



8 Bit PXI/PCI/VXI/LAN Digital Storage Oscilloscope Calibration Manual

M-Class Oscilloscope
Models ZT4211 and ZT4212

User's Manual: 0004-0000xx
Revision 1(prelim)

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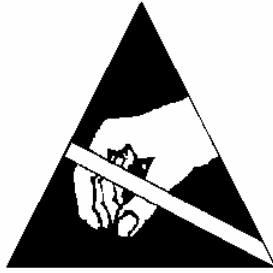
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Handling Precautions for Electronic Devices Subject to Damage by Static Electricity

This instrument is susceptible to Electronic Static Discharge (ESD) damage. When transporting, place the instrument or module in conductive (anti-static) envelopes or carriers. Open only at an ESD-approved work surface. An ESD safe work surface is defined as follows:

- The work surface must be conductive and reliably connected to an earth ground with a safety resistance of approximately 250 kilo Ohms.
- The surface must NOT be metal. A resistance of 30–300 kilo Ohms per square inch is suggested.

Ground the frame of any line-powered equipment, chassis, test instruments, lamps, soldering irons, etc., directly to the earth ground. To avoid shorting out the safety resistance, ensure that the grounded equipment has rubber feet or other means of insulation from the work surface.

Avoid placing tools or electrical parts on insulators. Do NOT use any hand tool that can generate a static charge, such as a non-conductive plunger-type solder sucker. Use a conductive strap or cable with a wrist cuff to reliably ground to the work surface. The cuff must make electrical contact directly with the skin; do NOT wear it over clothing.

Note: Resistance between the skin and the work surface is typically 250 kilo Ohms to 1 mega Ohm using a commercially-available personnel grounding device.

Avoid circumstances that are likely to produce static charges, such as wearing clothes of synthetic material, sitting on a plastic-covered stool (especially when wearing woolen material), combing the hair, or making extensive pencil erasures. These circumstances are most significant when the air is dry.

When testing static sensitive devices, ensure DC power is ON before, during, and after application of test signals. Ensure all pertinent voltages are switched OFF while circuit boards or components are removed or inserted.

Revision History

Rev	Date	Section	Description
1	1-15-08	All	Initial Release

Table of Contents

Test Setup	10
Environment	10
Recommended Equipment.....	10
Validation Tests.....	10
Calibration Tests	11
Calibration API	11
Validation Tests	17
Impedance Test	17
Trigger Level Test	18
Zero Offset Test	20
Zero Bias Test.....	22
Noise Test.....	24
DC Offset Test	27
DC Range Test	30
Internal 10MHz Clock Validation	35
Sample Rate Test	36
AC Coupling Test.....	38
Input Range Bandwidth Test.....	39
Filter Bandwidth Test	43
Trigger Bandwidth Test.....	44
Channel to Channel Skew Test.....	45
Calibration Tests	47
Range Calibration	47
Interleave Delta Calibration	50
Trigger Offset Calibration	52

List of Tables

Table 1: Operating Conditions	10
Table 2: Recommended Equipment	10
Table 3: Impedance Test Setup and Tolerances	17
26. Table 4: Trigger Level Validation Settings.....	18
Table 5: Trigger Level Test Setup and Tolerances.....	19
Table 6: Zero Offset Validation Settings	20
Table 7: Zero Offset Test Setup and Tolerances.....	21
Table 8: Zero Bias Test Setup and Tolerances	23
Table 9: Noise Validation Settings	24
Table 10: ZT450-50/51 Noise Test Setup and Tolerances	25
Table 11: ZT450-55/56 Noise Test Setup and Tolerances	26
Table 12: DC Offset Validation Settings	27
Table 13: DC Offset Test Setup and Tolerances	29
Table 14: DC Range Validation Settings	30
Table 15: DC Range Test Setup and Tolerances	34
Table 16: 10MHz Clock Validation Settings.....	35
Table 17: 10MHz Clock Validation Tolerances.....	35
Table 18: Sample Rate Validation Settings	36
Table 19: Sample Rate Test Setup and Tolerances	37
Table 20: AC Coupling Validation Settings	38
Table 21: AC Coupling Test Setup and Tolerances.....	38
Table 22: Range Bandwidth Validation Settings.....	39
Table 23: ZT450-50/51 Range Bandwidth Test Setup and Tolerances	40
Table 24: ZT450-55/56 Range Bandwidth Test Setup and Tolerances	42
Table 25: Filter Bandwidth Validation Settings	43
Table 26: Filter Bandwidth Test Setup and Tolerances	43
Table 27: Trigger Bandwidth Validation Settings	44
Table 28: Trigger Bandwidth Test Setup	44
Table 29: Channel to Channel Skew Validation Settings.....	45
Table 30: Channel to Channel Skew Test Setup and Tolerances	46
Table 31: Range Calibration Settings	47
Table 32: Range Calibration Setup and Tolerances	49
Table 33: Interleave Calibration Settings	50
Table 34: Interleave Calibration Setup and Tolerances.....	51
Table 35: Trigger Offset Calibration Settings.....	52
Table 36: Trigger Offset Calibration Setup and Tolerances.....	53

Test Setup



Environment

Validation and adjustment of the ZT4210 performance should be done under the following conditions.

Operating Conditions	
Ambient temperature	0°C to 40°C
Humidity	10 to 90%, non-condensing, up to +40 °C
Warm up time	30 minutes

Table 1: Operating Conditions

Recommended Equipment

All equipment should be properly calibrated prior to running any of the tests described in this document.

Test Equipment	Key Specifications
Digital Multimeter	
DC Source Measurement Unit	4 Wire Sense Mode 200V Range Accuracy: $\pm 0.02\%$ of range RMS Noise: 200.0mV < 500 μ V 2.0V < 1.8mV 20.0V < 20mV 200.0V < 150mV
AC Voltage Source	Frequency Range 1Hz to 1.2GHz Output Power -127dBm to +13dBm Harmonics: less than -35dBc

Table 2: Recommended Equipment

Validation Tests

The validation tests described in this document will validate the performance the ZT4210. The tests can be performed in any order. The ZT4210 Validation Checklist spreadsheet has been provided in which to record test results.

The Trigger Level, Zero Offset, Zero Bias, Noise, DC Offset and DC Range tests validate calibrated components. The instrument automatic calibration along with the calibration

procedures defined in this document can be used to correct for variation in the components over time.

The Impedance, Internal 10MHz Clock, Sample Rate, AC Coupling, Input Range Bandwidth, Filter Bandwidth, Trigger Bandwidth, and Channel to Channel Skew tests validate fundamental components of the instrument which are not calibrated. These components do not vary over time, but can be damaged by misuse.

Any validation test which repeatedly does not fall within the documented specification will require ZTEC Instruments Inc. warranty work to correct.

Calibration Tests

The calibration tests described in this document can be used to adjust the ZT450. Prior to running any of the calibration tests the full suite of validation tests should be performed to baseline the performance of the instrument. If any of the validation tests documented above as fundamental component tests do not perform within the documented specification do NOT attempt to calibrate the instrument.

The Range calibration should be performed prior to the Interleave Offset calibration. An automatic calibration of the instrument should be performed immediately following both the Interleave Offset and Trigger Offset calibrations.

The ZT4210 Calibration Checklist has been provided to record test results.

Calibration API

The following functions are provided in the class level drivers in order to adjust the internal gain codes.

ZT_ERROR ztscopeM_calibrate_save (ZT_HANDLE instr_handle)

Description: Function saves the calibration codes in the factory calibration EEPROM location. Note: You should only use this command if you have successfully completed a set of calibration and validation tests. You will be overwriting the existing factory defaults.

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

ZT_ERROR ztscopeM_calibrate_default (ZT_HANDLE instr_handle)

Description: Returns the instrument calibration data to factory standards.

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

ZT_ERROR ztscopeM_calibrate_restore (ZT_HANDLE instr_handle)

Description: Restores the factory default calibration data. This will reset all self-calibration data resulting from ztscopeM_calibrate_query that is used to automatically calibrate the zero DC offset, the DC offset adjust scale factor, and the ADC balance.

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

Outputs:

None

ZT_ERROR ztscopeM_calibrate_external_default (ZT_HANDLE instr_handle)

Description: Sets the instrument's external trigger codes to default values

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

Outputs:

None

**ZT_ERROR ztscopeM_calibrate_reference_oscillator_default (
ZT_HANDLE instr_handle)**

Description: Sets the instrument's reference oscillator code to default.

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

Outputs:

None

**ZT_ERROR ztscopeM_calibrate_gain_adjust (ZT_HANDLE instr_handle,
u16 channel,
f64 range,
f32 impedance,
u16 filter,
f32 frac_err);**

Description: Reads range gain code and adjusts value based on gain error.

Returns:

ZT_SUCCESS if gain code is changed.

ZT_FAILURE if gain code can not be changed.

Inputs:

instr_handle - The handle to the instrument being calibrated.
channel - The input channel being calibrated.
range - The input range being calibrated.
imped - The input impedance setting being calibrated.
filter - The input filter setting being calibrated.
frac_err - The gain error to correct, fraction of full scale

Outputs:

None

```
ZT_ERROR ztscopeM_calibrate_external_adjust (ZT_HANDLE instr_handle,  
                                             s32 frac_error);
```

Description: Adjusts the instrument's external trigger calibration settings.

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.
frac_error - The amount of fractional error to adjust for

Outputs:

None

```
ZT_ERROR ztscopeM_calibrate_reference_oscillator_adjust (  
                                             ZT_HANDLE instr_handle,  
                                             f64 clk_error)
```

Description: Adjusts the instrument's reference oscillator calibration settings

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.
clk_error - The amount of error to adjust for as a fraction of center frequency.

Outputs:

None

```
ZT_ERROR ztscopeM_calibrate_adc_data_query (ZT_HANDLE instr_handle,  
                                             s32 interleave,  
                                             u16 *i_zero_code,  
                                             u16 *i_gain_code,  
                                             u16 *q_zero_code,  
                                             u16 *q_gain_code)
```

Description: Returns the instrument's ADC calibration codes for each of the two submodules dependant on the interleave method.

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

interleave - The interleave method:

- 0: Independent Module 0
- 1: Interleaved Channel 1
- 2: Interleaved Channel 2
- 3: Independent Module 1
- 4: Interleaved Channel 3
- 5: Interleaved Channel 4

Outputs:

i_zero_code - The offset for submodule 0

i_gain_code - The full scale adjustment for submodule 0

q_zero_code - The offset for submodule 1

q_gain_code - The full scale adjustment for submodule 1

```
ZT_ERROR ztscopeM_calibrate_gain_data_query (ZT_HANDLE instr_handle,  
                s32 input_channel,  
                f64 range,  
                f64 impedance,  
                s32 filter,  
                u16 *gain_code)
```

Description: Returns the instrument's gain calibration settings.

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

range - The calibration range to be queried.

impedance - The calibration impedance to be queried.

filter - The calibration filter state to be queried.

Outputs:

gain_code - The full scale adjustment.

```
ZT_ERROR ztscopeM_calibrate_offset_data_query (ZT_HANDLE instr_handle,  
                s32 input_channel,  
                f64 range,  
                f64 impedance,  
                s32 filter,  
                u16 *zero_code,  
                u16 *gain_code)
```

Description: Returns the instrument's offset calibration settings.

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

range - The calibration range to be queried.

impedance - The calibration impedance to be queried.

filter - The calibration filter state to be queried.

Outputs:

zero_code - The offset.

gain_code - The full scale adjustment.

```
ZT_ERROR ztscopeM_calibrate_trigger_data_query (ZT_HANDLE instr_handle,  
                                                s32 input_channel,  
                                                u16 *zero_code,  
                                                u16 *gain_code)
```

Description: Returns the instrument's trigger calibration settings.

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

Outputs:

zero_code - The offset.

gain_code - The full scale adjustment.

```
ZT_ERROR ztscopeM_calibrate_external_data_query (ZT_HANDLE instr_handle,  
                                                u16 *zero_code,  
                                                u16 *gain_code)
```

Description: Returns the instrument's external trigger calibration settings

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

Outputs:

zero_code - The offset.

gain_code - The full scale adjustment.

```
ZT_ERROR ztscopeM_calibrate_reference_oscillator_data_query (  
                                                ZT_HANDLE instr_handle,  
                                                u16 *vcxo_code)
```

Description: Returns the instrument's reference oscillator calibration code.

Returns:

ZT_SUCCESS if command succeeds.

ZT_FAILURE if command fails.

Inputs:

instr_handle - The handle to the instrument being calibrated.

Outputs:

vcxo_code - Reference oscillator calibration code.

Validation Tests



Impedance Test

Specification: Input Channels (Ch 1 – 2) 50 or 1M Ohm \pm 1%
 External Trigger 10K Ohm \pm 2%
 External Clock 50 Ohm \pm 2%

Procedure:

1. Reset the instrument.
2. Set the instrument channel, impedance, range, and filter control to the value specified by the experiment table below.
3. Use a digital multimeter to measure impedance on the input connector.
4. Verify that the measured value is within the tolerance specified by the experiment table.

Experiment Table:

Channel	Impedance Setting (Ohms)	Range Setting (Vpp)	Filter Setting (On/Off)	Minimum Acceptable Impedance (Ohms)	Maximum Acceptable Impedance (Ohms)	
1 - 2	50	1	Off	49.5	50.5	
		0.5				
		0.25				
		0.1				
	1.00E+06	0.5	On			
		0.25				
		10				Off
		5				
External Trigger	1.00E+04	NA	NA	9800	10200	
External Clock	50	NA	NA	49	51	

Table 3: Impedance Test Setup and Tolerances

Trigger Level Test

Specification: 2% setting + 2% full scale + offset accuracy

Procedure:

1. Reset the instrument.
2. Disable the channel not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Sample Points	100k
Sample Rate	500MHz
Offset Reference	0.0
Offset Time	0.0
Range	5.0 Vpp
Impedance	50 Ohms
Offset	0.0
Coupling	DC
Filter	On
Attenuation	1.0

Table 4: Trigger Level Validation Settings

4. Setting the instrument to trigger at the level specified by the experiment table on a rising edge.
5. Use a DC voltage source to apply the voltage indicated in the experiment table to the channel being tested.
6. Clear the ZT42100 status tree by reading the status registers.
7. Increase the voltage of the source by the incremental value specified in the experiment table below.
8. Check the Operation Status register to determine if the instrument triggered.
9. Continue to increase the voltage of the source until the instrument triggers. Record the voltage at which the instrument triggers. (V_L)
10. Abort the instrument.
11. Clear the ZT4210 status tree by reading the status registers.
12. Set the instrument to trigger at the level specified by the experiment table on a falling edge.
13. Use a DC voltage source to apply the voltage indicated in the experiment table to the channel being tested.
14. Decrease the voltage of the source by the incremental value specified in the experiment table below.
15. Check the Operation Status register to determine if the instrument triggered.
16. Continue to decrease the voltage of the source until the instrument triggers. Record the voltage at which the instrument triggers. (V_H)
17. Verify that the average of V_H and V_L is within the tolerances specified by the experiment table below.
18. Repeat the test for each instrument channel.

Experiment Table:

Channel	Trigger Level (V)	Applied Signal (V)	Increment Value (V)	Minimum Trigger Average (V)	Maximum Trigger Average (V)
1 - 2	2.00	1.50	0.0031	1.86	2.14
		2.50			
	0.00	-0.50		-0.1	0.1
		0.50			
	-2.00	-1.50		-2.14	-1.86
		-2.50			

Table 5: Trigger Level Test Setup and Tolerances

Zero Offset Test

Specification: $\leq \pm 2\%$ of full scale

Procedure:

1. Disconnect all cables from the instrument.
2. Reset the instrument.
3. Run an automatic calibration of the instrument.
4. Disable the instrument channel not being tested.
5. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	100k
Sample Rate	500MHz
Offset Reference	0.0
Offset Time	0.0
Measurement Method	Entire Waveform
Measurement Edge	1
Offset	0.0V
Coupling	DC
Attenuation	1.0

Table 6: Zero Offset Validation Settings

6. Use the experiment table below to determine the remaining instrument settings.
7. Capture a waveform. Measure the average value of the waveform.
8. Verify that the measured value is within the tolerance specified by the experiment table.

Experiment Table:

Channel	Impedance Setting (Ohms)	Filter Setting	Range Setting (Vpp)	Minimum Acceptable Value	Maximum Acceptable Value
1 - 2	50	Off	10.00	-2.0000	2.0000
			5.00	-1.0000	1.0000
			2.00	-0.4000	0.4000
			1.00	-0.2000	0.2000
			0.50	-0.1000	0.1000
			0.25	-0.0500	0.0500
			0.10	-0.0200	0.0200
			0.05	-0.0100	0.0100

		On	10.00	-0.0040	0.0040
			5.00	-0.0020	0.0020
			2.00	-2.0000	2.0000
			1.00	-1.0000	1.0000
			0.50	-0.4000	0.4000
			0.25	-0.2000	0.2000
			0.10	-0.1000	0.1000
			0.05	-0.0500	0.0500
	1.00E+06	Off	100.00	-0.0200	0.0200
			50.00	-0.0100	0.0100
			20.00	-0.0040	0.0040
			10.00	-0.0020	0.0020
			5.00	-0.2000	0.2000
			2.50	-0.1000	0.1000
		On	1.00	-0.0400	0.0400
			0.50	-0.0200	0.0200
			0.20	-0.0100	0.0100
			0.10	-0.0050	0.0050
			100.00	-0.0020	0.0020
			50.00	-0.0010	0.0010
		On	20.00	-0.2000	0.2000
			10.00	-0.1000	0.1000
			5.00	-0.0400	0.0400
			2.50	-0.0200	0.0200
			1.00	-0.0100	0.0100
		On	0.50	-0.0050	0.0050
			0.20	-0.0020	0.0020
			0.10	-0.0010	0.0010

Table 7: Zero Offset Test Setup and Tolerances

Zero Bias Test

Specification: 50 Ohm Impedance $\leq \pm 40\text{mA}$
 1 MOhm Impedance $\leq \pm 1\text{nA}$

Procedure:

1. Disconnect all cables from the input channels.
2. Reset the instrument.
3. Perform an automatic calibration of the instrument.
4. Use the experiment table below to determine the settings of the instrument.
5. Use a digital multimeter to measure the current at the input connector.
6. Verify that the measurement is within the tolerances specified below by the experiment table.

Note: Bias current measurements will be limited by the accuracy of the digital multimeter.

Experiment Table:

Channel	Impedance Setting (Ohms)	Filter Setting	Range Setting (Vpp)	Minimum Acceptable Value	Maximum Acceptable Value
1 - 2	50	Off	10.00	-4.00E-02	4.00E-02
			5.00	-4.00E-02	4.00E-02
			2.00	-4.00E-02	4.00E-02
			1.00	-4.00E-02	4.00E-02
			0.50	-4.00E-02	4.00E-02
			0.25	-4.00E-02	4.00E-02
			0.10	-4.00E-02	4.00E-02
		0.05	-4.00E-02	4.00E-02	
		On	10.00	-4.00E-02	4.00E-02
			5.00	-4.00E-02	4.00E-02
			2.00	-4.00E-02	4.00E-02
			1.00	-4.00E-02	4.00E-02
			0.50	-4.00E-02	4.00E-02
			0.25	-4.00E-02	4.00E-02
	0.10		-4.00E-02	4.00E-02	
	0.05	-4.00E-02	4.00E-02		
	1.00E+06	Off	100.00	-1.00E-09	1.00E-09
			50.00	-1.00E-09	1.00E-09
			20.00	-1.00E-09	1.00E-09
			10.00	-1.00E-09	1.00E-09

			5.00	-1.00E-09	1.00E-09
			2.50	-1.00E-09	1.00E-09
			1.00	-1.00E-09	1.00E-09
			0.50	-1.00E-09	1.00E-09
			0.20	-1.00E-09	1.00E-09
			0.10	-1.00E-09	1.00E-09
		On	100.00	-1.00E-09	1.00E-09
			50.00	-1.00E-09	1.00E-09
			20.00	-1.00E-09	1.00E-09
			10.00	-1.00E-09	1.00E-09
			5.00	-1.00E-09	1.00E-09
			2.50	-1.00E-09	1.00E-09
			1.00	-1.00E-09	1.00E-09
			0.50	-1.00E-09	1.00E-09
			0.20	-1.00E-09	1.00E-09
			0.10	-1.00E-09	1.00E-09

Table 8: Zero Bias Test Setup and Tolerances

Noise Test

- Specification:** 20MHz Filter $\leq 0.25\%$ of range
 50 Ohm Impedance $\leq 0.5\%$ of range + 100mV
 1 MOhm Impedance $\leq 0.5\%$ of range + 1mV (ZT450-50/51)
 1 MOhm Impedance $\leq 0.5\%$ of range + 500 μ V (ZT450-55/56)

Procedure:

1. Disconnect all cables from the instrument.
2. Reset the instrument.
3. Run an automatic calibration of the instrument.
4. Disable the instrument channel not being tested.
5. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	100k
Sample Rate	500MHz
Offset Reference	0.0
Offset Time	0.0
Measurement Method	Entire Waveform
Measurement Edge	1
Offset	0.0V
Coupling	DC
Attenuation	1.0

Table 9: Noise Validation Settings

6. Use the experiment table below to determine the remaining instrument settings.
7. Capture a waveform. Measure the AC RMS value of the waveform.
8. Verify that the measured value is within the tolerance specified by the experiment table.

Experiment Table:

Channel	Impedance Setting (Ohms)	Filter Setting	Range Setting (Vpp)	Maximum Acceptable Value
1 - 2	50	Off	10.00	0.15000
			5.00	0.12500
			2.00	0.11000
			1.00	0.10500
			0.50	0.10250
			0.25	0.10125
			0.10	0.10050

		On	0.05	0.10025
			10.00	0.02500
			5.00	0.01250
			2.00	0.00500
			1.00	0.00250
			0.50	0.00125
			0.25	0.00063
			0.10	0.00025
			0.05	0.00013
			1.00E+06	Off
	50.00	0.25100		
	20.00	0.10100		
	10.00	0.05100		
	5.00	0.02600		
	2.50	0.01350		
	1.00	0.00600		
	0.50	0.00350		
	0.20	0.00200		
	On	100.00		0.25000
		50.00		0.12500
		20.00		0.05000
		10.00		0.02500
		5.00		0.01250
		2.50		0.00625
		1.00		0.00250
		0.50		0.00125
		0.20		0.00050
	0.10	0.00025		

Table 10: ZT450-50/51 Noise Test Setup and Tolerances

Channel	Impedance Setting (Ohms)	Filter Setting	Range Setting (Vpp)	Maximum Acceptable Value
1 - 2	50	Off	10.00	0.15000
			5.00	0.12500

			2.00	0.11000
			1.00	0.10500
			0.50	0.10250
			0.25	0.10125
			0.10	0.10050
			0.05	0.10025
		On	10.00	0.02500
			5.00	0.01250
			2.00	0.00500
			1.00	0.00250
			0.50	0.00125
			0.25	0.00063
			0.10	0.00025
			0.05	0.00013
	1.00E+06	Off	100.00	0.50050
			50.00	0.25050
			20.00	0.10050
			10.00	0.05050
			5.00	0.02550
			2.50	0.01300
			1.00	0.00550
			0.50	0.00300
			0.20	0.00150
			0.10	0.00100
		On	100.00	0.25000
			50.00	0.12500
			20.00	0.05000
			10.00	0.02500
			5.00	0.01250
			2.50	0.00625
			1.00	0.00250
			0.50	0.00125
			0.20	0.00050
			0.10	0.00025

Table 11: ZT450-55/56 Noise Test Setup and Tolerances

DC Offset Test

Specification: $\leq \pm (1\% \text{ offset} + 1\% \text{ full scale})$

Procedure:

1. Disconnect all cables from the instrument.
2. Reset the instrument.
3. Disable the instrument channel not being tested.
4. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	100k
Sample Rate	500MHz
Offset Reference	0.0
Offset Time	0.0
Measurement Method	Entire Waveform
Measurement Edge	1
Coupling	DC
Attenuation	1.0

Table 12: DC Offset Validation Settings

5. Use the experiment table below to determine the remaining instrument settings.
6. Capture a waveform. Measure the average value of the waveform.
7. Verify that the measured value is within the tolerance specified by the experiment table.

Experiment Table:

Channel	Impedance (Ohms)	Filter	Range (Vpp)	Offset Value (V)	Minimum Acceptable Value	Maximum Acceptable Value
1 - 2	50	Off	10.00	4.00	3.8600	4.1400
				-4.00	-4.1400	-3.8600
			5.00	2.00	1.9300	2.0700
				-2.00	-2.0700	-1.9300
			2.00	0.80	0.7720	0.8280
				-0.80	-0.8280	-0.7720
			1.00	0.40	0.3860	0.4140
				-0.40	-0.4140	-0.3860
			0.50	0.20	0.1930	0.2070
				-0.20	-0.2070	-0.1930

			0.25	0.10	0.0965	0.1035
				-0.10	-0.1035	-0.0965
			0.10	0.04	0.0386	0.0414
				-0.04	-0.0414	-0.0386
			0.05	0.02	0.0193	0.0207
				-0.02	-0.0207	-0.0193
		On	10.00	4.00	3.8600	4.1400
				-4.00	-4.1400	-3.8600
			5.00	2.00	1.9300	2.0700
				-2.00	-2.0700	-1.9300
			2.00	0.80	0.7720	0.8280
				-0.80	-0.8280	-0.7720
			1.00	0.40	0.3860	0.4140
				-0.40	-0.4140	-0.3860
	0.50		0.20	0.1930	0.2070	
			-0.20	-0.2070	-0.1930	
	0.25		0.10	0.0965	0.1035	
			-0.10	-0.1035	-0.0965	
	0.10	0.04	0.0386	0.0414		
		-0.04	-0.0414	-0.0386		
	0.05	0.02	0.0193	0.0207		
		-0.02	-0.0207	-0.0193		
	1.0E+6	Off	100.00	40.00	38.6000	41.4000
				-40.00	-41.4000	-38.6000
			50.00	20.00	19.3000	20.7000
				-20.00	-20.7000	-19.3000
			20.00	8.00	7.7200	8.2800
				-8.00	-8.2800	-7.7200
10.00			4.00	3.8600	4.1400	
			-4.00	-4.1400	-3.8600	
5.00			2.00	1.9300	2.0700	
			-2.00	-2.0700	-1.9300	
2.50			1.00	0.9650	1.0350	
			-1.00	-1.0350	-0.9650	

			1.00	0.40	0.3860	0.4140	
				-0.40	-0.4140	-0.3860	
			0.50	0.20	0.1930	0.2070	
				-0.20	-0.2070	-0.1930	
			0.20	0.08	0.0772	0.0828	
				-0.08	-0.0828	-0.0772	
			0.10	0.04	0.0386	0.0414	
				-0.04	-0.0414	-0.0386	
			On	100.00	40.00	38.6000	41.4000
					-40.00	-41.4000	-38.6000
		50.00		20.00	19.3000	20.7000	
				-20.00	-20.7000	-19.3000	
		20.00		8.00	7.7200	8.2800	
				-8.00	-8.2800	-7.7200	
		10.00		4.00	3.8600	4.1400	
				-4.00	-4.1400	-3.8600	
		5.00		2.00	1.9300	2.0700	
				-2.00	-2.0700	-1.9300	
		2.50		1.00	0.9650	1.0350	
				-1.00	-1.0350	-0.9650	
		1.00		0.40	0.3860	0.4140	
				-0.40	-0.4140	-0.3860	
		0.50	0.20	0.1930	0.2070		
			-0.20	-0.2070	-0.1930		
0.20	0.08	0.0772	0.0828				
	-0.08	-0.0828	-0.0772				
0.10	0.04	0.0386	0.0414				
	-0.04	-0.0414	-0.0386				

Table 13: DC Offset Test Setup and Tolerances

DC Range Test

Specification: $\leq \pm 1\%$ of full scale

Procedure:

1. Reset the instrument.
2. Disable the instrument channel not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	100k
Offset Reference	0.0
Offset Time	0.0
Measurement Method	Entire Waveform
Measurement Edge	1
Offset	0.0
Coupling	DC
Attenuation	1.0

Table 14: DC Range Validation Settings

4. Use the experiment table below to determine the remaining instrument settings.
5. Using a DC voltage source apply the voltage specified in the experiment table.
6. Capture a waveform. Measure the average value of the waveform.
7. Verify that the measured value is within the tolerance specified by the experiment table.

Experiment Table:

Channel	Sample Rate (MS/s)	Impedance (Ohm)	Filter	Range (Vpp)	Applied Voltage (V)	Minimum Acceptable Value	Maximum Acceptable Value
1 - 2	500	50	Off	10.00	4.00	3.9000	4.1000
					-4.00	-4.1000	-3.9000
				5.00	2.00	1.9500	2.0500
					-2.00	-2.0500	-1.9500
				2.00	0.80	0.7800	0.8200
					-0.80	-0.8200	-0.7800
				1.00	0.40	0.3900	0.4100
					-0.40	-0.4100	-0.3900
				0.50	0.20	0.1950	0.2050

					-0.20	-0.2050	-0.1950	
				0.25	0.10	0.0975	0.1025	
					-0.10	-0.1025	-0.0975	
				0.10	0.04	0.0390	0.0410	
					-0.04	-0.0410	-0.0390	
				0.05	0.02	0.0195	0.0205	
					-0.02	-0.0205	-0.0195	
			On	10.00	4.00	3.9000	4.1000	
						-4.00	-4.1000	-3.9000
				5.00	2.00	1.9500	2.0500	
						-2.00	-2.0500	-1.9500
				2.00	0.80	0.7800	0.8200	
						-0.80	-0.8200	-0.7800
				1.00	0.40	0.3900	0.4100	
						-0.40	-0.4100	-0.3900
				0.50	0.20	0.1950	0.2050	
						-0.20	-0.2050	-0.1950
				0.25	0.10	0.0975	0.1025	
						-0.10	-0.1025	-0.0975
				0.10	0.04	0.0390	0.0410	
						-0.04	-0.0410	-0.0390
				0.05	0.02	0.0195	0.0205	
						-0.02	-0.0205	-0.0195
		1.00E+06		Off	100.00	40.00	39.0000	41.0000
								-40.00
					50.00	20.00	19.5000	20.5000
							-20.00	-20.5000
					20.00	8.00	7.8000	8.2000
							-8.00	-8.2000
					10.00	4.00	3.9000	4.1000
							-4.00	-4.1000
					5.00	2.00	1.9500	2.0500
							-2.00	-2.0500
					2.50	1.00	0.9750	1.0250

					-1.00	-1.0250	-0.9750
				1.00	0.40	0.3900	0.4100
					-0.40	-0.4100	-0.3900
				0.50	0.20	0.1950	0.2050
					-0.20	-0.2050	-0.1950
				0.20	0.08	0.0780	0.0820
					-0.08	-0.0820	-0.0780
				0.10	0.04	0.0390	0.0410
					-0.04	-0.0410	-0.0390
			On	100.00	40.00	39.0000	41.0000
					-40.00	-41.0000	-39.0000
				50.00	20.00	19.5000	20.5000
					-20.00	-20.5000	-19.5000
				20.00	8.00	7.8000	8.2000
					-8.00	-8.2000	-7.8000
				10.00	4.00	3.9000	4.1000
					-4.00	-4.1000	-3.9000
				5.00	2.00	1.9500	2.0500
					-2.00	-2.0500	-1.9500
				2.50	1.00	0.9750	1.0250
					-1.00	-1.0250	-0.9750
				1.00	0.40	0.3900	0.4100
					-0.40	-0.4100	-0.3900
				0.50	0.20	0.1950	0.2050
					-0.20	-0.2050	-0.1950
				0.20	0.08	0.0780	0.0820
					-0.08	-0.0820	-0.0780
				0.10	0.04	0.0390	0.0410
					-0.04	-0.0410	-0.0390
	2500	50	Off	10.00	4.00	3.9000	4.1000
					-4.00	-4.1000	-3.9000
				5.00	2.00	1.9500	2.0500
					-2.00	-2.0500	-1.9500
				2.00	0.80	0.7800	0.8200

					-0.80	-0.8200	-0.7800
				1.00	0.40	0.3900	0.4100
					-0.40	-0.4100	-0.3900
				0.50	0.20	0.1950	0.2050
					-0.20	-0.2050	-0.1950
				0.25	0.10	0.0975	0.1025
					-0.10	-0.1025	-0.0975
				0.10	0.04	0.0390	0.0410
					-0.04	-0.0410	-0.0390
				0.05	0.02	0.0195	0.0205
					-0.02	-0.0205	-0.0195
			On	10.00	4.00	3.9000	4.1000
					-4.00	-4.1000	-3.9000
				5.00	2.00	1.9500	2.0500
					-2.00	-2.0500	-1.9500
				2.00	0.80	0.7800	0.8200
					-0.80	-0.8200	-0.7800
				1.00	0.40	0.3900	0.4100
					-0.40	-0.4100	-0.3900
				0.50	0.20	0.1950	0.2050
					-0.20	-0.2050	-0.1950
				0.25	0.10	0.0975	0.1025
					-0.10	-0.1025	-0.0975
				0.10	0.04	0.0390	0.0410
					-0.04	-0.0410	-0.0390
				0.05	0.02	0.0195	0.0205
					-0.02	-0.0205	-0.0195
		1.00E+06	Off	100.00	40.00	39.0000	41.0000
					-40.00	-41.0000	-39.0000
				50.00	20.00	19.5000	20.5000
					-20.00	-20.5000	-19.5000
				20.00	8.00	7.8000	8.2000
					-8.00	-8.2000	-7.8000
				10.00	4.00	3.9000	4.1000

					-4.00	-4.1000	-3.9000	
				5.00	2.00	1.9500	2.0500	
					-2.00	-2.0500	-1.9500	
				2.50	1.00	0.9750	1.0250	
					-1.00	-1.0250	-0.9750	
				1.00	0.40	0.3900	0.4100	
					-0.40	-0.4100	-0.3900	
				0.50	0.20	0.1950	0.2050	
					-0.20	-0.2050	-0.1950	
				0.20	0.08	0.0780	0.0820	
					-0.08	-0.0820	-0.0780	
				0.10	0.04	0.0390	0.0410	
					-0.04	-0.0410	-0.0390	
			On	100.00	40.00	39.0000	41.0000	
						-40.00	-41.0000	-39.0000
					50.00	20.00	19.5000	20.5000
						-20.00	-20.5000	-19.5000
					20.00	8.00	7.8000	8.2000
						-8.00	-8.2000	-7.8000
					10.00	4.00	3.9000	4.1000
						-4.00	-4.1000	-3.9000
					5.00	2.00	1.9500	2.0500
						-2.00	-2.0500	-1.9500
					2.50	1.00	0.9750	1.0250
						-1.00	-1.0250	-0.9750
					1.00	0.40	0.3900	0.4100
						-0.40	-0.4100	-0.3900
					0.50	0.20	0.1950	0.2050
						-0.20	-0.2050	-0.1950
					0.20	0.08	0.0780	0.0820
						-0.08	-0.0820	-0.0780
					0.10	0.04	0.0390	0.0410
						-0.04	-0.0410	-0.0390

Table 15: DC Range Test Setup and Tolerances

Internal 10MHz Clock Validation

Specification: $\pm 2.5\text{ppm}$ accuracy

Procedure:

1. Connect a precision 10MHz clock to channel 1 of the instrument.
2. Reset the instrument.
3. Disable channel 2.
4. Enter the following settings for the test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Sample Rate	5kHz
Offset Reference	0.0
Offset Time	0.0s
Trigger Source	Channel 1
Trigger Level	0.0
Trigger Polarity	Rising Edge
Channel 1 Range	5.0Vpp
Channel 1 Offset	0.0
Channel 1 Coupling	DC
Channel 1 Impedance	50 Ohm
Channel 1 Filter	Off
Channel 1 Attenuation	1.0
Measurement Method	Entire Waveform
Measurement Edge	1

Table 16: 10MHz Clock Validation Settings

5. Capture a waveform. Measure the frequency of the waveform.
6. Verify that the measurement is within the tolerances specified below by the experiment table.

Experiment Table:

Channel	Min. Measured Value (Hz)	Max. Measured Value (Hz)
External Output	0	25

Table 17: 10MHz Clock Validation Tolerances

Sample Rate Test

Specification: $\pm 0.5\%$

Procedure:

1. Reset the instrument.
2. Disable channel 2.
3. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Offset Reference	0.0
Offset Time	0.0
Trigger Source	Input Channel 1
Trigger Level	0.0
Trigger Polarity	Rising Edge
Range	2Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ohm
Filter	Off
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1

Table 18: Sample Rate Validation Settings

4. Use the experiment table below to determine the remaining instrument settings.
5. Use an AC voltage source to apply a +8dBm signal to channel 1 at the frequency indicated by the experiment table below.
6. Capture a waveform. Measure the frequency of the waveform.
7. Verify that the measurement is within the tolerances specified below by the experiment table.

Experiment Table:

Sample Rate (S/s)	Signal Frequency (Hz)	Minimum Measured Frequency (Hz)	Maximum Measured Frequency (Hz)
1.0000E+09	2.0000E+05	1.9900E+05	2.0100E+05
	1.0000E+05	9.9500E+04	1.0050E+05
	5.0000E+04	4.9750E+04	5.0250E+04

Sample Rate (S/s)	Signal Frequency (Hz)	Minimum Measured Frequency (Hz)	Maximum Measured Frequency (Hz)
5.0000E+08	2.0000E+05	1.9900E+05	2.0100E+05
	1.0000E+05	9.9500E+04	1.0050E+05
	5.0000E+04	4.9750E+04	5.0250E+04
2.5000E+08	2.0000E+05	1.9900E+05	2.0100E+05
	1.0000E+05	9.9500E+04	1.0050E+05
	5.0000E+04	4.9750E+04	5.0250E+04

Table 19: Sample Rate Test Setup and Tolerances

AC Coupling Test

Specification: 200 kHz high pass (50Ω)
10 Hz high pass (1 MΩ)

Procedure:

1. Reset the instrument.
2. Disable the instrument channel not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Offset Reference	0.0
Offset Time	0.0
Range	5Vpp
Offset	0.0
Coupling	AC
Impedance	50 Ohm
Filter	Off
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1

Table 20: AC Coupling Validation Settings

4. Use the experiment table below to determine the remaining instrument settings.
5. Use an AC voltage source to apply a +10dBm signal at the frequency specified in the experiment table below to the channel being tested.
6. Capture a waveform. Measure the AC RMS of the waveform.
7. Verify the measurement is within the tolerances specified by the experiment table.

Experiment Table:

Channel	Sample Rate (S/s)	Signal Frequency (Hz)	Minimum Acceptable Voltage (V)	Maximum Acceptable Voltage (V)
1 - 2	5.0000E+08	1.0000E+06	0.9716	1.0292
	1.0000E+08	2.5000E+05	0.8913	1.1220
	5.0000E+07	1.0000E+05	0.6310	0.7943
	5.0000E+06	1.0000E+04	0.0000	0.1585

Table 21: AC Coupling Test Setup and Tolerances

Input Range Bandwidth Test

Specification: 50 Ohm: 750MHz typical, 650MHz minimum
 450-50/51: 1MHz: 300MHz typical, 250MHz minimum
 450-55/56: 1MHz: 400MHz typical, 300MHz minimum

Procedure:

1. Reset the instrument.
2. Disable all channels not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Offset Reference	0.0
Offset Time	0.0
Offset	0.0
Coupling	DC
Filter	Off
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1

Table 22: Range Bandwidth Validation Settings

4. Use the appropriate experiment table below to determine the remaining instrument settings.
5. Use an AC voltage source to apply the signal specified in the experiment table to the channel being tested.
6. Capture a waveform. Measure the AC RMS of the waveform.
7. Verify that the measurement is within the tolerances specified by the experiment table below.

Experiment Table:

Channel	Impedance (Ohms)	Range (Vpp)	Signal Voltage (mVrms)	Signal Frequency (Hz)	Minimum Acceptable Voltage (V)	Maximum Acceptable Voltage (V)
1 - 2	50	1	300	1.001E+06	0.4121	0.4365
				2.501E+06	0.4074	0.4467
				5.001E+06	0.4074	0.4467
				1.000E+07	0.4050	0.4467
				2.500E+07	0.3958	0.4467

				7.500E+07	0.3936	0.4467
				2.000E+08	0.3846	0.4467
				5.000E+08	0.3780	0.4704
				6.500E+08	0.3369	0.4814
		0.5	150	1.001E+06	0.2061	0.2183
				2.501E+06	0.2037	0.2234
				5.001E+06	0.2037	0.2234
				1.000E+07	0.2025	0.2234
				2.500E+07	0.1979	0.2234
				7.500E+07	0.1968	0.2234
				2.000E+08	0.1923	0.2234
				5.000E+08	0.1890	0.2521
				6.500E+08	0.1685	0.2435
				1.00E+06	10	800
	2.501E+06	1.0864	1.1776			
	5.001E+06	1.0864	1.1776			
	1.000E+07	1.0802	1.1776			
	2.500E+07	1.0495	1.1776			
	5.000E+07	1.0495	1.1776			
	1.000E+08	1.0495	1.2546			
	1.750E+08	1.0081	1.2987			
	2.500E+08	0.8008	1.1311			
	5	800	1.001E+06			
			2.501E+06	1.0864	1.1776	
			5.001E+06	1.0864	1.1776	
			1.000E+07	1.0678	1.1776	
			2.500E+07	1.0617	1.1776	
5.000E+07			1.0556	1.1776		
1.000E+08			1.0316	1.2691		
1.750E+08			0.9089	1.2691		
2.500E+08			0.5508	1.1311		

Table 23: ZT450-50/51 Range Bandwidth Test Setup and Tolerances

Channel	Impedance (Ohms)	Range (Vpp)	Signal Voltage (mVrms)	Signal Frequency (Hz)	Minimum Acceptable Voltage (V)	Maximum Acceptable Voltage (V)
1 - 2	50	1	300	1.001E+06	0.4122	0.4367
				2.501E+06	0.4075	0.4468
				5.001E+06	0.4075	0.4468
				1.000E+07	0.4051	0.4468
				2.500E+07	0.3960	0.4468
				7.500E+07	0.3937	0.4468
				2.000E+08	0.3847	0.4468
				5.000E+08	0.3781	0.4706
				6.500E+08	0.3370	0.4816
		0.5	150	1.001E+06	0.2061	0.2183
				2.501E+06	0.2037	0.2236
				5.001E+06	0.2037	0.2236
				1.000E+07	0.2025	0.2236
				2.500E+07	0.1979	0.2236
				7.500E+07	0.1968	0.2236
	2.000E+08			0.1923	0.2236	
	5.000E+08			0.1890	0.2521	
	6.500E+08			0.1685	0.2435	
	1.00E+06	10	800	1.001E+06	1.0990	1.1641
				2.501E+06	1.0678	1.1508
				5.001E+06	1.0375	1.1508
				1.000E+07	1.0081	1.1508
				2.500E+07	1.0375	1.1641
				5.000E+07	1.0495	1.1981
				1.000E+08	1.0678	1.4240
				2.500E+08	1.0678	1.5083
				3.000E+08	1.0081	1.4240
		5	800	1.001E+06	1.0990	1.1641
				2.501E+06	1.0678	1.1508
				5.001E+06	1.0375	1.1508
1.000E+07				1.0081	1.1508	

				2.500E+07	1.0375	1.1641
				5.000E+07	1.0495	1.1981
				1.000E+08	1.0678	1.4240
				2.500E+08	1.0678	1.5083
				3.000E+08	1.0081	1.4240

Table 24: ZT450-55/56 Range Bandwidth Test Setup and Tolerances

Filter Bandwidth Test

Specification: 20 MHz or Bypass

Filter Stopband Rejection: approximately 3Db @ 20 MHz

Procedure:

1. Reset the instrument.
2. Disable all of the channels not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Sample Rate	2 GS/s
Offset Reference	0.0
Offset Time	0.0
Range	5Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ohm
Filter	On
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1

Table 25: Filter Bandwidth Validation Settings

4. Use an AC voltage source to apply a +10dBm signal at the frequency specified in the experiment table to the channel being tested.
5. Capture a waveform. Measure the AC RMS of the waveform.
6. Verify the measurement is within the tolerances specified by the experiment table below.

Experiment Table:

Channel	Signal Frequency (Hz)	Minimum Acceptable Voltage (V)	Maximum Acceptable Voltage (V)
1	1.0000E+06	0.97160	1.02920
	5.0000E+06	0.89130	1.12200
	2.0020E+07	0.56230	0.79430
	1.0000E+08	0.00000	0.17780

Table 26: Filter Bandwidth Test Setup and Tolerances

Trigger Bandwidth Test

Specification: $\geq 400\text{MHz}$

Procedure:

1. Reset the instrument.
2. Disable all channels not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Sample Rate	2 GS/s
Offset Reference	0.0
Offset Time	0.0
Range	5Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ohm
Filter	Off
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1
Trigger Level	0.2
Trigger Polarity	Rising Edge

Table 27: Trigger Bandwidth Validation Settings

4. Set the instrument to trigger on the channel under test.
5. Use an AC voltage source to apply the signal specified in the experiment table to the channel being tested.
6. Set the instrument to capture a waveform asynchronously.
7. Verify that the instrument captures a waveform.

Experiment Table:

Channel	Signal Power (dB)	Signal Frequency (Hz)
1 - 2	5	1.00E+07
	6	1.00E+08
	10	4.00E+08
	12	5.00E+08

Table 28: Trigger Bandwidth Test Setup

Channel to Channel Skew Test

Specification: $\leq 100\text{ps}$

Procedure:

1. Reset the instrument.
2. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Equivalent Time
Acquisition Count	1000
Equivalent Points	100
Trigger Mode	Normal
Sample Points	100
Sample Rate	500 MS/s
Offset Reference	0.0
Offset Time	0.0
Offset	0.0
Coupling	DC
Impedance	50 Ohm
Filter	Off
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	2
Trigger Source	Channel 1
Trigger Level	0.0
Trigger Polarity	Rising Edge
Measurement Reference	Percentage
Measurement Reference Low	0.0
Measurement Reference Mid	0.5
Measurement Reference High	1.0

Table 29: Channel to Channel Skew Validation Settings

3. Use the experiment table below to determine the instrument's vertical range.
4. Use an AC source to apply a 100MHz +13dB signal to both channels through a tee connector and equal length cables.
5. Capture a waveform. Measure the RCT of on both channels.
6. Swap the cables at the ZT450 inputs.
7. Capture a waveform. Measure the RCT of on both channels.

8. Subtract the average of the RCT measurements on channel 2 from the average of the channel 1 measurement.
9. Verify that the calculated skew value is with the tolerances shown in the experiment table below.

Experiment Table:

Range (Vpp)	Minimum Acceptable Skew (s)	Maximum Acceptable Skew (s)
5.0	-1.50E-10	1.50E-10
0.50		

Table 30: Channel to Channel Skew Test Setup and Tolerances

Calibration Tests



Range Calibration

Procedure:

1. Reset the instrument.
2. Disable the channel not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Sample Points	100k
Sample Rate	500MS/s
Offset Reference	0.0
Offset Time	0.0
Acquisition Mode	Normal
Acquire Continuously	Off
Trigger Mode	Automatic
Measure Method	Entire Waveform
Measure Edge	1
Offset	0.0
Coupling	DC
Attenuation	1.0

Table 31: Range Calibration Settings

4. Use the experiment table below to determine the remaining instrument settings.
5. Using a DC voltage source apply the positive voltage specified in the experiment table. (V_a)
6. Capture a waveform. Measure the average of the waveform (V_p).
7. Using a DC voltage source apply the negative voltage specified in the experiment table. ($-V_a$)
8. Capture a waveform. Measure the average of the waveform (V_n).
9. Calculate the gain error by averaging the quotients of the applied positive voltage and the measured positive voltage and the applied negative voltage and the measured negative voltage.

$$\text{gain_error} = V_a(V_n - V_p) / 2V_pV_n$$

10. Use the `zscopeC_gain_adjust` function to adjust the gain codes.
11. Adjust the vertical offset to a non-zero value and then return it to zero. (Note: This is to force the instrument to reload the adjusted gain codes.)
12. Repeat steps 5 through 11 until the gain error is less than 0.7%.

13. Repeat procedure for each combination of channel, range, impedance, and filter settings specified in the experiment table below.

Experiment Table:

Channel	Impedance (Ohm)	Filter	Range (Vpp)	Positive Applied Voltage (V)	Negative Applied Voltage (V)
1 – 2	1.00E+06	Off	100.00	40.00	-40.00
			50.00	20.00	-20.00
			20.00	8.00	-8.00
			10.00	4.00	-4.00
			5.00	2.00	-2.00
			2.50	1.00	-1.00
			1.00	0.40	-0.40
			0.50	0.20	-0.20
			0.20	0.08	-0.08
		0.10	0.04	-0.04	
		On	100.00	40.00	-40.00
			50.00	20.00	-20.00
			20.00	8.00	-8.00
			10.00	4.00	-4.00
			5.00	2.00	-2.00
			2.50	1.00	-1.00
			1.00	0.40	-0.40
			0.50	0.20	-0.20
	0.20		0.08	-0.08	
	50	Off	10.00	4.00	-4.00
			5.00	2.00	-2.00
			2.00	0.80	-0.80
			1.00	0.40	-0.40
			0.50	0.20	-0.20
			0.25	0.10	-0.10
		On	10.00	4.00	-4.00
			5.00	2.00	-2.00
			2.00	0.80	-0.80
			1.00	0.40	-0.40
			0.50	0.20	-0.20
0.25			0.10	-0.10	
			0.10	0.04	-0.04

			0.05	0.02	-0.02
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Table 32: Range Calibration Setup and Tolerances

Implementation Notes:

1. Each range is calibrated at 80% of the maximum peak to peak range. (Note: This translates to 40% of the maximum and minimum range values.) This ensures that the gain accuracy is better than 1% of full scale.
2. Each gain code should converge to an acceptable value within 25 iterations of the process.
3. In order to more accurately determine the gain error, use the DC source to determine the exact voltage applied to the device in place of the expected voltage.
4. Perform an interleave delta calibration immediately following a range calibration.

Interleave Delta Calibration

Procedure:

1. Reset the instrument.
2. Disable the channel not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Sample Points	100k
Sample Rate	2.5GS/s
Offset Reference	0.0
Offset Time	0.0
Acquisition Mode	Normal
Acquire Continuously	Off
Trigger Mode	Automatic
Measure Method	Entire Waveform
Measure Edge	1
Range	10Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ohms
Filter	On
Attenuation	1.0

Table 33: Interleave Calibration Settings

4. Using a DC voltage source apply the positive voltage specified in the experiment table. (Va)
5. Capture a waveform. Measure the average of the waveform (Vp).
6. Using a DC voltage source apply the negative voltage specified in the experiment table. (-Va)
7. Capture a waveform. Measure the average of the waveform (Vn).
8. Calculate the gain error by averaging the quotients of the applied positive voltage and the measured positive voltage and the applied negative voltage and the measured negative voltage.

$$\text{gain_error} = \frac{V_a(V_n - V_p)}{2V_pV_n}$$

9. Use the ztscopeC_interleave_adjust function to adjust the gain codes.
10. Adjust the vertical range to 5Vpp and then return it to 10Vpp. (Note: This is to force the instrument to reload the adjusted gain codes.)
11. Repeat steps 4 through 10 until the gain error is less than 0.7%.

Experiment Table:

Channel	Positive Applied Voltage (V)	Negative Applied Voltage (V)
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1 – 2	4.0	-4.0
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Table 34: Interleave Calibration Setup and Tolerances

Implementation Notes:

1. The interleave delta is calibrated at 80% of the 5Vpp range. (Note: This translates to 40% of the maximum and minimum range values.) This ensures that the gain accuracy across all ranges is better than 1% of full scale.
2. Each delta gain code should converge to an acceptable value within 25 iterations of the process.
3. In order to more accurately determine the gain error, use the DC source to determine the exact voltage applied to the device in place of the expected voltage.
4. Perform an automatic calibration of the instrument immediately following the completion of the range and interleave offset calibrations.

Trigger Offset Calibration

Procedure:

1. Reset the instrument.
2. Disable the channel not being tested.
3. Enter the following settings for each test.

Setup Item	Setting
Sample Points	100k
Sample Rate	500 MS/s
Offset Reference	0.0
Offset Time	0.0
Acquisition Mode	Normal
Acquire Continuously	Off
Trigger Mode	Normal
Measure Method	Entire Waveform
Measure Edge	1
Range	5 Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ohms
Filter	On
Attenuation	1.0
Trigger Level	0.0

Table 35: Trigger Offset Calibration Settings

4. Use the experiment table below to determine the remaining instrument settings.
5. Set the instrument to capture a waveform asynchronously on a rising edge trigger.
6. Using a DC voltage source apply a -0.5V signal to the channel under test.
7. Increase the signal voltage by the increment value specified in the experiment table below until the instrument triggers.
8. Record the signal voltage which triggered the instrument (V_L).
9. Send an abort command to the instrument.
10. Set the instrument to capture a waveform asynchronously on a falling edge trigger.
11. Using a DC voltage source apply a 0.5V signal to the channel under test.
12. Decrease the signal voltage by the increment value specified in the experiment table below until the instrument triggers.
13. Record the signal voltage which triggered the instrument (V_H).
14. Send an abort command to the instrument.
15. Set the instrument to trigger automatically.
16. Calculate the offset error by averaging the voltages at which the instrument triggered.

$$\text{offset_error} = (V_H + V_L) / 2$$

17. Using a DC voltage source apply a signal equivalent to the voltage value of the offset error to the channel under test.
18. Use the function `ztscopeC_trigger_offset_adjust` to adjust the offset code based on the offset error.
19. Adjust the vertical offset to a nonzero value and then return it to zero. (Note: This is to force the instrument to reload the adjusted gain codes.)
20. Capture a waveform. Measure the average of the waveform.
21. Use the `ztscopeC_trigger_offset_adjust` function to adjust the offset code by inputting the measured average as the offset error.
22. Repeat steps 18 through 20 until the gain error is less than 19.5mV.

Experiment Table:

Trigger & Capture Channel	Trigger Polarity	Applied Signal Voltage (V)	Signal Increment Value (V)
1 – 2	Rising Edge	-0.50	1.560E-03
	Falling Edge	0.50	-1.560E-03

Table 36: Trigger Offset Calibration Setup and Tolerances

Implementation Notes:

1. Perform an automatic calibration of the instrument immediately following the completion of trigger offset calibration.
2. After the automatic calibration completes use the `ztscopeC_save_calibration` function to store the range gain codes and interleave gain codes permanently.



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