WaveNow/WavePico Wireless Potentiostat/Galvanostat System User Guide

Table of Contents

Table of Tables

Table of Figures

1. Preface

1.1 Scope

This User Guide describes the WaveNow Wireless and WavePico Wireless 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 Wireless and WavePico Wireless 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 online at the following URL:

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

1.2 Copyright

This publication may not be reproduced or transmitted in any form, electronic or mechanical, including photocopying, recording, storing in an information retrieval system, or translating, in whole or in part, without the prior written consent of Pine Research Instrumentation, Inc.

1.3 Trademarks

All trademarks are the property of their respective owners. *Windows* is a registered trademark of Microsoft Corporation (Redmond, WA). *WaveNow®*, *WavePico™*, and *AfterMath®* are registered trademarks of Pine Research Instrumentation, Inc. (Durham, NC).

1.4 Use Limitation

The WaveNow Wireless or WavePico Wireless 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 Harmful or Corrosive Substances

The operator of the WaveNow Wireless or WavePico Wireless should have prior experience working in a chemical laboratory and knowledge of the safety issues associated with working in chemical laboratory. Electrochemical experiments may involve the use of harmful or corrosive substances, and the operator should wear personal protective equipment while working with these substances. At a minimum, the operator should wear the following items to avoid contact with harmful or corrosive substances:

- Eye protection (safety goggles, face shield, etc.)
- Laboratory coat (flame- and solvent-resistant)
- Solvent-resistant gloves
- Closed-toe shoes

Additional personal protective clothing and equipment may be required depending upon the nature of the chemicals used in an experiment. A complete discussion of chemical laboratory safety practices is beyond the scope of this user guide, and the reader is directed to the CHEMICAL SAFETY BIBLIOGRAPHY below for additional information.

CHEMICAL SAFETY BIBLIOGRAPHY

BIBLIOGRAPHIE DE SÉCURITÉ CHIMIQUE

1. American Chemical Society Committee on Chemical Safety Hazards Identification and Evaluation Task Force, *Identifying and Evaluating Hazards in Research Laboratories: Guidelines Developed by the Hazards Identification and Evaluation Task Force of the ACS Committee on Chemical Safety*; American Chemical Society, 2013.

2. National Research Council (US), Division of Earth and Life Studies, Board of Chemical Sciences and Technology, Committee on Prudent Practices in the Laboratory, *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, Updated Version*; National Academies Press, 2011.

3. American Chemical Society Committee on Chemical Safety. *Safety in Academic Chemistry Laboratories; 7th ed.*; American Chemical Society: State College, PA, 2003; Vol. 2.

L'opérateur du WaveNow Wireless ou WavePico Wireless doit avoir une expérience préalable de travail dans un laboratoire de chimie et la connaissance des mesures de sécurité associées aux travaux dans un laboratoire de chimie. Les expériences en électrochimie peuvent impliquer l'utilisation de substances nocives ou corrosives, et l'opérateur doit porter des équipements de protection individuelle lorsqu'il travaille avec ces substances. Au minimum, l'opérateur doit porter les articles suivants pour éviter le contact avec les substances nocives ou corrosives:

- *Protection des yeux (lunettes de sécurité, masque de protection facial, ect.)*
- *Blouse de laboratoire (résistante au feu et résistante aux solvants)*
- *Gants de protection résistants aux solvants*
- *Chaussures fermées*

Des vêtements et équipements de protection individuelle supplémentaires peuvent être requis en fonction de la nature des produits chimiques utilisés dans une expérience. Une discussion complète des pratiques de sécurité de laboratoire chimique est au-delà de la portée de ce guide de l'utilisateur, et le lecteur est dirigé vers la « BIBLIOGRAPHIE DE SÉCURITÉ CHIMIQUE » ci-dessus pour des informations supplémentaires.

1.6 Service and Warranty Information

For questions about proper operation of the WaveNow Wireless or WavePico Wireless systems or other technical issues, please use the contact information below to contact Pine Research directly.

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

If the WaveNow Wireless or WavePico Wireless 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 Wireless or WavePico Wireless 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.

1.7 Instrument Markings

Labels located on the side and back panels of each WaveNow Wireless or WavePico Wireless include information about the make, model, and serial number of the instrument. These labels also indicate any certifications or independent testing agency marks that pertain to the instrument (see Figure 1-1).

1	FCC Mark	Mark of the Federal Communications Commission (FCC) of the United States.
2	European CE Mark	WaveNow/WavePico Wireless systems that comply with one or more EU directives bear the CE mark. See the "CE Declaration of Conformity" attached to the end of this user guide for more details.
3	Serial Number Label	This label indicates the model and serial number of the instrument and includes a machine-readable bar code.
4	NRTL Mark	WaveNow/WavePico Wireless systems that bear the ETL/Intertek mark are listed by Intertek to UL 61010-1 (issued 11-MAY-2012; Ed. 3), CSA C22.2 #61010-1 (issued 11-MAY-2012; Ed. 3), and IEC 61010-1 (issued 10-JUN-2010; Corrigendum 1: 11-MAY-2011). Intertek is a Nationally Recognized Testing Laboratory (NRTL) recognized by the United States Occupational Safety and Health Administration (OSHA).
5	FCC Compliance Statement	This label indicates the instrument is in compliance with rules and regulations of the Federal Communications Commission (FCC) (see Section 1.13 for more details)
6	Environmental Labels	These labels indicate that the instrument has an Environment Friendly Use Period (EFUP) of forty years and that the instrument should be treated as recyclable electronic equipment at the end of its useful life.

Figure 1-1. WaveNow/WavePico Wireless Instrument Markings

1.7.1 Serial Number

For purposes of uniquely identifying a particular instrument, there is a label on the back panel of each WaveNow Wireless and WavePico Wireless that indicates the model number and the serial number. The serial number is also encoded with a machine-readable barcode on the same label (see Figure 1-1).

1.7.2 Model Numbers

The relationship between the model name and model number for the WaveNow/WavePico Wireless systems is described below (see Table 1-1). The model number has the format "AFTP**NXY**" where **N** is a single numeric digit (either 4 or 5), and **X** and **Y** are either blank or uppercase alphabetic characters. Pine Research part numbers for various components of the system (such as power cords, cell cables, and accessories) are described in more detail later (see Sections 4.3 and 7).

Model Number:	A	F	T	P	N	X	Y	Model Name
	A	F	T	P	4			**WaveNow Wireless**
	A	F	T	P	5			**WavePico Wireless**

Table 1-1. WaveNow/WavePico Wireless Instrument Model Numbers and Names

The WavePico Wireless is similar to the WaveNow Wireless, but it has a lower range of applied currents and current ranges (see specifications in Section 2.3 for more details).

1.8 Icons (*Icônes*)

Special icons are used to call attention to safety warnings and other useful information found in this document (see Table 1-2, Table 1-3, and Table 1-4).

Des icônes spéciales (voir Tableau 1-2, Tableau 1-3, et Tableau 1-4) sont utilisées pour attirer l'attention sur des avertissements de sécurité et d'autres renseignements utiles disponibles dans ce document.

	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 l'étape 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 1-2. Special Icons Used in this Document.

(Tableau 1-2. Icônes spéciales utilisées dans ce document)

	WARNING: **Indicates information needed to prevent injury or death to a person or to prevent damage to equipment.** *AVERTISSEMENT:* *Indique les informations nécessaires pour prévenir les blessures ou le décès d'une personne ou pour éviter d'endommager l'équipement.*
	ROTATING SHAFT HAZARD: **Indicates information needed to prevent injury or death to a person due to a high-speed rotating shaft.** *DANGER LIÉ À LA ROTATION DE L'ARBRE:* *Indique les informations nécessaires pour prévenir les blessures ou le décès d'une personne à cause de la vitesse élevée de rotation de l'arbre.*
	RISK OF ELECTRICAL SHOCK: **Indicates information needed to prevent injury or death to a person due to electrical shock.** *RISQUE DE DÉCHARGE ÉLECTRIQUE:* *Indique les informations nécessaires pour prévenir les blessures ou le décès d'une personne à cause d'une décharge électrique.*

Table 1-3. Safety Warning Icons Used in this Document.

(Tableau 1-3. Icônes d'avertissement de sécurité utilisées dans ce document)

	CAUTION:
	Indicates information needed to prevent damage to equipment.
	ATTENTION:
	Indique les informations nécessaires pour éviter d'endommager l'équipement.
	RISK OF ELECTROSTATIC DAMAGE:
	Indicates information needed to prevent damage to equipment due to electrostatic discharge.
	RISQUE DE DOMMAGES ÉLECTROSTATIQUES:
	Indique les informations nécessaires pour éviter d'endommager l'équipement à cause d'une décharge électrostatique.
	TEMPERATURE CONSTRAINT:
	Indicates when an operation or use of equipment is limited to a specified temperature range.
	CONTRAINTES DE TEMPÉRATURE :
	Indique lorsqu'une opération ou un usage de matériel est limité à une plage de températures spécifique.

Table 1-4. Other Safety Warning Icons Used in this Document

(Tableau 1-4: Autres Icônes d'avertissement de sécurité utilisées dans ce document)

1.9 Safety Labels (*Étiquettes de sécurité*)

Specific safety warnings are found on labels attached to the instrument (see Figure 1-2).

Les avertissements de sécurité spécifiques suivants se trouvent sur les étiquettes apposées sur l'instrument (voir Figure 1-2).

No operator serviceable components inside. Do not remove covers. Refer servicing to qualified personnel.

L'appareil ne contient pas de pièces réparables par l'utilisateur. Ne pas retirer les couvercles. Confier l'entretien au personnel qualifié.

Figure 1-2. Safety Warning Labels on Back Panel of Instrument

1.10 General Safety Warnings (*Avertissements de sécurité généraux*)

The following safety warnings pertain to general use of the instrument. More specific safety warnings are found in later sections of this document which pertain to particular operations and procedures involving the instrument.

Des avertissements de sécurité plus spécifiques se trouvent dans les sections suivantes de ce document, concernant les opérations et les procédures particulières relatives à l'instrument.

WARNING:

There are no user serviceable components inside the WaveNow/ WavePico Wireless chassis. Do not remove the chassis covers. Refer any service issue to qualified personnel.

AVERTISSEMENT:

Le châssis de l'appareil WaveNow/WavePico Wireless ne comporte aucune pièce pouvant être remplacée par l'utilisateur. Ne retirez pas les protections du châssis. Signalez tout problème d'entretien au personnel qualifié.

WARNING:

A factory-approved power supply is provided with the WaveNow/ WavePico Wireless. Do not use a power supply which is not factory-approved.

AVERTISSEMENT:

Une alimentation électrique approuvée par le constructeur est fournie avec l'appareil WaveNow/WavePico Wireless. N'utilisez pas une alimentation électrique non approuvée par le constructeur.

WARNING:

Connect the power supply to the AC mains using the power cord supplied with the WaveNow/WavePico Wireless and certified for the country of use (see Section 7 of this User Guide for more details). Do not replace this cord with an inadequately rated cord.

AVERTISSEMENT:

Connectez le bloc d'alimentation au secteur à l'aide du cordon d'alimentation fourni avec l'appareil WaveNow/WavePico Wireless et conforme aux réglementations du pays d'utilisation (pour plus de détails, consultez la partie 7 du présent mode d'emploi). Ne remplacez pas ce cordon par un cordon de calibre inadéquat.

WARNING:

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.

WARNING:

The switch on the back of the WaveNow/WavePico Wireless turns the power to the instrument on and off. Do not block access to the switch. The user must have access to the switch at all times.

AVERTISSEMENT:

L'interrupteur situé sur le derrière de l'appareil WaveNow/WavePico Wireless permet de couper l'alimentation. Ne bloquez pas l'accès à l'interrupteur. L'utilisateur doit avoir accès à l'interrupteur à tout moment.

WARNING:

Do not operate the WaveNow/WavePico Wireless in an explosive atmosphere.

AVERTISSEMENT:

N'utilisez pas l'appareil WaveNow/WavePico Wireless dans une atmosphère explosive.

CAUTION:

Do not operate the WaveNow/WavePico Wireless in wet or damp conditions. Keep all instrument surfaces clean and dry.

ATTENTION:

N'utilisez pas l'appareil WaveNow/WavePico Wireless dans un environnement mouillé et humide. Veillez à ce que toutes les surfaces de l'appareil soient toujours propres et sèches.

CAUTION:

Do not operate the WaveNow/WavePico Wireless if it has suffered damage or is suspected of having failed. Refer the instrument to qualified service personnel for inspection.

ATTENTION:

N'utilisez pas l'appareil WaveNow/WavePico Wireless 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.

WARNING:

Rotating shaft.

When connecting a WaveNow/WavePico Wireless system to an electrode rotator other than the Pine Research MSR or WaveVortex 10 rotator, carefully consider the magnitude of the WaveNow/WavePico Wireless rate control signal ratio (1 RPM/mV) and take steps to assure that the rotator is configured to use the same ratio.

Use extreme caution when operating the rotator at rotation rates above 2000 RPM.

AVERTISSEMENT:

Arbre tournant.

Lorsque vous connectez un système WaveNow/WavePico Wireless à une électrode tournante autre que le MSR ou le WaveVortex 10 de Pine Research, prenez en compte soigneusement le rapport du signal de contrôle de vitesse du WaveNow/WavePico Wireless (1 [tr/min]/mV) et assurez-vous que l'électrode tournante est configurée avec le même rapport.

Soyez extrêmement prudent lorsque vous utilisez l'électrode tournante à des vitesses de rotation supérieures à 2000 tr/min.

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

The WaveNow Wireless and WavePico Wireless 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 Wireless or WavePico Wireless instruments 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.**

1.12 Hazardous Material Information

Disclosure tables in both English and Mandarin are provided (see Table 1-5 and Table 1-6) that detail information pertaining to the list of hazardous substances classified under the Restriction of Hazardous Substances Directive (RoHS).

Hazardous Material Disclosure Table						
AFTP4, AFTP5						
Part Name	Hazardous Substances					
	Lead (Pb)	Mercury (Hg)	Cadmium (Cd)	Hexavalent Chromium (Cr (VI))	Polybrominated biphenyls (PBB)	Polybrominated diphenyl ethers (PBDE)
Main PCB	X	O	O	O	O	O
Dummy Cell	X	O	O	O	O	O
Aluminum 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:
wwyy8nn for AFTP4: ww indicates week; yy indicates year; and nn is the number of the item, starting with 01 each week.
wwyy9nn for AFTP5: 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; therefore, there may be the above noted materials present in the unit.

Table 1-5. Hazardous Materials Disclosure (English)

有害物质披露表						
AFTP4 和 AFTP5						
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
铝机壳	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：
wwyy8nn对应于AFTP4：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 。
wwyy9nn对应于AFTP5：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 1-6. Hazardous Materials Disclosure (Mandarin)

1.13 FCC Compliance Information

The following information pertains to regulations enforced by the Federal Communications Commission (FCC) of the United States of America.

Supplier's Declaration of Conformity **47 CFR § 2.1077 Compliance Information**	
Unique Identifiers	WaveNow Wireless (model number AFTP4)
	WavePico Wireless (model number AFTP5)
Responsible Party	Pine Research Instrumentation, Inc. 2741 Campus Walk Ave, Building 100 Durham, NC 27705 USA www.pineresearch.com Phone: +1 919-782-8320 Fax: +1 919-782-8323 Email: pinewire@pineresearch.com
FCC Compliance Statement (*e.g.*, products subject to Part 15)	This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Table 1-7. FCC Compliance Information and Declaration

1. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

2. NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

See following page for wireless module FCC compliance certificate.

TCB

**GRANT OF EQUIPMENT
AUTHORIZATION**

TCB

**Certification
Issued Under the Authority of the
Federal Communications Commission
By:**

Eurofins Product Service GmbH
Storkower Strasse 38c
D-15526 Reichenwalde,
Germany

Date of Grant: 05/29/2013

Application Dated: 05/29/2013

Microchip Technology Inc.
2355 W. Chandler Blvd.
Chandler, AZ 85224

Attention: Steve Caldwell

NOT TRANSFERABLE

EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and
is VALID ONLY for the equipment identified hereon for use under the
Commission's Rules and Regulations listed below.

FCC IDENTIFIER: T9JRN41-3
Name of Grantee: Microchip Technology Inc.
Equipment Class: Part 15 Spread Spectrum Transmitter
Notes: Class 1 Bluetooth Module
Modular Type: Single Modular

Grant Notes	FCC Rule Parts	Frequency Range (MHZ)	Output Watts	Frequency Tolerance	Emission Designator
	15C	2402.0 - 2480.0	0.0687		

Modular Approval. Power Output listed is conducted. The antenna(s) used for this
device must be installed to provide a separation distance of at least 20 cm from all
persons, and must not be co-located or operating in conjunction with any other antenna
or transmitter. This grant is valid only when the device is sold to OEM integrators and
the OEM integrators are instructed to ensure that the end user has no manual
instructions to remove or install the device. End users and installers must be provided
with antenna installation instructions and transmitter operating conditions for satisfying
RF Exposure compliance.
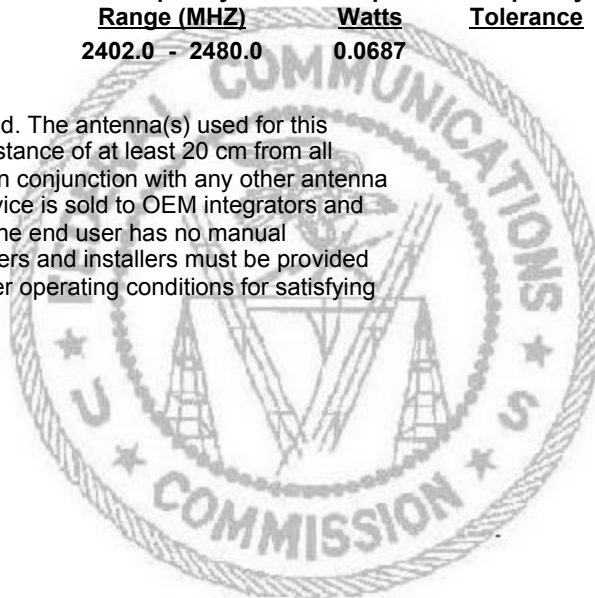
1.14 Software License

Purchase of a WaveNow Wireless or WavePico Wireless instrument includes a license to use the AfterMath software package to control the instrument and analyze data collected using the instrument. Pine Research understands that the WaveNow Wireless or WavePico Wireless 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 Wireless or WavePico Wireless in a laboratory with multiple computers.

PINE RESEARCH INSTRUMENTATION, INC.

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.

3. **Scope of License**: This License covers the software, user documentation and any related computer programs provided by PINE for use with one or more specific INSTRUMENTS. This License does not grant any proprietary or ownership rights in the SOFTWARE or related technology. The scope of this License is limited to an exclusive group of one or more specific INSTRUMENTS, where the members of this exclusive group are specifically enumerated and identified by make, model, and serial number at the time this License is purchased. The one or more specific INSTRUMENTS belonging to this exclusive group are hereafter referred to as the "DESIGNATED INSTRUMENTS".

4. **License**: PINE grants to LICENSEE a nonexclusive, nontransferable license to use the SOFTWARE in object code form on any computer which is connected to the DESIGNATED INSTRUMENTS for purposes of controlling the operation of the DESIGNATED INSTRUMENTS. The LICENSEE is not authorized to use the SOFTWARE to control the operation of any instruments other than the DESIGNATED INSTRUMENTS. PINE further grants to LICENSEE a nonexclusive, nontransferable license to use the SOFTWARE in object code form on up to five (5) other computers which are not connected to the DESIGNATED INSTRUMENTS for the sole purpose of analyzing data previously generated by the DESIGNATED INSTRUMENTS. PINE further grants permission to LICENSEE to make one (1) archival copy of the SOFTWARE for back-up purposes if required. Except as expressly authorized above, LICENSEE shall not: copy, in whole or in part, any of the SOFTWARE or documentation, modify the SOFTWARE, reverse engineer, reverse compile (de-compile), or reverse assemble all or any portion of the SOFTWARE, or rent, lease, distribute, sell or create derivative works of the SOFTWARE.

5. **Term and Termination**: The License hereby granted will continue in force until terminated, as set forth herein. If LICENSEE fails to pay any monies owed to PINE or its agents in connection with LICENSEE's purchase of the DESIGNATED INSTRUMENTS or this SOFTWARE, or violates any term of condition of this License, PINE or its agents may terminate this License immediately by giving notice of termination to LICENSEE.

6. **Limited Warranty**: PINE warrants the SOFTWARE to conform to the description of its function and performance. In the event that the SOFTWARE does not perform in accordance with this warranty, PINE agrees to repair or fix any non-conformity free of charge, or to refund any amount paid by LICENSEE for the SOFTWARE. Any modifications made to the SOFTWARE by LICENSEE shall void this warranty entirely.

7. **DISCLAIMER OF WARRANTY FOR SOFTWARE**. EXCEPT FOR THE EXPRESS WARRANTIES SET FORTH IN THIS AGREEMENT, PINE DISCLAIMS ALL IMPLIED WARRANTIES FOR THE SOFTWARE, INCLUDING

WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. PINE MAKES NO REPRESENTATIONS CONCERNING THE QUALITY OF THE SOFTWARE AND DOES NOT PROMISE THAT THE SOFTWARE WILL BE ERROR FREE OR WILL OPERATE WITHOUT INTERRUPTION.

8. **LIMITATION OF LIABILITY**. IN NO EVENT WILL PINE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, CONSEQUENTIAL OR OTHER DAMAGES ARISING OUT OF THE USE OF OR INABILITY TO USE THE SOFTWARE BY ANY PERSON, REGARDLESS OF WHETHER PINE IS INFORMED OF THE POSSIBILITY OF DAMAGES IN ADVANCE. THESE LIMITATIONS APPLY TO ALL CAUSES OF ACTION, INCLUDING BREACH OF CONTRACT, BREACH OF WARRANTY, PINE'S NEGLIGENCE, STRICT LIABILITY, MISREPRESENTATION AND OTHER TORTS. In no event shall PINE's liability or liability of PINE's suppliers exceed the price paid by the LICENSEE for the SOFTWARE. The foregoing limitations shall apply even if the above-stated warranty fails of its essential purpose.

9. **Ownership of SOFTWARE**: PINE has and will retain all ownership rights in the SOFTWARE, including all patent rights, copyrights, trade secrets, trademarks, service marks, related goodwill and confidential and proprietary information. LICENSEE will have no rights in the SOFTWARE except as explicitly stated in this Agreement. Title to the SOFTWARE and documentation remains solely with PINE. LICENSEE may not assign this Agreement or any rights under it and may not delegate any duties under this Agreement without PINE's prior written consent. Any attempt to assign or delegate without such consent will be void.

10. **Confidential Information**: LICENSEE agrees that aspects of the SOFTWARE embody or constitute trade secrets and/or copyrighted material of Pine. LICENSEE agrees not to disclose, provide, or otherwise make available such trade secrets or copyrighted material in any form to any third party without the prior written consent of PINE. LICENSEE agrees to implement reasonable security measures to protect such trade secrets and copyrighted material.

11. **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.

12. **Modifications, Taxes**: Any modification of this Agreement must be in writing and signed by PINE and LICENSEE. Terms and conditions set forth in any purchase order which differ from, conflict with, or are not included in this Agreement, shall not become part of this License unless specifically accepted by PINE in writing. LICENSEE shall be responsible for and shall pay, and shall reimburse PINE on request if PINE is required to pay, any sales, use, value added (VAT), consumption or other tax (excluding any tax that is based on PINE's net income), assessment, duty, tariff, or other fee or charge of any kind or nature that is levied or imposed by any governmental authority on the SOFTWARE.

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 Wireless and WavePico Wireless are portable instruments that are designed to connect to a personal computer (either via a wireless USB dongle or directly using a USB cable) and are controlled by Pine Research AfterMath software. The WaveNow Wireless and WavePico Wireless are potentiostat/galvanostat systems capable of controlling an electrochemical cell comprised of one working electrode, a reference electrode, and a counter electrode. Popular DC electrochemical test methods (such as Cyclic Voltammetry, Chronoamperometry, Pulse, and Square Wave Voltammetry, etc.) may be performed using the WaveNow Wireless and WavePico Wireless. Additionally, because the WaveNow Wireless and WavePico Wireless can be connected and controlled wirelessly without the need of a physical cable connection, they may be ideal for use in confined and/or remote experimental setups where the instrument/electrochemical system and controlling computer cannot or need not be physically connected or in close proximity (*e.g.*, gloveboxes).

The WaveNow Wireless and WavePico Wireless both feature one potential range (±8 V). The WaveNow Wireless has six current ranges (±150 mA to ±5 nA), making it suitable for most electroanalytical experiments. The WavePico Wireless has six current ranges (±1.5 mA to ±50 pA) and is designed for lower current applications; it may be necessary to properly ground the WavePico Wireless and shield electromagnetic fields (by use of a Faraday cage, for example) to accurately resolve sub-nanoampere current (see Section 6 for details on grounding strategies).

2.2 Software Description

The AfterMath scientific data analysis and instrument control software developed by Pine Research is included with each WaveNow Wireless and WavePico Wireless instrument. 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 and independently 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 are built into Aftermath. For example, if an operation divides a potential measured in millivolts by a current measured in nanoamperes, 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 stored together in one single archive file. Keeping related experiments together in an archive file eliminates the need to manage multiple individual data files on the hard drive. The internal archive hierarchy can contain as many subfolders, reports, plots, notes, experimental parameters, and data sets as desired (subject to available memory and storage).

- **Tools and Transforms.** Flexible tools can be placed on any graph to precisely measure quantities such as 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 Wireless and WavePico Wireless instruments offer the following electrode control modes: potentiostat (POT), galvanostat (GAL), open circuit potential (OCP), and zero resistance ammeter (ZRA). Uncompensated resistance (Ru) measurement is available via the positive feedback technique, and after it has been measured, the instrument circuitry can subsequently compensate for this resistance. The WaveNow Wireless and WavePico Wireless instruments do not support high-frequency AC methods such as electrochemical impedance spectroscopy (EIS).

> **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 Wireless and WavePico Wireless. All specifications at 23℃ unless otherwise stated.

ELECTRODE CONNECTIONS	
Reference Electrode	Sense line with driven shield
Counter Electrode	Drive line with grounded shield
Working Electrode	Separate sense and drive lines, each with driven shield (current measurement via passive shunt)
GROUND CONNECTIONS	
DC Common (signal ground)	The DC Common is isolated from the USB port, the instrument chassis, and earth ground. The DC Common is accessible via the Control Port on the back panel.
Chassis Terminal	The instrument chassis terminal is accessible via a banana jack (metal) on the back panel. The GRAY banana plug on the cell cable also provides an instrument chassis connection to allow convenient connection of the instrument chassis to a Faraday cage surrounding the electrochemical cell.
	As shipped from the factory, the instrument chassis and DC Common are connected via a green block connector plugged into the Control Port on the back panel. The green block connector intentionally shorts the instrument chassis and DC Common pins; to isolate those ground connections, the user may remove the green block connector from the instrument.
Earth Ground	No direct connection to earth ground is provided.

(specifications table is continued on the next page)

ELECTROMETER (REFERENCE ELECTRODE AMPLIFIER)	
Input Impedance	$> 10^{13}$ Ω in parallel with 7 pF
Input Current	6 fA leakage/bias current typical, < 100 fA max at 25℃
CMRR	> 73 dB $0 - 100$ Hz > 60 dB ≤ 1 kHz > 39 dB ≤ 10 kHz
Bandwidth	> 800 kHz (3 dB)

MEASURED POTENTIAL	
Ranges	± 8.0 V
Resolution (at each range)	250 µV per ADC bit
Accuracy	$\pm 0.2\%$ of reading, $\pm 0.05\%$ of range
ADC Input	16 bits
Filters	12 Hz, 1 kHz (3-pole, low pass Bessel filters)

APPLIED POTENTIAL (POTENTIOSTATIC MODE)	
Ranges	± 8.0 V
Resolution (at each range)	250 µV per DAC bit
Accuracy	$\pm 0.2\%$ of setting, $\pm 0.05\%$ of range, ± 1.0 mV
Thermal Drift	30 ppm/℃
DAC Output	16 bits
CV Sweep Rate (min)	10 µV/s (469 µV step per 46.9 s, 313 µV step per 31.3 s, or 78 µV per 7.8 s)
CV Sweep Rate (max)	10 V/s (10 mV step every 1.0 ms)

ROTATOR CONTROL CONNECTION (BACK PANEL)	
Connector Description	4-pin connector includes chassis ground, rotator enable output signal (+15 V tolerant), analog signal ground (DC Common), and analog rotation rate control output signal
Rate Control Signal	± 10.0 V
Resolution	5.12 mV per ADC bit (12 bit)
Digital Enable Signal	Open drain with 4.7 kΩ pull up to +4 V (TTL compatible)
Output Impedance	< 130 Ω

(specifications table is continued on the next page)

DATA ACQUISITION	
Point Interval*	1 ms (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)
EXTERNAL PORTS (FRONT AND BACK PANELS)	
Cell Port	HD-15 female connector
Interface Port	USB Type-B connector
Rotator Control Port	4-pin connector
GENERAL SPECIFICATIONS	
Power Required	5.0 VDC, 2 A (low voltage DC device)
Power Supply	Input Requirements: 100 to 240 VAC, 0.5 A, 50 to 60 Hz Output Power: 5 VDC, 2.0 A Power supply (included) has a C14 type input connector
Power Cord	Various international cables sold separately (C13 type)
LED Indicators	Power, USB/wireless connection, status, and overload
Instruments Dimensions	$55 \times 170 \times 130$ mm ($2.17 \times 6.69 \times 5.12$ in)
Instrument Weight	0.6 kg (1.25 lb)
Shipping Dimensions	$305 \times 254 \times 102$ mm ($12 \times 10 \times 4$ in)
Shipping Weight	1.8 kg (4 lb)
Temperature Range**	10℃ to 40℃
Humidity Range	80% RH maximum, non-condensing

* 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 s.

** It is recommended that the instrument primarily be used at or around room temperature (25℃). Varying operational temperature may affect accuracy.

2.3.2 WaveNow Wireless Specifications

The following specifications apply only to the WaveNow Wireless Potentiostat/Galvanostat System. The Common Specifications found in Section 2.3.1 apply as well. All specifications at 23℃ unless otherwise stated.

MEASURED CURRENT (25℃)	
Ranges	± 150 mA, ± 5 mA, ± 150 μA, ± 5 μA, ± 150 nA, ± 5 nA
Resolution (at each range)	4.70 μA, 157 nA, 4.70 nA, 157 pA, 4.70 pA, 157 fA
Autoranging	Yes
Practical Range§	1 pA to 150 mA
Accuracy	$\pm$ 0.2% of setting; $\pm$0.05% of range
Leakage Current	< 20 fA at 0 VDC, < 130 fA at 5 VDC
ADC Resolution	16 bits
Filters	12 Hz, 1 kHz (3-pole, low pass Bessel filters)
APPLIED CURRENT (GALVANOSTATIC MODE)	
Ranges	± 150 mA, ± 5 mA, ± 150 μA, ± 5 μA, ± 150 nA, ± 5 nA
Resolution (at each range)	4.70 μA, 157 nA, 4.70 nA, 157 pA, 4.70 pA, 157 fA
Accuracy	$\pm$ 0.2% of setting; $\pm$0.05% of range
DAC Resolution	16 bits
POWER AMPLIFIER (COUNTER ELECTRODE AMPLIFIER)	
Output Current	± 150 mA (maximum)
Short Circuit Current Limit	160 mA, all ranges
Compliance Voltage	> $\pm$ 11 V
Bandwidth	> 30 kHz (on fastest speed setting)
Slew Rate/Rise Time	180 V/ms (potentiostatic mode, on fastest speed setting)
	800 V/ms (galvanostatic mode, on fastest speed setting)

§ 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. Using proper grounding, a cell shielded by a Faraday cage, and coaxial cell cables, it is possible to routinely measure signals as low as 1 pA.

2.3.3 WavePico Wireless Specifications

The following specifications apply only to the WavePico Wireless Potentiostat/Galvanostat System. The Common Specifications found in Section 2.3.1 apply as well. All specifications at 23℃ unless otherwise stated.

MEASURED CURRENT (25℃)	
Ranges	$\pm$1.5 mA, $\pm$50 µA, $\pm$1.5 µA, $\pm$50 nA, $\pm$1.5 nA, $\pm$50 pA
Resolution (at each range)	47.0 nA, 1.57 nA, 47.0 pA, 1.57 pA, 47.0 fA, 1.57 fA
Autoranging	Yes
Practical Range‡	40 fA (with 1 Hz bandwidth) to 1.5 mA (full bandwidth)
Accuracy	$\pm$0.2% of reading plus $\pm$ 0.05% of five upper current ranges; $\pm$0.5% of 50 pA range*
Leakage Current	< 20 fA at 0 VDC, < 130 fA at 5 VDC
ADC Resolution	16 bits
Filters	12 Hz, 1 kHz (3-pole, low pass Bessel filters)
APPLIED CURRENT (GALVANOSTATIC MODE)	
Ranges	$\pm$1.5 mA, $\pm$50 µA, $\pm$1.5 µA, $\pm$50 nA, $\pm$1.5 nA, $\pm$50 pA
Resolution (at each range)	47.0 nA, 1.57 nA, 47.0 pA, 1.57 pA, 47.0 fA, 1.57 fA
Accuracy	$\pm$ 0.2% of setting; $\pm$0.05% of range
DAC Resolution	16 bits
POWER AMPLIFIER (COUNTER ELECTRODE AMPLIFIER)	
Output Current	$\pm$1.5 mA (maximum)
Short Circuit Current Limit	10 mA, all ranges
Compliance Voltage	> $\pm$ 11 V
Bandwidth	> 30 kHz (on fastest speed setting)
Slew Rate/Rise Time	180 V/ms (potentiostatic mode on fastest speed setting)
	800 V/ms (galvanostatic mode on fastest speed setting)

‡ 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. Using proper grounding, a cell shielded by a Faraday cage, and coaxial cell cables, it is possible to routinely measure signals as low as 40 fA.
* $\pm$1 pA offset

2.4 Standard Electrochemical Methods

The WaveNow Wireless and WavePico Wireless 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 AfterMath software documentation.

Simple Methods	Rotating Disk Methods
Open Circuit Potential (OCP)	Rotating Disk Electrode (RDE)
Constant Potential Electrolysis (BE)	Koutecký-Levich Series (KL-RDE)
Constant Current Electrolysis (BE)	Rotating Disk Electrolysis (BE-RDE)
Zero Resistance Ammeter (ZRA)	Rotating Disk Chronopotentiometry (CP-RDE)
Voltammetric Methods	Rotating Disk Ramp Chronopotentiometry (RCP-RDE)
Cyclic Voltammetry (CV)	**Stripping Voltammetry**
Linear Sweep Voltammetry (LSV)	Anodic & Cathodic Stripping Voltammetry (ASV)
Staircase Voltammetry (SCV)	Differential Pulse Stripping Voltammetry (DPSV)
Chronoamperometry (CA)	Square-Wave Stripping Voltammetry (SWSV)
Normal Pulse Voltammetry (NPV)	**Corrosion Methods**
Cyclic Step Chronoamperometry (CSCA)	Linear Polarization Resistance (LPR)
Differential Pulse Voltammetry (DPV)	Rotating Cylinder Voltammetry (RCE)
Square-Wave Voltammetry (SWV)	Rotating Cylinder Electrolysis (BE-RCE)
Double Potential Step Chronoamperometry (DPSCA)	Rotating Cylinder Eisenberg Study (EZB-RCE)
Galvanostatic Methods	Rotating Cylinder Polarization Resistance (LPR-RCE)
Chronopotentiometry (CP)	Rotating Cylinder Open Circuit Potential (OCP-RCE)
Ramp Chronopotentiometry (RCP)	Rotating Cylinder Chronopotentiometry (CP-RCE)
Staircase Potentiometry (SCP)	Rotating Cylinder Ramp Chronopotentiometry (RCP-RCE)
Cyclic Step Chronopotentiometry (CSCP)	**Spectroscopic Methods***
Uncompensated Resistance Methods	Spectroscopy (SPEC)
Positive Feedback (PF-RU)	Spectroelectrochemistry (SPECE)

Table 2-1. Electrochemical Techniques in AfterMath

*Access to these electrode methods requires a separate software license. If access to these experiments in conjunction with an Avantes spectrometer is needed, please contact Technical Service for assistance (see Section 1.6).

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 Wireless and WavePico Wireless systems, as shipped from the production facility, includes all parts, cables, and software necessary for their initial use (see Table 2-2).
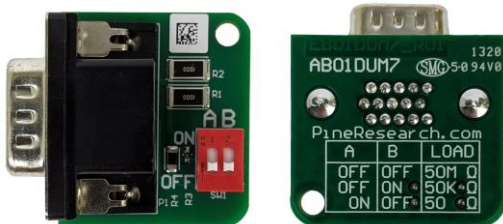

1	**Instrument**	A WaveNow Wireless or WavePico Wireless Potentiostat/Galvanostat
2	**USB Flash Drive**	Contains AfterMath software, drivers, and license files
3	**Cell Cable**	General-purpose HD-15 cell cable with bundle shield including four coaxial electrode lines and one instrument chassis line (see Section 4.3 for details)
4	**Dummy Cell**	A network of test circuits used to verify proper instrument operation (see Section 2.8 for details)
5	**Power Supply**	Input Requirements: 100 to 240 VAC, 0.5 A, 50 to 60 Hz Output Power: 5 VDC, 2.0 A Power supply (included) has a C14 type input connector compatible with a variety of international power cords (sold separately, see Section 7)
6	**Wireless USB Dongle**	Wireless communication device between computer and WaveNow Wireless or WavePico Wireless; plugs into computer USB port (see Section 3.3 for connection details)
7	**USB Interface Cable**	Physical communication cable between computer and WaveNow Wireless or WavePico Wireless (USB type A male to type B male)

Table 2-2. Main Components Included with WaveNow/WavePico Wireless

2.6 Front Panel Description

The front panel of the WaveNow Wireless and WavePico Wireless has four LED indicators, a cell cable port, and a label with the Pine Research logo and instrument name (see Table 2-3). The four LEDs indicate power, communications activity (wireless or USB), instrument status, and overload condition. Various colors and blink patterns are used by the LED indicators (see Table 2-4).

1	**LED Indicator Lights**	LEDs indicate status of the instrument
2	**Cell Cable Port**	HD-15 port that provides connection between instrument and cell cable
3	**Potentiostat Name**	WaveNow Wireless or WavePico Wireless
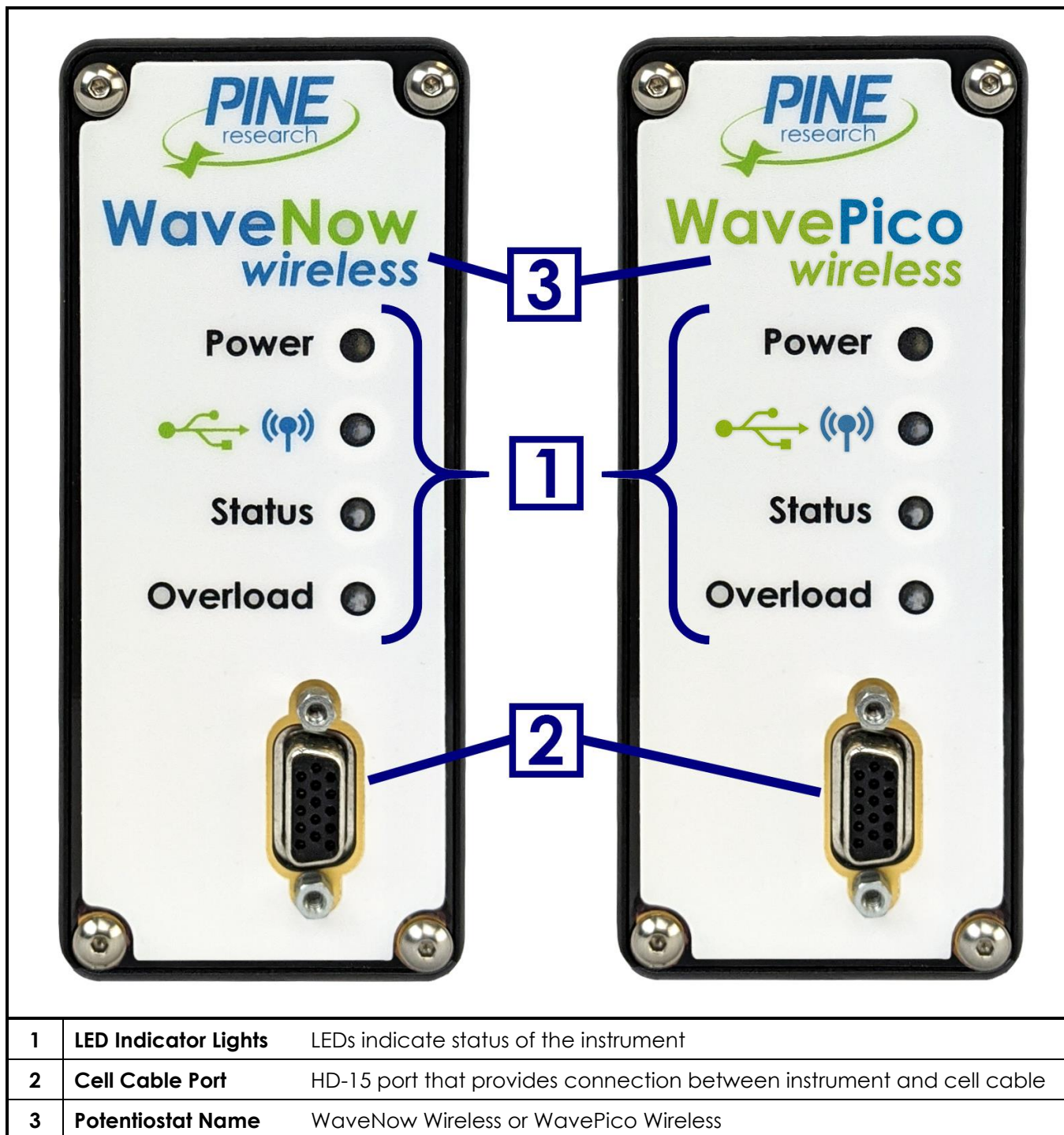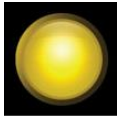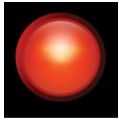
Table 2-3. Front Panel of WaveNow/WavePico Wireless

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.
Communication	blinking red	The communication LED will blink red whenever the instrument is trying to establish connection to a computer (but is not currently connected).
	blinking blue	The instrument is establishing a connection, either wirelessly (via wireless USB dongle) or physically (via USB cable), or data transfer is occurring wirelessly between the instrument and the computer.
	solid blue	The instrument has a wireless connection to the computer.
	slow blinking green	The instrument has established a USB connection to AfterMath.
	fast blinking green	The instrument is transferring data via USB connection to or from the computer.
Status	slow blinking green	The light flashes for one second, then is off for one second. This occurs when the instrument has successfully communicated with AfterMath and is idle (*i.e.*, not performing an experiment).
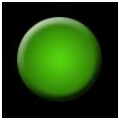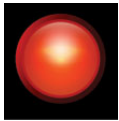
	fast blinking green	The light flashes for a half second then is off for a half second. This occurs when the instrument is performing an experiment.
	blinking orange	When the instrument is initially powered on, it performs a brief self-test. During this time, the status LED blinks orange. This state persists 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 for assistance.
Overload	not illuminated	No overload or out of range condition is occurring.
	solid or blinking red	Current limit has been reached, or counter and/or reference electrode are out of measurement range.

Table 2-4. Overview of WaveNow/WavePico Wireless LED Indicator Lights

2.7 Back Panel Description

The back panel of the WaveNow Wireless and WavePico Wireless has a USB cable input port, an auxiliary Control Port, a power switch, a power input port, and a banana jack connected to the instrument chassis (see Table 2-5). The Control Port is designed to be used with various accessories (electrode rotators, spectrometers, etc.), but it may also be employed in certain grounding strategies (see Section 6).
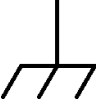
1	**USB Input Port**	USB jack (type B) for physical connection to computer
2	**Control Port**	4-pin connector includes chassis ground, rotator enable output signal (+15 V tolerant), analog signal ground (DC Common), and analog rotation rate control output signal. A green block connector is included that shorts pins 1 and 3 (instrument chassis and DC Common). To isolate instrument chassis and DC Common, remove the green block connector.
3	**Power Switch**	Controls whether power is "on" (|) or "off" (O)
4	**Power Input Port**	A low voltage (5.0 VDC, 2.0 A) power input connector
5	**Chassis Terminal**	Banana jack (metal) that provides a secure connection to the chassis of the instrument

Table 2-5. Back Panel of WaveNow/WavePico Wireless

2.8 Dummy Cell Descriptions

A dummy cell is a network of known resistors and/or capacitors that can be used to test a potentiostat to ensure that the instrument is working properly. The dummy cells included with the WaveNow Wireless (Pine Research part number AB01DUM7) and WavePico Wireless (Pine Research part number AB01DUM8) are shown along with their schematic diagrams below (see Figure 2-1).
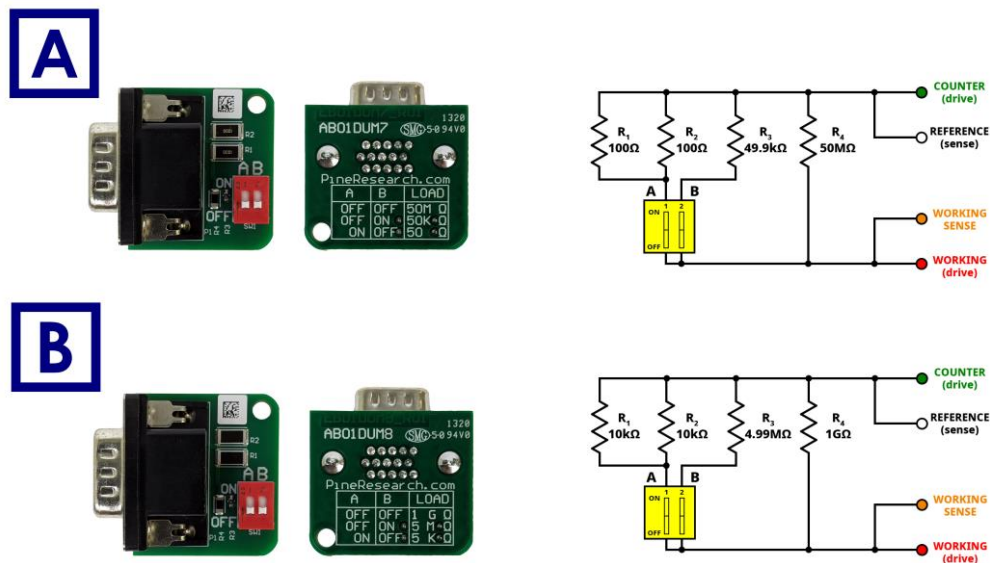
Figure 2-1. (A) WaveNow Wireless and (B) WavePico Wireless Dummy Cells

The dummy cell has a male HD-15 port, allowing it to be directly inserted into the cell cable port on the front panel of the instrument (see Figure 2-2). The dummy cell contains several resistors and two configuration switches, which are labeled "A" and "B" (see Figure 2-1). Additionally, the directions of "ON" and "OFF" positions for both switches are labeled on the dummy cell to the left of the switches. There are three usable ON/OFF combinations for switches "A" and "B" that change the effective resistive load of the dummy cell. These combinations are printed on the reverse side of the dummy cell and are also summarized in Table 2-6 and Table 2-7.

Figure 2-2. Dummy Cell Connected to WaveNow Wireless

"A" Switch Position	"B" Switch Position	Effective Load
OFF	OFF	50 MΩ
OFF	ON	49.9 kΩ
ON	OFF	50 Ω

Table 2-6. Valid WaveNow Wireless Dummy Cell Switch Combinations

"A" Switch Position	"B" Switch Position	Effective Load
OFF	OFF	1 GΩ
OFF	ON	4.99 MΩ
ON	OFF	5 kΩ

Table 2-7. Valid WavePico Wireless Dummy Cell Switch Combinations

3. System Installation

Setting up the WaveNow Wireless or WavePico Wireless in a laboratory consists of three basic steps: (1) physical installation, (2) software installation, and (3) system testing. The entire process usually requires about sixty minutes. The physical and software installation steps are described in this section (below), and the system testing procedures are described in the next section (see Section 4).

3.1 Physical Installation

The WaveNow Wireless and WavePico Wireless are portable instruments designed for use in a typical laboratory environment. Physical installation involves positioning the instrument and the computer that controls the instrument in suitable locations and connecting the instrument to a source of electrical power (*i.e.*, the AC Mains) and to the computer either wirelessly via a wireless USB dongle or physically via a USB cable.

> **NOTE:**
>
> **This unit must be operated with the supplied cell cable to ensure compliance with FCC regulations.**

3.1.1 Location

The instrument should be placed on a sturdy lab bench, table, or inside a glovebox or chamber in such a way that there is unobstructed access to the instrument's front and back panels; this ensures space for the cell cable, power cord, and USB cable (if connected physically) connections, as well as allows the user to see the LED lights on the front panel. There should also be at least two inches (50 mm) of clearance around the sides (left, right, and back) and above (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 front panel of the instrument. Thus, it is important to ensure that the instrument's physical location 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 Operation

For most standard potentiostats that require a physical connection to a computer (*e.g.*, USB cable), there are two practical ways to perform electrochemical experiments inside a glovebox. One option is to place both the potentiostat and electrochemical cell inside the glovebox; the other option is to place only the cell inside the glovebox while the potentiostat remains outside. These options may require that electrical power be present inside the glovebox to power the instrument, and the glovebox may also need to be equipped with special feedthroughs for the cell cables and/or the USB communication cable.

Taking full advantage of the wireless communication ability of the WaveNow Wireless and WavePico Wireless by placing both the instrument and the electrochemical cell inside the glovebox is by far the easiest and preferred approach to working with an electrochemical cell in a glovebox. By keeping the instrument close to the cell, the cell cables are shorter, minimizing interference from environmental noise sources. This approach also requires no glovebox feedthroughs because the computer can control the

WaveNow Wireless or WavePico Wireless remotely via the wireless USB dongle, making cable management simpler.

The instrument may be transferred into the glovebox by passing it through the glovebox antechamber. Any cables, power cords, or instrument accessories should also be transferred into the glovebox through the antechamber. When evacuating the antechamber, a gradual approach should be taken to prevent damage to instrument circuitry. The exact time needed to fully remove any residual air from the potentiostat and accessories varies by antechamber size and vacuum strength. While it is recommended to follow established glovebox user protocols, it is also suggested that the amount of time the instrument is exposed to vacuum be as short as possible. 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, gas valve actuators, vibrations, etc.). Once the instrument is placed inside the glovebox, it is a good idea to leave it in the glovebox; repeated cycling through the antechamber is not recommended.

In the unlikely case where it may be necessary to use a physical USB cable to communicate with the instrument inside the glovebox, the glovebox will need to 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) that 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).
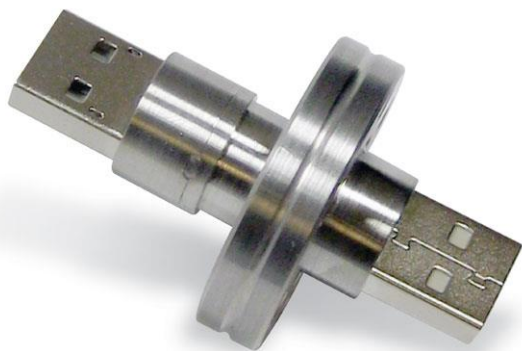
Copyright © Kurt J. Lester Company. Used with permission.

Figure 3-1. USB Cable Glovebox Feedthrough

3.1.3 Connecting the Power Supply to the Instrument

Figure 3-2. WaveNow Wireless with Low Voltage Power Supply Connected to Back Panel

The power supply provides the DC power required by the instrument (5 VDC, 2.0 A) 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 input port located on the back panel of the instrument (see Figure 3-2).

3.1.4 Connecting the Power Supply to the AC Mains

The WaveNow Wireless and WavePico Wireless power supply is connected to the AC Mains via an AC power cord. One end of the AC power cord is connected to the standard C14 connector on the power supply, and the other end is connected to the AC Mains (wall outlet). Pine Research offers power cords suitable for use in a variety of countries and regions (see Section 7).

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 A. 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 AC power cord must be positioned such that the user has 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 (wall outlet) without any obstructions.

CAUTION:

Connect the power supply to the AC Mains using the power cord supplied with the WaveNow Wireless or WavePico Wireless and certified for the country of use (see Section 7 of this User Guide for more details).

ATTENTION:

Connectez le bloc d'alimentation au secteur à l'aide du cordon d'alimentation fourni avec l'appareil WaveNow Wireless ou WavePico Wireless 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 its cord. The user must have access to disconnect the power supply or the power cord from the AC Mains at all times.

ATTENTION:

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 power switch located on the back panel of the instrument disconnects the instrument from the power source. Do not block access to the power switch. The user must have access to the power switch at all times.

ATTENTION:

L'interrupteur d'alimentation situé sur le derrière de l'appareil permet de couper l'alimentation. Ne bloquez pas l'accès à l'interrupteur. L'utilisateur doit avoir accès à l'interrupteur à tout moment.

3.2 AfterMath Software Installation

> **STOP:**
>
> **Do not use the USB cable or wireless USB dongle to connect the WaveNow Wireless or WavePico Wireless to the computer until after the software and driver installation are complete. It is important to first install AfterMath and the associated device driver software so that Microsoft Windows can properly detect the instrument.**

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 Speed	1 GHz (32-bit or 64-bit processor) minimum
Physical Memory	2 GB minimum recommended RAM; 4 GB minimum (for 32-bit processor) or 6 GB (for 64-bit processor) preferred
Screen Resolution	1366 × 768 (also known as HD) minimum 1920 × 1080 (Full HD or 1080p) or greater recommended
Operating System	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	Microsoft .NET Framework (version 4.0) Microsoft Visual C++ Runtime Library (version 8.0)

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. If they are missing from the computer, these components are available for free download from the Microsoft website. Up-to-date AfterMath and Microsoft Corporation download links are maintained on the Pine Research knowledgebase website.

> **TIP:**
>
> **The most up-to-date versions of the software required to operate the WaveNow Wireless and WavePico Wireless instruments may be found on the Pine Research knowledgebase at the following address:**
>
> **https://www.pineresearch.com/shop/knowledgebase/**

3.2.1 Step-by-Step Software Installation Instructions

AfterMath installation media is included with the WaveNow Wireless and WavePico Wireless. The installation media contains the latest release of AfterMath available at the time of purchase, the device drivers for communicating with the instrument, and the permissions files that activate 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 3-3 through Figure 3-13).
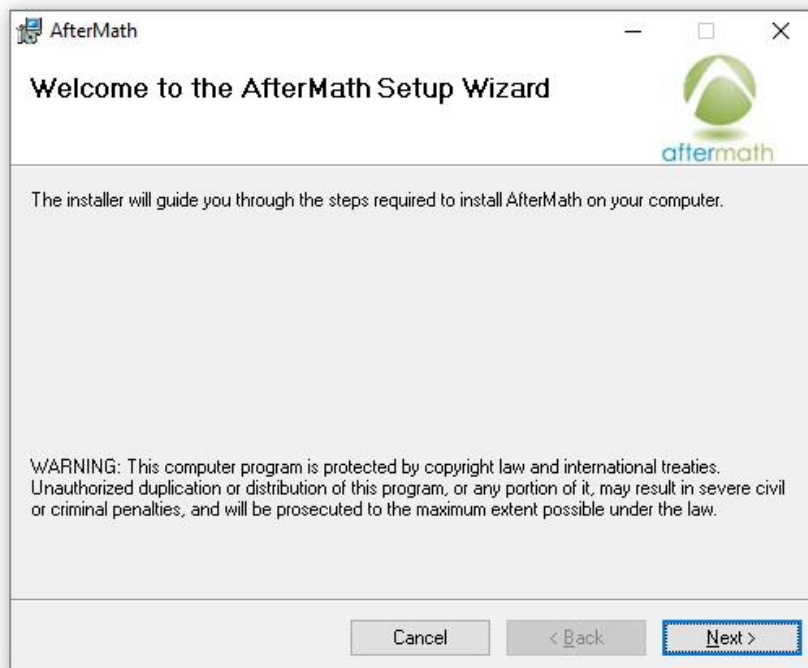
Figure 3-3. Welcome to AfterMath Setup Wizard Dialog Box
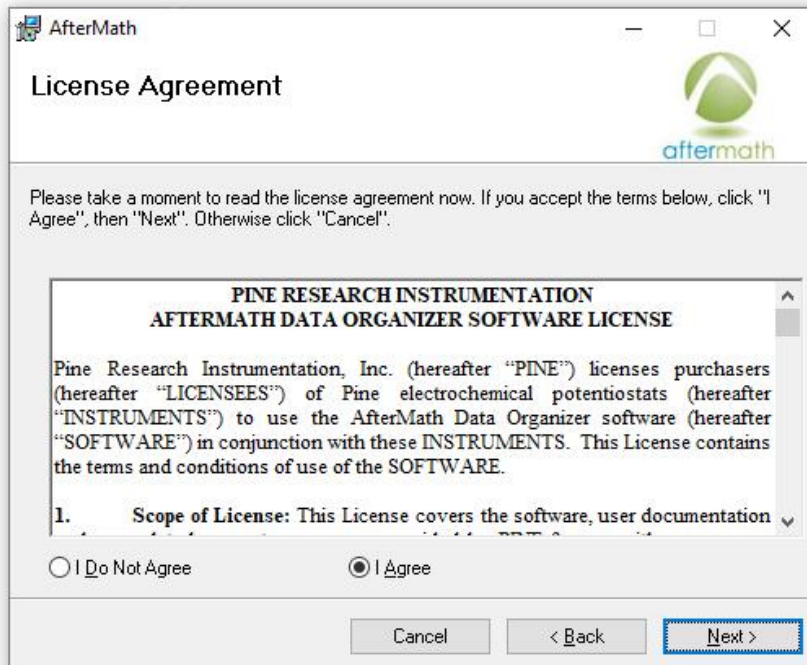
Figure 3-4. AfterMath Installation License Agreement
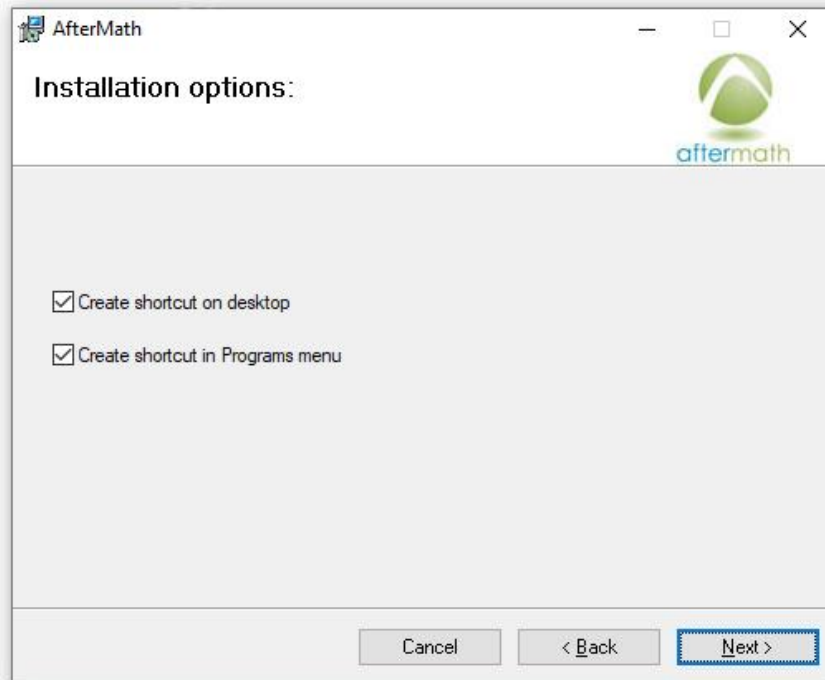
Figure 3-5. AfterMath Installation Options
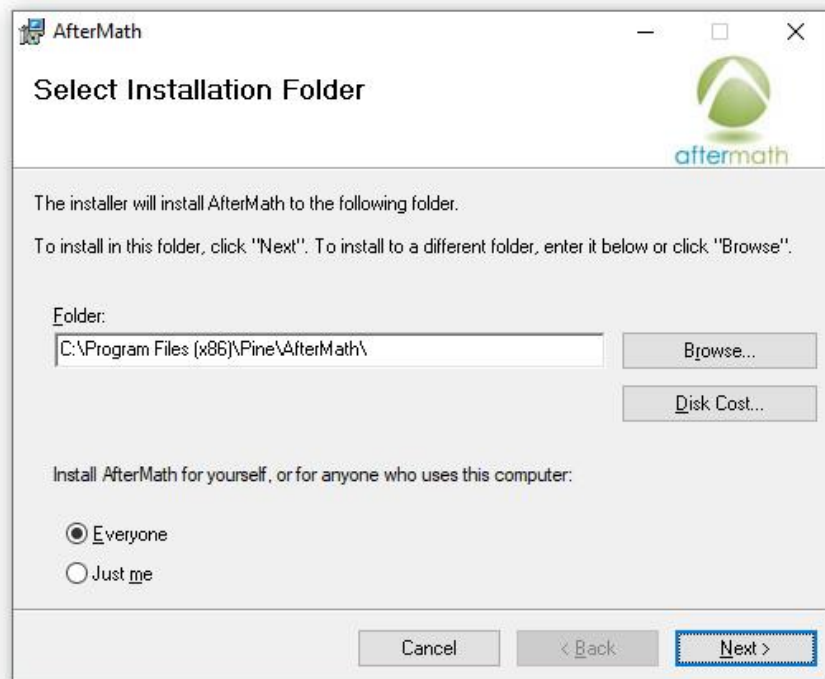
Figure 3-6. Selecting AfterMath Installation Folder and User Access
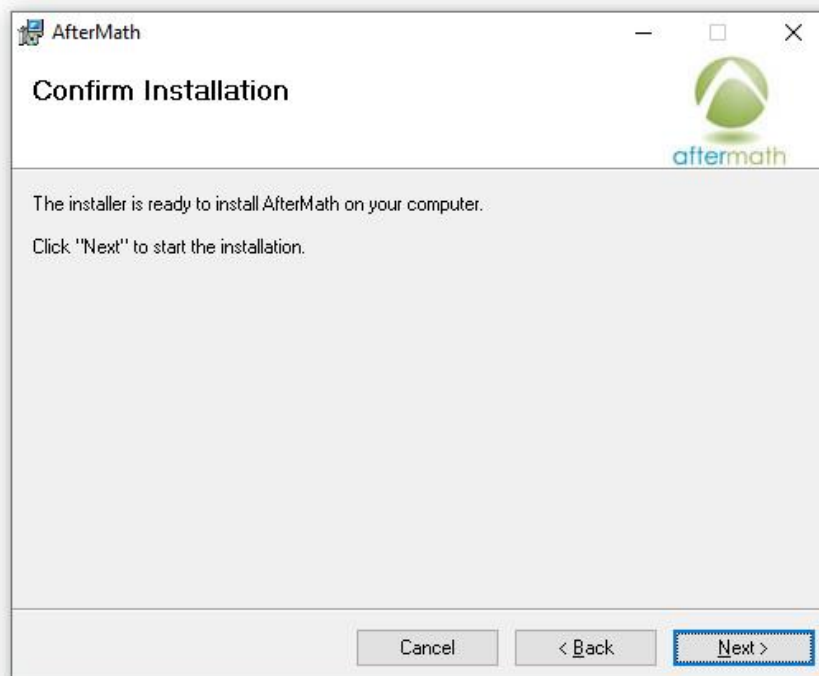
Figure 3-7. Confirm Installation of AfterMath
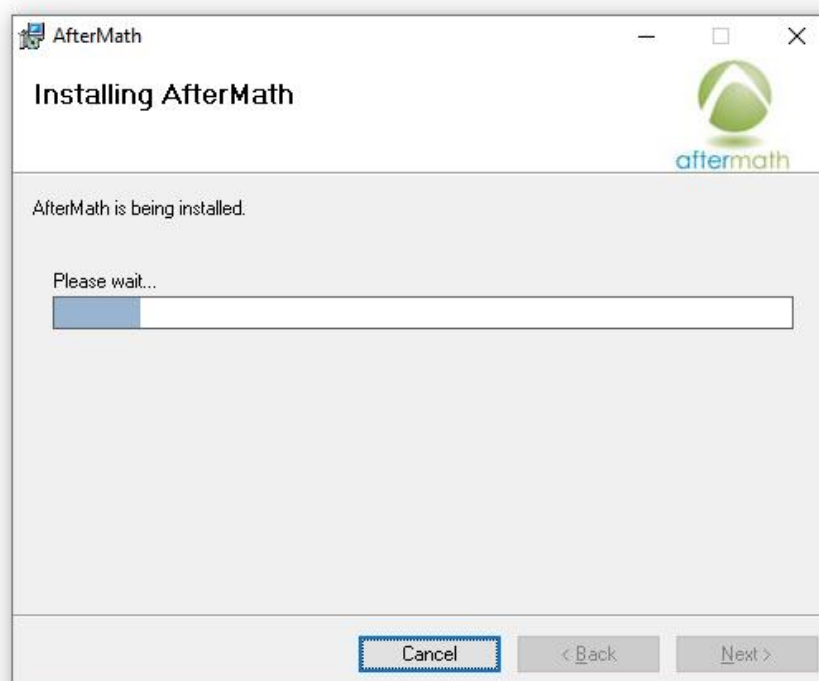
Figure 3-8. Installation Progress of AfterMath
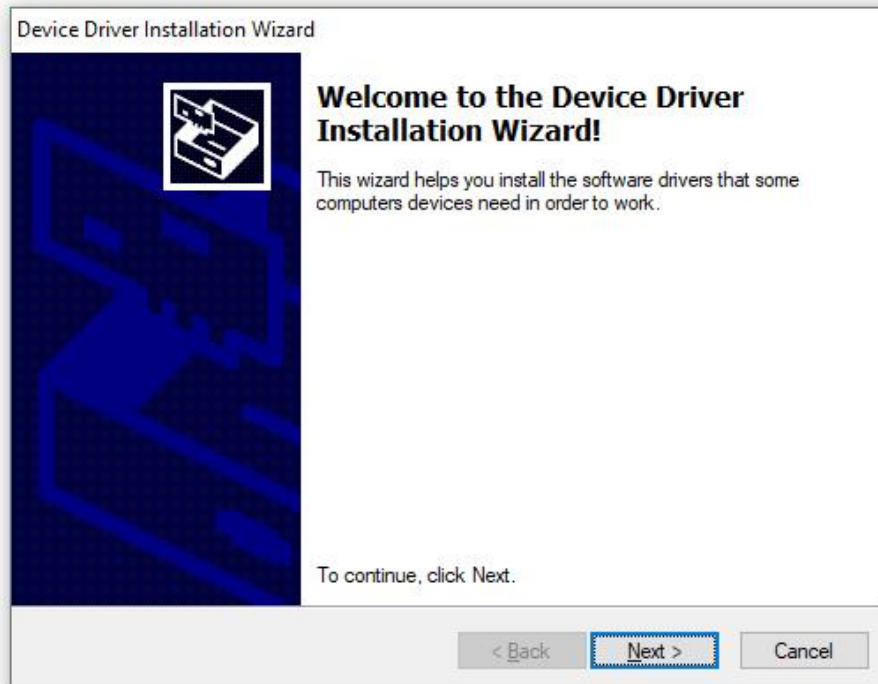
Figure 3-9. Device Driver Installation Wizard
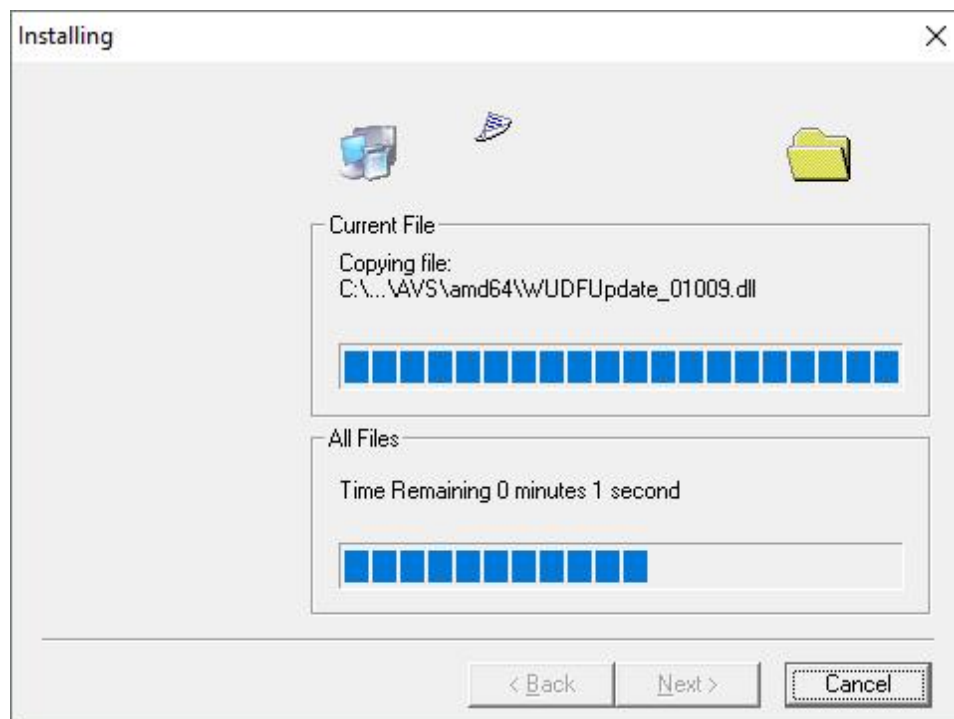
Figure 3-10. USB/Device Driver Installation Progress
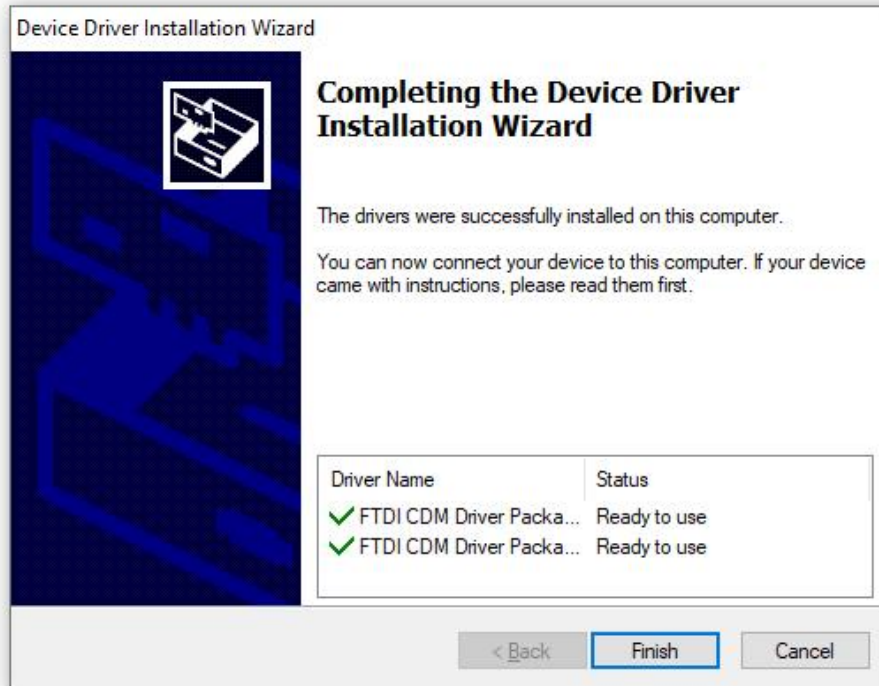
Figure 3-11. USB/Device Driver Installation Completion
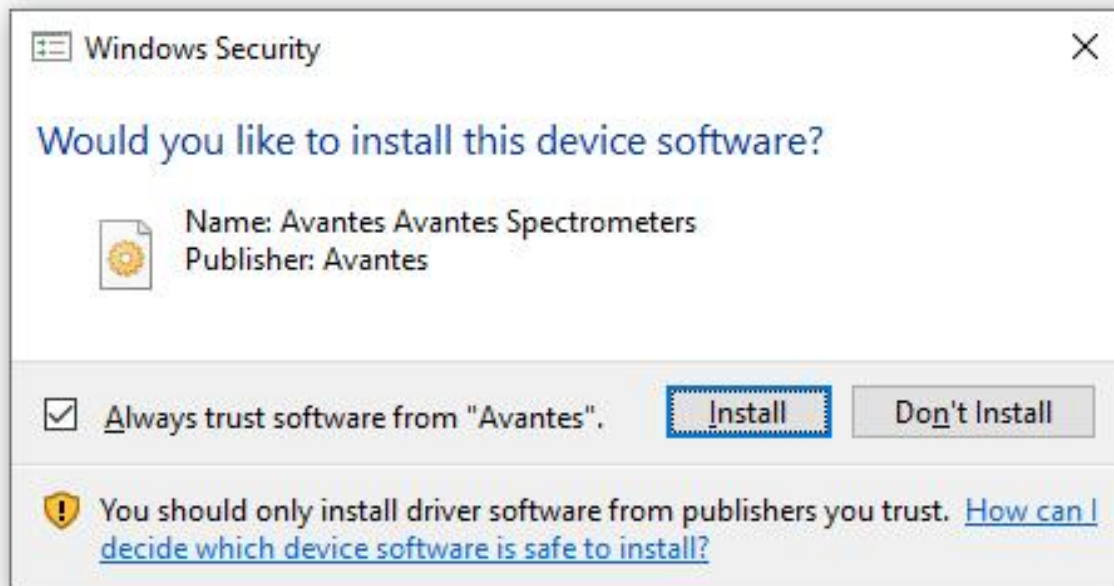
Figure 3-12. Windows Security Prompt to Install Device Software
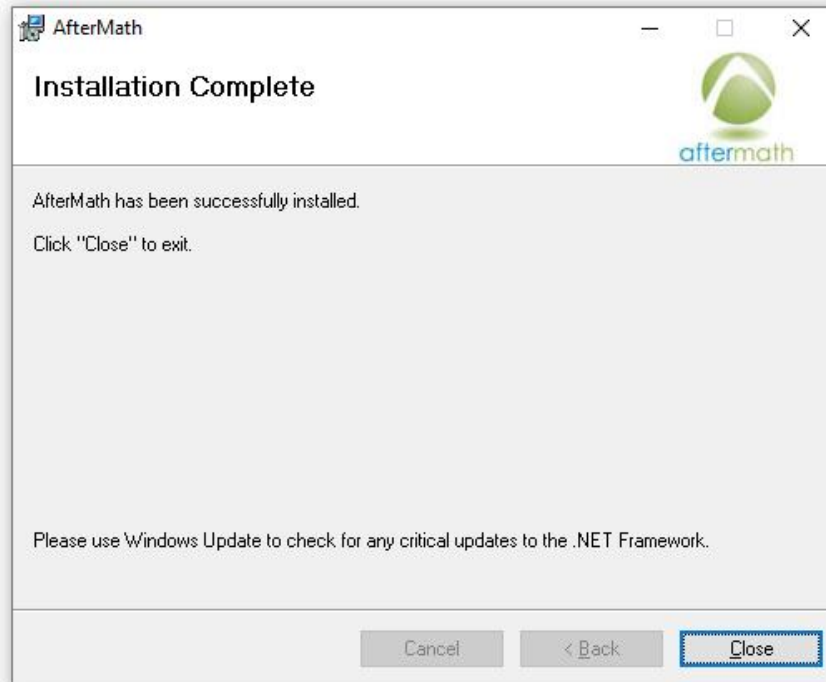
Figure 3-13. Confirmation of Successful AfterMath Installation

3.2.2 Permissions File Verification

On the installation media, there are license files, or "permissions files", which authorize a computer running AfterMath to control specific instruments (see Figure 3-14). If Aftermath is installed on the computer using the installation media shipped with a particular instrument, then these permissions files are automatically copied to the computer.

If AfterMath is downloaded directly from the internet and installed on a computer, then the permissions files may not be present on the computer. Users typically notice this condition when the AfterMath "Perform" button is disabled (gray shading – see Figure 3-15). To be sure the proper permissions files are on the computer, launch the AfterMath software. Separately, view the content on the installation media and locate the permissions files (ending in *.papx file extension). Next, drag and drop the permissions files from the installation media directly into the upper left section of the AfterMath window (see Figure 3-16). The AfterMath program will remember the permissions files even after the program is closed (*i.e.*, this step only needs to be performed once). A prompt may appear to allow AfterMath to make changes to the computer.

> **NOTE:**
>
> **Contact Technical Service for assistance (see Section 1.6) if there are any issues with software licensing or permissions files.**
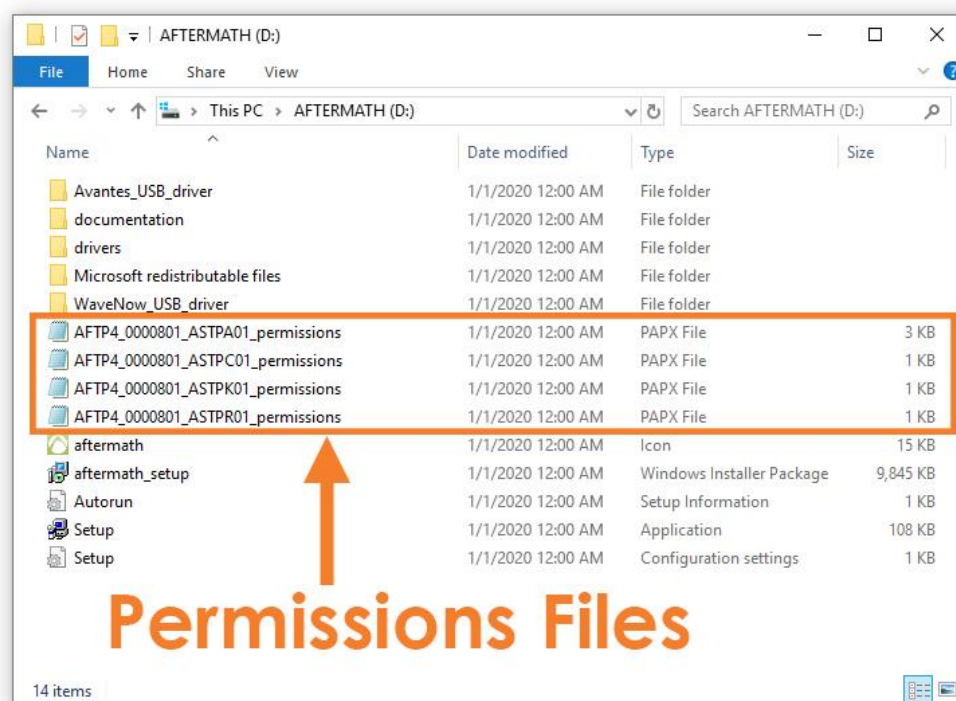
Figure 3-14. Permissions Files on Installation Media
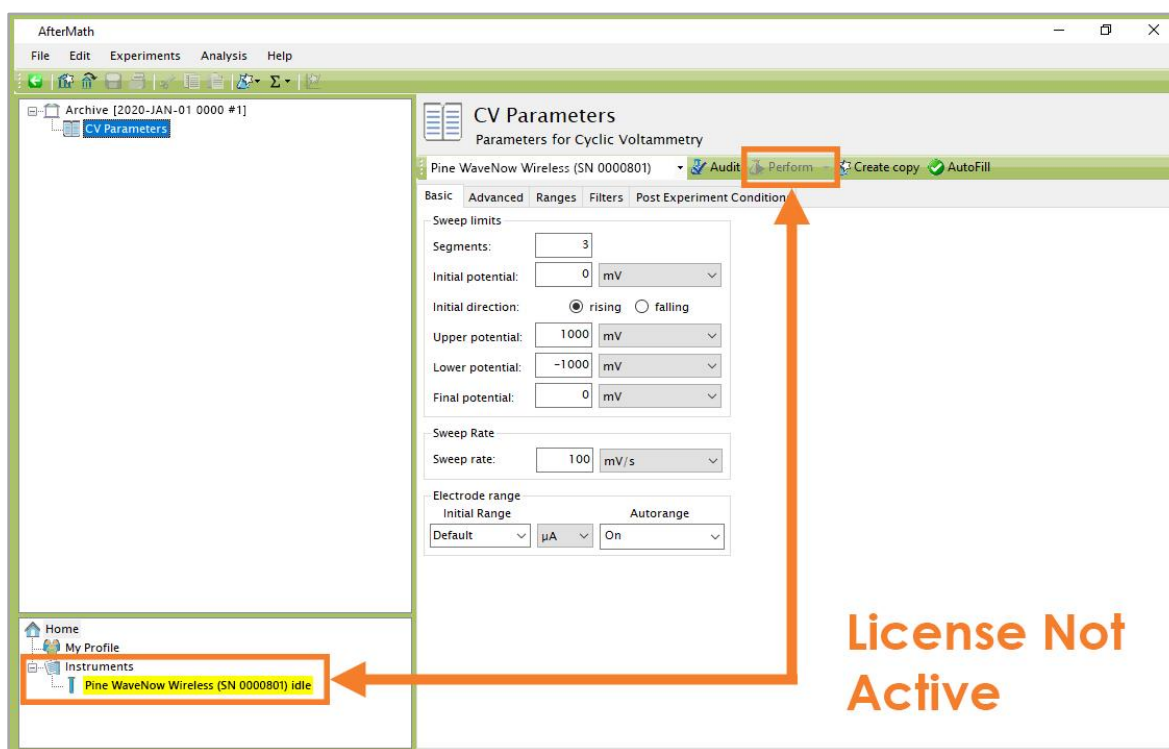
Figure 3-15. Indications that the AfterMath License is not Active
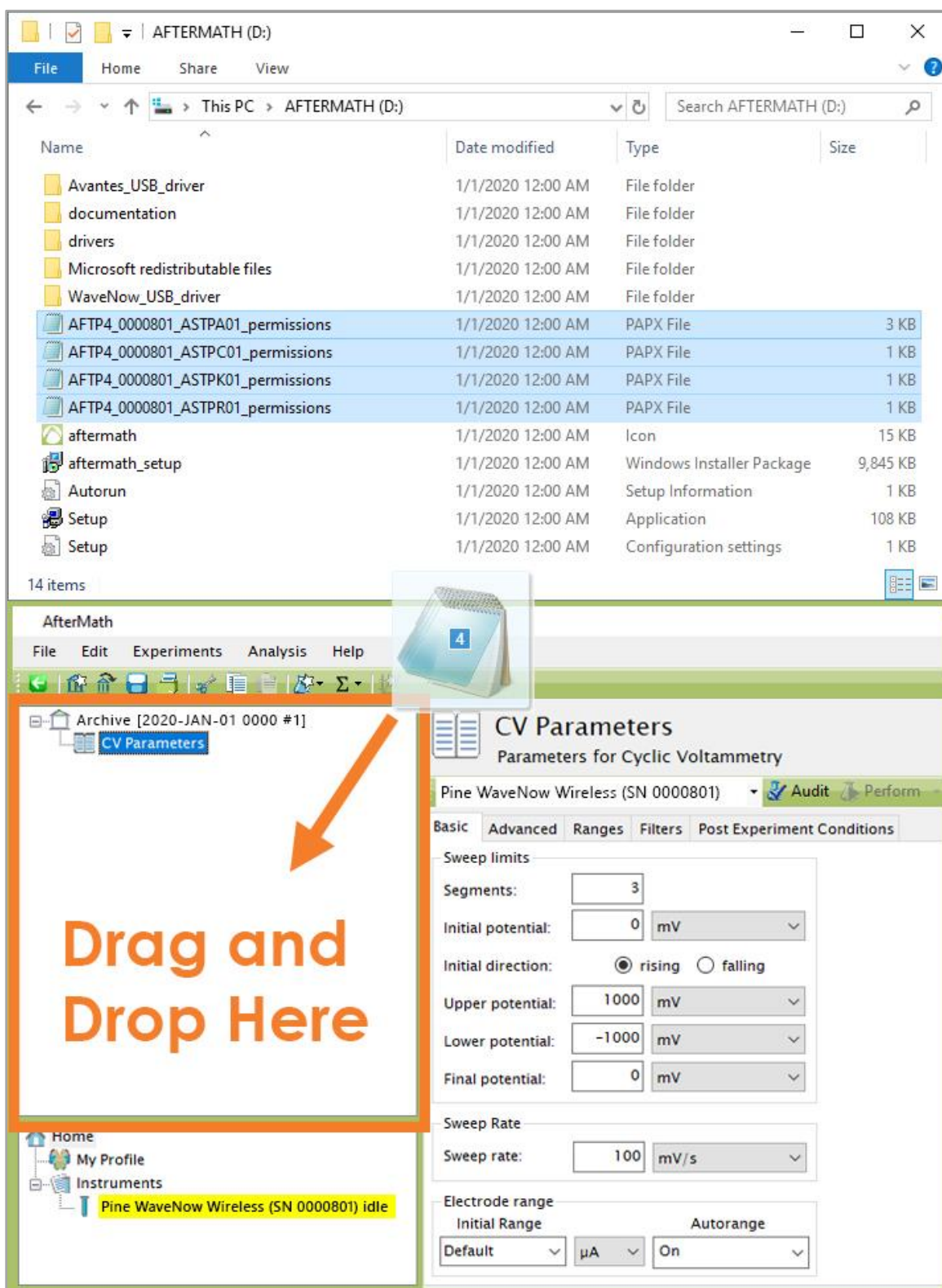
Figure 3-16. Copying Permissions Files to AfterMath

3.3 Connecting to the WaveNow Wireless or WavePico Wireless

The WaveNow Wireless and WavePico Wireless can be connected to a computer in one of two ways: either wirelessly using a wireless USB dongle, or physically using a USB interface cable. Both the wireless USB dongle and USB interface cable are supplied with the instrument. Whether using the wireless or physical connection method, the USB port on the computer must be capable of USB 2.0 (or better) data transfer rates.

> **NOTE:**
>
> **When troubleshooting wireless communication issues, it is suggested to first confirm the instrument is behaving properly using the hardwired USB interface cable before moving on to a wireless connection.**

3.3.1 Physical USB Cable Connection

The WaveNow Wireless or WavePico Wireless can be connected to a computer physically using the included USB interface cable (Type A male to Type B female – see Figure 3-17). When connected to AfterMath via USB cable, the communication status LED on the front panel is blue-green and flickers intermittently while the instrument is idle (see Figure 3-18). When running an experiment with significant data transfer occurring between the instrument and the host computer, the communication status LED flashes more rapidly or may even appear as a solid color.

If the USB cable and wireless USB dongle are connected to the computer simultaneously, the connection pathway will default to the physical USB cable over the wireless USB dongle. This is because hardwired data transfer rates are faster than wireless rates. The WaveNow Wireless and WavePico Wireless offer the benefit of wireless connection when it is difficult or impossible to physically connect the potentiostat and computer, but if both options are available, the user may opt for a hardwired connection in lieu of a wireless connection to improve data transfer rates and communication. When connected via USB cable, disconnect the wireless USB dongle from the computer and store it in a secure location for future wireless use.

> **NOTE:**
>
> **If both wireless and physical USB cable connection options are available, the user should consider connecting the WaveNow Wireless or WavePico Wireless directly via USB cable to improve data transfer rates and instrument communication.**

> **NOTE:**
>
> **When a hardwired USB connection is in use, it is recommended that the wireless USB dongle be disconnected from the computer.**

Figure 3-17. USB Cable Connection Between Potentiostat and Computer

Figure 3-18. Instrument Light Status during Hardwired USB Connection (Blue-Green)

3.3.2 Wireless USB Dongle Connection

To connect the WaveNow Wireless or WavePico Wireless to a computer wirelessly, insert the wireless USB dongle into an open USB port on the computer. When the dongle is connected to the computer but has not yet detected the instrument (likely because the potentiostat is either out of range or not yet powered on), a small red LED light will flash on and off slowly (see Figure 3-19). Ensure that electrical power is connected to the WaveNow Wireless or WavePico Wireless and the instrument power switch is in the "on" position (|).

The LED light that indicates the communications state of the instrument behaves in a manner similar to the corresponding LED on the wireless USB dongle. When the instrument is powered on but has not yet detected the dongle, the LED light is red and flashes slowly. Once a connection is established between the dongle and the instrument, both communication status LEDs (instrument and dongle) change to a solid blue color (see Figure 3-19 and Figure 3-20).

NOTE:

Each wireless USB dongle is configured for use with one specific WaveNow Wireless or WavePico Wireless instrument. A dongle configured for one instrument cannot be used to communicate with a different instrument.

If a wireless USB dongle has been damaged or misplaced, please contact Pine Research for assistance purchasing a replacement. In some cases, it may be necessary to physically send the WaveNow Wireless or WavePico Wireless to Pine Research to be able to reconfigure a new dongle for the instrument.

Figure 3-19. Wireless USB Dongle Indicating Connection Status (Red or Blue)

Figure 3-20. Instrument Light Status during Wireless Connection (Blue)

3.4 Installation Checklist

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

- ✓ The WaveNow Wireless or WavePico Wireless instrument is located in a secure, dry location

- ✓ Electrical Power is connected to the WaveNow Wireless or WavePico Wireless

- ✓ AfterMath software is installed on the computer

- ✓ The WaveNow Wireless or WavePico Wireless instrument is connected to a computer either via the wireless USB dongle or USB interface cable. It is suggested to first confirm the instrument is behaving properly and successfully connected to the computer via the hardwired USB cable first before testing the wireless USB dongle connection.

4. System Testing

This section describes how to test the WaveNow Wireless or WavePico Wireless potentiostat system. By connecting the potentiostat to a well-behaved network of resistors (using the 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 tests described here. When contacting Technical Service (see Section 1.6) for assistance, the tests described below are often the first suggested actions.**

4.1 Test Setup

4.1.1 Launch the AfterMath Software

Launch AfterMath, which should already be installed on the computer (see Section 3), and log into AfterMath (see Figure 4-1). Click "OK" on the AfterMath Login dialog window to launch the application.
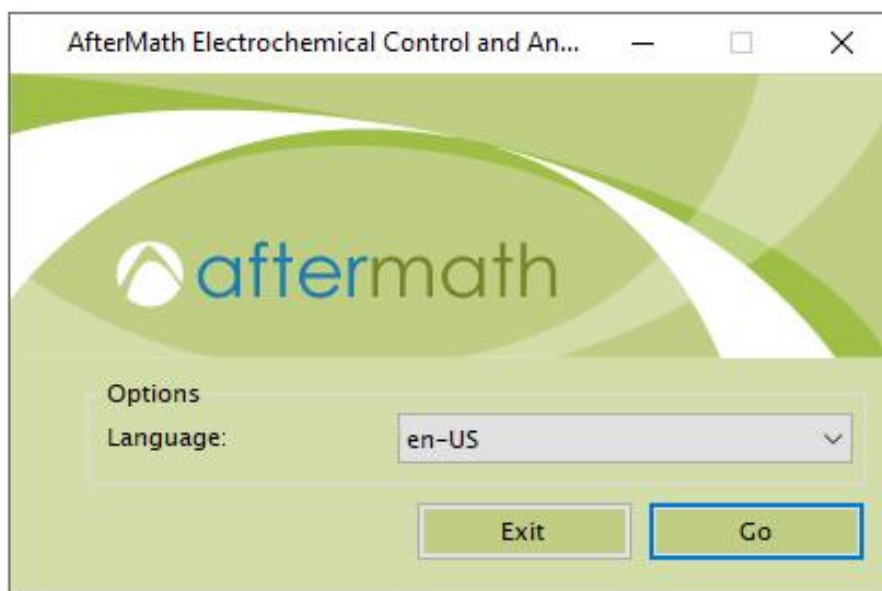
Figure 4-1. Initial Login Screen when Starting AfterMath

4.1.2 Verify Instrument Status

Turn on the instrument using the back panel power switch and wait for the WaveNow Wireless or WavePico Wireless to appear in the AfterMath instruments list. The instrument should appear along with its serial number under the "Instruments" node (see lower-left portion of the screenshot shown in Figure 4-2).
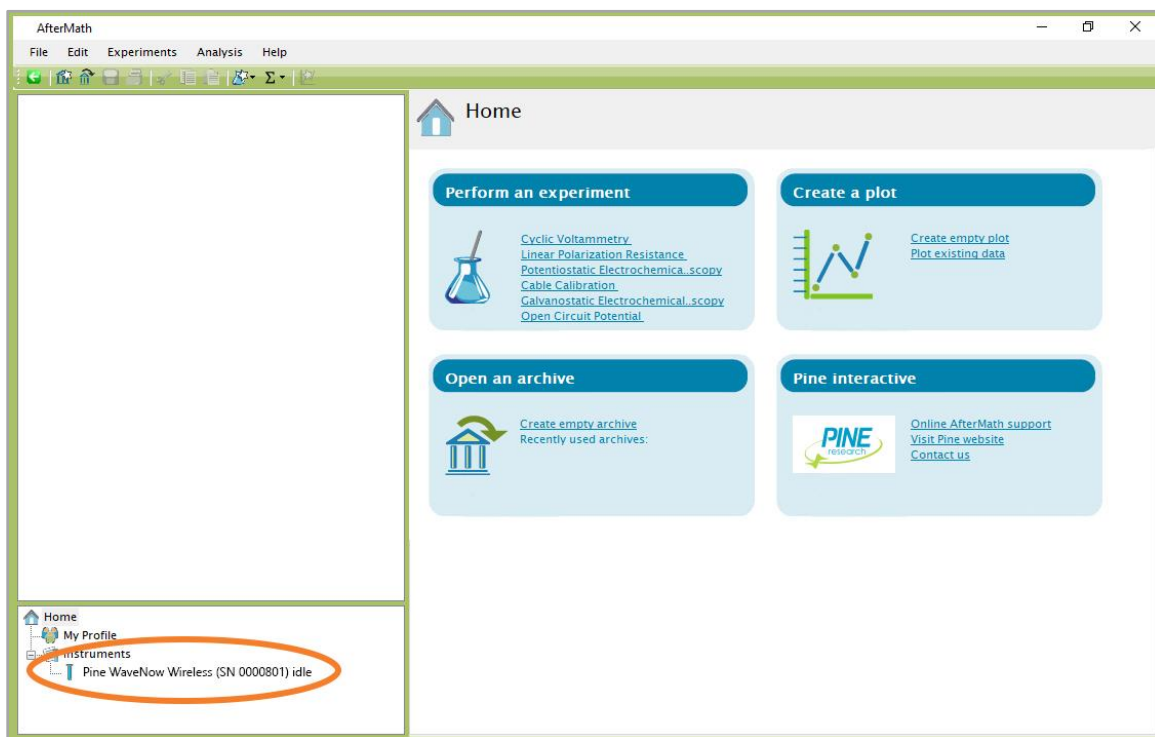
Figure 4-2. AfterMath Screenshot with Connected Instrument Circled

4.1.3 Confirm Connections

Check the status LED on the front panel of the WaveNow Wireless or WavePico Wireless. After about fifteen seconds, this LED should be green, indicating that the instrument is idle (see Figure 4-3). Also, the communication LED should either be solid blue (for a wireless connection) or flickering blue-green occasionally (for a physical USB connection) (see Table 2-4 for more information about LED indicators).

Figure 4-3. Indicator Lights on the Front Panel of the WaveNow Wireless

4.1.4 Review Instrument Status

Examine the instrument status display (see Figure 4-4). The information on the "Idle" tab may initially indicate that the cell is disconnected. If desired, the controls on this tab can be used to apply a known idle condition to the cell. In the example shown below (see Figure 4-4), the instrument is connected to the external cell, and the working electrode is set to idle under potentiostatic control while applying 1.2 V to the working electrode.
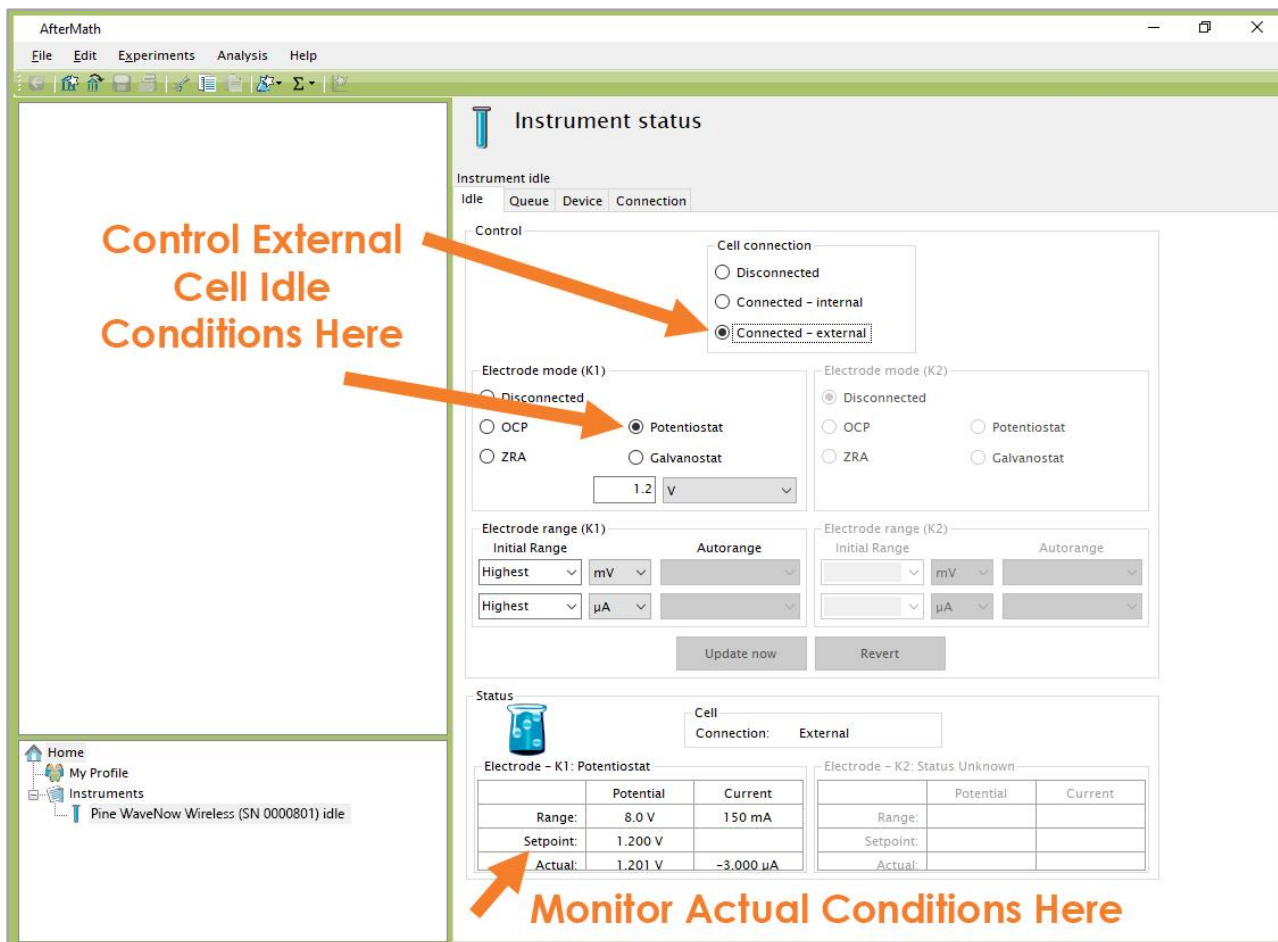
Figure 4-4. AfterMath Instrument Status Window showing External Cell Idle Conditions

4.2 WaveNow Wireless Dummy Cell Cyclic Voltammetry Experiment

> **NOTE:**
>
> Section 4.2 pertains only to the WaveNow Wireless. If using a WavePico Wireless, skip Section 4.2 entirely and jump to Section 4.3.

4.2.1 Connect to the Dummy Cell

Connect the WaveNow Wireless dummy cell (Pine Research part number AB01DUM7) to the cell port on the front panel of the WaveNow Wireless (see Figure 4-5). Adjust the two switches on the front of the dummy cell so that switch "A" is "OFF" and switch "B" is "ON", creating a resistive load of 49.9 kΩ (see Section 2.8 and Table 2-6 for dummy cell details, and see Figure 4-5 for image of dummy cell with proper switch configuration).

Figure 4-5. WaveNow Wireless Connected to Dummy Cell with $49.9\ \text{k}\Omega$ Resistor Setting

4.2.2 Create a Cyclic Voltammetry (CV) Experiment

From the AfterMath Experiments menu, choose Cyclic Voltammetry (CV). Doing so creates a "CV Parameters" node within a new archive. Configure the parameters as shown (see Figure 4-6).

1	Click on the "AutoFill" button. Note that default parameters appear automatically (including the Number of Segments, the Sweep Limits, and the Sweep Rate).
2	These parameters control the waveform used during the experiment.
3	Set the Electrode Range to "±150 μA" and set Autorange "Off" (this disables auto-ranging and selects the ±150 μA range for use throughout the test).

Figure 4-6. WaveNow Wireless Cyclic Voltammetry (CV) Parameters Dialog Window

4.2.3 Audit Experimental Parameters

Choose the WaveNow Wireless potentiostat in the drop-down menu if it is not already selected (see Figure 4-7, to the left of the "Audit" button), and then press the "Audit" button to check the parameters. AfterMath will perform a quick audit of the parameters to ensure that all parameters are specified and fall within allowed ranges.

4.2.4 Initiate the Experiment

Click the "Perform" button to initiate the CV experiment. The "Perform" button is located just to the right of the "Audit" button (see Figure 4-7).
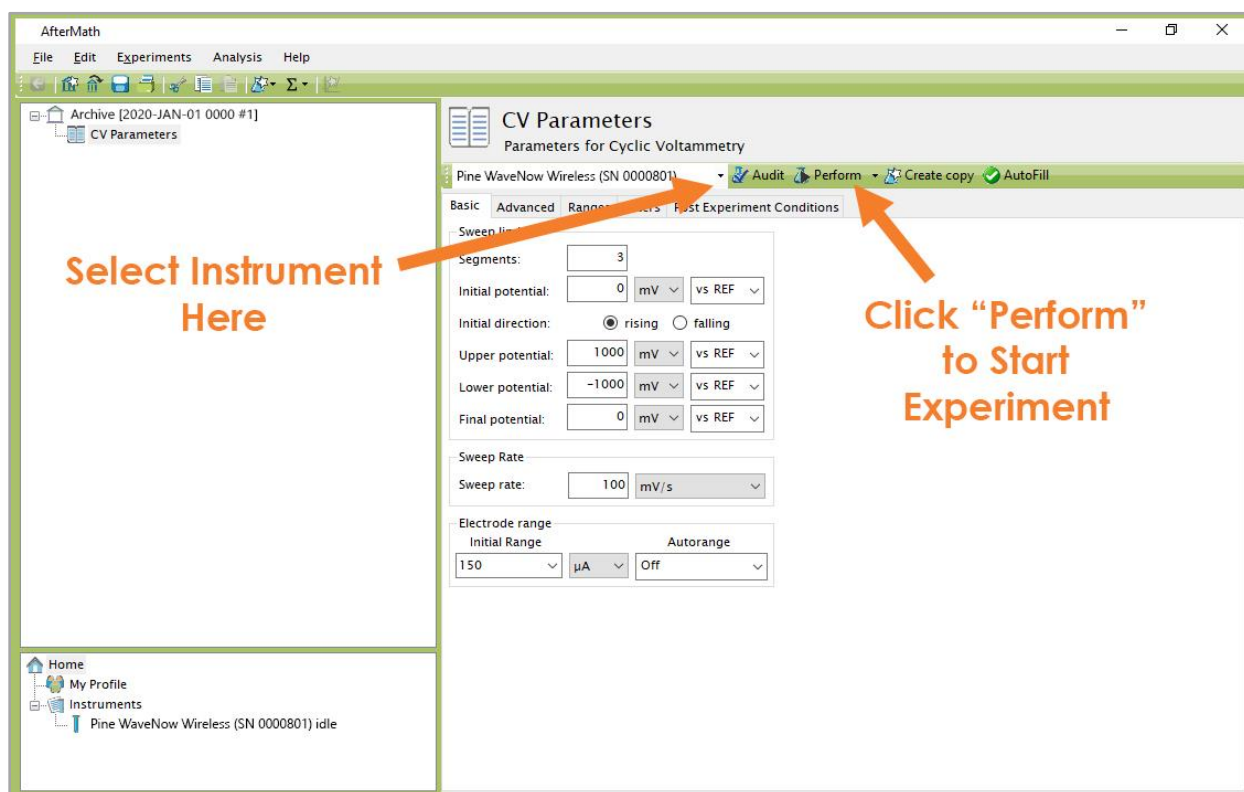
Figure 4-7. Location of Instrument Selection Menu and Perform Button

> **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 4-8).
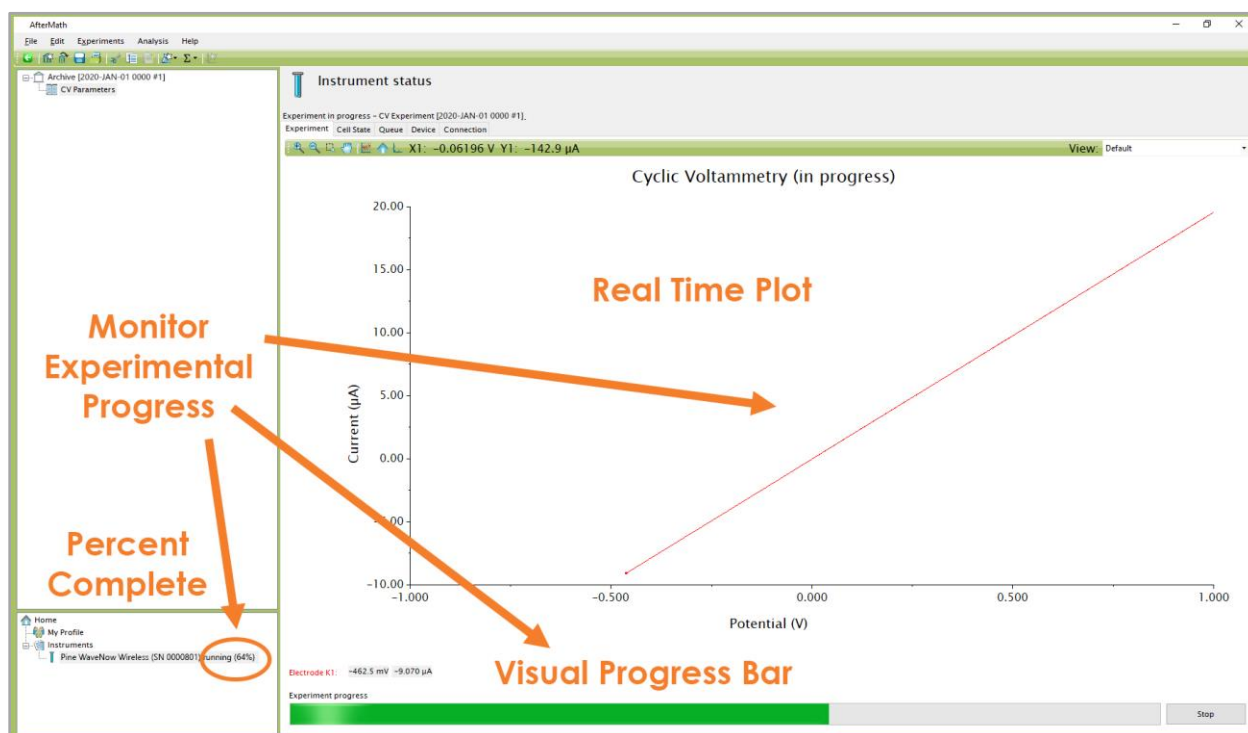
Figure 4-8. Monitoring the Progress of the WaveNow Wireless CV Experiment

4.2.6 Review the Results

When the experiment is complete, the results of the experiment are placed in a folder within the archive (see Figure 4-9). In addition to the main voltammogram plot, additional graphs are available in the "Other Plots" folder. The results can also be viewed in tabular form under the "experiment" node.

> **EXPECTED RESULT:**
>
> **The anticipated test result (see Figure 4-9) is a diagonal line. The slope of this line ($\sim20.04\ \mu S$) is the reciprocal of the dummy cell resistance ($\sim49.9\ k\Omega$).**
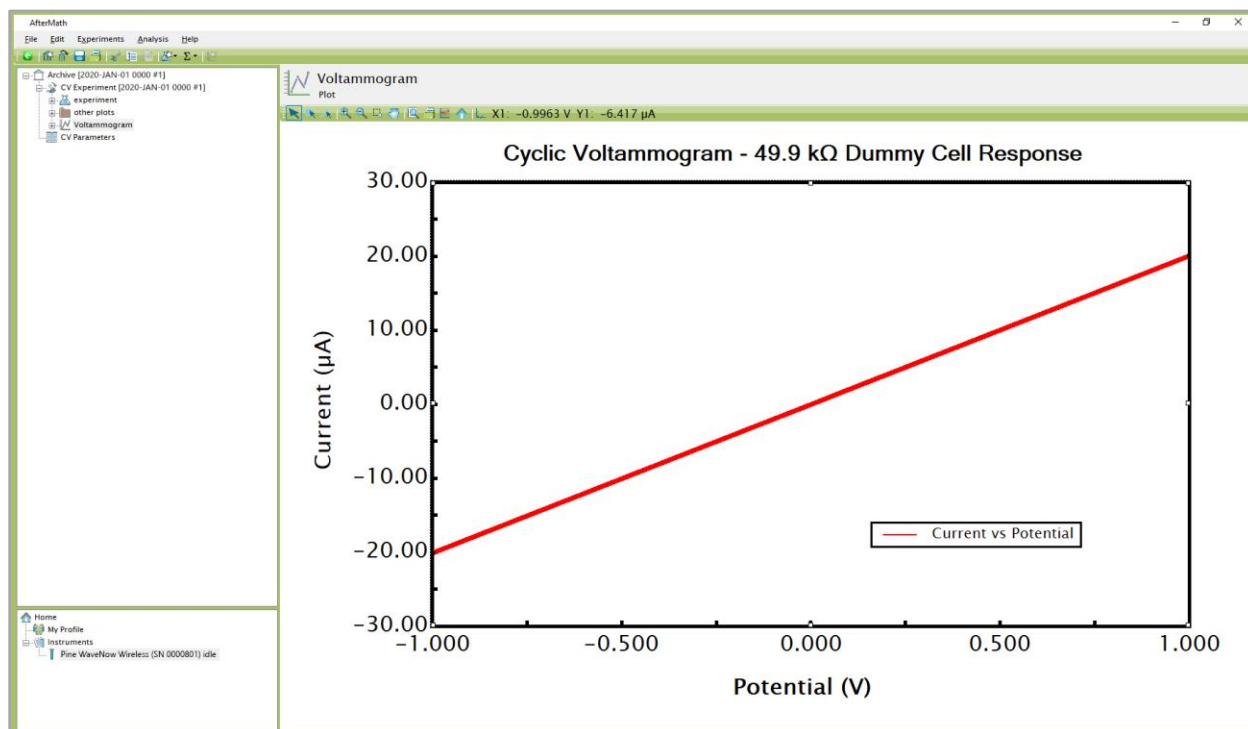
Figure 4-9. Anticipated Cyclic Voltammetry Results (WaveNow Wireless, $R = 49.9\,\mathrm{k\Omega}$)

4.2.7 Understanding the Results

With the dummy cell switches configured to present a 49.9 kΩ load (as shown in Figure 4-5), the plot of current vs. potential (as shown in Figure 4-9) appears as a diagonal line according to Ohm's Law as follows:

$$E = iR \quad \text{(Ohm's Law)} \tag{1}$$

where E is the potential, i is the current, and R is the resistive load. Considering that the cyclic voltammogram (see Figure 4-9) plots current along the vertical axis and potential along the horizontal axis, the slope ($\Delta i / \Delta E$) is equal to the reciprocal of the resistive load ($1/R = 1/49.9\,\mathrm{k\Omega} = 20.04\,\mathrm{\mu S}$).

To measure the experimental slope of the dummy cell data, right-click on the cyclic voltammogram trace, and then select the "Baseline" option from the "Add Tool" sub-menu. A baseline measurement tool appears on the voltammogram (see Figure 4-10), and two pink dots also appear that can be adjusted to change the endpoints of the baseline tool. However, since the entire trace is virtually a perfect straight line, the slope will not change appreciably regardless of the location of the endpoints.

For the example shown (see Figure 4-10), a slope of 20.09 µS is determined from the baseline tool, and the reciprocal is calculated as $1/20.09\,\mathrm{\mu S} = 49.8\,\mathrm{k\Omega}$, which is in good agreement with the anticipated load presented by the dummy cell.
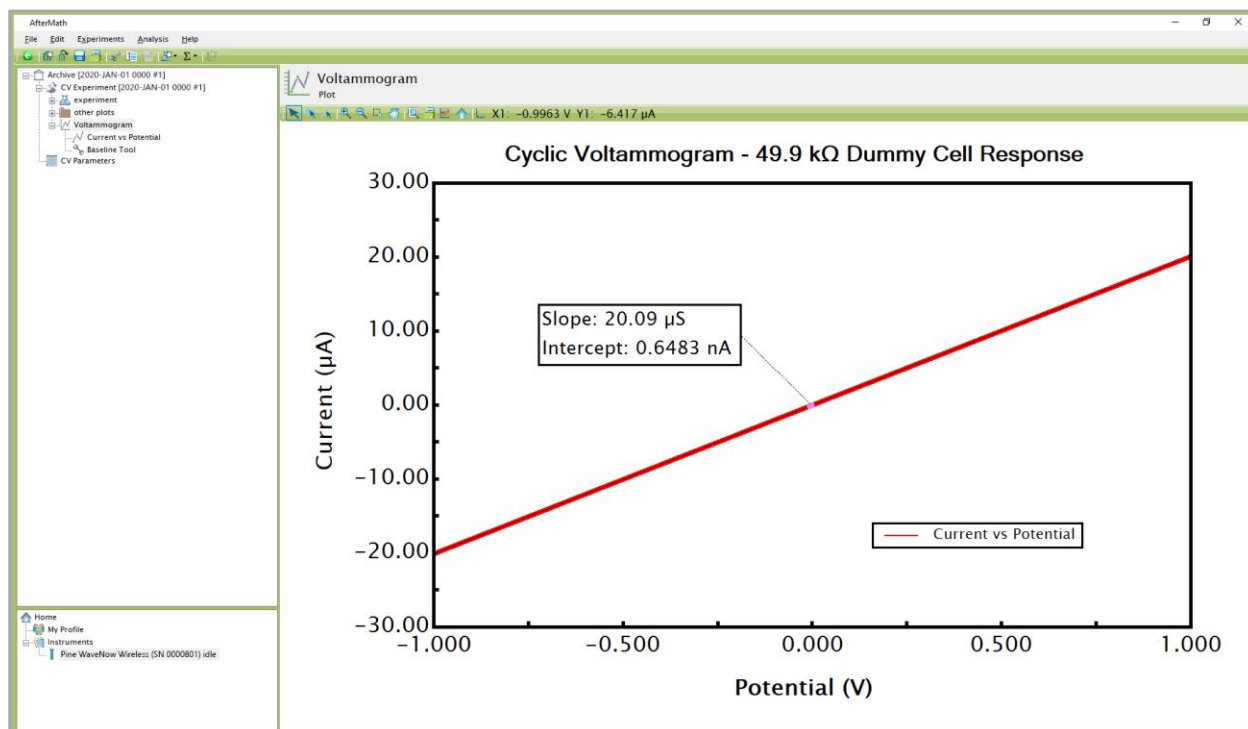
Figure 4-10. Observed Slope from Dummy Cell Experiment (WaveNow Wireless, $R = 49.9 \text{ k}\Omega$)

> **EXPLORE ADDITIONAL EXPERIMENTAL RESULTS:**
>
> Archive nodes often have a "+" sign next to the node name. Click on this "+" sign to open the node. In addition to the main plot produced by an experiment, additional results can be found in the "Experiment" node and in the "Other Plots" node. Nodes may be renamed and organized in folders as desired.

4.3 WavePico Wireless Dummy Cell Cyclic Voltammetry Experiment

> **NOTE:**
>
> This section pertains only to the WavePico Wireless. If using a WaveNow Wireless, skip Section 4.3 entirely.

4.3.1 Connect to the Dummy Cell
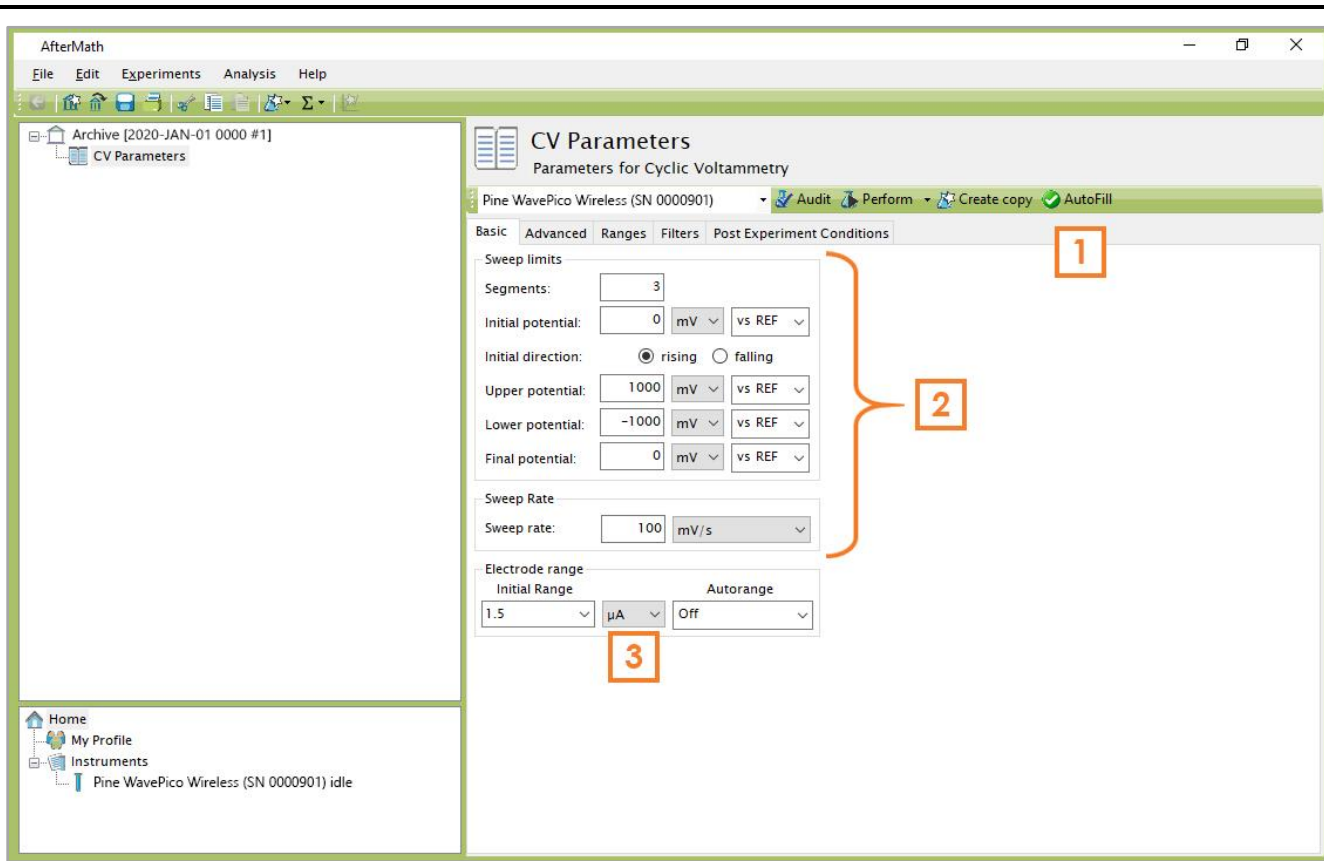
Connect the WavePico Wireless dummy cell (Pine Research part number AB01DUM8) to the cell port on the front panel of the WavePico Wireless (see Figure 4-11). Adjust the two switches on the front of the dummy cell so that switch "A" is "OFF" and switch "B" is "ON", creating a resistive load of 4.99 MΩ (see Section 2.8 and Table 2-7 for dummy cell details, and see Figure 4-11 for image of dummy cell with proper switch configuration).

Figure 4-11. WavePico Wireless Connected to Dummy Cell with $4.99\ \text{M}\Omega$ Resistor Setting

4.3.2 Create a Cyclic Voltammetry (CV) Experiment

From the AfterMath Experiments menu, choose Cyclic Voltammetry (CV). Doing so creates a "CV Parameters" node within a new archive. Configure the parameters as shown (see Figure 4-12).

1	Click on the "AutoFill" button. Note that default parameters appear automatically (including the Number of Segments, the Sweep Limits, and the Sweep Rate).
2	These parameters control the waveform used during the experiment.
3	Set the Electrode Range to "±1.5 µA" and set Autorange "Off" (this disables auto-ranging and selects the ±1.5 µA range for use throughout the test).

Figure 4-12. WavePico Wireless Cyclic Voltammetry (CV) Parameters Dialog Window

4.3.3 Audit Experimental Parameters

Choose the WavePico Wireless potentiostat in the drop-down menu if it is not already selected (see Figure 4-7, to the left of the "Audit" button), and then press the "Audit" button to check the parameters. AfterMath will perform a quick audit of the parameters to ensure that all parameters are specified and fall within allowed ranges.

4.3.4 Initiate the Experiment

Click the "Perform" button to initiate the CV experiment. The "Perform" button is located just to the right of the "Audit" button (see Figure 4-13).
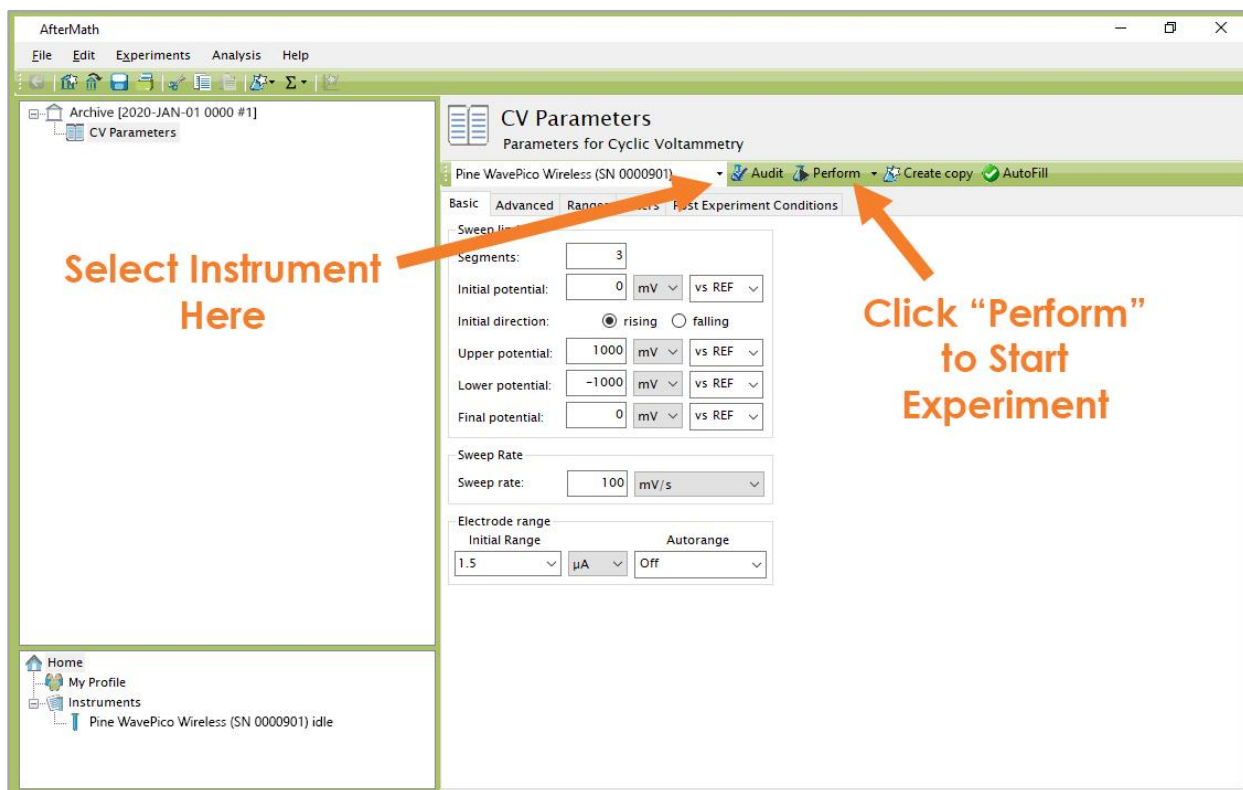
Figure 4-13. Location of Instrument Selection Menu and Perform Button

> **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).**

4.3.5 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 4-14).
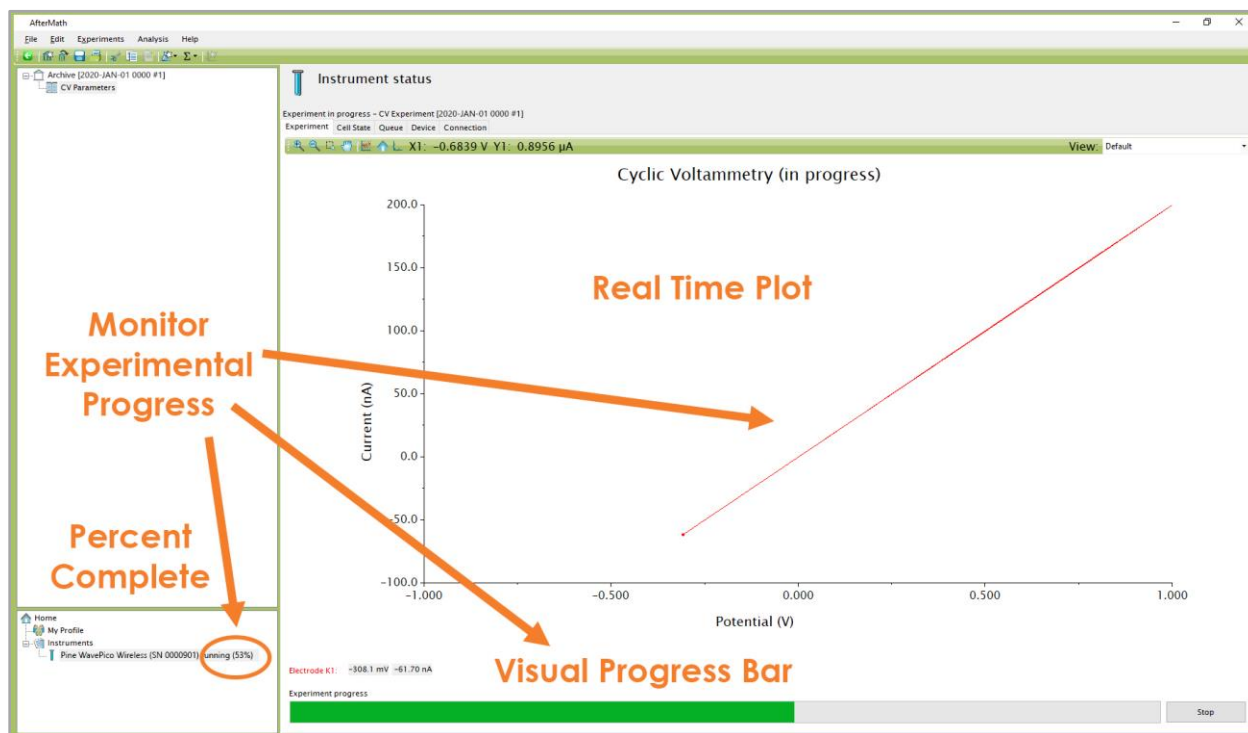
Figure 4-14. Monitoring the Progress of the WavePico Wireless CV Experiment

4.3.6 Review the Results

When the experiment is complete, the results of the experiment are placed in a folder within the archive (see Figure 4-15). In addition to the main voltammogram plot, additional graphs are available in the "Other Plots" folder. The results can also be viewed in tabular form under the "experiment" node.

> **EXPECTED RESULT:**
>
> **The anticipated test result (see Figure 4-15) is a diagonal line. The slope of this line (~ 199.9 nS) is the reciprocal of the dummy cell resistance (~ 4.99 MΩ.).**
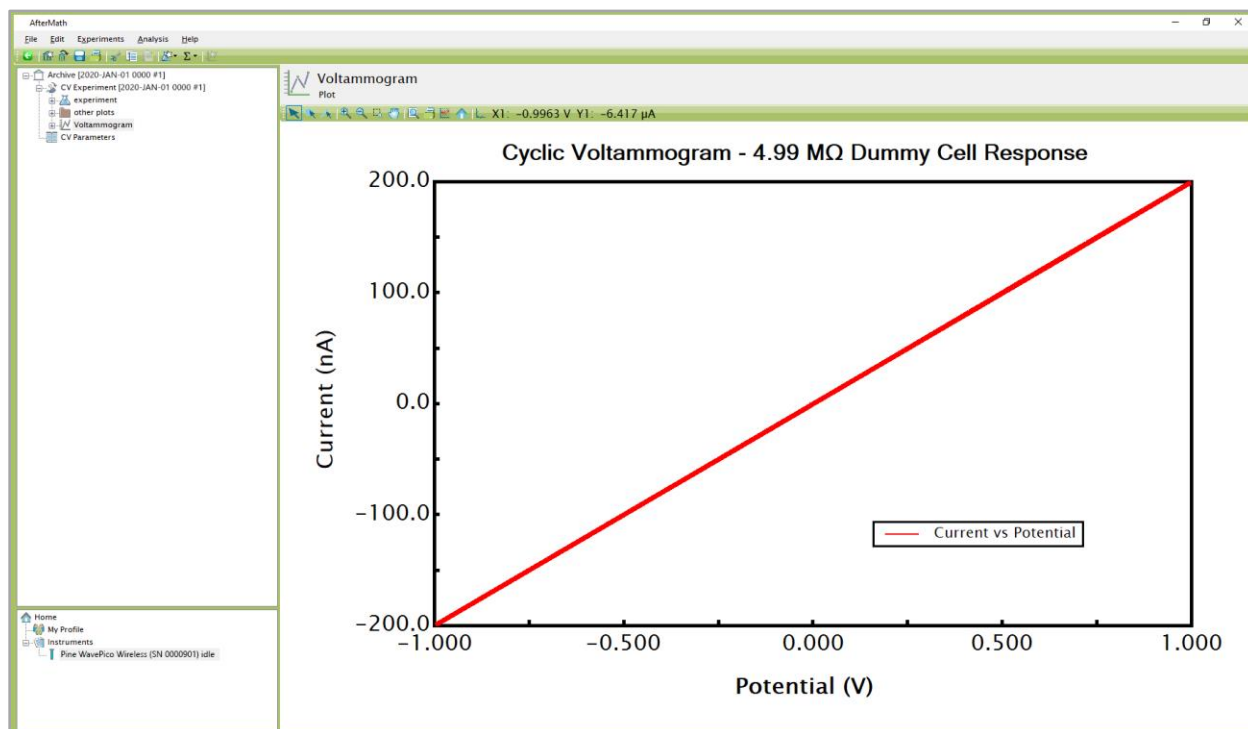
Figure 4-15. Anticipated Cyclic Voltammetry Results (WavePico Wireless, $R = 4.99$ MΩ)

4.3.7 Understanding the Results

With the dummy cell switches configured to present a 4.99 MΩ load (as shown in Figure 4-11), the plot of current vs. potential (as shown in Figure 4-15) appears as a diagonal line according to Ohm's Law as follows:

$$E = iR \quad \text{(Ohm's Law)} \tag{2}$$

where E is the potential, i is the current, and R is the resistive load. Considering that the cyclic voltammogram (see Figure 4-9) plots current along the vertical axis and potential along the horizontal axis, the slope ($\Delta i / \Delta E$) is equal to the reciprocal of the resistive load ($1/R = 1/4.99$ MΩ = 200.4 nS).

To measure the experimental slope of the dummy cell data, right-click on the cyclic voltammogram trace, and then select the "Baseline" option from the "Add Tool" sub-menu. A baseline measurement tool appears on the voltammogram (see Figure 4-16), and two pink dots also appear that can be adjusted to change the endpoints of the baseline tool. However, since the entire trace is virtually a perfect straight line, the slope will not change appreciably regardless of the location of the endpoints.

From the example shown (see Figure 4-16), a slope of 199.9 nS is determined from the baseline tool, and the reciprocal is calculated as $1/199.9$ nS = 5.00 MΩ, which is in good agreement with the anticipated load presented by the dummy cell.
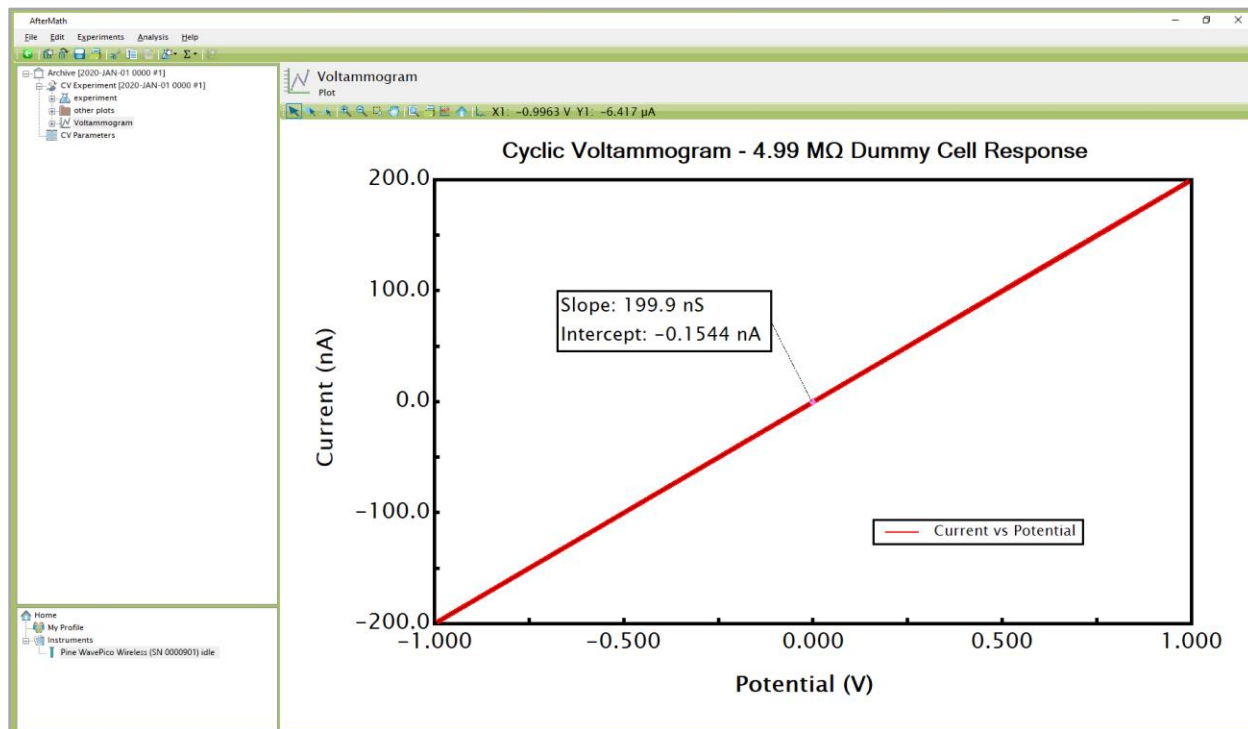
Figure 4-16. Observed Slope from Dummy Cell Experiment (WavePico Wireless, $R = 4.99 \text{ M}\Omega$)

EXPLORE ADDITIONAL EXPERIMENTAL RESULTS:

Archive nodes often have a "+" sign next to the node name. Click on this "+" sign to open the node. In addition to the main plot produced by an experiment, additional results can be found in the "Experiment" node and in the "Other Plots" node. Nodes may be renamed and organized in folders as desired.

5. Cell Cable Connections

This section describes how to connect several different kinds of electrochemical cells to the WaveNow Wireless or WavePico Wireless. Before proceeding, the user should be familiar with general concepts associated with electrochemical cells and experimentation. Using the WaveNow Wireless or WavePico Wireless cell cable (part number RRTPE40-T), connections can be made to simple two-terminal cells (such as batteries, fuel cells, solar cells, amperometry sensors, capacitors, resistors, and inductors), compact voltammetry cells, and traditional three-electrode voltammetry cells (including those that contain a rotating disk electrode).

5.1 Cell Cable Color Code

The front panel of the WaveNow Wireless and WavePico Wireless has a small cell connection port containing several signal lines that may be connected to the various working, counter, and reference electrodes present in an electrochemical cell. 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 carefully measure the potential at various electrodes.

> **NOTE:**
>
> **DRIVE lines are low-impedance lines used to drive current.**
>
> **SENSE lines are high-impedance lines used to measure potential.**

The WaveNow Wireless and WavePico Wireless cell cable breaks out the cell port connections to four shielded coaxial lines and one unshielded line (the GRAY instrument chassis line). The shielded coaxial lines terminate in banana plugs that are designed to be stacked as needed and directly connected to electrodes. Alligator clips that slide onto the banana plugs are included. A tabular summary of the color code for these lines is provided (see Table 5-1), as well as a complete pinout of the cell cable (see Table 5-2).

Color		Description	ID	Type
	WHITE	Reference Electrode	REF	Sense
	GREEN	Counter Electrode	CTR	Drive
	GRAY	Instrument Chassis		Ground
	RED	Working Electrode	WKG	Drive
	ORANGE	Working Electrode		Sense

Table 5-1. WaveNow/WavePico Wireless Cell Cable Color Description
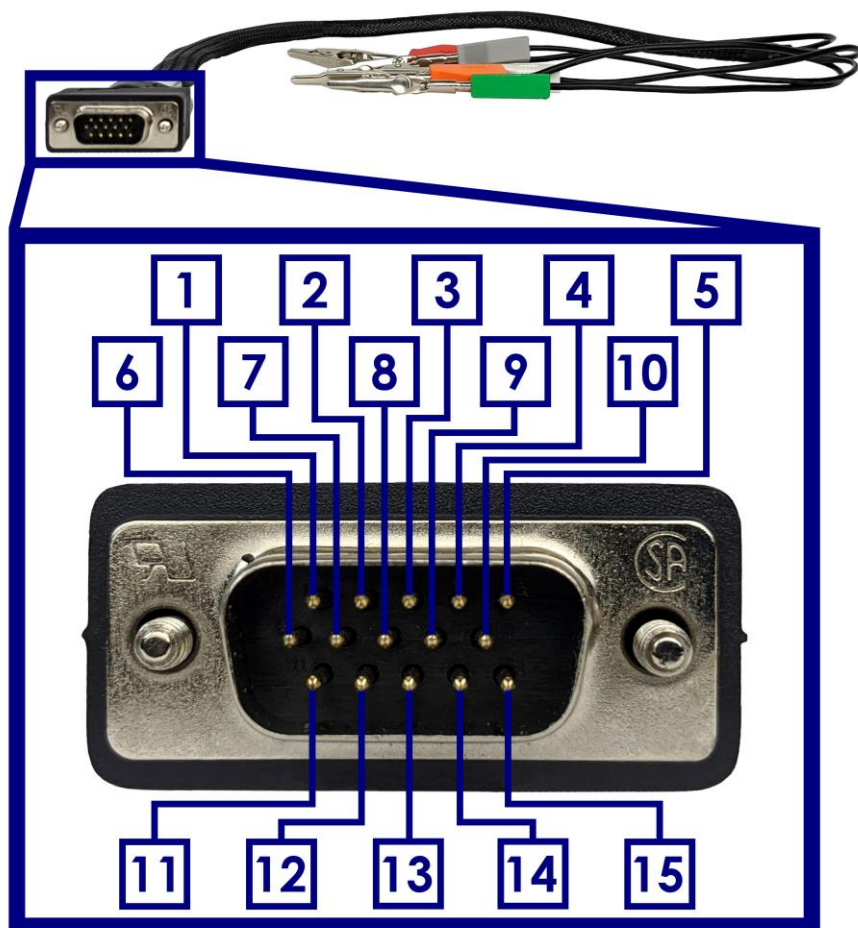
Pin	Signal	Pin	Signal
1	Reference Electrode	**9**	Unused
2	Reference Electrode Shield	**10**	Working Drive Shield
3	Working Sense	**11**	Counter Electrode Shield
4	Working Sense Shield	**12**	Instrument Chassis
5	Working Drive	**13**	Cell Cable Detect
6	Counter Electrode	**14**	Signal Ground
7	Unused	**15**	Instrument Chassis
8	Remote Amplifier Enable	**SH**	Cable Shield connects to Chassis

Table 5-2. WaveNow/WavePico Wireless Cell Cable Pinout

The GRAY instrument chassis line is often connected to a Faraday cage surrounding the electrochemical cell. Less commonly used grounding configurations are also possible with the WaveNow Wireless and WavePico Wireless using the Control Port on the back panel (see Table 2-5 and Section 6 for grounding strategies).

5.2 Experimental Configuration

With the proper cell cable configuration, several kinds of electrochemical systems can be connected to the WaveNow Wireless or WavePico Wireless. The following discussion of cell cable configurations assumes prior familiarity with the concepts associated with each type of electrochemical cell.

The WaveNow Wireless and WavePico Wireless cell cable has an HD-15 connector that fits the cell cable port located on the front panel of the instrument. There are two thumbscrews on the sides of the HD-15 connector that tighten into the cell cable port to provide a secure connection (see Figure 5-1).

Figure 5-1. Secure Connection of WaveNow/WavePico Wireless Cell Cable to Cell Port

As the cell cable emerges from the HD-15 connector, a conductive mesh shield runs along most of the cable length. This mesh shield is electrically connected to the instrument chassis and provides additional protection from environmental noise and ESD events. The instrument must be operated with a cable containing a mesh shield to maintain compliance with Federal Communications Commission (FCC) regulations.

At the cell end of the cable, multiple signal lines emerge from the mesh sleeve and terminate in banana plugs. All of these signal lines (except for the GRAY instrument chassis line) are coaxial (see Table 5-1 for signal line color code). The outer (shield) portion of each coaxial line further protects sensitive signals from environmental noise. Alligator clips (included) may optionally be installed on the banana plugs as needed.

5.2.1 Two-Electrode Setups

Typical examples of two-electrode setups are solid-state experiments that probe electrochemical behavior across a single interface, experiments that involve ion-selective electrodes (where the open circuit potential is measured between an ion-selective electrode and a reference electrode), and rechargeable batteries consisting of an anode and cathode. Simple experiments with common electronic components (resistors, capacitors, and inductors) also use a two-electrode arrangement (see Figure 5-2).
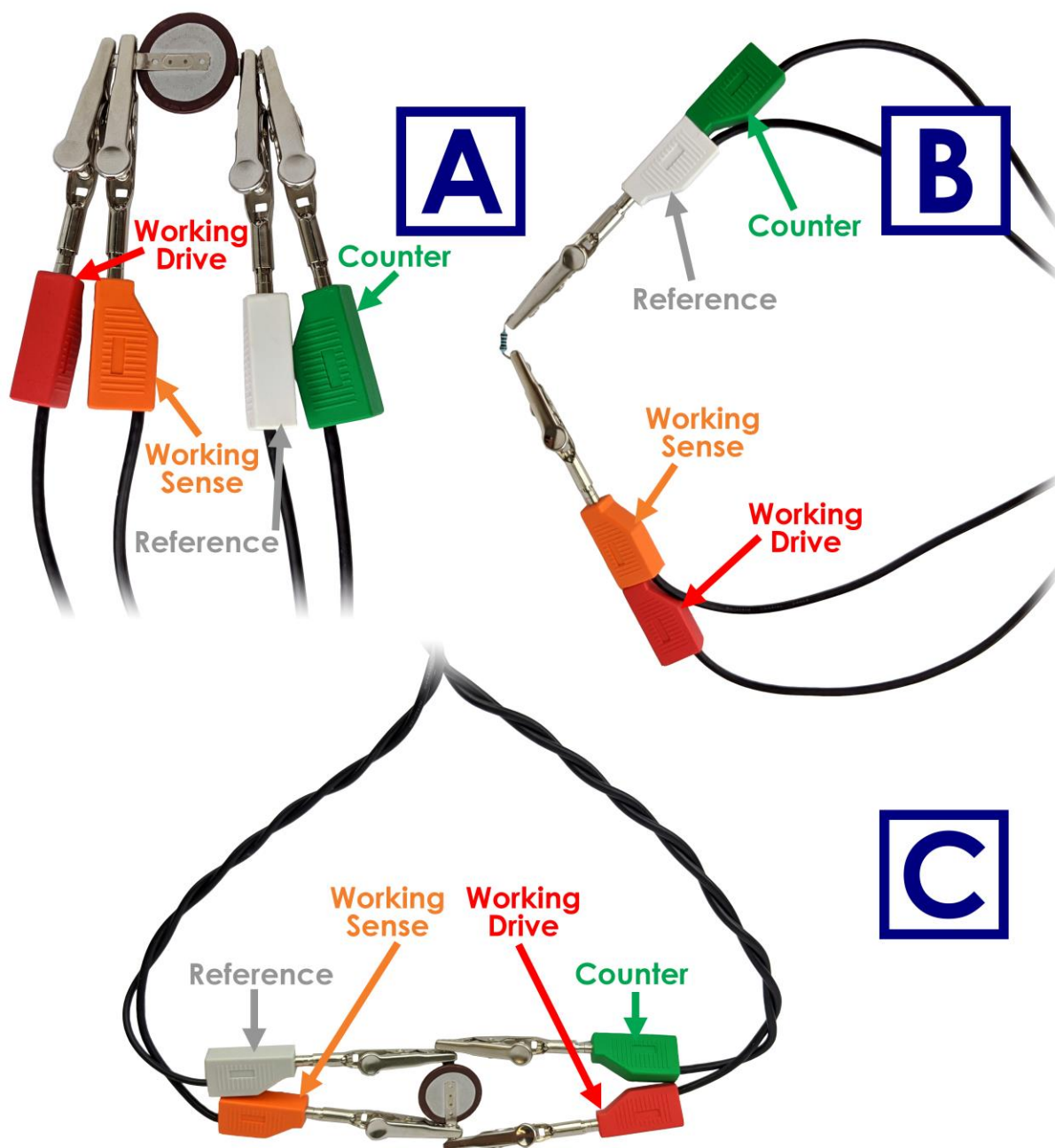
Figure 5-2. Examples of Two-Electrode Setups

The WaveNow Wireless and WavePico Wireless cell cable can be configured for two-electrode experiments in a few different ways depending on the system under study. For many electrochemical setups, it is acceptable to simply stack together two pairs of banana plugs. The banana plugs for the GREEN (counter electrode) and WHITE (reference electrode) leads are stacked together to form the first pair, and the banana plugs for the RED and ORANGE leads (working electrode drive and sense) are stacked together to form the second pair (see Figure 5-2, B). One pair of shorted leads is connected to one of the electrodes in the system, and the other pair is connected to the opposite electrode. Alternatively, each pair of leads can also be individually clipped to either electrode without stacking the banana plugs if desired (see Figure 5-2, A).

At low impedances (~10 Ω), cable inductance effects can be minimized by separately twisting the sense lines (ORANGE working sense and WHITE reference) and drive lines (RED working drive and GREEN counter) together (see Figure 5-2, C). The distance between the two sense lines (ORANGE and WHITE) should also be minimized as much as possible, and all connections should be closely spaced and secure to avoid added resistance from long electrode wires or leads. Conversely, at high impedances (above ~10 kΩ), cable capacitance effects can be minimized by separating the RED and ORANGE lines from the GREEN and WHITE lines as much as possible (see Figure 5-2, B).

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 pair is more positive than the GREEN/WHITE "reference" pair. For example, when connecting to a battery or fuel cell, the positive electrode (cathode) should be considered the working electrode and connected to the RED/ORANGE pair while the negative electrode (anode) should be connected to the GREEN/WHITE pair. This will ensure the proper current and voltage conventions are observed when performing charge/discharge or polarization curve experiments.

5.2.2 Three-Electrode Cells

In a traditional three-electrode cell, three different electrodes (working, counter, and reference) are placed in the same electrolyte solution. During three-electrode 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 WaveNow Wireless and WavePico Wireless cell cable can be configured for three-electrode experiments by appropriate connection of the drive and sense lines.

To drive current between the working and counter electrodes, the RED lead (working electrode drive) is connected to the working electrode, and the GREEN lead (counter electrode drive) is connected to the counter electrode. To measure potential between the working and reference electrodes, the ORANGE lead (working electrode sense) is also connected to the working electrode, and the WHITE lead (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 leads (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 banana plugs for the RED and ORANGE leads together before connecting to the working electrode (see Figure 5-3). Both of these leads must be connected to the working electrode for the potentiostat to properly control the electrochemical cell.

Figure 5-3. Working Electrode Sense and Drive Lines Shorted Together near the Electrode
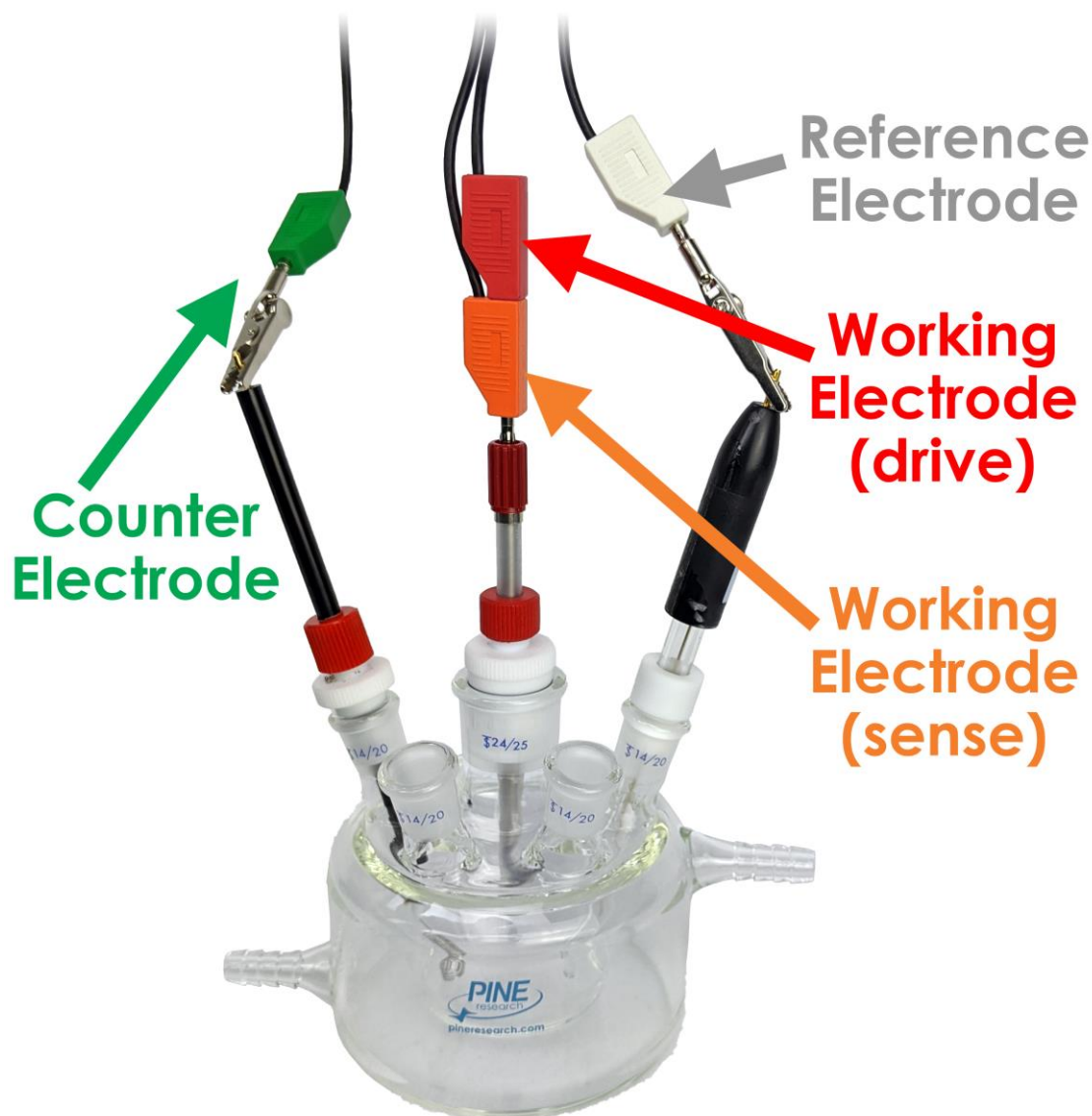
Figure 5-4. Typical Three-Electrode Cell Configuration

5.2.3 Connecting to Rotating Disk Electrodes (RDE)

The WaveNow Wireless and WavePico Wireless may be used in conjunction with an electrode rotator to perform Rotating Disk Electrode (RDE) experiments. These experiments are hydrodynamic variations of traditional three-electrode voltammetry. Rotating a working electrode with a disk geometry at a controlled rate establishes convective mass transfer 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, counter, and reference) but also providing a rotation rate control signal to the electrode rotator.

The WaveNow Wireless and WavePico Wireless cell cable can be used for these hydrodynamic experiments by making similar connections as those used in typical three-electrode cells (see Section 5.2.2). The GREEN lead (counter electrode drive) is connected to the counter electrode, and the WHITE

lead (reference electrode sense) is connected to the reference electrode. Connections of the RED and ORANGE leads (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.
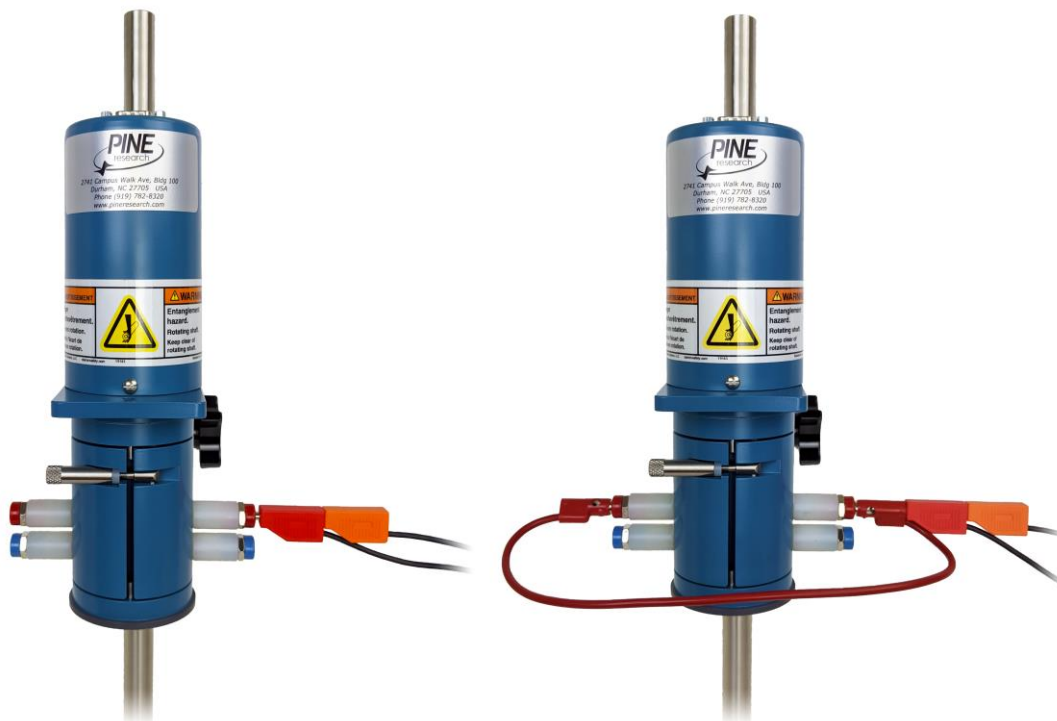
Figure 5-5. Working Electrode Connection for a Rotating Disk Electrode (RDE)

As an example of how connections are made to a rotating working electrode, consider the brush contacts on the popular Pine Research MSR Rotator system (part number AFMSRCE, see Figure 5-5). This rotator system features two pairs of opposing brushes on either side of the rotating shaft. The upper pair of brush contacts (RED) is used to make electrical contact with the rotating disk electrode mounted in the rotator. The RED and ORANGE cell cable leads (working electrode drive and sense) should be stacked together and connected to the upper pair of brush contacts. Note that for the Pine Research MSR Rotator, it is also common practice to use a short banana cable to connect opposing brushes (see Figure 5-5, right).

5.2.4 Rotation Rate Control

Many electrode rotators can accept rotation rate control signals from a potentiostat. The WaveNow Wireless and WavePico Wireless 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 output signals are presented at the Control Port (green block connector) on the back panel of the instrument (see Table 2-5). Special cables are available from Pine Research that may be used to connect these signals to various electrode rotator models.

CAUTION:

When connecting a WaveNow Wireless or WavePico Wireless system to an electrode rotator other than the Pine Research MSR or WaveVortex 10 Rotator, carefully consider the magnitude of the WaveNow Wireless or WavePico Wireless 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 Wireless ou WavePico Wireless à un rotateur à électrodes autre que le rotateur Pine Research MSR ou WaveVortex 10, faites très attention à la valeur du rapport du signal de contrôle de vitesse de l'appareil WaveNow Wireless ou WavePico Wireless ($1\ tr/min/mV$) et assurez-vous que le rotateur soit configuré avec le même rapport.

Connecting a Pine Research WaveNow Wireless or WavePico Wireless to a Pine Research MSR rotator requires a special cable (part number RRTPE50). One end of this cable has a small green connector that fits into the Control Port on the back panel of the WaveNow Wireless or WavePico Wireless. The other end of the cable connects to the MSR control unit at two locations (see Figure 5-6). The coaxial portion of the cable connects to the pair of INPUT jacks on the front panel of the control unit. The other part of the cable terminates at a banana plug that is connected to the MOTOR STOP jack (blue) on the back panel of the control unit.

Figure 5-6. Rotation Rate Control Connections for a Pine Research MSR Rotator

Figure 5-7. Rotation Rate Control Connections for a Pine Research WaveVortex 10 Rotator

Connecting a WaveNow Wireless or WavePico Wireless to a Pine Research WaveVortex 10 rotator requires a special cable (part number AKCABLE9-03). One end of this cable has a small green connector that fits into the Control Port on the back panel of the WaveNow Wireless or WavePico Wireless. The other end of the cable terminates at a large green connector which fits into the control port on the side of the WaveVortex 10 control unit (see Figure 5-7).

5.2.5 Compact Voltammetry Cell Cable Connections

The following information details how to use the WaveNow Wireless or WavePico Wireless with the Pine Research Compact Voltammetry Cell Kit (part number AKSPEKIT, available separately). A special cable is available (part number RRTPE04) with one end that connects directly to the potentiostat cell cable port and the other end terminating with a mini-USB-style plug. Within this shielded cable are four signal lines: working electrode (drive and sense), counter electrode (drive), and reference electrode (sense).

The Compact Voltammetry Cell Kit consists of a grip mount, cell cap, glass vial, and various screen-printed electrodes. Built into the grip mount is a mini-USB-style connector that can be directly connected to the cell cable. Circuitry within the grip mount makes electrical connection to the screen-printed electrode mounted to the bottom of the device (see Figure 5-8). This simple cable configuration makes the Compact Voltammetry Cell Kit ideal for use in educational settings and in confined spaces such as gloveboxes.

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

5.2.6 Compact Voltammetry Cell Cable with Reference Breakout

A version of the Compact Voltammetry cell cable with a special reference electrode breakout connection is also available (part number RRTPE05). This cable may be used with certain Compact Voltammetry Cells and with spectroelectrochemical cells offered by Pine Research. One end of this cable connects directly to the cell cable port on the WaveNow Wireless or WavePico Wireless 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: working electrode (drive and sense), counter electrode (drive), and reference electrode (sense).

The working and counter electrode lines feed into the mini-USB-style connector, but the reference electrode line terminates at the WHITE pin connector. The separate reference electrode lead allows use of an external reference electrode rather than the on-board reference on a screen-printed electrode. LowProfile (3.5 mm OD) reference electrodes are available that can be mounted in the small-diameter holes located in the cell cap of Compact Voltammetry and spectroelectrochemical ("Honeycomb") cells (see Figure 5-9).

NOTE:

When using the Compact Voltammetry cell cable with reference breakout (part number RRTPE05), an external reference electrode MUST be used. It is not possible to connect to the on-board reference of the screen-printed or honeycomb electrode using this cell cable.

If the user wishes to use the on-board screen-printed or honeycomb electrode reference, the Compact Voltammetry cell cable with no reference breakout (part number RRTPE04) must be used instead.
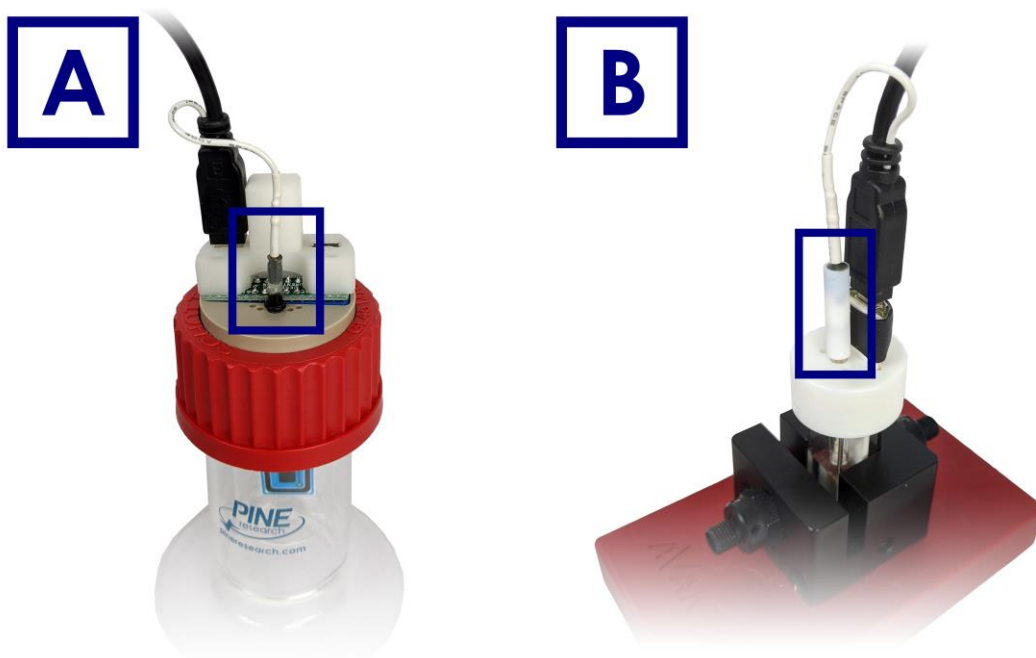

Figure 5-9. (A) Compact Voltammetry and (B) Spectroelectrochemistry Setups

6. Grounding Information

The general goal of an experiment grounding strategy is to reduce the level of noise in the electrochemical measurement caused by noise sources in the laboratory environment. To avoid issues with laboratory noise sources, it is important to properly ground all metal objects near an electrochemical setup and to make appropriate grounding connections between the potentiostat and any other electronic equipment used as part of the experiment.

6.1 Common 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 items that may electromagnetically interfere with a delicate electrochemical measurement.

The electrochemical setup, potentiostat, cell cable, and any other experimental equipment (*e.g.*, electrode rotator) should be located as far away from noise sources as possible. It is especially important that the cell cable is located well away from any digital noise sources such as mouse or keyboard cables, network cables, video cables, USB cables, cell phones, etc. The reference electrode cable is particularly sensitive to picking up noise from the environment. Also, any piece of laboratory equipment that 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.

6.2 Grounding Terminology

A potentiostat or other piece of electronic equipment generally has three types of grounding connections that 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 (see Figure 6-1). The power system infrastructure for a laboratory building usually has a long metal probe buried in the earth, and the third prong of the electrical outlets in the building is connected to this earth connection. Many scientific instruments have a three-prong power cord, which brings the earth ground connection to the instrument's power supply. Depending on the design of the instrument, the earth ground connection may or may not pass through the power supply to the circuitry inside the instrument.
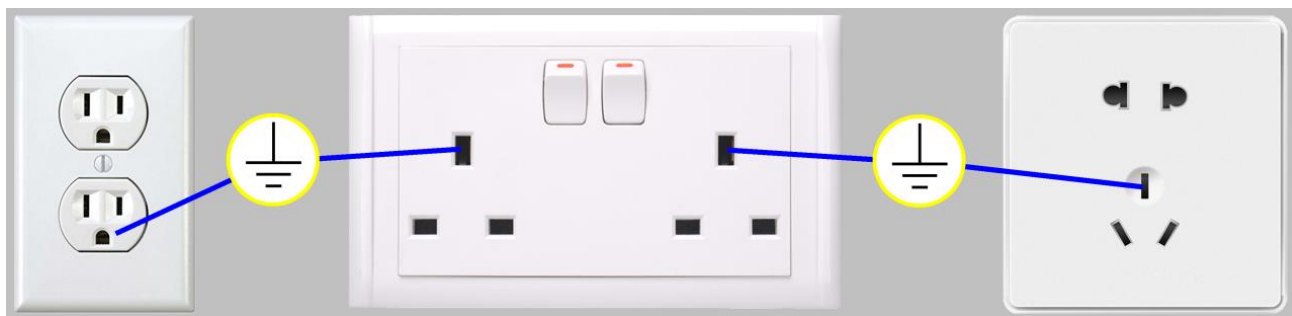
Figure 6-1. Location of Earth Ground on Common Electrical Receptacles

The power supply for the WaveNow Wireless and WavePico Wireless does not allow the earth ground connection to pass through to the instrument circuitry. As a result, there is no permanent, direct connection to the earth ground when the instrument is connected to the AC Mains (there is no connection to earth ground via the power cable plugged into a receptacle).

If necessary for a given experimental arrangement, a separate and deliberate connection to earth ground can be employed. A ground plug adapter is available from Pine Research (part number RRPA9838) that provides a convenient connection to the earth ground found on most electrical receptacles (see Figure 6-2).

Figure 6-2. A Typical Earth Ground Connection Adapter with Banana Cable

In general, a connection to earth ground need only be made if it helps to reduce (or, at least, has no effect on) the amount of noise in the electrochemical signals being measured. In some laboratory environments and for certain types of experiments (*e.g.*, low current measurements or AC methods), making a connection to earth ground may actually increase the amount of noise in the signal. Some trial-and-error experimentation may be necessary to decide whether or not to make a connection to earth ground.

6.2.2 Chassis Terminal

CHASSIS TERMINAL:

A metal case that surrounds and protects the electronic circuitry is called a chassis. A convenient connection point to this chassis is called a chassis terminal.

The metal case that contains the WaveNow Wireless or WavePico Wireless circuitry is the instrument chassis. The chassis helps to protect the circuitry from environmental noise sources and ESD events. There are two convenient access points to the instrument chassis: the GRAY banana plug on the cell cable (see Table 5-1) and the metal banana jack on the back panel (see Table 2-5).

The WaveNow Wireless and WavePico Wireless cell cable has a mesh shield that is directly connected to the instrument chassis (see Table 2-3 and Section 5.1). This mesh shield effectively extends the instrument chassis along the length of the cell cable until the point where the mesh terminates and the individual cable lines emerge.

Some experiments require that the cell cable be extended beyond its usual length. When the cell cable is extended beyond its normal length, the protection afforded by the mesh should also be extended whenever possible. One way to do this is to wrap the additional lengths of cable in aluminum foil and then make a deliberate connection between the foil and the instrument chassis.

When multiple measurement devices are used together in an experiment, it is common practice to connect the instrument chassis terminals for all of the instruments together. It is also common practice to place the electrochemical cell in a Faraday cage and connect the Faraday cage to the instrument chassis. These connections assure that the sensitive measurement circuitry in the various instruments and the electrochemical cell are all effectively sharing the same outer shield against environmental noise.

6.2.3 DC Common

DC COMMON:

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

The DC Common for the WaveNow Wireless or WavePico Wireless is the zero volt (0.0 V) reference point used by the waveform generation and signal measurement circuits. There is one available access point to the DC Common on the WaveNow Wireless or WavePico Wireless: the third pin labeled "COM" in the Control Port on the back panel of the instrument (see Table 2-5).

The WaveNow Wireless or WavePico Wireless may send or receive analog signals to and from other electronic instruments, such as a waveform generator, an x – y recorder, a digital oscilloscope, an electrode rotator, a spectrometer, or a quartz crystal microbalance. These other instruments also have a DC Common line that represents the common "zero volt" analog signal level. In general, the act of connecting a signal cable from the WaveNow Wireless or WavePico Wireless to another instrument connects the DC Common lines for both instruments.

The WaveNow Wireless and WavePico Wireless offer separate pins for DC Common and instrument chassis in the Control Port on the back panel (see Table 2-5). By default, the DC Common and instrument chassis on the WaveNow Wireless and WavePico Wireless are shorted by a green block connector that comes installed in the Control Port. If desired, the DC Common and instrument chassis can be disconnected and the instrument placed into a "fully floating" state by simply unplugging the green block connector from the Control Port (see Section 6.6 for further discussion).

The act of deliberately disconnecting the DC Common from the instrument chassis by removing the green block connector from the Control Port may or may not reduce the amount of environmental noise picked up by the potentiostat. For any given experimental configuration, some trial-and-error experimentation may be required to determine the optimal configuration.

There are situations in which a floating DC Common is required. The most common cases are those in which one of the electrodes (usually the working or counter electrode) is part of a third-party apparatus (such as a quartz crystal microbalance or an electroplating system), and the third-party apparatus is known to make a direct connection between the electrode and the instrument chassis or earth ground. When an electrode is known to be grounded by a third-party apparatus, it is critical that all of the analog measurement signals in the WaveNow Wireless or WavePico Wireless (including the DC Common) are floating with respect to the instrument chassis and/or earth ground. Otherwise, an undesirable short circuit pathway between the electrode and DC Common is likely to occur via the third-party apparatus.

Finally, it is important to be aware of cases where a hidden connection indirectly compromises the floating DC Common. These cases can occur when multiple instruments and/or computers are interconnected with the WaveNow Wireless or WavePico Wireless as part of a larger experimental configuration. One of the other instruments may make an internal connection between DC Common and the instrument chassis or earth ground. Finding and eliminating such hidden connections often requires some detective work using an ohmmeter.

6.3 Faraday Cages

When making sensitive electrochemical measurements (*e.g.*, electroanalytical methods employing DC currents less than one microampere ($< 1\ \mu A$)), it is very important to place the entire electrochemical cell inside a metal Faraday cage to shield the experiment from environmental noise. In addition, the portion of the cell cable (near the electrochemical cell) where the individual signal lines emerge from the protective mesh should also be placed inside the Faraday cage.

After placing the ends of the cell cable and the electrochemical cell inside of the Faraday cage, a secure electrical connection should made between the metal Faraday cage and the WaveNow Wireless or WavePico Wireless instrument chassis. This combination of the instrument chassis, the mesh around the cell cable, and the Faraday cage essentially puts the entire system (circuitry and cell) inside of an overall outer protective shield (*i.e.*, the cell cable mesh and the Faraday cage act as an extension of the instrument chassis).

A Faraday cage can either be purchased directly from a supplier or fabricated using inexpensive and commonly-found materials. Anything from a commercial electrical enclosure to a cardboard box lined with aluminum foil can serve as a functional Faraday cage (see Figure 6-3). A Faraday cage requires an internal volume large enough to contain the entire electrochemical cell and all of the banana plugs at the end of the cell cable that connect to the various electrodes. Care should be taken to ensure that the electrode connections do not accidently come into contact with the conductive walls of the Faraday cage. One way to prevent this accidental shorting of electrodes with the Faraday cage is to line the inner walls of the Faraday cage with a protective insulating material, such as plastic or cloth.
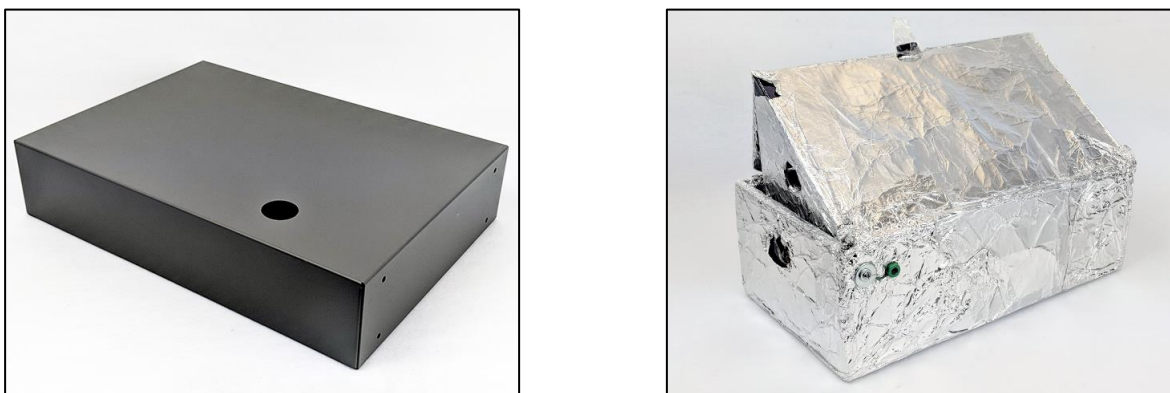
Figure 6-3. Common Examples of Faraday Cages

6.4 Metal Apparatus

Electrochemical cells are often mounted using various metal apparatus (such as ring stands or laboratory clamps). These mounts, along with any other metal objects located near the electrochemical setup, can interfere with sensitive electrochemical measurements, especially if they are simply allowed to "float" rather than being electrically connected to a known point in the system. Some trial-and-error may be required to determine the best way to ground such metal objects, but in many cases, a banana cable with an alligator clip (see Figure 6-4) can be used to connect the metal object to the instrument chassis, the earth ground, or to both.

Figure 6-4. Metal Objects Near the Electrochemical Cell Should Be Grounded

6.5 USB Isolation

It is important to note that while the most common mode of communication for the WaveNow Wireless and WavePico Wireless is via the wireless dongle, the instruments are also able to be connected to a

personal computer (tower, desktop, or laptop) via a USB cable (see Section 3.3). It is generally undesirable for the chassis of the instrument to be connected to the chassis of the computer. To help isolate the WaveNow Wireless and WavePico Wireless from the computer, the USB port (on the back panel) is mounted in a manner that helps prevent direct shorting between the instrument chassis and the computer chassis via the USB cable. Note that the USB shield line is capacitively coupled to the chassis of the WaveNow Wireless and WavePico Wireless.

The communications lines within a USB cable carry digital signals and at least one line that is connected to the DC Common of the computer. To prevent interaction between the circuitry inside the computer and the sensitive measurement circuitry inside the instrument, the WaveNow Wireless and WavePico Wireless have special circuitry that isolates the USB lines from the rest of the system. This prevents the DC Common of the computer from being connected to the DC Common of the instrument.

6.6 Grounding Strategies

The first step in determining the optimal grounding configuration for any electrochemical experiment is to understand the grounding configuration of the potentiostat itself. There are several possible ways in which the instrument chassis, the DC Common, and the earth ground might be connected. A summary of the most common configurations is provided (see Figure 6-5).

When the WaveNow Wireless or WavePico Wireless is shipped from the factory, a green block connector is pre-installed in the Control Port on the back panel that bridges the DC Common and instrument chassis (see Figure 6-5, A). This "DC Common-to-Chassis" configuration may be suitable for some electrochemical experiments; however, in other situations it may be better to disconnect this green block connector to isolate DC Common from instrument chassis and obtain a "Fully Floating" condition.

The "Fully Floating" arrangement is often required when one of the electrodes is actually part of a third-party apparatus (such as a quartz crystal microbalance or an electroplating system), and the third-party apparatus requires that the electrode be connected to the instrument chassis, the earth ground, or to both. In these cases, the DC Common should be allowed to float with respect to the instrument chassis to prevent an inadvertent short-circuit between the electrode and DC Common (via the third-party apparatus).

The WaveNow Wireless and WavePico Wireless are designed so that no part of the instrument circuit is connected to earth ground by default. While the external power supply does have an earth ground connection, the earth ground is not passed through the power supply to the instrument. If desired, a deliberate connection between earth ground and the instrument chassis may be made. Various cables and connectors (not included) can be used to make a connection from the instrument chassis terminal on the back panel of the instrument (or from the GRAY cell cable lead) to the third-prong on a nearby electrical receptacle (see Figure 6-2 and Figure 6-5).

If the instrument chassis is connected to the earth ground, the instrument may have a simple "Chassis–to–Earth Ground" connection (see Figure 6-5, C), or it may be "Fully Earth Grounded" (see Figure 6-5, D). In many cases, connections to earth ground can introduce unknown or unwanted sources of noise in the experimental results. If the experimental setup requires that the instrument be earth grounded, then some trial-and-error may be required to determine whether or not to also connect the DC Common to earth ground.

6.7 Grounding Third-Party Instrumentation

When using one or more third-party electronic instruments together with the WaveNow Wireless or WavePico Wireless, a common grounding strategy is to connect the instrument chassis of the WaveNow Wireless or WavePico Wireless to the chassis of the other instrument(s). All such connections should be

brought together to a single point. Any other metal objects located near the electrochemical cell (*e.g.*, ring stands, Faraday cage, clamps, etc.) should be connected to the same single point to avoid creating a possible grounding loop (see Figure 6-6).

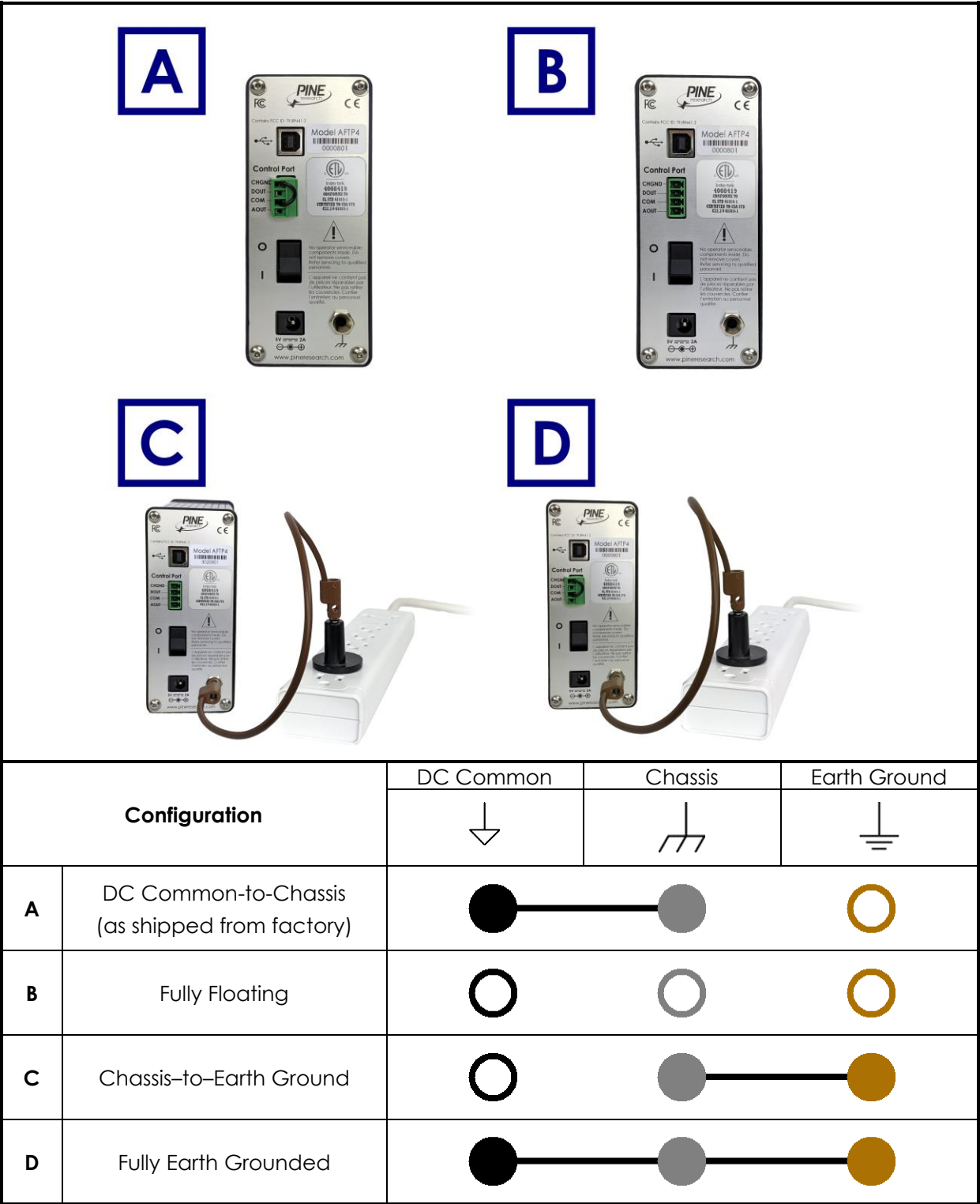|	Configuration	DC Common $\downarrow\!\!\!\!\bigtriangledown$	Chassis	Earth Ground
A	DC Common-to-Chassis (as shipped from factory)	●	●	○
B	Fully Floating	○	○	○
C	Chassis–to–Earth Ground	○	●	●
D	Fully Earth Grounded	●	●	●

Figure 6-5. Four Common Instrument Grounding Configurations

When using third-party instrumentation, a decision must be made regarding whether or not to connect the instrument chassis to the earth ground. Some third-party equipment may actually force such a connection to earth ground, and sometimes this connection is hidden from view inside the third-party instrument. Trial-and-error, as well as the use of an ohmmeter, may be required to analyze and fully understand the grounding configuration when multiple instruments are used together.

Just like the WaveNow Wireless and WavePico Wireless, third-party instruments also have their own DC Common line that represents the common "zero volt" analog signal level within the third-party instrument's circuit. When the WaveNow Wireless or WavePico Wireless is connected to an electrode rotator control unit, a spectrometer, a quartz crystal microbalance, or other third-party instrument, a connection is almost always made between the DC Common lines of the various instruments. In these cases, it is important to be aware of whether or not the DC Common of a third-party instrument happens to also be connected to earth ground or to the instrument chassis. Such connections are sometimes hidden within the third-party instrument. Again, some trial-and-error, as well as the use of an ohmmeter, may be required to confirm whether or not the DC Common is floating with respect to the instrument chassis (or with respect to earth ground).

Figure 6-6. Connect All Instrument Chassis Terminals to a Common Point

NOTE:

A grounding loop is often accidently created when ground connections are made in series from one instrument to the next. The resulting loop can act as a large antenna that injects environmental noise into sensitive signal measurements.

To prevent accidental creation of a grounding loop, bring all grounding connections together to a common point.

7. Power Supplies

The standard C14 connector on the WaveNow Wireless and WavePico Wireless power supply is compatible with a wide range of power cords available from Pine Research. Each of the available power cords is rated at 10 A (minimum), and each cord is designed for use in a specific country or region of the world.   Representative images and Pine Research part numbers are provided below (see Table 7-1).

Image	Description	Part Number	Notes
	Power Cord (USA)	EWM18B7	This cord is for use in the USA, Canada, Mexico, Brazil, Colombia, Saudi Arabia, and Taiwan
	Power Cord (Europe)	EWM18B8EU	This cord is for use in continental Europe, Korea, Russia, and Indonesia
	Power Cord (UK)	EWM18B8UK	This cord is for use in the United Kingdom, Ireland, Kuwait, Malaysia, Oman, Hong Kong, and Singapore
	Power Cord (China)	EWM18B8CN	This cord is for use exclusively in China

	Power Cord (South Africa)	EWM18B8SA	This cord is for use in South Africa
	Power Cord (Israel)	EWM18B8IL	This cord is for use exclusively in Israel
	Power Cord (Japan)	EWM18B8JP	This cord is for use exclusively in Japan
	Power Cord (South Korea)	EWM18B8KR	This cord is for use exclusively in South Korea
	Power Cord (Argentina)	EWM18B8AR	This cord is for use exclusively in Argentina

	Power Cord (Denmark)	EWM18B8DK	This cord is for use exclusively in Denmark
	Power Cord (Australia)	EWM18B8NZ	This cord is for use in Australia and New Zealand
	Power Cord (Switzerland)	EWM18B8CH	This cord is for use exclusively in Switzerland
	Power Cord (Italy)	EWM18B8IT	This cord is for use exclusively in Italy

Table 7-1. Select Power Cords Available from Pine Research

8. Glossary

Anodic Current
Anodic current is the 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 used to make connections between various electronic instruments. Each end of the cable has a banana plug.

Banana Jack
A banana jack is a female banana connector.

Banana Plug
A banana plug is a male banana connector. The banana plug consists of a cylindrical metal pin about 25 mm (1 in) long, with an outer diameter of about 4 mm (0.16 in), which can be inserted into a matching banana jack.

BNC Connector
The BNC (Bayonet Neill-Concelman) connector is a very common type of RF connector used for terminating coaxial cables.

Cathodic Current
Cathodic current is the 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
A 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. A 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 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 (CV)
Cyclic voltammetry is a DC electroanalytical method where the working electrode potential is repeatedly swept back and forth between two extremes while the working electrode current is measured.

Direct Current (DC)
Direct current is a type of electrical flow where the current travels in only one direction.

Dongle
A dongle is a small device (often USB-type) that plugs into a computer and enables connection to, and communication with (often wirelessly), a remote instrument (*e.g.*, potentiostat).

Dummy Cell	A dummy cell is a network of known resistors and/or other passive electronic components (*e.g.*, capacitors and inductors) that can be used to test a potentiostat to ensure that it is working properly. 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	Electroactive is 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)	Electrostatic discharge is the rapid discharge of static electricity between objects with different charges. Sensitive electronics in the path of an ESD event may suffer damage.
Faradaic Current	Faradaic current is 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 half-reaction is a balanced chemical equation showing how various molecules or ions are reduced (or oxidized) at an electrode surface.
Linear Sweep Voltammetry (LSV)	Linear sweep voltammetry is a DC experiment in which the working electrode potential is swept from initial value to final value at a constant rate while the current is measured.
Non-Faradaic Current	Non-Faradaic current is 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	Oxidation is the removal of electrons from an ion or molecule.
Redox	Redox is an adjective used to describe a molecule, ion, or process associated with an electrochemical (oxidation or reduction) reaction.
Reduction	Reduction is the 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	The standard electrode potential is a thermodynamic quantity expressing the free energy of a redox half-reaction in terms of electric potential.

Sweep Rate	Sweep rate, also called "scan rate", it is the rate at which the electrode potential is changed with time when performing a sweep voltammetry technique such as cyclic voltammetry or linear sweep voltammetry.
Three-Electrode Cell	A three-electrode cell is a common electrochemical cell arrangement consisting of a working electrode, a reference electrode, and a counter electrode.
Two-Electrode Cell	A two-electrode cell is a common electrochemical cell arrangement consisting of a working electrode and a counter electrode that also serves as the reference electrode.
Voltammogram	A voltammogram is 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 working electrode is 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 working electrode drive is 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 working electrode sense is 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 if there are 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 that allows 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 emails are 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. A live person can be reached by calling +1 (919) 782-8320.

EU Declaration of Conformity

In accordance with EN ISO 17050-1:2010

Object of the Declaration:

Products:	WaveNow Wireless Potentiostat, WavePico Wireless Potentiostat
Models:	AFTP4, AFTP5
Serial Numbers:	1820nnn and later (wwyynnn: where ww is the week of manufacture; yy is the year of manufacture; nnn is a number indicating model and sequence of build)
Manufacturer:	Pine Research Instrumentation, Inc. 2741 Campus Walk Ave., Building 100, Durham, NC, 27705, USA This declaration is issued under the sole responsibility of the manufacturer.
Technical File:	101 Industrial Drive, Grove City, PA, 16127, USA

The object of the declaration described above is in conformity with the relevant Union harmonization legislation:

2014/35/EU	The Low Voltage Directive
2014/30/EU	The Electromagnetic Compatibility Directive
2011/65/EU	The Restriction of Hazardous Substances Directive

Conformity is shown by compliance with the applicable requirements of the following documents:

EN 61326-1:2013	EMC Requirements for electrical equipment for measurement, control and laboratory use
IEC 61010-1:2010 AMD1:2016	Safety Requirements for electrical equipment for measurement, control and laboratory use
EN IEC 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Signed for and on behalf of:	Pine Research Instrumentation, Inc.
Place of Issue:	101 Industrial Drive, Grove City, PA, 16127, USA
Date of Issue:	10/13/2020
Name:	Joseph D. Hines
Position:	President
Signature:	