

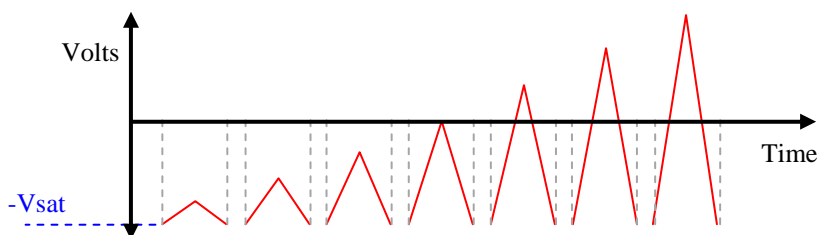
Application Note:
Creating a First Order Reversal Curves Test Definition in Vision
Rev A

Date: May 24, 2011

Author: Joe Evans

Discussion:

The First Order Reversal Curves (FORC) test consists of a series of monopolar hysteresis loops starting from the negative saturation point of the hysteresis loop. The results are then fed into a decomposition program to derive the Preisach distributions. The FORC test to measure these loops automatically may be constructed in Vision using the existing programming tools available in the Vision Library. A representative Voltage vs Time plot for a sample FORC test voltage profile is shown below.

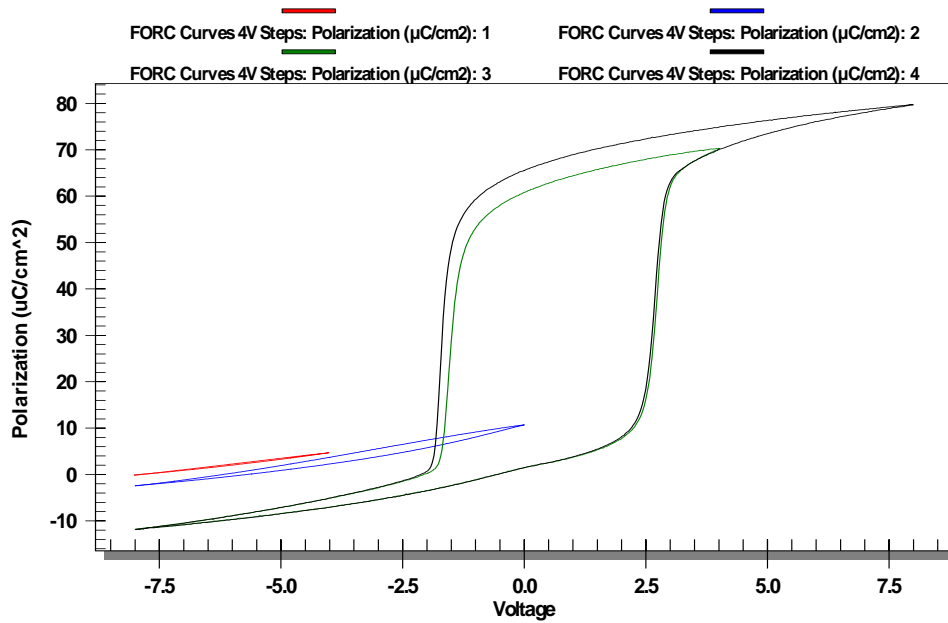


Each test consists of a monopolar half-hysteresis loop executed from an offset voltage. This mode is constructed in the Hysteresis Task menu using the controls denoted in the image at the top of Page 5. In this case, the test will start at the -8V saturation voltage by setting the “Hyst Offset” control to that value. The Monopolar Drive Profile Type is selected to produce the half-loop. The amplitude of the half-loop is set in the Vmax control. For instance, in this case where $V_{max} = 0.4V$, the tester DRIVE output will first step to -8V and then execute a half-triangle wave from -8V to -7.6V to -8V before stepping back to 0V. The integrator will only collect charge during the half-hysteresis loop, not during the steps to/from ground, so only the charge-change during the half-hysteresis loop will be recorded.

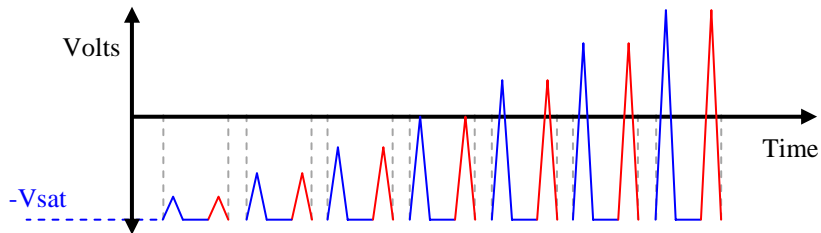
There is one exception to the description above. Some capacitors may generate so much charge during the step from zero volts to the offset voltage that the RETURN circuitry may not have time to “zero out” before the start of the monopolar loop. If such a situation occurs, all of measurements may not line up starting at zero. Such a situation is demonstrated in the next plot of four FORC loops 4 volts apart.

FORC Curves 4V Steps without Delay Period

[Type ABWHITE]



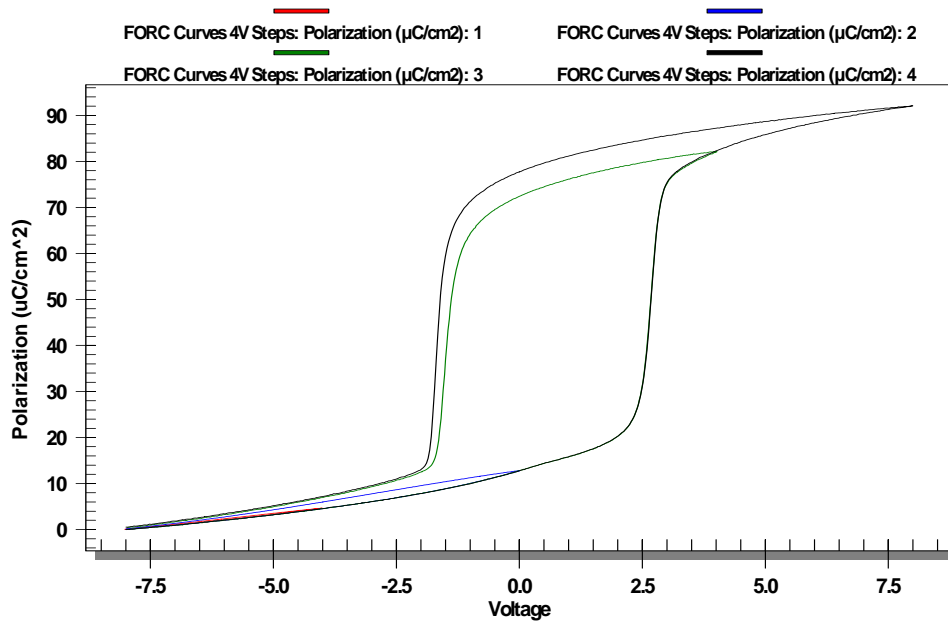
To solve this problem, turn on the Preset Loop in the menu. With the Preset Loop turned on, the tester will execute the delay between the preset and measurement loops as designated in the “Pre-Loop Delay” window of the menu on Page 5. This delay ensures that the RETURN circuitry is settled at the proper starting point before executing that measurement. The test waveform with preset and delay will look like the figure below:



The **BLUE** traces represent the Preset Loop and subsequent Delay Period before the measurement. The **RED** portion of each test is the measurement. The Delay Period cannot be invoked without turning on the Preset Loop. The effect of this change of setting can be seen in the measurement below executed on the same sample *with* the Preset Loop and Delay Period selected. Executing the Preset Loop does not affect the remanent polarization contribution to the test results because each test intentionally starts from the negative saturated polarization condition.

FORC Curves 4V Steps with Delay Period

[Type ABWHITE]



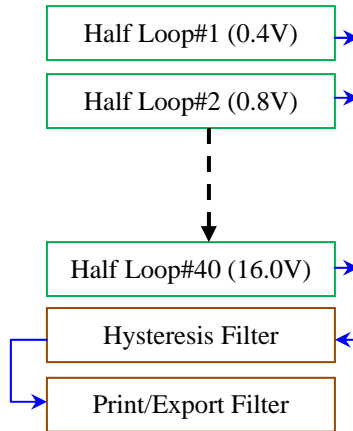
The default delay period between hysteresis loops when the Preset Loop is turned on is 1 second (1000 milliseconds). Some samples cannot withstand such a long period at the negative offset voltage. To alleviate this problem, reduce the length of the Delay Period. The Delay Period may be modified by the user to as low as 200 μs (0.2 milliseconds) on the Premier II, 1 millisecond on the RT66I and RT66B, and 1.25 milliseconds on the LC or SC. The delay period may also be made longer than one second.

The setting of the Auto-Amplification control is a critical consideration. With Auto-Amplification turned off, the tester amplification must be set manually and will not change during the test. This will minimize the number of loops executed during the test. However, for very square loops, the measurements of the non-switching portion of the FORC ensemble will be noisy because the signal will be so small compared to that of the saturated loop. With Auto-Amplification turned on, the system will automatically seek the best amplification level for each loop in the FORC series, giving a clean measurement with a high Signal-to-Noise Ratio (SNR) for the non-switching portions of the ensemble. Be aware that with Auto-Amplification turned on, the tester may execute multiple repetitions of the half-loop at each V_{max} setting to get the measurement SNR to its highest level for that half-loop.

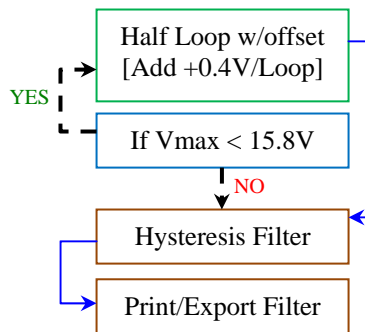
To execute with Auto-Amplification turned off, the proper amplification for the sample area must be found and set manually by the user prior to the FORC test. This is done by executing a *saturated* hysteresis loop with $V_{\text{offset}} = 0$ and Auto-Amplification turned on. The tester will settle at the proper amplification level and report that value on the data plot. Turn off the Auto-Amplification function and select that same amplification value for the FORC testing. The proper saturation voltage to use for the starting point of the FORC loops can also be found during this procedure.

Programming Vision

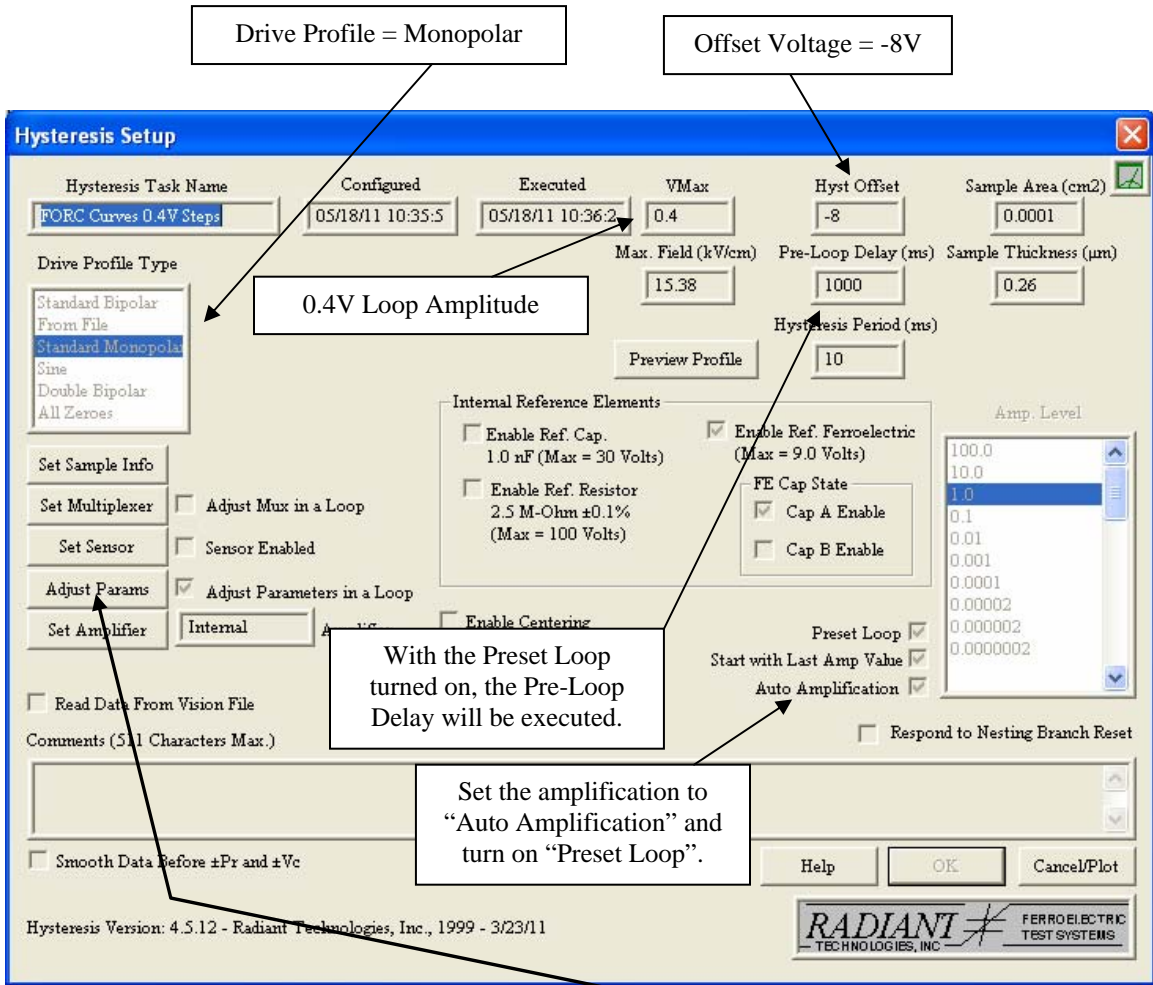
Forty loops may be executed in a program by putting forty sequential Hysteresis Tasks into the Vision Editor, each with another 0.4V added to Vmax. Use a single Hysteresis Filter Task to collect all of the loops into a single data file. A Print/Export Filter at the end of the program pointing to the Hysteresis Filter task will export all of the data in ASCII.



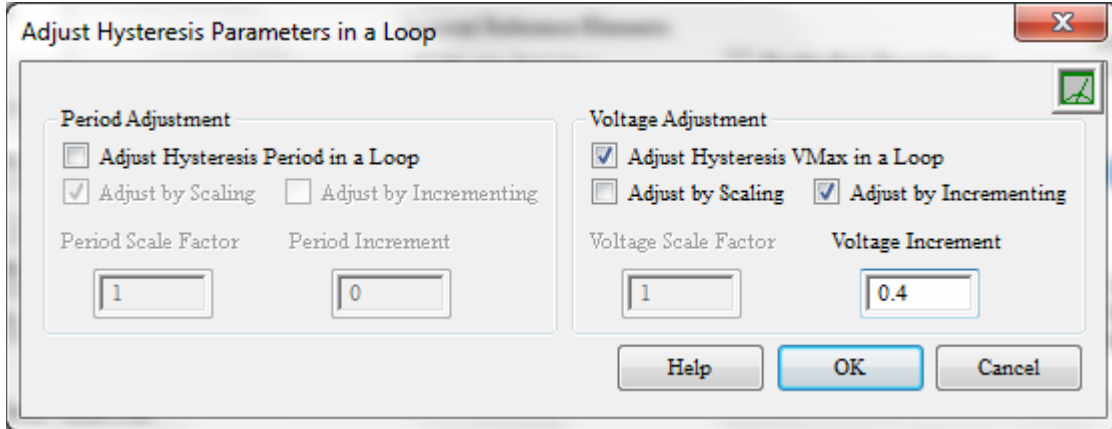
The same test may be executed in a more compact form using the Branch Task to loop around a single Hysteresis Task set to increment its Vmax on each loop.



The Hysteresis Task menu for this branching test is shown below with highlights.

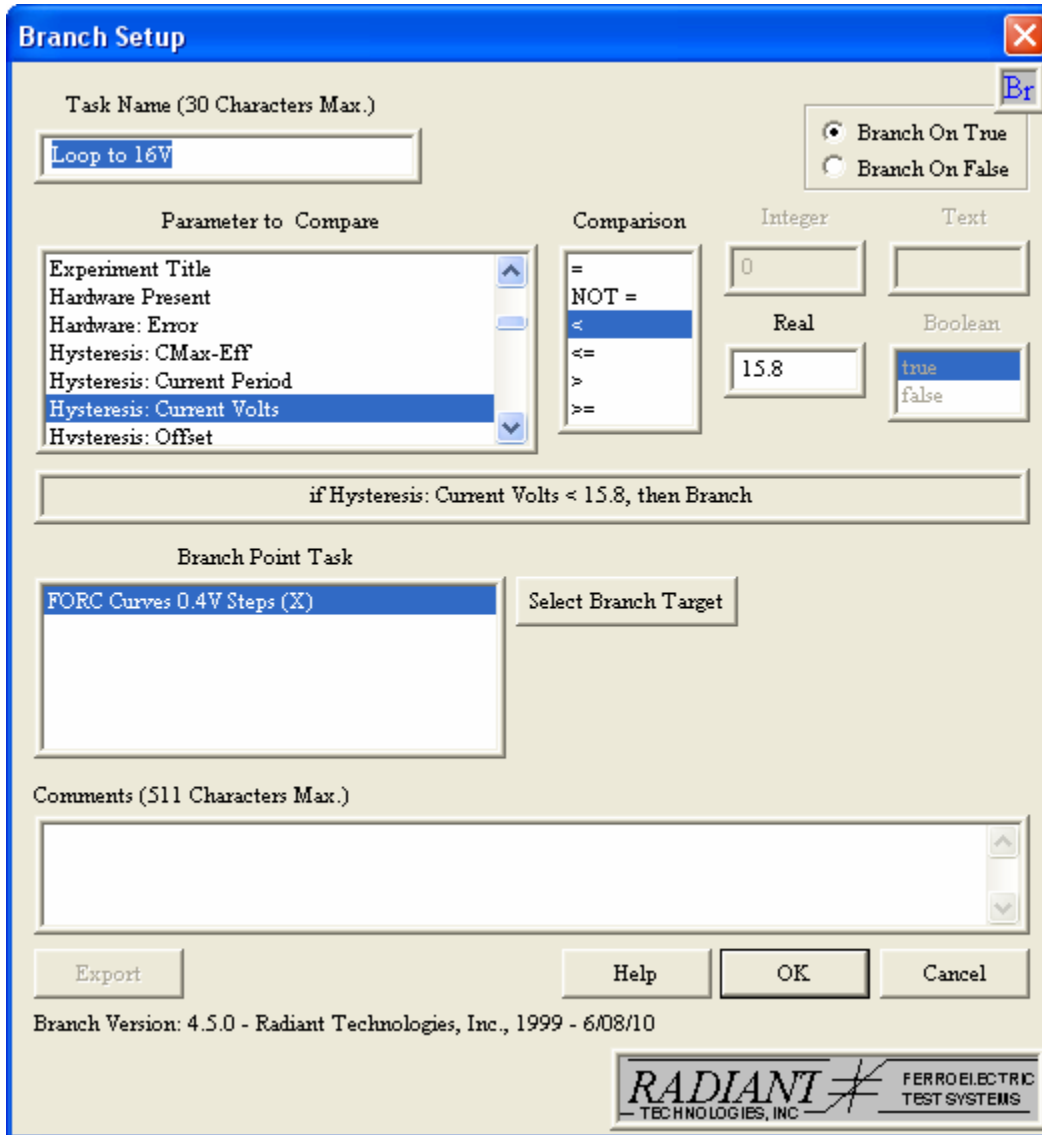


The Hysteresis Task may be set to increment its Vmax each loop by pressing the ADJUST PARAMS button on the Hysteresis menu.



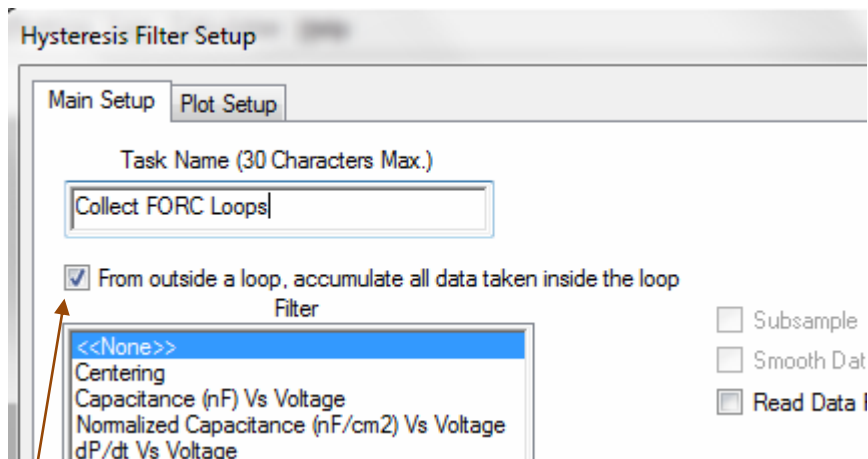
The menu above is set so that every time that Hysteresis Task is called inside a Branch Loop, +0.4V will be added to the previous Vmax value before the next test is executed. Since the starting voltage of each measurement is -8V, the amplitude of the half-loop must reach 16V to apply +8V across the sample on the last test.

The Branch Task menu to execute a test from -8V to +8V is shown below. The Branch Task is found in the Program Control folder of the Vision Library.



Note that the threshold value for the V_{max} limit is 15.8V, not 16V. The 16V value will probably work but computers are notorious for their tendency to inexactly represent numbers so the actual V_{max} variable in software may not exactly equal +16V when the “+16V Hysteresis Loop” is executed. The last voltage prior to the limit will be +15.6V so the +15.8V threshold in the Branch Menu eliminates any ambiguity to the computer about when to exit the Branch Loop.

The Hysteresis Filter placed outside the Branch Loop can be made to look inside the loop and collect *ALL* of the measured half-loops by checking the box at the top of the first page of the menu as shown below.



Check this box to collect all hysteresis measurements inside the loop.

If this box is not checked, the filter will collect only the last measurement executed inside the Branch Loop. Set the filter to <<NONE>> so that the raw measured data is collected in the filter without any mathematical manipulation. In the <<NONE>> mode, all measurements start at zero polarization plus or minus noise and drift.

Again, a Print/Export Filter task can close out the test to export the data to an ASCII file during program execution. The Print/Export Filter must point to the Hysteresis Filter. Look in the HELP files of the Print/Export task to learn how to configure the task for execution. To see the formatting by the Print/Export task of the exported data from the Hysteresis Filter, use the HELP button on the *Hysteresis Filter menu*.

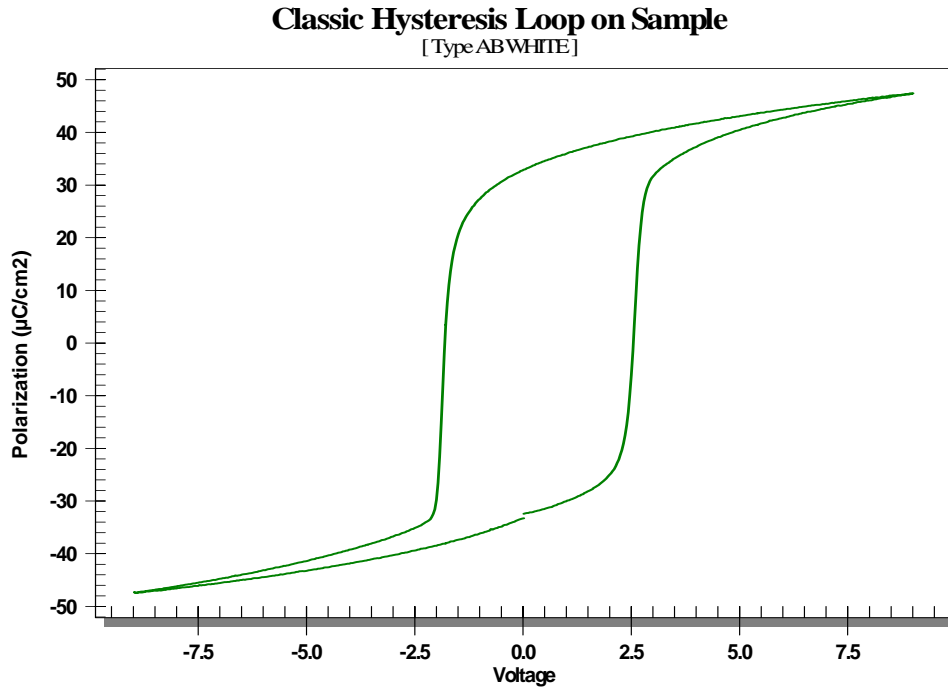
Note that there is a manual export function directly from the plot window of the Hysteresis Filter. Instead of putting a Print/Export task in the program, export the data from the Archive. To do this, open the Hysteresis Filter task from the Archive. All of the hysteresis loops will be displayed. Place the mouse cursor in the plot window, press the right mouse key, and select the "Export Dialog". Set the "Text" radio button in the upper right-hand corner of the menu and press OK. A new window will open. Choose the following settings:

- DATA (Not DATA and LABELS)
- TABLE : Points/Subsets (Not Subsets/Points)
- Maximum Precision

Press EXPORT and paste into a spreadsheet. Be sure to set the spreadsheet to place one number per cell. All forty collected loops will be exported in 80 columns using this manual transfer method.

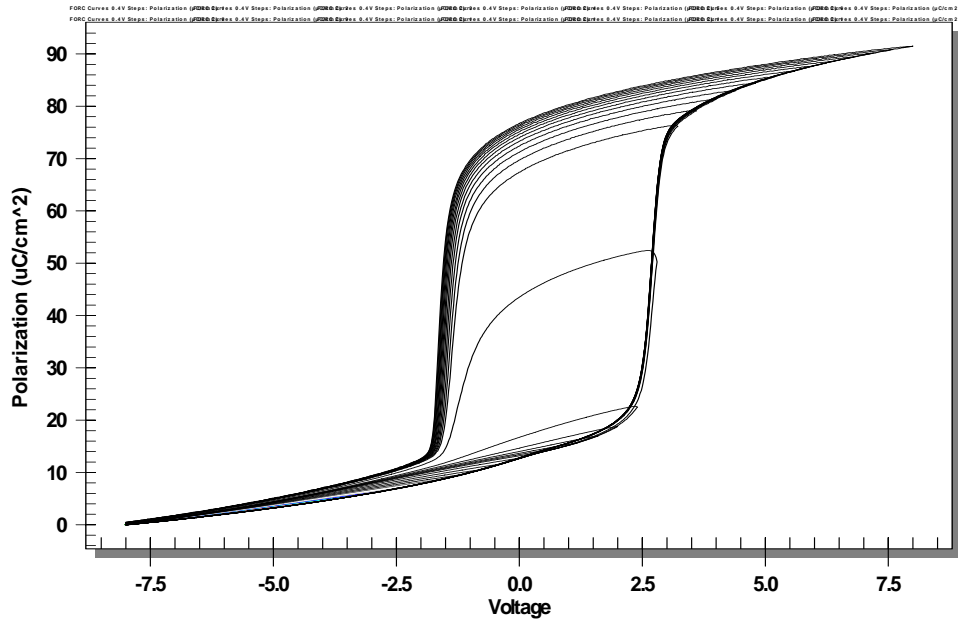
Results:

The program described above was executed on a Radiant Type AB 20/80 PZT capacitor using a Precision Premier II. The PZT was 2,600Å thick with platinum electrodes and packaged in a TO-22 transistor header. The traditional 8V hysteresis loop starting at zero volts is shown below.



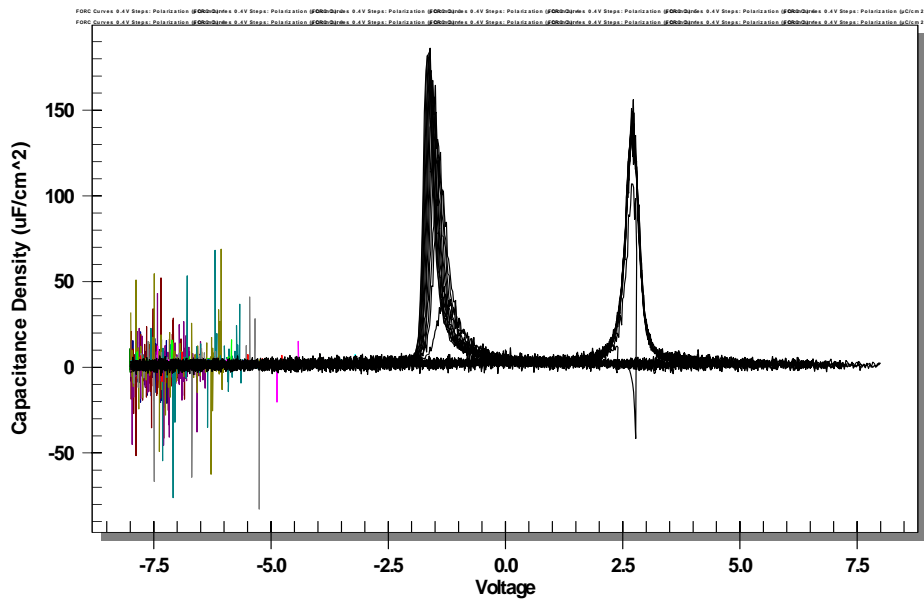
The loop is very square and saturates nicely. The 40-loop FORC test was then executed on this capacitor as described above. The forty loops are plotted together below.

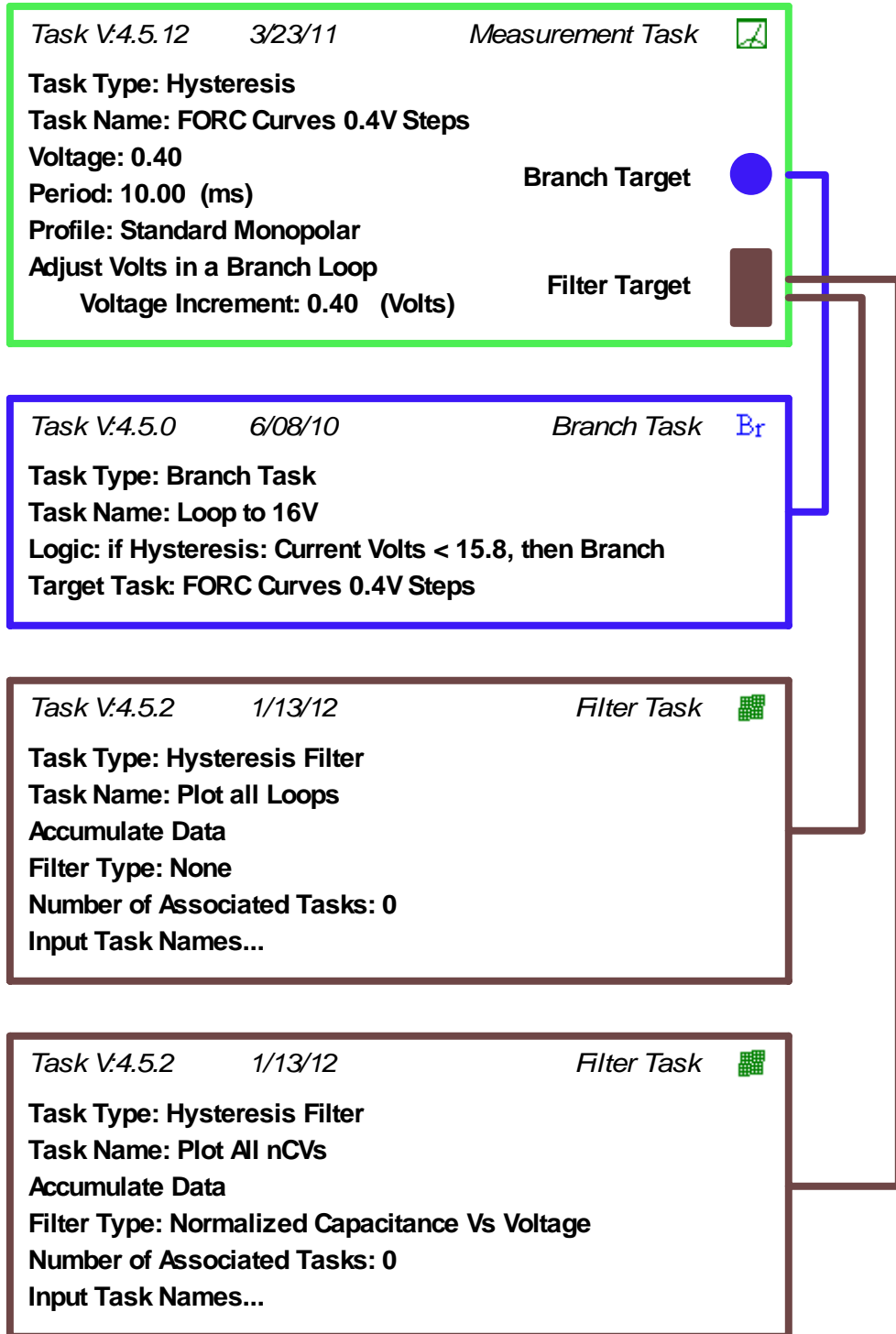
FORC Curves 0.4V Steps [Type ABWHITE]



The program description for this test exported from Vision is below. This version of the program does not include the Print/Export task. It does include a second Hysteresis Filter task to convert all of the FORC loops into large signal CV plots.

FORC nCV Curves 0.4V Steps [Type ABWHITE]





Now the Science:

There are advanced physical concepts that may be evaluated once the basic test described above is functional. The Waveform Task might be used prior to starting the Branch Loop to precondition the sample. What happens at different hysteresis frequencies other than 10ms? A third possibility would be to execute the test “backwards”, starting at +V_{sat} and running the half-loops in the negative direction. Finally, a radical departure from the literature would be to change the symmetry of the test by always testing with a +0.4V_{max} amplitude but incrementing the V_{offset} after each loop!

Conclusion:

This document describes how to create a standard Preisach FORC test using the Vision Library. Please contact Radiant for a copy of the test definition for your Library.