases with frequencies in the high frequency range ($Z \sim \omega L$).

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