WaveNow, WaveNano, WaveNowXV Potentiostat/Galvanostat System User Guide

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1. Preface

1.1 Scope

This User Guide describes the WaveNow, WaveNano, and WaveNow^{XV} Potentiostat/Galvanostat systems. This guide is written for the professional scientist or engineer (or student of science and engineering) and assumes a basic knowledge of scientific measurement and data presentation. Portions of this manual devoted to electrochemical concepts assume some familiarity with the subject of electrochemistry.

A small portion of this guide is dedicated to the subject of using the AfterMath software package to control the WaveNow, WaveNano, and WaveNow^{XV} instruments, primarily in the context of installing the instrument and verifying that it is working correctly. More extensive descriptions of how to use the AfterMath software are provided in the additional documents listed below:

- *AfterMath User Guide* (describes plotting and analysis functions)
- *AfterMath Electrochemistry Guide* (describes electrochemical techniques)

Both of the additional documents listed above are available at Pine Research Instrumentation's online site at the following URL:

https://www.pineresearch.com/shop/knowledgebase/aftermath/

1.2 Copyright

1.3 Trademarks

1.4 Use Limitation

The WaveNow, WaveNano, or WaveNow^{XV} instrument is not designed for use in experiments involving human subjects and/or the use of electrodes inside or on the surface of the human body.

Any use of this instrument other than its intended purpose is prohibited.

1.5 Service and Warranty Information

For questions about proper operation of the WaveNow, WaveNano, and WaveNow^{XV} systems or other technical issues, please use the contact information below to contact Pine Research directly.

TECHNICAL SERVICE CONTACT
Pine Research Instrumentation, Inc. **http://www.pineresearch.com** **Phone: +1 (919) 782-8320** **Fax: +1 (919) 782-8323**

If the WaveNow, WaveNano, or WaveNow^{XV} system or one of its components or accessories must be returned to the factory for service, please contact Technical Service (see: above) to obtain a Return Material Authorization (RMA) form. Include a copy of this RMA form in each shipping carton and ship the cartons to the Factory Return Service Address (below).

FACTORY RETURN SERVICE ADDRESS
Pine Instrument Company **ATTN: RMA # <RMA number>** **104 Industrial Drive** **Grove City, PA 16127** **USA**

RETURN MATERIAL AUTHORIZATION REQUIRED!

Do not ship equipment to the factory without first obtaining a Return Material Authorization (RMA) from Pine Research Instrumentation.

LIMITED WARRANTY

The WaveNow, WaveNano, or WaveNow^{XV} Potentiostat/Galvanostat instrument (hereafter referred to as the "INSTRUMENT") offered by Pine Research Instrumentation (hereafter referred to as "PINE") is warranted to be free from defects in material and workmanship for a one (1) year period from the date of shipment to the original purchaser (hereafter referred to as the "CUSTOMER") and used under normal conditions. The obligation under this warranty is limited to replacing or repairing parts which shall upon examination by PINE personnel disclose to PINE's satisfaction to have been defective. The customer may be obligated to assist PINE personnel in servicing the INSTRUMENT. PINE will provide telephone support to guide the CUSTOMER to diagnose and effect any needed repairs. In the event that telephone support is unsuccessful in resolving the defect, PINE may recommend that the INSTRUMENT be returned to PINE for repair. This warranty being expressly in lieu of all other warranties, expressed or implied and all other liabilities. All specifications are subject to change without notice.

The CUSTOMER is responsible for charges associated with non-warranted repairs. This obligation includes but is not limited to travel expenses, labor, parts and freight charges.

1.6 Icons (*Icônes*)

Special icons are used to call attention to safety warnings and other useful information found in this document (see: Table 1-1).

Des icônes spéciales (voir: tableau 1-1) sont utilisées pour attirer l'attention sur des avertissements de sécurité et autres renseignements utiles disponibles dans ce document.

CAUTION:

Indicates information needed to prevent injury or death to a person or to prevent damage to equipment.

ATTENTION:

Indique les informations nécessaires à la prévention de blessures corporelles ou de mort d'un individu ou à la prévention des dommages aux équipements.

STOP:

For a procedure involving user action or activity, this icon indicates a point in the procedure where the user must stop the procedure.

ARRÊT:

Dans une opération impliquant l'action ou l'activité d'un utilisateur, cette icône indique la partie de l'opération où l'utilisateur doit arrêter l'opération.

NOTE:

Important or supplemental information.

REMARQUE:

Renseignements importants ou complémentaires.

TIP:

Useful hint or advice.

CONSEIL:

Astuce ou conseil utile.

Table 1-1. Special Icons used in this Document.

(Tableau 1-1. Icônes spéciales utilisées dans ce document)

1.7 Bottom Panel Markings

The lower portion of the bottom panel of the WaveNow, WaveNano, or WaveNow^{XV} bears information to identify the instrument and to indicate any certifications or independent testing agency marks which pertain to the instrument (see: Figure 1-1).

Figure 1-1. WaveNow, WaveNano, and WaveNow^{XV} Bottom Panel Markings

1.7.1 Certifications and Listings

CE MARK:

The WaveNow, WaveNano, and WaveNow^{XV} instrument complies with one or more EU directives and bears the CE marking. See the "CE Declaration of Conformity" attached to the end of this manual for more details.

1.7.2 Serial Number

For purposes of uniquely identifying a particular instrument, there is a label on the bottom panel of each WaveNow, WaveNano, or WaveNow^{XV} that indicates the model number and the serial number. The serial number is also encoded with a machine readable barcode on the bottom panel of the instrument (see: Figure 1-1).

1.7.3 Model Numbers

The relationship between the model name and model number for the WaveNow, WaveNano, and WaveNow^{XV} potentiostats is described below (see: Table 1-2). The model numbers have the format "AFTP**X**" where **X** is a single alphanumeric character used to indicate the particular model name. Part numbers for power cords and other accessories are provided in more detail later (see: Section 2.5 and Section 5).

Model Number:	**A**	**F**	**T**	**P**	**X**	Model Name
	A	**F**	**T**	**P**	**1**	**WaveNow**
	A	**F**	**T**	**P**	**2**	**WaveNano**
	A	**F**	**T**	**P**	**3**	**WaveNow^{XV}**

Table 1-2. WaveNow, WaveNano, and WaveNow^{XV} Model Numbers

1.8 Safety Warnings (Avertissements de sécurité)

CAUTION:

Connect the Power Supply to the AC mains using the Power Cord supplied with the WaveNow, WaveNano, or WaveNow^{XV} and certified for the country of use. (see: Section 7 of this User Guide for more details).

AVERTISSEMENT:

Connectez le bloc d'alimentation au secteur à l'aide du cordon d'alimentation fourni avec l'appareil WaveNow, WaveNano, ou WaveNow^{XV} et conforme aux réglementations du pays d'utilisation (pour plus de détails, consultez la partie 7 du présent mode d'emploi).

CAUTION:

Do not block access to the Power Supply or the Power Cord. The user must have access to disconnect the Power Supply or the Power Cord from the AC mains at all times.

AVERTISSEMENT:

Ne bloquez pas l'accès au bloc d'alimentation ou au cordon d'alimentation. L'utilisateur doit être en mesure de déconnecter le bloc d'alimentation ou le cordon d'alimentation du secteur à tout moment.

CAUTION:

Connect the Power Supply to the AC mains using the Power Cord and appropriate plug style adapter supplied with the WaveNow, WaveNano, or WaveNow^{XV}.

AVERTISSEMENT:

Branchez l'alimentation au secteur à l'aide du cordon d'alimentation et de l'adaptateur de type de prise fourni avec WaveNow, WaveNano ou WaveNow^{XV}.

CAUTION:

The switch on the side of the WaveNow, WaveNano, or WaveNow^{XV} turns the power to the potentiostat on and off. Do not block access to the switch. The user must have access to the switch at all times.

AVERTISSEMENT:

L'interrupteur sur le côté du WaveNow, WaveNano, or WaveNow^{XV} permet l'allumage et l'arrêt du potentiostat. Ne pas bloquer l'accès à l'interrupteur. L'utilisateur doit avoir accès à l'interrupteur en tout temps.

CAUTION:

Provide proper ventilation for the WaveNow, WaveNano, or WaveNow^{XV}. Maintain at least two inches ($50\ mm$) of clearance around the sides (left, right, and back) and above (top) the instrument.

AVERTISSEMENT:

Assurez-vous que l'appareil WaveNow, WaveNano, ou WaveNow^{XV} soit correctement ventilé. Laissez au moins $50\ mm$ (2 po) autour de l'appareil (à gauche, à droite et derrière), ainsi qu'au-dessus.

CAUTION:

Do not operate the WaveNow, WaveNano, or WaveNow^{XV} in an explosive atmosphere.

AVERTISSEMENT:

N'utilisez pas l'appareil WaveNow, WaveNano, ou WaveNow^{XV} dans une atmosphère explosive.

CAUTION:

Do not operate the WaveNow, WaveNano, or WaveNow^{XV} in wet or damp conditions. Keep all instrument surfaces clean and dry.

AVERTISSEMENT:

N'utilisez pas l'appareil WaveNow, WaveNano, ou WaveNow^{XV} dans un environnement humide. Veillez à ce que toutes les surfaces de l'appareil soient toujours propres et sèches.

CAUTION:

Do not operate the WaveNow, WaveNano, or WaveNow^{XV} if it has suffered damage or is suspected of having failed. Refer the instrument to qualified service personnel for inspection.

AVERTISSEMENT:

N'utilisez pas l'appareil WaveNow, WaveNano, ou WaveNow^{XV} s'il a été endommagé ou si vous pensez qu'il est tombé en panne. Signalez l'appareil au personnel d'entretien qualifié pour qu'il soit examiné.

CAUTION:

When connecting a WaveNow, WaveNano, or WaveNow^{XV} system to an electrode rotator other than the Pine Research MSR rotator, carefully consider the magnitude of the WaveNow, WaveNano, or WaveNow^{XV} rate control signal ratio ($1\ RPM/mV$) and take steps to assure that the rotator is configured to use the same ratio.

AVERTISSEMENT:

Lorsque vous connectez un appareil WaveNow, WaveNano, ou WaveNow^{XV} à un rotateur à électrodes autre que le rotateur Pine Research MSR, faites très attention à la valeur du rapport du signal de contrôle de vitesse de l'appareil WaveNow, WaveNano, ou WaveNow^{XV} ($1\ tr/min/mV$) et assurez-vous que le rotateur soit configuré avec le même rapport.

1.9 Electrostatic Discharge Information

Electrostatic discharge (ESD) is the rapid discharge of static electricity to ground. An ESD event occurs when two bodies of different potential approach each other closely enough such that static charge rapidly passes from one object to the next. Sensitive electronics in the path of the discharge may suffer damage. Damaging ESD events most often arise between a statically charged human body and a sensitive electronic circuit. The human body can easily accumulate static charge from simple movement from one place to another (*i.e.*, walking across a laboratory).

Potentiostat users must always be aware of the possibility of an ESD event and should employ good practices to minimize the chance of damaging the instrument. Some examples of good ESD prevention practices include the following:

- Self-ground your body before touching sensitive electronics or the electrodes. Self-grounding may be done by touching a grounded metal surface such as a water pipe.
- Wear a conductive wrist-strap connected to a good earth ground to prevent a charge from building up on your body.
- Wear a conductive foot/heel strap or conductive foot wear in conjunction with standing on a grounded conductive floor mat.
- Increase the relative humidity in the air to minimize static generation.

The WaveNow, WaveNano, and WaveNow^{XV} Potentiostat/Galvanostat Systems have been tested and found to be compliant with the European EMC product specific Standard EN 61326-1:2013 for immunity and emissions. The immunity standard includes testing for ESD to IEC 61000-4-2:2008.

INFO:

The WaveNow, WaveNano, and WaveNow^{XV} instrument may be susceptible to ESD events that occur on or near the electrode cable assembly. Such an ESD event can result in data loss, corruption of data, loss of communication with PC, and instrument unresponsiveness. Addition of a metallic shield to the electrode cable will improve the immunity of the system to an ESD event.

1.10 Hazardous Material Information

Hazardous Material Disclosure Table						
AFTP1, AFTP2, AFTP3						
Part Name	Hazardous Substances					
	Lead (Pb)	Mercury (Hg)	Cadmium (Cd)	Hexavalent Chromium (Cr (VI))	Polybrominated biphenyls (PBB)	Polybrominated diphenyl ethers (PBDE)
PCB: Main	X	O	O	O	O	O
PCB: Dummy Cell	X	O	O	O	O	O
Mag Alloy Case	O	O	O	O	O	O

This table is prepared in accordance with the provisions of SJ/T 11364.

O: indicates that said hazardous substance contained in all of the homogeneous materials for this part is below the limit requirements of GB/T 26572.

X: indicates that said hazardous substance contained in at least one of the homogeneous materials for this part is above the limit requirements of GB/T 26572.

Note: the date of manufacture for this item may be coded in the serial number as follows:
wwyynn: ww indicates week; yy indicates year; and nn is the number of the item, starting with 01 each week.

Note: the unit meets EU RoHS requirements; China does not have the exemptions for hazardous materials in components as does the EU; therfore, there may be the above noted materials present in the unit.

Table 1-3. Hazardous Substances Disclosure (English).

有害物质披露表						
AFTP1, AFTP2, AFTP3						
部件名称	有害物质					
	铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (Cr (VI))	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
主电路板	X	O	O	O	O	O
虚拟电解池	X	O	O	O	O	O
镁合金机壳	O	O	O	O	O	O

本表格依据 SJ/T 11364 的规定编制。

O： 表示该有害物质在该部件所有均质材料中的含量均在 GB/T 26572 规定的限量要求以下。

X： 表示该有害物质至少在该部件的某一均质材料中的含量超出 GB/T 26572 规定的限量要求。

注： 该部件的制造日期可能会按照以下格式出现在序列号码中：
wwyynn：ww 表示周数； yy 表示年的最后两位数； nn 是该周序列号、每周都从01开始。

注： 该部件符合欧盟RoHS指标； 但是中国 不像欧盟那样 对零部件的有害物质有豁免，
所以该部件可能包含表中列出的物质。

Table 1-4. Hazardous Materials Disclosure (Mandarin)

1.11 Software License

Purchase of a WaveNow, WaveNano, or WaveNow^{XV} instrument includes a license to use the AfterMath software package to control the instrument and analyze data collected using the instrument. Pine Research Instrumentation understands that the WaveNow, WaveNano, or WaveNow^{XV} is used in a laboratory environment where multiple computers are present and where data acquired using one computer might be analyzed using a different computer. The following software license describes how AfterMath may be used with the WaveNow, WaveNano, or WaveNow^{XV} in a laboratory with multiple computers.

PINE RESEARCH INSTRUMENTATION

AFTERMATH DATA ORGANIZER SOFTWARE LICENSE

Pine Research Instrumentation, Inc. (hereafter "PINE") licenses purchasers (hereafter "LICENSEES") of Pine electrochemical potentiostats (hereafter "INSTRUMENTS") to use the AfterMath Data Organizer software (hereafter "SOFTWARE") in conjunction with these INSTRUMENTS. This License contains the terms and conditions of use of the SOFTWARE.

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9. **Applicable Law**: This License shall be governed by and construed in accordance with the laws of the State of Pennsylvania, United States of America, as if performed wholly within the State and without giving effect to the principles of conflict of law. If any portion hereof is found to be void or unenforceable, the remaining provisions of this License shall remain in full force and effect. This License constitutes the entire understanding and agreement between the parties with respect to the licensed use of the SOFTWARE.
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LICENSEE HAS READ THIS AGREEMENT AND UNDERSTANDS AND AGREES TO ALL OF ITS TERMS AND CONDITIONS.

2. Product Specifications

2.1 Instrument Description

The WaveNow, WaveNano, and WaveNow^{XV} are portable instruments that are designed to connect to a personal computer (via a USB cable) and are controlled by Pine Research AfterMath software. The WaveNow, WaveNano, and WaveNow^{XV} are potentiostat/galvanostat systems capable of controlling an electrochemical cell comprised of one working electrode, a reference electrode, and a counter electrode. The WaveNow and WaveNano feature one potential range ($\pm 4.0\ V$) while the WaveNow^{XV} features an extended potential range ($\pm 10.0\ V$). The WaveNow and WaveNow^{XV} have four current ranges (from $\pm 100.0\ mA$ down to $\pm 10.0\ \mu A$), making them suitable for most electroanalytical based experiments. The WaveNano has four current ranges (from $\pm 1.0\ mA$ down to $\pm 100.0\ nA$) for lower current applications; it is necessary to properly ground the WaveNano and shield electromagnetic fields (by use of a Faraday cage, for example) to accurately resolve sub-nanoampere current.

2.2 Software Description

The AfterMath scientific data analysis software is able to create high quality graphs and reports from experimental results. A licensed copy of AfterMath is included with each potentiostat purchased from Pine Research Instrumentation. AfterMath offers several important benefits:

Instrument Control. When started, AfterMath automatically detects all compatible instrumentation attached to the computer and provides complete control over each instrument. AfterMath can simultaneously control multiple instruments, and multiple experiments may be queued on each individual instrument. Even as new experiments are queued or running in the background, data acquired in previous experiments may be manipulated by the user.

Flexible Plotting. AfterMath has a powerful "drag-n-drop" feature that allows traces from one plot to be quickly and easily copied and moved to other plots. Preparing an overlay plot from several voltammograms is straightforward. AfterMath provides precise control over line sizes, point markers, colors, axis limits, axis labels, and tick marks. One or more text boxes may be placed anywhere on a plot, and the text may be formatted with any combination of fonts, font sizes, or colors as desired.

Scientific Units. Unlike graphing software designed for business and marketing applications, AfterMath is designed with scientific data in mind. Proper management of scientific units, metric prefixes, scientific notation, and significant figures is built into Aftermath. For example, if an operation divides a potential measured in millivolts by a current measured in nanoamps, then Aftermath properly provides the result as a resistance measured in megaohms.

Data Archiving. A unique and open XML-based file format allows data from several related experiments to be kept together in one single archive file. The archive file avoids the user having to search the hard drive for a set of related voltammograms. The internal archive hierarchy can contain as many subfolders, reports, plots, notes, experimental parameters, and data sets as desired.

Tools and Transforms. Flexible tools can be placed on any graph to precisely measure quantities like peak height and peak area. Multiple tools can be placed on a plot, and all such tools remain exactly where they are placed, even if the data archive is saved to a disk and reloaded at a later time. Fundamental mathematical operations (addition, multiplication, integration, logarithm, etc.) can be applied to any trace on any plot.

2.3 Instrument Specifications

The WaveNow, WaveNano, and WaveNow^{XV} portable USB instrument systems offer the following electrode control modes: potentiostat (POT), galvanostat (GAL), open circuit potential (OCP), and zero resistance ammeter (ZRA). These instruments do not offer an iR compensation mode.

INFO:

All specifications provided in this section are subject to change without notice.

2.3.1 Common Specifications

The following specifications are common to the WaveNow, WaveNano, and WaveNow^{XV}.

ELECTRODE CONNECTIONS	
Reference Electrode	Sense line with driven shield
Counter Electrode	Drive line
Working Electrode	Separate sense and drive lines, each with driven shield (current measurement via passive shunt)

GROUNDING	
DC Common (signal ground)	The DC Common is accessible via the black banana plug on the cell cable and the center pin on the Rotator Control Port
Chassis Connection	The metal case (chassis) is connected to the shield on the Cell Port and the shield on the USB Port. As shipped from the factory, the instrument chassis and DC Common are connected. A jumper on the circuit board may be removed to allow the DC Common to float with respect to the chassis.
Earth Ground	No direct connection to earth ground is provided. The chassis may (either intentionally or unknowingly) be connected to earth ground via a USB cable connected to a remote computer.

ELECTROMETER (REFERENCE ELECTRODE FOLLOWER)	
Input Impedance	$> 10^{14}\ \Omega$ in parallel with $< 20\ pF$
Input Current	$< 2\ pA$ leakage/bias current at $25^{\circ}C$
CMRR	$> 50\ dB\ at\ 10\ kHz;\ 80\ dB\ at\ 60\ Hz$
Bandwidth	$> 800\ kHz\ (3\ dB)$

ROTATION RATE CONTROL CONNECTIONS (SIDE PANEL)

Range	$\pm 10.5\ V$
Resolution	$5.12\ mV$ per DAC bit (12 bit)
Digital On/Off Signal	open drain (TTL compatible)
Output Impedance	$<\ 10\ \Omega$

DATA ACQUISITION

Clock Resolution	$500\ nsec$ (minimum time base)
Point Interval*	$500\ \mu sec$ (minimum)
Synchronization	simultaneous current & potential input
Raw Point Total	< 10 million per experiment

ACCESSORIES

Dummy Cell	external dummy cell (included)
Cell Cable	HD-15 male connector to multiple banana plugs via shielded coaxial cables (included), other designs available

EXTERNAL PORTS (SIDE PANELS)

Cell Port	HD-15 female connector
Interface Port	USB Type-B connector
Rotator Control Port	3-pin header connector

GENERAL SPECIFICATIONS

Power Required	$5.0\ VDC$, $2\ A$ (low voltage DC device)
Power Supply (included)	$100\ to\ 240\ VAC, 300\ mA, 50\ to\ 60\ Hz$
LED Indicators	power, USB, and status
Instrument Dimensions	165 x 100 x $29\ mm$
Instrument Weight	$280\ g\ (10\ oz.)$
Shipping Dimensions	260 x 260 x $360\ mm$
Shipping Weight	$1.4\ kg\ (3\ lb)$
Temperature Range	$10^{\circ}C\ to\ 40^{\circ}C$
Humidity Range	$80\ \%RH$ maximum, non-condensing

2.3.2 WaveNow Specifications

The following specifications apply only to the WaveNow Potentiostat/Galvanostat System. The Common Specifications found in Section 2.3.1 apply as well.

MEASURED CURRENT	
Ranges	$\pm 100\ mA, \pm 5\ mA, \pm 200\ \mu A, \pm 10\ \mu A$
Resolution (at each range)	$3.4\ \mu A, 170\ nA, 6.8\ nA, and\ 340\ pA$
Autoranging	yes
Practical Range§	$80\ nA\ to\ 100\ mA$
Accuracy	$\pm\ 0.2\%$ setting; $\pm 0.05\%$ of range
Leakage Current	$10\ pA\ at\ 25^{\circ}C$
ADC Input	16 bits
Filters	$2.5\ kHz$ (2-pole, low pass filter)

APPLIED CURRENT (GALVANOSTATIC MODE)	
Ranges	$\pm 100\ mA, \pm 5\ mA, \pm 200\ \mu A, and\ \pm\ 10\ \mu A$
Resolution (at each range)	$3.1\ \mu A, 156\ nA, 6.25\ nA, and\ 313\ pA$
Accuracy	$\pm\ 0.2\%$ setting; $\pm 0.05\%$ of range
DAC Output	16 bits

POWER AMPLIFIER (COUNTER ELECTRODE AMPLIFIER)	
Output Current	$\pm 100.0\ mA$ (maximum)
Compliance Voltage	$\pm\ 12\ V$
Speed	3
Bandwidth	$>\ 20\ kHz$ (on "fast" speed setting)
Rise Time	$180\ V/msec$ (on "fast" speed setting)

APPLIED POTENTIAL (POTENTIOSTAT MODE)	
Ranges	$\pm 4.0\ V$
Resolution (at each range)	$125\ \mu V$ per DAC bit
Accuracy	$\pm 0.2\%$ of setting, $\pm 1.0\ mV$
Thermal Drift	$< 0.01\%/℃$
DAC Output	16 bits
CV Scan Rate (min)	$10\ \mu V\ /\ sec$ ($125\ \mu V$ step every $12.5\ sec$)
CV Scan Rate (max)	$10\ V/sec$ ($10\ mV$ step every $1.0\ msec$)

Specifications continued on next page…

MEASURED POTENTIAL

Ranges	$\pm 4.0\ V$
Resolution (at each range)	$136\ \mu V$ per DAC bit
Accuracy	$\pm 0.2\%$ of setting, $\pm 0.05\%\ mV$
ADC Input	16 bits
Filters	$2.5\ kHz$ (2-pole, low pass filter)

* Data acquisition using the minimum point interval is possible for short duration bursts. The burst duration depends upon the available host PC USB bandwidth and is typically at least 3 seconds.

§ The "practical range" of measurable currents goes from the maximum current output of the amplifier down to the current level at which noise begins to interfere with the signal. Without taking any special precautions, the noise level on the WaveNow potentiostat ($\sim 40\ nA$) prevents practical measurement of signals with magnitudes below approximately twice the noise level ($\sim 80\ nA$).

2.3.3 WaveNano Specifications

The following specifications apply only to the WaveNano Potentiostat/Galvanostat System. The Common Specifications found in Section 2.3.1 apply as well.

MEASURED CURRENT	
Ranges	$\pm 1\ mA, \pm 50\ \mu A, \pm 2\ \mu A, \pm 100\ nA$
Resolution (at each range)	$34\ nA, 1.7\ nA, 68\ pA, and\ 3.4\ pA$
Autoranging	yes
Practical Range§	$100\ pA\ to\ 1\ mA$
Accuracy	$\pm\ 0.2\%$ setting; $\pm 0.05\%$ of range
Leakage Current	$10\ pA\ at\ 25^{\circ}C$
ADC Input	16 bits
Filters	$2.5\ kHz$ (2-pole, low pass filter)

APPLIED CURRENT (GALVANOSTATIC MODE)	
Ranges	$\pm 1\ mA, \pm 50\ \mu A, \pm 2\ \mu A, and\ \pm 100\ nA$
Resolution (at each range)	$31\ nA, 1.56\ nA, 62.5\ pA, and\ 3.13\ pA$
Accuracy	$\pm\ 0.2\%$ setting; $\pm 0.05\%$ of range
DAC Output	16 bits

POWER AMPLIFIER (COUNTER ELECTRODE AMPLIFIER)	
Output Current	$\pm 1.0\ mA$ (maximum)
Compliance Voltage	$\pm\ 12\ V$
Speed	3
Bandwidth	$>\ 20\ kHz$ (on "fast" speed setting)
Rise Time	$180\ V/msec$ (on "fast" speed setting)

APPLIED POTENTIAL (POTENTIOSTAT MODE)	
Ranges	$\pm 4.0\ V$
Resolution (at each range)	$125\ \mu V$ per DAC bit
Accuracy	$\pm 0.2\%$ of setting, $\pm 1.0\ mV$
DAC Output	16 bits
CV Scan Rate (min)	$10\ \mu V\ /\ sec$ ($125\ \mu V$ step every $12.5\ sec$)
CV Scan Rate (max)	$10\ V/sec$ ($10\ mV$ step every $1.0\ msec$)

Specifications continued on next page…

MEASURED POTENTIAL

Ranges	$\pm 4.0\ V$
Resolution (at each range)	$136\ \mu V$ per DAC bit
Accuracy	$\pm 0.2\%$ of setting, $\pm 0.05\%$ of range
ADC Input	16 bits
Filters	$2.5\ kHz$ (2-pole, low pass filter)

* Data acquisition using the minimum point interval is possible for short duration bursts. The burst duration depends upon the available host PC USB bandwidth and is typically at least 3 seconds.

§ The "practical range" of measurable currents goes from the maximum current output of the amplifier down to the current level at which noise begins to interfere with the signal. Without taking any special precautions, the noise level on the WaveNow potentiostat ($\sim 40\ nA$) prevents practical measurement of signals with magnitudes below approximately twice the noise level ($\sim 80\ nA$). With the WaveNano potentiostat, if you use a properly shielded cell and coaxial cell cables, it is possible to routinely measure signals as low as $100\ pA$.

2.3.4 WaveNow^{XV} Specifications

The following specifications apply only to the WaveNow^{XV} Potentiostat/Galvanostat System. The Common Specifications found in Section 2.3.1 apply as well.

MEASURED CURRENT	
Ranges	$\pm 100\ mA, \pm 5\ mA, \pm 200\ \mu A, \pm 10\ \mu A$
Resolution (at each range)	$3.4\ \mu A, 170\ nA, 6.8\ nA, and\ 340\ pA$
Autoranging	yes
Practical Range§	$80\ nA\ to\ 100\ mA$
Accuracy	$\pm\ 0.2\%$ setting; $\pm 0.05\%$ of range
Leakage Current	$10\ pA\ at\ 25^{\circ}C$
ADC Input	16 bits
Filters	$2.5\ kHz$ (2-pole, low pass filter)

APPLIED CURRENT (GALVANOSTATIC MODE)	
Ranges	$\pm 100\ mA, \pm 5\ mA, \pm 200\ \mu A, and\ \pm 10\ \mu A$
Resolution (at each range)	$3.1\ \mu A, 156\ nA, 6.25\ nA, and\ 313\ pA$
Accuracy	$\pm\ 0.2\%$ setting; $\pm 0.05\%$ of range
DAC Output	16 bits

POWER AMPLIFIER (COUNTER ELECTRODE AMPLIFIER)	
Output Current	$\pm 100.0\ mA$ (maximum)
Compliance Voltage	$\pm 12\ V$
Speed	3
Bandwidth	$>\ 20\ kHz$ (on "fast" speed setting)
Rise Time	$180\ V/msec$ (on "fast" speed setting)

ELECTROMETER (REFERENCE ELECTRODE FOLLOWER)	
Input Impedance	$>\ 10^{14}\ \Omega$ in parallel with $<\ 20\ pF$
Input Current	$<\ 2\ pA$ leakage/bias current at $25^{\circ}C$
CMRR	$>\ 50\ dB\ at\ 10\ kHz;\ 80\ dB\ at\ 60\ Hz$
Bandwidth	$>\ 800\ kHz\ (3\ dB)$

Specifications continued on next page…

APPLIED POTENTIAL (POTENTIOSTAT MODE)

Ranges	$\pm 10.0\ V$
Resolution (at each range)	$312.5\ \mu V$ per DAC bit
Accuracy	$\pm 0.2\%$ of setting, $\pm 1.0\ mV$
Thermal Drift	$< 0.01\%/℃$
DAC Output	16 bits
CV Scan Rate (min)	$25\ \mu V\ /\ sec$ ($312.5\ \mu V$ step every $12.5\ sec$)
CV Scan Rate (max)	$10\ V/sec$ ($10\ mV$ step every $1.0\ msec$)

MEASURED POTENTIAL

Ranges	$\pm 10.0\ V$
Resolution (at each range)	$340\ \mu V$ per DAC bit
Accuracy	$\pm 0.2\%$ of setting, $\pm 0.05\%$ of range
ADC Input	16 bits
Filters	$2.5\ kHz$ (2-pole, low pass filter)

* Data acquisition using the minimum point interval is possible for short duration bursts. The burst duration depends upon the available host PC USB bandwidth and is typically at least 3 seconds.

§ The "practical range" of measurable currents goes from the maximum current output of the amplifier down to the current level at which noise begins to interfere with the signal. Without taking any special precautions, the noise level on the WaveNow potentiostat ($\sim 40\ nA$) prevents practical measurement of signals with magnitudes below approximately twice the noise level ($\sim 80\ nA$).

2.4 Standard Electrochemical Methods

The WaveNow, WaveNano, or WaveNow^{XV}, together with the AfterMath software package, can perform many electrochemical techniques (see: Table 2-1). Further descriptions about how to configure and execute these techniques can be found in the documentation for the AfterMath software.

Simple Methods

- Open Circuit Potential (OCP)
- Constant Potential Electrolysis (BE)
- Constant Current Electrolysis (BE)
- Zero Resistance Ammeter (ZRA)

Voltammetric Methods

- Cyclic Voltammetry (CV)
- Linear Sweep Voltammetry (LSV)
- Staircase Voltammetry (SCV)
- Chronoamperometry (CA)
- Normal Pulse Voltammetry (NPV)
- Cyclic Step Chronoamperometry (CSCA)
- Differential Pulse Voltammetry (DPV)
- Square-Wave Voltammetry (SWV)
- Double Potential Step Chronoamperometry (DPSCA)

Galvanostatic Methods

- Chronopotentiometry (CP)
- Current Ramp Chronopotentiometry (CRP)
- Staircase Potentiometry (SCP)
- Cyclic Step Chronopotentiometry (CSCP)

Stripping Voltammetry

- Anodic & Cathodic Stripping Voltammetry (ASV)
- Differential Pulse Stripping Voltammetry (DPSV)
- Square-Wave Stripping Voltammetry (SWSV)

Rotating Disk & Cylinder Methods*

- Rotating Disk Electrode (RDE)
- Koutecky-Levich Series (KL-RDE)
- Rotating Disk Electrolysis (BE-RDE)
- Rotating Disk Chronopotentiometry (CP-RDE)
- Rotating Disk Ramp Chronopotentiometry (RCP-RDE)

Corrosion Methods*

- Linear Polarization Resistance (LPR)
- Rotating Cylinder Voltammetry (RCE)
- Rotating Cylinder Electrolysis (BE-RCE)
- Rotating Cylinder Eisenberg Study (EZB-RCE)
- Rotating Cylinder Polarization Resistance (LPR-RCE)
- Rotating Cylinder Open Circuit Potential (OCP-RCE)
- Rotating Cylinder Chronopotentiometry (CP-RCE)
- Rotating Cylinder Ramp Chronopotentiometry (RCP-RCE)

Spectroscopic Methods*

- Spectroscopy (SPEC)
- Spectroelectrochemistry (SPECE)

Table 2-1. Electrochemical Techniques in AfterMath

*Access to these electrode methods requires a different software license; by default, the WaveNow, WaveNano, or WaveNow^{XV} instruments are sold without these experiments. If you have a Pine Research electrode rotator or Avantes spectrometer and would like to access these experiments, please contact Pine Research Instrumentation for assistance.

TIP:

More information about configuring electrochemical techniques using AfterMath may be found by searching our knowledgebase.

https://www.pineresearch.com/shop/knowledgebase

2.5 System Components

The WaveNow, WaveNano, and WaveNow^{XV} systems, as shipped from the production facility, have include all parts, cables, and software necessary for use (see: Table 2-2).

1

2

3

4

5

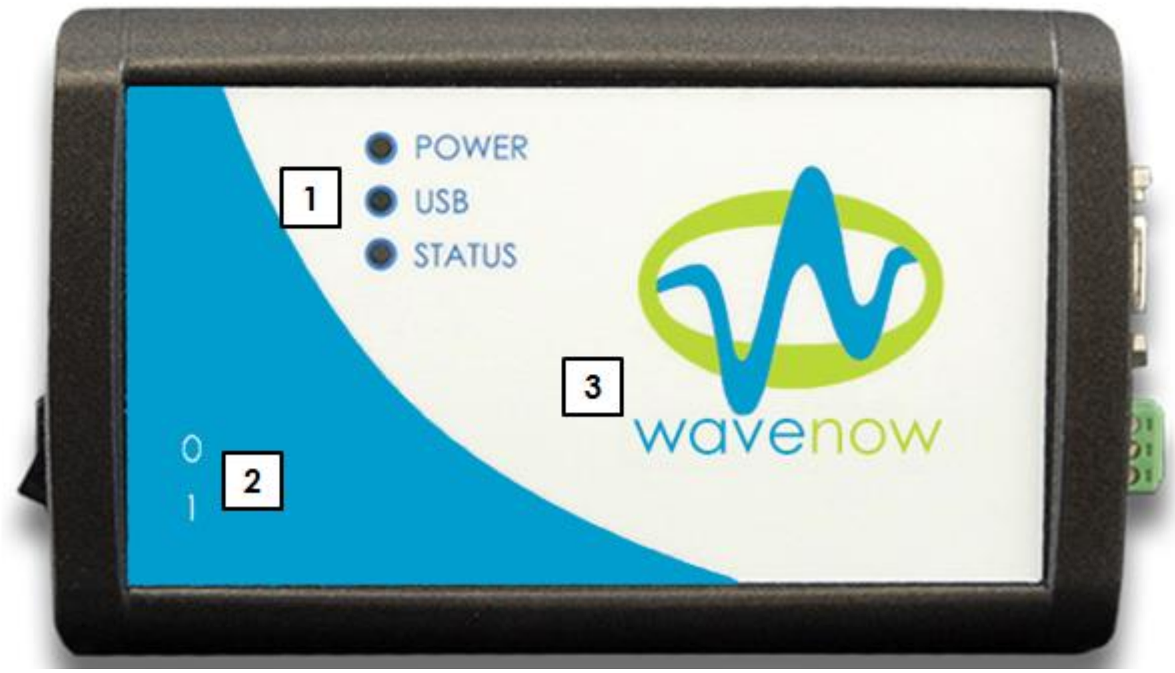
6

1	**Instrument**	A WaveNow, WaveNano, or WaveNow^{XV} potentiostat/galvanostat
2	**USB Flash Drive**	Contains AfterMath software, drivers, and license files
3	**Cell Cable**	General purpose cable to connect working, working sense, counter, reference, and ground lines from the electrochemical cell to the potentiostat (HD-15 connector)
4	**Dummy Cell**	A network of known resistors and capacitors that can be used to test the WaveNow, WaveNano, and WaveNow^{XV} to assure that the instrument is working properly
5	**Power Supply**	A $5\ VDC\ (2A)$ power supply. This power supply is compatible with any power source capable of providing $100\ to\ 240\ VAC$ $(50\ or\ 60\ Hz)$. Requires country specific power cord (see: Section 7)
6	**Interface (USB) Cable**	Communication cable between computer and WaveNow, WaveNano, or WaveNow^{XV} (USB type A male to type B male)

Table 2-2. Main Components Included with WaveNow Series Potentiostat

2.6 Top Panel Description

The top panel of the WaveNow, WaveNano, and WaveNow^{XV} contains three important LEDs, a power switch label, and the instrument's name (see: Figure 2-1). The three LEDs located on the top panel of the WaveNow, WaveNano, and WaveNow^{XV} are used to indicate power, USB activity, and instrument status. Each LED corresponds to one of these indicators, and the various colors that one LED can assume are described in more detail below (see: Table 2-3).



1	**LED Indicator Lights**	LEDs indicate the status of the instrument
2	**Power Selection**	Controls whether power is On (1) or Off (0)
3	**Potentiostat Name**	WaveNow, WaveNano, or WaveNow^{XV}

Figure 2-1. The Top Panel of the WaveNow (WaveNano and WaveNow^{XV} Differ by Color)

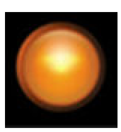
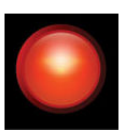
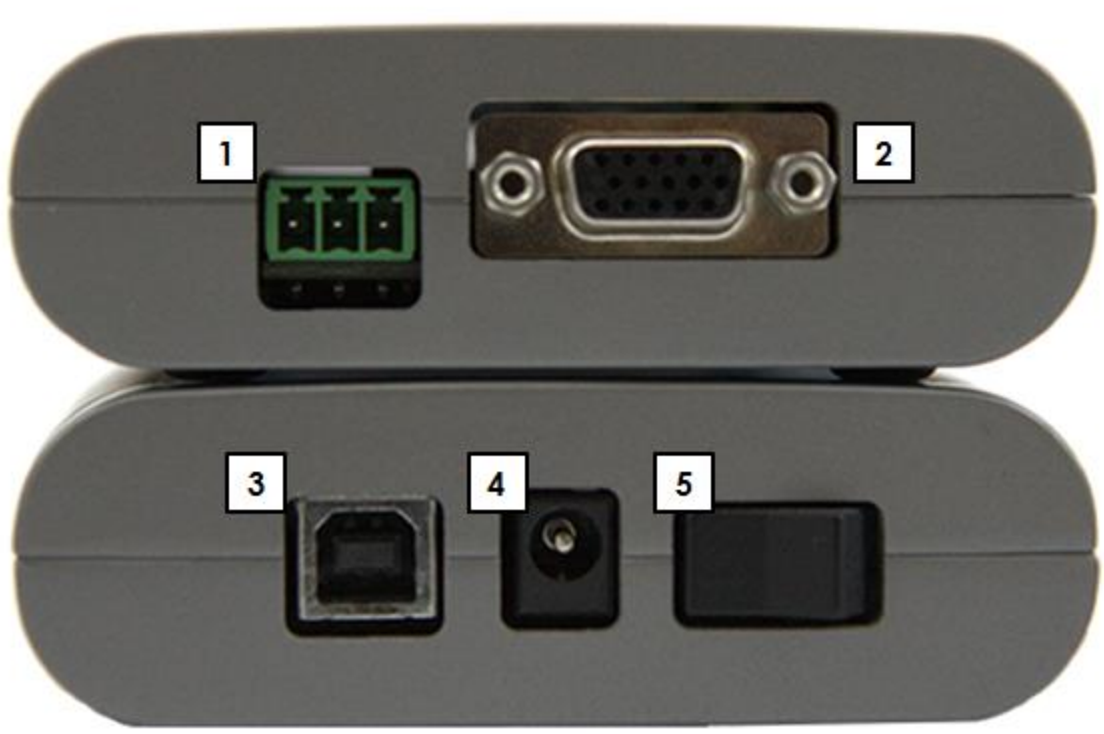
LED	LED Color/State	Indication
Power	 not illuminated	When the power LED is off, the instrument power switch is in the "off" position (or the power supply is not providing power).
	 solid yellow	When the power LED is solid yellow, the power supply is providing power to the instrument and the power switch is in the "on" position.
USB	 blinking green	The USB indicator will blink (or flicker) whenever data transfer occurs between the instrument and the computer.
	 not illuminated	No data is being transferred between the instrument and computer.
Status	 slow blinking green	One second illuminated, one second not illuminated. When the instrument has successfully communicated with AfterMath and is idle (*i.e.*, not performing an experiment).
	 fast blinking green	Half second illuminated, half second not illuminated. When the instrument is performing an experiment.
	 blinking orange	When the instrument is initially powered on, a brief self-test is performed, and during this self-test, the status LED is blinking orange. This state persists until the instrument successfully communicates with a computer running the AfterMath software package.
	 solid or blinking red	If the status LED is solid red or blinking red, then there is a serious problem with the instrument. Contact Pine Research Instrumentation for assistance.

Table 2-3. Overview of the WaveNow, WaveNano, and WaveNow^{XV} LED Indicator Lights

2.7 Side Panels Description

Connections to the instrument are made via several ports located on the side panels (see: Figure 2-2). One side panel has the power switch, power supply port, and USB communication port. The other side panel has the cell port and rotator control connection port.



1	**Rotator Control Port**	Green, three-pin header connector for rotation rate control
2	**Cell Port**	The HD-15 male connector connects to the cell cable
3	**USB Interface Port**	Type B female USB port connects to a computer through the USB Cable
4	**DC Power Port**	Accepts the power supply cable
5	**Power Switch**	Switch to turn the main power on/off

Figure 2-2. The Side Panels of the WaveNow, WaveNano, and WaveNow^{XV}

2.8 Bottom Panel Description

The bottom panel of the WaveNow, WaveNano, and WaveNow^{XV} identifies the connections, inputs, and outputs for the system (see: Figure 2-3).

1	**Cell Port**	The HD-15 male connector connects to the cell cable
2	**Auxiliary Output**	Green, three-pin header connector for rotation rate control
3	**USB Interface Port**	Type B female USB port connects to a computer through the USB Cable
4	**DC Power Port**	Accepts the power supply cable
5	**Power Switch**	Switch to turn the main power on/off

Figure 2-3. The Bottom Panel of the WaveNow, WaveNano, and WaveNow^{XV}

2.9 Dummy Cell Description

A dummy cell is a network of known resistors and capacitors that can be used to test a potentiostat to ensure that the instrument is working properly. The dummy cell included with the WaveNow and WaveNow^{XV} (part #: AB01DUM1) and WaveNano (part #: AB01DUM2) offers four separate networks which represent the extremes encountered during routine aqueous voltammetry experiments (see: Figure 2-4).

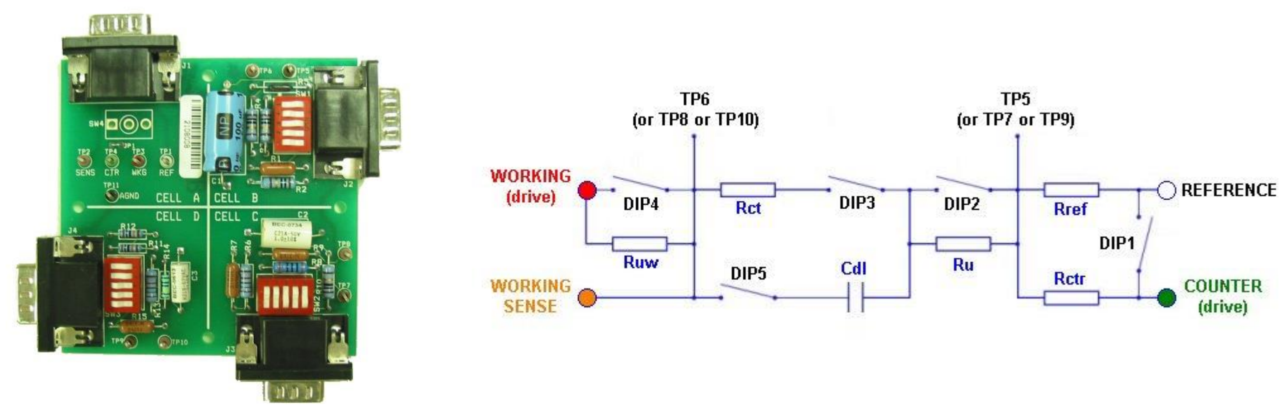


Figure 2-4. Dummy Cell (with Schematic Diagram)

The dummy cell circuit board contains four separate dummy cell circuits. Each circuit has the same schematic (see: Figure 2-4), but the values of the resistors and capacitors in each circuit are different (see: Table 2-4). Each of the four circuits has a male HD-15 connector which can be plugged directly into the cell port on the instrument (see: Figure 2-5).

Component	CELL B	CELL C	CELL D	CELL E‡
C_{dl}	$100\ \mu F$	$1\ \mu F$	$10\ nF$	$100\ pF$
R_{ct}	$10\ \Omega$	$1000\ \Omega$	$10^6\ \Omega$	$10^9\ \Omega$
R_u	$10\ \Omega$	$100\ \Omega$	$10^4\ \Omega$	$10^6\ \Omega$
R_{uw}	$1\ \Omega$	$10\ \Omega$	$1000\ \Omega$	$10^5\ \Omega$
R_{ref}	$1000\ \Omega$	$10^4\ \Omega$	$10^5\ \Omega$	$10^6\ \Omega$
R_{ctr}	$10\ \Omega$	$1000\ \Omega$	$10^5\ \Omega$	$10^6\ \Omega$

Table 2-4. Dummy Cell Resistance and Capacitance Values

*The first position, "CELL A", may be used for field verification of the instrument's calibration (along with the proper software and calibration instrumentation).

‡The circuit board included with the WaveNano potentiostat has a special position, "CELL E", in place of "CELL B". This special position offers a dummy cell with a $1\ G\Omega$ resistor which is ideal for testing very low current behavior.

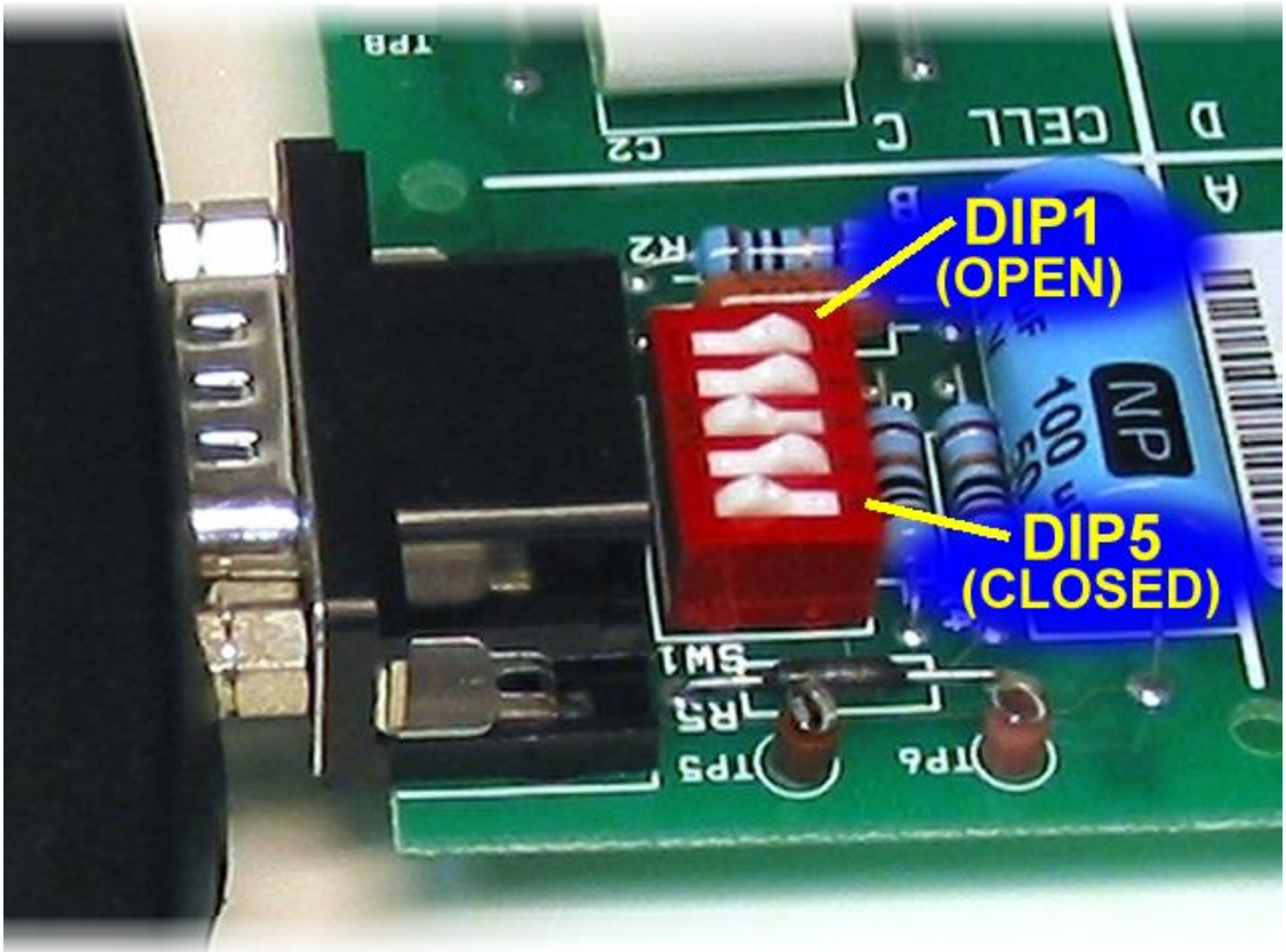
Figure 2-5. Dummy Cell Connected to the WaveNow

Dummy cells “B” through “E” each contain a red and white dip switch block. By using various settings of the five dip switches, it is possible to test the potentiostat against a variety of different loads, each of which might mimic the load presented by a “real” electrochemical cell.

In each configuration, the reference electrode is separated from the reference sense point (TP5, TP7, or TP9) by a resistor R_{ref}), and the counter electrode is also separated from this point by a resistor (R_{ctr}, which mimics the solution resistance). Similarly, the working electrode is separated from the working sense point (TP6, TP8, or TP10) by a small resistor (R_{uw}). Note that the R_{uw} value may be reduced to zero by closing the switch DIP4, and R_{ref} and R_{ctr} may be reduced by joining the reference and counter electrodes together by closing the DIP1 switch.

> **NOTE:**
>
> **If you are unfamiliar with dip switches, it can be difficult to discern whether a switch is closed or open. Refer to Figure 2-6 for examples of both a closed switch and an open switch.**

There are three common dip switch configurations used to test a potentiostat (see: Figure 2-6). Further testing details can be found in Sections 4.2 and 4.3.



Configuration	DIP1	DIP2	DIP3	DIP4	DIP5
Pure Resistive Load	open	closed	closed	open	open
Pure Capacitive Load	open	closed	open	open	closed
Randle's Circuit	open	open	closed	open	closed

Figure 2-6. Location and Use of the Dummy Cell Dip Switches

3. System Installation

Setting up the WaveNow, WaveNano, or WaveNow^{XV} system in a laboratory consists of three basic steps: (1) physical installation; (2) software installation; and (3) system testing. The entire process usually requires about 60 minutes. The physical and software installation steps are described in this section (below), and the system testing procedure is described in the next section (see: Section 4).

3.1 Physical Installation

The WaveNow, WaveNano, and WaveNow^{XV} are portable instruments designed for use in a typical laboratory environment. Physical installation involves positioning the instrument and the computer which controls the instrument in a suitable location and connecting the instrument to a source of electrical power (*i.e.*, the AC Mains) and to the computer via a USB cable.

3.1.1 Location

The instrument should be placed on a sturdy lab bench or table in such a way that there is unobstructed access to the instrument's side panels; this will ensure space for the cell cable, USB cable, and power cord connections. There should also be at least two inches ($50\ mm$) of clearance above the front panel (top) of the instrument. Particular care should be given to selecting a clean and dry location.

During normal use, the instrument is connected to an electrochemical cell via a cell cable plugged into the side panel of the instrument (several cable options are available based on the type of cell and electrode used, see: Section 5). Thus, it is important to ensure that the lab bench or table also has sufficient work space for securely mounting the electrochemical cell and for routing the cell cable between the instrument and the electrochemical cell.

3.1.2 Glovebox Installation

There are two practical ways to perform electrochemical experiments inside of a glovebox. Both require that electrical power be present inside the glovebox to power the instrument, and the glovebox must also be equipped with special feedthroughs for the cell cables, or preferably for the USB cable. These two approaches are discussed in more detail below.

Potentiostat and Electrochemical Cell in Glovebox

Placing the instrument and the electrochemical cell inside the glovebox is by far the easiest and preferred approach. By keeping the instrument close to the cell, the cell cables are shorter, minimizing interference from environmental noise sources. This approach requires that the glovebox be equipped with a special USB feedthrough port. This allows the computer controlling the instrument to be placed outside the glovebox, and the only signals passing through the wall of the glovebox are those in the USB communications cables. Inexpensive third-party USB cable feedthroughs are available (see: Figure 3-1) which fit into the standard KF style flanges found on most gloveboxes. Many Pine Research customers have successfully used feedthroughs offered by the Kurt J. Lesker Company (www.lesker.com).

The instrument may be safely passed into the glovebox through the antechamber. Any cables, power cords, or instrument accessories are also safe to bring into the glovebox through the antechamber. The exact time needed to fully remove any residual air from the potentiostat and accessories varies by antechamber size and vacuum strength; in addition to following established glovebox user protocols, it is recommended to place everything under vacuum overnight. Once inside the glovebox, operation of the potentiostat is identical to outside the glovebox, though some signal noise may be introduced by the glovebox environment (vacuum pumps, purging gases, vibrations, etc.). Once inside the glovebox, it is a good idea to leave it there; repeated cycling through the antechamber is not recommended.

Figure 3-1. USB Cable Glovebox Feedthrough

Figure 3-2. Cell Cable Glovebox Feedthrough

Electrochemical Cell Only in Glovebox

If the potentiostat must remain outside the glovebox, then it is possible to feed a special longer version of the cell cable through a port in the wall of the glovebox. A port with a KF-40 flange is ideal, and epoxy can be used to seal around the individual cell cable lines as they pass through the flange (see: Figure 3-2). To mitigate any signal noise picked up by the longer cell cable, an electrically conductive and earth grounded mesh may need to be installed around the cell cable bundle. Contact Pine Research Instrumentation for further details.

3.1.3 Electrical Power Variations

The power supply provides the DC power required by the instrument ($5\ VDC, 2.0\ Amps$) via a low voltage cable. One end of the low voltage cable is permanently connected to the power supply, and the other end is connected to the DC power port (located on the side panel of the instrument and marked "POWER IN").

The power supply may be connected to the laboratory electrical power (*i.e.*, the AC Mains) via an appropriate adapter or power cable. Instruments purchased prior to 2017 are equipped with a power supply that mounts directly to the AC Mains receptacle (see: Figure 3-3) while those purchased after 2017 are a power supply which connects to the receptacle via a power cable (see: Figure 3-4). In either case, the power supply is shipped with an adapter or power cable suitable for the country where the instrument is to be used (see: Section 7 for power cord information).

Figure 3-3. Power Supply (receptacle mounted style, shipped prior to 2017)

Figure 3-4. Power Supply (power brick style, shipped after 2017)

CAUTION:

Connect the Power Supply to the AC mains using the Power Cord and appropriate plug style adapter supplied with the WaveNow, WaveNano, or WaveNow^{XV}.

AVERTISSEMENT:

Connectez le bloc d'alimentation au secteur à l'aide du cordon d'alimentation et l'adaptateur de style bouchon approprié fourni avec le WaveNow, WaveNano, ou WaveNow^{XV}.

CAUTION:

Do not block access to the Power Supply or its cord. The user must have access to disconnect the Power Supply or the Power Cord from the AC mains at all times.

AVERTISSEMENT:

Ne bloquez pas l'accès au bloc d'alimentation ou son cordon. L'utilisateur doit être en mesure de déconnecter le bloc d'alimentation ou le cordon d'alimentation du secteur à tout moment.

CAUTION:

The switch on the side of the WaveNow, WaveNano, or WaveNow^{XV} turns the power to the potentiostat on and off. Do not block access to the switch. The user must have access to the switch at all times.

AVERTISSEMENT:

L'interrupteur sur le côté du WaveNow, WaveNano, or WaveNow^{XV} permet l'allumage et l'arrêt du potentiostat. Ne pas bloquer l'accès à l'interrupteur. L'utilisateur doit avoir accès à l'interrupteur en tout temps.

The local source of electrical power (*i.e.*, the AC Mains) must be a branch circuit protected by a circuit breaker rated between 10 and $15\ amps$. The AC voltage supplied by the AC Mains must be between 100 and $240\ VAC$, and the AC frequency must be between 50 and $60\ Hz$. The Power Supply and cord must be positioned in such a way that the instrument user has free and unobstructed access to these items. The user must be able to disconnect the instrument from the Power Supply and disconnect the power supply from the AC mains (receptacle) without any obstructions.

3.1.4 USB Cable Connection

The WaveNow, WaveNano, or WaveNow^{XV} is connected to a computer using the USB cable supplied with the instrument (Type A male to Type B female USB cable, see: Figure 3-5). The USB port on the computer must be capable of USB 2.0 (or better) data transfer rates.

Figure 3-5. USB Cable Connection between Potentiostat and Computer

3.2 AfterMath Software Installation

AfterMath is a software package designed to run on a personal computer using the Windows operating system. The minimum system requirements for the personal computer and operating system are listed below (see: Table 3-1).

Processor Class	Intel Pentium IV or equivalent/compatible
Processor Speed	1 GHz minimum recommended
Physical Memory	1 GB minimum recommended for 32 bit operating systems 2 GB minimum recommended for 64 bit operating systems
Screen Resolution	1024 x 768 pixels or greater required
Operating System	Windows XP (32-bit only), Windows Vista (32 or 64 bit), Windows 7 (32 or 64 bit), Windows 8 (32 or 64 bit), Windows 10 (32 or 64 bit)
USB Port	USB 2.0 must be available
Prerequisite Software	.NET Framework version 2.5.50727 Visual C++ 8.0 Runtime

Table 3-1. Computer System Requirements for AfterMath Software

Note that the prerequisite software (Visual C++ runtime and .NET Framework) are often already present on modern personal computers. In the event that they are missing from the computer, these components are available for free download from the website of Microsoft Corporation. Pine Research Instrumentation maintains updated links to recent AfterMath and Microsoft downloads at the following web address: https://www.pineresearch.com/shop/knowledgebase/software-downloads.

TIP:

If any problem is encountered during software installation, please consult the AfterMath knowledgebase:

https://www.pineresearch.com/shop/knowledgebase/aftermath/

3.2.1 Step-by-Step Software Installation Instructions

AfterMath is shipped with the WaveNow, WaveNano, or WaveNow^{XV} on removable media such as a CD-ROM or a USB data stick. The media contains the latest release of AfterMath available at the time of purchase, device drivers for communicating with the instrument, and the permissions file which implements the software license.

The installation media contains a file called "**setup.exe**". Launch this executable file and follow the instructions on the screen. Screenshots of a typical installation are provided below (see: Figure 3-6 through Figure 3-15).

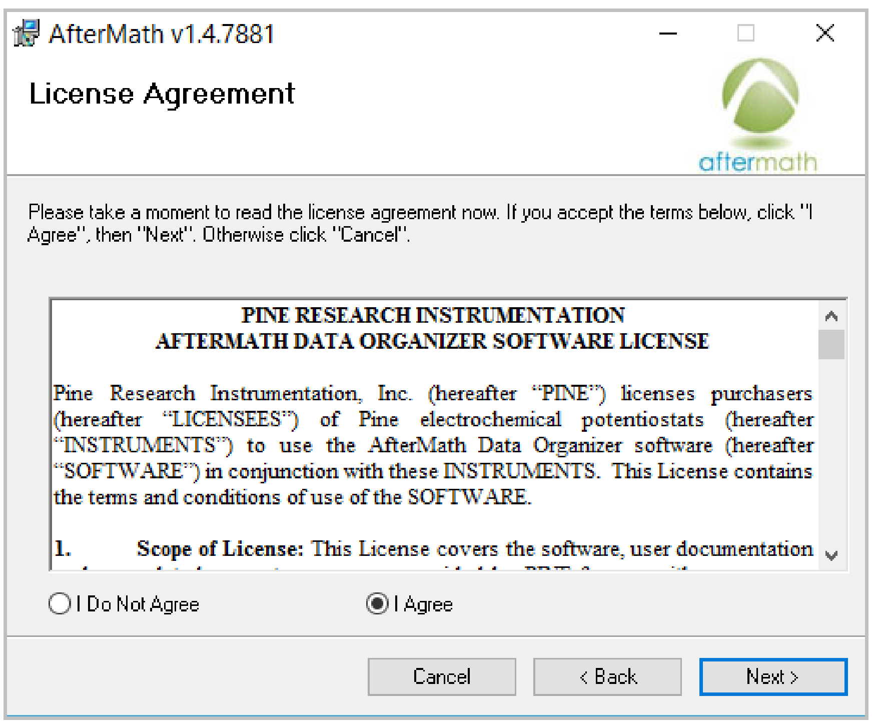


Figure 3-6. License Agreement Window during the Installation of AfterMath

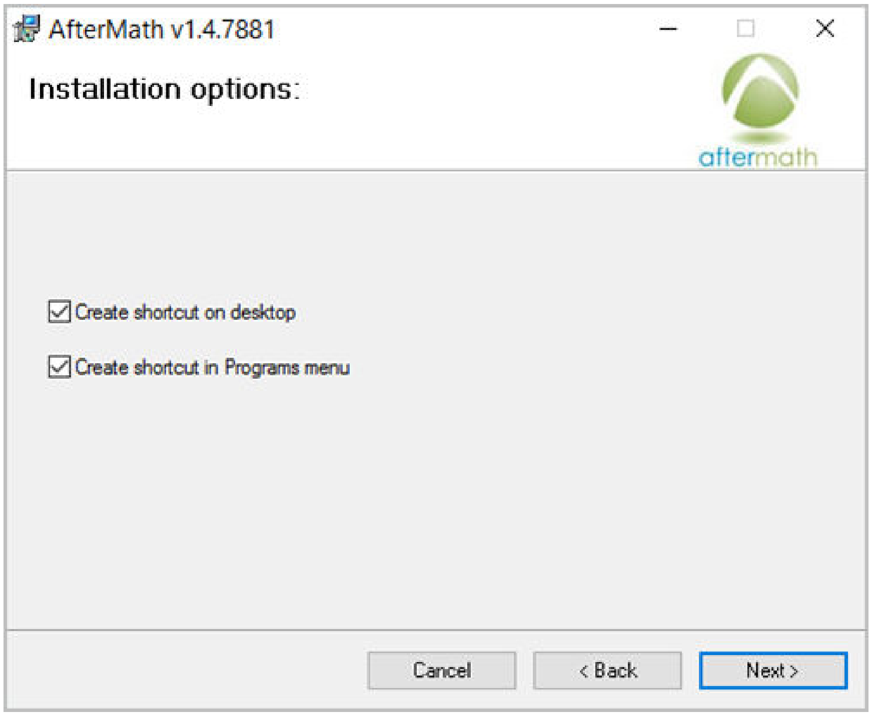


Figure 3-7. Installation Options Dialog during AfterMath Installation

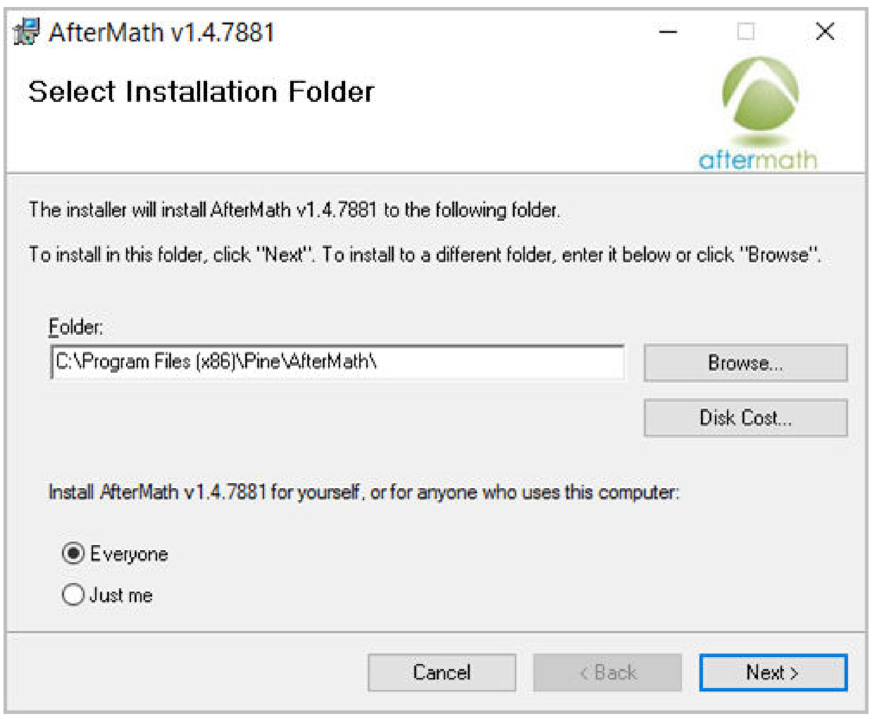


Figure 3-8. Select Installation Location and User Access (choose "Everyone")

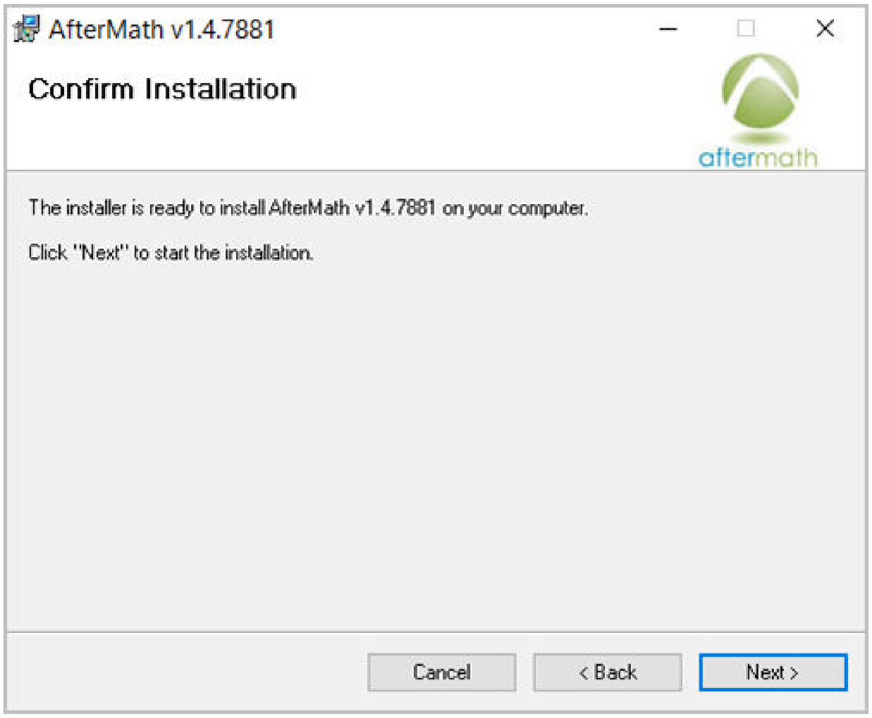


Figure 3-9. Confirmation of Installation Settings during the Installation of AfterMath

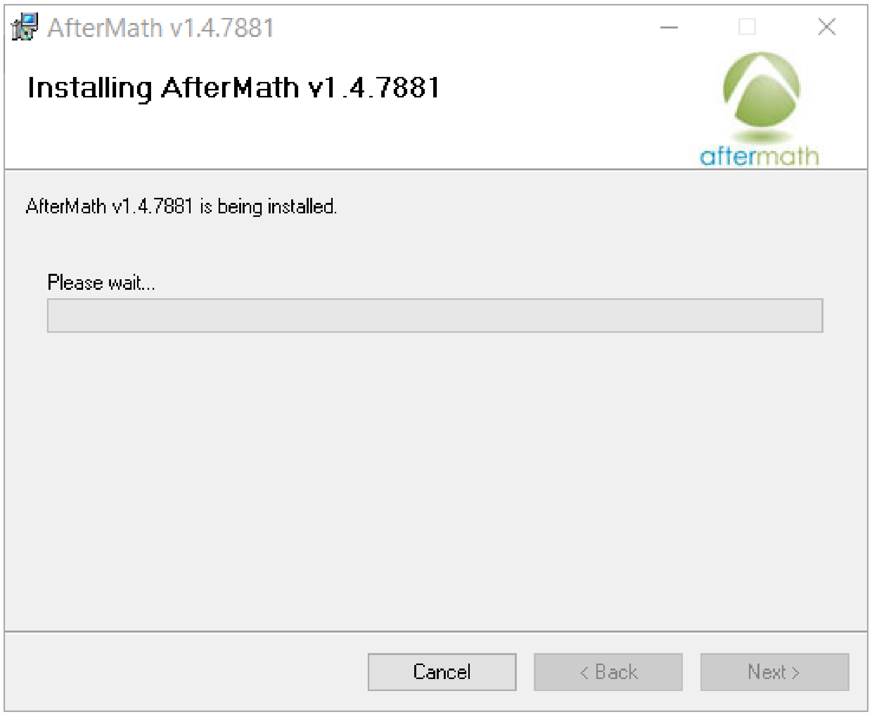


Figure 3-10. Dialog Box Showing Progress during AfterMath Installation

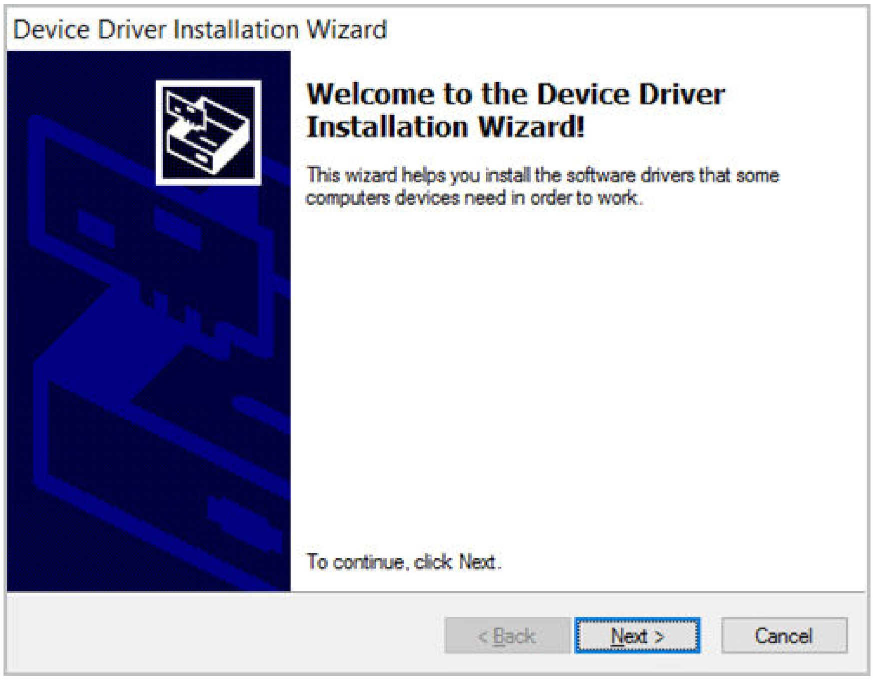


Figure 3-11. Automatic Device Driver Installation Wizard during AfterMath Installation

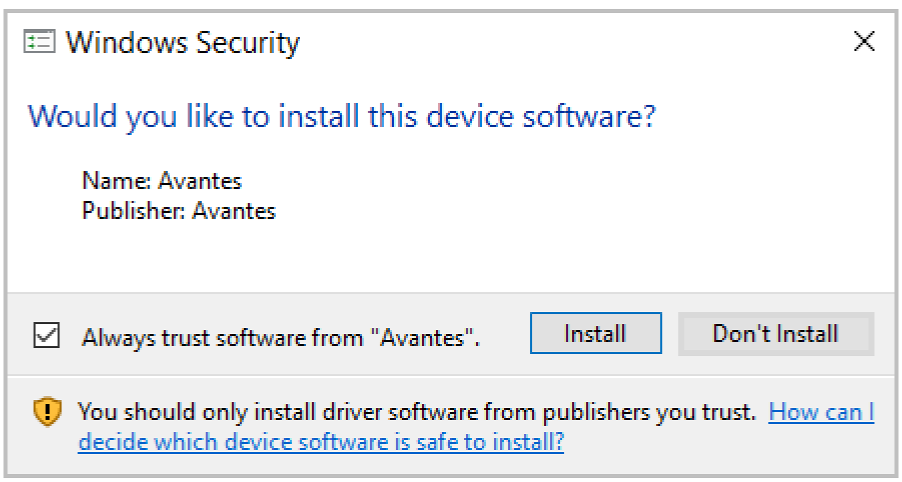


Figure 3-12. Windows Security Prompt to Install Device Software

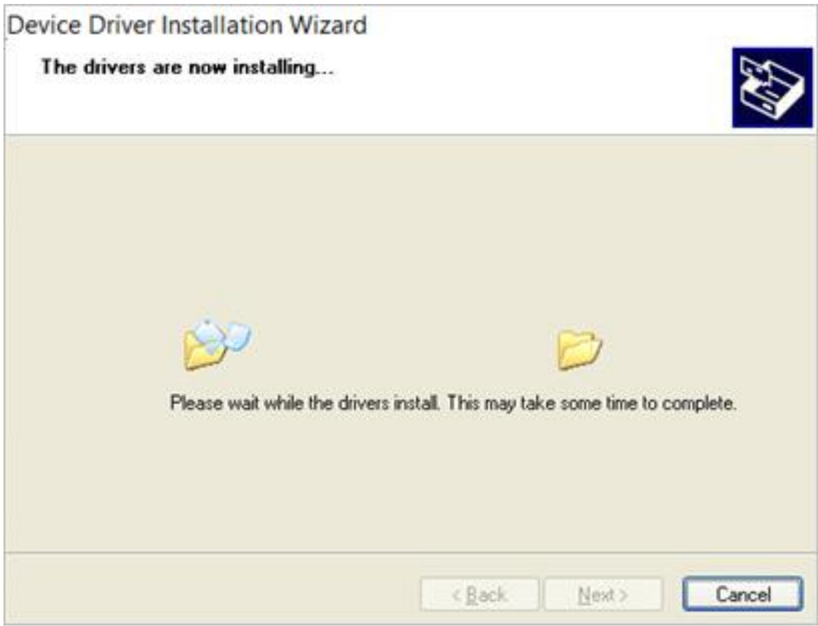


Figure 3-13. Device (USB) Driver Progress Window during AfterMath Installation

Figure 3-14. USB/Device Driver Installation Complete during AfterMath Installation

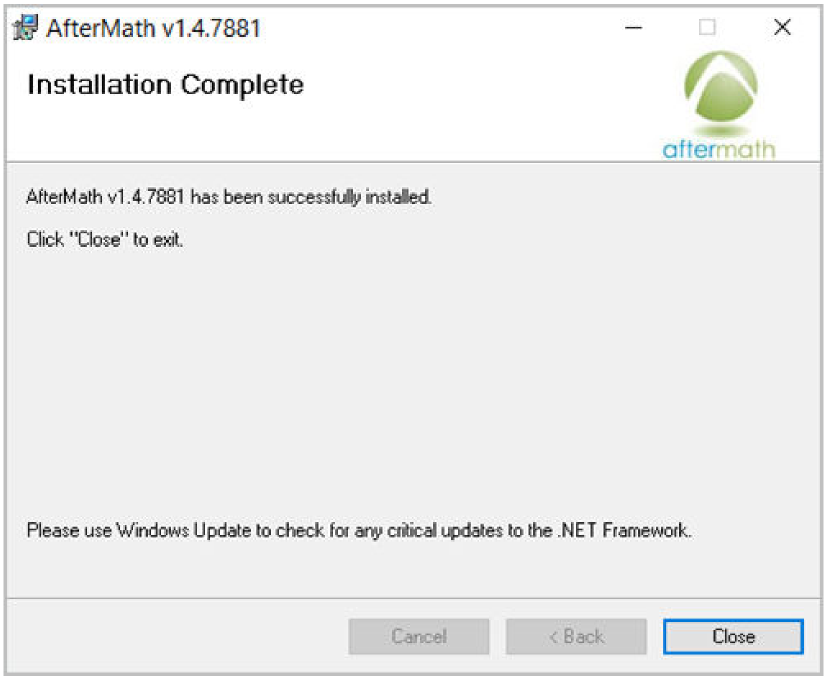


Figure 3-15. Windows Prompt to Indicate Successful Installation of AfterMath

3.2.2 Permission File Verification

On the installation media, there are licenses or "permission files" that authorize a computer running AfterMath to control specific instruments (see: Figure 3-16). If Aftermath is installed on the computer using the installation media shipped with a particular instrument, then these permission files are automatically copied to the computer.

If AfterMath is downloaded directly from the internet and installed on a computer, the permission files may not be present on the computer. This is most often noticed by the user when the AfterMath "Perform" button is disabled (gray shading, see: Figure 3-17). To assure the proper permissions files are on the computer, open the installation media and launch the AfterMath software. Create a new archive in AfterMath (this can be accomplished by selecting **Cyclic Voltammetry** from the **Experiments** menu). Next, simply drag and drop the permission files (all file names ending in "*.papx") from the installation folder directly into the archive (see: Figure 3-18). The AfterMath program will remember the permission files even after the program is closed (*i.e.*, this step only needs to be performed once). You may be prompted to accept changes by the AfterMath program.

> **NOTE:**
>
> **Contact Pine Research Instrumentation if you encounter any issues with software licensing or permissions files.**

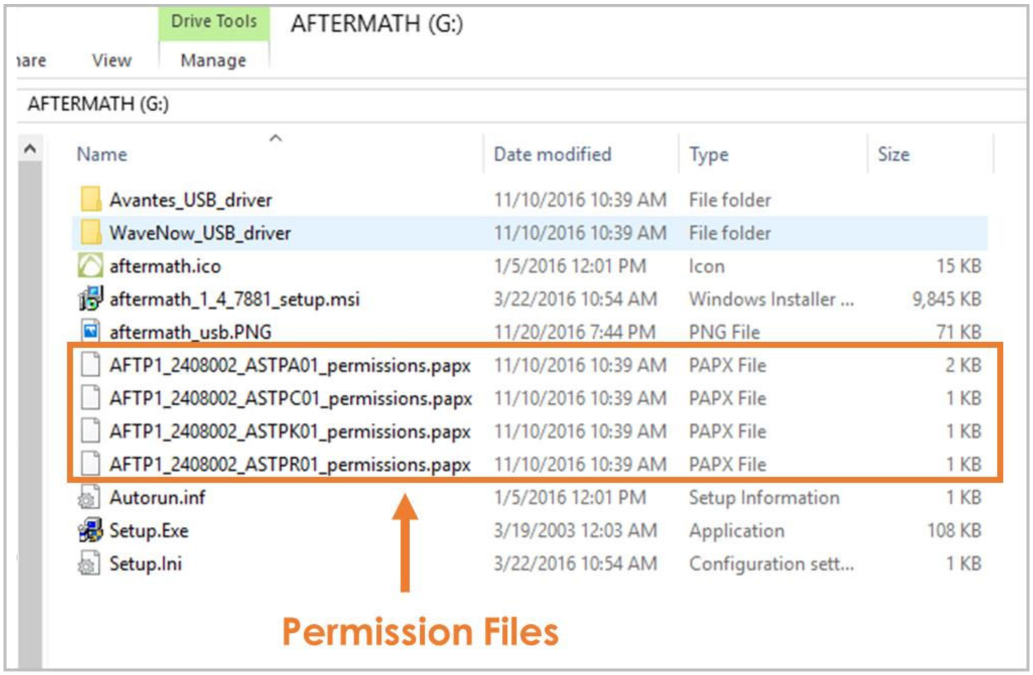


Figure 3-16. Permission Files on Installation Media

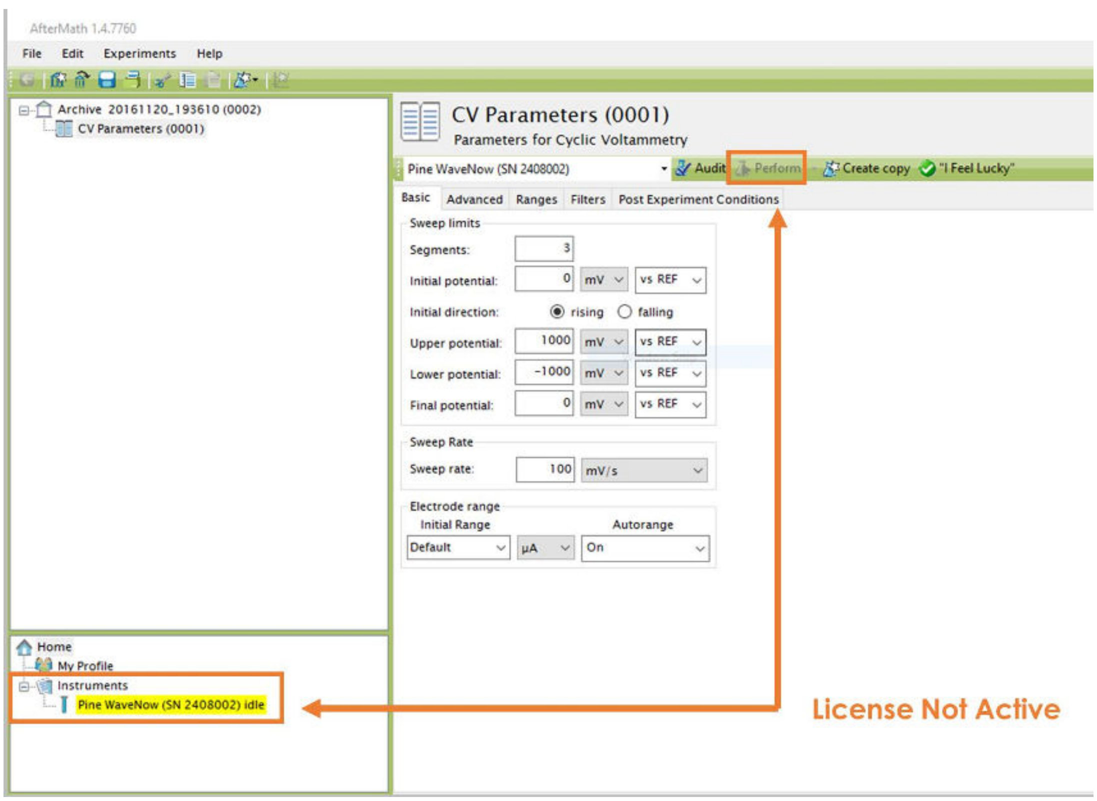


Figure 3-17. Indications that the AfterMath License is not Active

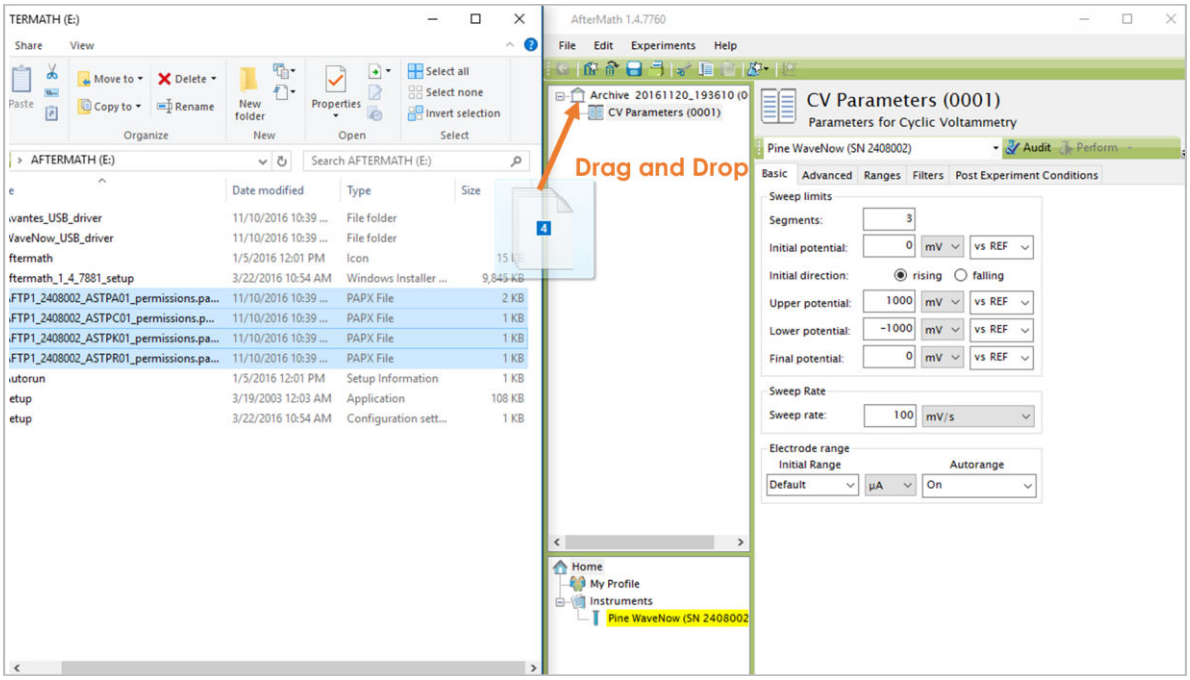


Figure 3-18. Copying Permission Files to AfterMath

3.3 Installation Checklist

The next section of this guide will describe testing a fully-installed WaveNow, WaveNano, or WaveNow^{XV}. Before proceeding, ensure the following installation steps have been completed:

- ✓ The WaveNow, WaveNano, or WaveNow^{XV} instrument is located in a secure, dry location with adequate space
- ✓ Electrical Power is connected to the WaveNow, WaveNano, or WaveNow^{XV}
- ✓ The WaveNow, WaveNano, or WaveNow^{XV} instrument is connected to a computer via the USB cable
- ✓ AfterMath software is installed on the computer

4. System Testing

This section describes a fast way to test the WaveNow, WaveNano, or WaveNow^{XV} potentiostat system. By connecting the potentiostat to a well-behaved network of resistors and capacitors (using the Universal Dummy Cell), the potentiostat circuitry can be tested to assure that it is working properly.

TIP:

To verify the instrument is operating correctly, perform the system test described here. This test is one of the first actions that will be suggested if you contact Pine Research for technical support.

4.1 Test Setup

4.1.1 Launch the AfterMath Software

Launch AfterMath (which should already be installed – see: Section 3) and log into AfterMath (see: Figure 4-1). Click "OK" on the AfterMath Login dialog window to start the program.

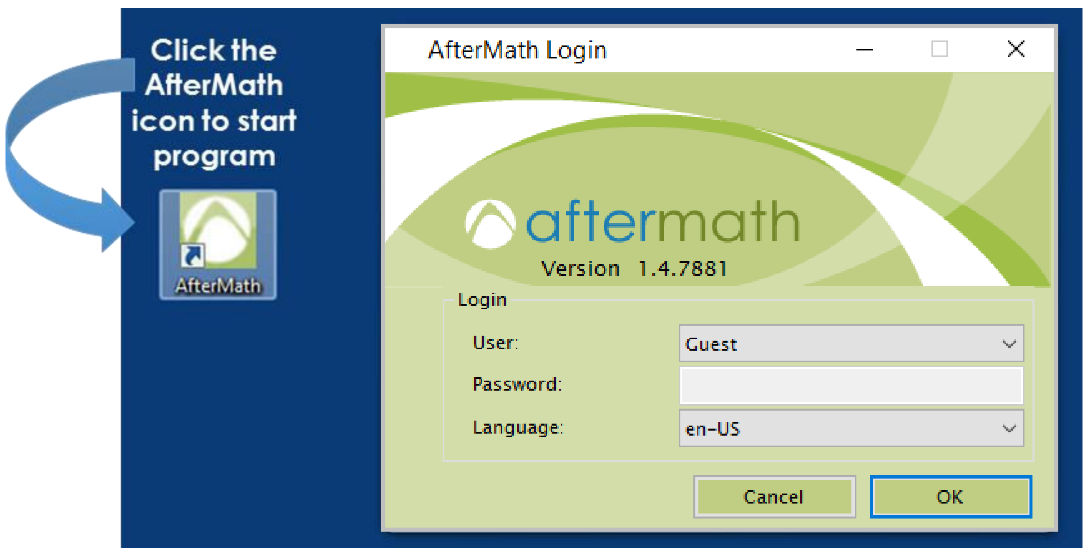


Figure 4-1. Initial Login Screen when Starting AfterMath

4.1.2 Verify Instrument Status

Turn on the instrument using the side panel power switch and wait for the WaveNow, WaveNano, or WaveNow^{XV} to appear in the AfterMath Instrument List. The instrument should appear along with its serial number under the "Instruments" node (see: Figure 4-2).

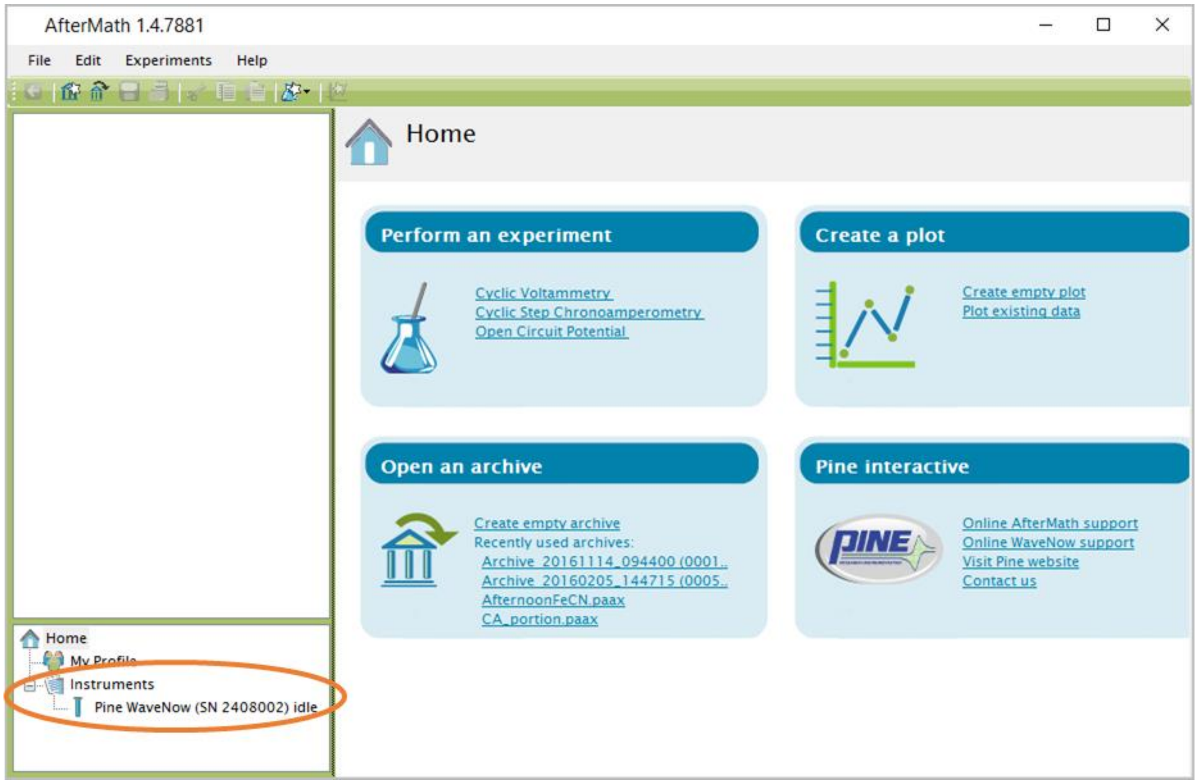


Figure 4-2. AfterMath Screenshot with the Instrument Status Circled

4.1.3 Confirm Connections

Check the status LED on the WaveNow, WaveNano, or WaveNow^{XV}. It should be green, indicating that the potentiostat is idle (see: Figure 4-3). The USB indicator light should flicker occasionally (see: Table 2-3 for more information about LED indicators).

Figure 4-3. LED Status Light on the Front Panel of the WaveNow, WaveNano, or WaveNow^{XV}

4.1.4 Review Instrument Status

Examine the instrument status display (see: Figure 4-2). Initially, the status may indicate that the cell is disconnected. If desired, the idle controls on the Instrument Status screen can be used to apply a known idle condition to the cell. In the example shown (see: Figure 4-2), the instrument is connected to the external cell, and the working electrode has been set to potentiostatic control while applying $+1.2\ volts$ to the first working electrode (K1).

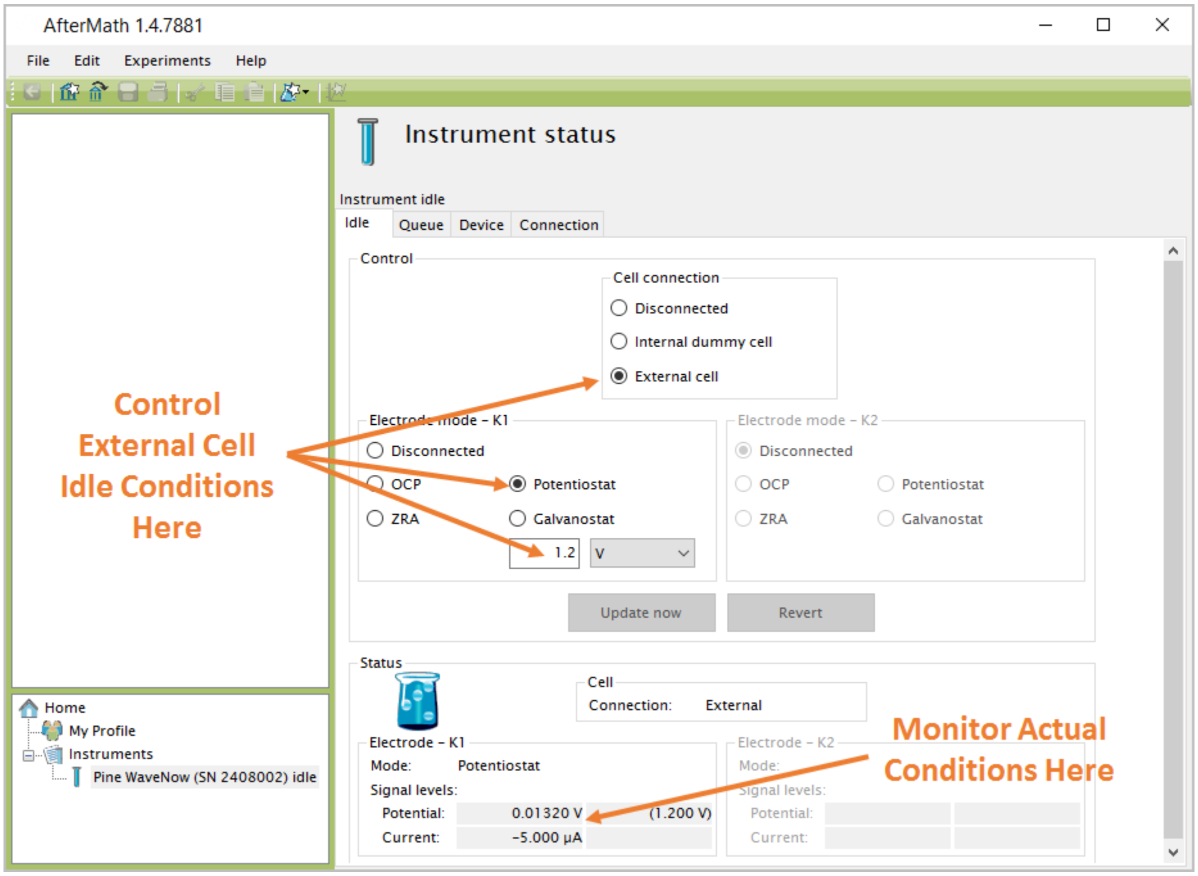


Figure 4-4. AfterMath Instrument Status Window showing External Cell Idle Conditions

4.2 Randle's Circuit Dummy Cell Verification Experiment

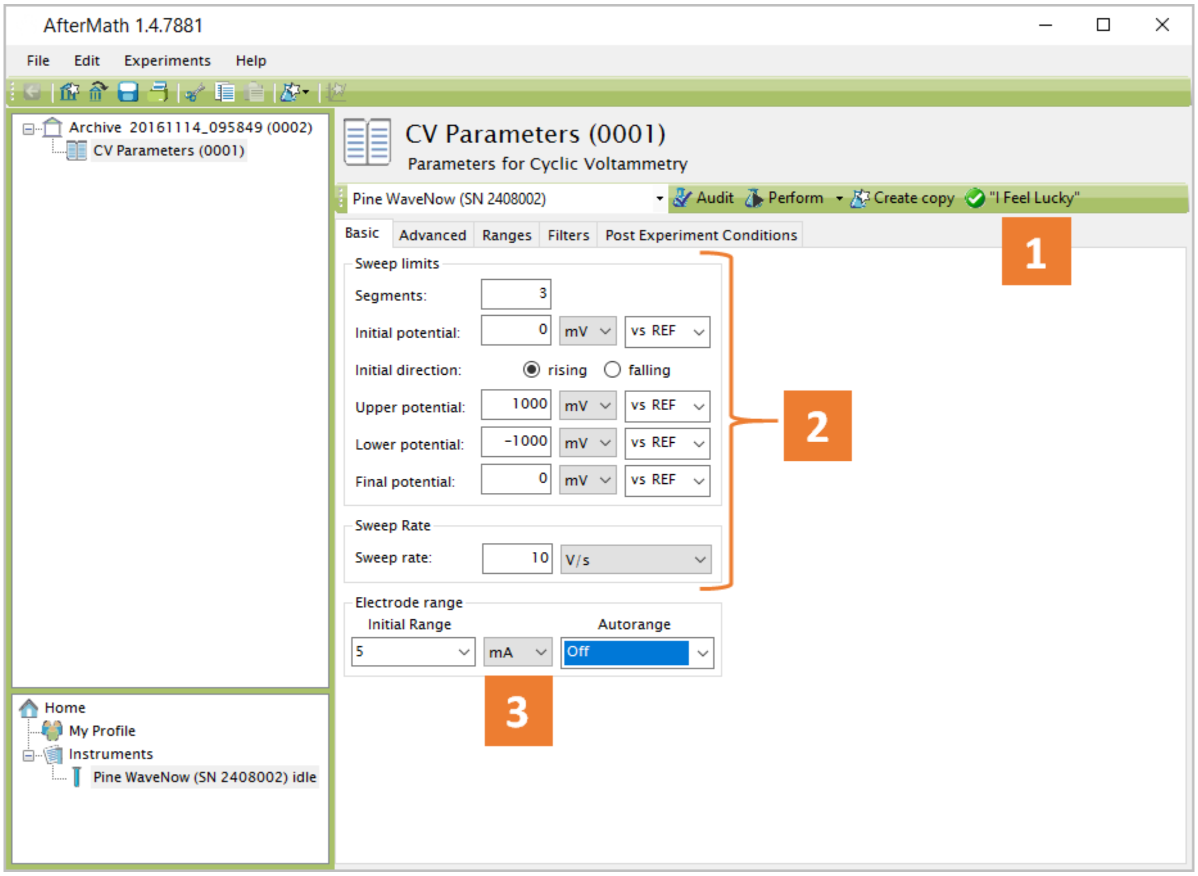
Recall that there are three configurations that are most useful for testing the behavior of a potentiostat (see: Figure 2-4). Step-by-step instructions are provided for the Randle's circuit configuration below, while typical results for pure resistive and capacitive loads are described in section 4.3.

4.2.1 Connect to the Universal Dummy Cell

Connect Dummy Cell "C" to the cell port of the WaveNow, WaveNano, or WaveNow^{XV}. The Dummy Cell dip switches are set to the Randle's Circuit by default, but verify these settings before proceeding (see: Figure 2-6).

4.2.2 Create a Cyclic Voltammetry (CV) Experiment

From the AfterMath Experiments menu, choose the Cyclic Voltammetry (CV) option from the list of available electrochemical techniques. A new CV specification is created and placed in a new archive. Configure the parameters as detailed below (see: Figure 4-5).



1	Click on the "I Feel Lucky" button
2	Note that the number of segments, sweep limits, and scan rate automatically fill. Change the sweep rate from $100\ mV/s$ to $10\ V/s$
3	Set the Electrode Range to "$5\ mA$", Autorange "Off." (This causes the $5\ mA$ range to be used throughout the test, without any current autoranging)

Figure 4-5. Cyclic Voltammetry (CV) Parameters Dialog Window

4.2.3 Audit Experimental Parameters

Choose the WaveNow, WaveNano, or WaveNow^{XV} potentiostat in the drop-down menu (see: Figure 4-6, to the left of the "Audit" button). Then, press the "Audit" button to check the parameters. AfterMath will perform a quick audit of the parameter values to ensure that all required parameters have been specified and are within allowed ranges.

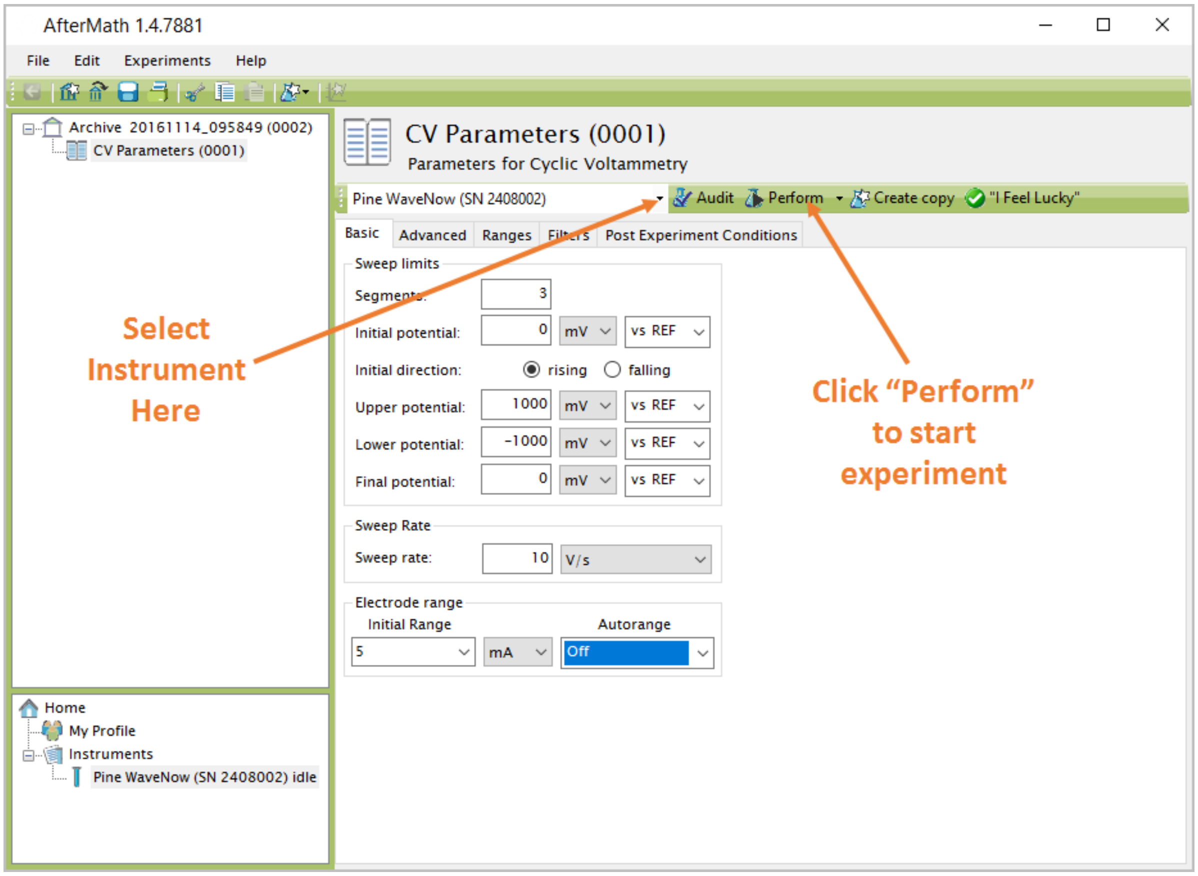


Figure 4-6. Location of Instrument Selection Menu and Perform Button (CV)

4.2.4 Initiate the Experiment

Next, click on the "Perform" button to initiate the cyclic voltammetry experiment. The "Perform" button is located just to the right of the "Audit" button (see: Figure 4-6).

NOTE:

If the "Perform" button is disabled (shaded gray), this is an indication that the AfterMath software on the computer is not licensed to control the instrument. The remedy for this issue is to obtain and install the appropriate permissions files (see: Section 3.2.2).

4.2.5 Monitor Experimental Progress

Monitor the progress of the experiment by observing the real time plot, the percentage complete value, and the progress bar (see: Figure 4-7).

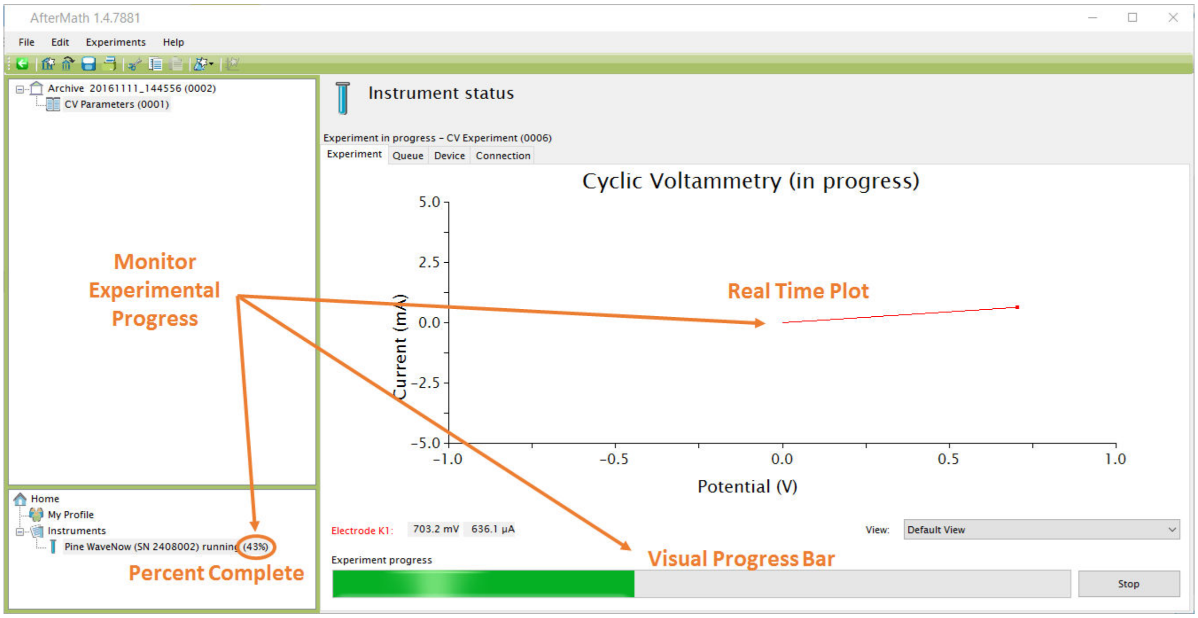


Figure 4-7. Monitoring the Progress of the Experiment

4.2.6 Review the Results

When the experiment is finished, the results of the experiment are placed in a study folder in the archive (see: Figure 4-8). In addition to the main voltammogram plot in the study folder, additional graphs are available in the "Other Plots" folder. The results can also be viewed in tabular form under the "experiment" node.

EXPECTED UNIVERSAL DUMMY CELL RESULT:

The anticipated test result is a diagonal trace (see: Figure 4-8) which is obviously not an actual voltammogram. The slope of this trace is inversely related to the total resistance in "Cell C" of the dummy cell ($\sim 1\ k\Omega$).

EXPLORE EXPERIMENTAL NODES:

Click on the "+" sign next to a node to open it. Additional data can be found in the "experiment" node. Nodes may be renamed and organized in folders as desired.

For a more thorough discussion of how to use the AfterMath software, please search the knowledgebase for the *AfterMath User Guide* at the following location on the internet:

www.pineresearch.com/shop/knowledgebase

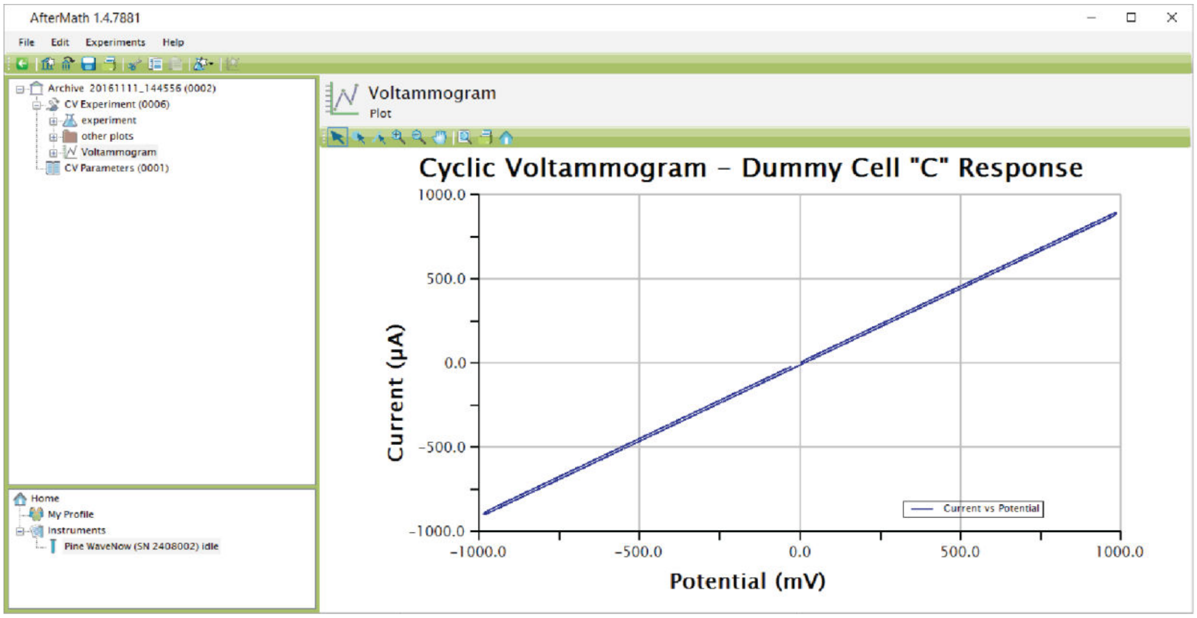


Figure 4-8. Anticipated Results for Cyclic Voltammetry (using Dummy Cell "C")

4.2.7 Understanding the Results

A Randle's circuit places the double-layer capacitance (C_{dl}), in parallel with the charge transfer resistance (R_{ct}), and another impedance element known as a Warburg element. The Warburg element cannot be simulated using simple resistors and capacitors because it represents the "real" diffusion processes, which occur in an actual solution in an electrochemical cell.

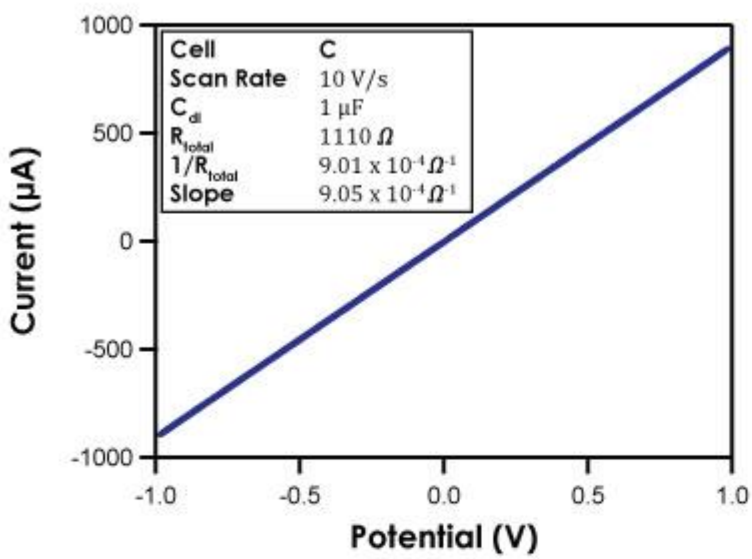


Figure 4-9. Typical Cyclic Voltammogram for a Randle's Circuit Response

The Randle's Circuit configuration for the dummy cell omits the Warburg element, but includes the parallel double-layer capacitance and charge transfer resistance (see: Figure 4-9). Due to the small resistances from R_u and R_{uw}, the total resistance represented by the dummy cell is slightly larger than R_{ct} (see: Table 2-4 for dummy cell component values).

4.3 Additional Dummy Cell Verification Experiments

4.3.1 Pure Resistive Load

The most basic configuration is Pure Resistive Load, where a resistor is used to mimic the charge transfer resistance (R_{ct}) at the electrode/electrolyte interface. A resistor is essentially a "two-electrode cell" and can be connected to the potentiostat like any other two-electrode cell (see: Figure 5-3). A cyclic voltammogram obtained using this dummy cell configuration should show a straight line with the slope inversely proportional to the R_{ct} resistance (see: Figure 4-10).

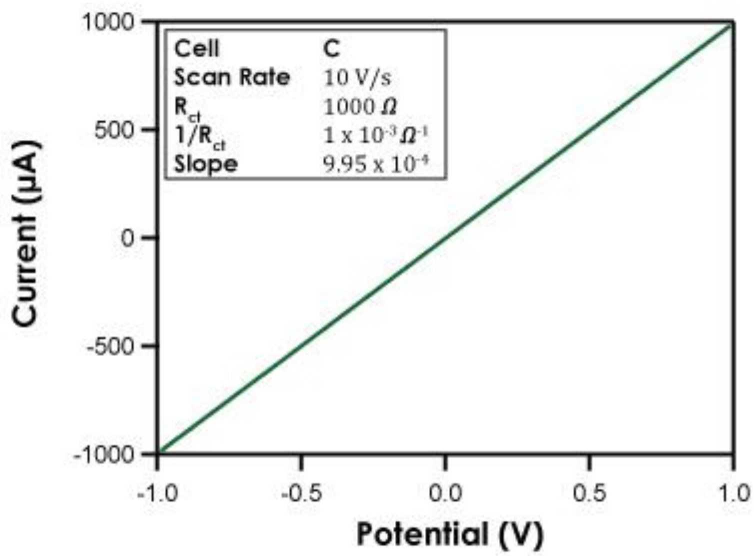


Figure 4-10. Typical Cyclic Voltammogram for a Pure Resistive Load Response

4.3.2 Pure Capacitive Load

A Pure Capacitive Load simulates an ideally polarizable electrode double layer. The charging current, i_{dl}, observed when using this capacitive load is given by the following equation,

$$i_{dl} = C_{dl}\upsilon$$

where C_{dl} is the capacitance that mimics the double-layer capacitance and the working electrode potential is being swept at a constant rate, υ. Very small charging currents can be produced using low sweep rates, a technique that is useful when evaluating the ability of a potentiostat to measure small currents.

Voltammograms produced by a pure capacitive load often appear as a rectangular box, and the height of the box (along the vertical axis) is twice the value of the charging current calculated according to the above equation (see: Figure 4-11). Also of note, oscillations occur at points where the sweeping potential suddenly switches direction. Most "real" electrochemical cells are less prone to exhibiting such oscillations.

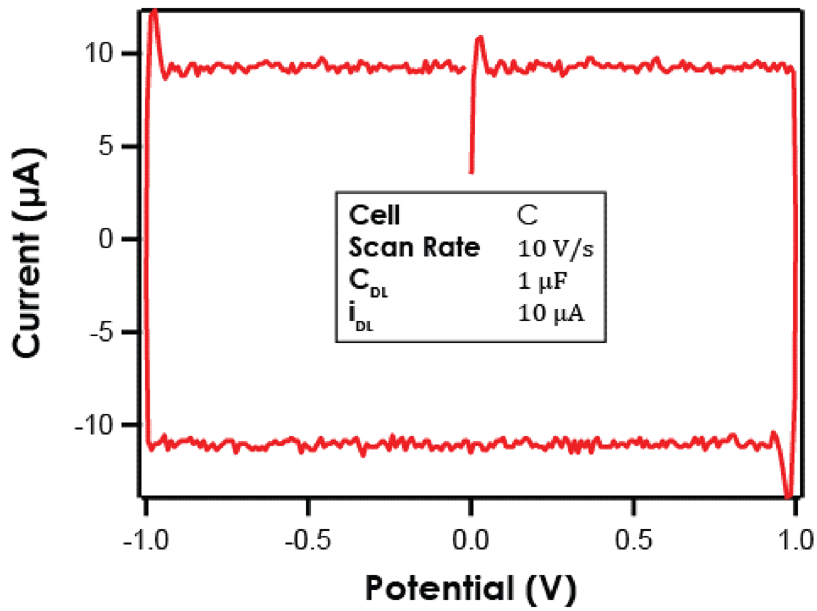


Figure 4-11. Typical Cyclic Voltammogram for a Pure Capacitive Load Response

5. Cell Cable Connections

The cell port presents several signal, shield, and grounding lines for the working, counter, and reference electrode connections. It is important to understand that some of the signal lines are low impedance DRIVE lines while others are high impedance SENSE lines. In general, the DRIVE lines are used to drive current through the electrochemical cell while the SENSE lines are used to measure potential at various electrodes. Very little current flows through the high impedance SENSE lines.

NOTE:

DRIVE lines are low impedance lines used to drive current.

NOTE:

SENSE lines are high impedance lines use to measure potential.

The cell cable breaks out the various cell port connections to shielded coaxial cables which terminate at stackable banana plugs. Alligator clips that slide on to the banana plugs are included. The banana plugs are color coded to indicate how they should be connected to the electrodes in the electrochemical cell (see: Table 5-1).

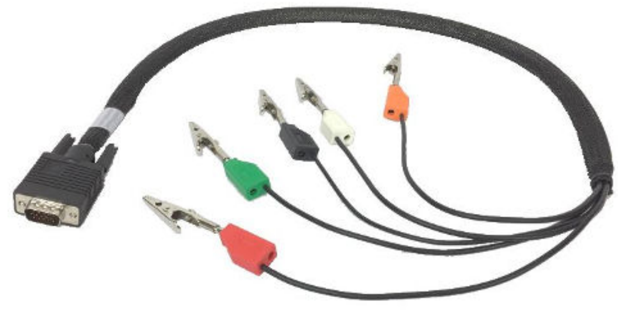
Color		Description	ID	Type
	WHITE	Reference Electrode	RE	Sense
	GREEN	Counter Electrode	CE	Drive
	BLACK	DC Common (signal ground)		Ground
	RED	Primary Working Electrode	K1	Drive
	ORANGE	Primary Working Electrode		Sense

Table 5-1. WaveNow, WaveNano, and WaveNow^{XV} Cell Cable Color Description

5.1 Cell Cable Options

With the proper cell cable connections, several kinds of electrochemical cells can be connected to the WaveNow, WaveNano, or WaveNow^{XV}, including two-electrode cells, traditional three-electrode voltammetry cells, rotating disk electrodes, rotating cylinder electrodes and screen-printed electrodes. In addition to the standard five-lead cell cable included with the instrument, other cable designs are available for specific purposes (see: Figure 5-1). The discussion of cell cable connections in this section assumes the reader is already familiar with general concepts associated with electrochemical cells and also understands the cell cable color coding scheme (see: Table 5-1).

Standard Five-Lead Cell Cable



Cell Cable with Mesh Shield

Compact Voltammetry Cell Cable

Compact Voltammetry Cell Cable with Reference Electrode Breakout

Figure 5-1. Cell Cables for use with the WaveNow, WaveNano, and WaveNow^{XV}

5.2 Standard Five-Lead Cell Cable

A standard five-lead cell cable is included with each WaveNow, WaveNano, or WaveNow^{XV} instrument. This cable (part #: AKCABLE5) may be used with a variety of two-electrode and three-electrode electrochemical cell configurations. This cable has a male HD-15 connector which fits the cell port on the instrument. There are two drive screws on the HD-15 connector which tighten into the cell port to provide a secure connection (see: Figure 5-2).

Figure 5-2. Securely Tighten the HD-15 Connector to the Cell Port

Five separate leads emerge from the HD-15 connector on the cell cable. Four of these leads carry signals in coaxial cables to protect signals from environmental noise. The fifth lead is a direct connection to the DC Common of the instrument. To avoid entanglement, the five leads are bundled together using a series of O-rings. These O-rings may be slid along the bundle as needed to increase or decrease the amount of slack between adjacent signal connections.

A variation of the standard cell cable is available which has an additional conductive mesh shield around the bundle of signal leads. This mesh shield is electrically connected to the chassis of the instrument and provides some additional protection from environmental noise and ESD events. While the mesh shield offers additional protection, it does constrain the amount of slack available at the end of the cable nearest the electrochemical cell.

5.2.1 Connecting to a Two-Electrode Cell

Solid-state experiments that probe the electrochemical behavior across a single interface and experiments that involve ion-selective electrodes (where the open circuit potential is measured between an ion-selective electrode and a reference electrode) are typical electrochemical experiments that require a two-electrode cell configuration. Simple experiments with common resistors or capacitors also use the two-electrode arrangement (see: Figure 5-3).

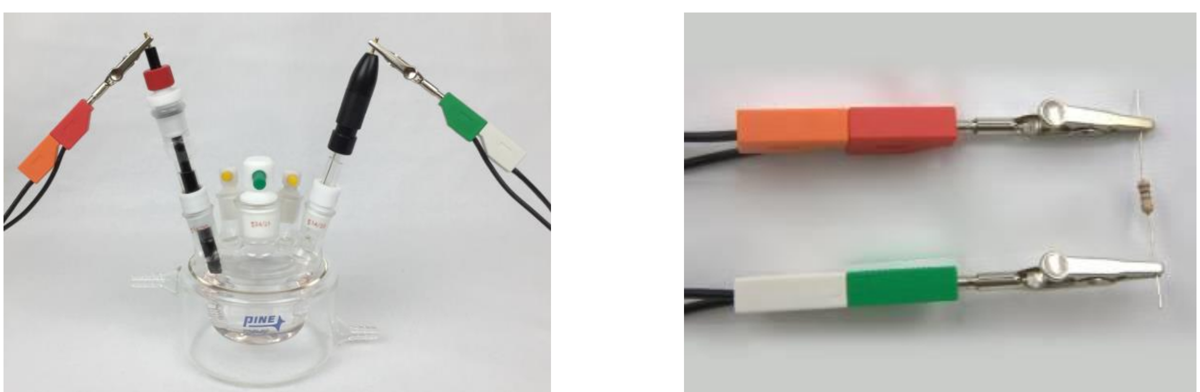


Figure 5-3. Examples of Two-Electrode Cells

The standard five-lead cell cable can be configured for such two-electrode experiments by carefully stacking together the banana plugs. The green (counter electrode) and white (reference electrode) plugs are shorted together, and the red and orange (working electrode drive and sense) are also shorted together (see: Figure 5-3). One pair of shorted banana connectors is connected to one of the electrodes in the cell, and the other pair is connected to the other electrode.

Using the recommended two-electrode polarity convention, the GREEN/WHITE pair should be connected to whichever electrode is considered to be the reference electrode. This convention assures that when the software applies a positive potential to the working electrode, the RED/ORANGE cell connection is more positive than the GREEN/WHITE "reference" cell connection.

5.2.2 Connecting to a Three-Electrode Cell

In a traditional three-electrode cell, three different electrodes (counter, reference, and working) are placed in the same electrolyte solution. During three-electrode voltammetry experiments, charge flow (current) primarily occurs between the working electrode and the counter electrode while the potential of the working electrode is measured with respect to the reference electrode. The standard five-lead cell cable can be used for such three-electrode experiments by appropriate connection of the drive and sense lines.

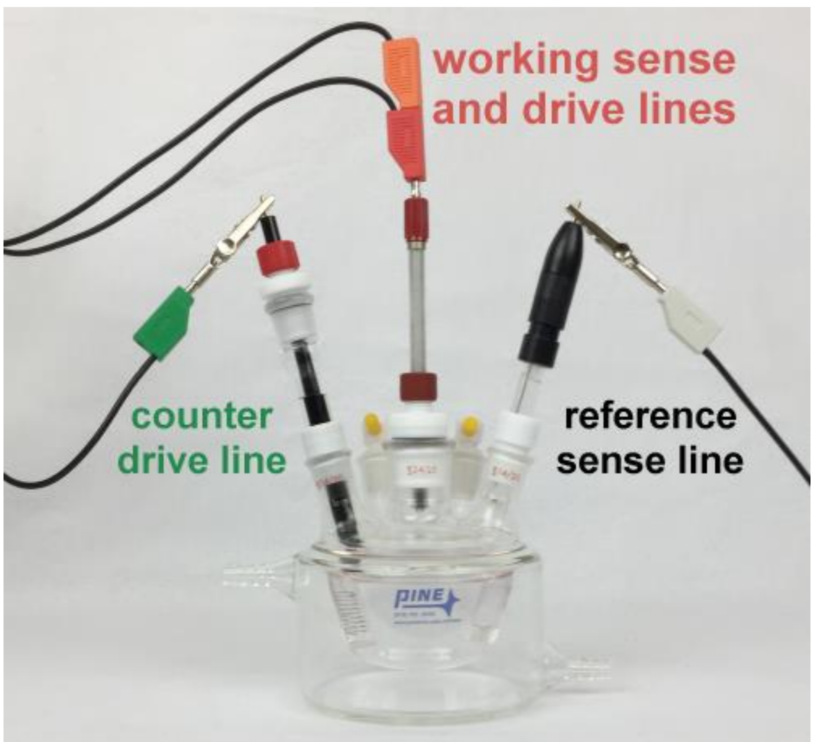


Figure 5-4. Traditional Three-Electrode Cell Connections

NOTE:

DRIVE lines are low impedance lines used to drive current.

SENSE lines are high impedance lines used to measure potential.

To drive current between the working and counter electrodes, the RED line (working electrode drive) is connected to the working electrode, and the GREEN line (counter electrode drive) is connected to the counter electrode. To measure potential between the working and reference electrodes, the ORANGE line (working electrode sense) is connected to the working electrode, and the WHITE line (reference electrode sense) is connected to the reference electrode (see: Figure 5-4).

Note that the three-electrode cell configuration requires both the RED and ORANGE lines (working electrode drive and sense) to be connected at a point very near the working electrode. An easy way to make this connection is to stack the RED and ORANGE banana plugs together prior to connecting to the working electrode (see: Figure 5-5). Both of these cables must be connected to the working electrode in order for the potentiostat to properly control the electrochemical cell.

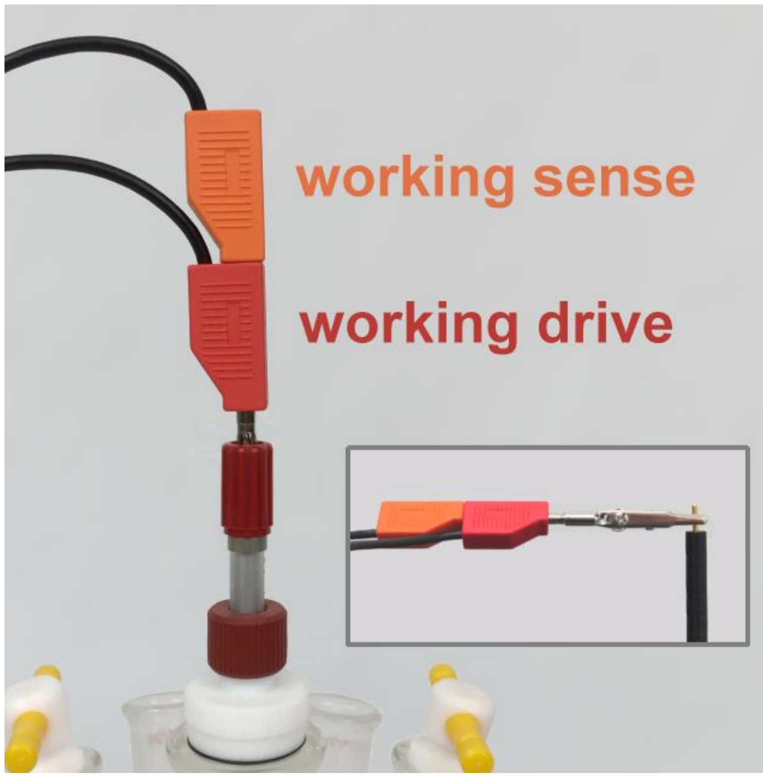


Figure 5-5. Connect Working Electrode Sense and Drive Lines Together Near the Cell

5.2.3 Connecting to Rotating Disk & Rotating Cylinder Electrodes (RDE & RCE)

The WaveNow, WaveNano, and WaveNow*XV* may be used in conjunction with an electrode rotator to perform Rotating Disk Electrode (RDE) or Rotating Cylinder Electrode (RCE) experiments. These experiments are hydrodynamic variations of traditional three-electrode voltammetry. Rotating the working electrode (which may have a disk or cylinder geometry) at a controlled rate sets up a well-defined flow of electrolyte solution (and dissolved electroactive species) towards the electrode surface. Connecting the potentiostat to a hydrodynamic experiment involves not only making connections to the electrodes (working, reference, and counter) but also providing a rotation rate control signal to the electrode rotator.

The standard five-lead cell cable can be used for such hydrodynamic experiments by making similar connections as those used in a traditional three-electrode electrochemical cell. The GREEN line (counter electrode drive) is connected to the counter electrode, and the WHITE line (reference electrode sense) is connected to the reference electrode. Connections of the RED and ORANGE lines (working electrode drive and sense) to the rotating working electrode are typically made via spring-loaded brush contacts which push against the shaft of the rotating electrode.

As an example of how connections are made to the rotating working electrode, consider the brush contacts on the popular Pine MSR Rotator system (see: Figure 5-6). This rotator system features two pairs of opposing brushes on either side of the rotating shaft. The upper pair of brush contacts (RED) are used to make electrical contact with a rotating disk or cylinder electrode mounted in the rotator. To make good contact on opposite sides of the rotating shaft, both of the red brushes (left and right sides) are used. A short banana jumper cable connects the opposing brushes together, and then the working electrode drive and sense lines (RED and ORANGE) are connected the jumper cable (see: Figure 5-6).

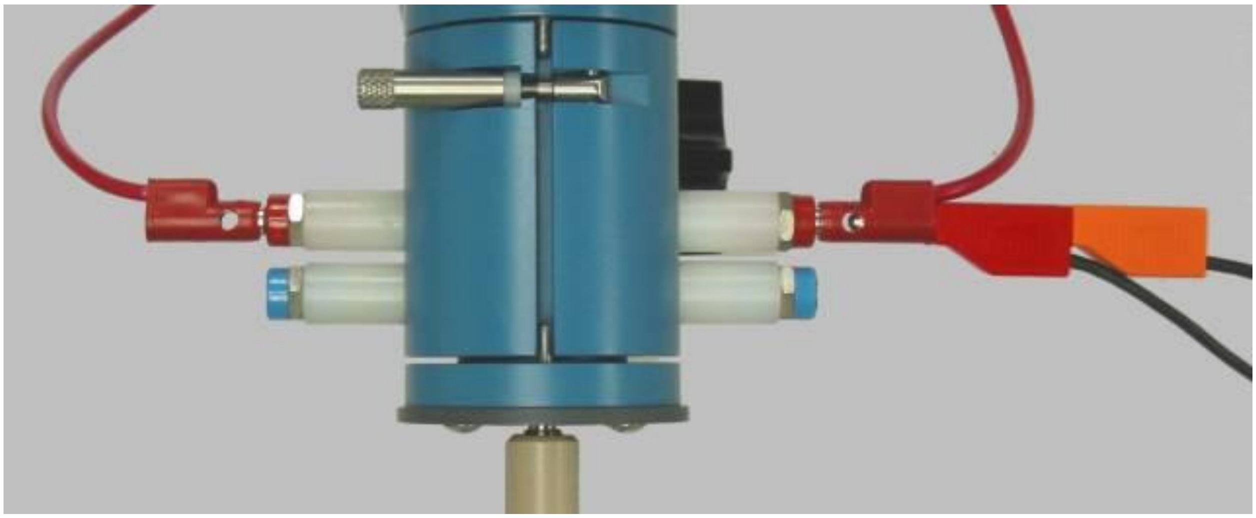


Figure 5-6. Working Electrode Connections for Rotating Disk or Cylinder Electrodes

NOTE:

The lower pair of brushes (blue) contacts on the MSR rotator system are not compatible with the WaveNow, WaveNano, and WaveNow*XV*. More information about rotating electrodes may be found in our knowledgebase:

www.pineresearch.com/shop/knowledgebase

Figure 5-7. Rotation Rate Control Connections for a Pine Research MSR Rotator

Many electrode rotators are able to accept rotation rate control signals from a potentiostat. The WaveNow, WaveNano, or WaveNow^{XV} instruments provide both a digital "on/off" signal and an analog rotation rate signal that can be used to control the motor on an electrode rotator. These signals are presented at the rotator control port on the side of the instrument (see: Figure 2-2). Special cables are available from Pine which may be used to connect these signals to various electrode rotator models.

CAUTION:

When connecting a WaveNow, WaveNano, or WaveNow^{XV} system to an electrode rotator other than the Pine Research MSR rotator, carefully consider the magnitude of the WaveNow, WaveNano, or WaveNow^{XV} rate control signal ratio ($1\ RPM/mV$) and take steps to assure that the rotator is configured to use the same ratio.

ATTENTION:

Lorsque vous connectez un appareil WaveNow, WaveNano, ou WaveNowXV using à un rotateur à électrodes autre que le rotateur Pine Research MSR, faites très attention à la valeur du rapport du signal de contrôle de vitesse de l'appareil WaveNow, WaveNano, ou WaveNowXV ($1\ tr/min/mV$) et assurez-vous que le rotateur soit configuré avec le même rapport.

Connecting a WaveNow, WaveNano, or WaveNow^{XV} to a Pine MSR rotator system requires a special cable (part #: AKCABLE4). One end of the cable has a small green connector which mates with the rotator control port (see: Figure 5-7). The other end of the cable is connected to two locations on the Pine MSR control unit. The first connection is made between the coaxial cable (terminated with a dual banana plug adapter) and the rotation rate INPUT jacks on the front panel of the control unit. The second connection is made between the single banana plug and the (blue) MOTOR STOP jack on the back panel of the control unit.

5.3 Compact Voltammetry Cell Cable Connections

The following information details how to use the Compact Voltammetry Cell Cable (part #: RRTPE04) with the WaveNow, WaveNano, and WaveNow^{XV} potentiostats, and also how to use it with the Pine compact voltammetry cell kit (available separately). One end of this cable connects directly to the cell port and the other end terminates with a mini-USB style plug. Within this shielded cable are four signal lines as follows: working electrode (drive and sense), counter electrode (drive), and reference electrode (sense).

The compact voltammetry cell kit consists of a grip, a cell cap, a glass vial, and various screen-printed electrodes. Built into the grip are mini-USB jacks which may be connected to the cell cable. Circuitry within the grip makes electrical connection to the screen-printed electrode mounted to the bottom of the grip (see: Figure 5-8). This simple cable configuration makes the compact voltammetry kit ideal for use in education settings and in confined spaces such as glove boxes.

Figure 5-8. Cable Connections for the Compact Voltammetry Cell Kit

TIP:

More information about the compact voltammetry cell kit can be found by searching the knowledgebase:

www.pineresearch.com/shop/knowledgebase

5.4 Compact Voltammetry Cell Cable with Reference Breakout

A version of the compact voltammetry cell cable with a special reference electrode breakout connection is available (part #: RRTPE05). This cable may be used with certain compact voltammetry cells and spectroelectrochemical cells offered by Pine. One end of this cable connects directly to the cell port and the other end terminates with a mini-USB style plug and a separate (white) reference electrode pin connector. Within this shielded cable are four signal lines as follows: working electrode (drive and sense), counter electrode (drive), and reference electrode (sense).

The working and counter electrode lines go into the mini-USB connector, but the reference electrode line terminates at the pin connector. The separate reference electrode lead allows use of an external reference electrode rather than a screen-printed reference electrode. LowProfile ($3.5\ mm$ OD) reference electrodes are available which can mount into the small diameter holes located in the cap of compact voltammetry and spectroelectrochemical ("Honeycomb") cells (see: blue squares in Figure 5-9).

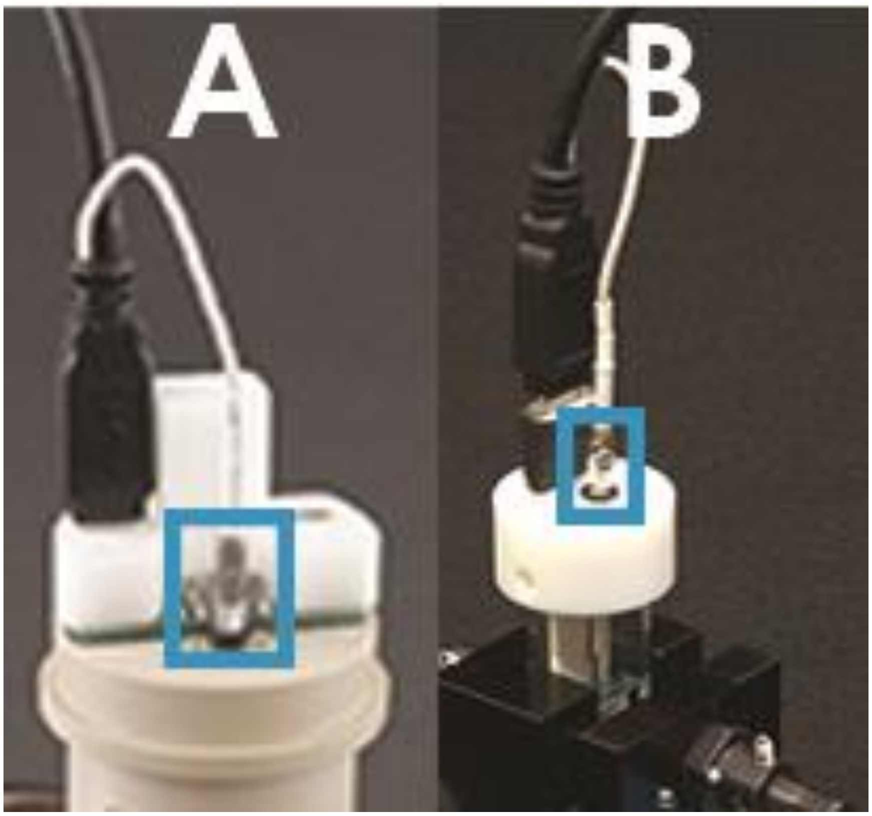


Figure 5-9. Cell Cable with Reference Breakout for use with A) Compact Voltammetry and B) Spectroelectrochemical Cells

6. Grounding Information

To avoid issues with signal noise when making electrochemical measurements, it is important to properly ground all metal objects near an electrochemical cell to the earth ground, and this generally includes the metal chassis of the potentiostat, the clamps and supports used to physically secure the electrochemical cell, and any peripheral equipment such as an electrode rotator or Faraday cage that may be used in conjunction with the potentiostat.

6.1 Common Environmental Noise Sources

A modern laboratory is often full of noise sources that can interfere with the measurement of small amplitude electrochemical signals. Computers, LCD displays, video cables, network routers, network cables, ovens, hotplates, stirrers, and fluorescent lighting are all examples of common laboratory equipment that may electromagnetically interfere with a delicate electrochemical measurement.

In general, the electrochemical cell, the cell cable, and the potentiostat should be located as far away from such noise sources as possible. It is especially important that the cell cable be located well away from any digital noise sources such as mouse or keyboard cables, network cables, video cables, cell phones, etc. The reference electrode cable is particularly sensitive to picking up noise from the environment.

A piece of laboratory equipment which intermittently draws a lot of current, such as an oven or hotplate under thermostatic control, should not be powered using the same branch circuit as the potentiostat. When such a piece of equipment goes through a power cycle, it may induce noise or a glitch in the electrochemical measurement.

The WaveNow, WaveNano, and WaveNow^{XV} potentiostats are designed to be connected to a personal computer (tower, desktop, or laptop) via a USB cable. The USB port on the WaveNow series potentiostats is optically isolated, and the USB cable is long enough that the WaveNow series potentiostats can be placed at a reasonable distance from the computer. Do not allow the USB cable to run alongside or across the cell cable as this may induce noise in the electrochemical measurement.

6.2 Grounding Terminology

When using a potentiostat in conjunction with other electronic instruments, it is often necessary to make various grounding connections between the potentiostat and the other instrumentation. A proper approach to making such connections begins with a good understanding of the terminology associated with grounding. A potentiostat or other piece of electronic equipment generally has three types of grounding connections which are often confused with one another: the earth ground, the chassis terminal, and the DC Common. These are discussed in more detail below.

6.2.1 Earth Ground

EARTH GROUND:

An earth ground connection is a direct physical and electrical connection to the Earth.

An earth ground connection is available in most modern laboratories via the third prong on the power receptacle for the local power system. The power system infrastructure for a laboratory building usually has a long metal probe buried in the earth, and the third prong in the building wiring is connected to this earth connection. Many electronic devices have a three prong power cord which brings the earth ground connection to the power supply for the device. Whether or not the earth ground connection passes through the power supply and to the internal circuitry of the device depends upon the design of the power supply.

The power supplies for the WaveNow, WaveNano, and WaveNow^{XV} potentiostats do not allow the earth ground connection to pass through to the instrument circuitry. This means that there is no permanent, direct connection to the earth ground when the instrument is connected to the AC Mains (*i.e.*, there is no connection to earth ground via the power cabled plugged into a receptacle). Nevertheless, an indirect, whether deliberate or inadvertent, connection to earth ground may occur when the potentiostat is connected to other electronic equipment. Such indirect connections are discussed in more detail below.

6.2.2 Chassis

CHASSIS:

A metal case which surrounds and protects the electronic circuitry is called the chassis.

The metal case that contains the WaveNow, WaveNano, or WaveNow^{XV} circuitry is the instrument chassis. The chassis helps to protect the circuitry from environmental noise sources and from ESD events. The instrument chassis is always in direct electrical contact with the shields on the USB Port and the Cell Port (see: Section 2.7).

Pine Research offers a few cell cable designs, available separately, which have shield lines that are directly connected to the instrument chassis via the shield on the Cell Port. These include the Compact Voltammetry Cell Cables and the Cell Cable with Mesh Shield (see: Figure 5-1). Use of these cables has the effect of extending the instrument chassis for some distance along the cell cable.

When a USB cable is connected to the instrument, the shield within the USB cable is directly connected to the instrument chassis. When the other end of the USB cable is connected to a computer, it is almost certain that a direct electrical connection between the instrument chassis and the computer chassis will be made. If the computer chassis happens to be connected to earth ground, then the USB cable becomes an indirect means by which the instrument chassis is connected to the earth ground.

Another consequence of connecting a USB device to a computer is that the computer will attempt to supply power to the device. However, special circuitry within the WaveNow, WaveNano, and WaveNow^{XV} isolates these USB power lines and the other USB signal lines from the remaining instrument circuitry.

While not a requirement for normal operation of the instrument, in some circumstances it may be desirable for the chassis to be connected to earth ground. A USB connection to a desktop (or tower) computer usually creates such an earth ground connection in an indirect fashion. If not, or if a battery powered laptop is being used, a deliberate connection to earth ground may be made via one of the drive screws on the Cell Port.

6.2.3 DC Common

DC COMMON:

In an analog circuit, such as a potentiostat, the DC Common is the zero reference point against which voltages are measured. This point is also known as the analog ground, signal ground, or signal common.

The DC Common for the WaveNow, WaveNano, and WaveNow^{XV} instruments is the zero volt reference point used by the waveform generation and signal measurement circuits. External connections to the DC Common may be made at the center pin of the Rotator Control Port or via the black banana plug on the Standard Five-Lead Cell Cable.

As shipped from the factory, the DC Common is connected to the instrument chassis via a jumper on the main circuit board (see: Figure 6-1). When using this default configuration, the researcher should be aware that the DC Common may also be in contact with earth ground because the chassis may be in contact with earth ground via the USB cable, as previously discussed. A grounding scenario where the earth ground, the instrument chassis, and the DC Common are all in direct electrical contact is suitable for most electrochemical experiments and tends to mitigate the effects of environmental noise.

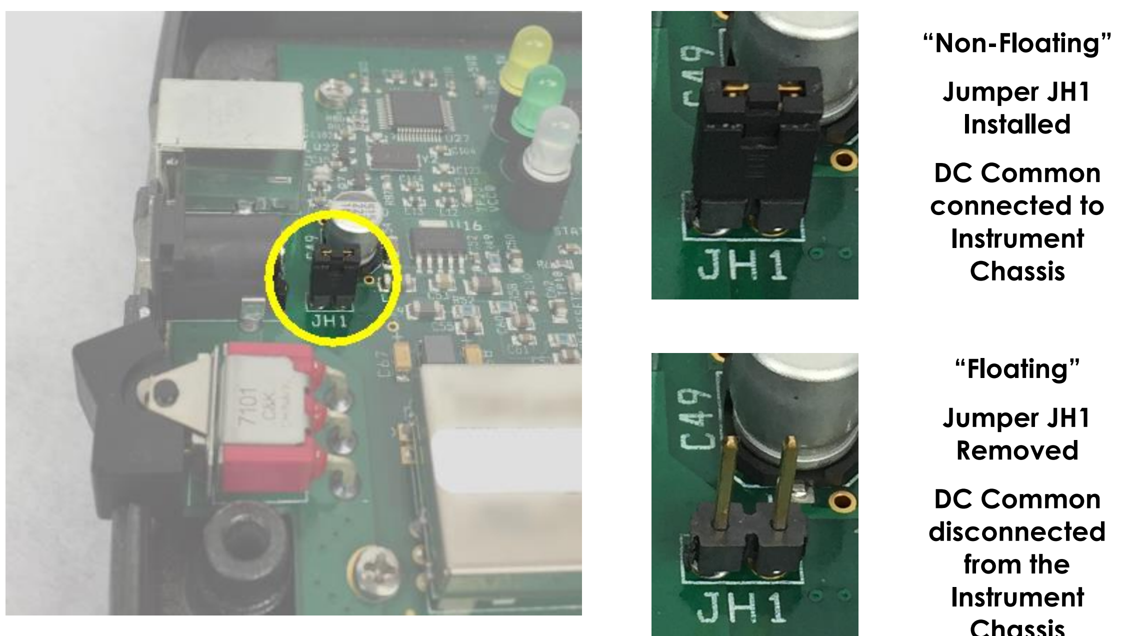


Figure 6-1. Floating vs. Non-Floating DC Common Configuration

There are, however, some experimental conditions where it is important for the DC Common to float with respect to the instrument chassis and with respect to earth ground. For example, when working with a quartz crystal microbalance (QCM), the QCM instrument will typically require that the working electrode be in direct contact with earth ground. The potentiostat cannot function correctly with the DC Common and the working electrode both connected to earth ground, but if the DC Common is configured so that it floats, then it becomes possible to put the working electrode at earth ground.

The WaveNow, WaveNano, or WaveNow^{XV} circuit board can be reconfigured so that the DC Common floats with respect to the chassis. To gain access to the circuit board, remove the four screws on the bottom of the case, which are usually hidden underneath rubber feet, and carefully open the instrument case. Locate the jumper designated as JH1. If this jumper is removed, then the DC Common is disconnected from the instrument chassis.

TIP:

There is a quick way to determine if jumper JH1 is installed or removed without opening the instrument case. Simply disconnect all cables from the instrument and use an ohmmeter to check for continuity between the shield on the Cell Port and the center pin on the Rotator Control Port. If there is continuity between these two points, then JH1 is installed, and the DC Common is not floating.

INFO:

Instruments manufactured prior to October 2016 do not have jumper JH1 on the circuit board, but in most cases, it is still possible to configure these instruments with a floating DC Common. Please contact Pine Research for further instructions.

6.3 Grounding Multiple Instruments

The general goal of a grounding strategy is to reduce the level of signal noise in the electrochemical measurement caused by noise sources in the laboratory environment. When a potentiostat is connected one or more additional pieces of electronic equipment (*i.e.*, a computer, an electrode rotator, a spectrometer, etc.), it is important to understand how or if each piece of equipment is connected to earth ground, how or if the chassis of each piece of equipment is connected to neighboring equipment, and how or if the DC Common lines of each piece of equipment are connected together.

While the details of proper grounding for any given experimental configuration may differ, a very common strategy is to bring all of the chassis connections for all of the instruments together to one single point. In addition, any other metal objects near the electrochemical cell, such as a cell clamp or support rod, should be connected to the same point. The reason that all connections are brought together to a single point is to prevent the creation of a grounding loop. A grounding loop is often accidently created when chassis connections are made in series going from one instrument to the next, and the resulting loop can act as antenna which injects more noise into sensitive measurements. Once all of the chassis connections are tied together at a single point, it may also be desirable to connect this point to earth ground.

Just like a potentiostat, other types of scientific instrumentation also have a DC Common line which represents the common zero analog signal level. When a potentiostat is connected to an electrode rotator control unit, a spectrometer, a quartz crystal microbalance, or other kind of instrument, it is very likely that the DC Common lines for each of the instruments will be connected together. The researcher should be aware of whether or not the DC Common of one of the other instruments happens to be held at earth ground or connected to its instrument chassis. This is especially important in those scenarios where the researcher intends for the DC Common of the potentiostat to float with respect to earth ground.

7. Power Supplies

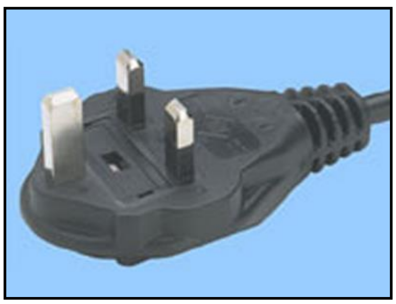
The standard C13 connector on the WaveNow, WaveNano, and WaveNow^{XV} power supply is compatible with a wide range of power cords available from Pine Research Instrumentation (see: Table 7-1 and Table 7-2). Each of the available power cords is rated at $10\ Amps$ (minimum), and each cord is designed for use in a specific country or region of the world. Pine Research part numbers are provided.

This cord is for use in the USA, Canada, Mexico, Brazil, Columbia, Korea, Mexico, Saudi Arabia, and Taiwan.

Power Cord (USA), part #:EWM18B7

This cord is for use in continental Europe, Russia, and Indonesia.

Power Cord (Europe), part #: EWM18B8EU



This cord is for use in the United Kingdom, Ireland, Oman, Hong Kong, and Singapore.

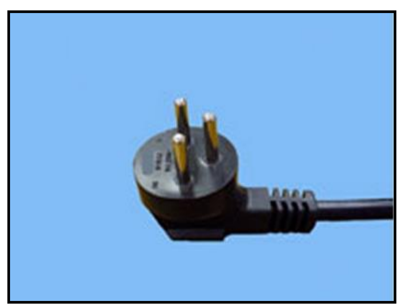
Power Cord (UK), part #: EWM18B8UK

This cord is for use exclusively in China.

Power Cord (China), part #: EWM18B8CN

This cord is for use in India and South Africa.

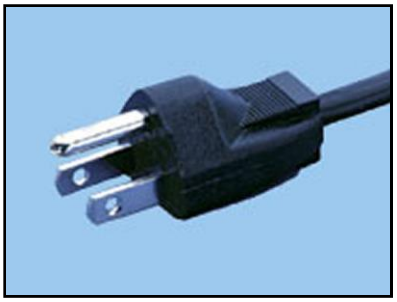
Power Cord (India), part #: EWM18B8IN



This cord is for use exclusively in Israel.

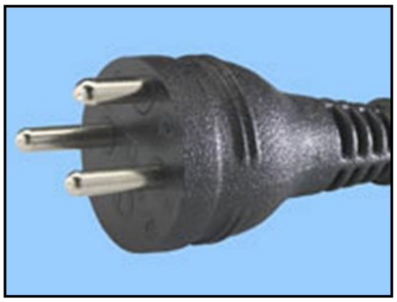
Power Cord (Israel), part #: EWM18B8IL

Table 7-1. Select Power Cords Available from Pine Research Instrumentation (Part I)



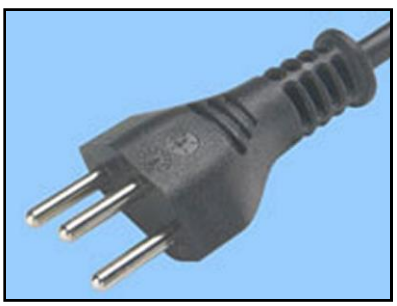
This cord is for use exclusively in Japan.
Power Cord (Japan), part #: EWM18B8JP

This cord is for use exclusively in Argentina.
Power Cord (Argentina), part #: EWM18B8AR



This cord is for use exclusively in Denmark.
Power Cord (Denmark), part #: EWM18B8DK

This cord is for use in Australia & New Zealand.
Power Cord (Australia), part #: EWM18B8NZ



This cord is for use exclusively in Switzerland.
Power Cord (Switzerland), part #: EWM18B8CH

This cord is for use exclusively in Italy.
Power Cord (Italy), part #: EWM18B8IT

Table 7-2. Select Power Cords Available from Pine Research Instrumentation (Part II)

8. Glossary

8.1 Important Terms used in this Guide

Anodic Current	Flow of charge at an electrode as a result of an oxidation reaction occurring at the electrode surface. For a working electrode immersed in a test solution, an anodic current corresponds to flow of electrons out of the solution and into the electrode.
Auxiliary Electrode	(see: Counter Electrode)
Banana Cable	A banana cable is a single-wire (one conductor) signal cable often to make connections between various electronic instruments. Each end of the cable has a banana plug. The plug consists of a cylindrical metal pin about 25 mm (one inch) long, with an outer diameter of about 4 mm, which can be inserted into a matching banana jack.
Banana Jack	Female banana connector
Banana Plug	Male banana connector
BNC Connector	The BNC (Bayonet Neill-Concelman) connector is a very common type of used for terminating coaxial cables.
Cathodic Current	Flow of charge at an electrode as a result of a reduction reaction occurring at the electrode surface. For a working electrode immersed in a test solution, a cathodic current corresponds to flow of electrons out of the electrode and into the solution.
Coaxial Cable	Coaxial cable, or coax, is an electrical cable with an inner conductor surrounded by a flexible, tubular insulating layer, surrounded by a tubular conducting shield. The term coaxial comes from the inner conductor and the outer shield sharing the same geometric axis. Coaxial cable is often used to carry signals from one instrument to another in situations where it is important to shield the signal from environmental noise sources.
Counter Electrode	The counter electrode, also called the auxiliary electrode, is one of three electrodes found in a typical three-electrode voltammetry experiment. The purpose of the counter electrode is to carry the current across the solution by completing the circuit back to the potentiostat.
Cyclic Voltammetry	An electroanalytical method where the working electrode potential is repeatedly swept back and forth between two extremes while the working electrode current is measured.
Dummy Cell	A known network of resistors and capacitors used to test a potentiostat. The dummy cell is used in place of an actual electrochemical cell when troubleshooting a potentiostat because the dummy cell provides a known response whereas the response from an actual cell is complicated by chemical phenomena.
Electroactive	An adjective used to describe a molecule or ion capable of being oxidized or reduced at an electrode surface.

Electrode	An electrode is an electrical conductor used to make contact with a nonmetallic part of a circuit.
Electrostatic Discharge (ESD)	The rapid discharge of static electricity to ground. Sensitive electronics in the path of an ESD event may suffer damage.
Faradaic Current	The portion of the current observed in an electroanalytical experiment that can be attributed to one or more redox processes occurring at an electrode surface.
Half-Reaction	A balanced chemical equation showing how various molecules or ions are reduced (or oxidized) at an electrode surface.
Linear Sweep Voltammetry	Experiment in which the working electrode potential is swept from initial value to final value at a constant rate while the current is measured.
K1	A symbol referring to the primary working electrode. Two connections (drive and sense) are required between the working electrode and the potentiostat.
Non-Faradaic Current	The portion of the current observed in an electroanalytical experiment that cannot be attributed to any redox processes occurring at an electrode surface.
Overpotential	The overpotential is the difference between the formal potential of a half-reaction and the potential actually being applied to the working electrode.
Oxidation	Removal of electrons from an ion or molecule.
Redox	An adjective used to describe a molecule, ion, or process associated with an electrochemical reaction.
Reduction	Addition of electrons to an ion or molecule.
Reference Electrode	A reference electrode has a stable and well-known thermodynamic potential. The high stability of the electrode potential is usually achieved by employing a redox system with constant (buffered or saturated) concentrations of the ions or molecules involved in the redox half-reaction.
Standard Electrode Potential	A thermodynamic quantity expressing the free energy of a redox half-reaction in terms of electric potential.
Sweep Rate	The rate at which the electrode potential is changed when performing a sweep voltammetry technique such as cyclic voltammetry.
Three-Electrode Cell	A common electrochemical cell arrangement consisting of a working electrode, a reference electrode, and a counter electrode.
Two-Electrode Cell	A common electrochemical cell arrangement when using a micro- or ultramicroelectrode consisting of a working and reference electrode
Voltammogram	A plot of current vs. potential from an electroanalytical experiment in which the potential is swept back and forth between two limits.

Working Electrode	The electrode at which the redox process of interest occurs. While there may be many electrodes in an electrochemical cell, the focus of an experiment is typically only on a particular half-reaction occurring at the working electrode.
Working Electrode Drive	The connection on a potentiostat or galvanostat through which charge flows to or from a working electrode. Drive lines have low impedance to allow significant charge flow (current) through the working electrode.
Working Electrode Sense	The connection on a potentiostat or galvanostat which measures the potential of a working electrode. Sense lines have a high input impedance so that the potential can be measured without significant charge flow (current) through the sense line.

9. Contact Support

After reviewing the content of this user guide, please contact Pine Research Instrumentation should you have any issues or questions with regard to the use of the instrument, accessories, or software.

Contact us anytime by the methods provided below:

9.1 Online

Our website has a contact form, which accepts users to submit technical support requests directly to Pine Research. Visit www.pineresearch.com/contact.

9.2 By E-mail

Send an email to pinewire@pineresearch.com. This is the general sales email and our team will ensure your email is routed to the most appropriate technical support staff available. Our goal is to respond to emails within 24 hours of receipt.

9.3 By Phone

Our offices are located in Durham, NC in the eastern US time zone. We are available by phone Monday through Friday from 9 AM EST to 5 PM EST. You can reach a live person by calling +1 (919) 782-8320.