EZM Electronics Studio
ESR-2501C "ESR Meter"
User's Manual

This user's manual is an unofficial document, not written or supported by the product's manufacturer. It was compiled by Paul Schmidt in April 2024 as a means to consolidate various sources of operational information. Since the manufacturer does not provide any kind of user's manual for this product, hopefully this document will serve the needs of customers who purchase the product and wish to know how to use it. All information herein is based on scraps of information and specifications found in various places online, plus the results of messages back and forth with an eBay seller of the product, plus empirical information gathered by the author. No guarantee is made by the author that all information herein is correct, or that some examples of the product might not differ in various ways, or that product damage might result from mis-use of the product due to any errant information herein. The author assumes no responsibility for personal injury or damage to this product or to other equipment that might result from following these instructions. This manual is intended to be used by competent individuals with adequate electronics training, who can read and understand the information herein and proceed to use the product with 'eyes open' and good electrical safety in mind.

OVERVIEW

The ESR-2501C (the "Tester") is a piece of electronic test equipment that can measure two secondary characteristics of capacitors. The Tester can measure these characteristics with the capacitor 'in circuit' or 'out of circuit' (with the capacitor connected to other circuit components, or with the capacitor connected to nothing besides the Tester, respectively).

The two characteristics measured by the Tester are "ESR" and "DCR":

- ESR is the abbreviation for 'Equivalent Series Resistance', which is the part of the capacitor's overall impedance which is not due to capacitive reactance. A simple theoretical model of a capacitor has the 'ideal capacitor' in series with a resistor, whose resistance is the measured ESR. The ESR value should be very low ($< 0.1\Omega$) in most types of capacitor, but will be somewhat higher (up to several Ohms) for various types of electrolytic capacitors (e.g. aluminum electrolytics, tantalum electrolytics). Aluminum electrolytic capacitors, in particular, often suffer from excessive ESR as they age, or have been exposed to elevated temperatures, or are being used in higher frequency circuits than they were designed for (e.g. an aluminum electrolytic capacitor designed for use as a filter in linear power supplies or audio circuits will likely have excessive ESR if used instead in a high frequency switching power supply circuit). ESR is frequency dependent, and should be insignificant in DC circuits. ESR typically ranges from a few Ohms down to nearly zero Ohms. The ESR of a good capacitor depends upon the type of dielectric material, capacitance value and voltage rating; use the 'typical readings' table of the specific Tester you are using, not the table from some other model or brand of tester. Lower ESR values are best, higher values are bad.

- DCR is the abbreviation for ‘DC Resistance’, which has nothing to do with the capacitive functionality and instead results from the physical metallic structure of the capacitor, i.e; from the resistance of the capacitor’s wire leads, as well as other internal metallic structures such as the plates. DCR is always present, whether in AC or DC circuits, and is not frequency dependent. However, DCR resulting from short-circuit failure of the plates is an indicator of a ‘bad’ capacitor. DCR resulting from the leads should be very low, usually in a fractional Ohms range, e.g. 0.1 Ohm, but since a properly functioning capacitor will have infinite resistance *across* the leads with only DC voltage applied, the resistance of the leads is negligible. Thus, a ‘good’ capacitor should have a DCR (across its leads) of a value significantly above a few Ohms. A rough rule-of-thumb is that the DCR of an aluminum electrolytic capacitor should be higher than 25~30 Ohms; any less, and there is probably some sort of short circuit inside the structure of the capacitor and it should be replaced and discarded. *Note that this DCR rule-of-thumb is opposite of that for ESR; <u>while low ESR values are good, low DCR values are bad, and vice-versa</u>.*

The Tester can be in either ESR mode or DCR mode at a given time; it cannot automatically switch between modes and must be selected to one mode or the other by the user. While in ESR mode, the Tester applies a low voltage (about 0.7V) square wave signal (better testers use a sine wave) across the capacitor under test, and calculates the ESR from the measurements is makes. When in DCR mode, the tester applies a low DC voltage of about 0.32V across the capacitor under test, and calculates the DCR from the measurements is makes. When measuring polarized capacitors’ DCR, connect the red test probe/clip to the capacitor’s (+) lead, and the black test probe/clip to the (-) lead. For ESR measurements, polarity of the test leads does not matter.

WHAT’S IN THE BOX

The Tester, besides itself (including the test cable and short test leads), comes with the following:

- USB power cable (USB ‘A’ plug at one end, small barrel connector at the other end
- 1 pair of test probes (aka ‘test pens’), with banana type connections to the Tester’s test leads; these are colored red (x1) and black (x1)
- 1 pair alligator clips, with banana type connections to the Tester’s test leads; these are colored red (x1) and black (x1)
- 4 ‘silver’ probe tips (which screw into the test probes)
- 4 ‘gold’ probe tips (which screw into the test probes)

WHAT’S <u>NOT</u> IN THE BOX (but needed)

- AC power adapter/charger (uses the included USB power cable); 5V, 1A minimum
- Lithium rechargeable battery, type 14500, 3.7V, typically 1600mAh

These are ‘must haves’; the Tester will not work without these, so the user must obtain them.

FRONT PANEL

The Tester’s front panel is shown in the photo below:

- LCD display (upper left); this is also backlighted; all status and test results appear here.
- ‘Typical readings’ chart (lower left); this applies to ESR readings only, and are somewhat specific to this model and brand of tester, and are guidelines only, NOT absolutes.
- Green button; a brief press when OFF will turn the power ON, a press of about 1 second while ON will toggle between the two modes (ESR & DCR), under some conditions, a short press will force the Tester to do another ‘zeroing’ calibration process.
- Red button; a brief press resets the Tester without needing to turn it OFF, a press of about 1 second will turn the Tester OFF.

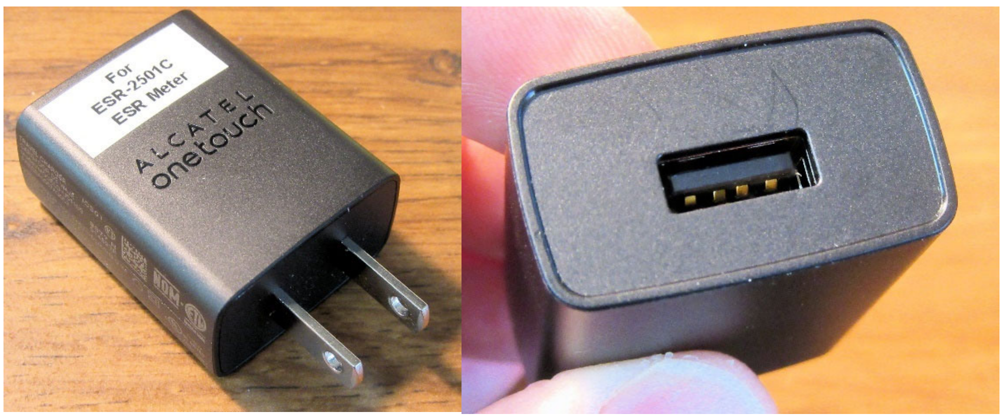
SIDE PANEL

The Tester’s left side panel is shown in the photos below:

- The included USB power cable (from the AC Adapter/Charger) plugs in as shown.
- The LED indicates ‘battery charging’ (RED), ‘battery charged’ (GREEN), USB cable and/or AC Adapter/Charge disconnected (OFF).

BATTERY & CHARGING

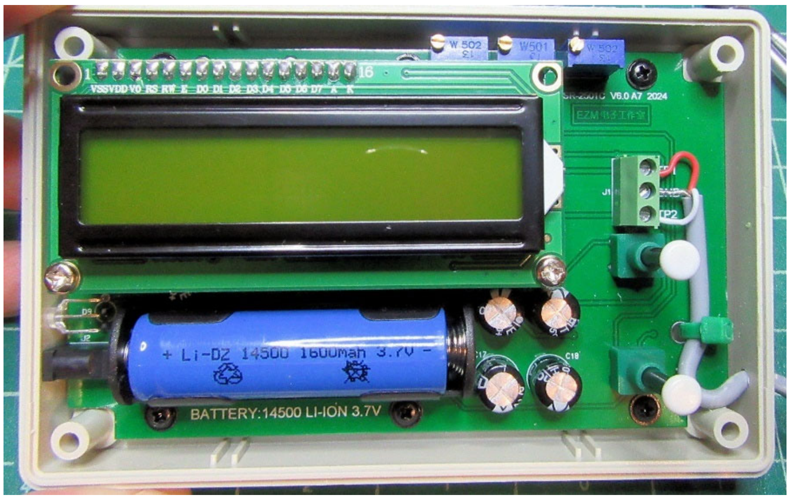
- The Tester will not function unless an appropriate battery is installed and charged. Also, the Tester will NOT function properly using the AC Adapter/Charger ONLY. Essentially, the AC Adapter/Charger (not included), connected to the Tester via the included USB power cable, will ONLY charge the battery, but the Tester does NOT get its operating power from the AC Adapter/Charger, it gets it ONLY from the charged internal battery.
- The necessary AC Adapter/Charger must be obtained separately by the user. It can be almost any kind of AC power adapter/charger used ubiquitously on seemingly every small portable electronic device these days. Suggested sources of such AC Adapter/Chargers: almost any old mobile phone charger, almost any 'wall wart' type USB power supply, the 'emergency travel needs' section of almost every automobile gas station's convenience store. The only critical characteristics are that it has a regulated 5VDC output, be capable of supplying at least 1A current, and have a 'USB-A' type socket connector to accept the included USB power cable.



Above: Typical AC Adapter/Charger (stolen from an old mobile phone),
with its 'USB-A' type cable connector visible (matches the included cable)

- The Tester is designed to use a type 14500 rechargeable Lithium battery, which produces 3.7V and has a typical capacity of 1600mAh. This type is commonly used for bicycle headlamps, wireless doorbells, etc; and is widely available from many sellers (e.g. Amazon) for about $7 each. Unfortunately, although this type of battery is usually used by itself, they are almost always sold in packs of 2 or 4, making it more expensive when you just need one of them for this Tester. A pack of two 14500 batteries is shown below.

- To install the battery into the tester, remove the four screws from the rear side of the tester's case, and lift the front of the case away from the rest of it, exposing the internal components. Orient the case with the LCD display towards the left, so the end of the case with the power cable jack and small round LED is on the left side; the main things inside the case are the printed circuit board and the smaller LCD display module. Just below the LCD module, find the battery holder (usually black in color). Orient the battery with its (+) side to the left, and press it down into the battery holder; it is best to insert one end of the battery, then while holding that end in place, press the opposite end of the battery down into the holder. See the photo below.



- Place the front of the case back onto the rest of the Tester, and use the four screws to re-attach the case halves together.
- Plug the USB end of the included USB power cable into the USB-A socket on your AC Adapter/Charger, and plug the AC Adapter/Charger into an AC outlet (make sure that the input voltage rating of your AC Adapter/Charger matched the voltage in your area of the world; most such AC Adapter/Charger products are 'universal voltage' and will easily work in places with 'AC Mains Power' as low as 100VAC and as high as 240VAC.
- Plug the opposite end of the included USB power cable into the barrel socket on the left side of the Tester. The adjacent LED should light up RED, indicting that there is a battery inside and that it is being charged. Depending on how empty the battery is, charging may take between 2 and 3 hours, and a fully charged battery is indicated by the LED changing from RED to GREEN.
- Unplug the USB power cable from the Tester; the LED will turn off. The Tester is now ready to use. *It is OK to leave the USB power cable attached during use, but it might get in the way during testing*.
- To save battery power, the Tester will automatically turn off if neither of its two buttons are pressed within a 5 minute period.
- If the battery discharges to a certain low level, the Tester will detect this condition, and a 'low battery' indication will appear on the LCD display, and after about 10 seconds the Tester will turn itself off.

TEST LEADS, PROBES/CLIPS and IN-CIRCUIT / OUT-OF-CIRCUIT TESTING

The Tester can be connected to capacitors that are currently 'in circuit' (they are part of a circuit) or 'out of circuit' (just by themselves laying on a workbench). As with any 'in circuit' tester, there is always the possibility of some corruption of the test process due to interaction of other components in the circuit, so testing 'out of circuit' is best if possible. If there is any doubt when testing 'in circuit', consider the option of disconnecting one of the capacitor's two leads, so the other components cannot influence the test.

The Tester has two options for connecting to the capacitor under test; the 'test probes' and the 'alligator clips'. When testing a capacitor that is soldered to a printed circuit board, and the best access is from the 'foil side' (the side opposite the side with the components), the test probes are probably the best choice. When testing a capacitor whose leads are accessible, either soldered to a circuit board or for 'out of circuit' testing, the alligator clips are probably best. Note that the Tester comes with spare tips for the test probes, and of two different types, although it is unclear when to use the 'silver' versus the 'gold' tips.

The test cable from the Tester splits near the end into two short test leads, each ending with a banana plug. Both the test probes and the alligator clips have banana sockets on them in order to receive the banana plugs on the test leads, allowing quick and easy changing of the connection method.

However, note that changing connection methods alters the overall test lead resistance by a significant amount, so it is critical that the Tester be re-calibrated (re-zeroed) after any change in test lead connections and/or immediately after changing between ESR and DCR modes (see section below on 'Zeroing').

Do NOT attempt to use the tester with extension banana test leads, or via any other scheme that adds wire length, as the extra resistance is probably outside of the tester's ability to 'zero out'.

Also make sure that whichever test lead connection is being used, that good electrical connections are being made to the capacitor under test. When probing to the foils of a circuit board, make sure that the test probe tips are pressed firmly enough to cut through any oxidation or solder flux that may be present; tiny amounts of extra resistance from such impurities can significantly affect the accuracy of the Tester's readings. When using the alligator clips, it is advisable to wiggle them around on the capacitor leads to make sure that their 'teeth' have bitten through any oxidation on those leads.

ZEROING THE TESTER (PROBE COMPENSATION)

When the Tester is first turned on, the display will prompt "Short probe!!!" and this remains until the tester detects that the user has shorted the test probes/clips together, after which the display reads "Probe compensate [compensation] zeroing!!!" for a few seconds; when this display changes to something else, the Tester has been calibrated and is ready for ESR tests.

Zeroing (probe compensation) is critical for proper Tester functioning, so be careful to do it when pretty much anything changes and whenever else the Tester prompts to do it.

As noted before, if the test lead connection method changes, the user must re-zero the Tester, and this can be done by shorting the test leads and pressing the Green button briefly, which will again give the prompts for shorting the probe(s) and zeroing. This can be touchy....depending on small differences in the duration of the button press, the Tester might remain in the same mode, or it might remain change modes, before prompting for shorting/zeroing; it might be necessary to try a few times, always checking the display AFTER zeroing to see which mode the Tester is currently in.

The Tester seems to be inconsistent regarding its need to re-zero immediately after changing from ESR to DCR mode; sometimes it will prompt for shorting and sometimes it will not. Regardless of whether the Tester prompts for shorting, the user should always short the probes immediately after changing to DCR mode, and then press the Green button to force a new zeroing (unless, of course, the Tester detects what the user is doing and automatically zeros, which seems to happen on occasion. It is a mystery.

Sometimes the Tester will prompt for shorting the probe(s), even though the user has changed nothing and has not pressed the Green button; simply comply with the request.

Especially in DCR mode, it is a good idea to briefly touch the test probes/clips together while watching the display; it should change to reflect shorted probes (0 Ohms) or open probes (> 25 Ohms). If the display does not react in this manner, then the user must force a new zeroing before performing any DCR tests (or else the test results will be wildly inaccurate).

In both the ESR and DCR modes, the upper right corner of the display will show a “CP” number, e.g. “CP=38”. This is the ‘probe compensation’ value, and it appears to be unitless, i.e. it is not in Ohms or any other unit. The CP number will be higher when there is more test lead resistance, and it can be into the high hundreds. It is not clear WHY the user needs to know this value, except perhaps to notice a high number, wonder why it is so high, and check to see if there are any loose test lead/probe/clip connections, etc; that might need to be remedied, then the Tester re-zeroed, before continuing.

TESTING LOW VALUE RESISTORS

The tester can be used to read the resistance of low value resistors; the manufacturer does not specify a maximum resistance for this, but empirical tests have shown that 25 Ohms is the maximum. The Tester must be in DCR mode for this, Also, this is only a DC test, and will not show any inductance or parasitic capacitance that the resistor might have. Compared to some less expensive Ohmmeters, this Tester might actually give more accurate low-Ohms readings.

RANGES

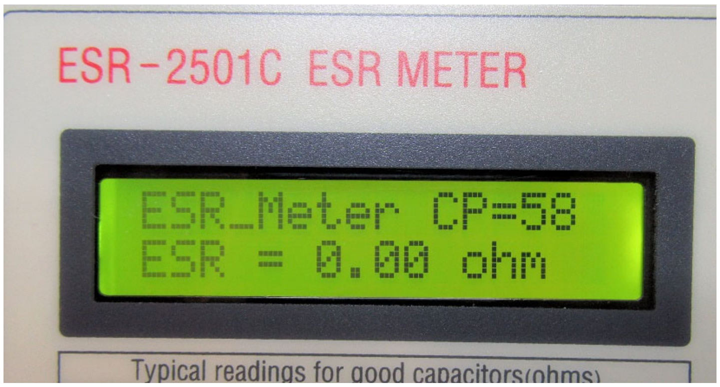
The Tester has two automatically determined resistance ranges for making ESR and DCR measurements, 0~5 Ohms and 5~25 Ohms; the switching is transparent to the user. Accuracy and resolution is better, by an order of magnitude, in the lower (0~5 Ohm) range.

DISCHARGE CAPACITORS BEFORE TESTING

While the manufacturer claims that the Tester has integral overvoltage protection, the Tester itself is marked next to the display that it is important to discharge a capacitor before testing it. Thus, it is good practice to short capacitors for a second or two before connecting this Tester's test probes/clips to that capacitor.

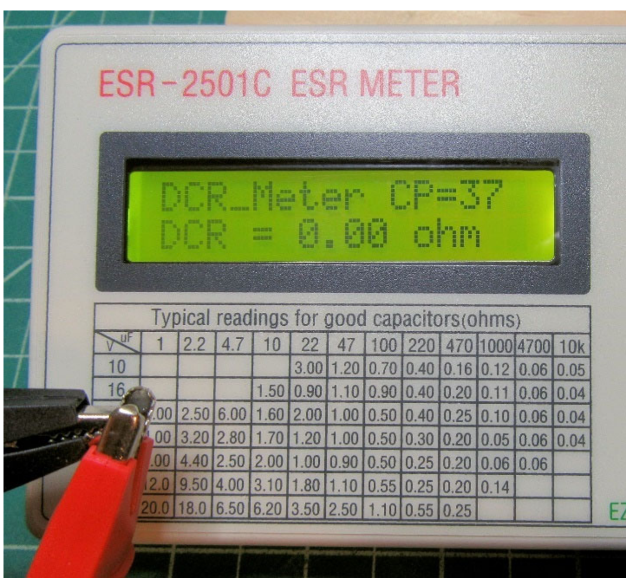
INTERPRETING THE DISPLAY

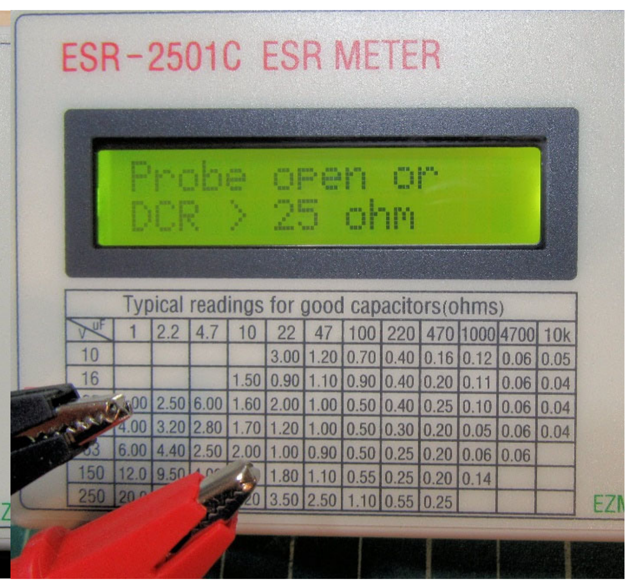
With the Tester in ESR mode, the display looks like this:



where "ESR_Meter" is the current mode, "CP=" is the probe compensation value, and "ESR =" is followed by the ESR value in Ohms.

With the Tester in DCR mode, the display looks like this:





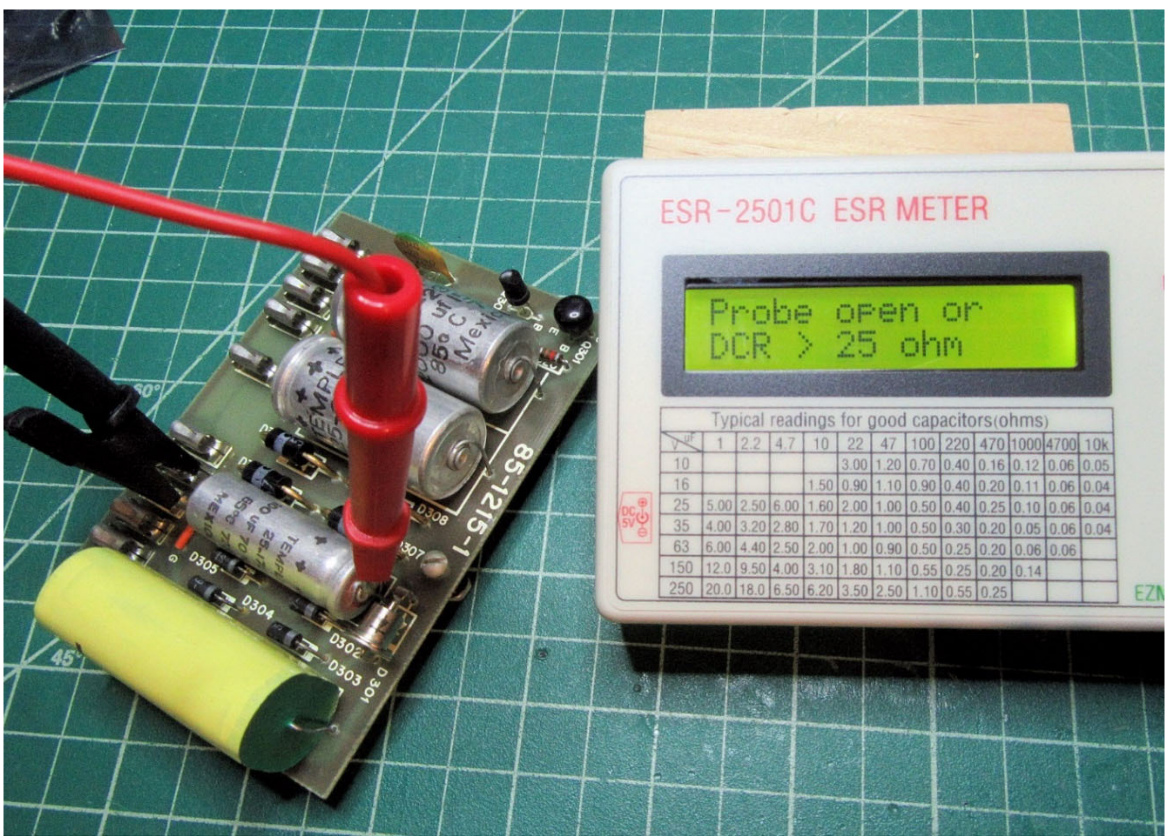
where "DCR_Meter" is the current mode. The left image shows the reading for a shorted capacitor (simulated here by shorted test leads), and the right image shows a typical reading for a capacitor with a DCR value significantly above the resistance expected from a shorted capacitor. Note that such different displays are only possible if the Tester has been properly zeroed while in DCR mode; otherwise, it is likely that only the left image will be shown regardless of short or no short.

SPECIFICATIONS

- Case material: ABS plastic
- Case dimensions: 125mm x 80mm x 32mm (about 5” x 3.15” x 1.25”)
- Weight: 200g (about 7oz)
- Resolution: 0.01Ω in 0~5Ω range, 0.1Ω in 5~25Ω range
- Accuracy: +/- 1.5% +/- 0.01Ω in 0~5Ω range, +/- 1.5% +/- 0.1Ω in 5~25Ω range
- ESR measuring signal frequency: ‘industry standard’ 100kHz, 0.7Vpp AC (+/- 0V)
    - *This ‘industry standard’ is for capacitors used in switching power supplies, not for lower frequency applications, so this Tester might not give results as accurate, in some situations, as ESR meters which use lower frequency test signals*
- DCR measuring ‘signal’: approx. + 0.5VDC
- Overvoltage protection: Tester has internal overvoltage protection across the test leads
- Battery: Common type 14500 Lithium battery, 3.7V and about 1600mAh capacity
    - *The Tester can be operated while the battery is being charged, although charging will be slower than with the Tester off, and power cable might get in the way*
    - *Charging time is between 2~3 hours*
- Working temperature: 10~40°C (about 50~104°F)

APPLICATION PHOTO

This image shows a typical arrangement of using the alligator clips to test an in-circuit capacitor on a printed circuit board. Note that the Tester here is in DCR mode and the display indicates a capacitor that is NOT shorted.



This image is of the Tester's front panel ESR chart:

Typical readings for good capacitors(ohms)												
V \ uF	1	2.2	4.7	10	22	47	100	220	470	1000	4700	10k
10					3.00	1.20	0.70	0.40	0.16	0.12	0.06	0.05
16				1.50	0.90	1.10	0.90	0.40	0.20	0.11	0.06	0.04
25	5.00	2.50	6.00	1.60	2.00	1.00	0.50	0.40	0.25	0.10	0.06	0.04
35	4.00	3.20	2.80	1.70	1.20	1.00	0.50	0.30	0.20	0.05	0.06	0.04
63	6.00	4.40	2.50	2.00	1.00	0.90	0.50	0.25	0.20	0.06	0.06	
150	12.0	9.50	4.00	3.10	1.80	1.10	0.55	0.25	0.20	0.14		
250	20.0	18.0	6.50	6.20	3.50	2.50	1.10	0.55	0.25			

The chart shows ESR values in Ohms, but to be meaningful, the user needs to interpret the ESR value against the capacitance in µF and the capacitor voltage. For example, the Tester might show an ESR reading of 2.00 for a 10µF capacitor, but whether this is a 'good' value depends on the capacitor's voltage; if the voltage is around 63 Volts, then the ESR of 2.00 is a typical 'good' value, but if the ESR reading is much higher, perhaps around 5, then that would be abnormally high for the rated capacitor voltage. On the other hand, if the 10µF capacitor is rated around 250V, then an ESR reading of 5 would be lower than the typical normal of 6.20 Ohms, which is 'very good'. Remember that low ESR readings are better than high ESR readings.

The values in this chart are not absolutes; they are typical, presumably based on averages of a number of sampled capacitors. The author has been compared this chart with similar charts on other brands of ESR meters, and the numbers are generally in line with what those show.

DCR VERSUS ESR: WHICH SHOULD BE TESTED FIRST?

This Tester defaults to ESR mode, which suggests that it is more important to test ESR before testing DCR. However, a number of other brands of tester actually perform the DCR test first, and only proceed to testing ESR if the DCR value is reasonable. Since this Tester has manual selection of mode, it is up to the user to determine a testing strategy.

The user should keep in mind that even capacitors with a fairly low DCR, but yet not shorted, might exhibit acceptable ESR readings, and thus the capacitor under test should be considered 'failed', yet the user would not know this if only the ESR is measured. A DCR reading of less than 25 Ohms should be considered 'bad', regardless of the ESR reading.

CAVEAT

This tester is designed to primarily test electrolytic capacitors, 1µF and greater. Its utility for smaller value electrolytics, and for other types of capacitors, is limited.