VersaStudio

Software Manual

PN: 224181 Rev B

VersaStudio Software

APPENDIX 1 – GLOSSARY OF EXPERIMENT PROPERTIES

APPENDIX 2 – GLOSSARY OF AXIS GRAPH OPTIONS

APPENDIX 3 – VERSASTUDIO DATA FILES

VersaStudio Software
for the VersaSTAT Series and PARSTAT 4000

1. Introduction

The VersaStudio family of software applications for electrochemistry research was developed for use with the VersaSTAT 3 (aka **V3**), VersaSTAT 3F (aka, **V3F**) VersaSTAT 4 (aka, **V4**) VersaSTAT MC (aka, **VMC**) and PARSTAT 4000 (aka, **P4K**). With VersaStudio, this group of potentiostats/galvanostats can perform a vast array of electrochemical techniques, both standard and custom. The VersaStudio was designed to be intuitive, flexible, and a visually appealing user interface, generating virtually limitless data streams and storing the results in easy-to-read text files. Additional features such as custom report generation and password security makes VersaStudio ideal for the multi-user lab setting. The VersaStudio makes "Echem Easy!"

1.1. About this manual

Chapter 2 explains the system feature of the hardware/software, showing the standard techniques associated with each system.

Chapter 3 describes how to start the software once installed, and demonstrates how easy it is to begin using the VersaStudio by performing checkout procedures for the system.

Note: For VersaSTAT MC systems with more than one channel, sections 4.4.3 and 4.4.4 should be reviewed carefully.

Chapter 4 contains complete instructions on VersaStudio's menu functions for performing experiments and analyses.

1.2. Technical Support

Remember that the worldwide staff at Princeton Applied Research continues to support the customer after purchasing the equipment and software. We provide top quality service, applications support, and a variety of helpful information in the form of application notes, technical notes, and training material. For more information, visit our web site at http://www.princetonappliedresearch.com, or in VersaStudio, select Help>About…, and select "visit us on the web."

2. Modules

2.1. Standard Techniques

The VersaStudio software is comprised of three main modules, each containing techniques and analysis tools unique to that module. The modules available are **Voltammetry** (research electrochemistry techniques), **Corrosion** (DC corrosion techniques), **Energy** (Battey-related techniques) and **Impedance** (electrochemical impedance spectroscopy techniques). The following is a list of the standard techniques available in each module:

Impedance
- Open Circuit
- Potentiostatic EIS
- Galvanostatic EIS

Energy
- Open Circuit
- Multi-Vertex Scan
- Constant Potential
- Constant Current
- Constant Power
- Constant Resistance
- Current CCDPL
- Power CCD
- Resistance CCD

Corrosion
- Open Circuit
- Linear Polarization
- Tafel
- Potentiodynamic
- Cyclic Polarization
- Potentiostatic
- Galvanic Corrosion
- Galvanostatic
- Galvanodynamic
- Zero Resistance Ammeter (ZRA)
- Electrochemical Noise (EN)
- Split LPR
- Galvanic Control LPR

Voltammetry
- Open Circuit
- Linear Scan Voltammetry
- Cyclic Voltammetry (Single)
- Cyclic Voltammetry (Multi-Cycle)
- Staircase Linear Scan Voltammetry
- Staircase Cyclic Voltammetry (Single)
- Staircase Cyclic Voltammetry (Multi-Cycle)
- Chronoamperometry
- Chronopotentiometry
- Chronocoulometry
- Recurrent Potential Pulses
- Recurrent Galvanic Pulses
- Fast Potential Pulses
- Fast Galvanic Pulses
- Squarewave Voltammetry
- Differential Pulse Voltammetry
- Normal Pulse Voltammetry
- Reverse Normal Pulse Voltammetry

2.2. Systems and Upgrades

The VersaStudio contains all the techniques of each module, but the V3, V3F and V4 hardware must be "enabled" to run each of the modules or techniques within that module. The V3, V3F and V4 can be purchased in one of six different configurations: the VersaSTAT 3-100, -200, -300, -400, -450, or -500 systems. VersaStudio is free to download and use as-is, but will only be able to run those experiments with the VersaSTAT product and model for which it has been optioned and programmed by the factory. The VersaSTAT MC and PARSTAT 4000 operates with all of the modules and techniques, as well as impedance techniques (VersaSTAT MC systems purchased prior to September 2012 must purchase upgrade to include Energy module as a -500 system). The following is a table of the four systems and the software techniques that each can perform:

VersaSTAT 3&4	-100	-200	-300	-400	-450	-500	VMC	PARSTAT4000
Techniques								
Open Circuit	X	X	X	X	X	X	X	X
LSV	X	X		X	X	X	X	X
CV (Single)	X	X		X	X	X	X	X
CV (Multi)	X	X		X	X	X	X	X
Staircase LSV		X		X	X	X	X	X
Staircase CV		X		X	X	X	X	X
Staircase CV - Multi		X		X	X	X	X	X
CA	X	X		X	X	X	X	X
CP		X		X	X	X	X	X
CC		X		X	X	X	X	X
RPP		X		X	X	X	X	X
RGP		X		X	X	X	X	X
FPP		X		X	X	X	X	X
FGP		X		X	X	X	X	X
NPV		X		X	X	X	X	X
RNPV		X		X	X	X	X	X
ZRA			X	X		X	X	X
Galvanic Corrosion			X	X		X	X	X
Cyclic Polarization			X	X		X	X	X
Linear Polarization			X	X		X	X	X

VersaSTAT 3&4	-100	-200	-300	-400	-450	-500	VMC	PARSTAT 4000
Tafel			X	X		X	X	X
Potentiostatic			X	X		X	X	X
Potentiodynamic			X	X		X	X	X
Galvanostatic			X	X		X	X	X
Galvanodynamic			X	X		X	X	X
Split LPR			X	X		X	X	X
Galvanic LPR			X	X		X	X	X
Echem Noise			X	X		X	X	X
Dynamic IR			X	X		X	X	X
Energy Open Circuit					X	X	X	X
Multi-Vertex Scan					X	X	X	X
Constant Potential					X	X	X	X
Constant Current					X	X	X	X
Constant Power					X	X	X	X
Constant Resistance					X	X	X	X
Current CCDPL					X	X	X	X
Power CCD					X	X	X	X
Resistance CCD					X	X	X	X
Potentiostatic EIS	*	*	*	*	*	*	X	X
Galvanostatic EIS	*	*	*	*	*	*	X	X
Loop		X	X	X	X	X	X	X
Time Delay		X	X	X	X	X	X	X
Message Prompt		X	X	X	X	X	X	X
Measure OC		X	X	X	X	X	X	X
Auxiliary Interface		X	X	X	X	X	X	X
Run External App.		X	X	X	X	X	X	X
DAC Output Cont.		X	X	X	X	X	X	X
Email		X	X	X	X	X	X	X
Auto CR Setup		X	X	X	X	X	X	X
Display Message								X
Condition		X	X	X	X	X	X	X
Deposition		X	X	X	X	X	X	X
Equilibration		X	X	X	X	X	X	X
Purge		X	X	X	X	X	X	X
iR Determination		X	X	X	X	X	X	X

* EIS capability (Impedance) is optionally available (FRA option) with any of the V3, V3F or V4 systems.

For example, if the VersaSTAT 3 is ordered as a VersaSTAT3-300 with FRA option, the VersaSTAT 3 hardware will be programmed to run only Corrosion and Impedance techniques, and not the Voltammetry techniques. Systems can be upgraded with more capability after the purchase, but some upgrades will require return to factory or local service representative for that upgrade. Please refer to the most recent brochure at the web site, http://www.princetonappliedresearch.com , for information and details on ordering all VersaSTAT options.

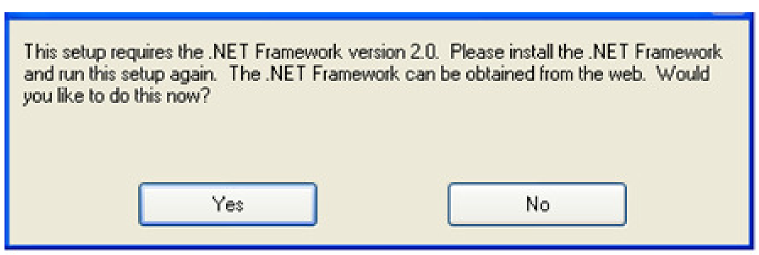
3. Installation and Startup

3.1. Installing VersaStudio from CD

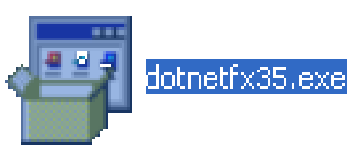
VersaStudio is supplied on compact disk (CD), and installation should auto-run once the CD is inserted into the computers CD-ROM drive. If it does not auto-run, execute the Setup.exe file on the CD to begin the installation. During the installation, the VersaStudio Setup Wizard will provide the default installation folder. NOTE: Please install in the default folder to avoid any potential conflicts with other programs. Once the installation procedure has completed, execute the VersaStudio icon from the Programs menu (Start>All Programs>VersaStudio).

Note: If you had an older version of the VersaSTAT control software called "V3-Studio" already installed, that software <u>will not be removed</u> by the VersaStudio installation. However, once VersaStudio is installed and the firmware updated inside the VersaStat hardware (section 3.3), the older V3-Studio software will not operate the VersaSTAT hardware reliably any longer. Therefore, it is recommended that the V3-Studio be removed using the Windows Control Panel "Add/Remove Programs" utility so as to not accidentally run the older version. The V3-Studio folder will not be removed, as this likely contains a "Data" folder with existing data from the V3-Studio operation. The V3-Studio data files can be opened and viewed with the newer VersaStudio software.

During the installation on older Windows systems, a message box may appear as below:



If this message box appears, select "No" for installing it from the web. Next, go to "My Computer" and select the CD-ROM drive (highlight) containing the VersaStudio disk. Select "File>Explore" and execute the file **dotnetfx35.exe** and install the Microsoft .NET Framework 3.5 from the VersaStudio CD.

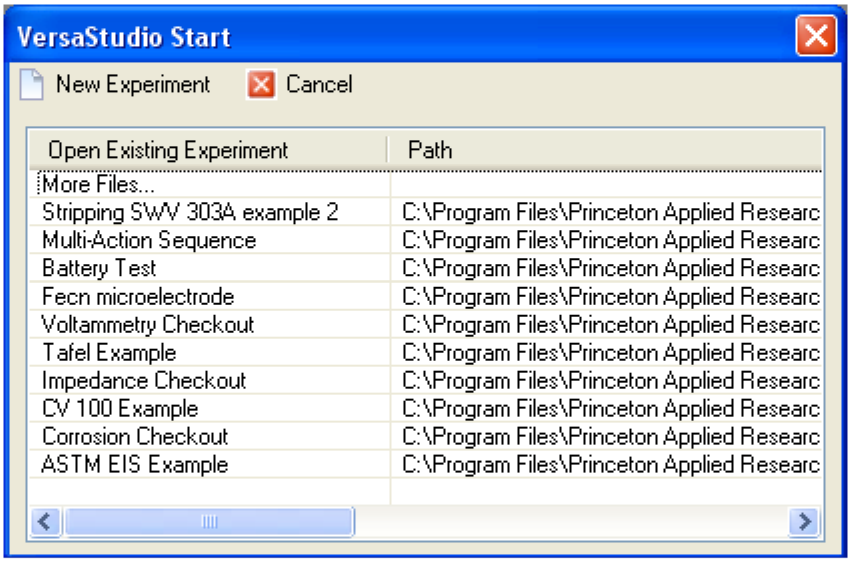


After installing the .NET Framework, re-start the VersaStudio installation.

3.2. Getting Started

Open the software from **Start > All Programs > VersaStudio.**

At execution, the following window appears:



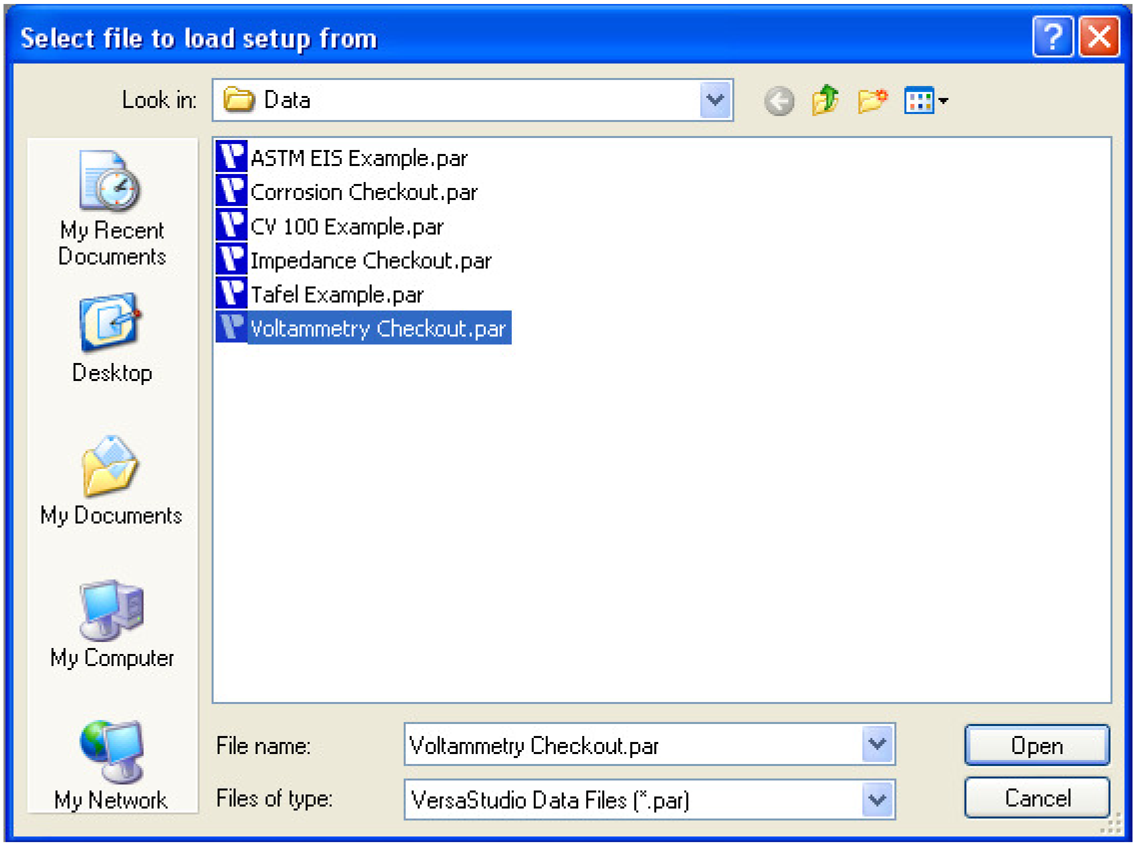
The options at this stage are as follows:

A) Select "New Experiment" to select the technique and setup the experiment properties for an entirely new experiment.
B) Select one of the 10 most recently ran experiments from the list box.
C) Select "More Files…" to select an experiment saved to a specific folder
D) Select "Cancel" to go directly to the main menu options in VersaStudio.

Note: If the hardware has been installed and connected to the computer, The VersaStudio software will auto-detect and connect to the hardware channel with which it communicates. If more than one channel is connected and detected (such as the multiple channels of a VMC), "No Instrument" is the default, and a channel must be selected in order to start programming a new experiment. To select different channels of a VMC or additional systems connected to the same computer, please refer to section 4.4.3.

Select **Cancel**, and from the main menu, select **Experiment>Load Setup**. There should be three files listed as **Voltammetry Checkout, Corrosion Checkout, and Impedance Checkout**.

Select one of the checkout files to run (Note: technique(s) must be available to actually run), and select **Open**.

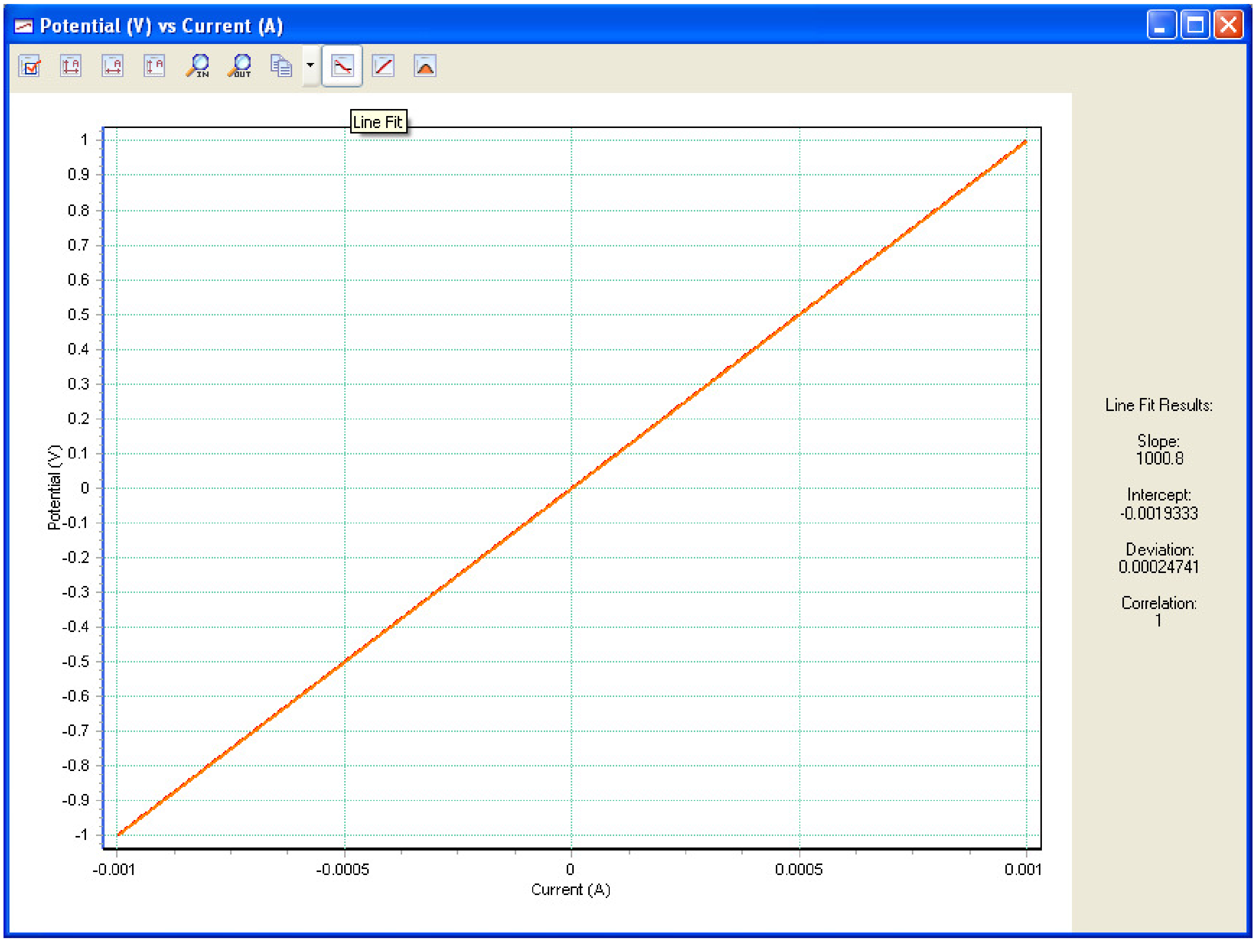


Enter a new filename for the checkout to be performed, and select **OK**.

An empty graph, Experiment Properties, and empty Data View window will appear. As this setup is complete as-is with the desired parameters already entered and set to the internal DC dummy cell (1kohm resistor), press the **Run** button on the main menu to begin running the checkout experiment, which will perform the experiment on the internal dummy cell (1K ohm resistor), such that no cell cable connections are needed.

Once the experiment is completed, the results for each should be as follows:

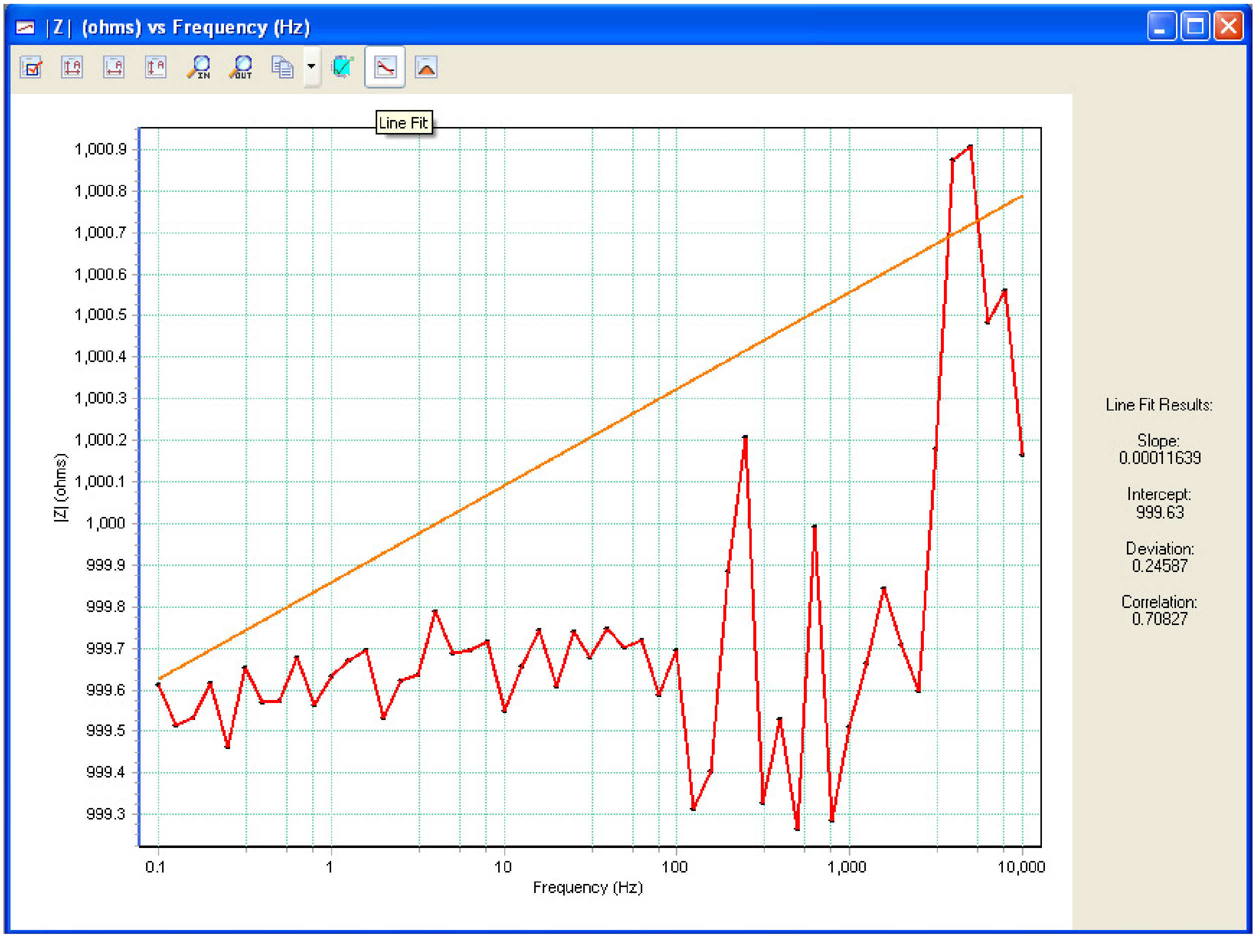
Voltammetry Checkout and Corrosion Checkout – After the data acquisition is complete, the following graph and data should be available (minus the Line Fit results):



Select all the data points (see section 4.3.1.2. on using the mouse to select data points) of the acquisition, and select the **Line Fit** button at the top of the graph window. The results should be Slope= 1000 ohms (+/- 10ohms), Intercept = +/- 4mV, and the vertices of the plot should be near +/-1V and +/-1mA as shown above.

Note: If data does not appear correct, insure that the "Cell" in the Advanced Properties is set to "Internal", and run again.

Impedance Checkout – After the data acquisition is complete, the following graph and data should be available (minus the Line Fit results):



Select all the data points (see section 4.3.1.2. on using the mouse to select data points) of the acquisition, and select the **Line Fit** button at the top of the graph window. The results should be Intercept = 1000 ohms (+/- 10ohms), with all the points on the graph at 1000 ohms, +/-20ohms. Note: the wide variance of +/-20 ohms is a result of using the internal dummy cell; the VersaSTAT systems utilize calibration constants that account for using the cell cable, so when using the internal dummy cell the data may have more error as a result.

Note: If data does not appear correct, insure that the "Cell" in the Advanced Properties is set to "Internal", and run again.

If the results for preceding checkout procedures are not within the specified ranges, it could mean that your system is in need of calibration and/or repair. For technical support, please contact the factory (www.princetonappliedresearch.com) or your local Princeton Applied Research representative for further instructions.

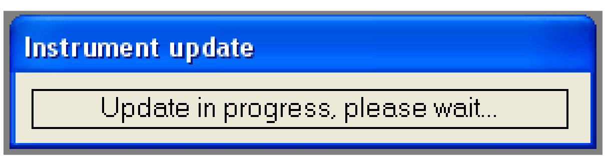
3.3. Firmware Updates

When newer versions of software are installed, it may be necessary to update the firmware within the hardware. The VersaStudio software checks the firmware of the connected hardware at start-up, and if there is a mismatch between the current version of the software and the firmware inside the hardware, the following message box will appear:

It is advised to answer "Yes" so that the current version will operate correctly on all actions.

Warning: If the firmware update process is interrupted (due to loss of power in the computer or the hardware, for example), this could corrupt the memory inside the hardware such that a return-to-factory for reporgramming would be required. It is very important that the update process not be interrupted, so it is recommended that all other programs running in Windows be closed prior to performing this update.

If "Yes" is selected to update the firmware, the following status window will appear:



The update process takes 1-2 min to finish. Upon completion, the system will automatically reset (re-boot) without having to cycle the power, so expect to temporarily loose communication with the system during the ~1min reset time period.

Note: If multiple channels are connected, it is advised to update each channel before proceeding to start a new experiment, particularly if connected to a VersaSTAT MC multi-channel system.

4. Main Menu Commands

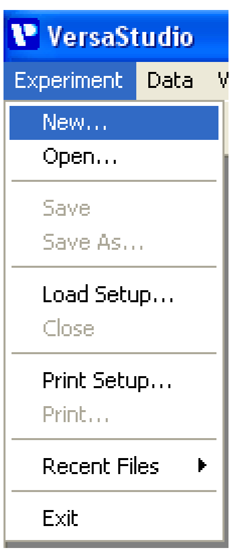
One can access the functions of VersaStudio in two ways.

Clicking on **Experiment, Data, View, Tools, Security, Window,** or **Help** in the top row opens a dropdown box, as shown in the sections below.

The icons on the second row **(New, Open, Save As, Print, Delete Data, Add Graph View, Show Properties, Show Data View, Show Overlay Manager, Show EI View, Select Instrument, Log In, Log Out, Auto Align Windows, Run, Stop, and Skip)** correspond to these functions, and will be mentioned in this manual together with the description of their respective function.

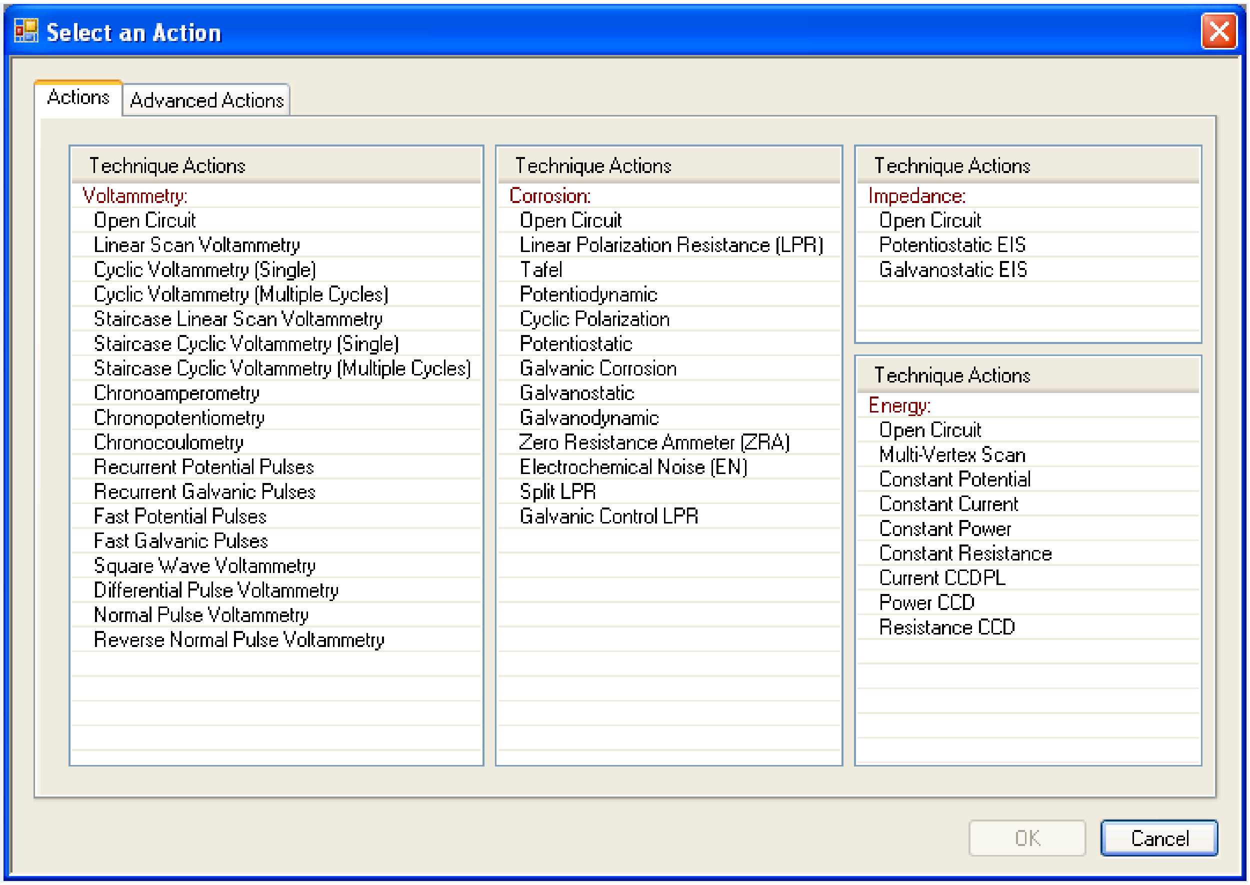
4.1. Experiment

4.1.1. New

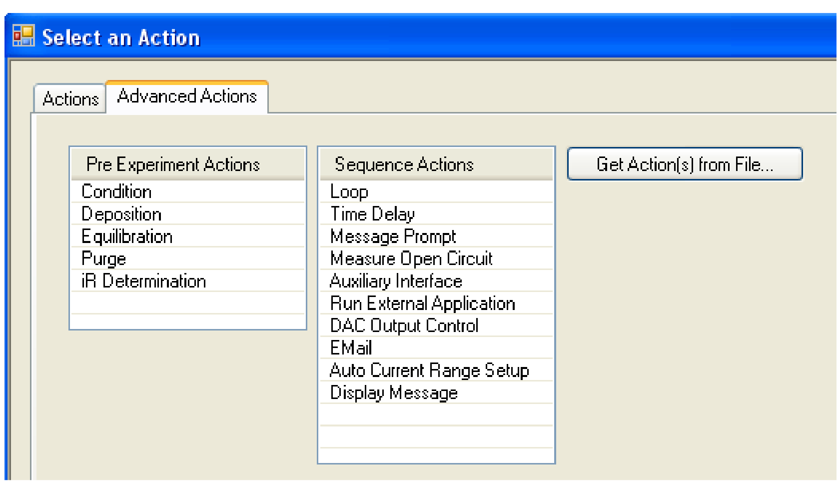


or

Clicking on **Experiment > New** opens the **Select an Action** box. This box can also be opened by clicking on the **New** icon, which is furthest to the left on the toolbar.



NOTE: Selecting the tab **Advanced Actions** will display the full list of available actions.



4.1.1.1. Creating a Single-Action Experiment

To create a new experiment, the user must select at least one action from the list. If the technique is available to the user, it will be listed in black; the grayed-out actions are not available to the user. Selecting one of the available actions will activate the OK button.

NOTE: The term "action" is used because of the unique way in which the systems can perform a series (or sequence) of experiments, pre-experiments, and/or analyses (cumulatively called “actions”). For most experiments, a single aechnique action will be all that is needed to perform the desired experiment as described in this section. For more advanced experiments, such as looping a single action or sequencing a series of different actions, refer to section 4.1.1.2.

4.1.1.1.1. Select an Action

The following is a listing and brief description of the available actions (provided the appropriate module was purchased and installed) from which to select.

Technique Actions

Voltammetry

Open Circuit:

Technique which does not apply any voltage or current (cell off), and simply measures the voltage difference between the working-sense and reference electrodes. The data is acquired for either a set period of time, or a minimum drift rate. **The current readings that are shown are the resolution limits for the current range on which the data was collected; these current magnitudes are artifacts, and should not be considered actual currents for the oc actions.**

Note: If the Open Circuit action is used in a sequence and followed by actions that apply voltages "vs OC" then the "Measure Open Circuit" action should immediately follow the "Open Circuit" action to re-set the open circuit voltage to its latest reading. Otherwise, the original oc (taken just prior to beginning the sequence) will be used. Alternatively, the "Common" section has an option to "Remeasure OC per Action" which will re-measure and re-set the OC before each and every action.

Linear Scan Voltammetry:

A single voltage ramp programmed from an initial potential to a final potential that progresses at a defined scan rate. Differs from Staircase LSV in that the step size is minimized automatically to as small a value as possible depending on the scan range and scan rate entered so as to approximate an analog ramp. To keep the step size to an "analog-like" level, the maximum scan rate is limited to 10V/s. To control the number of points acquired using this approach, the data acquisition is separated from any particular point, and spread out over the entire scan range to a maximum of 1000 points per scan.

Cyclic Voltammetry (Single):

A two stage voltage ramp programmed from an initial potential to a vertex potential, and from the vertex to a final potential at a defined scan rate. Technique also referred to as CV. Differs from Staircase CV in that the step size is minimized automatically to as small a value as possible depending on the scan range and scan rate entered so as to approximate an analog ramp. To keep the step size to an "analog-like" level, the maximum scan rate is limited to 10V/s. To control the number of points acquired using this approach, the data acquisition is separated from any particular point, and spread out over the entire scan range to a maximum of 2000 points per scan.

Cyclic Voltammetry (Multiple Cycles):

A two stage voltage ramp programmed from an initial potential to a vertex potential, and from the vertex to a second vertex potential at a defined scan rate. The scan can be repeated many times (cycles) between the two vertex potentials. Technique also referred to as Multi-CV. Differs from Staircase Multi-CV in that the step size is minimized to as small a value as possible depending on the scan range and scan rate entered so as to approximate an analog ramp. To keep the step size to an "analog-like" level, the maximum scan rate is limited to 10V/s. To control the number of points acquired using this approach, the data acquisition is separated from any particular point, and spread out over the entire scan range to a maximum of 2000 points per cycle.

Note: The preceding three actions (LSV, CV and Multi-CV) approximate an analog ramp, so the data acquisition is asynchronous with the digital (DAC) changes in the applied waveform. In order to remove any instrument artifacts as a result of a point acquired in the middle of such a change, these points are flagged and removed prior to data transfer. As the scan rate increases, more points will be acquired during a change, thus more points will be rejected and removed. Therefore, the faster the scan rate, the fewer number of data points (below the 2000/cycle it normally records) that will actually be acquired during a scan.

Staircase Linear Scan Voltammetry:

A single voltage scan programmed from an initial potential to a final potential that progresses at a defined step height per step time (which defines the scan rate). Used over regular LSV for faster scan rates.

Staircase Cyclic Voltammetry (Single):

A two step voltage scan programmed from an initial potential to a vertex potential, and from the vertex to a final potential (usually the initial potential) at a defined step height per step time (which defines the scan rate). Used over regular CV for faster scan rates.

Staircase Cyclic Voltammetry (Multiple Cycles):

A two step voltage scan programmed from an initial potential to a vertex potential, and from the vertex to a second vertex potential (usually the initial potential) at a defined step height per step time (which defines the scan rate). The scan can be repeated many times (cycles) between the two vertex potentials. Used over regular Multi-CV for faster scan rates.

Chronoamperometry :

A fast-rising potential pulse is enforced on the working-sense electrode of an electrochemical cell; the current flowing through this electrode is measured as a function of time. Technique also referred to as CA. **Note: For a Two-Step Chronoamperometry experiment, either insert two CA actions into the same sequence (each set at the desired potential step, and with the cell remaining ON at the end of the first step) or preferably, run a two step Fast Potential Pulse action if that action is available.**

Chronopotentiometry :

A fast-rising current pulse is enforced on the working-sense electrode of an electrochemical cell and the potential of this electrode is measured against a reference electrode as a function of time. Technique also referred to as CE. Note: For a Two-Step Chronopotentiometry experiment, insert two CE actions into the same sequence, each set at the desired current step, and with the cell remaining ON at the end of the first step.

Chronocoulometry :

A fast-rising potential pulse is enforced on the working-sense electrode of an electrochemical cell; the current flowing through this electrode is measured and integrated, reporting coulombs as a function of time. Technique also referred to as CC. For bulk electrolysis measurements, a Pre-Electrolysis parameter is provided to electrolyze and subtract out solvent background currents, with the sample of interest added after the Pre-Elect (s) stage to measure the total charge associated with the sample, minus the background current contributions.

Recurrent Potential Pulses

A multi-step chronoamperometry experiment that allows the user to set the number of steps (pulses) for the experiment. Also known as “Potential Cycling.”

Recurrent Galvanic Pulses

A multi-step chronopotentiometry experiment that allows the user to set the number of steps (pulses) for the experiment. Also known as “Galvanic Cycling.” **Note: The current range must be set to the same range for all steps to avoid overloads.**

Fast Potential Pulses

A 2-5 potential step experiment that is used for fast pulsing applications, such as pulsing electrodeposition.

Note: For Fast Potential Pulses, the data acquisition rate can be slower than the applied waveform. For instance, pulses may be set to ms widths, but data acquisition rate set in the range of seconds (thus, not collecting all of the data). This is advantageous when applying pulses for long durations which might acquire more data (potentially millions of points) than the system can process.

Fast Galvanic Pulses

A 2-5 current step experiment that is used for fast pulsing applications, such as pulsing electrodeposition.

Note: For Fast Galvanic Pulses, the data acquisition rate can be slower than the applied waveform. For instance, pulses may be set to ms widths, but data acquisition rate set in the range of seconds (thus, not collecting all of the data). This is advantageous when applying pulses for long durations which might acquire more data (potentially millions of points) than the system can process.

Squarewave Voltammetry

The potentiostat applies a series of forward and reverse pulses (both equal in duration, and defined as a frequency) superimposed on a linear staircase scan. The resulting currents of the forward and reverse pulses can be subtracted from one another to plot the difference current, useful for improving the sensitivity of analytical measurements. Technique also referred to as SWV.

Differential Pulse Voltammetry

The potentiostat applies a series of forward and reverse pulses (defined as a forward pulse and a reverse step) superimposed on a linear staircase scan. The resulting currents of the forward and reverse pulses can be subtracted from one another to plot the difference current, useful for improving the sensitivity of analytical measurements. Technique also referred to as DPV.

Normal Pulse Voltammetry

The potentiostat applies a series of potential pulses from a constant baseline equal to the initial potential, each pulse increasing by a defined increment (step height) to a final potential. The resulting currents of the forward and reverse pulses can be subtracted from one another to plot the difference current, useful for improving the sensitivity of analytical measurements. Technique also referred to as NPV.

Reverse Normal Pulse Voltammetry

The potentiostat applies a series of potential pulses from a constant baseline equal to the initial potential, each pulse increasing by a defined increment (step height) to a final potential. The resulting currents of the forward and reverse pulses can be subtracted from one another to plot the difference current, useful for improving the sensitivity of analytical measurements. Differs from NPV in that what is considered pulses and steps are reversed, such that the “pulse” is considered to be the step towards the baseline (initial potential). Technique also referred to as RNPV.

Corrosion

Open Circuit:

Technique which does not apply any voltage or current (cell off), and simply measures the voltage difference between the working-sense and reference electrodes. The data is acquired for either a set period of time, or a minimum drift rate. **The current readings that are shown are the resolution limits for the current range on which the data was collected; these current magnitudes are artifacts, and should not be considered actual currents for the oc actions.**

Note: If the Open Circuit action is used in a sequence and followed by actions that apply voltages "vs OC" then the "Measure Open Circuit" action should immediately follow the "Open Circuit" action to re-set the open circuit voltage to its latest reading. Otherwise, the original oc (taken just prior to beginning the sequence) will be used. Alternatively, the "Common" section has an option to "Remeasure OC per Action" which will re-measure and re-set the OC before each and every action.

Linear Polarization:

Corrosion technique that uses a single voltage scan or ramp programmed from an initial potential to a final potential (range generally limited to +/- 20mV vs. open circuit at Ecorr) that progresses at a defined step height per step time. Technique also referred to as LP. Provides capability to calculate corrosion rate.

Tafel:

Corrosion technique that uses a single voltage scan or ramp programmed from an initial potential to a final potential (range generally limited to +/- 250 mV vs. open circuit at Ecorr) that progresses at a defined step height per step time. Provides capability to calculate Tafel constants and corrosion rates.

Potentiodynamic:

Corrosion technique that uses a single voltage scan or ramp programmed from an initial potential to a final potential (range generally limited to +1.50V vs. open circuit at Ecorr) that progresses at a defined step height per step time. Provides a qualitative picture or "fingerprint" of a material, particularly as it relates to the tendency of the material to passivate.

Cyclic Polarization:

Corrosion technique utilizing a two step voltage scan or ramp programmed from an initial potential to a vertex potential, and from the vertex to a final potential, at a defined step height per step time. The vertex potential may also be defined by a specific current (Threshold Current) that limits the forward scan to the potential at which that current is reached. Technique also referred to as a CP or a "pitting scan," as it is used to determine the tendency of a material to undergo surface pitting or crevice corrosion.

Potentiostatic:

Corrosion technique that applies a constant potential on the working electrode of an electrochemical cell, with the current flowing through the electrode measured as a function of time. Provides the capability to change the potential during the experiment for critical pitting potential (CPP) experiments.

Galvanic Corrosion:

Corrosion technique which does not apply any voltage or current (cell off), and simply measures the free flowing current between two dissimilar, as well as the voltage difference between the working-sense and reference electrodes (the coupled potential). Requires special cable connections with the WE-SE leads connected to one specimen, and the Ground lead connected to the other. The CE lead is not used, and the reference lead is connected as usual to the reference electrode. Technique also referred to as GC.

Galvanostatic :

Corrosion technique that applies a constant current through the working electrode of an electrochemical cell, with the potential of the working-sense electrode measured as a function of time relative to the reference electrode. Technique is often used to break down a passive film with a constant current., or to determine a film thickness by stripping the film at a constant rate.

Galvanodynamic:

Corrosion technique that uses a single current scan or ramp programmed from an initial current to a final current, plotting the resulting potential vs. time. A typical use of this technique is to determine the relative susceptibility to localized corrosion as outlined in ASTM G100-89.

Zero Resistance Ammeter (ZRA):

Technique which does not apply any voltage or current (cell off), and simply measures the free flowing current between an anode and cathode, as well as the voltage difference between the working-sense and reference electrodes. Requires special cable connections with the WE-SE leads connected to the anode, and the Ground lead connected to the cathode. The CE lead is not used, and the reference lead is connected as usual to the reference electrode. If no standard reference is being used as with a two terminal connection, the RE lead would be connected to the ground, however this direct short of the RE and ground can cause some low level noise.

Note: In the ZRA connections, the current will flow as soon as the leads are connected (no cell off/on control available), so the experiment should be setup and ready to start to collect the data immediately after connecting the leads to the cell in a ZRA configuration.

Electrochemical Noise :

Corrosion technique that collects open circuit potential ZRA current data (see ZRA action for lead connections) in discrete segments of a definable duration. Special graph options are available to graph root mean square (RMS) of current and/or voltage of each segment.

Split LPR:

Corrosion technique where the cathodic scan is collected first, starting at open circuit voltage and scanning to a selectable cathodic maximum voltage. Following the cathodic scan, the system rests for either a set duration or until a minimum drift rate is achieved. Following the rest period, the anodic scan starts at the open circuit voltage and scan to a selectable anoidic maximum to complete the scan. The Split LPR is used when it is undesirable to take a large step from open circuit to a cathodic starting voltage several mVs from OCV.

Galvanic Control LPR:

The Galvanic Control LPR is used in place of potential control LPR when there is a risk for loss of potential control due to cell conditions that are conducive to a poorly functioning reference electrode. Where loss of potential control due to reference electrode failure could lead to full compliance potential overloads (stopping experiment, and damaging sample), a failure of the RE in GC LPR would merely result in obviously bad data points, allowing for the sample to be re-scanned.

Energy

Energy Open Circuit:

Technique which does not apply any voltage or current (cell off), and simply measures the voltage difference between the working-sense and reference electrodes. The data is acquired for either a set period of time, or a minimum drift rate. **The current readings that are shown are the resolution limits for the current range on which the data was collected; these current magnitudes are artifacts, and should not be considered actual currents for the oc actions.**

Note: If the Open Circuit action is used in a sequence and followed by actions that apply voltages "vs OC" then the "Measure Open Circuit" action should immediately follow the "Open Circuit" action to re-set the open circuit voltage to its latest reading. Otherwise, the original oc (taken just prior to beginning the sequence) will be used. Alternatively, the "Common" section has an option to "Remeasure OC per Action" which will re-measure and re-set the OC before each and every action.

Multi-Vertex Scan:

A voltage scan programmed from an initial potential to a final potential that progresses at a defined step height per step time (which defines the scan rate). Up to two additional vertices can be defined as well within the initial and final voltages.

Constant Potential:

Technique that applies a constant potential between the working/sense and reference leads of an electrochemical cell, with the current flowing measured as a function of time. Current is measured per defined time per point, or faster if Delta I (change in current) or Delta Q (change in capacity) is utilized. Generally used to trickle charge a battery to a defined current or capacity limit.

Constant Current:

Technique that applies a constant current between the working and counter leads of an electrochemical cell, with the voltage flowing measured as a function of time. Voltage is measured per defined time per point, or faster if Delta E (change in voltage) or Delta Q (change in capacity) is utilized. Generally used to charge and/or discharge battery to a defined voltage or capacity limit.

Constant Power:

Galvanodynamic technique that maintains a constant power level by monitoring the voltage and varying the current to maintain the requested power so long as the set current limit is not exceeded. Power and voltage are measured per defined time per point, or faster if Delta E (change in voltage) or Delta Q (change in capacity) is utilized. Generally used to discharge a battery to a defined voltage or capacity limit.

Constant Resistance:

Galvanodynamic technique that maintains a constant resistance level by monitoring the voltage and varying the current to maintain the requested resistance provided the needed current does not exceed that of the set current range. Resistance and voltage are measured per defined time per point, or faster if Delta E (change in voltage) or Delta Q (change in capacity) is utilized. Generally used to discharge a battery to a defined voltage or capacity limit.

Current CCDPL (Cyclic Charge-Discharge with Potential Limitation):

A sequence of Open Circuit, Constant Current, and Constant Potential actions within a loop (to define the number of desired cycles) to create a cyclic charge-discharge sequence with potential limitation. The constant current actions are generally set to charge or discharge to desired potential limits, then the constant potential is applied to this limit until a lower current limit is reached with rest periods (open circuit) in between charge-discharge events for set time or until potential limit is reached. Additional actions can be added or removed to this sequence as desired. The Current CCDPL action is intended to automatically build a common sequence used in battery research from existing actions.

Power CCD (Cyclic Charge-Discharge):

A sequence of Open Circuit, Constant Power, and Constant Current actions within a loop (to define the number of desired cycles) to create a cyclic charge-discharge sequence with discharge by constant power. The constant current actions are generally set to charge to desired potential limits, then the constant power is applied to discharge the battery to potential limit with rest periods (open circuit) in between charge-discharge events for set time or until potential limit is reached. Additional actions can be added or removed to this sequence as desired. The Power CCD action is intended to automatically build a common sequence used in battery research from existing actions.

Resistance CCD (Cyclic Charge-Discharge):

A sequence of Open Circuit, Constant Resistance, and Constant Current actions within a loop (to define the number of desired cycles) to create a cyclic charge-discharge sequence with discharge by constant resistance. The constant current actions are generally set to charge to desired potential limits, then the constant resistance is applied to discharge the battery to potential limit with rest periods (open circuit) in between charge-discharge events for set time or until potential limit is reached. Additional actions can be added or removed to this sequence as desired. The Resistance CCD action is intended to automatically build a common sequence used in battery research from existing actions.

Impedance

Open Circuit:

Technique which does not apply any voltage or current (cell off), and simply measures the voltage difference between the working-sense and reference electrodes. The data is acquired for either a set period of time, or a minimum drift rate. **The current readings that are shown are the resolution limits for the current range on which the data was collected; these current magnitudes are artifacts, and should not be considered actual currents for the oc actions.**

Note: If the Open Circuit action is used in a sequence and followed by actions that apply voltages "vs OC" then the "Measure Open Circuit" action should immediately follow the "Open Circuit" action to re-set the open circuit voltage to its latest reading. Otherwise, the original oc (taken just prior to beginning the sequence) will be used.

Potentiostatic EIS :

Electrochemical impedance spectroscopy (EIS) measures impedance (Z) by applying a sinusoidal (ac) voltage across a cell and measuring the resulting ac current along with phase shifts between the ac voltage and ac current. In this technique, a sequence of impedance measurements is carried out starting at an initial frequency and stopping at a final frequency.

Within this action, one can also perform EIS at a single frequency over several points by setting the initial and final frequency to the same value, and setting point spacing to linear and the desired number of points. To control the time/pt in this scenario, the use of Measurement Delay can be used to control the time in between points as precisely as possible given the algorithms used.

The DC potential within the EIS action can be applied as a step for a constant voltage relative to open circuit or reference, or the DC voltage can be applied as a ramp up to the final voltage which is then held constant for the entire EIS experiment. **NOTE: The "Scan" properties within the Potentiostatic EIS DC Properties are not a Mott-Schottky potential/EIS scan! The "scan" allows for the constant DC potential (final potential) to be set in a slower, ramp method with capacitive cells such as super capacitors that would overload if a voltage step were applied far from the open circuit voltage.**

Galvanostatic EIS:

Electrochemical impedance spectroscopy (EIS) measures impedance (Z) by applying a sinusoidal (ac) current across a cell and measuring the resulting ac potential along with phase shifts between the ac voltage and ac current. In this technique, a sequence of impedance measurements is carried out starting at an initial frequency and stopping at a final frequency.

Pre Experiment Actions

Condition:

Conditioning of the electrode (or sample) takes place with the cell on but before the start of the experiment (that is, before the Technique Action and data acquisition), by selecting either static (constant) or pulsing voltage (frequency up to 10Hz) and entering the appropriate conditioning voltage and duration.

Deposition:

Deposition, or preconcentration, is useful in stripping techniques to take advantage of the fact that some electroactive species precipitate after a redox process. The most common use is for lower detection limits of metal ions when determinations are performed with a mercury drop electrode. Deposition takes place before the experiment (Technique Action), with the cell on, purge off, and the stirrer activated (purge and stir functions at the Auxiliary Interface). A time setting controls how long a deposition (or preconcentration) potential is applied to the cell before proceeding to the Technique Action.

Equilibration:

Equilibration is used to set the working electrode at the same potential as the initial potential of the following Technique Action for a defined period of time to allow for an equilibration period prior to scanning. This is generally done after a deposition where a stirrer is used, or when the initial potential is different from open circuit, requiring a settling period.

Purge:

Sends a signal from the Auxiliary Interface of the potentiostat/galvanostat activate the purge solenoid on a 303A (via a Model 507 interface) or a Model 325 Faraday Cage for the specified period of time then turns the solenoid off.

iR Determination:

Uses a pulsing signal to determine the uncompensated resistance in an electrochemical cell, and uses this resistance value in the iR Compensation process for an experimental setup. Note: this action can operate stand-alone, or as an action in a sequence preceding a potential controlled Voltammetry action where the iR Compensation is enabled, and “Use Previous” is set to “Yes.”

Sequence Actions

Loop:

A function that allows a specific action or sequence of actions to be repeated a set number of iterations(cycles) or for a set period of time, whichever is reached first. The Loop action should be installed into a sequence prior to the actions that are to be repeated.

Note: If any actions that apply voltages "vs OC" are inside the loop, then the "Measure Open Circuit" action should immediately precede those actions to re-set the open circuit voltage to its latest reading. Otherwise, the original OC reading (taken just prior to beginning the sequence) will be used.

Time Delay:

A period of time to delay procession to the next action.

Message Prompt:

Used to issue a user-defined message prior to starting the following action or experiment. The sequence will halt until the prompt is cleared by the user.

Measure Open Circuit:

Used in a sequence to obtain a measurement of open circuit potential, and subsequently used as a point of reference for applied voltages "vs oc" or "vs Previous" within those actions immediately following.

Auxiliary Interface :

Provides direct control over the Auxiliary Interface at the rear panel of the VersaSTAT. See the VersaSTAT hardware manual for more details on the pin outs for the Auxiliary Interface.

Run External Application :

Provides capability to run an external, user written utility. For example, if the user writes a small program in Visual basic to set the temperature on a temperature controller, this action could be used to change the temperature between experiments. The program name (File Path), command line options (Parameters), and wait state may be entered for this action.

DAC Output Control:

Provides direct control over the voltage output (+/- 10V static) at the rear panel of the VersaSTAT. Normally used to control RDE rotation speed, this control can be added within a sequence to perform hydrmodulation experiments (adjusting speed of RDE between scans), or to control the a separate external device, such as a temperature bath with an external input for control.

Email:

Provides ability to send an email to notify users of completed experiments. Can also attach data file if desired. Assistance from local IT personnel may be required in determining local SMTP Server.

Auto Current Range Setup:

Provides ability to set the limits and starting point for automatic current ranging in DC (non-impedance) actions. This action is inserted prior to the action(s) where the desire is to control and limit how auto-current ranging proceeds. This action is very useful for energy-based applications (for example, fuel cell, battery, and super capacitor research) where it is suggested and **strongly recommended** to start auto-current ranging beginning at the 2A range, because these devices can produce large amounts of current that can damage more sensitive ranges if starting off on lower ranges. This action is also very useful for applications where noise may be an issue at the lower ranges, so preventing the system from "bouncing" between two lower ranges, one can set a lower limit to prevent the bouncing caused by noise (usually environmental noise).

Display Message:

An action specifically for the PARSTAT 4000 that allows for the insertion of a specific message inserted into one of the four lines available on the PARSTAT 4000's front panel display. This action can be inserted at multiple points throughout a sequence and the message changed at each point. To use this action, see section 4.4.2.2 on setting up the LCD display of the PARSTAT 4000.

Get Action(s) From File…

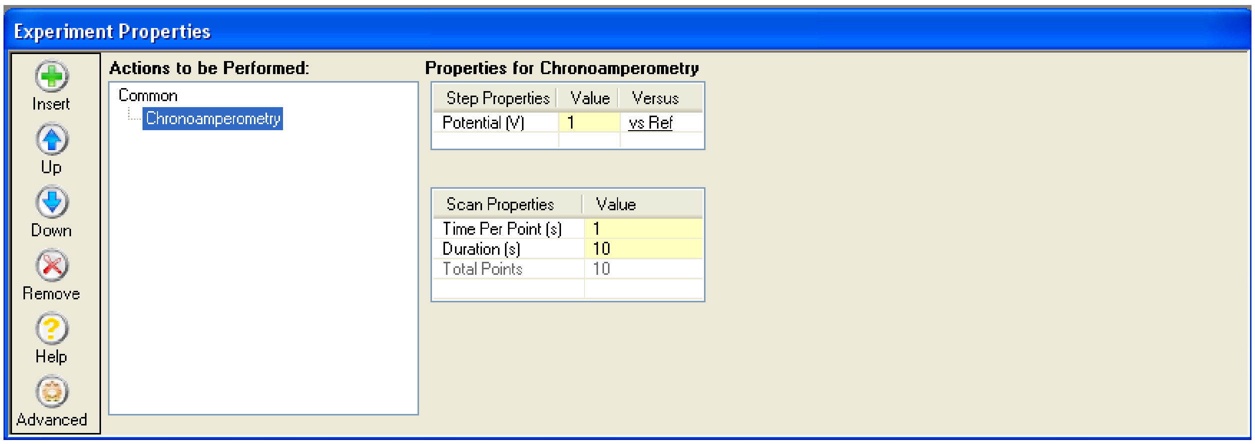
Allows a previously saved sequence (data file) to be added to a new sequence under construction. This utility is intended to save time in constructing new sequences by building from previously created sequences.

NOTE: It is not the intent of this manual to explain in detail the theory and uses of listed techniques, nor is this manual intended to be a tutorial for electrochemistry in general. For this information it is recommended that a review of the application notes on our website be performed. If further information is needed, please contact (email) our support department at pari.info@ametek.com.

4.1.1.1.2. Experiment Properties

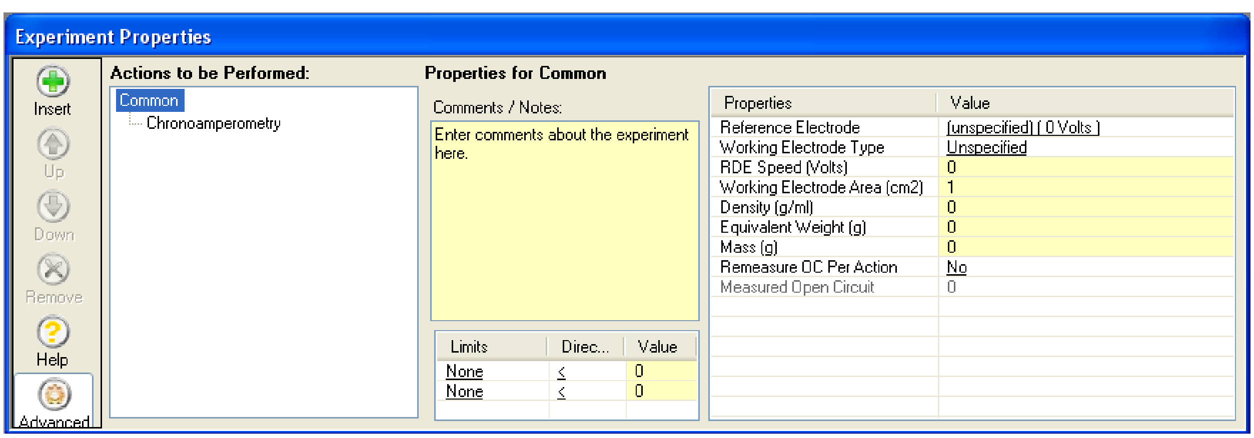
Select a technique action (Chronoamperometry, for example), and select **OK**. Enter a filename to which data collected will be saved and select **OK**. Set up parameters for that Technique Action will be displayed in the **Experiment Properties** window:

For the Experiment Properties window and the variables that may be changed, a box highlighted light yellow indicates a box where a value or text may be entered, and a box where the variable is underlined indicates the presence of a drop-down selection box for changing the variable to a pre-set selection. If a box is grayed-out, then that variable is read-only and cannot be changed.



NOTE: Please see Appendix 1 for definitions and descriptions of the parameters and variables that can be found in all actions available in VersaStudio.

The **Experiment Properties** box has a **Common** action for every single-action or multi-action experiment built. By clicking on either **Common** or **Chronoamperometry** each in turn, its properties are displayed.

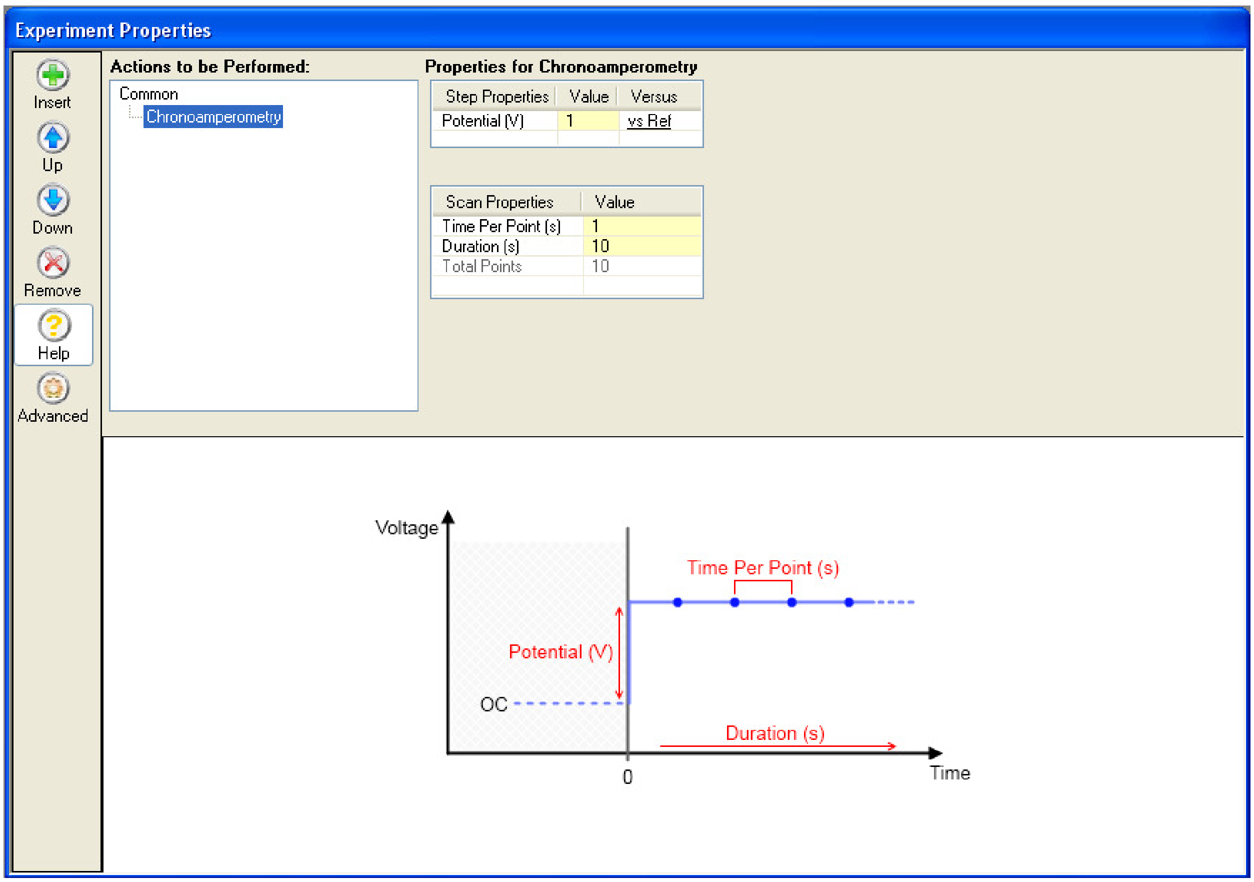


The **Common** is the section in which to add comments for the experiment, as well as set voltage and current **Limits** for the entire experiment. When these limits (also referred to as "**safety limits**") you have chosen for **Common** are exceeded, the entire experiment, whether a single action or a multi-action experiment, is halted. Also selectable in Common is the **Reference Electrode** type, **Working Electrode Type**, rotating disk electrode (**RDE Speed**), and **Working**

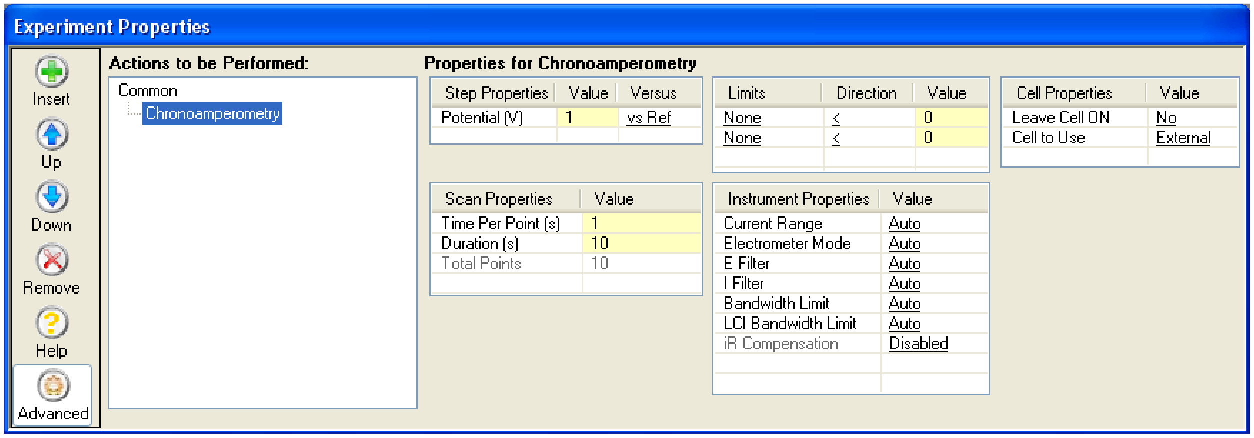
Electrode Area. **Density** and **Equivalent Weight** are used for corrosion rate calculations, while **Mass** is used to graph certain variables per gram of active material. The **Remeasure OC Per Action** is used for sequences where it is desired to measure the open circuit voltage before each and every action (as in battery research) when most potentials are set per open circuit.

Note: Making changes to the RE, WE, area, density, EW, and Mass parameters in the Common section post-acquisition requires that the data be saved, closed, and re-opened for the changes to take effect in graphing and/or data fits.

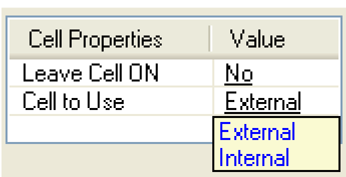
The "**Help**" selection on the Experiment Properties is for explaining the functionality of each of the action listed in the "**Actions to be Performed:**" window. Selecting an action (such as Chronoamperometry below) and selecting "Help" reveals a window with detailed diagram and/or explanation of that action. De-selecting the "Help" will close this view.



Highlight Chronoamperometry again, and select the **Advanced** button to the left to reveal more properties.



Set the **Cell to Use** by clicking the underlined variable (External in this case). Select **Internal** (internal 1000 ohm dummy cell) as the cell to use.



Click **Run** on the toolbar**.** A default graph and data box opens in addition to the **Properties** box.

Run opens a blank graph, starts the experiment, and plots the output in the graph and in the **Data View** window. **Stop** stops the experiment if you wish to stop it prematurely. The **Skip** button is useful when a multi-action sequence is running (section 4.4.1.2), and it is desired to proceed, or "skip," to the next segment (note: if it is a multi-action segment, it skip to the next segment in that action, not the next action in the sequence) or action in a sequence before the current action is completed.

Note: As of this software version, the "Skip" should not be used during an action where the Acquisition Mode = Average (or Auto) on Corrosion actions. Doing so will alter the data and segment association.

After the experiment is completed, the data graph, data view, and experiment properties will all be displayed on the screen.

4.1.1.2. Creating a Multiple-Action Experiment

There are two primary reasons for performing a multi-action experiment in a sequence:

1. Sequencing actions can increase throughput by automatically performing a series of experiments (selected by the user) over a long duration without requiring user intervention. Examples include long term charge/discharge experiments for batteries, or looping through an EIS experiment many times over a long duration to monitor impedance changes over time.
2. Sequencing actions facilitates the creation of customized waveforms and/or experiments without having to be proficient in a programming language or command set.

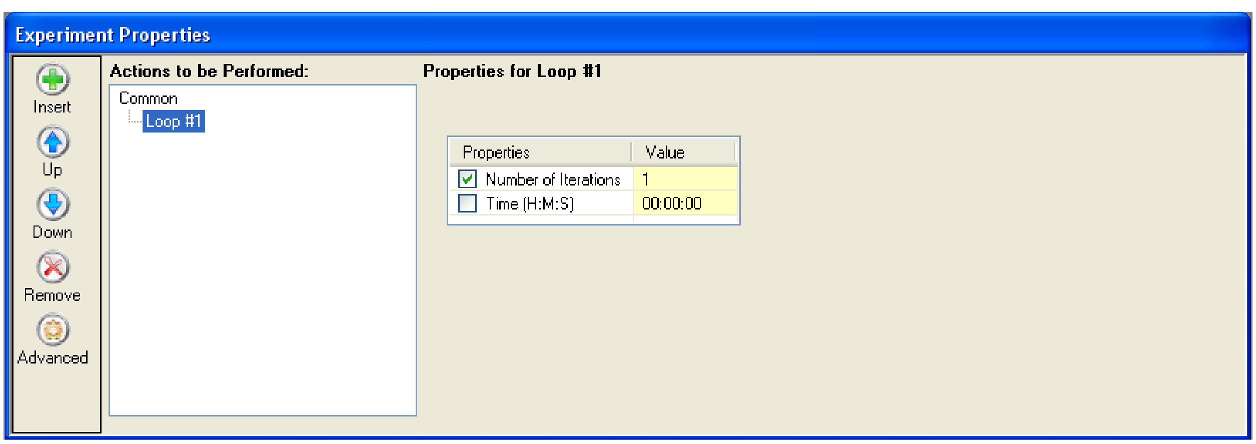
Each of these will be addressed in the following section.

4.1.1.2.1 Sequencing Actions

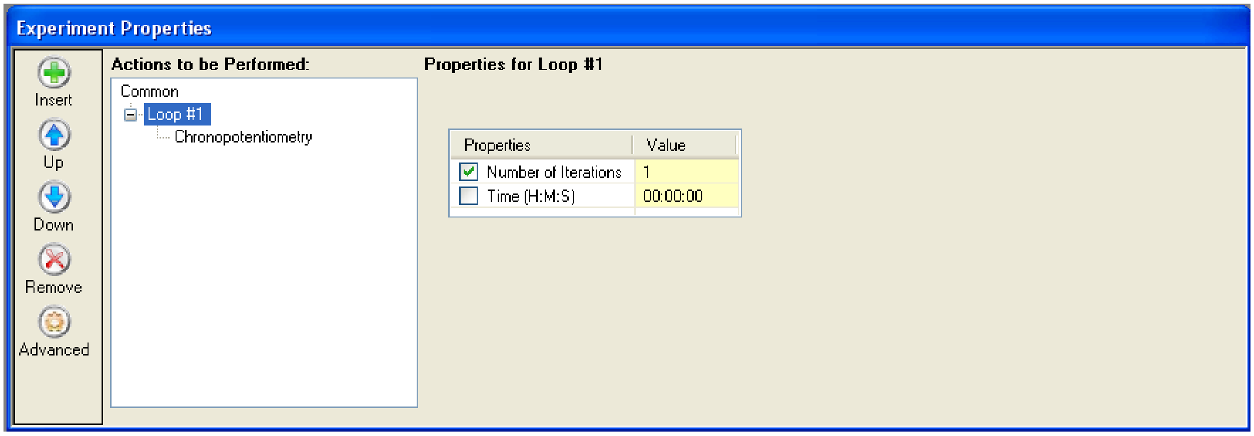
This section will describe how one might go about constructing a sequence of actions that would permit the discharge/charge cycling of a rechargeable battery, followed by impedance testing with discharge cycles, and a final charge cycle to complete the experiment.

NOTE: When running a multi-action experiment, the data output of the entire sequence of actions will be stored in a single data file, making it easy to build custom experiments with multi-action sequences and viewing the data as a single experiment. For multi-action sequences where viewing the entire sequence as a single experiment is not desired, a **Data Filter** (section 4.3.3.) feature is available to look at any specific action within the entire sequence. In the following example, it would be desirable to view all of the charge/discharge data as a single plot, but then it would also be desirable to view each of the EIS results as a stand-alone plot. With VersaStudio, both of these options are possible.

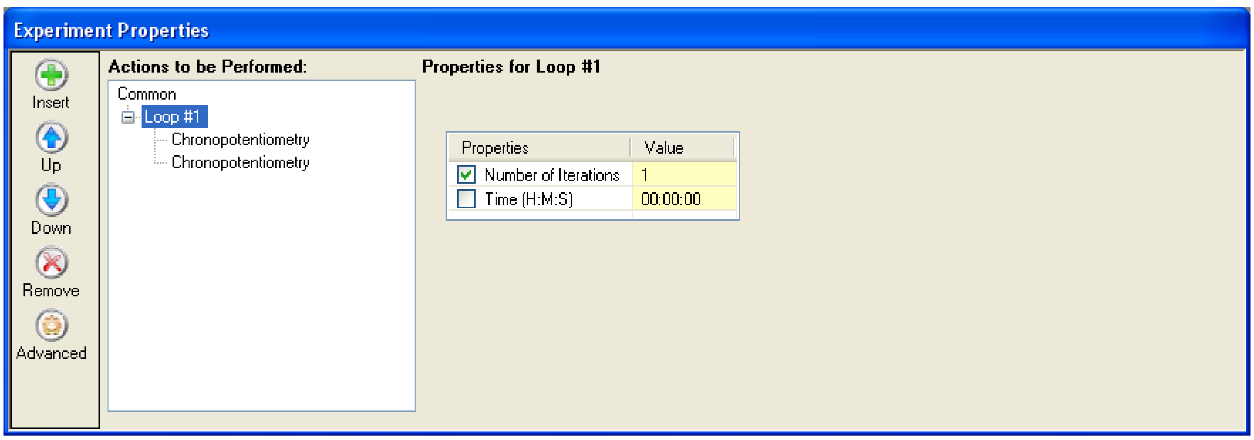
Start with **Experiment>New** as described in section 4.1.1. From the **Select an Action** window, choose **Loop** from the **Sequence Actions** category, and select **OK** to bring up the **Experiment Properties** window.



With the **Loop #1** highlighted, select the **Insert** button to the left of the Experiment Properties window to bring up the **Select an Action** window once more. This time, select the **Chronopotentiometry** action, and click **OK**.



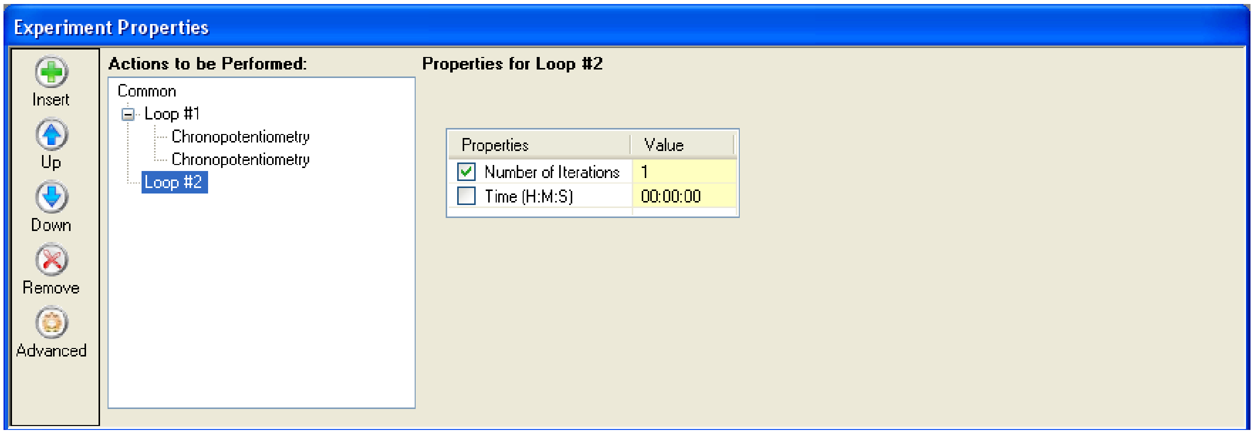
Repeat the previous steps to add a second Chronpotentiometry action to the sequence.



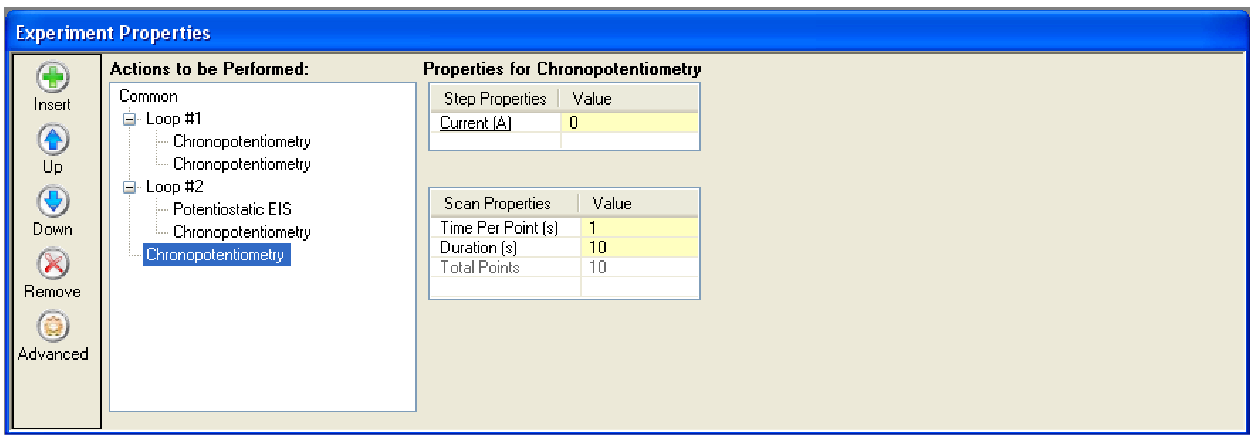
The two chronopotentiometry (galvanostatic) actions will be used to discharge and charge the battery.

NOTE: This first part of the sequence is an example of a multi-action sequence used to create a custom waveform, essentially a two step chronopotentiometry, or in battery terminology, a galvanic cycling waveform. The **Loop** will be set to the **Number of Iterations** to cycle the battery. Again, this feature is permissible due to all the data for each action (including all loops) being stored in a single data file.

To add the EIS and discharge sequences, highlight the word **Common** in the **Actions to be Performed** box, and select the **Insert** button again. From the action list, select **Loop** once again, then **OK**. This will add a second cycling sequence <u>separate</u> from the first.



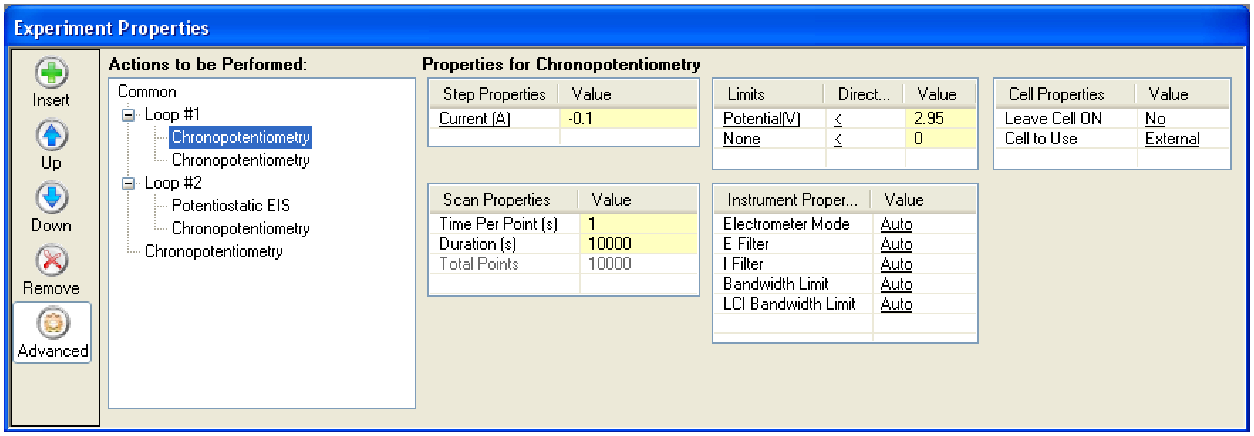
With the **Loop #2** highlighted, select the **Insert** button, and choose **Potentiostatic EIS** to add to the sequence. Repeat the **Insert** again for **Loop #2**, and add a third **Chronopotentiometry** action. Finally, select **Common** once again, and insert a fourth and final **Chronopotentiometry** action. The resulting sequence should appear as below.



NOTE: This entire sequence is an example of a multi-action sequence to perform a long duration experiment automatically with little to no user intervention required until entire sequence is completed.

Now that the sequence is built, one can highlight each action in the sequence, and set all the variables to the desired number of iterations (cycles), magnitudes, durations, and limits (see Appendix 1 for glossary of experiment properties). In the example below, the first Chronopotentiometry action is set to discharge the battery at -100mA for 10,000s, or when the voltage drops below the limit of 2.95V, whichever is reached first.

NOTE: The data acquired with a multi-action sequence (as well as multi-cycle experiments live multi-cyclic voltammetry) are saved as **segments**. There is a **segment limitation of 4000** for any given sequence and/or data file.



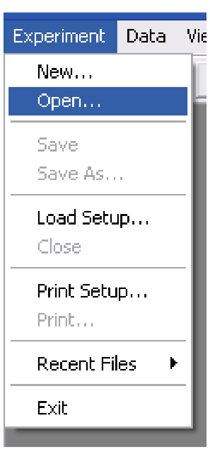
Once all the actions have been modified with the desired settings, go to **Experiment>Save** to save this sequence before running (which insures data saving to the PC hard drive as the experiment progresses), the click the **Run** button to start the sequence running. Depending on the number of iterations desired, this sequence could take hours or even days to complete. With the sequencing feature, it will all progress as desired without constant monitoring by the user.

4.1.1.3. Editing a Multiple-Action Experiment

Aside from inserting a new action, editing a multi-action sequence can be performed by:

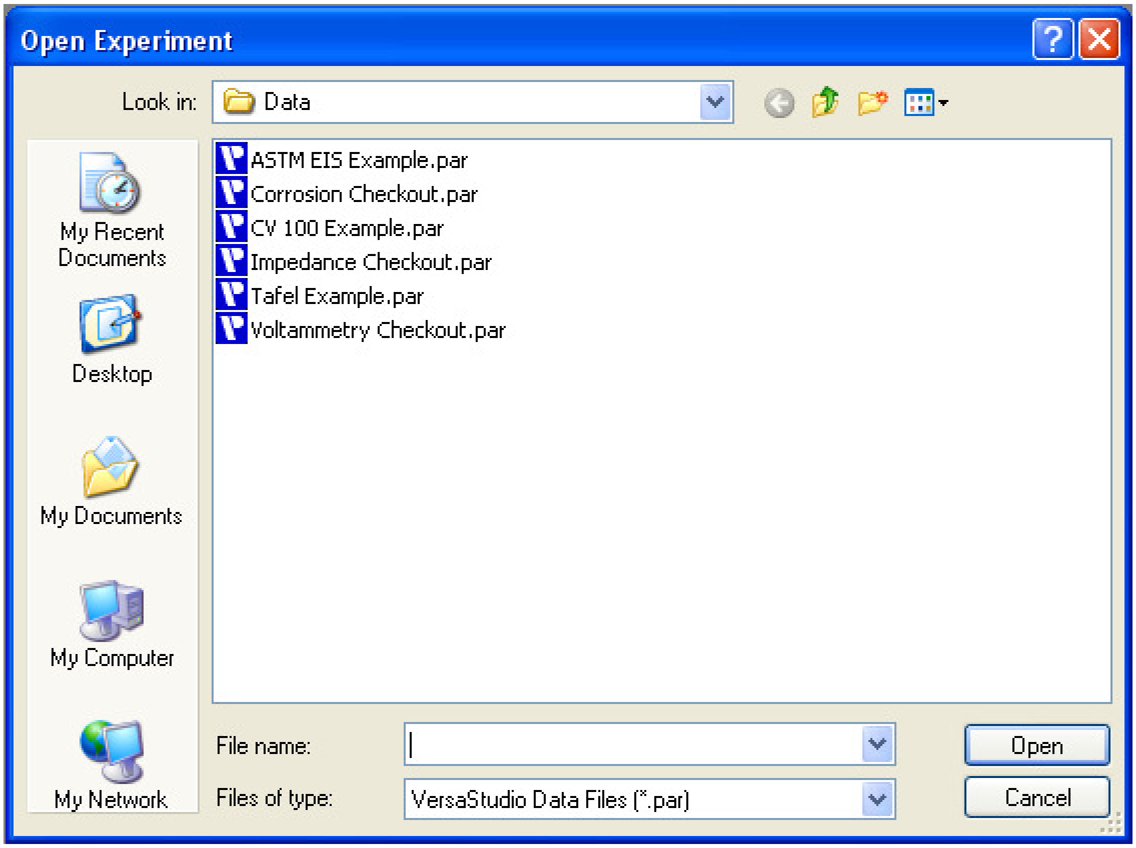
1. Selecting an action that is no longer needed, and clicking the "Remove" button.
2. Select an action in the sequence and move it within the tree to the appropriate location using the "Up" and "Down" buttons. **Note: Using the "Insert" function always places the actions to the bottom of the list. If an action is needed else where, it will be inserted at the bottom, then moved to the appropriate place within the sequence.**

4.1.2. Open



or

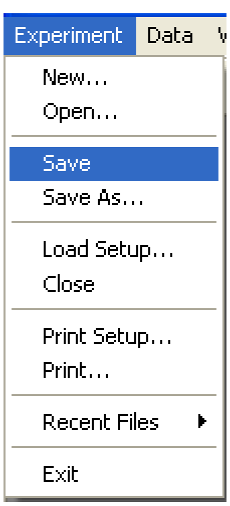
Open opens a previously saved experiment. Choose a file to open in a Windows file **Open** box.



When a valid file is selected, the **Open** box closes and the experiment will open. If another experiment were already open, it will ask to save any changes to that experiment before the **Open** box appears.

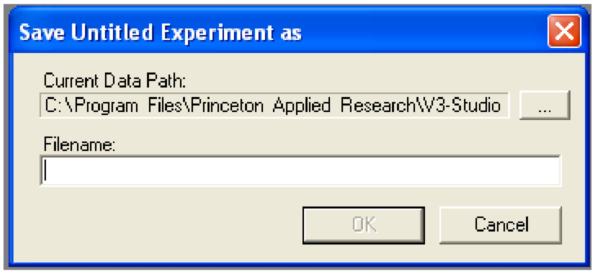
4.1.3. Save, Save As

To save data,…

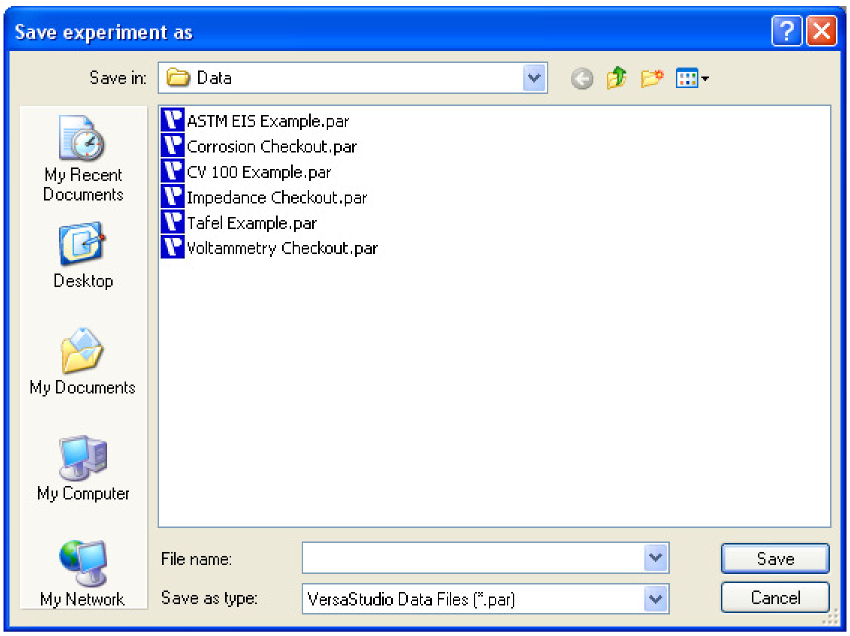


or

To save a new experiment, select **Save**, and enter the data path and name.

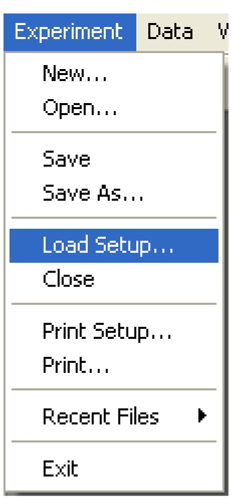


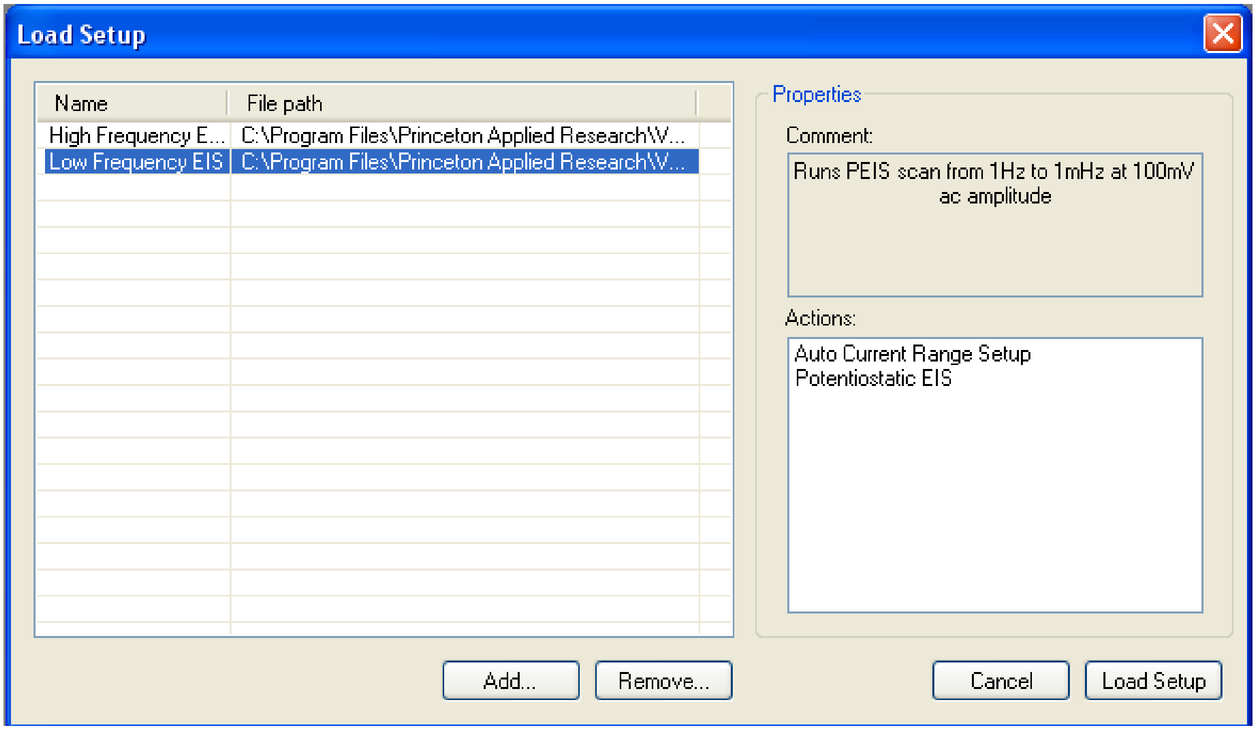
Save As saves the current file with a different name.



4.1.4. Load Setup

Load Setup takes you to the following window:

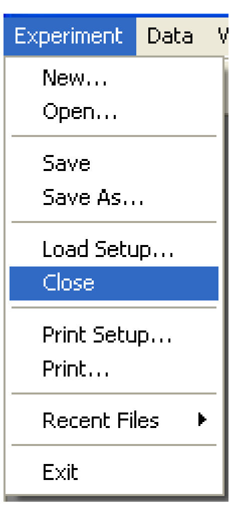




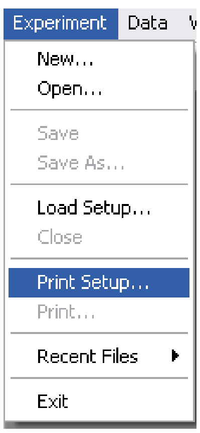
From this window, one can add previously acquired data files ("Add.." button) that are to be used as "setup templates" for subsequent experiments. When selecting from a list of files, the details of the actions within that setup, as well as comments, can be viewed to the right in the "Properties" as shown above. Selecting "Load Setup" button will ask for file name to be given to the new data set, then the Experiment Properties associated with the setup will appear ready to run the preset variables that make using a setup file easier and faster than starting from an all new experimental setup.

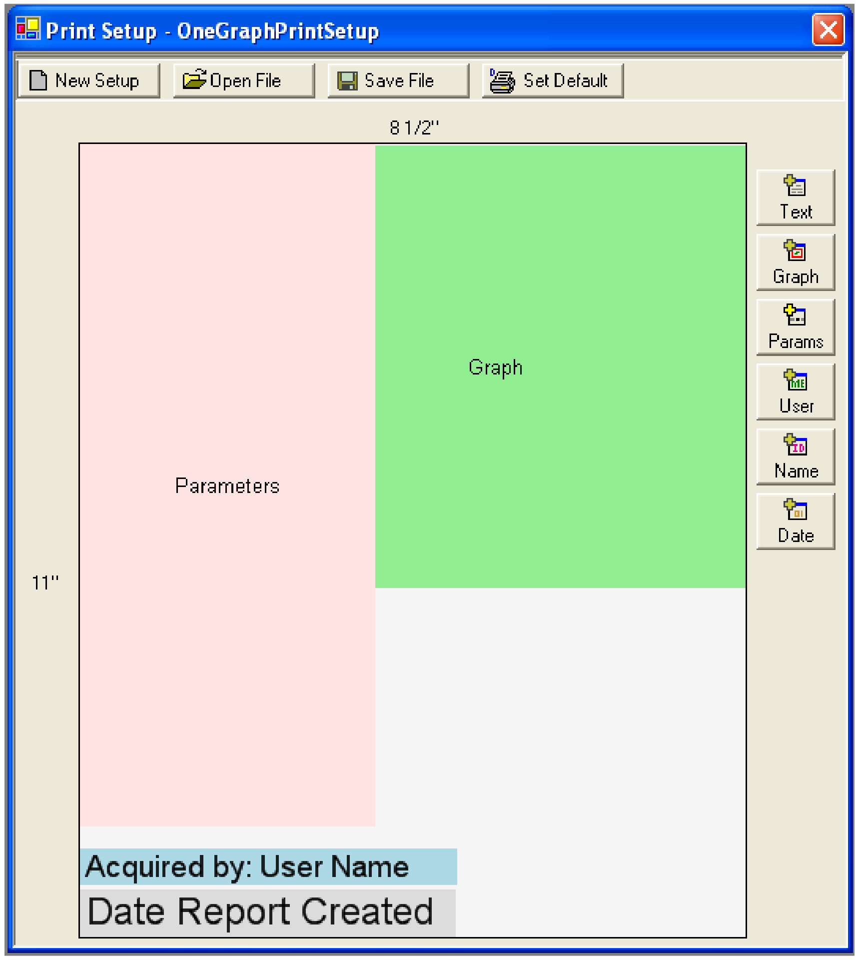
4.1.5. Close

Clicking on **Close** will close the experiment that is currently open on the screen.



4.1.6. Print Setup



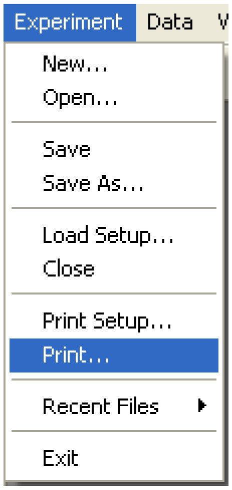


4.1.6.1. Custom Print Layout

Clicking on **Print Setup**… under **Experiment** opens the **Print Setup** box (the factory default "**OneGraphPrintSetup**" should be there initially), that lets the user create a custom layout in which one can place user **Text**, **Graph**, experiment parameters (**Params**), **User** name, experiment **Name**, or **Date**. Select **New** on the top row of buttons to clear the 8 ½" x 11" print area, and begin adding printable items from the right-side row of buttons. Once an item has been selected, it can be moved inside box (click and drag) to any location, and re-sized by clicking and dragging the lower right-hand corner of each item. Once the layout is constructed, it can be saved with **Save File** on the top row of buttons, and set as the new default layout to use with the **Set Default** button. To recall previously saved print layouts, use the **Open File** from the top row to select it from a listing.

4.1.7. Print

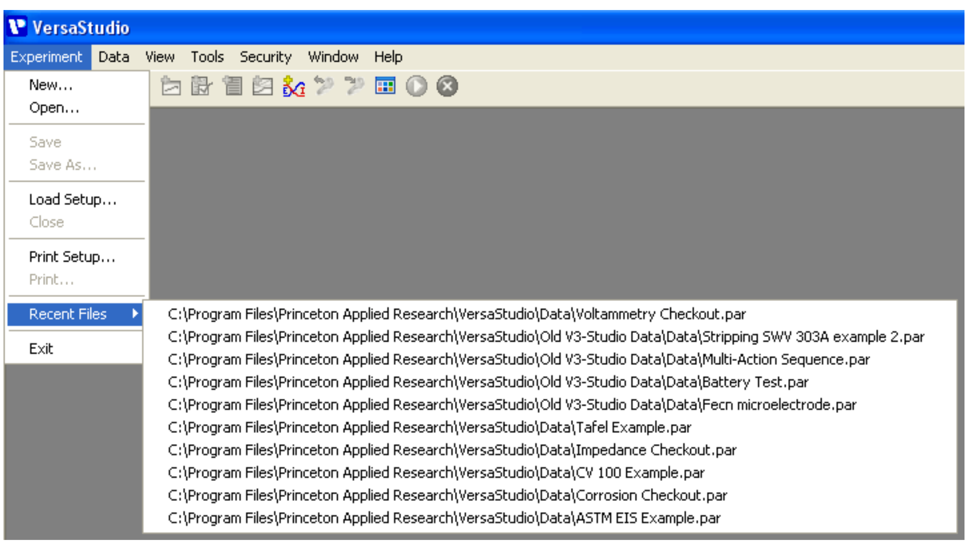
Print prints experiment results using a template already created and selected as default in **Print Setup**.



or

4.1.8. Recent Files

Recent Files displays the last ten files opened, and allows selection of any of the ten to re-open.

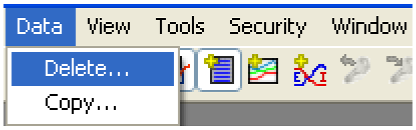


4.1.9. Exit

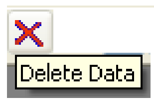
Exit closes the data set that is currently open on the screen..

4.2. Data

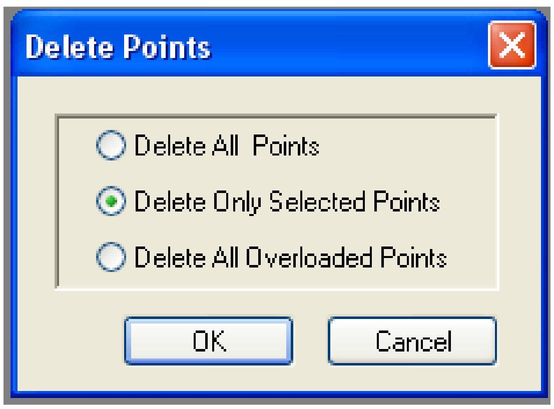
4.2.1. Delete



or



Delete permits the <u>permanent</u> deletion of data points.

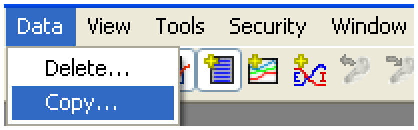


Delete All Points removes all data from the experiment, allowing for changes to the parameters or for running the same experiment again. A box asks you whether you really want to delete the data.

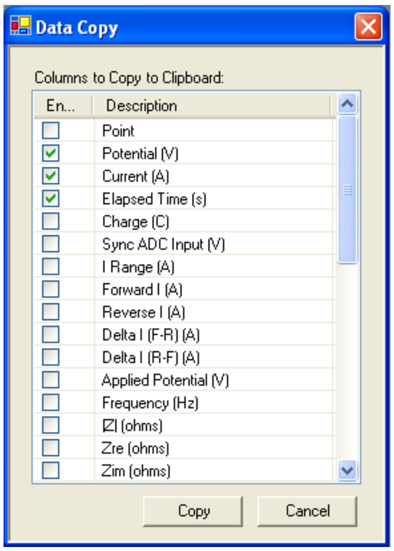
Delete Only Selected Points removes only the point(s) highlighted (selected) in the graph.

Delete All Overload Points removes all of those points where an overload (usually current overloads) during a measurement. Since an overload occurred, these points are considered invalid regarding their measured values, thus easy removal is supplied by this feature.

4.2.2. Copy

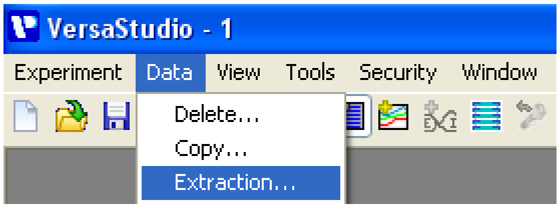


Copy allows the user to select the data parameters from a **Data Copy** window that are desired to be copied and pasted into another program (such as text file or spreadsheet).

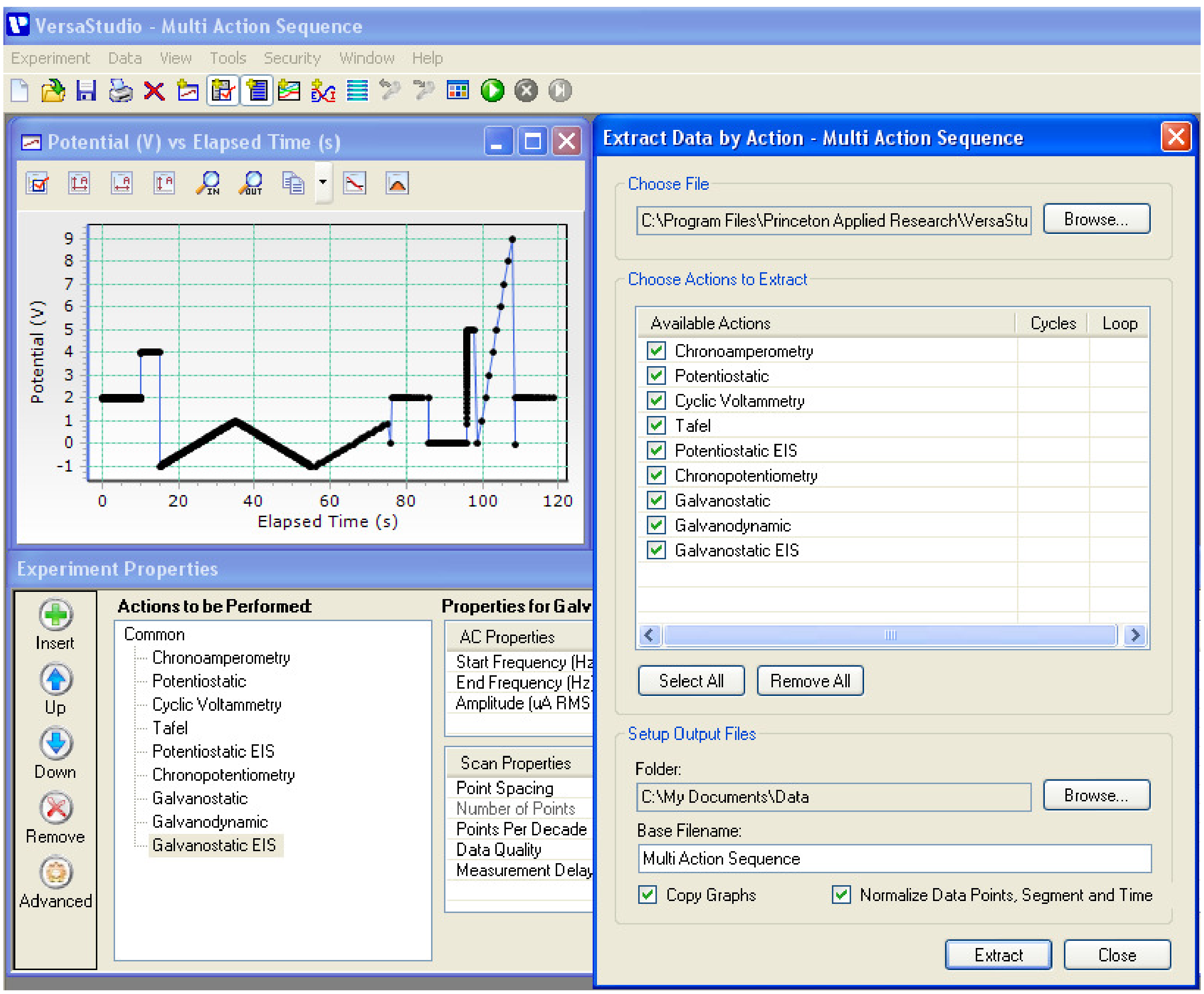


For example, select from the list of parameters those that are to be copied, and click **Copy** to send these columns of data to the Windows' Clipboard. The data (Tab delimited) can then be "pasted" into a separate spreadsheet with each column labeled as to the data variable below it.

4.2.3. Extraction…

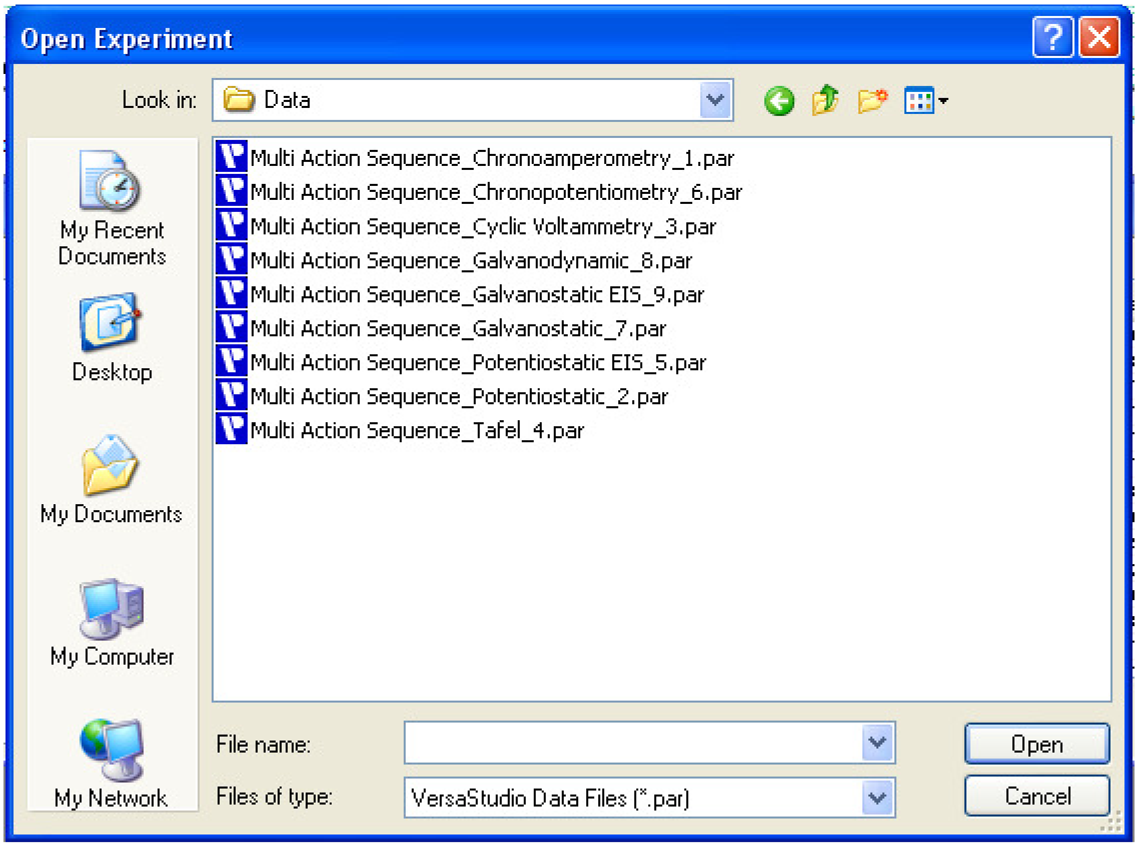


The **Extraction** feature allows experiments that were collected as sequences comprised of multiple actions to be broken up into individual data files, providing one action per data file.

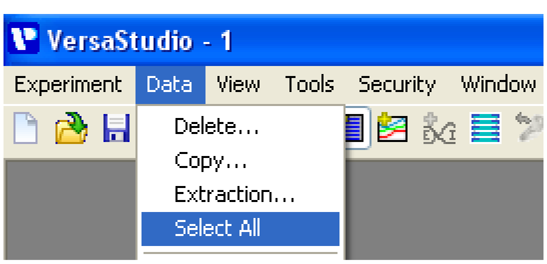


In the above example, a sequence was performed that comprised nine (9) different actions. The Extraction option window (shown to the right) provides the capability to select individual or all actions to extract, as well as cycles (for multi-cycle CVs) and loops. The resulting individual files formed can be saved to a folder defined by the user, as well as a unique base name. The "Normalize Data Points, Segment and Time" option sets each individual data files points, segment, and time beginning at zero as if were the only action performed.

The results from the extraction on the example data above are shown below. Mote that the base name is followed by the action name, as well as the order number where it appeared in the sequence.

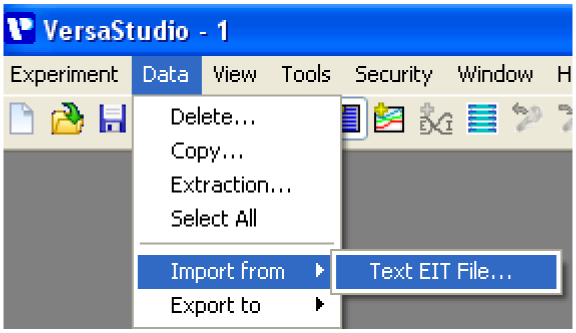


4.2.4. Select All

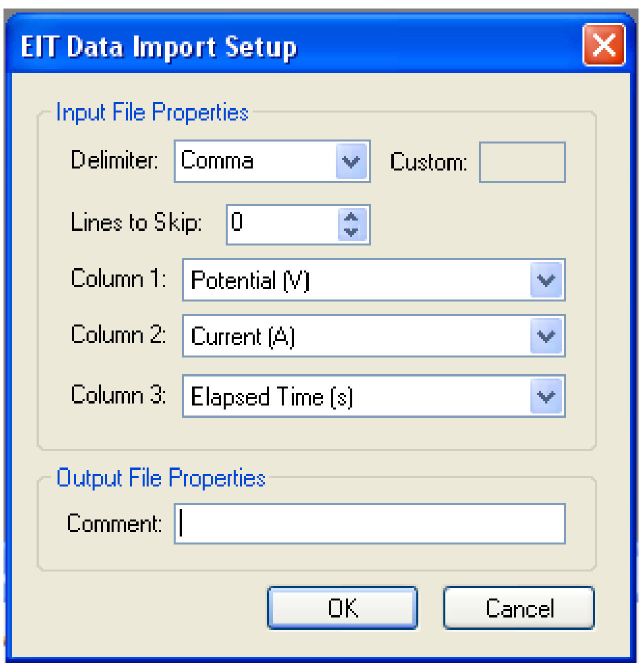


The “Select All” function selects all of the data points in an open data file.

4.2.5. Import From

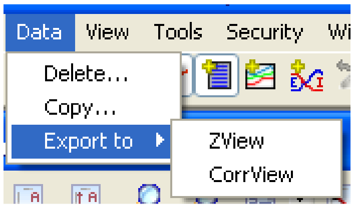


The "Import From" function permits the importation of text EIT data (voltage, current, and time) that might have been collected on a different system entirely. This feature is useful for comparing data collected on a different system form an earlier time. To import an EIT data file, it must be a text file with EIT listed in columns, and additional information must be provided before importing. If the Input File Properties are not completed properly, an error will be issued stating "Error Importing Data File, No Data Found."

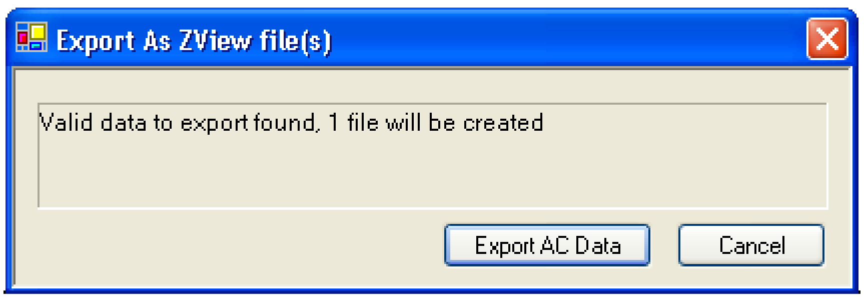


Note: If the text file has a header or parameter fields other than the raw EIT data, they must be "skipped" for the import process. Thus, the "Lines to Skip" is the number of lines in the data file to skip before getting to the EIT data columns.

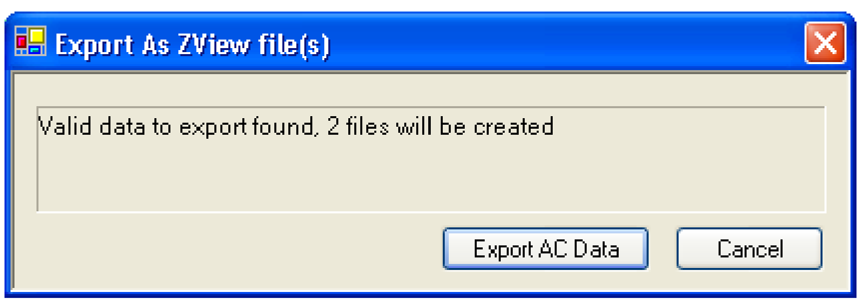
4.2.6. Export to



Export to allows the user to export certain VersaStudio data sets into a separate data file that can be opened and read by the Scribner and Associates software packages CorrView® and ZView®. Selecting a VersaStudio file that contains impedance data and exporting to ZView ("Export AC Data") creates a *.z data file that can then be opened and read by ZView.



If the VersaStudio file contains more than one set of data (for example, a sequence of different EIS scans), multiple data files will be created (one for each impedance action) with the same file name + a numerical index (fir example, filename.z and filename_2.z).



Note: Not all techniques or actions can be exported to CorrView or ZView. The actions that can be exported are:

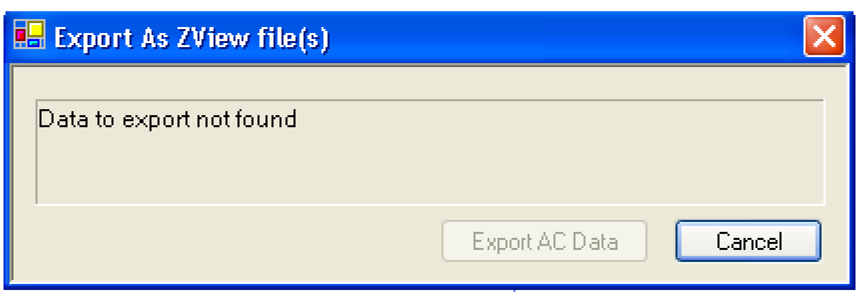
To CorrView:

"Potentiostatic"
"Open Circuit"
"Potentiodynamic"
"Cyclic Polarization"
"Linear Polarization"
"Galvanostatic"
"Galvanodynamic"
"Cyclic Voltammetry (Single and Multiple Cycles)"
"Staircase Cyclic Voltammetry (Single and Multiple Cycles)"
"Linear Scan Voltammetry"
"Staircase Linear Scan Voltammetry"
"Chronoamperometry"
"Chronopotentiometry"
"Chronocoulometry"
"Tafel"

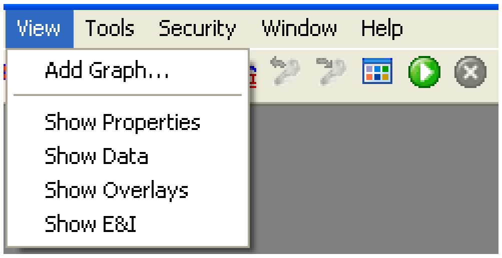
To ZView:

"Potentiostatic EIS"
"Galvanostatic EIS"

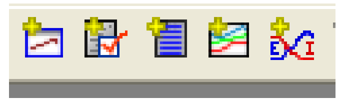
If no data was found within a VersaStudio file that can not be exported properly, the following message will appear:



4.3. View

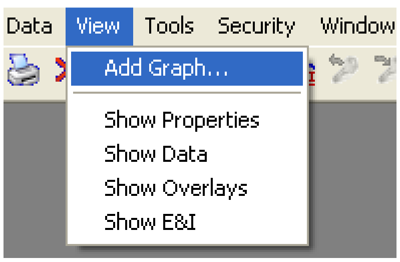


or

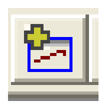


The five choices under **View** correspond to the five icons on the toolbar, **Add Graph View, Show Properties, Show Data View, Show Overlay Manager,** and **Show E&I View.**

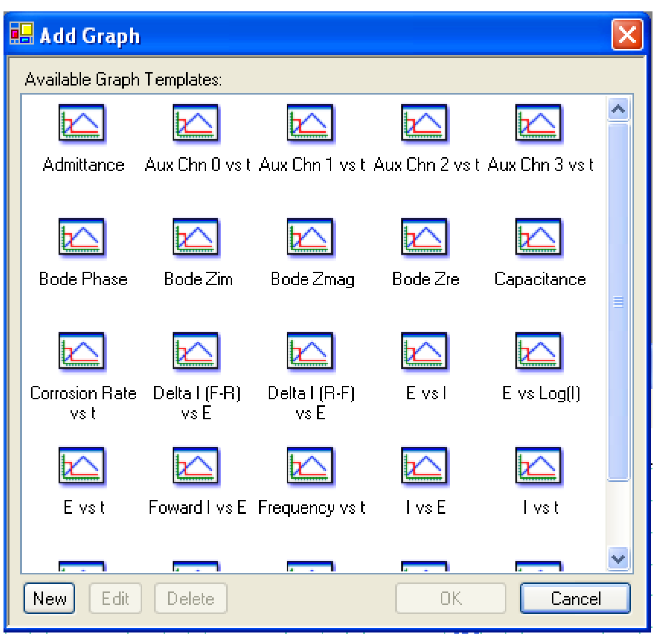
4.3.1. Add Graph View



or

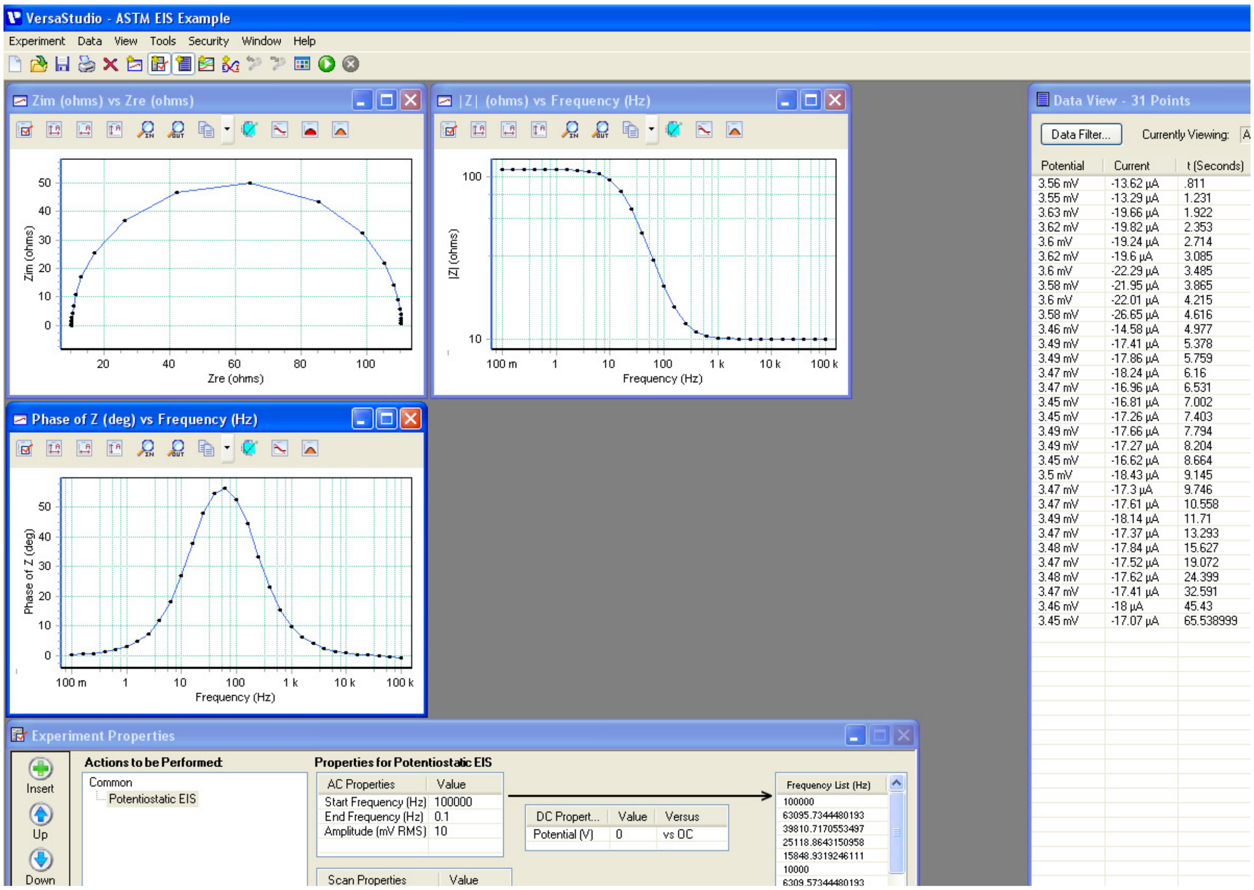


Add Graph will bring up the graph selection window. VersaStudio ships with several ready-made graphs to select from. Select the graph that best fits the desired experiment output, and click **OK**.

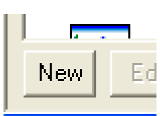


NOTE: If no graph is added to an experiment prior to selecting the **Run** button, a default graph will be placed on the screen. If a graph is added prior to selecting Run, only that graph will be displayed, not the default.

More than one graph may be added to an experiment or data set. In fact, there is no limit to the number to graphs that can be placed on a single screen, but practicality dictates that more than four is usually unnecessary.

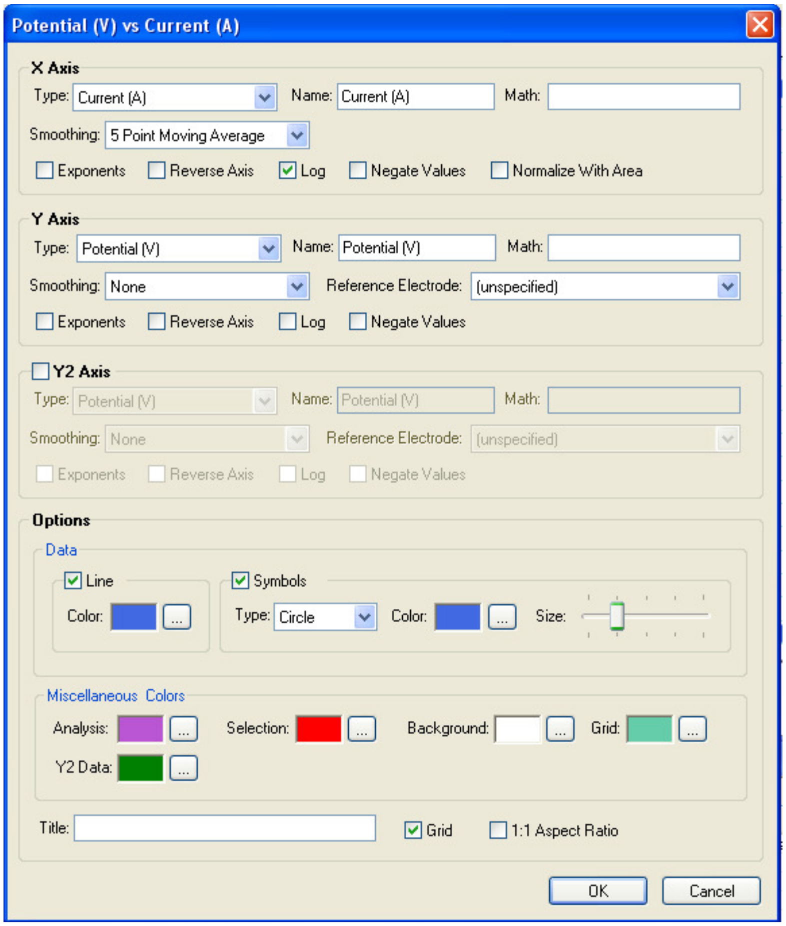


If there is no graph within the selection window that fits the experiment needs, an entirely new graph may be created by selecting **New** in the bottom corner.

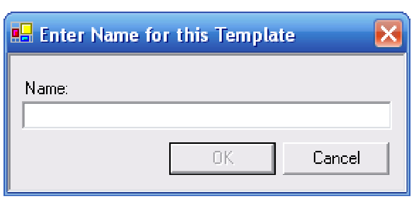


4.3.1.1. Graph Properties

By clicking **New**, the **Graph Properties** window appears, in which you may select the properties for the graph, such as the X and Y Axis types, whether to add a Y2 Axis, colors to use for the data, and graph title. For a complete listing of the different axis graph options, please see **Appendix 2**.



Once the graph is customized to the user's requirements, click **OK**. Enter a name in the **Enter Name for this Template** box for this template to be saved.

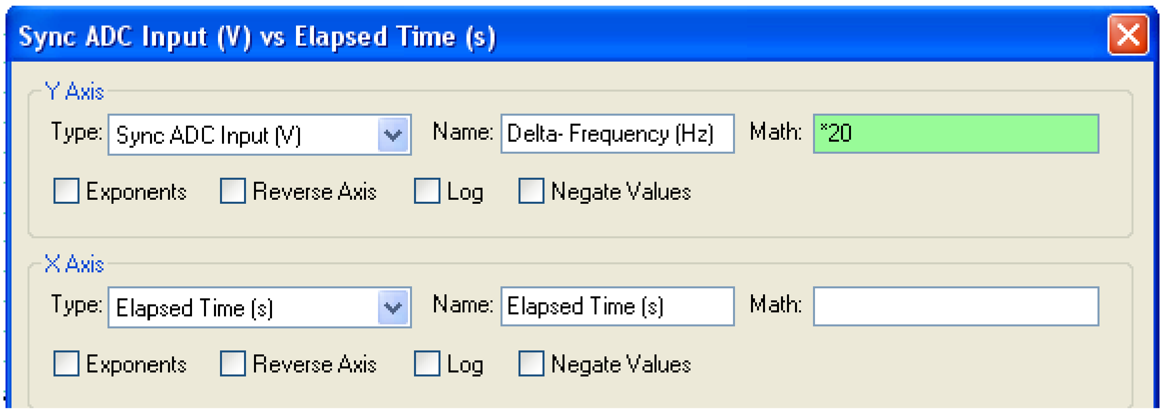


This new template will now be available for selection in the **Add Graph** window.

4.3.1.2. Graph Math

For some applications and experiments, it is desirable to convert the variable being measured and graphed (for example, SYNC ADC Input voltage) into the actual variable being measured (such as Temperature, pH, or QCM Frequency). To make this conversion in the graph, a **Math** input is available for each axis to perform mathematical conversions on any variable as desired. The factors that may be entered into the Math box are **addition (+), subtraction (-), multiplication (* or x), and division (/)**.

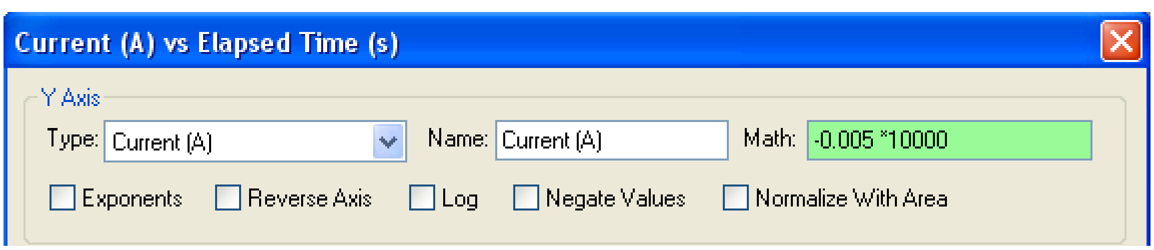
For example, if a QCM922 quartz crystal microbalance was being used for EQCM applications, and the delta-frequency output from the QCM922 was being sampled by the SYNC ADC Input of the potentiostat hardware system, it would be desirable to see the data in frequency, not voltage as the signal is output from the QCM922. To make this conversion, it is necessary to multiply the SYNC ADC Input by the factor that would convert the voltage output from the QCM922 into the correct frequency. Assuming the QCM922 was on the 200Hz frequency range, the output signal for frequency change is 200Hz/10V, or a factor of 20. Therefore, the Graph Properties of SYNC ADC Input vs. time would be changed as follows:



This change would show on the resulting graph as the change in frequency (Delta-Frequency (Hz)) of the QCM922 relative to time.

Furthermore, the Math can hold **multiple factors** that can be applied to the measured variable.

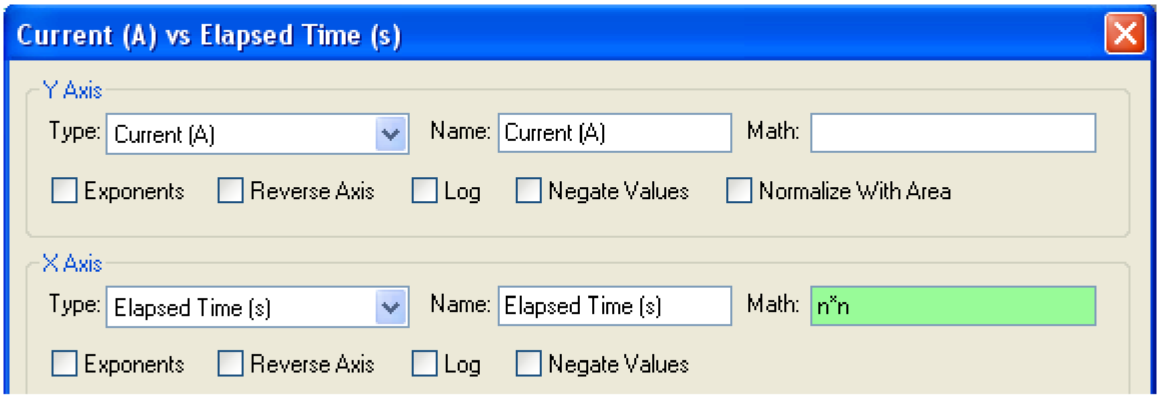
Note: Multiple variables are carried out on a *left-to-right order*, not according to the standard orders of mathematical calculations. For example, if one wanted to subtract 5mA from the current variable (to subtract background current) of a data set, then multiply that result by 10,000, it would be entered as:



Again, the factors are applied to the data in a left-to-right order, not the standard order of mathematics.

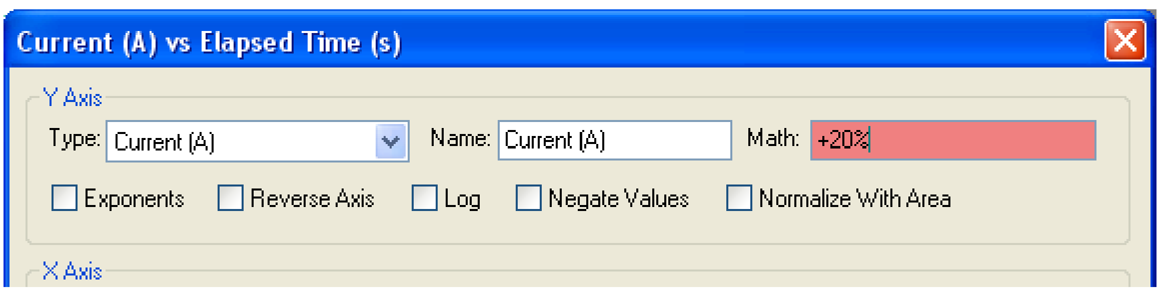
Note: The Math calculations only change the graphed data, not the actual data collected. To export the math-altered data, it would require using the Copy to Clipboard feature associated with that graph.

It might also be desirable to use the variable itself as a factor within the mathematical calculations. This can be accomplished by using the variable "**n**" within the Math box to represent the variable. For example to obtain the square of the time variable and present it graphically, it would be entered as follows:



Anytime the variable itself is to be used within the mathematical sequence, simply use "n" to represent the variable.

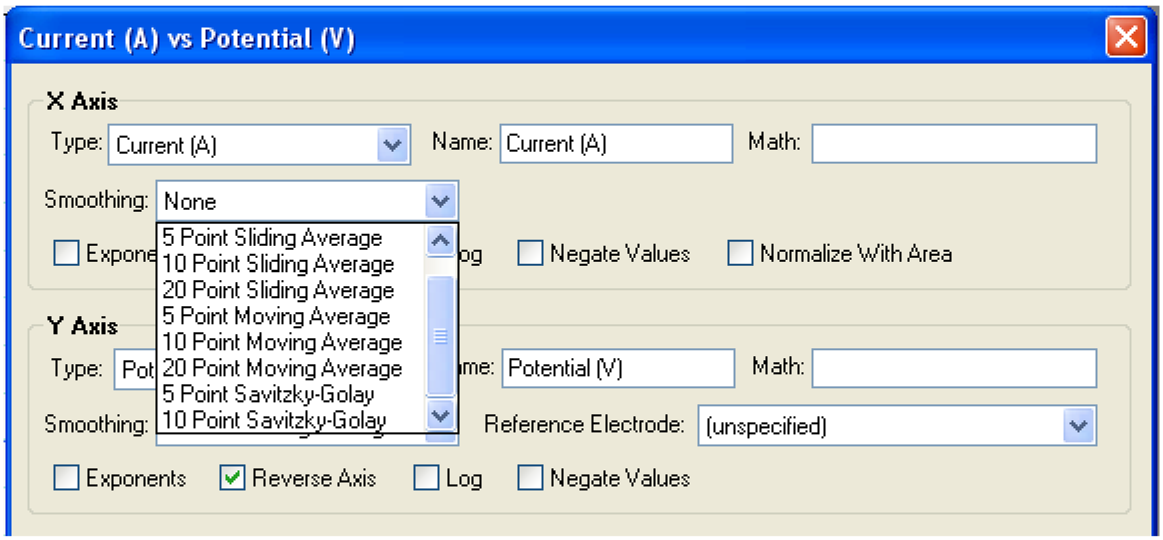
In using the Math box, it will either be indicated as "**green**" to note an acceptable formula, or it will be indicated "**red**" when it is incapable of understanding the entered information. For example, an alpha/numerical character that does not belong in Math box will show a red background as follows:



In the above example, the "%" is not recognized as being an acceptable variable, so no mathematical modification of the graph will occur in this situation. When an acceptable formula is added that will modify the graphical data, the background will be green as shown in previous examples above.

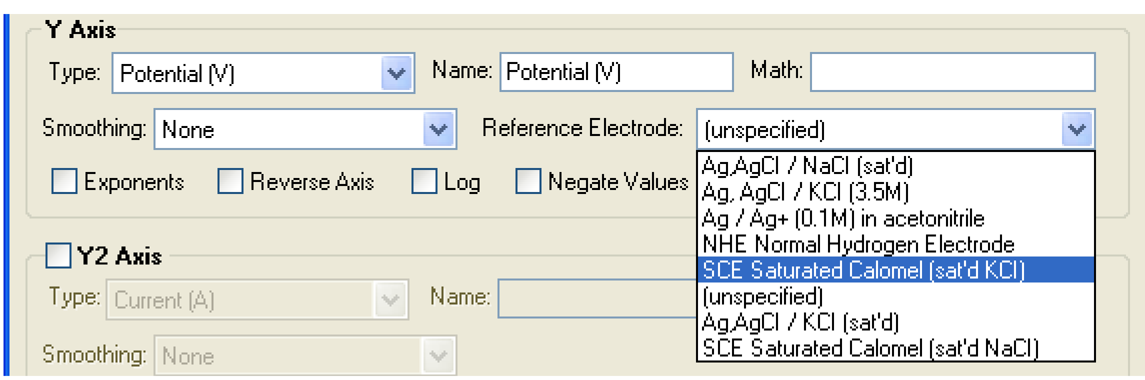
4.3.1.3. Smoothing Options

The Smoothing option in the graph properties allows the application of a sliding average (5, 10, 15, or 20 Point Sliding Average), moving average (5, 10, 15, or 20 Point Moving Average), or a Savitsky-Golay algorithm (5 or 10 point quadratic fit). Smoothing with either a Sliding Average or Savitzky-Golay can reduce the effects of noise or jitter, particularly on current data. A Moving Average is commonly used with time series data to smooth out short-term fluctuations and highlight longer-term trends.



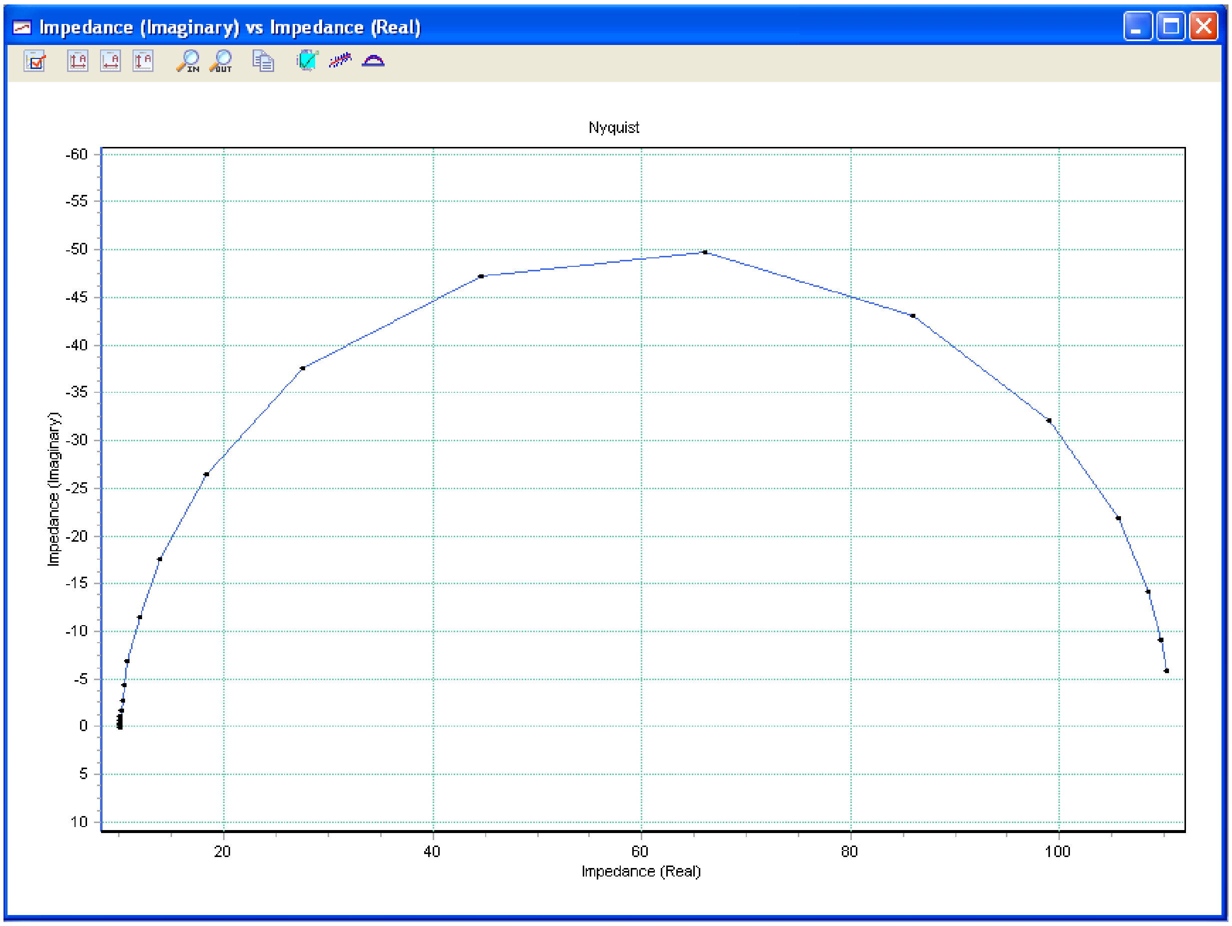
4.3.1.4. Reference Electrode Graph Options

The Reference Electrode option that appears in the graph properties when plotting Potential (V) is available to “shift” data relative to the reference electrode selection that was made in the “Common” section of the experimental setup. For example, if a SCE Saturated Calomel (sat’d KCl) were used and noted in the Common section, changing the graph properties to graph relative to a NHE Normal Hydrogen Electrode would shift the potential data positive by 242mV in the graph. **Note: Changing this graph property is temporary and cannot be saved; closing the data file will return the graph back to the reference electrode listed in the Common section.**

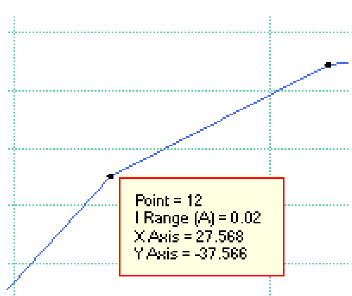


4.3.1.5. Graph Options

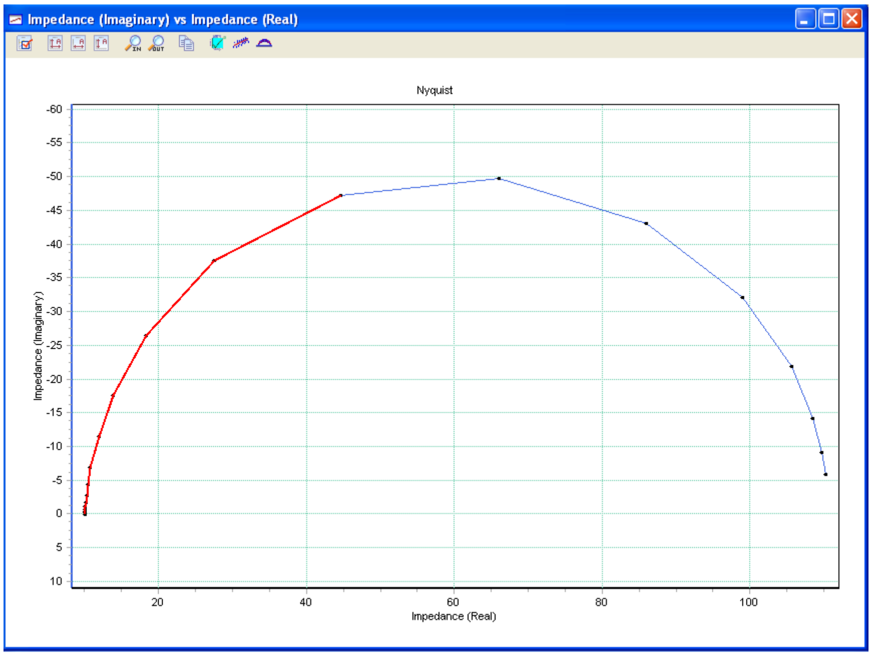
After adding a graph to the screen, it can be repositioned on the screen by clicking and holding with the mouse pointer on the blue bar at the top of the window, and dragging to the location of the user's choice. Likewise, the window can be re-sized by placing the mouse pointer along the edges of the graph window (or at the corners), and once the sizing arrows appear, click and hold down with the mouse pointer, and re-size the window by moving the mouse.



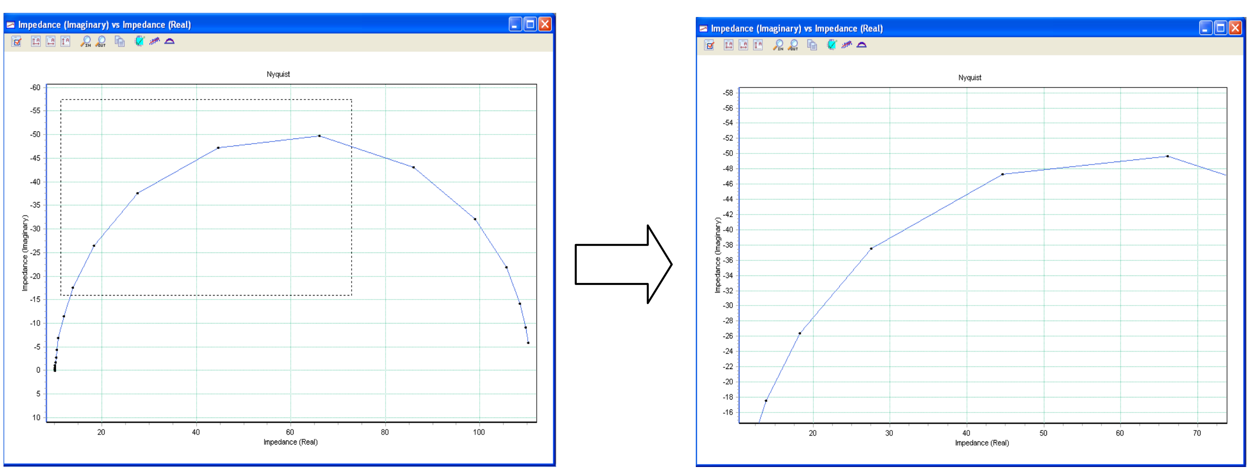
By placing the cursor at any point on a plot, a **Hover Box** is activated, displaying the relevant information associated with a particular data point in the plot. To select a different data point, simply move the mouse cursor to a particular point of interest in the graph, and hover for a brief period to allow the hover box to appear. See section 4.4.5.1. for more hover box options.



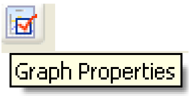
To **select data points in a plot**, simply click the mouse pointer on a point. To **select a range of data points is a plot**, click the mouse pointer at one end of the range, and while holding the left-button of the mouse down, drag the pointer to the opposite end of the range; the selected points will be highlighted. To **move the graphed data around within the defined area of the plot**, click and hold down on the middle mouse button (or scroll wheel) while moving the mouse cursor on the screen.



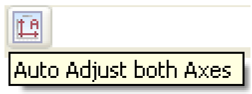
To zoom in on a section of a plot, right-click the mouse pointer and drag the mouse in a downward and to-the-right movement to draw a box around the section of the plot to be zoomed. Release the mouse button, and the plot will be redrawn



Within each graph window are a series of buttons across the top that perform specific functions. Some of the buttons are on every graph, while others only appear when the plot axis are specific for the action associated with the button (such as the **Circle** fit option in the Nyquist plot above).



Graph Properties opens the Graph Properties window to make any desired changes to the graph.

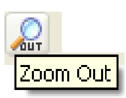


Auto Adjust both Axes re-sizes the plot within the graph window to the smallest possible scale that will encompass all the data points in the plot.

Auto Adjust X Axis Only re-sizes the X-Axis of the plot within the graph window to the smallest possible scale that will encompass all the data points in that axis.

Auto Adjust Y Axis Only re-sizes the Y-Axis of the plot within the graph window to the smallest possible scale that will encompass all the data points in that axis.

Zoom In re-sizes the plot within the graph window to magnify the center point of the graph. Selecting the button several times may be necessary to achieve the desired magnification.

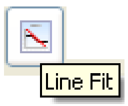


Zoom Out re-sizes the plot within the graph window to reduce the center point of the graph. Selecting the button several times may be necessary to achieve the desired view.

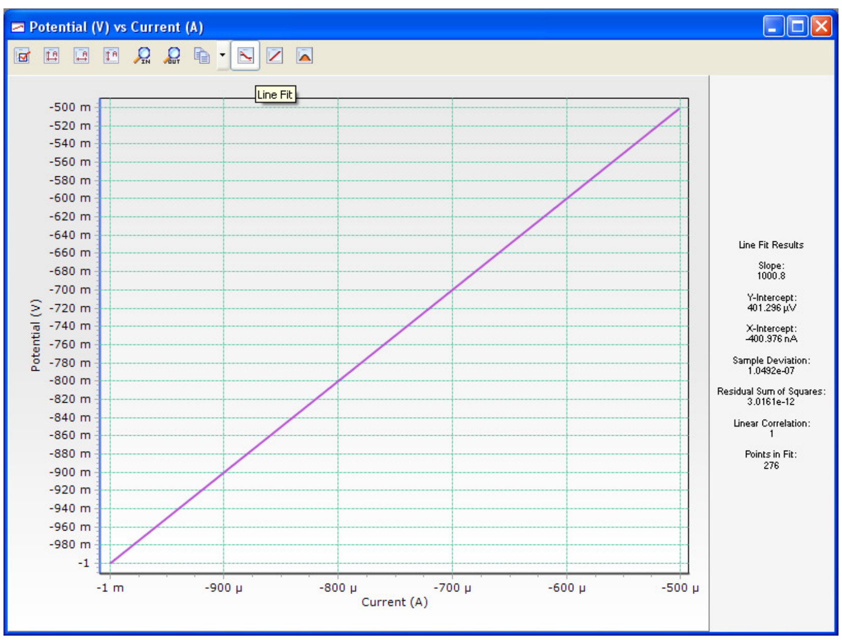
Copy to Clipboard places either the x-y data pairs, the graph, or the results of an analysis or fit onto the Windows clipboard where they can then be pasted into a separate software package, such as a spreadsheet.

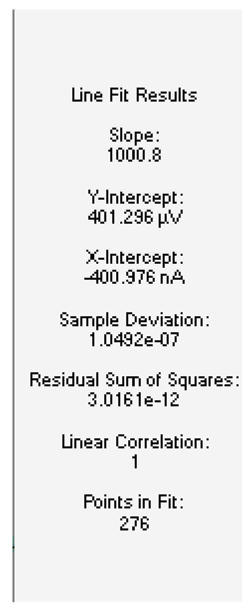
Copy Z Data for ZSimpWin selects all the data in the plot, copies the relevant information to the clipboard, and opens the EIS modeling software, ZSimpWin, into which the data can be pasted for detailed analysis and circuit modeling.

NOTE: ZSimpWin is a product distributed by Princeton Applied Research, and is sold separately from the VersaStudio software.

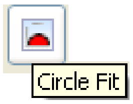


Line Fit provides Line Fit Results on selected data within a graph which appears to the right of the graph as follows:

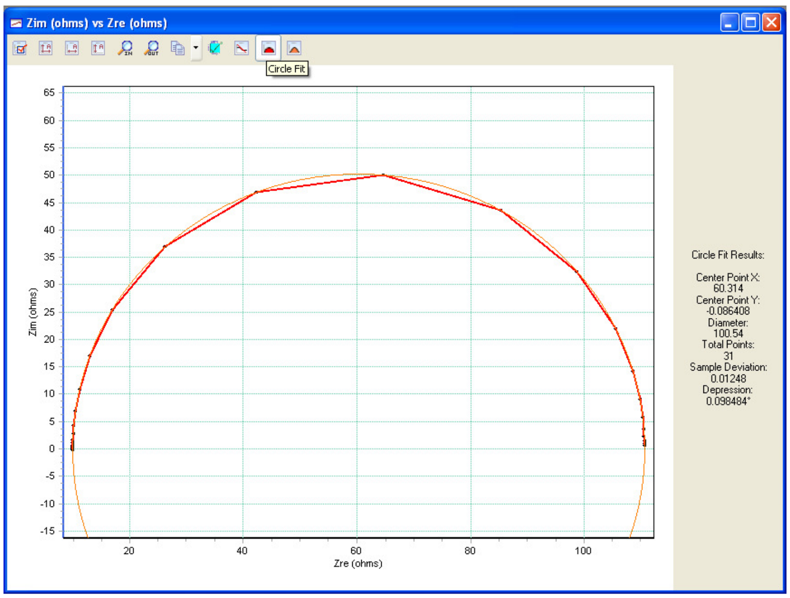


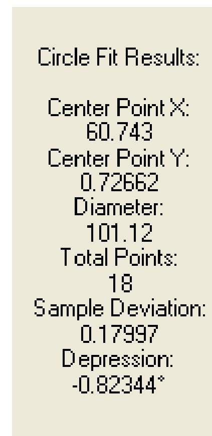


The line fit provides information on the slope, intercept, deviation, and correlation. The line fit can be used on any data set where this information is needed.

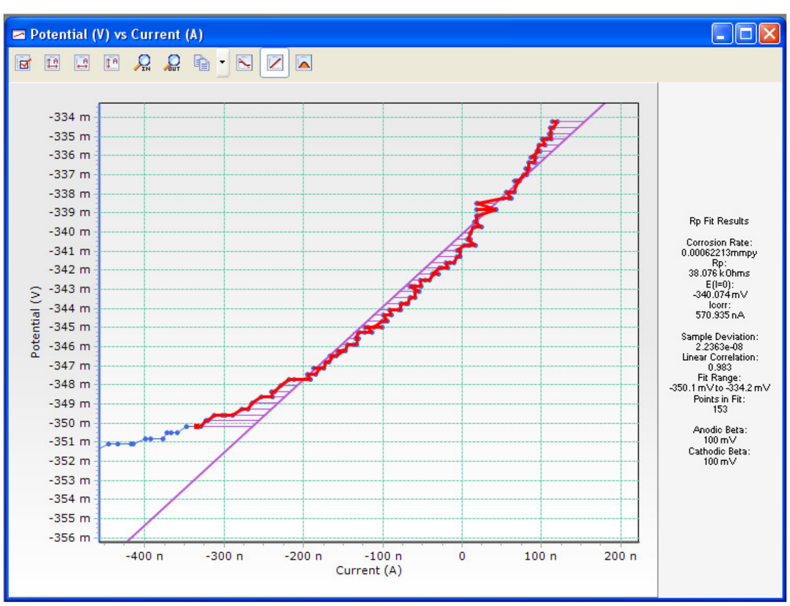


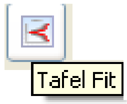
Circle Fit- Selecting data and then clicking the Circle Fit icon gives you Circle Fit Results which appear to the right of the graph. The circle fit information is used in EIS data analysis.



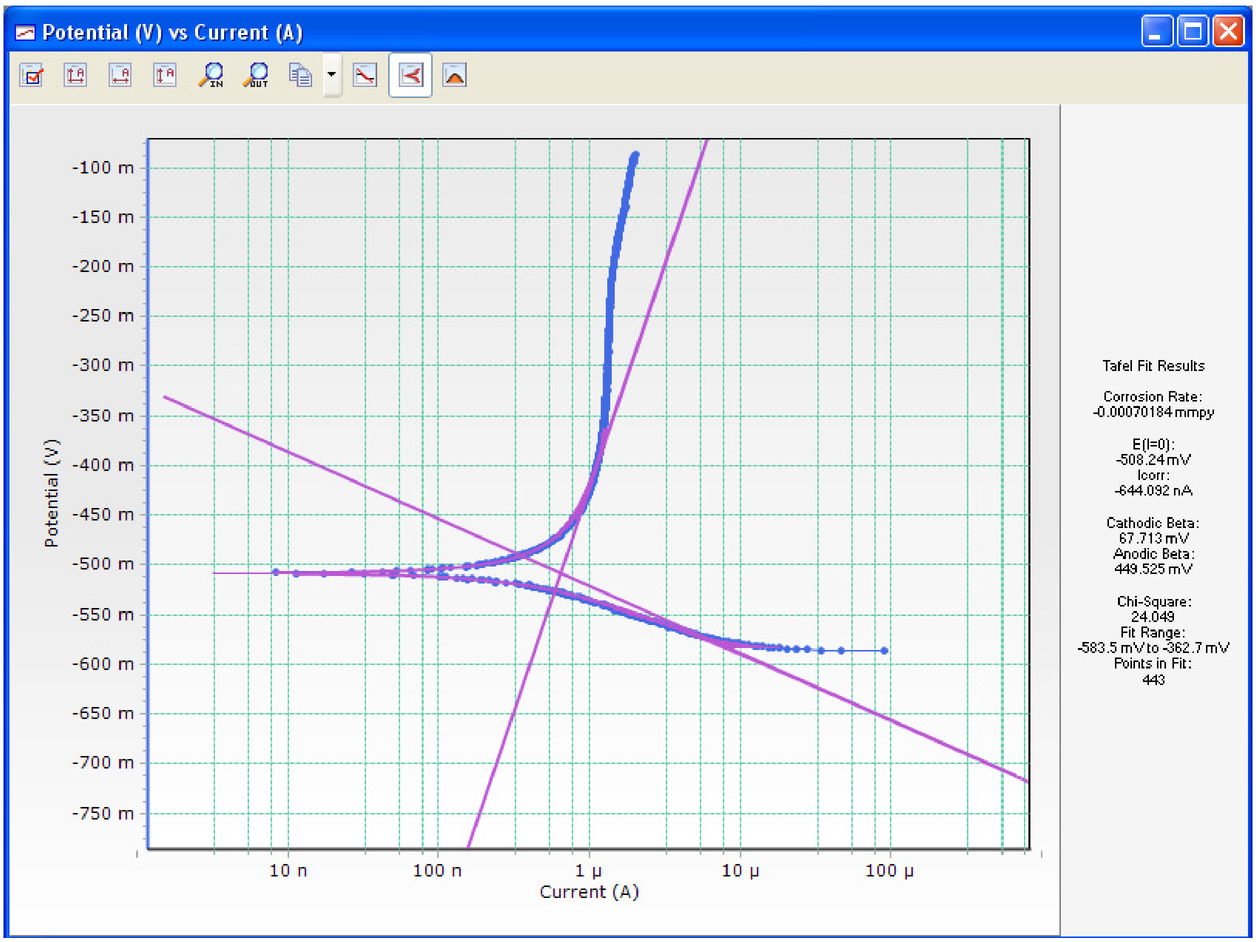


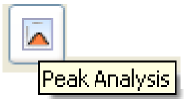
Rp Fit is an analysis tool used on E vs I plots in selected corrosion data (ie, linear polarization experiments) to perform a linear regression analysis to calculate the polarization resistance, then use this information to in turn calculate the corrosion current and corrosion rate. The Tafel constants used to calculate the corrosion rate for Rp (as well as the corrosion rate units) may be selected in the **Tools>Options…**menu.



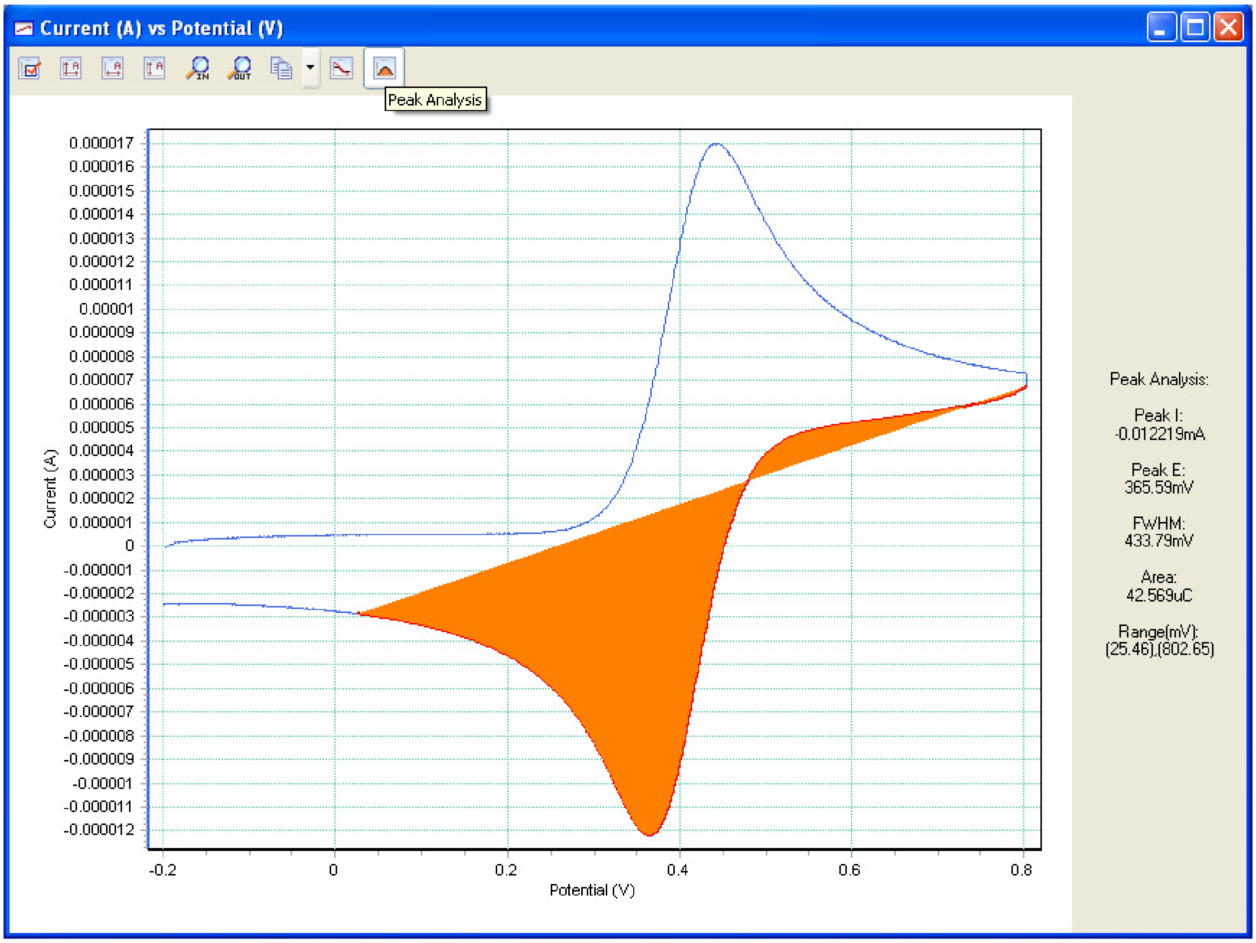


Tafel Fit is an analysis tool used on E vs log I plots in selected corrosion data (ie, Tafel experiments) to statistically fit the experimental data to the Stern-Geary model for a corroding system. Using the mouse, select the data lying within the Tafel region (ideally ±250 mV with respect to the corrosion potential). The **Tafel** analysis then calculates the corrosion current and the corrosion rate (in either millimeters per year or milli-inches per year) and overlays the beta lines on the graph of experimental data.

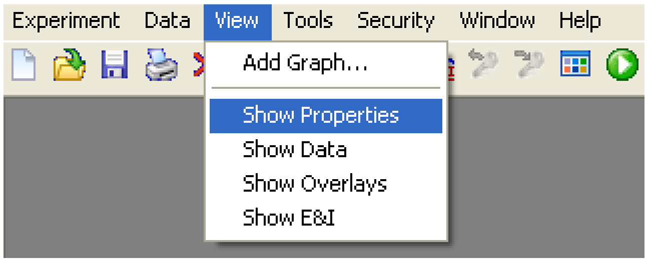




Peak Analysis is an analysis tool used for I vs. E plots for determining Peak Current, Peak Voltage, Full Width – Half Maximum (FWHM), Area (C), and Range (mV).

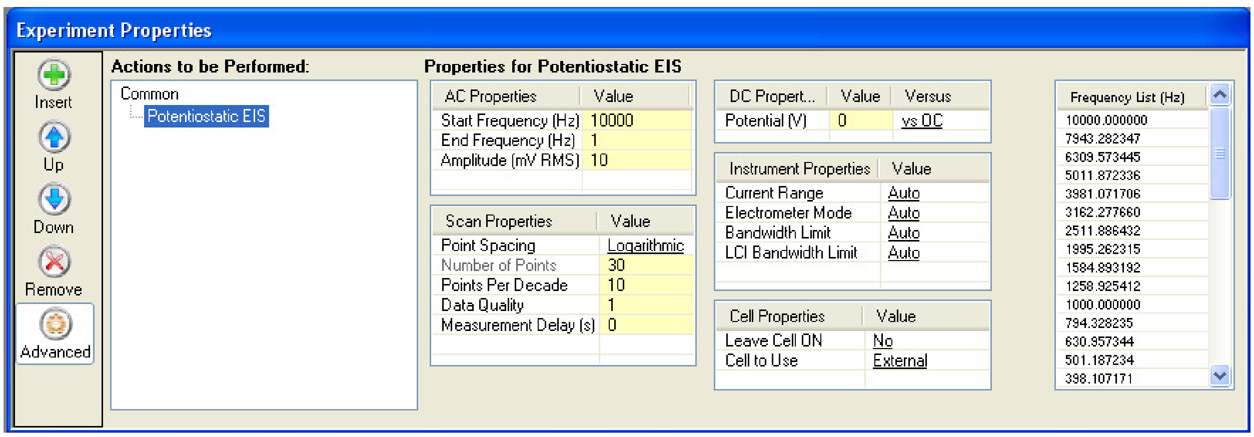


4.3.2. Show Properties

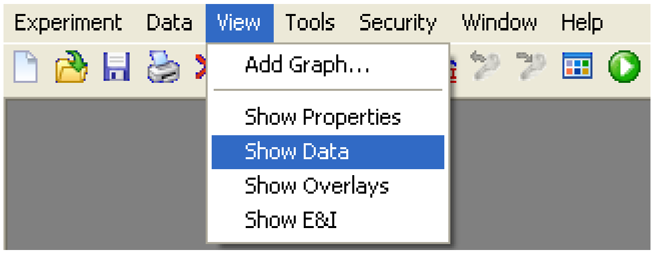


or

The **Show Properties** option can display or hide the Experiment Properties window



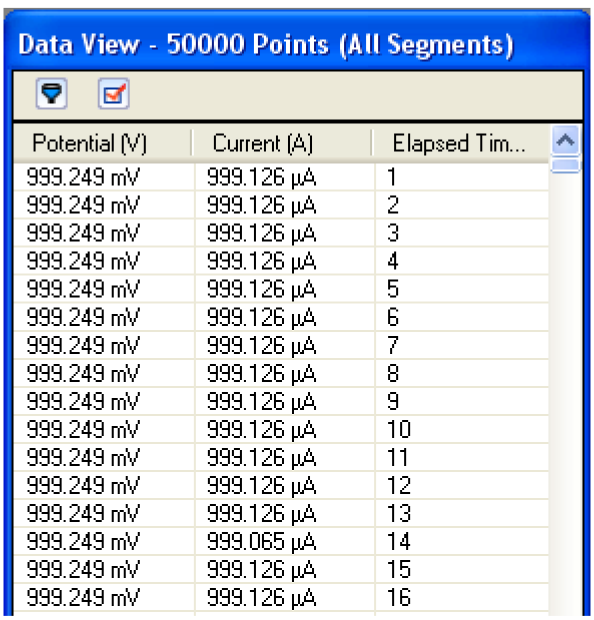
4.3.3. Show Data View



or

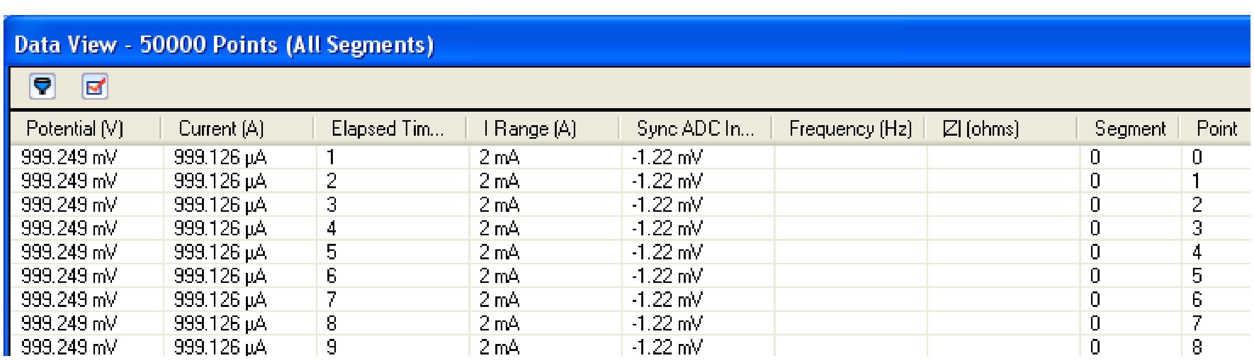
The **Show Data** option displays or hides the **Data View** window, which contains the data points being used to plot the graph.

The **Data View** window auto-scales to show the first three rows as shown below:


Data View - 50000 Points (All Segments)

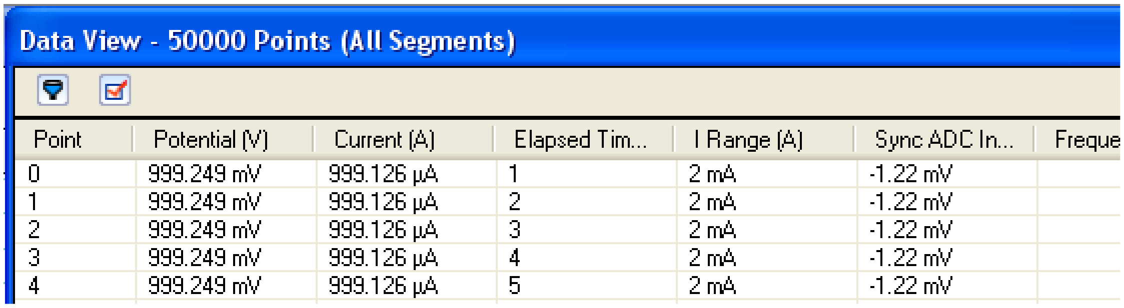
Potential (V)	Current (A)	Elapsed Tim...
999.249 mV	999.126 µA	1
999.249 mV	999.126 µA	2
999.249 mV	999.126 µA	3
999.249 mV	999.126 µA	4
999.249 mV	999.126 µA	5
999.249 mV	999.126 µA	6
999.249 mV	999.126 µA	7
999.249 mV	999.126 µA	8
999.249 mV	999.126 µA	9
999.249 mV	999.126 µA	10
999.249 mV	999.126 µA	11
999.249 mV	999.126 µA	12
999.249 mV	999.126 µA	13
999.249 mV	999.065 µA	14
999.249 mV	999.126 µA	15
999.249 mV	999.126 µA	16

This window may be expanded (shown below) to show other columns by “grabbing” the edge of the window with the mouse cursor and dragging the window open.


Data View - 50000 Points (All Segments)

Potential (V)	Current (A)	Elapsed Tim...	I Range (A)	Sync ADC In...	Frequency (Hz)	|Z| (ohms)	Segment	Point
999.249 mV	999.126 µA	1	2 mA	-1.22 mV			0	0
999.249 mV	999.126 µA	2	2 mA	-1.22 mV			0	1
999.249 mV	999.126 µA	3	2 mA	-1.22 mV			0	2
999.249 mV	999.126 µA	4	2 mA	-1.22 mV			0	3
999.249 mV	999.126 µA	5	2 mA	-1.22 mV			0	4
999.249 mV	999.126 µA	6	2 mA	-1.22 mV			0	5
999.249 mV	999.126 µA	7	2 mA	-1.22 mV			0	6
999.249 mV	999.126 µA	8	2 mA	-1.22 mV			0	7
999.249 mV	999.126 µA	9	2 mA	-1.22 mV			0	8

The Data View window can also be customized by using the "**Customize Columns**" option (right button at top of Data View menu) to add additional parameters to view, and the columns themselves can be re-arranged by clicking and dragging the header for the columns to different positions inside the Data View window ("Point" moved to first column in example below).

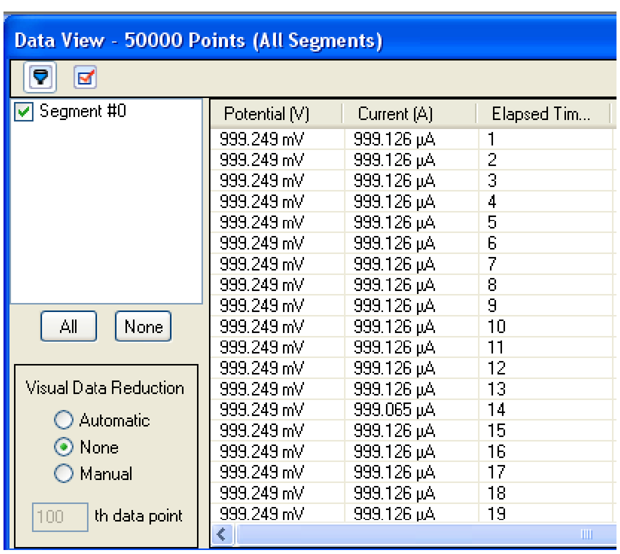


Point	Potential (V)	Current (A)	Elapsed Tim...	I Range (A)	Sync ADC In...	Freque
0	999.249 mV	999.126 µA	1	2 mA	-1.22 mV	
1	999.249 mV	999.126 µA	2	2 mA	-1.22 mV	
2	999.249 mV	999.126 µA	3	2 mA	-1.22 mV	
3	999.249 mV	999.126 µA	4	2 mA	-1.22 mV	
4	999.249 mV	999.126 µA	5	2 mA	-1.22 mV	

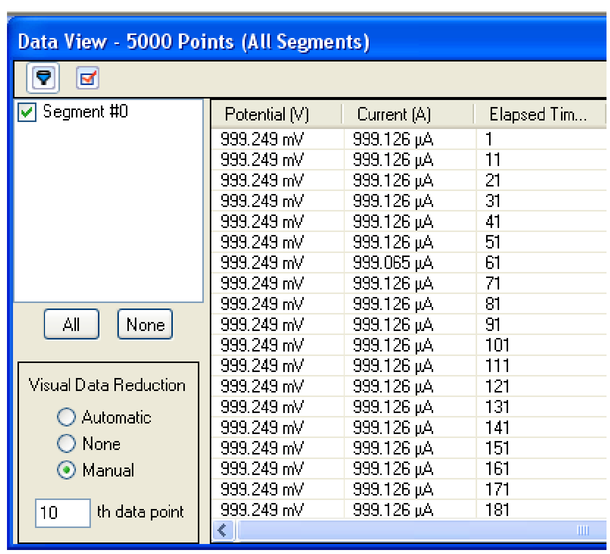
A **Data Filter** option (left button at top of Data View Menu) is provided to limit the data that is plotted in the graphs. Limiting the number of points graphed can speed up the graphical interface and the response time when interacting with the graph properties.

Note: At installation of VersaStudio, the "Visual Data Reduction" is set to "Automatic." With the setting at "Automatic" a 10:1 data reduction is done each time the graph reaches or surpasses 10K points.

In the example below, the **Visual Data Reduction** feature has been set to **None** for the example to the left, which would graph all 50K points. With the selection set to Manual and the selection box set to show every 10th data point, the data in the Data View and graph has been reduced to 5K points (a 10:1 reduction). This feature may be desired to speed up graphing when a large data set is being acquired and plotted. Selection of **Automatic** reduces the viewed data on the graph to a number of points that facilitates the fastest possible graphing speed. Selecting the **None** option shows all the data points collected.

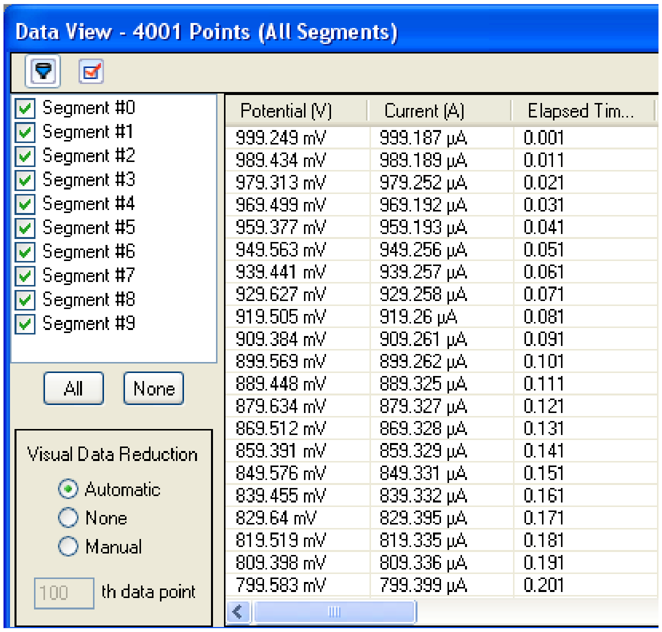


Potential (V)	Current (A)	Elapsed Tim...
999.249 mV	999.126 µA	1
999.249 mV	999.126 µA	2
999.249 mV	999.126 µA	3
999.249 mV	999.126 µA	4
999.249 mV	999.126 µA	5
999.249 mV	999.126 µA	6
999.249 mV	999.126 µA	7
999.249 mV	999.126 µA	8
999.249 mV	999.126 µA	9
999.249 mV	999.126 µA	10
999.249 mV	999.126 µA	11
999.249 mV	999.126 µA	12
999.249 mV	999.126 µA	13
999.249 mV	999.065 µA	14
999.249 mV	999.126 µA	15
999.249 mV	999.126 µA	16
999.249 mV	999.126 µA	17
999.249 mV	999.126 µA	18
999.249 mV	999.126 µA	19



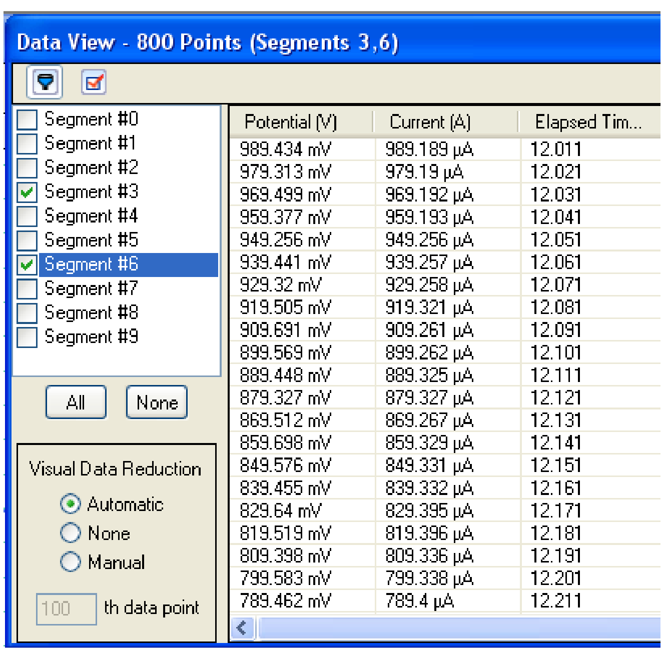
Potential (V)	Current (A)	Elapsed Tim...
999.249 mV	999.126 µA	1
999.249 mV	999.126 µA	11
999.249 mV	999.126 µA	21
999.249 mV	999.126 µA	31
999.249 mV	999.126 µA	41
999.249 mV	999.126 µA	51
999.249 mV	999.065 µA	61
999.249 mV	999.126 µA	71
999.249 mV	999.126 µA	81
999.249 mV	999.126 µA	91
999.249 mV	999.126 µA	101
999.249 mV	999.126 µA	111
999.249 mV	999.126 µA	121
999.249 mV	999.126 µA	131
999.249 mV	999.126 µA	141
999.249 mV	999.126 µA	151
999.249 mV	999.126 µA	161
999.249 mV	999.126 µA	171
999.249 mV	999.126 µA	181

A second feature of the Data Filter is the ability to choose segments to view. In a multi-action sequence as described in section 4.1.1.2.1., or for a Multi-Cyclic Voltammetry experiment, it may be desirable to view the results of only one of the experiments within the entire sequence. To determine the segment number, select a point on the plot of interest, then expand the **Data View** window to search for the highlighted data of interest and its segment number, as in the example below.



Potential (V)	Current (A)	Elapsed Tim...
999.249 mV	999.187 µA	0.001
989.434 mV	989.189 µA	0.011
979.313 mV	979.252 µA	0.021
969.499 mV	969.192 µA	0.031
959.377 mV	959.193 µA	0.041
949.563 mV	949.256 µA	0.051
939.441 mV	939.257 µA	0.061
929.627 mV	929.258 µA	0.071
919.505 mV	919.26 µA	0.081
909.384 mV	909.261 µA	0.091
899.569 mV	899.262 µA	0.101
889.448 mV	889.325 µA	0.111
879.634 mV	879.327 µA	0.121
869.512 mV	869.328 µA	0.131
859.391 mV	859.329 µA	0.141
849.576 mV	849.331 µA	0.151
839.455 mV	839.332 µA	0.161
829.64 mV	829.395 µA	0.171
819.519 mV	819.335 µA	0.181
809.398 mV	809.336 µA	0.191
799.583 mV	799.399 µA	0.201

Once the segment number is known, select **Data Filter**, and select only the segments of interest to view in the graphs (example below). The plots and the Data View window will then only contain data from those segments selected. This feature is useful when wanting to perform analyses on individual experiments that were run as a sequence of experiments in a multi-action setup.



Potential (V)	Current (A)	Elapsed Tim...
989.434 mV	989.189 µA	12.011
979.313 mV	979.19 µA	12.021
969.499 mV	969.192 µA	12.031
959.377 mV	959.193 µA	12.041
949.256 mV	949.256 µA	12.051
939.441 mV	939.257 µA	12.061
929.32 mV	929.258 µA	12.071
919.505 mV	919.321 µA	12.081
909.691 mV	909.261 µA	12.091
899.569 mV	899.262 µA	12.101
889.448 mV	889.325 µA	12.111
879.327 mV	879.327 µA	12.121
869.512 mV	869.267 µA	12.131
859.698 mV	859.329 µA	12.141
849.576 mV	849.331 µA	12.151
839.455 mV	839.332 µA	12.161
829.64 mV	829.395 µA	12.171
819.519 mV	819.396 µA	12.181
809.398 mV	809.336 µA	12.191
799.583 mV	799.338 µA	12.201
789.462 mV	789.4 µA	12.211

Finally, the "Comment" field will show comments specific for a particular data point. In the example below, there are three comments, **Code 1, Code 2, and Overload**.

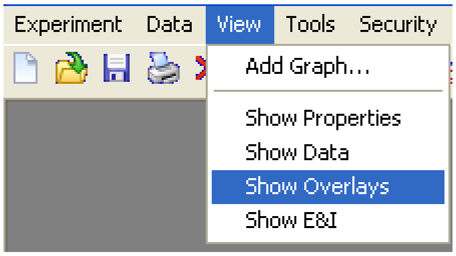
Potential (V)	Current (A)	Elapsed Tim...	I Range (A)	Sync ADC In...	Frequency (Hz)	|Z| (ohms)	Segment	Point	Comment
-3.335 mV	-3.478 µA	2.49	20 uA	-1.525 mV			0	248	
-2.415 mV	-2.487 µA	2.5	20 uA	-1.831 mV			0	249	
-1.495 mV	-1.494 µA	2.51	20 uA	-1.831 mV			0	250	
-575 µV	38.706 nA	2.52	2 uA	-1.831 mV			0	251	Code 01 (see help)
345.118 µV	711.742 nA	2.53	2 uA	-1.525 mV			0	252	
1.265 mV	1.551 µA	2.54	2 uA	-1.525 mV			0	253	Overload
2.798 mV	20.1 µA	2.55	20 uA	-1.831 mV			0	254	Code 02 (see help)
3.412 mV	14.672 µA	2.56	20 uA	-1.525 mV			0	255	
4.332 mV	10.582 µA	2.57	20 uA	-1.525 mV			0	256	

Code1 is an indication that the value for either the current or the voltage is near the resolution limit of the analog-to-digital converters (ADCs). In the example above, the Code 1 is for the voltage reading which was near the resolution limit for the voltage range. Points with Code 1 may not be considered accurate since they are at or near the limits of the resolution.

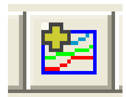
Code 2 is an indication that a hardware change occurred during the acquisition of that point. This change could be a current range change, or a gain change on the voltage or current channels. In the example above, it is most likely a current range change occurred given that the point prior was acquired on a different current range.

Overload indicates that the current was at the limit of the range during the acquisition of that point. Given that the current may have been larger than that indicated, this point cannot be considered accurate.

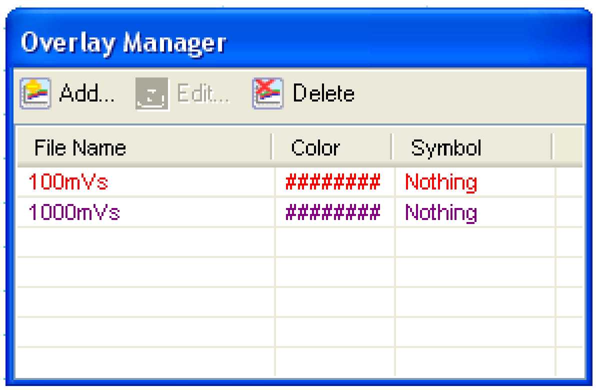
4.3.4. Show Overlay Manager



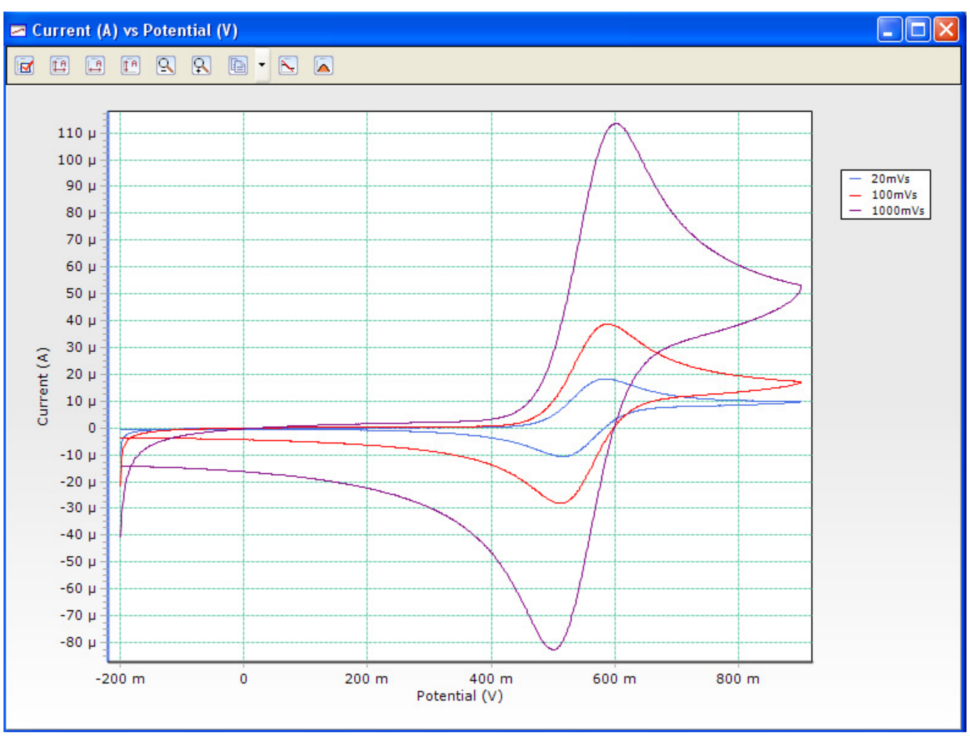
or



Show Overlays opens the **Overlay Manager**, and permits selection of additional data files to be added to the plot along with the active data file for graphical comparisons. In the example below, 20mVs is the active file, while 100mVs and 1000mVs are added as overlays..

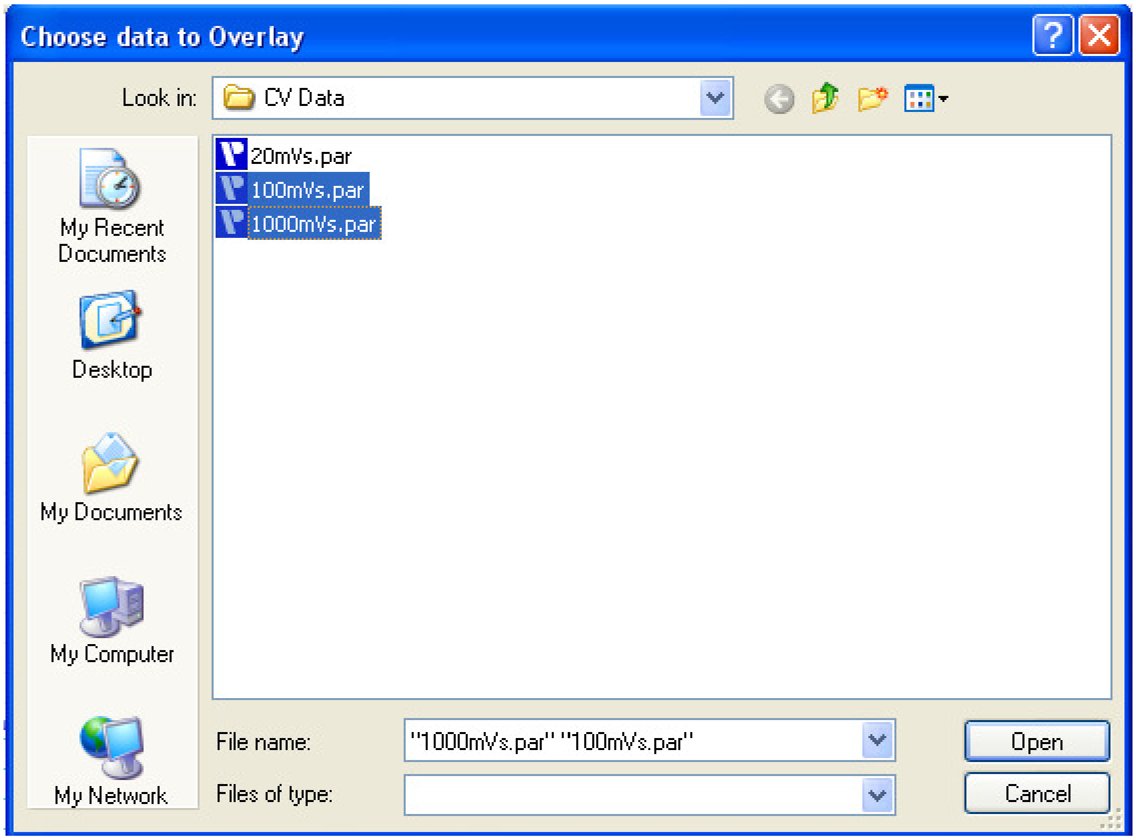


NOTE: Overlay data cannot be selected for any analysis; only the active data file can have points selected for analysis.



4.3.4.1. Add Overlay

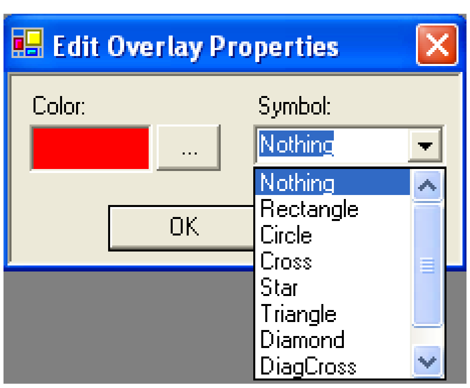
To select a file to be overlaid with the active data file, select **Add…** on the **Overlay Manager**. A window titled **Choose Data to Overlay** opens**,** which allows the user to select a file to be overlaid with the current data.



Note: The "Shift" key may be used to select a range of files to overlay, or the "Ctrl" key to select multiple files from the open window.

4.3.4.2. Edit Overlay

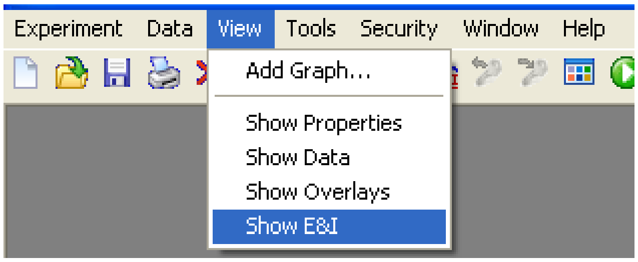
The **Edit** button in the **Overlay Manager** window opens this window, where colors and symbols can be chosen for the overlaid data.

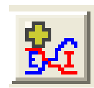


4.3.4.3. Delete Overlay

The **Delete** button simply removes the selected data file from the **Overlay Manager** list.

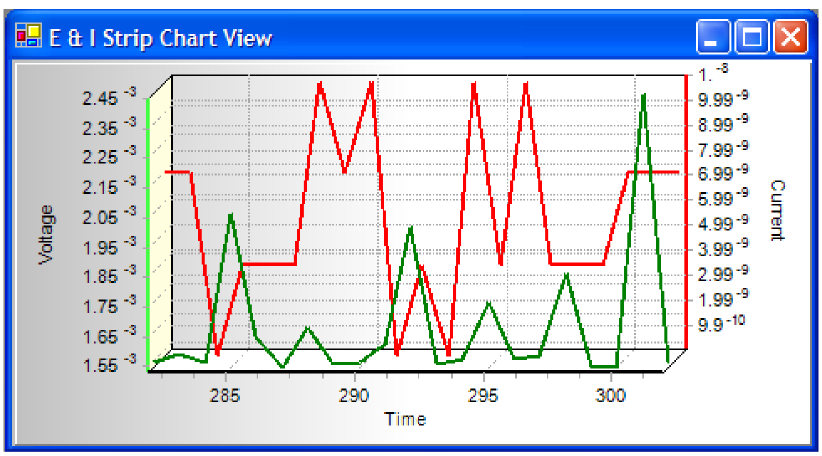
4.3.5. Show E&I View



or 

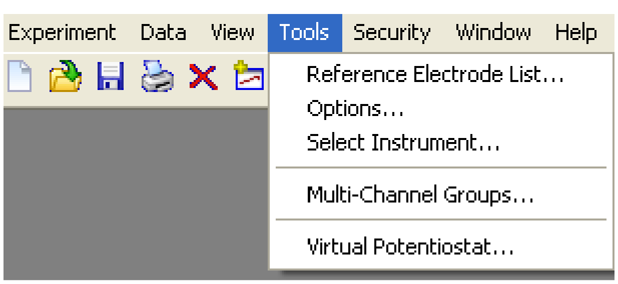
Show E&I opens up the **E & I Strip Chart View**, which is a real-time view of the voltage and current being measured by the system.

This window can be moved and resized horizontally and vertically by clicking and dragging on the margins of the box.

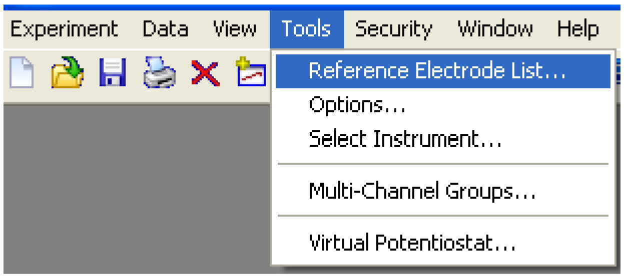


4.4. Tools

Selecting **Tools** on the main menu opens the following dropdown menu:

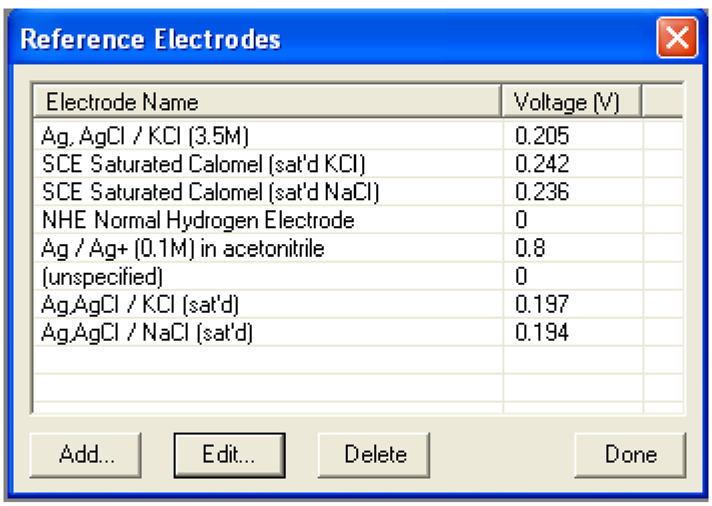


4.4.1. Reference Electrode List



The listing of **Reference Electrodes** is utilized in the **Common** action properties to note the reference electrode being used in an experiment.

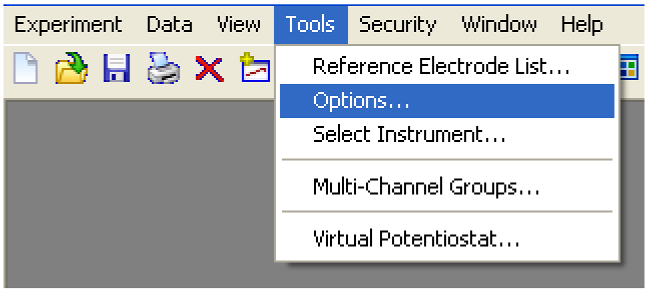
NOTE: Selection of a reference electrode in the **Common** properties does not offset the potential (voltage) readings; this is simply a notation of what was used during the experiment.



The list of **Reference Electrodes** can be added to with **Add…** button, or an existing one may be changed with the **Edit…** button.

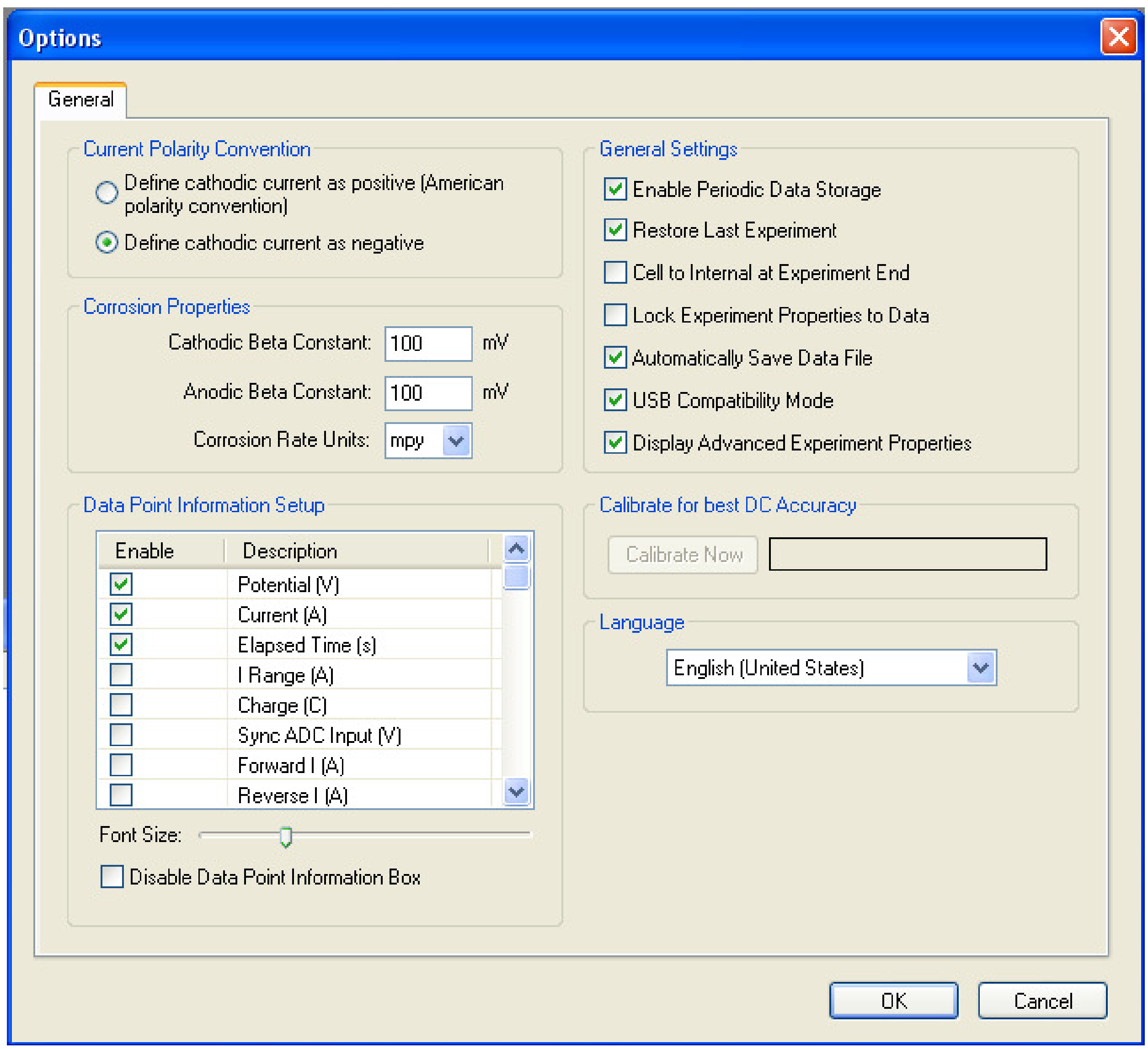
The **Voltage (V)** value for each reference electrode is the common potential relative to a Normal Hydrogen Electrode (NHE).

4.4.2. Options



4.4.2.1. General Parameters and Options

Clicking **Options…** enables selections for variables such as **Current Polarity Convention**, **Corrosion Properties**, **Data Point Information Setup**, **General Settings, Calibrate for best DC Accuracy, Language and Float Settings** (VersaSTAT 3F and PARSTAT 4000 only for float settings)**.**



Current Polarity Convention selects how the graph will display current (I) as either positive or negative. The hardware itself follows the American polarity convention (cathodic current = positive), but selecting the "cathodic current = negative" will change the settings appropriate for both potentiostatic and galvanostatic operations.

Beta Constants are used by the **Rp** analysis (section 4.3.1.5.) to calculate corrosion rates. Prior testing (Tafel tests) can be used to determine Tafel constants, and they can be input here for more accurate corrosion rate determinations.

Corrosion Rate Units are used by the **Rp Fit** and **Tafel Fit** (section 4.3.1.5.) to report corrosion rates as either milli-inches per year (mpy) or millimeters per year (mmpy).

In **Data Point Information Setup**, the user can enable/disable variables that appear in the Hover Box for data graphs. When the **Disable Data Point Information** box is checked, the hover box is not displayed on plots.

Enable Periodic Data Storage is a feature that saves the data from the instrument to the data file as the experiment progresses (important for long term experiments in the event of a computer or power failure to prevent complete data loss), and it can also save data from an instrument (or channel on a VMC) that is not the active channel selected. In other words, if you start an experiment on a channel, then select "No Instrument" to perform data analysis on a separate data file, the "Periodic Data Storage" will routinely check (every **5 minutes**) for data residing in the buffers of all channels connected and save that data to the data file on the PC as the experiment progresses.

Note: If you are running actions that perform data averaging during the acquisition (Acquisition Mode=Average, or when Acquisition mode=Auto for Corrosion actions), or if you are performing sequences that have both DC techniques (such as Cyclic Voltammetry) and AC techniques (such as Potentiostatic EIS) in the same sequence, the "Periodic Data Storage" <u>must be selected</u>, else the experiments will not proceed accordingly if the instrument or channels are not selected.

Restore Last Experiment will open the last data file associated with a particular instrument or channel when that channel is selected. If it is desired to select a channel and it NOT open the previously associated data, then de-selecting this option will permit that scenario as well.

Cell to External at Experiment End, if enabled, sets the system to the internal dummy cell (1Kohm resistor) at the end of a sequence. This feature is useful when there is excessive noise in the external cell (caused by a heater or stirrer at the cell, for example) that keeps the open circuit current reading in a state of "Overload" at the lowest current ranges.

Calibrate for best DC Accuracy is a fine adjustment of the internal DACs for any DC offsets to within +/- 1uV. This calibration should not be performed unless the unit is at operating temperature (power-on for at least 10 minutes). No external cell connection is required. The calibration process takes approximately 2 minutes to perform. Note: there is no "pass/fail" report after performing this calibration.

Lock Experiment Properties to Data will lock down the properties of all experiments that contain data. Disabling this feature allows the user to modify properties that contain data and select “Run” to quickly alter a variable and re-run an experiment. If this feature is enabled, then the variables cannot be changed and re-run until all of the data is selected and deleted from that file.

Automatically Save Data File will save any changes made to the data file (for example, any graphical changes, data deletions, data analyses, etc) automatically on exit. If the user prefers to be asked whether changes are to be saved on exit, then this option should be un-selected.

USB Compatibility Mode is utilized in some rare instances when multiple channels (such as VMC-4) or sub-standard USB chipsets cause communication lock-ups (screen freezes requiring re-start of both hardware and software). Enabling this parameter has proven to resolve this issue; however, enabling this parameter will slow down the USB communications speed and screen response time.

Language provides the capability to change a significant portion of text within the VersaStudio software to the local language specified in the Windows (Control Panel) Regional Settings, provided that language is supported by VersaStudio (listed in the drop-down menu). For example, if the Regional Settings are “German (Germany)”, and Language is set to “German” in VersaStudio, then a significant portion of the text within VersaStudio will be converted to German.

Display Advanced Experiment Properties is utilized when it is desired to always show the “Advanced” experiment properties by default in every experiment.

4.4.2.1.1. Setting Operation Modes of Float and Normal

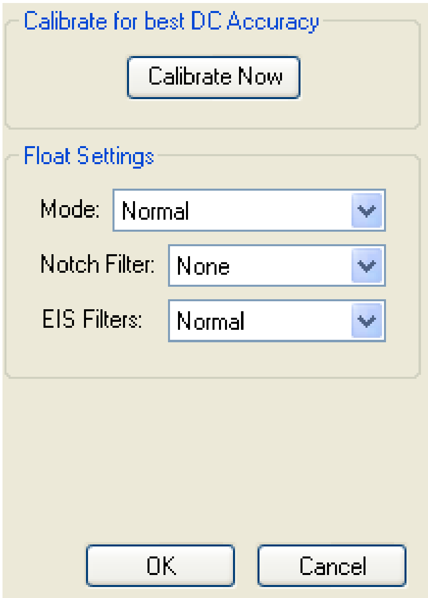
Float Settings only appears if a system capable of floating (cell leads isolated from ground in order to reasonably operate on a grounded cell) is connected (either a VersaSTAT 3F or PARSTAT 4000).

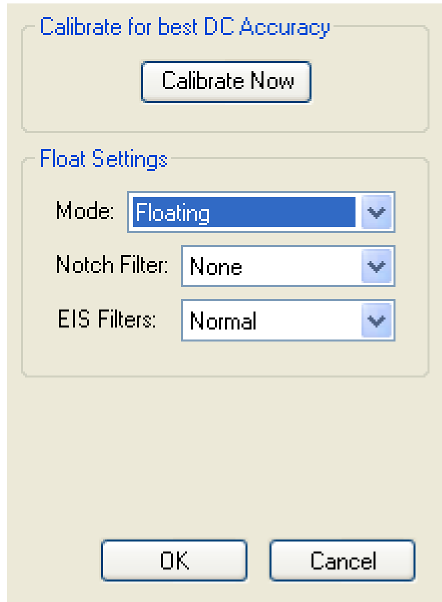
The VersaSTAT 3F and PARSTAT 4000 were designed to operate in either a “normal” mode or a “floating” mode. The floating mode provides the capability to operate with cells where one of the electrodes or the cell itself is at earth ground. Examples of earth grounded cells include autoclaves, strain apparatus, storage tanks and pipelines, and additional electrodes connected to a separate potentiostat that is not floating.

In floating mode, the internal ground of these systems (as well as the cell leads and external connections at the rear panel) is allowed to float with respect to earth ground which allows it to operate with these grounded cells.

NOTE: Instrument performance, particularly with regards to current and voltage noise, can be substantially degraded when operating in float mode on grounded cells, the level of degradation depending on the technique and the impedance between the electrodes and ground. Therefore specifications listed in the hardware manual apply only to isolated cells with the system set to normal mode.

The Options menu is where the mode can be changed to either "normal" or "floating" as shown below:

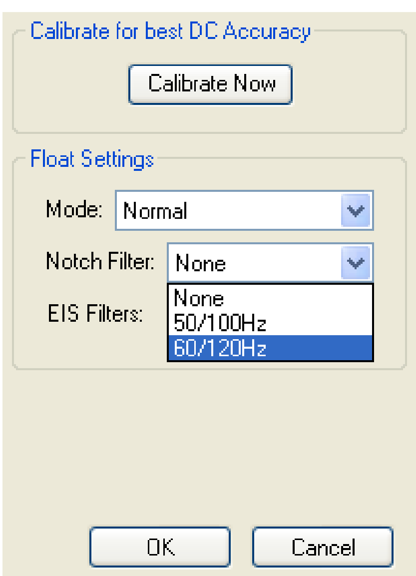




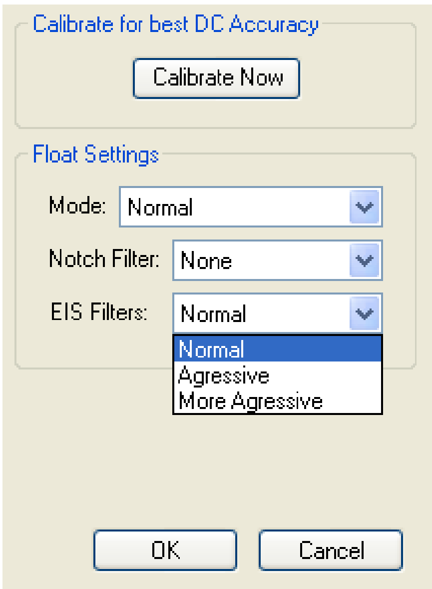
It is recommend that after one changes modes, a new calibration for DC accuracy be performed by selecting the "Calibrate Now" button above the Floating Settings option.

In addition to the mode selections, the VersaSTAT 3F and PARSTAT 4000 also provide additional filters that could be required with some cells in order to enhance the signal to noise.

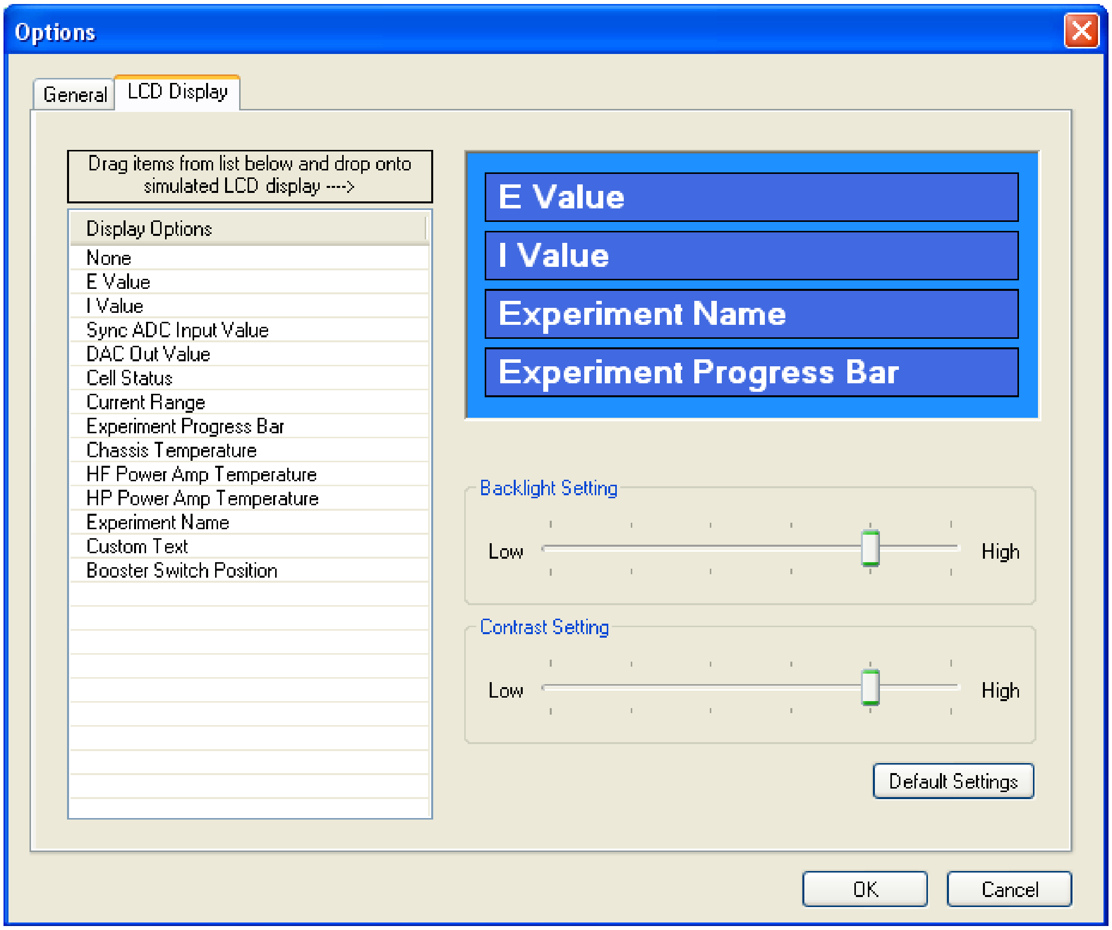
The "Notch Filter" is specific for those frequencies associated with line power (50/60Hz), and can reduce noise pick-up from power sources. The filter selection would depend on the line power frequency supplied to the VersaSTAT 3F. **Note: Notch Filters should be set to "None" if performing EIS actions**.



The "EIS Filters" are specific for those systems equipped with the FRA option to perform Electrochemical Impedance Spectroscopy (EIS), and can be used when performing EIS techniques where noise pickup from additional, grounded electrodes in the cell are degrading the EIS data. The selection of "Aggressive" should be tried first, then "More Aggressive" if needed.



4.4.2.2. LCD Display (PARSTAT 4000 Only)

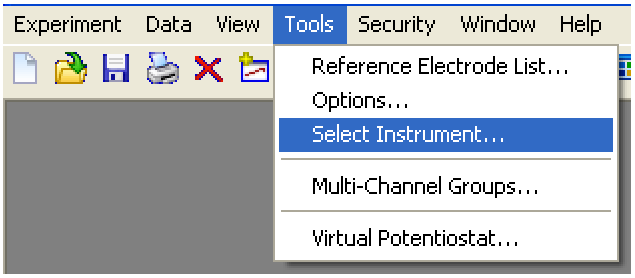


The LCD Display in the Options Menu allows for the front panel display of the PARSTAT 4000 to be customized and adjusted. Items listed in the "Display Options" box can be dragged and dropped into the simulated display to the left of it to create a custom appearance to the display with regards to what is displayed and its order (top to bottom) shown on the display. Once setup, the display will remain in this order even after cycling power on the hardware.

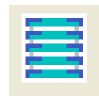
The "Display Text" option works in conjunction with the Advanced Action "Display Message" to add custom text messages to the display at any point in a sequence of actions. It could be a simple "Do Not Disturb!" message placed at the beginning to let others know that an important experiment is in progress, or it could be a series of messages placed throughout a sequence to visually note the experimental progress of a long sequence.

Other display options are present for diagnostic purposes, such as temperature of key circuits internal to the hardware.

4.4.3. Select Instrument

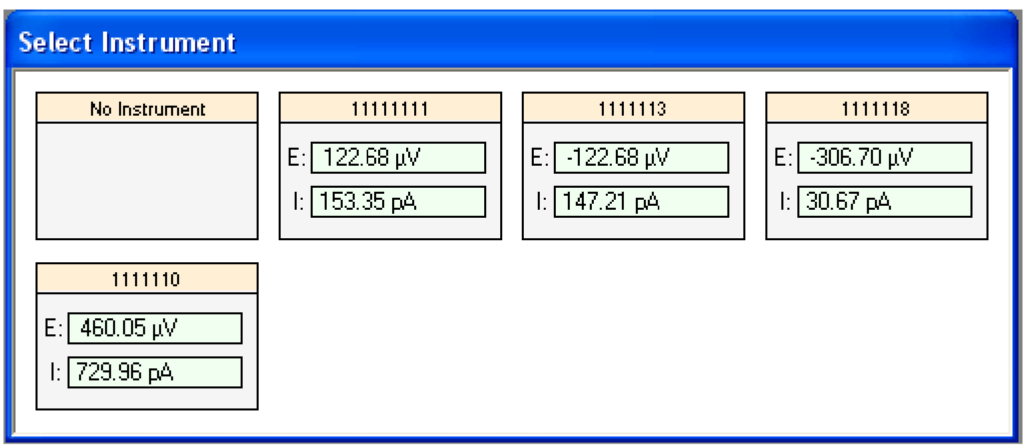


or



The "Select Instrument" option is beneficial for two functions: 1) analyzing data on the same computer while actively running an instrument and 2) performing experiments on multiple channels simultaneously**. Note: the terms "instrument" and "channel" are synonymous within this topic.**

If more than one system is connected to the same computer, or if a VersaSTAT MC is connected containing more than one channel, the "Select Instrument" window will be similar to the following 4-channel example:

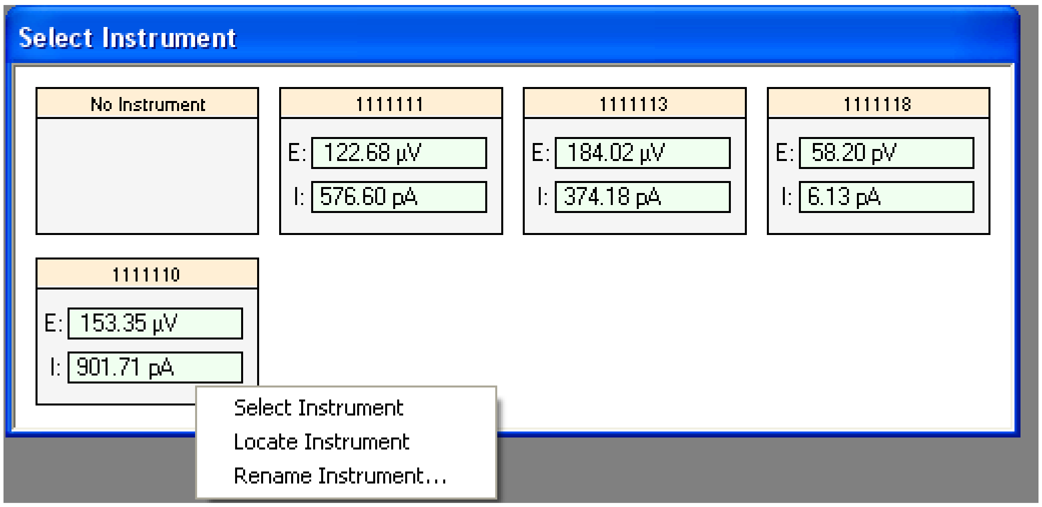


In this instance, the choices are to select either "No Instrument" or one of four connected channels. The instruments can be selected by double-clicking on the instrument of choice with the mouse pointer. **Note: This window can remain open and active for ease of selection and continuous viewing of channels actively acquiring data.**

The "**No Instrument**" option permits the opening and analysis of data files while performing experiments on other channels. As only one instance of VersaStudio can open in Windows at any given time, selecting "No Instrument" makes it possible to retrieve previously saved data files during actively running experiments without halting or interrupting those experiments.

Within VersaStudio, only one instrument (or channel) can be viewed graphically with the software at any given time. When multiple instruments (or channels) are connected to the same computer, only one can be active on the screen. With the "Select Instrument" option, it is possible to select one channel from multiple channels, set up and start an experiment on that channel, and then return to "Select Instruments" and choose a separate channel to set up and initiate an experiment on that channel as well. Up to 16 instruments can be connected and selected to run experiments simultaneously, however it is not possible to view the data collection on these channels simultaneously; viewing of the data can only be performed on one channel at any given time.

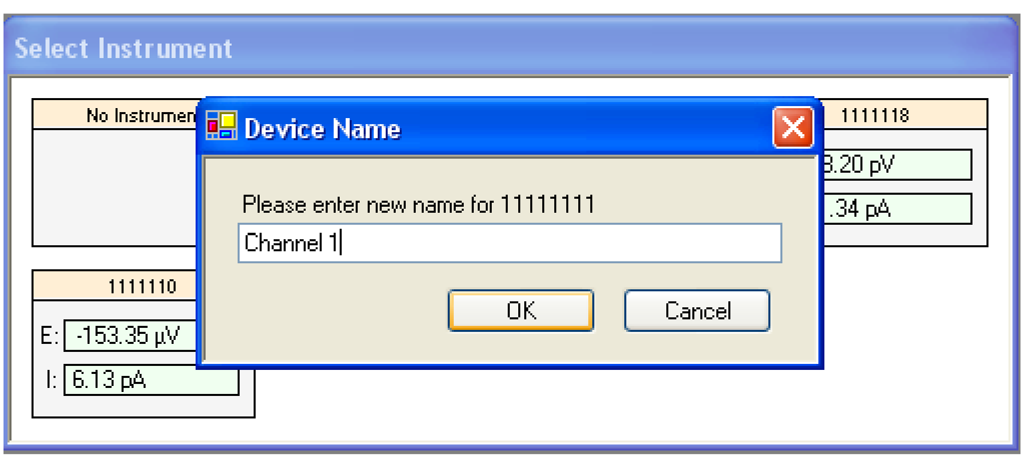
There are some additional features available on the "Select Instrument" window that can be found by placing the mouse pointer on an instrument and selecting the right-mouse button to reveal the options shown below:



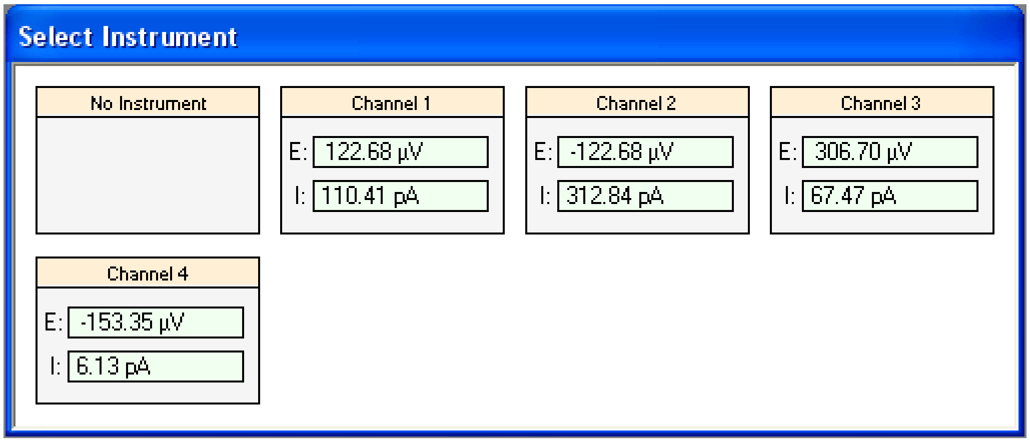
The "**Select Instrument**" option is the same as simply double-clicking on the instrument of choice to select it to be the active instrument.

The "**Locate Instrument**" feature is used to help determine which instrument is being selected. If one has forgotten the serial number or ID of a particular instrument, using the "Locate Instrument" will cause the "Ovl" LED on the front panel of that channel to flash for a few seconds enabling the user to know precisely which channel is being selected.

Every channel is serialized, and the serial number is the default identifier for each channel. However, it is possible to change ID of the channels using the "**Rename Instrument…**" option. For example, in the case of a 4-channel VersaSTAT MC, it may be desirable to rename the channels according to their order in the chassis.

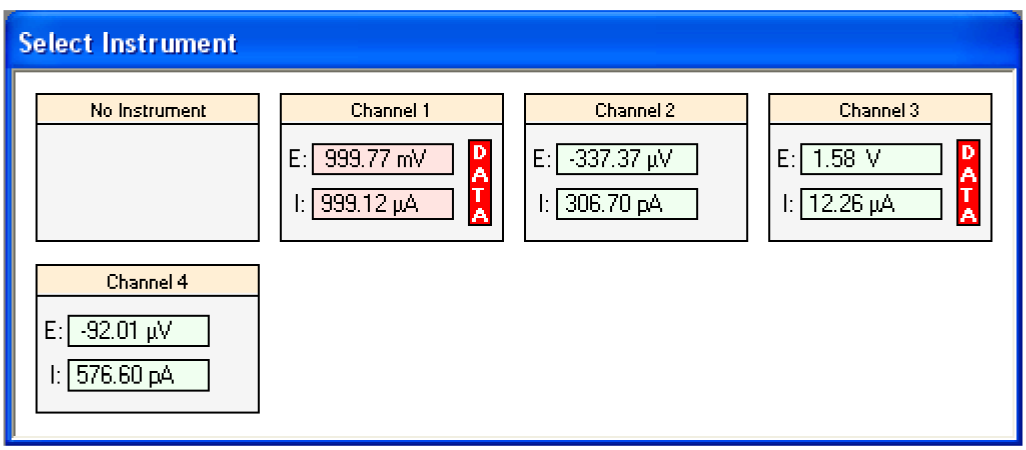


This process can be carried out on all four channels such that the window for “Select Instrument” appears as below:

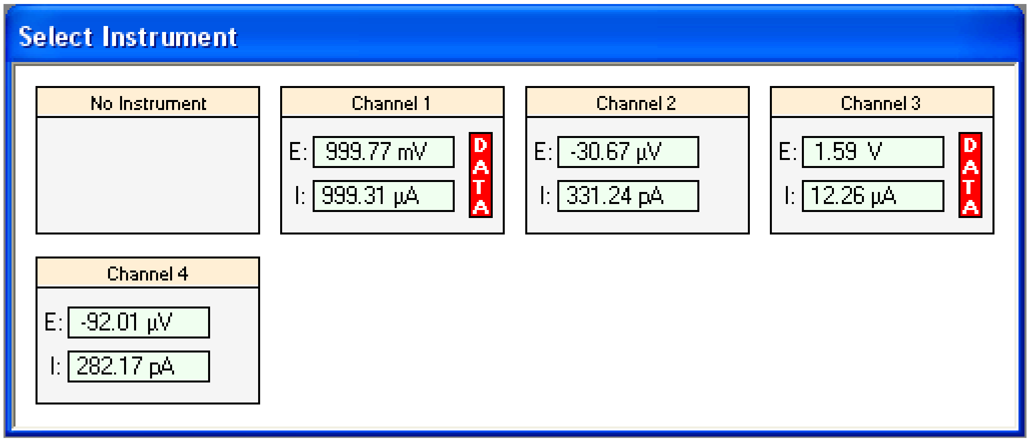


Note: The default serial number for each channel can always be obtained from the rear panel of the instrument if needed, or viewed in the software by returning to “Rename Instrument…” where it will always be shown above the line where the new name is entered.

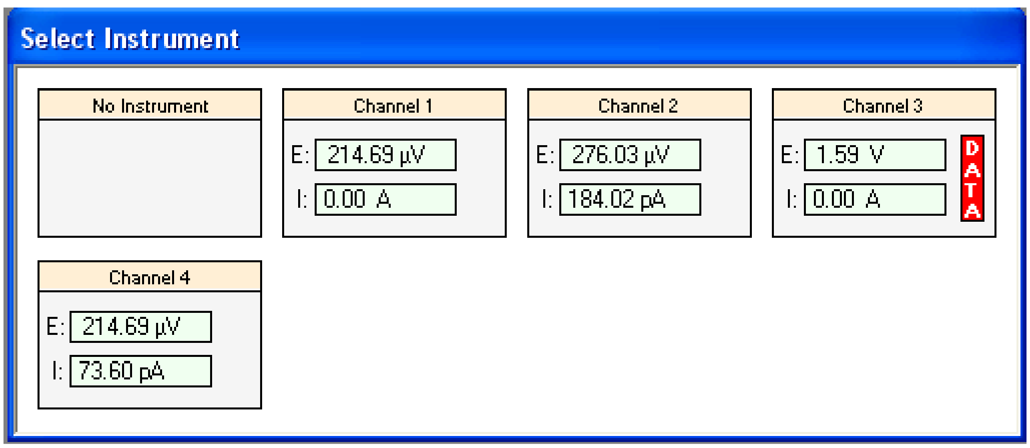
Example:
Shown below is the “Select Instrument” window with two experiments in progress: Channel 1 is running a Chronoamperometry experiment (1V applied to the internal 1Kohm dummy cell), while Channel 3 is running a Open circuit experiment.



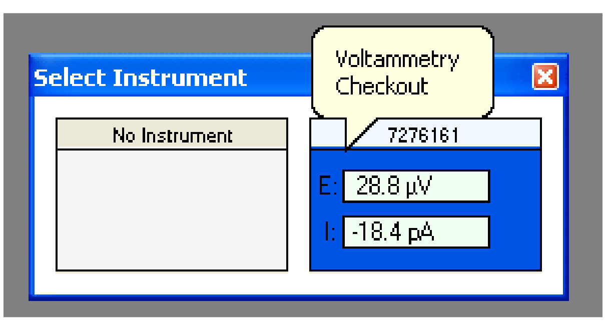
Both Channels have the tag “DATA” associated with them indicating that these channels are running an experiment, collecting data and storing it into the channels’ buffers. Also note that Channel 1 is “red” for the E and I values; this is indicating that the cell is on and the system is applying voltage to the cell. Channel 3 is not red, indicating that the cell is not on, which is precisely as it should be for an open circuit experiment. Either of the channels can be selected and their data transferred to the computer at any point.

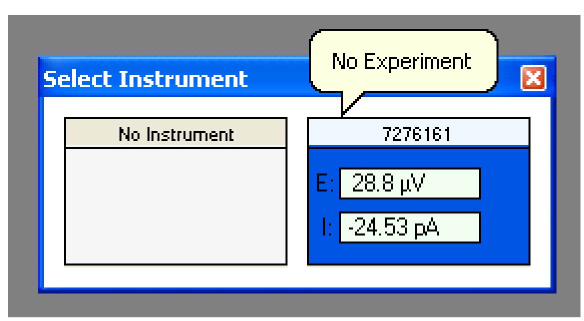


In the window above, both Channel 1 and Channel 3 still have "DATA" present, but the cell is no longer on at Channel 1 (E and I no longer "red"), indicating that the Chronoamperometry experiment has ended. The I and E indicators will remain at the values of the last point acquired until that channel is selected to transfer the data to the computer.



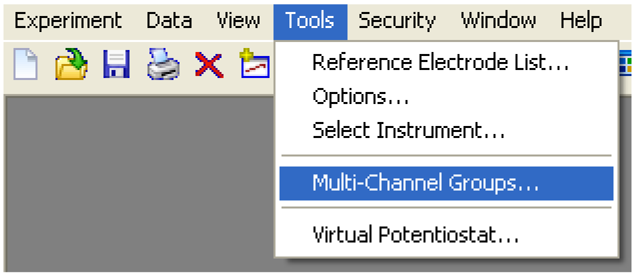
In the window above, Channel 1 has been selected and its data transferred to the computer and saved as noted by the absence of the "DATA" indicator. Channel 3 still has the "DATA" indicator present, and needs to be selected to transfer its data to the computer before powering off the hardware.



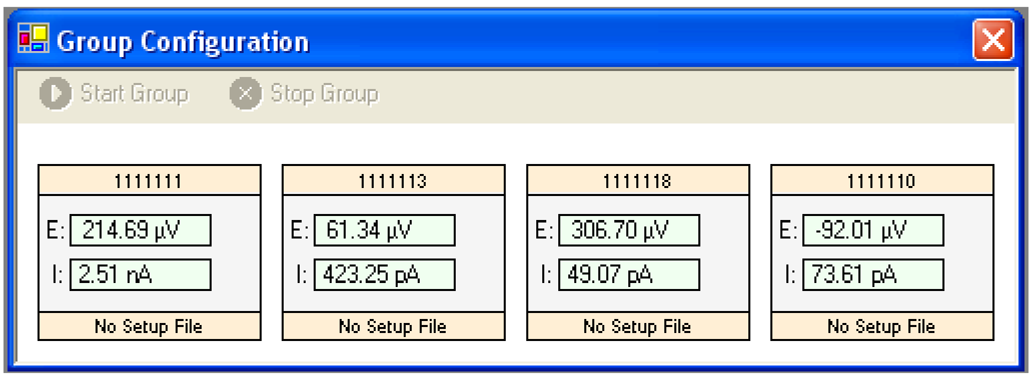


Using the mouse pointer to hover over the channel will cause a "bubble message" to appear (as shown above) that contains the name of the experiment currently active for that channel. The message "No Experiment" will appear if no data set is currently associated with a channel.

4.4.4. Multi-Channel Groups

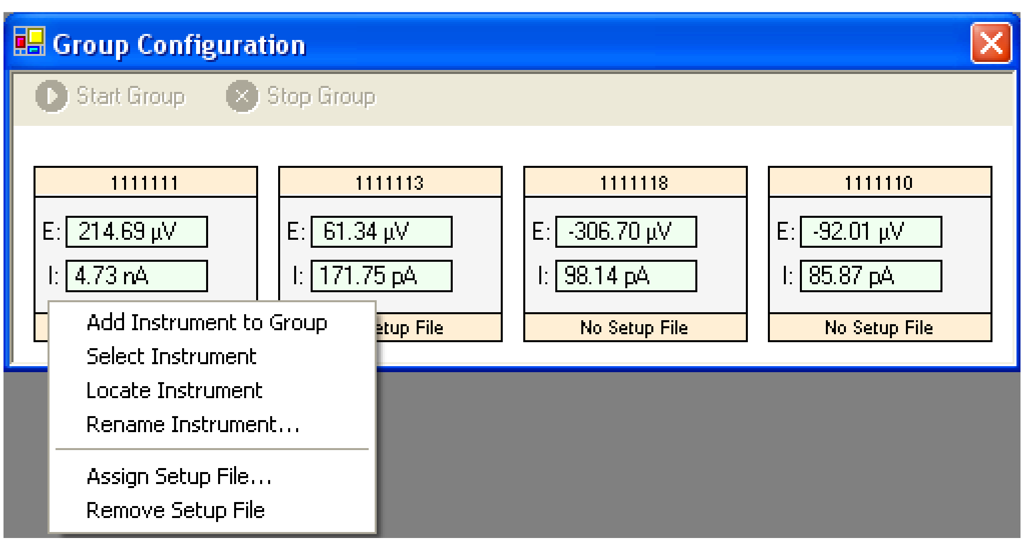


It is possible within VersaStudio to select and start experiments on multiple channels simultaneously. This option is available with "**Multi-Channel Groups…**" in the "Tools" menu. When selected initially, the window will appear as shown below:

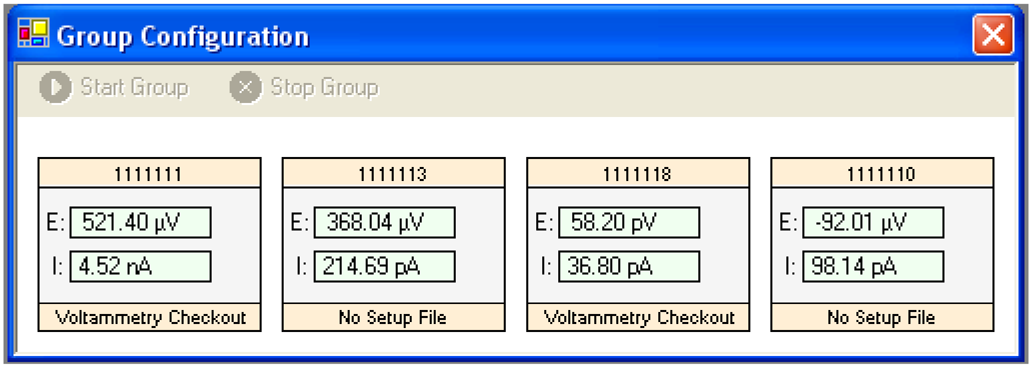


To start a group of channels simultaneously, the first step is to assign the setup file(s) to the desired channels. **Note: Any previously saved experiment (*.par file) can be used as a setup that file.** To assign a setup file, right-mouse-click on one of the channel selections and select "Assign Setup File…" as shown below:

.

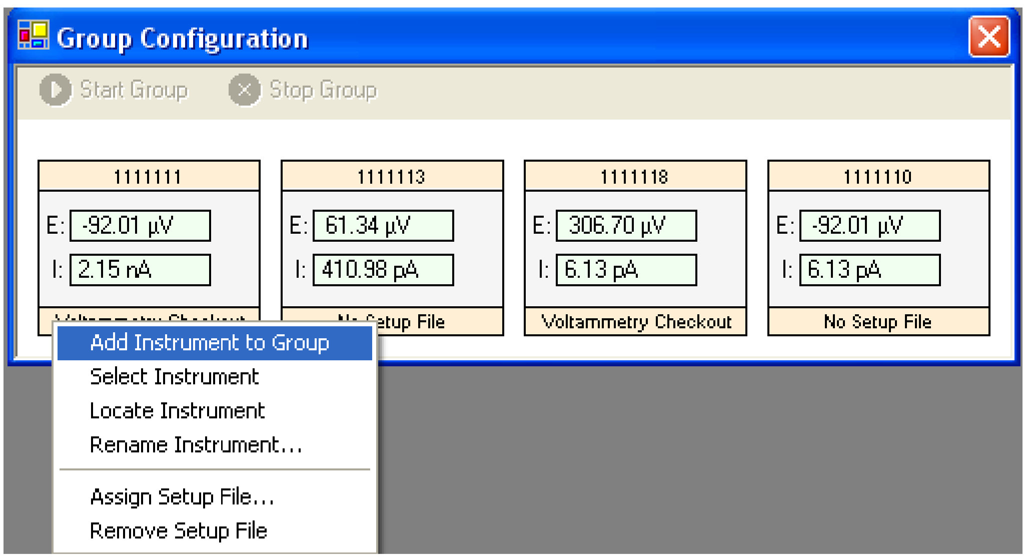


A selection from the existing *.par files can be made. In this example, the "Voltammetry Checkout.par" file (used in section 3.2) will be selected for channels 1 and 3 as shown below:

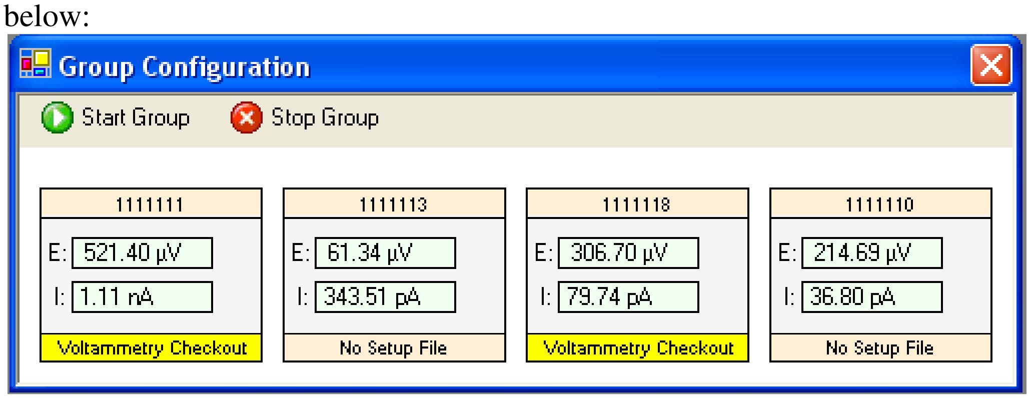


Note: The setup files do not have to be the same for all channels. In fact, each channel can be assigned a different setup file for simultaneous start if desired.

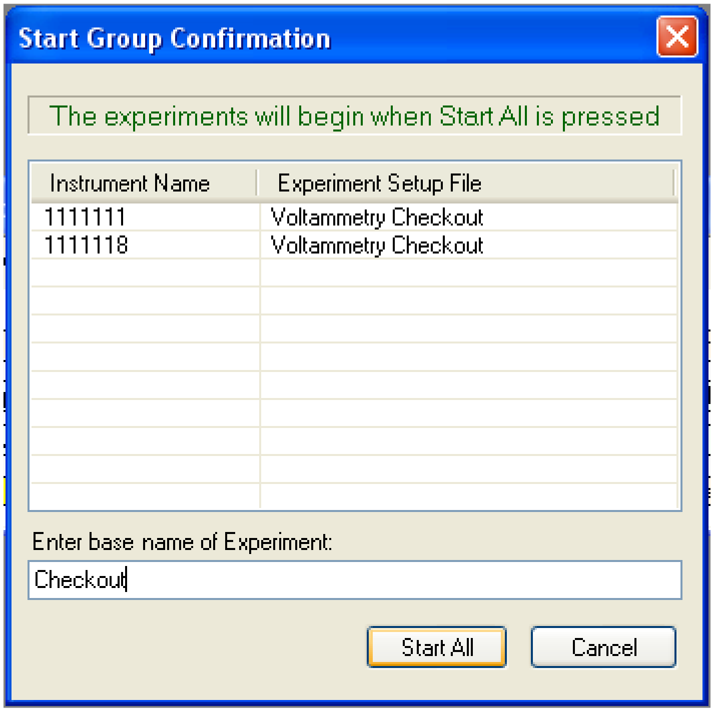
Once the setup files are assigned, right-mouse-click on those channels again and select "**Add Instrument to Group**"



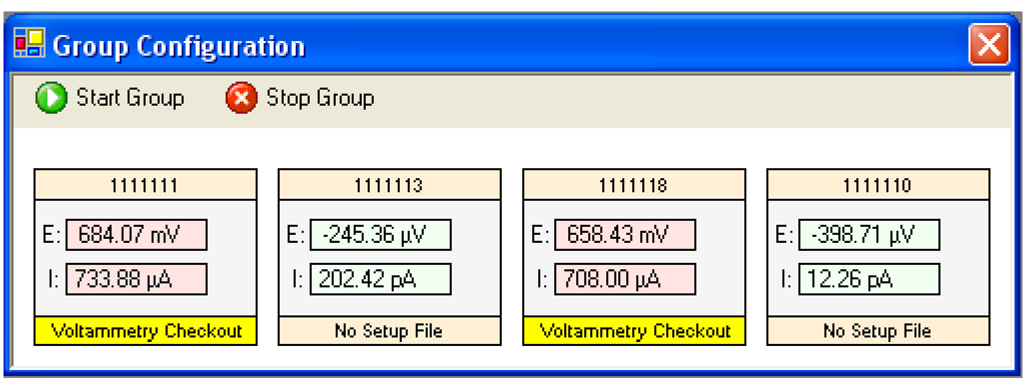
Once both channels have been selected, the field containing the setup name will be highlighted yellow, and both the "**Start Group**" and "**Stop Group**" functions become active as shown below:



Pressing the "Start Group" button brings up the window (shown below) to confirm the instruments and setup files, as well as assign a unique base name for the data files. Note: The resulting data files will be named "basename_channelname". In this example, the two resulting data files will be called "Checkout_1111111" and "Checkout_1111118."



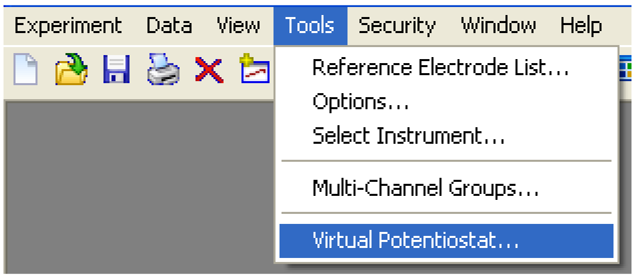
To start the experiments, press "**Start All**." The experiment will then start on both channels and return to the "Group Configuration" window. The two channels that are acquiring data will now have their E and I readings highlighted "red" to indicate that the cell is on and acquiring data as shown below.



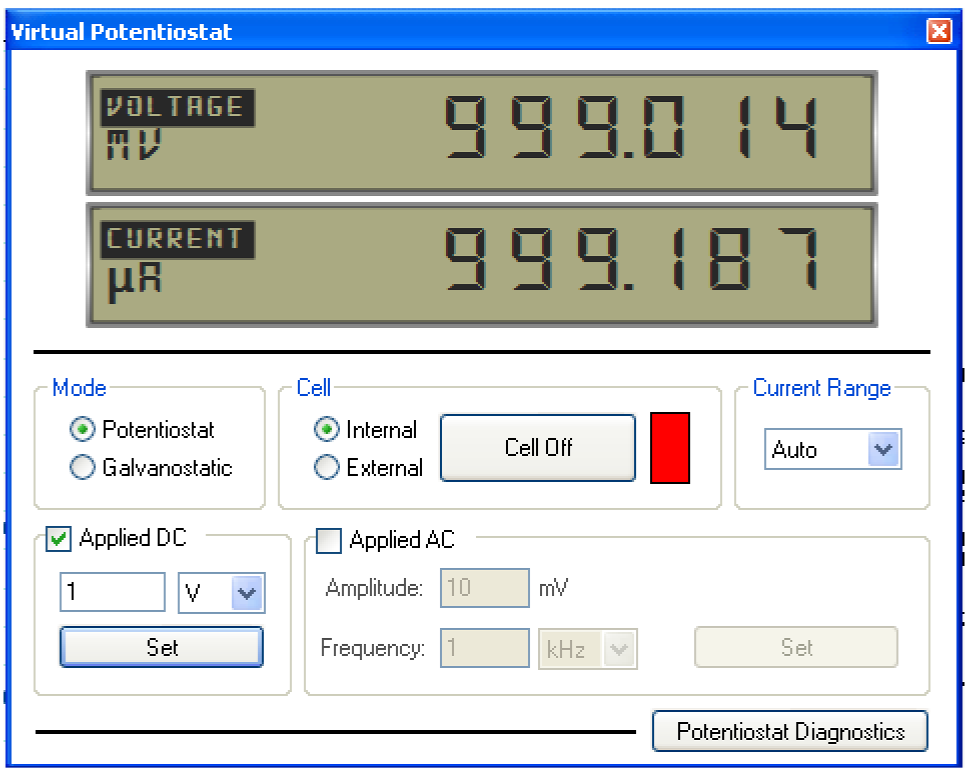
To view and download the data, close the "Group Configuration" window, and use "Select Instrument" option (previous section, 4.4.3) to toggle between the different channels. Once again, only one channel at a timer can be active and downloading the data from the channel to the computer. The remaining channels that are actively running are storing their data into the channel's buffer until selected by the user, at which point the data will be transferred to the computer for collection and viewing.

Note: It is advised to close the "Group Configuration" window after making any changes (by selecting the "X" to close the window or selecting a channel), and use the "Select Instrument" option to switch between the different channels for viewing data.

4.4.5. Virtual Potentiostat

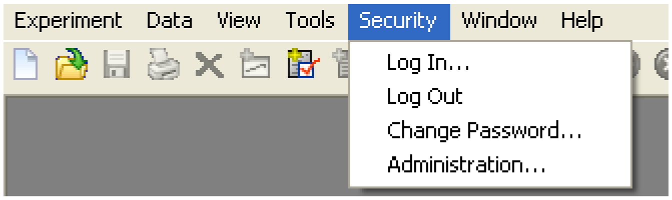


The Virtual Potentiostat provides an interface to basic controls that are useful for applying either a DC potential or current without running an actual experiment. A "meter reading" provides the voltage and current readings real-time.



In the screen shot above, a 1V potential is being applied to the internal DC dummy cell (1Kohm resistor). The Virtual Potentiostat can also be used to check internal voltages (Potentiostat Diagnostics button) of the circuit board to insure that they are operating within proper range.

4.5. Security



4.5.1. Log In, Log Out

Both **Log In** and **Log Out** open the **Log Into VersaStudio** window. **Log In** automatically logs out the previous user and logs in the present user. **Log Out** logs out the previous user.

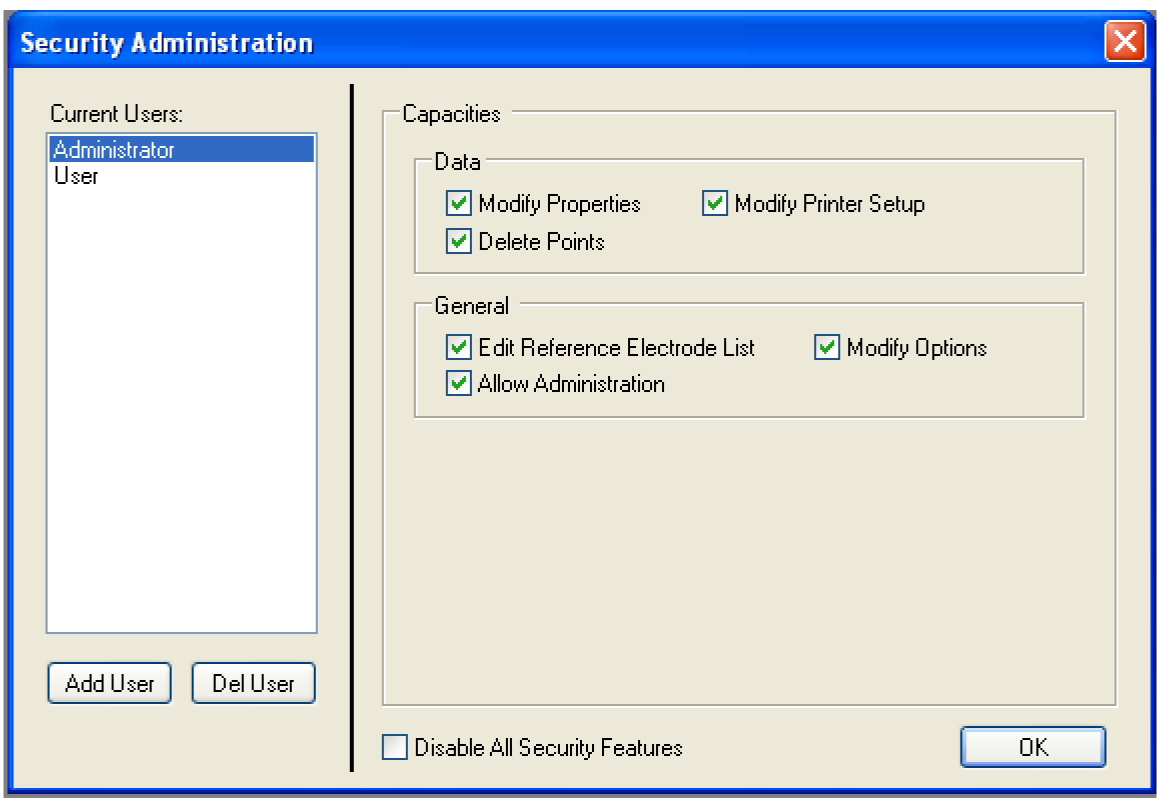
Note: The default password for "Administrator" is the word "administrator."

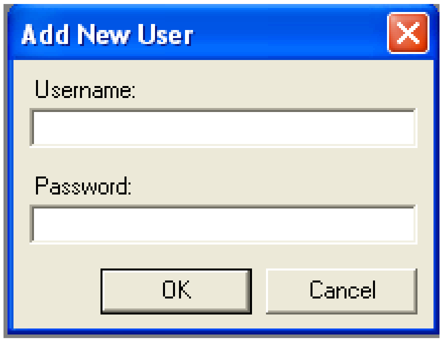
4.5.2. Change Password

Passwords can be changed by entering both the old password and a new password.

4.5.3. Administration

The administrator can apply restrictions for a given user by checking the applicable boxes in this window. When the **Disable All Security Features** box is checked, any user is able to perform any function in the VersaStudio software. Unchecking the box enables the administration restrictions to take effect.





4.5.3.1. Functions

Data

Modify Properties

Checking this box makes the user unable to change the properties set up for a given experiment.

Modify Printer Setup

Checking this box makes the user unable to change the template that is set up for printing.

Delete Points

Checking this box makes the user unable to delete data from experiments.

General

Edit Reference Electrode List

Checking this box makes the user unable to change the list of electrodes.

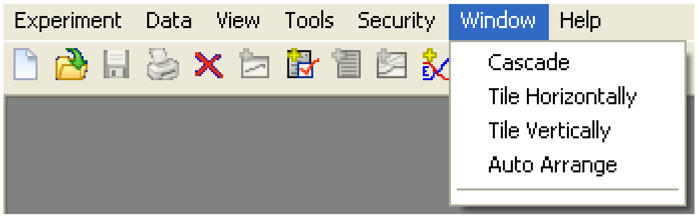
Modify Options

Checking this box makes the user unable to change the options window for the data information hover box

Allow Administration

Checking this box makes the user unable to make changes in administration functions.

4.6. Window



4.6.1. Cascade

Cascade causes all open windows to overlap from the top left to the bottom right.

4.6.2. Tile Horizontally

Tile Horizontally causes all open windows overlap in a horizontal direction.

4.6.3. Tile Vertically

Tile Vertically causes all open windows overlap in a vertical direction.

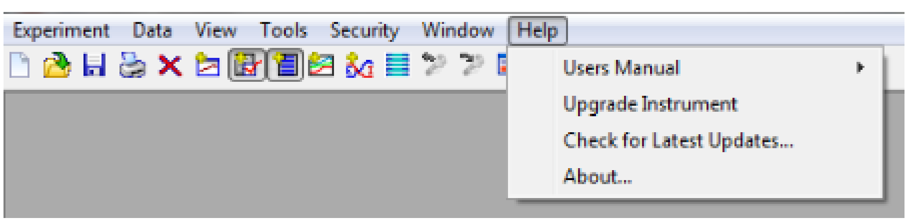
4.6.4. Auto Alignment

Auto Alignment causes all open windows are sized to fit the available area, in a layout preferred for electrochemical experiments.

4.6.5. Open Experiments

The graphs of the experiment that is open are listed below the line. Clicking on one makes it the active window.

4.7. Help

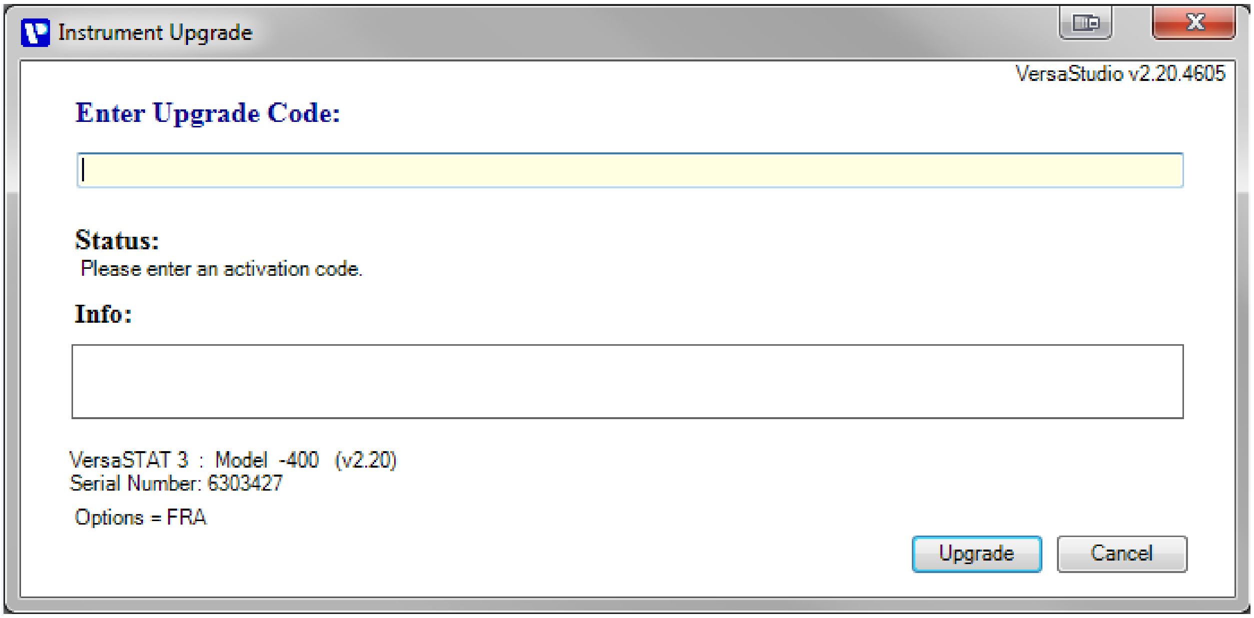


4.7.1. Users Manual

Online manual - Clicking on this opens a printable .pdf file.

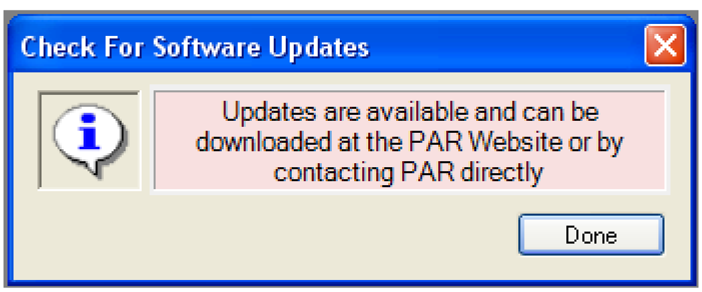
4.7.2. Upgrade Instrument

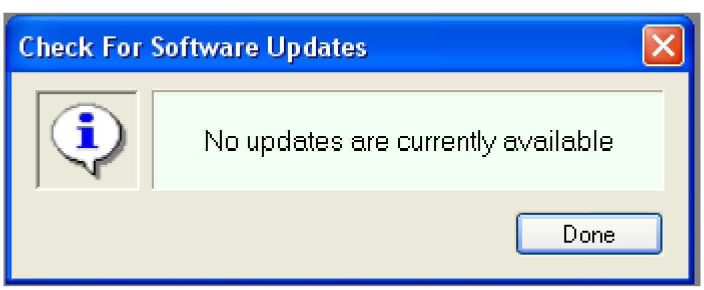
To upgrade an instrument in the field, acquire an upgrade code from the factory, enter that code into the “Enter Upgrade Code:” field, then press the “Upgrade” button. Once the Upgrade button is pressed it could take up to 5 seconds to complete.



4.7.3. Check for Latest Updates

VersaStudio will search a website (Note: PC must have internet access) which will compare the current version to what is currently running on the computer. The two possible responses are:





4.7.4. About

The software version number, Model, firmware (in brackets), Options, and link to the Princeton Applied Research web site are all listed in the **About** window.


About
Princeton Applied Research
AMETEK
VersaStudio v1.26.3244
Copyright 2008 All Rights Reserved
VersaSTAT 3 : Model -400 (v1.26)
Options = FRA
VersaSTAT 3
Visit us on the Web

Appendix 1.

Glossary of Experiment Properties

Acquire at Hold – Enables/disables data collection during a vertex delay.

Acquisition Mode – The mode used to collect a single data point. The setting "Average" acquires as many points as possible (at 10us) over the time per point or step time, and reports a single average of all the point collected over the last 50% of that time. For a 1ms time per point, that would equal 50 point. For step times greater than 1ms, the points are divided such that never more than 50 points are averaged for a single reported point. The setting "4/4" only collects and reports a single value sampled at the end of each time per point or step time. The setting of "Auto" selects either average or 4/4, depending on the preferred method for a given technique. The setting of "None" collects no data points at all during the experiment.

Amplitude (mA RMS) - The sine wave (ac) amplitude for galvanostatic EIS experiments. The maximum amplitude is 200mA rms.

Amplitude (mV RMS) – The sine wave (ac) amplitude for potentiostatic EIS experiments. The range is 0.1mV to 1.0V rms amplitude.

Anodic Max (V) – The ending voltage in the Split LPR action's final scan from open circuit to the maximum desired anodic voltage.

Apply Potential Change Now – Allows for the potential to be changed during the course of an experiment. Useful for performing ASTM-F746 experiments.

Bandwidth Limit – A range of damping filters within the control loop of the potentiostat that can help prevent oscillations when performing experiments on cells with high capacitance. The number and range of available bandwidth filters is dependent on the hardware model.

Cathodic Max (V) – The ending voltage in the Split LPR action's initial scan from open circuit to the maximum desired cathodic voltage.

Cell to Use – The VersaSTATs and PARSTAT 4000 have an internal 1000 ohm "dummy cell" that can be accessed by selecting "Internal" as the cell to use. This dummy cell is provided as a diagnostic tool to perform system checks on the instrument, and for training exercises. The "External" setting uses the cell that is connected at the cell leads.

Comments/Notes – Section where remarks describing the experiment or cell may be recorded.

Current (A) – The current magnitude to be applied for the duration of the step or pulse. **Note: For galvanostatic experiments, the units for the applied current can be changed by clicking on the "Current (A)" box in the Properties setup window.**

Current Range – Determines the maximum amount of current (I) that can be measured in the experiment. Selection of "Auto" results in the range(s) being automatically selected during the experiment that provides the best accuracy and resolution without exceeding a range magnitude. NOTE: With "Auto" selected, range changes utilize relays that do take a finite interval to change. If performing fast pulse/step experiments or scans greater than 20mV/s, range changes can introduce spikes (especially on capacitive cells) into the data. For that reason, it is strongly recommended that a set current range be used under these circumstances, and that the "Auto" feature only be used for these experiments to initially determine the proper range to set.

> **CAUTION: If your cell is an energy storage and/or energy producing cell (such as battery, fuel cell, or super capacitor), it is recommended that experiments be conducted set to the highest current rage (2A) first, and lower ranges used if determined acceptable to do so. The "Auto" setting should be avoided if possible to prevent excessive overloads on lower current ranges that could stress and ultimately damage the system.**

Cycles – Controls the number of cycles between the vertex potentials for cyclic voltammetry experiments.

Data Quality – A variable in both Potentiostatic and Galvanostatic EIS actions related to post-FFT data collection and averaging for improved data quality. The value entered is equal to the number of full cycles that will be collected and averaged. A setting of 3 would equal data collection on three full cycles and the average results reported. Note: increasing this variable directly increases the total experiment time; setting it to 3 triples the total time vs. setting of 1.

Delta E (mV) – A voltage setting by which the measurement must change from the previous measurement in order for that data point to be saved. This is generally used to reduce data points collected to only those points considered significant by the user. The rate at which data can be measured using this variable is determined by the Time Per Point and Delta Resolution variables, but can be no faster than the minimum acquisition rate of the hardware.

Delta I (mA) – A current setting by which the measurement must change from the previous measurement in order for that data point to be saved. This is generally used to reduce data points collected to only those points considered significant by the user. The rate at which data can be measured using this variable is determined by the Time Per Point and Delta Resolution variables, but can be no faster than the minimum acquisition rate of the hardware.

Delta Q (mQ or mAh) – A charge setting by which the measurement must change from the previous measurement in order for that data point to be saved. This is generally used to reduce data points collected to only those points considered significant by the user. The rate at which data can be measured using this variable is determined by the Time Per Point and Delta Resolution variables, but can be no faster than the minimum acquisition rate of the hardware.

Delta Resolution – A time variable that is used to set the number of samples taken between the time per point variable when either Delta I, Delta E, or Delta Q are utilized for data acquisition rates. For example, with a time per point of 1s and a Delta Resolution of 10, the data is sampled every 100ms (1s/10) to determine if the variable of interest has changed sufficiently to be recorded and saved as a way to reduce data points collected to only those points considered significant by the user.

Dispense – A TTL signal sent via the Auxiliary Interface (pin 3) to the Model 507 for dispensing/dislodging a mercury drop from the Model 303A SMDE.

Drift Rate (mV/min) – The minimum change in OCV allowed before ending the duration of an open circuit action earlier than the set duration.

Duration (s) – The time span of the applied potential, current, or open circuit measurement from beginning to end.

E Filter – Potential channel filter which reduce the effects of high frequency noise. The available filters depends on the hardware model.

E Resolution – Provides superior voltage measurement resolution when set to “High” in the Open Circuit action if oc is within +/-100mV vs Ref.

Electrometer Mode – The electrometer can be set to either Single-ended or Differential. For the most accurate measurements at 200mA and higher, Differential is the preferred setting, as this eliminates error associated with impedances on the working electrode lead. Single-ended is the most stable configuration, and is particularly useful for corrosion experiments and highly capacitive cells where oscillations can be an issue. **Note: Any 4-terminal (4 electrode) cell or connections require the Electrometer Mode = Differential for correct voltage readings.**

End Frequency (Hz) – The final frequency in an EIS experiment. If the End frequency is different from the Start frequency, a frequency sweep will occur with EIS data points collected at frequency intervals dependent on points and spacing variables.

Final Current (mA) – The current that is applied at the end of a scanning current experiment.

Final Potential (V) - The voltage that is applied at the end of the experiment, either versus the reference (absolute) or versus the open circuit (relative to oc).

Frequency (Hz) – The total period for one cycle of P1 and P2 conditioning potentials to be applied.

Frequency List – A visual display of the frequency points calculated from the frequency range and point spacing selected. If the Start and End frequencies are set to the same frequency, EIS data will be taken at that single frequency for the total number of points selected.

I Filter – Current channel filters which reduce the affects of high frequency noise. The available filters depends on the hardware model.

Initial Current (mA) – The current that is applied at the start of a scanning current experiment.

Initial Potential (V) – The voltage that is applied at the start of scanning potential experiment, either versus the reference (absolute) or versus the open circuit (relative to oc).

iR Compensation (ohms) – Enabled to compensate for the uncompensated resistance between the reference electrode and working electrode in cells where the solution resistance is large, or where the current magnitude may be high in order to apply the potential more accurately to that which is being requested. This property is technique dependent as follows:

For Voltammetry Actions: This parameter allows the user to enter an estimate for the uncompensated resistance between the reference electrode and working electrode. This feature can only be activated and used when running on a set current range. The uncompensated resistance couples with the cell current to introduce a potential error (drop) which prevents the working electrode potential from assuming the programmed value. The value entered for this parameter is used to adjust the applied potential to compensate for this error. The iR Determination action can be used to estimate the uncompensated resistance for the user, and entered automatically ("Use Previous" option) if placed together in a sequence, or it can be entered manually ("User Defined-ohms"). Caution: if the value entered is at or over the true uncompensated level, the entire system may oscillate. In case of oscillation, reduce the ohms to a lower percentage of the previous level (for example, 90%), and try that magnitude.

Note that the range of the resistance that can be compensated and its resolution is directly related to the current range. Below is a table of the maximum resistance and resolution for each current range:

CR	Max Resistance	Resolution
2A	5 ohms	1.22 mohms
200mA	50 ohms	12.2 mohms
20mA	500 ohms	122 mohms
2mA	5k ohms	1.22 ohms
200uA	50k ohms	12.2 ohms
20uA	500k ohms	122 ohms
2uA	5M ohms	1.22k ohms
200nA	50M ohms	12.2k ohms

For Corrosion Actions : The uncompensated resistance is determined during the scan via a pulsing routine, and the amount of correction needed is calculated and applied automatically. The system can be set to Auto current range for this compensation, but the **Step Time must be greater than or equal to 2 seconds**, which limits this compensation method to slower scan rates typical of corrosion experiments.

Note: When performing techniques with iR Compensation enabled, the preferred plot for potential is "Applied Potential" so as to not include the added compensation potential into the graph.

LCI Bandwidth Limit – A range of damping filters (Normal, Slow, and Very Slow) within the control loop of the VersaSTAT LC Low Current Interface that can help prevent oscillations when performing experiments on cells with high capacitance. There is no recommended setting other than Auto (which is "Normal"), and if oscillations occur, try stepping to "Slow" first, then "Very Slow" as a last resort.

Limits (Voltage, Current, Charge, and Aux Input) – Voltage, current, charge, and AUX Input (V) limits can be set for most dc-based Technique Actions. Once a limit is reached, that action is halted and proceeds to the next action (if listed). For a multi-action sequence, or an action with multiple segments (for example, CV or RPP) voltage and/or current limits can be set in the Common section of the sequence, and if reached, the entire sequence (or segments) will halt. The limits in the Common action are generally used as "safety limits."

Note: As of this software version, the "Limit" should not be used during an action where the Acquisition Mode = Average (or Auto) on Corrosion actions. Doing so will alter the data and segment association. To use the "Limits" in a corrosion action, set the Acquisition Mode = 4/4.

Limit |I| (mA) – An absolute current limit not to be exceeded when running certain actions, such as Constant Power.

Leave Cell ON – At the end of an experiment, it is normal for the cell to be turned off (Leave cell on = No). However, if the experiment is one part of a sequence that is to be carried out, it may be desirable to have the cell remain "on" as it proceeds to the next experiment. Note: In a sequence of experiments (actions), the cell will always be turned off at the end of the sequence regardless of the "Leave Cell On" setting.
Warning: Leaving the cell "ON" between certain actions can result in significant voltage and current spikes directly to the cell. Please avoid leaving the cell "ON" between the following actions:

1. Between any potentiostatic and galvanostatic action. Switching modes (pstat/gstat) with the cell on can result in spikes to the attached cell.
2. Between any EIS action and DC action. Switching modes (ac/dc) with the cell on can result in spikes to the attached cell.
3. Between any two galvanostatic actions that operate on different current ranges. Switching current ranges with the cell on in gstat mode can result in spikes to the attached cell.

Measurement Delay – A delay between each frequency measurement and between every current range change. This is useful for allowing cell to settle after current range changes, and for controlling the acquisition rate in single frequency vs. time EIS experiments.

Message – Inserts a pause in the sequence of actions to alert the user to perform a manual action before proceeding to the next action in the sequence.

Number of Iterations – The number of cycles that will occur for each action listed in a loop.
PFIR –Enables/disables the Positive Feedback IR compensation mode which, when enabled, minimizes applied voltage errors due to high resistances between the working and reference electrodes in an electrochemical cell.

Number of Segments – The total number of data blocks desired for an electrochemical noise experiment.

Point Spacing – Defines the point spacing for a frequency sweep as either linear spacing, or logarithmic spacing (points per decade).

Points Per Cycle – Total number of data points collected in a single cycle of a CV experiment.

Potential (V) – The voltage magnitude to be applied for the duration of the step or pulse.

Potential P1 (V) – The first potential setting for a pulse conditioning setup.

Potential P2 (V) - The second potential setting for a pulse conditioning setup.

Power (W) - The power magnitude to be applied for the duration of the experiment, either using a charging current or a discharging current.

Pre-Elect (s) – The pre-electrolysis setting in the chronocoulometry action is provided to electrolyze the solvent before the experiment starts and before the sample of interest is added. If the Pre-Elect(s) is utilized, an average current reading is taken at the end of the pre-electrolysis time, and that average current reading is subtracted from all subsequent readings during the normal duration of the experiment, thus providing net charge minus the solvent background.

Pulse Height – Amplitude of pulse in SWV or DPV pulse train.

Pulse Width – Duration of pulse in DPV, NPC, and RNPV.

Pulsing Voltage – Oscillating DC voltage applied to the cell during a conditioning period.

Purge – Sends a TTL logic signal from pin 8 of the Auxiliary Interface connector to activate the purge for A Model 507 or Model 325 Faraday Cage.

RDE Speed (Volts) – Controls the rotational speed of a rotating disk electrode (RDE), provided the DAC Output at the rear panel is connected to the rotating input control of the RDE itself.

Reference Electrode – Section for recording the type of reference electrode used in the experiment, along with its potential versus Normal Hydrogen Electrode (NHE).

Rest Duration (s) – The duration of open circuit following cathodic scan of the Split LPR action to allow the sample the opportunity to settle back to OCV.

Rest Drift Rate (mV/min) – The minimum drift rate of open circuit following cathodic scan of the Split LPR action to allow the sample the opportunity to settle back to OCV. If set and achieved before duration is reached, the anodic scan will start.

Resistance (ohms) – The resistance magnitude (or load) to be applied for the duration of the Constant Resistance experiment.

Scan Rate (mV/s) – The rate of change in a scanning potential or scanning current experiment. The scan rate is the step height (mV) divided by the step time (s).

Start Frequency (Hz) – The beginning frequency in an EIS experiment.

Segment Duration (s) – The duration in time of a block of data acquired in electrochemical noise action. Each block can be plotted with I RMS or E RMS versus total time.

Start Level (V) – The voltage setting which must be reached before the system will begin monitoring the threshold current. Prevents premature reversal of a CP scan at a passive or cathodic region where the current might exceed that of the threshold.

Static Voltage – Constant DC voltage applied to the cell during a conditioning period.

Step Height (mA) -– Determines the magnitude of the current change between two data points in a scanning current experiment.

Step Height (mV) – Determines the magnitude of the potential change between two data points in a scanning potential experiment.

Step Time (s) – Determines the period of time each step height is applied in a scanning potential or scanning current experiment.

Step Width (s) – Duration of the total cycle for noth forward and reverse pulses in DPV, NPV, and RNPV.

Stir – Sends a TTL logic signal from pin 9 of the Auxiliary Interface connector to activate the stirrer for A Model 507 or Model 325 Faraday Cage.

Threshold – Enables/disables the threshold current.

Threshold (mA) - The current (I) magnitude at which the scan will reverse back towards the final potential in the cyclic polarization experiment.

Time Per Point (s) – The period of time between the sampling of two data points.

Total Points – The total number of data points collected for the duration of the experiment. It is recommended that each experiment be limited to no more than 1 million points. Experiments with data points in excess of 1 million are at risk of slowing down the system to a level such that lock-ups of the system and loss of data is possible.

Trigger In – Delays the start of an experiment in a sequence until a TTL signal is received at the appropriate pin in the Auxiliary Interface.

Trigger Out – Issues a TTL signal to another device connected at the appropriate pin in the Auxiliary Interface.

Vertex (1 & 2)Potential (V) – The vertex potential is the ending potential of the first segment of a cyclic voltammetry experiment. For a multi-cycle CV, the scan cycles alternate between the Vertex 1 and Vertex 2 potentials.

Vertex Hold – The delay interval between the segments of a cyclic voltammetry experiment.

Vs Ref – A voltage setting relative to the reference electrode; the absolute value setting.

Vs OC – A voltage setting relative to the open circuit (oc) potential.

Vs Previous – Used in controlled potential experiments to set the potential relative to the last measured potential in a prior action.

Working Electrode Area (cm2) – Section for recording the working electrode area, used to graph current per unit area, and in corrosion rate calculations.

Working Electrode Type – Section for recording the type of working electrode used in the experiment.

Appendix 2.

Glossary of Axis Graph Options

Point – Useful for plotting multi-sequences linearly on a plot when elapsed time is different for each sequence.

Potential (V) – The measured DC voltage in volts for a given set of data.

Current (A) - The measured DC current in amps for a given set of data.

Elapsed Time (s) – The duration of a given experiment, including all sequences.

Charge (C) – The charge in coulombs for a given set of data.

Sync ADC Input (V) – The voltage readings in volts for data collected during an experiment at the SYNC ADC INPUT at the rear panel of the hardware.

I Range (A) – The hardware current range on which the current measurements were made during an experiment.

Forward I (A) – The DC current reading in amps of the forward going pulse in a pulse voltammetry experiment, such as SWV, DPV, or NPV. The current reading is taken at the end of each pulse.

Reverse I (A) - The DC current reading in amps of the reverse going pulse in a pulse voltammetry experiment, such as SWV, DPV, or NPV. The current reading is taken at the end of each pulse.

Delta I (F-R) (A) – The differential DC current reading in amps with the reverse pulse reading subtracted from the forward pulse reading providing the differential output. This plot is used for the pulse voltammetry techniques SWV, DPV, and NPV.

Delta I (R-F) (A) – The differential DC current reading in amps with the forward pulse reading subtracted from the reverse pulse reading providing the differential output. This plot is used for the pulse voltammetry technique Reverse Normal Pulse Voltammetry (RNPV).

Applied Voltage (V) – The control voltage requested between the reference and working-sense electrodes. This should be plotted alternatively to Potential (V) when using iR Compensation, as the Potential (V) graph is the measured potential which will include additional compensation potential.

Corrosion Rate (mpy) – When graphed in a multi-sequence LPR experiment (single LPR with Loop, or multiple LPR sequence), the corrosion rate is automatically calculated for each LPR scan, and plotted, generally vs. Segment or Elapsed Time. For correct corrosion rate calculations, the area, density, and equivalent weight should be entered in the Common section of the sequence during experimental setup.

Frequency (Hz) – The AC frequency of a voltage or current variable in an impedance experiment.

SQRT Frequency (Hz) – The square root of the AC frequency of a voltage or current variable in an impedance experiment.

1/ SQRT Frequency (Hz) – The reciprocal of the square root of the AC frequency of a voltage or current variable in an impedance experiment

|Z| (ohms) – The magnitude of the impedance, Z, in ohms.

Zre (ohms) – The real component of impedance, Z, in ohms.

Zim (ohms) – The imaginary component of impedance, Z, in ohms.

Phase of Z (deg) – The phase angle of impedance, Z, in degrees.

|Y| (S) – The magnitude of the admittance, Y, in siemens.

Yre (S) – The real component of the admittance, Y, in siemens.

Yim (S) – The imaginary component of the admittance, Y, in siemens.

Phase of Y (deg) – The phase angle of the admittance, Y, in degrees.

|C| (F) – The magnitude of the capacitance, C, in farads.

Cre (F) – The real component of the capacitance, C, in farads.

Cim (F) – The imaginary component of the capacitance, C, in farads.

1/C (F) – The reciprocal of the capacitance, C, in farads.

1/C^2 (F) – The reciprocal of the capacitance, C, squared in farads.

|Vac| (V) – The magnitude of the ac potential, Vac, in RMS volts.

Vacre (V) – The real component of the ac potential, Vac, in RMS volts.

Vacim (V) – The imaginary component of the ac potential, Vac, in RMS volts.

Phase of Vac (deg) – The phase angle of the ac potential, Vac, in degrees.

|Iac| (A) – The magnitude of the ac current, Iac, in RMS amperes.

Iacre (A) – The real component of the ac current, Iac, in RMS amperes.

Iacim (A) – The imaginary component of the ac current, Iac, in RMS amperes.

Phase of Iac (deg) – The phase angle of the ac current, Iac, in degrees.

Adv Aux Chn 0 (Volts) – Voltage magnitude for Channel 0 sampled with the Advanced Auxiliary Interface.

Adv Aux Chn 1 (Volts) – Voltage magnitude for Channel 1 sampled with the Advanced Auxiliary Interface.

Adv Aux Chn 2 (Volts) – Voltage magnitude for Channel 2 sampled with the Advanced Auxiliary Interface.

Adv Aux Chn 3 (Volts) – Voltage magnitude for Channel 3 sampled with the Advanced Auxiliary Interface.

Segment – A section of data defined by a particular Action or sequence of Actions.

E Gain – The electronic gain applied to a voltage measurement.

I Gain – The electronic gain applied to a current measurement.

I RMS (A) – The RMS current calculated from a segment of electrochemical noise data.

E RMS (V) – The RMS voltage calculated from a segment of electrochemical noise data.
Segment – A section of data defined by a particular Action or sequence of Actions.

Capacity (Ah) – Calculation used to quantify the charge/discharge accumulation of a battery from the DC Current and time measurements.

Resistance (ohms) – The DC Potential divided by the DC Current.

|Current| (A) – The absolute value of the DC Current.

Power (W) – The calculated measurement based on Potential × Current (V·A).

Energy (Wh) – Used to quantify the energy from the DC Current, DC Potential and time measurements.

CE-RE Potential (V) – This parameter requires a special cable connection to collect the data and graph properly. With a coaxial cable connected from the SYNC ADC Input to the counter electrode as a part of the measurement, this parameter will graph the voltage between the CE and RE electrodes. This is a calculated voltage based on the WE potential measurement subtracted from the measured compliance voltage (which is collected by the STNC ADC Input connection).

Appendix 3.

VersaStudio Data Files

Overview

VersaStudio data files are given the extension ".par" to provide a unique association with the VersaStudio software which Windows operating system recognizes and can open the VersaStudio software just by double-clicking on a *.par data file.

The VersaStudio data file format is ASCII (text) comprised of Parameter Fields and Data Fields

The Parameter Fields in the data files are labeled as Application, Action, Instrument, DataView, Overlays, etc. The information for each of these lists the settings for the many parameters associated with each experiment.

The Data Fields are labeled as "Segment" and contain the resulting data from performing the experiment. The data collected for each segment is arranged in rows for each data point collected, and each row is **comma delimited** as follows:

Segment #, Point #, E (Volts), I (Amps), Elapsed Time (seconds), Aux (Volts), I Range, Status (bit field), Applied E (Volts), Freq (Hertz), EReal, EImag, IReal, IImag, ZReal, ZImag

NOTE: The EIS data within the raw data file is un-calibrated and should not be used for data analysis. Only EIS data that is copied and pasted from within VersaStudio should be used for any data exportation and analysis.

The Status bit fields are defined as follows:

//Bit(s)	Description
//0-3	I Range
//4-5	E Gain
//6-7	I Gain
//8	ADC Out of Range (E or I Channel overload in document)
//9	FrontEnd Overload
//10	Hardware Change
//15	Booster Mode Set (switch on)
//16	E Channel Overload
//17	Power Amp Overload
//18	Current Overload
//19	Thermal Limit
//24	Cell disabled due to Overload
//25	Cell ON
//26	Excluded (user never sees this data)
//27	Hidden (user has chosen to not see this point)
//28	Selected
//29	iR Determination in Progress
//31	Wait for acknowledgment

The bit ranges for IRange and E&I gains are as follows:

The current range data is decoded as follows:

Data (D0-D3)	Current Range
b0000	2A
b0001	200mA
b0010	20mA
b0011	2mA
b0100	200µA
b0101	20 µA
b0110	2 µA
b0111	200nA
b1111	Incorrect Range

The E channel gain data is decoded as follows:

Data (D4-D5)	E Channel Gain
b00	X1
b01	X5
b10	X10
b11	X50

The I channel gain data is decoded as follows:

Data (D6-D7)	I Channel Gain
b00	X1
b01	X5
b10	X10
b11	X50