UNIVERSAL LIPO ESR METER INSTRUCTIONS

January 2016

GENERAL

Thank you purchasing your Universal ESR meter. This is the latest (and probably final) version of the meter which I first produced in 2010 and incorporates all the improvements and extra features introduced since then, also combining the capabilities of the standard 2S – 6S meter, the 1S – 6S meter and the now discontinued Single Cell meter.

The Universal meter has been electrically redimensioned to enable it to measure any lipo cell or pack from 1S up to 6S over the capacity range from 100mAh up to 10,000mAh.

The original ESR meter was developed to accurately measure the Internal Resistance of LiPo packs and individual cells so that the user could both determine the performance potential of their LiPos and track the decline in performance over the pack lifetime.

The IR (or ESR)* of a cell tells us more about the lipo than any other single measurement, but it cannot be used as a straight comparison without understanding that the figure is also dependant on cell capacity and temperature.

A limitation of the original meter is that many users would look at the ESR figure but wonder how to translate it into a simple performance figure with which they could compare different LiPo packs.

An equation has therefore been developed, based on the initial heat dissipated within the LiPo, which gives such a figure in the form of a maximum safe load current which can be drawn continuously from the LiPo without having a damaging effect on its life in number of cycles. The calculator, known as the "Lipotool", has been made available on line at http://www.jj604.com/LiPoTool/.

This calculator has now been incorporated into the ESR meter together with several other additional features such as charge state, Low Cell voltage warning and Over Range warning.

This means that the user can now input the capacity of the LiPo into the meter and read out the maximum safe current and the real practical “C” value of the pack directly.

The new version of the meter reads:-

LiPo Pack Voltage.

LiPo Pack ESR (Includes the resistance of leads + connector)

LiPo Cell Voltage for each individual cell.

LiPo Cell ESR – Cell only excluding leads and connectors with a true Kelvin 4 wire connection.

LiPo Cell Charge state as a percentage of fully charged.

LiPo Cell Maximum safe continuous current for long pack life.

LiPo Cell Practical real “C” value. (displayed as “αC”)

Note: The user must input the pack capacity in mAh to read the two last items.

*ESR stands for “Effective Series Resistance” It is conceptually a more accurate term than “Internal Resistance” as it includes the resistance of connectors and leads as well as the Internal Resistance of the cells in “Pack” measurements.

In “Cell” mode it is purely the Internal Resistance of the Cell, as the four terminal ‘Kelvin’ measurement system eliminates the effects of all other resistance in the power circuit.

OPERATION

The unit is normally self powered by the pack under test, the only control being an operate button.
ESR is measured at high current to simulate real operating levels. When connected to the pack, the display will read “Hold to set mAH” for approx. 3 seconds and then default to reading Pack voltage.

If you wish to just read Pack and Cell voltage, Charge State and ESR you can do so by toggling the operate button for Pack Voltage and ESR without connecting the search lead. For Cell Voltage and ESR connect the search lead to the appropriate two sockets in the balance connector and the meter will read Cell Voltage and charge state. Push the operate button to read Cell ESR. The operate button will now toggle the display between Voltage with % charge and ESR.

In order to read the maximum safe current and Real “C” for the Lipo you need to input the capacity of the pack in mAh. To do this refer to the attached “OPERATING SEQUENCE”

Note: You can only start to input mAh values when the meter is reading Voltage. If it is reading ESR pushing the button will toggle the display to Voltage. Then Press + Hold

SPECIFICATION

Mode	Max Range	ESR Res.	Accuracy	Voltage Res.	Accuracy
PACK	0-250mΩ	0.3mΩ	<3%	40mV	<0.5%
CELL	0-35mΩ	0.04mΩ	<2%	10mV	<0.3%

Absolute Maximum Input Voltage: 30V.

Protection: Unit is protected against reverse polarity on both main power and search wire inputs.

Limit warnings:

The meter will display “Cell voltage below 3.20V” for a low cell voltage.

The display will read “ESR Over-range” for Pack ESR of >250mΩ or Cell ESR of >35mΩ

Range: The unit can measure any LiPo pack of 1 – 6 cells in the range of 100mAh – 10,000mAh.

Note: There is no upper limit to the capacity of a lipo pack or cell that the meter will read ESR. The αC and Max Current can only be read for cells up to 10,000mAh due to memory storage limits.

Size: 45mm x 100mm x 130mm (1.8” x 4” x 5”)

Weight: 250g (9 oz)

Standard Connector: Deans

WARNING: Do not attempt to measure packs of over 6 cells. The Meter will suffer permanent damage.

OPERATING NOTES

(a) **Temperature**

The ESR of any LiPo is dependent on temperature; the lower the temperature, the higher will be the ESR. When comparing two packs therefore it is essential that you do so at the same temperature. Leave the two packs together for an hour or two to ensure this.

To demonstrate this, take a cell reading of cell 1 on a pack. Hold the palm of your hand against the flat side of cell 1 for only 15 seconds and take another reading. You will see that the ESR has fallen slightly.

The ESR of lipo packs can vary by 30 to 90% for a temperature change of 10^0 to 30^0C (50^0 to 85^0F).

(b) **Winter Flying**

The above demonstrates why it is important to warm your LiPos before use in cold conditions. If you launch with cold LiPos the voltage and power level is much lower, often to the point where the ESC will shut down on undervoltage. The current through the LiPo will heat it up (and damage it!), reduce the ESR and the power will gradually rise. This is why so many LiPos fail in cold weather. Therefore pre-warm your LiPos in winter.

(c) **Voltage Readings**

In Voltage mode the meter will read the pack or cell voltage, dependant on mode. It is not intended as a precision voltmeter as the resolution is limited, but it is accurate and consistent enough for general use and cell voltage comparison purposes.

(d) **Error Warnings**

(i) If you try to measure a pack which has an ESR >250milliohms or a cell of >35milliohms, the meter will display an "Over range" warning.

(ii) If any cell is less than 3.20V, the meter will display "Cell Voltage Low" and the meter will not measure ESR. Pressing the button will display the actual cell voltage for 3 seconds and then default to the low cell warning. Note that the meter will only read cell voltages down to 1.5V as a minimum voltage is necessary to change the meter to Cell mode.

Disconnect the search lead and toggle the meter to return to normal.

(e) **"Max I" and "αC" readings**

These readings are calculated using the Lipotool which is a rule of thumb, albeit a surprisingly accurate one. Approximations within the digital maths processor will result in the same **"Max I"** for slightly differing ESR values – This is not a processing error.

"αC" is a practical real value of **C** as it is understood by users ie it is the number you can multiply the pack capacity by, in Ah, to give a safe maximum current which will not have a deleterious effect on pack life. Read more details below under (g) The LiPotool.

(f) **State of Charge**

The ESR of a LiPo is largely independent of its state of charge but a fully charged pack will be 5 – 10% lower than one at storage charge. I would recommend measurements at the fully charged state for Lipotool use, although measurements at storage charge are equally useful for purely comparative purposes
It is possible to connect the meter in parallel with a working load (ESC + Motor) and monitor the ESR as the discharge proceeds.

This will clearly demonstrate the self heating effect and consequent fall in ESR as the battery temperature rises.

(g) The "LiPotool"

The original ESR meter was designed and built as an aid to my testing of LiPo batteries several years ago as the IR of a cell tells more about its performance capabilities than any other parameter. At the time I was involved in full capacity constant current discharge testing for several LiPo stockists in an attempt to directly compare the performance of various pack brands and 'C' ratings.

After much testing and comparing results, it became obvious that there was a close correlation between the maximum current delivery capability of a lipo cell and its IR.

In high power discharge testing, it was temperature rise which dictated the max current that could safely be drawn from a lipo pack. This temperature increase is caused by the load current passing through the effective resistance of lipo and the heat dissipated within the pack is a square law.

In conjunction with Mark Forsyth and John Julian (both qualified engineers and practising model flyers) the " LiPotool" was generated which specifies a maximum initial heat dissipation limit within the LiPo pack and calculates a maximum continuous current which may be drawn from the pack without exceeding this limit. We are not claiming that the LiPotool is a precise and exact tool, more a rule of thumb, but it has proved to be a surprisingly accurate guide when compared with the results of full discharge constant current testing of LiPo packs.

The current at which the packs showed obvious signs of overstress (excess temperature rise and voltage sag-and-recovery) invariably correlated with the predicted maximum current produced by the LiPotool.

It is somewhat conservative; aiming at a max continuous current which should ensure that your LiPos have a good lifespan. In real flying the LiPo will be subjected to surges and a practical safe surge is probably about 40% greater than the safe continuous current for the region of 10 seconds or so. This represents doubling the heat dissipated within the pack for the duration of the surge.

Where cells in a pack produce different maximum current or "C" readings, you should always rate a pack at the lower value as this is the weakest cell in the pack. (The weakest link in the chain.)

Readings of Real **"αC"** values from your meter may well disappoint, but this is generally because they have been so wildly exaggerated by so many suppliers that they have become a joke. Some LiPos, generally in the 20C and 25C categories are genuinely rated but I have never yet tested a LiPo capable of a genuine 40C continuous discharge without dangerously excessive temperature rise. Be suspicious of any claims of >35C.

(h) Internal battery

The internal electronics within the meter require a voltage of at least 6.5V to process the measurement, which is normally supplied by the Lipo under test, but a single Lipo cell (or a very weak or discharged 2S pack) is incapable of supplying this voltage. In this case the internal battery in the meter will supply the necessary voltage automatically as required but is not used at all in general use. The internal (PP3) battery should last for years depending on usage but is capable of about 8000 measurements of 1S lipos based on a 10 second time to take a reading. Avoid leaving a single cell connected to the power leads for long periods as this will deplete the internal battery.

(i) Measuring Single Cells

The meter is capable of measuring cells as small as 100mAh but the 4 wire Kelvin measurement, and therefore the Lipotool calculation, cannot be made because there is no balance connector to plug the search lead into. In any case, such small cells have IR values outside of the Cell Mode measurement range 0f 0 – 35milliohms and can therefore only be measured in Pack mode where the range is 0 – 250millioums. This means that the additional resistance of the leads and connector are included in the measurement figure. You will need a multi plug charger adapter lead to convert from the 'T' connector to any small single cell connector used on small single cells. These are available for at minimal cost on line or from most serious hobby stores.
The small micro connectors used on very small cells are very variable in their contact resistance and it is recommended that you take several readings and use the lowest as several insertions will help to remove the oxide film on contacts. Alternatively use a contact cleaner.

REMEMBER: FOR ACCURATE RESULTS YOU MUST TAKE ESR AND CURRENT READINGS AT 22 - 25^{0}C (72 - 77^{0}C)

HELP

If you have any problems or queries, you can always contact me by e – mail at wm.giles@zen.co.uk or by post at:

W.R.Giles, Briar Patch, Biggin Hall Lane, Thurlaston, Rugby, Warwickshire, CV23 9LD, UK.

ESR METER ANALYSIS VERSION – OPERATING SEQUENCE

Key: "PB" = Push Button Momentary "PBH" = Push button and hold >2Secs

ACTION	DISPLAY RESULT	NOTES
Connect Main Power Lead **Option**: PBH to set mAH*****	ESR Meter ver 2.0 Hold to set mAh	Display lasts 3 secs only
After 3 Seconds	ESR Meter ver 2.0 Pack = XX.XXv	Reading Pack voltage
PB – Audible bleep.	ESR Meter ver 2.0 Pack ESR = XX.X m.Ω	Reading Pack ESR which includes connector + wire
PB – No bleep	ESR Meter ver 2.0 Pack = XX.XXv	Reverted to previous state Reading Pack voltage

Now measure each cell IR and % charge in turn. You need to input mAh to read "C" and max I * See below

Insert search lead into balance connector for cell 1	ESR Meter ver 2.0 Cell = X.XXv XX% ch.	Reading Cell 1 voltage and Percentage charge state
PB - Bleep	Cell ESR = XX.XXm.Ω ("C" = XX max I = XXXA)*	Reading Cell IR, Real "C" value and max safe current for Cell 1
Move search lead to cell 2 position in balance conn.	ESR Meter ver 2.0 Cell = X.XXv XX% ch.	Reading Cell 2 voltage and Percentage charge state

PB - Bleep	Cell ESR = XX.XXm.Ω ("C" = XX max I = XXXA)*	Reading Cell IR, Real "C" value and max safe current for Cell 2
Repeat last two steps for each cell		

* Setting the pack capacity in order to calculate Real "C" and maximum safe current.

PBH – 2 secs – Bleep – Release. (Meter MUST be reading Voltage)	Set mAh hundreds 000mAh	Now ready to take 100s 0f mAh
PB to step 100s of mAH -Bleep at each step	Set mAH hundreds X00mAH	Each PB adds 100mAh up to 900mAh max
PBH – 2 secs – Bleep - Release	Set mAH thousands X00mAH	Now ready to take 1000s of mAh
PB to step 1000s 0f mAh – Bleep at each step	Set mAH thousands XX00mAH	Each PB will add 1000mAh Up to 10,000mAH max
PBH – 2secs – Bleep - Release	Capacity set to : XX00 mAh	Set capacity displayed for 3 secs Display then reverts to voltage

NOTES: (1) Loading in mAh quickly becomes intuitive. If you go past a value, carry on as the system recycles to zero after full range. You cannot get in a mess as there is only one button! You can always disconnect the power lead – the capacity memory will reset to zero after each disconnection.

(2) Max I is the maximum **continuous recommended current** which will result in a decent life span for the Lipo. Surges of up to 40% higher are generally acceptable for short periods ie 10 – 20 seconds. It is **ESSENTIAL** to take readings at 22^0C - 25^0C (72^0F - 77^0) for correct IR, Imax and real "C" readings.