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Precision Tester Specifications

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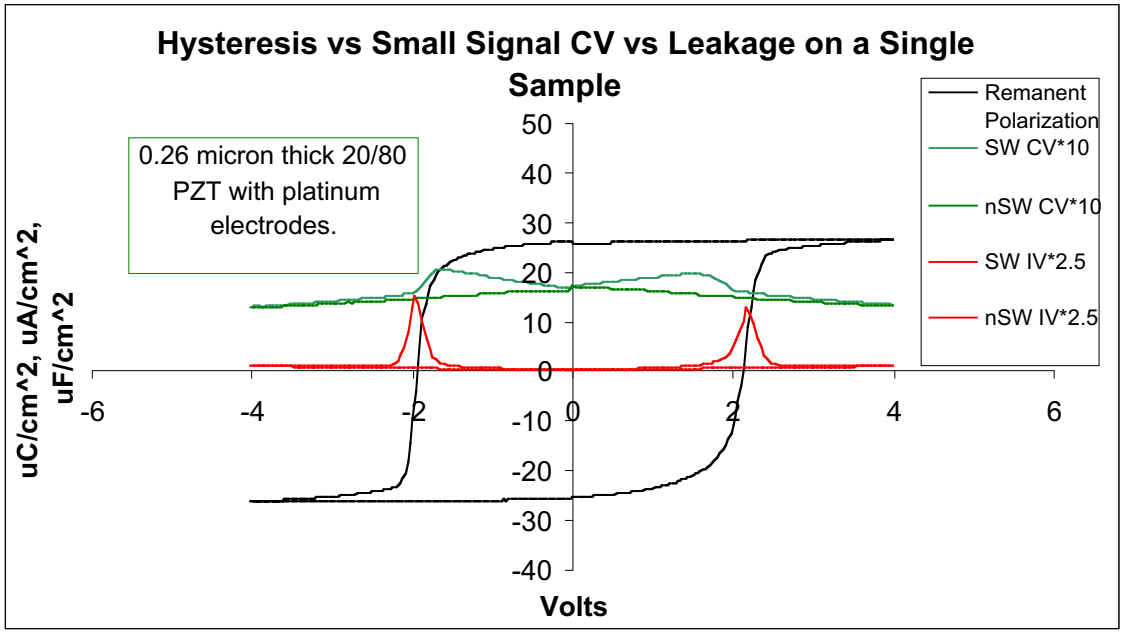
Radiant's Precision materials testers are designed unlike any other test instruments in the world. They can characterize the individual material properties of dielectric response, remanent polarization, piezoelectricity, pyroelectricity, and electrical leakage with no configuration change. More important is the fact that they can accurately determine the relationship between these characteristics in an integrated test environment. A virtual tester called Vision operates Radiant's tester hardware. Vision can construct complex programs with any number of tests to characterize all aspects of the sample in one execution while keeping track of the measurement results and the history of the sample being tested. Each Radiant tester is an extension of the Vision virtual tester and can execute any of the measurement tasks in the Vision Library. The type of tester determines the range of voltages, frequencies, and sample sizes that Vision may characterize with that tester. Only with a Radiant Precision tester can the researcher produce the plot below, executed in one hour on a Precision LC. The data shows the relationship in a single sample between the remanent polarization state and the values of its small signal capacitance and leakage.



If the sample had been in an AFM with a heated chuck, the tester could have captured the piezoelectric and pyroelectric responses as well as the ones shown in the figure.

The Precision Premier II, Radiant's most advanced tester, has the largest envelope in terms of frequency response, voltage range, and accuracy of any ferroelectric tester in the

world. It will make the measurements in the figure above with the highest fidelity over the largest frequency range.

Premier II Specifications:

- Output Range ±200V
  - 16-bit Arbitrary Waveform Generator output
  - 100 points in 50µs direct capture
  - 100 points in 10µs using interlace feature
  - 1000 points in 30 seconds
  - Pulse Widths down to 1µs and up to 1s
  - Vision controlled output ramp for maximum accuracy
- Polarization Measurement
  - 18 bit analog to digital converters – 19µV sensitivity on 10pF Csense
  - 0.5µs capture rate with 0.1µs interlace facility
  - Polarization, output voltage, and SENSOR inputs captured simultaneously
  - Minimum charge sensitivity -> 0.80fC
  - Minimum PZT capacitor area -> $0.1u^2$
  - Maximum charge measurement -> 5.3mC (526mC w/HVI attached)
  - Maximum PZT capacitor area -> $53cm^2$ (>$100cm^2$ w/HVI attached)
  - Maximum hysteresis loop frequency -> 100KHz
  - Minimum hysteresis loop frequency -> $1/30^{th}$ Hz
- 2 COMM channels for controlling high voltage amplifiers.
  - 1 legacy 26-pin COMM channel
  - 1 I^2C COMM channel
- 2 external 18-bit, ±10V SENSOR voltage inputs.
- Requires a desktop or laptop computer with USB1.0 Port or better
  Can be operated with Windows 2000™ ,Windows XP™, or Windows Vista™
- Will execute Hysteresis, Remanent Hysteresis, Small signal CV, IV, fatigue, imprint, retention, and piezoelectric displacement from one hardware configuration.

Tester Parameter	Premier II	LC	RT66B
Voltage Range (no external amp)	±200V	±200V	±10V
Voltage Range (w/external amp)	±10KV	±10KV	±10KV
Number of ADC Bits	18	16	14
Minimum Charge Resolution	0.80fC	30.5fC	122fC
Minimum Area Resolution* (assuming 1 ADC bit = 1μC/cm^2)	0.080μ^2	3.1μ^2	12.2μ^2
Maximum Charge Resolution	5.26mC	58μC	4.8μC
Maximum Area Resolution (assuming saturation polarization = 100μC/cm^2)	52.6cm^2	0.58cm^2	4.8mm^2
Max Charge Resolution w/HVI	526mC	5.8mC	480μC
Maximum Area Resolution (assuming saturation polarization = 100μC/cm^2)	>100cm^2	58cm^2	4.8cm^2
Max Hysteresis Frequency	100KHz	2KHz	0.2KHz
Min Hysteresis Frequency	0.03Hz	0.1Hz	0.1Hz
Min Pulse Width	0.5μs	50μs	50μs
Minimum Pulse Rise Time (5V)	400ns	40μs	40μs
Max Pulse Width	1s	1s	100ms
Max Delay between Pulses	40ks	40ks	40ks
Internal Clock	25ns	5μs	50μs
Minimum Leakage Current (assuming maximum current integration period = 20 seconds)	100fA	300fA	1pA
Maximum Small Signal Cap Freq.	1MHz	20KHz	2KHz
Minimum Small Signal Cap Freq.	1Hz	1Hz	10Hz
Output Rise Time Control	10^5 scaling	125KV/s fixed	2 settings
Input Capacitance	~60fF	1pF	1pF
Electrometer Input	Yes	Yes	Yes

* the minimum area resolutions depend upon the internal noise environment of the tester, the external noise environment, and the test jig parasitic capacitance.

Premier II Performance Summary:

The Precision Premier II tester is capable of executing a single pass hysteresis loop in 50µs with no interlacing of the data acquisition. The Premier II uses a 40MHz clock through a downcounter resulting in an effective maximum clock rate of 10MHz. The capture rate for the 18bit ADCs in the system is 2MHz. The driver for the Premier II will be able to interlace multiple loops to generate an effective capture rate of 10MHz on hysteresis and a total loop period of 10µs. This hysteresis measurement will be compatible with the loops measured by all of the Precision testers made by Radiant. The Premier II will execute a PUND pulse measurement with pulse widths ranging from 1µs up to 1s on capacitors with areas ranging from $0.5\mu^2$ up to multiple square centimeters. The Premier II will run all of the other measurement tasks now available in Vision including small signal CV, IV, leakage, remanent hysteresis, fatigue, imprint, retention, voltage breakdown, piezoelectric displacement, and others.

The Premier II is controlled internally by an embedded 8051 microprocessor. The microcontroller receives the test parameters and voltage profiles from the host, loads the voltages into high-speed memory, sets the clocks, and starts the acquisitions. The actual data acquisition is executed by dedicated logic under crystal clock control. The microcontroller then uploads the measured data to the host computer.

Enclosure:

The Premier II unit is housed the same enclosure as the Precision LC, making it useful either on the desktop or in a 19" rack. Each unit will have its own power pack, and will communicate with a host computer by USB.

Operating Systems:

The Premier II is controlled by Vision running on a separate computer using USB communications. The USB communications bus is the most popular high-speed serial communications standard today and it will remain embedded in personal computers for a long time to come. The operation of the USB communications standard is independent of the operating system running the computer. Its interface to the Microsoft Windows™ operating system should remain constant even as Windows evolves in the future. The Precision testers will operate on Windows 2000™, Windows XP™, Windows Vista™ and will continue to operate with future versions of Windows.

(Windows 2000, Windows XP, and Windows Vista are trademarks of Microsoft Corporation.)

Data Management Software:
Radiant Technologies actually offers only one tester: the Vision data management software. The Graphical Users Interface for Vision is the same for all testers, including the Premier II, and all of Radiant's Precision testers run under Vision. Any Precision tester from Radiant can be connected to the USB port of a host computer containing Vision. Vision will then recognize the tester and execute measurements with that tester. Vision contains all data acquisition and data analysis tasks in an attached library. Vision offers an editor where the user can combine individual tasks to create complex custom test programs. Vision stores all of the test info and test results as records in database files set up and managed by Vision. The Vision data management system is network compliant, allowing users to communicate results over a LAN or over the Internet. Using the programmability of Vision, the researcher or production test engineer may create a program to execute a complex test on a large number of samples and then let Vision execute the test unattended for 12 to 24 hours or longer.

Radiant provides a universal license for its Vision software so every researcher in the institution can load Vision on his or her laptop. They can program their tests off-line and then connect to the Precision testers to execute the measurements.

Charge Measurement Algorithm:
All of Radiant's testers starting with the RT66A in 1988 use a Virtual Ground input for the charge measurement. Radiant uses a hardware integrator behind the virtual ground to collect the charge generated by the test waveform. A hardware integrator essentially counts electrons. The Precision testers plot the data taken directly from the integrator output scaled only by the sense capacitor size to convert the measurements from volts to charge. The hardware integrator of the Premier II maintains a constant signal to noise ratio and a constant distortion envelope for the sample over the test system's entire measurement envelope.

Summary:
Radiant Technologies has striven to create a test environment that is universal across all of its testers and has minimal distortion of the measurements across each tester's performance envelope. The Precision Premier II will become the foundation of Radiant's product line for years to come, having the largest envelope in sample area and speed as well as having the least measurement distortion of any tester on the market. When combined with the power of the Vision data management system, the Precision Premier II will be capable of fully characterizing a sample in as little as $1/20^{th}$ of the time required by conventional testers.

Precision Tester Architecture:

In order to operate with Vision, the tester must have a very specific architecture that makes it an extension of the Vision virtual tester. To execute any test that Vision specifies the output of the tester must be able to produce arbitrary waveforms. To prevent distortion, the charge measurement circuitry must be able to follow whatever waveform generated by the Arbitrary Waveform Generator output (AWFG). Below are the critical design parameters that Radiant uses to create its integrated test environment along with a table comparing the different Radiant testers.

Voltage Output Stage:

The output of the test system must be an arbitrary waveform generator so it can generate any waveform for any test requested by Vision. This allows the tester to execute hysteresis, leakage, and CV without a configuration change. The parameters for an AWFG are its bit resolution, its conversion frequency, its voltage limits, and its current limits.

	Premier II	**LC**	**RT66B**
Resolution (bits)	16	12	12
Conversion Frequency	30MHz	250KHz	40KHz
Voltage Limits	±200V	±200V	±10V
Current Limits	12.5mA	12.5mA	12.5mA
Rise Time Control	Yes	Yes	Yes

*The 12.5mA current limit on the AWFG voltage output occurs during testing to prevent saturation of the measurement capacity of input electrometer. This increases the accuracy of the measurement.

Charge Input Stage:

The charge measurement circuits of the test system must hold the RETURN input at zero volts during the entire test and measure the total charge entering and leaving the sample. The critical features of the charge measurement are its frequency response, whether it is a charge amplifier or an electrometer, and the intrinsic distortion of the measurements

	Premier II	**LC**	**RT66B**
Resolution (bits)	18	16	14
Sampling Frequency	2MHz	100KHz	20KHz
Circuit Frequency Response	85MHz	4MHz	4MHz
Distortion Ratio*	850	2,000	8,000
Electrometer	Yes	Yes	Yes
Current Cancellation	50mA	50mA	50mA

*The higher the ratio of the test speed to the amplifier frequency response, the less distortion in the measurement. A ratio greater than ~700 gives less than 0.1% distortion.

**All Radiant testers have a built-in electrometer. The output voltage of the electrometer at any instance is the value of the total charge

exchanged with the sample during the test. The frequency response of the amplifiers noted above is the frequency response of the electrometer.

AWFG/Current Input Interaction:

The most critical factor controlling accuracy is the match between the AWFG output and the current measurement input of the tester. If the AWFG has too high of a rise time, the measurement input cannot follow the signal, resulting in polarization lost from the measurement. If the current output of the AWFG is too high, the input stage will saturate, again resulting in lost polarization. Frequency response is also a factor. It is better to have the input faster than the output or to match the output so the input can capture whatever the sample does in response to the output. Finally, no filtering or data post-processing can be used as they add phase delay to the results and distort the shape of the measured hysteresis relative the actual hysteresis.

	Premier II	**LC**	**RT66B**
Controlled Rise Time	Adjustable	Fixed	Fixed
Current Limit during Test	Yes	Yes	Yes
AWFG Frequency Capability	30MHz	4MHz	4MHz
Measurement Frequency Response	85MHz	4MHz	4MHz
Filtering	No	No	No
Simultaneous AWFG and Measurements*	Yes	Yes	Yes

*In all Radiant testers, the response of the sample to the last AWFG change is allowed to settle before it is captured. The output voltage is not allowed to change during the individual charge measurements. The next AWFG change occurs almost immediately after the digital sample of the sample's last charge state.