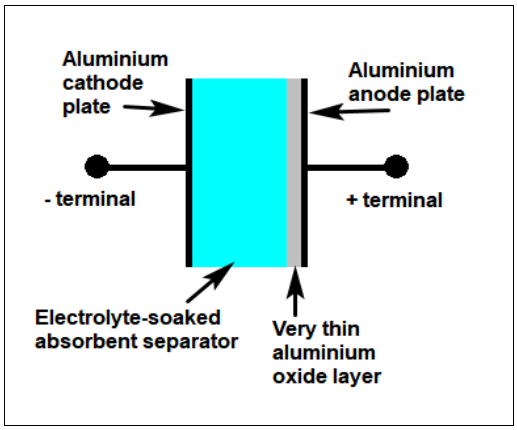
Bob's Blue2 ESR meter

Some theory

It's a well-known fact in the electronics repair business that electrolytic capacitors cause many more than their fair share of faults.

Capacitors consist of two metal “plates” separated by a non-conductive “dielectric” material. In non-polarised capacitors, each plate is directly connected to the outside world by a metallic conductor, but aluminium electrolytic capacitors are different. The dielectric material is in fact a very thin layer of aluminium oxide on the positive anode plate. The positive terminal connects to the anode plate in the usual way, but the electrical connection to the other side of the oxide layer is through a conductive liquid contained in an absorbent material. That liquid is the **electrolyte** which gives the capacitor its name.



The electrolyte has some electrical resistance and it is between the cathode plate and the aluminium oxide dielectric so it's called the “Equivalent Series Resistance” or “ESR”.

When a capacitor is new, the electrolyte has very low resistance. As the capacitor charges and discharges, the ESR causes only a slight extra voltage drop caused by the current flowing through it.

Over time and especially if a capacitor is subjected to heating from nearby components and/or high ripple current through it, the electrolyte can chemically deteriorate, evaporate or leak, causing its ESR to increase. When it increases enough, it will cause the circuit it's in to malfunction.

Excessive ESR leads to abnormally high ripple voltage across a capacitor which usually causes problems including loss of regulation in switching power supplies, hum in amplifiers, picture distortion in CRT monitors and TVs, and “weird” kinds of faults. **The ESR is temperature-sensitive and increases as the temperature drops**. If a piece of equipment works OK under warm conditions but malfunctions when cold, it's often a sign of electrolytic capacitors starting to fail.

Testing electrolytic capacitors

In the past, technicians tried to work out whether or not an electrolytic capacitor was defective by measuring its value with a capacitance meter. Unfortunately the capacitance is a function of the area of the plates and the *dielectric constant*, and very few failure mechanisms will affect either of those physical characteristics. If a capacitance meter gives a low or zero reading, most likely it's because the capacitor's ESR has become too high for the meter to function properly. Because the actual capacitance of failing electrolytic capacitors usually doesn't change very much, most ESR meters including this one concentrate on reading only the ESR.

What's “normal” ESR?

Some people have the idea that the ESR of a capacitor is a specific number like its capacitance and voltage rating. In reality it varies between manufacturers and with temperature, so the best we can do is have a good idea of a figure which it should not exceed.

ESR values cover a huge range. A good low voltage capacitor of thousands of µF can have an ESR of much less than 20mΩ (0.02Ω) while a 1µF 400V cap might read over 30Ω and be quite OK.

The chart on the front of the meter gives some fairly typical figures for a range of common electrolytic capacitors. I've reprinted a more detailed chart at the end of these notes, which won't fit onto the front of the meter.

You're probably thinking that normal and excessive ESR readings could be hard to tell apart, but you can relax. Years of practical repair experience has found that when a capacitor is causing a fault, its ESR reading is usually >10x higher than the figure on the chart and frequently over 30x higher. Sick electrolytic capacitors almost always stand out very clearly.

There's lots of detailed information about using ESR meters on the internet, for example at Jestine Yong's Electronic Repair Guide at http://www.electronicrepairguide.com/esrmeter.html and ESR Meter Hints on my website at http://bobparker.net.au/esr_meter/esrhints.htm

Using the meter

Batteries

First the basics. It's powered by two “AA” size cells, accessed by sliding the back door off.

They can be ordinary (preferably alkaline) or rechargeable NiMH types. Insert the positive ends first.

Once installed (being careful to observe polarity), they can be removed by either pulling them out after previously attaching a piece of sticky tape to their negative ends, or shaking them out by banging the case on the heel of your hand.

Operation

The meter's very simple to use. To turn it on, simply press the button located on the top left edge. With the probes separated, "**-**" will be showing on the left-hand display. This indicates a reading of more than 99Ω or an open circuit. If you see this when testing a capacitor, that capacitor is definitely bad!

To turn the meter off, give the button a quick push. After 5 minutes of not showing any new readings, it will switch itself off. When the battery voltage gets very low, the displays will dim to reduce the battery load and flash "**bA**" every two seconds.

Discharge those capacitors!

Some equipment faults can leave capacitors charged up to **dangerous** voltages and for very long periods (weeks!). Before trying to measure a cap's ESR, please make sure that it's not charged. I've found that a 100Ω 5W or similar wirewound resistor will quickly and safely discharge just about any capacitor you'll find in domestic electronic gear. The meter's designed to tolerate connection to 50V DC or less, but it's best to be careful.

Measurements

This meter is designed to measure the ESR of most electrolytic capacitors while they are still in their circuit. It utilises a pulsed low current measurement which produces a maximum of 50mV across the capacitor being tested, so that no semiconductors in the circuit will be turned on. The test leads are not polarised, and can be connected to capacitors either way around.

In almost all circuits, the capacitor being tested will have by far the lowest impedance to the test current pulses, so that other components will have negligible effect on the readings.

However, if there are more than one capacitor in parallel, the meter will be showing the parallel ESRs of all of them. Then it will be necessary to de-solder one lead of each of them, and test them one by one.

Once de-soldered, it's very important to let a capacitor cool back down to room temperature before measuring its ESR. **High temperature makes the ESR drop and can make a bad capacitor appear to be OK.**

Auto-ranging

The meter automatically changes ranges to cover ESRs from 0.001Ω up to 99Ω, with the appropriate decimal point for the range lighting up (or no decimal point for readings between 10Ω and 99Ω).

It's important to understand that when it's reading an ESR below 0.10Ω, the reading on the displays is in **milliohms (1/1000s of 1Ω)**. This is indicated by **both decimal points being illuminated**.

Especially when reading milliohms, the resistance of the probe tips becomes very significant. The shiny plating on the probes has been removed from the tips because it's too resistive. The bare brass slowly oxidises, which causes the readings to vary with how hard you're pressing the probe tips onto the capacitor leads. If it becomes a problem, lightly polish the probe tips with the piece of fine abrasive paper included with the meter.

Please note that it might not be possible to get a reading of exactly "**.0.0**" (0.000Ω) when holding the probe tips together, due to residual resistance in the probes themselves.

The talking version

Many professional electronic repair technicians who regularly use an ESR meter will have noticed that there's a general relationship between the physical size of electrolytic capacitors and their typical ESR readings. After a while, they don't need to consult the typical ESR figures chart very much because they have a pretty good idea of what reading to expect from a capacitor of a particular size.

It's those very experienced technicians who could benefit from having the ESR meter **actually say** what's on the displays, so they can keep their eyes on the probes.

The talking version of the meter is identical to the silent one, except that after turning on the meter, holding down the button for a few seconds puts it into the volume setting mode. It will display and say the volume, and each push of the button increases the volume from 1 up to 4 and then back to 0 (muted). Please let it fully say each setting before the next push. The meter will return to the measuring mode a few seconds after the last press.

The meter will say the first reading it sees, and not show a new reading until it's fully spoken the current one. Unfortunately, contact resistance between the probes and the capacitor tends to drop as you initially increase the physical pressure. You need to "stab" the probes onto the capacitor's leads so that the first reading will be the final reading, or wait for the meter to give a second and more accurate reading.

Very low resistance measurement

Because the meter can read down to milliohms, the resistance of printed circuit board tracks can easily be measured. This can make it a useful instrument for tracing short circuits.

Detailed approximate ESR values chart

On the last page is a full sized chart of fairly typical ESR figures for good electrolytic capacitors which you can print out and stick to the wall. It was created by **Adnan Ibna Islam** using an original Blue ESR meter. Visit his **Electronics Hobby Project For You** website at **https://ehpforyou.wordpress.com/**

	Rated Voltage										
Capacitance	10V	16V	25V	35V	50v	63V	100V	160V	250V	350V	450V
1μF				2.4	4.5	4.5	8.5	8.5	8.7	8.5	3.6
2.2μF			2	2.4	4.5	4.5	2.3	4	6.1	4.2	3.6
3.3μF			2	2.3	4.7	4.5	2.2	3.1	4.6	1.6	3.3
4.7μF			2	2.2	3	3.8	2	3	3.5	1.6	5.65
10μF		8	5.3	2.2	1.6	1.9	2	1.2	1.4	1.2	6.5
22μF	5.4	3.6	1.5	1.5	0.8	0.9	1.5	1.1	0.7	1.1	1.5
33μF	4.6	2	1.2	1.2	0.6	0.8	1.2	1	0.5	1.1	
47μF	2.2	1	0.9	0.7	0.5	0.6	0.7	0.5	0.4	1.1	
100μF	1.2	0.7	0.3	0.3	0.3	0.4	0.15	0.3	0.2		
220μF	0.6	0.3	0.25	0.2	0.2	0.1	0.1	0.2	0.2		
330μF	0.24	0.2	0.25	0.1	0.2	0.1	0.1	0.2	0.2		
470μF	0.24	0.18	0.12	0.1	0.1	0.1	0.1	0.1	0.15		
1000μF	0.12	0.15	0.08	0.1	0.1	0.1	0.1	0.1	0.1		
2200μF	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03		
3300μF	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03		
4700μF	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01		
10000μF	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01		