TN003 KXTJ2 Accelerometer Self-Test Operation and Character

Introduction

This technical note is intended to provide information about the operation and character of the KXTJ2 Self-Test. Self-Test is a standard feature in Kionix MEMS accelerometers that enables our customers to verify that the part is functional during static motion states. However, the customer must use the proper algorithm to ensure functionality. Applicable theories, plots, and equations are provided with this note as guidelines.

Self-Test Function

Kionix accelerometer devices are able to simulate actual acceleration readings by activating an electrostatic force that is applied to the sense element for X, Y and Z axes that causes the sensor mass to move and the outputs to change. This is achieved by writing to the **SELF_TEST** register as described below. The Self-Test function exercises the sense element and portions of the ASIC. During activation the device is able to output a signal as an acceleration value, but with the additional artificial stimulus applied. The utility of the Self-Test function to the user is to observe and verify that the sensor and communication are operating normally by comparing the change in outputs, that is to compare Self-Test = enabled outputs to the outputs during normal sensing, Self-Test = disabled. All axes are activated simultaneously, although each axis may vary in value.

The difference between the active Self-Test and the normal state are consistent at any stable (or non-dynamic) sensing state. For example, if the sensor is in a position to read outputs at +1g then the Self-Test will read an additional specified output such that the difference will be a fixed value. So that even if the sensor is in a position, for example to be reading -1g, then the difference between the "Active Self-Test" Outputs and the Normal Outputs will be the same value as the +1g difference. The product specification states the expected amount of output change. A formula for the Self-Test (ST) values is as follows:

$$ST(g) = \frac{(Output_{ST\ on} - Output_{ST\ off})}{Sensitivity}$$

If the device is moving, then the Self-Test difference may become difficult to resolve from the actual motion of the device and may not be useful. At these times, observing the varying outputs due to motion achieves an equivalent verification of operation and communication as Self-Test, thus making the Self-Test redundant.

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Self-Test Algorithm

The Self-Test (ST) command sequence follows this pattern:

A) Read Outputs (ST = disabled)
B) Set PC1 = 0
C) Set ST Polarity = 0 or 1
D) Set PC1 = 1
E) Activate ST
F) Read Outputs (ST = Enabled)
G) Deactivate ST (ST = Disabled) return to normal mode
H) Test Value = ($ST_{Enabled}$ – $ST_{Disabled}$) / Sensitivity

Measurement Methods

The KXTJ2 has 3 operational modes with regard to Self-Test (ST).

A) Normal Operation where the ST is not active
B) ST Polarity = 0 where the stimulated motion is additive
C) ST Polarity = 1 where the stimulated motion is subtractive

There are three measurement methods that can be used to verify operation:

A) Compare Outputs of ST Polarity = 0 to Normal Outputs
B) Compare Outputs of ST Polarity = 1 to Normal Outputs
C) Compare Outputs of ST Polarity = 1 to Outputs of ST Polarity = 0

The Self-Test values are consistent regardless of the acceleration g-range set in the control register, but the values obtained for these methods show manufacturing variation from part to part. The manufacturing variation for the KXTJ2 is shown below in the Production Distribution section.

Note that the data for the “difference” between positive and negative has the tightest distribution and is always positive in value. To obtain the difference requires first operating the self-test at the Self-Test Polarity = 0, saving the values to memory and then obtaining the values at Self-Test Polarity = 1, then subtracting the difference of the saved values and the new values.

The Self-Test (ST) command sequence follows this pattern:

A) Set PC1 = 0
B) Set ST Polarity = 1
C) Set PC1 = 1
D) Activate ST (ST = Enabled)
E) Read Outputs (ST = Enabled)
F) Set PC1 = 0
G) Set ST Polarity = 0
H) Set PC1 = 1
I) Activate ST (ST = Enabled
J) Read Outputs (ST = Enabled)
K) Deactivate ST (ST = Disabled) return to normal mode

$$ST_{Difference}(g) = \frac{(Output_{ST\ Positive} - Output_{ST\ Negative})}{Sensitivity}$$

Setting Self-Test

The operational registers for Self-Test can be accessed and set using the communication protocol outlined in the Product Specifications. The Polarity can be set by setting the Self-Test Polarity bit in appropriate register for the product.

Interrupt Control Register One

The self-test operation of the KXTJ2 has two modes or polarities of operations. STPOL = 0, called negative self-test, and STPOL = 1 called positive self-test.

INT_CTRL_REG1

This register controls the settings for the physical interrupt pin (7). Note that to properly change the value of this register, the PC1 bit in CTRL_REG1 must first be set to "0".

R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
0	0	IEN	IEA	IEL	0	STPOL	0	Reset Value
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	00010000
					I²C Address: 0x1Eh			

***STPOL* –** Self-Test polarity. 0=negative polarity, 1=positive polarity

SELF_TEST

When 0xCA is written to this register, the MEMS self-test function is enabled. Electrostatic-actuation of the accelerometer, results in a DC shift of the X, Y and Z axis outputs. Writing 0x00 to this register will return the accelerometer to normal operation. This register is write only.

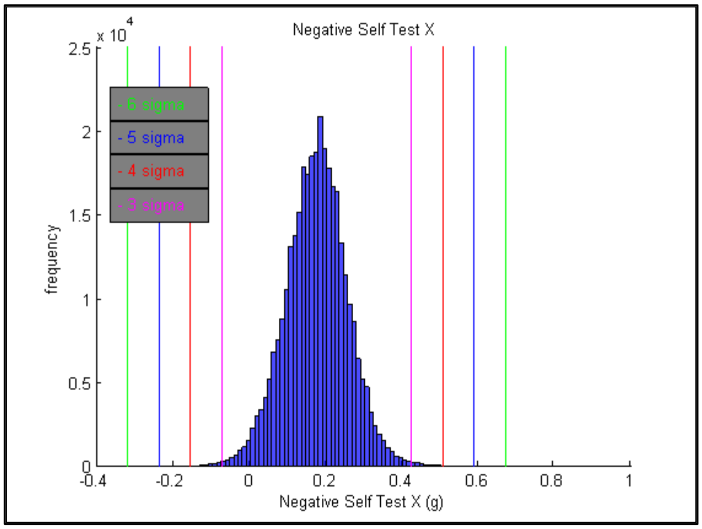
W	W	W	W	W	W	W	W	
1	1	0	0	1	0	1	0	Reset Value
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	00000000
					I²C Address: 0x3Ah			

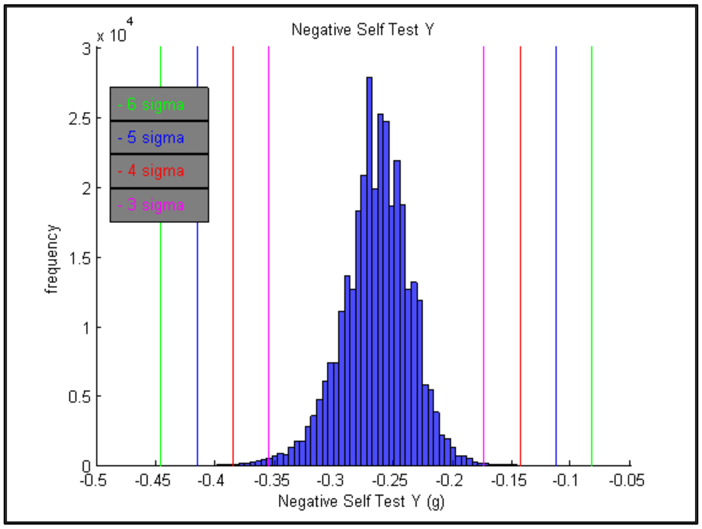
Production Distributions

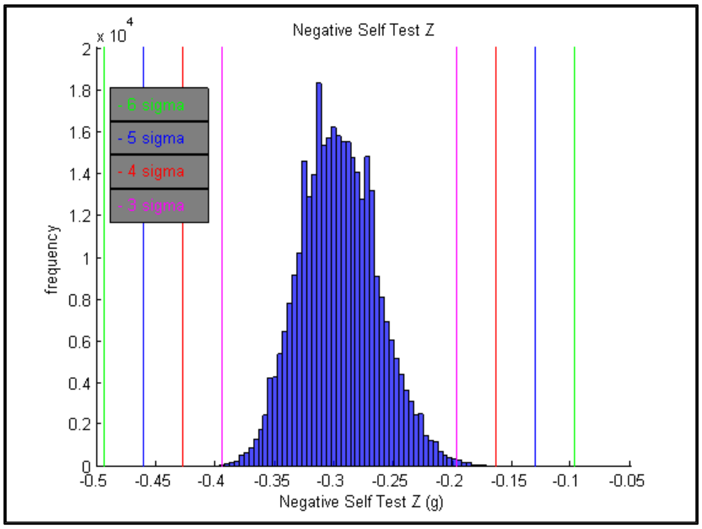
The self-test operation of the KXTJ2 has shown the following production distributions:

The sample quantity of parts analyzed is approximately 19 million parts, produced in 2015.

Self-Test setting Polarity = 0 (Negative)

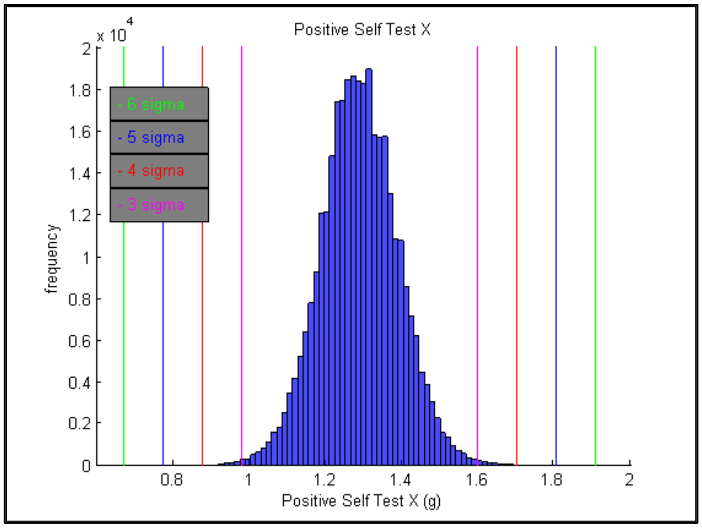


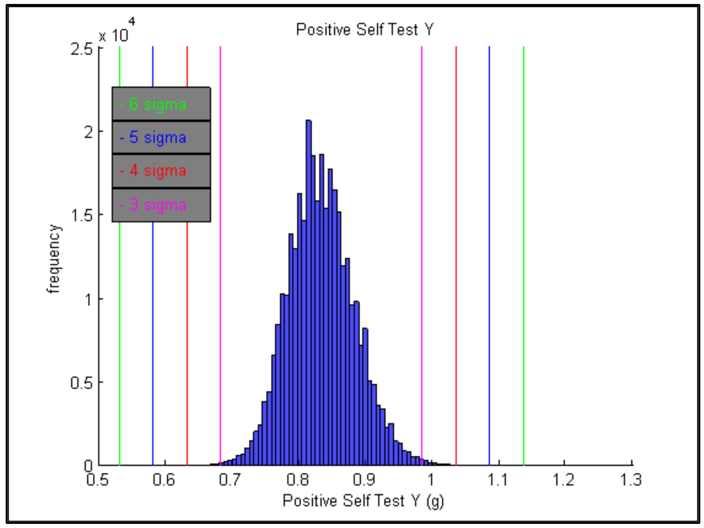


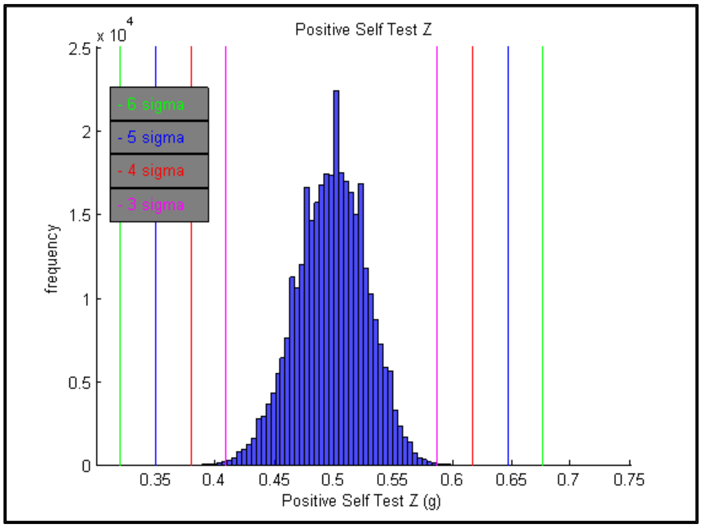


	X Neg ST	Y Neg ST	Z Neg ST	units
Average	0.18	-0.26	-0.3	g
Std.Dev.	0.082	0.03	0.033	g

Self-Test Polarity STPOL = 1 (Positive)

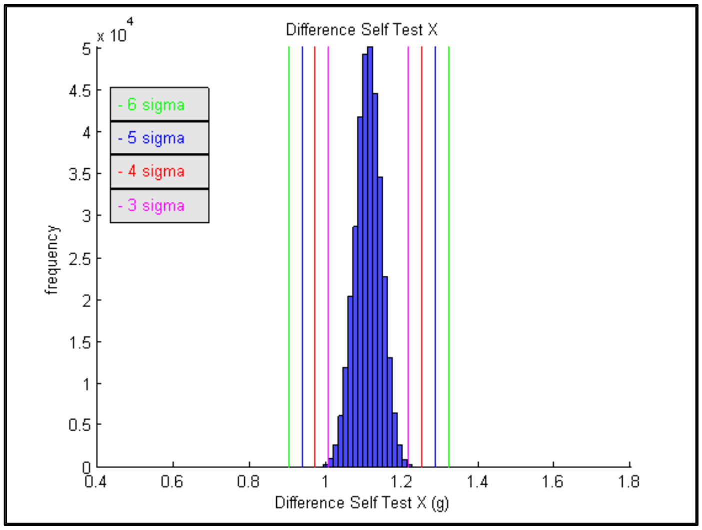


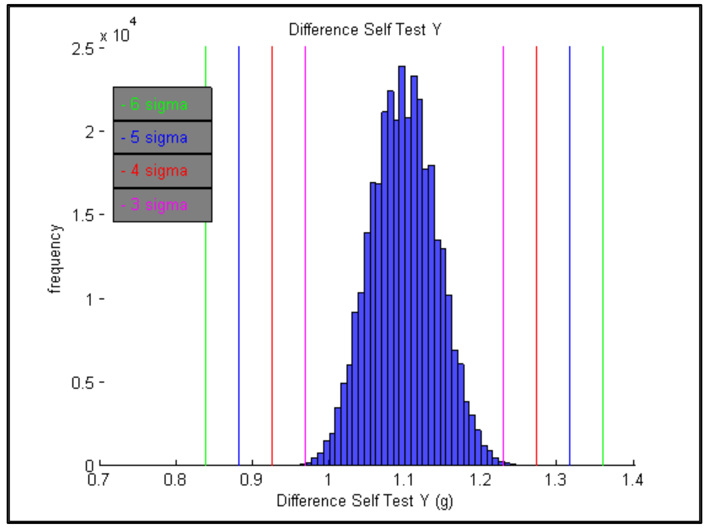


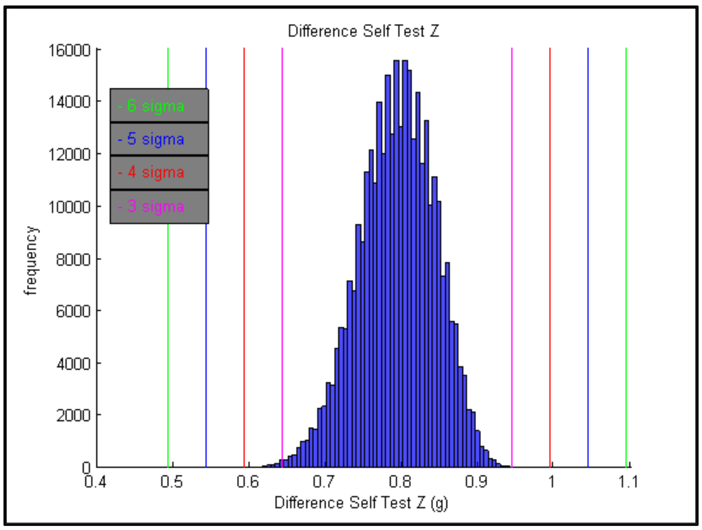


	X Pos ST	Y Pos ST	Z Pos ST	units
Average	1.29	0.83	0.5	g
Std.Dev.	0.103	0.05	0.03	g

Self-Test Difference Values (Positive – Negative)







	X Dif ST	Y Dif ST	Z Dif ST	units
Average	1.11	1.1	0.79	g
Std.Dev.	0.035	0.043	0.05	g