

EIS measurements with multisine

I-Introduction

EIS measurements are sometimes very long especially at low frequencies. It can be an important issue for systems varying with time. To overcome this problem, it could be useful to work in multisine impedance measurement mode. This measurement mode consists in exciting and measuring various frequencies in the same time contrary to the single sine measurement mode.

The multisine measurement is defined as the sum $u(t)$ of sinusoids at different frequencies with the same amplitude A and different phases Φ [1,2]:

$$u(t) = A \sum_{k=1}^N \cos(2\pi f_k t + \Phi_k) \text{ with the phase}$$

$\Phi_k = \Phi_1 - 2\pi \sum_{n=1}^{k-1} \frac{(k-n)}{N}$ and N the number of frequencies.

The EIS multisine measurement developed in EC-Lab[®] software is defined in order to reduce the crest factor defined by:

$$Cr(u) = \frac{u_M - u_m}{2u_{\text{eff}}} \text{ with } u_{\text{eff}} = A \sqrt{\frac{N}{2}} \quad [3,4]$$

The aim of this application note is to compare EIS measurements with and without multisine mode.

II-Experimental part

Electrochemical Impedance Spectroscopy measurements in single sine or multisine were done on a lithium-ion battery (ANR26650, A123 System). This 2.3 Ah battery, with nanophosphate as positive electrode, was studied using the PEIS technique.

All the measurements were done at 0 V vs the Open Circuit Potential, i.e. ~ 3.31 V. Impedance scans were done from 200 kHz down to 10 mHz.

Note that measurements were done with EC-Lab[®] software and 8 A booster kit. The multisine measurements are effective only below 1 Hz.

The other parameters are set to be equal to 20, 1 and 1 for the peak-to-peak amplitude (V_{pp}), the p_w value and the average N_a , respectively. The drift correction option was on.

The settings for the single and multisine measurements on lithium-ion battery are identical and multisine settings are reported in Fig. 1.

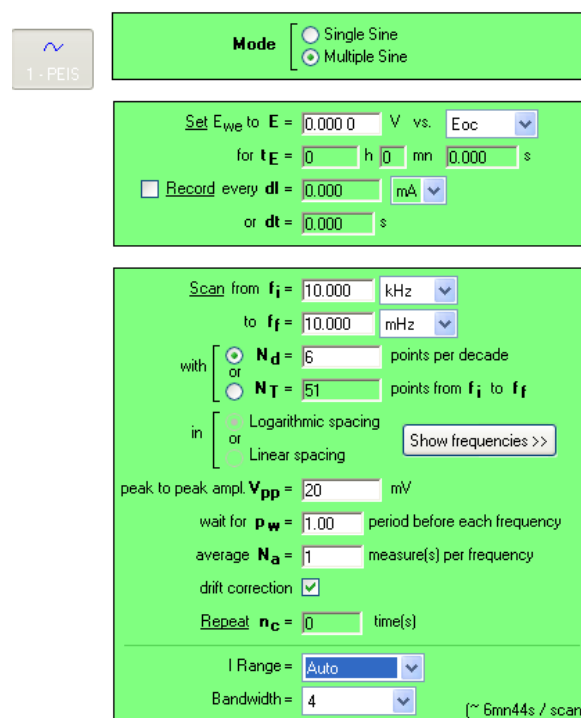


Fig. 1: EIS multisine measurement settings.

III-Results

Impedance diagrams obtained are shown in Fig. 2. The whole diagram is given in the top. As expected the impedance diagrams are superimposed, whatever the frequency. The right overlapping of single sine and multisine impedance diagrams is displayed in the zooms in low and high frequencies in Fig. 2 (middle and bottom).

Fig. 3 gives the time comparison for doing the both EIS experiments. Single sine measurement needs 20 min 38 s, whereas multisine measurement takes 5 min 22 s. It

is then obvious that multisine measurements are faster by a factor close to four times than measurements in single sine mode. This saving of time and thus a faster measurement is a good way to avoid the drift of some electrochemical systems.

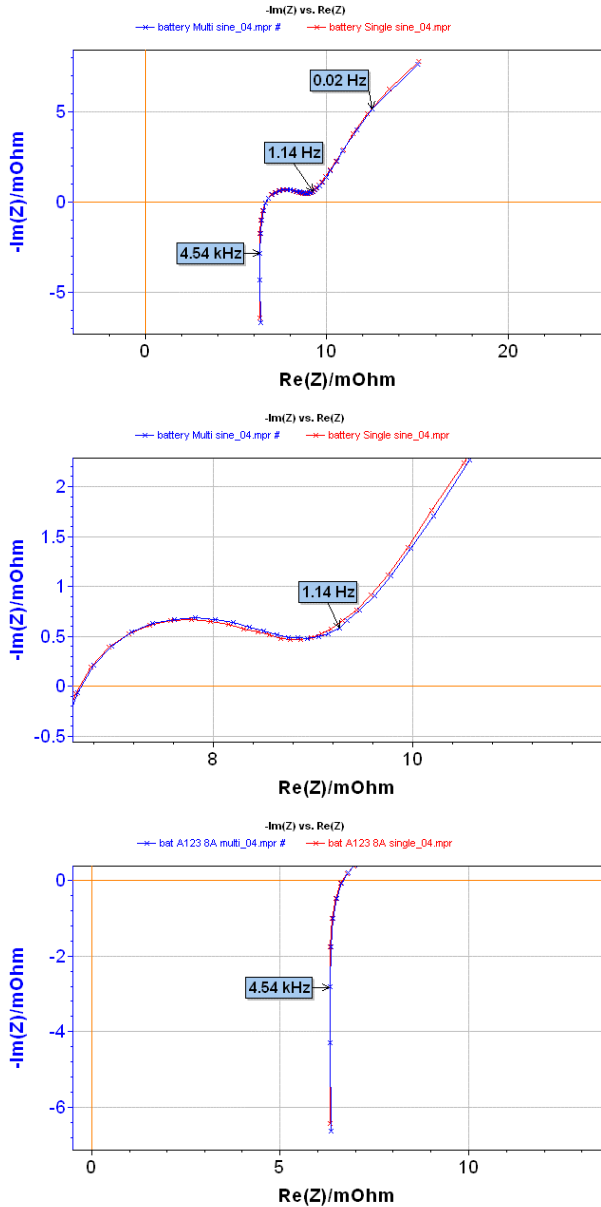


Fig. 2: Electrochemical Impedance Spectroscopy measurement on lithium-ion battery done with single sine (red line) and multisine (blue line) mode: total diagram in the top, zoom in the low frequencies range in the middle and zoom on the high frequencies range in the bottom.

IV-Conclusion

EIS measurement in multisine mode is a good means to spare time and therefore to avoid changes or drift of the electrochemical system with time. Depending on the system, EIS measurements allow the user to do experiment 3 to 4 times faster than in single sine mode with the same accuracy.

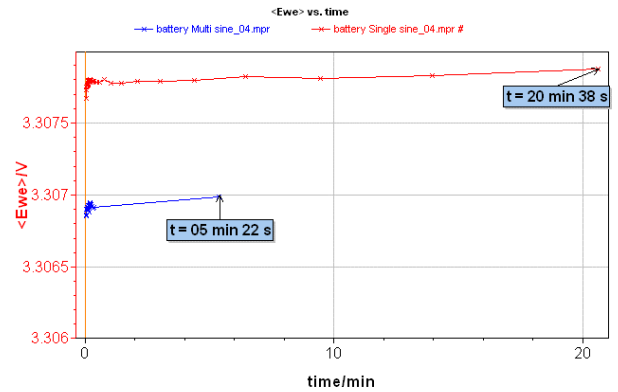


Fig. 3: Comparison of the Ewe vs. time for EIS measurement on lithium-ion battery using single sine (red line) or multisine (blue line) mode.

Nevertheless, user has to take care about the definition of experimental conditions. Indeed considering the principle of the multisine measurement, the excitation is defined for all the frequencies, by consequent each frequency is less excited than in single sine mode. This can imply noisy measurements. Nevertheless, increasing the level of excitation can bring to non-linear conditions for EIS measurement and then disturbed impedance results [5].

References:

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