Application Note

Using the 1900 LCR Meter for Medical Industry Capacitance Testing

In the medical industry, strict design requirements and regulatory standards are continuously increasing, affecting capacitors used in implantable medical devices (IMD's); this includes EMI filter capacitors used on sensing and pacing wires, tantalum capacitors used in the dc low voltage control circuitry, and metalized thin film capacitors used in energy storage. Even though each of these capacitor types is different, they fall under the same demands from the medical industry (Table 1).

Table 1: Medical Industry Demands

Industry Demand	Capacitor Requirement
Reduced size & weight	Improved design & manufacturing techniques
Reduced power loss	Low D_F, ESR, DCR
Increased resiliency to defibrillator output energy	High CV values

One strict design requirement is the reduction in size of IMD's.

Given the inherent liability concerns in the medical industry and need to perform accurate measurements over an increasingly difficult measurement range, choose an instrument with accuracy, resolution and capability, to make it a valuable R&D, Production and QA tool in characterizing capacitors (and other components) for the medical device industry.

Reduction in Size and Resultant Capacitor Loss

The reduction in size and weight of the IMD components is half the battle. Power loss must be minimized so that battery sizes can also be reduced, and battery lifetime must increase so that the IMD's do not have to be replaced as often. Two characteristics of capacitance that contribute to power loss in batteries are ESR and DF.

Equivalent Series Resistance (ESR)

Let's look at the impedance parameters that make up a capacitor's loss equation. The complex impedance of a capacitor (Z) is made up of a real part (R_S) and an imaginary part (X_S).

$$(1) \qquad Z = R_S + jX_S$$

At a single frequency, the complex impedance behaves as a series combination of ideal resistance and ideal reactance where ideal reactance is defined as:

$$(2) \qquad X_S = -1/(\omega C) = -1/(2\pi fC)$$

ESR can be described as a measure of the Total Loss of a capacitor, or:

$$ESR = R_S$$

However, in the real world components are not ideal and ESR cannot be described so simply. R_S is actually made up of three contributing factors as illustrated in Figure 1.

1. Actual series resistance (R_{AS}): The ohmic resistance in the leads and plates or foils. This conductor resistance value is typically low. It causes a power loss I^2R_{AS}. Its contribution to the total dissipation factor is $D_1 = \omega R_{AS}C$.

2. Leakage resistance (R_L): A parallel resistance due to leakage current in the capacitor. This R_L value is typically high. It causes a power loss of V^2/R_L. Its contribution to the total dissipation factor is $D_2 = 1/(\omega R_L C)$.

3. Dielectric loss (R_D): A parallel resistance arising from two phenomena: molecular polarization and interfacial polarization (dielectric absorption). This complex R_D can change with frequency in most any manner that is not abrupt. Its contribution to the total dissipation factor can be approximated by $D_3 = 1/ (\omega R_D C_B)$. One model is a frequency variable resistor (R_D) in series with a large blocking capacitor (C_B).

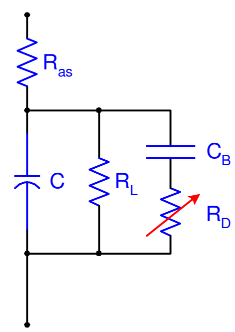

Figure 1: Equivalent Circuit with All 3 Capacitor Losses

Dissipation Factor (DF)

From Figure 1, the Total Loss contributions can now be defined as:

$$(3) \qquad ESR = R_S = R_{AS} + 1/R_L + 1/R_D$$

The Dissipation Factor (D_F) can be described as the ratio of energy lost and energy stored, or:

$$D_F = \text{Energy Lost/Energy Stored}$$

or

$$D_F = \text{Real Part of (Z) / (-) Imaginary Part of Z}$$

or

$$(4) \qquad D_F = D_1 + D_2 + D_3 = \omega R_{AS}C + 1/(\omega R_L C) + 1/(\omega R_D C_B)$$

Choosing a meter with high resolution and accuracy is important for the measurements of ESR and DF. Table 2 lists the DF and ESR measurement capabilities of the 1900 Series LCR Meter.

Table 2: 1900 Series DF and ESR Capability

Parameter	Range		Accuracy
	From	To	
DF	0.000 01	99.999	± .001
ESR	0.000 1mΩ	99.999 MΩ	± 0.1%

Capacitance/Voltage (CV)

To further increase the demand on capacitor performance, capacitors used in medical devices must absorb and withstand the energy of a defibrillator pulse almost instantly. As capacitor size decreases, it becomes more and more challenging to develop and manufacture capacitors with high CV (Capacitance/Voltage) values.

Capacitors with high CV values have the advantages of:

- Low leakage current
- Fast charging characteristics
- High peak currents
- Long service life
- High reliability

So another important factor in choosing an LCR meter is that the meter has the capabilities, resolution and accuracy to make measurements across a wide range frequency, test signal and capacitance.

Table 4: 1900 Series C, f & ac Output Capabilities

Parameter	Range		Accuracy
	From	To	
Capacitance	1p F	9.999 9 F	± 0.1%
Frequency	20 Hz	1M Hz	± (0.02% + 0.02 Hz)
DUT ac voltage	20 mV	1.0 V	± (2% + 5mV) @1 kHz
DUT ac current	1ΩA	150 mA	± (2% + 5ΩA) @1 kHz

Charged Capacitor Protection

Another important feature is Charged Capacitor Protection. Common practice should be to discharge a capacitor prior to attaching it to an LCR meter. However, due to the phenomenon of dielectric absorption, even when a capacitor is discharged, if it is left in an open circuit it builds up a charge again. Since the capacitors being tested have relatively high capacitance and voltage values, charged capacitor protection is a valuable feature. The 1900 Series has built-in charged capacitor protection to 1 joule.

The protection schemes are as follows:

- Series impedance protection
- Diode protection
- Fuse protection
- Spark gap protection.

Summary

Capacitors in IMD's require several measurements: D_F, ESR, DCR, and CV. The 1900 Series is one instrument that does them all. Whether used in R&D for its extensive (20) parameter testing capabilities, in Production for its computer controlled interface and binning capabilities, or in Quality Control for its ease of use and reliability, the 1900 Series LCR Meter is a well matched solution.