

# **EZware 7.0**

# **2013**

## OPERATING MANUAL

**VERSION 5.0**

### **EZware**

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NuVant Systems, Inc.

Crown Point, Indiana

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The EZware Software package is an executable that controls all models of NuVant potentiostat/galvanostats and bipotentiostats and some of the multichannel potentiostats. Variations due to specific instrument models are clarified within the manual.

<b>GLOSSARY.....</b>	<b>7</b>
Abbreviations for Step Impedance Spectroscopy (SIS) .....	7
<b>INSTRUMENT SPECIFICATIONS .....</b>	<b>8</b>
EZstat-Pro and Powerstat vs. EZstat-Basic and Basic 8.....	8
On-Board Function Generator vs. CPU Timing .....	8
EZstat-Pro.....	9
EZstat-Pro LC .....	10
EZstat-Pro EIS .....	11
EZstat-Basic.....	13
EZstat-Basic LC.....	15
Multichannel Potentiostat.....	16
1.1.1. EZstat-Basic 8.....	16
Powerstat-05 .....	17
Powerstat-20 .....	18
Powerstat-05E (16 bit).....	20
Powerstat-05E (18 bit).....	21
EZstat Mains Supply Input Specifications.....	22
EZstat Mains Power Cable Manufacturer Data .....	22
Powerstat Mains Supply Input Specifications .....	23
Powerstat Mains Power Cable Manufacturer Data .....	23
Overall Dimensions and Weight.....	24
<b>INTENDED USE OF EQUIPMENT .....</b>	<b>25</b>
<b>SAFETY .....</b>	<b>26</b>
General .....	26
Computer Control and System Safety.....	26
Grounding.....	27
ESD Protection .....	27
AC Supply Voltage .....	27
Placement and Surroundings of the EZstat and Powerstat .....	28
Normal Environmental Conditions for EZstat and Powerstat .....	28
Accessory Cables .....	29
Technical Assistance Contact Information.....	29
<b>HARDWARE CONVENTIONS.....</b>	<b>30</b>

<b>HARDWARE INSTALLATION .....</b>	<b>30</b>
Description of Controls and Connections.....	30
EZstat Front Panel.....	30
Powerstat Front Panel.....	31
Procedure for Connection of Electrode Cables to an Electrochemical Device.....	35
EZstat Back Panel .....	36
Powerstat Back Panel .....	38
<b>CLEANING AND MAINTENANCE .....</b>	<b>39</b>
<b>SERVICE AND REPAIR.....</b>	<b>39</b>
<b>SOFTWARE INSTALLATION .....</b>	<b>40</b>
<b>SOFTWARE AND INSTRUMENT STARTUP.....</b>	<b>41</b>
<b>RECIPE DESIGN .....</b>	<b>46</b>
General Recipe Notes.....	46
Cyclic Voltammetry.....	46
Linear Sweep Voltammetry.....	48
Multi Vertex Waveform .....	49
Programmable Potential Waveform – Hold/Ramp/Step.....	54
Battery Cycling.....	58
Differential Pulse Voltammetry.....	59
Normal Pulse Voltammetry.....	60
Step Impedance Spectroscopy (SIS) .....	61
Electrical Impedance Spectroscopy (EIS) .....	62
<b>STOPPING / RESTARTING AND EXPERIMENT.....</b>	<b>64</b>
<b>SAMPLE EXPERIMENTS.....</b>	<b>65</b>
Linear Voltammetry – Corrosion Experiment.....	65
Cyclic Voltammetry (5mM K <sub>4</sub> Fe(CN) <sub>6</sub> and K <sub>3</sub> Fe(CN) <sub>6</sub> in 1M KNO <sub>3</sub> ).....	69
Step Impedance Spectroscopy (3.78V Li ion battery).....	72
<b>DATA VISUALIZATION AND ANALYSIS .....</b>	<b>76</b>
Axes Rescaling .....	76
Saving Data.....	79
Data Analysis – Area Calculations.....	81

Data Analysis – SIS .....	90
Filters.....	94
Overlaying Data .....	97
Data Analysis – Tafel Plot.....	98
<b>TROUBLESHOOTING INFORMATION.....</b>	<b>103</b>
<b>APPENDIX.....</b>	<b>105</b>

## GLOSSARY

Listed below are the symbols used to identify windows and actions in the EZware software.

SYMBOL	WINDOW/ACTION	EXAMPLE
[Square brackets]	Window	[Edit Single Method]
<b>Bold</b>	Button press	<b>Last Run Data</b>
<b><u>Bold underline</u></b>	Experiment recipe header	<b><u>Linear Sweep Voltammetry</u></b>
<u>Underline</u>	End-user input	<u>Pretreatment Time [s]</u>
“Quotes”	End-user input options	“10”
<b>Bold</b> → <i>Italics</i> →Plain text	<b>Menu header</b> →1 <sup>st</sup> menu selection→2 <sup>nd</sup> menu selection	<b>Technique</b> → <i>Sweep Techniques</i> →Linear Sweep Voltammetry

### Abbreviations for Step Impedance Spectroscopy (SIS)

SIS Theory	
$t_0$	Beginning of the pretreatment period
$t_{p,i}$	Pulse initiation time
$t_{p,f}$	Pulse final time
$t_{r,f}$	End of relaxation time
$tpw = t_{pf} - t_{pi}$	Pulse width
$trp = t_{rf} - t_{pf}$	Relaxation period
$E(t) = E_{eq1}$	For ( $t_{p,i} - t_{interv} \leq t \leq t_{p,i}$ )
$E_{eq2}$	$\sim E(t_{r,f})$
$T$	RC time constant specific to differential equation
$i_p$	Pulse amplitude
$t_{interv}$	Sampling interval time

SIS Impedance Calculator	
$R_s$	Solution resistance
$R_{ct}$	Charge transfer resistance
$C_{dl}$	Double layer capacitance
$S_o$	$(1/Z_w)^*t$
$E$	Open circuit voltage
$Q$	Charge transferred during pulse
$dE/dQ^*$	Charge derivative of E

\*Q(coulombs)

## INSTRUMENT SPECIFICATIONS

### EZstat-Pro and Powerstat vs. EZstat-Basic and Basic 8

The EZstat-Pro and Powerstat series have a built-in function generator that enables high speed scans and a buffer that permits high rate data collection. Thus the EZstat-Pro and Powerstat series perform a number of advanced functions that the EZstat-Basic and EZstat-Basic 8 cannot. The functions that the EZstat-Basic and EZstat-Basic 8 cannot perform are grayed out in the EZstat-Basic and EZstat-Basic 8 software.

The EZstat-Pro and Powerstat series have a 16 bit AO control and AI data acquisition system. The EZstat-Basic and EZstat-Basic 8 have a 12 bit AO control and 14 bit AI data acquisition system.

### On-Board Function Generator vs. CPU Timing

Only the EZstat-Pro and Powerstat series utilize a high-precision, hardware-timed function generator. The EZstat-Basic and EZstat-Basic 8 are limited to the CPU-timed function generator. Consequently, the output wave-form update sampling rate is limited to 100S/s (150S/s in turbo mode) for the EZstat-Basic and Basic 8. The timing precision for EZstat-Basic and EZstat-Basic 8 depends on the computer hardware and the load on the CPU. Typically the precision is within 2ms.

Due to the limitations in the data acquisition hardware for the EZstat-Basic and EZstat-Basic 8, it is recommended not to perform experiments while also running other operations that demand high CPU usage. This will improve the timing accuracy in the output data update and prevent deviations in timing.

The following instrument specifications are for instruments purchased after October 1<sup>st</sup>, 2013. Specifications for older instruments can be found in the appendix.



## EZstat-Pro

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling, Step Impedance Spectroscopy with Analysis
<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	3 nA, 0.003% of FSR
Applied Current Accuracy	0.03% of FSR
Input Bias Current	500 pA
Input Impedance	250 GW parallel to 3 pf
Maximum Update Rate	4 µs
Maximum Scan Rate	500 V/s
IR Compensation	Manual, Potentiostat Mode 10 mA - 1 A Range
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3 µV, 300 µV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	GalvanoSTAT: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) PotentioSTAT: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A)
PotentioSTAT Min to Max	3 nA to 1 A
Best Resolution	GalvanoSTAT: 3 nA (0.003% of FSR) PotentioSTAT: 610 pA - 340 µA (0.06 - 0.003% of FSR In Order of Range)
Accuracy	GalvanoSTAT: 0.03% of FSR; PotentioSTAT: 0.3 - 0.03% of FSR Depending on Range
<b>Data Acquisition</b>	
Acquisition Speed	250 k samples/s (Aggregate) 125 k samples/s/ch. (min 2 channels)
DAC Resolution	16 bits
FSR: Full Scale Range	

## EZstat-Pro LC

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling
<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±10 mA
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±1 µA, ±10 µA, ±100 µA, ±10 mA)
Best Applied Current Resolution	40 pA, 0.004% of FSR
Applied Current Accuracy	0.04% of FSR
Input Bias Current	500 pA
Input Impedance	250 GW parallel to 3 pf
Maximum Update Rate	4 µs
Maximum Scan Rate	100 V/s
IR Compensation	None, Low Current Device
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3 µV, 300 µV (0.006%, 0.003% of Full Scale Range)
Accuracy	0.08 or 0.03% of Full Scale Range
<b>Current Measurement</b>	
Measured Current Ranges	GalvanoSTAT: 4 (±1 µA, ±10 µA, ±100 µA, ±10 mA) PotentioSTAT: 4 (±1 µA, ±10 µA, ±100 µA, ±10 mA)
PotentioSTAT Min to Max	3 nA to 10 mA
Best Resolution	GalvanoSTAT: 40 pA (0.004% of Full Scale Range) PotentioSTAT: 40 pA (0.004% of Full Scale Range)
3 s Coverage Factor Accuracy	GalvanoSTAT: 0.04% of Full Scale Range PotentioSTAT: 0.04% of Full Scale Range
<b>Data Acquisition</b>	
Acquisition Speed	250 k samples/s (Aggregate) 125 k samples/s/ch. (min 2 channels)
DAC Resolution	16 bits

## EZstat-Pro EIS

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling, EIS with Analysis
<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Potentiostat Slew Rate	0.2 V/µs
Bandwidth	10 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	3 nA, 0.003% of FSR
Applied Current Accuracy	0.03% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	4 µs
Maximum Scan Rate Potentiostat	500 V/s
Current raise rate Galvanostat	>64 A/ms
IR Compensation	Manual, Potentiostat Mode
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3 µV, 300 µV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	GalvanoSTAT: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) PotentioSTAT: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A)
PotentioSTAT Min to Max	3 nA to 1 A
Best Resolution	GalvanoSTAT: 3 nA (0.003% of FSR) PotentioSTAT: 610 pA - 340 µA (0.06 - 0.003% of FSR In Order of Range)
Accuracy	GalvanoSTAT: 0.03% of FSR; PotentioSTAT: 0.3 - 0.03% of FSR Depending on Range
<b>EIS Measurement</b>	
Frequency Range	10mHz - 10kHz
Max AC amplitude	200mV
AC Applied Potential Resolution	6µV

Min AC amplitude	60 $\mu$ V
<b>Data Acquisition</b>	
Acquisition Speed	250 k samples/s (Aggregate) 125 k samples/s/ch. (min 2 channels)
DAC Resolution	16 bits
FSR: Full Scale Range	

## EZstat-Basic

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling
<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±2.5 V)
Applied Potential Resolution	7 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pF
Maximum Update Rate	100 ms
Maximum Scan Rate	1 V/s
IR Compensation	Manual, Potentiostat Mode 10 mA - 1 A Range
External Control	None
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 µV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) Potentiostat: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A, )
Potentiostat Min to Max	15 nA to 1 A
Best Resolution	Galvanostat: 12 nA (0.01% of FSR) Potentiostat: 2.4 nA - 0.13 mA (0.24 - 0.013 % of FSR In Order of Range)
Accuracy	Galvanostat: 0.08% of FSR; Potentiostat: 0.08 - 1.5% of FSR Depending on Range
<b>Data Acquisition</b>	
Acquisition Time	100 µs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit
FSR: Full Scale Range	

## EZstat-Basic +5

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling
<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (0 ÷ 5 V)
Applied Potential Resolution	1.2 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	100 ms
Maximum Scan Rate	0.1 V/s
IR Compensation	Manual, Potentiostat Mode 10 mA - 1 A Range
External Control	None
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 µV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) Potentiostat: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A, )
Potentiostat Min to Max	15 nA to 1 A
Best Resolution	Galvanostat: 12 nA (0.01% of FSR) Potentiostat: 2.4 nA - 0.13 mA (0.24 - 0.013 % of FSR In Order of Range)
Accuracy	Galvanostat: 0.08% of FSR; Potentiostat: 0.08 - 1.5% of FSR Depending on Range
<b>Data Acquisition</b>	
Acquisition Time	100 µs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit
FSR: Full Scale Range	

## EZstat-Basic LC

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling
<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 μs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/μs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±2.5 V)
Applied Potential Resolution	1.2 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±1 μA, ±10 μA, ±100 μA, ±10 mA)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	100 ms
Maximum Scan Rate	0.1 V/s
IR Compensation	NA
External Control	None
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 μV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±1 μA, ±1 μA, ±10 μA, ±10 mA) Potentiostat: 4 ((±1 μA, ±1 μA, ±10 μA, ±10 mA )
Potentiostat Min to Max	3 nA to 10 mA
Best Resolution	Galvanostat: 40 pA (0.01% of FSR) Potentiostat: 40 pA (0.24 - 0.013 % of FSR In Order of Range)
3 s Coverage Factor Accuracy	Galvanostat: 0.04% of Full Scale Range Potentiostat: 0.04% of Full Scale Range
<b>Data Acquisition</b>	
Acquisition Time	100 μs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit
FSR: Full Scale Range	

## Multichannel Potentiostat

### 1.1.1. EZstat-Basic 8

Comes in a single chassis with the power supply enclosed and requires dual monitors and a computer to be configured by NuVant Systems. All 8 channels are entirely independent.

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling
<b>Cell Control</b>	
Compliance Voltage	±15 V
Max Output Current	±1 A
Rise Time	45 μs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/μs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±2.5 V)
Applied Potential Resolution	7 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 μA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pF
Maximum Update Rate	100 ms
Maximum Scan Rate	1 V/s
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 μV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±100 μA, ±1 mA, ±100 mA, ±1 A) Potentiostat: 4 (±1 μA, ±100 μA, ±10 mA, ±1 A, )
Potentiostat Min to Max	15 nA to 1 A
Best Resolution	Galvanostat: 12 nA (0.01% of FSR) Potentiostat: 2.4 nA - 0.13 mA (0.24 - 0.013 % of FSR In Order of Range)
Accuracy	Galvanostat: 0.08% of FSR; Potentiostat: 0.08 - 1.5% of FSR Depending on Range
<b>Data Acquisition</b>	
Acquisition Time	100 μs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit
FSR: Full Scale Range	



## Powerstat-05

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling, Step Impedance Spectroscopy with Analysis
<b>Cell Control</b>	
Compliance Voltage	±15 V
Max Output Current	±5 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.8 V/µs
Bandwidth	6 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 mA, ±1 A, ±3 A, ±5 A)
Best Applied Current Resolution	3 µA, 0.003% of FSR
Applied Current Accuracy	0.03% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	4 µs
Maximum Scan Rate	100 V/s
IR Compensation	Manual, Potentiostat and Galvanostat Modes, All Ranges
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3µV, 300µV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	GalvanoSTAT: 4 (±100 mA, ±1 A, ±3 A, ±5 A) PotentioSTAT: 4 (±100 mA, ±1 A, ±3 A, ±5 A)
PotentioSTAT Min to Max	1 mA to 5 A
Best Resolution	GalvanoSTAT: 3 µA (0.003% of FSR) PotentioSTAT: 3 µA (0.003% of FSR)
Accuracy	GalvanoSTAT: 0.03% of FSR PotentioSTAT: 0.03% of FSR
<b>Data Acquisition</b>	
Acquisition Speed	250 k samples/s (Aggregate) 125 k samples/s/ch. (min 2 channels)
DAC Resolution	16 bits
FSR: Full Scale Range	

## Powerstat-20

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling, Step Impedance Spectroscopy with Analysis
<b>Cell Control</b>	
Compliance Voltage	±10 V
Max Output Current	±18 A
Rise Time	60 us for 0.2 Ohm load (0%-100% signal)
Slew Rate	0.8 V/μs
Bandwidth	6 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 mA, ±0.8 A, ±3 A, ±18 A)
Applied Current Resolution by Range	±100 mA: 15 μA (0.015% of FSR), ±0.8 A: 53 μA (0.0067% of FSR), ±3 A: 0.12 mA (0.0039% of FSR), ±18 A: 0.56 mA (0.0031% of FSR)
Applied Current Accuracy by Range	±100 mA: 0.10% of FSR, ±0.8 A: 0.053% of FSR, ±3 A: 0.037% of FSR, ±18 A: 0.033% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	4 μs
Maximum Scan Rate	100 V/s
IR Compensation	Manual, Potentiostat and Galvanostat Modes, All Ranges
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3μV, 300μV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	GalvanoSTAT: 4 (±100 mA, ±0.8 A, ±3 A, ±18 A) PotentioSTAT: 4 (±100 mA, ±0.8 A, ±3 A, ±18 A)
PotentioSTAT Min to Max	1 mA to 18 A

Resolution by Range	PotentialSTAT and GalvanoSTAT are the same $\pm 100$ mA: 15 $\mu$ A (0.015% of FSR), $\pm 0.8$ A: 53 $\mu$ A (0.0067% of FSR), $\pm 3$ A: 0.12 mA (0.0039% of FSR), $\pm 18$ A: 0.56 mA (0.0031% of FSR)
Accuracy	PotentialSTAT and GalvanoSTAT are the same $\pm 100$ mA: 0.095% of FSR, $\pm 0.8$ A: 0.050% of FSR, $\pm 3$ A: 0.035% of FSR, $\pm 18$ A: 0.031% of FSR
<b><i>Data Acquisition</i></b>	
Acquisition Speed	250 k samples/s (Aggregate) 125 k samples/s/ch. (min 2 channels)
DAC Resolution	16 bits
FSR: Full Scale Range	

## Powerstat-05E (16 bit)

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling, EIS with Analysis
<b>Cell Control</b>	
Compliance Voltage	±15 V
Max Output Current	±5 A
Rise Time	25 μs for 1 Ω load (0%-100% signal)
Slew Rate	0.8 V/μs
Bandwidth	10 kHz (-3 dB, 1 Ω load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 mA, ±1 A, ±3 A, ±5 A)
Best Applied Current Resolution	3 μA, 0.003% of FSR
Applied Current Accuracy	0.03% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	1.2 μs
Maximum Scan Rate	100 V/s
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3μV, 300μV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±100 mA, ±1 A, ±3 A, ±5 A) Potentiostat: 4 (±100 mA, ±1 A, ±3 A, ±5 A)
Potentiostat Min to Max	.1 mA to 5 A
Best Resolution	Galvanostat: 3 μA (0.003% of FSR) Potentiostat: 3 μA (0.003% of FSR)
Accuracy	Galvanostat: 0.03% of FSR Potentiostat: 0.03% of FSR
<b>EIS Measurement</b>	
Frequency Range	10mHz - 10kHz
Max AC amplitude	200mV
AC Applied Potential Resolution	6μV
Min AC amplitude	60μV
<b>Data Acquisition</b>	
Acquisition Speed	250 k samples/s (Aggregate) 125 k samples/s/ch. (min 2 channels)
DAC Resolution	16 bits
FSR: Full Scale Range	

### Powerstat-05E (18 bit)

<b>Features</b>	Cyclic, Linear sweep, and Pulse voltammetry, Battery cycling, EIS with Analysis
<b>Cell Control</b>	
Compliance Voltage	±15 V
Max Output Current	±5 A
Rise Time	25 μs for 1 Ω load (0%-100% signal)
Slew Rate	1.6 V/μs
Bandwidth	10 kHz (-3 dB, 1 Ω load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 mA, ±1 A, ±3 A, ±5 A)
Best Applied Current Resolution	.3 μA, 0.003% of FSR
Applied Current Accuracy	0.03% of FSR
Input Bias Current	500 pA
Input Impedance	250 GW parallel to 3 pf
Maximum Update Rate	0.36 μs
Maximum Scan Rate	100 V/s
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	0.08μV, 8μV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±100 mA, ±1 A, ±3 A, ±5 A) Potentiostat: 4 (±100 mA, ±1 A, ±3 A, ±5 A)
Potentiostat Min to Max	.1 mA to 5 A
Best Resolution	Galvanostat: 0.08 μA (0.003% of FSR) Potentiostat: 0.08 μA (0.003% of FSR)
Accuracy	Galvanostat: 0.03% of FSR Potentiostat: 0.03% of FSR
<b>EIS Measurement</b>	
Frequency Range	10mHz - 10kHz
Max AC amplitude	200mV
AC Applied Potential Resolution	6μV
Min AC amplitude	60μV
<b>Data Acquisition</b>	
Acquisition Speed	500 k samples/s (Aggregate) 250 k samples/s/ch. (min 2 channels)
DAC Resolution	18 bits
FSR: Full Scale Range	

## EZstat Mains Supply Input Specifications

(EZstat Pro, EZstat-Basic, EZstat-Basic 8)

<b>Mains Supply Voltage</b>	<b>Mains Line Frequency</b>	<b>Mains Supply Current</b>	<b>Mains Supply Fuse Type</b>	<b>Fuse Size</b>	<b>Littell Fuse Part Number</b>
110 – 130 VAC	47 – 60 Hz	4 A	4 Amp Time Lag	2 X 5mm X 20mm	0215004.HXP
220 – 240 VAC	47 – 60 Hz	2 A	2 Amp Time Lag	2 X 5mm X 20mm	0215002.HXP

## EZstat Mains Power Cable Manufacturer Data

(EZstat-Pro, EZstat-Basic, EZstat-Basic – 8)

<b><i>North American Power Cord</i></b>	
Brand Name	Volex
Model Number	17501-10-B1
Rated Voltage	125V
Rated Current	10A

## Powerstat Mains Supply Input Specifications

Mains Supply Voltage	Mains Line Frequency	Mains Supply Current	Mains Supply Fuse Type	Fuse Size	Littel Fuse Part Number
115 VAC +/- 10%	50/60Hz	8 A	8 Amp Time Lag	2 X 5mm X 20mm	0215008.HXP
127 VAC +/- 10%	50/60Hz	8 A	8 Amp Time Lag	2 X 5mm X 20mm	0215008.HXP
230 VAC +/- 10%	50/60Hz	4 A	4 Amp Time Lag	2 X 5mm X 20mm	0215004.HXP

## Powerstat Mains Power Cable Manufacturer Data

<b><i>Saudi Arabia Power Cord</i></b>	
Brand Name	Lian Dung
Model Number	LT-318 + LT-501
Rated Voltage	250V
Rated Current	13A
<b><i>North American Power Cord</i></b>	
Brand Name	Volex
Model Number	17501-10-B1
Rated Voltage	125V
Rated Current	10A

## Overall Dimensions and Weight

### EZstat-Basic/Pro overall dimensions

- 9 in. wide / 22.9 cm
- 3 in. tall / 7.6 cm
- 8 in. deep / 20.3 cm

### EZstat-Basic/Pro power supply overall dimensions

- 4 in. wide / 10.2 cm
- 3 in. tall / 7.6 cm
- 7 in. deep / 17.8 cm

### EZstat-Basic/Pro overall weight

- 7.55 lbs. / 3.42 kg

### EZstat-Basic 8 overall dimensions

- 18 in. wide / 45.7 cm
- 9 in. tall / 22.9 cm
- 20 in. deep / 50.8 cm

EZstat-Basic 8 power supply is included in the instrument chassis

### EZstat-Basic 8 overall weight

- 50 lbs. / 22.68 kg

### Powerstat overall dimensions

- 19 in. wide / 48.26 cm
- 7.5 in. tall / 19.05 cm
- 22 in. deep / 55.88 cm including handles

Powerstat power supply is included in the instrument chassis

### Powerstat overall weight

- 50 lbs. / 22.68 kg



## INTENDED USE OF EQUIPMENT

The EZstat-Pro is a potentiostat/galvanostat that delivers up to 1 A at  $\pm 10$  V. The EZstat-Pro LC is a potentiostat/galvanostat that delivers up to 1 mA at  $\pm 10$  V. The EZstat-Basic is a potentiostat/galvanostat that delivers up to 1 A at  $\pm 2.5$  V. The EZstat-Basic LC is a potentiostat/galvanostat that delivers up to 1 mA at  $\pm 2.5$  V. The EZstat-Basic +5 is a potentiostat/galvanostat that delivers up to 1 A at 0 to 5 V. These devices are intended to be used on many types of electrochemical experiments including cyclic voltammetry, corrosion studies, coating, plating, polarography, pulse voltammetry, potential sweep, controlled current, battery cycling and numerous other experiments. Although it should not damage the EZstat, do not attempt to operate this equipment out of the specified voltage and current ranges.

The Powerstat is a potentiostat/galvanostat that delivers up to 5 A at  $\pm 10$  volts. It is intended for use in electrochemical experiments such as corrosion, coating, plating, polarography and pulse voltammetry, potential sweep, controlled current, battery cycling and many other experiments. Although it should not damage the Powerstat, do not attempt to operate this equipment out of the specified voltage and current ranges.

## SAFETY



### General

It is required that this equipment and software be operated only by trained and qualified persons familiar with safe laboratory practices.

The equipment and software described in this manual are supplied in safe condition. To avoid injury to an operator, safety precautions throughout this manual must be strictly adhered to whenever the equipment is operated.

The following symbols may be found on the instrument and within this manual. Use caution where these symbols are found.



**CAUTION: USE CAUTION WHERE THIS SYMBOL IS PRESENT!**  
YOU MUST CONSULT ALL CASES WHERE THIS SYMBOL IS MARKED, IN ORDER TO FIND OUT THE NATURE OF THE POTENTIAL *HAZARDS* AND ANY ACTIONS WHICH HAVE TO BE TAKEN TO AVOID THEM.



**ALTERNATING CURRENT: SINGLE PHASE ALTERNATING CURRENT**

### Computer Control and System Safety

Precautions should be taken to ensure sustained operation of the PC controlling the EZstat and Powerstat. The software and hardware are designed with the following fail-safe's in the event of a PC crash while the software is running: 1) During a shutdown the cell will automatically disable when the PC turns off; 2) During a re-boot the cell will automatically disable when Windows re-starts; and 3) During a PC unplug (PC power failure simulation) the cell will immediately disable. Yet, in event of a PC system STOP or other unforeseen failure of the PC hardware or software the load may remain in an 'ON' but uncontrolled state that may damage the EZstat and Powerstat.



## Grounding

For the safety of the operator and the equipment, the EZstat and Powerstat must be connected by means of a protective conductor to earth ground. Under no circumstances should the ground be bypassed. It is advisable not to unplug the instrument when not in use. This protection must not be disabled by the use of two-conductor extension cord or adapter, or any other type of connection that does not maintain connection to earth ground.

## ESD Protection

Electrostatic Discharge (ESD) can cause immediate or latent damage to electronic circuits. NuVant products are protected against ESD for intended use. It is possible to damage the product by delivering electrostatic discharges when touching, moving the product, or connecting leads. It is advisable for operators to ground and discharge themselves before touching the inside electronics on this product. It is advisable to ground and discharge any leads and the electrochemical cell before connection to the EZstat and Powerstat.



## AC Supply Voltage

AC voltage is present in the equipment when power is off. User must disconnect the appliance cord to remove mains voltage from the instrument. The appliance cord should be easily accessible by the user.

Before connecting the power supply to the equipment, make sure that the line voltage is appropriate. Never operate the equipment from a line voltage or frequency in excess of the specifications. Read the MAINS SUPPLY INPUT SPECIFICATIONS for voltage and fuse information. *The equipment may be damaged by the application of incorrect line voltage. Voltage and current conditions are sufficient to cause injury and possible death.*



## Placement and Surroundings of the EZstat and Powerstat

DO NOT place the instrument in a location where the user cannot access the appliance cord or power supply. Place the instrument in a location where the appliance cord can be easily disconnected by the user.

The EZstat and Powerstat should be placed on a flat, clean, hard surface that can support the weight of the instrument (7.55 lbs.). At least, 2 inches of space must be available at the rear to allow the flow of air. At least, 3 inches of space must be available on both sides to allow the flow of air. Obstructed airflow can lead to instrument malfunction over time. At no time should there be obstructions in front of the instrument. The user needs access to the controls and electrode cables located in front of the EZstat and Powerstat.

Do not place any objects on top of the EZstat or Powerstat.

## Normal Environmental Conditions for EZstat and Powerstat

The EZstat and Powerstat are designed to operate indoors, in a laboratory environment. Do not operate the instrument outdoors, as this may place the user in a hazardous situation due to unknown environmental conditions. Outdoor use of the instrument may cause a failure of operation due to environmental conditions. The EZstat and Powerstat are rated to operate at an altitude of up to 6562 feet, or 2000 meters. The ambient temperature for operation is between 41 degrees Fahrenheit / 5 degrees Celsius and 104 degrees Fahrenheit / 40 degrees Celsius.

Indoor use only

Operate between 41° F ~ 104° F / 5° C ~ 40° C

Altitude of no more than 6562 FT / 2000 M

Humidity of up to 80%

Pollution degree 2

Instrument operation outside of these conditions will reduce instrument lifetime.

Although the Main supply voltage can fluctuate with load conditions, the EZstat and Powerstat will continue to operate properly if these fluctuations do not exceed  $\pm 10\%$  of the specified instrument supply voltage. Main supply voltage settings on the EZstat and Powerstat have a specified range itself for that particular setting.  $\pm 10\%$  applies to the upper and lower limits of that setting. The main supply voltage frequency for operation is 50Hz to 60Hz.

## Accessory Cables

Only the cables supplied with the EZstat and Powerstat should be used. These cables include: Electrode Cable Assembly (*See Figure 1*), High Speed USB Cable, and AC Power Cable. Do NOT replace cables without contacting NuVant Systems Inc. Replacement cables must be procured from NuVant Systems.

## Technical Assistance Contact Information

NuVant Systems, Inc.  
130 N. West Street  
Crown Point, IN 46307  
Toll Free: 866-894-7337  
Office: 219-644-3231  
Fax: 219-779-9675

## HARDWARE CONVENTIONS

- Physical switches and connectors on the front panel relevant to operation are designated as **Bold Blue** text. For example, **Main Power Switch** and **Cell Enable Switch**.
- Physical switches and connectors on the back panel relevant to operation are designated as **Bold Red** text. For example **Data Communication Port**.

## HARDWARE INSTALLATION

### Description of Controls and Connections

This section provides a general description of the controls and indicators on the EZstat front and back panels.

#### EZstat Front Panel

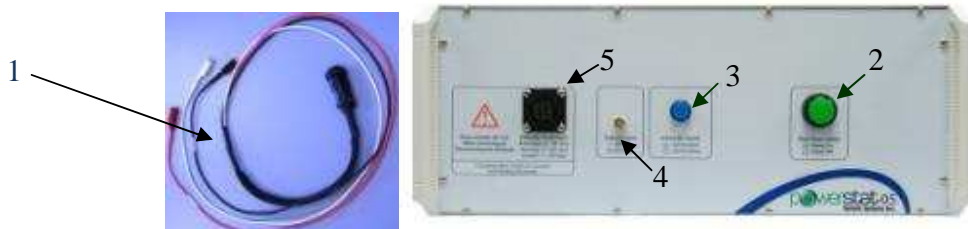
Figure 1 shows the EZstat front panel and cable assembly.



**Figure 1** EZstat Front Panel. Top image: instrument in plastic casing. Bottom image: instrument in metal casing

## Powerstat Front Panel

Figure 2 shows the Powerstat front panel and cable assembly.



**Figure 2** Powerstat Front Panel



**Figure 3** Separate Working and Working Sense Electrode Cables

**1. Counter, Working and Reference Electrode Cable Assembly** – The system allows current flow between the counter (Red) and working (Black) electrodes at a controlled current or potential. When under potential control, the applied potential is measured between the working and the reference (White) electrodes. The reference lead may be connected to an internal reference electrode. If no reference electrode is used, the reference lead must be connected to the counter electrode lead. For operation as a potentiostat or galvanostat all three leads must be properly connected. The EZstat must be used with the cables provided. Recent EZstat serial numbers have separate Working and Working Sense Cables, Figure 3. When using separate Working and Working Sense Cables all four cables must be connected.

**2. Main Power Switch** – This switch is used to turn the EZstat system on or off. Pressing this switch on will allow the main AC voltage to be applied to the transformers of the power supplies. Pressing this switch to the off position will disconnect the AC voltage from the transformers of

the power supplies. On the instruments with plastic casing, this switch lights green when on. The metal casing instruments light up when the power is on.

**3. Cell Enable Switch** – Places the test device in series with the potential follower board. Also acts as a safety feature, wherein the device is isolated from the current flow when the switch is in the off position. In the off position potential will still be measured but not controlled. When this switch is depressed AND the cell is enabled in the software this switch will illuminate. When the software control program is exited, this switch will not be illuminated even when depressed because exiting the software control program disables the cell automatically. There is no cell enable switch for the metal casing instruments. Cell enable is determined by the EZware software.

**4. External Input** – A standard BNC connector allows connection to an external signal source. Signals of up to  $\pm 10$  volts can be applied to this connection. The input impedance is 47K Ohms. There is no external input connector on the metal casing instruments.

**5. Electrode Connector** – Attach the electrode cable assembly to this connector. On the instruments with plastic casing, this connector is a twist-lock type with the addition of a “keyed” connection. The electrode cable can be installed in only one way, thus ensuring the safest cable installation. On the instruments with metal casing, this is a 15 pin rs232 connector.



**Caution: Make sure the Cell Enable switch is in the Disabled position before installing the Electrode cable.**

## Powerstat-20 Front Panel

Figure 4 shows the Powerstat 20 front Panel along with the cables that are required:





**Figure 4:** PowerStat-20 front Panel & Cables Assembly

All the cables need to be connected to the electrochemical device under investigation (description follows)

- 1. Power Supplies Switches.** Before the instrument can be used the power supplies switches need to be turned ON.
- 2. Main Power Switch.** After the power supplies switches (1) are turned ON the instrument main power switch is turned ON.
- 3. Cell Enable Switch.** The Cell Enable switch needs to be turned ON when ready to perform the experiment. Turn ON the Cell Enable switch only after all the cables are properly attached to the electrochemical cell under investigation.
- 4. High Current Working & Counter Electrode Cable Connectors.** The high current cables 7 attach to these connectors. The RED cable attaches to the RED connector and the BLACK cable attaches to the BLACK connector. **PROPER CARE MUST BE EXERCISED SO THAT THESE CABLE NEVER SHORT TO EACH OTHER.**

**5. Electrometer Power Connector.** The electrometer cable 8 attaches to this connector. The red and black alligator clips at the opposite end of cable 8 are the connectors of the sense leads and they attach to the electrochemical cell where the thick high current cables attach, matching the colors (RED to RED and BLACK to BLACK).

**6. Electrometer Sense Lead.** The electrometer Sense Lead connects to the electrometer box (black box embedded in cable 8) via the banana plug.

**7. High Current Cables.** The RED and BLACK high current cables connect to connectors 4.

**8. Electrometer Cable.** The electrometer cable connects to connector 5.

## Powerstat-20 Back Panel

Figure 5 shows the Powerstat 20 back Panel.



**Figure 5:** PowerStat-20 Back Panel

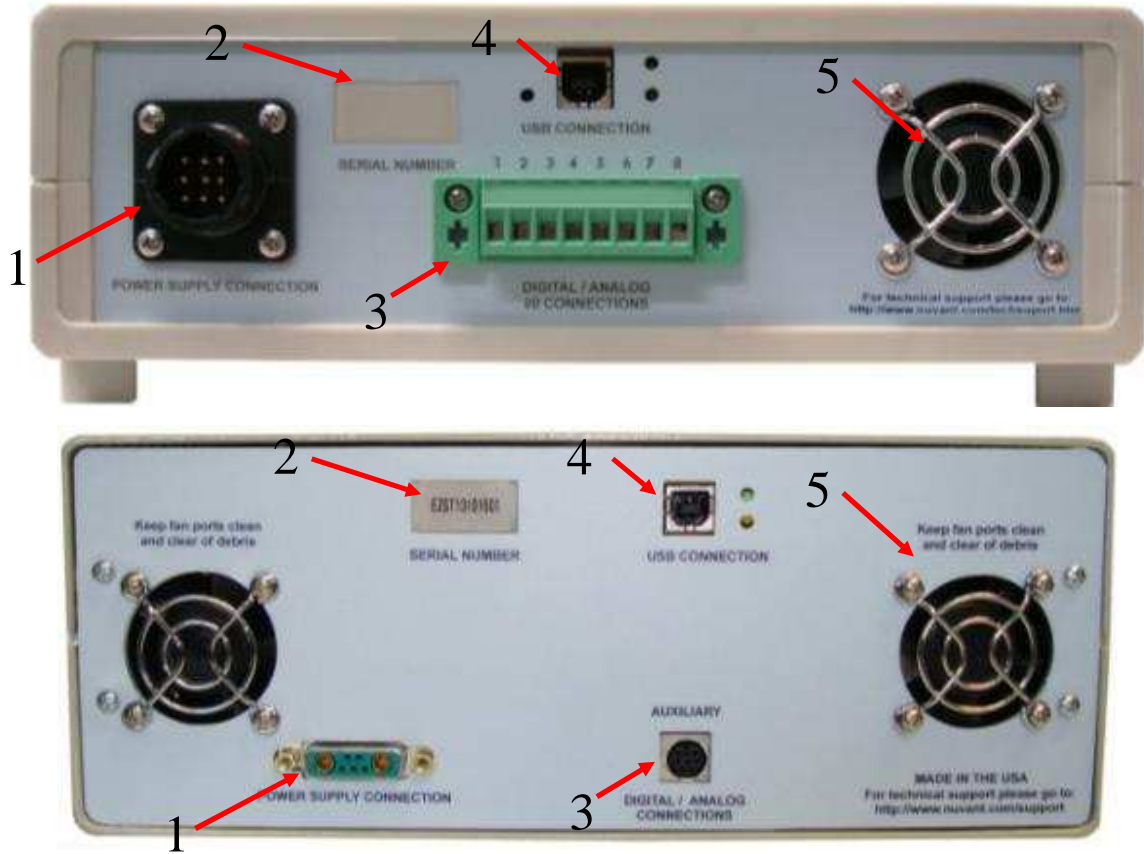
1. **Main Power Connector.** Cable 9 (shown in Fig. 4) connects to the main power connector 1. It is very likely that the user will have to provide his/her own connector to accommodate the wall power outlet specific to the country where the instrument will be used.
2. **USB Cable.** A standard USB cable (cable 10 in Fig. 4) connects the instrument to the computer via connector 2.
3. **K-type Thermocouple Connectors.** The instrument provides the possibility to read 2 temperature channels using 2 K-type thermocouples connected to receptacles 3
4. **Cooling Fans.** Care must be exercised to never obstruct the cooling fans 4.

## Procedure for Connection of Electrode Cables to an Electrochemical Device

Electrodes should never be connected or disconnected from the EZstat of Powerstat when the cell is enabled. If the software is running, disable the cell using the software AND by putting the **Cell Enable Switch** in the out position, whether or not it is illuminated. For operator safety, and protection of the EZstat and Powerstat electronics, always connect and disconnect electrodes in the following order (NOTE: counter, reference, working sense (if available), and working electrodes must ALL be connected to the electrochemical device. In a typical 3-electrode system the working sense is shorted to the working electrode):

- 1) Electrode connection;
  - a) With the cell disabled connect the Green Ground lead, if used;
  - b) With the cell disabled connect the White Reference electrode lead;
  - c) With the cell disabled connect the Red Counter electrode lead
  - d) If present, with the cell disabled connect the Black Working Sense electrode lead;
  - e) With the cell disabled connect the Black Working electrode lead.
  
- 2) Electrode disconnection;
  - a) With the cell disabled disconnect the Black Working electrode lead;
  - b) If present, with the cell disabled disconnect the Black Working Sense electrode lead;
  - c) With the cell disabled disconnect the Red Counter electrode lead;
  - d) With the cell disabled disconnect the White Reference electrode lead;
  - e) With the cell disabled disconnect the Green Ground lead, if used;
  - f) Do not enable the cell unless all electrodes are connected correctly.

### EZstat Back Panel



**Figure 6** EZstat Back Panel Top image: instrument in plastic casing. Bottom image: instrument in metal casing

**1. AC Power Input** – The EZstat is supplied with an external power supply. Two different units are available, 120 VAC, 47-60 Hz and 220 VAC 47-60 Hz. Within the power supply there is either a 2 A or 4 A slow blow fuse (see table on page 17). NuVant recommends that the power supply be kept at least 1 foot away from the EZstat to reduce the signal noise from the power supply.



**2. Serial Number Plate** – Removal of or defacing the serial number plate will void the warranty.

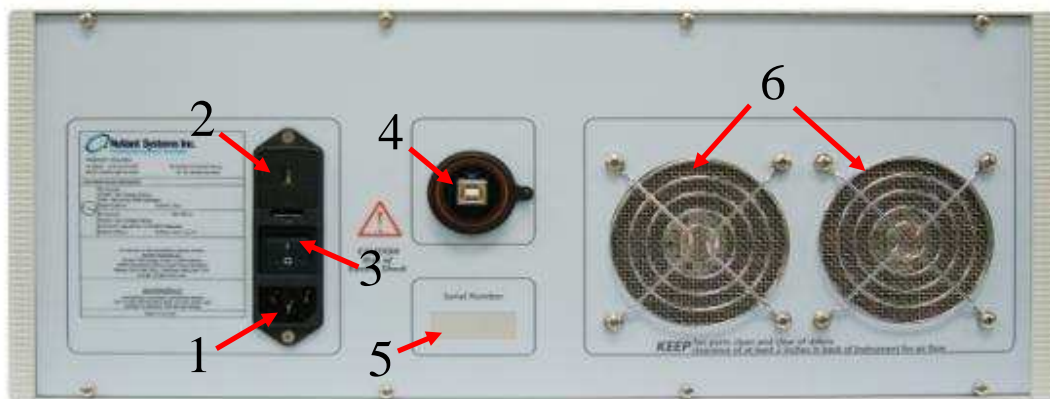
**3. Digital Analog I/O Connections** – This feature provides the user with the ability to attach peripheral equipment to the EZstat. Control is accomplished using the EZstat/LabVIEW operating platform without the addition of other DAQ cards. If you would like assistance using these Input/Output connections, please contact NuVant Systems for additional information. From left to right: Pin 1 is Analog output (AO1); Pin 2 is Analog input (AI5); Pin 3 is Digital Input/Output (P1.6); Pin 4 is Digital Input/Output (P1.7) Pins 5~8 are unused.

**4. Data Communication Port** – The data acquisition (DAQ) port communicates with a computer using a USB cable. Use only the cable provided by NuVant.

**5. Cooling** – Allow at least 2 inches of space behind, above and to the sides of the EZstat. Periodically inspect the fan ports to make sure debris does not obstruct air flow.

**6. External Power Supply** – The external power supply is used to convert the 120 VAC line voltage to appropriate DC voltages for the EZstat.

## Powerstat Back Panel



**Figure 7 Powerstat Back Panel**

**1. AC Power Input** – 8 A at 250 VAC Slow blow fuse for voltage selections of 115/127VAC or 4 A at 250 VAC Slow blow fuse for voltage selection of 230 VAC 50~60Hz. Use only the supplied power cable to run this instrument. Contact NuVant systems if a replacement is needed.

**2. Main Power Voltage Selector Switch and AC Fuse Holder** – External AC fuse holder. 8 A at 250 VAC Slow blow fuse for voltage selections of 115/127VAC or 4 A at 250 VAC Slow blow fuse for voltage selection of 230 VAC 50~60Hz.

**3. AC Main Power Switch** – AC main power switch. This must be on for the front panel **Main Power Switch** to illuminate.

**4. Data Communication Port** – The data acquisition (DAQ) port communicates with a computer using a USB cable. Use only the cable provided by NuVant.

**5. Serial Number Plate** – Removal of or defacing the serial number plate will void the warranty.

**6. Cooling Fan** – Allow at least 2 inches of space behind and to the sides of the cooling fans. Periodically inspect the fan ports to make sure debris does not obstruct air flow.

**7. AC Power Cable** – The power cable must be plugged firmly into the back of the instrument. The other end of the power cable must be plugged into a grounded circuit of the correct polarity and voltage. The voltages are: 115/127VAC or 230VAC 50~60Hz. Have a certified electrician verify the earth grounding of the wall outlet. Do not replace this cable with any other similar cable. This power cable supplied is rated for the instrument.

**8. USB Data Communication Cable** – Do not connect this cable to the computer until the software is installed. Ensure this cable is inserted completely into the instrument and computer during use. Do not connect a USB extension cable to this cable. Do not replace this cable without contacting NuVant Systems to obtain an appropriate cable.

PowerStat 20 Front and Back Panels

## CLEANING AND MAINTENANCE

The EZstat and Powerstat require minimal maintenance. The instrument must be clean and free of oil, dust and debris. If a buildup occurs, unplug the instrument from the mains **AC Power Input**. Use a soft cloth to wipe the instrument clean. If necessary, use a small amount of soap and water on the cloth to remove deposits. Make sure all the switches, connectors and fan ports are clean. A small brush can be used to clean the fan ports. Check the fan ports regularly for buildup. If there is visible damage, worn electrode cables or power cable, do NOT operate the instrument. Contact NuVant for replacement cables or for return of instrument for repair.



## SERVICE AND REPAIR

ONLY NuVant is authorized to service and repair the EZstat and Powerstat. ONLY NuVant staff should open the chassis or remove instrument components. ONLY NuVant



Systems can verify safe operation of the instrument after a repair. If there are doubts about instrument functionality, contact NuVant at (219) 644-3231.

## SOFTWARE INSTALLATION

The EZware installation DVD includes the LabVIEW Runtime Engine, the NI-DAQmx driver, the NI-Serial driver and the EZware software. Version specific installation instructions are provided with each EZware installation DVD. *Users are urged to read the instructions before installing the software and connecting hardware. Please note that the recommended pattern is to install the software prior to connecting the hardware so all hardware is automatically recognized by both the Windows and National Instruments New Hardware Wizards.*

- 1.0 Install the LabVIEW Runtime Engine using the default installation options. Restart the computer after installation is complete.
- 2.0 Install NI-DAQmx with the default installation options. Restart the computer after installation is complete.
- 3.0 If the temperature and/or mass flow controller options are ordered, the NI-Serial driver on the installation DVD must also be installed. Installation and COM port configuration instructions are provided under separate cover when these options are ordered.
- 4.0 Install the EZware software. A re-boot is not required after installing the EZware software.
- 5.0 Connect the USB cable provided to the back of the EZstat or Powerstat but do not plug it into the computer yet.
- 6.0 Apply power to the EZstat by connecting and plugging in the external power supply. Ensure the physical Cell Enable switch is in the out (off) position. Press the power switch on the front panel. This power switch should illuminate green and you should hear the sound of the cooling fan when the instrument is on.
- 7.0 Connect the USB cable to your computer and wait to see the new hardware installed twice. The hardware must be recognized first by Windows and then by the National Instruments Measurement & Automation Explorer (MAX).

NuVant provides periodic software upgrades to ensure that instruments are working at the highest efficiency. Current versions of the EZware software are available through [www.nuvant.com](http://www.nuvant.com). Contact NuVant for additional information if necessary.

The NI-DAQmx driver and LabVIEW Runtime Engine may be downloaded from the National Instruments website [www.ni.com](http://www.ni.com) or through the following sites:

LabVIEW 2012 Runtime Engine: <http://joule.ni.com/nidu/cds/view/p/id/3710/lang/en>

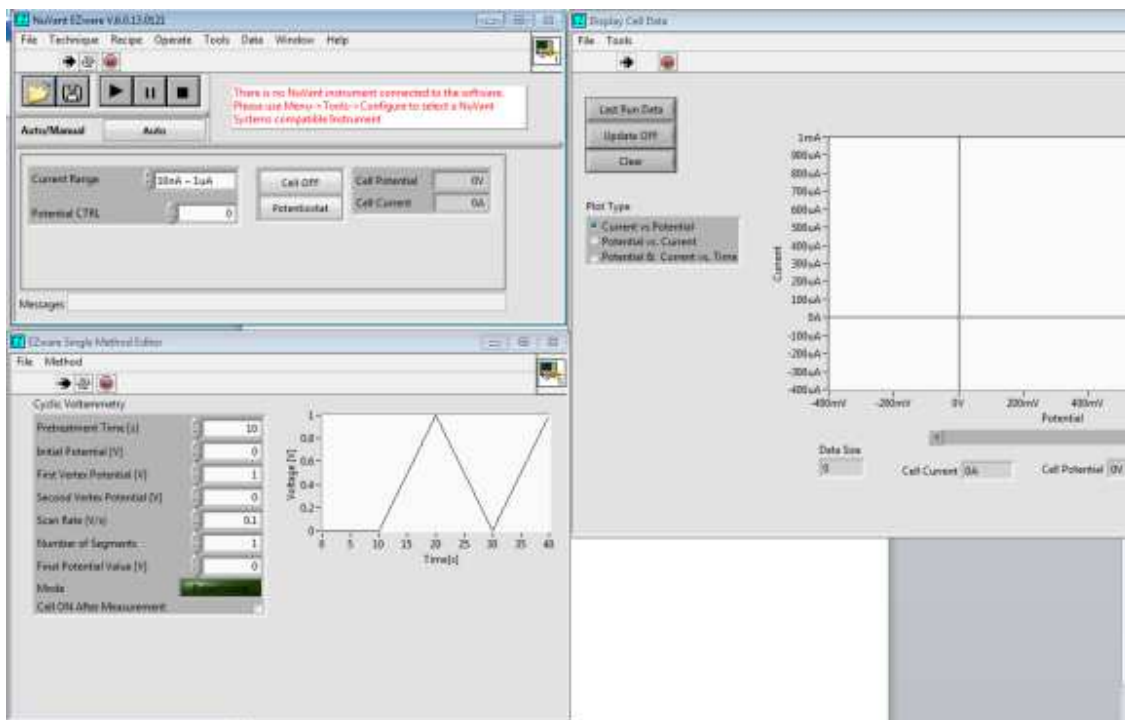
NI-DAQmx v9.7 Driver: <http://joule.ni.com/nidu/cds/view/p/id/3811/lang/en>

NI Serial Driver: <http://joule.ni.com/nidu/cds/view/p/id/3680/lang/en>



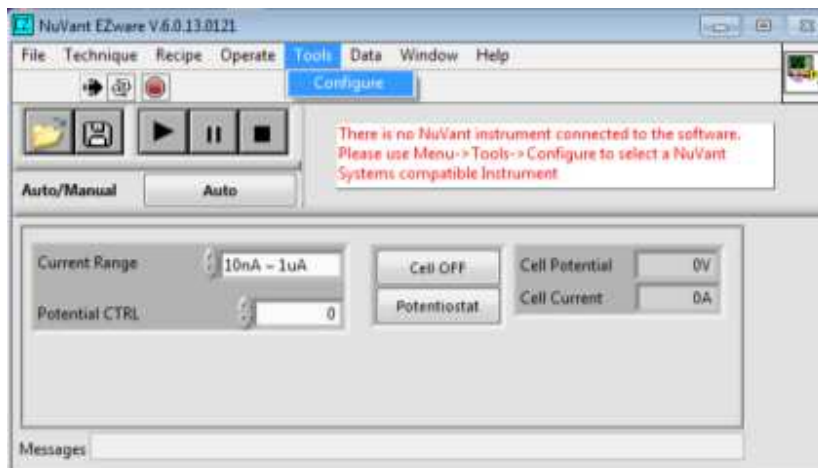
## SOFTWARE AND INSTRUMENT STARTUP

1. When the software is opened, three windows will open simultaneously: [NuVant EZware], [Display Cell Data], and [Edit Single Method] (Fig. 6).



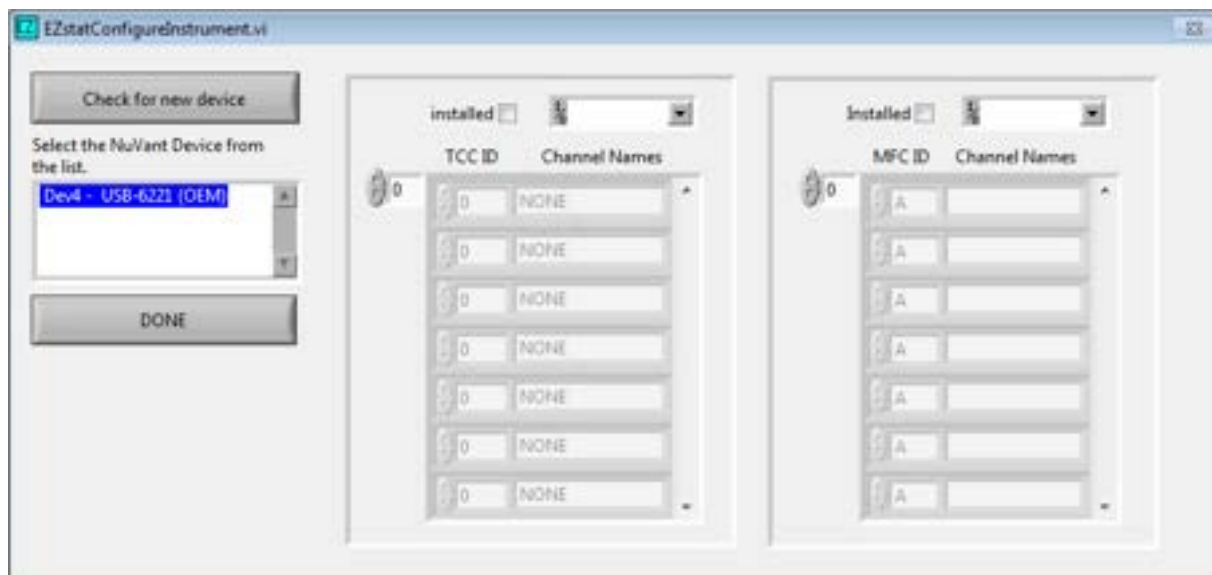
**Figure 6.** Startup windows of the EZware software

- [NuVant EZware] will show red text, indicating that there is no instrument connected to the software. Select **Tools**→*Configure* in [NuVant EZware] to connect the instrument to the software (Fig. 7).



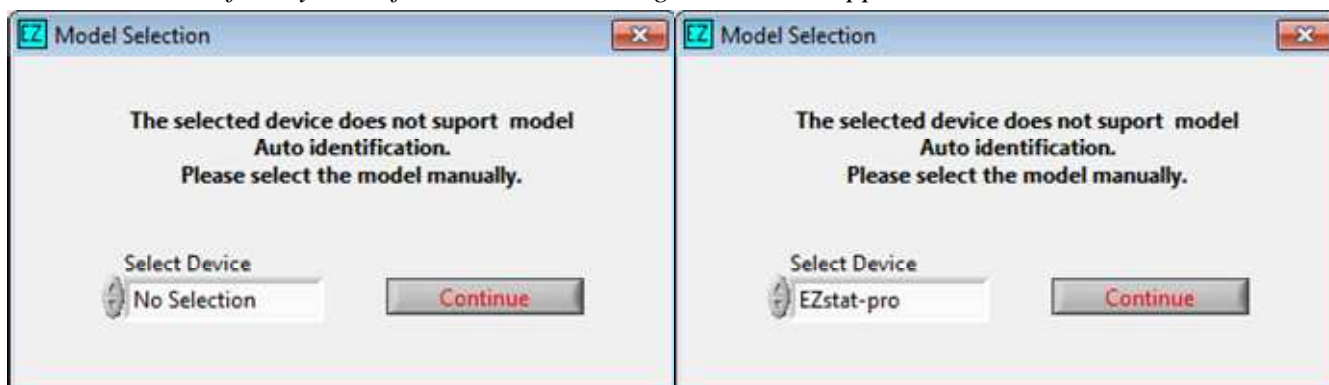
**Figure 7.** Connection of instrument to software

- Configure* will open [Configure Instrument]. If the instrument is properly connected to the computer, the device will be listed in the box on the left of the window (Fig. 8, highlighted in blue). If the device is not listed, ensure that the instrument is properly connected and turned on, and then click **Check for new device**. Once the instrument is indicated on the device list, highlight the device and click **Done**.



**Figure 8.** [Configure Instrument] window

- In [Model Selection] (Fig. 9), click the arrows or the “No Selection” text to display the instrument options and select the proper instrument model. Warning: Make sure the right model is selected, otherwise the instrument will not function properly. Click **Continue** to save the proper instrument. *Note: newer instrument models will automatically be identified by the software and this dialog box will not appear.*



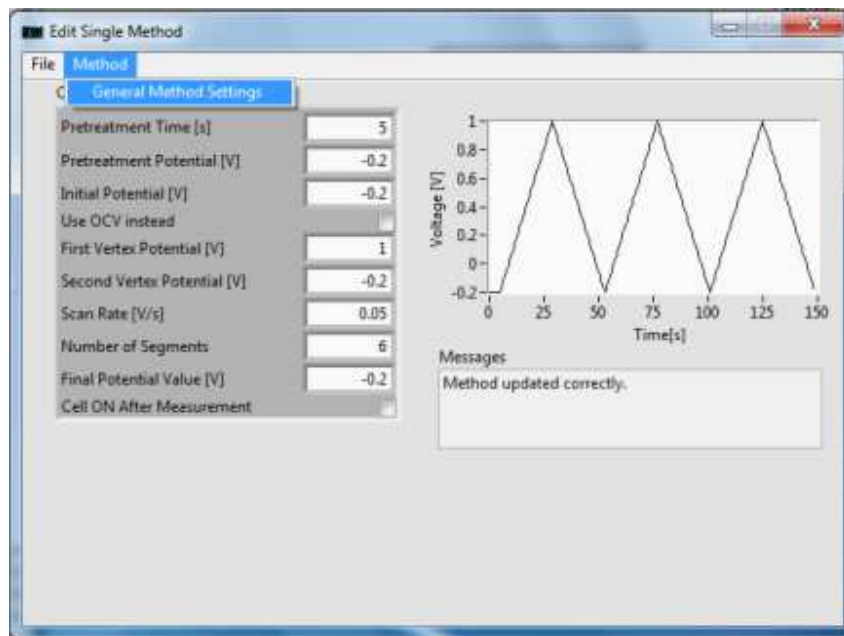
**Figure 9.** [Model selection]

- [NuVant EZware] will now display the logo for the selected instrument.



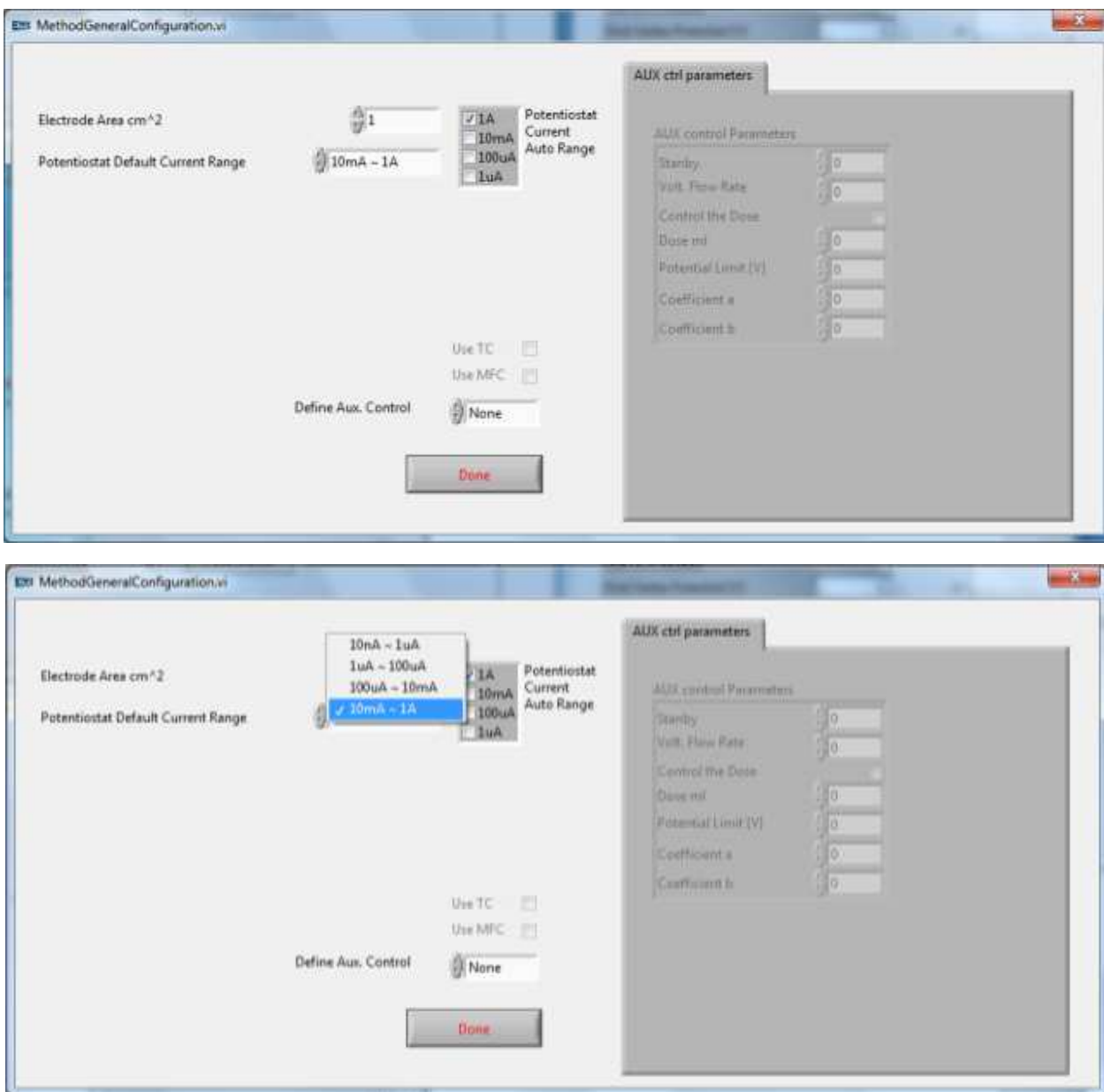
**Figure 10.** [NuVant EZware] with the instrument selected

6. Select **Method**→*General Settings* in [Edit Single Method] to choose the proper instrument settings for the experiment (Fig. 11).



**Figure 11.** [General settings]

7. In [General Configuration], click the text box next to Potentiostat Default Current Range to select the proper current range. If the scan rate of the sweep experiment is 100 mV/s or less, auto-ranging can be used. To utilize the auto-range option, first select the starting range via the text box next to Potentiostat Default Current Range and then select the required ranges located in the gray box next to Potentiostat Current Auto Range. Click **Done** to save the settings. (Fig. 12)



**Figure 12.** [Method General Configuration] with current range selection

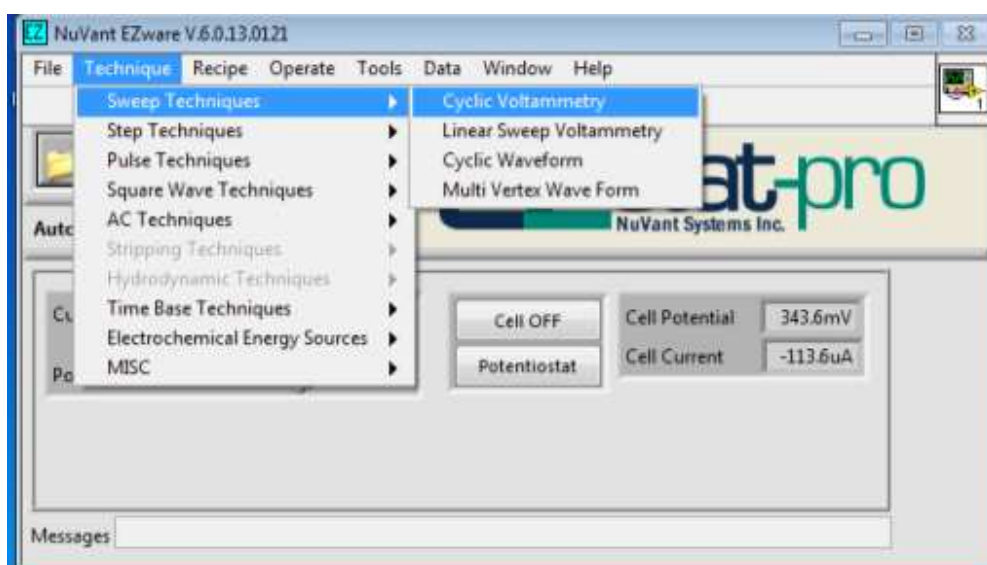
## RECIPE DESIGN

### General Recipe Notes

- At any point, an experiment can be reset to the default settings by going to [NuVant EZware] **File**→ *New*.
- Many of the following experiments are described with the recipe editor in potentiostat mode. When galvanostat mode is available, the green **Mode** button will be activated in [Edit Single Method].

### Cyclic Voltammetry

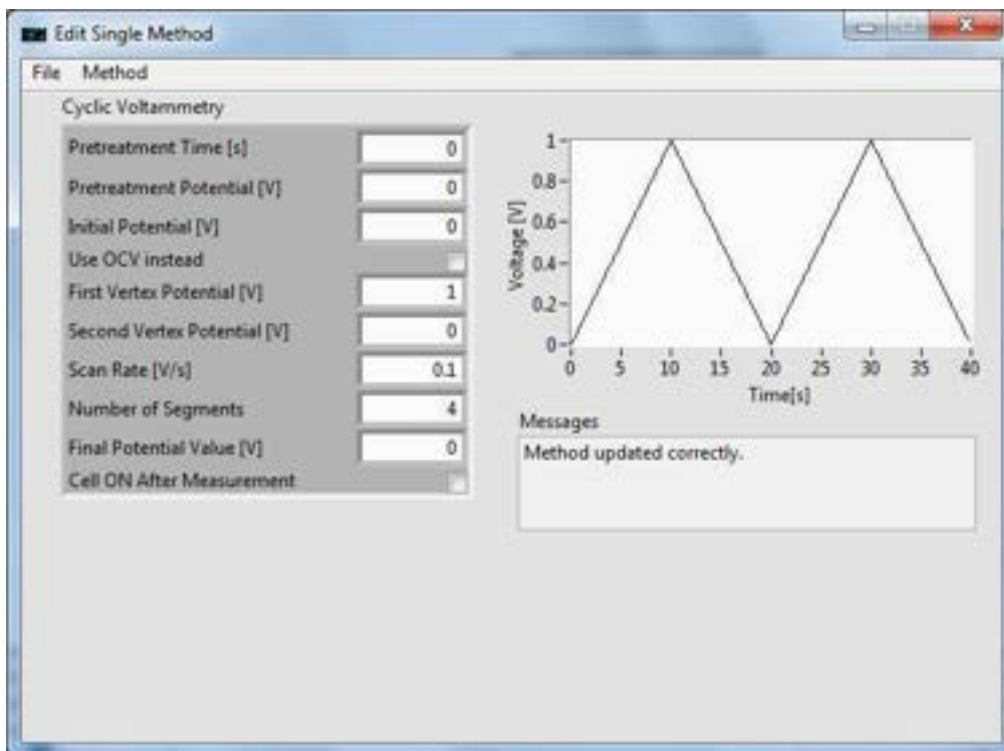
1. For cyclic voltammetry, go to [NuVant EZware] **Technique**→ *Sweep Techniques*→ Cyclic Voltammetry (Fig. 13).



**Figure 13.** Cyclic voltammetry

2. [Edit Single Method] shows the input boxes for **Cyclic Voltammetry**. Pretreatment Time [s] is the duration at a soak potential, Pretreatment Potential [V]. After the pretreatment period, the scan will begin at the Initial Potential [V]. Often, the Pretreatment Potential [V] and the Initial Potential [V] will be the same. The scan will proceed to the First Vertex Potential [V] from the Initial Potential [V] and then to the Second Vertex Potential [V]. The Number of Segments is the number of each individual anodic and cathodic scan. If the user wants two full scan cycles, there will be four

segments. The Final Potential Value [V], if selected as a different value from the Second Vertex Potential [V], scans from the Second Vertex Potential [V] to the selected value. This scan is in addition to the Number of Segments chosen. If the Cell ON After Measurement box is selected, the potential will soak at this value when the experiment is complete. Once the desired values have been entered into the window, the waveform will be displayed on the right of the window (Fig. 14).



**Figure 14. Cyclic Voltammetry recipe editor**

## Linear Sweep Voltammetry

- For a linear sweep voltammetry, go to [NuVant EZware] **Technique**→*Sweep Techniques*→Linear Sweep Voltammetry. [Edit Single Method] will now show the input boxes for **Linear Sweep Voltammetry**. Pretreatment Time [s] is the duration at a soak potential, Pretreatment Potential [V]. After the pretreatment period, the scan will begin at the Initial Potential [V]. Often, the Pretreatment Potential [V] and the Initial Potential [V] will be the same. The scan will proceed to the First Vertex Potential [V] from the Initial Potential [V]. In linear sweep voltammetry, there is no reverse scan. Standby Potential Value [V] can only be used if the Cell ON After Measurement box is selected. If this option is used, then the potential will soak at the desired value when the experiment is completed.

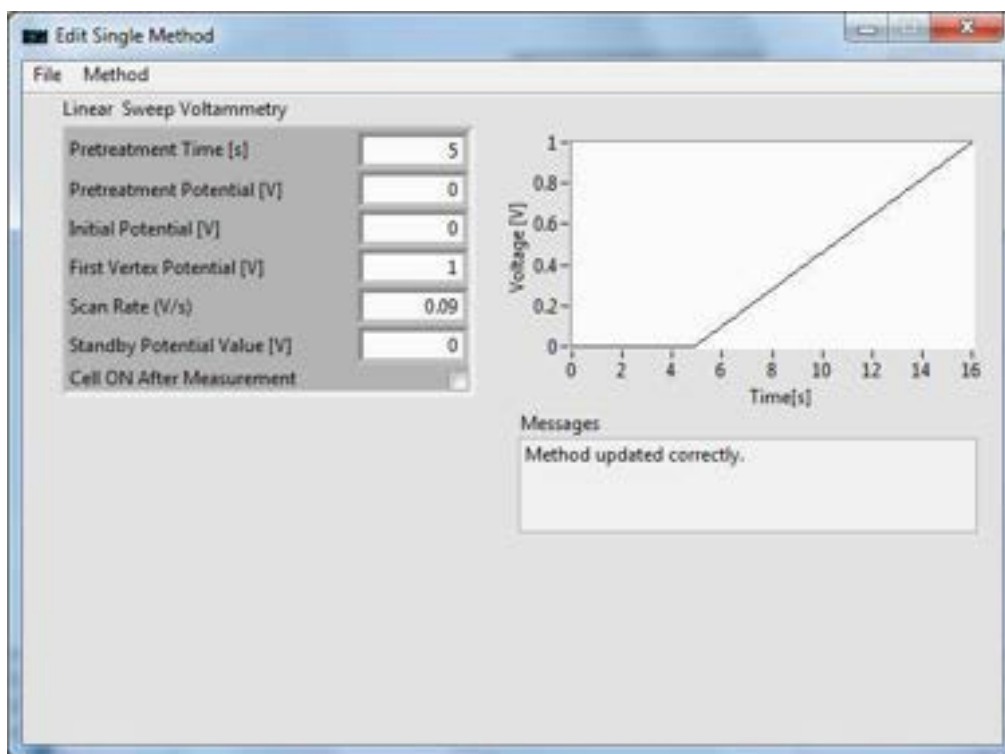
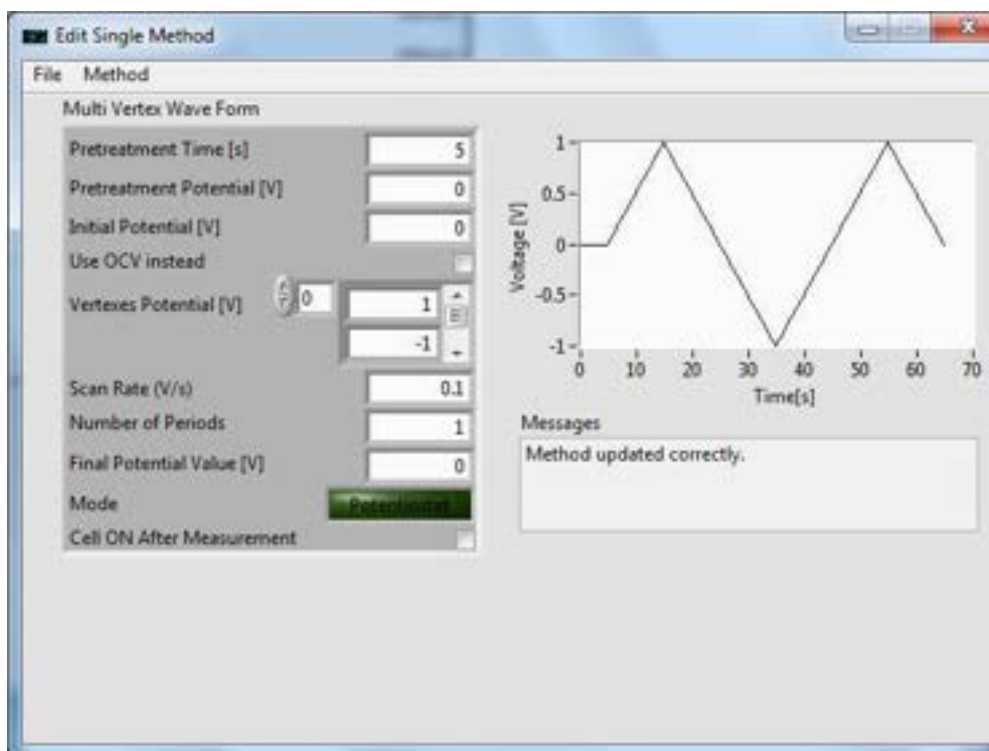


Figure 15. Linear Sweep Voltammetry



## Multi Vertex Waveform

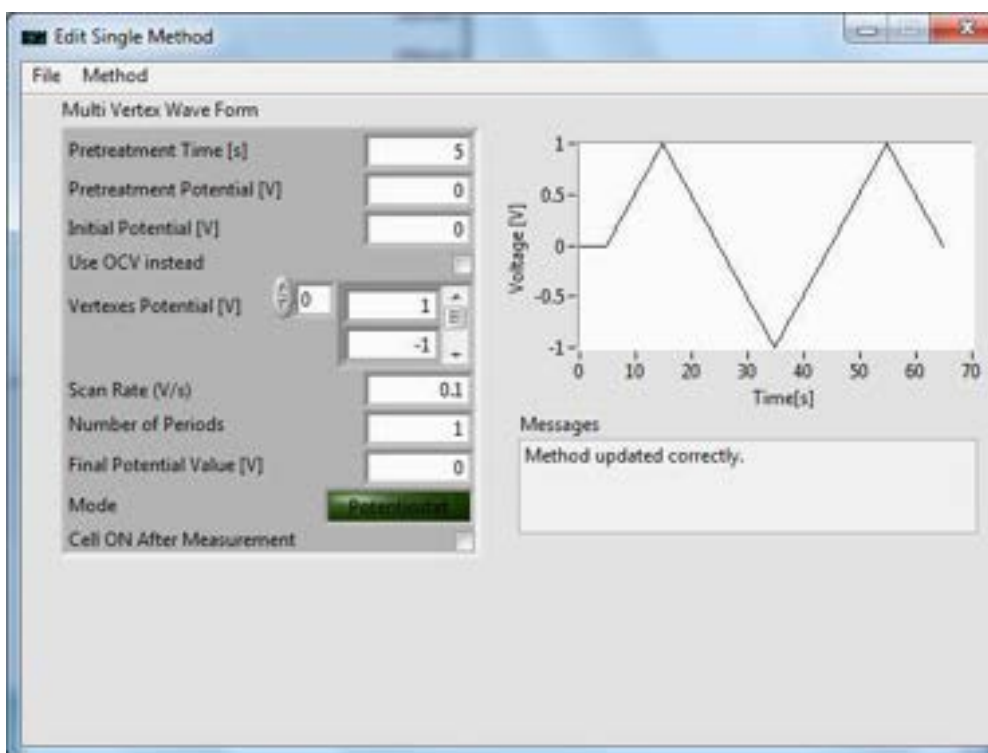
1. For multi vertex waveform, go to [NuVant EZware] **Technique**→*Sweep Techniques*→Multi Vertex Waveform. [Edit Single Method] shows the input boxes for **Multi Vertex Waveform** (Fig. 16).



**Figure 16. Multi Vertex Waveform recipe editor**

Pretreatment Time [s] is the duration at a soak potential, Pretreatment Potential [V]. After the pretreatment period, the scan will begin at the Initial Potential [V]. Often, the Pretreatment Potential [V] and the Initial Potential [V] will be the same. The scan will proceed to the First Vertex Potential [V] from the Initial Potential [V]. Vertices Potential [V] allows for the user to select any number of vertices and their respective potential values. The first vertex potential is labeled “0” in the left box, and its corresponding potential value is entered in the right box. The scan will proceed from the Initial Potential [V] to the Vertex Potential [V] “0”. To create more vertices, change the left box to “1” and select the potential value for this vertex. Create more vertices if necessary. The Number of Periods is the number of times the scan from the Initial Potential [V] to the First Vertex Potential [V] and back to the Initial Potential [V] is repeated. Figures 17a through 17d show how to set the vertex potentials to the desired

values so that the waveform follows the pattern described above. The example experiment has a pretreatment of 0 V for 10 s, followed by a 100 mV/s scan to 1V, a 100 mV/s scan to 500 mV, and a 100 mV/s scan back to 1V. The scan from 1V to 500 mV and back to 1V is repeated (the Number of Periods is 2). In Figure 17c, the Final Potential Value [V] is set to 0.5 V, meaning that after the 2 periods are complete, the potentiostat will scan back to a final potential of 0.5 V. This scan is in addition to the Number of Periods chosen. If the Cell ON After Measurement box is selected, the potential will soak at this value when the experiment is complete. To demonstrate an alternate view, in Figure 17d, the Final Potential Value [V] is set to 0 V.



**Figure 17a.** Vertex Potential 0 set to 1 V

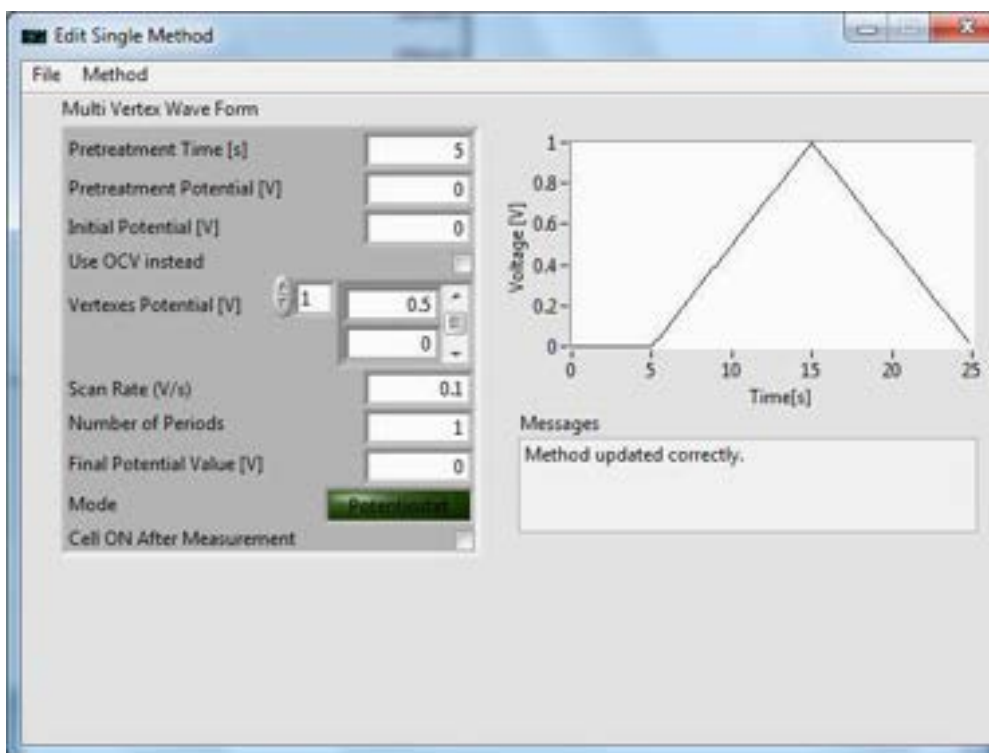
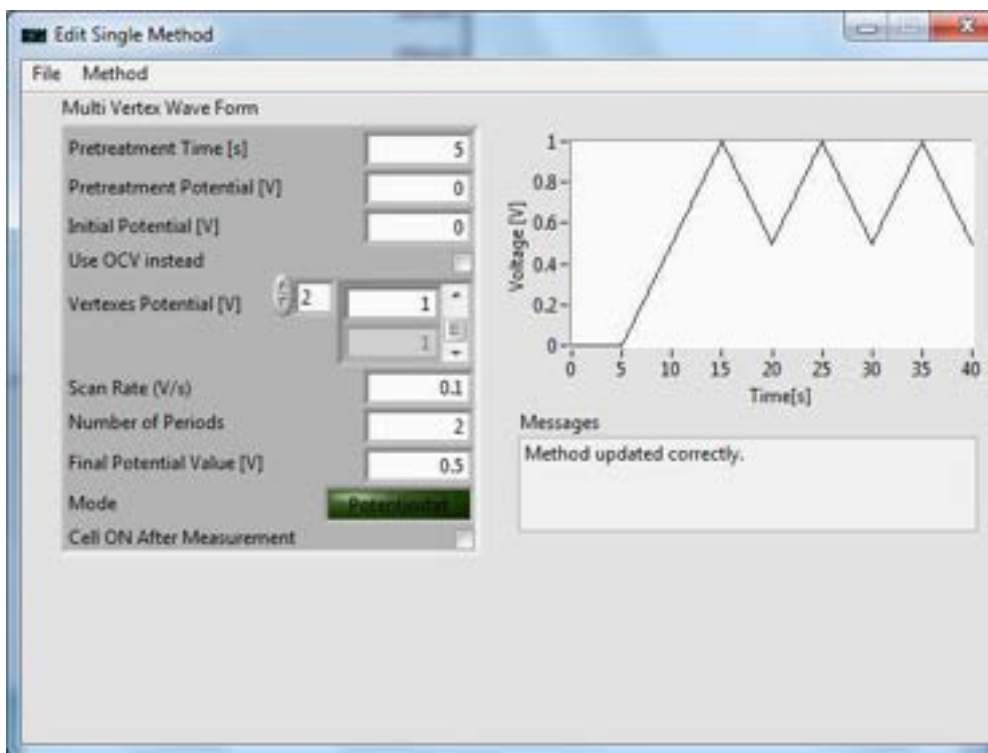


Figure 17b. Vertex Potential 1 set to 0.5 V



**Figure 17c.** Vertex Potential 2 set to 1 V

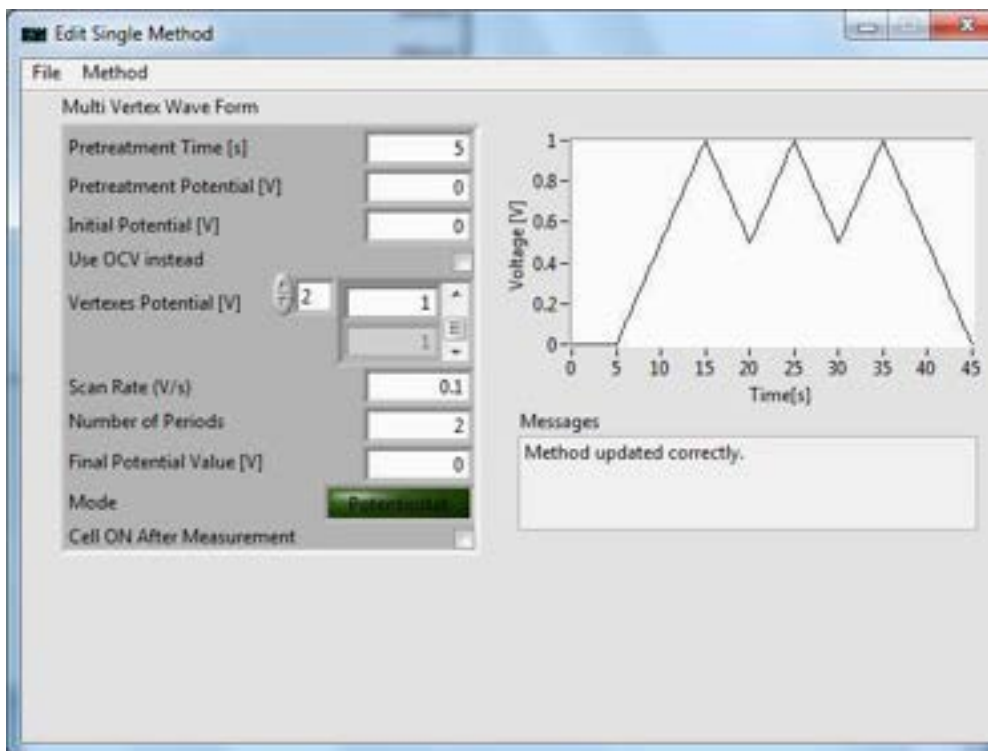
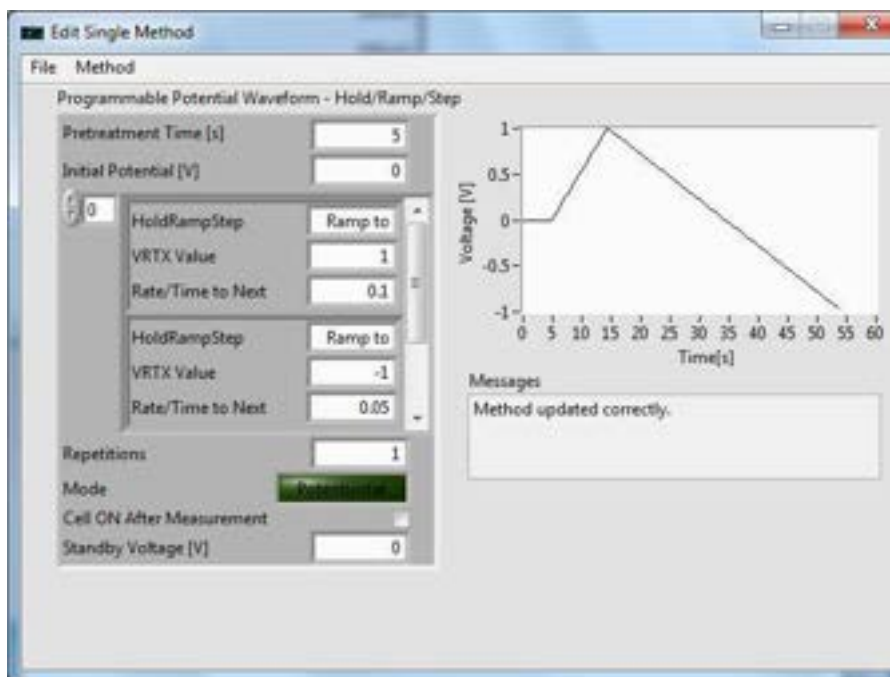


Figure 17d. Final Potential Value set to 0 V

## Programmable Potential Waveform – Hold/Ramp/Step

- For programmable potential waveforms, go to [NuVant EZware]  
**Technique**→*MISC*→Programmable Potential Waveform – Hold/Ramp/Step. [Edit Single Method] shows the input boxes for **Programmable Potential Waveform – Hold/Ramp/Step** (Fig. 18a-f).



**Figure 18a. Programmable Potential Waveform** recipe editor

Pretreatment Time [s] is the duration at a soak value, Initial Value. After the pretreatment period, the scan will begin at the Initial Potential [V]. Steps in the experiment are inserted via the arrow buttons circled in red in Figure 18b. The first step after the pretreatment is step “0”. By clicking the box next to Hold/Ramp/Step (Fig. 18d), the user can select the potential or current control required. VRTX Value is the set point of the Hold/Ramp/Step. Rate/Time to Next is scan rate or time between steps, depending on which control mode the user is in. In Figure 18b, step “0” is a “ramp to” 1 V at a rate of 0.5 V/s. Figure 18c shows step “1” set to a “ramp to” -1 V at a rate of 1 V/s. Figure 18d and 18e show the selection of step “2”, which is initially grayed out, as “step to”, and the selection of “step to” as 0.5 V. In the case of the “step to” selections, the Rate/Time to Next input box is not used and can be ignored. Figure 18f shows a final “ramp to” 0 V at 1 V/s in step “3”. Repetitions, if used, will repeat the experiment starting at step “0”. If the Cell ON After Measurement box is selected, the potential will soak at the Standby Value when the experiment is complete.

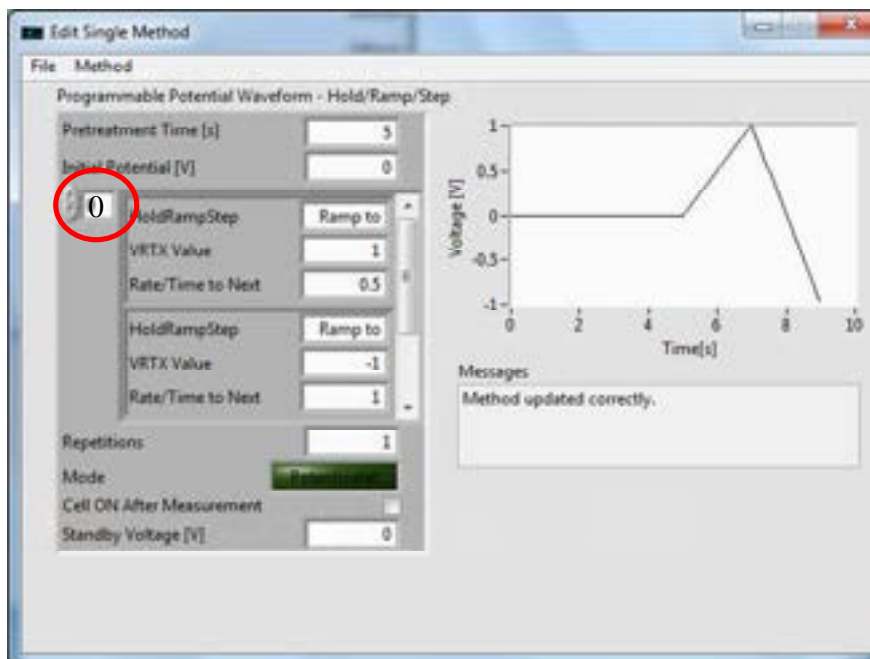


Figure 18b. Selecting experimental steps and “ramp to” 1V in step “0”

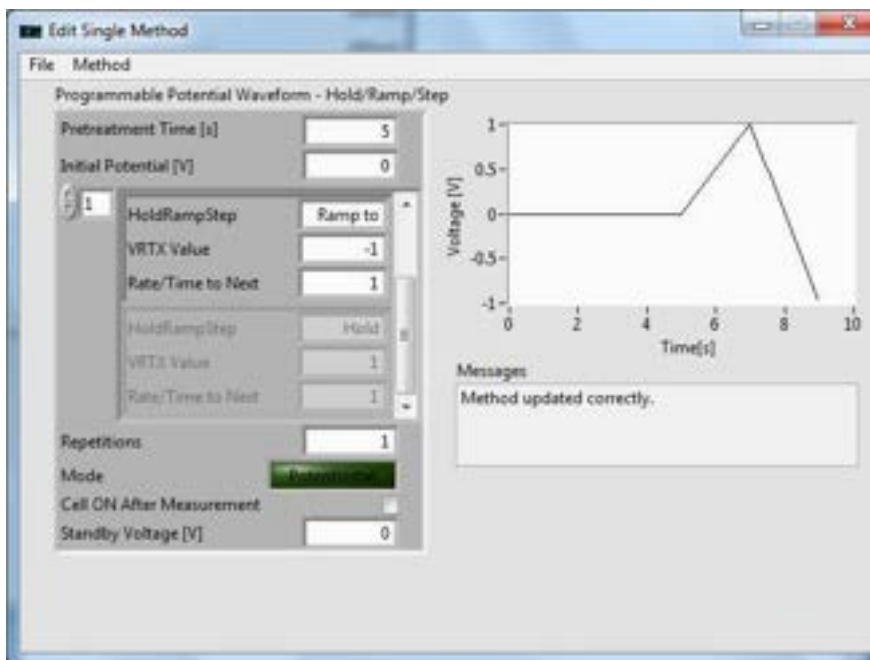


Figure 18c. “Ramp to” -1V in step “1”

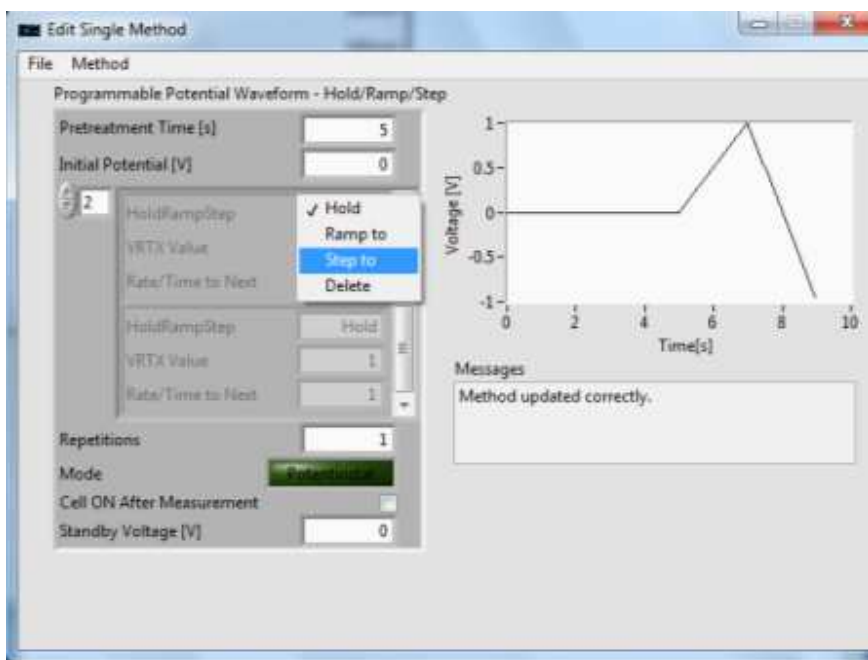


Figure 18d. Selection of “step to” in step “2”

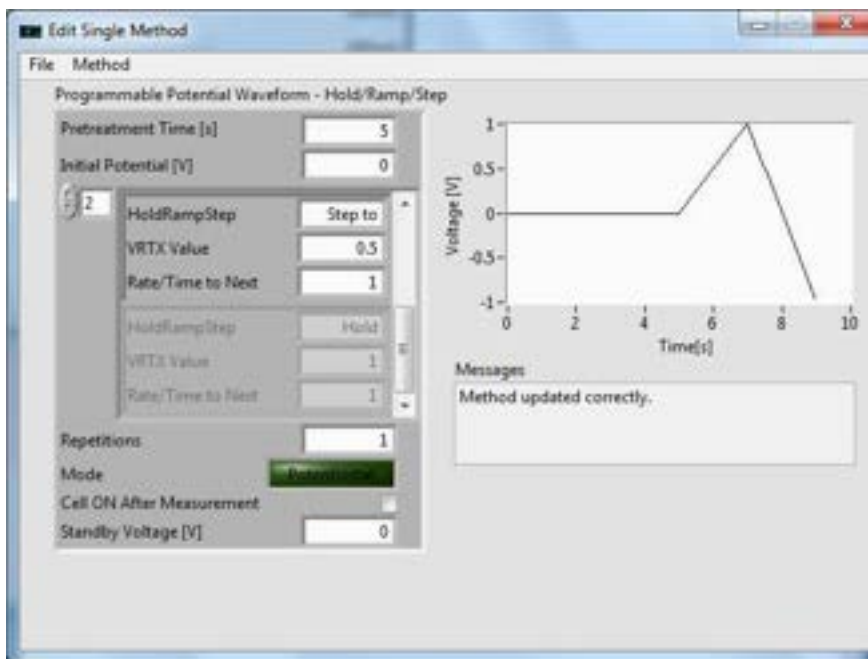
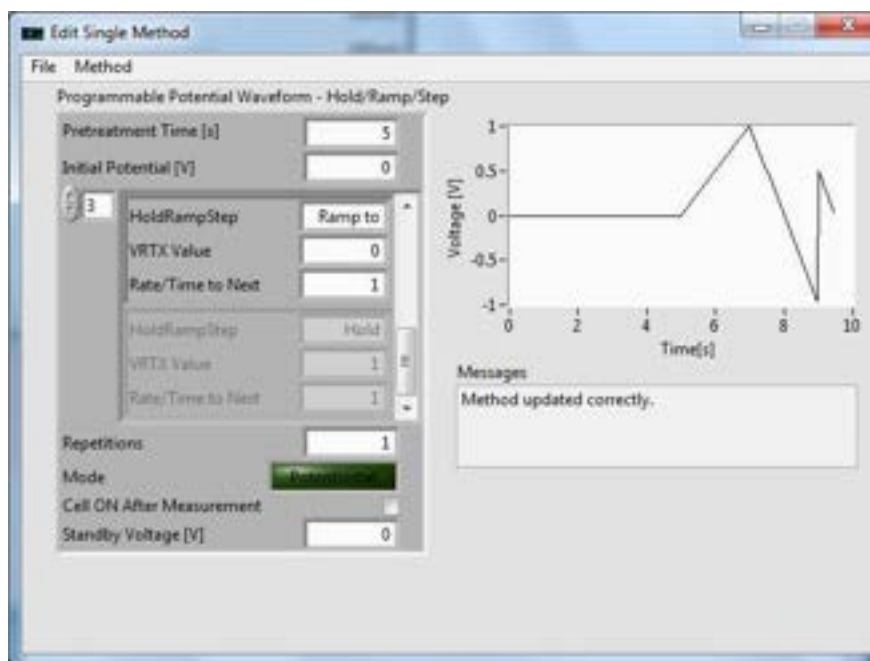


Figure 18e. “Step to” 0.5 V in step “2”

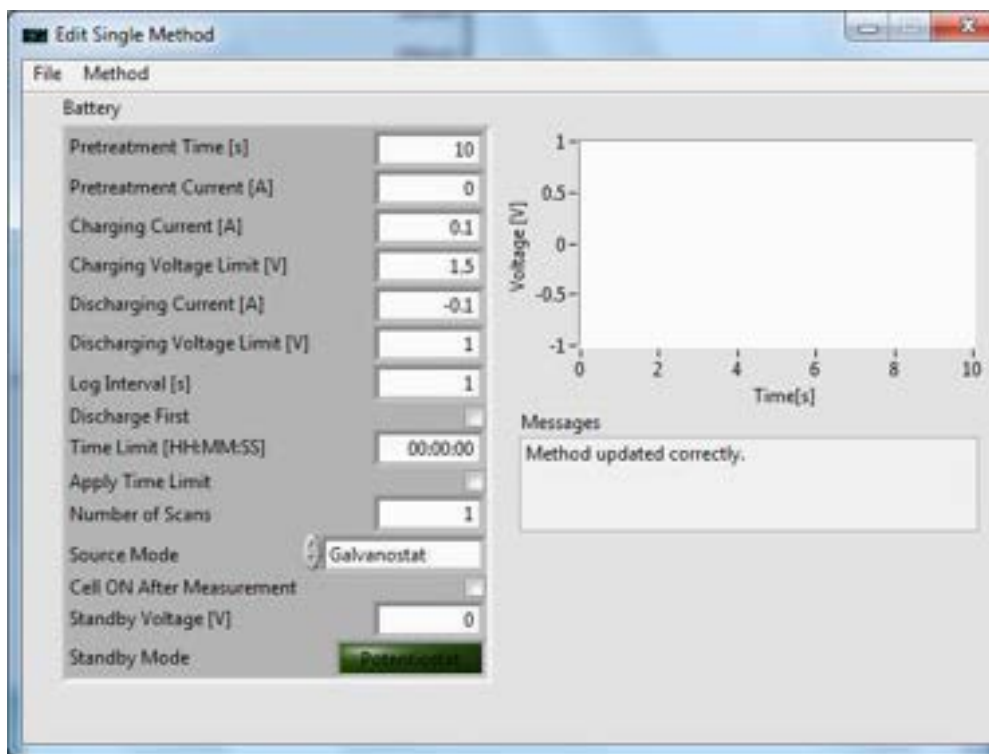




**Figure 18f.** “Ramp to” final 0V

## Battery Cycling

1. For battery cycling, go to [NuVant EZware] **Technique**→*Electrochemical Energy Sources*→Battery. [Edit Single Method] shows the input boxes for **Battery** (Fig. 19).

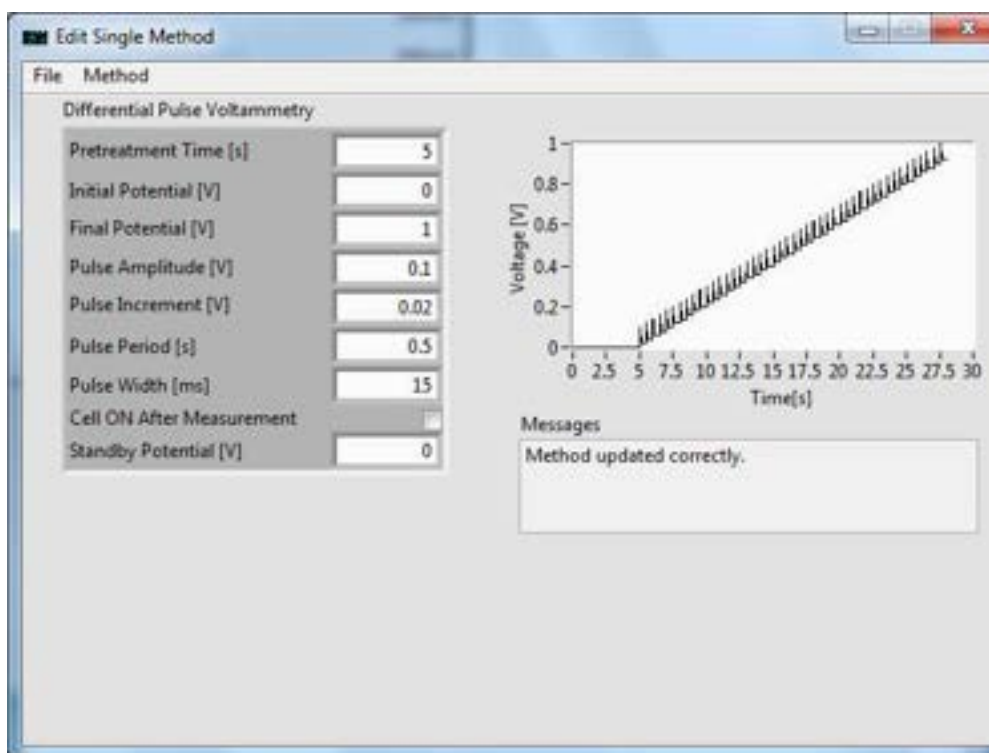


**Figure 19.** Battery recipe editor

Set Source Mode to “Galvanostat”. Pretreatment Time [s] is the duration at a soak current, Pretreatment Current [A]. Charging Current [A] is the soak current, which continues until the voltage reaches the Charging Voltage Limit [V]. Discharging Current [A] is the soak current, which continues until the voltage reached the Discharging Voltage Limit [V]. Log Interval [s] is the period between acquired points for the charging and discharging. The recipe is defaulted to perform the charging first. The discharge can be performed first by selecting Discharge First. Time Limit [s] will stop the experiment after a certain period of time, superseding any potential limits set. Number of Repetitions determines how many times a charge/discharge or discharge/charge cycle is performed.

## Differential Pulse Voltammetry

1. For differential pulse voltammetry, go to [NuVant EZware] **Technique**→*Pulse Techniques*→Differential Pulse Voltammetry. [Edit Single Method] shows the input boxes for **Differential Pulse Voltammetry** (Fig. 20).

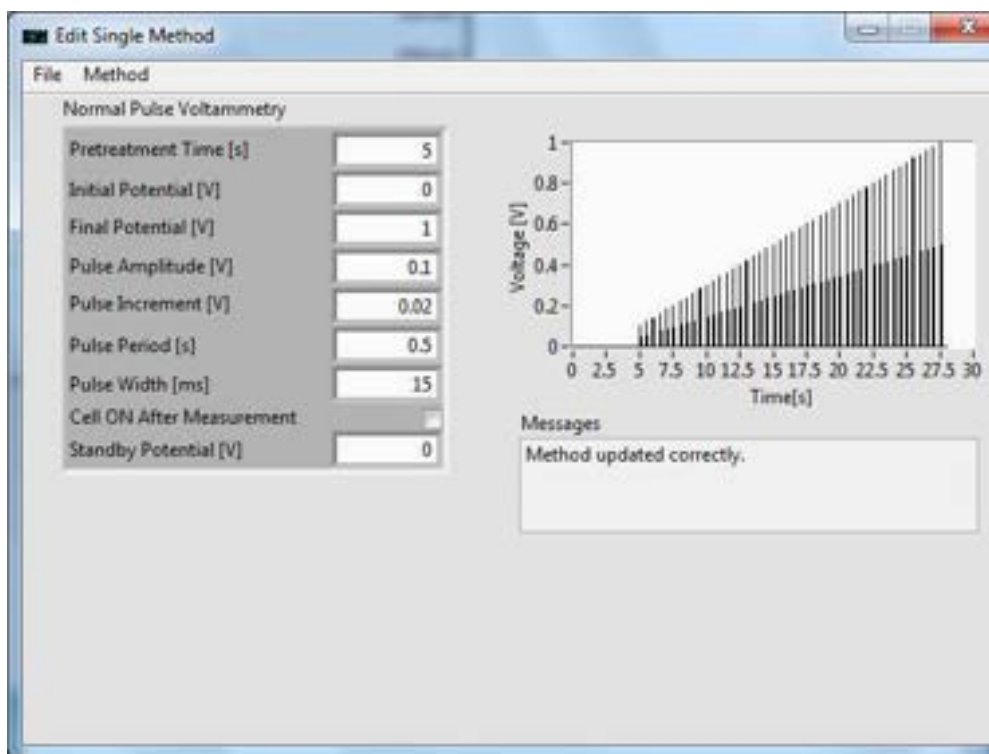


**Figure 20. Differential Pulse Voltammetry recipe editor**

Pretreatment Time [s] is the duration at a soak potential, Initial Potential [V]. After the pretreatment period, the scan will begin at the Initial Potential [V]. Final Potential [V] is last potential step value of the experiment. Pulse Amplitude [V] is the magnitude of each pulse. Pulse Increment [V] is the change in potential after one period. Pulse Period [s] is change in time after one period. Pulse Width [s] is the change in time during each pulse. Standby Potential [V] sets the cell to a desired potential at the end of the experiment, only if Cell ON After Measurement is selected.

## Normal Pulse Voltammetry

- For normal pulse voltammetry, go to [NuVant EZware] **Technique**→*Pulse Techniques*→Normal Pulse Voltammetry. [Edit Single Method] shows the input boxes for **Normal Pulse Voltammetry** (Fig. 21).

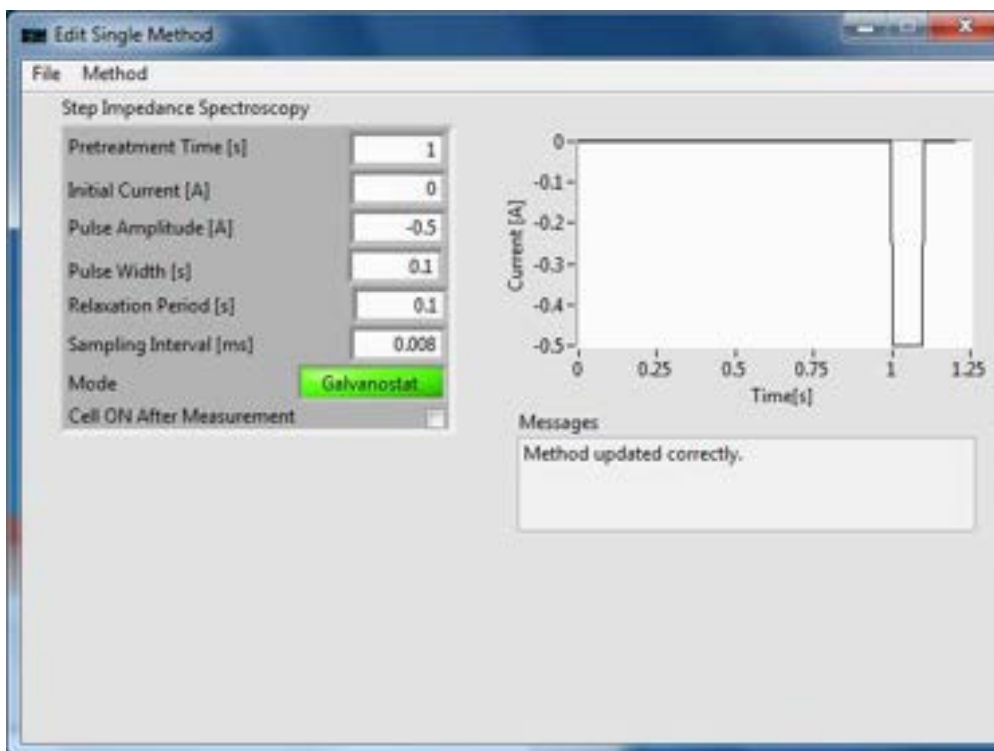


**Figure 21.** Normal Pulse Voltammetry recipe editor

Pretreatment Time [s] is the duration at a soak potential, Initial Potential [V]. After the pretreatment period, the scan will begin at the Initial Potential [V]. Final Potential [V] is last potential step value of the experiment. Pulse Amplitude [V] is the size of the initial pulse. Pulse Increment [V] is the change in potential between each pulse potential. Pulse Period [s] is change in time after one period. Pulse Width [s] is the change in time during each pulse. Standby Potential [V] sets the cell to a desired potential at the end of the experiment, only if Cell ON After Measurement is selected.

## Step Impedance Spectroscopy (SIS)

- To set up a step impedance spectroscopy (SIS) recipe, go to [NuVant EZware] **Technique**→*Step Techniques*→Step Impedance Spectroscopy. [Edit Single Method] shows the input boxes for **Step Impedance Spectroscopy** (Fig. 22).



**Figure 22. Step Impedance Spectroscopy** recipe editor

Pretreatment Time [s] is the duration at a soak current, Initial Current [A]. After the pretreatment period, the scan will begin at the Initial Current [A]. Pulse Amplitude [A] is the size of the pulse. For a battery discharge experiment, the sign of the pulse amplitude value should be opposite to that of the displayed battery voltage in the [NuVant EZware] window. For a charge experiment, the sign should be the same. Pulse Width [s] is the duration of the pulse. Relaxation Period [s] is the length of time after the pulse that the current sits at the Initial Current [A]. Sampling Interval [ms] is the period between acquired points during the experiment.

## Electrical Impedance Spectroscopy (EIS)

Note: EIS is only available for the EZstat-Pro EIS. To use the EIS feature, please download the EIS software, [NuVant EZware-EIS], available at <http://nuvant.com/download-software/software/>, or install the EZware-EIS provided in the CD.

1. The EIS software controls are located on the main [NuVant EZware-EIS] window.

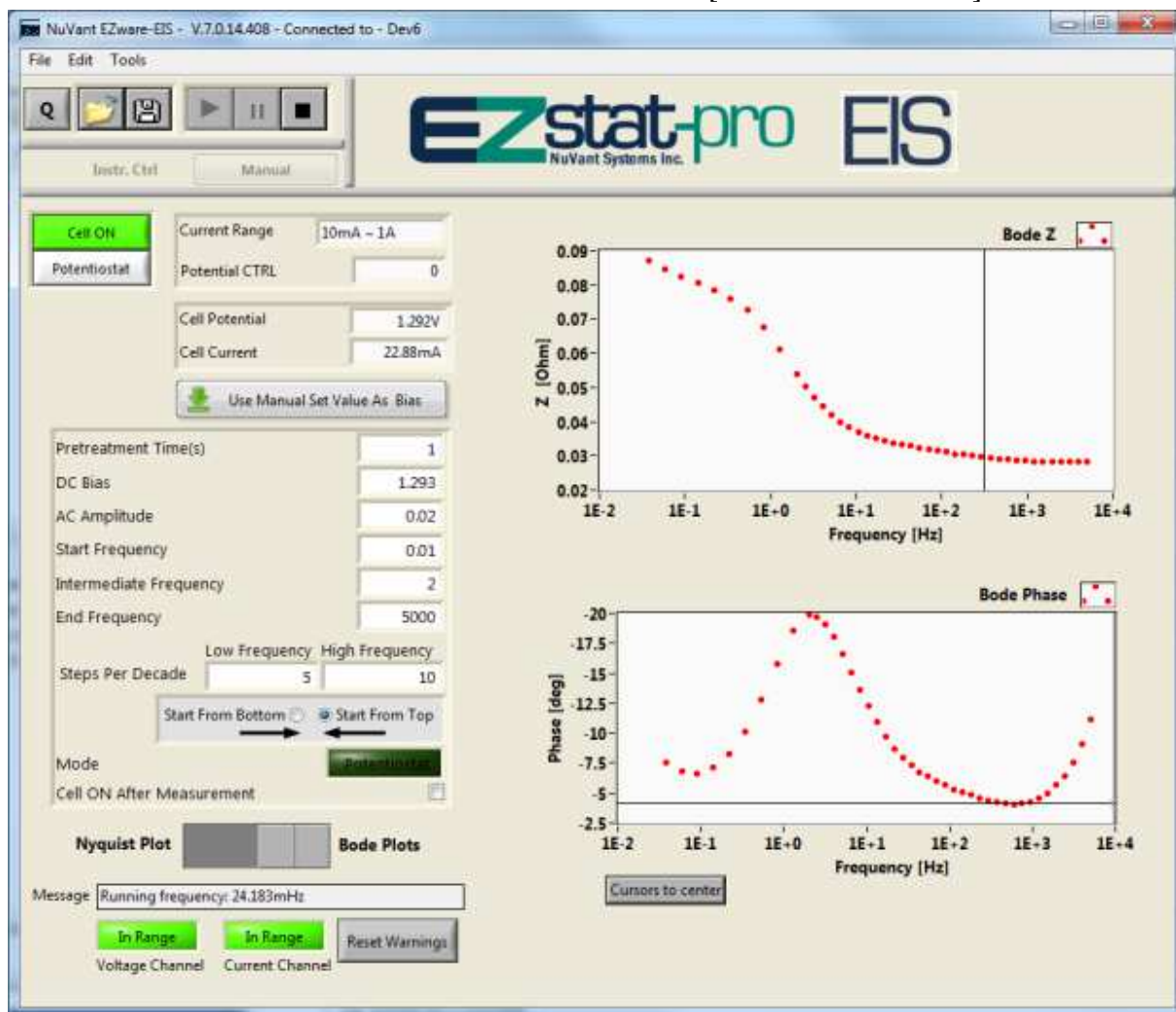


Figure 23. EIS control window in galvanostat mode

The instrument can perform in “Galvanostat” or “Potentiostat” mode using the button on the top left of the window (seen here as “Galvanostat”). When running a recipe, select the current range for the EIS test by going to **Edit**→*General Settings*. It should not be confused with the current range on the front panel, which is used when in manual mode. If during the scan any of the potential or current channels go out of range, the measurement should be repeated with different

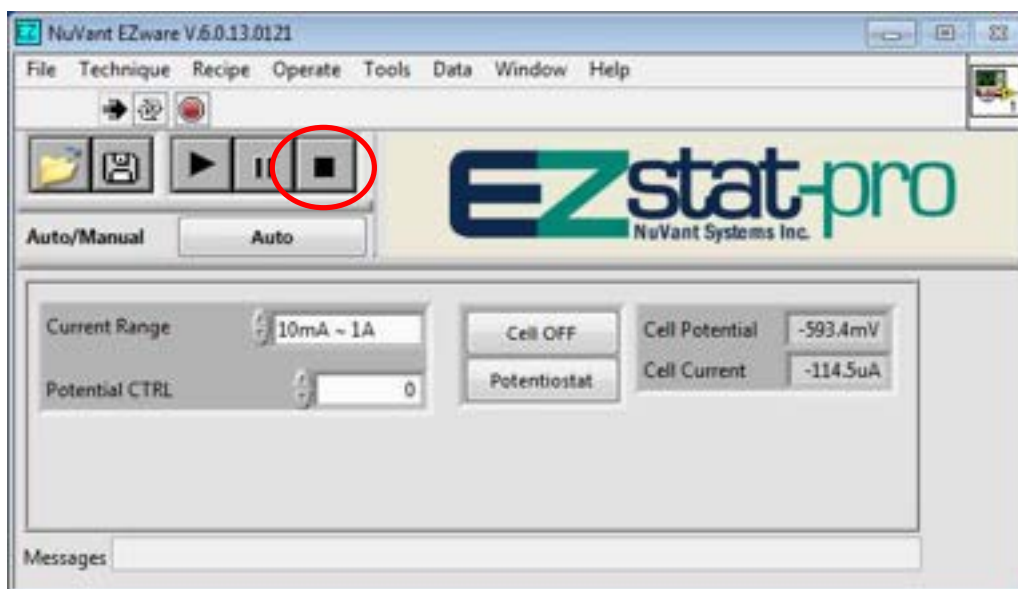
amplitudes and proper current ranges. Before each measurement make sure the **In Range** indicators are properly reset (indicators are green).

Cell Potential and Cell Current display the respective potential and current values of the system in real-time. In manual “Galvanostat” mode, the end-user can select a value for Current CTRL. In manual “Potentiostat” mode, the end-user can select a value set the Potential CTRL and use this value as the DC Bias by pushing **Use Manual Set Value as Bias**. Enter the Pretreatment Time (s), DC Bias (if not already selected), AC Amplitude, Start Frequency, Intermediate Frequency, End Frequency. Choose the Steps per Decade for Low Frequency (between the start and intermediate frequencies) and High Frequency (between intermediate and end frequencies). Decide whether to “Start From Bottom” or “Start From Top” by selecting one of these options. The resulting data can be displayed as either **Nyquist Plot** or **Bode Plot** by using the slider button. The resulting data is displayed on the right half of the screen.

After the data is collected **File**→*Export* saves the data as .csv file or a file compatible with the publicly available EIS Spectrum Analyser: <http://www.abc.chemistry.bsu.by/vi/analyser/>

## STOPPING / RESTARTING AND EXPERIMENT

1. An experiment can be stopped and restarted. To stop an experiment, click on **Stop** in [NuVant EZware] (Fig. 24.). Data from the unfinished experiment can be saved, as outlined in the AXES RESCALING / SAVING DATA section.



**Figure 24.** Stopping an experiment

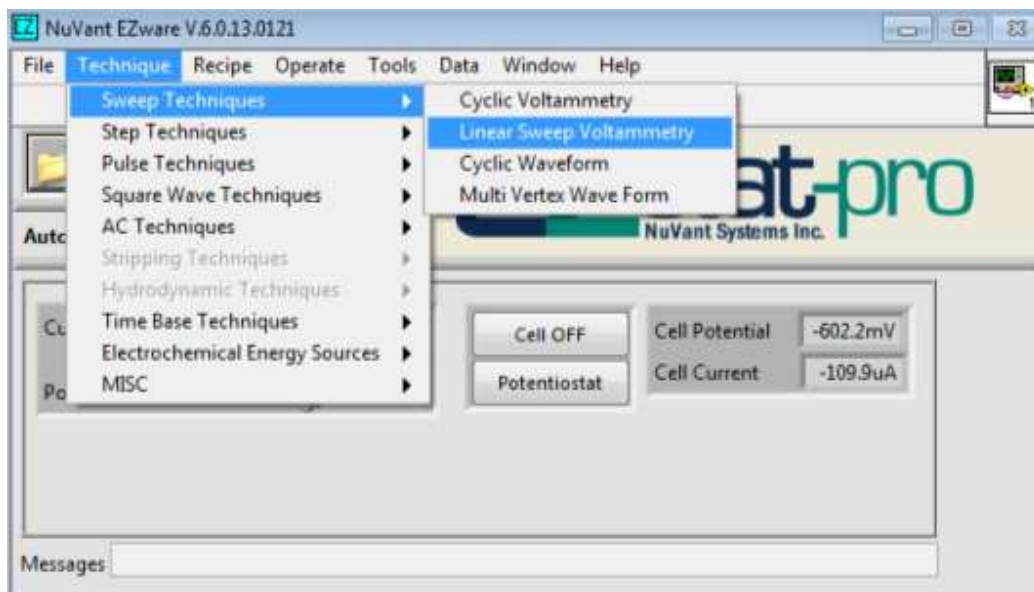
2. Once the experiment has been stopped, aspects of the experimental setup, such as the recipe, can be modified. Once the user is satisfied with the changes, the experiment can be restarted by selecting **Start** in [NuVant EZware]. Note: the experiment will restart from the beginning, not from the point where it was stopped.



## SAMPLE EXPERIMENTS

### Linear Voltammetry – Corrosion Experiment

1. For a corrosion experiment, select [NuVant EZware] **Technique**→*Sweep Techniques*→  
Linear Sweep Voltammetry(Fig. 25).



**Figure 25.** Linear Sweep Voltammetry

2. [Edit Single Method] now displays the input boxes for **Linear Sweep Voltammetry** (Fig. 26). The proper values can be input into the fields on the left of the window.

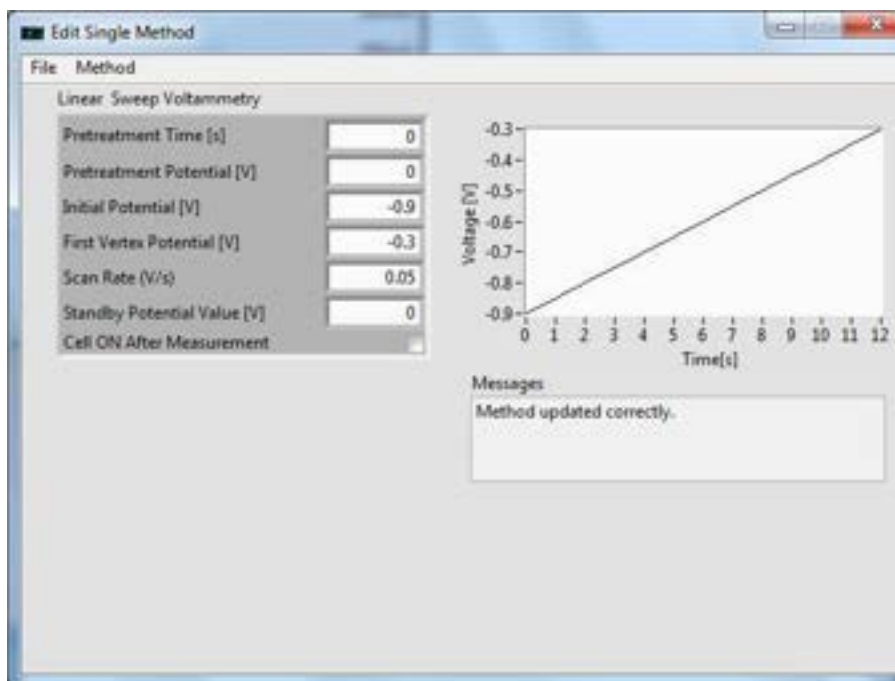


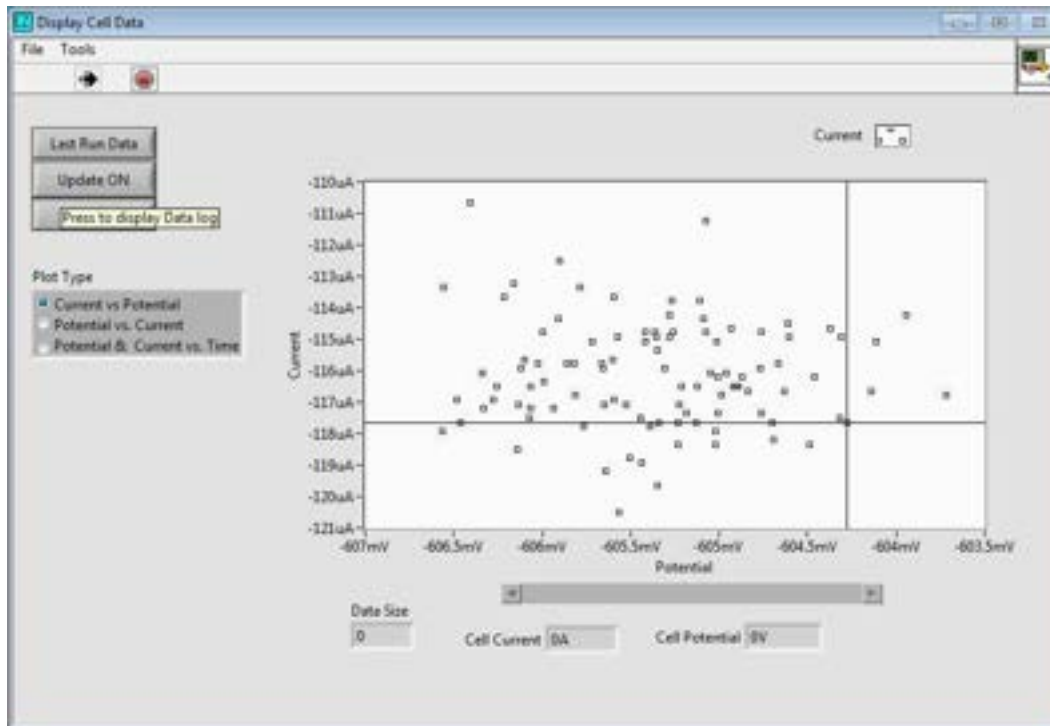
Figure 26. Linear Sweep Voltammetry recipe editor

3. To start the experiment, click **Start** in [NuVant EZware].



Figure 27. Starting the recipe

- The data collection is visualized in [Display Cell Data]. To see the data, **Update** needs to be selected to read **Update On** (Fig. 28).



**Figure 28.** [Display Cell Data]

- To change the style of the graph, click the style image at the top right of the window. Hover over *Common Plots* and select the desired style. The axes can also be changed to any of the options listed on the left of the window (Fig. 29).

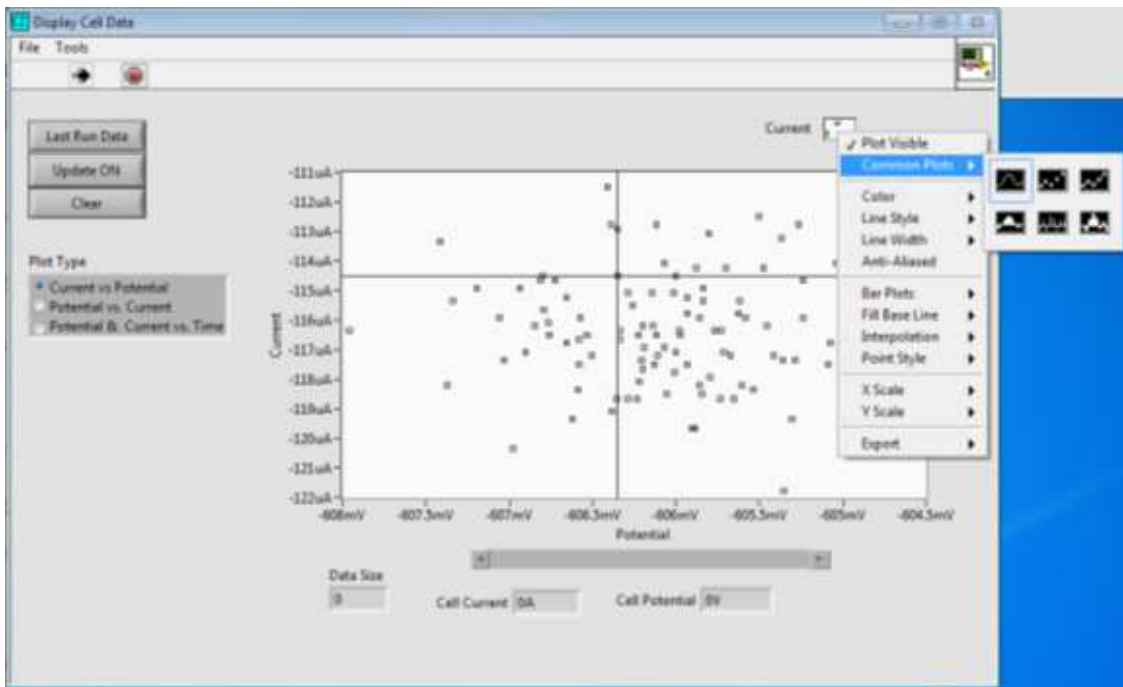


Figure 29. Data display style and axes change

- When the experiment is complete, the final, unfiltered data can be visualized by clicking **Last Run Data** on the top left of the window.

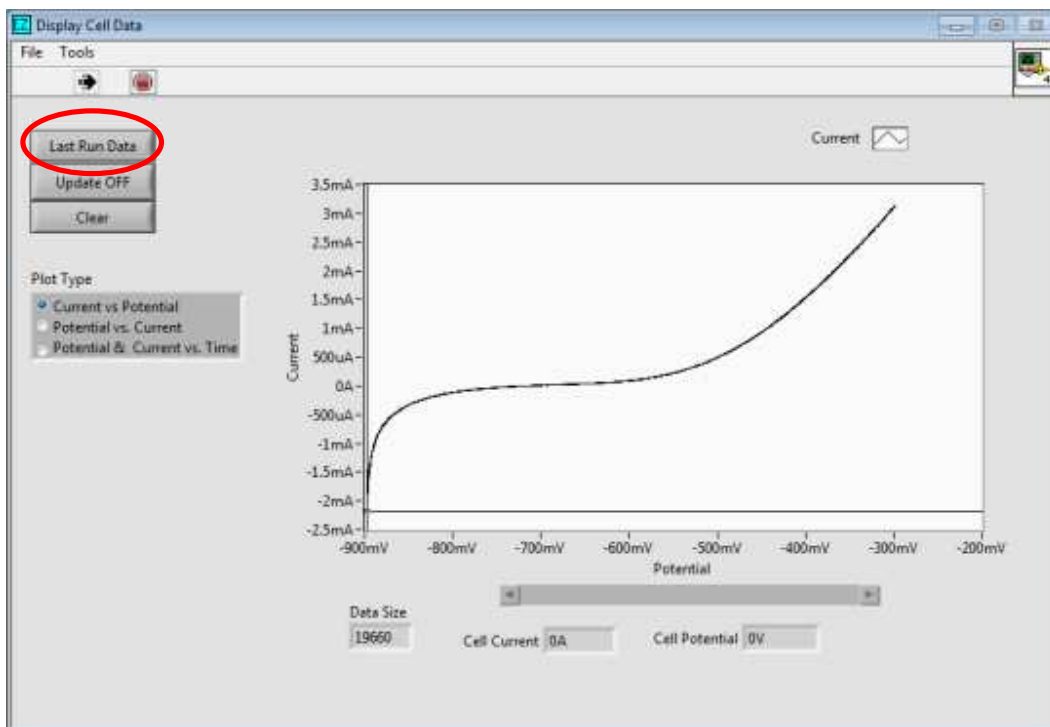
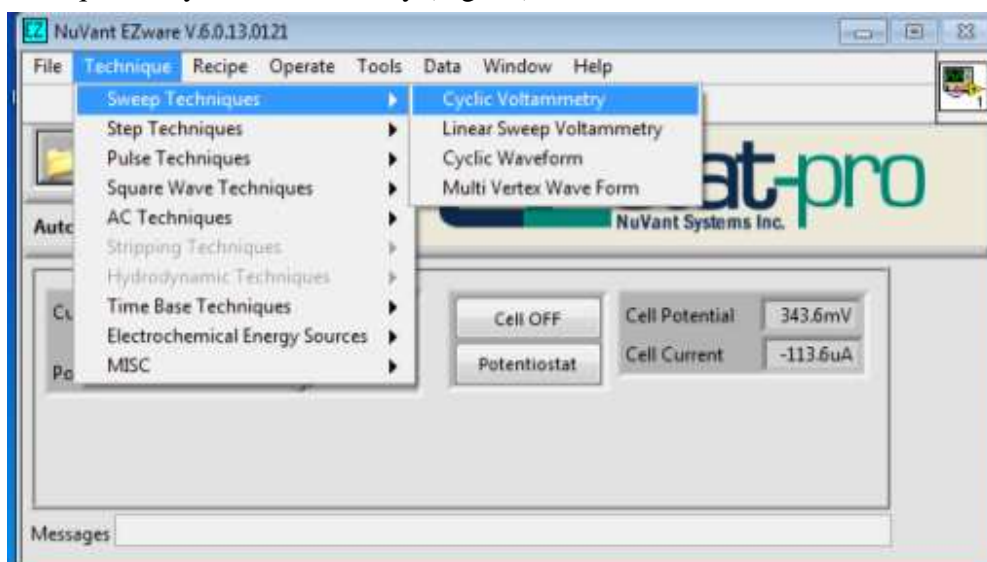


Figure 30. Completed data collection (Last Run Data)

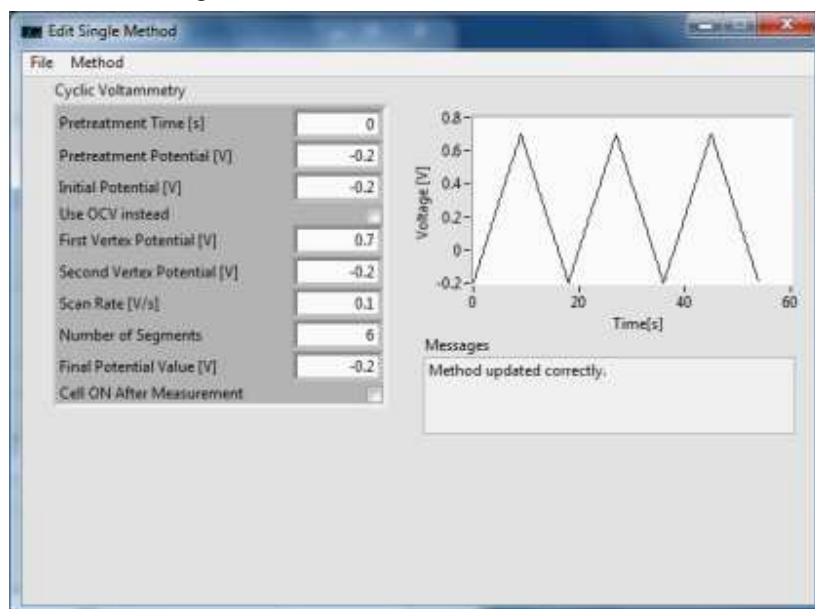
## Cyclic Voltammetry (5mM $K_4Fe(CN)_6$ and $K_3Fe(CN)_6$ in 1M $KNO_3$ )

1. For a cyclic voltammetry experiment, go to [NuVant EZware] **Technique**→*Sweep Techniques*→Cyclic Voltammetry (Fig. 31).



**Figure 31.** Cyclic voltammetry selection

2. [Edit Single Method] now shows the input boxes for **Cyclic Voltammetry**. Once the desired values have been entered into the window, the waveform will be displayed on the right of the window (Fig. 32).



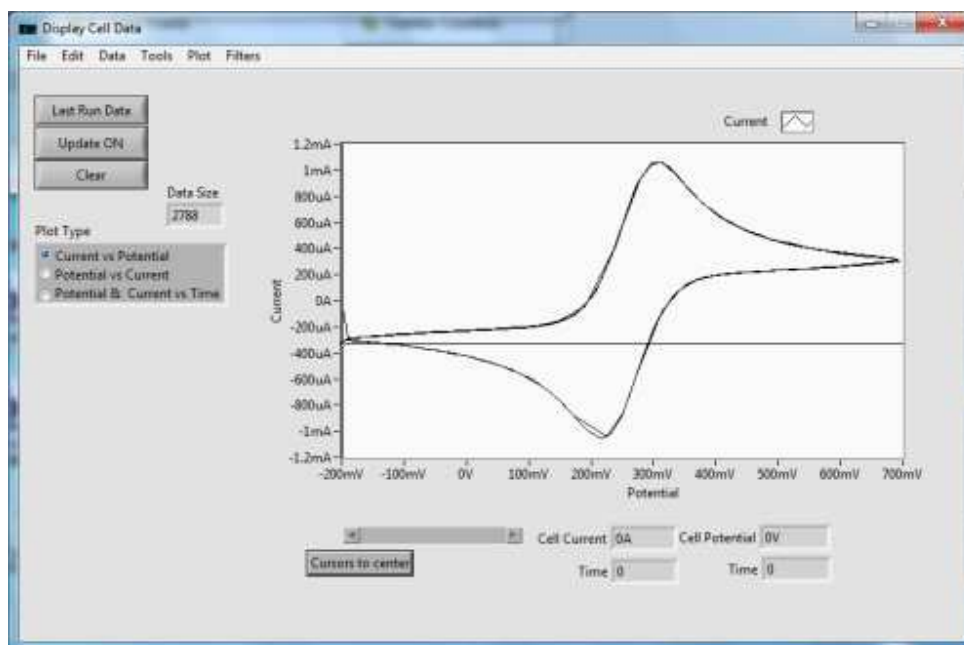
**Figure 32.** Cyclic Voltammetry

- When the recipe is complete, the experiment can be started by clicking **Start** in [NuVant EZware] (Fig. 33).

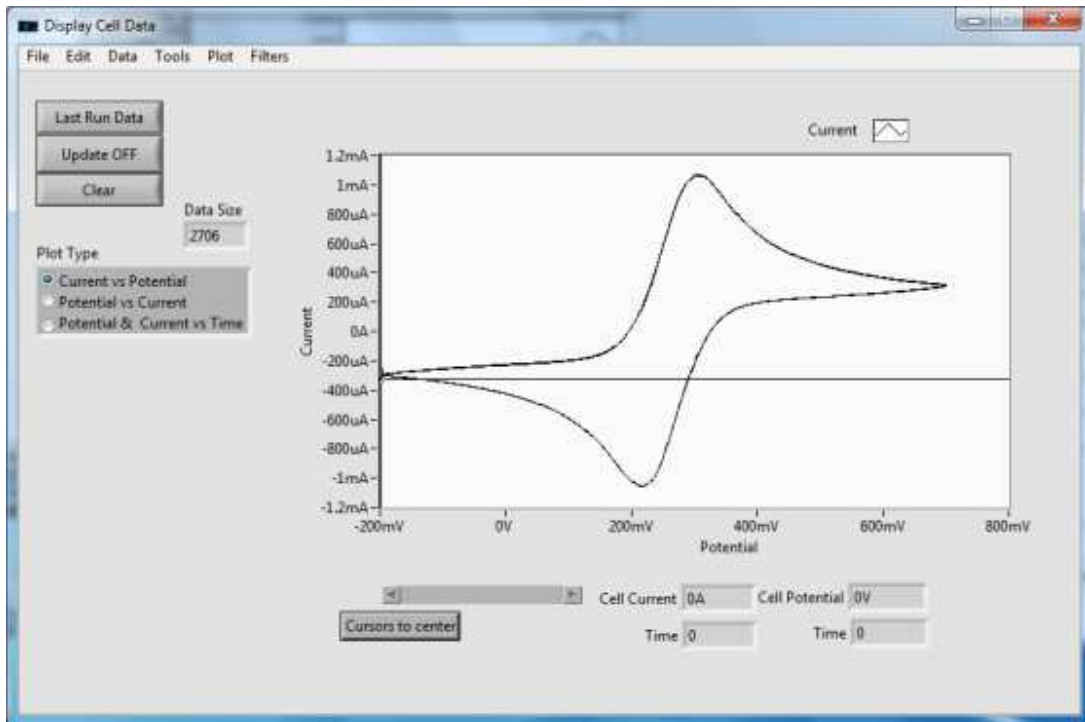


**Figure 33.** Starting the recipe

- [Display Cell Data] shows the data being collected as the experiment is running (Fig. 34a). Once the experiment is complete, the final data can be viewed by clicking **Last Run Data** on the right of the window (Fig. 34b).



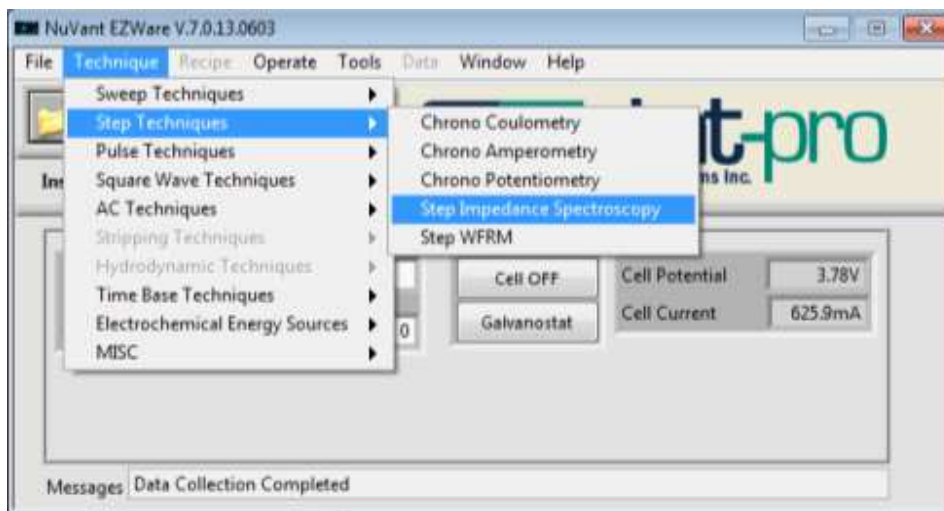
**Figure 34a.** Real time data collection



**Figure 34b.** Completed data collection

## Step Impedance Spectroscopy (3.78V Li ion battery)

1. To set up a step impedance spectroscopy (SIS) recipe, go to [NuVant EZware] **Technique**→*Step Techniques*→Step Impedance Spectroscopy. [Edit Single Method] shows the input boxes for **Step Impedance Spectroscopy** (Fig. 35).



**Figure 35.** SIS selection



- [Edit Single Method] now shows the input boxes for **Step Impedance Spectroscopy**. Once the desired values have been entered into the window, the waveform will be displayed on the right of the window (Fig. 36).

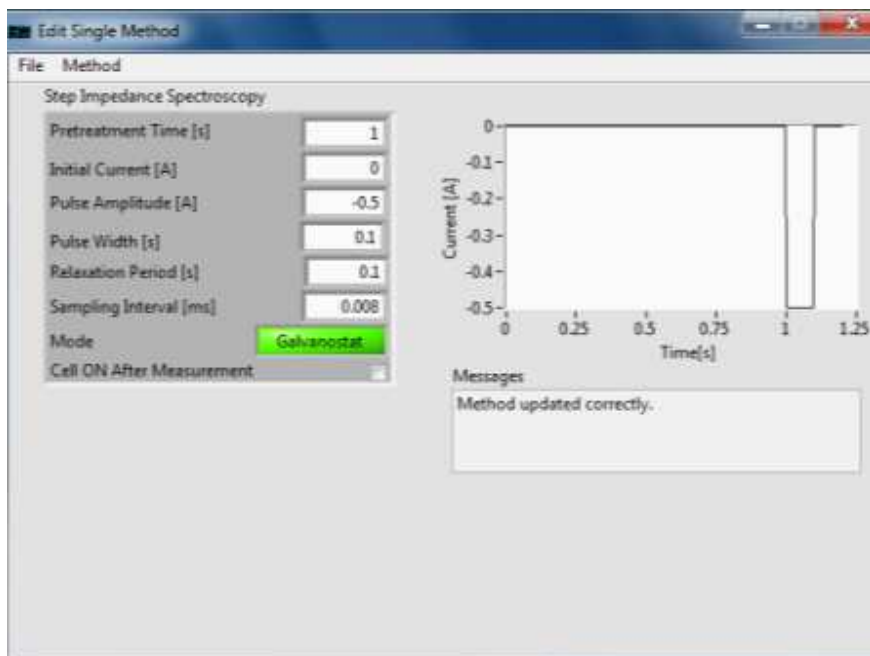


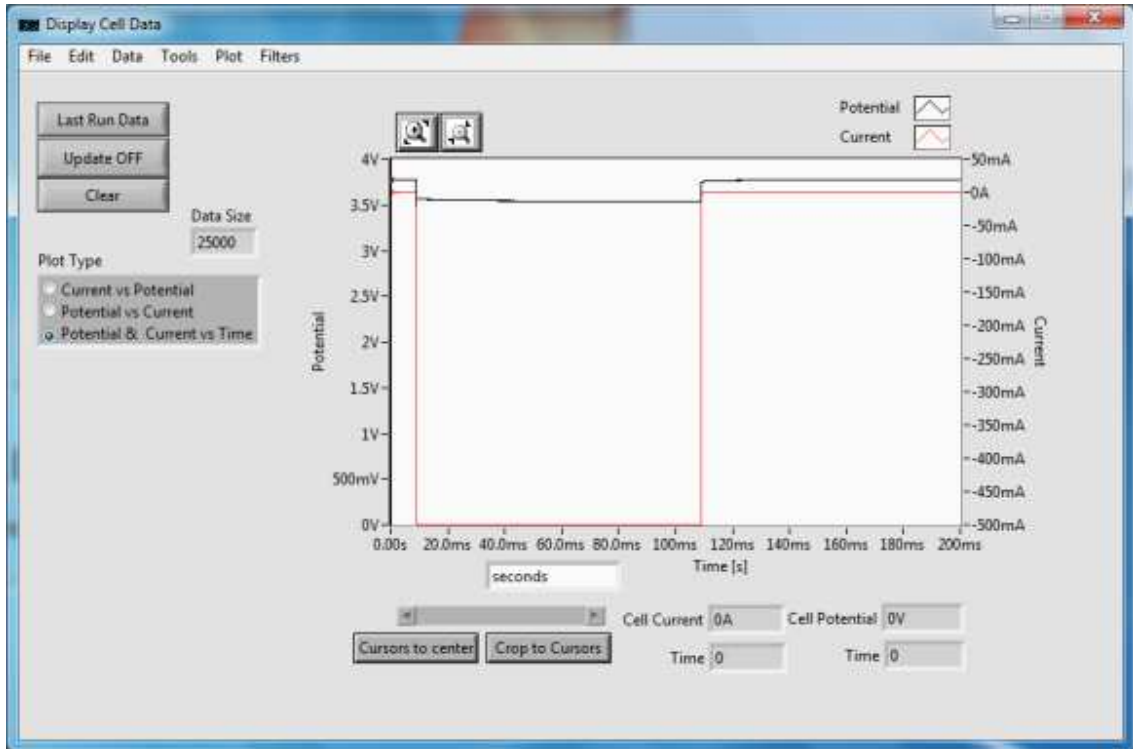
Figure 36. SIS

- When the recipe is complete, the experiment can be started by clicking **Start** in [NuVant EZware] (Fig. 37).



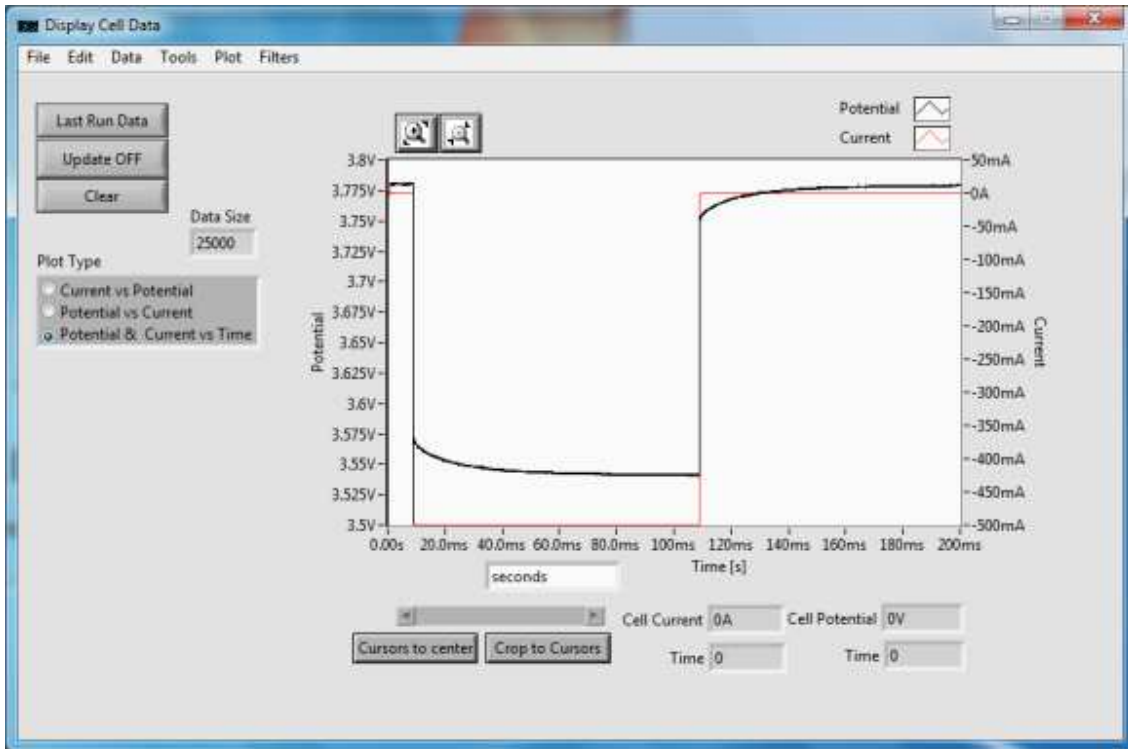
Figure 37. Starting the recipe

- The data can be seen by going to the [Display Cell Data] window. Figure 38 shows the data after the experiment is complete.



**Figure 38.** Completed data collection

- Right-clicking on the potential axis enables the user to autoscale the axis, as seen in figure 39.

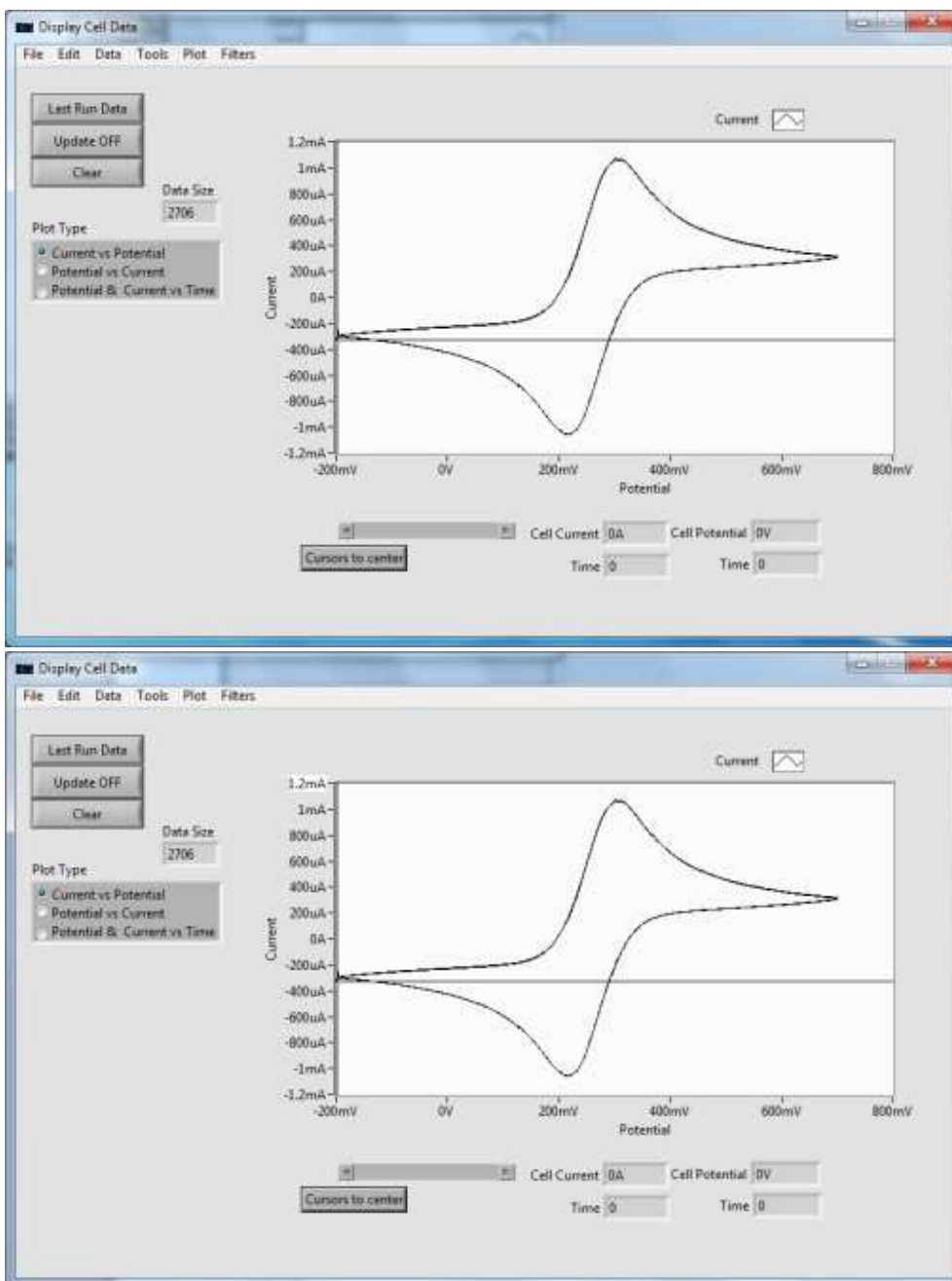


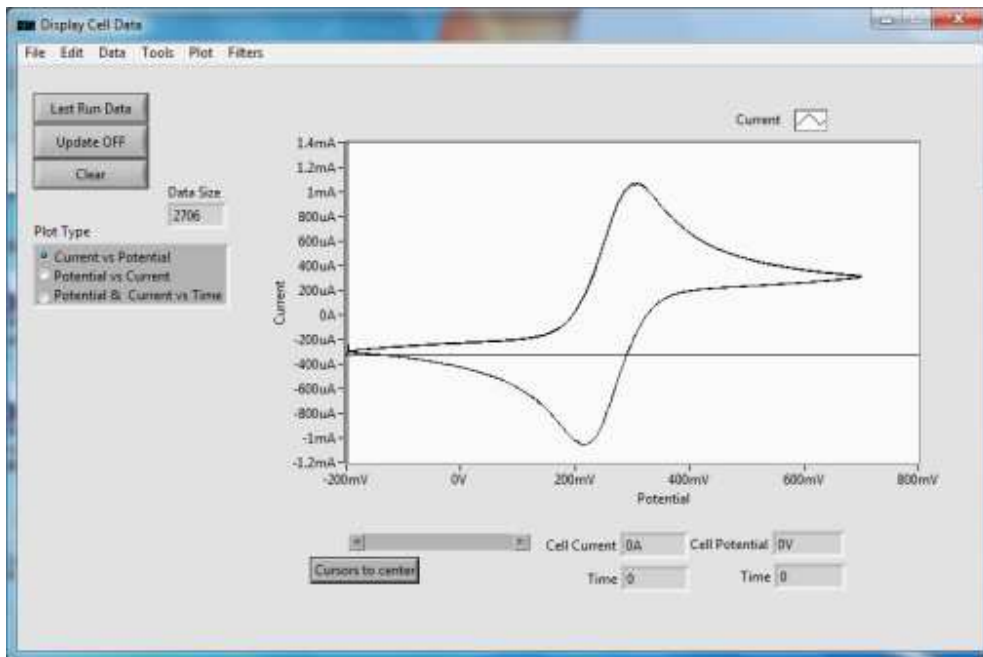
**Figure 39.** Completed data collection after autoscale

## DATA VISUALIZATION AND ANALYSIS

### Axes Rescaling

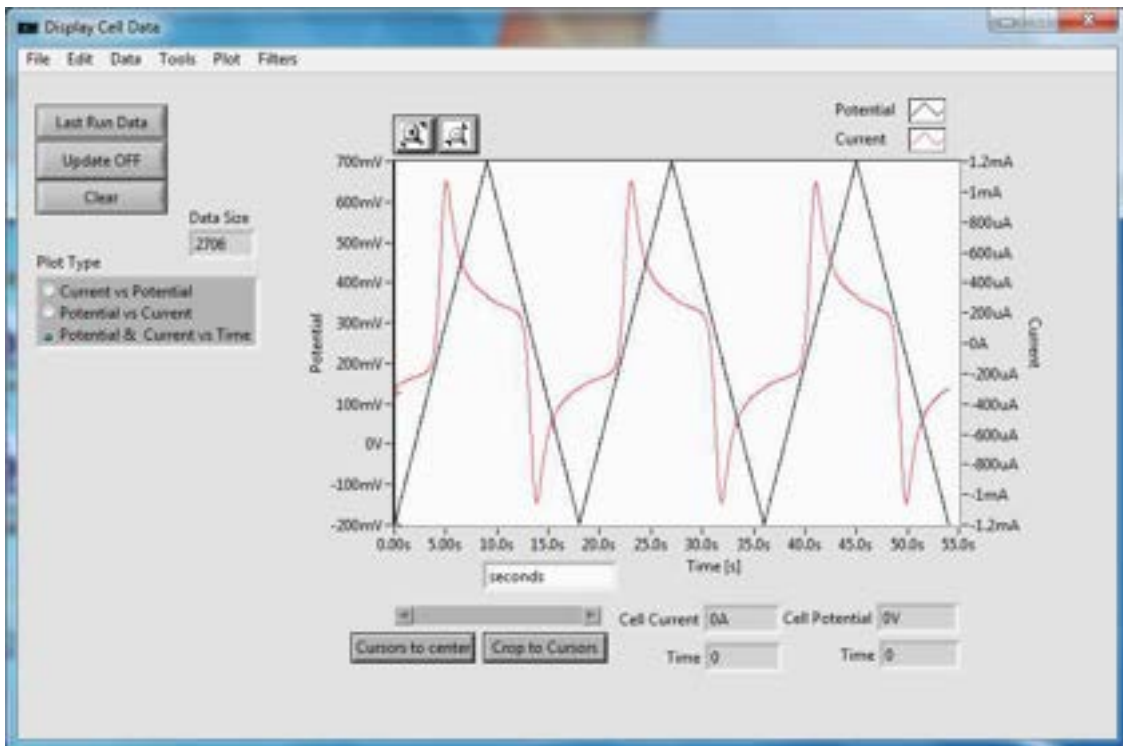
1. The following images of Figure 40 demonstrate how to rescale the y-axis. The same procedure can be applied to rescale the x-axis. Double clicking a value on either axis highlights the value and allows the user to input a desired value.





**Figure 40. Rescaling axis**

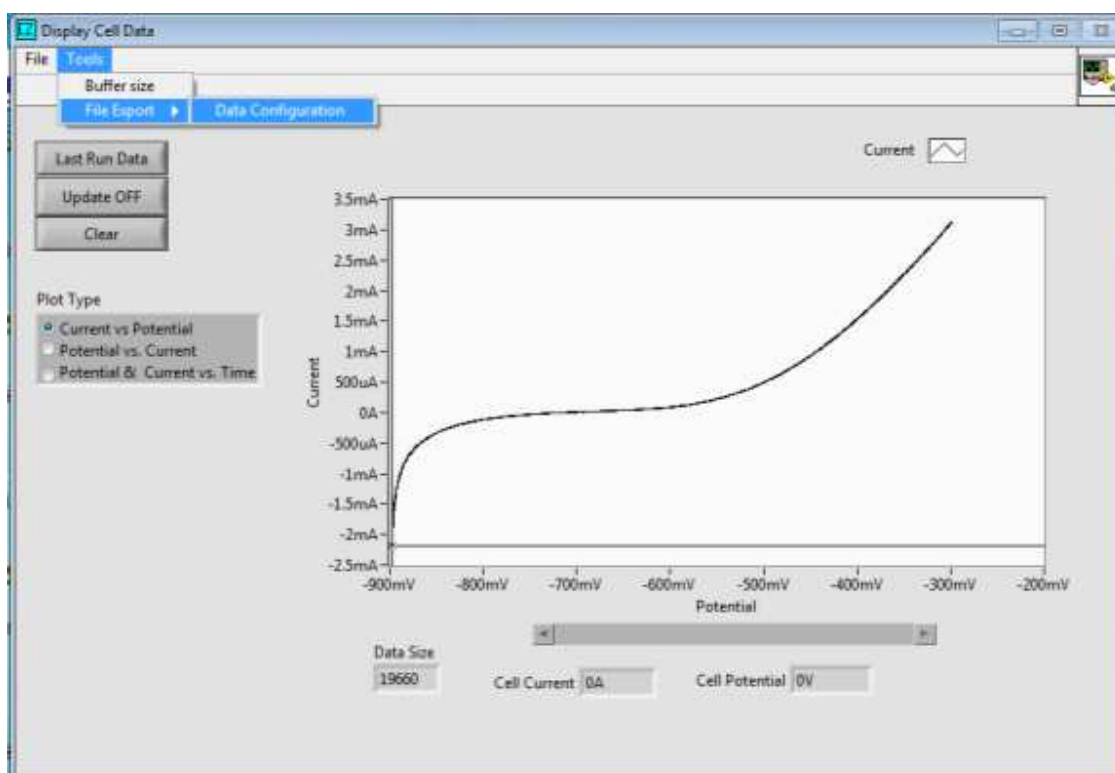
2. The left side of [Display Cell Data] allows for the user to change what data is displayed on the axis. Figure 41, for example, shows the display for potential and current versus time. The potential is the left y-axis and the black data set. The current is the right y-axis and the red data set.



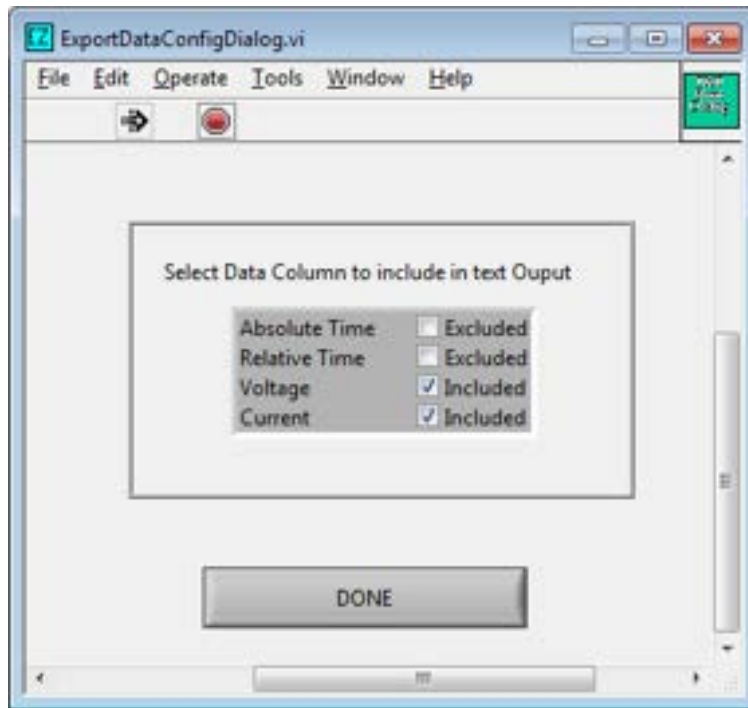
**Figure 41.** Potential and Current vs. Time

## Saving Data

- Final data can be exported via two options. In order to open the recipe file and data in EZware, the file must be saved as a “.nuvdt” file. To do this, go to **File**→*Save* and save in the desired location. This option will save all experimental settings that are currently entered in all recipe editors and method settings. For experiments that create large data files, the user will be prompted to save the file as a “.nuvdt” file when the experiment is started. The second option is to save the data as a “.csv” file, which can be read by other data processing programs. To access this option, go to **Tools**→*File Export*→*Data Configuration* (Fig. 42). A dialogue box appears allowing the user to select the output data (Fig. 43). Once the export data is selected, go to **File**→*Export as* and save in the desired location.



**Figure 42.** Saving data as a “.csv” file

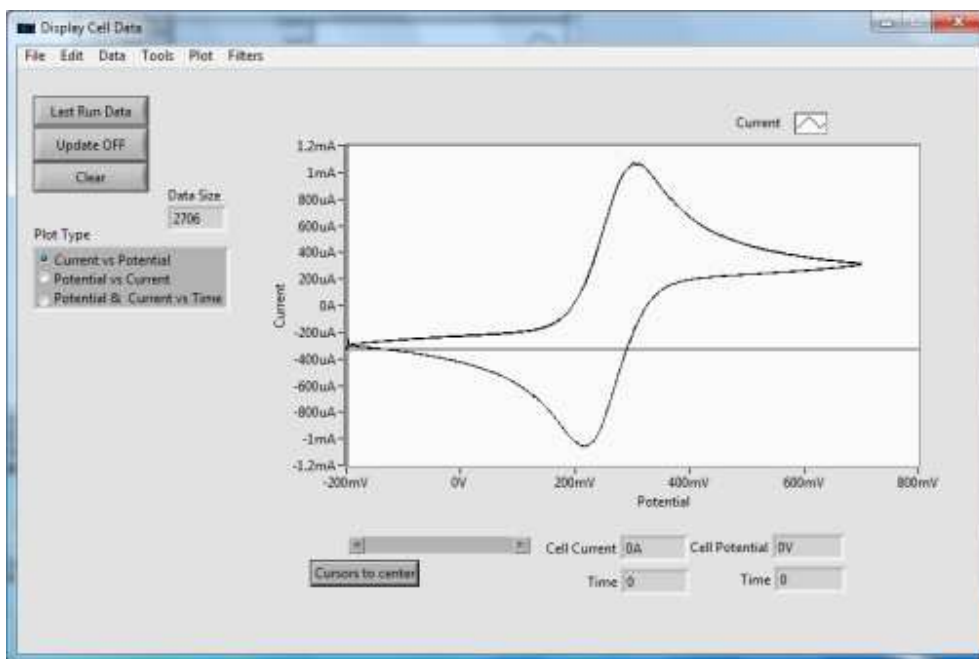


**Figure 43.** Data selection for export

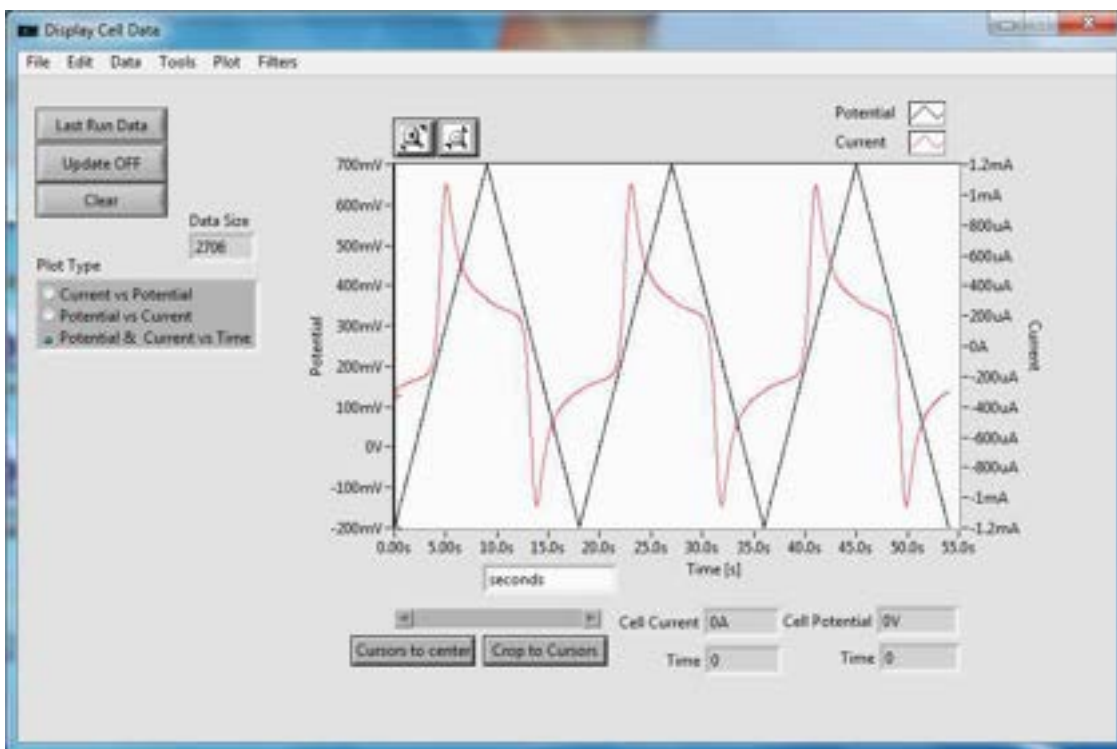


## Data Analysis – Area Calculations

1. With the final experimental data, the user can analyze it in [Display Cell Data]. Figure 44a shows an example of final data collected from an experiment. Figure 44b shows the same data viewed as Potential & Current vs, Time, where the black line is potential and the red line is current. Viewing the data in this method allows the user to crop the entire data set to the section of data that is going to be analyzed.

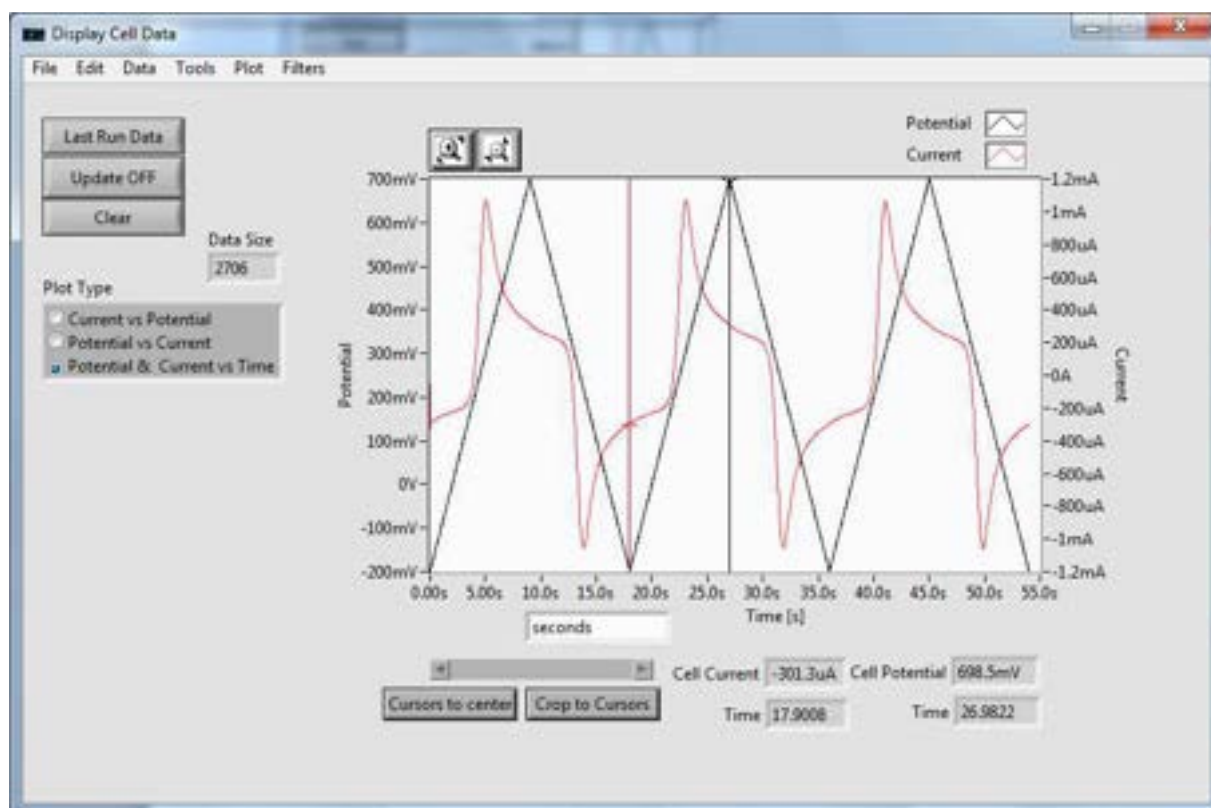


**Figure 44a.** Last run data to be used in analysis.



**Figure 44b.** Last run data viewed as Potential & Current vs. Time

2. To crop the entire data set to a smaller section of data, move the red and black cursors so that they are the end points of the desired data window. As an example, Figure 45 shows the cursors moved so that the data window is the second full anodic scan.



**Figure 45.** Data cursors moved to show data window selected for analysis

3. After the desired data window has been selected, click **Crop to Cursors**, located at the bottom of the window. [Display Cell Data] will now show only the data selected (Figure 46). To analyze this data, go to **Data**→*Analyze Selected*.

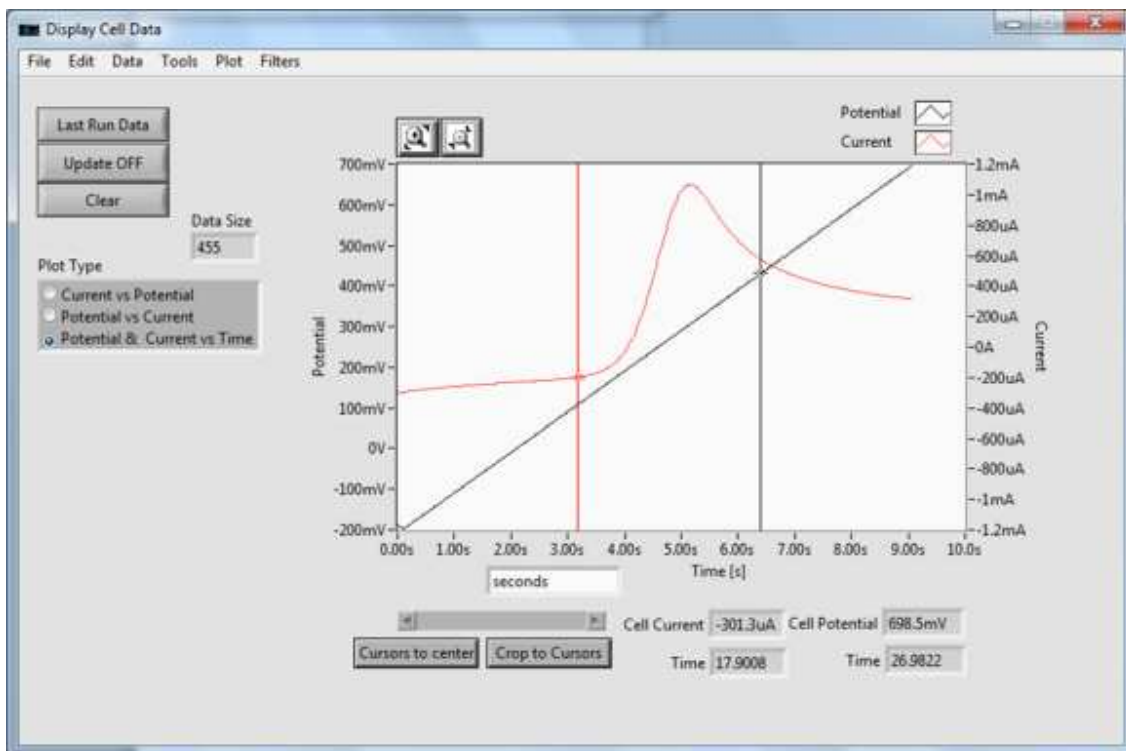
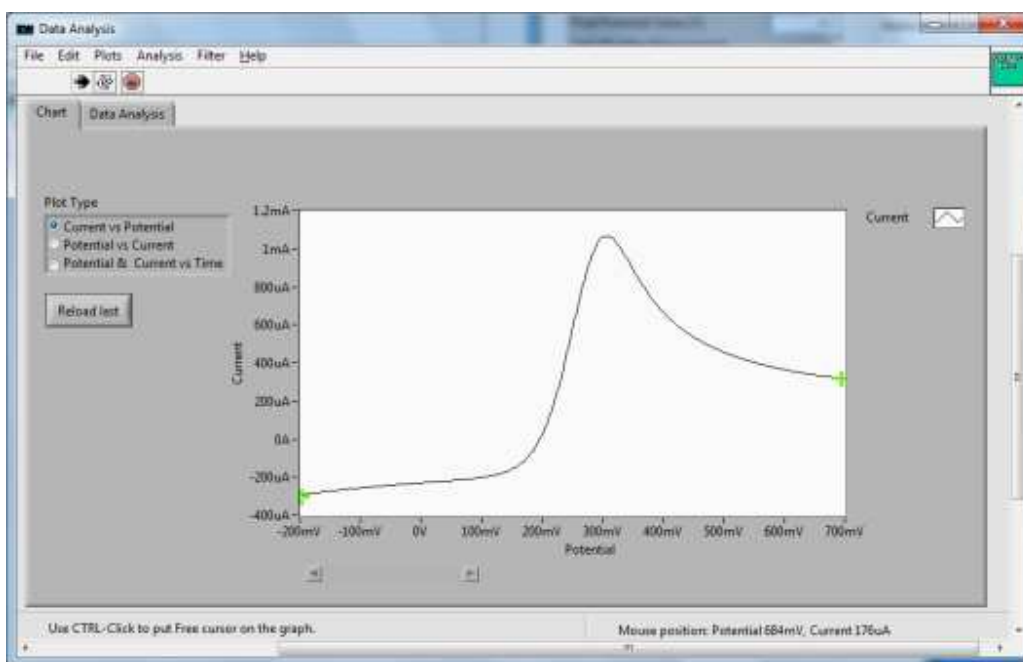


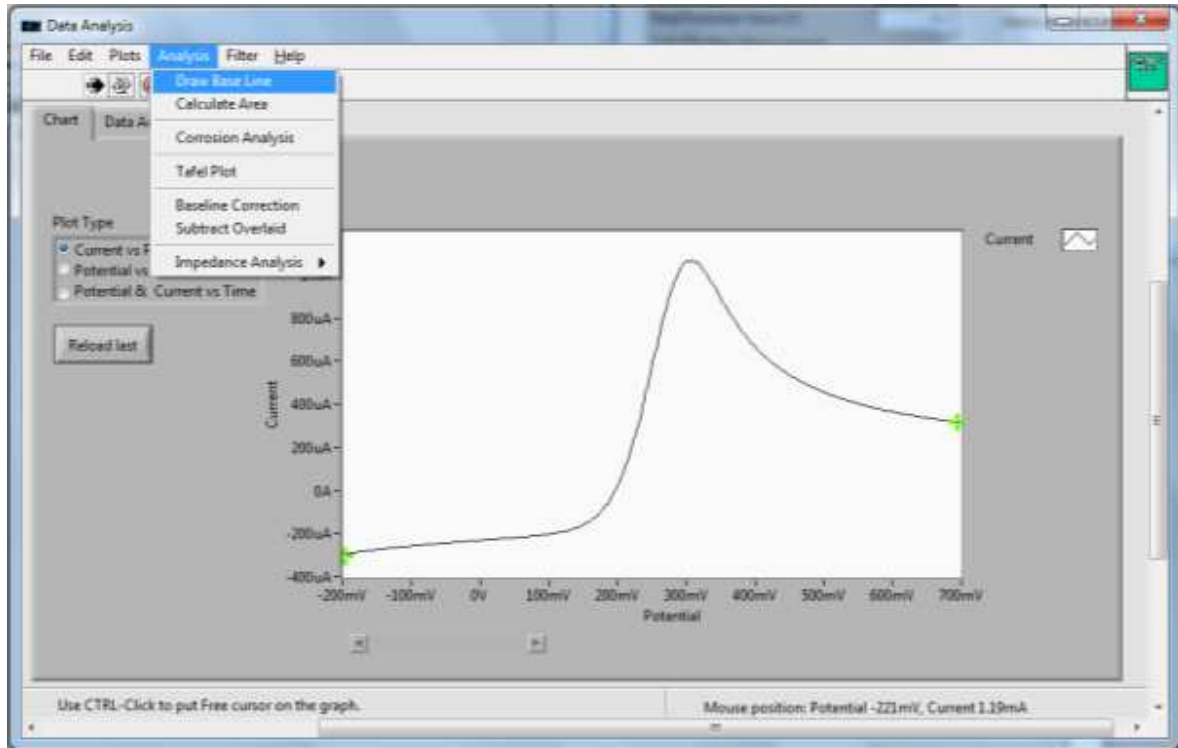
Figure 46. Selected data for analysis

4. [Analyze Data] will open displaying the data the user has selected from the full data set. By going to **Plots**→*Plot Cursors*→*Cursor Along Plot*, and clicking the mouse while holding CTRL, two cursors can be placed on the data. These cursors are used to draw a baseline on the data and can be moved to any desired location on the data. Figure 47 shows [Analyze Data] with the cursors moved to the endpoints of the data.

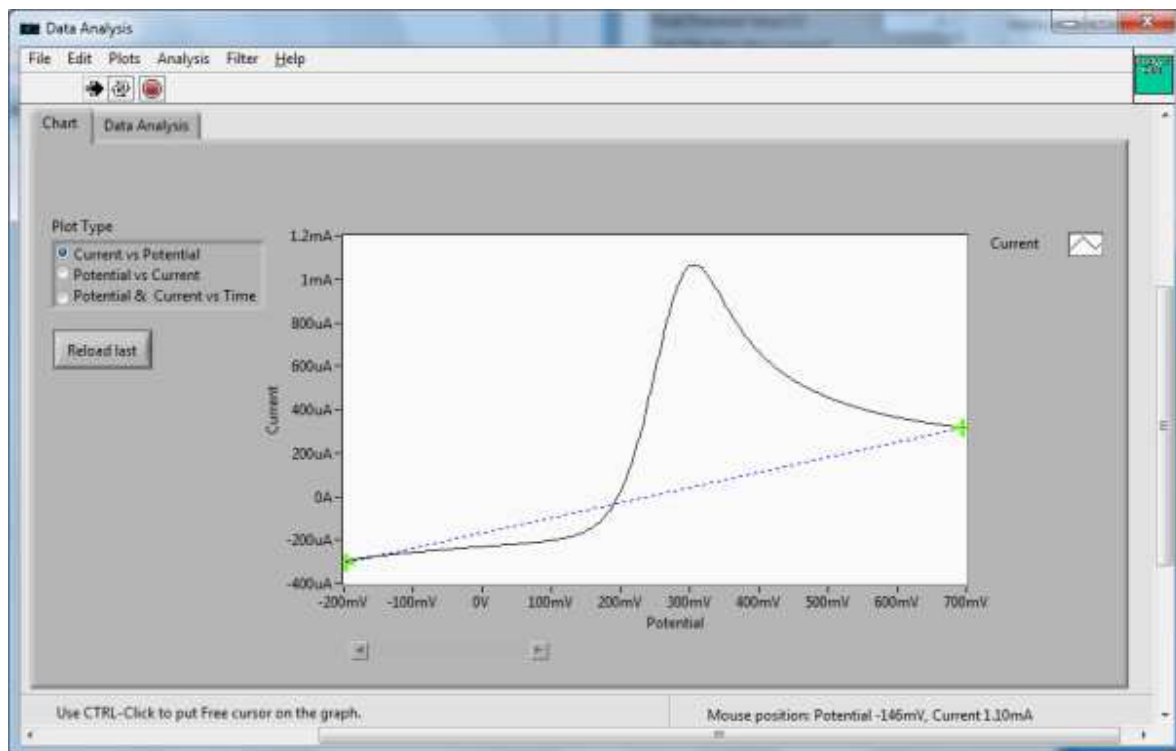


**Figure 47.** [Analyze Data] window with the cursors moved to data endpoints

- To draw a baseline, go to **Analysis**→**Draw Base Line** (Figure 48a). The baseline will be drawn between the two green cursors (Figure 48b). If the cursors are moved, the baseline will move with them (Figure 48c).



**Figure 48a.** Drawing a base line



**Figure 48b.** Baseline drawn between cursors

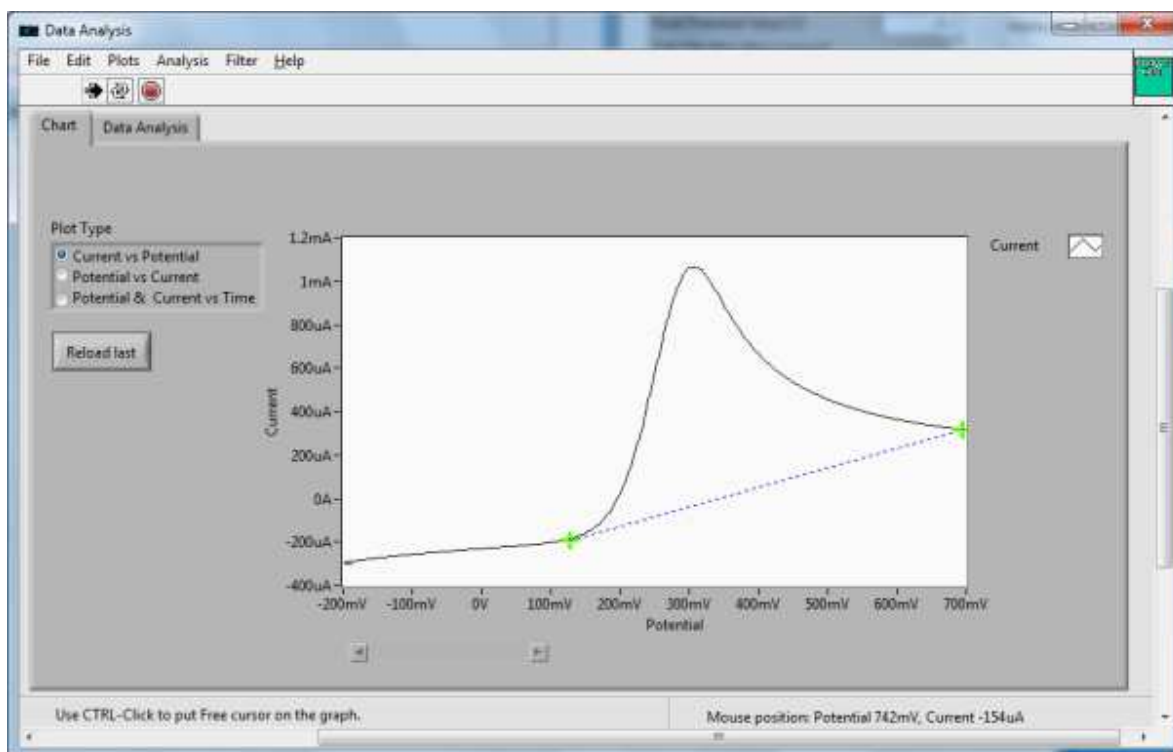
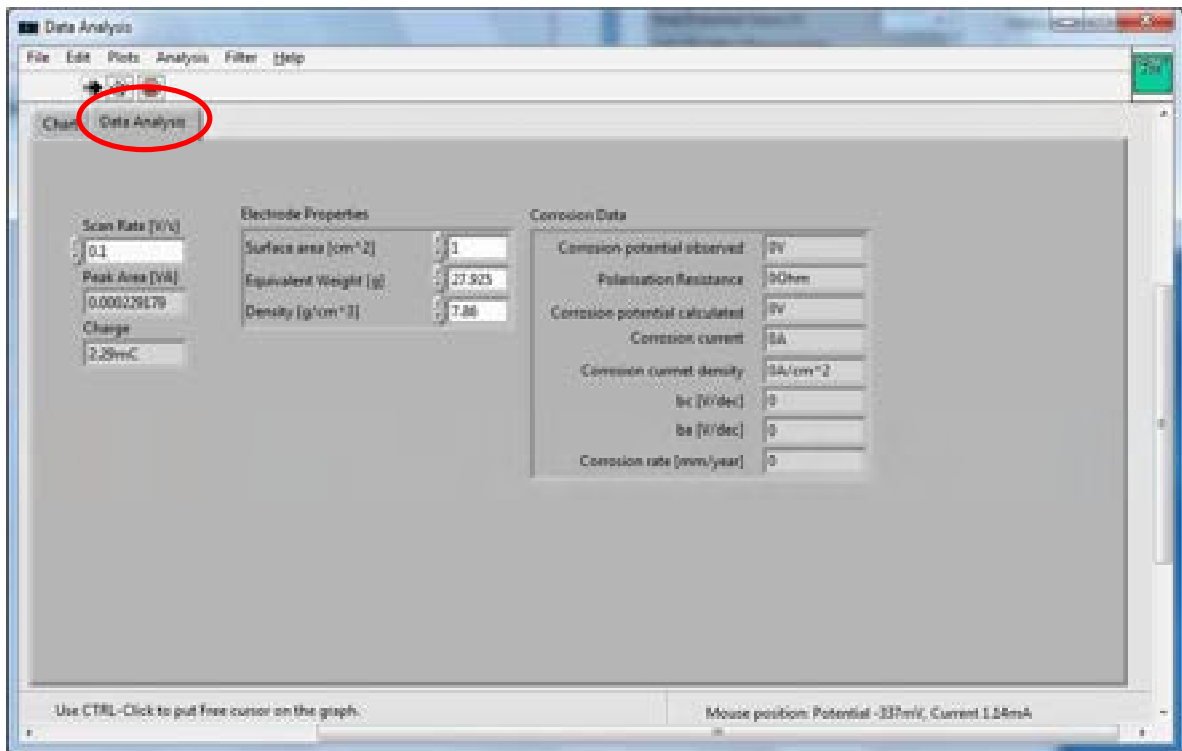


Figure 48c. Baseline moving with cursors

- The area of the curve can be calculated by going to **Analysis**→*Calculate Area*. To view the calculated area, click **Data Analysis**, shown in Figure 49. The user can input the scan rate of the experiment to obtain the calculated charge in Coulombs.





**Figure 49.** Calculated peak area and charge

## Data Analysis – SIS

1. [Display Cell Data] **Data**→*Analyze Selected* (Figure 50) opens the [Data Analysis] window (Figure 51).

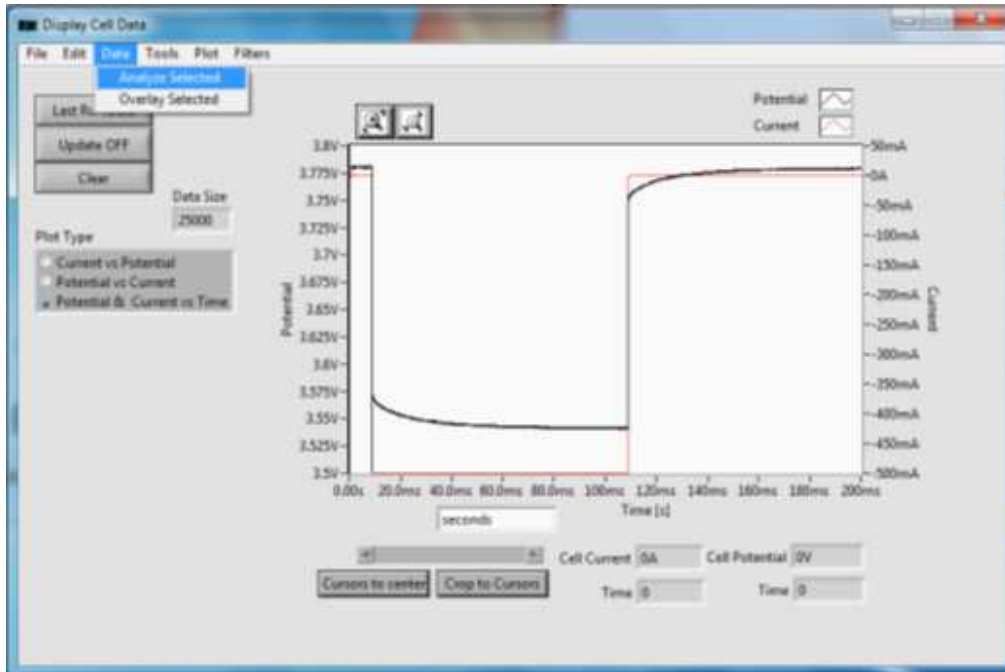


Figure 50 Opening [Data analysis] window

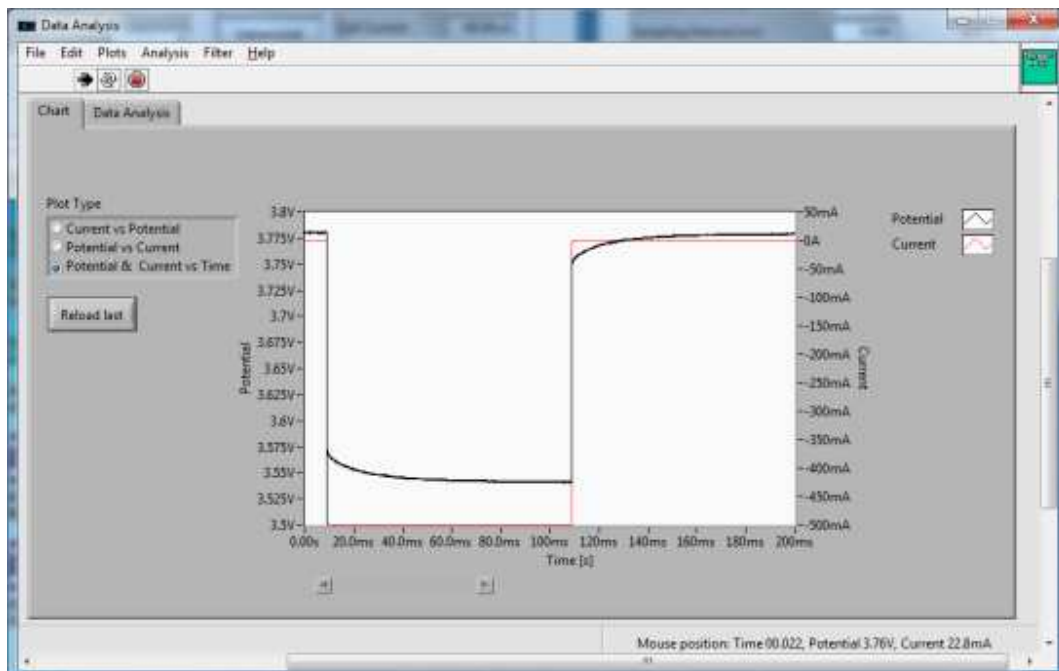


Figure 51 [Data analysis] window

- [Data Analysis] **Analysis** → *Impedance Analysis* → Step Impedance Spectroscopy (Figure 52) opens the [Step Impedance Calculator] window (Figure 53).

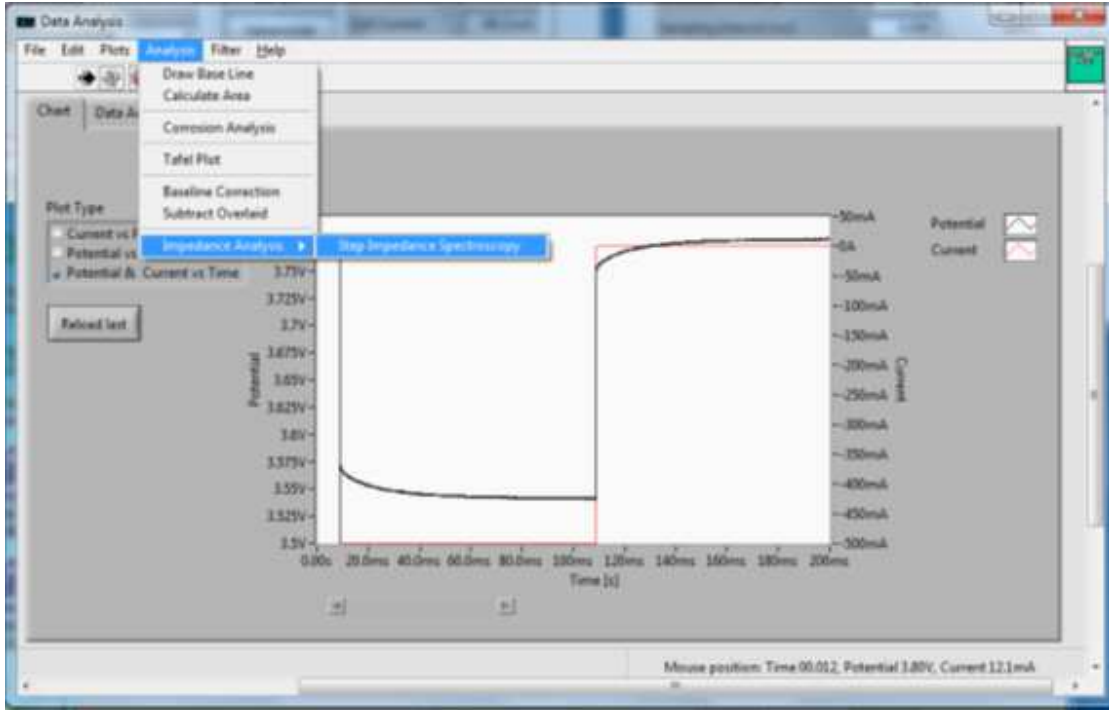


Figure 52 Opening [Step impedance calculator]

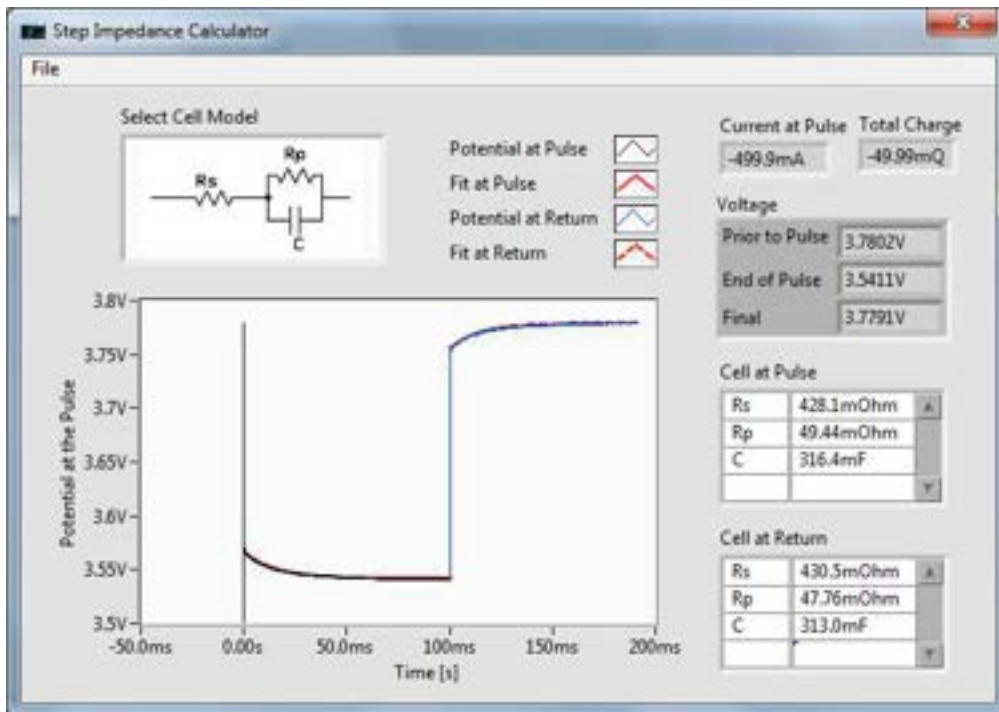
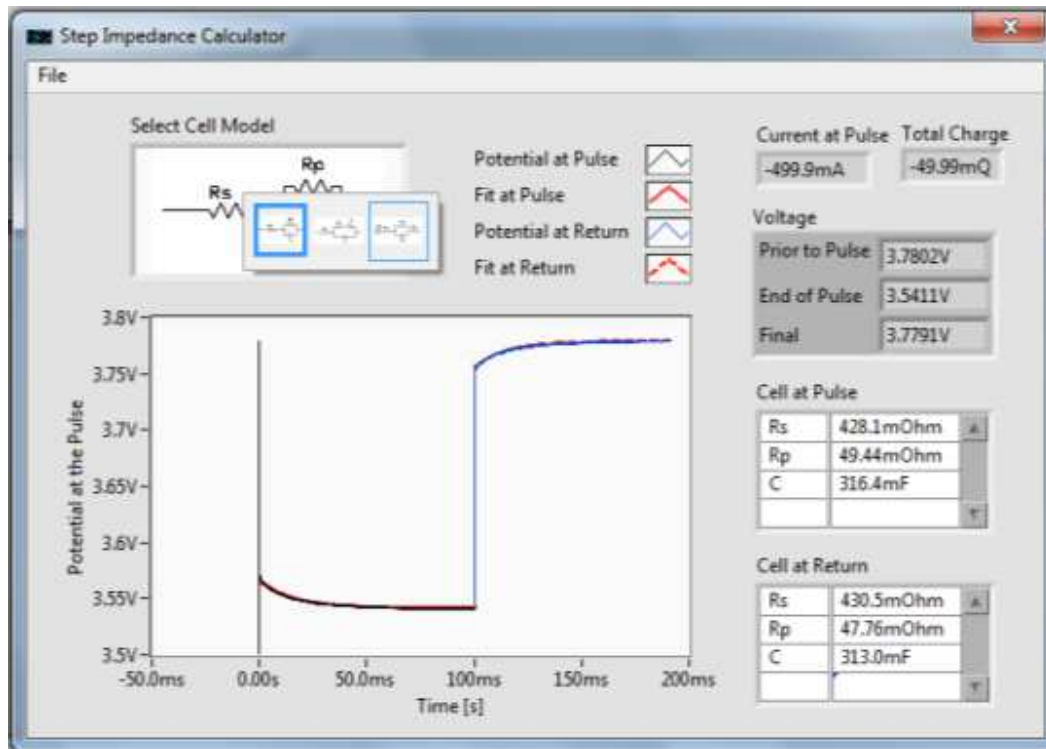


Figure 53 [Step impedance calculator]

3. Select Cell Model allows the user to select the circuit that best represents the device he or she is using for the experiments by clicking the image and choosing one of the listed options. In figure 54 the first option is a simple electrochemical cell. The second and third options are batteries.



**Figure 54** Selecting a cell model

- Figure 55 shows the third option (battery) selected. Descriptions for the variables are listed in the glossary in the “SIS Impedance Calculator” chart.

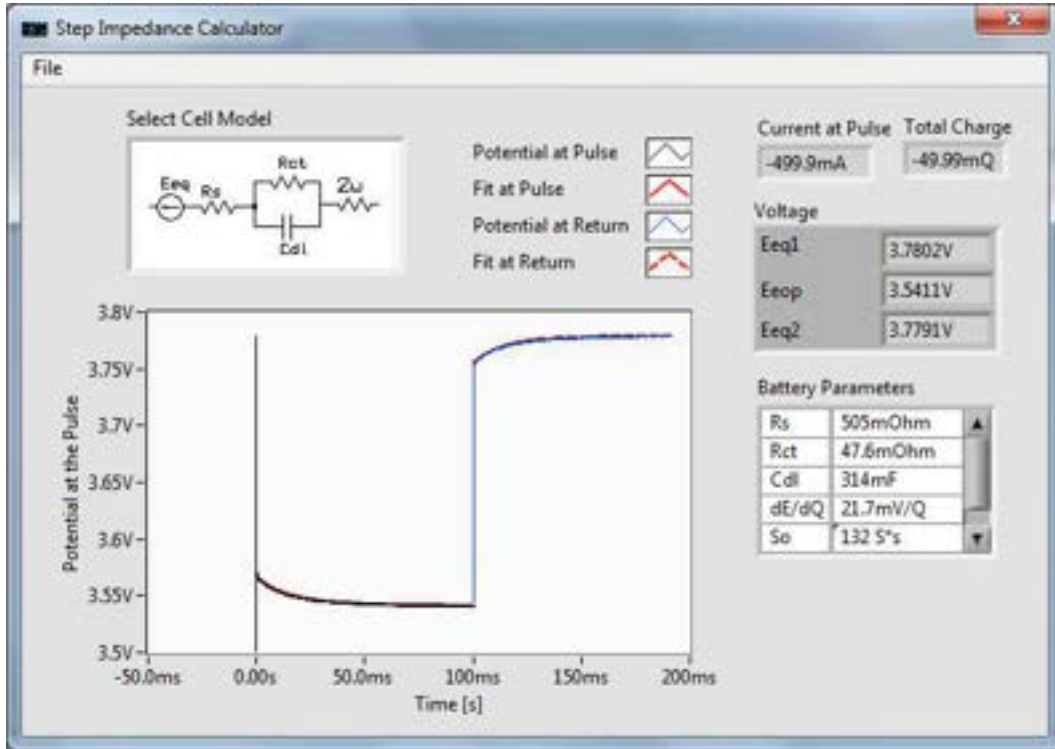
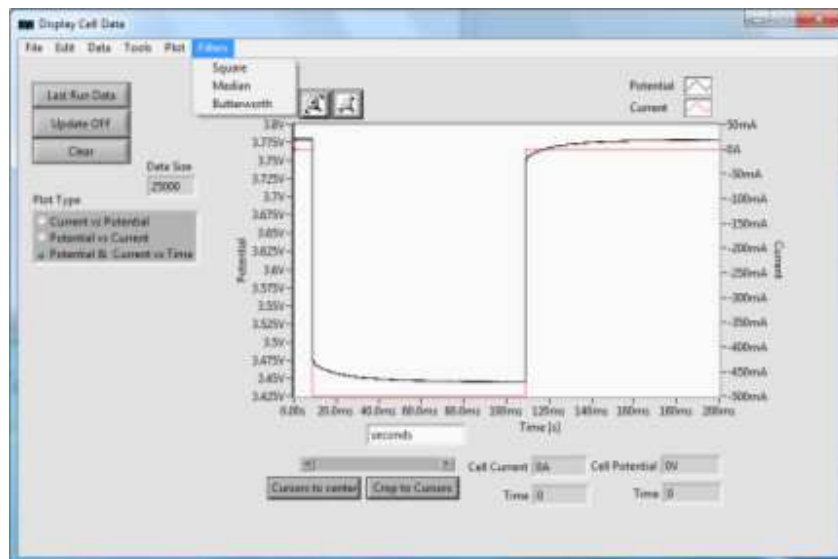


Figure 55 Battery cell model

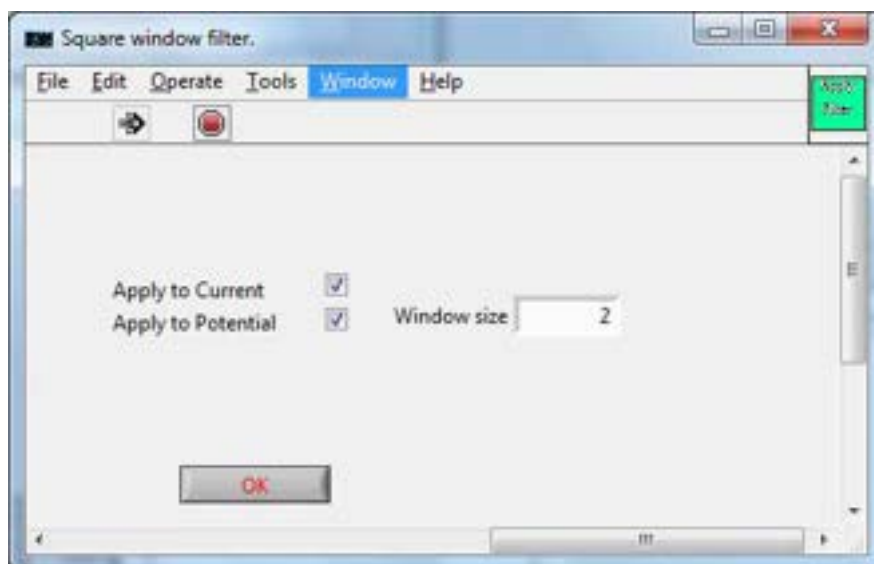
## Filters

1. Data filters can be accessed by going to [Display Cell Data] → **Filters** → *Square*, *Median*, *Butterworth* (Figure 56).



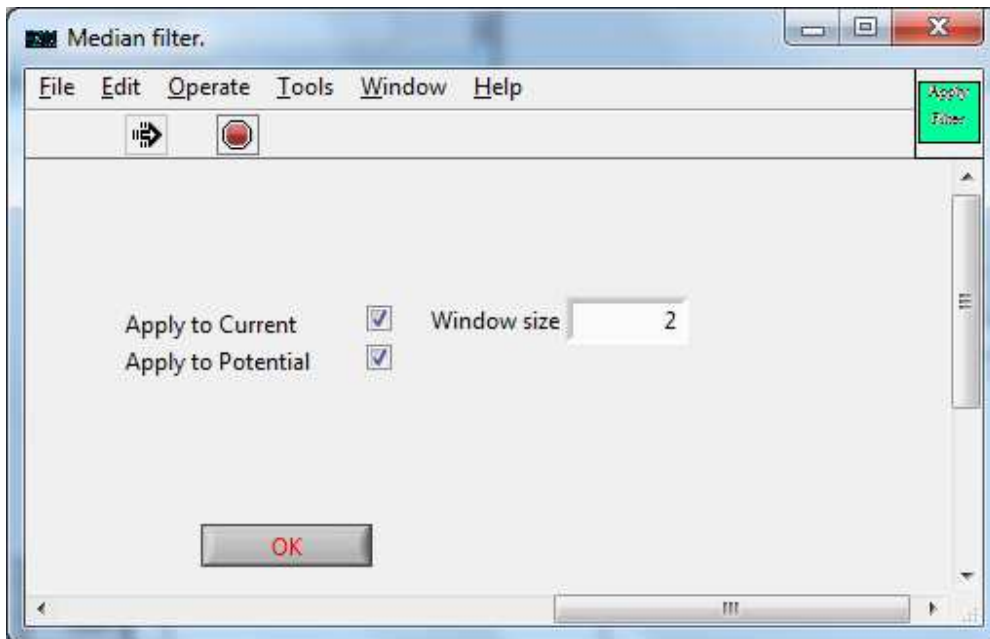
**Figure 56.** Filter selection

2. [Square filter] is shown in figure 57. In this window, the user can select to apply the filter to the current, potential, or both. Window Size is the number of points that are used to average. The total number of data points remains the same after filtering. For example, if the Window Size is 2, point 2 will be replaced with the average value of points 1 and 2, point 3 will be replaced with the average value of points 2 and 3, and so on.



**Figure 57.** [Square filter]

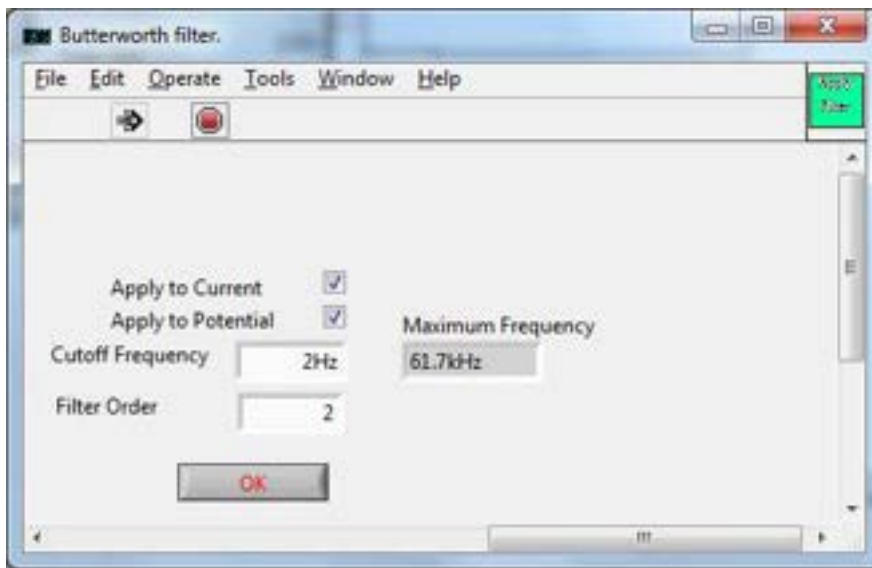
3. [Median filter] is shown in figure 58. In this window, the user can select to apply the filter to the current, potential, or both. Window Size is the number of points that are used to find the median. The total number of data points remains the same after filtering. For example, if the Window Size is 3, point 2 will be replaced with the median value of points 1, 2 and 3.



**Figure 58.** [Median filter]

4. [Butterworth filter] is shown in figure 59. In this window, the user can select to apply the filter to the current, potential, or both. Maximum Frequency is the suggested maximum value for Cutoff Frequency. Cutoff Frequency is the value at which to apply a low pass filter. Only the frequency below the Cutoff Frequency will be allowed to pass. Any value above the Cutoff Frequency will be blocked. The Filter Order applies to how steep the cutoff transfer function will be. The higher order leads to better frequency resolution, but might result in larger ripples in the passband. For more information, visit:

[http://zone.ni.com/reference/en-XX/help/371361J-01/ivanlconcepts/ivac\\_butterworth\\_filters/](http://zone.ni.com/reference/en-XX/help/371361J-01/ivanlconcepts/ivac_butterworth_filters/)

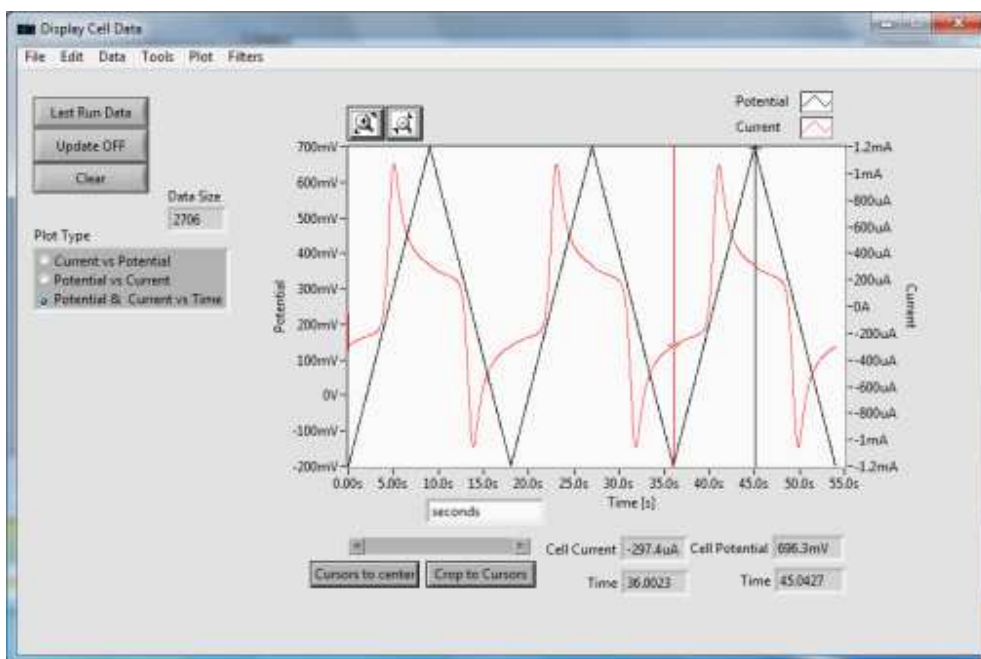


**Figure 59.** [Butterworth filter]



## Overlaying Data

1. If the user has already selected a section of data from [Display Cell Data] to analyze, another set of data can be selected from the window to overlay on top of the first. To do this, return to [Display Cell Data] and select **Last Run Data**, located on the top left of the window. This will redisplay all of the originally collected data. In Figure 60, the third anodic scan is selected.

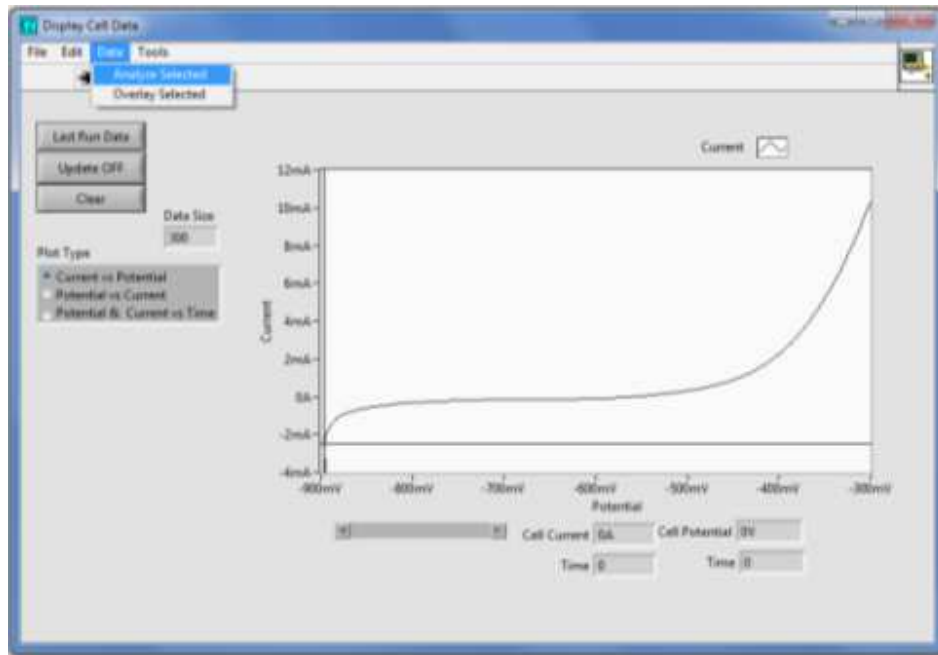


**Figure 60.** Second anodic scan chosen for data overlay

2. Once the data is selected, select **Crop to Cursors** to display only the desired data window. To overlay the data, go to **Data**→*Overlay Data*. Once selected, [Analyze Data] will now display two data sets, the original data set as a black line and the overlaid (second) data set as a green line.
3. By going to **Analysis**→*Subtract Overlaid*, the user can subtract the overlaid green data from the original black data and analyze the new data as desired.

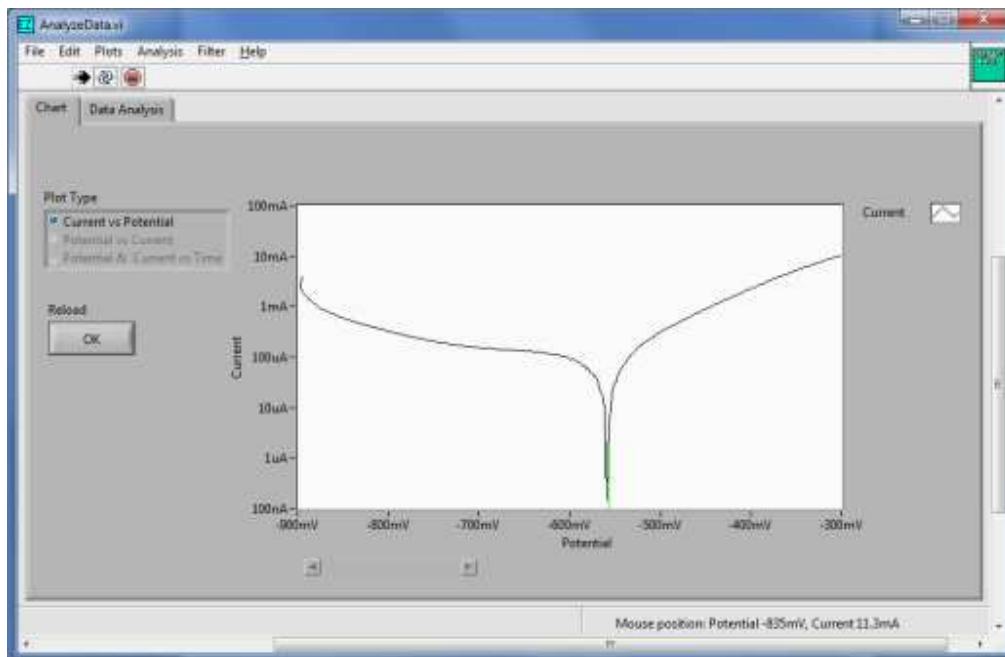
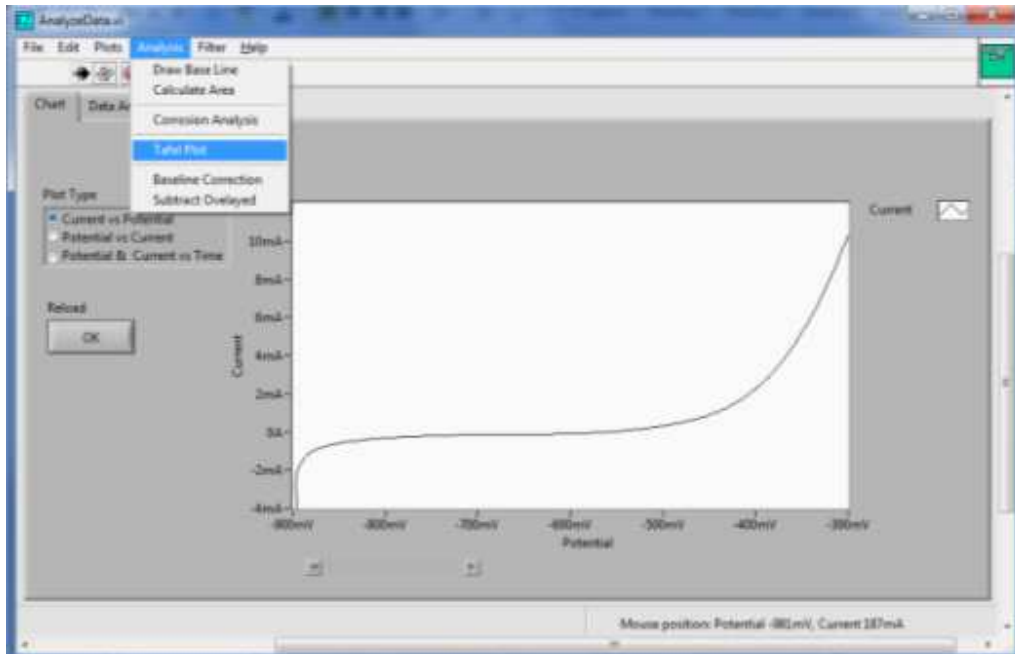
## Data Analysis – Tafel Plot

1. Corrosion data can be analyzed in [Display Cell Data]. In this window, select **Data**→*Analyze Selected* (Fig. 61).



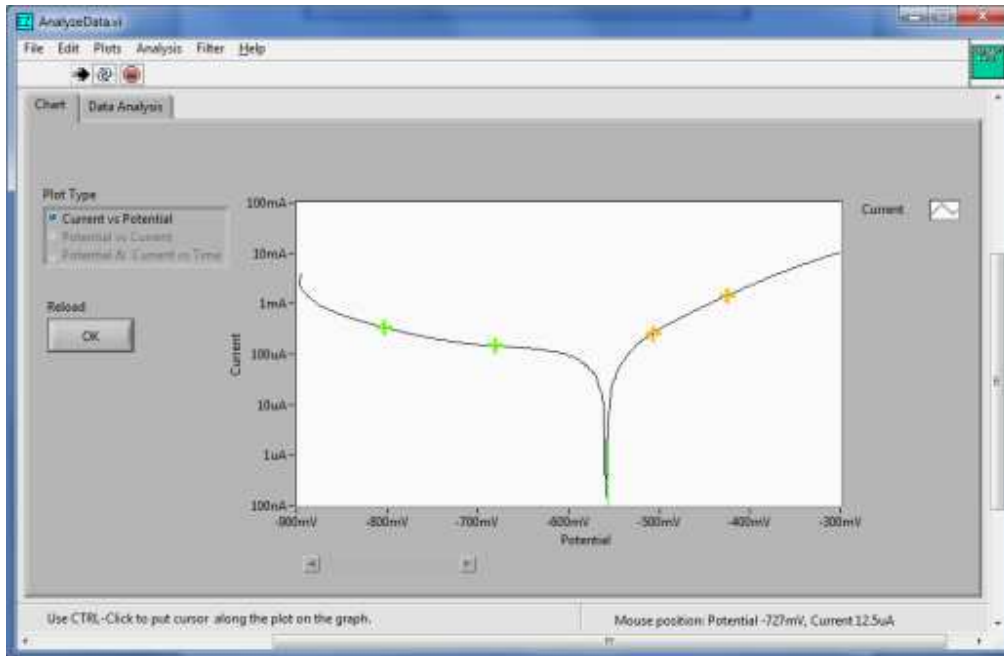
**Figure 61.** Corrosion data analysis

- [Analyze Data] will now be displayed. Go to **Analysis**→*Tafel Plot*, to view the collected data as a Tafel Plot (Fig. 62).



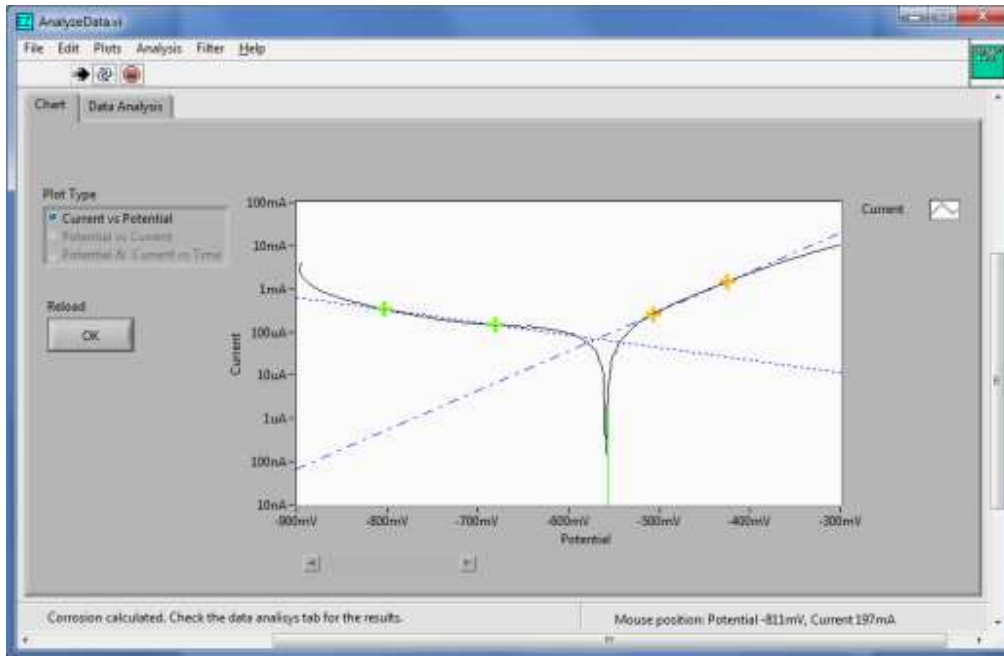
**Figure 62.** Converting corrosion data (top image) to Tafel Plot (bottom image)

- By going to **Plots**→*Plot Cursors*→*Cursor Along Plot*, and clicking the mouse while holding CTRL, four cursors can be placed on the data (two green and two yellow), shown in Figure 63.



**Figure 63.** Placement of cursors for corrosion analysis

4. To draw two straight lines, one between each pair of cursors, go to **Analysis**→*Corrosion Analysis* (Fig. 64). The lines will move with movement of the cursors.



**Figure 64.** Straight lines drawn between cursors for corrosion analysis

- The corrosion analysis results can be viewed by going to **Data Analysis** at the top of the graph window (Fig. 65). The user can enter the Surface area (cm<sup>2</sup>), Equivalent weight (g) and Density (g/cm<sup>3</sup>) in the **Electrode Properties** input boxes.

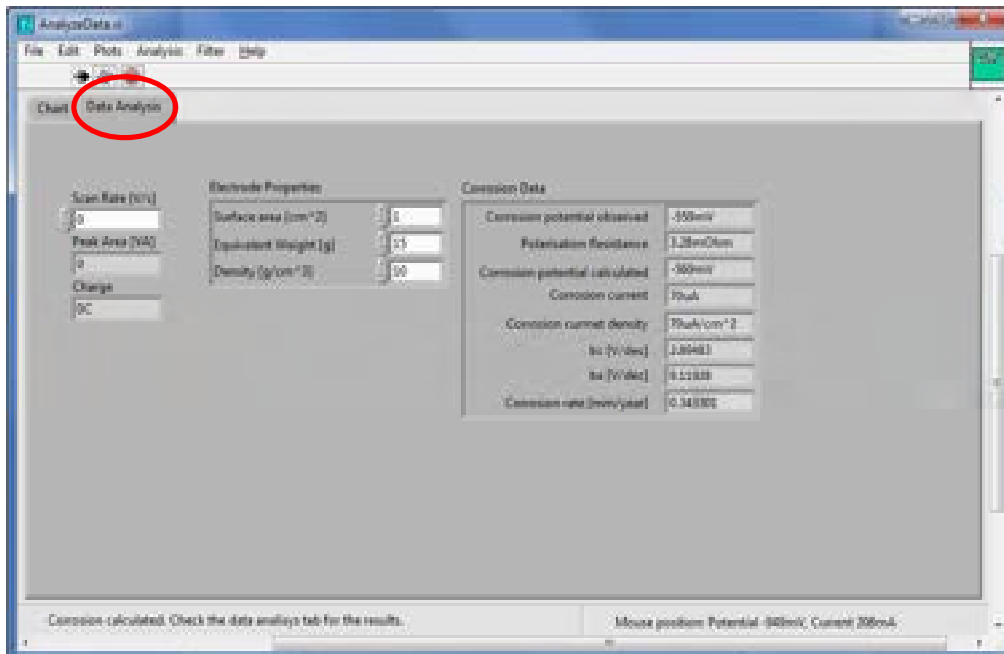


Figure 65. Corrosion analysis calculations

## TROUBLESHOOTING INFORMATION

Information adapted from: Bard, A. J.; Faulkner, L. R. *Electrochemical Methods: Fundamentals and Applications*; 2nd ed.; John Wiley & Sons, Inc.: New Jersey, 2001, p 654-656.

If you are experiencing difficulties with your electrochemical experiment, check the following troubleshooting tips before submitting a customer service request:

### Software

1. Make sure that both the LabVIEW and NiDAQ software are up to date.
2. Check that you are using the most up to date version of the appropriate EZware software. If you are unsure, the most recent versions of all software can be found at <http://nuvant.com/download-software/software/>

### Instrument/Experimental

1. Ensure that the electrodes are properly connected to the instrument and the electrochemical system. If using a typical three electrode system, the working electrode sense lead (if provided) is shorted to the working electrode lead.
2. Check that the potential and current ranges fall within the instrument capabilities. In the recipe file, make sure that the correct current range has been selected for the experiment. You will not get accurate data if your current output is greater than the instrument specifications.
3. If you are seeing an atypical data plot, first check that the instrument is operating correctly by replacing your electrochemical system with a resistor. Connect the working electrode and working electrode sense leads to one side of the resistor, and the reference electrode and counter electrode leads to the other side of the resistor. Run your recipe using this setup. If the resulting data follows the correct voltage parameters and has a current output proportional to your resistor value, the software and instrument are working correctly. The problem is due to the electrochemical cell. If you do not see the correct data, contact technical support via the Customer Support Form at <http://nuvant.com/contact-us/>.
4. If the resistor data is correct, the electrochemical cell can be checked. Make sure that all the electrodes are undamaged (wire leads are in contact with the electrode surface). If a wet electrochemical cell is being used, make sure that the cell was purged with inert gas prior to running the experiment and that the purge is not in the solution while running the experiment (purge can be maintained above the line of your solution).
5. Connect the counter and reference electrode leads to the counter electrode (the reference electrode will not be connected to any electrode leads) and run the experiment. If the

resulting data is that of the expected data plot with a potential shift, there is a problem with the reference electrode. Check that there are no air bubbles around or in the reference electrode, specifically at the tip of the electrode. Try an alternate electrode if the problem still occurs. If the resulting data does not look like the expected data plot with the reference electrode bypassed, there is a problem with either the counter or working electrodes. The working electrode should be polished and cleaned.

If these suggestions do not solve the problem you are experiencing, contact NuVant Systems at <http://nuvant.com/contact-us/>.



## APPENDIX

Instrument specifications for instruments purchased prior to October 1, 2013. Step Impedance Spectroscopy only available for instruments purchased after October 1, 2013.

### EZstat-Pro

<b><i>Cell Control</i></b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	3 nA, 0.003% of FSR
Applied Current Accuracy	0.03% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pF
Maximum Update Rate	4 µs
Maximum Scan Rate	100 V/s
IR Compensation	Manual, Potentiostat Mode 10 mA - 1 A Range
External Control	1 AO, 1 AI, 2 DO
<b><i>Potential Measurement</i></b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3 µV, 300 µV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b><i>Current Measurement</i></b>	
Measured Current Ranges	Galvanostat: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) Potentiostat: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A)
Potentiostat Min to Max	3 nA to 1 A
Best Resolution	Galvanostat: 3 nA (0.003% of FSR) Potentiostat: 610 pA - 340 µA (0.06 - 0.003% of FSR In Order of Range)
Accuracy	Galvanostat: 0.03% of FSR; Potentiostat: 0.3 - 0.03% of FSR Depending on Range
<b><i>Data Acquisition</i></b>	
Acquisition Time	8 µs
Acquisition Speed	125 kS/second
DAC Resolution	16 bits
FSR: Full Scale Range	

## EZstat-Pro LC

<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±10 mA
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±1 µA, ±10 µA, ±100 µA, ±10 mA)
Best Applied Current Resolution	40 pA, 0.004% of FSR
Applied Current Accuracy	0.04% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	4 µs
Maximum Scan Rate	100 V/s
IR Compensation	None, Low Current Device
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3 µV, 300 µV (0.006%, 0.003% of Full Scale Range)
Accuracy	0.08 or 0.03% of Full Scale Range
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±1 µA, ±10 µA, ±100 µA, ±10 mA) Potentiostat: 4 (±1 µA, ±10 µA, ±100 µA, ±10 mA)
Potentiostat Min to Max	3 nA to 10 mA
Best Resolution	Galvanostat: 40 pA (0.004% of Full Scale Range) Potentiostat: 40 pA (0.004% of Full Scale Range)
3 σ Coverage Factor Accuracy	Galvanostat: 0.04% of Full Scale Range Potentiostat: 0.04% of Full Scale Range
<b>Data Acquisition</b>	
Acquisition Time	8 µs
Acquisition Speed	125 kS/second
DAC Resolution	16 bits

## EZstat-Basic

<b><i>Cell Control</i></b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±2.5 V)
Applied Potential Resolution	7 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pF
Maximum Update Rate	100 ms
Maximum Scan Rate	1 V/s
IR Compensation	Manual, Potentiostat Mode 10 mA - 1 A Range
External Control	None
<b><i>Potential Measurement</i></b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 µV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b><i>Current Measurement</i></b>	
Measured Current Ranges	Galvanostat: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) Potentiostat: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A, )
Potentiostat Min to Max	15 nA to 1 A
Best Resolution	Galvanostat: 12 nA (0.01% of FSR) Potentiostat: 2.4 nA - 0.13 mA (0.24 - 0.013 % of FSR In Order of Range)
Accuracy	Galvanostat: 0.08% of FSR; Potentiostat: 0.08 - 1.5% of FSR Depending on Range
<b><i>Data Acquisition</i></b>	
Acquisition Time	100 µs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit
FSR: Full Scale Range	

**EZstat-Basic +5**

<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (0 ÷ 5 V)
Applied Potential Resolution	1.2 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	100 ms
Maximum Scan Rate	0.1 V/s
IR Compensation	Manual, Potentiostat Mode 10 mA - 1 A Range
External Control	None
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 µV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) Potentiostat: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A, )
Potentiostat Min to Max	15 nA to 1 A
Best Resolution	Galvanostat: 12 nA (0.01% of FSR) Potentiostat: 2.4 nA - 0.13 mA (0.24 - 0.013 % of FSR In Order of Range)
Accuracy	Galvanostat: 0.08% of FSR; Potentiostat: 0.08 - 1.5% of FSR Depending on Range
<b>Data Acquisition</b>	
Acquisition Time	100 µs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit
FSR: Full Scale Range	

## EZstat-Basic LC

<b>Cell Control</b>	
Compliance Voltage	±25 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±2.5 V)
Applied Potential Resolution	1.2 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±1 µA, ±10 µA, ±100 µA, ±10 mA)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	100 ms
Maximum Scan Rate	0.1 V/s
IR Compensation	NA
External Control	None
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 µV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±1 µA, ±1 µA, ±10 µA, ±10 mA) Potentiostat: 4 ((±1 µA, ±1 µA, ±10 µA, ±10 mA )
Potentiostat Min to Max	3 nA to 10 mA
Best Resolution	Galvanostat: 40 pA (0.01% of FSR) Potentiostat: 40 pA (0.24 - 0.013 % of FSR In Order of Range)
3 s Coverage Factor Accuracy	Galvanostat: 0.04% of Full Scale Range Potentiostat: 0.04% of Full Scale Range
<b>Data Acquisition</b>	
Acquisition Time	100 µs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit

## Multichannel Potentiostat

### EZstat-Basic 8

<b><i>Cell Control</i></b>	
Compliance Voltage	±15 V
Max Output Current	±1 A
Rise Time	45 µs for 1 Ohm load (0%-100% signal)
Slew Rate	0.2 V/µs
Bandwidth	8 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±2.5 V)
Applied Potential Resolution	7 mV
Applied Potential Accuracy	< 0.4% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 µA, ±1 mA, ±100 mA, ±1 A)
Best Applied Current Resolution	60 nA, 0.06% of FSR
Applied Current Accuracy	0.35% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pF
Maximum Update Rate	100 ms
Maximum Scan Rate	1 V/s
IR Compensation	Manual, Potentiostat Mode 10 mA - 1 A Range
External Control	None
<b><i>Potential Measurement</i></b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V)
Resolution	12 µV, 1.2 mV (0.03%, 0.01% of FSR)
Accuracy	0.15% or 0.08% of FSR
<b><i>Current Measurement</i></b>	
Measured Current Ranges	Galvanostat: 4 (±100 µA, ±1 mA, ±100 mA, ±1 A) Potentiostat: 4 (±1 µA, ±100 µA, ±10 mA, ±1 A, )
Potentiostat Min to Max	15 nA to 1 A
Best Resolution	Galvanostat: 12 nA (0.01% of FSR) Potentiostat: 2.4 nA - 0.13 mA (0.24 - 0.013 % of FSR In Order of Range)
Accuracy	Galvanostat: 0.08% of FSR; Potentiostat: 0.08 - 1.5% of FSR Depending on Range
<b><i>Data Acquisition</i></b>	
Acquisition Time	100 µs
Acquisition Speed	10,000 samples/second
DAC Resolution	14 bit
FSR: Full Scale Range	

**Powerstat-05**

<b><i>Cell Control</i></b>	
Compliance Voltage	USA $\pm 25$ V, IEC $\pm 15$ V
Max Output Current	$\pm 5$ A
Rise Time	45 $\mu$ s for 1 Ohm load (0%-100% signal)
Slew Rate	0.8 V/ $\mu$ s
Bandwidth	6 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 ( $\pm 10$ V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 ( $\pm 100$ mA, $\pm 1$ A, $\pm 3$ A, $\pm 5$ A)
Best Applied Current Resolution	3 $\mu$ A, 0.003% of FSR
Applied Current Accuracy	0.03% of FSR
Input Bias Current	500 pA
Input Impedance	250 G $\Omega$ parallel to 3 pf
Maximum Update Rate	4 $\mu$ s
Maximum Scan Rate	100 V/s
IR Compensation	Manual, Potentiostat and Galvanostat Modes, All Ranges
External Control	1 AO, 1 AI, 2 DO
<b><i>Potential Measurement</i></b>	
Measured DC Potential Ranges	2 ( $\pm 50$ mV, $\pm 10$ V) Autoranging
Resolution	3 $\mu$ V, 300 $\mu$ V (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b><i>Current Measurement</i></b>	
Measured Current Ranges	Galvanostat: 4 ( $\pm 100$ mA, $\pm 1$ A, $\pm 3$ A, $\pm 5$ A) Potentiostat: 4 ( $\pm 100$ mA, $\pm 1$ A, $\pm 3$ A, $\pm 5$ A)
Potentiostat Min to Max	1 mA to 5 A
Best Resolution	Galvanostat: 3 $\mu$ A (0.003% of FSR) Potentiostat: 3 $\mu$ A (0.003% of FSR)
Accuracy	Galvanostat: 0.03% of FSR Potentiostat: 0.03% of FSR
<b><i>Data Acquisition</i></b>	
Acquisition Time	8 $\mu$ s
Acquisition Speed	125 kS/second
DAC Resolution	16 bits
FSR: Full Scale Range	

**Powerstat-20**

<b>Cell Control</b>	
Compliance Voltage	±10 V
Max Output Current	±18 A
Rise Time	60 μs for 0.2 Ohm load (0%-100% signal)
Slew Rate	0.8 V/μs
Bandwidth	6 kHz (-3 dB, 1 Ohm load)
Applied DC Potential Ranges	1 (±10 V)
Applied Potential Resolution	0.3 mV
Applied Potential Accuracy	< 0.04% FSR
Current Autoranging	In Galvanostat Mode
Applied DC Current Ranges	4 (±100 mA, ±0.8 A, ±3 A, ±18 A)
Applied Current Resolution by Range	±100 mA: 15 μA (0.015% of FSR), ±0.8 A: 53 μA (0.0067% of FSR), ±3 A: 0.12 mA (0.0039% of FSR), ±18 A: 0.56 mA (0.0031% of FSR)
Applied Current Accuracy by Range	±100 mA: 0.10% of FSR, ±0.8 A: 0.053% of FSR, ±3 A: 0.037% of FSR, ±18 A: 0.033% of FSR
Input Bias Current	500 pA
Input Impedance	250 GΩ parallel to 3 pf
Maximum Update Rate	4 μs
Maximum Scan Rate	100 V/s
IR Compensation	Manual, Potentiostat and Galvanostat Modes, All Ranges
External Control	1 AO, 1 AI, 2 DO
<b>Potential Measurement</b>	
Measured DC Potential Ranges	2 (±50 mV, ±10 V) Autoranging
Resolution	3μV, 300μV (0.006%, 0.003% of FSR)
Accuracy	0.08 or 0.03% of FSR
<b>Current Measurement</b>	
Measured Current Ranges	Galvanostat: 4 (±100 mA, ±0.8A, ±3 A, ±18 A) Potentiostat: 4 (±100 mA, ±0.8 A, ±3 A, ±18 A)
Potentiostat Min to Max	1 mA to 18 A
Resolution by Range	Potentiostat and Galvanostat are the same ±100 mA: 15 μA (0.015% of FSR), ±0.8 A: 53 μA (0.0067% of FSR), ±3 A: 0.12 mA (0.0039% of FSR), ±18 A: 0.56 mA (0.0031% of FSR)
Accuracy	Potentiostat and Galvanostat are the same ±100 mA: 0.095% of FSR, ±0.8 A: 0.050% of FSR, ±3 A: 0.035% of FSR, ±18 A: 0.031% of FSR
<b>Data Acquisition</b>	
Acquisition Time	8 μs
Acquisition Speed	125 kS/second
DAC Resolution	16 bits
FSR: Full Scale Range	



## A

AC main power switch, 35  
AC power input, 34, 35  
AC supply voltage, 27  
accessory cables, 29  
analyze data, 81  
area calculations, 85  
axes, 64  
axes rescaling, 73

## B

baseline, 82  
battery cycling, 55  
butterworth filter, 93

## C

calculate area, 78  
cell enable switch, 32  
cell model, 89  
cell ON after measurement, 44, 45, 47, 51, 56, 57  
change axes, 64  
charge, 85  
charging current [A], 55  
charging voltage limit [V], 55  
check for new device, 39  
circuit, 89  
cleaning, 36  
common plots, 64  
computer control, 26  
configure instrument, 39  
contact information, 29  
cooling, 34  
corrosion analysis, 99  
corrosion experiment, 62  
counter electrode, 31, 33  
CPU, 8  
crop data, 78  
crop to cursors, 80, 94  
csv, 76  
current range, 41  
cursor, 81, 97  
cutoff frequency, 93  
cyclic voltammetry, 43, 66

## D

DAQ, 34, 35  
data analysis, 73, 85, 87  
data collection, 64  
data communication port, 34, 35  
data visualization, 73  
default settings, 43  
density, 99  
differential pulse voltammetry, 56  
digital analog I/O connections, 34  
dimensions, 24  
discharge first, 55  
discharging current [A], 55  
discharging voltage limit [V], 55  
display cell data, 64, 74

## E

edit single method, 41  
electrical impedance spectroscopy, 59  
electrode connector, 32  
electrode properties, 99  
electrostatic discharge, 27  
environmental conditions, 28  
equivalent weight, 99  
export data, 76  
external input, 32  
external transformer, 34  
EZstat back panel, 33  
EZstat front panel, 30

## F

filter order, 93  
filters, 91  
final potential [V], 57  
final potential value [V], 45, 47  
first vertex potential [V], 43, 45, 46  
function generator, 8

## G

galvanostat mode, 43  
general configuration, 41  
general recipe notes, 43  
grounding, 27

## H

hardware conventions, 30  
hardware installation, 30  
hold/ramp/step, 51

## I

impedance analysis, 88  
initial current [A], 58  
initial potential [V], 43, 45, 46, 51, 56, 57  
instrument specifications, 8  
intended use, 25

## L

LabVIEW Runtime Engine, 37  
last run data, 65, 67  
linear sweep voltammetry, 45, 62  
logging interval [s], 55

## M

main power switch, 31  
mains power cable, 22, 23  
mains supply, 22, 23  
maintenance, 36  
maximum frequency, 93  
median filter, 92  
model selection, 40  
multi vertex waveform, 46

## N

NI-DAQmx, 37  
NI-Serial driver, 37  
noise, 34  
normal pulse voltammetry, 57  
number of periods, 46, 47  
number of repetitions, 55  
number of segments, 43  
nuvdt, 76

## O

overlay data, 94

## P

potentiostat mode, 43

PowerStat back panel, 35  
PowerStat front panel, 31  
Powerstat-05E, 21  
pretreatment current [V], 51, 55, 56, 57  
pretreatment potential [V], 43, 45, 46  
pretreatment time [s], 43, 45, 46, 51, 55, 56, 57, 58  
programmable potential waveform, 51  
pulse amplitude [A], 58  
pulse amplitude [V], 56, 57  
pulse increment [V], 56, 57  
pulse period [s], 56, 57  
pulse width [s], 56, 57, 58

## R

rate/time to next, 51  
reference electrode, 31, 33  
relaxation period [s], 58  
repair, 36  
rescale axes, 73  
restart an experiment, 61

## S

safety, 26  
sampling interval [ms], 58  
saving data, 73  
second vertex potential [V], 43  
serial number plate, 34, 36  
service, 36  
**SIS impedance calculator**, 7  
**SIS theory**, 7  
software installation, 37  
specifications, 8  
square filter, 91  
standby potential [V], 56, 57  
standby value, 51  
startup, 38  
step impedance calculator, 88  
**step impedance spectroscopy**, 7, 58, 69, 87  
stop an experiment, 61  
subtract overlaid, 94  
surface area, 99  
symbol, 7

## T

Tafel plot, 96  
technical assistance, 29  
time limit [s], 55

timing, 8

## **U**

unfiltered data, 65

USB, 34, 35, 36, 37

## **V**

vertexes potential [V], 46

VRTX value, 51

## **W**

waveform, 66, 70

weight, 24

window size, 91, 92

working electrode, 31, 33

working sense electrode, 31, 33