Free-fall Sensing for Drop-Force Modeling Using Kionix MEMS Tri-Axis Accelerometer

Introduction

This application note describes how to use a Kionix MEMS tri-axis accelerometer as a free-fall sensor for drop force modeling applications. Required theory, equations, and sample event signatures are provided with this note as guidelines for characterizing drop force models.

Free fall Sensing

When a tri-axis accelerometer is stationary, its total acceleration it measures is 1g ($9.8m/s^2$), regardless of orientation. This total acceleration can be calculated from the X, Y, and Z outputs of the accelerometer using Equation 1 below. When a tri-axis accelerometer is dropped in any orientation, it is in free-fall and the measured acceleration on all three axes is 0g. Therefore, the total acceleration is zero as well. Total acceleration can be monitored to sense that the accelerometer has been dropped, and to measure its free-fall time. Note that this signature cannot accurately be observed when using a dual axis accelerometer because, when horizontally oriented, the X and Y-axis outputs are the same (0g), whether the accelerometer is stationary or in free-fall.

$$a_{total} = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

Equation 1: Total Acceleration

The Drop Test

The purpose of the drop test was to address a product warranty situation in which a manufacturer guarantees that a product will survive a 4ft (1.219m) drop to concrete. A Kionix KXM52 equipped development board was used to conduct this experiment. The development board sends the analog accelerometer outputs to a Texas Instruments MSP430F149 micro for ADC, and transmits via serial port to a PC for data logging, processing, and plotting. Please refer to the Kionix application note entitled "AN002 *Interfacing the Kionix KXP94 or KXR94 Tri-Axis Accelerometer with the Texas Instruments MSP430F149 Microprocessor to Measure Tilt and Other Motions*" for a detailed description of the Kionix development board used in this experiment.

The Kionix development board was mounted in a metal project box such that the accelerometer was located near the center of mass. Mounting near the center of mass will ensure that centripetal accelerations remain negligible throughout the experiment. With the PC logging data at a rate of 250 samples per second, the enclosure was dropped from a height of approximately 4ft. The logged total acceleration data for the entire event was plotted over time in order to observe the signature in Figure 1 below. For this calculation, the total time in free-fall was considered to be the interval of time between the point at which the object crossed .5g on the way to free-fall to the point at which the object again crossed .5g upon impact.

36 Thornwood Dr. - Ithaca, NY 14850
tel: 607-257-1080 — fax: 607-257-1146
www.kionix.com — info@kionix.com

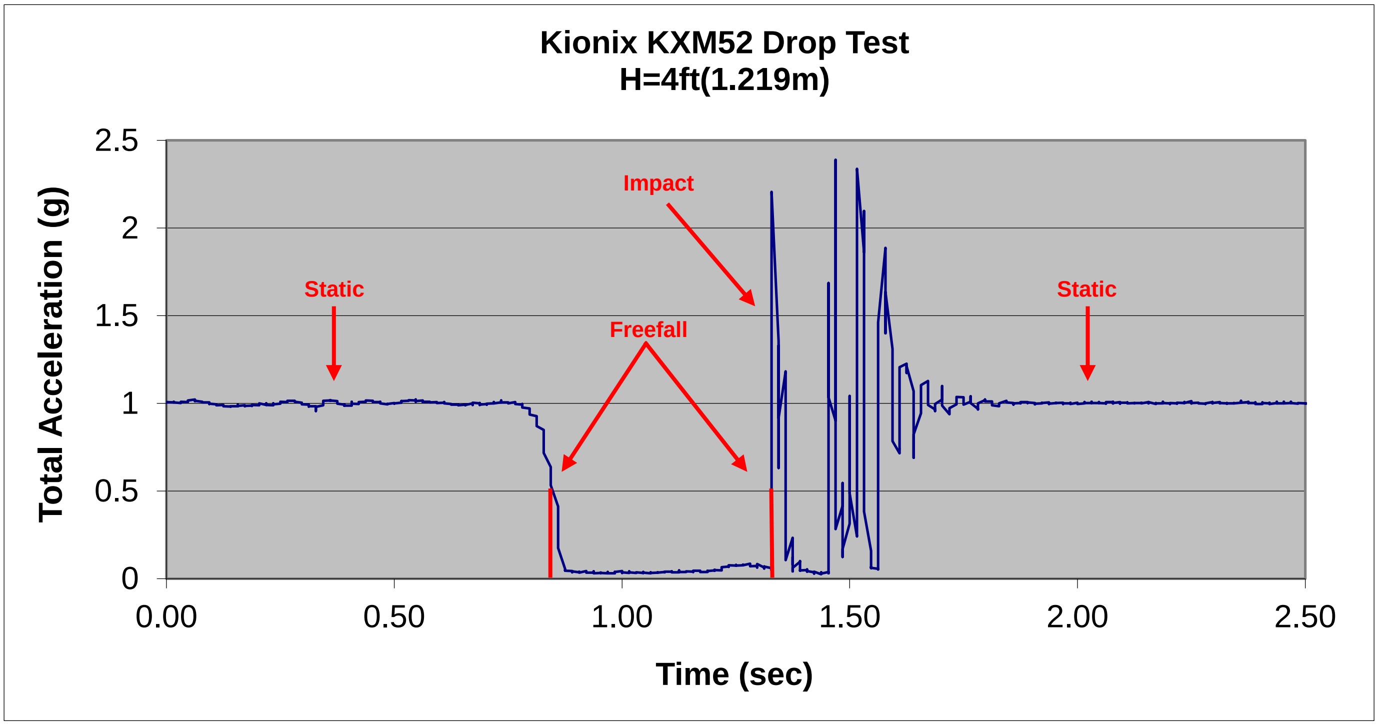

Figure 1: Drop Test Signature

Based on the data collected, the free-fall time was .498 seconds. Equation 2 can be used to calculate the height at which the object was released to free-fall. In this case, the object, in fact, did fall from a height of approximately 1.219m (4ft).

$$h = \frac{\left(gt^2\right)}{2}$$

Equation 2: h = drop height (m), t = time (s), g = 9.8m/s^2

Approximate Impact

According to JEDEC (Joint Electron Device Engineering Council) Mechanical Shock spec JESD22-B104-B the peak acceleration felt by an object can be approximated by the height from which it was dropped. Please see the specification for object and drop surface assumptions. In this case, the Kionix accelerometer sensed that the object was dropped from a height of approximately 1.219m, which would correlate to peak acceleration on impact of approximately 1700g. Please see the JEDEC Acceleration peak vs. drop height plot in Figure 2 below:

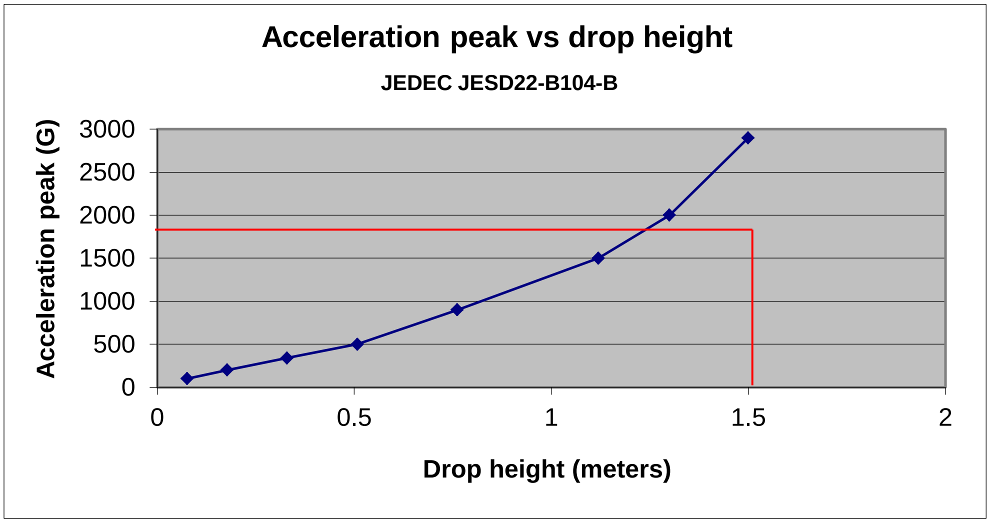

Figure 2: JEDEC Acceleration Peak vs. Drop Height

Implementation Suggestions

The accelerometer must be mounted as close as possible to the center of mass of the object to be tested to eliminate any centripetal acceleration that the accelerometer will sense if the object rotates during free-fall. If the accelerometer is not mounted at the center of mass, the measured acceleration during free-fall will be nonzero, and equal to ω^2R, where ω is the rotations per second and R is the distance the accelerometer is from the center of mass. Please contact Kionix at info@kionix.com for further suggestions and recommendations on mounting the accelerometer, and the effects of centripetal acceleration.

The Kionix Advantage

A Kionix tri-axis accelerometer can be used successfully to characterize event signatures that may potentially void manufacturer's warranties. Kionix technology provides for X, Y, and Z-axis sensing on a single, silicon chip. One accelerometer can be used to enable a variety of simultaneous features including, but not limited to:

Hard Disk Drive protection
Vibration analysis
Tilt screen navigation
Sports modeling
Theft, man-down, accident alarm
Image stability, screen orientation & scrolling
Computer pointer
Navigation, mapping
Game playing
Automatic sleep mode

Theory of Operation

Kionix MEMS linear tri-axis accelerometers function on the principle of differential capacitance. Acceleration causes displacement of a silicon structure resulting in a change in capacitance. A signal-conditioning CMOS technology ASIC detects and transforms changes in capacitance into an analog output voltage, which is proportional to acceleration. These outputs can then be sent to a micro-controller for integration into various applications. For product summaries, specifications, and schematics, please refer to the Kionix MEMS accelerometer product sheets at http://www.kionix.com/parametric/Accelerometers