



± 5g X-axis Accelerometer Specifications

PART NUMBER:

KXD94-7138
Rev. 4
Oct-2015

Product Description

The KXD94-7138 is an X-axis, silicon micromachined accelerometer with a full-scale output range of +/-5g (49 m/s/s). The sense element is fabricated using Kionix's proprietary plasma micromachining process technology. Acceleration sensing is based on the principle of a differential capacitance arising from acceleration-induced motion of the sense element, which further utilizes common mode cancellation to decrease errors from process variation, temperature, and environmental stress. The sense element is hermetically sealed at the wafer level by bonding a second silicon lid wafer to the device using a glass frit. A separate ASIC device packaged with the sense element provides signal conditioning and self-test. The accelerometer is delivered in a 5 x 5 x 1.2 mm DFN plastic package operating from a 2.50V - 5.25V DC supply. The X axis output is provided on an **analog** output pin. Alternately there is a buffered output (VMUX). The Enable pin must be **high** for normal operation and **low** for power shutdown.

There are 4 factory programmable modes of operation for the KXD94:

- Mode 00** – The X axis output is read through the **digital** SPI interface, which is also used to command Selftest and Standby Mode. The digital I/O pads are powered from a separate power pin, and will interface to 1.8V logic.
- Mode 01** – The X axis output is provided on an **analog** output pin. The KXD94 also features an integrated **multiplexer** (X). The Enable pin must be **high** for normal operation and **low** for power shutdown.
- Mode 10** – The X axis output is provided on an **analog** output pin. The KXD94 also features an integrated **multiplexer** (X, Aux In). The Enable pin must be **high** for normal operation and **low** for power shutdown.
- Mode 11** – The X axis output is provided on an **analog** output pin. The KXD94 also features an integrated **multiplexer** (X, Aux In). The Enable pin must be **low** for normal operation and **high** for power shutdown.

The KXD94-7138 is factory programmed to be in MODE 10.



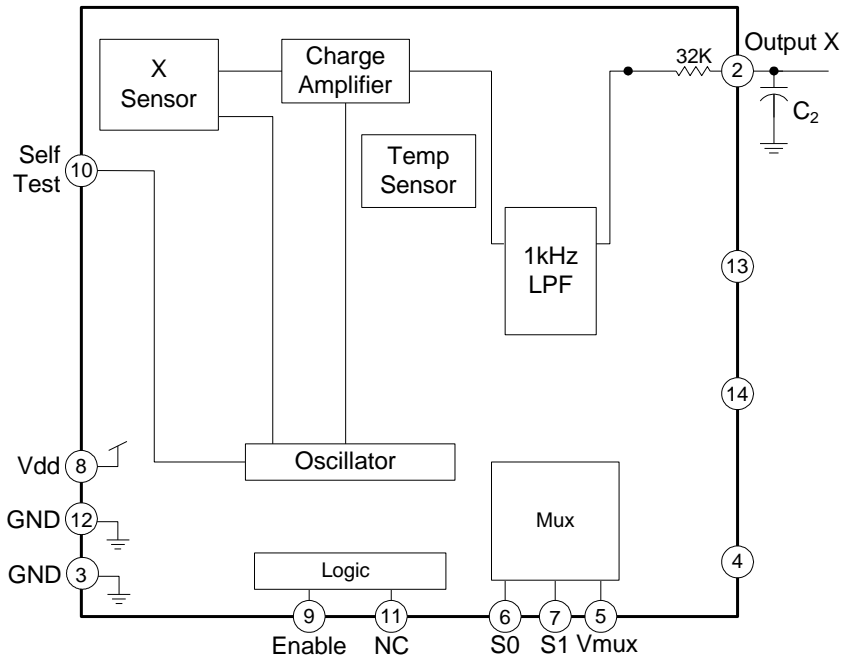


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Functional Diagram



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Product Specifications

Table 1. Mechanical

(specifications are for operation at 5V and T = 25C unless stated otherwise)

Parameters		Units	Min	Typical	Max
Operating Temperature Range		°C	-40	-	125
Zero-g Offset	!	V	2.42	2.5	2.58
Zero-g Offset Variation from RT over Temp.		mg/°C		1	5.5
Sensitivity	!	mV/g	386	400	414
Sensitivity Variation from RT over Temp.		%/°C		0.01	0.03
Offset Ratiometric Error (Vdd = 5V ± 5%)		mg		0.5	1.5
Sensitivity Ratiometric Error (Vdd = 5V ± 5%)		%		1.6	3
Non-Linearity		% of FS		0.1	0.5
Cross Axis Sensitivity		%		2	3
Self Test Output change on Activation		g	5.5	6.5	
Bandwidth (-3dB) ¹		Hz	640	800	960
Noise Density (on filter pins)		μg / √Hz		100	

! Denotes Special Characteristics: These characteristics have been identified as important to the customer.

Notes:

1. Internal 1 kHz low pass filter. Lower frequencies are user definable with external capacitors.



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Table 2. Electrical

(specifications are for operation at 5V and T = 25C unless stated otherwise)

Parameters		Units	Min	Typical	Max
Supply Voltage (V _{dd})	Operating ^{1,2}	V	4.75	5	5.25
Current Consumption	Operating ³	! μA	700	1100	1500
	Standby	μA		-	5
Input Low Voltage ⁴		V	-	-	0.2 * V _{dd}
Input High Voltage ⁵		V	0.8 * V _{dd}	-	-
Analog Output Resistance (R _{out})		kΩ	24	32	40

! Denotes Special Characteristics: These characteristics have been identified as important to the customer.

Notes:

1. Supply voltage must be ramped to 80% of V_{dd} in 60mSec or less. The ASIC does not monitor V_{dd} voltage levels and ramping V_{dd} may result in failure. Note- The voltage cannot cycle during the start-up period.
2. The operating voltage range of the KXD94 is 2.5V to 5.25V but the performance for that range is not validated by this specification.
3. Tolerance for current at V_{dd}=5v.
4. Voltage level for logic '0'. I.e. disable selftest function
5. Voltage level for logic '1'. I.e. enable selftest function

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Table 3. Environmental

Parameters		Units	Min	Target	Max
Supply Voltage (V _{dd})	Absolute Limits	V	-0.3	-	7.0
Maximum Operating Temperature Range		°C	-40	-	125
Storage Temperature Range		°C	-55	-	150
Mech. Shock (powered and unpowered) ⁶		g	-	-	5000 for 0.5ms
ESD	HBM	V	-	-	3000

6. Mechanical shock abuse can cause offset shifts

CAUTION:
ELECTROSTATIC
SENSITIVE COMPONENT



Caution: ESD Sensitive and Mechanical Shock Sensitive Component, improper handling can cause permanent damage to the device.



This product conforms to Directive 2002/95/EC of the European Parliament and of the Council of the European Union (RoHS). Specifically, this product does not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), or polybrominated diphenyl ethers (PBDE) above the maximum concentration values (MCV) by weight in any of its homogenous materials. Homogenous materials are "of uniform composition throughout."



This product is halogen-free per IEC 61249-2-21. Specifically, the materials used in this product contain a maximum total halogen content of 1500 ppm with less than 900-ppm bromine and less than 900-ppm chlorine.

Soldering

Soldering recommendations available upon request or from www.kionix.com.



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Application Schematic

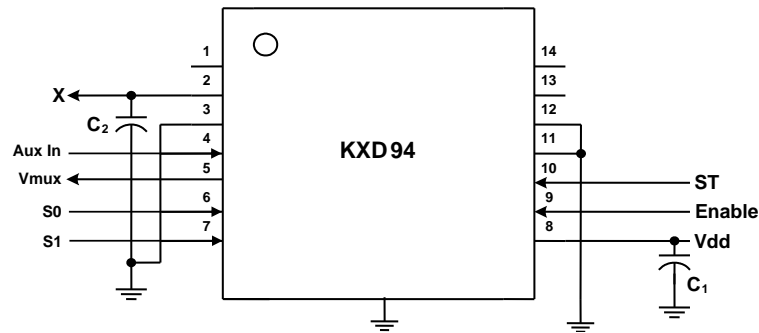


Table 4. KXD94 Pad Descriptions

Pad	Name	Description
1	NC	Not Connected Internally (can be connected to Vdd or Gnd)
2	X output	Analog output of the x-channel. Optionally, a capacitor (C ₂) placed between this pin and ground will form a low pass filter. Connect to Vdd or Ground if not used.
3	GND	Ground
4	Aux In	Auxiliary input for multiplexer. Connect to Vdd or Ground if not used. Input Impedance is 1KΩ
5	Vmux	Multiplexed analog output. Do not connect if multiplexer is not used.
6	S0	MUX selector 0 (See Output Select Table). Connect to Vdd or Ground if not used.
6 [†]	SDO	SPI Serial Data Output
7	S1	MUX selector 1 (See Output Select Table). Connect to Vdd or Ground if not used.
7 [†]	SCLK	SPI Communication Clock
8	Vdd	The power supply input. Decouple this pin to ground with a 0.1uF ceramic capacitor (C ₁).
9	Enable	Enable: High - Normal operation; Low - Device is in standby, power down mode
9 [†]	nCS	SPI Chip Select
10	ST	Self test. The output of a properly functioning part will increase when Vdd is applied to the self-test pin. (see Table 2)
10 [†]	SDI	SPI Serial Data Input
11	NC	Not Connected Internally (can be connected to Vdd or Gnd)
12	GND	Ground
13	DNC	Reserved – Do Not Connect
14	DNC	Reserved – Do Not Connect
	Center pad	Ground

Note 1: Pins 6,7,9,and 10 are used for SPI communication when nCS (Chip Select) is low.

Important Technical Note: Power Up / Power Down

Proper functioning of power-on reset (POR) is dependent on the specific Voff and Toff profile of individual applications. It is recommended to minimize Voff and maximize Toff. The application should be evaluated with the range of Voff and Toff expected within the application as POR performance can vary depending on these parameters. In order to guarantee proper reset regardless of Voff and Toff, a software reset can be issued via the SPI protocol. Please refer to Technical Note **KXR94 and KXD94 Accelerometer Reset Sequence** document to ensure proper POR function in your application.

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Application Design Equations

The bandwidth is determined by the internal 1kHz low pass filter. The user can lower the bandwidth by placing filter capacitors connected from pins 2, 13 and 14 to ground. The response is single pole. Given a desired bandwidth, f_{BW} , the filter capacitors are determined by:

$$C_2 = C_3 = C_4 = \frac{4.97 \times 10^{-6}}{f_{BW}}$$

The response time (RT) is determined by the equation:

$$RT = 5 \times R_{int} \times C_{ext}$$

R_{int} is the 32KΩ internal resistor. C_{ext} is the external resistor C_2 , C_3 , and C_4 .

Output is a function of t (time) for constant Resistance and Capacitance. Out_{tn} is the output during normal operation. The function for output during selftest actuation is described by:

$$Output = Out_{tn} * (1 - e^{-t/RC})$$

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Multiplexed Output of the KXD94

Multiplexer Data Select

The KXD94 features an integrated 4-channel multiplexer. This feature reduces system MCU requirements to only 1 ADC and 2 digital I/O's. The KXD94 uses two select inputs (S0, S1) to control the data flow from Vmux, which is a high impedance output. When a microprocessor toggles the select inputs, the desired output is attained based on the Output Select Table 5. Note that logic 0 is GND and logic 1 is Vdd.

Table 5. Output Select Table

S0	S1	Vmux
0	0	X Output
0	1	Not used
1	0	Not used
1	1	Aux. In

Data Sampling Rate

When operating in its multiplexed mode, the KXD94 has the ability to achieve very high data sampling rates. Internally, the sensor element (X, Aux) are sequentially sampled in a “round robin” fashion at a rate of 32KHz per axis. Note that this is a differential capacitance sampling of each sensor element, which stores an analog voltage on the filter cap for each axis. Combine this high sensor element-sampling rate with the short 5µS settling time of the integrated multiplexer, and the user can achieve a performance very close to that of the X and Aux In analog outputs. This is more than sufficient to eliminate any aliasing in the final application since the KXD94 will be operating with a typical bandwidth of ~50Hz and a maximum of 1000Hz.

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KXD94 Digital Interface

The Kionix KXD94 digital accelerometer has the ability to communicate on a SPI digital serial interface bus. This flexibility allows for easy system integration by eliminating analog-to-digital converter requirements and by providing direct communication with system micro-controllers.

The serial interface terms and descriptions as indicated in Table 6 below will be observed throughout this document.

Table 6. Serial Interface Terminologies

Term	Description
Transmitter	The device that transmits data to the bus.
Receiver	The device that receives data from the bus.
Master	The device that initiates a transfer generates clock signals and terminates a transfer.
Slave	The device addressed by the Master.

The chip will ignore all SPI activity when nCS is held high, and the analog function will run. The analog function is powered down whenever nCS is low, but the SPI bus will function, allowing communication to enable and reset the KXD94.



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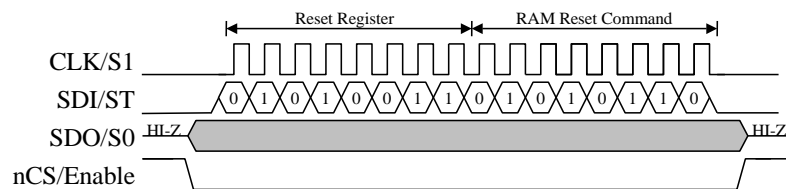
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Accelerometer SPI Reset Sequence:

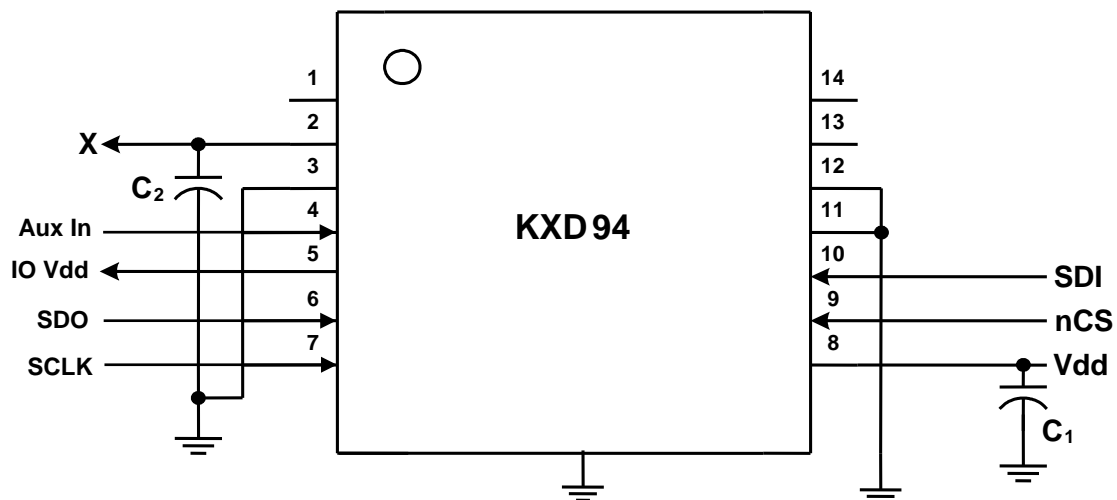
1. Power up KXD94
2. Toggle nCS (Pin 9)
 - a. nCS low to select
 - b. nCS high for at least 200nS (SCLK = 5MHz)
 - c. nCS low to select
3. Send Reset Command per Figure 2 (SDI is latched on rising edges of CLK) Note that it takes 16mSec for the Reset command to execute.

Figure 2. Reset command timing Diagram



4. Set nCS to high (Logic '1') for Normal Analog Operation.

Figure 3. Application Schematic for SPI Reset





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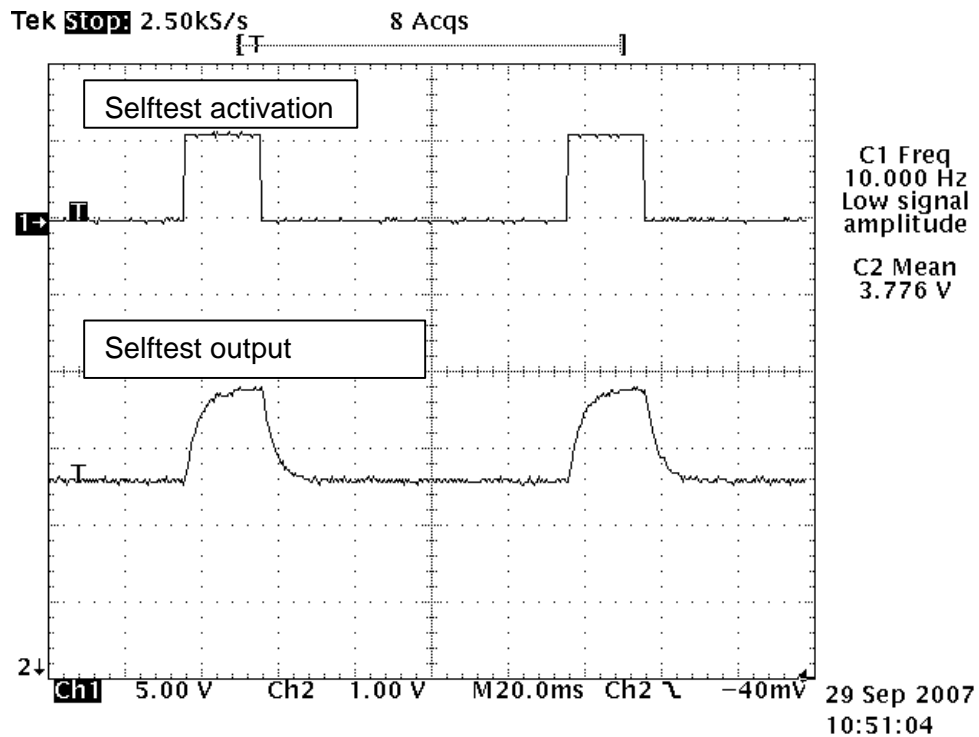
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Self Test Function

The selftest is activated when 'logic 1' is applied to the ST pin (See Figure 1). An electrostatic force is applied to the sense element that causes the mass to move and the output increases. The selftest function exercises the sense element and ASIC blocks. The output change of the selftest function is modified by the internal 1kHz LPF and the external LPF that is defined by the ASIC internal resistance and the external capacitor. Figure 4 is an example of the selftest output with a 50Hz external LPF. The selftest is actuated at 10 Hz and 25% duty cycle.

Figure 4: Selftest Function for KXD94



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Test Specifications

The performance parameters and characteristics are validated by Design methodology; Design Validation tests; and Product-Production Validation tests. A test control plan has been developed to verify product conformance to specification prior to shipment. Table 7 is a summary of these tests.

Table 7. Test Specifications

Parameter	Specification	Test Conditions
Zero-g Offset @ RT	2.5 +/- 0.08 V	25C, Vdd = 5 V
Sensitivity @ RT	400 +/- 14 mV/g	25C, Vdd = 5 V
Current Consumption -- Operating	700 <= Idd <= 1500 uA	25C, Vdd = 5 V



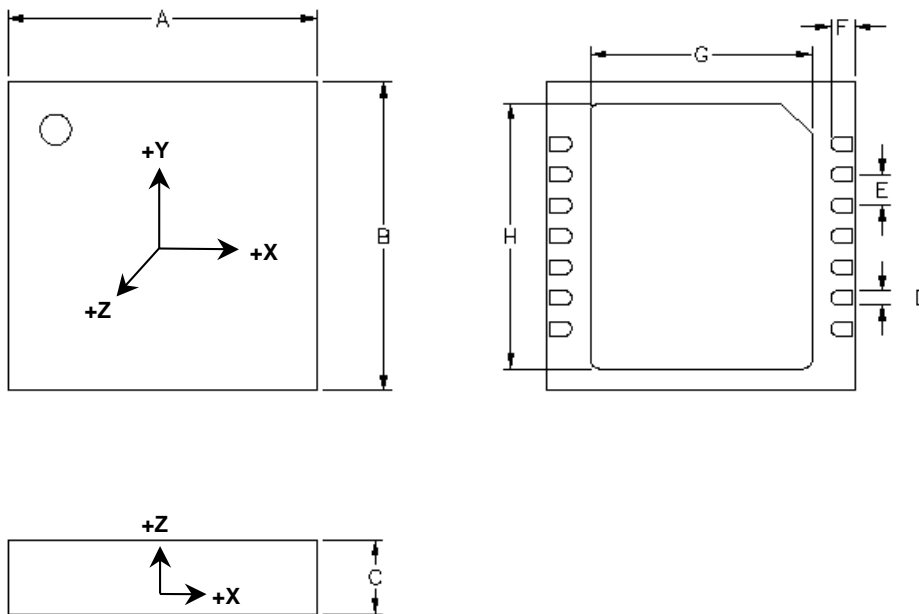
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Package Dimensions and Orientation

Figure 5. 5x5x1.2mm DFN Package and Acceleration sign convention



All dimensions and tolerances conform to ASME Y14.5M-1994

Dimension	mm			inch		
	Min	Nom	Max	Min	Nom	Max
A		5.00			0.197	
B		5.00			0.197	
C	1.10	1.20	1.30	0.043	0.047	0.051
D	0.18	0.23	0.28	0.007	0.009	0.011
E		0.50			0.020	
F	0.35	0.40	0.45	0.014	0.016	0.018
G	3.50	3.60	3.70	0.138	0.142	0.146
H	4.20	4.30	4.40	0.165	0.169	0.173

When device is accelerated in +X direction, the corresponding output will increase.
Y and Z outputs are not available on this product.



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Static X Output Response versus Orientation to Earth's surface (1g):

Position	1	2	3	4	5	6
Diagram					Top Bottom	Bottom Top
X	2.5 V	2.9 V	2.5 V	2.1 V	2.5 V	2.5 V
X-Polarity	0	+	0	-	0	0

↓ (1g)

Earth's Surface

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Notice

Precaution on using KIONIX Products

1. Our Products are designed and manufactured for application in ordinary electronic equipment (such as AV equipment, OA equipment, telecommunication equipment, home electronic appliances, amusement equipment, etc.). If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), transport equipment, traffic equipment, aircraft/spacecraft, nuclear power controllers, fuel controllers, car equipment including car accessories, safety devices, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property (“Specific Applications”), please consult with the KIONIX sales representative in advance. Unless otherwise agreed in writing by KIONIX in advance, KIONIX shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any KIONIX’s Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASS III	CLASS III	CLASS II b	CLASS III
CLASS IV		CLASS III	

2. KIONIX designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:
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 - b) Installation of redundant circuits to reduce the impact of single or multiple circuit failure
3. Our Products are designed and manufactured for use under standard conditions and not under any special or extraordinary environments or conditions, as exemplified below. Accordingly, KIONIX shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any KIONIX’s Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc., prior to use, must be necessary:
 - a) Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
 - b) Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
 - c) Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl₂, H₂S, NH₃, SO₂, and NO₂
 - d) Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
 - e) Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
 - f) Sealing or coating our Products with resin or other coating materials
 - g) Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
 - h) Use of the Products in places subject to dew condensation
4. The Products are not subject to radiation-proof design.
5. Please verify and confirm characteristics of the final or mounted products in using the Products.



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6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse. Is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.
7. De-rate Power Dissipation (Pd) depending on ambient temperature (Ta). When used in sealed area, confirm the actual ambient temperature.
8. Confirm that operation temperature is within the specified range described in the product specification.
9. KIONIX shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.
2. In principle, the reflow soldering method must be used; if flow soldering method is preferred, please consult with the KIONIX representative in advance.

For details, please refer to KIONIX Mounting specification.

Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.
2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. KIONIX shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
 - a) the Products are exposed to sea winds or corrosive gases, including Cl₂, H₂S, NH₃, SO₂, and NO₂
 - b) the temperature or humidity exceeds those recommended by KIONIX
 - c) the Products are exposed to direct sunshine or condensation
 - d) the Products are exposed to high Electrostatic
2. Even under KIONIX recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.
3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

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4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

Precaution for Product Label

QR code printed on KIONIX Products label is for KIONIX's internal use only.

Precaution for Disposition

When disposing Products please dispose them properly using an authorized industry waste company.

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Revision History

REVISION	DESCRIPTION	DATE
1	Added special characteristics identification to tables 1 & 3. Adjusted tolerances of operating current.	20-Oct-2009
2	Added POR design note	12-May-2014
3	Revised POR description	04-May-2015
4	Revised Axis Description	30-Oct-2015

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