Main Vision Manual

User guide
2021

Table of Contents

Introduction

Vision Program for Precision Testers

The Precision Family of Ferroelectric Testers

The Precision Materials Analyzer family of ferroelectric testers provides a full range of high-speed, high-precision ferroelectric material characterization instruments to meet every budget and research need. A comparison of model cost, speed and voltage capability is given at Vision Testers. All systems are capable of internally-generated sample stimulus voltages of 10.0 Volts[1]. Most systems include internal amplifiers that allow 100.0-Volt measurements. 200.0-Volt and 500.0-Volt options are also available. Voltages of up to 10,000 Volts can be used by adding an accessory High Voltage Amplifier (HVA) and High Voltage Interface (HVI). The researcher may connect any existing amplifier, provided a logic unit (known as an ID Module) is obtained from RTI. The latest HVI model, released in 2017, has the ID module built into the instrument. It is programmed for delivery at Radiant Technologies, Inc., but may be reprogrammed at any time by the user.

The Vision Program

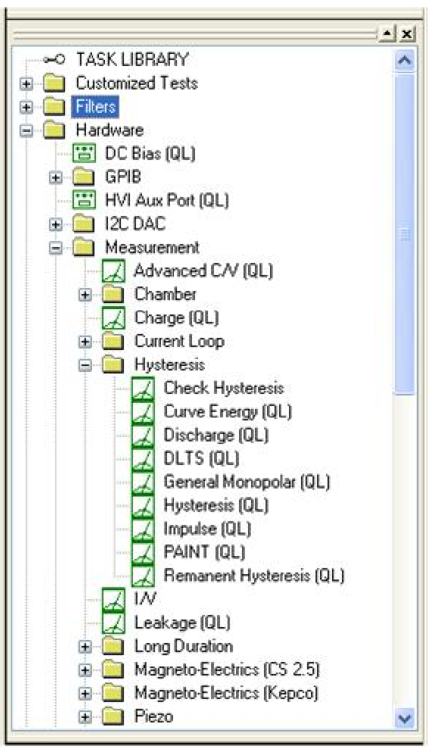
A single, unifying program, called Vision, provides a consistent compatible interface across all hardware architectures. It is designed with the understanding that what is important in ferroelectric testing is maintaining a complete and accurate history of the signals applied to, and the responses of, a sample. The researcher has the capability to create custom experiments that are as simple or elaborate as required. Experiments can be run, rerun, reconfigured and repeated. As an experiment is executed, it is saved along with the measured data to be recalled for reuse. Data can easily be recalled for examination. On-board tools are available to provide data analysis and comparison of multiple data vectors. Data may be exported directly to Excel, Word, text files or a printer for analysis and publication. Data are organized into archives that hold both the data and the experiments that produced them. These archives are uniquely named and are written to individual files that may be sorted and stored in any way that is most logical to the researcher. These files can be emailed or written to an external data storage (USB drive, CD, etc.) for use by other researchers that are running the Vision program. Vision can be installed on non-tester computers for the purpose of recalling and reviewing data or creating experimental Test Definitions.

This manual provides a complete description and set of instructions for the use of Vision Version 5.x.x. (As of this writing, Vision 5.26.4 is being shipped.) The system is large and complex, but is designed so that the new user can begin to get immediate results without exhaustive training. Much of the detail of the program is segmented into Tasks that perform specific functions. Tasks may be very simple or very complex, but the user need only learn to use the Tasks that are important to the research at hand. The manual gives a complete overview of the program, a number of tutorial sessions, step-by-step operating procedures for the most common operations in Vision and a detailed description of each Task including a discussion of every control that appears on every dialog. The Task descriptions are also available using the *Click For* *Task Instructions* button on any dialog associated with the Task.

The Vision program, its Tasks and its drivers, as well as these help pages, are under constant development. In order to use the most up-to-date and efficient release of the Vision program please visit the Vision download form regularly. The current Vision version and release date are noted near the top of the form. If an update is in order, fill in the form and click *Submit*. You will be linked to the Vision installer download page. Review the information on the page. Then click the installer download button and install or update per the instructions on the page.

A Note on Vision Structure and Versioning

The Vision program is a framework program that provides services to Vision Tasks. Tasks are semi-independent agents that perform the work within the program. Tasks loaded by Vision at runtime into the Task Library. Some Tasks are also loaded into the Vision QuikLook Menu.



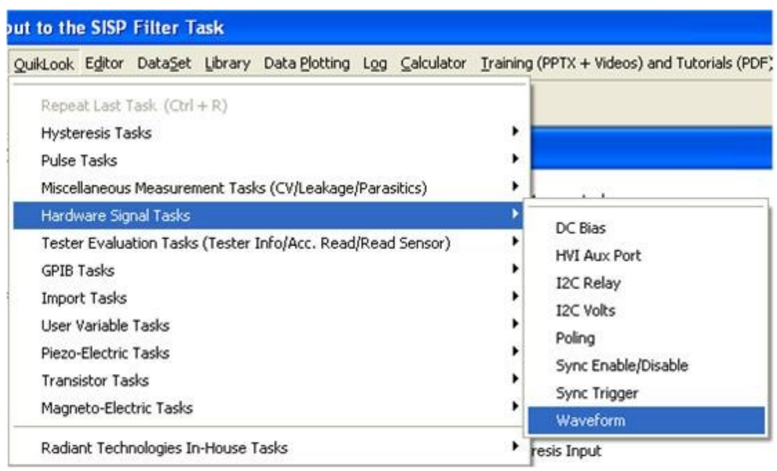


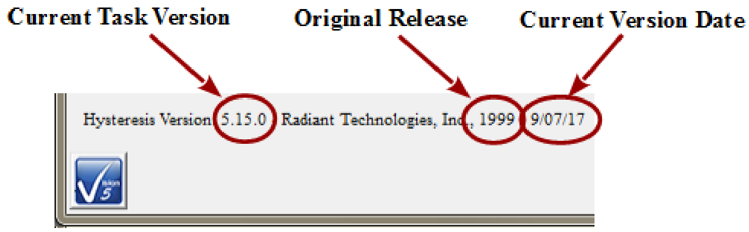
Figure 1 - Tasks in the Task Library and Figure 2 - Task in the QuikLook Menu.

The Vision program version is divided into three sections. The first is the main version. It represents major changes or additions to the program that occur infrequently. The current version is "5". The second digit represents changes to the main framework program that happen frequently but are of significant influence on the program. At this writing the second digit in the Vision version is "12". In some cases these changes will not be apparent to the customer. The final digit (currently "10") represents minor changes. In all cases, changes to the Vision version number refer only to changes to the framework program, not to changes to individual Tasks or groups of

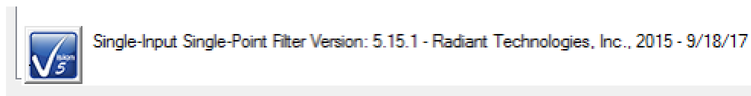
Tasks. The Vision version can be seen by going to Help->About Vision. Note that the "(R)" in the version number indicates that this is a release compilation of the program for customers.

Figure 3 - The "About Vision" Dialog.

As a semi-independent agent, each Task has its own version. The first two numbers of the Task version will always agree with the first two digits of the Vision program version. When the Vision version was updated to "5.12.0" all Tasks were also updated to "5.12.0". After that point, the Vision program version - representing changes to the framework - and the Task version will diverge as changes are made to individual Tasks. Task versions will also differ from each other. The configuration dialog for each Task will show the Task version, the date of the version and the initial release year. Measurement Tasks that present data in a dialog will show the same information on that dialog.



Hysteresis Task Version 5.15.0



Single-Input Single-Point Filter Task Version 5.15.1

Figure 4 - Task Versions.

The "About Vision" dialog of **Figure 3** also shows a "Driver Version". The Driver is a Windows DLL program that takes input from Vision and formats it so that it can be understood by the tester. It communicates the information to the tester and receives tester response. The response is reformatted for, and passed back to, the Vision program. The driver program version will generally resemble the Vision version but is completely independent.

If you are having trouble with your tester, your Vision program or with Windows interface to either we will often ask you for the Vision and/or Driver version. Vision provides tools that make it easy for you to obtain that information in a suitable format and send it to us. If we need such information we will guide you to those tools.

Licensing
Vision is freely distributed to any and all parties who have an interest without further license. The program may be downloaded any number of times and may be instaled on any number of host computers. The practical uses of the program are limited without a Precision tester, but the program is fully operational with or without a tester. With no tester present, data-collecting Tasks will generate meaningless synthetic data. Any party can register a DataSet taken by any other party to review archived data and investigate the construction of the experiment (Test Definition).

Licensing Custom Task Suites
A number of groups of Vision Tasks, known as Custom Task Suites must be purchased and licensed before they will operate. The Tasks are freely distributed with Vision. Any user can open the Task configuration dialog for review and to access the Task Instructions. Any user can review Custom Task data collected by a licensed installation of the Custom Task. However, to operate the Task it must be licensed. The license is in the form of a file named Security.sec that is placed in C:\Program Files (x86)\Radiant Technologies\Vision\System. The Task is coded to the Task Suite or Task Suites being purchased. It is also coded to an embedded ID in the tester for which it is purchased. In order for a Custom Task to operate, the security.sec file must be in

place and the specified tester must be connected to the Vision host and powered.

The security.sec file may be copied to any number of host computers. However, it cannot be transferred to any other Precision Tester.

Task Suites include:

- Chamber (Pyroelectric): Set Temperature/Measure at a series of temperatures. This offers automatic control of a variety of thermal controllers.
  - Chamber: Measure using PUND.
  - Remanent Chamber: Measure using Remanent Hysteresis.
- Piezo: Measure the sample polarization ($\mu C/cm^2$) and displacement response. The displacement response is measured by an external displacement detector and captured as a voltage at the SENSOR port.
  - Piezo: Basic measurement. Normally used for bulk samples. There are minimal onboard noise reduction tools.
  - Advanced Piezo: Normally used for thin film samples with data taken from an AFM. There are advanced noise reduction tools and extensive data processing.
  - Piezo Filter: Gather, operate on, store and plot Piezoelectric data from one or more Piezo and/or Advanced Piezo Task.
- Transistor: Capture transistor drain current as a function of V_{Source} and V_{Gate}.
  - Transistor Current: Transistor response at a single V_{gs} and V_{ds}.
  - Transistor IV: Transistor response at a single V_{ds} over a range of V_{gs}.
  - Transistor Curve Trace: Series of Transistor responses at a single V_{ds} over a range of V_{gs}. V_{ds} changes at each sweep.
- Magneto-Electric: Capture sample polarization ($\mu C/cm^2$) as a function of a variable magnetic field provided by a Helmholtz coil. Older installations used a KEPCO BOP 36 current amplifier to provide stimulus to the Helmholtz coil. These also used a Lakeshore 425 Gaussmeter to calibrate the field at the sample. Later measurements us the RTI CS 2.5 current source to drive the Helmholtz coil. Hall Effect sensors are built into a shield box to directly detect the magnetic field at measurement time. M.E. Tasks are divided into Kepco and CS 2.5 groups.
  - Magneto-Electric Response: Hysteresis style polarization ($\mu C/cm^2$) over a periodic magnetic field (G).
  - DC Field: Set and hold a fixed DC magnetic field (G) for a user-specified period of time (s).
  - Single-Point C/V (MR): measure sample small-signal capacitance (nF) using a magnetic field (G) stimulus.

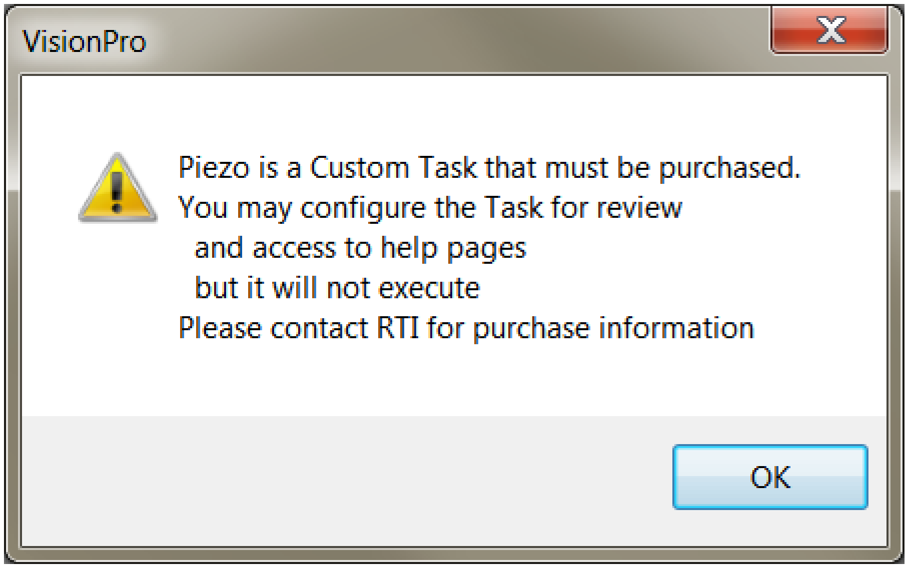


Figure 5 - Notice Appears when Unlicensed Piezo is Accessed. The Configuration Dialog will Open when the Notice is Closed.

A small note on text format in these Help pages.
There is not a large list of various textual representations in the Vision help pages. However, these few rules do apply:

1. Vision key words are always capitalized, as in Task, DataSet or Test Definition.
2. Names of controls on dialogs are italicized as in *Task Name* , *VMax* or *Comments* .
3. Text within controls is specified in quotations. For example '... and set *Task Name* to "5.0-Volt Hysteresis".'
4. References to figures and tables with in text are set in bold type as in '... **Figure 7** represents...'.

A small note on Vision documentation
This collection of documents forms the main Vision manual. It, along with Task-specific and dialog-specific help, accessed by clicking *Click For Task Instructions*/*Click For Dialog Instructions* on any Vision dialog, form the complete set of program documentation. The Vision program changes frequently. Documentation will normally lag behind program updating, sometimes by significant periods of time. One consequence is often that an image of a dialog or set of controls in the documents to not exactly resemble the program windows being discussed. Nevertheless, Vision is designed to grow naturally so that older documentation will still be correct and helpful, even where it may be incomplete.

Note that Task Instructions will provide more detailed Task-specific information that is also likely to be more up-to-date than these general Vision help pages. The Task Instructions should form the major reference for the Vision program.

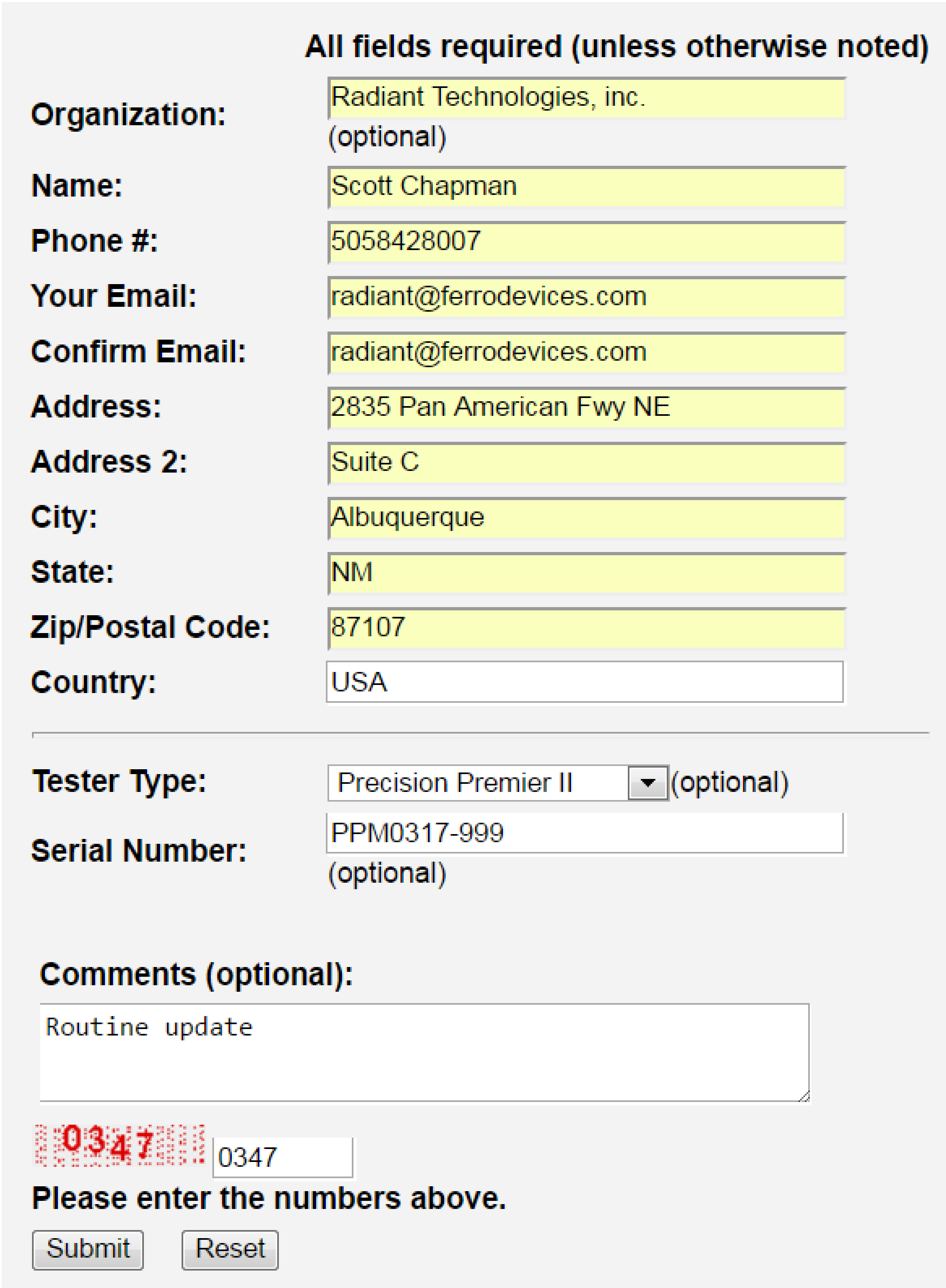
System Requirements

All modern Windows-based host computers have sufficient resources to install and operate the Vision program. Vision should install and operate correctly under 32-bit and 64-bit Windows operating system from Windows XP through Windows 10. However Radiant Technologies, Inc. can no longer provide customer support for installations on Windows versions older than Windows 7.

Maintaining Vision

The Vision program does not have tools installed on the host computer to search for version updates. However, the Vision program is upgraded very frequently. Two or three version updates in a week are not unheard of. Often these updates include significant improvements or important fixes. Furthermore, the first request when you are asking Radiant Technologies, Inc. for assistance will be to ensure that you are running the latest Vision.

To update Vision, go to http://www.ferrodevices.com/1/297/download_vision_software.asp, fill in the form and click *Submit*. You will be linked to the Vision Installer Download page. Review the information on the page and click the download button. Acknowledge all warning. Allow the file to download and then run it. The installer will quickly update most installations. Older Vision installations must be uninstalled before the installer will write the newer version. Uninstalling using the standard Windows program uninstall tool will leave custom files such as security.sec and custom DataSets in place.



All fields required (unless otherwise noted)

Organization:	Radiant Technologies, inc. (optional)
Name:	Scott Chapman
Phone #:	5058428007
Your Email:	radiant@ferrodevices.com
Confirm Email:	radiant@ferrodevices.com
Address:	2835 Pan American Fwy NE
Address 2:	Suite C
City:	Albuquerque
State:	NM
Zip/Postal Code:	87107
Country:	USA
Tester Type:	Precision Premier II (optional)
Serial Number:	PPM0317-999 (optional)

Comments (optional):

Routine update

0347 0347

Please enter the numbers above.

Submit Reset

Figure 6 -Vision Install/Update Form.

Vision 5 Presentation and Installer

Announcing the Release of Vision 5.0

The instructions in this document have been updated as of 21 March 2017

This page is used to install the latest version of the Vision program - Vision 5.12. Use the installer on this page to install Vision to host computers that have never had Vision installed or to update computers that have older versions of the program already installed.

Requirements

Vision may be installed on any Windows host computer running Windows 7. These include Windows 7, Windows 8, Windows 8.1 and Windows 10. Windows XP and Windows Vista are no longer supported. The same installer can be used for 32-Bit and 64-Bit host computers. For documentation purposes, 64-Bit host computers are assumed.

The Vision program installed from this page will operate all Precision Testers, regardless of model or age, that connect to a separate host computer through a USB cable. It does not operate the Precision Workstation or original Precision Pro/Premier with internal CPUs.

The Vision 5.6.x release offered a more up-to-date installer than previous versions. Changes include:

- **New look.**
- **No random "Disk Space Errors"**
- **C++ Manifest installation is embedded instead of executing after the installation. The installation may require a reboot, but will only execute on initial installation. Updates will not require a re-installation of the manifest.**
- **Vision 5.6.x included a data plotting library update. The data plotting appearance is slightly different. The right-click Export bug has been repaired.**
- **Installer updates to Version 5.6.8 and later do not need to have the previous Vision installation uninstalled. Just download the installer and run it. Older files will be updated by date and new files will be written.**

To Update Existing Vision Installations:

- Copy C:\DataSets\xplorerdb.cpu and C:\DataSets\Editor List.EL to temporary locations. You may not find all three of these files, depending on your use of Vision. C:\DataSets\xplorerdb.cpu is the important file. **NOTE: If the existing Vision Version is 4.9.2 or later this step does not need to be taken.**
- Go to Start->Settings->Control Panel and select "Add or Remove Programs..." **NOTE: If you are updating from Vision 5.6.8 or later, this step and the next step do not need to be taken. The latest installer will update the existing installation**
- When the program list is populated, scroll down to and double-click "Vision". Allow the program to completely uninstall.
- Download the installer under the Vision 5 download button below.
- Run the downloaded installer. Acknowledge all warnings and allow the installation to proceed. At the end of the installation a separate Microsoft Visual C++ program will run that will update Windows files to run with the Vision program. Allow this program to run to completion.
- Return the backed up xplorerdb.cpu, and Editor List.EL to C:\DataSets\, overwriting the files from the installer. Note that you will not need to repeat the backup or restore steps in the future. **NOTE: If the Vision Version being updated is 4.9.2 or later this step does not need to be taken.**

To Install Vision to a Fresh Host Computer:

Note that you must install Vision before connecting your Precision tester for the first time. Simply download the installer under the Vision 5 download button below, and run the installer. Acknowledge all warnings and allow the installation to proceed.

DOWNLOAD
Vision 5

Latest Vision Installer - Vision 5.12.10 - 21 March 2017

Support for Windows XP and Vista has ended.

NOTE: This installer is not for use with the Precision Workstation or original Precision Premier/Pro with on-board

Figure 7 - Vision Installer Download Page

Contact Radiant Technologies, Inc.

Mr. Joe Evans	President
Ms. Michelle Bell	Marketing and Sales
Mr. Bob Howard	Hardware Design and Construction
Mr. Spencer Smith	Hardware Design and Vision/Hardware Interface (Driver)
Mr. Scott Chapman	Software Design and Programming, Training, Customer Support
2835 Pan American Fwy NE Suite B and C	
Albuquerque, NM 87107	
1-800-289-7176	
505-842-8007	Voice
505-842-0366	FAX
radiant@ferrodevices.com	
www.ferrodevices.com	Process and Clean Room
www.ferroelectrictesters.com	Precision Testers

.

Precision Testers and Accessories

Introduction

Before providing a complete discussion of the Vision program, this manual will summarize the hardware that Vision is intended to control. The primary hardware to control is a member of the Radiant Technologies, Inc. Precision Tester Family. This section will revisit tester installation. Then a simplified discussion of tester theory and circuitry is presented to give a glimpse of activities "under the hood". This discussion will be important in understanding the meaning of various controls in the Vision configuration dialog later on. An important discussion in this section is the theory of the virtual ground circuitry used in the Precision tester family and a comparison between virtual ground and the familiar Sawyer Tower measurement.

The special circumstances of high-voltage measurements and magneto-electric measurements each are presented in their own section. These sections will, of necessity, introduce Precision tester accessories available from Radiant Technologies, In. Each accessory will be examined in more detail later in the section.

The tester discussion to this point will have been general and applicable to every model in the Precision family. In the next section the specifications, features and limitations of each model are presented.

As already noted, the final section will provide complete details on all of the available Radiant accessories. The purpose, structure and use of each accessory is discussed. The accessory is then placed in the larger context of its association with the Precision tester family and other accessories.

Safety

Symbols Appearing on Equipment

- Electrical Shock Hazard: Do not touch DRIVE, HV DRIVE, RETURN or HV RETURN terminals while the Precision tester and/or Precision High-Voltage Interface (HVI) and/or High-Voltage Amplifier (HVA) is/are turned on.

- Burn Hazard: Touching this surface could result in bodily injury. To reduce risk of injury allow the surface to cool before touching.

Terms that May Appear in the Manual

Warning: Warning statements identify conditions or practices that could result in injury or loss of life.

Caution: Caution statements identify conditions or practices that could result in damage to the instrument(s).

General Safety Precautions

Use the Power Cord Provided: To avoid fire hazard and provide proper grounding, use only the AC power cord provided with the equipment.

Avoid Electric Overload: To avoid electric shock or fire hazard, as well as damage to the equipment, do not apply a voltage to a terminal that outside the range specified for that terminal

Avoid Electric Shock: To avoid electric shock do not touch the DRIVE, HV DRIVE, RETURN or HV RETURN connectors while the equipment is turned on.

Ground the Equipment: These instruments are electrically grounded through the ground conductor of the provided AC power cords. To avoid electric shock and damage to the equipment the ground conductor must be connected to earth ground. Before making connections to the input and output terminal of these products ensure that the equipment is properly grounded.

Do Not Operate Without Covers: To avoid electric shock or fire hazard do not operate these instruments with the covers removed.

User Proper Fuses: To avoid electric shock or fire hazard use only the fuse type and rating specified for the instrument. Fuses are specified in the individual instrument specifications.

Indoor Use Only: These instruments are intended for indoor use only.

Mount the Equipment Properly: The equipment should be stacked firmly on a bench or mounted in an equipment rack using the correct rack-mounting hardware.

Do Not Operate in Wet or Damp Conditions: To avoid electric shock and damage to the instrument do not operate these devices in wet or damp conditions. Humidity limits are included in the individual instrument specifications.

Do Not Operate in an Explosive Environment: To avoid injury or fire hazard do not operate this equipment in an explosive environment.

Operate in the Proper Environmental Conditions: The equipment must be operated within the specified temperature and humidity range. Ranges are published for each instrument in the instrument's specifications.

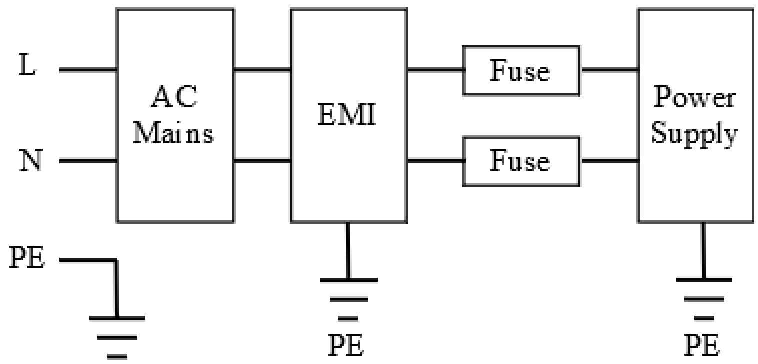
Product Protection Precautions

Use the Proper Power Source: Do not operate these instruments from a power source that is different from the voltage parameters listed in the individual instrument specifications.

Provide Proper Ventilation: To prevent the instrument from overheating provide the proper ventilation..

Do Not Operate with Suspected Failures: If you suspect that there is damage to an instrument have it inspected by qualified personnel.

Power Supply Block Diagram



Service and Maintenance

Do not open the equipment. No user-servicable parts inside. Refer servicing to Radiant Technologies, Inc.

Failure to observe these precautions and/or use of the equipment in a manner not specified by Radiant Technologies, Inc. may impair the protection provided by the equipment.

Precision Testers

Tester Installation

As of this writing Vision 5.20.0 is being distributed. With version 5.20.0 Vision can no longer be installed under Windows XP. This document considers tester installation only under Windows 7, 8, 8.1 and 10.

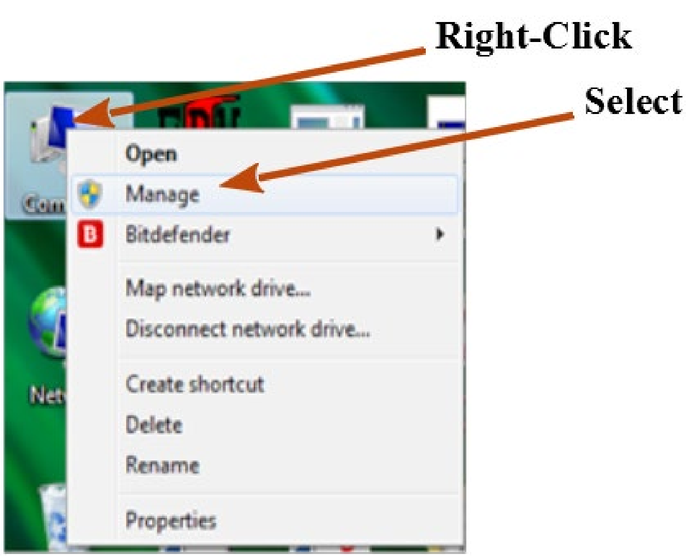
NOTE: The Vision program must be installed to the Vision/tester host computer before attempting to install the tester.

Windows 7 Installation

All generations of Precision tester operate through the Windows WinUSB driver. WinUSB is not necessarily native to Windows 7. The Vision installer includes the appropriate Windows driver, WinUSB.DLL.

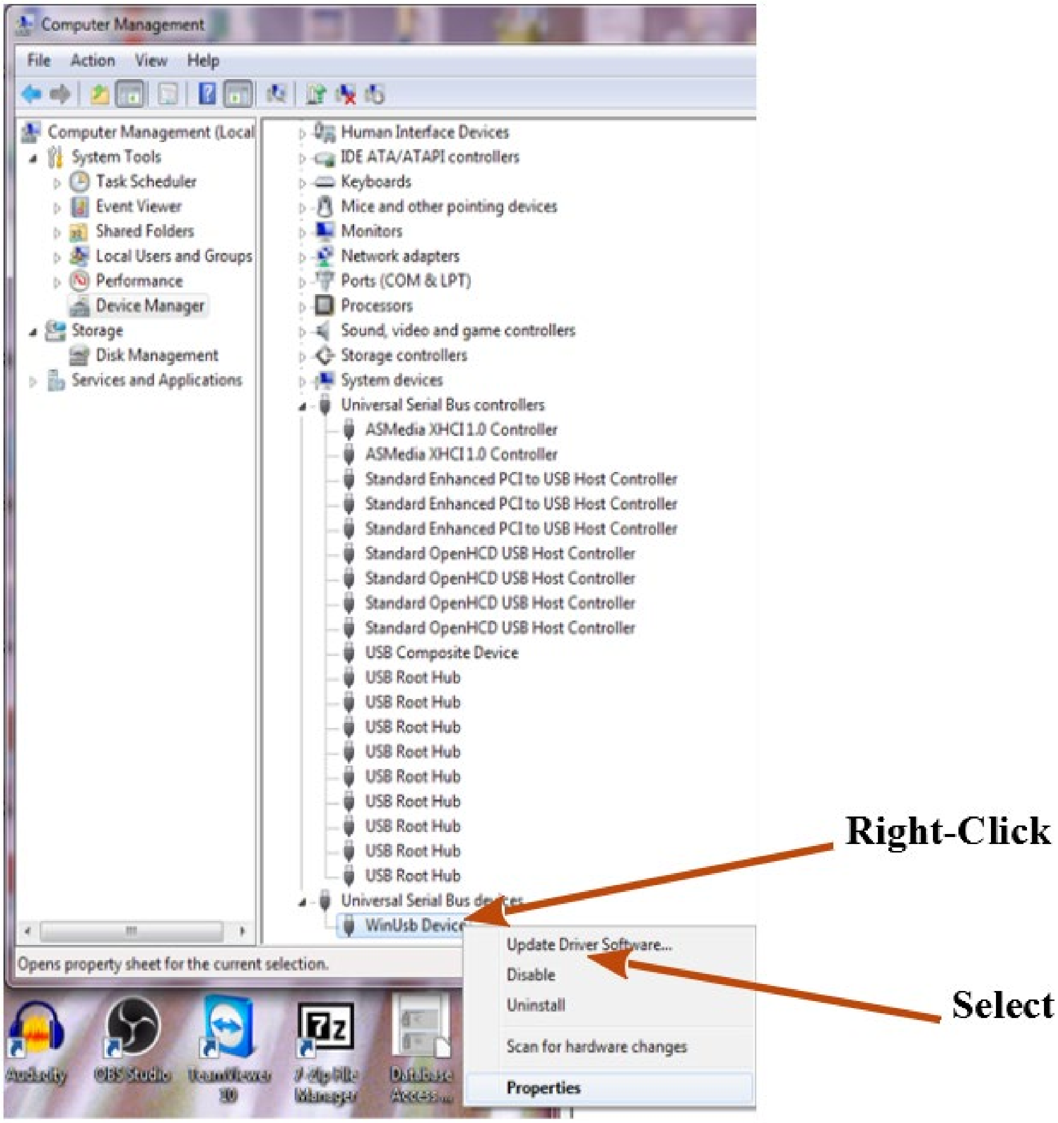
All Precision Testers and several accessories must be installed to Windows. Connect the instrument to a Vision host USB port (a USB 3.0 port is recommended) and power on. Windows will attempt to install the tester, but it will fail because it does not know how to find the driver. The tester must be installed manually. The figures below show the installation of a Precision LC II tester.

1. On the Windows 7 desktop, right-click the "Computer" icon and select "Manage from the popup menu.

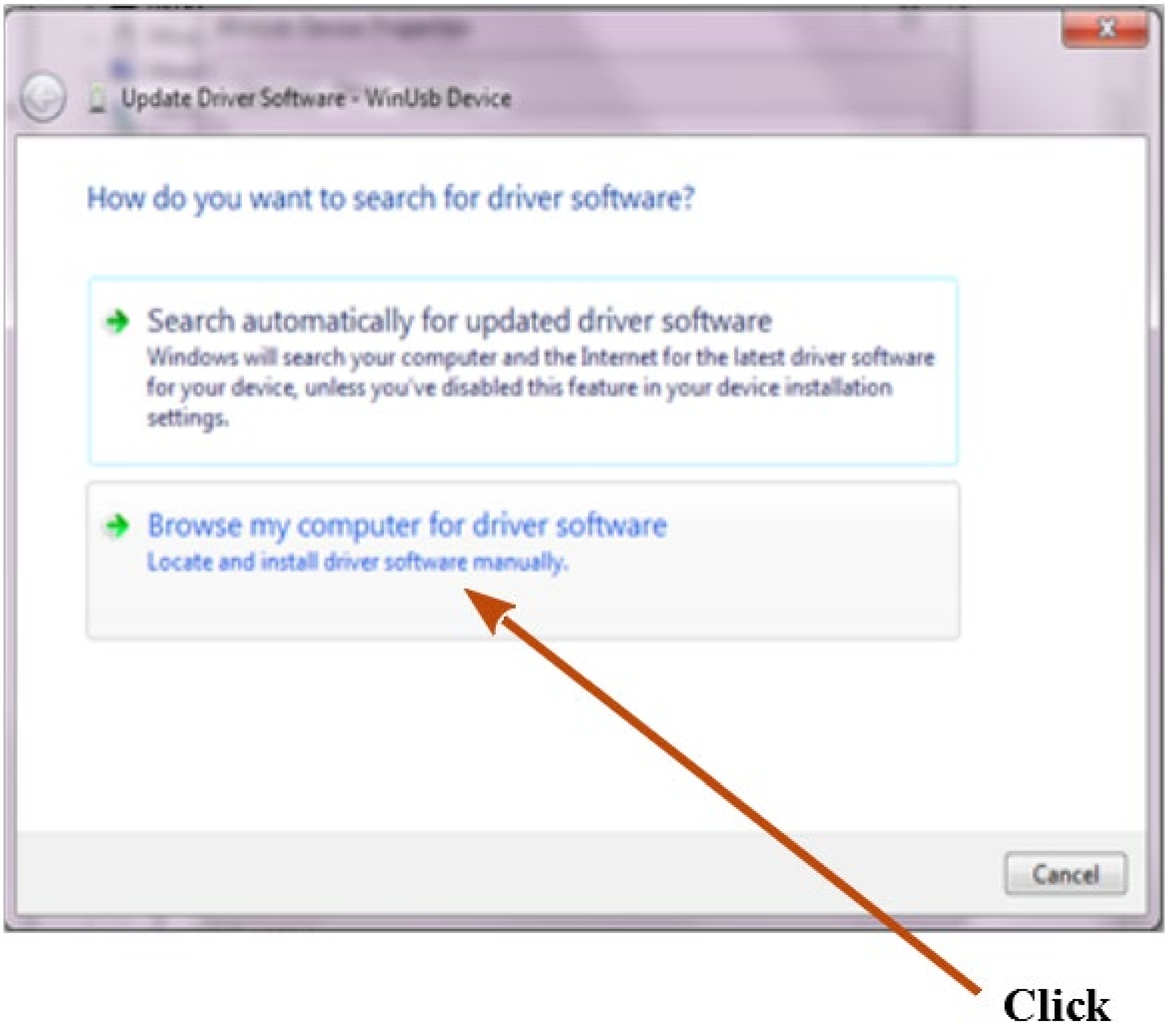


2. In the left pane of the window that appears select "Device Manager". In the right pane expand the "Universal Serial Bus devices" folder and select "WinUSB device". (The device may also appear as "Unknown device" and may appear somewhere else in the device tree.)

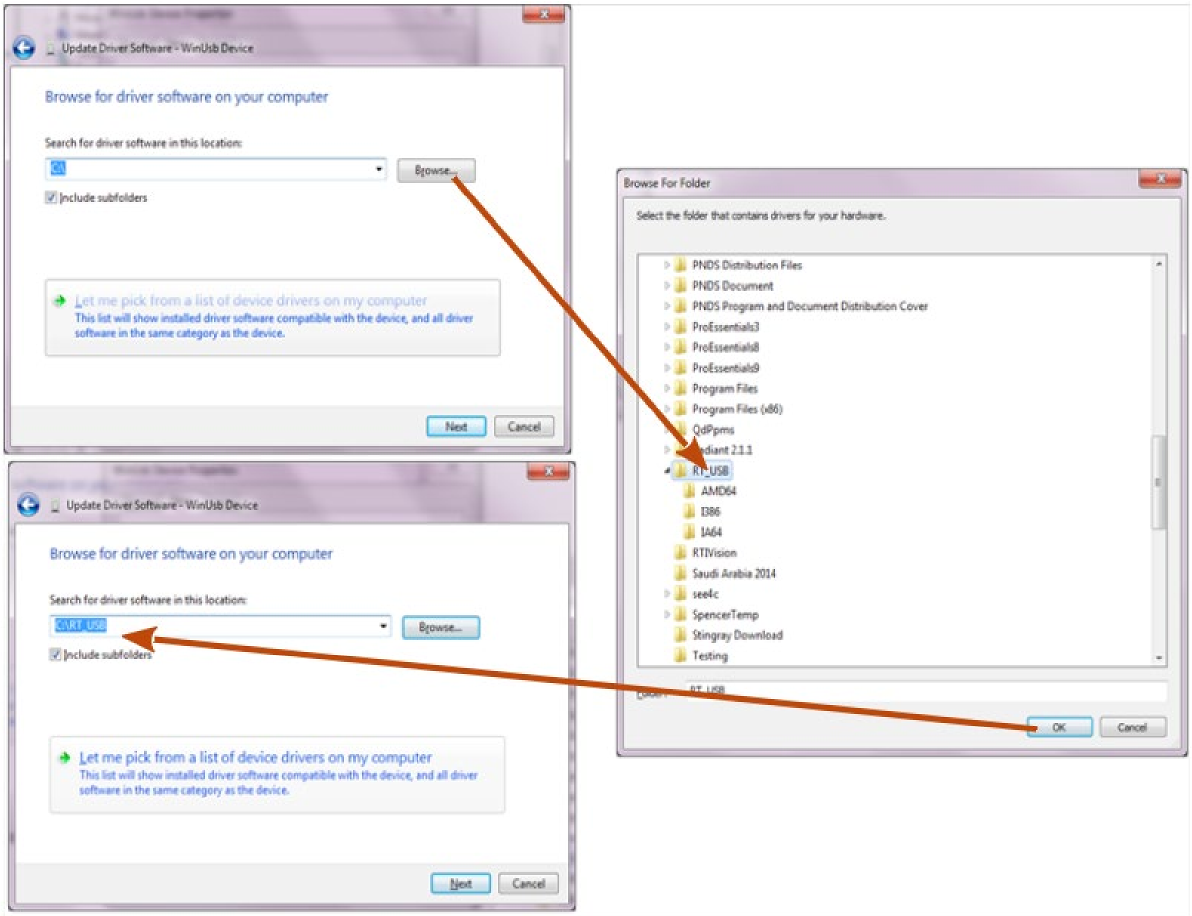
Right-click and select "Update Driver Software..." from the popup menu.



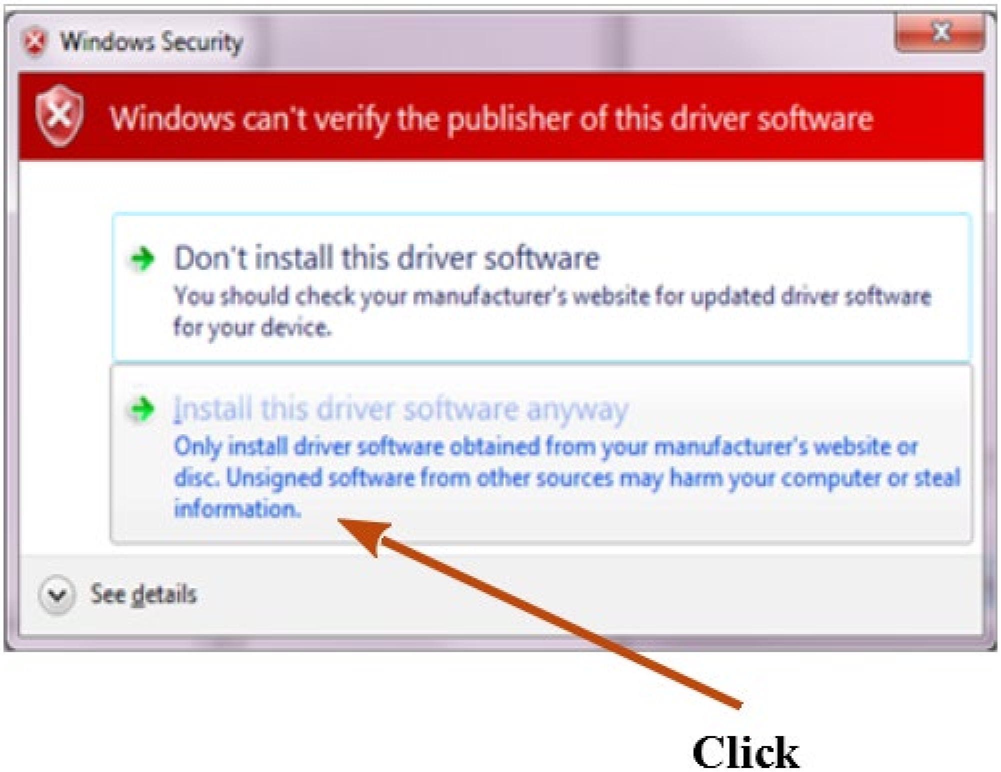
3. In the window that appears, click the *Browse my computer for driver software* option.



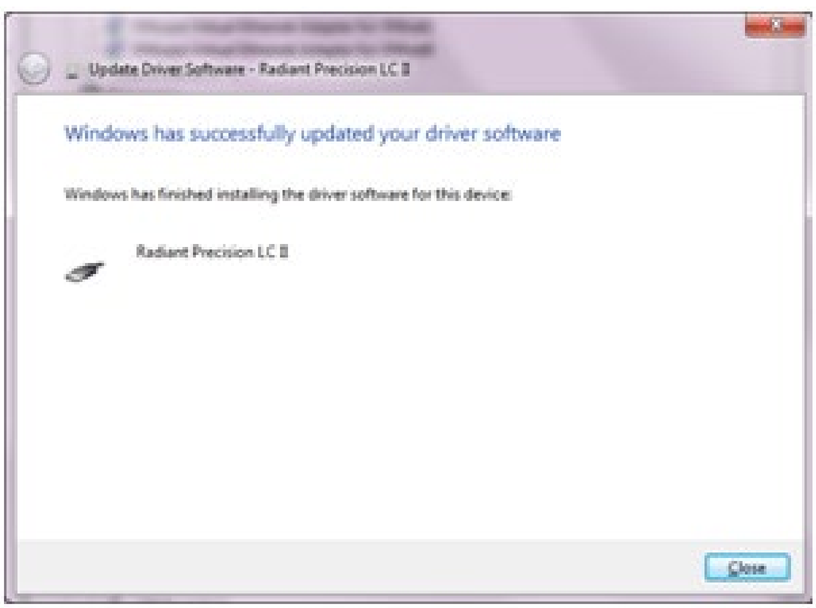
4. In the next window, click the *Browse* button. In the file explorer window navigate to and select C:\RT_USB. Click *OK* to close the explorer and update the file path.



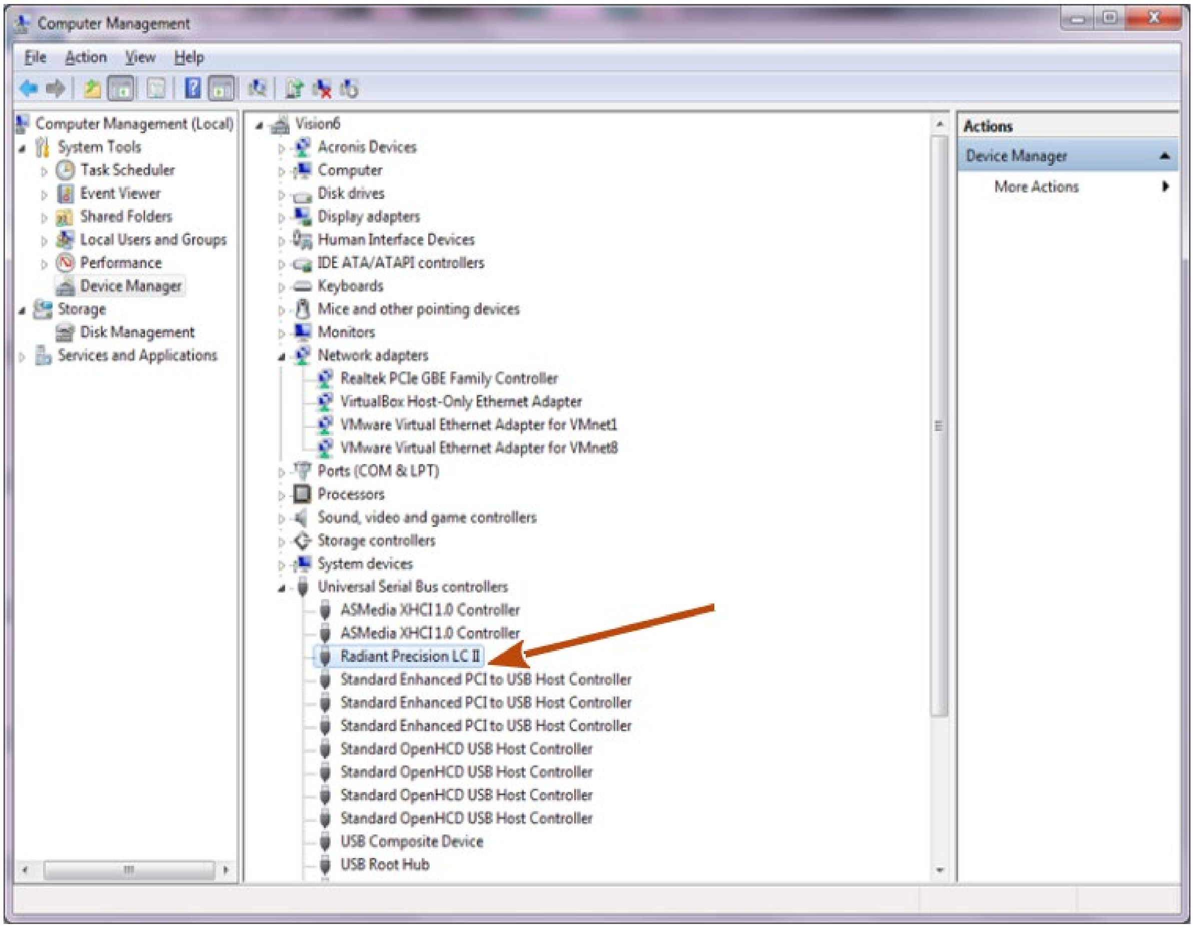
5. A warning appears that indicates that the driver for the tester is not digitally signed. Click the *Install this driver software* anyway selection.



6. Allow the installation to proceed. This may take several seconds. When the installation is complete a notice appears that indicates that "Windows has successfully updated your driver software". The tester (or accessory) names will be displayed.



7. When the notice is closed, the instrument will appear, by name, in the Device Manager.



Windows 8, 8.1 and 10 installation

All testers distributed after 2014, and all USB accessories, will install themselves to Windows 8, 8.1 or 10 with no action from the user other than to connect the instrument to a Vision host USB port and to power on the device. Devices older than 2014 must be manually installed as in the previous (Windows 7) section. However, under these operating systems the host computer must be rebooted with Driver Signature Enforcement disabled before connecting the instrument and proceeding with the driver installation. The steps to disable Driver Signature Enforcement differ between Windows 8, 8.1 and 10 and between various releases of Windows 10. Here are the steps for Windows 8, 8.1 and the latest release of Windows 10. If the steps do not work, Googling "Disable Driver Signature Enforcement Windows xxx" will produce a large number of links that will demonstrate the process.

Windows 8

1. Move the cursor to the lower-right display corner.
2. Click the “Settings” icon (gear icon).

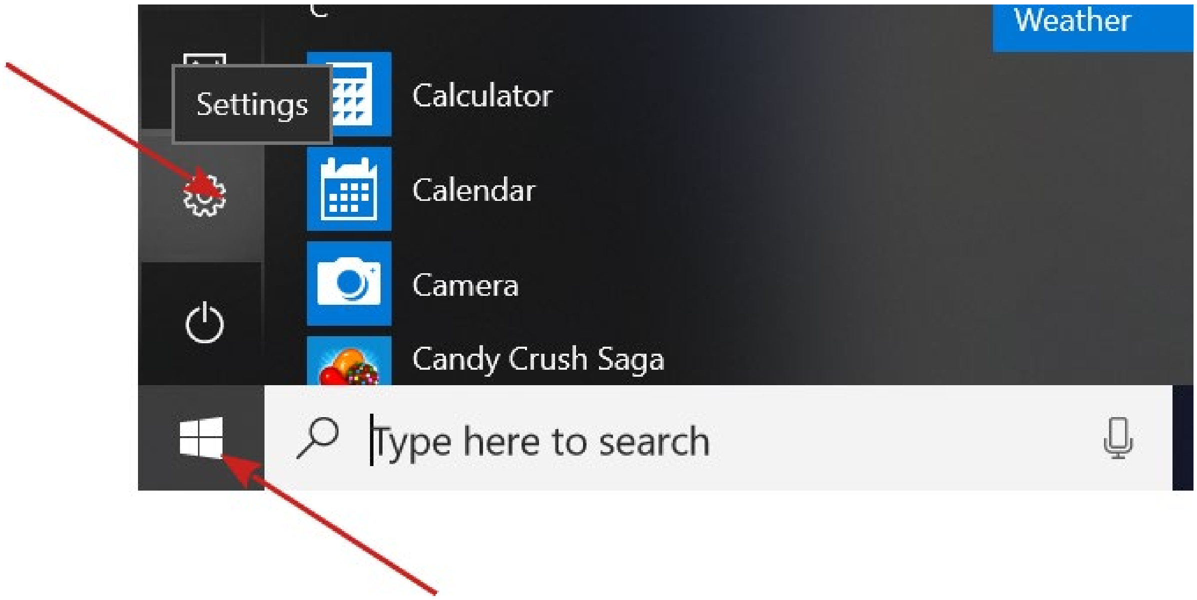
3. Select "Change PC Settings"
4. Choose "General", and then scroll to bottom of right pane, under "Advanced Settings" click "Re-start Now" button.
5. Choose "Troubleshoot" icon, choose "Advanced Options" icon, choose "Startup Settings" icon.
6. Click the "Restart" button. Upon restarting, Windows will display a selection menu.
7. Choose "7) Disable driver signature enforcement".
8. After the machine boots up, connect the RTI Tester.
9. Open the Device Manager by using the keystrokes <WindowsKey+X> to open a list of options and then select the Device Manager.
10. Find the Tester under "Unknown Devices."
11. Right click on the Tester and choose Update Driver Software.
12. Browse to NGS.INF in the C:\RT_USB folder as discussed under **Windows 7 Installation**, above.
13. Allow the installation to proceed as above.

Windows 8.1

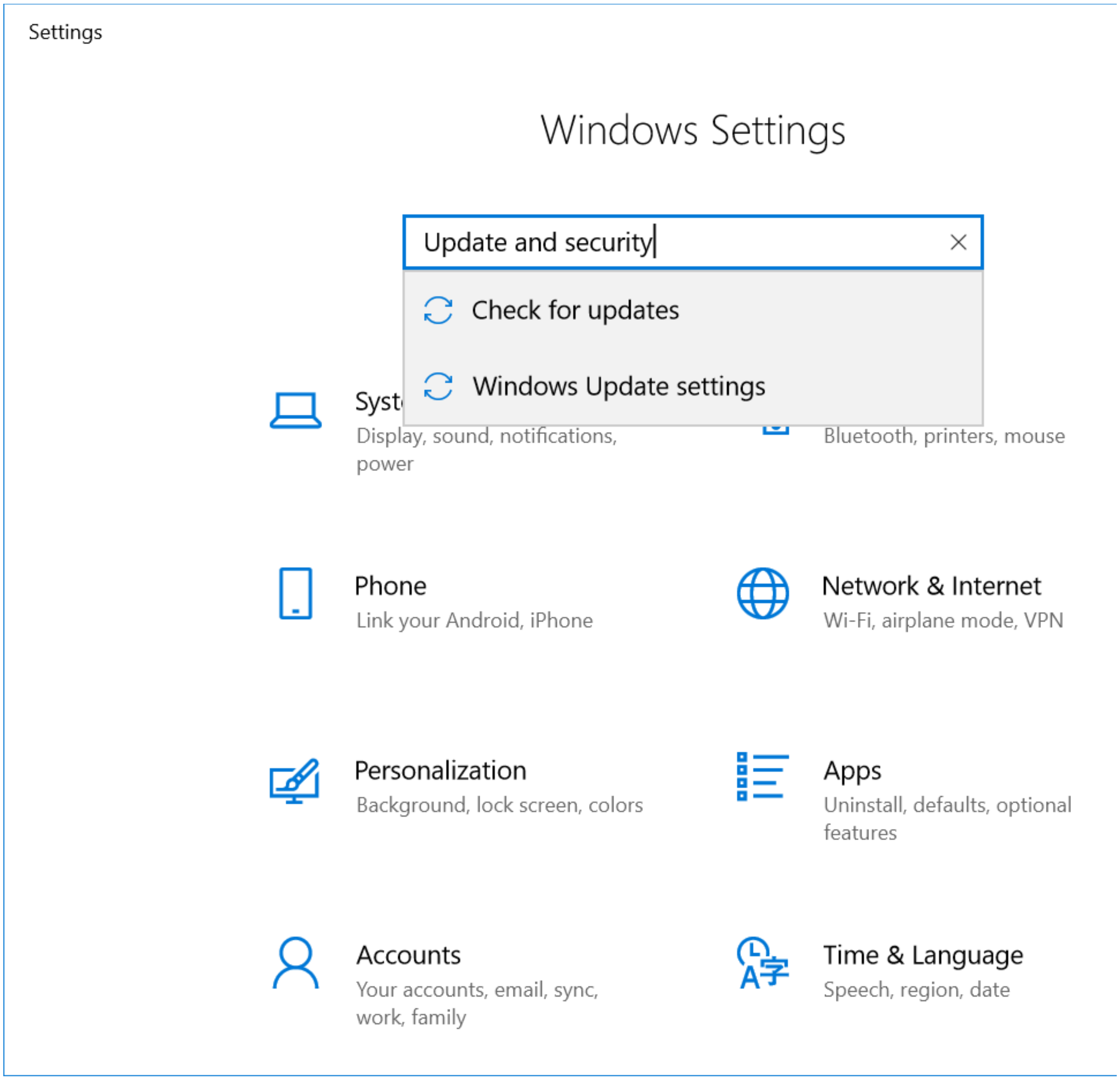
1. Move the cursor to the lower-right display corner.
2. Click the "Settings" icon (gear icon).
3. Select "Change PC Settings"
4. Select "Update and Recovery"
5. Select "Recovery"
6. Select "Advanced Startup"
7. Select "Restart Now"
8. Select "Troubleshoot"
9. Select "Advanced Options"
10. Select "Startup Settings"
11. Select "Restart"
12. On restart, press '7' to disable Driver Signature Enforcement.
13. After the machine boots up, connect the RTI Tester.
14. Open the Device Manager by using the keystrokes <Windows Key+X> to open a list of options and then select the Device Manager.
15. Find the Tester under "Unknown Devices."
16. Right click on the Tester and choose Update Driver Software.
17. Browse to NGS.INF in the C:\RT_USB folder as discussed under **Windows 7 Installation**, above.
18. Allow the installation to proceed as above.

Windows 10

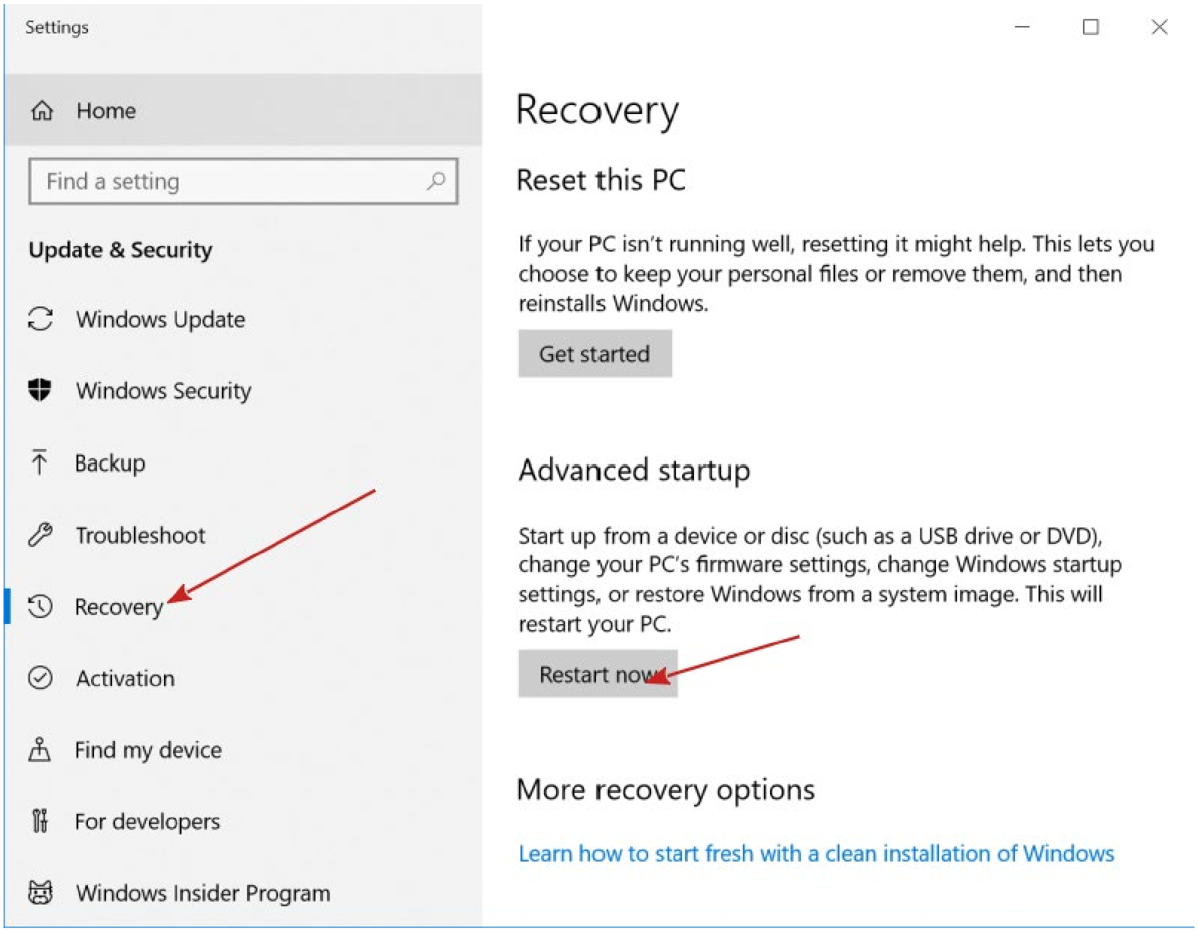
1. Click the Start button and choose the Settings icon.



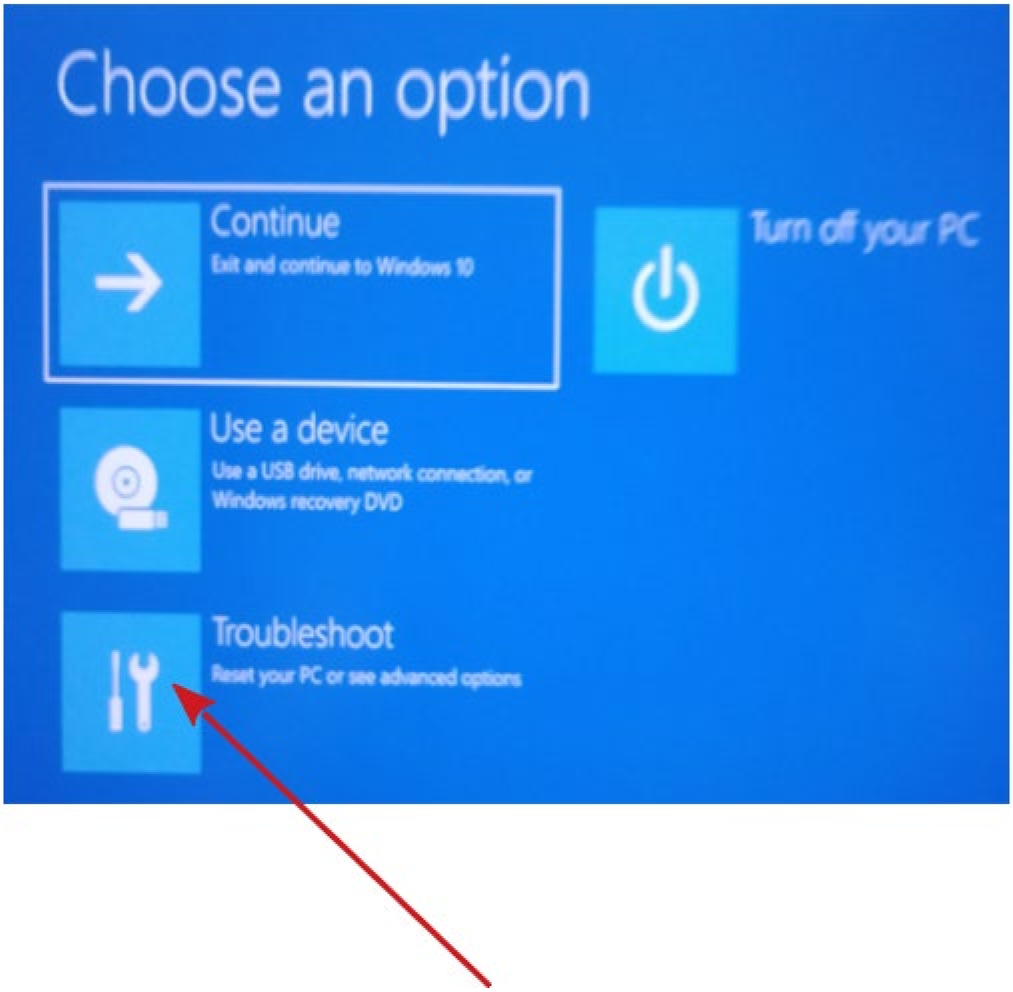
2. In the window that appears type "Update and Security" into the text box and conduct the search.



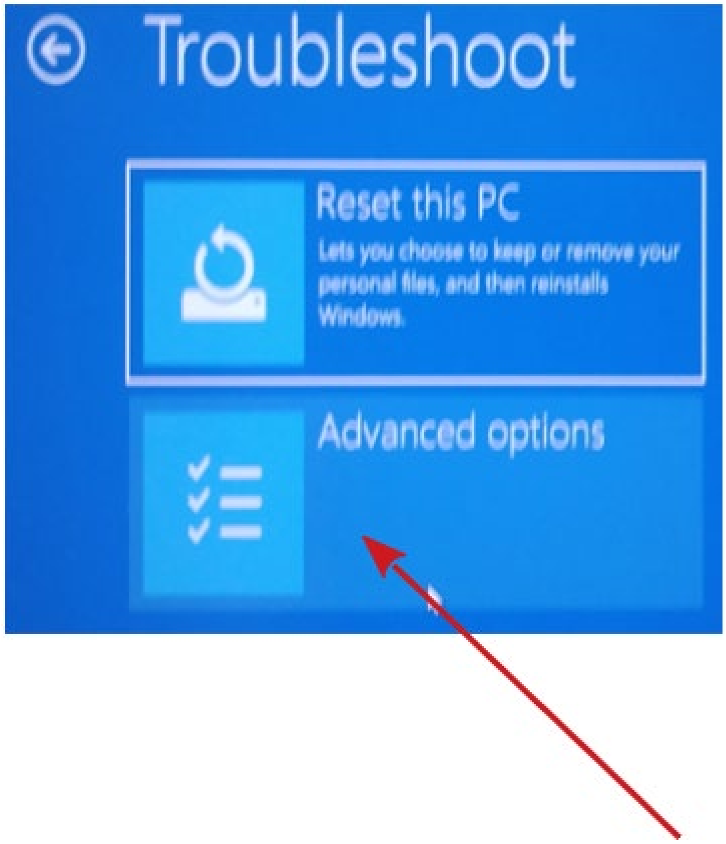
3. In the next window select "Recovery" on the left pane and click Advanced Startup->*Restart Now*.



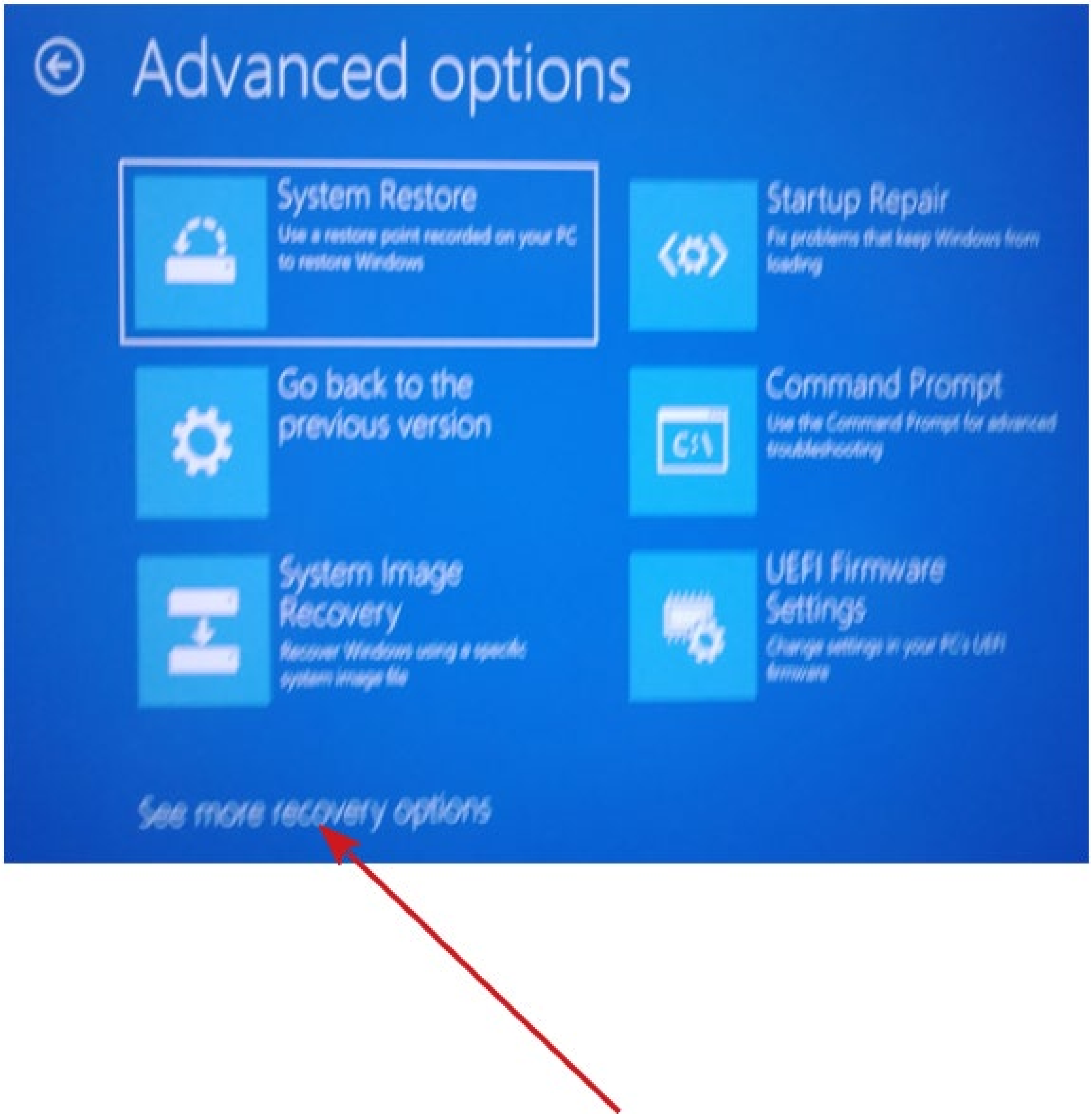
4. Windows will shut down and reboot. Before shutting down it needs to be provided with instructions for the reboot. In the first window that appears, click *Troubleshoot*.



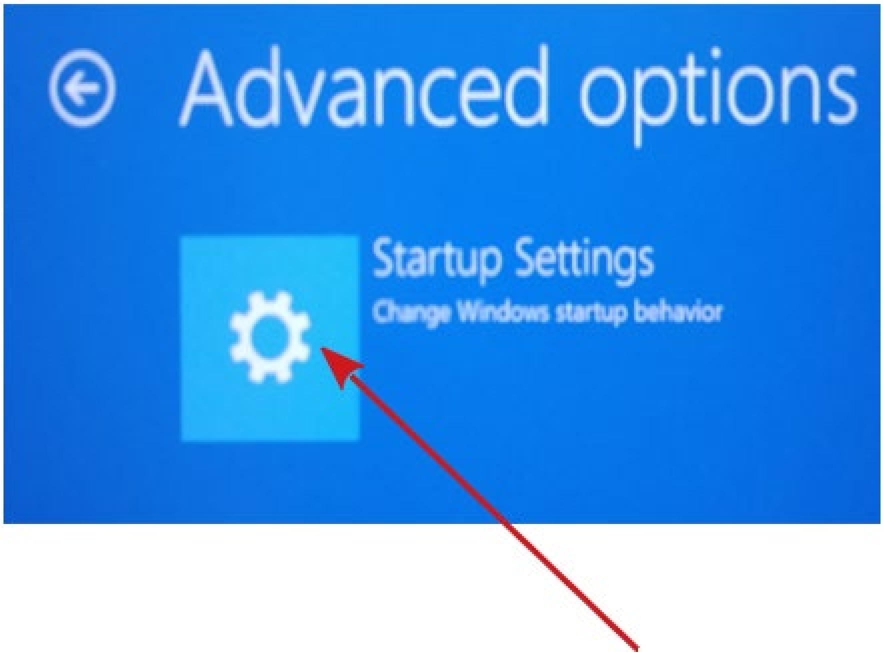
5. In the next window click *Advanced Options*.



6. Then you need to click *See more recovery options*.

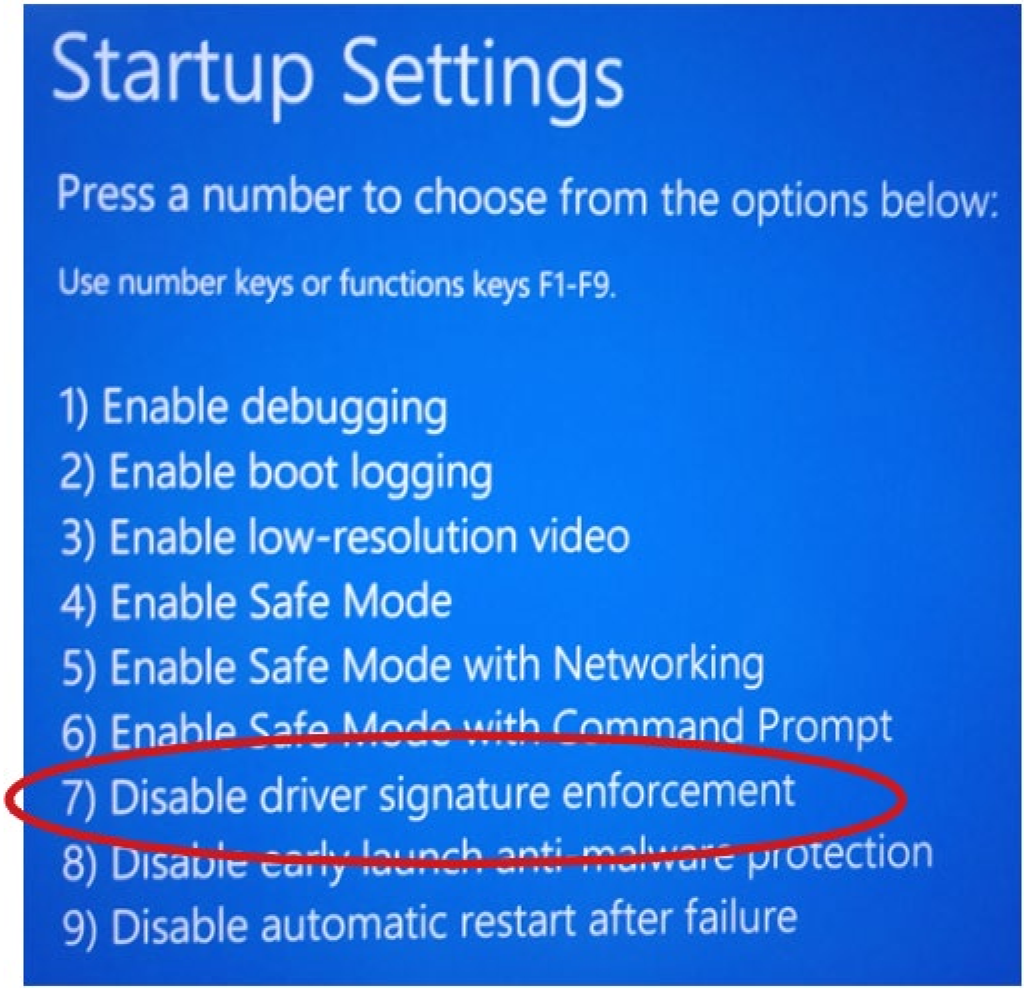


7. Click the *Startup Settings* button.



8. Click the *Restart* button.

9. Windows will reboot. Before the operating system starts you are provided with a list of options. Press '7' to start Windows with Driver Signature Enforcement disabled.



10. The tester may now be installed. Please note that:

- When Windows is rebooted again Driver Signature Enforcement will be renabled.
- These specific steps may not apply to your version of Windows. You may need to search for the proper procedures or Google "Disable Driver Signature Enforcement Windows 10".

Tester Theory

Virtual Ground

All Precision testers operate by measuring the electrical charge (µC) stimulated at one electrode of the sample under test by a voltage stimulus applied to the opposite electrode. This is compared to the more traditional Sawyer Tower method below. In the Precision tester the charge is captured at the RETURN port, passed through an amplification stage and into an integrator whose voltage output relates directly to the charge input. A simplified diagram is shown in **Figure 1**.

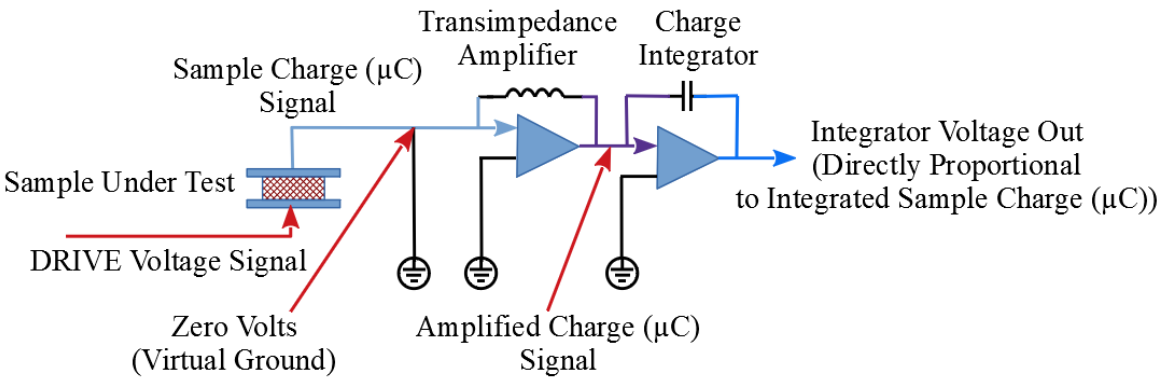


Figure 1 - Virtual Ground

The circuit is called "Virtual Ground" because the Sample Charge (µC) Signal enters the Transimpedance Amplifier at zero Volts. This will be an important consideration in comparing Virtual Ground measurements to Sawyer Tower measurements.

Virtual Ground Vs Sawyer Tower

An earlier standard for measuring the response of a non-linear sample under test - and one still taught to students - is the Sawyer Tower Circuit. In this much simpler circuit the voltage drop across a Sense Capacitor that is in series with the sample under test is measured. This voltage drop can then be directly related to the voltage drop across the sample under test. Here, then, the voltage across the sample, rather than the current through the sample, is measured. The simple circuit is shown in **Figure 2**.

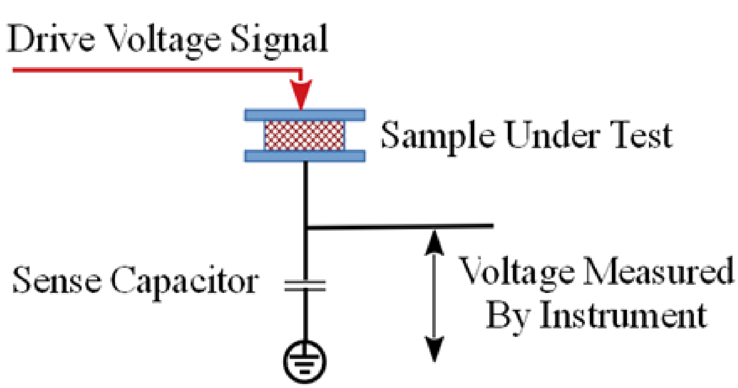


Figure 2 - Sawyer Tower

The Sawyer Tower circuit has the advantage of simplicity. There, however, the advantages end. There are three main problems with the Sawyer Tower technique:

Sense Capacitor
The Sense Capacitor is the critical element in the circuit. It must be a capacitor whose value is very precisely known. Furthermore the Sense Capacitor should be approximately ten times the capacitance of the Sample Under Test. That means that the sample capacitance needs to be well-estimated in constructing the Sawyer Tower circuit. The 10 X size ratio of the Sense Capacitor to the Sample Under Test is chosen to reduce Back Voltage. The Virtual Ground circuit uses a fixed, precisely-known integrating capacitor that is designed to measure samples with a wide range of capacitances. The value of the capacitor does not need to be selected by, or known to, the user.

Back Voltage from the Sense Capacitor
As the Drive Voltage Signal peaks and begins to return to zero Volts during a Hysteresis measurement, the charge accumulated by the Sense Capacitor will create a back voltage at the sample electrode opposite the the Drive Voltage Signal (**Figure 3**). The effect of this Back Voltage combines with the influence of the Drive Voltage Signal to distort the sample's voltage response.

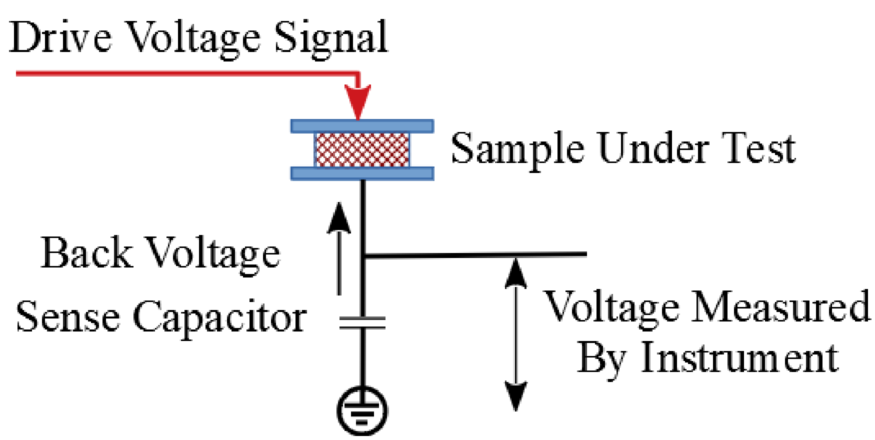


Figure 3 - Back Voltage in a Sawyer Tower Measurement

With the sample response held at 0.0 Volts at the RETURN port, the Virtual Ground circuitry allows for no Back Voltage to be applied to the sample RETURN electrode and does not distort the measurement.

Parasitic Capacitance
All electronic circuits have capacitance. In the case of the Sawyer Tower circuit this capacitance can be modeled as a single constant capacitor in parallel with the Sense Capacitor (**Figure 4**). The parasitic capacitance sums with the Sense Capacitor, increasing its to-

tal capacitance. Since the parasitic capacitance is constant the contribution of this capacitance to error varies with the size of the Sense Capacitor. The contribution, as a percentage of the total, is larger for smaller Sense Capacitors.

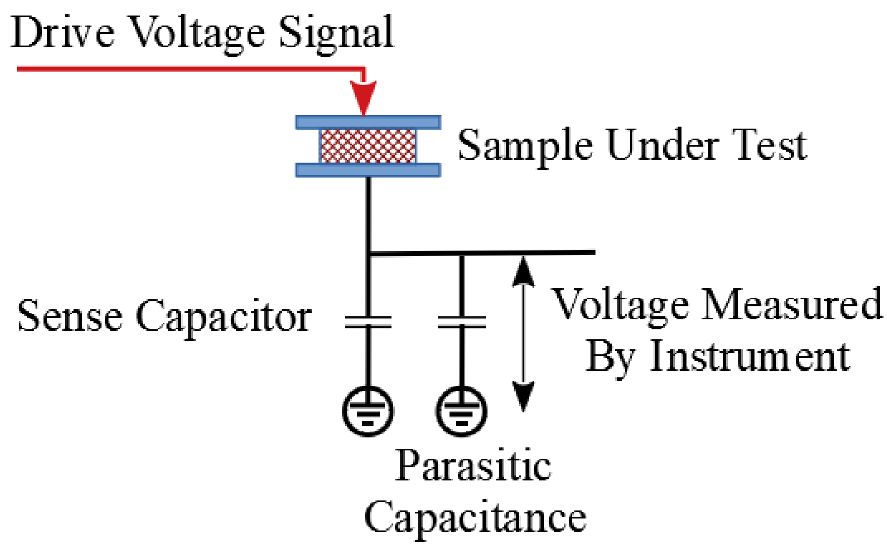


Figure 4 - Sawyer Tower Parasitic Capacitance

Virtual Ground circuitry also has parasitic capacitance. However, on the RETURN signal side of the circuit, the capacitance is modeled between the zero-Volt Virtual Ground input of the circuit and earth ground. (**Figure 5**.) With no voltage across the parasitic capacitance the capacitor model introduces no contribution to the measured signal.

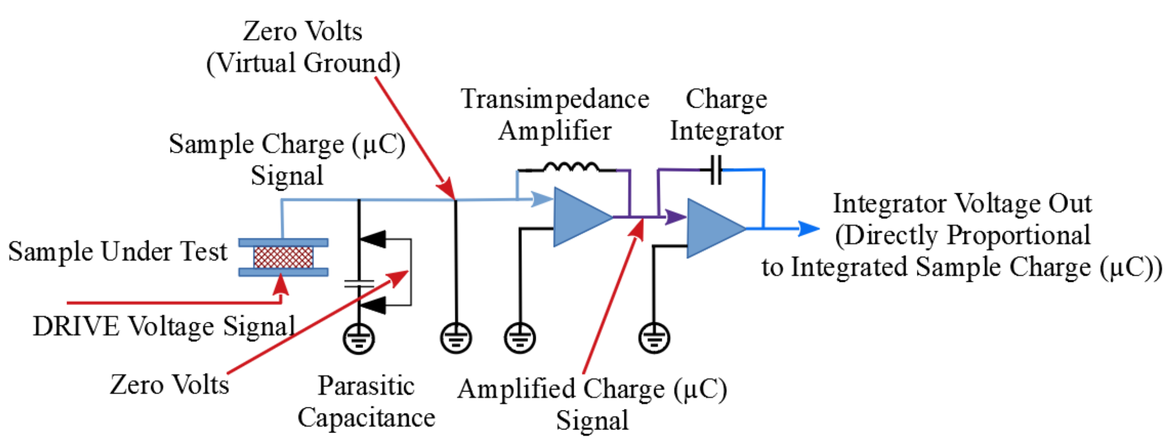


Figure 5 - Virtual Ground Parasitic Capacitance

Note that the Transimpedance Amplifier, the Charge Integrator and other tester circuitry also add parasitic capacitance that does affect the measured data beyond the RETURN port. Normally this capacitance is insignificant with respect to the strength of the measured signal and can be ignored. For measurements on very small capacitors that return very low measured signals, Vision provides tools to characterize and remove tester parasitic capacitance contributions to the data.

Simplified Hysteresis Measurement Sequence

The Hysteresis - or PE (Polarization Vs Field) - measurement is the primary non-linear characterization measurement made, within Vision, by the Precision Tester. Several measurements are derived directly from the Hysteresis measurement. In Vision, the basic Hysteresis measurement is performed using the Hysteresis Task. This is a discussion of the process involved in making the Hysteresis measurement. This discussion is heavily simplified.

1. The measurement begins with the user configuring the Task's measurement parameters (**Figure 6**).

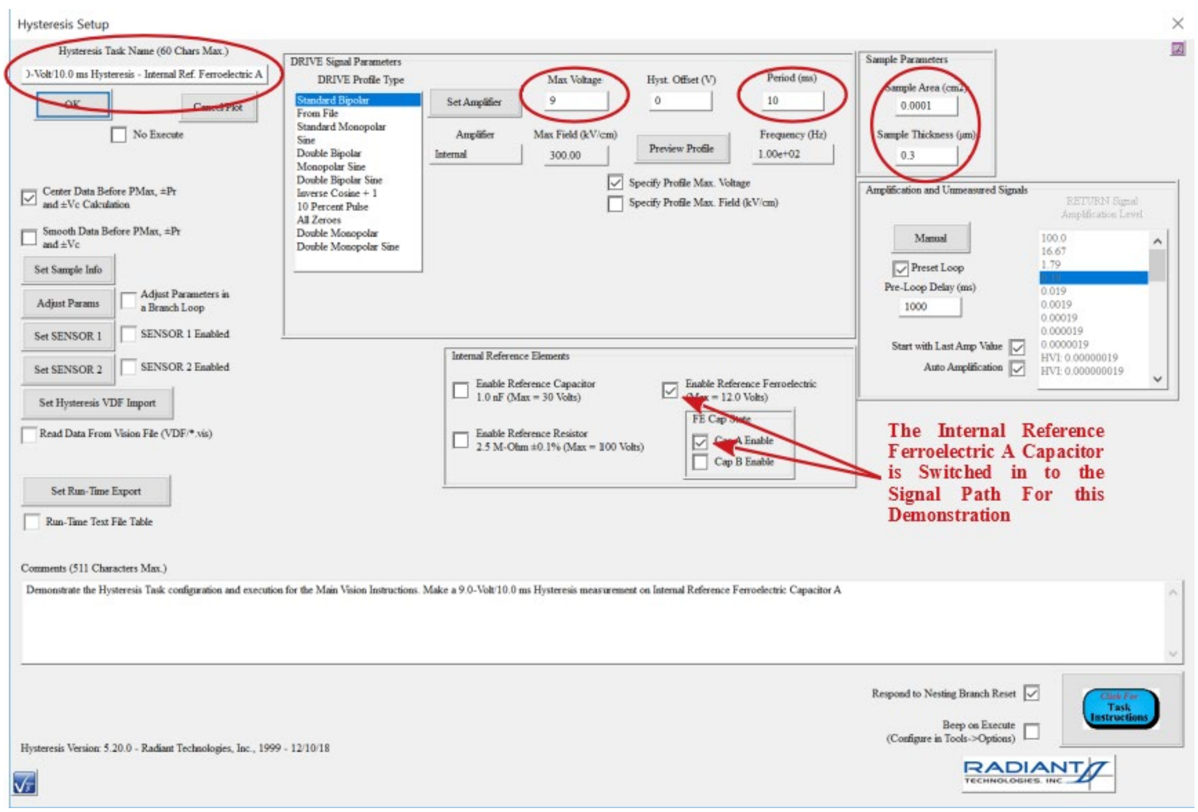


Figure 6 - Hysteresis Task Basic Configuration

There are a large number of configuration options. However, the main parameters to configure are:

**Task Name* - The Task will be permanently archived under this name. It is important to assign a unique and meaningful *Task Name*.

**Max Voltage* - This value will be used to define the DRIVE voltage profile as discussed below. A bipolar triangular voltage profile will be applied with peaks at ±*Max Volt-*

age.

Period (ms) - This value will be used to define the DRIVE voltage profile as discussed below. This is the duration of the DRIVE voltage profile sweep in milliseconds. It is equivalent to 1000/Frequency (Hz).

Sample Area (cm2) - The surface area, in cm^2, of the smaller of the two sample electrodes. The sample charge (µC) response to the DRIVE Voltage will be normalized by this term to generate the standard non-linear sample response parameter of Polarization (µC/cm^2).

Sample Thickness (µm) - This is the depth, in microns, of the ferroelectric material between the sample electrodes. This is primarily a documentation parameter. However, it is integral in the DRIVE signal strength calculation if data are to be plotted as a function of electric field (kV/cm).

Enable Reference Ferroelectric and *Cap A Enable* - Checking these controls for the purpose of this discussion switches a built-in Radiant Technologies, Inc. 4/20/80 PNZT sample into the signal path for measurement.

The next several steps refer to **Figure 7**.

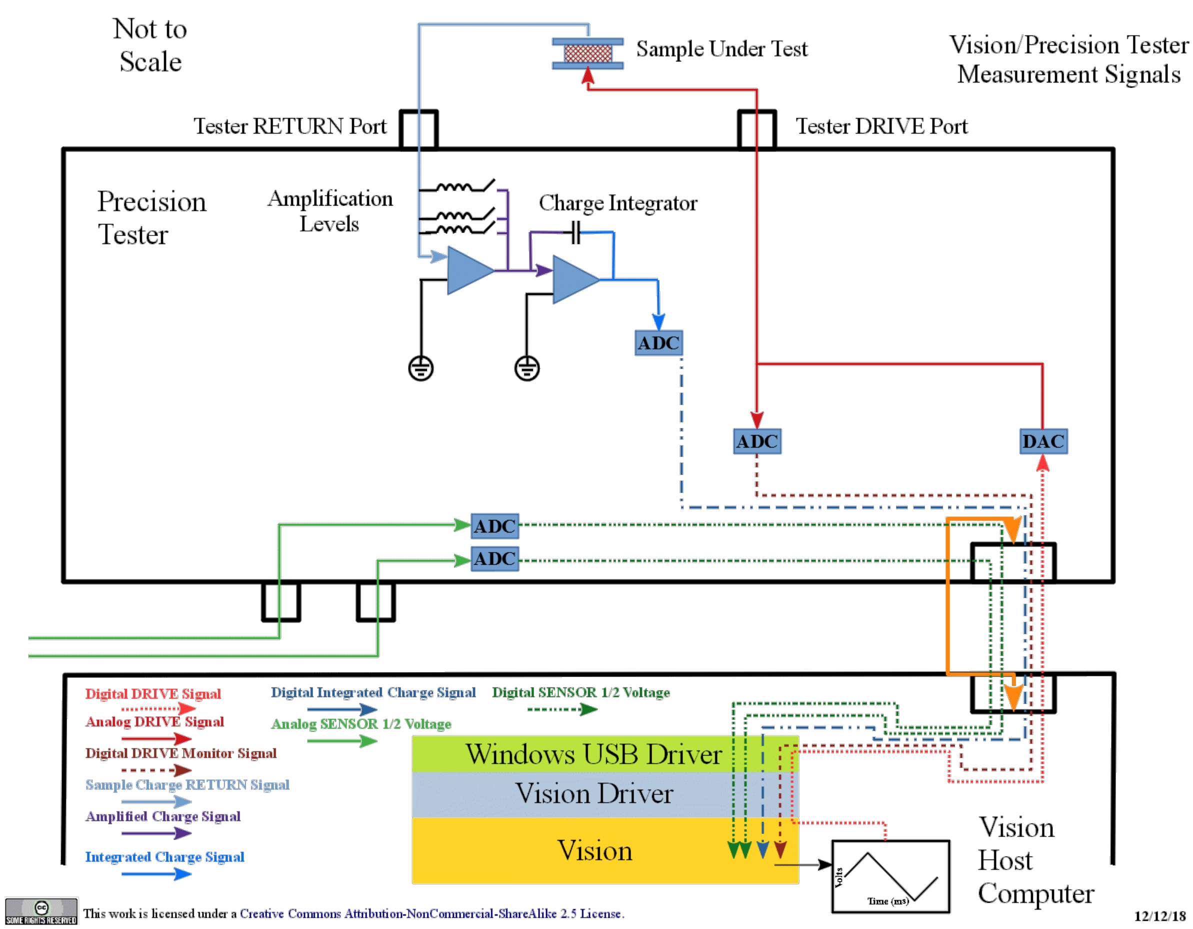


Figure 7 - Hysteresis Task Measurement Sofware and Hardware

Signals.

2. On execution, Vision creates a list of voltages that form a single bipolar triangular waveform between -*Max Voltage* and +*Max Voltage* Volts. The list is a series of discrete, real-valued voltages with a fixed voltage step magnitude between each list entry. The number of entries (points) in the list is the maximum number that can be applied give the voltage step size, the delay between each step (*Period (ms)*/points), the tester model capability and, possibly, the user-programmed upper limit.
3. Vision converts the voltage list into a second, binary list, whose entries are recognized by the tester circuitry as voltage commands.
4. Vision passes the binary voltage list, along with a binary representation of the *Period (ms)*, the number of sample point and the amplification level to the Vision Driver. Note that, to the user, the Vision Driver is indistinguishable from the Vision program.
5. Through the Windows USB Driver, the Vision host computer USB port and the tester USB port, the driver switches in the assigned amplification level. (See the discussion below.)
6. The Vision Driver passes the voltage list and a step delay through the Windows USB Driver, the Vision host computer USB port and the Precision tester USB port, to the tester's Digital-To-Analog Converter (DAC). The step delay (ms) is given by Period (ms)/(Points - 1)
7. The DAC converts the command to a voltage and passes the signal, through the tester DRIVE port, to the Sample Under Test.
8. The DAC also passes the voltage to an Analog-to-Digital Converter (ADC) that converts the actual voltage out back to a digital word. The ADC passes the digital word back, through the Windows USB Driver to the Vision Driver.
9. The sample responds to the voltage applied at one electrode by moving charge onto or off of the opposite electrode.
10. The charge (μC) moved by the sample enters the tester RETURN port.
11. The charge (μC) enters an amplification stage where the current amplifier selection either amplifies or deamplifies the signal.
12. The amplified/deamplified signal enters the integrators where it is integrated with all previous charge captured in the measurement.
13. The voltage out of the integrator, which is directly proportional to the charge (μC) generated by the tester, is converted to a digital value by an ADC and passed to the Vision Driver.
14. If enabled, one or two voltages, in the ±10.0-Volt range can be captured at the tester SENSOR 1 and/or SENSOR 2 port simultaneously with the integrator output capture. These are converted to a digital value by an ADC and passed to the Vision Driver.
15. The Vision Driver bundles the DRIVE voltage output data, the Charge Integrator output voltage data and, if enabled, the SENSOR 1 and/or SENSOR 2 data and passes them back to Vision.
16. Vision converts the digital data from the driver back to meaningful voltages.
17. Vision converts the Charge Integrator voltage to charge (μC) data and normalizes the data by the *Sample Area* (cm^2) to generate Polarization ($\mu C/cm^2$) data.
18. Vision archives the data, passes them to any Filter Tasks that may be associates with the Hysteresis Task and produces a data plot.

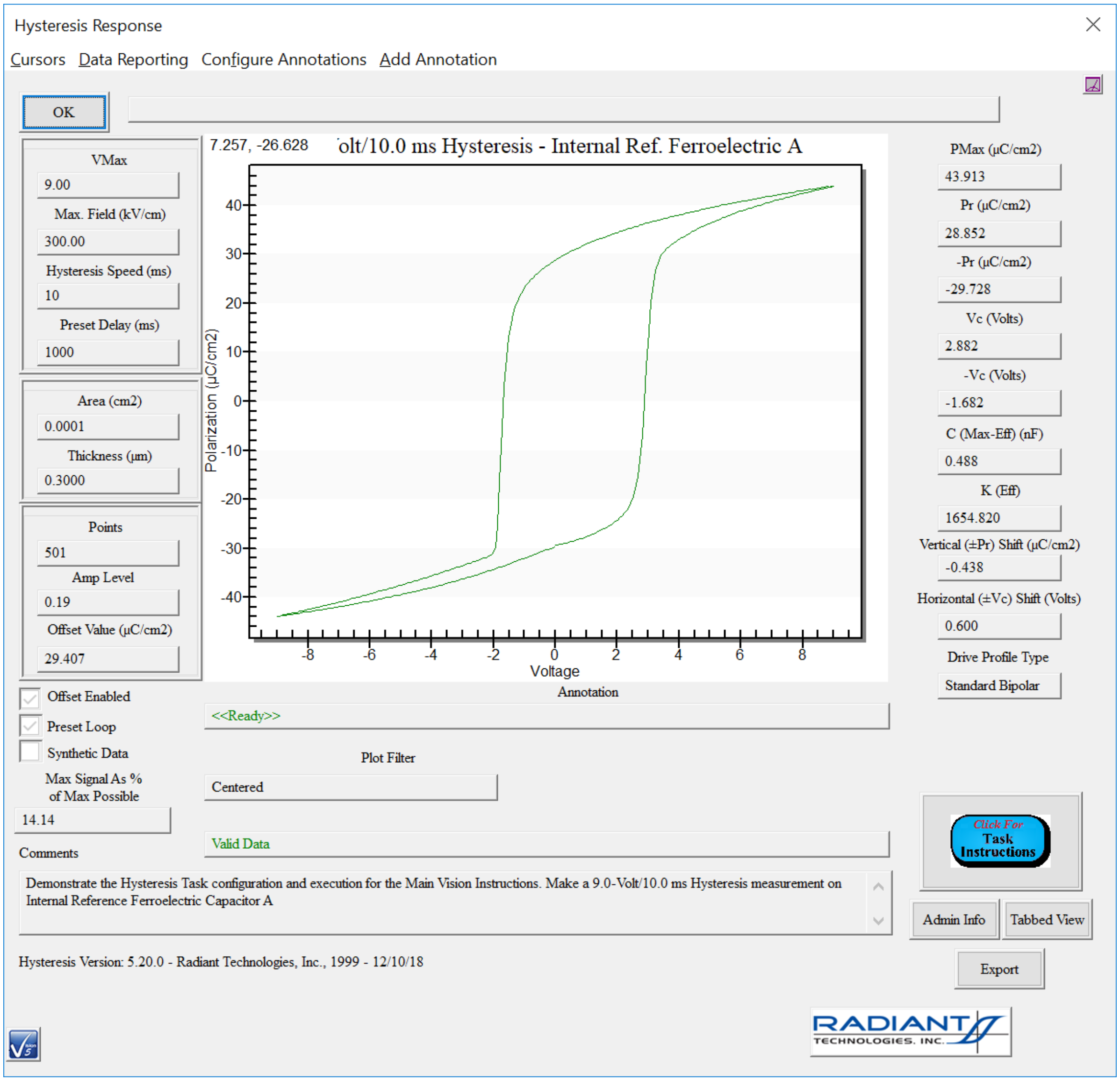


Figure 8 - 9.0-Volt/10.0 ms Internal Reference Ferroelectric Hysteresis Measurement.

Hysteresis DRIVE Voltage Profile

DRIVE Profile Options

The Hysteresis Task offers many DRIVE Voltage Profile options. Eleven automatic profiles and a custom profile are offered. In addition any profile may be shifted vertically by specifying a *Hyst Bias*. The user can completely specify a DRIVE Profile by selecting a *DRIVE Profile Type*, assigning a *Max Voltage*, specifying the *Period (ms)* and, perhaps, assigning a *Hyst Bias*. The period is the duration of the entire DRIVE profile in milliseconds. For bipolar profiles this is equivalent to 1000 / Frequency (Hz) => Frequency (Hz) = 1000 / Period (ms). For double-bipolar profiles, the factor is 2000 and for monopolar sequences the factor is 500. A final complexity is that the profile strength and offset may be specified in units of Electric Field (kV/cm). Here, Electric Field (kV/cm) is given by:

$$\text{Electric Field (kV/cm)} = \text{Voltage} / (1000\ \text{V/kV} \times \text{Sample Thickness}\ (\mu\text{m}) \times 10^{-4}\ \text{cm}/\mu\text{m}) \quad (1)$$

This option is selected by checking *Specify Profile Max Field (kV/cm)* on the configuration dialog. In this case dialog controls are relabeled *Max Voltage => Max Field (kV/cm)* and *Hyst Bias (V) => Hyst Bias (kV/cm)*.

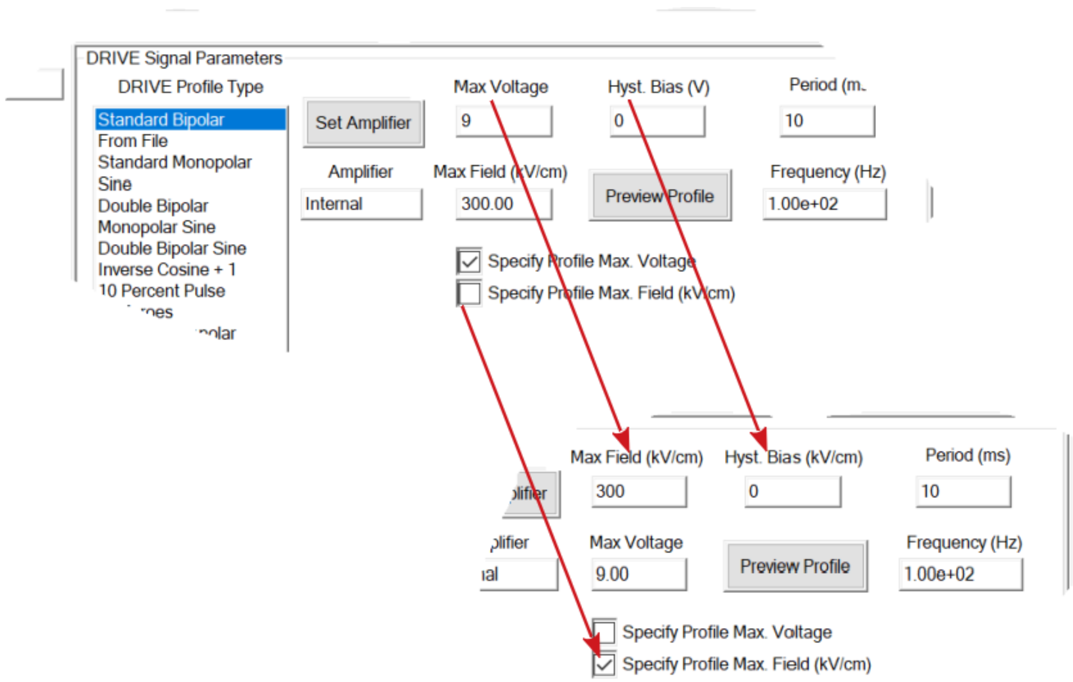
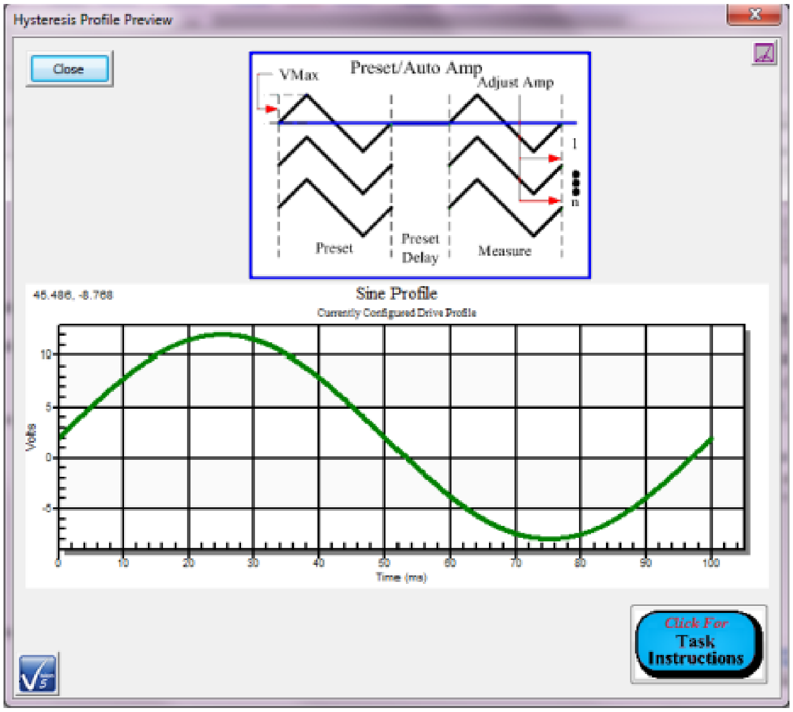
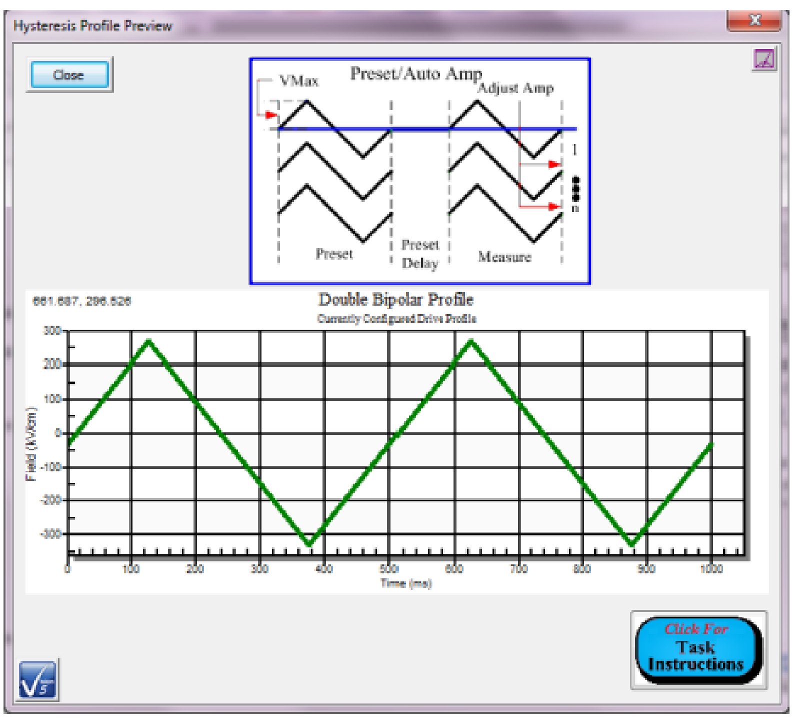


Figure 9 - Hysteresis Configuration - Specify Electric Field (kV/cm).

Figure 10 shows two profile options. The figure is generated by clicking the *Profile Preview* button on the configuration dialog.



10.0-Volt/100.0 ms Bipolar Sinusoid with +2.0-Volt Offset

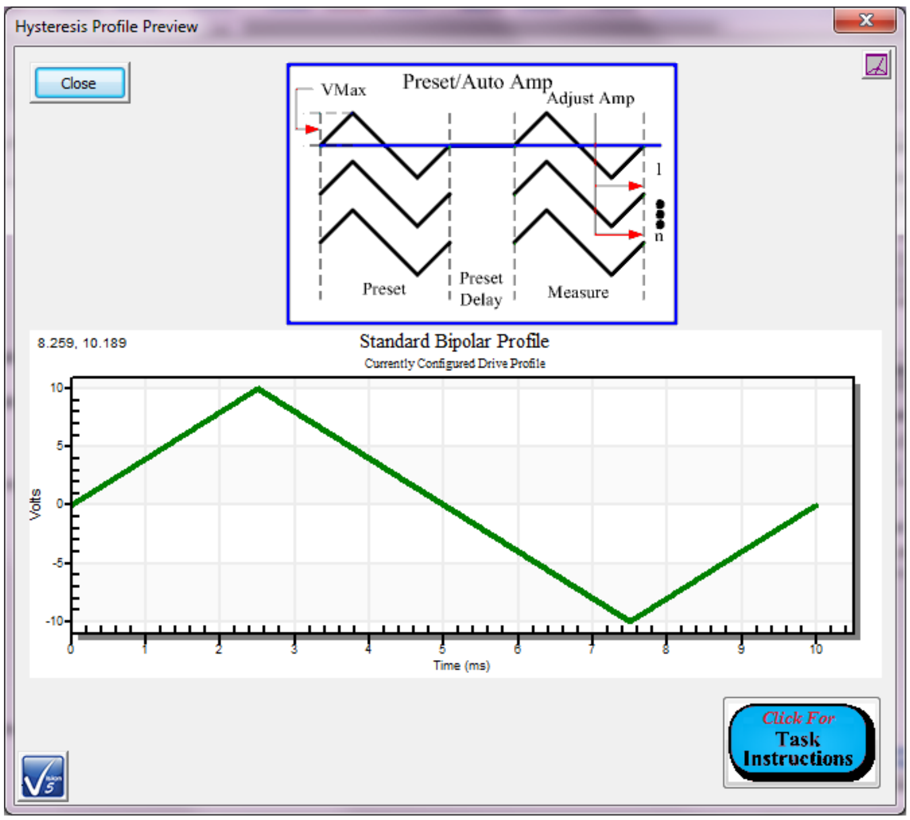


300.0 kV/cm/1000.0 ms Double Bipolar Profile with -30.0 kV/cm Offset

Figure 10 - Example Hysteresis DRIVE Profiles.

Example DRIVE Profile

Each DRIVE Profile is composed of a sequence of discrete real-valued voltages. While the user completely specifies the profile with a *DRIVE Profile Type* selection, *Max Voltage*, *Period (ms)* and possibly *Hyst Bias (V)*, the program takes these parameters and constructs the voltage list. For this example the default "Standard Bipolar" *DRIVE Profile Type* will be used with a *Max Voltage* of 10.0 V and a 10.0 ms *Period (ms)*. *Hyst Bias (V)* is 0.0 V. The first point in the list is always 0.0 V. (The *Hyst Bias (V)* parameter is passed separately to the driver).



10.0-Volt/10.0 ms Standard Bipolar DRIVE Profile

Figure 11 - 10.0-Volt/10.0 ms Standard Bipolar Hysteresis Profile.

The Standard Bipolar profile starts at 0.0 V, rises linearly to +10.0 V, then falls linearly at the same rate to -10.0 V before rising again to a final value of 0.0 V. Note that the total magnitude of the voltage traversed is 4 x 10.0 V = 40.0 V.

The program begins by determining the number of points over which to space the voltages in the list. The number of points specified is the maximum possible number (always the highest-precision) given several conditions:

- Tester Model - Precision LC and RT66B testers have a maximum point count of 500 pts. The Precision RT66C and all Precision testers older than 2014 have a 2000-point limit. All other testers have a 32,000-point limit.
- The user-specified point ceiling (see below).
- The measurement *Period (ms)* related to the minimum step time of the tester model being used. (See tester specifications for a particular model.) This parameter can adjust the point count downward for very fast measurements.
- The measurement *Max Voltage* related to the minimum voltage step of the tester model being used. (See tester specifications for a particular model.) This parameter can adjust the point count downward for very low-voltage measurements.

The DRIVE Profile list always begins and ends at 0.0 Volts. (Any Hyst Bias (V) is passed separately to the Vision Driver and applied to the waveform there.) For the Standard Bipolar profile of this example, each voltage is determined by incrementing or decrementing the previous voltage by a fixed magnitude of (4 x Max Voltage)/(Points - 1). For a 20001-point waveform this step voltage is given as (4 x 10)/20000 = 0.002 V. **Figure 12** shows a partial list of the example DRIVE Profile voltages at 20001 points. This list was generated from the results of an actual measurement. The data do not represent the DRIVE Profile voltages requested by Vision. They represent the actual DRIVE voltages that were applied at each sample point as discussed in Step 9 of **Simplified Hysteresis Measurement Sequence**, above.

Point	Time (ms)	Drive Voltage
1	5.0000e-04	0.0011
2	1.0000e-03	0.0014
3	1.5000e-03	0.0040
4	2.0000e-03	0.0045
5	2.5000e-03	0.0064
6	3.0000e-03	0.0091
7	3.5000e-03	0.0105
8	4.0000e-03	0.0118
9	4.5000e-03	0.0140
10	5.0000e-03	0.0163
11	5.5000e-03	0.0184
12	6.0000e-03	0.0214
13	6.5000e-03	0.0222
14	7.0000e-03	0.0250
15	7.5000e-03	0.0262
16	8.0000e-03	0.0293
17	8.5000e-03	0.0309
18	9.0000e-03	0.0327
19	9.5000e-03	0.0346
20	1.0000e-02	0.0367
21	1.0500e-02	0.0390
22	1.1000e-02	0.0404
23	1.1500e-02	0.0429
24	1.2000e-02	0.0454
25	1.2500e-02	0.0465
26	1.3000e-02	0.0487
27	1.3500e-02	0.0505
28	1.4000e-02	0.0528
29	1.4500e-02	0.0552
30	1.5000e-02	0.0569
31	1.5500e-02	0.0587
32	1.6000e-02	0.0614
33	1.6500e-02	0.0632
34	1.7000e-02	0.0645
35	1.7500e-02	0.0659
36	1.8000e-02	0.0689
37	1.8500e-02	0.0706
38	1.9000e-02	0.0728
39	1.9500e-02	0.0742
40	2.0000e-02	0.0768
41	2.0500e-02	0.0784

Figure 12 - Hysteresis Standard Bipolar Partial Point Sequence, Sample Time (ms) and Sample Voltage List.

Figure 12 also lists the sample time (ms) for each point relative to the first-captured point. The sample time is captured by the driver at the time of the measurement. The list should increment time (ms) by a constant value that is very close to the ideal time of Period (ms)/(Points - 1). Here, 10.0 ms / 20000 = 0.0005 ms. The actual DRIVE Voltage, Charge (µC), Sample Time (ms), SENSOR 1 voltage and SENSOR 2 voltage parameters are captured at each point after the voltage at that point has been stable for the constant period.

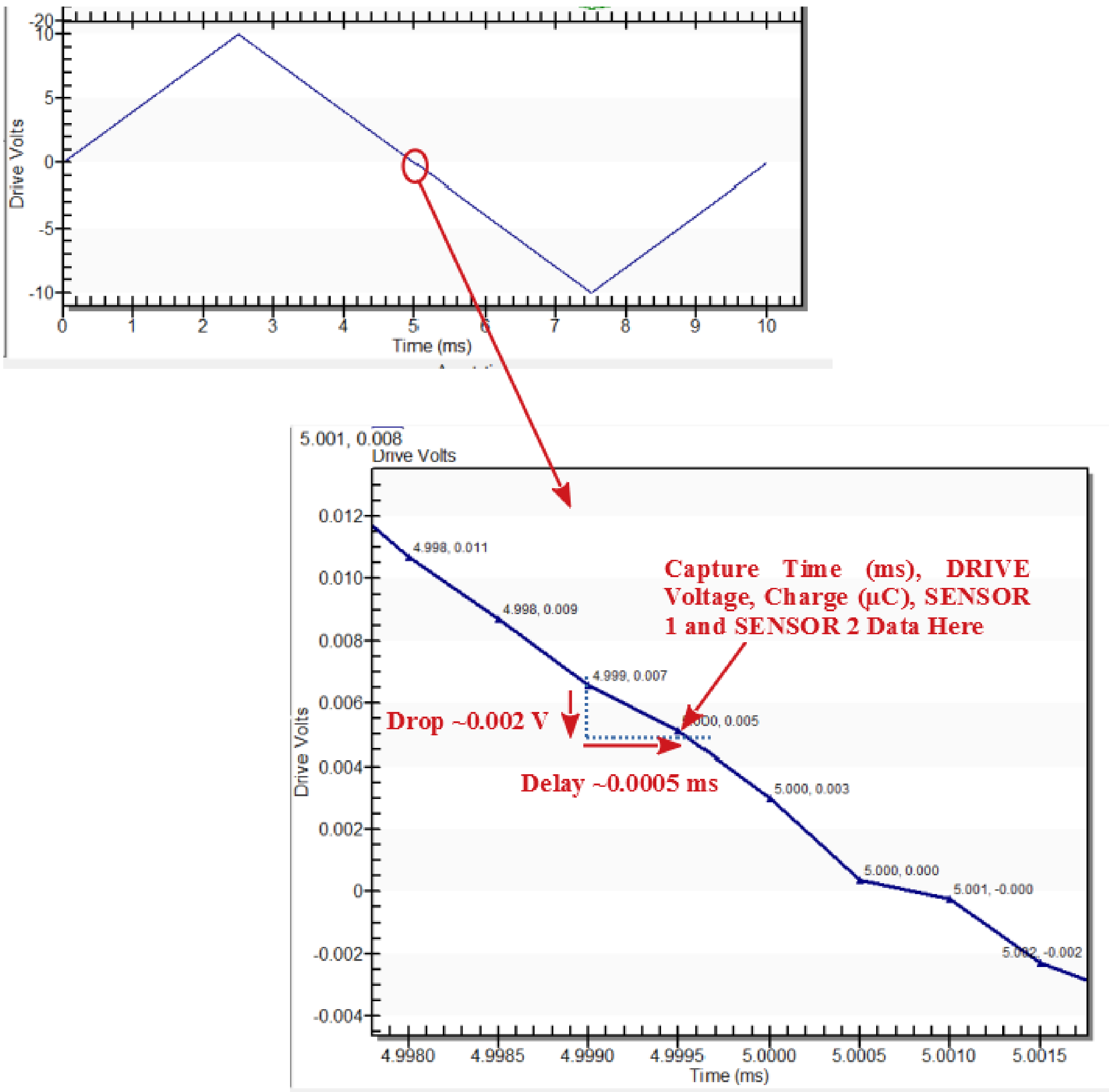


Figure 13 - Zoomed DRIVE Profile After Sample Measurement.

In **Figure 13**, the DRIVE Profile represents actual measured DRIVE Voltage and Step Delay (ms) data. These differ from the ideal data of **Figure 11**.

User-Specified Voltage Ceiling

With the exception of the Precision RT66C tester, all Precision model testers released since 2014 are capable of generating up to 32,000-point Hysteresis measurements. The Precision RT66C has an upper limit of 2000 points. (These numbers are approximate. The actual limit is somewhat higher.) Vision will always build the DRIVE Profile voltage waveform using the maximum number of points given the test conditions. For most testers the user can specify and upper bound on that number of points. To set the limit, go to Tools->Options->Measurement and Test Definition Execution and adjust the selection in *Hysteresis-Based Task Point Limit*. The selection becomes permanent between Vision program executions until it is changed.

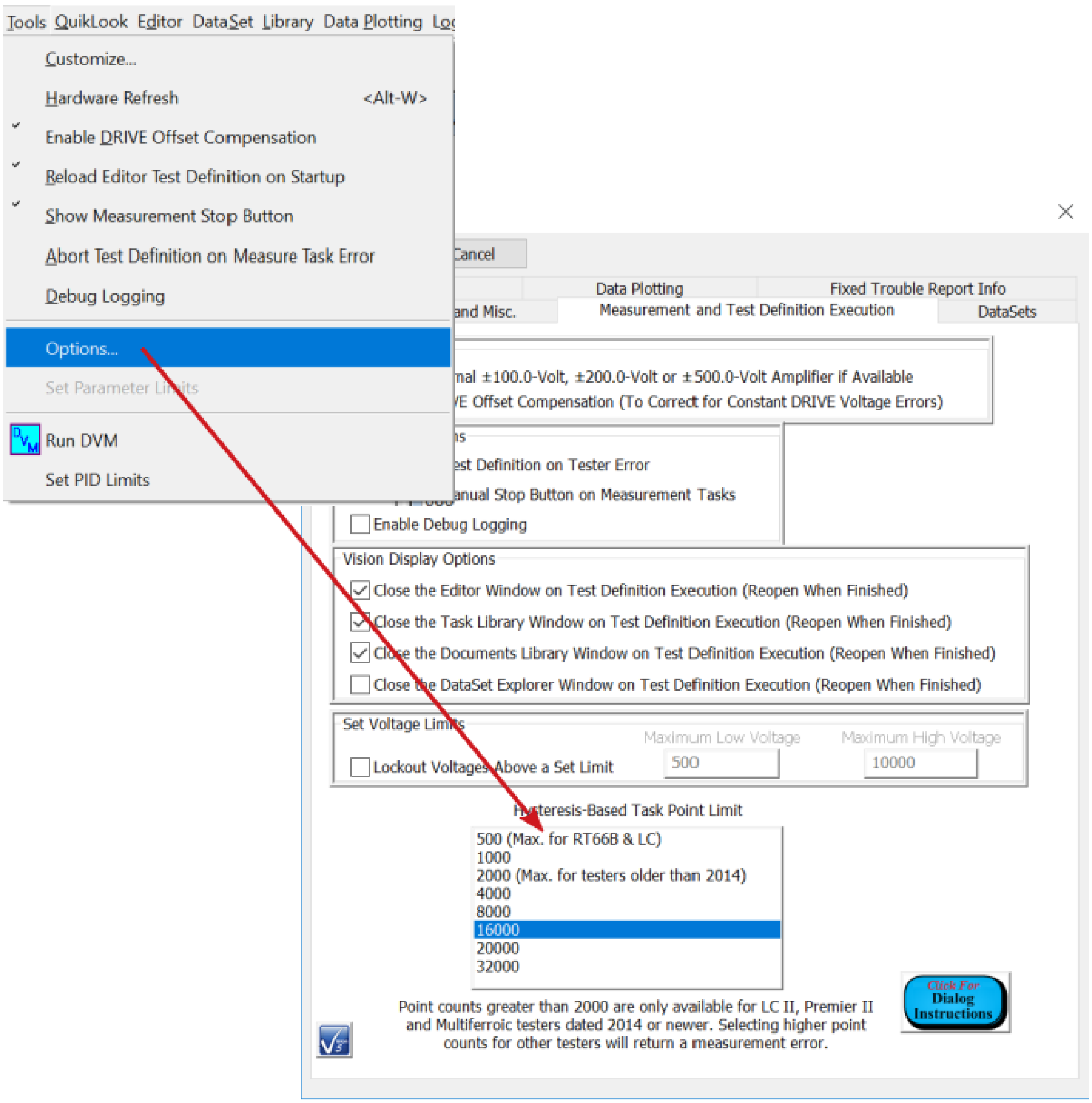


Figure 14 - User-Specified Hysteresis Profile Point Limit.

Amplification Levels

The sample charge (µC) response to the DRIVE stimulus voltage is captured by the integrating circuit at the Precision tester RETURN port after passing through a variable amplification stage. The output of the amplifier/input to the integrator is in the ±5.0-Volt range A quality measurement will have a peak amplifier output that is within 5% and 95% the output range (±0.25 to ±4.75 Volts). If the signal is outside this range, then the amplification should be adjusted to boost or reduce the signal into the range. The user has three options for setting the amplification level:

1. Manual Amplification: *Auto Amplification* is unchecked and an appropriate *RETURN Signal Amplification Level* is selected. In this option a single measurement will be made at the amplification level selected by the user and the data returned regardless of the quality. An improperly-selected amplification level may show data that are saturated (level too high) or very noisy (level too low). If the amplification level is too far out-of-range, the measurement may return an error. Note that a saturated measurement could not be made for **Figure 15** without generating an error.

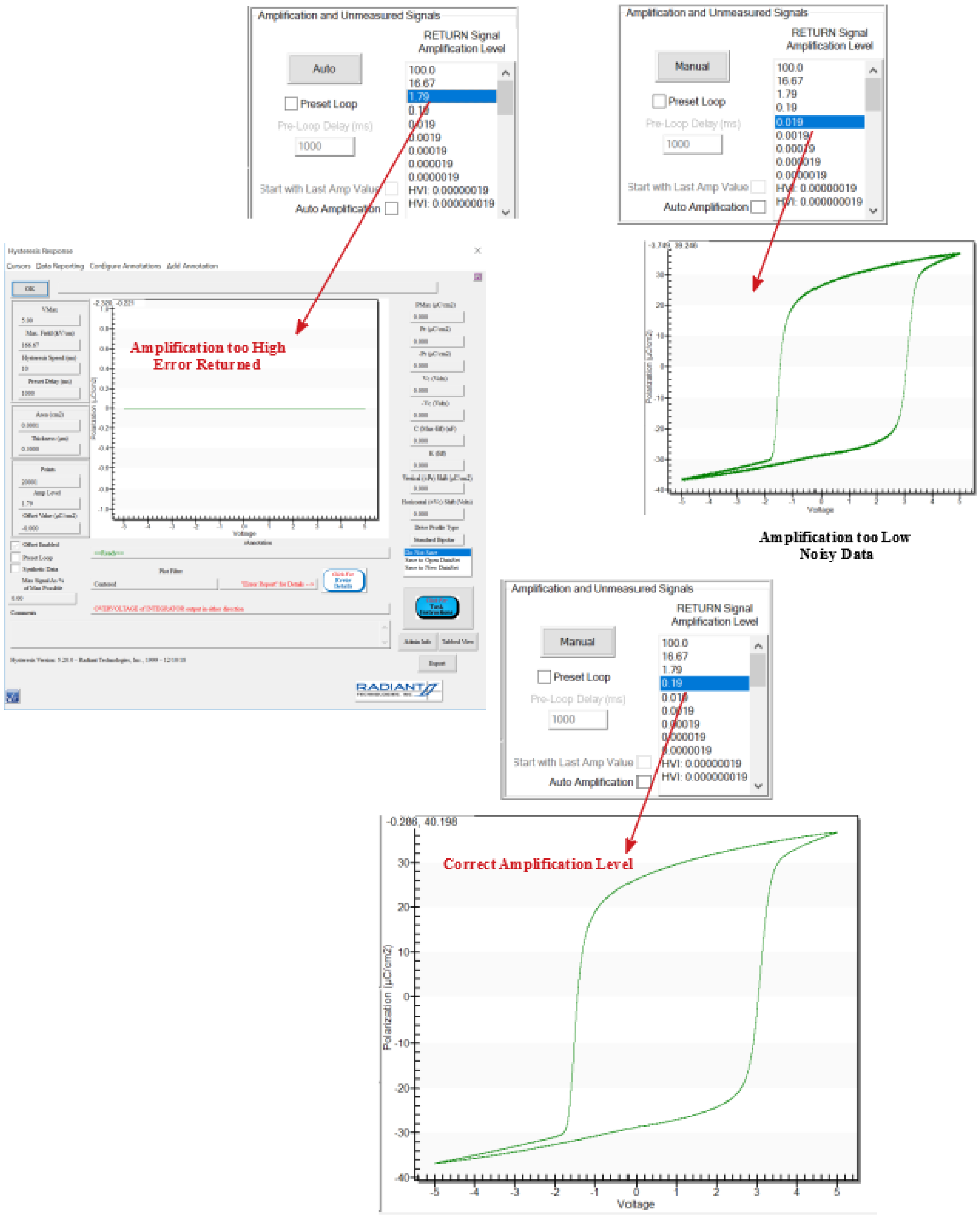


Figure 15 - Results of Manual Amplification Settings.

2. Auto Amplification - Start at *RETURN Signal Amplification Level*: *Auto Amplification* is checked, *Start with Last Amp Value* is unchecked and the initial amplification level is se-

lected in *RETURN Signal Amplification Level*. In this case the driver sets the amplification level to the value selected in *RETURN Signal Amplification Level*. A measurement is made and the returned integrated charge (µC) data are examined. If the data are outside of the 5% to 95% range the amplification level is adjusted one step up or one step down and the measurement is repeated. The process is repeated until a correct measurement is detected. If the number of amplification levels is exhausted before finding the correct level, an error is returned.

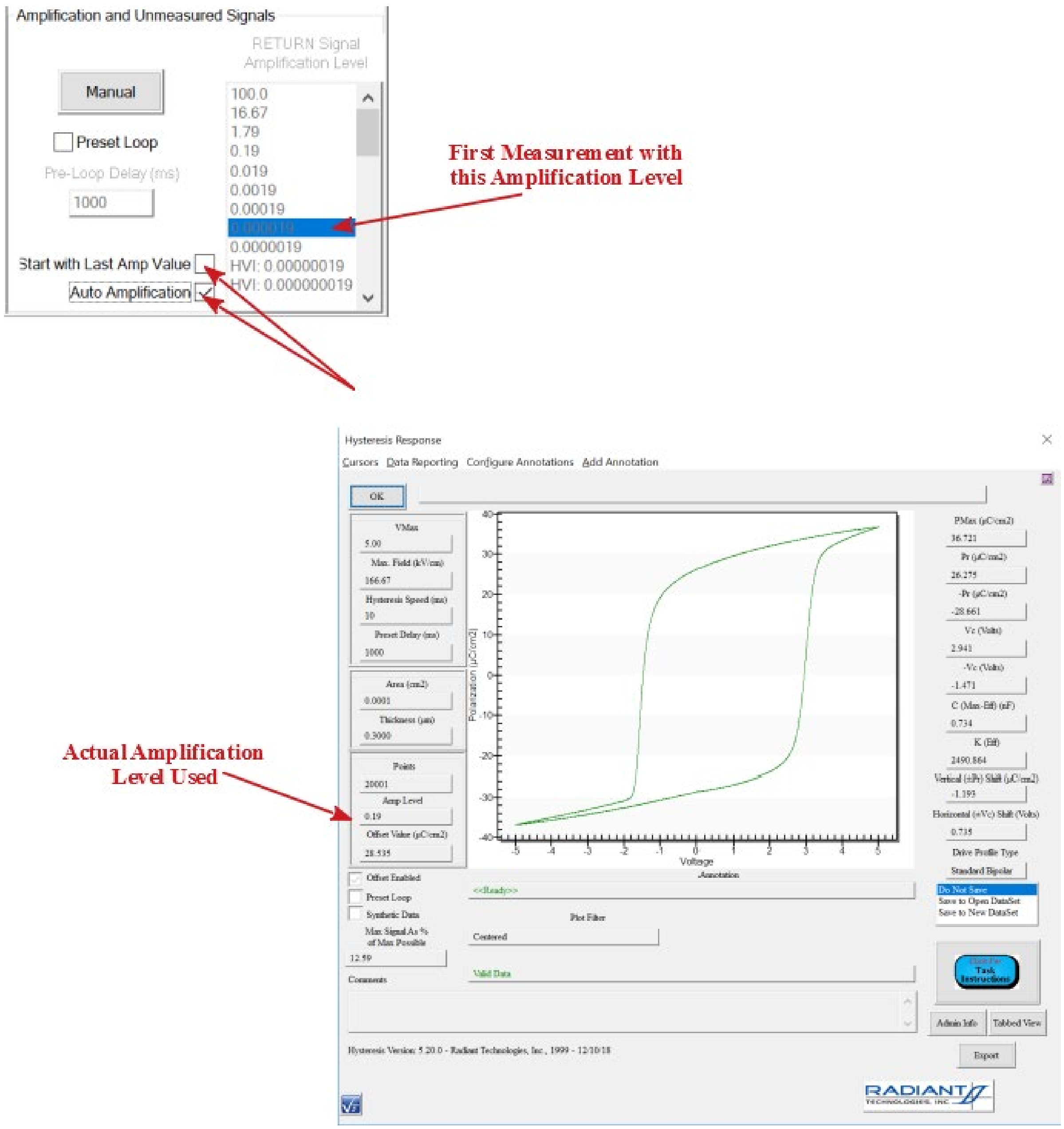


Figure 16 - Results of Auto-Amplification/Specific Initial Am-

plification Level.

3. Auto Amplification - Start at last valid amplification level: *Auto Amplification* is checked, *Start with Last Amp Value* is checked. This is very similar to option 2. However, instead of starting at the amplification level specified in *RETURN Signal Amplification Level* Vision sets the initial amplification level to the final amplification level of the last previous valid measurement. Once again, a measurement is made and the returned integrated charge (µC) data are examined. If the data are outside of the 5% to 95% range the amplification level is adjusted one step up or one step down and the measurement is repeated. The process is repeated until a correct measurement is detected. If the number of amplification levels is exhausted before finding the correct level, an error is returned.

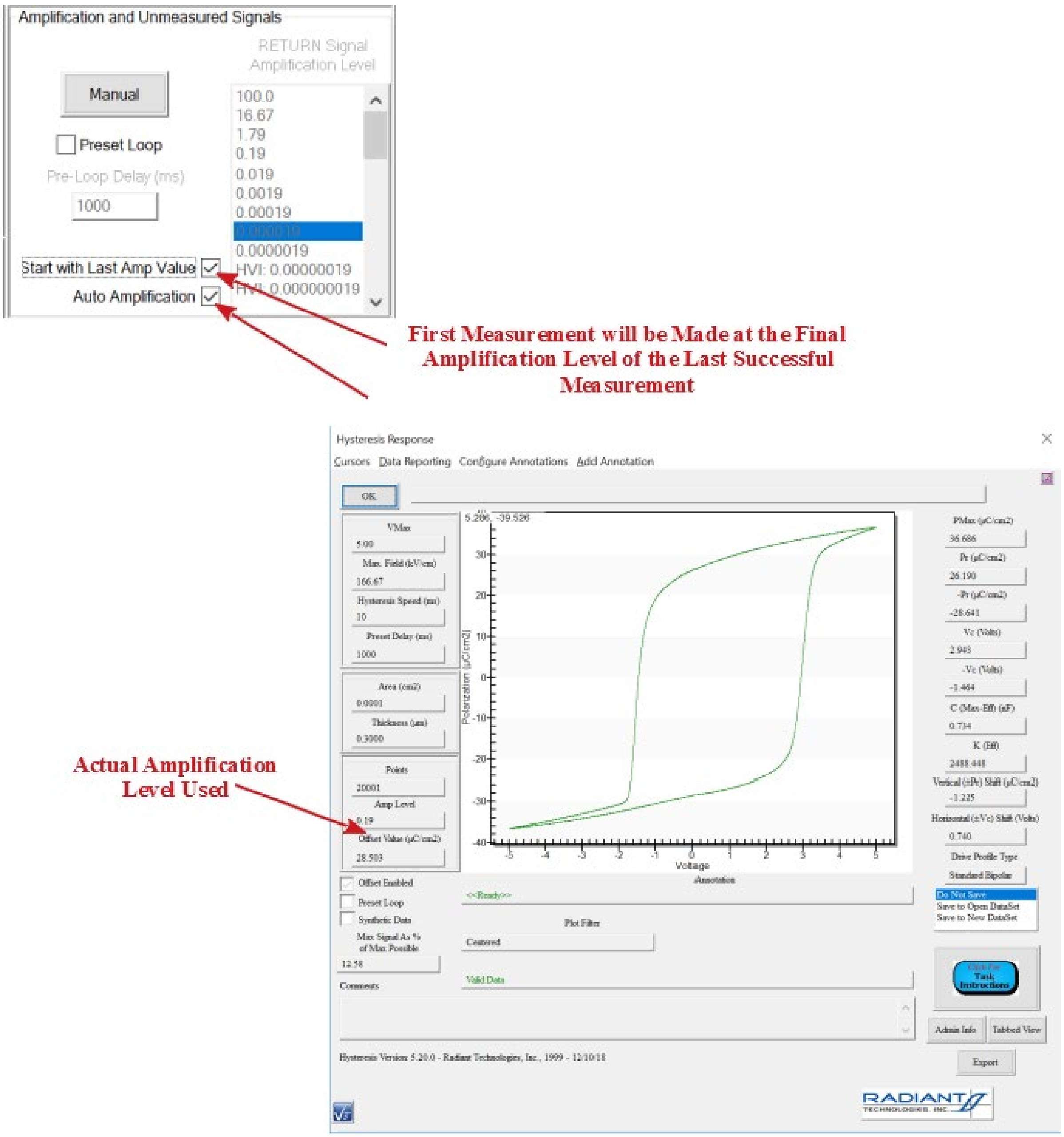


Figure 17 - Results of Auto Amplification/Start at Last Valid Amplification level.

Tester Operation

This section of the Main Vision Manual address common Precision Tester operation, making sample measurements using the Precision tester alone. Move-involved measurement such as high-voltage, piezo-electric or magneto-electric measurements are addressed in other sections. Note that the measurement voltage using a tester alone is limited in Vision software to ±500.0 Volts. However, the maximum voltage that may be applied without returning a measurement error depends on the tester model. Models are available with voltage ranges of ±10.0 V, ±30.0 V, ±100.0 V, ±200.0 V and 500 V.

Vision Startup

On startup, Vision will detect any tester that is connected to the Vision host computer and powered provided the tester has been correctly installed on the host computer as in Tester Installation. Vision will also detect any I2C accessories connected to the tester. Discussion of any such accessory is beyond the scope of this topic.

When the program opens, the detected tester will be displayed in the Tester Selection dialog. If no tester is detected, the dialog will show "No Tester Attached". The dialog displays the tester's name and type. The name may be changed in the dialog and written back to the tester EEPROM.

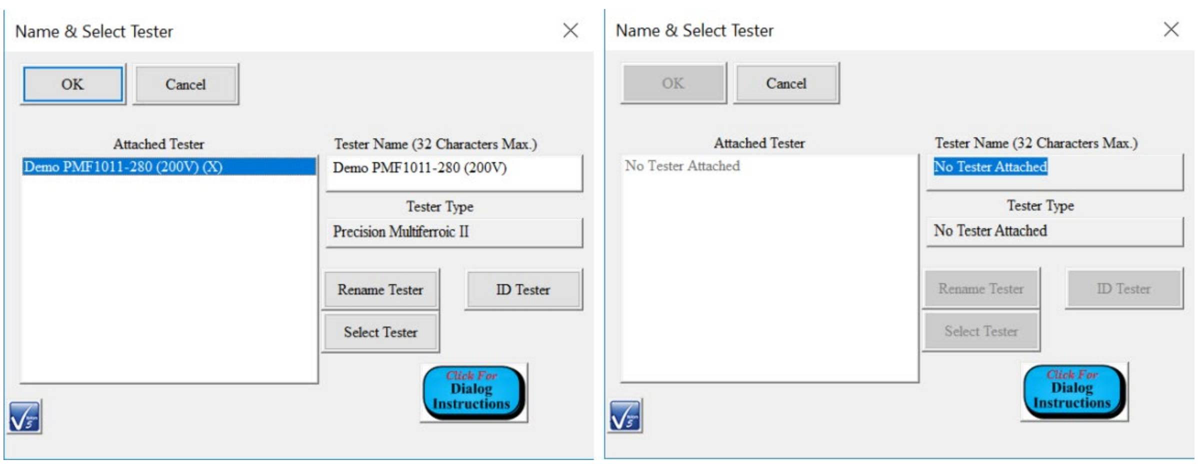


Figure 1 - The Tester Selection Dialog Appears on Vision Startup.

When the Tester Selection dialog is closed the user will be prompted to remove any connection from the tester DRIVE port to begin a calibration. Note that for rack=mounted testers with rear-panel DRIVE port connections to other instruments, removing the DRIVE connection is not critical. Close the prompt to enter a brief calibration period. The calibration period is indicated by the presence of the Stop Measure Ramp Offsets? button. When the button disappears the calibration is complete and Vision is in its idle state.

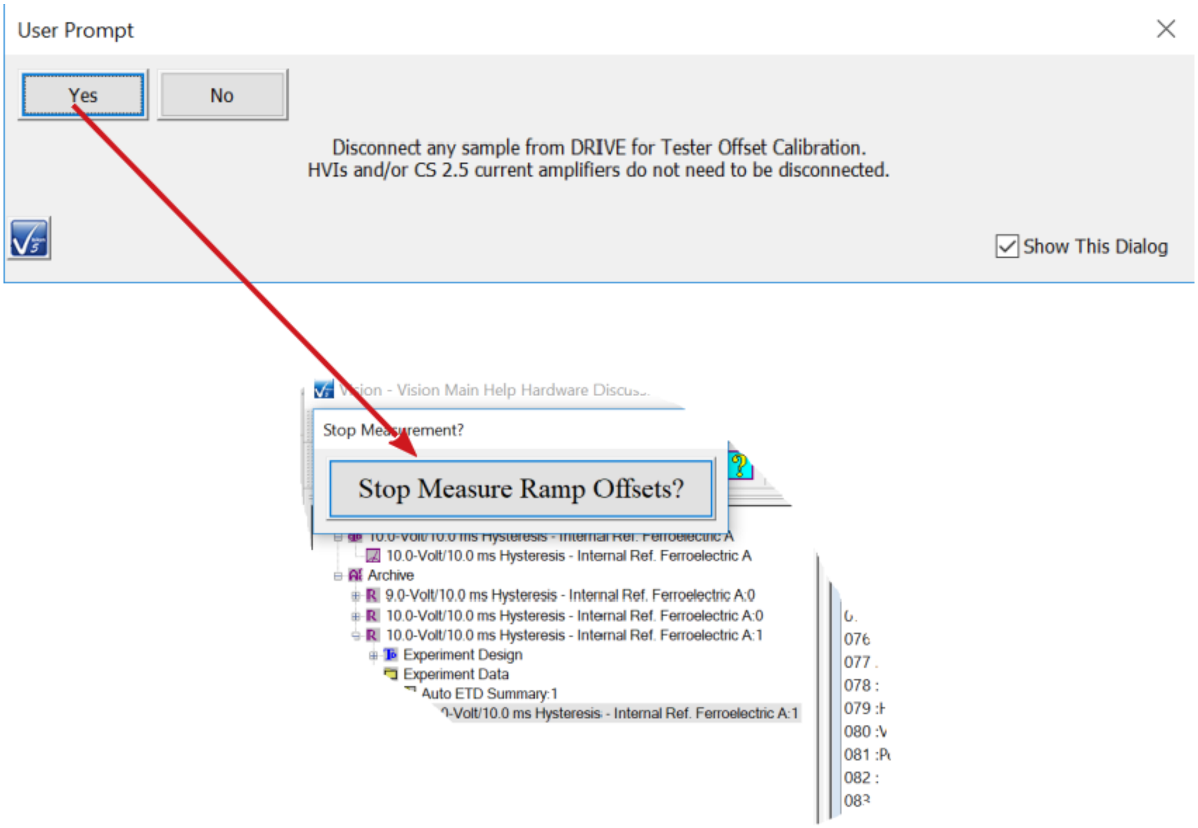


Figure 2 - Tester Calibration Period.

Hardware Refresh

Any time there is a hardware change within Vision, a Hardware Refresh must be performed to cause Vision to redetect all connected hardware. For example if Vision is started with the Precision tester turned off, when the tester is turned on a Hardware Refresh must be performed. Likewise, if an I2C accessory is connected or disconnected (powered on or off) Vision must be notified through a Hardware Refresh. To initiate a Hardware Refresh, select Tools->Hardware Refresh. Or simply press <Alt-W>. Vision will detect the connected Precision tester and any connected I2C accessories. The startup procedures of **Figures 1** and **2** will be reiterated.

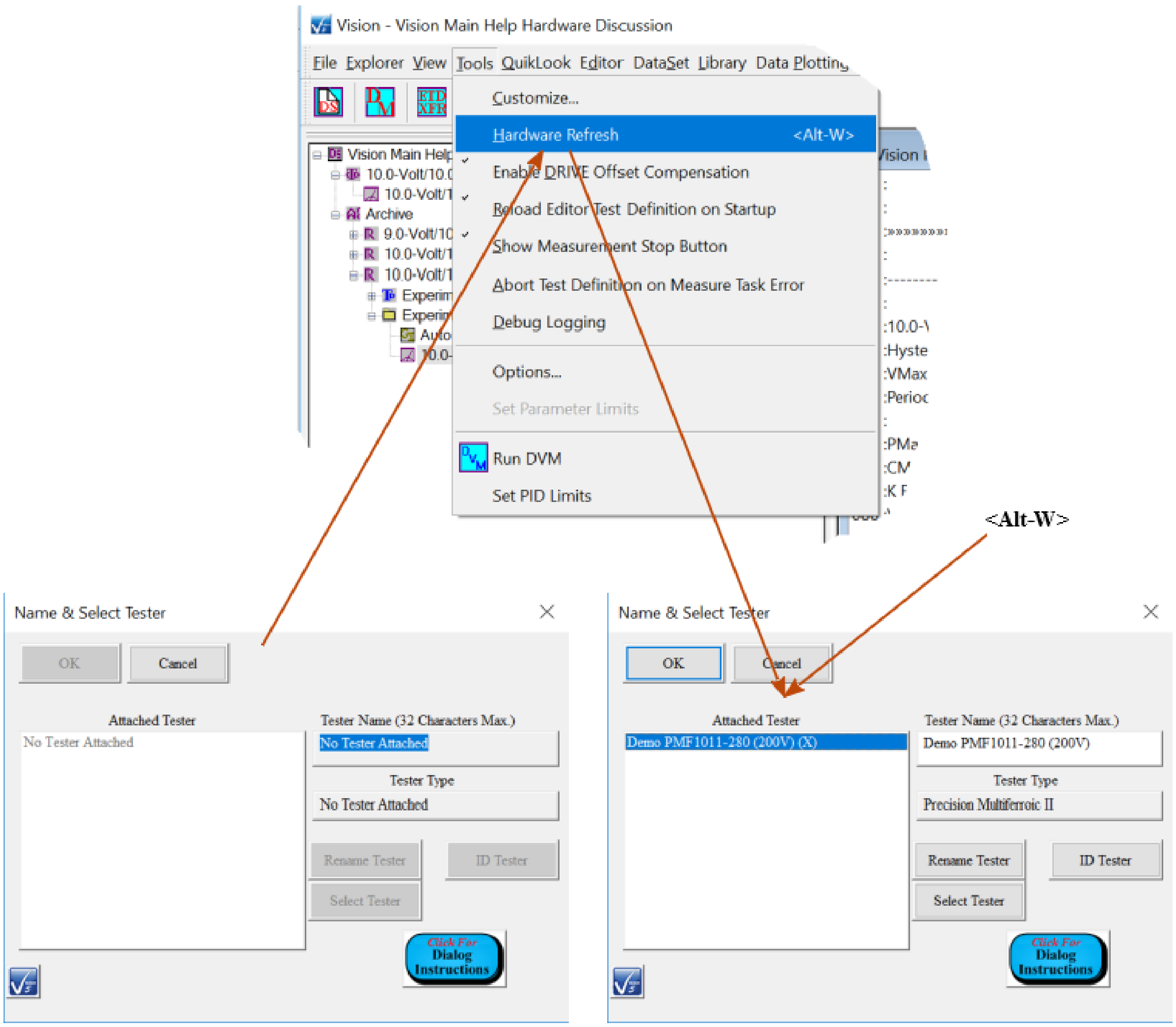


Figure 3 - Hardware Refresh.

Tester Connections

Connecting the Precision tester to a sample to be measured is largely at the user's discretion. **Figure 4** shows the tester connections to a commercial linear capacitor using the minigrabber connections. The basic rule is that the DRIVE port, that carries the voltage signal is connected to one sample electrode. The zero-Volt RETURN port is connected to the opposite electrode. Connections make be to probe pins, clips, sample holders, etc. Use of devices such as the minigrabbers shown is not recommended. These offer no signal shielding. Generally both DRIVE and RETURN connections should be through shielded BNC cables. If the connections are to be made to a sample with electrodes of differing sizes, for reasons that are beyond the scope of this discussion, it is recommended that the DRIVE signal be attached to the larger electrode. For example, on a wafer with many samples defined by small top electrodes, the DRIVE should be applied to the common bottom electrode while the RETURN signal is taken from the single-sample top electrode. Note that connections between the Precision tester and the sample are identical if they are taken from the tester's front-panel or rear-panel DRIVE and RETURN ports. These ports are electrically identical between the front and back of the tester.

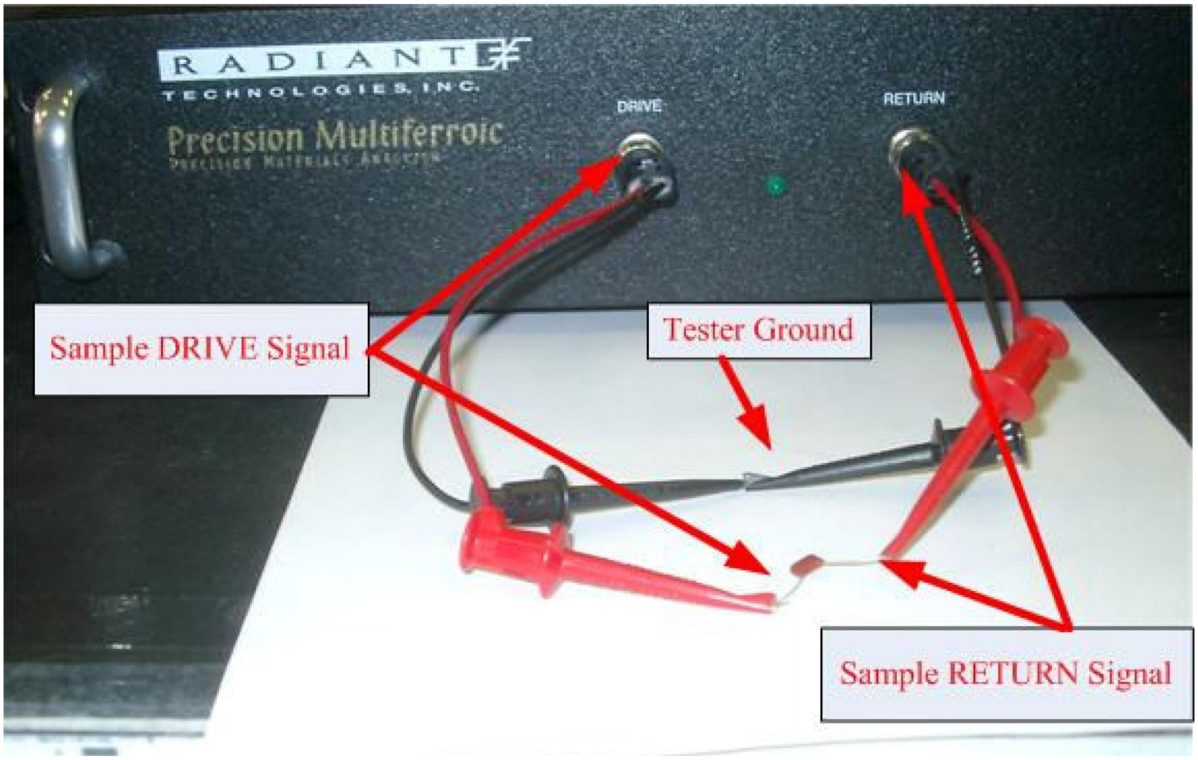


Figure 4 - Basis Sample Connection to a Precision Tester.

For basic measurements there are only two other important connections:

- The AC Power connection may be between 110 and 240 Volts at 50 Hz or 60 Hz. What is critical is that the middle pin of the power cable be connected to a solid and stable earth ground. Damage to the tester will occur if a solid ground is not available at the wall socket.
- The green banana connector at the tester rear panel represents a connection to the tester's chassis and, by extension, to earth ground. This connector must be attached to any other equipment in the experiment. This might include a High-Voltage Interface (HVI), a High-Voltage Amplifier (HVA), a CS 2.5 Current Source, external waveform generators, etc. It should also be connected to any metal in the experiment. This might include the rack in which the tester is mounted, any metal tables, a probe station, etc.

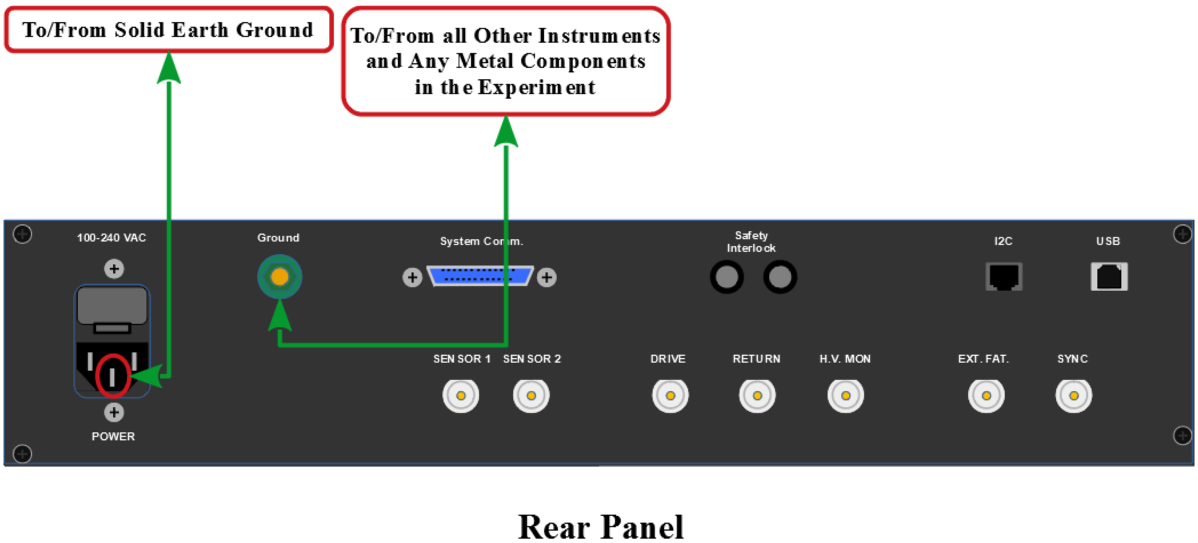


Figure 5 - Critical Precision Tester Grounding Point.

Making Measurements

Precision tester measurements are made using Vision Measurement Tasks. A large array of Measurement Tasks is available. But, in general, the Tasks specify these common parameters:

- Task Name: All Tasks include a Task Name. This does not relate directly to the measurement. However, the Task is permanently archived in Vision under this name. For documentary purposes and identification of the Task in the Archive. It is very important to assign a unique and meaningful Task Name. Up to 60 characters may be assigned. This allows for detailed description.
- Sample Area (cm^2): This value documents the sample under test. It is also use to normalize the measured charge (µC) to generate the measured polarization ($\mu C/cm^2$) data.
- Sample Thickness (µm): This also documents the sample under test. It may be used if the user intends to specify the DRIVE signal strength and/or plot data in units of Electric Field (kV/cm). The conversion is:

Electric Field (kV/cm) = Voltage / (1000 V/kV x Sample Thickness (µm) x 10^{-4} cm/µm) (1)

- One or more maximum DRIVE voltages: Each Measurement will stimulate the sample with a voltage through the DRIVE port. In general there are two types of stimulus. Pulse-type Tasks cause the DRIVE port to step directly to the assigned maximum voltage with the ramp to voltage defined by the tester model - generally 40 ns. Hysteresis-type Tasks ramp to the maximum voltage over a series of intermediate steps. There are representative Tasks in either type that may make repeated measurements, in an execution, of independently-varying maxima.
- Some form of measurement time: For Pulse-type Tasks the measurement time is defined as a Pulse Width (ms). This is the time between the beginning of the rise to voltage and the signal sampling. For Hysteresis-type Tasks a Period (ms) is defined and represents the

time over which the complete measurement cycle occurs.

- Amplification level specification: In all Measurement Tasks the sample charge (µC) response to the DRIVE port stimulus voltage is captured at the tester RETURN port and passed to an integrator for detection. Before being passed to the integrator the charge is amplified or deamplified by a Transimpedance Amplifier that has various selectable gains. In manual mode, the user selects a specific amplification level and the measurement is made at that level. The data are returned regardless of the quality. If the amplification level is too high, the integrator will be over-driven and the Task will return an error. If it is too low, the data may be very noisy. In automatic amplification the measurement is made at an initial amplification level. The software then evaluates the return data and, if the data are too strong or two weak, the amplification level is decremented or incremented one level and the measurement is repeated. The process continues until the data are within an acceptable range. If the proper amplification level cannot be isolated, the Task returns an error.

For much more detail on measurement parameters and, especially, amplification levels, please see the preceding Tester Theory topic.

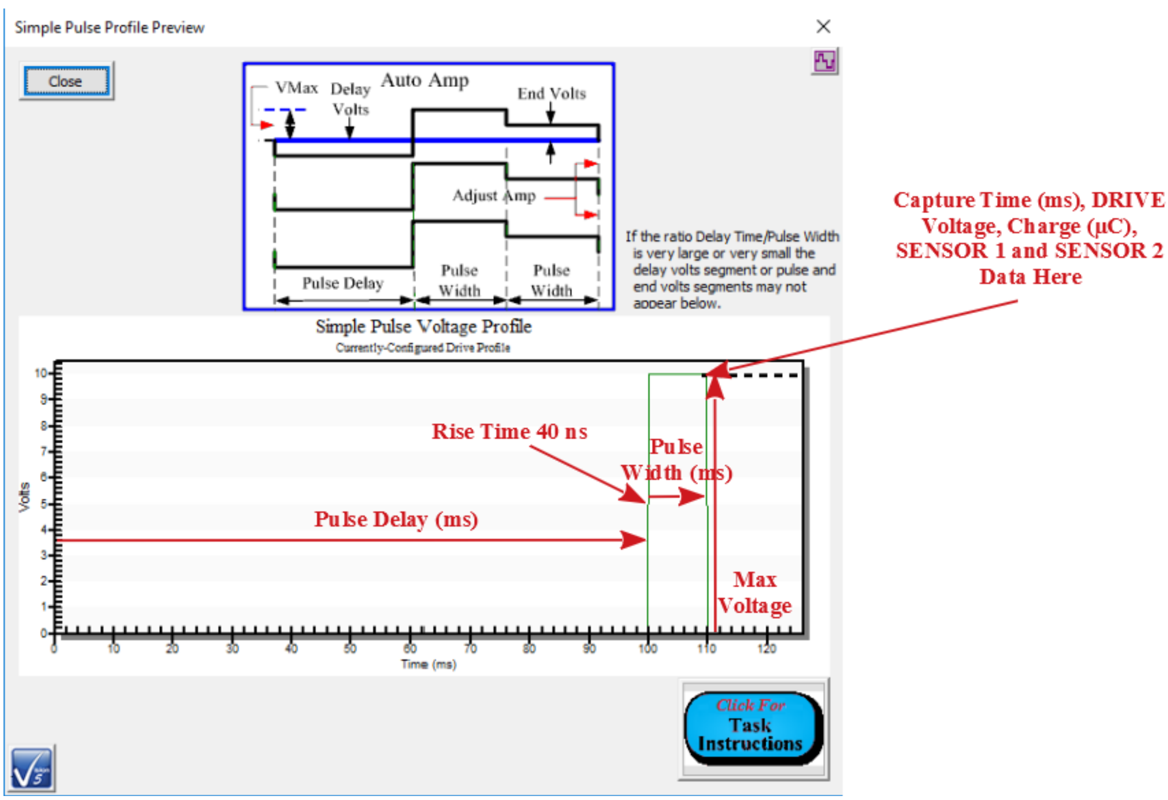


Figure 6 - Pulse-Type DRIVE Profile

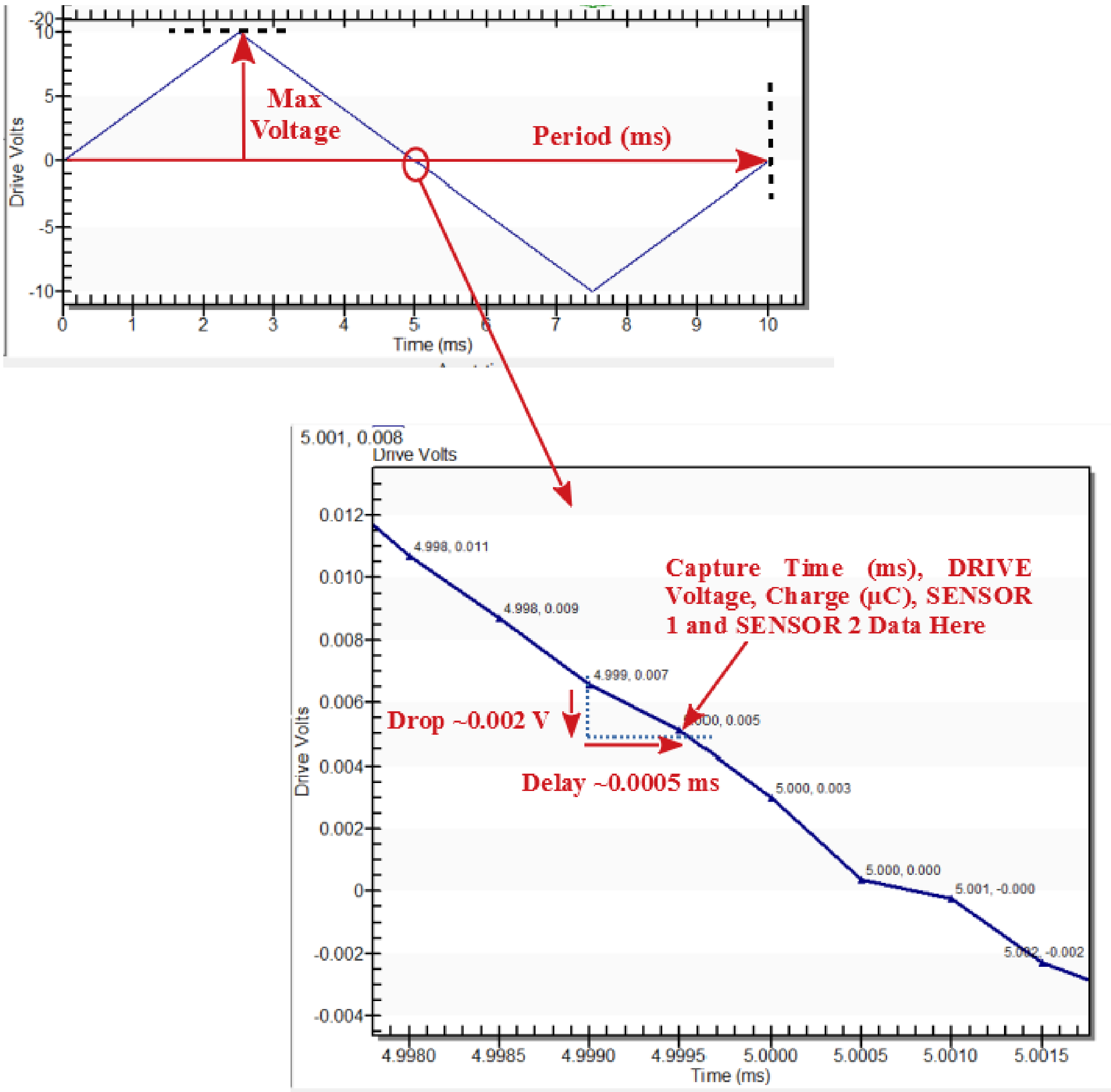


Figure 7 - Hysteresis-Type Drive Profile

Procedure

Configure the Measurement Task

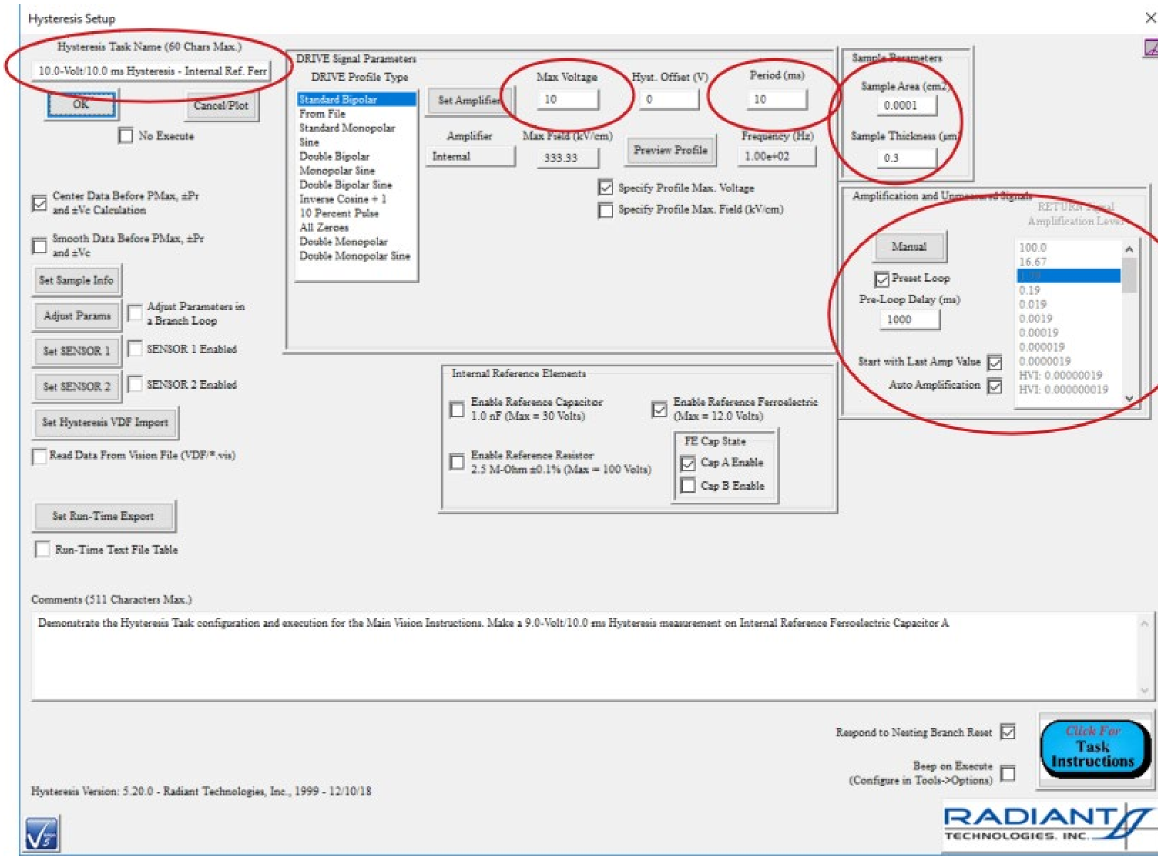


Figure 8 - Configure the Hysteresis Task.

Execute the Measurement Task:

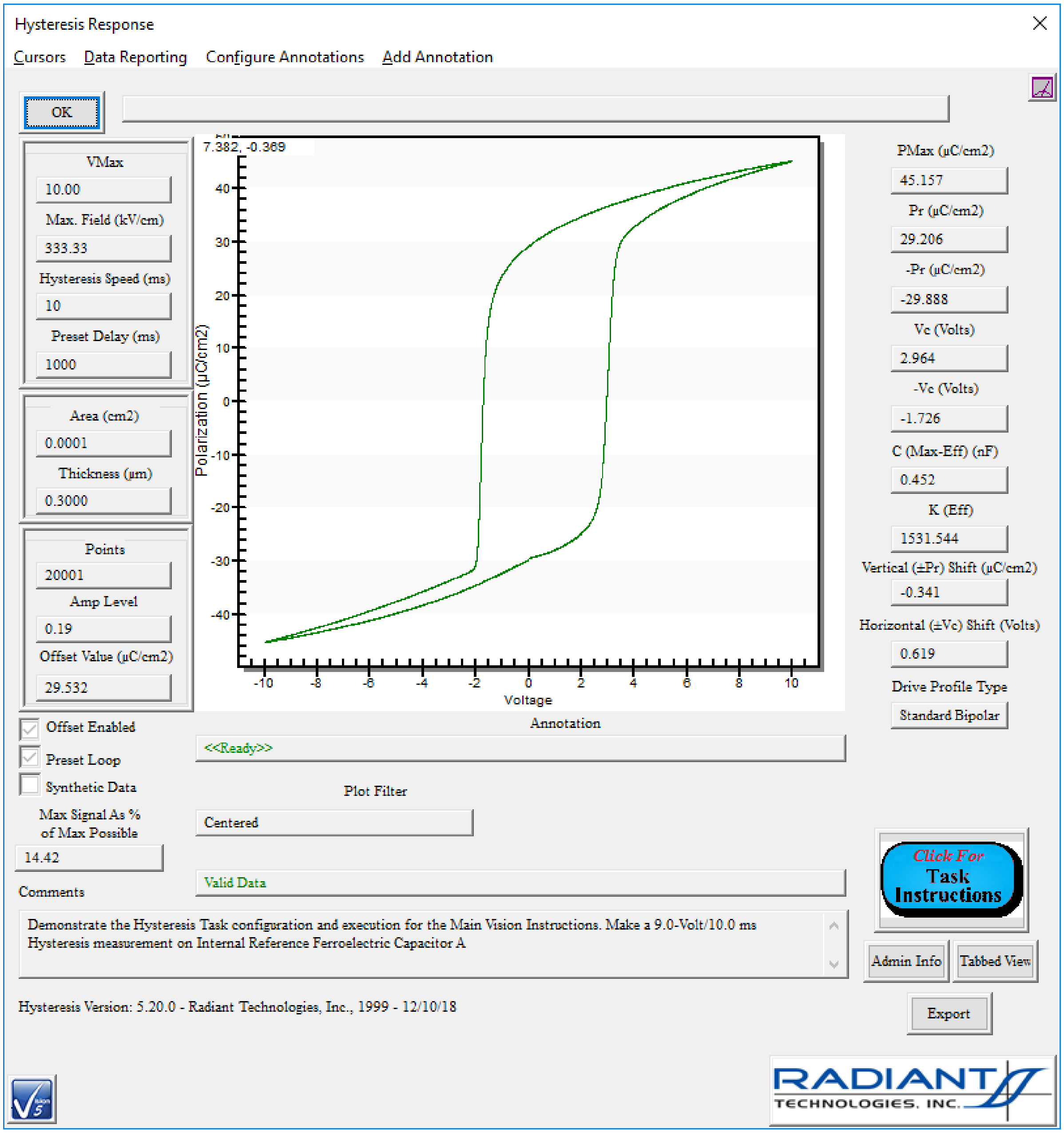


Figure 9 - Hysteresis Task Measured Data.

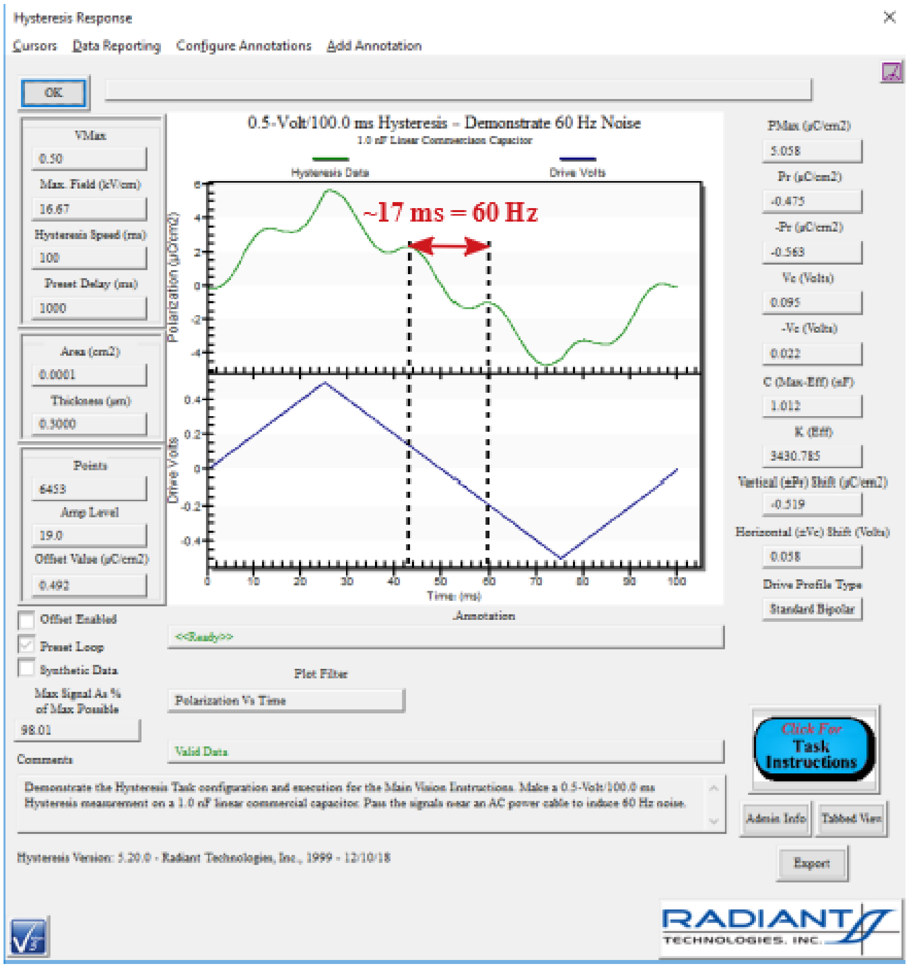
Mitigating 50 Hz/60 Hz Noise

Environmental noise is a factor in all measurement. Environmental noise is introduced by the physical configuration and location of the experiment. The noise is highly dependent on the strength of the charge signal (µC) returned by the sample. Noise generally produces a very small signal that becomes less and less relevant as the measured sample signal grows. There are generally two types of noise:

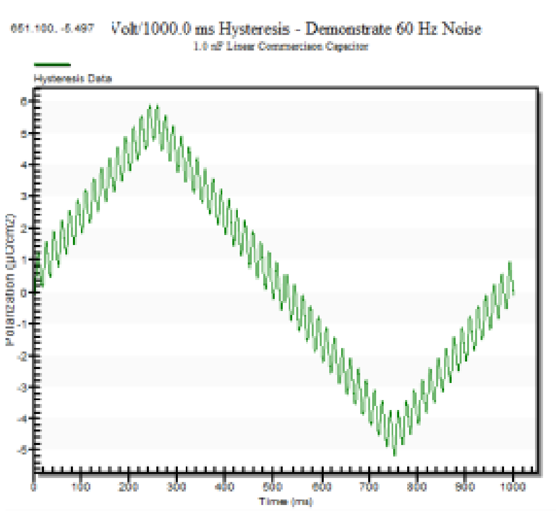
- Random noise can be mitigated by making repeated measurements and averaging them. Passing a smoothing filter over a single measurement will also reduce noise. Vision is equipped to perform both types of noise reduction.
- Period noise is normally introduced by one or more electrical sources and will normally have a frequency of 50 Hz or 60 Hz depending on the laboratory's power source. This noise cannot be mitigated by post-processing the data. It must be mitigated before the measurement. This section will present guidelines for mitigating periodic noise.

Figure 1 shows the effects of 60 Hz noise on a Hysteresis measurement of a 1.0 nF commercial linear capacitor. The measurement was made at 0.5 Volts to reduce the charge signal and enhance the noise. The sample was connected to the tester DRIVE and RETURN ports using minigrabbers that have no shielding. The minigrabbers were wound around the Precision tester's AC power cord to ensure the introduction of the noise.

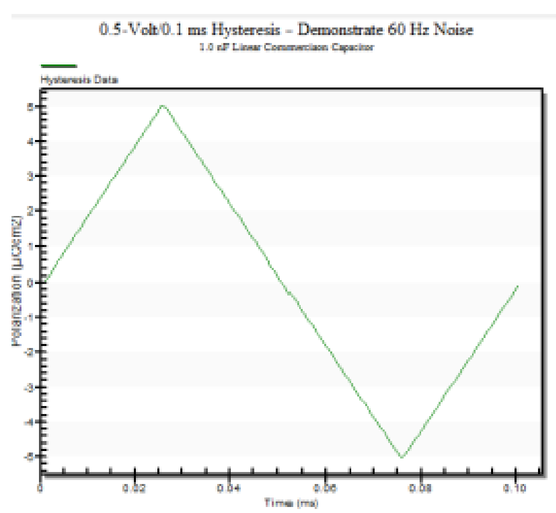
Since the noise is of a constant frequency, its effect is dependent on the speed of the measurement. In the figure a 100.0 ms (10 Hz) signal clearly shows the 60 Hz noise. It is easy to demonstrate that the period of the noise is 1000/60 = ~17 ms. The figure also shows a 1000.0 ms measurement and a 0.1 ms measurement. The 1000.0 ms measurement is especially noisy because it contains 60 full cycles. The 0.1 ms measurement is significantly shorter than one full cycles of the noise. It shows no effects from the 60 Hz environmental noise. In all figures the polarization (µC/cm2) data are plotted as a function of time to demonstrate the periodicity of the noise.



0.5-Volt/100.0 ms Hysteresis



0.5-Volt/1000.0 ms Hysteresis



0.5-Volt/0.1 ms Hysteresis

Figure 1 - Influence of 60 Hz Environmental Noise.

Figure 2 shows a 10.0-Volt/1000.0 ms measurement under the same physical test conditions. With a strong sample charge (µC) signal the 60 Hz noise is barely evident.

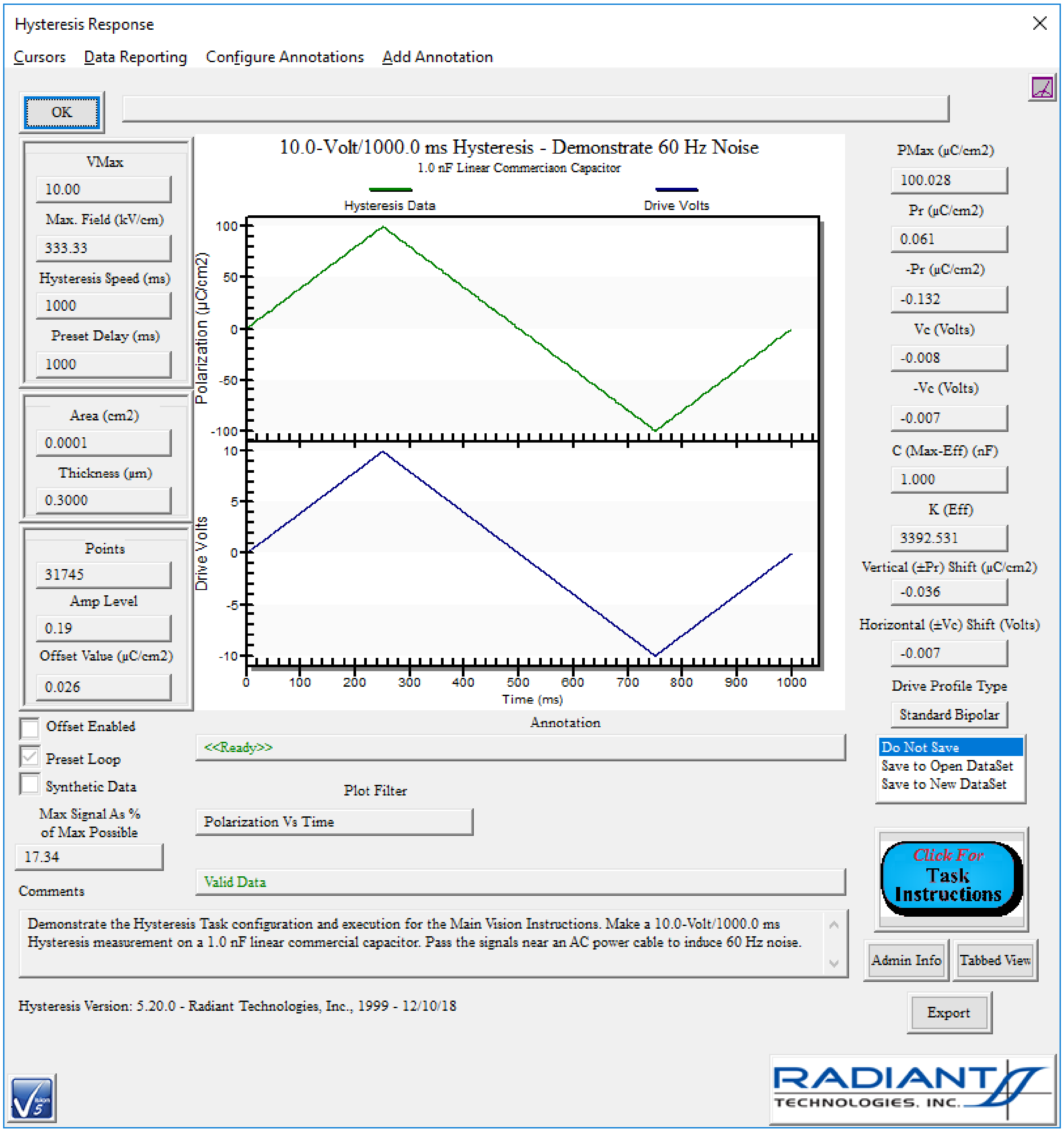


Figure 2 - Strong Sample Charge (µC) Signal Reduces the Effects of the 60 Hz Noise.

Mitigation

Period noise must be addressed before the measurement occurs. If such noise is entering the data, the following steps are recommended to help mitigate it:

- Make DRIVE and RETURN signal cables as short as possible.
- Keep DRIVE and RETURN signal cables as far as possible from the AC power cables connected to the equipment. In particular be sure that DRIVE and RETURN cables do not cross over power cables.
- Use only coaxial (BNC) DRIVE and RETURN cables. For example, the minigrabbers [short red and black cables with clips] that we provide with the system have BNC connectors, but do not provide coaxial shielding.
- Make sure that the tester is firmly grounded at the green rear-panel banana plug to any other equipment in the experiment (High-Voltage Interface, Amplifier, Current Source, etc.).
- Make sure that the tester is firmly grounded to any metal components in the experiment (tables, probe stations, shelving, equipment racks, etc.).
- Turn off as much other equipment in the lab as possible. especially equipment with rotating motors - fans, etc.
- Turn off the overhead fluorescent lamps if possible.
- Above all, ensure that the ground connector of the AC power cables is connected to a solid earth ground.

High-Voltage Setup and Operation

Standing alone, the maximum DRIVE voltage output of a tester depends on the model purchased. Models are available with ±10.0-Volt, ±30.0-Volt, ±100.0-Volt, ±200.0-Volt or ±500.0-Volt internal amplifiers. The Vision program will allow for up to ±500.0 Volts to be programmed without special configuration. With the addition of accessory hardware, the Precision tester can be made to apply DRIVE signals of up to ±10,000.0 Volts.

Signals above ±500.0 Volts are not generated by the Precision tester, but by an external High-Voltage Amplifier (HVA). The Precision tester applies a low-voltage model of the intended DRIVE voltage that is amplified by a fixed gain factor by the HVA. The high-voltage output of the HVA is then applied to the sample. **Figure 1** shows the front and rear panels of a Trek Model 609B 10 kV amplifier. The tester may drive any model amplifier provided the amplifier characteristics (output-to-input gain ratio, slew rate, maximum current, etc.) are made available to Radiant Technologies, Inc. (See more detail below.) The Trek Model 609B amplifier is the most common amplifier and is often bundled into Precision tester purchases.

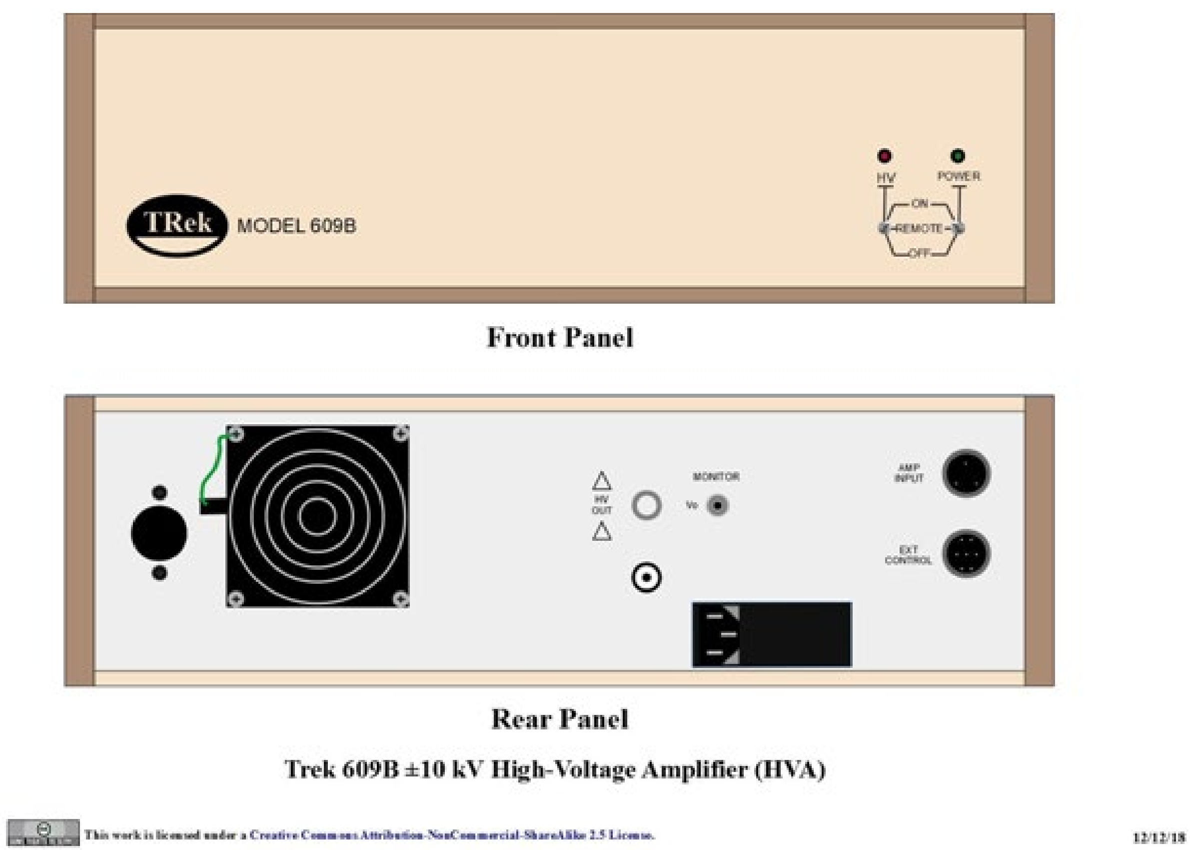


Figure 1 - Trek Model 609B ±10 kV High-Voltage Amplifier (HVA).

Signals are not passed directly between the Precision tester and the High-Voltage Amplifier. Note, in particular, that the tester is not capable of inputting or outputting a signal greater than

±500.0 Volts. Instead signals are passed through a Radiant Technologies' accessory High-Voltage Interface (HVI). The HVI serves as a protection device for equipment, the sample under test and people. It detects dangerous fault conditions and halts low-voltage input into the HVA and high-voltage output. In particular, if the sample shorts the high-voltage HV DRIVE signal from one electrode to the zero-Volt HV RETURN signal the high-voltage RETURN condition is detected and the signals are immediately halted. The HVI then returns an error to the Measurement Task. **Figure 2** shows the HVI front and rear panels.

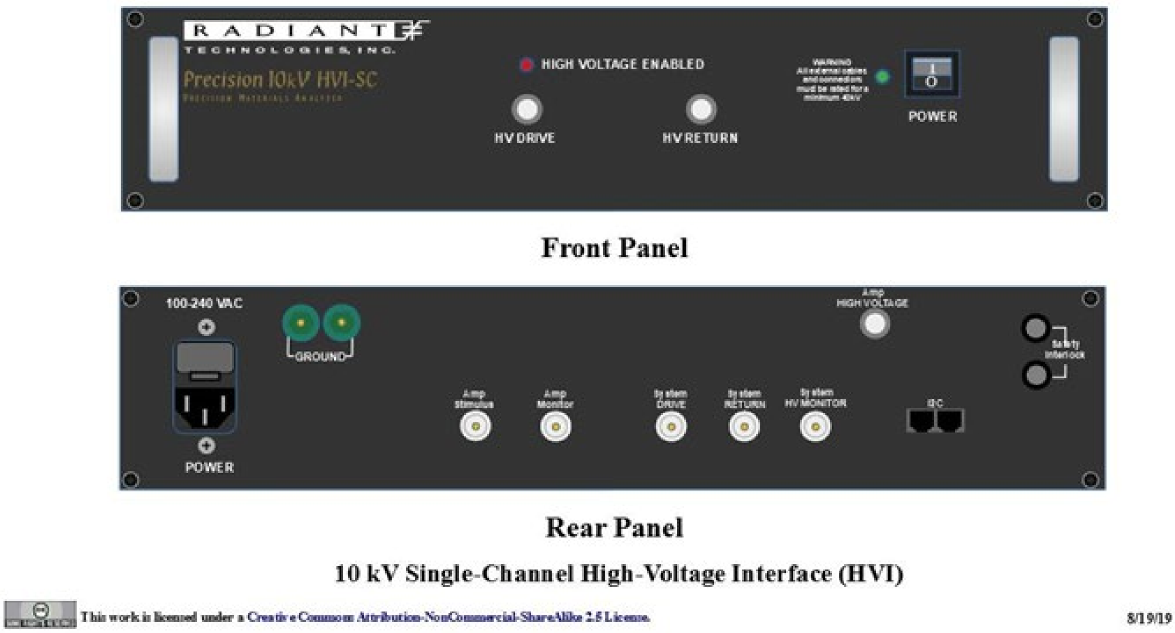


Figure 2 - Radiant Technologies' Precision High-Voltage Interface (HVI).

The Radiant Precision HVI has passed through several generations. These include:

- Early versions that require parallel-port logic communications. These are still supported by all testers except the RT66B and RT66C.
- Two-channel versions that could connect two separate amplifiers to be switched in software. These are also still supported.
- Versions that required an external EEPROM ID Module that contained logical information regarding the High-Voltage Amplifier specifications. This information is required by Vision to properly construct the HVA low-voltage input signal.

Modern HVIs are single-channel and use an I2C bus to conduct logical communication. They also contain the amplifier specifications internally and can be reprogrammed, by the user, for any amplifier that is known to Radiant Technologies, Inc. The list of known amplifiers can be extended simply by present the manufacturer name, model number and specifications to Radiant Technologies, Inc.

The remainder of this document will concern itself only with the most-current revision of the High-Voltage Interface.

Equipment Setup

Figures 3 and **4** duplicate the front- and rear-panel images of **Figures 1** and **2**. In this case the figures are annotated with a description of each of the connectors on the accessories.

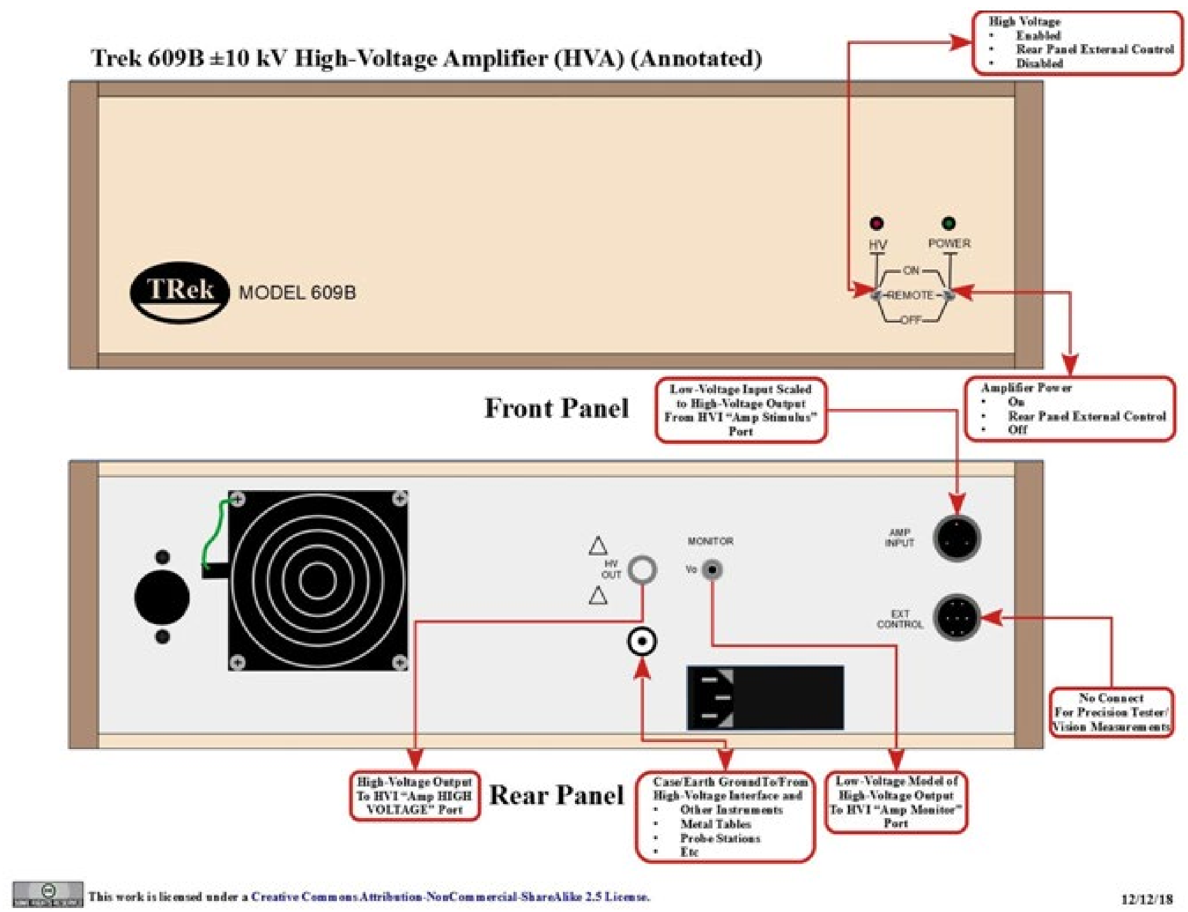


Figure 3 - Trek Model 609B ±10 kV High-Voltage Amplifier (HVA) with Annotated Connectors.

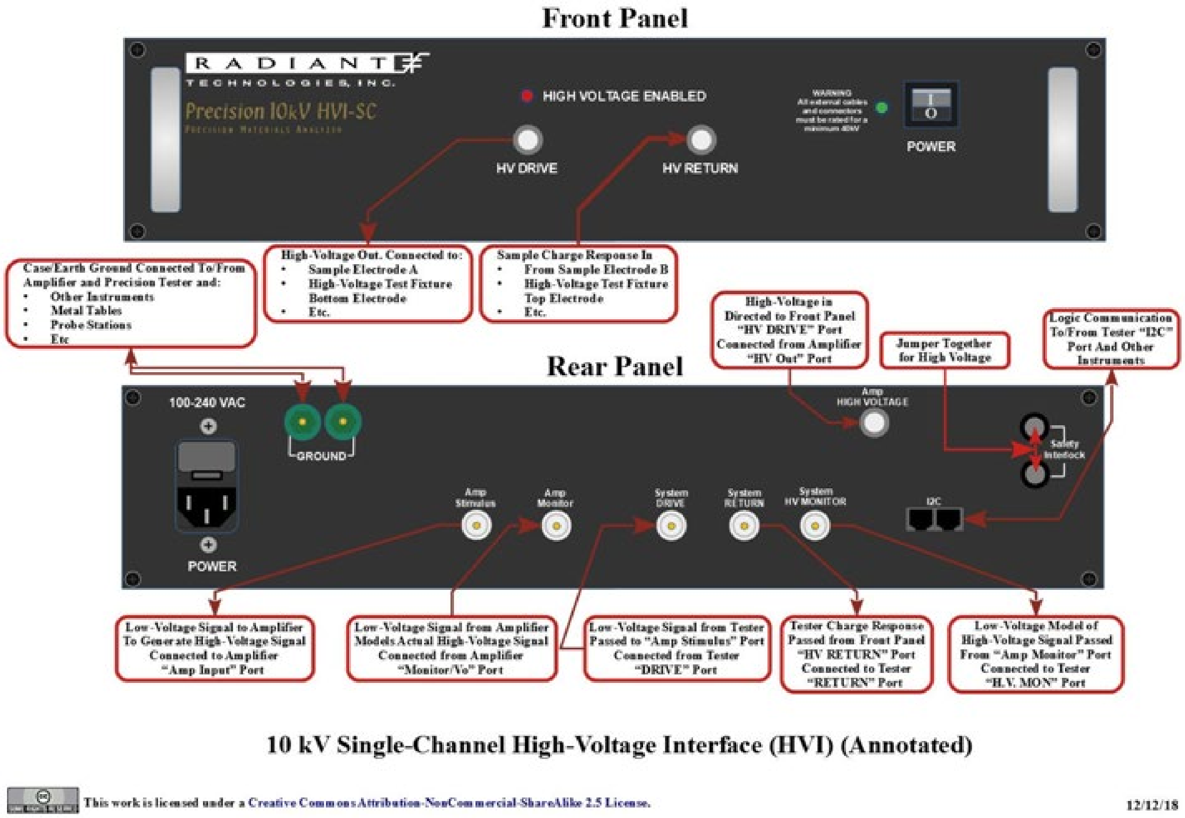


Figure 4 - Radiant Technologies' Precision High-Voltage Interface (HVI) with Annotated Connectors

Figure 5 shows a map of the connections between the Precision tester and the Precision HVI and between the HVI and the HVA.

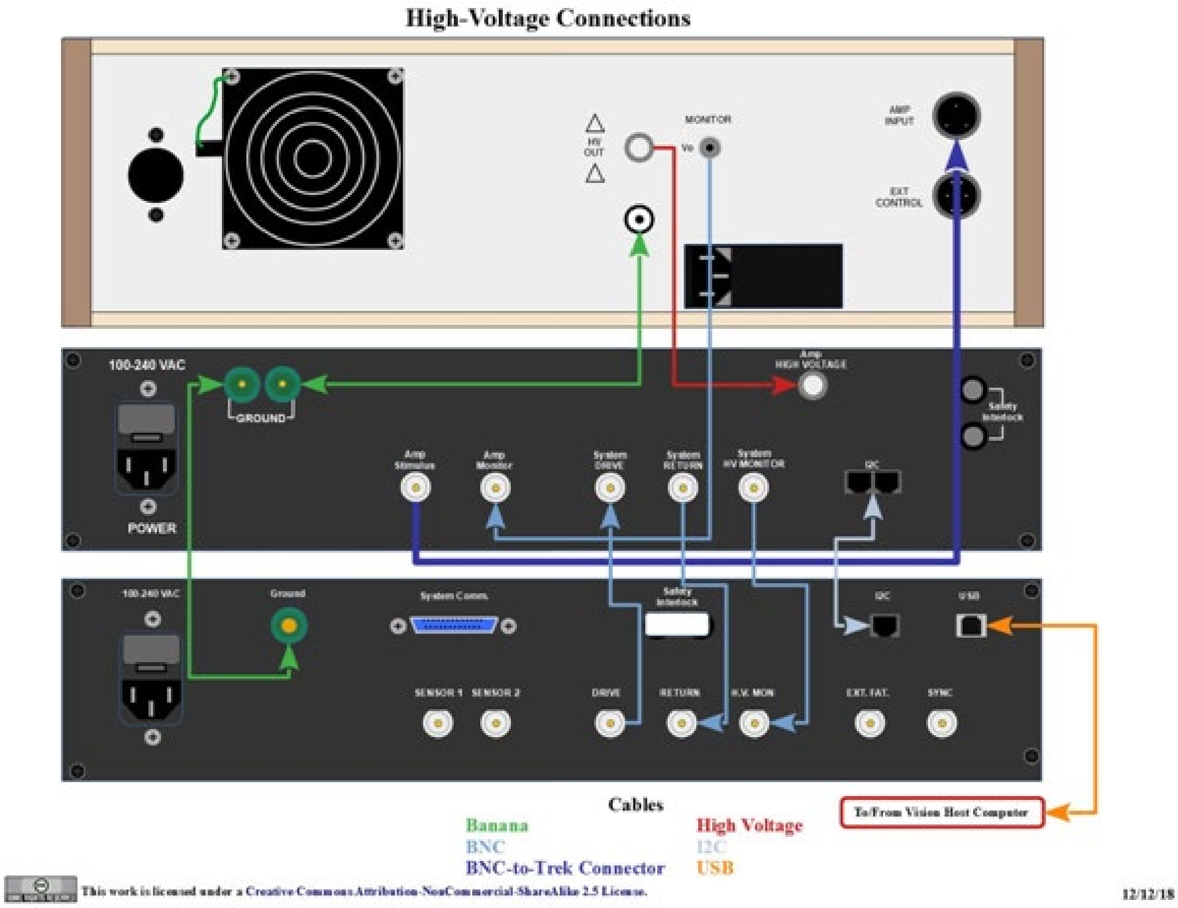


Figure 5 - High-Voltage Hookup.

Table 1 details the connections in **Figure 5**.

Cable From	Cable To	Type	Figure Color	Discussion
Tester "USB"/ Vision Host "USB"	Vision Host "USB"/ Tester "USB"	Printer-style USB	Orange	This cable carries tester and accessory logic to the Vision host computer. It carries hardware signal commands from the host computer to the tester. It carries measurement data from the tester to the Vision host computer.
HVI "I2C"	Tester "I2C"	I2C (Similar to telephone)	Grey	This cable carries logical information about the HVI to the tester. It also carries information about the HVA, that is embedded in the HVI, to the Precision tester.
Tester "DRIVE"	HVI "System DRIVE"	BNC	Light Blue	A low-voltage signal to be amplified by the HVA to generate the intended high-voltage signal. This signal is passed through the HVI "Amp Stimulus" port to the HVA "AMP INPUT" port.
HVI "System RETURN"	Tester "RETURN"	BNC	Light Blue	The sample charge (µC/cm2) response to the high-voltage stimulus. This signal is passed directly from the HVI front-panel "HV RETURN" port through the HVI to the tester "RETURN" port.
HVI " System HV	Tester "H.V. MON"	BNC	Light Blue	A low-voltage representation of the actual high-voltage signal generated by the HVA. This is passed from the HVA "MONI-

MONITOR				TOR" port through the HVI "Amp Monitor" port. This is passed to Vision to be used as the actual applied voltage.
Tester "Ground"	HVI "GROUND"	Banana	Green	This connection connects the chassis of all three instruments to a common earth ground. It should also be connected to any other instruments in teh experiment as well as any metal components including mounting racks, cabinets, tables, probe stations, etc.
HVI "GROUND"	HVA Ground (Unlabeled)	Banana	Green	This connection connects the chassis of all three instruments to a common earth ground. It should also be connected to any other instruments in teh experiment as well as any metal components including mounting racks, cabinets, tables, probe stations, etc.
HVI "Amp Stimulus"	HVA "AMP INPUT"	BNC-to-Trek Input	Dark Blue	This is the low voltage signal into the HVA input. It is the signal that is amplified by a fixed gain factor to generate the intended high-voltage HV DRIVE signal to stimulate the sample. This signal is passed directly from the tester "DRIVE" port, through the HVI "System DRIVE" port and out the "Amp Stimulus" port to the amplifier. The amplifier-end connector will differ depending on amplifier manufacturer and model. The HVA labeling may also differ.
HVA "MONITOR"	HVA "Amp Monitor"	BND	Light Blue	A low-voltage representation of the high-voltage output of the HVA. The amplifier generates this signal and passes it through the HVI "Amp Monitor" and "System HV MONITOR" ports to the tester "H.V. MON" port. The tester passes this voltage to Vision to be used to represent the actual applied voltage.
HVA "HV OUT"	HVI "Amp HIGH VOLTAGE"	Insulated High-Voltage Cable	Red	This is the amplfier's high-voltage output that is stimulated by the low-voltage stimulus input at the HVA "AMP INPUT" port. It is passed through the HVA rear-panel "Amp HIGH VOLTAGE" port through to the front-panel "HV DRIVE" port and out to the sample.

Connecting to a sample.

The Radiant High-Voltage Bundle comes with several red 10 kV cables that have a rubber high-voltage sleeve to provide more than 10 kV isolation. Cables come with connectors for the High-Voltage Test Fixture (HVTF) or HVDM/HVDM II High-Voltage Displacement Meter. Unterminated cables are also provided to allow the user complete flexibility in connecting to the sample.

Connections between the High-Voltage Interface (HVI) and the sample are largely at the user's discretion. The basic connections are between the HVI "HV DRIVE" port and one sample electrode and between the opposite electrode and the HVI "HV RETURN" port.

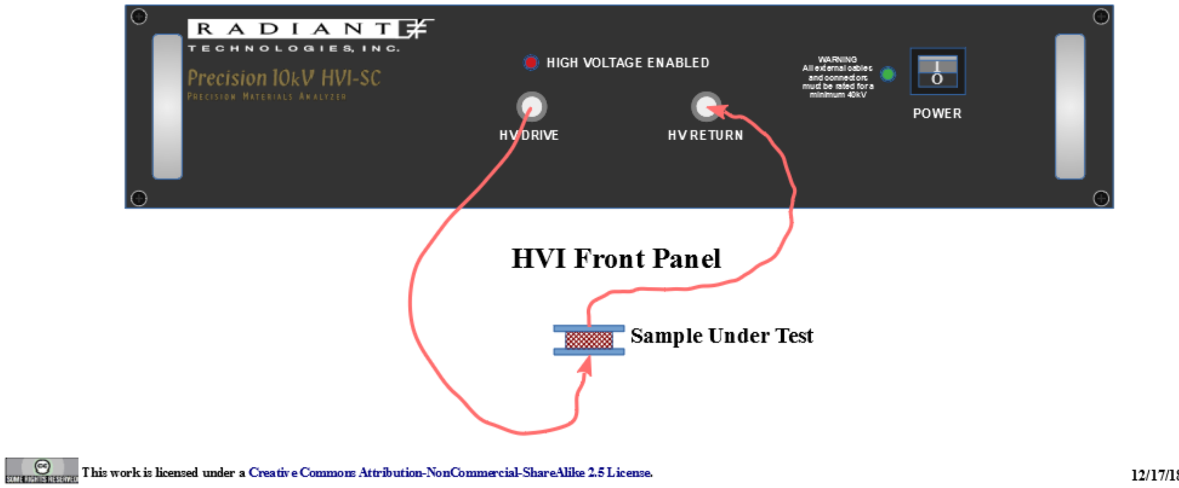


Figure 6 - High-Voltage Connections Between the HVI and the Sample.

Radiant offers a number of accessories to apply high-voltage to bulk ceramics:

- High-Voltage Test Fixture (HVTF): This is a bare-bones cylindrical test fixture that accepts the HVI HV DRIVE signal at one port (normally the bottom port) and connects the sample response to the HVI HV RETURN at the other (top) port. The sample is completely contained within the test fixture. The test fixture provides a fixed bottom electrode to contact the sample bottom electrode and a floating top electrode whose height adjusts to accommodate the sample thickness. It makes electrical contact to the top sample electrode through the force of gravity. The sample is in a reservoir that may be filled with mineral oil, or other fine oil, to prevent high-voltage arcing through air around the sample. The Teflon test fixture may be placed in an oven and heated to a maximum of 230° C. (As discussed elsewhere in this manual, Vision may control the oven provided it is a model that is known to Vision.)

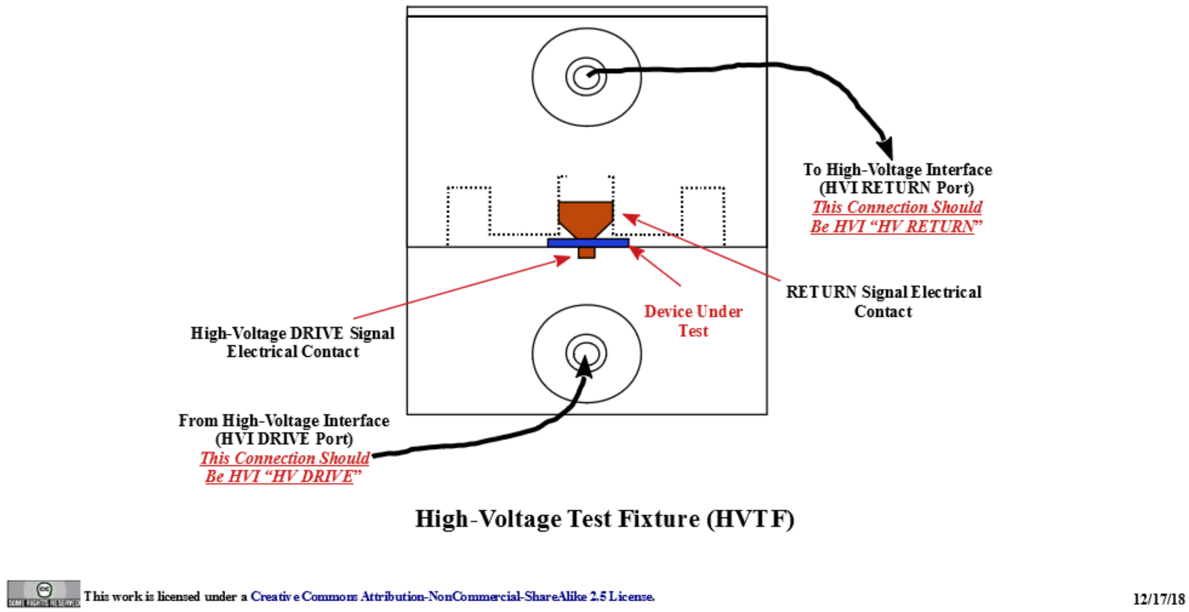
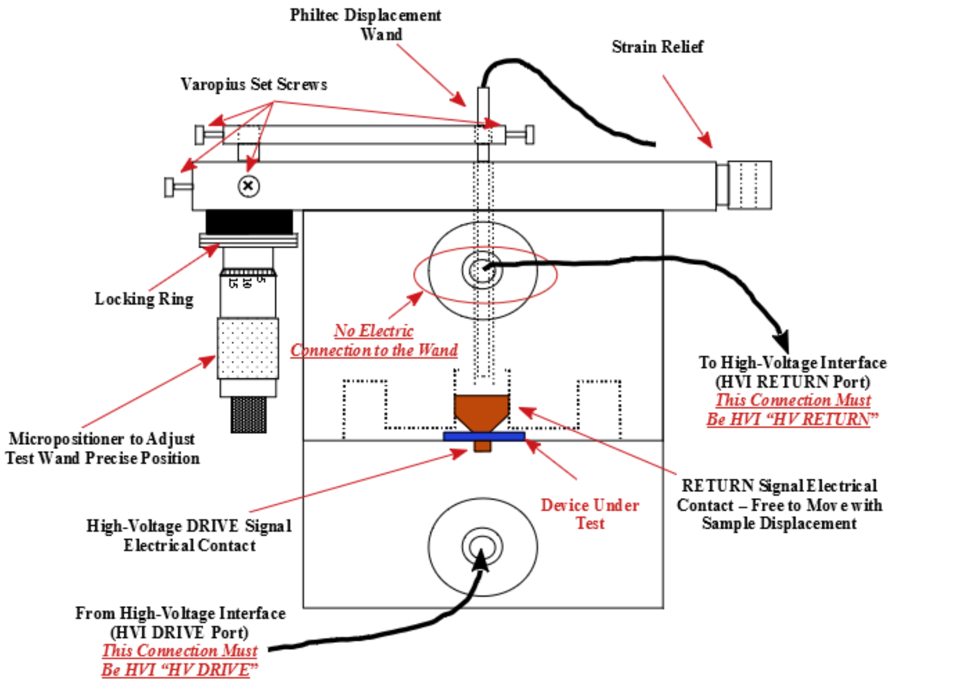
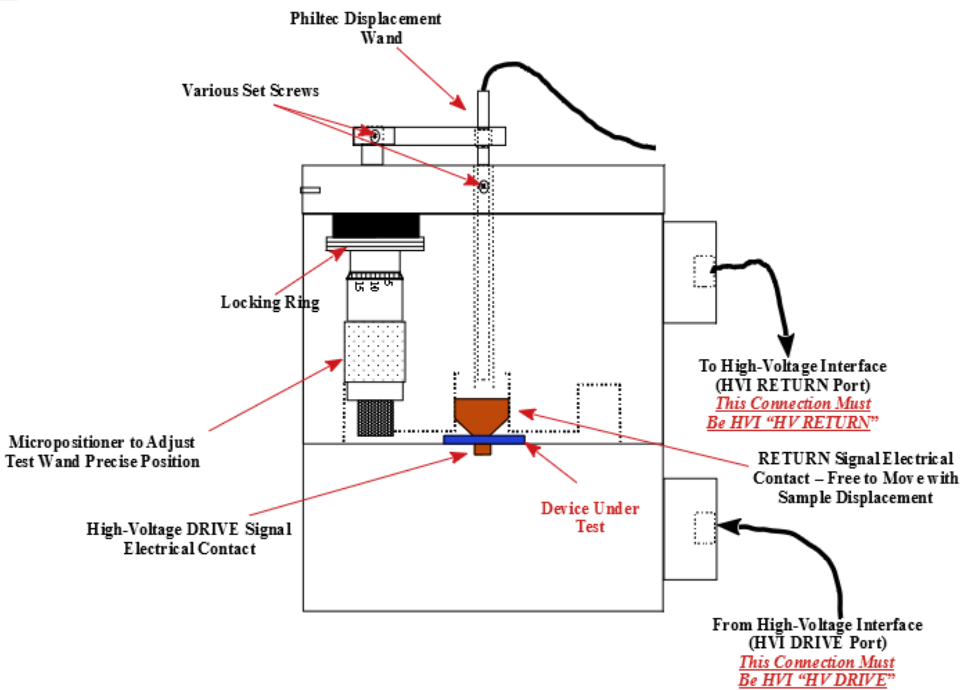


Figure 7 - High-Voltage Test Fixture (HVTF).

- High-Voltage Displacement Meter (HVDM): This accessory augments the basic HVTF by adding hardware that allows the test fixture to include a Philtec displacement detection wand for customers who are measuring displacement of high-voltage bulk piezoelectric samples. The basic test fixture is identical to the HVTF and all properties discussed above apply. In addition a stability arm is positioned over the top of the test fixture and connected to a micrometer that allows for precise vertical positioning. The stability arm has a hole that is exactly centered over the floating top electrode of the test meter. Friction sleeves placed in the hole allow Philtec detection wands to be held firmly and exactly vertically above the electrode to detect vertical motion of the electrode as the sample responds piezo-electrically to the DRIVE voltage. The Philtec detection wand is a fiber bundle that operate by detecting changes in the angle of deflection of light reflected from the electrode surface. A family of friction sleeves allows a variety of diameters of detection wands to be used.



High-Voltage Displacement Meter (HVDM)



High-Voltage Displacement Meter (HVDM) (Side View)

Figure 8 - High-Voltage Displacement Meter (HVDM).

- High-Temperature High-Voltage Displacement Meter (HVDM II): In this accessory the design of the HVDM is further extended by including internal heating of the sample contained in the HVDM II. The HVDM II includes a heating lamp and on-board electronic control of temperature (°C) and temperature ramp rate (°C/min.). The Vision program provides complete control of the HVDM II through a USB channel. The HVDM II must be connect to a USB port the the Vision host computer that is separate from the tester port.

  Two enhancements are planned for this instrument:

  - Auto-calibration: Each time the temperature settles at the set point, the Philtec displacement detector must have its position and return voltage strength recalibrated. In the current model this must be done manually by the user. A model is being designed that will automatically calibrate the detection system.
  - Very high-temperature: A model of this test fixture is planned that will offer much higher temperatures than the 230 °C limit of the current model.

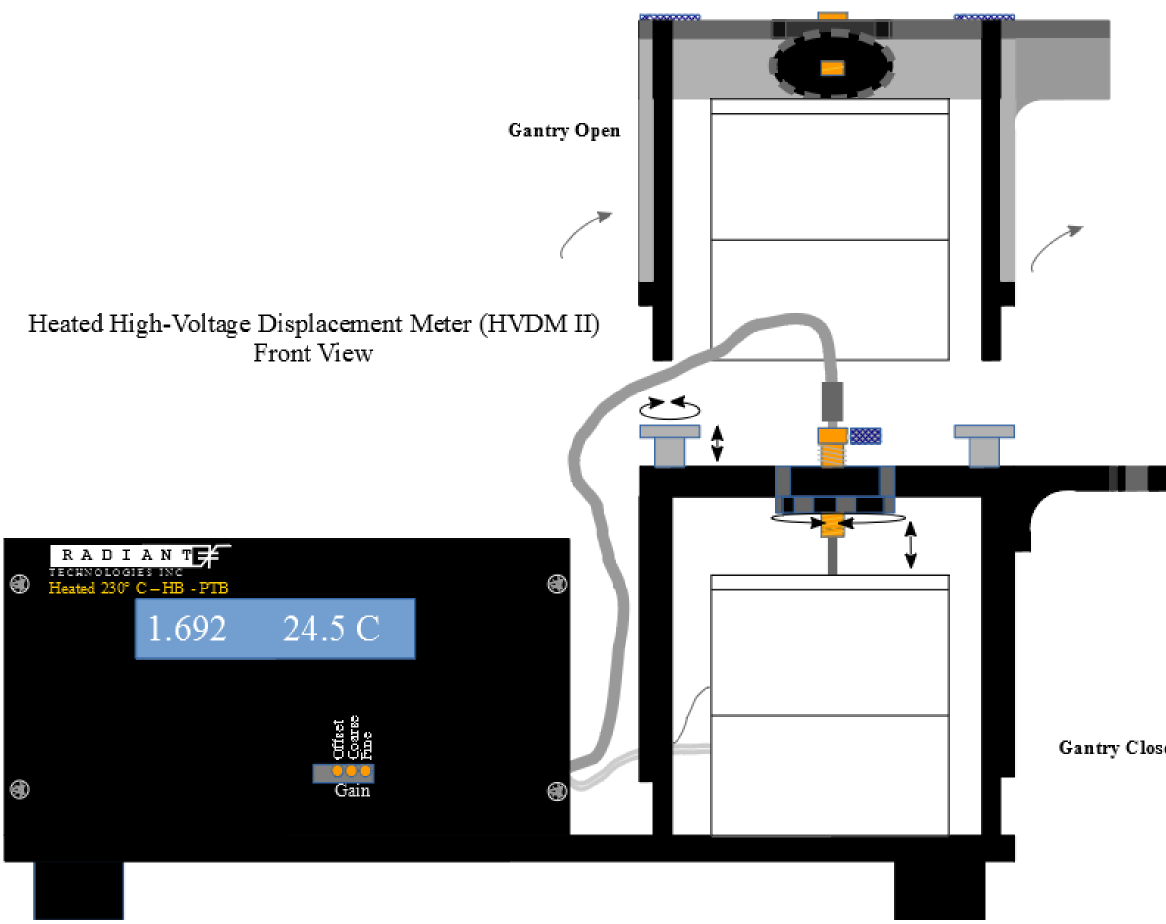


Figure 9 - Heated High-Voltage Displacement Meter (HVDM II) Front View.

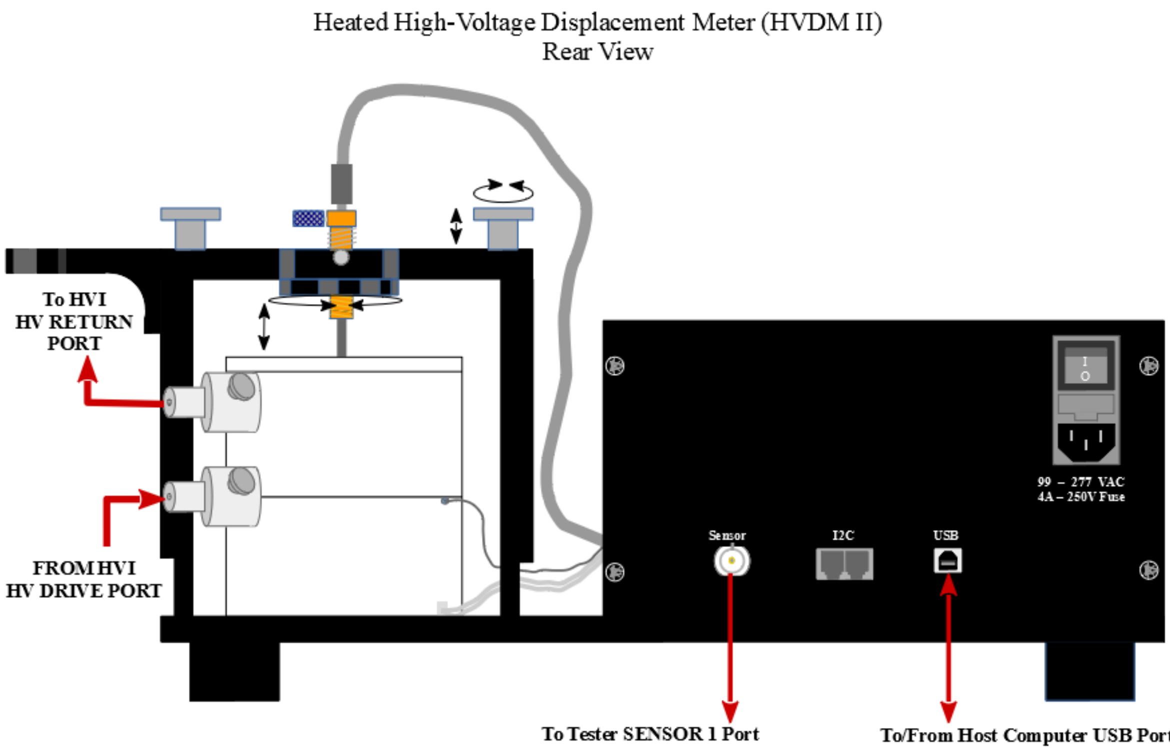


Figure 10 - Heated High-Voltage Displacement Meter (HVDM II) Rear View.

- High-Temperature Test Fixture (HTTF): This is a small family of test fixture that are designed to operate at much higher temperatures than the HVDM II. These test fixtures are made of Macor and with nickel electrical connections. Macor is a fragile ceramic that has a very low coefficient of thermal expansion. The test fixtures are very simple and are designed for use in a tube furnace or oven. The sample is placed on a nickel disk that serves as the electrical connection for the sample's bottom electrode. A nickel probe is lowered onto the top electrode. Electrical connections are made to nickel bolts with wingnuts. Macor "cables" (known as "straws") are provided to extend the electrical connections outside of the furnace or oven.

  Figure 11 shows test fixtures intended for 3" and 4" tube furnaces. The 4" version also has a test chuck that can allow it to be inserted into a 6" furnace. (This is not shown.) A test stand, with Macor standoffs, allow the 6" chuck to be lifted off the metal floor of a furnace to prevent high-voltage arcing to the furnace.

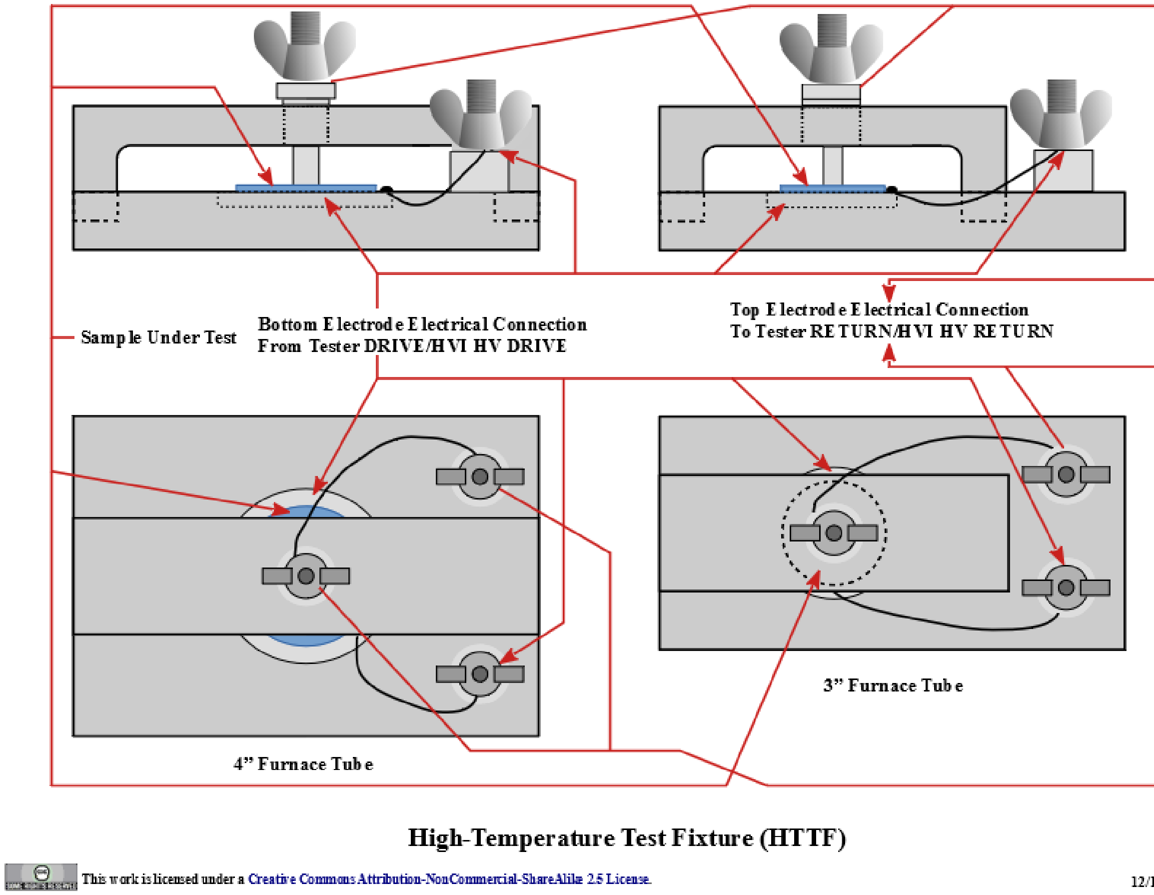


Figure 11 - 3" and 4" High-Temperature Test Fixtures (HTTF).

Vision Control of High-Voltage Measurements

Depending on tester model, up to ±500.0 Volts may be applied to a sample without requiring an HVI/HVA pair. Vision limits programming of any measurement to ±500.0 Volts unless a high-voltage measurement is specified. Each Hardware Task has a pair of controls labeled *Set Amplifier* and *Amplifier*. *Amplifier* is a read-only indicator of the status of the selected amplifier. It will indicate "Internal" or "High-Voltage". with "Internal" displayed, a maximum of ±500.0 Volts may be programmed. With "High Voltage" in the *Amplifier* control the maximum is adjusted to ±10,000.00 Volts. To switch between the two, click the *Set Amplifier* button. A subdialog opens that allows the internal or accessory HVA to be selected as the amplifier.

With Internal Voltage Source selected, External High Voltage is not selected. HVI Channel is forced to a value of '0' and disabled. When the dialog is closed, Amplifier will show "Internal" and Max Voltage will be limited to ±500.0 Volts. With External High-Voltage checked, Internal Voltage Source is unchecked. HVI Channel is set to '1' and enabled. It may also be set to '2', but this is very rare. It may only be set to '2' for older two-channel HVIs that have a HVA connected to their second channel. When a late-model HVI, that does not require an external HVA ID Module, is detected, Set/Change Selected Amplifier is enabled. This button opens a subdialog (not shown) that can be used to change the selected HVA provided the HVA model has been programmed for inclusion in the subdialog. When the subdialog is closed Amplifier with show "High Voltage" and Max Voltage will have a limit of ±10,000.0 Volts.

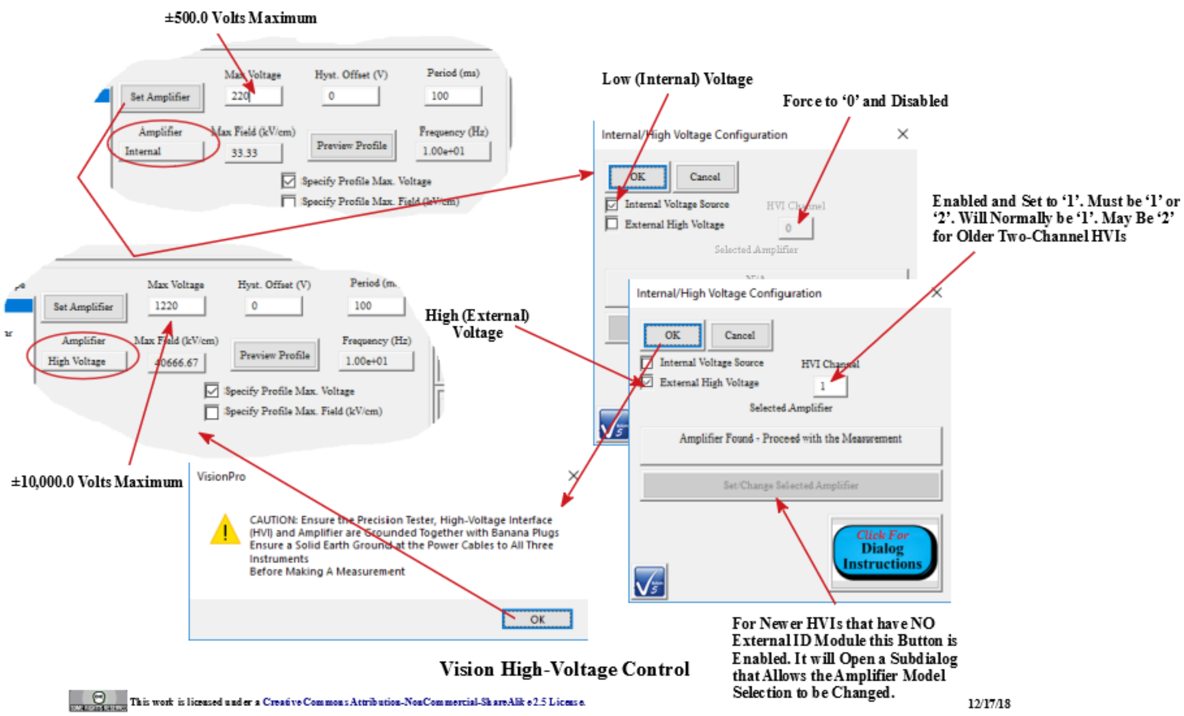


Figure 12 - Internal Low-Voltage/External High-Voltage Configuration.

Much more complete information regarding high-voltage measurement configuration and execution can be found in the Task Instructions for individual Tasks or in the Tutoral VII - High-Voltage Operations pages of this manual.

Magneto-Electric Setup and Operation

Magneto-Electric Measurement Process and Procedures.

In the magneto-electric measurement, the Vision program and Precision tester is used to generate a voltage profile that is scaled to an intended magnetic profile. The magnetic profile, generated in a Helmholtz coil, induces a charge (µC) response in the sample that is captured at the Precision tester RETURN port and passed back to the Vision program.

A simplified diagram of the experiment and its signals is given in **Figure 1**.

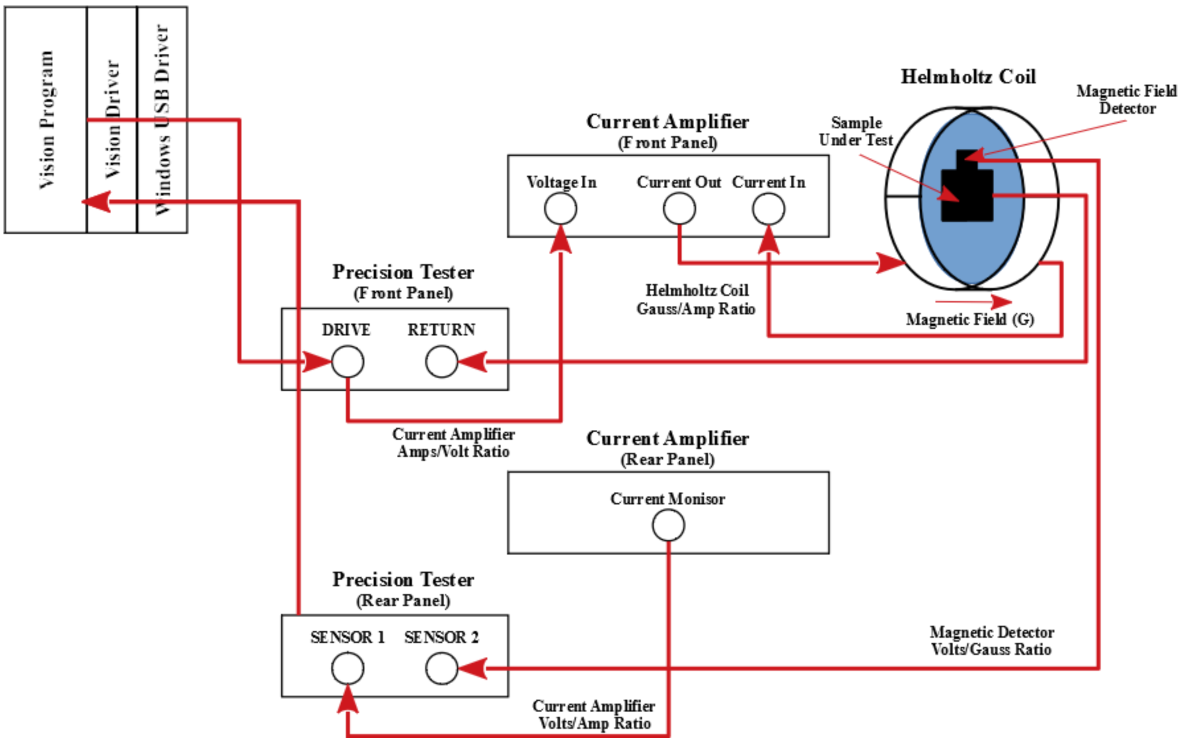


Figure 1 - Simplified Magneto-Electric Experiment Configuration and Signals.

The process proceeds as:

1. Vision generates a voltage profile that is linearly scaled to produce the intended magnetic field. The field generated is given by:

$$Helmholtz\ Coil\ Magnetic\ Field\ (G) = DRIVE\ Voltage\ \times Current\ Amplifier\ \ A\,/\,V\ \ \times Helmholtz\ Coil\ \ G\,/\,A \quad (1)$$

Conversely, the DRIVE Voltage to be applied is determined by:

$$DRIVE\ Voltage = Helmholtz\ Coil\ Magnetic\ Field\ (G) \times \frac{1}{Current\ Amplifier\ \ A/V} \times \frac{1}{Helmholtz\ Coil\ \ G/A} \quad (2)$$

2. Vision passes the current DRIVE voltage through the Vision Driver and the Precision Tester DRIVE port to the Current Amplifier Voltage In port.
3. The Current Amplifier converts the Voltage In to a Current Out that is related to the Voltage in by the Current Amplifier A/V ratio.
4. The Current Amplifier converts the current out to a voltage model of the current out that is passed from the Current Amplifier Current Monitor port through the Precision Tester SENSOR 1 port to the Vision Driver. This model will have its own V/A ratio.
5. The Current Amplifier Current Out is passed to Helmholtz Coil input, through the coil and through the Helmholtz Coil output ot the Current Amplifier Current In Port.
6. The current through the Helmholtz Coil induces a magnetic field (G) this is related to the current through the Helmholtz Coil by the coil's G/A ratio.
7. The magnetic field (G) of the Helmholtz Coil induces a charge (µC) response n the Sample Under Test that is passed through the Precision Tester RETURN port to the Vision Driver.
8. A Magnetic Field Detector generates an output voltage that is linearly related to the magnetic field by the detector's V/G ratio. The output voltage is passed through the Precision Tester SENSOR 2 port to the Vision driver.
9. The Vision Driver passes the actual DRIVE voltage vector, the integrated RETURN charge (µC) data, and the SENSOR 1 and SENSOR 2 voltages.
10. Vision converts, stores and plots the following data:

- Integrated RETURN Port Voltage -> charge (µC) -> Polarization (µC/cm^2)
- Actual DRIVE Voltage -> Estimated Applied Field by Equation (1).
- SENSOR 1 Voltage -> Estimated Applied Field by:

Magnetic Field (G) = SENSOR 1 Voltage x 1/(Amplifier Current Monitor V/A ratio) x Helmholtz Coil A/G ratio. (3)

- SENSOR 2 Voltage -> Actual Applied Field by:

Magnetic Field (G) = SENSOR 2 Voltage x 1/(Magnetic Detector G/V ratio). (4)

Magneto-Electric Measurement Instruments.
Any current amplifier may serve in **Figure 1**, provided an appropriate current output (±2 A) is within the amplifier's limitations. Early editions of the Magneto-Electric Bundle included shipment of the Kepco BO 36 Voltage/current amplifier. The amplifier did not include the "Current Monitor" port of **Figure 1**. Instead, a Radiant Technologies RCSi Current Sensor (not shown) was included in the current signal path between the Kepco amplifier and the Helmholtz coil input. The output of the RCSi was passed to the Precision Tester SENSOR 1 port.

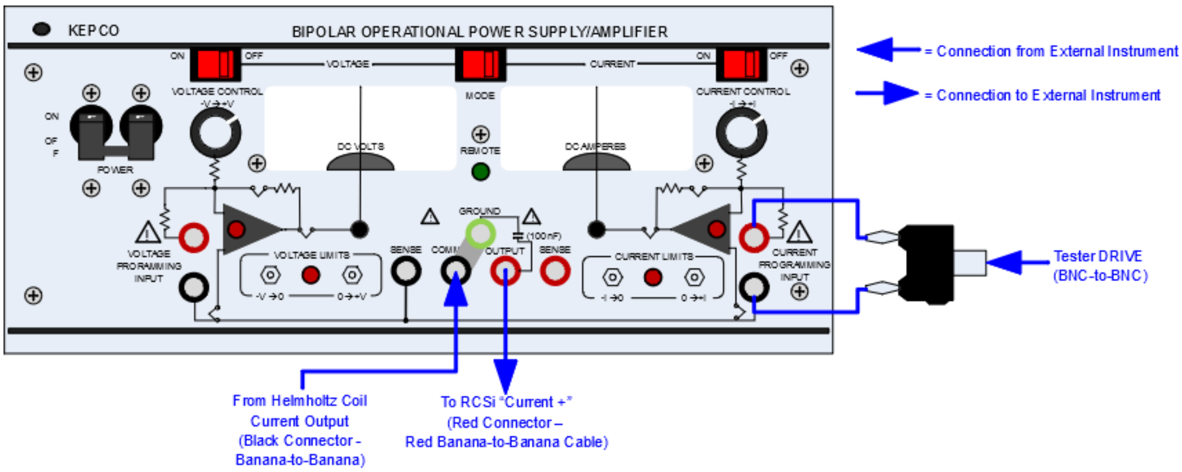


Figure 2 - Kepco BOP 36 Current Amplifier and Connections.

Modern distributions of the Magneto-Electric Test Bundle include the Radiant Technologies, Inc. CS 2.5 Current Source (**Figure 3**).

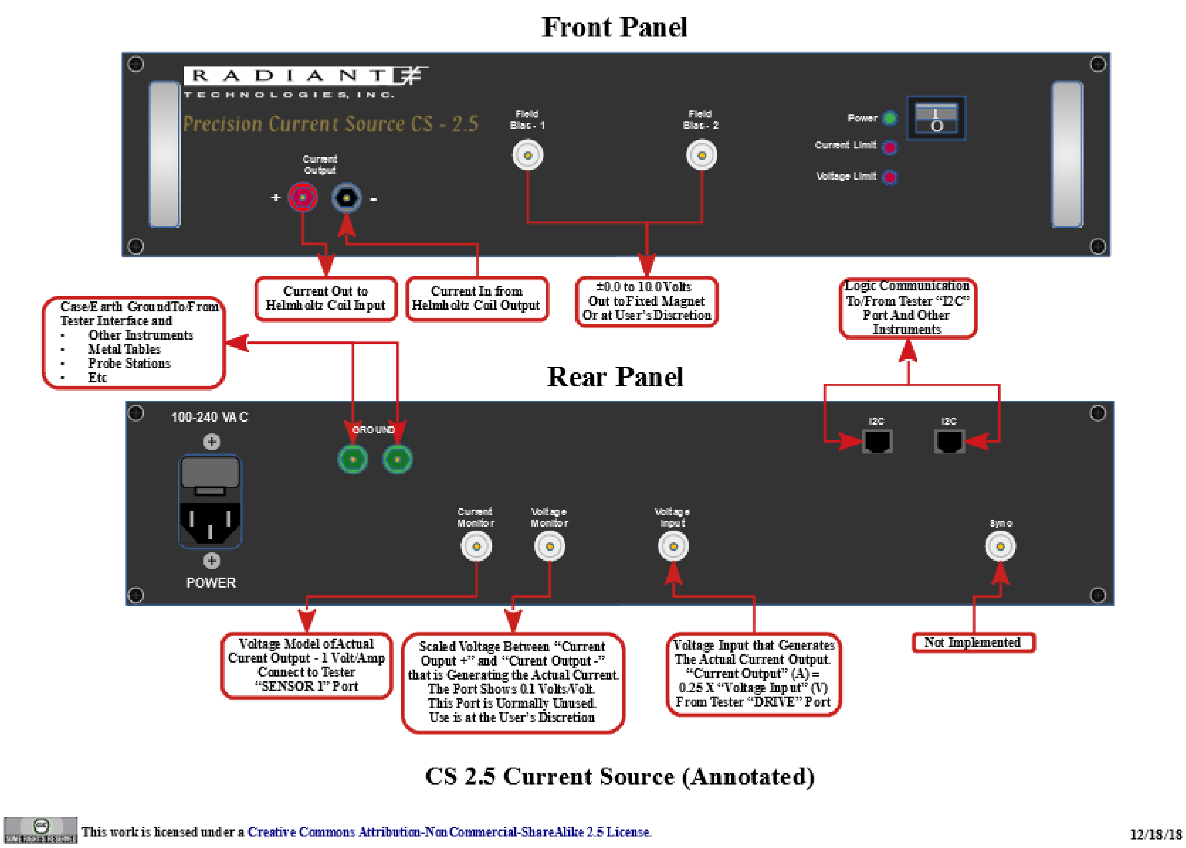


Figure 3 - Radiant Technologies, Inc. CS 2.5 Current Source and

Connections.

The Magneto-Electric Test Bundle includes a Lakeshore MH-6 Helmholtz Coil. This is a 6" coil that generates approximately 26.0 Gauss/Amp. The exact G/A ratio is labeled on the coil.

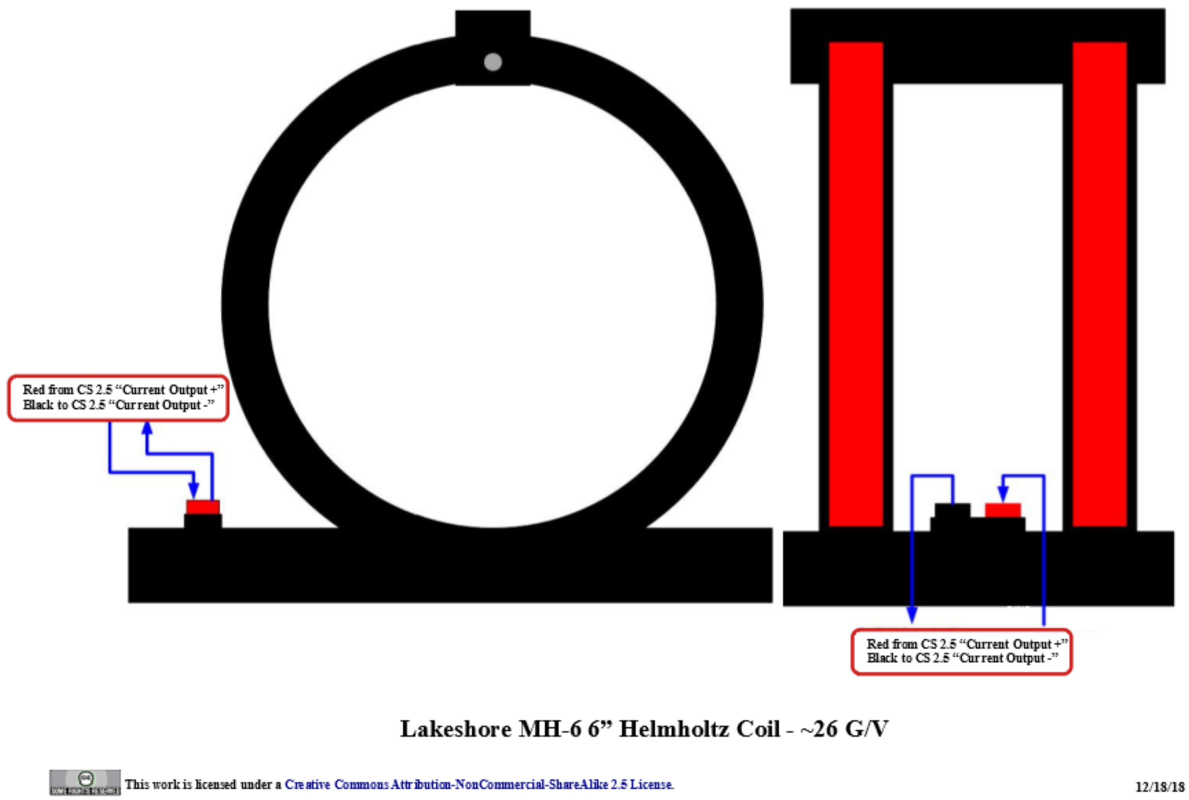


Figure 4 - Lakeshore MH-6 Helmholtz Coil.

To provide complete services for holding a sample and making electrical contact to it, Radiant Technologies offers a copper shield box and attached fingerboard. The shield box is transparent to the magnetic field. But it is impenetrable to environmental electrical noise such as 50 Hz/60 Hz signals. Sample response to the magnetic field is often in units of picoCoulombs. For such low signals the shielding of the sample from external signals is required.

Figure 5 shows the side view of a thin-film shield box. The sample is mounted to a small socket board that is plugged into the green circuit board (known as a fingerboard) within the shield box. The fingerboard is screwed to a mount that allows rotational freedom within the magnetic field. Two Hall Effect sensors are mounted to the board. A vertical sensor (shown as C18) detects electrical field that is parallel to the face of the fingerboard when the sample orientation is parallel to the earth's surface as shown in **Figure 5**. The second Hall Effect sensor has its face in the plane of the fingerboard. It detects magnetic field that is normal to the surface of the fingerboard when the sample orientation is rotated 90°.

Signals from the sample fingerboard are discussed immediately below. However, **Figure 5** shows that the signals are routed through short SMA cables connected to the body of the shield box before being routed to/from the Precision Tester. This provides additional noise shielding as the shielding of the signal cables is grounded to the shield box. This ensures that the shield box holds a common ground plane with the Precision Tester chassis and with other instruments in the experiment.

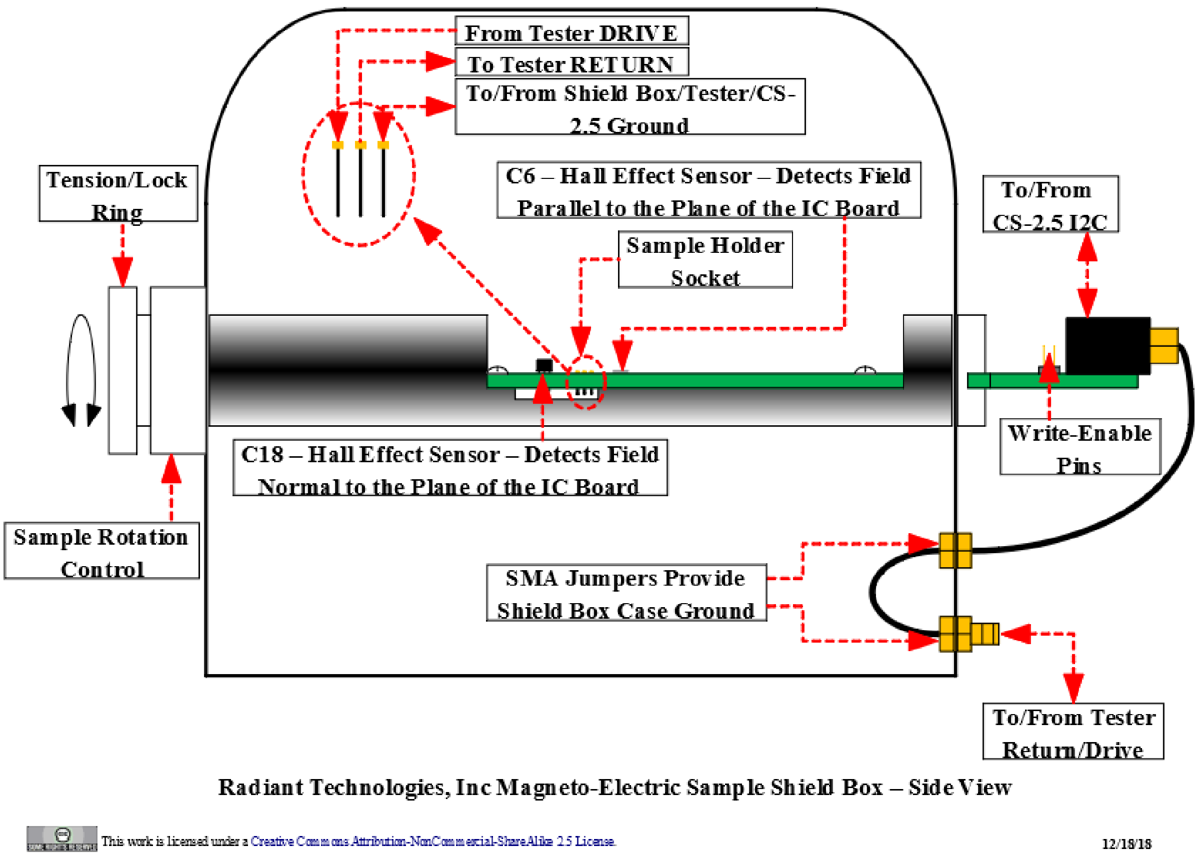


Figure 5 - Thin-Film Magneto-Electric Shield Box - Side View.

Figure 6 shows a top view of the shield box with the fingerboard in the same orientation as in **Figure 5**. This provides a more-detailed view of the fingerboard and its connections, detectors and signals. In a normal magneto-electric measurement, the sample is soldered onto a mounting board with DRIVE, RETURN and Ground pins that are inserted, in the proper orientation, to the fingerboard connector. The DRIVE and RETURN signals are routed to the SMA connectors on the external portion of the fingerboard. For a magneto-electric measurement, the signal pin of the DRIVE connector is grounded to the outer shell of the connector using a short grounding plug. This ensures that the DRIVE introduces no signal to the measurement. The RETURN SMA is connected, through the shield box body, to the Precision Tester RETURN port. It carries the charge (pC) response of the samle to the stimulus magnetic field.

Note that the DRIVE SMA may be connected directly to the DRIVE port on the Precision Tester. This will disconnect the tester DRIVE port from the current amplifier so that no magnetic signal is induced. With this simple change the electric charge response of the sample can be measured just as in a standard electrical measurement.

The fingerboard contains an EEPROM that holds the characteristics - primarily Volts/Gauss gain and offset - of the two Hall Effect sensors. The active sensor may be selected in Vision through the I2C port. The selected sensor output will be switched to the Sensor output from which it can be connected to the Precision Tester SENSOR 2 port. The EEPROM can be queries by Vision for the appropriate gain and offset values to apply to the voltage measured at SENSOR 2 to convert the voltage back to the detected magnetic field.

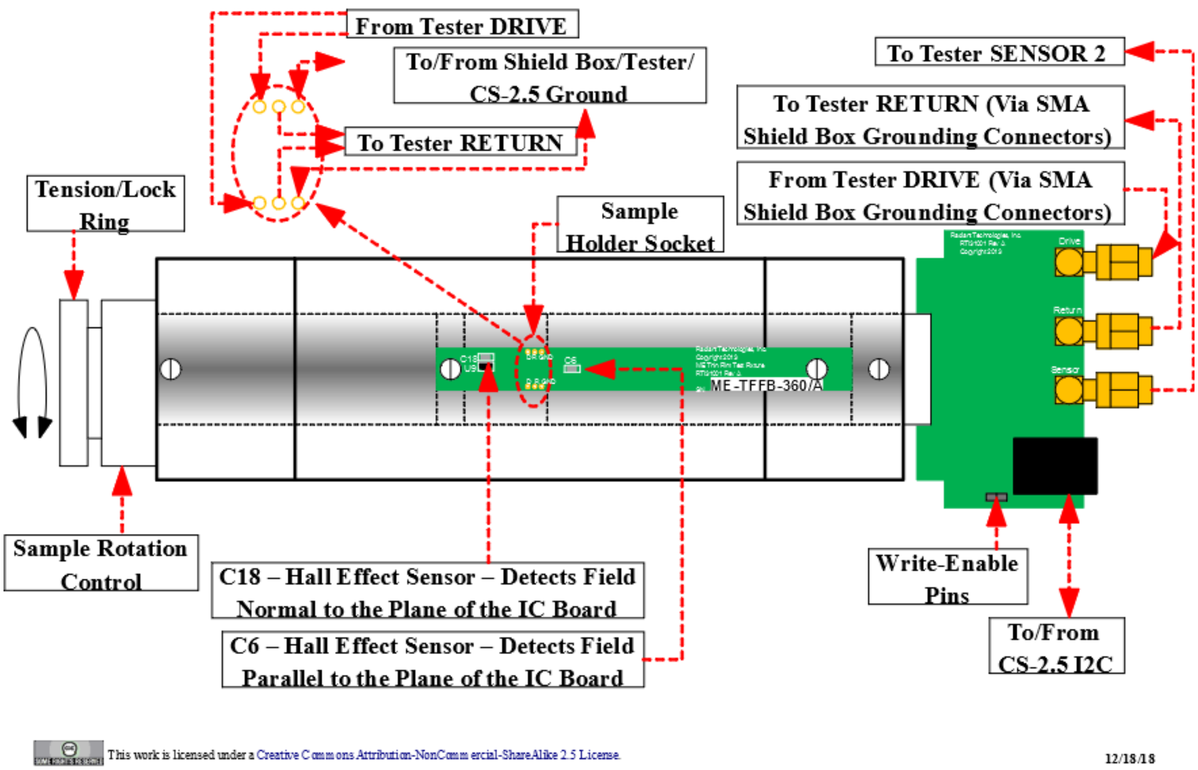
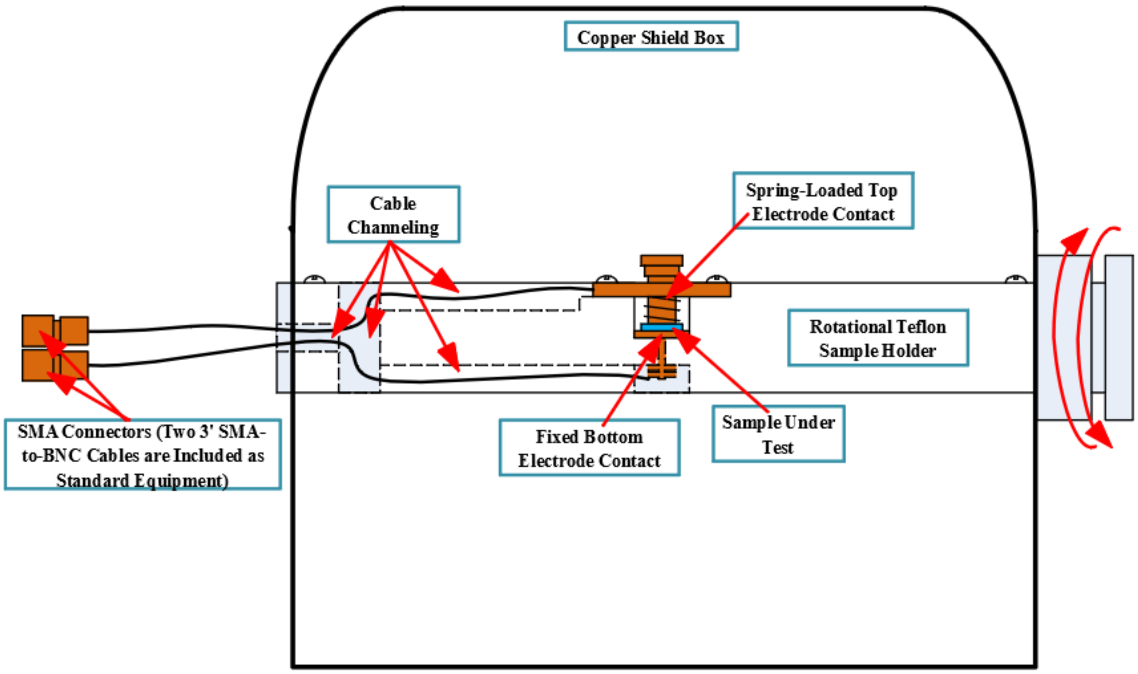


Figure 6 - Thin-Film Magneto-Electric Shield Box - Top View.

Figure 7 shows an early edition of the bulk sample shield box. The current version is similar in the method of contacting and holding the sample. However, the current bulk shield box includes the same fingerboard electronics as described above.



Shielded Rotational Magneto-Electric Sample Holder for use with a 6" Lakeshore Helmholtz Coil

Figure 7 - Bulk Sample Magneto-Electric Shield Box - Side View.

Figure 8 shows the connections made between the Precision Tester and the CS 2.5 Current Source. Not shown are the connections between the CS 2.5 Current Source "Current Output +"/"Current Output -" ports and the Helmholtz Coil. Also not shown are the connections between the fingerboard Return and Sensor ports and the Precision Tester RETURN and SENSOR 2 ports.

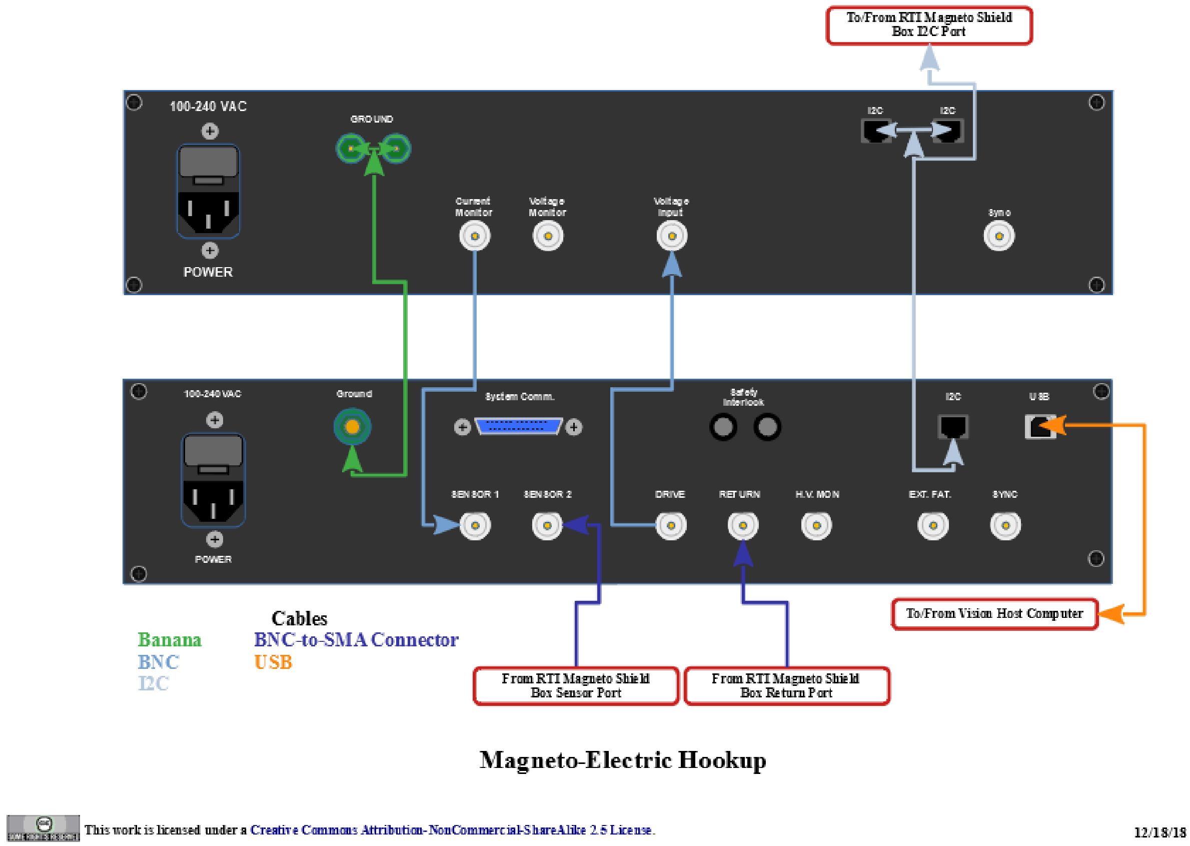


Figure 8 - Magneto-Electric Connections.

Table 1 offers a more-complete description of the connections to be made.

Cable From	Cable To	Type	Figure Color	Discussion
Tester Gound	CS 2.5 Ground	Banana	Green	This cable connects the instruments' chassis to a firm earth ground. This connection point should also be attached to any metal components in the experiment - metal tables, probe stations, equipment racks, etc.
CS 2.5 I2C	Tester I2C	I2C (Telephone)	Grey	This cable carries identifying information from the CS 2.5 Current Source to the Vision program. It also relays Hall Effect Sensor selection from Vision to the fingerboard and Hall Effect Sensor parameters from the fingerboard to Vision.
Finger-board I2C	CS 2.5 I2C	I2C (Telephone)	N/A	This cable carries the Hall Effect Sensor selection from Vision, through the Precision Tester and CS 2.5 Current Source to the Fingerboard. It passes parameters for the selected Hall Effect Sensor back along the logic path to Vision.
Tester USB	Vision Host SUB	Printer-Type USB	Orange	Logical connection between the Vision host computer and the Precision Tester allow commands and parameters to be passed from Vision to the tester and allow data to be passed from the Precision Tester back to Vision.

Tester DRIVE	(CS 2.5 Voltage Input)	BNC	Light Blue	This cable carries a DRIVE stimulus that is converted by the CS 2.5 Current Source to a current (A) value that is passed to the Helmholtz Coil where it is again converted to a magnetic field. The magnetic field is given by the DRIVE voltage x CS 2.5 A/V x Helmholtz Coil G/A. This signal may also be routed directly to the Fingerboard Drive connector to perform a direct electrical measurement.
CS 2.5 Current Monitor	Tester SENSOR 1	BNC	Light Blue	This is a voltage that is returned from the CS 2.5 Current Source to the Precision tester at SENSOR 2 for use by Vision. This is a voltage representation of the exact current that is being generated by the CS 2.5. The ratio of this voltage is exactly 1.0 V/A.
Fingerboard Sensor	Tester SENSOR 2	BNC-to-SMA	Dark Blue	This cable carries the output voltage of the selected Fingerboard Hall Effect Sensor to the Precision Tester SENSOR 2 port. It can be scaled and offset by parameters queried from the Fingerboard EEPROM to convert the voltage back to a magnetic field value.
Fingerboard Return	Tester RETURN	BNC-to-SMA	Dark Blue	This cable carries the sample's Charge (pC) response to the magnetic field back through the tester to Vision for conversion, storage and plotting.
Fingerboard Drive	(Tester DRIVE)	BNC-to-SMA	N/A	For magnetic measurements this connector will be jumpered together using a short pigtail cable to ground the signal pin to the outer shield. This port may be connected to the Tester DRIVE port for direct electrical measurements.
CS 2.5 Current Output +	Helmholtz Coil Red	Banana	N/A	This connection carries the ordered current (A) from the CS 2.5 Current Source to the Helmholtz Coil output. This current drives the Helmholtz Coil output magnetic field (G)
Helmholtz Coil Black	CS 2.5 Current Output -	Banana	N/A	The current (A) through the Helmholtz coil is carried back through this cable to the CS 2.5 Current Source, completing the circuit.

Constant DC Magnetic Field

The discussion above describes the signals and equipment configuration for a base magnetoelectric measurement as in **Figure 9**.

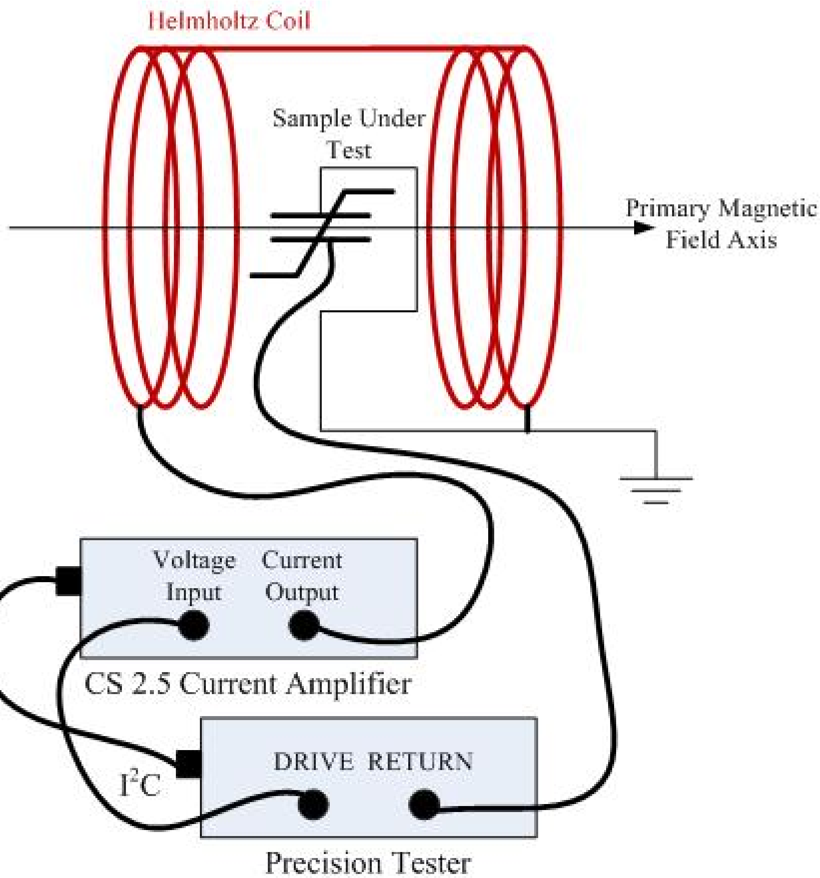


Figure 9 - Basic Magneto-Electric Experiment Configuration.

The Radiant Technologies' Magneto-Electric Bundle and Vision program allow this basic experiment to be augmented with the addition of a fixed DC magnetic field within which the basic measurement is made. This is shown in **Figure 10**.

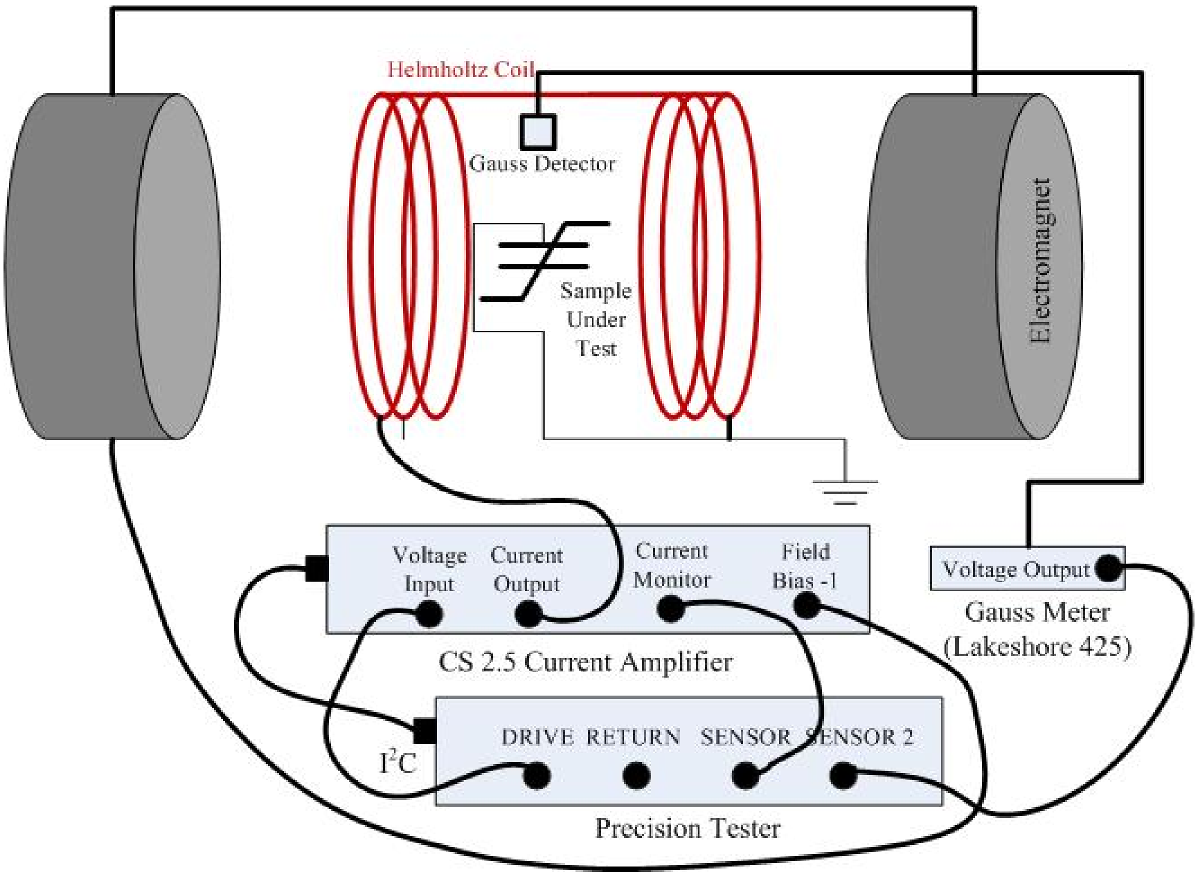


Figure 10 - Magneto-Electric Experiment Configuration with Fixed DC Magnets.

(Note that **Figure 10** shows a Lakeshore 425 Gaussmeter. This magnetic field detection device has been supplanted by the Hall Effect sensors embedded in the shield box as described above. Among other advantages, the Hall Effect sensors will detect the magnetic field simultaneously with a sample measurement. The Lakeshore 425 detector cannot be left in place with the shield box inserted into the Helmholtz coil. The Lakeshore 425 Gaussmeter is no longer offered with the RTI Magneto-Electric Bundle.)

The DC magnetic field is normally applied by a set of fixed electromagnets (not provided by Radiant Technologies, Inc.) These are normally controlled through a magnet-specific current amplifier. The original Kepco Magneto-electric Bundle included the RTI I2C Voltage Controller (not shown) to act as a programmable voltage input to the current amplifier. In the CS 2.5 Magneto-Electric Bundle, this device has been supplanted by the CS 2.5 Current Source itself. In addition to the current amplifier function of the CS 2.5, the instrument can also be programmed to output specific voltages from the Field Bias-1 and/or Field Bias-2 port(s) (**Figure 3**). Either of these may serve to apply the programmed voltage input to the fixed DC magnets. The voltage out must be in the ±10.0 Volt range and is related to the DC magnetic field out by:

DC Magnetic Field = Field Bias-x DC Voltage x Amplifier Current (A)/Volt Ratio x Magnet Field/A Ratio.

The Magneto-Electric Response Task (M.E.R. Task) will allow the DC field to be applied over a user-specified ramp time and user-specified number of ramping steps before a measurement is made.

Vision Control of Magneto-Electric Measurements

A number of Vision Tasks operate either the generic (Kepco) or CS 2.5 Current Source Magne-to-Electric activities. The Tasks are grouped together either under "Generic" or "CS 2.5 " paths in the TASK LIBRARY or under QuikLook. The primary magneto-electric Measurement Task is the Magneto-Electric Response (M.E.R.) Task. The Task configuration dialog is shown in **Figure 11**.

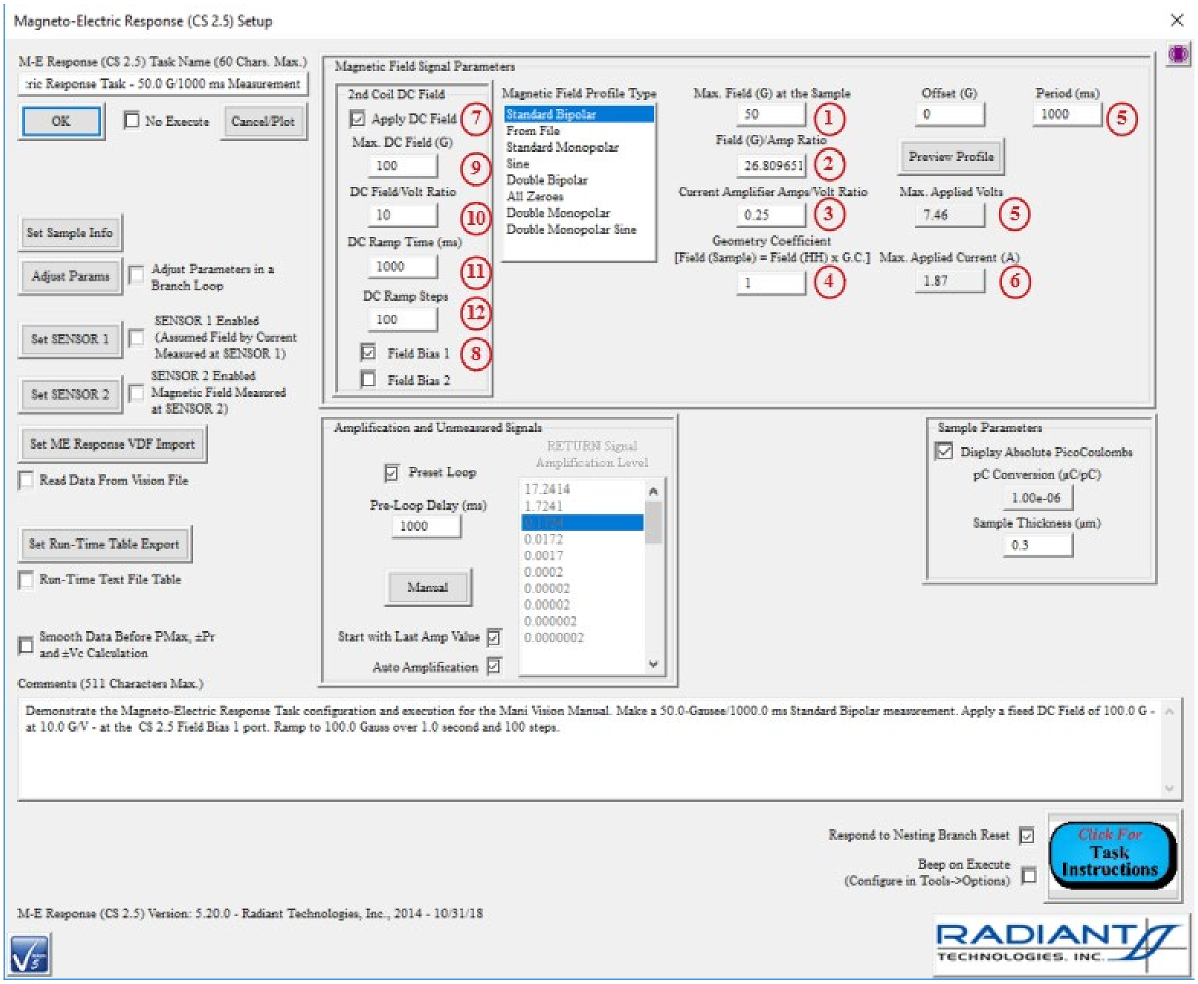


Figure 11 - Magneto-Electric Response Task Configuration.

The Task configuration is very similar to a Hysteresis Task configuration except that the signal is applied in units of Gauss, with conversion terms to determine the Precision Tester DRIVE voltage. A secondary DC magnetic field is also configured. Configuration includes:

- 1 *Max Field (G) at the Sample*: This is equivalent to the Hysteresis Task Max Voltage control. It specifies the maximum waveform magnetic field to apply in units of Gauss.
- 2 *Field (G)/Amp Ratio*: This is the "Helmholtz Coil G/A" term from Equation (1) above. This value is published on a sticker affixed to the Lakeshore MH-6 Helmholtz Coil. It is the calibrate magnetic field (G) that will be generated for a current of 1 Amp.
- 3 *Current Amplifier Amps/Volt Ratio*: This is the "Current Amplifier A/V" term from Equation (1) above. This value is stored in the CS 2.5 EEPROM and automatically read by the CS 2.5 Magneto-Electric Response Task. This is the CS 2.5 current (A) that will be generated from a 1.0-Volt DRIVE stimulus input.
- 4 *Geometry Coefficient*: This is a non-zero positive value less than or equal to 1. It represents a know reduction in applied magnetic field at the sample due to sample position and/or orientation. The *Max Field (G) at the Sample* will be scaled by the inverse of this term to a Helmholtz Coil value that is of the correct strength to apply the program field at the sample. This term will normally remain at a value of 1.0.
- 5 *Max Applied Volts*: This a read-only control that displays the voltage that is to be applied at the Precision Tester DRIVE port to generate the *Max Field (G) at he Sample*. This value is given by:

Max Applied Volts = *Max Field (G) at the Sample* x 1/*Field (G)/Amp Ratio* x 1/*Current Amplifier Amps/Volt Ratio* x 1/*Geometry Coefficient* (5)

- 6 *Max Applied Current (A)*: This is a read-only control that displays the current generated by the CS 2.5 with an input of *Max Applied Volts*. It is given by:

Max Applied Currnet (A) = *Max Applied Volts* x *Current Amplifier Amps/Volt Ratio*

- 7 *Apply DC Field*: Checking this box indicates that fixed electro-magnets are to apply a DC bias field governed by the controls in this section. The field will be generated in response to the voltage out of Field Bias 1 or Field Bias 2. Checking this box enables *Field Bias 1*, *Field Bias 2*, *Max DC Field (G)*, *DC Field/Volts Ratio*, *DC Ramp Time (ms)* and *DC Ramp Steps*.
- 8 *Field Bias 1/Field Bias 2*: These controls are enabled if *Apply DC Field* is checked. Otherwise they are disabled. Checking one of these controls unchecks the

other. The checked control determines with of the two Field Bias x ports on the CS 2.5 with be used to control the fixed electro-magnets.

- 9 *Max DC Field (G)*: This control is enabled if *Apply DC Field* is checked. Otherwise it is disabled. This is the value of the fixed DC magnetic field to be applied by the electro-magnets. The measurement will not begin until the DC magnetic field is steady at this value.
- 10 *DC Field/Volt Ratio*: This control is enabled if *Apply DC Field* is checked. Otherwise it is disabled. This value is comprised of the combination of the electro-magnet G/A ratio and the magnet's amplifier A/V ratio. The value in this control determines the maximum voltage output by the CS 2.5 Field Bias 1 or Field Bias 2 port. That voltage is given as 1/*DC Field/Volt Ratio.*
- 11 *DS Ramp Time (ms)*: This control is enabled if *Apply DC Field* is checked. Otherwise it is disabled. This is the period over which the DC magnetic field will rise "linearly" from 0.0 G to *Max DC Field (G)*. "Linear" is in quotes because the field rise is actually taken in discrete steps.
- 12 *DC Ramp Steps*: This control is enabled if *Apply DC Field* is checked. Otherwise it is disabled. This is the number of discrete magnetic field steps to apply over *DS Ramp Time (ms)* until *Max DC Field (G)* is reached. Each steps will increment the DC Field by *Max DC Field (G)*/*DC Ramp Steps*.

Tester Troubleshooting

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Precision Tester Family (Models and Specifications)

Precision Tester models are detailed under this topic

Precision RT66C

The Precision RT66C is perfect for a researcher looking for a flexible unit at an affordable price. The RT66C Test System has a Hysteresis frequency rating of 1 kHz. The RT66C is offered in a +/- 200V built-in drive volt option. The RT66C can be expanded to 10 kV with the addition of a 10 kV High Voltage Interface (HVI) and a High Voltage Amplifier (HVA).

The Precision RT66C offers the lowest-cost professional-quality member of the Radiant Technologies, Inc. Precision tester family. The RT66C physically differs from other testers in testers in the family by:

- The tester has a height of 1 U. All other Precision testers are 2 U high.
- The tester does not offer a parallel port for logic communications to older High-Voltage Interfaces (HVIs).
- The RT66C has only one SENSOR port. Other tester models offer two ports.
- The RT66C is limited to a ±200-Volt model. ±10.0-Volt, ±30.0-Volt, ±100.0-Volt and ±500.0-Volt models are not offered.

RT66C Appearance

Figure 1 - Precision RT66C Front and Rear Panels.

RT66C Specifications

Parameter	Value
AC Power	100 to 240 VAC 50-60 Hz
Fuse	1.25 Amp/250 VAC SB
Operating Temperature	0° to 40° C
Operating Humidity	85% Noncondensing
Elevation	0 to 3000 m

Voltage Range (built-in drive voltage)	±200 V
Voltage Range with an external amplifier and High-Voltage interface (HVI)	10 kV
Number of ADC Bits	14
Minimum Charge Resolution	122 fC
Minimum Area Resolution (assuming 1 ADC bit = 1µC/cm2)	12.2 μ^2
Maximum Charge Resolution	4.8 µC
Maximum Area Resolution (assuming saturation polarization = 100µC/cm^2)	4.8 mm^2
Maximum Charge Resolution with High-Voltage Interface (HVI)	480 µC
Maximum Area Resolution (assuming saturation polarization = 100µC/cm^2) w/o HVI	4.8 cm^2
Maximum Hysteresis Frequency	1 kHz
Minimum Hysteresis Frequency	1/8th Hz
Minimum Pulse Width	500 µs
Minimum Pulse Rise Time (5 V)	500 µs
Maximum Pulse Width	100 ms
Maximum Delay between Pulses	40 ks
Internal Clock	50 µs
Minimum Leakage Current (assuming max current integration period = 1 seconds)	10 pA
Maximum Small Signal Cap Frequency	2 kHz
Minimum Small Signal Cap Frequency	10 Hz
Output Rise Time Control	2 settings
Input Capacitance	1 pF
Electrometer Input All Test Frequencies for all test at any speed	Yes

* The minimum area resolution under actual test conditions depends upon the internal noise environment of the tester, the external noise environment, and the test jig parasitic capacitance.
*** Tester specifications are subject to change without notice.

Table 1 - Precision RT66C Specifications.

RT66C Port Definitions

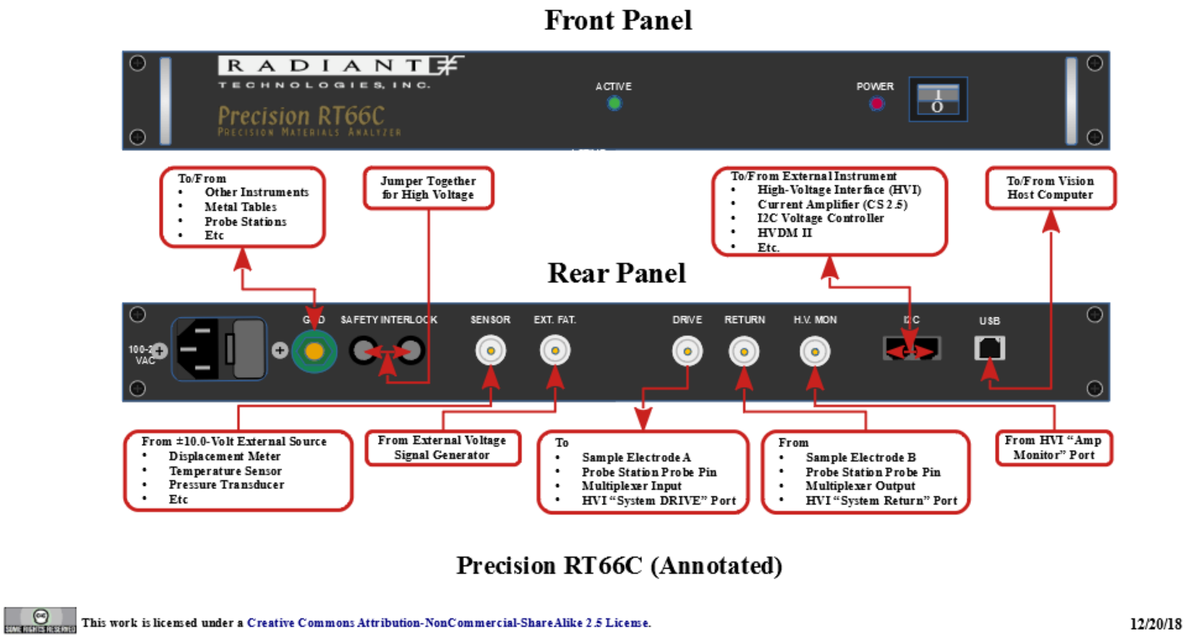


Figure 2 - Precision RT66C Port Definitions.

Port Name	Connector Type	Discussion
GND	Banana	This is a direct connection, through the tester chassis, to earth ground. This port should be connected to the ground connections of all other equipment in the experiment. This port should be connected to any metal components in the experiment such as tables, probe stations, equipment racks, ets.
SAFETY INTER-LOCK	Jumper	These two pins must be connected together with the jumper that was shipped with the tester to enable high-voltage measurements.
SENSOR	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezoelectric displacement. Capture of this port is enabled in software.
EXT. FAT.	BNC	This port can be connected, in software, directly to the DRIVE port output to allow the voltage from an external signal generator to be applied to the connected sample.
DRIVE	BNC	This port outputs a software-specified voltage, in the ±200.0-Volt range, that is used to stimulate one electrode of the sample under test.
RETURN	BNC	This port captures the charge (µC) response at one

		electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode.
H.V. MON	BNC	For high-voltage measurements above ±200.0 Volts, using accessory High-Voltage Interface (HVI) and High-Voltage Amplifier (HVA) insturments, this port captures a low-voltage model of the high-voltage signal that is being applied to the sample. This signal is generated by the HVA and passed through the HVI to the H.V. MON port.
I2C	I2C (Telephone)	This connector offers logical signals passed between the RT66C and any of various accessory instruments such as a High-Voltage Interface (HVI), a CS 2.5 Current Source (for magneto-electric measurements and general purpose applications) and/or an I2C Voltage Controller. All of these are manufactured and offered by Radiant Technologies, Inc.
USB	Printer-Type USB	This port provides the logical connection between the Precision RT66C and the Vision program host computer.

Table 2 - Precision RT66C Port Definitions.

Precision LC II

The Precision LC II is a full-featured Precision tester at a lower cost than the Precision Premier II, Precision Multiferroic II or Precision pMEMS testers. The Precision LCII is an ideal general purpose tester with a broad test range for thin films and bulk ceramics. The Precision LC II tester has a frequency rating of 5 kHz at +/-200V built-in to the system. The Precision LC II Test System makes testing of thin films and bulk ceramics a fast and simple process.

The Precision LCII executes Hysteresis, Pulse, Leakage, I/V and C/V measurements without changing sample connections. With the addition of extra fixtures, the Precision LCII can measure pyroelectric, magneto-electric, transistor, cryogenic and bulk and/or thin film piezoelectric properties.

The Precision LCII II is offered with a variety of internal amplifiers. Models that operate at ±10V, 30V, 100V, 200V, and 500V are available. The Precision LCII operating voltage can be expanded to 10 kV with the addition of a high voltage interface and amplifier.

Precision LC II Appearance

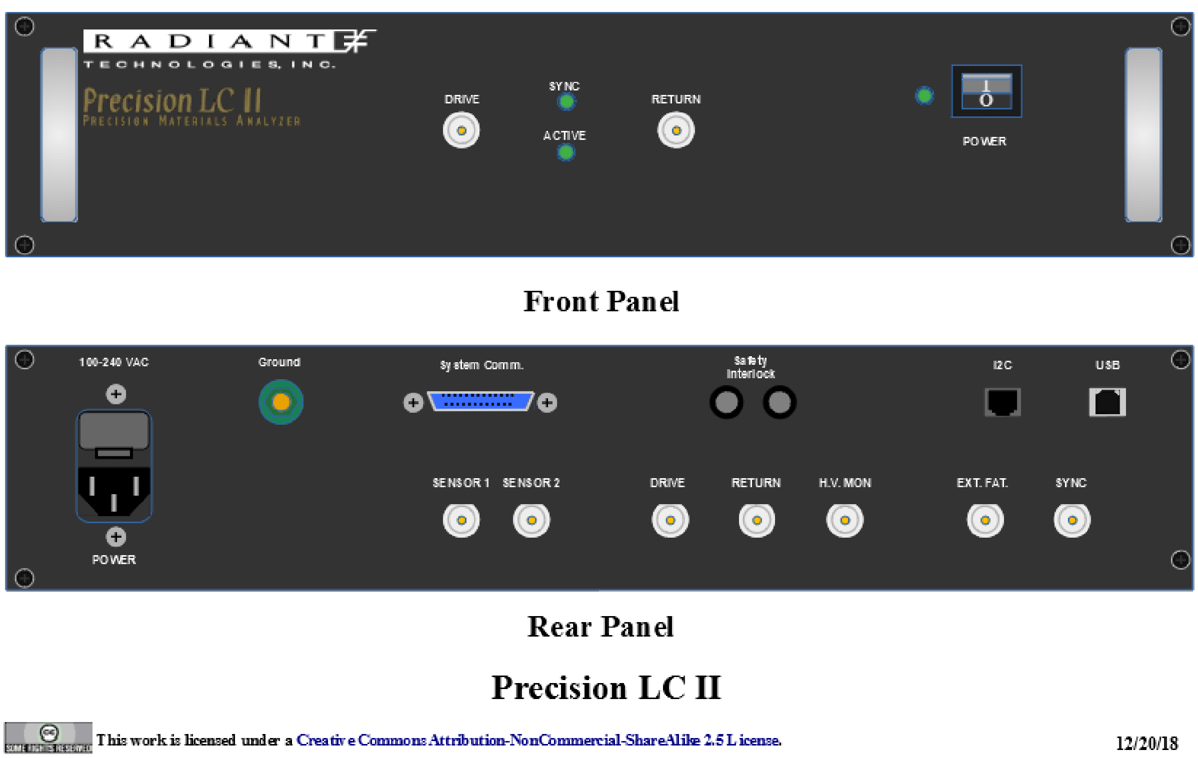


Figure 1 - Precision LC II Front and Rear Panels.

Precision LC II Specifications

Parameter	Value
AC Power	100 to 240 VAC 50-60 Hz
Fuse	1.25 Amp/250 VAC SB
Operating Temperature	0° to 40° C
Operating Humidity	85% Noncondens-ing
Elevation	0 to 3000 m
Voltage Range (built-in drive voltage)	±10 V, ±30 V, ±100 V, ±200V or ±500 V
Voltage Range with an external amplifier and High-Voltage interface (HVI)	10 kV
Number of ADC Bits	18
Minimum Charge Resolution	<10.0 fC
Minimum Area Resolution (assuming 1 ADC bit = 1μC/cm2)	1.0 μ^2
Maximum Charge Resolution	276.0 μC
Maximum Area Resolution (assuming saturation polarization = 100μC/cm^2)	2.76 cm^2
Maximum Charge Resolution with High-Voltage Interface (HVI)	27.6 mC
Maximum Area Resolution (assuming saturation polarization = 100μC/cm^2) w/o HVI	>100cm^2
Maximum Hysteresis Frequency	5 kHz @ 10 V 5 kHz @ 30 V 5 kHz @ 100 V 5 kHz @ 200 V 2 kHz @ 500 V
Minimum Hysteresis Frequency	0.03 Hz
Minimum Pulse Width	50 μs
Minimum Pulse Rise Time (5 V)	40 μs
Maximum Pulse Width	1 s
Maximum Delay between Pulses	40 ks
Internal Clock	25 ns
Minimum Leakage Current (assuming max current integration period = 1 seconds)	1 pA
Maximum Small Signal Cap Frequency	20 kHz
Minimum Small Signal Cap Frequency	1 Hz
Output Rise Time Control	103 Scaling
Input Capacitance	-6 fF
Electrometer Input All Test Frequencies for all test at any speed	Yes

* The minimum area resolution under actual test conditions depends upon the internal noise environment of the tester, the external noise environment, and the test jig parasitic capacitance.

*** Tester specifications are subject to change without notice.

Table 1 - Precision LC II Specifications.

Precision LC II Port Definitions

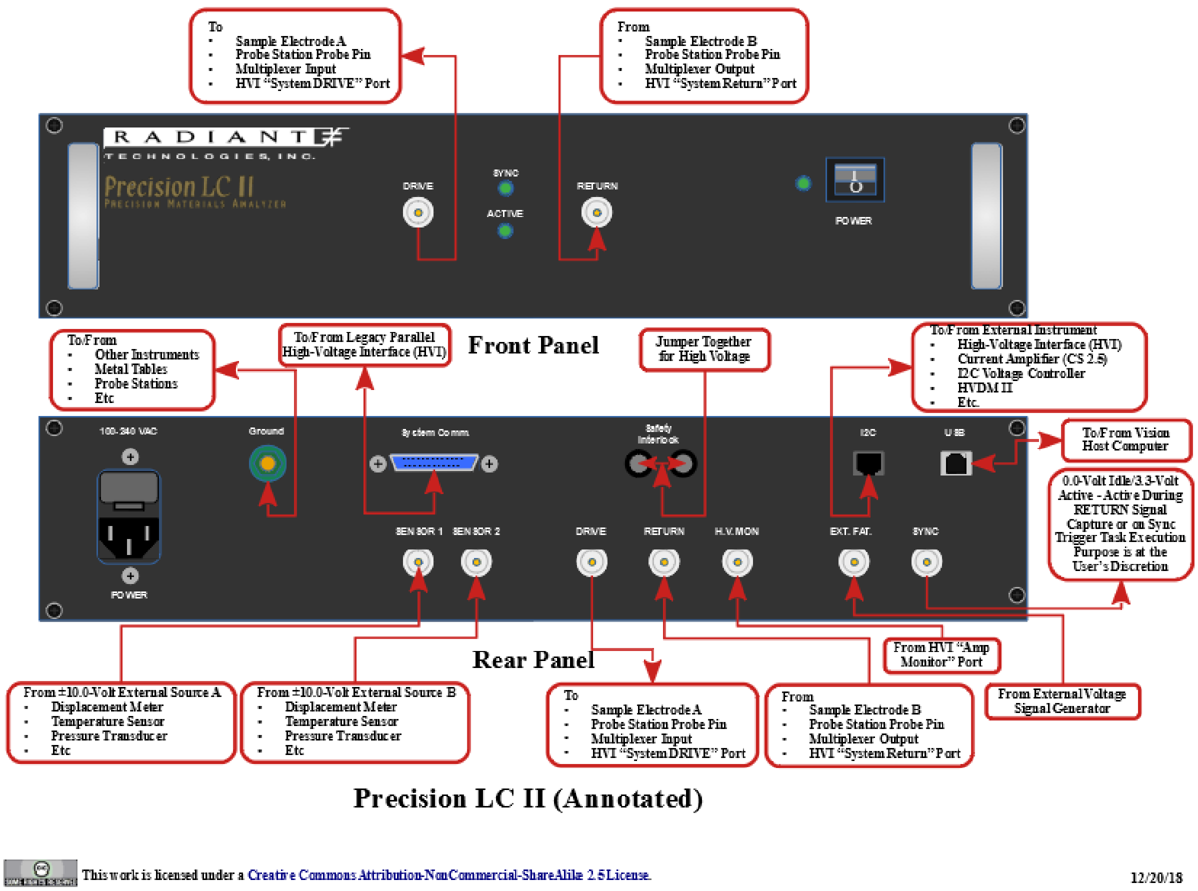


Figure 2 - Precision LC II Port Definitions.

Port Name	Connector Type	Discussion
Front Panel		
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the rear-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (µC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
Rear Panel		
Ground	Banana	This is a direct connection, through the tester chassis, to earth ground. This port should be connected to the ground connections of all other equipment in the experiment. This port should be connected to any metal components in the experiment such as tables, probe stations, equipment racks, etc.
System Comm.	25-pin D-Type	This port is included specifically to allow logical communications between the tester (and Vision program) and the very old two-channel parallel High-Voltage

	Parallel	Interface (HVI).
SAFETY INTERLOCK	Jumper	These two pins must be connected together with the jumper that was shipped with the tester to enable high-voltage measurements.
SENSOR 1	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezo-electric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 2. Including two ports allows more flexibility in capturing data from multiple instruments.
SENSOR 2	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezo-electric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 1. Including two ports allows more flexibility in capturing data from multiple instruments.
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the front-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (µC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
H.V. MON	BNC	For high-voltage measurements above ±200.0 Volts, using accessory High-Voltage Interface (HVI) and High-Voltage Amplifier (HVA) insturments, this port captures a low-voltage model of the high-voltage signal that is being applied to the sample. This signal is generated by the HVA and passed through the HVI to the H.V. MON port.
EXT. FAT.	BNC	This port can be connected, in software, directly to the DRIVE port output to allow the voltage from an external signal generator to be applied to the connected sample.
SYNC	BNC	This port is normally held at 0.0 Volts. It rises to 3.3 Volts to indicate that the sample charge (µC) is being captured and integrated at the tester RETURN port. The port may also be used as an external trigger by configuring and execution the Vision SYNC Trigger Task.
I2C	I2C (Telephone)	This connector offers logical signals passed between the LC II and any of various accessory instruments such as a High-Voltage Interface (HVI), a CS 2.5 Current Source (for magneto-electric measurements and general purpose applications) and/or an I2C Voltage Controller. All of these are manufactured and offered by Radiant Technologies, Inc.
USB	Printer-Type USB	This port provides the logical connection between the Precision LC II and the Vision program host computer.

Table 2 - Precision LC II Port Definitions.

Precision Premier II

The Precision Premier II is an advanced tester that has a large test envelope in terms of frequency response, voltage range and accuracy. The Premier II has a fast Hysteresis frequency rating of 250 kHz at +/-10 V built-in to the system. The Premier II tester makes testing of thin films and bulk ceramics a fast and simple process.

The Premier II executes Hysteresis, Pulse, Leakage, I/V and C/V measurements without changing sample connections. With the addition of extra fixtures, the Premier II can measure pyroelectric, magneto-electric, transistor, cryogenic and bulk ceramics and/or thin film piezoelectric properties.

The Precision Premier II is offered in a ±10.0 V, 30.0 V, 100.0 V, 20.0 0V and 500.0 V built-in drive volt option. The Premier II can be expanded to 10 kV with the addition of a high voltage interface and amplifier.

Precision Premier II Appearance

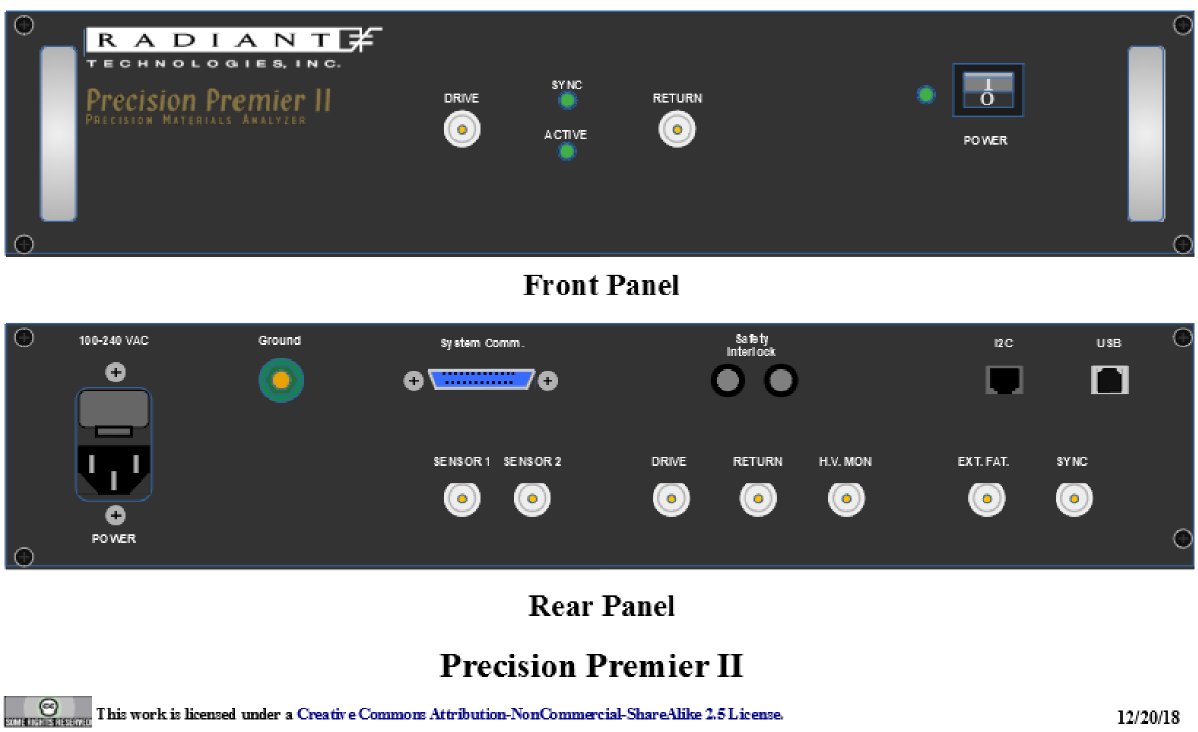


Figure 1 - Precision Premier II Front and Rear Panels.

Precision Premier II Specifications

Parameter	Value

AC Power	100 to 240 VAC 50-60 Hz
Fuse	1.25 Amp/250 VAC SB
Operating Temperature	0° to 40° C
Operating Humidity	85% Noncondensing
Elevation	0 to 3000 m
Voltage Range (built-in drive voltage)	±10 V, ±30 V, ±100 V, ±200V or ±500 V
Voltage Range with an external amplifier and High-Voltage interface (HVI)	10 kV
Number of ADC Bits	18
Minimum Charge Resolution	0.8 fC
Minimum Area Resolution (assuming 1 ADC bit = 1µC/cm2)	0.08 μ^2
Maximum Charge Resolution	5.26 mC
Maximum Area Resolution (assuming saturation polarization = 100 µC/cm^2)	52.6 cm^2
Maximum Charge Resolution with High-Voltage Interface (HVI)	526 mC
Maximum Area Resolution (assuming saturation polarization = 100 µC/cm^2) w/o HVI	>100 cm^2
Maximum Hysteresis Frequency	50 kHz @ 10 V 50 kHz @ 30 V 50 kHz @ 100 V 50 kHz @ 200 V 2 kHz @ 500 V
Minimum Hysteresis Frequency	0.03 Hz
Minimum Pulse Width	0.5 µs
Minimum Pulse Rise Time (5 V)	400 ns
Maximum Pulse Width	1 s
Maximum Delay between Pulses	40 ks
Internal Clock	25 ns
Minimum Leakage Current (assuming max current integration period = 1 seconds)	1 pA
Maximum Small Signal Cap Frequency	1 MHz
Minimum Small Signal Cap Frequency	1 Hz
Output Rise Time Control	105 Scaling
Input Capacitance	-6 fF
Electrometer Input All Test Frequencies for all test at any speed	Yes

* The minimum area resolution under actual test conditions depends upon the internal noise environment of the tester, the external noise environment, and the test jig parasitic capacitance.
*** Tester specifications are subject to change without notice.

Table 1 - Precision Premier II Specifications.

Precision Premier II Port Definitions

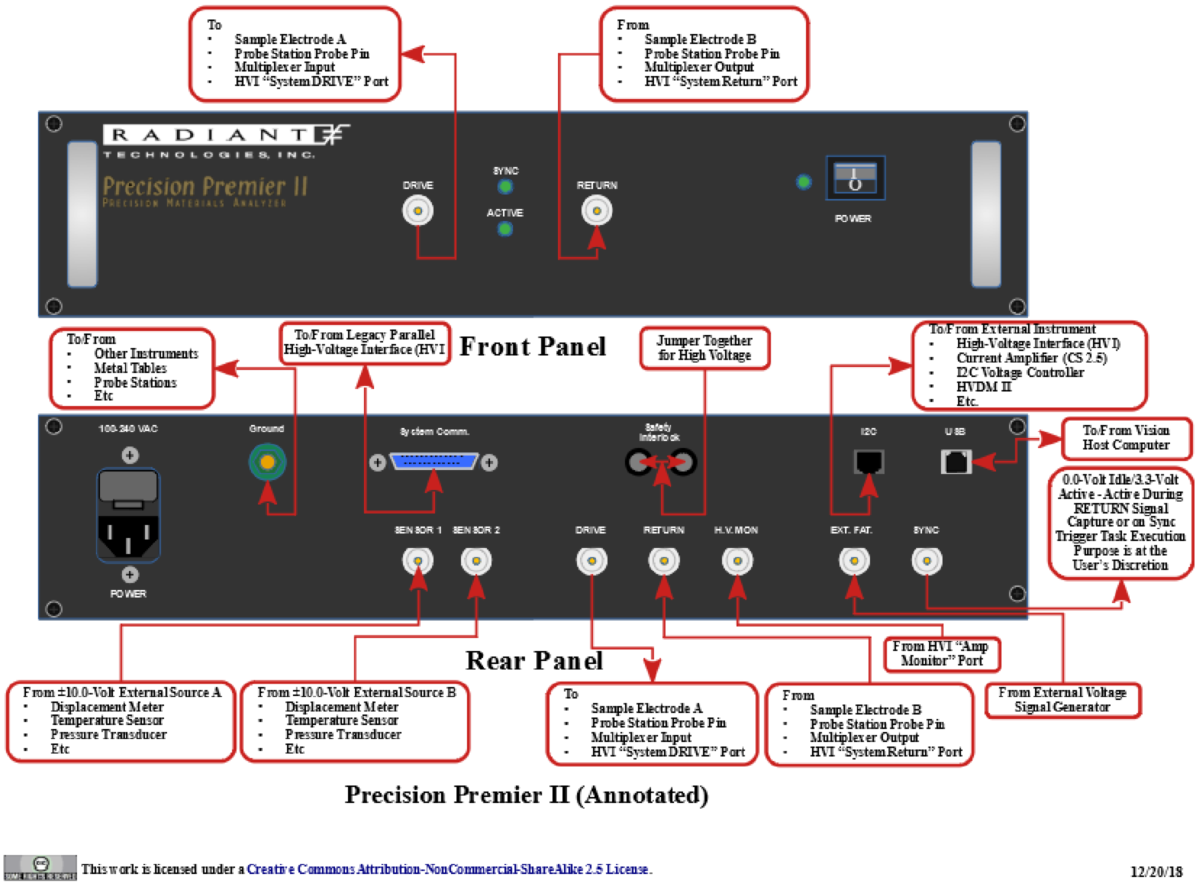


Figure 2 - Precision Premier II Port Definitions.

Port Name	Connector Type	Discussion
Front Panel		
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the rear-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (µC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
Rear Panel		
Ground	Banana	This is a direct connection, through the tester chassis, to earth ground. This port should be connected to the ground connections of all other equipment in the experiment. This port should be connected to any metal components in the experiment such as tables, probe stations, equipment racks, etc.
System Comm.	25-pin D-Type Parallel	This port is included specifically to allow logical communications between the tester (and Vision program) and the very old two-channel parallel High-Voltage Interface (HVI).

SAFETY INTERLOCK	Jumper	These two pins must be connected together with the jumper that was shipped with the tester to enable high-voltage measurements.
SENSOR 1	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezo-electric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 2. Including two ports allows more flexibility in capturing data from multiple instruments.
SENSOR 2	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezo-electric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 1. Including two ports allows more flexibility in capturing data from multiple instruments.
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the front-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (µC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
H.V. MON	BNC	For high-voltage measurements above ±200.0 Volts, using accessory High-Voltage Interface (HVI) and High-Voltage Amplifier (HVA) insturments, this port captures a low-voltage model of the high-voltage signal that is being applied to the sample. This signal is generated by the HVA and passed through the HVI to the H.V. MON port.
EXT. FAT.	BNC	This port can be connected, in software, directly to the DRIVE port output to allow the voltage from an external signal generator to be applied to the connected sample.
SYNC	BNC	This port is normally held at 0.0 Volts. It rises to 3.3 Volts to indicate that the sample charge (µC) is being captured and integrated at the tester RETURN port. The port may also be used as an external trigger by configuring and execution the Vision SYNC Trigger Task.
I2C	I2C (Telephone)	This connector offers logical signals passed between the LC II and any of various accessory instruments such as a High-Voltage Interface (HVI), a CS 2.5 Current Source (for magneto-electric measurements and general purpose applications) and/or an I2C Voltage Controller. All of these are manufactured and offered by Radiant Technologies, Inc.
USB	Printer-Type USB	This port provides the logical connection between the Precision LC II and the Vision program host computer.

Table 2 - Precision Premier II Port Definitions.

Precision Multiferroic II

The Precision Multiferroic II Ferroelectric tester is the most advanced test system on the market. The Multiferroic II has a unique frequency rating of 270 kHz at +/-100 V built-in to the system. The Multiferroic II tester makes testing of thin films and bulk ceramics a fast and simple process.

The Multiferroic II executes Hysteresis, Pulse, Leakage, I/V and C/V measurements without changing sample connections. With the addition of extra fixtures, the Multiferroic II can measure pyroelectric, magnetoelectric, transistor, cryogenic and bulk and/or thin film piezoelectric properties.

The Precision Multiferroic II is offered with a variety of internal amplifiers. The Multiferroic II is offered with a ±100.0 V, 200.0 V and 500.0 V built-in drive volt option. The Multiferroic II can be expanded to 10 kV with the addition of a high voltage interface and an amplifier.

Precision Multiferroic II Appearance

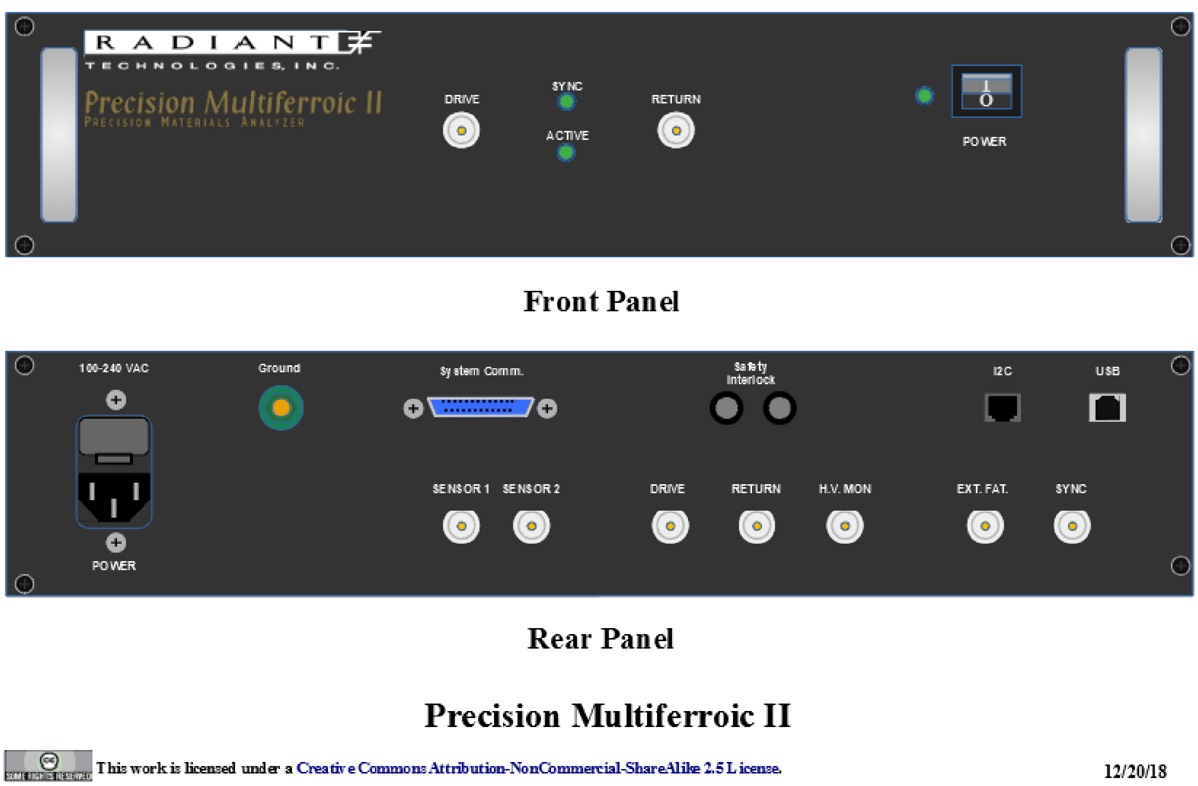


Figure 1 - Precision Multiferroic II Front and Rear Panels.

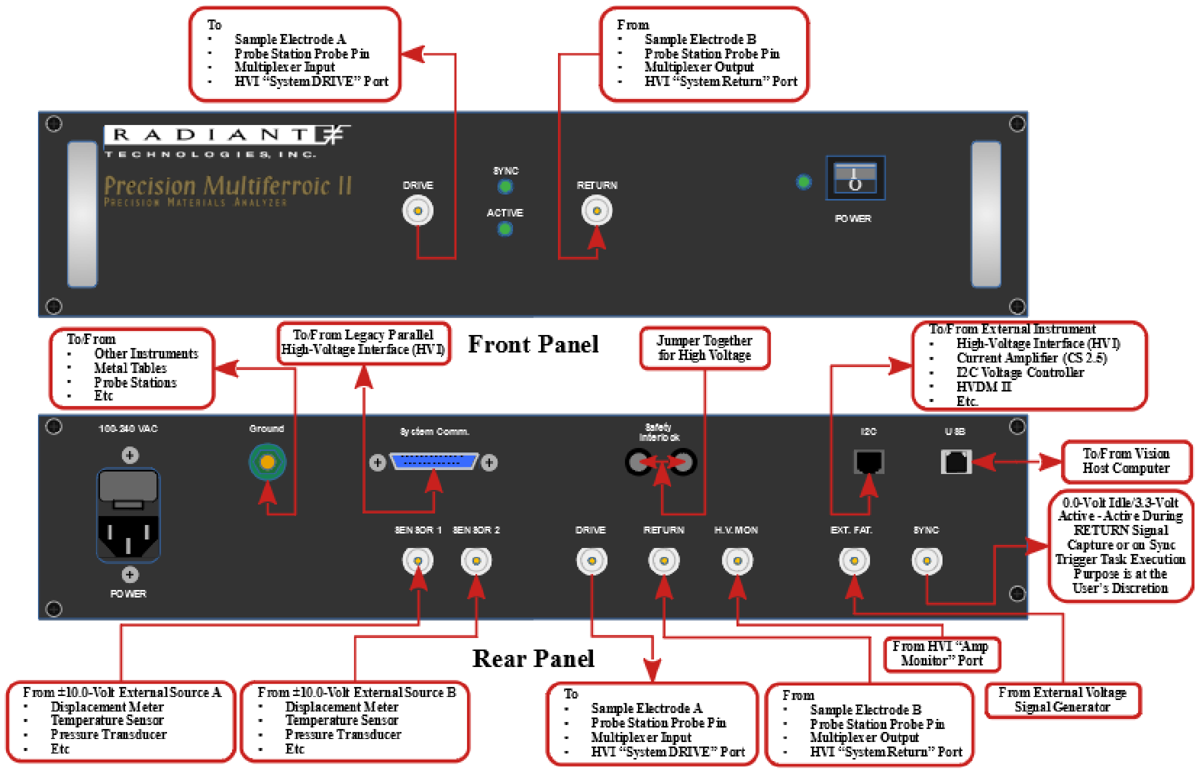
Precision Multiferroic II Specifications

Parameter	Value
AC Power	100 to 240 VAC 50-60 Hz
Fuse	1.25 Amp/250 VAC SB
Operating Temperature	0° to 40° C
Operating Humidity	85% Noncondensing
Elevation	0 to 3000 m
Voltage Range (built-in drive voltage)	±10 V, ±30 V, ±100 V, ±200V or ±500 V
Voltage Range with an external amplifier and High-Voltage interface (HVI)	10 kV
Number of ADC Bits	18
Minimum Charge Resolution	0.8 fC
Minimum Area Resolution (assuming 1 ADC bit = 1μC/cm2)	0.08 μ^2
Maximum Charge Resolution	5.26 mC
Maximum Area Resolution (assuming saturation polarization = 100 μC/cm^2)	52.6 cm^2
Maximum Charge Resolution with High-Voltage Interface (HVI)	526 mC
Maximum Area Resolution (assuming saturation polarization = 100 μC/cm^2) w/o HVI	>100 cm^2
Maximum Hysteresis Frequency	270 kHz @ 10 V 270 kHz @ 30 V 270 kHz @ 100 V 100 kHz @ 200 V 5 kHz @ 500 V
Minimum Hysteresis Frequency	0.03 Hz
Minimum Pulse Width	0.5 μs
Minimum Pulse Rise Time (5 V)	400 ns
Maximum Pulse Width	1 s
Maximum Delay between Pulses	40 ks
Internal Clock	25 ns
Minimum Leakage Current (assuming max current integration period = 1 seconds)	1 pA
Maximum Small Signal Cap Frequency	1 MHz
Minimum Small Signal Cap Frequency	1 Hz
Output Rise Time Control	105 Scaling
Input Capacitance	-6 fF
Electrometer Input All Test Frequencies for all test at any speed	Yes

* The minimum area resolution under actual test conditions depends upon the internal noise environment of the tester, the external noise environment, and the test jig parasitic capacitance.
*** Tester specifications are subject to change without notice.

Table 1 - Precision Premier II Specifications.

Precision Premier II Port Definitions



Precision Multiferroic II (Annotated)

 12/20/18

Figure 2 - Precision Multiferroic II Port Definitions.

Port Name	Connector Type	Discussion
Front Panel		
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the rear-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (µC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
Rear Panel		
Ground	Banana	This is a direct connection, through the tester chassis, to earth ground. This port should be connected to the ground connections of all other equipment in the experiment. This port should be connected to any metal components in the experiment such as tables, probe stations, equipment racks, etc.
System Comm.	25-pin D-Type Parallel	This port is included specifically to allow logical communications between the tester (and Vision program) and the very old two-channel parallel High-Voltage Interface (HVI).
SAFETY INTERLOCK	Jumper	These two pins must be connected together with the jumper that was shipped with the tester to enable high-voltage measurements.

SENSOR 1	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezo-electric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 2. Including two ports allows more flexibility in capturing data from multiple instruments.
SENSOR 2	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezo-electric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 1. Including two ports allows more flexibility in capturing data from multiple instruments.
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the front-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (μC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
H.V. MON	BNC	For high-voltage measurements above ±200.0 Volts, using accessory High-Voltage Interface (HVI) and High-Voltage Amplifier (HVA) insturments, this port captures a low-voltage model of the high-voltage signal that is being applied to the sample. This signal is generated by the HVA and passed through the HVI to the H.V. MON port.
EXT. FAT.	BNC	This port can be connected, in software, directly to the DRIVE port output to allow the voltage from an external signal generator to be applied to the connected sample.
SYNC	BNC	This port is normally held at 0.0 Volts. It rises to 3.3 Volts to indicate that the sample charge (μC) is being captured and integrated at the tester RETURN port. The port may also be used as an external trigger by configuring and execution the Vision SYNC Trigger Task.
I2C	I2C (Telephone)	This connector offers logical signals passed between the LC II and any of various accessory instruments such as a High-Voltage Interface (HVI), a CS 2.5 Current Source (for magneto-electric measurements and general purpose applications) and/or an I2C Voltage Controller. All of these are manufactured and offered by Radiant Technologies, Inc.
USB	Printer-Type USB	This port provides the logical connection between the Precision LC II and the Vision program host computer.

Table 2 - Precision Multiferroic II Port Definitions.

PiezoMEMS (pMEMS)

Introduction

Thin-piezoelectric-film technology is leaving the laboratory to become commercial. The PiezoMEMS Analyzer is offered as a research tool in the development of this technology. Much thicker bulk capacitors are being embedded as actuators and sensors inside their own electronic circuitry. Multi-disciplinary teams of mechanical, electrical, and reliability engineers now work alongside materials engineers to create new and novel devices. Classic engineering tools such as impulse response, impedance analysis, and resonance characterization must be integrated with traditional polarization, piezoelectric, pyroelectric, and magneto-electric measurements. To control circuits containing embedded ferroic capacitors, asynchronous or semi-synchronous digital and analog functions must run independent-of or in-parallel-with crystal-clock-controlled ferroic measurements. Communication with embedded controllers and custom digital circuitry is critical. Together these requirements demand an extremely complex test environment.

Radiant Technologies' Precision PiezoMEMS Analyzer integrates digital, analog, and communications circuit functions with the existing non-linear materials measurement capabilities of the Precision Multiferroic Non-linear Materials Tester, all supervised by Radiant's Vision programmable test environment. The PiezoMEMS Analyzer not only measures piezoelectric properties of actuator and sensor elements of a commercial product, it will communicate with the product's electronic logic, talk to embedded microprocessors, supply asynchronous voltages and pulses, and measure sensor frequencies.

Capabilities

The PiezoMEMS Analyzer combines the following capabilities:

- A fully functional, high speed, non-linear ferroic properties tester ranging up to +/-200 V capable of Hysteresis, PUND, Leakage, CV, piezoelectric displacement, thermal, and magnetoelectric measurements. The PiezoMEMS Analyzer is expandable to 10 kV.
- Asynchronous/semi-synchronous ±10 V arbitrary analog pulse generator with programmable delay. In delay mode, the delay is specified by the user and triggered on a sample measurement by the tester's SYNC signal. The trigger may occur only on the first detected SYNC signal or may repeat at each detected SYNC. The pulse is applied at the pMEMS' V1/FREQ channel.
- An asynchronous 16-bit, ±10 V, 10^{12} ohm input-impedance voltage measurement port.
- Two independent ±10 V DC bias generators.
- 2 Hz to 60 MHz frequency counter for measuring oscillator circuits.
- 7- and 8-Bit output and 8-Bit input parallel digital ports for setting, controlling, and reading digital ICs or communicating with microprocessors.
- Arbitrary I^2C custom programmable I/O for communicating with I2C capable microprocessors and logic circuits.
- Built in LCR impedance measurement port.

Precision pMEMS Appearance

Front Panel

Rear Panel

Figure 1 - Precision pMEMS Front and Rear Panels.

Precision pMEMS Specifications

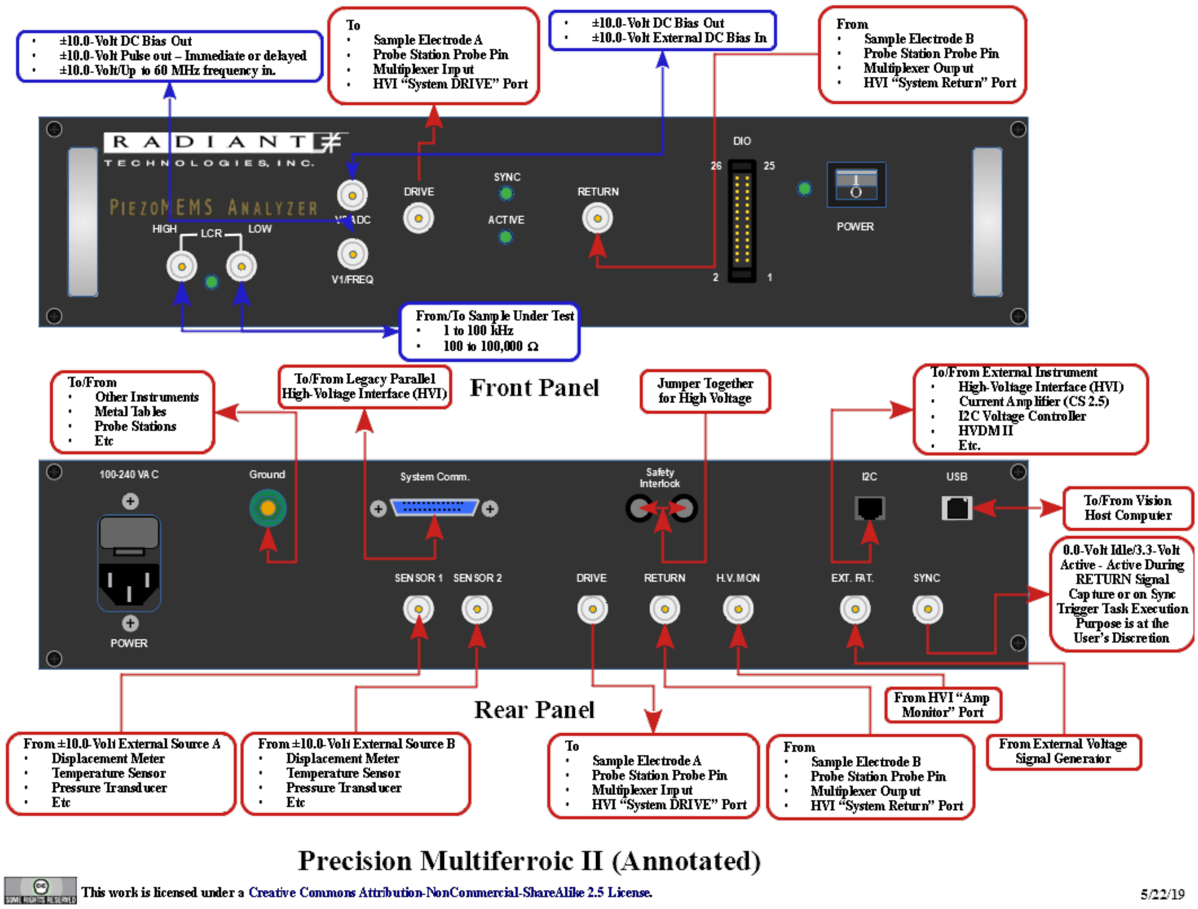
Parameter	Value
AC Power	100 to 240 VAC 50-60 Hz
Fuse	1.25 Amp/250 VAC SB
Operating Temperature	0° to 40° C
Operating Humidity	85% Noncondensing
Elevation	0 to 3000 m
Voltage Range (built-in drive voltage)	
Voltage Range with an external amplifier and High-Voltage interface (HVI)	
Number of ADC Bits	
Minimum Charge Resolution	
Minimum Area Resolution (assuming 1 ADC bit = 1µC/cm2)	
Maximum Charge Resolution	
Maximum Area Resolution (assuming saturation polarization = 100 µC/cm^2)	
Maximum Charge Resolution with High-Voltage Interface (HVI)	
Maximum Area Resolution (assuming saturation polarization = 100 µC/cm^2) w/o HVI	
Maximum Hysteresis Frequency	
Minimum Hysteresis Frequency	

Minimum Pulse Width	
Minimum Pulse Rise Time (5 V)	
Maximum Pulse Width	
Maximum Delay between Pulses	
Internal Clock	
Minimum Leakage Current (assuming max current integration period = 1 seconds)	
Maximum Small Signal Cap Frequency	
Minimum Small Signal Cap Frequency	
Output Rise Time Control	
Input Capacitance	
Electrometer Input All Test Frequencies for all test at any speed	
pMEMS-Only Components	
V1/FREQ: Pulse Mode	• ±10.0-Volt Pulse • User-programmed pulse width • Immediate or delay modes - Delay mode triggers on measurement SYNC signal.
V1/FREQ and V2/ADC: DC Bias Mode	• Two independent ±10.0-Volt DC voltages
V2/ADC: Voltage Capture Mode	• Voltage input of up to ±10.0 Volts • 16-Bit ADC • 10^{12} Ω input impedance.
V1/FREQ: Frequency Counter Mode	• Up to 60 MHz
LCR Impedance/Capacitance Measurement Port	• 1 to 100 kHz □□100 to 100,000 Ω
DIO Port	• 7-Bit output latch. • 8.-Bit output latch • 8-Bit input latch

* The minimum area resolution under actual test conditions depends upon the internal noise environment of the tester, the external noise environment, and the test jig parasitic capacitance.
*** Tester specifications are subject to change without notice.

Table 1 - Precision pMEMS Specifications.

Precision pMEMS Port Definitions



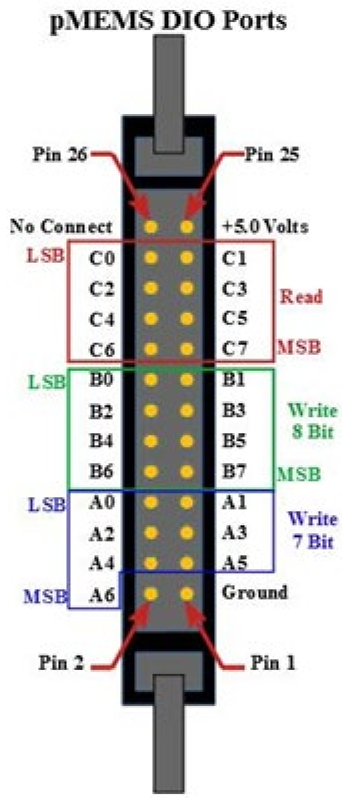


Figure 2 - Precision pMEMS Port Definitions.

Port Name	Connector Type	Discussion
Front Panel		
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the rear-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (µC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
LCR HIGH	BNC	Connect one sample electrode hear for LCR analysis.
LCR LOW	BNC	Connect the opposite sample electrode hear for LCR analysis.
V1/FREQ	BNC	This port can be programmed to output a DC voltage in the ±10.0-Volt range using the pMEMS Voltage Task. The pMEMS Pulse Task can be programmed to provide a pulse voltage in the ±10.0-Volt range of user-programmed duration. The pulse may be immediate or triggered on the pMEMS tester SYNC signal associated with a measurement. For the SYNC-triggered signal a delay may be programmed between the trigger and the pulse. The pulse may be programmed to trigger only on the first instance of the SYNC signal or repeatedly at every instance of the SYNC signal. As an input the frequency of a signal in the ±10.0-Volt range can be captured by

		the pMEMS Frequency Counter Task.
V2/ADC	BNC	This port can be programmed to output a DC voltage in the ±10.0-Volt range using the pMEMS Voltage Task. The pMEMS Read Volts Task will capture an input voltage ±10.0-Volt range. The the pMEMS Voltage Task was used to write a voltage to the port, this Task will read that output voltage.
DIO	26-Pin DIN	This port is used to write a 7-bit or 8-bit digital word or to read an 8-bit digital word using the pMEMS DIO Task. The 7-bit A output port comprises pins 2 through 8, with the most-significant bit (MSB) at pin 2. The B port is also an output port of 8 bits on pins 9 through 16 with pin 9 as the MSB. Digital logic input is read at the C port on pins 17 through 24, with pin 17 as MSB. Pin 1 is tied to tester chassis ground. Pin 25 carries 5.0 Volts. No connection is made to pin 26.
Rear Panel		
Ground	Banana	This is a direct connection, through the tester chassis, to earth ground. This port should be connected to the ground connections of all other equipment in the experiment. This port should be connected to any metal components in the experiment such as tables, probe stations, equipment racks, etc.
System Comm.	25-pin D-Type Parallel	This port is included specifically to allow logical communications between the tester (and Vision program) and the very old two-channel parallel High-Voltage Interface (HVI).
SAFETY INTERLOCK	Jumper	These two pins must be connected together with the jumper that was shipped with the tester to enable high-voltage measurements.
SENSOR 1	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezoelectric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 2. Including two ports allows more flexibility in capturing data from multiple instruments.
SENSOR 2	BNC	This port captures the voltage output, in the ±10.0-Volt range, of any external instrument. The SENSOR voltage is captured simultaneously with data captured at the RETURN port. The purpose is to collect any externally-detected parameter such as temperature, pressure, light intensity or, in particular, sample piezoelectric displacement. Capture of this port is enabled in software. This port is independent of SENSOR 1. Including two ports allows more flexibility in capturing data from multiple instruments.
DRIVE	BNC	This port outputs a software-specified voltage, with voltage limits specified by the purchased internal amplifier, that is used to stimulate one electrode of the sample under test. This connection is identical to the front-panel DRIVE port. Either port may be used based on convenience.
RETURN	BNC	This port captures the charge (µC) response at one electrode of the sample under test as stimulated by the DRIVE output voltage at the opposite electrode .This connection is identical to the rear-panel RETURN port. Either port may be used based on convenience.
H.V. MON	BNC	For high-voltage measurements above ±200.0 Volts, using accessory High-Voltage Interface (HVI) and High-Voltage Amplifier (HVA) insturments, this port captures a low-voltage model of the high-voltage signal that is being applied to the sample. This signal is generated by the HVA and passed through the HVI to the H.V. MON port.
EXT. FAT.	BNC	This port can be connected, in software, directly to the DRIVE port output to allow the voltage from an external signal generator to be applied to the connected

		sample.
SYNC	BNC	This port is normally held at 0.0 Volts. It rises to 3.3 Volts to indicate that the sample charge (μC) is being captured and integrated at the tester RETURN port. The port may also be used as an external trigger by configuring and execution the Vision SYNC Trigger Task.
I2C	I2C (Telephone)	This connector offers logical signals passed between the LC II and any of various accessory instruments such as a High-Voltage Interface (HVI), a CS 2.5 Current Source (for magneto-electric measurements and general purpose applications) and/or an I2C Voltage Controller. All of these are manufactured and offered by Radiant Technologies, Inc.
USB	Printer-Type USB	This port provides the logical connection between the Precision LC II and the Vision program host computer.

Table 2 - Precision pMEMS Port Definitions.

Radiant Technologies Accessories

<TODO>: Insert description text here... And don't forget to add keyword for this topic

High-Voltage Interface (HVI)

The High-Voltage Interface (HVI) is a safety instrument that transfers signals between a High-Voltage Amplifier (HVA) and a Precision tester when making measurements at voltages above the internal capabilities of the tester and up to ±10,000 Volts. The HVI routes the tester's low-voltage model of the intended signal to the HVA where it is amplified and returned, through the HVI HV DRIVE port to one sample electrode. The sample's charge response is collected from the opposite electrode at the HVI HV RETURN port and passed to the Precision tester. The HVI also passes a low-voltage model of the high-voltage signal out of the HVA from the HVA to the tester to be used to represent the actual voltage being applied.

Logic signals are passed between the HVI and the Precision tester through an I^2C interface. The logic signals indicate the presence of the High-Voltage Interface to the tester and Vision software. They also provide the tester with HVA-specific information such as voltage output-to-voltage input ratio (amplifier gain factor), ramp rate (Volts/sec.), high-voltage output-to-low-voltage monitor scale factor, etc. Previous versions of the HVI required a separate HVA ID Module to represent the amplifier logic. Changing to an amplifier with different specifications would require a new ID Module. The current version of the HVI maintains the amplifier characteristics internally in an EEPROM. No ID Module is required. A new amplifier can be selected in software provided its characteristics have been specified to Radiant Technologies, Inc. and it has been incorporated into the C:\RT_USB\AccessorEEProm.txt file.

The primary purpose of the HVI is to detect voltages above 0.0 V at the HV RETURN port. This would represent an event that has caused the HV DRIVE voltage signal to short through and/or around the sample. In this case the voltage output into the amplifier is immediately terminated, protecting both equipment and the equipment operators. All high-voltage signals, along with the (normally) 0.0-Volt HV RETURN signal, are through 40,000-Volt monoaxial cables with rubber shielding sleeves.

High-Voltage Interface (HVI) Appearance

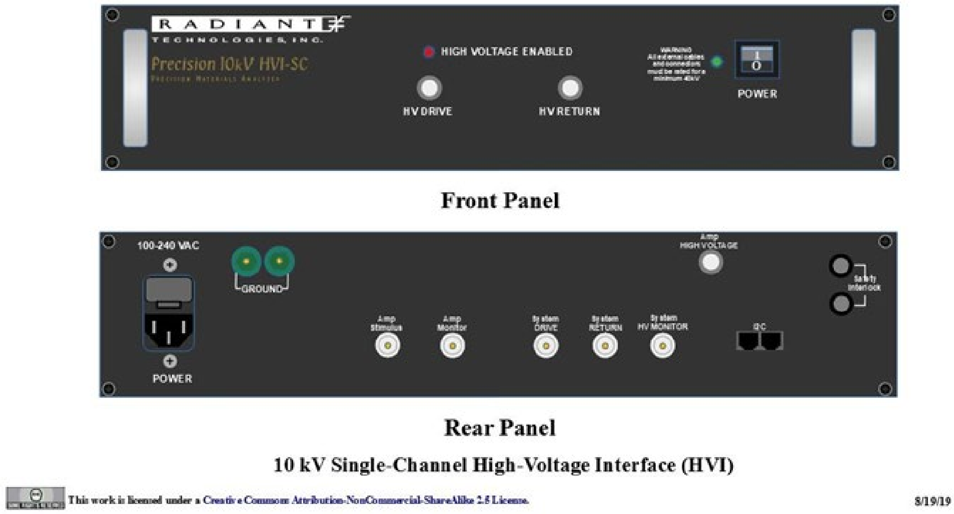


Figure 1 - HVI Front and Rear Panels.

Safety Features of The High Voltage Interface

- Test path fully insulated with 50kV insulation to protect the end user.
- High speed protection during breakdowns (less than a microsecond).
- High voltage amplifier disconnected by HVI on dead shorts.
- Safety Interlock on rear panel of HVI prevents high voltage application if not closed.
- Unique amplifier identification procedure by the host computer prevents unassigned high voltage excursions.

Tester/HVI/HVA Connections

Figure 2 repeats **Figure 1** with annotations indicating the connections to be made. Note that much more detail is provided in this document under Precision Testers and Accessories->Precision Testers->High-Voltage Setup and Operation.

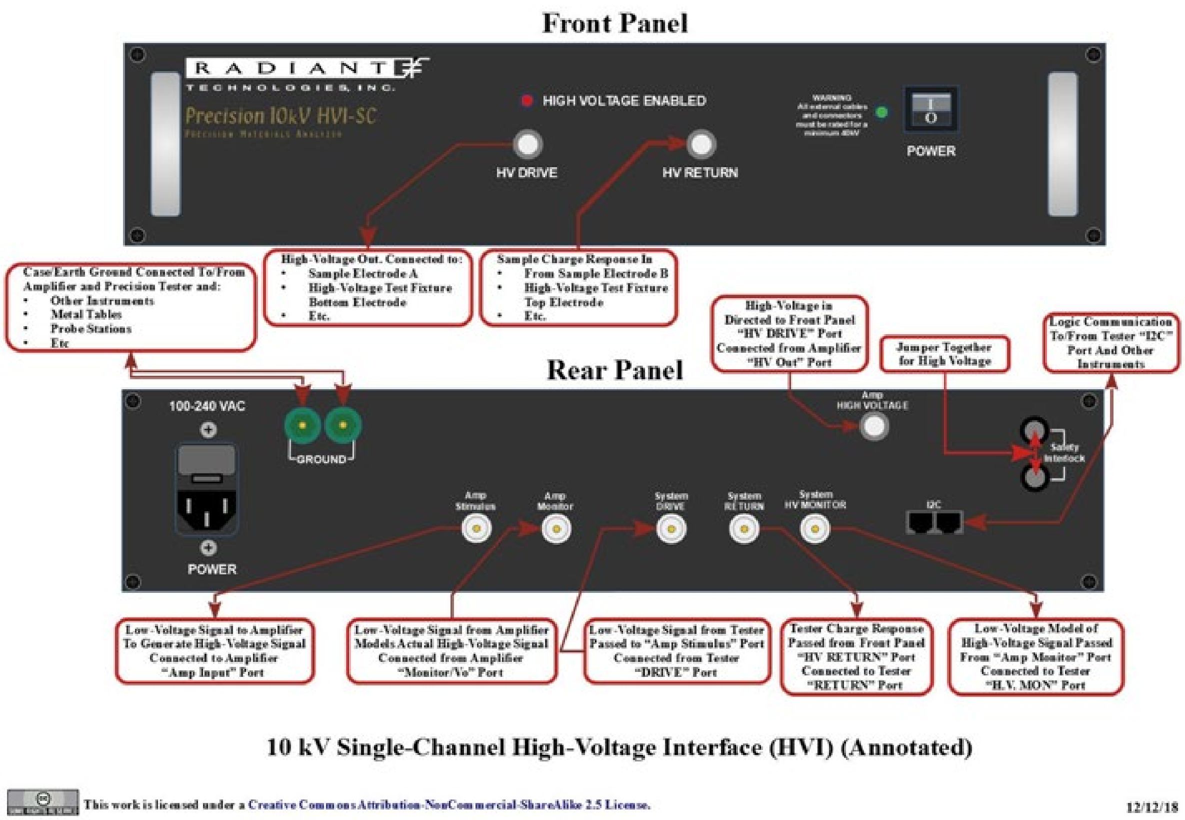


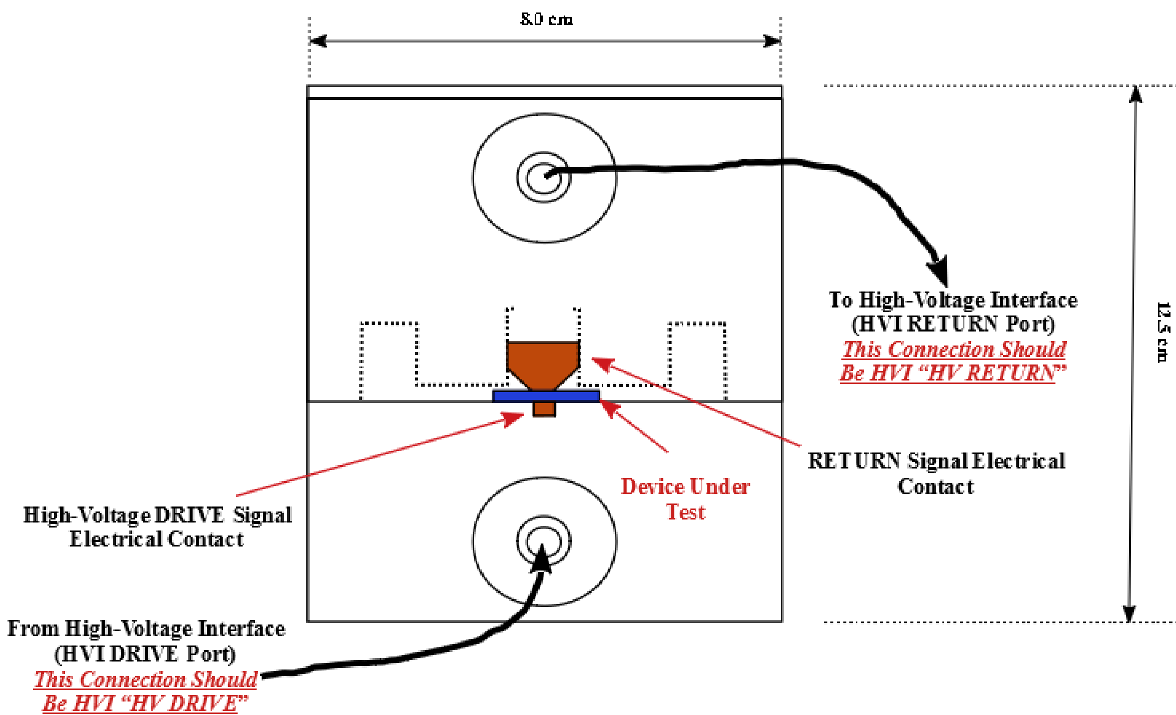
Figure 2 - HVI Front and Rear Panels - Connections Annotated.

High-Voltage Test Fixture (HVTF)

The High-Voltage Test Fixture (HVTF) provides a safe test environment for measure bulk sample response to up to ±10,000 Volts. The sample is placed in the center of the chamber of the open test fixture, with the bottom electrode contacting the bottom (HV DRIVE/High-Voltage) electrode. The sample reservoir may be filled with mineral oil or other fine oil to prevent the voltage from arcing around the sides of the sample. When the top is placed onto the sample, the top electrode, which is free to move vertically to accommodate samples of varying thickness, contacts the sample top (HV RETURN/0.0-Volt) electrode to collect the sample charge. The HVTF bottom connector is normally connected to the High-Voltage Interface (HVI) HV DRIVE port and the top connector is cabled to the HVI HV RETURN port.

The HVTF is made of Teflon providing safe electrical insulation to 10 kV. The Teflon fixture may be heated to a temperature as high as 230° C, if the fixture is placed in an oven.

High-Voltage Test Fixture (HVTF) Appearance



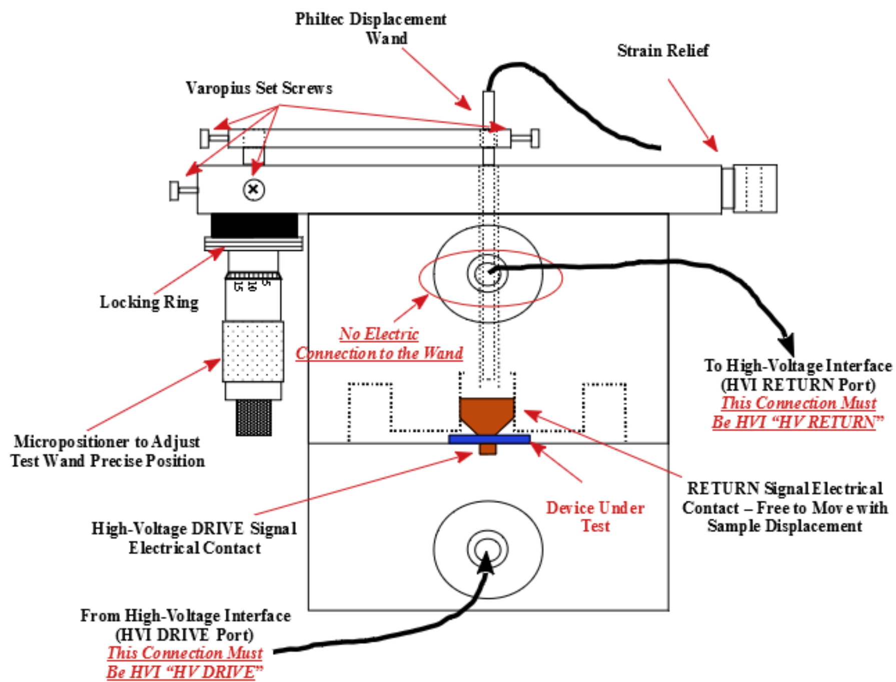
High-Voltage Test Fixture (HVTF)

High-Voltage Displacement Meter (HVDM)

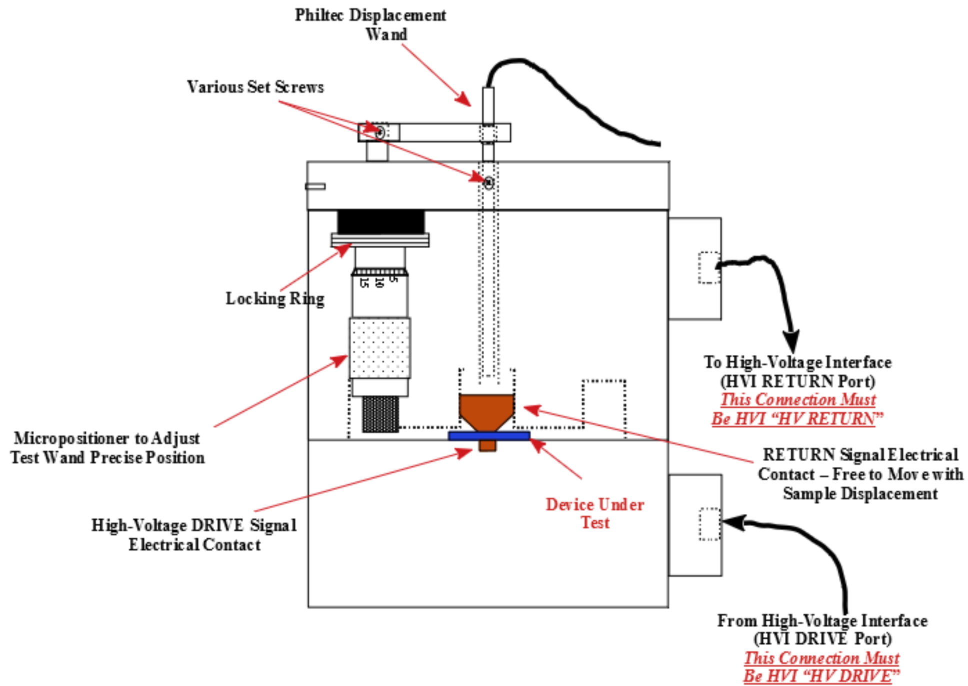
The High-Voltage Displacement Meter (HVDM) is very similar to the [High-Voltage Test Fixture (HVTF)](). The HVDM adds to the HVTF a micropositioner and a stability arm that allows a Philtec-style photonic displacement sensor wand to be precisely positioned above the HVTF top electrode. This wand can then be used to detect piezoelectric sample displacement with the application of voltages of up to ±10,000 Volts. The detected displacement is converted by the displacement sensor that can be collected at the Precision tester SENSOR 1 or SENSOR 2 port simultaneously with the sample charge (μC) response to an HV DRIVE stimulus voltage. [This video]() shows the use of the HVDM in calibrating and configuring an MTI 2000 Fotonic Displacement Detector.

As with the HVTF, the HVDM can be taken to a temperature as high as 230° C, provided an oven large enough to receive the HVDM and sensor wand is available.

High-Voltage Displacement Meter (HVDM) Appearance



High-Voltage Displacement Meter (HVDM)

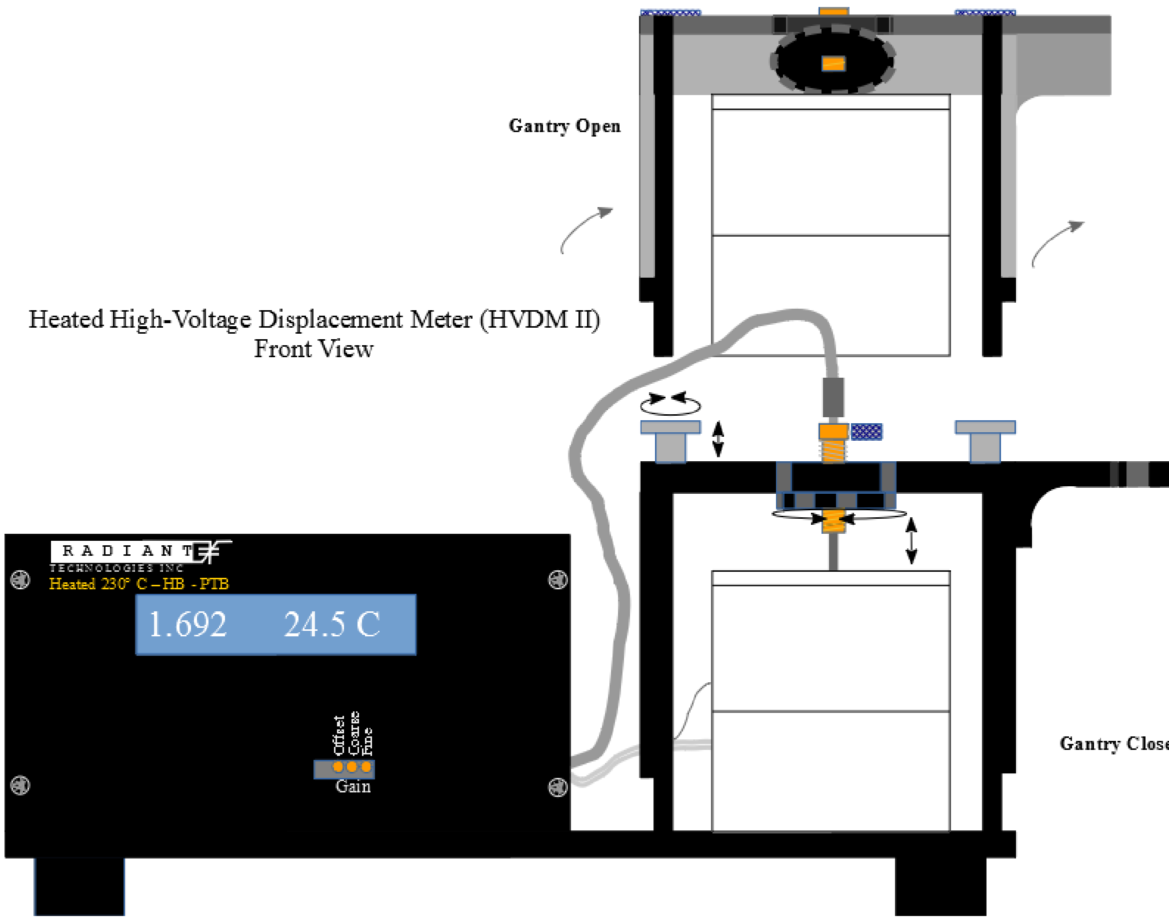


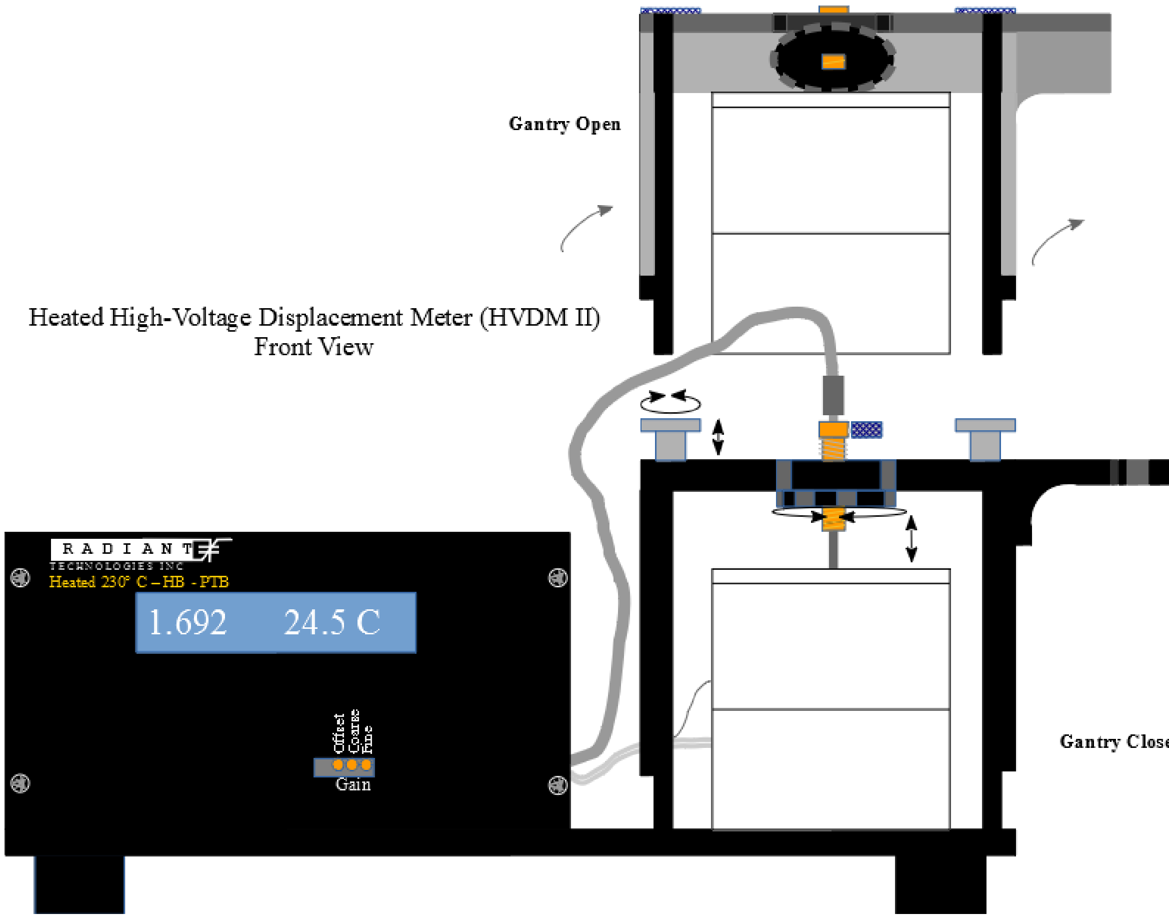
High-Voltage Displacement Meter (HVDM) (Side View)

Heated High-Voltage Displacement Meter (HB-PTB) or (HVDM II)

The Heated High-Voltage Displacement Meter - with designations HB-PTB or HVDM II - extends the capability of the High-Voltage Displacement Meter (HVDM) by adding electronics that combine an Philtec displacement sensor and a heater element that is controlled directly by the Vision program, through a separate USB channel.

Heated High-Voltage Displacement Meter (HB-PTB/HVDM II) Appearance





HB-PTB Operating Specifications

Operating Voltage	90-277 VAC 50/60 Hz
Fuse	4 A 250 VAC SB
Environment Operating Temperature	0° to 40° C
Environment Operating Humidity	85% Noncondensing

Safety

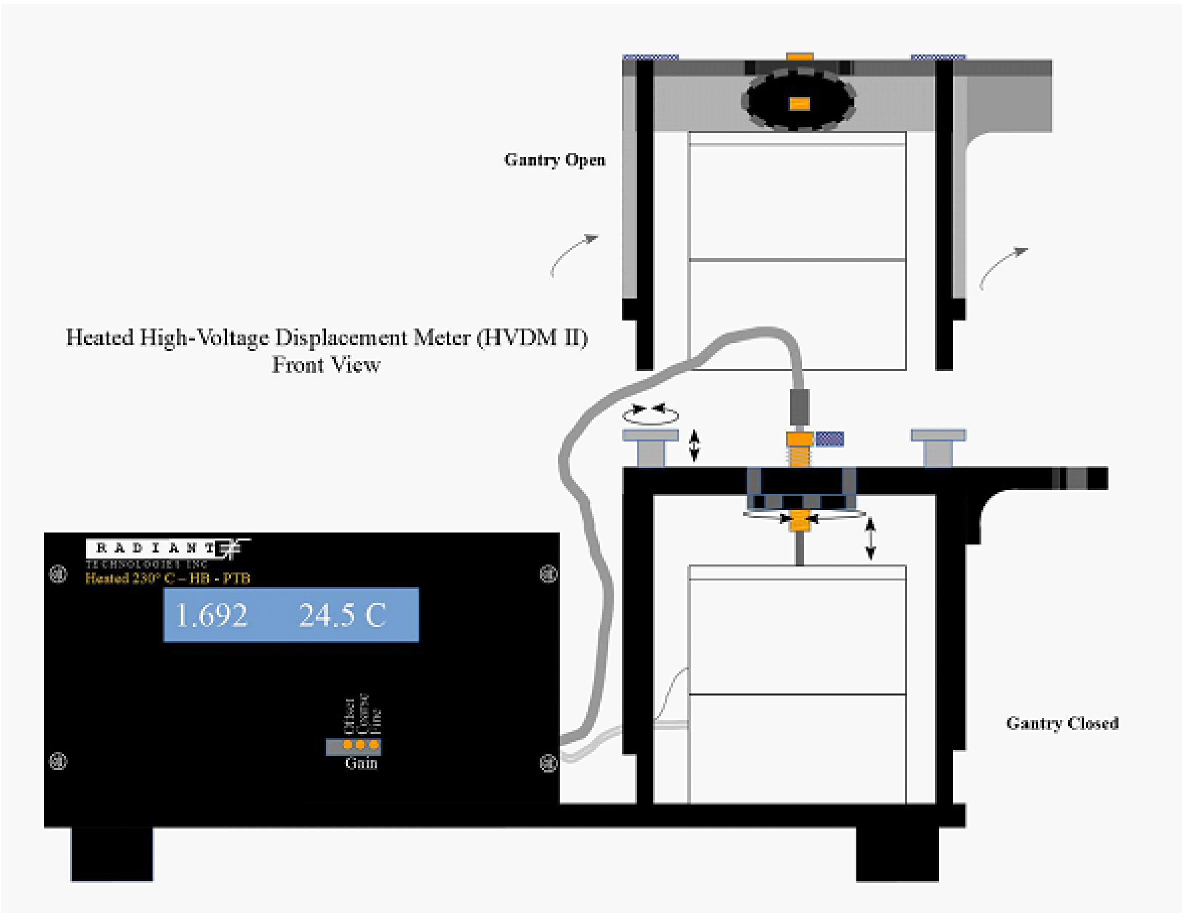
The HB-PTB can reach internal temperatures or 230° C. Do not open the test fixture or attempt to touch your sample or internal parts of the HB-PTB before allowing the instrument to cool completely. The Vision Read Temperature Task can be used to monitor the internal temperature of the instrument.

Recalibration

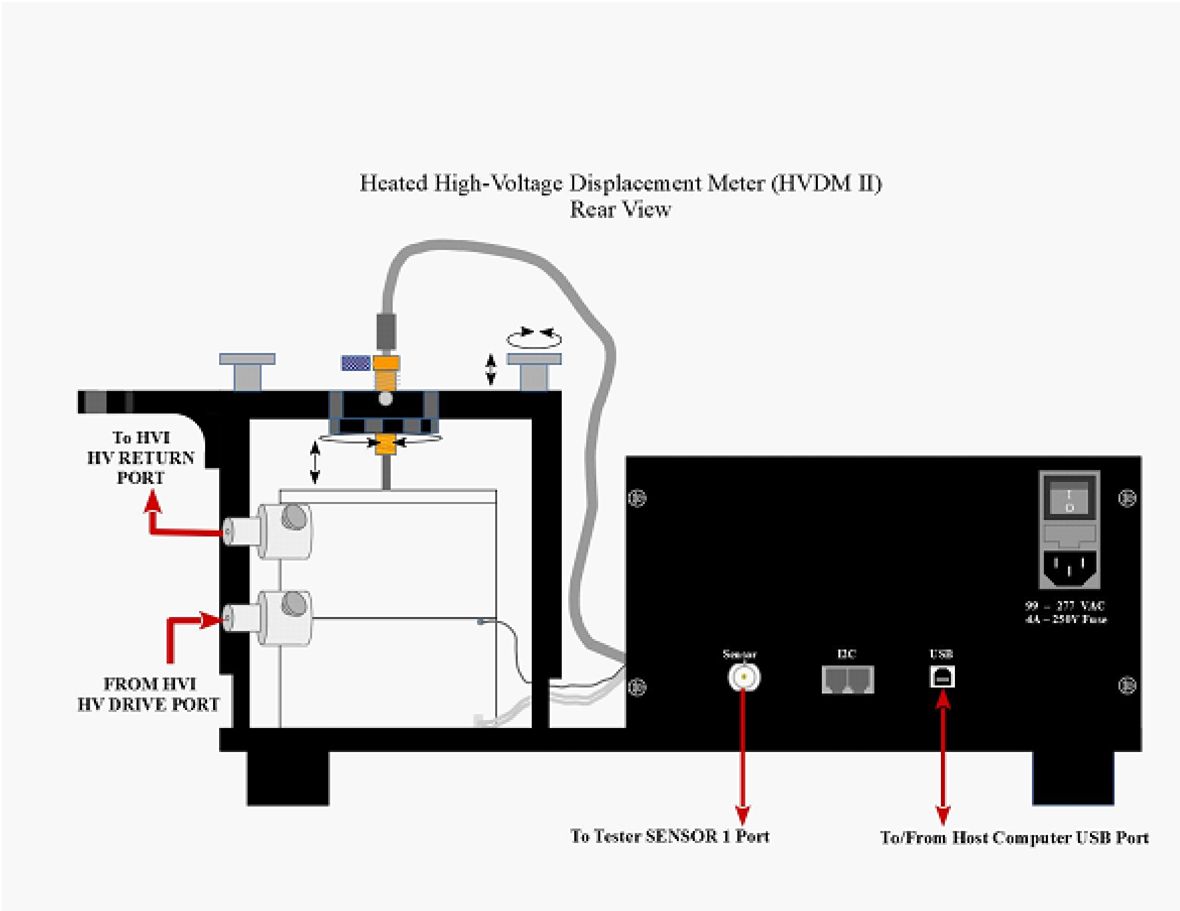
Note that when operating over a range of temperatures, the Philtec displacement sensor will need to be repositioned after every temperature range to return the output to the 5.0-Volt position. This is the result of thermal expansion as the temperature changes. This requires supervision of an experiment that is being conducted over several temperatures. Future improvements to the HVDM are planned that will automatically keep the Philtec sensor positioned for optimal output.

Installation, Configuration, Calibration and Operation

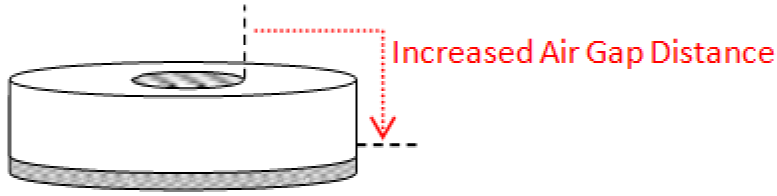
Introduction:
This document is the set of instructions for setting up and operating the Radiant High HB-PTB system. Please contact Radiant Technologies with any questions.



Description:
The HB-PTB system allows testing of high-voltage ceramics formed into a disk capacitor at temperatures of up to 230° C. The HB-PTB Test Fixture (referred to, here, as the HVDM II) connects to a Radiant Non- linear Materials Tester via rubber-coated high-voltage cables rated to 50 kV DC or 10 kV AC. The unit is constructed with Teflon and holds the sample under test during high voltage application. When combined with the insulated high-voltage cables from the tester, the entire high voltage test path is completely enclosed with insulation rated to 10,000 Volts or higher to provide a safe operating environment for the user despite the high voltages.



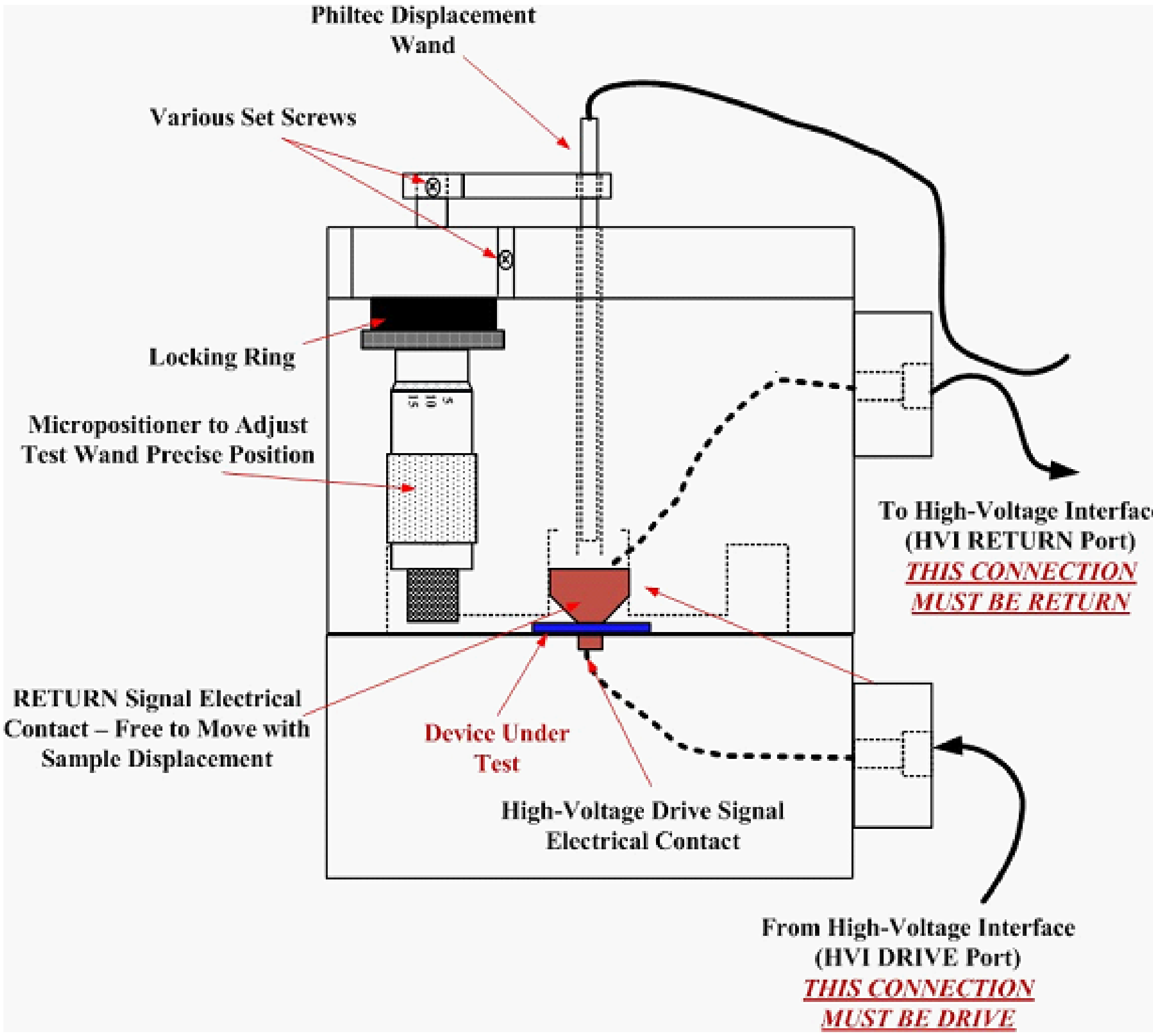
The well of the HVDM II may be filled with an oil to prevent air-gap breakdown around the edge of the sample during high voltage application. It is not necessary to use oil if the geometry of the electrodes of the sample is modified to increase the air-gap to a distance that that can with-stand the voltages targeted in the specified test procedures.



Two cross section views of the fixture at different angles with a sample (blue) are shown below. The bottom electrical contact button is fixed in the well of the HVDM II. The top electrode is free floating to accommodate samples of various heights. Each is wired to a dedicated high voltage connector.

The free floating top electrode allows measurement of the sample by the PhilTec displacement sensor that is incorporated into the HB-PTB. The sensor can be seen in the cross-section of the HVDM II, below, as the vertical wand extending down nearly to the top surface of the top electrode contact. If the sample surface moves, the electrodes surface moves. That movement is viewed and measured by the wand.

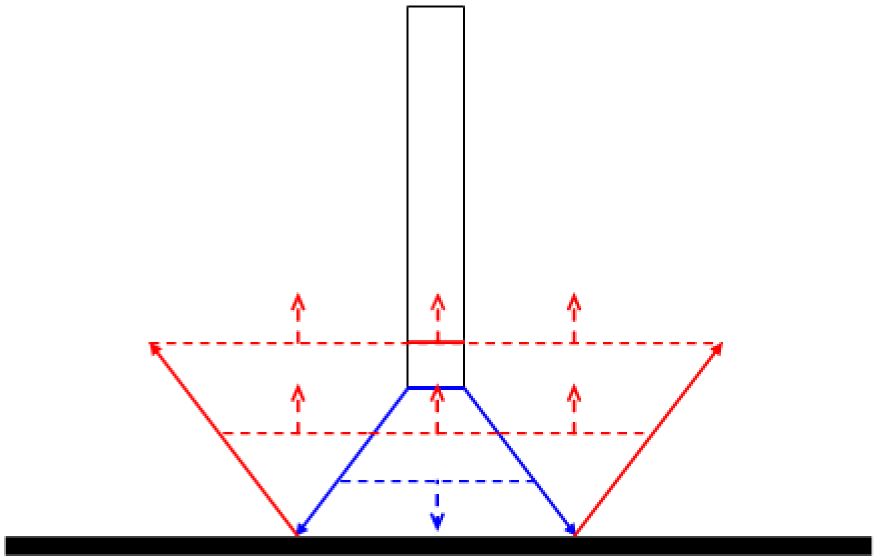
Note that the figures represent the standard HVDM test fixture. They show a stability arm and micrometer that are incorporated into that test fixture. The HB-PTB frame serves the purposes of the stability arm and micrometer.



Of note is the geometry of the displacement measurement. Photonic displacement wands such as those used by PhilTec or MTI measure the distance *between the tip of the wand and the sample surface.* Therefore, when the sample surface moves upwards, it gets closer to the wand *and the wand reports a smaller distance*. Measurements will appear upside down. To correct this inversion, *place a negative sign in front of the scale factor entered into the SENSOR setup menu.*

Theory of Calibration:

The photonic sensor wand emits non-coherent light from a fiber bundle. The ends of the fibers in the bundle have curvature so the beam of light exiting the tip of the wand has a specific divergence angle. The light reflects from the sample surface and travels back to the wand with the same divergence angle. A second optical fiber bundle in the wand intermixed with the first, collects the reflected light and channels it to a detector. Because of the divergence angle of the light, the amplitude of the reflected light seen by the detector will be a fixed function of the distance to the sample surface. With proper calibration, that amplitude is linearly related to the distance between the sample surface to the tip of the sensor wand.



The best performance occurs when the wand is perpendicular to the sample surface. The HVDM II architecture ensures that the wand is perpendicular to the top surface of the free floating top electrode contact.

If the wand is lowered to a point just above the top surface of the free floating top electrode, the amplitude of the light reflected from the electrode surface into the wand decreases to a minimum. As the tip is raised away from the surface from that point the amplitude of the reflected light increases, as indicated by the alphanumeric display on the HB-PTB front panel. At the optimal calibration distance, the intensity will peak and then decline as the wand continues away. Because the divergence angle of the light is fixed by the fiber optic bundle, the peak reflected signal occurs at a known distance from the sample surface. The calibration procedure consists of setting the wand at that peak height above the surface, manually adjusting the voltage output of the HB-PTB control unit to read approximately 10.0 Volts, and then lowering the wand *back towards the sample surface* to the half-way point as indicated by a 5.0-Volt reading on the HB-PTB display. The output of the HB-PTB to the tester SENSOR input will then have a scale factor of -5.0 microns/Volt for all tests.

NOTE: The next four pages contain step-by-step instructions for loading, calibrating and testing with the HB-PTB. They may be printed separately and posted near the test station.

Installation:

- With the gantry open, insert the sample into the HVDM II by removing the top. Ensure that the sample is centered in the HVDM II well and that the sample bottom electrode makes contact with the HVDM II bottom electrode.

- Place the HVDM II top straight down onto the HVDM II bottom. This allows the free-floating HVDM II top electrode to contact the sample top electrode.

- Close the gantry.

- Connect the HVDM II bottom electrode to the Radiant Technologies' High-Voltage Interface (HVI) H.V. DRIVE port. Note that this port will produce the high-voltage signal. NOTE: It is important that this signal be connected to the HVDM II bottom electrode and not to the top electrode. Connecting to the top electrode risks high voltage arcing to the displacement detection wand.

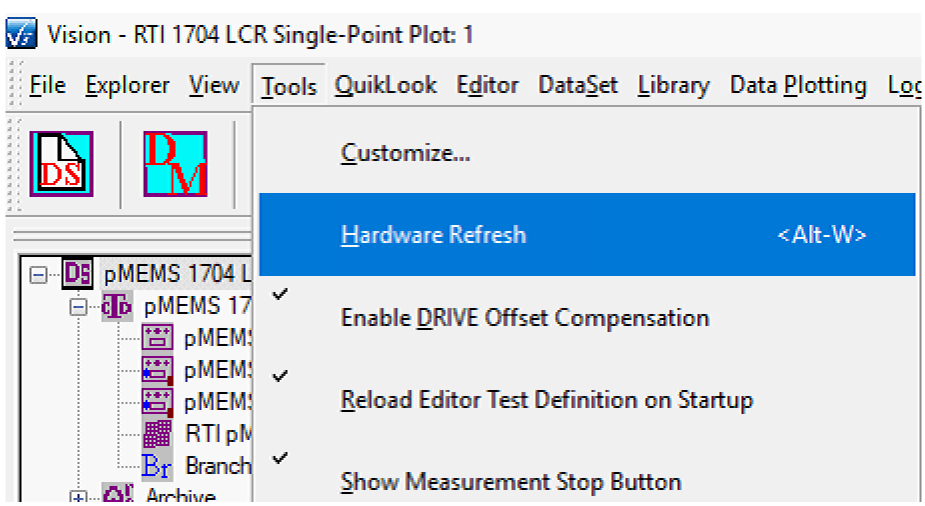
- NOTE: Please see the Main Vision Manual and distribution cover letters for details about high-voltage configuration and operation. This discussion is beyond the scope of this document.

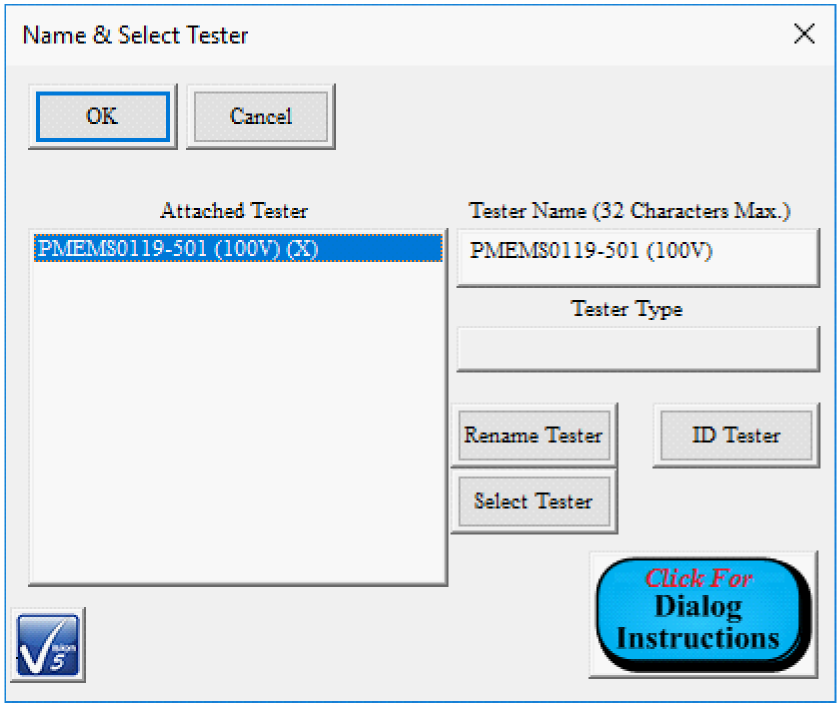
- Plug the HB-PTB control unit into a power receptacle. It accepts 100 V to 220 V, 50 or 60 Hz single-phase and automatically selects the correct settings internally.

- Connect the coaxial cable from the HB-PTB rear-panel Sensor port to the SENSOR 1 BNC port on the rear panel of the tester.

- Connect the HB-PTB rear-panel USB port to the Vision host computer that will be controlling the HB-PTB and the Precision tester.

- Turn on the HB-PTB, then start Vision on the host computer. Note that, if Vision is already running when the HB-PTB is connected, then Vision must be informed of the presence of the instrument by doing a Hardware Refresh. Select Tools->Hardware Refresh or press <Alt-W>. You will need to repeat the tester calibration performed at startup.





WARNING: ***The HV RETURN should always be connected to the top half of the HVDM to prevent arcing to the sensor wand.*** The PhilTec displacement sensor wand is metal coated and will sit less than one millimeter from the top surface of the top electrode contact during testing. If the HV DRIVE from the Precision HVI is connected to the top electrode contact, it will easily arc to the metal cladding of the sensor wand. The HV RETURN of the Precision HVI *never leaves ground potential* at any time even during sample breakdown. It should always be connected to the top electrode of the HVDM so both the electrode and the sensor wand will be at the same potential.

NOTE: See Appendix A for the instructions to install the HB-PTB to the Vision host computer.

Loading the Wand:

WARNING: Do not attempt to load the sample with the displacement detector wand inserted into the gantry.

- With the HB-PTB gantry closed, loosen the set screw at the detection wand sleeve.
- Manually insert wand through the sleeve and into the top of the HVDM II.
- Continue to insert manually until the probe is nearly touching the top surface of the top electrode of the HVDM II.

- Gently tighten the set screw to hold the wand in place.

  CAUTION: Be sure not to over tighten the set screw and bend the wand.

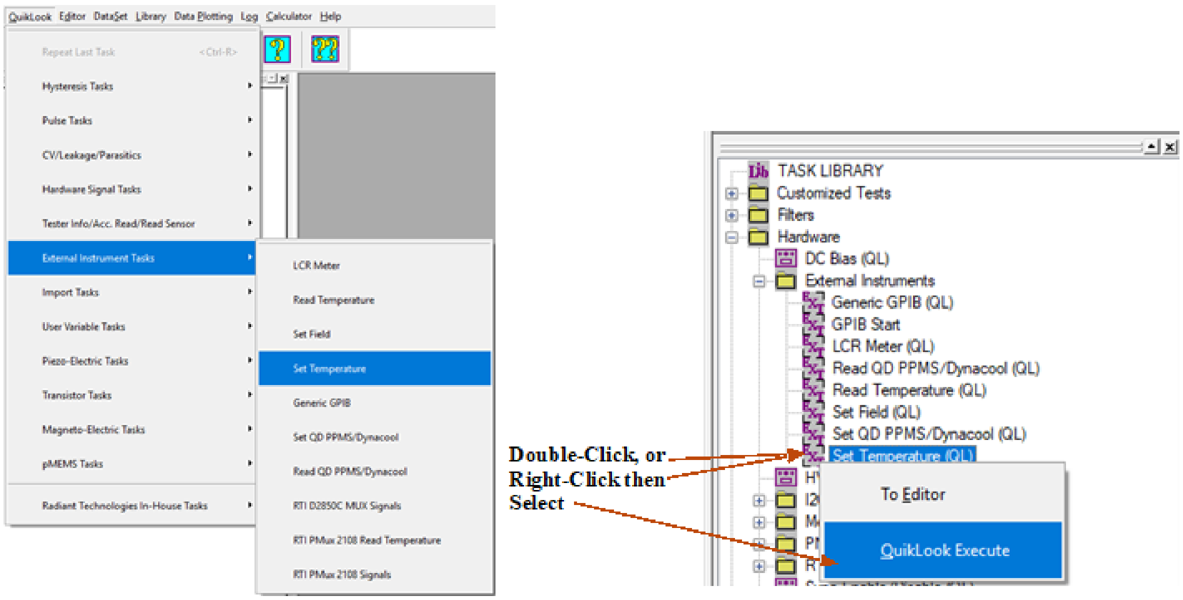
- Using the adjustment ring, adjust the wand upward (away from the top of the HVDM II electrode) until a maximum is found on the display output.

- With a small screwdriver, adjust the coarse, then fine, Gain screws at the HB-PTB front panel until the HB-PTB reads approximately 10.0 Volts. It is not critical that the value be exactly 10.0 Volts but should be as close as possible.

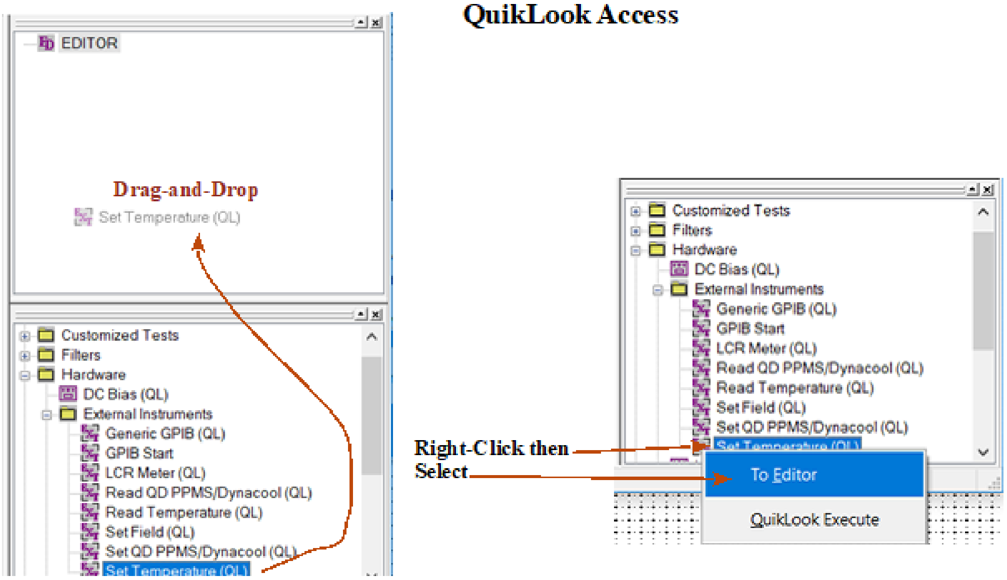
- Using the adjustment ring, move the wand ***downward*** (towards the top of the HVDM II) until the HB-PTB display reads approximately 5.0 Volts. This places the displacement detection in the center of the detection range. This is the most-linear portion of the range and allows freedom of detection in both the positive and negative directions. Note that there will be very little clearance between the wand tip and the top of the HVDM II top electrode.

Controlling HVDM II Temperature

The HVDM II test fixture temperature is controlled using the Vision Set Temperature and Read Temperature Tasks. Both Tasks are available from the QuikLook menu under QuikLook->External Instrument Tasks->…. Both are available in the TASK LIBRARY under TASK LIBRARY->Hardware->External Instruments->….

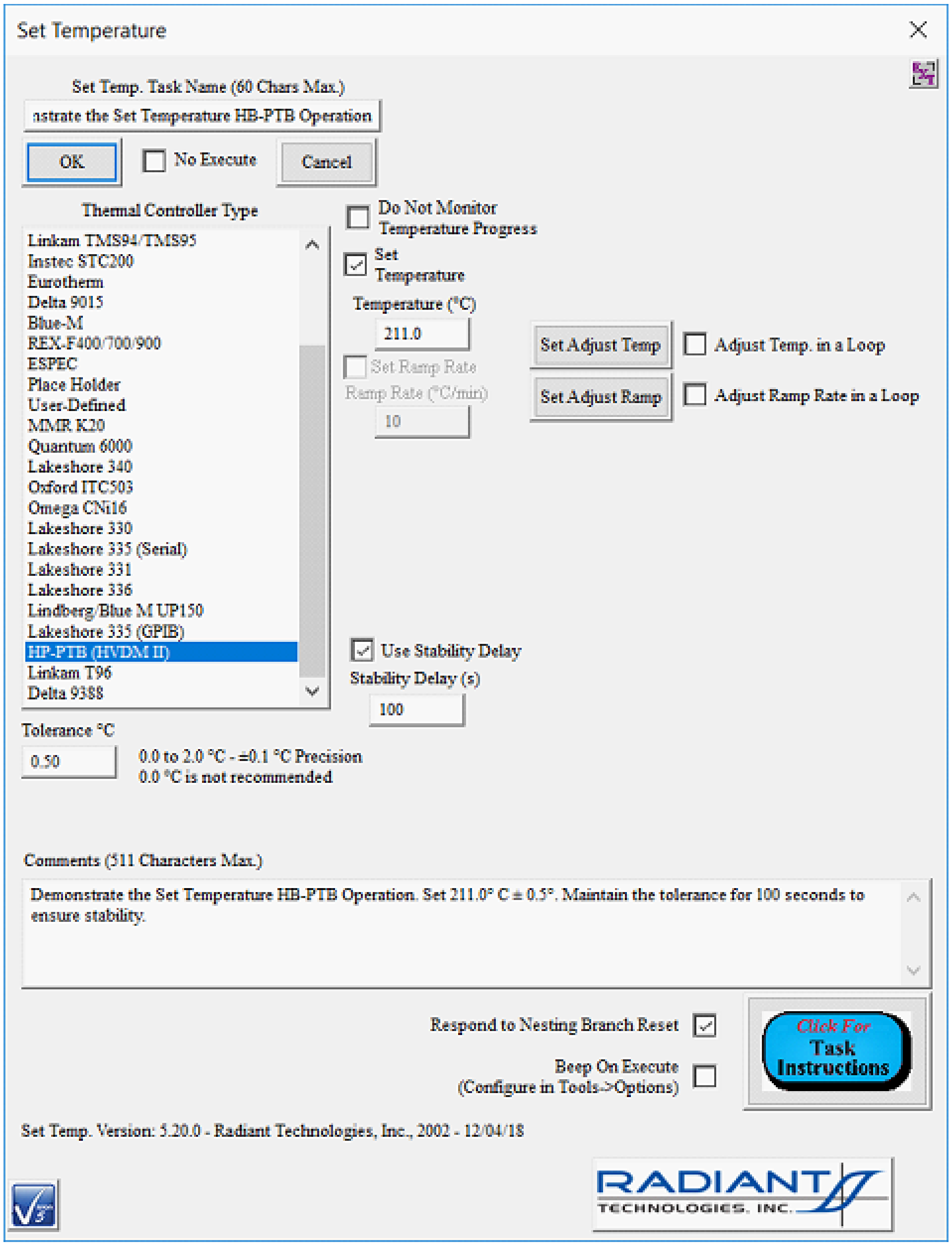


QuikLook Access

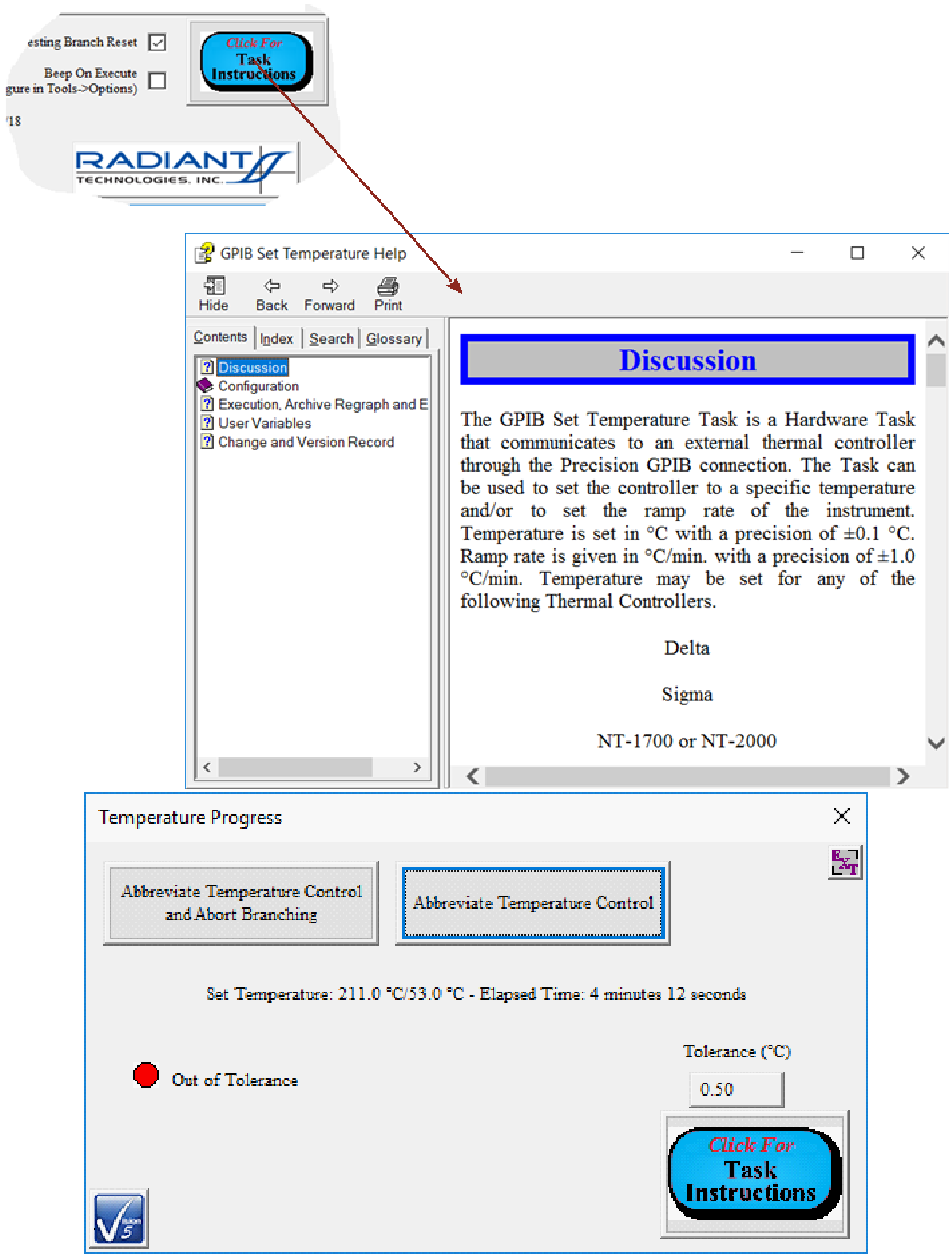


Editor Test Definition Access

To control the temperature, select the Set Temperature Task. When the configuration dialog appears the important elements are to select “HB-PTB (HVDM II)” in the *Thermal Controller Type* list and to set the intended temperature in *Temperature (°C)*. A *Tolerance °C* should be set to allow a small range of acceptable temperatures. If *Use Stability Delay* is checked, the Task will not exit control until the actual temperature remains within ± *Tolerance °C* for a period defined in *Stability Delay (s)*.



For all Tasks, see the Task Instructions for complete theory, configuration and execution details.



Set Temperature Task Progress Dialog.

To monitor the current temperature without adjusting the set point, use the Read Temperature Task. See the Task Instructions for complete details.

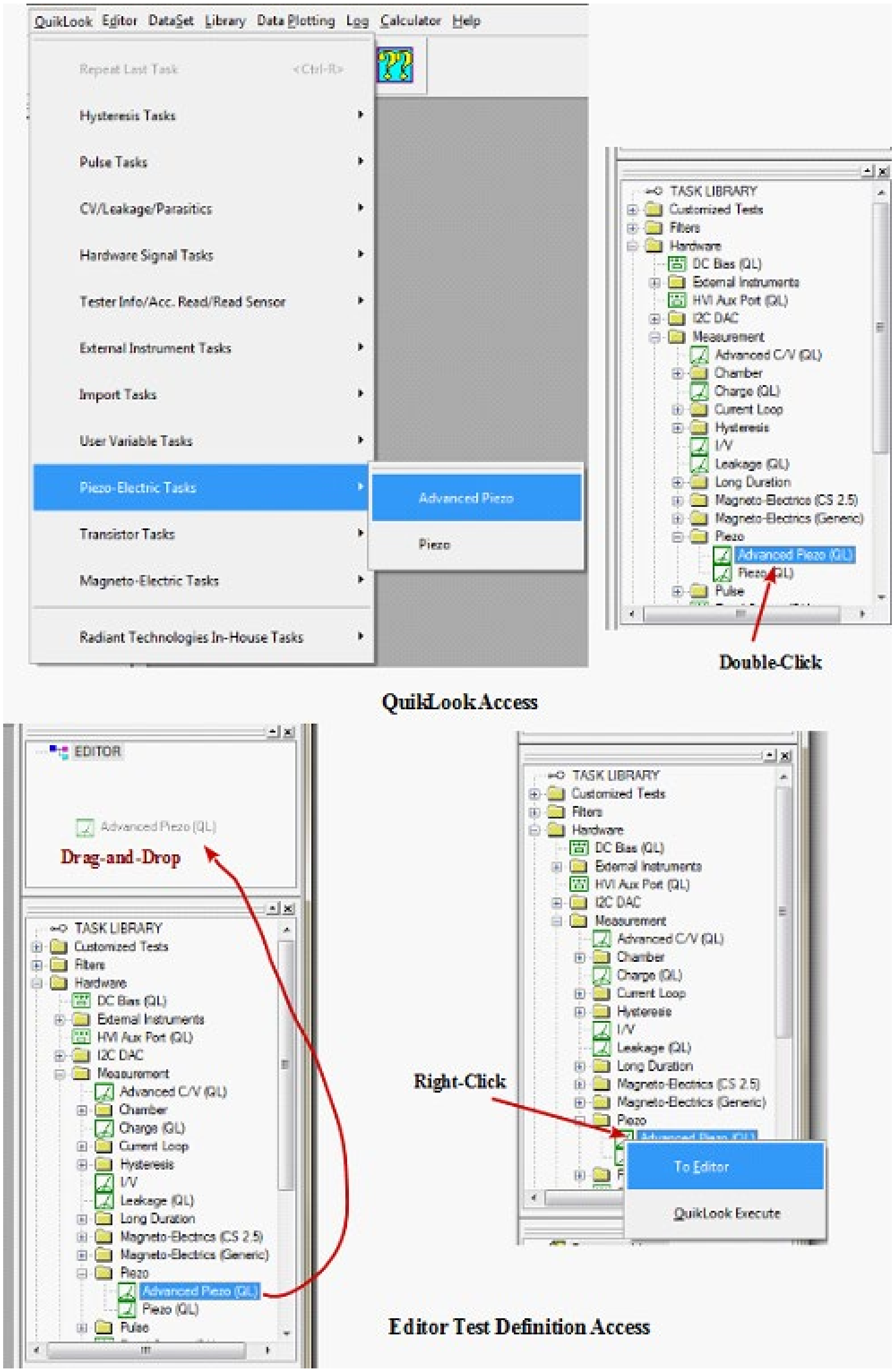
Note that the Precision tester is not required to operate the Set Temperature or Read Temperature Task.

Measuring Sample Displacement

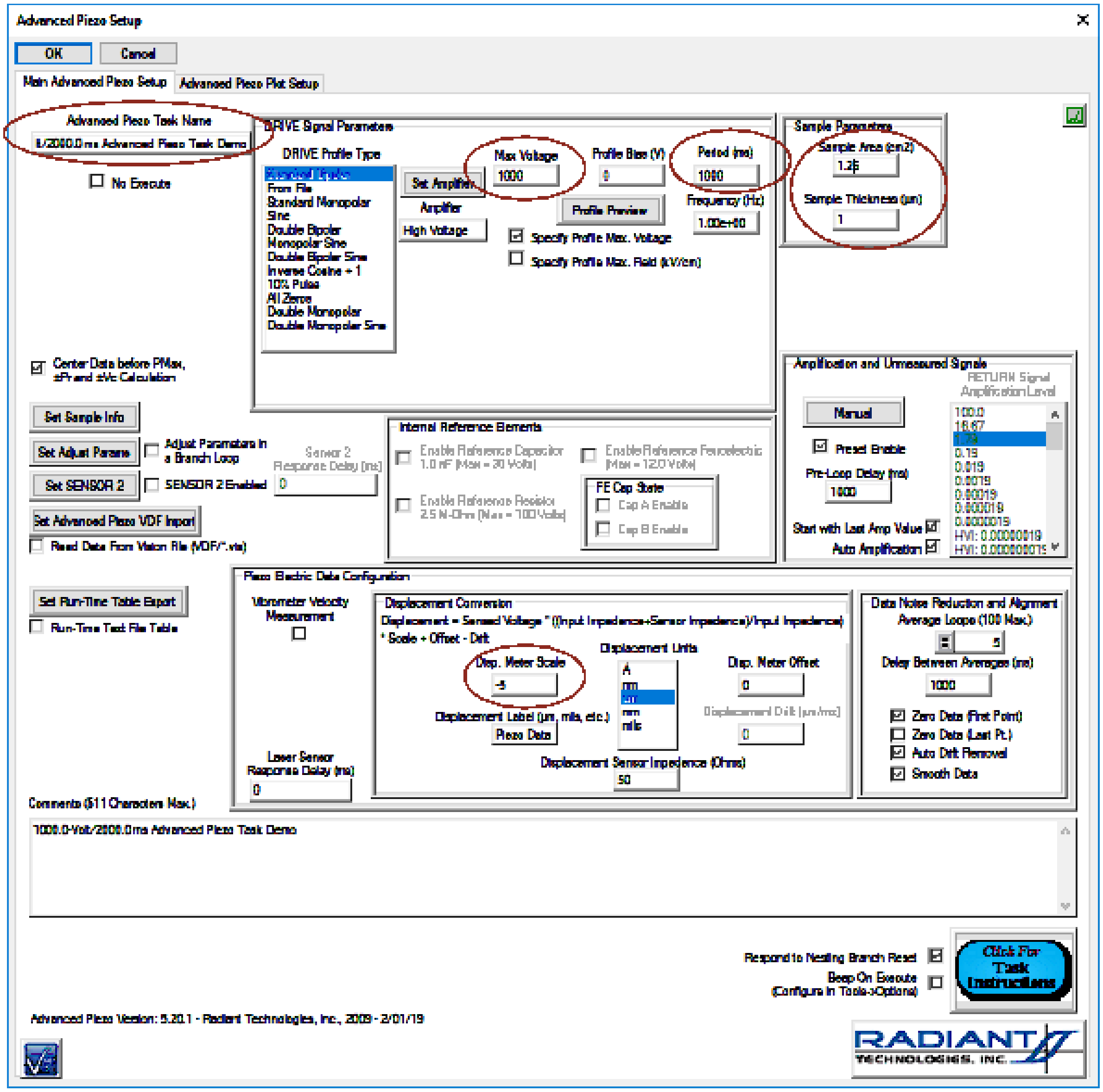
Sample displacement is measured using either the Piezo Task or the Advanced Piezo Task. The Advanced Piezo Task is intended for thin-film samples with small displacements producing very small signal response with respect to circuit and environmental noise. It offers repeated measurements that are averaged together and a number of other random noise reduction tools. Normally, for high-voltage, bulk sample responses as measured by the HB-PTB the Piezo Task offers a faster and simpler response that is quite acceptable. Nevertheless, the Advanced Piezo Task is quite capable of providing quality HB-PTB data.

In order to operate the Piezo and Advanced Piezo Tasks, along with the Piezo Filter Task, the Tasks must be licensed. Most of Vision is freely distributed and may be downloaded and installed by anyone on any number of host computers. However, there are several Task Suites, including the Transistor Task Suite, the Magneto-Electric Task Suite, the Pyro-electric (Chamber Task Suite) and the Piezoelectric Task Suite for which the Tasks must be purchased. All Tasks in these Custom Task Suites are distributed with Vision and are available to anyone who downloads and installs Vision. Anyone may open a Task configuration dialog for review and to access the Task Instructions. Anyone may review archived data taken by a licensed installation of the Custom Task. However, to configure and execute a Custom Task a license must be purchased. The license is in the form of a file named Security.sec that is copied into C:\Program Files (x86)\Radiant Technologies\Vision\System. The file is coded to the Task Suite(s) that has/have been purchased. It is also coded to an identifier that is embedded in the Precision tester for which it was purchased. The license may be copied to any number of host computers but it cannot be transferred to users of other testers.

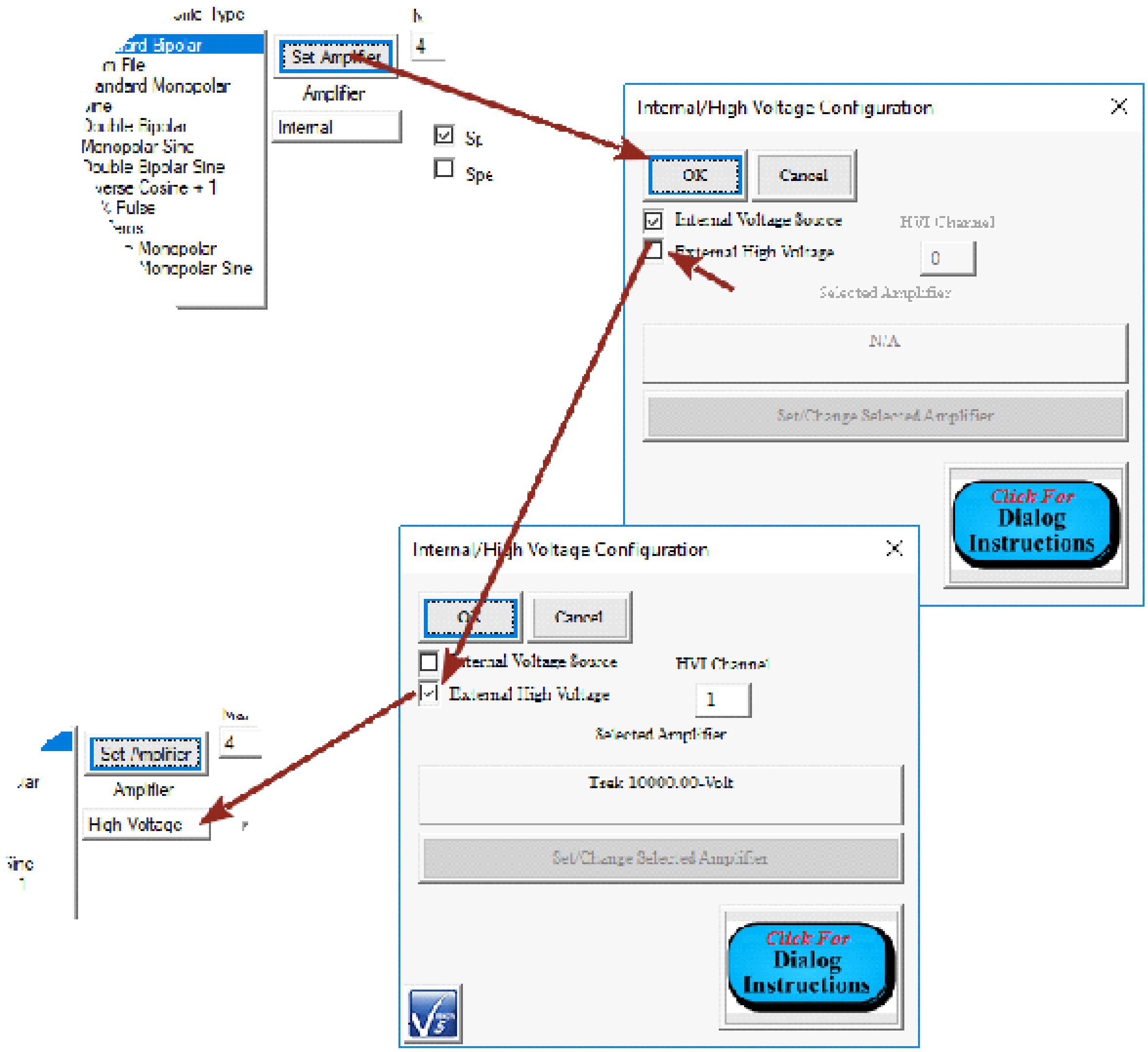
The Piezo and Advanced Piezo Tasks are QuikLook Tasks found in QuikLook->Piezo-Electric Tasks->…. They are also found in TASK LIBRARY->Hardware->Measurement->Piezo->…



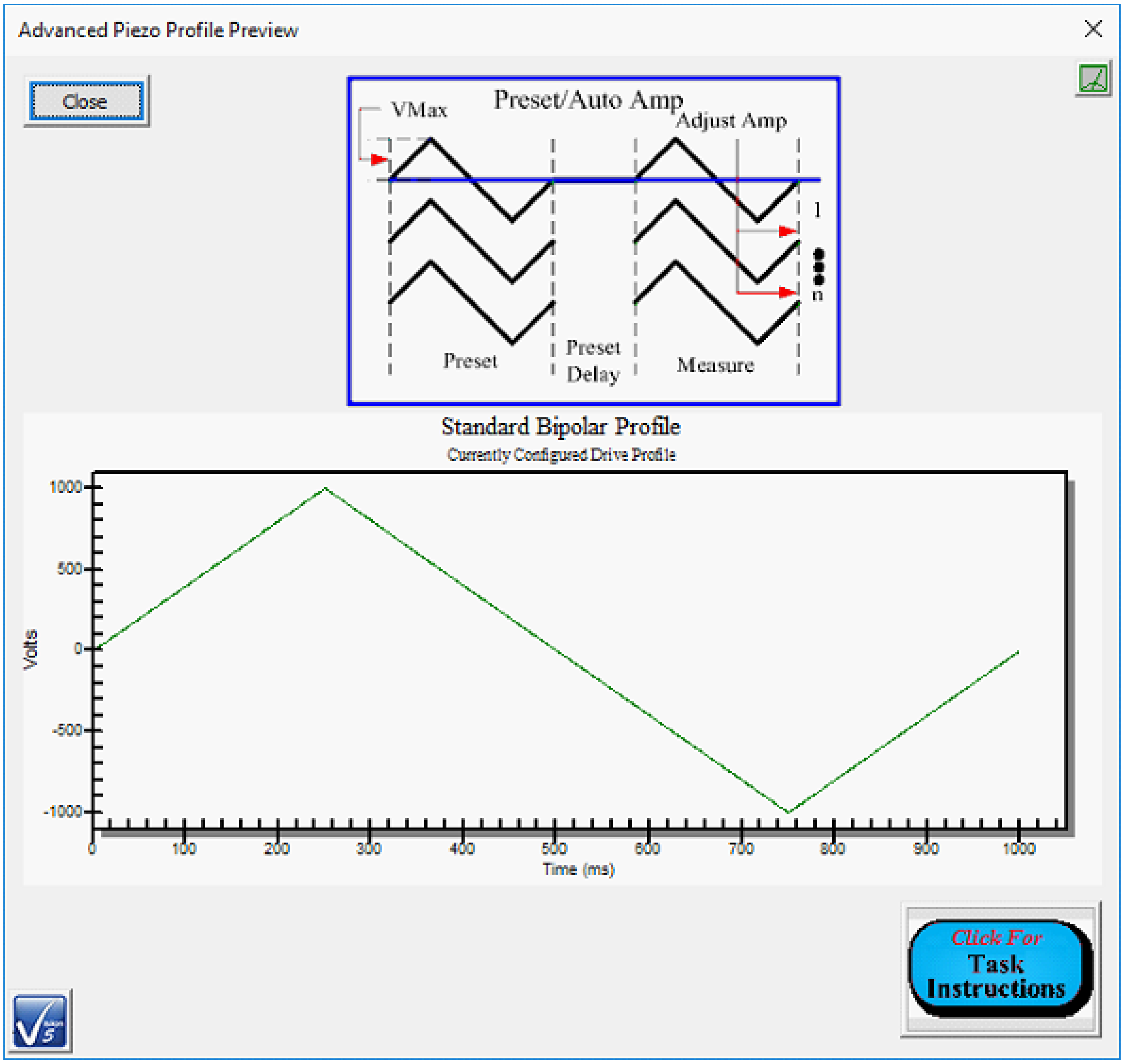
When the dialog opens:



- Provide a unique and meaningful *Task Name*.
- Click *Set Amplifier* to open a subdialog. In the dialog check *External High Voltage* and click *OK* to close. *Amplifier* will be updated from “Internal” to “High Voltage”

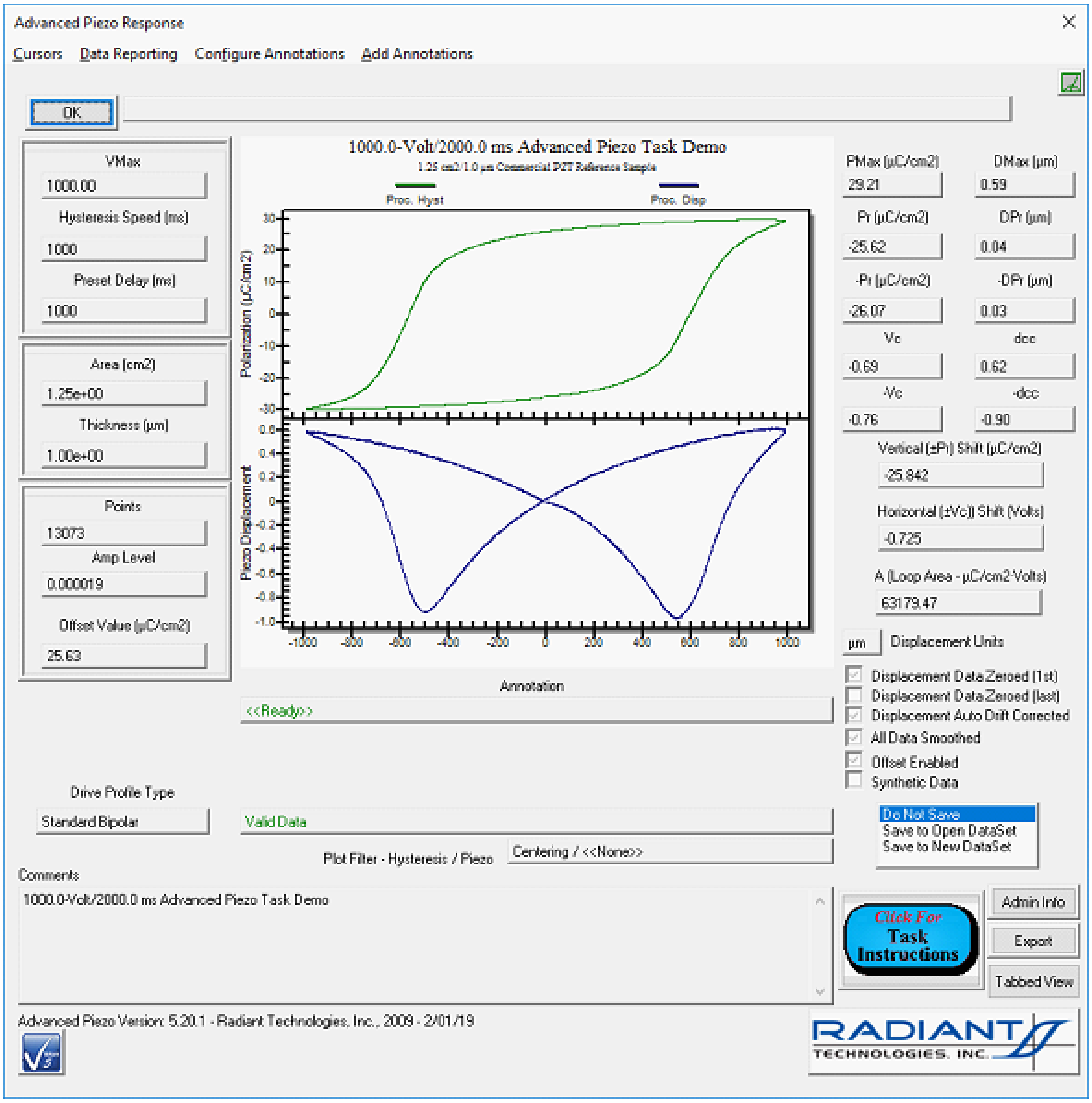


- Assign an appropriate *Max. Voltage*. Note that, if you are using the commercial piezoelectric standard provided by Radiant Technologies, Inc., do not exceed 1100 Volts.
- Assign an appropriate *Period (ms)*. For "Standard Bipolar" DRIVE Profile Type, the *Period (ms)* is equivalent to 1000/Frequency (Hz). To review the DRIVE profile click *Profile Preview*.



- Provide the correct *Sample Area (cm2)* and *Sample Thickness (µm)* dimensions. Note that *Sample Area (cm2)* is used to normalize the sample charge (µC) response to produce the correct measurement units of polarization (µC/cm^2). *Sample Thickness (µm)* is recorded primarily for sample documentation. However if electric signal strength is to be specified and/or plotted in units of electric field (kV/cm), rather than voltage, then the *Sample Thickness (µm)* parameter is used to scale voltage to derive electric field (kV/cm). See the Task Instructions for complete discussion.
- In *Disp. Meter Scale* enter -5. This scales the SENSOR 1 port voltage from the HB-PTB to displacement (µm).

The figure shows the response of the standard commercial PZT reference disk provided by Radiant Technologies, Inc. at 1000.0 Volts



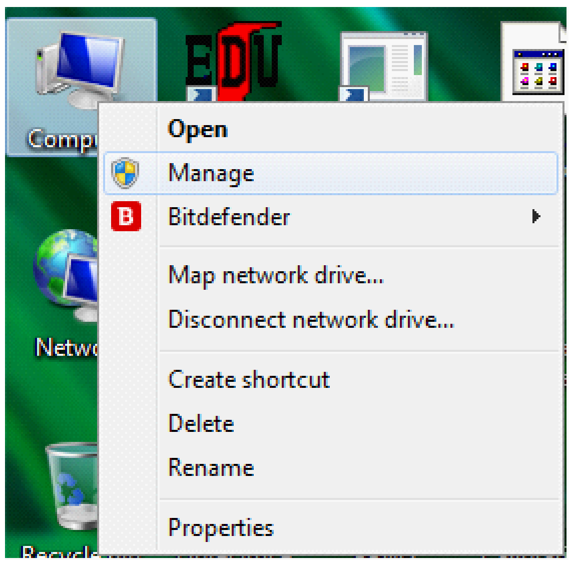
Appendix A: Installing the HB-PTB to the Vision Host Computer/Windows

The HB-PTB, along with the Precision tester, must be installed to the Windows operating system after the Vision program is installed. It is highly recommended that the latest version of Vision be installed. Vision updates can be checked and downloaded by visiting https://www.ferrodevices.com/1/297/download_vision_software.asp. Fill in the form and click *Submit*. You will be linked to the Vision Installer download page. Click the download button and then run the program. Acknowledge any warnings and allow the download and installation to proceed. The installer will update any existing installations or install a fresh version of the program.

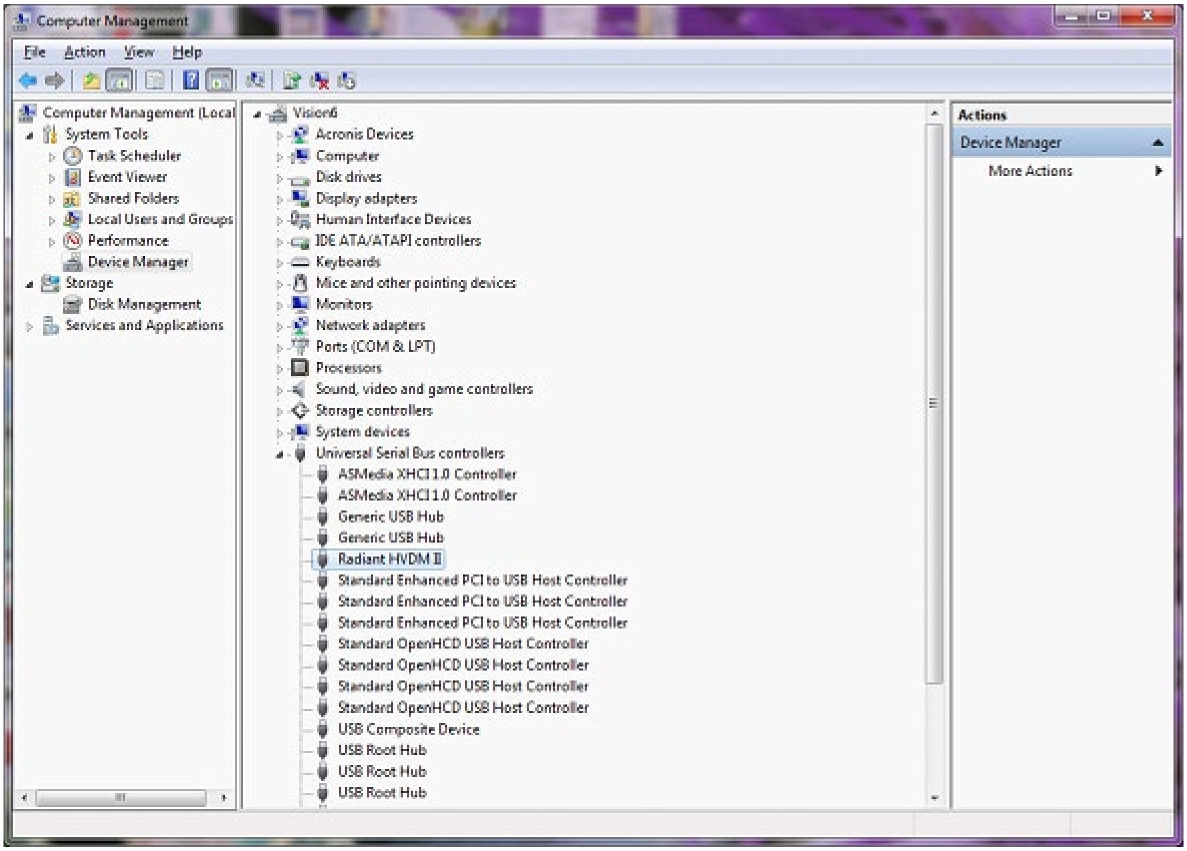
Vision, the Precision tester and the HB-PTB may be installed to Windows 7, 8, 8.1 or 10. Windows XP and Vista are no longer supported.
To install the HB-PTB to Windows 8, 8.1 or 10, simply connect the instrument to the host computer and turn it on. The instrument will automatically install itself with no further action by the user.

To install the HB-PTB to Windows 7, connect the instrument to the host computer and turn it on. Windows will attempt to install the instrument, but will fail. Follow these steps:

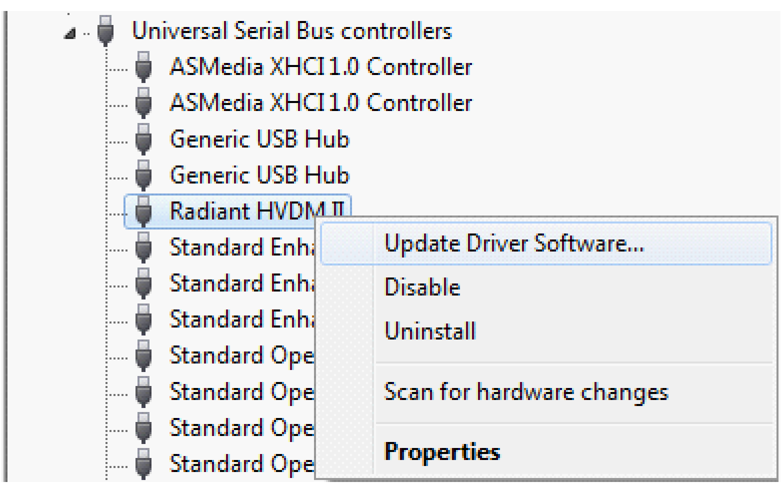
- On the Windows desktop, right-click on the "My Computer" icon and select "Manage".



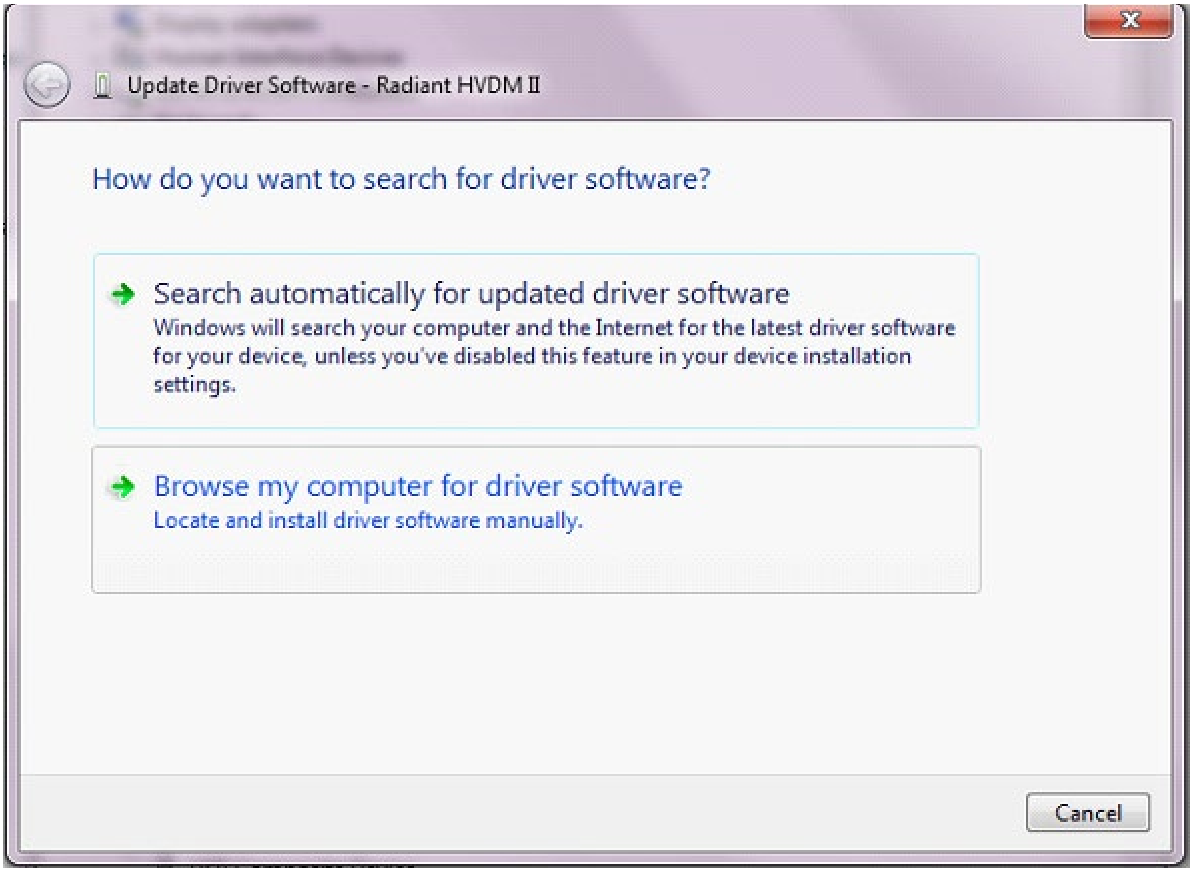
- In the window that appears select "Device Manager" in the left pane and open the "Universal Serial Bus controllers" folder in the right pane. The device will appear as "Unknown Device" or "WinUSB Device" or similar entry. (In the figure, the HB-PTB has already been installed.)



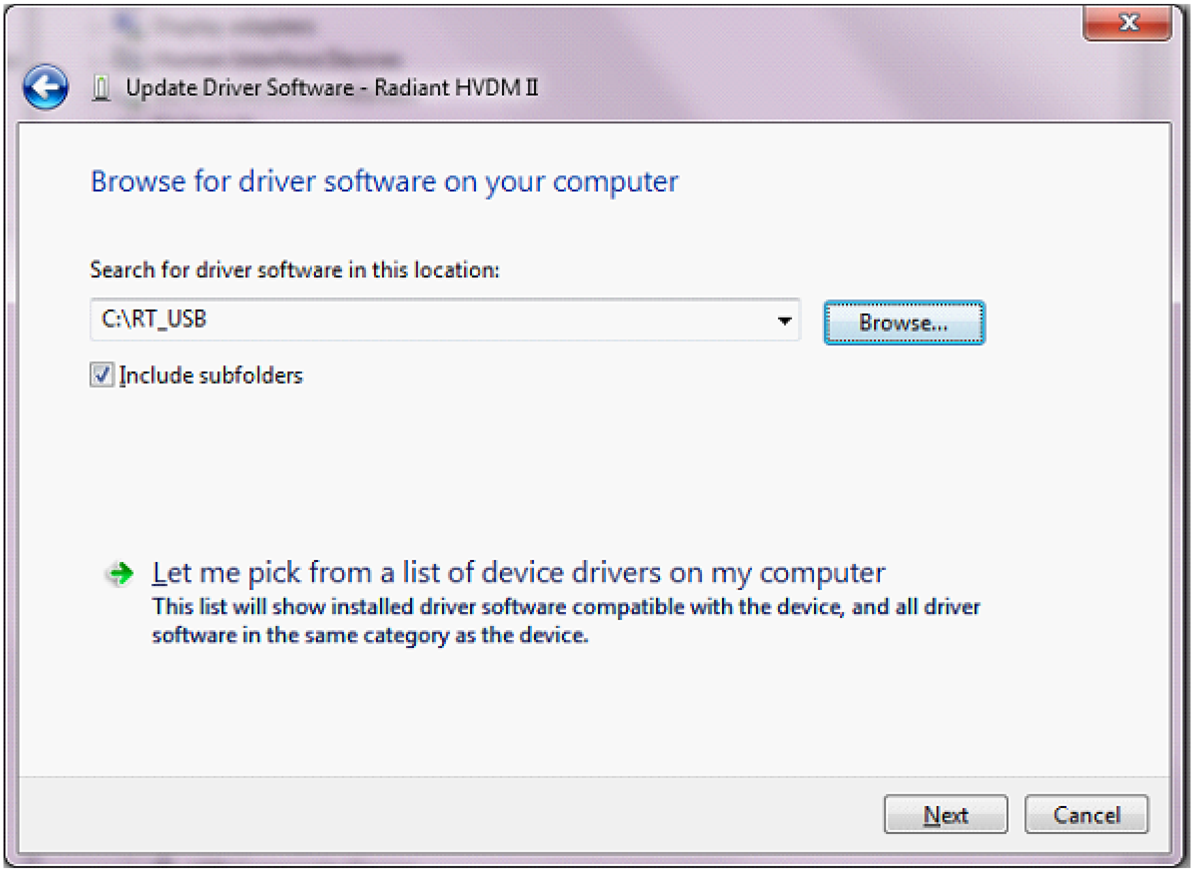
- Right-click on the device entry in the folder and select “Update Driver Software…”



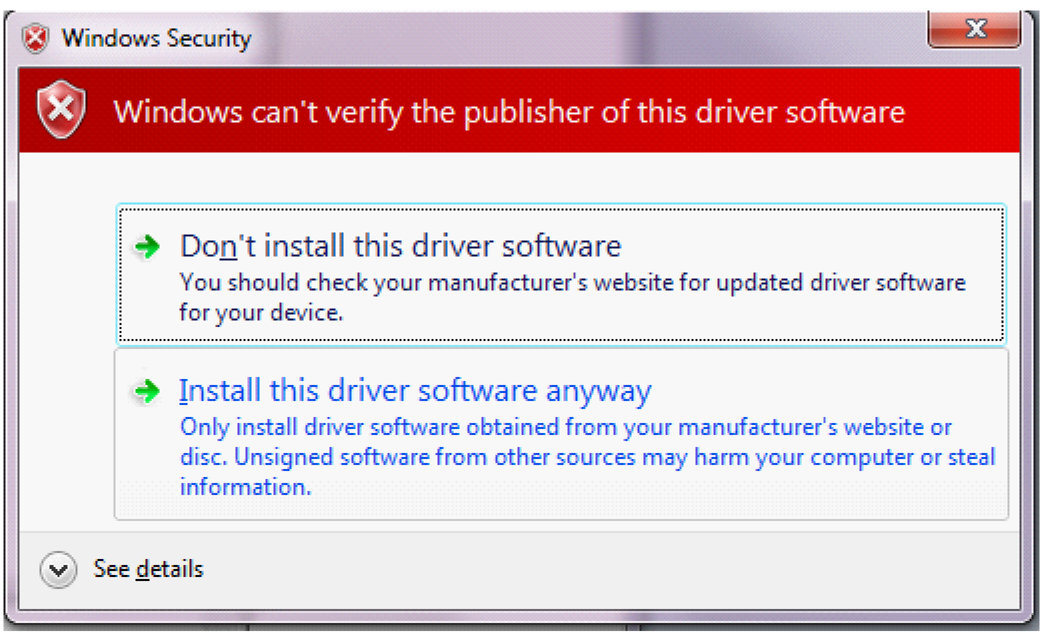
- In the window that appears click *Browse my computer for driver software*.



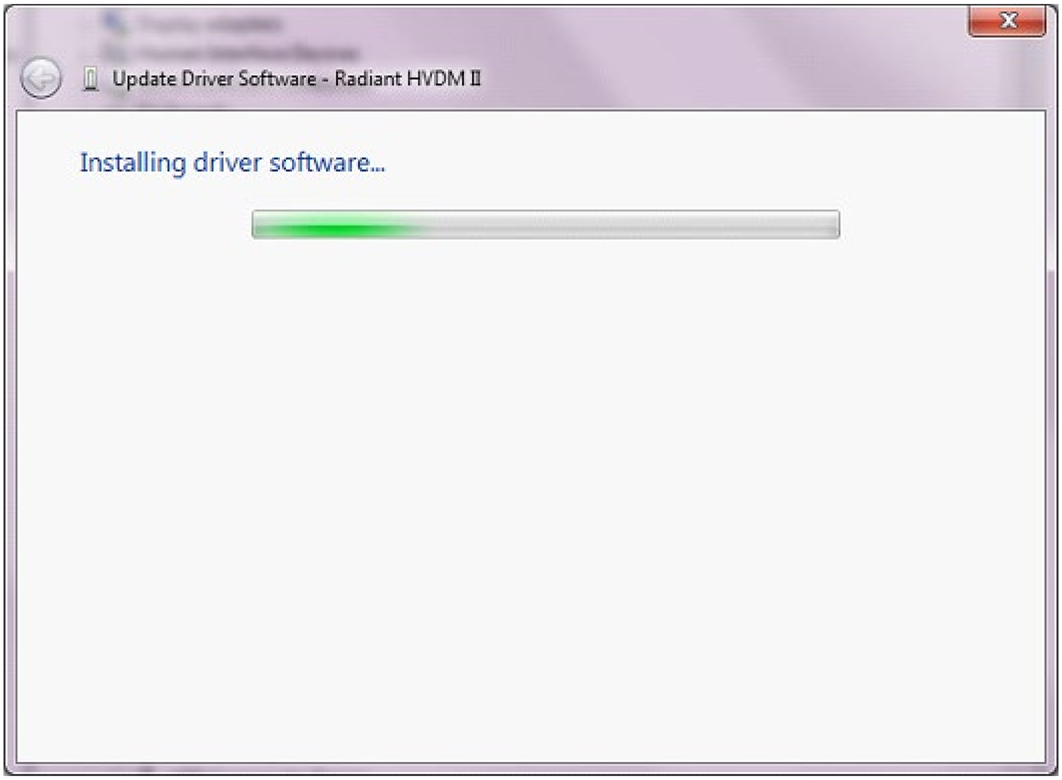
- In the window that appears, click *Browse* and use the standard Windows browser dialog that appears to navigate to and select the C:\RT-USB folder.

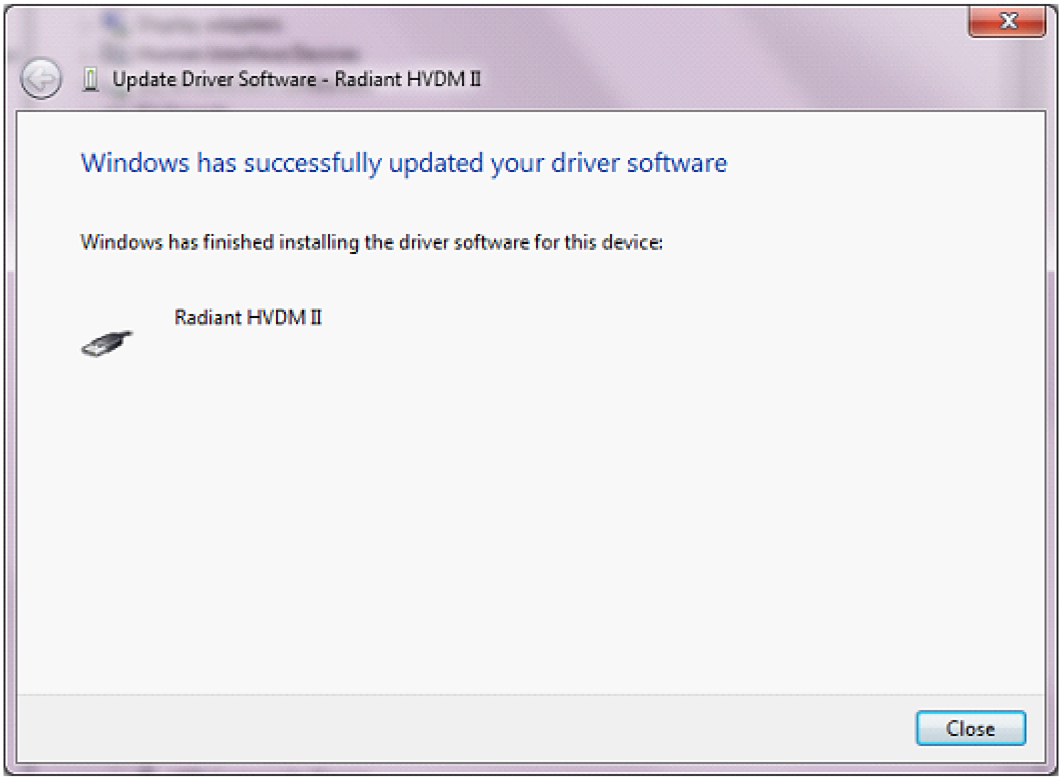


- Click *Next* to start the installation. A warning will appear since the drive is not signed. Click *Install this driver software anyway* to allow the driver installation to continue.



- The driver installation will proceed. When the installation is complete, a window will appear that displays the “Radiant HVDM II” name indicating that the installation was successful.





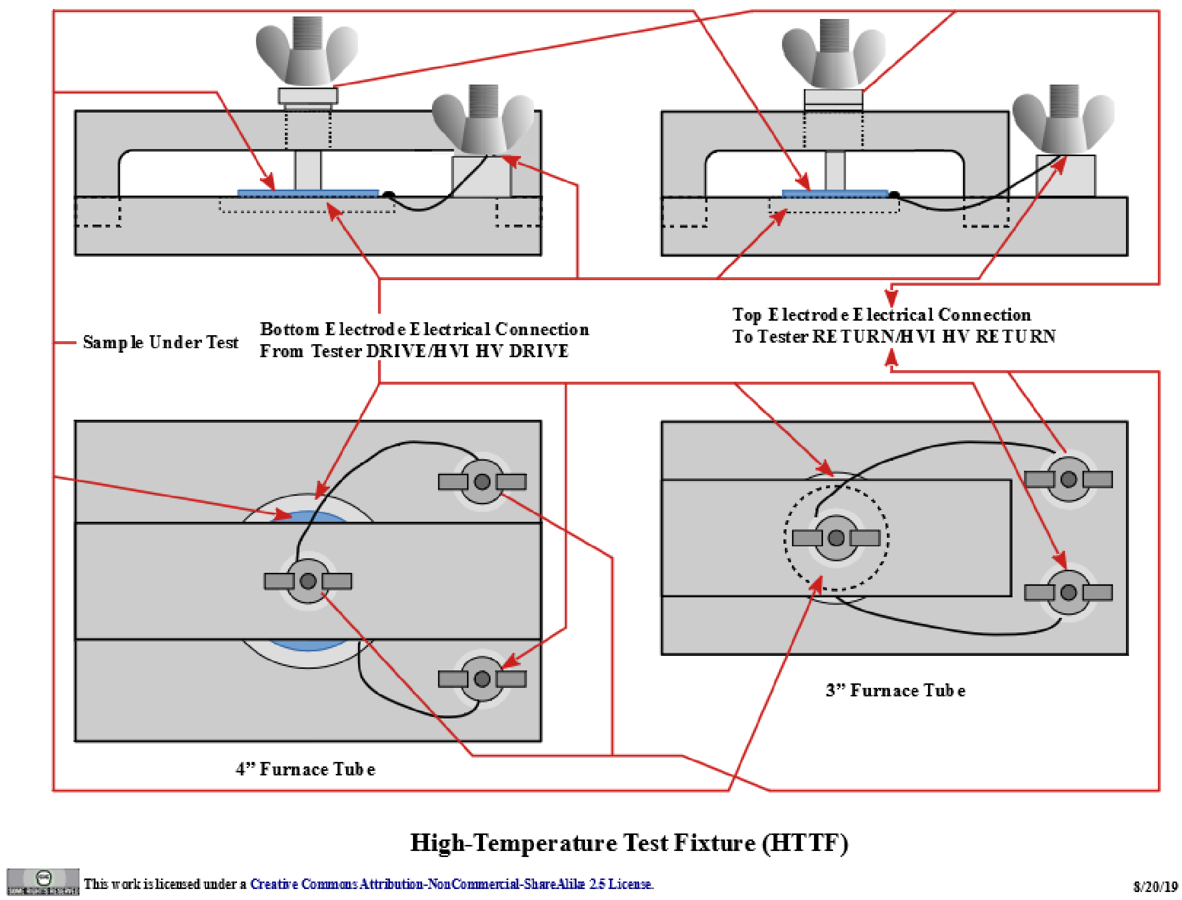
- Close the window and the "Radiant HVDM II" instrument will appear in the Device Manager as in the figure of step 2. The HB-PTB is now ready to use.

High-Temperature Test Fixture (HTTF)

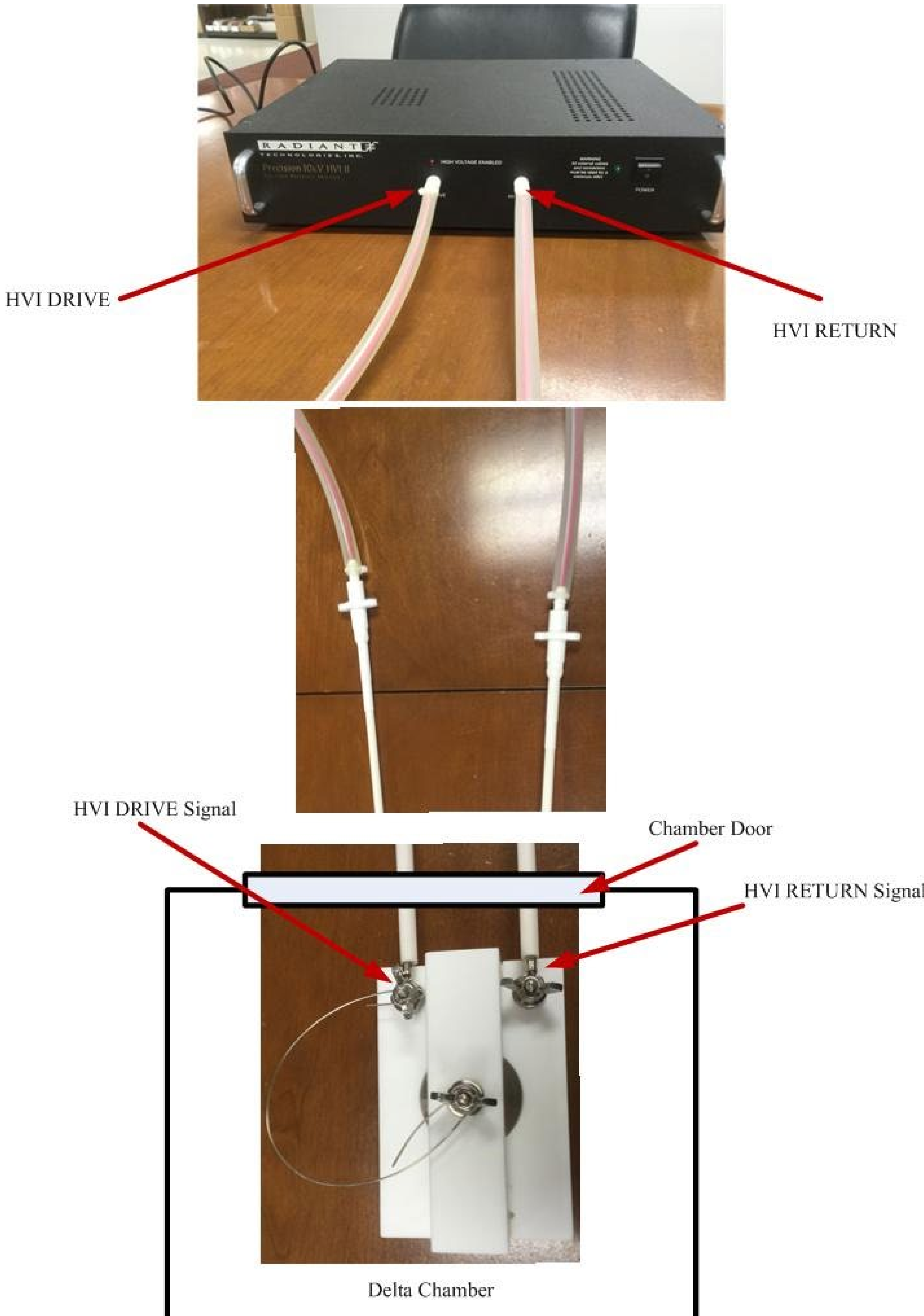
Two models of the High-Temperature Test Fixture (HTTF) - the 3" and 4" - are designed to perform high-voltage measurements at high temperatures in a furnace tube. The size of the test fixture to be used depends on the diameter of the tube. The MACOR™ ceramic used allows measurements at up to ±10,000 Volts and 650° C.

MACOR™ tube carry electrical connections between the High-Voltage Interface HV DRIVE and HV RETURN ports to and from wing nuts on the test fixture. The HV DRIVE connection is routed by the fixture to an embedded metal plate on which the sample sits. This plate makes electrical connection to the sample bottom electrode. The HV RETURN signal is routed from a plunger that lowers to engage the sample top electrode. The MACOR™ tubes can pass through the end of the furnace tube or through openings in a chamber door to engage the test fixture and the sample.

High-Temperature Test Fixture (HTTF) Appearance



High-Temperature Test Fixture (HTTF) Electrical Connections.


HVI DRIVE
HVI RETURN
HVI DRIVE Signal
Chamber Door
HVI RETURN Signal
Delta Chamber

CS 2.5 Current Source

The CS 2.5 Current Source is a general-purpose current amplifier with a 2.0 A limit and a 4.0 A/V current gain factor. A 1.0 V/A monitor output allows the user to detect the actual current being output by the CS 2.5. In addition to current output in response to voltage input, the CS 2.5 can be programatically ordered to a DC output current of a maximum of 2.0 A, with no voltage input.

The CS 2.5 also offers two independently-programmable DC voltage output ports - Field Bias 1 and Field Bias 2 - with limits of ±10.0 Volts. Voltage output is also programmatically controlled.

Although the CS 2.5 serves as a general-purpose current and voltage source, it was developed in conjunction with the Magneto-Electric measurement bundle and is included in sales of the ME bundle. In this use, the current output is fed through a commercial Helmholtz Coil that generates a magnetic field that is linearly related to the current through the coil. A 6" Lakeshore MH-6 Helmholtz Coil, with a gain factor of approximately 26.0 G/A, is provided as standard with the Magneto-Electric bundle.

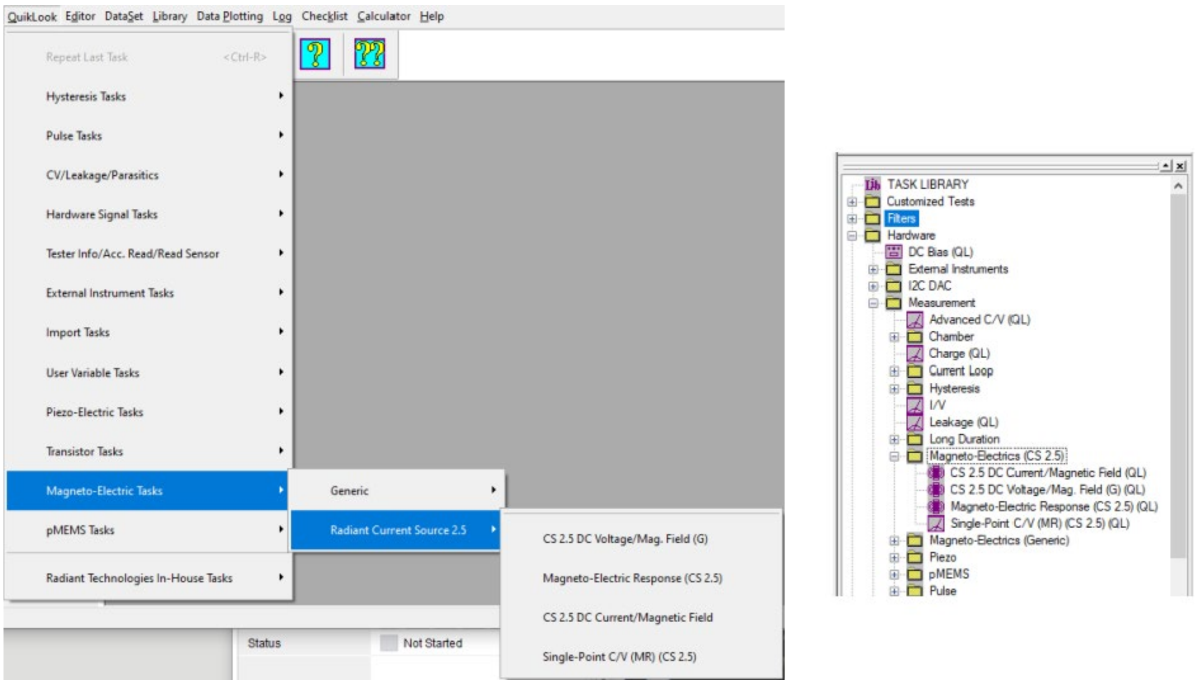
In conjunction with the magnetic field application of the CS 2.5, the Field Bias-1 and Field Bias-2 port are provided as input voltage to commercial current amplifiers that normally drive fixed electromagnets. The standard sample response to a variable magnetic field generate in the Helmholz Coil is often taken inside a larger magnetic field generated by fixed electromagnets. Such fixed magnets are not normally provided as part of the Magneto-Electric bundle.

The Vision program includes the following Tasks that directly control the CS 2.5 Current Source:

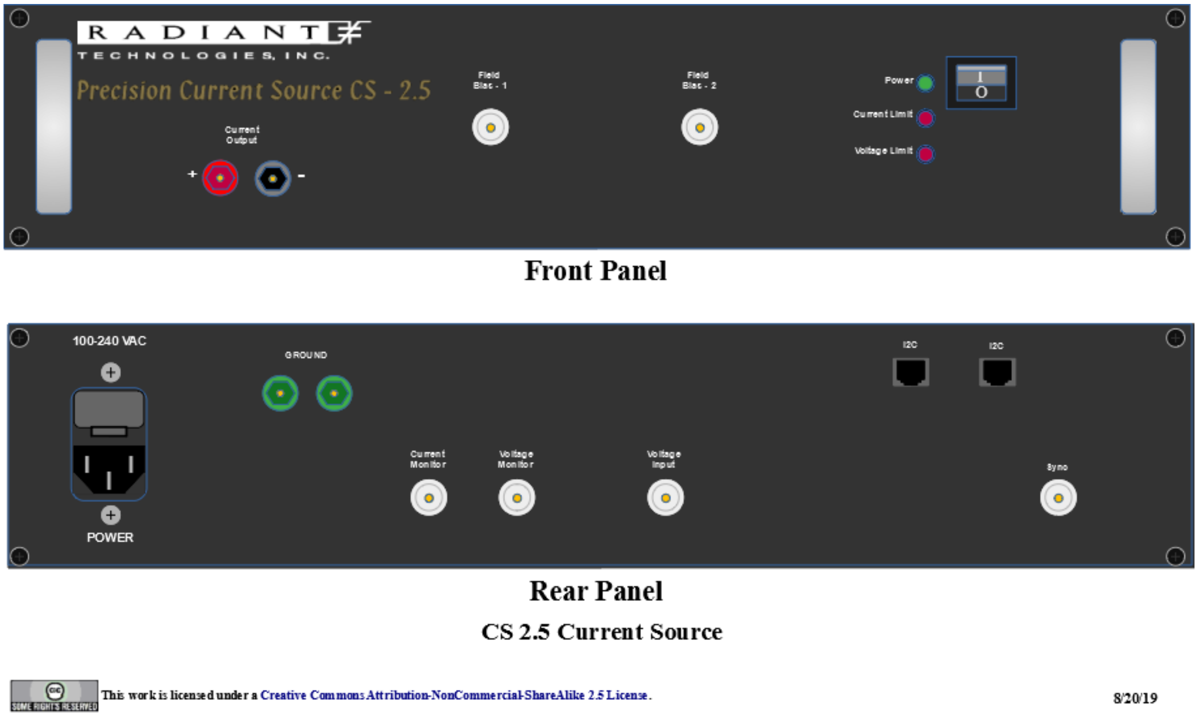
- CS 2.5 DC Current/Magnetic Field - This Task generates a fixed DC current output of a maximum of 2.0 A. The output may be specified in units of Current (A) or of Magnetic Field (G). If Magnetic Field (G) is specified the user provides the Helmholtz Coil's Magnetic Field (G)/Current (A) gain ratio. For this Task the CS 2.5 generates its output current (A) programmatically and takes no voltage input.
- CD 2.5 DC Voltage/Magnetic Field - The Task programatically generates fixed output voltages at the CS 2.5 Field Bias - 1 and/or Field Bias - 2 ports. The output voltage may be specified either in units of Volts or as Magnetic Field (G) with the electromagnet Field (G)/Volt ratio specified.
- Magneto-Electric Response - This Task is similar to the Hysteresis Task. It generates a charge response in the sample. In this case, the response is induced by a variable magnetic field (G) from the Helmholtz coil, stimulated by a voltage input/current output at the CS 2.5. The user must provide the desired maximum magnetic field (G), the Helmholtz Coil's Field (G)/A ratio and the CS 2.5 Current (A)/Volt ratio. The Current (A)/Volt ratio is stored in the CS 2.5 EEPROM and is updated automatically in the Task configuration dialog. The current output of the CS 2.5 is stimulated by the tester's DRIVE port output,

whose voltage DRIVE profile is determined by Vision based on the mentioned parameters and ratios. The Task may also be configured to apply a DC magnetic field using voltage-controlled electromagnets.

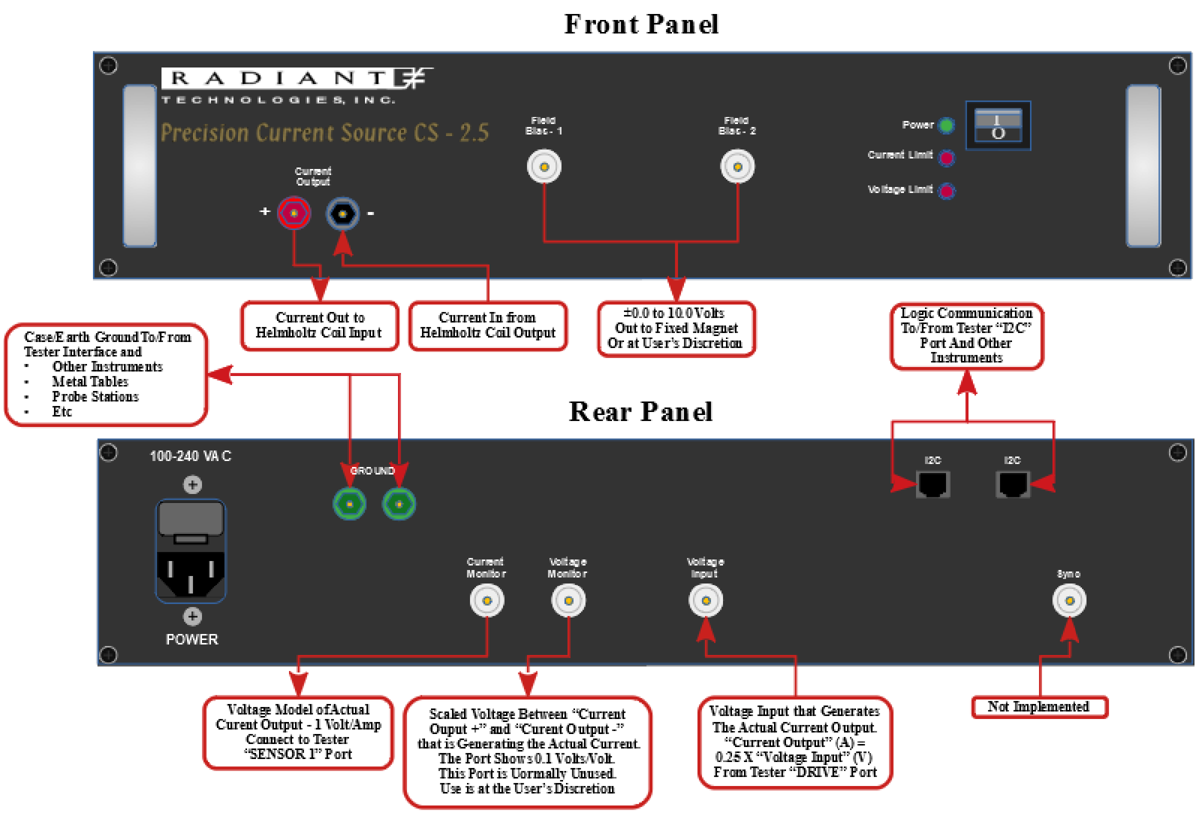
- Single-Point C/V (MR) - This is a conventional electrical single-point C/V measurement that has the additional component in the ability to control a DC magnetic field though external electromagnets and the Field Bias - 1 or Field Bias - 2 port. The user may also opt to apply a DC current programmatically.



CS 2.5 Current Source Appearance



CS 2.5 Current Source Electrical Connections.



CS 2.5 Current Source (Annotated)

RTI D2850C 8-Channel Multiplexer with Thermocouple

<TODO>: Insert description text here... And don't forget to add keyword for this topic

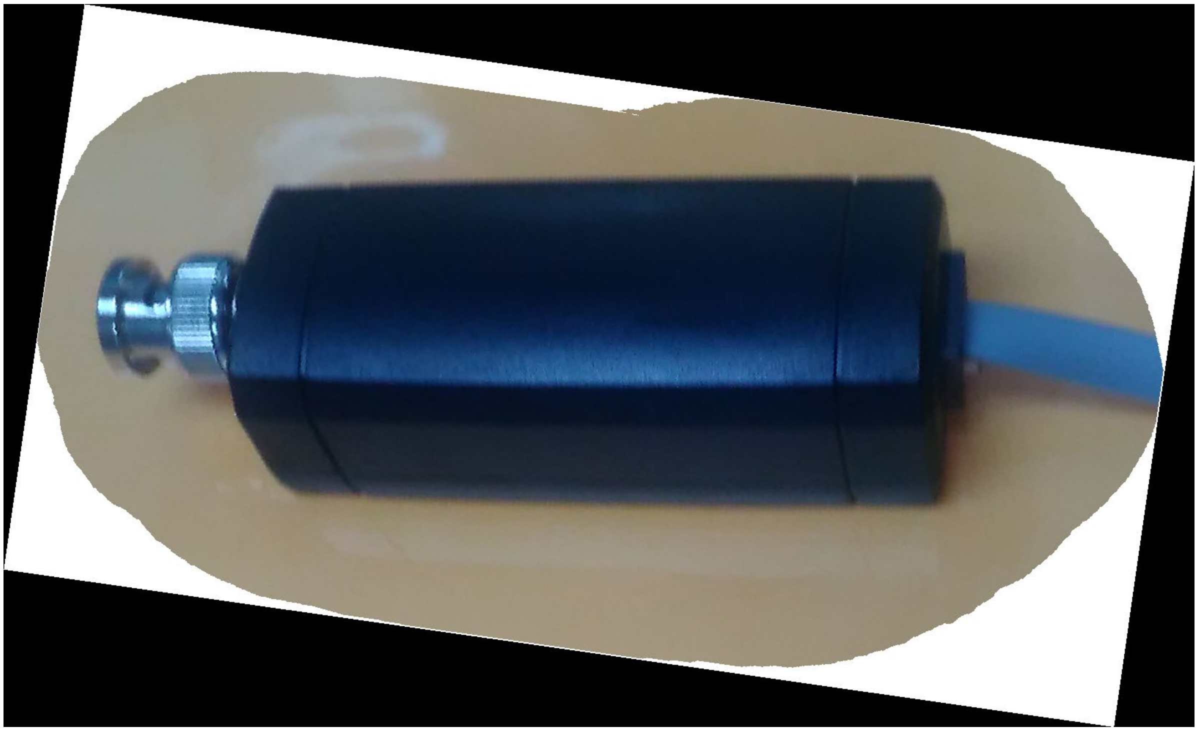
RTI pMUX 2108 8-Channel Rack-Mounted Multiplexer with Thermocouple

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Precision Nano-Displacement Sensor (PNDS)

<TODO>: Insert description text here... And don't forget to add keyword for this topic

I2C Voltage Controller (I2C DAC)



The I2C Voltage Controller is general-purpose voltage source/detector in the ±10.0-Volt range.

E31

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Standard RTI Samples

AB/AD Capacitors - Packaged Ferroelectric Samples

Ferroelectric Component Technical Description

Each die is packaged in a four-lead TO-18 header. One lead connects to the case and is labeled as GND. The common lead is connected to Pin 1. The two independent leads from the two capacitors are connected to Pins 2 and 4.

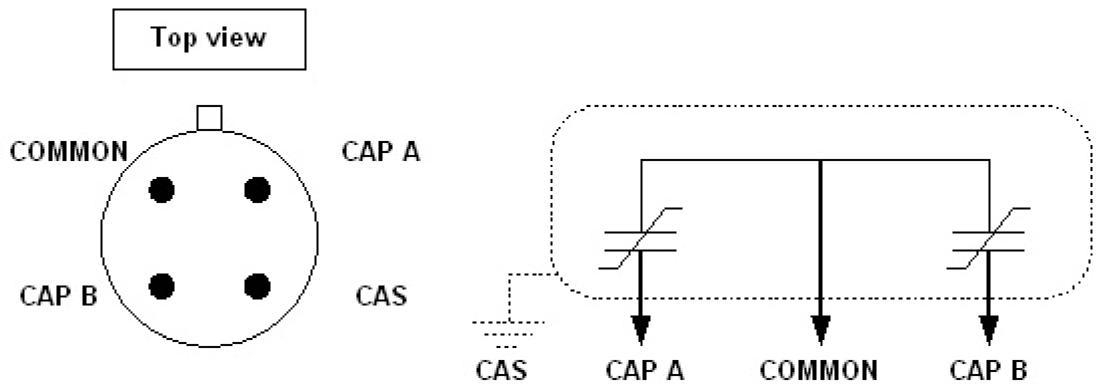


Figure h.1.1 – Available Ferroelectric Sample Pin-Out.

Temperature Range

-55°C to 125°C. Do not exceed 125°C.

Maximum Test Voltages

- Type AA/AB => 9V
- Type AC => 36V
- Type AD => 5V

Part Numbers

- "AA" => Die RC2-AAA 2700Å 4% niobium doped 20/80 PZT (4/20/80 PNZT)
- "AB" => Die RC2-AAA 2550Å undoped 20/80 PZT
- "AC" => Die RC2-AAA 1µ 4% niobium doped 20/80 PZT (4/20/80 PNZT)
- "AD" => Die RC2-AAA 1200Å 4% niobium doped 20/80 PZT (4/20/80 PNZT)

Capacitor:	Capacitor Size:
Blue	100,000 μ^2
Orange	40,000 μ^2
White	10,000 μ^2
Yellow	4,000 μ^2
Black	1,000 μ^2
Red	400μ^2
Silver or Green	100μ^2

Total Lead Content per Package

- Type AA/AB =>1.62 micrograms
- Type AC =>6.48 micrograms
- Type AD =>0.69 micrograms

Recovery

The platinum electroded capacitors are prone to fatigue and imprint. They are tested at their saturation voltage at packaging and may be imprinted when received. As well, they will imprint at room temperature after use. There is a recovery procedure that will fully recover the capacitor from imprint. As well, the recovery procedure will recover from 60% to 80% of fatigue loss. The recovery procedure may be executed multiple times on a capacitor. To recover a capacitor, execute a 9V (Type AA or AB), 36V (Type AC) or 5V (Type AD) square wave at 1 Hz for 100 s on each capacitor at room temperature.

Magneto-Electric Samples

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Piezoelectric Samples

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Cantilevers

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Bulk Ceramic Disk

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Thin Film (AFM/PNDS)

<TODO>: Insert description text here... And don't forget to add keyword for this topic

Precision Tester Internal Reference Elements

1.0 nF ±10% Commercial Linear Capacitor		
2.5 MW ±1% Commercial Linear Resistor		
Radiant Technologies, Inc. Type AB White Ferroelectric Capacitor	RTI Ferroelectric Capacitors	