12/13/14 Bit PXI/PCI/VXI/LXI Digital Storage Oscilloscope Calibration Manual

M-Class Oscilloscope
Models ZT4421, ZT4422,
ZT4431, ZT4432,
ZT4441, ZT4442

User's Manual: 0004-000078
Revision 1b

December 7, 2009

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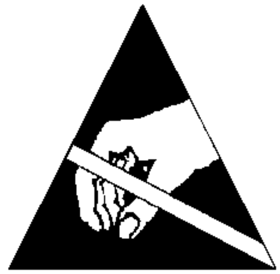

Handling Precautions for Electronic Devices Subject to Damage by Static Electricity

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	9-25-09	All	Initial Release
1a	10-16-09	RMS Noise Validation	Revised specification
1b	12-7-09	Validation	Fixed Typos

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Test Setup

Environment

Validation and adjustment of the ZT4400 performance should be done under the following conditions.

Operating Conditions	
Ambient temperature	20 °C to 30 °C
Humidity	10 to 90%, non-condensing, up to +40 °C
Warm up time	30 minutes

Table 1.1: 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: ± 0.02% of range RMS Noise: 200.0 mV < 500 µV 2.0 V < 1.8 mV 20.0 V < 20 mV 200.0 V < 150 mV
AC Voltage Source	Frequency Range 1 Hz to 1.2 GHz Output Power -127 dBm to +13 dBm Harmonics: less than -35dBc

Table 1.2: Recommended Equipment

Validation Tests

The validation tests described in this document will validate the performance the ZT4400. The tests can be performed in any order. The ZT4400 Validation Checklist spreadsheet has been provided in which to record test results.

The Trigger Level, Zero Offset, DC Offset and DC Range tests validate calibrated components. The instruments 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, Noise, Internal 10 MHz 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 ZT4400. 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, then do not attempt to calibrate the instrument.

In order to correctly compensate for variation in the instrument the order of the calibration tests are significant. The tests should be performed in the following order: Internal 10MHz, Input Range, then External Level calibration. Finally, an instrument automatic calibration should be performed. Use the Trigger Level, Zero Offset, DC Offset and DC Range validation tests to confirm the results of the calibrations before saving the new calibration data.

The ZT4400 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 ZT4410. Calibration commands are provided by their SCPI syntax as well as their class driver call.

Calibration Save Command

The Calibration Save Command 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.

SCPI

Command Syntax

CALibration:SAVE #HBEAD

Query Syntax

None

Parameters

None

Class Driver Call

ZT_ERROR ztscopeM_calibrate_save (ZT_HANDLE instr_handle)

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle – The handle to the instrument being calibrated.

Outputs:

None

Calibration Default Command

The Calibration Default Command returns the instrument calibration data to default values. This command will set all calibration codes on the instrument to fundamental hardware defaults. Using this command will put your instrument into a known state from which calibration can proceed.

SCPI

Command Syntax
CALibration:DEFault #HBEAD

Query Syntax
None

Parameters
None

Class Driver Call

ZT_ERROR ztscopeM_calibrate_default (ZT_HANDLE instr_handle)

Returns:
ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:
instr_handle – The handle to the instrument being calibrated.

Outputs:
None

Calibration Restore Command

The Calibration Restore Command returns the instrument to factory default calibration. This will reset all self-calibration data resulting from the *Calibrate Query* that is used to automatically calibrate the zero DC offset, the DC gain scale factor, the ADC balance, the input trigger zero offset, the input trigger gain scale factor, and the external trigger zero offset.

SCPI

Command Syntax
CALibration:RESTore

Query Syntax
None

Parameters
None

Class Driver Call

ZT_ERROR ztscopeM_calibrate_restore (ZT_HANDLE instr_handle)

Returns:
ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:
instr_handle – The handle to the instrument being calibrated.

Outputs:
None

Calibrate External Default Command

The Calibrate External Default Command returns the instrument's external trigger calibration settings to default values.

SCPI

Command Syntax
CALibration:EXTernal:DEFault #HFACE

Query Syntax
None

Parameters
None

Class Driver Call

ZT_ERROR ztscopeM_calibrate_external_default (ZT_HANDLE instr_handle)

Returns:
ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:
instr_handle – The handle to the instrument being calibrated.

Outputs:
None

Calibrate Reference Oscillator Default Command

The Calibration Reference Oscillator Default Command sets the instrument's reference oscillator code to a default value.

SCPI

Command Syntax
CALibration:ROSCillator:DEFault #HFACE

Query Syntax
None

Parameters
None

Class Driver Call

ZT_ERROR ztscopeM_calibrate_reference_oscillator_default (ZT_HANDLE instr_handle)

Returns:
ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:
instr_handle – The handle to the instrument being calibrated.

Outputs:
None

Calibration Gain Adjust Command

The Calibration Gain Adjust Command adjusts the instrument's gain calibration settings. The settings are calibrated for the current range, impedance and filter settings.

SCPI

Command Syntax

CALibration:GAIN<n>:ADJust #HBEAD, <error>

Query Syntax

None

Parameters

Name	Type	Range	
<n>	Discrete	1	Input Channel 1
		2	Input Channel 2
		3	Input Channel 3
		4	Input Channel 4
<error>	Float	0.0 to 1.0 fraction of full scale	

Class Driver Call

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

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 – Not Used
impedance – Not Used
filter – Not Used
frac_err – The gain error to correct, fraction of full scale

Outputs:

None

Calibration External Adjust Command

The Calibration External Adjust Command adjusts the instrument's external trigger calibration settings. The passed in error is the amount of fractional error to adjust for.

SCPI

Command Syntax

CALibration:EXTernal:ADJust #HFACE,<error>

Query Syntax

None

Parameters

Name	Type	Range
<error>	Float	0.0 to 1.0 fraction of full scale

Class Driver Call

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

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

Calibrate Reference Oscillator Adjust Command

The Calibrate Reference Oscillator Adjust Command adjusts the instrument's reference oscillator calibration settings.

SCPI

Command Syntax

CALibration:ROSCillator:ADJust #HFACE,<error>

Query Syntax

None

Parameters

Name	Type	Range
<error>	Integer	Parts per million (PPM) adjustment

Class Driver Call

ZT_ERROR ztscopeM_calibrate_reference_oscillator_adjust (ZT_HANDLE instr_handle, s32 clk_error)

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 in PPM.

Outputs:

None

Calibration ADC Data Query

The Calibration ADC Data Query returns the instrument's zero offset and gain calibration settings dependant on the interleave mode. The <zero_code> is the zero input offset adjustment and the <gain_code> is the full scale gain adjustment at the current range, impedance and filter settings. ADCs 3 and 4 are only available for 4-channel instruments.

SCPI

Command Syntax

None

Query Syntax

CALibration:ADC:DATA? <interleave> → <zero_code>,<gain_code>

Parameters

Name	Type	Range
<interleave>	Discrete	0 ADC1 Straight (INP1) 1 ADC1 Crossed (INP2) 2 ADC2 Crossed (INP1) 3 ADC2 Straight (INP2) 4 ADC3 Straight (INP3) 5 ADC3 Crossed (INP4) 6 ADC4 Crossed (INP3) 7 ADC4 Straight (INP4)
<zero_code>	Integer	0 to 65535
<gain_code>	Integer	0 to 65535

Class Driver Call

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)

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, see above.

Outputs:

i_zero_code – The ADC offset
i_gain_code – The ADC full scale adjustment
q_zero_code – Not Used
q_gain_code – Not Used

Calibration Gain Data Query

The Calibration Gain Data Query returns the instrument's gain calibration settings. The <gain_code> is the full scale adjustment at the current range, impedance and filter settings.

SCPI

Command Syntax

None

Query Syntax

CALibration:GAIN<n>:DATA? → <gain_code>

Parameters

Name	Type	Range	
<n>	Discrete	1	Input Channel 1
		2	Input Channel 2
		3	Input Channel 3
		4	Input Channel 4
<gain_code>	Integer	0 to 65535	

Class Driver Call

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

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle – The handle to the instrument being calibrated.
Range – Not Used
impedance – Not Used
filter – Not Used

Outputs:

gain_code – The full scale adjustment.

Calibration Offset Data Query

The Calibration Offset Data Query returns the instrument's offset calibration settings. The <gain_code> is the full scale adjustment. Calibration settings depend on current range, impedance and filter settings.

SCPI

Command Syntax

None

Query Syntax

CALibration:OFFSet<n>:DATA? → <gain_code>

Parameters

Name	Type	Range	
<n>	Discrete	1	Input Channel 1
		2	Input Channel 2
		3	Input Channel 3
		4	Input Channel 4
<gain_code>	Integer	0 to 65535	

Class Driver Call

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)

Returns:

ZT_SUCCESS if command succeeds.
ZT_FAILURE if command fails.

Inputs:

instr_handle – The handle to the instrument being calibrated.
Range – Not Used
impedance – Not Used
filter – Not Used

Outputs:

zero_code – Not Used
gain_code – The full scale adjustment.

Calibration Trigger Data Query

The Calibration Trigger Data Query returns the instrument's trigger calibration settings. The <zero_code> is the offset. The <gain_code> is the full scale adjustment.

SCPI

Command Syntax

None

Query Syntax

CALibration:TRIGger<n>:DATA? → <zero_code>,<gain_code>

Parameters

Name	Type	Range	
<n>	Discrete	1	Input Channel 1
		2	Input Channel 2
		3	Input Channel 3
		4	Input Channel 4
<zero_code>	Integer	0 to 65535	
<gain_code>	Integer	0 to 65535	

Class Driver Call

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

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.

Calibration External Data Query

The Calibration External Data Query returns the instrument's external trigger calibration settings. The <zero_code> is the offset. The <gain_code> is the full scale adjustment.

SCPI

Command Syntax

None

Query Syntax

CALibration:EXTernal:DATA? → <zero_code>,<gain_code>

Parameters

Name	Type	Range
<zero_code>	Integer	0 to 65535
<gain_code>	Integer	0 to 65535

Class Driver Call

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

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.

Calibration Reference Oscillator Data Query

The Calibration Reference Oscillator Data Query returns the instrument's reference oscillator calibration code.

SCPI

Command Syntax

None

Query Syntax

CALibration:ROSCillator:DATA? → <vcxo_code>

Parameters

Name	Type	Range
<vcxo_code>	Integer	0 to 65535

Class Driver Call

ZT_ERROR ztscopeM_calibrate_reference_oscillator_data_query (ZT_HANDLE instr_handle, u16 *vcxo_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 Validation

Specification:

50 Ω ± 1% (Channels 1-4)
1 MΩ ± 1% (Channels 1-4)
± 2% (External Input)

Procedure:

1. Reset the instrument.
2. For the desired channel, set the impedance, and range 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.
5. Repeat for all table options.

Experiment Table:

<table>
<tr><th>Channel</th><th>Impedance Setting (Ω)</th><th>Range Setting (Vpp)</th><th>Minimum Acceptable Impedance (Ω)</th><th>Maximum Acceptable Impedance (Ω)</th></tr>
<tr><td rowspan="3">1 – 4</td><td>50</td><td>5.0</td><td>49.5</td><td>50.5</td></tr>
<tr><td rowspan="2">1M</td><td>5.0</td><td rowspan="2">9.90E+05</td><td rowspan="2">1.01E+06</td></tr>
<tr><td>10.0</td></tr>
<tr><td rowspan="2">External Input</td><td>50</td><td rowspan="2">NA</td><td>49</td><td>51</td></tr>
<tr><td>1M</td><td>9.80E+05</td><td>1.02E+06</td></tr>
</table>

Table 2.1: Impedance Test Setup and Tolerances

DC Range Validation

Specification:

± 0.25% of full scale range

Procedure:

1. Disconnect all cables from the instrument.
2. Reset the instrument.
3. Disable the instrument channels which will not be tested.
4. Connect a 10 MHz clock to the external input of the instrument.
5. Enter the following settings for each test using the primary sweep time for the appropriate instrument option.

Setup Item	Setting
Acquisition Type	Average
Number of Acquisitions	64
Trigger Mode	Normal
Trigger Source	External Input
Trigger Level	0.0
Trigger Polarity	Rising Edge
Sample Points	100k
Offset	0
Coupling	DC
Attenuation	1.0
ZT4420 Primary Sweep Time	200us
ZT4430 Primary Sweep Time	400us
ZT4440 Primary Sweep Time	250us
ZT4420 Interleaved Sweep Time	100us
ZT4430 Interleaved Sweep Time	200us
ZT4440 Interleaved Sweep Time	120us
Offset Time	Half of the Sweep Time

Table 2.2: DC Range Validation Settings

6. Use the experiment table below to determine the remaining instrument settings.
7. Use a voltage source to apply the voltage specified by the experiment table below.
8. Capture a waveform. Measure the average value of the waveform.
9. Verify the measured value is within the tolerance specified by the experiment table.
10. Repeat steps 8 through 9 reversing the polarity of the voltage source.
11. Repeat steps 7 through 10 using the interleaved sweep time for the correct instrument option.
12. Repeat steps 7 through 11 until all vertical settings, listed in Table 2.3, are checked for the channel under test.
13. Repeat steps 7 through 12 for both filter states.
14. Test all channels: repeat steps 4 through 13 for all channels.

Experiment Table:

Chan	Filter	Impedance (Ω)	Range (V)	Applied Voltage (V)	Min. Average Value (V)	Max. Average Value (V)
1 - 4	On/ Off	50	0.040	0.016	0.01596	0.01604
				-0.016	-0.01596	-0.01604
			0.080	0.032	0.03192	0.03208
				-0.032	-0.03192	-0.03208
			0.200	0.080	0.07980	0.08020
				-0.080	-0.07980	-0.08020
			0.400	0.160	0.15960	0.16040
				-0.160	-0.15960	-0.16040
			1.00	0.400	0.39900	0.40100
				-0.400	-0.39900	-0.40100
			2.00	0.800	0.79800	0.80200
				-0.800	-0.79800	-0.80200
			5.00	2.000	1.99500	2.00500
				-2.000	-1.99500	-2.00500
			10.00	4.000	3.99000	4.01000
				-4.000	-3.99000	-4.01000
		1M	0.200	0.080	0.07980	0.08020
				-0.080	-0.07980	-0.08020
			0.400	0.160	0.15960	0.16040
				-0.160	-0.15960	-0.16040
			1.00	0.400	0.39900	0.40100
				-0.400	-0.39900	-0.40100
			2.00	0.800	0.79800	0.80200
				-0.800	-0.79800	-0.80200
			5.00	2.000	1.99500	2.00500
				-2.000	-1.99500	-2.00500
			10.00	4.000	3.99000	4.01000
				-4.000	-3.99000	-4.01000
			25.00	10.000	9.97500	10.02500
				-10.000	-9.97500	-10.02500
			50.00	20.000	19.95000	20.05000
				-20.000	-19.95000	-20.05000

Table 2.3: DC Gain Setup and Tolerances Settings

Zero Offset Validation

Specification:

±(0.25% full scale range + 1 mV)) @ +25 °C (50 Ω)
±(0.25% full scale range + 5 mV)) @ +25 °C (1MΩ)

Procedure:

1. Disconnect all cables from the input channels.
2. Reset the instrument.
3. Run an automatic calibration of the instrument.
4. Disable all channels which are not being tested.
5. Connect a 10 MHz clock to the external input of the instrument.
6. Enter the following settings for each test using the sweep time for the appropriate instrument option.

Setup Item	Setting
Acquisition Type	Average
Number of Acquisitions	64
Trigger Mode	Normal
Trigger Source	External Input
Trigger Level	0.0
Trigger Polarity	Rising Edge
Sample Points	100k
Time/Div	10 µs
Offset Time	0.0
Offset	0.0
Coupling	DC
Attenuation	1.0
ZT4420 Sweep Time	200us
ZT4430 Sweep Time	400us
ZT4440 Sweep Time	250us
Offset Time	Half of the Sweep Time

Table 2.4: Zero Offset Validation Settings

7. Set Low Pass filter to On
8. Use the experiment table below to determine the remaining instrument settings.
9. Capture a waveform. Measure the average value of the waveform.
10. Verify the measurement is within the tolerances specified below by the experiment table.
11. Repeat steps 8 through 10 until all vertical settings, listed in Table 2.5, are checked for the channel under test.
12. Set Low Pass filter to Bypass and repeat steps 8 through 11.
13. Test all channels: repeat steps 4 through 12 for all channels.

Experiment Table:

Channel	Impedance (Ω)	Range (V)	Min. Average Value (V)	Max. Average Value (V)
1 - 4	50	0.040	-0.0011	0.0011
		0.080	-0.0012	0.0012
		0.200	-0.0015	0.0015
		0.400	-0.002	0.002
		1.00	-0.0035	0.0035
		2.00	-0.006	0.006
		5.00	-0.0135	0.0135
		10.00	-0.026	0.026
	1M	0.200	-0.0055	0.0055
		0.400	-0.006	0.006
		1.00	-0.0075	0.0075
		2.00	-0.01	0.01
		5.00	-0.0175	0.0175
		10.00	-0.03	0.03
		25.00	-0.0675	0.0675
		50.00	-0.13	0.13

Table 2.5: Zero Offset Setup and Tolerances

Offset Validation

Specification:

±(0.25% full scale range + 0.5% offset + 1 mV)) @ +25 °C (50 Ω)
±(0.25% full scale range + 0.5% offset + 5 mV)) @ +25 °C (1 MΩ)

Procedure:

1. Disconnect all cables from the input channels.
2. Reset the instrument.
3. Run an automatic calibration of the instrument.
4. Disable all channels that are not being tested.
5. Connect a 10 MHz clock to the external input of the instrument
6. Enter the following settings for each test using the sweep time for the appropriate instrument option.

Setup Item	Setting
Acquisition Type	Average
Number of Acquisitions	64
Trigger Mode	Normal
Trigger Source	External Input
Trigger Level	0.0
Trigger Polarity	Rising Edge
Sample Points	100k
Time/Div	10 µs
Offset Time	0.0
Coupling	DC
Attenuation	1.0
ZT4420 Sweep Time	200us
ZT4430 Sweep Time	400us
ZT4440 Sweep Time	250us
Offset Time	Half of the Sweep Time

Table 2.6: Offset Validation Settings

7. Set the Low Pass filter to On.
8. Use the experiment table below to determine the remaining settings of the instrument.
9. Capture a waveform. Measure the average value of the waveform.
10. Verify the measurement is within the tolerances specified below by the experiment table.
11. Repeat steps 8 through 10 until all vertical settings, listed in Table 2.7, are checked for the channel under test.
12. Set the Low Pass filter to Bypass and repeat steps 8 through 11.
13. Test all channels: repeat steps 4 through 12 for all channels.

Experiment Table:

Channel	Impedance (Ω)	Range (V)	Offset (V)	Min. Average Value (V)	Max. Average Value (V)
1 - 4	50	0.040	0.016	0.0148	0.0172
			-0.016	-0.0172	-0.0148
		0.080	0.032	0.0306	0.0334
			-0.032	-0.0334	-0.0306
		0.200	0.080	0.0781	0.0819
			-0.080	-0.0819	-0.0781
		0.400	0.160	0.1572	0.1628
			-0.160	-0.1628	-0.1572
		1.00	0.400	0.3945	0.4055
			-0.400	-0.4055	-0.3945
		2.00	0.800	0.7900	0.8100
			-0.800	-0.8100	-0.7900
		5.00	2.000	1.9765	2.0235
			-2.000	-2.0235	-1.9765
		10.00	0.000	-0.0260	0.0260
			0.000	-0.0260	0.0260
	1M	0.200	0.080	0.0741	0.0859
			-0.080	-0.0859	-0.0741
		0.400	0.160	0.1532	0.1668
			-0.160	-0.1668	-0.1532
		1.00	0.400	0.3905	0.4095
			-0.400	-0.4095	-0.3905
		2.00	0.800	0.7860	0.8140
			-0.800	-0.8140	-0.7860
		5.00	2.000	1.9725	2.0275
			-2.000	-2.0275	-1.9725
		10.00	4.000	3.9500	4.0500
			-4.000	-4.0500	-3.9500
		25.00	10.000	9.8825	10.1175
			-10.000	-10.1175	-9.8825
		50.00	0.000	-0.1300	0.1300
			0.000	-0.1300	0.1300

Table 2.7: Offset Setup and Tolerances

RMS Noise Validation

ZT4440 and ZT4430 Specification:

(0.05% of full scale range + 75 µV)	(50Ω Full Bandwidth)
(0.025% of full scale range)	(50Ω + 20 MHz Filter)
(0.05% of full scale range + 1 mV)	(1MΩ Full Bandwidth)
(0.025% of full scale range + 500 µV)	(1MΩ + 20 MHz Filter)

ZT4420 Specification:

(0.05% of full scale range + 75 µV)	(50Ω Full Bandwidth)
(0.04% of full scale range)	(50Ω + 20 MHz Filter)
(0.05% of full scale range + 1 mV)	(1MΩ Full Bandwidth)
(0.04% of full scale range + 500 µV)	(1MΩ + 20 MHz Filter)

Procedure:

1. Reset the instrument.
2. Connect a 10MHz clock to the external input of the instrument.
3. Enter the following settings for each test.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Trigger Source	External Input
Trigger Level	0.0
Trigger Polarity	Rising Edge
Sample Points	1M
Time/Div	5 ms
Offset Time	0.0
Coupling	DC
Attenuation	1.0
Offset	0.0

Table 2.9: Noise Validation Settings

4. Use the experiment table below to determine the settings of the instrument.
5. Capture a waveform. Measure the AC RMS of the waveform.
6. Verify the measurement is approximately the value specified below by the experiment table.
7. Test all channels: repeat steps 4 through 6 for all channels.

Experiment Table:

Channel	Filter	Impedance (Ω)	Range (V)	ZT4440 or ZT4430 Approx. Value (Vrms)	ZT4420 Approx. Value (Vrms)
1 – 4	Off	50	0.040	9.500E-05	9.500E-05
			0.080	1.150E-04	1.150E-04
			0.200	1.750E-04	1.750E-04
			0.400	2.750E-04	2.750E-04

Channel	Filter	Impedance (Ω)	Range (V)	ZT4440 or ZT4430 Approx. Value (Vrms)	ZT4420 Approx. Value (Vrms)
			1.00	5.750E-04	5.750E-04
			2.00	1.075E-03	1.075E-03
			5.00	2.575E-03	2.575E-03
			10.00	5.075E-03	5.075E-03
		1M	0.200	1.100E-03	1.100E-03
			0.400	1.200E-03	1.200E-03
			1.00	1.500E-03	1.500E-03
			2.00	2.000E-03	2.000E-03
			5.00	3.500E-03	3.500E-03
			10.00	6.000E-03	6.000E-03
			25.00	1.350E-02	1.350E-02
			50.00	2.600E-02	2.600E-02
	On	50	0.040	1.000E-05	1.000E-05
			0.080	2.000E-05	2.000E-05
			0.200	5.000E-05	5.000E-05
			0.400	1.000E-04	1.000E-04
			1.00	2.500E-04	2.500E-04
			2.00	5.000E-04	5.000E-04
			5.00	1.250E-03	1.250E-03
			10.00	2.500E-03	2.500E-03
		1M	0.200	5.500E-04	5.500E-04
			0.400	6.000E-04	6.000E-04
			1.00	7.500E-04	7.500E-04
			2.00	1.000E-03	1.000E-03
			5.00	1.750E-03	1.750E-03
			10.00	3.000E-03	3.000E-03
			25.00	6.750E-03	6.750E-03
			50.00	1.300E-02	1.300E-02

Table 2.10: Noise Setup and Tolerances

External Input Trigger Level Validation

Specification:

± 20 mV

Procedure:

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

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Normal
Trigger Source	External

Table 2.11: External Input Validation Settings

3. Use a voltage source to apply a voltage to the external input.
4. Set the device to trigger at 1 V on the rising edge.
5. Setup the voltage source to start at 0.7 VDC, ramp the voltage up in 5 mV steps.
6. Monitor the device to capture the voltage level when it triggers.
7. Verify the voltage is within the tolerances specified below by the experiment table.
8. Set the device to trigger at -1 V on the falling edge.
9. Setup the voltage source to start at -0.7 VDC, ramp the voltage down in 5 mV steps.
10. Monitor the device to capture the voltage level when it triggers.
11. Verify the voltage is within the tolerances specified below by the experiment table.

Experiment Table:

Channel	Applied Voltage (V)	Min. Measured Value (V)	Max. Measured Value (V)
External Input	1.00	0.98	1.02
	-1.00	-1.02	-0.98

Table 2.12: External Input Setup and Tolerances

Internal 10 MHz Clock Validation

Specification:

± 2.5 ppm accuracy

Procedure:

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

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Time/Div	10 ms
Offset Time	0s
Trigger Source	Channel 1
Trigger Level	1.0
Trigger Polarity	Rising Edge
Channel 1	Enabled
Channel 1 Range	5.0 Vpp
Channel 1 Offset	0
Channel 1 Coupling	DC
Channel 1 Impedance	50 Ω
Channel 1 Filter	Off
Channel 1 Attenuation	1.0
External Output	Enabled
External Output Source	Reference Event
External Output Polarity	Positive

Table 2.13: 10 MHz Clock Validation Settings

4. Capture a waveform. Measure the frequency of the waveform.
5. 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 2.14: 10 MHz Clock Validation Tolerances

Sample Rate Validation

Specification:

± 0.5%

Procedure:

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

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

Table 2.15: Sample Rate Validation Settings

3. Use the experiment table below to determine the remaining instrument settings.
4. Use an AC voltage source to apply a +8 dBm signal to the channel being tested at the frequency indicated by the experiment table below.
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:

Trigger & Capture Channel	Sample Rate (S/s)	Time/Div	Signal Frequency (Hz)	Minimum Measured Frequency (Hz)	Maximum Measured Frequency (Hz)
1 - 4	1.0000E+09	1 µs	1.0100E+06	1.0050E+06	1.0151E+06
	5.0000E+05	2 ms	1.0000E+03	0.9950E+03	1.0050E+03

Table 2.16: Sample Rate Setup and Tolerances

AC Coupling Validation

Specification:

200 kHz High Pass (50 Ω)
10 Hz High Pass (1 MΩ)

Procedure:

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

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	10k
Offset Time	0.0
Range	2 Vpp
Offset	0.0
Coupling	AC
Impedance	50 Ω
Filter	Off
Attenuation	1.0

Table 2.17: AC Coupling Validation Settings

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

Experiment Table:

Channel	Sample Rate (S/s)	Time/Div	Signal Frequency (Hz)	Minimum Measured Value (Vrms)	Maximum Measured Value (Vrms)
1 - 4	2.0000E+08	5 μs	1.0000E+06	0.5457	0.5781
	2.0000E+07	50 μs	1.0000E+05	0.3158	0.4092
	2.0000E+06	0.5 ms	1.0000E+04	0.0000	0.0892

Table 2.18: AC Coupling Setup and Tolerances

Trigger Level Validation

Specification:

± (2% full scale range + 5 mV + offset accuracy)

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	Average
Number of Acquisitions	32
Trigger Mode	Normal
Sample Points	100
Time/Div	10 ns
Offset Time	50 ns
Range	2 Vpp
Impedance	50 Ω
Offset	0.0
Coupling	DC
Filter	Off
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1

Table 2.19: Trigger Level Validation Settings

4. Use the experiment table below to determine the remaining instrument settings.
5. Use an AC voltage source to apply a 100 Hz signal at the signal level indicated in the experiment table to the channel being tested.
6. Capture a waveform. Measure the average value of the waveform.
7. Verify that the measurement is within the tolerances specified below by the experiment table.

Experiment Table:

Channel	Signal Power (dBm)	Trigger Polarity	Trigger Level	Minimum Average Value (V)	Maximum Average Value (V)
1 - 4	10	Falling Edge	0.7071	0.641107	0.773107
		Rising Edge	-0.7071	-0.773107	-0.641107

Table 2.20: Trigger Level Setup and Tolerances

Trigger Bandwidth Validation

Specification:

DC to 250 MHz 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	Normal
Sample Points	1000
Offset Time	0
Range	5 Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ω
Filter	Off
Attenuation	1.0
Trigger Polarity	Rising Edge

Table 2.21: Trigger Bandwidth Validation Settings

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

Experiment Table:

Channel	Time/ Div	Trigger Level (V)	Signal Frequency (Hz)	Signal Magnitude (dBm)
1 - 4	100 ns	0.25	1.00E+06	5.0
			1.00E+07	5.0
			1.00E+08	5.0
			2.50E+08	5.0
External Input	N/A	0.1	1.00E+07	-8.0
			1.00E+08	-8.0
			2.50E+08	-5.0

Table 2.22: Trigger Bandwidth Setup

Range Bandwidth Validation

Specification:

50Ω: DC to 300 MHz typical, 250 MHz minimum (-3 dB)
1MΩ: DC to 300 MHz typical, 250 MHz minimum (-3 dB)

Procedure:

1. Reset the instrument.
2. Disable all channels not being tested.
3. Enter the following settings for each test using the sweep time for the appropriate instrument option.

Setup Item	Setting
Acquisition Type	Normal
Trigger Mode	Automatic
Sample Points	100k
ZT4420 Sweep Time	100 µs
ZT4430 Sweep Time	200 µs
ZT4440 Sweep Time	125 µs
Offset Time	0
Offset	0.0
Coupling	DC
Filter	Off
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1

Table 2.23: Range Bandwidth Validation Settings

4. Use the 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.

Experiment Table:

Chan	Impedance (Ω)	Range (Vpp)	Signal Volt (mVrms)	Signal Freq. (Hz)	Min. Measured Value (Vrms)	Max. Measured Value (Vrms)
1 - 4	50	10	999	2.500E+08	0.7071	1.0581
		5	999	2.500E+08	0.7071	1.0581
		2	500	2.500E+08	0.3540	0.5610
		1	200	2.500E+08	0.1416	0.2119
		0.5	100	2.500E+08	0.0707	0.1059
		0.25	50	2.500E+08	0.0353	0.0529
		0.1	25	2.500E+08	0.0177	0.0265
		0.05	10	2.500E+08	0.0070	0.0106
	1M	10.0	999	2.500E+08	0.7079	1.0581
		2.0	500	2.500E+08	0.3539	0.5296

Table 2.24: Range Bandwidth Setup and Tolerances

Filter Bandwidth Validation

Specification:

Stopband rejection approx. 3 dB at 20 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	100k
Sample Rate	500 MHz
Time/Div	20 µs
Offset Time	0
Range	5Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ω
Filter	On
Attenuation	1.0
Measure Method	Entire Waveform
Measure Edge	1

Table 2.25: Filter Bandwidth Validation Settings

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

Experiment Table:

Channel	Signal Voltage (Vrms)	Signal Frequency (Hz)	Minimum Measured Value (Vrms)	Maximum Measured Value (Vrms)
1 – 4	0.800	2.0100E+07	0.5047	0.6354

Table 2.26: Filter Bandwidth Setup and Tolerances

Harmonics & Distortion Validation

Dynamic Range, 10.7 MHz (typical):

ZT442X (12-bit Digitizer)

50Ω Input Range (Vpp)	Signal-to Noise Ratio (SNR) (dBc)	Total Harmonic Distortion (THD) (dBc)	Signal-to-Noise + Distortion (SINAD) (dBc)	Spurious Free Dynamic Range (SFDR) (dBc)
10.0	61.2	-62.8	58.9	65.0
5.0	59.0	-64.3	57.9	65.0
2.0	60.0	-62.8	58.2	65.0
1.0	58.2	-64.3	57.3	65.0
0.4	55.7	-64.1	55.1	65.0
0.2	50.5	-64.9	50.4	63.3
0.08	49.4	-63.9	49.3	55.5
0.04	43.5	-63.1	43.4	48.9

ZT443X (13-bit Digitizer)

50Ω Input Range (Vpp)	Signal-to Noise Ratio (SNR) (dBc)	Total Harmonic Distortion (THD) (dBc)	Signal-to-Noise + Distortion (SINAD) (dBc)	Spurious Free Dynamic Range (SFDR) (dBc)
10.0	61.2	-62.8	58.9	65.0
5.0	59.0	-64.3	57.9	65.0
2.0	60.0	-62.8	58.2	65.0
1.0	58.2	-64.3	57.3	65.0
0.4	55.7	-64.1	55.1	65.0
0.2	50.5	-64.9	50.4	63.3
0.08	49.4	-63.9	49.3	55.5
0.04	43.5	-63.1	43.4	48.9

ZT444X (14-bit Digitizer)

50Ω Input Range (Vpp)	Signal-to Noise Ratio (SNR) (dBc)	Total Harmonic Distortion (THD) (dBc)	Signal-to-Noise + Distortion (SINAD) (dBc)	Spurious Free Dynamic Range (SFDR) (dBc)
10.0	61.2	-62.8	58.9	65.0
5.0	59.0	-64.3	57.9	65.0
2.0	60.0	-62.8	58.2	65.0
1.0	58.2	-64.3	57.3	65.0
0.4	55.7	-64.1	55.1	65.0
0.2	50.5	-64.9	50.4	63.3
0.08	49.4	-63.9	49.3	55.5
0.04	43.5	-63.1	43.4	48.9

Table 2.27: Dynamic Range Specifications

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	Normal
Sample Points	100k
Range	2 Vpp
Offset	0.0
Coupling	DC
Impedance	50 Ω
Filter	Off
Attenuation	1.0

Table 2.28: Harmonics and Distortion Validation Settings

4. Use the experiment table below to determine the remaining instrument settings.
5. Use an AC voltage source to apply +9 dB 10.7 MHz signal to the channel being tested. ZTEC suggests filtering the signal at the input to the instrument in order to eliminate any noise from the AC source.
6. Capture a waveform.
7. Enable calculation channel 1. Set calculation channel 1 to perform an FFT of the captured waveform using a Hanning window.
8. Measure the SNR and THD of the FFT in calculation channel 1.
9. Verify that the measurement meets the minimum requirements specified by the experiment table below.

Experiment Table:

Channel	Sample Rate(Hz)	Time/Div	Offset Time (s)	Measurement	Minimum Measured for SNR, Maximum Measured for THD Value (dB)
1	1.00E+09	10us	1.250E-05	SNR	40.0
3				THD	-40.0
2	0.50E+09	20us	2.500E-05	SNR	40.0
4				THD	-40.0

Table 2.29: Harmonics & Distortion Setup and Tolerances

Calibration Tests

Internal 10 MHz Calibration

Procedure:

1. Reset the instrument.
2. Connect a precision 10 MHz +10 dBm signal to the external input of the instrument.
3. Set the reference oscillator source to external.
4. Use the zbind_blkin function to read an unsigned 32 bit integer value from the memory address 0x9010007C. (F_{EXT})
5. Set the reference oscillator source to internal.
6. Use the zbind_blkin function to read an unsigned 32 bit integer value from the memory address 0x9010007C. (F_{INT})
7. Calculate the error by subtracting the measured internal rate from the measured external rate.

$$error = F_{INT} - F_{EXT}$$

8. Use the ztscopeM_calibrate_reference_oscillator_adjust function to adjust the codes.
9. Repeat steps 6 through 8 until the error is less than 25.

Implementation Notes:

1. Each code should converge to an acceptable value within 10 iterations of the process.

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	10,000
Sample Rate	200 MS/s
Time/Div	5 µs
Offset Time	0.0
Acquisition Mode	Normal
Trigger Mode	Normal
Measure Method	Entire Waveform
Measure Edge	1
Offset	0.0
Coupling	DC
Attenuation	1.0

Table 3.1: 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

$$gain\_error = 1 - \frac{V_A \times (V_N - V_P)}{2 \times V_N \times V_P}$$

10. Use the ztscopeM_calibrate_gain_adjust function to adjust the gain codes.
11. Repeat steps 5 through 10 until the gain error is less than 0.25%.
12. Repeat procedure for each combination of channel, range, impedance, and filter settings specified in the experiment table below.

Implementation Notes:

1. Each range except the maximums is calibrated at 90% of the maximum peak to peak range. (Note: This translates to 45% of the maximum and minimum range values.) This ensures that the gain accuracy is better than 0.25% of full scale.
2. Each gain code should converge to an acceptable value within 10 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 external level calibration immediately following a range calibration.

Experiment Table:

Channel	Impedance (Ω)	Filter	Range (Vpp)	Positive Applied Voltage (V)	Negative Applied Voltage (V)
1 - 4	1M	Off	50.00	22.5	-22.5
			25.00	11.25	-11.25
			10.00	4.5	-4.5
			5.00	2.25	-2.25
			2.00	0.9	-0.9
			1.00	0.45	-0.45
			0.400	0.18	-0.18
			0.200	0.09	-0.09
		On	50.00	22.5	-22.5
			25.00	11.25	-11.25
			10.00	4.5	-4.5
			5.00	2.25	-2.25
			2.00	0.9	-0.9
			1.00	0.45	-0.45
			0.400	0.18	-0.18
			0.200	0.09	-0.09
	50	Off	10.0	4.5	-4.5
			5.0	2.25	-2.25
			2.0	0.9	-0.9
			1.0	0.45	-0.45
			0.400	0.18	-0.18
			0.200	0.09	-0.09
			0.080	0.036	-0.036
			0.040	0.018	-0.018
		On	10.0	4.5	-4.5
			5.0	2.25	-2.25
			2.0	0.9	-0.9
			1.0	0.45	-0.45
			0.400	0.18	-0.18
			0.200	0.09	-0.09
			0.080	0.036	-0.036
			0.040	0.018	-0.018

Table 3.2: Range Calibration Setup and Tolerances

External Level Calibration

Procedure:

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

Setup Item	Setting
Acquisition Mode	Normal
Trigger Mode	Normal
Trigger Source	External Input
Trigger Polarity	Rising Edge
Trigger Impedance	50 Ω

Table 3.3: Trigger Offset Calibration Settings

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

$$gain\_error = 1 - \frac{V_H - V_L}{2}$$

15. Use the function ztscopeM_calibrate_external_adjust to adjust the gain code based on the gain error.
16. Repeat steps 4 through 15 until the gain error is less than 1%.

Implementation Notes:

1. Perform an automatic calibration of the instrument immediately following the completion of external level calibration.
2. After the automatic calibration completes use the ztscopeM_save_calibration function to store the range gain codes and interleave gain codes permanently.

Experiment Table:

Trigger Source	Trigger Level (V)	Trigger Polarity	Applied Signal Voltage (V)	Signal Increment Value (V)
External Input	1.0	Falling Edge	-0.50	0.5E-03
	-1.0	Rising Edge	0.50	-0.5E-03

Table 3.4: Trigger Offset Calibration Setup and Tolerances

ZTEC Instruments