ESR Meter For 2 – 6 Cell Lipo Packs

OVERVIEW

A Lipo pack can be considered as a perfect stable voltage source in series with a small series resistance: its ESR, or Equivalent Series Resistance. Also known as IR or Internal Resistance.
This resistance or ESR, is made up of the total resistances of each cell plus the resistance of the interconnections, the power leads and the contacts of the power connector. Once we have chosen a pack, the only one we have any control over is the connector which represents only a small percentage of the total.
It is the ESR which dictates how the pack is likely to perform, both in the short term; ie holding its output voltage and delivering more power, and in the longer term, its probable life in number of cycles.
Measuring ESR requires special equipment as a typical value is a tiny fraction of an ohm, and also because ESR is measured across a live power source, ie a cell or battery.

ESR – The effects

What does ESR do? In a nutshell, it drops volts, wastes power and heats up and damages the battery. Thus we are looking for the Lipo with the lowest ESR.
If we take a good 3S 2250mAh pack as an example with a pack ESR of, say 15 milliohms, then if the motor is taking 40A, the voltage delivered to the motor is 0.6V higher than a poorer pack with an ESR of 30milliohms. An extra volt drop of 0.6V doesn't sound much but it is about 5.5 – 6% of the motor volts and will result in 10 – 12% less power at the prop. which is significant and noticeable. The other effect is that the better pack has an internal power dissipation of 24Watts heating it whilst the poorer pack has 48W so it gets a lot hotter and as a result is likely to have a shorter life.
The equation is complicated by the fact that the ESR has a negative temperature coefficient (heat reduces the ESR), but in essence the above holds true

Operation
The unit is self powered by the pack under test, the only controls are a mode switch and an operate button. ESR is measured at high current to simulate real operating levels.
When connected to the pack, the display will read the voltage of the pack if switched to 'Pack'. If the meter is switched to 'Cell' and the search connector plugged into two adjacent pin positions on the balance connector, the meter will read the voltage of the cell corresponding to those two positions. Moving the search connector allows measurement of any cell in the pack.
To take an ESR reading it is only necessary to press the operating button and the unit will display ESR for about 3 seconds and then revert to reading voltage. In 'Pack' mode it will read the ESR of the whole pack plus the connector and leads. This is a practical measurement as it is measuring the total resistance in the circuit that the ESC will see in practice.
In 'Cell' mode it will read the ESR of just the individual cell that the search wire is connected to via the balance connector, excluding all other leads and connectors. In the 'Cell' mode the instrument is using a true 4 wire Kelvin connection enabling the user to very accurately compare the ESRs of each individual cell in the pack.

SPECIFICATION

Mode	Measurement Range	ESR Resolution	Accuracy	Voltage Res.	Voltage Acc.
Pack	0 – 250 Milliohms	0.3 Milliohms	<3%	40mV	<0.5%
Cell	0 – 30 Milliohms	0.04 Milliohms	<2%	10mV	<0.3%

Measurement current: 16A.
Maximum Pack Voltage: 30V.
Protection: Unit is protected against reverse polarity on both main power and search wire inputs.
Range: The unit can measure any Lipo pack of 2 – 6 cells in the range of 500mAh – 6000mAh.
Size: 45mm x 100mm x 130mm (1.8" x 4" x 5")
Weight: 200g (7 oz)
Standard Connector: T-Plug

OPERATING NOTES

(a) **Temperature**
The ESR of any lipo is dependant 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 to 30 deg.cent (50 to 85F).

(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) **Interpreting Values**
"Pack" Readings
In this mode the meter measures the total resistance of the cells + the resistance of the links between cells + resistance of the leads + the resistance of the connector. This is the effective resistance in the circuit in real conditions. You can assume that leads plus a good 50A connector have a resistance of about 4 - 6 milliohms. Try to take readings at the same temperature, say 20deg.cent so that you know what is a good reading for a particular pack size. Eg a good 3S 2250 20C pack will be about 15 – 20 milliohms whereas a poor pack will 40 milliohms +. Some packs have a higher ESR but also a high temperature coefficient so that their initial voltage drop is higher but reduces due to self-heating. They may finish up hot with a similar performance to the lower ESR pack, but they are hotter, more highly stressed and likely to have shorter lives.
"Cell" Readings
In Cell mode the meter reads only the ESR of the cell corresponding to the two adjacent pin positions on the balance connector. The reading is taken as a 4-Wire Kelvin connection so that only the cell is measured and very accurately. No other wires or contacts are included in this value so that you can now accurately compare all the cells in the pack. Some makers claim that their cells are "Resistance matched" and this can be checked.
When a pack is damaged or dying, it is invariably one cell which is deteriorating and this will be shown in the ESR value rising, so you can trace the degeneration of your lipos and know which are the better ones.

(d) **Voltage Readings**
In default mode the meter will read the pack or cell voltage, dependant on switch position. 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.

(e) **Current Operating Level**
The unit uses a 16 Amp constant current pulse to measure the ESR of a pack. This is large enough to facilitate an accurate measurement of a large capacity pack but small enough to be acceptable to a small lipo without damage.

(f) **Error Readings**
If the main input is reverse connected to a pack the unit will not be damaged, but the display will not appear. Reversing the cell measuring search lead (much more likely) will again cause no damage but will result in a reading of about 0.6V.
If the search lead is left open circuit it will read zero voltage and about 40milliohms (Over-range) if the 'Read ESR' button is pressed.
The lowest voltage at which a battery pack which can be measured is 6.0V, so that a 2 cell LiFe (A123) is marginal although a 90% discharged 2S lipo is OK.

(g) **State of Charge**
The ESR of a lipo is largely independent of its state of charge unless the pack is completely exhausted, which is unwise in any case. 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.