R A D I A N T
T E C H N O L O G I E S ,   I N C .

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6 March 2013

From: Scott P. Chapman
        Radiant Technologies, Inc.

To: Precision NGS Tester and Piezo Task Suite Owner

Subj: General MTI2000 and Piezo Task Setup and Operation. High-Voltage Displacement Meter (HDVM) Configuration.

Dear Piezo Task User:

This letter accompanies the delivery of your Piezo Task Suite, either with a Precision NGS test system or subsequent to that delivery. Please note that, as of Vision 4.2.0, the Piezo Task Suite is available to all users of the Vision software. Users who have not purchased the Piezo Task Suite are able to configure the Task and access the Help pages for review. On configuration, they will see a warning that the Task must be purchased before it may be used. Those users who have not purchased the Task will not be able to execute it. Customers who have purchased the Task receive and additional file, named Security.sec, that is placed in c:\Program Files\Radiant Technologies\Vision\System. That Task is specifically keyed to the tester for which it has been purchased. It cannot be used with any other tester and is not transferable. (Note that the security.sec file is placed in c:\Program Files\Radiant Technologies\Vision\System even for 64-bit Windows versions, even though the program is located on the file path: c:\Program Files (x86)\Radiant Technologies\Vision\System. In that case the file path must be created manually for the security.sec file.)

Although any displacement meter that provides a voltage in the ±10.0 Volt range that is linearly related to the displacement being measured may be used with the Piezo Task, most customers working with bulk materials will be using the MTI2000 or MTI2100 Displacement Meter. (Thin film experimenters will normally use an AFM to detect displacement. This letter does not cover AFM configuration.) This letter provides additional instructions, beyond the scope of the Piezo Task help pages, regarding the configuration and calibration of the MTI Photonic Sensor. It then associates the MTI with the Piezo Task to provide a complete guideline for Task use. However, this guideline does not preclude a thorough review of the Piezo Task help pages.

The first section of this letter summarizes the configuration and calibration of the MTI Photonic Sensor. The second section incorporates the MTI configuration into the configuration of the Piezo Task. Finally the third section adds the High-Voltage Displacement Meter in to the experimental configuration.

Please note that the Piezo Task Suite now includes an Advanced Piezo Task and a Piezo Filter Task along with the Standard Piezo Task. Users who have purchased the Piezo Task since the release of Vision 4.2.0 should receive the entire Piezo Task Suite. Users who have not received the Advanced Piezo and Piezo Filter Tasks may upgrade their Vision installations to the current version (4.6.0 or later) and download the entire Piezo Task Suite from www.ferrodevices.com\tdownload.html. Users who own the original Precision Premier or Precision Workstation Testers (with an onboard CPU) cannot yet upgrade to Vision 4.x.x.

MTI SUMMARY

Initial Setup

This is a brief discussion of the steps taken to configure and calibrate the piezoelectric measurement equipment so that Vision software may make measurements. A more detailed discussion is presented below. This outline is not intended to replace a thorough review of the MTI2000 operating manual provided with the MTI2000 hardware. Please refer to that manual for questions or any possible confusion that result from this discussion.

1. Connect a BNC coax cable between the "CH1 Displacement" output of the MTI2000 back panel ("CH2 Displacement" if you are using the channel 2 plug-in module) and the "SENSOR" or "SENSOR 1" input on the rear panel of the Precision tester. (**Figure 1** shows the standard configuration using a RTI Simple Test Station. The configuration of the HVDM for displacement measurements is discussed further below.)
2. Press the push-button on the front pane of the measurement plug-in of the MTI2000 to select Range 1. The LED marked "1" should be lit. (For the 2032RX probe model, select "Low Resolution".)
3. Check the rear panel of the MTI2000 for correct switch settings. "Offset OUT" for the appropriate channel and "Light Source ON".
4. Position the probe over the sample in the position that you want to make the measurement. Ensure the probe is perpendicular to the sample from all directions.
5. Place the MTI2000 Mode switch in the "Cal" position.
6. Adjust the distance between the probe and the sample until the meter value is maximized, showing the optical peak.
7. Calibrate the MTI2000 by pressing the "CAL SETPOINT" button.
8. Turn the mode switch to "Displacement".
9. Press the "VOLTS/EU" button on the front panel to set the display to "Volts" as indicated by the green LED.
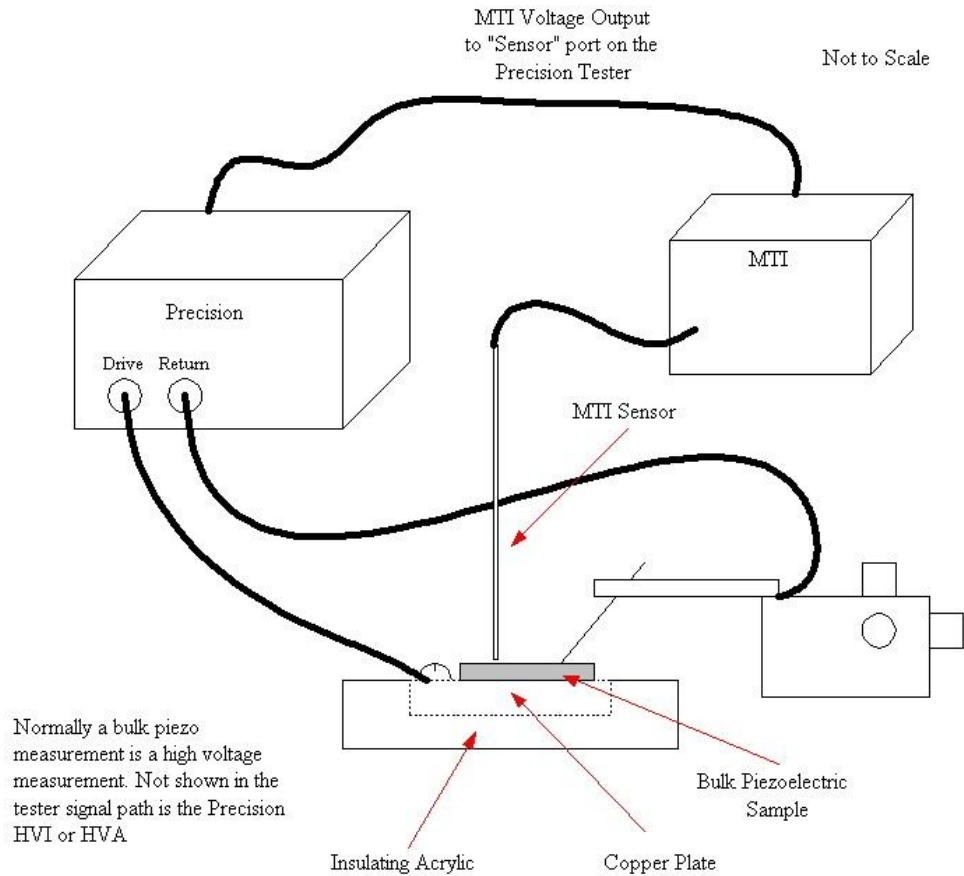10. Lower the probe towards the sample until the display reads approximately 3.5 V.

MTI Voltage Output
to "Sensor" port on the
Precision Tester

Not to Scale

MTI

Precision

Drive Return

MTI Sensor

Normally a bulk piezo
measurement is a high voltage
measurement. Not shown in the
tester signal path is the Precision
HVI or HVA

Bulk Piezoelectric
Sample

Insulating Acrylic   Copper Plate

Figure 1 - Typical Piezo Task Experimental Configuration.

For the 2032RX High-Resolution Probe

If you have the 2032 RX probe, perform these additional steps. Otherwise, skip them.

11. Select the "High Resolution" mode on the sensor module.
12. Adjust the "Offset" adjustment knob at the top of the sensor plug-in module until the digital display reads "0".

DETAILED MTI CONFIGURATION

Initial Setup

1. Connect a BNC coax cable between the "CH1 Displacement" output of the MTI2000 back panel ("CH2 Displacement" if you are using the channel 2 plug-in module) and the "SENSOR" or "SENSOR 1" input on the rear panel of the Precision tester.
2. Press the push button on the front panel of the measurement plug-in module of the MTI2000 to select Range 1. The LED marked "1" should be lit. . (For the 2032RX probe model, select "Low Resolution".)
3. Check the rear panel of the MTI2000.

   - "CH1 Offset" = "out" (down position).
   - "CH2 Offset" = "out" (down position).
   - "Light Source" = "On" (up position).

4. Position the probe over the sample in the position that you want to make the measurement.

   - The probe must be as close to perpendicular to the sample as possible.
   - The surface should have good reflectance of the probe light as shown by the signal strength during calibration. If not, place a piece of self-adhesive reflective tape over the spot to be sensed.

     NOTE: If a calibration error occurs, it means that the surface reflectance is too low.

   - You can tell if you have the probe perpendicular to the sample surface by lowering it until it lightly touches the surface of the sample. Look for the pattern of light escaping from the rim of the probe tip to be as close to uniform as possible.

     NOTE: For samples on which the electrodes occupy a significant percentage of the total area of the sample, the electrodes will warp the sample during the piezo test. Therefore, the displacement sensed at different locations over the electrode will appear to be different.

5. Place the MTI2000 Mode switch to "Cal".

   - The Mode switch is on the right hand side of the front panel.

6. Find the optical peak for the sensor.

   - Lower the probe tip until it almost touches the sample surface.
   - Raise the probe tip until the number in the display reaches its maximum. Leave the probe at that position.

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7. Calibrate the MTI2000 by pressing the "CAL SETPOINT" button.

- The CAL SETPOINT button is on the front panel under the display.
- The system will calibrate the sensor.
- During calibration, the display will increase until it reaches a value near 10.00. If it reaches this value and the "CAL ERROR" light is not lit, you may proceed. If "CAL ERROR" is lit, it is most likely an indication that the probe is not perpendicular to the sample surface.

For Probe 2032R and Probe 2032RX Plug-Ins

8. Turn the Mode switch to "Displacement".
9. Press the "VOLTS/EU" button to set the display to volts.

- Make sure the green "VOLTS" LED is lit.
- The "VOLTS" LED is to the right of the display.

10. Lower the probe towards the sample surface until the display reads approximately 3.5V. .

For the 2032RX High-Resolution Probe

If you have the 2032 RX probe, perform these additional steps. Otherwise, skip them.

11. Select the "High Resolution" mode on the sensor module.
12. Adjust the "Offset" adjustment knob at the top of the sensor plug-in module until the digital display reads "0".

PIEZO TASK CONFIGURATION

Note that with the release of Vision 4.2.0, the Piezo Task Suite includes the additional Tasks Advanced Piezo and Piezo Filter. This letter does not address those Tasks. Please refer to the help pages for detail regarding those Tasks.

The Piezo Task appears in both the QuikLook Menu and the Library. It is nearly identical in configuration and execution to the Hysteresis Task. The main difference is that the Sensor acquisition is automatically enabled. This allows voltages captured at the "SENSOR" port at the rear of the tester to be read by the software and available for display and analysis. The MTI2000 output signal is connected to the sensor port, so that this is the value read during Task data acquisition.

Figure 2 shows the Piezo Task configuration dialog.
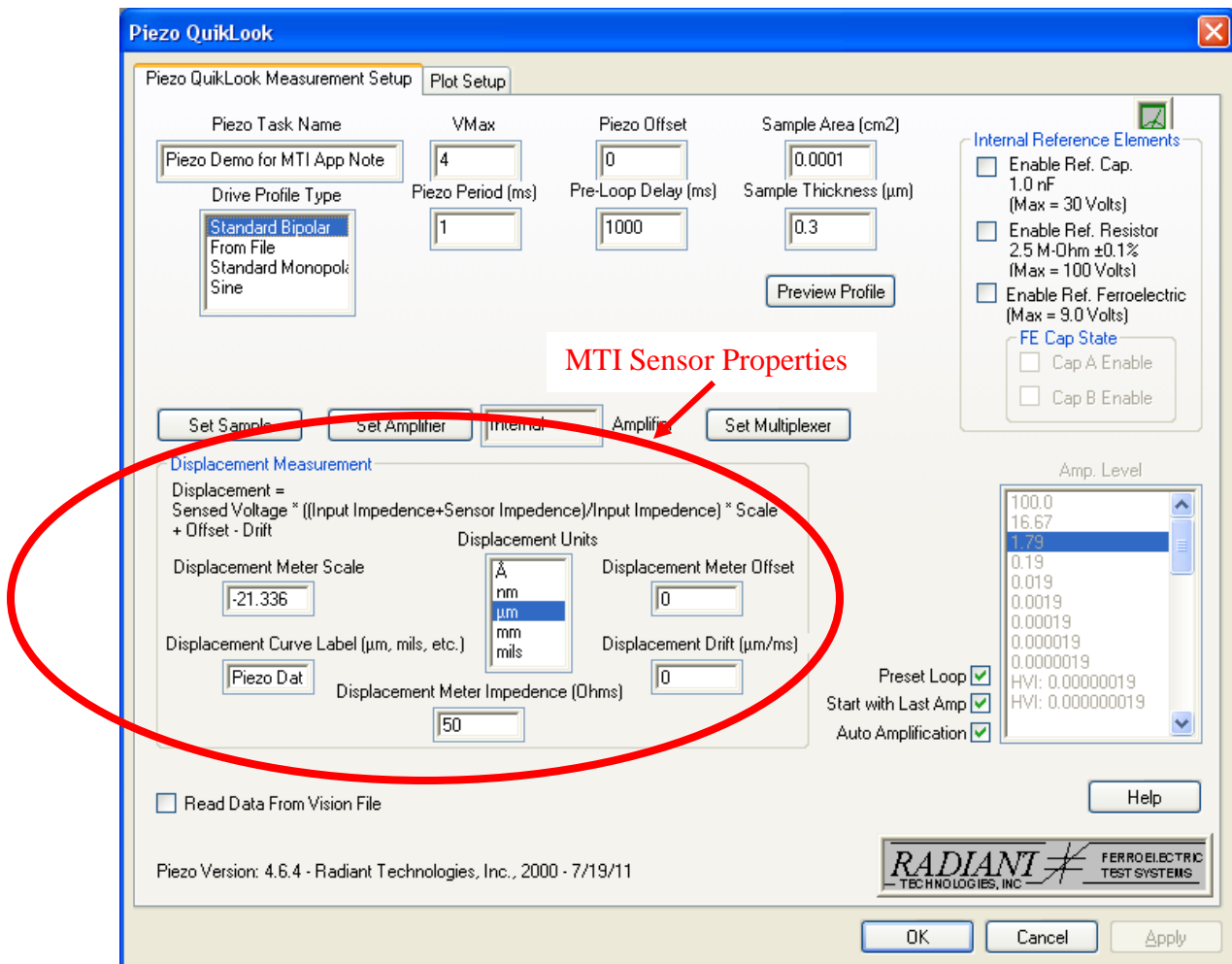
Figure 2 – Vision Version 4.6.4 Piezo Configuration.

Configuring Piezo beyond the standard Hysteresis setup is primarily concerned with parameters that affect the measured MTI sensor voltage. These controls are grouped under the "Displacement Measurement" (QuikLook) or "Displacement Configuration" (Library) heading. The controls are as follows:

- **Displacement Meter Scale** – The signal read from the MTI is a voltage that is linearly related to the measured displacement. As a result the signal can be converted back into displacement using the function:

  Displacement (µm) = Scale Factor (µm/V) x Measured Volts + Offset (µm)

  This control is where the Scale Factor in the equation is entered. This value can be read from the plug in test head unit inserted into the MTI. Pull out the unit and read the value from the label on the test head side. Normally this is given in µ-in per mV. These units will need to be scaled to produce the proper units – normally µm/V. The distance unit can be anything that the user desires, but the voltage unit must be read in whole volts. The conversion from µ-in./mV to µm/V is given by

  Scale (µm/V) = (Scale (µ-in/mV) x 2.53 (µ-cm/µ-in) x 0.01 (µm/µ-cm))/(0.001 V/mV)

  Note that the default value is given as –21.336 µm/V. This is the conversion for the test plug in at Radiant Technologies, Inc.. The value is negative because positive displacement of the sample reduces the distance between the sample surface and the sensor, resulting in a negative detected displacement.

- **Displacement Meter Offset** – This is the "Offset" term in the linear conversion between sensed voltage and displacement in the equation given in the previous section.

- **Displacement Curve Label** – A text label to be associated with the displacement measurement on the data plot.

- **Displacement Units** – This list selector allows the user to specify the units that the drift is to be reported in. The selection in this control should match the units of conversion specified in the Displacement Meter Scale control and in the Displacement Drift control, if Displacement Drift is not zero.

- **Displacement Drift** – This term is used to correct the measured data over the duration of the measurement for physical linear drift in the displacement detected that is unrelated to any stimulus signal applied to the sample. Such drift is common to AFM sensors used in measuring displacement of thin film piezoelectric materials. This value does not apply to the MTI measurement and should be left at the default value of zero. Where it is used, the drift must be characterized in advance and known to the experimenter to be properly entered, here. The drift should be entered in the same units indicated in the Displacement Units control.

- **Displacement Meter Impedance** – This is the output impedance of the MTI main frame connection that is made to the Sensor input on the Precision tester. Entering this value allows the software to correct for small errors in the measured data caused by impedance matching. The complete conversion of the sensed voltage includes this correction factor. It is displayed on the dialog and is given by:

Displacement =
Sensed Voltage x (Input Impedance + Meter Impedance)/Input Impedance x Scale + Offset – Drift

Before QuikLook execution, or after recalling the Piezo Task from a DataSet Archive, the data display is also configured. Again this configuration is similar to the Hysteresis plot configuration, with the addition of a few capabilities that relate to the displacement data.
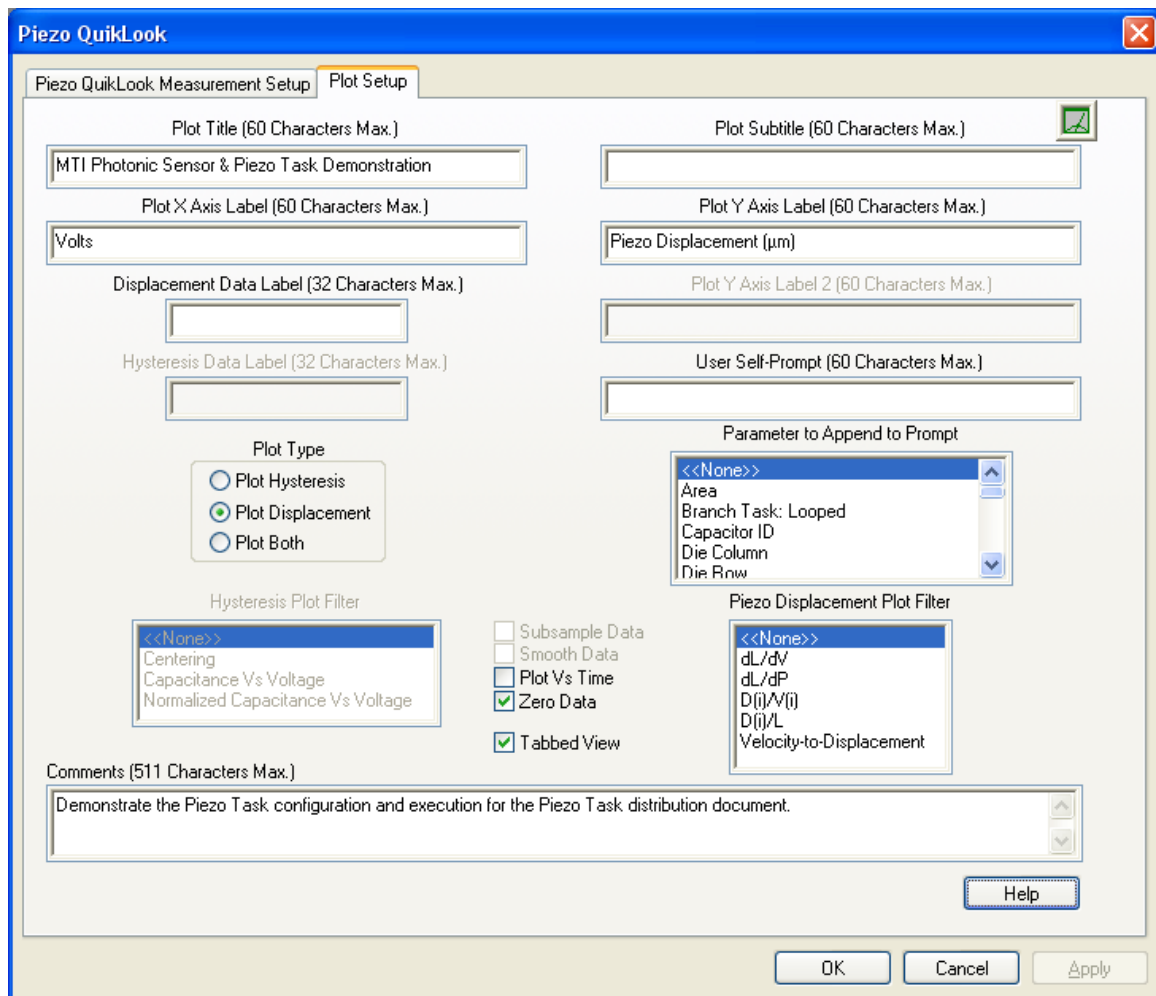
Figure 3 – Vision Version 4.6.0 Piezo Display Configuration.

The user may opt to plot Hysteresis Data only, Displacement Data only or both (as shown in the figure above). If *Plot Displacement* is selected (or *Both*), the displacement data will normally be plotted directly as μm Vs Voltage. These data may also be plotted as a

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function of measurement time, in which case, the measurement voltage will also appear as data on the plot. Several filters can also be applied to the displacement data including change in displacement per change in voltage, change in displacement per change in polarization and simple total displacement per total voltage. These filters are described in more detail in the Piezo Task help pages.

A *Zero Data* control functions as an additional displacement filter and is used to remove slow drift in the data. The *Drift* control in the main configuration dialog (not normally used with the MTI) removes drift during the actual measurement. The *Zero Data* control removes slower drift that tends to show sequential displacement measurements moving along the displacement axis. Zero data normalizes the data by subtracting the displacement value at the first measured data point from all data points, forcing the displacement to always appear to originate at zero displacement. Subsequent measurement will produce data that overlies all previous data.

THE HIGH-VOLTAGE DISPLACEMENT METER (HVDM)

Introduction:

Radiant Technologies, Inc. offers four types of high voltage test fixtures, including the Simple Test Fixture of **Figure 1**. The High Voltage Test Fixture (HVTF), has been very popular due to its ease of use and its safety features when working with high voltage ceramic samples. Radiant has a second version of the HVTF, designated the HVDM, that allows the MTI2000 Displacement Meter to monitor the piezoelectric displacement of the sample in the HVTF during high voltage testing. The HVDM simplifies the fixture requirements for the MTI2000 displacement sensor. It also decreases the effects of external vibration noise on the measurements and improves the signal-to-noise ratio of the displacement measurement.

Construction:

The HVDM is made of high-temperature Teflon and is able to withstand exposures of up to 200° C, making it ideal for both high-voltage and high-temperature testing. The HVDM separates into two parts: the bottom half holds the sample while the top half mounts the MTI sensor wand. The sample is placed in a chamber in bottom half of the fixture. A copper electrode fixed in the bottom of the chamber contacts the electrode on the bottom of the sample. A 25 kV cable connects the copper contact to an external 25 kV electrical connector. The chamber is sealed so it may be filled with insulating oil to protect the sample from the arcing that may occur in "open air". The top half of the fixture fits over the bottom half, sealing the chamber. The top half of the fixture has an unclamped copper electrode that is held in place against the top sample electrode by gravity. This contact is free to move up or down to allow for varying thicknesses of sample. It will also move vertically when the sample changes size piezoelectrically. The top electrode has its own external connector. The test fixture is attached to the Precision High Voltage Interface (HVI) DRIVE and RETURN connectors. IT IS IMPORTANT TO

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NOTE THAT THE HVI HV RETURN CONNECTION MUST ALWAYS BE MADE TO THE TOP CONNECTOR NEAR THE MTI SENSOR WAND TO PREVENT ARC-ING. When the chamber is closed the sample is fixed and completely isolated from the external world giving a high degree of high-voltage protection to other equipment and operators. Note that when the HVDM is used in high-temperature testing, sufficient time should be allowed at the test temperature in the oven to ensure that the sample, within the chamber, has reached that same temperature as the oven.
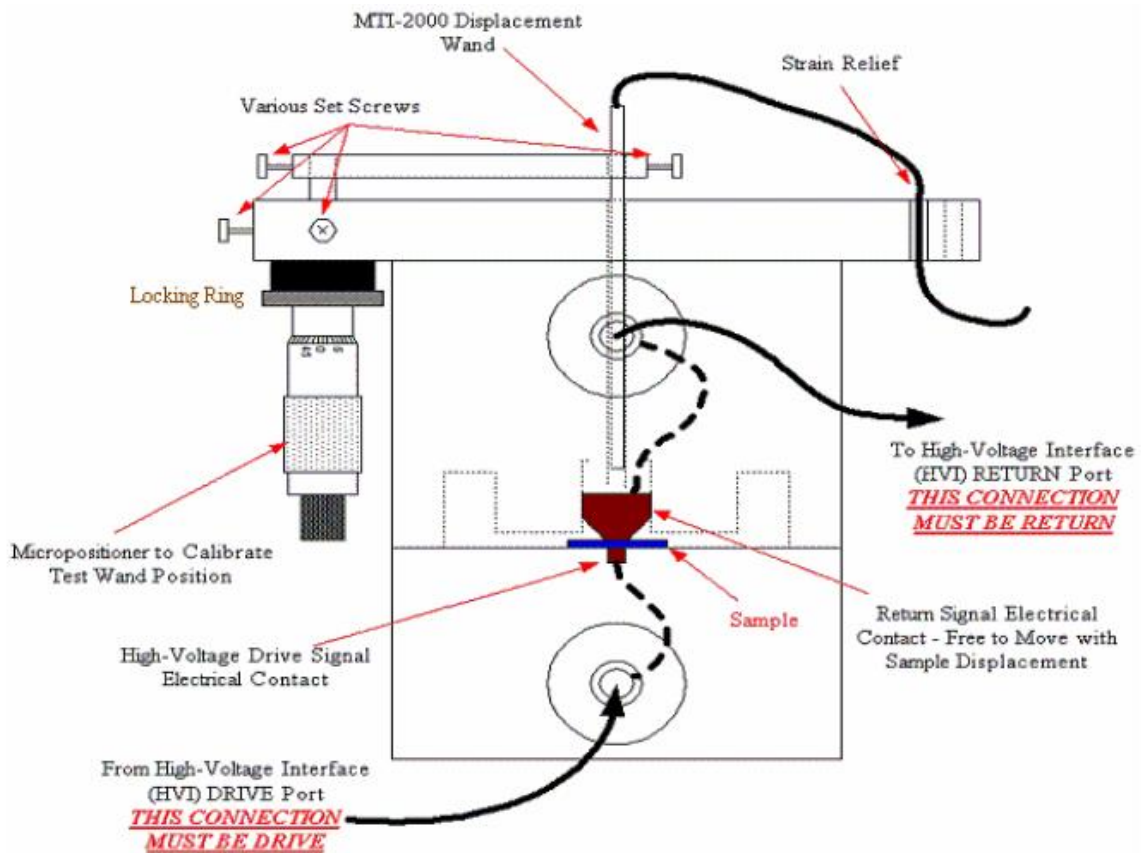
Figure 4 - High Voltage Displacement Measurement Fixture.

A micropositionable chuck system is built onto the top of the fixture. The chuck has an arm with a mounting hole for the MTI2000 sensor wand. The mounting hole in the chuck aligns with a similar hole in the Teflon at the top of the fixture. The wand is inserted through the two holes and slides in until it can stare at the top surface of the high voltage electrode. The electrode is copper and provides a high reflection surface for the MTI sensor wand. The strength of the reflected signal reaches 80% of the system limit, tens times higher than the 8% signal amplitude generated when looking directly at the electrodes on ceramic capacitors. Set screws in the chuck hold the wand in place. The contact is free to move with displacement of the sample and that motion is detected by the MTI-2000 displacement meter and recorded by the Vision Piezo Task.

Mounting the MTI Sensor Wand:

CAUTION: DO NOT MOUNT THE SENSOR WAND BEFORE LOADING THE SAMPLE. IF THE SENSOR WAND IS SET FOR A THINNER SAMPLE, THE TOP ELECTRODE OF THE FIXTURE MAY DAMAGE THE TIP OF THE SENSOR WAND WHEN YOU LOAD THE THICKER SAMPLE.

1. Twist the Locking Ring to unlock the micrometer.

2. Using the micrometer, move the chuck to a position about 2mm to 4 mm from the top surface of the fixture.

3. Using a "+" screw driver, unscrew the set screw to allow room for the wand to fit through the mounting hole.

4. Insert the MTI sensor wand through the hole in the chuck and through the hole in the top surface of the fixture until the wand touches the electrode inside the fixture.

5. Tighten the set screw to hold the wand in place.

   CAUTION: BE SURE NOT TO TIGHTEN THE SET SCREW TOO SECURELY TO AVOID BENDING OR DAMAGING THE MIT SENSOR WAND.

6. Loop the sensor cable from the wand through one of the stress relief slots on the side of the test fixture.

7. Connected the analog output of the MTI2000 control box to the SENSOR input of the Precision tester using coax cable.

8. Connect the electrical cables between the HVDM and the Precision High Voltage Interface.

   CAUTION. The MTI sensor wand is clad in metal that is connected to earth ground through the power supply of the MTI control unit. The sensor wand sits only 1 mm from the surface of the top electrode of the fixture when in the calibrated position. If you connect the HV DRIVE signal from the High Voltage Interface (HVI) to the top electrode, it will arc to the cladding of the MTI sensor wand. Our experience is that this arcing will not damage the MTI control unit, the HVI, or the Precision tester. However, there is no guarantee that damage will not occur. Furthermore, data are invalidated when arcing occurs. The HV RETURN signal from the HVI is always ground potential. Therefore, ALWAYS CONNECT THE "HV RETURN" SIGNAL FROM THE HVI TO THE TOP HVDM ELECTRODE NEAR THE SENSOR WAND.

NOTES:

To use the HVDM at elevated temperature, you must verify with Radiant that your fixture has a micrometer capable of withstanding your intended test temperature. The

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standard MTI sensor wand is for use only at room temperature. MTI sells a separate high temperature version of their sensor capable of reaching 200° C.

The MTI2000 sensor looks at the top electrode of the fixture. Therefore, the sample may be covered in oil without affecting the accuracy of the MTI2000 measurement.

Calibrating the MTI Sensor Wand:

1. Load the sample in the fixture and assemble the two halves of the fixture. Warning: Be sure to raise or remove the MTI sensor wand when loading a new sample to prevent damage to the top of the sensor wand.

2. Mount the sensor wand according to the instructions above.

3. Select "Range 1" in the upper left-hand corner of the control unit.

4. Set the MODE switch on the right middle portion of the front panel of the MTI2000 control unit to "CAL".

5. Press the button on the front panel of the control unit marked "Volts/EU". This will set the front display to the actual voltage level generated by the return signal to the sensor wand. The maximum is 10 V.

6. Using the micrometer on the HVDM, raise or lower the sensor wand until the voltage signal indicated on the front panel of the control unit is at its maximum. This maximum should occur between 8 V and 9 V.

7. Once the wand height above the electrode has been set to maximize the return signal, press the "Cal Set Point" button on the front panel and wait for the calibration routine to complete. The calibration routine is complete when the "Cal in Progress" LED goes out.

8. If at this point the "Cal Error" LED is on, refer to the MTI 2000 instruction manual for the procedures to follow.

9. If there is no error in the calibration routine, set the MODE switch to "Displacement".

10. Using the micrometer, lower the wand towards the surface of the top electrode until the sensor voltage is around 3.5 V. (Any voltage in the range 2.0 V to 4.0 V is acceptable.)

11. Twist the Locking Ring on the micrometer to lock the micrometer and the wand into position.

    IMPORTANT: The support arm holding the sensor wand is connected directly to the shaft of the micrometer controlling the height of the wand. Micrometers have play in their rotational position. This play is called "backlash" in the specification sheets of micrometers. The backlash on the micrometer of the HVDM will cause the support arm holding the wand to have a little play laterally, allowing the wand to move laterally across the surface of the electrode. That surface will most likely not be perfectly parallel with the wand so a change in the displacement will ap-

pear on the meter from the play of the support arm. <u>You eliminate this play using the locking ring on the micrometer. After positioning the arm and the wand correctly and executing the calibration procedure, be sure to "lock" the micrometer with the locking ring</u>.

If you have a 2032 sensor with the 3 mm-diameter sensor wand, you are ready to make measurements. At this point, the unit will output to SENSOR the same reading that is on the front display, (3.5 V – or in the range of 2 V to 4 V). If you are using the PIEZO Task, it will subtract out this bias so the first measurement point is zero. If you make the measurements using any other Task, they will not subtract out the bias. You can manually adjust the bias going to sensor using the rheostat on the rear panel of the MTI control unit. The rheostat on the rear panel does not affect the front panel display. It inserts a bias into the analog signal going to SENSOR so SENSOR can see zero while the front panel shows 2 V or 4 V.

If you have a 2032RX sensor, it is 10 times more sensitive than the 2032 sensor if you switch to Range 2. Switch to Range 2, unlock the micrometer, and adjust the micrometer to bring the voltage display on the front panel of the control unit to within the 0 V to 10 V range. Then, lock the micrometer again. Finally, there is a small rheostat in the upper left-hand corner of the front panel of the control unit for the 2032RX. (The rheostat is not there for the 2032.) Adjust the Rheostat on the front panel until the front display shows 0 V.

You are now ready to make measurements. When you select a measurement Task, turn on the SENSOR measurement in that Task to capture the output of the MTI2000. (Sensor capture is automatic for the Piezo Task.) Set the "Sensor Scale" to the conversion factor for your MTI2000 unit. The calibration figure for your particular unit is located on the side of the amplifier unit for the sensor wand. You must pull that amplifier unit from the mainframe to see the calibration label.

When entering the scale factor, use a negative number. The reason is that the MTI sensor wand is seeing the distance between its tip and the top surface of the sample. When the sample expands, its surface moves towards the tip, causing the MTI output signal to decrease. If you use a positive scale factor, the measurement will be correct but upside down.

The setup menu for the SENSOR input has a "Sensor Offset" value you may input. This value is subtracted from the measured data and it is another way to zero your measurements.

The "Sensor Label" is used to label the vertical axis on the data presentation. It must match the scale factor.

> NOTE: If you enter the scale factor in units of picometers instead of microns and select the "Displacement / Volts" plotting option in PIEZO, the units of the vertical axis of the data plot will be "pm/volt", the units of d_{33}.

The final value to input is the output impedance of the MTI2000. Vision uses this number to correct the measured data from voltage division that might take place between the output of the sensor unit and the input of the Precision tester.

NOTE: The output impedance of the MTI2000 is 10,000 Ω.

You may now take data.

<u>Example Data</u>

Below is a photograph of the HVDM prior to loading the sample.

Figure 5 - The Two Halves of the HVDM

Note the two electrodes of the HVDM in **Figure 5**. The top copper electrode on the portion with the micrometer is free to move vertically in its shaft.

Figure 6 shows the HVDM and MTI2000 control unit. A 2032 sensor wand is mounted on the HVDM.

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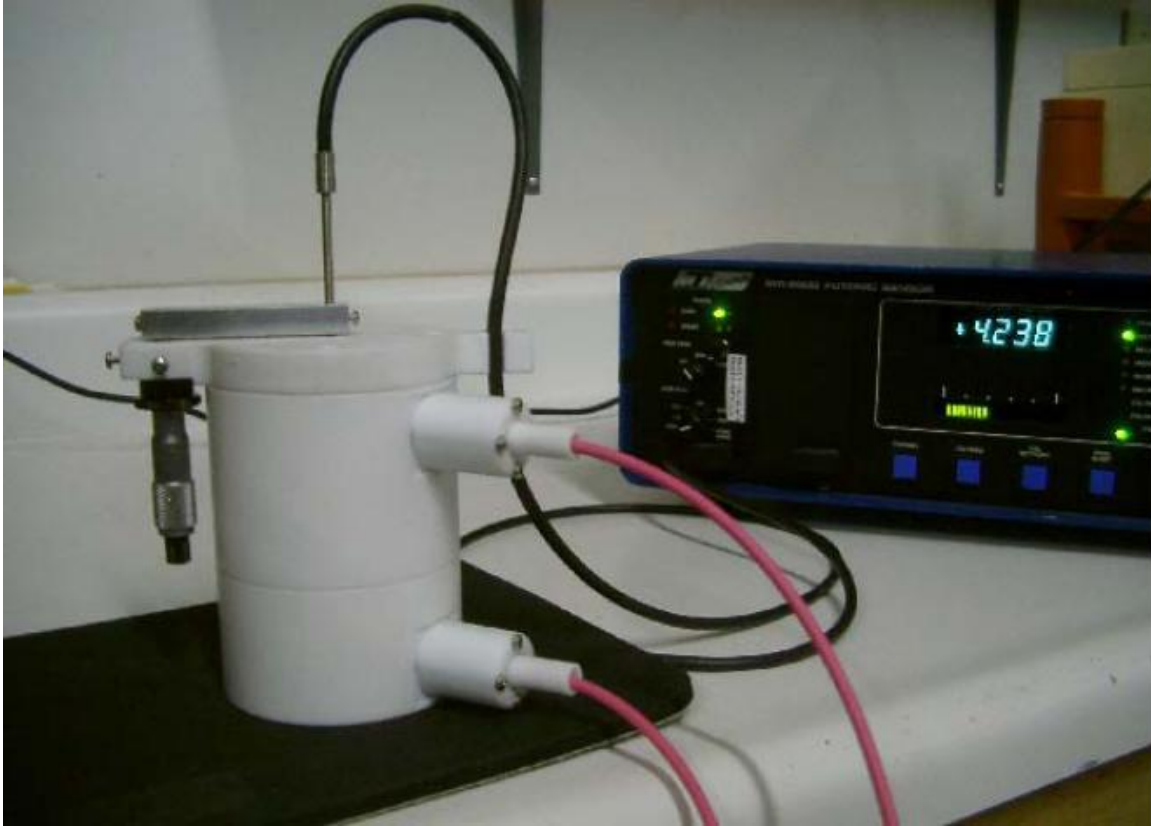
Figure 6 - HVDM and MTI2000 Control Unit with 2032 Sensor Wand.

The 2032 sensor wand has a resolution of less than 0.02 μm. But, typical noise levels on the measurement due to external vibrations run about 0.06 μm to 0.08 μm. This noise level can be reduced using an air table and acoustic shielding. Therefore, in a typical laboratory arrangement like that shown above, the 2032 sensor wand is good for measuring displacements with a total throw greater than 0.5 μm. Below that amplitude, signal-to-noise issues begin to affect the data. The SNR can be improved with averaging. Look in the "Filters" folder of the Vision Library for the specific Filter Tasks to execute averaging. Contact Radiant if you want help in setting up Vision test programs. (With the release of the Version 4.2.0 Piezo Task Suite, the Advanced Piezo Task provides several automatic noise reduction features.)

The 2032RX wand is ten times more sensitive than the 203. Because of its higher SNR, it is the best choice for measuring ceramic actuators at less than 10 kV. The 2032RX is sensitive enough to see vibrations in the building imparted by the HVAC system. If you do not have an air table for isolation, put the HVDM on the floor to eliminate the table sway. Even better, go to the lowest floor in the building and place the HVDM on the concrete slab. (The lowest floor may be the basement!) It is the most stable and most quiet location in any building.

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Finally, the MTI2000 control unit has a cooling fan. For sensitive measurements, you should place the control unit on a separate bench of shelf from the HVDM so the vibrations from the fan do not affect the test. Set the Low Pass Filter on the front panel of the control unit to 100 Hz and make your measurements at 1 Hz (1000 ms) or slower. I get my best butterfly loops using a 10-second or 20-second hysteresis period. A close-up of the HVDM is shown in **Figure 7**.

Figure 7 - Close-Up of the Loaded HVDM.

Using the fixturing shown in the figures above, I measured a 300 μm thick, hot-pressed 2/65/35 PNZT ceramic sample. The sample had an area of 3.8 cm^2. The hysteresis of the sample is shown in **Figure 8**.
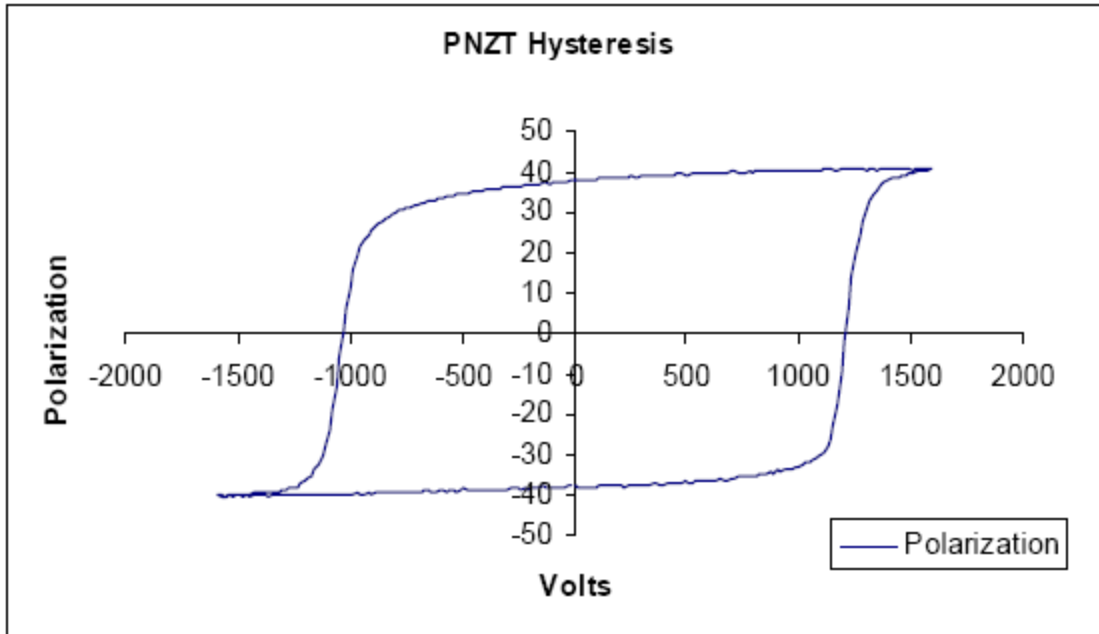
Figure 8 - Hysteresis Loop of the Sample at 1600 V.

The displacement of the top electrode caused by the sample during actuation is in **Figure 9**.
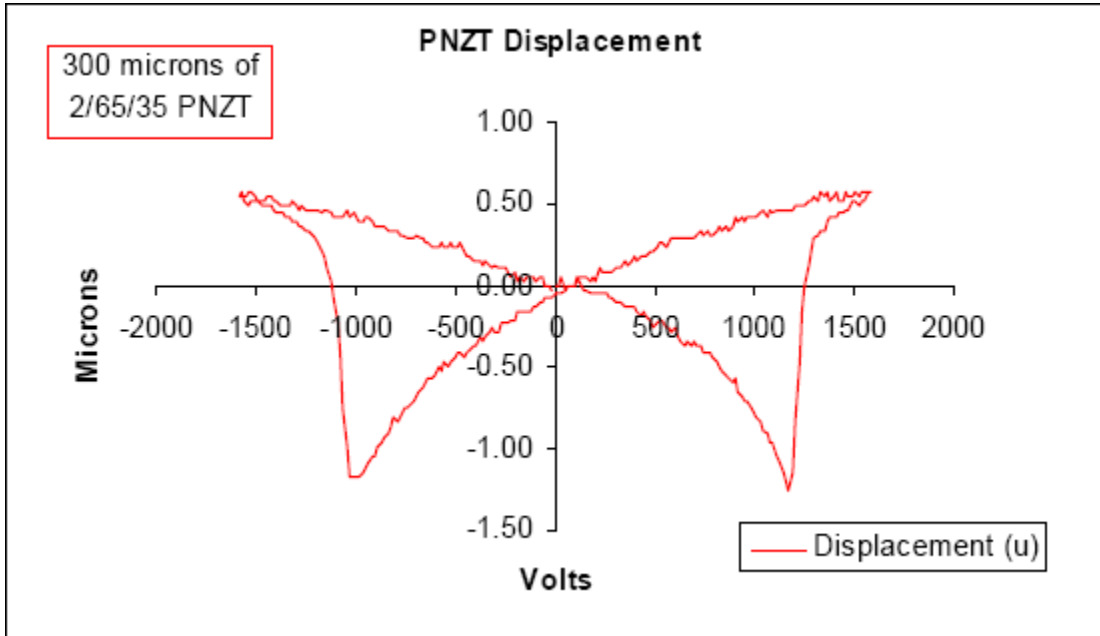
Figure 9 - Displacement Loop of the Sample at 1600 V.

To verify that none of the displacement or polarization results originated from parasitics in the HVDM, I created a "capacitor" consisting of 1.3 mm of 3M Sticky Pad papers. It

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had no electrodes. I placed the sticky pad between the electrodes of the HVDM and made a 2000-Volt measurement for polarization and displacement. They are shown together in **Figure 10**.
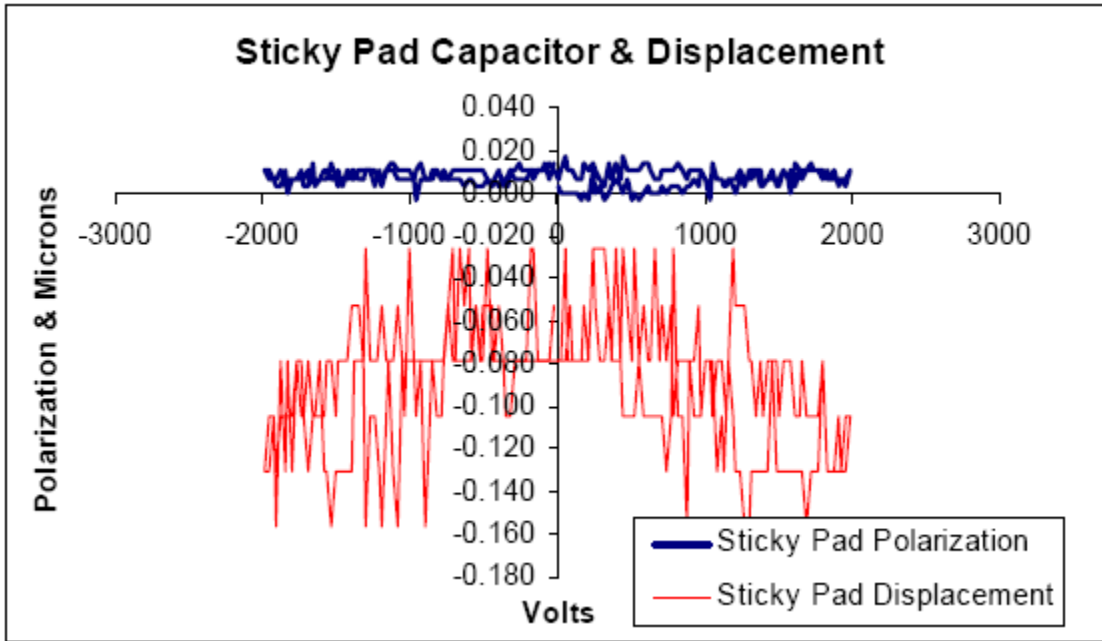
Figure 10 - Polarization and Butterfly Loop of a Sticky Pad.

The PNZT sample is compared to the "Sticky Pad Capacitor" below.
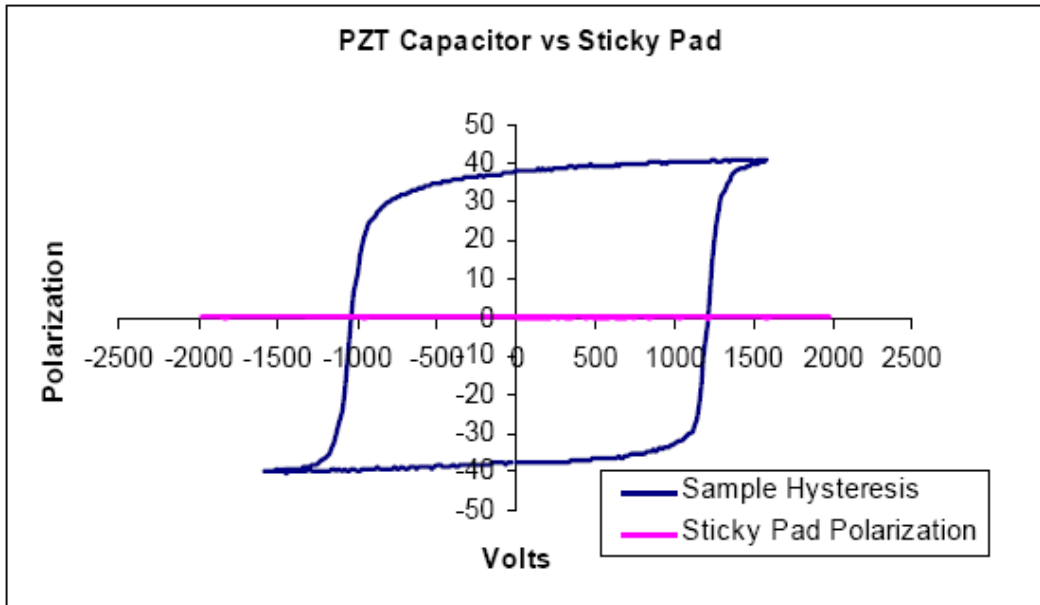
Figure 11 - Polarization of a PNZT Ceramic Vs a Null Capacitor.
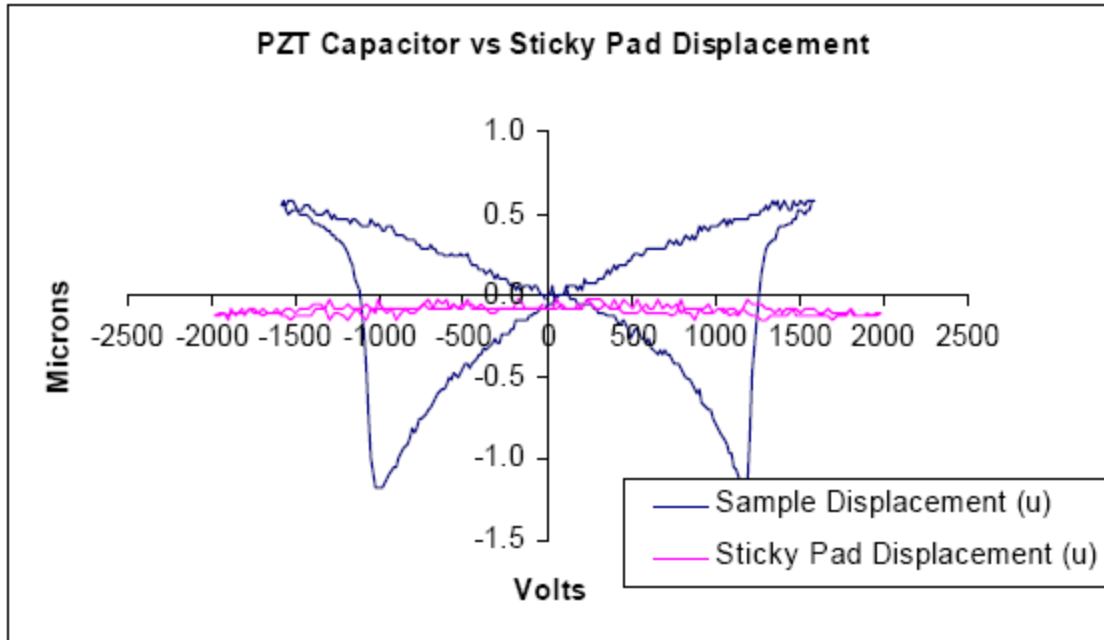
Figure 12 - Displacement of a PNZT Ceramic Vs a Null Capacitor.

The simple conclusion is that the HVDM adds almost no parasitics to the measurement of a typical ceramic sample.

This letter has provided complete documentation of the use of the MTI Photonic Sensor and the High-Voltage Test Fixture. Additional detail regarding the MTI 2000/2100 Photonic Sensor may be found in the instrument manual, shipped with the MTI. The document also provides an overview of the Piezo Task Sensor configuration to properly capture detected displacement. Much more detail is provided in the Piezo Task help pages, accessed directly through the *Help* button on the Piezo Task configuration dialog. The user should also refer to the help documentation for the Advanced Piezo and Piezo Filter Tasks. If these resources are not sufficient, please contact me immediately with any questions, comments or difficulties.

Good luck in your research.

Sincerely,

Scott P. Chapman
Computer Engineer

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