

User Manual

Ferroelectric Analyzer

Model DX-FE2000

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Contents

1 General Overview	3
2 Measurement program introduction and software description	6
2.1 Dynamic Hysteresis Measurement – DHM	6
2.1.1 Measurement procedure and typical measurement	6
2.1.2 Executing a Dynamic Hysteresis Measurement	8
2.1.3 Software description	8
2.2 Piezo Measurement – PZM	11
2.2.1 Measurement procedure and typical measurement	11
2.2.2 Execution a Piezo Measurement	13
2.2.3 Software description	13
2.3 Breakdown Measurement - BDM	16
2.3.1 Measurement procedure and typical measurement	16
2.3.2 Executing a Breakdown Measurement	16
2.3.3 Software description	16
2.4 Poling Measurement - POM	18
2.4.1 Measurement procedure and typical measurement	18
2.4.2 Executing a Poling Measurement	18
2.4.3 Software description	18
2.5 Pulse Measurement - PM	20
2.5.1 Measurement procedure and typical measurement	20
2.5.2 Executing a Poling Measurement	20
2.5.3 Software description	21
2.6 CV Measurement - CVM	23
2.6.1 Measurement procedure and typical measurement	23
2.6.2 Executing a CV Measurement	24
2.6.3 Software Description	24
2.7 Leakage Current Measurement - LM	26
2.7.1 Measurement procedure and typical measurement	26
2.7.2 Executing a Leakage Current Measurement	26
2.7.3 Software Description	27

1 General Overview

General Software tasks are the control of hardware components, extraction and further analysis of the measurement data.

As shown in Fig. 1.1 the *Graphical User Interface (GUI)* pilots the *Measurement Service*. All interactions between the user and the data acquisition from the *Measurement Hardware* is done within the *GUI*. The *Measurement Service* controls the work of the *Measurement Hardware* and interprets all responses. It informs the *GUI* to display measurement status and results.

The DX-FE2000 Software unites the *GUI* and the *Measurement Service* running as one application on the *Measurement Hardware*. The DX-FE2000 Software is used to generate the excitation signal and to acquire, interpret, save and review measurement data.

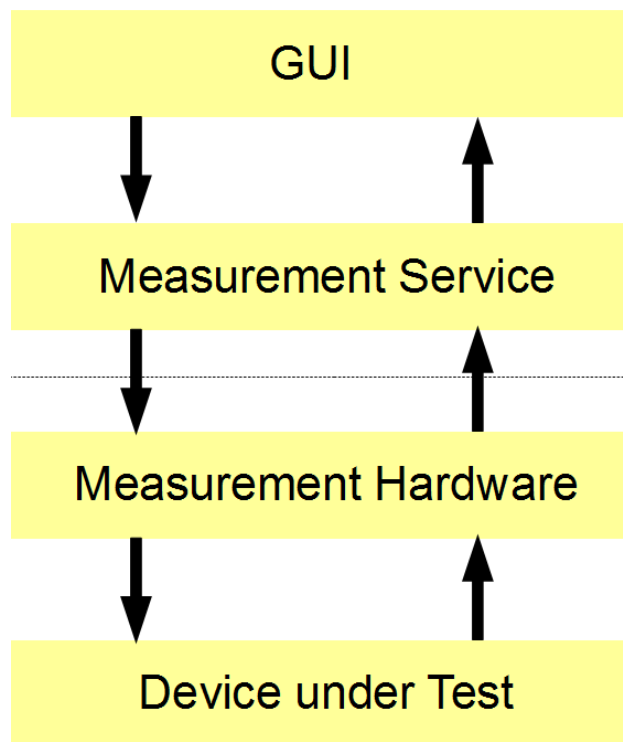


Fig. 1.1: Structure of DX-FE2000 Measurement System.

After starting the DX-FE2000 Software it is possible to execute different kinds of measurements. The GUI of the DX-FE2000 Software visualizes the measurement results as is shown in Fig. 1.2.

Thereby the GUI is divided into two logical parts. This arrangement complies with human preferences of comprehension.

Input parameters

Data Visualization

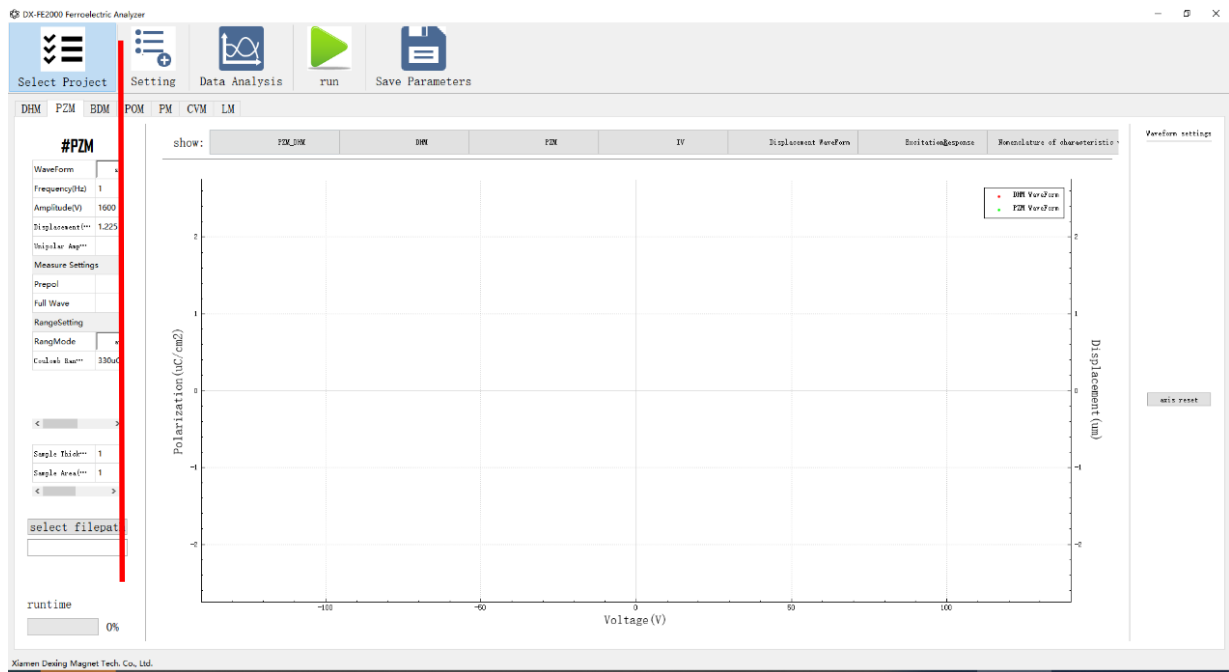


Fig. 1.2: Main program window of the DX-FE2000 Software

The DX-FE2000 software performs a variety of measurements including DHM, PZM, BDM, POM, PM, CVM, LM. By clicking on the “Select Project” tab and selecting the desired test type from the test item types that appear. By clicking on the “Setting” tab, you can adjust the counting parameters in the pop-up parameter settings screen. Notice that every time you modify a parameter, you must click the “Save Parameters” option to save the operation, the set parameter can take effect. The High Voltage Amplification can be adjusted as needed.

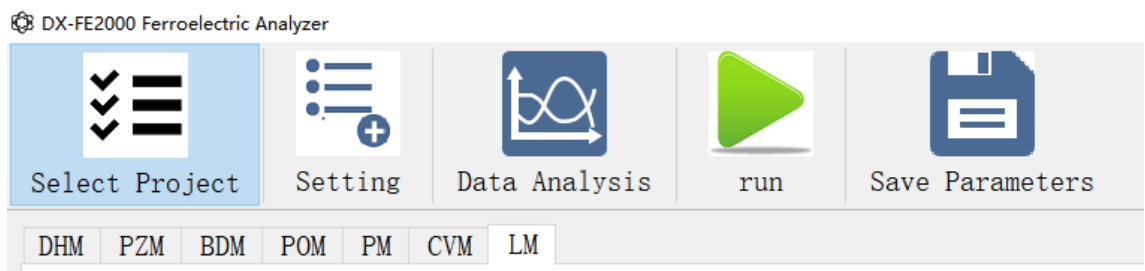


Fig. 1.2 Selecting Test Item Type

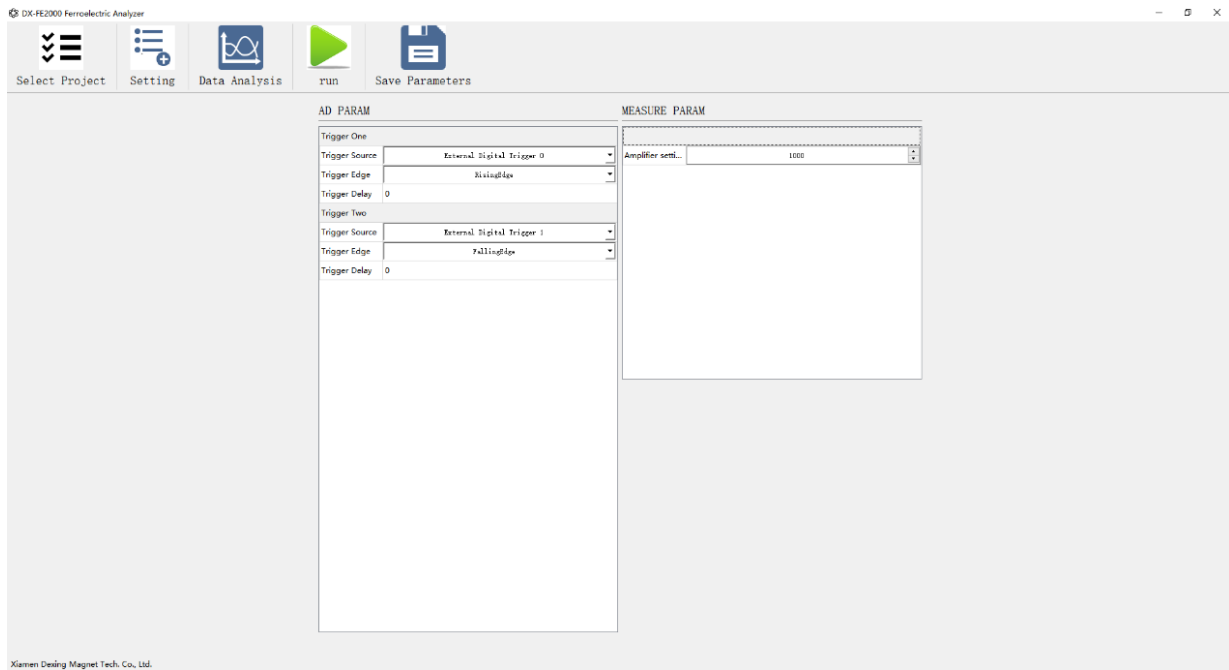


Fig. 1.3 Parameter Settings

Check any basic measurement type, click on the “select filepath” button at the bottom left of the software, you can change the data storage location, the dialog box shown in Fig 1.3.

2 Measurement program introduction and software description

2.1 Dynamic Hysteresis Measurement – DHM

2.1.1 Measurement procedure and typical measurement

The DHM records the hysteresis loop of a ferroelectric material and assists to examine the influence of process parameters on the shape of the hysteresis loop. Measurement parameters like amplitude or frequency of the excitation signal can be varied. The software extracts the characteristic values like P_r , V_c etc. from the hysteresis loop.

Typically an excitation signal needs to be generated to record the hysteresis return line, such as the triangle wave signal shown in Fig 2.1. If the “Prepol” setting is checked, a prepolarized pulse signal and three bipolar excitation signals are generated. Each signal is followed by a relaxation time of 1 second. The prepolarization pulse and the second pulse of the excitation signals determine the polarization state of the material. After the prepolarization pulse treatment, the material has a negative relaxation remanent magnetization polarization state. After the second pulse treatment, it ends up under a positive relaxation remanent magnetization polarization. The corresponding hysteresis return line of the bipolar excitation signal is shown on the right side of Fig 2.1.

To record the hysteresis loop the first pulse of the first signal starts in the negative relaxed remanent polarization state (P_{rel-}) and turns into the positive saturation (P_{max+}). When the voltage is equal to zero volt the polarization reaches the positive remanent polarization state (P_r+). Afterwards it turns into the negative saturation (P_{max-}) and then back to the remanent polarization state (P_r-). This point is normally not equal to the starting point (P_{rel-}) because of the loss of polarization over time.

The third signal starts in the positive relaxed remanent polarization state (P_{rel+}), turns into the negative saturation (P_{max-}) crosses the polarization axis at zero volts excitation signal in the negative remanent polarization state (P_r-). Then the sample is driven into the positive saturation (P_{max+}) and finally ends in the positive remanent polarization state (P_r+) when the voltage is zero. A software calculation balances the hysteresis loop respectively to the values $P(V_{max+})$ and $P(V_{max-})$.

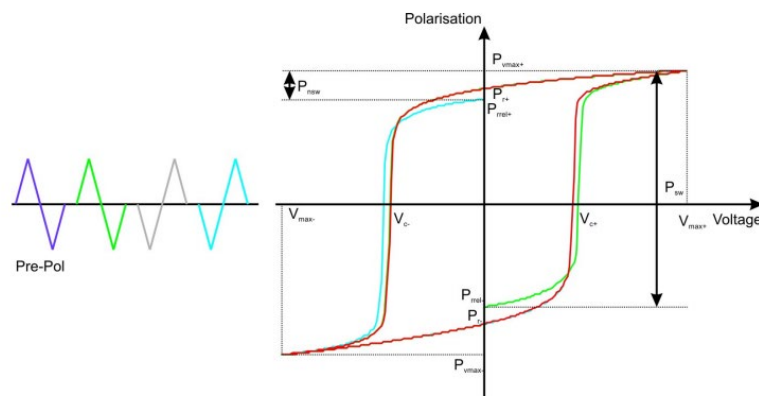


Fig. 2.1 Polarization vs. Voltage graph of a Dynamic Hysteresis Measurement with prepolarization.

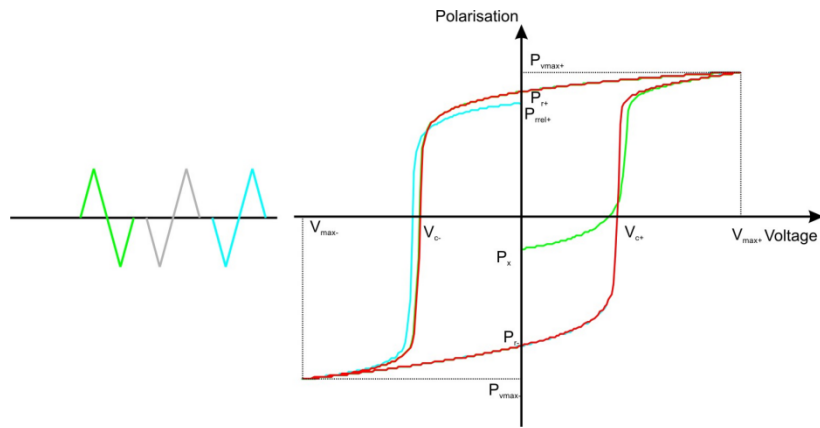


Fig. 2.2 Polarization vs. Voltage graph of a Dynamic Hysteresis Measurement without prepolarization

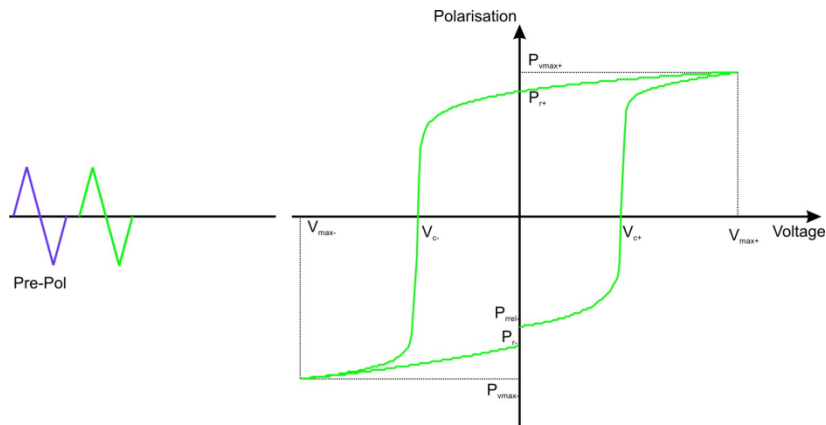


Fig. 2.3 Polarization vs. Voltage graph of a single loop Dynamic Hysteresis Measurement with prepolarization

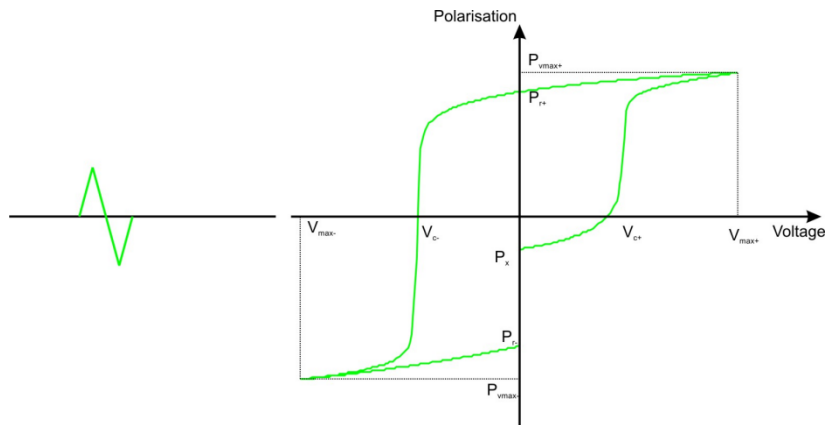


Fig. 2.4 Polarization vs. Voltage graph of a single loop Dynamic Hysteresis Measurement without prepolarization

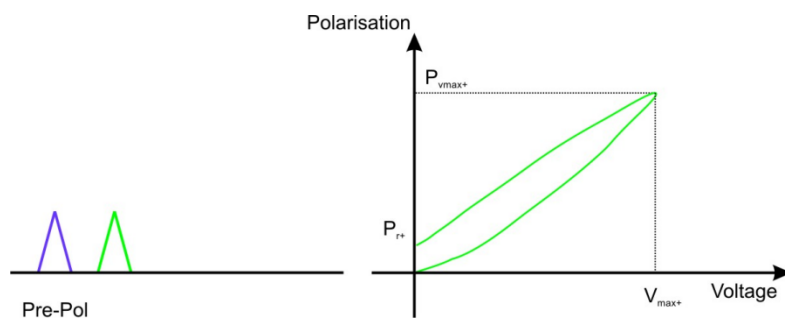


Fig. 2.5 Polarization vs. Voltage graph of a unipolar, single loop Dynamic Hysteresis Measurement with prepolarization

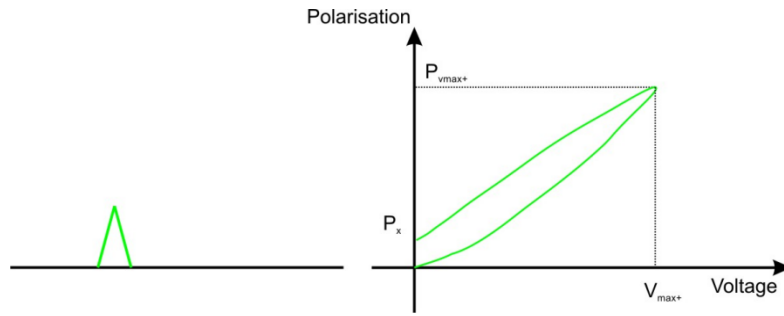


Fig. 2.6 Polarization vs. Voltage graph of a unipolar, single loop Dynamic Hysteresis Measurement without prepolarization

2.1.2 Executing a Dynamic Hysteresis Measurement

Click DHM in the “Select Project” dialog box of DX-FE2000 software, adjust the parameters and click “Save Parameters”, then press “Run” button to execute DHM measurement.

The DX-FE2000 software allows the monitoring of different types of measurements during the measurement process. Select the type of measurement to be monitored by clicking on the “DHM”, “Excitation Response”, “IV”, “Nomeclature of characteristic” tab in the upper right corner of the measurement screen. tab in the right corner of the measurement screen to select the type of measurement to be monitored.

2.1.3 Software description

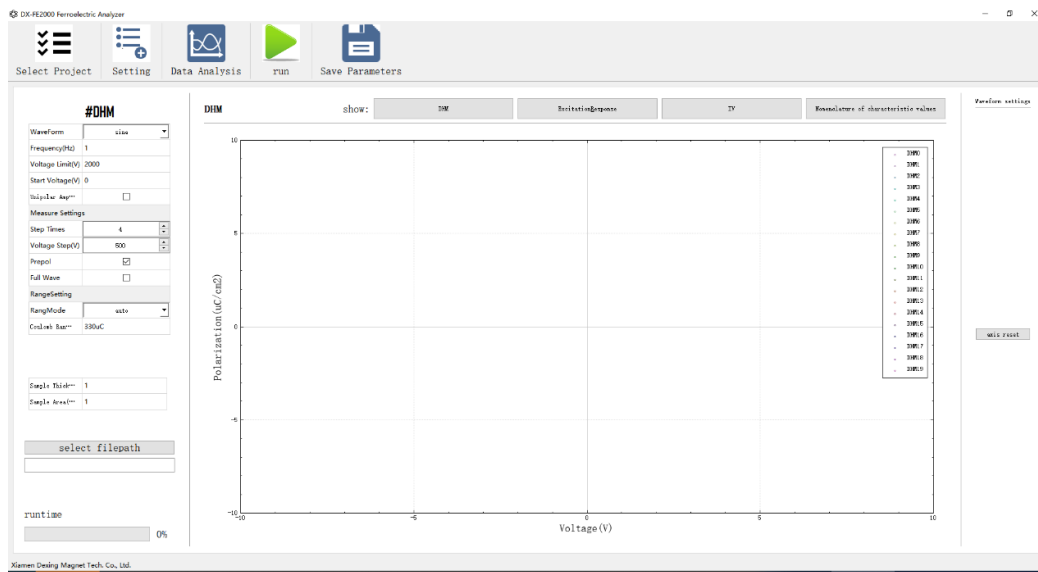


Fig. 2.7 DHM Measurement Interface

Table 2.1: Input Test Parameters

Name	Range values	Unit	Description
Waveform	sine or triangle wave		waveform of the excitation signal
Frequency	0.01Hz to 1Mhz	Hz	varies depending on hardware
Voltage Limit	0 to 10 kV	V	voltage threshold of the signal
Start Voltage	0 to 10 kV	V	voltage value at start of measurement
Unipolar Amplification	enabled or disable		unipolar voltage amplitude, only positive part of the staircase waveform is generated
Measurement settings			
Step Times	customizable		number of voltage increases
Voltage Step	customizable		voltage step, incremental voltage per step
Prepol	enabled or disable		setting the polarization state before measurement
Full Wave	enabled or disable		full-wave testing, excitation signals using positive and negative polarity
Measurement range setting			
Range Mode Range	Manual or Automatic		range selection with automatic or manual adjustment
Coulomb Range	from 330 to 0.0033	μC	range of charge measurement
Sample Parameter Setting			
Sample Thick	customizable	μm	Thickness of the test sample
Sample Area	customizable	cm^2	Are of the test sample

Table 2.2: Graphic column parameters

Value	Description	
DHM	X-axis	Voltage (kV)
	Y-axis	Polarization($\mu\text{C}/\text{cm}^2$)
IV	X-axis	Voltage (kV)
	Y-axis	Current(μA)
Excitation Response	X-axis	Time(s)
	Y-axis	Voltage profile(V); charge curves (μC)

Table 2.3: Nomenclature of characteristic values

Value	Unit	Description
V _{max+}	V	maximum voltage
P _{r+}	uC/cm ²	positive state of remanent polarization of the dynamically measured hysteresis loop
P _{rrel+}	uC/cm ²	positive state of relaxed remanent polarization, relaxed for one second in the P _{r+} state.
P _{vmax+}	uC/cm ²	state of polarization when the stimulating signal reaches its maximum value – positive saturation
V _{c+}	V	positive coercive voltage, voltage at which the polarization crosses the x-axis with increasing voltage values
I _{pk+}	uA	peak current
P _{sw}	uC/cm ²	= (P _{max+} – P _{rrel-}): change of polarization when the sample is switched from the negative state of the relaxed remanent polarization into the positive saturation
V _{max-}	V	minimal voltage
P _{r-}	uC/cm ²	negative state of remanent polarization of the dynamically measured hysteresis loop
P _{rrel-}	uC/cm ²	negative state of relaxed remanent polarization
P _{vmax-}	uC/cm ²	minimal positive polarization strength
V _{c-}	V	negative coercive voltage
I _{pk-}	uA	negative peak current
P _{nsw}	uC/cm ²	= (P _{max+} – P _{rrel+}): change of polarization when the sample is driven into the positive saturation from the positive state of the relaxed remanent polarization
V _{cShift}	V	medium of V _{c+} and V _{c-}

2.2 Piezo Measurement – PZM

2.2.1 Measurement procedure and typical measurement

The Piezo Measurement (PZM) performs hysteresis measurements and records simultaneously sample displacement data. Therefore it is necessary to capture the sample strain by an additional external displacement sensor. This combination allows a comfortable and comprehensive investigation of the frequency dependence of the hysteresis loop and the piezoelectric or electrostrictive displacement in the hardware limited range.

The influence of process parameter can be examined on the shape of the butterfly curve. The measurement parameters such as excitation signal, frequency and amplitude of the excitation signal can be varied.

The voltage excitation signal is shown in Fig. 2.8 for a triangular voltage excitation. If selected, the prepolarization pulse establishes a defined polarization state. In the case of a positive Amplitude, it is the negative state of relaxed remanent polarization. The prepolarization pulse is followed alternatively by one or three consecutive bipolar excitation signals. Each signal is separated by a defined relaxation time entered in the field *Delay*. The butterfly curve and the hysteresis loop corresponding to the bipolar excitation signal are shown in Fig. 2.8.

The hysteresis loop corresponding to pulse no.1 starts in the negative relaxed remanent polarization state (P_{rel-}) and turns into the positive saturation (P_{max+}). When the voltage equals zero the polarization reaches the positive remanent polarization state (P_r+). Following the curve it turns into the negative saturation (P_{max-}) and then back to the remanent polarization state (P_r-). P_r- is usually not equal to the starting point (P_{rel-}) because of the polarization loss over time.

The butterfly loop is centered automatically to start at zero displacement.

To gather additional information about the hysteresis loop, two additional cycles can optionally be applied. The second loop is applied to change the sample into the positive remanent polarization state. No data are sampled during this loop. The third loop starts in the positive relaxed remanent polarization state (P_{rel+}), turns into the negative saturation (P_{max-}) and crosses the polarization axis at zero volt excitation signal in the negative remanent polarization state (P_r-). Then the sample is driven into the positive saturation (P_{max+}) and ends in the positive remanent polarization state (P_r+) when the voltage is zero. The polarization loops are centered to the values $P(+V_{max})$ and $P(-V_{max})$. The parameters V_{c-} , P_r- , P_{rel-} are extracted from the data of the first loop and respectively the parameters V_{c+} , P_r+ , P_{rel+} from the third loop. The closed hysteresis loop is plotted with the second half of the first and the second half of the third loop. The data of the first and third cycle are displayed for the displacement.

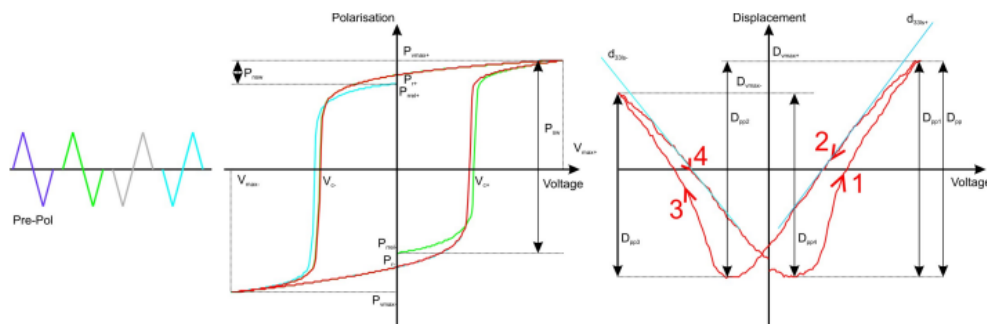


Fig. 2.8 Polarization vs. Voltage graph of a Piezo Measurement with prepolarization

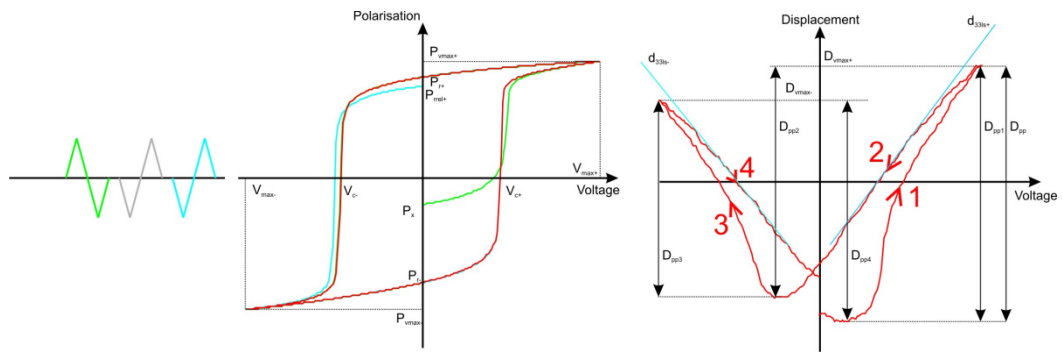


Fig. 2.9 Polarization vs. Voltage graph of a Piezo Measurement without prepolarization

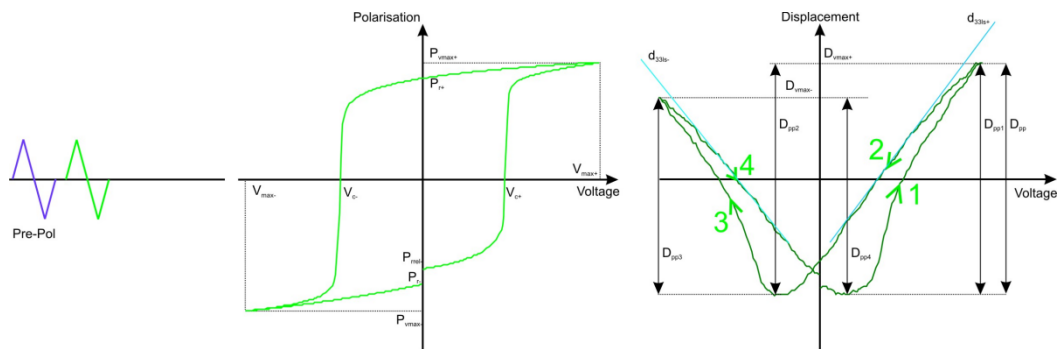


Fig. 2.10 Polarization vs. Voltage graph of a single loop Piezo Measurement with prepolarization

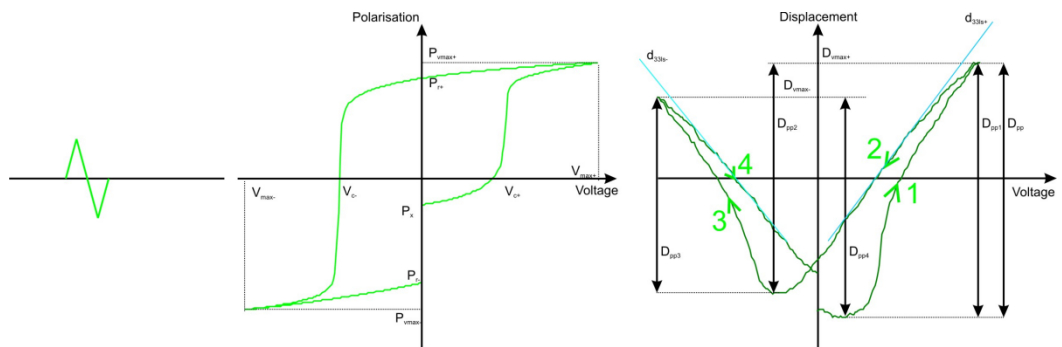


Fig. 2.11 Polarization vs. Voltage graph of a single loop Piezo Measurement without prepolarization

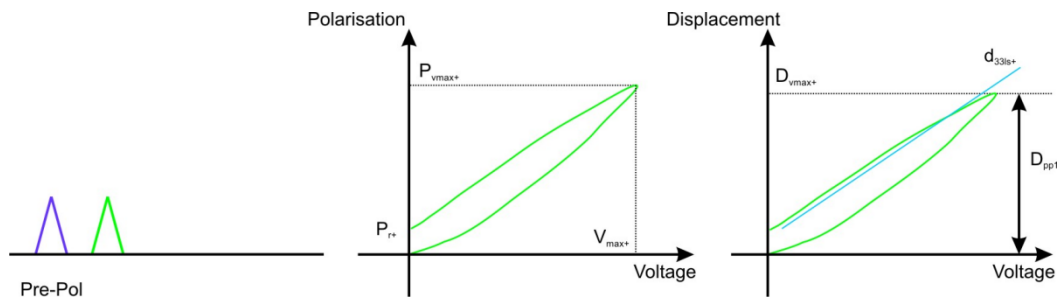


Fig. 2.12 Polarization vs. Voltage graph of a unipolar, single loop Piezo Measurement with prepolarization

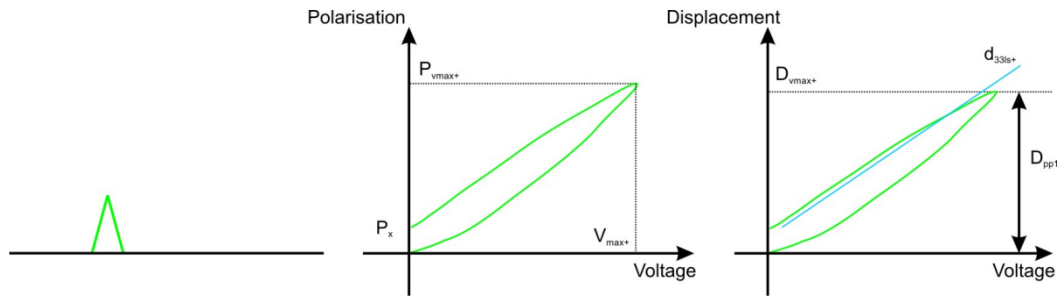


Fig. 2.13 Polarization vs. Voltage graph of a unipolar, single loop Piezo Measurement without prepolarization

2.2.2 Execution a Piezo Measurement

Click PZM in the “Select Project” dialog box of DX-FE2000 software, adjust the parameters and click “Save Parameters”, then press “Run” button to execute PZMM measurement.

The DX-FE2000 software allows the monitoring of different types of measurements during the measurement process. Select the type of measurement to be monitored by clicking on the “PZM_DHM”, “DHM”, “PZM”, “IV”, “Displacement Waveform”, “Excitation Response” “Nomenclature of characteristic values”. tab in the upper right corner of the measurement screen. tab in the right corner of the measurement screen to select the type of measurement to be monitored.

2.2.3 Software description

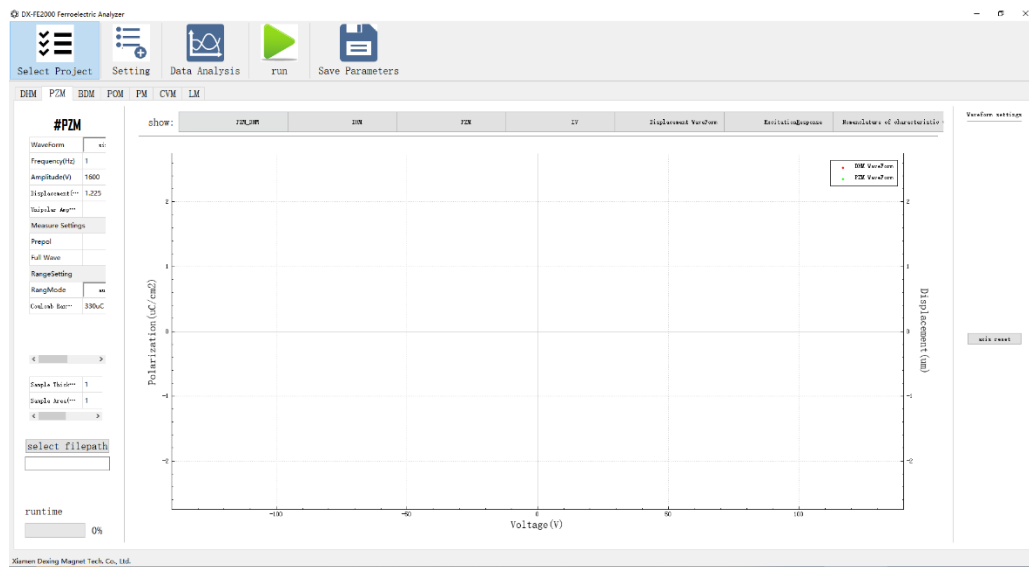


Fig. 2.14 PZM Measurement Interface

Table 2.4: Input Test Parameters

Name	Range value	Unit	Description
Waveform	Sine, triangle or square wave		waveform of the excitation signal
Frequency		Hz	frequency of a signal
Amplitude	Amplitude	V	amplitude limits are specified in the Hardware Manual
Displacement		$\mu\text{m/V}$	varies according to hardware
Unipolar Amplification	enabled or disable	V	Unipolar voltage amplitude measurement, the excitation signals are all positive polarity voltages
Measurement settings			
Prepol	enabled or disable		Setting the polarization state before measurement
Full Wave	enabled or disable		Full-wave testing, excitation signals using positive and negative polarity
Measurement range setting			
Range Mode Range	Manual or Automatic		range selection with automatic or manual adjustment
Coulomb Range	from 330 to 0.0033	μC	ranges range of charge measurement

Table 2.5: Nomenclature of characteristic values

Value	Unit	Description
$V_{\text{max}+}$	V	maximum voltage
$P_{\text{r}+}$	$\mu\text{C}/\text{cm}^2$	positive state of remanent polarization of the dynamically measured hysteresis loop
$P_{\text{rrel}+}$	$\mu\text{C}/\text{cm}^2$	positive state of relaxed remanent polarization, relaxed for one second in the $P_{\text{r}+}$ state.
$P_{\text{vmax}+}$	$\mu\text{C}/\text{cm}^2$	state of polarization when the stimulating signal reaches its maximum value - positive saturation
$V_{\text{c}+}$	V	positive coercive voltage, voltage at which the polarization crosses the x-axis with increasing voltage values
$I_{\text{pk}+}$	μA	peak current
P_{sw}	$\mu\text{C}/\text{cm}^2$	$= (P_{\text{max}+} - P_{\text{rrel}-})$: change of polarization when the sample is switched from the negative state of the relaxed remanent polarization into the positive saturation
$V_{\text{max}-}$	V	minimal voltage

Pr-	$\mu\text{C}/\text{cm}^2$	negative state of remanent polarization of the dynamically measured hysteresis loop
Prrel-	$\mu\text{C}/\text{cm}^2$	negative state of relaxed remanent polarization
Pvmax-	$\mu\text{C}/\text{cm}^2$	minimal positive polarization strength
Vc-	V	negative coercive voltage
Ipk-	μA	negative peak current
Pnsw	$\mu\text{C}/\text{cm}^2$	= ($P_{\text{max}+} - P_{\text{rrel}+}$): change of polarization when the sample is driven into the positive saturation from the positive state of the relaxed remanent polarization
VcShift	V	medium of $V_{\text{c}+}$ and $V_{\text{c}-}$

Table 2.6: Nomenclature of characteristic values

Value	Unit	Description
D_{pp}	nm	peak to peak displacement between maximum measured displacement point and minimum measured displacement point
D_{pp1}	nm	peak to peak displacement between maximum measured displacement point and minimum measured displacement point in first quarter
D_{pp2}	nm	peak to peak displacement between maximum measured displacement point and minimum measured displacement point in second quarter
D_{pp3}	nm	peak to peak displacement between maximum measured displacement point and minimum measured displacement point in third quarter
D_{pp4}	nm	peak to peak displacement between maximum measured displacement point and minimum measured displacement point in fourth quarter
$D_{\text{vmax}+}$	nm	Displacement at $V_{\text{max}+}$
$D_{\text{vmax}-}$	nm	Displacement at $V_{\text{max}-}$
$d_{33\text{ls}}$	nm/V	average d_{33} value of total measurement, linear regression of all D vs V points
$d_{33\text{ls}+}$	nm/V	average d_{33} value of positive side, linear regression slope D vs V values from V_{max} to 0V (non-switching)
$d_{33\text{ls}-}$	nm/V	average d_{33} value of negative side, linear regression slope D vs V values from $-V_{\text{max}}$ to 0V (non-switching)

2.3 Breakdown Measurement - BDM

2.3.1 Measurement procedure and typical measurement

The Breakdown Measurement (BDM) makes it possible to evaluate the electrical insulation of a material. It helps to determine the thickness that is required to withstand a certain voltage level.

The slope waveform increases voltage linearly up to a voltage limit; if the voltage limit is negative, the voltage is decreased accordingly. If a breakdown is detected due to either of enabled stop conditions, the measurement is immediately stopped without e.g. reaching the voltage limit.

2.3.2 Executing a Breakdown Measurement

Click BDM in the "Select Project" dialog box of DX-FE2000 software, adjust the parameters and click "Save Parameters", then press "Run" button to execute BDM measurement.

The DX-FE2000 software allows the monitoring of different types of measurements during the measurement process. Select the type of measurement to be monitored by clicking on the "Breakdown Measurement Waveform", "IV WaveForm", "Noneclature of characteristic values" tab in the upper right corner of the measurement screen. tab in the right corner of the measurement screen to select the type of measurement to be monitored.

2.3.3 Software description



Fig. 2.15 Breakdown Measurement Interface

Table 2.7: Input Test Parameters

Name	Range values	Unit	Description
Breakdown parameter			
Voltage Step		V	Incremental voltage per step
Voltage Limit		V	maximum voltage
Step Duration		ms	time to reach the set maximum voltage value
Waveform	Ramp Waveform		Excitation signal waveform
Exit condition			
Current limit	enabled or disable		Measurement will stop when the current limit setting condition is reached
Stop Current			Measurement stops when the current setting value is reached

Table 2.8: Nomenclature of characteristic values

Value	Unit	Description
V	V	Breakdown voltage
I	μA	Breakdown current
R	Ω	Resistive
Resistivity	$\Omega\cdot\text{mm}$	Resistivity
E	V/mm	Breakdown field
J	A/cm^2	Breakdown current density
Q	C/cm^2	Breakdown current density
t	s	Breakdown time
I _{pk+}	A	High peak current
I _{pk-}	A	Small peak current
Selected stop conditions		one or more stop conditions
Stopping conditions reached		one or more stop conditions

2.4 Poling Measurement - POM

2.4.1 Measurement procedure and typical measurement

Poling conditions of piezoelectric materials have a strong influence on the electrical and electromechanical properties of the sample. Therefore the DX-FE2000 Software provides the opportunity to investigate these influences with the help of the Poling Measurement (POM). In comparison to the hysteresis or piezo measurement the POM is not able to derive characteristic values, but to establish a defined poling state of the sample. To do so, it is possible to vary all parameters that effect the poling conditions and so the properties of the device. During the poling sequence the voltage, current and temperature are monitored and displayed after poling measurement has finished.

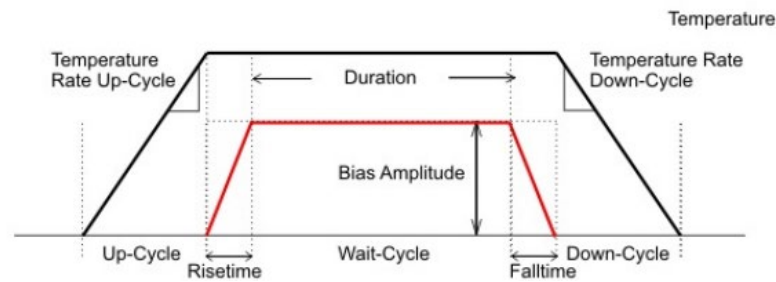


Fig. 2.16 Excitation Signal Schematic

2.4.2 Executing a Poling Measurement

Click POM in the "Select Project" dialog box of DX-FE2000 software, adjust the parameters and click "Save Parameters", then press "Run" button to execute POM measurement.

The DX-FE2000 software allows the monitoring of different types of measurements during the measurement process. Select the type of measurement to be monitored by clicking on the " Poling Measurement Waveform ", "IV WaveForm", "Nomeclature of characteristic" tab in the upper right corner of the measurement screen. tab in the right corner of the measurement screen to select the type of measurement to be monitored.

2.4.3 Software description

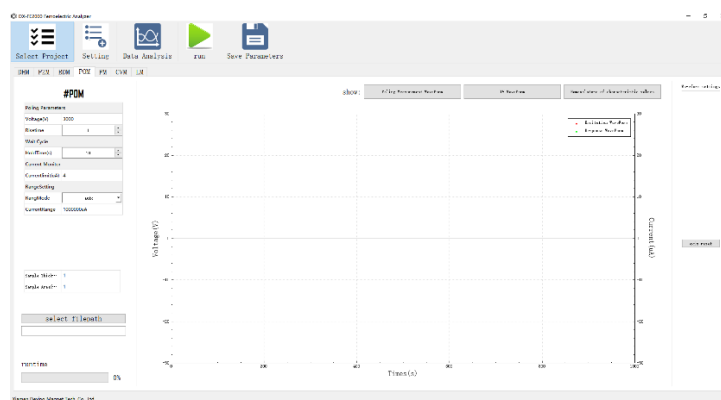


Fig. 2.17 Poling Measurement Interface

Table 2.9: Input Test Parameters

Name	Range values	Unit	Description
Polarization parameter			
Voltage	0 V to Max. Voltage	V	amplification for voltage
RiseTime	customizable	s	time for voltage ramp rising
Waiting period			
Hold Time	customizable	s	time where voltage are kept constant
Monitoring Current			
Current Limit	customizable	μA	current threshold
Measurement range setting			
Range Mode Range	Manual or Automatic		range selection with automatic or manual adjustment
Current Range			Current range, 9 levels from 1,000,000 μA to 0.01 μA.

Table 2.10: Nomenclature of characteristic values

Value	Unit	Description
I _{pk+}	A	maximum peak current
I _{pk-}	A	minimum peak current
I _{av}	A	average current during 70 to 90 percent of wait cycle
V _{av}	V	average voltage during 70 to 90 percent of wait cycle
R _{av}	Ω	average resistance during 70 to 90 percent of wait cycle
T _{av}	°C	average temperature
Reached Condition Info	Stop	one or more stop conditions

2.5 Pulse Measurement - PM

2.5.1 Measurement procedure and typical measurement

The Pulse Measurement (PM) records the current response of the Device under Test (DUT) after the application of a sequence of pulse excitation signals. One typical measurement is the very common PUND pulse sequence with two positive and two negative consecutive pulses (PUND = positive up negative down). The software of the PM calculates the $P(V)$ curve and characteristic values of the sample. But this is not possible for all variations of the applied signal scheme. In comparison to the DHM the PM uses unipolar rectangular pulses. The rise time of these pulses is adjustable.

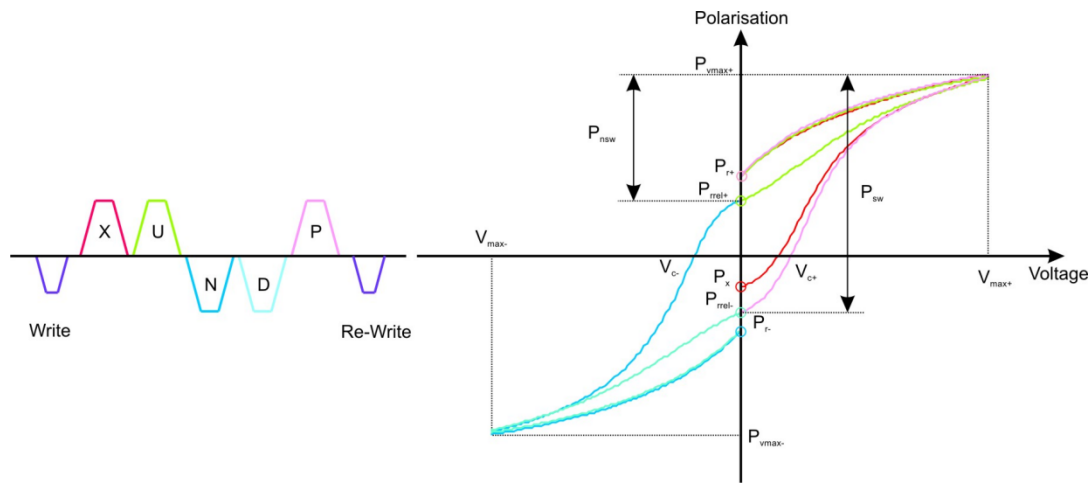


Fig. 2.18 PUND waveform and its measurement results

2.5.2 Executing a Poling Measurement

Click PM in the "Select Project" dialog box of DX-FE2000 software, adjust the parameters and click "Save Parameters", then press "Run" button to execute PM measurement.

The DX-FE2000 software allows the monitoring of different types of measurements during the measurement process. Select the type of measurement to be monitored by clicking on the "DHM", "Voltage segments", "Excitation Response", "Nomenclature of characteristic" tab in the upper right corner of the measurement screen. tab in the right corner of the measurement screen to select the type of measurement to be monitored.

2.5.3 Software description

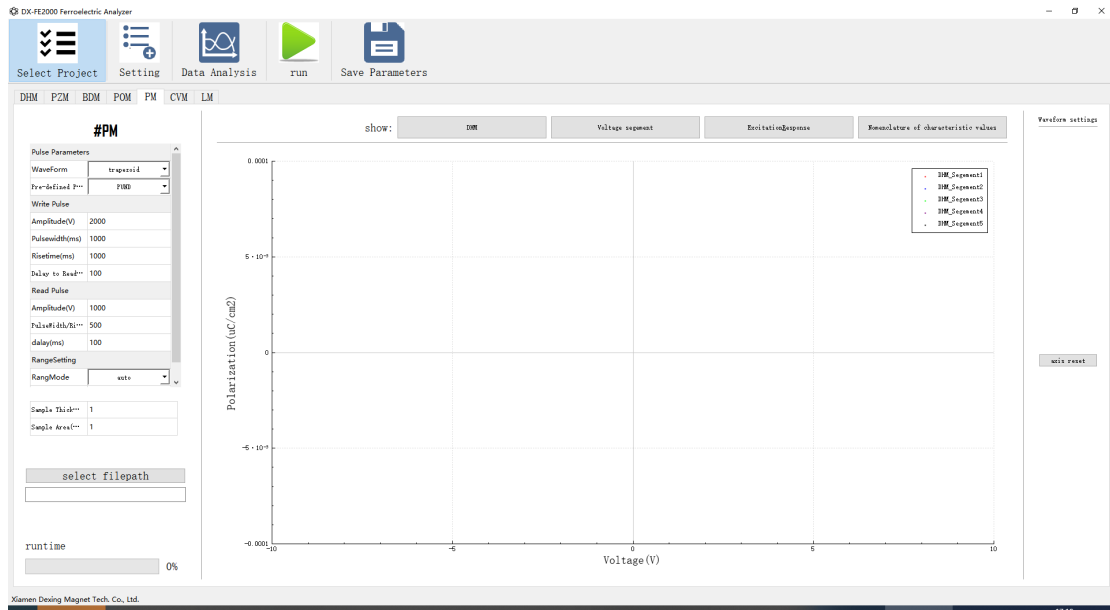


Fig. 2.19 Poling Measurement Interface

Table 2.11: Input Test Parameters

Value	Range values	Unit	Description
Pulse parameters			
Waveform	trapezoidal pulse		the waveform of the pulse
Pre-define Pulse	PUND		Predefined pulse sequence
Write pulse			
Voltage Limit		V	
Pulwidth		ms	pulse duration without rise and fall time
Risetime		ms	time of the rising edge of the pulse
Delay to Read		ms	time between write pulse and first read pulse
Read pulse			
Amplitude		V	Maximum voltage value of write pulse
Pulwidth		ms	time of the rising edge of the rectangle pulse
Measurement range setting			
Range Mode Range	Manual or Automatic		range selection with automatic or manual adjustment
Coulomb Range	from 330 to 0.0033	μC	ranges range of charge measurement

Table 2.12: Nomenclature of characteristic values

Value	Unit	Description
V _{max+}	V	maximum voltage
P _{r+}	$\mu\text{C}/\text{cm}^2$	positive remanent polarization value of the positive reference read pulse
P _{rrel+}	$\mu\text{C}/\text{cm}^2$	positive state of relaxed remanent polarization, relaxed for one second in the P _{r+} state. Equal to the positive state of remanent polarization of the quasi statically measured loop
P _{vmax+}	$\mu\text{C}/\text{cm}^2$	positive saturation polarization of each recorded hysteresis loop (at measuring positive voltage)
V _{c+}	V	positive coercive voltage, voltage at which the polarization crosses the <i>x</i> -axis with increasing voltage values
I _{pk+}	A	peak current
V _{max-} , P _{r-} , P _{rrel-} , P _{vmax-} , V _{c-} , I _{pk-} are the analogous values with negative field and polarization direction		
P _{sw}	$\mu\text{C}/\text{cm}^2$	= (P _{max+} - P _{rrel-}): change of polarization when the sample is switched from the negative state of the relaxed remanent polarization into the positive saturation
P _{nsw}	$\mu\text{C}/\text{cm}^2$	= (P _{max+} - P _{rrel+}): change of polarization when the sample is driven into the positive saturation from the positive state of the relaxed remanent polarization
dP _{sw}	$\mu\text{C}/\text{cm}^2$	=(P _{sw} - P _{nsw})
R _{av}	Ω	average resistance
W _{loss}	uJ/cm^2	lost energy in hysteresis cycle

2.6 CV Measurement - CVM

2.6.1 Measurement procedure and typical measurement

The DX-FE2000 software allows small-signal capacitance versus voltage ($C(V)$) and loss angle tangent ($\tan(\delta)(V)$) measurements on samples. Measurement parameters such as excitation signal, frequency and amplitude of the excitation signal can be changed.

The prepolarization pulse establishes a defined polarization state, usually the negative state of relaxed remanent polarization, after reaching $-V_{\max}$. This pulse is followed by a number of consecutive unipolar excitation signal pulses, depending on the entered input parameters. The unipolar pulses are DC biased voltage pulses with an superimposed sine wave AC small signal. The DC bias starts at zero volt, increases with each pulse up to the desired maximum excitation voltage $+V_{\max}$, decreases to $-V_{\max}$ and back to zero. The capacitance and loss tangent are derived from the AC small signal current response of the sample measured by the virtual ground.

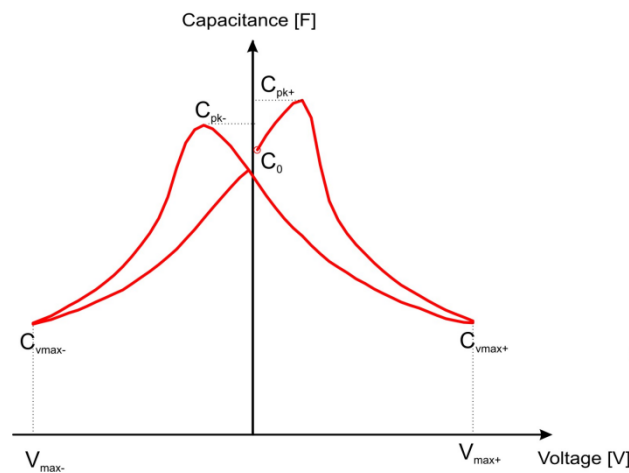


Fig. 2.20 Evaluation of typical parameters for bulk samples of CV Measurement.

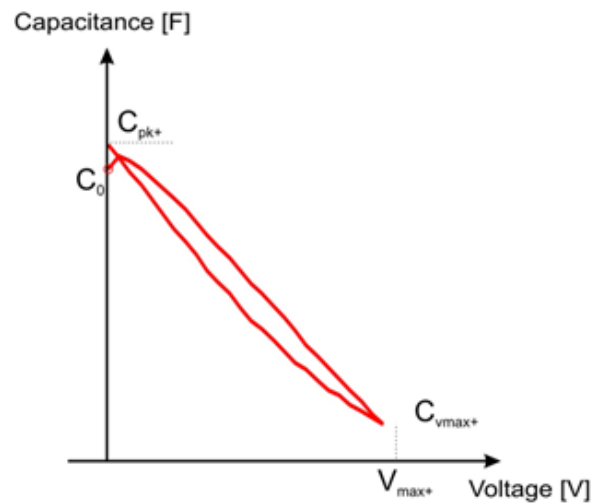


Fig. 2.21 Evaluation of typical parameters for bulk samples of CV Measurement.

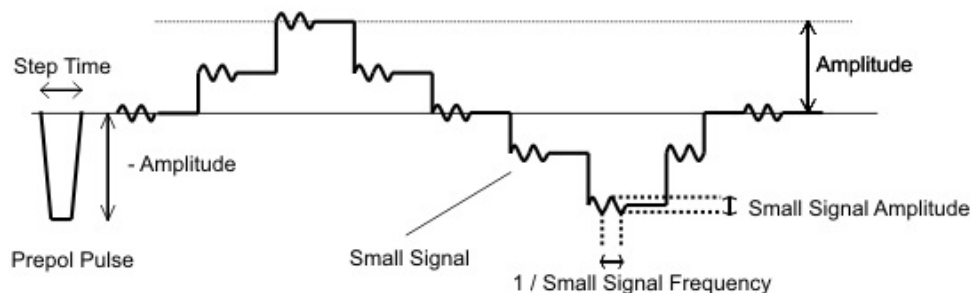


Fig. 2.22 Measurement Signal Schematic

2.6.2 Executing a CV Measurement

Click CVM in the "Select Project" dialog box of DX-FE2000 software, adjust the parameters and click "Save Parameters", then press "Run" button to execute CVM measurement.

The DX-FE2000 software allows the monitoring of different types of measurements during the measurement process. Select the type of measurement to be monitored by clicking on the “Excitation Response”, “CVM WaveForm”, “Nomeclature of characteristic” tab in the upper right corner of the measurement screen. tab in the right corner of the measurement screen to select the type of measurement to be monitored.

2.6.3 Software Description



Fig. 2.23 CV Measurement Interface

Table 2.13: Input Test Parameters

Name	Range values	Unit	Description
Waveform	step or triangle waveforms		excitation signal waveform
Amplitude	Amplitude	V	Maximum voltage varies depending on hardware selected
Unipolar Amplification	enabled or disable		unipolar voltage amplitude, only positive part of the staircase waveform is generated
Prepol	enabled or disable		setting the polarization state before measurement
LineSteps	customization		number of linear voltage increases
Small Signal Waveforms			
Frequency	customization	Hz	frequency of a signal
Amplitude	greater than 100	V	Maximum voltage varies depending on hardware selected
LoopTimes	customization		number of small signal cycles
Measurement range setting			
Range Mode Range	Manual or Automatic		range selection with automatic or manual adjustment
Coulomb Range	330 to 0.0033	μC	range of charge measurement

Table 2.14: Nomenclature of characteristic values

Value	Unit	Description
Step		number of steps in the measurement process
Vstep	V	voltage value of the step in which the measurement process is taking place
Capacitance	F	capacitance value of the measurement result

2.7 Leakage Current Measurement - LM

2.7.1 Measurement procedure and typical measurement

The LM performs an I vs. V measurement on a sample. This allows the detection of high leakage currents in the sample, which can affect the shape of the hysteresis loop, especially at high voltages and low frequencies.

Within the Leakage Current Measurement a special step shaped voltage waveform will be applied to the sample and a virtual ground amplifier measures the current response at each voltage step. A ferroelectric capacitor can be considered as a model of parallel capacitors, RC-time constants and a voltage dependent resistor. Thus, the current response due to an applied staircase waveform has to be analyzed to extract the leakage current information, because it results only from the voltage dependent resistive part of the sample.

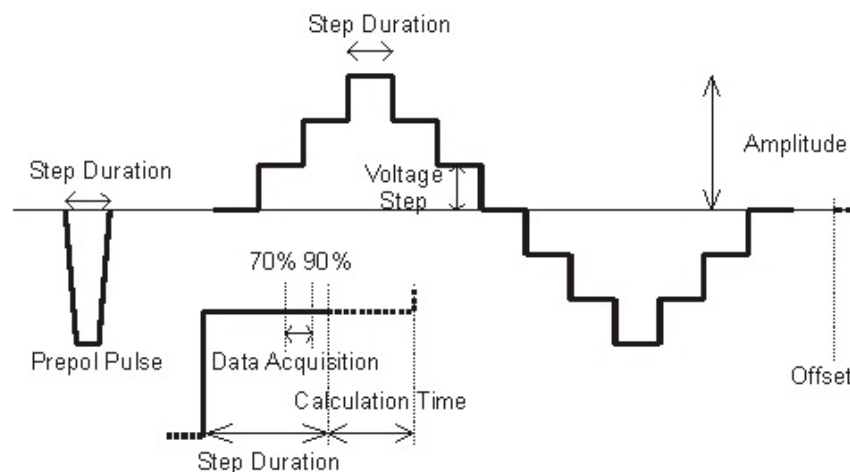


Fig. 2.24 Excitation Signal Schematic

2.7.2 Executing a Leakage Current Measurement

Click LM in the "Select Project" dialog box of DX-FE2000 software, adjust the parameters and click "Save Parameters", then press "Run" button to execute LM measurement.

The DX-FE2000 software allows the monitoring of different types of measurements during the measurement process. Select the type of measurement to be monitored by clicking on the "Excitation Response", "Leakage Current Waveform", "Nomenclature of characteristic values" tab in the upper right corner of the measurement screen. tab in the right corner of the measurement screen to select the type of measurement to be monitored.

2.7.3 Software Description

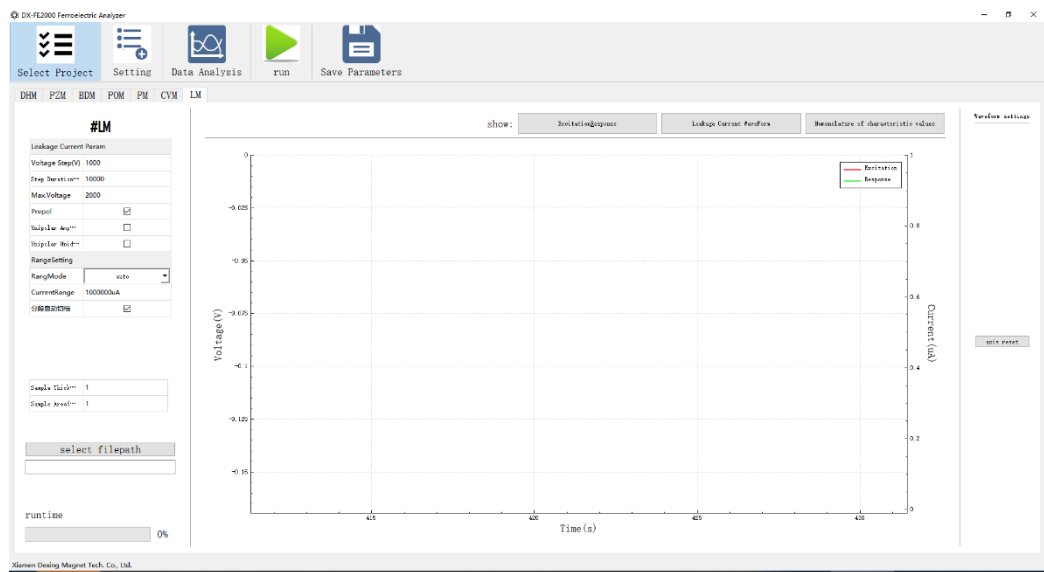


Fig. 2.25 Leakage Current Measurement Interface

Table 2.15: Input Test Parameters

Value	Range values	Unit	Description
Leakage current parameters			
Voltage Step	0 V to Max. Voltage	V	incremental voltage per step
Step Duration	0 to 1000000	ms	time during voltage is kept constant
Max.Voltage	0 V to Max. Voltage	V	maximum voltage finally reached by the test signal
Prepol	enabled or disable		Setting the polarization state before measurement
Unipolar Amplification	enabled or disable		unipolar voltage amplitude, only positive part of the staircase waveform is generated
Unipolar Unid	enabled or disable		unipolar and unidirectional voltage amplitude, the signal is reduced to the increasing positive edge
Measurement range setting			
Range Mode	Manual or automatic		software adapts the current range automatically during measurement to the best fitting range
Current Range	1,000,000 to 0.01	μA	maximum current range in measurement

Table 2.16: Nomenclature of characteristic values

Value	Unit	Description
V	V	Voltage value
Iav	μA	Current
Rav	Ω	Average resistance