

## Why Z METERS™ Read Electrolytics Differently Than Bridges

It might seem that all methods of measuring capacitance value should produce the same readings. This is not, however, true when testing electrolytic capacitors. The capacity of an electrolytic capacitor changes with applied frequency. Therefore, an electrolytic should not be used to compare the accuracy of different testing methods.

Most digital capacitor testers find value by measuring the time needed to charge the unknown capacitor through a precision resistor. The time-constant gives the capacitor value. Since electrolytics show their highest value at DC, an R-C time constant tester shows a value higher than marked on the capacitor. This value,

however, is accurate. It shows how the capacitor works in DC circuits.

As we will see later, the variation in value does not cause testing problems if you apply the capacitor's tolerance to your Z METER™ readings.

### Why The Readings Vary

Electrolytics show the largest value variations. By comparison, you will not see a difference if you test a parallel bank of film capacitors totalling several microfarads. They will read the same on a bridge or on the Z METER. An electrolytic capacitor of the same value, shows a large variety of readings, depending on the test

frequency used. To find out why, Sencore turned to Dr. J. A. Tunheim, Dean of the Physics Department at South Dakota State University, Brookings, South Dakota.

Dr. Tunheim published a 98 page report entitled, "Relationships Between Values of Capacitance Measured by the Sencore LC53 Z Meter™ and Other Standard Techniques." The study explored several possible causes of the frequency effects. Calculations showed that the variations were not the result of series inductance or resistance, frequency changes in the dielectric constant of the aluminum oxide, or effects of the paper spacer. None of these causes had enough effect (below a megahertz) to explain why values changed so much at frequencies of several kilohertz.

The one remaining variable was the relaxation effects of the molecules in the electrolyte solution. The abundance of water played the largest role. The report

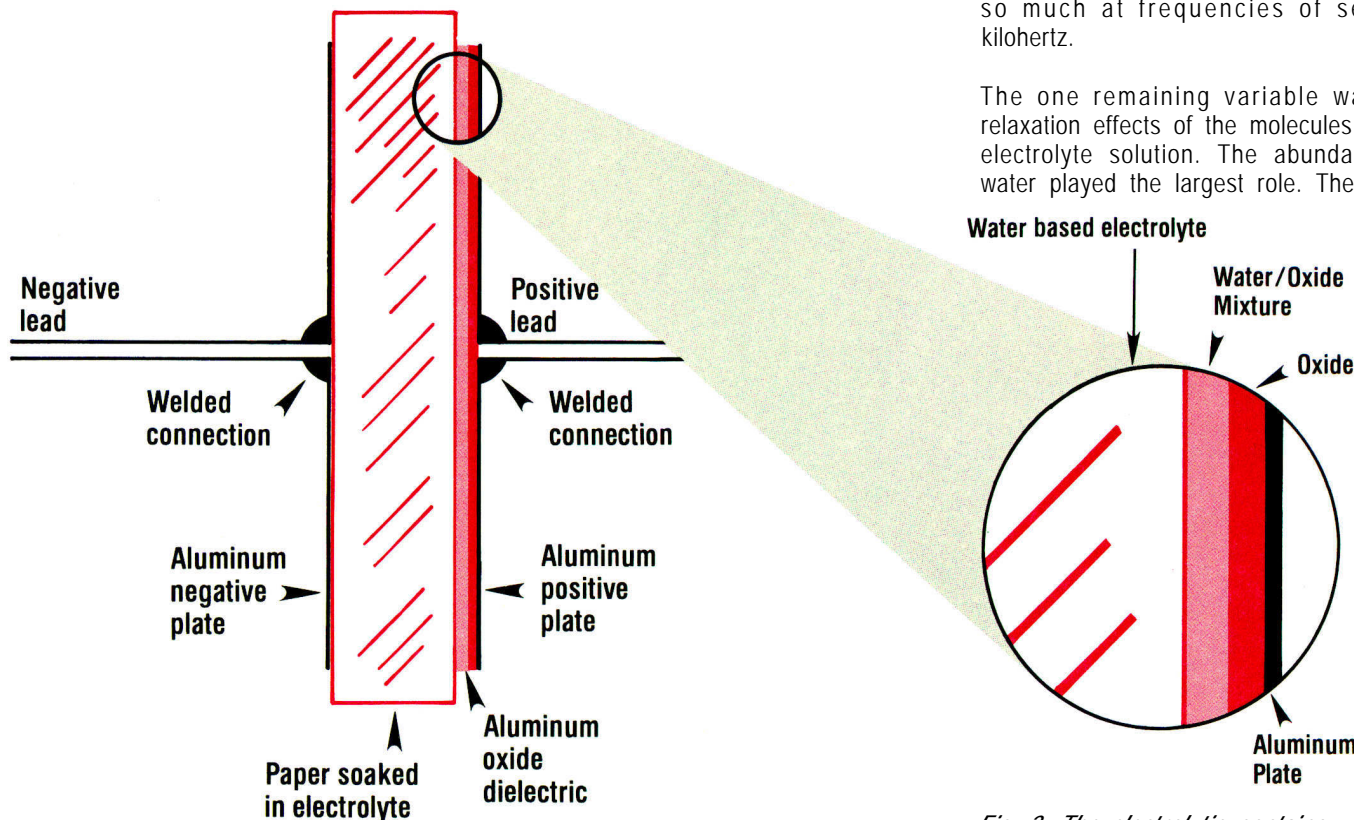


Fig. 1: The basic parts of an electrolytic capacitor.

Fig. 2: The electrolytic contains water in the paper spacer and part of the oxide layer. This water causes the value to change with frequency.

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explains: "Water molecules, however, are known to give a relaxation frequency in the one kilohertz region (Hasted, 1973). Since the relaxation frequency is the frequency at which the molecules cannot follow the alternating electric field, this would result in a drop of the dielectric constant in the observed frequency range."

The experimenters used the Debye relaxation equation for dipolar molecules along with information published by K. S. Cole in 1941. The theoretical values from these formulas agree closely with the measured values, as shown in Fig. 3. The solid line is the predicted value change, while the crosses mark lab results.

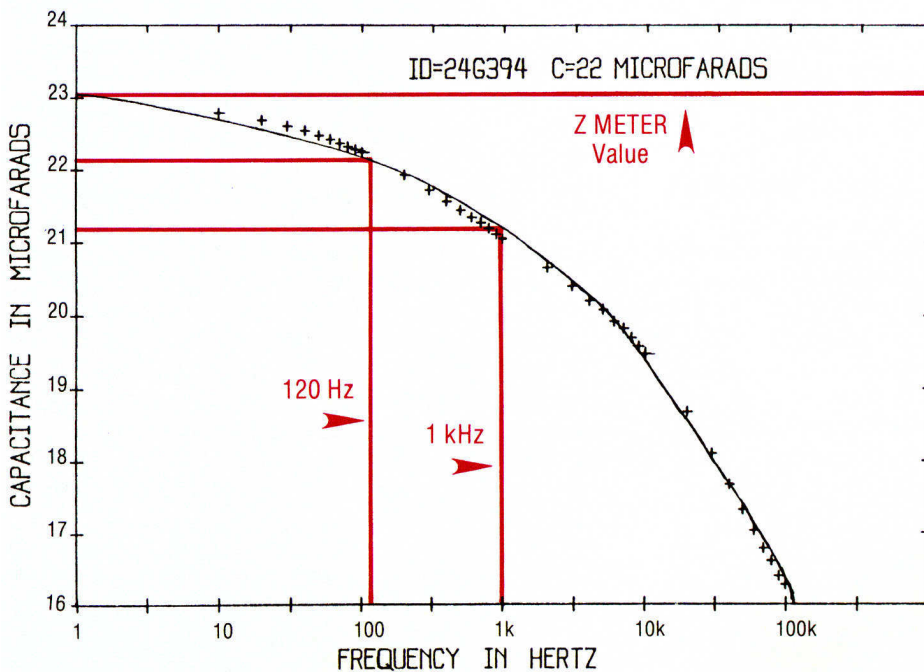


Fig. 3: Test results (+ 's) from the SDSU study compared to theoretical values (solid line).

The graph shows the results on a capacitor marked 22 µF. The first point to notice is at 120 Hz. Most electrolytics are marked with the value determined with a 120 Hz impedance bridge. The 120 Hz value (22.2 µF) is close to the marked value.

Next look at the lowest frequency on the graph. It agrees directly with the Z METER reading of 23.1 µF. By comparison, notice that a 1000 Hz bridge shows the value (21.2 µF) lower than the marked value by nearly the same amount as the Z METER reads it higher. In each case, you get a different value. But all readings are correct for the test methods used. The problem is in the component being tested, not in the test method.

## Apply The Manufacturer's Tolerance

The researchers tried to find a way to use these formulas to convert readings made with a bridge to those made with a Z METER. This didn't work because, "The relaxation time would be dependent on the amount of water and the specific components of the capacitor." These variables are not published.

However, the Sencore Application Engineering Department found that is not necessary to calculate a conversion. Simply apply the capacitor's rated tolerance to the Z METER readings.

None of the capacitors read outside their tolerance. We found capacitors with looser specs (such as -20%, + 100%) showed a wider variation than those with tighter specs (such as +/-20%). Plotting the frequency responses showed that the capacitors with the wider tolerances had much wider frequency changes than those with lower percentages. The manufacturer's tolerances predict the amount of change you should allow when testing capacitor value. Simply remember to apply these tolerances to your Z METER readings.

## Value Rarely Changes

Most electrolytic problems do not affect value. Be sure to use the Z METER to test for leakage, dielectric absorption, and equivalent series resistance every time. These failures are much more common. And, these failures are more likely to affect the circuit's operation.

**For more information,  
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Electrolytics have a wide variety of tolerances. Many have a tolerance of -20%, +80%. Thus, a capacitor marked 100 microfarads could have a value as low as 80 µF (100 minus 20%) or as high as 180 µF (100 plus 80%) and still be within tolerance.

We wanted to find out if the difference in readings between the Z METER and a 120 Hz bridge would ever cause the Z METER to read a good capacitor outside its rated tolerance. We tested 512 electrolytics of different values and voltage ratings with the Z METER and the 120 Hz reading on a Hewlett Packard 4192A impedance analyzer. The 4192A applies test frequencies from 5 Hz to 13 MHz, and sells for \$13,900.