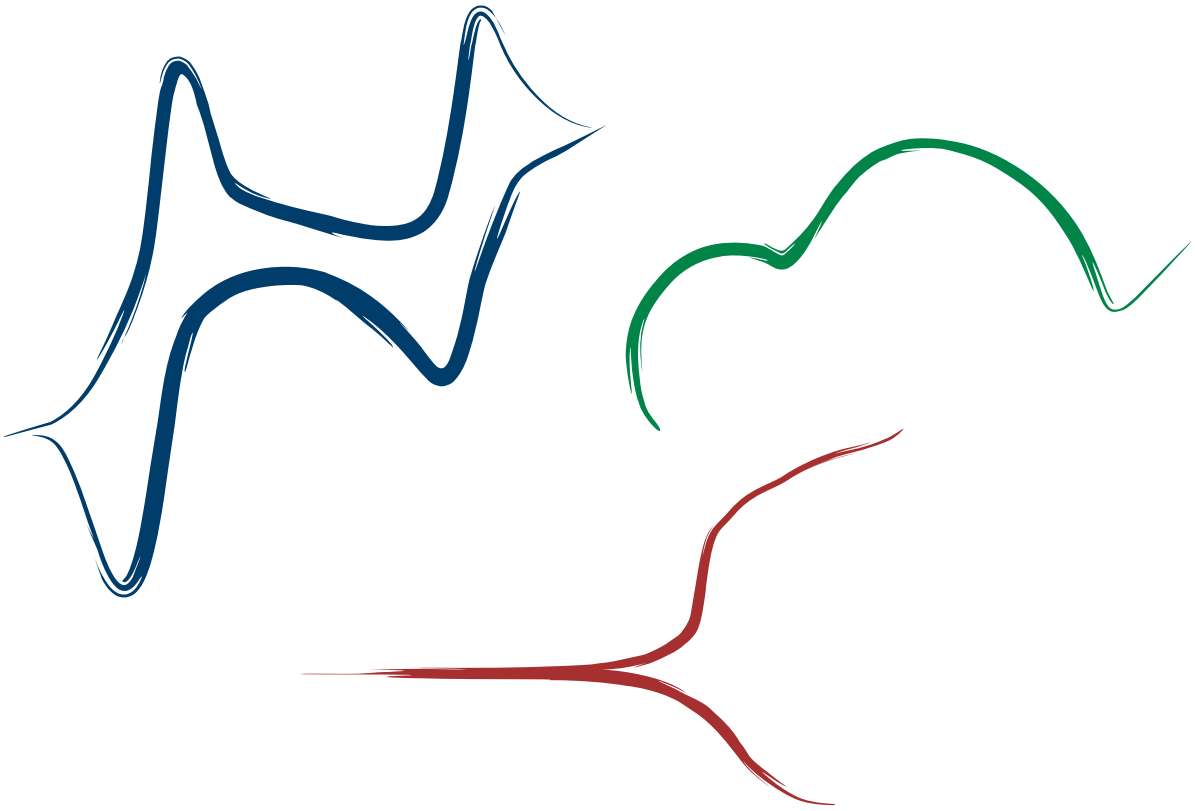
Echem Analyst 2™ Software

Operator's Guide



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If You Have Problems

Please visit our service and support page at https://www.gamry.com/support-2/. This page contains information on installation, software updates, and training. It also contains links to the latest available documentation. If you are unable to locate the information you need from our website, you can contact us via e-mail using the link provided on our website. Alternatively, you can contact us one of the following ways:

Internet	https://www.gamry.com/support-2/	
Telephone	(215) 682-9330 9:00 AM–5:00 PM	US Eastern Standard Time
	(877) 367-4267	Toll-free US & Canada Only

Please have your instrument model and serial numbers available, as well as any applicable software and firmware revisions.

If you have problems in installation or use of a system containing Echem Analyst 2 software, please try to call from a phone next to your computer, where you can type and read the screen while talking to us.

We will be happy to provide a reasonable level of free support for registered users of the Echem Analyst 2 software. Reasonable support includes telephone assistance covering the normal installation, use, and simple customization of a computerized system containing Echem Analyst 2 software connected to a Windows®-compatible computer.

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Table of Contents

Chapter 1: Introduction to this Guide

The Echem Analyst 2™ software is Gamry Instruments' dedicated data-analysis program, the companion to Gamry Instruments' data-acquisition program called Framework™. Data files generated by experiments in Framework software then can be analyzed in the Echem Analyst 2. The Echem Analyst 2 is a single program that runs data-analysis for all types of experiments, such as those used in DC Corrosion, EIS, and Physical Electro-chemistry.

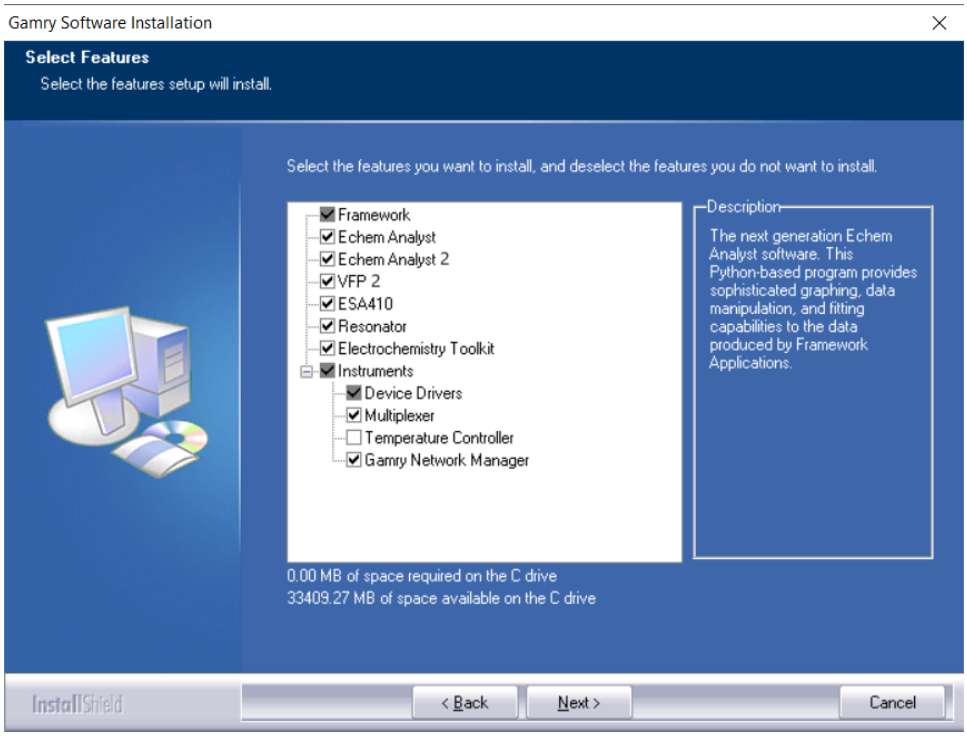
The Echem Analyst 2 is designed with the specific functions to make data analysis as straightforward as possible. This manual explains the most common analysis routines. The tools discussed here in the examples are common to many data files created by other experiments. This document is a guide and is not intended to have the same scope as the on-line help or a complete operating manual. In order to create a concise document, we assume you have a working knowledge of Windows®-based applications. We ignore details about common functions, such as opening, saving, and closing files, so as not to obscure the goal of this guide.

Chapter 2: General Information and Overview

Installation

The Echem Analyst 2 software is only available via download on Gamry's website. If you already own one of our instruments, use Gamry's Client Portal to download the latest installation file. The latest version can be found here: https://www.gamry.com/support-2/software-updates-3/

During the installation process, you have the option to add additional features to the installation. By default, the Echem Analyst 2 software is already pre-selected among others such as Gamry Framework. Features you do not want to be installed can be manually removed or added again.



Follow the next steps during the installation procedure. Once installed, you are ready to use the Echem Analyst 2 software. You may install copies of the Echem Analyst 2 on multiple computers. Often users prefer the convenience of performing data-analysis at an office workstation, rather than the laboratory setting.

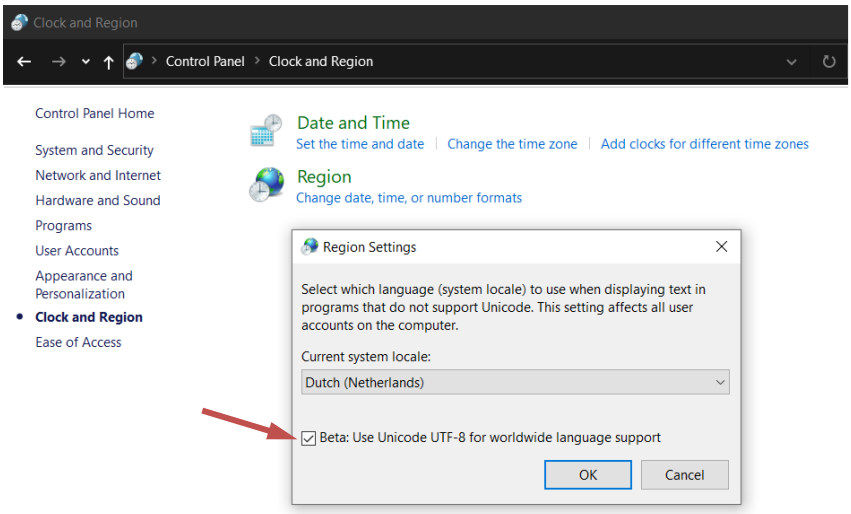
File Formats

Gamry data files acquired using Framework software have the extension `*.DTA`. All `*.DTA` files are ASCII text, and therefore you can open them directly into various programs, such as Excel® or Origin®. When `*.DTA` files are opened in Echem Analyst 2, then saved, their extension becomes `*.gpf`. All `*.gpf` (Gamry Project File) files include information on curve-fits and graphing options, thus `*.gpf` files are only viewable in Echem Analyst 2.

Do **not** delete your `*.DTA` files! They are the raw data and may need to be re-loaded for certain analyses, such as area normalization.

Gamry's previous data analysis version, the Echem Analyst, used a different file format which saved their data as `*.GData` (Gamry Data) files. These files can't be opened anymore in the newest Echem Analyst 2 version and require the older Echem Analyst version. Please contact your local Gamry representative or Gamry support for more information or directly visit our website at www.gamry.com.

Depending on the region where you live in, the number format may differ to the standard Gamry file format. Hence, we suggest checking the Windows® Region Settings of your computer and enabling Unicode UTF-8 support.



For best international character display support, use Unicode UTF-8 settings in Windows.

Open a Gamry Data File

There are several different methods to open data files in the Echem Analyst 2:

1. Launch the Echem Analyst 2 icon on your desktop. 

   Then use the **File** > **Open** function.

2. Use the link on your desktop to open the **My Gamry Data** folder. 

   Double-click on the data file. You may have to instruct your computer to associate the `*.DTA` extension with the Echem Analyst 2 program.

3. There are two quick ways to open a recent Gamry Data File:

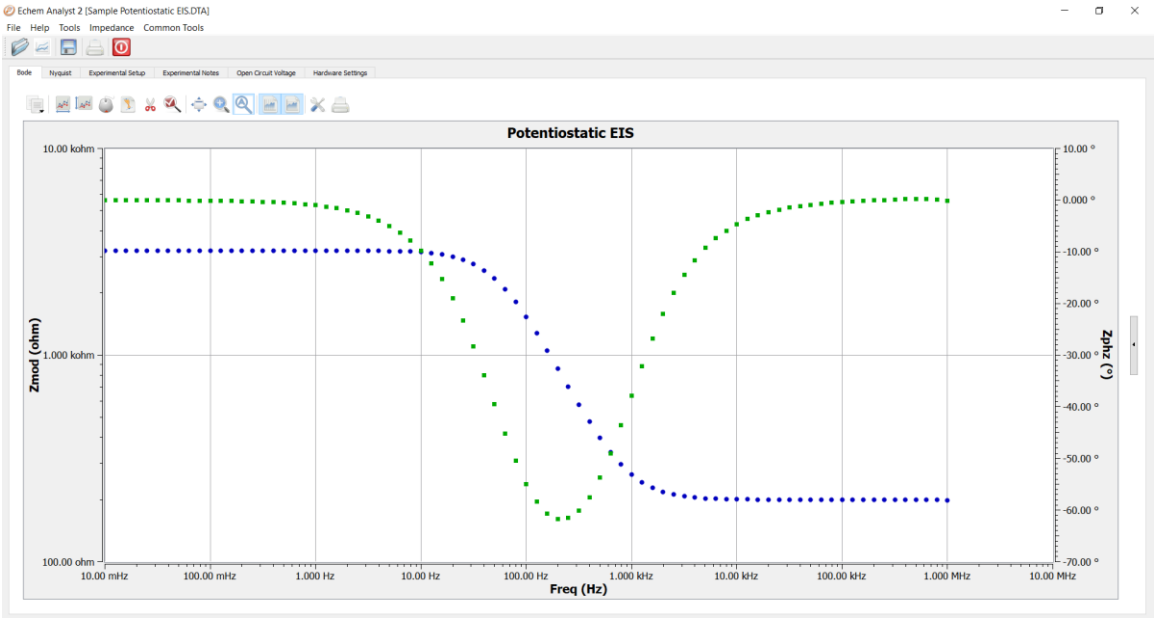
a. Within Gamry Framework, go to the **Analysis** menu. The last eight generated data files are listed for quick access. The Echem Analyst 2 automatically launches and opens the selected data file.

b. Within the Echem Analyst 2, go to the **File** menu **> Open Recent**. Select a data file from the sub-menu.

By default, files acquired in the Framework are saved into the **My Gamry Data** folder. A shortcut for **My Gamry Data** is installed on the Windows® desktop. You can change this default under **Tools** > **Options**, which opens the **Gamry Analysis Framework Options** window. Choose the **General** tab and change the **Path** for each type of data file as desired.

Do **not** change the directory for any Analysis Script Files! These are the Python programs that do the actual analysis.

The data set appears in the main window. The menu items, tabs, and toolbar are adjusted for the particular type of data set you chose. In the example below, a Potentiostatic EIS data set is shown:



Note the tab-based display. The **Experimental Setup** tab displays all the information from the parameters used to run the experiment, such as voltage, time, etc. The **Experimental Notes** tab stores any notes written into the setup screen in Framework. The **Open Circuit Voltage** tab shows the voltage measured during the initial delay of the experiment. The **Hardware Settings** tab records in-formation on the filters, ranges, gains. Additional information on date of last calibration, software version, etc. is also stored here.

Overlay multiple data files

You can overlay multiple data files to compare individual data sets within a single graph. Generally, Gamry data files (`*.DTA`) with similar data format can be overlaid. Overlay compatibility depends hereby on the `TAG` label within the data file. It is listed in the second line of any Gamry data file, as shown in the example for a chronoamperometric file (`CHRONOA`) below:

```
EXPLAIN
TAG   CHRONOA
TITLE LABEL Chronoamperometry Scan  Test &Identifier
DATE  LABEL 8/31/2004   Date
TIME  LABEL 11:41:21    Time
NOTES NOTES 4     &Notes...
...
```

The table below shows the overlay compatibility for the various `TAGs`:

TAG	**Experiment**
`PWR800_GALVEIS`	PWR Galvanostatic EIS
`GALVEIS`	Galvanostatic EIS
`PWR800_EISPOT`	PWR Potentiostatic EIS
`EISPOT`	Potentiostatic EIS
`PWR800_HYBRIDEIS`	PWR Hybrid EIS
`HYBRIDEIS`	Hybrid EIS
`PWR800_CV`	PWR Cyclic Voltammetry
`CV`	Cyclic Voltammetry
`CHRONOA`	Chronoamperometry
`CHRONOP`	Chronopotentiometry
`GALVANOSTATIC`	Galvanostatic
`POTENTIOSTATIC`	Potentiostatic
`MULTI_STEP_CHRONOAMP`	Multi-step Chronoamperometry
`MULTI_STEP_CHRONOPOT`	Multi-step Chronopotentiometry
`REPEATING_CHRONOA`	Repeating Chronoamperometry
`REPEATING_CHRONOP`	Repeating Chronopotentiometry
`PWR800_READVOLTAGE`	PWR Read Voltage
`CORPOT`	Corrosion Potential
`POTENTIODYNAMIC`	Potentiodynamic
`CYCPOL`	Cyclic Polarization
`EISMON`	PWR Single Frequency EIS
`PWR800_GALVEISMON`	PWR Galvanostatic Single Frequency EIS
`PWR800_HYBRIDEISMON`	PWR Hybrid Single Frequency EIS
`CV`	Cyclic Voltammetry
`CVEQCM`	EQCM Cyclic Voltammetry
`CHRONOA`	Chronoamperometry
`CHRONOAEQCM`	EQCM Chronoamperometry
`REPEATING_CHRONOAEQCM`	EQCM Repeating Chronoamperometry
`CHRONOP`	Chronopotentiometry
`CHRONOPEQCM`	EQCM Chronopotentiometry
`REPEATING_CHRONOPEQCM`	EQCM Repeating Chronopotentiometry
`LSV`	Linear Sweep Voltammetry
`LSVEQCM`	EQCM Linear Sweep Voltammetry
`CPC`	Controlled Potential Coulometry
`CHRONOC`	Chronocoulometry
`CHRONOCEQCM`	EQCM Chronocoulometry

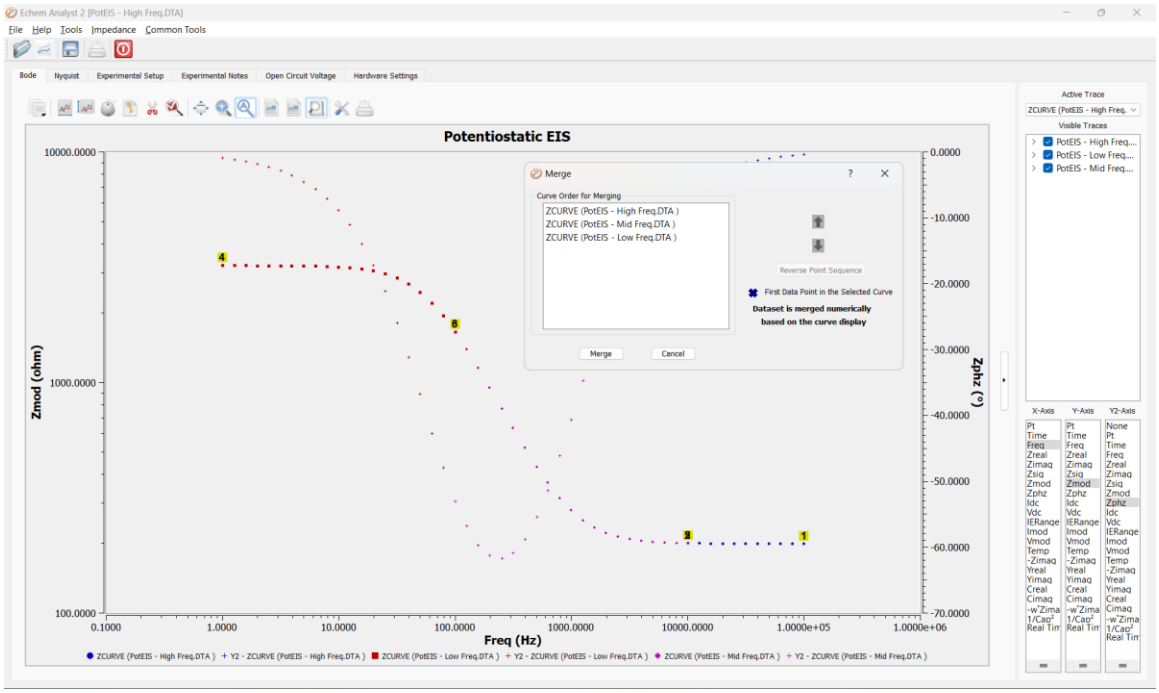
1. Open the Echem Analyst and a data data file (`*.DTA` or `*.gpf`).
2. Go to the **File menu > Overlay Files**. The feature is grayed out if no file is open.
3. The Open File dialog box appears. Select any `*.DTA` file you wish to overlay with the currently open file. Click **Open** to confirm your selection.
4. The Echem Analyst adds the selected files to the open file. The new data sets are also listed to the right under **Visible Traces**. They can be individually selected and worked with.

   An error message appears if a data file is incompatible for overlaying.

Merge individual data files

Besides overlaying multiple files to compare different data sets, the Echem Analyst 2 offers an option to "stitch together" data files. The **Merge** feature allows the user to merge individual data sets which are then treated as a single data set.

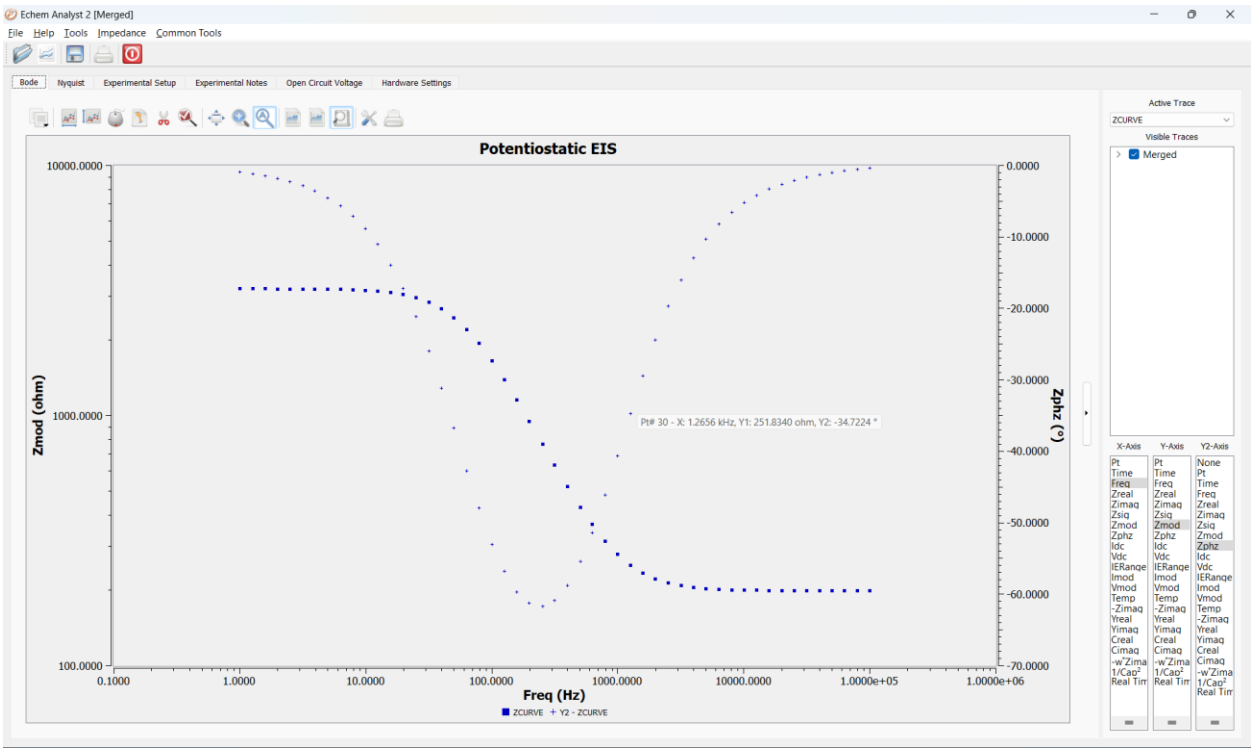
5. To access the feature, go to the **File menu > Merge Files**.
6. The Open File dialog box appears. Select any `*.DTA` file you wish to merge. Click **Open** to confirm your selection.
7. The Echem Analyst opens the selected file in a single data plot and the **Merge** dialog box as shown below.



8. Each individual data set shows two numbers at the beginning and end of their data curve. They depict the order of merged data points, following the order 1 → 2 → 3 → 4 → etc.

The curve order and subsequentially the point order is important. Once merged, data points will follow this order. Any data fit will be calculated incorrectly if the order is not correct, e.g., if EIS data are arranged from mid to high to low frequencies.

9. Change the order for merging in the **Merge** dialog box. Select a curve and move it up or down in the order using the arrow symbols on the right side. You will notice that the numbers in the data plot will change accordingly, with the top curve starting from 1 → 2, the second curve 3 → 4, etc.
10. If required, reverse a data set's sequence by pressing the **Reverse Point Sequence** button.
11. Press **Merge** when done. The new "merged" data plot is shown with the file now being treated a single data set.



Working with Plots in the Echem Analyst 2

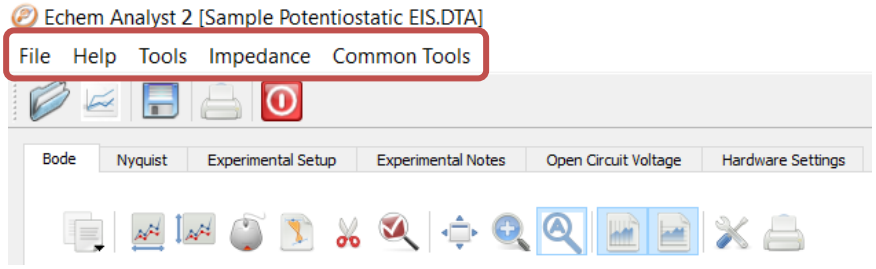
Menu

The Echem Analyst 2 displays at the top line the **menu bar**. Three functions are universal which are **File**, **Help**, and **Tools**.

- **File**
  - Open, overlay, merge, and save data files, print your data, and exit the software
- **Help**
  - Includes the user manual and software information
- **Tools**
  - Tools to customize software scripts
  - Options to customize the graph interface
  - Perform EIS Batch Fit on your data

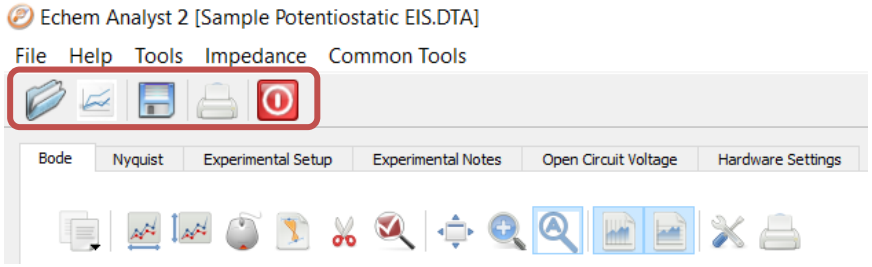
The other commands in the menu depend on the data file and the experiment type. The raw data file (`*.DTA`) includes a line that indicates the type of experiment used to generate the file in Echem Analyst 2.

The first command is named after the experiment type and includes experiment-specific commands. The second is called **Common Tools** and includes various functions to format the graph, see Chapter 3:Common Tools.



Menu toolbar

The most common file commands are separately listed in the **Menu toolbar** below the **Menu bar**.



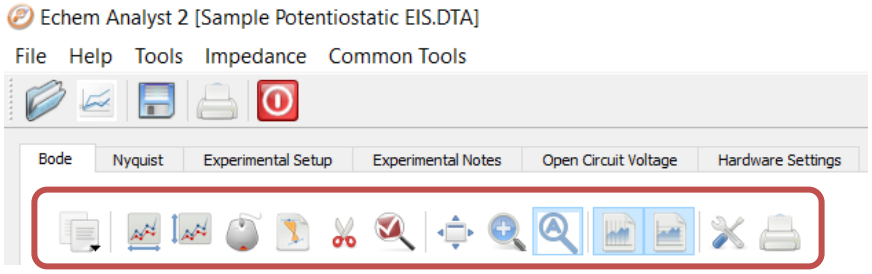
The following chart lists all commands on the Menu toolbar.

Table 2-1
Menu toolbar functions

Button	Name	Function
	Open File	Open a `*.DTA` or `*.gpf` data file.
	Open Overlay	Open a `*.DTA` file of the same experiment type to overlay with the current data.
	Save	Save data file as Gamry Project File `(*.gpf)`
	Print	Print the plot.
	Exit	Close the Echem Analyst 2.

Graph toolbar

The Echem Analyst 2 boasts a number of graphical tools to help you get the most information out of your data. After you open a data set, these tools appear in the toolbar immediately above the plot.



The Graph toolbar includes general functions for replotting, graph formatting, and data handling. The following chart lists all commands on the Graph toolbar.

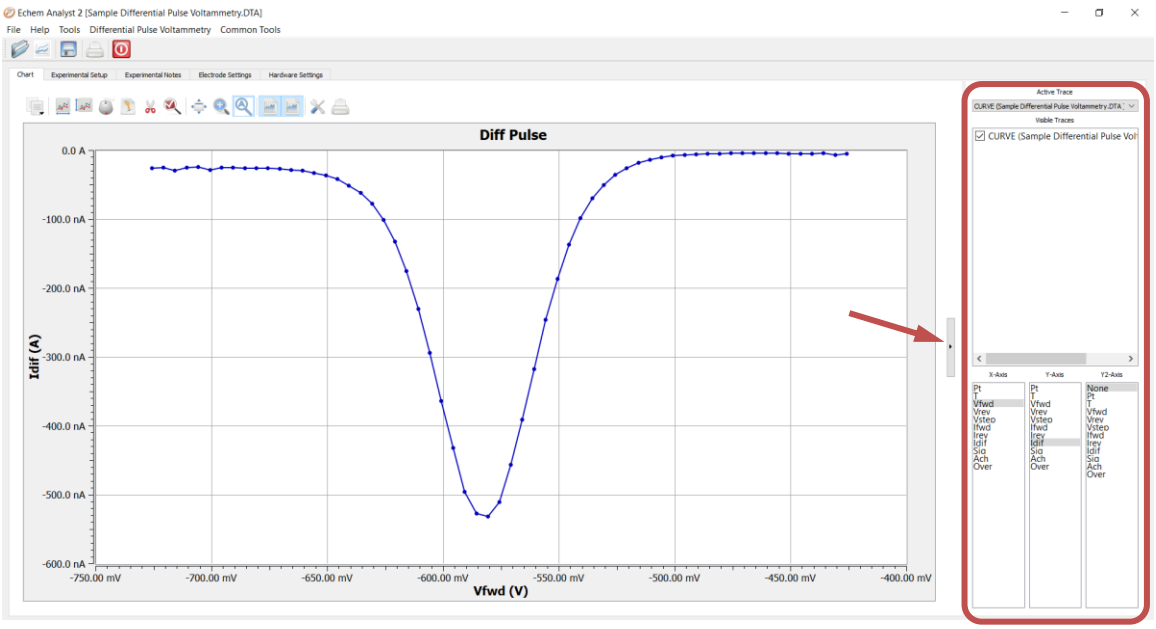
Table 2-2
Graph toolbar functions

Button	Name	Function
	Copy to clipboard	Copy the selection to the Windows® clipboard. Paste the file directly in Microsoft programs for reports or presentations.
	Select X Region	Select a desired region of the plot across the x-axis.
	Select Y Region	Select a desired region of the plot across the y-axis.
	Select Portion of Curve using the Mouse	Left-click on the active trace using the mouse to select a section of the curve.
	Draw Freehand Line	Draw a line on the plot.
	Enable/Disable Points	Enable or disable points settings.
	Show/Hide Disabled Points	Show or hide data points not being used in the plot.
	Pan	Let's you see different areas of a zoomed view.
	Zoom	Zoom in on a selected region.
	Auto-Scale	Automatically adjust x-axis and y-axis range to display the full curve.
	Vertical Grid	Toggle between showing and hiding vertical grid lines on the plot.
	Horizontal Grid	Toggle between showing and hiding horizontal grid lines on the plot.
	Properties…	Open the **GamryChart Properties** window, so that you can adjust effects, colors, markers, lines, etc.
	Print Chart	Print the plot.

Changing the Axes on a Plot using the Curve Selector

To choose a different variable plotted on an axis, use the **Curve Selector** button as follows. The example shown below is a Differential Pulse Voltammetry plot:

1. With the plot open and displayed on the screen, click the **Curve Selector** button on the right side.



   The Curve Selector area appears on the right side of the window.

2. Choose which trace is active by clicking the drop-down menu in the **Active Trace** area.

   The Active Trace is the data series on which the analysis will be performed. Use this if multiple files or cycles are displayed on the graph.

3. Choose which trace is visible on the plot by activating the checkbox next to the desired trace(s) in the **Visible Traces** area.

   Visible Traces also contains any **data fits** that are performed.

4. Choose which variable is plotted on the x-axis by highlighting the variable in the **X-Axis** column.

5. Choose which variable is plotted on the y-axis by highlighting the variable in the **Y-Axis** column.

6. Choose which variable is plotted on the second y-axis by highlighting the variable in the **Y2-Axis** column.

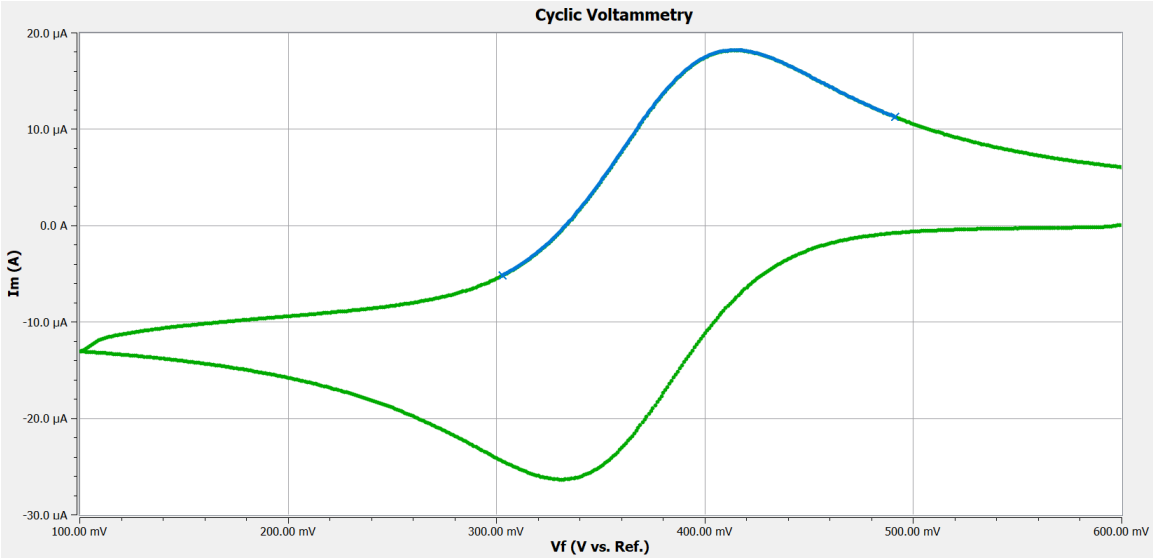
If there is a data column graphed on the **Y2-Axis**, those data appear in a different color and a different scale.

Selecting Portions of a Curve for Analysis

For certain types of analysis, you must select a region of the curve, for example, within the **Peak Find** function in Cyclic Voltammetry or Tafel Fit function in Potentiodynamic.

- Left-click the mouse on the **Select Portion of Curve using the Mouse** button in the **Graph Toolbar**.

- Use the left mouse-button to select each endpoint of the curve. Each endpoint is marked with a blue cross. The selected portion of the curve is shown as a thick blue line. In the figure below, the color of the data was changed to red for contrast to the selected region.



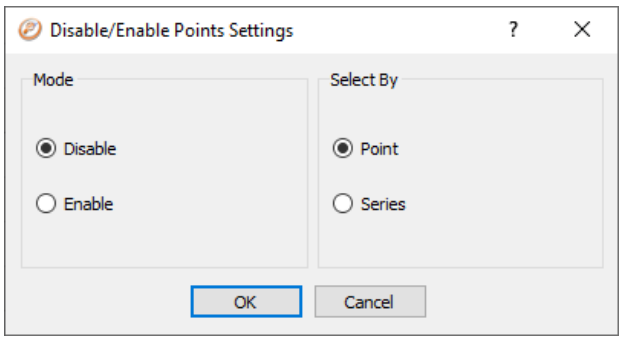
- Another click on the **Select Portion of Curve using the Mouse** button clears the selected region and readies the graph for a different region to be selected.

Enable/Disable Points of a Curve

In some cases, measurement data can contain data points that are clear outliers caused by noise or other sources or some points are not useful for fitting data. In such cases, points can be disabled and back again enabled.

Disable Data Points

1. In the **Graph Toolbar**, click the **Enable/Disable Points** button. 
2. The Disable/Enable Points settings window appears.

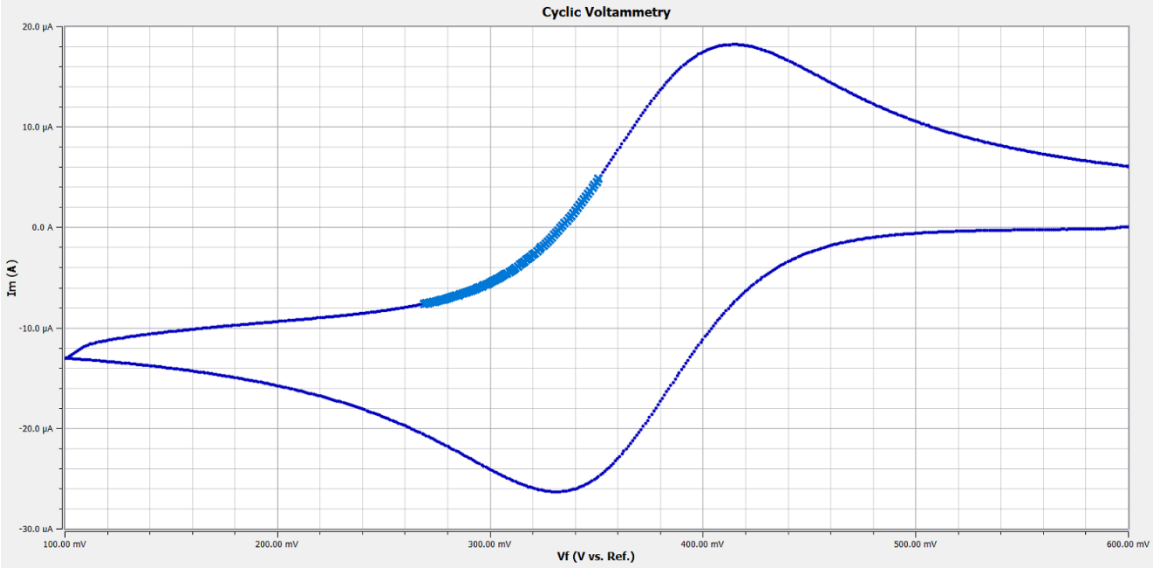


3. Select the **Disable mode**.

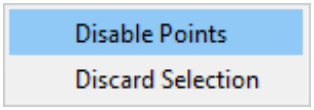
   If you want to disable only single points, select **Point** on the right side.

   For disabling a range of data points, select **Series** on the right side.

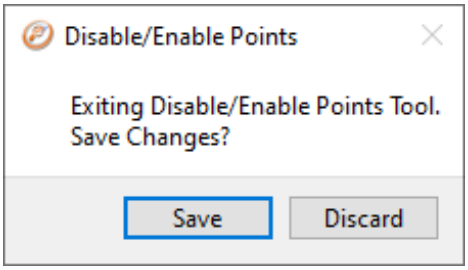
4. Within the data plot, select the points you want to disable. All marked points are highlighted by a blue ✖.



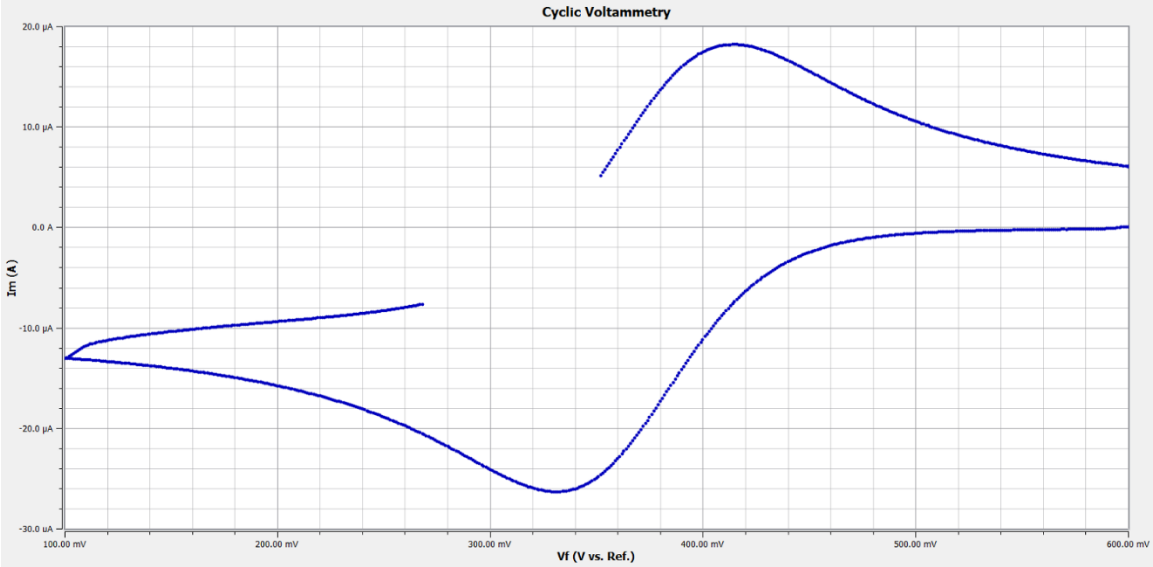
5. Confirm or discard your selection by either **right click** your mouse



   or click the **Enable/Disable Points** button in the **Graph Toolbar**.

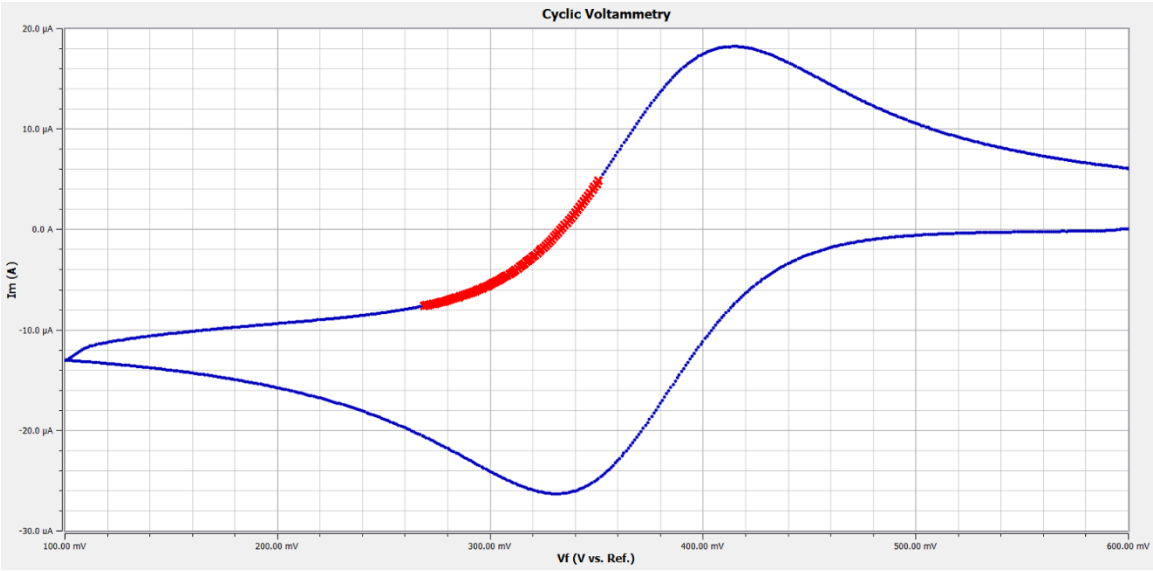


6. The data curve is shown without the disabled data points.



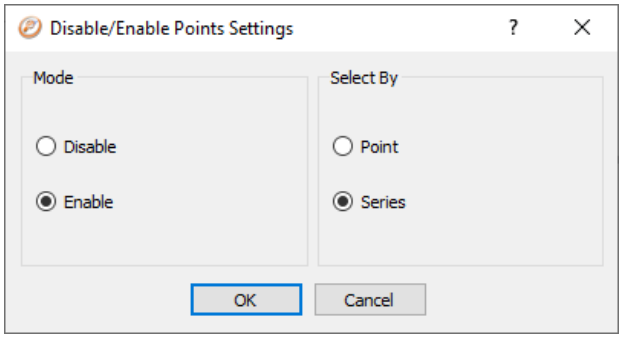
7. If you want to see all the disabled points in your data curve, click the **Show/Hide Disabled Points** button in the **Graph Toolbar**.

   All disabled points are highlighted with a red ✖.



Enable Data Points

1. In the **Graph Toolbar**, click the **Enable/Disable Points** button.
2. The Disable/Enable Points settings window appears.



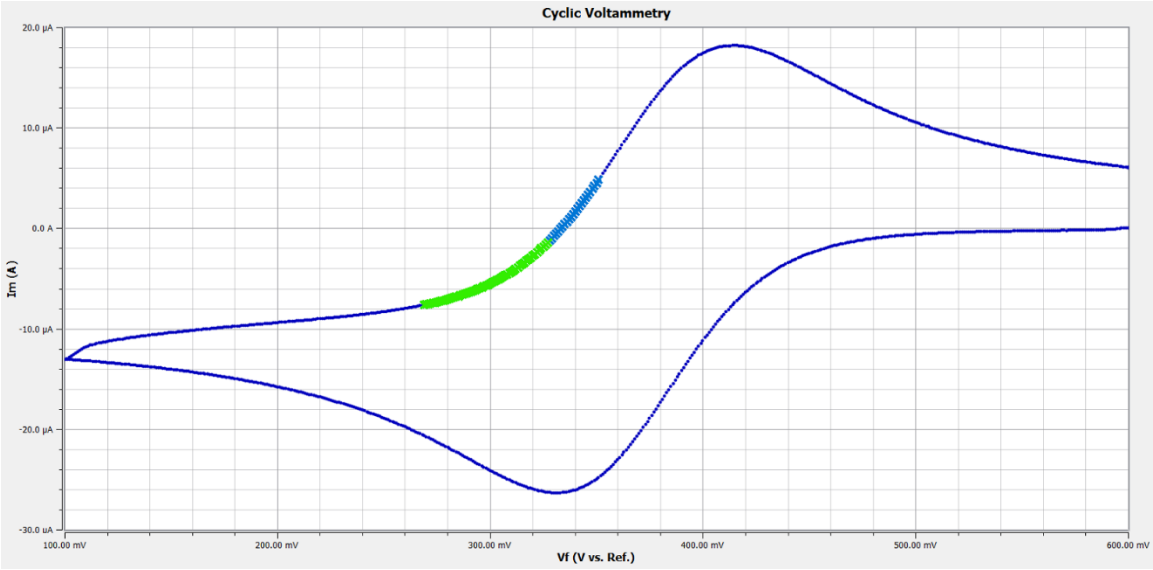
3. Select the **Enable mode**.

   If you want to enable only single points, select **Point** on the right side.

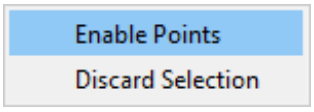
   For enabling a range of data points, select **Series** on the right side.

4. The data plot shows all disabled points highlighted by a blue ✖.

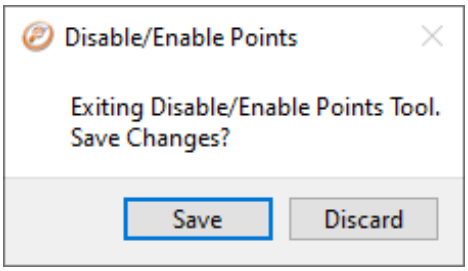
   Select the data points you want to enable again. The selected points are highlighted by a green ✖.



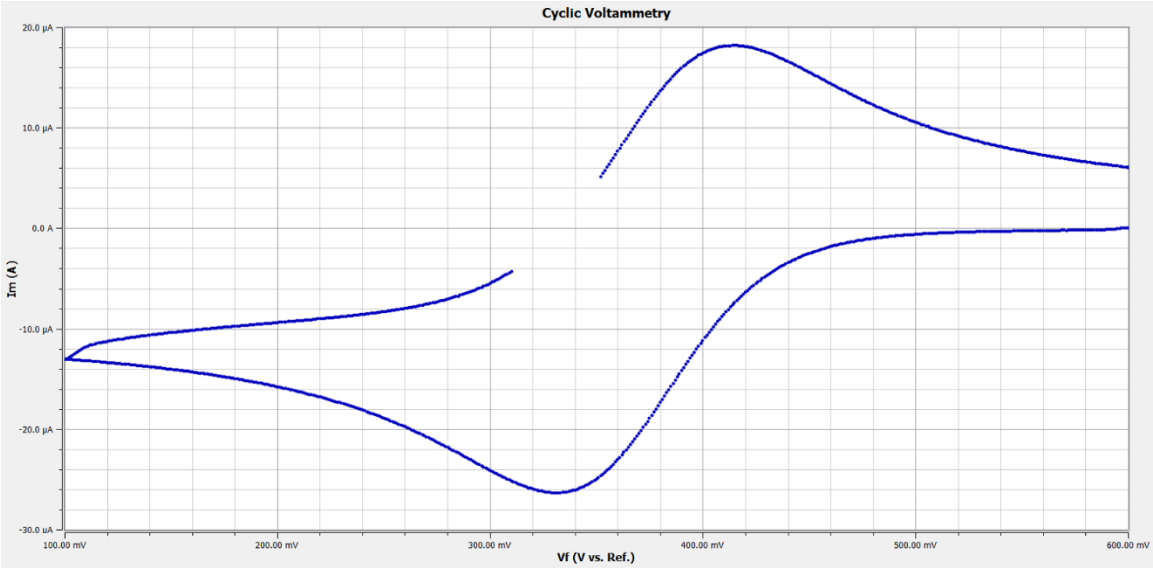
5. Confirm or discard your selection by either **right click** your mouse



   or click the **Enable/Disable Points** button in the **Graph Toolbar**.



6. The data curve is shown with all the enabled points again and without the remaining disabled data points.



7. If you want to see all the disabled points in your data curve, click the **Show/Hide Disabled Points** button in the **Graph Toolbar**.

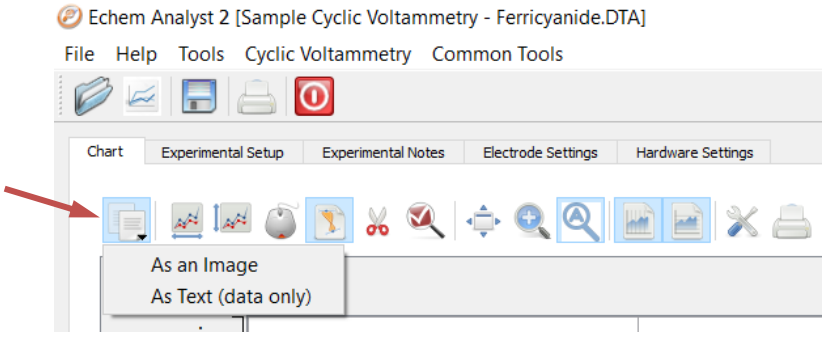
   All disabled points are highlighted with a red ✖.

Cut and Paste Images and Data

Many users want to present, publish, or otherwise share their data and charts from the Echem Analyst 2. The **Copy to Clipboard** button allows to copy data as an Image or as Text (data only) to the clipboard for further processing.

As an Image

1. In the **Graph Toolbar**, click the **Copy to Clipboard** button.



2. In the drop-down menu select **As an Image**.
3. An image of the graph enters the clipboard. You can paste this file into a presentation program such as Word® or PowerPoint®.

   This is a quick and easy way to import a picture of the graph for a presentation or report

As Text

1. In the **Graph Toolbar**, click the **Copy to Clipboard** button.
2. In the drop-down menu select **As Text** .
3. The Gamry Data File is copied in ASCII format to the clipboard.

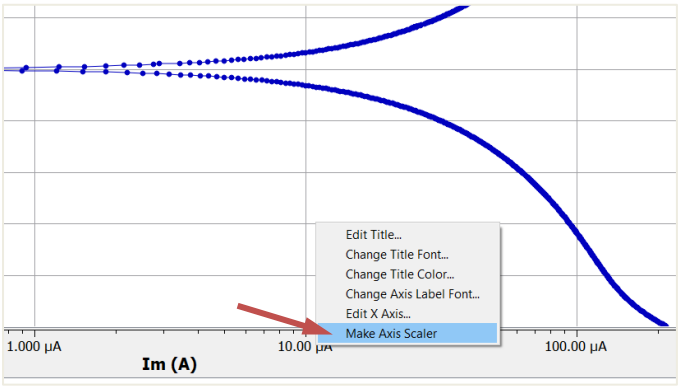
Because Gamry Data Files are ASCII text, they can be opened easily in other graphing programs, such as Excel® or OriginLab®. Right-click on the DTA file, select **Open With**…, and select your desired program. These programs, however, do not contain fitting routines specific to the analysis of electrochemical data. This **As Text** feature lets you fit the data in Echem Analyst 2 and then copy and paste the data and fit into another graphing program.

This is a quick and easy way to import both the data and the fit into another graphing program.

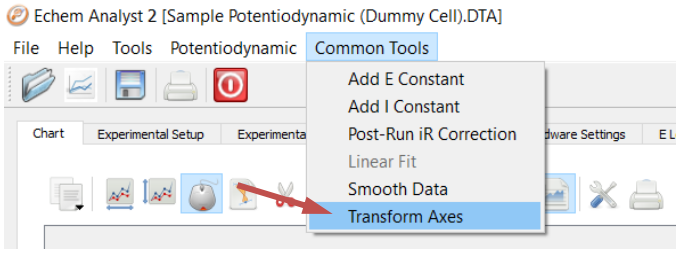
If you are using the **As Text** feature, be sure to note the currently graphed parameters. The coordinates of the currently displayed graph are copied and can be pasted to other graphing programs.

Plotting Conventions

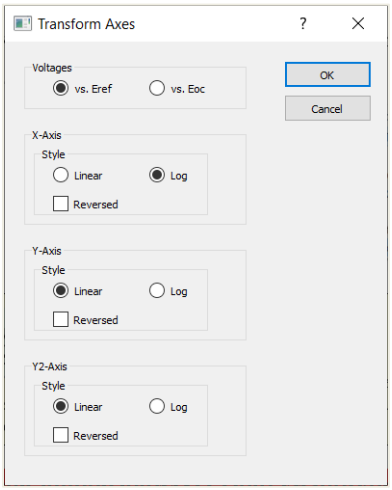
By right-clicking the mouse on a non-zero value on an axis, you can choose to show that particular axis in **Log Scale** (logarithmic) or linear scale (when Log Scale is inactive).



You can also use the **Transform Axes** selection (if available) under the **Common Tools** menu.



- The **Transform Axes** window appears.



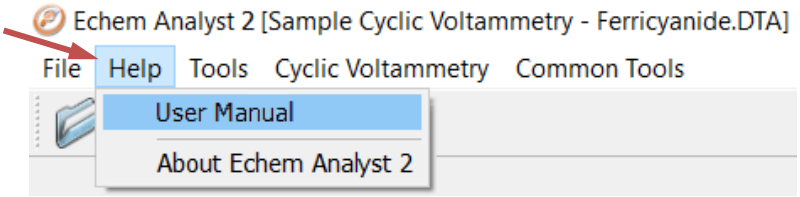
You can also reverse the direction of the numbers when **Reversed** is active.

Axis display options vary, depending on the selected experiment type. Non-available options are either grayed out or not listed.

Default plotting of graphs is auto-scale. Therefore, note the y-axis' scale when a plot first appears. If bad data points obscure your data because of auto-scaling, you can choose to disable and hide those offending points.

Getting Online Help and Version Number

In the main menu, choose **Help**.



- Click **User Manual** to open the Echem Analyst 2 operator's guide and obtain information about various commands and functions of the Echem Analyst 2.
- Click **About Echem Analyst 2** to view the software version number.

Chapter 3: Common Tools

While each type of experimental data has its own method and parameters, there are certain commands that are common to many analyses. This section shows you these **Common Tools**.

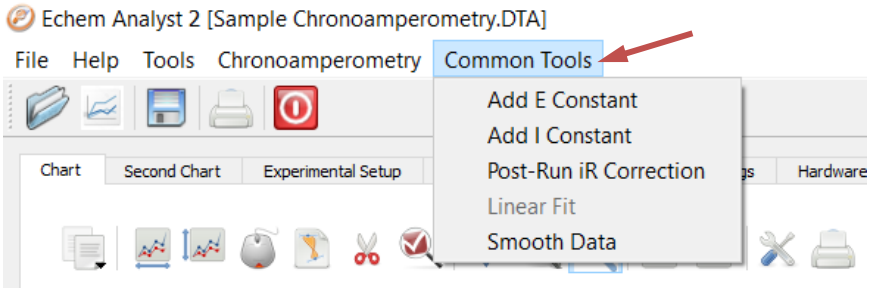
Accessing Common Tools

1. Open a dataset.

   In the menu, the function **Common Tools** appears.

2. Choose **Common Tools**.

   A drop-down menu appears.



3. Select the desired command.

   In this example, Chronoamperometry's **Common Tools** includes five commands: **Add E Constant**, **Add I Constant**, **Post-Run iR Correction**, **Linear Fit**, and **Smooth Data**.

   Note that Linear Fit is inactive. This command requires at first to select a portion of the curve to be active.

The list of **Common Tools** functions varies depending upon the type of experiment.

Table 3-1
List of Common Tools functions

Command	Type of experiment	Result
Add E Constant	Cyclic Voltammetry, DC Voltammetry, Differential Pulse Voltammetry, Galvanic Corrosion, Normal Pulse Voltammetry, Pitting Scan, Polarization Resistance, Potentiodynamic Scan, Square-Wave Voltammetry	Adds a constant potential to all voltages in the plot. Used to easily convert between different Reference Electrode's scales.
Add I Constant	Chronoamperometry, Chronopotentiometry, Cyclic Voltammetry, Galvanic Corrosion, Pitting Scan, Polarization Resistance, Potentiodynamic Scan	Adds a constant value to all currents in the plot.
C from CPE, omega(max)	Potentiostatic EIS, AC Voltammetry, Mott-Schottky	Calculates capacitance from previously fit CPE values and data from the Nyquist plot.
C from CPE, R(parallel	Potentiostatic EIS, AC Voltammetry, Mott-Schottky	Calculates capacitance from previously fit CPE and fit R data.
Linear Fit	Chronoamperometry, Potentiostatic EIS, AC Voltammetry, Chronocoulometry, Chronopotentiometry, Cyclic Voltammetry, DC Voltammetry, Differential Pulse Voltammetry, EMF Trend, Galvanic Corrosion, Mott-Schottky, Normal Pulse Voltammetry, Polarization Resistance, Potentiodynamic Scan, Square-Wave Voltammetry	When a region of the plot is selected, fit the data to $y = mx + b$.
Post-Run iR Correction	Cyclic Voltammetry, Polarization Resistance, Potentiodynamic Scan	Corrects a previously run scan for voltage-drop caused by *iR*.
Smooth Data	Chronoamperometry, Chronopotentiometry, Cyclic Voltammetry, DC Voltammetry, Differential Pulse Voltammetry, EMF Trend, Galvanic Corrosion, Normal Pulse Voltammetry, Pitting Scan, Polarization Resistance, Potentiodynamic Scan, Square-Wave Voltammetry	Smooth data. Useful for locating peaks in regions of high data-density.
Transform Axes	Galvanic Corrosion, Pitting Scan, Polarization Resistance, Potentiodynamic Scan	Changes x- and y-axes from linear to logarithmic, etc.

Chapter 4: Experiment Tabs

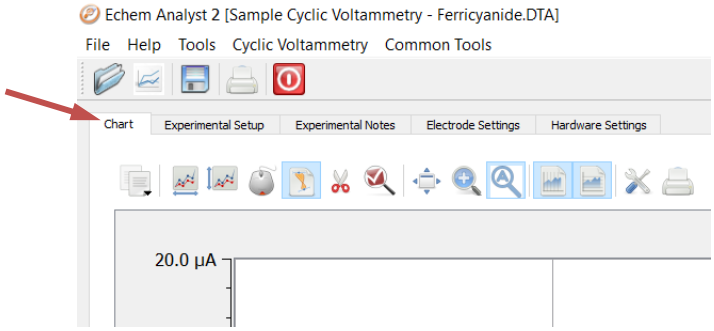
When analyzing an experiment in the Echem Analyst 2 by opening a `*.DTA` file, the **Experiment Window** opens, displaying a default data curve. The experiment window is divided into various sub-tabs, each displaying various information about the measurement data, experimental setup, hardware settings, and additional notes.

The various **Experiment Tabs** are discussed using a **Cyclic Voltammetry** experiment data file.

Chart

By default, graph is displayed in the Echem Analyst 2 when opening a `*.DTA` file. The plotted curve depends hereby on the experiment and is displayed within the first tab.

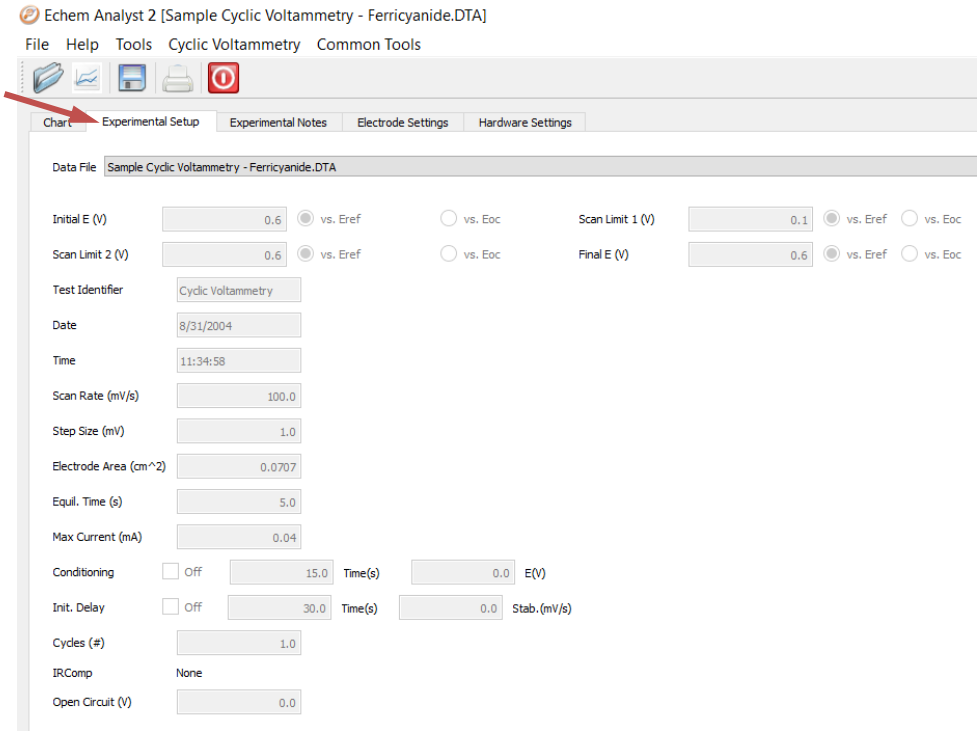
Depending on the experiment, more than one chart can be listed under the **Experiment Tabs**. In this example, only one chart tab is displayed.



Data points, axis format, and graph layout can be formatted using the t**oolbar** functions and experiment-dependent menu functions.

Experimental Setup

The **Experimental Setup** tab shows the experiment parameters set in Gamry Framework™ software.

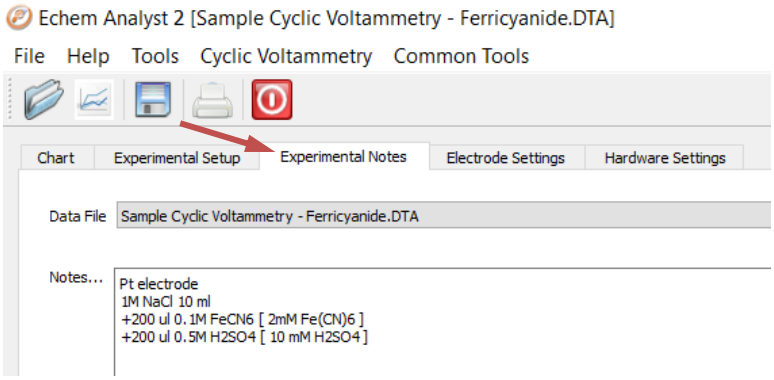


This example has many of the same parameters as other experiments. It shows:

Parameter	Information
Initial E, Scan Limit 1, Scan Limit 2, Final E Test Identifier	The potentials defining the waveform, and whether measured vs. a reference electrode (Eref) or the open circuit potential (Eoc). Adds a constant value to all currents in the plot.
Time	Time the experiment was started.
Scan Rate	How fast (in mV/s) the scan was taken.
Step Size	The interval between potentials.
Electrode Area	The size of the electrode.
Equil. Time	How much time was spent letting the electronics settle before the scan was started.
I/E Range Mode	Automatically adjusted or fixed I/E (Current) Range mode.
Max Current	The current value that sets the I/E Range in Fixed Mode and determines the range in which to start in Auto Mode.
Conditioning	Whether off or on, for how long, and under what potential. This Potential is vs. Reference.
Init. Delay	Whether off or on. This is when the Eoc is measured.
Cycles	Number of how many voltammetry cycles were run.
IR Comp	If IR Compensation was used and the mode.
Open Circuit	The value of the open-circuit voltage (Corrosion Potential). It is the value of the last point in the Initial Delay.
Sampling Mode	Data-acquisition mode (for Reference family Potentiostats).

Experimental Notes

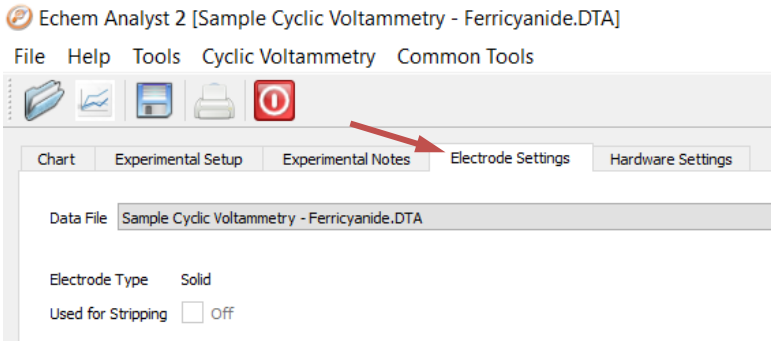
Any notes entered in the Framework™ software are automatically displayed in the **Experimental Notes** tab. You may enter any additional comments about the experiment in the **Notes…** field.



This is a version of a modern laboratory notebook. Enter as many details about your experiment as you can. Information here can help you avoid having long strings of descriptive file names.

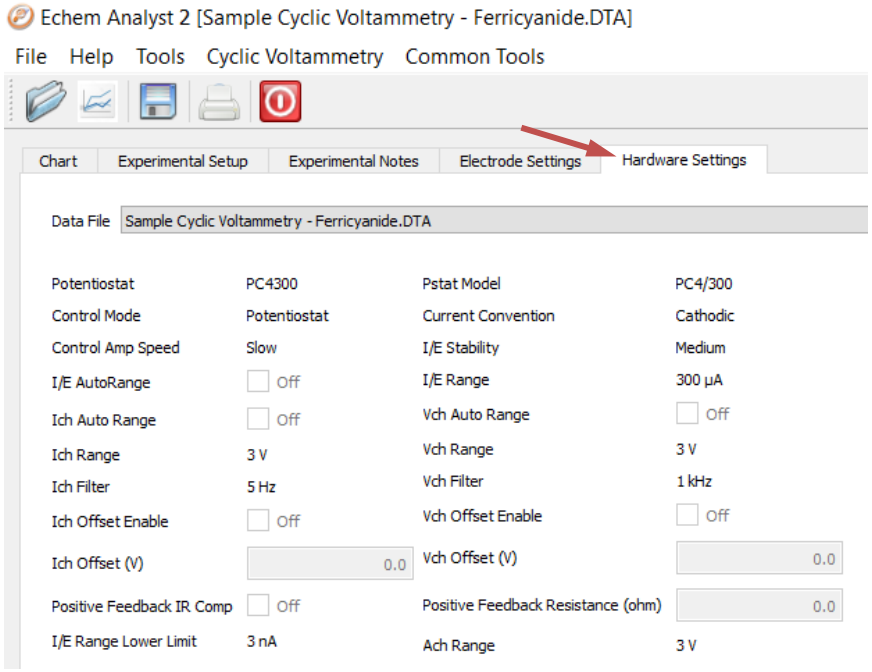
Electrode Settings

The **Electrode Settings** tab documents any specific settings and information about the electrode used in the experiment, e.g., Electrode Type. The **Electrode Settings** tab is not available for all experiments.



Hardware Settings

The **Hardware Settings** tab documents the hardware settings that were used when the experiment was run, e.g., everything from the offsets, filters, and gains to the last time the potentiostat was calibrated.

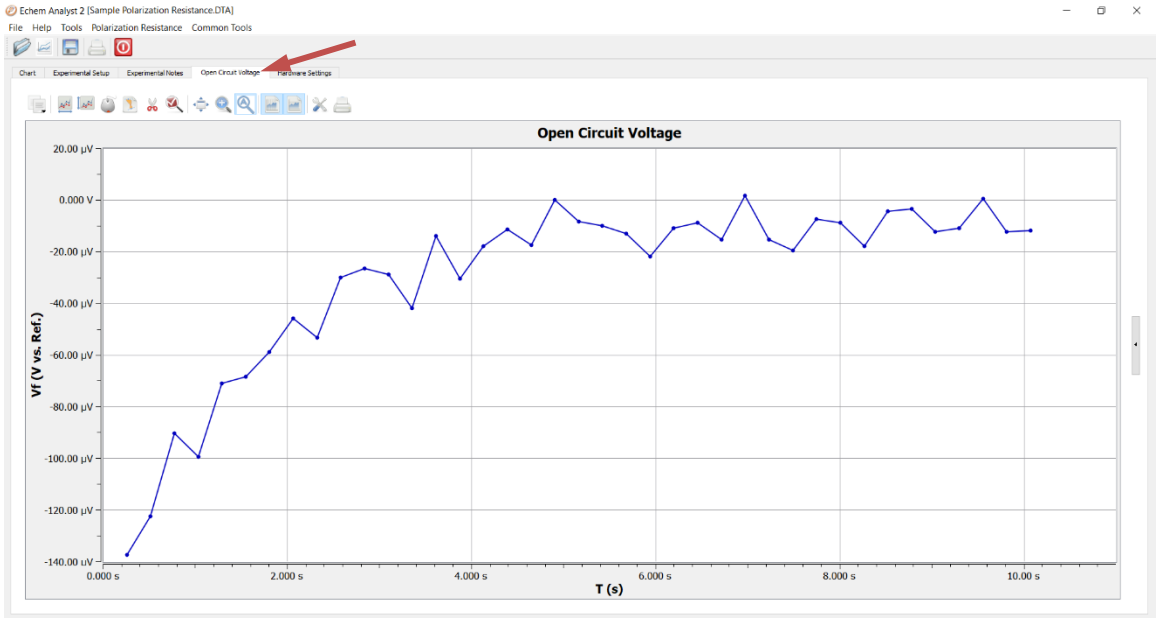


The **Hardware Settings** displayed in this example are listed in the table below. A detailed explanation of these parameters is beyond the scope of this guide.

Parameter	Information
Potentiostat	Shows the potentiostat's label.
Control Mode	How the experiment was controlled.
Control Amp Speed	Shows the speed of the control amplifier.
I/E AutoRange	Shows if the I/E AutoRange function was enabled.
Ich AutoRange	Shows if the Ich AutoRange function was enabled.
Ich Range	Shows the Ich range (gain). 3 volts = ×1 Gain.
Ich Filter	Shows the Ich cut-off filter frequency.
Ich Offset Enable	Shows if Ich Offset was enabled.
Ich Offset	Shows the Ich offset voltage.
Positive Feedback IR Comp	Shows if the IR positive feedback was enabled.
I/E Range Lower Limit	Shows the lowest available I/E Range available to use in this experiment.
Ach Select	Shows the input connector for Ach.
DC Calibration Date	Shows the date of last DC calibration
Framework Version	Shows the Framework Version when experiment was performed.
Pstat Model	Gives the model number of the potentiostat.
Current Convention	Shows which currents are positive.
I/E Stability	Shows the I/E stability speed.
I/E Range	Shows the I/E (or current) range used.
Vch AutoRange	Shows if Vch autoranging is enabled.
Vch Range	Shows the maximum value for Vch.
Vch Filter	Shows the Vch cut-off filter frequency.
Vch Offset Enable	Shows if Vch Offset was enabled.
Vch Offset	Shows the Ich offset voltage.
Positive Feedback Resistance	Shows the positive feedback resistance applied to the system.
Ach Range	Shows the voltage range of the auxiliary channel.
Cable ID	Gives the type of cable connected to the system (for Reference family potentiostats only).
AC Calibration Date	Shows the date of last AC calibration.
Instrument Version	Shows the Firmware Version of a Reference family potentiostat.

Open Circuit Voltage

The **Open Circuit Voltage** tab is active if the experiment includes an open circuit potential measurement before the actual experiment. It is required for any experiment that uses potential reference versus Eoc.

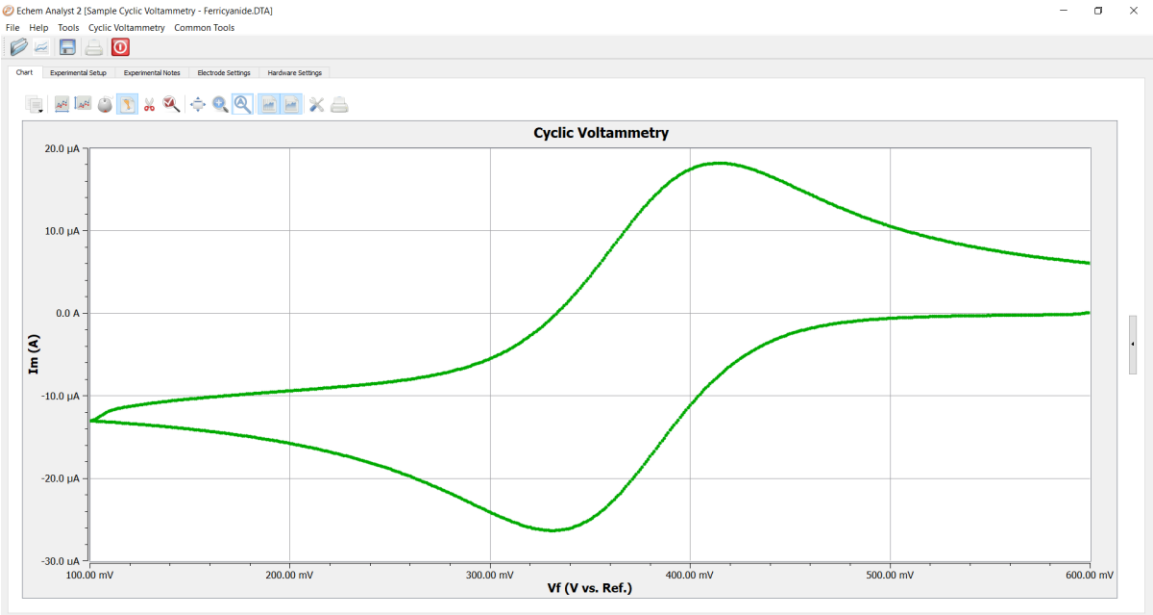


Because default plotting of graphs is auto-scale, please note the y-axis' scale when the **Open Circuit Voltage** first appears.

Chapter 5: Analysis of Cyclic Voltammetry Data

The figure below shows the cyclic voltammogram of a sample cyclic voltammetry file that installs in `\My Gamry Data\` when Gamry Instruments' Framework software is installed.

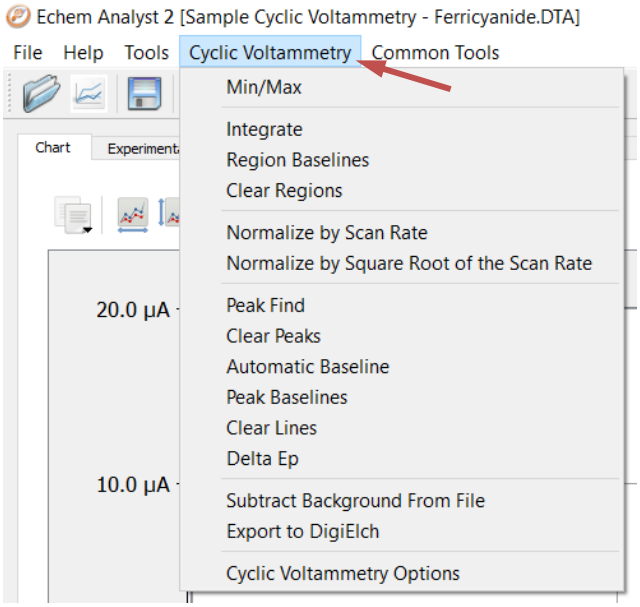
Figure 5-1
Cyclic Voltammogram of Ferricyanide in an aqueous NaCl solution on a Pt working electrode



Cyclic Voltammetry Special Tools

This menu analyzes the cyclic voltammetry data.

1. In the main menu, choose **Cyclic Voltammetry**. A drop-down menu appears.



2. Choose the desired tool.

Tool	Function	Notes
Min/Max	Finds the minimum and maximum currents and voltages within the dataset. Results appear in a window below the plot.	
Quick Integrate	Integrates to find the total charge. Results appear in a window below the plot.	For multi-cycle CV experiments.
Integrate	Integrates over a specified portion of the plot to find the total charge.	Portion of the curve must be selected.
Region Baselines	Defines a line as the baseline for a specified region.	Region must be selected.
Normalize by Scan Rate	Normalizes the dataset based on the scan rate.	
Normalize by Square Root of the Scan Rate	Normalizes the dataset based on the square-root of the scan rate.	
Peak Find	Finds peaks within a specified region of the dataset.	Portion of the curve must be selected.
Clear Peaks	Clears all peaks found within the dataset.	Peaks must be identified.
Automatic Baseline	Finds the baseline automatically.	Peaks must be identified.
Peak Baselines	Defines a line as a baseline for a specified peak.	Peaks must be identified.
Clear Lines	Clears all lines from the dataset.	Lines must be associated with graph.
Delta Ep	Finds the potential difference between two peaks.	Peaks must be identified
Subtract Background from File	Subtracts a background amount from the dataset.	
Export to DigiElch	Exports the file to a DigiElch-compatible format.	
Options	Changes units and grids for plotting the data.	

Integrating the Voltammogram

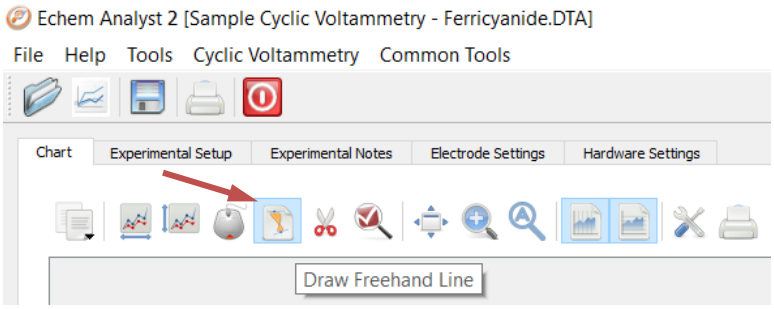
All integration methods integrate current versus time to get the total charge. There are two different ways to integrate under a curve with Echem Analyst 2.

Integrate

Integrate requires you first to select a portion of the curve. See how to select a portion of the curve in the "Selecting Portions of a Curve for Analysis paragraph in Chapter 2. After an integration is performed, you can change the baseline from the default 0 A to another line, either a line that you draw, or an **Automatic Baseline**.

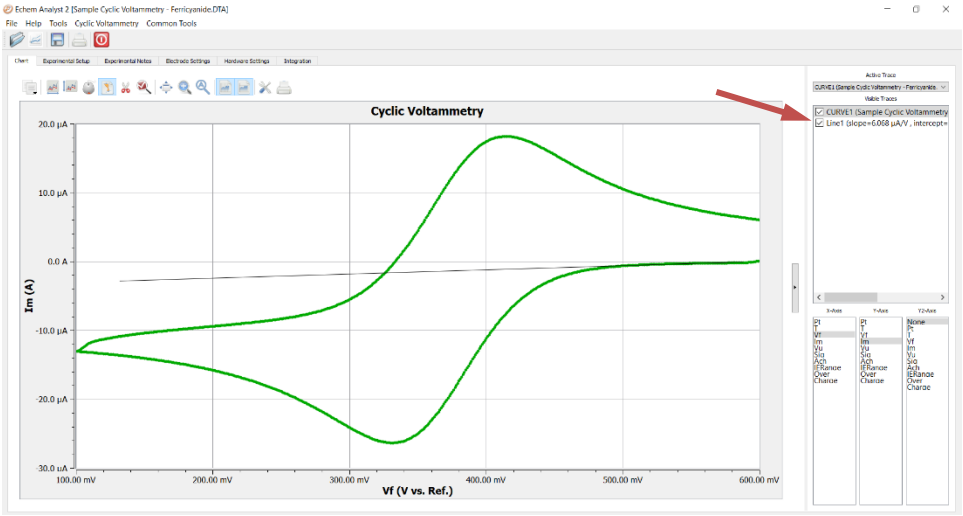
1. Open the data file.

2. Select the **Draw Freehand Line** button.



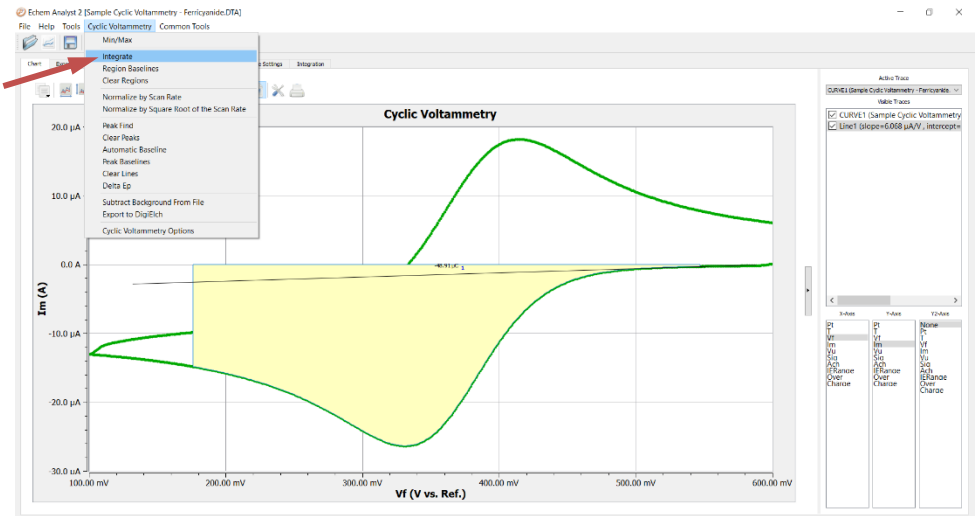
3. Left-click and hold on the graph to place an anchor point. Holding down the mouse button, extend the line with the mouse. Move or extend the line as you wish.

4. Click next to the line to accept. After you accept the line, it turns from blue to a black solid line. The line is added to the **Visible Traces** window on the right side where the line can be edited or deleted.



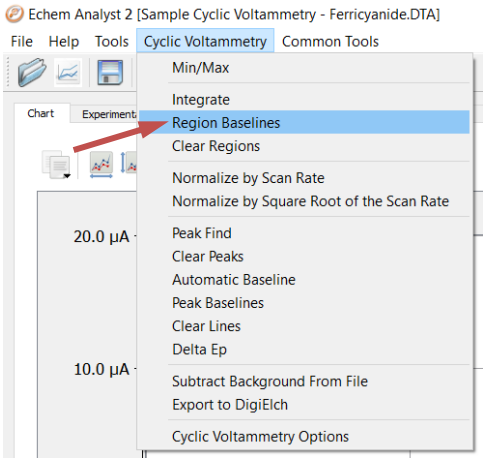
5. Select the portion of the curve to integrate. This function is described in detail earlier.

6. Select **Integrate** from the **Cyclic Voltammetry** menu.



This integrates the selected section between the curve and the zero line and display the calculated charge of the area.

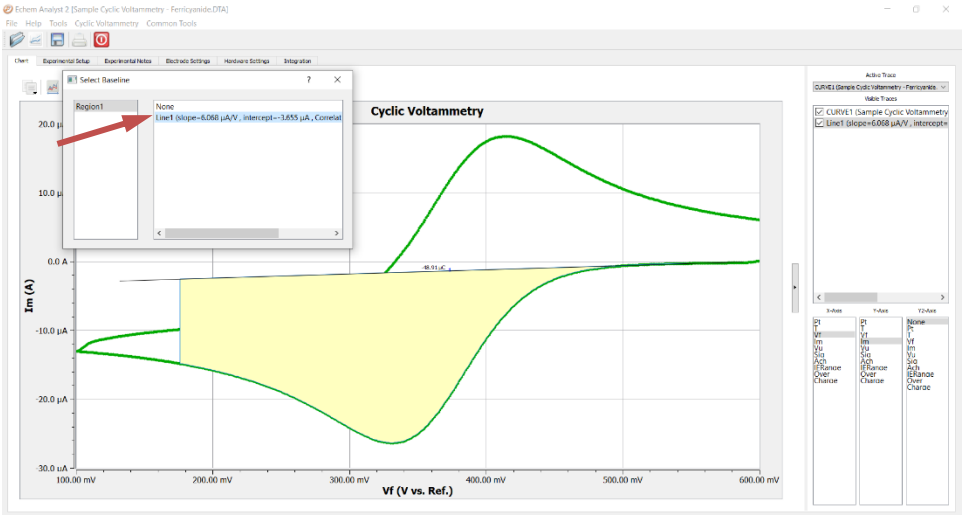
7. To change the baseline to the desired user-drawn line, select **Region Baselines** from the **Cyclic Voltammetry** menu.



The **Region Baseline Settings** window appears.

8. Select the desired baseline from the available lines. You may draw multiple lines from which to choose.

The integrated region moves from the default 0 A baseline to the user-drawn line.

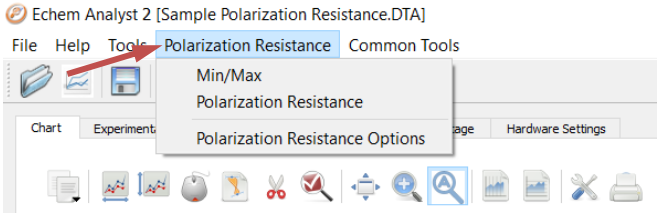


Chapter 6: Modeling Polarization Resistance Data

Polarization Resistance Special Tools

This menu analyzes the polarization resistance data.

1. In the main menu, choose **Polarization Resistance**.



   A drop-down menu appears.

2. Choose the desired tool:

Tool	Function
Min/Max	Finds the minimum and maximum currents and voltages within the dataset. Results appear in a window below the plot.
Polarization Resistance	Within a selected portion of the curve, finds the polarization resistance.
Polarization Resistance Options	Changes units and grids for plotting the data.

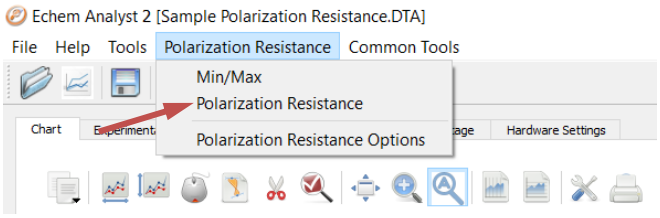
Finding the Polarization Resistance

Method 1: Manual Entry of the Tafel Constants

Finding the **Polarization Resistance** requires you first to select a portion of the curve. See how to select a portion of the curve in the "Selecting Portions of a Curve for Analysis" paragraph in Chapter 2.

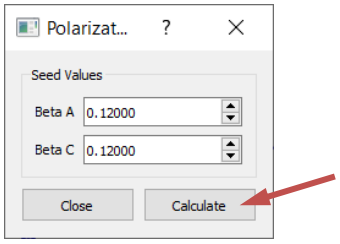
1. In the main menu, choose **Polarization Resistance**.

   A drop-down menu appears.



2. Choose **Polarization Resistance**.

   The **Polarization Resistance** window opens.

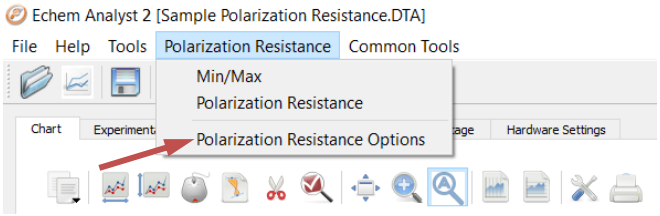


3. In the **Seed Values** area, enter anodic (**Beta A**) and cathodic (**Beta C**) Tafel constants.
4. Click the **Calculate** button.
5. The calculated **Corrosion Rate** appears in a window below the plot.

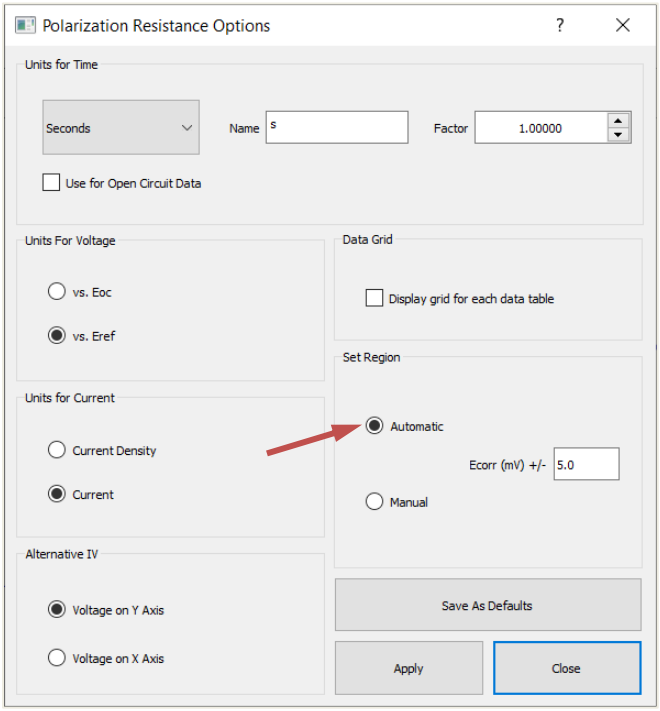
Method 2: Automatic Selection of Voltage Region

The Echem Analyst 2 offers another way to automatically select the voltage region over which this analysis is done.

1. In the **Polarization Resistance** menu, choose **Polarization Resistance Options**.



The **Polarization Resistance Options** window opens.



2. Select the **Automatic** radio button, specify the region around Ecorr to use, and click the **Save as Defaults** button. You are prompted directly for Tafel constants when a polarization resistance file is opened.

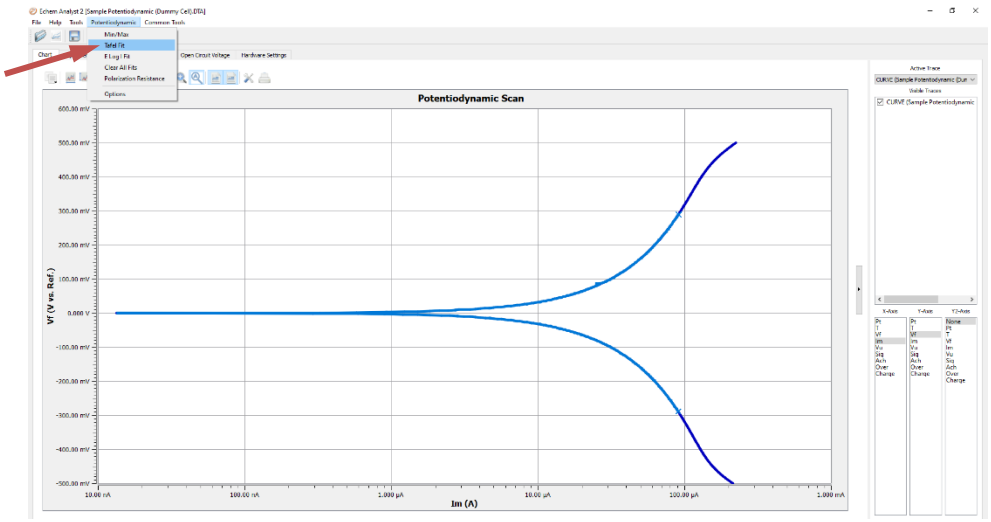
This is how Gamry Instruments' RpEc Trend experiments calculate the corrosion rate.

Chapter 7: Modeling Potentiodynamic (Tafel) Data

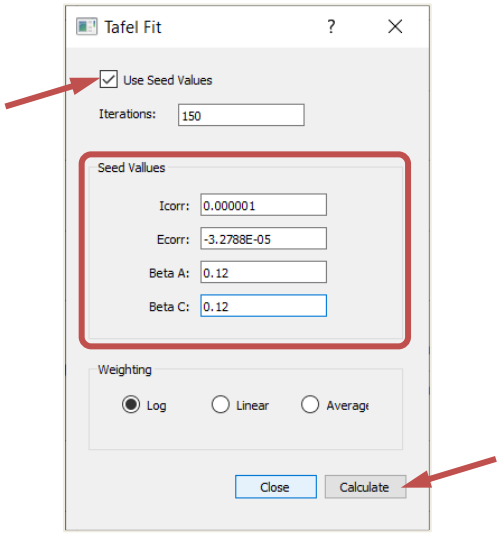
A Tafel experiment is also a very popular electrochemical corrosion technique. The following analysis is performed on the sample Potentiodynamic data file.

Tafel Fit

1. Select the region over which to perform the Tafel fit. This region must encompass the Ecorr (open-circuit potential).
2. Select **Tafel Fit** from the **Potentiodynamic** menu:



3. A **Tafel Fit** window appears where you may input seed values optionally for the fit.

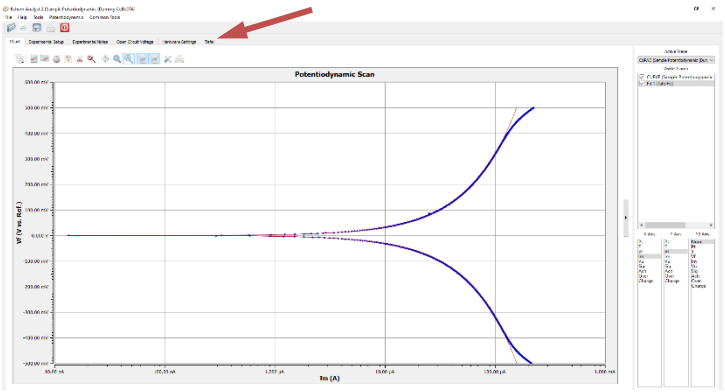


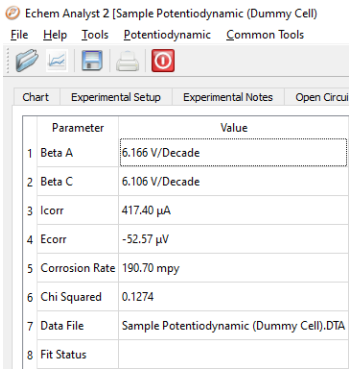
The better the information we provide the fitting routine, the more likely it will be able to generate an acceptable fit.

If you have reasonable starting parameters for the fit, input them in the **Seed Values** area, and check the **Use Seed Values** checkbox. If you do not have any confidence at all in your range of parameters, do not check the Use Seed Values checkbox.

We recommend using the seed values supplied by the Echem Analyst 2.

4. Click the **Calculate** button.
5. When you click the **Calculate** button, the changes can be subtle. The following events occur:
    - The parameters in the **Tafel Fit** window become the fit parameters.
    - A fit line is displayed on the graph.
    - A new **Tafel** tab is created (to the right of the **Hardware Settings** tab) that holds the information about the fit.





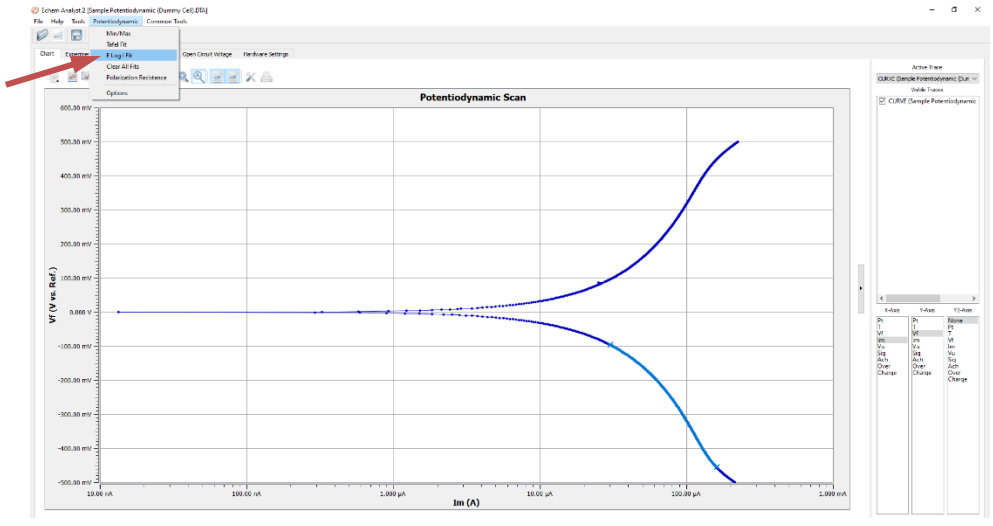
E Log I Fit

The **E Log I** fit is a useful fit if you want to fit the data one branch (anodic or cathodic) at a time. This can be important if one branch doesn't show linear behavior, but the other does.

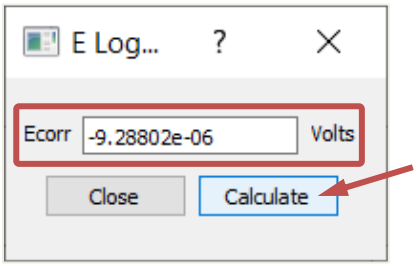
The fit is called **E Log I** because of the semi-logarithmic nature of a Tafel plot. The x-axis is the logarithm of current, while the y-axis is potential on a linear scale.

Method

1. Select a portion of the curve.
   Here you need only the linear section of one of the branches. This selection does not include **Ecorr**, i.e., Eoc (open-circuit potential).
2. Select **E Log I Fit** from the **Potentiodynamic** menu.

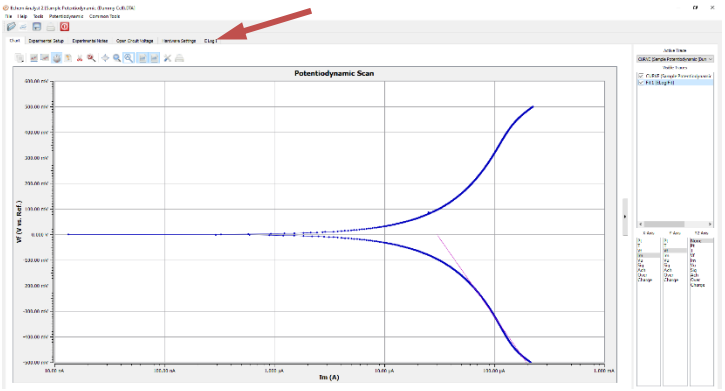


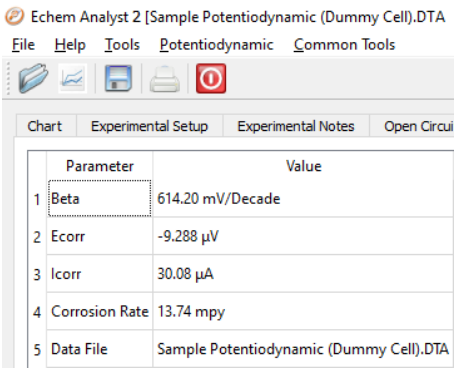
3. In the **E Log I Fit** window, enter an approximate value for **Ecorr**.



4. Click the **Calculate** button.

   A single branch of the Tafel data is fit. The fit is shown on the graph, and the results of the fit are contained in a new **E Log I** tab.





	Parameter	Value
1	Beta	614.20 mV/Decade
2	Ecorr	-9.288 µV
3	Icorr	30.08 µA
4	Corrosion Rate	13.74 mpy
5	Data File	Sample Potentiodynamic (Dummy Cell).DTA

You can run a **Polarization Resistance** fit on these Potentiodynamic data if the axes of current are changed to the linear scale. Generally, we suggest running a separate experiment on a new sample of the same material because of the more polarizing, more destructive nature of the **Potentiodynamic** experiment.

Chapter 8: Modeling EIS Data

The data-analysis features shown here are common to many of the AC-based techniques. By far the most popular type of AC experiment is **Potentiostatic EIS**.

Bode and Nyquist Plot View

Click the **Bode** tab or the **Nyquist** tab of the plot you prefer to work with. All fits are displayed on both the Bode and Nyquist plots. Because they are different representations of the same data, the fit results are identical.

Figure 8-1
Bode plot

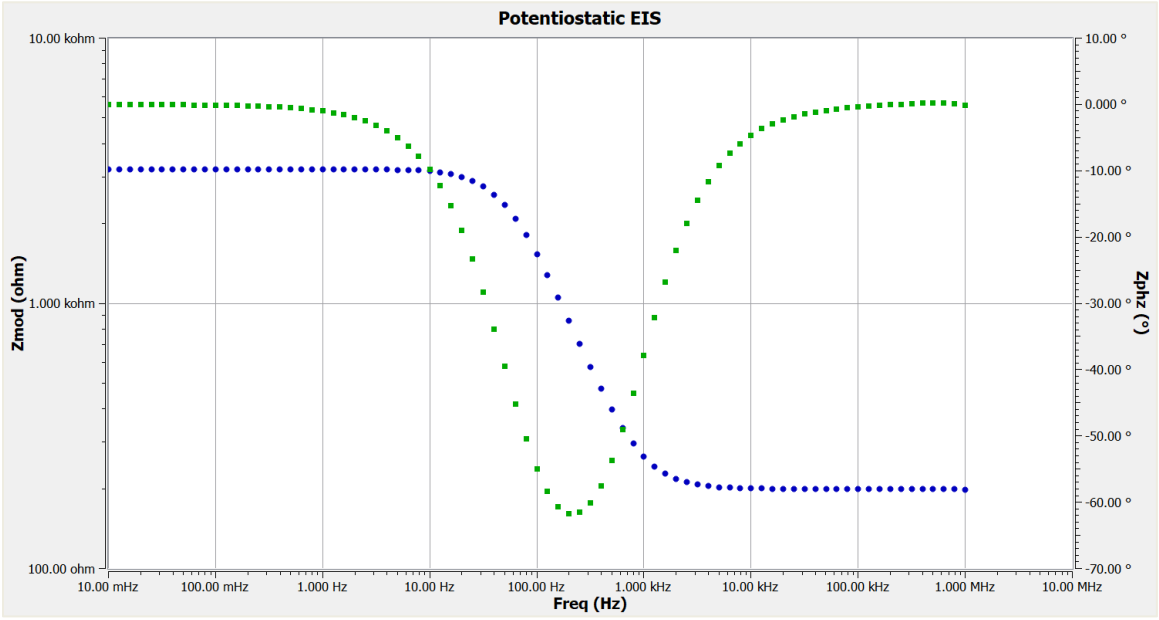
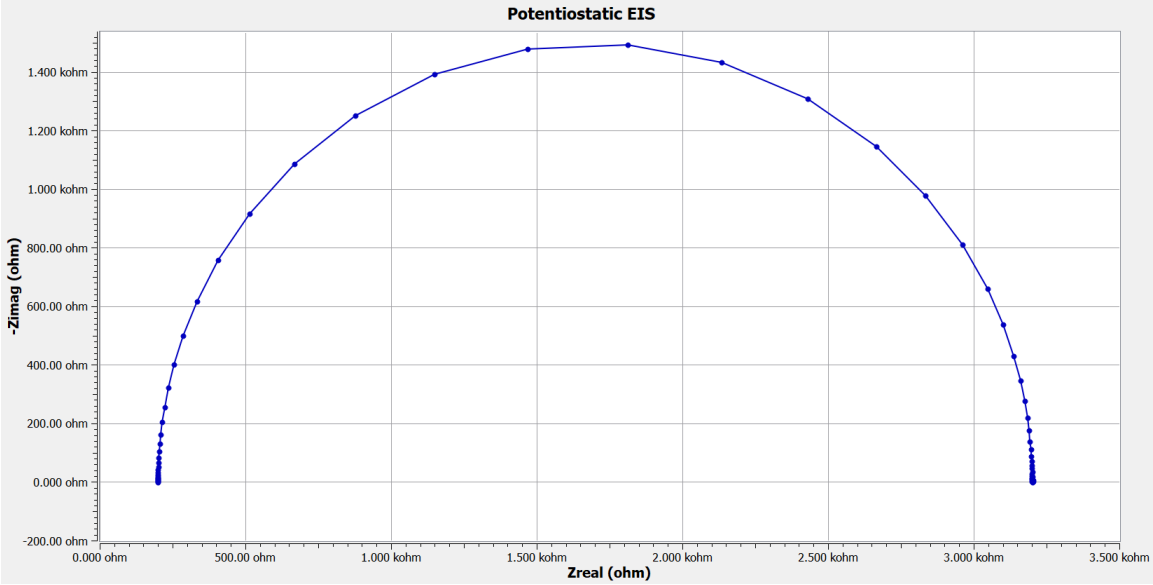


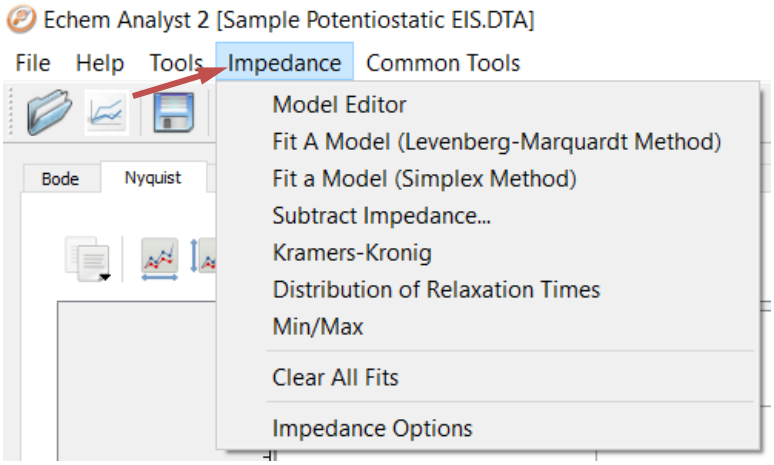
Figure 8-2
Nyquist plot



EIS Special Tools

EIS data-analysis uses an equivalent-circuit approach. This menu creates and runs fits for EIS data. Commands in this menu allow you to build an equivalent-circuit model in the **Model Editor**, then fit that model to your data. This menu also lets you run advanced procedures, such as **Subtract Impedance**, and run **Kramers-Kronig transforms**.

1. In the main menu, choose **Impedance**.
2. A drop-down menu appears.



3. To create or edit an equivalent circuit, choose **Model Editor**.
4. The **Impedance Model Editor** window appears. See the next page for how to use it.
5. Choose your fitting method.

   To fit the data using the **Levenberg-Marquardt method**, choose **Fit A Model (Levenberg-Marquardt Method)**.

   - The **Select Model File** window opens.
   - Choose the appropriate model file and click the **OK** button.

   To fit the data using the **Simplex method**, choose **Fit A Model (Simplex Method)**.

   - Simplex method weighs the user's seed values less. We recommend using the Simplex method.
6. To subtract an impedance from the data, choose **Subtract Impedance**….
7. The **Impedance Subtraction** window appears.
8. Choose your parameters:

Method	Function
Element	Choose a circuit element from the drop-down menu.
Model	Browse for a previously defined model.
Spectrum	Browse for a data-set.

   Click the **Close** button.

9. To use the **Kramers-Kronig method**, choose **Kramers-Kronig**. Kramers-Kronig is a model-independent transform that checks the EIS data for consistency.

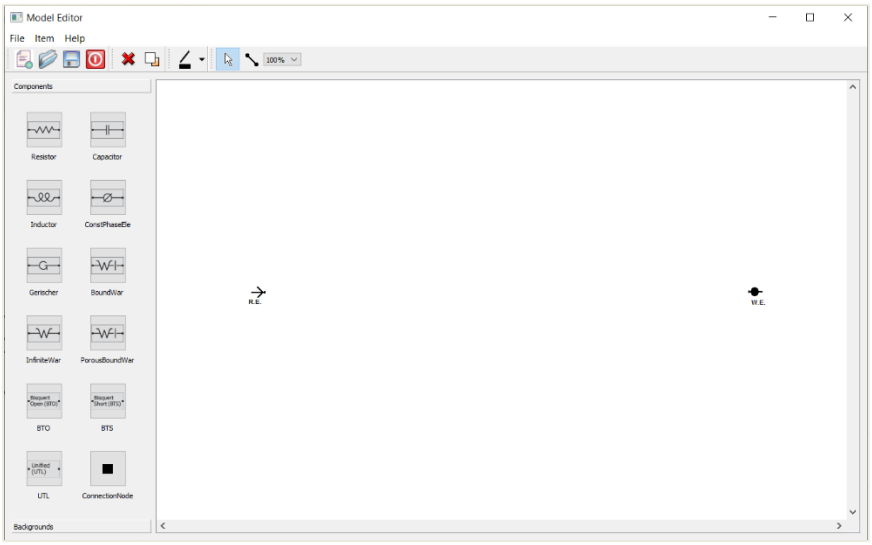
   The **Kramers-Kronig** window appears.

10. To clear all fits from the plot, choose **Clear All Fits**.

11. To change time or impedance units, choose **Options**. This option lets you normalize the data and fits to the normalized area.

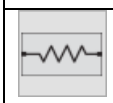
The Model Editor

The **Impedance Model Editor** allows you to create an equivalent circuit. You can select between a variety of circuit elements to build your own model or open a pre-built model.



There are several pre-loaded models. Often users find it convenient to start with one of these models and edit it as needed.

Figure 8-3
Circuit Elements

Symbol	Element	Comments
	Resistor	Abbreviated as *R*. $Z = R$
	Capacitor	Abbreviated as *C*. $Z = -i/\omega C$
	Inductor	Abbreviated as *L*. $Z = i\omega L$
	Constant Phase Element	Models an inhomogeneous property of the system, or a property with a distribution of values. Often abbreviated as CPE.
	Connection Node	Add a connection to the model.
	Gerischer Element	Models a reaction in the surrounding solution that happened already; also used for modeling a porous electrode. Often abbreviated as G.
	Infinite Warburg	Models a linear diffusion to an infinite planar electrode. Often abbreviated as W.
	Bounded Warburg	Models diffusion within a thin layer of electrolyte, such as electrolyte trapped between a flat electrode and a glass microscope slide. Often abbreviated as T.
	Porous Bounded Warburg	Models diffusion through a thin layer of electrolyte, such as electrolyte trapped between an electrode and a permeable membrane covering it. Often abbreviated as O.
	Bisquert Open (BTO)	Transmission line with $Z_B \equiv \infty$ boundary condition. Only pore reactions are considered; base electrode is insulating.
	Bisquert Short (BTS)	Transmission line with $Z_B \equiv 0$ boundary condition. Only pore reactions are considered; electrode is non-insulating.
	Unified (UTL)	Transmission line with a variety of free parameters.

Building an Equivalent Circuit

1. Adding an **element:**
    - Left-click on an element symbol.
    - Left-click on the open area to place the **element**.
2. Connecting elements:
    - Click on the **Add Connector Line** symbol in the toolbar.

- Left-click one end of the wire and drag the end to the element.

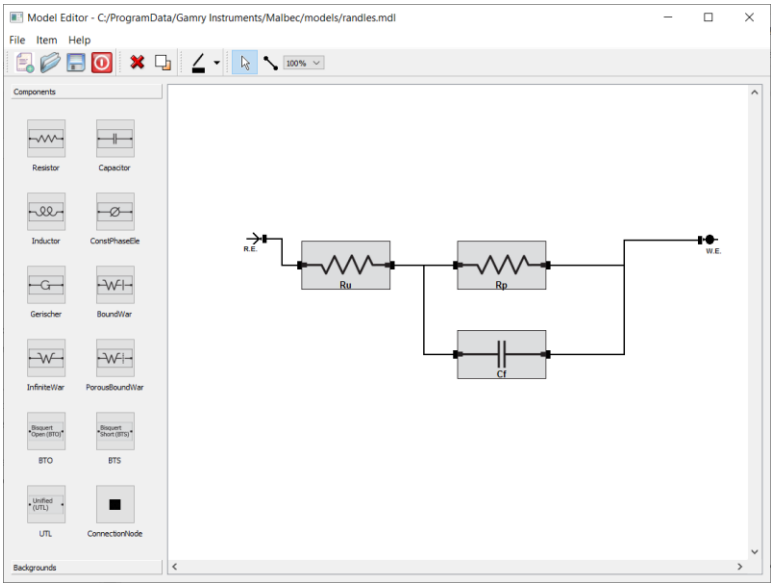
  The element's border turns blue when the wire's end reaches the element.
- Add a **Connection Node** if additional connections are required.

Be sure to connect the circuit to the reference-electrode symbol 

and the working-electrode symbol 

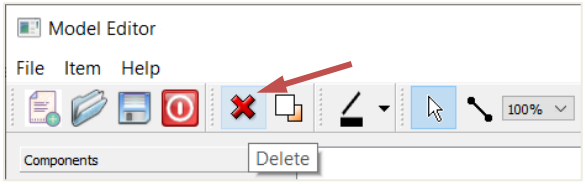
.

Here is an example of a simple equivalent circuit (a **Randles model**) constructed in the **Impedance Model Editor**:



3. Deleting an element:
   - Right-click on the element.

     The **Delete** command appears. Press Delete.
   - Left-click on the **Delete** symbol in the toolbar.

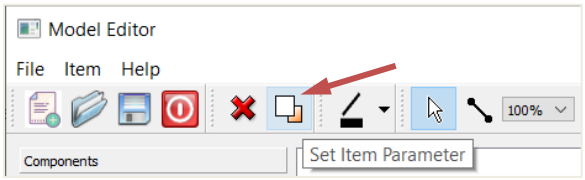


   Left-click on any element to be deleted.
4. Relabeling and fixing parameters for an element:

The **Set Item Parameter** tool lets you rename the element, specify its parameters, and set a **Lower** and **Upper Limit** for its value. Renaming the element helps you distinguish between elements of the same type during fitting. Giving the program limits on the parameters may help the mathematical algorithm. For example, we know values are generally positive, so a Lower Limit = 0 is reasonable to set. There are two way to set element parameters:

- Left-click on an **element**.

  Left-click on the **Set Item Parameter** symbol in the toolbar.

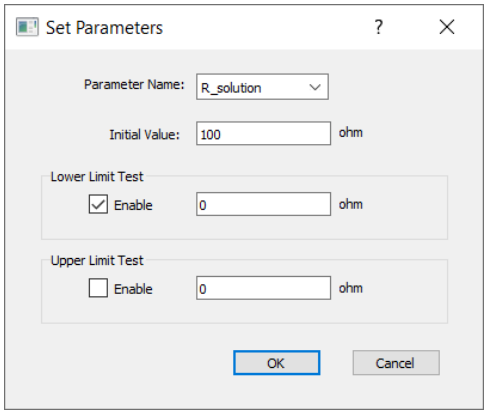


  The **Set Parameter** window appears.

- Right-click on the name of the element (in this example a resistor).

  The **Set Item Parameter** command appears. Press Set Item Parameter.

  The **Set Parameter** window appears:



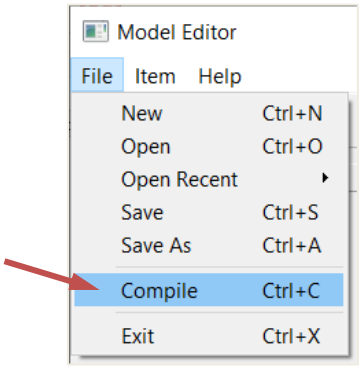
- Enter a new **Parameter Name**.
- Enter an **Initial Value**, i.e., the first trial value for fitting.
- In the **Lower Limit Test** and **Upper Limit Test** fields, enter lower and upper limits, and check the **Enable** checkbox, as desired.
- Click the **OK** button.

The **Set Parameter** window closes and the element is set to these parameters.

Compiling the Equivalent Circuit

When the **equivalent circuit** is complete, the circuit can be compiled before use to check for connectivity of the wires. Compiling is only used to check connections

1. Click **File > Compile** in the Model Editor menu.



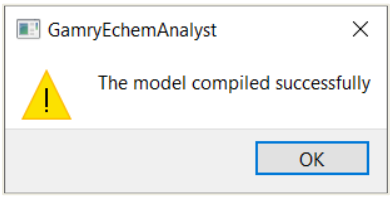
The software compiles the **equivalent circuit**.

2. If there is a problem, such as a missing connection, an error message appears, and a red box outlines the problem element.

   Click the **OK** button to continue.

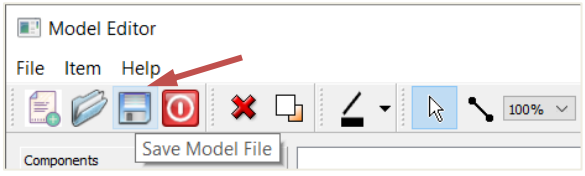
3. Inspect the schematic and make necessary corrections.

   If the equivalent circuit compiles properly, a message appears to confirm the successful compiling process.



   Click the **OK** button to continue.

4. Save the **equivalent circuit** with an `*.mdl` extension by clicking the **Save Model File** button in the toolbar.



   The **File Save As** window appears.

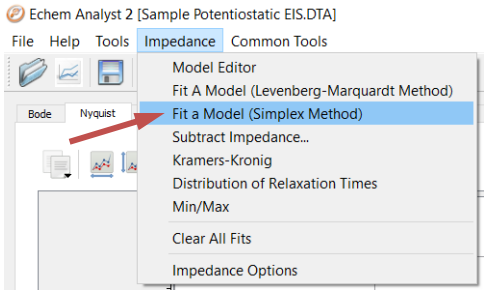
   The default folder for saving model equivalent circuits is the **Models folder**.

5. Name and save the file here or choose a different folder.

   The **File Save As** window closes.

Fitting the Data to the Equivalent-Circuit Model

1. With the data open and plotted, click Impedance, and choose **Fit A Model (Simplex Method)**.



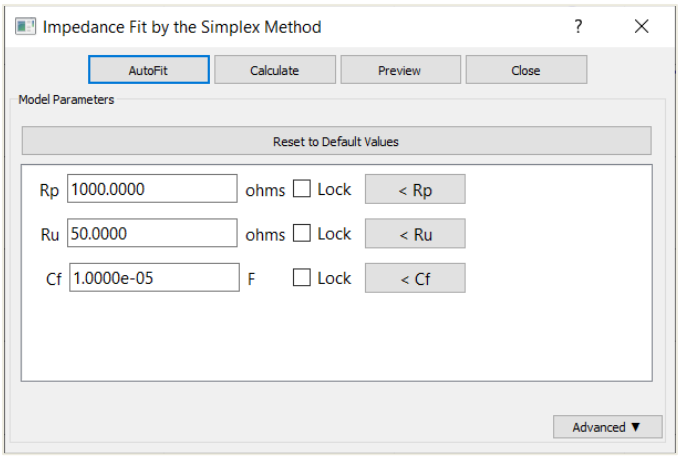
   The **Select Model File** window appears.

2. Choose the desired model.

   The default folder for models is the Models folder. This Models folder is by default in the `C:\ProgramData\Gamry Instruments\Echem Analyst 2\models` directory.

   Click the **Open** button.

3. The **Select Model File** window closes and the **Impedance Fit by the Simplex Method** window appears.



4. Click the **AutoFit** button or set parameters.

   Enter estimates for all the circuit elements in the **Model Parameters** area. Fix particular elements by enabling their **Lock** checkboxes.

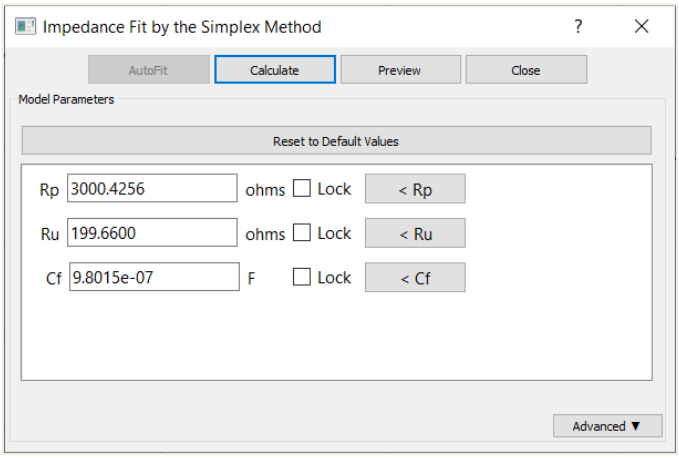
   - In this example, we try 50 Ω for *Ru*, 1000 Ω for *Rp*, and 10 μF for *Cf* and leave all of them free (unlocked).

5. If you don't use the **AutoFit** button, click the **Calculate** button to start the fit.

   The software attempts to fit the model to the data. When finished, the fitted parameters appear next to each circuit element.

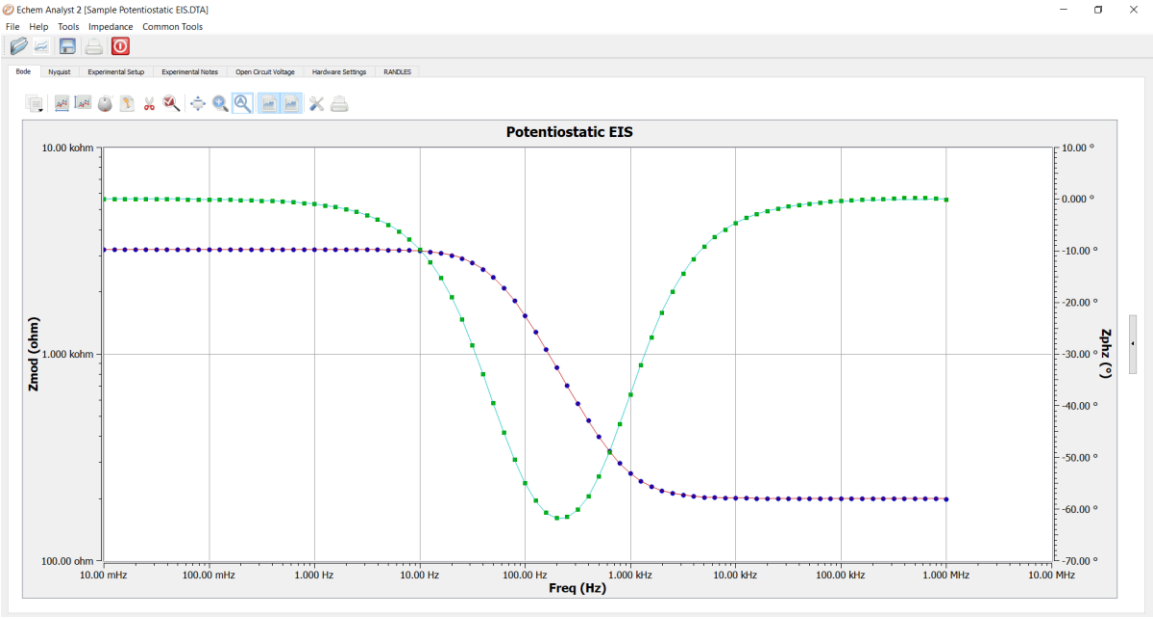
   The model in this example gives following fit parameters:

   - *Rp* = 3 kΩ
   - *Ru* = 199.7 Ω (solution resistance)
   - *Cf* = 980 nF



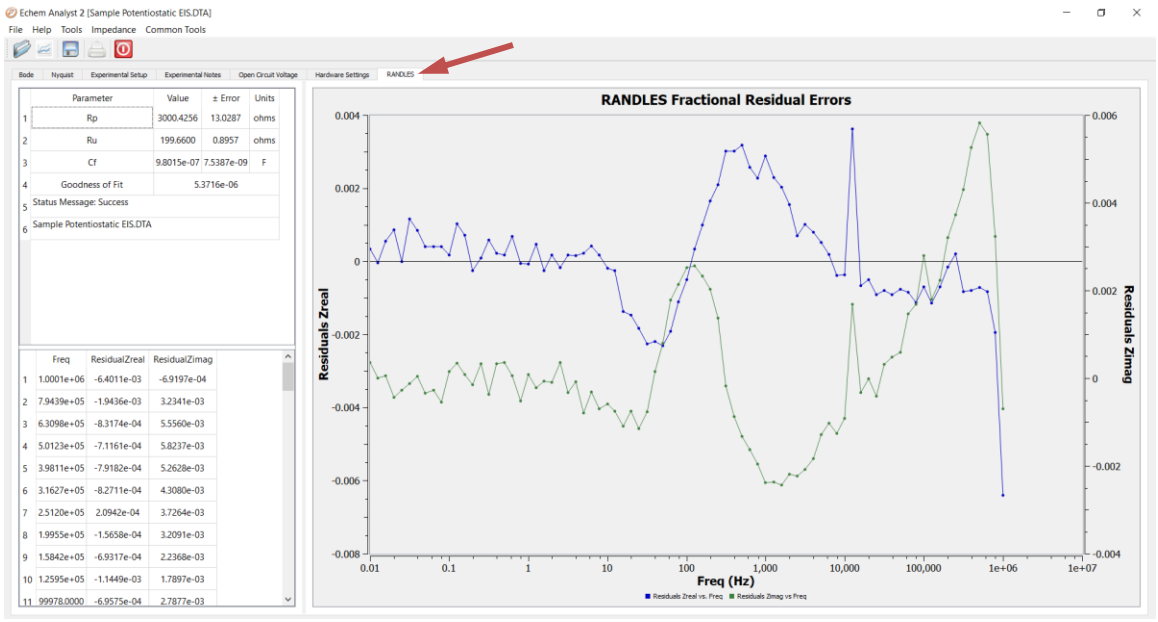
If your fit fails, try different starting **Model Parameters**, or even a different equivalent-circuit model.

Like other Echem Analyst 2 fits, the fit also appears superimposed upon the data and a new tab is created that contains those results.



If you try another fit using the same model, it will display a second fit and add a counter to the fit's name. If you fit to another model, the fit results of both models will be displayed.

This new tab shows the residual errors and goodness of fit, along with the various plotting tools. Residuals are a point-by-point **Goodness of Fit**, which quantifies how closely the data match the fit. A smaller number indicates a better fit.



The blue data (**Zreal**) correspond to the y1-axis (on the left); the green data (**Zimag**) correspond to the y2-axis (on the right).

Appendix A: Headings in Data-File Columns

DC Data Files

Abbreviation	Meaning
Pt	Point number
T	Time
Vm, Vf	Measured voltage
Im	Measured current
Vu	Uncompensated voltage
Sig	Signal from the signal generator
Ach	Auxiliary channel
IE Range	I/E (Current Measurement) range on which measurement was made
Over	Any overloads. Numeric record of different overload types
0	No overloads

EIS Data Files

Abbreviation	Meaning
Freq	Frequency
Zreal, Zimag, Zmod, Zphz	Calculated values of impedance
Idc, Vdc	DC component of current and voltage
Yreal, Yimag	Admittance (calculated from *Z*)

Appendix B: Current Conventions According to Framework™ and Echem Analyst 2

The current convention in the Framework software for all experimental packages is that an anodic/oxidation current is positive.

To change the current convention (whether anodic/oxidation currents or cathodic/reduction currents are positive), in the menu **Tools > Options > Units** tab, specify the current you want represented as positive. The current convention can be changed by editing the experimental script (contact Gamry Instruments or your Gamry Instruments representative if you need to do this). Regardless of the current convention used in the Framework, it can be changed in the Echem Analyst 2 to the one you desire (see below for exceptions).

The current convention affects all experiments run under the Physical Electrochemistry and Pulse Voltammetry heading. No other data files are affected.

To change the current convention in the Echem Analyst 2, in the menu **Tools > Options > Units** tab specify the current you want represented as positive

To change the current convention in other experimental packages (DC Corrosion, EIS, etc.) please contact Gamry Instruments or your Gamry Instruments representative.

Appendix C: Index