ModuLab®

electrochemistry

Application Guide

# DC/EIS cell analysis techniques
# AC Voltammetry

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Application Guide: AGML08

## Introduction

AC voltammetry is a powerful diagnostic technique that can be used on solid electrodes and mercury systems. It is used primarily for kinetic studies since it can decouple mass transfer and kinetic processes in the frequency domain. This is essentially the basis of all impedance techniques. This demonstration experiment describes some of the unique features of ModuLab including the ability to measure full frequency impedance spectra whilst applying a ramped DC voltage offset.

## Key system capabilities used in this demonstration

- FRA can apply multi-sine waveforms allowing full frequency analysis at different potentials during a linear potential ramp.
- Single sine and multi-sine techniques are available in linear and staircase modes
- Higher order harmonics can be measured as a function of potential
- Single sine AC waveform can be applied anywhere on the step in staircase mode

## Equipment required for this demonstration

- ModuLab potentiostat, 1MHz FRA option, ModuLab test cell.

## Connections

- Connect the ModuLab potentiostat to the corresponding connections on the test cell using the connection diagram shown in the following experiment.

## Experiment setup

Select "AGML08 AC Voltammetry" in the "ModuLab Application Guide" project

| Step # | Purpose |
|---|---|
| Step 1 | Run an AC voltammetry with single frequency, swept sine or multi-sine impedance at the required polarization points in the DC scan |

Additional test possibilities:

- Multi-step experiments could be used to run a sequence of AC voltammetry tests with a different impedance mode selected for each step (single frequency, swept sine and multi-sine / FFT)
- Linear or stepped scan waveforms may be used
- Higher voltage levels can be run by adding the HV options (up to 100 V)

## Notes on setup

Consult the setup files in the ModuLab demonstration software for more details.

## Data presentation and analysis

A detailed analysis of the results is beyond the scope of this note. However, we shall focus on the performance of the system. Figures 1a and 1b show the applied voltage and measured waveforms for an AC cyclic voltammogram using a single frequency stimulus (100 Hz in this instance). One can clearly see the AC waveform in the time domain at intervals of 1 s (see Figure 1b for more detailed diagram of single waveform)

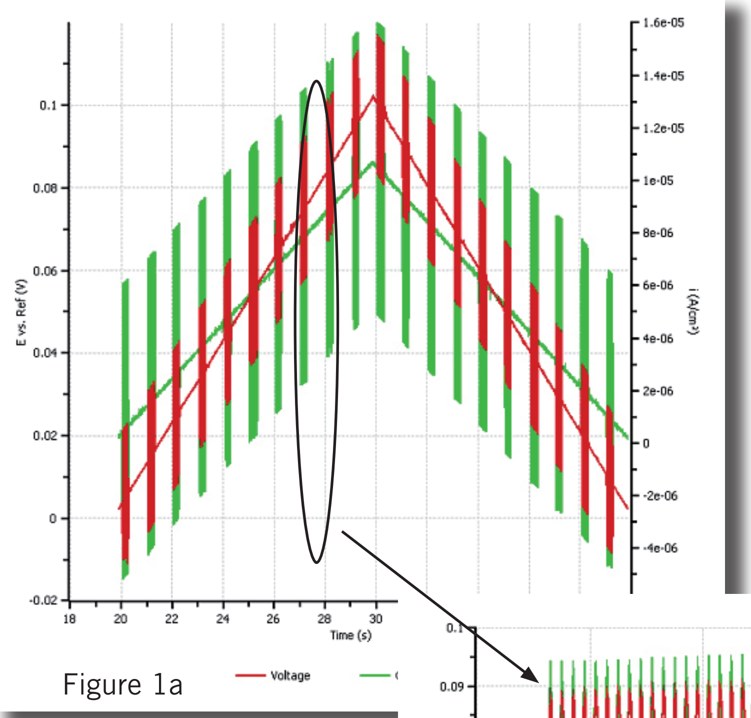


Figure 1a

Voltage and Current response of the cell using single sine AC Voltammetry technique. Frequency = 100 Hz

Figure 1b below is an enlarged section showing individual sinusoidal waveforms

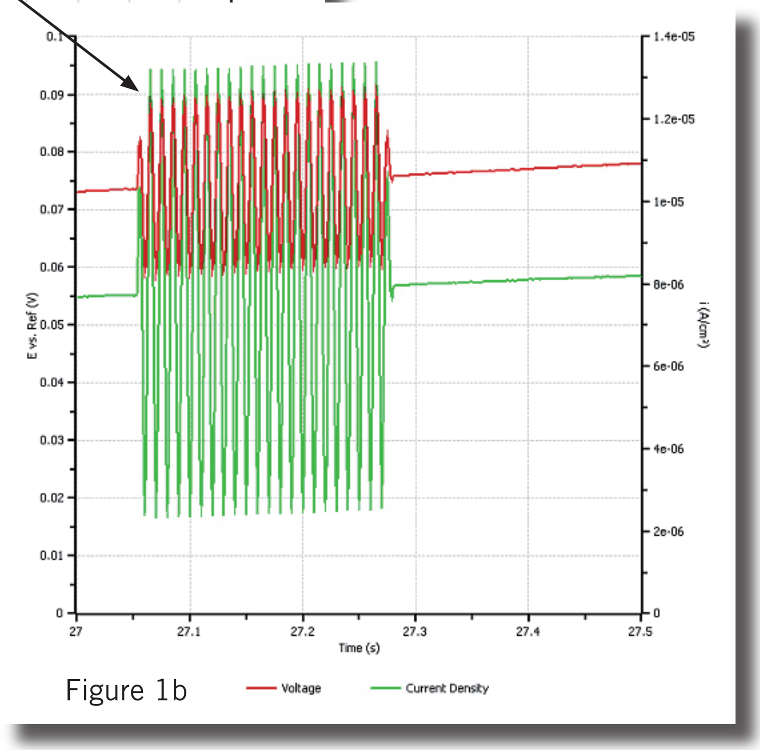


Figure 1b

Full frequency multi-sine analysis is available in ModuLab. Figure 2 demonstrates this capability. Figure 2a shows the applied DC waveform with the multi-sine waveforms clearly visible in the plot. The complex plane diagrams for each AC measurement are shown in Figure 2b. It is important to note that the DC sweep rate should not exceed the measurement period for the AC component. Therefore, DC sweeps less than 1 mV $s^{-1}$ are recommended. Such a feature may allow chemists to decouple mass transport and kinetic terms more rapidly and during dynamic changes to the cell.

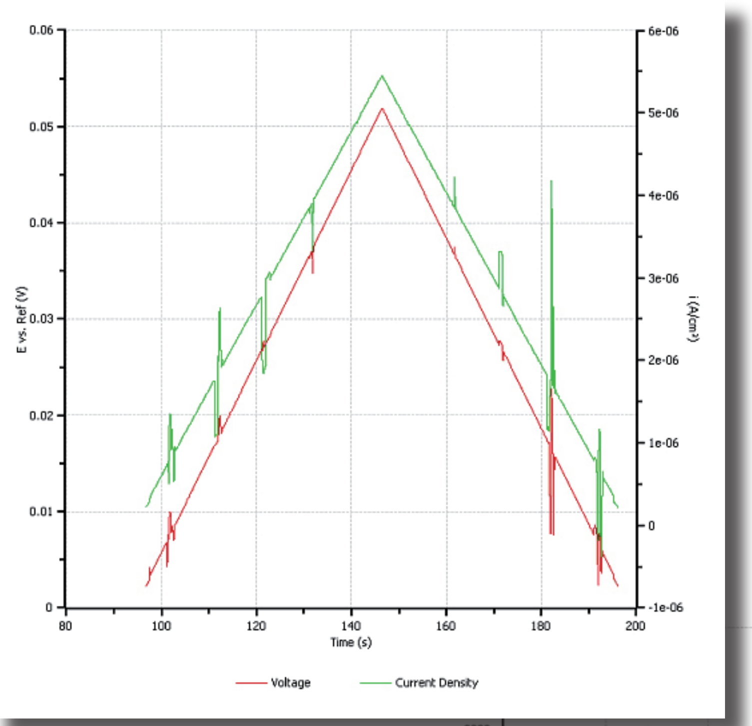


Figure 2a Multi-sine waveforms superimposed upon ramped DC potential - Voltage (red) and Current (green) are shown.

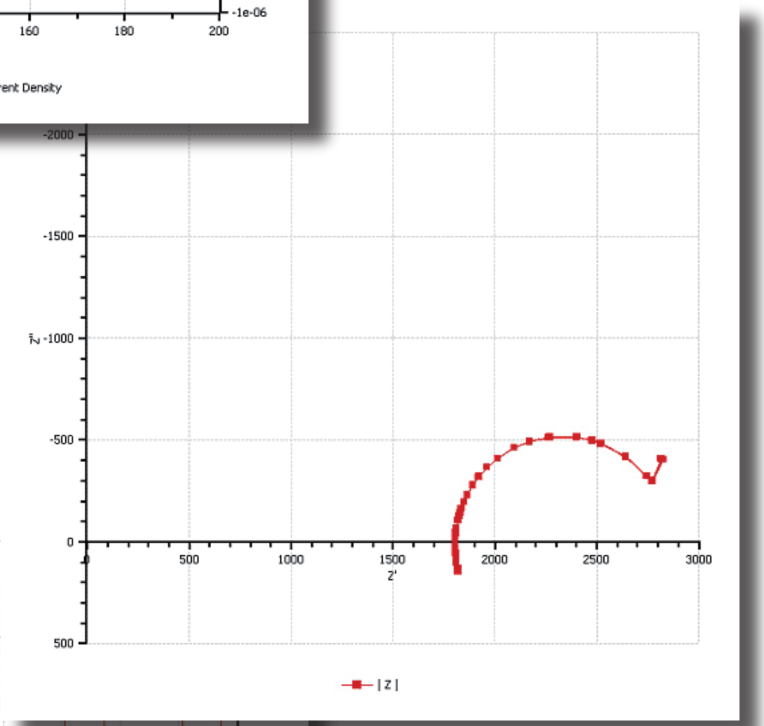


Figure 2b Complex plane diagrams of ten impedance spectra recorded from AC voltammetry experiments. Note that results are overlaid.

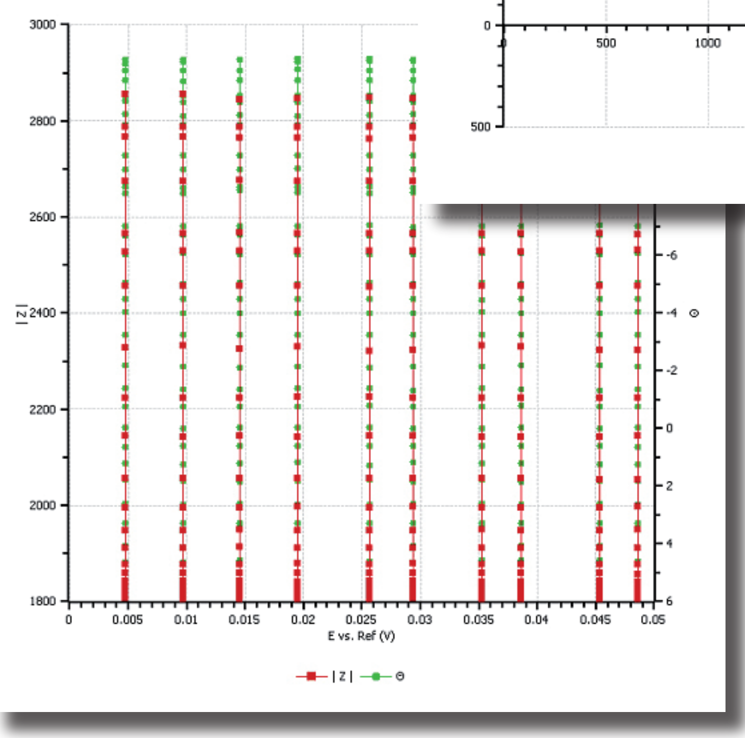


Figure 2c Magnitude and Phase as a function of applied potential showing ten broadband impedance measurements from 10 kHz to 1 Hz.

Additional benefits of the system include the ability to add high voltage options to increase measurement capability from the 8 V bias capability of the core card, to 100 V with the HV 100 option. This will be of use to fuel cell stack engineers. Furthermore, since the technique is available in current control mode coupled with the feature that the AC waveform can be applied anywhere on the step, complete AC characterisation of a stack is possible in a single experiment.

## Summary

The speed of measurement, coupled with the multi-sine capability of Solartron's FRA technology will enable electrochemists to probe interfacial mechanisms in ways that were previously unobtainable with legacy products. Experimental possibilities are further enhanced by the addition of high voltage option cards and power boosters that are available with ModuLab.

Application Guide

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