Measuring Equivalent Series Resistance in Electrolytic Capacitors

By
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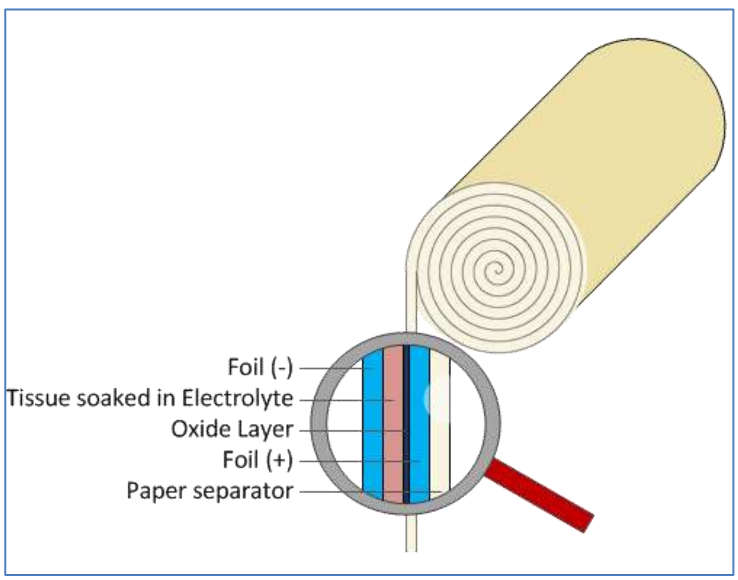
Overview

What is a capacitor? Physically it is two plates separated by an insulator. As such, they look like an open circuit in DC applications, and at higher frequencies of AC, they look like a short. Two of the more common applications that exploit these characteristics are coupling circuits together and filtering.

Several materials are used in making capacitors, and the properties of these materials lead to the various types of capacitors. They can be polarized, having a specific plus and minus, and they can be non-polarized. It is the materials used in the construction of a capacitor that determines whether it is polarized or not. Almost all electrolytic capacitors are polarized.

Electrolytic Capacitors

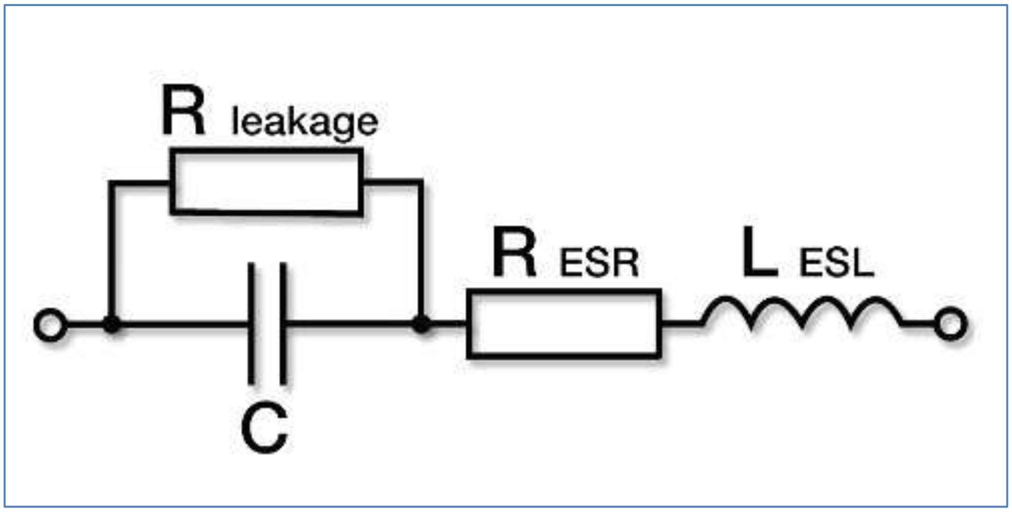
Since the vast majority of today's electronics use DC voltages, ordinary AC house current is fed into a device's power supply where the AC is changed into DC and at voltage levels required by the circuits. Most power supply rectifying circuits do not produce very "clean" DC, and it must be filtered before being delivered to the main circuitry of the device.



Electrolytic capacitors are typically used for this function, because electrolytic capacitors have a large capacity for holding a charge - the larger the plates, the larger the capacity. However, power supply environments are not particularly electrolytic friendly. Many electronic device failures can be traced to failed electrolytic capacitors.

Theory vs Reality

The perfect capacitor has only capacitance in terms of electrical properties. In schematics the capacitor is represented by the ---| |--- symbol, and electrolytics by $-)|^{+}-$ symbol. The curved line always represents the negative pole of the capacitor. In the real world, capacitors have other electrical properties than capacitance.



An equivalent circuit is shown here. The $R_{leakage}$ represents the amount of resistance the dielectric has to the flow of electrons. It is not uncommon for electrolytics to have more leakage than other types of capacitors. The C represents the ideal capacitance. The R_{ESR} represents the equivalent series resistance, and L_{ESL} represents the equivalent series inductance. One of the major factors in L_{ESL} is the length of the leads on the capacitor. It is also this property that gives the capacitor its self-resonance; this can become significant at high frequencies.

Ideally, leakage and ESR are negligible; however, electrolytics typically do not age well. Over time and/or heat, the electrolyte dries out. This causes the ESR to increase and the cap generates more heat. Often the capacitance value changes as well, but not always. That is why it is important to test a suspect electrolytic for ESR as well as it capacitance value.

ESR is an undesirable property in an electrolytic capacitor, because it causes the capacitor to heat up, and this accelerates the drying out of the electrolytic compound. Capacitance often lowers with age.

Measuring ESR

!*!*! WARNING !*!*!

Always discharge all capacitors before testing them, regardless of method used.

Method 1 – Oscilloscope and Signal Generator

1. Set the signal generator at about 200kHz square wave at 1vpp.
2. Set the scope at 200mV per div and 1uS time.
3. Using a T adapter, connect generator to scope and to short clip leads for dut.
4. Connect electrolytic capacitor under test observing proper polarity.
5. Observe results on scope screen. If the cap is good, both the top and bottom of the square wave will meet. Spikes may be observed and are okay. They result from reflections in the clip leads and other inductive factors. If the cap has significant ESR, the top and bottom of the waveform will not meet, and the distance can be measured. Typically, anything more than about 10 – 15mV is not good. The wave may also appear rounded due to RC time constant, and the difference between top and bottom will be > 10-15mV. In either case the cap is bad.

Method 2 – Using a home-built ESR meter (schematic included)

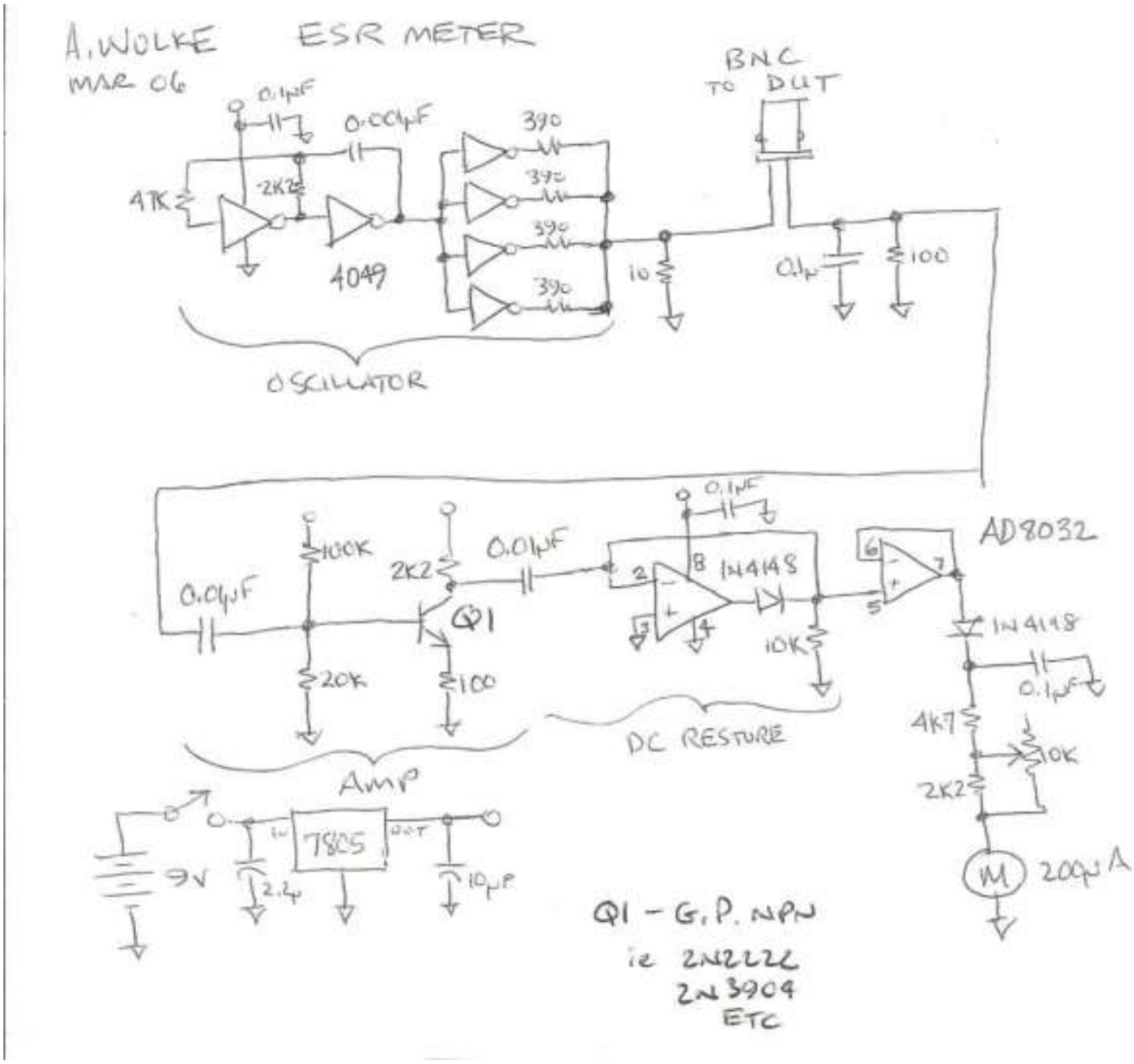
1. Construct the meter and test it for proper operation. Calibrate the meter reading at full scale using a precision resistor decade box.
2. Turn on the meter and zero the reading at full scale by shorting the test leads together.
3. Connect test leads to cap under test observing proper polarity and read the meter. Any more than a couple of ohms indicates a cap with too much ESR.

Method 3 – Using a commercially-built ESR meter

Ebay is a reasonable source for cheap ESR meters. I recommend getting one that can measure capacitance, inductance, and ESR. These are typically under $20 including the shipping (from China)

As for performing the testing – follow any included instructions. However, most of them work the same way. Turn the unit on. Connect test leads to the cap and the measurement is given in the meter's read out.

Alan Wolke’s, W2AEW, schematic for an ESR meter. I have built this and it works great.



Sources

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(3) Wolke, Alan. W2AEW. YouTube series, video #135 “Measure Capacitor ESR with an Oscilloscope and Function Generator” https://www.youtube.com/watch?v=115erzCCxgE

(4) Wolke, Alan. W2AEW. YouTube series, video #5 “My ESR meter project from 2006” https://www.youtube.com/watch?v=bmYAgat-sOQ

(5) Wolke, Alan. W2AEW. YouTube series, video #138 “How to measure output impedance” https://www.youtube.com/watch?v=ieAhBejHe2M

(6) The ARRL Handbook for Radio Communications. 2015 edition. Section 2.7.