

Three-parameter Multisine Fitting Method for Minimization of the Measurement Time in Online EIS Battery Monitoring

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Abstract: Electrochemical impedance spectroscopy (EIS) is a widely used technique for characterizing lithium-ion batteries. It provides valuable insights into various physical and chemical processes and can effectively estimate battery state parameters such as the State of Charge (SOC) and the State of Health (SOH) [1]. Recently, significant research has focused on implementing EIS *in-situ* and *in-operando*, enabling its use "online" while the battery operates in real-time conditions [2]. Among the various EIS approaches, multisine EIS is particularly promising for online battery characterization, as it reduces measurement time by simultaneously exciting multiple frequency tones [3]. However, further improvements are needed to shorten the measurement time even further without compromising the lower limit of the measurement bandwidth, f_{min} . This work proposes the usage of a three-parameter fitting method together with multisine excitation for EIS of battery cells instead of standard approaches such as sine-sweep excitation and FFT-based estimation of the frequency components. The proposed method reduces the measurement time to a fraction of $1/f_{min}$ and preserves the measurement bandwidth, maintaining the minimum frequency f_{min} . The method was tested through simulations using a multisine excitation composed of four tones of equal amplitude at random frequencies, combined with additive Gaussian noise resulting in SNR of 30 dB. With all frequency points known a priori, the method estimated the magnitude and phase of the frequency components with less than 0.4% error in magnitude and 4 mrad in phase. These results were obtained with a measurement time of 0.4 s. An even shorter time can be obtained by relaxing the accuracy target or improving the SNR. Thanks to the three-parameter multisine fitting method, it is possible to apply multisine EIS with a measurement time of only 400 ms while capturing information down to 1 Hz, significantly enhancing the feasibility of online battery monitoring and diagnostics.

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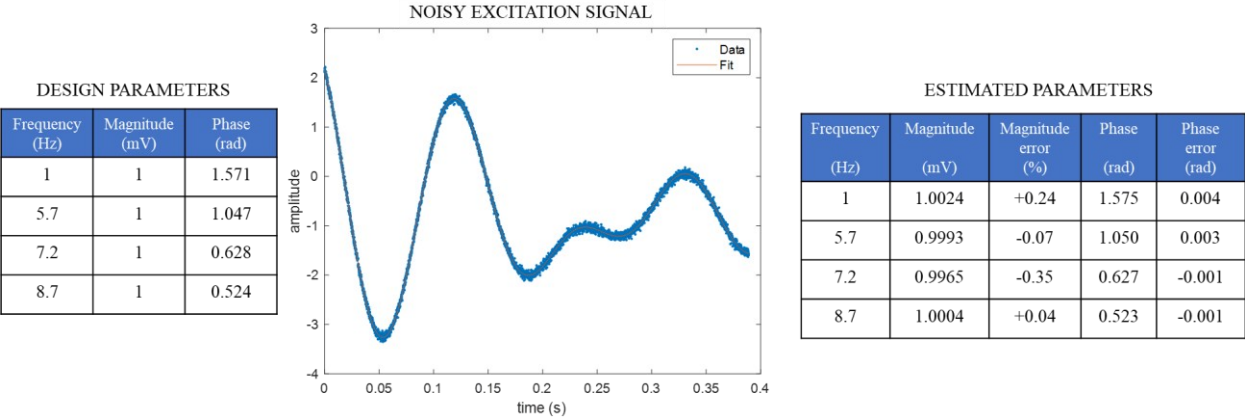


Figure 1. Simulation results of the proposed 3-parameter multisine fitting method. The left table reports the design parameters of the multisine excitation signal. The central graph shows the multisine signal with additive noise over the measurement window of 0.4 seconds. The right table summarizes the results of the estimation method, highlighting the errors in magnitude and phase. For a simpler comparison, the estimated parameters refer to the excitation signal but they can mapped to the battery impedance.

References

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