Equivalent Series Resistance and Capacitance of Electrolytic Capacitors Meter

« ESR-micro v3.1»

(Brief description and operation instructions)

"ESR micro v3.1" is a device for measuring the equivalent series resistance (ESR) and capacitance value of electrolytic capacitors without removing them from the printed circuit board. This instrument is an irreplaceable assistant to every self-respecting electronics technician.

As every good electronics technician knows, the cause of the vast majority of defects in electronic equipment is defective electrolytic capacitors. They are usually the cause of such defects as the shorted HOT (Horizontal Output Transistor) in CRT Televisions, the failure of the Power Supply ICs and transistors and so on. In most cases it is those capacitors, which are under heat for a long time, that fail quicker. The other failure of capacitors, such as short-circuiting, or a low DCR (Direct Current Resistance), are extremely rare.

The searching for bad capacitors using a multimeter or capacitance meter is sometimes impossible, as the capacitance value of a faulty capacitor may only differ slightly from the nominal value, but the ESR value can be quite large. Thus the ESR is the most important parameter to measure when checking for faulty capacitors.

The theory behind ESR can be explained as follows. As it is known, a capacitor consists of thin conducting plates to which are fastened electrodes, a dielectric which separates the plates (usually aluminum oxide), and the electrolyte. All of this is placed in an aluminum case. While in use, a capacitor has a lot of electrochemical processes happening internally, including corrosion at the joints between the plates and electrodes. This, in turn, causes the deterioration of passing alternating current through the capacitor, which then causes heat, and consequently, causes the above process to accelerate even faster.

We can picture the ESR as an imaginary resistor in series with an "ideal capacitor".

The measurement method is the same as the one used in the well-known ESR meter developed by Bob Parker (ESR meter K7214). A similar meter is now sold by Anatek Corp. as "The Blue ESR Meter".

While being tested, the capacitor is supplied with short pulses of constant current (in this version the pulse width is 2 uS). The amplitude of these pulses is then analyzed. An "ideal capacitor" with ESR=0 will have pulses with zero amplitude. The higher the ESR, the greater the pulse amplitude will be. A microcontroller measures the pulse amplitude, analyzes it, and calculates the ESR value. Using this method, a capacitor with a low capacitance value (1-10 uF), will have an ESR reading slightly higher than the actual value, due to the fact that for the time equal to the test pulse width, the capacitor will have charged up to a certain voltage level, which will cause an error to the accuracy of the measurement of the ESR.

For example, a capacitor with 1 uF capacitance with a 30 mA current charge for 2 uS will have charged up to voltage U=t*I/C=60 mV. That would be consistent with the measured ESR = U/I=60/30=2 ohms. With the same current a capacitor with a 100 uF capacitance will charge to 0.6 mV. The accuracy of the ESR measuring in this case would be 0.02 ohms.

Measuring capacitance is achieved by measuring the time it takes to charge the capacitor to a certain voltage level (in this case up to 0.2 V) and by the formula C=t*I/U. It should be noted that the measurement of

the capacitance of capacitors with high ESR in this way gives a slightly lower value (because of above mentioned initial voltage step).

Specifications:

Measurement Ranges:	Capacitance	1-60,000 uF
	ESR	0-150 ohms
Power consumption:	Active mode	3.5 mA
	Stand-By	almost 0
Display:		LCD COG ("Chip-On-Glass")
Power supply:		6 V (2xCR2032 batteries)
Battery voltage range:		3.6-6V

Using the Device

"ESR-micro v3.1" (fig.1) has the only button: "Mode Set".

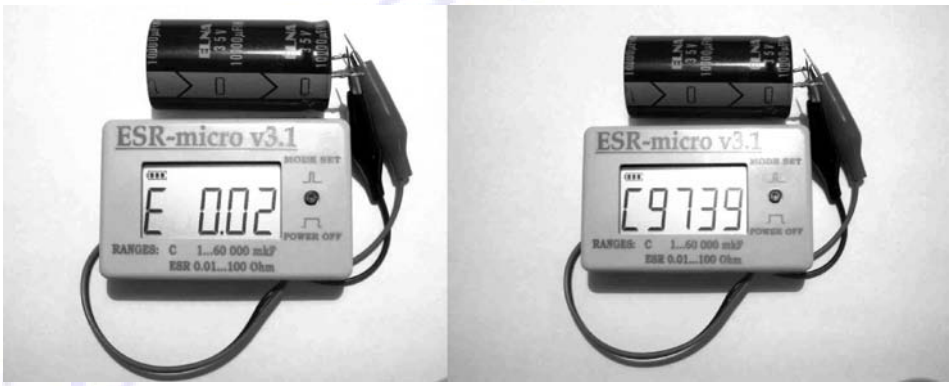

Fig.1

After a short press of the button, the unit will turn on, and the greeting "HELLO" will show. After that the unit will go into operation. There are 3 modes of operation: The indication of capacitance, the indication of ESR, and alternating indication of both values. The ESR is displayed in ohms, and the capacitance is displayed in microfarads. Note that if the capacitance measured is greater than 9999 uF (it needs 5 digits for displaying), the far left digit will show a number instead of the symbol "C".

To select the mode you need, use a short press of the button. The device will cycle between the different modes (ESR, C, C-ESR, ESR etc.). If you press and hold the button for more than 3 seconds, the unit will turn off. The next time you turn on the meter, it will operate in the mode that was used before the unit turned off.

The capacitor to be tested is connected to either lead with "crocodile" clamps, or when the capacitor is being tested without removing it from the circuit board, use the built in needle probes attached to the "crocodile" clamps at the tips to probe the solder joints on the circuit board. This can greatly increase the efficiency of the testing procedure.

It should be noted that if multiple capacitors are connected in parallel (usually used to filter power supply) the device will show the TOTAL capacitance of all of them. This can also affect the ESR reading.

The maximum possible value of measured capacitance is 60,000 uF (in home appliances there are almost never any capacitors with a value higher than this). If the total capacitance is higher than this value, the display will show «C----». Similarly if the value for ESR is higher than 160 ohms, the display will show «E----».

Power supply indication

There is small display situated at the top left corner of the LCD (small bar scale), that shows the supply voltage, that consists of 3 segments. If all segments are on, the battery voltage is greater than 3.9 V. If 2 segments are on, the voltage is between 3.7-3.9 V. If 1 segment is on, 3.5-3.7 V. And if all segments are off, the voltage is lower than 3.5 V.

The batteries need to be replaced if the voltage is lower than 3.6-3.7V.

Automatic shut down

The unit will turn off automatically after 40 seconds after the last measurement. The power consumption in that mode is almost none. The device can also be turned off with the press of the button for 3 seconds.

Probe lead resistance calibration

To compensate for the probes resistance, there is a "calibration mode". To enter this mode, the probes must be connected to each other BEFORE the device is turned on. In this mode, when the meter turns on, the display will show "CALIB" and then it will automatically switch to ESR mode, with the probe lead resistance having been compensated for. It must show no more than 0.01 ohms, if it does, try re-calibrating the meter. The probe resistance compensation value is stored to eeprom memory, and does not need to be done every time, only when the batteries are changed, or when you want to make sure that they are calibrated properly.

Hint: If you are working with very small ESR values, such as low ohms resistors, it can help to calibrate either the probe tips, or alligator clamps beforehand, depending on which method you are using to measure with. For example, if you are connecting a capacitor or low ohms resistor to the alligator clamps, connect the alligator clamps to each other for the calibration mode. Likewise, if you are using the needle probes, try pushing both needle probes into the same solder joint, or even the head of a small Phillips screw, and then calibrate the meter for the best accuracy. This is to help compensate for the very small difference in resistance between the alligator clamps and needle probes.

Notes

WARNING! Do not connect the probes to a charged capacitor! It may cause the meter to malfunction.

A pair of lithium batteries, CR2032 or CR2025, is used for the power supply. They need to be installed with the positive side (noted with "+" on the battery) facing up.

Also it needs to noted that EVERY method of measuring will give slightly DIFFERENT values of measured ESR. You can use the table from Bob Parker's device (table1). The maximum ESR values for "ESR-micro v3.1" are practically the same. But due to the smaller test pulse width in this meter, the maximum values for capacitors with capacitance lower than 10-20 uF became a bit lower. Good capacitors in this range (<20 uF) give readings of no more than 4-5 ohms.

	10V	16V	25V	35V	63V	160V	250V
1				14	16	18	20
2.2			6	8	10	10	10
4.7			15	7,5	4,2	2,3	5
10		6	4	3,5	2,4	3	5
22	5,4	3,6	2,1	1,5	1,5	1,5	3
47	2,2	1,6	1,2	0,5	0,5	0,7	0,8
100	1,2	0,7	0,32	0,32	0,3	0,15	0,8
220	0,6	0,33	0,23	0,17	0,16	0,09	0,5
470	0,24	0,2	0,15	0,1	0,1	0,1	0,3
1000	0,12	0,1	0,08	0,07	0,05	0,06	
4700	0,23	0,2	0,12	0,06	0,06		

Table1

Another interesting thing to note, that different capacitors (even with the same capacitance value!) may have different maximum ESR values. For example, you can take a look at table 2. (It was taken from http://my.execpc.com/~endlr/esr.html)

Capacitor Type:	22 uF part	100 uF part	Freq. measured: Hz	Comments
Std. aluminum	7-30	2-7	120	
Low-ESR aluminum	1-5	0.3-1.6	100k	
Solid aluminum	0.2-0.3		500	MnO_2 electrolyte
Sanyo OS-CON	0.04-0.07	0.03-0.06	100k	TCNQ electrolyte
Std. solid tantalum	1.1-2.5	0.9-1.5	100k	SMD
Low-ESR tantalum	0.2-1	0.08-0.4	100k	SMD, for P.S. filtering
Wet-foil tantalum	2.5-3.5	1.8-3.9	not stated	H_2SO_4 electrolyte
Stacked-foil film	<.015		100k	
Ceramic	<.015		100k	X5R, Y5V

Table 2

Besides the ESR and capacitance measurements, "ESR-micro v3.1" may also be used for the measurement of resistance of low-ohms resistors with accuracy about 0.1-0.2 ohms. Cheap multimeters can also do that, but their accuracy is only about 0.5-0.8 ohms.

Warranty - 1 year from the date of purchasing.

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