Measuring Capacitor Impedance and ESR.

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Introduction

In power system design, capacitors are used extensively for improving noise rejection, lowering power system impedance and power supply filtering, to name a few. In addition to the capacitance, an important parameter to consider when characterizing capacitors is Equivalent Series Resistance or ESR. The impedance profile will indicate capacitor value, resonant frequency and ESR value.

Switching power supplies, where frequencies range from 50-1000 KHz, include capacitors for input/output stage filtering. Characterization of capacitor ESR is important because it affects control loop stability, output voltage ripple, output impedance and overall efficiency.

This application note discusses a method for characterizing the impedance of a capacitor using the Circuit Sleuth Network/Impedance analyzer.

Test setup considerations.

ESR values are typically less than 1 ohm and are measured at relatively high frequencies. It is important to consider the physical layout of the test setup when characterizing capacitor impedance. Connections and lead lengths must be managed to minimize parasitic effects.
Some items to consider:

1. Manage lead lengths.
2. Make connections with good contact and solder if applicable. Keep in mind that, solder, if used as a <u>path</u> for conduction, will affect the measurement especially in the milliohm region.
3. Temperature effects, if applicable.
4. The measurements described here require a reference resistor with a negligible series inductance. A precision resistor is preferred, or, it is possible to substitute a resistor that has a measured known value. A 50 – 100 milliohm value for the reference resistor is acceptable.

Remember the PHYSICS and know your test setup!

Capacitor Impedance measurement and the equivalent circuit model.

The test setup for measuring the impedance of a capacitor is shown in figure 1. The manufacturer's specified capacitance is 150 uf and an ESR value of 0.36 ohms @ 100Khz. The figure shows C1 represented by a capacitor, C, and an equivalent series resistance, ESR. Reference resistor, Rs, is used to sense the current through C. The value of the reference resistor is entered into the parameters tab on the virtual front panel of the analyzer. Because this is a relatively low impedance test, it is recommended that an isolation transformer be used to connect the signal source to the device under test. It is also useful to connect an oscilloscope to the output of the source to observe the frequency sweep as the test progresses.

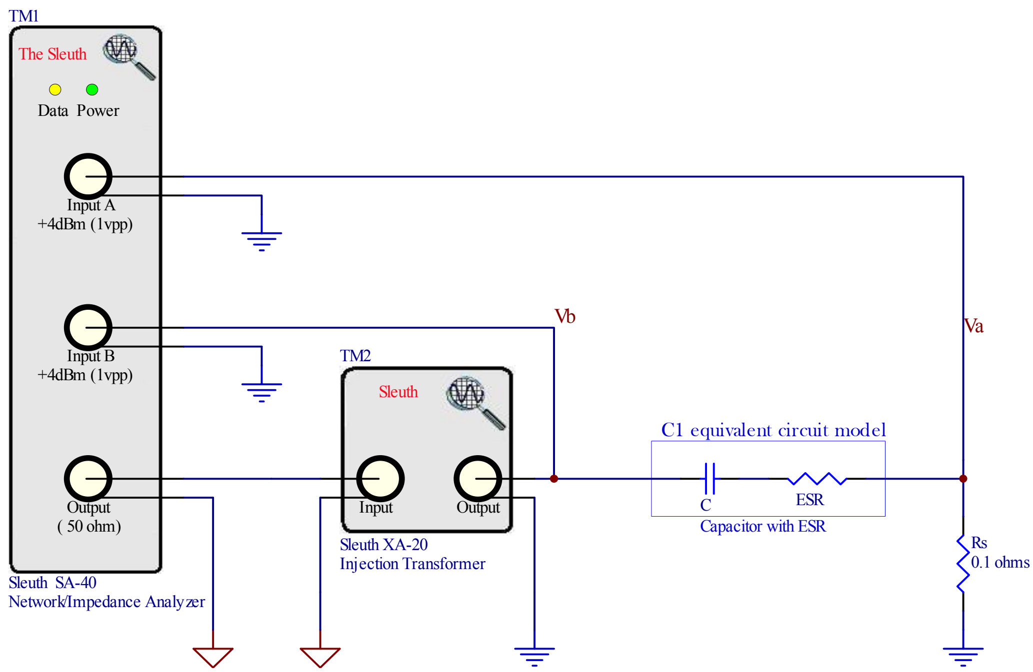

Figure 1. Test setup for measuring a capacitor.

Figure 2 illustrates the Circuit Sleuth virtual front panel in the impedance measurement mode. The controls located under the PARAMETERS tab are used to set the analyzer up for the desired frequency range, number of test points, excitation signal amplitude, etc. As shown, measurements were taken over the frequency range of 10 Hz to 1 Mhz with a logarithmic frequency and magnitude scale. The magnitude of the impedance is displayed. The low frequency region is dominated by the capacitance value (C). The high frequency region (>10 KHz) is dominated by the ESR.

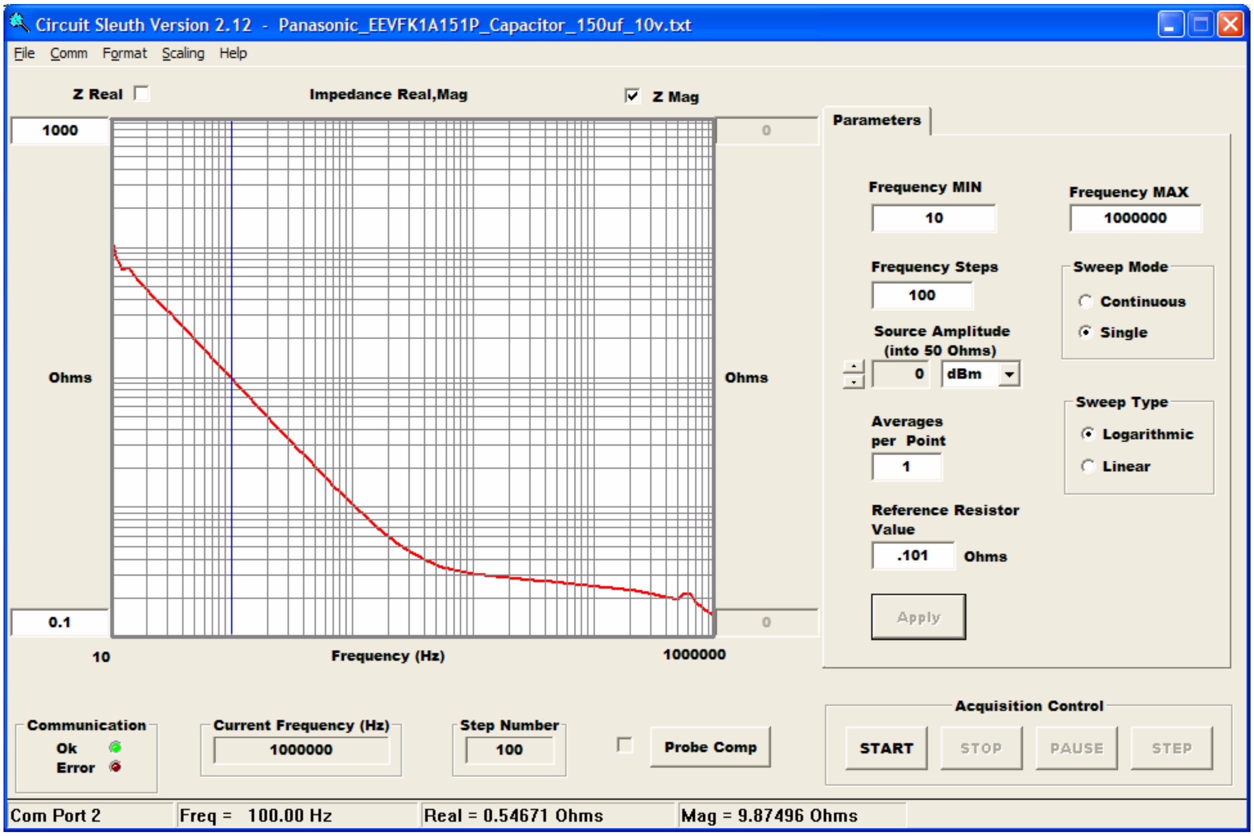

Figure2. Virtual front panel displaying the test parameters and results of the impedance of a 150uf, 10v electrolytic capacitor indicating a magnitude of 9.87 ohms @ 100 Hz.

The cursor is displayed indicating a magnitude of 9.87 ohms @ 100 Hz. The capacitance can be calculated by the following formula:

$$C = \frac{1}{2\pi \cdot Mag \cdot f} = \frac{1}{2\pi \cdot 9.87 \cdot 100} = 161\mu F \quad (1)$$

This is within the 20% tolerance specified for the part.

Figure 3, shows the cursor positioned in the high frequency region measuring an ESR value of 0.24 ohms @ 100 KHz.

The manufacturers specification of ESR is 0.36 ohms (max)@100 KHz.

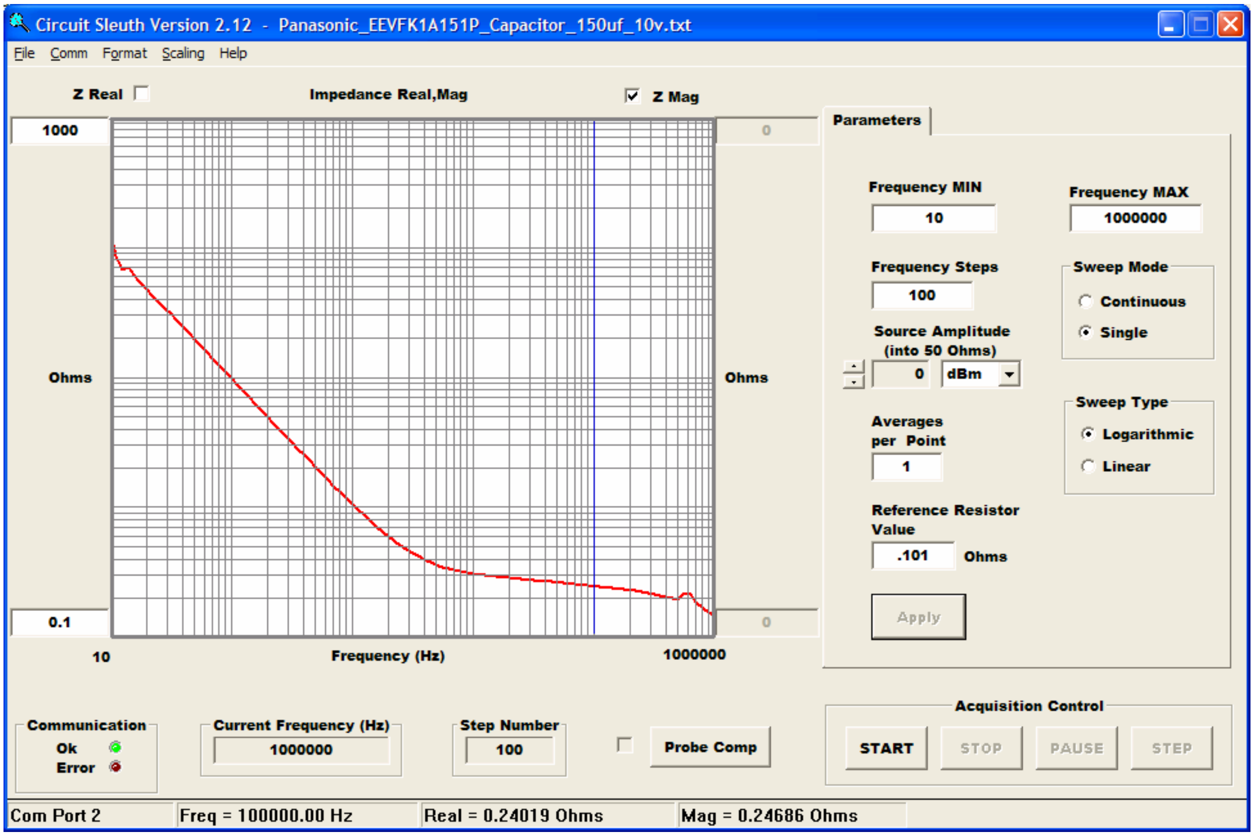

Figure 3. Virtual front panel displaying the test results of the ESR of a 150uf, 10v electrolytic capacitor indicating a magnitude of 0.24 ohms @ 100 kHz.

The model of the capacitor along with its equivalent ESR is shown in figure 4. This is an improved representation of a physical capacitor and can be used in a simulation package for predicting the theoretical performance of the circuit.

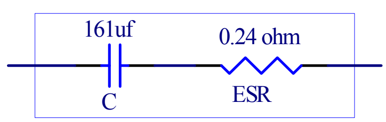

Figure 4. Capacitor equivalent circuit model including ESR.

Summary

This application note showed how to measure the impedance characteristics of a commercially available SMT electrolytic capacitor. In addition to capacitance value, an important characteristic of a capacitor used in a switching power supply input or output circuit is its associated equivalent series resistance or ESR. It is important for designers to have an idea of capacitor ESR because it affects the stability and efficiency of switch mode power supplies. A capacitor physical model, suitable for use in a circuit simulation, was derived enabling designers to better predict theoretical circuit behavior.